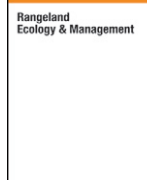




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Technical Note

High-Temporal Resolution Photography for Observing Riparian Area Use and Grazing Behavior<sup>☆</sup>M.H. Nichols<sup>a,\*</sup>, G.B. Ruyle<sup>b</sup>, P. Dille<sup>c</sup><sup>a</sup> Research Hydraulic Engineer, US Department of Agriculture (USDA)—Agricultural Research Service (ARS), Southwest Watershed Research Center, Tucson, AZ 85719, USA<sup>b</sup> Professor, School of Natural Resources, University of Arizona, Tucson, AZ 85719, USA<sup>c</sup> Senior Research Programmer/Analyst, Robotics Institute, Carnegie Mellon University, Pittsburgh, PA 15213, USA

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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 3-mo 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-ha site within the Apache-Sitgreaves National Forest in east central Arizona, United States where elk (*Cervus elaphus nelsoni*) and cattle grazed. Photographs were taken every 30 sec for 38 d, after which an electric fence was installed to restrict cattle access and the time step was increased to every 3 min. 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.

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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 gauging 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

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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 subirrigated 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 sec from 10 June 2014 through 24 July 2014 (1 680 images per day) and image collection continued every 3 min 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 6 min 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](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, 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 images 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 2 days between 10 June 2014 and 7 July 2014 before 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 2 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 8 d in 2 238 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 8 d 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 8 d 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 5 min before 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

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