Road mortality of freshwater turtles in Palawan, Philippines

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https://doi.org/10.69721/TPS.J.2019.11.1.08

ABSTRACT

The impact of road mortality on freshwater turtle populations on a global scale could be significant enough to cause the extinction of sensitive species. Essential data on roadkill abundance, composition, spatial patterns, and temporal distribution is needed for crafting mitigation strategies. To provide such information, a survey was conducted along the highway section (67 km) connecting Aborlan and Puerto Princesa City in Palawan, Philippines. Collection of data was done four times a month from January 2010 to December 2015. A total of 127 road-killed turtles belonging to two species of the Geoemydidae family were recorded, 102 (80.3%) of which were classified as the Southeast Asian Box Turtle (*Cuora amboinensis*) and 25 (19.7%) were identified as the Asian Leaf Turtle (*Cyclemys dentata*). The increase in road traffic noticed during the survey period possibly caused the corresponding increase in the roadkill counts of *C. amboinensis*, which is a more common species. Concurrently, the decline in the road-kill counts of *C. dentata* may indicate a severe drop in the population of this less common species. Roadside habitat types, time of the day, and presence of water bodies are found to be important predictors of road-killed turtles. High densities of road-killed turtles clustered in short segments of the road which identified as hotspots. Effective mitigating measures to curve down the impact of road mortality on turtle populations must be implemented and focusing the conservation strategies along the hotspots is considered an efficient and practical option.

Keywords: freshwater turtle, roadkill, road ecology

INTRODUCTION

The continuously expanding road networks traversing across the different terrestrial ecosystems cause considerable habitat degradation and fragmentation. To some extent, paved roads act as a barrier that causes separation of wildlife populations across the habitat fragments. Keyghobati (2007) explained that prolong genetic isolation brought by habitat fragmentation has an overall detrimental effect on the wildlife population. Likewise, the growing number of motor vehicles pose direct threat to wildlife species that cross the roads in search for food, mate, shelter and breeding grounds (Gibbs and Shriver 2002; Ament et al. 2007; Coelho et al. 2008; Glista et al. 2008; Bernardo 2011; Kociolek et al. 2011; Langen et al. 2012; Cook and Blumstein 2013; Crump et al. 2016). In some places where large wild

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animals are involved in vehicle collisions, the accidents caused considerable damage to vehicles and sometimes even result in human fatalities. Litvaitis and Tash (2008) suggested that the incidence of a wildlife-vehicle collision is not only a threat to the survival of wildlife population, but is also a concern for human safety, especially if it involved large wildlife species such as deer and moose.

Wildlife roadkill cases are getting more common nowadays. Restaurants offering meals prepared from the meat of road-killed wildlife are gaining popularity in countries where large mammals are involved in vehicle collisions. The increasing number of wildlife mortalities resulting from vehicle collisions also caught the attention of some scientists and conservationists. Some of them investigated the different aspects of road ecology to understand the causes (Cook and Blumstein 2013; Sosa and Schalk 2016), impacts (Coelho et al. 2008; Glista et al. 2008; Kociolek et al. 2011) and to come up with possible mitigating measures that can be implemented to curve down the volume of affected wildlife (Van Manen et al. 2001; Schutt 2008; Ford et al. 2011; Rytwinski et al. 2016).

Among the wildlife species affected by vehicle collisions, freshwater turtles are considered as one of the most frequently affected (Gibbs and Shriver 2002; Steen and Gibbs 2004; Langen et al. 2007; Langen et al. 2012). Being sluggish, turtles are exposed to road traffic much longer as compared to other fast moving wildlife. Moreover, the cryptic coloration of most turtle species makes them less noticeable to drivers, particularly during nighttime.

Turtles are also usually associated with bodies of freshwater (Lim and Das 1999; Diesmos et al. 2008; Schoppe 2008). Thus, the proximity of the road to freshwater habitats such as swamps, ponds, rice fields, streams, and rivers is one of the important predictors of road mortality among turtles (Langen et al. 2012). The high density of turtles crossing along particular road segments and the high number of vehicles passing along the area might result to a high concentration of road-killed turtles on specific locations called hot spots (Langen et al. 2007). Furthermore, they also mentioned that road mortalities along the hotspots might reach a scale that could endanger the local turtle population. Similarly, Gibbs and Shriver (2002) declared that the resulting mortalities from the simulation of turtle movements in areas with many road networks and high traffic volume are high enough to cause substantial population decline in the area.

Road mortality is another addition to the countless threats that greatly affect the turtle population in the wild. Some of the persistent problems that take a significant toll on turtle populations are global warming (Converse et al. 2005), habitat destruction (Sirois et al. 2014), food and medicine trade (Cruz et al. 2007; Diesmos et al. 2008; Schoppe 2008; Krishnakumar et al. 2009) and pet trade (Cruz et al. 2007; Diesmos et al. 2008; Schoppe 2008;

Lyons et al. 2013). The declining trend of the turtle population globally is much alarming as they are poorly studied and are given less conservation priority.

The prospects of developing more road networks soon coupled with the increasing volume of road traffic in places with high biological diversity such as the island of Palawan, highlight the need to study the impact of vehicle-induced mortality to freshwater turtles and other wildlife species as well. Palawan is considered by many as the last frontier in the Philippines because of its pristine environment and unique biological diversity. The province is also endowed with many beautiful tourist spots and abundant natural resources which attract a huge number of tourists and migrants annually. The ballooning population of the province is estimated to be growing at a rate of 2.66% annually (NSO 2013). Developments in the different municipalities resulted in clusters of developed areas in both the southern and northern part of the province. To reach these sprawling developments in the countryside, more road networks are built. Although most of the roads cut across a variety of habitat types such as forest, wetlands, grasslands and mixed agricultural areas, very few studies mentioned the incidence of roadkills in the province (Esselstyn et al. 2004; Tabaranza et al. 2008; Bernardo 2011).

Preliminary investigation of wildlife road mortalities along the national highway in central Palawan revealed an overwhelming number of road-killed bird and mammal species (Bernardo 2011). However, the previous study did not include reptiles particularly freshwater turtles in the report. Hence, the study was conducted to provide baseline information on species composition, relative abundance, spatial patterns, and temporal trends of road-killed turtles. It also identified important predictors of road mortality among freshwater turtles. Finally, road segments with a high number of roadkills were identified as roadkill hotspots. These pieces of information could be used in crafting effective mitigation strategies in the future.

METHODS

Time and Place of the Study

The roadkill survey was conducted in the national highway segment stretching between Puerto Princesa City and the municipality of Aborlan in the province of Palawan, Philippines. The concrete road which spans to about 67 km along the eastern coast of the province served as the transect for the survey. The selected road section traverses different kinds of habitats such as forests, grassland, lowland rice fields, a mixed agricultural area, ponds, creeks, rivers, and streams. The survey was conducted four times a month at regular intervals and lasted from January 2010 to December 2015.

Data Collection

The survey was done on board a motorcycle travelling at a regulated speed of 40 km hr^{-1}. All the freshwater turtles killed by motor vehicles found lying in the road were counted, identified, and the exact locations were determined using a Global Positioning System (GPS) transceiver. Roadside habitat types which are categorized as either forest habitat or open habitat (no trees or very few stranding trees) and the presence of bodies of water were also determined. Data gathering was made early in the morning, to record the nighttime roadkills and another run in the afternoon to record daytime roadkills. Specimens recorded during the morning run were removed from the road to avoid being counted again in the afternoon run. The combined counts of the morning and afternoon run comprised the sample.

Data Analysis

The roadkill data were reported using descriptive statistics, which includes frequency counts and percentages. The relationship between times of the day when the collision happened (daytime and nighttime), and roadside habitat types (forested habitat and open habitat) with the species of road-killed turtles were analyzed using the Chi-square test of independence. Road-kill hotspots were identified based on the abundance and clustering of roadkills along specific road segments.

RESULTS

The only two species of freshwater turtles known to be present in the study area were both recorded during the survey. These are the Southeast Asian Box Turtle (*C. amboinensis*) and Asian Leaf Turtle (*C. dentata*), both of which were members of the Geoemydidae family. A total of 127 road-killed freshwater turtles were recorded during the six years' survey period. Among these, 102 (80.3%) were identified as the Southeast Asian Box Turtle (*C. amboinensis*) while the remaining 25 (19.7%) were identified as the Asian Leaf Turtle (*C. dentata*) (Table 1).

The data clearly show that relatively more *C. amboinensis* individuals were killed by motor vehicles than *C. dentata* annually within the 6-year sampling period. Moreover, the total number of road-killed turtles within the six-year sampling period showed a substantial increase of 26%. However, the observed frequencies of the two recorded species exhibited different trends.

All road-killed freshwater turtles were adults except for one specimen of a juvenile *C. amboinensis*. The sex distribution of the roadkills was not included in the analysis as many samples were crushed, and sex identification becomes difficult and may lead to erroneous results. Roadkills were easily

identified down to species level because of highly recognizable body markings. The *C. amboinensis* can be easily identified by the yellow-green lines marking the head region while the *C. dentata* has unmistakable orange stripes in the head region and the plastron is yellowish brown with many dark-brown stripes (Figures 1 and 2).

Table 1. Abundance of the road-killed turtles recorded in the study area for the sampling years 2010 to 2015.

Turtle Species	Sampling Year						Total	%
	2010	2011	2012	2013	2014	2015		
Coura amboinensis	13	15	14	18	19	23	102	80.3
Cyclemys dentata	6	5	7	4	2	1	25	19.7
Total	19	20	21	22	21	24	127	100

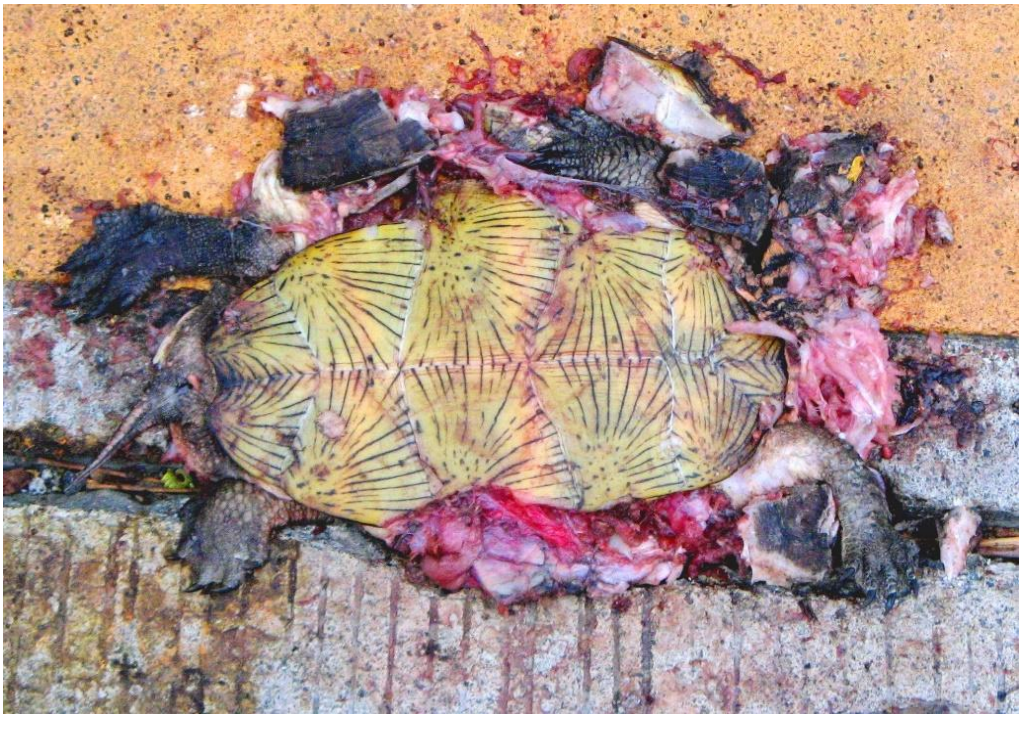

Figure 1. Road-killed Asian Leaf Turtle (*Cyclemys dentata*).

Figure 2. Road-killed Southeast Asian Box Turtle (*Coura amboinensis*).

The frequency of *C. amboinensis* killed by motor vehicles showed a noticeable increase of 77% from 2010 to 2015. In contrast, the frequency of road-killed *C. dentata* exhibits a remarkable decline of 83% within the six sampling years.

The study unfolded that the two species of road-killed turtles were mostly found in road sections with different roadside habitat types. Among the 25 road-killed *C. dentata* that were recorded during the survey, 23 carcasses (92%) were found in road sections near streams with forest cover. Meanwhile, the remaining two specimens (8%) were recorded in the sections of the road with non-forested roadside habitat but closed to slow flowing rocky streams which are connected to the nearby forest in its upstream and downstream sides. On the contrary, most of the *C. amboinensis* carcasses were found in more exposed roadside habitats such as creek, ponds, rice fields, waterlogged grassland, and small exposed streams. Out of the 102 road-killed *C. amboinensis*, 89 carcasses (87%) were found in non-forested roadside habitats. The Chi-square test of the data revealed a significant relationship between the road-killed turtle species and roadside habitat types [$X2(1, N=127)=62.09, p<.05$] (Table 2).

Table 2. Chi-square test for species of road-killed turtles by roadside habitat types [$X^2(1,N=127)=62.09$, $p<.05$].

Species of road-killed turtles	Roadside Habitat Type		Total
	Forested roadside habitat	Non-forested roadside habitat	
Coura amboinensis	13	89	102
Cyclemys dentata	23	2	25
Total	36	91	127

The study also revealed that most of the carcasses found during the survey were accidentally killed during nighttime (1800 to 0600). Out of the total of 127 recorded roadkills, 115 (90.5%) were accidentally killed during the night. Both of the affected species followed a similar pattern. Among the 102 *C. amboinensis* carcasses, 91 (89%) were road-killed during nighttime. Similarly, out of the 25 recorded carcasses of *C. dentata*, 24 (96%) were also road-killed during the night. The Chi-square test of the data revealed a significant relationship between the turtle species and the time of the day when the vehicle collision happened [X2 (1, N=127)=147.41, p<.05] (Table 3).

Table 3. Chi-square test for species of road-killed turtles by the time of day when the road collision happened [X^2 (1,N=127)=147.41, p<.05] .

Species of road-killed turtles	Time of the day when the road collision happened		Total
	Daytime	Nighttime	
Coura amboinensis	11	91	102
Cyclemys dentata	1	24	25
Total	12	115	127

The spatial distribution of road-killed turtles was analyzed by plotting the coordinates of all the spotted roadkills in every one-kilometer segments of the surveyed road using the Global Positioning System (GPS). The results revealed that all the road-killed turtles were found only in 38% of the road segments hence exhibiting a non-random pattern. Moreover, it was also found out that the cases of turtle and vehicle collisions clustered in high densities along specific short segments of the road with nearby bodies of water such as streams, ponds, canals, rice fields, swamps, and waterlogged flats. These

specific road segments with a high density of roadkills were considered as roadkill hotspots for freshwater turtles (Figure 3).

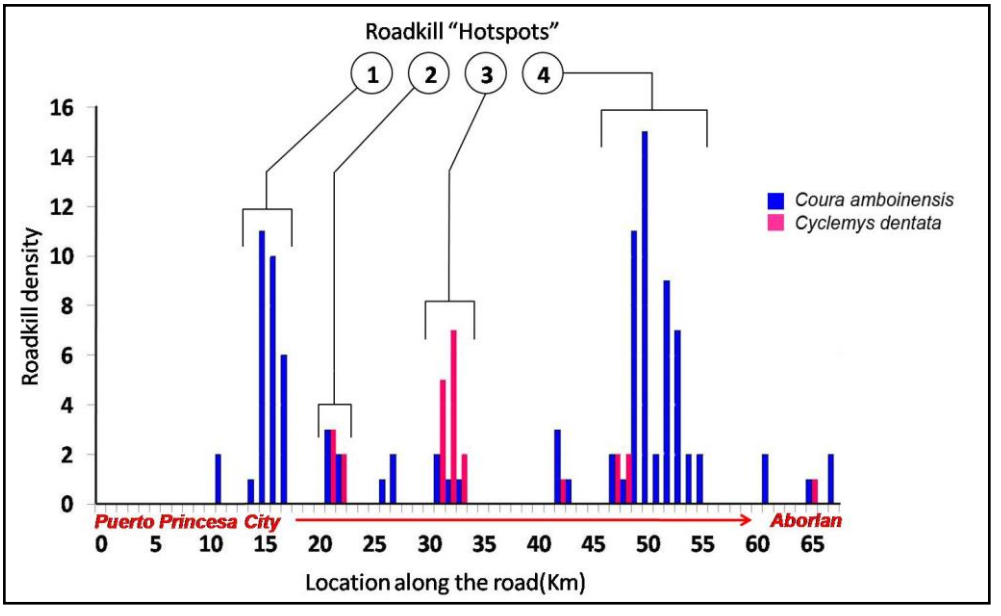

Figure 3. Abundance of road-killed turtles along specific segments of the road connecting Puerto Princesa City and Aborlan in Palawan for sampling years 2010 to 2015.

DISCUSSION

The result of the study revealed that several numbers of freshwater turtles were killed in motor vehicle collisions. Considering the frequency of data collection, the findings of this study only showed a small proportion of the total number of individual turtles affected by vehicle collisions. The annual figure is expected to be much higher if daily roadkills would be accounted.

Out of the four known species of freshwater turtles in Palawan, only two species were recorded in the study area. The roadkill data confirmed the presence of *C. amboinensis* and *C. dentata* in this particular geographic location. Two other freshwater turtles, namely *Dogania subplana* and *Siebenrockiella leytensis*, which are also known to be found in Palawan (Diesmos et al. 2008) were not recorded in the study area. *Dogania subplana* is commonly found in the southern municipalities of Palawan while the *S. leytensis* is mostly found in the northern part of Palawan (Diesmos et al. 2008). These species were not found in the study area despite rigorous searching in the roadside habitats.

Within the six years study period, *C. amboinensis* always have higher annual roadkill counts than the *C. dentata*. One of the possible reasons for the disparity of roadkill counts between the two species of turtles is the presence of more *C. amboinensis* individuals in the study area relative to the *C. dentata* (pers. obs.). Diesmos et al. (2008) noted that *C. amboinensis* is a reasonably common species in areas within its habitat range. This species is also known to thrive in a variety of natural and man-made bodies of water (Lim and Das 1999; Diesmos et al. 2008; Schoppe 2008, Schoppe and Das 2011). On the other hand, Diesmos et al. (2008) stated that the *C. dentata* is a relatively less common species that is usually restricted to bodies of water associated in forested habitats and less likely found in altered habitats and man-made bodies of water.

The increasing trend of roadkill incidences involving *C. amboinensis* could be attributed to the increase in the volume of vehicles traversing the road section surveyed. Based on personal observation and accounts of terminal dispatchers, passenger van drivers and police officers manning the checkpoints, a noticeable increase in road traffic were observed within the six-year survey period. The rise in motor vehicles plying the road was primarily contributed by passenger shuttle vans, delivery vans, and new private motor vehicles. This observation concurs with the results of the simulation of collision models done by Litvaitis and Tash (2008) where they asserted that the increasing traffic volume would result to a corresponding increase in the estimated probability of wildlife and vehicle collisions and the risk for slow moving animals such as turtles are considerably higher. However, given that the actual counting of motor vehicles was not included in this study and the roadkill cases of *C. dentata* showed a declining trend, then the impact of traffic volume remains a possible answer that needs to be verified.

Contrariwise, the trend of *C. dentata* roadkill cases declined within the six-year sampling period. One of the possible explanations is that a considerable reduction in the population of *C. dentata* along the roadside habitats could have occurred during the survey period, and it affected the density of the roadkills. The abundance of this turtle species in habitats near the road may not be as many as that of the *C. amboinensis* which can thrive well in man-made habitats (Lim and Das 1999; Diesmos et al. 2008; Schoppe 2008). Several studies in the past attested that high densities of road collisions adversely affected the population of sensitive turtle species (Gibbs and Shriver 2002; Beaudry et al. 2008; Litvaitis and Tash 2008). The difference in size and connectivity of habitats preferred by these species of turtles are also presumed to affect the roadkill patterns. The habitat preference of the *C. dentata* appears to be restricted to areas with bodies of water and have relatively good forest cover. This species usually prefers swamps and small streams with forest vegetation (Diesmos et al. 2008). The distance of separation and lack of connectivity between these streams limit the

replenishment of new individuals, particularly on roadside populations which are severely affected by vehicle collision mortalities.

On the other hand, open wetlands preferred by *C. amboinensis* are usually wide and connected to other wetlands far from the road. In-migration of turtles from adjacent habitats to roadside areas is likely contributing to the stability of *C. amboinensis* population in the roadside habitats. Langen et al. (2012) asserted that the population declines resulting from road mortality would be less if the roadside habitats have high connectedness with other suitable wetland areas because the spillover of individuals moving in from distant habitats will restock the roadside population.

Another point to consider is the habitat modification that took place in some portions of the surveyed road. Within the 6-year sampling period, it was noticed that some portions of the forested roadside habitats underwent agricultural and agroforestry developments. Clearing the roadside forest vegetation could have driven the *C. dentata* turtles in the upstream or downstream part which is already far from the road. This scenario is plausible because, unlike the *C. amboinensis* which prefers many open wetlands, the *C. dentata* is associated with forested streams and does not thrive well in human-altered habitats (Diesmos et al. 2008).

The relatively high incidence of road-killed turtles despite low traffic volume during nighttime is an indication that more turtles cross the road during the night. Although *C. amboinensis* is also active at daytime, the hot road pavement most likely prevented the turtles from crossing the road during the day. Among the 11 recorded *C. amboinensis* killed during the daytime, 10 (91%) were found during rainy or extremely cloudy days wherein the road pavement is relatively cool and wet. The only *C. amboinensis* roadkill specimen recorded during the sunny day was most likely killed in the morning when the temperature of the road pavement is still tolerable. Similarly, the only recorded *C. dentata* which died during daytime was also recorded on a rainy day when the nearby stream was flooded with storm runoff. The flooding of nearby stream might have disturbed and driven the turtle to cross the road. This turtle species is known to be active at night and usually hiding in rocks, sand, gravel, and crevices in the stream banks during daytime (Diesmos et al. 2008). Being active at night might explain why almost all *C. dentata* was killed during nighttime.

The significant relationship between the road-killed turtle species and the roadside habitat types [$X^2(1,N=127)=62.09$, $p<.05$] and significant relationship between the turtle species and the time of the day when the vehicle collision happened [$X^2(1,N=127)=147.41$, $p<.05$] strongly suggests that the types of roadside habitats and the time of the day may serve as important predictors of road mortalities among freshwater turtles.

The presence of high density of roadkills in road segments near bodies of water confirmed the dependency of these species of turtles to aquatic habitat (Lim and Das 1999; Diesmos et al. 2008; Schoppe 2008). Moreover, the clustering of roadkills, along certain road, segments strongly suggests that the presence of bodies of water near the road could also be considered an important predictor of road-kill incidences among freshwater turtles. This finding concurs with the observation of Langen et al. (2012) who claimed that the proximity of roads to bodies of water is one of the important predictors of road mortality among three species of freshwater turtles (*Chelydra serpentina, Chrysemys picta, and Emydoidea blandingii*) in St. Lawrence County, New York State, United States of America.

Identifying the turtle roadkill hotspots is an important baseline in site-specific implementation of conservation efforts (Langen et al. 2012). Focusing the road mortality mitigations along hotspots could be a useful and practical option because it prioritizes high impact areas in much shorter road segments.

The number of roadkills encountered during this study is only a small proportion of the actual number of individuals affected by road mortality. If daily counts were made, the figures could be several folds higher which could be high enough to compromise the effective breeding population size of vulnerable species of turtles in the roadside habitats in the long term (Gibbs and Shriver 2002; Beaudry et al. 2008; Litvaitis and Tash 2008). Also, the exploitation of turtles for food, medicine and pet trade (Gavino and Schoppe 2004; Cruz et al. 2007; Diesmos et a. 2008; Krishnakumar et al. 2009) along roadside habitats could be much higher than in other locations due to the ease of access to the area. Turtles are very slow growing animals which take a considerably longer time before they reach sexual maturity as compared to other vertebrates. Moreover, the matured reproducing individuals lay only a small number of eggs (Ernst et al. 2000).

As a consequence severe exploitation, habitat reduction or alteration, and high incidence of road mortality through time might seriously reduce the sufficient population of these turtles in roadside habitats which may eventually end to localized extinction. Currently, the two species of turtles affected by road mortality accounted in this study are protected by the Philippine Wildlife Act (R. A. 9147). Likewise, both turtles are also listed in the Red List of Globally Threatened Species by the International Union for the Conservation of Nature. The Southeast Asian Box Turtle (*C. amboinensis*) is listed as "Vulnerable" while the Asian Leaf Turtle (*C. dentata*) is listed as "Near-Threatened" (IUCN 2016). The geographic distribution of these turtles is considerably wide, but the anthropogenic activities taking place within their known geographic range are severely affecting the population of these species. Aside from habitat degradation, these turtles are also commonly collected for medicine, food and pet trade (Cruz et al. 2007; Diesmos et al. 2008; Schoppe 2008; Krishnakumar et al. 2009; Lyons et al. 2013). Because of the rampant

illegal trade, both species are listed under Appendix II of the Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES 2017).

The high volume of road-killed turtles and the increasing trend in the overall roadkill frequency observed in this study suggest that road mortality resulting from vehicle collision is one of the emerging threats to the population of the freshwater turtles living in the roadside habitats. The prospects of road development and the growing traffic volume in Palawan might endanger the existence of these turtles in the long run, particularly the species that already showed a decreasing roadkill count. Moreover, identified predictors of road mortality among freshwater turtles such as types of roadside habitat, presence of bodies of water and time of the day are worth considering in crafting mitigating strategies. Focusing on the implementation of mitigation and conservation efforts on identified roadkill hotspots will ensure its effective and efficient implementation.

This study recommends immediate implementation of effective mitigating measures such as road users' education in the form of billboards, warning signage, and pamphlets. These measures will improve the drivers' awareness, alertness, and behaviour towards crossing turtles and other wildlife as well. Installation of barrier fences or steep concrete ramps and bypass channels are also recommended particularly in hotspot areas. Furthermore, assessment of roadside habitat and habitat fragmentation must also be conducted to understand its impact on turtle populations. Lastly, additional studies on road-killed turtles in the northern and southernmost part of Palawan is also recommended to know if the road mortality also affects the two other species of freshwater turtles, namely *D. subplana* which is found exclusively in Southern Palawan and *S. leytensis* which is found solely in Northern Palawan.

ACKNOWLEDGMENTS

The researcher would like to express his sincerest appreciation to the private lot owners who allowed him to explore the roadside habitats located inside their properties. The author also would like to extend gratitude to all the people who helped during the conduct of the study and for the valuable comments and suggestions of the two anonymous external reviewers that helped improve this paper.

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ARTICLE INFO

Received: 22 November 2018
Revised: 16 May 2019
Accepted: 03 June 2019
Available online: 08 July, 2019