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Research Paper

Habitat use by barn owls across a rural to urban gradient and an assessment of stressors including, habitat loss, rodenticide exposure and road mortality

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A R T I C L E I N F O

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A B S T R A C T

Urbanization and agricultural intensification resulting in habitat loss is having a profound negative effect on grassland and farmland birds worldwide. Barn owls (*Tyto furcata*), as a species, have been affected by this intensification. To evaluate how urbanization and agricultural intensification affects barn owls we sought to address: 1) how human land use influences barn owl hunting behavior and diet, and 2) do habitat and prey choice influence the likelihood of barn owls consuming anticoagulant rodenticide (AR) exposed prey. We radio tagged 11 owls across the rural-urban landscape gradient in the Lower Mainland, British Columbia, and collected sufficient location data on 10 barn owls. We found that the 95% kernel home-ranges ranged from 1.0 to 28.5 km^2 (n = 10) and were positively correlated with the proportion of urban land use within home-ranges. Barn owls across all landscapes selected roadside grass verges significantly more than other habitat types within home-ranges, which may reflect the loss of grassland associated agriculture in the region. The risk of consuming AR exposed prey was highest in roadside grass verges compared to other habitat types. However, the overall likelihood of consuming AR exposed prey significantly decreased when the proportion of grass patches within home-ranges increased, which suggests smaller linear grass sections are more likely to contain AR exposed small mammal prey. These results highlight the need to retain and enhance hunting habitat for barn owls during urban development and to mitigate the risk of barn owl road mortality along major highways.

1. Introduction

Urban development is responsible for some of the greatest local extinction rates and losses of native species worldwide (McKinney, 2002). The reasons urbanization is having such profound effect on species richness compared to other threats is first, due to the direct loss of habitat that occurs when land is covered with buildings and infrastructure, and becomes impermeable. Second, unprecedented human population growth over the last century has resulted in the total footprint of urban sprawl surpassing the geographical area of protected native landscapes in many jurisdictions (Benfield, Raimi, & Chen, 1999). Urbanization and sprawl fragment the remaining habitats into discrete patches, and populations into smaller units due to the barrier effects of roads and railways. Fragmentation can have a disproportionate impact on wildlife, restricting access to resources, or causing direct mortality from collisions with vehicles (Forman et al., 2003; Jaeger et al., 2005).

The agricultural landscape has also become a less viable habitat for native species due to new agricultural practices that have increased crop yields, resulting in a farming system that is highly dependent on agro-chemicals (i.e. fertilizers, herbicides and pesticides) and heavy machinery (Krebs, Wilson, Bradbury, & Siriwardena, 1999; Elliott, Wilson, & Vernon, 2011). Consequently, the agricultural landscape is less diverse and more heavily utilized, with large monoculture fields, often with no hedgerows or grassy field margins (Norris, 2008; Poggio, Chaneton, & Ghersa, 2010). Many species associated with agricultural lands, particularly birds, have experienced population declines and range contractions over the last three decades (Fuller et al., 1995; Peterjohn, 2003; Brennan & Kuvlesky, 2005; Donald, Sanderson, Burfield, & van Bommel, 2006; Doxa et al., 2010).

Certain species are more adept at coping with human landscape modifications than others and are even capable of persisting in landscapes as they become increasingly urban (Bird, Varland, & Negro, 1996; Boal & Mannan, 1998). However, species that inhabit more intensively human modified landscapes may be at a greater risk of being exposed to anthropogenic threats such as trauma from collisions with vehicles and buildings (Hager, 2009). Exposure to chemical contaminants like lead, persistent organic pollutants and polycyclic

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aromatic hydrocarbons can also be greater in urban environments (Newsome et al., 2010; Henny et al., 2011; Morrissey et al., 2014; Elliott, Brogan, Lee, Drouillard, & Elliott, 2015). Many chemical stressors are persistent and bioaccumulative and thus most evident in predators, which feed at higher trophic levels (Henny & Elliott, 2007).

The barn owl (genus *Tyto*) is an iconic farmland bird. The genus *Tyto* is typically divided into three groups (*Tyto alba, Tyto furcata, Tyto delicatula*), each of which have several daughter taxa giving barn owls (*sensu lato*) a worldwide distribution (König & Weick, 2008). Like many other cosmopolitan raptors, barn owls have shown some resilience to land use changes, and still persist in intensive agricultural landscapes and in areas that are becoming increasingly urban. However, barn owls are now experiencing population declines and contractions across their range in many parts of the world. This is due to agricultural intensification and urbanization which is causing habitat loss, habitat degradation and fragmentation, and road mortality (Taylor, 1994; Marti, Alan & Bevier, 2005; Hindmarch, Krebs, Elliott, & Green, 2012; Hindmarch & Elliott, 2015).

The core Canadian barn owl (*Tyto furcata*) population is found in southern British Columbia in the Lower Mainland and the Fraser Valley. Grassland associated agriculture has historically been a dominant feature in both regions, but there have been considerable changes in crop types and land use over the last 50 years (Elliott et al., 2011; Metro Vancouver, 2012). Based on land use conversion, blueberries and greenhouse-grown vegetables are the most rapidly expanding crops in the region, (Metro Vancouver, 2012). These changes, along with urbanization, have contributed to a 53% decline in grassland habitats surrounding barn owl nest/roost sites in the Lower Mainland over the last two decades (Hindmarch et al., 2012). The remaining grassland habitats are often quite fragmented and border urban lands, or are confined to field edges and grassy-roadside verges along major highways. As a result road mortality is also a concern, and likely has a strong negative effect on the local population (Preston & Powers, 2006). The threats from the loss of habitat and nest sites were the main reasons barn owls were recommended to be upgraded in 2014 to '*threatened*' in Western Canada (COSEWIC, 2014).

High density human developments and farming also attract commensal pest species such as rats (*Rattus* sp.) and house mice (*Mus musculus*) (Feng & Himsworth, 2014). Consequently, the need for rodent control may be greater in human modified landscapes (Riley et al., 2007; McMillin, Hosea, Finlayson, Cypher, & Mekebri, 2008). The primary method for controlling commensal rodents worldwide is the use of anticoagulant rodenticides (hereafter ARs) (Corrigan, 2001). Second generation ARs (hereafter SGARs), introduced in the 1970s as a result of Norway rats' (*Rattus norvegicus*) resistance to the first generation ARs (hereafter FGARs), are now the most commonly used ARs worldwide in both rural and urban settings (Corrigan, 2001). However, SGARs are designed as highly toxic compounds to avoid the development of resistance in target species, and hence a single feed of SGARs is sufficient to kill the target species (Eason, Murphy, Wright, & Spurr, 2002; Fisher, O'Connor, Wright, & Eason, 2003). SGARs are also metabolized slowly, increasing the risk of toxic accumulation in the livers of predators that feed on poisoned prey (Erickson & Urban, 2004). The documentation of secondary AR contamination of raptors through the consumption of poisoned prey has been increasing over the last three decades (Newton, Wyllie & Freestone, 1990; Stone, Okoniewski & Stedelin, 1999; Lambert, Pouliquen, Larhantec, Thorin, & L'Hostis, 2007; Walker et al., 2008; Albert, Wilson, Mineau, Trudeau, & Elliott, 2010; Murray, 2011; Christensen, Lassen, & Elmeros, 2012).

AR residue testing in small mammals points to rats as the main exposure route for the uptake of ARs in non-target predators (Elliott et al., 2014; Geduhn, Esther, Schenke, Mattes, & Jacob, 2014). However, a wide array of non-target prey species documented in the diet of barn owls (Taylor, 1994; Hindmarch & Elliott, 2015) have been detected with AR residues, such as voles (*Microtus* sp.), shrews (*Sorex* sp.), deer mice (*Peromyscus maniculatus*), wood mice (*Apodemus sylvaticus*), songbirds (*Passeridae*) and insects (Tosh et al., 2012; Elliott et al., 2014; Geduhn et al., 2014).

The propensity of barn owls to nest and roost in structures that are often permanently baited with SGAR bait stations, such as barns and industrial buildings, combined with an increasingly urban and fragmented landscape could increase their risk of consuming rodenticide-laden prey. Our goal was to increase our understanding of barn owls' hunting behavior and diet across a rural to urban landscape continuum in the Lower Mainland, and assess the extent to which risks such as AR exposure and road mortality are indirectly driven by land use within their associated home-ranges. Our two main research questions were (1) How does human land use influence barn owl hunting behavior and diet?, and (2) Do habitat and prey choice influence the risk of barn owls consuming AR exposed prey?

2. Methods

2.1. Study area and trapping locations

The study was conducted in the Lower Mainland, British Columbia, Canada in the following municipalities: Richmond, Surrey, Delta, Burnaby and New Westminster, from May 2010 to June 2014 (49°8′0″ North, 122°18′0″ West; Fig. 1). Prior to European settlement in the mid nineteenth century, the low lying floodplains were dominated by grassland and low shrub vegetation, while higher elevations were covered primarily by coniferous forest (North & Teversham, 1983). Today the landscape ranges from agricultural land to suburban to highly urban, with the remaining lower elevation grassland and forested habitats facing ongoing development pressure as the projected human population in the region is expected to increase by 50% by 2036 (Storen, 2011).

In the breeding seasons of 2011 and 2012, we focused on locating and radio tagging barn owls in urban landscapes, and in 2013 the focus was on barn owls in agricultural landscapes. Previous records of barn owls nesting in urban areas of the Lower Mainland were limited and outdated. Hence we surveyed for urban barn owl nest and roost sites in order to identify key areas for trapping (Hindmarch & Elliott, 2015). Our focus was on structures with permanent openings near the roof for nesting and roosting, such as old, tall industrial buildings and bridges or overpasses. If permission was obtained from the landowner, we would inspect the inside and perimeter of the structure for barn owls or indications of their presence such as pellets or feathers. If evidence of barn owls was present, we targeted the surrounding grass habitat for trapping. In the summer of 2013, we trapped barn owls in agricultural landscapes by using recent survey records of where barn owls had been observed hunting.

2.2. Trapping and monitoring

We trapped barn owls using bal-chatri traps placed along the perimeter of grass habitats such as grass fields and field margins. In urban landscapes, we placed bal-chatri traps in the middle of the grassy verges of highway access ramps, or in undeveloped patches of residual grassed areas. We monitored traps at all times from a vehicle, and when a barn owl was trapped, we immediately processed it.

We used Holohil RC-1C radio transmitters with mortality switch (6 g), and a battery life of up to 12 months. The transmitter was attached with a leg-loop harness made out of 3 mm thick natural rubber. The design and size of the harness was determined by the weight of the barn owl following estimates by Naef-Daenzer (2007). The natural rubber was adhered with generic superglue (cyanoacrylate) and was expected to disintegrate or break apart within a year, resulting in the transmitter falling off the barn owl. The transmitter and rubber harness weighed 7 g which is < 2% of the body mass of the barn owls we trapped (range: 413–561 g), and well within the 5% guidelines for