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FOREST BIRDS USE VEGETATED FAUNA OVERPASS TO CROSS MULTI-LANE ROAD

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ABSTRACT

Although wildlife overpasses have been constructed in many countries to provide safe crossing passages over roads, most have been focused on larger species of mammals. Bird use of these large structures has largely been ignored, although the impact of roads on birds is of increasing concern, especially among smaller, forest-interior species. We studied birds crossing a four-lane road over the road either above the surface or via a vegetated wildlife overpass near Brisbane, Australia, over two years. A total of 14 species were detected crossing the road between the forest edges away from the structure. These were mainly larger species (median weight 110g). In contrast, 25 species of mainly smaller species (median weight 15g) were detected using the wildlife overpass, primarily within the dense planted foliage, with an additional 14 species crossing the road directly above the structure. Although detected only occasionally during the study, the presence of species typically known only from the forest interior in the foliage of the wildlife overpass was especially noteworthy. Moreover, there was strong evidence that the wildlife overpass was being actively used as a corridor. Thus, as many smaller forest-dwelling species appear to be reluctant to cross roads, the construction of this vegetated wildlife overpass appears to have facilitated opportunities for movement that has been exploited by local species. Finally, these results strongly suggest that many of the large number of wildlife overpasses could be converted into safe passages over roads for a much larger proportion of the local biodiversity than has often been previously considered.
Keywords: wildlife overpass; road-barrier effect; ecological corridor.

RESUMO

AVES FLORESTAIS UTILIZAM *WILDLIFE OVERPASSES* COM VEGETAÇÃO PARA ATRAVESSAR RODOVIA. Embora *wildlife overpasses* venham sendo construídos em muitos países para prover passagens seguras sobre estradas, a maioria tem como foco grandes espécies de mamíferos. O uso dessas grandes estruturas pelas aves tem sido amplamente ignorado, embora o impacto das estradas nas aves seja uma preocupação crescente, especialmente para espécies florestais pequenas. Nós estudamos a travessia de uma estrada de quatro pistas pelas aves, tanto pela superfície quanto por um *wildlife overpass*, próximo à Brisbane, Austrália, durante dois anos. Um total de 14 espécies foram detectadas cruzando a estrada entre as margens da floresta distantes da estrutura. Estas eram principalmente espécies de grande porte (peso médio de 110g). Por outro lado, 25 espécies, quase todas de menor porte (peso médio de 15g), foram identificadas utilizando o *wildlife overpass*, sobretudo no interior da densa folhagem, com um adicional de 14 espécies atravessando a rodovia diretamente sobre a estrutura. Embora detectadas apenas ocasionalmente durante o estudo, a presença de espécies tipicamente conhecidas como exclusivas do interior de mata na folhagem do *wildlife overpass* é especialmente digna de nota. Além disso, existem fortes evidências de que o *wildlife overpass* foi ativamente utilizado como um corredor. Portanto, como muitas pequenas espécies florestais parecem relutar em atravessar rodovias, a construção desse *wildlife overpass* parece ter oferecerecido mais oportunidades para o movimento, o qual passou a ser explorado pelas espécies locais. Finalmente, os resultados sugerem fortemente que vários

dos *wildlife overpass* podem ser convertidos em passagens seguras sobre as estradas para uma proporção muito maior da biodiversidade local do que se costumava considerar previamente.
Palavras-chave: *wildlife overpass*; efeito-barreira de rodovia; corredor ecológico.

RESUMEN

AVES DEL BOSQUE UTILIZAN *WILDLIFE OVERPASSES* CON VEGETACIÓN PARA ATRAVESAR CARRETERA DE VARIOS CARRILES. A pesar de que *wildlife overpasses* hayan sido construidos en muchos países para constituir puntos de paso seguro sobre carreteras, la mayoría tiene foco en especies de grandes mamíferos. El uso de estas estructuras por aves ha sido ampliamente ignorado, a pesar de que el impacto de carreteras sobre las aves sea una preocupación creciente, especialmente para especies pequeñas del interior del bosque. Estudiamos durante dos años el paso de aves sobre una carretera de cuatro carriles, tanto por la superficie como por un *wildlife overpass*, cerca de Brisbane, Australia. Un total de 14 especies fueron detectadas cruzando la carretera entre los márgenes del bosque distantes de la estructura. Éstas eran principalmente especies de gran porte (mediana del peso 110g). En contraste, 25 especies, casi todas de menor porte (mediana del peso 15g), fueron identificadas utilizando el *wildlife overpass*, sobre todo al interior del follaje plantado denso, con 14 especies adicionales atravesando la carretera directamente sobre la estructura. A pesar de ser detectadas ocasionalmente durante el estudio, vale la pena resaltar la presencia de especies típicas del interior del bosque en el follaje del *wildlife overpass*. Adicionalmente, hay fuertes evidencias de que el *wildlife overpass* fue utilizado activamente como un corredor. Por lo tanto, como muchas especies pequeñas de bosque parecen evitar atravesar carreteras, la construcción de este *wildlife overpass* con vegetación parece haber ofrecido oportunidades para el movimiento, que fueron explotadas por especies locales. Finalmente, los resultados sugieren fuertemente que varios de los *wildlife overpasses* podrían ser convertidos en pasos seguros sobre las carreteras para una proporción mucho mayor de la biodiversidad local de lo que se pensaba previamente.
Palabras clave: *wildlife overpass*; efecto de barrera de carretera; corredor ecológico.

INTRODUCTION

The impacts and influences of roads, road networks and traffic on biodiversity have developed into a major research theme in recent years (Fahrig & Rytwinski 2009, Taylor & Goldingay 2010). Road networks dramatically exacerbate the on-going impacts associated with habitat fragmentation and the resulting isolation of populations within the remaining fragments (Benítez-López *et al.* 2010, Kociolek *et al.* 2011). Addressing and ameliorating such concerns is a primary challenge of the burgeoning field of road ecology (see Forman *et al.* 2003, Beckmann *et al.* 2010).

A fundamental concept of road ecology is that of the road-barrier effect (Forman & Alexander 1998). Put simply, roads often present some level of impediment to the movement of animals, from that of a minor hindrance to a complete blockage, with the relevant significance relating to key characteristics of the taxa and the road and traffic itself (Garcia-Gonzalez *et al.* 2012). Considerable research attention has been directed towards the types of animals most likely to be impacted by roads such as reptiles, amphibians and small mammals (Fahrig & Rytwinski 2009). Birds, however, have received relatively less attention from road ecologists (Kociolek *et al*. 2011). The assumption appears to be that birds, being able to fly above the road, are unaffected by the same impacts and influences as other taxa, with the implication that the road-barrier effect is of little consequence (Jacobson 2005). Birds, however, may be the taxa most frequently killed by collisions with vehicles and may be especially influenced by habitat changes (Benítez-López *et al.* 2010, Tremblay & St. Clair 2011).

Critically, several studies have demonstrated marked differences between bird species' willingness to cross roads, with the width of the gap being of particular importance (St. Clair *et al.* 1998, Tremblay & St. Clair 2009). For many smaller, forest-dwelling species, even narrow roads may represent a complete barrier (Laurance *et al.* 2004). Tremblay & St. Clair (2009), for example, found a gap of only 45m to be a significant threshold for the movements of small forest interior species, beyond which there was a 50% deduction in the willingness to cross. Given that the distance between the habitats on either side of any road of more than two lanes typically exceeds this distance, the implications for population isolation for many small bird species may be profound (Laurance *et al.* 2009, Kociolek *et al*. 2011).

To overcome or reduce the barrier-effect on the movements of fauna, a wide variety of purpose-designed crossing structures have been installed throughout the world. These include a range of underpasses and various forms of fauna overpass (Glista *et al.* 2009, Beckmann *et al.* 2010). Extensive studies of the effectiveness of these structures have concluded that sizable numbers of animals of many species do use them, that road mortality is significantly reduced and that connectivity of populations on either side of the road can be restored (Mata *et al.* 2008, van der Ree *et al.* 2009). Nonetheless, important issues remain, including whether movements are sufficient to ensure population viability and – critically – which species are crossing and which are not (Corlatti *et al.* 2009, van der Ree *et al.* 2009). While the results of many studies of fauna use of structures have been unexpectedly positive (for exemple, Bond & Jones 2008, Mata *et al.* 2008), the capacity of crossing structures to assist safe passage and enhance population persistence for local entire vertebrate communities is a crucial issue (Beckmann *et al.* 2010).

Because of their relatively large size, flexibility of design and potential to provide an integrated and seamless transition between the habitats on either side of the road, fauna overpasses represent the most comprehensive form of crossing structure. However, to date most fauna overpasses have been designed primarily for the movement of larger mammal species (Glista *et al.* 2009, Beckmann *et al.* 2010). Such species tend to prefer relatively open habitat and wider structures, features that may deter smaller species and non-mammal taxa (Mata *et al.* 2008). Nonetheless, recent studies of vegetated 'green bridges', which combine areas of denser recreated habitat with open areas, indicate that a diversity of species will use such structures as a corridor of continuous habitat (Bond & Jones 2008, Mata *et al.* 2008, Hayes & Goldingay 2009, Beckmann *et al.* 2010). Despite the obvious assistance such overpasses could provide for bird movements (St. Clair 2003), remarkably little investigation of bird use of these structures has been undertaken (compare to Keller *et al.* 1996).

Although they are the most expensive and structurally challenging of all crossing structures (Beckmann *et al.* 2010), fauna overpasses are increasingly being constructed, especially throughout Europe (Corlatti *et al.* 2009). One of the first fauna overpasses constructed in Australia was erected in 2004 to provide habitat connectivity over a major four-lane road near Brisbane in eastern Australia (Bond & Jones 2008). Studies since 2004 have demonstrated regular crossings by a variety of larger mammals as well as the establishment of numerous species of amphibian and reptile (Veage & Jones 2007, Taylor & Goldingay 2010).

The monitoring of birds on the overpass was not considered until the vegetation had developed, although informal sightings of birds on the structure were recorded regularly during routine monitoring field trips. These observations showed that a small number of larger, locally common generalist species foraged daily in the open surface of the structure. Smaller species were, however, not detected regularly until 2008, four years after construction, when several species were noted moving through the rapidly developing plantings. Numerous studies (for example, St. Clair 2003, Laurance *et al.* 2004) of gap-crossing in birds have shown that many birds, most notably edge-averse forest interior species, are often reluctant to cross forest gaps of more than about 45m; this is especially likely when the gap also carries traffic (Tremblay & St. Clair 2009). Compton Road, with a width of about 80m between the forest edges on either side, therefore, represented a significant barrier to at least some of the species resident in the neighbouring forests. The introduction of the overpass, however, may provide a possible safe corridor for the movement of smaller birds.

To investigate these issues we compared the species crossing the road at sites away from the fauna overpass with those using the overpass. We predicted that there would be low similarity between the species using the structure to cross the road and those flying over the road, and that the average body size of those flying over the road would be larger. A short summary of the first few months of this study was published by Jones & Bond (2010); the present paper presents findings obtained over two years of observations.

METHODS

The Compton Road fauna overpass (27° 36' 53.11" S, 153° 05' 03.12" E) is one component of the Compton Road Fauna Array which includes two large purpose-designed underpasses, three rope bridges and a series of poles designed for use by gliding marsupials (Veage & Jones 2007). The array is located along 1.3km of the four-lane Compton Road, a major arterial road approximately 22km from the Central Business District of Brisbane, Australia. The suite of crossing structures allows safe movement of fauna from the forested reserves either side of the road, Karawatha Forest (950ha) to the south and Kuraby Bushland (140ha) to the north. The reserves are nationally recognized conservation areas and support over 100 species of birds, including several threatened and regionally significant species (Veage & Jones 2007). The road is fully enclosed by 1.4m high exclusion fencing.

The overpass is hour-glass in shape and 70m long, has a base width of 20m and is 15m wide at the mid-point (Figure 1). The height of the surface of the structure is 8m with a 5.4m clearance within both tunnels. The surface of the structure was covered in 30cm to 1.3m of soil topped with hydromulch and planted at a density of 70 shrubs and 6 trees per $100m^2$. A detailed survey of the recreated vegetation conducted four years after construction detected 45 species, most of which had been planted with the remainder self-propagating (Jones *et al.* 2011). The structure of the vegetation now closely resembles the dense understory of the surrounding subtropical eucalyptus forest and is remarkably similar in species richness (Jones *et al.* 2010).

Figure 1. The Compton Road fauna overpass showing vegetation as developed about five years after construction.

Bird movements across the road were surveyed weekly from March 2008 until April 2010. Birds crossing the road away from the overpass were detected in four 80 x 10m transects positioned perpendicular to the road 100m and 200m to the east and west of the overpass. The observer stood immobile on the road side of the exclusion fence and counted, and identified all birds crossing the road lower than canopy height during 5 min observation sessions; bird detected higher than the canopy were excluded as were birds flying along the road and not crossing. For birds using the overpass, four separate 20 x 10m transects were positioned along the structure parallel to the road. Each overpass transect was spaced as far apart as possible with two along the base of the slope and two others along either end of the flat top. The observer remained immobile at one end of the transect so as not to disturb birds. All birds detected were identified and counted, and were recorded as being seen as either: (1) within the foliage on the overpass; or (2) flying above the overpass but below the level of the surrounding canopy.

Bird abundance data was transformed (square-root) to rectify statistical normalcy. The mean abundances for the four separate counts of crossing away from the overpass (road transects) and those undertaken on the overpass (overpass transects) were compared using ANOVA tests, with all overpass transects averaged into a single transect because of the lack of spatial and temporal independence. As no significant differences were found, road and overpass surveys were treated as independent for subsequent analyses. The similarity of the species richness of road, overpass foliage and above overpass counts were compared using Sorenson's Index (Krebs 1999).

The mean number of species and the abundances of birds crossing the road away from the overpass were compared to those using the overpass by considering those detected within the foliage on the overpass, those detected directly above the overpass, and these two categories combined using a one-way ANOVA of the transformed data. All statistical analyses were performed on SPSS Statistics (v.18.0, 2009).

RESULTS

A total of 14 species of bird were detected flying across the road from forest to forest and away from the vicinity of the overpass during the study (this excluded species flying higher than the canopy and aerial species such as swallows) . In contrast, a total of 25 species were detected crossing the road within the foliage on the overpass; a further 14 species were recorded flying directly above overpass. In all, 28 species appeared to cross the road in association with the structure with 19 of these detected only in the overpass foliage and three only above the overpass. Nine species crossed the road both on and away from the structure although three species (rainbow lorikeet, noisy friarbird and spangled drongo) were at least twice as likely to cross above the overpass as away from the structure (Table 1).

Table 1. Weight and mean number of individuals per survey for species detected crossing Compton Road away from the overpass, within the foliage on the overpass and above the overpass (means < 0.01 rounded up).

Species	Weight (g)	Over road	Overpass foliage	Above overpass
Pacific black duck *Anas superciliosa*	1010			0.01
Sulphur-crested cockatoo *Cacatua galerita*	800	0.03		
Channel-billed cuckoo *Scythrops novaehollandiae*	680	0.01		0.01
Laughing kookaburra *Dacelo novaeguinae*	780			0.01
Torresian crow *Corvus orru*	520	0.38	0.04	0.13
Galah *Eolophus roseicapilla*	330	0.02		
Australian magpie *Cracticus tibicen*	305	0.05		
Rainbow lorikeet *Trichoglossus haematodus*	120	0.49		1.10
Figbird *Specotheres viridis*	125			

Continuation Table 1

Species	Weight (g)	Over road	Overpass foliage	Above overpass
Black-faced cuckoo-shrike *Coracina novaehollandiae*	110	0.03		0.04
Pale-headed rosella *Platycercus adscitus*	100		0.03	0.02
Noisy friarbird *Philemon corniculatus*	100	0.05	0.04	0.11
Olive-backed oriole *Oriolus sagittatus*	100	0.01		
Grey butcherbird *Cracticus torquatus*	95	0.01		
Pied butcherbird *Cracticus nigrogularis*	90			
Scaly-breasted lorikeet *Trichoglossus chlorolepidotus*	85	0.09	0.08	0.11
Spangled drongo *Dicrurus bracteatus*	75	0.02	0.03	0.05
Grey shrike-thrush *Colluricincla harmonica*	65		0.03	
White-throated treecreeper *Cormobates leucophaeus*	20		0.01	
Eastern yellow robin *Eopsaltria australis*	20		0.12	
Willy wagtail *Rhipidura leucophrys*	20		0.01	
Rainbow bee-eater *Merops ornatus*	18			0.01
Golden whistler *Pachycephala pectoralis*	18		0.02	
Black-faced monarch *Monarcha frater*	16		0.02	
Varied sittella *Daphoenositta chrysoptera*	15		0.01	
Leaden flycatcher *Myiagra rubecula*	15		0.01	
Yellow-faced honeyeater *Lichenostomus chrysops*	15	0.02	0.23	0.01
White-throated honeyeater *Melithreptus albogularis*	15	0.06	0.10	0.03
Scarlet honeyeater *Myzomela sanguinolenta*	11		0.06	
Silvereye *Zosterops lateralis*	10		0.31	0.13
Brown honeyeater *Lichmera indistinct*	10		0.06	
Red-backed fairy-wren *Malurus melanocephalus*	10		0.16	
Variegated fairy-wren *Malurus lamberti*	10		0.04	
Striated pardelote *Pardelotus striatus*	10		0.01	
Red-browed finch *Neochmia temporalis*	9		0.19	
Grey fantail *Rhipidura fuliginosa*	8		0.03	
Rose robin *Petroica rosea*	7		0.01	
Weebill *Smicrornis brevirostris*	6		0.03	

Although detected only occasionally during the study, the presence of species typically known only from the forest interior in the foliage of the overpass was especially noteworthy. These species included the white-throated treecreeper, varied sitella, black-faced monarch and rose robin (Table 1).

The list of species detected flying over the road was substantially different to those detected in the foliage of the overpass. Among the 14 and 25 species recorded for these two zones respectively, only six were common to both (Sorenson's C=0.153). In contrast, the lists of species observed over the road (14 species) and above the overpass (14 species) had nine species in common (Sorenson's C=0.321).

There was a significant difference in the mean species richness of birds detected above the road compared to those detected using the overpass, with almost twice as many species being detected on the overpass. There were, however, no significant differences in the number of individuals detected per survey either crossing the road away from the structure, crossing the road with the foliage on the overpass or above the overpass. When the birds detected within the foliage were combined with those seen directly above, the mean number of individuals associated with the overpass was substantially but not significantly higher than that detected crossing the road (Table 2).

Although the species detected above the road varied in size from the sulphur-crested cockatoo (800g) to the white-throated honeyeater (15g), most of these birds were larger species with the median weight of this group (110g) just lower than the most abundant species detected, the rainbow lorikeet (120g). This species comprised fully 41.2% of all birds recorded; combined with the Torresian crow, these two species made up over 72% of all birds crossing the road away from the overpass.

The mean weight of all road species was 158.4±254.5g. In contrast, the mean weight of species detected within the foliage of the overpass was only 47.6+102.8g (range 110-6g). The five most abundant of the foliage-associated species – all smaller insectivores – comprised 57.6% of the total with the most common species, the silvereye (18.4%) weighing only 10g. Indeed, the median weight of these birds was 15g, equivalent to the second most abundant species, the yellow-faced honeyeater (13.7%).

DISCUSSION

Despite the presence of many fauna overpasses throughout the world (Corlatti *et al.* 2009), with some having been constructed over fifty years ago, remarkably little has been published on the use of these structures by birds. Indeed, the only similar study known to us (Keller *et al.* 1996) was an investigation of bird use of two overpasses in Germany which found that many more birds used the structure than flew over the road, with forest species being predominant. As an appreciation of roads as partial or complete barriers to the movements of a wide variety of taxa continues to grow, and evidence of the concomitant fragmentation of populations mounts (Corlatti *et al.* 2009, Clark *et al.* 2010), the potential for expanding the utility of these major structures is becoming clearer. The findings of the present study provide powerful support for this perspective.

As with most fauna overpasses, the Compton Road overpass was designed and constructed primarily for the passage of larger mammals between the forested reserves on either side of the road while keeping them safely away from the traffic below. To facilitate this aim, the structure was planted with abundant vegetation eventually to provide a natural and seamless extension of the surrounding habitat (Jones *et al.* 2011). However, as movements by the main species of concern (wallabies and kangaroos) would be impeded by full coverage of dense understory, approximately 30% of the surface area of the structure was left open and planted only with grasses (Bond & Jones 2008). Nonetheless, most of the overpass now resembles a dense subtropical eucalyptus forest, typical of the local area (Jones *et al.* 2010).

Although some birds – mainly corvids and predatory species – were observed on the overpasses soon after construction, the first sightings of smaller

Table 2. Mean species richness and abundance per survey for birds detected crossing Compton Road above the road, within the foliage on the overpass and above the overpass (n=93 surveys); with results of ANOVA (square root transformed) comparison of means for birds detected above road with those using overpass (foliage and above overpass combined) (Tukey's post-hoc: significant separation indicated by different letters).

Component of data	Over road	Overpass foliage	Above overpass	Overpass foliage and above	ANOVA
Species richness	0.56±0.90 a	0.95±0.11 b	0.49±0.06 a	1.49±0.71 b	F=6.68, *p*=0.0076
Abundance	1.44±0.89	1.85±0.01	4.94±5.61	6.79±5.15	N.S.

species coincided with the development of a dense and mainly continuous expanse of mainly local native species of planted shrubs and tree saplings (D. Jones unpublished data). This relationship between the presence of an extensive belt of dense sheltering vegetation and the movement of smaller species of passerine birds was first suspected after about three years development of the vegetation when the structure of the rapidly growing shrubs and smaller trees resembled a typical early successional stage of the local forests (Jones *et al*. 2011).

Both the species richness and the abundances of the birds detected within the foliage of the overpass were far greater than expected. Indeed, the 25 species using the overpass represented almost 40% of all species detected during separate studies of birds in the surrounding forest (Veage & Jones 2007). Thus, if, as is now widely suspected (Laurance *et al.* 2009, Tremblay & St. Clair 2009, 2011), many smaller forest-dwelling species were reluctant or unlikely to cross the road, the construction of the overpass over Compton Road appears to have provided an opportunity to facilitate movement that has been exploited by the local birds. The utility of the overpass as a habitat corridor seems to have been further confirmed by the relatively densities of birds found within the overpass foliage compared to the more typical densities within the expanse of the neighbouring forests (Veage & Jones 2007). It should be appreciated, however, that the relatively high numbers of birds seen on the overpass were of moving birds concentrated into the relatively narrow (15m at the narrowest point) belt of vegetation on the structure; to date, no birds appear to have established residential home ranges or territories on the overpass. While this spatially constricted corridor appeared not to have deterred the passage of birds, the implications for the movements of conspecifics through territories that may become to be established on the structure have yet to be investigated.

Possibly even more significant than the numbers of species using the overpass was the discovery of numerous birds generally regarded as being edge-intolerant, forest-interior species moving over the structure. These include species such as the varied sittella, rose robin and black-faced monarch, all found in relatively low numbers within the forest (Veage & Jones 2007) and known to be sensitive to disturbance (Sewell & Catterall 1998). While the utility of the structure for many of the smaller species detected appears to have been dependent on the presence of dense understory vegetation (Jones & Bond 2010), this feature seems to be especially important to the forest-interior species (Laurance *et al.* 2009). Remarkably, even species rarely seen below the canopy within the forest (such as white-throated treecreeper and varied sittella) were detected within overpass foliage less than 4m in height (D. Jones unpublished data). Detailed investigations of the relationship between vegetation structure height on overpasses and usage by bird species may, therefore, prove valuable for attempts to enhance their attractiveness to a wider diversity of birds.

Although road ecologists have only recently turned their attention to birds, it has become obvious that roads present highly variable levels of permeability, from little or no hindrance to that of a complete barrier (St. Clair 2003). The species least likely to fly across a typical road are primarily forest-dwelling songbirds (Tremblay & St. Clair 2009), although many exceptions exist within guilds (see Laurance *et al.* 2004). Significantly, several studies have discerned critical gap-width thresholds beyond which a majority of birds will not fly with 45m being defining. As this distance is narrower than many roads, the barrier implications of roads in excess of two lanes may be critical for large numbers of smaller bird species.

In the present study, some birds were detected flying over the busy four-lane road during every observation session, crossing a forest-to-forest distance of about 80m. However, virtually all of these species were relatively large in size; smaller passerines did not appear to cross the road away from the overpass. In direct and obvious contrast, virtually all of the species detected crossing the road within the foliage on the overpass were smaller in size.

The unexpectedly positive results of this modest study suggest that the barrier and filter effects of many roads may be successfully reversed through the use of carefully vegetated overpasses. Perhaps more importantly, these results strongly suggest that many of the large number of fauna overpasses could be converted into safe passages over roads for a much larger proportion of the local biodiversity than has often been previously considered.

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