

# Status and monitoring of Short-eared Owls (*Asio flammeus*) in North and South America

## Estatuto e monitorização da coruja-do-nabal (*Asio flammeus*) na América do Norte e do Sul

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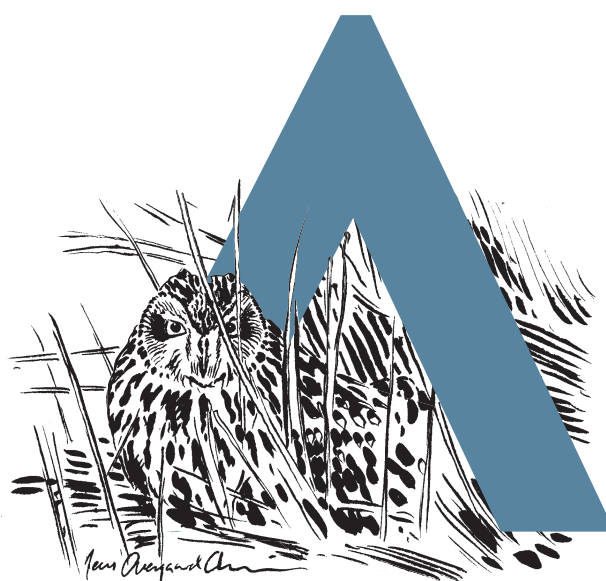
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## ABSTRACT

The breeding range of the Short-eared Owl (*Asio flammeus*) in North America includes all 13 Canadian provinces and territories, and approximately 25 states in the United States; the wintering range extends south to northern Mexico. It is listed as a species of Special Concern in Canada under the Species at Risk Act and subject to special protection in Mexico, but is not covered under the United States Endangered Species Act, although NatureServe has ranked the species as imperiled or critically imperiled in 21 states. In South America, it is found in eight countries, and is considered vulnerable in Argentina. Its conservation status is highly influenced by assessment of population trends, which are derived from multiple sources, each of which has advantages and limitations. In North America, both the Breeding Bird Survey and Christmas Bird Count reveal a widespread decline over the past half century, especially in the midwest and northeast United States. Several second-generation state and provincial breeding bird atlases have shown a reduction in the occurrence of Short-eared Owls compared to initial results approximately 20 years earlier. Overall though, traditional multi-species monitoring programs have not been effective at assessing Short-eared Owl populations. The Western *Asio flammeus* Landscape Study (WfLS) is the first regional monitoring effort specific to this species, using standardized surveys and modeling the results using occupancy analysis. Over its first three years, it has already yielded

valuable data on population fluctuations, and the WAfLS approach can be readily adapted to other regions. In South America, monitoring to date has been more limited and further research is required, but it is thought there have also been widespread declines related to habitat loss.

**Keywords:** *Asio flammeus*, monitoring, Short-eared Owl, status, trends

## RESUMO

A área de reprodução da coruja-do-nabal (*Asio flammeus*) na América do Norte inclui as 13 províncias e territórios Canadianos e 25 estados nos Estados Unidos. A área de invernada estende-se para Sul até ao norte do México. Está listada como espécie de *Special Concern* no Canadá no âmbito da Lei de Espécies em Risco e sujeita a proteção especial no México, mas não está abrangida pela Lei de Espécies Ameaçadas nos Estados Unidos, apesar de a organização *NatureServe* ter classificado a espécie como ameaçada ou criticamente ameaçada em 21 estados. Na América do Sul, está presente em oito países e é considerada vulnerável na Argentina. O seu estatuto de conservação é muito influenciado por estudos de tendências populacionais derivados de várias fontes, cada uma com vantagens e limitações. Na América do Norte, o Censo de Aves Nidificantes e a Contagem de Aves no Natal revelam um declínio generalizado ao longo do último meio século, especialmente no médio-oeste e no nordeste dos Estados Unidos. Vários atlas de aves reprodutoras de segunda geração, ao nível do estado ou da província, revelaram uma diminuição da ocorrência de coruja-do-nabal comparativamente aos resultados obtidos cerca de 20 anos antes. No geral, porém, os programas de monitorização multi-específicos não têm sido eficazes na avaliação das populações de coruja-do-nabal. O *Western Asio flammeus Landscape Study* (WAfLS) é o primeiro esforço de monitorização regional dirigido a esta espécie através de métodos de censo padronizados e modelação de resultados com análise de ocupação. Nos primeiros três anos, o estudo já produziu informação importante sobre flutuações populacionais e a abordagem WAfLS pode ser facilmente adaptada a outras regiões. Até à data, a monitorização na América do Sul tem sido mais limitada, sendo necessária mais investigação, embora se estime que também tenham ocorrido declínios generalizados devido à perda de habitat.

**Palavras-chave:** *Asio flammeus*, coruja-do-nabal, estatuto, monitorização, tendências

## Introduction

The Short-eared Owl (*Asio flammeus*) has the largest global distribution of any owl species; in the western hemisphere, its range extends from the northern edge of Alaska (71.3°N) to the southern tip of South America (55.7°S) (Duncan 2003). In North America, it breeds in all 13 Canadian

provinces and territories and roughly 25 states in the United States (U.S.), including Alaska and most of the lower 48 states north of approximately 42°N; its regular wintering range extends from five provinces in southern Canada throughout the lower 48 states and into northern Mexico (Wiggins

et al. 2006). In South America, the Short-eared Owl is a permanent resident of most of Chile, Argentina, Paraguay, and Uruguay, and parts of Brazil, Peru, Colombia, and Venezuela. Although widespread, the species is uncommon to rare in much of its range, and has experienced long-term declines in North America, as well as in parts of Europe (COSEWIC 2008, European Commission 2016). Multiple threats to the species have been recognized, including loss of habitat through intensification of agriculture, urbanization and reforestation; and mortality through rodenticide poisoning, vehicle collisions, and mowing and harvesting (Duncan 2003, Wiggins et al. 2006, BirdLife International 2016, Environment Canada 2016).

Despite these concerns, relatively little conservation action has targeted Short-eared Owls, in part because its population status and trends are poorly documented in much of its range (Booms et al. 2014). In North America, there are several long-term programs to monitor bird populations, such as the Breeding Bird Survey (BBS), Christmas Bird Count (CBC), and breeding bird atlases (BBAs), but all of these have limitations in documenting trends in Short-eared Owls (Booms et al. 2014). Limited conservation funding and efforts tend to focus on other species for which declines are clearly documented and overlook those such as the Short-eared Owl where trends are less clear. In South America, knowledge about the distribution and abundance of the Short-eared Owl is even more limited.

Our objectives were to: 1) Summarize the status of the Short-eared Owl throughout its North and South American range; 2) Evaluate and compare existing sources of long-term bird data for effectiveness at monitoring Short-eared Owl trends; 3) Implement and evaluate a monitoring protocol specific to the Short-eared Owl; and 4) Provide recommendations to improve Short-eared Owl trend and status assessments.

## Methods

### Status review

We compiled the current legal status for the Short-eared Owl for each country (and in Canada and the U.S., for each province, territory, and state) by consulting the official websites for the relevant department in each jurisdiction (e.g., Ministry of Natural Resources, Division of Wildlife). We accessed the most recent (2016) national (N) and state/provincial/territorial (S) conservation rankings for the Short-eared Owl in North America through NatureServe Explorer (NatureServe 2018).

### Trend analysis

The North American BBS is a standardized citizen science roadside survey that was started in 1966 and has become the basis for population and trend estimates for hundreds of species (Hudson et al. 2017). Each BBS route comprises 50 stops, 800 m apart, and is surveyed once annually during the peak of the breeding season. The Canadian Wildlife Service derives population trends for species from BBS data using a hierarchical Bayesian model (Smith et al. 2014). We reviewed long-term (1970-2016) and short-term (2006-2016) BBS trends for the Short-eared Owl at the national scale (U.S. and Canada), for the entire BBS study area (continental-scale), and for individual states and provinces. We did not use the published estimates of population trends from the BBS data (e.g., Sauer et al. 2017, ECCC 2017a) that rely on year-to-year, pairwise comparisons of abundance between the first and last years, because they are designed to be sensitive to annual population fluctuations that are well supported by the data (Smith et al. 2014). Because Short-eared Owl observations in the BBS data show extreme annual fluctuations (annual indices of abundance regularly fluctuate by a factor of two between years)

that most likely reflect movements of owls in and out of the BBS survey-area and not continental population fluctuations, we instead used an alternative estimate of long-term trend that is less sensitive to annual fluctuations. This estimate uses the slope of a log-linear regression through the published indices of annual abundance as a better estimate of the overall average rate of change in the population (hereafter, “slope-trend”). Using the full Markov chain Monte Carlo (MCMC) output from the standard hierarchical Bayesian analysis, we calculated the 95% credible intervals of these slope-trends as a measure of uncertainty. We calculated trends for the full BBS study area (“North America”), Canada, the U.S., and each of the states and provinces, to demonstrate the spatial patterns in population trends.

BBAs have been published for 41 U.S. states and eight Canadian provinces, and are currently underway for the first time in an additional province. They typically are based on field observations from hundreds of volunteer participants over a period of several years, and map the distribution of possible, probable, and confirmed breeding records for each species in a region. In jurisdictions where “second generation” atlases have been completed, maps or text generally illustrate changes in populations since the first atlas. We focused on the 13 states and six provinces where a second atlas has been completed, to describe changes in the occurrence of Short-eared Owls.

The CBC was started at 25 locations in 1900 and has grown to be an annual tradition throughout North America and beyond. Data are collected once annually between 14 December and 5 January at each 24 km radius count circle, maintained in the same place over time. Population trends are derived from the CBC data using a hierarchical Bayesian model (Soykan et al. 2016). We included updated long-term (1970-2016) and short-term (2006-2016) trend estimates at the continental scale,

as well as long-term trends for states and provinces (Meehan et al. 2018). As we did for the BBS, we used the full MCMC output to calculate slope-trends for each state and province, Canada, the U.S., and North America (Canada and the U.S. combined).

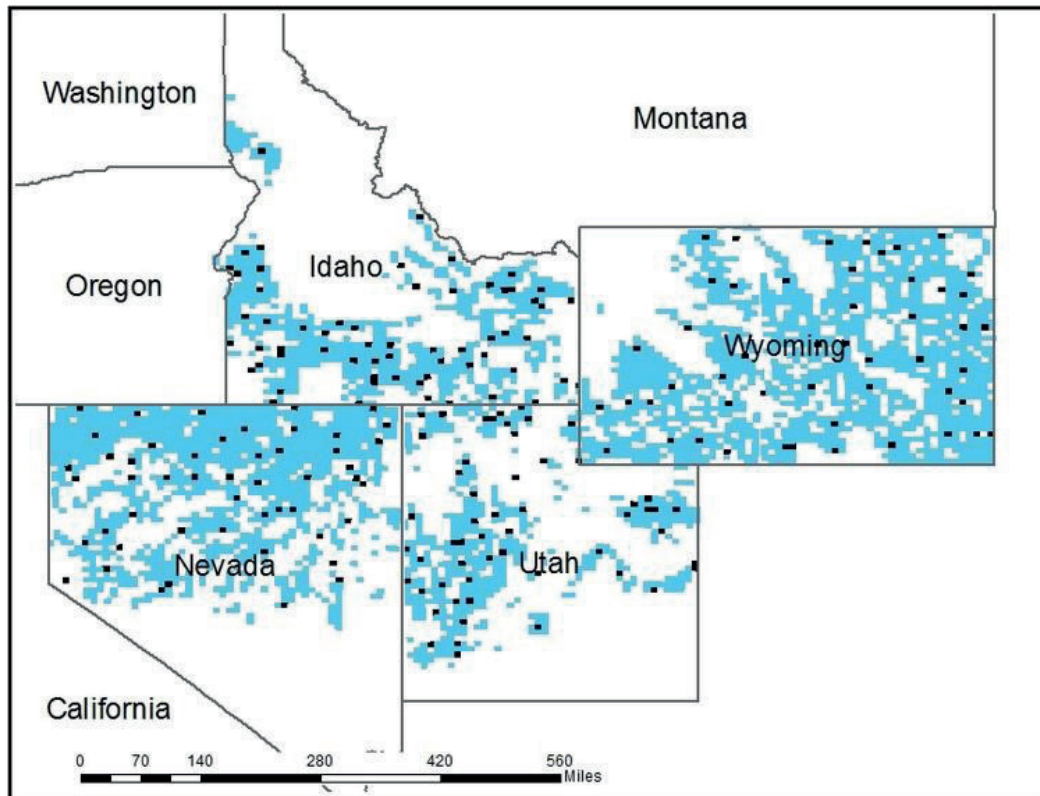
The most recently developed citizen science portal for bird data is eBird, founded by the Cornell Lab of Ornithology and National Audubon Society in 2002 (Sullivan et al. 2009). Unlike the BBS, BBAs, and CBC, which have formal methods, timelines, and analytical frameworks, eBird encourages observations to be reported from anywhere at any time. Although standard approaches to trend estimation from eBird data have yet to be established, existing tools for exploring the database allow for generation of simple summaries. We explored differences in winter (December to February) and summer (June-July) distribution as a complement to BBS and CBC results, using the ‘species maps’ feature and filtering for the most recent decade (2008 to 2017).

## Standardized monitoring - WAfLS

To better understand population changes at a regional scale, we established the Western Asio flammeus Landscape Study (WAfLS) in Idaho and Utah in 2015 (Miller et al. 2016b). Surveys were repeated in 2016 (Miller et al. 2016a) and expanded in 2017 to also include Nevada and Wyoming (Miller et al. 2017). We stratified this region by first laying a 10 x 10 km grid over the four states, and within these grid cells, we quantified presumed Short-eared Owl habitat, i.e., areas of grassland, shrubland, marshland/riparian, and agriculture land cover classes (Wiggins et al. 2006), choosing grids for our stratum with at least 70% land cover consisting of any of these four classes. The result consisted of 9,460,000 ha in Idaho, 10,260,000 ha in Nevada, 7,760,000 ha in Utah, and 13,810,000 ha in Wyoming (Fig. 1).

**Figure 1** - Western *Asio flammeus* Landscape Study Project survey strata (blue squares) and spatially-balanced survey transects (black squares) for Short-eared Owl surveys during the 2017 breeding season across the United States of Idaho, Nevada, Utah, and Wyoming.

**Figura 1** - Locais de amostragem estratificada (quadrados azuis) e transectos de monitorização espacialmente equilibrados (quadrados pretos) do *Western Asio flammeus Landscape Study Project* para monitorização de corujas-do-nabal durante a época de reprodução de 2017 nos Estados Unidos de Idaho, Nevada, Utah e Wyoming.



We selected a spatially-balanced sample of 50 survey transects per state within the stratum using a Generalized Random-Tessellation Stratified (GRTS) process (Stevens Jr. & Olsen 2004) (Fig. 1). For each transect, we delineated a ~9 km survey route along secondary or tertiary roads, which was the maximum survey length feasible using the protocol, and our justification for choosing a 10 x 10 km grid (Larson & Holt 2016).

Larson & Holt (2016) report that under favorable conditions Short-eared Owls can be correctly identified up to 1,600 m away, with high detectability up to 800 m.

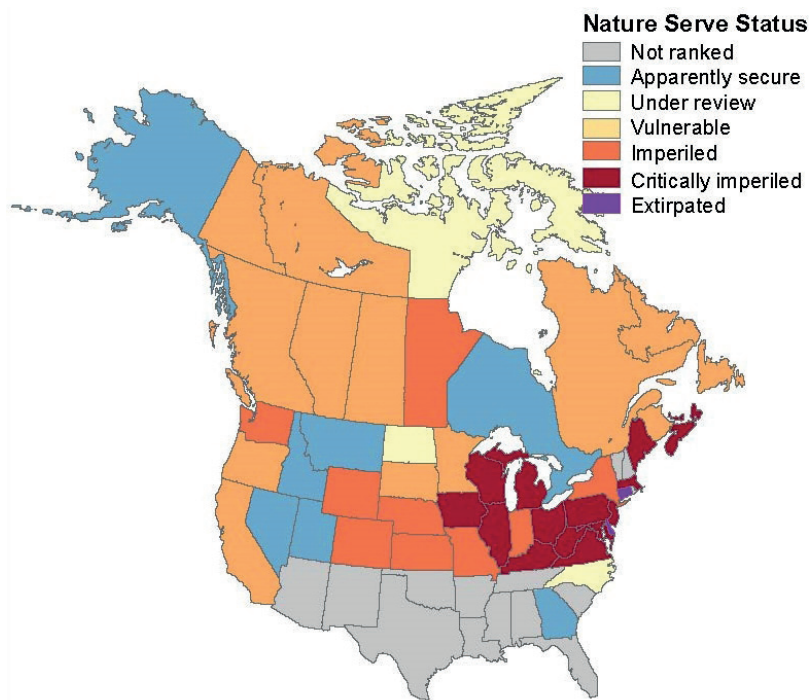
Calladine et al. (2010) had a mean initial detection distance of 500 – 700 m, with a maximum recorded value of 2,500 m. As our analysis method is robust against false negative detections, but less so against false positive detections, we chose to assume a larger average initial detection distance of 1 km. Therefore, we considered all land within 1 km of the surveyed points as sampled habitat.

We recruited volunteers to complete survey routes across the four states (Fig. 1). Approximately two-thirds of our volunteers were non-professional citizen scientists, whereas one-third were professional



**Figure 2** - NatureServe status of the Short-eared Owl (*Asio flammeus*) in all states, provinces, and territories in the United States and Canada.

**Figura 2** - Estatuto *NatureServe* da coruja-do-nabal (*Asio flammeus*) em todos os estados, províncias e territórios dos Estados Unidos e Canadá.



biologists either volunteering to survey routes or assigned by their agency or company to complete the route (e.g., on restricted lands). We provided reference materials (e.g., owl identification), a procedure manual, a freely accessible YouTube training video (Paprocki 2017), maps, civil twilight schedules, and datasheets to volunteers to promote survey quality. We asked volunteers to submit data via an online portal.

Observers attempted to complete two surveys per transect, one during each of two three-week survey windows, scheduled in relation to elevation. Survey timing was chosen to coincide with courtship, the period of highest detectability when

male Short-eared Owls perform elaborate courtship flights. Observers surveyed eight to 11 points, separated by approximately 800 m, during the 90-minute span from 100 to 10 minutes prior to the end of local civil twilight (Larson & Holt 2016). At each point observers performed a 5-minute point count, noting each individual bird minute-by-minute (e.g., for an owl observed only during minutes 2 and 3 of the 5-minute period, we would assign a value of “01100”).

We performed multi-scale occupancy modeling for its strength in evaluating fine-scale (point-scale in our case) habitat associations and providing a more refined alternative to abundance

estimation. (Nichols et al. 2008, Pavlacky et al. 2012). We implemented a minute-by-minute replacement design, allowing for simultaneous evaluation of detection, point-scale occupancy, and transect-scale occupancy (Nichols et al. 2008).

We also performed Maximum Entropy (MaxEnt) modeling, which provides study-wide habitat mapping, integrating current and future climate scenarios into the predictions (Phillips et al. 2006, 2017). We produced study-wide raster maps of the proportion of each cover type within 150 m of each 30 × 30 m pixel on the landscape (e.g., shrubs, sage, grass, etc.). Similarly, we created study-wide maps of elevation, slope, roughness, and an ecological relevant sample of the 19 standard climate variables derived from 1960–1990 (worldclim.org, Hijmans et al. 2005). All values were then resampled down to 30-second blocks (~1 km, matching resolution of the climate data) using bilinear interpolation. We used all presence and pseudo-absence (locations that we failed to detect owls but cannot be certain that they were absent) observations from the past three years (2015–2017) in the analysis. The result is that the model best represents Idaho with three years of data, then Utah with two years of data, and lastly Nevada and Wyoming with the most limited data.

We conducted all statistical analyses in Program R and Program Mark (White & Burnham 1999, R Core Team 2017). We used the R package “RMark” to interface between Program R and Program Mark for the multi-scale occupancy modeling (Laake 2014). We used R package “AICcmodavg” to rank all models (calculating AICc), and to perform model averaging (Mazerolle 2015). We used R package “dismo” (Hijmans et al. 2017), interfacing with the MaxEnt software engine (Phillips et al. 2017), for all MaxEnt analyses. We used R package “ENMeval” for ranking and evaluating MaxEnt models (Muscarella et al. 2014).

## Regional documentation in South America

In South America, the status and distribution of the Short-eared Owl remains poorly understood in most regions. Proyecto Asio was launched in 2015 in honour of the late Argentinian naturalist Juan Carlos Chebez, who was instrumental in the establishment of several national parks and other protected areas. He was a leading voice for endangered species who had noted concerns over the decline of Short-eared Owl in Argentina due to anthropogenic causes and lamented the limited knowledge about the species.

Taking advantage of the growth of social media networks, and in particular the many nature photographers and bird watchers eager to share their observations, we established a Facebook group for Proyecto Asio (Facebook 2017). Members are invited to share all of their sightings, including photo documentation, location, habitat, and date. The data are compiled annually, summarizing occurrences by locality, province, and habitat, which together provides an overview of Short-eared Owl numbers, including statistics such as mortalities (Morici 2016, 2017).

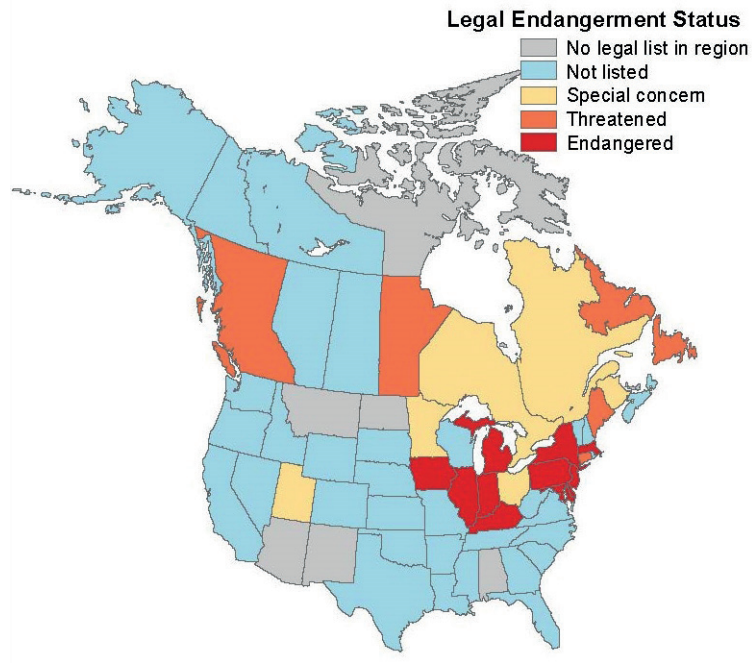
## Results

### Status review

The Short-eared Owl is listed as Special Concern in Canada (ECCC 2017b) and Vulnerable in Argentina (MAyDS y AA 2017) and is subject to special protection in Mexico (Semarnat 2010). but has it no official national conservation status in other countries in North or South America. In Canada it is also listed as Threatened in two provinces and Special Concern in four others, while in the U.S. it is Endangered in 12 states, Threatened in two states, and Special Concern in three states (Fig. 2).

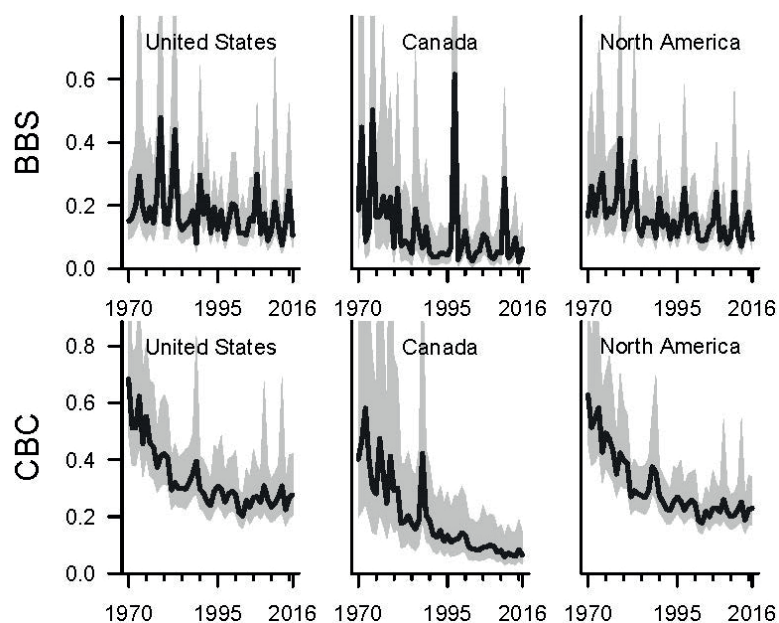
**Figure 3** - Legal status of the Short-eared Owl (*Asio flammeus*) in all states, provinces, and territories in the United States and Canada.

**Figura 3** - Estatuto legal da coruja-do-nabal (*Asio flammeus*) em todos os estados, províncias e territórios dos Estados Unidos e Canadá.



**Figure 4** - Short-eared Owl (*Asio flammeus*) population trajectories from 1970 to 2016 based on Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) data for the United States, Canada, and North America. Black lines indicate the estimated mean count of Short-eared Owls on a BBS route or CBC circle within the regions included in each analysis (see maps in Figures 5 and 6). The grey areas around the black lines represent the 95% credible intervals on the estimated means.

**Figura 4** - Tendências populacionais de coruja-do-nabal (*Asio flammeus*) de 1970 a 2016 com base em dados do *Breeding Bird Survey* (BBS) e do *Christmas Bird Count* (CBC) para os Estados Unidos, Canadá e América do Norte. As linhas pretas indicam o número médio estimado de corujas-do-nabal no BBS ou no CBC, nas regiões incluídas em cada análise (ver mapas nas Figuras 5 e 6). As áreas a cinzento em torno das linhas pretas representam os intervalos de 95% de confiança das médias estimadas.





NatureServe (2018) has also ranked the status of Short-eared Owl in North America at the state (U.S.) and provincial and territorial (Canada) level. It considers the species critically imperiled (S1) in 12 states and three provinces, imperiled (S2) in nine states and one province, vulnerable (S3) in four states, six provinces, and two territories, and possibly extirpated (SH) in two states and the District of Columbia; the species is only classified as apparently secure (S4) in six states and one province, unranked in three states and one territory, and too scarce to be assessed in the other 13 states (Fig. 3). Status is particularly poor in the U.S. Midwest (S1 or S2 in seven of eight states) and Northeast (S1, S2, or SH in 10 states, and unranked in the other three), while the few apparent strongholds of the species based on assessed status are Ontario, Alaska, and four states in the Intermountain West: Montana, Idaho, Nevada, and Utah. The Short-eared Owl and Long-eared Owl (*Asio otus*) are the only owl species in North America to be considered extirpated from multiple states (NatureServe 2018). Despite the preponderance of S1-S3 ranks throughout North America, NatureServe (2018) lists the Short-eared Owl as secure (N5) in the U.S. and apparently secure (N4) in Canada, although the U.S. rank has not been updated since 1997, whereas Canada's was reviewed in 2012 and 2018.

### Trend analysis

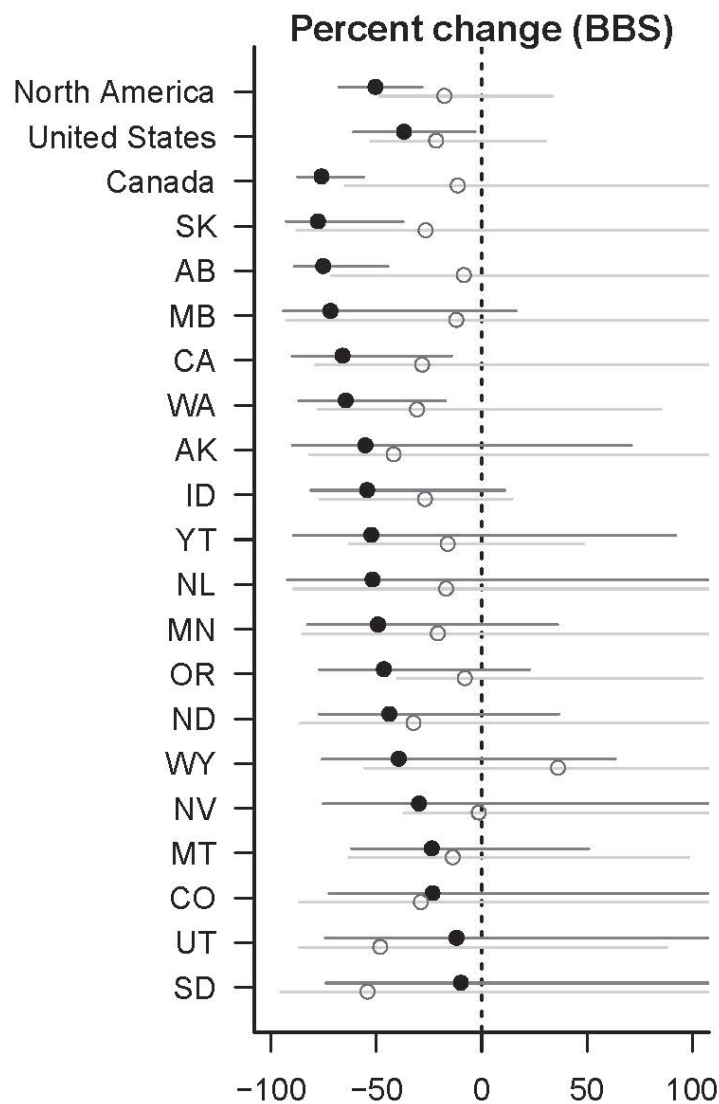
Since 1970, Short-eared Owl populations have declined in North America (Canada and the U.S.) by approximately 51% according to the BBS, which surveys during the breeding season, and by approximately 62% according to the CBC, which surveys during the non-breeding season (Fig. 4, and the open circles in Figs. 5 and 6). In Canada, the species' population has decreased by more than 50% since 1970 in all provinces, while in the U.S. state-level populations show a more mixed response and include

some states where the species population has changed little or even increased (states near the bottom of the plots in Figs. 5 and 6). Because the Short-eared Owl is recorded infrequently by the BBS, sufficient data exist for long-term trend analysis in only 12 states, four provinces, and one territory. While trends are negative across all jurisdictions, populations that breed in the Great Plains of the U.S. appear to be declining at a slower rate than those elsewhere (Fig. 7). Similarly, there are sufficient long-term CBC data for analysis for 27 states and four provinces; of these, 22 (71%) show a cumulative decline of at least 50%, and there is an increasing trend in only five central states, from Oklahoma northeast to Indiana (Fig. 8). The most recent (2006-2016) BBS trends suggest a continuing widespread decline across North America, whereas CBC data over this period show a more stable pattern in the U.S. but a continuing decline in Canada (Fig. 1 and the open circles in Figs. 5 and 6).

Second-generation BBAs have been completed in six provinces and 13 states (Cadman et al. 2007, Federation of Alberta Naturalists 2007, New York State Breeding Bird Atlas 2007, Ellison 2010, Youngman 2011, Wilson et al. 2012, Renfrew 2013, Stewart et al. 2015, Colorado Bird Atlas Partnership 2016, Mollhoff 2016, Rodewald et al. 2016, Breeding Bird Atlas Explorer 2017a,b, Iowa Department of Natural Resources 2017, Mass Audubon 2017, Quebec Breeding Bird Atlas 2017, South Dakota Game, Fish, and Parks no date). The number of squares with possible, probable, or confirmed breeding evidence declined in 10 atlases (range -17% to -100%; mean -62%), remained unchanged in three atlases, and increased slightly in five atlases (range 5% to 17%; mean 10%) (Fig. 9). Of the 12 atlases reporting the number of squares with confirmed breeding, seven had a decline (range -20% to -100%; mean -58%), three were unchanged (all remaining at zero), and only one increased (from one

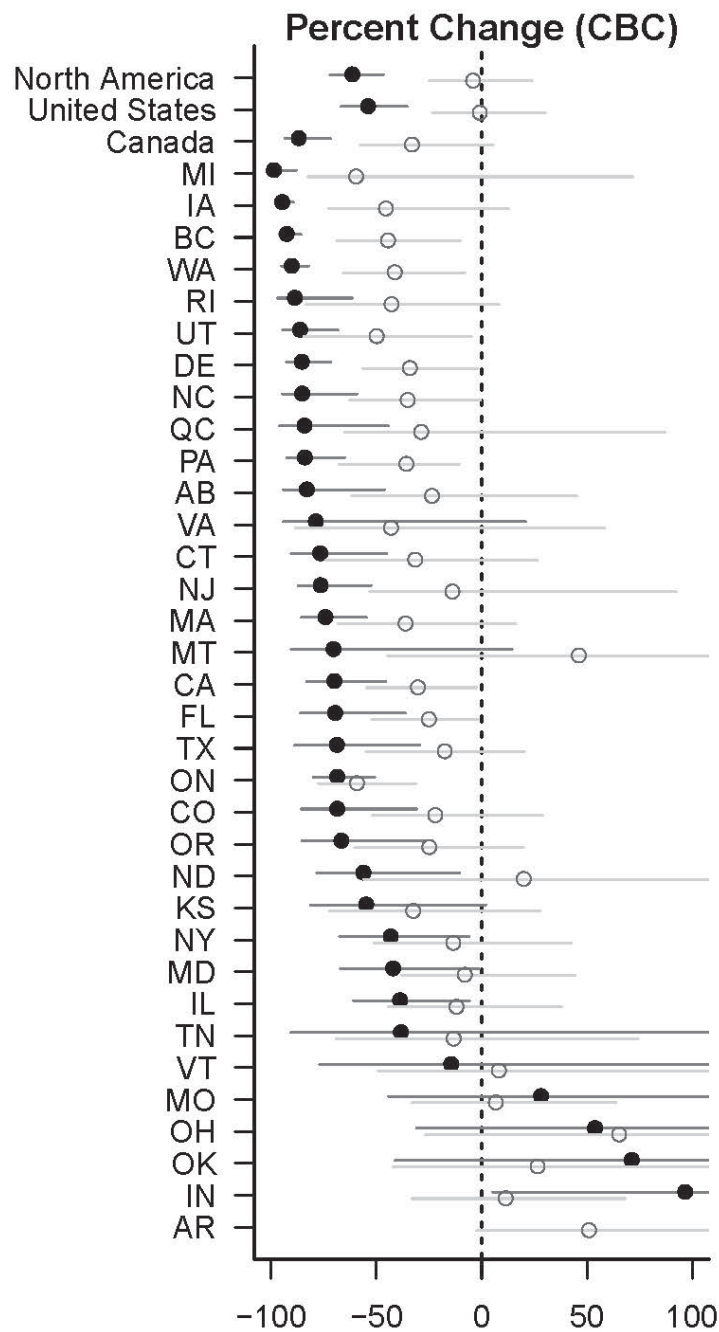
**Figure 5** - Estimated changes in Short-eared Owl (*Asio flammeus*) populations over the long-term (1970-2016; black lines, solid circles) and short-term (2006-2016; gray lines, open circles), from the Breeding Bird Survey (BBS) for North America, United States, Canada, and individual states and provinces with enough data for analysis. Points represent the mean estimated change in the population (e.g., -50 represents a 50% decrease in population over the associated time-period), and error bars show the 95% credible intervals around the estimated change.

**Figura 5** - Variação das estimativas populacionais de coruja-do-nabal (*Asio flammeus*) calculadas a partir do *Breeding Bird Survey* (BBS) no longo prazo (1970-2016; linhas pretas, círculos pretos) e curto prazo (2006-2016; linhas cinzentas, círculos sem preenchimento), na América do Norte, Estados Unidos, Canadá, e estados e províncias com dados suficientes para análise. Os pontos representam a variação média estimada da população (por exemplo, -50 representa uma diminuição de 50% na população ao longo do período de tempo associado) e as barras de erro mostram os intervalos de confiança de 95% da alteração estimada.



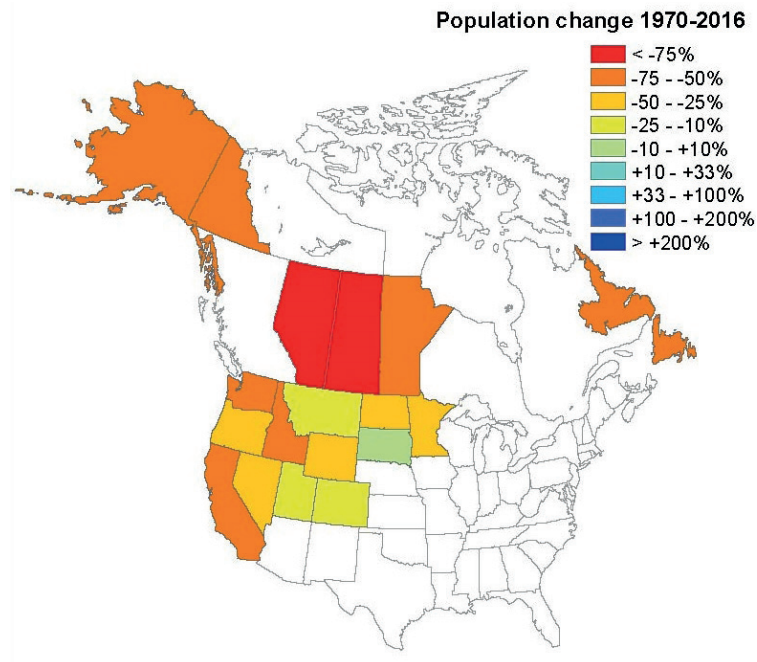
**Figure 6** - Estimated changes in Short-eared Owl (*Asio flammeus*) populations over the long-term (1970-2016; black, solid circles) and short-term (2006-2016; gray, open circles), from the Christmas Bird Count (CBC) for North America, United States, Canada, and individual states and provinces with enough data for analysis. Points represent the mean estimated change in the population (e.g., -50 represents a 50% decrease in population over the associated time-period), and error bars show the 95% credible intervals around the estimated change.

**Figura 6** - Variação das estimativas populacionais de coruja-do-nabal (*Asio flammeus*) calculadas a partir do *Christmas Bird Count* (CBC) no longo prazo (1970-2016; círculos pretos, sólidos) e a curto prazo (2006-2016; cinza, círculos sem preenchimento), na América do Norte, Estados Unidos, Canadá, e estados e províncias individuais com dados suficientes para análise. Os pontos representam a variação média estimada da população (por exemplo, -50 representa uma diminuição de 50% na população ao longo do período de tempo associado) e as barras de erro mostram os intervalos de confiança de 95% da variação estimada.



**Figure 7** - Cumulative Short-eared Owl (*Asio flammeus*) population change in states, provinces, and territories of United States and Canada from 1970 to 2016, based on Breeding Bird Survey data.

**Figura 7** - Variação cumulativa da população da coruja-do-nabal (*Asio flammeus*) em estados, províncias e territórios dos Estados Unidos e Canadá de 1970 a 2016, com base nos dados do *Breeding Bird Survey*.



**Figure 8** - Cumulative Short-eared Owl (*Asio flammeus*) population change in states, provinces, and territories of United States and Canada from 1970 to 2016, based on Christmas Bird Count data.

**Figura 8** - Variação cumulativa da população da coruja-do-nabal (*Asio flammeus*) nos estados, províncias e territórios dos Estados Unidos e Canadá de 1970 a 2016, com base nos dados do *Christmas Bird Count*.

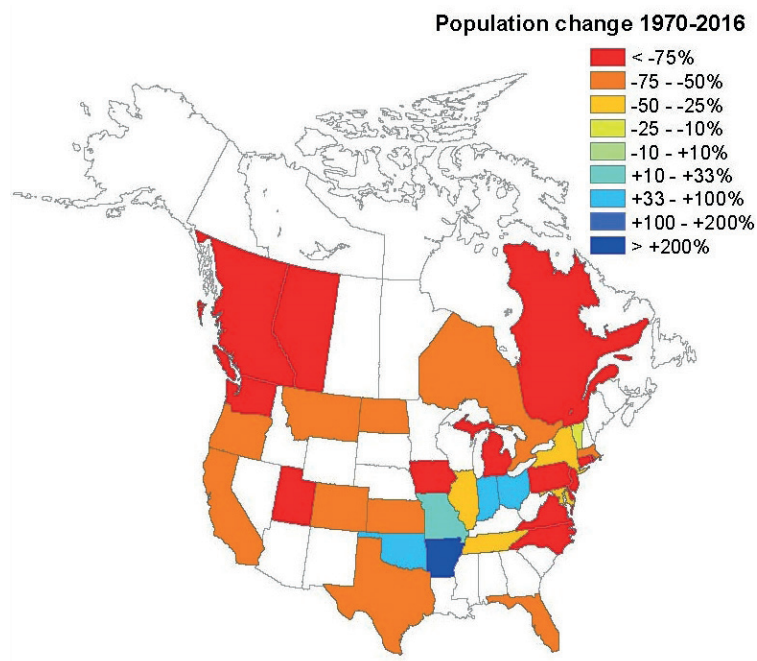
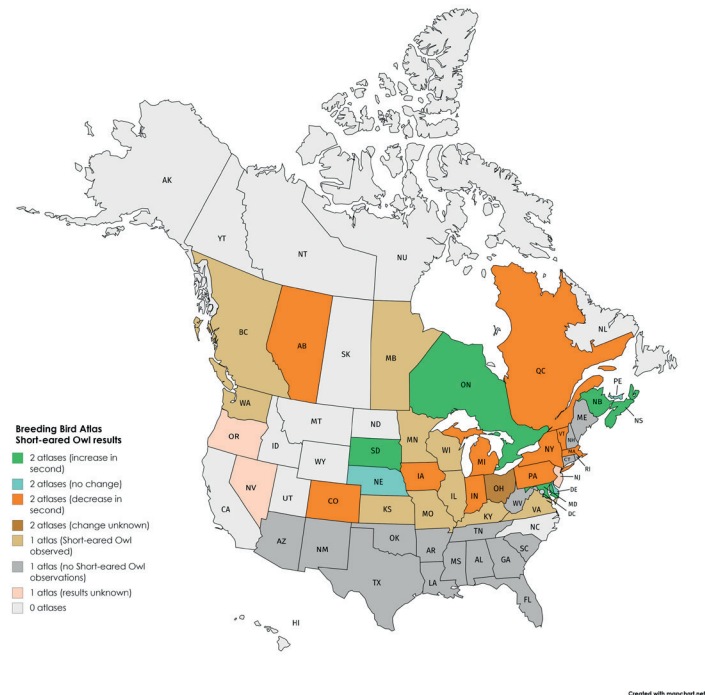


Figure 9 - Breeding Bird Atlas results for the Short-eared Owls (*Asio flammeus*) across the United States and Canada.

Figura 9 - Resultados do *Breeding Bird Atlas* para a coruja-do-nabal (*Asio flammeus*) nos Estados Unidos e Canadá.



to two squares).

Three of five jurisdictions reporting increases between atlases were in Canada. In the Maritime provinces, the number of occupied blocks remained unchanged in Prince Edward Island and increased marginally in New Brunswick and Nova Scotia. Of note, however, the majority (76%) of blocks with detections during the first atlas were no longer occupied during the second, but these local losses were offset by records at other sites where none were documented previously (Lauff 2015). Similarly, in Ontario, only 12 squares were occupied during both Ontario BBA periods, but there were observations in 59 new blocks, whereas there were no new records for 51 blocks with data from the first atlas (Gahbauer 2007). This pattern was also apparent in some jurisdictions showing overall declines. For example, only five survey blocks were occupied during both

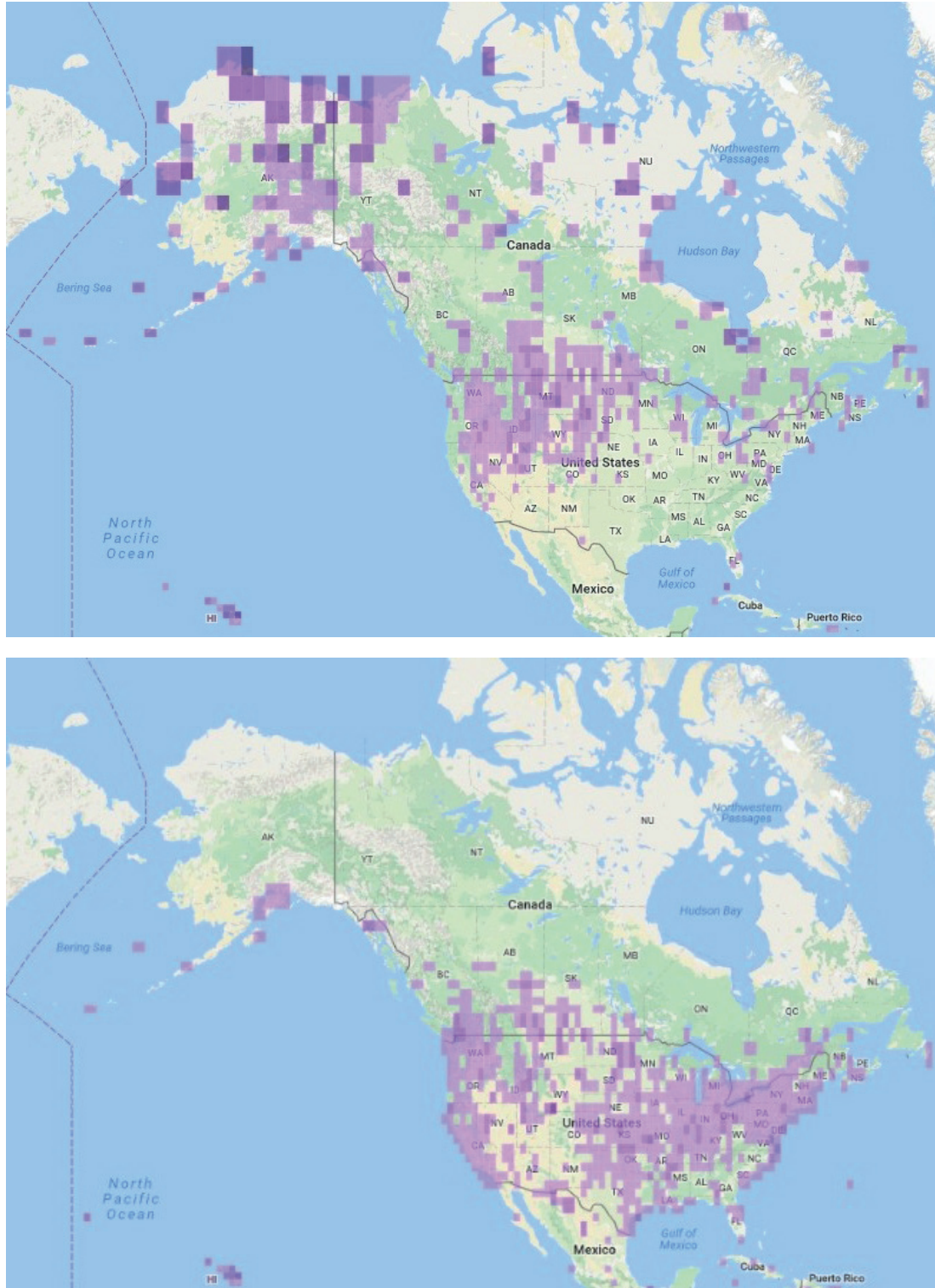
New York BBAs, compared to 31 just in the first and 19 only in the second (New York State Breeding Bird Atlas 2007).

An additional 30 jurisdictions have completed a first BBA, 27 (90%) of which have readily available results. Of these, 17 (63%) reported no Short-eared Owls (Nicholson 1997, Wiedenfeld & Swan 2000, Benson & Arnold 2001, Florida Fish and Wildlife Conservation Commission 2003, Reinking 2004, Corman & Wise-Gervais 2005, Haggerty 2009, Schneider et al. 2010, South Carolina Breeding Bird Atlas 2015, Breeding Bird Atlas Explorer 2017c,d,e,f,g,h, Arkansas Breeding Bird Atlas no date, Goodman no date). In the other 10 jurisdictions the species was consistently rare, with possible, probable, or confirmed breeding evidence at a mean of 0.4% of squares with survey data (range 0.1% to 1.0%) in eight states specifying coverage (Cutright 2003, Breeding Bird



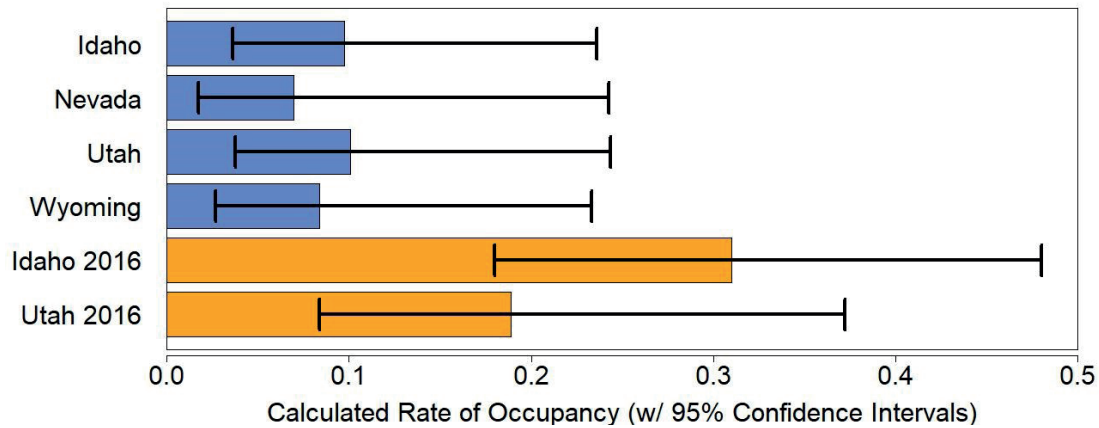
**Figure 10** - All eBird records for the Short-eared Owl (*Asio flammeus*) in North America during a) Summer (June-July) and b) Winter (December-February) for 2008-2017. From lightest to darkest, the five shades of purple represent geographic blocks in which 0-2%, 2-10%, 10-25%, 25-40%, or 40-100% of checklists submitted include Short-eared Owl.

Figura 10 - Registos totais do eBird para a coruja-do-nabal (*Asio flammeus*) na América do Norte durante a) o verão (junho-julho) e b) o inverno (dezembro-fevereiro), em 2008-2017. Do mais claro para o mais escuro, os cinco tons de roxo representam blocos geográficos nos quais 0-2%, 2-10%, 10-25%, 25-40% ou 40-100% das listas de verificação enviadas incluem a coruja-do-nabal.



**Figure 11** - 2017 Estimated Short-eared Owl (*Asio flammeus*) survey occupancy rates in four United States with 95% confidence intervals (blue) and 2016 results for comparison (orange).

**Figura 11** - Taxas de ocupação estimadas da coruja-pequena (*Asio flammeus*) em 2017 em quatro Estados Unidos com intervalos de confiança de 95% (azul) e resultados de 2016 para comparação (laranja).



Atlas Explorer 2017i,j,k,l,m,n, Pfannmuller et al. 2017), and a mean of 1.8% in two provinces (range 1.0% to 2.7%) (Cannings 2015, Artuso 2017).

Reviewing eBird data at the continental scale over the past 10 years provides a snapshot of distribution and relative abundance to complement other survey data. Summer (June to July) observations show breeding season concentrations in the northwest lower 48 U.S. states and adjacent southern Canadian prairies, as well as in parts of Alaska, whereas records in the eastern half of the continent are much more scattered (Fig. 10a). Winter (December to February) records show a somewhat more uniform distribution across most of the lower 48 states and adjacent southern edge of Canada, with the most notable gap in distribution associated with the Rockies and upper Great Plains (Fig. 10b). There appears to be a heavier relative concentration in eastern North America in winter, and overall there is relatively little overlap between the areas with the most observations in summer and winter.

### Standardized monitoring - WAfLS

In 2017, 330 people took part in surveys

for project WAfLS, contributing 4,315 volunteer hours and traveling 91,077 km to complete the surveys, including preparation, training, and travel to and from survey areas. Short-eared Owls were detected on 13 of the 174 survey grids that were completed.

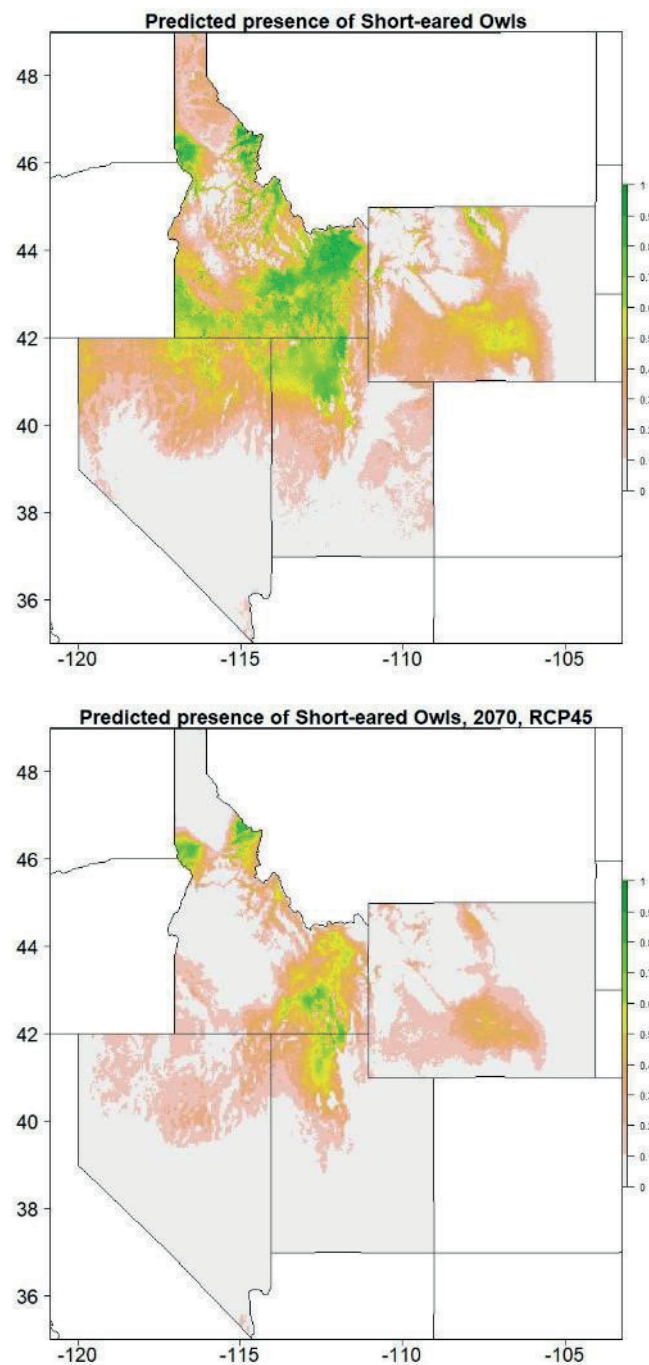
There was a higher probability of detecting Short-eared Owls in low wind speeds and close to the end of civil twilight (dusk). In the 3<sup>rd</sup> year of the program there were no significant habitat associations at the point scale. However, fewer Short-eared Owls were present at survey points with either high or low amounts of grazing.

In 2017, Short-eared Owl grid occupancy in Idaho declined significantly by about one third from 2016 (no confidence interval overlap, Fig. 11). The decline was less dramatic in Utah.

Short-eared Owls within the WAfLS study area were more likely to be found in locations where it was warmer than average and where temperatures were less variable. They were also more likely to be found in locations with higher precipitation per month throughout the year and at lower, but not the lowest, elevations. Short-eared Owls favored cropland, shrubland, and marshland over monotypic cheatgrass and more complex grasslands.

**Figure 12** - Predicted habitat suitability for Short-eared Owl (*Asio flammeus*) presence using current and 2070 climate scenarios, derived from MaxEnt model LQ0.5 using presence and pseudo-absence data (2015-2017) from Western *Asio flammeus* Landscape Study Project. Green represents areas of high predicted presence (>70%), yellow represents moderate predicted presence (40 - 60%), brown represents low predicted presence (< 30%), and white represents near zero predicted presence. Future climate was projected using the Representative Conservation Pathway 4.5 assumptions generated by Hadley Centre Global Environment Model version 2.

**Figura 12** - Adequação de habitat prevista para a presença de coruja-do-nabal (*Asio flammeus*) usando os cenários climáticos atual e previsto para 2070, derivados do modelo MaxEnt LQ0.5, usando dados de presença e pseudo-ausência (2015-2017) do *Western Asio flammeus Landscape Study Project*. A cor verde representa áreas de alta probabilidade de presença (> 70%), o amarelo representa probabilidade de presença moderada (40 - 60%), o castanho representa baixa probabilidade de presença (<30%) e o branco representa probabilidade de presença próxima de zero. O clima futuro foi projetado usando as premissas do *Representative Conservation Pathway 4.5* geradas pelo *Hadley Center Global Environment Model* versão 2.



Using all variables we plotted the current likelihood of Short-eared Owl land use (Fig. 12a) and then projected future Short-eared Owl land-use by replacing climate variables within the model with future climate variable projections for the year 2070 (Fig. 12b). This assessment of climate-induced change is conservative as it assumes no change in land cover which is expected to change with climate.

### Regional documentation in South America

Since the inception of Proyecto Asio in 2015, over 2,380 members have joined the Facebook group, and more than 200 records have been submitted. The rate of data submission doubled in 2017 likely due to an increase in participation rather than a change in abundance. Reports were numerous from the Pampas ecoregion, followed by Mesopotamian Savannas, Chaco, Patagonia, Prepuna, Puna, Monte Desert, and High Andes. Patterns in the data suggest some short- and medium-distance seasonal movements. Of note, there appears to be a high post-reproductive concentration along the central Andes, which is a relatively small area that may have disproportionate importance for Short-eared Owl in Argentina.

## Discussion

Although Canada, Mexico, and Argentina are the only countries in the Americas to have recognized Short-eared Owl as a species at risk at a national level, it is evident that the species is also of significant conservation concern in much of the U.S., with nearly one-quarter of states having listed it as endangered. The NatureServe (2018) non-legally binding status assessment of Short-eared Owl status in North America shows a similar overall pattern, though it highlights numerous additional states, provinces, and

territories where the species is imperiled or vulnerable, including several that are primarily frequented by the species in winter. Our interpretation is that the species is not considered secure anywhere in North America. It appears to be in greater jeopardy in the eastern half of the continent and its status is particularly tenuous in the southern part of the breeding range. In Canada, the national legal status is scheduled for reassessment in 2021, and recent declines are close to meeting the threshold for being considered Threatened (M.A. Gahbauer, unpubl. data).

BBS results indicate an overall long-term decline of the Short-eared Owl in North America, with a stable or increasing population trend largely limited to the northern Great Plains states where abundance estimates for this species are highest. While the network of BBS routes (>4,100) is extensive, observers are generally highly skilled, and there is a well-established analytical framework for the data, the survey is not optimal for Short-eared Owl because the species has low activity levels during the early morning BBS survey period (Swengel and Swengel 2009, 2013). Additionally, the BBS survey season (late May to early July) occurs after the Short-eared Owl's courtship period and peak of detectability (March to mid-May). With approximately 80 BBS detections across North America in an average year (Pardieck et al. 2017), small differences in observations can have a disproportionate effect on influencing trends, and over much of the continent, data are too sparse to allow for any analysis at all.

CBC data also showed an overall long-term decline of the Short-eared Owl in North America. However, there was a core area, extending from Oklahoma in the southwest and northeast to Ohio, that showed both long-term and short-term increases. It is unclear whether this represents an increase in the populations wintering in this region, or a redistribution of wintering owls that



formerly occurred in surrounding states where moderate to steep declines have been recorded over the same time period. CBC data have been used to show a shift in wintering distribution for other open-country raptors such as the Northern Harrier (*Circus hudsonius*), Rough-legged Hawk (*Buteo lagopus*), and Golden Eagle (*Aquila chrysaetos*) (Paprocki et al. 2014). Given that we know little about population connectivity in Short-eared Owls, it would be valuable to undertake an analysis to determine whether its winter population has redistributed or if there were discrete regional population trends. There are on average just under 700 Short-eared Owls reported on North American CBCs annually (National Audubon Society 2010), far more than by the BBS. However, Short-eared Owls are less active during daylight hours in winter and are likely not well detected away from communal roosts. Additionally, since CBC dates are predetermined, interannual variation in weather conditions can have considerable effects on both observer effort and owl distribution and detectability, and results are therefore most reliable at larger temporal and spatial scales.

In most states and provinces where a second breeding bird atlas has been completed, there were substantial declines in the number of survey blocks where Short-eared Owl were observed and/or confirmed as breeding. Even in areas reporting modest overall increases, such as four Canadian provinces, most of the previously occupied areas no longer reported Short-eared Owls. This may reflect the nomadic tendency of the species but could also be due to limiting factors. In areas with relatively extensive potential breeding habitat remaining, the Short-eared Owl may be able to maintain a stable regional population. Where such habitat is limited, local extirpations may not be offset by new occurrences elsewhere. Breeding Bird Atlas projects typically involve extensive field effort, often including

areas that are remote or otherwise difficult to access, and there can be a focus on documentation of regionally rare species. However, BBA survey effort is infrequent (often a 5-year period every 20 years), which for a nomadic species may not accurately reflect fluctuations, especially since adjacent jurisdictions rarely synchronize their atlas efforts.

Despite the limitations of the BBS, BBAs, and CBC with respect to detecting Short-eared Owls, all three data sources agree that there have been widespread and, in many cases, substantial declines throughout much of North America. Only South Dakota shows a modest long-term increase based on BBS data, and just five provinces and states with a second completed BBA reported an increase in the number of Short-eared Owl detections, and most of those were attributed to expanded search effort. The more strongly positive CBC trends from a few central states represent an intriguing exception to the overall pattern and warrant further investigation.

Although existing broad-scale surveys have enough data for trend analysis in at least some states, provinces, and territories, sample sizes are in most cases too small to allow for a high confidence analysis of trends, especially over short time intervals. Moreover, detections are so scarce that they are of minimal value in deriving population estimates. This highlights the need for targeted survey efforts such as WAfLS, which are specifically designed to generate annual population estimates that over time will allow for more rigorous trend determination. Results from the program's first two years already established its viability for estimating regional population trends, identifying important Short-eared Owl habitat associations, and providing insight into which habitats in the region may be most important for conservation and further study (Miller et al. 2016a, 2016b). With a third year of data in 2017 and the



inclusion of two more states, differences among years are becoming apparent, and the understanding of the regional population is increasing. The success of engaging a large group of participants, mostly (82%) non-professional citizen-scientist volunteers, in a statistically-rigorous survey for Short-eared Owls across a broad geographic region suggests that this is a model that can readily be applied to other areas.

In 2017, for the first time, there were insufficient Short-eared Owl detections to produce a quality abundance estimate for any of the states. However, occupancy rates, generally more reliable than abundance estimates, decreased to about one-third of their 2015 and 2016 values in Idaho, and were anecdotally down in Utah as compared to 2016. This sharp decline may signify a continued decline in the population and/or its distribution in relation to prey availability (Clark 1975, Korpimäki & Norrdahl 1991, Johnson et al. 2013). Wiggins et al. (2006) and Johnson et al. (2013) suggested that consistent surveying over a period exceeding multiple prey cycles is required before estimating trends.

Multi-scale occupancy analysis provided key insight into owl detectability relative to weather, timing, and point scale impacts such as grazing. Consistent with Larson & Holt (2016), our results noted an increase in the probability of detection during surveys conducted toward the end of civil twilight. The probability of detection was higher in calmer wind conditions due to strong winds negatively affecting surveyors and male Short-eared Owl courtship flights. In 2016, we started collecting data on grazing activity around survey points. In 2017, Short-eared Owl occupancy was higher in areas with moderate evidence of grazing and was lower in areas of no grazing or high degrees of grazing. This contrasts Larson & Holt (2016) who found no detections in grazed habitats and suggests that the influence of such habitat impacts varies

across the species' range and warrants further investigation.

The forecast effects of climate changes on Short-eared Owl population distribution and trends suggests that is a threat to this species. Short-eared Owls were associated with habitats where precipitation occurs throughout the year with only a moderate level of seasonal variation. Climate predictions for our region suggest that annual precipitation may remain constant or slightly increase, but that the seasonality of precipitation is expected to shift with summers continuing to become drier. Climate change associated range contractions suggests a difficult conservation scenario is needed to conserve the species.

In South America, standardized surveys have not yet been implemented, but the growing success of Proyecto Asio in documenting the status of the Short-eared Owl in Argentina has resulted in increased attention on its conservation. Most notably, the compiled results were part of the evidence used to support the recent designation of the Short-eared Owl as Vulnerable in Argentina (MAyDS y AA, 2017). There is growing interest from naturalists in other South American countries to expand the project to a continental scale, which would allow for a much-needed boost to understanding the distribution and status of the species, with potential for conservation status assessments, designations and the implementation of management actions elsewhere.

We conclude that multiple sources of existing data suggest that the Short-eared Owl is experiencing long- and short-term declines across much of North America, and possibly also in South America. However, confidence is limited in some of the trend data due to small sample sizes, and this may impede implementation of necessary conservation and management measures. Therefore, a Short-eared Owl specific population monitoring effort is needed, and we encourage the expansion of standardized

citizen-science programs such as WAfLS. Such programs can generate reliable estimates to serve as the basis for trend analysis, while also yielding new insights into habitat use. We also encourage the expansion of the Proyecto Asio across South America. This is especially needed in parts of the continent where the population warrants special attention. In combination with improved population monitoring, understanding Short-eared Owl demography is critical for long-term conservation of the species. While a long-term population decline is evident, the drivers of the decline remain unknown as there are scant demographic data available. Breeding ecology studies would be particularly useful in assessing the impacts of habitat characteristics (e.g., habitat fragmentation, livestock grazing) on nesting success. Greater understanding of the status, distribution, and demography of Short-eared Owls throughout the Americas will facilitate effective application of conservation efforts.

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