INNOVATIONS

A Simple Approach to Collecting Useful Wildlife Data Using Remote Camera-Traps in Undergraduate Biology Courses

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Abstract: Remote camera-traps are commonly used to estimate the abundance, diversity, behavior and habitat use of wildlife in an inexpensive and nonintrusive manner. Because of the increasing use of remote-cameras in wildlife studies, students interested in wildlife biology should be exposed to the use of remote-cameras early in their academic careers. Although there is a rich literature on the use of remote-cameras in wildlife studies, few have provided meaningful examples within an academic course setting. Due to the time constraint of a typical semester, many laboratory exercises generate data sufficient for the activity but lack inference to actual wildlife populations. This article describes a series of laboratory exercises that are both useful to student learning and provide relevant biological data. Students use remote-cameras to measure diversity, diel behavior (i.e. over a 24-hour period) and the relative abundance of mammals in a biological corridor. Other abundance methods such as mark-recapture or random encounter models that require marked individuals and/or extensive temporal and spatial methodology are often not practical in a course framework. The approach described in this article teaches students about research design and local wildlife abundance and behavior, using simple methodologies employed over a three-lab period.

Keywords: Remote camera-traps, wildlife, inquiry-based, biological corridor, undergraduate students.

INTRODUCTION

Inquiry-based laboratory exercises can encourage the scientific process and help instill a sense of scientific discovery within students (National Science Foundation, 1996, National Research Council, 2000). Laboratory experiences that further provide students with real-world skills together with an inquiry-based approach would better prepare students for successful careers in the sciences (Millenbah and Millspaugh, 2003).

Remote camera traps are becoming a common way to assess wildlife populations (O'Brien et al., 2003, Yasuda, 2004, Swan and Perkins, 2014). The popularity of remote-cameras is largely due to their cost-effectiveness and passive, non-intrusive capability to monitor wildlife. Because of the increasing use of remote-cameras in wildlife management and conservation biology, students interested in these disciplines should be exposed to the use of remote-cameras early in their academic careers. Although remote camera studies abound in the literature (O'Brien et al., 2003, Yasuda, 2004, Janecka et al., 2011, Anile et al., 2014), few examples of simple, yet relevant exercises have been provided within an academic course framework (Locke et al., 2005, Grigione and Farkas, 2012). Often, exercises designed for students provide basic training on the use of remote-cameras that only generate sufficient data for the learning experience. These types of studies, although useful in educating students on the basic use of remote-cameras, lack a study design that would generate relevant data that could be inferred to actual wildlife populations, such as abundance estimates, temporal habitat usage and diversity over temporal and spatial scales. Some effective metrics that are often applied in large research studies such as mark-recapture or random encounter modeling require marked individuals and/or extensive spatial and temporal sampling (Royle and Nichols, 2003, Sollman et al., 2013). Although these methods generate the most reliable camera-based wildlife population data (Royle and Nichols, 2003, Sollman et al., 2013), the time, space and effort required might not be feasible in a typical semester and in a typical undergraduate course, assuming other topics and laboratory activities are planned throughout the semester. Therefore, there is a need to balance simplicity with a methodology sufficient enough to generate meaningful biological data and to provide students with a realistic learning experience.

This paper describes a multi-laboratory exercise for undergraduate conservation biology, wildlife biology or animal behavior courses that teach a real-world skill with an inquiry-based approach using remote-camera technology. Furthermore, the lab sequence teaches students how to design a simple remote-camera study that generates useful data on local wildlife populations. The exercise involves students deploying remote-cameras in a biological corridor used by wildlife in an urban area. Students use a relative abundance index that allows them to compare data with other courses, across temporal and spatial scales (O'Brien et al., 2003, Yasuda, 2004). With these data, students can also identify local mammal diversity and diel (i.e. over a 24-hour period) behavior within the biological corridor. This exercise will also help students further develop the ability to design and implement a simple, yet realistic scientific field study and communicate scientific findings in written and oral format.

Remote-Camera Applications

Students were first educated on the common use and applications of remote-cameras in wildlife studies during a regular class lecture. Remote-cameras have been used to successfully measure wildlife diversity (O'Brien et al., 2003, Yasuda, 2004), estimate wildlife abundance (O'Brien et al., 2003, Janecka et al., 2011, Anile et al., 2014), examine animal behavior and habitat use (Yasuda, 2004, Vine et al., 2009, Ariefiandy et al., 2015) and determine the presence of cryptic and/or rare species (O'Brien et al., 2003, Vine et al., 2009, Schruhl et al., 2010) throughout the world. For these reasons, remote-cameras are commonly used by state and federal wildlife management agencies (Heilbrun et al., 2003), with non-government wildlife organizations (O'Brien et al., 2003, Afriefiandy et al., 2015) and in academic research studies (Vine et al., 2009, Anile et al., 2014, Rodgers et al., 2014). The broad application of remote-cameras makes an understanding of their use a priority for any student interested in pursuing a career in wildlife biology.

Although remote-cameras have been successfully utilized to examine a wide variety of species, the methodologies used can be just as diverse, all with strengths and weaknesses. For example, species abundance can be estimated with mark-recapture, random encounter and detection probability modeling but require extensive spatial and temporal sampling (Anile et al., 2014, Rodgers et al., 2014). Mark-recapture studies also require marked individuals, often felines with natural coat markings that can be used to identify individuals (Janecka et al., 2011, Anile et al., 2014). Random Encounter Models (REM) are utilized to estimate species abundance without the use of marked individuals but require the calculation of the detection zone area (Anile et al., 2014, Swann and Perkins, 2014). Another commonly used method to estimate abundance of unmarked individuals is the Relative Abundance Index (RAI), which is simply the number of detections of a species per unit time (O'Brien et al., 2003, Swan and Perkins, 2014). Although this method is easier to employ, compared to previously mentioned techniques, it often produces biased estimates of relative abundance (Sollmann et al., 2013, Swan and Perkins, 2014). However, in some cases, the RAI has been found to correlate with other methods such as mark-recapture and line-transect and is useful when other methods cannot be employed (O'Brien et al., 2003, Lynam et al., 2007). Many studies have also utilized scat-analysis, line-transects, genetic analysis and spotlighting to confirm camera-based abundance estimates of particular species (O'Brien et al., 2003, Vine et al., 2009, Anile et al., 2014).

Camera placement can also influence study results. Studies have found that with some species, such as felines, camera placement on game trails or near roads was most effective but generated a biased estimate (Anile et al., 2014, Sollmann et al., 2013). Heilbrun et al. (2003) and Anile et al. (2014) found that bobcats (*Lynx rufus*) and European wildcats (*Felis silvestris silvestris*), respectively, responded inconsistently to baited cameras while Yasuda (2004) and Vine et al. (2009) found that baited cameras were effective with nocturnal and cryptic species, other than felines, and reduced the amount of sampling time required. Because each remote-camera methodology has strengths and weaknesses, careful consideration and clear objectives are needed for a study to be successful.

LABORATORY PROCEDURES

The application of remote cameras is so diverse that their use can take on many forms in academic course work. For example, students may wish to examine wildlife diversity and behavior on campus; estimate urban wildlife abundance; monitor wildlife use of a particular habitat such as a meadow or pond; monitor wildlife road crossings; monitor the influence of human disturbances on abundance, diversity and behavior over time. This paper, however, provides an example of the use of remote-cameras to estimate wildlife diversity, diel behavior and relative abundance of wildlife within a biological corridor (The Little River Floodplain) near the Westfield State University campus, Westfield, MA. However, the lab can be adapted to meet other needs and interests.

This study requires two lecture and three laboratory periods to complete. The study can be repeated in different semesters and for multiple years so that future classes can build long-term data sets. First, students are assigned appropriate literature as homework to review regarding camera-trap case studies (See: O'Brien et al., 2003, Yasuda, 2004, Anile et al., 2014) and biological corridor theory (See: Rosenberg et al., 1997, Falcy and Estades, 2007, Cushman et al., 2013). Students are also required to research the types of wildlife they would likely encounter in our region and explore the various reasons why wildlife would utilize the Little River biological corridor. The Little River corridor connects core habitats in the Berkshire Hills with patches of habitat in nearby urban regions. During a regular lecture period, students were introduced to Google Earth (Little River, 2015) and MassGIS (regional open-source geographic software) (MassGIS, 2015) to delineate the boundaries of the Little River biological corridor and to help identify basic habitat characteristics such as vegetation and corridor boundaries (Figure 1).

Figure 1. Map of the study area. The Little River and associated wildlife corridor start on the left in the Berkshire Hills core habitat region and move past Westfield State University and through the city of Westfield, eventually connecting to other small habitat areas near the cities of Holyoke, Springfield and West Springfield further to the right. Image adapted from Google Earth (Little River 2015).

Outside of class, students meet in small groups of 3-4 people to discuss the assigned papers, share their findings on regional wildlife and corridor delineation and to develop appropriate objectives and methodologies for their study. To help students develop appropriate objectives, they are asked to consider themselves as a wildlife biologist, transportation specialist, city planner and/or a local resident concerned about the diversity and abundance of wildlife utilizing the corridor. While in these roles, students are then asked to generate appropriate questions that a wildlife biologist or city planner, for example, would want to know. We then discuss the group conclusions as a class in the next lecture. Appropriate questions may be: 1. What species of wildlife utilize the corridor? 2. When do these species utilize the corridor? 3. How many of each species are utilizing the corridor? 4. How do we answer these questions with limited time and resources? Students then develop appropriate objectives to address these and/or other questions. Some objectives might be: A. Utilize remote-cameras to measure species diversity and diel behavior within the Little River corridor. B. Utilize remote-cameras to estimate relative abundance for each species within the Little River corridor. C. Share data between classes over multiple years and in different seasons. Finally, the class agrees upon study objectives and we prepare for lab one.

Lab One: Camera-Trap Setup

During the first lab, students are instructed on the proper set-up, use and care of remote trail cameras. We use waterproof, remote, digital cameras with built-in infrared motion sensors and LED flash for daytime and nighttime use (Moultrie M-880, 8.0 MP Infrared Trail Camera, Moultrie Inc., Calera, AL 35040). Cameras are set with a photo delay of 30 seconds and programmed to take photos at anytime of the day. Each photo is stamped with the time and day and stored on a 32 GB memory card. Cameras use eight AA batteries that power the cameras for at least two weeks without intervention.

We use approximately eight cameras for seven days in October and again in March in two separate classes following the same methods. Groups of three to four students work together to set an individual camera. The eight cameras are set perpendicular across the Little River floodplain from one terrace to the next, spanning the width of the entire floodplain. Each camera is set approximately 50-100 m apart and adjacent to animal trails (Yasuda, 2004). Cameras are attached and locked to trees approximately one meter off the ground and set at a slight, downward angle in order to detect both small and large mammals. Each camera is baited with 454 g of salted peanuts during both studies to encourage animal encounters during the study period (Yasuda, 2004). Cameras are left alone until retrieved during the next laboratory period the following week.

Labs Two and Three: Camera Retrieval and Data Analysis

During lab two, students retrieve the cameras and return to the classroom. The photographs are examined for all of the cameras and each mammal is identified to species using Whitaker's (1996) Field Guide to Mammals. The time of day is recorded for each individual mammal observed. We divide the day into four distinct periods in order to estimate diel activity in observed wildlife. We consider morning to be the two hours after sunrise, evening to be the two hours before sunset and daytime and night to be the remaining time periods. Students calculate the amount of trapping effort (recorded in days) for each camera from the time the camera is set to the time it is retrieved. Total trapping effort is determined as the total of the camera-days for all cameras during each study period.

Table 1. Results of our class camera-trap study within the Little River Corridor, Westfield, MA, March 2014. Encounters represent the total number of photographs taken of each species at different periods of the day for the entire March study period. Daily encounter rate represents a total study relative abundance estimate for March.

March		Encounters					Daily
Taxa		Morning	Day	Evening	Night	Total	Encounter Rate
Gray squirrel	*Sciurus carolinensis*	19	28	6	2	55	0.98
Eastern chipmunk	*Tamias striatus*						
Eastern cottontail	*Sylvilagus floridanus*				1	1	0.02
Opossum	*Didelphis virginiana*						
Small rodent	Muridae						
Whitetail deer	*Odocoileus virginianus*						
Raccoon	*Procyon lotor*				8	8	0.14
Gray fox	*Urocyon cinereoargenteus*				6	6	0.11
Eastern coyote	*Canis latrans*				4	4	0.07
Bobcat	*Lynx rufus*				1	1	0.02
Black bear	*Ursus americanus*	2		2	4	8	0.14
	Total	21	28	8	26	83	

Students also calculate the camera-encounter rate, which is a relative abundance index (O'Brien et al., 2003, Yasuda, 2004) for each species observed. The encounter rate is determined by dividing the total number of independent sightings of an observed species from all the cameras by the total number of camera days for that study period (O'Brien et al., 2003). We follow O'Brien et al. (2003) and define an independent sighting as photographs of different individuals and/or individuals of the same species taken at least 0.5 hours apart per camera, if they can not be determined as separate individuals.

The students share the data from each camera with the class and create tables that summarize all the combined data that address the research objectives. These tables illustrate the diversity, number of sightings and relative abundance for each species they observe for all cameras together. Tables 1 and 2 represent examples of findings from two separate classes from the spring and fall of 2014. Students also create figures that illustrate the frequency of sightings during the morning, day, evening and night. Figure 2 represents an example of diel frequency of mammal sightings during the spring and fall of 2014.

During the third lab, students are given time to complete the photographic analysis, summarize and compile class data and work on presenting their data in report and oral format. Each student is provided with an example of a well-written lab report and an example of a proper oral presentation. Students are required to write a full report including an abstract, introduction, methods, results, discussion and literature cited. Students also present their findings as a PowerPoint presentation.

DISCUSSION

This lab teaches students about local wildlife diversity, behavior, abundance and the importance of biological corridors. It further educates students regarding study design and objectives, camera-traps,

Table 2. Results of our class camera-trap study within the Little River Corridor, Westfield, MA, October 2014. Encounters represent the total number of photographs taken of each species at different periods of the day for the entire October study period. Daily encounter rate represents a total study relative abundance estimate for October.

October		Encounters					Daily
Taxa		Morning	Day	Evening	Night	Total	Encounter Rate
Gray squirrel	*Sciurus carolinensis*	83	150	42	14	289	6.88
Eastern chipmunk	*Tamias striatus*		2	1		3	0.07
Eastern cottontail	*Sylvilagus floridanus*				2	2	0.05
Opossum	*Didelphis virginiana*	1			100	101	2.40
Small rodent	Muridae				19	19	0.45
Whitetail deer	*Odocoileus virginianus*	1		1	10	12	0.29
Raccoon	*Procyon lotor*			5	109	114	2.71
Gray fox	*Urocyon cinereoargenteus*				16	16	0.38
Eastern coyote	*Canis latrans*				1	1	0.02
Bobcat	*Lynx rufus*						
Black bear	*Ursus americanus*						
	Total	85	152	49	271	557	

data analysis and report preparation. The use of the camera-encounter rate as a relative abundance index simplifies the lab, as opposed to more time and space demanding approaches like mark-recapture and random encounter modeling. The relative abundance index provides a simple metric that relates to wildlife abundance that can be compared with other classes temporally and spatially. Simply stated, as the daily encounter rate for a particular species increases, it can be assumed that the abundance of that species also increases (O'Brien et al., 2003, Yasuda, 2004). However, students are also educated about mark-recapture and random encounter modeling to ensure they understand that other methods exist that may be more applicable to work they may conduct in their future careers.

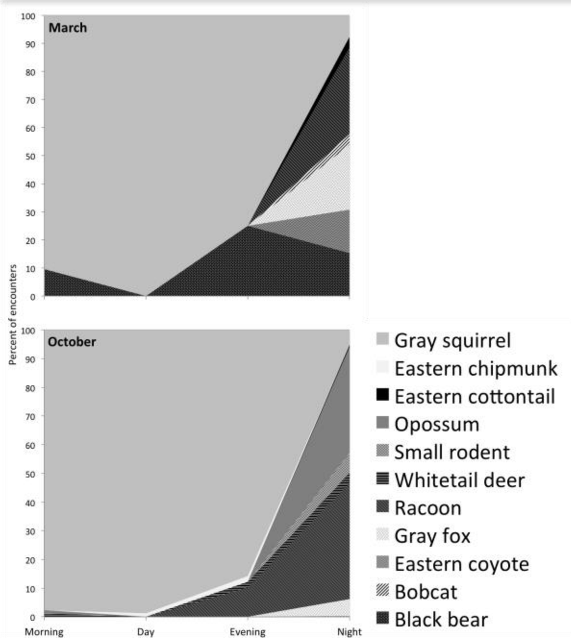

Figure 2. Percent of encounters (appearances per time of day) of each species photographed from the Little River Corridor in March and October 2014.

Descriptive, field-based labs like this one are unlike experiments, where each variable is carefully controlled. Therefore, it is impossible to determine exactly what is influencing the observed. This can generate good discussion among students who can explore the possible combination of variables that may be influencing their observations and they can appreciate the variability that may exist in their data. It also allows for students to generate new questions, research objectives and design new studies.

For example, it is necessary to identify sources of variability that may influence both the diel and daily encounter rates of an organism (Yasuda, 2004). During our study, March 2014 was unseasonably cold in western Massachusetts with snow and cold temperatures prominent throughout the entire month. Cold temperatures and snow likely influenced species behavior and density. For example, black bears (*Ursus americanus*) emerging from a long winter were probably hungry and more likely to find the bait while gray squirrels may have been more abundant in the fall, before snow accumulation and were beginning to gather food for winter. The abundance, presence and absence of other species such as opossum (*Didelphis virginianus*) may have been influenced with the time of year and whether some species would utilize the area during that period. Smaller mammals such as gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), eastern cottontail (*Sylvilagus floridanus*), small rodents (Muridae) and raccoon (*Procyon lotor*) may reside within the Little River corridor while larger mammals such as whitetail deer and black bear may only use the corridor to move from one area to the next.

One of the potential problems with baited cameras is the likelihood of repeated observations, thus generating a biased relative abundance estimate (Sollmann et al., 2013, Swan and Perkins, 2014). Some species may be more attracted to the bait than others and return more often (Yasuda, 2004, Anile et al., 2014). For example, bobcats and wildcats often responded inconsistently to bait in past studies (Heilbrun et al., 2003, Anile et al., 2014) while black bears were more predictable and will linger until the bait is completely consumed, as observed in our study. A high number of squirrel observations in our study, for example, were likely due to repeat observations because of the bait and relatively small home range of squirrels. Therefore, baited remote-cameras may generate bias for some species and should be used with caution (Yasuda, 2003). However, the lack of bait may reduce the number of encounters and necessitate longer and more strategic camera placement, especially for nocturnal and cryptic species (Yasuda, 2004, Vine et al., 2009). It was clear in our study that most species preferred a nocturnal behavior, suggesting that baited cameras improved encounters with these species.

Potential bias can be avoided with further sampling. Laboratory studies that are limited to a few laboratory periods are likely to be biased unless extended across semesters and seasons for multiple years. Increased sampling will capture and expose trends in wildlife abundance and behavior (Yasuda, 2004). Therefore, this laboratory can be conducted in spring and fall semesters for multiple years in order to develop long-term data sets. Students can utilize these augmented data sets each semester in order to develop a more complete analysis of wildlife diversity, abundance and behavior. Students are also encouraged to maintain consistency from one year to the next when collecting biological data for comparison. For example, comparing relative abundance estimates from baited remote-cameras each year would be much more effective than comparing different methods that require a different set of assumptions and metrics.

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