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A Refined Approach for Short-eared Owl Detection and Nest Localization in Arctic Environments

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ABSTRACT.—Short-eared Owl (*Asio flammeus*) populations have experienced substantial declines in North America, but long-term data from the Arctic are limited. We assessed the efficiency of aerial survey methods to evaluate nesting abundance, productivity, and population trends. We compared three helicopter-based survey methods across areas of varying sizes using line transects spaced at different intervals in northern Québec, Canada. Additionally, we documented nest detection rates from the aircraft with and without supplementary ground confirmation. We surveyed 962 km by helicopter and detected 54 Short-eared Owls, including 23 flushed individuals. Detection rates varied in relation to survey intensity, from ~2 to >6 owls/100 km. Flush rates followed a similar pattern (0.8–4.1 flushes/100 km). Nest detection ranged from 0.5 to 2.1 nests/100 km, depending on the method. Overall, we located 10 nests—half from the air and half from the ground—in dwarf birch (*Betula nana*) shrubland. Our results demonstrate that helicopter surveys are effective for detecting Short-eared Owls in remote arctic habitats, particularly when using intensive or targeted search methods. The number of detected nests remained relatively low, however, suggesting that, even with high-effort methods, locating nests is challenging due to their cryptic placement, the species' low flushing tendency, and the species' low overall density in the landscape. The fact that pairs tend to nest near one another suggests that more intensive searches should be targeted around a detected nest or individual. Overall, a strategic combination of the tested survey techniques can provide a realistic and scalable option for monitoring Short-eared Owls in remote tundra landscapes.

KEY WORDS: *abundance*; *detection methods*; *helicopter survey*; *productivity*; *tundra*.

UN ENFOQUE REFINADO PARA LA DETECCIÓN Y LOCALIZACION DE NIDOS *ASIO FLAMMEUS* EN AMBIENTES ÁRTICOS

RESUMEN.—Las poblaciones de *Asio flammeus* han experimentado disminuciones importantes en América del Norte, pero los datos de seguimiento a largo plazo provenientes del Ártico son escasos. Evaluamos la eficiencia de distintos métodos de prospección aérea para estimar la abundancia de parejas nidificantes, la productividad y las tendencias poblacionales. Comparamos tres métodos de censo con helicópteros en áreas de distintos tamaños utilizando transectos lineales separados a diferentes intervalos en el norte de Quebec, Canadá. Además, documentamos las tasas de detección de nidos desde la aeronave, con y sin confirmación complementaria desde tierra. Recorrimos 962 km en helicóptero y

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detectamos 54 *Asio flammeus*, incluidos 23 individuos que levantaron vuelo al ser perturbados. Las tasas de detección variaron en función de la intensidad del muestreo, desde ∼2 hasta >6 búhos/100 km. Las tasas de individuos que levantaron vuelo siguieron un patrón similar (0.8–4.1 individuos que volaron/100 km). La detección de nidos varió entre 0.5 y 2.1 nidos/100 km, dependiendo del método utilizado. En total, localizamos 10 nidos—la mitad desde el aire y la otra mitad en tierra—en matorrales de abedul enano (*Betula nana*). Nuestros resultados demuestran que los censos en helicóptero son eficaces para detectar a *Asio flammeus* en hábitats árticos remotos, especialmente cuando se emplean métodos de búsqueda intensivos o dirigidos. Sin embargo, el número de nidos detectados se mantuvo relativamente bajo, lo que sugiere que, incluso utilizando métodos de gran esfuerzo, localizar nidos es difícil debido a su ubicación críptica, a la baja tendencia de la especie a levantar vuelo ante perturbaciones y a su baja densidad general en el territorio. El hecho de que las parejas tiendan a nidificar unas cerca de otras sugiere que las búsquedas más intensivas deberían dirigirse alrededor de un nido o individuo previamente detectado. En conjunto, una combinación estratégica de las técnicas de prospección evaluadas puede proporcionar una opción realista y escalable para el seguimiento del *Asio flammeus* en paisajes remotos de tundra.

[Traducción del equipo editorial]

UNE APPROCHE PERFECTIONNÉE POUR LA DÉTECTION DU *ASIO FLAMMEUS* ET LA LOCALISATION DE SES NIDS DANS LES ENVIRONNEMENTS ARCTIQUES

RÉSUMÉ.—Les populations de *Asio flammeus* ont connu un déclin important en Amérique du Nord, mais les données à long terme provenant de l'Arctique sont limitées. Nous avons évalué l'efficacité des méthodes de relevé aérien pour estimer l'abondance des nids, la productivité et les tendances démographiques. Nous avons comparé trois méthodes de relevé par hélicoptère dans des zones de tailles variables, en utilisant des transects linéaires espacés à différents intervalles dans le nord du Québec, au Canada. De plus, nous avons documenté les taux de détection des nids depuis l'aéronef, avec et sans confirmation supplémentaire au sol. Nous avons survolé 962 km en hélicoptère et détecté 54 *Asio flammeus*, dont 23 individus débusqués. Les taux de détection variaient en fonction de l'intensité du relevé, allant d'environ 2 à plus de 6 hiboux par 100 km. Les taux de débusquage ont suivi une tendance similaire (0.8 à 4.1 envols/100 km). La détection des nids variait de 0.5 à 2.1 nids/100 km, selon la méthode. Au total, nous avons localisé 10 nids—la moitié depuis les airs et l'autre moitié depuis le sol—dans des zones de buissons de bouleaux nains (*Betula nana*). Nos résultats démontrent que les relevés par hélicoptère sont efficaces pour détecter les *Asio flammeus* dans les habitats arctiques isolés, en particulier lorsqu'on utilise des méthodes de recherche intensives ou ciblées. Le nombre de nids détectés est toutefois resté relativement faible, ce qui suggère que, même avec des méthodes exigeant beaucoup d'efforts, la localisation des nids est difficile en raison de leur emplacement discret, de la faible tendance de l'espèce à s'envoler lors d'un dérangement et de sa faible densité globale dans le paysage. Le fait que les couples aient tendance à nicher à proximité les uns des autres suggère qu'il faudrait concentrer les efforts de recherche autour d'un nid ou d'un individu repéré. Dans l'ensemble, une combinaison stratégique des techniques de recensement testées peut constituer une option réaliste et adaptable pour la surveillance des *Asio flammeus* dans les paysages de toundra isolés.

[Traduction par les auteurs]

INTRODUCTION

The Short-eared Owl (*Asio flammeus*) is associated with open habitats, such as grasslands, wetlands, and tundra (Wiggins et al. 2020). Since the 1970s, Short-eared Owl populations have declined 50–70% in North America (Booms et al. 2014, Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2021, Gahbauer et al. 2021). In Canada, this led to the species being listed as a species of special concern under Canada's Species at Risk Act in 2012, and more recently to a threatened status recommendation by COSEWIC (2021).

Long-term data supporting the decline of the Short-eared Owl (e.g., Christmas Bird Counts and North American Breeding Bird Surveys) come almost exclusively from areas located outside of the Arctic tundra in the United States and southern Canada. Relevant initiatives have documented the species' occurrence (e.g., Hunt and Gahbauer 2004, Gagnon et al. 2015) and modeled its habitat

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preferences (Miller et al. 2016, Hachey and Lemaître 2020). In these areas, conversion and fragmentation of grassland and wetland habitats for urbanization and agriculture are considered serious threats and could be linked with the observed decline of Short-eared Owls (COSEWIC 2021).

Short-eared Owls can be found in relatively large numbers in remote areas where vast expanses of tundra and wetland remain, and they tend to nest semicolonially (Wiggins et al. 2020). For example, during surveys for Ontario's second breeding bird atlas (2001–2005), helicopter surveys in the Hudson Bay Lowland resulted in a probability of observation seven times higher than the provincial average (Gahbauer 2007). Similarly, Shaffer (2019) reported that most Short-eared Owls in Québec appeared to be breeding in remote northern areas of the province, farther north than previously thought. Ultimately, these subArctic and Arctic areas may act as source populations for the species. Indeed, Short-eared Owls can disperse widely and breed hundreds of kilometers away from their natal site (Saurola 2002, Calladine et al. 2024).

Considering the apparent significance of Canada's north for the species, there is a pressing need for enhanced efforts to accurately document the distribution, abundance, and trends of these remote Short-eared Owl populations. Furthermore, this region faces two major threats: ongoing territorial development (including mining, railroad construction, and the building of hydroelectric power plants in the Canadian north) and shrubification of the low Arctic tundra (i.e., increased presence and growth of shrubs where they were previously less dominant) induced by climate change, which is expected to further reduce suitable breeding habitats for this species (COSEWIC 2021). It is thus crucial to assess the abundance, productivity, and population trends within this ecosystem before these threats have a greater impact on the species.

In Québec, the Short-eared Owl has been classified since 2003 as susceptible to be threatened or vulnerable and has had its own recovery plan since 2021 (Équipe de rétablissement des oiseaux de proie [EROP] 2021). The second provincial breeding bird atlas highlighted a significant decline for the species across the southern portion of the province; the number of units where the species was observed dropped from 120 to 52 between the first and second atlas surveys (Robert et al. 2019). Shaffer (2019) estimated that fewer than 100 breeding pairs could be found in Southern Québec annually. No inventory specifically designed for Short-eared Owls has been conducted in Nunavik, the vast region of northern Québec, where the species is thought to be more abundant during the breeding season than in southern Québec. Considering the overall situation of the species in the province, the species recovery plan recommended conducting surveys aiming to document population parameters and habitat use of the Short-eared Owl in Nunavik (ÉROP 2021).

Surveying Arctic regions poses many challenges. The territory is vast, with only a few sparse communities located mostly along the coastlines. There are no access roads outside of these villages. To resolve this issue, Booms et al. (2010) suggested a method for inventorying Short-eared Owls using helicopters in Alaska, flying linear transects at heights of 5–15 m above vegetation tops at approximately 40 km/h. This method allowed for counting owls in flight, but more importantly, the helicopter could prompt a flushing response from owls on or near the ground, likely indicating nesting activity. Although this method showed promise, its effectiveness in reliably locating nests was not quantified in relation to other potential survey methods. Given the potential to improve our understanding of Arctic-nesting Short-eared Owl populations, further investigation of this method was warranted.

This study aimed to assess the effectiveness of aerial surveys of varying intensity to gather data on abundance, productivity, and population trends for Short-eared Owls in the Arctic. Specifically, we compared three helicopter survey methods covering grids of various sizes and including line transects of variable spacing. Additionally, we documented nest detection rates from the aircraft with and without additional ground-based observations, and assessed clustering of locations where owls were detected.

METHODS

Study Area. Our study area was located in the vicinity of Kuujjuaq, Québec, Canada (58.1°N, 68.4°W; Fig. 1), within the shrub tundra biome characterized by generally low vegetation, relatively flat terrain, and some sparse rocky outcrops (Ministère des Forêts, de la Faune et des Parcs 2022). In 2023, we conducted surveys near Lake Ballantyne (∼70 km NW of Kuujjuaq) and along the Kuukuluk and Marralik Rivers (∼45 km NE of Kuujjuaq), down to the southern limits of the tundra biome. Short-eared Owls depend heavily on small mammal abundance for breeding (Wiggins et al. 2020). Several indicators suggested that 2023 was a high-prey year in the study area. Indeed, during surveys we

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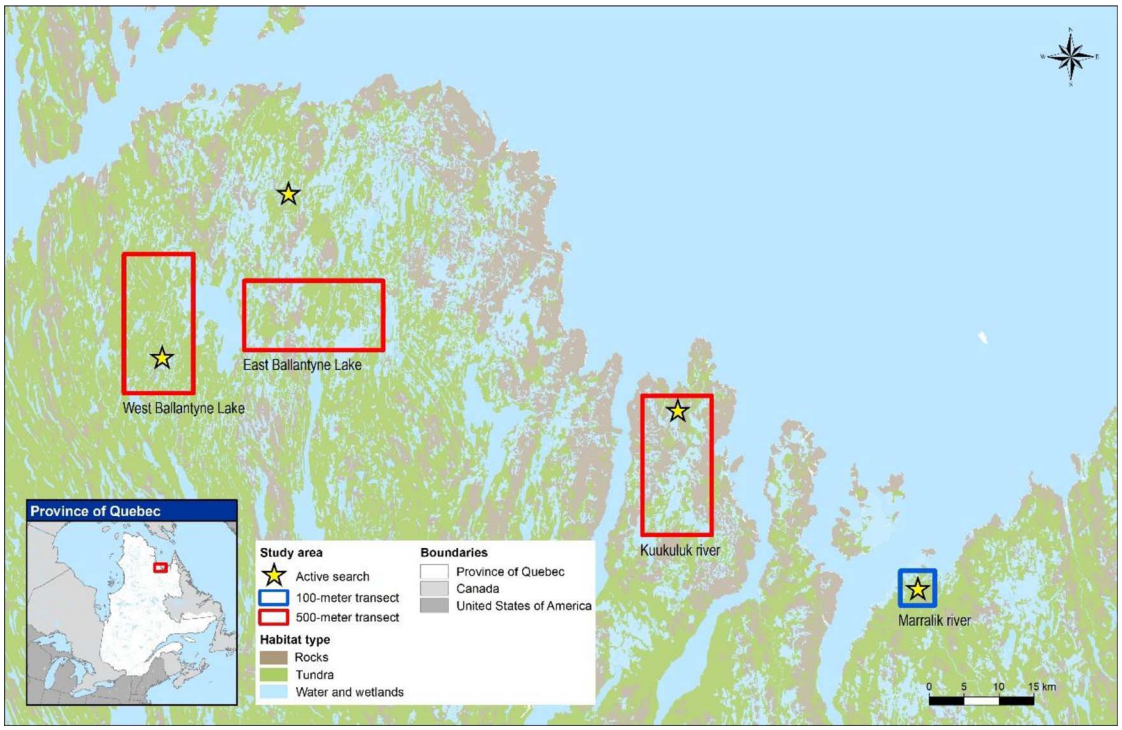


Figure 1. Study area in the Kuujjuaq region, Nunavik, Québec, Canada. Red rectangles represent the three 10 × 20-km extensive survey grids (500-m transect spacing) and the blue rectangle represents the 5 × 5-km intensive survey grid (100-m spacing). Stars indicate the approximate centers of the four ~2.5 × 2.5-km patches of suitable habitat where active searches were conducted.

observed small mammals directly from the helicopter and noted numerous freshly dug holes around nest sites. Fresh lemming (*Lemmus* and *Dicrostonyx* spp.) runways were also common, and several camera traps detected small mammals.

Surveys. We conducted surveys between 20 and 27 June 2023, using an A-Star 350 SD2 helicopter flying at approximately 40 km/h. We flew approximately 5 m above the vegetation, aligning with the minimum height used and suggested by Booms et al. (2010). The pilot, an observer in the front seat, and two additional observers in the rear seats were continuously watching for owls (perched or flying) in front, on the sides, and directly below the aircraft. When an owl was observed taking flight or seen flying, we recorded the GPS location of the aircraft and visually estimated the bird's distance and direction relative to the helicopter. Because distance and bearing were estimated visually, positional uncertainty increased with the bird's distance from the aircraft. Based on repeated field experience, close-range estimates (<50–75 m) generally had an accuracy within a few tens of meters, while observations made at greater distances (>150–200 m) carried proportionally larger uncertainty. Presented values are intended to provide an approximate indication of positional error rather than precise locations. Because detection opportunities arise from the linear distance covered along transects, we expressed survey effort per kilometer traveled. Average travel speeds were highly consistent among the three survey methods (36.7–42.7 km/h), so expressing effort per hour would have yielded nearly identical values.

We tested three survey methods. The first, called extensive survey, consisted of flying along 20-km-long transects distributed systematically every 500 m within a 10 × 20-km grid. We surveyed three such grids. We positioned grids by cross-referencing generally suitable habitats identified from satellite imagery (such as open grasslands, wetlands, and tundra) with previous observations of Short-eared Owls reported during the breeding season in previous years on participatory science platforms (eBird

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[Sullivan et al. 2009] and Suivi des populations d'oiseaux en peril [QuébecOiseaux 2026]; Fig. 1). Naturally, these long transects also crossed through unsuitable habitats, such as rocky areas and waterbodies. In these cases, we temporarily stopped data recording and increased flight speed to move efficiently to the next stretch of suitable habitat. As a result, we surveyed 100% of the transect segments that overlapped suitable habitat, but did not sample 100% of each grid's surface.

The second method, called intensive survey, was identical to the extensive survey except transects were spaced 100 m apart and the survey covered only a single 5 × 5-km grid (Fig. 1).

The third method, called active search, covered four compact patches of suitable habitat, each approximately 2.5 × 2.5 km in size (Fig. 1). We identified these survey areas using the same habitat-screening criteria as for the grid-based surveys (satellite-derived open habitats and past regional observations), but differed from grid areas in that they consisted almost exclusively of suitable habitat with no major rocky outcrops or large waterbodies. Within each of these ~6 km^2—patches, we flew habitat-guided transects spaced 100 m apart. The helicopter routes followed microhabitat cues—particularly dwarf birch (*Betula nana*), wetlands, and open tundra—and could deviate up to 50 m from the planned transect line when adjacent microhabitats appeared more suitable for nesting Short-eared Owls than the habitat directly beneath the aircraft.

The active search areas included two located within the extensive grid, one within the intensive grid, and one outside of any grid. We flew all active searches at times apart from the grid-based surveys, and we analyzed those data independently. Surveyors did not use prior detections from other methods to orient flight paths within these areas, ensuring that each method remained operationally independent.

Locating Nests. When the helicopter flushed owls, the observers conducted a thorough search from the aircraft by circling around the take-off location to find eggs or owlets in a radius of about 25 m (Booms et al. 2010). A flush event refers to an occurrence in which the helicopter disturbed an owl, causing it to fly away from its nest, roost, or resting spot. If two individuals took flight simultaneously, we recorded it as one flushing event. If eggs or owlets could not be located from the aircraft, we would land about 150–200 m away from the take-off location and shut down the helicopter engine. We would then wait for the owl to return to its nest. Once we had a good idea of where the nest might be, we walked to the location to find the nest. Similar to Booms et al. (2010), we did not conduct nest searches when owls were first seen flying at a distance, because these observations did not provide enough clues about potentially occupied nests.

Given the semi-colonial nature of the species (Wiggins et al. 2020), we assessed whether clustering occurred within the surveyed grids using nearest-neighbor distances of flush events and confirmed nests compared to a set of five random locations within the same grids where we detected at least five owls. We simulated 999 sets of five random points per grid and compared nearest distances using ANOVAs in R (R Core Team 2023).

RESULTS

During 7 d of field work, we flew 962 km and detected 54 owls (Table 1). Of those, 31 owls were already in flight when detected and 23 were flushed by the helicopter. We estimated the mean flush distance from the helicopter as 7 ± 15 m SD (range 0–60 m). We detected flying individuals from an

Table 1. Detection of Short-eared Owls in Nunavik, Québec, Canada, using three helicopter-based survey methods.

Method	Distance Sampled in Suitable Habitat (km)	Individuals Observed in Flight		Flush Events[a] (1 or 2 individuals)		Nests Found		
		Number	Per 100 km	Number	Per 100 km	Number	Per 100 km	Detection Rate (nests/flush)
Extensive survey	592	11	1.9	5	0.8	3	0.5	0.6
Intensive survey	128	5	3.9	4	3.1	2	1.6	0.5
Active search	242	15	6.2	10	4.1	5	2.1	0.5
Total	962	31		19[b]		10		

[a] A flush event occurred when the helicopter disturbed an owl, prompting it to take flight from its nesting, roosting, or resting spot. If two individuals took flight simultaneously, we recorded it as one flush event.

[b] We detected a total of 23 owls during the 19 flush events.

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average estimated distance of 170 ± 211 m from the helicopter (range 0–700 m).

Using the extensive method, we observed an average of two flying Short-eared Owls per 100 km of linear transect, half the value we observed with the intensive method (Table 1). The active search method further increased our detection rate, yielding more than 6 owls/100 km. We observed similar patterns for the flush rate, which ranged from 0.8 to 4.1 flushes/100 km with the extensive and active search methods, respectively.

Nest detection remained low overall, as we found approximately 0.5 nest/100 km of linear transect using the extensive method, and ranging from 1.6 (intensive survey) to 2.1 (active search) nests/100 km with the other methods. Overall, we detected 10 nests as a result of 19 flush events (53%; Table 1). All nests we found were in shrub habitats composed mainly of dwarf birch.

Of the 10 nests found, seven contained only eggs, one contained a mixture of eggs and nestlings, and two contained only nestlings. The 10 documented nests contained an average of 6.9 eggs or nestlings (range 2–11; Table 2). The age of the nestlings varied greatly, ranging from approximately 2–3 d old to more than 15 d old (Fig. 2; aging based on Wiggins et al. 2020). We located half of these nests directly from the helicopter. Four of these nests contained eggs that contrasted with the surrounding vegetation. We detected another nest from the helicopter when an incubating female was observed during an inspection of the flush location for a male. The female never flushed, but we confirmed the nest contents 2 d later (two eggs and seven nestlings). We located the other five nests (three containing eggs and two containing nestlings) during ground searches after landing the helicopter near a flush location. On 25 June, after a failed attempt to locate a nest from the helicopter, we found a juvenile Short-eared Owl opportunistically as it was walking on the tundra (Fig. 2), after the helicopter had landed 120 m away from the flush location. Because the young owl had walked away from its nest, we did not consider this a nest-location event.

Short-eared Owls exhibited a clustered breeding distribution in the Arctic tundra. Flush events and confirmed nests were located significantly closer to one another than expected under a random spatial distribution within the two survey grids where at least five owls were detected. Mean nearest-neighbor distances among observations were 1.07 km versus 3.22 km for random points in the Kuukuluk River grid ($F_{7,999} = 2.67$, $P = 0.001$) and 1.33 km versus 3.03 km in the Marralik River grid ($F_{8,999} = 2.40$, $P = 0.002$).

DISCUSSION

Although understanding nesting abundance, productivity, and population trends for the threatened Short-eared Owl is important, few studies have addressed the species in the tundra (e.g., Therrien 2010) due to prohibitive costs and logistical constraints (Booms et al. 2010). Therefore, limited information exists about the efficiency of survey methods, despite their importance for the development of viable long-term monitoring plans. Repeated surveys through time would improve understanding of conservation needs and help to guide management efforts for the species (Booms et al. 2010).

Our results highlight notable differences in detection rates across the three survey methods we compared, with the intensive grid method significantly outperforming the extensive grid method. The active search method, in particular, yielded the highest detection rates for both flying and flushed owls. This outcome underscores the value of targeted,

Table 2. Short-eared Owl nests found in the Kuujjuaq area, Nunavik, Québec, Canada, in June 2023.

Date	Latitude	Longitude	Number of Eggs	Number of Nestlings	Search Method
20-Jun-23	58.775799	−69.076894	11	0	Helicopter
20-Jun-23	58.761808	−68.993622	2	7	Helicopter
23-Jun-23	58.476410	−67.998018	0	7	Ground
23-Jun-23	58.457845	−67.988997	10	0	Helicopter
24-Jun-23	58.241000	−67.489632	7	0	Ground
24-Jun-23	58.235676	−67.494456	2	0	Helicopter
24-Jun-23	58.228644	−67.521868	5	0	Ground
25-Jun-23	58.239663	−67.483150	0	6	Ground
26-Jun-23	58.254917	−67.385555	6	0	Ground
26-Jun-23	58.712299	−69.103143	6	0	Helicopter

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Figure 2. Variation in color and size of Short-eared Owl nestlings observed during a 7-day study in June 2023 in northern Québec, Canada.

high-effort methods for detecting Short-eared Owls, especially in areas where the species' density appears low. The short flushing distances (mean 7 m, maximum 60 m) we observed suggest that nesting Short-eared Owls were reluctant to take flight when approached, even by a helicopter (also see Booms et al. 2010). This behavior likely reflects a reliance on camouflage—supported by their cryptic plumage—rather than flight as a primary defense mechanism (Wiggins et al. 2006). In addition, movement significantly enhances detectability, given that we detected flying owls at much greater distances (mean 170 m, maximum 700 m) than sedentary or flushed owls. This behavior emphasizes the need for more intensive and active survey methods to account for nesting individuals, which may be undercounted based on less-intensive approaches.

Nest detection rates during aerial surveys were nonetheless relatively low, depending on the method used. This indicates that detecting nests remains a significant challenge, largely due to the aforementioned cryptic behavior of Short-eared Owls (Møller et al. 2019) and the camouflaged nature of their nests (Wiggins et al. 2020). Nest detection from the helicopter depended on our ability to visually distinguish eggs or nestlings against the surrounding vegetation. Such visual cues, when visible, were often subtle, however, emphasizing the need for careful attention to small contrasts given that, even when we flushed owls, finding the nest was not guaranteed. The clustering tendency of Short-eared Owls reported here and elsewhere (Wiggins et al. 2020) suggests, however, that researchers could capitalize on this behavior and target areas where active searches could be conducted to increase detection. Indeed, once an owl is flushed or a nest is detected, there is a higher probability of finding another one nearby within a few kilometers (Arroyo and Bretagnolle 1999). Searches within a 10-km radius of a known nest should, therefore, yield a higher nest detection rate than elsewhere across the landscape (Arroyo and Bretagnolle 1999).

To our knowledge, the only prior published study on locating Short-eared Owl nests using helicopter surveys is Booms et al. (2010), which found only two nests after flushing 28 owls, yielding a 7% nest-finding success rate. They speculated that the low detection rate was not due to missed nests, given that the solid white eggs of Short-eared Owls typically contrast significantly with the surrounding vegetation. Our results suggested, however, that while the eggs are visually contrasting, owls often position their nests in a way that surrounding vegetation obscures detection from above. Indeed,

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only four of the 10 nests (40%) we located were identifiable using the white eggs as a clue, and nearly half of the nests containing only eggs (3/7) could not be detected from the helicopter. These findings suggest that despite the conspicuous color of the eggs, the owls' nesting behavior and environmental factors make nest detection particularly difficult.

It is also worth noting that while we detected relatively few nests overall, it remains unclear to what extent that reflected low density across the landscape (limited availability) or low success at observing those nests that were present (limited detection rate). Further studies comparing survey methods over grids where the absolute abundance is known are warranted to estimate actual detection rates of the evaluated methods.

Recent advances in using unmanned aerial vehicles (hereafter drones) to study wildlife offer potential alternatives for raptor studies (Charbonneau et al. 2024, Spaulding et al. 2024). However, this technology remains poorly suited for broad-scale nest detection of a cryptic and irruptive species such as the Short-eared Owl. First, most drone systems still suffer from limited endurance and operational range (battery life, payload constraints). This restricts coverage to a few kilometers in a single flight, which is insufficient for the large territories of tundra-nesting owls and the remote nature of the Arctic ecosystem. Second, although drones may induce weaker behavioral responses than helicopters (Charbonneau and Lemaître 2021), this reduced disturbance may paradoxically lower detection probability for flushed or mobile individuals compared to helicopter surveys. Third, helicopter surveys allow immediate landing and on-site verification (e.g., ground checks, observer repositioning) whereas drones generally remain airborne and remote, limiting adaptability in the field. For these reasons, drones are not yet a viable operational alternative for large-scale Arctic surveys, although future developments (extended endurance and automated detection) may help overcome some of these limitations.

Ground observations thus seem an important complement to aerial surveys and resulted in greater overall effectiveness during our study. For example, ground inspections confirmed nest contents when aerial observations were inconclusive, such as in cases where an incubating female remained stationary near a flushed male. Additionally, ground searches proved valuable for revealing juvenile owls that were missed during aerial surveys. Thus, we strongly recommend incorporating a ground observation period when a nest cannot be located from the air after flushing an owl. This technique effectively doubled our nest detection rate, highlighting the value of combining aerial and ground-based methods for accurate and comprehensive nest monitoring.

Our study also highlighted significant variation in nesting phenology among Short-eared Owls. While some nests contained unhatched eggs, others already had owlets that were old enough to leave the nest. Booms et al. (2010) and Wiggins et al. (2020) also reported wide variations in nest-initiation dates in the species. Given that nestlings lose their whitish color and adopt a more camouflaged pattern within only a few days after hatching, repeating the surveys twice in a season could improve detection of early and late nests.

While owlets remain too young to be mobile, landing away from a flush location and waiting for the female to return can help observers locate a nest. This method allowed us to find five nests that were otherwise undetectable from the helicopter, including two that contained only nestlings. Finding juveniles that have walked away from the nest would likely require more time waiting for an adult to bring them food, which would then reveal their presence and indicate a successful nesting attempt. Again, repeating the surveys a few weeks apart could help reduce the challenges of dealing with early and late nests.

The significantly higher detection rates observed with the active search method highlight its potential for population estimation. This method also required enhanced efforts, tighter logistical coordination, and increased financial resources, however, which may limit its scalability for large-scale or long-term surveys. In contrast, the intensive grid method—though slightly less effective for nest detection—offers a practical and efficient compromise. This method's closer transect spacing improved detection rates compared to the extensive grid, while flight time was reduced over unsuitable habitats by increasing speed. The intensive grid method also required less effort than active searching and allowed for a more standardized and repeatable survey design.

We conclude that the intensive grid method, although it did not estimate absolute abundance, represents a realistic and scalable option for monitoring Short-eared Owls in remote tundra landscapes. Insights from our study can support the development of robust monitoring programs for this elusive and declining species in northern environments.

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