Connecting Great Horned Owl (*Bubo virginianus*) Space Use and Diet in an Urban Park

Arina Martin, Stephen Blake, Sharon L. Deem, Jeffrey Meshach, Jamie Palmer, Anthony Dell, August Wise, Avery Valenciano, and Stella F. Uiterwaal

Volume 13, 2026 Urban Naturalist No. 87

Urban Naturalist

♦ The *Urban Naturalist* is an open-access, peer-reviewed, and edited interdisciplinary natural history journal with a global focus on urban and suburban areas (ISSN 2328-8965 [online]).

♦ The journal features research articles, notes, and research summaries on terrestrial, freshwater, and marine organisms and their habitats.

♦ It offers article-by-article online publication for prompt distribution to a global audience.

♦ It offers authors the option of publishing large files such as data tables, and audio and video clips as online supplemental files.

♦ Special issues - The *Urban Naturalist* welcomes proposals for special issues that are based on conference proceedings or on a series of invitational articles. Special issue editors can rely on the publisher's years of experiences in efficiently handling most details relating to the publication of special issues.

♦ Indexing - The *Urban Naturalist* is a young journal whose indexing at this time is by way of author entries in Google Scholar and Researchgate. Its indexing coverage is expected to become comparable to that of the Institute's first 3 journals (*Northeastern Naturalist*, *Southeastern Naturalist*, and *Journal of the North Atlantic*). These 3 journals are included in full-text in BioOne.org and JSTOR.org and are indexed in Web of Science (clarivate.com) and EBSCO.com.

♦ The journal's editor and staff are pleased to discuss ideas for manuscripts and to assist during all stages of manuscript preparation. The journal has a page charge to help defray a portion of the costs of publishing manuscripts. Instructions for Authors are available online on the journal's website (http://www.eaglehill.us/urna).

♦ It is co-published with the *Northeastern Naturalist*, *Southeastern Naturalist*, *Caribbean Naturalist*, *Eastern Paleontologist, Journal of the North Atlantic*, and other journals.

♦ It is available online in full-text version on the journal's website (http://www.eaglehill.us/urna). Arrangements for inclusion in other databases are being pursued.

Cover Photograph: Adult female Great Horned Owl (nicknamed Astrid) and her chick in Forest Park, Saint Louis Missouri. Photo taken by Dr. Stephen Blake.

The ***Urban Naturalist*** (ISSN # 2328-8965) is published by the Eagle Hill Institute, PO Box 9, 59 Eagle Hill Road, Steuben, ME 04680-0009. Phone 207-546-2821 Ext. 4. E-mail: office@eaglehill.us. Webpage: http://www.eaglehill.us/urna. Published on an article by article basis. **Special issue proposals are welcome**. The *Urban Naturalist* is an open access journal. **Authors**: Submission guidelines are available at http://www.eaglehill.us/urna. **Co-published journals:** The *Northeastern Naturalist*, *Southeastern Naturalist*, *Caribbean Naturalist*, and *Eastern Paleontologist*, each with a separate Board of Editors. The Eagle Hill Institute is a tax exempt 501(c)(3) nonprofit corporation of the State of Maine (Federal ID # 010379899).

2026 *Urban Naturalist* 87:1–14

Connecting Great Horned Owl (*Bubo virginianus*) Space Use and Diet in an Urban Park

Arina Martin[1,2*], Stephen Blake[2,3], Sharon L. Deem[4], Jeffrey Meshach[5], Jamie Palmer[4], Anthony Dell[6,7], August Wise[2,8], Avery Valenciano[2,9], and Stella F. Uiterwaal[2,4,6,7,10]

Abstract – With increasing urbanization, many raptor species have readily adjusted to living in urban areas. However, raptors continue to face significant anthropogenic threats that result in high rates of morbidity and mortality. Great Horned Owls (*Bubo virginianus*) occur in cities across the United States, yet few studies have documented their ecology in urban areas. Here, we investigated the health, diet, movement, and activity of one female Great Horned Owl in Forest Park, Saint Louis, Missouri, one of the largest urban parks in the United States. We used GPS and accelerometry data combined with pellet analysis to examine how this owl used an oasis of green space within a densely developed urban landscape. We describe patterns in space use, demonstrating widespread use of developed areas both inside and outside of the park, and show increased use of areas outside of park boundaries in months with higher space use. We compare dietary data with those of other urban and rural Great Horned Owls, show seasonal variation in diet, and identify correlations between movement, diet, and temperature, suggesting variable energetic demands and intake throughout the annual cycle. Lastly, we provide detailed health information on this healthy and reproductively active female owl to complement our current understanding of baseline health values for Great Horned Owls in urban settings. These findings offer a uniquely detailed insight into how one Great Horned Owl exploited an urban landscape, providing novel data on the ecological trade-offs that may confront urban raptors to help inform planning for raptor conservation in urban green spaces.

Introduction

As habitat and dietary generalists, *Bubo virginianus* Gmelin (Great Horned Owls) are widespread across North and South America. These owls are predominantly sedentary, with very few individuals demonstrating other movement strategies (Holt Jr 1996, Rohner 1997). Great Horned Owls frequently nest in urban parks and suburban areas (Bennet and Bloom 2005, Bosakowski and Smith 1997, Holt Jr 1996, Lambert 1981, Rullman and Marzluff 2014, Smith et al. 1999), and while few studies have stated explicitly that Great Horned Owls also roost in urban areas, this behavior is suggested in many

[1]Oregon State University Department of Integrative Biology, 3029 Cordley Hall, 2701 SW Campus Way, Corvallis, OR, USA, 97331. [2]Saint Louis University Department of Biology, 3507 Laclede Ave, St. Louis, MO, USA, 63103. [3]Max Planck Institute of Animal Behavior, Am Obstberg 1, 78315 Radolfzell am Bodensee, Germany. [4]Saint Louis Zoo Institute for Conservation Medicine, 1 Government Drive, St. Louis, MO, USA, 63110. [5]World Bird Sanctuary, 125 Bald Eagle Ridge Road, Valley Park, MO, USA, 63088. [6]Living Earth Collaborative, Washington University in St. Louis, 1 Brookings Drive, Campus Box 1137, St. Louis, MO, USA, 63130. [7]National Great Rivers Research and Education Center, Lewis and Clark Community College, 1 Confluence Way, East Alton, IL, USA, 62024. [8]National Audubon Society, Upper Mississippi Regional Office, 301 Riverlands Way, West Alton, MO, USA, 63386. [9]Kansas State University College of Veterinary Medicine, 1800 Denison Ave, Manhattan, KS, USA, 66506. [10]Center for Conservation Technology and Innovation, Smithsonian Conservation Biology Institute, 1500 Remount Rd, Front Royal, VA, USA, 22630. [*]Corresponding author: martarin@oregonstate.edu.

Associate Editor: Jose Ramirez-Garofalo, Rutgers University.

studies, e.g. Hindmarch and Elliott (2015). As such, urban Great Horned Owls may be entirely reliant on heavily modified landscapes throughout the year.

Predator use of urban environments is highly dependent on resource availability. Urban areas can contain a higher biomass of potential prey items than rural habitats (Rullman and Marzluff 2014) and competition with other predators may be more limited (Dwyer et al. 2018, Hager 2009). Despite the potential benefits of living in cities, urban raptors also face increased anthropogenic threats from building and vehicle collisions, rodenticide poisonings, and electrocutions (Deem et al. 1998, Hager 2009, Murray and Sánchez 2021). In fact, as large raptors, Great Horned Owls may be particularly vulnerable to human-wildlife conflicts (Washburn et al. 2025). Zoonotic diseases such as avian influenza, avian pox, and trichomonosis are additional threats to urban raptors since city habitats can serve as reservoirs for pathogens. These diseases are often spread through stagnant water that serves as breeding grounds for infectious agents and through other infected wildlife that serve as easy prey for raptors (Boal et al. 1998, Dwyer et al. 2018).

Despite these threats increasing with rapid urbanization, the foraging habits of urban raptors are not well understood. While the diets of Great Horned Owls in rural North America have historically been well-documented (Bogiatto et al. 2003, Marti and Kochert 1996, Wink et al. 1987, Zimmerman et al. 1996), less attention has been directed to how their diets vary across environmental gradients, particularly within urban habitats (Hindmarch and Elliott 2015, Kopij 2016). Urbanization is known to alter the diet composition of many species (Gámez et al. 2022, Scholz et al. 2025), signaling a need to better understand the diets of urban raptors. The presence of raptors in cities also suggests the potential for these environments to sustain multiple trophic levels, especially since Great Horned Owls are also known to engage in intraguild predation by preying on smaller raptors (Hindmarch and Elliott 2015, Washburn et al. 2025). Thus, understanding how these predators forage in cities will help to improve our understanding of the ecological health of urban ecosystems.

Foraging is also tightly linked to energetics: prey intake provides energy for growth, maintenance, and reproduction, but foraging behaviors such as movement also require energy expenditure (Brown et al. 2004, Potter et al. 2018). Temperature is known to alter energetic demands and foraging behavior through its effects on metabolic rate, often displaying a unimodal relationship characterized by an optimum temperature (Sentis et al. 2012, Uiterwaal and Delong 2020). In urban environments, temperatures can often exceed those of rural habitats due to "heat island" effects (Jabbar et al. 2023, Szulkin et al. 2020). As such, urban predators may experience temperatures substantially above their optima, increasing their energetic demands. Certain species behaviorally compensate for these increased urban temperatures (Johnson et al. 2019, Saikumari et al. 2025), but these relationships have not been empirically documented in Great Horned Owls. Tri-axial acceleration (or activity) is a commonly used metric of energy expenditure (Hernández-Pliego et al. 2017) and when paired with data on movement, prey intake, and environmental conditions, can identify key patterns contributing to the energetic trade-offs of predators.

With this focused study, we aimed to begin addressing these knowledge gaps by examining the health, movement, activity, and diet of one urban Great Horned Owl over a full annual cycle. We used a combination of clinical and laboratory health diagnostics, GPS telemetry, triaxial accelerometry, and pellet analysis to evaluate relationships between the health, movement, activity, and diet of this urban Great Horned Owl. We further explored the connection between foraging and energetics, hypothesizing that activity, movement, and diet metrics would be correlated with each other and with temperature, reflecting their inherent biological relationships. Although our study was restricted to a single individual, the integration of multiple data types offers novel insights for ecologists and habitat managers and provides a template for future studies.

Methods

Study area

Forest Park is a large urban park located in Saint Louis, Missouri, USA (38.639, -90.284) which is visited annually by over 15.5 million people (Forest Park Forever 2025). The 526-hectare park contains nearly 78.5 ha of restored forests, woodlands, tall grass prairies, and a reconstructed river system. Great Horned Owls are year-round residents in the park, and although their abundance and distribution are not known, they are known to both roost and nest within the park and adjacent urban areas. In 2020, we identified the roost of a pair of Great Horned Owls near Klein Prairie, located on the eastern edge of Forest Park near a major metropolitan area and hospital (Fig. 1). The roost was located within a cluster of non-native *Pinus strobus* L. (Eastern White Pine) near a river boardwalk between a large highway to the east and 3.6 ha of restored prairie to the west. Anthropogenic noise and light pollution from the adjacent highway and hospital is prominent; including sirens, low-flying helicopters, vehicle traffic, streetlamps, and hospital lights.

Tagging and tracking

We captured the female of the pair of Great Horned Owls on the evening of 25 October 2021 with the approval of the Saint Louis Zoo Institutional Animal Care and Use Committee and Wild Bird Sanctuary Station Permit 21110. We used a bal-chatri trap baited with two live pigeons (Bloom et al. 2007). The owl was handled for less than 60 minutes for physical examination, placement of a telemetry backpack, and sample collection using standard raptor handling techniques (Arent and Martell 1996). The backpack consisted of an e-OBS GmbH (Munich, Germany) telemetry tag (Bird Battery 1AA) equipped with a UHF beacon,

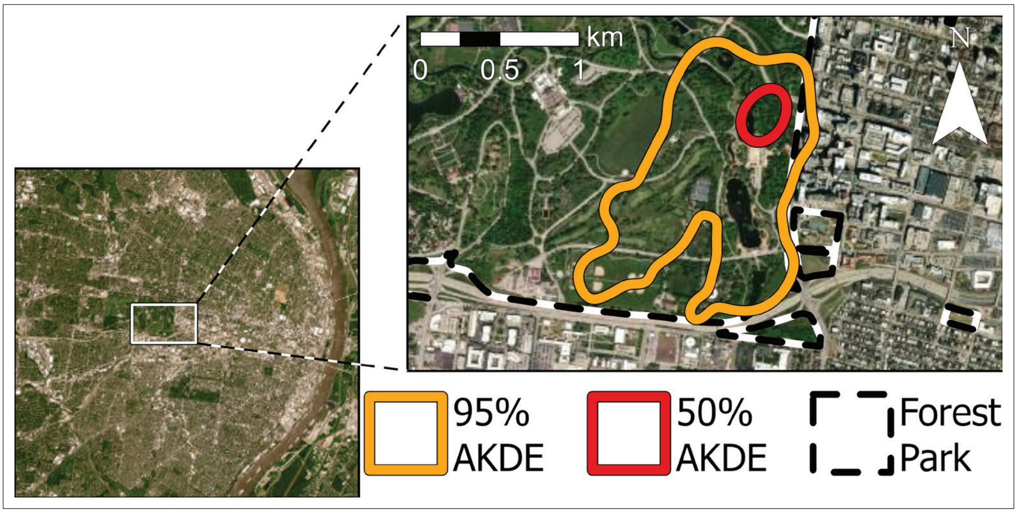

Figure 1. 95% (yellow) and 50% (red) AKDE home ranges of the female Great Horned Owl with the southeastern boundary of Forest Park, Saint Louis, Missouri indicated by a dashed line. The smaller inset map shows the urban coverage of Saint Louis city surrounding the park.

fastened using Teflon ribbon and aluminum crimps. We programmed the tag to collect a burst of tri-axial accelerometer data every two minutes and a GPS location every 2 hours. The owl showed fidelity to her roosting site, facilitating the remote downloading of data from the tag using a handheld receiver approximately every 2 weeks. Estimated battery life for the telemetry tag was 2 years at the programmed settings.

Health data collection and analysis

We measured body mass to the nearest gram using a Pesola Spring scale (Pesola AG, Schindellegi, Switzerland). We assigned a 0–5 body score (0 = severely emaciated, 3 = ideal, 5 = obese) based on the condition of the pectoral muscles, presence of subcutaneous body fat, and overall condition (Scott 2021). We conducted a full physical exam to identify any abnormalities or damage and to check for the presence of ectoparasites, which were collected and preserved in 70% ethanol.

We collected 2.0 mL of blood from the medial metatarsal vein using a 23-gauge needle and 3 mL syringe. Blood was kept in a cooler in the field and then at -20 °C overnight. In the laboratory, we determined packed cell volume (PCV) using microhematocrit tubes and plasma total solids using a temperature-compensated optical refractometer (Deem et al. 2012). In addition, we estimated white blood cell (WBC) counts and performed a manual differential by counting number of WBCs and calculating relative and absolute values for each WBC type (Deem et al. 2012). PCV and WBC counts and differentials are informative of general health status, with PCV providing information regarding potential anemia and WBC counts with differentials informing of possible acute and/or chronic infections. Remaining blood was sent to the Midwest Veterinary Laboratory (Saint Louis, Missouri) for a complete blood count (CBC) with differential and basic metabolic panel and to Bird Sexing Solutions (Antelope, California) for sex determination.

Pellet collection and processing

We collected a total of 210 pellets from below the roost approximately once a week between October 2021–September 2022. Great Horned Owls usually produce 1 pellet per day (Graber 1962, Marti 1973); however, we note that 2 owls used the roost, the tagged female and her mate. Therefore, pellets collected could have been produced by either individual.

Before dissection, we recorded the dry weight, length, and width of fully intact pellets. We also collected intact cranial and postcranial bones for identification. In some cases, we also collected bone fragments that contained identifiable anatomical remains (for example, a femoral or humeral head). We weighed and measured the length of each bone and identified each to the lowest taxonomic level possible while remaining conservative in our identifications (Bover et al. 2014, Fauteux et al. 2014, Johnson 2016). We used paired and unpaired mandibles for mammals and paired and unpaired femurs for birds to estimate the minimum number of individuals (MNI) in each pellet (Lambert 1981). We also used paired and unpaired mandibles (mammals) and femurs (birds) to estimate the overall MNI consumed across taxa to quantify prey proportionality in the diet. We removed data collected in October 2021 for this analysis since only 1 pellet was collected during that month.

Data analyses

To estimate home range, we first fit a continuous time movement model (CTMM; Calabrese et al. 2016) to the movement data (including stationary and non-stationary locations) and used this to generate 95% and 50% autocorrelated kernel density estimates (AKDEs). We performed an unsupervised classification of one-meter resolution Planet Lab SkySat

Imagery from 16 April 2024 to generate a land cover raster and estimate land cover composition of the home range (more details in Uiterwaal et al. 2026). We also divided the movement data by month and estimated both monthly range size and mean speed using CTMM. We intersected monthly ranges with park boundaries to determine the proportion of each monthly range that fell within park boundaries. We also used tri-axial acceleration data to estimate daily overall dynamic body acceleration (ODBA), which we used as a proxy for energy expenditure (Halsey et al. 2019). For each month, we estimated the mean daily ODBA as well as the total monthly ODBA.

We estimated the daily foraging rate as MNI consumed per month using mandible or femur counts divided by the number of pellets, assuming 1 pellet is produced per day (Graber 1962, Marti 1973). We calculated this both by prey taxonomic group as well as for all prey combined. We then estimated daily biomass intake (Field et al. 2013, Pagels and Blem 1984) using taxon-specific wet mass estimates for prey obtained from the literature or from direct measurements of individuals from Forest Park collected for other research. We converted both foraging rates and biomass intake to monthly rates for comparison with movement data. Lastly, we used Pearson's product moment correlation to test for association between paired monthly movement and foraging metrics. We also tested for correlations between monthly mean temperature and monthly movement or foraging metrics. We obtained temperature data for Saint Louis City using Weather Underground (Wunderground) historical weather data (Weather History & Data Archive | Weather Underground 2024). We completed all analyses using *R* (v4.5.2, R Core Team 2025).

Results

Based on physical and laboratory findings, the Great Horned Owl in this study was healthy at the time of capture. Blood sex determination confirmed the owl to be female, and she was aged as AHY (after hatch year, i.e., adult) given her pairing with another owl. The owl was subjectively categorized slightly above ideal weight (mass = 1.704kg, body score = 3.5). However, this weight was still within normal limits and may have been of physiological value for the time of year, as individuals would be in preparation for the colder temperatures and higher energetic demands of early winter (Randloph 1973). Most absolute WBC counts were within normal range, although the basophil count was lower than the reference ranges (Ammersbach et al. 2015a, b). Additionally, a high percentage of lymphocytes present may have been associated with an infectious, inflammatory or neoplastic condition that was subclinical at the time of handling (Jones 2015). We collected mite-like ectoparasites from the feathers, though we did not identify them to species. We also found a low number of *Haemoproteus* spp. parasites in the blood smear, which we did not identify to species. Both parasites are commonly found in asymptomatic, free-living raptors, although clinical disease may be associated with *Haemoproteus* spp. infections, especially during other stressors such as rehabilitation and captive care (Valkiunas 2004). For a complete summary of physical and laboratory findings, see Supplemental File 1, available online at https://eaglehill.us/urnaonline/suppl-files/urna-249-Martin-s1.pdf.

We identified 2,155 bones within the collected pellets and identified them to the lowest taxonomic level while remaining conservative. When estimating MNI (Fig. 2A), we found that prey items which could not be identified below the order Rodentia and *Peromyscus* spp. mice accounted for a large proportion of the diet (23.31% and 22.88%, respectively), followed by murids (18%), birds (Aves, 10.59%), *Microtus* spp. voles that could not be identified to species (9.75%), *Microtus ochragaster* Wagner (Prairie Vole [9.75%]), rats (*Rattus*

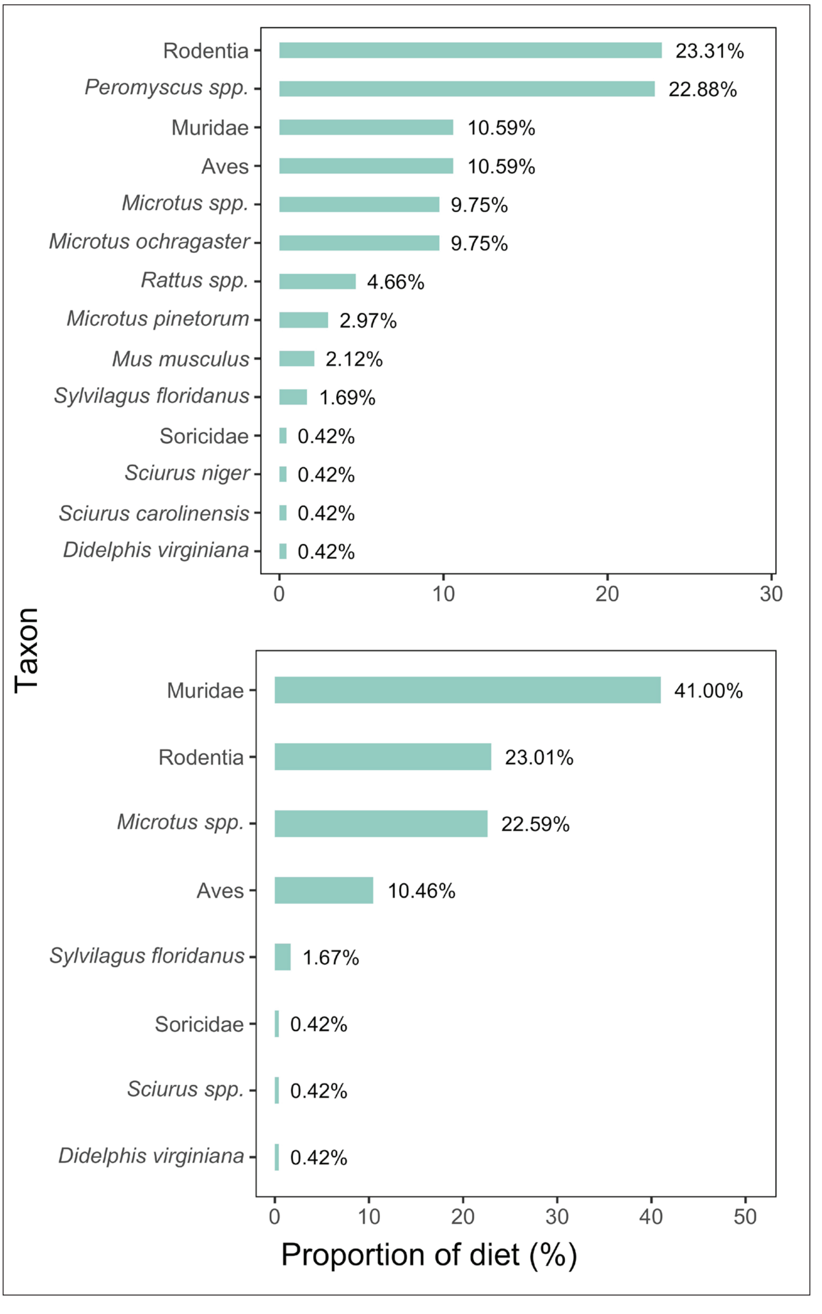

Figure 2. Proportions of the total diet composed of each prey item. Pellets used to examine diet were collected from the roost of the pair of Great Horned Owls, of which the female was tagged. Paired and unpaired mandibles were used to determine MNI for all mammalian specimens, while paired and unpaired femurs were used for avian specimens. Panel (A) shows the diet when specimens were identified to the lowest taxonomic level possible while remaining conservative. In Panel (B) *Sciurus* spp. contains both *S. carolinensis* and *S. niger*, Muridae contains *Mus musculus*, *Peromyscus* spp. and *Rattus* spp., and *Microtus* spp. contains *M. pinetorum*, *M. ochragaster*, and any *Microtus* spp. bones that were unidentifiable to species.

spp., 4.66%), *Microtus pinetorum* Le Conte (Pine Vole [2.97%]), *Mus musculus* L. (House Mouse [2.12%]), and *Sylvilagus floridanus* Allen (Eastern Cottontail Rabbit [1.69%]). Shrews (Soricidae), *Sciurus niger* L. (Fox Squirrel), *Sciurus carolinensis* Gmelin (Eastern Gray Squirrel), and *Didelphis virginiana* Kerr (Virginia Opossums) each accounted for 0.42% of the overall diet. When generalizing taxa in order to examine higher-order-level differences (Fig. 2B), we found that murids overall made up 41% of the diet, followed by specimens identified to the level of Rodentia (23.01%) and *Microtus* spp. voles (22.59%). Birds composed 10.46% of the overall diet and Eastern Cottontail Rabbits composed 1.67%, while shrews, squirrels (*Sciurus* spp.) and Virginia Opossums each made up 0.42% of the diet.

Generalized taxa data were used to compute seasonal diet composition (Fig. 3). We found avian bones in pellets consistently throughout the year, with a notable increase in May and September. Voles, murids, and Eastern Cottontail Rabbits were also common prey items across seasons. Squirrels, shrews and Virginia Opossums appeared to be more supplementary prey items, with squirrels present in December, March and September, opossums in January, March, April and May, and shrews only present in January.

The e-OBS GmbH telemetry tag was active for one year. A complete summary of fixes gathered from this tag can be found in Supplementary File 1. The 50% and 95% AKDE home ranges (Fig. 1) were 42.68 ha (95% CIs: 40.71–44.67 ha) and 95.04 ha (95% CIs: 90.77–99.54 ha), respectively. The 50% AKDE home range primarily consisted of the area immediately surrounding the roosting location, while the 95% AKDE home range indicated more areas used outside of the roost. Land cover in the 95% AKDE was barren (15%), developed (17%), forest (43%), herbaceous (19%), and water (6%; Fig. 4). Land cover in the 50% AKDE was barren (3%), developed (10%), forest (71%), herbaceous (1%), and water (15%; Fig. 4). Barren land cover consisted of soil- or sand-dominated land, such as golf courses or baseball fields.

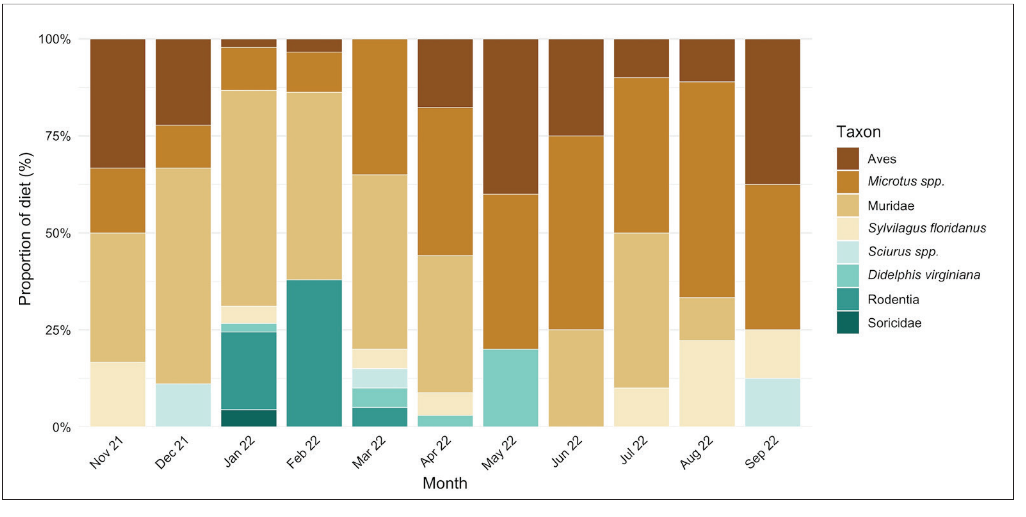

Figure 3. A comparison of the proportion of the diet composed of the MNI of each taxon per month. Pellets used to examine diet were collected from the roost of the pair of Great Horned Owls, of which the female was tagged. Paired and unpaired mandibles were used to determine MNI for all mammalian specimens, while paired and unpaired femurs were used for avian specimens. Note that in this figure, *Sciurus* spp. contains both *S. carolinensis* and *S. niger*, Muridae contains *Mus musculus, Peromyscus* spp. and *Rattus* spp., and *Microtus* spp. contains *M. pinetorum, M. ochragaster,* and any *Microtus* spp. bones that were unidentifiable to species. Numbers above bars indicate the number of pellets collected and analyzed per month.

There was a positive correlation between monthly mean temperature and monthly 95% AKDEs that approached significance ($p = 0.073$, Fig. 5A). There was also a significant positive correlation between monthly mean temperature and monthly 50% AKDEs ($p = 0.024$, Fig. 5B). Monthly 95% AKDEs showed a significant negative correlation with the proportion of the range within park boundaries ($p = 0.012$, Fig. 5C), indicating that monthly range expansion occurred outside of the park and into heavily urbanized areas. There was a positive correlation between mean monthly temperature and monthly mean speed that approached significance ($p = 0.062$, Fig. 5D), as well as a significant positive correlation between monthly mean speed and monthly biomass intake ($p = 0.031$, Fig. 5E). All other tested correlations were neither significant nor approaching significance, including those involving ODBA.

Discussion

The Great Horned Owl in this study was healthy based on physical and laboratory diagnostics, a finding that was supported by successful fledging of two chicks in 2025. The pair also made several nesting attempts near the roost during this study, though all were unsuccessful. This may have been due to a lack of available nesting sites as Great Horned Owls are secondary cavity nesters (Rusch 1982) and old, hollow trees are often removed in urban

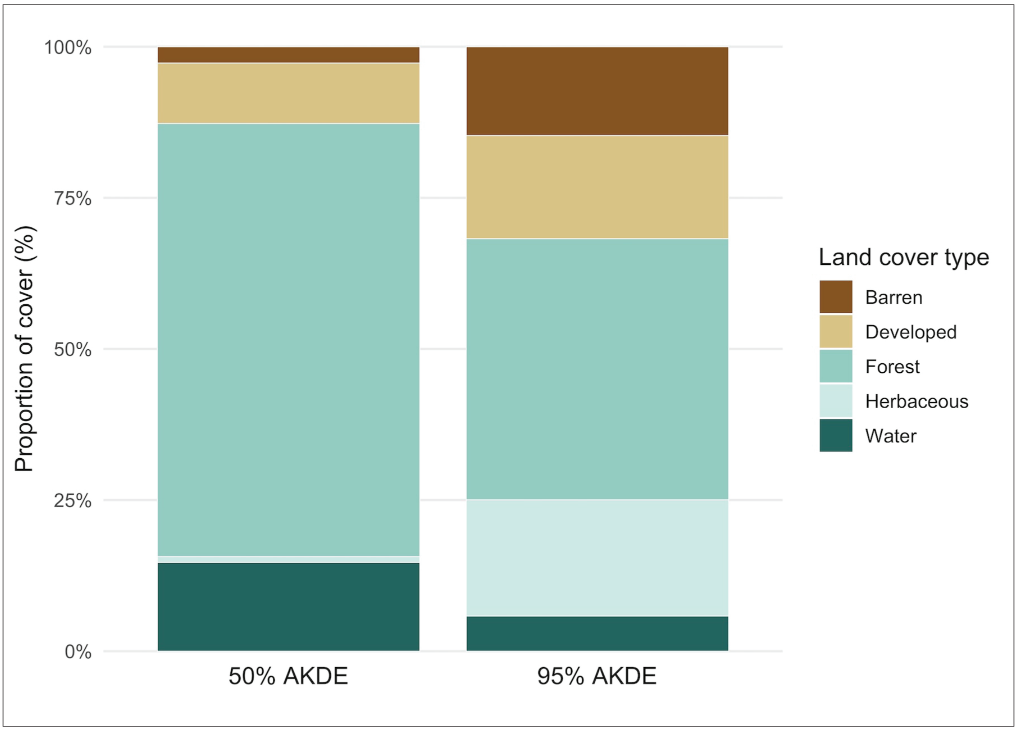

Figure 4. Land coverage in the 50% AKDE home range of the female Great Horned Owl (consisting primarily of her roosting location) and 95% AKDE home range (indicating her most used areas outside of her roost). Land cover in the 50% AKDE home range consisted mostly of forested land (71%) followed by water bodies (15%), developed areas (10%), barren land (consisting of dirt- or sand-dominated space, 3%) and herbaceous coverage (1%). Land cover in the 90% AKDE home range was forest (43%), herbaceous (19%), developed (17%), barren (15%), and water (6%).

parks for visitor safety. The assessment of a healthy, reproductively active Great Horned Owl was a positive finding given that urban raptors generally – and Great Horned Owls more specifically – have significant morbidity and mortality associated with anthropogenic impacts of urban areas (Deem et al. 1998, Franson and Little 1996).

Murids were the most common prey species found in the pellets, with *Peromyscus* mice being the most abundant taxonomic group within this general categorization (Fig. 2). This finding coincided with those of other studies that found *Peromyscus* mice to be abundant in the diets of both rural (Bogiatto et al. 2003, Zimmerman et al. 1996) and urban (Hindmarch and Elliott 2015) Great Horned Owls. We also found proportions of avian specimens comparable to other urban parks (Hindmarch and Elliott 2015). This suggests increased consumption of avian prey in more urbanized environments, given that most rural studies – with the exception of Bogiatto et al. (2003) – report very few avian specimens (Lambert 1981, Marti and Kochert 1996, Zimmerman et al. 1996).

Eastern Cottontail Rabbits and squirrels comprised a minor proportion of the diet, consistent with observations made by Hindmarch and Elliott (2015) in urbanized settings, yet in contrast to studies focused on Great Horned Owls in rural areas (Marti and Kochert 1996; Zimmerman et al. 1996). Notably, while Eastern Cottontail Rabbits account for less than 2% of the overall diet when estimated using MNI, their remnants were found in pellets from 7 out of the 11 months included in this analysis. These results suggest that Eastern Cottontail Rabbits were a common supplementary food source, likely due to the large caloric potential of these prey items compared to smaller taxa such as shrews or birds.

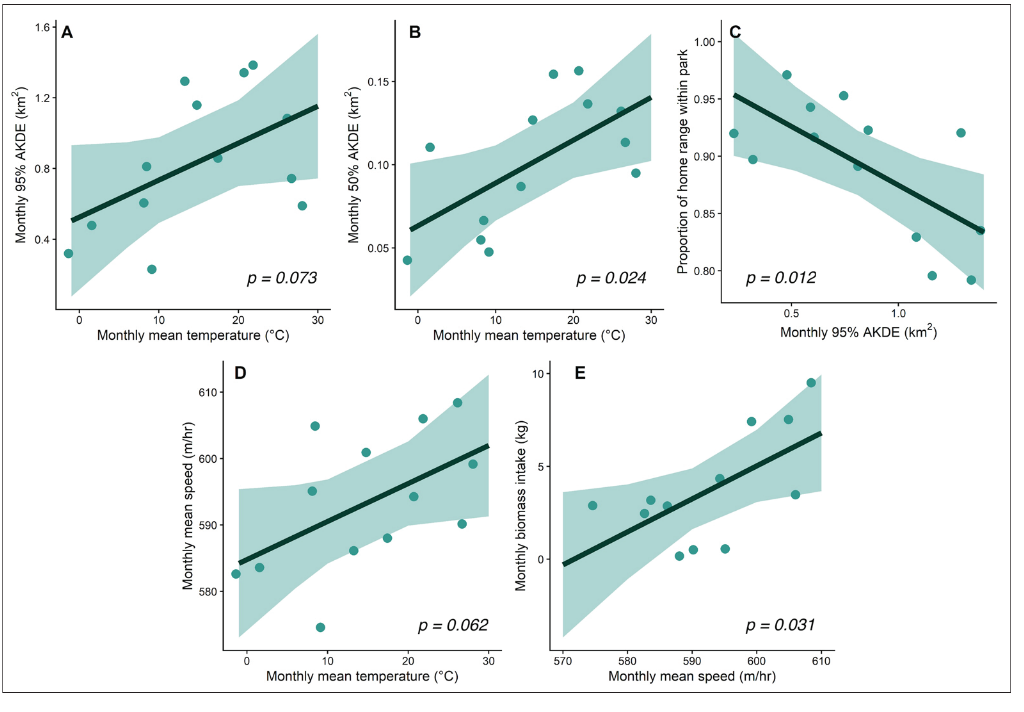

Figure 5. Significant (A, B, C, E) and near significant (D) correlations between movement and foraging metrics of the Great Horned Owl, and temperature with lines of best fit and 95% confidence intervals.

Additionally, we found that voles constituted a smaller proportion of the overall diet here as compared to findings from rural landscapes in Oregon (Kopij 2016) and Idaho (Marti and Kochert 1996) and from both rural areas and urban parks in British Columbia (Hindmarch and Elliott 2015). The lower proportion of voles in the diet of these owls could be attributed to habitat differences between these studies, as many vole species prefer wetter habitats (Marti and Kochert 1996, Missouri Department of Conservation 2025). Two out of the three aforementioned studies describe a large body of water (either a lake or river) as a prominent feature of the landscape, whereas waterways only accounted for 6% of this owl's overall range (95% AKDE), possibly explaining the smaller role of voles in this diet.

Variation in the observed diet likely reflected the availability of prey in the home range (Kopij 2016, Zimmerman et al. 1996). During colder months (December through February) when many small mammals shift the timing of their activities to conserve energy (Guiden and Orrock 2020) and vegetation cover is lowest, the diet was more diverse, consistent with previous studies (Kopij 2016, Zimmerman et al. 1996). The increase of avian specimens in May and September supports this opportunistic foraging strategy based on prey availability, given increased songbird abundance during migratory periods (Robbins 2018).

Several studies record high abundances of rats in the diets of urban Great Horned Owls (Hindmarch and Elliott 2015, Lambert 1981, Wink et al. 1987); however rats constituted less than 5% of the prey individuals found in the diet of this Great Horned Owl (Fig. 2). Rats are common targets of rodenticide applications within major cities, and rodenticide poisoning poses a serious concern to city predators, especially raptors (Hindmarch and Elliott 2015, Murray and Sánchez 2021). Additionally, rats are not the sole taxon susceptible to rodenticide poisoning, with biomagnification of these poisons occurring in mesopredators that can also become prey to urban raptors, such as Virginia Opossums (Buckley et al. 2024). Studies focusing on the dietary breadth and habitat use of urban raptors such as Great Horned Owls can help inform the growing understanding of urban trophic structure and potentially influence urban wildlife management decisions, especially when it comes to rodenticide applications.

Home range estimates for Great Horned Owls vary widely, with few studies quantifying range size using telemetry. Bennet and Bloom (2005) report the mean core range (50% AKDE) size for 5 female Great Horned Owls living in a semi-urban environment as 27 ha and placed the mean boundary of home ranges (95% AKDE) at 180 ha. Other studies of Great Horned Owl home ranges in more rural areas report vastly larger estimates ranging from 300 ha to 600+ ha (Frank and Lutz 1997, Petersen 1979). Thus, our Great Horned Owl's core and home ranges are more consistent with other reports on semi-urban owls.

The core range consisted largely of forested land followed by developed land (Fig. 4). The roost lies on the east border of the park, adjacent to a major highway and hospital system, as well as a large visitor parking lot which contributes to the amount of developed land in the area. In her overall home range, this owl used more forested and herbaceous areas, although she continued to spend time in developed areas both inside and outside of the park. Much of her expansion outside of the core range was southward (Fig. 1). Given that the adjacent hospital system often produces substantial anthropogenic noise pollution, this southward expansion away from the hospital may have benefited foraging efforts. The inclusion of more forested and herbaceous areas in the broader home range also suggests preferences for hunting in these habitats since denser vegetation is likely to support higher prey densities (Zimmerman et al. 1996). This may also be suggestive of the importance of forested patches within urban landscapes to provide urban raptors with foraging areas that are more secluded from anthropogenic noise pollution. We also found a significant correlation between overall range size (95% AKDE) and the proportion of the range that fell outside of park boundaries (Fig. 5). We found no such correlation with core range size (50% AKDE), highlighting high roost fidelity. Yet, as this owl increased her range she increasingly used more urban areas. We speculatively attribute this to territoriality between other nesting Great Horned Owls in the park (Baumgartner 1938, Bennet and Bloom 2005), although this claim requires further investigation.

We found clear connections between temperature, movement, and diet. In colder months, the core range and overall range were smaller and mean speed was slower, indicating decreased movement activity. This aligns with energetic expectations, suggesting a behavioral trade-off that reduces energy expenditure for movement in favor of heat conservation in colder months. However, we note that reproductive behavior could also underlie the observed result, as both mating and nesting behavior can decrease movement. The breeding season of the Great Horned Owl is one of the earliest of the North American owls (Baumgartner 1938) and nest as early as January or February in Missouri (Missouri Department of Conservation 2025). As we had tagged the female of this pair, it is possible that this decrease in movement during these months could potentially be reflective of her nesting attempts; however, our limited scope does not allow us to attribute causation to these findings.

Movement is critical to the predation process, with increased movement capacity often increasing encounter rates and success in prey capture. We did not detect a correlation between any of the tested movement metrics and the number of prey individuals consumed, as would be expected with increased encounter rates as movement increases. We did, however, identify a significant positive correlation between prey biomass intake and mean speed. This finding suggests that increased movement capacity better enables individuals to find and capture larger prey. Our data, however, do not allow us to directly examine causation between biomass intake and monthly speed.

Predators are vital to the health and functioning of ecosystems (Glasser 1979). As urbanization continues to fragment native habitat, it also alters predator regimes (Rullman and Marzluff 2014) and increases human-wildlife conflicts (Soulsbury and White 2015). Our results showed consistent exploration of urban areas outside of park boundaries by this female Great Horned Owl, which increases chances of human-wildlife conflicts, morbidity, and mortality, especially when faced with high-traffic roadways. Trophic dynamics can also be greatly altered by human influence (El-Sabaawi 2018, Warren et al. 2006). Given that predators are expected to decline with increased urbanization (El-Sabaawi 2018), the continued presence of raptors in cities may make them one of the few remaining top predators in these areas (Donázar et al. 2016, Sergio et al. 2008).

This case study highlights the complex interplay between environmental conditions, habitat use, and foraging behavior of an urban avian predator. Together, our findings contribute to our understanding of how urban raptors navigate ecological and human-imposed pressures, and they underscore the importance of considering both natural and anthropogenic factors when managing urban wildlife habitats. We emphasize, however, the limited scope of our project with a single individual. We hope to have provided a template for future research involving multiple individuals across urban gradients, as this research is necessary to determine relationships between movement ecology, foraging strategy, urbanization, and management of wildlife.

Acknowledgements

Funding for this project was provided by the Saint Louis Zoo Institute for Conservation Medicine, Saint Louis University, the National Great Rivers Research and Education Center, and a Living Earth Collaborative seed grant from Washington University in Saint Louis. We thank Maris Brenn-White and Rimsha Malik for assisting with the capture of the owl. We also thank Johan Rhodin and Mark Glenshaw for their assistance in locating the roost, and Katy Huffman for her help in processing pellets. We also thank Amy Witt and Forest Park Forever. Finally, we thank the city of Saint Louis for permission to conduct this study.

Literature Cited

Ammersbach M., H. Beaufrère, A. Gionet Rollick, and T. Tully. 2015a. Laboratory blood analysis in Strigiformes—Part I: hematologic reference intervals and agreement between manual blood cell counting techniques. Veterinary Clinical Pathology 44(1):94–108.

Ammersbach M., H. Beaufrère, A. Gionet Rollick, and T. Tully. 2015b. Laboratory blood analysis in Strigiformes—Part II: plasma biochemistry reference intervals and agreement between the Abaxis Vetscan V2 and the Roche Cobas c501. Veterinary Clinical Pathology 44(1):128–140.

Arent L. and M. Martell. 1996. Care and management of captive raptors. Reference manual. The Raptor Center at University of Minnesota, St Paul, Minnesota, USA. 179 pp.

Baumgartner F.M. 1938. Courtship and nesting of the great horned owls. The Wilson Bulletin 50(4):274–285.

Bennet J.R. and P.H. Bloom. 2005. Home range and habitat use by great horned owls (*Bubo virginianus*) in Southern California. Journal Of Raptor Research 39(2):119–126.

Bloom P.H., W.S. Clark, and J.W. Kidd. 2007. Capture Techniques. Pp. 193–219, *In* D.M. Bird and K.L. Bildstein (Eds.). Raptor Research and Management Techniques. Raptor Research Foundation, Washington, DC, USA. 464 pp.

Boal C.W., R.W. Mannan, and K.S. Hudelson. 1998. Trichomoniasis in Cooper's hawks from Arizona. Journal of Wildlife Diseases 34(3):590–593.

Bogiatto R.J., B.A. Sardella, and J.J. Essex. 2003. Food habits of great horned owls in Northeastern California with notes on seasonal diet shifts. Western North American Naturalist 63(2):258–263.

Bosakowski T. and D.G. Smith. 1997. Distribution and species richness of a forest raptor community in relation to urbanization. Journal of Raptor Research 31(1):26–33.

Bover P., A. Valenzuela, C. Guerra, J. Rofes, J. Alcover, J. Ginés, J. Fornós, G. Cuenca-Bescós, and A. Merino. 2014. The Cova des Pas de Vallgornera (Llucmajor, Mallorca): A singular deposit bearing an exceptional well preserved Early Pleistocene vertebrate fauna. International Journal of Speleology 43(2):175–192.

Brown J.H., J.F. Gillooly, A.P. Allen, V.M. Savage, and G.B. West. 2004. Toward a metabolic theory of ecology. Ecology 85(7):1771–1789.

Buckley J.Y., M.H. Murray, N.U. De La Sancha, M. Fidino, K.A. Byers, R. Fyffe, and S. Magle. 2024. Widespread exposure to anticoagulant rodenticides among common urban mesopredators in Chicago. Science of The Total Environment 952:175883.

Calabrese J.M., C.H. Fleming, and E. Gurarie. 2016. ctmm: an r package for analyzing animal relocation data as a continuous-time stochastic process. Methods in Ecology and Evolution 7(9):1124–1132.

Deem S.L., J.L. Rivera-Parra, and P.G. Parker. 2012. Health evaluation of Galapagos hawks (*Buteo galapagoensis*) on Santiago Island, Galapagos. Journal of Wildlife Diseases 48(1):39–46.

Deem S.L., S.P. Terrell, and D.J. Forrester. 1998. A retrospective study of morbidity and mortality of raptors in Florida: 1988-1994. Journal of Zoo and Wildlife Medicine: Official Publication of the American Association of Zoo Veterinarians 29(2):160–164.

Donázar J.A., A. Cortés-Avizanda, J.A. Fargallo, A. Margalida, M. Moleón, Z. Morales-Reyes, R. Moreno-Opo, J.M. Pérez-García, J.A. Sánchez-Zapata, I. Zuberogoitia, et al. 2016. Roles of raptors in a changing world: From flagships to providers of key ecosystem services. Ardeola 63(1):181–234.

Dwyer J.F., S. Hindmarch, and G.E. Kratz. 2018. Raptor mortality in urban landscapes. Pp. 199–213, *In* C.W. Boal, C.R. Dykstra (Eds.). Urban Raptors: Ecology and Conservation of Birds of Prey in Cities. Island Press/Center for Resource Economics, Washington, D.C., USA. 320 pp.
El-Sabaawi R. 2018. Trophic structure in a rapidly urbanizing planet. Functional Ecology 32(7):1718–1728.
Fauteux D., G. Lupien, F. Fabianek, J. Gagnon, M. Séguy, and L. Imbeau. 2014. An illustrated key to the mandibles of small mammals of eastern Canada. The Canadian Field-Naturalist 128(1):25–37.
Field D.J., C. Lynner, C. Brown, and S.A.F. Darroch. 2013. Skeletal correlates for body mass estimation in modern and fossil flying birds. PLOS ONE 8(11):e82000.
Forest Park Forever. 2025. Forest Park Forever. Available online at https://www.forestparkforever.org. Accessed 17 May 2025.
Frank R.A. and R.S. Lutz. 1997. Great horned owl (*Bubo virginianus*) productivity and home range characteristics in a shortgrass prairie. General Technical Report. US Department of Agriculture, Forest Service, St. Paul, Minnesota, USA. 4 pp.
Franson J.C. and S.E. Little. 1996. Diagnostic findings in 132 great horned owls. Journal of Raptor Research 30(1):1–6.
Gámez S., A. Potts, K.L. Mills, A.A. Allen, A. Holman, P.M. Randon, O. Linson, and N.C. Harris. 2022. Downtown diet: A global meta-analysis of increased urbanization on the diets of vertebrate predators. Proceedings of the Royal Society B: Biological Sciences 289(1970):20212487.
Glasser J. 1979. Role of predation in shaping and maintaining the structure of communities. American Naturalist 113(5):631–641.
Graber R.R. 1962. Food and oxygen consumption in three species of owls (Strigidae). The Condor 64(6):473–487.
Guiden P.W. and J.L. Orrock. 2020. Seasonal shifts in activity timing reduce heat loss of small mammals during winter. Animal Behaviour 164:181–192.
Hager S.B. 2009. Human-related threats to urban raptors. Journal of Raptor Research 43(3):210–226.
Halsey L.G., J.A. Green, S.D. Twiss, W. Arnold, S.J. Burthe, P.J. Butler, S.J. Cooke, D. Grémillet, T. Ruf, O. Hicks, et al. 2019. Flexibility, variability and constraint in energy management patterns across vertebrate taxa revealed by long-term heart rate measurements. Functional Ecology 33(2):260–272.
Hernández-Pliego J., C. Rodríguez, G. Dell'Omo, and J. Bustamante. 2017. Combined use of tri-axial accelerometers and GPS reveals the flexible foraging strategy of a bird in relation to weather conditions. PLOS ONE 12(6):e0177892.
Hindmarch S. and J.E. Elliott. 2015. Comparing the diet of great horned owls (*Bubo virginianus*) in rural and urban areas of southwestern British Columbia. The Canadian Field-Naturalist 128(4):393.
Holt Jr J.B. 1996. A banding study of Cincinnati area great horned owls. Journal of Raptor Research 30:194–197.
Jabbar H.K., M.N. Hamoodi, and A.N. Al-Hameedawi. 2023. Urban heat islands: A review of contributing factors, effects and data. IOP Conference Series: Earth and Environmental Science 1129(1):012038.
Johnson E.V. 2016. A skeletal comparison of selected small mammals. Reference guide. University of Exeter. 10 pp.
Johnson J.C., J. Urcuyo, C. Moen, and D.R. Stevens. 2019. Urban heat island conditions experienced by the Western black widow spider (*Latrodectus hesperus*): Extreme heat slows development but results in behavioral accommodations. PLOS ONE 14(9):e0220153.
Jones M.P. 2015. Avian hematology. Veterinary Clinics of North America: Exotic Animal Practice 18(1):51–61.
Kopij G. 2016. Diet of the great horned owl, *Bubo virginianus*, along a vegetation gradient in Oregon. Northwestern Naturalist 97(1):63–65.
Lambert A. 1981. Presence and food preferences of the great horned owl in the urban parks of Seattle. The Murrelet 62(1):2–5.
Marti C.D. 1973. Food consumption and pellet formation rates in four owl species. Wilson Bulletin 85(2):178-181.

Marti C.D. and M.N. Kochert. 1996. Diet and trophic characteristics of great horned owls in Southwestern Idaho. Journal of Field Ornithology 67(4):499–506.

Missouri Department of Conservation. 2025. Voles (Meadow Mice). Available online at https://mdc.mo.gov/discover-nature/field-guide/voles-meadow-mice. Accessed 17 May 2025.

Murray M.H. and C.A. Sánchez. 2021. Urban rat exposure to anticoagulant rodenticides and zoonotic infection risk. Biology Letters 17(8):20210311.

Pagels J.F. and C.R. Blem. 1984. Prediction of body weights of small mammals from skull measurements. Acta Theriologica 29:367–381.

Petersen L.R. 1979. Ecology of great horned owls and red-tailed hawks in Southeastern Wisconsin. Technical Bulletin. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA. 66 pp.

Potter T.I., H.J. Stannard, A.C. Greenville, and C.R. Dickman. 2018. Understanding selective predation: Are energy and nutrients important? PLOS ONE 13(8):e0201300.

R Core Team. 2025. *R: A language and environment for statistical computing* (Version 4.5.2) Computer software. R Foundation for Statistical Computing.

Randolph J.C. 1973. Ecological energetics of a homeothermic predator, the short-tailed shrew. Ecology 54(5):1166–1187.

Robbins M. 2018. The Status and Distribution of Birds in Missouri. 2nd ed. Lawrence, KS: University of Kansas Libraries. 342 pp.

Rohner C. 1997. Non-territorial ‘floaters’ in great horned owls: space use during a cyclic peak of snowshoe hares. Animal Behaviour 53(5):901–912.

Rullman S. and J.M. Marzluff. 2014. Raptor presence along an urban–wildland gradient: Influences of prey abundance and land cover. Journal of Raptor Research 48(3):257–272.

Rusch D.A. 1982. Great Horned Owl. Pp. 171-172, *In* D.E. Davis (Ed.). CRC Handbook of Census Methods for Terrestrial Vertebrates. CRC Press, Inc. Boca Raton, Florida, USA. 424 pp.

Saikumari V., M. Ramesh, Praveena, R.S. Hiremath, Sindhuja, and Sunil. 2025. Urban heat islands as evolutionary laboratories for rapid thermal adaptation in synanthropic birds. Journal of Animal Environment 17(4):141–154.

Scholz C., T. Teige, K.P. Ngoufack Djoumessi, S. Buchholz, F. Pritsch, A. Planillo, and C.C. Voigt. 2025. Dietary diversification of an insect predator along an urban-rural gradient. Landscape and Urban Planning 256:105273.

Scott D.E. 2021. Handling and physical examination. Pp. 1–10, *In* D.E. Scott (Ed.). Raptor Medicine, Surgery, and Rehabilitation. CAB International, Wallingford, Oxfordshire, United Kingdom. 360 pp.

Sentis A., J.-L. Hemptinne, and J. Brodeur. 2012. Using functional response modeling to investigate the effect of temperature on predator feeding rate and energetic efficiency. Oecologia 169(4):1117–1125.

Sergio F., T. Caro, D. Brown, B. Clucas, J. Hunter, J. Ketchum, K. McHugh, and F. Hiraldo. 2008. Top predators as conservation tools: ecological rationale, assumptions, and efficacy. Annual Review of Ecology, Evolution, and Systematics 39:1–19.

Smith D.G., T. Bosakowski, and A. Devine. 1999. Nest site selection by urban and rural great horned owls in the Northeast. Journal of Field Ornithology 70(4):535–542.

Soulsbury C.D. and P.C.L. White. 2015. Human–wildlife interactions in urban areas: a review of conflicts, benefits and opportunities. Wildlife Research 42(7):541.

Szulkin M., J. Munshi-South, and A. Charmantier. 2020. Evolutionary Consequences of the Urban Heat Island. Pp. 91–111, *In* M. Szulkin, J. Munshi-South, and A. Charmantier (Eds). Urban Evolutionary Biology. Oxford University Press, Oxford, United Kingdom. 320 pp.

Uiterwaal S.F. and J.P. Delong. 2020. Functional responses are maximized at intermediate temperatures. Ecology 101(4).

Uiterwaal S.F., A. Wise, M. Cain, S.L. Deem, A. Dell, C. Ferree, A. Martin, R.L. Korotev, J. Palmer, D. Tylka, et al. 2026. Urban habitat restoration increases native bird diversity in the Midwestern United States. Ecological Applications 36(2):e70207.

Valkiunas G. 2004. Avian Malaria Parasites and other Haemosporidia. 1st ed. Boca Raton, Florida: CRC Press, Inc. 946 pp.

Warren P., C. Tripler, D. Bolger, S. Faeth, N. Huntly, C. Lepczyk, J. Meyer, T. Parker, E. Shochat, and J. Walker. 2006. Urban food webs: Predators, prey, and the people who feed them. Bulletin of the Ecological Society of America 87(4):387–393.

Washburn B.E., B.J. Massey, A.C. Sonnek, and T.J. Pitlik. 2025. Assessing mitigation translocation as a tool to reduce human–great horned owl conflicts. Environmental Management 75(3):654–662.

Weather Underground. 2024. Weather History & Data Archive | Weather Underground. Available online at https://www.wunderground.com/history. Accessed 17 May 2024.

Wink J., S.E. Senner, and L.J. Goodrich. 1987. Food habits of great horned owls in Pennsylvania. Proceedings of the Pennsylvania Academy of Science 61(2):133–137.

Zimmerman G., P. Stapp, and B. Van Horne. 1996. Seasonal variation in the diet of great horned owls (*Bubo virginianus*) on shortgrass prairie. The American Midland Naturalist 136(1):149–156.