GEOGRAPHIC AND HABITAT FIDELITY IN THE SHORT-EARED OWL (*ASIO FLAMMEUS*)

Kristen L. Keyes

Department of Natural Resource Sciences
Macdonald Campus
McGill University, Montreal

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DEDICATION

To those farmers everywhere,
who, like my mother and father,
recognize their role as stewards of the Earth,
and work towards harmony and balance
for all creatures that make it home.

ABSTRACT

Over the past half a century, the Short-eared Owl (*Asio flammeus*) has experienced a severe population decline across North America. Many aspects of Short-eared Owl natural history are poorly understood, thus hampering the development of effective management plans. The overall goal of this thesis was to help to fill the knowledge gaps that exist, and at the same time provide a foundation for future studies. The specific objectives were three-fold: 1) to investigate Short-eared Owl spatial origins across North America in the context of nomadic, migratory and/or philopatric movements; 2) to develop a practical visual survey protocol aimed at improving monitoring efforts and facilitating assessments of across season landscape-level habitat use; and 3) to describe nest site characteristics, success, and causes of failure. Stable isotope analysis was used to investigate spatial origins of Short-eared Owls, and while exploratory in nature, evidence was provided that the species may exhibit different movement strategies across their North American range. The volunteer visual survey protocol developed here was successful over a trial period, and should become a reliable monitoring scheme to track abundance and distribution through time. Based on the comparison of sites ‘used’ versus ‘available’ on two islands on Lake Ontario near Kingston, in eastern Ontario, the Short-eared Owl’s use of forest cover during the winter appears to be dependent on seasonal effects. Also, during the breeding season in this geographical area, grazed grassland with scattered trees should be considered important habitat. Short-eared Owls exhibited a tendency for loose nesting aggregations in areas that were predominantly tall grasses, and often on grazed grassland. Fledging success was low and both anthropogenic and natural causes of mortality were identified. The findings of this study will contribute greatly to the current understanding of Short-eared Owl natural history, and the techniques described will be valuable tools for subsequent research and conservation initiatives.

RÉSUMÉ

Au cours de la dernière moitié du siècle, la population du hibou des marais (*Asio flammeus*) a subi d'un déclin sévère à travers l'Amérique du Nord. Plusieurs aspects de leur histoire naturelle sont mal compris, entravant ainsi le développement de plans de gestion efficaces. Le but principal de cette thèse était d'essayer de combler le manque de notions à l'égard du hibou des marais tout en assurant une base pour les études ultérieures. Les objectifs spécifiques comportent trois volets: 1) examiner les origines spatiales à travers l'Amérique du Nord en lien avec les déplacements nomades, migratoires et/ou philopatriques; 2) développer un protocole pour les sondages visuels visant à améliorer les efforts de surveillance, et à faciliter l'évaluation de l'utilisation de l'habitat à travers les saisons à l'échelle du paysage; et 3) décrire des sites de nidification, le succès des nids et les causes d'échec de la nidification. L'analyse des isotopes stables était utilisée pour examiner les origines spatiales, et malgré son aspect exploratoire, cette méthode a démontrée que l'espèce pourrait posséder différentes stratégies de déplacement à travers l'Amérique du Nord. Le protocole mis en place pour les sondages visuels accomplis par des bénévoles fût un succès durant la période d'essai, et devrait être une méthode de surveillance sûre pour suivre l'abondance et la distribution de l'espèce à travers le temps. Sur la base d'une comparaison des sites 'utilisés' et 'disponibles' sur deux îles du Lac Ontario près de Kingston dans l'est de l'Ontario, l'importance du couvert forestier durant l'hiver semblent dépendre des effets climatiques saisonniers. Aussi, durant la saison de reproduction dans cette région, le pâturage avec les arbres épars doit être considérés comme l'habitat essentiel. Les hiboux des marais ont démontré une tendance pour les nids faiblement agrégés, dans des régions principalement constitués de hautes herbes et souvent dans les pâturages. Le succès d'envol était faible, et les causes de mortalité naturelles et anthropiques étaient identifiées. Les conclusions de cette étude vont contribuer énormément à la compréhension de l'histoire naturelle du hibou des marais, et les techniques décrites seront des outils de valeur pour la recherche et les efforts de conservation dans l'avenir.

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ACKNOWLEDGEMENTS

When I first learned of the plight of the Short-eared Owl over three years ago, I did not have the slightest idea of the exciting challenges that would lie ahead. As I reflect over the many experiences I have been fortunate to accrue, I am eternally grateful to many people and organizations who made this project both possible, and successful. There are some people who may have been unintentionally omitted from this list, and to whom I would also like to extend my sincere appreciation.

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PREFACE

This thesis consists of four chapters, and is manuscript-based with the inclusion of scientific names and literature cited in each chapter. The style of the Journal of Raptor Research is used throughout. The first chapter is a general overview and literature review, including the objectives of my study. The second chapter is an exploration of the stable isotope technique for identifying spatial origins and movement strategies used by the Short-eared Owl across North America. The third chapter describes a novel visual survey protocol and its applicability to the identification of critical habitat. The fourth chapter provides details of nest site selection, success and causes of failure in an eastern Ontario population. An overall synthesis and conclusion is also included. All chapters except the general introduction will be submitted to peer-reviewed journals for publication.

CONTRIBUTIONS OF CO-AUTHORS

For all chapters that will be submitted to refereed journals, I am the first author, as I was responsible for the project design, fund acquisition, field research, analyses, and manuscript preparation. Also for each manuscript, M.A. Gahbauer is listed as second author, and D.M. Bird as final author, in recognition of their extensive contributions to all aspects of this study as my thesis supervisors. K.A. Hobson and S.L. Van Wilgenburg are co-authors on the second chapter due to their involvement with data analyses and presentation. K. Hennige is a co-author on the third chapter because of his involvement with the development and implementation of a visual survey protocol, as well as his dedication to ongoing studies of the eastern Ontario Short-eared Owl population.

1 General introduction

1.1 The North American Short-eared Owl decline

The current global population estimate for the Short-eared Owl (*Asio flammeus*) is 2 000 000, whereas the North American estimate is 700 000 (Rich et al. 2004). Drastic population declines have occurred over the past few decades; according to Breeding Bird Survey (BBS) data, the species suffered a mean annual decline of 4.6% from 1966 through 2005 across North America, which corresponds to a cumulative loss of about 85% (M. Gahbauer pers. comm.). As of 2009, the Short-eared Owl was considered possibly extirpated in four states/provinces, critically imperiled in 16, imperiled in seven, vulnerable in 14, apparently secure in three, secure in two, and not ranked or under review in three (NatureServe 2010). In Canada, the Short-eared Owl has had Special Concern status since 1994, although the updated status report by the Committee on the Statues of Endangered Wildlife in Canada indicated that it nearly meets the criteria for Threatened status (Wiggins 2008).

Declines in the North American Short-eared Owl population have been attributed to several factors, which are not mutually exclusive. Causes of mortality include shootings, collisions with aircraft, trains, automobiles and barbed wire fencing, mutilations by farm machinery, and pole-trapping by game keepers (Clark 1975). The effects of pesticides and contaminants have not been studied in detail, but raptors such as the Short-eared Owl that consume mainly herbivorous small mammals often accumulate only modest concentrations (Wiggins et al. 2006). Habitat loss is arguably the leading threat, primarily the loss of open habitats to agricultural crops, but also losses due to urban expansion (Wiggins et al. 2006, Wiggins 2008). As this ground-nesting species requires relatively large tracts of open grassland, reforestation in certain areas may be considered a threat. Increased predation pressure in fragmented landscapes and near rural developments is also a concern (Wiggins et al. 2006). Often, seemingly appropriate habitat across the species range is not occupied, suggesting that factors other than habitat loss, such as levels of prey or predation, may affect distribution and abundance (del Hoyo et al. 1992).

1.2 Short-eared Owl natural history and techniques used to address the current information deficit

1.2.1 Distribution

The Short-eared Owl is a cosmopolitan species, found on every continent except Australia and Antarctica. It is unique among the family Strigidae, or typical owls, for having colonized some of the world's most remote oceanic islands. Ten subspecies are currently recognized; *Asio flammeus flammeus* (hereafter referred to as *A. f. flammeus*) is predominant across the northern hemisphere and the others occur mainly as isolated island populations (Mikkola 1983, del Hoyo et al. 1992). In North America, the species has an extensive distribution ranging from northern Alaska to central Mexico, and from the west to east coast (Fig. 1-1) (Mikkola 1983, Wiggins et al. 2006).

From an ecological niche perspective, the Short-eared Owl is most similar to the African Marsh Owl (*Asio capensis*), which replaces it across most of Africa, particularly south of the equator (Mikkola 1983). Morphologically, it is most similar to the sympatric Long-eared Owl (*Asio otus*); these species are sole members of the genus *Asio* in North America. While chromosomally similar (Belterman and De Boer 1984), the genetic distance between them is unusually large (Randi et al. 1991, del Hoyo et al. 1992). The Long-eared Owl is an arboreal species associated with wooded habitats and adjacent open areas for hunting, while in contrast the Short-eared Owl is largely associated with open grassland habitat (Johnsgard 2002). Despite these differences, a specimen at the Canadian Museum of Nature was recently recognized as a hybrid between the two species (Gosselin and Keyes 2009).

1.2.2 Feeding habits

Traditionally, the Short-eared Owl has been considered one of the most diurnal strigids (Mikkola 1983), but it has also been described as crepuscular (Voous 1989, del Hoyo et al. 1992, Wiggins 2008) and even nocturnal (del Hoyo et al. 1992). Across North America the peak hunting period for wintering birds is from about two hours before sunset to sunset (Clark 1975), with a concentration in the 30-minute period preceding evening civil twilight (Swengel and Swengel 2002). Increased activity during daytime hours may occur during the nesting season when young require care and protection, and also at other times of the year when diurnal raptors are scarce (i.e. Red-tailed Hawk, *Buteo jamaicensis*) (del Hoyo et al. 1992). As well, activity during daylight hours shows a positive correlation with cloud cover (Swengel and Swengel 2002), and Clark (1975) suggested the Short-eared Owl might be forced to hunt diurnally when prey is insufficiently available nocturnally. In central Alberta, Priestley et al. (2008) found no temporal pattern to sightings in winter during daylight hours. In the United Kingdom, the best times to survey are within four hours of first light, or within four hours before dark (Calladine et al. 2008), although slight differences between the incubation, chick-rearing and fledging stages are apparent (Calladine et al. 2010).

A summary of the prey items found in approximately 16,100 pellets recorded by at least 33 authors in 23 publications across North America indicated 94.8% mammals, of which voles (*Microtus* spp.) accounted for 60.6%, and 5.1% birds (Clark 1975). In Massachusetts, breeding and wintering season diets were 83% and 95% small mammals, respectively, of which 93.8% and 97.9% were meadow voles (*Microtus pennsylvanicus*) (Holt 1993a). Similarly, meadow voles accounted for 97.2% of the wintering season diet in central New York (Stegeman 1957), and 71.1% and 93.7% during two years of study in Toronto, Ontario (Snyder and Hope 1938). Over 10 years of study in Finland, *Microtus* spp. accounted for anywhere from 4 to 91% of the Short-eared Owl breeding season diet (Korpimäki and Norrdahl 1991). In the southern United States and Mexico, however, the diet consists of other small mammals, namely the northern pygmy mouse (*Baiomys taylori*) that replaces *Microtus* spp. (Valdez-Gómez et al. 2009).

The consumption of *Microtus* spp. may not be a result of preference, but of opportunistic hunting to take the most vulnerable species in open country habitat (Clark 1975). Further evidence for this hypothesis includes an increased proportion of avian prey items during the winter when *Microtus* spp. may be unavailable due to snow and frost (Mikkola 1983), and also in the diets of individuals occupying islands and coastal areas (Holt 1993b). Thus, while generally considered a specialist, the Short-eared Owl may also be considered opportunistic, or according to Mikkola (1983),'…often monophagous, only eating voles, but it can adapt itself locally and manifest an individually developed specialization, depending on the prevailing conditions'.

1.2.3 Breeding and reproduction

During the breeding season, the Short-eared Owl actively maintains a territory for hunting and nesting. Mean territory size in Scotland was 16.2 hectares (Lockie 1955), compared to 64.7 hectares in Massachusetts (Holt 1992) and 73.9 hectares in Manitoba (Clark 1975). Both territory size (Pitelka et al. 1955) and clutch size (Lockie 1955) are generally larger in years of increased vole abundance, and eggs are often laid earlier (Lockie 1955, Mikkola 1983). Average clutch size of 186 nests in North America was 5.61, with a distinct increasing trend towards larger clutches at more northerly latitudes (Murray 1976).

Along with the Snowy Owl (*Bubo scandiacus*), the Short-eared Owl is unique among the North American owls in that it lays its eggs on the ground, in a bowl of dried grass with a few downy owl feathers. The female incubates the eggs for approximately 21 days, at which time semi-altricial young hatch asynchronously at intervals of one to two days. The young develop rapidly and at two weeks of age, pre-fledge by wandering up to 200 m away from the nest on foot (Clark 1975). Fledging occurs at four to five weeks, and while it is unknown exactly how long the fledged young are dependent on parental brooding, this period is likely to last at least one to two weeks (Urner 1923), and maybe as long as seven weeks (Voous 1989). Clark (1975) noted one juvenile that continued to beg for food 25 days after fledging, though it had also begun to hunt independently.

1.2.4 Habitat requirements

Across its global distribution, the Short-eared Owl is mainly associated with open country, including grassland, savanna, moorland, tundra, marsh, and montane forest. In North America, suitable habitats include those that support populations of cyclic small mammals, such as large expanses of prairie and coastal grasslands, heathland, shrub-steppe and tundra (del Hoyo et al. 1992). Differences in habitat use between the breeding and wintering seasons exist; wintering habitat typically includes old fields, grain stubble fields, hay meadows, pastures, and inland or coastal marshes (Johnsgard 2002).

Short-eared Owls are often gregarious at winter roost sites, which are described as protected from the weather, close to hunting areas, and relatively free from human disturbance (Clark 1975). These roosts are occasionally characterized by fairly dense coniferous vegetation; at least 5 cm of snow on the ground serves as the stimulus to abandon ground roosting and commence roosting in trees, probably due to a loss of cryptically coloured surroundings (Bosakowski 1986). Clark (1975) noted an increasing trend in the number of owls at a roost with the progression of winter, and documented 60 owls at a single roost in the Niagara region of Ontario in late January 1969. However, winter habitat selection has not been studied in detail, and most regional summaries neglect to mention typical winter habitats (Wiggins 2004).

In addition to open grasslands, breeding season habitat includes moorlands, marshlands, bogs and dunes, and sometimes previously forested areas that have been cleared (Mikkola 1983). A recent study on the Fraser River Delta of British Columbia found Short-eared Owl abundance to increase with thatch height, to a threshold of 11 cm, and with thatch percent cover, to a threshold of 80% (K. Huang et al. unpubl. data). Of 63 nests across North America, habitat was 55% grassland, 24% grain stubble, 14% hayland and 6% low perennials (Clark 1975). Clark (1975) suggested that the primary requirements for nesting are open conditions that support an adequate food base, with a tendency towards drier sites. If a sufficient prey base exists, wintering areas may become breeding areas (Clark 1975, del Hoyo et al. 1992).

1.2.5 Movement strategies

The Short-eared Owl is generally considered a nomadic species moving in relation to cyclic vole populations. In the northern hemisphere vole populations usually peak every three to four years, with infrequent two-, five-, and six-year cycles also known (Krebs and Myers 1974). In western Finland, increasing microtine (i.e. *Microtus* spp.) densities resulted in rapid immigration of Short-eared Owls, while decreasing densities resulted in rapid emigration, thus suggesting a numerical response coincident with changing prey densities (Korpimäki and Norrdahl 1991). A strong numerical response was described on Amherst Island, Ontario, with the synchronous declines in prey and predators occurring over the span of about only 10 days (Phelan and Robertson 1978). Various instances of irruptions during vole peak years have been reported; during the winter of 2005-2006 over 100 owls wintered on the dry lakebed of Beaverhill Lake east of Edmonton, Alberta (Priestley et al. 2008).

Nomadism is typical of cyclic, compared to random fluctuations in food abundance; greater clutch size, juvenile survival, and intervals between successive peak years also favor such movement patterns over that of site tenacity (Andersson 1980). The Short-eared Owl had the second largest mean clutch size of seven North American owl species studied by Murray (1976), but low juvenile survival is apparent (Lockie 1955, Holt 1992). The Short-eared Owl exhibits the four characteristics of nomadic specialization outlined by del Hoyo et al. (1992). *High mobility* – satellite telemetry data from western North America recently revealed movements of up to 7000 km between breeding grounds in Nome, Alaska, and wintering grounds in central Mexico (J. Johnson pers. comm.). *High investment in social facilitation* – communal winter roosts often contain more than 20 individuals, sometimes more than 100, and may be interspecific with Long-eared Owls (Voous 1989). *Some degree of food specialization* – the Short-eared Owl diet is generally considered specialized towards microtine voles, as previously discussed. *Breeding opportunism* – breeding will commence 'whenever and wherever food is in unlimited supply and the weather is mild enough to stimulate reproductive behaviour' (Voous 1989). During vole peaks, two broods may be reared (Cramp 1985), but breeding may be completely forgone when food is in very limited supply (Lockie 1955).

Despite suggestive evidence that the Short-eared Owl is a predominantly nomadic species, such movement patterns are often confused with migration and juvenile dispersal (Wiggins et al. 2006, Johnson et al. 2008). In North America, Johnsgard (2002) classified the Short-eared Owl as a relatively migratory species in the northern part of its range, though the exact pattern and scale of migration is not well understood. The same breeding areas may be used from one year to the next, but it is not known if the same individuals are involved (Wiggins 2008). Clark (1975) noted one instance in which the same winter roost was occupied for eight consecutive years, and therefore posed the question, 'If this owl is not behaviourally bound to any traditional wintering ground, then why have owls persisted in returning to this same area winter after winter regardless of the density of the vole population?'.

1.2.6 Techniques for assessing movement strategies

To date, four approaches have been used to study movement patterns: leg banding, colour-marking, radio telemetry and satellite telemetry. As of 2004, a total of 2997 owls has been banded in Canada and the United States, with a recovery rate of only 1.7%, or 50 recoveries (M. Gahbauer pers. comm.). These records fail to provide much information on long-distance movement, as only eight recoveries were from beyond 1000 km of the banding location and 30% were within the same geographical 10-minute block as the banding location. Clark (1975) is apparently the sole researcher to use colour-marking; this was achieved by painting a bar, or bars, diagonally across the dorsal wing surface, and used mainly to document local occurrence.

Reynolds and Gorman (1999) used radio telemetry to document the relationship between vole activity cycles, and the effect of seasonality on vole diurnality, vole population size, day length and energetic constraints of breeding. In North America, Schmelzer (2005) proposed the use of radio telemetry to assess breeding site fidelity and habitat use in Newfoundland and Labrador. Recent advances in satellite telemetry may contribute greatly to improving the current understanding of Short-eared Owl movement patterns. As previously noted, data from western North America recently revealed movements of up to 7000 km between breeding grounds in Nome, Alaska, and wintering grounds in central Mexico (J. Johnson pers. comm.). However, this remains a costly approach that is only feasible for researchers and biologists operating on a fairly sizeable budget.

Stable isotope analysis is a relatively novel approach that is used to assign geographic origins to individual organisms (i.e. birds, mammals and insects). This method is based on the premise that isotopes of the light elements (i.e. carbon, hydrogen, nitrogen, oxygen and sulphur) are powerful forensic recorders of dietary sources that can be spatially interpolated or explicitly linked to on-the-ground and large-scale patterns in the landscape and hydrosphere (Wassenaar 2008). Using feathers collected from 264 individual raptors of 12 species from 255 locations across most of North America, Lott and Smith (2006) produced a raptor-specific base map representing the relationship between deuterium ratios in feathers and precipitation. The study accounted for regional variation in the described relationship that may occur from the latitude effect (deuterium depletion with increasing latitude), the altitude effect (deuterium depletion with increasing altitude), and the coast effect (deuterium depletion with increasing distance from the coast). The isotope technique for migration studies is advancing quite rapidly, but the comparison of standardized results across different taxa would be advantageous to understand continental deuterium patterns found in the inert keratin of feathers (Lott and Smith 2006).

1.3 Research rationale

It is apparent that the Short-eared Owl is declining at an incredible rate that may ultimately lead to the disappearance of the species across much, if not all, of its North American range. Efforts are urgently needed to halt and eventually reverse this decline; Newfoundland and Labrador is currently the only province or territory in Canada to have proposed a management plan (Schmelzer 2005). A poor understanding of many aspects of Short-eared Owl life history, along with a limited conservation status, has hampered the development of such efforts. Until this critical knowledge is acquired, the North American Short-eared Owl population will likely continue to experience a downward trend.

It is also noteworthy that capitalizing on the appeal of charismatic species to the general public has often resulted in enhanced conservation efforts (i.e. Burrowing Owl, *Athene cunicularia*). In the case of the Short-eared Owl, a predictable outcome will be the conservation of the grassland ecosystem as a whole, including other flora and fauna that may be at risk. Thus, an underlying goal throughout this research project has been public education and outreach using the Short-eared Owl as a flagship species to address the importance of grassland conservation and the development of best management practices. It is likely that the results of this study may eventually be applied to other regions of the Short-eared Owl's global distribution.

1.4 Research objectives

The number of studies conducted to date on North American Short-eared Owls is small; in particular, those that focus on large-scale movement patterns and year-round habitat use are lacking. This research project was therefore focused around three main objectives: 1) documenting *geographic fidelity* across North America in the context of nomadic compared to migratory tendencies; 2) developing a visual survey protocol to improve *monitoring* efforts and facilitate assessments of *landscape-level habitat use* across seasons; 3) describing aspects of breeding biology including *nest site characteristics and fledging success*.

1.4.1 Geographic fidelity

The first objective was to use deuterium stable isotope analysis to determine the spatial origin(s) of individual owls, and thus the extent to which individuals are nomadic or show fidelity to breeding and wintering sites. This involved the collection of feather samples from within the North American wintering, breeding, and year-round ranges. Samples from juveniles were necessary to calibrate existing precipitation (Bowen et al. 2005) and raptor-specific deuterium base maps (Lott and Smith 2006) for the Short-eared Owl. Then, a collection of samples from adults was necessary to discern individual origins.

1.4.2 Monitoring and landscape-level habitat use

The second objective was to investigate the habitat used by a localized population of Short-eared Owls during a breeding and wintering season. To accomplish this goal, it was necessary to develop a standardized protocol to monitor the presence of Short-eared Owls as no such scheme had yet been devised. Thus, effort was also dedicated to evaluating a volunteer-based roadside survey protocol. Land cover and all associated features of the landscape were assessed at each site surveyed for owl activity, and sites were compared based on those that were used (i.e. owls present) and those that were available (i.e. owls absent).

1.4.3 Nest site characteristics and fledging success

The third objective of this study was to describe aspects of the breeding biology of all nesting Short-eared Owls within the same localized population mentioned above. Based on observations during standardized roadside surveys, sites where courtship behaviour was observed were monitored regularly for as long as breeding activity was detected (i.e. some or all stages of territory establishment, incubation, hatching, pre-dispersal movement and fledging). Aspects studied included nest site characteristics (i.e. microhabitat), fledging success and causes of mortality.

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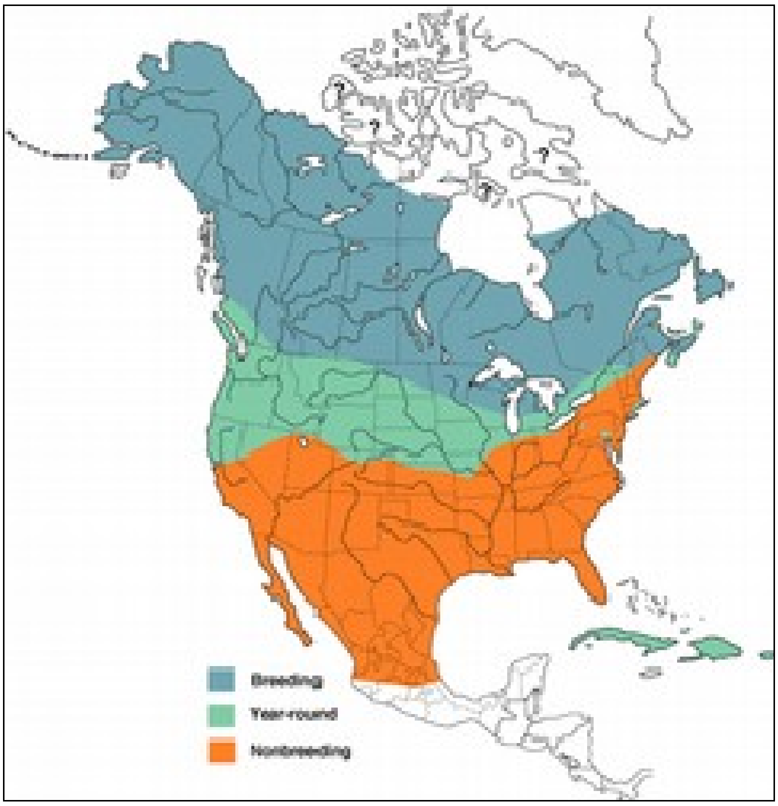

Figure 1-1. Approximate North American Short-eared Owl distribution map (taken from Wiggins et al. 2006).

Connecting statement 1

As outlined in the previous chapter, the Short-eared Owl requires immediate conservation attention in order to halt and eventually reverse the ongoing population decline across North America. However, a better understanding of Short-eared Owl natural history is required to direct such efforts. Several movement strategies have been suggested, but conclusive evidence is lacking. Stable isotope analysis has great potential to address this gap in knowledge. I used the technique to investigate spatial origins across North America, and addressed patterns of geographic fidelity that will facilitate more accurate population estimates in the future.

2 Short-eared Owl (*Asio flammeus*) spatial origins across North America: a stable isotope approach

2.1 Abstract

Many aspects of Short-eared Owl (*Asio flammeus*) natural history are poorly understood, including the extent to which the species may be nomadic, migratory and/or philopatric across North America. Deuterium stable isotope analysis is a commonly used technique for addressing such ecological questions, based on defined latitudinal trends in precipitation (δD_p) that are incorporated into feathers (δD_f). We employed this approach to study Short-eared Owl spatial origins across continental North America. Using samples from 46 juveniles at known locations, we calibrated two species-specific feather isoscapes based on a growing season deuterium isoscape and a raptor-specific deuterium isoscape (δD_r). Slightly more variation was explained by a regression analysis of δD_p and δD_f than that of δD_r and δD_f (i.e. $r^2 = 0.69$ vs. 0.64), thus the growing season deuterium isoscape was used to investigate spatial origins. Two maps were prepared to graphically represent the frequency of Short-eared Owl occurrence. The first represented results of all feathers sampled ($n = 147$), thus all previous locations, and the second displayed results of the first primary feather (P1) ($n = 69$), which is most likely to be grown on the breeding grounds. Maps were similar, with the greatest concentration of Short-eared Owls appearing to be within central Alaska and across western Canada, which is largely a result of sampling locations. At least three owls were sampled in each of 10 locales (i.e. specific geographic areas such as Toronto, eastern New York state), and results from five locales within the year-round range indicated that breeding likely occurred at more northerly latitudes. However, an examination of differences between two generations of feathers from five owls indicated that Short-eared Owls might also show site fidelity within the year-round range. Thus, our observations suggest different movement strategies may exist regionally across North America, and we advocate further use of this technique to better understand Short-eared Owl movement strategies.

2.2 Introduction

Migration is usually associated with regular, large-scale movements between geographical areas used at different times during the year, but many variations of this pattern exist (Hobson and Norris 2008). Nomadism is one such variant; Andersson (1980) defined nomadism as 'a tendency of adults as well as juveniles to move widely in search for food, and to settle and breed where it is locally abundant'. Adult nomadism is associated with large clutch size and high juvenile survival, and by cyclic prey fluctuations with long intervals between years of abundance (Andersson 1980). Nomadic species specializing on *Microtus* voles often exhibit rapid numerical responses (i.e. changes in natality, mortality, immigration and emigration) to changes in densities of prey, and show an incredible ability to track prey numbers without time lags (Korpimäki and Norrdahl 1991).

The Short-eared Owl (*Asio flammeus*) is generally described as a nomadic species, moving in relation to *Microtus* prey cycles in boreal (Korpimäki and Norrdahl 1991) and grassland habitats (Phelan and Robertson 1978, Poulin et al. 2001). However, such movement patterns are often confused with migration and juvenile dispersal (Wiggins et al. 2006). Recently, a satellite telemetry study revealed movements of up to 7000 km between breeding grounds in Nome, Alaska, and wintering grounds in central Mexico (J. Johnson pers. comm.). Many gaps exist in the current understanding of Short-eared Owl movement strategies, as natal philopatry (Holt 1992) and winter roost fidelity (Clark 1975) have also been suggested.

Mark-and-recapture techniques (e.g. leg banding) have been used to study movements of many species, but are poorly suited to the Short-eared Owl, which is extremely difficult to capture and has low encounter rates. As of 2004, only 1.7% (i.e. 50 of 2997) of all individuals banded in Canada and the United States have been recaptured or encountered (M. Gahbauer pers. comm.). Colour-marking (Clark 1975) and radio telemetry (Reynolds and Gorman 1999) may be useful to study movements over limited distances, but again rely upon the development of effective capture techniques. Satellite telemetry offers an exciting alternative, but requires a substantial research budget (Hobson and Norris 2008). Stable isotope analysis, in contrast, is one of the most widely used, affordable techniques for tracking animal movements (Chamberlain et al. 1997, Hobson and Wassenaar 1997), as it does not require capture (i.e. carcasses or incidentally found feathers may be used). This approach has not yet been used to study Short-eared Owl movements.

Stable isotope analysis is based on the premise that isotopes of the light elements (e.g. carbon, hydrogen, nitrogen, oxygen and sulphur) are powerful forensic recorders of diet that can be ultimately linked to defined patterns in the landscape and hydrosphere (Wassenaar 2008). Hydrogen holds particular promise because the ratio of protium (light hydrogen) to deuterium (heavy hydrogen) in rainfall shows a well-defined geographic pattern in rainfall that is reflected in feather keratin (Hobson 2008). Base maps of deuterium (expressed in delta notation, δD_p) in mean annual and mean growing season precipitation exhibit defined depletion with latitude, in incremental bands across North America (Meehan et al. 2004, Bowen et al. 2005). The deuterium isotopic composition of feather keratin (δD_f) can then be used to link individual birds to the general latitude where feather growth occurred. Lott and Smith (2003) calibrated the deuterium base map prepared by Meehan et al. (2004) specifically for raptors, but encouraged researchers to calibrate all pre-existing maps for the specific species of interest.

One of the caveats of the successful application of the stable isotope technique for the study of avian movement patterns is the selection of one or more feathers that will most accurately answer the question of interest. The sequence of moult in Short-eared Owls requires further study (Pyle 1997a), but prebasic moults are believed to be primarily complete, and when incomplete (approximately 20% of North American birds), one to six outer secondary flight feathers are retained (Pyle 1997a, 1997b). The moult occurs mainly on the summer grounds, but in some individuals it may be completed during migration (Pyle 1997b). Thus, to be confident that feathers chosen for isotope analysis were grown on the breeding grounds, they would need to be one of, if not *the* first feathers moulted.

To determine the feathers that would most accurately reflect breeding grounds, we began by investigating Short-eared Owl moult sequence. We then calibrated an existing growing season deuterium base map for the Short-eared Owl. Finally, we used the Short-eared Owl feather isoscape to investigate spatial origins and trends potentially indicative of migratory, nomadic and/or philopatric behaviour.

2.3 Methods

2.3.1 Feather sample collection

We examined 254 museum specimens at the Canadian Museum of Nature, the Royal Ontario Museum, and the Royal Alberta Museum to document Short-eared Owl moult. Based on subsequent discussion with Peter Pyle (pers. comm.), we concluded that the first primary feather (P1) is likely the first to be moulted, with progression towards the outermost primary (P10). Thus, P1 was sampled wherever possible, unless more than one generation of feathers was visible, in which case, a second and sometimes third primary or secondary flight feather were sampled for comparison. Small samples (i.e. 1-2 cm^2) were collected from the proximal, trailing edge of feathers to limit any possible effects on flight.

To calibrate a Short-eared Owl isoscape, feather samples were collected from 48 hatch-year owls from four museum collections (n = 41), and three researchers (n = 7) (see Acknowledgements) (Fig. 2-1). P1 was routinely sampled, except from eight museum specimens due to difficulty in accessing the desired feather without damaging the wings. In those cases, samples were collected from adjacent feathers (i.e. P2, n = 6; P3, n = 1; P4, n = 1) that were the next most likely to represent the isotopic signature of the breeding grounds. Hatch-year samples included young in juvenal plumage and those having undergone the presupplemental or preformative moult. Juvenal plumage is the first plumage subsequent to the natal down that is retained by the juvenile; only body feathers are replaced during the presupplemental moult which normally occurs between July and October (Pyle 1997b). We included owls in both plumage stages (Lott and Smith 2006) and hereafter refer to these samples as 'juvenile feathers'. Nestlings in downy plumage were not included because they may have δD values that reflect the parents' wintering location rather than the nesting location (Duxbury et al. 2003).

August 31 was chosen as the cut-off date for the collection of juvenile feather samples. A limited amount of information exists on juvenile dispersal, but movements of any great distance away from the breeding grounds are not likely to commence until at least this time. After fledging at four to five weeks, Short-eared Owls are dependent upon parental brooding for at least one to two weeks (Urner 1923), and maybe as long as seven weeks (Voous 1989). Thus, even in the case of an exceptionally early breeding season at the southern edge of the breeding range (i.e. egg laying in mid-March), it is unlikely that dispersal will commence before late July, and long-distance movement probably occurs even later, during the fall migratory period. This may begin in mid-August, but the beginning of September is most likely, with continuation into October or November at northern latitudes (Wiggins et al. 2006).

To investigate the spatial origin(s) of individual owls, and thus the extent to which individuals are nomadic or show fidelity to breeding and/or wintering sites, feather samples were collected from adult owls, or in the case of hatch-year individuals, those captured post-dispersal (i.e. after 31 August). Thirty-three people across Canada and the United States (see Acknowledgements) collected samples (n = 147) from live owls, carcasses and incidentally discovered feathers. However, only samples collected from P1 (n = 69) were included in the final analysis of spatial origins. To test differences in isotopic signature between years, five owls contributed samples from two generations. Additional feathers (n = 29) were collected from the Hawaiian subspecies (Pueo, *Asio flammeus* *sandwichensis*) to explore isotopic variation in a resident population. Nine owls from Hawaii contributed samples from two (*n* = 7) or three generations (*n* = 2) of feathers. All samples were collected and transferred under the appropriate provincial/state and federal permits.

2.3.2 Stable isotope laboratory methods

All feather sample preparation was conducted by K. Keyes at the soil science laboratory of the Macdonald campus of McGill University in Ste. Anne-de-Bellevue, Quebec. Starting on the 8 November 2010 for five consecutive days, all feather samples were cleaned of surface oils and debris using a 2:1 chloroform:methanol solution, and air-dried for at least 48 hours. Samples weighing 0.35 (± 0.02) mg were packaged into silver capsules (Elemental Microanalysis 4 x 3.2 mm) and sent to the Stable Isotope Hydrology and Ecology Research Laboratory at the National Water Research Institute (Environment Canada, Saskatoon, Saskatchewan) for analysis. All samples were analyzed in the same laboratory by the same individual to limit potential variation between laboratories, as suggested by Lott and Smith (2006).

The on-line pyrolysis and continuous-flow isotope-ratio mass spectrometry (CF-IRMS) techniques described by Wassenaar and Hobson (2003, 2006) were used to determine the deuterium composition of the non-exchangeable component of samples. The δD results are reported in parts per thousand (‰) difference from the Vienna Standard Mean Ocean Water - Standard Light Antarctic Precipitation (VSMOW-SLAP) standard scale. Hydrogen-isotope reference material yields a 6-month running SD of ± 3.3‰, and keratin standards used for the comparative equilibration are both accurate and precise with SD of ± 0.3‰ to ± 0.8‰ (Hobson et al. 2009). To limit potential variation caused by seasonal shifts in ambient conditions (Dansgaard 1964, Wassenaar and Hobson 2000, Wassenaar 2008), all samples were analyzed in the fewest sequential runs possible in late November 2010.

2.3.3 Statistical analyses

To derive feather isoscapes to which origins of individual owls could be assigned, we used ordinary least squares regression of known-source Short-eared Owl (δD_f) feathers against predicted growing season deuterium (GSD) from the precipitation base map (δD_p) (Bowen et al. 2005), and the raptor-specific deuterium (RD) base map (δD_r) (Lott and Smith 2006). Two outliers, each having $\delta D > -50‰$, were removed from the set of juvenile feather samples ($n = 46$) to facilitate the strongest calibrations possible (K. Hobson pers. comm.). As abrupt changes in δD over short distances (regional effects) were accounted for in the North American GSD and RD maps, and the number of juvenile samples in this study was limited, no further spatial analyses were warranted.

Using the Raster Calculator in the Spatial Analyst tool of ArcMap version 9.3 (Environmental Systems Research Institute 2008), each grid cell on the GSD (25 km^2) map was multiplied by the slope of the regression equation, with subtraction of the intercept ($\delta D_f = 0.603 \times \delta D_p - 42.354$). Each grid cell on the RD (3 km^2) map was corrected using a similar approach ($\delta D_f = 0.606 \times \delta D_r - 41.161$). To limit the geographic extent of consideration to that where moult may occur, the resulting feather maps (Short-eared Owl growing season deuterium, SEOW-GSD; Short-eared Owl raptor deuterium, SEOW-RD) were restricted to the breeding and year-round ranges, using an on-line data source (NatureServe 2010) and the Extract Values by Mask function of the Spatial Analyst tool. The resulting isoscape maps are spatial representations of predicted isotope ratios.

To assess spatial origins of individual owls, cumulative frequency maps were constructed using the SEOW-GSD base map. To account for potential sources of error in assigning birds to their putative origins, each individual owl was assigned a range of plausible δD values, by buffering the measured δD_f by $\pm$ 12‰, corresponding to $\pm$ 1 SD of the residuals from the SEOW-GSD regression. Then, each grid cell containing any value within the calculated range received a “1”, and all other cells received a “0” (Wunder and Norris 2008). This procedure was repeated for each sample ($n = 147$), and the summation of ones and zeros was applied to the maps to graphically represent the Short-eared Owl frequency distribution. To control for feather type, a second set of maps was prepared using only samples from P1 ($n = 69$), most likely to represent breeding origins.

2.4 Results

2.4.1 Preparation of a Short-eared Owl isoscape

The relationships between juvenile Short-eared Owl feathers (δD_f) and both GSD δD_p ($F = 95.65$, df = 1 and 45, $r^2 = 0.69$, $P \leq 0.000$) (Fig. 2-2) and RD δD_r ($F = 76.98$, df = 1 and 45, $r^2 = 0.64$, $P \leq 0.000$) (Fig. 2-3) were similar, but the former explained slightly more variation. The regression equations used to prepare the SEOW-GSD ($\delta D_f = 0.603 \times \delta D_p - 42.354$) (Fig. 2-4) and SEOW-RD ($\delta D_f = 0.606 \times \delta D_r - 41.161$) (Fig. 2-5) maps were also similar. However, our species-specific discrimination factors (DF) (i.e. GSD -42.4‰; RD -41.2‰) were different from that of the North American raptor-specific factor (i.e. -5.6‰, Lott and Smith 2006), and the only other study of an owl species to date, the Flammulated Owl (*Otus flammeolus*) (i.e. -8‰, Meehan et al. 2004).

2.4.2 Distribution of spatial origins

The SEOW-GSD map was selected for the analyses of spatial origins because it was slightly more robust than the SEOW-RD map (i.e. $r^2 = 0.69$ vs. 0.64), and calibration was direct compared to circular calibration (i.e. feather units on feather units) of the SEOW-RD map (S. Van Wilgenburg pers. comm.). Relatively positive δD_f values ($n = 11$) were not represented on the map of previous locations (Fig. 2-6) or the map of breeding spatial origins (Fig. 2-7). The overlap of only two feather samples from the winter range with the most positive value of the year-round range (-60‰) (i.e. -49.8 ± 12‰; -49.3 ± 12‰) was negligible.

The frequency map of previous locations indicated that the most abundant isotopic region (i.e. -115‰) of North America included 35% of all owls sampled, in consideration of the ± 12‰ buffer (i.e. 52 of 147). The region of lowest abundance (i.e. 67‰, 68‰, 72‰) included only 14% of all owls sampled (i.e. 21 of 147). The separation was more pronounced on the frequency map of breeding origins, with 49% (i.e. 34 of 69) of owls included in the region of highest abundance (i.e. -114‰, -115‰), and only 10% (i.e. 7 of 69) in the region of lowest abundance (i.e. -138‰, -139‰, -140‰). Geographical abundance trends were similar for both maps, with the highest frequencies in central Alaska and across the western Canada, from British Columbia in the west to Hudson Bay in the east.

Ten general areas surrounding seven cities, one island, and the geographic centre of eastern and western New York state (hereafter referred to as locales) were each represented by at least three samples from P1, and together serve as a good proxy to investigate potential movement strategies (Table 2-1). For two locales within the breeding range (Tok and Nome, Alaska) expected values (according to the SEOW-GSD value for the general area (i.e. Toronto city or geographical center of western New York state)) were more depleted than those observed (i.e. origins further south), but the differences were variable (range of differences: 10.5‰ and 23.2‰). The opposite trend was observed for five of six locales (Vancouver, British Columbia; Toronto and Amherst Island, Ontario; Montreal, Quebec; Chicago, Illinois) within the year-round range, with observed values that were more depleted than expected (i.e. origins further north). Differences were generally quite large (range of differences: -40.2‰ to -29.3‰). Within the wintering range, the observed values for two locales (eastern and western New York state; 13.0‰ and 15.4‰, respectively) were more enriched than expected (i.e. origins further south). Feather samples collected from two Hawaiian islands, Lana'i (*n* = 4) and Maui (*n* = 26), differed in mean δD_f, but variation was considerable: Lana'i (mean ± SD) -10.2 ± 31.2‰ and Maui 28.4 ± 36.7‰.

2.4.3 *Patterns of between-generation δD_f*

Two generations of feathers were collected from five Short-eared Owls in western Canada (Table 2-2). Between-generation differences ranged from 7.3‰ to

74.6‰, and four of five owls displayed overlap (i.e. ± SD) between δD_f measured for different generations. Two owls from the same location displayed very small differences in δD_f (7.7‰, 7.3‰), though collection occurred three years apart. Two or three generations of feathers were collected from nine Short-eared Owls in Hawaii (Table 2-3). Between generation differences ranged from 93.4‰ to 1.4‰, and the mean difference (mean ± SD) was 36.9 ± 29.1‰ ($n = 13$). Two owls with three generations of feathers displayed differences between all generations.

2.5 Discussion

2.5.1 Utility of a Short-eared Owl feather isoscape

While past studies have applied a generic discrimination factor to account for ecological and physiological differences between δD_p and δD_f (Meehan et al. 2003, Langin et al. 2007, Sarasola et al. 2008), caution has been expressed against this approach (Bowen et al. 2005, Hobson 2005). Instead, researchers have advocated the calibration of existing base maps for particular species by analyzing feathers from samples of known origin (Bowen et al. 2005, Hobson 2005). Museum specimens are a valuable resource for such samples; the effect of varying collection year has been described as negligible (Lott et al. 2003, Smith and Dufty Jr. 2005). Calibration was critical for our study because the stable isotope technique has not been applied to the Short-eared Owl, and only to one other species of owl (Flammulated Owl) that occupies a very different (i.e. forested) habitat (Meehan et al. 2004).

Calibration of both the GSD map (Bowen et al. 2005) and the RD map (Lott and Smith 2006) yielded similar regression equations, but the former was preferred for three main reasons. First, the SEOW-RD map involved calibration of a calibrated surface, potentially confounding the original weighted average growing season δD_p values calculated by Meehan (2004) and used for preparation of the RD base map. Second, the RD map was deemed overly complex for our purpose, which was to look at broad spatial origins across a vast potential breeding range. Third, the surface prepared by Bowen (2005) has been described as robust during previous research (S. Van Wilgenburg pers. comm.).

In North America, Meehan et al. (2004) noted a DF of -8.0‰ for the Flammulated Owl, and a widely cited study of 12 species of diurnal raptors by Lott and Smith (2006) recorded -5.6‰. The greater than expected Short-eared Owl DF of -42.4‰ is likely because the previously noted DFs are based on the Meehan et al. (2004) δD_p surface, such that inherent differences exist from that prepared by Bowen (2005). The Short-eared Owl DF was similar to inland generalist raptors (-40.0‰) (Lott et al. 2003) based on Hobson and Wassenaar (1997), suggesting that it is both valid and predictive. Thus, although the geographic scope of our juvenile samples was limited, we argue that the SEOW-GSD isoscape provides the truest assessment of spatial origins given currently available information.

2.5.2 Spatial origins

According to the frequency map of previous locations, the regions most frequented by the Short-eared Owl in North America were central Alaska, and across western Canada to the Pacific Ocean in the west and the northern shores of Hudson Bay in the east. (Note: due to the nature of isotopic differences occurring in continuous latitudinal contours, Short-eared Owl distribution is interrupted within such bands, and restricted to suitable open country habitat.) It is possible that the observed distribution is an artifact of sample size and distribution; of 147 samples used to prepare the frequency map, within the breeding and year-round ranges the most concentrated collection areas were Alaska (n = 29; P1, n = 19) and south-central British Columbia, Alberta, Saskatchewan and Manitoba (n = 38; P1, n = 20). The map of breeding origins showed a similar pattern, which may also be a sampling artifact. However, it seems that the major collection locations corresponded to the areas of feather growth for all feather types, not just those grown on the breeding grounds (i.e. P1). We therefore provide further evidence to support the notion that Short-eared Owl moult occurs primarily on the breeding grounds, rather than during migratory or nomadic movements. As a further test, we suggest the systematic comparison of intra-individual variation among feathers (Smith and Dufty Jr. 2005, Smith 2008).

Based on our assessment of Short-eared moult, as well as that previously described (Pyle 1997a, Pyle 1997b), it is reasonable to consider the map of breeding origins as a good descriptor of geographic regions deserving of attention for the conservation of breeding habitat. Across the prairies, where the endangered Burrowing Owl (*Athene cunicularia*) occurs, opportunities exist to model a conservation plan after pre-existing schemes (Alberta Burrowing Owl Recovery Team 2005). Conservation potential also exists in Alaska, where a Short-eared Owl research program employing satellite telemetry is in place, and interest exists to expand conservation efforts (T. Booms pers. comm.).

Within the Short-eared Owl's breeding range, individuals sampled from two locales displayed very different mean observed δD_f values, which may initially be interpreted as evidence for nomadic behaviour. We caution against such conclusions; the most parsimonious explanation is increased isotopic complexity on the SEOW-GSD map along the Rocky Mountains due to variable topographic relief. For these locales however, observed mean δD_f values were more enriched than expected, possibly due to evaporative water loss in adults during periods of incubation and chick-rearing (Meehan et al. 2003, Smith and Dufty Jr. 2005, Langin et al. 2007). The relatively large, glandular cecae of owls, relative to other types of carnivorous birds (Clench and Mathias 1995), may also account for isotopic enrichment. A greater ability to absorb water along the digestive tract, preferentially of the lighter isotopes, may increase availability of deuterium for incorporation into feathers.

The potential enrichment effects of evaporative cooling and physiology of the cecae should affect all Short-eared Owls. Thus, mean δD_f from locales within the year-round range, which were more depleted than expected, indicate that the individuals we sampled likely bred at more northerly latitudes. Sample sizes for each locale were small (*n* = 3 (4 locales); *n* = 14 (1 locale)), but the standard deviation for the mean of each locale was less than the difference between observed and expected δD_f. Results from the state of New York, located within the wintering range, are perplexing. High variability existed around sample means, but more enriched δD_f values than expected warrant further study, because individuals sampled in New York are assumed to breed further north, based on the wintering range limit.

2.5.3 Patterns of between-generation δD_f

Of five owls inspected for differences between generations, minor differences for three indicate a strong likelihood for site fidelity. Two of these owls were collected as carcasses at the Vancouver Airport (differences 7.7‰, 7.3‰), within the year-round range, and the third was collected from the Suffield area in southern Alberta (difference 10.5‰). In contrast, another owl collected in the same area had isotopic results that strongly suggested nomadism (difference 74.6‰). The final owl was collected near Riverton, Manitoba, within the breeding range. The between-generation difference for this owl was intermediate (21.9‰). Thus, based on these preliminary results, we hypothesize that Short-eared Owls may exhibit site fidelity to breeding latitudes within the year-round range. Also, the suggestion that high-latitude vole-eating raptors generally exhibit a numerical response (i.e. immigration and emigration) to fluctuating prey densities, but more likely a functional response (i.e. prey switching) at lower latitudes, may apply (Phelan and Robertson 1978, Korpimäki and Norrdahl 1991).

Samples collected from nine owls on the Hawaiian islands of Lana'i and Maui exhibited a significant range of between-generation differences (1.4‰ to 93.4‰). The two islands are located approximately 20 km apart, and as there is no documented inter-island movement of Pueo (J. Penniman pers. comm.), isotopic signatures vary significantly over exceptionally short distances. Overall, the mean isotopic signature for Lana'i samples was approximately 40‰ less than that of the samples from Maui, and samples were much more enriched relative to continental North America.

We suggest two explanations for the extreme isotopic variation, including enrichment, observed in Hawaii. First, Lott et al. (2006) described enriched δD_f that can result from a coastal prey base as ocean waters typically range between 5‰ and -5‰. Second, increased complexity can occur due to the altitude effect (i.e. deuterium depletion with altitude) (Hobson 2008), such that increased topographic relief, which characterizes the volcanic Hawaiian landscape, may cause pronounced differences over short distances. Therefore, it seems that an appraisal by Hobson (2005), that some geographic areas may be too isotopically complex to successfully apply the stable-isotope technique, is applicable to the Hawaiian islands.

2.5.4 Directions for future research

This study served as an investigation of the validity of the stable isotope technique for studying movements of the Short-eared Owl, a species generally assumed to be nomadic. Our results, though preliminary, indicate that it would be logical to pursue this technique further in response to the urgent need for more basic species information, particularly that of movement strategies. Recent advancements to this technique are promising, and should provide more robust results relative to the map lookup approach used here. Likelihood-based assignment, which converts likelihoods to probabilities using Bayes' Rule, allows researchers to identify where isotopic signatures are most likely to have been generated (Royle and Rubenstein 2004). Wunder and Norris (2008) described a stochastic extension to the likelihood-based assignment approach, which accounts for both analytical and spatial interpolation error. Especially in consideration of the unique opportunity to compare different generations of feathers from the same individual, we encourage further studies of this nature on both the Short-eared Owl, and other owl species for which movement patterns are poorly described.

2.6 Acknowledgements

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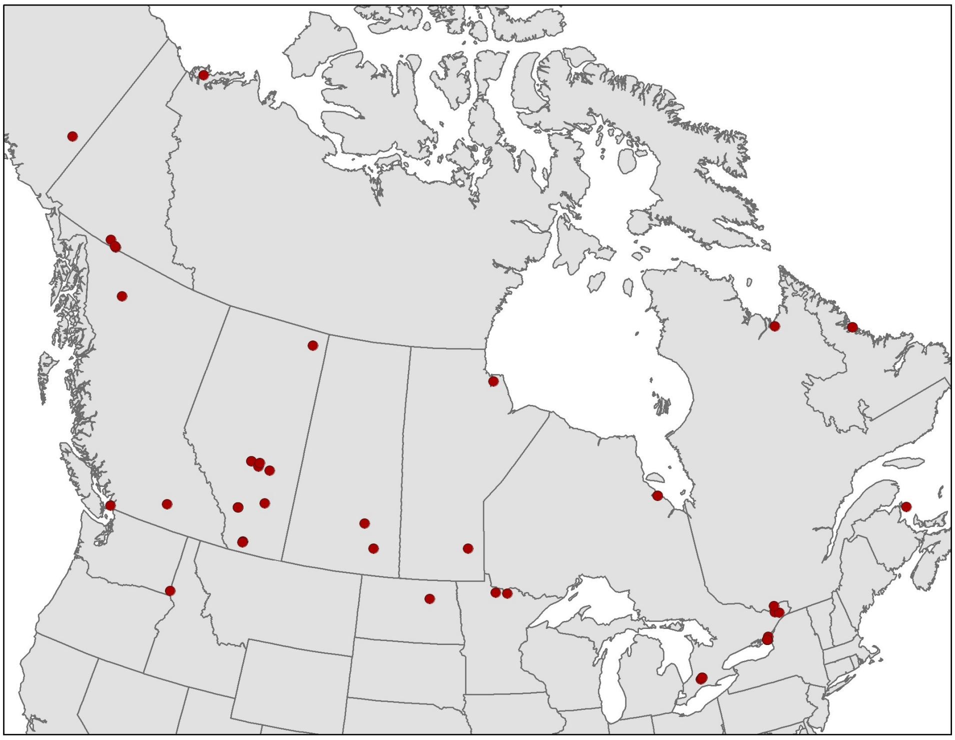

Figure 2-1. Map of North America showing sample locations of juvenile feathers ($n = 46$) used to calibrate the Short-eared Owl feather isoscape.

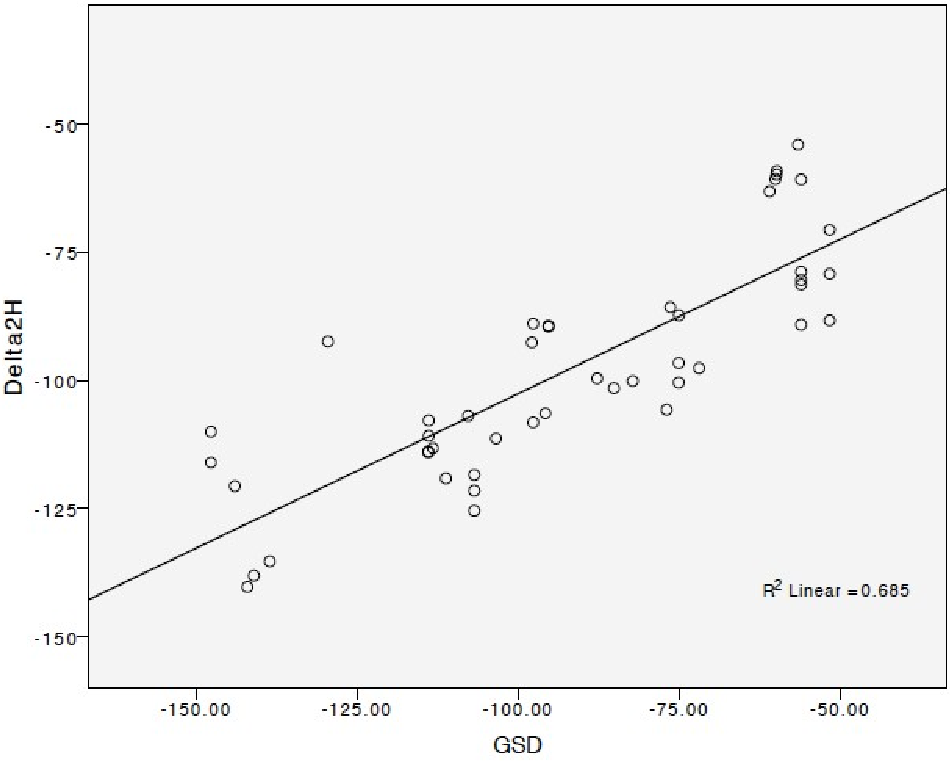

Figure 2-2. Regression model showing the relationship between δD in Short-eared Owl feathers (Delta2H) and growing season deuterium (GSD) in precipitation (*n* = 46) ($\delta D_f = 0.603 \times \delta D_p - 42.354$). Estimates on the x-axis are from Bowen et al. (2005).

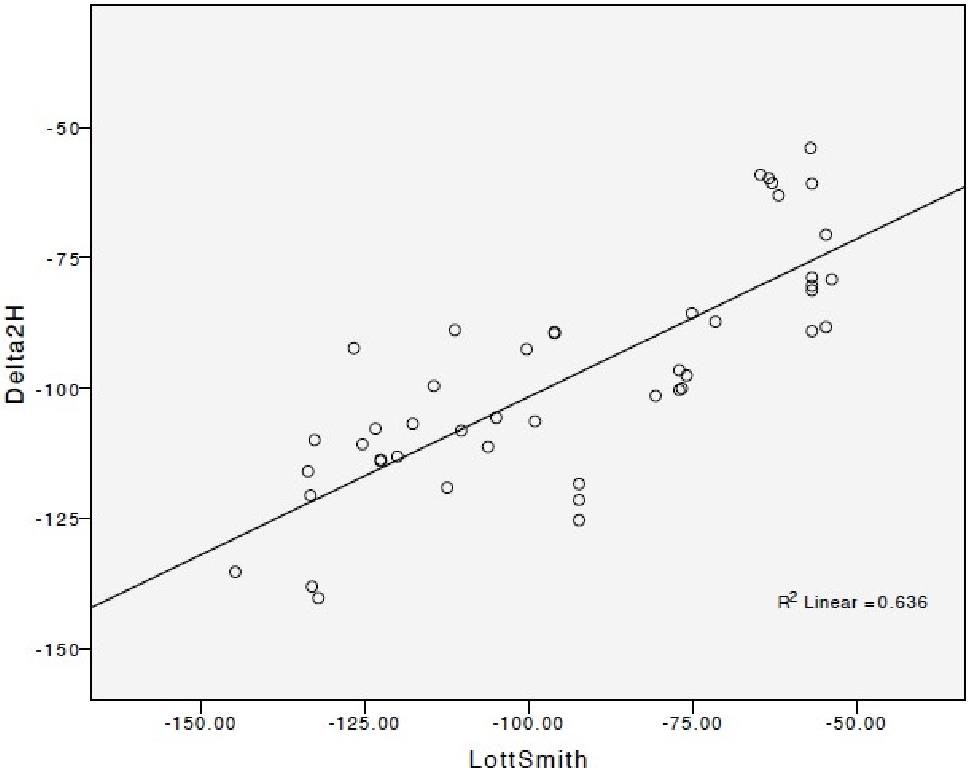

Figure 2-3. Regression model showing the relationship between δD in Short-eared Owl feathers (Delta2H) and raptor feathers (LottSmith) (n = 46) ($\delta D_f = 0.606 \times \delta D_r - 41.161$). Estimates on the x-axis are from Lott and Smith (2006).

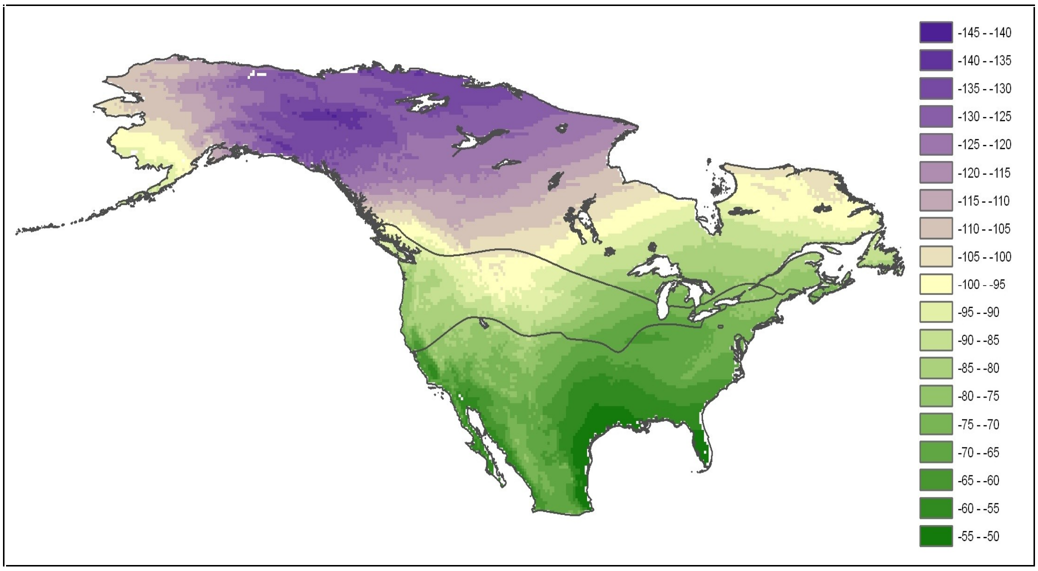

Figure 2-4. Map of δD_f for the Short-eared Owl in North America, prepared from a regression ($\delta D_f = 0.603 \times \delta D_p - 42.354$) of known origin samples ($n = 46$) and expected values (δD_p) based on growing season deuterium in precipitation (Bowen et al. 2005). The breeding, year-round and wintering ranges, as indicated by the geographic extent presented, are delineated by two bold lines running west to east across southern Canada and central United States.

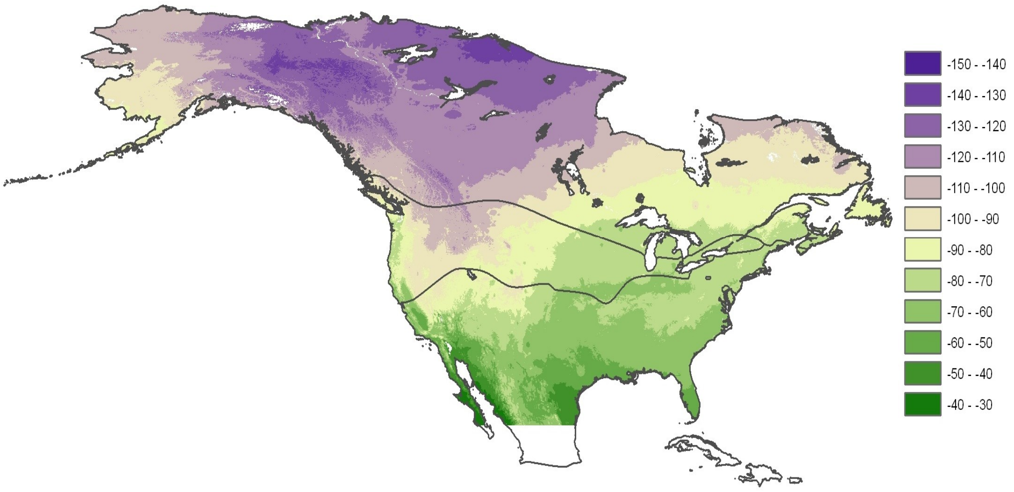

Figure 2-5. Map of δD_f for the Short-eared Owl in North America, prepared from a regression ($\delta D_f = 0.606 \times \delta D_r - 41.161$) of known origin samples ($n = 46$) and expected values (δD_r) based on the raptor-specific deuterium base map (Lott and Smith 2006). The breeding, year-round and wintering ranges, as indicated by the geographic extent presented, are delineated by two bold lines running west to east across southern Canada and central United States.

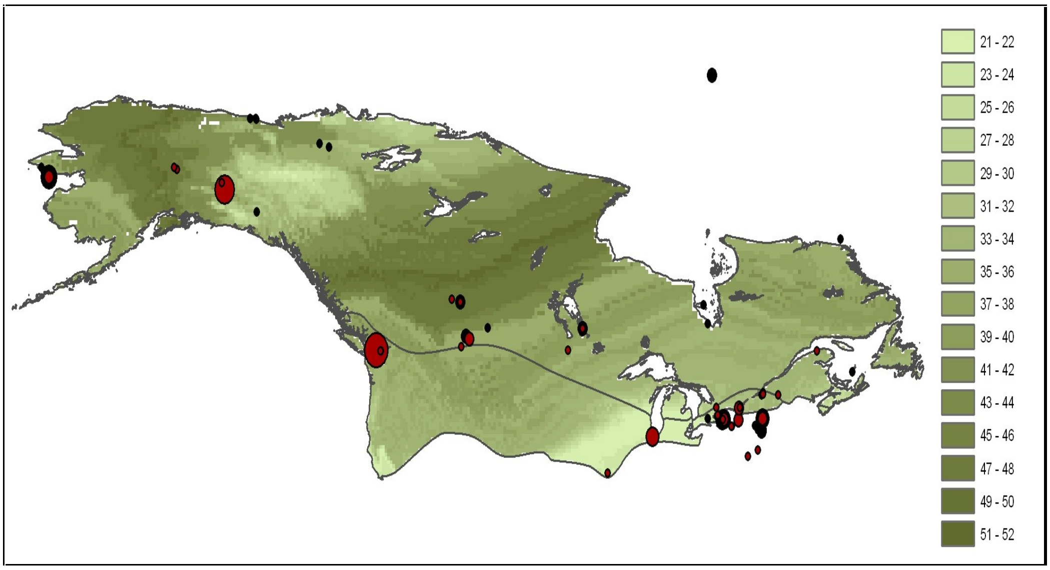

Figure 2-6. Map depicting the previous locations of Short-eared Owls in North America (*n* = 147). Feather type was not controlled and thus, samples may have been grown away from the breeding grounds. Red points represent sampling locations for the first primary feather (P1) samples, and black points correspond to samples not from P1; point size is relative to the number of samples collected. The scale corresponds to the number of samples that included a particular isotopic value, such that darker areas represent higher frequency of occurrence. The breeding and year-round ranges are delineated by a bold line running west to east across southern Canada; the wintering range is not presented here as feathers are grown on the breeding grounds.

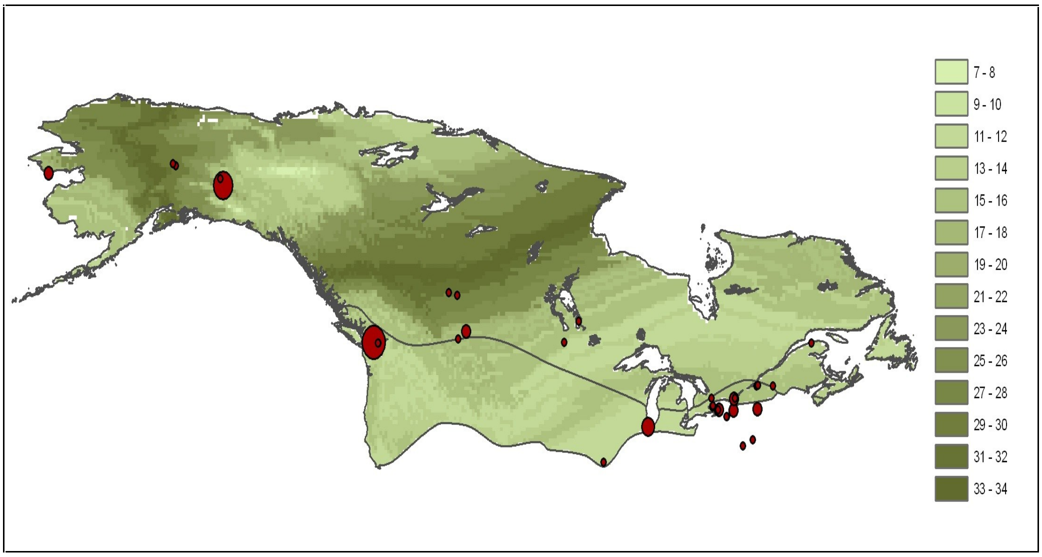

Figure 2-7. Map depicting the spatial breeding origins of Short-eared Owls in North America (*n* = 69). All samples represented were from the first primary feather (P1), and thus, were grown on the breeding grounds. Red points represent sampling locations; point size is relative to the number of samples collected. The scale corresponds to the number of samples that included a particular isotopic value, such that darker areas represent higher breeding abundance. The breeding and year-round ranges are delineated by a bold line running west to east across southern Canada; the wintering range is not presented here as feathers are grown on the breeding grounds.

Table 2-1. Expected and observed δD_f (‰) for 10 locales across North America with at least three Short-eared Owl feather samples of Short-eared Owls collected from P1, thus representing potential source breeding areas.

Location (n)[a]	Expected δD_f[a]	Observed δD_f range	Observed mean δD_f ± SD[b]	Difference δD_f[c]
Tok, Alaska (13)	-129.2	-65.7, -140.2	-106.0 ± 21.3	23.2
Nome, Alaska (3)	-103.9	-69.6, -138.9	-93.4 ± 39.5	10.5
Vancouver, B.C. (14)	-91.2	-86.7, -146.0	-120.5 ± 18.0	-29.3
Medicine Hat, AB (3)	-102.7	-54.4, -116.6	-86.2 ± 31.1	16.5
Toronto, ON (3)	-74.3	-104.9, -123.6	-114.5 ± 9.4	-40.2
Amherst Island, ON (3)	-76.7	-97.9, -123.4	-108.1 ± 13.5	-31.4
Montreal, QC (3)	-78.5	-109.3, -122.5	-116.1 ± 6.6	-37.6
western New York state (8)	-74.3	-33.5, -94.0	-58.9 ± 22.7	15.4
eastern New York state (4)	-76.7	-44.3, -79.3	-63.7 ± 15.7	13.0
Chicago, Illinois (5)	-66.5	-76.4, -133.3	-100.7 ± 25.3	-34.2

[a] Location refers to the general area where feather samples were collected, thus expected δD_f is a value for the general area (i.e. Toronto city or geographical center of western New York state).

[b] Corresponds to one standard deviation of the regression equation residuals used in the preparation of the SEOW-GSD feather surface.

[c] Difference between expected and observed mean δD_f.

Table 2-2. δD_f (‰) of two generations of feathers collected from five Short-eared Owls in western Canada.

ID	Date	Location	1st generation δD_f (± 12)[b]	2nd generation δD_f (± 12)	Difference δD_f
A10	Jul 2006	50º06.21’ N[a]	-116.6	-42.0	74.6
		111º22.36’ W	(-128.6, -104.6)	(-54.0, -30.0)	
A14	2004 or 2005	50º13.02’ N[a]	-98.0	-87.5	10.5
		111º09.53’ W	(-110.0, -86.0)	(-99.5, -75.5)	
A36	1 Feb 2010	49º11.36’ N	-126.8	-119.1	7.7
		123º10’52 W	(-138.8, -114.8)	(-131.1, -107.1)	
A44	23 Mar 2007	49º11.36’ N	-145.2	-152.5	7.3
		123º10’52 W	(-157.2, -133.2)	(-164.5, -140.5)	
A63	19 Jul 2009	51º03.14’ N	-88.1	-110.0	21.9
		96º50.18’ W	(-100.1, -76.1)	(-122.0, -98.0)	

[a] Locations are based on limited available information.

[b] Corresponds to one standard deviation of the regression equation residuals used in the preparation of the SEOW-GSD feather surface.

Table 2-3. δD_f (‰) of two or three generations of feathers collected from nine Short-eared Owls (*A. flammeus sandwichensis*) in Hawaii.

ID	Date	Island	1st generation δD_f	2nd generation δD_f	3rd generation δD_f	Difference δD_f [a]
A151	10 Aug 2009	Lana'i	7.5	-0.3	N/A	7.8
A154	17 May 2010	Maui	60.7	66.3	N/A	5.6
A157	n/a Dec n/a	Maui	99.0	74.8	N/A	24.2
A160	09 Aug 2010	Maui	25.6	41.7	N/A	16.1
A161	02 Mar 2009	Maui	18.8	60.3	N/A	41.5
A164	31 Jul 2009	Lana'i	8.7	-56.5	N/A	65.2
A168	15 Dec 2007	Maui	69.8	16.2	81.4	53.6, 65.2, 11.6
A174	05 Sep 2008	Maui	-23.1	-24.5	N/A	1.4
A176	05 May 2009	Maui	-50.1	43.3	13.1	93.4, 30.2, 63.4

[a] First value corresponds to difference between 1st and 2nd generation; second value corresponds to difference between 2nd and 3rd generation; third value corresponds to difference between 1st and 3rd generation.

Connecting statement 2

In the previous chapter I presented evidence to suggest that the Short-eared Owl exhibits different movement strategies across its North American range. This information will be invaluable to facilitate more accurate population estimates, but only in combination with a reliable monitoring scheme to systematically document trends of Short-eared Owl abundance and distribution. In this chapter I describe and validate a volunteer-based survey protocol, and use the results of a trial period to identify important wintering and breeding season habitat at the landscape-level for an eastern Ontario population.

3 Short-eared Owl (*Asio flammeus*) occupancy, detectability and habitat use across seasons on Amherst Island and Wolfe Island in eastern Ontario

3.1 Abstract

In general, trends of the North American Short-eared Owl (*Asio flammeus*) population have been based on monitoring schemes that are not designed to detect crepuscular species. Similarly, the lack of management plans is due in large part to a scarcity of information on important habitat during the wintering and breeding seasons. We therefore developed and evaluated a visual survey protocol, and investigated year-round habitat use based on comparison of 'used' and 'available' sites. Weekly surveys were conducted at 45 sites on Amherst Island and Wolfe Island for 13 weeks between November 2009 and February 2010, and for 12 weeks between April and July 2010 (biweekly from mid-May). Using the program Presence to assess occupancy (i.e. proportion of sites occupied) and detectability (i.e. probability of detecting Short-eared Owls during a single survey, given at least one is present), the model that assumed constant detectability was a poorer fit than that which accounted for the effects of differing site and survey characteristics. According to the survey-specific model, our protocol was precise; observed and predicted occupancy was similarly low during the winter (0.18 (O), 0.19 ± 0.06 (P)), and during the breeding season (0.24 (O), 0.25 ± 0.07 (P)). Detectability was generally low based on the constant model (wintering 0.31 ± 0.05; breeding 0.31 ± 0.05), but was quite variable depending on the week (wintering 0.00 to 0.83 ± 0.15; breeding 0.00 to 0.79 ± 0.19), thus indicating the need for repeated surveys. We used logistic regression to investigate possible correlation of 12 habitat variables with the presence or absence of Short-eared Owls. During the winter, the forest cover class was weakly significant and negatively correlated ($P = 0.09$) with the occurrence of owls. Grazed grassland and scattered trees were both significantly ($P \leq 0.05$) and positively correlated with the occurrence of owls during the breeding season. We advocate the careful consideration of these habitat variables in all future management plans, and suggest wide use of this protocol to monitor trends of abundance and distribution.

3.2 Introduction

The Short-eared Owl (*Asio flammeus*) is mainly associated with open country, including grassland, savanna, moorland, tundra, and marsh. In North America, this includes large expanses of prairie and coastal grasslands, heathland, shrub-steppe and tundra (del Hoyo et al. 1992). A recent study on the Fraser River Delta of British Columbia found Short-eared Owl abundance to increase with thatch height, to a threshold of 11 cm, and with thatch percent cover, to a threshold of 80% (K. Huang et al. unpubl. data). Clark (1975) suggested that the primary requirements for nesting are open conditions that support an adequate food base, with a tendency towards drier sites. However, little information exists on which particular features of the open country environment Short-eared Owls may prefer.

Winter habitat selection has been studied even less, and most regional summaries neglect to mention typical winter habitats (Wiggins 2004). Johnsgard (2002) noted that it may include old fields, grain stubble fields, hay meadows, pastures, and inland or coastal marshes. Short-eared Owls are often gregarious at winter roost sites, which are occasionally characterized by fairly dense coniferous vegetation (Clark 1975). The accumulation of snow serves as the stimulus to abandon ground roosting and commence roosting in trees, probably due to a loss of cryptically coloured surroundings (Bosakowski 1986).

Before realistic conservation and/or management goals may be established, more detailed information on important habitat use across seasons is needed. Investigations within the species year-round range seem ideal, as opportunities exist to monitor habitats that are preferred during both the wintering and breeding seasons. Of paramount importance for proper descriptions of such preferred areas is the development of a feasible survey protocol with the highest possible Short-eared Owl detection rate.

Short-eared Owls are largely crepuscular, and due to their elusive nature, detection rates recorded to date have been low (Clark 1975, Calladine et al. 2008). In Wisconsin and elsewhere in the Midwest, highest detection occurred 30 minutes before evening civil twilight (28 to 37 minutes after sunset), followed closely by the next earlier 30-minute period, and then from 60 to 90 minutes before twilight and 30 minutes after (Swengel and Swengel 2002). Calladine (2010) reported that Short-eared Owls were visible only 4.8% of daylight hours during the breeding season, and Swengel and Swengel (2002) noted that more owls were visible during casual encounters compared to formal surveys. In central Alberta, Priestley et al. (2008) found no temporal pattern to sightings in winter during daylight hours.

D. Johnson (pers. comm.) suggested an intensive continent-wide monitoring scheme that would include yearly visual sampling of 1,000 1-km^2 sample plots, visited three times per breeding season, for two hours before and 30 minutes after sunset. Following up on this proposal, we developed a volunteer roadside survey protocol to: 1) estimate occupancy and detectability; and 2) use the occupancy results to evaluate habitat requirements across seasons.

3.3 Methods

3.3.1 Study area

We conducted this study on two islands near the city of Kingston, in eastern Ontario, where Lake Ontario flows into the St. Lawrence River (Fig. 3-1). Amherst Island (geographic centre at 44º08′N, 76º43′W) has an area of 70 km^2 and a resident population of approximately 400 people that typically more than doubles in the summer. The soil type on most of the island is Napanee clay, a poorly drained soil with low organic matter content suitable only for hay and pasture, or crops that can survive with excess moisture. Lansdowne clay and Farmington loam cover much less of the island, and while agricultural productivity of the former is relatively good, that of the latter is poor, even for grazing (Gillespie et al. 1963). As such, the landscape is composed of undulating meadow and pasture, mainly for sheep and beef cattle, interspersed with remnants of mixed deciduous forest and marshlands. Amherst Island is recognized internationally for its frequently abundant numbers of wintering hawks and owls, including a tremendous concentration in one area on the eastern part of the island known as the Owl Woods.

Wolfe Island (geographic centre at 44º10′N, 76º22′W) has an area of 124 km^2 and a resident population of 1200 people that typically doubles or even triples in the summer. The landscape is quite similar to that of Amherst Island, however the predominant soil type is Lansdowne clay. Whereas this soil completely dries out only during the summer season, it is among the best for agriculture of the clay-textured soils in the area (Gillespie et al. 1966). Thus, dairy farming and cash cropping, including corn, wheat and soy, cover a greater area on Wolfe Island compared to Amherst Island, relative to size.

BirdLife International has recognized both Amherst Island and Wolfe Island as Important Bird Areas (IBA) of Canada (Birdlife International 2010). This designation is based on several species of owls, hawks, waterfowl, shorebirds and geese for which habitats have been identified on the islands. According to Weir (2008), the Short-eared Owl has nested on both islands intermittently for at least the past 100 years, usually following a winter with abundant voles. However, it is the rarest regular breeding owl of the six species frequenting the area, and is classified as a ‘fairly regular uncommon to common resident’. Since 1954, the species has been present on one or both islands every winter with the exception of 1972-73; it invaded Amherst Island and Wolfe Island in the same winter only eight times between 1954 and 2007 (Weir 2008). Thus, these islands comprise one of the known locations within the North American year-round range with ideal habitat that supports the Short-eared Owl across seasons.

3.3.2 Data collection – visual Short-eared Owl surveys

Survey routes and corresponding point count sites were selected in September 2009. We aimed for complete coverage of all apparently suitable Short-eared Owl habitat on both islands. Identification of such areas was based on knowledge of land cover acquired through ground-truthing during the 2009 breeding season, and also through extensive conversations with landowners and local birders. Although Short-eared Owls are known to move into coniferous areas during the winter for roosting, depending on snow cover and severity of ambient conditions, adjacent open areas are always required for hunting. Thus, we focused on all open areas that may be used year-round for roosting and/or foraging.

The islands were divided into three survey routes each, with eight or nine point count sites along each route that were each surveyed along a 180° range, to a distance of 300 m, on one side of the road (Fig. 3-2) (Appendix 3-1). Sites on the same side of the road were spaced a minimum of 650 m apart, such that no overlap existed between two sites. However, in some instances where suitable habitat existed on both sides of the road, two distinctly separate point counts were conducted from the same site. Our protocol contrasted with other avian surveys (i.e. Breeding Bird Survey (U.S. Geological Survey 2001), Nocturnal Owl Survey (Takats et al. 2001)) in that sites were not equidistant from one another. This was necessary for two reasons: 1) the goal was to cover all suitable Short-eared Owl habitat; and 2) changes in habitat (i.e. unsuitable for Short-eared Owls) forced some sites to be more distantly spaced than others. As the level of volunteer assistance was not adequate to survey Wolfe Island in its entirety, we excluded the area east of Bayfield Bay. It has fewer historical records of Short-eared Owls (K. Hennige pers. comm.), perhaps because vole populations occur at higher densities on the western landmass of the island than on areas of the mainland (Birdlife International 2010).

We conducted evening visual surveys weekly during the wintering season and the start of the breeding season, from the last week of November 2009 until mid-May

2010. During incubation and fledging, when owls are likely to maintain a territory rather than travel and forage freely, we conducted surveys bi-weekly from mid-May until mid-July 2010. Seventeen volunteers from the Kingston Field Naturalists (KFN) participated in surveys. Each volunteer received extensive written instructions and on-site explanation of survey protocol, and was screened for accurate identificaton of the species of interest. As a precautionary step, to decrease the possibility of mis-identifications, we limited observations to within 300 m of the survey site.

Surveys began between 75 and 60 minutes before sunset, and finished within 30 minutes following sunset as set by the moon phase calculator for Kingston, Ontario (refer to www.timeanddate.com). We rotated between surveying routes forwards (i.e. starting at site 1) and backwards (i.e. starting at site 8 or 9) every other week so that the same sites were not surveyed at the same approximate time on each survey. At the start and end of each survey, observer(s) recorded wind speed, cloud cover, precipitation and temperature (Appendix 3-2). Surveys were not conducted during windy conditions greater than five on the Beaufort scale, heavy precipitation and/or extreme cold (i.e. < -15°C). Upon arrival at a site, one or two observer(s) remained silent for a four-minute period, during which they noted all Short-eared Owls seen or heard within 300 m, along a field of view of 180°. For each owl, observer(s) recorded the time of sighting, the quadrat observed (Appendix 3-1), and specific details on behaviour(s) and/or vocalization(s).

3.3.3 Data collection - habitat surveys

Between 2 June and 13 July 2010, we conducted habitat surveys at 66 sites for which we were granted landowner access (Fig. 3-2). Habitat surveys were conducted within the sites covered by the visual point counts. We walked the areas to record GPS (Global Positioning System) coordinates along the perimeter of the survey area and to physically flag these points to assist with estimations of land cover classes. We visually assessed and estimated the percent coverage of eight land cover types within each site (Table 3-1) (Centre for Topographic Information 2009), and we recorded GPS coordinates around the perimeter of each land cover type. We also separately counted the number of wooden and metal fence posts, trees and electrical transmission poles within each site.

3.3.4 Statistical analyses

To investigate the success of our visual Short-eared Owl survey protocol, the program Presence version 2.3 (Hines 2006) was used to estimate occupancy and detectability. Calculations were based on detection histories of repeated sampling through time (Bailey and Adams 2005). As the goal of this analysis was to examine two seasons independently, and Presence assumes a 'closed' occupancy state, observations during the month of March (i.e. 28 February to 30 March 2010) were removed because this period may have included a transition between wintering and breeding populations. The first courtship display was observed on 31 March 2010, thus it is likely that most transitory owls had vacated the island during the defined period. Only routes that were surveyed at least half of the total number of weeks were included, thus controlling for variable effort. In total, 45 sites were surveyed for 13 weeks during the winter and 12 weeks during the breeding season. Two models were developed: 1) constant detectability model – assumed detectability was independent of site (e.g. habitat variables) and survey (e.g. weather conditions, observers) characteristics; and 2) survey-specific detectability model – assumed detectability was dependent on site and survey characteristics.

To verify our field estimates of percent cover of different land cover types, we tested a random sample of 10 sites that each included at least two types. Using ArcGIS version 9.3 NASA Blue Marble high resolution imagery (Environmental Systems Research Institute 2008), we created polygons around each survey site and land cover type within the site, and then calculated the area (m^2) of each feature to determine actual percent cover of each land cover type (Fig. 3-2). This resulted in a comparison of field estimates to GIS results for 32 features, with a mean difference of 2.6%. This small difference validated the use of our field estimates for all subsequent analyses.

To investigate the importance of habitat variables on the occurrence of Short-eared Owls, we used simple logistic regressions for each of the 12 independent variables (i.e. measured habitat variables). The R statistical package version 2.10.1 (Research Core Development Team 2009) was used for these analyses. The dependent variable was binary (i.e. the presence or absence of Short-eared Owls on each of 66 sites). At least one Short-eared Owl observation on a site during each time period indicated that the site was 'used' (i.e. present), while no observations corresponded to an 'available' (i.e. absent) site (Johnson 1980, Jones 2001).

As some of the independent variables in this study were highly correlated, none were excluded from the analysis so as to limit the possibility of missing any variables that might be important considerations in a future Short-eared Owl management plan. The same approach was used to determine if a Bonferroni correction (i.e. $\alpha = 0.05/12$) would be necessary to account for the problem of multiplicity. While this correction will decrease the likelihood of type I errors (i.e. false significance findings), it will also increase the likelihood of type II errors (i.e. significance findings overlooked) (Cabin and Mitchell 2000). Cabin and Mitchell (2000) noted the importance of biological significance and common sense over blind adherence to P values. Thus, considering current grave concerns over the recent North American Short-eared Owl population decline, the possibility of type II errors was deemed of greater importance in this study, and the Bonferroni correction was not applied.

3.4 Results

3.4.1 Survey occupancy and detectability

The Akaike Information Criterion (AIC) used to assess model fit indicated that in both the wintering and breeding seasons, the survey-specific model (i.e.

detectability dependent on survey and site characteristics) provided a better description of the data than the constant model (i.e. detectability independent of survey and site characteristics) (Tables 3-2, 3-3). Overall, Short-eared Owl occupancy on Amherst Island and Wolfe Island was low. A greater proportion of sites was recorded as occupied during the breeding season than during the winter (i.e. 0.24 vs. 0.18). The estimated occupancy rate was also greater during the breeding season; the constant model provided the most conservative estimate during the winter, but the survey-specific model did so during the breeding season.

Across seasons, detectability was similar based on the constant model, but was generally low. Detectability based on the survey-specific model was dependent on the week surveys were conducted. Highest probability of detection for one week was during the winter (i.e. maximum of 0.83 ± 0.15), followed closely by the breeding season (i.e. maximum of 0.79 ± 0.19). At sites where no owls were observed in the winter, their probability of actually being occupied ranged from 0.4 to 2.3% with the constant model, and from 0.1 to 1.5% with the survey-specific model. During the breeding season the range was from 0.1 to 1.7% with the constant model, and from 0.3 to 1.8% with the survey-specific model.

3.4.2 Landscape-level habitat use across seasons

Of the 12 habitat variables investigated, two were significant ($P \leq 0.05$) and positively correlated with the occurrence of owls during the breeding season: grazed grassland and the presence of scattered trees (Table 3-4). During the winter, only forest cover was weakly significant ($P = 0.09$), and negatively correlated with the presence of owls.

3.5 Discussion

3.5.1 Validity of a Short-eared Owl visual survey protocol

As indicated by the better fit of the survey-specific model, it is likely that differences among site characteristics and survey conditions affect detectability.

Swengel and Swengel (2002) noted that diurnal activity increased positively with cloud cover but was negatively correlated with wind and precipitation; this is also likely true of the peak period of activity that preceeds sunset. Detectability also varied greatly among grasslands and among years (Swengel and Swengel 2002). Within the breeding season, Calladine et al. (2010) noted that the stage of breeding, and time of day within some stages, were significant factors accounting for the proportion of time Short-eared Owls were observed by surveyors.

A comparison of the proportion of sites occupied based on survey records compared to the survey-specific model illustrate that our protocol (see section 3.3.2) has a high level of precision. During the winter, the difference was minimal (i.e. 0.18 recorded vs. 0.19 ± 0.06), such that the overall proportion of sites occupied on Amherst Island and Wolfe Island recorded through volunteer surveys was similar to that estimated statistically. During the spring, a slightly higher level of occupancy (i.e. 0.24 recorded vs. 0.25 ± 0.07) was also precisely characterized. Several possible explanations exist for higher occupancy during the breeding season than the winter, but two seem most plausible. First, large groups of Short-eared Owls are often observed hunting together during winter (Weir 2008), possibly because roosts serve as information centers for finding food (Ward and Zahavi 1973). Therefore, while overall abundance was higher in winter, activity was likely concentrated in fewer core areas. But it is also possible that due to chance, or factors that have not yet been identifed, the sites we selected may have been preferred during the breeding season.

Low detectability overall based on the constant model (i.e. 0.31 ± 0.05 (wintering) vs. 0.31 ± 0.05 (breeding)) indicates the need for repeated sampling, as the Short-eared Owl is both rare and elusive. Detectability was only slightly greater during the winter than during the breeding season based on the survey-specific model (i.e. maximum 0.83 ± 0.15 (wintering) vs. 0.79 ± 0.19 (breeding)). This is contrary to the expectation that Short-eared Owls would be more visible during the breeding season when young require care and protection (del Hoyo et al. 1992, Swengel and Swengel 2002). Swengel and Swengel (2002) also described higher detectability preceding civil twilight during the spring and early summer than in fall and winter. Thus, it seems probable that the slight increase in detectability during winter on Amherst Island and Wolfe Island is due to the afore-mentioned explanation, of larger wintering groups of owls being more visible relative to those present during the breeding season.

The low likelihood of owls being present at a site where none were observed (i.e. 0.1 to 1.5% (wintering); 0.3 to 1.8% (breeding)) further validates the usefulness of our protocol, as these results are the consequence of many replicates. As population indices to date have been based on general surveys (i.e. Breeding Bird Survey, Christmas Bird Count) that are unlikely to accurately detect the abundance of crepuscular species, Short-eared Owl population decline estimates such as up to 85% between 1966 and 2005 (M. Gahbauer pers. comm.) are associated with great uncertainty. Therefore, as this protocol is reliable, and requires minimal logistical and financial investment, we advocate its immediate use across North America. However, the level of effort required should be evaluated based on the density of owls in a particular area, such that areas of low density may not necessitate weekly visits. We also encourage further consideration of how site-specific and survey-occasion covariates may influence occupancy and detectability.

3.5.2 Habitat considerations

The Short-eared Owl is generally described as a species of open-country habitat, but few studies have investigated selection for particular land cover types. Foraging requirements are similar throughout the year, focusing on areas with high small mammal populations (Cramp 1985, del Hoyo et al. 1992, Wiggins et al. 2006), but the mention of grazed grassland is limited in the literature. For example, Clark (1975) noted that nests were located in 55% grassland, 24% grain stubble, 14% hayland and 6% low perennials, but did not make reference to the specific percentage of grazed grassland used for nesting. Thus, the finding that grazed grassland is significant during the breeding season at the landscape scale and at the microhabitat level (see chapter 4) should have important implications for Short-eared Owl conservation. The unexpected positive correlation with scattered trees indicates that such features of the landscape may be selected for, as perches for territory surveillance and/or defense (K. Keyes unpubl. data).

Short-eared Owls are known to seek roosting sites in coniferous stands once snowfall exceeds 5 cm (Bosakowski 1986), but the forest land cover class was negatively, albeit quite weakly, correlated with winter occurrence. This may be due to the fact that the winter of 2009/2010 on Amherst Island and Wolfe Island was uncharacteristically mild with little snowfall. Thus, two possible biological explanations for the observed avoidance of forested areas might be: 1) Short-eared Owls could actually concentrate hunting activity in the most exposed areas, where prey would be more visible and therefore vulnerable; and 2) snow cover did not exist to promote roosting in trees.

While no other Ontario species at risk have been recently confirmed on the grasslands of Amherst Island and Wolfe Island, the Eastern Meadowlark (*Sturnella magna*) is fairly common, and is currently under review by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Similarly, the Grasshopper Sparrow (*Ammodramus savannarum*), Field Sparrow (*Spizella pusilla*) and American Kestrel (*Falco sparverius*) have all been observed on the island(s), and are listed as mid-priority candidates for COSEWIC assessments. Clearly, with the Short-eared Owl serving as a flagship species for grassland habitat stewardship, other species will benefit.

3.6 Acknowledgements

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Table 3-1. Eight land cover classes used to assess landscape-level habitat at sites surveyed for Short-eared Owls (modified from Centre for Topographic Information 2009).

Cover Class	Description
Grazed grassland	Land used to pasture livestock (cattle, sheep and horses).
Crop	Annually cultivated cropland and woody perennial crops; lands that generally change from bare cover to green/vegetated cover during the growing season.
Fallow	Formerly grazed grassland, crop or hay, but has not been used for such uses in at least the previous growing season, and which has not yet reached the stage of shrubland.
Hay	Periodically or annually cultivated cropland, including tame grasses and other perennial crops such as alfalfa and clover grown alone or as mixtures for hay.
Wet	Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes (semi-permanent or permanent wetland vegetation, including swamps, sloughs, marshes etc.).
Developed	Land that is predominantly built-up or developed and vegetation associated with these land covers. This includes road surfaces, buildings and paved surfaces, and farmsteads.
Forest	Predominantly forested or treed areas, including at least 10-25% crown closure of coniferous, broadleaf and mixedwood.
Shrubland	Predominantly woody vegetation of relatively low height (generally ± 2 m). Also includes grass or grassland wetlands with woody vegetation and regenerating forest.

Table 3-2. Occupancy and detectability results of visual Short-eared Owl surveys conducted weekly (*n* = 13) during the winter of 2009/2010 at sites (*n* = 45) on Amherst Island and Wolfe Island.

	AIC	Naïve occupancy[a]	Proportion of sites occupied (± SE)	Probability of detection (± SE)
Model #1 (constant)	150.13	0.18	0.19 ± 0.06	0.31 ± 0.05
Model #2 (variable)	136.54	0.18	0.19 ± 0.06	0.00 ± 0.00 to 0.83 ± 0.15[b]

[a] Naïve occupancy refers to the occupancy rate as recorded during visual Short-eared Owl surveys.

[b] Range refers to largest and smallest probabilities of detection of 13 independent weeks.

Table 3-3. Occupancy and detectability results of visual Short-eared Owl surveys conducted weekly (*n* = 12) during the breeding season of 2010 at sites (*n* = 45) on Amherst Island and Wolfe Island.

	AIC	Naïve occupancy[a]	Proportion of sites occupied (± SE)	Probability of detection (± SE)
Model #1 (constant)	186.29	0.24	0.25 ± 0.07	0.31 ± 0.05
Model #2 (variable)	181.06	0.24	0.25 ± 0.07	0.00 ± 0.00 to 0.79 ± 0.19[b]

[a] Naïve occupancy refers to the occupancy rate as recorded during visual Short-eared Owl surveys.

[b] Range refers to largest and smallest probabilities of detection of 12 independent weeks.

Table 3-4. Coefficients of logistic regression analyses of measured habitat variables (*n* = 12) assessed on sites (*n* = 66) on Amherst Island and Wolfe Island surveyed for Short-eared Owls during the winter of 2009/2010 and the breeding season of 2010.

Variable	Wintering (95% CI)	Breeding (95% CI)
Pasture	0.001 (-0.017, 0.019)	0.018 (0.002, 0.036)**
Crop	-0.042 (-0.185, 0.008)	-0.011 (-0.062, 0.017)
Fallow	0.000 (-0.026, 0.021)	-0.003 (-0.031, 0.018)
Hay	0.009 (-0.008, 0.027)	-0.014 (-0.037, 0.004)
Wet	-0.007 (-0.241, 0.082)	-0.030 (-0.388, 0.069)
Developed	-0.103 (-0.328, 0.025)	-0.148 (-0.421, 0.001)
Forest	-0.200 (-0.510, -0.024)*	0.035 (-0.037, 0.106)
Shrubland	0.004 (-0.073, 0.047)	-0.007 (-0.124, 0.038)
Wooden fence posts	0.004 (-0.003, 0.010)	0.002 (-0.004, 0.009)
Metal fence posts	-0.002 (-0.016, 0.009)	0.007 (-0.003, 0.017)
Hydro poles	0.060 (-0.117, 0.241)	-0.006 (-0.182, 0.164)
Trees	-0.013 (-0.114, 0.046)	0.062 (0.011, 0.128)**

*Result is significant at p=0.09; **Result is significant at $p \leq 0.05$.

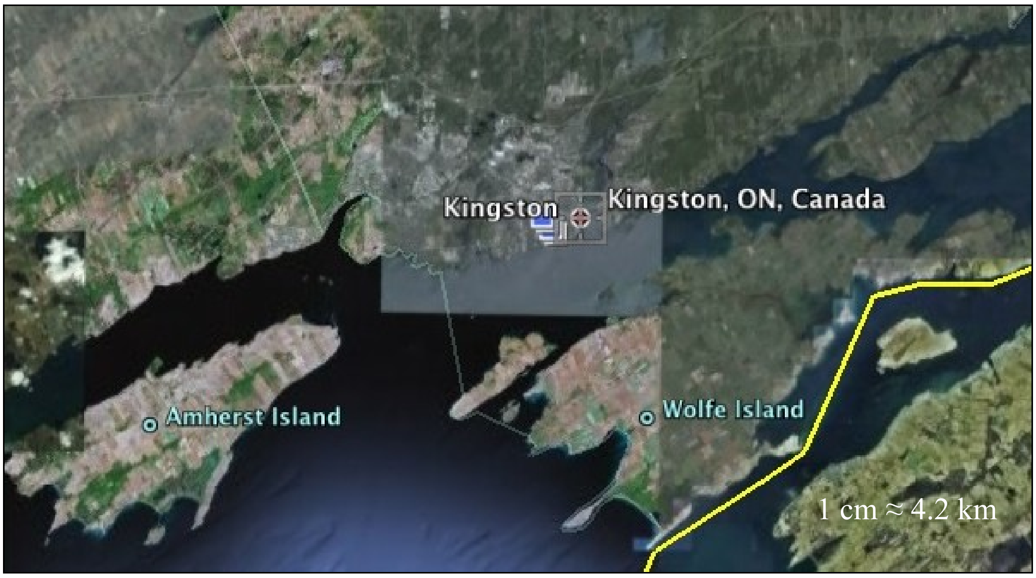


Figure 3-1. Aerial view of Amherst Island (44º08′N, 76º43′W) and Wolfe Island (44º10′N, 76º22′W), located where Lake Ontario flows into the St. Lawrence River (Google Earth 2010).

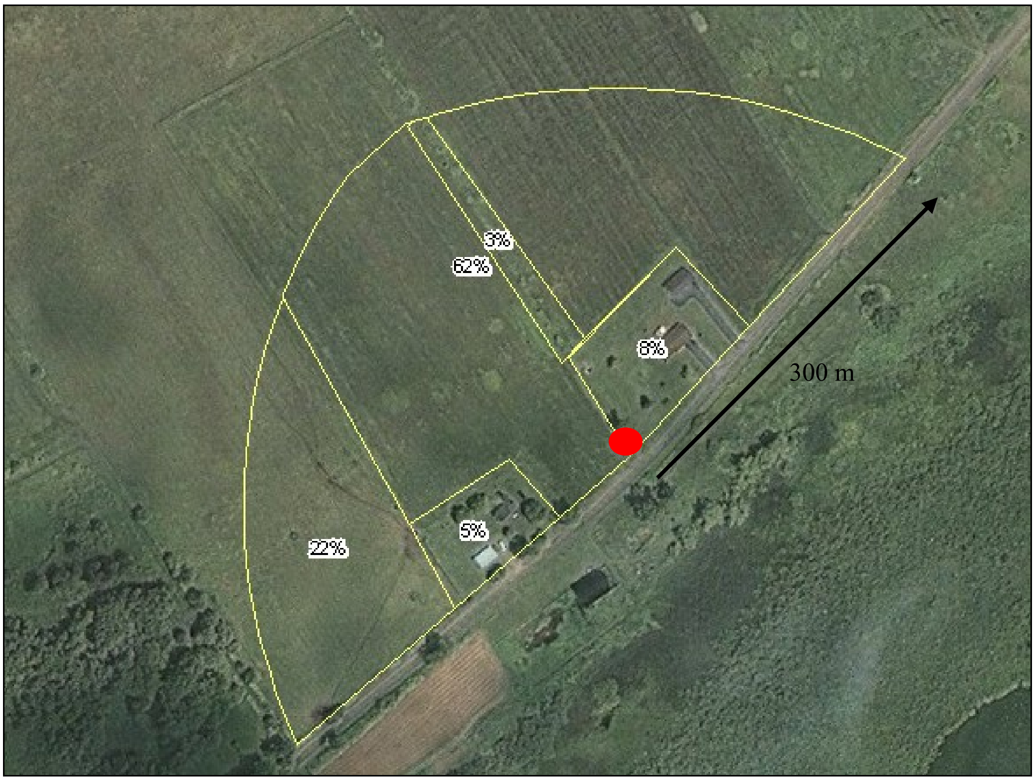
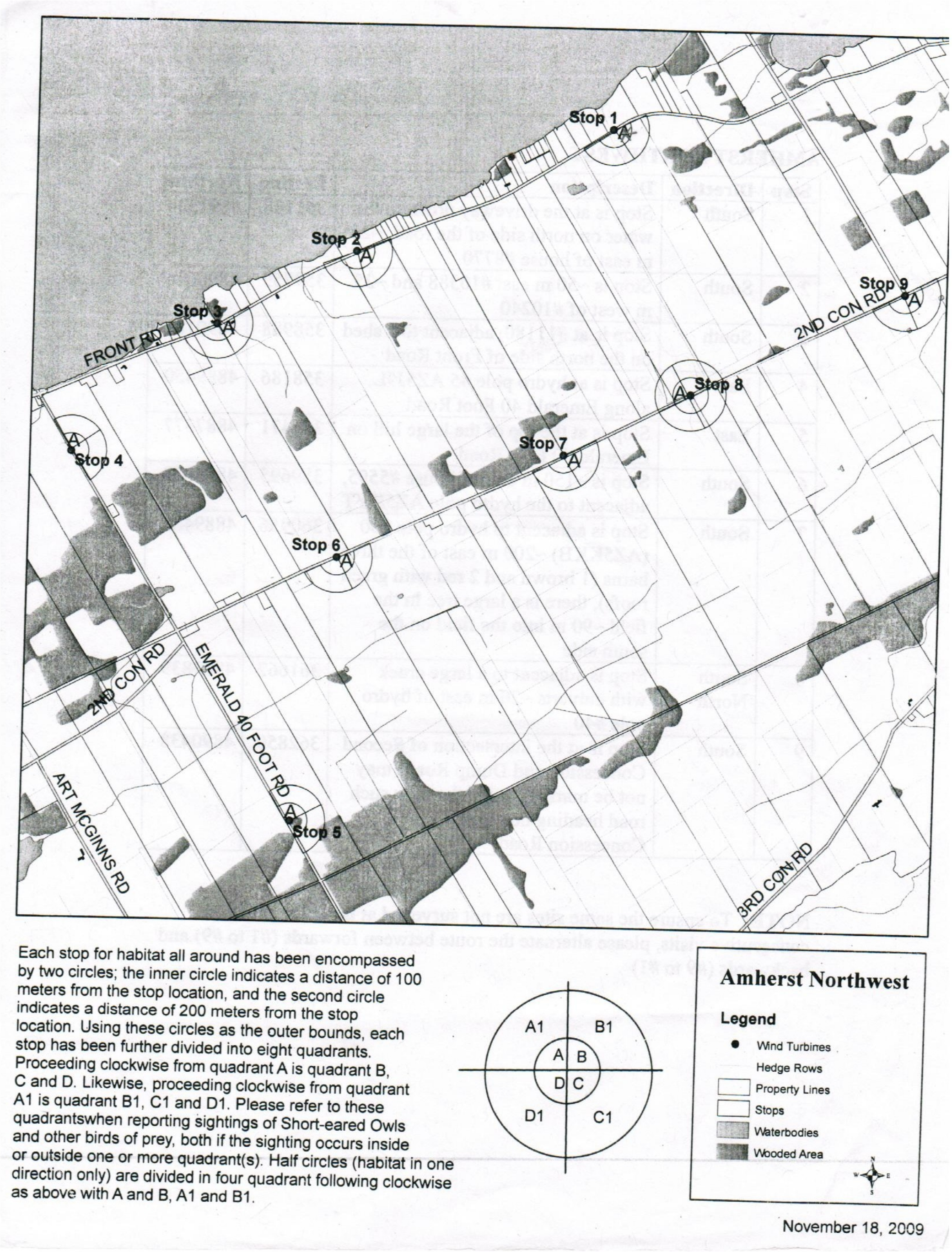


Figure 3-2. Example of one of 66 sites surveyed for Short-eared Owls using the visual survey protocol developed in this study. The red dot represents the survey site where volunteers recorded all Short-eared Owls observed within a 300 m radius. Polygons with corresponding percentages represent different land cover types as determined through intensive habitat surveys.

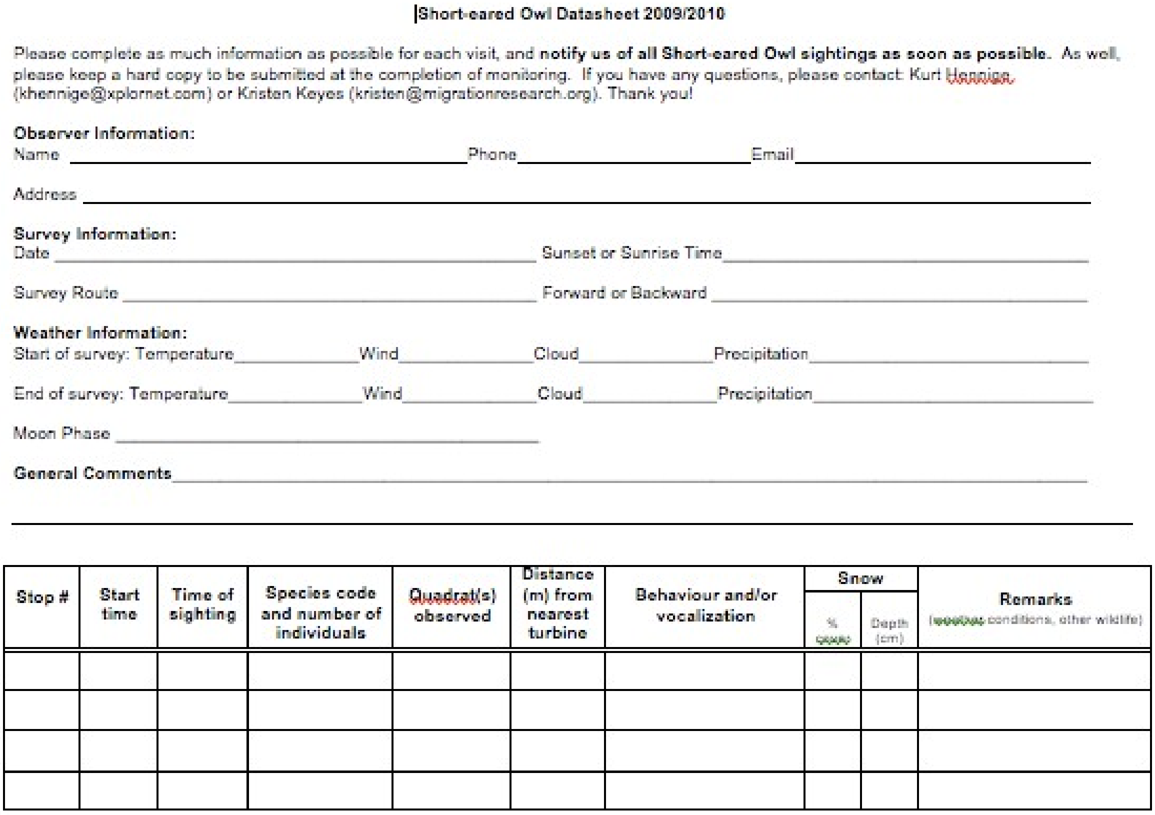
Appendix 3-1. Example survey route (please note that as described in section 3.3.2, stop 8 consisted of two survey sites, one on each side of the road).



Each stop for habitat all around has been encompassed by two circles; the inner circle indicates a distance of 100 meters from the stop location, and the second circle indicates a distance of 200 meters from the stop location. Using these circles as the outer bounds, each stop has been further divided into eight quadrants. Proceeding clockwise from quadrant A is quadrant B, C and D. Likewise, proceeding clockwise from quadrant A1 is quadrant B1, C1 and D1. Please refer to these quadrantswhen reporting sightings of Short-eared Owls and other birds of prey, both if the sighting occurs inside or outside one or more quadrant(s). Half circles (habitat in one direction only) are divided in four quadrant following clockwise as above with A and B, A1 and B1.

November 18, 2009

Appendix 3-2. Short-eared Owl visual survey data sheet.



Short-eared Owl Datasheet 2009/2010

Please complete as much information as possible for each visit, and **notify us of all Short-eared Owl sightings as soon as possible.** As well, please keep a hard copy to be submitted at the completion of monitoring. If you have any questions, please contact: Kurt Hennige, (khennige@xplornet.com) or Kristen Keyes (kristen@migrationresearch.org). Thank you!

Observer Information:

Name ______________________ Phone ______________ Email ________________

Address ____

Survey Information:

Date ______________________ Sunset or Sunrise Time ______________________

Survey Route ______________________ Forward or Backward ______________________

Weather Information:

Start of survey: Temperature__________ Wind__________ Cloud__________ Precipitation______________

End of survey: Temperature__________ Wind__________ Cloud__________ Precipitation______________

Moon Phase ______________________

General Comments ____

Stop #	Start time	Time of sighting	Species code and number of individuals	Quadrat(s) observed	Distance (m) from nearest turbine	Behaviour and/or vocalization	Snow		Remarks (weather conditions, other wildlife)
							% cover	Depth (cm)	

Connecting statement 3

In the preceding chapters I described the movement strategies and important habitat that address why Short-eared Owls appear when and where they do, thus contributing necessary information to the serious knowledge gaps that exist. In order to outline concrete conservation priorities however, information is also required on factors that may contribute to the Short-eared Owl's realized reproductive capacity. In this chapter I describe nest sites at the microhabitat scale, fledging success, and causes of failure in the same local population I studied in the previous chapter.

4 Short-eared Owl (*Asio flammeus*) nest site characteristics, success and associated threats on Amherst Island and Wolfe Island in eastern Ontario

4.1 Abstract

In recent decades, the Short-eared Owl (*Asio flammeus*) has experienced a severe population decline across North America. Little information exists concerning nest site characteristics, nesting success, and causes of reproductive failure. Seven breeding territories were monitored on Amherst Island and Wolfe Island in eastern Ontario during the breeding seasons of 2009 and 2010. On Amherst Island, territories were concentrated in the south-central region of the island in 2009, and towards the eastern end in 2010, thus indicating a possible inclination for loose nesting aggregations. Five of seven territories were located on grazed grassland; vascular plants typically grown for pasture and/or hay were common. The combination of wooden fence posts and page wire fencing was frequent on territories, possibly due to a preference for wooden versus metal posts for perching, an avoidance of electric or barbed wire fencing, and/or possibly because this type of fencing commonly surrounded sites where owls nested. Of four nests discovered, all were within 540 m of a wetland, and 1500 m of a human dwelling. Mean elevation and vegetation height at nests discovered at the egg and/or nestling stage were 81.3 m asl and 54.8 cm, respectively ($n = 3$); a general decrease in vegetation height was observed with distance from the nest, but relative elevation was variable. Mean composition of vegetation at these nests consisted of 70% grasses, 25% herbs and 5% bare ground; percentage cover of grasses was less away from the nest, but that of herbs and bare ground was greater. The Short-eared Owl appears to use nest sites that confer greater concealment and protection from predators. Five of seven nests fledged young; mean fledgling success was 2.1 young per nest. Causes of nestling and fledgling mortality included mammalian (i.e. raccoon, *Procyon lotor*) and avian (i.e. Great Horned Owl, *Bubo virginianus*) depredation, as well as nest destruction by farm machinery.

4.2 Introduction

Among the many aspects of Short-eared Owl (*Asio flammeus*) biology that remain poorly understood, nest site characteristics, fledging success rates and associated causes of mortality are particularly lacking. One of the main reasons why nesting tendencies are documented inadequately is the elusive nature of this species and an associated difficulty in locating nests (Lockie 1955). While Short-eared Owl courtship displays prior to territory establishment are highly visible, subsequent breeding season behaviour is often inconspicuous until young have fledged (Pitelka et al. 1955, Clark 1975). The species is known to be highly gregarious during winter (Clark 1975, Bosakowski 1986), and speculation exists of sociality during the breeding season as well (Wiggins et al. 2006).

Short-eared Owl pair formation usually begins as communal roosts disband in mid-February, and continues until June (Wiggins et al. 2006). On Amherst Island and Wolfe Island, pair formation more frequently occurs in March, but may be earlier or later depending on seasonal effects (K. Hennige pers. comm.). This stage in the breeding chronology is identified by highly visible courtship displays; the male ascends in tight circles to a height between 30 and 150 m before uttering the monotonous courtship call and engaging in a shallow stoop with about 5-10 wing claps under the body (Wiggins et al. 2006).

The Short-eared Owl is unique among owls that nest in Ontario in that it lays its eggs on the ground, in a bowl of dried grass with a few downy owl feathers. In addition to open grasslands, breeding habitat includes moorlands, marshlands, bogs and dunes, and sometimes previously forested areas that have been cleared (Mikkola 1983). Clark (1975) suggested that the primary requirements for nesting are open conditions that support an adequate food base, with a tendency towards drier sites. A recent study on the Fraser River Delta of British Columbia found Short-eared Owl abundance to increase with thatch height, to a threshold of 11 cm, and with thatch percent cover, to a threshold of 80% (K. Huang et al. unpubl. data). Of 63 nests across North America, the surrounding habitat was generally classified as 55% grassland, 24% grain stubble, 14% hayland and 6% low perennials (Clark 1975).

During the breeding season, several causes of anthropogenic and natural mortality have been identified. These include shootings, collisions with aircraft, trains, automobiles and barbed wire fencing, mutilations by farm machinery, and pole-trapping by gamekeepers (Clark 1975). Increased mammalian depredation as a result of habitat fragmentation may be considered an indirect, anthropogenic threat (Wiggins 2008). Nest failure may also occur naturally due to flooding (Mikkola 1983), or depredation by larger avian predators such as the Red-tailed Hawk (*Buteo jamaicensis*) (del Hoyo et al. 1992) or the Great Horned Owl (*Bubo virginianus*) (Bluhm and Ward 1979). Our study documented general habitat characteristics and microhabitat at nest sites, as well as nest success and causes of failure.

4.3 Methods

4.3.1 Study area

For a description of the study area, refer to section 3.3.1.

4.3.2 Data collection

During the 2009 breeding season, non-standardized surveys (i.e. from a vehicle while driving slowly around the islands) beginning on 25 April were used to detect courtship, though reports from local birders prior to this date were of great value. In 2010, standardized surveys (refer to section 3.3.2) were used to detect courtship activity; these surveys were continuous from the previous fall. Once a courtship display was detected, the site was visited at least twice per week to confirm the establishment of a territory and the presence of a breeding pair. Within one month of observing courtship activity, the general area was searched for a nest using the ‘duck drag’ technique (D. Holt pers. comm.). This involved two people walking through the area while pulling a heavy 27 m rope between them to flush the nesting female, thus revealing the location of the nest.

Upon discovery of a nest site, various characteristics of the surrounding area were recorded (i.e. land use and prominent features of the landscape). Also, the dominant vascular plant species present at each site were recorded through visual inspection of the immediate area (~50 m^2). Once nests were vacated due to fledging, nest depredation and/or destruction, microhabitat was assessed. Quadrats (1 m^2) were placed directly over the empty nest, as well as at 5, 10, 15, 25 and 50 m along line transects in each of the four cardinal directions (Bonham 1989). At each quadrat, elevation (above mean sea level, precision ≥ 3 m) was recorded using a hand-held GPS unit (Garmin ETrex 12 channel), vegetation composition (i.e. grasses:herbs:bare ground (note: bare ground often included flattened, dead vegetation from the previous season)) was estimated by two observers (same for each site), and four measurements of vegetation height (i.e. within each quarter of the quadrat) were averaged. Other data recorded include distance to, and type of, the nearest body of water, human structure and fence line.

To document nest progression, all nests were visited once per week. Once the young had reached the pre-dispersal stage, and thus wandered away from the nest on foot, the site was routinely visited at dusk (keeping a minimum distance of 200 m from the nest) until the male was observed performing food deliveries to the begging young (Clark 1975). Juveniles were found by searching the area where a delivery was observed as young Short-eared Owls that have not yet fledged remain still upon approach (D. Holt pers. comm.). Owls were banded using size six metal lock-on bands; feather samples and a series of morphological and plumage measurements were collected from each individual.

Exhaustive efforts to deploy up to 10 radio transmitters through the capture of both fledged juveniles during the breeding season, and adults during the breeding and wintering seasons, proved unsuccessful. Only one hatch-year owl was captured and harnessed with a 9 g radio transmitter, in June 2009 (Model RI-2CM(12), Holohil Systems Ltd.), and was tracked using a hand-held receiver (Model TRX-1000S, Wildlife Materials, Inc.) and antenna (3 Element Folding

Yagi, Wildlife Materials, Inc.). Efforts to detect a signal continued until July 2010, via both ground reconnaissance and surveys from an aircraft, but were unsuccessful.

The capture techniques attempted were many: (1) Verbail traps; (2) Bal-chatri traps baited with domestic mice (*Mus musculus*), wild meadow voles (*Microtus pennsylvanicus*), wild House Sparrows (*Passer domesticus*) and/or wild European Starlings (*Sturnus vulgaris*); (3) up to four mist nets (60 mm black mesh) arranged in a square, and alternatively in a line along a hedgerow, often with a Short-eared Owl specimen and an audio lure (i.e. Short-eared Owl vocalizations) mounted on a fence post; (4) two dho-gaza nets with a mechanical Great Horned Owl and an audio lure (i.e. Great Horned Owl vocalizations); (5) various modifications and combinations of the above (refer to Bloom et al. (2007) for further descriptions).

4.4 Results

4.4.1 Breeding chronology and nest success

Over two seasons of study and complete coverage of all islands, six Short-eared Owl breeding territories were discovered on Amherst Island, and one was discovered on Wolfe Island (Table 4-1). In 2009, the three territories located on Amherst Island were clustered in the south-central region of the island (Fig. 4-1a), while in 2010 this clustering shifted to the eastern end (Fig. 4-1b). Over two years, the earliest courtship observation occurred on 6 April, and the latest occurred on 24 May. The clutch sizes of nests discovered at the egg and/or nestling stage were generally large (range: 6-8, mean = 7, SD = 1, n = 3), but fledging success was variable (range: 0-5, mean = 2.1, SD = 1.9, n = 7). Two of seven nests did not fledge any young due to mammalian depredation and farm machinery, and two young at another nest were depredated by a Great Horned Owl that occupied a nearby territory. One nest fledged a single juvenile, while three nests fledged three, and another fledged five.

A hatch-year owl from the Eves site was captured using a mist net and the Short-eared Owl juvenile food begging call as a lure (uttered by a field worker), and harnessed with a 9 g radio transmitter on 10 June 2009. It remained on its natal territory for the duration for the tracking period, until 8 July 2009, at which point it relocated off the island. All members of the Eves family unit, as well as those from the adjacent Kilpatrick family unit, relocated on the same date. Dispersal was coincident with the onset of the haying season on a field adjacent to the Eves territory.

4.4.2 General habitat features and land use patterns

Of seven territories, one was located in a hayfield, one in a fallow field (i.e. early succession), and five in grazed grassland, although livestock was not put to pasture until nesting was started, and in three cases completed (Table 4-2). All sites were located on land that had been used for the same purpose for at least 10 years previous, except for the Eves and Kilpatrick sites that within the last four years were converted to pasture from crop rotation via hay, and to hay directly from a crop rotation, respectively. Three of four nest sites located at the egg and/or nestling stage were within 1000 m of an active dwelling (range: 370-1500, mean = 767, SD = 526, n = 4) and all were within 540 m of a marsh or pond (range: 175-540, mean = 366, SD = 181, n = 4). The combination of wooden fence posts and page wire fencing (i.e. metal grid style) was the most common fence type on five of seven territories.

The most frequently observed vascular plant species were birdsfoot trefoil (*Lotus corniculatus*) and cow vetch (*Vicia sativa*) (present at five of seven sites); Canada goldenrod (*Solidago canadensis*) and reed canary grass (*Phalaris arundinacea*) (present at four of seven sites); smooth brome grass (*Bromus inermis*), red clover (*Trifolium pratense*), redtop (*Agrotis gigantean*), timothy (*Phleum pratense*), thistle (*Cardus* spp.*,* *Cirsium* spp. and *Silybum* spp.) and sedge (*Carex* spp.) species (present at three of seven sites) (Table 4-3).

4.4.3 Microhabitat at nest sites

While four nests were discovered at the egg and/or nestling stage, the Wolfe site was completely destroyed by farm machinery prior to the collection of microhabitat data. Analysis of three nests on Amherst Island indicated variable changes in elevation from the nest to 50 m away (Fig. 4-2). The pattern was most defined for the KFN nest, with a nest elevation of 80 m asl compared to a mean of 75.5 m (SE = 0.7) at 50 m from the nest. This was not the case for the Kilpatrick site however, with a nest elevation of 82 m asl compared to a mean (± SE) of 83.8 ± 0.9 m asl at 50 m from the nest (Appendix 4-1).

The height of vegetation was greater at the nest compared to all distances away from the nests, with a mean height (± SE) at 0 and 50 m of 54.8 ± 2.6 cm and 40.4 ± 1.6 cm, respectively (Fig. 4-3). The height of vegetation decreased from the nest to the 5 and 10 m distance, before gradually increasing or remaining constant at greater distances. Percent vegetation cover of grasses was higher at the nest site (70.0 ± 13.2%) than at any other distance away from the nests (Fig. 4-4). The percent cover of both herbs and bare ground (n.b. included dead, flattened vegetation from the previous season) generally increased with distance from the nest.

4.5 Discussion

The count of three nests in 2009 and four nests in 2010 resulted in a small sample size for study. In consideration of the fact that the current understanding of Short-eared Owl breeding biology is quite minimal however, knowledge gained from the territories and nests discovered in this study is particularly relevant.

4.5.1 Nest site characteristics

Courtship was observed at all sites where nesting was later confirmed through the discovery of a nest and/or fledglings. Nests appeared to be loosely aggregated in a specific area of Amherst Island in 2009, and a different area in 2010. As courtship surveys covered the entire islands, and the nests of all pairs were located, this clustering is not a function of sampling, but rather a real phenomenon. The finding supports previous speculation that the species may be a facultative colonial nester; nests have been found as close as 55 m apart (Wiggins et al. 2006). This may result from an aggregated food source rather than social inclination or pressure (Voous 1989). However the food abundance hypothesis may not apply to Amherst Island, as general observations by K. Keyes (unpubl. data) and landowner accounts indicated an even, relatively high density of voles across the island in 2009 and 2010. In addition, the apparent dispersal of two adjacent family units off Amherst Island at the same time further supports the notion that the Short-eared Owl may display gregarious behaviour not only during the winter (Stegeman 1957, Voous 1989), but possibly during the breeding season as well.

There is little mention in the literature regarding Short-eared Owls using grazed grassland. Thus, it was unexpected that 71% of the nests in this study were located on grazed grassland occupied by beef cattle or sheep. The occurrence of a nest in a hay field, and another on grazed grassland, both of which were used for soybeans and corn three to four years prior, indicates that Short-eared Owls may not require perpetual grassland habitat. The combination of page wire fencing with wooden fence posts was dominant on all territories; electric, barbed, and page wire fencing are all found on the islands. This may suggest that wooden fence posts serve as ideal perches on breeding territories, rather than metal fence posts and/or barbed or electric fencing, as observed by K. Keyes (unpubl. data). Barbed wire has been recognized as a potential threat to Short-eared Owls in flight (Clark 1975, Wiggins et al. 2006, Weir 2008); one was found impaled on barbed wire on Amherst Island during this study (B. Livingstone pers. comm.). Such fencing has also been confirmed as a threat to the Burrowing Owl (*Athene cunicularia*) (Todd 2001), another species found in open country habitat.

All four nests discovered at the egg and/or nestling stage were within 540 m of a pond or marsh. It is unknown if the owls actively used such wet areas, but similar to observations by Clark (1975), it is likely that an open area capable of supporting an abundant prey base with a drier site for nesting are the main nesting requirements. A residence and farm within 1500 m of each of the four nests discovered may indicate that complete avoidance of human activity is unlikely, though it has been noted during the winter (Clark 1975). A 10.8% increase in the Amherst Island population between 2001 and 2006 (Loyalist Township 2007), which is reportedly ongoing (J. Scott pers. comm.), may have begun to limit the number of isolated nest sites. However, the discovery of one winter roost on Amherst Island in January 2010 that contained 18 owls in a single red cedar (*Juniperus virginiana*), approximately 3 m from an occupied residence, further suggests that moderate human activity may not be a deterrent to the Short-eared Owl.

The most frequently observed vascular plants on territories in this study were consistent with a similar study in southern and eastern Ontario (Hunt and Gahbauer 2004) which found birdsfoot trefoil, Canada goldenrod, red clover, and timothy at four of five sites, and carex *spp.,* cow vetch and reed canary grass at three of five sites. Smooth brome grass, redtop and thistle *spp.* were also noted by Hunt and Gahbauer (2004). Most of the vascular plants mentioned are common in open fields, roadsides and meadows (Legasy and LaBelle-Beadman 1995). In particular, reed canary grass, red clover and smooth brome grass are all cultivated for forage and pasture in Ontario (Legasy and LaBelle-Beadman 1995, OMAFRA 2003). Thus, it appears that on the islands studied, Short-eared Owls will nest in areas managed for agriculture, with the exception of those used for row crops (e.g. corn or soybeans).

Once the elevation degree of precision (≥ 3 m) was taken into account, only the KFN nest was clearly located on a site at a higher elevation compared to the surrounding area within 50 m. In contrast, taller vegetation and a greater percentage of grasses than the surrounding area characterized all three nests. Clark (1975) noted a tendency to select drier sites, likely to prevent nest destruction caused by flooding (Mikkola 1983). Taller vegetation provides better concealment, thus decreasing the likelihood of depredation. Cramp (1985) noted thick cover at most nests, and the only two nests that fledged young in a study by Lockie (1955) were located under a thick clump of tufted hair-grass.

The mean vegetation height at nests in this study (mean = 54.8 cm, SE = 2.6, *n* = 3) was higher than that reported by Holt (1992) (mean = 45.1 cm, SE = 1.7, *n* = 9). However, the mean percent vegetation cover of grasses at the nest site (mean = 70%, SE = 13.32, *n* = 3) was lower (mean = 90%, SE = n/a, *n* = 9), possibly because of the dominance of matted down residual beach grass (*Ammophila breviligulata*) in Holt's (1992) study. The percent cover of grasses at nests in our study was greater than the surrounding area (i.e. within 50 m), but that of herbs and bare ground actually increased with distance. Comparatively, of 28 nests in Montana, within 15 m of the nest site composition was 85% grasses (Wiggins et al. 2006), suggesting that vegetation cover at nest sites might vary with availability at different locations.

4.5.2 Fledging success and associated threats

Fledging success in this study (mean = 2.1, SD = 1.9, *n* = 7) was lower than studies in Manitoba (mean = 3.1, SD = 1.6, *n* = 9) (Clark 1975) and Massachusetts (mean = 3.2, SD = 2.2, *n* = 22) (Holt 1992). Of seven nest sites discovered in this study, one was completely depredated, likely by a family of raccoons that occupied a nearby shed. The other known cause of natural mortality in this study was the loss of two juveniles that had pre-fledged, and appeared to have been killed by a Great Horned Owl that occupied a territory nearby. Bluhm and Ward (1979) reported a similar depredation event in Manitoba. A study of 24 nests in Stirlingshire, Scotland found that only five persisted to hatch, and two to fledging, due to depredation by Carrion Crows (*Corvus corone*) and foxes (*Vulpes vulpes*) (Lockie 1955). Another nest in our study was completely destroyed by farm machinery when the area was plowed for row crops after lying fallow for almost a decade. Clark (1975) noted mutilations by such equipment, and discussions with landowners on Amherst Island and Wolfe Island indicated this to be an unfortunately frequent event. Clearly, the Short-eared Owl faces many threats, and an effective species management plan will require an integrated approach among researchers, legislators, and landowners.

4.6 Acknowledgements

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Table 4-1. Chronology, clutch size, fledging success and cause of mortality for nest sites of Short-eared Owls located on Amherst Island and Wolfe Island in 2009 and 2010.

Nest ID	Island/ Year	UTM[a]	Date courtship first observed	Date nest located	Clutch size	# young fledged (fledging success)	Cause of mortality
Eves	Amherst 2009	n/a	2 May	n/a	n/a	3 (n/a)	n/a
Kilpatrick	Amherst 2009	364743 E 4889121 N	2 May	31 May	n/a[b]	1 (n/a)	n/a
McGinn	Amherst 2009	361380 E 4886730 N	24 May	1 June	7	0 (0%)	Mammalian depredation
KFN	Amherst 2010	370057 E 4893448 N	6 April	13 May	6	5 (83%)	n/a
Front Road	Amherst 2010	n/a	31 March	n/a	n/a	3 (n/a)	Great Horned Owl depredation
Willard	Amherst 2010	n/a	6 April	n/a	n/a	3 (n/a)	n/a
Wolfe	Wolfe 2010	385960 E 4889663 N	29 April	20 May	8	0 (0%)	Farm machinery

[a] Coordinates correspond to NAD 1983, UTM zone 18N.

[b] Nest located after all juveniles had dispersed from the nest on foot.

Table 4-2. General habitat features and land use patterns of nest sites of Short-eared Owls located on Amherst Island and Wolfe Island in 2009 and 2010.

Nest ID	Human infrastructure[a]	Fence line(s)/fence post(s)[a]	Water classification[a]	Current land use[b]	Past land use
Eves	Residence and beef farm (n/a)	Page wire/wooden (n/a)	Lake Ontario (n/a)	Pasture for beef cattle	Hay (4 years) preceded by crop rotation (i.e. corn and soybeans)
Kilpatrick	Abandoned shack (~160) Residence and beef farm (~1500)	Barbed and page wire/ wooden (~120)	Pond (~175) Lake Ontario (2000)	Hay	Hay (3-4 years) preceded by crop rotation (i.e. corn and soybeans)
McGinn	Residence and beef farm (~400)	Electric, barbed and page wire/wooden (~85)	Marsh (~500)	Pasture for beef cattle	Pasture for 80-100 years
KFN	Residence and horse farm (~370)	Page wire/ ~2/3 metal and 1/3 wooden (120)	Marsh (~540) Lake Ontario (~635)	Conservation area serving as late season pasture	Current pattern for past 25 years
Front Road	Residence (2) (n/a)	Barbed and page wire/ wooden (n/a)	Lake Ontario (n/a)	Pasture for beef cattle and hay mosaic	Current pattern for past 30+ years
Willard	Seasonal caravan (n/a) Residence and sheep farm (n/a)	Page wire/~1/2 wooden and 1/2 metal (n/a)	Lake Ontario (n/a)	Sheep pasture and fallow old field with isolated conifers	Current pattern for past 30+ years
Wolfe	Residence and beef farm (~800)	Page wire/wooden (~250)	Natural spring (~400) Marsh (~250)	Fallow old field until plowed late May	Fallow for past 10 years

[a] Includes type of nearest dwelling, fence line or body of water, and distance to each, if applicable (m).

[b] Current land use refers to the years used as a nest site.

Table 4-3. Dominant vascular plant species at nest sites of Short-eared Owls on Amherst Island and Wolfe Island in 2009 and 2010.

Nest ID[a] Species	Eves	Kilpatrick	McGinn	KFN	Front Road	Willard
Alsike clover					X	
Birdsfoot trefoil	X	X	X		X	X
Blue-stem goldenrod					X	
Blue vervain	X					
Canada goldenrod	X	X		X	X	
Carex *spp.*	X	X			X	
Cat-tail	X					
Common fleabane	X	X				
Common St. John’s wort						X
Cow vetch		X	X	X	X	X
Daisy fleabane					X	
Dandelion					X	
Danthonia						X
Milkweed		X				X
Quack grass				X		X
Red clover	X	X	X			
Redtop	X	X				X
Reed canary grass	X	X		X		X
Rough-fruited cinquefoil					X	
Salix *spp.*	X					
Slender sedge	X			X		
Smooth brome grass	X	X	X			
Thistle *spp.*		X	X	X		
Timothy	X	X	X			
Wild carrot		X			X	
Wild raspberry	X					

[a] Wolfe site not included as it was destroyed by farm machinery prior to data collection.

Figure 4-1a. Approximate locations of breeding territories of Short-eared Owls on Amherst Island (44º08′N, 76º43′W) in 2009: Eves (red), Kilpatrick (yellow), McGinn (blue).

Figure 4-1b. Approximate locations of breeding territories of Short-eared Owls on Amherst Island (44º08′N, 76º43′W) in 2010: KFN (red), Front Road (yellow), Willard (blue).

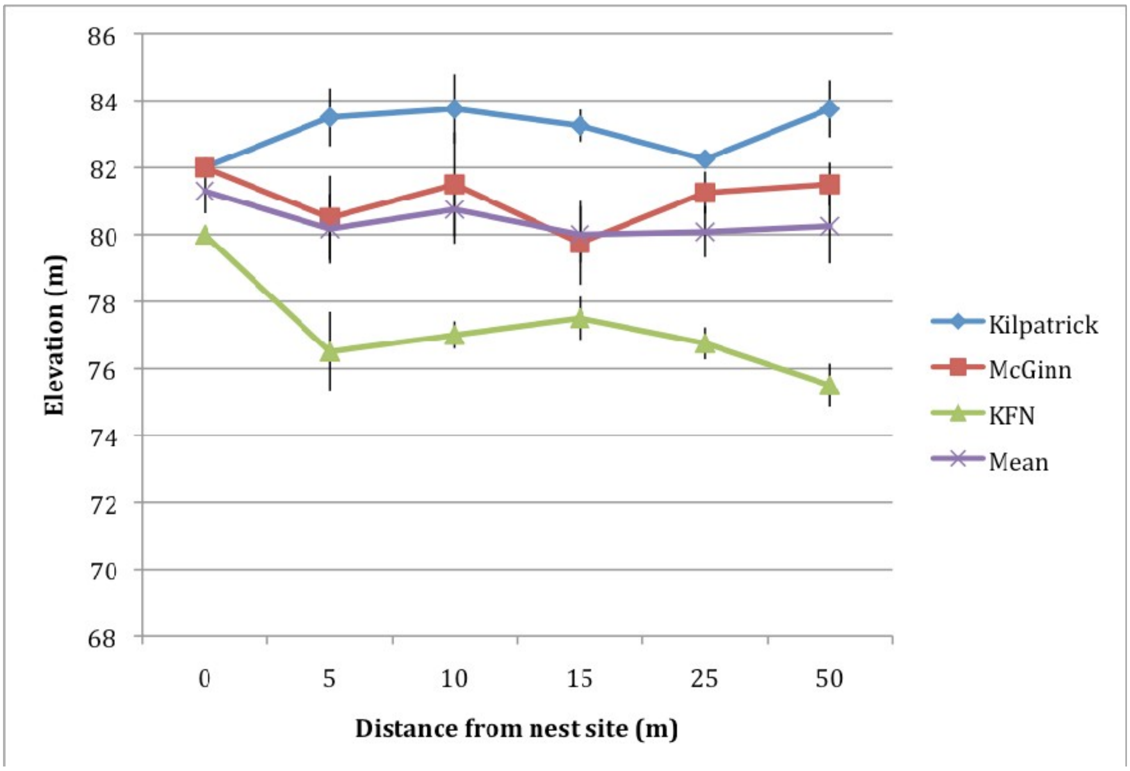

Figure 4-2. Mean elevation (± SE) at varying distances from nest sites of Short-eared Owls discovered pre-dispersal on Amherst Island in 2009 (Kilpatrick and McGinn) and 2010 (KFN). Data points represent one value at each nest site (i.e. 0 m) ($n = 1$), and a mean ($n = 4$) for the remaining distances (i.e. 5, 10, 15, 25, 50 m) as data were collected along the four cardinal directions.

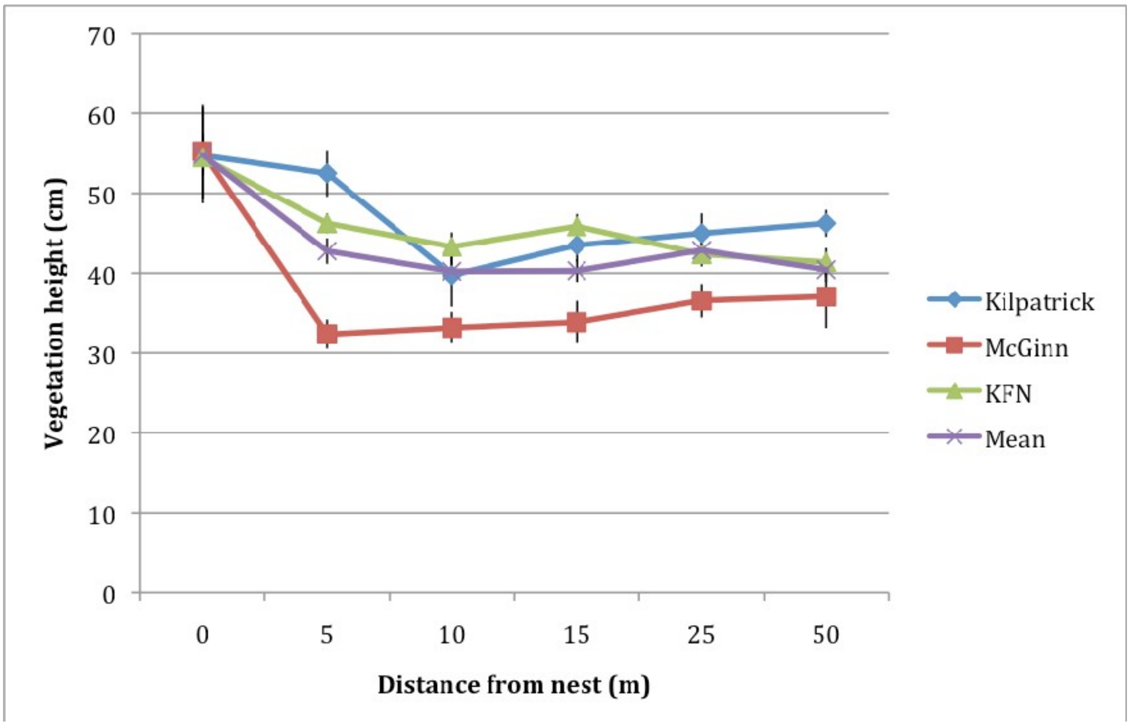

Figure 4-3. Mean vegetation height (± SE) at varying distances from nest sites of Short-eared Owls discovered pre-dispersal on Amherst Island in 2009 (Kilpatrick and McGinn) and 2010 (KFN). Data points represent a mean at each nest site (i.e. 0 m) (*n* = 4), and for the remaining distances (i.e. 5, 10, 15, 25, 50 m) (*n* = 16) along the four cardinal directions.

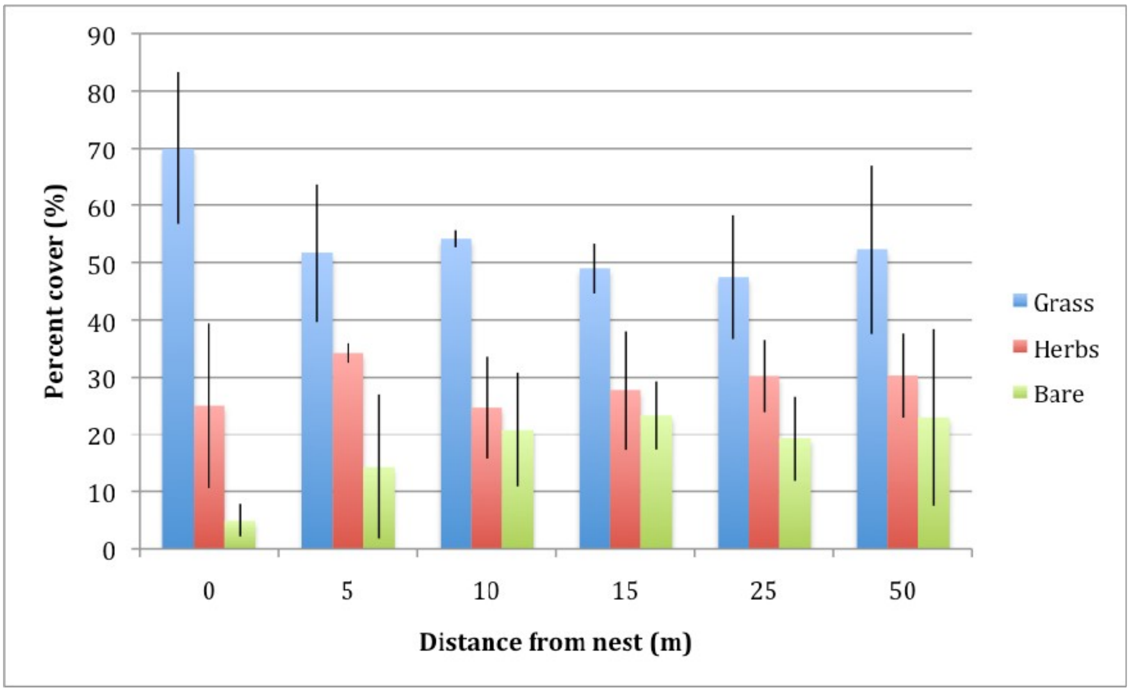

Figure 4-4. Mean percent vegetation cover (± SE) of grasses, herbs and bare ground at varying distances from nest sites of Short-eared Owls discovered pre-dispersal on Amherst Island in 2009 (Kilpatrick and McGinn) and 2010 (KFN). Values for each cover class represent a mean at the nest sites (i.e. 0 m) (*n* = 3), and for the remaining distances (i.e. 5, 10, 15, 25, 50 m) (*n* = 12) along the four cardinal directions.

Appendix 4-1. Microhabitat features of nests of Short-eared Owls discovered pre-dispersal on Amherst Island in 2009 (Kilpatrick and McGinn) and 2010 (KFN).

		Nest ID			
		Kilpatrick	McGinn	KFN	Mean
Elevation	Nest[a]	82.0	82.0	80.0	81.3
(m asl)	5[b]	83.5	80.5	76.5	80.2
	10[b]	83.8	81.5	77.0	80.8
	15[b]	83.3	79.8	77.5	80.0
	25[b]	82.3	81.3	76.8	80.1
	50[b]	83.8	81.5	75.5	80.3
Composition	Nest[a]	75:25:0	45:50:5	90:0:10	70:25:5
(% grass:	5[b]	55:23:22	22:77:1	78:2:20	52:34:14
herbs:	10[b]	47:11:42	22:77:1	76:5:19	54:25:21
bare ground)	15[b]	49:19:32	41:58:1	57:6:37	49:28:23
	25[b]	58:12:30	32:66:2	61:13:26	51:30:19
	50[b]	48:31:21	51:39:10	57:22:21	52:30:18
Mean	Nest[c]	54.8	55.3	54.5	54.8
vegetation	5[d]	52.5	32.4	46.3	42.8
height	10[d]	39.8	33.2	43.3	40.2
(cm)	15[d]	43.5	33.9	45.9	40.3
	25[d]	45.0	36.6	42.4	42.9
	50[d]	46.3	37.1	41.4	40.4

[a] One measurement at the nest.

[b] Mean of measurements taken along the four cardinal directions.

[c] Mean of four measurements at the nest.

[d] Mean of four measurements taken along each of the four cardinal directions.

Synthesis and conclusion

Like many species before it, the Short-eared Owl has experienced a drastic population decline over only half a century. Many landowners with whom I have had the privilege of interacting told of days not so long ago when the Short-eared Owl silhouette was a common sight against the setting sun in open country habitats. Little action has been taken to increase our knowledge of this poorly understood species, and it follows that without such critical information, few conservation and management efforts have been developed. The three manuscripts in this thesis serve the necessary purpose of investigating some basic, yet unanswered questions. The manuscripts were not intended to be purely academic in nature, but to provide a foundation, with practical tools for researchers and lay people alike, to ensure the continued existence of the Short-eared Owl. Whereas this study is framed in a North American context, I consider the results to be applicable across the species' global distribution.

Geographic fidelity

In the vast majority of Short-eared Owl literature, one will come across a statement describing the species as nomadic. Many accounts exist of large groups appearing in areas with abundant microtine prey bases seemingly overnight, and vacating the areas equally fast. However, evidence from a scant number of previous studies, combined with recent advances in satellite telemetry, indicates that other movement strategies may exist. In his exhaustive treatise of Short-eared Owl ecology, Clark (1975) posed the question, 'if this owl is not behaviourally bound to any traditional wintering ground, then why have owls persisted in returning to this same area winter after winter regardless of the density of the vole population?'

I presented data from deuterium isotope analysis to indicate that different movement strategies are likely used across the North American range. However, as this approach has not previously been used for the Short-eared Owl, the results are exploratory. Nonetheless, I have demonstrated that stable isotope analysis offers researchers an affordable technique to better understand Short-eared Owl movements. An added advantage of this technique is the great opportunity for anyone to contribute to such research, not just biologists who may be capturing owls, but anyone who may come across a carcass or incidental feathers. I therefore suggest the collection of additional feather samples from across the continent, particularly from owls that possess more than one generation of feathers, to further the investigation of nomadism, migration and/or philopatry. A better understanding of movement strategies, including connectivity between breeding, wintering, and year-round grounds, will facilitate the development of conservation schemes that incorporate all applicable geographical regions.

Monitoring

To date, population estimates have been based on monitoring programs that are poorly suited to detect the crepuscular habits of the Short-eared Owl. To facilitate more accurate population estimates, I developed and evaluated a feasible volunteer-based visual survey protocol. The program was a success, with keen involvement of members of a local naturalist club. Although rates of occupancy and detectability were low, as expected due to species being both rare and elusive, this protocol was precise and reliable based on repeat weekly surveys designed to detect the Short-eared Owl when it is most active. As a result of the initiation of this monitoring program on Amherst Island and Wolfe Island, surveys are ongoing, and will serve as a good basis for long-term monitoring of a local population. I suggest the use of this protocol across North America as a consistent method to record trends in abundance and distribution. However, the level of effort required should be evaluated based on the density of owls in a particular area, such that areas of low density may not necessitate weekly visits.

Important habitat considerations

To forage, the Short-eared Owl requires open country habitat during both the wintering and breeding seasons. However, the particular features of this environment that are preferred have not been well documented. It is clear that without this information, it will be difficult to identify important habitat. I used the results of the visual survey protocol described above to examine the importance of 12 habitat variables at the landscape-level across seasons. Snow cover serves as the stimulus to abandon ground roosting during the winter, however I found the opposite that in years of less snow, Short-eared Owls may avoid forested areas, and may roost in extremely close proximity to residential structures. Thus, I advocate further study of wintering season habitat, which I hypothesize might vary considerably depending on seasonal effects.

During the breeding season, grazed grassland with scattered trees appears to be preferred in areas where such habitat is available, which is not universal across the Short-eared Owl range. Thus, conservation schemes should carefully consider the inclusion of grazed grassland, and best management practices might include maintaining some large trees, typically deciduous in the grasslands of eastern Ontario, for the breeding season. At the microhabitat scale, I monitored seven territories over two breeding seasons to investigate nest site characteristics, success, and causes of failure. Short-eared Owls seemed to exhibit loose nesting aggregations in areas that were predominantly tall grasses (i.e. 55 cm), and again often on grazed grassland. Personal observations indicated that wooden fence posts are preferred as perches for territory surveillance; the maintenance of such fence posts is a practical management implication. Causes of mortality in this study could be attributed to anthropogenic (i.e. agricultural machinery) and natural (i.e. raccoon and Great Horned Owl depredation) factors, thus indicating that breeding season threats facing the Short-eared Owl are many, but to a certain extent in the case of the former, they are manageable.

In consideration of the fact that grasslands are one of the most threatened ecosystems worldwide, it seems prudent to capitalize on the charismatic appeal of the Short-eared Owl. Thus, applying the findings of this study to future research and conservation initiatives will benefit many species that share the same open country habitat, not only in North America, but also around the globe.