Received: 9 July 2025 | Revised: 18 April 2026 | Accepted: 12 May 2026

DOI: 10.1002/jwmg.70238

THE JOURNAL OF WILDLIFE MANAGEMENT

THE WILDLIFE SOCIETY

RESEARCH ARTICLE

Enhancing detection of short-eared owls in Québec: Habitat quality, seasonal occurrence, and avian proxies

C. Casabona Amat[1] | M.-H. Hachey[2] | P. Côté[3] | J.-F. Therrien[1,4] | J. Lemaître[5]

[1]Observatoire d'oiseaux de Tadoussac, Les Bergeronnes, QC, Canada

[2]QuébecOiseaux, Montréal, QC, Canada

[3]Conservation de la nature Canada, Montréal, QC, Canada

[4]Hawk Mountain Sanctuary, Orwigsburg, PA, USA

[5]Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, Québec, QC, Canada

Correspondence

C. Casabona Amat, Pavillon Abitibi-Price, Bureau 2113, 2405, rue de la Terrasse, Université Laval, GV1 0A6, Québec (Québec), Canada.

Email: claracasabona@hotmail.com

Abstract

The short-eared owl (*Asio flammeus*) is one of the most widely distributed owl species in the world. However, several indicators suggest a decline in its population globally. In Canada, the Committee on the Status of Endangered Wildlife in Canada recently suggested the species be listed as threatened. Despite concerted efforts to gain a deeper understanding of the factors contributing to the decline in short-eared owl populations, there remains a significant dearth of information, particularly concerning its nesting environment. Using data from the Endangered Bird Monitoring Program from 1994 to 2019, we developed a breeding-season habitat quality model to identify the most suitable nesting areas in southern Québec, Canada. We also examined site fidelity at the species level by quantifying the proportion of sites repeatedly occupied across breeding seasons. We further evaluated whether presence during the non-breeding period predicted subsequent breeding-season presence, which could improve detection of short-eared owl during surveys. Finally, we tested for a correlation with several other bird species to act as reliable proxies of short-eared owl presence using freely available citizen-science data. Three covariates (altitude above sea level, proportion agriculture, proportion forest) best explained the probability of the species' occurrence. We observed low site fidelity, with only 17% of the sites being occupied in multiple years during the breeding season, and differences in short-eared owl habitat use between non-breeding and breeding seasons, emphasizing the importance of understanding inter-seasonal habitat dynamics for effective conservation. Several species have been regularly observed simultaneously with short-eared owls in high-quality habitat such as the clay-colored sparrow (*Spizella pallida*) and willow flycatcher (*Empidonax traillii*), but the most indicative species to act as a proxy seems to be the vesper sparrow (*Pooecetes gramineus*). This species could serve to enhance detection rates for short-eared owls in high-quality breeding habitats during the reproductive season.

KEYWORDS

Asio flammeus, breeding season, eastern North America, land cover, non-breeding season, proxy, short-eared owl, site fidelity

The short-eared owl (*Asio flammeus*) is commonly found across vast open landscapes on nearly every continent (Wiggins et al. 2020). Despite its wide distribution, there are growing concerns about the species' declining populations worldwide, with estimates suggesting a loss of 60% of its populations since 1970 (Rosenberg et al. 2019). This decline is particularly notable in North America (−1.6% per year over 50 years; Meehan et al. 2022), where the short-eared owl was once a relatively common breeder (Wiggins et al. 2020). At the national level, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recently recommended that the short-eared owl be listed as threatened (COSEWIC 2021), and in Québec it is on the list of species eligible for designation under the Act Respecting Threatened or Vulnerable Species (RLRQ, c. E-12.01) since 2003.

One of the main threats to the short-eared owl seems to be loss and degradation of nesting habitat, largely due to conversion of natural grasslands into agricultural lands or residential areas (Booms et al. 2014, Stanton et al. 2018, Wiggins et al. 2020). In temperate regions, this species often nests in pastures and hayfields, which have been increasingly converted into annual crops like corn and soybeans, land cover types the species tends to avoid (Shaffer 2019). In addition to agricultural lands, the species nests in marshes and wetlands, which have also declined in recent decades in eastern North America, primarily owing to land conversion and development, including drainage for agriculture, urban expansion, and road infrastructure (Pellerin and Poulin 2013, Zou et al. 2024), further reducing breeding opportunities. These large-scale landscape changes have greatly reduced the availability of suitable breeding environments in southern Québec, where current estimates suggest fewer than 100 breeding pairs remain (Shaffer 2019). Southern Québec therefore represents the core breeding region for the species within the province and the area where conservation actions and monitoring efforts are currently concentrated. However, the species scarcity in southern Québec further complicates monitoring efforts, necessitating proactive identification of highly favorable habitat to increase detection likelihood during surveys and improve documentation of territorial presence for conservation efforts.

Aspects of the species' natural history complicate population assessments. Traditional monitoring methods commonly used across North America, such as the Breeding Bird Survey or the Christmas Bird Count, mostly take place during daylight hours and are poorly suited for this crepuscular species (Booms et al. 2014). Limited vocalizations (Clark 1975), cryptic plumage, and ground-nesting behavior within dense vegetation (Rivard et al. 2011) further reduce detectability. Finally, the species' nomadic and irruptive movements make surveys challenging. In most areas across its North American range, short-eared owl movements favor regions harboring abundant prey (Poulin et al. 2001, Wiggins et al. 2020, Miller et al. 2023). Although they may return to the same breeding areas over consecutive years, the extent to which the same regions are also used during the non-breeding season remains uncertain. Similarly, the composition of avian communities associated with short-eared owl presence is poorly understood.

Because traditional survey methods yield low detection rates, detection of short-eared owls could be enhanced using other avian species as proxies. Species with conspicuous behaviors and vocalizations, if consistently associated with short-eared owls, may improve both the accuracy and the applicability of habitat models, as demonstrated elsewhere (Morelli 2015). Our first objective was to identify habitat covariates that best predict the presence of short-eared owls in temperate, continental ecosystems typical of eastern North America (i.e., southern Québec). To do so, we developed a breeding season habitat quality model (HQM), a spatial model predicting the probability of occurrence of short-eared owls based on environmental covariates, using breeding records data from citizen-science observation. Second, we evaluated whether observations made during the non-breeding season predicted breeding-season presence. Third, we aimed to identify bird species that could serve as proxies for short-eared owl presence in high-quality breeding habitats.

STUDY AREA

The study area covered 400,000 km^2 in the southern portion of the province of Québec, Canada. We defined this region based on documented occurrences of short-eared owls south of 50.5° latitude—the northern boundary of southern Québec (Robert et al. 2019). This latitude roughly delineated the agro-forested breeding landscapes of short-eared owls from the taiga and tundra ecosystems farther north, as reported in the Endangered Bird Monitoring Program (Suivi des populations d'oiseaux en péril du Québec; SOS-POP). This collaborative database, spearheaded by QuébecOiseaux and the Canadian Wildlife Service, with the support of the Ministère de l'Environnement, de la Lutte aux Changements Climatiques, de la Faune et des Parcs (MELCCFP), aims to pinpoint crucial habitats for endangered bird species and ensure their ongoing monitoring over time. Both professionals and amateur ornithologists actively contribute to this initiative. The SOS-POP database contains information about endangered birds, including breeding categories, locations, and observation dates. For this study, we created a 100-km-radius buffer around each known short-eared owl location (www.quebecoiseaux.org/fr/sos-pop, accessed 22 Jun 2021). These buffers were meant to capture potential dispersal or movement of species across landscapes, acknowledging that many ecological connectivity models require a maximum dispersal distance to define habitat networks. In doing so, we excluded from the study area large areas of forest, which are inhospitable for the species. The global merged buffer represented the likely range of the species in southern Québec during the breeding period. We excluded cells entirely composed of water. We then merged all these polygons to create our study area (Figure 1).

The region experienced 4 distinct seasons: spring (Mar–Jun), summer (Jun–Sep), autumn (Sep–Dec), and winter (Dec–Mar). The average annual temperature ranged from 3°C to 6°C, and average annual precipitation was approximately 1,000 mm, consisting of snow during winter and rain in spring and summer (Gérardin and McKenney 2001). The landscape was diverse: 66% of the area was dominated by mixed and boreal forest, interspersed with 8% wetlands, and 6% consisted of agricultural lands, mostly adjacent to human settlements in lowland areas. Elevation ranged from sea level to roughly 1,100 m, with generally flat to rolling topography (Ménard et al. 2013).

METHODS

Breeding season habitat quality model

We used observations from the SOS-POP database (1994–2019) to develop a habitat quality model (HQM) for short-eared owls. We restricted observations to the breeding period using standardized breeding evidence codes to exclude migrating individuals (Robert et al. 2019; F. Shaffer, Canadian Wildlife Service, personal communication)

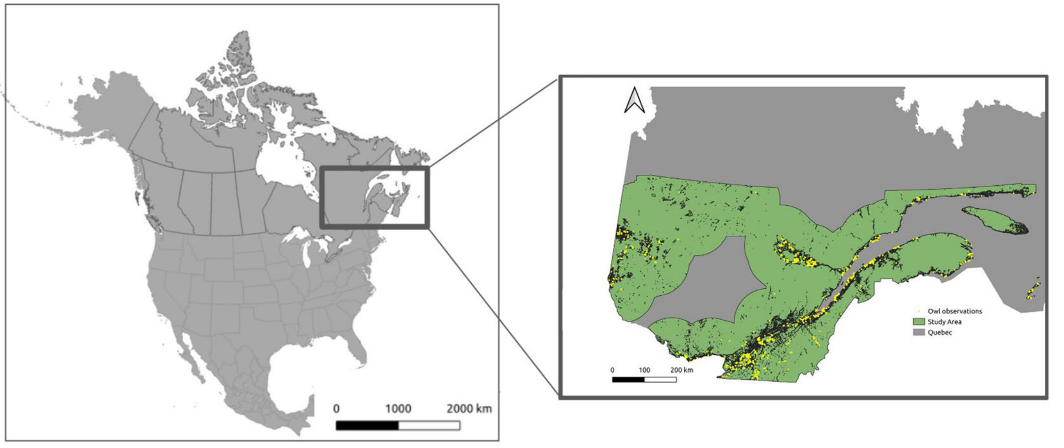

FIGURE 1 Study area in southern Québec, Canada, and short-eared owl observations used to build the habitat quality model from 1994 to 2019.

and we prioritized precise location information, at the second (<150 m) or minute (<1.5 km) level, to accurately capture the surrounding habitat.

We divided the study area into 800 × 800-m grid cells (64 ha), reflecting short-eared owl territory size (Wiggins et al. 2020). We evaluated 14 candidate environmental variables based on ecological relevance and previous models (Miller et al. 2016; Table S1), including land cover, topography, and climate. We derived land cover variables (agricultural, fallow, forested, wetland, inhabited) from ecoforestry maps (Ministère des Ressources naturelles et des Forêts 2021) and excluded natural grasslands because of their rarity and lack of representation in available datasets (Fyson et al. 2024). Additional spatial data included water bodies and the St. Lawrence River (Ministère des Ressources naturelles et des Forêts 2012). We obtained topographic (slope and altitude) and climatic variables (average annual temperature and precipitation) from provincial and global datasets (Fick and Hijmans 2017, Ministère des Ressources naturelles et des Forêts 2017, Natural Resources Canada 2021).

We used MaxEnt to model habitat suitability using presence-only data (Gormley et al. 2011, Royle et al. 2012) and fitted models using 15 replicate runs with random partitioning of occurrence data (80% training, 20% testing). We adjusted model settings to improve convergence following established recommendations (Young et al. 2011, Merow et al. 2013), and variable selection was based on correlation analysis and contribution to model performance (Blanchette and Landry 2015; Appendix S1). The final model retained 7 variables: agricultural land, fallow land, forested areas, slope, altitude, temperature, and precipitation ($r < 0.6$).

For each cell, our HQM provided a probability of short-eared owl occurrence during breeding season, ranging from 0 (null probability of finding the species) to 1 (100% probability of finding it). The probability was expressed as logistic values: 0–0.24 (not suitable), 0.25–0.49 (poorly suitable), 0.50–0.74 (suitable), and 0.75–1 (very suitable). We then translated these values into 4 levels of habitat quality (1: null, 2: low, 3: good, and 4: high). We evaluated model performance using mean area under the receiver operating characteristic curve (AUC) across replicates, which quantifies a model's ability to discriminate between presence and background (or absence) locations (Young et al. 2011) and ranges from 0.5 (no better than random) to 1.0 (perfect discrimination).

For an external validation database and to expand the seasonal observation analysis, we extracted short-eared owl observations from other citizen-science databases (i.e., eBird and NatureCounts). eBird is a semi-standardized citizen-science project where observers submit records in the form of lists of species encountered (Sullivan et al. 2009). We retrieved 2,712 observations of the species from 2014 to 2023, distributed across southern Québec from eBird. The

NatureCounts dataset contributed an additional 415 observations from various sources (Lepage 2019), including the Québec Breeding Bird Atlas and Québec Nocturnal Owls Survey (Table S2). After restricting the dataset to breeding-season observations (May–August) with spatially precise coordinates, we retained 383 records for model validation.

Seasonal site use

We assessed the presence of short-eared owls at locations where the species was recorded during the non-breeding (December to April) or breeding (May to August) seasons to evaluate whether observations during the non-breeding season could serve as indicators for their presence during the reproductive season. We established a distinct site identification system to correlate observations between the breeding and non-breeding seasons. We delineated sites by consolidating adjacent observation points within an 800-m radius (64 ha), corresponding to the typical spatial scale of a short-eared owl territory, which often spans an area of 50–100 ha during the breeding season (Wiggins et al. 2020).

We tested seasonal differences in habitat quality using a cumulative link mixed model, with habitat quality class (null, low, good, high) as the ordered response variable, season as a fixed effect, and year as a random intercept to account for repeated observations and variation in sampling effort. We implemented the model in R using the ordinal package (Christensen 2023), with parameters estimated by maximum likelihood (Breslow and Clayton 1993).

Identifying avian species as proxies for short-eared owl presence

To identify potential species that could be used as a proxy for the presence of short-eared owls within a high-quality habitat, we used a comprehensive analysis of all bird species in the study area using eBird data collected during the overall nesting season in the region (1 June to 31 August, to exclude potential migrants) from 2013 to 2022 (version: EBD_relJul-2023; Cornell Lab of Ornithology, Ithaca, New York, USA, dataset compiled July 2023). Restricting to this recent decade also ensured that proxy analyses reflected current habitat associations rather than historical distributions.

For each checklist, metadata included information on location, date, and sampling effort. We retained complete checklists with standardized effort (<500 minutes, <5 km), resulting in 131,024 lists with 2,174,049 observations. We then restricted analyses to lists within high-quality habitat (HQM level 4), yielding 32,488 lists. Sites were classified as owl-present when at least one short-eared owl record was available from SOS-POP, eBird, or NatureCounts within a 5-km radius during the study period. Sites without any known short-eared owl records were classified as owl-absent. This resulted in 196 owl-present sites and 5,440 owl-absent sites.

We created 100 subsets of checklist data, each randomly selecting 50 owl-present and 50 owl-absent sites (100 checklists per subset) to ensure balanced comparisons and reduce spatial bias. We retained checklist species detected in more than 5% of sites in the subset, resulting in 195 species included in the analysis. We quantified species associations using a relative occurrence frequency (ROF) and a co-occurrence index (CI), and tested differences between owl-present and owl-absent sites using Wilcoxon signed-rank and chi-squared tests (Appendix S2).

RESULTS

Habitat quality model

We obtained 159 short-eared owl high-quality breeding observations from the SOS-POP database to build the habitat quality model using MaxEnt and created a map displaying habitat quality classes associated with the probability of occurrence. Most of the study area's habitat quality was null (94%) and the rest was either low (3%), good (1%), or high (1%; Figure 2). High-quality habitats were primarily associated with low elevation and agricultural landscapes. Model performance was high (training AUC = 0.958; validation AUC = 0.937), and the model's gain was 2.238, which indicates an effect 9 times higher than that of random distribution (i.e., exp(2.238)). Mean altitude (29.2%), agricultural land (27.7%), and forest cover (23.3%) together accounted for 80.2% of model contribution (Table 1). Mean altitude also produced the highest jackknife training gain (1.2), indicating that it contained the greatest amount of unique predictive information among the variables considered. The probability of occurrence decreased with elevation and forest cover, while agricultural land showed a unimodal relationship, peaking at intermediate values (~70%; Figure 3). Variables with lower contributions had weaker or inconsistent effects on occurrence probability (Figure 3).

Among the 383 observations from the breeding period from external sources we used to validate the HQM, 51% of the recorded owl sightings were in cells identified as high-quality habitats (level 4), and 23% in good-quality habitats (level 3). Notably, these habitat categories combined accounted for only about 2% of the total area studied. This pattern provides independent support for the habitat quality model and its ability to identify suitable breeding habitat for short-eared owls.

Seasonal site use

Using the 2,656 short-eared owl observations from eBird and NatureCounts and through the application of an 800-m buffer, we identified 612 sites where short-eared owls were observed. During the breeding season, the owls were observed in 185 sites. Among these, 17% had observations in more than one year, but only 6% had observations during consecutive years. During the non-breeding season, short-eared owls were observed in 501 sites. Within these, 30% displayed observations during more than one year, and 11% in consecutive years. Only 12% of all sites (n = 74) had observations during both the non-breeding and breeding seasons.

Predictions from the cumulative link mixed model revealed significant seasonal differences in habitat use. The fixed effect estimate for the breeding season was 1.0678 (SE = 0.1379, Z = 7.742, P < 0.001), indicating that the

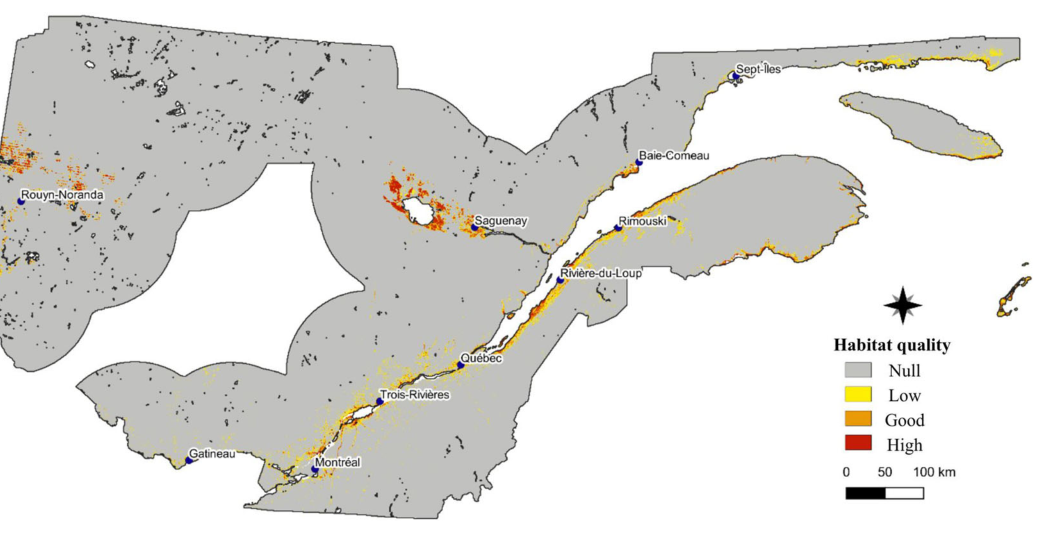

FIGURE 2 Habitat quality model (HQM) for short-eared owl in Québec, Canada (1994–2019) with color codes for habitat quality classes. The HQM is freely available and can be downloaded from Données Québec (https://www.donneesquebec.ca/recherche/dataset/mqh-hibou-marais-quebec-meridional).

TABLE 1 Relative contribution (%) and jackknife training gain of environmental variables included in the habitat quality model for short-eared owl in southern Québec, Canada, 1994–2019. Training gain values indicate the predictive information provided by each variable when used alone in the MaxEnt model.

Environment variables	Relative contribution (%)	Training gain
Mean altitude	29.2	1.2
Percentage of agricultural lands	27.7	0.8
Percentage of forested areas	23.3	1.0
Percentage of fallow lands	8.6	0.4
Average annual temperature	6.6	0.3
Average annual precipitation	2.5	0.1
Percentage of zero slope	2.1	0.3

odds of observing the species in higher-quality habitats (level 4) were 2.9 times greater during the breeding season compared to the non-breeding season. The random effect variance for year was 0.1657 (SD = 0.407), indicating moderate variability among years; in some years, the probability of owls selecting high-quality habitats was approximately 50% higher or 34% lower than the average, likely reflecting fluctuations in environmental conditions or survey effort. Threshold coefficients estimated to define the cut-off points between habitat quality levels suggest that habitat use in winter differs from that in the breeding season (Figure 4).

Other species as proxies of owl occurrence

Among the 195 species analyzed, the vesper sparrow (*Pooecetes gramineus*) stood out as the only species with both a high relative occurrence frequency (ROF = 0.74 ± 0.11 [SD]) and composite index (CI = 2.6), indicating a strong association with the presence of short-eared owls. The Wilcoxon statistic (V) for the vesper sparrow was 0 ($P < 0.001$), indicated that all paired differences between present and absent categories leaned entirely in one direction; vesper sparrows were observed, on average, 2.7 times more frequently in sites with short-eared owls than in sites without short-eared owls (Figure 5). This consistent difference highlights a clear distinction in occurrence between sites with and without short-eared owls, supporting a strong positive association between vesper sparrow presence and short-eared owl presence in high-quality habitats.

Other species also showed associations with the presence of short-eared owls, but their Wilcoxon statistics were >1, indicating less consistency in paired differences compared to the vesper sparrow. This was particularly the case for the clay-colored sparrow (*Spizella pallida*; ROF = 0.20, CI = 2.6, $V = 0$, $P < 0.001$) and the willow flycatcher (*Empidonax traillii*; ROF = 0.30, CI = 2.5, $V = 14$, $P < 0.001$).

DISCUSSION

We developed a habitat quality model for the short-eared owl to identify areas most conducive to detecting the species during the breeding season, using high-quality occurrence data. Developed to help guide conservation efforts in this declining species, this model is based on similar biological knowledge and empirical observations and provides practicable applications for conservation planning. Altitude best explained probability of presence during the breeding season. Similar to the findings by Miller et al. (2018) in western North America, the probability of

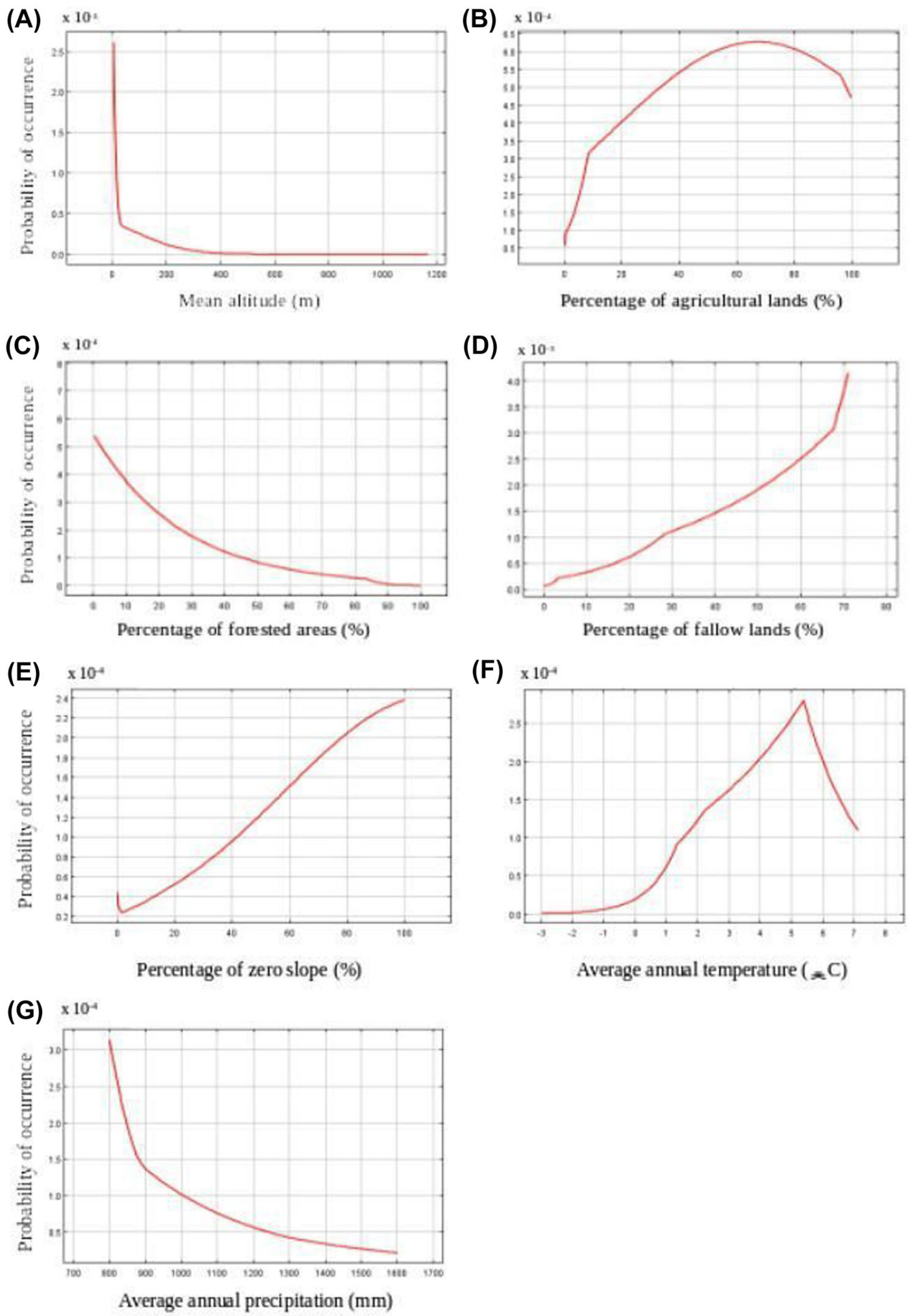

FIGURE 3 Probability of occurrence of the short-eared owl in Québec, Canada (1994–2019) as a function of the following individual variables: mean altitude (A), percentage of agricultural land (B), percentage of forested areas (C), percentage of fallow land (D), percentage of zero slope (E), average annual temperature (F), and average annual precipitation (G). The value for the probability of occurrence is very low because in the raw output format, the sum of the values assigned to each of the cells is equal to one (Phillips 2017); note the differences in scale among frames.

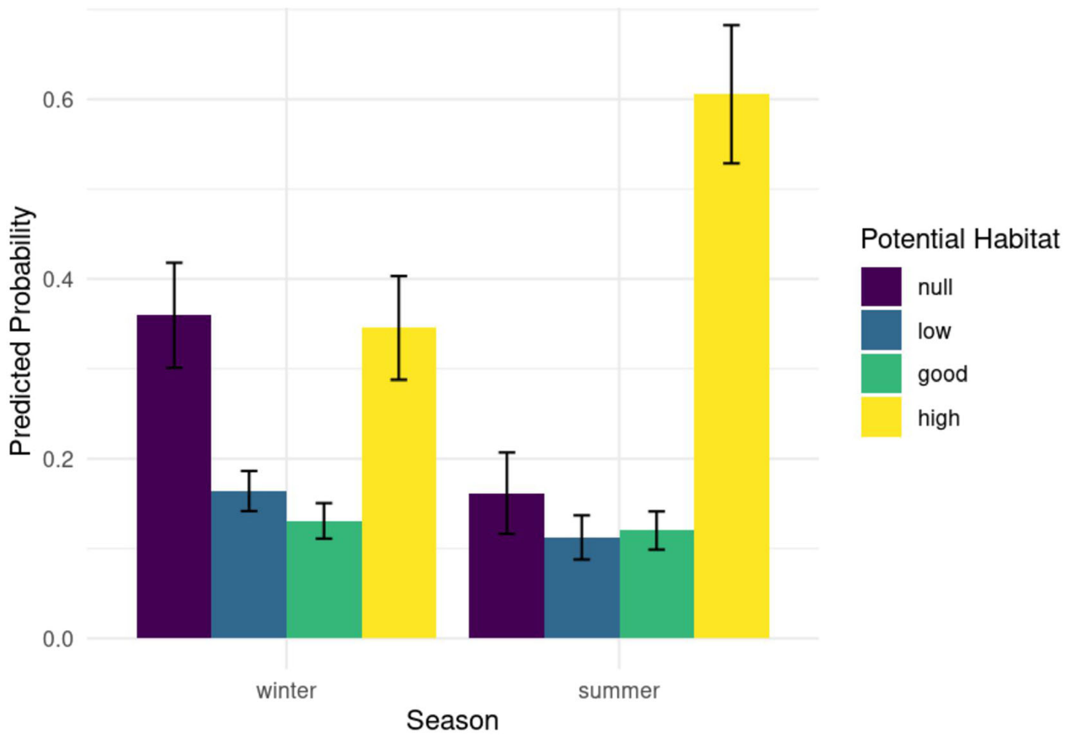

FIGURE 4 Predicted probabilities of short-eared owl occurrence in Québec, Canada across habitat quality classes during the breeding and non-breeding seasons in 1994–2019. The bars represent the predicted probabilities for each habitat classification, ranging from lowest to highest potential, with error bars indicating the 95% confidence intervals.

detecting the species dropped significantly with an increase in elevation. Indeed, short-eared owl presence is much higher along the St-Lawrence River, where altitudes are low, and also in agricultural areas that occur predominantly in lowlands. The percentage of agricultural land was the second variable contributing most to the model. The proportion of forested areas was also useful in predicting occurrence, which is not surprising considering the short-eared owl is an open-area species (Booms et al. 2014, Miller et al. 2016, Shaffer 2019).

The probability of short-eared owl presence increased substantially with the percentage of agricultural land but then declined after it reached 70%. Despite the importance of open areas such as agricultural environments for the short-eared owl (Herkert et al. 1999, Miller et al. 2016, SOS-POP 2021), the species might also seek habitat diversity for nesting. This hypothesis aligns with the results of Miller et al. (2018), who observed a decrease in short-eared owl presence when the proportion of agricultural, fallow, and grassland areas reached 100% within a 150-m radius. Our model performed well, with training and validation AUC values of 0.958 and 0.937, respectively. Although AUC values from presence-only models should be interpreted cautiously (Yackulic et al. 2013), they nevertheless indicate strong discrimination between observed and background locations.

Habitat quality models derived from MaxEnt are approximations of ecological reality and therefore have inherent limitations. First, the choice of environmental variables included in the MaxEnt analysis is constrained by the availability and resolution of spatial data. For instance, the period to which these variables relate must closely correspond to when presence points were collected. However, available data do not always meet this criterion. Meteorological layers, for example, were created from WorldClim data (1970–2000), while presence data were collected from 1994 to 2019. The discrepancy is more problematic for land cover layers, as some components can change abruptly or disappear, such as after forest harvesting or the conversion of a wetland into agricultural land. The layers used for our

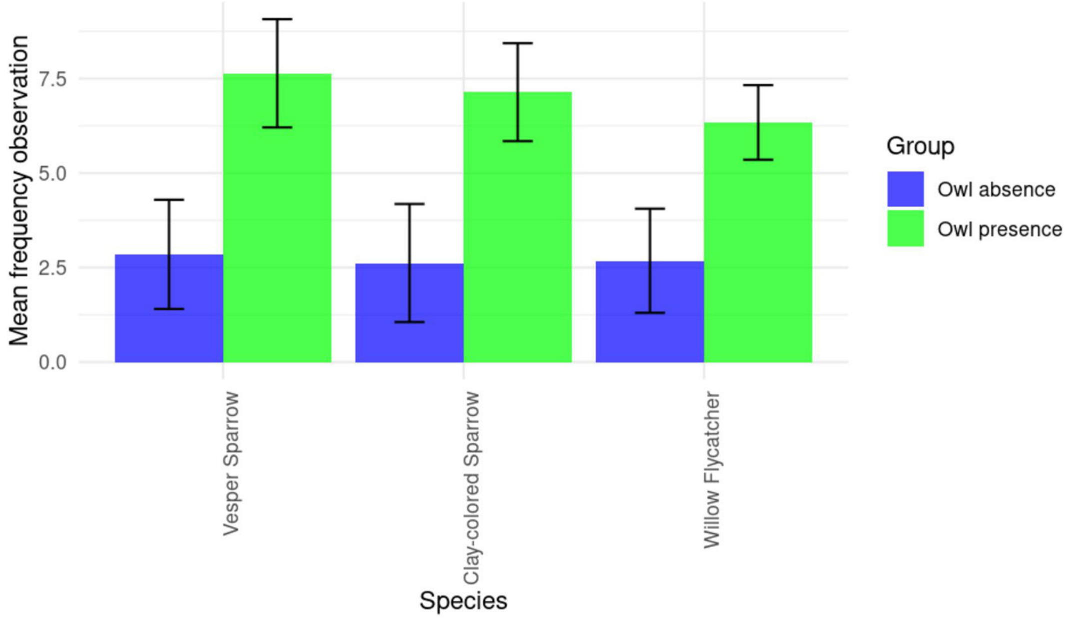

FIGURE 5 Best avian species to act as proxy for short-eared owl presence in high-quality habitats in Québec, Canada, 2013–2022. This bar plot displays the mean observation values of candidate proxy species in the presence and absence of short-eared owls. Each species is ordered by decreasing mean value in owl presence (green bars) and owl absence (blue bars). Error bars indicate the standard deviation for each group.

HQM were produced from 2003 data, a 9-year difference from our oldest occurrence records. Changes in land cover during this interval could have skewed certain model results. Although some habitat changes may have occurred during this interval and could have influenced certain model results, landscape change in southern Québec has primarily involved shifts within agricultural systems and localized urban expansion, while the dominant matrix of forest and agricultural land has remained relatively stable (Jobin et al. 2010, Fyson et al. 2024).

Our agricultural land layer did not distinguish between perennial and annual crops. However, this distinction is important for the short-eared owl, as annual crops are rarely used as breeding habitat (Wiggins et al. 2020). From 1993 to 2014, the proportion of Québec's agricultural land used for annual crops doubled between 1993 and 2014 (33% to 66%; Drapeau et al. 2019). This represents a significant habitat loss that our model cannot account for, as the affected lands retained an agricultural purpose. Lastly, the very weak influence of wetlands, a cover type favored by the short-eared owl, on the model may stem from the infrequent inventorying of peat bogs within the territory (COSEWIC 2008).

The analysis of seasonal occurrence revealed that only a small proportion of sites consistently hosted short-eared owls during both the breeding and non-breeding seasons. Habitat use differed between seasons, with a higher probability of detecting owls in high-quality breeding habitats during the breeding season. These results suggest that observations made during the non-breeding season may not reliably predict breeding occurrence. This finding is consistent with previous studies on the nomadic movements and irruptive breeding behavior of short-eared owls (Miller et al. 2023) that can be a response to prey availability, leading to high inter-season variation in occurrence.

Three species showed associations with high-quality short-eared owl habitat, but vesper sparrow exhibited the strongest and most consistent relationship. Within high-quality habitat, vesper sparrows were observed nearly 3 times more frequently at sites where short-eared owls were detected (7.64%) than at sites where they were absent (2.85%). The link between vesper sparrow occurrence and high-quality owl habitat highlights the shared reliance of both species on Québec's open grassland and agricultural environments, which are crucial for the breeding and hunting activities of short-eared owls (Wiggins et al. 2020, Miller et al. 2022). The vesper sparrow's affinity for transition zones between ecosystems, such as the edges of grasslands and woodlands or lightly vegetated areas in agricultural landscapes, aligns well with the ecological niches occupied by short-eared owls in Canada (Anstey et al. 1995). Despite the promising role of the vesper sparrow as a proxy species, it is important to consider that the associations observed may be influenced by the specific regional and temporal context of the data used, and the presence of this proxy species might not always reliably indicate owl presence in different areas or under different environmental conditions. Habitat changes and anthropogenic factors can alter species distributions, potentially affecting the reliability of proxy species as indicators. The study by Miller et al. (2023) highlights the importance of broad geographic monitoring to account for the nomadic nature of short-eared owls, emphasizing the need for multi-regional approaches.

MANAGEMENT IMPLICATIONS

Our model for habitat quality sheds new light on the relative importance of factors influencing the distribution of the short-eared owl in southern Québec. We recommend that this exercise be repeated using, if possible, more precise habitat data such as those becoming available from Agriculture and Agri-food Canada (Fisette et al. 2013) or Cropscape (Han et al. 2012). We also suggest simultaneously taking measures to improve the accuracy of data collected regarding nesting habitat. This could be achieved, for example, by adapting the SOS-POP monitoring protocol so that data collection matches the approach used in the new bird-monitoring protocol developed by the provincial environment ministry (MELCCFP). Beyond habitat modeling, our results highlight 2 additional implications for management. First, the limited overlap between breeding and non-breeding sites underscores the need for season-specific monitoring protocols, as observations made during the non-breeding season cannot reliably predict breeding occurrence. Second, the strong association between vesper sparrow presence and high-quality owl habitat suggests that proxy-based surveys using this more detectable species could improve the efficiency of short-eared owl monitoring, but this relationship should be formally tested. Integrating such proxy species into existing survey protocols may increase detection rates while reducing survey effort.

ACKNOWLEDGMENTS

We thank the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP) for financial and logistical support; colleagues who contributed to this study through discussions and technical support; the Équipe de Rétablissement des Oiseaux de Proie du Québec; the Observatoire d'Oiseaux de Tadoussac; and all participants who contributed data to the SOS-POP program. Artificial intelligence tools were used solely for language editing and clarity; all analyses, interpretations, and references were generated and verified by the authors.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

This study relied exclusively on previously collected observational data obtained from existing databases, including SOS-POP, eBird, and NatureCounts. No animals were captured, handled, banded, tagged, or experimentally manipulated by the authors as part of this research. Therefore, institutional animal care and use approval was not required.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

C. Casabona Amat https://orcid.org/0000-0001-8729-9217

REFERENCES

Anstey, D. A., S. K. Davis, D. C. Duncan, and M. Skeel. 1995. Distribution and habitat requirements of eight grassland songbird species in southern Saskatchewan. Saskatchewan Wetland Conservation Corporation, Regina, Saskatchewan, Canada.

Blanchette, P., and F. Landry. 2015. Modèle de répartition spatiale du dindon sauvage au Québec: présentation d'une méthode et de son application. Direction de la faune terrestre et de l'avifaune, Direction générale de l'expertise sur la faune et ses habitats, Secteur de la faune et des Parcs, Ministère des Forêts, de la Faune et des Parcs, Québec, Canada.

Booms, T. L., G. L. Holroyd, M. A. Gahbauer, H. E. Trefry, D. A. Wiggins, D. W. Holt, J. A. Johnson, S. B. Lewis, M. D. Larson, K. L. Keyes, and S. Swengel. 2014. Assessing the status and conservation priorities of the short-eared owl in North America. Journal of Wildlife Management 78:772–778.

Breslow, N. E., and D. G. Clayton. 1993. Approximate inference in generalized linear mixed models. Journal of the American Statistical Association 88:9–25.

Clark, R. J. 1975. A field study of the short-eared owl, Asio flammeus, in North America. Wildlife Monographs 47:1–67.

Committee on the Status of Endangered Wildlife in Canada [COSEWIC]. 2008. COSEWIC assessment and status report on the Short eared Owl (Asio flammeus) in Canada. COSEWIC, Ottawa, Canada.

Committee on the Status of Endangered Wildlife in Canada [COSEWIC]. 2021. Short-eared owl (Asio flammeus): COSEWIC assessment and status report. COSEWIC, Ottawa, Canada.

Christensen, R. 2023. Ordinal: regression models for ordinal data. R package version 2023.12-4.1. https://cran.r-project.org/package=ordinal

Drapeau, P., A. Leduc, B. Jobin, L. Imbeau, and M. Desrochers. 2019. Changements d'habitat et de répartition des oiseaux nicheurs d'un atlas à l'autre. Pages 34–55 *in* M. Robert, M.-H. Hachey, D. Lepage, and A. R. Couturier, editors. Second atlas of the breeding birds of southern Québec. Regroupement QuébecOiseaux, Canadian Wildlife Service (Environment and Climate Change Canada), and Bird Studies Canada, Montréal, Québec, Canada.

Fick, S. E., and R. J. Hijmans. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37:4302–4315.

Fisette, T., P. Rollin, Z. Aly, L. Campbell, B. Daneshfar, P. Filyer, A. Smith, A. Davidson, J. Shang, and I. Jarvis. 2013. AAFC annual crop inventory. International Conference on Agro-geoinformatics 2:270–274.

Fyson, V. K., J. F. Wilmshurst, and C. Callaghan. 2024. The changing agricultural landscape in Canada's Mixedwood Plains Ecozone (2011–2022) and the implications for biodiversity. Facets 9:1–11.

Gérardin, V., and D. W. McKenney. 2001. Une classification climatique du Québec à partir de modèles de distribution spatiale de données climatiques mensuelles: vers une définition des bioclimats du Québec. Ministère de l'Environnement, Québec, Canada.

Gormley, A. M., D. M. Forsyth, P. Griffioen, M. Lindeman, D. S. L. Ramsey, M. P. Scroggie, and L. Woodford. 2011. Using presence-only and presence–absence data to estimate the current and potential distributions of established invasive species. Journal of Applied Ecology 48:25–34.

Han, W., Z. Yang, L. Di, and R. Mueller. 2012. CropScape: a web service based application for exploring and disseminating US conterminous geospatial cropland data products for decision support. Computers and Electronics in Agriculture 84:111–123.

Herkert, J. R., S. A. Simpson, R. L. Westemeier, T. L. Esker, and J. W. Walk. 1999. Response of northern harriers and short-eared owls to grassland management in Illinois. Journal of Wildlife Management 63:517–523.

Jobin, B., C. Latendresse, M. Grenier, C. Maisonneuve, and A. Sebbane. 2010. Recent landscape change at the ecoregion scale in Southern Québec (Canada), 1993–2001. Environmental Monitoring and Assessment 164:631–647.

Lepage, D. 2019. NatureCounts: a data management system for biodiversity monitoring and conservation. Bird Studies Canada, Saskatoon, Saskatchewan, Canada. https://www.naturecounts.ca

Meehan, T. D., G. S. LeBaron, K. Dale, A. Krump, N. L. Michel, and C. B. Wilsey. 2022. Trends in relative abundance for birds wintering in the continental USA and Canada: Audubon Christmas Bird Counts, 1966–2021. Version 4.0. National Audubon Society, New York, New York, USA.

Ménard, S., M. Darveau, and L. Imbeau. 2013. The importance of geology, climate, and anthropogenic disturbances in shaping boreal wetland and aquatic landscape types. Ecoscience 20:399–410.

Merow, C., M. J. Smith, and J. A. Silander Jr. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. Ecography 36:1058–1069.

Miller, R. A., N. Paprocki, M. J. Stuber, C. E. Moulton, and J. D. Carlisle. 2016. Short-eared owl (Asio flammeus) surveys in the North American Intermountain West: utilizing citizen scientists to conduct monitoring across a broad geographic scale. Avian Conservation and Ecology 11(1):3.

Miller, R. A., C. Battistone, H. Hayes, M. D. Larson, C. Tomlinson, E. Armstrong, N. Paprocki, J. B. Buchanan, Z. Nelson, J. D. Carlisle, and C. E. Moulton. 2018. Western Asio flammeus Landscape Study annual report. Version 1.0. Intermountain Bird Observatory, Boise, Idaho, USA.

Miller, R. A., J. B. Buchanan, T. L. Pope, J. D. Carlisle, C. E. Moulton, and T. L. Booms. 2022. Short-eared owl land-use associations during the breeding season in the western United States. Journal of Raptor Research 56:273–286.

Miller, R. A., J. B. Buchanan, T. L. Pope, J. D. Carlisle, C. E. Moulton, and T. L. Booms. 2023. Temporal and spatial population dynamics of the nomadic short-eared owl across the western United States. Journal of Wildlife Management 87:e22369.

Ministère des Ressources naturelles et des Forêts. 2012. Geographic and administrative database Données Québec. https://www.donneesquebec.ca. Accessed 6 Jul 2021.

Ministère des Ressources naturelles et des Forêts. 2017. Slope class (BDTQ) Données Québec. https://www.donneesquebec.ca. Accessed 6 Jul 2021.

Ministère des Ressources naturelles et des Forêts. 2021. Carte écoforestière originale et résultats du quatrième inventaire. Québec, Canada. Accessed 6 Jul 2021.

Natural Resources Canada. 2021. Canadian digital elevation model Government of Canada. https://open.canada.ca/data/en/dataset/7f245e4d-76c2-4caa-951a-45d1d2051333. Accessed 6 Jul 2021.

Morelli, F. 2015. Indicator species for avian biodiversity hotspots: combination of specialists and generalists is necessary in less natural environments. Journal for Nature Conservation 27:54–62.

Pellerin, S., and M. Poulin. 2013. Analyse de la situation des milieux humides au Québec et recommandations à des fins de conservation et de gestion durable. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs, Québec, Canada.

Phillips, S. J. 2017. A brief tutorial on MaxEnt. American Museum of Natural History, New York, New York, USA. http://biodiversityinformatics.amnh.org/open_source/MaxEnt/

Poulin, R. G., T. I. Wellicome, and L. D. Todd. 2001. Synchronous and delayed numerical responses of a predatory bird community to a vole outbreak on the Canadian prairies. Journal of Raptor Research 35:288–295.

Rivard, A., F. Shaffer, and G. Falardeau. 2011. Suivi de la nidification des espèces d'oiseaux en péril à l'île aux Grues et l'île aux Oies, été 2007. Environment Canada, Canadian Wildlife Service, Québec, Canada.

Robert, M., M.-H. Hachey, D. Lepage, and A. R. Couturier, editors. 2019. Second Atlas of the Breeding Birds of Southern Québec. Regroupement QuébecOiseaux, Canadian Wildlife Service (Environment and Climate Change Canada), and Bird Studies Canada, Montréal, Québec, Canada.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra. 2019. Decline of the North American avifauna. Science 366:120–124.

Royle, J. A., R. B. Chandler, C. Yackulic, and J. D. Nichols. 2012. Likelihood analysis of species occurrence probability from presence-only data for modelling species distributions. Methods in Ecology and Evolution 3:545–554.

Shaffer, F. 2019. Hibou des marais. Pages 312–313 *in* M. Robert, M.-H. Hachey, D. Lepage, and A. R. Couturier, editors. Second Atlas of the Breeding Birds of Southern Québec. Regroupement QuébecOiseaux, Montréal, Québec, Canada.

Suivi des populations d'oiseaux en péril du Québec [SOS-POP]. 2021. Banque de données sur les populations d'oiseaux en situation précaire au Québec. Regroupement QuébecOiseaux, Montréal, Québec, Canada.

Stanton, R. L., C. A. Morrissey, and R. G. Clark. 2018. Analysis of trends and agricultural drivers of farmland bird declines in North America: a review. Agriculture, Ecosystems & Environment 254:244–252.

Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142:2282–2292.

Wiggins, D. A., D. W. Holt, and S. M. Leasure. 2020. Short-eared owl (Asio flammeus). Birds of North America. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.sheowl.01

Yackulic, C. B., R. Chandler, E. F. Zipkin, J. A. Royle, J. D. Nichols, E. H. C. Grant, and S. Veran. 2013. Presence-only modelling using MaxEnt: when can we trust the inferences? Methods in Ecology and Evolution 4:236–243.

Young, N., L. Carter, and P. Evangelista. 2011. A MaxEnt model v3.3.3c tutorial (ArcGIS v10). Colorado State University, Fort Collins, Colorado, USA.

Zou, Z., C. Huang, M. W. Lang, L. Du, G. McCarty, J. C. Ingebritsen, J. Harner, R. Griffin, W. Gong, and J. Lu. 2024. Hotspots of wetland loss to impervious surfaces in the conterminous United States. Science of the Total Environment 948:174787.

Associate Editor: Ying Chen.

SUPPORTING INFORMATION

Additional supporting material may be found in the online version of this article at the publisher's website.

How to cite this article: Casabona Amat, C., M.-H. Hachey, P. Côté, J.-F. Therrien, and J. Lemaître. 2026. Enhancing detection of short-eared owls in Québec: Habitat quality, seasonal occurrence, and avian proxies. Journal of Wildlife Management e70238. https://doi.org/10.1002/jwmg.70238