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Original Articles

Assessing indirect measures of abundance and distribution with remote cameras: Simplifying indices of activity at pygmy rabbit burrows

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ABSTRACT

Estimating abundance or distribution of species that are scarce or difficult to detect is challenging for wildlife biologists. Pygmy rabbits (*Brachylagus idahoensis*) are secretive, sagebrush (*Artemisia* spp.) obligates of conservation concern that occupy the Intermountain West, USA. These unique leporids are difficult to monitor; however using remote cameras in conjunction with ranking of burrow activity may help refine sampling techniques for these mammals. We classified and deployed remote cameras at 405 burrows of pygmy rabbits between 2006 and 2010 in six study areas across Utah, USA. We ranked burrows based on the appearance of fecal pellets, as well as the condition of burrow entrances. We also documented the presence of pygmy rabbits and potential competitors and predators of pygmy rabbits at burrows using remote cameras. We used mixed-effects, zero-inflated negative binomial models and AIC model selection to evaluate the relative influences of burrow activity ranking, season, and rate of photographs for potential competitors and predators of pygmy rabbits on photo rates of pygmy rabbits. The top 2 models supported a simplified (active or inactive) burrow classification system and accounted for 45% of AIC weight. Rates of pygmy rabbit photographs were further influenced by meters from habitat edge ($\beta = 0.0008 \pm 0.0004$, 95% CI = 7.07E-05–0.002), photo rate of cottontail rabbits ($\beta = 0.31 \pm 0.11$, 95% CI = 0.08–0.53), and were higher during summer than other times of the year ($\beta = 0.38 \pm 0.19$, 95% CI = 0.01–0.74). Mean number of days to detection of pygmy rabbits at burrow complexes classified as active was four (SE = 0.61), and a two-week sampling period was needed to capture 81% of first detections. Our results refine commonly used ranking criteria of burrow complexes to a 2-level scale (active and inactive), and also emphasize the use of remote cameras as an effective technique for quantifying activity of pygmy rabbits at burrow complexes. Such information can help researchers and land managers more effectively survey this species for conservation and management efforts.

1. Introduction

Surveys of species that are scarce or difficult to detect are challenging for managers seeking information on abundance or distribution. In these situations, biologists often adopt indirect methods to monitor populations; such as the identification of hair, scat, or tracks. Although practical and objective, indirect methods may reflect the distribution of field signs rather than the species and are not always accurate (Harrington et al., 2009; Lyra-Jorge et al., 2008). Basing management strategies on data subject to these inaccuracies creates uncertainty and can limit the efficacy of management plans. It is possible to improve the accuracy of surveys that use indirect methods by using relatively new techniques such as DNA identification (Harrington et al., 2009; Kindberg et al., 2009; Mills et al., 2000) or remote cameras (McCallum, 2013; Rowcliffe and Carbone, 2008), depending on species and question of interest. Using remote cameras is one of the fastest growing techniques

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for surveying a wide range of terrestrial animals, particularly those that are elusive or rare and of conservation concern (McCallum, 2013; O'Connell et al., 2011; Shannon et al., 2014).

Pygmy rabbits (*Brachylagus idahoensis*) are secretive, sagebrush (*Artemisia* spp.) obligates of conservation concern that occupy the Intermountain West, USA (Flinders, 1999; Green and Flinders, 1980a; Lee et al., 2010). A 12-month finding was released by the United States Fish and Wildlife Service indicating that pygmy rabbits did not warrant listing under the Endangered Species Act (USFWS, 2010). Nonetheless, pygmy rabbits remain a sensitive species in many western states creating a need for methods to inventory and monitor their abundance and distribution. These rabbits dig their own burrows (Flinders, 1999; Green and Flinders, 1980a; Katzner and Parker, 1997), and spend much of their time within 100 m of burrow complexes (Heady and Laundré, 2005; Pierce et al., 2011; Sanchez and Rachlow, 2008). Pygmy rabbits prefer areas of tall (mean of 56–98 cm), relatively dense (21–45%) sagebrush cover (Green and Flinders, 1980b; Edgel et al., 2014; Flinders, 1999; Larrucea and Brussard, 2008b; Weiss and Verts, 1984). Additionally, activity of pygmy rabbits has been shown to be reduced near habitat edges (Pierce et al., 2011). This preference for areas of tall, dense sagebrush coupled with their secretive behavior make it difficult to use direct observation as a survey method for pygmy rabbits (Larrucea and Brussard, 2009; Lee et al., 2010; Pierce et al., 2011; Sanchez et al., 2009).

Current techniques used to monitor presence and estimate relative abundance of these semi-fossorial mammals rely on ranking burrows based on the appearance of fecal pellets and the condition of burrow entrances (Roberts, 2001; Sanchez et al., 2009; Ulmschneider et al., 2004). These classification schemes assign a relative rank (i.e., active, recently active, old, and very old) to burrows on one of several different scales (Roberts, 2001; Sanchez et al., 2009; Ulmschneider et al., 2004). Ranking schemes are useful to classify burrow complexes of these mammals and have provided beneficial information for the conservation and management of this species (Roberts, 2001; Sanchez et al., 2009; Ulmschneider et al., 2004); however, pygmy rabbits may still occupy areas and use burrows that are classified as inactive and at which old fecal pellets are found (Larrucea and Brussard, 2008a). Moreover, the current ranking schemes have either four (Roberts 2001; Sanchez et al., 2009) or six (Ulmschneider et al., 2004) levels and require simultaneous evaluation of the condition of burrow entrances, freshness and amount of fecal pellets, as well as presence and status of any diggings. These indicators are not mutually exclusive and it can be difficult to determine which level should be assigned to a given burrow (e.g., pellets suggest high levels of activity, but burrow entrance is collapsed and there are no fresh diggings suggesting low levels of activity).

Remote cameras provide a method to independently evaluate classification of burrow activity. Remote cameras have proven valuable in the study of wildlife species that are uncommon and difficult to observe (Cutler and Swann, 1999; Mace et al., 1994; McCain and Childs, 2008). These devices may also reduce observer error and bias and can be less costly and time consuming compared with surveys by observers (Cutler and Swann, 1999; Lee et al., 2010; Whiting et al., 2009). Further, modern cameras require relatively little maintenance in the field allowing investigators to photo-capture animals of interest rather than handling individuals through trapping and can be used to estimate abundance under certain circumstances (Gardner et al., 2010; Stanley et al., 2005). Remote cameras have been used to study the behavior, diel and seasonal activity, habitat selection, distribution, and presence of pygmy rabbits at burrow complexes (Larrucea and Brussard, 2008a,b, 2009; Lee et al., 2010), but not to evaluate classification of burrows.

Classification of burrow complexes, and the use of remote cameras have been two effective methods to survey for and monitor pygmy rabbits (Larrucea and Brussard, 2008a,b; Lee et al., 2010; Pierce et al., 2011). Use of these two methods simultaneously; however, holds promise to refine census techniques for these mammals (USFWS, 2010). Our objective was to use remote cameras to investigate how photo rates of pygmy rabbits (i.e., intensity of current use) were associated with rankings of burrow occupancy from two commonly used classification schemes. Additionally, we identified environmental factors associated with activity of pygmy rabbits including potential competitors and predators of pygmy rabbits, time of year, and distance to edge. Because it may take several weeks of photo surveying to document pygmy rabbits at a site (Larrucea and Brussard, 2008a), we investigated how long a camera needed to be set, at differing levels of burrow activity, before detecting a pygmy rabbit. Our results provide important information that will refine survey techniques for this lagomorph of conservation concern, and provide an example of how remote cameras can improve indirect methods of monitoring the abundance and distribution of rare or elusive species.

2. Methods

We evaluated photo rates of pygmy rabbits at burrow complexes in six areas of Utah, USA, between March 2006 and August 2010 (Fig. 1). Elevations in these areas ranged between 1709 m and 2419 m. We collected weather data at the nearest station to each study area from 1893 to 2010 (Western Regional Climate Center 2010). The range of temperatures among study sites was similar, and annual precipitation varied from 19 cm to 26 cm each year. All study areas occurred in sagebrush-steppe habitat (Lee et al., 2010; Pierce et al., 2011); upper hillsides of those areas were dominated by juniper (*Juniperus* spp.), pinyon pine (*Pinus edulis*), and aspen (*Populus tremuloides*); whereas lower elevations contained big sagebrush (*A. tridentata* ssp.) and wet, grassy valley bottoms, which were mostly agricultural fields (Lee et al., 2010; Pierce et al., 2011).

We focused our study in big sagebrush communities that were also occupied by potential competitors of pygmy rabbits, such as black-tailed jackrabbits (*Lepus californicus*) and cottontails (*Sylvilagus* spp.). Mammalian and avian predators of pygmy rabbits that occurred in those areas included coyotes (*Canis latrans*), badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*), red foxes (*Vulpes vulpes*), bald eagles (*Haliaeetus leucocephalus*), barn owls (*Tyto alba*), bobcats (*Lynx rufus*), ferruginous hawks (*Buteo regalis*), golden eagles (*Aquila chrysaetos*), great horned owls (*Bubo virginianus*), long-eared owls (*Asio otus*), northern harriers (*Circus cyaneus*), prairie falcons (*Falco mexicanus*), ravens (*Corvus corax*), red-tailed hawks (*B. jamaicensis*), rough-legged hawks (*B. lagopus*), short-eared owls (*A. flammeus*), and Swainson's hawks (*B. swainsoni;* Larrucea and Brussard, 2009; Lee et al., 2010; Pierce et al., 2011).

2.1. Classifying pygmy rabbit burrows

We located all known burrow complexes of pygmy rabbits ($n = 405$) in our study areas between March 2006 and August 2010. Burrow complexes typically consist of two to five entrances spanning up to 4 m without overlap between nearby complexes. We recorded the number of entrances and GPS coordinates for each burrow. We then simultaneously assigned a rank to burrow complexes based on two established systems (Roberts, 2001; Sanchez et al., 2009; Ulmschneider et al., 2004). The first ranking system included 4 levels of burrow activity: active, recent, old, and very old (Hays, 2001; Roberts, 2001; Sanchez et al., 2009). This rank-