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An Evaluation of Two Low-Cost Thermal Imaging Cameras for Wildlife Damage Management Objectives

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ABSTRACT: The value of thermal imagery has been well documented for use in many aspects of wildlife damage management and other animal identification purposes. As technology has improved, prices for these devices continue to become more affordable. Two thermal imaging cameras were evaluated to determine effectiveness and utility of the devices under environments potentially encountered in the field. We tested the FLIR One (FLIR ONE) for an iPhone smart phone, and the FLIR Scout TK Compact Monocular (FLIR TK) device. Photographs of domestic animals and wildlife species were collected at distances of 3m-50m. A survey was developed and administered to professionals working with wildlife or domestic animals, containing paired images for each camera taken from similar distances and color palette. Survey participants (n = 52) reported the FLIR ONE camera produced more favorable images at closer distances ($P < 0.05$), and the FLIR TK at longer distances ($P < 0.05$). Overall, participants preferred ($P < 0.05$) the FLIR TK for producing the most desirable or useful images. Results of this study suggest both the FLIR TK and FLIR one thermal imaging cameras have the potential to be useful in collecting images of animals under low light conditions.

KEY WORDS: domestic animals, low-cost, thermal imaging, wildlife

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INTRODUCTION

Thermal cameras capture infrared radiation emitted by biological organisms using a passive sensor mechanism (Gade and Moeslund 2014). While infrared light was discovered in 1800, by astronomer William Herschel (Rowan-Robinson 2013), development of the first infrared imaging and scanning devices occurred in the late 1940s for military purposes (Gade and Moeslund 2014).

Commercial development and availability of thermal imaging products for the non-military sector began in 1983. Since that time, the application of the technology has continued to expand. Numerous reviews are available describing thermal imaging general use (Gade and Moeslund 2013), wildlife applications (Bipad-Cilulko et al. 2013), agricultural applications (Vadivambal and Jayas 2011, Ishimwe et al. 2014), and medical purposes (Lahiri et al. 2012, Ring and Ammer 2012).

Recent applications of the technology for human medicine include evaluation of skin conditions (Curran et al. 2015) and burns (Renkielska et al. 2014). General physiological conditions of athletes (Chudecka et al. 2015) as well as emotional conditions associated with psychophysiology (Ioannou et al. 2014) have been reported. Surgical applications related to tissue perforations (Hardwicke et al. 2016) and assistance in cardiac procedures (Kaczmarek 2016) have been accomplished using thermal imaging technology.

Agricultural applications of thermal imaging have predominantly evolved as a method to evaluate changes in surface body temperature as a measure of stress and health in swine (Jara et al. 2016, Zjang et al. 2016, Islam et al. 2015, Soerensen and Pedersen 2015), cattle (Montanholi et al. 2015, Cook et al. 2016, Taveres Dantas et al. 2016), and poultry (Herborn et al. 2015). Behavior and disease conditions in domestic cats have also been evaluated using thermal imagery (Waddell et al. 2015, Foster and Ijichi 2017).

Most wildlife application of thermal imaging are based upon locating and identifying animals in darkness (Bipad-Cilulko et al. 2013). Utilization of the technology in stress and behavioral studies have been reported in songbirds (Jerem et al. 2015), waterfowl (Austin et al. 2016), flying squirrels (Horton et al. 2015) and various primates (Kano et al. 2015, Ioannou et al. 2015, Dezecache et al. 2017).

Directly related to wildlife damage, thermal imagery has been utilized extensively in applications ranging from mitigation of deer-vehicle collisions (Jared et al. 2017) to wildlife species interaction with trains (Kumar and Selvakumar 2016). Thermal imaging has also played a significant role when lethal removal of animals is necessary such as deer (Hognett 2005), swine (Pinkston 2008), and kangaroo (Hampton and Forsyth 2016).

While significant potential for uses of thermal imaging have been reported, the cost of thermal imaging units are often prohibitive. As technology has advance, the cost of these units have been decreasing significantly. While costs have decreased, as might be expected, more affordable units often lack the temperature sensitivity and resolution of images necessary for many applications. The objective of this study was to evaluate thermal image quality of animals obtained from two low-cost thermal cameras.

METHODS

This study was conducted on the 1,215-ha Berry College Wildlife Refuge (BCWR) within the 11,340-ha Berry College campus in northwestern Georgia. The BCWR was within the Ridge and Valley physiographic province with elevations ranging from 172 m to 518 m (Hodler and Schretter 1986). The BCWR was characterized by campus-related buildings and facilities for the student body of 2,200, interspersed with expansive lawn, hay fields, pastures, woodlots, and larger forested tracts. Berry College also maintains an equine center, dairy, sheep and beef cattle herds, and respective facilities as part of the undergraduate academic program within the BCWR area. Thermal images of domestic livestock, companion animals, free-ranging white-tailed deer and Eastern grey squirrel were obtained within the BCWR. A private residence consisting of a 7.3-ha small farm that included domestic livestock and companion animals, approximately 20 km from the Berry College entrance, was also utilized to obtain thermal camera images for this study.

We used the FLIR Scout TK compact monocular (FLIR TK) for this study (FLIR Systems Inc., Wilsonville, OR). According to the manufacturer, this thermal vision monocular device can capture images of people and animals at greater than 90 m distance. It has capabilities for obtaining still photographs or video images. Six different color palettes are available to provide options to maximum color contrasts as an indication of temperature differences. The unit captures images in the long infrared wavelengths (7.5 - 13.5 um). Battery life is reported to be >5 hours. Current retail price is approximately $600 US.

The second thermal camera evaluated was the FLIR One (FLIR ONE) for iOS (FLIR Systems Inc., Wilsonville, OR). The FLIR ONE is a miniature thermal imaging device compatible for either iOS or android-based smart phones. Application driven software provides the ability to utilize the smart phone to store visual or video images acquired by the thermal device. One unique feature of the FLIR ONE is the presence of a two-camera system. A thermal camera and a more conventional HD digital camera are utilized simultaneously to blend the temperature contrasts of the thermal image with an outline basis of the digital camera image. Multiple color palette settings are available to provide different color contrasts representing temperature differences within the field of view. The unit also operated in the long infrared wavelengths typical for most commercially available thermal imaging devices (8.0 - 14.0 um). Battery life is approximately one hour. Retail of this device is approximately $200 US. For this study, an iPhone (Seven-Plus, Apple Inc., Cupertino, CA), purchased in 2017 was utilized in conjunction with the FLIR ONE camera.

Still thermal images of non-restrained domestic and wild animals were collected from July 12, 2017 - December 18, 2017. Thermal images were collected from domestic dogs (*Canis lupus familiaris*), cats (*Fel*is *catus*), cattle (*Bos taurus*), goats (*Capra aegagrus hircus*), chickens (*Gallus gallus domesticus*), horse (*Equus ferus caballus*), donkey (*E. africanus asinus*) and mice (*Mus musculus*). Wild species photographed included the Eastern gray squirrel (*Sciurus carolinensis*), and white-tailed deer (*Odocoileus virginianus*). Photographs were obtained using each camera at the same distance with the same field of view. Images were captured using two of the color palettes similar for both cameras. For each camera, white being hot created a gray scale of temperatures with darker shades associated with cooler temperatures. The rainbow palette produces images where lighter colors represent hotter images, with darker colors representing cooler contrasts. Distance from the

Table 1. Thermal images obtained from different species and grouping of animals by distance and size.

Distance m (Group)	Size of Animal Kg (Group)	Species
3m (1)	>225 (4) 25-55 (3) 25-55 (3) <.1 (1)	Cattle (*Bos taurus)* Dog (*Canis lupus familiaris)* Goat (*Capra aegagrus hircus*) Mice (*Mus musculus*)
5m (1)	0.4-7 (2) <.1 (1) 0.4-7 (2)	Cat (*Felis catus*) Mice Squirrel (*Sciurus carolinensis*)
10m (2)	0.4-7 (2) 0.4-7 (2) <.1 (1) 25-55 (3)	Cat Cats Mice White-tailed deer (*Odocoileus virginianus*)
15m (2)	0.4-7 (2) 25-55 (3)	Chickens (*Gallus gallus domesticus*) and Goat
20m (3)	>225 (4) 0.4-7 (2)	Cattle Cats
30m (3)	>225 (4) 25-55 (3)	Donkey (*Equus africanus asinus*) White-tailed deer
40m (4)	>225 (4)	Horse (*Equus ferus caballus*)
50m (4)	25-55 (3)	White-tailed deer

Table 2. Thermal imaging camera selection (Mean ±SE) based on paired animal photographs when FLIR TC Camera = 1 and FLIR ONE Camera = 2.

Professional Activity			Species Distance			Species Size		
Species	*n*	Mean±SE	Group	% Images	Mean±SE	Group	% Images	Mean±SE
Wildlife	33	1.51 ± 0.02^a	1	30.0	1.66 ± 0.02^a	1	20.0	1.75 ± 0.03^a
Domestic	16	1.42 ± 0.02^b	2	33.3	1.56 ± 0.02^b	2	33.3	1.47 ± 0.02^b
None	2	1.40 ± 0.05^b	3	23.3	1.24 ± 0.02^c	3	26.7	1.36 ± 0.02^c
			4	13.3	1.26 ± 0.03^c	4	20.0	1.36 ± 0.02^c

Different superscripts within each column differ by ($P < 0.05$)

animals (3 m - 50 m) were determined using a Leica Rangemaster CRF 900 (Leica Camera Inc., Allendale, NJ,). Information related to thermal photographs were recorded, and images were downloaded from each camera to an external portable hard drive (Seagate Free Agent, Cupertino, CA).

A survey was developed and administered via email using a commercially available platform (Survey Monkey, San Mateo, CA). Survey participants were requested to provide their sex, and professional interests or responsibilities with wildlife species or domestic animals. The survey consisted of 17-paired photographs that were obtained from each thermal camera at the same distance. In each case, one photograph was from one camera while the second image was obtained by the second thermal camera in the same color palette. Fifteen of the paired photographs included photographs in both the white-hot and rainbow color palette of the same animal(s) at the same distance. The remaining two pairs had one species in the white-hot palette, while the second pairing contained a different species portrayed in the rainbow palette. All photos were labeled as being from Camera A or Camera B. No information related to species or distances that photographs were obtained was provided and paired images were ordered to a manner to preclude consecutive paired photos from being the different color palette of the same animal/distance. Survey recipients were requested to identify which of each paired photograph was most useful for identification of a species. The final three questions of the survey requested a determination of which camera overall was more useful, and what the individual would be willing to pay for each thermal device based on a Likert scale of $0 to $1,000, in $200 increments.

A web-based link to the survey was sent via email to 153 individuals, with animal related professions that could potentially benefit from access to thermal imaging devices. Approximately 60 individuals were faculty and technical staff predominantly from two state universities with wildlife related departments. Faculty and technical staff (n = 53) from two institutions with animal science departments were also included. A third group of regional professionals selected for this survey included: USDA-APHIS Wildlife Services (n = 15), Georgia Department of Natural Resources (n = 6), Directors of animal control centers (n = 4) in counties adjacent to Berry College (Floyd County, Georgia), and research and field staff (n = 15) from the Joseph W. Jones Ecological Research Center, Newton, Georgia.

Difference in perception of camera images were determined using the univariate ANOVA analysis procedures of IBM SPSS 25.0 (SPSS 25.0 2017). Images selected from the respective camera was the dependent variable. Fixed variables included sex of survey participants, primary professional focus on wildlife or domestic animals, thermal image palette, size of the animal, and distance from the camera to the animal. For analytical purposes, animals were placed into one of four groups based upon size. Similarly, all images of animals were placed within one of four groups related to distance from the camera. Duncan's Multiple Range Test was utilized for further analysis fixed effects with significant differences among means. In addition to main effects, all possible interactions for all fixed variables were analyzed. One-way analysis of variance was utilized to determine differences in the overall selection of the most favored camera, and perceived value of each camera.

The Berry College Institution Animal Care and Use Committee (IACUC No. 2016-17-021) approved all animal related procedures incorporated in this study. Approval of the survey instrument was obtained by the Berry College Institutional Review Board (Protocol No. 20174-18-018).

RESULTS AND DISCUSSION

In order to provide a robust analysis, thermal images of animals collected was placed within defined groups by distance (n = 4) from the camera and size (n = 4) of the animal (Table 1). There was an attempt to provide a variety of sizes of animals, ranging from mice to horses, with images obtained at distances that would be useful for detection and identification of a given species during low light conditions.

We received 52 completed surveys; representing a 34% response rate from the 153 individuals provided the opportunity to complete the web-based survey. Approximately 65% (n = 33) of respondents indicated a professional focus related to wildlife, while 32% indicated domestic animals. These proportions are similar to the proportions of wildlife and domestic animal related professionals among the 153 individuals requested to complete the survey.

Differences in preference among the paired images obtained from the FLIR TK and FLIR ONE devices is presented in Table 2. There was a preference for the FLIR ONE camera ($P < 0.05$) for images obtained at closer distances (3 - 15 m) and relatively smaller animals (mice, squirrel, chicken, cats). In contrast, survey participants preferred (P < 0.05) the FLIR TK camera at the longer distances generally depicting larger species. Survey participants self-identifying as professionals working with domestic animals had a preference (P < 0.05) toward selecting images obtained from the FLIR TK camera, while those working with wildlife tended to place equal emphasis on each camera. There were no differences (P > 0.05) in camera image selected due to sex of survey participant, palette color of images, or any subsequent interaction among main effects.

Difference in preference for the FLIR ONE camera at closer distances likely related to more favorable ability to focus on the image compared to the FLIR TK at these distance. Additionally, the FLIR ONE uses a secondary light based camera that effectively provides an outline of animals and other physical components within the field of view. Superimposing the outlines of features with the thermal imaging camera provides greater reference points and context for the given image. While effective at close distances, the combining of the images becomes less effective at greater distances. In contract, the FLIR TK appears to be better suited for obtaining images at distances >10m, including the ability to focus the device. The FLIR TK does appear to inherently magnify the image compared to the FLIR ONE. It is recognized that size of species is confounded with distance between the animal and camera. This was necessary limit the number of images in order to have a survey that could be completed in a reasonable time, and to provide a broad assortment of animals and distances. Smaller animals (group 1-2) at longer distances tended to result in thermal images that provided limited value for survey participants without the context of the photograph. It was interesting that no differences in camera preference were attributed to the image color palettes of white-hot compared to a rainbow effect with many different colors representing temperature contrasts. Regardless, from a practical standpoint, an individual has the ability to rapidly change a desired palette on either camera based upon their preference and given circumstances.

Survey participants overall preferred (P < 0.05) the FLIR TK (69.6%) to the FLIR ONE (32.4%) (Table 3). Participants were asked to place a value on each camera ranging from $0 to $1,000 in $200 increments. Individuals indicating an overall preference for the FLIR TK placed a higher value (P < 0.05) on that device compared to the FLIR ONE. Those favoring the FLIR ONE placed a dollar value that tended to be higher, but not different from the FLIR TK. From an anecdotal perspective, survey participants with experience using thermal cameras tended to place higher values on both cameras, compared to individuals with no experience with the devices. The current retail price of the FLIR TK is approximately $600 US, while the FLIR ONE retails for $200 US.

While the FLIR ONE camera retails at 1/3 the cost of the FLIR TK, there are a number of considerations that survey participants were not provided. The FLIR ONE camera is designed to work as an attachment to either an Apple or Android smart phone. The camera uses its own battery, but imaging and memory space for captured photographs or video utilizes the capacity of the smart phone via a software application. Thus, the cost or at least access to a smart phone should be considered. For some applications, the reported battery life of one hour may be a limiting factor. It should also be noted that the protective case on the smartphone used in this study had to be removed in order to attach the FLIR ONE to the lightening port. This could increase the risk of damage to the phone in some instances.

Survey participants placed the value on the FLIR TK quite close to retail price. This device is marketed for outdoor enthusiast, and appears to have sufficient protection from the elements to be useful for wildlife damage management objectives. The camera battery is reported by the manufacturer to last more than five hours, providing a more generous time of operation compared to the FLIR ONE. From the author's perspective, the weakness of the FLIR TK was primarily limited to capture of clear images at distances greater than one meter. However, at a distance of 50 m, white-tailed deer in a hayfield could not be discerned beyond being a hot spot in either color palette within the environment. This is much shorter than the 90 m effective distance suggested by the manufacturer.

For the purposes of this survey, specific distances and limited palette choices for photographs were obtained to provide consistency for comparative purposes. In addition, survey participants were not provided any context related to species, distances or circumstances for

Table 3. Thermal imaging camera preference and perceived value.

Thermal Imaging Camera	Overall Selection *n*	%	Camera Value ($) Overall Selection = FLIR TC *n*	Mean±SE	Camera Value ($) Overall Selection = FLIR ONE *n*	Mean±SE
FLIR TC	36	68.6[a]	36	622.86±51.55[a]	16	506.25±78.78[a]
FLIR ONE	16	31.4[b]	36	408.57±49.60[b]	16	587.50±74.10[a]

Different superscripts within each column differ by (P < 0.05) each photo. From a more practical standpoint, the user of either camera would likely have the flexibility to reduce the limitations for each camera by simply changing the distance or palette color to provide the best possible quality of image. Both the FLIR TK and FLIR ONE thermal imaging cameras have the potential to be useful in collecting images of animals under low light conditions.

AUTHOR DISCLOSURE

The author of this paper has no financial ties or received any support from FLIR Inc. Thermal imaging cameras utilized in this study were purchased from retail outlets.

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