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Handheld thermal-imaging devices as important tools in wader fieldwork

Tim Oortwijn[1,2*], James A. Johnson[3], Zachary M. Pohlen[3] & Jan A. van Gils[1,2]

[1] *Department of Coastal Systems, NIOZ Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, the Netherlands*
[2] *Conservation Ecology Group, Groningen Institute for Evolutionary Life Sciences (GELIFES), University of Groningen, PO Box 11103, 9700 CC Groningen, the Netherlands*
[3] *U.S. Fish and Wildlife Service, Migratory Bird Management, 1011 East Tudor Road, Anchorage, AK 99503, USA*
* *Corresponding author: tim.oortwijn@nioz.nl*

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Thermal-imaging technology makes far infrared radiation visible and enables the observation of variations in temperature (e.g. a warm object in a colder environment). Recent advancements in the technology have substantially improved its application for wader fieldwork. Here, we show how handheld thermal-imaging devices are helpful for detecting the cryptic nests (from over 100 m) and chicks of Red Knots *Calidris canutus* and for monitoring during mist-net catches at night. Their use improves efficiency of fieldwork and reduces disturbance.

Keywords

camouflage

catching

shorebirds

nest

night vision

Red Knot

Calidris canutus

INTRODUCTION

Birds use different strategies to avoid predation of their nests and chicks, such as nesting in cavities where predators cannot enter or behaving cryptically to avoid being detected by predators. Waders fall into the latter category, with most species nesting on the ground, after which precocial chicks leave the nest within a few hours and forage independently. Eggs, chicks and their parents are often well-camouflaged, making it difficult not only for predators to find them, but also for researchers.

The difficulty of finding wader nests varies by species and is influenced by several factors, including the degree of camouflage, the concealment of nests, behavioral traits, and nest density. Red Knot *Calidris canutus* nests are among the most difficult to find due to the birds' cryptic plumage and behavior. Incubating birds remain on the nest even when approached as close as 2 m, while the non-incubating mate silently forages out of sight, sometimes more than 4 km away (pers. obs.). Additionally, nest densities are typically low, ranging from less than 1 to 3 pairs/km^2 (Schekkerman *et al.* 2003, pers. obs.). Rope-dragging to find Red Knot nests has proven to be highly inefficient (Tulp *et al.* 1998). Another method involves directly observing pairs or individuals during egg laying and incubation, but this approach is very time-consuming and results in very few nests being discovered (pers. obs.).

Another method for locating cryptic wader nests employs thermal imaging, which in wader studies is often used on drones (also UAVs, unmanned aerial vehicles; Israel & Reinhard 2017, Stander *et al.* 2021). Low Red Knot nest density, however, also makes drone searches inefficient, particularly because of the limited time when conditions are favorable, i.e. when there is no solar radiation and the environment is in thermal equilibrium (Stander *et al.* 2021), which is relatively short in Arctic summer nights.

Handheld thermal-imaging devices have been used less frequently in wader studies, with earlier applications having limited detection ranges, impractical designs, and high costs (Boonstra *et al.* 1995, Johnson & Brusseau 2012). Recent advancements in technology, however, have led to improved thermal sensitivity and resolution, greater portability, and reduced costs (McCafferty 2013, Keller *et al.* 2019, Wilson *et al.* 2023).

Here, we demonstrate the utility of handheld thermal-imaging devices in wader fieldwork. We used them to locate Red Knot nests and chicks at a breeding site in Alaska and to monitor nocturnal mist-net catches at a nonbreeding location in West Africa.

METHODS

We used three types of thermal-imaging devices: Pulsar Helion XP50, Pulsar Helion 2 XP50 Pro (both monoculars) and Pulsar Merger LRF XP50 (binoculars). While all devices performed well, we preferred the binoculars because of the added comfort of using both eyes. Specifications of these binoculars are as follows: waterproof, NETD (noise equivalent temperature difference) < 25 mK, 640 ×480 pixels (17 µm), frame rate 50 Hz, magnification 2.5–20x, field of view (horizontal × vertical) 12.4 × 9.3 degrees, 21.8 × 16.3 m @ 100 m, battery life 10 hrs, operating temperature -25–50°C, priced around 5,000 Euros / 5,400 USD (in 2023). The device also has a built-in laser rangefinder (accurate to 1 m) and the capability to record videos or photos (see figures and video in this article).

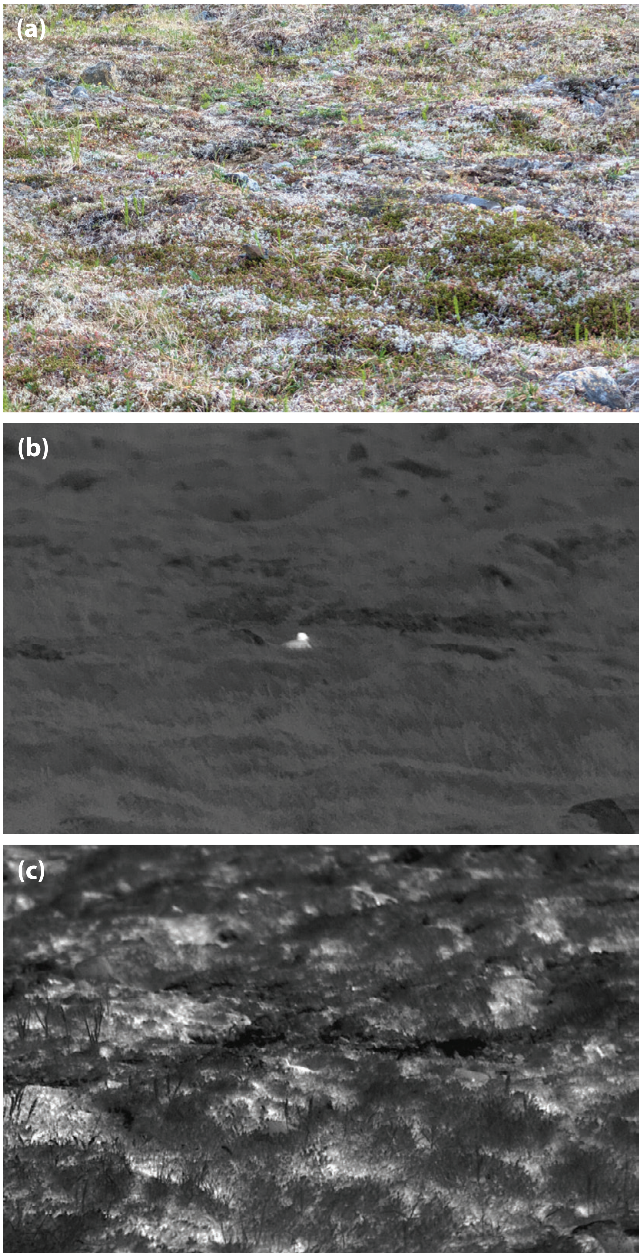

Fig. 1. (a) An incubating Red Knot under ambient viewing conditions; **(b)** the same knot through thermal-imaging binoculars under optimal conditions at the same time, and from the same distance (about 8 m); **(c)** the same nest site through thermal-imaging binoculars under sunny conditions. Note that the warm lichens look similar to the bird (photos: (a) Lorenzo Micolucci; (b&c) TO).

We used these thermal-imaging devices to search for nests and chicks of *roselaari* Red Knots in northwestern Alaska (64.0°N, 166.0°W), where their breeding ecology has been studied since 2010 (e.g. Tomkovich *et al.* 2018, Johnson *et al.* 2020, Lameris *et al.* 2022). Under optimal conditions, we estimated the detection range of the thermal binoculars for incubating adults at two nests. We approached the nests from a starting distance of 150 m, recording our ability to detect the incubating adult at 10-m intervals. We repeated this process for each of the four cardinal directions.

During the brood-rearing stage, we recaptured Red Knot chicks every three days to measure their growth rates and estimate survival. To locate these broods, we glued a VHF radio transmitter to the back of the attending adult (typically the male, although see Tomkovich *et al.* 2018 for exceptions), which we captured with a mist net on the nest or later with the aid of chick calls (Johnson *et al.* 2020). We could then find the general location of the chicks by tracking the adult's radio signal until it began uttering 'alarm' calls (Miller *et al.* 2023) and approaching the researchers. The chicks would then be stationary and hidden, sometimes scattered across several 10s of meters. Before we used thermal-imaging devices, we waited until the chicks began moving again, but this was time-consuming and there was often uncertainty whether all chicks in the brood were accounted for, a necessity for accurately estimating survival rates. Here, we examined the utility of the thermal-imaging devices to resolve these problems.

Additionally, we used the thermal-imaging binoculars to monitor mist-net catches of waders during dark nights in Banc d'Arguin, Mauritania (19.9°N, 16.3°W).

RESULTS & DISCUSSION

Finding wader nests

The thermal-imaging devices proved highly effective in locating incubating birds, making them stand out from their surroundings under optimal conditions (Figs. 1 & S1). This success led to the discovery of 16 nests in 2024, out of roughly 20 nests in the study area (an estimate based on three additional broods that were later encountered). Most studies using thermal imaging recognize that optimal conditions occur in the absence of direct solar radiation, which can create a mosaic of varying temperatures in the environment and reduce the contrast of incubating birds (Fig. 1). Stones and lichens absorb and retain heat, sometimes mimicking the appearance of birds even after sunset. Therefore, the best conditions typically occur early in the morning, after direct sunlight has been absent for several hours. These conditions can extend to late morning on cloudy days. Conversely, dense fog and heavy rain reduce detection ranges. Rain, however, tends to equalize environmental temperatures, potentially recreating optimal conditions.

Maximum detection distances varied depending on the surrounding habitat and topography and ranged between 40–120 m (Fig. 2). Incubating adults were always visible within 40 m, and in direct line of sight, they were detectable from distances >100 m. Therefore, using thermal imaging for nest monitoring eliminates the need to closely approach nests, reducing disturbance and potentially the risk of predation.

In our study areas, Red Knots breed in sparsely vegetated tundra, typically choosing slightly elevated spots for nesting, likely to enhance visibility or prevent flooding by snowmelt or rain. This, combined with their tendency to remain tightly on the nest, makes Red Knot nests relatively easy to detect with thermal-imaging devices. For other species that nest within dense vegetation, where direct views of the birds are obstructed, handheld thermal-imaging devices are less effective at longer distances (Boonstra *et al.* 1995). At closer distances, however, even camouflaged birds within vegetation are visible if there is a direct line of sight to any part of their body during optimal conditions. For species that flush from the nest when researchers are still distant (e.g. *Pluvialis* spp.), it is important to detect the incubating bird before it flushes. By walking in that direction, the nest can still be located even after the bird flushes, as the warm eggs will be visible once they come in direct view, albeit at a closer range than the incubating bird. Other incubating waders discovered using thermal imaging during this study included American Golden Plover *Pluvialis dominica*, Pacific Golden Plover *Pluvialis fulva*, Western Sandpiper *Calidris mauri*, and Rock Sandpiper *Calidris ptilocnemis*. Additionally, nests of other bird species were found, including Rock Ptarmigan *Lagopus muta*, Horned Lark *Eremophila alpestris*, Snow Bunting *Plectrophenax nivalis*, Lapland Longspur *Calcarius lapponicus*, Golden-crowned Sparrow *Zonotrichia atricapilla*, and Kittlitz's Murrelet *Brachyramphus brevirostris*.

Finding wader broods

The therma-imaging devices improved our ability to find chicks. When the radio signal indicated that an attending adult was nearby, the brood could be located quickly, and the number of (foraging) chicks present determined more easily from a distance, minimizing disturbance to the adult and chicks. If any hiding chicks were missed during captures, they could be found relatively easily with the thermal-imaging devices (Fig. 3). Chicks are generally easy to find under optimal conditions, as described for locating nests, but they could still be located during less optimal conditions. Moving chicks are particularly easy to detect, and they are searched for at closer distances. In addition, because natal plumage is less insulative, chicks radiate more heat than adults (Chappell 1980) and are therefore more visible (Fig. 3).

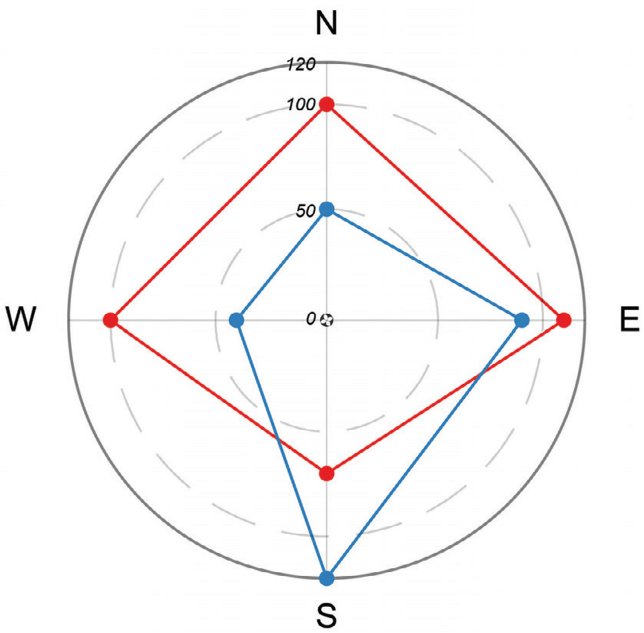

Fig. 2. Maximum detection distance (meters) for two incubating Red Knots viewed under favorable conditions from each of the four cardinal-compass directions. Variation in distance was induced by the topography surrounding the nest by either blocking or enabling a direct line of sight.

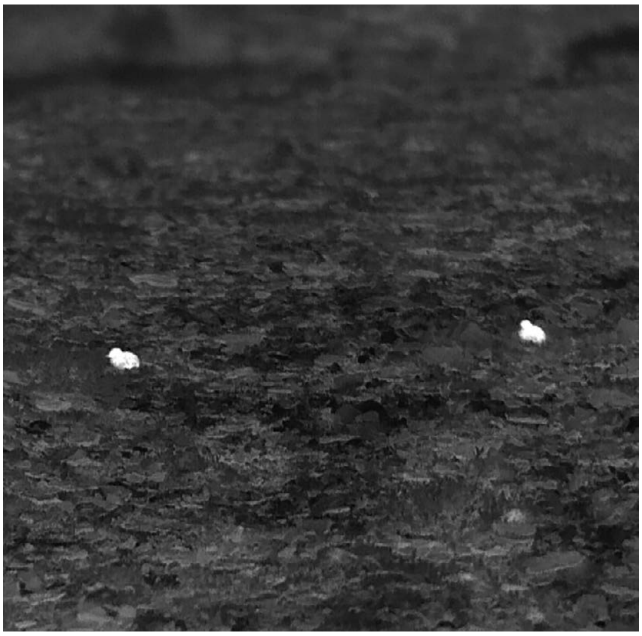

Fig. 3. Six-day-old Red Knot chicks viewed through thermal-imaging binoculars by approaching researchers, distance ~ 6 m (photo: TO).

Capturing waders at night

In addition to finding cryptic nesting birds during daylight, thermal imaging also provides 'night vision', which can be very useful for catching non-breeding waders with mist nets in the dark (Video S1), and we highly recommend its use for this purpose. With thermal-imaging devices, it is possible to monitor exactly what is happening at the nets and to determine how many birds are caught, and when. This ensures quick action when necessary and prevents disturbance at the wrong moment. In addition, it provides information when the targeted birds are not caught (e.g. if the nets are not perfectly positioned) and can help investigators reduce bycatch. For example, in Mauritania, when targeting Red Knots, we used thermal imaging to wait until smaller waders (mostly Dunlins *Calidris alpina*) passed through the capture area before opening the nets. Thermal imaging can also be useful when night-lighting (or dazzling), a catching method used in the dark where a bird is 'stunned' by bright light allowing a net to be dropped over it (Benítez-López *et al.* 2011). Thermal-imaging devices like the one we used enable researchers to sneak up on birds to the preferred distance, which can be measured accurately with the integrated rangefinder, before switching on the light.

In conclusion, handheld thermal-imaging devices can improve the efficiency of fieldwork greatly while reducing disturbance. Although we focus here on Red Knots, we believe that the devices have much broader applicability.

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ONLINE SUPPLEMENTARY INFORMATION

Video S1. A nocturnal mist-net catch in Banc d'Arguin, Mauritania using seven 18-meter nets (128 meters total) and filmed from approximately 50 meters. Birds are flying from the right towards a high tide roost on the left. Red Knots are flying in dense flocks in the back and some are ending up in the last two nets.

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