Downloaded from http://rsbl.royalsocietypublishing.org/ on June 25, 2018

BIOLOGY LETTERS

rsbl.royalsocietypublishing.org

Research

Cite this article: Ellis WA *et al*. 2016 Daylight saving time can decrease the frequency of wildlife–vehicle collisions. *Biol. Lett.* **12**: 20160632. http://dx.doi.org/10.1098/rsbl.2016.0632

Received: 11 August 2016
Accepted: 31 October 2016

Subject Areas:
behaviour, ecology

Keywords:
wildlife–vehicle collisions, daylight saving, wildlife conservation, conservation

Author for correspondence:
Robbie S. Wilson
e-mail: r.wilson@uq.edu.au

Electronic supplementary material is available online at https://dx.doi.org/10.6084/m9.figshare.c.3573249.

THE ROYAL SOCIETY PUBLISHING

Animal behaviour

Daylight saving time can decrease the frequency of wildlife–vehicle collisions

William A. Ellis[1], Sean I. FitzGibbon[1], Benjamin J. Barth[1], Amanda C. Niehaus[2], Gwendolyn K. David[2], Brendan D. Taylor[4], Helena Matsushige[1], Alistair Melzer[5], Fred B. Bercovitch[6], Frank Carrick[3], Darryl N. Jones[7], Cathryn Dexter[7], Amber Gillett[8], Martin Predavec[9], Dan Lunney[9] and Robbie S. Wilson[2]

[1]School of Agriculture and Food Science, [2]School of Biological Sciences, and [3]Centre for Mined Land Rehabilitation, The University of Queensland, Brisbane, Queensland 4072, Australia
[4]PO 73 New Brighton, New South Wales 2483, Australia
[5]Koala Research Centre of Central Queensland, School of Medical and Applied Sciences, Central Queensland University, Rockhampton, Queensland 4702, Australia
[6]Primate Research Institute and Wildlife Research Center, Kyoto University, 41-2 Kanrin, Inuyama 484-8506, Japan
[7]Environmental Futures Research Institute, Griffith University, Queensland 4111, Australia
[8]Australia Zoo Wildlife Hospital, Beerwah, Queensland 4519, Australia
[9]Science Division, Office of Environment and Heritage NSW, P.O. Box 1967, Hurstville, New South Wales 2220, Australia

RSW, 0000-0002-0116-5427

Daylight saving time (DST) could reduce collisions with wildlife by changing the timing of commuter traffic relative to the behaviour of nocturnal animals. To test this idea, we tracked wild koalas (*Phascolarctos cinereus*) in southeast Queensland, where koalas have declined by 80% in the last 20 years, and compared their movements with traffic patterns along roads where they are often killed. Using a simple model, we found that DST could decrease collisions with koalas by 8% on weekdays and 11% at weekends, simply by shifting the timing of traffic relative to darkness. Wildlife conservation and road safety should become part of the debate on DST.

1. Introduction

Daylight saving time (DST) is used across most of the USA and Europe and parts of Australia to prolong daylight in summer evenings; it is a contentious policy, often disparaged by the public and media. Implemented during WWI to reduce energy demands, DST may actually increase modern energy usage as people run air conditioners for longer [1]. DST may also interfere with sleep [2], decrease health and well-being [3], and increase traffic fatalities [4] as people struggle to adjust their internal biological clocks [5]. But—as we show here using wild koalas (*Phascolarctos cinereus*)—DST may have important benefits to wildlife conservation that need to be part of any debate on its abolishment or implementation.

More than 350 million vertebrates are killed on US roads every year [6], causing around $1bn in damage [7], and the situation worsens as we extend residential, commercial and agricultural zones [8,9], further fragmenting natural habitats [10,11]. Collisions causing injury to drivers usually involve large animals such as deer or moose, camels, and kangaroos, wallabies and emus, but the ecological cost of collisions with smaller, endangered or vulnerable species must also be accounted for. Road strikes are the single largest factor associated with population declines of koalas in Queensland, Australia [9], which are classified as vulnerable by the Queensland Nature Conservation Act 1992 and Commonwealth

© 2016 The Author(s) Published by the Royal Society. All rights reserved.

Downloaded from http://rsbl.royalsocietypublishing.org/ on June 25, 2018

Environment Protection and Biodiversity Conservation Act 1999. Driver education and signage has had little impact on vehicle–deer collisions in the USA [7], and speed limits have not reduced koala deaths in Australia [9]. However, collisions with wildlife are most likely to occur during twilight or darkness [12,13], overlapping with the evening commute, so shifting daylight hours via DST may reduce the probability of road casualties for both humans and wildlife.

In this study, we amalgamate data on the movements of wild, semi-urban koalas with the timing and volume of vehicular traffic to estimate how the implementation of DST in Queensland, Australia, would likely decrease koala mortality on weekdays and at weekends, simply by shifting the timing of traffic.

2. Material and methods

We used data from the Queensland Department of Transport and Main Roads (QTDMR) to quantify traffic flow for three main arterial roads in semi-urban Brisbane—Finucane Road, Redland Bay Road and Mt Cotton Road—which transit natural bushland and urban developments and have substantial populations of wildlife. Koalas are often killed on these roads [9]. We also acquired data from QTDMR [13] on reported wildlife–vehicle incidents involving vehicular damage in Queensland.

To determine the frequency and timing of road crossings by semi-urban koalas, we tracked 25 individuals in two locations in southeast Queensland: Coomera and Redlands. Until recently, Coomera was high-quality koala habitat; now it is a mix of building sites, established houses, new roads and small patches of remnant vegetation. Redlands is an increasingly urbanized region where arterial roads and heavy traffic pass through bushland patches containing koalas and other mammals. We tracked 14 koalas (7 male, 7 female) in Coomera from October 2009 until October 2010, and 9 female koalas in Redlands from September 2009 until October 2010.

Koalas were captured and collared using standard methods [14]. Each koala was fitted with a Sirtrack koala-GPS collar (Havelock North, New Zealand) (150–160 g) and released into its tree of capture; each collar also had a standard VHF radio transmitter for tracking from the ground (three element yagi; Sirtrack, Havelock North, New Zealand) [14]. Each GPS collar recorded location of the koala once every 2 h for 10 months.

Each time a move was detected, the hour corresponding to the second fix was recorded as the hour of the move. Stationary collar tests [14] determined that horizontal dilution of precision (HDOP) values of 2.1 were accurate to 10 m. From 11 445 GPS locations at Coomera, 5170 conformed to our accuracy criteria and there were 1182 koala moves greater than 10 m. At Redlands, 4531 of 7952 GPS locations conformed to our criteria and there were 2355 koala moves greater than 10 m. We compared koalas' GPS locations with aerial imagery to determine when road crossings occurred.

To model the collision risk between koalas and vehicles, we tracked two additional koalas at a higher sampling frequency (15 min) between November 2010 and February 2011. From these data, we recorded 1866 koala moves greater than 10 m from 5227 GPS locations, with 2352 of these accurate enough to include in our analyses. We then compiled these koala movements with traffic data to create a simple model of collision risk, using the product of the proportion of koala movements per hour (k) and the proportion of traffic occurring per hour (v) as: $k \times v$.

3. Results and discussion

Traffic flows ranged from around 1600 vehicles per hour (vph) at Mt Cotton Road to around 3000 vph at Finucane Road. Weekday flows peaked at 07.00–08.00 h and 15.00–17.00 h, corresponding with commuter traffic (figure 1*a*); at weekends, peak traffic occurred at 11.00 h, with volumes remaining elevated at dusk (figure 1*b*) (see supplementary material for data).

In 2014, 1348 collisions were reported in Queensland that involved wildlife and caused damage to vehicles (QTDMR); collisions peaked around dusk regardless of time of year—shifting from 1700–1800 h during the darker months (April–September) to 1800–1900 h during the lighter months (October–March) (figure 1*c*). Overall, the number of collisions increased with increasing hours of darkness, doubling between the lightest and darkest months of the year (figure 1*d*) (Pearson's product-moment correlation: $r_p = 0.81$; $p < 0.001$). In subtropical Queensland, darkness lasts only 3.3 h longer in the winter (13.8 h) than it does in the summer (10.5 h), so the pattern we observe here would likely be magnified at higher latitudes where seasonal variation is greater.

Most reported collisions with animals, and those most probable to cause damage, are with larger mammals such as kangaroos, wallabies, wombats and emus [15]. Yet in southeast Queensland, vehicles cause more than 300 koala deaths every year and are one of the greatest causes of their population decline in this area (Australian Department of Sustainability, Environment, Water, Population and Communities). Koalas typically rest during the day and become active during the early evening and throughout the night, when they move from resting to foraging trees [16,17]. They spend only 10% of their time on the ground. In our study, koalas regularly traversed open areas, vegetative strips and roadside vegetation, but they crossed roads less frequently. Even so, we recorded a total of 45 road crossings by five individual koalas (two at Coomera and three at Redlands), with 49% of crossings occurring during evening twilight (approximately 16.00–20.00 h) and 64% occurring during late evening twilight or darkness (approx. 18.00–04.00 h) (figure 2*a*).

Two koalas tracked at 15 min intervals showed similar movement patterns to those previously tracked at 2 h intervals, becoming most active around 16.00 h. Koala activity and vehicular traffic both peak in the late afternoon/early evening period in southeast Queensland (figures 1*a*,*b* and 2), suggesting that policies to reduce this overlap might reduce collision rates. We used these koala activity and traffic data to create a simple index of koala–vehicle collision risk, assuming that the frequency of collisions between koalas and vehicles in any given hour would be a product of the probability of a koala moving and the proportion of traffic occurring in that hour. Shifting standard time forward by 1 h reduced the overlap between peak koala and traffic periods (figure 2*c*,*d*), particularly during the evening, resulting in an estimated 8–11% drop in koala strikes during the week and weekend, respectively (table 1) (GLM; $F_{2,5} = 23.5$; $p < 0.001$). Although non-significant, collision risk seemed to decrease relatively more during the weekend (figure 2*d*) than during the week (figure 2*c*) (GLM; $F_{2,5} = 4.2$; $p = 0.06$), because DST on weekdays reduced the likelihood of evening collisions but caused a slight increase in collision risk during the morning commute.

In southeast Queensland, koala populations have declined by 80% since 1998. Our study suggests that a measure as simple as implementing DST could, with relative ease, prevent many koala deaths each year. We hope that our study will encourage the Queensland government to consider the benefits of implementing DST, but we also hope it inspires

Downloaded from http://rsbl.royalsocietypublishing.org/ on June 25, 2018

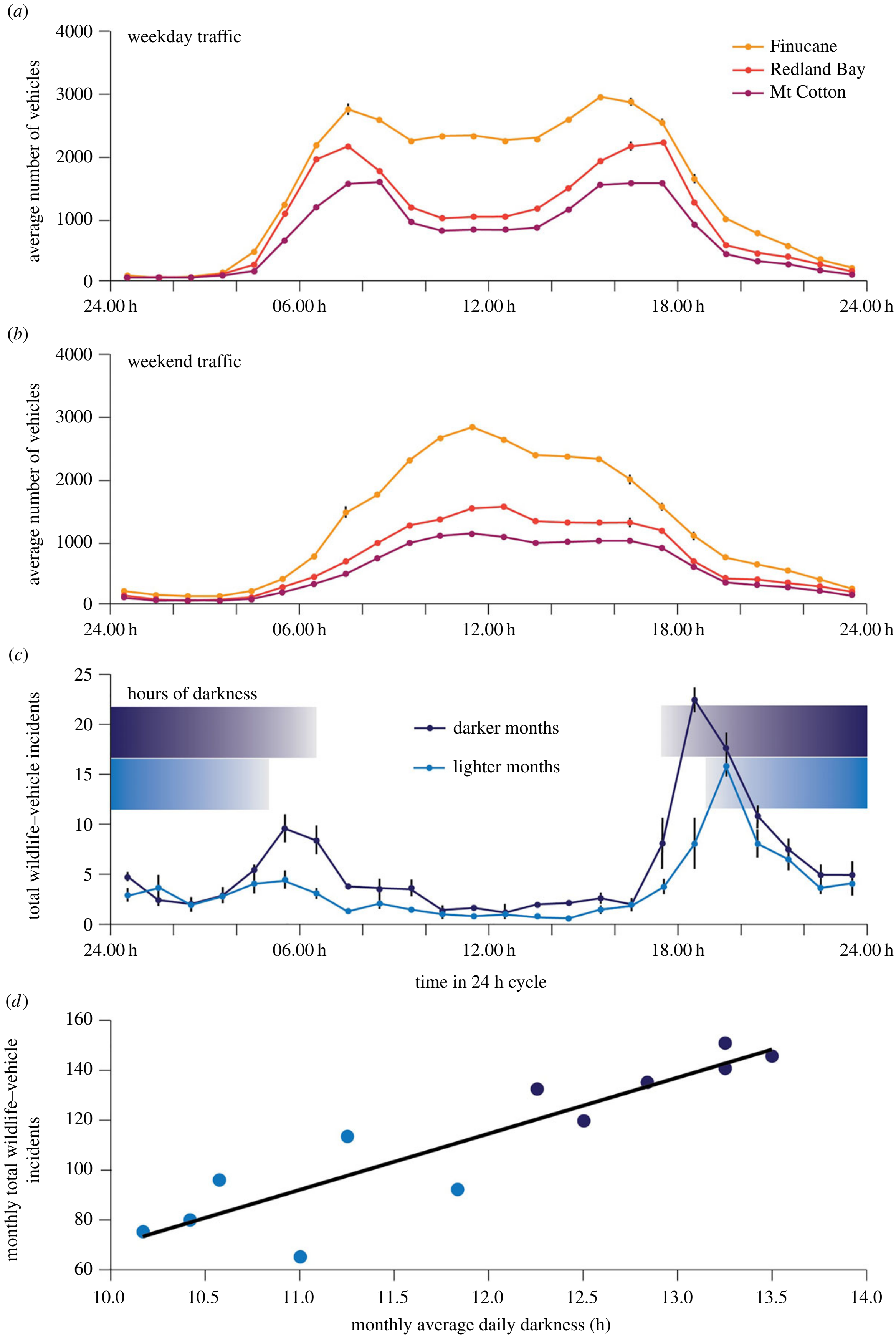

Figure 1. Average number of vehicles per hour on Redland Bay, Mt Cotton and Finucane roads on weekdays (*a*) and weekends (*b*). Average number of reported wildlife–vehicle collisions in Queensland per hour for the darkest (April–September; purple) and lightest (October–March; blue) halves of the year (*c*). Average hours of darkness per month in Brisbane (sunset to sunrise) versus total wildlife–vehicle collisions for that month ($r_p = 0.81$; $p < 0.0001$) (*d*). Standard errors based on variation among days of the week (or weekend) are provided. (Online version in colour.)

other studies to explore the value of DST to wildlife conservation—particularly in those regions considering its abolishment. Koalas are not likely to cause human fatalities, but kangaroos, deer, moose and other large mammals are. Our idea is simple, yet to our knowledge no one has presented evidence of this kind in favour of DST, and there are many

Downloaded from http://rsbl.royalsocietypublishing.org/ on June 25, 2018

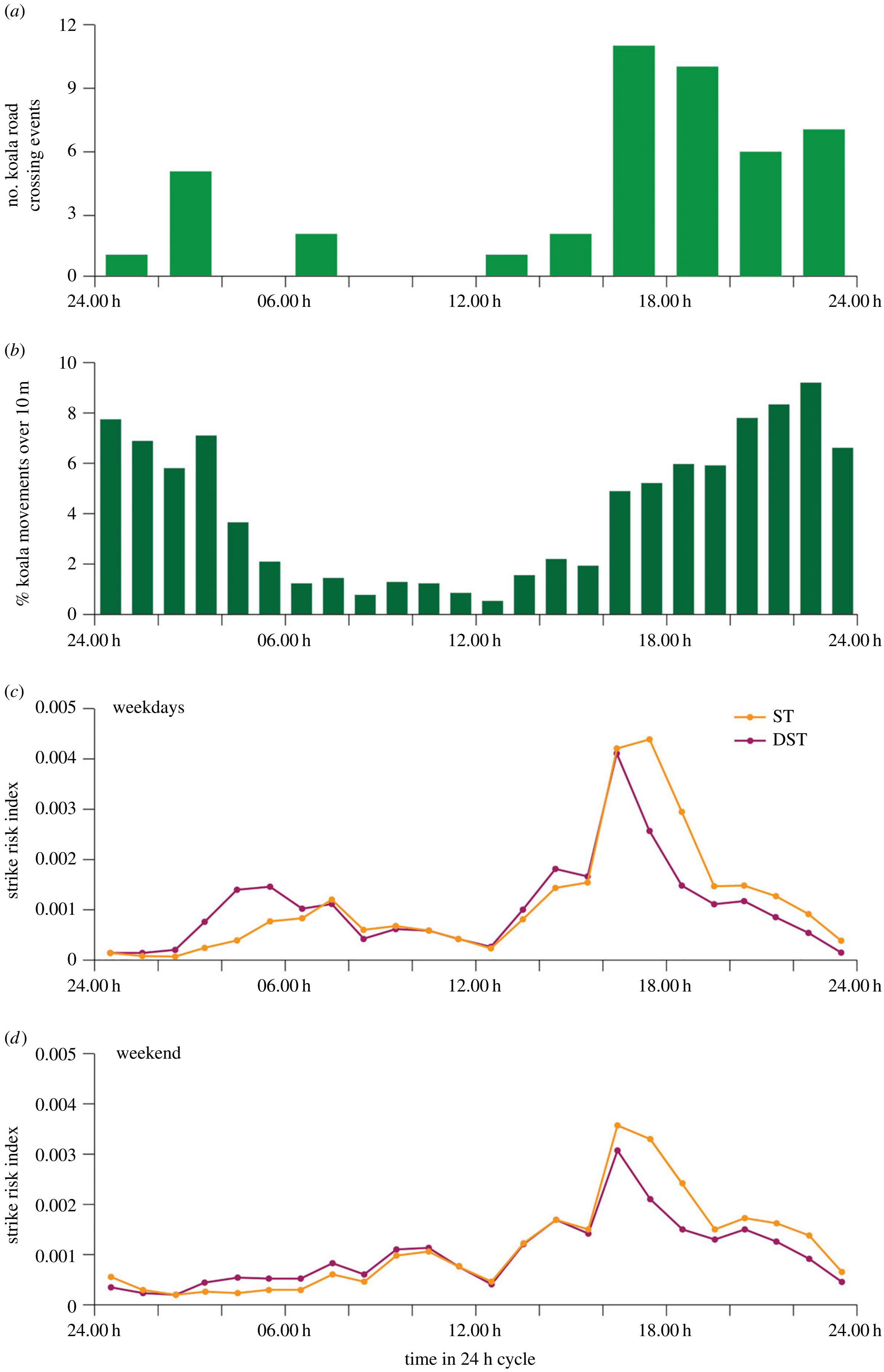

Figure 2. (*a*) Total number of koala road crossings ($N = 45$) during each 2 h time interval. (*b*) Per cent moves per hour for koalas tracked at 15 min intervals ($N =$ 1185 fixes). The index of koala–vehicle collision risk was calculated each hour across a 24 h cycle for summer periods with standard time (ST) or DST for weekdays (*c*) and weekends (*d*). Categorical predictors of collision risk—weekend/weekday and DST/ST. (Online version in colour.)

potential avenues for expansion of this work. For example, DST should have a lower impact at higher latitudes, because of the naturally long days in summer, and in areas with lower densities of wildlife or humans. The relative impact of DST would also be highly influenced by species-specific activity patterns and location-specific traffic flow volumes,

Downloaded from http://rsbl.royalsocietypublishing.org/ on June 25, 2018

Table 1. Comparative index of collision risk based on the proportion of koala movement and hourly volume of vehicular traffic on three main arterial roads in southeast Queensland. We found a significant difference between DST (daylight saving time-shifted) and ST (standard time) (GLM; $F_{2,5} = 23.5$; $p < 0.001$) but not weekday versus weekend (GLM; $F_{2,5} = 4.2$; $p = 0.06$). Categorical predictors of collision risk—weekend/weekday and DST/ST.

	weekday			weekend		
	Redland Bay	Mt Cotton	Finucane	Redland Bay	Mt Cotton	Finucane
index of collision risk with ST	0.0286	0.0280	0.0267	0.0273	0.0279	0.0257
index of collision risk with DST	0.0263	0.0256	0.0244	0.0242	0.0247	0.0230
change in collision risk with DST	−8.1%	−8.6%	−8.4%	−11.0%	−11.3%	−10.5%

which means that in some locations, and for some species, adoption of DST may increase collision risk. Experimental trials are needed to examine before/after scenarios, because the temporal flow of traffic may not simply shift by an hour. Here, we find that DST could shift the temporal pattern of traffic volumes relative to koala movement patterns, thereby having a positive conservation outcome on this species.

Ethics. Methods approved by University of Queensland animal ethics committee (CMLR/937/08/ARC/RIOTINTO, ZOO/ENT/115/04/RT) and San Diego Zoo Global IACUC (no. 09-006) and conducted under permits from Queensland Department of Wildlife and Heritage (WITK05609808, WISP05609708, WISP00491303, WISP05609708).

Data accessibility. All supporting data can be found in the electronic supplementary material tables.

Authors' contributions. R.S.W., W.A.E. and S.I.F. conceived the idea. W.A.E., S.I.F. and B.J.B. collected data. R.S.W., A.C.N. and W.A.E. analysed data and wrote the paper. All authors discussed design, interpreted data, discussed implications and co-authored the paper. All authors approved the manuscript and agree to be held accountable for the content therein.

Competing interests. We declare we have no competing interests.

Funding. This project was supported by Australian Research Council grants awarded to R.S.W. (LP0669687 and FT150100492) and a wildlife conservation grant to W.A.E. by San Diego Zoo.

Acknowledgement. We thank Ami Fadhillah Amir Abdul Nasir and Romane Cristescu.

References

1. Kotchen M, Grant L. 2011 Does daylight saving time save energy? Evidence from a natural experiment in Indiana. *Rev. Econ. Stat.* **93**, 1172–1185. (doi:10.1162/REST_a_00131)
2. Harrison Y. 2013 The impact of daylight saving time on sleep and related behaviours. *Sleep Med. Rev.* **17**, 285–292. (doi:10.1016/j.smrv.2012.10.001)
3. Kountouris Y, Remoundrou K. 2014 About time: daylight saving time transition and individual well-being. *Econ. Lett.* **122**, 100–103. (doi:10.1016/j.econlet.2013.10.032)
4. Smith AC. 2016 Spring forward at your own risk: daylight saving time and fatal vehicle crashes. *Am Econ. J. Appl. Econ.* **8**, 65–91. (doi:10.1257/app.20140100)
5. Kantermann T, Juda M, Merrow M, Roenneberg T. 2007 The human circadian clock's seasonal adjustment is disrupted by daylight saving time. *Curr. Biol.* **17**, 1996–2000. (doi:10.1016/j.cub.2007.10.025)
6. Forman RTT, Alexander LE. 1998 Roads and their major ecological effects. *Ann. Rev.* **29**, 207–231. (doi:10.1146/annurev.ecolsys.29.1.207)
7. Hedlund JH, Curtis PD, Curtis G, Williams AF. 2004 Methods to reduce traffic crashes involving deer: what works and what does not. *Traffic Injury Prev.* **5**, 122–131. (doi:10.1080/15389580490435079)
8. Garrett LC, Conway GA. 1998 Urban encroachment on the wilderness: moose-vehicle collisions in Anchorage, Alaska, 1991–1995. *Int. J. Circumpolar Health* **57**, 527–531.
9. Dique DS, Thompson J, Preece HJ, Penfold GC, de Villiers DL, Leslie RS. 2003 Koala mortality on roads in southeast Queensland: the koala speed-zone trial. *Wildl. Res.* **30**, 419–426. (doi:10.1071/WR02029)
10. Fahrig L. 2001 How much habitat is enough? *Biol. Conserv.* **100**, 65–74. (doi:10.1016/S0006-3207(00)00208-1)
11. McKinney ML. 2002 Urbanization, biodiversity, and conservation. *Bioscience* **52**, 883–890. (doi:10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2)
12. Langley RL, Higgins SA, Herrin KB. 2006 Risk factors associated with fatal animal-vehicle collisions in the United States, 1995–2004. *Wildl. Environ. Med.* **17**, 229–239. (doi:10.1580/06-WEME-OR-001R1.1)
13. Department of Transport and Main Roads. 2009 *2004 Road traffic crashes in Queensland*. Atherton, QLD: Queensland State Government.
14. Ellis W, Bercovitch F, FitzGibbon S, Roe P, Wimmer J, Melzer A, Wilson R. 2011 Koala bellows and their association with the spatial dynamics of free-ranging koalas. *Behav. Ecol.* **22**, 372–377. (doi:10.1093/beheco/arq216)
15. Rowden P, Steinhardt D, Sheehan M. 2008 Road crashes involving animals in Australia. *Accid. Anal. Prev.* **40**, 1865–1871. (doi:10.1016/j.aap.2008.08.002)
16. Mitchell P. 1990 The home ranges and social activity of koalas— a quantitative analysis. In *Biology of the koala* (eds AK Lee, KA Handasyde, GD Sanson), pp. 171–187. Sydney, Australia: Surrey Beatty and Sons.
17. Logan M, Sanson G. 2002 The effects of tooth wear on activity patterns of free-ranging koalas (*Phascolarctos cinereus* Goldfuss). *Aust. J. Zool.* **50**, 281–292. (doi:10.1071/ZO01022)