A BETTER SOLUTION FOR PHOTO-CLASSIFICATION, AUTOMATIC STORAGE AND DATA INPUT OF CAMERA DATA FROM WILDLIFE CROSSING STRUCTURES

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ABSTRACT

Infrared-operated cameras have been used in wildlife studies for over two decades. Since their inception the technology has changed considerably and they are now commonly seen as an inexpensive, efficient and non-invasive method of data collection. Camera use in ecological field studies is rapidly increasing worldwide to help address important species conservation and management objectives. However, given that digital cameras can automatically record large numbers of photographs, data management rather than data collection, has quickly become the rate-limiting step in field studies. For example, photos must be downloaded and interpreted before analyses can be conducted. All of this is time-consuming and takes away time from field research and data analysis, essentially requiring a part- or full-time technician to manage and process camera data. There have been few attempts to develop photo-classification database programs to aid in the process of interpretation and storage of photographs from digital cameras. Databases that exist have been designed primarily for biodiversity monitoring and occupancy analysis. Many studies monitoring wildlife use of road crossing structures have relied on cameras as a data collection tool. These studies face the same issues as other ecological studies regarding interpretation, data input and storage. Until now, we are unaware of any photo-classification program or software that assists researchers monitoring wildlife use of crossing structures to efficiently classify and manage the growing and demanding mass of photographs continuously collected in the field. The purpose of our presentation is to describe a semi-automated photo-classification system we have developed and refined through nearly a decade of monitoring crossing structures in Banff National Park, Alberta. We currently monitor year-round 40 crossing structures using 48 cameras. Bi-weekly checks result in on average over 300,000 photos annually to review, analyse, classify and input into our database. Our customized image processing and storage application uses Microsoft Access software, a widely available front-end database program. The application is designed so that once photographs are uploaded to crossing structure folders in a processing "cache" or folder, project personnel review the photographs, classify species, number and sex of individuals, direction of travel and any other information pertinent to the monitoring objective (behaviours, predator-prey interactions, small mammal presence, unique photos, etc.). The application allows for a quick and efficient classification of photographs, automatically inputs the classified data into a master database, and stores the photographs in an archived photograph folder. The system is user-friendly and citizen scientists, a critical resource

for our project, can be trained to use it in a few hours. The application is designed in Access to be flexible to research needs and can readily be customized to field data and research objectives outside of crossing structure monitoring. We describe the photo-classification system and provide examples of how it has evolved during the last decade and how it is being used today. We will highlight how the Banff application is different from other image processing software available today, what the limitations are, and how others can customize it to meet the needs of other field-based ecological studies. Last, we discuss the integration of citizen scientists in photo-classification work and what the future needs are for improving the system.

INTRODUCTION

Infrared-triggered cameras (camera traps) have been used in wildlife studies for decades (Kucera and Barrett 1993, Mace et al. 1994, Cutler and Swann 1999). Since their inception, camera technology has changed considerably, the most dramatic shift probably happening when cameras became digital. They are now commonly seen to be an efficient and largely noninvasive method of data collection (Kucera and Barrett 2011, O'Connell et al. 2011). Camera trap use in ecological field studies is rapidly increasing worldwide to help address important species conservation and management objectives (O'Connell et al. 2011). However, digital camera traps often record large numbers of photographs. While this is one of their advantages, the photos have to be downloaded and interpreted before analyses can be conducted. All of this is time-consuming and takes away time from field research and data analysis, essentially requiring a part- or full-time technician to manage and process camera data. Incidentally, this is not a problem unique to digital camera traps: Animal tracking systems using global positioning system (GPS) technology, and other remote and automatic sensors logging biological information from animals all create vast amounts of digital data but do not require each record to be visually interpreted (Rutz and Hays 2009, Urbano et al. 2010).

Many studies monitoring wildlife use of road crossing structures have relied on cameras as a data collection tool (Ford et al. 2009, Gagnon et al. 2011). These studies face the same issues as other ecological studies regarding interpretation, data input and storage. However, they often also attempt to classify animal behavior around the crossing structures, making data collection from images even more complex. There have been a few attempts to develop photo-classification database programs to aid in the process of interpretation and storage of the digital photographs (Meek et al, 2012; Table 1). Most of them have been designed primarily for biodiversity monitoring and occupancy studies, which typically only collect a limited amount of information from photos, such as date, time, species and number of individuals (Sundaresan et al. 2011). As most projects have very specific needs, and varying degrees of IT/programming skills available, there is unfortunately no "one fits it all" solution. When our project began using digital camera traps in 2005 (Clevenger et al. 2009), after more than a decade of using sand tracking to monitor wildlife crossing structure use (Clevenger and Waltho 2000, 2005), we faced these exact problems, and decided to create a semi-automated database tailored to our needs. There are many ways to do this, and while our approach is not necessarily the "absolute best", it has worked very well, and we have continued to improve and refine it over the years.

The purpose of this paper is to describe our project, outline our photo-classification system, talk about points to consider which are not usually covered in publications, and solutions to those challenges. We hope that it will be useful for similar camera-based projects that assess wildlife crossing structure performance and function or other ecological field studies.

TABLE 1 Programs providing viewing and coding options on screen, as of 2012

Program name:	Author:	Program requirements:	Requires programming skills:
Camera Base 1.5.1	Matthias Tobler	MS Access or Run-time program	No
DeskTeam	TEAM Network	?	No
Jim Sanderson's program	Jim Sanderson	?	yes
Photospread	Kandel et al.	MS Excel	yes

THE LITERATURE

Scientific publications from ecological projects involving camera traps generally focus on technical details of cameras, survey methods and statistical analysis, but usually do not mention data management strategies, classification methods and quality control measurements (Nichols 2010, Hamel et al. 2013, McCallum in press). To some degree this level of technical information would not be expected in scientific papers, were it not for the fact that these are problems stemming from fairly new technologies that many biologists have not much experience with. There is thus not much to find in recent literature. Table 1 gives an overview of the published programs that aid in classifying large quantities of photographs from camera traps.

SURVEY OF WILDLIFE CROSSING PROJECTS

To get an idea of how other projects of similar design and scope as ours handle their digital imagery data, we conducted an informal survey among colleagues. From the results of the survey, it soon became apparent that most projects did not have access to an Information Technology (IT)-department like the TEAM network (Fegraus et al. 2011), and either did not have a budget for or did not consider a database consultant to set up a more customized database. Some large projects still relied on simple spreadsheets and transcribing data from field notes to spreadsheet. Many projects employed dozens of cameras for long periods of time, yielding up to hundreds of thousands of photos yearly for the largest projects. Obviously, each project had found a solution they could live with, but many showed interest in a more efficient solution for their task, citing that paying for staff to process the photos was a large part of their budget, and automating things would be desirable. It seemed that most projects only conducted a limited amount of quality control of the data processing, sometimes citing the fact that the large amount of data made errors less consequential. When directly questioning technicians of other projects, the consensus with regards to ideal maximum classification duration was four hours. Everyone voiced concern about loss of focus and increased errors during longer workdays.

OUR SYSTEM

Overview and evolution of cameras in Banff research

All Banff wildlife crossing structures were initially monitored for large mammal use since 1996 using track pads (Clevenger and Waltho 2000, 2005; Clevenger et al. 2009). When the first two wildlife overpasses were completed in 1997, we started to use active infrared-triggered 35mm cameras at the overpasses in addition to raked track pads (TrailMaster, Lenexa, Kansas; 2 on each overpass) as a second detection method. Since 2005, when trail cameras started to come down in price from $USD 1200 to $USD 600, we increasingly began using motion-sensitive digital cameras to supplement track pads to monitor species use of the crossing structures. As part of the photograph EXIF data, these cameras (Reconyx Inc., Holmen, Wisconsin) provide information on date, time and ambient temperature during each crossing event.

While using hair-snagging and DNA-based techniques to research how populations of grizzly and black bears might benefit from crossing structures (Clevenger and Sawaya 2010, Sawaya et al. in press) we found it informative to have cameras at the crossing structures recording animal behaviour. Starting in 2006, as more cameras were deployed in the study area, there was an obvious need for a more efficient means of classifying photographs from the field and inputting data to our MS Access database. Metadata from the photographs (date, time, crossing structure name, temperature) could easily be transferred to the database, but information on species occurrence, age class, gender, number of individuals, direction of travel and behaviours had to be inputted by hand.

We found through monitoring animal movement at the crossing structures with both track pads and cameras that cameras were a more reliable, cost effective and less invasive means of monitoring crossing structure use than tracking alone (Ford et al. 2009). In November 2010, we stopped recording track pad data along with camera data at the crossing structures. All of the constructed crossing structures built by the end of 2012 have remote cameras operating. There are currently 49 cameras being used to monitor 39 wildlife crossing structures.

All crossing structures are visited every 2-3 weeks to change batteries and download images from camera memory cards. Photos are classified using Microsoft Access software and our project's customized image classification form. The image classification allows us to quantify (1) baseline data on species passage/avoidance at the wildlife crossing structures and (2) species behaviour and response to crossing structures types of same design on new and old sections of highway.

We attempt to identify photographs to species, which is usually possible. We estimate the number of individuals, their direction of travel and whether they moved through the crossing structure. Large mammal species consist of wolves (*Canis lupus)*, coyotes (*C. latrans)*, cougars (*Puma concolor)*, lynx (*Lynx canadensis)*, black bears (*Ursus americanus)*, grizzly bears (*U. arctos)*, wolverine (*Gulo gulo)*, mule deer (*Odocoileus hemionus)*, white-tail deer (*O. virginianus*) elk (*Cervus elaphus)*, bighorn sheep (*Ovis canadensis)* and moose (*Alces alces)*. Photographs of small- and medium-sized mammals and other vertebrates (birds) are also identified as accurately as possible. Since these species are not central to our studies we note their occurrence during the classification process should anyone be interested in them in the future.

We currently monitor year-round 39 crossing structures using 49 cameras. Bi-weekly checks result in on average over 300,000 photos annually to review, analyse, classify and input into our database.

Description of system

To meet the demands of more than 20,000 photos coming into our office every two weeks, we realized there was an urgent need for a fast and efficient means to classify photos and input data into our database. Since we were already storing our data in an MS Access database, we created a Form in our database with all the basic fields of information that we already had in the database and any additional information that we wanted to tag photos or data entries (Figure 1). Metadata from the photographs were transferred automatically to the database (date, time, crossing structure name, temperature). We created data categories for the following: species, age class, gender, number of individuals, direction of travel, and passage. For each of the above we compiled a list of possible entries that would appear in scroll-down tabs, e.g., species (=all species names), age class (=adult, adult with young, etc.), and passage (=yes, no, hesitation, etc.). The data categories can be changed as additional species may appear at the crossings or data classification becomes more refined over time or changes with research project objectives.

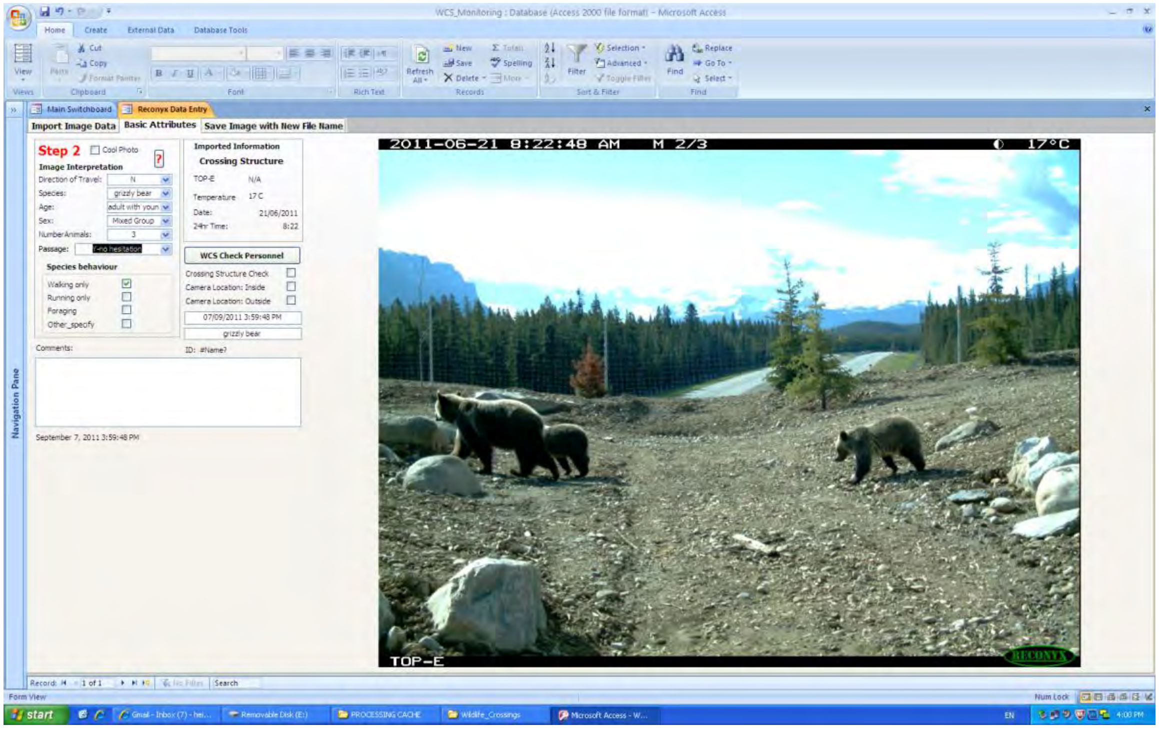

FIGURE 1. Screenshot of photo-classification form used in Banff National Park, Alberta.

The classification process

Citizen scientists play a key role in our project data collection and classification. We count on the part-time help of 3-4 citizen scientists that help either check the crossing structures, i.e., switching out CF/SD cards, replacing batteries if needed, etc., or assist photo-classifying crossing structure photographs brought in from the field. These volunteers have been working on the project for 3-4 years and know our system well.

When photos arrive at the office from the field they are uploaded into two different folders, an “Archive” folder and a “Processing Cache” folder. The Archive folder is a repository of all the crossing structures photos and is not modified in any way. The Processing Cache folder holds all the photographs that have been brought in from the field and need to be processed or photo-classified. In both Archive and Processing Cache folders, each crossing structure has a folder with its name and for crossing structures with two cameras we have a folder for each camera, e.g., Wolverine Overpass_East and Wolverine Overpass_West (Figure 2).

To classify photos the classifier opens the Form and a short-cut (“Classify WCS photos”), which allows you to go directly to the folders in Processing Cache and the crossing structure (folder) with the photos needing to be classified, e.g., East Gate Underpass. By opening the crossing structure folder one or more (Reconyx) files, e.g., 100RECNYX-44, will be present. By opening the folder the classifier will find all the photos taken during a given period that corresponds to a crossing check, usually covering two weeks. The classifier scrolls through the photos one by one. The first photo should be of our research staff closing the camera and signaling that the camera is operational. The classifier scrolls through the photos until the first animal appears and the processing begins. There will be five photographs triggered (if cameras are configured to take five consecutive photos per trigger event) but only one needs to be processed. After reviewing all five photographs of this first animal (or more photographs if it lingered in front of the camera) the

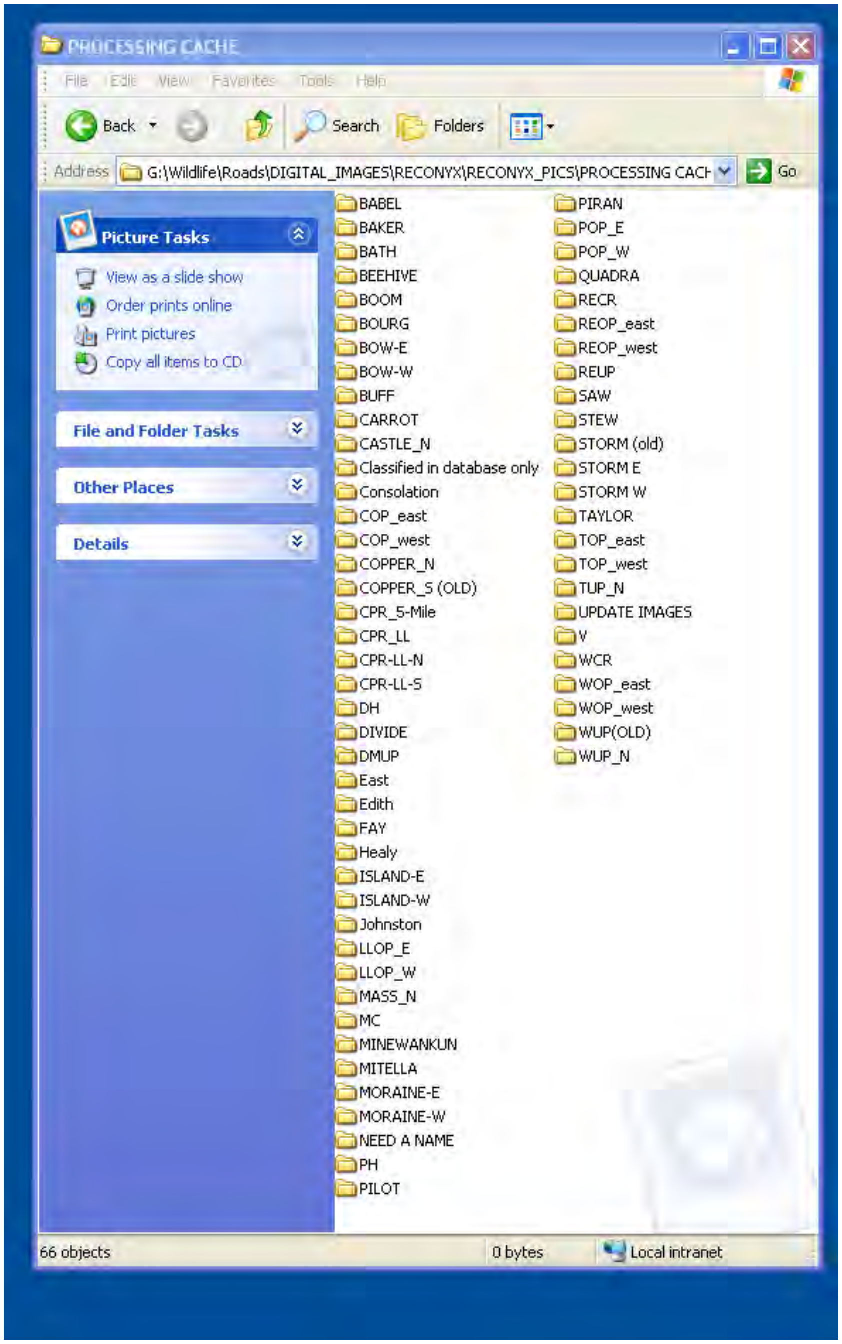

FIGURE 2. Folders in Processing Cache that store photographs uploaded from each wildlife crossing structure camera.

photograph that most clearly identifies the crossing event is selected, e.g., file name M0000804. Going back to the database form and the “Interpretation” or Basic Attributes Page, the classifier interprets what has transpired in the photos using the scroll-down tabs and check boxes that input all the information that is to be transmitted to the database.
We have prepared a user-friendly manual for people who are starting to photo-classify for their first time. It is titled, Banff Wildlife Crossing Project Photo-classification Manual. In the manual it describes the different protocols for data input and also interpretation. For example:

<u>Gender:</u> *Available for ungulates during certain times of the year (antlers or stumps), ungulates with fawns and bears with cubs (females). Classify a mother with young as a “Female” data entry, with “adult with young” in the age category. Male ungulates tend to have thicker necks when antlerless, but look for antler stubs in the spring/early summer. Err on the side of ‘unk’ if you cannot distinguish because of time of year.*

<u>Passage:</u> *Did the animal turn back? It will be difficult to tell in some cases since animals may leave the field of view and come back. At this point it will be difficult to tell if it is the same animal. Take your best guess if it is the same animal or not. In addition, the second option included below will only be obvious for camera located outside of crossing structures.*

Options include:

1. ***N-approach-hesitates***
2. ***N-enters turns back***
3. ***Not applicable*** *(this would only be checked for human construction and is the default for staff camera check = “WCS personnel”.*
4. ***N-outside avoidance*** *(this is used when an animal just travels in front of the crossing structure, not showing any intention to approach or go through it)*
5. ***Unknown***
6. ***Y-hesitates then passes***
7. ***Y-no hesitation***

To finish the data entry for this species, the classifier clicks on the tab “Save Image with New File Name”. To complete the sequence and save the event the classifier clicks the “Update File Name” box. When they click this box a generated name appears that includes the Species_Date_Number_and Code below the New File Name. By clicking on the “Rename File and Set Form to New Record” box, this will save the event and take the classifier back to the beginning to select another image to classify.

Efficiency

Once volunteers are trained, familiar with the protocols, have experience photo-classifying and know how to resolve some of the identification and input issues that may arise, they can be of great assistance to the project. Their assistance results in substantial time savings that normally one or more of our staff would have to be involved in. The volunteers are able to classify approximately 500 photos per hour, while one of the authors (MB) who regularly classifies photos is able to classify between 700-1000 photos per hour. For everyone on any given day, the number of photos classified per hour decreases as more time is spent classifying.

THE NEED FOR QUALITY CONTROL

As described earlier, the methods of our project evolve, and since 2008, we have been working with volunteers (citizen scientists) to help with the growing number of photos collected. While quality assessment of data processing is always necessary, the increased number of people involved required increased the necessity to check for errors. The technical aspects of photo downloading, camera placement and maintenance are keys to acquiring quality images with high probability of detection. This party of our project is the responsibility of project staff; however, equally important is the human factor in photo-classification.

Currently, we have four citizen scientists who regularly help with photo-classification. They are retired professionals of various backgrounds, and spend three to four hours per week in our office. It takes roughly 10 hours each to train them on the system. It helps that they are generally familiar with computers, databases and IT systems, and wildlife identification. Close supervision is necessary during classification in the early weeks, but soon volunteers are able to work independently with high levels of confidence.

When dealing with large data sets such as ours, data quality is often perceived as less important, with the idea that large effects would be significant in a statistical analysis regardless. However, in a recent effort to clean up the database, we attempted to quantify the amount of errors that occurred during classification. We conducted extensive and systematic checks on all photo data between 2005 and 2012. The main findings were surprising. Among carnivores, incorrect species identification occurred in approximately 5-10% of all crossing events. This due to identification errors as well as simple tactical mistakes in data processing, e.g., “coyote” and “cougar” are next to each other in the scroll-down list.

Routine checks of volunteer and staff data entry produced similar error rates, i.e., up to nearly 10% of entries require some manipulation after checking. Most of the errors are (in order of frequency): deer species recognition, wolf - coyote recognition, inadvertent errors/slips, missing/misinterpretation of behaviours, wrong age-class, or gender attribution, or missed events

It is difficult to assess the impact of a 10% error occurrence when we are dealing with >200,000 records, each of which contains several attribute fields. Given that there are likely other classification errors, which are more difficult to correct, it seems that this is by no means a negligible factor when it comes to analyzing the data. We can certainly only speak for our own project, but in our case we believe the extra effort spent on routinely double-checking all entries is warranted and necessary to ensure quality data. Table 2 describes solutions we developed for these main sources of classification errors.

TABLE 2 Main problems and solutions in photo-classification in our project

	Main problems	Solutions
a	Species recognition: Suboptimal image quality or only part of animal visible.	Ongoing feedback to individual classifiers about their errors to facilitate learning. Use of adequate equipment (e.g. monitors) to enable classification of dark images and to avoid having to manipulate photos (contrast, illumination), which is too time-consuming.
b	Behaviour classification	Ongoing feedback to individual classifiers about their decisions and errors, and ongoing training. Discussion in groups, having examples available.
c	Loss of focus leading to less effort and more inadvertent errors	Sharing the workload among more people. Limiting the number of hours classifying by each individual. Varying the photos (some crossing structures are more difficult because of species, number of animals, etc).

RECOMMENDATIONS

In the future, we are working to implement several improvements in our database design to help reduce errors, improve speed and maximize data capture per unit effort:

- Signature for classifier name on each entry.
- More details of camera settings (if necessary).
- Other options like CameraBase (see http://www.atrium-biodiversity.org/tools/camerabase/) that are not needed for our study, but would be necessary for surveys etc. where cameras are moved among sites.
- We recommend that anyone setting up a new monitoring project (large or small) should put in as much effort as possible in database management design and photo-classification strategies in order to avoid sifting through 200.000 photos and an Excel spreadsheet.

HUMAN CONSIDERATIONS

We highlight the importance of designing a database and data management system that facilitates comprehensive error checking, which includes easy access to the images behind the entries. To reduce transcription errors, classification information should be automated wherever possible (e.g., site name, date of photo), so the classifier can focus on the tasks where interpretation is really required (e.g., species, behavior). Implementation of routine error checking protocols appears to be greatly advisable.

We believe that a single, dedicated technician would be overwhelmed by the task of doing photo-classification work on our project two to four full days each week, as errors due to lack of focus and motivation would become more common. It is also a great opportunity to involve interested public in the research as citizen scientists and thus increase public awareness, as long as appropriate training and quality control can be provided. Motivated classifiers are better able to recognize subtle behavioral differences, and will spend the effort to analyze bad quality (mostly night) photos, greatly increasing the amount of data available for analysis. Last but not least, the use of well-trained volunteers may be an opportunity to save on technician salaries, if the volunteers can be retained for long enough to warrant their training.

BIOS

Mirjam Barrueto is currently a research associate working on the Banff highway mitigation research. She obtained her BSc degree in her native Switzerland and a MSc degree in ecology from the University of British Columbia. Mirjam assisted with long-term research on red squirrel ecology and behaviour in the Yukon before coming to Banff to be part of another long-term research project. She is keenly interested in applied research that addresses conservation biology at local and large landscape scales. When not crunching numbers and doing fieldwork for the Banff project, she can be found scaling the high peaks in Rockies (and skiing down them) or going for a leisurely 100 km run in the woods.

Tony Clevenger has carried out research since 1996, assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony is currently a member of the U.S. National Academy of Sciences Committee on *Effects of Highways on Natural Communities and Ecosystems*. He has published over 60 articles in peer-reviewed scientific journals and has co-authored three books including, *Road Ecology: Science and Solutions* (Island Press, 2003) and *Safe Passages: Highways, Wildlife and Habitat Connectivity* (Island Press, 2010). Tony is a graduate of the University of California, Berkeley, has a Master's degree from the University of Tennessee, Knoxville and a Doctoral degree in Zoology from the University of León, Spain.

Adam Ford is a terrestrial ecologist, focusing on the effects of human activity on the movement of individual animals and the consequences of these activities for wildlife populations. The bulk of this work has addressed the extent to which transportation infrastructure alters ecological processes at the landscape-scale. Adam's research career is highlighted by work on several threatened or endangered species in a variety of biomes, from burrowing owls in the semi-arid grasslands of SE Alberta, to grizzly bears in Banff National Park, and more recently, African wild dogs in the private ranchlands of rural Kenya.

Ben Dorsey has worked in Banff and Yoho National Parks as a biologist for the past six years. He designed and built the photo classification database and has been a part of the Banff highway mitigation research since 2007. He completed his MSc research analyzing factors affecting railway mortality along the Canadian Pacific Railroad in Banff and Yoho National Parks.

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