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LIMITATIONS OF FAR INFRARED THERMAL IMAGING IN LOCATING BIRDS

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Abstract.—The utility of far infrared (FIR) thermal imaging devices to detect and census birds in the field was examined. A Thermovision 210 was used to survey individuals and/or nests of Great-horned Owls (*Bubo virginianus*), Pileated Woodpeckers (*Dryocopus pileatus*), Northern Flickers (*Colaptes auratus*), Barrow's Goldeneyes (*Bucephala islandica*), Buffleheads (*Bucephala albeola*), Mallards (*Anas platyrhynchos*), Green-winged Teal (*Anas crecca*), Lapland Longspurs (*Calcarius lapponicus*) and Pectoral Sandpipers (*Erolia melanotos*). Thermal imaging was successful in determining activity at nests of all four cavity-nesting species and in finding nests of Arctic tundra birds if their approximate location was known. FIR thermal imaging was not useful, however, in detecting the active, open nests of Mallards or Green-winged Teal, nor was it useful in locating resting waterfowl or Great-horned Owls. It was successful at locating Arctic tundra birds. These differences are largely attributable to variation among species in the insulative property of nests or feathers. It is concluded that FIR imaging will be of limited utility in censusing most avian populations, although it may provide a useful, abeit expensive tool, to assess nest occupancy of cavity- or burrow-nesting birds, or to determine the activity of birds in open habitats.

LIMITACIONES EN EL USO DE IMÁGENES TERMALES CON RADIACIÓN INFRAROJA EXTREMA PARA LOCALIZAR AVES

Sinopsis.—Se examinó la utilidad de aparatos de detectar imágenes termales con radiación infraroja extrema (FIR) para detectar y muestrear aves en el campo. Se utilizó un "Thermovision 210" para monitorear individuos y/o nidos de *Bubo virginianus, Dryocopus pileatus, Colaptes auratus, Bucephala islandica, B. albeola, Anas platyrhynchos, A. crecca, Calcarius lapponicus* y *Erolia melanotos*. El uso de imágenes termales fue útil para determinar actividad en los nidos de todos las aves que anidan en cavidades y para hallar nidos en la tundra ártica si su localización aproximada se conocía. Sin embargo, el uso de imágenes termales FIR no fue útil en detectar los nidos abiertos activos de *Anas platyrhynchos* y *A. crecca,* ni fue útil para localizar aves acuáticas en descanso o individuos de *Bubo virginianus*. Fue util en localizar aves de la tundra ártica. Estas diferencias se atribuyen grandemente a variaciones interespecíficas en las propiedades insuladoras de los nidos o de las plumas. Se concluye que el uso de imágenes termales FIR será de utilidad limitada para censar la mayoría de las poblaciones de aves, aunque puede ser una herramienta útil, aunque costosa, para confirmar ocupación de nidos en aves que anidan en cavidades o en huecos, o para determinar la actividad de aves en zonas abiertas.

A major problem in studying animals in the field is finding them. Trapping and marking techniques are frequently employed, yet these methods are not always feasible. Alternatively, researchers have relied on visual sightings of the study animals or their signs (i.e., tracks, nests, etc.), but such techniques are severely constrained by the limits of human vision. Our vision is restricted to objects emitting or reflecting light in the visible band (0.4–0.7 μm), which represents only a small fraction of the total electromagnetic spectrum. Visual location and censusing can be enhanced, however, through the use of devices that convert the non-visible to the visible spectrum.

One such device is the far infrared (FIR) sensor. All objects with temperatures above absolute zero emit radiation at the far infrared end of the spectrum, the intensity varying with the temperature of the source. Far infrared sensors convert far infrared energy into visible images by focussing thermal radiation onto an array of supercooled detectors. Each detector emits a voltage signal proportional to the temperature it perceives and these signals are then amplified and transmitted to an array of light-emitting diodes that create a visible image (Hill and Clayton 1985). Objects that are warmer than adjacent objects by as little as 0.1 C can be detected at distances of up to 500 m.

FIR thermal imagers have been used extensively in industry (e.g., to detect electrically defective computer chips and circuit boards, hot spots in electrical breaker boxes, and problem areas in distillation towers), and in physiological studies on thermography to detect heat differentials on the body (e.g., Klir and Heath 1992). To our knowledge, no one has used this technology to locate birds or their signs. We evaluated the potential utility of FIR thermal sensors as a new tool to detect birds in the wild.

METHODS

We field-tested two devices. The Inframetrics 522L (manufactured by Inframetrics, Bedford, Massachusetts) gave a very clear image but was bulky and required liquid nitrogen as a coolant (newer versions are thermoelectrically cooled). This was the first device we used in a field test in the Yukon in a variety of situations. We ruled it out because it was awkward and heavy in the field. The Thermovision 210 ($29,950 US) (manufactured in Sweden by Agema Infrared Systems, Danderyd, Sweden; distributors in Canada: 905-637-5696; and in the United States: 201-867-5390) was the best all-purpose device.

The Thermovision 210 is portable, rugged, thermoelectrically cooled, and easy to handle. It detects infrared radiation between 2 and 5 μm, weighs 1.5 kg, looks slightly larger than a 35 mm camera, is made of aluminum casting, and delivers a thermal resolution of 0.1 C at 30 C. It has a recommended operating range between −10 C and 55 C and we used it at −5 C with good performance. It has a 8° vertical × 16° horizontal field of view, a minimum focal range of 0.4 m, and images are seen directly on a small viewfinder. Images can be clarified through three major controls: a focus control, a brightness control and a contrast control, which can increase or decrease the contrast of the object relative to the background. A video output permits images to be viewed on a TV monitor or an image can be frozen on the viewfinder and then output to a video camera recorder for a permanent record. The latter can then be printed with a video printer. The Thermovision 210 also has the useful feature of reverse polarity so that hot images of animals or sites can be either seen as white images against a dark background or as dark images against a white background. Power is supplied through NiCad 6-v battery packs (0.85 kg each), which last about 4 h when charged.

We carried out field tests designed to detect animals or their signs under a range of conditions. We first assessed the general utility of the device by obtaining images of foraging Canada Geese (*Branta canadensis*) at the Metro Toronto Zoo (43°41′N, 79°38′W). We then conducted a field test in the central interior of British Columbia (51°43′N, 121°21′W), where we searched for nests of four species of cavity-nesting birds, including Pileated Woodpeckers (*Dryocopus pileatus*), Northern Flickers (*Colaptes auratus*), Barrow's Goldeneye (*Bucephala islandica*), and Bufflehead (*Bucephala albeola*). We also searched for nests of two species of ground-nesting waterfowl: Mallards (*Anas platyrhynchos*) and Green-winged Teal (*Anas crecca*). In the Kluane Lake area of the southern Yukon (60°57′N, 138°12′W), we tried to locate Great-horned Owls (*Bubo virginianus*) resting in spruce. Finally, at Walker Bay on the Kent Peninsula, Northwest Territories (68°22′N, 108°04′W), we tried to locate Lapland Longspurs (*Calcarius lapponicus*) and Pectoral Sandpipers (*Erolia melanotos*) in the Arctic tundra.

RESULTS AND DISCUSSION

Foraging Canada Geese.—Thermal images were readily generated for foraging geese feeding in an open field (Fig. 1). The body outline was obvious as were distinct "hot-spots" which are presumably areas where core temperature is highest and/or insulation lowest. The geese were censused in the early morning (0700 hours) when ambient temperatures were cool (approximately 7 C). FIR thermal imaging clearly offers potential to monitor large birds feeding in open areas. Such techniques might be particularly useful for night time observation or when direct visual contact is difficult, though night-vision goggles (Hill and Clayton 1985) are a cheaper alternative for some of these uses. Moreover, the technique may also be used to give direct estimates of surface temperature (Agema Infrared Systems makes the Thermovision 450 which allows remote temperature measurement).

Nests of cavity-nesting birds.—We examined three nests of Barrow's Goldeneyes (all in nest boxes), and one nest each of Bufflehead, Pileated Woodpecker and Northern Flicker (all in natural cavities in dead aspen). The two woodpecker nests contained nestlings, whereas the goldeneye and Bufflehead nests contained eggs that were being incubated. Early in the morning (0400–0700 hours) when ambient temperatures were still cool (approximately 10 C) we could easily detect a glow at the nest en-

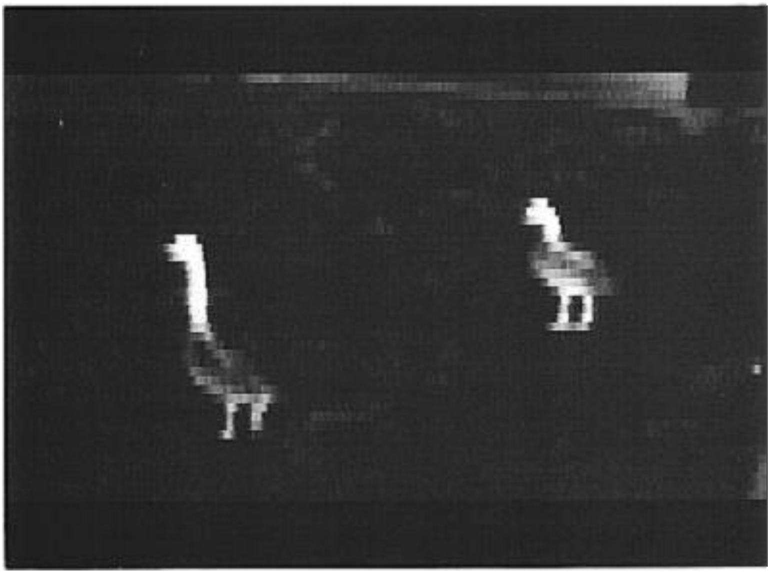

FIGURE 1. Thermal image of two foraging Canada Geese.

trance for the goldeneye nests, the Pileated Woodpecker nest and the flicker nest (the Bufflehead nest was not checked in the morning). The nest boxes of the goldeneyes also glowed at the lower base of the box. When checked in the afternoon when ambient temperatures ranged from 18 to 25 C, the goldeneye nests maintained a distinct thermal profile, as did the Bufflehead nest. In all cases, the nest entrance was clearly visible. We could not detect the entrance of the Pileated Woodpecker nest after 1000 hours (temperature not monitored), however. The entrance of the nest faced east and consequently was warmed quickly once the sun rose.

In all of the above cases, the location and activity of the nests were known before-hand. We were unsuccessful in locating new cavity nests using the FIR thermal sensor. Background "hot-spots" were sufficiently common even during the coolest part of the night (1200–0300 hours) to mask the location of any active nests. Several promising sites turned out to be patches of lichen, bark or other material that retained a higher thermal profile than the surrounding material.

Ground-nesting waterfowl.—We were unable to locate a nest of a Green-winged Teal or a Mallard using FIR imaging although the location of each nest was known. The teal nest contained a complete clutch and was believed to be in the early stages of incubation when censused. The eggs were cool to the touch, however, and the female may not have been on the nest prior to our visit. In contrast, the Mallard nest was well into incubation when surveyed and a female flushed from the nest as we approached. We could not locate the nest using the FIR thermal sensor, however, until we were within 1 m and standing directly over the nest. The down around and over the eggs, and the emergent vegetation shielded the nest effectively. We were also unable to locate any other nests of either emergent-nesting or upland-nesting waterfowl using the thermal sensor. Even at 0300 hours, too many random hot-spots (stumps, rocks, etc.) existed to render the FIR thermal sensor useless. The FIR thermal sensor was also ineffective in detecting individuals of Green-winged Teal, Mallard and Goldeneye on several small ponds, when the birds were within 5–10 m. Presumably, the high insulative properties of the feathers prevented detectable losses of infrared radiation.

Great-horned Owls.—We made visual contact with a Great-horned Owl sitting near its nest and tried to obtain a thermal image of it with the device. We were unable to pick up a thermal image of the resting bird but when it flew, hot-spots could be seen from underneath its wings. Hence, the insulation provided by the features must have been sufficient to minimize the thermal differential with ambient conditions.

Arctic tundra birds.—We tried to locate birds (primarily Lapland Larkspurs and Pectoral Sandpipers) resting or foraging on the tundra. These were readily obvious as glowing objects, even when they were not immediately visible because of their cryptic coloration. It was particularly effective in finding birds that were immobile. Nests of these ground-nesting birds (with or without the adults) were obvious with the device, but their approximate location had to be known before-hand. It was not effective as the sole tool in finding nests because of the extremely low density of birds in this area. We found that the major limitation in the tundra was that one could not simply scan the general area and pick up all the birds; the distance at which the image was focussed was critical. If the birds were not within the focussing distance, the image was blurred. We found that the best time for location of birds was early in the day before the sun had a chance to heat up the ground and on cloudy days.

CONCLUSIONS

The FIR thermal imaging devices that we tested hold limited potential for use in locating birds or their active nests. FIR thermal imaging can detect active cavity nests when background infrared radiation is low and can provide a useful tool to monitor the activity of nests at known locations. This may be especially advantageous when the locations of a large number of nest sites are known but activity cannot be quickly or easily assessed. For example, FIR imaging may be useful to census quickly nest use for burrow-nesting seabirds. Unfortunately, FIR thermal sensors will not be suitable as a method to detect new nest sites of cavity-nesting birds, though there is some potential of tundra nesting birds if the density of nests is reasonably high. Potential nest sites at more southern latitudes are quickly obscured by the scatter of random "hot-spots" in the background. The device we tested was also not useful in detecting nests that were heavily shielded or insulated, nor was it successful in detecting well insulated adult birds, such as Great-horned Owls or ducks. It was however useful in detecting smaller passerines and ground-dwelling shorebirds in the tundra which are more poorly insulated.

Far infrared scanners have been successful in wildlife studies (e.g., using aircraft to census Sandhill cranes [Sidle et al. 1993] or large mammals [Croon et al. 1968, Graves et al. 1972]). These studies, however, used infrared linescanning devices (Barrett and Curtis 1992). Linescanners have an array of detectors that scan a series of narrow strips to build up the image as the instrument is moved over a specified area. In contrast, thermal imagers have sensors that scan in both directions at once giving greater detail and hence a more accurate picture. Thermal scanners have the advantage of small size and portability, which permits their use in the field.

There are, however, a number of limitations of thermal imaging devices. First, FIR thermal sensors can be used optimally only at certain times of the day or under certain weather conditions. As detection of either the animal or heat emanating from an active nest or burrow relies on a thermal differential to ambient temperature, we have found that the best time to maximize the differential is during the early morning when the heat from the previous day has largely dissipated and the sun has not yet had a chance to heat the ground or vegetation. Thereafter, it becomes increasingly difficult to distinguish between hot-spots caused by sun flecks and those caused by animals. A thermal differential can also be maintained by working on overcast days, after rains, or in winter when snow cover is present. Second, it may be difficult or impossible to detect some animals or their nests because their feathers, down or nests have high insulative properties, which minimize the thermal differential between them and the environment. Third, a number of objects can absorb and radiate infrared radiation, even when ambient temperatures are low. These random hot-spots readily mask active sites, and so severely limit the utility of thermal sensors as a tool to detect new nest sites or activity centers. Fourth, focussing at the correct distance is crucial and thus a general scanning of an area may fail to detect birds that are actually there. Finally, far infrared thermal imaging devices are very expensive. Unless they are shared among numerous researchers for a variety of applications, it may be difficult to justify the cost.

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