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China's wildlife camera-trap monitoring needs a unified standard

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Abstract: Conserving biodiversity relies on the effective monitoring of species in a timely and credible way. Camera traps provide images and metadata for many mammal species and are now used widely enough that they can provide a viable method for biodiversity monitoring. Camera-trapping is rapidly deployable, allows standardization of protocols, and provides a voucher specimen (i.e. image) with relevant information about the species' location, time and date of capture, and other capture details (camera model, etc.). This technique has resulted in millions of images being captured and stored for current and future examination of biodiversity. Camera-trapping has become particularly popular in China. Multiple institutions are running their own monitoring programs and collecting and storing wildlife images and associated metadata. There is an urgent need to standardize the metadata format in order to share data across institutions and with the larger conservation community. Global data sharing repositories, such as Wildlife Insights, exist but will need China's data to effectively track global efforts for achieving sustainability. Three steps are needed for this to occur: common data standards, data sharing agreements and data embargo policies. We urge the Chinese conservation community to develop the policies and the mechanisms needed to share wildlife images within China and with the international community.

Key words: camera-trapping; metadata; Aichi Biodiversity Targets; wildlife data repositories; data embargos

1 Introduction

The world conservation community has identified the biodiversity of species and their status as critical measures of sustainability (Mittermeier et al, 1998; Brooks et al, 2006; Tilman et al, 2017). In an increasingly human-dominated landscape, global metrics of biodiversity allow international entities to track progress toward sustainability (Pereira & Cooper, 2006; Lohbeck et al, 2016; Proença et al, 2017). At the global scale, biodiversity metrics will be major indicators toward reaching the Aichi Biodiversity Targets (O'Connor et al, 2015) and the UN sustainable development goals. At the regional scale, the practical function of protected areas is to protect and sustain a diversity of species for the enjoyment and support of human livelihoods (Naughton-Treves et al, 2005). Monitoring biodiversity is the means by which protected areas measure their resources and their ability to protect them. Trends in critical species become the metric by which a reserve judges its management actions especially protection (Li et al, 2012; Wetzel et al, 2015).

The traditional system of counting species and their distribution is through the collection and curation of voucher specimens which document the species and their location at a specific time, as well as ancillary metadata such as collection technique and collector, etc. These voucher specimens and their data are the core of museums throughout the world and provide a critical baseline of the world's biodiversity (Suarez & Tsutsui, 2004; Edwards, 2004). In this time of global climate change and rapid human expansion, it is essential that biological diversity measures keep track with the rate of change and allow policy/management decisions to be made rapidly using current data (Visconti et al, 2016; Santini et al, 2017; Kays et al, 2020). Some scientific advances have provided the needed utility. For example, the advent and development of remote sensing technology provides an excellent tool for tracking changes in land use, fire monitoring, forest fragmentation, and changes in plant productivity (O'Connor et al, 2015; Skidmore et al, 2015). However, satellite or airborne sensors rarely detect changes in the animal communities that rely on habitat features and not all habitat changes (or lack of change) reflect changes in wildlife populations due to disease, poaching or the influx of exotic species (Pereira & Cooper, 2006; Steenweg et al, 2017). Critical wildlife species need a monitoring system that accurately reflects changes in abundance and distribution, without disrupting the species, and is capable of rapid acquisition and processing (Rowcliffe & Carbone, 2008). In addition, biodiversity monitoring would benefit from a metric that can engage the participation of citizen scientists through their contribution of data (McShea et al, 2016; Forrester et al, 2017).

Camera traps are a system that can reliably detect many large-bodied species (e.g., ungulates, carnivores and some primates) and has been tested extensively enough to identify the amount of sampling needed to accurately monitor guilds of species (O'Connell et al, 2010; Meek et al, 2014; Kays et al, 2020). The issue of data associated with the image is critical: an image only becomes a specimen if it contains the species' name, the location, the date (and time) collected, the collection device, and the collector (Forrester et al, 2016); and these details are called metadata and must be associated with the image through a unique ID. There are additional covariates associated with the camera placement itself (detection distance, amount of vegetation, and weather conditions) that help explain some of the variability between locations (O'Connell et al, 2010; Meek et al, 2014). All records at a single location are correlated with these associated data, as some locations and time periods record more specie and species differ in their detectability as well as their abundance. If multiple projects are to be added to the same database then the list of required information grows, such as use of bait or lure, and spatial array of cameras used in the project. All these details call for some limits on the protocols used to deploy the cameras, but also strict adherence to a standard format for the metadata associated with each image (Forrester et al, 2016; McShea et al, 2016; Ahumada et al, 2020). These metadata standards are not only important for a single project or research group but are required for sharing of data across institutions, agencies or countries (Ahumada et al, 2020). We advocate that a more efficient voucher system, camera trap images, exists for many species, and what this system lacks to be implemented is a standard metadata format and an administrative framework.

2 Current status of camera-trapping in China

Camera traps were introduced to China in the 1990s and have been widely used for wildlife monitoring and research in the past 25 years (Li et al, 2014; Zhu et al, 2017; Xiao, 2019). They are deployed in most of China's national nature reserves for wildlife surveys and assessments. Research institutes and universities have established a series of monitoring networks with camera traps. The platforms established across broad landscapes and for long durations include: the China BON Mammal Diversity Observation Network led by MEE's Nanjing Institute of Environmental Sciences (China BON-Mammal; Li et al, 2018), the Sino BON Mammal Diversity Monitoring Network led by the Chinese Academy of Sciences (Sino BON-mammal; Xiao et al, 2014, 2017, http://www.cameradata.ioz.ac.cn), the camera-trap monitoring network established by Peking University across the Mountains of Southwest China biodiversity hotspot (Li et al, 2010, 2012), the long-term Tiger-Leopard Observation Network (TLON) established by Beijing Normal University (Wang et al, 2016), the State Forestry and Grassland Bureau (http://139.159.240.228:8041/cameramath/loginController.do?login#) and the biodiversity monitoring system for China's protected areas established by the Chinese Academy of Forestry (http://www. papc.cn).

These current camera-trap monitoring programs are extremely helpful to survey China's large mammals and monitor their population trends to inform conservation activities. Tools for automatically identifying species from the images are being developed and included in the image database in order to quickly process the large amount of images collected from the field. Some database have tools for analysis and some capacity for report writing. Most of camera-trap surveys in China adopt a grid system of various sizes (e.g., 1 km × 1 km, 2 km × 2 km, 3.6 km × 3.6 km) for sampling, and the basic format of the image database are similar, which makes future data-sharing among different monitoring platforms technically possible.

The remaining issues are how to mobilize the willingness of data-share and at the same time guarantee the fairness of data-sharing among different platforms. The sampling size and sampling durations are allowed to vary according to the aim of different monitoring programs, as long as they meet the minimum requirements (i.e., a grid sampling system and a minimum sampling duration of 30 days). The focus for data-sharing will be the format standards for wildlife images and associated data, which serve two purposes: (1) to provide the needed structure to accomplish the research or monitor an individual landscape, and (2) to provide the broader biodiversity metric across a large landscape of country, continent or planet (Ahumada et al, 2020). This second, broader goal is not a first priority for most researchers or managers, but is critical for tracking biodiversity metrics that encompass regions broader than any single project can provide (Jetz et al, 2012). The challenge will be giving the individual researcher or manager the ability to produce their needed outputs and yet have the data accessible for the broader mission. Due to China's vast territory, the effort of any individual agency will not be enough for monitoring China's large- and medium-sized mammals, and data sharing is a necessity for the country's future conservation planning.

3 Standards and policies for data sharing

There are multiple software packages currently available for tagging images and assigning information at each level of organization. Examples are Digikam, Adobe Bridge, and Adobe Lightroom. These programs allow organizations or individuals to catalogue and track their wildlife detections. Rapid advances in Artificial Intelligence (AI) will streamline processing through the identification of empty sequences and eventually species identification (Norouzzadeh et al, 2018; Thau et al, 2019). The current features of these programs can not fulfill the user's need of sharing information across platforms beyond a simple download and reformatting of information. Even this reformatting process involves some cross-validation of data language and format to ensure information is properly transferred. Data sharing first needs a shared language and data standard, and here we recommend the shared data standard proposed by Forrester et al (2016). In this proposal, the images themselves are given a unique identifier and grouped into sequences and the deployment of a camera captures a series of image sequences as different species and individuals move in front of the sensor. These deployments are organized into sub-projects or projects, depending on the complexity of the effort. Each level of organization has metadata associated with it and the levels are placed in a relational database (Fig.1), such that routine searches and sorts can isolate the needed information (McShea et al, 2016; Ahumada et al, 2020). This standard has the required data fields of project ID, location of camera, image identifier, date camera out, date camera in, time and date of photograph, species ID, number of individuals, and camera model. Other metadata associated with the camera (i.e. temperature, use of lure, staff ID, habitat) are valuable, but optional. We strongly encourage the conservation community in China to adopt the practice of storing camera traps images using these minimal standards to set the stage for future data sharing.

There are camera trap repositories that currently have data sharing and embargo policies in place. The international data repositories work under the assumption that sharing data allows for improved models and metrics for wildlife as they increase sample size, as well as temporal and spatial extent of the data on each species (Jetz et al, 2012). Whereas individual species of concern might be too rarely detected for rigorous model creation in one study, the combination of similar studies by different partners makes analysis possi-

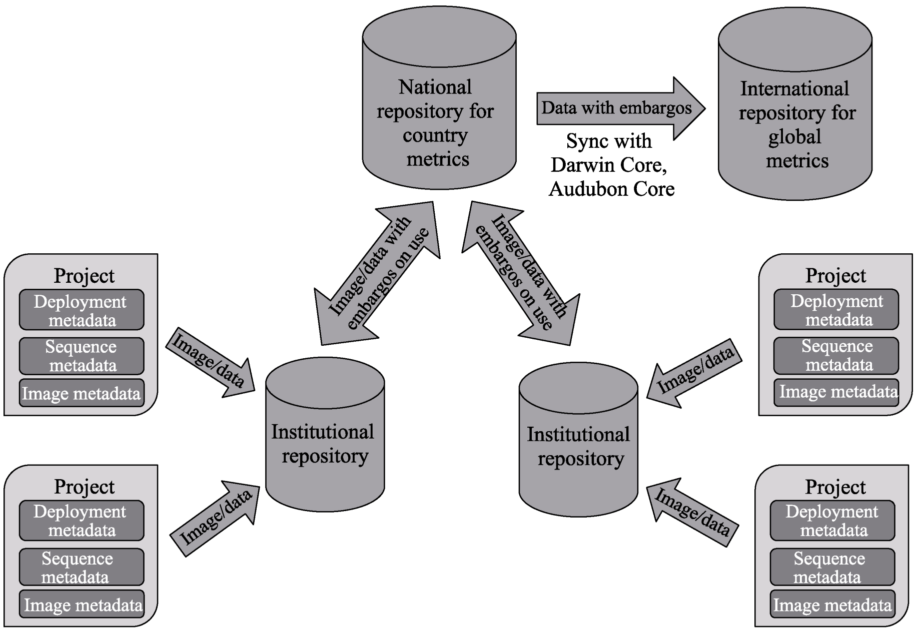

Fig. 1 A common camera-trapping metadata structure and schema for data flow between institutional repositories and national and international repositories

ble. Whereas a single project may have an emphasis on estimating density of a large carnivore, the “by-catch” from this well-funded project may be invaluable to those working on less charismatic species. Examples of international shared repositories are eMammal (http://www.emammal.si.edu), which is being coordinated by the Smithsonian Institution, and Wildlife Insights (http://www.wildlifeinsights.org) which is being developed by a consortium of NGOs including Conservation International, World Wildlife Fund, Wildlife Conservation Society, Zoological Society of London, North Carolina Museum of Nature, and Smithsonian Institution. The international repositories offer a model for data sharing. Data are input from multiple sources using a common platform (desktop application for eMammal and web-based for Wildlife Insights) and metadata structure (McShea et al, 2016; Ahumada et al, 2020). By creating web-based portals with drop-down options for data entry, citizen scientists can add data into these repositories without having to understand the complex data format. The data are then accessible to the global community through a public-facing website with reasonable embargos on sensitive information (location of endangered species and species of concern), as well as a permission structure that offers each project to set an embargo time prior to it becoming public. Both repositories encourage data submission by offering tools that make data uploads easier and provide analysis and report writing tools that might not otherwise be available to the data provider. For Wildlife Insights these include the use of AI to identify species and detailed summary statistics (Thau et al, 2019). For eMammal it is the emphasis on the management of citizen scientists and the expert review of data from volunteers (McShea et al, 2016; Forrester et al, 2017). Without access to valuable tools the repositories would not garner the support of individuals within the camera trap community. Both these platforms eventually make all data public (with the exception of endangered species).

One concern among Chinese researchers and government officials is the use of data outside any sharing agreements and there are other data repository which have similar concerns. ForestGEO (https://forestgeo.si.edu/) is a data repository where individual databases on forest demographics are curated at a single site (with a common field survey protocol and a standard metadata structure) with a public-facing information website on the size and parameters of each dataset. However, prior to access to any dataset the Project Manager for a dataset must release the dataset through an email link. This database contains multiple datasets from China and may provide the data control needed for important datasets, yet allow sharing between approved collaborators. A separate data sharing mechanism is developed within the Chinese Forest Biodiversity Monitoring Network in China (CForBio, www.cfbiodiv.org). Researchers who ask for collaboration and data sharing need to send proposals to PIs of other plots, with explanation on proposed research questions, authorship options and data required. The participant data owner will receive the R code from the applicant to run the analysis with their data, and send back results without sharing the raw data. Both of these examples highlight how concerns for publication fairness or sharing of sensitive data do not preclude establishing a common database.

4 Recommendations

The global mandate to sustain biodiversity demands international cooperation (Proença et al, 2017; Steenweg et al, 2017; Kissling et al, 2018). Many of the species of concern cross regional, and national, boundaries and any metrics to track these species will rely on cooperation between agencies and independent researchers within countries, as well as between countries that share the management of many species (Ahumada et al, 2020). We must develop the means to work across political and administrative boundaries, and this starts with communication between the entities generating the data. There are reasonable steps that will move the camera trap community toward cooperation. First, creating a forum to discuss issues both at the global scale and within each target country. Second, have these participants decide on a shared metadata structure or at least determine the commonalities of each independent dataset, “cross-walk” the data fields within each repository, create APIs to connect data repositories and established common monitoring protocols and data standards. Third, insure that more data goes into these large repositories by offering incentives through ease of upload and shared analysis tools. Fourth, set the rules for data sharing, both within the country and between cooperating countries. Each country will need to set rules that are appropriate for their participants, but the ultimate goal is sharing critical data. Ultimately the last step would be to contribute to the global repository via a portal that sends either raw or processed data for the use of global metrics and the examination of species with cross-boundary distributions.

The world conservation community needs China’s participation to truly measure our shared progress toward a sustainable planet. The pathway of participation is first by sharing within the wildlife community of Chinese researchers and agencies, and then deciding as a group how to share with the wider community of conservationists. This is the way by which China’s rich wealth of biodiversity will be evident to the world community and their progress on conservation measures will be quantifiable. During the past two decades, China actively participates in the international affairs of biodiversity monitoring and conservation, with increasing role and influence within the global conservation community. China has initiated or started to lead the establishment of several international biodiversity big data platforms. For example, the Chinese government recently announced that China will set up an International Research Center of Big Data for Sustainable Development Goals to facilitate the implementation of the 2030 Agenda for Sustainable Development. The establishment of a unified data standard and a common data sharing mechanism will provide the necessary foundation for the development and construction of these international data platforms.

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