Wildlife species prone to road kill: case in Rawa Aopa Watumohai National Park, Southeast Sulawesi, Indonesia

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Abstract. Wild animals sometimes accidentally got killed when they try to cross the road in their habitat. However, data and information on the road kill/mortality of wild animals in Indonesia was still lacking. The objective of this study was to record and analyze the road kill (e.g., species and number) along the 22.4 km highway in Rawa Aopa Watumohai National Park, Southeast Sulawesi. Road kills were observed during February-March 2020 through series of driving along the highway by motorcycle. Data collected were species and number of road kill, as well as number of vehicles passing by. A total of 529 individuals from 37 species were found accidentally killed of which about half (49.3%) happened along the beginning of the highway (km 0-10). Species prone to road kill were identified, namely 19 species of bird (mostly Tricoloured Munia, Lesser Coucal, Zitting Cisticola), 3 species of small mammals (mostly Ricefield Rat), 10 species of reptiles species (mostly Water Monitor and Matana Mud Snake), and 5 species of amphibians species (mostly Crested Toad). Big mammals (Booted Macaque, Wild Boar) were not prone to road kill. There was a positive correlation ($r=0.721$) between the number of vehicle and the number of road kill.

1. Introduction

Many highways had to crossed natural landscape, causing habitat fragmentation and sometimes cutting the home range of certain wildlife species. The vehicle on highway accidentally may hit wildlife causing cause of death to the wildlife species when the species crossing the highway. This road kill incident has been reported to be the main cause for the decreased wildlife population in some areas, including in Eastern Africa [1], India [2], and Taiwan [3].

Roadkill also has been reported in Rawa Aopa Watumohai National Park in Southeast Sulawesi. The National Park is a home for 321 wildlife species, including 28 mammals, 218 birds [5], 10 amphibians, and 32 reptile species [6]. In 2009, a highway funded through “The Eastern Indonesia National Road Improvement Project (EINRIP)” has been built [4]. There was a report mentioning that the highway had some harmful impact on certain wildlife, including Amboina Box Turtle ($Cuora amboinensis$), which often found dead along the highway [7]. This species has been listed as Vulnerable by IUCN [8] and CITES Appendix II. There is a possibility that many other species also have been killed on the highway.

In Indonesia, until now there has been only one report on the impact of highway on wildlife, namely the highway of Sanggi-Bengkunat in Bukit Barisan Selatan National Park in South Sumatra Province [9]. Therefore, the research on the roadkill in Rawa Aopa Watumohai National Park is considered important to provide additional information on road kill in national parks. The objective of this study was to record and analyze the road kill (wildlife species and number) along the 22.4 km highway in Rawa Aopa Watumohai National Park, Southeast Sulawesi, and reveal the species prone to road kill.
2. Methods
A series of survey was conducted along the 22.4 km highway, from Bombana gate in the south to South Konawe gate in the north (figure 1), totalling 627.2 km from 28 replications. The highway crossed several ecosystem types, including savanna (dominant ecosystem; 22,963 ha), lowland tropical forest, swamp, and mangroves. Data were collected for 28 days, by driving a vehicle at a constant speed [10], using the highway as the main transect, as has been practiced in other researchers [11]. The observation was conducted by two persons driving a motorcycle with speed of 20-40 km/hour, twice a day (morning at 6am and late afternoon at 4 pm).

Observers made a stop on the shoulder when dead wildlife species was spotted. Sites for all road kill found was recorded by using Global Positioning System (GPS) type GPSmap 76CSx and marked the roadkill on the road using white spray paint (pylox). After being identified to the species level (or at least family level), the remains were removed to avoid double counting.

The estimation of the number of vehicle was conducted by using multicounter application from a point of observation, one hour period for each observation. Sampled countings were repeated five times a day (7-8 am, 12 am -1 pm, 5-6 pm, 10-11 pm, 3-4 am, local time). F-test was used to identify the differences in the number of vehicle. The Pearson’s correlation was employed to see the correlation between the number of vehicle and the road kill.

![Figure 1](image-url)

**Figure 1.** Study area in Rawa Aopa Watumohai National Park (Southeast Sulawesi, Indonesia), showing position of highway surveyed.

3. Results and discussion
During the observation days, there were 37 species died along the highway, totaling 529 road kill cases, of which 453 cases were able to be identified. Roadkill cases are found in many countries outside Indonesia, but only report certain classes of animals or specific species. For example, 18 species and 10 mammal families have died on roads in Brazil [12]. Meanwhile, in eastern Austria, 252 individuals were reported on the road, consisting of 180 amphibians and 72 reptiles [13].
Some remains were unable to be identified due to their poor condition. The identified road kill consisted of 263 amphibians (51%), 120 birds (23%), 63 mammals (12%), and 69 reptiles (14%) (table 1). Daily roadkill rate was 37.8 cases, ranging 18-69 cases. The number of road kills was considerably quite high. There has been no previous report from the National Park Authority on the roadkill, indicating that the road kill was overlooked by the Pak Authority.

For birds, the highest road killed was Tricoloured Munia (*Lonchura Malacca*, figure 2). This species has been known to inhabit lowland area, including in savanna [14], and often spotted flying low crossing the highway, resulting in a high road kill. Road kill in mammals was dominated by Ricefield Rat (*Rattus argentiventer*, figure 3) and Malayan Civet (*Viverra tangalunga*), both have been known to be easily adapted to human activities [15,16]. There was no road kill of big mammal during the study period, for example Booted Macaque (*Macaca ochreata*) and Wild Boar (*Sus scrofa*), although these two species were often seen around the highway.

The highest road kill among all wildlife was amphibians (n=263; 58.1%), of which 143 cases involving Crested Toad (*Ingerophrynus biporcatus*, figure 4), almost all (99%) happened near savanna ecosystem. Savanna has been known to be the main habitat for this [6] and during the survey this toad was often spotted hopping on asphalt of the highway at night, and thus increasing possibility of being hit by vehicle. Common Water Monitor (*Varanus salvator*, figure 5) and Matana Mud Snake (*Hypsiscopus matannensis*) were prone to collision for reptiles. This species often seen basking on the highway in the early and late afternoon. The habit of scavenging hunt of this species [17] might also contributed to its high road kill.

Based on parts of highway, the road kill cases were mostly happened on km 1 to 10 (from the main gate of Bombana, table 2, figure 6). The highway can be divided into three zones based on the number of wildlife mortality: red zone (hotspot zone; more than 10 mortality/km), yellow zone (less than 10 mortality/km) and green zone (no mortality).

Based on habitat types, almost all mortality due to road kill happened in savanna (95%). Other road kills happened in the tropical lowland forest (4%) and mangroves (1%). It seemed that the occurrence of water had some influence to the road kill. About 72% roadkill cases were found near water sources, including small creek and waterlogged. Rainfall in Rawa Aopa Watumohai National Park is moderate. The 2020 Provincial Statistics Bureau shows that the rainfall in South Konawe Regency is 166.7
mm/year in 2019. Therefore, every water source in the National Park will be very important for the survival of the species.

**Table 1.** Species killed along the Rawa Aopa Watumohai National Park highway during February-March 2020, listed based on family’s alphabetical order.

| No | Family            | Species                  | Common Name          | Frequency |
|----|-------------------|--------------------------|----------------------|-----------|
| 1  | Ardeidae          | *Ixobrychus sinensis*    | Yellow Bittern       | 2         |
| 2  | Apodidae          | *Aerodramus fuciphagus*  | Edible-nest Swiftlet | 2         |
| 3  | Campephagidae     | *Lalage sueurii*         | White-shouldered Triller | 2        |
| 4  | Caprimulgidae     | *Caprimulgus affinis*    | Savanna Nightjar     | 1         |
| 5  | Cuculidae         | *Centropus bengalensis*  | Lesser Coucal        | 13        |
| 6  | Estrildidae       | *Lonchura malacca*       | Tricoloured Munia    | 16        |
| 7  | Hirundinidae      | *Hirundo tahitica*       | Pacific Swallow      | 1         |
| 8  | Muscicapidae      | *Saxicola caprata*       | Pied Bush Chat       | 1         |
| 9  | Passeridae        | *Cisticola exilis*       | Golden-headed Cisticola | 5        |
| 10 | Passeridae        | *Cisticola juncioides*   | Zitting Cisticola    | 13        |
| 11 | Passeridae        | *Cisticola sp.*          | Cisticola            | 10        |
| 12 | Passeridae        | *Passer montanus*        | Eurasian Tree Sparrow | 2         |
| 13 | Pycnonotidae      | *Pycnonotus aurigaster*  | Sooty-headed Bulbul  | 5         |
| 14 | Phasianidae       | *Synoicus chinensis*     | Asian Blue Quail     | 4         |
| 15 | Railidae          | *Amaurornis phoenicurus* | White-breasted Waterhen | 1        |
| 16 | Railidae          | *Gallirallus torquatus*  | Barred Rail          | 4         |
| 17 | Railidae          | *Lewinia striata*        | Slaty-breasted Rail  | 1         |
| 18 | Turnicidae        | *Turnix suscitator*      | Barred Buttonquail   | 1         |
| 19 | Zosteropidae      | *Zosterops chloris*      | Lemon-bellied White-eye | 6        |
|    | Unidentified bird |                         |                      |           |
| 20 | Muridae           | *Rattus argentiventer*   | Ricefield Rat        | 33        |
| 21 | Muridae           | *Rattus sp.*             | Rat                  | 22        |
| 22 | Viverridae        | *Viverra tangalunga*     | Malayan Civet        | 2         |
|    | Unidentified mammal|                        |                      |           |
| 23 | Colubridae        | *Calamaria nuchalis*     | Narrow-headed Reed Snake | 1        |
| 24 | Colubridae        | *Dendrelaphis pictus*    | Painted Bronzeback   | 8         |
| 25 | Colubridae        | *Lycodon capucinus*      | Common Wolf Snake    | 10        |
| 26 | Elapidae          | *Ophiophagus hannah*     | King Cobra           | 1         |
| 27 | Homalopsidae      | *Hypsiscopus matannensis*| Matana Mud Snake     | 17        |
| 28 | Typhlopidae       | *Ramphotyphlops braminus*| Brahminy Blind Snake | 1         |
| 29 | Xenopeltidae      | *Xenopeltis unicolor*    | Sunbeam Snake        | 1         |
| 30 | Gekkonidae        | *Gekko gecko*            | Tokay Gecko          | 1         |
| 31 | Varanidae         | *Varanus salvator*       | Common Water Monitor | 19        |
| 32 | Goemydidae        | *Cuora amboinensis*      | Amboina Box Turtle   | 3         |
|    | Unidentified reptiles|                    |                      | 69        |
| 33 | Bufonidae         | *Ingerophrynus biporcatus*| Crested Toad        | 143       |
| 34 | Dicroglossidae    | *Fejervarya cancrivora*  | Crab-eating Frog     | 7         |
| 35 | Dicroglossidae    | *Fejervarya limnocharis* | Alpine Cricket Frog  | 28        |
| 36 | Dicroglossidae    | *Fejervarya sp.*         | Frogs                | 49        |
| 37 | Rhacophoridae     | *Polypedates iskandari*  | Iskandar’s Draco     | 17        |
|    | Unidentified amphibian|                    |                      | 2         |

Some of the species found are protected species. Two species found crashed on the main road were categorized as vulnerable according to the IUCN red list, namely *Cuora amboinensis* and *Ophiophagus hannah*. According to CITES, there are 4 species included in the Appendix II list, namely *Cuora amboinensis*, *Gekko gecko*, *Varanus salvator*, and *Ophiophagus Hannah*. Apart from the protected species that were hit on the main road, there are also 3 species which are endemic to Sulawesi Island. These animals are *Polypedates iskandari*, *Hypsiscopus matannensis*, and *Calamaria nuchalis*. 
**Table 2.** Hotspot zone in Rawa Aopa Watumohai National Park highway and number of road mortality per 10 km.

| Zone (Criteria)          | Length (km) | Site (Km) | Roadkill/10Km |
|--------------------------|-------------|-----------|---------------|
| Red (≥10 mortality/10 km)| 2.6         | 1-10      | 261           |
|                          | 5.4         | 10-20     | 147           |
|                          | 1.5         | 20-23     | 63            |
| Average roadkill/10km    |             |           | 157.0         |
| Yellow (1-9 mortality/10 km)| 1.5       | 1-10      | 19            |
|                          | 1.8         | 10-20     | 23            |
|                          | 0.6         | 20-23     | 16            |
| Average roadkill/10km    |             |           | 19.3          |
| Green (no mortality)     | 5.8         | 1-10      | 0             |
|                          | 2.8         | 10-20     | 0             |
|                          | 0           | 20-23     | 0             |
| Average road kill/10 km  |             |           | 0.0           |

**Figure 6.** Hotspot of roadkill along Rawa Aopa Watumohai National Park highway.
The average number of vehicles that use the highway was 350 vehicles/day, consisted of motorcycles (53%), cars (40%), buses (1%), trucks (5%), and bicycle (1%). Based on time, there was a significant different on the traffic volume among the time of the day ($F_{4,345}=17.05$, P<0.01). The highest traffic intensity was during late afternoon (5-6 pm) dominated by motorcycles, and the lowest in early morning (3-4 am), dominated by cars (table 3). Statistical analysis suggested that there was a strong positive correlation between the number of vehicle and the road kill ($r=0.721$, n=14, P<0.01).

Table 3. Average number of vehicles (motorbikes, cars and trucks) passing on the highway of Rawa Aopa National Park from 15 February - 27 March 2020 (N = 14) by time category.

|          | Early morning | Morning | Afternoon | Late Afternoon | Evening |
|----------|---------------|---------|-----------|----------------|---------|
| **Motorbike** | Mean ± SD     | Range N | Mean ± SD | Range N        | Mean ± SD | Range N |
|           | 1.00±0.96     | 0-3     | 50.3±9.10 | 40-75          | 36.70±14.10 | 16-54   |
|           | 91.60±45.50   | 14-181  | 7.80±6.80 | 0-28           |
| **Car**   | Mean ± SD     | Range N | Mean ± SD | Range N        | Mean ± SD | Range N |
|           | 4.60±2.17     | 1-9     | 23.0±8.07 | 14-36          | 40.10±12.40 | 18-67   |
|           | 53.5±13.00    | 34-76   | 18.2±5.70 | 9-28           |
| **Truck** | Mean ± SD     | Range N | Mean ± SD | Range N        | Mean ± SD | Range N |
|           | 1.10±1.21     | 0-4     | 4.3±1.90  | 1-7            | 6.60±2.89  | 3-12    |
|           | 7.90±3.10     | 3-13    | 3.00±2.15 | 0-7            |
| **All vehicles** | Mean ± SD     | Range N | Mean ± SD | Range N        | Mean ± SD | Range N |
|           | 6.71±2.07     | 0-9     | 77.57±20.21 | 0-75         | 83.57±19.86 | 0-67    |
|           | 153.28±42.05  | 0-181   | 29.07±7.95 | 0-28           |

Some suggestions to reduce the number of roadkill are: (a) provision and addition of more signage on the presence of wildlife species, especially on the red zone near Bombana and South Konawe gate, (b) provision of wildlife crossing signage in all identified red zones along the highway, and (c) set a speed limit in the red zones, (d) building some road bumps to force the speed reduction of the vehicles.

4. Conclusion

The highway that crossing the Rawa Aopa Watumohai National Park was found as a cause of the animal roadkills, especially in the nearby savanna. There were 529 roadkill cases averaging 37.8 individuals/day, involving 37 species. Species prone to road kill were identified, namely 19 species of bird (mostly Tricoloured Munia, Lesser Coucal, Zitting Cisticola), 3 species of small mammals (mostly Ricefield Rat), 10 species of reptileses species (mostly Water Monitor and Matana Mud Snake), and 5 species of amphibians species (mostly Crested Toad). Big mammals (Booted Macaque, Wild Boar), however, were not prone to road kill. There was a positive correlation ($r=0.721$) between the number of vehicle and the number of road kill.

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Acknowledgments
We thank the Rawa Aopa Watumohai National Park for permit granted to us (Surat Izin Masuk Kawasan Konservasi No. SL03 / T.22 / TU / KSDAE / 01/2020, issued on 27 January 2020) to conduct this research. We would like to extend our thanks and appreciation to the Park’s staff: Ali Bahri (Head of the Park), Benny Ernmyadi Purnama (Head of SPTN II), and other colleagues (Aris, Ana, Acho, Ikhsan Fajrin, Brigdal Karhut, dan Harnum Nurazizah). This research was generously funded by Asosiasi Pengusaha Eksportir Kura-kura dan Labi-Labi Indonesia (APEKLI). We also thanks to Maraden Purba (APEKLI) and Amir Hamidy (Pehimpunan Herpetofauna Indonesia). Furthermore we would like to thank the International Collaboration Office (ICO) and Center for Transdisciplinary and Sustainability Sciences (CTSS) of IPB University to support funding for this publication.