Use of Remote Surveillance Motion-Activated Cameras for Monitoring Rural Archaeological Sites

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ABSTRACT

Use of remote surveillance camera platforms popularized for the big-game hunting market can assist archaeologists, land managers, and researchers in protecting cultural resources from vandalism and looting while also providing a multifaceted management tool. Ranging from active to passive, and film to digital camera systems, these platforms can provide another research tool to assess use and visitation of archaeological and historical sites by humans and nonhumans. In the United States, there is little published information on the use of these platforms for archaeological purposes, as most studies result from wildlife biology research and management applications. Users of these camera systems must understand their strengths and weaknesses and make careful considerations of the methods employed at a site.

Introduction

Over the last few years, advances in remote surveillance camera technology have moved the technology from corporate or industrial uses into the hands of individuals. Today, motion- and heat-triggered "game" cameras are used by wildlife biologists and sportsmen alike to monitor the movement of key species, yet archaeologists and cultural resource managers continue to be largely unaware of the potential benefits of this technology. Archaeological and historical sites can benefit from the judicious use of this technology to monitor and assess adverse impacts in a relatively inexpensive manner. Compared to traditional site monitoring with personnel performing infrequent site visits, these cameras allow researchers and federal land managing agencies to capture most animal or human intrusion on the site with a minimal input of time and energy.

Remote Surveillance Cameras: The Technology

Over the last decade, there has been a major boom in the production of motion-triggered "game" cameras for use by sportsmen, wildlife biologists, and resource managers. There appears to be a distinct paucity of peer-reviewed articles dealing with the technological specifications of these camera systems, however, and unless otherwise noted, much of the information below comes from personal use and product websites.

Camera systems break down into two basic technologies, active and passive. Law-enforcement efforts continue to use active systems, though this technology costs more to purchase and requires specialized skills to install, as it involves additional setup and maintenance with more components, a camera, and sensor node(s). In an active system, such as that from Eagle Telonics, Inc., the platform receives a constant signal from the sensor and takes a single photograph or series of photographs when triggered by the motion or seismic disturbance of an animal or human. Passive systems have gained popularity among researchers as they are single-component camera systems with built-in heat and motion sensors that automatically trigger the camera for photography.

Passive systems measure ambient heat in the surrounding area and couple that with movement detection. The sensor system measures the immediate area to detect moderate to severe changes in air temperature, and if there is associated movement, takes a picture or series of pictures (Swann et al. 2004:358). A major positive of a passive system is that the camera detects heat and movement over an extended area, compared to the invisible tripwire of an active apparatus. Passive systems have a detection cone that radiates from the sensor and extends upwards of 50 to 100 ft. away from the camera, whereas an active system detects an object by means of the external sensor and receiver. A major negative with a passive camera system is the relatively high number of false triggers. False triggers in a passive system result from a higher than average ambient air temperature (especially during the summer) coupled with movement of vegetation by wind (Swann et al. 2004:362). Use of digital cameras decreases the relative cost of false positives, as they do not result in wasted film, only extra disk space. Finally, both types of sensor platforms take day and night photos. Older platforms used a flash for night photos and were obtrusive to the research. Newer cameras have infrared flashes that provide limited illumination but do not alert the target (Figure 1).

Through most of the 1990s and early 2000s, the majority of active and passive systems used 35 mm film or 8 mm video cameras. Use of standard cameras required a substantial number of site visitations to replace the film regularly. In recent years, most passive camera systems are or have been outfitted with digital cameras of varying megapixel resolution. The use of digital cameras in these systems has provided researchers the opportunity to take hundreds or even thousands of pictures during a single deployment, with minimal maintenance or site visitation to replace film. Today, passive-system designs are divided into three basic groups: (1) *Film camera*—these are generally 35 mm camera systems; (2) *External digital camera*—these camera systems come with a motion- and/or heat-triggered sensor, but the user must provide the digital camera to be inserted in the provided mount; and (3) *Built-in digital camera*—these systems tend to be more expensive and include a digital camera that is part of the equipment and cannot be removed, except for maintenance.

There are positives and negatives for each type of camera system employed, and some of these are summarized here. The reader may also review Parker et al. (2008). While most users are moving away from film-based remote camera systems, there are still a number of researchers using that platform, which warrants some inclusion in the discussion. A major problem with film cameras is the limited number of images that can be taken during a single deployment, with most film rolls containing 24 or 36 exposures. As the camera is motion triggered, an entire roll of exposures could be used in a single day if there were

Figure 1. Infrared enhanced photo of an unknown female hunter moving through an archaeological site in western Montana near dusk. (Photo by authors, using a Reconyx platform, 2008.)

substantial activity at a particular site. If the user programs the camera system to take a single photo each day or once a week to monitor landscape changes, however, then this system might be quite useful. Another positive for this system is that there rarely is need to change batteries, and thus the camera can remain deployed for a significant timeframe without maintenance, except for periodic film changing.

A major positive of digital over film cameras, as discussed earlier, is the potential to take hundreds of pictures during a single deployment depending on the size of the memory card used and the megapixel quality of the digital camera. For example, a 1 MP camera could take upwards of a thousand pictures on a 1 GB memory card. Most new digital camera systems use standard off-the-shelf memory cards that many individuals use in personal cameras or cell phones, which negates the need for specialized skills or technologies for transferring or downloading the image files. Parker et al. (2008:6–7) demonstrated the relative cost-effectiveness of both systems, highlighting the long-term savings of a digital platform.

In particular, the major problem with both digital camera systems is battery life; for a summary see Swann et al. (2004:362). Young (2008) compared the three major types of batteries based on temperature and load currents, showing that batteries in colder temperatures "store electricity well . . . [but] don't supply power well" (Young 2008:1). Young (2008) demonstrated that the best overall battery for all conditions is the nickel metal hydride (NiMH), followed by lithium (Li), and then alkaline (Al) batteries. A standard passive digital camera system has approximately one month of battery life, which is dependent upon the number of images taken. In a high activity area, such as a developed archaeological site, the camera might take hundreds of pictures per day, which depletes the batteries at a quicker pace than a camera deployed in a remote area with less visitation. There are researchers who have successfully developed a nearly permanent remote camera using solar panels and marine batteries; though concealment of this type of platform would be a major issue for site-surveillance purposes (Locke et al. 2005).

Construction of these camera systems varies with the manufacturer, and there is a substantial range in quality. Currently most of the major manufacturers of motion- and/or heat-triggered camera systems are primarily focusing on the needs of the recreational hunter, with professional users secondary. The intended market demographic is important to consider when purchasing a camera, as those designs specifically targeted at hunters tend to be of cheaper construction, thus keeping prices more affordable. Institutions, government agencies, and interested professionals should consider purchasing a professional-quality camera system from higher-end dealers such as Reconyx (Figure 2). These systems tend to have more security features to protect the camera from being stolen or damaged, and the dealers provide service and warranty for their products. In particular, some high-quality systems may have the optional choice

Figure 2. Reconyx PM35C31 Silent Image Professional camera measuring 8.75 in. high, 7.5 in. wide, and 4 in. thick, with *(left)* and without camouflage *(right)*. (Photo by Don Merritt, 2010.)

of bear-proof external steel cases, password encryption of the software, and other security features. It is important to remember that none of these systems is completely tamper or bulletproof, and many are stolen during deployment.

Programming of these camera systems remains an important facet of the technology's usage by both professionals and the public. Film camera systems have basic programming abilities and do not offer the same range of possibilities as a digital platform. Users can set up personal preferences and program nearly all the operations of a digital camera system. For example, a user can program how many pictures to take during a single trigger event, from just one to one per second, or one per 1/90 of a second, depending on the quality of the digital camera used. In addition, most digital camera platforms allow the images to be stamped with the date, time, temperature, and name of the camera or location. These stamps can provide a critical role in understanding peak times of site usage or pin down a timeline for a looting or vandalism event.

Some camera platforms have an option of setting the sensitivity from low to high. A low-sensitivity setting will most likely result in capturing only large animals, such as deer, elk, or humans (Figure 3). Meanwhile, a high-sensitivity setting will photograph almost all movement in front of the system, including mice, squirrels, and even insects. Users must remember that a higher-sensitivity setting will result in many more photographs and thus decrease the longevity of the battery.

Wildlife biologists in Texas created a prototype remote camera system that transmitted photographs, in near real time, via satellite to a website that researchers could monitor at leisure (Locke et al. 2005). There was an extensive cost to this system, however, as everything had to be specifically ordered and made for the project. In

Figure 3. A black bear investigating a tree near a Chinese rock-hearth feature in western Montana. (Photo by authors, using a Reconyx platform, 2008.)

2007, HunterDeerCam began selling a consumer-market digital camera system that stores photographs on installed memory cards, but also transmits the files via cell-phone signals to an online account so the user can remotely monitor the activity from any computer with Internet access. This advancement in technology is exciting, as it allows even more freedom and flexibility in managing distant resources without site visitations, and if the camera is discovered and destroyed by vandals or natural events the photographic record will survive, providing evidence of the adverse impact and leading to possible prosecution.

As this technology increases in popularity, there seems to be a precipitous decline in the overall pricing for these camera systems. For instance, for use in archaeological site monitoring in western Montana, the authors purchased a Reconyx camera in 2006 for nearly $3,000. Two years later the same platform sold for only $1,600, and now a more compact version sells for less than $700. In general, a high-quality digital camera system can be purchased for $300 to $1,000. Despite the drop in price, the resolution quality and programming capabilities have increased, and pictures may now routinely be taken in color.

Previous Studies

Since the late 1990s, the use of heat- and/or motion- triggered cameras to monitor movements of wildlife and humans in remote areas has increased, and there is now a substantial body of literature pertaining to studies using this technology, including Herrantz et al. (2002), Bridges et al. (2004), Diaz et al. (2005), Heilbrun et al. (2006), Locke et al. (2005, 2006), and Roberts et al. (2006). As noted by Swann et al. (2004:357), the use of infrared (heat) sensor cameras began in the 1960s, but did not become commonplace in the field of wildlife biology until they were commercially produced, and thus substantially cheaper. Wildlife biologists have employed this technology to answer important research questions regarding conservation of various species, and these cameras have become indispensable tools for policymaking and mitigation (Swann et al. 2004:357–358; Heilbrun et al. 2006:69).

Uses of similar technology for cultural resource management purposes are relatively rare, and the authors were only able to find a few examples (Coder and Andrews 1993; Stuart and McManamon 2004; Ardizonne et al. 2005). With the exception of Stuart and McManamon (2004) and Ardizonne et al. (2005), the majority of published remote camera studies comes from Grand Canyon National Park (GCNP) in Arizona (Coder and Andrews 1993; Coder et al. 1994, 1995; Coder et al. 1996; Leap et al. 1997; GCNP 1998, 1999, 2002, 2003; Leap and Kunde 2000; Dierker et al. 2001; Dierker and Leap 2004, 2005). In the 1991 field season, archaeologists at Grand Canyon National Park placed cameras at key archaeological sites along the Colorado River to monitor changes to the physical landscape (Coder and Andrews 1993:3). These cameras were specifically designed to take a single snapshot per day over an extended period, usually a year, to monitor stochastic changes, such as erosion or landslides, and their affect on cultural resources (Coder and Andrews 1993:3).

Data retrieved from studying these time-lapse photographs allowed cultural resource managers to allocate stabilization and personnel funds to high-risk archaeological sites accurately. For the expressed purpose of studying adverse impacts from erosion and other physical landscape changes, these cameras succeeded, providing an efficient means of remotely monitoring archaeological sites, and were an important early use of this technology for management purposes (Coder et al. 1995:8). The Grand Canyon archaeologists discontinued use of these stationary cameras in the mid-1990s, however, as they did not provide sufficient recording of less-drastic changes to the landscape (Dierker and Leap 2005:44). The use of remote cameras at the Grand Canyon was a pioneering study in the assessment of impacts to a site over the long term.

Archaeologists and cultural resource managers also use remote platforms in security settings around the country, though little published information exists regarding cameras utilized, their deployment, and associated costs. Indeed, the only reference the authors were able to find was a brief mention that Joshua Tree National Park in California was using remotely operated surveillance video cameras to keep watch for illegal activities within the park boundaries (Stuart and McManamon 2004). The technology employed by the National Park Service is substantially different from the camera used in the case studies, but the purpose remains the same.

Spagnolo et al. (2003) and Ardizzone et al. (2005) are expanding the field of remote surveillance of archaeological sites in Italy. Spagnolo et al. (2003) used the improving technology of both surveillance cameras and mainframe computers to program software that automatically tracks individuals on an archaeological site and continuously monitors their posture. Posture estimation is one means of using remote cameras to detect suspicious activity, such as stooping to pick up an artifact in a restricted zone, and alert proper authorities (Spagnolo et al. 2003:277). Expanding on the work of Spagnolo et al. (2003), Ardizzone et al. (2005) designed an integrated surveillance system at an archaeological site in Italy. Ardizzone et al. (2005:79–80) used a system of surveillance video cameras coupled with motion sensors that trigger the cameras. Ardizzone and his coauthors expressed the hope that using redundant detection systems will help to cut down on false alarms and increase the chances of catching illegal activity (Ardizzone et al. 2005:79).

Archaeological Applications

From the above discussion, the main functions of remote camera technology are apparent, including site monitoring for looting and adverse landscape alterations. As readily discussed in many other sources (King 2003; Gibson 2006:3), there has been distinct decline in the budget levels of federal agencies that steward cultural resources on public lands. This decline is coupled with the ever-increasing number of archaeological and historical sites under their charge and with increased commercial encroachment on lands once viewed as protected. As noted by Gibson (2006:3–4), even in the remote and isolated portions of southern Idaho, the recreational use of public lands has increased significantly over the last decade. This growth of recreational use of public lands increases the number of potential visitors to archaeological sites within the boundaries of these holdings and has directly resulted in an increase of looting, vandalism, and unintentional disturbance to in situ cultural resources (Gibson 2006:6), and not only in Idaho (General Accounting Office [GAO] 1987).

These facts leave cultural resource managers in a quandary; first their budgets are shrinking, and second the impacts to archaeological sites are increasing at an alarming rate. This reality is forcing professionals to use their limited budgets creatively, and remote surveillance cameras can be one means of accomplishing this effort. These cameras can benefit the stewardship activities of land managers in several ways (Table 1).

Method and Technology Considerations

Just as with other facets of archaeology, users of these camera platforms must be explicit about their methods and choose technology appropriate for the expressed goal of the proposed project. As discussed earlier, there is a wide range of features, functionality, and costs associated with each system. Currently there are cameras for a variety of applications and budgets, from $50 film camera systems to $2,000 multimegapixel wireless platforms. Consumers should not choose based merely on the price of the equipment, but on the ability of the technology to meet the needs of the proposed work. If the resources manager feels a need for a series of cameras across a region of public lands, there might be a need to maximize both the cost and flexibility of the systems. Purchasing a high-end camera system provides the most flexibility of programming options, highest quality of images, and most likely, the longest survival of the equipment in field situations. In addition, high-quality images would be required for successful prosecution of looters or vandals.

Once the researcher has selected the right camera system for the proposed project, there is a need to understand explicitly the methods to be employed. It is not the purpose of this paper to provide all the answers on the best means of protecting remote archaeological sites, but to outline some ideas on how to implement such camera technology. Table 2 provides a series of questions remote camera users should pose before, during, and after fieldwork.

Table 1. Potential applications of remote camera technology in archaeology.

Provide security for sites in areas of high potential for looting or vandalism, by deterrence or prosecution.
Supply physical evidence for prosecuting looters under the Archaeological Resources Protection Act.
Assess site impacts from wildlife and nonlooting human activity, such as recreational offroad vehicles, hiking, camping, fires, etc.
Perform studies of site visitation and usage to help steer management of specific resources.
Conduct studies of visitor movement within guided or unguided interpretive sites.
Remotely monitor a particular site or landscape during various parts of the day, week, month, etc., through time-triggered photography.

Table 2. Method questions and answers for remote camera surveillance in archaeology.

Question	Answer
1. Do I have the technical competency to program, install, and maintain this technology?	While personal technical competency will vary substantially, relatively cheap digital "game" camera technology is factory loaded to work out of the box. In addition, most systems come with clear instructions for operation. Overall, these systems are almost easier to operate than a standard digital camera that a researcher might have for personal use, as the user points it in the focus direction, turns it on, and then leaves. As all disclaimers state, individual experience may vary.
2.What is the purpose of the camera?	Is the camera supposed to deter looting and vandalism, assess site impacts, or aid in the study of site-use by visitors? Ideally, determining the extent of the camera's purpose should have been performed before purchase, but the flexibility of this technology allows multiple uses restrained only by the creativity of the user.
3. How do I want the camera to operate?	As discussed in the technology section, these cameras provide a multitude of settings to be personalized for each use. After answering question No. 2, it should be clear whether what is wanted is a total photographic record of all movement, a sample of each activity, or a scheduled daily photograph showing landscape changes or assessment of the site during key parts of the day.
4.Where should I place the camera?	Ideally, the researcher should have an idea of where to place the camera based on the answers to No. 2, before even purchasing a system. If the plan for the camera is to deter looters, then it should be placed in an area conspicuous to all visitors. If the plan is to catch someone in the act of an illegal activity, then perhaps an inconspicuous location providing an overview of critical areas for protection is appropriate. If looking at visitor usage of a site, perhaps focus on areas designed for movement within the area (trails, interpretive signs, etc.), or place several cameras to get an overall idea of intrasite movement.
5. Should the camera be concealed or not?	This is a question partially determined by the answer to No. 2, but not necessarily completely straightforward. If the researcher is attempting to deter looters, then a nonconcealed camera placed in a conspicuous area would provide the best solution. A conspicuous camera may easily become a victim of theft or vandalism itself, or at least a convenient target for shooting practice. Concealing the camera is important if trying to catch illegal action while it is occurring. In addition, the camera should be concealed if the plan is merely trying to monitor movement of visitors to a site or assess site impacts. A conspicuous camera can cause animals and humans to alter their behavior, and the resulting data might be biased.
6. How often will I be able to check the batteries and images?	Ideally, the researcher should change out all batteries and memory cards every month, but field testing by the authors proves that if the camera is in a remote and less-traveled spot, then the batteries will last substantially longer, perhaps up to two months due to fewer images taken. Regardless, unless the researcher is using a wireless camera system, the images should be checked every month in case a crime has been committed. If the site chosen is geographically remote, then perhaps upgrading to a solar-powered system would be worth the extra financial investment.
7.Will the images be saved, and how will they be stored?	Depending on the number of cameras, the length of deployments, and the relative usage of an area, a researcher may come back from the field with as few as a dozen or as many as a thousand images. This can quickly fill up hard disk space on a personal or organizational computer, and digital archiving in CD or DVD format will most likely be necessary. In addition, users should work closely with law-enforcement professionals to handle the images properly in case of their potential use in criminal or civil legal proceedings. As noted by Locke et al. (2005:362), images from a camera can provide the public an educational foray into a topic in a fun and interactive manner, in this case possibly as a means of bringing awareness to the problems and legality of looting archaeological and historical sites.

Proper concealment is paramount for most applications, and commercial products are available to assist, including bark, leaf covers for all seasons and types of vegetative settings, camouflage netting, and even fake rock covers for concealment in areas lacking vegetation. Placement of the camera high in a tree hides (Figure 4) the system effectively, but may reduce the details in a photo needed for prosecution of a criminal offense. While placing the camera at or near ground level (Figure 5) could give a better angle on and resolution of activity, it increases the difficulty in concealment. Regardless of the size or location of the camera system at the site, the more natural the camouflage, the easier it is to hide. Using locally available natural materials provides the best camouflage. In wooded areas, branches, leaves, moss, and even soil can hide a camera system more effectively than synthetic materials. In areas with little or no tree cover, such as meadows or clearings, grasses and other natural materials could be used in conjunction with commercial camouflaging to conceal a camera system. Use of modified and hollowed tree stumps allows a camera to be set up in nearly any situation or landscape. The key point is to camouflage the camera in the most natural way possible, as even freshly broken branches will still be an obvious alteration to the natural landscape. Sometimes even the best camouflage fails, and installation of an inexpensive "dummy" camera can focus attention away from the real platform.

As discussed in the final question of Table 2, use of this technology is an ideal situation for an interdisciplinary union of archaeologists or cultural resource managers with allied fields such as wildlife biology and law enforcement. Besides wildlife biologists, recreation planners and landscape architects can use data gleaned from these camera studies to plan site visitation better and design trails that steer users in archaeologically sensitive ways. Incorporation of other research interests can potentially defray costs through multiple budgetary programs, elicit better cooperation between archaeologists and other "ologists" in the government, educational, and private sectors, or improve the chances of successful technology grants through the National Park Service or other venues.

Conclusions

The use of remote surveillance cameras has come a long way since their inception in the 1960s, especially in the field of wildlife biology. Archaeologists and land manag-

Figure 4. Camouflaged Reconyx camera deployed at an archaeological site in western Montana. (Photo by Don Merritt, 2007.)

ers must become more familiar with this technology, and now is the perfect time. Prices for equipment have fallen substantially over the last few years, reaching levels of affordability not only for government agencies, but also private individuals and researchers. Recent court cases have shown that surveillance cameras are legal for use in areas in which individuals have no reasonable expectation of privacy, such as public spaces and lands (GAO 2003). Thus, land mangers now have the technology and authority to enact more aggressive and far-reaching monitoring plans for archaeological and historical sites on public lands. It is quite possible that there are many other resource managers and archaeologists using remote cameras in their work, but they do not appear to be publishing on the use of this technology.

Even with all the benefits of this technology, these cameras should not be a replacement for public outreach and education as a means of protecting cultural resources (Smith and Ehrenhard 1991; Jameson 1997; De Cunzo and Jameson 2005). Cameras are merely short-term, stopgap measures, designed to answer immediate needs of site protection and site monitoring, or if used creatively, to help accurately plan site visit strategies. Ideally, the technology should be used in concert with other site protection strategies, such as public education and signage. The National Center for Preservation Technology and Training (NCPTT) received funding from the Louisiana Army National Guard to host a symposium bringing together federal land management agencies in 2008. At this symposium archaeologists, tribal representatives, and federal law-enforcement specialists presented overviews of institutional approaches to site surveillance and, indeed, served as "the first step in assessing national needs for remote site technologies and in creating a broad national approach towards their incorporation into resource management" (NCPTT 2011). While little formal action resulted from this symposium, the effort was successful in growing awareness of technology, legal precedents, and law-enforcement techniques within cultural resources management. Use of relatively cheap passive digital surveillance platforms can allow more archaeological and historical site monitoring and, it is hoped, sponsor increased site protection and preservation.

Figure 5. Visitors to an archaeological site in western Montana, unaware of the camera platform only feet away. (Photo by authors, using a Reconyx platform, 2008.)

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