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RESEARCH PAPER

INVESTIGATION ON THE ROAD MORTALITY OF ANURAN SPECIES ON THE IKORODU-EPE/EJIRIN-IJEBU ODE ROADS IN LAGOS AND OGUN STATES, NIGERIA

A. B. Onadeko[1] and **O. S. Ogoanah**[2]
[1]*Department of Zoology, Faculty of Science, University of Lagos, Akoka, Nigeria*
[2]*Department of Animal and Environmental Biology, University of Benin, Benin City, Nigeria*
Corresponding author: onadeko2002@yahoo.com / aonadeko@unilag.edu.ng

ABSTRACT
The effect of road kills of anuran species by vehicular traffic on the Ikorodu-Epe/Ejirin-Ijebu Ode road in Lagos and Ogun States was investigated. The mean traffic density on the road during the survey (between 18:30-20:30hr and 06:00 and 07:00hr) was 127±45 vehicles/hr, which ranged between 72 and 216 vehicles/hr. A total of 738 anuran road mortalities among eight species were recorded [661 (89.6%) were identifiable, while 77 (10.4%) were not]. Ptychadena pumilio had the highest mortality of 67±27.1 individuals, while Xenopus muelleri and Aubria subsigillata were the least susceptible to road kills. This respectively represented 2.66±1.5 and 2.66±3 individuals each. Most mortality (256 individuals) occurred on the section of the road bordered by grassland/tertiary vegetation. However there was no significant difference (at P> 0.05) between the anurans killed along the different vegetation structures bordering the road ($F_{2,21}$ = 0.415). About 473 live anurans belonging to five species were observed of which P. pumilio, the highest constituted the greatest number (81±42.9), while the least Hoplobatrachus occipitalis 7.3±4.2 was recorded. Both species had greater live counts than road kills compared to other anuran species that had greater road kills than live counts recorded. The greatest number of live anurans was recorded at where grassland/tertiary vegetation occurred. This constituted a total of 198 individuals (41.8%), while the least occurred at the secondary/primary vegetation which had 95 individuals (20%). However, the difference was not significant ($F_{2,12}$ = 0.600) at P> 0.05. It is evident that anuran migration is an integral part of their biological activity. However vehicular traffic sadly possesses a negative effect on this activity. Precautionary measures are necessary to reduce population decline and possible extinction of not only the anuran species but also other wildlife species, which is a positive direction in the conservation of biological diversity.

Keywords: *Vehicular traffic, anuran, mortality, vegetation, road kill, conservation*

INTRODUCTION
Apart from anthropogenic activities such as habitat destruction, industrialization and logging that lead to the reduction of anuran species, road kills have also been another vicious avenue of their demise. Mortality from road-kills may figure among the important causes of decline in amphibian populations and species extinction worldwide (Coelho *et al*., 2012). According to Mazerolle (2004), there has been

a rise in the development of roads in the various regions of the world in the last half of the 20th century to accommodate the growing needs for quicker transportation and the greater number of cars. This increment has a negative implication, as roads can be deadly especially for small-sized animals such as small mammals, reptiles and amphibians (Adams and Geis, 1983; Fahrig *et al*., 1995; Ashley and Robison, 1996; Haxton, 2000; Hels and Buchwald, 2001).

The creations of roads also have an adverse effect on amphibian habitation such as habitat loss and fragmentation (Carr and Fahrig, 2001). Fragmentation may lead to isolation of populations which again may result in a reduced population size. This is due to the fact that forest fragments may interrupt migration patterns and increase the accessibility of human incursions leading to a variety of activities that may negatively affect these populations. This might even lead to the risk of extinction of some species (Bennett, 1990). Many major roads stretch over thousands of kilometers or more. These areas on which these roads were created were once habitats to millions of animal species now rendered homeless, dead or may have even led to the extinction of some endemic species.

There are many other effects resulting from the creation of roads, such as the avoidance of roadside area due to modified behavior of organisms (deMaynadier and Hunter, 2000), aquatic and terrestrial communities adjacent to roads are modified due to the exhaust of vehicle or its run off (Turtle, 2000; Trumbulak and Frissell, 2000) and increased predator activity near roads (Boulet and Darveau, 2000).

Direct mortality is the ill-effect resulting from the creation of roads (Clark *et al*., 1998; Hels & Buchwald, 2001). Amphibians, due to their activity pattern, population structure and preferred habitats, aquatic breeding species are more vulnerable to traffic mortality than most other animal species. Meek (2012) observed that road-kill had a strong temporal aspect and was associated mostly with migratory movements. This is especially observed during seasonal migration by obligate pond-breeding amphibians that have to cross heavily travelled roads both to and from breeding sites (Holdgate, 1989). Mazerolle *et al*. (2005) observed both from field surveys and experiments that amphibians tend to remain immobile at the approach of a vehicle, which increases the chance of being killed.

In general, road traffic poses a severe threat to anuran species due to their slow capacity of movement (especially slow moving species), their inability to notice the danger from cars in time and to make successful attempts to avoid them. In Nigeria, many roads stretch over 100km or more in tropical regions that are homes to a high diversity of anuran species (Onadeko and Rodel, 2009). Because amphibians have been documented to decline from multiple threats world-wide including transportation infrastructure, which plays a role in this process, this study aimed 1) to detect road mortality of the anuran population along the Ikorodu-Epe/Ejirin-Ijebu Ode roads and 2) to examine whether road kills occurred randomly or at specific spots related to anuran species migratory pathways. The results of this study would aid in understanding the potential environmental impacts of more road creation on anuran populations.

MATERIALS AND METHODS

Study site and survey area

The study site is located in two states (Lagos and Ogun) in Nigeria. The area studied was on the Ikorodu-Epe/Ejirin-Ijebu Ode roads connecting the two towns of Epe (in Lagos state) and Ijebu-Ode (in Ogun state). The two lane road (one in each direction) is about 26km long and the width between 6-8m at different parts along it. Prominent towns located along this road include Irete, Odo-Jabore, Igisile and Ala-Ijebu. The vegetation along the road is dominated by grassland and tertiary growth occasioned by few secondary/primary forests and swamps (Plate 1).

Quantification of road kills and habitat association

Considering the seasonal variation of anuran activity, the surveys were conducted during the rainy season in the months of June, July and August 2010 and 2011. The survey was carried out mainly during precipitation or after heavy

Plate 1: Segments of road bordered by A) Secondary/primary forests and B) Grasses and tertiary vegetation

rains. The road was divided into portions of six segments based on vegetation and landscape types (Table 1). Location of each road segment was recorded at its midpoint with a Garmin Etrex Global Positioning System (GPS) recorder. There were five walks in each segment during the year where all dead anurans were recorded and collected (removed from the road), which allowed for easy counting of new mortality cases. Live specimens crossing during the survey were also recorded and identified. The walk was considered as a form of line transect where the road became the transect (Klauber, 1939). The anurans collected were identified to species level (if identifiable) and recorded as unidentified if such individual could not be categorized into genus or species.

Traffic intensity

We used vehicle encounter rate to represent traffic volume (Gu *et al.,* 2011). The vehicle encounter rate was calculated by the number of vehicle divided by the survey time. Hourly traffic levels were conducted during the period of survey and analysis applied to mean values (vehicles/h). Every vehicle (trucks, buses, cars and motorbikes) encountered during the survey was recorded.

Data analysis

Data on anuran killed and those recorded alive were collated separately to arrive at the total number of road kills and those crossing respectively at the different survey sites according to vegetation structure. The Analysis of Variance (ANOVA) was used to ascertain the significant differences at $P > 0.05$ exist between the numbers killed and the live specimens observed at the different vegetation structures bordering the road respectively.

RESULTS

During this preliminary survey, a total of 738 anuran road mortalities among eight species were recorded [661 (89.6%) and were identifiable, while 77 (10.4%) were not] for the years of 2010 and 2011 (Table 2). The mean traffic density on the road during the survey (between 18:30-20:30hr and 06:00 and 07:00hr) was 127 ±45 vehicles/hr, ranging between 72 and 216 vehicles/hr. *Ptychadena pumilio* had the high-

Table 1: Vegetation type, distance, time, location and duration of survey of the various road segments

Road segments	Length	Width	Vegetation/landscape type bordering road	Number of walks	Time of Survey (2010, 2011)	Global positioning System (GPS)
1	1 km	6m	Secondary/primary (A_{VEG})	5	June 18:30-20:30hr	060 37' 956'' N 030 53' 491'' E
2	500m	7m	Secondary/primary (A_{VEG})	5	June 06:00-07:00hr	060 46' 281'' N 030 52' 804'' E
3	1 km	8m	Grassland/tertiary (B_{VEG})	5	July 18:30-20:30hr	060 39' 491'' N 030 52' 361'' E
4	500m	7m	Grassland/tertiary (B_{VEG})	5	July 06:00-07:00hr	060 44' 783'' N 030 52' 615'' E
5	1 km	7m	Swamp/tertiary (C_{VEG})	5	August 18:30-20:30hr	060 37' 581'' N 030 55' 591'' E
6	500m	8m	Swamp/tertiary (C_{VEG})	5	August 06:00-07:00hr	060 38' 032'' N 030 54' 022'' E

A_{VEG} = (Type A-Vegetation) referred to secondary/primary vegetation, B_{VEG} = (Type B-Vegetation) referred to grassland/tertiary vegetation and C_{VEG} = (Type C-Vegetation) referred to swamp/tertiary vegetation.

est mortality recorded which was 67±27.1 individuals followed by *Amietophrynus regularis* (61.7±14.5 individuals), while the species least susceptible to road kills were *Xenopus muelleri* and *Aubria subsigillata* which had 2.66 ±1.5 and 2.66±3 respectively. Most mortality (256 individuals) occurred on the section of the road where the vegetation was mainly of the tertiary type of vegetation bordering the road.

In Fig. 1, it was observed that the highest road kills in the secondary/primary vegetation ($\underline{A_{VEG}}$) along the road was *Amietophrynus regularis* (46 individuals), while the least was *Xenopus muelleri* (1 individual). For the grassland/tertiary vegetation (B_{VEG}), *Ptychadena pumilio* had the greatest road kills (90 individuals). There were no records of *Hoplobatrachus occipitalis* and *Aubria subsigillata* killed in this section of the vegetation bordering the road. *A. regularis* also had the highest record of road kills in the swampy region with the least being the *Xenopus sp. A. regularis* had the highest percentages of individuals killed in both A_{VEG} and C_{VEG} vegetation bordering the road, which recorded 28.3% and 30.9% respectively (Fig. 2). *P. pumilio* had the highest mortality in the B_{VEG} which was 34.6%. The other anuran species (*H. occipitalis, A. subsigillata* and *X. muelleri*) generally had few percentages of road kills when compared to the others.

A total of 473 anurans belonging to five species were observed crossing the road during the survey (Table 3). The number of *P. pumilio* (81±42.9 individuals) was the greatest while the least was *H. occipitalis* (7.3±4.2 individuals). Both *P. pumilio* and *H. occipitalis* had greater live counts than road kills (Tables 2 and 3) compared to other anuran species that had more road kills than live counts recorded.

The highest crossing of anurans across the road was at B_{VEG} vegetation with a total of 198 individuals (41.8%), while the least occurred at A_{VEG} vegetation, which had 95 (20%) crossing. Fig. 3 shows that *P. pumilio* highest crossing in all the different

Table 2: Description of vegetation type bordering the road surveyed and anuran mortality record of Ikorodu-Epe/ Ejirin-Ijebu Ode road

Vegetation/ landscape type along road	Road segments	Anuran Species Killed in (June/July/August)								Total	Uniden-tified Speci-men
		Amiet-ophrynus regularis	*A. maculatus*	*Ptychadena pumilio*	*P. mascare-niensis*	*P. oxyrhyn-chus*	*Hoploba-trachus occipitalis*	*Xenopus muelleri*	*Aubria subsigillata*		
Secondary/ primary	1	08-10-15	07-04-05	08-07-09	07-05-04	02-03-02	01-02-02	00-01-00	00-01-01	104	8
(A_{VEG})	2	04-06-03	06-06-03	03-06-04	04-05-02	02-01-02	00-00-01	00-00-00	00-00-00	58 *162	13
Grassland/ tertiary	3	15-18-09	11-14-09	21-15-19	10-08-09	02-01-03	00-00-00	01-00-02	00-00-00	167	21
(B_{VEG})	4	08-05-06	03-05-04	14-09-12	07-06-04	03-02-01	00-00-00	00-00-00	00-00-00	89 ^256	4
Swamp/ tertiary	5	14-20-16	09-12-10	16-18-13	04-05-05	03-00-01	03-01-02	02-00-01	01-02-01	159	17
(C_{VEG})	6	10-07-08	04-04-07	10-07-10	01-04-03	01-01-02	01-01-00	01-00-00	00-01-01	84 $^{+}$243	14
Mean±SD		61.7±14.5	41±8.6	67±27.1	31±11.5	10.7±2.3	4.66±4.1	2.66±1.5	2.66±3	661	77

** = total number of identified anurans killed on 1.5km of road bordered by secondary and primary vegetation*
*** = sum total number of identified and unidentified anurans killed on 1.5km of road bordered by secondary and* primary vegetation
^ = total number of identified anurans killed on 1.5km of road bordered by grassland and tertiary vegetation
^^ = sum total number of identified and unidentified anurans killed on 1.5km of road bordered by grassland and tertiary vegetation
+ = total number of identified anurans killed on 1.5km of road bordered by swamp and tertiary vegetation
++ = sum total number of identified and unidentified anurans killed on 1.5km of road bordered by swamp and tertiary vegetation

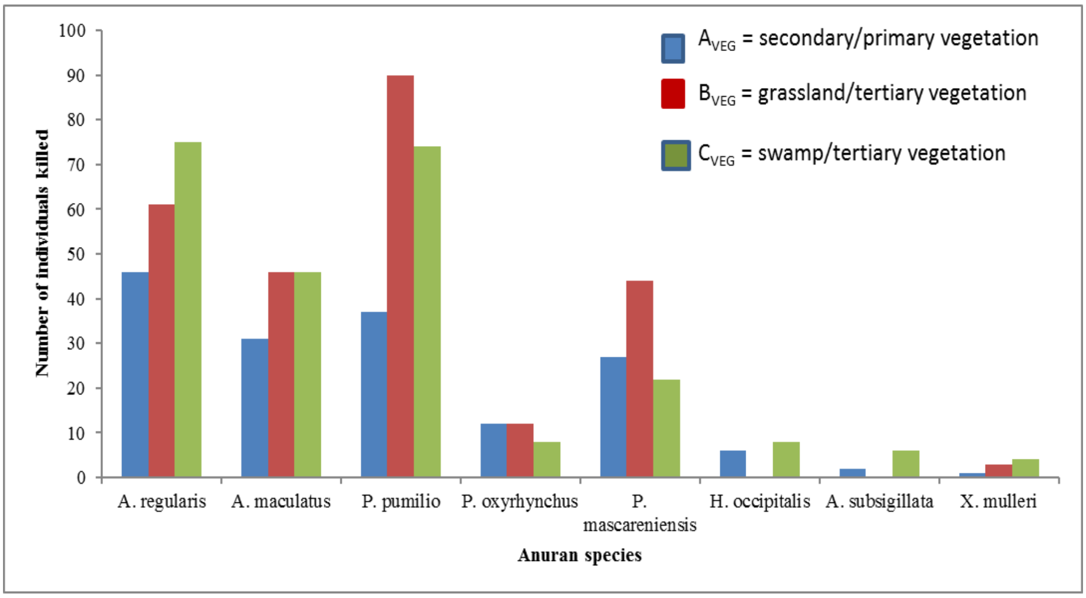

Fig. 1: Number of individual anuran species killed at different vegetation types bordering along Ikorodu-Epe/Ejirin-Ijebu Ode road

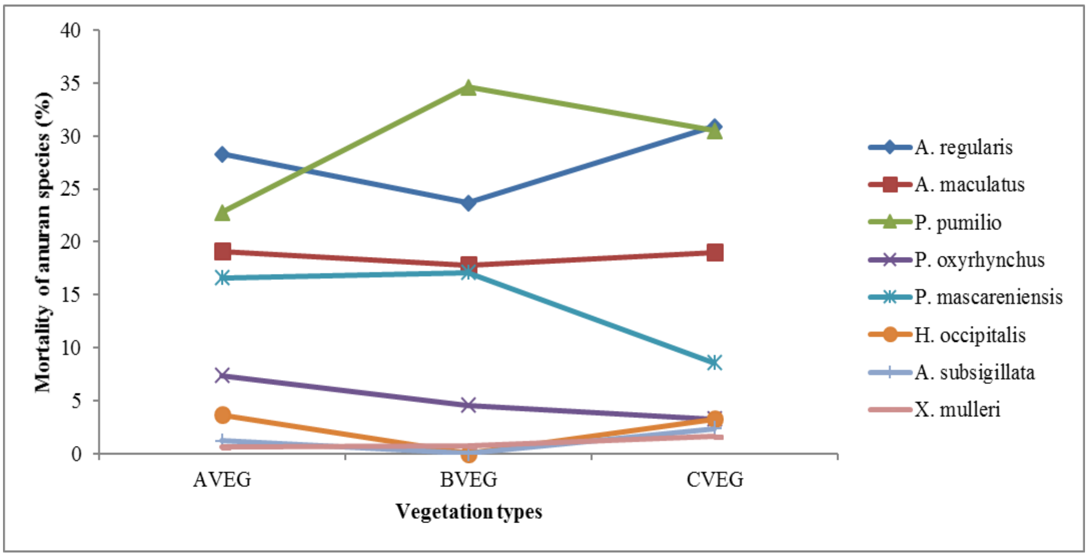

Fig. 2: Percentage mortality of anuran species observed at different vegetation structures bordering along the Ikorodu-Epe/Ejirin-Ijebu Ode road

Table 3: Description of road surveyed and live anuran species recorded along the Ikorodu-Epe/Ejirin-Ijebu Ode road

Vegetation/ landscape type bordering road	Road segments	Anuran Species Crossing in (June/July/August) *Amietophrynus regularis*	*A. maculatus*	*Ptychadena pumilio*	*P. mascareniensis*	*Hoplobatrachus occipitalis*	Total	Sum Total
Secondary/ primary (A_{VEG})	1	04/02/03	01/02/06	09/12/11	03/05/08	01/03/00	70	95
	2	02/03/02	02/00/03	03/04/03	01/00/01	01/00/00	25	
Grassland/ tertiary (B_{VEG})	3	07/06/09	03/03/02	30/18/21	05/09/04	00/01/00	118	198
	4	02/01/01	03/02/01	21/16/21	03/03/01	01/02/02	80	
Swamp/ tertiary (C_{VEG})	5	09/07/10	06/04/04	16/16/14	03/08/06	02/01/03	109	180
	6	04/05/03	06/08/07	12/09/07	00/02/02	02/01/03	71	
Mean±SD		26.7±11	21±12.1	81±42.9	20.7±4.5	7.3±4.2		473

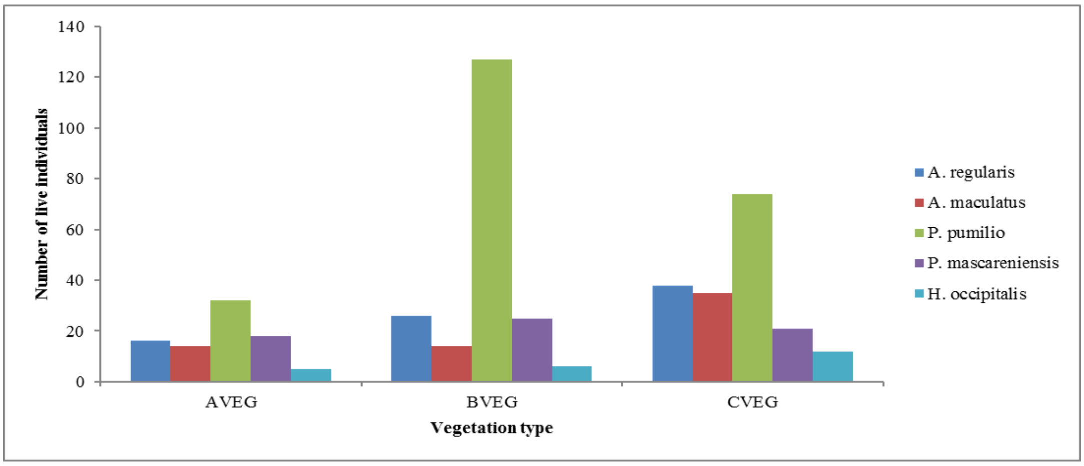

Fig. 3: Number of live anuran species at the different vegetation structures bordering the Ikorodu-Epe/Ejirin-Ijebu Ode road

vegetation structures bordering the road while *H. occipitalis* was the least.

ANOVA shows that there was no significant difference at P> 0.05 between the anurans killed along the different vegetation structures bordering the road ($F_{2,21}$ = 0.415). The greatest numbers of live anurans were recorded where grassland/tertiary vegetation occurred, which constituted a total of 198 individuals (41.8%), while the least occurred at the secondary/ primary vegetation, which had 95 individuals (20%). However, the differences were not significant ($F_{2,12}$ = 0.600) at P> 0.05.

DISCUSSION

Our preliminary data on anuran road-kills revealed that vehicular traffic activity has a huge effect on anuran survival and diversity. Because of increasing human population and the need of adequate transportation, construction of roads are often situated along the edge of geographic features that provide different habitats to anuran species, breeding and foraging sites. In most cases, the road construction divides or cuts habitats into smaller fragments (Dodd *et al*., 2004) which cause road-kill problems as long as the animals are active (Puky, 2003). These situations represent a true picture of south-western Nigeria, a tropical nation that supports a high diversity of anuran population (Onadeko and Rodel, 2009). However, most surveys are underestimated, as some road-kills are likely to be lost due to scavenging, total obliteration by vehicular impact or some individuals may die off the road where they are not seen.

The spatio-temporal pattern of anuran road-kill is influenced by various factors, one of which is habitat characteristics. From our results, the highest mortalities occurred along the road bordered by grasses and tertiary vegetations despite the absence of two species (*H. occipitalis* and *A. subsigillata*) in this section of vegetation. This was due to the high occurrence of *P. pumilio* which is the most dominant species in that environment. They inhabit mostly the grasses close to the roadside and during rains (especially at night); they were observed crossing the road frequently. Many of these species were killed as a result of their huge population compared to the other anuran species. Similar observations by Ashley and Robinson (1996) also revealed that *Rana pipens* road kill was significantly associated with roadside vegetation. According to Gu *et al*. (2011), wet grassland is one of the most important habitats for amphibians. They observed that high population density and frequent activity of the amphibian in such areas contribute to the large number of road mortalities.

Water is another important factor associated with anuran movement. The swampy environment bordering the road had the second greatest mortality rate. *A. regularis* had the highest mortality, followed closely by *P. pumilio* then *A. maculatus.* This finding agrees with that for Meek (2012) that in Western France most road kills were recorded for the common toad *Bufo bufo* that constituted 39% of all mortalities. Most anuran temporal movement pattern is based on the availability of water mostly for breeding purposes or hibernation during the dry season. The moist swampy environment provides avenues for such sought habitats, hence, the high mortalities observed in this section of the road. This phenomenom was demostrated in the studies done by Beshkov and Jameson (1980) on *Bombia varigata* that amphibian movement was often associated with water.

In this study, it was revealed that secondary/primary vegetation bordering the road had the lowest mortality rate compared to the other vegetation structures, though there was no significant difference ($P > 0.05$) among the species' mortality. This shows that the road kills of anuran species are relatively the same along the different vegetation structures owing to the fact that the entire environment is tropical in nature and it harbours a huge diversity and abundance of these species. The secondary/primary vegetation may have a slightly lower mortality results since it is a more stable environment and some anuran species may not necessarily need to migrate to find more suitable environmental conditions. As observed by Meek (2012), habitat type is one of the parameters largely associated with inter-specific differences in road-kills including extent of movement and precipitation.

There was a significant difference ($P < 0.05$) of live counts among anuran species from the results of the entire survey period. This maybe due to the difference in the relative abundance and activity pattern of the various species. For example, *P. pumilio* was the most abundant in all the vegetation structures which maybe due to their high abundance. *H. occipitalis* was the least abundant and since they are semi-aquatic species, this might limit their activities in the terrestrial environment.

Within the same duration of the survey time, the mortalities and live crossing of different anuran species were recorded. Some species great mortalities but low live counts, while some had low mortalities and great live counts (Tables 2 and 3). For example, *A. regularis* had 182 road kills and 80 individuals crossing the road while *P. pumilio* had 201 road kills and 243 live counts. Out of the total individuals of each species, *A. regularis* and *P. pumilio* had 69.4% and 45.2% mortality respectively. The difference in the percentage mortality of these species might be due to their morphological structure and activity. *A. regularis* are much larger and slower than *P. pumilio* that are smaller in size and faster. Despite the fewer movements of the toads across the road, more might be killed as a result of large body size, which caused slow movement. There were more movements of the frogs but fewer were killed due to their smaller size and faster movement across the road, which reduced the risk of being killed. This finding agrees with most authors who stressed that velocity is an important factor (Rosen and Lowe, 1994; Schlupp and Podloucky, 1994; van Langevelde and Jaarsma, 1997), as most vulnerable species are day-active and slow moving species. Hels and Buchwald (2001) also clearly stated that one of the three most important factors determining species vulnerability to road mortality is the velocity of the species. This reinterates the fact that *P. pumilio* is smaller with a greater velocity than *A. regularis* that is larger, having a slower velocity. Therefore *A. regularis* will have a greater mortality rate than *P. pumilio*, since its velocity rate of crossing the road is slower.

CONCLUSION AND RECOMMENDATION

It is no doubt that this study provides evidence that vehicular traffic posses a negative effect on anuran population within the tropical region. Anurans maybe the vertebrate group with the highest mortality or most impacted worldwide from road kills.

In trying to reduce anuran road mortality, the construction of barriers in conjunction with underpasses or tunnels could separate vehicles from these organisms (Close, 1995; Ryser and Grissenbacher, 1989; Kobylarz, 2001; Puky, 2003), which would allow them to travel between different habitats. The public, especially drivers, could be educated and alerted with anuran crossings through the posting of road signboards in special areas with high diversity and abundance of anuran population. These precautions could go a long way in helping to reduce the population decline and possible extinction of not only some of the anuran species but also other wildlife species, which is a positive direction in the conservation of biological diversity.

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APPENDIX I

Statistical analysis of different vegetation with anurans mortalities

Descriptives

Species

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	8	20.2500	17.23576	6.09376	5.8405	34.6595	1.00	46.00
2	8	32.0000	33.45359	11.82763	4.0321	59.9679	.00	90.00
3	8	30.3750	30.47218	10.77354	4.8996	55.8504	4.00	75.00
Total	**24**	**27.5417**	**27.23645**	**5.55962**	**16.0407**	**39.0426**	**.00**	**90.00**

ANOVA

Species

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	648.583	2	324.292	.415	.666
Within Groups	16413.375	21	781.589		
Total	**17061.958**	**23**			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Species

	(I) vegetation	(J) vegetation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	1	2	-11.75000	13.97846	.410	-40.8198	17.3198
		3	-10.12500	13.97846	.477	-39.1948	18.9448
	2	1	11.75000	13.97846	.410	-17.3198	40.8198
		3	1.62500	13.97846	.909	-27.4448	30.6948
	3	1	10.12500	13.97846	.477	-18.9448	39.1948
		2	-1.62500	13.97846	.909	-30.6948	27.4448

APPENDIX II

Statistical analysis of different vegetation with live anurans crossing

Descriptives

Species

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
1	5	18.4000	14.09965	6.30555	.8930	35.9070	4.00	42.00
2	5	39.6000	49.55098	22.15987	-21.9257	101.1257	6.00	127.00
3	5	36.0000	23.71708	10.60660	6.5514	65.4486	12.00	74.00
Total	**15**	**31.3333**	**31.79548**	**8.20956**	**13.7256**	**48.9411**	**4.00**	**127.00**

ANOVA

species

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1286.933	2	643.467	.600	.564
Within Groups	12866.400	12	1072.200		
Total	**14153.333**	**14**			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Species

	(I) vegetation	(J) vegetation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
LSD	1	2	-21.20000	20.70942	.326	-66.3219	23.9219
		3	-17.60000	20.70942	.412	-62.7219	27.5219
	2	1	21.20000	20.70942	.326	-23.9219	66.3219
		3	3.60000	20.70942	.865	-41.5219	48.7219
	3	1	17.60000	20.70942	.412	-27.5219	62.7219
		2	-3.60000	20.70942	.865	-48.7219	41.5219