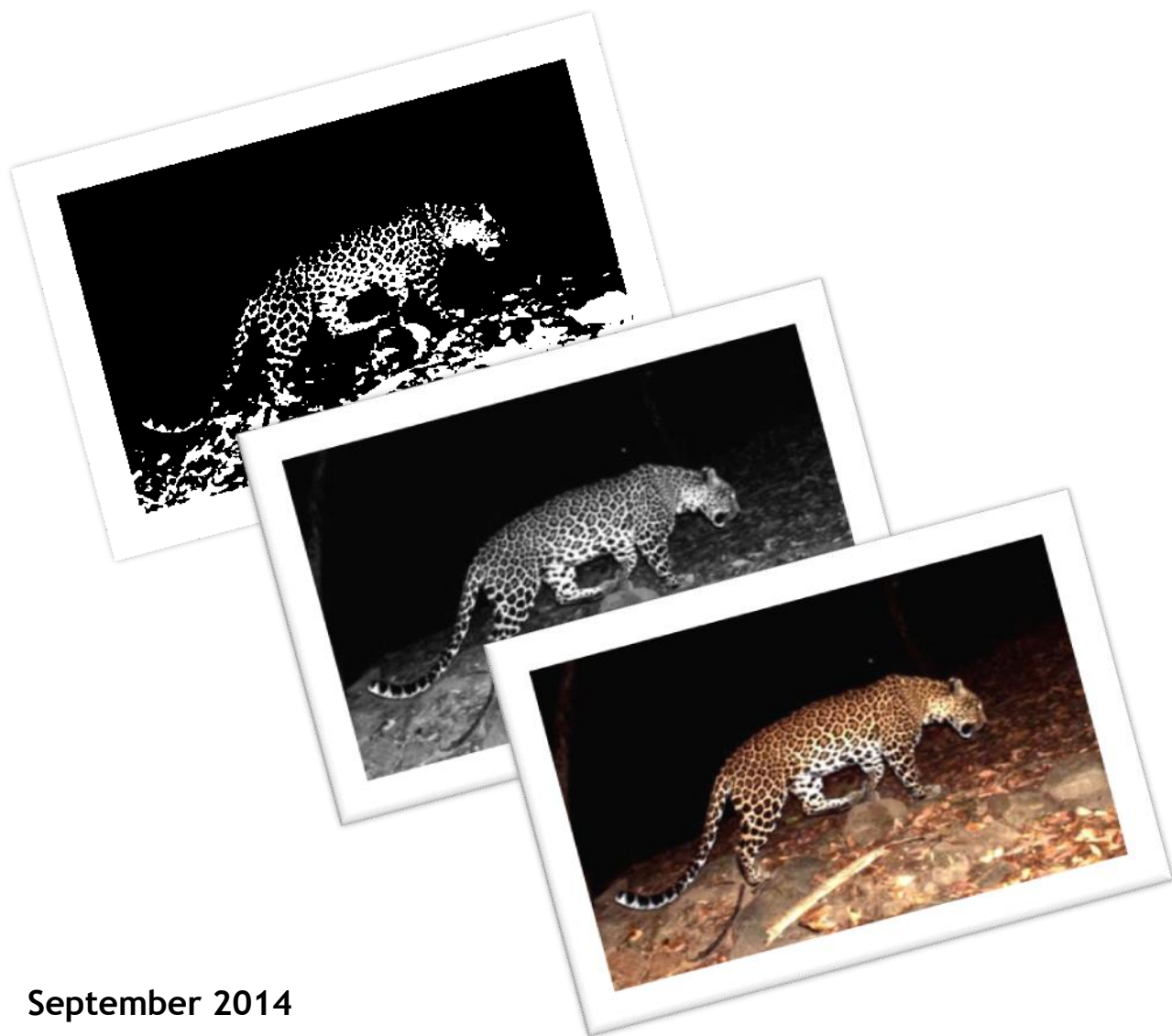


Publishing Camera Trap Data A Best Practice Guide

Cadman, M. & González-Talaván, A. (eds.)

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NORWEGIAN BIODIVERSITY
INFORMATION CENTRE



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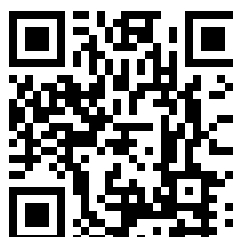


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Executive Summary

This guide is a product of the Indo-Norwegian project "*Capacity building for Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES)*" focussed on capacity building in biodiversity informatics for enhanced decision-making, improved nature conservation and sustainable development. The pilot-project is actively supported by both the Indian and the Norwegian Governments.

Capacity enhancement is an essential component of many global initiatives such as the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES)¹ and the Global Biodiversity Information Facility (GBIF). The Norwegian Government acknowledges the need for capacity enhancement and has developed and initiated several projects addressing capacity enhancement needs in partner countries.

The goal of this pilot project is to enhance capacity in Biodiversity Informatics at the Wildlife Institute of India (WII) and the Norwegian Institute for Nature Research (NINA). The pilot project is initiated and funded by the Norwegian Ministry for Foreign affairs², the Norwegian Environmental Ministry³ and the Norwegian Environmental Agency⁴. The pilot project is also highly welcomed and explicitly supported by the Government of India.

The Wildlife Institute of India (WII) identified in May 2012 a great interest among Indian biodiversity stakeholders for a system that could enhance the management and usability of biodiversity-related multimedia data.

This guide is a contribution to enhance the existing capacity in the capture and online publishing of a particular type of data: multimedia data captured through camera traps. By compiling the best practices on the many aspects to be considered while designing and executing projects using this data capture method, we aim to facilitate the work of project managers and participants for a more efficient project execution and the achievement of sound results.

This text is based on successfully implemented global standards, best practices and the existing technical framework for data publishing developed by the Global Biodiversity Information Facility (GBIF).

The current version of the guide is based on thorough literature reviews and experiences from several camera-trapping projects in India, Norway and South Africa. Based on real user needs, user experiences, existing standards and technological frameworks we hope that this guide will catalyse the usage of camera-trapped biodiversity data in decision-making for a sustainable future.

¹ <http://www.ipbes.net/>

² <http://www.regjeringen.no/en/dep/ud.html?id=833>

³ <http://www.regjeringen.no/en/dep/kld.html?id=668>

⁴ <http://www.miljodirektoratet.no/english/>

About the Project Partners

These are the institutions and international networks that have made the production of this best practice guide possible:

WII: the Wildlife Institute of India

The Wildlife Institute of India, established in 1982, is an autonomous organization under the Ministry of the Environment & Forests of India. WII's mandate is to train government and non-government personnel, conduct research and provide advice on matters of conservation and management of wildlife resources. WII serves as the coordinating node for GBIF activities in India and has played an important role in assessing policy and institutional constraints and opportunities for development and customization of data publishing frameworks for environmental assessment.

The major contributions from WII to the project are:

- Project coordination;
- Expertise in camera trap projects;
- User needs identification;
- Data capture and standardization; and
- Organization of training courses and workshops.

Website: <http://www.wii.gov.in/>

NINA: the Norwegian Institute for Nature Research

NINA is responsible for long-term, strategic research and commissioned applied research to facilitate the implementation of international conventions, decision-support systems and management tools, as well as to enhance public awareness and promote conflict resolution. The institute was established in 1988, employs a staff of approximately 240 and directs well-equipped laboratories and facilities at seven locations in Norway. NINA offers broad-based ecological expertise covering the genetic, population, species, ecosystem and landscape level, in terrestrial, freshwater and coastal marine environments. NINA addresses a wide variety of interdisciplinary issues involving both ecologists and social scientists, and plays an important role in research activities in Europe and other international setups. NINA is experienced in dealing with natural and human aspects of resource and biodiversity management in developing countries and Eastern Europe, and has actively contributed to capacity building and technology transfer by means of research cooperation and consultancy activities. NINA's activities encompass resource assessment and monitoring, development of methodologies, environmental impact assessments, community-based resource management, and analysis of natural, anthropogenic and socio-economic aspects of biodiversity and resource management. NINA's staff provides comprehensive and up-to-date scientific

About the Project Partners

expertise, and guarantees top-quality services in commissioned research and consultancy tasks.

The major contributions from NINA to the project are:

- General project management and coordination;
- Expertise in camera trapping projects on lynx;
- Experience from the construction of the Norwegian biodiversity infrastructure; and
- Expertise from several research projects on wildlife-human interactions in Norway and India.

Website: <http://www.nina.no/>

GBIF: the Global Biodiversity Information Facility

GBIF was established by countries as a global mega-science initiative to address one of the great challenges of the 21st century: harnessing knowledge of the Earth's biological diversity.

GBIF envisions a world in which biodiversity information is freely and universally available for science, society, and a sustainable future. GBIF's mission is to be the foremost global resource for biodiversity information, and engender smart solutions for environmental and human well-being.

To achieve this mission, GBIF encourages a wide variety of biodiversity data holders, generators and users across the globe to discover and publish (make discoverable) data according to global standards through its network.

The major contributions from GBIF to the project are:

- Guidance in standardization, data sharing, biodiversity informatics and capacity building; and
- Documentation and dissemination.

Website: <http://www.gbif.org/>

NBIC: Norwegian Biodiversity Information Centre

NBIC is the national source of information about biodiversity in Norway. Its main function is to supply the public with updated and accessible information on Norwegian species and ecosystems. NBIC became operational in January 2005. As a national source of information, the goal of NBIC is to make existing information about biodiversity accessible through the Internet. NBIC also works to increase the relevance of biodiversity and raise public awareness about it. Its objective is to provide any public debate with up-to-date, correct information. This will help to make biodiversity an important factor in any related decision-making processes.

The major contributions from NBIC to the project are:

About the Project Partners

- Expertise from building the Norwegian biodiversity infrastructure; and
- Expertise on web technologies and online data dissemination.

Website: <http://www.biodiversity.no/>

NHM: the Natural History Museum of the University of Oslo

The Natural History Museum hosts the main node of the Global Biodiversity Information Facility (GBIF) in Norway in close relation with the two other Norwegian GBIF data nodes at the Museum IT (MUSIT) and the Norwegian Institute for Nature Research (NINA).

GBIF Norway was established at the Natural History Museum in 2005 with the mission to make information from Norwegian museum collections and other sources available to the international GBIF network and to coordinate GBIF-related activities in Norway. GBIF-Norway cooperates closely with NBIC.

The major contributions from NHM to the project are:

- Expertise from building the Norwegian biodiversity infrastructure; and
- Data repatriation of Indian specimens kept in Norwegian museum collections.

Website: <http://www.gbif.no/about>

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1. Introduction

1.1. The bigger picture

The world is facing unprecedented challenges related to biodiversity, with biodiversity loss and degradation of ecosystems taking place more rapidly and extensively than in any comparable time in human history (MA, 2005). This holds negative impacts for human health and well-being and compromises sustainable socio-economic development.

The **Intergovernmental Platform on Biodiversity & Ecosystem Services**⁵ (IPBES) was established as an intergovernmental body for assessing the state of the planet's biodiversity, its ecosystems and services. Its assessments depend on sound biodiversity data, freely accessible and in standardized formats, that facilitate scientific analysis and comparison of datasets of diverse types, between countries and over time.

Knowledge about the identity, occurrence, abundance and behaviour of organisms forms the backbone of our understanding of the biological world, and is essential for monitoring the state of natural ecosystems, for developing sound environmental management policies and making ecologically sustainable development decisions.

Over the past decade, the **Global Biodiversity Information Facility**⁶ (GBIF) has been striving to make digital biodiversity data freely and openly available via the Internet for scientists, researchers, decision-makers and the general public. GBIF promotes a suite of standards and data publishing tools that can be used to capture, publish and discover primary biodiversity data. As far as biodiversity data are concerned, GBIF and IPBES are complementary (GBIF 2010a). A wide variety of biodiversity data are already available through GBIF.org and other automated mechanisms, thanks to the effort of data publishers worldwide.

With the advent of technologies such as digital photography and camera traps, large volumes of biodiversity data are being generated through multimedia objects. **Multimedia resources** can provide reliable evidence for the occurrence of species at a particular place and time, and there is growing recognition that biodiversity-related multimedia objects can be used as reliable biodiversity records, as long as the supporting information is verifiable.

With the increasing need for a high volume of credible, high-quality data for research, instruction and decision-support, biodiversity information systems and networks must now mobilize primary data associated with both traditional and non-traditional sources, including multimedia resources such as camera trap images.

⁵ <http://www.ipbes.net/>

⁶ <http://www.gbif.org/>

1.2. Scope of this guide

Multimedia objects related to biodiversity are created and managed by a wide cross-section of communities and individuals, including research scientists, wildlife managers and interested members of civil society. These multimedia objects are potentially a rich source of information, but currently much of this is not captured, stored or disseminated in any kind of systematic way.

One of the reasons for this has been the lack of guidelines that describe the equipment, methods, standards and workflows for capturing and managing the biodiversity data associated with multimedia objects. The same applies for publishing and making them openly accessible in exchangeable formats. Hence, the need for this best practice guide.

In short, the guide **aims to**:

- Provide an overview of the role of multimedia data, and particularly camera trap data, as a vital resource in biodiversity science, scientific research, wildlife management and other applied aspects of ecology and biodiversity science;
- Describe the equipment, methods and workflows involved in the collection, management and publishing of multimedia resources;
- Explain the standards, tools and protocols that apply to capturing, managing and publishing biodiversity data associated with multimedia resources;
- Describe derived metadata that could be captured from camera-trapping;
- Provide guidance on how to enhance the fitness for use of multimedia objects; and
- Highlight and emphasize the practical applications of biodiversity data extracted from multimedia objects.

Throughout the guide, case studies and examples are used to illustrate the tools, methods and processes that are described.

The Guide does not:

- Cover camera-trapping in aquatic or sub-surface environments;
- Provide details on how to use these resources in decision-making and conservation practices, nor address the full spectrum of end-user needs;
- Provide comprehensive coverage of the scientific analysis of data associated with multimedia objects;
- Assess any commercial or third party products. Where specific products are mentioned, suggested or recommended for use, this is done simply on the basis of the authors' personal experience.

This is a rapidly developing field and this guide will therefore need to be updated in the future. We have attempted to capture what can currently be considered to be robust best practices that are applicable across a range of circumstances.

This guide includes information gleaned from published findings as well as informal consultations with practitioners who have been working extensively in this field and learning by doing. We advise readers to use this guide in conjunction with other documents offering guidance in this field of work, in particular the manual published by Meek, Ballard & Fleming (2012), which provides a comprehensive introduction to camera-trapping based on wildlife surveys in Australia. Many other authors (e.g. TEAM, 2011) deal in detail with the selection of camera trap types, how they work, camera trap settings for different types of survey and data analysis, but include only brief sections on data storage and management.

1.3. Target audiences

This guide has been written with the following general audiences in mind:

- Wildlife and biodiversity resources managers;
- Biodiversity and conservation scientists and researchers;
- Biodiversity data publishers working with multimedia resources;
- Database and information network managers;
- University lecturers and students working with biodiversity information; and
- Amateur naturalists and citizen scientists.

In addition, there are other potential users who may find this guide useful, even if they are not generators or publishers of data, but who benefit from using the biodiversity data mobilized from multimedia resources (e.g. policy makers, legislators, law enforcement agencies, anti-poaching teams).

1.4. How to use this guide

It is likely that different audiences will find different parts of this guide useful. While those leading camera trap projects will probably find all parts useful, those working in the field or with the digital data derived from the images will probably want to concentrate on certain parts.

This is a summary of the different components of the guide:

Chapter 2 provides an introduction to the use of camera traps for biodiversity research. It also gives an overview of potential uses of the data obtained through them. Probably all members of a camera trap project would find this chapter useful.

Chapter 3 gives insight on the organization of projects with a camera trap component and on the different factors that need to be considered. Project managers will probably find this chapter most useful.

Chapter 4 highlights some of the aspects to have in mind when planning and executing the deployment of camera traps in the field. It will be especially interesting for those having to install, configure and maintain the traps.

Chapters 5 and 6 are addressed to those who will manage the digital data associated with the project. Chapter 5 gives recommendations on how to capture, prepare and manage the digital files and their associated data. Chapter 6 deals specifically with how to publish those data on the internet following international standards.

1.5. Needs and opportunities in India and Nepal

The project that supported the production of this guide included an initial step to assess the needs and the current level of use of camera-trapping, their characteristics and applications.

This was done through a survey in 2012 which showed that the predominant applications are the analysis of distribution patterns, and monitoring populations of selected species. Few data users exchange their image data freely with others, and few data are currently published.

Based on the responses received, it was observed that:

- A large volume of high-quality, camera trap images of threatened fauna exists;
- 96% of the respondents possess digital images from 41 protected and non-protected areas spread over 20 Indian states and Nepal;
- The majority of the users (71%) own their data; and
- Common leopard, tiger and black bear are the three major species studied.

Despite the existence of a large body of camera trap data, the survey also established that:

- Very few of the respondents (13%) make image data freely available to others, and data-sharing policies and guidelines are required;
- Incentives are needed to encourage data owners to contribute and exchange data;
- Easy-to-follow data management and publishing protocols are currently lacking; and
- There is general endorsement of the need for a national infrastructure for storing and managing camera trap data, particularly to make available data gathered using public funds.

Many of the findings of the preliminary study highlighted the need to document best practices. This guide aims to meet that need.

2. The Use of Camera Traps in Biodiversity Research and Conservation

2.1. A brief history

Camera-trapping refers to the use of remotely-triggered cameras that automatically take images of animals that move in front of them. This method is most often used to capture images of medium to large sized terrestrial mammals and birds, but has also been used for arboreal mammals and other non-mammalian groups. The use of camera traps in wildlife monitoring, research and management has escalated rapidly in the last ten years and camera-trapping methodology has undergone significant and rapid advances over this time.

The first camera traps were invented and used in the late 1890s. They were manually operated systems used for photographing animals at night and their use was of more interest to wildlife photographers than scientists or wildlife managers.

In the early 1920s, camera-trapping as a tool for wildlife monitoring was pioneered in India in the forests along the Himalayan foothills by the forester F.W. Champion, and this early work served as an inspiration to later generations of camera trap users (see the special contribution below).

It was after the invention of automated camera traps in the 1980s that wildlife researchers started using this method more extensively as a means of inventorying animals and estimating their abundance. As the types of devices available have advanced, researchers have identified more and more opportunities for their use in an ever-widening range of applications, and the number of publications using camera trap data has increased exponentially.



Figure 1: One of the most remarkable photographs of wild tigers taken by F.W. Champion in the 1920s. © Copyright James Champion, reproduced with permission.

A pioneer in the use of camera trapping: F.W. Champion in the 1920s

Special contribution by James Champion & Abishek Harihar.

Camera-trapping was pioneered in the 1920s in forests along the Himalayan foothills by F.W. Champion, who was a forester in the Imperial Forest Service in British India. Using trip wires, pressure plates and magnesium flash (which could be used just once every night), Champion obtained some of the most remarkable images of tigers and other species including black bear, sloth bear, dhole (Asiatic wild dog), striped hyena, fishing cat, leopards and other species.

A rare, early conservationist, F.W. Champion's deep fascination for tigers meant that he hated issuing permits to visiting dignitaries to shoot tigers in his forest area. Instead he often sent them off to areas where the chances of encountering tigers were very low. He penned his experiences in the jungles in two fascinating books, *With a Camera in Tigerland* (1927) and *The Jungle in Sunlight and Shadow* (1934), which have inspired generations of foresters and naturalists alike. He recognized that individual tigers could be told apart based on their distinct stripe patterns, a fact which forms the basis of the modern capture-recapture methodology being used to enumerate tigers worldwide. His legacy continues in the foothill forests, where camera-trapping is now being used successfully to scientifically monitor the tiger population.

2.2. The use of multimedia objects as a primary biodiversity data source

As stated in the introduction, appropriately documented multimedia objects can be used as reliable sources of **primary occurrence data**, testifying the occurrence of certain species at a given location and time.

As primary data, the uses of these objects span many disciplines, from scientific uses such as in taxonomy, biogeography or genetics, to very practical uses in areas such as impacts of climate change, public health or wildlife trade control.

Readers can find out more about the generic uses of such data in the comprehensive manual *Uses of Primary Species-Occurrence Data*, published by GBIF and authored by A. Chapman⁷ (Chapman, 2005c). Specific cases of applied data use can be found in the GBIF.org newsroom⁸ and the annual GBIF Science Review⁹.

⁷ http://old.gbif.org/orc/?doc_id=1300

⁸ <http://www.gbif.org/newsroom/uses>

⁹ http://old.gbif.org/orc/?doc_id=5984

2.3. Use of camera trap data in biodiversity science and conservation

There are certain **characteristics of camera-trapping** as a data collection method that make it especially suitable for certain uses, closely linked to science and conservation. Some of these characteristics are:

- It is a non-invasive method of data collection that generally causes minimal disturbance to the target species;
- It provides geo-referenced photographic evidence that serves as an objective record of the animal's presence, activity patterns, behaviour, and visual characteristics that enable identification even at the level of individuals.
- It is cost-efficient: high quality data can be obtained at a low cost, also in terms of staff time.
- Camera traps can be left unattended in the field for several weeks, and thus are ideally suited for studying rare, elusive, and nocturnal or crepuscular animals that avoid humans or that are otherwise difficult to study (e.g. animals with large home ranges, low abundance or secretive habits).
- Although most camera-trapping studies are designed to target particular species or guilds of animals (e.g. small carnivores), the cameras also generate a significant inventory of other aspects of the biodiversity of the site and the human use of the area during the time they are deployed in the field. In most cases these images remain inaccessible and unused, even if they could contribute significantly to address gaps in biodiversity information.

These characteristics of camera-trapping makes it especially suitable for the following **uses**:

- Composing faunal **inventories**;
- Estimating the occupancy, density and dynamics of **populations**;
- Describing **habitat** preferences;
- Registering **behaviour** and activity patterns; and
- Registering inter-specific **interactions**.

With regard to wildlife **conservation and decision-making for sustainable development**, the following specific use cases that are worth highlighting:

- **Understanding population trends**: Camera-trapping is a particularly effective way to estimate population densities and monitor populations, especially when the animals concerned have large home ranges, small population sizes and cryptic behaviour patterns (e.g. jaguars, tigers). Accurate population data, in combination with estimates of carrying capacity and other population trends, provide important information for ensuring that sufficient areas are available to maintain viable population sizes. Density estimates from multiple sites and habitat types will provide the scientific data needed to develop population models for conservation programmes and to justify existing and new protected areas for the target species.

The use of camera traps in biodiversity research and conservation

- **Assessing poaching locality:** Species such as tigers, jaguars and leopards are identifiable at the individual level due to their distinct pelage patterns. This has been particularly useful in linking poached tiger skins to their natural habitats. Comparing seized skins against a database of tiger images can be used to identify the site from which the tiger has been poached, often without any need for molecular forensic tests.

2.4. Examples of practical use cases of camera trap data

The table below includes some examples of the diversity of organisms that have been targeted in research projects that have used camera traps as data collection method:

| Group studied | Reference |
|---|--|
| Pollinators of flowers | Carthew, 1993 |
| Birds and small mammals | Paull <i>et al.</i> , 2011 |
| Snow leopard in the Himalayas | Jackson <i>et al.</i> , 2006 |
| Bobcat in northern California | Larrucea <i>et al.</i> , 2007 |
| Tigers in India | Harihar, Gandav & Goyal, 2009 and 2011 |
| Lynx in Norway | Odden & Linnell, 2012 |
| Fauna of the humid tropics | Karanth & Nichols, 1998; Rovero & De Luca, 2007; Tobler <i>et al.</i> , 2008 |
| Large African herbivores (i.e. buffalo, elephant) | Winterbach & Bothma, 1998; Kerley, <i>et al.</i> , 2012 |
| Chinese mountain cat | Sanderson, 2007 |
| Abbott's duiker | Rovero <i>et al.</i> , 2005 |
| Giant elephant-shrew (new species) | Rovero <i>et al.</i> , 2008 |

Table 1: Some examples of groups studied via camera-trapping.

The three short case studies below summarize some especially **representative examples** of use of camera trap data.

Use case 1: Monitoring tigers in Rajaji National Park

Following the creation of inviolate space as a result of voluntary resettlement of pastoralist *Gujjars* from Chilla range in the eastern part of Rajaji National Park (RNP) in northern India, a significant recovery of tiger population has been documented. Continuous annual monitoring using camera traps has been conducted since 2004-05 during a 45-day period in winter following the closed capture-recapture methodology.

The monitoring has documented an increase in tiger density from 2.9 (2004-05) to 7.1 individuals/100 km² (2011-12).

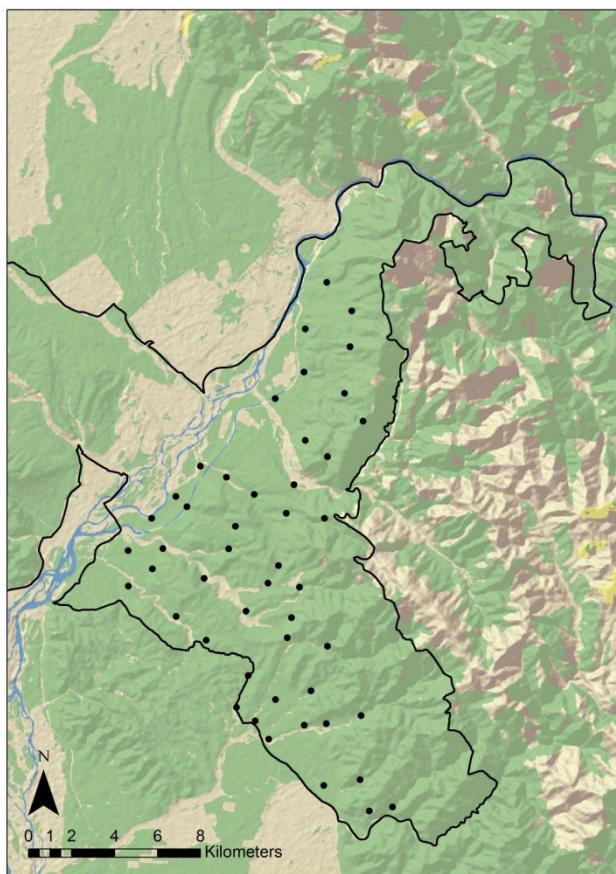


Figure 2: Eastern Rajaji National Park with camera trap locations indicated as black dots.

Seven of the last eight sampling seasons (2004-2011) presented high individual turnover: very few individuals stayed across years and most of them came in one year and were not seen again. This could be explained if the animals were using eastern RNP as a passage area from the source population established in Corbett Tiger Reserve towards the newly available disturbance-free habitat.

Breeding females and cubs were photographed every year, reflecting this rise in population density.

Coinciding with a rise in tiger density, the density of leopards in the park declined from 9.76 (2004-05) to 2.07 individuals/100km² (2007-08) indicating competitive interactions between the two large carnivores.

Recent monitoring in December 2011 has revealed the presence of 13 individuals (three males and 10 females) in Eastern RNP. Most individuals captured that year were also photographed in the previous years, indicating a possible stabilization of the population in this area.

For more details see Harihar *et al.* (2009) and Harihar *et al.* (2011).

Use case 2: Camera trap image helps to identify poached tiger skin

The hunting of tigers is the most immediate threat to the remaining wild populations of these endangered animals. Despite the increased conservation efforts across a range of countries, a substantial demand still exists for tiger parts and products.

When the skin of a poached tiger is seized, ascertaining the origin of the individual involves forensic examination using molecular genetic techniques. However, when a database of live tiger pictures obtained via camera traps is available, it is possible to directly assign individual identity to the skins.

On 9 February 2012, tiger skin and bones were seized in Najibabad (northern India). The poachers declared that the individual was killed in a non-protected forest area close to the Rajaji National Park. Previous studies had produced a photo database of individual tigers in that area, that could be used for comparison. Standard visual comparison procedures identified the individual as a female, captured on camera once along the south eastern boundary of the park in October 2009.

The use of camera traps in biodiversity research and conservation

In the case of India, a national database of tiger photo-captures could greatly help law enforcement agencies in identifying the sites most vulnerable to poaching.

For more details, see Hiby L. *et al.* (2009).



Figure 3: Images of the poached skin and of the living tiger captured via camera traps.

Use case 3: The use of non-targeted images

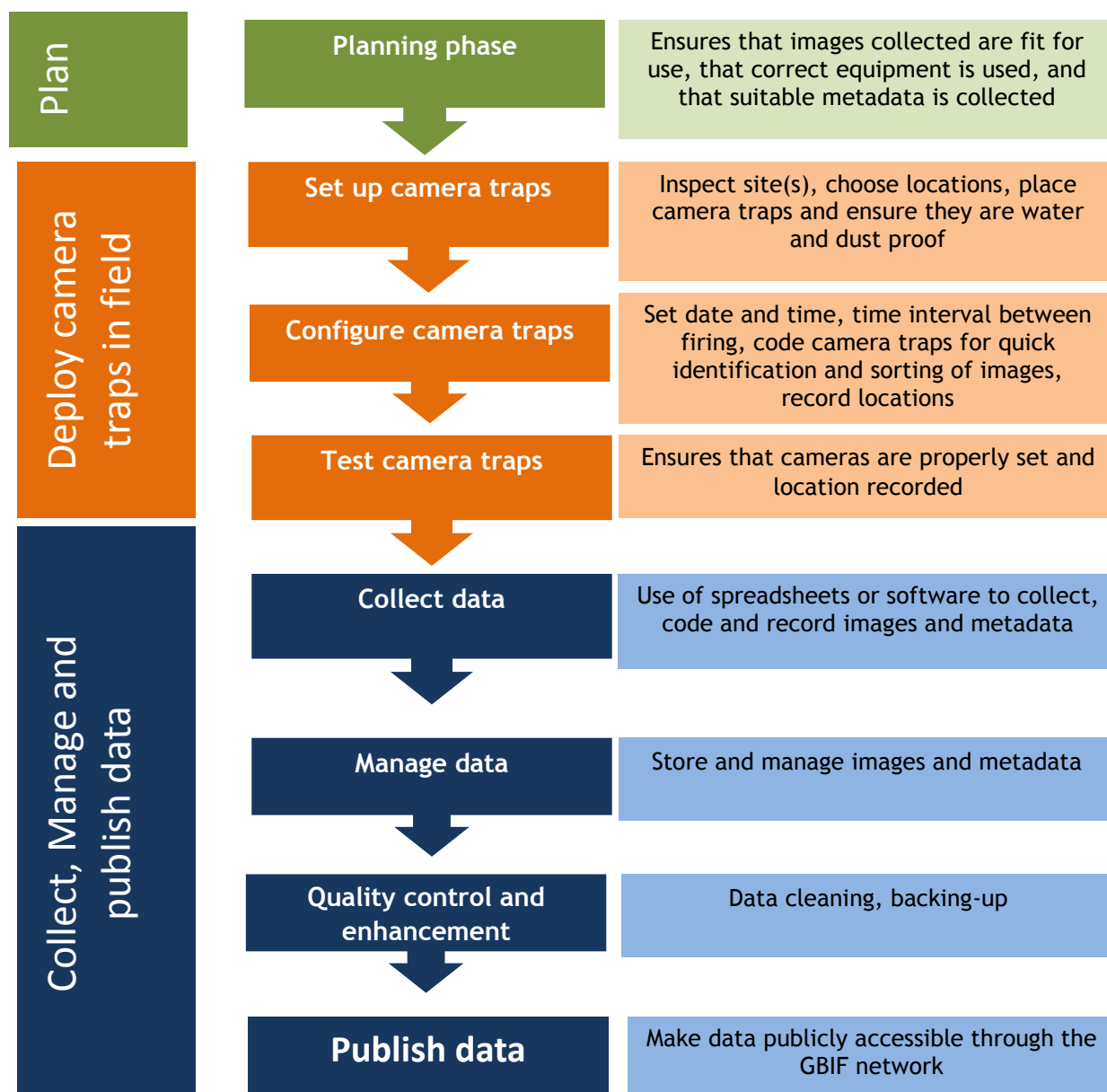
The research project carried out in the Rajaji Corbett landscape in India mentioned in Use Case 1 above was designed with a focus on tigers. But in the course of the study, images of more than 25 additional species of mammals, 7 species of birds as well as the use of natural resources by local communities (collection of grass, fodder, fuel wood), livestock grazing and poachers were obtained.

These photo-captures included an image of a rusty-spotted cat (*Prionailurus rubiginosus*), listed as vulnerable by IUCN in 2012 and previously believed to be confined to Sri Lanka and south India. From the same research project, incidental photo captures of common leopard (*Panthera pardus*) and striped hyena (*Hyaena hyaena*) resulted in the first photographic capture-recapture based density estimates for both species (Harihar *et al.* 2009, Harihar *et al.* 2010).

These cases illustrate the role that non-target camera trap images can have in filling gaps in our biological knowledge of species inventories and occurrences, particularly in countries like India where camera-trapping studies have been conducted across the country.

3. Planning a Data Collection System Based on Camera-Trapping

A generalised workflow for a camera-trapping project is shown in the figure below. It has been adapted from various published sources (including Sanderson, 2004; Rovero, *et al.*, 2010; Meek, *et al.*, 2012) as well as expert opinion from practitioners in the field.



Following the colour coding used in the schema above, chapter 3 of this guide deals with the planning phase (green), chapter 4 with the deployment of camera traps in the field (orange) and chapters 5 and 6 with the collection, management and publishing of data (blue).

3.1. Plan the project from start to finish

This guide does not cover all the aspects of the planning of a project, as projects are as diverse as the objectives defined for each of them. However, the following aspects relating to camera traps need to be covered in the project plan:

- The survey design must generate **data** that are suitable for the intended purpose. It may seem self-evident, but practical experience shows that during the design phase, different constraints may jeopardize this basic principle;
- The right **equipment** must be purchased, and deployed and used correctly. Changing procedures or equipment during a survey can be very costly and time-consuming (Pettit, pers. comm, 2012). Detailed information on equipment is given below (Section 3.3);
- The **deployment** plan must be reasonable and feasible. It needs to include the number of stations and their expected placement (taking into account the spacing between them and their accessibility) and the frequency with which they are to be checked. Local expertise is critical to choosing the most suitable camera trap sites.
- The right **team** has to be engaged in the project. The number of people required to run a camera trap survey depends on many factors (two to five people per area are normal numbers). Much of the work can be carried out by field assistants after careful training but we recommend that a biologist or a technician oversees the survey to manage the data and solve technical problems. Detailed planning is needed before starting field work.

3.2. Comply with any relevant laws and regulations

Camera trap users must understand their legal rights and responsibilities prior to deploying their devices. Rules and regulations for using camera traps for research or wildlife monitoring may vary from one country to another, or even within a country depending on the institutional or land-tenure contexts (e.g. who owns the land? Is it a declared protected area?). So it is very important that enough attention is given to find out about any regulations that may apply to the study.

For example, in Norway, all that is required is permission from the landowner, but in other countries (e.g. Sweden) permission from the county administrators is needed.

If there is any chance that the cameras may capture images of people during the course of the survey, it is important that you comply with any relevant legislation regarding privacy and other workplace or public image issues.

In some situations, it may also be necessary to obtain clearance from bodies that ensure compliance with animal ethics regulations, especially if lures or bait are to be used to attract the animals to the devices.

3.3. Choosing the right equipment and technology

It is essential that the right camera trap type is chosen to ensure that the resulting data are fit for the intended use. With the rapidly growing number of camera trap models available and the evolving technology, choosing the right model can be difficult. Our aim is not to recommend a specific brand or model, but rather to describe *important criteria for*

choosing the right camera trap type for a particular type of study. Those requiring more specific information can refer to Rovero *et al.* (2010), TEAM (2011) and Meek *et al.*, 2012.

We suggest considering at least the following criteria: trigger mechanism, trigger speed, type of flash, camera technology, battery life and cost.

The trigger mechanism: active and passive sensors

Camera traps are usually triggered by an infra-red sensor detecting a moving object that is warmer than the ambient temperature, such as animals, people or even vehicles passing in front of them.

Passive infra-red sensors (PIR) detect heat-in-motion. The sensor triggers the image-recording device (i.e. the camera) when something warmer than the ambient temperature passes in front of the sensor. Most commercially available camera traps use passive sensors. While well-suited to studies of birds and mammals, they are less effective at detecting reptiles and amphibians as their body temperature is close to the ambient temperature. These camera traps should not be positioned where there is direct sunlight, as this creates convection waves that could trigger the sensor, resulting in empty or ‘ghost’ images.

Active infra-red sensors (AIR) are similar to some door sensors and consists of two components: a transmitter and a receiver (Figure 4). The transmitter emits a beam of light that is detected some distance away by a second component (the receiver). When the beam of light is broken by a passing animal, the detector unit triggers the camera to take a picture.

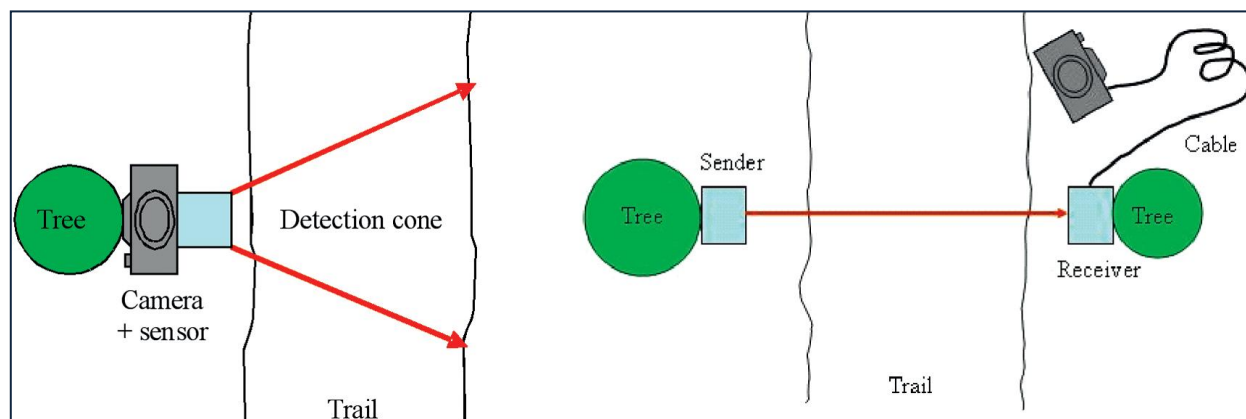


Figure 4: Schematic representation of Passive (left) and Active (right) camera trap systems (from Rovero, *et al.*, 2010)

Passive sensors detect objects within a detection zone (also called opportunity cone). The apex of the zone starts at the small sensor within the camera trap and expands outwards in a circle. The detection zone increases with the distance from the sensor but is still much smaller than the field of view of the camera. As a consequence, the position of the animal in the photo depends on (a) the size of the detection zone (which is influenced by how close the camera is to the animal), (b) the trigger speed, and (c) the speed at which the passing animal is moving (Rovero *et al.*, 2010).

The main advantage of the passive sensor system is that camera traps are designed as a single unit that can be very small and easy to set. Active sensor camera trap systems consist of two or more units and so they might be more difficult to position (Figure 4).

| Sensor system | Advantages | Disadvantages |
|----------------|--|---|
| Passive sensor | Comprises a single unit. Easier to set up. Detects animals of a wide range of sizes. | Placing the animal in the centre of the frame may be difficult. Can be triggered falsely by the sun. |
| Active sensor | Positioning the subject is more precise. Not activated by the sun. | Made of 2-3 units, so is more complex to position and programme. More expensive. |

Table 2: Main advantages and disadvantages of different sensor systems in camera traps.

Trigger speed

The trigger speed (the time between detection of the animal and shutter release) must be carefully selected to suit the target animal, the type of study and the camera trap location. Fast trigger speed is usually preferred for faunal inventories to increase the chances to record rare or elusive species.

Camera traps set along trails require a faster trigger speed, because animals may pass through the frame quickly, whereas camera traps set at locations such as mineral licks, baited stations, water-holes or under fruit trees can be slower since the animal is likely to stay in the area longer and pause in front of the camera trap.

Trigger speed is often slow in less expensive digital cameras (sometimes exceeding 2 seconds), resulting in many empty photographs.

Types of flash

Cameras with an **infra-red flash** use arrays of LED lights. Images taken with an infra-red flash are often in greyscale (black and white) or tinged reddish pink. Infra-red flash is less noticeable by passing animals, uses less energy and is usually associated with quicker shutter speeds. On the other hand, it may be difficult to identify the animal or to detect details of markings in the images, due to the lack of colour.

Incandescent (or white) flash uses xenon gas technology, which enables taking clear, colour-rich images by day or by night. White flash tends to be very bright but brief, uses more energy and is associated with slower shutter speeds. It is well-suited to studies where detailed colouration or marking needs to be visible, but has the disadvantage that it might frighten or disturb passing animals, and thus influencing their behaviour. There are strategies that have proven to be effective in minimizing the disturbance caused by the flash, without compromising the images taken (see Meek *et al.*, 2012).

Camera trap technology: film or digital cameras?

35mm film cameras were the standard tool used in camera traps in previous decades. Over the last few years, digital cameras have become readily available and widely used, and only a few manufacturers still make film camera traps.

Earlier digital camera trap models copied the design of film camera traps with a standard digital camera connected to the motion sensor. Modern digital camera traps usually consist of a camera and a sensor integrated on a single board.

The biggest advantage of digital over film camera traps is that they can store thousands of images on a memory card. Cameras can be left in the field for a much longer period of time without the need to check them. Also, images can be viewed immediately in the field whereas film must first be developed. Data management is more easily achieved with digital photographs that avoid the necessity of scanning film.

| Technology | Advantages | Disadvantages |
|-------------------------------------|---|---|
| Film camera | Fast trigger speed (mostly). Low power requirements. | Very few models still available. Must be checked often as film fills up quickly. All photos must be developed before a selection can be made, and have to be converted to digital formats for capturing on databases. |
| Digital camera | Can store many images. Easy to delete unwanted or unusable images. Digital images easier to manage. | Slower trigger speeds (generally). High per-day power requirements. |
| Digital camera with infra-red flash | Animals less frightened by flash. Lower power consumption. | Night photos are in black and white only, making identification difficult. Difficult to recognize coat patterns. |
| Digital camera with white flash | Clear, colour images by day or night. | Uses more power. Animals may be frightened or their behaviour affected by bright flash. |

Table 3: Comparison of different camera technologies.

Still, video and time-lapse capabilities

Another important feature of the camera trap is whether it can take only still images, or whether it has video or time-lapse capabilities. A video function can be useful for behavioural studies, although camera traps with a video function usually use more batteries; it may be worth considering if a sequence of still shots would suffice.

Some camera traps also have time-lapse functionality. This allows the operator to determine times at which the camera will be inactive, regardless of animal activity within the detection zone. Some cameras with infra-red sensors have a dual functionality and can also be set to time-lapse, but others have no sensors and can be used only as time-lapse devices.

Battery life

Battery life varies greatly among camera trap models: some last a few weeks, others run for two or more months and can take thousands of photographs. Battery life can be affected by:

- The number of photographs taken;
- The flash technology (infra-red flashes generally uses less battery than white ones);
- The weather conditions (e.g. low temperatures).

To conserve power, some digital cameras go into 'sleep mode' after a certain amount of time. This saves battery but can greatly increase the time it takes to take the first picture. Some camera trap models can be connected to an external battery or a solar panel. As a general rule, it is always wise to use the battery type recommended by the manufacturer of the camera trap.

It is advisable to test the performance of the camera trap using different batteries in the real setting where it will be used, before investing in a large number of them.

Cost of camera traps

The cost of camera traps ranges widely from about US\$ 120 for a basic model, through to around US\$ 550 for a mid-range model, and more than US\$ 1000 for a top-end model (see Meek *et al.*, 2012, for a detailed comparison of camera costs). The choice of camera trap model is obviously affected by the number of units needed and the total budget.

Performance and characteristics vary between models, so cost should not be the only criterion for choosing camera traps. The apparent cash savings you make buying a cheaper model may carry high costs in terms of poor quality images, or data that are unsuited for the particular study.

Five variables should be considered when you assess the cost-effectiveness of camera trap models (Rovero *et al.*, 2010):

- the cost of the camera traps, including batteries;
- the costs of field visits to the camera traps for battery/film replacement,
- the total duration of the survey;
- the number of images taken per unit of time; and
- the resolution and quality of the images captured.

The use of high quality, rechargeable batteries is a cost-saving strategy if the camera-trapping survey is intended to run more than a few months, as the higher cost of rechargeable batteries is recovered. Similarly, if visiting the camera traps is expensive, then more expensive camera traps that have longer battery life can decrease the total costs.

Less expensive camera trap models almost invariably get ruined sooner by moisture; their slow trigger speed will result in fewer photographs and a greater number of animals missed, and poor resolution results in poor images that may not be usable.

Summary of points to consider in choosing camera traps that best suit the study

Camera traps should be bought for a specific purpose. Do not buy any equipment before you have defined a purpose and a rigorous method that can be followed to achieve an empirical outcome. Table 4 below summarizes the key aspects of a study that should be considered and the camera features that are best suited to them.

| Issue or question | Camera trap features to consider |
|---|--|
| Is the study species easy or difficult to differentiate from others in the survey area? | Colour images will help with identification, but infrared flash that results in black and white images will impede identification. Video records of behaviour may help with identification. |
| Do you need to identify specific (individual) animals? | Colour images will assist with identification of markings, so use incandescent flash (takes colour day and night). |
| How big or small is the animal? | Images of small animals may be over-exposed if the camera is set too close. A wide detection zone is best for larger animals. |
| Is the animal fast-moving or hard to detect? | For fast-moving (e.g. flying) animals use camera traps with fast trigger speed, fast recovery time and wide detection zone; this will ensure rapid firing and multiple photos. |
| Is the animal nocturnal or diurnal? | Flash-type is important. Colour images are preferable (especially for nocturnal animals) High-trigger speed is needed at night. Passive or active cameras pros and cons need consideration. |
| Is the animal easily frightened/disturbed? | Incandescent flash will spook some animals (though infra-red is still detectable). |
| Do you want to study behaviour? | Infra-red flash with additional video options are best. |
| Do you want to identify species or make inventories? | Video facilities are unnecessary. |
| Is the study short or long-term? | Battery life and power-demand of the camera trap are critically important; for longer-term studies use batteries with greater power output and longer life, and check them more often. |

Table 4: Camera trap features best suited to different types of study.
(adapted from Meek *et al.*, 2012)

4. Setting up the Data Capture System in the Field

This chapter deals with the very practical task of setting, maintaining and collecting data from the camera traps to ensure the achievement of the project objectives.

4.1. Setting up the traps

Inspect the area for optimal camera trap placement.

Prior to placing the camera traps, inspect the area selected for monitoring for at least 30 days in order to identify all locations that show preferential usage by the target animals. Record and map the locations under evaluation using a GPS unit. Pre-existing knowledge of signs of wildlife presence and spots where animals frequently pass can be of great help when choosing locations.

Choose locations for camera traps.

Drawing on information gathered in the first step, select locations that provide optimal opportunities for recording focal species and that adequately cover the home range of the target animals. The optimal location of cameras will ultimately depend on the purpose of the study and the type of animal. As a general rule, camera traps should be placed at **favoured spots and routes of travel**.

Statistical models assume that all individuals in the population have a non-zero capture probability. That means that cameras should be placed to ensure that all individuals live within range of a camera and thus have some possibility of being photographed. When individuals share similar capture probabilities, the resulting variances within the sample will be lower. That does not mean that cameras need be positioned to guarantee identical capture probabilities for every individual in the monitoring area.

Cameras should be placed at least 1.5-2.0 km from any neighbouring sample areas, although this figure may need to be adjusted to adapt to differences in home ranges.

These **home ranges** of the focal species are an important consideration when placing camera traps, so some knowledge of the home range size of each focal species is necessary. For example, the home ranges of felids are generally proportional to their body size (Sunquist & Sunquist 2002), so small felids require a finer camera-trapping grid than larger felids.

Standardizing camera-trapping grids for a particular species can be difficult because the home range of a species may vary from region to region. Home ranges frequently encompass several microhabitats, but camera trap placement should be **based on the behaviour of the target species** rather than microhabitat usage (unless specifically required by the study).

Square grids, hexagonal grids, or other geometric figures are unlikely to provide adequate area coverage for sampling. Camera locations should generally be chosen **using maps and a**

geographic information system. Once approximate locations have been selected, camera traps should be placed at obvious favoured spots or travel routes (Fegraus *et al.*, 2011).

It is important to consider the **safety** of the camera traps. If possible, camera traps should be located where the likelihood of tampering, vandalism or theft is very low and where the animals themselves are unlikely to dislodge or damage the instruments. In places of high risk, we suggest locking camera traps to a tree or post. Most models provide cables that can be locked and custom-built metal boxes in which the camera can be secured.

Place camera traps

As a general rule, place camera traps approximately 50-100 cm above and parallel to the ground on a tree, rock, or wooden stake. For small animals like rodents, a height of 20 cm is best, but for larger animals 100 cm or greater would be appropriate.

Camera traps are usually placed in pairs, although in some studies a single camera at each location may suffice.

Set pairs of camera traps to face each other, at a **distance** of 4-5 m, so that both sides of an individual will be photographed when the trap is triggered (this facilitates identification of individuals as described by Karanth & Nichols, 2002 and Trolle & Kéry, 2003). Offset the cameras slightly to avoid the flash from one interfering with the other. Do not set the cameras too close to the point of detection: if they are too close to the animal the images may be blurry or washed out (Meek *et al.*, 2012).

Regarding the **angle**, camera traps are usually set perpendicular to the trail in order to obtain a good side image of the passing animal. On very narrow trails or when using camera models with slower trigger times, they can also be placed slightly off-perpendicular (i.e. 60° between the camera and the trail) to increase the path length in the frame (Rovero *et al.*, 2010). Some practitioners (Meek *et al.*, 2012) favour a 45° angle to a) increase the chance of detecting the animals and b) decrease the effect of the blind spot that some cameras have in the middle of the lens, when the animal approaches directly from the front.

We recommend always **testing** the detection zone in the field. This is especially easy with digital models, although film models often have a sensor test mode (i.e. a red flash) that allows testing of the detection zone.

It is important that the locations chosen provide optimal opportunities for photographing the animals without causing them undue disturbance. The ground in front of the camera should be kept clear of debris and tall vegetation. Otherwise unwanted results may be obtained: obscured animals, reflected flash, over-exposed images or cameras being falsely triggered (for some models). In areas with rapidly-growing vegetation or accumulating snow it is necessary to check the site frequently to ensure the camera is not obscured. On the other hand, clearing may result in avoidance of the area by some animals (Pandav, pers. comm., 2012), so some compromise may be necessary.

Other strategies to place the animal in the ideal place for a photograph could be:

- Placing obstacles such as branches can be used to guide the animal's path;
- Using a scent or bait lure can be used to attract passing wildlife to the camera trap. Many lures have been developed that are especially useful for carnivores (Trolle & Kery, 2005; Long *et al.*, 2007).

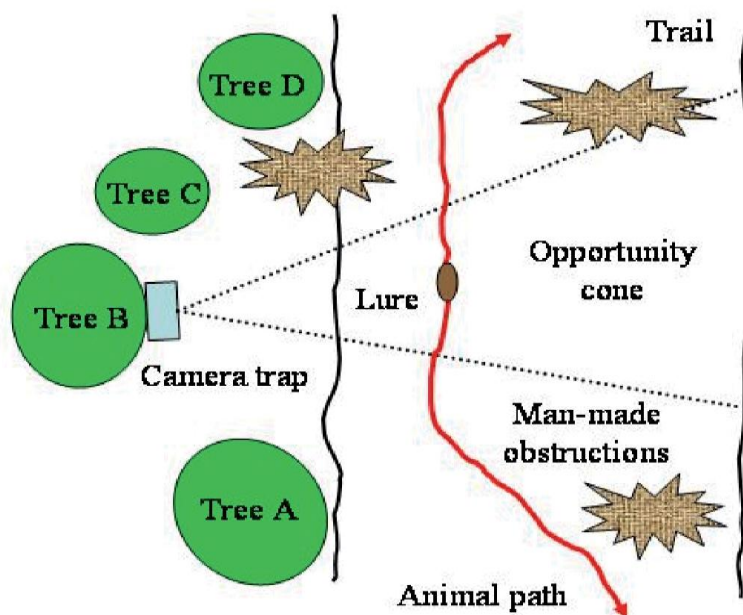


Figure 5: Hypothetical example illustrating some of the factors that need to be considered when placing camera traps in the field. Beside a suspected animal trail are four trees A-D. Trees A and D are too close to the trail for the camera trap, and Trees B and C offer the best opportunities for good photographs. The camera trap is placed on tree B that is furthest from the trail. The camera trap sensor can still register a subject on the far right side of the trail. (From Rovero *et al.*, 2010)

4.2. Configure the traps in the field

Configuring the camera traps involves preparing, testing and coding the cameras before deployment; setting the sensors, date, time and time interval; and recording data about each individual camera trap.

Prepare and test cameras

All cameras should be prepared and tested before going to the field so that they simply need to be activated once in the field. Those handling the cameras should read the user manual and follow the manufacturer instructions carefully.

There are some elements that need to be considered when installing the camera traps in the field:

- **Weather:** camera traps are often deployed in the field for a long time and under harsh conditions. Thus, they must be well sealed. Carefully inspect all seals to ensure there are no leaks. Dirt on the seal allows water to enter so camera traps should also

be as dust-proof as possible. There is a big difference between models, with some models being simply “rain-proof” while others are highly water-proof and resistant to humidity. Silicone, tape, and other arrangements can be used to seal camera traps, however a well sealed model is much preferred. Consider a small package of silica gel or other desiccant to absorb moisture inside the camera trap housing.

- **Coding:** each camera trap must be coded (uniquely numbered) for identification purposes. Write the code with a permanent marker on the housing of each camera trap. If the camera allows it, set it to print the code at the bottom of each photograph. If this is not an option then take a picture of a whiteboard showing the camera trap code with the date and time: this allows identification of rolls of film or memory cards from the first picture. When using film, write the camera trap code and the start and end dates on the outside of the film roll to easily track film from the field to development.
- **Set the date and time:** make sure that the date and time are carefully set on each camera using the 24-hour clock, and re-check the date in the field when installing the camera trap.
- **Setting the sensor sensibility:** setting this parameter correctly is critical, especially in some passive-sensor camera traps. We recommend higher sensitivity when working in hot climates and when targeting small species.
- **Setting the time interval between photos (delay time):** If the camera model allows it, set them to run continuously, with a 1-2 minute delay between photos. Make sure that the two cameras of a pair do not fire simultaneously (this will cause over-exposure). For some applications (e.g. if groups of animals usually travel together), it may be desirable to record sequences of images with shorter delays. Be aware that frequent triggering may affect battery life and how frequently the films or memory cards need to be replaced/emptied.

4.3. Test the traps and record data about them

Once the camera traps are configured, test each pair of camera traps by placing yourself between them while displaying the location number as the cameras take a picture. This test demonstrates that cameras are properly set and records the trap location, so that there is no question as to the origin of the images.

The images captured by the camera trap will be of little use without data about the location. For each camera trap (or pair), it is recommended that data are recorded to reflect:

- **Deployment** information: camera code, position, time and day of camera trap activation and by whom, any other useful information such as weather conditions;
- **Monitoring** information: battery type and dates they were changed; film/card type, dates changed and by whom; any notes relating to signs of animal activity and human interference;

Setting up the data capture system in the field

- **Site information:** the site name, GPS location, camera code, a description of the habitat, distance to the next nearest camera-trapping site or proximity to human habitation, signs of animal activity, etc. To assign a site code, assign each camera trap location its own number and assign letters A and B to the cameras in each pair.

Ideally, this information should be recorded on pre-configured datasheets, of the type shown in the example below.

| | | |
|--|--|--------------------------------|
| Site code: | Date set: | Date retrieved: |
| | | |
| Name(s) of recorder (s): | Location: | |
| | | |
| Location description | | |
| GPS co-ordinates | East | North |
| Other location information | Proximity to next nearest camera trap: | Proximity to human settlement: |
| General habitat description: | | |
| Habitat types:[customize for location] | Type a: | Type b: |
| Type c: | Type e: | Type f: |
| Camera details | | |
| Camera type: | Camera code(s): | Camera direction: |
| Camera height: | Battery types: | Battery replacement date: |
| Card/film replacement date: | Card/film type: | Number of images: |
| Lure/Bait | | |
| Yes/no: | Type: | Distance to lure/bait: |
| Other notes | | |
| | | |

Table 4: Example of a camera-trapping data sheet showing the categories of information that should ideally be recorded. This example is adapted from those in other published sources, and is intended to serve as an example that could be customized for a specific project.

4.4. Camera trap maintenance

Camera traps will need to be checked regularly (at least once every three to four weeks and in some cases even more often) to detect traps that have been moved by animals or that have problems of any kind.

Setting up the data capture system in the field

When checking camera traps the following data should be recorded: number of photographs taken, battery level, whether film or batteries were changed, as well as any observations about the camera (See data sheet in Table 4). This can help in estimating average battery life and, in cases in which cameras have stopped working, can be used to work out when the camera failed. If possible, one or two spare camera traps should be taken to replace those that may have stopped working. We also recommend checking the date and time setting of each camera trap every time the camera trap is visited.

5. Data Management

Camera-trapping can potentially generate thousands of images, especially in long term studies. This makes sorting, storing and managing these images and their associated (meta)data an important issue.

The systems used by different projects are diverse, and often they are not designed using commonly accepted standards. This makes data archiving, sharing and access difficult (Meek, *et al.*, 2012; Morris *et al.*, 2013). In this section we recommend best practices that can help overcome this problem.

In 2005, the European network ENBI produced a manual of best practice relating to digital images of biological specimens (Häuser *et. al.*, 2005), with several chapters that are directly applicable to the management of data from camera trap images. Those readers interested in advanced techniques for image edition, file archival, etc. are recommended to consult this guide.

5.1. Image file collection and management

Once the camera traps have been set up and configured, the next step in the workflow is the collection of the camera trap data: this includes both the images taken and their associated information (metadata). Data collection (also called data creation or sampling effort) will differ slightly depending on the type of camera technology used.

Image collection from film cameras

Film camera traps may need to be checked as often as every one to two weeks to make sure they do not run out of film. If at least one of the cameras at a camera trap location has taken more than 18 out of 36 photographs, exchange the film in both of the camera traps at that site at the same time. In any case, change film monthly in all cameras to avoid moisture damage.

The film will need to be processed and the analogue images digitised. All photographs need to be scanned in a high-resolution, lossless compression format (i.e. RAW, TIFF) and stored electronically. There are multiple ways to digitize analogue images. The following resources may be of use in this process:

- http://www.computer-darkroom.com/pdf_files/archive-scans.pdf
- <http://lifehacker.com/5557695/the-step+by+step-guide-to-digitizing-your-life>
- <http://www.basic-digital-photography.com/how-to-scan-old-photos.html>

Once the images have been stored electronically, the data management practices will be the same as for working with digital cameras.

Image collection from digital cameras

While digital camera traps can store more images than film models, their autonomy depends more on the battery life. Most models can run for up to one month and those equipped with an infrared flash can run for up to 2 months and store thousands of images.

Monitor and adjust camera traps regularly during the sampling effort at intervals appropriate to the animals being studied and the nature of the investigation. Battery life, image storage capacity, the expected number of photographs and location accessibility are other aspects to take into account. If cameras are taking excessive numbers of photographs of the same individuals (as often happens with animals like peccaries or large terrestrial birds), the delay between trigger intervals can be increased.

Collect and replace memory cards from digital cameras and download the images onto a suitable image-viewing device (laptop or hand-held device). Be sure to record the day and time each card was retrieved.

Code images by assigning unique file names

A camera trap can potentially capture hundreds of images. To facilitate quick identification and sorting of images, a unique file name (unique identifier) should be assigned using a consistent format. The file name should contain elements to denote the following:

- Geographic location
- Camera trap code
- Date and time of collection
- Sequential photo number
- The object in the image

While the date and time are usually captured on each image, only some digital camera traps allow imprinting the camera trap code on each photograph. For other camera traps, the camera trap code must be tracked throughout the study (e.g. by taking a picture with the relevant camera information when changing film rolls/memory cards and consistently labelling film rolls as explained in section 4.2 above).

Here are two examples of how file names for camera trap images may be formatted:

Sanderson (2004) from the TEAM group recommends the file name format 'XXXXXIDxNNddmmyyyhhmm.jpg'. These are the components of such names:

| Component | Meaning |
|-----------|---|
| XXXXX | Station acronym |
| IDx | Identifies the camera. <i>ID</i> is the camera trap camera number. <i>x</i> is 'A' or 'B' referring to each camera in the pair. |
| NN | Species number on the Excel spreadsheet |
| dd | Day |
| mm | Month |
| yyyy | Year |
| hh | Hour |
| mm | Minute |

Table 5: Components of a file name suggested by Sanderson, 2004.

Researchers working in India (Ghosh, pers. comm.) use a file name format that looks like 'CTP050612011001A00049a'. The components of the name are in this case:

| Component | Meaning |
|-----------|--|
| CTP | Refers to the definition of the dataset, i.e. camera trap photographs. |
| 05 | State code, in this case for Uttarakhand from Census of India. |
| 061 | District code, for Pauri from Census of India. |
| 2011 | Year in which photograph was captured. |
| 001A | Alpha-numeric code for the camera trap ID; the first three digits refer to the trap number, and A/B is added referring to each camera in the pair. |
| 00049 | Refers to the sequential photo capture number from a particular camera. |
| a | The lower case 'a' helps distinguish between multiple objects in the same photograph. When there are several animals in a photograph, the photo is duplicated for each animal (each one with their corresponding data sheet) and assigned a letter sequentially ('b', 'c'...). |

Table 6: Components of a file name suggested by Ghosh.

Record the data on the datasheets and enter the data

We recommend using two data forms: one for information on all camera trap locations (discussed in section 4.3), and another to collect information about each photograph. Data forms can be generated using any spreadsheet software such as OpenOffice Calc or MS Excel.

The image data sheets should include all information that can be extracted from the image: date and time, species name, GPS location and other biological information relevant to the study (e.g. age, sex, number of individuals, reproductive status). In some cases, such as studies estimating population density using the capture-recapture framework, an identification at the level of individuals can be made: that must also be reflected in the form.

Quality control and quality enhancement during image collection

All relevant data should be registered and collected carefully to ensure consistent quality levels. This also applies to the step of collecting the images. While it is important to record the total number of photographs taken, those images that are superfluous or of poor quality should be discarded. This includes empty images, those taken during camera set-up and retrieval and any blurry/poor resolution images.

Initial image editing

Some teams do quick editing as they collate the images. These edits can include altering the resolution, brightness, contrast and zooming in/cropping the image to focus on the biodiversity object. If any images have been enhanced or modified in any way, the methodology used always needs to be described and captured in the image data sheet.

Data management

The original camera trap image should always be archived unaltered, and renamed using a persistent identifier as described above. All images captured in a sampling session should be kept together in the same folder.

The original image can be cropped to focus on specific sections of the image and 'child' objects can be generated in the process. In the example below, the captured image includes two tigers. To manage each occurrence individually, the image can be cropped and the image of each tiger can be treated as an individual object with a unique record in the database.

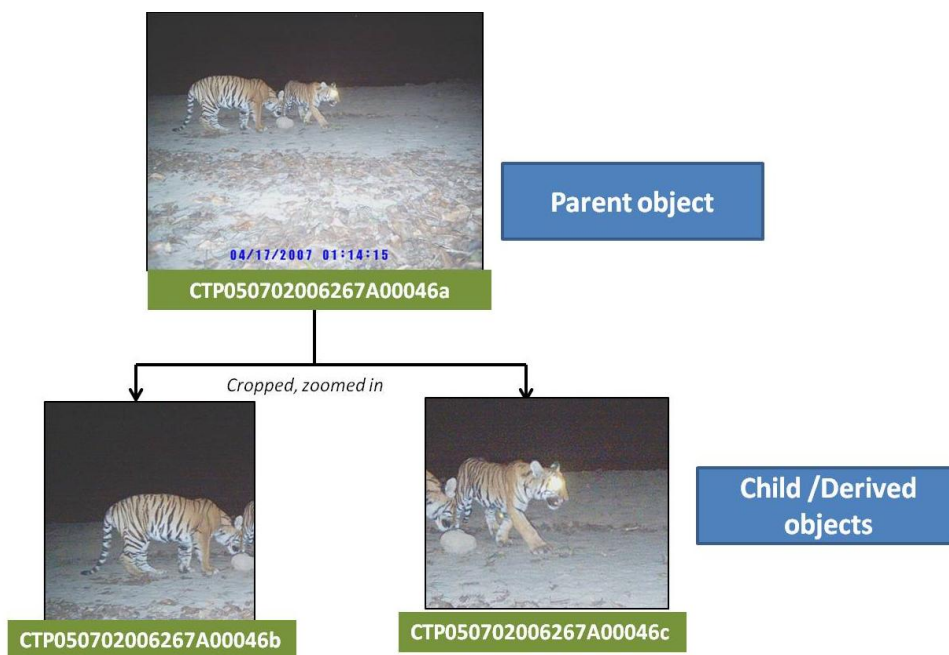


Figure 6: Creating child objects form a parent image

Derived/child objects usually are marked with a suffix ('b', 'c',...) at the end of the unique identifier, instead of the 'a' assigned to the parent object. Both 'parent' and 'child' images must reference each other in the image data sheet.

Manage the image file archives

Camera trap data must be always well organized to avoid confusion and any possible data loss. Photographs must always have, at the very least, date, time, and camera trap site code information.

Managing photographs from film camera traps requires some additional steps. Some teams recommend printing all photographs in a roll as thumbnails, and then selecting the photos of interest to be printed full-sized, digitized and archived. The camera trap code should always be part of the folder name and/or in a text file in each folder.

In terms of software solutions, there are several alternatives available:

- Software specialized in managing camera trap images: e.g. MapView, DeskTeam, CameraBase. See Meek *et al.*, 2012 for a comprehensive list;
- Special digital asset management systems (DAM) designed to manage images. A useful summary of these can be found at <http://www.damroundup.com/category/reviews>;
- Spreadsheets and simple desktop databases are still among the cheapest and easiest ways to manage images and their associated information.

Whichever software you use, consider a dual-screen computer system, as this makes data entry and management easier (i.e. you can see the image in full detail and the database at the same time).

5.2. Biodiversity data collection and management

When recording the biodiversity information related to the images, it is important to choose a system that will make the management, exchange and publishing of the information as easy as possible. Adhering to **international standards** will ensure that you build on the experience of experts in the field and that you can immediately benefit from existing tools and collaboration mechanisms.

Spreadsheet applications (e.g. OpenOffice Calc or MS Excel) are still the most commonly used software for managing biodiversity data associated with camera trap images. While they are simple to design and use, their main disadvantage is that re-organizing data for different analyses can be time consuming. Later in this chapter we will present a spreadsheet template based on an international standards.

Relational databases are probably a richer alternative, either as desktop applications (e.g. MS Access, Filemaker) or database servers (e.g. MySQL, SQL Server). Desktop applications are easier to use and they include easy-to-use tools for building data-access forms and queries. On the other hand, server applications might be useful when different people need access to the data simultaneously but they are more difficult to set up and maintain.

There are also **specific software products** designed to manage biodiversity camera trap data. For example, Camera Base is based on MS Access and can manage biodiversity data together with the camera trap digital images. The software has a wide range of analysis and data-export options built-in, including activity patterns, capture-recapture analysis, occupancy analysis, and species accumulation and richness estimation. Camera Base can be accessed at: <http://www.atrium-biodiversity.org/tools/camerabase/>.

Choosing a biodiversity data management system

When choosing a system to capture and manage biodiversity data associated with the images, it is essential to be clear about the **final products** that are needed to fulfil the project requirements. You need to choose a system that supports any operation needed to produce those products. You also need to have in place a **procedure** well defined from the start so

the final users can access data that can be effectively analysed and managed using their preferred management tools.

The image data management system should be based on **well-established and readily available software** to avoid possible disruptions caused by the maintenance of very specialized software (especially if the IT capacity available to you is relatively low). Using freeware and avoiding expensive licenses as far as possible will help to keep costs down.

Easy-to-use systems should be preferred. The ease with which researchers can integrate the management system into their existing workflows will influence how effectively it is taken up.

The data should be stored and managed in a way that makes it easily **exchangeable** with other systems.

In summary, the biodiversity data management system chosen must (from Morris *et al.*, 2013):

- Leverage the data for scientific analysis;
- Facilitate free and open access to the data; and
- Assist in better management of these resources.

5.3. Dataset metadata management

The generic definition of **metadata** is 'data that refer to or describe other data'. In the context of this manual, we use metadata to refer to the descriptive information that accompanies a group of camera-trap images (defined as a dataset).

Metadata are an essential part of any data management system as they help users to find the dataset among a collection of datasets, and also understand their content and potential usability. Metadata are especially critical at the time of data publishing. GBIF for example, requires all datasets published through the network to include appropriate metadata, both for digital and non-digital datasets (GBIF, 2011c).

In the particular context of multimedia resources, metadata provide a powerful tool for organizing and searching through the growing libraries of image, video and audio content instead of having to browse through their content (MWG, 2010).

Dataset metadata standards, documents and data elements

There are existing, clearly defined standards and guidance on how to write metadata for biodiversity datasets related to multimedia objects. GBIF has defined a **metadata profile** (GBIF, 2011b), suitable for the publishing of resources via its network. This profile describes which information is needed (in the form of elements/fields), in which format. A **metadata document** refers to the combination of the contents of all those fields for a given dataset.

The types of data elements (or fields) described in a metadata profile include the 'who, what, where, when and how' of the resource, as well as other elements such as technical data

about the images or the cameras (e.g. resolution, pixel size etc), physical data relating to the site or other project data, associated parties, etc.

Filling a metadata document for each of your datasets is good documentation practice, whether or not you plan to publish the information online. If you are publishing your data, completing a metadata document will take you a significant way along the process.

Authoring a dataset metadata document

There are several ways to author a metadata document that complies with the existing international standards: **preconfigured templates** (such as the one provided with the GBIF Spreadsheet processor¹⁰), or specific tools such as the **GBIF Integrated Publishing Toolkit (IPT)**. Section 6.2 describes in detail how to author a metadata document as part of the data publishing flow.

5.4. Quality control and enhancement

To obtain the highest quality of data possible is usually a concern for both the data producers and users. In the realm of biodiversity data, issues related to data quality have become more evident since data began to be aggregated and published on the internet. Continuous efforts have been made to address potential data quality issues at all levels of the data management chain, starting from data collection.

Over the years, the concept of 'data quality' has progressively been replaced by that of '**fitness for use**', as it is widely admitted that the quality of data is measured in relation to their intended use. It is thus essential that data users define which level of quality or precision is required by their intended analysis (e.g. which geographical or taxonomic definition), and to have mechanisms to evaluate if a given data record or dataset complies with those requirements.

To find out more about the concept of quality and fitness for use in relation to biodiversity data, we would recommend you to consult three resources published by GBIF: *Principles of Data Quality*¹¹ (Chapman, 2005b), *Principles of Data Cleaning*¹² (Chapman, 2005a), and the *GBIF Position Paper on Future Directions and Recommendations for Enhancing Fitness-for-Use Across the GBIF Network*¹³ (GBIF, 2010b).

In the first two guides, A. Chapman calls for adherence to six basic data quality principles: accuracy, precision, fitness-for-use, effectiveness, efficiency and transparency.

- **Accuracy:** refers to how correct the data are. For example, is the organism correctly identified or is the correct locality supplied? If the data are correct, then they are accurate.

¹⁰ <http://tools.gbif.org/spreadsheet-processor/>

¹¹ http://www.gbif.org/orc/?doc_id=1229

¹² http://www.gbif.org/orc/?doc_id=1262

¹³ http://www.gbif.org/orc/?doc_id=2777

- **Precision or resolution:** refers to the exactness or level of detail of the data. In the case of occurrence data, if only the broad area of occurrence is given, the precision of the data is low. If exact geographic co-ordinates are supplied, then the precision of the data is high.
- **Quality or fitness for use:** In the context of this guide, data are described as fit for (potential) use, if they are suitable for the intended purpose. GBIF, for example, strives to publish only high quality data that are maximally fit for use. Data of low accuracy and low precision are poor quality data that will, generally, not be fit for many uses. High quality data are both accurate and precise, as well as being comprehensive, complete, up to date, easy to access and interpret and consistent with other sources.
- **Effectiveness:** this is the likelihood that the data, or a method, might have of achieving the intended outcomes.
- **Efficiency:** relates to the ratio of output to input.
- **Transparency:** relates to how complete, accurate and precise the information is that describes the dataset (i.e. the metadata). Transparency enhances accessibility and also the fitness-for-use of the data.

Each of these principles can be applied to the primary biodiversity data obtained via camera traps and to the tools, protocols and practices that are used while managing and publishing the information.

Quality issues in descriptive fields

At the time of describing the contents of a multimedia object and while composing the metadata document, it is important to be consistent with the terminology used and, whenever possible, align with any existing conventions.

The GBIF guide *Terms used in bionomenclature: the naming of organisms (and plant communities)* (Hawksworth, 2010) serves as a very good reference for precise but workable definitions of terms to be used when describing many aspects related to a camera trap picture and dataset.

Quality issues in the geographic information

Geospatial information is a critical domain where inaccuracies and mistakes make the data fit for fewer uses. It is important to make sure that you obtain **the most precise geographic information possible**, and to reflect it in the image file, the description of the file, and the dataset metadata.

It is important that, during the planning phase of the project, you get hold of any relevant geographic resources you may need during the project: maps (paper and digital), gazetteers, list of administrative units (with their abbreviations and correct names), etc. GPS units can help a lot while defining the position of the cameras, but be aware that not all GPS receivers have the same degree of accuracy, depending on the weather conditions, tree coverage, etc.

Georeferencing / geotagging

Georeferencing or **geotagging** is the process of embedding geographical information (i.e. latitude and longitude coordinates) into an image file. Some software and websites can use these geo-tags to display the images in a map (e.g. GIS programs, Google Earth/Maps, Bing maps).

A visual representation of the location of the species aids in revealing spatial patterns. Additionally, it enables the discovery of the images using generic image search engines that are compatible with geotagging.

When the camera trap does not do automatic geotagging (most of the more basic models do not), you can use specific **software** to perform this operation. As part of the WII-NINA-GBIF pilot project, eight geotagging software packages were reviewed and rated according to different criteria (file format accepted, ease of use, map interface). At the end of this analysis, **GeoSetter**¹⁴ scored highest as an open access option for MS Windows computers. It permits easy organization of images and file conversions, it accepts a variety of file formats and it can be used in multiple languages.

In case you need to work with older archives of images that do not have geographic coordinates assigned, you can still produce estimates based on any existing description of the locality of the camera. This process is called **retrospective georeferencing**. The GBIF manual *Biogeomancer, Guide to Best Practices in Georeferencing*¹⁵ (Chapman & Wieczorek, 2006) is a very useful reference for this process.

Working with sensitive data

Camera trap projects frequently work with rare, endangered or commercially valuable species, and also frequently within the limits of protected areas. The unprotected distribution of sensitive data about these species has been a major concern when sharing primary biodiversity data (via the internet or other means). In the case of camera trap data, species which are particularly threatened by poaching, collectors etc. are typical examples.

When working with the geographical information related to these species, it is recommended to obscure such sensitive data and produce either diffused geographical information that will be used at the time of publishing, or to consider not sharing this information at all. Documenting any modification and any decision taken regarding sensitive data, and how users can access the detailed information, is crucial to maintain the usability of the data. Another best practice guide¹⁶ developed by GBIF (Chapman & Grafton, 2008) includes practical guidance on how to proceed in these cases.

¹⁴ <http://www.geosetter.de/en/>

¹⁵ http://www.gbif.org/orc/?doc_id=1288

¹⁶ http://www.gbif.org/orc/?doc_id=1233

6. Data Publishing

There are many benefits associated with publishing, storing and making biodiversity data accessible via digital, web-based systems. For example, data publishing:

- Is a quick way to make the data available for further use;
- Expands the diversity of groups that can contribute and access data;
- Enables new ways to use and re-use research findings;
- Facilitates inter-disciplinary movement of data;
- Enables observation, measurement and networking at an unprecedented level;
- Enhances reproducibility; and
- Allows post-publishing and comparative analyses.

In the context of GBIF, ‘publishing biodiversity data’ is the process through which biodiversity datasets are made publicly accessible in a standardized format, via an online access point. This access point is recorded in a registry managed centrally by GBIF. Published datasets can then be discovered and accessed via the global GBIF.org website and associated web services, as well as many other websites and software tools.

In the particular case of the camera trap images, it is also important to make available the original images for further study and analysis by interested parties.

6.1. Publishing the digital images

There are many ways to publish digital image files on the internet, from generic web servers that just provide public URLs for the files, to specialized services such as Panoramio¹⁷, Flickr¹⁸ or Picasa (a list of such websites can be found in Wikipedia¹⁹). Some of these services also allow you to publish certain parts of the information associated with the images and perform searches based on those data.

Some GBIF partners have gone further and have developed solutions to publish biodiversity-related images together with the biodiversity information associated with them (e.g. the Biodiversity Images Portal²⁰ maintained by GBIF Spain). These systems can offer additional functionality for data users.

The minimum requirement for the system chosen to publish the images is to provide a URL that gives access to the original image. This URL should be reflected in the image data templates and management systems, and you will use it at the time of data publishing. The URLs for other versions of the images (e.g. different quality versions, thumbnails) can also be recorded, if available.

¹⁷ <http://www.panoramio.com/>

¹⁸ <https://www.flickr.com/>

¹⁹ http://en.wikipedia.org/wiki/List_of_photo-sharing_websites

²⁰ http://www.gbif.es/Imagenes_in.php

6.2. Publishing the biodiversity data via GBIF

The process of **publishing** via the GBIF network makes datasets universally accessible over the Internet. It includes the following general steps:

- **Capturing the data** in a consistent, exchangeable format;
- **Preparing** the data for publication;
- Making the **dataset accessible** through a GBIF-compatible mechanism;
- **Registering the dataset** in the GBIF registry; and
- The central services of GBIF **index** the data and make them discoverable and available.

Data publishing tools and mechanisms

The preferred mechanism to publish biodiversity data through the GBIF network is the **Darwin Core Archive (DwC-A)** file format. These files include the data to be published together with the metadata document that describes the dataset, packaged together and ready to be accessed by the indexing services.

There are several tools to transform primary biodiversity data into a Darwin Core Archive:

- The GBIF Spreadsheet Processor²¹
- The GBIF Integrated Publishing Toolkit (IPT)²²
- The Darwin Core Archive Assistant²³

In the following sections we will explain how to publish using the GBIF Integrated Publishing Toolkit, after using a simple template to format the data.

More customized options will be available once the full cycle of data publishing is enabled for a richer standard: the Audubon Core. Section 6.5 provides more information about this option.

Becoming an endorsed GBIF data publisher

To be able to publish data via the GBIF network, you first need to be **endorsed as a data publisher** by an existing GBIF Participant node manager. Your institution may already be an endorsed data publisher, so it is worth looking at the list of active GBIF publishers²⁴.

If your institution is not yet a publisher and you live in an existing GBIF Participant country²⁵, you should normally contact the national node for that country, whose contact details you can find under the 'Participation' tab on the country page at GBIF.org. GBIF recommends that you make contact with your national node before registering, as they will often be able to offer good advice and support in the data preparation process.

²¹ <http://tools.gbif.org/spreadsheet-processor/>

²² <http://www.gbif.org/ipt>

²³ <http://tools.gbif.org/dwca-assistant/>

²⁴ <http://www.gbif.org/publisher/search>

²⁵ <http://www.gbif.org/participation/list>

If your country is not currently a GBIF Participant, there are alternative options for endorsement including through GBIF Participant Organizations²⁶.

Once you have identified a suitable Participant node to endorse your institution as a publisher, or if you need advice on where you could get endorsed, you should contact the GBIF helpdesk²⁷. They will then seek formal endorsement on your behalf, and register you as a publisher. You will need to provide the following information:

- Name of your institution;
- Name and email address of an administrative contact;
- Name and email address of a technical contact;
- The name of the GBIF Participant node by which the data publisher should be endorsed.

In case of doubt, please refer to the data publishing section of GBIF.org²⁸.

Using a generic template to prepare data for publishing

Using the spreadsheet template suggested in this manual is a straightforward way to publish the basic biodiversity information associated with a camera trap image. It also enables exposing the images associated with those occurrence records.

The template can be downloaded from <http://links.gbif.org/dcsmst>. You can use any generic spreadsheet software to open it (e.g. OpenOffice Calc, MS Excel).

This template is based on 45 terms from the Darwin Core standard²⁹ and 14 from the Simple Multimedia extension³⁰. It has two data sheets on it:

- Readme: a simple page with information about the template.
- Occurrence+Multimedia: the records related to the camera trap images, which attest the presence of a species and/or an individual.

Each row in the 'Occurrence+Multimedia' tab refers to the occurrence of an organism and, in the case of the camera trap data, a photograph. Please remember that, as discussed in section 5.1, the same photo can be duplicated (and edited) when there is more than one organism or individual captured in a single image.

The template includes in-line help in the form of comments that appear if you hover the mouse pointer over the name in the first row. It will give you advice on what to include in each field.

It is up to you to decide how to use the template. You can:

²⁶ <http://www.gbif.org/participation/list#other>

²⁷ helpdesk@gbif.org

²⁸ <http://www.gbif.org/publishingdata/summary>

²⁹ http://en.wikipedia.org/wiki/Darwin_Core

³⁰ <http://tools.gbif.org/dwca-validator/extension.do?id=http://rs.gbif.org/terms/1.0/Multimedia>

- Use the template as a simple table for quick data capture, writing directly into the datasheet; or
- Export the data from the system where you are managing them, so they match the suggested schema. You can then copy and paste the data into the template, or import it through the data import mechanism in your preferred spreadsheet software.

You can find detailed information about how to fill the Darwin Core terms in another guide developed by GBIF³¹ (GBIF, 2010a). For more information about the simple multimedia extension, please visit the GBIF extensions website³².

Publishing data using the GBIF IPT (1): connecting the data

We recommend you to use the **GBIF Integrated Publishing Toolkit** (GBIF IPT) as the mechanism to make biodiversity data associated with camera traps available online. This software platform was designed to facilitate easy and efficient publishing of biodiversity data on the internet. It accepts data in digital form as delimited text files, MS Access spreadsheets, Darwin Core Archives or hosted in a SQL-compatible database. The IPT also supports automatic registration of the dataset.

In the practical guidance outlined here, we will use the GBIF IPT to author the metadata document and to connect the template filled with data described in the previous section.

The first step in this process is to find a suitable instance of the GBIF IPT. Many national nodes and international organizations maintain hosting environments based on the IPT to support data publishing within their domain. Please contact your relevant node (as described above in relation to endorsement) to explore this possibility. The alternative would be to install your own instance of the GBIF IPT if you have an open web server available. Instructions about how to set up an IPT instance can be found in the IPT manual³³ (Wieczorek, 2011).

In any case you will need an account into the IPT instance that has at least manager rights (with or without registration rights). Once logged into the IPT instance, follow these steps³⁴:

- go to the 'Manage Resources' area using the main menu. At the bottom of the page you will find the area to create new resources. Give it a short name, and select the 'occurrence' type. Do not load any file at this stage. Click on 'Create'.
- Once the resource is created, go to the 'Source Data' section of the dataset overview page and select your filled template using the 'Browse...' button. Confirm by clicking 'Add'.
- In the following screen, change the number of header rows to 1, and select the worksheet 'Occurrence+Multimedia'. If you click on 'Analyse' after that, you should see that 59 columns have been detected. Click on 'Save'.

³¹ http://links.gbif.org/gbif_dwc-a_guide_en_v1.1

³² <http://rs.gbif.org/extension/gbif/1.0/multimedia.xml>

³³ <http://code.google.com/p/gbif-providertoolkit/wiki/IPT2ManualNotes>

³⁴ These instructions refer to the IPT version 2.1.1 or earlier.

- Back in the dataset overview page, go to the 'Darwin Core Mappings' section and choose 'Darwin Core Occurrence'. Click on 'Add'. Confirm the selection of your data source by clicking on 'Save'.
- Most of the field mapping should have been done for you automatically if you respected the original template format. You only need to find the fields 'source' and 'rightsHolder' in the grey boxes on the left and disconnect them by choosing the first (empty) row in the drop down menu. Those fields refer to the image in our template and not to the occurrence record itself, so we will link them later. Click on 'Save'.
- Now you have to follow a similar process, but with the simple multimedia extension. Go to 'Darwin Core Mappings' and choose 'Simple multimedia' this time. Click on 'Add'. Confirm the source selection and the automatic assignments in the following screen by clicking 'save'. The automatic assignments should be fine in this case.

That finishes the mapping and connection of the data. The next step is to describe the dataset as a whole.

Publishing using the GBIF IPT (2): describing the data

To compile and publish metadata using the IPT, follow these steps:

- Look for the grey box labelled 'Metadata' and click on 'Edit'.
- The system will take you through the twelve sections into which a metadata document is divided. Compulsory fields are marked with an asterisk (*). You will not be allowed to publish the resource unless the compulsory fields on the 'basic metadata' page are filled. Click 'save' after having gone through each section. The menu on the right will allow you to go to any section directly.
- You can choose to what extent you would like to document your dataset. As a general rule, the better the metadata, the higher the chances of the data being discovered and used, and the greater credit the publisher (you) will receive. GBIF has produced a how-to guide³⁵ (GBIF, 2011c) and reference guide³⁶ (GBIF, 2011b) to assist publishers while completing a metadata document.
- Once you have completed at least the mandatory metadata, the alert message on the dataset overview page will disappear and you will be allowed to continue with the publishing process.

Publishing using the GBIF IPT (3): registering the data with GBIF

Registration is the final step in the data publication. In the **registration** process you make the GBIF global systems aware of the existence of your dataset, and request it to be indexed and included in the network.

³⁵ http://www.gbif.org/orc/?doc_id=2821

³⁶ http://www.gbif.org/orc/?doc_id=2820

The GBIF IPT supports automatic registration in the GBIF network. These are the final steps you need to follow:

- In the dataset overview page, go to the 'Published Release' section and click on 'Publish'. This will generate all the final files needed for the publishing of your dataset. The IPT will analyse the contents of the dataset according to the field mapping defined. If any issues are found you will be presented with an error message, guiding you to where the problem may be. You will need to solve any critical errors before you can continue. Once the process is completed successfully and back in the dataset overview page, you will find links to the Darwin Core Archive with the full dataset and also the metadata document in EML and RTF format.
- The next step is to make the dataset **public** in the dataset management page. Making it public will expose the data and metadata to anyone knowing the address.
- The last step is to register the data with GBIF. For that, select your organization from the drop down menu in the 'Visibility' grey box and click on 'Register'. That will make GBIF aware that your data is ready for indexing.

Once registered, your dataset will be immediately discoverable via GBIF.org using the metadata information that you provided. It will also be automatically queued for data **indexing**. Depending on the size of the dataset, indexing can take anywhere from minutes to days. If problems are encountered during indexing, the GBIF Helpdesk will work with you to resolve them as quickly as possible.

After the indexing, the publishing process is considered finished and you should be able to access your data and the associated images through GBIF.org and any other website or tool connected to the GBIF network. Congratulations!

6.3. Receiving credit after data publication: data citation

At the moment of data publication, it is important to define your preferred method to be cited when other users make use of the published data. This is one of the benefits that data publishers receive for their effort.

GBIF have produced two guides (Lane, 2008 and GBIF, 2012b) that deal with issues related to data citation in the online environment. We would recommend those interested to check those resources when filling the field 'resourceCitation' in the metadata document at the moment of data publication.

The situation around citation will substantially improve in 2015 with the implementation of DOI (Digital Object Identifiers³⁷) for datasets published using GBIF.

³⁷ http://en.wikipedia.org/wiki/Digital_object_identifier

6.4. Additional benefits from publishing data online: data papers

Data papers are a mechanism through which data publishers can author and publish metadata describing primary biodiversity datasets as citable academic papers (Chavan & Penev, 2011). In this way, data custodians and publishers can obtain formal credit for the work done when capturing, curating and describing the data.

The purpose of a data paper is:

- To provide a citable journal publication that brings scholarly credit to data publishers;
- To describe the data in a structured, human-readable form; and
- to bring the existence of the data to the attention of the scholarly community.

A data paper describes data, rather than reporting a research investigation – it contains facts about data, not hypotheses and arguments based on the data, as found in a conventional research article. The description should include important elements that document, for example, how the dataset was collected, the taxa it covers, the spatial and temporal ranges and regional coverage of the data records, provenance information concerning who collected and who owns the data, details of which software was used to create the data or could be used to view the data, and so on.

As we have seen in section 5.3, all that type of information for a camera trap project is gathered in a metadata document. Once the data has been published online, tools like the GBIF IPT allow the generation of a data paper manuscript that can be used to start the process of publication as a data paper.

Pensoft journals and GBIF have been pioneers in the development of the concept of data papers. In the Pensoft website³⁸ you can find more information about how to publish data papers and links to more detailed documents.

The Nature Publishing Group offers another option through its *Scientific Data* journal, which accepts ‘data descriptors’ based on similar principles to data papers.³⁹

6.5. The future of multimedia data storage and exchange: the Audubon Core

The GBIF Multimedia Resources Task Group (Morris, 2013) together with Biodiversity Information Standards (TDWG) developed a new standard, the **Audubon Core** schema⁴⁰, designed for describing multimedia objects in biodiversity. This schema was designed to accommodate specific requirements from multimedia objects (e.g. relationships between objects, intellectual property rights, versioning). Parts of this schema has been used in the project that originated this guide for management and publishing of camera trap data.

³⁸ <http://www.pensoft.net/page.php?P=23>

³⁹ <http://www.nature.com/sdata/>

⁴⁰ http://terms.tdwg.org/wiki/Audubon_Core

The Audubon Core **schema** consists of 80 terms of which six are mandatory:

- Identifier
- Type
- Title
- Metadata language
- Copyright Owner
- Copyright Statement

A full list of all the terms is available in http://terms.tdwg.org/wiki/Audubon_Core. Many of these terms have an associated vocabulary (controlled list of terms) to ensure interoperability.

One Audubon Core **metadata record** is a set of terms with their values describing a multimedia object and its attributes.

By describing multimedia resources with consistent metadata, the Audubon core facilitates (Morris, et al., 2013):

- Enhanced discovery of multimedia resources;
- Evaluation of fitness for use prior to fetching a resource;
- Use of metadata records as potential taxon evidence, or for other inferences such as species interactions or habitat preferences;
- The production of identification aids; and
- The gathering and sharing of resources contributed by a wide variety of data custodians.

Data publishing using the Audubon Core

The Audubon Core standard has already been accepted by Biodiversity Information Standards (TDWG), and different practical implementations were under development at the time of publication of this guide. Among the most relevant of these implementations is the development of an IPT extension that will allow the publishing of rich information about metadata resources using a similar methodology to that explained earlier in this chapter.

Once this process for multimedia data publishing is in place, this guide will be updated accordingly to reflect the new situation.

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Abishek Harihar, PhD Candidate, Durrell Institute of Conservation and Ecology, University of Kent, Canterbury (United Kingdom), and Research Affiliate, Wildlife Institute of India. Email: abishek.harihar@gmail.com.

Alberto González-Talaván, Senior Programme Officer for Training. Global Biodiversity Information Facility Secretariat, Copenhagen (Denmark). Email: training@gbif.org.

Dr. Andre Pittet, Chief Project Advisor, CEDT, Indian Institute of Science, Bangalore (India). Email: apittet@cedit.iisc.ernet.in

Arild Lindgaard, Senior Adviser, Norwegian Biodiversity Information Centre, Trondheim (Norway).

Dr. Bivash Pandav, Scientist E, Department of Endangered Species Management, Wildlife Institute of India, Dehradun (India). Email: bivash.pandav@wii.gov.in

Frank Hanssen, Senior GIS- Analyst, Norwegian Institute for Nature Research, Trondheim (Norway). Email: Frank.Hanssen@nina.no.

Prof. Graham Kerley, Director of the African Centre for Ecology, Nelson Mandela Metropolitan University, Port Elizabeth (South Africa). Email: graham.kerley@nmmu.ac.za

Dr. John Linnell, Senior Researcher, NINA, Trondheim (Norway).

Dr. John Odden, Senior Researcher, NINA, Oslo (Norway).

Dr. Fridtjof Melhum, Director of Research and Head of the Department of Research and Collections, University of Oslo (Norway).

Mousumi Ghosh, Senior Project Assistant, GBIF Project: Capacity Building in Biodiversity Informatics; Wildlife Institute of India; Dehradun (India).

Roald Vang, IT-Development Section Leader, Norwegian Institute for Nature Research, Trondheim (Norway).

Dr. S. P. Goyal, Scientist G, Department of Animal Ecology and conservation Biology, Wildlife Institute of India, Dehradun (India). Email: goyalsp@wii.gov.in.

Tim Hirsch, Deputy Director and Head of Participation, Global Biodiversity Information Facility Secretariat, Copenhagen (Denmark). Email: training@gbif.org.

Dr. Vishwas Chavan, Senior Programme Officer for Data Mobilization, Global Biodiversity Information Facility Secretariat (until 2014).

8. Appendices

8.1. Glossary

Note: The definitions here apply mostly to the context of this guide. We have used definitions that are already well-established in the published literature, wherever possible.

Audubon Core: a set of controlled vocabularies designed to describe biodiversity multimedia resources. These vocabularies address issues such as the management of the media and collections, descriptions of their content, their taxonomic, geographic and temporal coverage and ways to retrieve, attribute and reproduce them.

Biodiversity: the variability amongst living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (definition applied by the Convention on Biological Diversity - CBD).

Camera trap: remotely-triggered camera that automatically takes images of animals passing in front of it/them. This term is considered interchangeable with all of the following: remote camera, trail camera, game camera, sensor camera, phototrap, and remote-sensing camera.

Child objects (also called derived objects): each of the objects (i.e. images) resulting from the duplication and modification of an original camera trap image.

Data publishing: a process through which data are made freely and openly available in standardized formats, via an internet access point.

Darwin Core: an internationally standardized set of terms for describing the identity and occurrence of organisms.

Darwin Core Archive: a standardized file format in which data must be presented in order to publish it through the GBIF infrastructure.

Detection zone: the area in which a camera trap is able to detect the heat signature and motion of a target animal.

DwC: please see Darwin Core.

DwC-A: please see Darwin Core Archive.

Event: the period of time from the first trigger to the last photo in a sequence encompassed by the extent of independent behaviour of the target.

Field of view: the area captured in a photograph.

Fitness for use (describing data): the suitability, effectiveness or usefulness of biodiversity data in delivering accurate, authenticated, replicable and scientifically valid evidence for analysis and forecasting in conservation and management of natural resources.

Incandescent: white flash used by some camera traps.

Lure (also called **bait**): a term used to refer to an attractant designed to bring the target animal into the detection zone to increase the probability of it being captured in a photographs.

Memory card: a removable digital storage medium that is currently the standard in digital camera traps.

Metadata: data about other data. In the context of this guide, information (data) about a dataset.

Metadata document: the combination of the contents of all metadata fields for a given dataset.

Multimedia resources: Multimedia resources can include pictures, artwork, drawings, photographs, sound clips, videos, animations, presentation materials, interactive online media, and the likes.

Multimedia collection: is an assemblage of multimedia resources, whether curated or not and whether electronically accessible or not. For the purposes of this document we regard a collection of multimedia resources itself as a ‘multimedia resource’.

Multimedia Resources Task Group (MRTG): work group created by GBIF in 2008 to suggest strategies to expand the types of primary biodiversity data that the GBIF network can discover and publish through the mobilization of multimedia resources (Morris, 2008).

Persistent identifier: a unique identification code that can be permanently applied to an object so that it can always be unambiguously referenced; there are different types of persistent identifiers each with slightly different applications. The more common ones are GUID (Globally Unique Identifier), URL (Uniform Resource Locator), LSID (Life Sciences Identifier) and URI (Universal Resource Identifier) and DOI (Digital Object Identifier). For more information, see GBIF 2011a.

Primary biodiversity data: digital text or multimedia data recording the occurrence of organisms in nature.

Sensitivity: an adjustable setting that reflects the camera’s response to heat in motion for passive infrared sensors.

Time lapse: a setting on some cameras that allows the user to prescribe certain times at which the camera will be inactive, regardless of animal movement in the detection zone; some cameras have dual functionality, but others do not have an infrared sensor and operate purely as time-lapse devices.

Trigger Speed (also called **response time**): the difference between detecting heat in motion and capturing the image; the slower the trigger speed, the lower the chances of capturing the animal in photos.

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8.3. Internet resources

Camera traps:

Tropical Ecology Assessment and Monitoring Group (TEAM), Centre for Applied Biological Studies. <http://www.teaminitiative.org>.

Terrestrial vertebrate monitoring protocol adopted by TEAM:

<http://www.teamnet.work.org/en/protocols/bio/terrestrial-vertebrate/>

Camera-trap email discussion group: <http://uk.groups.yahoo.com/group/cameratraps/>

Detailed reviews, comparisons and technical details on various digital models:

<http://www.trailcampro.com/>

A selection of camera-trap producers' web-sites:

- <http://www.reconyx.com>
- <http://www.huntingcamonline.com>
- <http://www.trailmaster.com>
- <http://www.cuddeback.com>
- <http://www.snapshotsniper.com>
- <http://www.stealthcam.net>
- <http://www.camtrakker.com>

For multimedia data

GBIF Multimedia Resources Task Group:

<http://wiki.gbif.org/gbif/wikka.php?wakka=MultimediaResourcesTaskGroup>

Camera Base, a free software for managing camera-trap data:

<http://www.atrium-biodiversity.org/tools/camerabase/>

Comparison of digital asset management systems:

<http://www.damroundup.com/category/reviews>

For data publishing:

Audubon Core Wiki: http://species-id.net/wiki/Audubon_Core.

Audubon Core Terminology: http://species-id.net/wiki/Audubon_Core_Term_List#References.

GBIF Integrated Publishing Toolkit: <http://www.gbif.org/ipt>.

GBIF data publishing guidelines: <http://www.gbif.org/publishingdata/summary>.

Appendices

Others

Biodiversity Information Standards (TDWG): <http://www.tdwg.org>.

Catalogue of Life: <http://www.catalogueoflife.org>.