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Road Mortality of Herpetofauna along Selected Roads in Georgetown, Guyana – A Baseline Study

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Abstract

Expanding road networks introduce threats to herpetofauna populations, through pollution, habitat fragmentation, population isolation, and vehicular traffic. Traffic, especially, increases the risk of extirpation of urban herpetofauna populations by introducing the threat of direct mortality. In Guyana, there are no mitigation measures specifically employed against road mortality, and prior to this study, no research had been conducted on herpetofauna road mortality. Thus, this baseline study was conducted to document the following: which herpetofauna species are affected by road mortality; the international conservation statuses of these species; and the distribution of road mortality. The team conducted 500metre long transect surveys along three major roads in Georgetown over a single wet and dry season, from 04:00hrs to 06:00hrs. Sixteen (16) species were encountered, and road mortality predominantly affected amphibian species. Despite this, the three most frequently encountered species were the cane toad (*Rhinella marina*), red-snouted tree frog (*Scinax ruber*), and brown-banded water snake (*Helicops angulatus*). Of the recorded species, only the green anaconda (*Eunectes murinus*), spectacled caiman (*Caiman crocodilus*), and gold tegu (*Tupinambis teguixin*) were of international conservation concern. Meanwhile, the water coral (*Hydrops triangularis*) may require local population monitoring since it is data deficient on the IUCN Red List. Road mortality increased along roads with seasonally flooded fields, coinciding with the presence of grasses, trees, and concrete, but not culverts and canals. While road mortality was greater during the dry season, it was not found to be affected by rainfall, temperature, and humidity. These results represent a framework for future research, policy making, and urban development planning.

Keywords: herpetofauna, road ecology, road mortality

1. Introduction

As global herpetofauna populations decline, there is greater need to monitor contributors to mortality and mitigate their effects. The expansion of road networks, for instance, place herpetofauna populations under strain by introducing habitat fragmentation, pollution, and direct mortality through vehicular collisions or intentional killing[8,12,19,21], but little research has been conducted in the urban spaces of the neotropics[8,12]. Furthermore, the effect of roads on herpetofauna populations has not been studied in Guyana, despite the increase in road infrastructure as the country develops.

With the increase in road infrastructure, there will be a corresponding increase in habitat fragmentation[16,34] and an increase in road substrate. Herpetofauna are known to utilize roads to move between habitat patches to find mates, spawning locations, or food[8], or to thermoregulate[10,23,31,35].Thus, herpetofauna will interface with and utilize roads more frequently, which increases their probability to be subject to road mortality by vehicular collision[8,16] or intentional killing[16].

Moreover, road mortality through vehicular collisions directly reduces the size of herpetofauna populations[10,25,35], increasing their risk of extirpation[3,17,22]. This risk heightens in areas with low quality habitats or that are heavily fragmented because they increase the need for herpetofauna to move between habitat patches more frequently[12,31] and tend to support smaller populations of herpetofauna[11,13,20].

While road mortality may not directly eliminate a species from a locale, its demographic shifting and bottlenecking effects on a population may sufficiently reduce the population size below the minimum viable population threshold[34]. Turtles, for instance, experience dissimilar mortality between the sexes[32] and populations experience overall negative growth due to road mortality[16]. Additionally, road mortality may create a functional barrier to movement between habitat patches, effectively isolating populations and ensuring a reduction in population sizes and their viability[3,8,22,34].

Species diversity is also prone to decrease over time through road mortality or habitat degradation. Along roads, habitats often become degraded and lead to certain species, such as *Bufo melanostictus*[35] or *Pristimantis variabilis*[25], proliferating and outcompeting other species that require more pristine habitats[10,34]. Still, reduced species diversity may be attributed to road-mortality-induced extirpation.

However, the habits of herpetofauna species play a key role in the determining the effect of road mortality on their populations. Most species utilize roads for basking, scavenging, or crossing to breed or forage[3,10,16,19,23,31], thus placing them at risk of road mortality. Several species typically forego this risk by avoiding roads altogether; most stream-dwelling and arboreal species would not use roads in their movement[35], while other species live sedentary lifestyles[16,31,35], or move away from roads[9,10,25,34,35]. Fast-moving species such as racer snakes or *Mabuya* species, despite crossing roads, avoid road mortality due to their speed[10,35], while slower-moving species tend to be more prone to road mortality. Species that tend to spend more time on roads, such as hognose snakes or long-bodied snakes, are also at higher risk of road mortality[10,21].

The natural history of species and features of the environment produce variations in road mortality. Wetlands and wetlands-resembling habitats host higher species richness and abundance[3,10] so, roads bisecting wetlands experience more road mortality[22]. Similarly, areas with natural habitat note increased overall road mortality[31] because they can support larger populations. Road mortality tends to increase during mating seasons, after hatching, and during seasonal migrations of species because crossing is more frequent[8,16,28,31]. These periods often coincide with specific weather conditions, but road mortality is generally affected by precipitation, temperature, and humidity, increasing as temperature and humidity increase[6,23], and in high precipitation[28] or after precipitation[31,35]. Increases in traffic volume may amplify road mortality[16,31,34], but it depends on other variables, such as weather, that determine the level of activity of herpetofauna[31]. Speed limits can increase or decrease road mortality[34], depending on drivers, whereby higher speed limits would not allow drivers to spot herpetofauna to avoid them[10,34] and lower speed limits can reduce the accidental collisions, but increase intentional killing[16,19,31].

Research on herpetofauna road mortality has only been conducted in a portion of the neotropics[8,12], and no road mortality data has been collected in Georgetown, Guyana. As such, this project sought to answer the following questions: What species are subject to road mortality? How many individuals are affected? Are these species of international conservation importance? How are the incidences of herpetofauna road mortality distributed? The collective answers to these questions will provide the baseline information on the diversity and conservation importance of affected species, and the effect of various environmental factors on the distribution of their mortalities. Furthermore, the researchers posit that environmental factors influence herpetofauna road mortality. Nevertheless, these data can inform mitigation measures for road mortality and will provide a foundation for further studies.

2. Methods

Sampling was carried out at three study sites within Georgetown: Thomas Road, Railway Embankment, and Camp Street. While all were major roads, they were differentiated based on the presence/absence of seasonally flooded fields on either side of the road.

Thomas Road was a tertiary road with two lanes that linked Camp Street (6°49'18.0"N 58°09'27.1"W) and Irving Street (6°49'06.0"N 58°08'43.4"W). It was surrounded by canals and seasonally flooded fields, with the Guyana National Park on the northern side of the road, and an abandoned field on the southern side of the road. Thus, it was categorized as a road bordered by two seasonally flooded fields. The road was 6.99 m wide, 1390 m in total length, and 2.34 m in height relative to the surrounding area, with a speed limit of 50 km/hr.

Similarly, the Railway Embankment was a road with two lanes; however, it was a secondary road stretching from Sheriff Street (6°49'15.2"N 58°08'03.6"W) to beyond Georgetown's boundaries. It was surrounded by a seasonally flooded field on its southern side, and a canal and buildings on the northern side. Additionally, there was a trench that stretched along the southern side of the road, 10.70 m from it, and bisected it at 6°49'20.9"N 58°07'12.7"W. Thus, it was categorized as a road bordered by one seasonally flooded field. The road was 10.69 m wide, 3230 m in total length of the section within Georgetown, and 0.06 m in height relative to the surrounding area, with a speed limit of 60 km/hr.

Meanwhile, Camp Street was a secondary road with a section composed of four lanes separated by a walkway through the middle of the road. The four-lane section of the road stretched from Cowan Street (6°49'09.1"N

58°09'29.8"W) to North Road (6°48'42.5"N 58°09'37.0"W). It was surrounded by buildings, with no seasonally flooded fields on either side; however, the walkway in the middle of the road had trees and regularly maintained grasses. Thus, it was categorized as a road bordered by no seasonally flooded fields. The road was 9.79 m wide on each half, 852 m in total length of the four-lane section, and 0.03 m in height relative to the surrounding area, with a speed limit of 50 km/hr.

To quantify herpetofauna road mortality along each road, pedestrian surveys were conducted[10,23]. Once sampling was complete, a species list was compiled, each species was cross-referenced with the IUCN Red List and CITES Appendices, and spatial distribution maps were created from GPS mapping performed during the pedestrian surveys.

Data collection occurred over a 90-day period – 45 days in the dry season (Aug 2018 – Oct 2018) and 45 days in the wet season (Dec 2018 – Feb 2019). Within these 45-day periods, each road was sampled for 30 days. To distribute sampling throughout each season, sampling was carried out for nine days at a time, followed by five-day non-sampling intervals. Each day of sampling involved sampling two roads for one hour each.

Surveys were conducted by a team of three individuals along a 500-m transect on each road, from 04:00 hours to 06:00 hours. The team walked along the transect once on each side of the road so that a total of 1000 m was covered during each sampling occasion[10]. Live specimens and whole and partial carcasses of herpetofauna were assigned unique GPS points, examined, identified, and tallied, while non-herpetofauna specimens were only recorded. The dead remains were collected if it could have been safely removed from the road. Several photographs with reference measurements were taken for dead remains not collected. Specimens were taken to the Centre for the Study of Biological Diversity (CSBD), University of Guyana to confirm their identification, sex, and age with the assistance of Scientific Officers, use of museum collections and identification manuals. Following this, dead specimens of good condition were used as voucher specimens within the wet museum of the CSBD, while damaged or decomposed dead remains were discarded.

Additionally, supplementary data were recorded, including time the survey was conducted, and overall weather. Measurements of daily average precipitation, temperature, and humidity, respectively, were collected from the Hydrometeorological Service of the Ministry of Agriculture, Guyana.

Data were analyzed using R (Version 3.5.3) using the Kruskal-Wallis test, Mann-Whitney U test, logit regression model, and Spearman Rank Correlation, along with descriptive statistics. The descriptive statistics depicted relative abundance of species by representing the number of individuals of each species as a percentage of the total number of individuals encountered at each transect, and for each season. The Kruskal-Wallis test determined whether the amount of road mortality varied among study sites. The Mann-Whitney U test was then used to determine which study sites varied from each other based on the amount of road mortality. In contrast, the logit regression model was used to determine whether the presence/absence of road mortality on a given day was affected by daily average precipitation, temperature, or humidity, respectively. Similarly, the Spearman Rank Correlation was used to determine whether the amount of road mortality on a given day was affected by daily average rainfall, temperature, or humidity, respectively.

3. Results

Overall, 16 species from 9 families and 12 genera of herpetofauna were observed. Amphibians constituted 4 species while reptiles comprised 12 species. Twelve of the total 16 herpetofauna species were recorded during the final data collection period while the additional 4 species were noted from the preliminary data collection period noted and opportunistic encounters. Of the former 12, 4 species were amphibians (cane toad [*Rhinella marina*], red-snouted tree frog [*Scinax ruber*], Orinoco lime tree frog [*Sphaenorhynchus lacteus*], whistling frog [*Leptodactylus fuscus*]) and 8 species were reptiles (green anaconda [*Eunectes murinus*], three-lined ground snake [*Atractus trilineatus*], brown-banded water snake [*Helicops angulatus*], water coral [*Hydrops triangularis*], ratonel [*Pseudoboa neuwiedii*], black-headed snake [*Tantilla melanocephala*], Antilles leaf-toed gecko [*Hemidactylus palaichthus*], Guyana *Kentropyx* [*Kentropyx borckiana*]). The amphibians belonged to 3 families (Bufonidae, Hylidae, and Leptodactylidae) while the reptiles belonged to 4 families (Boidae, Colubridae, Gekkonidae, and Teiidae). Meanwhile, the latter 4 species were reptiles (spectacled caiman [*Caiman crocodilus*], brown sipo [*Chironius fuscus*], fer-de-lance [*Bothrops atrox*], gold tegu [*Tupinambis teguixin*]) belonging to 3 families (Alligatoridae, Colubridae, and Viperidae).

Most of the collected species were categorized as Least Concern on the IUCN Red List and were not listed on any CITES appendix. However, the green anaconda (*E. murinus*) was listed as Not Evaluated on the IUCN Red List, and the water coral (*H. triangularis*) was listed as Data Deficient on the IUCN Red List. The green anaconda and spectacled caiman (*C. crocodilus*) were listed on CITES appendix II, requiring permits for export of live individuals or products made from the species because their populations may be at risk of decline in the absence of controlled trade. The spectacled caiman was also listed on CITES appendix I, requiring permits for import of live individuals for scientific purposes, while commercial trade is prohibited because their populations are threatened with decline.

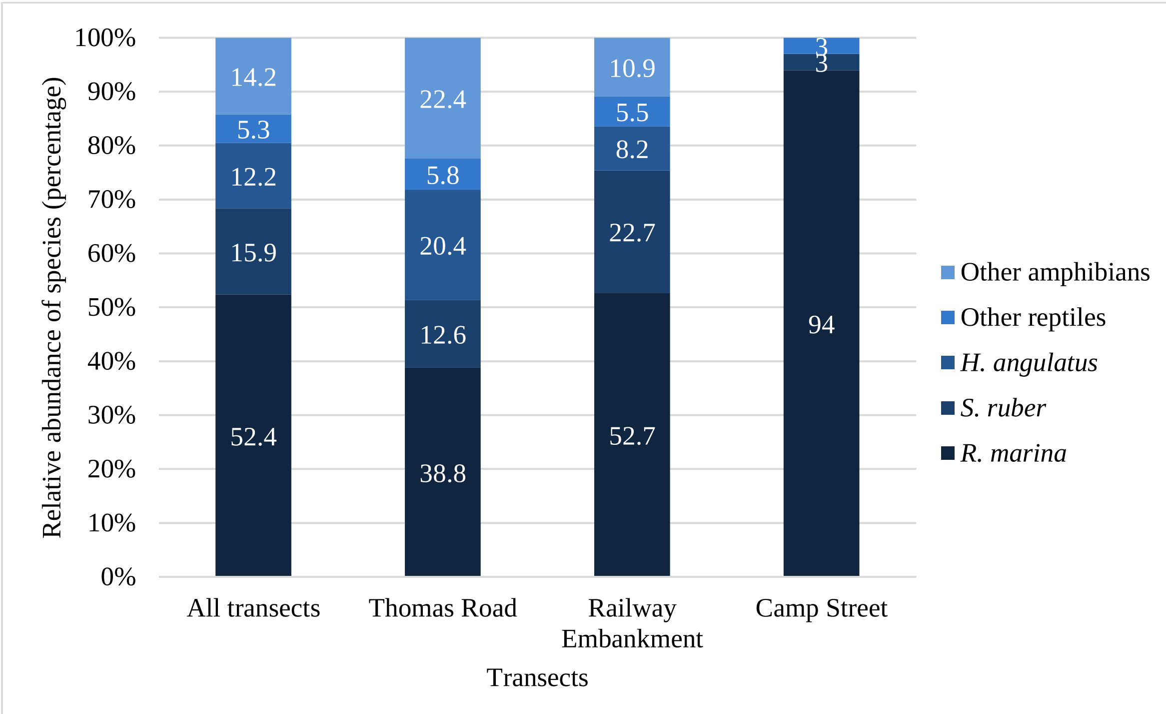


Figure 1. Relative abundance (by percentage) of species at all sites and at each site

By grouping taxa (amphibians vs reptiles) across all sites, amphibians accounted for 82.5% (n = 203) of herpetofauna road mortalities, while reptiles only comprised 17.5% (n = 43). By site, this ratio became exaggerated from Thomas Road to Railway Embankment to Camp Street as reptiles constituted decreasing amounts of herpetofauna road mortalities (26.2% to 13.7% to 3%) while amphibians saw continual increases (63.8% to 86.3% to 97%). The cane toad (*R. marina*) represented over half of all herpetofauna road mortalities (52.4%, n = 129), while the next two most abundant species (red-snouted tree frog [*S. ruber*] and brown-banded water snake [*H. angulatus*]) constituted 15.9% (n = 39) and 12.2% (n = 30), respectively. No other species exceeded 10 individuals, but their combined road mortality constituted 19.5% (n = 48) of the total. These values may vary from actual mortality ratios because the group 'Other amphibians' that constituted 14.2% (n = 35) of the total comprised mainly of individuals identified only to family or genus. Across sites, the cane toad experienced increasing mortalities as did the amphibian taxon, unlike other species. However, the red-snouted tree frog noted its highest mortalities at Railway Embankment.

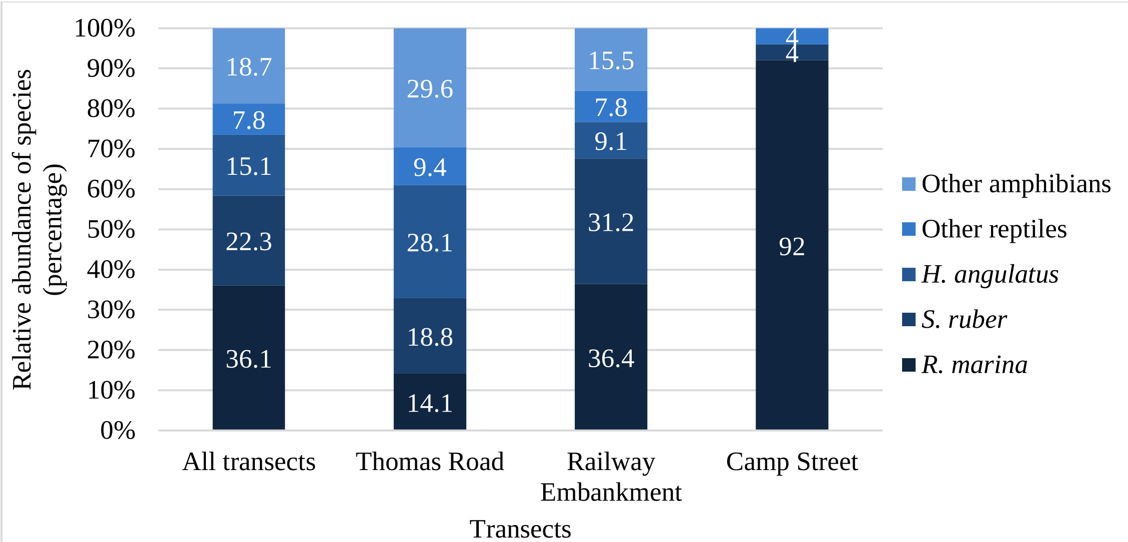


Figure 2. Relative abundance of species (by percentage) at all sites and at each site during the dry season (Aug-Oct)

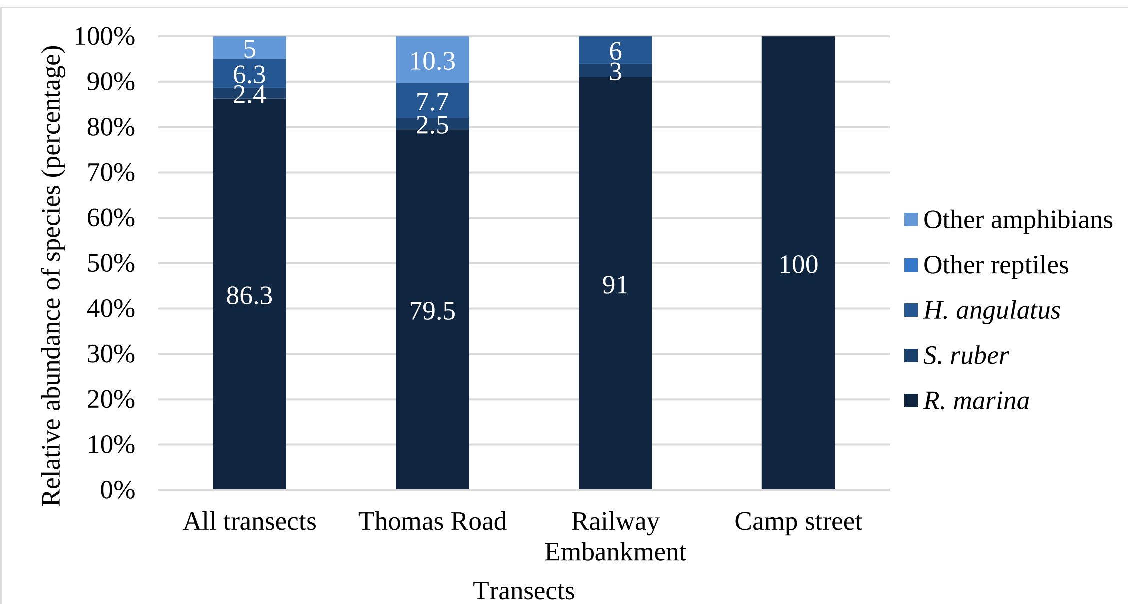


Figure 3. Relative abundance of species (by percentage) at all sites and at each site during the wet season (Nov-Jan)

Mortalities were predominantly encountered during the dry season (67.5%, n = 166) as the wet season comprised the remaining 32.5% (n = 80). Again, across all sites, amphibians constituted a majority of herpetofauna road mortalities (77.1%, n = 128), while reptiles constituted 22.9% (n = 38). However, the wet season showed a greater disparity where amphibians accounted for 93.7% (n = 75) of mortalities while reptiles represented 6.3% (n = 5). Regardless, the overall trends were maintained on this seasonal basis (Fig. 3, 4).

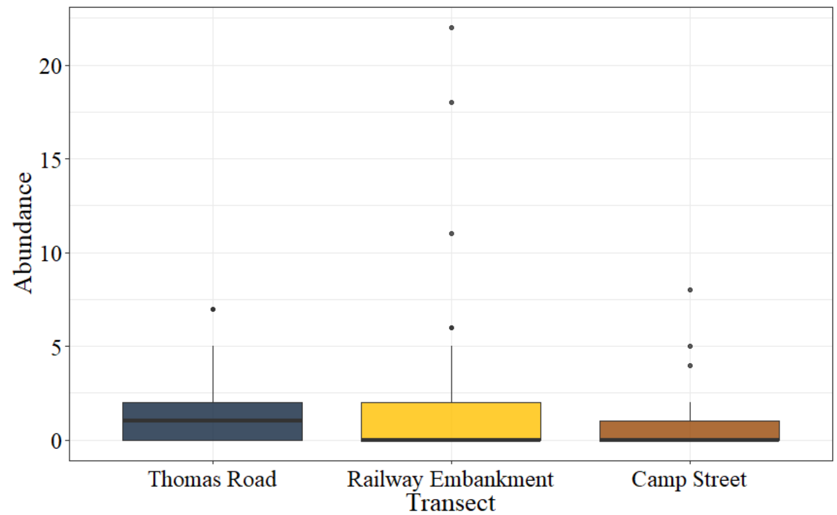


Figure 4. Number of specimens encountered at each site

Road mortality varied between the roads (H^2 = 17.001, p = 2e^{-4}), whereby Thomas Road (mean rank = 1.72) and Railway Embankment (mean rank = 1.83) experienced similar amounts of mortality (Fig. 8), but each over three times more than Camp Street (mean rank = 0.55). Furthermore, this illustrates that roads with seasonally flooded fields tend to experience higher levels of mortality than those without (W = 2529, p = 1.48e^{-5}), but there is no statistical discernable difference in the levels of mortality between roads with one or two seasonally flooded fields (W = 2119, p = 0.026).

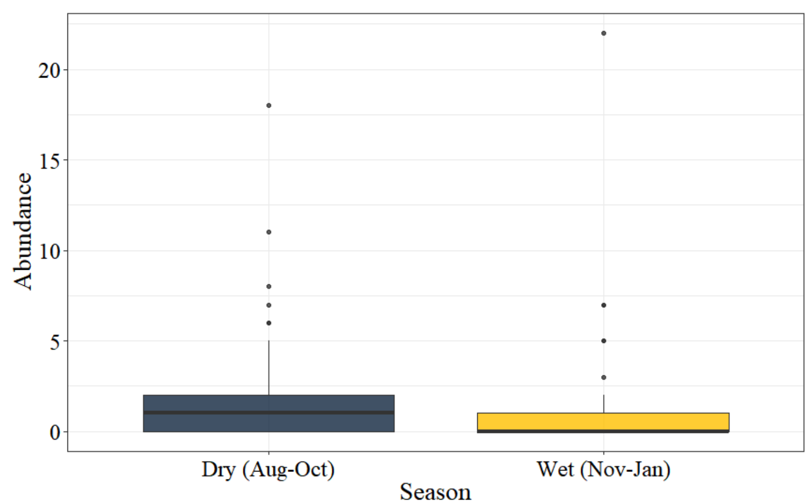


Figure 5. Number of specimens encountered in each season of sampling across all sites

Mortalities were twice as frequent in the dry season than the wet season (W = 5433, p = 4.54e^{-4}). In the wet season, half of the sampled days experienced no mortalities on any road, while the dry season half of the sampled days noted no more than one mortality on any road (Fig. 9). Furthermore, more mortalities generally occurred on a given day during the dry season (n = 7) than the wet season (n = 2). However, both seasons noted abnormally high amounts of mortality on a few days, up to 22 mortalities in the wet season and 17 in the dry season.

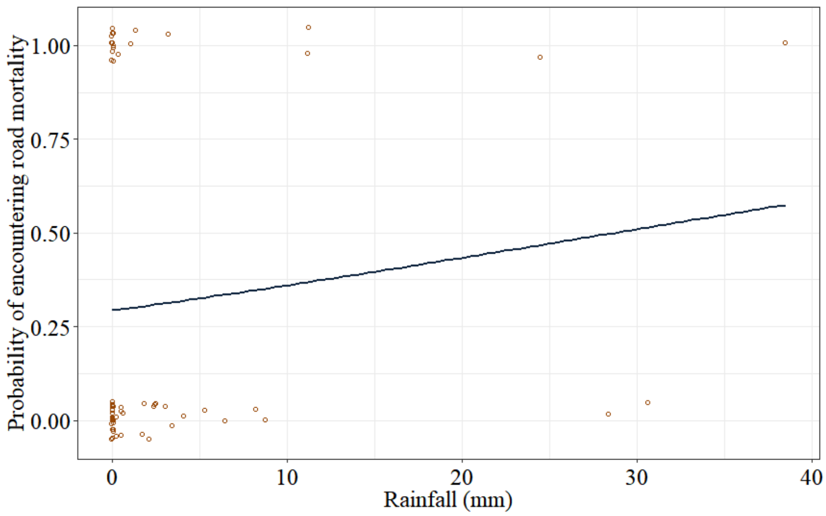
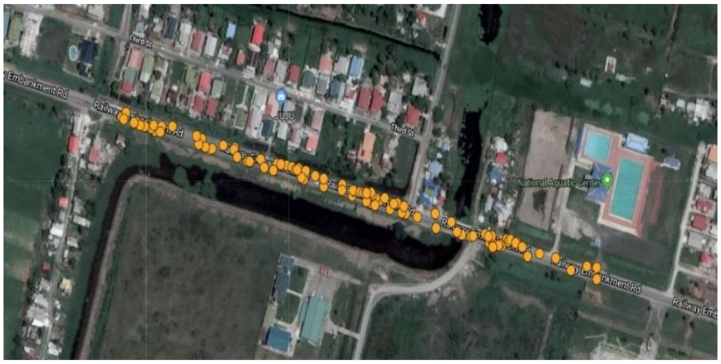


Figure 6. Rainfall and the likelihood of encountering road mortality at Camp Street

Despite the variation across seasons, changes in precipitation, temperature, and humidity mostly did not affect the likelihood of encountering road mortality on a given day. However, when there is no rainfall on Camp Street (Fig. 10), the likelihood of encountering herpetofauna road mortality is approximately 0.28 ($Z = -2.829$, $p = 4.13e^{-3}$). Similarly, variation in precipitation, temperature, and humidity, respectively, had no effect on the amount of mortalities encountered on a given day.

Map 1. Spatial distribution of road mortality along transect on Thomas Road



Map 2. Spatial distribution of road mortality along transect on Railway Embankment

Map 3. Spatial distribution of road mortality along transect on Camp Street

Although road mortality was ubiquitous along the roads, mortalities were generally clustered around vegetation and areas overlaid with concrete, and seemingly reduced in areas surrounding culverts and canals. Along Thomas Road (Map 1), mortalities occurred more often near to tree cover and high grasses, unlike the area surrounding the culvert. Similarly, at Railway Embankment (Map 2), mortalities clustered in areas with high grasses while the region immediately surrounding the canal experienced relatively less mortalities than other sections of the road. Although Camp Street (Map 3) also noted more mortalities towards tree cover and grasses, areas completely covered with concrete experienced higher mortalities than the rest of the road with open drains.

A simple model for road mortality rate was used, whereby mortality rate was calculated by total number of individuals divided by the distance sampled and the number of days sampled. For this study, the distance sampled at a site was a constant 0.5 km, and the number of days sampled per site was a constant sixty (60) days.

The road mortality rates were 3.67 individuals/km/day at Railway Embankment, 3.43 individuals/km/day at Thomas Road, and 1.10 individuals/km/day at Camp Street. These values roughly translate to 4 individuals/km/day at Railway Embankment, 3 individuals/km/day at Thomas Road, and 1 individual/km/day at Camp Street.

4. Discussion

Herpetofauna road mortality occurs ubiquitously in Georgetown, Guyana and predominantly affects amphibians. The most frequently encountered species, being the cane toad (*R. marina*), red-snouted tree frog (*S. ruber*), and brown-banded water snake (*H. angulatus*), were not found to be under imminent threat of extinction. Roads with seasonally flooded fields on one or both sides experience high mortality opposed to those without. Mortality occurs more frequently during the dry season, but it is seemingly unaffected by daily weather changes in either season.

Although road mortality is widespread, species diversity (16 species) was relatively low for pedestrian surveys[10,29,35]. This can be attributed to sampling similar habitats, leading to major overlap of species between areas, unlike studies that sampled various habitats[35]. Also, sampling effort may not have affected our value considering a similar study over 1000 days only yielded 18 species of snakes[10].

As expected, amphibian species are at higher risk of road mortality[14]. Bufonid species, especially, account for most road mortalities because they obtain higher population densities[10,27,35] and are less capable of successfully crossing roads[18]. Reptile mortalities are often composed largely of snake species[35], as road substrates slow down their movement[1]. Moreover, the brown-banded water snake constitutes approximately 85% of recorded snake mortalities, possibly due to the wide availability of its habitats in the study areas[24] and less road utilization by other species, such as the generally sedentary black-headed snake (*Tantilla melanocephala*)[26].

Only the green anaconda (*Eunectes murinus*), spectacled caiman (*Caiman crocodilus*), gold tegu (*Tupinambis teguixin*), and water coral (*Hydrops triangularis*) may be important to international conservation. The former three species are involved in trade, which coupled with road mortality can negatively affect long term population viability[22], but road mortality encountered for these species were only single instances so this may not be an issue. Meanwhile, water coral populations need to be monitored to inform conservation practices, because the population status and corresponding effect of road mortality are unknown.

Nevertheless, local conservation of herpetofauna species should be considered, especially because their urban populations tend to be relatively small. These species provide benefits to urban environments[2,7], preventing disease spread by reducing the pest population, and fueling their ecosystems as prey. Furthermore, their presence in an environment serves as an indication of ecosystem health[4,7].

This conservation may be more pressing for species that are more vulnerable. Species with less exposure to roads or with high abundance may require less concern[8,9,27]. However, analysis and relevant conservation must be done in a case-by-case scenario because species may be more vulnerable at one road than at another[9].

Furthermore, road mortality varies through space and time, and this needs to be considered to inform appropriate conservation practices[8]. Habitats provide incentives for crossing roads[23,28], so road mortality is higher along roads with seasonally flooded fields on one or both sides than without[22]. Road mortality is expected to be greater along the road with seasonally flooded fields on both sides than that with only one seasonally flooded field[22,31]. Railway Embankment being 1.5 times wider, having a higher speed limit, and possibly experiencing greater traffic volume may account for this greater road mortality[8] despite more individuals (live and dead) being encountered at Thomas Road. Additionally, the authors speculate that the habitat on the other side of Railway Embankment consisting of trees, tall grasses, and a large open drain may be equivalent to a seasonally flooded field in its capacity as a habitat for the encountered species. Moreover, road mortality is greater during conditions of the sampled dry season (higher daily temperature and humidity, and unexpected higher daily precipitation) as individuals search for foraging grounds or move from natal grounds and reptiles are more active with the higher temperatures[18,23]. Despite this, the wet season produces several instances of abnormally high road mortality, possibly due to mass migrations of amphibians to breeding pools[5,8,18]. However, road mortality is seemingly unaffected by changes in daily precipitation, temperature, or humidity, contradicting previous studies[15,18,35]. Thus, the authors propose that high removal rates of carcasses or small populations unable to exhibit variation to daily weather may explain the lack of relationships on this scale[9,33].

Regardless, rates of road mortality across Thomas Road and Railway Embankment indicated herpetofauna road mortality is occurring at relatively high rates as compared to other studies[10,29]. This may be due to high traffic volumes resulting in repressed populations, and thus lower road mortality rate[27], on the roads sampled in those studies. However, the road mortality rate at Camp Street matches those studies and lower than the other sites. While this can be attributed to repressed populations or high carcass removal rate[27], Camp Street may be similar to the roads in those studies because they have little natural habitat surrounding the road. Meanwhile, relatively high rates at Thomas Road and Railway Embankment may not only be owed to the presence of more natural habitat and larger populations[10], but the usage of pedestrian surveys as it records more individuals than driving surveys[23]. Additionally, these mortality rate values are conservative because the model used does not account for observer bias or carcass removal[10,30].

It should also be noted that this study does not provide a holistic view of road mortality within Georgetown, Guyana. While the roads were sampled thoroughly within the slated time-period, Georgetown contains more than 60 major roads with various other habitats not sampled in this study. Hence, these data are not representative of the entirety of Georgetown. Additionally, roads were only sampled at one interval throughout the day, so diurnal species may not be captured in this study due to carcass removal[10,30]. Moreover, some of the encountered individuals were unable to be identified to species, so values may be underestimated.

Nevertheless, this study shows that in this urban environment of Georgetown, Guyana, mostly species with stable global populations are affected by road mortality, and the most abundant of these are those better adapted to living in urban environments. Environmental factors, including surrounding habitat and seasonality, tend to affect road mortality, while others, such as daily weather patterns do not. As seasonally flooded fields are replaced by grasses and concrete, the mortality of species such as the cane toad (*R. marina*) are exaggerated, but mortality remains concentrated around sections of road used for crossing by herpetofauna. Moreover, the consistent traffic along these roads leave herpetofauna more vulnerable to road mortality during dry seasons, but seemingly reduce the impact of daily weather patterns in fluctuating road mortality. As a whole, the existing pressures on herpetofauna populations, such as habitat loss, are magnified by road mortality in Georgetown, Guyana, increasing their risk of extirpation.

5. Management Implications

Herpetofauna road mortality needs further research for effective conservation strategies across Georgetown. The sampling period is too short for trends to be accurately identified.[8] Thus, management practices should be general, and their employment needs to be carefully planned along all roads and monitored for their effectiveness. These can include reducing speed limits and constructing speed bumps, drift fences and road drainage tunnels.[8,16,28,34] Nevertheless, this study provides a basis for this future research and should be used to educate the public on herpetofauna road mortality within these areas.

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