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Supplementary Material

Road mortality of the eastern long-necked turtle (*Chelodina longicollis*) along the Murray River, Australia: an assessment using citizen science

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MaxEnt environmental variables

We carried out an analysis on MaxEnt to determine the environmental predictors of turtle death, including road size, climate, distance to water, spatial density of water bodies, distance to forest and distance to urban areas. We obtained a shapefile of the local road network from Geoscience Australia (2006), and rasterised it with a cell resolution of 500 m^2 using ArcGIS 10.3.1. The road size variable had 5 levels: track, minor road, secondary road, principal road, and dual carriageway. In addition to road size, our environmental variables of interest included

Euclidean distance to water and focal neighbourhood mean of water (circular radius of 6 km) to model water body density. These layers were created after rasterising and collating natural surface water information layers provided by Geoscience Australia (2015), specifically surface water polygon features (selecting canal, farm dam area, lake, reservoir, settling pond, swamp, watercourse area), surface hydrology points (selecting farm dam, spring and water hole), and the already rasterised 9 seconds DEM Derived Stream Network v1.1.3 (Geoscience Australia 2011). Furthermore, we obtained the 19 bioclimatic variables obtained from Worldclim (Hijmans *et al*. 2005), which we downloaded at a pixel resolution of 30 arc seconds (~1 km^2) and then resampled to match the greater cell resolution of the other variables. Finally, we used a land classification raster to estimate distances to urban and forested areas (ESA and UCLouvain, 2011). We converted all our variables to the equal areas coordinate system GDA Australia Albers 1994 coordinate system, to avoid distortions due to the large size of our study area (Brown 2014). All environmental variables we used were clipped to the road network.

We calculated Pearson correlation coefficients between all continuous variables in a pairwise fashion to limit multicollinearity over our study area. We calculated the Spearman rank correlation coefficients between continuous variables and the road size variable, treating road size as an ordinal variable. We only kept the variables which had $r < 0.7$ (Dormann *et al*. 2013), and for each pair of highly-correlated variables we kept the variable that we considered most representative for turtle road kill distribution.

MaxEnt bias files and data thinning

We created the two bias layers in ArcGIS to represent sampling effort, and used them in MaxEnt to give a weight to the background data (Fourcade *et al.* 2014). For the “background model” we limited the selection of background points to an area encompassed by a buffered minimum-convex polygon based on the observations locations (Kremen *et al*. 2008; Brown

2014). Then, for the “density model”, we calculated a Gaussian Kernel density raster using all *C. longicollis* road mortality observations, and used this as bias layer (Philips *et al*. 2009). Furthermore, we also thinned the data by randomly choosing one road kill observation for every 6 km^2 to correct for bias. We considered this area relevant as 6 km is the greatest distance *C. longicollis* has been observed travelling in one movement (De Oliveira Ferronato 2015). Therefore, 35 observations were used for the thinned model.

Model evaluation techniques

The four models were evaluated using their area under the curve (AUC), which is computed automatically by MaxEnt, by averaging the AUC value of the 15 repeats. The five models were also compared using their AICc values (Zeng *et al*. 2016), which were calculated using the programme ENMTools (Warren *et al*. 2010), averaging the values of 15 replicates from the MaxEnt models in their raw output format. They were further compared with the calculation of Schoener’s D statistic for niche overlap, also computed using ENMTools (Warren *et al*. 2008). Finally, the ranks of permutation importance and percentage contribution of each environmental variables were compared between models through the calculation of paired Spearman's rank correlation coefficients. We used the ‘10 percentile training presence Logistic threshold’ as a threshold to classify a road ‘likely’ or ‘unlikely’ to cause turtle road kill (Kramer-Schadt *et al*. 2013).

Supplementary references

Brown, J.L. (2014) SDMtoolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses. *Methods in Ecology and Evolution* **5**(7), 694–700.

ESA and UCLouvain (2011). Land cover, Australia and New Zealand (Part of ESA GlobCover 2009 Project) (Data Basin Dataset). Available at: http://www.arcgis.com/home/item.html?id=1520c5dbb143431db7ac95f9c4186c3f [Accessed 10 May 2017]

De Oliveira Ferronato, B. (2015). Ecology of the Eastern long-necked turtle (*Chelodina longicollis*) along a natural-urband gradient, ACT, Australia. Ph.D. Thesis, University of Canberra, Canberra.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., García Marquéz, J. R., Gruber, B., Lafourcade, B., Leitão, P. J., Münkemüller, T., McClean, C., Osborne, P. E., Reineking, B., Schröder, B., Skidmore, A. K., Zurell, D., Lautenbach, S. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography* **36**, 27–46.

Geoscience Australia (2006). GEODATA TOPO 250K Series 3, Bioregional Assessment Source Dataset. Available at: http://data.bioregionalassessments.gov.au/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f [accessed 10 April 2017].

Geoscience Australia (2011). 9 Second DEM Derived Streams v1.1.3. Available at: https://ecat.ga.gov.au/geonetwork/srv/eng/search#!b1ac96de-0c92-2e88-e044-00144fdd4fa6 [accessed 10 April 2017].

Geoscience Australia (2015). Surface Hydrology Points (Regional). Available at: https://researchdata.ands.org.au/surface-hydrology-points-regional/774439?source=suggested_datasets [accessed 10 April 2017].

Geoscience Australia (2015). Surface Hydrology Lines (Regional). Available at: https://ecat.ga.gov.au/geonetwork/srv/eng/search#!1186e898-14b5-812e-e053-10a3070a76f0 [accessed 10 April 2017].

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* **25**, 1965-1978.

Kramer-Schadt, S., Niedballa, J., Pilgrim, J.D., Schroder, B., Lindenborn, J., Reinfelder, V., Stillfried, M., Heckmann, I., Scharf, A.K., Augeri, D.M., Cheyne, S.M., Hearn, A.J., Ross, J., Macdonald, D.W., Mathai, J., Eaton, J., Marshall, A.J., Semiadi, G., Rustam, R., Bernard, H., Alfred, R., Samejima, H., Duckworth, J.W., Breitenmoser-Wuersten, C., Belant, J.L., Hofer, H. & Wilting, A. (2013). The importance of correcting for sampling bias in MaxEnt species distribution models. *Diversity and Distributions* **19**, 1366–1379.

Kremen, C., Cameron, A., Moilanen, A., Phillips, S. J., Thomas, C. D., Beentje, H., Dransfield, J., Fisher, B. L., Glaw, F., Good, T. C., Harper, G. J., Hijmans, R. J., Lees, D. C., Louis Jr., E., Nussbaum, R. A., Raxworthy, C. J., Razafimpahanana, A., Schatz, G. E., Vences, M., Vieites, D. R., Zjhra, M. L. (2008). Aligning conservation priorities across taxa in Madagascar with high-resolution planning tools. *Science* **320**, 222-226.

Supplementary tables and figures

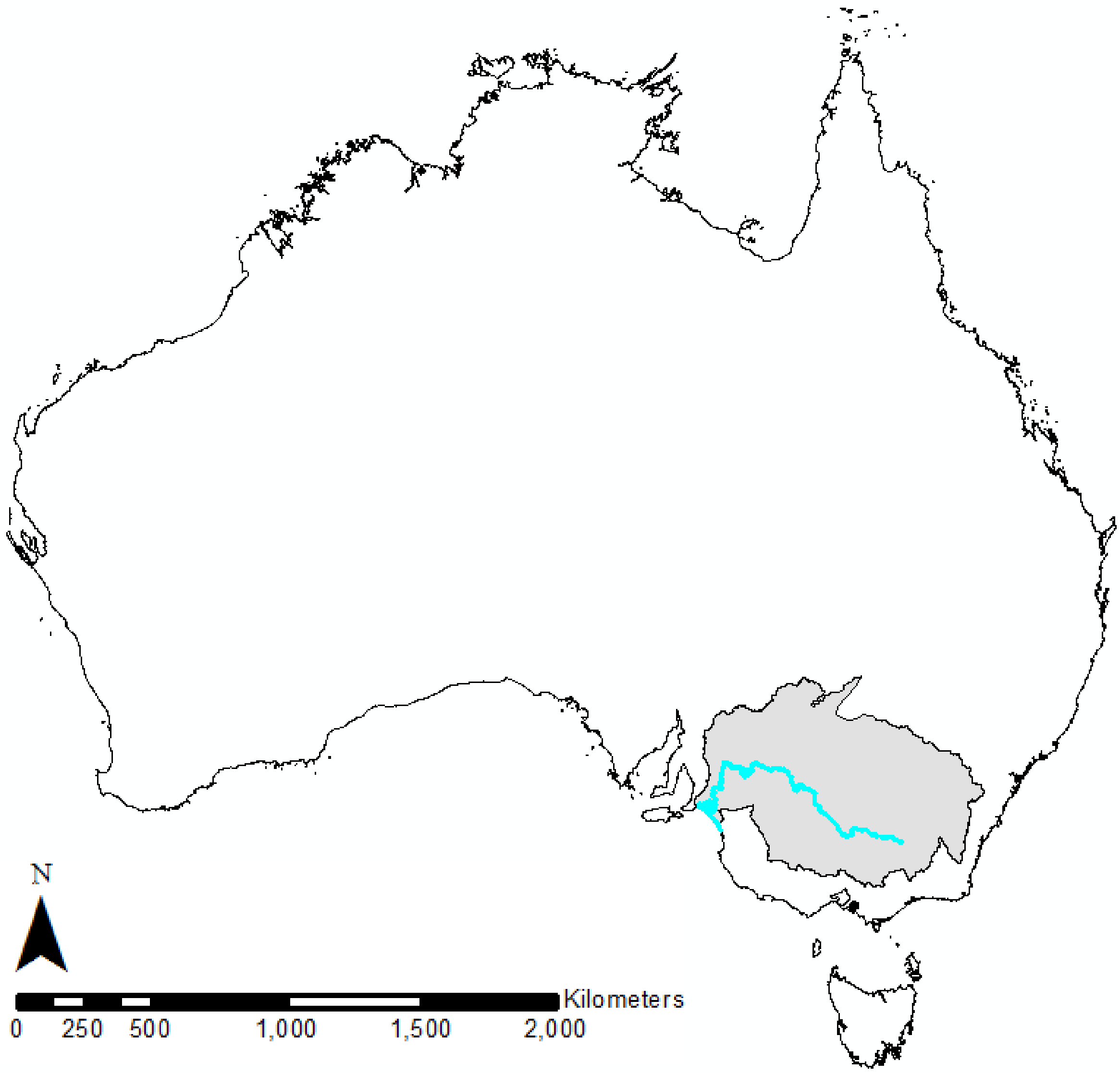

Fig. S1. Map of Australia highlighting the study area in light grey, which is part of the Murray Darling Basin in dark grey (Commonwealth of Australia (Murray-Darling Basin Authority) 2012). The study area includes the Victorian Murray (VIC), Wimmera-Mallee (VIC), Murrumbidgee (NSW), Lachlan (NSW), Northern Victoria (VIC), NSW Murray and Lower Darling (NSW), Eastern Mount Lofty Ranges (SA), SA Murray River (SA) and SA Murray Region (SA). The Murray River is highlighted in blue.

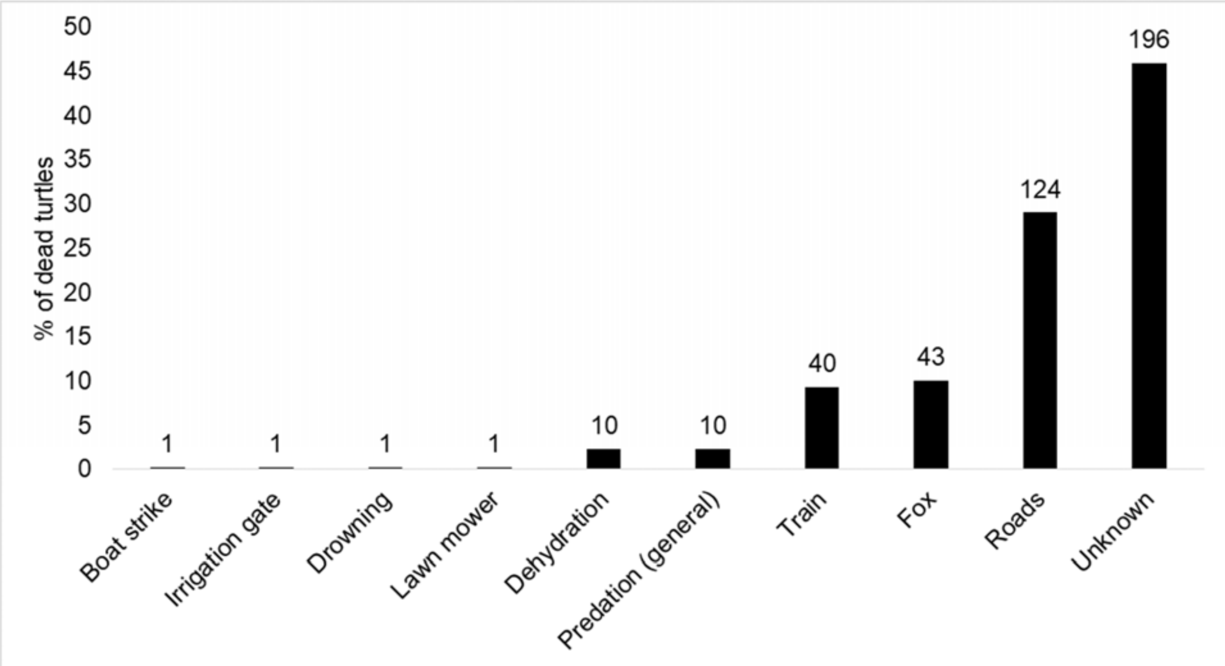

Fig. S2. Turtle death causes reported by TurtleSAT, all species combined. Above each bar the count of turtles killed is reported.

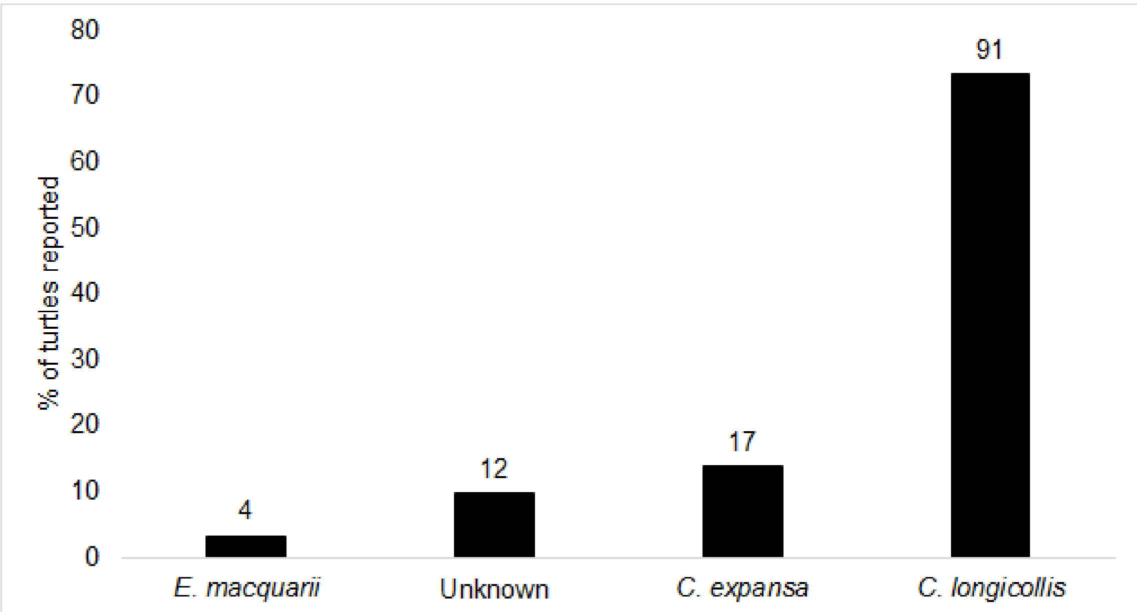

Fig. S3. Road kill counts varied among species, with more *C. longicollis* individuals reported dead compared to the other species. Above each bar is reported the number of turtle observations.

Table S1. Parameter estimates of variables in logistic regression (GLIMMIX) for *C. longicollis*.

	Estimate	St. Error	DF	t value	p value
January	0.208	0.923	165	0.22	0.822
February	0.811	1.059	165	0.77	0.445
March	1.400	0.856	165	1.64	0.103
April	-0.677	0.945	165	-0.72	0.475
May	-12.01	360.1	165	-0.03	0.973
September	-1.138	1.264	165	-0.90	0.369
October	1.118	0.775	165	1.44	0.151

November	2.373	0.783	165	3.03	0.003 ***
December	-0.015	1.104	165	-0.01	0.989
Rainfall	0.085	0.025	165	3.42	0.001 ***
Temperature	-0.060	0.043	165	-1.41	0.161
Solar exposure	0.053	0.037	165	1.44	0.150

Table S2. The maximum solar exposure on the day or day before a *C. longicollis* was killed differed between age groups (critical α = 0.016).

	Df	Sum Sq	Mean Sq	F value	p value
Age	2	2.046	1.023	8.514	< 0.001 ***
Sex	2	0.113	0.057	0.471	0.626

Table S3. The Tukey post hoc test showed a significant difference between “unknown” and adult individuals, as well as juveniles and adults.

	Diff	lwr	upr	p adj
Juvenile-Adult	0.385	0.003	0.767	0.048 *
Unknown-Adult	0.239	0.087	0.390	< 0.001 ***
Unknown-Juvenile	-0.146	-0.531	0.239	0.640

Table S4. The maximum amount of rain that fell on the day or day before a *C. longicollis* was killed differed between age groups (critical α = 0.016).

	Df	Sum Sq	Mean Sq	F value	p value
Age	2	20.70	10.35	5.940	0.004 ***
Sex	2	0.270	0.137	0.079	0.924

Table S5. The Tukey post hoc test revealed the differences between age groups in rainfall on the day or day before a *C. longicollis* was killed are due to the “unknown” age group.

	Diff	lwr	upr	p adj
Juvenile-Adult	-0.400	-1.853	1.054	0.791
Unknown-Adult	0.781	0.204	1.357	0.005 ***
Unknown-Juvenile	1.180	-0.284	2.645	0.140

Table S6. The maximum temperature on the day or day before a *C. longicollis* was killed differed between age groups (critical $\alpha = 0.016$).

	Df	Sum Sq	Mean Sq	F value	p value
Age	2	0.457	0.228	6.756	0.002 ***
Sex	2	0.076	0.038	1.125	0.328

Table S7. The Tukey post hoc test revealed the differences between age groups in temperature on the day or day before a *C. longicollis* was killed are due to the “unknown” age group.

	Diff	lwr	upr	p adj
Juvenile-Adult	0.101	-0.102	0.303	0.468
Unknown-Adult	-0.109	-0.189	-0.028	0.005 ***
Unknown-Juvenile	-0.209	-0.413	-0.005	0.043 *

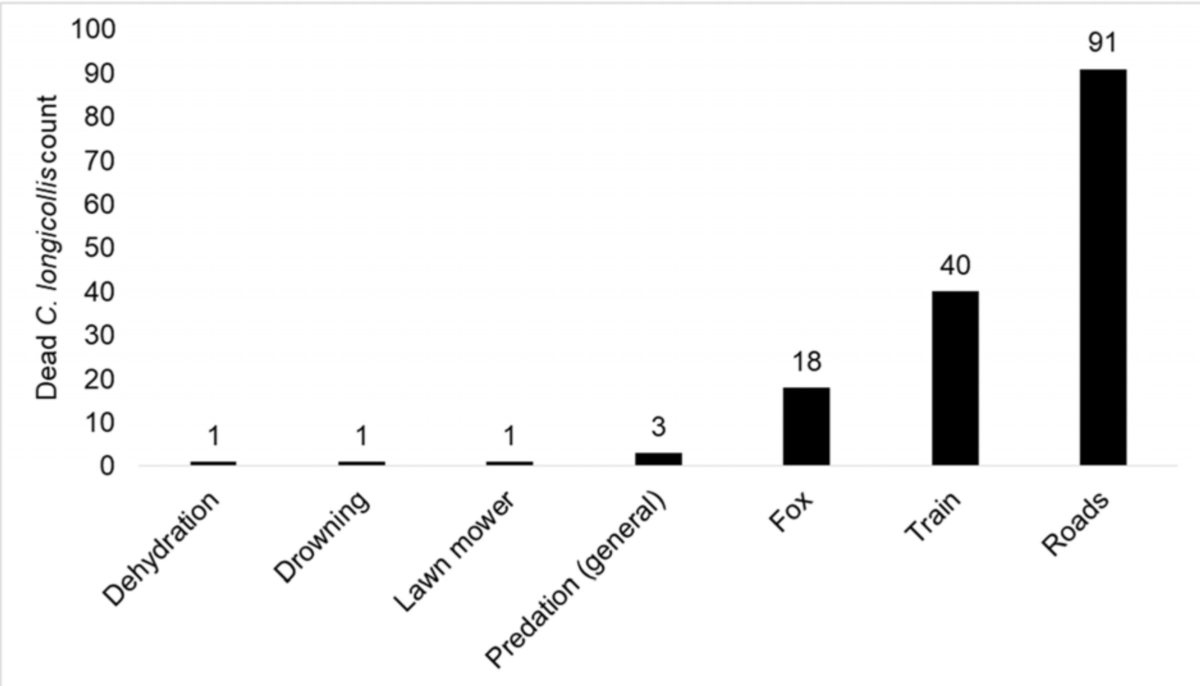

Fig. S4. *Chelodina longicollis* causes of death reported by TurtleSAT users. Above each bar the count of turtles killed is reported. For 100 *C. longicollis* the cause of death was not reported.

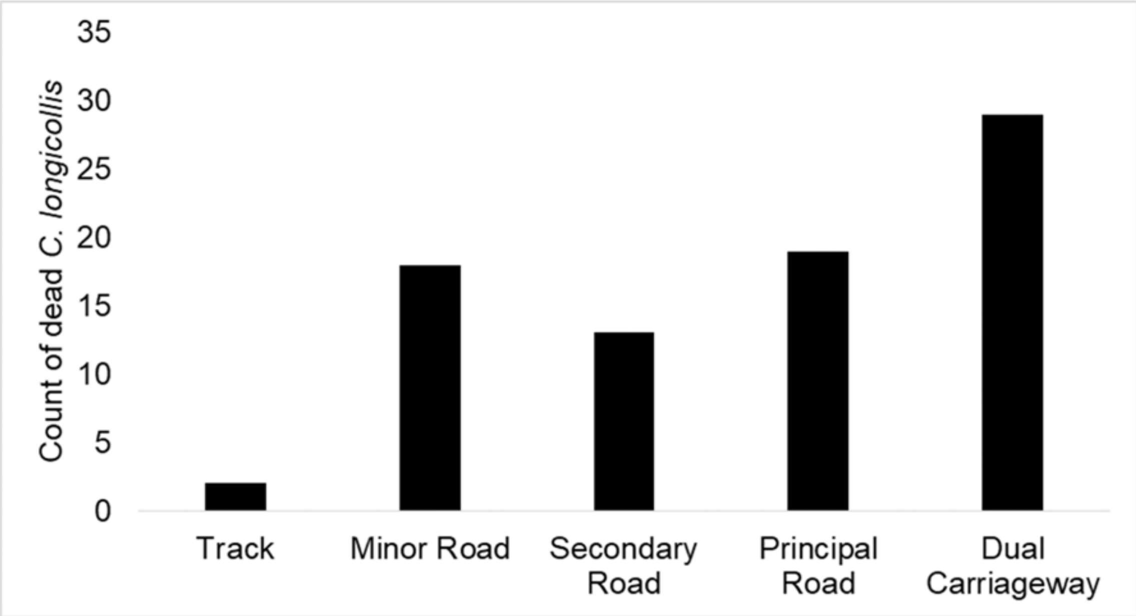

Fig. S5. Count of *C. longicollis* road kill observations per road size.

Table S8. Schoener's D values for logistic models of *C. longicollis* (0 = no niche overlap, 1 = identical models).

	No corrections	Thinned	Density	Background
No bias corrections	1			
Thinned	0.75	1		
Density	0.82	0.79	1	
Background	0.79	0.70	0.78	1

Table S9. The ranked importance and contribution of the predictor variables did not differ between MaxENT models of *C. longicollis*.

Percent contribution			
	No corrections	Density	Background
Density	S = 20.75, rho = 0.87, $p < 0.001$[1]		
Background	S = 43.26, rho = 0.74, $p = 0.020$[1]	S = 29.17, rho = 0.82, $p = 0.003$[1]	S = 28, rho = 0.83, $p = 0.006$
Thin	S = 31.19, rho = 0.81, $p = 0.004$[1]	S = 59.36, rho = 0.64, $p = 0.050$[1]	
Permutation importance			
	No corrections	Density	Background
Density	S = 4, rho = 0.95, $p < 0.001$		
Background	S = 34, rho = 0.79, $p = 0.009$	S = 30, rho = 0.82, $p = 0.007$	

Thin	S = 54, rho = 0.67, *p* = 0.040	S = 50, rho = 0.70, *p* = 0.030	S = 50, rho = 0.70, *p* = 0.030

[1] p-value may not be exact because of ties.