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Abstract

As thermal infrared imaging technology has improved, it has increasingly been used for estimating sizes of wildlife populations. The greatest bias of thermal infrared surveys is the lack of known detection rates to adjust for visibility bias. As with visual surveys, a measure of detection rate is needed to provide unbiased estimates. We assessed the detection rate of white-tailed deer (*Odocoileus virginianus*) using a thermal infrared sensor (1.2 – 5.9 μm) from an aerial platform. Similar characteristics between thermal signatures of people and deer allowed us to use people in a reclined or horizontal position as surrogates for deer. We conducted a census of 2.56 km^2 within which 20 people were randomly placed. We detected 75.0% of the people ($n = 20$) across the area and 93.8% of the people ($n = 16$) when the effect of water was taken into consideration. Thermal signatures of people and deer occupying flooded areas were likely masked by the surrounding thermal signature of water. We found the method worked well in bottomland hardwood forests under dry conditions. As with visual aerial population counting methods, detection rates for an area should be developed to provide unbiased estimates.

Introduction

Thermal infrared technology has been used in wildlife-related studies for several decades (Graves et al., 1972; Havens and Sharp, 1998; Belant and Seamans, 2000). Most applications relate to estimating population sizes (Graves et al., 1972; Wiggers and Beckerman, 1993; Sabol and Hudson, 1995). Population studies using thermal infrared technology have included two techniques: cameras using infrared-triggers and thermal infrared surveys. Infrared triggered cameras have been used to take still photographs of individuals for population studies (Jacobson et al., 1997; Koerth et al., 1997). These studies typically use a capture-recapture approach based on the ability to identify individual animals by physical characteristics, such as antler size and shape. The applicability of this method is limited by initial cost, manpower, likelihood of baiting animals, and ability to distinguish among individuals.

Thermal infrared surveys have been used as another method to assess population size for large mammals and birds (Wiggers and Beckerman, 1993; Cobb et al., 1997; Focardi et al., 2001). These studies commonly employed thermal infrared technology using the 8 – 14 μm wavelengths, but other studies using wavelengths in the 1 – 6 μm range have also been used (Best et al., 1982; Boonstra et al., 1994). Addison (1972) compared the 3-5 μm and 8-14 μm wavelengths and found the 3-5 μm system had better spatial resolution and concluded the 3-5 μm range should "prove superior for the detection of animals." Thermal infrared imaging systems have been deployed from fixed- and rotor-wing aircraft (Hansen and Beringer, 1996; Naugle et al., 1996). Results have been mixed, often due to different methodologies and lack of standards. However, while the application of thermal infrared technology in deer surveys has been limited, it provides a better estimate than spotlight counts (Naugle et al., 1996) and is well suited for deciduous stands during the dormant season (Wiggers and Beckerman, 1993).

Even though the technology has been applied for several decades, there remains a need to address basic questions of proper use and methodology. The most recurrent need is information on detection rates of selected species. A known detection rate allows adjustments to be made to derived population estimates. Detection rates using thermal infrared imaging are comparable to visibility models for visual aerial surveys. Visibility models and detection rates for visual aerial surveys have been produced for a number of species including elk (*Cervis elaphus*), moose (*Alces alces*), bighorn sheep (*Ovis canadensis*), mule deer (*O. hemionus*), and white-tailed deer (Samuel et al., 1987; Ackerman, 1988; Peterson and Page, 1993; Bodie et al., 1995; Anderson et al., 1998; Beringer et al., 1998). Currently, detection rates for thermal infrared imaging are lacking. Our objective was to assess the detection rate of white-tailed deer using thermal infrared technology from an aerial platform for a bottomland hardwood forest.

Materials and Methods

The study was conducted on a 2.56 km^2 site on Choctaw

Island Wildlife Management Area (CIWMA) located in Desha county, Arkansas (Lat. 33° 35' 47" N, Long. 91° 11' 20" W). The CIWMA is approximately 3200 ha in size and composed of bottomland hardwood forests, cottonwood plantations, and open fields. Dominant tree species are oaks (*Quercus* spp.), pecan (*Carya illinoensis*), and eastern cottonwood (*Populus deltoides*). Detection assessment was conducted in the bottomland hardwood forest vegetation type only. The entire area was subject to seasonal flooding. Topography was flat and elevation ranged from 33.5 to 46.0 m.

Body temperatures of deer range from approximately 37.2 °C to 39.4 °C (DelGuidice et al., 2001), whereas the average human body temperature is 37 °C. Preliminary work indicated humans have slightly lower thermal signatures than deer (Kissell, unpub. data); therefore, slightly lower detection rates were expected. We substituted humans for deer to provide surrogate minimum detection rates. Given humans have lower thermal signatures than deer, we assumed that if we could detect humans we would be able to detect deer.

Twenty random locations within the study site were generated using the Animal Movements extension (Hooge et al., 1999) of ArcView 3.3 (ESRI, Inc., Redlands, CA). Random locations were imported into GeoExplorer 3 global positioning system (GPS) units (Trimble, Inc., Sunnyvale, CA) as waypoints. Individual persons were sent to a single waypoint within the study site. The true location of each individual was collected using GPS units upon reaching the random location. This allowed us to verify the true locations of individuals. Individuals assumed a reclined or horizontal position on or above the ground (i.e., in lounge chairs) to simulate the dorsal surface area of a deer.

Slightly overlapping, parallel transects were established and surveyed from a Cessna 182 fixed-wing aircraft. Flights were conducted at ≈ 457 m above ground level (AGL) with transects ≈ 110 m wide and at a speed of ≈ 130 kph. We considered flights at 305 m and 610 m AGL. However, experience indicated the speed of the plane was too fast relative to the ability to distinguish thermal signatures at 305 m AGL, and resolution was too poor to distinguish identifying features of individual animals at 610 m AGL. The flight was conducted approximately 1.5 hrs following sunset (2000 hrs) and terminated prior to 2200 hrs. The maximum temperature during the day preceding the flight was 18.3 °C, and the temperature declined from 12.2 °C to 10.6 °C during the flight. Flight paths (latitude, longitude, World Geodetic System of 1984, altitude (feet)), speed (miles per hour), date and time were recorded by an onboard GPS unit. The study area was surveyed using an IR-M700 thermal imager equipped with a 50 mm lens (Mitsubishi, Inc., Ontario, Canada) mounted in the belly of the plane. The thermal spectrum ranging in wavelength from 1.2 to 5.9 μm was used. Output was conducted through an RS170, 75 Ω connection to a digital video camera (Sony DCR-TRV900) containing a mini-digital video tape. The GPS signal was routed through a video encoder-decoder (VED). Locations of the plane obtained from the GPS unit were recorded on the audio portion of the video tape. The VED labeled the video with a continuous stream of positions as well as time, date, speed, and altitude information. GPS locations, obtained once each second, were used to geo-reference frames on the digital tape. Double counting was prevented by use of GPS locations integrated with videography. GPS data were transferred into a geographic information system (GIS).

Video was reviewed using a high resolution, 1000 line, black and white Sony PVM-137 13" monitor. Thermal signatures were recorded as people, deer, possible deer, possible people, or unknown. Known locations were compared to locations identified from the video. The percentage of people correctly identified was calculated.

Results and Discussion

The study was conducted on 7 March 2003. Twenty people participated in the detection study. Four of the 20 people were located in water and 16 on dry land. None of the four people located in water were detected and only one person on dry land was not detected. We detected 75.0% of all people (Table 1). Taking into account only the people on dry land and therefore removing the effects of water, we detected 93.8% of the people.

The main bias of thermal infrared imaging is that detection rates have not been estimated for the various species it has been used to detect (Haroldson, 1999). Our assumption that thermal signatures of people could be used as surrogates for deer appeared to be met, as we misidentified some people as deer upon review of the tape (Table 1). Given this misidentification, there is a clear need for species delineation based on thermal signatures of similar species.

Our study may have been influenced by three sources of bias. First, thermal loading of trees can negatively affect results. The amount of heat retained by vegetation, and trees in particular, is dependent upon daily ambient temperatures, the physiological activity of plants, and the amount of water available for evapotranspiration. While this was an apparent factor, it did not appear to greatly influence our results. Thermal loading has been addressed most often by conducting surveys either late at night (e.g., after 0100 hrs) or in the early morning prior to heating of the earth (Havens and Sharp, 1998). In mountainous areas this is also preferred for safety (Dunn et al., 2002). In the Mississippi Alluvial Valley the topography is flat, and the risks of flying at night are lessened.

Second, individuals of the same species do not produce

Table 1. Number of thermal signatures classified as people or deer during a thermal infrared census flight on the Choctaw Island Wildlife Management Area, Desha County, Arkansas on 7 March 2003.

		Identified As	
	Detected	People	Deer
People	15	10	5
Deer	55	0	55

the same thermal signatures. While most individuals appeared to produce similar thermal signatures, some individuals were "hotter" and some "cooler." This may have been caused by body size, differences in insulative coat quality, activity level, slight but not complete canopy coverage, wind, or a combination of these factors. To minimize the effects of this potential bias, we recommend sampling when the target species is most active and during a time with little or no wind.

Third, there is the potential for misidentification if two species on the study area are of similar size. On our study site there was only one large herbivore, white-tailed deer. However, numerous medium-sized mammals occurred on the study site. These included coyotes (*Canis latrans*), bobcats (*Lynx rufus*), raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), and nine-banded armadillos (*Dasypus novemcinctus*). Animals the size of bobcats and smaller were observed to display smaller thermal signatures. One coyote, distinguished by its size and movement, was delineated. Thermal signatures of deer and reclined/horizontal people were similar in most instances. Groups of deer and other mammals were readily distinguishable from people, though people were mistaken for single deer upon tape review (Table 1). Species delineation may be achieved by collecting imagery from a lower altitude above the ground at a slower speed. However, the tradeoff is the area sampled would be reduced given the lower altitude.

When using thermal wavelengths ranging from 1.2 – 5.9 μm we found that water, in addition to vegetation, was important in masking thermal signatures. Water loses its heat slower than the terrestrial environment and as a result effectively masks heat sources within it. We expected people to be detectable even under these conditions given the temperature difference. However, the background thermal signature of the water affected our ability to distinguish other thermal signatures.

The one individual located on dry land but not observed was under a tree that masked or hid the thermal signature. While all individuals were under little or no canopy cover (< 5%), the undetected individual was masked by a limb of a tree. The flight path allows for a parallax view that minimizes the effect of canopy cover. However, if the feature obstructing the view (e.g., a limb) is oriented along the same direction as the flight path, it will be undetectable. The undetected individual was under such a feature that was oriented along the flight path. Thermal infrared imaging is not capable of penetrating conifer or evergreen canopies and has been recommended for use during winter in deciduous or low profile vegetation types. Thermal infrared imaging has been used successfully in grassland and agricultural communities (Naugle et al., 1996), in pecan groves (Wiggers and Beckerman, 1993), in areas of sparse conifers (Havens and Sharp, 1998), and in deciduous hardwoods during winter (L. Davis, pers. comm.). However, under evergreen or coniferous vegetation the technology has not been effective (Dunn et al., 2002).

As with visual aerial population counting methods, accurate detection rates for an area should be developed to provide unbiased estimates (Pollock and Kendall, 1987). To date, no detection rates have been reported for thermal infrared imaging using known, free-ranging populations or marked animals. While we have not provided detection rates for deer directly, we believe this is an important first step in providing a minimum detection rate and the associated methodology. The detection rate determined in this study was specific to the CIWMA. The study was not replicated in other bottomland hardwood forests and inferences beyond the CIWMA drawn from this study should be viewed with caution.

We believe conduct of research using aerial thermal infrared videography is best suited for areas of deciduous forests or areas of low-growth vegetative forms that are not prone to flooding. Additionally, data collection under conditions of calm winds is favorable for consistent thermal signature delineation. We recommend that when thermal infrared imaging is used a species and site-specific detection rate be developed.

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