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Source: Journal of Raptor Research, 49(1) : 66-74

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/jrr-14-00012.1

J. Raptor Res. 49(1):66–74

WHEN OWLS GO TO TOWN: THE DIET OF URBAN BARRED OWLS

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Abstract.—We investigated the diet of Barred Owls (*Strix varia*) inhabiting urban environments in the Lower Fraser Valley of southwestern British Columbia, Canada. Our objective was to use the diet information to gain insight into the pathways of exposure to anticoagulant rodenticides (ARs) previously documented in this owl species. In particular, we examined whether such exposure is driven by the consumption of rodents commonly targeted during AR application, Norway rats (*Rattus norvegicus*), black rats (*Rattus rattus*) and house mice (*Mus musculus*), or if the secondary exposure is via consumption of native non-target rodents feeding at outdoor bait-stations. We identified 688 prey items from eight urban nest/roost sites. Rats (54.5%) were by far the most common prey, followed by field voles (*Microtus townsendii*; 19.3%), and deer mice (*Peromyscus maniculatus*; 5.2%). The consumption of rats was positively correlated with the degree of urban development within Barred Owl home ranges ($r_p = 0.70$, $r^2 = 0.48$, $P < 0.05$, one-tailed). Barred Owls consumed predominantly younger rats, as the average rat weight was 103 ± 51.7 grams ($n = 164$). Surprisingly, no house mice were found in the prey remains, supporting the assumption that house mice seldom venture outdoors and therefore are not a likely vector of ARs to owls. If we assume more intensive AR usage in urban environments, then the higher consumption of rats in urban areas implicates rats as the likely pathway for secondary AR exposure to Barred Owls in urban landscapes.

Key Words: *Barred Owl*; *Strix varia*; *diet*; *rats*; *rodenticide*; *urban.*

CUANDO LOS BÚHOS VAN A LA CIUDAD: LA DIETA URBANA DE *STRIX VARIA*

Resumen.—Investigamos la dieta de individuos de *Strix varia* que habitan ambientes urbanos en Lower Fraser Valley, al suroeste de la Columbia Británica, Canadá. Nuestro objetivo fue utilizar la información de la dieta para conocer las vías de exposición a rodenticidas anticoagulantes (RAs) que han sido documentados previamente en esta especie. En particular, examinamos si dicha exposición es provocada por el consumo de roedores que comúnmente son el blanco de las aplicaciones con RA, *Rattus norvegicus*, *Rattus rattus* y *Mus musculus*, o si existe una exposición secundaria por el consumo de roedores que no son el blanco de RAs, pero que se alimentan en estaciones de cebo al aire libre. Identificamos 688 restos de presas en ocho áreas urbanas usadas para la cría/posadero. Las ratas (54.5%) fueron con creces la presa más común, seguidas por *Microtus townsendii* (19.3%) y *Peromyscus maniculatus* (5.2%). El consumo de ratas estuvo positivamente correlacionado con el grado de desarrollo urbano dentro del ámbito de hogar de *S. varia* ($r_p = 0.70$, $r^2 = 0.48$, $P < 0.05$, una cola). *S. varia* consumió preferentemente ratas jóvenes ya que el peso promedio de las ratas fue de 103 ± 51.7 gramos ($n = 164$). Sorprendentemente, ningún individuo de *M. musculus* fue encontrado en los restos de presas, lo que apoya la suposición de que *M. musculus* raramente se aventura hacia las áreas rurales y por lo tanto es improbable que sea un vector de RAs para los búhos. Si asumimos que existe un uso más intensivo de RAs en ambientes urbanos, entonces un mayor consumo de ratas en áreas urbanas implica que las ratas son probablemente la vía de exposición secundaria de *S. varia* a RA en paisajes urbanos.

[Traducción del equipo editorial]

Human settlements, including the highest density urban areas, are commonly found in locations that are also the best habitats for other biota. Those include estuaries, productive valley bottoms, and lake and riverine shorelines, and thus, increasing urbanization is considered an important threat to biodiversity (McKinney 2002). However, some wildlife species, including raptors, survive and reproduce in urban environments. Cooper's Hawks (*Accipiter cooperii*), Sharp-Shinned Hawks (*Accipiter striatus*), and European Northern Goshawks (*Accipiter gentilis*) prey on songbirds at urban backyard feeders (Powers 1996, Boal and Mannan 1998, Rutz 2008); Peregrine Falcons (*Falco peregrinus*) nest on high-rise buildings or under city bridges (Bird et al. 1996), and Eastern

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Screech-Owls (*Megascops asio*) nest successfully in various human-made structures in suburban landscapes in central Texas (Gehlbach 2008).

The Barred Owl (*Strix varia*) is a medium-sized raptor that has also found niche spaces in urban ecosystems across North America (Bird et al. 1996, Mazur and James 2000, Harrold 2003, Dykstra et al. 2012). Inhabiting urban landscapes is associated with an increase in anthropogenic threats, such as trauma from collisions with vehicles and buildings (Hager 2009). Exposure to chemical contaminants such as lead, persistent organic pollutants, and polycyclic aromatic hydrocarbons can also be greater in urban environments (Van Metre et al. 2000, Li et al. 2001, Newsome et al. 2010, Henny et al. 2011). High-density human developments also attract traditional commensal pest species such as rats (*Rattus* sp.) and house mice (*Mus musculus*; Feng and Himsworth 2013). Consequently, the need for pest control, particularly for rats, is greater in urban settings (Riley et al. 2007, McMillin et al. 2008). The primary method for controlling commensal rodent infestations worldwide is the use of anticoagulant rodenticides (ARs; Corrigan 2001). Second generation ARs in particular are persistent, bioaccumulative, and highly toxic compounds (Parmar et al. 1987, U.S. EPA 2004), and their spread as contaminants to raptors has been documented worldwide (Merson et al. 1984, Stone et al. 1999, Lambert et al. 2007, Walker et al. 2008, Albert et al. 2010, Lima and Salmon 2010, Murray 2011, Thomas et al. 2011).

In southwestern British Columbia, Barred Owls are particularly affected by AR usage. Barred Owl carcasses from 1993–2003 had substantial exposure to ARs, with 92% ($n = 23$) of carcasses testing positive for one or more ARs (liver samples; Albert et al. 2010), and 12% diagnosed as having died from AR poisoning. Among samples collected between 2005 and 2011, 100% of the owl carcasses ($n = 66$) tested positive for one or more ARs (J. Elliott unpubl. data). Elliott et al. (2014) tested for AR residues in small mammals in and around agricultural buildings and found AR residues almost exclusively in rats. With the exception of one field vole (*Microtus townsendii*), no non-target rodents contained AR residues. This supports the hypothesis that rats may be an important, if not the primary, vector responsible for secondary exposure of non-target predators in landscapes with intensive AR usage (McMillin et al. 2008).

The Barred Owl historically inhabited the forests of eastern North America, but has over the last century expanded its range northwest throughout the boreal forest and all the way to the Pacific Northwest (Mazur and James 2000). In 1943, the Barred Owl was first documented in British Columbia (Campbell et al. 1990). Subsequently, in 1966 the first sighting in southwestern British Columbia was documented in the municipality of Surrey (Campbell et al. 1990), and since then they have become widespread in the region (Audubon 2011).

Barred Owls are capable of capturing a wide range of prey species and are very efficient at subsisting on temporarily or seasonally abundant prey species, such as beetles, amphibians, songbirds (including nestlings), young rabbits (*Sylvilagus floridanus*), and worms (Livezey 2007, Streby et al. 2008). Nevertheless, their diet typically is dominated by one or two species, presumably those that are most abundant and locally profitable (Wilson 1938, Mazur and James 2000 and references therein, Livezey 2007 and references therein). In the Pacific Northwest, rodents are the most important prey group (Hamer et al. 2001, Livezey 2007, Wiens et al. 2014).

Several researchers have investigated the diet of Barred Owls in a variety of regions (Mazur and James 2000, Livezey 2007); however, most studies were conducted in forest, grassland, and agricultural settings, and few have been in more urban areas. Such information would be of particular interest for rapidly urbanizing regions, such as the Lower Fraser Valley of British Columbia, where the loss of forests and agricultural lands surrounding urban centers may push owl and other wildlife into the remaining green spaces, including parks, suburban woodlots, and fragments of undeveloped land.

The goal of our study was to document the diet of Barred Owls inhabiting suburban and urban landscapes in southwestern British Columbia. Because of the high incidence and concentrations of AR residues in Barred Owls (Albert et al. 2010, J. Elliott unpubl. data), we also investigated whether there was a relationship between the degree of urbanization surrounding nest/roost sites, and the proportion of commensal rodents (*Rattus norvegicus, R. rattus, Mus musculus*) in their diet.

Methods

Study Area. We conducted surveys for Barred Owl nest and roost sites from December 2010 to June 2013 throughout the Lower Fraser Valley in the municipalities of Richmond, Vancouver, Burnaby, Delta, Surrey and New Westminster (847 km^2), in southwestern British Columbia, Canada (49°8.0′N, 122°18.0′W; Fig. 1). The area includes some of the

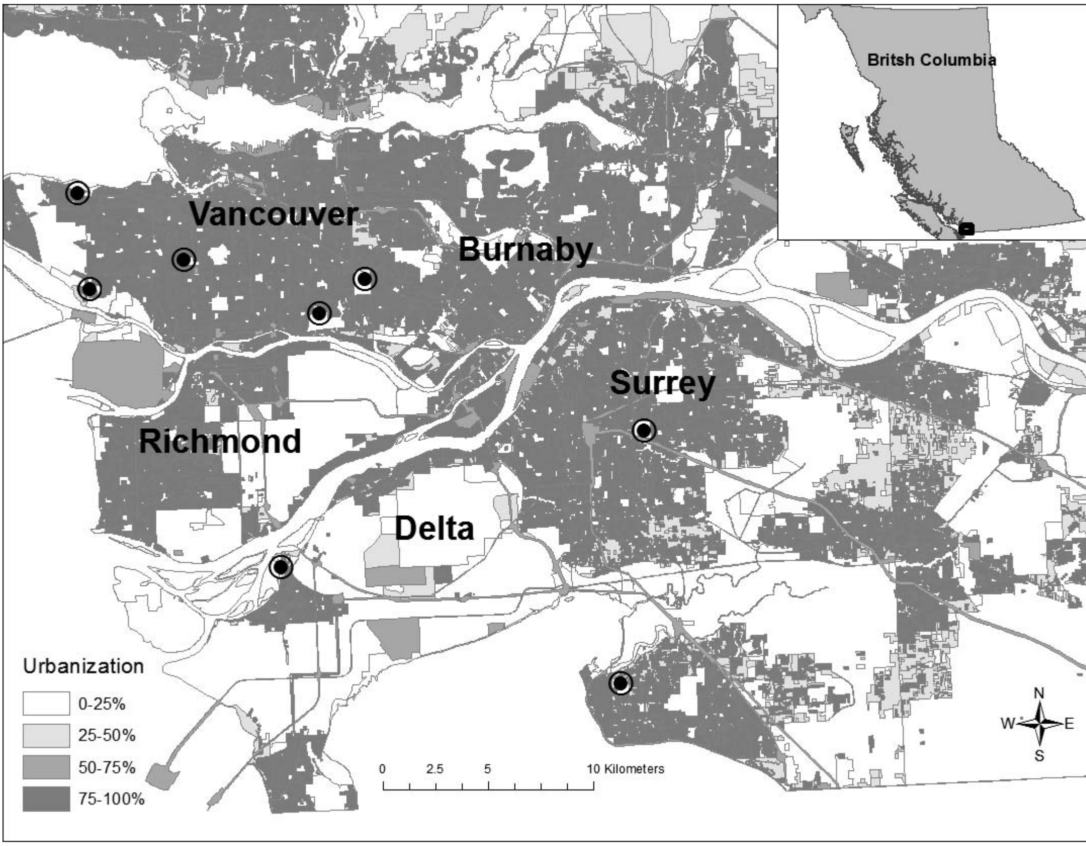

Figure 1. Study area in the Lower Fraser Valley, British Columbia, Canada. Barred Owl diet was assessed at the marked nest and roost site locations.

main stopover sites for birds migrating on the Pacific flyway, and encompasses important areas of wildlife habitat such as the Alaksen National Wildlife Area, Burns Bog, Boundary Bay, as well as large urban green spaces such as Stanley Park and Pacific Spirit Park. Prior to European settlement, the low-lying floodplains were dominated by grassland and low shrub vegetation, whereas higher elevations were covered primarily by coniferous forest (North and Teversham 1984). Today, the landscape ranges from agricultural land to suburban and 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 50% by 2036 (Storen 2011).

Owl Surveys and Pellet Collection. Suitable areas to survey for nest/roost sites and subsequent pellet and prey remains were found with the help of local naturalist clubs and by surveying urban parks and green spaces for any signs of owl presence such as excreta, feathers, and pellets. To confirm the presence of Barred Owls, and to determine specific locations to search for pellets, we used call-playbacks at dusk, following the nocturnal owl survey guidelines for North America (Takats et al. 2001). If we found pellets or prey remains, and we were able to verify that they were from Barred Owls, either by observing Barred Owls or their molted feathers, we revisited the site every 2–3 mo and collected additional pellets and prey remains. Collection of pellets and prey remains at nest/roost sites is a widely used and accepted method for examining owl diets (see Marti et al. 2007 for a review of sampling methodologies for raptor diet studies). Incidental observations of predation at these sites were also included in our data set. We included sites only if the total number of prey found was ≥50 prey items, and prey from different years were pooled so that each site provided only one sample over the entire duration of the study. We determined whether breeding had occurred by listening at dusk to survey for nestling Barred Owls between April and July. The nestlings were quite vocal at 4–5 wk of age and actively followed the parents, begging for food. We also searched for evidence of rodenticide use within parks or green spaces, specifically black bait stations placed alongside the perimeter of buildings or other structures within the park, and measured the distance from the bait stations to the nearest nest/roost.

Pellet Analysis. We dissected pellets and identified mammalian prey items from bone remnants and fur using Nagorsen (1996) and Nagorsen (2005). Avian prey remains were identified and categorized based on bones, feathers, gizzard sac, bill, or feet. We determined the number of individuals of any species within each pellet by pairing each skull with the correct number of ischia, left and right mandibles, tibiae/fibulae, or in the case of birds, each skull with sternum, gizzard sac, and feet. We assembled the remaining bones contained within the pellet to determine the minimum number of additional individuals. For smaller prey items ($<$100 g), we assumed the remains of each prey were contained within a single pellet, as it is rare for bones from one small prey item to be parcelled into two successive pellets (Raczynski and Ruprecht 1974). We estimated rat weights following Morris (1973). We classified unidentified songbird (*Passeriformes* sp.) remains as either (1) small songbirds ($<$30 g) or (2) medium songbirds (30–80 g). We considered all exoskeleton remains as order Coleoptera.

Land Use and Spatial Analysis. We quantified the amount of urban land within a 1-km radius (3 km^2, 300 ha) of each nest/roost site from digitized data layers using Geographic Information System (GIS) software (ArcMap 10). Urban land consisted of residential and industrial categories, and industrial included commercial and institutional lands. We used a 1-km radius as this approximates the average home range for Barred Owls, which was estimated to be approximately 3 km^2 (Nicholls and Warner 1972, Mazur and James 2000, Johnsgard 2002). Land use within the circular plots was derived from a 2006 Vancouver Regional District land-use layer map, which categorizes land parcels based on zoning (Metro Vancouver 2008). We compared the 2006 land-use layer map with 2010 Bing Ortho photos (Bing Maps 2010) to correct for any recent changes in land use or discrepancies in current land use and zoning.

We conducted a one-way correlation analysis to assess whether the consumption of commensal rodents increased with the amount of urban land within the circular plots. We used IBM SPSS 19 (IBM SPSS, IBM Inc., Armonk, New York, U.S.A.) for all statistical analyses.

Results

We found eight suburban and urban nest/roost sites regularly occupied by Barred Owls throughout the year. All sites were in parks situated in residential neighborhoods, and the amount of urban land within the circular plots (3 km^2) ranged from 53.6% to 89.5% (Fig. 1, Table 1). We documented bait stations along the perimeter of buildings and outbuildings (e.g., sheds and garages) in four parks where Barred Owls were nesting. In one of the four parks, a bait station was fastened next to a stream approximately 100 m from the nearest building. In these parks, the distance from the roost/nest site and the location of the AR usage ranged from 50 to 250 m. All the bait stations contained products with the active ingredient bromadiolone, which is the only second generation AR now registered for outdoor use in Canada (Health Canada 2012).

Pellets and prey remains were found underneath nest/roost trees. As a result, some of the pellets were weathered considerably, and it was impossible to determine the exact number of pellets collected, but in total, we identified 16 different species from 688 prey remains. Rats were the primary prey item recorded (54.5% for all prey remains combined; $\bar{X}$ = 56.4 ± 16.3% [mean ±SD, n = 8 sites]), followed by field voles (*Microtus townsendii*; 19.2%, $\bar{X}$ = 17.6 ± 18.0%), and there was an inverse relationship between the proportions of the two species (r_p = −0.95, r^2 = 0.89, $P < 0.01$). The proportion of rats in the diet was positively correlated with the amount of urban land within the circular plots (r_p = 0.70, r^2 = 0.48, $P < 0.05$, one-tailed, Fig. 2).

Barred Owls consumed predominantly smaller, most likely younger adult rats, with an average mass of 103 ± 51.7 grams (n = 164), most commonly in the 120-g category (Fig. 3). Other species were only marginally represented in the diet, with each contributing $<$15% of the total at each site (Table 1). Finally, we documented no house mice in the diet.

Discussion

In North America, Barred Owls are recognized as a generalist predator traditionally associated with forested ecosystems, where small mammals are often the

Table 1. Prey species and/or taxon (%) found in Barred Owl pellets collected in suburban and urban landscapes from December 2010 to June 2013 in the Lower Fraser Valley, British Columbia, Canada. Sites: F.R. = Ferry Road, F.V.= Fraserview, M.P.= Musquieam Park, C.P.= Crescent Park, B.C.P.= Bear Creek Park, C.P.B.= Central Park Burnaby, K.P.= Kits Park, V.D.= Van Dusen.

	Sites (Percent Urban Land Within Plot Circles)								
Prey Types	F.R. (53.6)	F.V. (57.1)	M.P. (58.3)	C.P. (64.5)	B.C.P. (65.0)	C.P.B. (69.7)	K.P. (75.8)	V.D. (89.5)	Sum
Order Rodentia									
Microtus townsendii	26.0	33.8	55.0	4.2	10.0	1.2	9.6	-	19.2
Microtus oregoni	-	-	-	-	1.1	-	-	-	0.1
Peromyscus maniculatus	4.0	2.6	2.3	13.5	3.3	14.6	-	1.1	5.2
Rattus sp.	64.0	36.4	23.7	51.0	66.3	59.8	54.8	83.1	52.8
Rattus norvegicus	-	-	3.1	1.0	-	-	-	-	0.7
Rattus rattus	-	-	1.5	-	-	-	6.8	-	1.0
Sciuridae sp.	-	-	-	1.1	2.5	-	-	-	0.5
Order Lagomorpha									
Sylvilagus floridanus	-	-	-	3.1	-	-	2.7	-	0.7
Order Soricomorpha									
Scapanus orarius	-	2.6	0.8	2.1	12.2	3.7	6.8	3.4	3.9
Neurotrichus gibbsii	-	-	-	3.1	1.1	-	-	-	0.6
Sorex sp.	-	13.0	9.2	2.1	-	1.2	-	-	3.5
Order Passeriformes									
Passeriformes (30–80 g)[1]	4.0	7.8	2.3	4.2	1.1	7.3	4.1	6.7	4.5
Passeriformes (<30 g)[1]	2.0	3.9	-	9.4	2.2	1.2	-	-	2.3
Corvus brachyrhynchos	1.3	-	1.5	2.1	-	-	1.4	-	0.7
Order Anura									
Rana catesbeiana	-	-	-	-	-	2.4	-	-	0.3
Order Coleoptera	-	-	0.8	3.1	-	8.5	13.7	5.6	3.8
# Prey	50	77	131	96	90	82	73	89	688

[1] Unidentified songbirds were allocated into two categories based on mass (g).

dominant prey group in their diet (Mazur and James 2000, Johnsgard 2002, Livezey 2007, Wiens et al. 2014). We found that rats, field voles, and deer mice (*Peromyscus maniculatus*) constituted the primary prey for Barred Owls living in suburban-to-urban landscapes in the Lower Fraser Valley. We documented a variety of other species, but their contribution to the overall diet was minimal. The prevalence of rats in the diet was positively correlated with the amount of urban development surrounding each nest/roost site, although sample size was small. The higher consumption of rats in urban environments demonstrated the opportunistic behavior of the Barred Owl, as individuals from two rural Barred Owl nest sites consumed predominantly field voles (50% and 87%, respectively), and only 11% and 1% rats (S. Hindmarch unpubl. data; concurrent study in rural areas of Delta and Surrey, B.C., Canada). In addition, we found an inverse relationship between the proportion of rats and field voles in the urban diet, most likely reflecting the availability of these prey species in the urban landscape.

Higher rat consumption in urban environments has been previously documented for Great Horned Owls (*Bubo virginianus*), such as those nesting in urban parks in Seattle, Washington (Lambert 1981). In addition, the Eurasian Eagle-Owl (*Bubo bubo*) consumed more rats when nesting in suburban landscapes in Trento, Italy, and Braşov, Romania, where rats were an abundant year-round food source but rabbits (*Oryctolagus cuniculus*; the main prey of eagle-owls in southern Europe) were scarce (Marchesi et al. 2002, Sandor and Ionesco 2009). Overwintering Long-eared Owls (*Asio otus*) in the city of Milan, Italy,

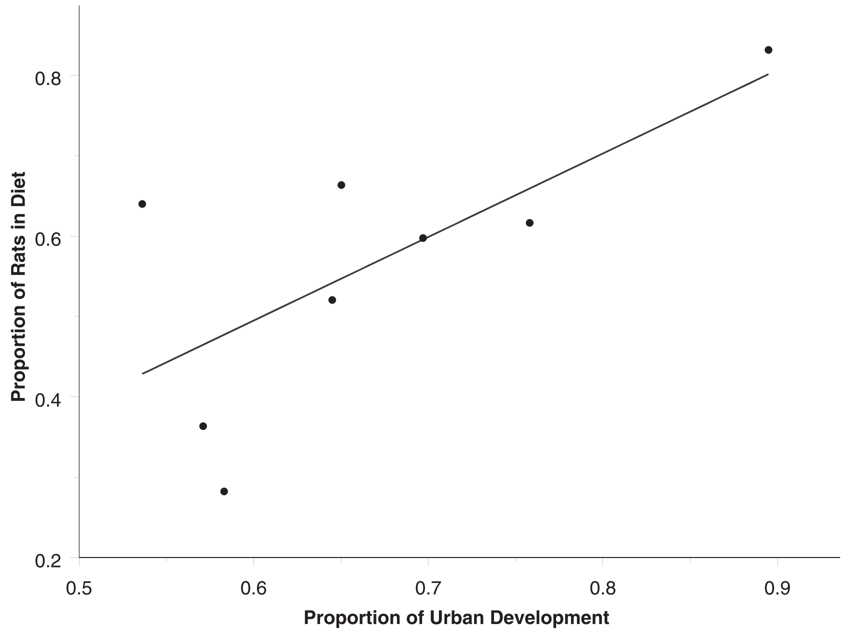

Figure 2. Relationship between the proportion of urban development within circular plots surrounding nests/roosts (3 km^2) and the proportion of rats in the diet of Barred Owls (r_p = 0.70, r^2 = 0.48, $P < 0.05$, one-tailed).

also ate primarily rats (65.2% of the consumed biomass; Pirovano et al. 2000). Urban Tawny Owls (*Strix aluco*), also in northern Italy, had a seasonally diverse diet, with rodents (primarily rats) being the main prey in the autumn and winter, and then birds, in particular sparrows (Passeridae), the most important component during spring and summer (Galeotti et al. 1991). In our study, the rats consumed by the

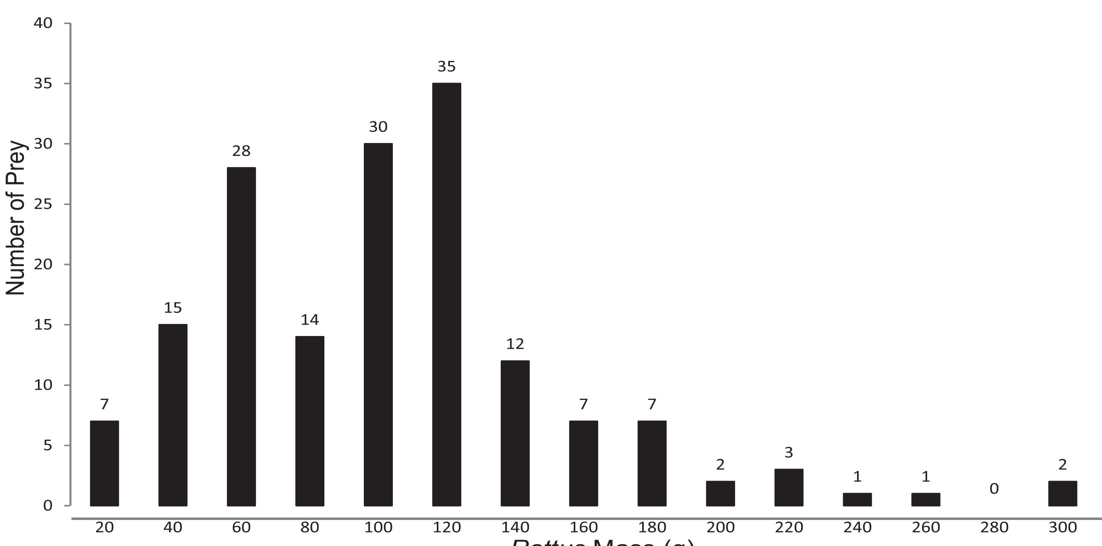

Figure 3. Mass classes of rats (±10 g) consumed by Barred Owls in urban/suburban Lower Fraser Valley, British Columbia, Canada. Average mass: 103 ± 51.7 g, n = 164. Mass (g) of rats estimated by measuring the lower jaw (mandible) of rat prey remains, and following Morris's (1979) suggested conversion table of jaw length to body weight.

urban Barred Owls were smaller (103 grams) than the typical Norway rats (142 grams) trapped in Vancouver (Himsworth et al. 2014). Younger, smaller rats are likely more naive and less risky to capture than larger adult rats.

Interestingly, in an extensive urban-vs.-rural study of Barred Owl diet conducted during the breeding season in Mecklenburg County, North Carolina, birds were the main prey of urban Barred Owls (Cauble 2008). Apparently, there were a great number of bird attractors, such as bird feeders and baths in residential neighborhoods, which resulted in a substantial urban bird population. Further, Cauble (2008) argued that the typical open understory in parks and residential gardens made birds easily available for Barred Owls. Urban Tawny Owls in Poland also consumed predominantly birds during the breeding season, and the proportion of the different bird species in the diet reflected their availability in the urban landscape (Zalewski 1994). In both studies, the rural Barred Owls and the suburban Tawny Owls had significantly different diets compared to their urban counterparts, which demonstrated the capacity of both species to establish territories in a variety of habitat types, and adapt to hunting locally profitable prey species.

Previous analyses of rodenticide concentrations in Great Horned Owl, Barred Owl, and Barn Owl (*Tyto alba*) carcasses collected between 1988 and 2003 in southwestern British Columbia showed that Barred Owls were most frequently exposed to ARs (92%), had the highest concentrations of the more toxic and persistent second generation anticoagulant rodenticides (SGARs), and the most incidences of death caused by SGAR poisoning (12%). Great Horned Owls were also highly exposed at 70%, followed by Barn Owls at 62% (Albert et al. 2010). More recently, all the Great Horned and Barred owl carcasses sampled between 2005 and 2011 tested positive, and 75% of Barn Owls had residues of one or more SGARs in their livers (J. Elliott unpubl. data). Our results, documenting the year-round presence of Barred Owls in urban landscapes, often where SGAR bait stations are used within 1 km of nest/roost sites, suggest that Barred Owls are at high risk of exposure and accidental poisoning by rodenticides. The diet in the urban environment implicates rats as the main pathway for that exposure, as demonstrated by Elliott et al. (2014).

Rats and house mice are the main targets during AR application, but non-target species such as squirrels (*Sciuridae* spp.; Stone et al. 1999, U.S. EPA 2004), voles, and sparrows (*Passer* and *Melospiza* spp.) also directly consume bait (Elliott et al. 2014). Surprisingly, we found no house mice in the prey remains, supporting the assumption that house mice seldom venture outdoors, and are therefore not a likely vector of ARs to owls. Likewise, the total consumption of birds was low (7.5%) and squirrel remains (n = 4) were documented only for three Barred Owl pairs nesting in two urban parks. The low presence of squirrels and birds in the diet suggests that they are not a vector of ARs to owls.

In summary, the wide range of prey species documented in this study confirmed that Barred Owls are highly opportunistic predators, as shown elsewhere (Mazur and James 2000, Johnsgard 2002, Cauble 2008). Yet our diet data also showed that urban Barred Owls in southwestern British Columbia fed primarily on two rodent taxa, rats and voles, and there was an inverse relationship between the two. Further, the proportion of rats in the diet was positively correlated with the amount of urban development within the landscape surrounding the nests/roosts, resulting in rats being the primary prey consumed at six of the eight sites. The high proportion of rats in the diet points to rats as the main pathway for secondary AR exposure to Barred Owls. Finally, the use of SGARs in urban parks in conjunction with the year-round presence of Barred Owls in these areas provides further evidence of the risk of secondary AR poisoning to these owls, as reported by Albert et al. (2010) and Thomas et al. (2011).

ACKNOWLEDGMENTS

We thank Paul Levesque and Alexa and Jamie Coote, for their great help in looking for owl pellets. In many instances their efforts consisted of crawling around in the rough understory of urban parks. Also, we thank the two independent reviewers for their knowledgeable insights and efforts in reviewing an earlier version of this report.

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Received 22 January 2014; accepted 9 May 2014