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Analysis of Accidents Involving Animals along the Padamara-Karangcegak Road from a Geospatial Perspective

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Abstract. The development of traffic systems affects nature directly and indirectly. New-built roads can directly destroy the habitat of animals and cause accidents, both to animals and humans. Animal-vehicle collisions on roads can affect the structure of the food chain. This would be a problem if they occurred regularly, because some species of animals that were important to the ecosystem would cease to exist. Geospatial records of the frequency of animal accidents and habitat along the Padamara-Karangcegak road could be used to analyse the correlation between the dominance of animal species involved in accidents and the potential width of their habitat along the road. Qualitative description was used as the research method, based on primary data analysis of the distribution of accidents, and secondary data of land use taken from Google Earth satellite images, which were then processed by the Geographic Information System. The results obtained during observations from April to July 2016 showed that there was a correlation between animal habitat and the accidents that occurred. Animals with a wider habitat were involved in more accidents than those without an extensive habitat.

Keywords: accident, animal, road, geospatial

Abstrak. Perkembangan sistem lalu lintas mempengaruhi alam secara langsung dan tidak langsung. Jalan yang baru dibangun dapat secara langsung menghancurkan habitat hewan dan menyebabkan kecelakaan, baik kecelakaan pada hewan maupun manusia. Tabrakan hewan dan kendaraan di jalan dapat mempengaruhi struktur rantai makanan. Ini akan menjadi masalah jika kecelakaan tersebut terjadi secara teratur, karena beberapa spesies hewan yang penting bagi ekosistem akan lenyap. Catatan geospasial tentang frekuensi kecelakaan hewan dan habitat di sepanjang jalan Padamara-Karangcegak dapat digunakan untuk menganalisis korelasi antara dominasi spesies hewan yang terlibat dalam kecelakaan dan potensi luas habitat mereka di sepanjang jalan. Penelitian ini menggunakan metode deskripsi kualitatif, berdasarkan analisis data primer dari distribusi kecelakaan, dan data sekunder berupa penggunaan lahan yang diambil dari citra satelit Google Earth, yang kemudian diproses oleh Sistem Informasi Geografi. Hasil yang diperoleh selama pengamatan dari April hingga Juli 2016 menunjukkan bahwa ada korelasi antara habitat hewan dan kecelakaan yang terjadi. Hewan dengan habitat yang lebih luas jangkauannya lebih banyak mengalami kecelakaan daripada hewan yang tidak mempunyai habitat yang luas.

Kata kunci: Kecelakaan, Hewan, Jalan, Geospasial

1. Introduction

Since 2000, the global roadway network length has increased by approximately 12 million lane-km (Dulac, 2013). Among ASEAN member countries, in 2007 Indonesia had the largest transport infrastructure, with a length of 396,362 km, and the largest paved road system, at 221,905 km (ERIA Study Team, 2010). The development of the transportation pathways can result in immediate destruction and displacement of existing ecosystems, as well as the reconfiguration of local land use, as transport infrastructure affects its structure and function, and has direct effects of ecosystem components, including species composition (Coffin, 2007). It also disrupts horizontal ecological flow, alters landscape spatial patterns, and inhibits the development of the important species which exist within (Forman & Alexander, 1998).

Roads are often built or improved to allow greater access to new development areas, which will have direct and indirect ecological effects on split land use. The nature of road systems as network structures renders vast areas of the landscape as road-affected, with small patches of isolated habitat remaining beyond the ecological influence of roads (Coffin, 2007). Roads, railways and other linear infrastructure are pervasive components of most landscapes throughout the world. Combined with the effect of vehicles, they have the potential to cause mortality in wildlife, severely disrupt animal movement and increase the risk of local extinction (Ree *et al*., 2007). Animal mortality due to collisions with vehicles has become one of the negative interactions of human transportation technology in terms of animal survival.

Major roads cause barrier effect and fragmentation on wildlife habitats that are suitable places for feeding, mating, socializing, and hiding (Gülci & Akay, 2015)mating, socializing, and hiding. Due to wildlife collisions (Wc; wild animals face long-term population declines due to increasing collisions with vehicles, which can result in death and financial loss (Theobald, *et al*., 1997)species conservation and animal welfare. In Sweden, vehicle collisions with moose (MVC. Road construction has killed living organisms that move slowly, has injured those who live adjacent to roads, and has altered physical conditions under the roads. Vehicle crashes also affect the demographics of many species, both vertebrate and invertebrate (Trombulak & Frissell, 2001)mortality from collision with vehicles, modification of animal behavior, alteration of the physical environment, alteration of the chemical environment, spread of exotics, and increased use of areas by humans. Road construction kills sessile and slow-moving organisms, injures organisms adjacent to a road, and alters physical conditions beneath a road. Vehicle collisions affect the demography of many species, both vertebrates and invertebrates; mitigation measures to reduce roadkill have been only partly successful. Roads alter animal behavior by causing changes in home ranges, move- ment, reproductive success, escape response, and physiological state. Roads change soil density, temperature, soil water content, light levels, dust, surface waters, patterns of runoff, and sedimentation, as well as adding heavy metals (especially lead. Significant extinction of biodiversity will occur due to population-limited animal movement, increased mortality, habitat fragmentation and edge effects, the invasion of exotic species, or increased human access to wildlife habitats (Findlay & Bourdages, 2000). Fragmentation of habitats is defined as a landscape-scale process involving extinction and separated habitat (Fahrig, 2003)with different authors measuring fragmentation in different ways and, as a consequence, drawing different conclusions regarding both the magnitude and direction of its effects. Habitat fragmentation is usually defined as a landscape-scale process involving both habitat loss and the breaking apart of habitat. Results of empirical studies of habitat fragmentation are often difficult to interpret because (a, meaning that separate animal habitats no longer form a whole ecosystem.

The restricted movement of animals may reduce both direct and indirect habitat connectivity through changes in traffic flow. Habitat connectivity is essential for species survival and can be maintained in landscapes with well-connected habitat networks (Van Strien & Grêt-Regamey, 2016). It is therefore very important to understand the broad spatial pattern of the landscape to overcome the ecological impact of roads, such as the presence of currents and movements, for example in wildlife corridors throughout the land. Therefore, an ecological approach provides a useful theoretical framework for analysis of such transportation issues (Forman & Hersperger, 1996).

The incidence of accidents involving animals in some countries had been widely studied; for example, in the United States. It has beeen proven that speed limits, differences in rural and urban land use, and the presence of white-tailed deer habitats has had an increased impact on the risk of animal collisions with vehicles (Lao *et al.*, 2011) The government in Australia found that animal accidents was an issue of concern, and that night time travel was a significant risk factor when comparing animal accidents to other serious accidents (Diaz-Varela, *et. al.,* 2011). Animal collisions with vehicles was a serious problem for road planners and biologists concerned with traffic safety, species conservation and animal welfare (Seiler, 2005)species conservation and animal welfare. In Sweden, vehicle collisions with moose (MVC. On the other hand, in Indonesia the government pays less attention to the issue of animal accidents and has taken no action to solve the problem.

The incidence of road accidents involving animals is often not only about dangers to drivers, such as injury or even death, but also about the survival of the animal species, as an inseparable part in the continuity of the food chain in an ecosystem. Therefore, data collection on the frequency of animal accidents is urgently required. Systematically collected data on animal accidents would allow for an evaluation of the effectiveness of mitigation measures in reducing the number of animal-vehicle collisions (Huijser, *et. al.*, 2007)property and wildlife, and the number of animal-vehicle collisions has substantially increased across much of North America over the last decades. Systematically collected animal-vehicle collision data help estimate the magnitude of the problem and help record potential changes in animal-vehicle collisions over time. Such data also allow for the identification and prioritization of locations that may require mitigation. Furthermore, systematically collected animal-vehicle collision data allow for the evaluation of the effectiveness of mitigation measures in reducing the number of animal-vehicle collisions. In the United States and Canada, animal-vehicle collision data are typically collected and managed by transportation agencies, law enforcement agencies and/or natural resource management agencies. These activities result in two types of data: data from accident reports (AR data. The other most important data concern the interconnected spread of land use due to the presence of roads, which is used as an approach in determining the spatial pattern of animal habitats. Beside use in mitigation, such data can also provide suggestions for redesigning roads to be more welcoming to wild animals.

Study of the phenomenon of accidents may involve the aid of Geographic Information System (GIS) analysis, in which geospatial techniques are widely used to analyse the spread of spatial phenomena in order to facilitate the determination of properties in a certain phenomenon (Osayomi & Areola, 2015). Geographic Information System Technology has become a popular tool for visualisation of accident data and hot spot analysis on the highway or road (Erdogan, *et. al.*, 2008).

GIS is nowadays an important approach to solving problems related to the environment, land use change and business, among others. It provides visualised and analytical solutions to any type of geographic problem (Jonsson, 2017). This study aims to analyse the mapping results of animal accidents using GIS and to establish their correlation with animal habitats in a more spatially informative and understandable way. It is expected that the research will provide accurate information about the location of animal accidents that occur frequently in certain areas; for example, as shown by GIS analysis of road accidents involving wandering dogs in the urban area of Naples (Mennonna et al., 2018). It mentions that in the analysis of road safety, in addition to the most accurate statistical data, there is a need to observe information geographically (Mennonna et al., 2018). GIS is an important tool for viewing spatial data involving accidents. Apart from statistical data, it gives information about the presence of geographical hotspots, which makes it possible to better understand phenomena. This type of tool permits merging of accident and spatial data, such as geocodes and accident locations. It also helps in calculation of the frequency and rate of accidents (Hua, 2005; Erdogan *et al.*, 2008; Mennonna *et al.*, 2018).

Another study entitled "Spatial Modeling of Wildlife Crossing: GIS-based Approach for Identifying High-priority Locations of Defragmentation across Transport Corridors" found that the GIS-based approach was effective in identifying high priority locations of defragmentation across transport corridors (Jonsson, 2017). Moreover, in another study entitled "Geographical information system analysis on road accidents involving wandering dogs in the urban area of Naples", it was found that application of GIS in the urban area of Naples showed that there are five hotspots where the risk of road accidents involving wandering dogs was higher. These dogs, as well as other free-moving animals, represent an increasing problem on urban roads in Italy, despite efforts to reduce this kind of population. Knowledge of this phenomenon is crucial in order to increase the safety of both dogs and drivers (Mennonna et al., 2018). In Italy, only a few studies have been conducted in which GIS technology was used to evaluate road accident risk due to wild animals, particularly deer and wild boar ((Direzione generale Sviluppo Economico Settore Politiche Agroambientali, 2008; Primi, *et. al.*, 2010starting from a territorial information system implemented in a GIS environment. Landscape structure indices and local qualitative and quantitative variables were correlated to identify the most frequent predisposing factors of collisions. Statistical tests of the considered parameters indicated a higher frequency of collisions in the evening hours of late summer and autumn ($P<0.05$; Mennonna *et al.*, 2018). Based on these studies, use of GIS is necessary in this research to identify the animal accidents that occur in the research location. Moreover, the Indonesian government pays little attention to animal extinction or animal habitat. To the best of our knowledge, this study is the first to identify and analyse animal accidents, and will hopefully encourage the government to consider animal protection, as well as that of humans as the road users.

2. Methods

The location used in this study was the Padamara-Karangcegak road. It is an accessibility network which plays an important role in the socio-economic movement, as well as in the development of many industries established on this side road of the corridor, attracting many people to move and settle in the area (Sutomo & Shalihati, 2014). The function of the road is also an alternative link that connects the activities of two towns, namely Purwokerto City and Purbalingga City, Central Java Province, Indonesia.

The road is 8.08264 km in length, based on calculations from Google Maps with the aid of GIS software. The research was conducted in 2016. The research method used was qualitative descriptive, which aimed to describe the nature of the research results in a systematically written form with easy sentences. Primary and secondary data methods were used to analyse the data using GIS, with ArcGIS 9.3 software assistance to process the data.

The first step was an observation step as a data collection technique. This was performed through observation, documentation retrieval, and systematically and direct recordings related to accidents involving animals and their location, coordinated by the Global Positioning System. The observations were made by tracing along the Padamara-Karangcegak road to locate any animal accidents. The results of the information obtained were then used to calculate the number of animal accidents and the animal groups involved, as well as the location of the accidents spatially. The second step was data collection on potential habitat by land use interpretation of remote sensing data obtained from Google Earth. Identification of the existing land use along the Padamara-Karangcegak road was made by using visual interpretation techniques through ArcGIS 9.3 software.

The study was limited to several animal species, selected based on their size. The animals should not be too small in order to make identification easier. The other consideration was the length of road. A more detailed list of the types of animal involved in accidents is given in Table 1.

Table 1. Grouping of Animals Species

Animal Species	Animal Type
Amphibians	Frogs
Reptiles	Snakes
Aves	Chicken
Mammalia	Dogs, Cats, Rats

The next step was to create a map of the incidents of animals involved in collisions on the Padamara-Karangcegak road by: 1) locating the coordinates of the animal accident scenes with GPS during the observation; 2) plotting the coordinates of the animal accident scenes on Padamara-Karangcegak road to become a digital map by utilising GIS of ArcGIS 9.3 software; 3) converting the distribution of animal accidents to shapefile (.shp) and JPG (.jpg) format as the output results.

The potential habitat of animals was determined based on the use of land along Padamara-Karangcegak road, with reference to the model of the potential habitat of animals based on land use by Shalihati (2014), and is shown in Table 2.

The potential habitat of animals based on the land use around this geospatial location was also determined through utilisation of GIS with ArcGIS 9.3 software; the records also limited land use geospatially according to the administrative borders of the villages around the study site. The steps taken were as follows: 1) creation of a digital map of the land use along and around Padamara-Karangcegak road extracted from satellite images from Google Earth; 2) overlaying of the digital map of land use on its administrative boundaries; 3) tabulation of the attributive data of the land use and potential habitat of each type of animal, referring to table 2; and 4) receving of output results of these processes, which were digital maps of the habitat of each type of animal in .shp format.

Finally, the digital data of the distribution of the animal accidents and the habitats of the animals were presented to establish the correlation between the distributions of certain accidents to animals in their potential habitats.

Table 2. Distribution of Potential Habitat in Land Use

No.	Land Use	Animal Type					
		Amphibian	Reptile	Ave	Mammal		
		Frog	Snake	Chicken	Dog	Cat	Rat
1.	Freshwater	v	V				
2.	Thickets	v	V	v			v
3.	Buildings				v	v	v
4.	Gardens	v	V	v	v	v	v
5.	Settlements			v	v	v	v
6.	Grass			v			
7.	Rice Fields	v	V				v
8.	Land Fields			v			

v : potential habitat

3. Results and Discussion

Padamara-Karangcegak road is the connecting the two districts, and is also an alternative way to reach either Purbalingga town centre or Purwokerto town centre in Banyumas; it is open for use by bikes, cars and trucks. The data on animal accidents on Padamara-Karangcegak road from April to July 2016 showed that 20 frogs, 27 snakes, 3 chickens, 4 cats and 35 rats were injured and evetually died on the spot. However, the data on crashes involving dogs was not obtained in the same period. The data show that mammals were the dominant animals in crashes. There were 39 incidents of mammalian crashes, followed by 27 incidents of reptile crashes, 20 with amphibians and three with aves. Satellite images, taken from Google Earth, were used to trace the land use along and around the road. Figure 1 showed that landuse was dominated by paddy fields, with 765.22 Ha, settlements with 252.38 Ha, gardens with 20.3 Ha and grass with 6.6 Ha.

Potential habitats based on spatial land use for each type of animal were varied by adjusting the provisions in Table 2. As a result, an area of 1.037.89 Ha was potential habitat for mammals, with 6.6 Ha not suitable; 785.52 Ha was potential for reptile habitat areas, and 258.98 Ha unsuitable; 785.52 Ha was potential habitat for amphibians, while 258.98 Ha was not a potential area for them. Finally, the potential of ave habitat area was 279.28 Ha, with 765,22 Ha being unsuitable.

Based on the geospatial results, the distribution of accidents and habitat of each species along Padamara-Karangcegak road are shown in Figure 2 (frogs), Figure 3 (snakes), Figure 4 (chickens) and Figure 5 (cats and rats). Figure 3 and Figure 4 show the distribution of accidents involving snakes and chickens, which were geospatially seen on the road where land was not used for settlements, with 59% and 66% of incidents respectively. In Figure 2 and Figure 5, it can be seen that the distribution of cats and rats appeared geospatially dominant on the road where land was for settlement, with a percentage incidence for frogs of 70%, and for cats and rats of 75% and 69% respectively. The distribution of recorded animal accidents showed an identical pattern along the road from east to west, without any concentration of animal accidents in certain locations.

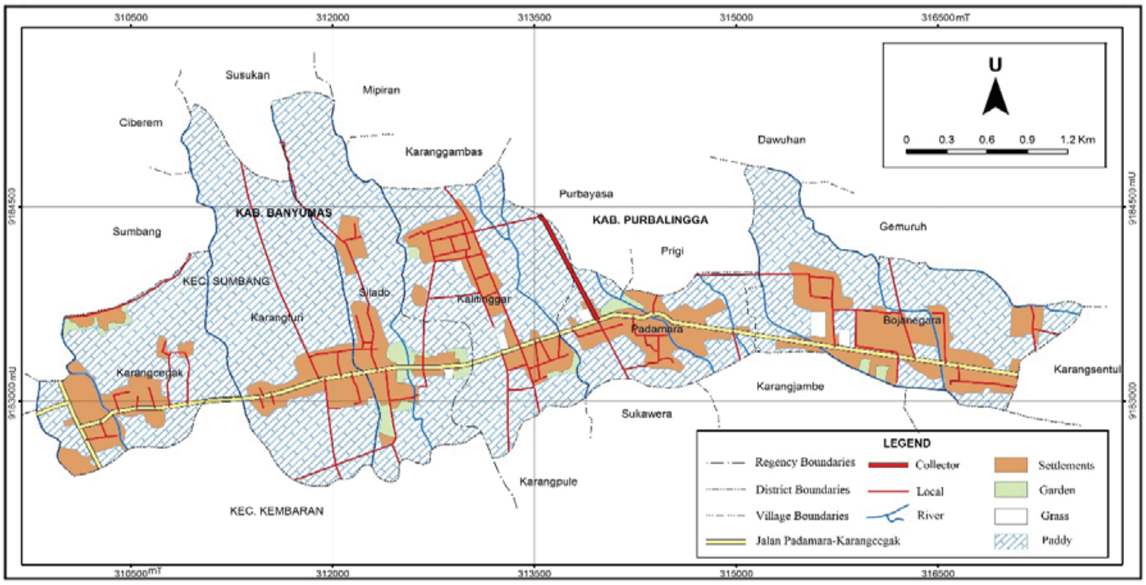

Figure 1. Land use along the Padamara-Karangcegak road

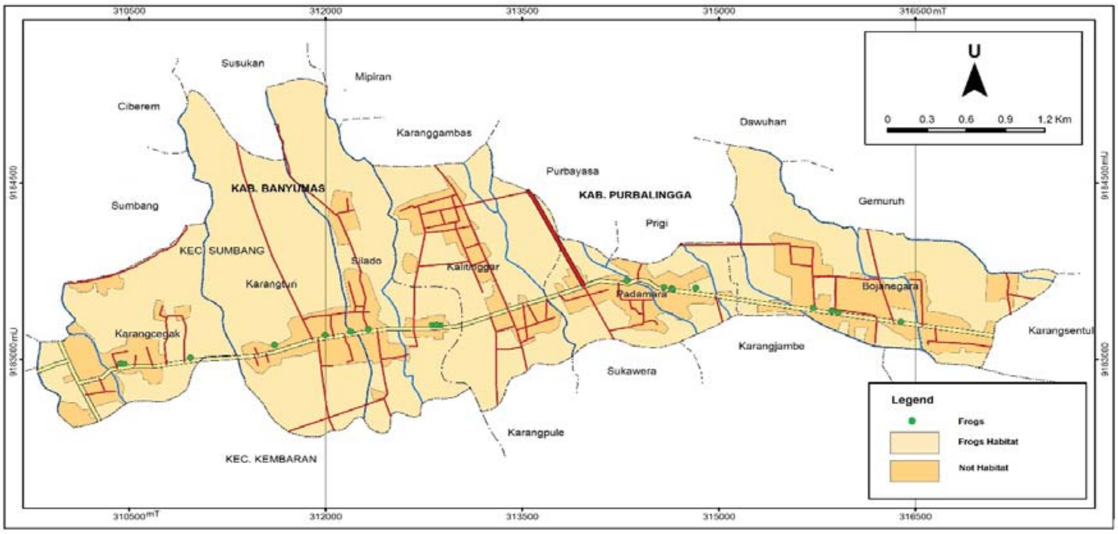

Figure 2. Distribution of Accidents and Habitats of Frogs

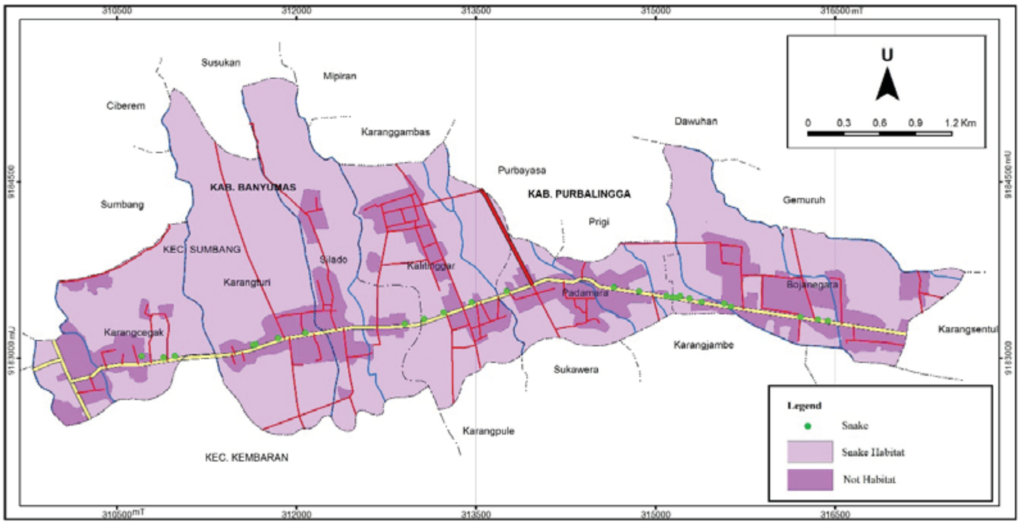

Figure 3. Distribution of Accidents and Habitats of Snakes

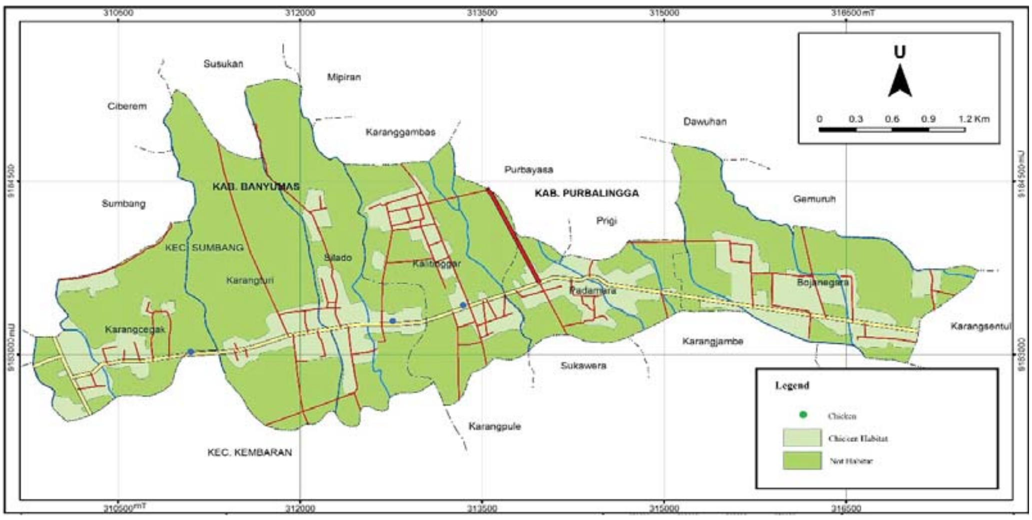

Figure 4. Distribution of Accidents and Habitats of Chickens

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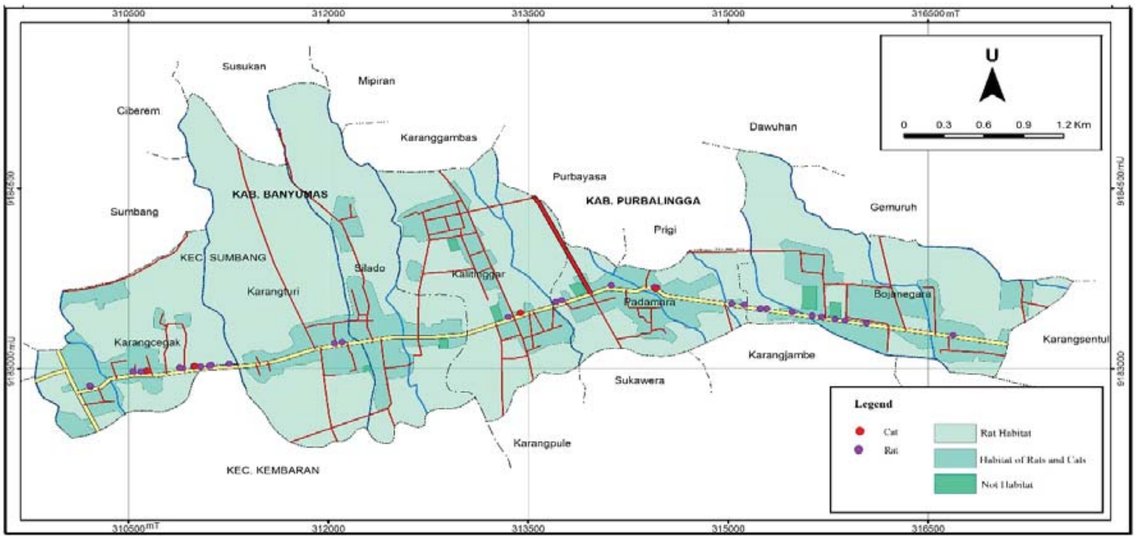

Figure 5. Distribution of Accidents and Habitats of Cats and Rats

Figure 6. Condition of animals involved in accidents

The large number of animal accidents was correlated with the spatial extent of the potential habitat of each animal. This can be proven from the frequency of animal accidents of cats and rats, since both kinds of animal have a more extensive habitat than other animals.

Figure 6 shows examples of the results of animal accidents.

Implication the loss of frogs, which is one type of amphibian, this may affect the nutrient cycling rates (Beard, *et al.*, 2003). A similar situation would occur with snakes, which play an important role in the food chain of each ecosystem and more prone to passing vehicles on the road (Pragatheesh & Rajvanshi, 2013)we present the ecological impacts of the highway on snakes in this Tiger Reserve. We surveyed this highway section for a total of 430 road cruising days spread equally across three seasons and over two years from August 2008 to July 2010. We collected data on different variables influencing use of road side habitat, the road surface and the factors influencing mortality of snakes. We recorded a total of 490 snake road kills (approx.1.13 snakes/10km/ day, and also with chickens, cats and rats, as they are an integral part of nutrient and food chains.

Chickens are widely used in Indonesia as roaming pets, but many are bred or developed for meat. According to Wang & Jiang (2011) equaling 30 m2 per chick and 60 m2 per chick, were applied on Leymus chinensis (L. chinensis, chickens also help to restore grassland ecosystems. Similar to chickens, cats are also much-loved pets, with their soft fur and tameness, and which are also natural predators of rats.

Therefore, it is important that the animals can act as the perpetrators of ecosystem sustainability, so serious attention needs to be paid to reducing animal accidents on the road. Collisions between vehicles and wild animals is a serious problem that needs extensive mitigation measures, such as road fences and the provision of cross-ing structures (Malo *et al.*, 2004), while Seiler (2005)species conservation and animal welfare. In Sweden, vehicle collisions with moose (MVC argues that effective mitigation methods will depend on integrated management of land use, animal population, increased driver responsibilities and the involvement of road authorities, including landowners and the general public. It can also be achieved by enforcing speed limits, installing alarms around roads that are prone to animal accidents, or providing safe road space for animals to wander in. With such policies, it is expected that the animals, as well as their habitats, will continue to exist.

4. Conclusion

The data on animal accidents obtained from April to July 2016 show that there were certain locations of accidents ascertained by using GIS, which is in line with the research by Jonsson (2017), who states that the GIS-based approach is effective for identifying high priority locations of defragmentation across transport corridors. Rats are mostly found as the victims of accidents, followed by frogs, snakes, cats and chickens. Based on the type of animal, mammals experienced the most accidents, followed by amphibians, reptile and aves. The data also show that there was a correlation between animal habitat and the accidents that occurred. Animal with a wider habitat experienced more accidents than those without an extensive habitat.

It is assumed that transport had an impact on the death of the animals, which are very important in balancing necessary human ecosystems. Therefore, the government should consider the best ways to overcome this problem. It is often pointed out that regulations would only be beneficial for humans; however, it is a very demanding task to reduce the number of animal-vehicle collisions on roads.

Future Research

More detailed analysis should be made before deciding other locations for study areas along the new Pemalang-Batang highway, located in Central Java, Indonesia. This highway was recently built in 2018, so it is believed that many animals will have lost their habitats. It is predicted that the animals, especially wildlife, are still trying to find new habitats. They may wander around when vehicles are passing on the highway, meaning accidents cannot be avoided. The research is expected to make the government consider installing new kinds of road sign so that road users will be more careful when travelling.

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