African golden cats, citizen science, and serendipity: tapping the camera trap revolution

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The use of camera traps for wildlife research and monitoring is increasing and this is yielding significant observations at an accelerating pace. Yet many potentially valuable observations are overlooked, misinterpreted or withheld. Using our first-ever images of a wild African golden cat (*Caracal aurata*) catching prey, we consider practical challenges and opportunities for more effective image management systems. In particular we highlight the benefits of online image archives and assessments.

Key words: *Profelis aurata*, *Felis aurata*, camera trap, meta-data, bias, data mining, citizen science, data archives.

Little is known about most of the world's mammal species especially in habitats, such as rugged mountain forests, where sites are hard to access and species are elusive. In this context technical developments such as camera traps offer exciting advances. Yet our abilities to collect such data increasingly outpace our capacity to evaluate them. We need help.

In this communication we first report the increasing use of camera traps. Next we introduce and detail an example in which we almost missed the first recorded images of an African golden cat (*Caracal aurata*) catching prey. Such examples illustrate the challenges many of us face in handling data. We then consider how an online volunteer-centred 'citizen science' system could improve our assessments.

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THE INCREASING USE OF CAMERA TRAPS

Camera traps are automated, motion- or heat-triggered, cameras. These cameras offer various advantages over other wildlife survey and monitoring approaches (e.g. Cutler & Swann 1999; Silveira *et al.* 2003; De Bondi *et al.* 2010; Espartosa *et al.* 2011; Burton 2012). Though once expensive, technically demanding and delicate (e.g. Rice 1995; Cutler & Swann 1999), such cameras have become progressively cheaper, simpler and more reliable. The result is that camera use is increasing and images are being gathered at an accelerating rate (Pyle 2003; Rowcliffe & Carbone 2008). The growing worldwide use of these cameras raises the frequency of valuable but unanticipated observations. New species, remarkable behaviours, and surprising range extensions are being reported (e.g. Rovero *et al.* 2005; Rovero *et al.* 2008; Dobson & Nowak 2010). But the assessment and sharing of significant wildlife images, and related information, is a demanding and imperfect process. Interesting images are easily overlooked.

OUR OBSERVATIONS

In 2010 we began an annual camera trap survey in Bwindi as part of the Tropical Ecology Assessment and Monitoring Network (TEAM; www.teamnetwork.org, see also Ahumada *et al.* 2011). We used Reconyx RM45 passive infra-red camera traps set to record continuously in high sensitivity mode (Reconyx 2008) for 30 days at each of 60 pre-selected sites on a regular grid (one camera per km^2). No bait was used. After the cameras were recovered the images were compiled, classified by content, and uploaded to the TEAM archive (Fegraus *et al.* 2011, see also http://www.teamnetwork.org).

The African golden cat (*C. aurata*) is Africa's least known cat species (Brodie 2009) and the largest terrestrial carnivore in the mountain forests of the Bwindi Impenetrable National Park ('Bwindi') in southwestern Uganda (Sheil 2011; Mugerwa *et al.* 2013). Previous synonyms include *Felis aurata* and *Profelis aurata*. What we know about their diet is based primarily on a few small studies of their scats (Davenport 1996; Hart *et al.* 1996; Sunquist 2001). From anecdotal accounts we believe that these solitary cats stalk and rush their prey, killing with a bite to the back of the neck (Kingdon 1971). Observations are rare. In 2010 our image classifications included 34 African golden cat observations from 15 of the 60 camera locations (sets of images with less than one hour a)

b)

Fig. 1. Two close-ups of an African golden cat rushing and then carrying a rodent prey, where the prey is facing us lower mid-right (**a**) and the prey is held in the cat's mouth facing the camera (**b**).

between them at a single site are combined in one observation). One of these observations proved of particular interest (for a full account see Sheil & Mugerwa, in press).

On the night of 15 July 2010, a camera located in forest approximately 2.5 km from the nearest road or park boundary, recorded 12 images of one cat (location: UTM (35M) E 804770, N 9885567, at 2095 m above sea level). One image showed a cat catching a prey item, and seven showed it carrying this rodent (see selected close-ups in Fig. 1). These unique images show that African golden cats hunt on the ground, rush their prey and carry their victims away to consume them.

Image characterization takes time and care. In one image, the eye reflections of the rodent were seen only after the initial images classifications were completed. Errors and oversights cannot be entirely eliminated. In Bwindi National Park we generated 15 912 images in the TEAM survey of

2010 although 13.4% of these were unidentifiable (Mugerwa *et al.* 2013). The entire TEAM archive, which includes multiple sites, has more than one million images of which 53 612 were unidentifiable as of 14 April 2013 (http://www.teamnetwork.org/netstats). The number of errors and omissions on named images is currently unknown (a sample-based review is currently under discussion). Means to better assess all such images is necessary.

AVAILABLE DATA

When researchers find something of potential interest, such as reported here, they must then decide whether and how to share it. They may choose to submit it as a short communication for peer-review to an appropriate journal. Some discoveries are never reported while those that occur in newsletters, reports or blogs may be misleading. For example, one news release concerning images of an 'unknown carnivore' in Borneo gathered global coverage (Holden 2005). Later a peer-reviewed paper indicated that the image was of a known species of flying squirrel (*Aeromys thomasi*) (Meijaard *et al.* 2006). This correction has largely been ignored (E. Meijaard, pers. comm. to D.S., 1 December 2012).

Current practices can result in inaccurate, biased and incomplete reporting. Data limitations must not result in uncertain conclusions. Efforts to reduce uncertainties or distortions are essential and fundamental to scientific good practice (Møller & Jennions 2001; Ioannidis 2005).

Building a data community

Systematic approaches to store, assess and share images could address these problems. Automated image analyses and recognition is coming, and accessing new expertise (e.g. taxonomists) will remain crucial. Here we focus on the development of public image archives that add value through online citizen-science assessments or crowd-sourcing (Dickinson *et al.* 2012). Others have noted the need to archive trap images (Rowcliffe & Carbone 2008). TEAM network maintains an online data archive for more than one million project images. The images are identified and uploaded by the contributing researchers and become publically accessible (with rules to respect intellectual property, Fegraus *et al.* 2011). The Smithsonian Wild project also hosts a public image archive: their 200,000 or so images derive from various research activities and intends to accept photographs from external sources in the future. Image management and assessment is performed by the researchers and archive managers (see http://smithsonianwild.si.edu/). Although both TEAM and Smithsonian Wild are exploring how best to enable users to help identify images, neither has yet implemented tools to do so.

The Galaxy Zoo Project exemplifies the potential of outsourcing image assessment to large numbers of volunteers (Fortson *et al.* 2011, see also http://www.galaxyzoo.org). The success of the project has led to application in other fields including ecology. One such study, though not an open data-sharing or data storage exercise, uses volunteers as a means to classify images of large animals in the Serengeti and should provide useful lessons in such data handling (see https://www.zooniverse.org).

Research-data archiving systems have been intensively reviewed (e.g. Newman *et al.* 2011; Bach *et al.* 2012). Such systems, including the processes and tasks that they require and facilitate, need to be defined, built and refined with the close involvement of the researchers who contribute and use the data (Piwowar *et al.* 2008; Moritz *et al.* 2011). In the longer term broader goals may be feasible, especially by tapping into the expertise and interests embodied in networks such as the IUCN species survival commission specialist groups.

In the TEAM system data flow and quality are eased by uniform standard formats, protocols, audit trails, a centrally coordinated network and clear policies on data-sharing (Baru *et al.* 2012). Specific image handling lessons from the TEAM network include the need for the characterisation of multiple animals per image, standardizing of taxonomic authorities, facilitating offline data management by image producers, and the value of allowing batch processing.

Flexibility to accommodate unanticipated opportunities is valuable. For example, images from a camera trap network established to monitor European brown bears (*Ursus arctos*) in Asturias, Spain, have subsequently helped assess an unexpected outbreak of scabies in wolves (*Canis lupus*) (Oleaga *et al.* 2011).

Researchers have various reservations about data sharing (Pryor 2009; Cragin *et al.* 2010). Loss of control, issues of intellectual property, and professional credit are significant concerns (Moritz *et al.* 2011; Enke *et al.* 2012; Huang *et al.* 2012). Researchers often wish to publish their results before releasing their data, and most favour specific collaborations over a public-access system (Pryor 2009). Camera trap images represent a major effort by researchers and, like many ecological data, have significant potential for re-use (Zimmerman 2008).

Researchers contribute images to open archives in order to forge new collaborations, to derive more from their efforts, and for wider public engagement. Evidence suggests that papers with public data receive more citations (Piwowar *et al.* 2007). Sharing will improve as systems and norms evolve (Pryor 2009) and some donors already encourage data release (Piwowar *et al.* 2007). As the TEAM project shows researchers will share data if their funders require it and suitable guidelines and safeguards are in place.

Volunteers typically share a project's goal, find the tasks engaging and share in the excitement of discovery. Their main task is image assessment. Species identification requires experience and expertise, but volunteers can apply diagnostic check-lists (e.g., Meijaard *et al.* 2006). There is scope to use prescribed criteria to assess animal behaviours, physical appearance and other image content. Guidance, training and quality controls can be automated. We know from examples such as the Galaxy Zoo Project that opportunities to develop a broader community with scope for their own projects and interests are also valued. As systems and goals evolve, specialist volunteers may help develop and maintain the cyber-systems – as found in the open source development model for software (e.g., http://www.oss-watch.ac.uk). A major benefit from such engagement is in creating opportunities for public outreach (Novacek 2008; Newman *et al.* 2012).

TEAM and Smithsonian Wild are two camera trap data providers within a much larger camera trapping community. The camera trap community includes many large non-governmental organizations (e.g. the Wildlife Conservation Society), universities, zoos and government agencies. Ideally, these data providers will exchange and share information amongst each other, with the public, and with other organizations interested in ecological data, including GBIF (http://www.gbif.org/) and DataOne (http://www.dataone.org/). Camera traps are only one example of the increasing use of digital technology in wildlife research. Tapping these advances depends on reliably compiling, evaluating and sharing data.

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