9-8-2022

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Abstract

The southern flying squirrel (*Glaucomys volans*) is considered a species of greatest conservation need in Nebraska and listed as threatened in the state. Historically, the geographic range of the southern flying squirrel in Nebraska has been restricted to five eastern counties from a northern suburb of Omaha, Douglas Co., southward in the four counties of Sarpy, Otoe, Nemaha, and Richardson, all bordering the Missouri River on the east. In late November of 2018, a resident of Lincoln, Lancaster Co., Nebraska, contacted the Nebraska Game and Parks Commission about an animal found dead in his yard. This animal proved to be a southern flying squirrel, which was 50 to 70 miles [80 to112 km] west of the known geographic range of the species. Two additional individuals were subsequently observed at the original residence as were individuals in at least a total of 10 neighborhoods throughout the city of Lincoln. Clearly, a population of the southern flying squirrels is established and reproducing in Lincoln, but their origin is unknown. The source of this city-dwelling population may be from released or escaped pets, a natural dispersal from the Missouri River via the Platte River and Salt Creek, or inadvertent translocation when moving timber or fire wood.

Keywords: dispersal, *Glaucomys volans*, Nebraska, Rodentia, Sciuridae, species of greatest conservation need, threatened, urban forest

DOI:10.32873/unl.dc.tnas.42.5

On 21 November 2018, one of us (MJP) was contacted with a report of a possible southern flying squirrel (*Glaucomys volans*) found dead in Lincoln, Lancaster County, Nebraska. The message included several photographs of the individual discovered "drowned" in a flowerpot. A homeowner found the dead animal in his yard in the Country Club neighborhood in the vicinity of South 31st and Van Dorn streets. The homeowner noted that the animal appeared uncommon for the area, so he preserved it until he could get more information. The animal was eventually transmitted to Patricia Freeman, Professor Emeritus, University of Nebraska State Museum (USNM), who confirmed the identification of the frozen specimen as a southern flying squirrel. The squirrel was prepared as a scientific voucher specimen by one of us (TEL) and is catalogued in the USNM (ZM-31041). This was the first documented record of the southern flying squirrel in Lincoln. The occurrence of flying squirrels in Lincoln was a surprise because the nearest known record of the species was from near Nebraska City 50 miles [80 km] to the east along the Missouri River.

The external and cranial measurements of this individual were as follows (in mm): total length 222; length of tail vertebrae 107; length of hind foot 30; length of ear 20; greatest length of skull 33.54; condylobasal length 29.95; zygomatic breadth 19.59; interorbital breadth 7.13; mastoid breadth 17.15; length of maxillary toothrow 6.82. This male flying squirrel weighed 41.19 g at preparation and had testes measuring 7 mm in length and 4 mm in width.

On 25 November 2018, a live flying squirrel was found in a box removed from the attic of the home where the first dead squirrel was found. The box was opened outside where the release of the animal was recorded and later posted online (Nebraska Game and Parks Commission 2022). Although the squirrel is visible for only a moment, it was clear to Dr. Freeman and to us that it was indeed a flying squirrel. The homeowner reported there are many mature trees, especially oaks (*Quercus* sp.), in the neighborhood that flying squirrels could be using. He indicated that he had not seen any evidence of more flying squirrels on his property. On 2 February 2019, a third (or possibly a recapture of the released animal) flying squirrel was taken at this same residence. The homeowner was assisted by the Nebraska Wildlife Rescue Team, Inc. (NWRT), in safely capturing the animal. The flying squirrel was photographed, and the picture was then shared with MJP for the record (Nebraskaland Photo Library 2022).

Lincoln resident Sheila Wilson-Carroll reported seeing a flying squirrel gliding between trees in the northern portion of Wilderness Park at dusk in spring 2018 while she was trail riding. Although there is no supporting documentation, Ms. Wilson-Carroll has some familiarity with southern flying squirrels because she has encountered them before during frequent visits to Indian Cave State Park in Richardson County. Wilderness Park is a heavily forested area of 1,472 acres [596 hectares] in southwestern Lincoln. Wilderness Park's forest ecosystem is a transition zone between red oak-hickory and bur oak-elm-walnut forest formations (Pound and Clements 1900:334), with 40 species of trees (Klein 1998:Appendix C). Salt Creek and several tributaries flow through the park and are subject to periodic flooding.

A juvenile southern flying squirrel was rescued on 9 May 2019 in the Eastridge neighborhood of eastern Lincoln in the vicinity of the Eastridge Elementary School and Taylor Park. NGPC Conservation Officer Dina Barta rescued this animal and photographed it before placing it with the NWRT. Homes in this part of Lincoln were built in the 1960s and early 1970s with large oaks, American sycamore (*Platanus occidentalis*), black willow (*Salix nigra*), and sugar maple (*Acer saccharum*), that were planted when the development was new, and Taylor Park is recognized as a landscape steward site in the Nebraska Statewide Arboretum. On 30 August 2019, NWRT released this flying squirrel and the one removed from the Country Club residence on 2 February 2019 at Indian Cave State Park, an area known to have an established population of southern flying squirrels in southeastern Nebraska.

On 8 April 2020, one of us (SMD) went to the Greater South neighborhood of Lincoln to investigate a report of flying squirrel activity on a utility pole. This area is east of Memorial Park along 33rd to 40th Streets, between South Street and Highway 2, in the general vicinity of Lincoln Southeast High School. The neighborhood is characterized primarily by homes constructed in the 1920s to early 1970s with relatively large yards, mature trees, and landscaping. When SMD arrived at the reported location, he found two young flying squirrels still in their nest that had been removed from a utility pole. He took the two juveniles to Nebraska Wildlife Rehab, Inc., of Omaha. The flying squirrels were identified as one male and one female. The male later died, but the female survived and remained in care with the Nebraska Wildlife Rehab.

On 7 June 2020, Officer Barta found what appeared to be the tail of a flying squirrel in a yard only four blocks west from where the pair was found on the utility pole. The tail was discovered in the Memorial Park area of Lincoln, which runs along S 33rd Street from South Street to Sheridan Boulevard. This area lies just to the east of the Country Club neighborhood. The resident reported what he believed was Eastern Screech Owls (*Megascops asio*) activity the previous evening. A photograph shows about half the length of a tail, which looks to be dorso-ventrally flattened, giving the appearance that hair is coming from the sides of the tail. The color of the tail is a match to the specimens at the USNM contributing to our belief that it is from a flying squirrel.

On 25 August 2020 around 1000 hrs Central Daylight Time, maintenance technician Donald Bouwens was working on the "boot" of a utility pole located off Franklin Street between S 52nd and S 53rd streets in the established neighborhood of Woods Brothers Fairview Acres in southeastern Lincoln, when a flying squirrel emerged and surprised him. He was able to capture a photograph of the flying squirrel while it was in close proximity to him (**Figure 1**). He tapped on the boot to see if any others individuals would exit but no more did. Mr. Bouwens then shared his observation and photograph with the NGPC. He reported to one of us (MJP) that he had never seen anything like it before in Lincoln during his 40 years of working outdoors on utility maintenance.

On 17 October 2020, Richard Rebarber, a homeowner in the Country Club area near S 31st Street and Sheridan Boulevard, reported a southern flying squirrel in his house. He did not photograph the animal but contacted a wildlife removal professional, Habib Rubeiz of After Hours Pest Control who recognized the species. The animal was safely removed from the residence and released unharmed in Lincoln. The homeowner later contacted his colleague, Professor of Biology Sabrina Russo, at the University of Nebraska–Lincoln (UNL) who found his description of the animal consistent with a southern flying squirrel:

> … an extremely small gray squirrel (like those on the East Coast), but with a small, flattened tail and nocturnal eyes. The rodent was grayish (no stripes), and larger than a mouse, but smaller than the common red squirrels in Nebraska. It had a squirrel's posture when I first saw it, as it was perched on a basket handle for a long time. The tail was not like one of a typical squirrel, but rather it was smaller and flatter and it did not stick up. I would describe it as a little furry beaver tail. I don't remember the color of its belly/underside. On 17 October

Figure 1. Photograph of a southern flying squirrel (*Glaucomys volans*) in Lincoln, Nebraska. This photograph was taken on 25 August 2020 by Donald Bouwens, Charter Communications Maintenance Technician, on a utility pole during routine maintenance of power lines.

> 2020 from 1 am to 3 am, it ran in and out of our air returns, up and down stairs, behind furniture, and from room to room in our house. It ran up the curtains repeatedly. Once the exterminator and I saw it launch itself from the top of a curtain rod and glide diagonally across the room. It was not aggressive or threatening, even though it seemed scared. The squirrel was eventually cornered and the exterminator wrapped it in a blanket and took it outside and we watched it run away. It was extremely difficult to catch. Very agile and quick. It appeared very flat as it ran from room to room, that strange little tail behind it.

In late 2020, one of us (SMD) contacted a Lincoln resident who mentioned on Facebook that she sometimes sees a flying squirrel at her residence. Her home was in the Myrtle Heights subdivision in the vicinity of Lincoln East High School and upon request she submitted a picture of the squirrel, indicating the photograph was taken in June 2020. The squirrel was confirmed as a southern flying squirrel and was pictured eating from a bird feeder.

On 24 March 2021, another Lincoln resident contacted NGPC to report a flying squirrel he saw in his backyard. He submitted the following narrative: "It was on a bird feeder with sunflower seeds that hangs from a 50 to 60-year-old oak in my backyard. I was on a deck, which had a line-of-sight view of the feeder that hangs about 15 feet [4.5 m] from the ground. It was about 9 p.m. on 3/20 [20 March 2021]. I got some video and given the size and general descriptions I was pretty certain, although I don't know what other species it could be confused with. We live near 40th and Van Dorn in an area with a good number of really old oaks." The video was obtained by the NGPC and SMD confirmed it to be a flying squirrel.

Another report was made to NGPC's Service Center in Omaha and included pictures of a flying squirrel that was seen in south Lincoln [SW 5th Street] about three weeks prior. SMD requested further details and received the following: "August 19th late afternoon [2021.] The little guy was hiding by the down spout on south side of a building just east of the front door of the west business in that building." This report was in the West "A" Neighborhood and is adjacent to Salt Creek and ~650 m from the north end of Wilderness Park.

On 8 December 2021, UNL Landscape Services Associate Director Jeffrey Culbertson reported four flying squirrels that "flew" out of an old hollow oak tree during tree trimming on the university's East Campus. Larkin Powell, Professor of Conservation Biology, fielded the report and immediately shared the finding with staff of the NGPC, as he recognized it was an unusual occurrence. The landscape crew was able to capture video footage of one of the flying squirrels that gained attention from local news media (Lincoln Journal Star 2022). This spurred efforts to gather additional reports in Lincoln.

The most recent report (12 January 2022) was submitted because a Lincoln resident had seen the media coverage of the flying squirrels found on UNL East Campus. This flying squirrel was found dead on the sidewalk in the Bethany neighborhood near 67th Street and Leighton Avenue. The carcass was recovered by one of us (SMD), confirmed to be a southern flying squirrel, and is now in the collections of USNM (ZM-31914). The external and cranial measurements of this individual were as follows (in mm):

total length 245; length of tail vertebrae 104; length of hind foot 30; length of ear 20; greatest length of skull 36.10; condylobasal length 32.80; zygomatic breadth 21.09; interorbital breadth 8.09; mastoid breadth 18.06; length of maxillary toothrow 7.18. This male flying squirrel weighed 65.68 g at preparation and had testes measuring 12 mm in length and 7 mm in width.

There is evidence to indicate that flying squirrels may be expanding west of the city as well. On 7 September 2020 at Bur Oak Wildlife Management Area in Seward County, Matthew Walker reported witnessing a small gray squirrel with white sides and belly on a cloudy evening close to sunset. He said the squirrel must not have been more than 8 inches [~20 cm] long including the tail. He instantly thought "flying squirrel" but did not immediately realize that it would be outside of its expected geographic range. He heard something hit the ground and then saw the squirrel run into a stand of oak trees where invasive eastern redcedars (*Juniperus virginiana*) and understory woody vegetation had recently been cleared.

With recent occurrences of southern flying squirrel in at least 10 separate neighborhoods of Lincoln, many having good documentation, we believe that there is an established population in the city (**Figure 2**). If this is true, the next questions will be: what is the source of this population? Early photographs of Lincoln in 1868 and 1872 show no visible trees, but only an open flat prairie clearly indicating this is not a population of flying squirrels "original" to this area of Nebraska. We are not aware of any other recent geographic range expansions of the southern flying squirrel elsewhere in Nebraska.

Based on the results of a recent study undertaken in the parks of New York City (Keefe and Giuliano 2004), the current "habitat" of Lincoln can be evaluated to its long-term sustainablity for a population of flying squirrels. They (Keefe and Giuliano 2004:60) found at a landscape scale that the squirrel populations were "highest in forests with lower tree densities and deciduous canopy cover." These areas were believed to offer more space for gliding and better detection of potential predators. They also found that preferred areas had diverse forest types, mast producing trees, and large trees with cavities for nesting and storage of food. Lincoln's 133 city parks and established neighborhoods certainly offer a diversity of forest types and mast producing trees, such as bur oak, red oak, red mulberry, hackberry, black walnut, sugar maple, and Kentucky coffee tree (*Gymnocladus dioicus*). The one conservation challenge may be the preservation of old and dead trees with tree holes because these are quickly removed by property owners and the City of Lincoln because of liability issues.

Documentation of the geographic distribution of *G. volans* in Nebraska is not extensive, with Jones (1964) reporting specimens from four locations and citing earlier authors for mention of these squirrels at eight other places. This information is dated and in need of being revisited. The first mention in the literature of southern flying squirrel from Nebraska was by W. Edgar Taylor (1888), then a professor at Peru State, who described color variation in five specimens. These animals were collected in October–November 1885 and winter 1887 from "near Nebraska City, Nebraska, on the Missouri river" (Taylor 1888:745). The ultimate fate of these specimens is unknown. Merritt Cary ([1905]), in an unpublished manuscript, recorded southern flying squirrels in Omaha, Douglas County, and Bellevue, Sarpy County. Southern flying squirrels were reported in Peru, Nemaha County, by Myron Swenk who stated, "Mr. H. H. Reimund informs me that it is yet found commonly at Peru, and that a pair bred on the State Normal campus there in the summer of 1907, one of them having been captured in June of that year" (Swenk 1908:32).

Three flying squirrels were collected by W.F. Wilkens in the vicinity of Nebraska City on 23 December 1913. These specimens eventually found their way to Hastings Museum in Hastings, Nebraska, where Jones examined them prior to the publication of his mammals of Nebraska in 1964. J. Knox Jones, Jr. (1964:150), recorded the collecting locality as "10 mi SE Nebraska City." Our recent inquiry about these specimens revealed that they were listed as missing in a 1991 inventory of the Hastings Museum collection and the current curatorial staff was unable to find them in a search of their collections. Our survey of online resources of appropriate institutions found no record of the specimens being transferred to another museum.

In 1915, Myron Swenk described a new subspecies of flying squirrel, *Pteromys volans nebrascensis*, based on a specimen from Nebraska City, Otoe County, and measurements given by Taylor (1888). Swenk (1915) considered this population to be larger in overall size and with darker feet and toes. He based this description on a single adult male captured 26 November 1914 by Ellen Ware (holotype: originally no. 286 Collection of State Entomologist, University of Nebraska; now catalogued in the mammal collection of the Museum of Vertebrate Zoology, University of California-Berkeley, MVZ 31865). Subsequent to Swenk's description, Ellen Ware captured

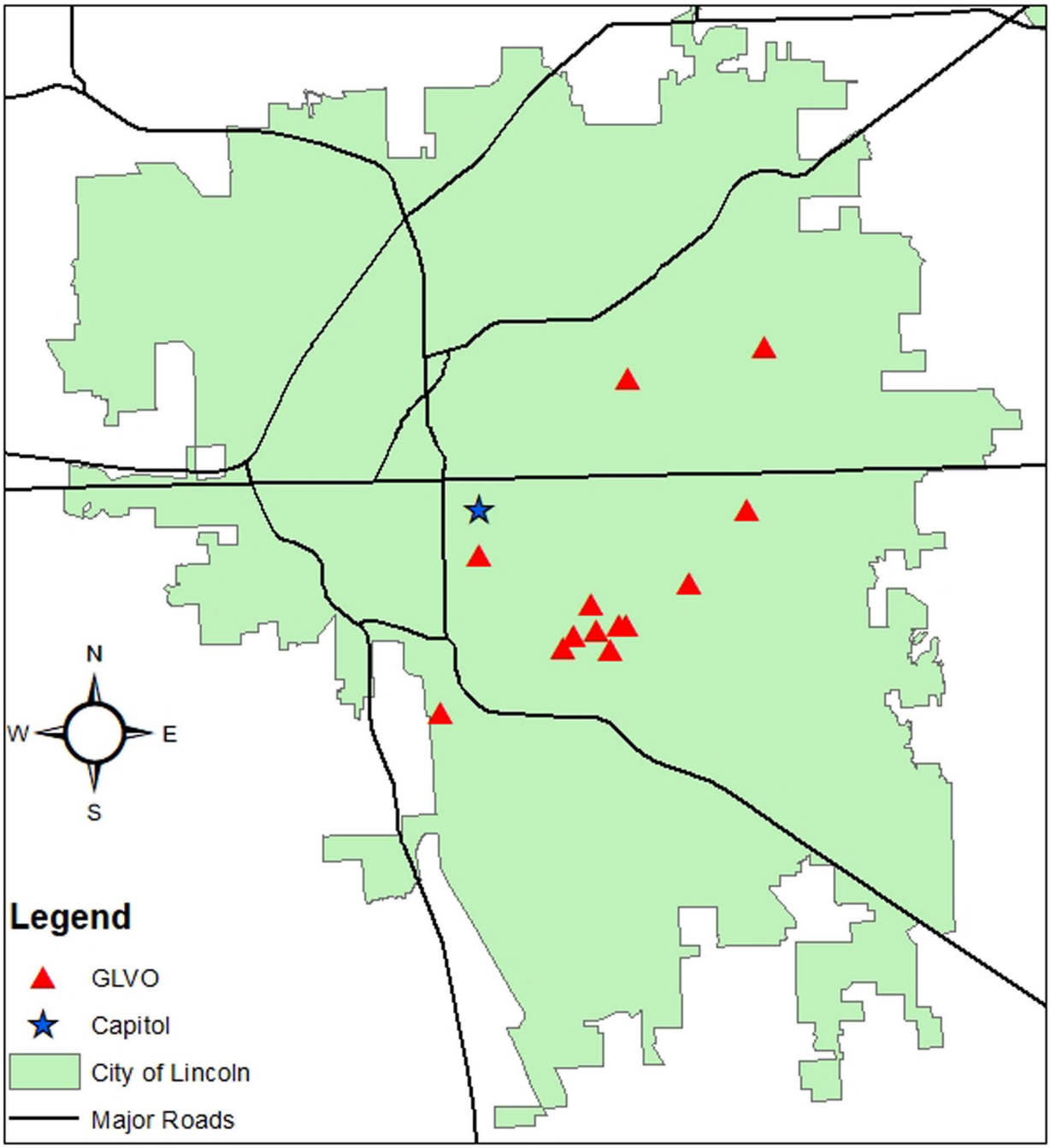

Figure 2. Map of the City of Lincoln, Nebraska. This map indicates the locations (red triangles) where there have been verified sightings, photographs, and specimens of the southern flying squirrels (GLVO) recorded in the city.

an immature male on 17 October 1915 in Nebraska City (original number 306; now UNSM ZM-4295). Just three years later, Howell (1918:23) in his revision of flying squirrels examined the holotype, concluding, "The skull and hind feet measure exactly as in typical examples" of *G. volans volans*.

Ralph Velich (1954) reported the taking in March 1950 of a southern flying squirrel in Fontenelle Forest, which keeps more than 2,000 acres [810 hectares] of riparian forest, prairies, and swamps in preservation along the Missouri River. This nature center is located adjacent to Bellevue, Sarpy County. Common native trees in the forest

include sugar maple, bur oak (*Quercus macrocarpa*), red oak (*Q. rubra*), green ash (*Fraxinus pennsylvanica*), bitternut hickory (*Carya cordiformis*), shagbark hickory (*C. ovata*), plains cottonwood (*Populus deltoides*), and hackberry (*Celtis occidentalis*). Velich (1954:429) stated, "The skull is in the writer's collection of study skin material." The current location of this skull is unknown but may have been sold as part of Ralph W. Velich Estate lots #392 or #393 on 23 January 2009 (Richard Opfer Auctioneering, Inc., Lutherville, MD). Velich (1954) also presented reports of flying squirrels taken near the South Omaha Bridge, Douglas County, just north of Fontenelle Forest. Finally, he recorded that a tree-cutting crew had seen a flying squirrel in the winter of 1953–1954 at Florence, Douglas County ". . .when they were cutting down a large elm tree" (Velich 1954:429). This location would be the farthest north point from which flying squirrels have been reported in Nebraska.

Jones (1964) added a female flying squirrel from 1 mi. [1.6 km] NNW of Peru, Nemaha County, obtained by J. R. Alcorn on 21 April 1958 (University of Kansas Museum, KU 77949). Jones (1964) also had a report from a farmer in 1956 that flying squirrels were still present 4 mi. [6.4 km] E Barada, Richardson County, which is just to the south of Indian Cave State Park. The only other specimen of a southern flying squirrel from Nebraska of which we are aware is a female from Indian Cave State Park, Nemaha County, obtained 25 November 1986 (UNSM ZM-16472). This squirrel was found dead in a nest box by personnel of NGPC. Indian Cave State Park is about 3,400 acres [1375 hectares] of eastern deciduous forest composed of oaks, hickories (*Carya* sp.), and basswood (*Tilia americana*), with some remnants of tallgrass prairies directly adjacent to the Missouri River.

In summary, the existing records of the southern flying squirrel in Nebraska have extended from the north side of Omaha southward in the counties of Douglas, Sarpy, Otoe, Nemaha, and Richardson, all bordering the Missouri River on the east. In this succession of counties, no records are available from Cass County, just south of the Platte River mouth. This is the area of Nebraska that is classified as Eastern Upland Oak Bluff Forest by Rolfsmeier and Steinauer (2010). According to Rolfsmeier and Steinauer (2010:10): "In Nebraska, this system occurs mostly on loess bluffs associated with the Missouri River from eastern Knox County downstream. It also extends westward along the south side of the Platte River to Saunders County and occurs sporadically westward in the Nemaha River drainage of Richardson and eastern Pawnee counties." This eastern deciduous forest includes a variety of trees, with the exact composition depending on the distance and elevation from the Missouri River. Some of the species found in this forest type include American hophornbeam (*Ostrya virginiana*), basswood, black walnut (*Juglans nigra*), black oak (*Quercus velutina*), chinkapin oak (*Q. muhlenbergii*), red oak, hackberry, bitternut hickory, and shagbark hickory. These forests have existed from long before settlement of eastern Nebraska, but years of logging, fire suppression, and other disturbances have tended to replace the native forests with more homogenous secondary growth forests. The factors that limit the geographic range of southern flying squirrels north of Omaha are unclear at this point, but with this forest type along the south side of the Platte River, extending into Saunders County, would provide an appropriate corridor for southern flying squirrel to reach the vicinity of modern-day Mahoney State Park and the mouth of Salt Creek.

For a natural dispersal of southern flying squirrels to Lincoln from the Platte River the logical route would be along Salt Creek, although the distance is approximately 30 straight-line miles [48 km] and certainly longer along the winding route of the creek and no flying squirrels have been reported from this area. The next issue that needs to be addressed is whether the habitat along Salt Creek is suitable as a dispersal corridor for southern flying squirrel? Rolfsmeier and Steinauer (2010) considered this riparian forest along the creek to be Eastern Dry-Mesic Bur Oak Forest and Woodland, with the dominate trees being hackberry and bur oak along with scattered honey locust (*Gleditsia triacanthos*), black walnut, plains cottonwood, elms (*Ulmus* sp.), bitternut hickory, red mulberry (*Morus rubra*), Ohio buckeye (*Aesculus glabra*), and American sycamore.

Southern flying squirrels do not disperse on the ground over any significant distance so a corridor of appropriate trees is necessary. The appropriate trees are oaks, hickories, and other mast producing trees, which provide the necessary food for immediate consumption and storage for winter months. Generally, these squirrels require mature stands of forest, containing tall older or dead trees with holes usually initiated by woodpecker or similar birds that provide nesting sites and places to store food for winter (Muul 1968, Taulman and Smith 2004, Zweep et al. 2018). These requirements may be minimally met by maturing riparian forests along the lower Platte River and Salt Creek. One hundred and fifty years of fire suppression in eastern Nebraska may have

allowed forests to develop to this point, but encroachment of agricultural fields are limiting the area of the riparian forests. Elsewhere on the Great Plains in Kansas (Kunz et al. 1980) and Oklahoma (Stangl et al. 1992, Braun and Revelez 2005), the southern flying squirrel has been documented moving westward in riparian habitat along rivers. In the Lower Peninsula of Michigan, before 1981 southern flying squirrels occupied the southern half of the peninsula, but now they occur throughout the peninsula (Myers et al. 2009:1442). In the Upper Peninsula of Michigan, southern flying squirrels appeared in the south in the late 1930s and it was "… suggested that these populations might have been founded by escaped pets …" but this was discounted when population moved north and east appearing in wilderness areas. These geographic range expansions in Michigan were attributed to climate change with rising temperatures (Myers et al. 2009). These earlier studies indicate *Glaucomys volans* is capable of increasing its geographic range in situations that are similar to ours.

However, at this point, we are not able to pinpoint the origin of the southern flying squirrels population in Lincoln, Nebraska, because of at least two other potential explanations. First, we are well aware that southern flying squirrels are regularly available in the online pet trade, both legal and illegal (Knowles 2020). Indeed, these squirrels may represent escaped or released former pets. If they are the result of releases, then this likely has occurred more than one time in Lincoln. The other alternative could be that the Lincoln population is the result of an accidental translocation of individuals, such as through the moving of timber or fire wood. Population genetics studies may hold some potential for resolving this problem, but recent analyses have not found separate lineages within this species (Arbogast 1999, 2007, Kerhoulas and Arbogast 2010).

These novel detections of southern flying squirrels are noteworthy, and we recommend additional efforts to document the species in the state. More records and data on this species will be helpful to wildlife professionals as they will be tasked with management decisions for this growing urban population.

Acknowledgements We are particularly grateful to the citizen reporters who shared their observations, photographs, and videos of southern flying squirrels in and near Lincoln, Nebraska, including an anonymous homeowner in the Country Club neighborhood; Sheila Wilson-Carroll; Matthew Walker; NGPC Conservation Officer Dina Barta; Charter Communications maintenance technician Donald Bouwens; Richard Rebarber; Sabrina Russo; Jeffrey Culbertson; Larry Isley; Jana Langhorst; Lorri Grueber; Robert Tewes, Lincoln Parks and Recreation Forestry Department; and Larkin Powell. We thank Nebraska Wildlife Rescue Team, Inc., and Nebraska Wildlife Rehab, Inc., of Omaha for their helpful involvement. We appreciate the time and efforts of Teresa Kreutzer-Hodson, Curator of Collections/Program Director, Hastings Museum, in checking the museum's collections and records for information on Nebraska flying squirrels and to Robert M. Timm, Curator Emeritus, Natural History Museum and Biodiversity Institute, University of Kansas, for information on a Nebraska flying squirrel held in the collection. We thank Patricia W. Freeman, Curator Emeritus, University of Nebraska State Museum for investigating the initial report of a flying squirrel and confirming the record. Ted Genoways did the final preparation of the photograph for Figure 1.

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