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DISTRIBUTION OF THE PLAINS POCKET GOPHER (*GEOMYS BURSARIUS*) IN THE GRASSLAND PHYSIOGRAPHIC REGIONS OF INDIANA

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ABSTRACT. We conducted surveys for plains pocket gophers (*Geomys bursarius*) in nine counties in central and northern Indiana. The estimated mean (± 1 SD) population from road surveys was 512 ± 440 individuals which is lower than previous surveys. Gophers were not found in Warren and Tippecanoe counties where they were historically present and showed a decline in Benton and northern Jasper counties. The decline in northern Jasper County may have been in part due to the timing and intensity of our survey work. Northern Newton County shows mounding activity presumably indicating healthy populations. More than a dozen clusters of mounds were observed along the eastern edge of White County in an area where mounding activity was not previously detected. Finally, we analyzed the spatial pattern of gopher mounds detected during this and three previous surveys in Indiana to delineate eight putative Indiana subpopulations. The geographic extent of these subpopulations incorporates 404 km of roads within suitable habitat.

Keywords: Density, distribution, *Geomys bursarius*, plains pocket gopher, program DISTANCE

The plains pocket gophers (*Geomys bursarius*) is a species of special concern in Indiana due to a limited distribution in grassland physiographic regions of northwest Indiana (Fig. 1; Heaney & Timm 1983; Thorne 1989). This species was likely distributed throughout northwest Indiana prior to 1900 (Evermann & Butler 1894). Three surveys conducted since 1947 have shown declining populations. Conaway (1947) conducted a limited survey showing discontinuous and scattered Indiana populations within the range of pre-settlement populations. The second, and more thorough, survey found gophers in several northwestern Indiana counties with the majority of populations located in Jasper and Newton counties (Tuszynski 1971). The most recent survey identified population distribution as declining relative to previous surveys (Thorne 1989). We report results of a survey conducted in the summer of 2008 in the grassland physiographic regions of northwest Indiana in addition to those sites where gophers were previously identified. Our objectives were (1) to determine the current distribution of gophers in Indiana using surveys of roadside and railroad right-of-ways and line-transects on selected public lands with suitable habitat; (2) to determine burrowing activity using the sign-count inventory method (Reid et al. 1966); and (3) to combine data on observed mound locations from all gophers surveys within Indiana (Conaway 1947; Tuszynski 1971; Thorne 1989) to define putative subpopulations based upon geographic proximity of mounds.

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METHODS

Study area.—We searched portions of nine Indiana counties within the Iroquois Till Plains region of northwestern Indiana (Gray 2000; Benton, Carroll, Cass, Jasper, Newton, Pulaski, Tippecanoe, Warren and White counties; Fig. 1) for gopher mounding activity from May–August 2008. The grassland physiographic regions of Indiana are the only portions of the state where gophers have been located (Conaway 1947; Tuszynski 1971; Thorne 1989). Within this region we searched areas occurring within potentially suitable habitat (cover classes of 21 {open}, 31 {barren}, 52 {shrub}, 71 {grassland/herbaceous}, or 81 {pasture/hay}) from USGS Indiana landcover data (USGS 2002). These designations corresponded to vegetative conditions in which gophers were

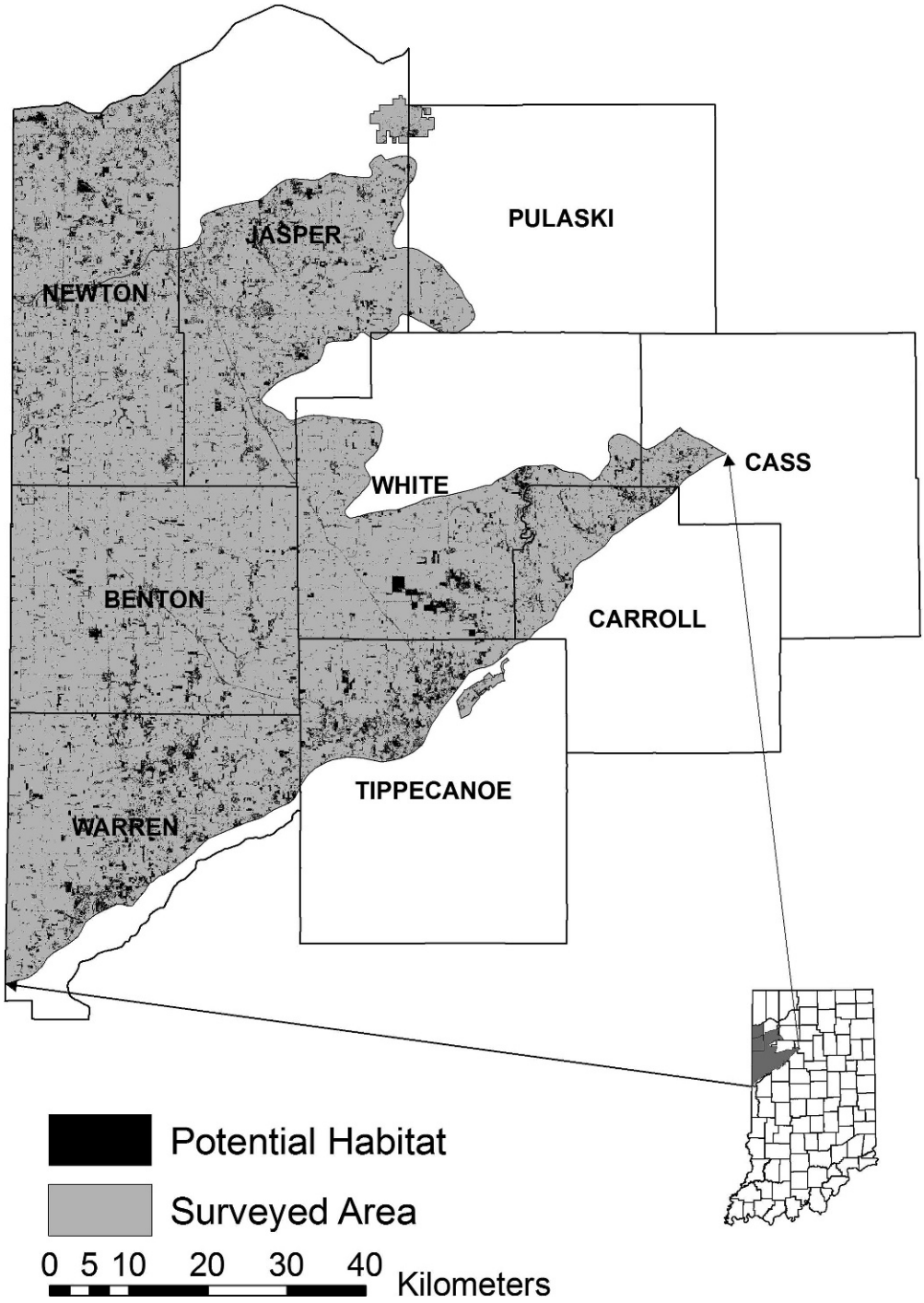

Figure 1.—Location of Iroquois Till Plains region of northwestern Indiana (inset) is the shaded area. The potential plains pocket gopher habitat is indicated by dark shading within the Iroquois Till Plains region.

documented to occur during the 1988 survey (Thorne 1989).

Road survey.—During May–June 2008 we surveyed roadsides located within suitable cover-types in the grassland physiographic region of northwestern Indiana (Fig. 1) for signs of above-ground activity indicated by mounding (Andersen 1988; Jones et al. 1983, 1985). Mounds are visible from a vehicle and have a unique shape and texture (Thorne 1989). Fresh mounds can be distinguished by their characteristic triangular, or deltaic, shape with a round patch of soil located at the apex (Macdonald 2006). Examination of the USGS cover types (USGS 2002) within Iroquois Till Plain physiographic province indicated approximately 1341 km of targeted survey roads within the Iroquios till plain (see Study area above) indicating suitable habitat. We searched the right of way and surrounding habitat for mounds on all road segments within our study area that were not on primary high speed roads (greater than 55 mph). Searches were conducted by a passenger while the driver maintained a speed of 30–40 km/hr. Once mounds were sighted a Trimble® GeoXT™ handheld GPS unit from the GeoExplorer® 2004 series (©Trimble Navigation Limited) was used to georeference the position of the vehicle with a precision less than one meter. A laser range finder (Bushnell Yardage Pro Sport 450, in yards) or a measuring tape (in feet and inches) was used to measure distance from the center of the road to the center of the mounds. We recorded date, distance, name of the road, land use type, and took photos of mounds to confirm any questionable mounding activity (i.e., mounds made by gophers, moles, woodchucks, or coyotes). Mounds without the characteristic shape (Macdonald 2006) were omitted.

Transect survey.—We implemented an additional 30 walking transects within polygons of suitable habitat on public lands. Within these public lands we selected the 30 largest polygons (ranging from 0.7–0.9 km^2) of suitable habitat from the USGS landcover which indicated these public lands contained polygons of potentially suitable habitat ranging in size from 0.2 ± 0.1 km^2. Within each of the 30 selected polygons transects were located by intersecting the centroid of the polygon with a random point along its perimeter. The total length of the 30 transects was 16 km (0.5 ± 0.2 km). We walked each transect once in July (after road survey was completed). The number of mounds observed was recorded, and the perpendicular distance from the foot transects to each mound was recorded in meters.

Data analyses.—*Distance sampling analysis:* Data on mound occurrence from both roadside surveys and walking transects were geo-referenced. We used the program DISTANCE 5.0 (Burnham et al. 1980; Buckland et al. 2000; Thomas et al. 2002) to estimate mound density (accounting for decreasing detection probability as a function of distance from observer) for roadside and foot transect surveys. DISTANCE estimated density based on the detection probability and the effective strip width. The effective strip width is the distance from the transect at which the number of animals detected beyond this point exactly equals the number of animals missed within this distance (Buckland et al. 2000). We fit data with different combinations of four types of key functions and three types of series expansion with no constraints on monotonocity. We first used the complete data set of all mounds ($n = 544$) for analysis. None of the models had a good fit to the distribution as indicated by a high P-value ($P < 0.00001$; Zar 2009). We pooled the data by grouping observations on the same transect as a cluster ($n = 135$). We also truncated our data set by deleting all observations closer than three yards ($n = 3$) as well as the 10% of observations furthest from the transect ($n = 14$; suggested by Swann et al. 2004). The pooled data were analyzed using ''cluster'' option in DISTANCE and gained better fits ($P = 0.79$). After selecting the best combination of key functions and series expansions, we compared densities of clusters and densities of mounds estimated by different types of size-biased regression methods provided by DISTANCE.

Subpopulation definition: First, we estimated gopher maximum dispersal distance as the square root of home range size multiplied by 40 (Bowman et al. 2002). We used the upper bound of spring and summer average home range size in Minnesota (66 ± 23 m^2; Zinnel 1992) and found a maximum dispersal distance of 378 m.

Next, we combined all known mound locations from all survey periods into a single coverage (Fig. 2). Using this coverage we calculated the distance (299 ± 539 m) to the nearest occurrence of another mound in any

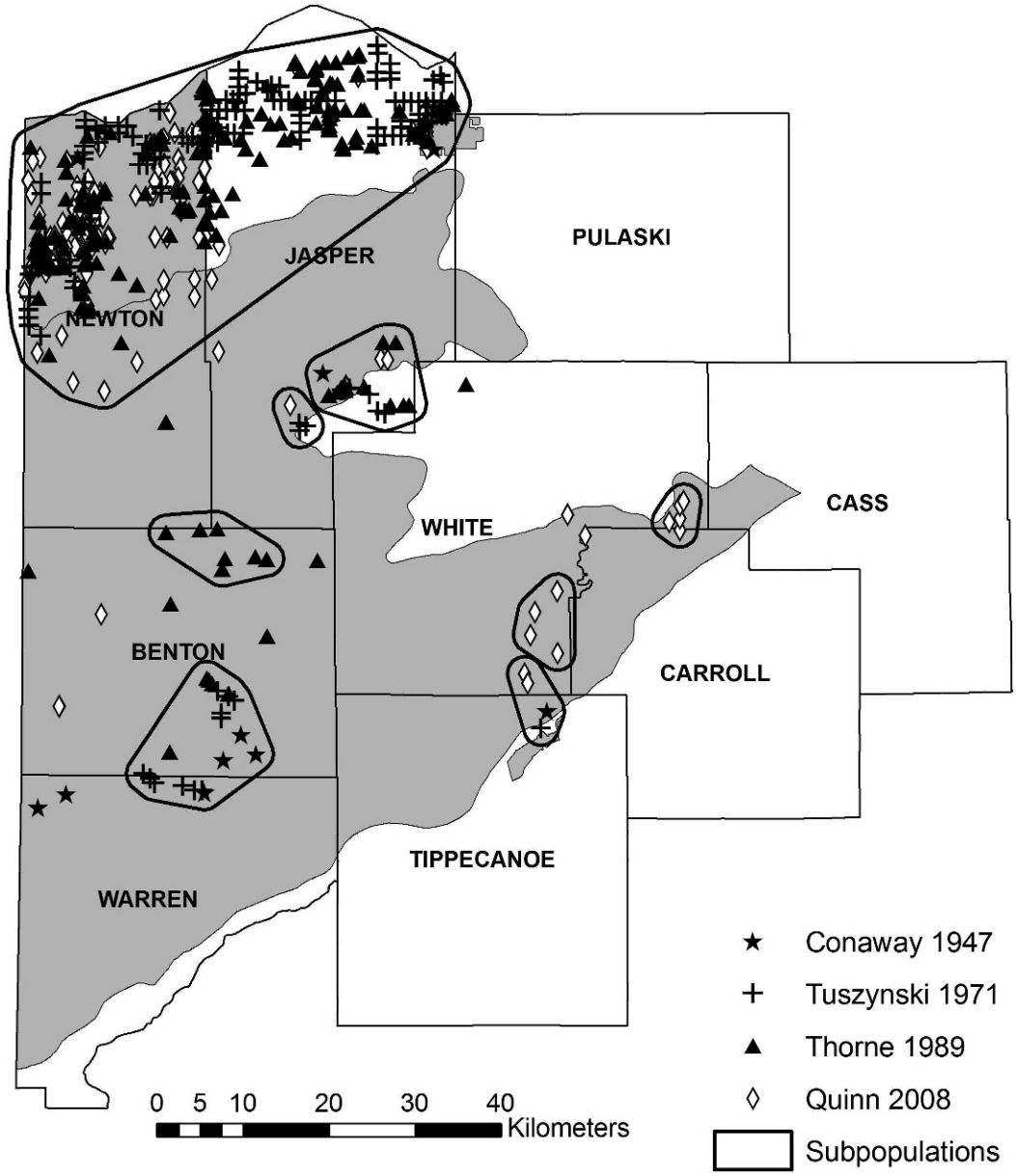

Figure 2.—Location of all plains pocket gopher mounds observed within the Iroquois Till Plains region and northern Newton County while conducting road, transect, and historic location surveys during the summer of 2008.

other survey for each observed mound. We calculated the mean ± one standard deviation (944 ± 655 m) distance to the nearest mound for those mounds further than estimated dispersal distance from their nearest neighbor. We used the upper 95% confidence interval (2254 m) of this latter distribution to create a buffer around each mound location from all surveys. Where these buffers overlapped (indicating a neighboring mound nearer than 2254 m) and included at least three distinct mound observations we classified those mounds as belonging to a putative subpopulation of gophers in Indiana. Finally, we took all of the mound locations defining putative subpopulations and generated the minimum

convex polygon that encompassed all of those points. We buffered that polygon by 2 km (approximate estimated distances between geographically distinct clusters of mounds) to define our putative subpopulations of gophers in Indiana (Fig. 2).

RESULTS

Road and transect survey.—We drove a total of 2345 km of roads during 30 working days of roadside surveys. Considering the effective distance from the road at which we could detect mounds we searched a total area of 4988 km^2. In addition to driving roads throughout the Iroquois Till Plain we included Willow Slough Fish and Wildlife Area, Jasper-Pulaski Fish and Wildlife Area, Kankakee Sands, Prophetstown State Park, and the northern half of Newton County. We searched a total of 512 km^2 of potential habitat for gophers (10% of the surveyed area). Within this area we located 611 mounds, 544 mounds during road survey, and 67 from the walking transect survey.

The analysis from DISTANCE showed the best combinations of key function and series expansion for the roadside surveys were uniform and cosine. The goodness of fit test was 0.79 when the cluster estimation method was regressing *ln*(cluster size) against perpendicular distance of mounds (model fit = 0.71). The estimated density of mound clusters was 26 ± 21 clusters per km^2. The effective strip width of detection was 20 inches (0.5 m). The average and estimated cluster sizes were four mounds per cluster. Combining these values provides an estimated density of 94 ± 79 mounds per km^2 in our survey area.

Sparks and Andersen (1988) measured the average mound production rates in Willow Slough Fish and Wildlife Area. From their calculations we used a mean rate of 19 mounds observed per gopher during June (four mounds/day) to convert our estimate of density of mound clusters to density of individual gophers. Since mound persistence was primarily a function of mowing we estimated mounds would be detectable for 21 days following their creation (three week mowing cycle; pers. comm. Kanakee Sands staff). Thus, to estimate the number of gophers present we divided the density of mounds (D) by the number mounds produced in 21 days (92 mounds). We converted the mound density from one mound in 21 days to 0.01 ± 0.01 individual/hectare. We multiplied this density estimate by the area of potential habitat and estimated 512 ± 440 gophers in the surveyed area.

We surveyed 31 walking transects rather than the intended 30 because one transect in Jasper-Pulaski Fish and Wildlife Areas was divided by a ditch we could not cross. We located 67 mounds and removed the top 15% of the data. The detection functions did not differ significantly. The Δ Akaike's Information Criterion (AIC) values with different combinations of series expansion ranged from 0 to 4.11. The estimated mound density provided by the best model (Hazard-rate hermite polynomial) was 2052 ± 889 mounds/km^2. This mound density acquired from walking transect survey converts to 0.2 ± 0.1 individuals/hectare.

Historic location survey.—Among the 193 historic locations (Thorne 1989) 36 of the sites contained mounds, 117 had no mounding activity, and 40 sites could not be located due to errors in the reported projections. In northern Jasper County only 6 of the 68 historic sites we surveyed contained mounds. By contrast, 30 of 70 historic locations surveyed in Newton County still contained mounds.

Subpopulation definition.—Our analysis delineated eight subpopulations (Fig. 2) ranging in size from 28 to 1443 km^2 (mean = 252 ± 484 km^2). The total area of land types suitable for gophers within these subpopulations was 160 km^2. This is smaller than the 512 km^2 of potentially suitable habitat across the total surveyed area. Within these subpopulations there was a total of 404 km of roadside habitat passing through suitable habitat while the larger study area encompassed 1342 km of roads through similar habitat.

DISCUSSION

Consistent with results of previous surveys (Tuszynski 1971; Thorne 1989) our survey documents a decreasing geographic distribution of gophers in Indiana which presumably corresponds to a decline in the overall abundance within Indiana. Our survey shows the historic populations in Tippecanoe and Warren counties are absent. Furthermore, the two locations in Benton County mark a dramatic decrease from the 15 locations where Thorne (1989) observed gophers. However, it should be noted that Tuszynski (1971) observed mounds at five locations in Benton County. Thus, it is unclear if some of the apparent fluctuations in

populations in Indiana are attributable to changes in gopher distribution or variation in probability of detection across the various surveys. This uncertainty is reinforced by our observation of numerous clusters of mounds in eastern White County near the Carroll County line. The occurrence of gophers in this vicinity was not noted by either Tuszynski (1971) or Thorne (1989). Given the limited vagility and dispersal range of this fossorial species it is unlikely that these new gopher populations resulted from dispersal. Thus, the parsimonious explanation is that considerable variation in detection probability exists when using the presence of mounding activity to assess the occurrence of gophers. A consequence of this variation is that apparent species absences in mound-based surveys may reflect a failure to detect the presence of mounding activity at the time of sampling rather than the true absence of the species from a locality.

Our results suggest the status of gophers in northern Jasper County may be an area of considerable conservation concern for the Indiana population of this species. Only 9% (6/68) of the historic locations we revisited in northern Jasper County contained mounds while 43% (30/70) of the historic locations we revisited in northern Newton County contained mounds. Some of this difference is undoubtedly attributable to methodological differences. The historic sites in northern Jasper County were the last field surveys we conducted in July, and mounding activity is known to decrease as the summer progresses. Detection probabilities also decline with taller vegetation later in the summer. Based on this variation we expect some of the apparent declines in northern Jasper County may not reflect as dramatic a decline in gopher status. Furthermore, the historic locations in northern Jasper and Newton counties were north of the Iroquois Till Plain ecotype where we implemented our comprehensive roadside surveys. Nonetheless, the trend that only six of 68 historic locations in northern Jasper County continued to contain mounds is of concern. The two remaining historic mound locations occurred in roadside habitat. Based upon the cover types where we observed mounds throughout our entire survey, it is clear that roadside habitats are critical for gophers throughout Indiana.

Our surveys suggest northern Newton County still contains large populations. The areas around Kankakee Sands and Willow Slough are areas with the highest species densities and are critical for the gopher status in Indiana. The combination of this observation and the apparent decline of populations in northern Jasper County suggest a need to consider the availability of routes for dispersal and recolonization between the northern Newton County populations and the more western portions of the northern Jasper County populations where gophers once occurred.

Variation in detection probability has been alluded to as a mechanism possibly underlying several patterns we observed. When interpreting our results it is important to recall that we sampled using a distance-based technique to estimate densities. Distance-based estimates incorporate decaying probability of detection as a function of the distance between the observer and the mound in estimating densities. Thus, our surveys should have been more explicit about the extent of the area surveyed relative to the historic work; and, in turn, our estimated densities are much lower than those developed by Thorne (1989) and Tuszynski (1971). Another of our results that merits this consideration is the higher density estimates obtained from our foot transect data relative to the roadside surveys. It is intuitive that an observer walking on the ground will conduct a much more thorough inventory than one while driving at 30 km per hour. Our use of the distance-based analysis criteria elucidates the implications of the increased sampling efficiency for the resulting density estimates. Thus, future surveys might consider expanded use of sampling from walking transects in selected strata of the sampling area to decrease bias in the estimates. Previous research has demonstrated the use of distance-based sampling techniques to estimate the density of many biological phenomena (Thomas et al. 2002), and this approach holds great promise for estimating mound densities of numerous species of gophers.

In concurrence with surveys conducted roughly 20 (Thorne 1989) and 40 years ago (Tuszynski 1971), our results suggest that the geographic distribution and presumably abundance is declining. However, these conclusions are based upon surveys of mounds; and our results also suggest that inference regarding abundance based upon mound surveys may be problematic. Our use of distance-based analyses undoubtedly provided more realistic treat-

ment of mound detection probability and thus effective area surveyed and ultimately mound density. However, the use of the mound density as a surrogate for gopher density can be problematic for a number of reasons (Reid et al. 1966; Bandoli 1987). The frequency of mounding activity may have more to do with local soil and vegetative conditions than with actual density so the use of this sampling technique for anything beyond presence and absence data is likely to be challenging. Thus, future studies actual densities from trapping surveys should be paired with concurrent mound surveys to discern the feasibility of mound-based indices for insights into the status of gophers in Indiana. Such live trapping of gophers could provide genetic samples which could be used to estimate the connectivity of remnant populations. These connectivity values could provide insights into the likelihood that human land uses (e.g., agricultural fields or major highways) are serving as barriers to the movements of gophers within Indiana. Finally, our work suggests that roadside strips of vegetation continue to be a critical source of remnant habitat for this species in Indiana. We do not believe that any particular vegetative type (e.g., prairie grass restoration) was critical. Instead the narrow strips of remnant grasslands of any type simply represent the majority of the remaining habitat and thus are invaluable for that reason.

Future roadside mound surveys in Indiana should be conducted within boundaries of the putative subpopulations defined in our results rather than across the entire Iroquois Till Plains eco-region. Such refinements in search effort will dramatically reduce the effort necessary to conduct roadside surveys from 1342 km of road driven to 404 km driven. Such reduction in total search effort will make it feasible to conduct multiple searches during annual surveys, greatly reducing the chance of failing to detect gophers where they are present. Furthermore, such intensive sequences of surveys within these focal areas where they have historically been found in Indiana can be used to construct a history of when each subpopulation occurred which could be used to develop estimates of the probability or persistence of Indiana's population. Finally, these putative subpopulations, which were determined based upon the spatial pattern of observed mounds across three surveys and 38 years, can also serve as hypothetically distinct populations and those hypotheses should be assessed using genetics estimates of the relatedness of individuals from these populations.

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