Three-year monitoring of roadkill trend in a road adjacent to a national park in Panama

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INSIGHTS

Three-year monitoring of roadkill trend in a road adjacent to a national park in Panama

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Abstract

Roadkill monitoring can provide important information about spatial and temporal trends on roadkill events. These studies are important for conservation, but there are few examples from Central America. Here, I identified in a road near a national park in Panama that monthly vertebrate roadkill events decreased with increases in temperature and precipitation.

Abstract in Spanish is available with online material.

KEYWORDS
human–wildlife conflict, mitigation measures, road mortality, wildlife–vehicle collision

1 | INTRODUCTION

Road networks bring multiple negative effects for biological conservation, including habitat fragmentation, habitat loss, chemical, and noise pollution (Van der Ree et al., 2015). Moreover, roads may directly impact animals by causing changes in home ranges, movement, escape behavior, and possibly even their physiology (Trombulak & Frissell, 2000). One of the most obvious impacts of road networks is wildlife roadkills, which is one of the major sources of vertebrate mortality globally (Hill et al., 2019). However, for many countries, roadkill research is practically non-existing (Schwartz et al., 2020), such as the case of Central America (Pinto et al., 2020). Therefore, there is a substantial underestimation of the impacts of road networks on biodiversity in the region.

Understanding the spatial and temporal patterns that influence mortality of wildlife provides the basis for mitigating wildlife threats in areas of ecological importance. Given that roadkill risk depends on multiple factors associated with roads, monitoring of local networks is needed to establish regional and global patterns (Balčiauskas et al., 2020). An underrepresented country is Panama, which is listed within the countries with the highest human footprint on vertebrate communities (Venter et al., 2016). To the best of my knowledge, only one study focused on documenting roadkills in Panama, and it lacked any statistical analysis (Contreras & González, 2018). Other studies used roadkills of certain species to study population dynamics (Hody et al., 2019).

Therefore, it is crucial that local biologists collect and analyze roadkill data. Here, this study monitored roadkills during three years in a road parallel to the Camino de Cruces National Park (CCNP) and surrounding areas. I examined which taxa were more vulnerable to vehicle collisions and whether there were spatial and temporal trends (year and season) in roadkill numbers. I also examined whether precipitation and temperature were influential, possibly as a result of an effect on activity patterns, and predicted that increases in both factors should lead to lower roadkill events, similar to other regions. Such data can ultimately be used to implement safety infrastructures for animal crossings or policies for mitigation.

2 | METHODS

I carried out this study in the paved two-lane road Omar Torrijos, starting in the village of Paraíso (9.0327° N, 79.6263° W) traversing

through the City of Knowledge (COK, 9°01′52.9″N 79°37′21.7″W), until the Metropolitan Park (~12.7 km combined, 8°59′02.2″N 79°32′51.4″W). Most of the lanes facing the northernmost side are situated next to CCNP, which is composed primarily of rainforest (A1 – B1– B2 in Figure 1). The southernmost lane is facing mostly disturbed habitats, including suburban areas and the Panama Canal (A1 – A2 in Figure 1). The section B1 – B2 passes through a suburban area (Clayton) and is also facing the CCNP and Metropolitan Park to the north (Figure 1).

The monitoring by car started from August 1, 2017, to August 1, 2020, between four and five days during weekdays and at least one day during weekends. The constant traffic jams from approximately 07:00 h to 09:00 h (monitoring of A1 -A2) and from 17:00 h to 19:00 h (monitoring of B1 – B2) allowed to travel at around 20 km

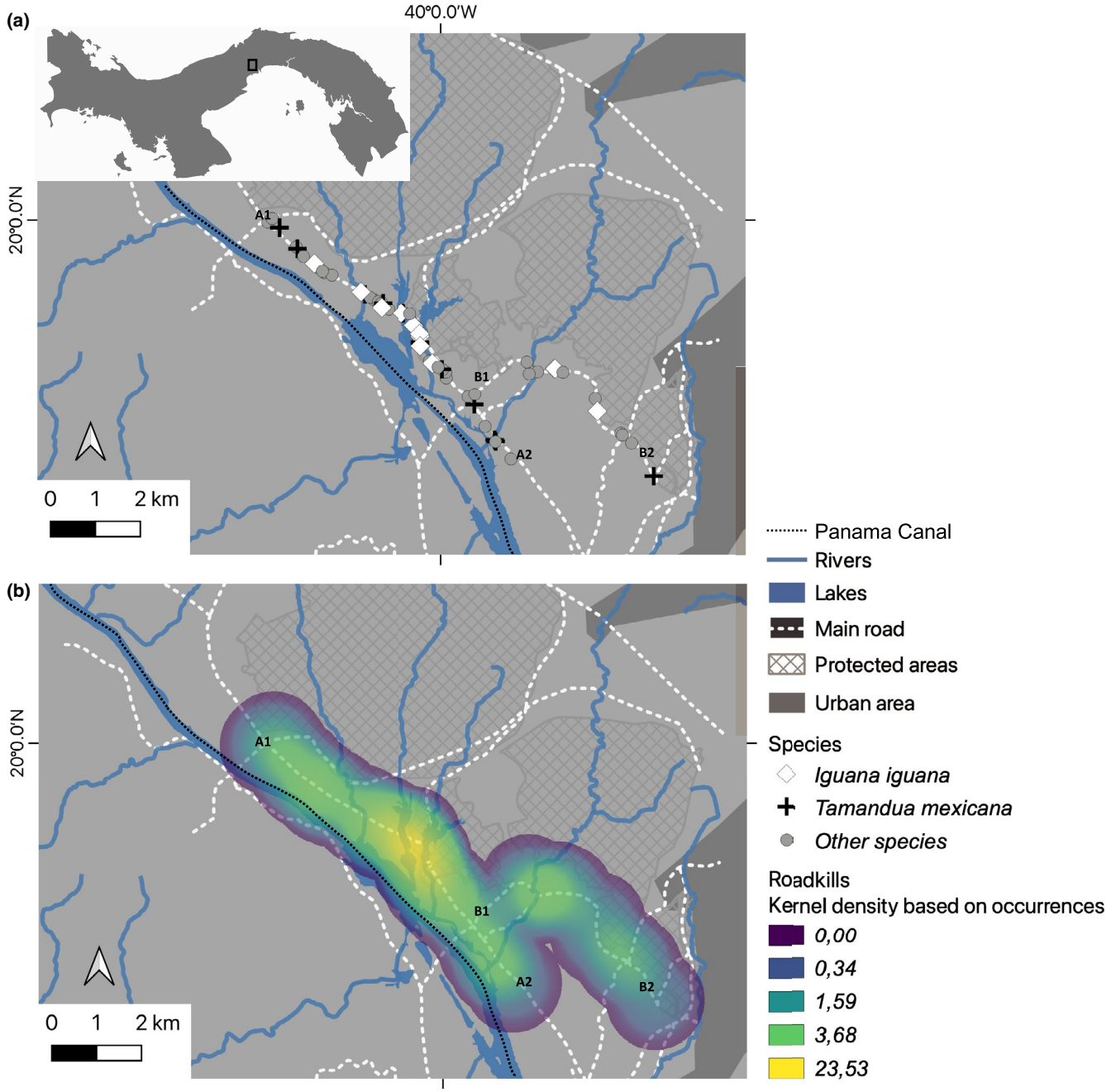

FIGURE 1 Location of the study road in the map of Panama and details on roadkill events for Green Iguanas (*Iguana iguana*), Tamanduas (*Tamandua mexicana*), and other species (a). Heatmap of roadkills along the study road (b). A1 – A2 indicates the section from Paraiso to COK, and B1 – B2 indicates the section from COK to the Metropolitan Park. The clear gray color indicates secondary forests and suburban areas. Map of Panama: Free vector map. The hot spots of roadkills were built using the kernel density map (distance decay function) in QGIS. The darkest blue color indicates the lowest density of roadkills in the area and the yellow color indicates the highest density of roadkills. Figure was edited on Power Point

/ h for most of the route (official speed limit is 60 km/h). This allowed clear visualization and identification of cadavers by two observers. However, I excluded amphibian roadkills, given their low persistence (Santos et al., 2011).

Due to the measures against COVID-19, from March 25, 2020, to August 1, 2020, I monitored one or two times per weekday and at least once during weekends. Medium-sized roadkills are expected to have maximum persistence times between 16 and 25 days (Santos et al., 2011); thus, these data are reliable for comparison with previous months.

I carried out a generalized linear model with Poisson family in R (R Core Team, 2020) to evaluate the effects of year, season, and taxa on monthly roadkill counts. Given the lower frequency of surveys from March 2020, I used the log-transformed sampling effort per week in days as an offset variable. I classified roadkills recorded from 1 December to 30 April and from 1 May to 30 November as occurring in the dry and rainy seasons, respectively. For balanced comparisons among seasons across years, I used for the dry season the period from 1 December to 31 March. For the rainy season, I used the period from 1 August to 30 November. Moreover, I removed three unknown cadavers for the analysis.

I included the average monthly precipitation and temperature for the Metropolitan Park (Paton, 2019a,2019b) as covariables. I first constructed a full model with season and taxa interaction and performed model simplification using Akaike's information criteria (AIC). I tested for overdispersion in the reduced model and for multicollinearity among variables (Table S1). I had enough samples for iguanas (*Iguana iguana*) and tamanduas (*Tamandua mexicana*) to run separate analysis.

For the spatial analysis, I performed a 2D Ripley's K to test for non-random spatial distribution and afterward a 2D hot spot identification analysis as implemented in Siriema (Coelho et al., 2014).

3 | RESULTS

I recorded a total of 79 roadkills (bird: 4, mammals: 47, reptiles: 25, unknown: 3, Figure 1, Table S1), belonging to 20 species, which is equivalent to 0.006 vertebrates / km / day. There were no significant differences in overall roadkills between years (Table S2A, Figure S1) and seasons (Figure 2a, Table S2A). There was no interaction between taxa and season (interactions in Table SA) suggesting that no taxa varied in roadkill frequencies between seasons. Total bird roadkills were less frequent than mammal and reptile roadkills (Table S2B). There were no differences between mammals and reptiles roadkills (Z = 2.1, p = 0.1). The number of roadkills tended to decrease with increases in temperature (Table S2B, Figure 2b) and precipitation (Table S2B, Figure 2c). Importantly, neither precipitation nor temperature showed collinearity (VIF: 1.56 and 1.56, Table S3). Temperature and precipitation were negatively correlated (Pearson's r = −0.6, t = −3.4, df = 21, p = 0.002).

A separate analysis of iguanas (n = 18) and tamanduas (n = 17) showed similar trends—with decreases in roadkills with increasing temperature (iguana: Table S4B; tamandua: Table S4D). However, decreases in roadkills with increasing precipitation were significant for iguanas (Table S4B) and not for tamanduas (Table S4C). There was no effect of season or year for iguanas (Table S4A) and tamanduas (Table S4C).

I found a roadkill aggregation and a hot spot in the portion of the road A1-A2 around 4.0 km, which is the most prominent curved section and bordered by water in both sides (Figure 1b, Figure S2). A separate spatial analysis for mammals and reptiles provided similar trends as compared to the overall data (Figure S3). For the portion B1 – B2, there was no evidence of roadkill aggregation (Figure S2).

4 | DISCUSSION

This study is a step in improving our understanding of roadkill research in Panama. Anecdotal reports of emblematic species by the news media are common; yet the subject is receiving little attention by specialists (Pinto et al., 2020). Although some local biologists keep personal records of roadkills, data are mostly unavailable, and I am not aware of local organizations monitoring roadkills. The overall roadkill rates seem similar to other neotropical regions (Ferreira et al., 2014; Zanzini et al., 2018), and further studies may shed some light on the intensity of road networks for wildlife in the country.

Here, I identified that temperature and precipitation influence the probability of roadkill events near a national park in central Panama. The lack of interaction between season and taxa indicates that both endothermic and exothermic animals were equally influenced, and the mechanisms of innate thermal regulation and behaviors associated are not the main drivers of roadkill events. However, studies in other regions found specific higher mortality for reptile or mammals during the rainy season (Miranda et al., 2017, Abra et al., 2021, respectively). The number of roadkills tended to decrease with increases in precipitation and temperatures, similar to other studies (Ruiz-Capillas et al., 2014 but see Ferreguetti et al., 2020). A possibility is that animals' activity decreases during rainy days (Hanya et al., 2018); however, it may depend on the species (Ascensão et al., 2019). I could not examine this possibility for most species due to low sample sizes. Additionally, the average traffic speed is likely to decrease during the months of higher precipitation (Peng et al., 2018) and therefore the probability of wildlife collision. In fact, several studies obtained a positive relationship between roadkill numbers and traffic flow (Ruiz-Capillas et al., 2014, Lodé, 2019 but see Carvalho et al., 2017). Future studies should evaluate factors that influence traffic flow and its consequences for wildlife collisions.

The lower mortality associated with increases in temperatures may be linked to decreases in activity, as reported for mammals (Maccarini et al., 2015). For iguanas, this effect seems counterintuitive since locomotory activity in reptiles is thought to be associated with temperature (Bennett, 1990), which should increase their roadkill probability. However, body temperature and activity are not entirely linked in iguanas (Tosini & Menaker, 1995). Moreover, physiological responses related to activity in reptiles are likely to rely

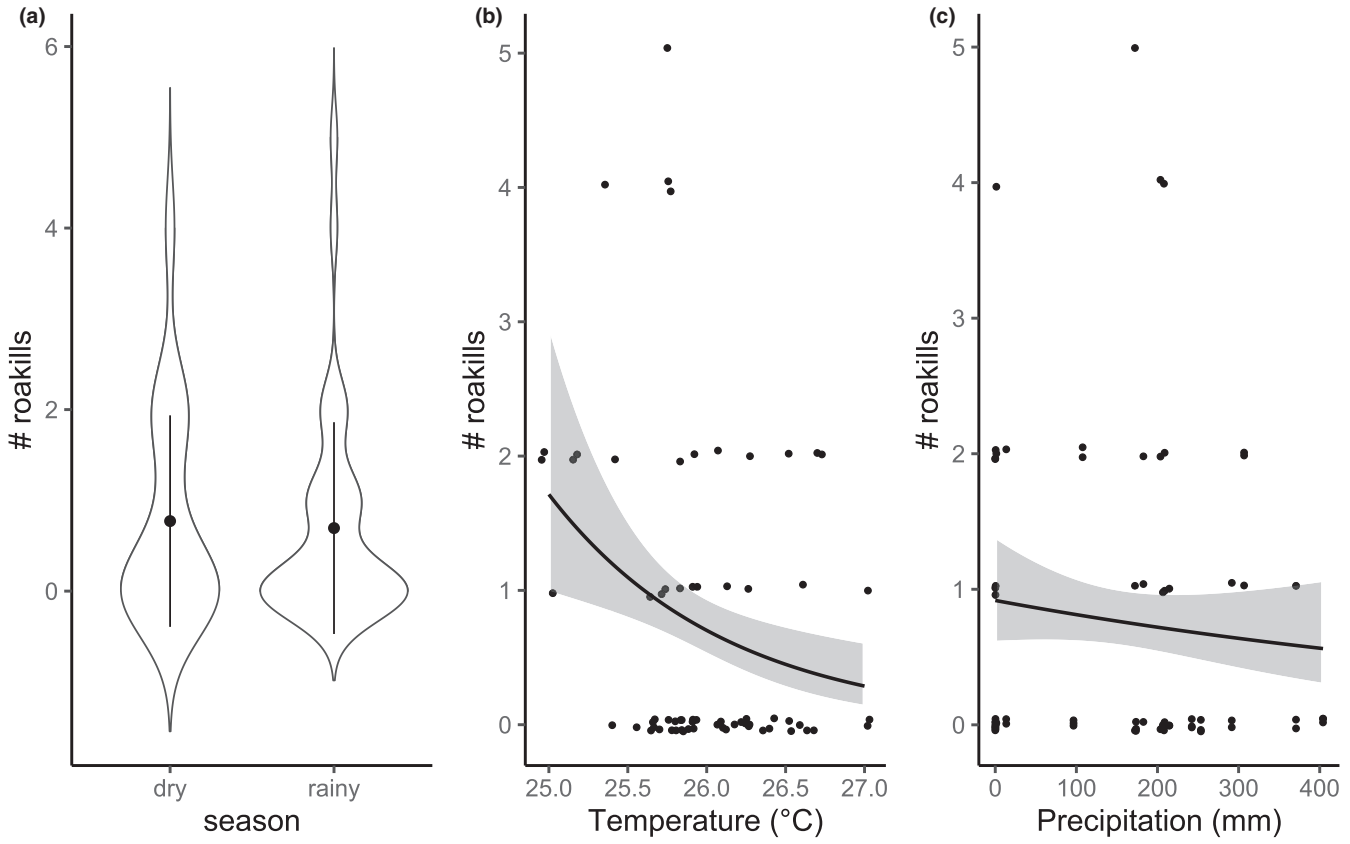

FIGURE 2 Roadkill frequencies per season in the study road (a) and relationship with temperature (b) and precipitation (c). In violin plot (a), the dots represent means and the vertical lines indicate standard deviations. Shaded areas in b and c represent 95% confidence intervals

on other factors than just ambient temperature (Berg et al., 2017). Perhaps, during cool days, iguanas are more prone to move closer or remain longer on the road to use the heat trapped in the road as seen in temperate zones (Andrews et al., 2006). Future work should examine the use of roads as a heat source for reptiles in the tropics and its consequences on roadkill events.

Roadkill probability is likely to be associated with the biology and ecology of each species (Rincón-Aranguri et al., 2019). For instance, Rodda (1990) found in Venezuela seasonal differences in the roadkill sex ratio of iguanas, apparently associated with territorial behavior, forcing subordinate males to search for unoccupied territories, which would increase vehicle collision risk. Importantly, the effect of abiotic factors on roadkill probability may be species specific. For instance, in sloths, activity levels correlate with ambient temperature (Andrés et al., 2015); therefore, their roadkill probability should increase with temperature, opposite to my results. In fact, some studies have found this trend for armadillo roadkills, including variation in the effects of abiotic factors along the day or season, resulting in differential roadkill frequencies (Inbar & Mayer, 1999). More work could be done to examine whether the effects of abiotic factors vary during the day or season in tropical regions.

An important consideration is that the effect of abiotic factors may be region specific. Garriga et al. (2017) found variation in different roads in temperate zones, even with opposite effects for the same abiotic factor. Similar trends may be observed in tropical regions, as it would be the case of studies that found a positive correlation between roadkills and precipitation (Ferreguetti et al., 2020), contrary to my results. Therefore, there is a need for more studies in the region that examine abiotic factors and other potentially influential variables (sex, age, weight, species commonness, activity patterns, among others).

My monitoring found a hot spot of mortality in 4.0 km, which is a curved section of the road and potentially more dangerous for wildlife than straight lines (Arango-Lozano & Patiño-Siro, 2020 but see Delgado-Trejo et al., 2018). However, this curved section is the closest point to water, which may be influential on roadkill events (Bueno et al., 2015). However, some studies showed a species-specific effect (Ascensão et al., 2017) with opposite trends (Freitas et al., 2015). Additionally, although there was no significant effect of year, the lowest values in 2020 suggest a decrease in roadkills, perhaps related to lower traffic during the lockdown (Nguyen et al., 2020). However, a reduction in mortality could result from population depletion due to massive mortality (Ascensão, Kindel, et al., 2019). It is not clear whether the work done for widening the road—started in November 2018 and canceled in February 2019—influenced roadkill events.

Further evaluation is needed to develop effective animal crossings either for multispecies or single species (Teixeira et al., 2013). If the aim is to protect endangered species, which are often less frequent roadkills (Pinto et al., 2020), then long-term studies are required. Meanwhile, urgent strategies to mitigate roadkills could be

to implement speed bumps (Machado et al., 2015), increase road visibility (Reed & Woodard, 1981), or reduce speed limits (Hobday & Minstrell, 2008). In the case of this study road, I would recommend the installation of speed bumps in the hot spot around 4.0 km. There is an urgent need in Panama to start planning for fauna passages and other mitigation measures associated with roads. Government institutions should establish units in charge of studying road ecology, composed of biologists and engineers in order to reduce the conflict between wildlife and humans. Finally, no mitigation measure can be effective without a profound change of the drivers' behavior, which requires educational programs and stricter law enforcement of traffic regulations.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.n02v6wwxb (Gálvez, 2021).

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SUPPORTING INFORMATION

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