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Koala mortality on roads in south-east Queensland: the koala speed-zone trial

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Abstract. In 1995, the Queensland Parks and Wildlife Service, the Queensland Department of Main Roads and Redland Shire Council initiated the Koala Speed Zone Trial in the Koala Coast, south-east Queensland. The aim of the trial was to assess the effect of differential speed signs on the number of koalas (*Phascolarctos cinereus*) hit by vehicles in the Koala Coast from 1995 to 1999. On the basis of information collected by the Queensland Parks and Wildlife Service 1407 koalas were hit by vehicles in the Koala Coast during the five-year study (mean 281 koalas per year, range 251–315). Monitoring of vehicle speeds by the Queensland Department of Main Roads suggested that there was no significant reduction in vehicle speed during the trial period from August to December. Consequently, there was no evidence to suggest that a reduction in the number of koalas hit by vehicles occurred during the trial. Approximately 70% of koalas were hit on arterial and sub-arterial roads and approximately 83% did not survive. The location of each koala hit was recorded and the signed speed limit of the road was noted. Most koalas that were hit by vehicles were young healthy males. Pooling of data on koala collisions and road speed limits suggested that the proportion of koalas that survived being hit by vehicles was slightly higher on roads with lower speed limits. However, vehicle speed was not the only factor that affected the number of koalas hit by vehicles. It is suggested that habitat destruction, koala density and traffic volume also contribute to road-associated koala mortality in the Koala Coast.

Introduction

Little is known about the effects of road-associated mortality on native Australian wildlife populations (Coulson 1997; Jones 2000). Although road kills do not appear to exert significant pressure on many populations of common species, there is some evidence to suggest that populations that are small, fragmented or declining, or that repeatedly come into contact with roads, may be adversely affected by the impacts associated with road development (Brown 1989; Bennett 1991; Jones 2000).

Many koala (*Phascolarctos cinereus*) populations that live close to urban areas are under considerable threat as a result of road-associated mortality (Phillips 1990; Thompson 2001). On Phillip Island, Victoria, koalas killed on roads account for approximately 60% of mortality and have been identified as a major cause for the decline of a once healthy koala population (Lee and Martin 1988; Backhouse and Crouch 1990). Studies at Port Macquarie and Iluka in New South Wales found that motor vehicles are the main cause of injury and death in small fragmented koala populations (Lunney *et al.* 1996; Martin and Handasyde 1999). Post-mortems conducted on koalas from Port Macquarie have shown that ~30% die as a result of being struck by motor vehicles (Canfield 1987).

In south-east Queensland, information collected by the Queensland Parks and Wildlife Service (QPWS) indicates that vehicles on roads are a major cause of mortality in local koala populations living in heavily urbanised environments. In this region, koala deaths have been monitored since 1988, with more intensive monitoring since 1995 due to the operation of a koala ambulance that transports sick and injured koalas to a local koala hospital (Kraschnefski 1999). An average of ~300 koalas per year were hit by vehicles in the Koala Coast (20 km south-east of Brisbane) since 1995, with most hit between August and December (Nattrass and Fiedler 1996; Thompson 2001). This accounts for ~30% of koalas admitted to the koala hospital and is the single most common cause for admission (Kraschnefski 1999).

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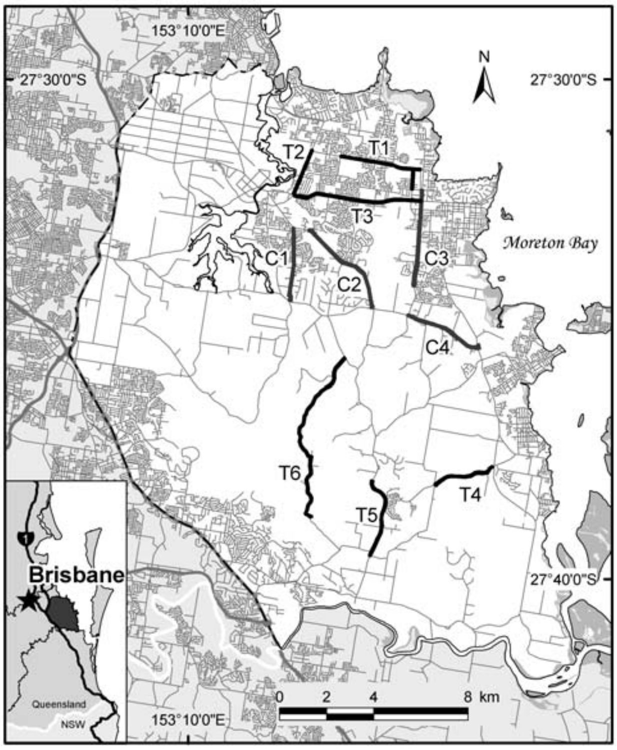

Fig. 1. Map of the Koala Coast showing the locations of the trial and control sites where vehicle speed and koala collisions were monitored.

In those parts of the koala's distribution where it has been identified that road-associated mortality significantly affects local populations, a number of management strategies aimed at reducing koala mortality on roads have been proposed. Lunney *et al.* (1996) suggested that local government in northern New South Wales needed to adopt policies related to appropriate warning signs and reduction of speed limits where appropriate. Smith (1990) suggested that traffic flow through koala habitat should be designed to minimise traffic volume and speed and that warning signs should be erected as a matter of course. Nattrass and Fiedler (1996) found that 22 of 23 koalas hit by vehicles in one suburb in Redland Shire (south-east Queensland) were hit on arterial roads with speed limits greater than 60 km h^{-1}. It has been postulated that a reduction in traffic speed will provide motorists more time to avoid a collision with a koala and if a collision does occur the chance of the koala sustaining fatal injuries is decreased (Queensland Department of Main Roads 2000). While management strategies aimed at reducing koala mortality on roads have been recommended, assessments of their effectiveness are poorly represented in the literature.

This paper provides the results of a five-year trial aimed at assessing the effect of differential speed signs on koala mortality on roads in the Koala Coast. Specific objectives of the trial were to assess the effectiveness of compulsory differential speed signs in (i) lowering vehicle speed at night from August to December, and (ii) reducing the number of koalas hit by vehicles. This paper also provides some discussion on the impacts of koala mortality associated with roads on local koala populations.

Methods

The study area

The Koala Coast covers an area of 375 km^2 and is located 20 km south-east of Brisbane, Queensland. The region is bordered by the Gateway Arterial and Manly Road to the north, the Logan River to the south, Moreton Bay to the east and the Pacific Highway to the west. The Koala Coast contains areas of extensive urban and industrial development, agricultural lands and remnant bushland. Most remnant vegetation in the region has been classified as Nerang–Beenleigh open-forest alliance (Elsol and Dowling 1978). This vegetation type characteristically contains a mixture of tree species, most commonly *Eucalyptus siderophloia*, *E. carnea*, *E. tindaliae*, *E. microcorys*, *E. resinifera*, *E. propinqua*, *Corymbia citriodora* and *C. intermedia*.

Within the Koala Coast, a number of connecting arterial and sub-arterial roads run north–south and east–west across the entire study area. Speed limits on these various arterial roads are 60–100 km h^{-1}. However, ~85% of the roads in the study area are residential streets with speed limits of 50–60 km h^{-1}.

Procedure

The trial was conducted over five years, from 1995 to 1999. Ten arterial and sub-arterial roads within the Koala Coast were selected for the trial; six roads were selected as trial sites (T1–T6) and four were chosen as control sites (C1–C4) (Fig. 1). Fig. 2 shows the locations of dead koalas reported to QPWS during the study.

Differential speed signs were erected on the six trial sites approximately every 500 m. The speed signs were termed differential

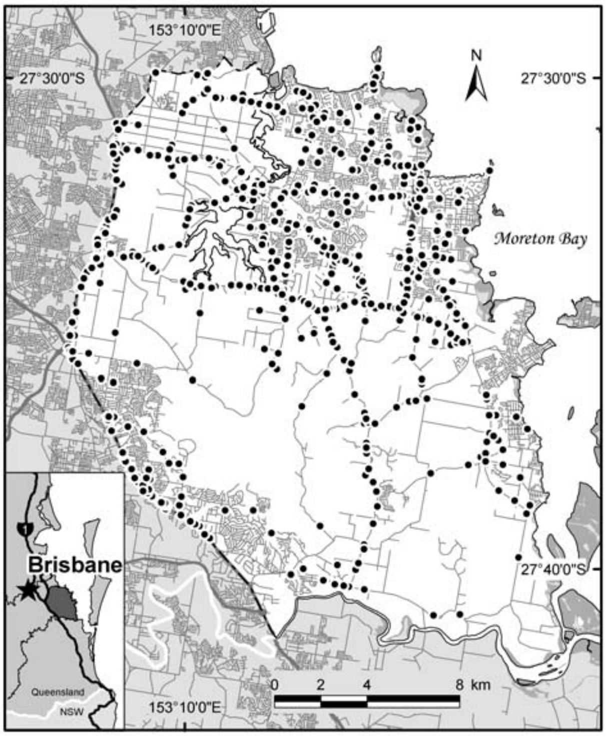

Fig. 2. Map of the Koala Coast showing locations of dead koalas (closed circles) that were reported to QPWS during the five-year study.

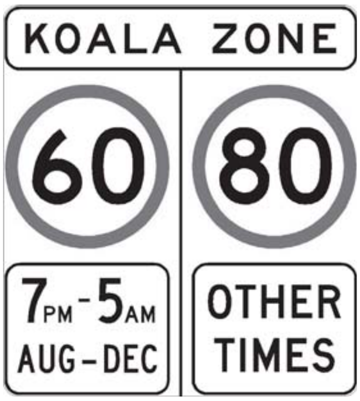

Fig. 3. An example of a differential koala speed-zone sign used during the study.

as they displayed two different speed limits and instructions on when each speed limit was enforceable (Fig. 3). The lower speed limit was enforceable between 1900 (7 PM) and 0500 (5 AM) hours from August to December, the trial period. The higher speed limit was enforced during all other times. Queensland Police often issued speed-infringement notices to motorists at the lower speed on an *ad hoc* basis during routine vehicle speed enforcement. No differential speed signs were erected on control sites.

During the trial period, motorists were legally required to reduce vehicle speed as indicated by the signs between 1900 and 0500 hours. The period from January to July was the control period, during which motorists were not required to reduce vehicle speed. The trial period was selected on the basis of historical records collected by QPWS that suggested that most reports of koala fatalities came from the period from August to December (Nattrass and Fiedler 1996). If a reduction in road-associated koala mortality were achieved during these months, this would be of greatest benefit to the local koala population.

During the trial, many of the differential speed signs at the trial site T6 were vandalised such that only one speed sign (south bound) remained at the site. Consequently, data from this site were not analysed.

The Queensland Department of Main Roads monitored vehicle speed on four of the five trial sites and three of the four control sites before and during the trial period. The methodology used is provided in QDMR (2000). Average Annual Daily Traffic (AADT) data were collected by the Queensland Department of Main Roads using portable counters, permanent counters and manual intersection counts for the period 1994–98.

In 1990, the Moggill Koala Hospital was established in Brisbane by QPWS to cater for the needs of sick and injured koalas (Kraschnefski 1999). In 1995, the koala ambulance commenced operation collecting sick and injured koalas from the Koala Coast and surrounds. This enabled data to be collected by QPWS on koalas that had been hit by vehicles for the duration of the trial. Data from 1994 were collected by the Moggill Koala Hospital and have been provided as pre-trial baseline data. Details of koala location, sex, age, disease, injury status and the speed limit of the road on which each koala was hit were obtained where possible.

Results

During 1995–99, 1407 koalas were hit by vehicles in the Koala Coast and reported to QPWS. The number of koalas hit by vehicles ranged from 252 to 315 each year (mean 281). Arterial and sub-arterial roads accounted for ~70% of koala hits within the region (Fig. 4). Approximately 17% (233) of koalas hit during the trial were successfully released after rehabilitation; the remaining 83% died. In the pre-trial year (1994) 240 koalas were hit by cars in the Koala Coast and reported to QPWS. There was a steady increase in the number of koalas hit each year as the trial progressed. This peaked in 1996 and 1997 at 314 and 315 koalas per year respectively. The number of koalas hit then decreased to 252 in 1999 (Fig. 4).

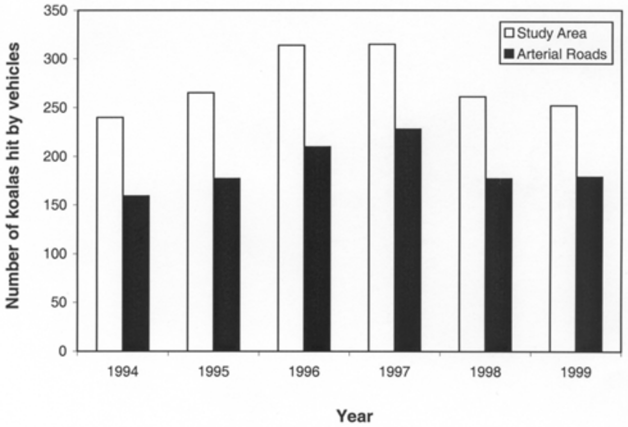

Fig. 4. The number of koalas hit by vehicles in the Koala Coast (Study Area) and on arterial and sub-arterial roads (combined) during 1994–99 (data from1994 have been included as a baseline).

The number of koalas hit on trial sites during the trial period ranged from 11 to 19 (Table 1). More koalas were hit on control sites (20–25) than on trial sites during the trial period (Table 1). Most koalas were hit on T3, C4 and C2. To determine whether the differential speed signs reduced the number of koalas hit by vehicles during the trial period, a comparison was conducted between the mean ratio of the number of koalas hit by vehicles on trial sites and control sites during the trial period (X_t) and the mean ratio of the number of koalas hit by vehicles on trial sites and control sites during the control period (X_c) as follows:

$$X_t = \Sigma_{i=1-5}(T_{ti}/C_{ti})/5,$$

$$X_c = \Sigma_{i=1-5}(T_{ci}/C_{ci})/5,$$

where T_t = no. of koalas hit on trial sites during the trial period, C_t = no. of koalas hit on control sites during the trial period, T_c = no. of koalas hit on trial sites during the control period, and C_c = no of koalas hit on control sites during the control period

From the data in Table 1, X_t = 0.71 and X_c = 0.66. There is no evidence to suggest that fewer koalas were hit by vehicles during the trial period in 1995–99 ($t = 0.14$, $P > 0.1$).

Vehicle speed was monitored on four trial and three control sites before and during the trial period. While a significant decrease in vehicle speed on some trial and control roads was detected for some years, there was no evidence to suggest that vehicle speed decreased signi-

Table 1. The number of koalas hit by vehicles on trial and control sites during the two periods of the study

Site	Trial period (August–December)					Control period (January–July)				
	95	96	97	98	99	95	96	97	98	99
Trial site										
T1	7	2	4	6	5	7	6	10	5	6 6
T2	1	0	1	1	1	0	3	2	5	1
T3	10	12	9	11	5	6	3	5	12	3
T4	1	0	0	1	0	0	1	0	0	0
T5	0	4	2	0	0	1	0	1	1	1
Totals	19	18	16	19	11	14	13	18	23	11
Control sites										
C1	3	2	2	3	1	2	0	2	7	1
C2	7	11	8	14	13	12	7	7	6	9
C3	3	4	0	4	4	6	2	4	2	6
C4	7	7	14	4	7	4	15	18	8	3
Totals	20	24	24	25	25	24	24	31	23	19

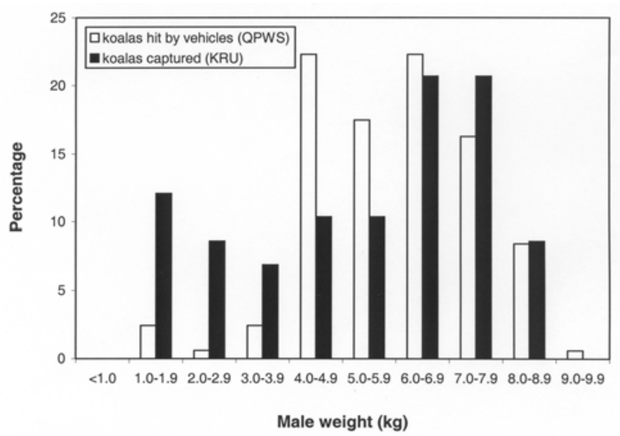

Fig. 5. Weights of male koalas hit by vehicles (data collected by QPWS) and male koalas captured (data collected by KRU) in the Koala Coast in 1998.

ficantly on trial sites during the trial period for the duration of the study (Queensland Department of Main Roads 2000) (Table 2). Given that this is the case, it would be expected that no reduction in the number of koalas hit by vehicles during the trial would be observed. Results outlined above confirm this.

Koalas hit by vehicles

For each year from January 1995 to December 1999, morphological data were collected from koalas hit by vehicles during the trial and control periods. Morphological data collected in 1998 (n = 261 independent koalas) were compared with unpublished morphological data collected by the Koala Research Unit (KRU) within QPWS. The KRU sample came from 141 independent koalas captured between May and July 1998 as part of a detailed study on the population dynamics of koalas at three sites within the Koala Coast.

During 1995–99, an average of 61% of independent koalas hit by vehicles were males (range 55–70%). Unpublished data from the KRU suggests that 41% (n = 58) of independent koalas captured in 1998 were males, suggesting that a disproportionate number of male koalas were hit by cars (χ^2 = 16.4, P < 0.001). A comparison of the weights of koalas collected by KRU in 1998 with the weights of koalas hit by vehicles in 1998 (data collected by QPWS) revealed that a disproportionate number of male koalas between 4.0 and 5.9 kg were hit by vehicles (χ^2 = 39, P < 0.001) (Fig. 5).

Koalas captured by the KRU and collected by QPWS were assigned to age classes on the basis of tooth wear (Gordon 1991). A disproportionate number of male koalas at tooth wear Class 3, or approximately 2–4 years of age (Gordon 1991), were hit by vehicles (χ^2 = 35, P < 0.001) (Fig. 6). This age corresponds to the 4.0–5.9-kg weight class. The frequency distribution of weight and age for female

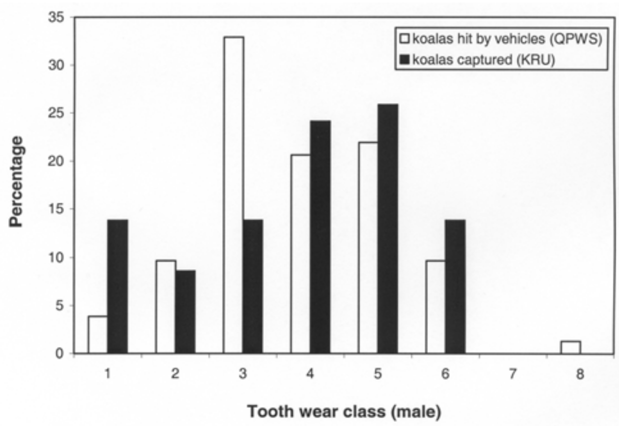

Fig. 6. Tooth-wear classes (Gordon 1991) of male koalas hit by vehicles (data collected by QPWS) and male koalas captured (data collected by KRU) in the Koala Coast in 1998.

Table 2. The signed speed limit and the mean vehicle speed before and during the trial period
Sourced from Queensland Department of Main Roads (2000). All changes in mean vehicle speed for trial and control sites were not significant

Site	Before trial period (July)			During trial period (November)		
	Speed limit (km)	Mean vehicle speed (km h^{-1})	± 95% conf. limits	Speed limit (km)	Mean vehicle speed (km h^{-1})	± 95% conf. limits
Trial sites						
T1	70	66.3	2.5	60	64.5	6.5
T2	70	74.9	4.7	60	72.1	4.8
T3	80	78.6	5.8	60	73.9	8.0
T4		–	–		–	–
T5	80	85.1	8.1	60	81.6	7.0
Control sites						
C1	60	69.9	3.1	60	66.6	3.8
C2	70	84.0	18.1	70	85.1	6.6
C3	70	65.0	5.2	70	60	6.6
C4		–	–		–	–

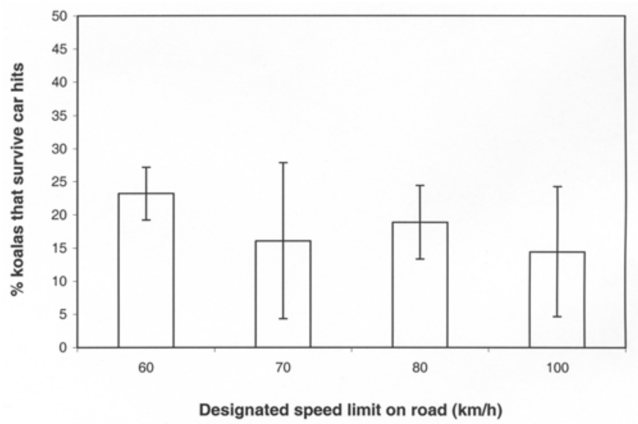

Fig. 7. Proportion of koalas that survive being hit by vehicles on roads with designated speed limits of 60–100 km h^{-1} in the Koala Coast during 1995–99.

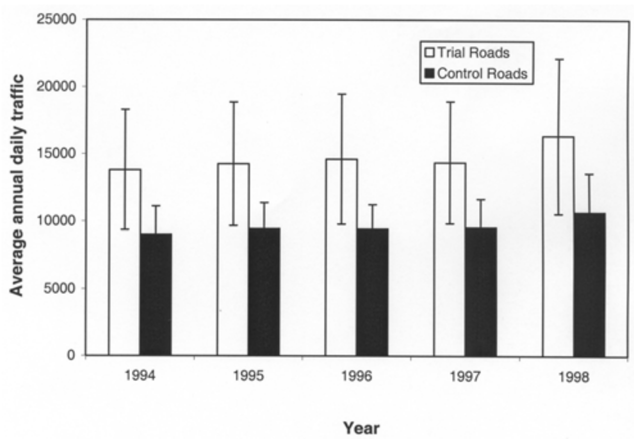

Fig. 8. Mean traffic volume (measured as Average Annual Daily Traffic) for trial and control sites in the Koala Coast during 1994–98 (sourced from Queensland Department of Main Roads and Redland Shire Council).

koalas hit by vehicles and females captured by KRU in 1998 was similar.

During the trial 161 koalas with clinical signs of disease (mainly cystitis and conjunctivitis) were hit by vehicles, accounting for approximately 12% (range 7–18%) of the total number of koalas hit on roads during the trial. In 1998, 11% of koalas hit by vehicles showed clinical signs of disease. Data collected by KRU in 1998 suggests that 16% of koalas captured showed signs of disease. There is no evidence to suggest that the proportion of diseased koalas hit by vehicles differs significantly from that found by the KRU ($\chi^2 = 2.3$, $P = 0.13$).

Traffic speed and volume

Fig. 7 illustrates the survival rate of koalas hit by vehicles on roads assigned different speed limits. The data have been pooled for 1995–99. Of the 1407 koalas hit by vehicles in the Koala Coast during this period ~60% (n = 851) of records included the speed limit of the road. There is no evidence to suggest that more koalas survive a collision with a car on roads with lower speed limits than on roads with higher speed limits than would be expected by chance ($\chi^2 = 2.6$, $P = 0.46$) (Fig. 7).

Mean traffic volume (measured as AADT) on the trial sites during 1994–98 was significantly higher than on the control sites (t-test, $t = 8.92$, $P < 0.001$) (Fig. 8). Since 1994, traffic volume has steadily increased on trial and control sites.

Discussion

The koala speed-zone trial

The results of the trial suggest that the placement of differential speed signs on some arterial and sub-arterial roads in the Koala Coast did not significantly reduce vehicle speed and, we suggest, consequently did not significantly reduce the number of koalas hit by vehicles. In a report provided to QPWS, Queensland Department of Main Roads (2000) suggested that massive and consistent police enforcement be imposed as a means of reducing the speed of motorists during the koala breeding season. Although this may have helped to ensure that the treatment of reduced speed was imposed in the trial period, it may not be an appropriate management outcome.

Queensland Police routinely monitored vehicle speed on some trial sites during the trial period. While some motorists received speeding infringement notices during the trial, Queensland Police were unable to commit to increased enforcement during the trial owing to a lack of resources. Given that resources were not made available for the trial, then it would be expected that continued support for heavy enforcement would not be considered a priority by Queensland Police in the future. In addition, while there was generally a higher proportion of koalas hit by vehicles from August to December, animals were hit on roads all year (Table 1). This would require the differential speed signs to take effect throughout the year, not simply during the koala breeding season. This would require a greater need for enforcement as roads are currently designed to accommodate vehicles travelling at speeds greater than the limits on the differential speed signs. Furthermore, there was no significant difference in the number of koalas that survived a collision with a vehicle on roads with lower speed limits than on roads with higher speed limits (Fig. 7). This suggests that vehicle speed may have to be a great deal less than 60 km h^{-1} as ~80% of koalas hit by vehicles on roads with speed limits greater than 60 km h^{-1} did not survive. Most importantly, however, it must be recognised that road-associated koala mortality appears to be a function of a number of factors, not vehicle speed alone, as has been stated by Nattrass and Fiedler (1996).

Results from various studies that have investigated the impacts of roads on wildlife suggest that the issue of vehicle speed is complex. On Phillip Island in the late 1980s, a reduction in the number of koalas being killed on roads was noticed after speed limits were reduced and road-toll notification signs were erected (Martin and Handasyde 1999). However, the reduction in koala mortality was more likely to be associated with a reduction in the population on the island, rather than the speed signs (Martin and Handasyde 1999). In contrast, in a study of the impacts of a road upgrade on dasyurid carnivores, Jones (2000) found that an eastern quoll population recovered after measures were put in place to reduce vehicle speed. It was suggested that an increase in vehicle speed was the major change associated with the upgrade that was likely to influence the rate of collisions between vehicles and wildlife. Results from this study suggest that survival of koalas is only marginally higher on roads with speed limits of 60 km h^{-1} than on roads with speed limits of 80 km h^{-1}. Given that a significant reduction in vehicle speed was not reported in this study, the notion that collisions with koalas can be avoided at a reduced vehicle speed remains untested.

Other causal factors

Koala density has been recorded for 24 sites across the Koala Coast (Dique *et al.* 2001). The highest koala densities are generally found toward the centre of the Koala Coast, with significant population densities recorded for a number of small bushland remnants. The locations of koalas that have been hit by vehicles (Fig. 1) show a large density of koalas hit by vehicles in the vicinity of C1 and C2. Koala densities greater than 1.0 koalas ha^{-1} have been recorded at a bushland site adjacent to C1. The combination of large population density and high traffic volume recorded for C2 and to the west of C4 (traffic volume approximately 10 000 AADT) may increase the probability of a koala being hit by a vehicle in that region. In areas of relatively low koala population density and low traffic volume, for example T4 with a koala density ~0.1 koalas ha^{-1} (Dique *et al.* 2001) and traffic volume of ~1500 AADT, QPWS received fewer reports of koalas hit by vehicles during the study. It would appear that the risk of a collision between a vehicle and a koala is greatest when high volumes of traffic moving at high speeds travel through areas of relatively high koala population density.

With rapid urbanisation of the region (Catterall and Kingston 1993) and increases in habitat destruction for residential development, there is potential for road-associated koala mortality to increase. The decline of koalas on Phillip Island appeared to be a result of increased traffic volume due to a growing tourism market and a reduction in habitat for urban development (Martin and Handasyde 1999). The KRU has been monitoring a koala population for the past five years at a bushland site adjoining C1 that is currently being cleared for residential development. Over the five-year monitoring period there has been an increase in koala dispersal from the site, particularly by sub-adult males typically 20–36 months of age (Dique *et al*. 2003). The results of the present study suggest that a disproportionate number of young adult male koalas are hit by vehicles and are reported to QPWS (Figs 5, 6). This provides further evidence for the argument that any increase in vegetation removal associated with residential development may contribute to an increase in the rate of road-associated koala mortality. Further investigation of development history and land clearing in the Koala Coast over the past five years may provide additional insight into the role of habitat destruction in road-associated koala mortality and is beyond the scope of this study.

Implications for the koala population of the Koala Coast

The koala population of the Koala Coast is nationally significant as it is the largest natural koala population living in close proximity to a capital city. Given the pressure it is currently facing as a result of rapid urbanisation of south-east Queensland (Catterall and Kingston 1993), the future for the species here is uncertain. As discussed above, the distribution and density of koalas across the Koala Coast and the increases in traffic volume and habitat destruction associated with increases in urbanisation may play an important role in koala mortality on roads. What remains unclear is the impact that a high level of mortality associated with roads is having on the Koala Coast koala population.

As a result of monitoring koala mortality on roads across the region since 1994, some inference can be made from the data provided by this study. Fig. 4 shows an increase in the number of koalas that were hit by vehicles from 1994 to 1997 followed by a decrease in 1998 and 1999. The initial increase in the number of koalas reported is potentially related to a number of factors, including an increase in habitat removal for urban development, an increase in traffic volume and speed and an increase in community concern for koala welfare stemming from advertisements for koala-management programs by local wildlife organisations. However, of most concern is the decrease in reports since 1997. Other studies have reported that there is some evidence to suggest that a decline in road-associated mortality of a species may be a reflection of a decline in the population of the species (McCaffrey 1973; Mallick *et al.* 1998; Jones 2000). If this is the case for the regional koala population in the Koala Coast, questions arise as to how to halt the decline through appropriate management.

The long-term status of this significant koala population remains uncertain due to removal of habitat and increases in traffic volume resulting from urban expansion and the associated need for further development of the arterial road system. In order to effectively conserve koalas in the Koala Coast, appropriate management strategies that address road-associated koala mortality must be developed. It is envisaged that a successful management strategy would: include provisions for safe koala movement across roads and, in some instances, exclusion from roads; provide mechanisms for raising community awareness of the problems facing urban koala populations; and, most importantly, provide planning guidelines to reduce habitat loss associated with future urban development. However, management options such as these have not been evaluated, therefore, further research is required to determine whether they would be effective and, indeed, practical.

Acknowledgments

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