Handbook for wildlife monitoring using camera-traps

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FOREWORD

Studies on the diversity and abundance of wildlife are important to assess the status of its population in our environment. It is highly significant because local communities in Sabah still consider hunting as traditional practices. Usage of the camera trap method can help estimate the population size and density of wildlife in a forest area.

Use of camera trap technique is still new in Sabah. Various approaches have been introduced by many researchers in various locations. Its use has been adapted to various situations. This has raised the need to provide a guide for researchers who want to use camera traps in a more orderly and systematic manner in their future research. The manual is intended to document the research method based on previous experiences by many researchers in Sabah.

The involvement of local communities was given priority as most of the forests and wildlife habitat is located in the outskirts of the villages in the interior of Sabah. It is important for the local communities to understand these techniques, so that they can help the researchers or the community themselves, to estimate the wildlife population in the forest surrounding them. This knowledge is useful in managing the natural resources at village level and will be increasingly important in the future when `Tagal System' is extended to cover the forest habitat.

Preparation of this manual has taken over a year period and has undergone a series of workshops involving various agencies and stakeholders for refinement. Therefore, approaches and techniques contained in it are of value-added and appropriate to the situation in Sabah. It is hoped that this manual will provide useful guidance to interested parties and can be applied and practiced when there is an opportunity to study the wildlife using this technique.

On behalf of Sabah Parks, I would like to thank JICA for providing financial allocation to fund this project. The Wildlife Department, Forestry Department, Yayasan Sabah, Global Diversity Fund (GDF), World Wide Fund for Nature (WWF) and Indigenous Peoples Network of Malaysia (JOAS), have played their role in supporting this effort. The manual is hoped to create some value for community development in the future.

PAUL BASINTAL
Director of Sabah Parks
March, 2012

STATEMENT

For practicing wildlife management, quality data with scientific bases are prerequisite. In actual fact, however, available data are often imperfect – e.g. it is difficult to obtain precise estimate on the density and population size of the target wildlife species in a timely manner for management actions. To minimise potential errors in the management decisions, advanced techniques such as the camera-trapping method introduced in this manual will be useful. I am confident that it provides practical information for wildlife studies particularly in the wet tropics since it has been developed on the basis of pilot studies including a field work in the Crocker Range Park in Sabah, Malaysia.

Community involvement has been a critical issue in wildlife management since it concerns those who are closely associated with the concerned wildlife, in such a way as the relevant species being the sources of food and income. This manual contains a section on collaboration between researchers and local communities in hope of being a practical guide for a variety of stakeholders. I hope it will be widely used by researchers as well as wildlife managers and other practitioners.

The study was conducted by a team organized by an NGO, Hutan, under the scope of the Bornean Biodiversity and Ecosystems Conservation Programme Phase II (BBEC II). Much gratitude is extended to the following researchers: Marc Ancrenaz, Andrew J. Hearn, Joanna Ross, Rahel Sollmann, and Andreas Wilting.

Motohiro Hasegawa
Chief Advisor
BBEC Phase II (2007-2012)
Japan International Cooperation Agency (JICA)
March, 2012

References

Appendices

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PART 1: THEORIES AND CONCEPTS OF CAMERA-TRAPPING

Chapter 1: GENERALITIES ABOUT WILDLIFE MONITORING

For hundreds of years naturalists have been interested in identifying animal species, their distribution (presence or potential absence), and behaviour (social interactions, diet, etc). More recently, with species extinction rates increasing throughout the globe, it has become important to not only determine the species composition in a given area, but to attempt to gain an understanding of the population dynamics: how many individuals are living in the area of interest (population size), and is the population increasing or decreasing over time (population trend)? If a population of conservation concern appears to be in decline, other questions arise: how can the decline be stopped, and how can the population be managed better to ultimately stabilise it. To answer these questions 3 different levels of wildlife conservation-related activities need to be distinguished:

- **Wildlife Survey:** assessing wildlife presence (and possibly abundance and status) in a particular area at a given time.
- **Wildlife Monitoring:** repeated surveys of wildlife species through time in a particular area to investigate temporal changes of the populations.
- **Wildlife Management:** attempts to balance what is needed to maintain healthy wildlife populations with the needs of people.

Many methodologies for studying wildlife have been developed and an extensive literature can be found on this subject (e.g., White and Edwards, 2000; Bennun *et al*., 2002; Long *et al*., 2008; O'Connell *et al*., 2011). In general, methods are selected according to the environment, the group of species of interest, the goal of the study and other constraints that are inherent to a given project (availability of human or financial resources for example). **Invasive methods** have a direct impact on the animal (e. g. live trapping, killing for specimens, etc.), while **non-invasive methods** do not require capturing and handling animals (e.g. transect surveys, sign surveys, camera-trapping, etc.).

Studying animals in tropical rainforests is a major challenge for scientists and wildlife managers for two main reasons:

- **Animal ecology**: rainforest species generally are primarily shy and secretive by nature, and difficult to observe in the wild. In addition, animal communities of tropical and equatorial forests are highly diverse and rather complex to study.
- **Environmental variables**: in general there is low visibility in the forest; the terrain and climatic conditions are often harsh; areas of interest are usually remote and have limited infrastructure.

However, the development of modern technologies is helping to overcome some of these challenges and is allowing more precise and accurate monitoring strategies than in the past. Indeed, techniques such as camera-trapping, DNA analysis and scat detection by specially trained dogs, and the progress made in the interpretation and analysis of such data (satellite imagery, ecological modeling, etc.) make efforts in the field more rewarding than ever before.

Aim of this manual

Camera-trapping is a useful and widely used tool to study wildlife. It is generally regarded as non-invasive, it can gather information on a range of species simultaneously and continuously, over large survey areas and for several months at a time. Due to these and other reasons, it is an increasingly popular survey method, but carried out badly will not give reliable information regarding the species or area of interest.

This manual is designed to be used as a practical guide book for researchers and area managers who are planning to use camera-traps for the monitoring of wildlife in tropical forests. It is not a comprehensive review on the subject, and should not be used as such. Rather, this document is intended to be used as a set of step-by-step instructions to allow teams of field researchers to use camera-traps effectively in different situations by answering several basic questions about this methodology and pointing the interested reader in the right direction for more in-depth coverage of specific topics.

Chapter 2: BRIEF REVIEW OF CAMERA-TRAPPING FOR WILDLIFE STUDIES: ADVANTAGES AND DISADVANTAGES

2.1 Introduction: The basics of camera-traps

Camera-trapping is an increasingly popular method to study wildlife. While there are several types of camera-traps, all models have the same basic principle: a photo (and / or video) camera protected by some sort of weather proof housing, coupled to a mechanism that allows the camera to be triggered automatically when an animal moves in front of it.

There are two main types of camera-traps: analogue and digital. Digital camera-traps are becoming increasingly popular over film ones. Modern digital camera-traps usually do not have a separate camera unit, but record the photographs digitally onto a memory card. In addition, some camera-traps have the ability to record video. Camera traps can be passive (heat in motion sensor) or active (infra-red beam established across a potential animal path). In the wet tropics and in difficult terrain, passive systems are generally preferred over active ones. Some pros and cons of each type are summarised in Part 1, chapter 4.3 of the Manual.

2.2 The advantages of camera-traps

Camera-traps have the invaluable advantage of working independently of an observer once they have been set up – at least as long as their batteries and picture storage (either film, or, today, mostly digital SD cards) permit. This means that it is possible to simultaneously sample large areas for extended periods of time with relatively low personnel demands. **Working day and night**, camera-traps are ideally **suited for detecting rare and cryptic species** an observer may rarely, if ever, encounter. For example, camera-traps in Danum Valley Conservation Area, Sabah, Malaysia recorded the bay cat (*Catopuma badia*) seven times over 3,520 trap nights – although the same species was never directly observed by the researchers in this area. They are an **ideal tool for remote areas**, since they do not need to be accessed daily. Consequently, camera-traps can be used to investigate a wide range of topics:

- **a.** The simplest use of camera-traps is to **document the presence of species** within the area of interest.
- **b.** **Activity patterns and certain aspects of species' behaviour** can also be easily determined.
- **c.** Since the exact locations of camera-trap records are known, the resulting data allow for the **analysis of spatial patterns of species' occurrence**.
- **d.** Subdividing a period of continuous sampling into discrete time intervals simulates repeated sampling at each camera site. This allows the **incorporation of species detection probability** when looking at patterns of occurrence.
- **e.** Similarly, for species that bear individually recognizable marks (spots or stripes, or artificial tags), camera-traps yield the necessary **repeated individual detection/non-detection data to apply capture-recapture models** and estimate population abundance and density in a statistically sound manner.
- **f.** Last, but not least, camera-traps provide first hand material about wildlife that is ideally suited to **address the general public and raise their awareness** for a project or conservation issue. After all, a picture of an animal is much more accessible and compelling than any number the most intensive study may provide.

2.3 The constraints of camera-traps

- **2.3.1 Biological constraints**

Species/animal
Camera-traps are ideally suited to sample **medium to large sized, ground-dwelling mammals** (and some terrestrial birds such as pheasants). Small mammals, such as rodents, are often too small to be detected reliably by the cameras, or may simply move more easily through dense vegetation and thus be less likely to pass in front of a camera. Predominantly arboreal species, such as most primates or squirrels, will rarely, if ever, be detected by ground-based camera-traps. Although some species such as orang-utans (*Pongo* ssp.) may be captured by cameras the inferences that can be made from these data are limited due to the fact that camera-trapping is not the ideal tool to monitor this species. The same holds true for predominantly aquatic mammals such as otters.

Habitat
The habitat can impact the usefulness of camera-traps in several ways. Open habitats such as grasslands or wetlands, but also the relatively open understory of primary rainforest may present few obvious landscape features along which animals could predictably move. In the absence of predicted travel routes the optimal choice of camera location is unclear. In such open habitats an animal may be just as likely to walk behind the camera-trap, and outside of the detection zone, which will result in fewer detections and less efficient collection of data.

Environmental
Camera-traps work well under dry conditions and in areas of low humidity. That is not to say that they are not effective or a suitable choice in the humid tropics, but camera-life may be reduced and extra care needs to be taken when setting and checking the cameras to keep them dry. Some tips are included in Part 2, section 2.3.3.

- **2.3.2 Non-biological constraints**

High initial and running costs
An obvious limitation of camera-traps are the **high initial costs to purchase the equipment** (models range from about US$ 80 to over US$ 600 per unit, see Part 1, Chapter 4.4), as well as the **costs related to keeping the equipment running**, such as batteries, memory cards, or film development in the case of 35 mm cameras. The cost of data storage facilities such as external hard drives and equipment to download from digital cameras in the field, such as card readers, must also be considered. Transportation to the survey sites may be costlier than for other survey methods due to having to transport all the cameras. However, these costs need to be balanced against the costs of obtaining the same data with another survey method, for example, many hours of walking transects. In addition, for extremely elusive species other survey methods may prove fruitless.

Logistics and personnel
The demands of installing and checking the cameras are considerable and depend not only on the size of the survey area but also on local logistics. For example, can the camera locations be reached by car, boat or any other vehicle? Are appropriate vehicles available and is there a team member qualified to operate them? How far is the study location from where the survey team is based? Do satellite camps need to be created? If all cameras need to be accessed by walking, the overall project will take much longer than if the same survey area can be accessed by car. These, and many other logistical factors, influence how many people need to be employed to keep a camera-trap study running.

Special training
Camera-traps are fairly easy to operate, however each model has its own idiosyncrasies and so all team members have to be familiar with the models deployed, have an understanding of how the cameras work and be trained in how to set up and check camera-traps independently. Team members also have to be dedicated to the project to spend many hours reaching a particularly difficult location or trying to get a malfunctioning camera-trap to work again.

Data processing
Camera-traps may collect a large amount of data, but data need to be processed, i.e., the species recorded need to be identified and the information entered into a spreadsheet or data base before any analyses can be performed. Again, depending on the number of photographs obtained, it may need several trained people in order to process all the primary data.

2.4 Conclusion

The use of camera-traps has enormous potential for the surveying and consequent management of wildlife and can be used to answer a number of important questions. Their use in the tropical rainforest environment can alleviate the challenging conditions of surveying for cryptic and elusive species. However, the use of camera-traps is not a panacea. Careful thought must go into the planning of any camera-trap project, the question must be well defined and the available resources considered. However, a successful camera-trap project is very rewarding and may return results no other survey method would have provided.

Chapter 3: PROJECT PLANNING

Camera-traps can collect data on a range of aspects of animal ecology, conservation and behaviour. **Adequate project planning is essential** to guarantee that you collect the right data you need in order to answer your research or management questions and involves planning on several levels.

3.1 Research questions and objectives

First, you should make a clear statement about what the research question is and what the objectives of your project are, i.e., what do you want to learn from the camera-trapping data you are going to collect? The objectives of a camera-trapping study may include:

a. The species **composition of medium to large sized mammals** within the study area.
b. The confirmation of **presence of a particular species** (maybe a rare or endangered species such as a cat) in a study area.
c. The analysis of the **spatial distribution**, the **activity pattern** or the **abundance** of one or several species.

Secondly, we need to consider the timeframe of the study:

a. Is the study carried out **once** in one particular area?
b. Is it **repeated** in the same area so that you can learn about **temporal trends of a species' abundance or species richness**?
c. Is it conducted in **several study areas to compare** the results?

As discussed before, camera-traps can yield data on all of these research questions and several more, but the way you have your camera-traps collect data may vary according to your research interest.

3.2 Selection of wildlife measure

The decision of which wildlife measure to use is a key aspect of project planning. Again, this decision should ideally be dictated only by your research question(s). However, different measures require different efforts. Their usefulness and feasibility depend both on the research question as well as the logistical, financial, temporal and personnel resources available to a project.

Text box 1: Keeping track of sampling effort.

Regardless of what your research objective may be, you should keep track of the sampling effort of your study. In camera-trapping studies, sampling effort is usually expressed as the number of trap days (sometimes also called trap nights) accumulated by a camera-trap (or all traps in a survey). The number of trap days of a single camera is simply the number of days this camera was operational in the field, and the total effort of a survey is the sum of all trap days over all cameras.

Periods in which a camera did not work (because it ran out of battery power, or storage space, or was damaged, etc) should be subtracted from the effort. However, when upon checking we find that a camera-trap is not working, we do not necessarily know when it stopped. A good way to approximate this date is to use the date of the last picture the camera took and calculate the number of trap days from the day the camera was set up (or last checked) until the day the last picture was taken. Some camera-traps can be programmed to take one test picture every day, so that the last day the unit worked can be determined.

When setting up two camera-traps per station (for capture-recapture sampling), one survey day should not be counted as 2 trap days but only as 1 trap day, as under these settings both cameras together make up one sampling unit and do not accumulate effort independently. This also means that only if both cameras stopped working these days need to be subtracted from the effort.

Knowledge of the effort accumulated by camera-traps is important for most analyses. The more days a camera is working, the more likely it is to record a species, or the more pictures of a given species it is likely to accumulate. If sampling effort was exactly the same at all camera-traps, we would not need to account for it in our analyses. However, under field conditions it is rarely if ever possible to guarantee this sort of complete standardization. Keeping track of the sampling effort of each camera-trap should therefore be an integral part of any camera-trapping study.

- **3.2.1 Presence/Absence**

Research Question: Is a particular species present in our study site?

The simplest way to look at camera-trapping data is to identify species that were recorded within a sample and determine these as present, while determining any other non-recorded species as absent.

Problem - False Absence: one has to keep in mind that even with the best sampling, **failure to detect a species is not proof of its absence**. No matter what method we apply, our ability to detect species will never be perfect. We simply may not have spent enough time and effort in a study area to detect a rare species; or a species' ecology precludes its detection by our sampling methods (for example, it is much more difficult to detect a tree-dwelling species with sampling methods that focus on the ground, such as camera-traps or track surveys). We may have inadvertently sampled only parts of our study area with certain habitat features, which some species may avoid - and thereby avoid being recorded. Some of these issues can be counterbalanced by an adequate study design that covers all habitat types within a study area (to capture species with different habitat requirements) and the use of complementary survey methods (camera-traps, track surveys for ground dwelling mammals, and transect or spotlight surveys that also capture tree-dwelling mammals). Some authors provide means to 'guesstimate' the effort needed to determine a species' absence (Carbone *et al*., 2001; Tilson *et al*., 2004) but such estimates are likely to vary among study areas. In conclusion, a photographic record is definite evidence of that species' presence in the study area during the sampling period, but conclusions about the absence of a species should be avoided.

- **3.2.2 Species richness**

Research Question: How diverse is our study area in terms of large to medium sized mammals?

A large body of literature details how we can estimate the number of species that are occurring at a site even if you have failed to detect some of these species, for example with species accumulation curves (for a review see Colwell and Coddington, 1994) or capture-recapture based approaches (Boulinier *et al*., 1998). In addition to number of species you record there are several indices that describe species richness in terms of how diverse your species assemblage is. Two commonly used measures are Simpson's diversity index (Simpson, 1949) and the Shannon's diversity index (Krebs, 1989), also called Shannon-Wiener index. However, both indices need some information about the abundance of the observed species. Although studies have used relative photographic frequencies as abundance indices, we do not recommend this approach (see section '*Species where individuals cannot be identified*' below).

- **3.2.3 Distribution**

Research Question: Where in our study area/study landscape does my species of interest occur and which ecological factors influence its occurrence?

As camera-traps are distributed in space, we can also look at the **spatial distribution** of the photographic records of a species. Distribution can be studied at several spatial levels: **over large landscapes** when you want to investigate a species' geographic distribution, **but also regionally or locally**, if you want to get an idea about smaller scale habitat and space use. We can use information about the locations we sampled (such as habitat type, distance to water, distance to human settlement – anything that might be important to the species we are studying) to see whether any of these characteristics have an influence – positive or negative – on our target species being present at a sampled location. You could perform regression analysis on the data of where you did and did not detect the species, the number of photographs at each sampling point, or, for some species, the number of individuals. However, neither of these analyses corrects for imperfect detection (false absence).

An alternative is the use of so-called **occupancy models**, which **account for imperfect detection**. These models are extensively discussed in the book by McKenzie *et al*. (2006). Briefly, these models reduce your photographic count data to a binary (1/0) format describing the detection (1) or non-detection (0) of the focal species at sampling sites during repeated visits. They use this information to estimate both the probability of a site being occupied, and the probability of detecting the species in an occupied site. Thus, these models take care of our imperfect ability to detect species, which is likely to vary, depending on the species and/or sample site. Output measures are the **percentage of the total area occupied (PAO)** and the **probability of occupancy** of a sampled site, both of which may be parameters of interest for species monitoring on a larger scale.

- *Advantage:* Since the approach only requires detection/non-detection data, it is potentially less effort-intensive than actual abundance surveys (see below).
- *Disadvantage:* When monitoring occupancy or distribution over time, we may fail to detect trends in abundance that do not affect a species' distribution, that is, for example, a species may become rarer in our study site but still be found essentially at the same sampling points.

- **3.2.4 Abundance**

Research Question: How abundant is a particular species? What is the population density?

The most refined measure for wildlife monitoring is abundance or density (abundance per unit area). The ideal for any monitoring program would of course be to achieve total counts of all individuals in the population of interest. The first obvious problem is that in order to count individuals we have to be able to distinguish one from another – which unless one considers capturing and artificially marking them can only be done for species with unique features such as spots or stripes. However, we also have to consider the problem of imperfect detection. In the same way as detecting species, our ability to detect individuals in a population is imperfect. That is, we have no way of knowing for certain if the individuals we detected constitute the entire population or whether we missed some, and if so, what proportion this might be. Depending on whether or not individuals can be identified based on camera-trap photographs, approaches to obtain measures of abundance and/or density differ.

A) <u>Species where individuals cannot be identified</u>

In addition to detecting a given species at a camera station, the photographic records provide information about how many times that species was recorded there. However, unless we are able to assign records to distinct individuals, such information cannot be used to actually establish abundance.

Relative Abundance Indexes: it is conceivable that the number of records of a species should be related to its abundance and so many studies use such **record frequencies as abundance indices** or measures of relative abundance of a species in relation to others. For camera-traps, one of the most frequently used abundance index is the RAI ("Relative Abundance Index": Carbone *et al*., 2001; O'Brien *et al.*, 2003), which is based on the number of pictures of the species of interest per 100 trap nights. Another abundance index is the percentage of photos of the target species in relation to all animal photos.

- *Advantage:* Such indices are easily calculated and the reasoning behind them seems intuitive.
- *Disadvantage:* There are severe drawbacks in using RAIs, which relate – again – to our imperfect ability to detect species. Camera-traps may be better suited to pick up some species than others, depending on how, where and when they are set. For example, camera-traps are frequently set up along roads, so that we will bias our sample towards species that like to walk along roads. Thus an increase in the number of pictures of these species does not necessarily mean they are more abundant. The problem might be reduced if we only look at a single species rather than comparing several species. But even then, our ability to record this species may vary between sampling sites (due to environmental characteristics or differences in sampling), or with time (due to climate, seasonal behaviours etc.). There may be some circumstances under which the use of such indices may be reasonable. For example, if you are only interested in one species in one study area, and if you want to study trends of the species' abundance over time. If you maintain your study setup (i.e. number of cameras, sites where cameras are deployed, way in which cameras are deployed, and season in which you sample) throughout the entire study, changes in the abundance index may indeed reflect changes in the focal species' abundance. However, **there is no guarantee that detection of a species does not change over time**, and so differences in your photo-counts may reflect changes in detection rather than in abundance.

Models to estimate densities of non-identifiable species: Rowcliffe *et al*. (2008) proposed a model which estimates density from camera-trapping data of non-identifiable species, where encounter frequencies are essentially functions of the density of a species and its movement speed and rate. These **models require random placement** of camera-traps relative to animal movement (i.e. you must not target areas with known animal activity, such as roads for cats) and that **animal movement speed and rate are known** or can be estimated. **Both requirements are often unrealistic**, especially for rare and elusive species such as the ones encountered in the equatorial forests: random camera-trap placement generally results in very low picture numbers and may be logistically unfeasible; and the estimation of movement speed requires either additional telemetry data or video traps. Moving speed estimates based on footage of the latter are unlikely to be realistic, since they only represent an extremely short time window of movement.

A different approach is suggested by Royle and Nichols (2003), where the variation in detection probability of a species in space is used to estimate its abundance at each sampling point. This model is essentially a variation on regular occupancy models and only requires detection/non-detection data. A central problem with this model is how to interpret results. The model gives us **estimates of**

abundance at each camera-trap, but under most circumstances this cannot be translated into a meaningful estimate for the entire study area.

Conclusion: unfortunately, there is **no straight answer** as to what to do when your aim is to study a species where individuals cannot be identified. Researchers are continuously working on modelling approaches towards estimating density from such data. But for now, we suggest you **avoid using RAIs** whenever possible and either:

(a) consider **moving away from abundance** (towards occupancy),

(b) consider **using different methodologies** that can render individual-level data (distance sampling, non-invasive DNA sampling),

(c) if you insist on using RAIs, interpret them with care and think about what kinds of bias the issue of imperfect detection may have introduced into your data.

B) Individually identifiable species

Capture-recapture models: for species in which individuals can be distinguished, abundance is generally estimated from a sample of the population of interest using capture-recapture (CR) approaches (Otis *et al*., 1978, Karanth and Nichols, 1998). Similar to occupancy models, CR models estimate the probability of detecting an individual and use this probability in conjunction with the number of observed individuals to estimate actual abundance.

- *Advantage:* the approach accounts for individuals that may be present in the study area but never actually detected. While it requires some statistics, there are several user-friendly and free-of-charge programs available to perform CR analysis.
- *Disadvantage:* for abundance to be meaningful we need to know what area it refers to. Unless we sampled a clearly defined space such as an island or an enclosure, we need to consider that animals may move beyond the area we actually sampled, so that estimating the area the abundance calculation refers to is problematic.

Alternative – Spatial Capture-recapture (SCR) models: a recent development addressing this problem in a modelling framework are “Spatial Capture Recapture” models (SCR), which make use of the spatial information of captures to model animal movement both within and beyond the sampling grid and explicitly incorporate this movement into the density estimation (Efford, 2004; Royle and Young, 2008). There are several software packages available to run SCR models.

- *(S)CR models and population dynamics:* repeated over time, both regular and spatial CR models in combination with camera-trapping can be used to estimate parameters of population dynamics, such as survival rate or rate of population change (Karanth *et al*., 2006; Gardner *et al*., 2010).
- *Data requirements of (S)CR models:* (S)CR models are rather complex models with a set of parameters that need to be estimated with some degree of precision in order to get a meaningful abundance/density estimate. Therefore, these models require a fair amount of data. You cannot perform CR-models on data collected on a single individual. While there is no set lower limit, you should aim to ’capture’ at least maybe 5 individuals, and each of them several times, preferably at several traps. When conditions for these models can be met, they will yield the most reliable information on the size and temporal trends of a population/species.

Text box 2: Application of the capture-recapture approach to Bornean mammals.

Several species of Bornean mammals have patterned coats; the distinctive markings allowing identification of individuals from photographic data.

Sunda clouded leopard *Neofelis diardi*

Marbled cat *Pardofelis marmorata*

Leopard cat *Prionailurus bengalensis*

Malay civet *Viverra tangalunga*

Banded palm civet *Hemigalus derbyanus*

Banded linsang *Prionodon linsang*

3.3 Distribution of camera-traps in the field*:* a note about spatial autocorrelation and the spacing of camera-traps

Environmental conditions are likely to be more similar at places, and therefore sampling units, that are closer together, than at places/units that are further apart. Consequently, units close together may yield more similar data. This phenomenon is termed **spatial autocorrelation**. For CR models and SCR models, spatial autocorrelation is not a problem. Indeed, it is beneficial if the same individual is photographed at more than one camera-trap. However, if you are looking at a species' occupancy and habitat associations, you should try to avoid spatial autocorrelation. In order to achieve this, camera-traps should be spaced far enough apart that the same individual is **NOT** recorded at several traps. In addition, a random sampling design eliminates the problem of autocorrelation of landscape features affecting results. As it is seldom possible to fully avoid spatial autocorrelation, there are mathematical means to find out if your data are spatially autocorrelated and – to some degree - to account for it. If you are interested in the issue of spatial autocorrelation, look for topics such as Moran's I (Cliff and Ord, 1973), or conditional autoregressive (CAR) models (Besag *et al.*, 1991).

Box 3: Spatial autocorrelation and RAIs.

The already problematic relative abundance indices (RAI) are further complicated by spatial autocorrelation. If you study several species and one of them moves more widely (because it has larger home ranges, or it just roams large areas, such as bearded pigs), this wider-ranging species will be exposed to more sampling units than a species that has a very small home range and very restricted movements. As a consequence, you will obtain more pictures of a single individual of the wide ranging species than that of an individual of the species with restricted movements. Your RAI for the wide ranging species will be artificially inflated – your wide-ranging species will appear more abundant.

Box 4: Camera placement along trails, ridgelines.

If all camera-traps are set up along trails or ridgelines, some individuals might follow these predefined trails. Under these circumstances, sampling stations are not independent from each other. Again, the spacing between the cameras is important, as the chances that the same animal is photographed along a predefined trail is higher if cameras are spaced closer together. Adequate spacing again depends on the movement of the target species, which may be wider along such landscape features because of the ease of traveling they provide.

3.4 Duration of the study: single sampling session or repeated sampling for monitoring?

Deciding upon the duration of your study is partly influenced by:

- the objectives and research questions of your work
- the biology of your focal species (single or multiple)
- the ecology of your study site
- the resources available

Single sampling session: How long should I sample for?

If you do not want to look into temporal trends of any kind of wildlife measure, then you will most likely only sample your area(s) of interest once.

Any wildlife measure is only meaningful for a time frame in which it remains stable – during which your study system is 'closed'. The study system can be a population or a species assembly, and the consideration applies to abundance just as it applies to the distribution of a species or species composition. Boxes 5 and 6 explain what this means.

Box 5: Abundance and demographic closure of populations.

A population is termed 'demographically closed' when no individuals die or are born during a given time (generally the time of your study). If we sample a species with a fast reproductive cycle over, say, two continuous years, our estimate of abundance will contain animals that were alive at the beginning but died during the course of the sampling, and animals that were not alive in the beginning and were recruited into the population throughout the duration of the study – thus we will overestimate abundance. This situation represents a violation of the assumption of *demographic closure*.

Box 6: Movement and geographic closure.

If parts of the study population move or migrate into or out of the survey area, the population is not geographically closed but open. Such migrations may not be seasonal; they can take place on a larger temporal scale. For example, bearded pigs in Borneo are thought to migrate through large areas in irregular patterns following mass-fruiting events. That means that if the sampled area is small compared to the migration movements of the pigs, a survey one year may detect large numbers whereas a survey the following year at the same site may detect very few. This observation may be incorrectly attributed to a sharp decline in pig abundance while in truth, several groups found in the sampled area before have migrated to an area where there are no active surveys. Migration into and out of the study area violates population closure *geographically*.

As a consequence, you have to make sure that your sampling takes place within a time frame during which whatever measure you apply is unlikely to change. With rare and elusive species, you will need to find a compromise between sampling long enough so that you collect enough data to answer your research question, but short enough so that the closure assumption is not violated. The actual amount of time depends on the biology of your target species. For example, for large cats researchers generally use 2-3 months (Henschel and Ray, 2003; Silver, 2004).

Repeated sampling for monitoring: how often and at what intervals do I repeat sampling?

Of course, changes in wildlife measures over time are often the focus of management oriented studies, rather than a single snapshot in time. Note that with repeated sampling, **any single sample should still consider the issue of 'system closure'** (see single sampling session). How often you repeat a sample is in reality most likely a question of how long you can keep a long-term project running. If you want to talk about trends, you should really sample a given area several times, not just twice. If you sample an area twice, differences in your wildlife measure may very well just reflect random fluctuation and not an actual trend.

The intervals for repeated samples should be dictated again by the ecology of your species and your study area. In a nutshell, you want to make sure that **as many parameters as possible remain the same between repeated samples**. That means that, for example, repeat samples should be obtained during the same season as the first sample. Otherwise, you will not be able to discriminate whether the differences in your data were caused by the seasons or by an actual population trend.

To investigate the causes resulting in an increase or decrease in your wildlife measure it is important to record the environmental conditions carefully. In years of a mass fruiting in your study area the numbers of recorded animals might be much higher than in the years before, as a result of immigration into your study site to exploit the available resources. On the other hand, unfavourable conditions in terms of food availability might cause animals to migrate to neighbouring areas, but not reflect an actual population decline on a larger scale. Only if these environmental conditions are monitored parallel to the camera-trapping surveys can conclusions about the causes of trends be drawn.

3.5 Comparability and accuracy

How can I ensure that the collected data from several sampling periods are comparable?

As mentioned above, in repeated sampling you want to keep as many parameters of your sampling as constant as you can – the study setup, the season – so the differences you do detect in your wildlife measure can actually be attributed to population changes in time. **By keeping sampling parameters constant, you increase data comparability**. The same holds true for comparisons among different study sites. Of course, it is unlikely that the study design, i.e. the camera set up, can be completely standardized across sites. One study site may have a good road network where most of your cameras can be set up along existing roads, while others may only have few roads, so that most of your cameras are located along smaller game trails, or trails you had to establish. These unavoidable differences (but also other factors you may not even be able to observe such as differences in home range size) may lead to differences in the detection probability of your focal species. Remember that both capture-recapture models and occupancy models can account for such differences, so that estimates of abundance or occupancy will be comparable among sites. Photographic counts, such as relative abundance indices, however, may be biased by such differences in study design, to such an extent that conclusions drawn based on differences in these counts may be wrong.

How accurate does your estimate need to be?

While more accurate measures are obviously preferable, **higher levels of accuracy require larger amounts of data** (Krebs, 1989), which usually translates into larger effort and costs. If you want to be able to monitor the population trends of a rare endangered species and want to pick up even small changes in the species' abundance, your estimates of abundance need to be very accurate. Of course, you do not necessarily know beforehand how much effort you will have to dispense in order to collect enough data and reach a particular level of accuracy. **It is advisable to perform some preliminary study** to get an idea of the amount of data you will collect with a certain amount of effort to help you with your project planning. In reality, often other limitations, such as money, time and equipment will dictate the amount of data you eventually collect. But thinking about these issues will help you to understand the ideal you should be striving for, and the limitations you may encounter.

3.6 Characteristics of the target species

Ideally, you should obtain some basic information about your target species before planning your study. This basic information can originate from literature searches (articles published in peer-reviewed journals; unpublished reports and grey literature), from interviews with people who know the area or from a preliminary study. Consider that for many areas available species lists are inaccurate (as species were misidentified) and/or incomplete.

It helps to have a general idea about whether the species of interest is **rare or abundant** in your study area. If it is rare, you may have to dispense considerable trapping effort to gather sufficient data for an analysis; if it is very rare you may even have difficulties detecting it at all, in which case the analytical options are limited.

If you know about the **habits of your target species** and want to increase the number of records, camera-traps can be set up in a way that maximizes the probability of the focal species being captured. For example, in capture-recapture studies of large cats, which often use roads as travel routes, camera-traps are preferentially installed along roads. Another example is the placement of ground based camera-traps at canopy gaps. These gaps force predominantly arboreal species such as the binturong to descend to the ground and thereby increase their chances of being photo-trapped. This type of targeting may be risky when you aim to study several species, because your setup may favour one species more than the other – that is, your study setup introduces differences in the detectability of your study species. Again, approaches that account for imperfect detection reduce this problem, but if only photographic counts (such as RAI) are considered the species you targeted with your camera setup will be overrepresented, while the other species may be underrepresented.

The species' **ranging behaviour** is important for study design as well. If you use CR models, your network of camera-traps should not contain gaps large enough to encompass the entire home range of an individual (Otis *et al*., 1978). In contrast, for analysis with occupancy models, camera-traps should be distributed so that a home range does not contain more than one camera to avoid autocorrelation of detection/non-detection data (see *Note on autocorrelation* above). For both assumptions you need to know something about the movements of your target species. These assumptions also imply that **a setup that works for one species does not necessarily work for another**.

3.7 Characteristics of the study area

For simplicity, we will only consider the case of a single study area, but the same principles hold true for studies in several areas.

- **Study area versus sampled area:** first, in many cases your study area will be too large to be sampled entirely. As a consequence, you may have to choose a part of the area to actually conduct your study in – we will refer to this area as the **sampled area**. If your aim is to learn something about the entire study area, your sampled area has to reflect the entire study area and its set of environmental conditions, such as:
    - cover all habitat types, including altitudinal variation
    - cover all types of human impacts
- **Remoteness**: you need to consider how far you and your team will be based from the actual study or sampled area, or whether it is possible and advantageous to camp in the field.
- **Access:** some parts of the study area may be difficult to access. Yet, in order to achieve representative coverage of the study area, such regions should be included in the sampled area. In this case, include extra time and possibly extra equipment and personnel when planning for the installation and checking of these hard-to-access camera-traps.
- **Flooding:** parts of the study area may be flooded and inaccessible during parts of the year, or rising flood waters may prevent access to cameras.
- **Heat and humidity:** it is likely that any study area in the tropics, even at high altitude, will be exposed to high temperatures and high levels of humidity for prolonged periods of time. Some parts of the study area may be exposed to higher levels of heat, for example, very degraded, open areas while areas under a closed canopy may be cooler. While camera-traps can function in these less than ideal conditions their effectiveness and working life may be reduced. See Part 2, section 3.1. for information about reducing humidity related problems.
- **Human use:** finally, the study area may be used by people for a variety of reasons, so that interference or theft of camera-traps could become an issue.

Knowing your study area, the difficulties it poses to your study and the risks the equipment may face will largely help you to plan your camera-trapping study.

3.8 Capacities (man power, equipment, funding etc.)

- **What are the required capacities?**

We said at the beginning of the project planning section that ideally, your research question should guide your study design. Still, in reality, **often, the capacities you have**, in terms of man power, funding or equipment, **will limit or even decide upon your study design**.

During field work
Some wildlife measures require a large amount of data. For example, abundance and density, and trends of these measures over time, require data on many individuals sampled over a considerable area. If you only have a handful of cameras at your disposal, you will not be able to monitor the population dynamics of rare species. If you have many cameras, sufficient funds are necessary to pay for vehicles and staff to install and check them and batteries to keep them functioning. If the intention is to monitor a population over time, you have to consider securing funding over a prolonged period of time.

After field work
Even when field work is over, you will need man power to process the data camera-traps accumulated. Remember that data processing, just as camera installation and checking, requires some degree of training and needs to be supervised in the beginning (see also the next chapter).

- **Project planning – Conclusion**

In summary, we believe that the best way of planning for all these aspects of a camera-trapping study is to **implement a small preliminary pilot study** – this will familiarize you with your study species and area and give you an idea of the amount of data collected with a certain amount of effort. If you are uncertain about whether the data you intend to collect will answer the question you have – consult a biostatistician.

3.9 Decision tree: What wildlife measure should you use?

The following decision tree aims to provide you with guidance as to what wildlife measure to use given your study objective, and points you to the chapters in this manual that will provide more information on background and capacity requirements. We do not discuss the pros and cons of each measure within this decision tree – thus, make sure you read the more detailed introduction to the measure you want to use in Part 1 of the manual.

START

SINGLE SPECIES → GO TO 1

MULTIPLE SPECIES → GO TO 2

1. SINGLE SPECIES FOCUS - WHAT IS YOUR RESEARCH QUESTION?

1.1 Is my focal species present in the study area?

Measure: Presence

Method: No specific design or analytical approach

Description: Part 1, Chapter 3.2.1

Capacity requirements: Part 2, Chapter 1.2

1.2 How is my target species distributed in space? Where is it present?

Measure: Distribution, occupancy

Method: Preferably occupancy models, else regression models

Description: Part 1, Chapter 3.2.3

Capacity requirements: Part 2, Chapter 1.3

1.3 What is the size/density of my target species' population?

Measure: Abundance, density

1.3.1 Can you distinguish individuals of your target species?

Yes → ***Method***: Preferably spatial capture-recapture models, else non-spatial capture-recapture models

Description: Part 1, Chapter 3.2.4 b

Capacity requirements: Part 2, Chapter 1.4

No → go to 1.3.2

1.3.2 Is a random study setup relative to animal movement feasible and is animal movement speed and rate known or can be estimated?

Yes → ***Method***: Random Encounter Model

Description: Part 1, Chapter 3.2.4 a

Capacity requirements: equivalent to large occupancy study – Part 2, Chapter 1.3

No → ***Method***: Royle-Nichols model

Description: Part 1, Chapter 3.2.4 a

Capacity requirements: equivalent to large occupancy study – Part 2, Chapter 1.3

1.4 How does the distribution/abundance/density of my target species change over time?

Measures: Trends in distribution/abundance/density

Methods, Descriptions, Requirements: See 1.2 (distribution) and 1.3 (abundance/density) and repeat over time; for formal extension of models to open-population situations see primary literature

2. MULTIPLE SPECIES FOCUS - WHAT IS THE FOCUS OF YOUR RESEARCH?

2.3 Which species are present in my study area?

Measure 1: Presence

Method: No specific design or analytical approach (but use additional surveys to complete presence list: Part 2, Chapter 5)

Description: Part 1, Chapter 3.2.1

Capacity requirements: Part 2, Chapter 1.2

Measure 2: Species richness

Method: Diversity Indices

Description: Part 1, Chapter 3.2.2

Capacity requirements: Part 2, Chapter 1.2

2.4 How do the distributions of my focal species relate to each other?

Measure: Distribution, occupancy

Methods, Descriptions, Requirements: See 1.2; for formal model extension to multi-species studies see primary literature

2.5 What are the sizes and densities of all my focal species' populations?

Measure: Abundance, density

Methods, Descriptions, Requirements: See 1.3 for single-species approach and apply to all species

Chapter 4: PERSONNEL AND EQUIPMENT

4.1 Personnel requirements

The personnel requirements of a camera-trapping project can be quite demanding. These requirements will vary from project to project and they are also likely to vary with different stages of any project. Certain aspects of the project will also require some specific training. All team members will have their own strengths and skills.

- **Project leader**: this person will spend little time in the field, but will make the initial decisions regarding the project planning and so some experience of the field site is vital. It is likely that this person will have conceived the project and secured funds and so a large portion of his/her time will be spent writing reports and analysing data.
- **Field coordinator**: it is imperative to have a reliable field co-ordinator (although under some circumstances this role may be taken by the project leader). This person will spend more time in the field overseeing the choice of camera sites, co-ordinating camera deployment and retrieval and will make day-to-day decisions about the project. Therefore, this person must have some understanding of the research; for example, they need to understand why cameras are spaced a given distance apart, why it may be important to survey continuously, or why a certain size of study area has been chosen. They do not necessarily have to have a good understanding of data analysis.
- **Research assistants**: as a minimum, two research assistants are also needed. The research assistants will undertake the majority of the camera checks and therefore need to be able to set up and operate the camera-traps without supervision. They should be able to make decisions in the field, such as whether a malfunctioning camera-trap should be brought in or whether it would be more worthwhile left in place, or whether a camera-trap should be moved slightly. All team members need to be physically fit and be organized so that there are charged or new batteries available when needed etc.

Box 7. Camera-trapping at Ulu Segama Forest Reserve, Sabah.

A camera-trap survey of Ulu Segama Forest Reserve was conducted in 2007. There were 22 camera stations of which 16 could be easily accessed by car, the other six were accessed by walking, the furthest station requiring about one hour's walk to reach it. However, it was possible to locate all cameras along roads or existing trails. The cameras were spaced 1.5 – 2.0 km apart and covered an area of around 60 km^2. This project was managed successfully with a team comprising of two leaders (who both spent considerable time in the field), two full time research assistants and a volunteer assistant. With easy access to camera sites and a relatively large team, all cameras were checked at least once each week of the survey and there was no loss of data from camera malfunctions, dead batteries, full memory etc. The survey ran for three months, cameras were deployed over 1-2 weeks and retrieved in five days.

Box 8. Camera-trapping at Tabin Wildlife Reserve, Sabah.

Tabin Wildlife Reserve was surveyed with camera-traps in 2009. A total of 75 camera sites were deployed, covering just over 160 km^2 with only six sites easily accessible by car, the remaining 69 sites could only be accessed by walking and some required overnight camping. In addition, there were very few existing trails in the forest and a network of new trails needed to be cut. A team comprising of two leaders, one field co-ordinator and two full time assistants managed the majority of the field work. Three or four additional team members were employed during the phase of trail cutting at the beginning and again at the end to ensure more rapid camera retrieval. Nevertheless, it was not possible to check cameras as often as desired and some trap nights were lost due to malfunctions or battery life not being as long as expected from previous surveys.

4.2 Transportation

Every survey area will have its own unique features that dictate the best form of transport to use. In addition, aspects of the survey team, such as the number of people and abilities (including licences) to operate certain vehicles will influence the transport used. Most surveys will make use of a car at some point, however in the absence of maintenance, logging roads quickly degrade, especially bridges, and it is useful to conduct a mapping survey of the area, determining which roads are suitable and safe to access by car. Often old logging roads can only be accessed by motorbike, or ATV (All Terrain Vehicle), the obvious disadvantage being that less equipment and people can be transported at any one time. It may also be very costly and difficult to obtain parts needed for the maintenance of an ATV in more remote areas and this must be taken into account during project planning. If the survey area is in riverine forest, it is logical to locate the majority of the camera-traps so they can be accessed from the river and reach the sites by boat. Or it may be useful to use a small inflatable boat to cross a river, so saving time walking to a point where it is safe to cross. Whatever mode of transport is decided upon for any given survey, the cost of buying or hiring a vehicle, the cost of fuel (which may become considerable) and maintenance, and possibly the cost of hiring an extra team member with specific skills, must be included at the project planning stage.

Figure I. *A vehicle allows easier access to camera sites and transportation of equipment only if the roads are safe and passable by car; often old logging roads are only accessible by motorbike*.

4.3 Camera-trap characteristics

There are many different models of camera-trap commercially available and an important step of project planning is to conduct a thorough review of the current models and to choose appropriately. Many projects inherit equipment from previous projects or equipment may be donated directly from a funder and in these cases there may not be a choice to make. However, the overall goals and logistical constraints of the project will often dictate which type of camera to choose. Here, we review the advantages and disadvantages of the main types and features of camera-traps.

- **Passive or active trigger**: early camera-traps were triggered by trip wires or track plates. Today, irrespective of the operational mode, we can distinguish between two triggering systems:
    - **Passive:** The camera is equipped with a heat in motion sensor that triggers the camera when an object with a temperature different to the ambient temperature moves through the sensor's field of detection. Passive systems may not trigger if the animal's body temperature and ambient temperature are similar. Direct sunlight, sun-warmed vegetation, and sometimes even high ambient temperatures may cause false triggers with this system.
    - **Active**: In an active system, an infrared beam is actively established across the potential travel path of the target animal(s) and the camera is triggered when this infrared beam is broken. This system provides more flexibility in setup (the height of the beam can be adjusted for the target species, for example) but is triggered by anything breaking the infrared beam, including vegetation, rain or large insects. Also, since the trigger comprises separate units (emitter and receiver), the equipment becomes heavier and more cumbersome to transport and also requires two supports one extra to fix the trigger units.

  In the wet tropics and in difficult terrain, passive systems have several advantages over active ones. Under a closed canopy falling vegetation is common and will trigger active systems whereas passive cameras will be largely unaffected. Most surveys in tropical forests involve accessing remote areas, often by walking, and thus the advantages of the smaller and lighter passive units may be particularly relevant.

- **Digital or film:** the next choice to make is whether to purchase film or digital cameras. Film cameras tend to be cheaper than digital, although there are now some low cost digital models on the market. However, once the cost of buying films and having them processed is taken into account, there may not be much difference in the overall cost. In addition, film cameras take a maximum of 36 frames and so should only be used in situations where it is possible to check the cameras frequently. The number of photos that a digital camera-trap can store depends on the file size of the images and the capacity of the memory card used, but as a minimum they should be able to store 250 photographs. The advantage of film cameras is that there is virtually no delay between the camera being triggered and the photograph being taken as the camera is always on. Digital models "sleep" to save battery power in between photo-events and so once the camera is triggered there may be a slight delay as the camera "wakes up". However, this delay is minimal in modern digital models, particularly among the more expensive models.

- **White or infrared flash**: some digital cameras have a white flash and some have an infra-red flash. The advantage of the white flash is that very clear photos are taken at night-time, whereas the infrared flashes may be more likely to give blurry images. This might not be a problem if the aim of the study is to document species presence, however it can be very problematic to identify individual animals from their coat pattern with a blurry photograph.

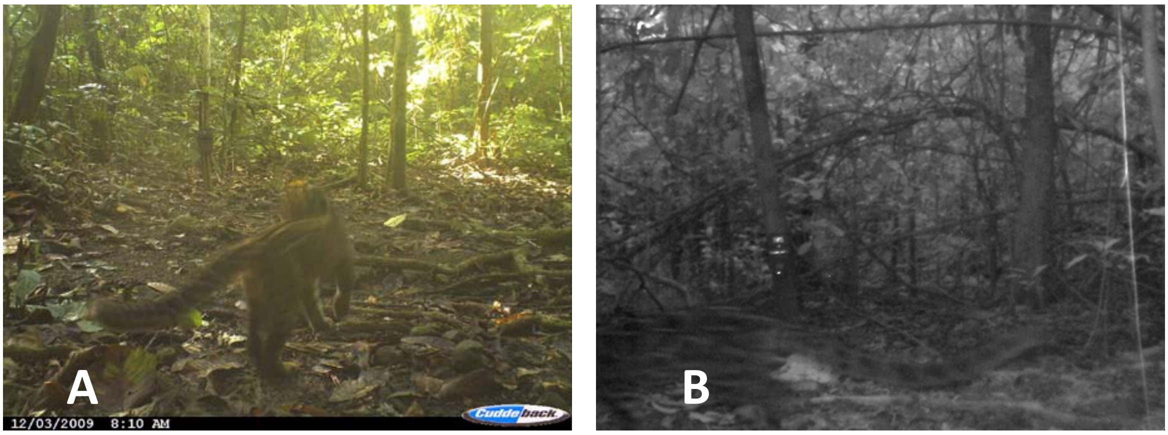


Figure II. *Image A shows a marbled cat and B a clouded leopard. Although it is possible to identify both to species, the animals are blurred and the coat patterns difficult to identify. Image A was taken with a model using a white flash, however the flash did not trigger. B was taken with an infrared model and although the flash has triggered the resulting image is still too blurry to enable individual identification.*

A disadvantage of the white flash is that the bright light may cause a behavioural response in the animals so that they start to avoid the camera-traps; this will reduce future detection probabilities and will restrict appropriate data analysis methods. A further possible disadvantage is that the white flash is more noticeable to any people who may be using the forest at night.

- **Photo or video trap**: it is also possible to use video camera-traps or to purchase models with a video setting. These tend to be more expensive than the equivalent model without the video setting, but have the advantage of recording behaviour that may not be apparent from a still image. Additional individuals may be recorded, for instance a cub following its mother, and due to seeing the animal in different positions it may be easier to identify a small animal or one that is at some distance from the camera. The disadvantages are that each file is larger than a still image, so fewer records can be stored on the same capacity memory card, the batteries will be used more quickly and the images are of lower resolution so it may be more difficult to identify the animal. Further, in some models the delay before the video starts is longer than for a photograph, thus smaller fast moving animals are more likely to be missed.

- **Minimum time between photos**: all models will have a minimum time between photos, at which time the flash is recharged (for white flash models) and the data written to the memory card. During this time a passing animal will not be able to trigger the camera. If the time between photographs is too great, information such as whether animals are travelling in pairs or groups, or whether there are young animals with adults will be lost. It is therefore preferable to choose a model in which this time is as short as possible, or which can be adjusted to suit your requirements. The only disadvantage of a short time lag between events is that the memory card may become full with images of a single animal that has lingered in front of the camera, such as if the camera is set at a salt lick or fruiting tree, or if the animal is simply curious about the camera. Large memory stick sizes today mean that this is less likely to be a problem.

- **Using different camera models in one survey**: most projects will use different types of cameras and under these conditions, the more reliable units are set at the most promising locations and the units that need the most frequent attention are set at the sites that are easiest to access. However, using different models may introduce an additional source of variation in detection probability – a slow camera-trap may fail to record small species/individuals that a fast model is able to pick up. Ideally, you should test that your cameras work equally well for your target species.

- **Testing your potential models**: whenever possible buy one or two units to test in the field before purchasing the full amount required, or at least contact people who have used camera taps in similar conditions. Sometimes cameras will perform very well for several months, but do not have the longevity required for long projects.

Table I: some pros and cons of different types of camera-traps.

Film cameras	**Digital cameras**
Relatively cheap	Relatively expensive
Cost of film and processing can become considerable	Cheaper over long term
Wait for processing	Instant results (including test photos)
Faster start-up	Slower start-up
Max 36 photos (more labour intensive)	Upwards of 250 photos (less labour intensive)
Only record day and time (printed)	Records time and date
Fewer photos per battery life	Many more photos per battery life
Active infared	**Passive infared**
Relatively expensive	Relatively cheap
Height of beam can be adjusted, so avoiding smaller, non-target species	More difficult to avoid non-target species
More likely to be falsely triggered by rain or large insects	More likely to be falsely triggered by sun-warmed vegetation or shadows moving across the ground
Relatively more awkward to set up	Relatively easy to set up

4.4 Current camera-trap manufacturers and prices

There is a growing number of camera-trap manufacturers that regularly come out with new camera-trap models. It is therefore almost impossible to provide an up-to-date account of models and prices, since ***both constantly change***. Therefore, here, we give an overview of some of the most frequently used manufacturers and their current (as of late 2011) price ranges for different camera-trap models. We cite some prominent features of the current models, but there are too many models and each model has too many details to provide exhaustive descriptions. We further provide links to the manufacturers as well as to some online stores selling camera-traps. These can be visited to see which specific models are available and how much they cost.

Remember that available models and prices will vary with time and by seller. Before you buy, inquire with the seller/manufacturer about warranty and repair service; for example, manufacturers may sell models they no longer produce for a special price but may not be able to repair them any longer**. We recommend purchasing a small number of camera-traps first to test them under your specific field conditions, and only proceed to buy a larger number if they performed adequately.**

- **Bushnell**

URL: http://www.bushnell.com
Current models:
Trophy Cam – digital camera-trap, available with white or infrared flash, can take videos with sound
Price: from 200 to 300 US$, depending on features

- **Camtrakker**

URL: http://www.camtrakker.com/
Current models:
MK-10 – digital camera-trap with both white and infrared flash in the same unit, come with a 3-year warranty
Price range: 400 – 550 US$, depending on features

- **Cuddeback**

URL: http://cuddeback.com/
Current models:
Attack – new 2011 series; digital camera-trap with white or infrared flash; video options available
Price range: 200 - 250 US$, depending on features
Capture - digital camera-trap with white or infrared flash
Price range: 150 – 200 US$, depending on features

- **Reconyx**

URL: http://www.reconyx.com/
Current models:
HyperFire®Professional – this is their research series of camera-traps, uses infrared flash, can take sequential pictures at near-video speed
Price range: 450 – 650 US$

- **Trailmaster**

URL: http://www.trailmaster.com/
Current models:
Trailmaster has many models that fall into three broad categories:
Active infrared models – Infrared beam can be set up separately from the camera
Price range: 200 to 460 US$
Passive infrared models – passive infrared sensor
Price range: 130 – 180 US$
Video models – for high quality video monitoring
Price range: 600 – 700 US$

- **Wildview**

URL: http://www.wildviewcam.com/
Current models:
X2IR, X5IR, X8IR – infrared flash, can take short video sequences, X2IR cheapest model currently on the market
Price range: 80 – 150 US$

- **Other brands**

The manufacturers below also produce camera-traps within the same general price range. This is likely not an exhaustive list:
Covert (http://www.dlccovert.com)
Leafriver (http://www.myleafriver.com)
Leupold (http://www.leupold.com/)

Moultrie (http://www.moultriefeeders.com/catalog.aspx?catid=gamecamera)
Plotwatcher (http://day6outdoors.com/)
Primos (http://www.primos.com/landing_page2.aspx)
Recon (http://www.reconoutdoors.com/features.htm)
Scoutguard (available through sellers below)
Spypoint (http://www.spypoint.com)
Stealth Cam (http://www.stealthcam.net/)
Uway (http://www.uwayoutdoors.com/)
Wildgame (http://www.wildgameinnovations.com)

- **Sellers**

You can buy a range of models through these – and many other – sellers. On their sites you may also find customer reviews and model comparisons:
Cabela - http://www.cabelas.com
HCO - http://www.hcodealer.com/
TrailcamPro - http://www.trailcampro.com
Amazon – http://www.amazon.com
Fifield Seed&Feed Store - http://www.fifieldseednfeed.com/

4.5 Additional equipment

In addition to the camera units themselves, there is a lot of extra equipment that needs to be acquired, either borrowed or written into the funding proposal during the project planning stage. This includes, but is not limited to:

- **Field equipment:**
  - ✓ GPS units
  - ✓ Notebooks or data sheets and pens/pencils (pencils are better in the rain)
  - ✓ Spare batteries in battery boxes (batteries discharge if they touch each other)
  - ✓ Card readers or spare memory cards. Spare memory cards are the better option. If the data are all downloaded in the field and the memory cards formatted, the only copy of those data are on the card reader until the team return to base camp. Card readers can, and do, malfunction
  - ✓ Silica gel in suitable containers (film canisters with tiny holes drilled in work well if there is room in the camera case)
  - ✓ Umbrella to keep the cameras dry during checking in the rain
  - ✓ Cloth to dry the unit before opening and to clean the lens if needed
  - ✓ Watch (some cameras need the date and time re-setting if the batteries run out, alternatively use the time on the GPS)
  - ✓ Vegetation cutters/parangs to re-clear the area in front of the cameras
  - ✓ Specific equipment to open the cameras: e.g. spanners, screwdrivers, padlock keys
  - ✓ Spare camera-traps, if possible to replace damaged or broken units
  - ✓ Equipment to re-locate a camera-trap if necessary e.g. mallet, spare screws, wire
  - ✓ Camping equipment (if needed)

- **“Office” equipment:**
  - ✓ Laminated map of the study area showing camera-traps
  - ✓ Laptop/PC and suitable software
  - ✓ Data storage facilities e.g. external hard drives and **backup copies**
  - ✓ Battery chargers if rechargeable batteries are used (rechargeable tend to be cheaper over the long term, but have a higher initial cost, they also do not last as long in the field)

PART 2. PRACTICAL ASPECTS OF CAMERA-TRAPPING

Chapter 1: PROJECT DESIGN

Introduction

This part of the manual provides further practical advice regarding how to design and implement your camera-trapping study. We will recommend a standardized approach for wildlife monitoring in Sabah for three measures: a) presence, b) distribution and c) abundance for species in which individuals can be distinguished. Due to the limitations discussed in Part 1, Chapter 3.2, we will not address measures of relative abundance. Based on our own practical experience we provide advice regarding the likely personnel and equipment requirements for each of these three approaches. Nevertheless, we would like to point out that these estimates largely depend on your study area, and in some regions actual resource requirements may differ markedly from those suggested here. Again, a preliminary pilot study will give you an idea of what to expect in your particular study area.

1.1 General requirements

- **Field coordinator**: it is essential that the field coordinator should be present in the field for the full duration of both the pilot study and the initial camera-trap set-up phase. The field coordinator will be able to provide guidance during these periods and will also gain first-hand knowledge of the intricacies and site-specific logistical pressures involved. We also suggest that the field coordinator is present in the field for up to 50% of the initial data collection phase.

- **Camera-trap set-up**: the actual spatial distribution of your camera-traps will vary according to the specific measure that you choose to investigate (see below). Nevertheless, regardless of the measure of interest, given that the species targeted with camera-traps are usually highly mobile, setting camera-traps closer together than 1km will rarely be necessary or advisable. Furthermore cameras should be distributed over an area (preferable a square) as opposed to set up along a line or transect, as most analyses require an area based approach.

1.2 Requirements to assess SPECIES PRESENCE

- **Aim:** to compile a list of medium to large terrestrial mammals present in your study area.

- **Limitations:**
    - Provides no information about distribution, abundance, or population trends.
    - High chance to miss rare species (depending on your survey effort) or species with specific survey requirements (e.g., strictly arboreal species such as gibbons or strictly burrowing species such as moles). Consider also applying complementary survey techniques (see Chapter 5).

- **Equipment:** preferably 10+ camera-traps, but smaller numbers can also provide useful information. A minimum of one handheld GPS unit.

- **Personnel requirements:** a minimum of one field coordinator and one or two research assistants, the latter being required only if the field coordinator is unavailable to work in the field. Note, for safety reasons a minimum of two field personnel should be in the forest at all times. If more cameras are used additional staff may be needed.

- **Set up options and requirements:**
  - Single camera-traps can be set up at each station.
  - Preferably cameras should be stratified among the different habitat types present in the study area, to ensure that as many species as possible are exposed to trapping.
  - Capture probabilities should be maximized (e.g. placing cameras along roads, trails ridgelines, salt-licks etc.). Baits can also be used to attract animals.

1.3 Requirements to assess DISTRIBUTION / OCCUPANCY

- **Aim:** to estimate the percentage of study area/landscape occupied by target species and/or understand factors that influence its occurrence.

- **Limitations:** this does not provide information on abundance.

- **Equipment**: at least 10 cameras if your target species is relatively easy to detect; otherwise (and preferably) at least 20. A minimum of one handheld GPS unit.

- **Personnel requirements**: a minimum of 1 field coordinator and 2-3 research assistants (depending on the number of cameras).

- **Setup options and requirements**:
  - Single cameras can be set up at each station.
  - The study area should be **divided into grid cells or blocks of habitat (or, in a landscape, habitat fragments/patches)** and camera-traps should be deployed so that they can determine presence within each of these sampling units.
  - Depending on species and the size of your sampling unit, you may want to deploy several cameras per unit to achieve better area coverage and detectability (preferred for very rare species).
  - To avoid spatial autocorrelation**, sampling unit size should be at least as large as a home range**. If you have no information on species home range, we suggest a minimum size of 2 km^2 for smaller mammals and 10 km^2 for larger mammals.
  - There is no need to sample all grid cells in your study area, but your sample of **grid cells must cover a representative portion of the area** (i.e., represent all environmental conditions).
  - You should cover **at least 20 sampling units**. Traps can be shifted from one sampling unit to another to reduce equipment needs, but they have to stay at one site long enough to collect an adequate amount of data. For the rare and elusive forest carnivores we suggest at least six weeks of sampling of any given spot. If your study species is detected easily, this amount of time could be reduced to three weeks. Your overall study duration should not be longer than 3 months (see above).
  - In addition, for each grid cell you need to collect the information on environmental covariates you want to use in the model (see Part 2 Chapter 5 on vegetation surveys). Recall that occupancy refers to areas, and your habitat covariates should therefore adequately describe the entire area of the sampling unit, not just the specific point location of your camera-trap.

1.4 Requirements to assess ABUNDANCE

- **Aim:** to estimate abundance and population density in a study area.

- **Limitation:** this works only for species where individuals can be distinguished (or in populations where a portion of individuals is marked).

- **Equipment:** a minimum of 40 cameras (20 pairs), although if the species of interest is easily detected 20 (10 pairs) may suffice.

- **Personnel requirements**: minimum 1 field coordinator and up to 4 research assistants (depending on the number of cameras).

- **Setup options and requirements:**
    - Two traps per site need to be deployed to photograph both flanks of a passing animal.
    - Trap spacing should be tailored to your target species and smaller than the home range diameter of a breeding female (usually the smallest home range in the population). For many species of small carnivores, for example the mobile cats, 1 km should be adequate, but some species like the Malay civet may require a trap spacing of 0.5 km.
    - Trap setup can either follow a systematic grid, adapted to local logistics, or you can divide your study area into grid cells smaller than the species' home range and place at least one camera station in each cell.
    - The trapping grid should be large enough to encompass several individuals to meet data requirements. As in occupancy, traps can be shifted to achieve greater area coverage, but traps should remain in one site long enough to collect adequate data.
    - We recommend sampling at least 20 stations.

Text Box 9: Requirements for conventional and spatial capture-recapture models.

To estimate density with **conventional capture-recapture models**, you need to estimate the effective sampled area. Usually, this is done by obtaining some estimate of movement from the camera-trapping data itself and applying this distance as a buffer to the camera grid (see Chapter 4.2). This approach has two shortcomings:

1. Our knowledge of movement is limited by the trapping grid. To adequately capture individual movement the trapping grid therefore has to be large – rules of thumb say **the grid should be at least 4 times the size of the average home range** (Bodrup-Nielsen, 1983; Maffei and Noss 2008)**.**

2. **Density becomes a function of the buffer width**, so that studies determining buffers in different ways cannot readily be compared. Additionally, **the trap array cannot have "holes"** that is, an area without any camera-traps large enough to contain an entire home range (Karanth and Nichols, 1998).

Since spatial capture-recapture models explicitly model animal movement and circumvent the need to estimate the effective sampled area, they are **more flexible in terms of study design** (Royle and Young, 2008). They can cope with the situation when some of the grid cells have no cameras in them. The trapping grid should not be too small compared to individual movement, but since estimates of movement are model based, the grid does not have to cover several times the average home range, as long as the overall amount of data (i.e. the number of individuals and recaptures at multiple locations) is sufficient.

Chapter 2: CAMERA SET-UP

2.1 Choice of camera locations

Regardless of the statistical framework employed, the primary aim of any camera-trapping project is to obtain photographic records of the species, or group of species, of interest. The success or failure of this is largely dependent on camera location in relation to the biology of the target species. Many rainforest mammals exist at low population densities and therefore cameras should be placed at locations chosen to maximise capture probability. There are two main steps to choosing the camera locations: firstly, in the office, and secondly, the fine-scale placement during which decisions are made in the field.

- **2.1.1 In the office**

The use of topographic maps and satellite imagery, including computer software such as Google Earth are invaluable at this stage. The identification and location of habitat features such as ridge lines and rivers can help determine camera placement and also result in more efficient and rapid camera deployment. If the goal of the survey is to research animal use of a particular feature, such as a salt lick, or use of a watering area, it is necessary to know where such features are and how they relate to each other spatially. Depending on the particular question being asked, it may also be desirable to base the placement of a camera according to its distance from a particular habitat feature, such as forest edges, rivers or human habitation.

Careful scrutiny of maps of the study area is therefore an essential first step. Proposed camera locations can then be plotted on the map and re-plotted as necessary to achieve the desired size of survey area, camera density and coverage of habitat features. It is also enormously useful at this stage to plan the access to each camera location and to make the best use of features such as roads, existing trails and river access points in the study area. Once the camera locations are chosen they need to be uploaded onto a GPS unit to aid location in the field.

- **2.1.2 In the field**

Once in the field it is necessary to make some adjustments to the chosen camera locations. When approaching the location stored in the GPS unit it is important to be observant to the surrounding forest and to notice habitat features such as small ridge lines or streams that may not have been shown on the map. It is vital to walk beyond the provisional camera location and to assess the habitat there also. How much deviation from the proposed locations depends on the desired camera spacing; if cameras are to be placed 1-2 km apart then placing a camera 100-200 m away from the suggested point is acceptable, if a smaller overall grid is used with tighter camera spacing then there is not so much leeway. Most camera-traps are designed to be fitted onto a tree and therefore, the presence or absence of trees of suitable size may dictate the exact camera location. In some areas this may cause bias and so it is advisable to consider alternative methods of camera attachment, such as carrying stakes into the field.

Knowledge of the target species (e.g., its use of salt licks, mud wallows, trails or roads; what its prints or scats look like) is essential and it is logical to place a camera where sign of the target species is seen. In the absence of animal sign, it is useful to target animal trails, existing human trails and especially areas where trails intersect one another. Other productive areas are river crossing points, ridgelines, or where a trail becomes narrowed due to cliffs on either side. Targeting a camera at a fruiting tree will give good results for frugivorous species, which may in turn attract carnivores into the area. Once the actual camera locations are chosen it is vital to remember to store the location in the GPS and on paper, and to update the map accordingly on returning from the field.

2.2 Camera set-up

The actual fine-scale set-up of the camera-trap in the forest can be as important as the choice of overall location with regard to the likelihood of obtaining a photo capture of your target species. The exact set-up is dependent on the topography of the surrounding land, camera model and target species.

- **2.2.1 Camera height**

The height that the camera is fixed is in part determined by the target species. Passive infra-red cameras are a common choice but rely on sensing the body heat of an animal as it passes the camera. The camera is, therefore, most likely to trigger if the area of sensitivity is aimed at the largest part of the animal's body, in most instances this will be the flank. For small carnivores setting the camera so the sensor is 30-40 cm above the ground gives good results. If the aim of the study is to obtain records of large animals the cameras can obviously be set higher, but smaller species might be missed. On the other hand, larger mammals are usually also picked up by cameras at a lower height and therefore this might be more useful to obtain data on a range of species simultaneously. Sometimes it may be desirous to set the camera high to prevent the batteries or film being used rapidly from photographs of smaller, non-target species, however with good quality batteries and high capacity memory cards in digital cameras, this will usually not be a problem. If there is a risk of flooding in the survey area there may be advantages in setting the camera higher than the anticipated river level and angling the camera towards the ground. However, the disadvantages of this set-up are that it is more difficult to target the area of sensitivity, the resulting photographs are not so useful for identifying individuals as the flank does not usually show and it is more difficult to obtain demographic data such as the sex of the photographed animals.

- **2.2.2 Camera angle**

Whenever possible choose a camera location where the ground is relatively flat. However, in many tropical forest areas the ground is not flat. It may slope in either parallel or perpendicular directions (or both) in relation to the camera. The angle of the camera in relation to the ground, and in particular the trail or targeted area, is an important aspect of camera set up. This can be somewhat time-consuming and awkward to set up but it is essential to get right nevertheless. Passive infra-red cameras have an area of sensitivity that is predominantly horizontal and therefore the camera needs to be angled such that this area remains horizontal in relation to the slope of the trail. The easiest way to achieve this is to angle the camera unit, along with the sensor (if separate), such that the resulting images are horizontal within the frame. If the ground slopes upwards or downwards perpendicular to the camera the area of sensitivity may end up pointing too low (into the ground) or too high (into open air) and again a passing animal will not trigger the camera. Likewise, any dips, hollows, car ruts, etc. in front of the camera may result in an animal, especially a small one not triggering the mechanism.

Most cameras will include a test mode during which it is possible to move in front of the camera and to see (usually by a flashing LED on the camera) whereabouts on the trail an animal will trigger the camera. It is important to remember that most animals are smaller than people and therefore it is necessary to crawl rather than walk in front of the camera during the test to ensure that the camera is not registering on the person's head for example.

Figure III. *Testing the camera during set up*.

- **2.2.3 Distance to trail**

The distance the camera is set up from the trail depends in part on the camera model and in part on the target species. With all camera models there is a delay between the camera being triggered and the photograph being taken, although with film cameras and some higher end digital models, this lag is negligible (see section 4.3 – Part 1). If the camera model being used has a slow response time (>1 second) and it is located very close to the trail, the animal may have passed out of the camera's field of view by the time the photograph is taken and so a "blank" photo or a photo of only the animal's tail will result. However, the benefits of placing the camera some distance from the trail need to be weighed against the problems of identifying small species if they are captured far from the camera and are consequently very small in the image. This is especially a problem if the goal of the study is to identify individuals of small species such as patterned carnivores. Indeed, if the area is very open it may be necessary to funnel the animal's travel route past the camera and so bring it close enough to allow identification.

This can be achieved by careful camera placement and/or by using fallen trees and branches to direct the animal to the desired location. A generalisation would be to place cameras with a slow response about 3 m from the expected travel route and faster responding cameras around 2 m away. However, it is best to determine the exact distance from the results of pilot surveys using the same cameras that will be used during the main survey.

Text Box 10: Paired camera set-up for capture-recapture approach.

- Species that have patterned coats are marked asymmetrically, therefore in order to identify individuals accurately it is necessary to photograph both flanks simultaneously
- To achieve this, a pair of cameras needs to be set up with one camera on either side of the trail or road, facing each other
- It may be necessary to angle the camera slightly away from each other to prevent the flashes interfering with each other

Example of a leopard cat captured with a paired camera set-up.

Text Box 11: Baiting camera-traps.

It is possible to bait a camera-trap to try to obtain photos of a specific species. Baits are food based whereas lures are scent or sound based. In general lures are better than food based baits as the food will be taken by the first animal to pass the camera; this is likely to be a more common animal such as a bearded pig rather than the elusive species that the camera has probably been set for.

- Advantages
  - A bait or lure placed at a camera-trap may increase the detection probability of a species or individual by encouraging an animal to walk in front of the camera that may otherwise have walked behind it.
  - Effective lures can cause the target animal to linger in front of the camera, and be subject to multiple exposures. These additional resultant photographs can aid later identification and determination of gender.

- Disadvantages
  - The batteries may be used up or memory may be filled with photographs of the same animal. However, with good quality batteries and high capacity memory cards this should not be a problem, but is likely to be with film cameras.
  - There are slight complications concerning the analysis of data, for instance it may be necessary to use the behaviour model for CR analysis if the bait/lure is thought to cause a behavioural response to trapping.
  - The extent to which a particularly good lure might cause an animal to move beyond its usual home range boundary and the implications that this might have for data analysis must be considered.
  - Baits and lures are generally used to increase the chance of photographing elusive species; these are usually the top carnivores in any given system. If these species or individuals visit a site more frequently due to the presence of bait or lures this might affect the movements of smaller carnivores and prey species, so limiting the inferences that can be made about these species.
  - Commercially available lures can be difficult to obtain and will add costs to the project and may not give the desired results. In the heavy rains, common to the tropics, lures wash away quickly and so may be ineffective.
  - All cameras in all sites should be treated the same way. If it is difficult to reach some cameras they will be checked less often and therefore will have the lure renewed less often than in areas where the cameras are easier to access. This may result in differences in detection between cameras.

- **2.2.4 Vegetation clearing**

Once the camera location has been chosen it is necessary to clear any vegetation that might affect the camera's performance or the quality of the resulting photographs. Vegetation, such as long grass, in the camera's field of view can make it difficult or even impossible to identify the photographed animal, either by directly obscuring the target animal or by causing the camera to auto focus on the vegetation itself, rendering the animal's image blurry. It is also possible for sun-warmed vegetation to move in the wind and cause false triggers of the camera. This last problem can become very problematic if it occurs to such an extent as to use up battery power or film or memory space and also adds to the task of data processing once the images are retrieved. Due to the increased amount of available sunlight and the increased abundance of fast-growing grasses, cameras placed along logging roads tend to be more prone to problems caused by vegetation than those in the closed forest. Consequently more attention should be paid to removing potential problem plants in such areas. Problem vegetation can be cut down to ground level or may even be removed entirely from the ground; the latter may be preferential in open areas, such as roads and tree fall gaps, as under such resultant bright conditions vegetation can grow surprisingly quickly. The removed vegetation can be used to create animal funnels (see section 2.2.3).

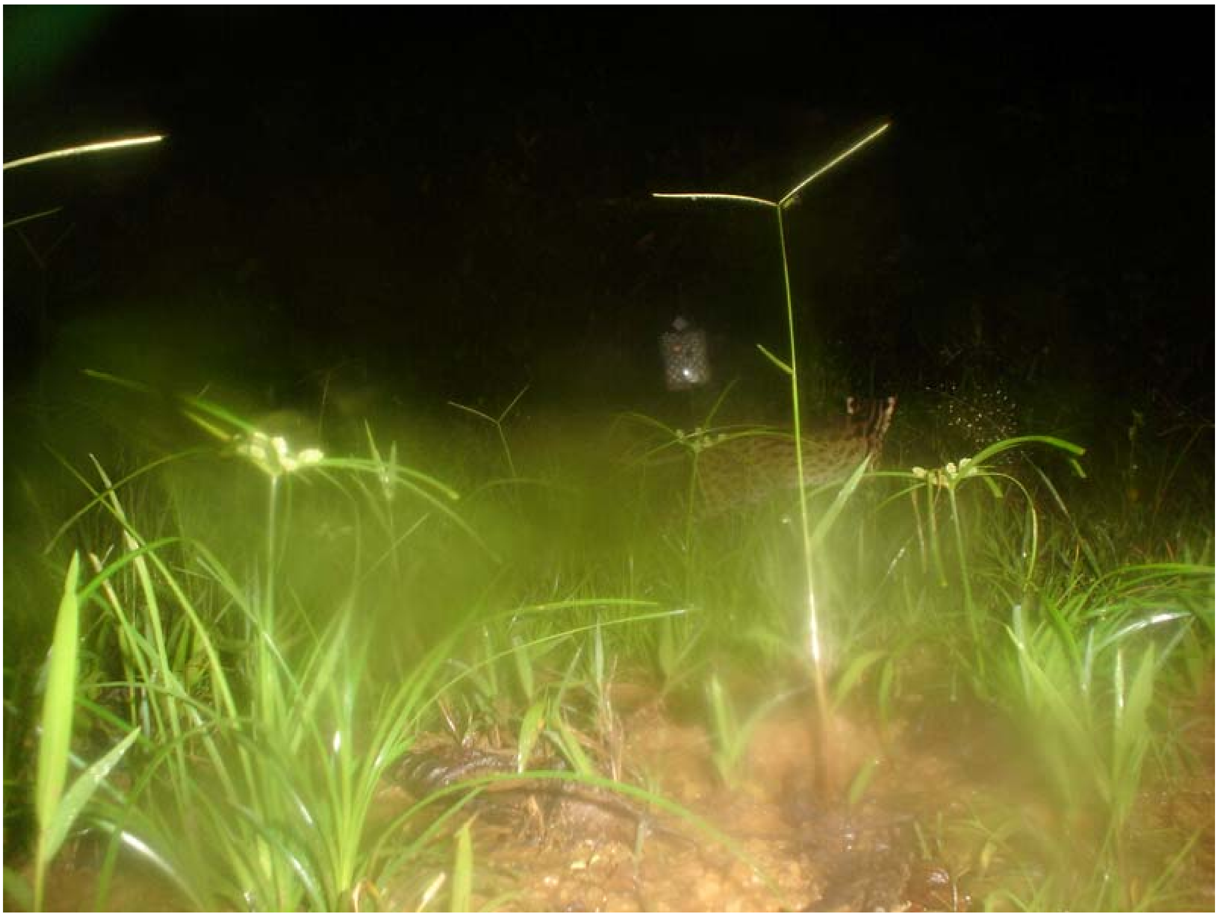


Figure IV. *When vegetation is not cut back sufficiently, or cameras are not checked frequently animals can be obscured in the photograph.*

- **2.2.5 Last steps**

The very last thing to do after setting up the camera is to make the camera take a photograph before leaving it. This ensures that the camera has been turned on and is working correctly, and also allows the number of trap nights to be worked out accurately if the paper notes are not clear or are lost. If film cameras are used it is useful to have a system where the assistant is photographed holding a piece of paper with the camera site written on it. Although digital downloads can be stored by creation dates, this storage system is easily confounded once files or images are processed and edited.

2.3 Other considerations

- **2.3.1 Interference from animals**

Some species are curious by nature and may disturb the cameras, either reducing their effectiveness, or at times, causing the cameras to become non-operational. The inquisitive nature of some animals, such as terrestrial primates, and in particular pig-tailed macaques, often leads them to interfere with the camera units themselves, resulting in the cameras being rotated or tipped such that they are no longer precisely pointed at the target area. If the camera can be opened easily the nimble fingers of primates may achieve this and leave the camera exposed to rain, or even turn the camera off if it has external buttons or switches. It is important to try to anticipate this and to fix the camera firmly in place, with screws where possible, to the tree or stake. Other, larger animals such as elephants or bears may damage the cameras, even if they are fixed strongly in place. For protection from these species a metal box, perhaps with spikes welded can be a useful deterrent and is advisable (Figure V).

Figure V. *Examples of different types of animal deterrent. A shows a metal box with welded spikes. The box was designed to either be fixed to a tree or to a stand-alone post as shown; it could also be locked with a padlock. B shows the same style of box fixed onto a pyramid-shaped stack of fallen Macaranga logs bound together by metal banding and camouflaged with vegetation. Set up B was extremely effective against elephant damage and was easy to set up in an area where the team had access to a chain saw, a lot of fallen trees and several camera sites could be reached by car.*

- **2.3.2 Interference from people**

Many areas of tropical forest experience different types of use by people. These may include tourists, school and university groups, researchers, local villagers or outsiders, etc., and while it will usually be advisable to avoid such high use areas it may not always be possible. In addition, the nature of the research may dictate that some cameras are placed along trails heavily used by people. Most people will be curious about the cameras which will usually result in multiple unwanted images. Some people's curiosity may lead them to open the camera or otherwise inadvertently modify the careful set-up. Occasionally people will be suspicious of the motives behind the use of camera-traps and consequently may move or damage the cameras. In addition, there is also the chance that cameras will be stolen, perhaps by poachers not wanting to get their images recorded. The risk of camera theft is typically higher when cameras are placed along logging roads and ridgelines, as poachers often use these features to hunt along. A polite explanatory notice attached to each camera may help to alleviate this, as will the distribution of leaflets or giving talks in local villages and at tourist resorts. In both cases a padlock on the camera can help, but ultimately if someone wants to remove the camera they will almost certainly find a way to do so.

- **2.3.3 High rainfall and humidity**

All camera-traps rely on some form of electronics and as such are prone to problems resulting from the very high humidity and rainfall in tropical forests. With film cameras, the film tends to swell over time and can jam within the film casing. Sometimes the high humidity can be so detrimental that the camera ceases to function completely. It is therefore wise to include silica gel within the casing of the camera whenever possible to absorb the moisture from the air within the box. Re-useable silica gel, purchased within Malaysia from laboratory suppliers or photographic equipment dealers, is often the cheapest and best option if the facilities exist to dry it out between camera checks. Alternatively, several camera-trap suppliers now offer non-reusable silica products which can be purchased when ordering the camera-traps. Many camera-traps now have effective rain proof cases, but the continued opening of the case when checking the camera, particularly when the operator's hands are wet from rain, can allow sufficient moisture to settle on the electronics to eventually cause it to stop working. Rain is to be expected at any time in Sabah, so plan ahead and have some form of effective cover to work under when opening the camera cases, such as a small canvas or tarpaulin or even an umbrella if weight is an issue. A clean towel can be used to dry the hands of the person handling the camera, and to carefully dry and clean the waterproof seal – typically a rubberised O-ring. Even a tiny piece of grit or dirt on the seal can allow water to penetrate the casing, so ensure that this is inspected each and every time the camera unit is opened to the elements.

An additional problem of high rainfall is that of splashing mud over the camera to the extent that the camera lens becomes covered and consequently it is impossible to identify the individuals or even the species that has triggered the camera. This is a particular problem on old logging roads, which tend to be muddy, and when setting the cameras low for small animals. To some extent, careful camera placement, placing 0.5 by 0.5 m squares of plywood directly under the cameras or leaving a pile of leaves weighted down with small branches in front of the cameras can help alleviate this difficulty. But it is not always possible to avoid this problem altogether.

Chapter 3: STUDY DURATION AND CHECKING CAMERA-TRAPS

3.1 Checking the cameras

- **3.1.1 Interval**

Camera-traps need to be regularly visited in the field to download the photographs or change the film, to replace the batteries and replenish the desiccant, and to otherwise ensure that the unit is still operational. Clearly this can be a significant logistical undertaking and so the frequency of such checks requires careful planning. The actual frequency of checks depends largely on the logistics of each project, the equipment used and the characteristics of the study area. Functionality can vary considerably between camera models, film camera being restricted to 36 exposures, whereas some high end digital cameras are able to take several thousand images and remain operational after two months. Again, a pilot survey will provide essential information on battery longevity and rate of memory or film usage. Even if battery and memory limitations are adequately dealt with camera-traps may become inoperative due to water ingression, animal or human interference, or from mud on the lens, fallen branches or growing vegetation blocking the field of view, or the camera may break for no apparent reason. Thus camera stations should ideally be visited frequently enough to reduce the time any camera-traps are non-operational. As a general guideline, and in the absence of knowledge resulting from a pilot study, we suggest a 2 week checking schedule, with the frequency increasing in areas of high human and/or elephant presence. Where risk of camera interference is low, and where high end digital cameras are used, monthly camera checks may be sufficient.

- **3.1.2 Checking procedure**

On arrival at the camera site the first thing to do is to check whether or not the camera is still functioning (i.e., trigger it), and if not, to note whether this is because the batteries have run out or the memory has been used up or for another reason. The next step is to download the data or swap the memory card or change the film and to replace the batteries if needed. If rechargeable batteries are used, it is sensible to replace them every time the cameras are checked. Make sure to record if the batteries are changed or not. If you swap memory cards, make sure you clearly associate the card with the camera it was taken from; similarly, if data is downloaded, associate the download file with the camera to enable swifter data processing back at the office. It is very time consuming if a set of photos cannot easily be allocated to the correct camera site. In our experience, electronic devices such as a netbook or a tablet PC are extremely useful to save and also to view photos in the field. This can give information such as whether there is vegetation in the way, whether there is a problem with sunlight causing “blank” photos or how well the camera is performing in terms of number of images of animals. These may be deciding factors as to whether a camera should be moved or not, for instance out of the direct sun, or because there are very few photos of animals. The last thing to do in the field is to check that the set-up is still appropriate as detailed in sections 2.2 and 2.3. On return to the office it is necessary to back up the data immediately and (if no computer devices were used in the field) to move the photographs into appropriately named folders on the computer.

3.2. Study duration and repeating intervals

In Part 1, Chapter 3, we discussed what to consider when planning the duration and repetition interval of a study.

- **Study duration**: in summary, the duration should capture a timeframe in which we can reasonably assume that the wildlife measure of interest remains stable, for example, abundance does not change. For the medium and large mammals targeted with camera-traps, **2-3 months of sampling are usually adequate**.

- **Repetition**: repetition of samplings should be implemented so that the maximum number of factors the researcher can control for remains the same throughout all repetitions. Otherwise, it will be difficult or impossible to distinguish between differences in your wildlife measure brought about by an actual temporal trend, or by changes in your study design, the season of the year, etc.

In the tropical forests of Borneo, the **dry and wet seasons likely influence most wildlife measures**. Thus your study design should follow a yearly cycle. If you are interested in contrasting both seasons, of course you can do so, but **be aware that a dry season sample does not constitute a repetition of a wet season sample and vice versa**. If there are differences, and you are interested in measures for both seasons, you can either do two samples per year – one in each season – or, if this entails too much effort and costs, sample your study area at 1.5-year intervals: for example, year 1: dry season, year 2: wet season, year 3: skip, year 4: dry season, and so on.

Even if you decide to limit your study to a single season (for example, your study area may not be accessible during the wet season, thus limiting your efforts to this period), you may want to consider sampling once every 2 years. Although it will take you twice as long to accumulate any number of repetitions that on a yearly cycle, for long lived species with a slow population turnover the 2-year design will still give you enough temporal resolution to study changes in your wildlife measure.

The number of repetitions is crucial when studying changes or trends over time in wildlife measures. Two repeats will give you only a snapshot in time, one interval of change, and the measure of change you obtain may be positive or negative by mere coincidence. There is no golden rule as to how many repetitions you need to truly describe a trend. But we would recommend using **at least five repeats** for any meaningful investigation of trends, while results based on any lower number of repetitions should be treated as preliminary.

Chapter 4: DATA PROCESSING

4.1 Initial data sorting

Sorting and efficiently storing the resulting data from the camera-traps can be a very time consuming, although rewarding process. The recommendations made here are not essential and there is some flexibility depending on the time and staff available for data processing. The first step is to make sure all downloads are copied into the correct site folders on the computer, if no computer device is used in the field. If there is sufficient data storage space it is useful to keep an unedited, raw version of all data.

The next step is to record the start and stop date and time for each camera in order to calculate the survey effort. The start date and time are taken from the last photograph that is taken during camera set-up and the stop date and time are taken from either the last photograph, in the case of a malfunction, or the first photograph taken of the team as they approach the camera to check it. It is useful to record the total number of images taken and also the number of blank photographs during this period as this gives some indication of how well the camera has functioned. Very few images of animals or many blank images may indicate a problem with the sensitivity, or placement of the camera. Each blank photo must be carefully scrutinized as small animals, or even larger animals such as bearded pigs in the background vegetation can be difficult to spot. Scrolling from the previous image to the next in question can be a useful technique as often a small animal can be seen to 'appear' in the image. Blank photos can then be deleted. Depending on the research question being asked the number and group size of people may be of interest, so this can also be recorded, otherwise delete the images of people.

Next, the files need to be renamed with an appropriate format, including survey area, location number and photograph number. This can be done using software such as Photoshop, or Microsoft Office Picture Manager, the latter however, does not give a warning if files are accidently renamed with the names of existing files and the original files will be lost.

At this stage, depending on available resources it may be necessary to simply pull out the photographs of the species of interest and to log only these photos. If time is not restricted then the photos are logged into a spreadsheet, following a similar format to that suggested in appendix I. It should be noted that PCs using the Windows Vista operating system and some Mackintosh sometime display information incorrectly when viewing the "Exif" data with their associated file; earlier and later versions of Windows do not have this problem.

There are several software programs available to assist with managing camera-trap data that can be very useful and save a lot of time for projects generating a lot of pictures, such as Camerabase (http://www.atrium-biodiversity.org/tools/camerabase) and Photospread (www.ericabelson.com/photospread).

4.2 Statistical analysis

Here, we provide a brief introduction into some analytical techniques. Since there is a considerable body of literature on the analysis of camera-trap data and the main focus of this manual is a practical one, we will refer you to existing literature for further reading regarding analytical options for your camera-trapping data. Essentially, this section will expand some aspects we mentioned in the *Selection of wildlife measure* (Part 1, section 3.2) but we will not reiterate the pros and cons of the different measures. You can find examples for spreadsheets that store and organize your data in the Appendix 1.

- **4.2.1 Count statistics and trapping success**

The most basic level of analysis of your data is compiling some descriptive count statistics:

- number of cameras used
- the amount of effort they accumulated (number of trap-nights; see text box 1)
- number of pictures obtained (in total and of your focal species)
- If you are looking into distribution and related issues, the number of sample sites your species was detected at.

Photographic count statistics are also the base for relative abundance indices (RAI), the most frequently used index is the number of pictures of the focal species obtained per 100 trap days. Remember that **we do not recommend using the RAI as a measure of abundance**. It may be interesting as **a measure of trapping success**, i.e., the amount of effort needed to obtain a picture of your target species. This index can be calculated as:

Number of pictures / [(Number of trap nights) x 100]

You can either calculate the index per camera-trap and observe how it varies across your study site; or you can calculate one value for the entire study area (i.e., dividing the number of ALL photos of your target species by the TOTAL EFFORT). You can obtain all information necessary for this basic analysis from a spreadsheet organized as shown in Appendix 1.

- **4.2.2 Occupancy**

Occupancy models (MacKenzie *et al*., 2006) can give insight into patterns of **distribution and space use** of a species while accounting for imperfect species detection. They combine a model describing:

- whether or not a sample unit (grid cell, habitat fragment) is occupied by the species of interest – this process is governed by the probability of occupancy;

and ***IF*** the species occupies a site

- whether or not it is detected – this is governed by the probability of detection.

Both probabilities can be modelled as functions of covariates describing the camera-trap sites – i.e. habitat, climatic or other variables that you think may influence the probability of a species occupying a site or being detected. By model definition, in single-season models **occupancy remains stable and does not change during the survey**. But you can use time-specific covariates on detection probability, if you believe that detection varied during the survey (e. g., due to climate). In addition, so-called **open (multiple season) models** are useful to you if you have data from surveys repeated over a larger time frame, which allow you to model changes in occupancy over time.

- **Assigning sampling occasions**: the probability of detection is estimated based on repeated visits to each study site (often also referred to as sampling occasion). Since camera-trap sampling is generally continuous (cameras work throughout the entire study), you have to define what a repeated visit means in your study. The assignment of occasions is somewhat arbitrary. As a guideline:

- ✓ you want to avoid having too many occasions (no more than 10)
- ✓ you do not want to have too many occasions without detections (this will lower the detection probability, and these models do not work well with detection probabilities that are very close to 0, or to 1 for this matter)
- ✓ you do not want to condense your data more than necessary

For rainforest mammals, **occasion lengths between 5 and 10 days** are probably adequate, but the final decision will depend on your data. Occasions should have constant length throughout your study, but if they don't, you can adjust for that by including occasion length as a covariate on detection probability (because the longer you sample a spot, the higher the probability that you detect your target species).

If for whatever reason some cameras did not work during all occasions, **missing data can be accommodated**.

- o **Constructing occupancy model matrices**: once you have decided upon occasion length, you then construct the actual detection/non-detection matrix (for an example see Appendix 1c) where each row represents a camera-trap and each column represents an occasion, and each cell contains either a '1' or a '0', depending on whether your focal species was (1) or was not (0) detected at that camera-trap during that occasion (observe that it does not matter *how many times* the species was detected; if you photographed it *at least once*, the entry becomes a (1). In addition to this matrix, you need a matrix with all site (and/or occasion) specific covariates you may want to use in the model. Make sure the order of camera-traps is the same in the detection/non-detection matrix and the covariate matrix.

- o **Occupancy software**: occupancy models can be implemented using either the free software PRESENCE (Hines, 2006) or the 'unmarked' package in the free software R (Fiske *et al*., 2011). While using 'unmarked' requires you to be familiar with R, the package runs more stable than PRESENCE and gives you more flexibility to work with the model output. Donovan and Hines (2007) provide an extensive introduction into occupancy modelling and many worked examples for PRESENCE online. Also the program MARK (White and Burnham 1999), better known for capture-recapture analysis, can be used for occupancy modelling.

- o **Further reading**: this short paragraph is by no means a full description of occupancy modelling. For a thorough coverage of the topic see the book by MacKenzie *et al.,* 2006.

- **4.2.3 Estimating abundance and density**

- o **Regular capture-recapture models**: if you are dealing with a species where individuals are identifiable from pictures, you can estimate population abundance and density using capture-recapture models (e.g. Otis *et al.,* 1978). As mentioned earlier, this can also be done when only a portion of your population is marked and identifiable but here, we will briefly introduce the case of species where each individual bears unique markings.

- o **Constructing the capture history matrix**: capture-recapture models are very similar to occupancy models in that they require you to **structure your data into distinct visits or**

occasions. But instead of listing species detection/non-detection for each camera-trap, you need to construct a detection/non-detection matrix for each individual on each occasion, collapsing the data of your entire study area. So if, say, on occasion alpha, individual A was photographed *n* times at *m* different cameras, the matrix entry for individual A on occasion alpha will be '1'. If it wasn't photographed anywhere, the entry will be '0'. For an example, see Appendix 1 d.

Text Box 12 : Options to model detection in capture-recapture models.

Modelling of detection probability is a key issue of capture-recapture models. However, detection may not be constant across time and individuals. Incorporating such sources of variation in detection is important to derive adequate estimates of abundance. Some standard models are generally included in software packages for capture-recapture models. These include models that account for:

- variation of detection in time, for example, due to weather conditions
- a behavioural response to trapping, that is, different probabilities for the first detection and any subsequent detection (this is usually more of an issue with live-trapping, where a previously captured individual may subsequently avoid trap devices, or when bait is used that cause an individual to return to the trapping device more frequently to look for more)
- individual heterogeneity in detection

This last source of variation is especially problematic and can arise very easily when individuals have different exposure to the trap array (the home range of one may be completely within the trap array, while the home range of another individual may only contain one or two cameras on the edge of the array) or because different demographic groups have different probabilities of being detected.

More complex models for detections can be built by combining these sources of variation, and there is also a class of models that allow including individual covariates (for example, age or sex) to model detection (Huggins, 1989). However, as with any model, increasing the number of parameters requires a larger sample size.

Further reading: We suggest the Handbook of Capture Recapture Analysis by Amstrup *et al.* (2005) as a source for further information on this topic.

- **Software for regular capture-recapture models**: capture-recapture models can be implemented in the free software CAPTURE (Rexstad and Burnham, 1991) and MARK (White and Burnham 1999). The former consists of a restricted set of models only for closed populations (i.e. population size remains stable during your study). The latter includes CAPTURE as an application, and in addition contains a variety of models for both closed and open populations (open population = for studying population dynamics).

- **Transforming abundance into density estimates and major problems**: a major issue with these regular capture-recapture models is how to transform abundance into a density estimate. Especially mobile species like medium to large mammals are able to move on and off the trapping grid, so that our estimate of abundance refers to an area that is larger than the area actually covered by camera-traps. However, the size of this larger area is unknown.

The standard approach towards estimating this area often called the *effective sampled area* is to use information on individual movement from the camera-trapping data itself:

1. For each individual that has been captured at more than 1 trap, calculate the distances between these traps using GIS software
2. Determine the maximum distance for each individual
3. Calculate the mean maximum distance moved across all individuals captured at more than 1 trap

Originally, **half this mean maximum distance is called the MMDM** (Karanth and Nichols, 1998; but it can also be referred to as 1/2MMDM), and **the full mean maximum distance is referred to as fMMDM**.

A buffer with the width that equals the MMDM or fMMDM is then placed around the trap polygon to approximate the effective sampled area. This can be done in a GIS program such as ArcGIS. There is no consensus as to which measure is more adequate. Alternatively, if telemetry data on the focal species in the study area is available, it can be used to obtain more reliable movement estimates (e.g., Soisalo and Cavalcanti, 2006).

Note that the **choice of the buffer directly influences your density estimate**, so that studies using different ways to determine the buffer are not readily comparable. Also, depending on the size of your camera-trap grid, you may not capture the full extent of movement of your focal species, which would lead to an underestimated area and an overestimate in density. Finally, since choice of the buffer depends on you, you can somewhat 'create' the density estimate you feel most comfortable with by choosing a particular buffer.

- **Further reading:** the body of literature on capture-recapture modelling is vast, but some recommended sources detailing the conceptual framework are the monographs on closed population capture-recapture models by Otis *et al.* (1978); on open population models by Pollock *et al*. (1990); the book on studying animal populations by Williams *et al.* (2002) and the aforementioned handbook by Amstrup *et al.* (2005). Also, see Karanth and Nichols (1998) and Karanth *et al*. (2006) for pioneering work in applying these models to camera-trapping data.

- **4.2.4 Spatial capture-recapture models**

Spatial capture-recapture (SCR) models use the spatial information from captures to estimate density while accounting for individual movement (Efford, 2004; Royle and Young, 2008). Simplified, these models assume that each individual has an activity center (similar to a home range center) and that it moves in a circular area around this center. While moving around, the individual encounters camera-traps, and the number of times it will encounter a given trap is a decreasing function of the distance of that trap to the individual's activity center. That means the further away the trap is from the activity center, the less often will the individual encounter the trap. To allow for movement off the trapping grid, the grid is embedded into a larger area called the state-space. While this may sound like the buffering done in regular CR models, the difference is that for the SCR models the width of the buffer will not influence the density estimate, as long as the buffer is chosen wide enough. The model essentially estimates the number of activity centers in the state-space, which can then be translated into a density estimate. In addition, SCR models estimate parameters associated with the movement model (the model that describes the relationship between the number of times the animal will encounter a given trap as a function of the distance to its activity center). SCR models have **several advantages over regular CR models**:

- ✓ They make use of all the data, i.e., there is no need to condense data into a binary detection/non-detection format
- ✓ they also make use of the spatial information of individual captures, thus extracting more information from the available data
- ✓ in doing so, they explicitly incorporate animal movement into the model and do not rely on an ad hoc approach
- ✓ modeling of individual and site-specific covariates is straight forward
- ✓ since they represent a unified approach to density estimation, estimates are comparable across different studies

- o **SCR software**: although SCR models are a relatively recent development, there are already a few software applications available to implement these models. DENSITY (Efford *et al*., 2004) is a stand-alone program, while "secr" (Efford, 2011) and SPACECAP (Singh *et al*., 2010) are software packages that need to be accessed through R. SCR models can also relatively easily be written in R and run in WinBUGS (Gilks *et al.*, 1994). For example code see Royle and Gardner (2011) or Royle and Dorazio (2008). Again, although this requires some familiarity with R, it gives you great modeling flexibility.

- o **Preparing the data**: the data format will depend on the software you use for analysis, but in general you will have to compile information of captures of each individual at each camera-trap at each sampling occasion. In R this kind of data structure can be a three-dimensional array (with the dimensions 'individual', 'camera-trap' and 'sampling occasion'). In spreadsheet programs like Excel, you can list all detections and use different columns to identify the individual, trap and sampling occasions (for an example, see Appendix 1 e).

- o **Further reading**: there is a growing body of literature on SCR models and recommended reading includes the section on SCR models in the book about hierarchical modeling by Royle and Dorazio (2008) and the SCR chapter by Royle and Gardner (2011) in the recent camera-trapping book by O'Connell *et al*., (2011).

Chapter 5: ADDITIONAL SURVEYS

Introduction

Camera-trapping is one of the most up-to-date methods of surveying wildlife, with several advantages over other techniques. However, there are some techniques that will yield information complementary to that collected by camera-traps and researchers should consider applying the techniques as a supplement to camera-trapping.

5.1. Environmental surveys around camera-traps

Vegetation surveys around the camera-trap stations provide important information for a more comprehensive analysis of camera-trapping data. A detailed description of the surroundings of a camera-trap can provide valuable information about habitat associations of different species. These observed habitat preferences of a species of interest can be used to extrapolate and predict suitable areas outside the study area based on land-cover data or satellite images. As some species prefer to use human made trails or roads, and others might avoid these habitats, the characterisation of the microhabitat around the camera-trapping stations allows to account for these factors in the statistical analysis of the camera-trapping data (e.g. road/trail can be added in the analysis as a factor influencing the capture probability).

As a basic standard the following data should be recorded at each camera-trap station:

- Photographs of the camera-trapping station, its surrounding and the canopy
- Canopy height (using a range finder) and Canopy closure (preferable measures with a spherical densiometer) of the surrounding forests (note that to reduce the sampling bias several measurements in 3-5 directions - 10-50 m of the camera-traps - of the stations should be taken)
- Age of the forest (assessed based on the DBH of surrounding trees)*
- Distance of the camera to roads, human trails, wildlife trails
- Distance to the next fruiting trees (if present)
- Were the cameras set up along a ridge line, close to a wallow, etc.?
- Distance to the next water source (streams, ponds, rivers) (if present)

In addition to these environmental aspects, anthropogenic disturbances such as cutting signs, logging activities, hunting, etc. should be noted as well.

All these environmental data can be used in occupancy models and in spatial capture-recapture models. Of course, potential explanatory variables in these models are not limited to this list and depend on the scale and focus of the study.

5.2. Transect surveys

An abundant literature exists about recce walks and line transects (see the manual “Wildlife Surveys and Monitoring Techniques” being developed for Sabah). Further see Mathai *et al.*, (in press) for a review on the use of transect surveys for Bornean carnivores.

- **5.2.1 Night spotlight surveys**

In Chapter 2.1 it was pointed out that many rainforest mammals are nocturnal and some live almost exclusively in the canopy. Other nocturnal species live in flood-prone areas. In both cases camera-trapping surveys are inappropriate methods to study these species. Here night spotlight surveys can assist to record these species. Three different night spotlights surveys can be conducted:

- **on foot**
  - **Advantages:**
    - ✓ surveys can be conducted in remote areas
    - ✓ shy species that rarely come close to roads or rivers can be detected
  - **Disadvantages:**
    - ✓ it can be extremely challenging to walk during the forest in the night
    - ✓ only a small area can be covered

- **from a vehicle (car or motorcycle)**
  - **Advantages:**
    - ✓ large areas can be surveyed
    - ✓ bright and powerful spotlights can be used
    - ✓ generally visibility is better along roads
  - **Disadvantages:**
    - ✓ restricted to roads, which do not allow surveying a straight line, which is required for some analytical approaches (e. g. distance sampling)
    - ✓ some species might avoid roads and therefore remain undetected

- **with a boat along the river banks**
  - **Advantages:**
    - ✓ large areas can be surveyed
    - ✓ bright and powerful spotlights can be used
    - ✓ remote areas can be surveyed
  - **Disadvantages:**
    - ✓ restricted to rivers, which do not allow surveying a straight line
    - ✓ some species might avoid using river banks and therefore remain undetected

- **5.2.2 Recce walks**

Recce walks are used to collect data about wildlife species, habitat types and human activities simultaneously. The basic principle is to follow a line of least resistance through the survey area by following easy paths along old trails, ridge-tops, water bodies, or through areas with cleared understorey, etc. Dense vegetation areas or steep areas are avoided. The general idea is to cover longer distances in shorter time than strict line-transects, thus decreasing costs and increasing efficiency. Recce walks are very important to undertake when entering new areas or compartments during pilot surveys. These recces will provide information about the spatial distribution (presence/absence) and relative abundance of species of interest as well as habitat types and degradation stages. Recce walks are sometimes combined with short line transects. “Guided recces” imply for the teams to not deviate more than 40^{o} from a predetermined bearing while no predetermined direction is followed during “Travel Recces”. Guided recces provide more precise indexes than travel recces. Although absolute density estimates are not derived from recce walks, this methodology is a potential way for monitoring population trends in remote areas.

- **Advantages**:
  - ✓ easy to conduct
  - ✓ allow for covering several km per day
- **Disadvantages**
  - ✓ provide qualitative (or semi-quantitative at best) indexes only

- **5.2.3 Line transects**

Line transects involve cutting straight lines that follow a pre-determined compass bearing. Line transects are used to count direct sightings of animals or the signs of their presence (nests, dungs, footprints) in the forest. Although they remain a major and efficient way to survey wildlife in tropical forests, line-transects are time-consuming and require significant human and financial resources. The starting point of each transect is selected randomly from topographical maps. In the field the starting point is identified with a GPS. The direction follows a precise bearing that is kept constant along the entire length of the transect. Along each transect, a team of two clears a straight line path and confirms the bearing with a compass. A second team of two to three people follows, recording data. With enough data, line transects allow for estimating abundance and densities, which is not possible with recce-walks.

- **Advantages**:
    - ✓ provide density estimates under certain circumstances
- **Disadvantages:**
    - ✓ time consuming
    - ✓ cover small areas
    - ✓ involves cutting of plants

5.3. Interview surveys

Interview surveys are a way to collect information that complement the results of field studies and to integrate some knowledge about social and economic factors that may be critical to understanding of the status of the species we are interested in (Meijaard *et al*., 2011, Mohd.-Azlan *et al.*, in press).

- **Advantages:**
    - ✓ if done at the beginning of the study, interviews get the community excited about the project and provide an opportunity to get people on your side; this can reduce camera thefts
    - ✓ interviews provide a venue to identify field assistants who are very familiar with the forest
    - ✓ get information that the cameras do not record or ancillary information (Meijaard *et al.*, 2011)– e.g. level of hunting, species targeted, other forest products that are important to local people
    - ✓ get local people's ideas and opinions about areas that are used by wildlife or by certain species to place cameras accordingly
    - ✓ get local people's perceptions about population trends or changes in relation to fruiting, seasonality etc.

- **Disadvantages:**
    - ✓ reliability of the information, which can be difficult to test
    - ✓ difficulties to collect information on sensitive topics: sometimes local people will say what they think a researcher wants to hear rather than the truth, especially with sensitive issues such as hunting or trade
    - ✓ need for carefully designed questionnaires (sampling frame and scheme), proper training of the data acquisition team, and adequate analysis (assessing data quality, using proper statistical tools, etc.)
    - ✓ if carried out beforehand especially if there are no tangible benefits to the local community, this might just alert people to where the cameras are in the forest and so increase the problem of camera theft

A crucial part of interview surveys is sharing the results with the communities after interview data have been processed and analysed.

PART 3: INVOLVEMENT OF LOCAL COMMUNITIES IN CAMERA-TRAP ACTIVITIES

Introduction

Failure to involve local communities in the management of natural resources results in a general lack of support for conservation and subsequent degradation of protected areas, and in the over-exploitation of non-protected areas. Local and central authorities in charge of biodiversity conservation often have limited human and financial resources and empowering local communities is a way to address this issue. However, encouraging the participation of local communities in conservation activities remains a challenge. Proper incentives need to be identified and developed to influence and to motivate people and to show them that it is more worthwhile to maintain rather than degrade natural resources. In the "participatory biodiversity monitoring" approach, community members who are the prime users of a resource are actively involved in the development and the implementation of the monitoring programme. If they receive sufficient training, they can become "citizen scientists" or volunteers who are empowered with knowledge and jurisdiction to monitor their own wildlife resources.

Figure VI. *Learning how to set and operate camera-traps can empower local communities.*

- **Advantages of participatory monitoring**:
  - ✓ cheap alternative to more sophisticated approaches
  - ✓ by increasing the number of observers taking part in the study/field activities, this approach allows the collection of a significant amount of information throughout vast areas (greater survey efforts)
  - ✓ through empowerment, this is a powerful approach to produce high-level conservation management intervention
  - ✓ major tool to raise awareness about environmental issues

- **Disadvantages of participatory monitoring**:
  - ✓ requires time to initiate a strong capacity building process over a long and continuous period of time (time resource)
  - ✓ often, this approach is less accurate and results can be difficult to compare because monitoring is difficult to standardize

Pragmatically, local communities need to be involved at all phases of a project (design, planning and implementation) to achieve significant results (Borrini-Feyerabend *et al*., 2004; Berkes, 2004; Ancrenaz *et al*., 2007). Some crucial factors that will determine the success or failure of a monitoring program will include for example (Danielsen *et al*., 2003):

- Involvement of representatives of the local communities in developing the local application of the methods
- Existing community-based monitoring systems are recognized and built upon
- Focus is at the village/local level, where management decisions are taken
- Monitoring activities are kept simple
- Monitoring activities are fitted into the day-to-day work of the local people
- A close collaboration is established between the resource users (community members mainly, but also outsiders if this applies) and the “official” resources managers (staff from the state agency in charge of the area)
- There is a mutual trust between local communities, government staff and other actors (NGOs, research institutions, private companies, etc).

Chapter 1: ADVANTAGES OF CAMERA-TRAPS IN A PARTICIPATORY MONITORING PROGRAM

Although participatory monitoring can potentially generate a wealth of information, this approach is subject to two major sources of biases: (1) **sample selection** (spatial units that are surveyed are not representative of the larger region) and (2) **detection biases** (spatio-temporal changes of observers and observer-efforts) (Yoccoz *et al.*, 2001). If not dealt with adequately, such bias will render any resulting data unusable in the context of developing appropriate management decisions. Fortunately, as discussed in previous chapters, the application of camera-traps can be standardized in easily replicable ways, which will eliminate or strongly reduce inter-observer biases. This type of bias is a major constraint in monitoring programmes dealing with many observers that are based on direct/indirect counts of animals.

In addition, due to the inherent nature of camera-trapping, the collection and analysis of data can be undertaken locally. Such localisation of data acquisition and handling will encourage local ownership and will empower communities, enabling the rapid development and implantation of management decisions to address issues and threats identified during the monitoring activities (Danielsen *et al*., 2005; Mishra *et al*., 2009).

Camera-trapping approaches may also yield higher quality data. Identifying a species in a photograph is considerably easier than from a furtive glimpse of an animal in the forest, and correct identification can actually be controlled by a scientist. Basic skills needed to operate the camera-traps can be acquired easily following proper training, and thus this technology applies especially well for local communities. In addition, pictures of animals collected from the traps can be shared with all community members, even those people who are not regular forest-users and who are not familiar with wildlife. This is an essential component of awareness and education activities prerequisite activities to build legitimacy and support by local communities in conservation activities.

Chapter 2: GOALS OF COMMUNITY-BASED CAMERA-TRAPPING STUDIES

A consultation process involving discussions, interviews or participatory workshops is needed to determine the needs and the major expectations of the community and to shape the community programme that will be initiated. After the goals of the programme have been clearly identified, it can be determined if a community-based camera-trapping study is needed or not, and if such an approach can yield the necessary data for the programme.

Some examples of such studies are given below.

2.1 Camera-trap programme for the development of hunting plans and analysis of local resource use

To develop a "Hunting Plan", the study targets mainly game species that are commonly harvested by the community (deer, bearded pigs, porcupines in the Sabah context). At the beginning of the study, camera-traps will provide qualitative information that complement local knowledge. In particular, a well-designed camera-trapping study could enhance the basic understanding of the population demographics (sex ratio, group size, presence of young, time of a breeding season, etc.). It will also provide some information about some of the environmental features found in the region (location of preferential feeding grounds, presence of salt licks or other features that are attracting wildlife, fluctuations of seasonal abundance of the prey populations; etc). In this case, camera-traps are deployed at sites with the highest probability of capture to maximize the amount of information collected in order to develop the harvesting plan.

After the target area for analysis has been mapped, camera-trapping can be used for the evaluation of hunting pressure from the proposed hunting activities on the game population and develop hunting regulations with a minimum impact. At this stage, camera-traps can also be placed along trails to control the presence of outsiders who would come and hunt illegally in the target area.

Here we have to stress that due to the inherent problems linked to camera-traps (i.e. inability to distinguish between individuals for most game species), it will be extremely difficult or even impossible to obtain quantitative abundance estimates that would allow managers to make inferences about the densities of target species within and outside a hunting area. It is, therefore, an establishment of a mechanism for long-term monitoring is critical to maintain the impact at a minimal level, and engagement of the local people is essential to attain sustainable use of local resources. For verification of the data, it is necessary to conduct additional field activities such as line transects and other abundance surveys, regular community interviews, etc.

Text Box 13: The need of analysis of local resource use in Crocker Range Park.

Hunting game species for local trade and for local consumption is deeply rooted in the culture and traditions of local communities living close to Crocker Range Park in Eastern Sabah. The BBEC Phase II and Sabah Parks have initiated a pilot project to study hunting pressure to determine optimum resource use by local people.

The goal of the project is directed to the need of the local community to hunt game species for their living. In a close dialogue between Sabah Parks and several local communities, two sites were selected to develop the project: Liawan Ulu (located within Crocker Range with a very low hunting pressure) and Ulu Senagang/Mongool Baru (close to the village of Keritan), in the Keningau district. Both sites are located at the upper limits of the mixed lowland dipterocarp forests and have been logged in the past. At the onset of the project, the knowledge present in the community was used and research activities were designed in a dialogue with the community. Representatives of the local community were directly involved in research activities and trained to become para-ecologists. The community was responsible for the different surveys, which consisted of recce-walks and camera-trapping surveys. Ultimately, the community is also involved in the development of hunting regulations and is empowered in the management of their wildlife resources (through the Honorary Wildlife Warden scheme, under the Sabah Wildlife Enactment, 1997).

This study provided qualitative information about species ecology (group size, breeding season, etc.) that were discussed with the communities during a series of village participatory workshops. Images and videos proved to be amazing tools to engage with the communities and to discuss with them about optimum use of resources (i.e. game species) including regulations about hunting area and quotas. However due to the limitations inherent to camera-trapping approaches, it was difficult to determine abundance of game species in a scientifically confident manner.

In summary, the provision of photographs facilitated the dialogue on the optimum use of wildlife including regulations about hunting area and quotas. Although this short term study was unable to develop these quotas, due to a limited understanding of the abundance of game species in the Crocker Range Park, this study paved the road for further activities and developments.

2.2 Camera-trap programme for tourism activities

At the beginning of such a programme, camera-traps are used to assess the presence and the location of iconic species that will be the target of tourism activities. This study will provide a list of species that can be spotted in the area, which is always appreciated by tourists. Traps are placed to investigate where the most promising areas for encountering wildlife are located. They are set at different heights to target species of different sizes (like smaller species such as rodents) or that are more arboreal. Some traps should also target areas that are important for wildlife such as salt licks or feeding/breeding grounds after these features have been identified. In the longer-term, camera-trapping could also be used to develop a community-based “scientific tourism” product where tourists are offered first-hand experience about the use of camera-trapping for studying wildlife. Tourists can follow local field research assistants in the forest to check the traps, they can download the images and see how the data are processed or analysed, etc. Educational materials (posters, slide shows, talks) regarding the local mammal fauna can be developed based on the data collected by camera-traps.

2.3 Camera-trap program for education/awareness activities

Communities will support a conservation strategy only if they find it legitimate. They will find it legitimate only if they gain sufficient knowledge and understanding of the situation. This is achieved through awareness raising and education. By producing images of the animals living in the surroundings of the village, camera-trapping is a powerful tool for increasing awareness of the community about the value of biodiversity. The *Feline Photo Project* (Text box 14) shows a successful example of the use of camera traps to mitigate conflicts with large carnivores in northern Mexico.

Text Box 14: The Feline Photo Project – an example for community outreach and conservation with the help of camera-traps.

The Northern Jaguar Project (NJP) and Naturalia, two NGOs actuating in northern Mexico, created the Feline Photo Project (http://www.northernjaguarproject.org/outreach/feline-photo-project) to enhance jaguar conservation on private properties in the range of the northernmost jaguar population. Under the project, camera-traps are set on participating ranches, and ranch owners receive a monetary reward (equal to the local bounty offered for dead jaguars) for each jaguar photograph taken by the camera-trap on his/her property (as well as smaller rewards for other felines). This scheme encourages ranchers to tolerate these big predators that sometimes attack their cattle on their properties.

While the Feline Photo Project targets human-predator conflict, the idea can easily be adjusted to other conservation and research foci. For example, this kind of project could generate presence records of little known species, rewarding the first person to prove the species' presence with a camera trap picture in a certain area; or it could be developed as an on-going monthly competition for the best picture of a certain species, kindling an interest in the local community for having such species in their vicinity. Such a program would have to be initiated with a short workshop for participants about how to set up a camera-trap. Alternatively, participants could be accompanied by a project team member in setting up the trap. A potential concern that has to be considered in planning such a project is the safety of the camera-traps from theft when set in publicly used areas.

There is an endless number of ways to use pictures with school children (games such as puzzles, quizzes, identification, etc.) and adults alike (PowerPoint presentations, exhibitions, etc.), to produce flyers, brochures, posters or even books, as well as other material. Animated footage captures people's attention more easily and video traps could be used to record behavioural sequences that will fascinate the audience.

2.4 Empowering local communities for monitoring and managing their wildlife resources

A few pre-requisites are needed to develop community-based wildlife monitoring using camera-traps.

Some villagers need to be identified and trained properly: experienced staff from government agencies and NGOs or researchers can provide the expertise. In the long-term, some supervision has to be available to ensure that the monitoring programmes run smoothly (see below) and that they yield analysable data.

People who have been properly trained and who are in charge of the monitoring need to be empowered to intervene directly in the field and in management decisions resulting from their activities. In Sabah, a provision of the "Sabah Wildlife Enactment, 1997" as well as other Enactments allow for community members to be appointed as "Honorary Wildlife Wardens". Under the provision of the different Enactments, people who are official wardens are entrusted with the same rights as rangers from government departments. In Sabah, the "Warden dan Ranjer Kehormat Sabah" was recently created to gather all the wardens throughout the State. It is thus essential for community members who are selected to carry out the monitoring to be gazetted as wardens.

A durable source of funding needs to be identified for the monitoring to be undertaken over several years. This funding can originate from a State Agency, from NGOs or from private sources nationally or internationally.

2.5 Establishing a Central Point for data processing, data storing and supervision

Although local communities can be entrusted to implement monitoring activities involving camera-trapping, there is still a need to provide adequate supervision to ensure quality of data.

A key for the success of community-based monitoring activities is to offer regular assistance and supervision when needed. For example, villagers need to discuss and to share their results and concerns with people who can provide technical and professional assistance, they need to know how to address malfunctioning equipment and who to contact with problems, etc. Ideally, this assistance is provided regionally by organizations that are active within or close to the area covered by the community.

In addition, all these efforts need to be centralized at the state-level. Indeed, despite the increasing and now widespread use of camera-traps throughout Sabah, a place where data and images could be centralized has yet to be created. Unless a central point acting as a data base for storing information is established, it is feared that most information collected by communities, scientists or staff from government agencies alike won't be fully used. The newly created "Sabah Biodiversity Centre" could act as this central point and as a catalyst for community involvement in camera-trapping activities.

Text Box 15: Involving communities in a state-wide species distribution monitoring program.

Estimating abundance and density of populations and monitoring trends over time requires large amounts of individual-level data. The occurrence of species on the other hand only requires species-level detection/non-detection data, which are comparatively easy to collect with camera-traps for a wide array of species. On a larger scale, monitoring the occurrence of species may be an adequate substitute and a much more feasible (though still work intensive) alternative to abundance monitoring (MacKenzie *et al*., 2006).

Trained "citizen scientists" and community camera trapping programs could readily be integrated into such large-scale monitoring efforts, adding to the number of sampling points without significantly increasing the logistic effort required to monitor them.

While such an approach would be interesting, it would also require substantial centralized planning and coordination, preliminary studies to assess the reliability of data collection by chosen communities and maximize standardization, let alone sufficient funding. Probably, such a program should not be based entirely on community-based sampling, since coverage of different environmental settings (in this example, maybe protected or otherwise remote areas with minimum human interference) needs to be assured. It is probably not advisable to begin working with a local community with such an elaborate project, but it does serve as an example of how community involvement could benefit a large-scale systematic study.

2.6 Safety requirements and team organisation

Safety should remain a constant and major concern when field research assistants are entering the forest to carry out their activities. Many problems can be faced in the forest, such as being lost, fall and subsequent injury (from minor cuts to major injuries like broken bones), snake bite, tree fall, etc.

In order to minimize the risks arising when a community-based camera-trapping project is developed, a few safety guidelines must be followed:

- Villagers who are in charge of the study need to follow proper basic first aid training before initiating the study
- A team is constituted of a minimum of two field research assistants: people should never go alone in the forest
- Make sure that the following equipment is always carried in the forest: compass, basic first aid kit, torchlight, survival and energy food, cell phone (since many areas in Sabah are covered by with a telephone network)
- An appropriate “Emergency Action Plan” needs to be discussed and developed with the community at the beginning of the project

Last but not least, health insurances and other liability schemes that are covering risks encountered during field activities need to be covered by the organizing project.

2.7 Final thoughts: camera-trapping in conservation; from ecological research to community involvement

Camera-traps are widely applicable in ecological and conservation-related research. Parts 1 and 2 of this manual outline how to plan, implement and analyse data from a camera-trapping study for research questions ranging from creating species lists to monitoring species demographics. While today camera-traps have become an indispensable tool in the study of mammals, one of the features that make this technique stand out among the many ways to survey wildlife is that it yields not ‘only’ data, but also compelling material with which we can engage the public. Pictures obtained by camera-traps can be used to educate local communities about the wildlife they share their resources with. The relatively ease in which camera-trap surveys can be standardized makes them an ideal tool for participatory research. The potential of such participatory approaches, some examples of which we discuss in Part 3, lies as much in empowering local communities and integrating them in resource management processes, as in being a complementary method to 'non-participatory' research that can greatly increase a project’s spatial coverage and man power. Obviously, there is no one technique that fits all research questions, and though versatile, camera-traps have their limitations. However, camera-traps may well form the core of comprehensive research or community projects addressing the study and management of medium to large sized mammals in the tropics.

REFERENCES

Amstrup, S. C., T.L. McDonald, and B.F.J. Manly. 2005. *Handbook of Capture-Recapture Analysis*. Princeton University Press.

Ancrenaz M., L. Dabek L, and S. O'Neil. 2007 The Costs of Exclusion: Recognizing a Role for Local Communities in Biodiversity Conservation. *PLoS Biology*, 5(11): e289. doi:10.1371/journal.pbio.0050289.

Bennun, L., Davies, G., Howell, K., Newing, H., and Linkie, M. 2002. *African forest biodiversity: a field survey manual for vertebrates.* G. Davies, Ed. Earthwatch Europe, UK. 172 pp.

Berkes, F. 2004. Rethinking community-based conservation. *Conservation Biology*, 18 (3): 621-630.

Besag, J., J. York, and A. Mollié. 1991. Bayesian image restoration, with two applications in spatial statistics. *Annals of the Institute of Statistical Mathematics*, 43 (1): 1–20.

Bodrup-Nielsen, S. 1983. Density estimation as a function of live-trapping grid and home range size. *Canadian Journal of Zoology*, 61 (10): 2361-2365.

Borrini-Feyerabend, G., A. Kothari, and G. Oviedo, G. 2004. *Indigenous and Local Communities and Protected Areas: Towards Equity and Enhanced Conservation*. IUCN, Gland, Switzerland and Cambridge, UK. xviii + 111pp.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. *Ecology,* 79 (3): 1018–1028.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. R. Ginsberg, M. Griffiths, *et al*. 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation,* 4 (1): 75–79.

Cliff, A. D., and J. K. Ord. 1973. *Spatial autocorrelation*. London, UK: Pion Press.

Colwell, R. K., and J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences,* 345 (1311): 101-118.

Danielsen, F., M. Mendoza, P. Alviola, D. Balete, M. Enghoff, M. Poulsen, and A. Jensen. 2003. Biodiversity monitoring in developing countries: what are we trying to achieve? *Oryx*, 37 (4): 1-3.

Danielsen, F., A. Jensen, P. Alviola, D. Balete, M. Mendoza, A. Tagtag, C. Custodio, and M. Enghoff.2005. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodiversity and Conservation*, 14: 2633-2652.

Donovan, T. M. and J. Hines. 2007. Exercises in occupancy modelling and estimation. http://www.uvm.edu/envnr/vtcfwru/spreadsheets/occupancy/occupancy.htm.

Efford, M.G. 2004. Density estimation in live-trapping studies. *Oikos*, 106 (3): 598–610.

Efford, M. G. 2011. secr: Spatially Explicit Capture-Recapture Models. R package version 2.1.0. http://CRAN.R-project.org/package=secr.

Efford, M. G., D. K. Dawson, and C. S. Robbins. 2004. DENSITY: software for analysing capture-recapture data from passive detector arrays. *Animal Biodiversity and Conservation,* 27 (1): 217–228.

Fiske, I., R.B. Chandler, and J.A. Royle. 2011. Unmarked: Models for Data from Unmarked Animals. R package version 0.9-0. http://CRAN.R-project.org/package=unmarked.

Gardner, B., J. Reppucci, M. Lucherini, and J. A Royle. 2010. Spatially explicit inference for open populations: estimating demographic parameters from camera-trap studies. *Ecology,* 91 (11): 3376–3383.

Gilks, W. R., A. Thomas, and D. J. Spiegelhalter. 1994. A Language and Program for Complex Bayesian Modelling. *Journal of the Royal Statistical Society. Series D (The Statistician)*, 43 (1): 169-177.

Henschel, P. and J. Ray. 2003. *Leopards in African Rainforests: Survey and MonitoringTechniques*. WCS Global Carnivore Program website.

Hines, J. E. 2006. *PRESENCE software to estimates patch occupancy rates and related parameters*. Patuxent Wildlife Research Center, Laurel, Maryland. www.mbr-pwrc.usgs.gov/software/presence.html.

Huggins, R. M. 1989. On the statistical analysis of capture experiments. *Biometrika*, 76 (1): 133-140.

Karanth, K. U., and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology,* 79 (8): 2852–2862.

Karanth, K. U., J. D. Nichols, N. S. Kumar, and J. E. Hines. 2006. Assessing tiger population dynamics using photographic capture-recapture sampling. *Ecology*, 87 (11): 2925–2937.

Krebs, C. 1989. *Ecological Methodology*. HarperCollins, New York.

Long, R. A, P. MacKay, W. J Zielinski, and J. Ray. 2008. *Noninvasive survey methods for carnivores*. Island Pr.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. *Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence*. Elsevier, New York.

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 (1): 71–75.

Mathai, J., D. Jathanna, and J.W. Duckworth. 2012, in press. How useful are transect surveys for studying carnivores in the tropical rainforests of Borneo? *Raffles Bulletin of Zoology*.

Meijaard E., K. Mengersen, D. Buchori, A. Nurcahyo, M. Ancrenaz *et al*. 2011.Why Don't We Ask ? A Complementary Method for Assessing the Status of Great Apes. *PLoS ONE*, 6(3): e18008.doi: 10.1371/journal.pone.001808.

Mishra, B., R. Badola, and A. Bhardwaj. 2009. Social issues and concerns in biodiversity conservation: experiences from wildlife protected areas in India. *Tropical Ecology*, 50 (1): 147-161.

Mohd-Azlan, J., J.L. Belant, and E. Meijaard. 2012, in press. Uning secondary information to study carnivores in Borneo. *Raffles Bulletin of Zoology*.

O'Brien, T. G, M. F. Kinnaird, and H. T. Wibisono. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation,* 6 (2): 131–139.

O'Connell, A. F., J. D. Nichols, and K. Ullas Karanth. 2011. *Camera-traps in Animal Ecology: Methods and Analyses*. 1st ed. Springer.

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*, 62: 1–135.

Pollock, K. H., J.D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical Inference for Capture-Recapture Experiments. *Wildlife Monographs*, 107 (1): 3-97.

Rexstad, E., and K.P. Burnham. 1991. *User's Guide for Interactive Program CAPTURE*. Colorado Cooperative Fish & Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

Rowcliffe, J. M., J. Field, S.T. Turvey, and C. Carbone. 2008. Estimating animal density using camera-traps without the need for individual recognition. *Journal of Applied Ecology*, 45 (4): 1228-1236. doi:10.1111/j.1365-2664.2008.01473.x.

Royle, J. A., and R. M. Dorazio. 2008. *Hierarchical modeling and inference in ecology*. London, UK: Academic Press.

Royle, J. A., and B. Gardner. 2011. Hierarchical spatial capture-recapture models for estimating density from trapping arrays. In O'Connell, A.F., Nichols, J.D., Karanth, U.K. (Eds.) *Camera-traps in animal ecology*. Methods and analyses. 163-190. New York: Springer.

Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. *Ecology*, 84 (3): 777–790.

Royle, J. A., and K. V. Young. 2008. A hierarchical model for spatial capture-recapture data. *Ecology*, 89 (8): 2281–2289.

Silver, 2004. *Assessing jaguar abundance using remotely triggered cameras*. Wildlife Conservation Society, Jaguar Conservation Program.

Simpson, E. H. 1949. Measurement of diversity. *Nature*, 163 (4148): 688–688.

Singh, P., A. M. Gopalaswamy, A. J. 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.

Soisalo, M. K, and S. 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 (4): 487–496.

Tilson, R., H. Defu, J. Muntifering, and P. J. Nyhus. 2004. Dramatic Decline of Wild South China Tigers Panthera Tigris Amoyensis: Field Survey of Priority Tiger Reserves. *Oryx,* 38 (01): 40-47.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study Supplement*, 46: 120-138.

White, L. and A. Edwards. 2000. *Conservation research in the African rainforest: a technical handbook*. Wildlife Conservation Society, New York, USA. 444 pp.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. *Analysis and management of animal populations: modeling, estimation, and decision making*. San Diego, USA and London, UK: Academic Press.

Yoccoz, N., J. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution*, 16: 446-453.

APPENDIX I: Example of data sheet

Appendix 1.a.: Basic information to be included for each camera trap operating in the field

The following frame can be used as a basic data sheet and brought to the field for data collection.

Name of the Study Area: General GPS location:
Team who installed the CT: Team who checks the CT:

CT ID	Location of the CT			Active Period			Site Specific Variables				Results			
	Latitude	Longitude	WP Nb	Installation Date	Removal Date	Effort Trap days	Set Up	Var. 1	Var. 2	Var. 3	Species A	Species B	Species C	Comments
A														
B														
C														
….														

Legend:

CT ID: Camera Trap Identification (number)
Location of the CT: WP Nb: Waypoint Number (read from the GPS)
Active period: This gives the survey effort (or number of days the trap has been active)
Site specific variables: This describes the micro-environmental conditions encountered at the CT site:
Set up: Write down if the CT is located along a road (active or not); a trail; a salt lick; at a random location in the forest; etc
Variables: Environmental variables that need to be recorded for each CT site: habitat type (forest; clearing; swamp; etc) - canopy height –canopy opening – logging activities – etc

Appendix 1.b.: Records to be processed

The following Table can be replicated in an Excel file or Dbase file or equivalent for processing information that is originating from the field.

Species	CT ID	Date	Time	Individual ID*	Nb. Ind.	Nb. Females	Nb. Males	Nb. Young	Occasion**	Primary sample***	Observations
A											
B											
C											
….											

Legend:

Individual ID*: for identifiable species only
Nb. Ind.: Number of Individuals recorded in the picture
Nb. Females: Number of Females
Nb. Males: Number of Males
Nb. Young.: Number of Cubs or Juvenile
Occasion**: For capture-recapture and occupancy modeling
Primary sample***: If sampling is repeated over a long time frame

Appendix 1.c.: Building an Occupancy matrix

The following Table can be replicated in a Spreadsheet (Excel, Dbase or equivalent format) to generate an Occupancy Matrix.

CT ID	**Occasions**			**Site Variables**			**Occasion Specific Variables**					
	Occ. 1	**Occ.2**	**Occ.3**	**Var.1**	**Var.2**	**Var.3**	**Var1 (Occ1)**	**Var 1 (Occ2)**	**Var 1 (Occ3)**	**Var 2 (Occ1)**	**Var 2 (Occ2)**	**Var y (Occ y)**
A	1	1	0									
B	0	1	1									
C	0	0	0									
….												

In this example, we test three different sampling occasions (Occ. 1; 2; 3) and three Environmental Variables (Var. 1; 2; 3)

Appendix 1.d.: Building a Capture-Recapture matrix

The following Table can be replicated in a Spreadsheet (Excel, Dbase or equivalent format) to generate a Capture – Recapture Matrix.

	Individual	Occasion 1	Occasion 2	Occasion 3	Occasion y
Species A	A	1	1	0	….
	B	1	1	1	….
	C	0	1	0	….
	….	….	….	….	….
Species B					
Species Y					

This format is the basic format for single-season closed population models. The input format for multi-season analysis will depend on the Models and the Programs used for data analysis.

Appendix 1.e.: Building a Capture-Recapture matrix

The following Table can be replicated in a Spreadsheet (Excel, Dbase or equivalent format) to generate a Spatial Capture – Recapture Matrix.

Individual	CT ID	Occasion	Primary survey	Individual Covariate 1	Individual Covariate 2	Individual Covariate Y

- This format has one line per record. If organized in "R" software, the data can be stored in array format (individuals x sites x occasions)
- Site-specific covariates should be stored together with trap coordinates in UTM in a separate spreadsheet

APPENDIX II: Trouble shooting guide/FAQ

Upon reception of the cameras, the field coordinator or project leader needs to perform a few verifications before sending the camera-traps to the field:

- Acquire a sufficient number of batteries, battery charger and memory cards
- Test all cameras and return the non-functional units to the supplier with the warranty card. Tests should include:
    - Testing the sensor by walking in front of the camera and have it take a test picture;
    - Testing the camera settings, e.g. does the time and date appear on the picture?
    - Testing the flash by taking a picture in the dark;
    - Testing that the camera is NOT activated at random by setting it up towards an empty space and monitoring it for several minutes during which it should not take any pictures.
- Ensure that all cameras are numbered or otherwise uniquely identified before sending them to the field

The following points relate to common problems encountered in the field when the cameras have been operating for a period of time and so cannot usually be returned to the supplier:

1. **The camera does not turn on**:
    a. Test the camera with new batteries, if it is still not functioning, bring it in from the field and dry it thoroughly – placing it in an airtight container with silica gel crystals for a few days is best. However, bear in mind that if the camera starts to function again it may not be reliable under field conditions.

2. **The camera is not taking photographs/not triggering**:
    a. Try using new batteries;
    b. Check the available memory and replace the memory card if it is full;
    c. Check all setting are correct, e.g. make sure the camera is not in test mode (how to switch modes will depend on the model you use);
    d. Try triggering it under cooler conditions or by waving a match/lighter in front of the sensor – the ambient temperature may be too high for the sensor to detect a warm-blooded creature passing. If this helps, consider setting this camera in a shadier spot;
    e. If the problem persists the camera needs to be taken in from the field, it is worth drying it in an airtight container filled with silica gel.

3. **The camera triggers but the photographs are not saved on the memory card**:
    a. Check there is sufficient capacity remaining on the memory card;
    b. Try a different memory card, which is working in other cameras - if the problem persists, the camera-trap has a problem;
    c. Make sure that memory cards of a capacity recommended by the camera manufacturer are being used, some camera models cannot write to high capacity memory cards;
    d. Make sure the card has previously been formatted in accordance with the camera manufacturer's recommendations. Some cameras cannot read cards if they are formatted externally;
    e. If the camera will not write to any memory cards but has the capacity to save images internally, it may still be useful in the survey, but placed in a location where it can be checked frequently.

4. **The memory card cannot be read by the computer**:
    a. Make sure the card is not “locked”. Most memory cards have a sliding switch on the side that, when set to locked, prevents the card being formatted. This may also prevent the card being read;
    b. Try using an external/different card reader;
    c. Use the most expensive memory cards that the project can afford.

5. **The photographs are black and white or oddly coloured**:
    a. If the camera has an infra-red flash then black and white photos will result at night, or under low-light conditions, sometimes even in the middle of the day which may be unexpected, but does not necessarily mean there is a problem with the camera. If the photos are useable there is no reason to remove the camera from the survey;
    b. Sometimes the white balance in the camera malfunctions and oddly coloured photographs can result. The aims of the project and the extent to which images are affected will dictate whether or not it is worth keeping the unit operating in the field, for instance it may be possible to identify the species, but rather more difficult to identify an animal to individual by its coat pattern;
    c. Check if there is a problem of condensation on the lense.

6. **The flash does not trigger:**
    a. Check that the flash is activated and make sure you test the camera under conditions for which the flash is set (e.g. in the dark if you set the flash to only work at night);
    b. If it doesn’t help this is not something that is easy to fix. However, unless there are extra cameras available, it is probably worthwhile keeping the unit in the field, it will continue to record data on diurnal and crepuscular species, but the fact that it is not working continuously must be taken into account when trapping effort is calculated. It should be moved to a less promising site;
    c. Increasing the contrast of the image using photo editing software can often help with dark photographs.

7. **The photographs are overexposed**:
    a. Setting the camera further away from the predicted travel route of the animals can help with overexposed photos;
    b. Make sure there is no vegetation or other obstruction that will reflect the flash and cause overexposing;
    c. If you have cameras set up in pairs facing each other, make sure it is not the flash of the opposite camera that is interfering;
    d. Check whether there are different settings for the flash and use the setting appropriate for the camera location. For example a camera set in a very open area may require a more powerful flash (higher setting) than one set within more dense vegetation.

8. **The camera is taking lots of “blank” photos:**
    a. Test the unit with new batteries. Some cameras will take photographs continuously as the batteries run out, the problem will be rectified with new batteries;
    b. Make sure the camera is not being triggered by sun-warmed vegetation moving in front of the sensor, cut back any overhanging leaves and other vegetation. However, if the false triggers are occurring at night, vegetation is not the problem;
    c. This problem may be caused by humidity and bringing the camera in from the field and drying it in a container with silica gel may help;
    d. Ensure that no insects mainly ants have settled within your camera and trigger your cameras.

9. **The time and date have changed and are now incorrect:**
    a. It is important to determine whether the camera was set up incorrectly or whether there is a fault in the camera. Some models do not operate with the 24-hour clock system and it is easy to incorrectly set the am or pm option;
    b. If the batteries have run out completely the time and date may revert to a default setting, check the settings each time the batteries are replaced;
    c. Sometimes units malfunction and record a completely incorrect time and/or date. In these cases it may be possible to use the data for certain purposes, for instance to record the species, but not for determining activity patterns;
    d. If the time and date have been set incorrectly by field staff, it may be possible to work out the correct date and time if the camera is one of a pair and the other camera has the correct settings. However, this cannot be done reliably if the camera has malfunctioned as this is likely to be random.

10. **The camera settings have reverted to default settings:**
    a. Some camera models will revert to all default settings when the batteries run out and haven't been replaced for some time; some models may revert every time the batteries are changed. Although frustrating, this does not necessarily mean there is a problem with the camera. All team members should be aware of how the cameras will behave when the batteries need replacing, know the desired settings and how to change them if need be. Avoid this problem by replacing batteries BEFORE they run out.

11. **The battery life is very short:**
    a. Use the highest quality batteries that the project can afford. Do not try to save money with cheap batteries;
    b. There is a limit to how many times rechargeable batteries can be charged and as they reach or pass this limit the length of time they will operate for is reduced;
    c. Test the unit with new batteries;
    d. Check whether the memory card is full. Some camera models will continue triggering and using battery power even when the memory is full.

12. **The camera does not trigger all the time:**
    a. It can be difficult to know if the camera is not working properly or if it has been located in an area with little animal movement. However if the camera is one of a pair it may be apparent that one camera is missing many of the animals that have been recorded by the other camera;
    b. It may be possible to change the sensitivity setting on the camera, try changing it to the highest setting;
    c. Check the field set-up of the camera and make sure the height and angle are appropriate;
    d. Again, high temperatures may make it difficult for the camera to detect warm-blooded animals passing; this is something you will simply have to live with in tropical areas.

13. **The camera has leaked:**
    a. It is unlikely that the camera will still be functioning if it has leaked, it will probably need to be removed from the survey and dried in an airtight container using silica gel. It is also unlikely to be very reliable in the future;
    b. Check the casing for obvious splits or cracks; it is worth sealing these and seeing if the camera will function again. Also check the clasp and the windows covering the lenses;

c. Make sure the rubber seal on the camera is free from grit or any other debris when the camera is closed – even a very small piece of debris will allow water through the seal;
d. Try to check whether the camera has been tampered with – it is possible that there was not a problem with the camera, but that somebody external of the project has opened it and not closed it correctly;
e. Never open the camera in the rain, always use an umbrella or similar to shield the camera when checking in bad weather. Take towels to the field to dry your hands when checking the camera.

14. **There are ants or other insects in the camera or protective casing:**
    a. It is fairly common to find an ants' nest in the camera box, especially if a protective outer case is used. Unless these are causing problems such as false triggers or have managed to enter the camera itself, they can usually be ignored;
    b. These will quite often move out when they are disturbed as the camera is checked, it might be necessary to relocate the camera slightly;
    c. Using an insect repellent might prevent ants or other insects from living in the camera housing, however the smell from the repellent might cause other animals to stay away, affecting the results of the survey so it is best to not use these.

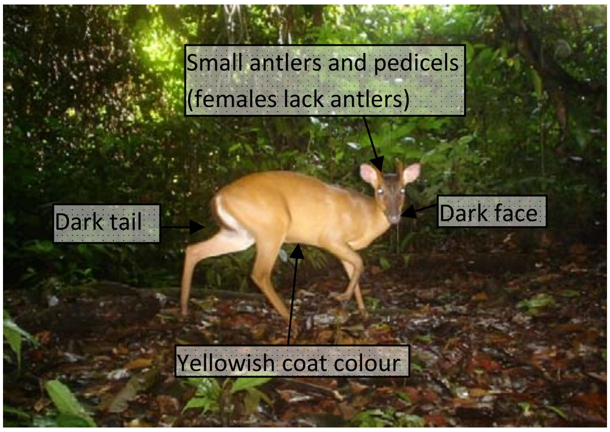
15. **Large animals have tampered with the camera**: some species like elephants or monkeys may be very inquisitive and play with or destroy cameras. Check our recommendations of how to set cameras in Chapter to see how to prevent such problems.

In general, warranty time is different for different manufacturers. If you cannot fix the camera problem yourself and still have a warranty, always send the camera back to the manufacturer. This may take time, so also consider working with locals on fixing smaller problems, such as broken or scratched lense covers.

Appendix III: Photographs for ID

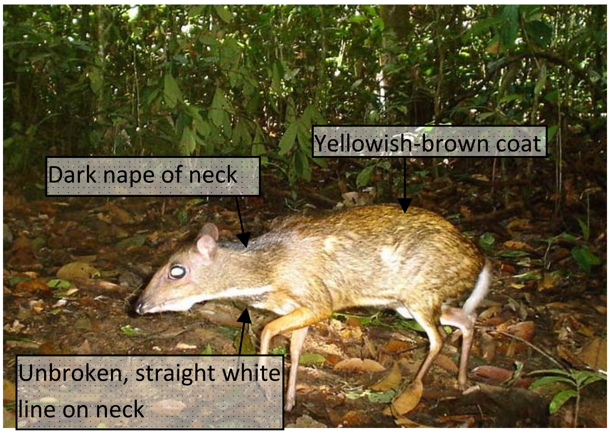
Camera taps will record any species that pass by and trigger the camera; following are some examples of the more commonly recorded species, with annotations to help distinguish between easily confused species. All photographs by Andrew Hearn and Joanna Ross, except flat-headed cat, hairy-nosed otter and ferret-badger by Andreas Wilting.

Kijang, jantan Bornean yellow muntjac, male



Kijang, jantan, red muntjac, male

Pelanduk, lesser mouse deer



Napoh, greater mouse deer

Babi hutan, bearded pig

Babi hutan, bearded pig juveniles

Tembadau, jantan, banteng, male

Tembadau, betina, banteng, female

Rusa, jantan, sambar deer, male

Rusa, betina, sambar deer, female

Harimau dahan, Sunda Clouded leopard

Kucing batu, leopard cat

Kucing dahan, marbled cat

Kucing merah, bay cat

Kucing hutan, flat-headed cat

Musang tanggalung, Malay civet

Musang belang, banded palm civet

Musang pulut, common palm civet

Musang memerang, otter civet

Musang lamri, masked palm civet

Musang hitam pudar, Hose's civet

Musang binturong, binturong

Bambun ekor pendek, short-tailed mongoose

Bambun ekor panjang, collared mongoose

Beruang, sun bear

Teledu, Malay badger

Mengkira, yellow throated marten

Memerang licin, smooth otter

Memerang kecil, small-clawed otter

Memerang kumis, hairy nosed otter

Beruk, pig-tailed macaque

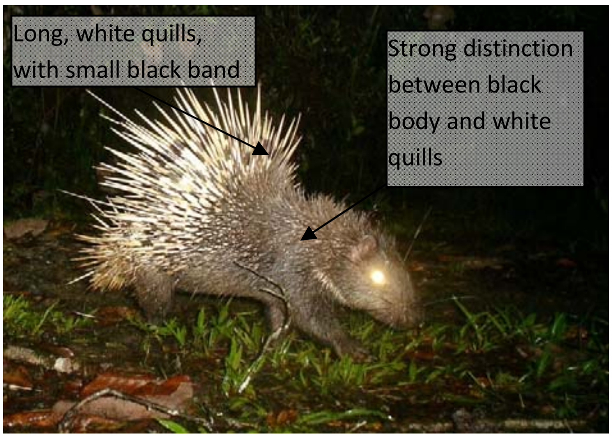
Kera, long-tailed macaque

Orang hutan, Orang utan

Tenggiling, pangolin

Landak Borneo, thick-spined porcupine

Landak raya, common porcupine



Landak padi, long-tailed porcupine

Tikus bulan, moonrat

Gajah, Bornean pygmy elephant

Pulasan lamri, ferret-badger