CHAPTER 4

Camera Trapping Protocols for Wildlife Studies (With Emphasis on Tiger Density Estimation)

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Introduction

Camera trapping, or photographing wildlife through the use of automatic trip cameras, has a long history in wildlife biology, first employed in 1877 (Guggisberg 1977) to photograph animals for aesthetic reasons. Recently, there has been a dramatic increase in commercially available, lightweight, relatively inexpensive, digital cameras and this has led to widespread use of remote camera traps for a variety of purposes in wildlife science. Camera traps can be used to document presence of a target species or to conduct a species inventory for a target area. In the 1990s a major advance came with the linking of capture-mark-recapture (CMR) statistical analyses to large-scale camera-trap grids for abundance and density estimation (Karanth 1995, Karanth and Nichols 1998). This technique is well-suited for animals such as most felids that are already marked with bold coat patterns that make them individually recognizable in photographs.

Tigers once roamed in the variety of habitats in Asia from the Caspian sea to the Russian Far East (Global Tiger Recovery Program 2010). Since then, the human world population has increased dramatically, causing large portions of natural habitats to vanish, squeezing tigers into only ~7% of their historic range (Sanderson et al. 2006) and reducing their population to only ~3,000 individuals (Global Tiger Recovery Program 2010). Recognized as endangered since 1975 (Morell 2007), the global tiger population and its habitat have steadily declined (Chundawat et al. 2010). Therefore, this chapter will use tigers as a focal species for conducting density estimation. In addition, we provide protocols for camera survey design, camera field set up, data entry and organization, and data summary and analysis for all photographs returned from field studies.

Warning: Due to the ability of digital cameras to take multiple shots with each triggering and their high sensitivity, there is often an enormous amount of data (i.e., photographs) to sort through to gain meaningful information. It is important to plan for ample time in photographic data entry and to enter all data on *all* animals including humans as these data can often be used as predictor variables for target species in future analyses. Plus they provide much-needed species inventory data on the animals of Bhutan.

Camera Placement and Maintenance in the Field

Camera set up

Camera traps are particularly well-suited to surveying terrestrial mammals, especially those known to use roads or trails as travel paths. Placing cameras on such paths is efficient and increases trapping rates. In forested environments, cameras can easily be attached to trees with bungee cords or nylon webbing straps. In areas with few trees, stakes can be used effectively. It is important not to place cameras too close to trails because digital cameras tend to have slow trigger speeds and many animals may be missed resulting in numerous blank photos and/or tail tips only. We suggest placing cameras at 2–4m from the center of the trail (Figure 4.1). Conversely, cameras should also not be placed so far off the trail that the night flash cannot illuminate the field of view—often ~6–8m for white flash and longer for infrared. Each camera brand should have its specifications for flash illumination. However, past 5m, it may be hard to distinguish animals—especially for smaller species and/or individual ID. Finally, we have seen the best placement is on level, flat ground and fairly low to the ground (20–40cm — or knee height).

However, on steep and rugged terrain, it is difficult to find such ideal location for camera placement that would accommodate two cameras as in Figure 4.1. In such cases, we recommend finding a location that can accommodate one camera on one side of the trail and another within 50 meters along the other side of same trail. If cameras are placed over ruts in a road/trail, or high on a tree, animals can escape "capture" by being under the camera's sensor. We have seen this many times when obtaining only ear tip photographs, as an animal travels in ruts or investigates a camera trap at close range. Lowering cameras to knee height and parallel to the ground does not hinder photographs of larger species such as tigers, but be prepared to obtain only knees and bellies of elephants or other large ungulates!

Figure 4.1. Example of field camera placement with 2 cameras per station. Cameras are attached to trees with bungee cords (left) or nylon webbing straps (right) and are backed off from the center of the trail (2–4m) so that they can capture the whole image of the animal (rather than a tail tip). Trail width in this instance is ~2m. It is important to clear vegetation surrounding the cameras' view finders and sensors as this will prevent false triggering and will provide clear, unobstructed, images. Repeated clearing of vegetation is often necessary. Trail width measurements are useful in predicting trap rates for some species.

When individual ID is needed, it is necessary to use 2 cameras per station to obtain both sides of the tiger because the stripes are different on the right and left sides. Some researchers argue that one should not place cameras directly facing each other because white flashes can create washout in the opposing camera. This is not an issue with infrared flash, and it is a relatively minor issue even with white flash cameras. A very slight angle is usually sufficient to prevent wash-out. Having the second camera within the view field of the first allows for photographs that can reveal interesting behavior as animals investigate or vandalize cameras (Fig. 4.2).

When setting up cameras for the first time, we advise using a "set up" data sheet that has some basic information such as: GPS location (UTM coordinates usually preferred), unique station number, unique camera number(s), physical description of location, and some basic habitat features such as: type of habitat, land use code (e.g., protected, unprotected, private, etc.), canopy cover, trail type (Appendix 4.1).

In particular trail width and canopy cover have been shown to be a good predictors of species trapping rates for some felids (Davis et al. 2011).

Figure 4.2. Camera traps placed in opposing pairs can capture interesting animal behaviors such as this bear and cub in Virginia USA.

Camera checks for maintenance and proper functioning

Camera equipment placed at a field site is usually subject to extreme weather conditions and malfunctions are commonplace. Therefore, frequent camera checks are necessary to ensure proper functioning and researchers should always bring extra cameras to replace malfunctioning ones. We advise doing a first camera check at about 10 days into a study to make sure everything is operational and to determine photographic rates and battery drain (most modern camera traps have a battery meter). After this initial camera check, digital cameras can be checked every 14–21 days. However, cold climates may require more frequent check at ~every 10 days. Going beyond 21 days is risky—especially if animal damage is an issue—because you can lose weeks of data if an early malfunction occurred or a camera was damaged by an animal. We recommend not going > 14 days between camera checks.

Appendix 4.2 gives an example of a camera checking data sheet (different from a set up data sheet) useful for keeping track of battery drain, photographs taken, and general malfunctions. At each camera check, it is useful to bring the previous camera checking sheets, or copies thereof, into the field to evaluate the performance of the camera at the last camera check. Alternatively, you can create a list of potential malfunctions noted from examining the previous data downloaded from the memory cards. Past experience has revealed that there is a temptation to rush camera checks and assume everything is in order when, in fact, some cameras have minor or major malfunctions. Checking sheets of possible malfunctions help prevent mistakes.

It can be very easy to lose track of what data came from which camera when downloading camera memory cards to a computer. An easy solution is to trigger each camera with a placard that, at minimum has: station code, camera number, and date (Figure 4.3).

Figure 4.3. Camera traps need frequent field checks (left above) and general maintenance (e.g., replace malfunctioning camera, check battery life, and change memory cards). Additionally, at each check, all information should be recorded on a data sheet (see Appendix 4.2) and placards should be used to check that cameras trigger properly and to double-document the date and station (right

Alternatively, a stake can be placed into the ground within the camera's viewfinder that documents the station code and camera number. However, we prefer the placard method, because the date (even time) written on the placard, can later be used to recalibrate a camera whose data/time stamp has become corrupted. All cameras should be set to display both the time and the date on the photographic image as this information is essential in future analyses. All cards should be downloaded at the end of each camera check and images examined to determine if possible malfunctions are occurring.

There is often a lot of field gear and equipment to bring when setting and checking remote cameras in the field. It is easy to forget critical items such as keys to padlocks (when cameras are locked). Appendix 4.3 provides gives a list of useful items to bring when camera trapping to prevent forgetting something important.

Should cameras be baited?

Given the extensive use of remote cameras in the field today, it is surprising that there have been relatively few studies systematically addressing the impact of baited versus non-baited camera traps. While using bait (olfactory lures or meat) to draw in carnivores is commonly done in presence/absence studies, most studies estimating abundance do not bait cameras for fear of changing animal behavior and luring animals in that would otherwise not already be present in the camera grid. But there are studies that have used bait in order to increase trapping rates for the purpose of mark-recapture analysis (sardines for ocelots: Trolle and Kery 2003; chicken pieces for Malagasy carnivores: Gerber et al. 2010). Additionally, Gerber et al. (2011) found that bait did not change abundance estimates for Malagasy civets. Still other studies do not mention if they used bait or not. In some instances, trap rates may be so low for very elusive species that baiting is necessary. Baiting is probably not a concern for inventory studies but should be further explored for abundance/density estimation. In general, baiting takes more time and can be very messy (especially for meat), and logistically problematic. Tigers, and many other felids, have been successfully surveyed without baiting camera traps.

Species Inventory or Distribution Studies from Camera Traps

Survey design

The design of any camera-trap survey depends on the purpose of the study and can change for different target species. In areas where not much on species compositions and distributions are known, use of camera traps would be highly valuable and provide great insight and baseline data on species occurrence in these areas. It can even be done as part of a tiger density estimation survey. For documenting species presence or conducting species inventories, there is currently no standard for number of camera stations, spacing between cameras, or duration of surveys (Kelly 2008). However, Carbone et al. (2001) suggested through simulation modeling that at least 1000 trap nights would be needed to document tiger presence if tigers occurred at densities of 0.4 to 0.7 tiger per 100km^2. Wegge et al. (2004) provide some insight into how increasing camera saturation can decrease the total number of trap nights needed to detect individual tigers. In their species inventory, Tobler et al. (2008) captured 86% of species assumed to be in the area in 2340 trap nights. Most studies use a minimum of 1000 trap nights but more may be needed for rare species and many current studies strive for 2000 trap nights per survey.

Camera placement and spacing are flexible for inventory studies and often include targeting likely areas with more cameras while not surveying unlikely areas. However, studies addressing habitat use should stratify by habitat type to make meaningful comparisons. Use of 1 camera per station is sufficient for this type of study since individual identification in not necessary, but note that all data is lost if the camera malfunctions or is vandalized at a particular station.

Data entry, summary, and analysis: trap nights and trap success

Number of trap nights (or trap days) is calculated as the number of camera *stations* times the number of nights each station is operational. When there are 2 opposing cameras per station, this is still only considered one camera *station* since cameras are at the same location. Therefore, only distinct camera stations, and not distinct cameras, should be used in calculating trap nights. It is important to subtract any days where a camera station was non-operational due to malfunction, battery drain, or human/animal vandalism. If using 2 opposing cameras, as long as one camera is operational (i.e., if only 1 of the 2 cameras malfunctions), the station is usually still considered operational. If an event occurs that knocks cameras askew (e.g., pointing directly up into the air or at the ground) these should not be counted as operational even if photographs are obtained of tree tops and dirt.

Useful summary data to present include the total number of trap nights for an entire survey, the total number of photograph "events" for each species and the trap rates for each species for an entire survey. Trap rates require determining the number of trap nights and dividing the photo events by trap nights. In addition to calculating total number of trap nights across an entire survey, it is important to determine trap nights for each camera station independently to determine if stations have high malfunction rates and need replacement cameras or need to be excluded in future analyses due to low samples sizes. Additionally trap rates for each camera station are useful in determining hotspots (or coldspots) of animal activity. Finally trap rates per camera station should be presented in addition to the total number of photographs of each species at each camera station because it is unlikely that all camera stations will be operational for the same number of days, due to unpredictable malfunctions and some stations being in the field longer than others. Obviously, a camera station that is up for a longer time is more likely to obtain more photos, therefore dividing the number of capture events by number of trap nights (i.e., trap success) is more appropriate than the number of raw photographs of each species.

Trap success (a.k.a. trap rate, photographic capture rate, photographic capture index, etc.), is usually calculated as the number of independent photographic capture "events" per 100 trap nights (See Appendix 4.4).

$$Trap\ Success = \frac{\#\ of\ capture\ events\ of\ target\ species}{\#\ of\ trap\ nights} \times 100$$

Some studies do not multiply by 100, but this can lead to very small numbers that are difficult to graph or interpret for very rare species. Using the 100 multiplier also allows relatively easy interpretation. For example, if trap success was 6.0, this would be interpreted as obtaining 6 photographs of the target species in 100 trap nights (i.e., 6 photos with 1 station running for 100 nights or with 10 stations running for 10 nights). It should be noted however, that this is not a direct percentage because it is possible to photograph more than one target species per day per station, and this can lead to a value of over 100 for trap success of very common species.

In past studies a capture "event" has been defined as an independent photograph of a species that occurs within either a ½ hr or a 1 hr time frame from the date and time stamp of the first photo of the species (Kelly 2003). The choice of time frame is somewhat arbitrary and is up to the researcher but either ½ or 1 hr should be sufficient and probably will not make much too much difference. If you use ½ hr data, however, that can be combined later to 1 hr if need be, whereas if you use 1 hr, you cannot go back to using ½ hr unless you go back to the raw data. So ½ hr is perhaps more flexible.

If there are numerous photographs of an individual within the specified time period, care should be taken to determine if the event is 1 individual, or several. If two animals can be distinguished in the photographs, or even in a single photograph, it should be recorded as 2 capture events. If it is not possible to tell if there are 2 or more animals, then err on the side of caution and add the animal as a single event. If the study is using 2 cameras per station, it is important not to double enter the same animal photographed by both opposing cameras. Even if both opposing cameras record the animal, there is still only 1 capture event. This can make data entry extremely tedious because it requires examining photographs from both sides of the trail simultaneously to prevent double entries. Setting up a data entry system with 2 laptops or a computer with extra monitors can greatly ease data entry from multiple cameras simultaneously (Figure 4.4).

A)

B)

Figure 4.4. Example for how to enter data when you have more than one camera operational per camera station. Attaching a laptop to an extra monitor A) or using 3 monitors attached to one computer B), can ease data entry and aid in avoided double-entry of the same animal photographed in separate cameras at the same station.

Appendix 4.5 gives an example spreadsheet for organizing data entry on all species, including humans (and their vehicles), for inventory or distributional studies, but we advise that this be part of all studies (even abundance/density studies). In this spreadsheet, each row or record represents a trap event within a ½ hr time period, and notes the species, # of photos, # animals in photos, etc. (Appendix 4.5). Once the data is entered into such a spreadsheet, it is fairly straight forward and relatively simple to use "pivot tables" in Microsoft Excel to summarize data by species or by camera station (or both) and to convert into trap rates. This data provides a very useful summary of total species occurrence over a whole survey (Figure 4.5a) and the trap rates across the study site of a target species (Figure 4.5b). The data also can be useful to indicate what influences target species presence or trap rate (Figure 4.6).

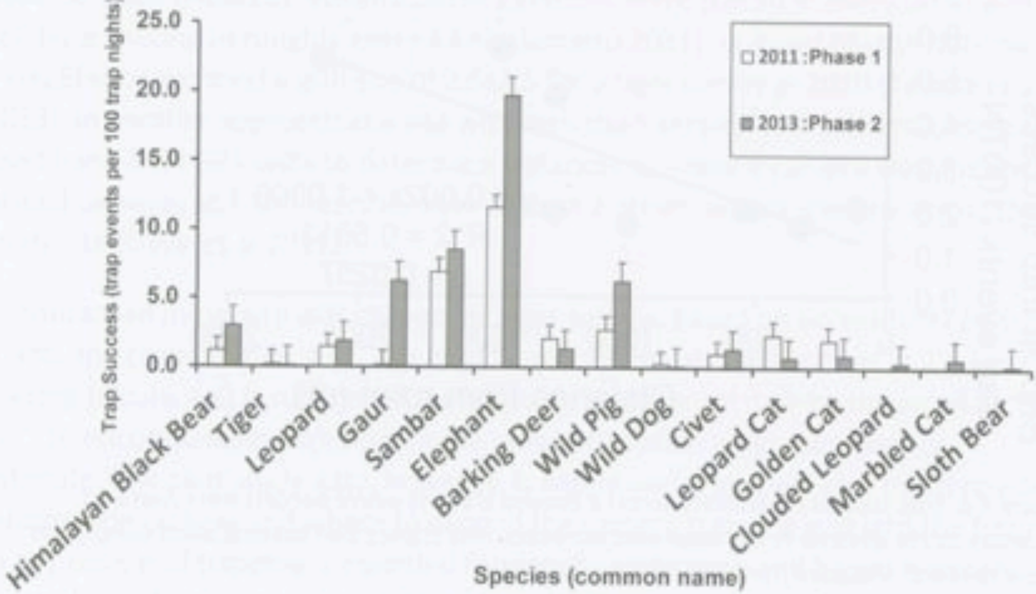


Figure 4.5a. Average trap success (and SEs) for each species across 15 camera stations in 2 different years of the study. This gives an indication that sambar deer and elephant may be easy to trap with camera traps, but that the carnivores have low trapping rates and the effort may need to be large to gain information on these species.

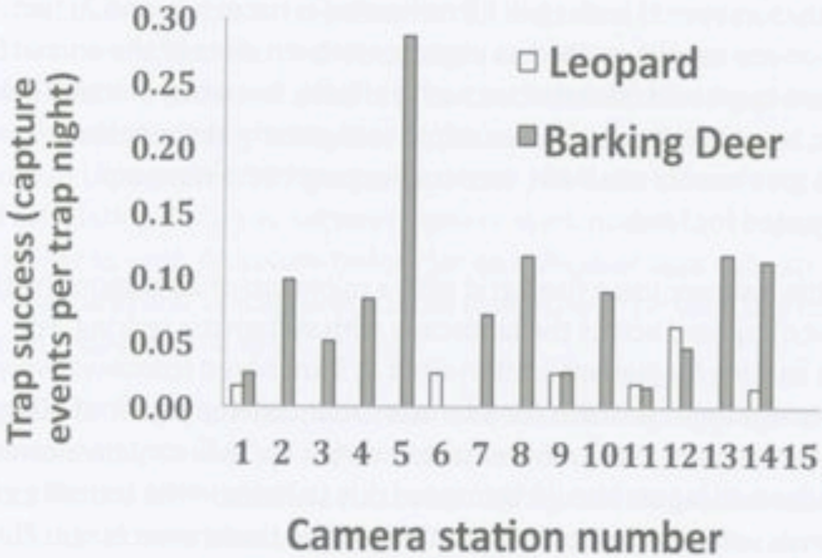


Figure 4.5b. Trap success for leopard and barking deer across 15 camera stations during 1 year of study. Deer are ubiquitous being found at all stations except station 6 and 15; whereas leopard are much more rare across the study site.

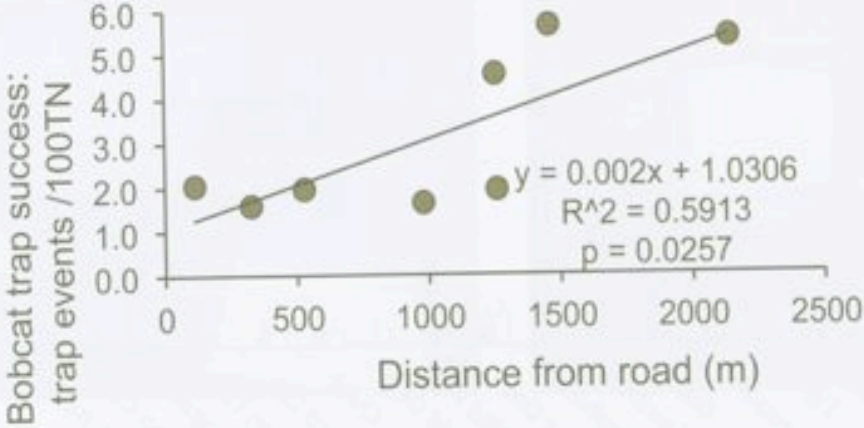


Figure 4.6. Trap success for bobcats across 8 camera stations where bobcats were captured, increases as the distance to the main road increases. This implies that bobcats avoid using areas closer to roads. (Adapted from Kelly and Holub 2008).

Species Abundance / Density from Camera Traps

Survey design

Unlike species inventories, which have highly variable survey design, there are well-established protocols and active research regarding camera station survey design for abundance and density estimation. There are 2 main requirements for abundance/density surveys: 1) individual identification is necessary and 2) two cameras per station are usually needed to photograph both sides of the animal for positive ID. Because most wild felid species such as tigers, leopards, marbled cats, clouded leopards, leopard cats, etc., have unique coat pattern that enable individual ID, and they readily use trails, camera trapping techniques are particularly well-suited for felids.

Most studies within a survey use a fixed grid with a minimum of 20 stations (with 2 cameras per station), spread across the landscape with systematic spacing. For example, camera spacing for jaguars is often cited at 3 km based (conservatively) on the smallest home range recorded for 1 female radio-collared jaguar of 10 km^2 (Rabinowitz and Nottingham 1986). This ensures every 9 km^2 will contain a camera trap; hence no individual jaguar should be missed due to holes in the trapping grid. In fact, most animals will have 3–4 camera stations within their home range. This also ensures that every animal has a probability of being captured, a necessary assumption of mark-recapture models commonly used in data analysis (Otis et al. 1978). The spacing is often larger for tigers at 3–5 km between stations due to their much larger home range. An approach for Sumatran tigers used a 2X2 km^2 grid, overlaid upon the study site and camera stations were placed in every other grid cell for a spacing of roughly every 4 km^2 (Sunarto 2011). In Royal Manas National Park, Bhutan we used a grid size of 2.5x2.5 for a tiger survey in 2010 (Tempa et al. 2013). In another approach at a site with high road density, researchers in Belize used hand-held GPS units to determine distances to nearest camera stations and placed cameras at 3 km intervals from at least 2 other camera stations across the study site (Davis et al 2011).

In Bhutan, an initial site was chosen for tiger surveys based on accessibility by trails, roads, and rivers (Figure 4.7). The original placement of camera traps at 2.5 km spacing (Figure 4.8) is sufficient for pilot study work, but it may be too small at ~25 km^2, to encompass enough tiger home ranges to obtain a rigorous density estimate. The pilot study data, however, is highly useful and will give much needed information on how and where to expand the camera trapping grid into the future. In any case, grid trapping is essential for density estimation and bigger is usually better for wide-ranging species. Thus, for a tiger survey in Jigme Singye Wangchuck National Park in 2013, we used a 5x5 km^2 grid.

Data entry, summary, and analysis: abundance and density

We advise entering data on all species in addition to the target species following the protocol laid out above. However, data entry and formatting for abundance/density estimation is unique and does differ depending on the software used to analyze the data (see Chapter 2). In general however, capture histories must be created for each individual tiger identified. A good way to keep track of tiger IDs and to provide a quick way to check IDs of incoming photos, is to create a spreadsheet displaying both sides of the animal and all the dates and locations recorded (Appendix 4.6). This can also form the basis for creating capture histories and calculating distances between camera stations and for keeping track of animals from year to year. A capture history for an individual tiger consists of a set of 0s (non-capture) and 1s (captures). Some researchers use each day that a camera station is operational as a

Program CAPTURE utilizes numerous models including heterogeneity, M(h); behavior M(b); time M(t); and combinations of these effects, to determine which model fits the CMR data best (Otis et al. 1978). Included in the analysis is a test for population closure whereby a high p-value indicates that you cannot reject the null of "closed" population (i.e., high p-value is good in this case!). CAPTURE can be run as a stand-alone program (freely available) or from within Program MARK (however the closure test is not automatically available in MARK). The stand-alone CAPTURE and the one embedded within Mark use discriminant function analysis to rank

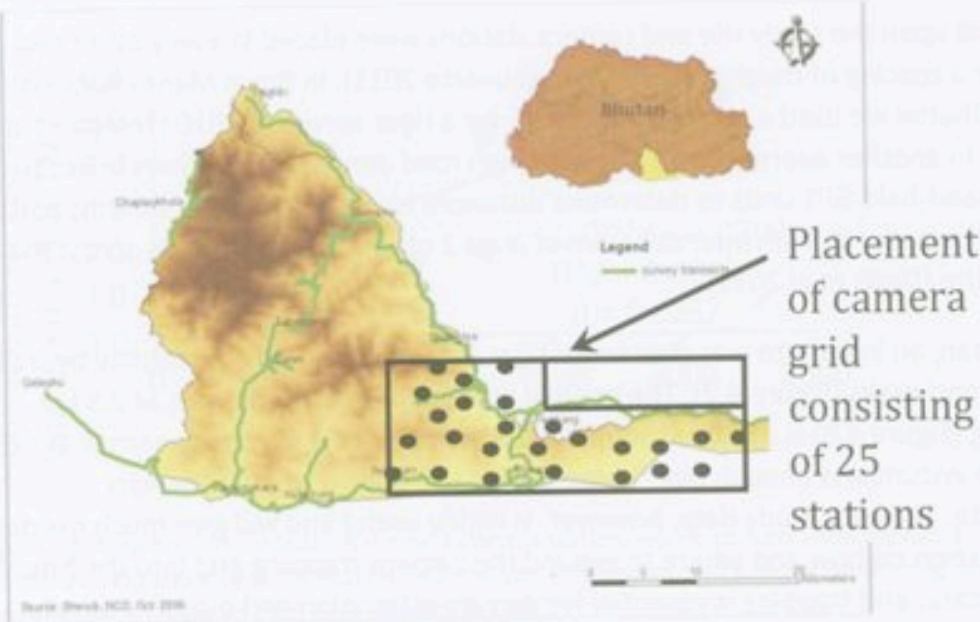


Figure 4.7. Royal Manas National Park. The black box denotes the suggested location of an initial tiger camera trap grid centered on a network of trails, rivers, and roads. A distance between traps of ~2km, with a minimum of 25 camera stations (2 cams per station) will result in a survey area ~25 km^2.

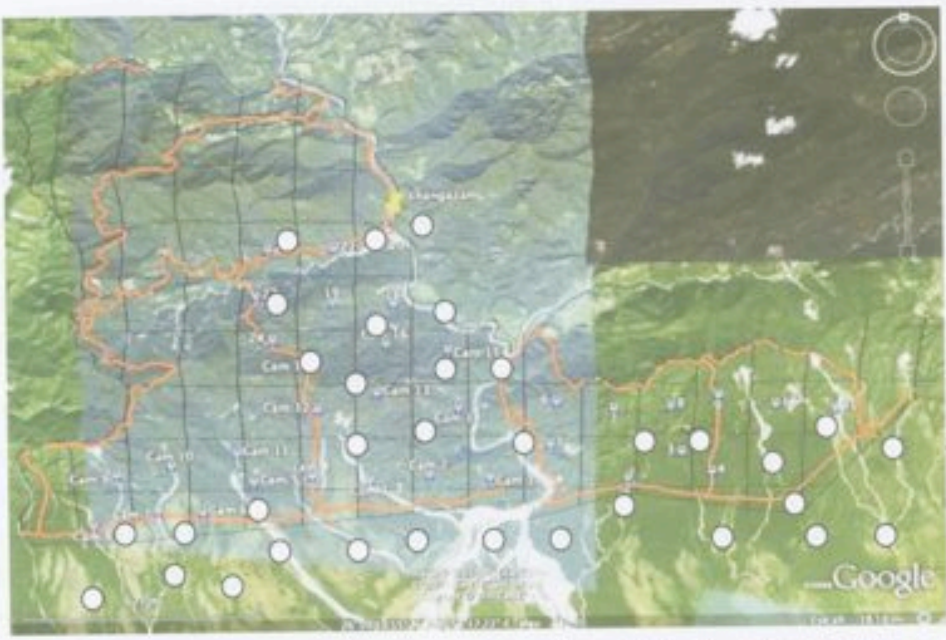


Figure 4.8. Actual placement of initial camera trapping grid for tigers in Royal Manas National Park placing cameras in each 2x2 km grid cell placed across the landscape to systematically survey for tigers. Blue symbols represent camera stations.

models. Data can also be run in Program MARK to estimate abundance using maximum likelihood estimation (MLE) and Akaike information Criterion (AIC; Akaike 1973) for model selection. While the statistical implementation in MARK is thought to be superior, we have found that sometimes datasets with very low numbers of animals and low capture rates run better or more consistently in Program CAPTURE.

Because camera grids are often different sizes and can change size and shape over time in longitudinal studies, it is necessary to convert abundance estimates from CAPTURE or MARK into densities for comparative purposes. Therefore, researchers must divide the resulting abundance estimate by an effective trap area. Determining the effective trap area is the sticky, problematic part. Because animals roam far and wide, and not all animals detected live within the camera trap grid but can be photographed at the edges (edge effects), there is uncertainty about the area sampled. The most common methods to estimate survey area are 1) to create a minimum convex polygon (MCP) connecting camera stations and add a buffer surrounding that MCP (commonly done in tiger studies), and 2) to create circular buffers surrounding each camera station and dissolve the buffers (commonly done in jaguar and ocelot studies). Buffering points is more consistent because camera "grids" are often oddly shaped across the landscape and can lead investigators to create MCPs somewhat subjectively. Buffering points eliminates creating an MCP around trapping grids.

To date, most studies determine the buffer size using the mean maximum distance moved (MMDM) between camera locations among all individuals recaptured at least once (Dice 1938; Wilson & Anderson 1985). Traditionally ½ MMDM is added as the buffer, and is meant to represent a surrogate for the radius of the animal's home range. Determining the distance moved between cameras can be done using ARC GIS or some other mapping software. Alternatively, using the Pythagorean Theorem is do-able over relatively short distances. Determining the variance in the density estimate is tricky because it requires incorporating variance in the abundance estimate and variance in the area surveyed, which is based on the variance in the distances moved across individuals. The delta-method is commonly used and well-documented in Nichols and Karanth (2002).

The ad-hoc techniques for estimating effective survey area are problematic because they are influenced by trap spacing and size of trapping grid (Dillon & Kelly 2007; Maffei et al. 2008). Additionally, ½ MMDM has been shown to be a poor proxy for home range radius for some populations (Soisalo and Cavalcanti 2006—jaguars; Dillon and Kelly 2008—ocelots) but not others (Maffei et al. 2008—

ocelots). Because of the problem noted above, new camera trapping analysis techniques for abundance/density estimation are rapidly developing and will likely replace the common method of using program CAPTURE/MARK and MMDM methods. We therefore recommend also using Program DENSITY, which is a free download and is fairly user friendly. DENSITY is a simulation-based method of fitting models to the trap array data. Resulting estimates do not depend on trap layout. Probability of detection declines radially with increasing distance from the fixed home-range centers, and the density of the centers is the parameter of interest (Efford et al. 2009). We supply input files and descriptions for entering data into Programs CAPTURE (Appendix 4.7), MARK (Appendix 4.8), and DENSITY (Appendix 4.9).

At this time, Program SPACECAP is not particularly user friendly, sometimes requires a working knowledge of R programming, and requires many hours of computing time to run analyses. While we foresee the use of SPACECAP increasing in the future, we do not provide more information here but refer the reader to Singh et al. (2010).

Presentation of results for abundance/density estimation should, at a minimum, include the number of camera stations, number of trap nights, number of individual animals captured and recaptured, MMDM (if used), effective survey areas size, CMR technique used, and best model selected, closure test results (if using CAPTURE), abundance estimates, and density estimates with standard errors.

Some Challenges and Limitations to Consider in Camera Trapping

Start-up costs for camera trapping surveys can be high, particularly for abundance estimation which requires a minimum of 20 stations (40 cameras) and we advise starting with at least 60 cameras because malfunctions always occur. In addition, camera lifespan is only ~3 years especially if used for extensive time periods. Additionally, camera models vary widely in price (currently \$65–\$1500 USD per unit), quality (image, durability, trigger speed) and features (event delay, sensitivity, video capability). Some are very easy to use and others require programming or are less intuitive. Many websites are available that rank camera models and supply user input. New users should seek this type of input. In addition, several papers evaluate camera types (Swann et al. 2004, Kelly and Holub 2008)

The trade-off between image quality and quick trigger speed for digital cameras has not yet been resolved. Studies of carnivores that require individual ID need both clear images and a quick trigger, and many users are currently frustrated with most digital cameras.

Probably everyone using camera traps has experienced some theft or animal damage, even with cameras that are locked down and secured. This can be devastating to a study, especially if theft is large. Certain animals, like elephants and black bears, find cameras offensive or just plain fun toys. Bears in Virginia, for example, bit, chewed and otherwise rolled around with, ~20 out of 40 remote cameras destroying a large number (Kelly pers. exp.). In south Asia, elephants are a major cause of camera loss. Researchers should be prepared and perhaps refer to other studies that have found creative solutions to deter theft and animal damage (Grassman et al. 2005, Karanth and Nichols 2002, Fiehler et al. 2007).

Camera trapping is greatly enhanced by an established trail system. Carnivores especially, readily use trails and if a study site lacks trails, time should be spent creating a trail system, both for the ease of research and to increase capture success. Animals will come to use such trails over time (Maffei et al 2004). Use of old roads (e.g., old logging roads) is highly desirable for larger carnivores.

Open habitats may be at a disadvantage relative to closed forest habitats in camera trap studies since they lack natural "funnels" to channel animals in front of remote cameras. Animals will use game trails in these open habitats, but high trail density, which often occurs in savannahs, can also lead to decreased trapping rates for carnivores (Henschel and Ray 2003) likely due to inability to saturate all trails with cameras.

Finally, data organization and input is intensive for camera trap studies. But it is essential to spend the time to complete it. The photographs are "proof of life" for species occurrence. Camera trapping can provide an excellent means to attain this inventory data and to obtain the density estimates for tigers and other species. This is highly relevant for tiger conservation as we strive to prevent tiger extinction in the wild.

Literature Cited

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Proceedings of the 2nd International Symposium on Information Theory, 267-281, Budapest.

Akademiai Kiado, Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, R. Laidlaw, A. Lynam, D. W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'Brien, J. Seidensticker, D. J. L. Smith, M. Sunquist, R. Tilson, and W. N. W. Shahruddin. 2001.The use of photographic rates to estimate densities of tigers and other cryptic mammals. Animal Conservation **4**:75-79.

Chundawat, R. S., B. Habib, U. Karanth, K. Kawanishi, J. Ahmad Khan, T. Lynam, D. Miquelle, P. Nyhus, Sunarto, R. Tilson, and S. Wang. 2010. *Panthera tigris*. In IUCN Red List of Threatened Species.

Davis M.L.; Kelly, M.J. and D.S. Stauffer. 2011. Carnivore coexistence and habitat use in the Mountain Pine Ridge Forest Reserve, Belize. Animal Conservation **14**: 56-65.

Dillon, A., and M. J. Kelly. 2007. Ocelot Leopardus pardalis in Belize: the impact of trap spacing and distance moved on density estimates. Oryx **41**:469-477.

Dillon, A., and M. J. Kelly. 2008. Ocelot home range, overlap and density: comparing radio telemetry with camera trapping. Journal of Zoology **275**:391-398.

Efford, M. 2004. Density estimation in live-trapping studies. Oikos **106**:598-610.

Efford, M.G. 2007. Density 4.0: Software for spatially explicit capture-recapture. Department of Zoology, University of Otago, Dundelin, New Zealand. Available at http://www.otago.ac.nz/density

Efford, M. G., D. K. Dawson, and D. L. Borchers. 2009. Population density estimated from locations of individuals on a passive detector array. Ecology **90**:2676-2682.

Fiehler, C. M., B. L. Cypher, S. Bremner-Harrison, and D. Pounds. 2007. A theft-resistant adjustable security box for digital cameras. Journal of Wildlife Management **71**: 2077-2080.

Gerber, B., Karpanty, S.M.; Crawford, C., Kotschwar, M. and J. Randrianantenaina. 2010. An assessment of carnivore relative abundance and density in the eastern rainforests of Madagascar using remotely-triggered camera traps Oryx: **44**:219-222.

Gerber, B.D.; Karpanty, S.M. and M.J. Kelly. 2011. Evaluating the potential biases in carnivore capture-recapture studies associated with the use of lure and varying density estimation techniques using photographic-sampling data of the Malagasy civet. Population Ecology **54**:43-54.

Global Tiger Recovery Program. 2010. Global Tiger Recovery Program: Executive Volume. http://www.globaltigerinitiative.org/

Grassman Jr LI, Tewes ME, Silvy NJ, Kreetiyutanont K. 2005. Ecology of three sympatric felids in a mixed evergreen forest in North-central Thailand. Journal of Mammalogy **86**:29-38.

Guggisberg, C.A.W. 1977. Early wildlife photographers. Taplinger, New York.

Henschel, P. and J. Ray. 2003. Leopards in African rainforests: survey and monitoring techniques. Report for Wildlife Conservation Society: Global Carnivore Program.

Karanth, K. U. 1995. Estimating tiger Panthera tigris populations from camera-trap data using capture-recapture models. Biological Conservation **71**:333-338.

Karanth, K. U., and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology **79**:2852-2862.

Karanth, K.U. and J.D. Nichols. 2002. Monitoring tigers and their prey: A manual for researchers, managers and conservationists in tropical Asia. Centre for Wildlife Studies; Bangalore, India.

Kelly, M. J. 2008. Design, evaluate, refine: camera trap studies for elusive species. Animal Conservation **11**:182-184.

Kelly, M. J., and E. L. Holub. 2008. Camera trapping of carnivores: Trap success among camera types and across species, and habitat selection by species, on Salt Pond Mountain, Giles County, Virginia. Northeastern Naturalist **15**: 249-262.

Morell, V. 2007. Can the wild tiger survive? Science **317**: 1312-1314.

Maffei, L., E. Cuellar, and A. Noss. 2004. One thousand jaguars (Panthera onca) in Bolivia's Chaco? Camera trapping in the Kaa-Iya National Park. Journal of Zoology **262**:295-304.

Maffei, L., and A. J. Noss. 2008. How small is too small? Camera trap survey areas and density estimates for ocelots in the Bolivian chaco. Biotropica **40**:71-75.

MoA, RGoB. Biodiversity Action Plan for Bhutan. 2002. Keen Publishing (Thailand) Co., Ltd.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical-inference from capture data on closed animal populations. Wildlife Monographs:7-135.

Nichols, J. D., and K. U. Karanth. 2002. Statistical concepts: Estimating absolute densities of tigers using capture-recapture sampling. Pages 121-137 in K. U. Karanth, andJ. D. Nichols, editors. Monitoring tigers and their prey: A manual for researchers, managers and conservationists in tropical Asia. Centre for Wildlife Studies, Bangalore.

Rabinowitz, A. R., and B. G. Nottingham. 1986. Ecology and behavior of the jaguar (*panthera-onca*) in belize, central-america. Journal of Zoology **210**:149-159.

Rexstad, E., and K. P. Burnham 1991. User's guide for interactive program CAPTURE: abundance estimation of closed animal populations. Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, CO; Colorado, United States.

Royle, J. A., M. Kery, R. Gautier, and H. Schmid. 2007. Hierarchical spatial models of abundance and occurrence from imperfect survey data. Ecological Monographs **77**:465-481.

Sanderson, E., J. Forrest, C. Loucks, J. Ginsberg, E. Dinerstein, J. Seidensticker, P. Leimgruber, M. Songer, A. Heydlauff, T. O'Brien, G. Bryja, S. Klenzendorf, and E. Wikramanayake. 2006. Setting priorities for the conservation and recovery of wild tigers: 2005-2015. WCS, WWF, Smithsonian, and NFWF-STF, New York - Washington, D.C.

Singh, P., A. M. Gopalaswamy, J. A. Royle, N.S. Kumar and K. U. Karanth 2010. SPACECAP: A program to estimate animal abundance and density using bayesian spatially-explicit capture-recapture models. Wildlife Conservation Society - India Program, Centre for Wildlife Studies, Bangalore, India. Version 1.0.

Soisalo, M. K., and S. M. C. Cavalcanti. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture-recapture sampling in combination with GPS radio-telemetry. Biological Conservation **129**:487-496.

Sunarto 2011. Ecology and restoration of Sumatran tigers in forest and plantation landscapes. PhD Disseratation. Virginia Tech, March 2011.

Swann, D. E., C. C. Hass, D. C. Dalton, and S. A. Wolf. 2004. Infrared-triggered cameras for detecting wildlife: an evaluation and review. Wildlife Society Bulletin **32**:357-365.

Tempa, T., M. Hebblewhite, L. S. Mills, T. Wangchuk, N. Norbu, T. Wangchuk, T. Nidup, P. Dendup, D. Wangchuk, Y. Wangdi, and T. Dorji. 2013. Royal Manas National Park, Bhutan: a hot spot for wild felids. Oryx 47:207-210.

Tobler, M. W., S. E. Carrillo-Percastegui, R. L. Pitman, R. Mares, and G. Powell. 2008. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. Animal Conservation **11**:169-178.

Trolle, M., and M. Kery. 2003. Estimation of ocelot density in the pantanal using capture-recapture analysis of camera-trapping data. Journal of Mammalogy **84**:607-614.

Wang SW. 2008. Understanding ecological interactions among carnivores, ungulates and farmers in Bhutan's Jigme Singye Wangchuck National Park. PhD Disseratation Cornell University. 151 pages.

Wangchuk T, Thinley P, Younten D, Tshering K, Wangchuk S. 2006. A Field Guide to Mammals of Bhutan. Thimphu.

Wegge, P., C. P. Pokheral, and S. R. Jnawali. 2004. Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. Animal Conservation **7**:251-256.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and Removal Methods for Sampling Closed Populations Los Alamos National Laboratory, Los Alamos, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study **46**:120-139.

Wilson, K. R., and D. R. Anderson. 1985. Evaluation of two density estimators of small mammal population size. Journal of Mammalogy **66**:13-21.

Appendix 4.1: Example of a "Set-up" Camera Data Sheet for the Initial Deployment of Camera Traps in the Field

Data Sheet for initial camera set up only

SITE: Royal Manas National Park (RMNP): March- May 2009

Survey #1: camera station SET UP

Camera Station #	Camera #s	Physical location	date (D/M/Y)	GPS location Easting (UTM X)	GPS location Northing (UTM Y)	Road (R), Trail (T), New Trail (NT), Game Trail (G)	width of road or trail in meters	Canopy cover (%) at station *	Land use **	Habitat type ***	Notes
RMNP01	MT04 / MT15	Batsuki	11/03/09	90°42[illegible]9	26°4[illegible]89	T	1.8	80	PA	F	tiger tracks nearby
RMNP02	MT01 / MT08	Kawapani	11/03/09	90°38.811	2[illegible]°47.532	G	1.0	90	[illegible]	F	small animal game trail
RMNP03	MT12 / MT14	Zorwong	12/0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P[illegible]	F	Old logging road - still occasionally used by vehicles, cameras locked

* Canopy cover: 0 = 0-10%, 10 = 10 - 20%, 20 = 20 -30%, 30 = 30 -40%, 40 = 40-50%, 50 = 50-60%, 60 = 60 - 70%, 70 = 70 - 80%, 80 = 80 - 90%, 90 = 90 - 100%. ** Land use: P pastural, C crops, PL plantation, PA protected area, R roads, BA built up area. *** Habitat: F forest, W woodland, G grassland, B bushland, T thicket, WG wooded grassland, AA Afro-Alpine, M mangrove, FS fresh water swamp, SS saline swamp (/ = transition between two types), R riverine

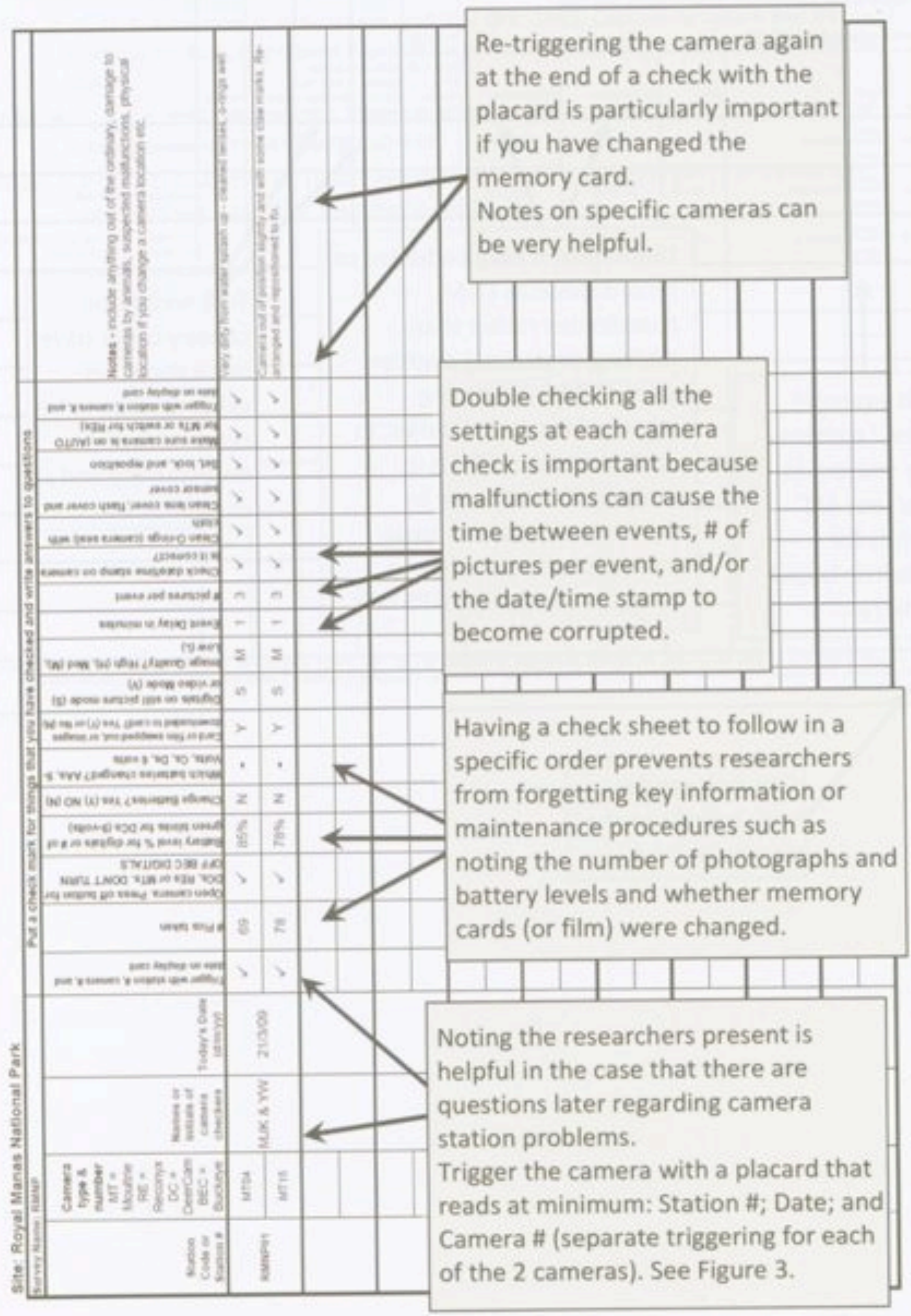
This example uses 2 cameras per station. In this case MT stands for Moultrie brand cameras.

Ultimately, it may be better to record these as UTM coordinates rather than lat/long or decimal degrees since UTM is becoming standard for most studies. In addition, since UTM is in meters, it is very easy to determine distances away from cameras or between cameras even when GPS fails.

Trail width and canopy cover have been shown in other studies to be predictors of detectability and / or habitat use.

Can make codes very specific to the particular study

Appendix 4.2: Example of a Camera Checking Datasheet (Different From a Set-up Datasheet) Used When Monitoring Cameras for Proper Functioning in the Field



Appendix 4.3: Example of List of Equipment to Bring When Camera Trapping

EQUIPMENT FOR CAMERA TRAP CHECKING

Equipment to Bring for All Camera Types

- Map
- Compass
- GPS unit
- GPS coordinates of cameras
- Extra AA batteries for GPS unit
- Radio and/or cell phone
- Data sheet
- Keys for padlocks (if cameras are locked)
- Laminated sheet (or dry erase board) or placard, for writing date, camera, and station number
- Sharpie
- Ball point pen or pencil
- Dry erase pen
- Rag to wipe off dry erase pen
- Extra Bungee Cords or nylon webbing
- Extra ziplock baggies to put film or cards in from cameras
- Extra sign (camera trapping "project sign" if needed)
- Alcohol prep pads for cleaning debris from camera O-rings.
- Umbrella –if raining
- Tape measure (for taking trail measurements)
- Machete, panga, or other vegetation cutting device (for clearing vegetation around camera)
- Swiss army knife, leatherman or some kind of multi-tool
- Weapons to protect yourself from dangerous animals (mace, shotgun, etc.).

Equipment for DEERCAM Cameras

- Two 9-volt batteries per unit
- 2 AA batteries per unit
- Film for each camera unit
- Extra DEERCAM UNIT for malfunctions

Equipment for MOULTRIE Cameras

- D batteries (6 per unit)
- Extra Moultrie camera for malfunctions
- Extra SD memory cards to swap out

Equipment for BUCKEYE cameras

- Charged 6-volt battery (1 per unit)
- Extra Buckeye camera for malfunctions
- Extra SD memory cards to swap out

Equipment for RECONYX cameras

- C batteries (6 per unit) or 8 AAs for some models
- Extra Reconyx camera for malfunctions
- Extra compact flash (CF) memory cards or SD cards depending on the model number to swap out

> **Note:** If it is raining use EXTREME CAUTION because cameras are very susceptible to moisture which causes malfunctions. Use an umbrella or wait until rain ceases.

Appendix 4.4: Example Spreadsheet for Keeping Track of the Number of Traps Nights per Station and Total

Mountain Pine Ridge Forest Reserve 3rd survey (3P) Camera trapping: July - Sept. 2005							
Station # or Code	**Physical Location**	**UTM X**	**UTM Y**	**Date Begin**	**Date End**	**Minus Days of Cam. Malfunc.**	**# of Trap Nights**
3P1	1967 Line off of Oak Burn	0291788	1881313	06/20/05	09/19/05	0	91
3P2	Pinol Line, 0.5km from Granite Cairn	0292955	1879718	06/20/05	09/19/05	0	91
3P3	Log trail of Granite Cairn near 1961 line	0295416	1879718	06/20/05	09/19/05	21	70
3P4	Little track off of North Line	0295115	1881838	06/20/05	09/19/05	11	80
3P5	Block 8 East Line	0297997	1880908	06/20/05	09/19/05	0	91
3P6	Butler Line; 1km from Orchard Hill Line	0300005	1882818	06/20/05	09/19/05	0	91
3P7	Butler Line; 0.5 km from end of line	0297661	1883578	06/20/05	09/19/05	0	91
3P8	Codd Line	0297180	1878163	06/20/05	09/19/05	0	91
3P9	Track off Granite	0301235	1877953	06/21/05	09/19/05	19	71
3P10	Baki Line	0298996	1876168	06/21/05	09/19/05	6	84
3P11	Brunton South of Baki Line	0300607	1874659	06/21/05	09/19/05	0	90
3P12	Devil's	0300635	1872131	06/21/05	09/19/05	0	90

	Drive						
3P13	Kin Lock	0297143	1870786	06/21/05	09/19/05	0	90
3P14	Granite Basin Road	0297608	1873835	06/21/05	09/19/05	0	90
3P15	Morris Road off Winward	0294867	1873067	06/20/05	09/19/05	0	91
3P16	Rainbow Creek of of Raspa Road	0292615	1872103	06/21/05	09/19/05	26	64
3P17	Inner Circle near #2 Line	0289947	1873822	06/21/05	09/19/05	0	90
3P18	Mountain Cow Road by Creek	0295070	1877388	06/22/05	09/19/05	0	89
3P19	1960 Line near Anderson	0292936	1875862	06/22/05	09/19/05	0	89
3P20	1960 Line near Windward	0295824	1874995	06/22/05	09/19/05	0	89
3P21	Espat Road	0289528	1867797	06/22/05	09/19/05	0	89
3P22	Brunton near Espat Junction	0292463	1869231	06/22/05	09/19/05	1	88
3P23	Tower Road #2	0289345	1870852	06/22/05	09/19/05	10	79
Average days operational per camera station							**86.04**
Total number of trap nights							**1979**

In the spreadsheet, format the columns 'Date Begin' and 'Date End' as date then use the functions to subtract 'Date End' from 'Date Begin'. Finally, subtract days of malfunction from that to automatically calculate trap nights for each station.

The 'minus days of cam malfunc' column is not automatic and is somewhat tedious to determine as researchers must painstakingly go through the photographs from each station to determine how many days a station may have malfunctioned. In this case, most stations had zero malfunctions but a few had days to 2-3 weeks of malfunction problems. Only if both cameras malfunction at the same time, is the whole station considering non-functioning.

Appendix 4.5: Example of Data Entry Spreadsheet for Raw Photo Data with Two Cameras per Station

We suggest entering all data on all species including non-target species and humans as this information can be important in predicting target species presence or abundance.

Common name	Scientific Name	Station #	# animals in photo	# of photos	Date (M/D/Y)	Time	Frame #	Cam #(s)	Notes	Human Type	vehicle-foot
White-tailed deer	Odocoileus virginianus	7MLBS01	1	6	11/01/10	10:42	121-126	RX01			
Black Bear	Ursus Americanus	7MLBS01	1	3	11/01/10	18:38	127-129	RX01			
White-tailed deer	Odocoileus virginianus	7MLBS01	2	1;6	11/03/10	1:42	633;136-141	BEC17;RX01	doe and fawn		
Raccoon	Procyon lotor	7MLBS01	1	3	11/03/10	3:28	142-144	BEC17;RX01			
Human	Homo sapiens	7MLBS01	9	7;63	11/03/10	8:45	634-641;145-192;1-15	BEC17;RX01	change card	Research	foot
Human	Homo sapiens	7MLBS01	1	2;1	11/03/10	17:36	642-643;16	BEC17;RX01		Unknown	vehicle
White-tailed deer	Odocoileus virginianus	7MLBS01	1	1	11/06/10	1:45	645	BEC17	Buck		
White-tailed deer	Odocoileus virginianus	7MLBS01	1	1;3	11/06/10	4:55	646;22-24	BEC17;RX01			
Human	Homo sapiens	7MLBS01	2	5;16	11/07/10	12:55	647-655;25-40	BEC17;RX01		Research	foot
Human	Homo sapiens	7MLBS02	4	12;21	08/12/10	14:02	1-12;1-21	MT215;RE07		Research	on foot
Gray Squirrel	Sciurus carolinensis	7MLBS02	1	3	08/15/10	16:47	22-24	RE07			
Human	Homo sapiens	7MLBS02	1	1	08/16/10	8:32	22	MT215		unknown	on foot
Raccoon	Procyon lotor	7MLBS02	1	3	08/18/10	2:18	[illegible]-27	RE07			
Human	Homo sapiens	7MLBS02	4	3	08/21/10	11:17	[illegible]-12	MT215		Tourist	on foot
Raccoon	Procyon lotor	7MLBS02	1	1	08/25/10	4:15	[illegible]01	RE07			
White-tailed deer	Odocoileus virginianus	7MLBS02	1	6;3	08/25/10	13:29	16[illegible]1;4-6	MT215;RE07			
Unknown		7MLBS02	1	3	08/28/10	13:53	[illegible]-12	RE07			
Human	Homo sapiens	7MLBS02	3	21;21	08/29/10	13:44	22-30;5[illegible]66;16-27;1-9	MT215;RE07	change card	Research	on foot
Black Bear	Ursus americanus	7MLBS02	1	2	08/29/10	19:21	[illegible]-11	RE07			
Black Bear	Ursus americanus	7MLBS02	1	3	08/30/10	9:02	[illegible]7-69	MT215			
Eastern Chipmunk	Tamias [illegible]	7MLBS02	1	2	09/01/10	11:16	[illegible]6-17	RE07			
Human	Homo sapi[illegible]	7MLBS02	1	27;31	09/05/10	10:30	79-84;1-[illegible]; 19-30;1-18	MT215;RE07		Hunter	on foot
White-tailed deer	Odocoileus virg[illegible]	7MLBS02	1	3	[illegible]	[illegible]	[illegible]	[illegible]			
Dog	Canis lupus familiaris	7MLBS02	1	1;2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]ng dog		
Black Bear	Ursus americanus	7MLBS02	1	6;8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] moved cam		

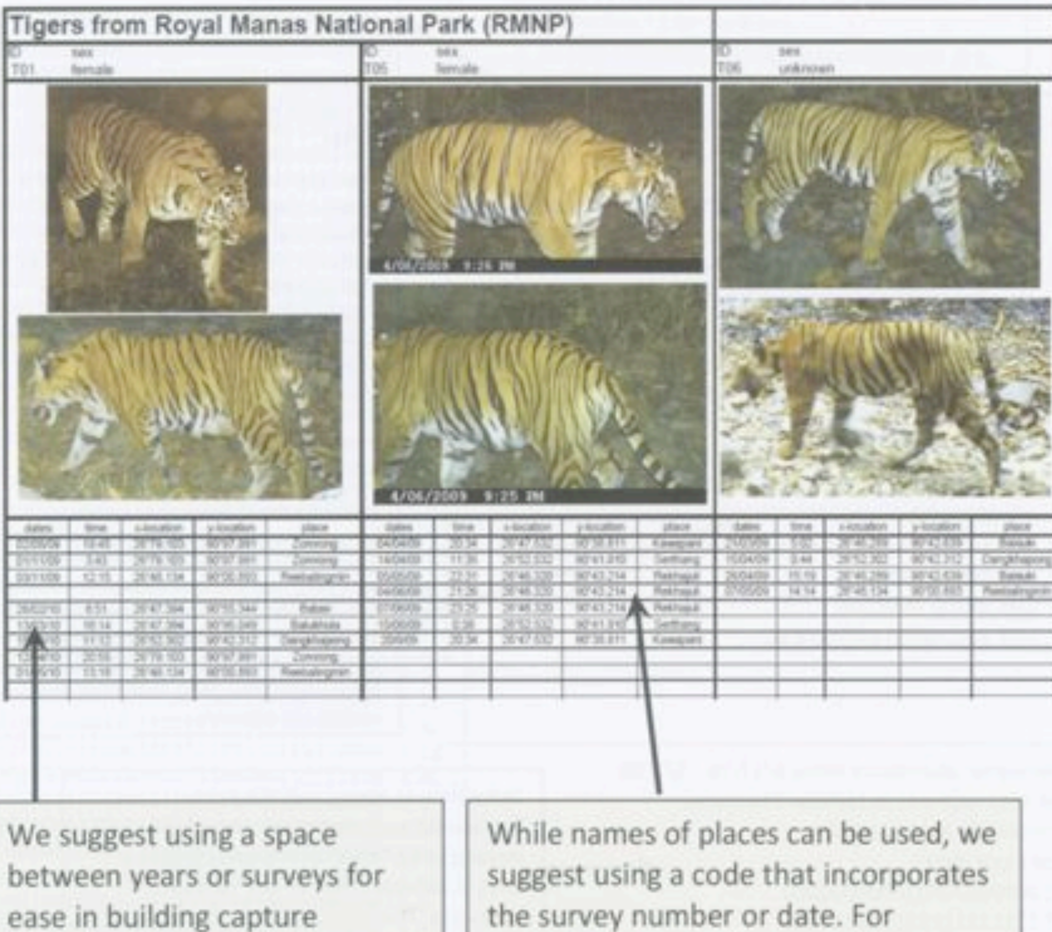
It is a good idea to note the image or frame number in case you need to locate a particular image later. In this case the semi-colon separates the image numbers of the first camera from the second. Likewise, the camera numbers are noted in the next column separated by a semicolon when both cameras fired. When there is only 1 camera noted, only 1 of the two cameras captured the image.

We suggest starting with common and scientific names followed by the camera station code. In this example 7MLBS01, and the following Station 7MLBS02, are separated by a blank row. The 7 refers to the fact that this is the 7th survey at Mountain Lake Biological Station (MLBS) and the 01 and 02 are different stations.

Perhaps the trickiest part is determining the number of independent "events" or "captures". Most camera studies use either 30 min or 1 hr as the cut-off for when to consider a new capture as another record or a new event. In this spreadsheet each row is an event and new events are not counted until 30 min has passed. However, there can be more than 1 event in a photo such as in the third record where 2 deer were photographed in one picture. The numbers of photos taken are noted with the first number being the one taken by the first camera noted in the Cam #(s) column, and the second number, after the semicolon being the number of photos taken by the second camera.

Appendix 4.6: Example of Data Organization for Tigers "Captured" at Remote Camera Stations

Using 2 cameras per stations allows photographs to be obtained from both the right and left sides of the animal. Printing out such reference sheets as this makes for easier identification as new photographs come in from the field. Additionally it is easy to build capture histories for each individual from this reference sheet.



We suggest using a space between years or surveys for ease in building capture histories. Time should be recorded in military time and we suggest converting to UTM locations rather than lat/long.

While names of places can be used, we suggest using a code that incorporates the survey number or date. For example these stations could be labeled as RMNP01 for Royal Manas National Park camera station 01. The following year could be labeled 02RMNP01 – signifying the 2nd survey as Royal Manas National Park but same location 01.

Appendix 4.7: Example Input Files for Program CAPTURE

Can easily be run from the USGS website by creating input files in notepad and then copying and pasting input files such as these notepad files below in the text boxes directly into the site and click perform analysis.

http://www.mbr-pwrc.usgs.gov/software/capture.html

```
title='jaguar abundance 4Pine 6/17/06 - 9/7/06'
task read captures occasions=42x matrix
format='(T1,A3,1X,42F1.0)'
read input data
J25 00000000001000000000100000000000000000000
J27 011101101111111100101110011111111011111110
J36 100000000000001000000000000000000000001100
J39 000000001001001000001000000000100000000000
J40 000000000000000000000001000000000000000000
J41 101100001010100101001001001110100011100100
J42 000000000000000000001000000000000000000000
J43 000000000101001000000000000001000000000000
J44 000100000001000000000000000000000000000000
J47 000000000001000000000000001000000100000000
J49 000000000001000000000000010100100000000000
task closure test
task model selection
task population estimate all
```

First line – title in quotations, the program does not read things in quotations.

Second line – tells the program there are 42 capture occasion or "days" of the survey.

Third line – what is the data format? T1 is tells the program that the data starts in column one. A3 says that the individual animal ID is 3 characters long (if it said A4 that would mean 4 characters long). 1X means that there is 1 space before the capture history starts. 42F1.0 means that there are 42 capture occasions and that 1 is a capture and 0 is a non-capture

Fourth line – read the input data that follows the above format.

Following the 4th line is the capture history for each individual animal. In this case, 42 capture days.

The final lines are telling the program to conduct the closure test, conduct model selection, and give the estimates for all the models: M(o), M(h), M(b), M(t) and various combinations.

```
title=jaguar abundance 4Pine 6/17/06 - 9/7/06'
task read captures occasions=21x matrix
format='(T1,A3,1X,21F1.0)'
read input data
J25 000001000010000000000
J27 111111110111111111111
J36 100000010000000000010
J39 000011010010000100000
J40 000000000000100000000
J41 110011111011011101110
J42 000000000010000000000
J43 000011010000010000000
J44 010001000000000000000
J47 000001000000010010000
J49 000001000000011000000
task closure test
task model selection
task population estimate all
```

Same data as above, but this time "collapsed: such that there are only 21 instead of 42 "days" of the survey. Each 2 days in collapsed into 1 "day" or capture occasions. This often works better in program CAPTURE due to the large number of zeros in the original data which can cause difficulty in analysis. Too many zeros can cause the program to crash or have difficulty in finding any structure in the data ,leading to the M(o) model being selected as the best model.

We highly recommend collapsing the data in this way – but note the changes in the 4 input lines to reflect the different number of 'days' in the capture history.

Appendix 4.8: Example Input Files for Program MARK

Input files (file_name.inp) created in notepad for a single group or divided by sex. Do not include titles below.

Input- One group – capture history for each individual for 34 days. Capture (1) and no capture (0). Last column indicates 1 groups: one abundance estimates for whole population

```
0110001000000110010000001000000000  1;
0000000100000101001000010000000000  1;
1010010100101110011110001100001010  1;
1111101111100100111111100111110000  1;
0001000000010101010100000110111010  1;
1101001110110101101111101101110001  1;
1001100011010100000010100011100101  1;
0100100000011110001100110010010011  1;
000000000000100110000000010010100  1;
0000100100001011000011010000000000  1;
1000100000001000000000110000000000  1;
0000100000000000000111000000000010000  1;
000000000000000000 0 00000000000001  1;
0000000110101010000000000000001001000  1;
0000000000000000000000100000100000 1;
Etc...
```

Input- Two groups – capture history for each individual for 34 days. Capture (1) and no capture (0). Last 2 columns indicate 2 groups: male (1 0) and female (0 1). Two abundance estimates – 1 for each sex.

```
0110001000000110010000001000000000  0 1;
0000000100000101001000010000000000  0 1;
1010010100101110011110001100001010  0 1;
1111101111100100111111100111110000  0 1;
0001000000010101010100000110111010  1 0;
1101001110110101101111101101110001  1 0;
1001100011010100000010100011100101  1 0;
0100100000011110001100110010010011  1 0;
0000000000001001100000000010010100  1 0;
0000100100001011000011010000000000  1 0;
1000100000001000000000110000000000  0 1;
0000100000000000000111000000000010000  1 0;
000000000000000000 0 00000000000001  0 1;
0000000110101010000000000000001001000  0 1;
0000000000000000000000100000100000  0 1;
Etc...
```

Input- One group sex as a covariate– capture history for each individual for 34 days. Capture (1) and no capture (0). Last 2 columns indicate 2 groups: male (1 0) and female (0 1). Two abundance estimates – 1 for each sex.

```
0110001000000110010000001000000000  1 1;
0000000100000101001000010000000000  1 1;
1010010100101110011110001100001010  1 1;
1111101111100100111111100111110000  1 1;
0001000000010101010100000110111010  1 0;
1101001110110101101111101101110001  1 0;
1001100011010100000010100011100101  1 0;
0100100000011110001100110010010011  1 0;
0000000000001001100000000010010100  1 0;
0000100100001011000011010000000000  1 0;
1000100000001000000000110000000000  1 1;
0000100000000000000111000000000010000  1 0;
000000000000000000 0 00000000000001  1 1;
0000000110101010000000000000001001000  1 1;
0000000000000000000000100000100000  1 1;
Etc...
```

Appendix 4.9: Example Input Files for Program DENSITY

Input files (File_name.inp) created in notepad for a single group or divided by sex. Do not include column headings or titles. Below, there is only one "session" or survey.

Camera station codes and locations – required for all data entry formats

Station	UTM_X	UTM_Y
VOH01	749271.1006	7650068.358
VOH02	749333.5212	7650599.186
VOH03	749545.745	7651120.356
VOH04	749317.8578	7651757.134
VOH05	749806.2043	7651663.242
VOH06	750056.9424	7651180.293
VOH07	750395.6051	7650723.296
VOH08	749810.8982	7650780.468
VOH09	749308.4597	7649553.647
VOH10	749752.6581	7649832.653
VOH11	750082.4613	7650326.717
VOH12	750570.7086	7650158.59
VOH13	750596.9657	7649677.087
VOH14	750130.7628	7649408.716
VOH15	750367.3902	7648739.212
VOH16	750851.2446	7648376.684

1 Group = 1 density estimate for all animals

Session	animal ID	day of capture	place of capture
1	F02	1	VOH07
1	F010	2	VOH10
1	F011	2	VOH13
1	F011	2	VOH12
1	F015	2	VOH16
1	F09	2	VOH09
1	F010	3	VOH11
1	F015	3	VOH16
1	F05	3	VOH07
1	F09	3	VOH09
1	F010	4	VOH11
1	F010	4	VOH10
1	F013	4	VOH22
1	F016	4	VOH17
1	F05	4	VOH07
1	F01	5	VOH01
1	F01	5	VOH20
1	F015	5	VOH16
Etc			

2 Groups = males (1 0) and females (0 1) – two density estimates one for each sex

Session	animal ID	day of capture	place of capture	sex code
1	F02	1	VOH07	1 0
1	F010	2	VOH10	1 0
1	F011	2	VOH13	1 0
1	F011	2	VOH12	1 0
1	F015	2	VOH16	0 1
1	F09	2	VOH09	1 0
1	F010	3	VOH11	1 0
1	F015	3	VOH16	0 1
1	F05	3	VOH07	0 1
1	F09	3	VOH09	1 0
1	F010	4	VOH11	1 0
1	F010	4	VOH10	1 0
1	F013	4	VOH22	1 0
1	F016	4	VOH17	1 0
1	F05	4	VOH07	0 1
1	F01	5	VOH01	1 0
1	F01	6	VOH20	1 0
1	F011	7	VOH26	1 0
1	F011	7	VOH12	1 0
Etc.....				

1 Group = 1 density estimate - sex as a variable that influences the single density estimate

Session ID	animal capture	day of capture	place of covariate	sex
1	F015	25	VOH16	0
1	F015	29	VOH16	0
1	F016	4	VOH17	1
1	F016	9	VOH17	1
1	F016	24	VOH17	1
1	F019	26	VOH24	0
1	F02	1	VOH07	1
1	F02	18	VOH07	1
1	F02	19	VOH06	1
1	F02	21	VOH05	1
1	F020	15	VOH25	0
1	F020	21	VOH25	0
1	F020	23	VOH25	0
1	F020	33	VOH25	0
1	F021	13	VOH26	0
1	F021	26	VOH26	0
1	F022	12	VOH25	1
1	F022	13	VOH25	1
Etc....				