Online ISSN: 2588-3526

Journal of Wildlife and Biodiversity

Volume 6 (3): 72-86 (2022) (http://www.wildlife-biodiversity.com/)

Research Article

On the Road Again: Touring iNaturalist for roadkill observations as a new tool for ecologists

Shem Unger

Department of Biology, Wingate University, Bridges Science Building, Wingate, North Carolina 28174, USA, Email: s.unger@wingate.edu

Received: 29 January 2022 / Revised: 17 February 2022 / Accepted: 28 February 2022/ Published online: 25 April 2022. Ministry of Sciences, Research, and Technology, Arak University, Iran.
How to cite: Shem, U.(2022). On the Road Again: Touring iNaturalist for roadkill observations as a new tool for ecologists, 6(3), 72-86.
DOI: https://doi.org/10.22120/jwb.2022.300322.1479

Abstract

As human populations continue to increase and utilize highways, the potential negative impact of roadways on wildlife mortality (roadkill), is expected to increase accordingly. Documenting vertebrates killed on roadways can be time consumptive for local wildlife managers researching population trends of predominantly mammals and reptiles encountered. New citizen science observations taken on cell phones using the application iNaturalist provide a potentially powerful new tool to inform roadkill occurrence and its impact across taxonomic groups and geographic areas. To this end, I downloaded and surveyed data observations on iNaturalist for “road kill” and “dead on road” or “DOR”, within the United States, resulting in 17,926 total observations following database quality control, spanning 1973 to February of 2022. Overall of the 710 distinct species identified as roadkill, reptiles were the most frequently reported (12,127 observations), with eight of the top ten reported observations of roadkill being snakes. Mammals represented 3,094 observations followed by birds and amphibians, with 1,363 and 1,342 observations, respectively. Interestingly, I noted some differences for a season of roadkill observations with summer having the highest reports of roadkill for both reptiles and amphibians, with more reports of mammals as roadkill in fall. This study contributes to our body of knowledge on roadkill ecology and can provide wildlife diversity biologists with a new avenue using citizen science data as this smartphone application becomes increasingly utilized for research on biodiversity.

Keywords: roadkill, vertebrate biology, scavenging ecology, iNaturalist, biodiversity, road mortality, conservation, citizen science, road ecology

Introduction

As a component of urban and road ecology, monitoring the species impacted by wildlife-vehicle collisions and ensuing species distribution and overall population trends across taxonomic groups has received increased attention (Schwartz et al., 2020). The negative impact of heavily used roadways on wildlife is well documented, with roads causing direct mortality (roadkill), on a variety of predominantly vertebrate taxa, including mammals (Kreling et al., 2019), birds (Erickson et al., 2005; Grilo et al., 2020), amphibians (Shin et al., 2020), reptiles (Bhandarkar & Paliwal, 2021). Some studies have found with increases in road traffic, there are ensuing increases in roadkill mortalities (Eloff & Van Niekek, 2008), indicating roadkill as a result of traffic is a threat to the biodiversity of many ecosystems (D'Amico et al., 2015). Many of these roadkill provide a food source for scavengers (Schwartz et al., 2018), but may become increasingly detrimental to wildlife diversity over time and as the human population continues to grow, and subsequent use of roads increases. While these studies on vertebrates highlight the large effect of anthropogenic roads on millions of vertebrates annually and are vital components to monitoring trends, they rely on a large number of volunteers for reporting roadkill (Yue et al., 2019), managing volunteers for projects, and maintaining of country-specific databases (Chyn et al., 2019). However, at present, there are more recent technological methods at wildlife biologists' disposal to study the impact of roads on reptiles with the increasing use of citizen scientists with cell phones.

Citizen science has emerged as a powerful tool for conservation biologists and wildlife managers to incorporate in monitoring the presence and absence and even population trends of species. However, much of the data generated from citizen science projects is either underutilized or not used for scientific research (Theobald et al., 2015). One application, iNaturalist (www.inaturalist.org), has increased in its use by citizen scientists, with observations used to identify species (Nugent 2018), and detect invasive species (Mo & Mo, 2022), and monitor trends in rare threatened species (Wilson et al., 2020). Subsequently, this application has also been used for bio blitz surveys involving the general public since 2008 (Rokop et al., 2022) and to encourage participation by citizen scientists in various avenues of research (Aristeidou et al., 2021). Recent studies have found volunteer roadkill and wildlife observations to be reliable sources of data (Waetjen & Shilling, 2017), yet few studies have assessed the potential of this increasingly popular application to determine trends of roadkill observations both within taxonomic groups or across larger geographic areas. While not a replacement for more traditional wildlife-vehicle collision studies where roads are surveyed to identify roadkill aggregations hotspots (Santos et al., 2017), the use of citizen science databases provides an additional method for monitoring trends in roadkill occurrence. Therefore, increasing our knowledge base using readily available public datasets may add to our ability to monitor and manage wildlife associated with road traffic collisions.

Herein, I report on the overall taxonomic trends for roadkill in terrestrial vertebrates across the United States, where data observations are readily available online. In addition, I examine the relative seasonal timing of these roadkill observations and relative frequency across geographic regions (states). This data provides an avenue for renewed research utilizing citizen science observations to study roadkill ecology, scavenging ecology, and the impact of roads on native animals across the United States and abroad.

Materials and methods

On March 1, 2022, I downloaded observations from iNaturalist (www.inaturalist.org), under the Explore tab, using the geographic filter for "USA" and additional filter of "bird", "amphibian" "reptile" and "mammal", using only verifiable observations. Next, I included a search with the description/tag of "road kill" within each observation. I then downloaded cvs file, saved as an excel file. To include common observations of dead on road or DOR, I repeated this procedure using both "DOR" and "dead on-road" description/tag, resulting in a total of 20,584 observations. To ensure I did not include repeat observations, I combined downloaded excels into one document and found any potential repeat observations using the data "remove duplicates" function. I further quality controlled the dataset by manually reading each of the description data to remove any non-roadkill-related observations (i.e. observations of vultures reported consuming dead organisms, or "Crested Caracara eating dead snake" in the road, or "hawk eating roadkill rabbit" etc.). I removed observations for which there was no clear geographic information, and for observations not successfully identified organisms observed down to species. I further removed any observations that were not "research-grade" or identification confirmed by at least two naturalists.

I performed a word count for description included in observation and reported on overall trends in data including date of observation range, state observed in, etc. I also qualitatively assessed the description of roadkill observations to investigate whether any natural history information was included along with observations. Moreover, I include information on taxonomic groupings, including total number of animal Phyla, Class, Order, Family, Genus, and Species. The number of unique species and observations per larger taxonomic group were data sorted in excel. The database was also manually checked to ensure that each observation was treated as a unique observation or unique entry in the dataset (i.e. not more than one individual per observation).

To analyze differences across the four major taxa (Classes: Reptilia, Mammalia, Aves, and Amphibia), I ran a Chi-square analysis. To analyze seasonal trends, I compared observations across 4 seasons using meteorological start dates for each season and each season lasting 3 months, with winter Dec 1 start date, spring March 1, summer June 1, and fall September 1, by running a Chi-square analysis for major vertebrate taxa categories (mammals, reptiles, birds, and amphibians). I also ran a Spearman correlation analysis on the number of observations and total population for each state (obtained 2022, U.S Census Bureau; www.census.gov), as well as the number of observations within each state and total lane miles for each state (obtained 2022, U.S. Department of Transportation Federal Highway Administration; highways.dot.gov). Lastly, I examined the number of roadkill observations by year to further characterize roadkill observations annually in iNaturalist, or if observations by citizen scientists utilizing the application increased over time.

Results

The completed dataset included 17,926 observations, of which 12,127 were reptiles, 3,094 were mammals, 1,363 were birds, and 1,342 were amphibians. Observations represented 710 unique species in total from across 122 taxonomic families, including 236 distinct reptile species, 131 distinct mammal species, 258 distinct bird species, and 85 distinct amphibian species. Eight of the top ten most observed roadkill species were snakes (Table A1). Observations for taxa of roadkill (DOR), were significantly different, X^2 (1, N = 17,926) = 7,131.3, $p < 0.001$. Moreover, there was a significant effect of season for observation of roadkill taxa, X^2 (9, N = 17,926) = 1,891.5, $p < 0.001$. The month with the highest number of roadkill observations on iNaturalist was May, with the highest total roadkill seasonal observations during summer (6,115 observations), followed by Spring (5,899 observations). Across taxa, the most observed roadkills were during summer for reptiles (4,492), fall for mammals (1,025), spring for birds (397), and summer for amphibians (560), (Fig. 1). There was a significant association between the number of roadkills observed across each of the 50 states and lane miles within that state, Spearman r = 0.336, p = 0.0171, as well as a significant association between the number of state-specific roadkills and the overall population of that state, Spearman r = 0.521, $p < 0.001$. Therefore, there was a stronger correlation between roadkill observations and overall state population than between roadkill observation and lane miles. The two most populated states, California and Texas, accounted for 57.3% of total roadkill observations (8,588 observations for Texas, 1,680 observations for California), followed by the states of Florida, Alabama, Arizona, Colorado, North Carolina, New Mexico New York, and Virginia, in that order for observations of roadkill.

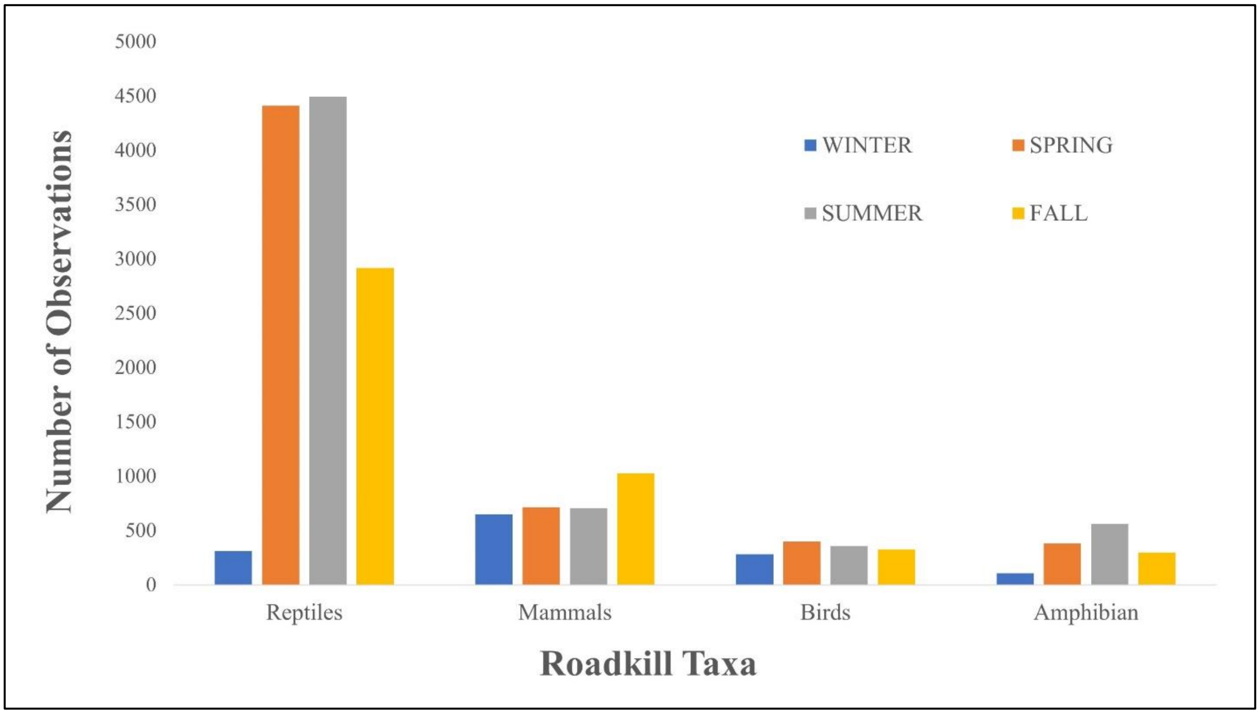

Figure 1. The number of observations of roadkill taxa by season in iNaturalist used in this study.

The Earliest observation includes an image observed in 1973 of *Crotalus oreganus*, or Pacific Rattlesnake (but uploaded more recently into iNaturalist), and February 26, 2022 (a few days before data retrieval/access) of a dead Coyote, *Canis latrans*. The majority of roadkill observations occurred between 2015 to 2022, 90.8%, and indicated an increase each subsequent year since 2012, except for 2022, as the data for this study was obtained on March 1, 2022. The median word count for the description of observation was three, with a mean word count of 6.94, a max word count of 329 words and a minimum of one. Qualitative analysis of the description of roadkill uploaded to iNaturalist by citizen scientists was variable, with many simply stating “DOR”. However several provided additional information on roadkill with details on species age or observations of natural history (Table 1).

The most frequently observed roadkill on iNaturalist (Table A1) was the Gopher Snake, *Pituophis catenifer* (1,129 observations), followed by the Western Diamondback Rattlesnake, *Crotalus atrox* (717 observations), and by the Western Ribbon Snake, *Thamnophis proximus* (628 observations). The most frequent roadkill mammal included the common raccoon, *Procyon lotor* (323 observations), followed by the Virginia Opossum, *Didelphis virginiana* (265 observations), and the Striped Skunk, *Mephitis mephitis* (299 observations). Birds were represented by the Turkey Vulture, *Cathartes aura* (106 observations), Great Horned Owl, *Bubo virginianus* (74 observations), and Black Vulture, *Coragyps atratus* (66 observations). Additionally, amphibian roadkill included the Gulf Coast Toad, *Incilius nebulifer* (325 observations), American Bullfrog, *Lithobates catesbeianus* (96), and Northern Leopard Frog, *Lithobates pipiens* (82 observations). Worthy of note, other representative taxa for which there were more than 50 roadkill observations included several reptiles, the Pond Slider Turtle, *Trachemys scripta* (212 observations), the Painted Turtle, *Chrysemys picta* (observations), and the Common Snapping Turtle, *Chelydra serpentina* (130 observations), as well as another amphibian including the Eastern Newt, *Notophthalmus viridescens* (71 observations).

Table 1. Example descriptions of roadkill taxa are included in iNaturalist from this study.

Taxa	**Example of Observation Descriptions**
Reptiles	*"Recent DOR, rattle removed"*
	"Sadly, it looks like somebody intentionally killed this snake for no good reason as it crossed the road"
	"DOR, obviously done on purpose as the rattle was removed"
	"DOR by stream crossing"
	"I saw turtle looking for place to nest and lay eggs day before, then I saw it next day completely demolished by a car"
	"Dead on road, victim of a car tire"
	"One of several species killed by maintenance crew driving and mowing this road"
	"Found dead and dried on road, likely roadkill as head was flattened"
	"DOR, removed from road to protect scavengers from similar fate"
	"Looks like an intentional killing, it was on road"

Mammals	*"Badger was road killed"* *"Road killed juvenile Coyote, looks like vehicle was damaged due to metal objects embedded in body"* *"First porcupine I have seen outside of a zoo and it was DOR, I did have an interesting and educational conversation with the TXDOT employee who stopped to remove the carcass from the highway"* *"Witnessed the accident"* *"Road killed, unfortunately the otter was trapped by the concrete barrier"* *"First wild bear sighting, too bad it was dead"*
Birds	*"We found this road-killed Barn Owl just hours after it had been hit, carcass in good condition"* *"Dead on Road, flew into a moving car and was killed on impact"* *"DOR recent fledgling"* *"Road-killed immature"*
Amphibians	*"Toads were all over the roads this night! Had to drive slowly not to kill any"* *"Roadkill being munched on by a banana slug"* *"Road killed. With eggs"* *"Dead on road, struck by car"* *"Gravid female found dead on road"*

Discussion

Our study provides novel reporting on an emerging citizen science application and its use as a new tool to investigate the incidence of roadkill across the United States. A similar approach could be utilized in other geographic regions or by examining more observations within specific taxa of interest to researchers, possibly species in decline or with designated conservation or protection status. Our results are similar to other studies which found both reptiles to be the most frequently observed roadkill (Selvan et al., 2012), with snakes being the most vulnerable to direct mortality from roads (Andrews et al., 2006). However, other studies have reported mammals as the most frequently observed roadkill, especially in tropical regions (Freitas et al., 2013) and temperate regions (Hobday & Minstrell, 2008). Interestingly, several of the descriptions provided by citizen scientists making roadkill observations, expressed regret regarding seeing and reporting the roadkill, while others included natural history information (i.e., if the observation was adult, juvenile, or in some cases had eggs, etc.). Still, others reported witnessing the specific road collision and noted for several observations that rattles were removed from roadkill rattlesnakes.

While informative, there are several factors not specifically studied in this research, but could be retrieved from iNaturalist or similar citizen science databases. For example, I do not report on the specific time of observations, due to several observations missing that identifier or to the uncertainty associated with an observer encountering a roadkill. In addition, it is likely several environmental factors are involved in the ability of citizen scientists to observe roadkills, i.e., weather, road visibility, temperature, etc. Some studies have found an overall high rate of roadkill carcass removal by scavengers (Hastings et al., 2019), including ~89% of roadkill removed within 24 hrs. (Ratton et al., 2014), with others finding 60% to 97% of bird or snake carcasses disappearing within 36 hours (Antworth et al., 2005). This indicates that the amount of roadkills reported in iNaturalist is most likely an underestimation of total roadkill events across taxa and season. Alternatively, an observation of a roadkill reported may have been identified as a mammal or bird, but not down to species, also leading to those observations not being included in this study. Roadkill reporting is also likely variable and may also be affected if in some geographic areas, drivers are unlikely to use iNaturalist or if there are less citizen scientists. Subsequently, other studies have found high rates of road mortality rates for reptiles and birds, as they may be not only removed by scavengers but also due to their overall smaller body size, be more difficult to detect (Teixeira et al., 2013). Moreover, there is a likely bias in counting carcasses from a moving vehicle, which can further lead to underestimating road mortality death rates (Slater, 2002).

Seasonal variation in roadkill among the same taxa in this study (reptiles, mammals, birds, amphibians), has been reported to increase with temperature with peak road casualties in fall and spring (Garriga et al., 2017). Other studies have highlighted the later-summer movement of frogs and fall hatching events in turtles as influencing roadkill (Farmer & Brooks, 2012). Amphibian road mortality has been documented to be associated with both temperature and rainfall, with the highest roadkills being noted in summer (Coelho et al., 2012). Studies in reptiles found peak roadkills in summer, specifically in snakes during August and for other reptiles, and turtles, in June (MacKinnon et al., 2005), consistent with our findings. It is likely that not only season but local environment and habitats, the proximity of roads to wildlife crossing, water sources, roads near protected natural areas, etc., influences annual roadkill variability in local ecosystems.

Previous studies have utilized similar sized datasets comparing trained road patrols and citizen scientist to generate comparable taxonomic observations of roadkill (Periquet et al., 2018). While the observations by citizen scientists using the iNaturalist application may only represent one component of how often and the overall density and relative timing of vertebrate roadkill, it may serve to provide state agencies and department of transportation offices avenues to collaborate and examine trends within their own geographic areas. Collaborations may go a long way to mitigate the impact roads place on local wildlife populations. I noted an overall increase in observations of roadkill over the last decade in this dataset, indicating that annual reporting of roadkill is likely to continue to increase as citizen scientists report more observations of wildlife each year. Moreover, further studies could compare citizen scientist observations with research into wildlife corridors or specifically defined areas where roadkills may be potentially concentrated. Many methods are currently being assessed to decrease the incidence of roadkill in local hotspots including virtual fencing (Fox et al., 2018), gravel-mound barriers (Snow et al., 2011), and even road tunnels and guided fences (Helldin & Petrovan, 2019). Further study could incorporate the ecological groups of the most represented roadkill species, as this could be influenced by landscape factors, particularly for snake roadkill fauna (Rincon-Aranguri et al., 2019).

Conclusion

I recommend wildlife managers utilize citizen science data, as it is likely that reporting of roadkill could also be used to look not only at animals being directly impacted negatively by roads, but to examine connections between more rare animals if their representation in citizen science databases is lacking, potentially due to those species in question being rarer or in decline. There remains much to be discerned regarding citizen science data as one piece of the wildlife management puzzle. While this study focused on roadkill species within the U.S., largely because this is where many observations are available for this citizen science application, the methods presented in this study could be applied to other geographic areas and habitats or individual species could be studied for their observations on this smartphone application. It is estimated that over one million vertebrates are killed on roads each day in the U.S (Loss et al., 2014), and this number likely varies but may over time have an impact on the conservation of several taxa, including reptiles. Among the more alarming trends reported in this study include the large representation of observations for roadkill snakes, many of which are negatively directly impacted by roads. Therefore, I encourage researchers studying the impact of roads on wildlife mortalities and potential loss of biodiversity to utilize this free database of citizen science observations in their local geographic area.

Acknowledgments

This research is supported by the Wingate University Biology Department and followed protocols outlined in the Wingate Biology Research Review Board. I thank David and Myra Seitz for their inspiration in Biology.

References

Andrews, K. M., Gibbons, J. W., & Jochimsen, D. M. (2006). Literature synthesis of the effects of roads and vehicles on amphibians and reptiles. Washington DC. Federal Highway Administration (FHWA), U.S. Department of Transportation Report No. FHWA-HEP-08-005.

Aristeidou, M., Hererodotou, C., Ballard, H. L., Young, A. N., Miller, A. E., Higgins, L., & Johnson, R. F. (2021). Exploring the participation of young citizen scientists in scientific research: the case of iNaturalist. Plos one, 16, e0245682. https://doi.org/10/1371/journal.pone.0245682

Antworth, R. L., Pike, D. A., & Stevens, E. E. (2005). Hit and run: effects of scavenging on estimates of roadkilled vertebrates. Southeastern Naturalist, 4, 647-656. https://doi.org/10.1656/1528-7092(2005)004[0647:HAREOS]2.0CO;2

Bhandarkar, S., & Paliwal, G. (2021). Road kill of snakes (Squamata: Serpents) on state highway 276: a case study in protected forest area of Deori Forest range Gondia. Journal on New Biological Reports, 10, 7-10.

Chyn, K., Lin, T., Chen, Y., & Fitzgerald, L. (2019). The magnitude of roadkill in Taiwan: patterns and consequences revealed by citizen science. Biological Conservation, 237, 317-326. https://doi.org/10/1016/j.biocon.2019.07.014

Coelho, I. P., Teixeira, F. Z., Colombo, P., Coelho, A. V. P., & Kindel, A. (2012). Anuran road-kills neighboring a peri-urban reserve in the Atlantic forest, Brazil. Journal of Environmental Management, 112, 17-26. https://doi.org/10.1016/j.envman.2012.07.004

D'Amico, M., Roman, J., Reyes, L., & Revilla, E. (2015). Vertebrate road-kill patterns in Mediterranean habitats: Who, when and where. Biological Conservation, 191, 234-242. https://doi.org/10.1016/j.biocon.2015.06.010

Eloff, P., & Van Niekerk, A. (2008). Temporal patterns of animal related tragic accidents in the Eastern Cape, South Africa. South African Journal of Wildlife Research, 38, 153-162.

Erickson, W. P., Johnson, G.D., & Young, D. P. (2005). A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service General Technical Report PSW-GTR 191: 1029-1042.

Farmer, R. G. & Brooks, R. J. (2012). Integrated risk factors for vertebrate roadkill in southern Ontario. Journal of Wildlife Management, 6, 1215-1224. https://doi.org/10.1002/jwmg.358

Fox, S., Potts, J. M., Pemberton, D., & Crosswell, D. (2018). Roadkill mitigation: trialing virtual fence devices on the west coast of Tasmania. Australian Mammalogy, 41, 205-211. https://doi.org/10.1071/AM18012

Freitas, S.R., Sousa, C. O. M, & Bueno, C. (2013). Effects of landscape characteristics on roadkill of mammals, birds and reptiles in a highway crossing the Atlantic forest in southeastern Brazil. Proceedings of the 2013 International Conference on Ecology and Transportation. Arizona. 1-11.

Garriga, N., Franch, M., Santos, X., Montori, A., & Lorente, G. A. (2017). Seasonal variation in vertebrate traffic casualties and its implications for mitigation measures. Landscape and Urban Planning, 157, 36-44. https://doi.org/10/1016/j.landurbplan.2016.05.029

Grilo, C., Koroleva, E., Andrasik, R., Bil, M., & Gonzalex-Suarex, M. (2020). Roadkill risk and population vulnerability in European birds and mammals. Frontiers in Ecology and the Environment, 18, 323-328. https://doi.org/10.1002/fee.2216

Hastings, H., Barr, J., & Bateman, P. W. (2019). Spatial and temporal patterns of reptile roadkill in the north-west Australian tropics. Pacific Conservation Biology, 25, 370-376. https:doi.org/10.1071/PC18082

Heldin, J. O., & Petrovan, S. O. (2019). Effectiveness of small road tunnels and fences in reducing amphibian roadkill and barrier effects of retrofitted roads in Sweden. PeerJ, e7518. https://doi.org/10.7717/peerj.7518

Hobday, A.J., & Minstrell, M.L. (2008). Distribution and abundance of roadkill on Tasmanian highways: human management options. Wildlife Research, 35, 712-726.

Kreling, S.E., Gaynor, K. M., & Coon, C. A. (2019). Roadkill distribution at the wildland-urban interface. Journal of Wildlife Management, 83, 1427-1436. https://doi.org/10

Loss, S.R., Will, T. & Marra, P.P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. Journal of Wildlife Management, 78, 763-771. https://doi.org/10.1002/jwmg.721

MacKinnon, C.A., Moore, L. A., & Brooks, R. J. (2005). Why did the reptile cross the road? Landscape factors associated with road mortality of snakes and turtles in the south eastern Georgian Bay area. Proceedings of the Parks Research Forum of Ontario (PRFO) and Carolinian Canada Coalition (CCC) Annual General Meeting. 153-166.

Mo, M., & Mo, E. (2022). Using the iNaturalist application to identify reports of Green Iguanas (*Iguana iguana*) on the mainland United States of America outside of populations in Florida. Reptiles and Amphibians, 29, 85-92. https://doi.org/10.17161/randa.v29i1.16269

Nugent, J. (2018). iNaturalist: citizen science for 21st-century naturalist. Science Scope, 41, 12.

Periquet, S., Roxburgh, L., le Roux, A., & Collinson, W. J. (2018). Testing the value of citizen science for Roadkill studies: A case study from South Africa. Frontiers in Ecology and Evolution, 6, 15. https://doi.org/10.3389/fevo.2018.00015

Ratton, R., Secco, H., & Rosa, C. (2014). Carcass permanency time and its implications to the roadkill data. European Journal of Wildlife Research, 60, 543-546.

Rincon-Aranguir, M., Urbina-Cardona, N., Galeano, S. P., Bock, B. C., & Paez, V. P. (2019). Road kill of snakes on a highway in an Orinoco Ecosystem: landscape factors and species traits related to their mortality. Tropical Conservation Science, 12, 1-8. https://doi.org/10.1177/1940082919830

Rokop, M., Srikanth, R., Albert, M., Radonic, C., Vincent, R., & Stevenson, R. (2021). Looking more carefully: a successful bioblitz orientation activity at an Urban Public University. Citizen Science: Theory and Practice, 7, 1.

Santos, R. A. L., Ascensao, F., Ribeiro, M. L., Bager, A., Santos-Reis, M., & Aquiar, L. M. S. (2017). Assessing the consistency of hotspot and hot-moment patterns of wildlife road mortality over time. Perspectives in Ecology and Conservation, 15, 56-60. https://doi.org/10.1016/j.pecon.2017.2017.03.003

Schwartz, A. L.W., Williams, H. F., Chadwick, E., Thomas, R. J., & Perkins, S. E. (2018). Roadkill scavenging behavior in an urban environment. Journal of Urban Ecology, 4, 1-7. https://doi.org/10.1093/jue/juy006

Schwartz, A. L.W., Shilling, F.M., & Perkins, S.E. (2020). The value of monitoring wildlife roadkill. European Journal of Wildlife Research, 66, 18.

Selvan, K. M., Sridharan, N., & John, S. (2012). Roadkill animals on national highways of Karnataka, India. Journal of Ecology and the Natural Environment, 4, 363-365.

Shin, Y., Jeong, D., & Borzee, A. (2020). Mass displacement of Korean clawed salamanders (*Onychodactylus koreanus*) and the threat of road-kill. The Herpetological Bulletin, 151, 28-31. https://doi.org/10.33256/hb151.2831

Slater, F.M. (2002). An assessment of wildlife road casualties- the potential discrepancy between numbers counted and numbers killed. Web Ecology, 3, 33-42. https://doi.org/10.5194/we-3-33-2002

Snow, N. P., Andelt, W. F., & Gould, N. P. (2011). Characteristics of road-kill locations of San Clemented Island foxes. Wildlife Society Bulletin, 35, 32-39. https://doi.org/10.1002/wsb.4

Teixeira, F. Z., Coelho, A. V. P. , Esperandio, I. B., & Kindel, A. (2013). Vertebrate road mortality estimates: effects of sampling methods and carcass removal. Biological Conservation, 157, 317-323. https://doi.org/10.1016/j.biocon.2019.09.006

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E., Wagner, C., HilleRislambers, J., Tewksbury, J., Harsch, M. A., & Parrish, J. K. (2015). Global change and local solutions: tapping the unrealized potential of citizen science for biodiversity research. Biological Conservation, 181, 236-244. https://doi.org/10.1016/j.biocon.2014.10.021

Waetjen, D. P., & Shilling, F. M. (2017). Large extent volunteer roadkill and wildlife observation systems as sources of reliable data. Frontiers in Ecology and Evolution, 5, 89. https://doi.org/10.3389/fevo.2017.00089

Wilson, J.S., Pan, A. D, General, D. E. M., & Koch, J. B. (2020). More eyes on the prize: an observation of a very rare, threatened species of Philippine bumble bee, *Bombus irisanensis*, on iNaturalist and the importance of citizen science in conservation biology. Journal of Insect Communication, 24, 727-729. https://doi.org/10.1007/s10841-020-00233-3

Yue, S., Bonebrake, T. C. & Gibson, L. (2019). Informing snake roadkill mitigation strategies in Taiwan using citizen science. The Journal of Wildlife Management, 83, 80-88. https://doi.org/10.1002/jwmg.21580

Table A1. More frequently observed species of roadkill or DOR totals on iNaturalist for the U.S.A. and common name. Only includes species for which there are at least 50 observations.

SPECIES	COMMON NAME	TOTAL
Pituophis catenifer	Gopher Snake	1129
Crotalus atrox	Western Diamondback Rattlesnake	717
Thamnophis proximus	Western Ribbon Snake	628
Masticophis flagellum	Coachwhip Snake	621
Pantherophis obsoletus	Black Rat Snake	456
Thamnophis marcianus	Checkered Garter Snake	400
Coluber constrictor	Eastern Racer Snake	395
Thamnophis sirtalis	Common Garter Snake	343
Incilius nebulifer	Gulf Coast Toad	325
Procyon lotor	Common Raccoon	323
Mephitis mephitis	Striped Skunk	299
Opheodrys aestivus	Rough Green Snake	292
Pantherophis emoryi	Great Plains Rat Snake	292
Didelphis virginiana	Virginia Opossum	265
Crotalus oreganus	Pacific Rattlesnake	249
Agkistrodon contortrix	Copperhead Snake	241
Storeria dekayi	Dekay's Brownsnake	230
Trachemys scripta	Pond Slider Turtle	212
Dasypus novemcinctus	Nine-banded Armadillo	211
Agkistrodon piscivorus	Cottonmouth Snake	196

Rhinocheilus lecontei	Long-nosed Snake	178
Crotalus horridus	Timber Rattlesnake	170
Nerodia erythrogaster	Plain-bellied Water Snake	170
Arizona elegans	Glossy Snake	149
Chrysemys picta	Painted Turtle	148
Crotalus viridis	Praire Rattlesnake	147
Erethizon dorsatum	North American Porcupine	144
Urocyon cinereoargenteus	Gray Fox	143
Ophisaurus attenuatus	Slender Glass Lizard	137
Pantherophis spiloides	Gray Rat Snake	136
Nerodia rhombifer	Diamondback Water Snake	132
Chelydra serpentina	Common Snapping Turtle	130
Odocoileus virginianus	White-tailed Deer	129
Crotalus scutulatus	Mojave Rattlesnake	124
Phrynosoma cornutum	Texas Horned Lizard	123
Canis latrans	Coyote	121
Pantherophis alleghaniensis	Eastern Rat Snake	118
Sciurus niger	Fox Squirrel	118
Terrapene carolina	Common Box Turtle	116
Heterodon platirhinos	Eastern Hognose Snake	111
Diadophis punctatus	Ring-necked Snake	109
Masticophis taeniatus	Striped Whipsnake	108
Cathartes aura	Turkey Vulture	106
Sciurus carolinensis	Eastern Gray Squirrel	103
Lampropeltis californiae	California Kingsnake	102
Lontra canadensis	North American River Otter	99
Nerodia fasciata	Banded Water Snake	98
Lithobates catesbeianus	American Bullfrog	96
Thamnophis elegans	Western Terrestrial Garter Snake	93
Micrurus tener	Texas Coral Snake	91

Anaxyrus boreas	Western Toad	86
Nerodia sipedon	Common Water Snake	83
Lithobates pipiens	Northern Leopard Frog	82
Taxidea taxus	American Badger	81
Lampropeltis calligaster	Yellow-bellied Kingsnake	80
Lampropeltis triangulum	Milk Snake	77
Lynx rufus	Bobcat	77
Neogale vison	American Mink	75
Pantherophis guttatus	Corn Snake	75
Bubo virginianus	Great Horned Owl	74
Lampropeltis holbrooki	Speckled Kingsnake	71
Lithobates sphenocephalus	Southern Leopard Frog	71
Notophthalmus viridescens	Eastern Newt	71
Thamnophis radix	Plains Garter Snake	71
Sus scrofa	Wild Boar	70
Crotalus adamanteus	Eastern Diamondback Rattlesnake	69
Farancia abacura	Mud Snake	69
Coragyps atratus	Black Vulture	66
Strix varia	Barred Owl	61
Crotalus cerastes	Sidewinder Snake	58
Salvadora grahamiae	Eastern Patch-nosed Snake	58
Haldea striatula	Rough Earth Snake	57
Masticophis schotti	Schott's Whipsnake	56
Lampropeltis splendida	Desert Kingsnake	53
Terrapene ornata	Ornate Box Turtle	53
Conepatus leuconotus	American Hog-nosed Skunk	52
Elgaria multicarinata	Southern Alligator Lizard	52
Storeria occipitomaculata	Redbelly Snake	52
Tyto alba	Barn Owl	52
Lithobates berlandieri	Rio Grande Leopard Frog	50