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Incidences of Road Kills and Injuries of Komodo Dragons Along the North Coast of Flores Island, Indonesia

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Abstract.—**The development of roads coinciding with human expansion and settlement can lead to substantial habitat degradation and biodiversity impact. For terrestrial animals, roads can also result in direct mortality or injury due to motor vehicle collisions. Flores is the largest among the five islands harboring Komodo Dragon (*Varanus komodoensis*) in southeast Indonesia. With few and scattered protected areas and a rapidly expanding human population, Komodo Dragons and their natural habitat are increasingly under threat, particularly on the north coast of Flores. In this study we used opportunistic surveys and roadside monitoring to record the incidence of vehicle related Komodo Dragon injury and mortality along a recent road development in northern Flores. We found eight incidents of Komodo Dragon injury (n = 2) and mortality (n = 6) occurring over a 5-y period. All reported casualties occurred during the cooler dry season and were concentrated along an approximately 2-km section of road that intersecting high-quality dry Monsoon Forest habitat. We argue that preventive measures including road warning signage, speed bumps, and possibly underpasses should be used to raise driver awareness, reduce vehicle speed, and decrease impacts to this small and declining Komodo Dragon population in northern Flores.**

Key Words.—human expansion; mitigation measures; road development; reptiles; *Varanus komodoensis*; wildlife vehicle collisions

Introduction

The development of roads can have direct and indirect impacts on natural habitats and biodiversity (Jha and Bawa 2006; Alkemade et al. 2009; Seto et al. 2012). Among the main consequences of road construction and expansion are habitat fragmentation (Spellerberg 1998; Fahrig 2003; Zhang et al. 2015). Roads can also produce edge-effects for wildlife populations (Forman and Alexander 1998; Fuentes-Montemayor et al. 2009; Laurence et al. 2009; Porensky and Young 2013) or disrupt their movement and migratory routes (Andrews et al. 2008; Klar et al. 2009). Collisions with vehicle can also be an important source of wildlife mortality and injury (Hobday and Minstrell 2008; Saenz-de-Santa-Maria and Teller 2015; Lima Santos et al. 2017).

Animal mortality or injury arising from vehicle collisions are taxonomically indiscriminate with mammals (Keller and Bender 2007; Clements et al. 2014), birds (Laurance et al. 2004; Benitez-Lopez et al. 2010), and reptiles and amphibians commonly reported (Andrews et al. 2008; Duengkae and Chuaynkern 2009; Quintero-Angel et al. 2012; Islam and Saikia 2014; Mazerolle 2015). Reptiles and amphibians are especially susceptible to vehicle related impacts due to their slower movements (Andrews et al. 2008; Baskaran and Boominathan 2010). For example, a study in western Arizona, USA, indicated that reptiles and amphibians had a two- to four-fold higher incidence of vehicle mortality compared to birds and mammals (Filius et al. 2020). Mortality due to vehicle collisions can thus be a significant threat to the persistence of small populations of rare or threatened species (Forman and Alexander 1998).

The Komodo Dragon (*Varanus komodoensis*) is the largest lizard species in the world and has an important ecological role as an apex predator (Jessop et al. 2006, 2019, 2020). This species is listed as Vulnerable by the International Union for Conservation of Nature (IUCN; 2014), and is highly restricted to four islands located in the Komodo National Park, Indonesia, and a few fragmented populations on the island of Flores (Ciofi and De Boer 2004; Jessop et al. 2007, 2018; Ariefiandy et al. 2015). Populations of this species on Flores have decreased as a consequences of anthropogenic activities, such as illegal hunting of Komodo Dragon prey, conversion of natural habitats into cultivated areas, and expansion of human settlements (Ariefiandy et al. 2015, 2020).

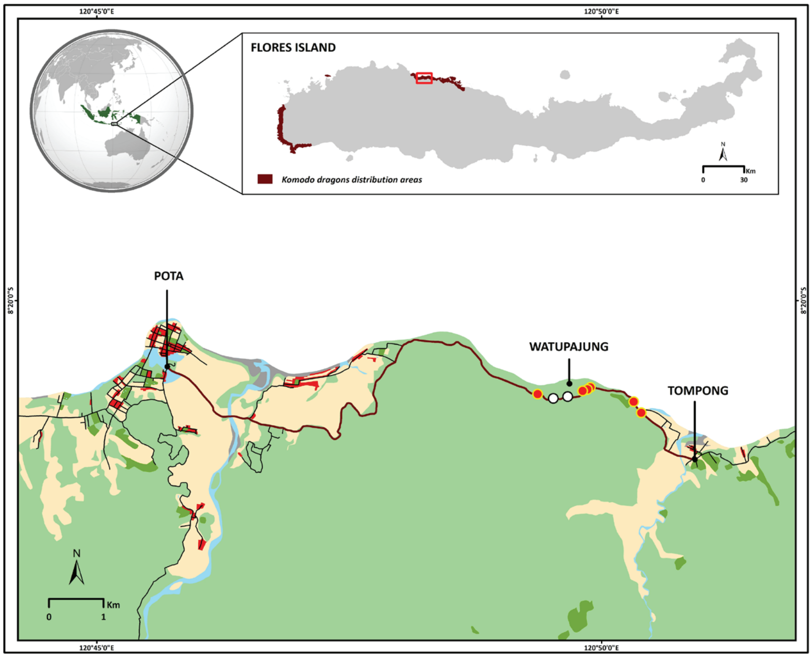

Figure 1. Land cover and locations of Komodo Dragon (*Varanus komodoensis*) - vehicle collisions in the study area. Land cover include settlements (dark red), cultivated areas (light brown), dry Deciduous Monsoon Forest (light green), Savannah Woodland (dark green), swamps (grey), water bodies (light blue), and roads (thin lines). The 12-km road surveyed in this study is shown as a red, thick line. Locations of road kills (red dots inside yellow circles) of Komodo Dragons and those that survived with and without injury (white dots inside black circles).

On the coast of north Flores, the recent expansion of the road network has allowed the development of human settlements into coastal habitats that harbor small populations of Komodo Dragons. Although we understand the impacts of some human-related activities on Komodo Dragons on Flores, we do not yet know how recently developed roads further impact them. Between 2012 and 2018, we documented the incidence of motor vehicle-related collisions causing Komodo Dragon injury and mortality on Flores Island. Compiling this information will provide data useful to the local and central governments to mitigate the risk of vehicle collisions on Komodo Dragons.

Materials and Methods

***Study site*.**—We conducted our study along a 12-km bitumen sealed road segment that passed through Komodo Dragons habitat (Fig. 1). The road survey area stretched eastwards from the township of Pota (08°20'39"S, 120°45'42"E) to Tompong (08°21'33"S, 120°50'56"E). The road section was established in 1993 as part of the Trans Flores Highway, a national government project aimed at improving regional infrastructure and development in eastern Indonesia. Initially the road was built unsealed, which prevented year-round use because the wet season causing intermittent closures; however, in 2012 the road was sealed with bitumen allowing for year-round use.

The road has an average width of 5–7 m and is at an elevation of 10–55 m above sea level. It is characterized by straight sections intermixed with bends when traversing hills along the coast. Of particular importance is that this road passed through Watu Pajung, an area of undisturbed Dry Deciduous Monsoon Forest interspersed with Savannah Woodland, which is occupied by Komodo Dragons (e.g., Watu Pajung; Fig. 1). Cars and motorcycles using this road travelled at speeds of up to 60 km/h.

***Data collection*.**—We used two approaches to compile data on vehicle-related injury and mortality of Komodo Dragon. First, we informally and opportunistically interviewed local community members to ask them of their knowledge of vehicle-related incidences involving Komodo Dragons for the period between 2012 and 2015. This period spanned the time after which the road was sealed and before we commenced our second effort to collect data. From January 2016 until December 2018, we conducted twice weekly road-based surveys to record incidence of mortality or injury of Komodo Dragons within the study area. We used a motor bike travelling at 40 km/h to survey the road at different times of the day across the study duration. If we encountered a dead or injured Komodo Dragon, we recorded the date, time, and coordinates of the location using a Geographic Positioning System (GPS) device. We also recorded the age class of the lizard and the vehicle type

Figure 2. (Left) The study area in which we surveyed a section of the road that passed through pristine habitat occupied by Komodo Dragons, *Varanus komodoensis* (Photographed by Muhammad Azmi). (Right) A dead subadult Komodo Dragon as a result of a collision with a motorcycle at Watu Pajung, Flores Island, Indonesia. (Photographed by Arsyad M. Kasim).

causing the injury or death of Komodo Dragons at the site of incident. We used ArcMap 10.8 (Esri, Redlands, California, USA) to overlay the coordinate location of road-kill accidents with Land Use Land Cover data from national legal maps of Peta Rupa Bumi Indonesia (https://tanahair.indonesia.go.id/portal-web).

Results

From our surveys we compiled eight reports of vehicle related accidents to Komodo Dragons (Table 1). Vehicle collisions resulted in Komodo Dragon mortality in six of eight (75%) incidences (Fig. 2). For the remaining two non-lethal incidents, one individual was visibly injured but the other was not. Cars and light trucks, rather than motorcycles, were responsible for most incidents. It was evident, however, that all the incidents reported were clustered by time of year (Table 1) and locality (Fig. 1), with all incidents occurring from June to August coinciding with the cooler dry season (Table 1). Additionally, all incidents were aggregated along an approximately 2-km stretch of road, where roadside habitats remained free of human disturbance.

Discussion

People rely on the roads that increasingly intersect natural habitats to enhance their connectivity between rural and urban areas (Brovarone and Cotella 2020). Consequently, vehicles traffic can be a major cause of wildlife mortality and especially for slower moving animals (Andrews et al. 2008). Our results are consistent with the consequences of road expansion into natural habitats, which is often associated with environmental impacts (Forman and Alexander 1998; Verán-Leigh et al. 2019). Here we report eight incidents of Komodo Dragon mortality or injury resulting from at least one or two vehicle collisions per year.

Land clearing by humnas already challenge Komodo Dragon persistence on the north central coast of Flores (Ariefiandy et al. 2015, 2020). Our results indicate that road collisions were associated with killed or injured sub adult and adult Komodo Dragons. Given the naturally higher juvenile mortality in this species, elevated mortality in both older age classes would be expected to further increase the demographic consequences of vehicle collisions for this population (Jones et al. 2020).

Table 1. The incidence of vehicle related mortality and injury to Komodo Dragons (*Varanus komodoensis*) between 2013 and 2018 along the Pota to Tompong development road on the north coast of Flores, Indonesia. Area names are the local designations.

No.	Date	Area	Age Class	Fate	Possible Cause
1	22 August 2013	Tompong	Juvenile	Dead	Unknown
2	3 June 2014	Watu Pajung	Subadult	Dead	Unknown
3	12 June 2015	Tompong	Adult	Dead	Unknown
4	6 July 2015	Watu Pajung	Adult	Dead	Motorcycle collision
5	4 August 2016	Watu Pajung	Juvenile	Dead	Vehicle collision
6	14 August 2016	Watu Pajung	Juvenile	Dead	Car/light truck collision
7	1 August 2017	Watu Pajung	Unknown	Survived without visible injury	Vehicle collision
8	26 June 2018	Watu Pajung	Subadult	Survived with tail injury	Vehicle collision

We suggest that for this Komodo Dragon population, which is likely at low density and in decline, these additional impacts to the species from vehicle collisions may be too much for the population to withstand.

We found that vehicle collisions were aggregated both in terms of time of year and to a specific section of the road. In the Amazon, road development can potentially attract reptiles and amphibians for multiple reasons including basking, access to carrion, and because roads can facilitate longer distance movements across open habitats (Sartorius et al. 1999). Similar factors may explain why Komodo Dragon access the road we studied and invariably result in injury or mortality. Because of their size, Komodo Dragons require a relatively long basking time in the morning to reach their preferred body temperature (Harlow et al. 2010a,b). Roads may provide ideal basking sites for this species so they can quickly increase their temperature above ambient temperature more so than other microhabitats. Additionally, increased movement rates during the dry season when Komodo Dragons access seasonal food resources (e.g., bird and turtle eggs) or mates could further increase their risk of vehicle collision (Auffenberg 1981; Purwandana et al. 2016).

The most likely reason that all Komodo Dragon mortalities and injuries occurred within the Watu Pajung area is because it comprises the last fragments of coastal natural habitat used by Komodo Dragon in this area of North Flores. That this area is also separated by human modified landscapes from any other Komodo Dragon habitat means that the vehicle related mortality is unlikely to be offset by Komodo Dragon immigration because the species has limited dispersal capacity (Jessop et al. 2018). Komodo Dragons are particularly susceptible to human disturbance and are typically found in either protected or remote coastal areas on western and northern Flores (Ariefiandy et al. 2020). Because this section of road is relatively short (about 2 km), it could be feasible for the local or central government authorities to device and implement strategies to minimize vehicle related impacts on Komodo Dragons. Installing vehicle collision warning and reduced speed signs (e.g., 40 km/h) could represent a relatively inexpensive way to improve driver awareness and lower vehicle speed, which may reduce Komodo Dragon road kills. These measures may also help prevent injury to humans or damage to vehicles (i.e., motorbikes) that could arise from collisions with Komodo Dragons. Along Tasmanian highways, road sections with speed limits had a much lower incidence of wildlife mortality than those sections without (Hobday and Minstrell 2008). More effective, but costlier, strategies could include constructing road obstacles (e.g., speed bumps) to enforce reduced speed within the Watu Pajung road section, and constructing roadside fencing and underpasses, which would prevent road access to Komodo Dragons and stop vehicle collisions (Forman and Alexander 1998; Hobday and Minstrell 2008). Clearly, any future infrastructure road-developments planned for other areas within the Flores Komodo Dragon distribution should implement these mitigation measure to prevent similar impacts. Ideally, any planning of future roadworks would also consider avoiding core habitats of Komodo Dragons, as this would be the best way to ensure that the associated impacts to wildlife are avoided altogether.

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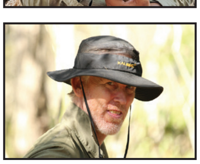

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