Technical Note

High temporal resolution photography for observing riparian area use and grazing behavior

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Abstract

Observation is a simple method of acquiring information and is a critical step in the scientific method for both developing and investigating testable hypotheses. Cameras have long played a role in observation and as technology advances, new tools and methods for collecting, interrogating, and displaying large quantities of high-resolution images have evolved. We describe an automated digital time-lapse camera system and present an example field deployment to observe the temporal and spatial patterns of riparian use by humans and animals during a three month period. We also describe software tools for image interrogation and visualization as well as new information gathered through their use. The system was tested in 2014, in a 2.4 hectare site within the Apache-Sitgreaves National Forest in east central Arizona, USA where elk (*Cervus elaphus nelsoni*) and cattle grazed. Photographs were taken every 30 seconds for 38 days after which an electric fence was installed to restrict cattle access and the time step was increased to every three minutes. We observed that elk exhibited the unique behavior of standing in and traveling within the stream channel while grazing and tended to graze and lie in close proximity to the channel. Cattle drank from, but typically did not enter the stream channel and tended to lie away from the channel. Recreational use by people had the distinct impact of dispersing elk from the riparian

corridor. Zoomable time-lapse videos allowed us to observe that in contrast to the cattle, elk grazed while lying down. High temporal resolution photography is a practical tool for observing phenomena that are important for local resource management.

Keywords: time-lapse photography, grazing, Arizona, riparian, cattle, elk

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Introduction

How, when, and where do animals graze in riparian areas? Bits and pieces of answers might be found scattered in the body of literature that describes carefully designed field experiments set up to sample and interpret specific measurements from within highly variable natural settings. The use of modern sensors, including global positioning systems (Schlecht et al. 2004) and accelerometers (Yoshitoshi et al. 2013) to support such research has been demonstrated for monitoring animal distributions and grazing behavior. However, at any given site, simply watching can both inform local management and provide insight leading to site specific testable hypotheses. Watching, however, is not always easy, especially over long-time periods at remote sites subject to inclement weather and long periods of inactivity.

During the past several years, technological advances in hardware, software, and data visualization tools have allowed for the development of systems for observing and analyzing data. For example, high temporal resolution photography can be employed to observe and quantify the temporal and spatial behavior of resource use in managed riparian landscapes. The use of time-lapse photography for quantifying cattle use of riparian meadows is not unprecedented (Gillen et al. 1985), however a recent attempt to use digital photography to study grazing concluded that cameras are not viable tools for monitoring (McIlroy et al. 2011) due in part to limited image resolution and the time and effort involved in image processing. These limitations have diminished as technical advances in digital cameras and more efficient supporting image evaluation tools have evolved. Time-lapse photography can now be coupled with traditional monitoring methods to better understand resource use and impacts.

In east central Arizona riparian areas are often managed through forage use guidelines for livestock. Forage use can be assessed using traditional vegetation monitoring techniques (Holechek et al. 2004; Smith et al. 2005). Another method of gaging the impact of grazing use is stubble height (Clary and Leininger 2000), which is a measure of the height of vegetation left ungrazed (USDI 2006). However,

attribution of vegetation impacts to individual grazing species in riparian areas where livestock share the use of forage with wildlife species such as Rocky Mountain Elk (*Cervus elaphus nelsoni*) is not possible through traditional vegetation monitoring methods. In addition, although a large body of literature documents the impacts of cattle grazing on riparian resources, the conclusions are often inconsistent suggesting that, as pointed out by Lucas et al. (2004), response to grazing is likely to be very site specific. There is a distinct need for site specific data and the tools with which to collect such data. We assembled and deployed a time-lapse camera system at a remote field site to test the use of high resolution time-lapse photography as a practical tool for adding value to traditional monitoring methods.

Methods

The study was conducted in east central Arizona in a riparian meadow along the East Fork of the Little Colorado River on the Apache-Sitgreaves (A-S) National Forest at an elevation of approximately 2774 m. The area is managed by the US Forest Service to support multiple uses including wildlife, recreation, and cattle grazing. A high temporal resolution time-lapse camera system was deployed and operated from 10 June 2014 through 30 August 2014 to observe riparian area use. On 8 July 2014, 120 cows with calves were allowed into the pasture. The cattle were removed from the riparian area on 15 July 2014 and access was restricted by a temporary electric fence.

The study site includes a 2.4 ha area defined by the field of view of the camera. The field of photographic observation consists of forested area, grassed uplands, and a sub-irrigated riparian meadow traversed by a perennial stream that is the primary focus of grazing impacts. Soils within the riparian area have been identified by the A-S Terrestrial Ecosystem Survey as Aquic Argiborolls, deep clay loams and loams occurring on gently sloping swales and wet meadows. Plant communities are dominated by grasses, sedges, rushes and forbs. Major grass species found include tufted hair grass

(*Deschampsia cespitosa* (L.)), meadow barley (*Hordeum brachyantherum* Nevski) and red top (*Agrostis gigantea* Roth). *Carex* species are dominated by beaked sedge (*Carex rostrata* Stokes), but also include small wing sedge (*Carex microptera* Mack) and silver sedge (*Carex platyphylla* Carey). Upland species include Arizona fescue (*Festuca arizonica* Vasey), cinquefoil (*Potentilla* sp.), common yarrow (*Achillea millefolium* L. var. *alpicola* (Rydb.) Garrett), woodsorrel (*Oxalis* sp.), and fleabane (*Erigeron* sp.).

A 15 megapixel Canon A1300 off the shelf, point and shoot, digital camera was mounted inside a weatherproof Pelican case. The camera power supply was modified to run from a 12V car battery that was charged with a 25 Watt solar panel. Power from the 12V battery was supplied to the camera by connecting the battery to a Morningstar SunSaver 6 solar charge controller and out through a 3.3V regulator. Power to the camera was accomplished by replacing the AA alkaline camera batteries with dummy batteries wired to the voltage regulator. Images were collected from 0500 h through 1900 h every 30 seconds from 10 June 2014 through 24 July 2014 (1,680 images per day) and image collection continued every three minutes through 30 August 2014 (278 images per day). Images were stored on the camera's 32 GB SDHC flash card. The site was visited approximately weekly to verify that the hardware was working and to swap the SD card.

CHDK (<http://chdk.wikia.com/wiki/CHDK>), a free firmware enhancement that allows for programmatic camera control, was used to run a script that specified the start and stop times and image capture interval. CHDK was installed on the camera's memory card along with the script to accomplish the time-lapse imaging. Individual still images were stitched to create videos (approximately six minutes per 14 real time hours per day) using Microsoft Movie Maker and Adobe Premiere Elements. These videos allowed us to rapidly scan through the images and identify those individual images that contained animals or people. After the initial screening, a web-based time-lapse editor developed at the CREATE lab within the Robotics Institute at Carnegie Mellon University

(http://timemachine.cmucreatelab.org/wiki/Main_Page, accessed 1 November 2016) was used to create zoomable videos of specific sequences of images that contained information of interest, for example grazing animals or the presence of people. This online tool allows detailed observation that takes advantage of the high resolution of individual images.

Within each image, individual animals were digitized and image pixel coordinates were recorded using the interactive graphics capabilities of the symbolic mathematical computation program Mathematica (Wolfram Research 2016). In addition, each animal was characterized as grazing, lying, or standing. Grazing animals were identified by head position and we did not distinguish between those eating and drinking. Grazing locations in relation to the stream, the riparian corridor, and uplands were identified. Animal group behavior was characterized by length of time in images (arrival time and departure time). Lastly, human use was simply observed and described.

Results

Zoomable time-lapse sequences can be viewed at <http://tucson.ars.ag.gov/videos/mnichols> (accessed 1 November 2016) on a desktop PC through browsers supporting HTML 5 video such as Google Chrome. At this time the use of mobile devices is not supported. Assessment of individual imaged allowed the following detailed observations describing when and where grazing occurred, and the video zoom capability allowed us to observe animal behavior. Grazing generally occurred during morning and mid to late afternoon hours. An elk herd was observed on two days between 10 June 2104 and 7 July 2014 prior to the rotation of cattle into the area. On 28 June 2014 as many as 37 elk were observed during a total of 2.88 h (21% of daylight hours), and on 30 June 2014 as many as 39 elk were observed during a total of 1.98 h (14 % of daylight hours). The composite spatial distribution of elk and proximity to the stream channel during the two days can be seen in Figure 1. With the exception of a few individual animals, elk were not observed in the study site from 8 July 2014 through 15 July 2014 when the cattle

had access. From 8 through 15 July 2014 cattle were observed on each of the eight days in 2238 images. These images cover 18.65 h of cattle use out of the 112 h (16.6 % of daylight hours). The composite spatial distribution of cattle during the eight days can be seen in Figure 2. The composite figures show that elk tended to graze and rest in closer proximity to the stream channel than did cattle, and cattle grazed over a wider spatial extent than did elk. Installation of the electric fence effectively kept both elk and cattle out of the riparian corridor from 15 July 2014 through 30 August 2014. Elk exhibited the unique behavior of standing in (Figure 3) and traveling within the stream channel while grazing (<http://tucson.ars.ag.gov/videos/mnichols> accessed 1 November 2016). In addition, elk were observed to graze while lying down.

The camera also captured recreational use of the study site including hiking, fishing, and horse riding. Although a dirt road that bisects the study area between the forested area and uplands is closed to vehicles, off-highway vehicle (OHV) use was observed both on and off road on eight days during the study period. On 28 June 2014, the presence of an OHV was responsible for dispersing elk that were grazing in the riparian area. It is clear from the imagery that the elk heard the OHV five minutes prior to observation of the OHV in an image.

Discussion

We have presented a method for collecting high-temporal resolution images and demonstrated its use to collect a substantial set of observations that show distinct riparian area and stream channel use by cattle and elk, and recreational users. Both individual images and composite videos created through high-resolution time-lapse photography provide insight into the spatial and temporal characteristics of riparian area use. The system has the obvious limitation of working only during daylight hours, but offers the benefit of collecting ancillary observations of rainfall, hydrologic response, and vegetation green-up.

The system is a practical method for developing site-specific knowledge that can inform defensible management decision.

Although focused on an area of limited extent, this case study identified distinct differences in cattle and elk distributions, with higher frequency of elk in closer proximity to the stream channel and a wider spatial distribution of grazing cattle. The collected images and resultant zoomable videos allowed us to observe that elk exhibited the unique behavior of standing in and traveling within the stream channel while grazing, as well as the unexpected observation that elk graze while lying. These behaviors were not known to the authors or local land managers prior to observing them through time-lapse photography. Knowledge of these behaviors may lead to altered or additional monitoring to quantify their impacts. Through site specific information, such as that gathered through high resolution time-lapse photography, stronger linkages between actual riparian use and science-based management strategies can be developed.

Time-lapse photography also identified the impact of recreational use as a factor that should be considered in future management strategies. OHV travel is a popular recreational use of public lands and is one of the fastest growing outdoor activities (Cordell et al. 2008). As the number of recreational OHV users increase, the direct and indirect effects of OHV travel are going to increase (Ouren et al. 2007). The presence of OHVs complicates management of riparian areas where decisions are usually based on general knowledge of elk behavior derived in the absence of such perturbations. Clearly, OHVs had a direct impact on elk behavior in this study.

Implications

Although digital photography is not a replacement for traditional rangeland monitoring, it is demonstrably a practical tool for gathering detailed complimentary data where management of site specific resource concerns requires additional information. High temporal resolution photography over

long time periods can fill critical information gaps at various levels of data interrogation. After images are collected, a large numbers of files can be rapidly reviewed using readily available software tools. Observations of interest can be further analyzed to document specific characteristics, such as grazing behavior, to develop site specific information to support both monitoring designs and management decisions. Although we demonstrated the use of high temporal resolution photography at a specific site to observe riparian use, the system can be deployed to observe a wide range of phenomena.

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Figure captions

Figure 1. Composite spatial distribution of elk on 6/28/2014 and 6/30/2014. Grazing animals are represented by the blue dots, lying animals by the brown dots, and standing animals by the yellow dots.

Figure 2. Composite spatial distribution of cattle from 7/8/2014 through 7/15/ 2014. Grazing animals are represented by the blue dots, lying animals by the brown dots, and standing animals by the yellow dots.

Figure 3. A typical elk grazing scene with detail showing elk standing in the stream channel.