

Ecography

**ECOG-04863**

Callaghan, C. T., Major, R. E., Cornwell, W. K., Poore, A. G. B., Wilshire, J. H. and Lyons, M. B. 2019. A continental measure of urbanness predicts avian response to local urbanization. – *Ecography* doi: 10.1111/ecog.04863

**Supplementary material**

## Appendix 1.

**Table A1.** A table of the 94 species observed in the Blue Mountains and the total number of observations for each species. Also included is the number of continental observations, from eBird, used to assign continental-scale urban scores. Only species with > 10 local records were considered for analysis, and 2 were removed as outliers (Appendix 2).

Species	Scientific Name	Number of local observations	Number of continental observations	Included in regression
Eastern Spinebill	<i>Acanthorhynchus tenuirostris</i>	412	27990	Yes
Red Wattlebird	<i>Anthochaera carunculata</i>	390	84046	Yes
Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	383	80030	Yes
Pied Currawong	<i>Strepera graculina</i>	291	65858	Yes
Crimson Rosella	<i>Platycercus elegans</i>	269	45991	Yes
Australian Magpie	<i>Gymnorhina tibicen</i>	229	158615	Yes
Yellow-faced Honeyeater	<i>Caligavis chrysops</i>	210	35557	Yes
White-throated Treecreeper	<i>Cormobates leucophaea</i>	179	28238	Yes
Spotted Pardalote	<i>Pardalotus punctatus</i>	117	36944	Yes
Rainbow Lorikeet	<i>Trichoglossus haematodus</i>	111	117290	Yes
Brown Thornbill	<i>Acanthiza pusilla</i>	108	48114	Yes
Satin Bowerbird	<i>Ptilonorhynchus violaceus</i>	108	12580	Yes
Gray Butcherbird	<i>Cracticus torquatus</i>	104	59384	Yes
Australian King-Parrot	<i>Alisterus scapularis</i>	103	22845	Yes
New Holland Honeyeater	<i>Phylidonyris novaehollandiae</i>	96	39402	Yes
Gray Fantail	<i>Rhipidura albiscapa</i>	93	77707	Yes
Common Myna	<i>Acridotheres tristis</i>	74	62497	Yes
Silver-eye	<i>Zosterops lateralis</i>	70	58159	Yes
Rock Pigeon	<i>Columba livia</i>	66	29618	Yes
Australian Raven	<i>Corvus coronoides</i>	65	53001	Yes
Rufous Whistler	<i>Pachycephala rufiventris</i>	59	38256	Yes
Eastern Yellow Robin	<i>Eopsaltria australis</i>	52	35185	Yes
Gray Shrikethrush	<i>Colluricincla harmonica</i>	49	50951	Yes

Eurasian Blackbird	<i>Turdus merula</i>	48	43878	Yes
White-naped Honeyeater	<i>Melithreptus lunatus</i>	48	9612	Yes
Striated Thornbill	<i>Acanthiza lineata</i>	44	11878	Yes
Eastern Whipbird	<i>Psophodes olivaceus</i>	42	29452	Yes
Laughing Kookaburra	<i>Dacelo novaeguineae</i>	41	70107	Yes
White-browed Scrubwren	<i>Sericornis frontalis</i>	40	43541	Yes
Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>	38	15908	Yes
Pacific Koel	<i>Eudynamys orientalis</i>	36	15357	Yes
House Sparrow	<i>Passer domesticus</i>	35	36193	Yes
Superb Lyrebird	<i>Menura novaehollandiae</i>	34	4247	Yes
Lewin's Honeyeater	<i>Meliphaga lewinii</i>	33	35617	Yes
Yellow-tailed Black-Cockatoo	<i>Calyptorhynchus funereus</i>	33	13862	Yes
Golden Whistler	<i>Pachycephala pectoralis</i>	29	31744	Yes
Little Wattlebird	<i>Anthochaera chrysoptera</i>	23	28734	Yes
Black-faced Cuckooshrike	<i>Coracina novaehollandiae</i>	19	55254	Yes
Galah	<i>Eolophus roseicapilla</i>	19	80009	Yes
Crested Pigeon	<i>Ocyphaps lophotes</i>	18	69964	Yes
Superb Fairywren	<i>Malurus cyaneus</i>	17	86836	Yes
Noisy Miner	<i>Manorina melanocephala</i>	16	89821	Yes
Welcome Swallow	<i>Hirundo neoxena</i>	15	109006	Yes
Magpie-lark	<i>Grallina cyanoleuca</i>	14	131621	Yes
White-eared Honeyeater	<i>Nesoptilotis leucotis</i>	14	9179	No
Noisy Friarbird	<i>Philemon corniculatus</i>	13	25532	Yes
Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	13	4524	Yes
Scarlet Myzomela	<i>Myzomela sanguinolenta</i>	13	14387	Yes
Masked Lapwing	<i>Vanellus miles</i>	12	80029	Yes
Mistletoebird	<i>Dicaeum hirundinaceum</i>	11	25640	Yes
Pilotbird	<i>Pycnoptilus floccosus</i>	11	749	No

Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>	10	9686	Yes
Gang-gang Cockatoo	<i>Callocephalon fimbriatum</i>	9	5248	No
Leaden Flycatcher	<i>Myiagra rubecula</i>	9	13615	No
Tree Martin	<i>Petrochelidon nigricans</i>	8	18471	No
Variegated Fairywren	<i>Malurus lamberti</i>	8	15152	No
Wonga Pigeon	<i>Leucosarcia melanoleuca</i>	8	7094	No
Red-browed Treecreeper	<i>Climacteris erythrops</i>	7	1286	No
Sacred Kingfisher	<i>Todiramphus sanctus</i>	7	25194	No
Brown-headed Honeyeater	<i>Melithreptus brevirostris</i>	6	7435	No
Little Corella	<i>Cacatua sanguinea</i>	6	30860	No
Shining Bronze-Cuckoo	<i>Chrysococcyx lucidus</i>	6	9331	No
Brown Cuckoo-Dove	<i>Macropygia phasianella</i>	5	10589	No
Red-browed Firetail	<i>Neochmia temporalis</i>	5	33456	No
Brown Gerygone	<i>Gerygone mouki</i>	4	9410	No
Common Cicadabird	<i>Edolisoma tenuirostre</i>	4	6728	No
Maned Duck	<i>Chenonetta jubata</i>	4	56221	No
Scarlet Robin	<i>Petroica boodang</i>	4	7211	No
Crescent Honeyeater	<i>Phylidonyris pyrrhopterus</i>	3	3293	No
Crested Shrike-tit	<i>Falcunculus frontatus</i>	3	3933	No
Olive-backed Oriole	<i>Oriolus sagittatus</i>	3	22539	No
Striated Pardalote	<i>Pardalotus striatus</i>	3	44295	No
Wedge-tailed Eagle	<i>Aquila audax</i>	3	11006	No
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>	2	2836	No
Black-faced Monarch	<i>Monarcha melanopsis</i>	2	6181	No
European Starling	<i>Sturnus vulgaris</i>	2	53070	No
Long-billed Corella	<i>Cacatua tenuirostris</i>	2	10453	No
White-throated Needletail	<i>Hirundapus caudacutus</i>	2	3515	No
Beautiful Firetail	<i>Stagonopleura bella</i>	1	906	No

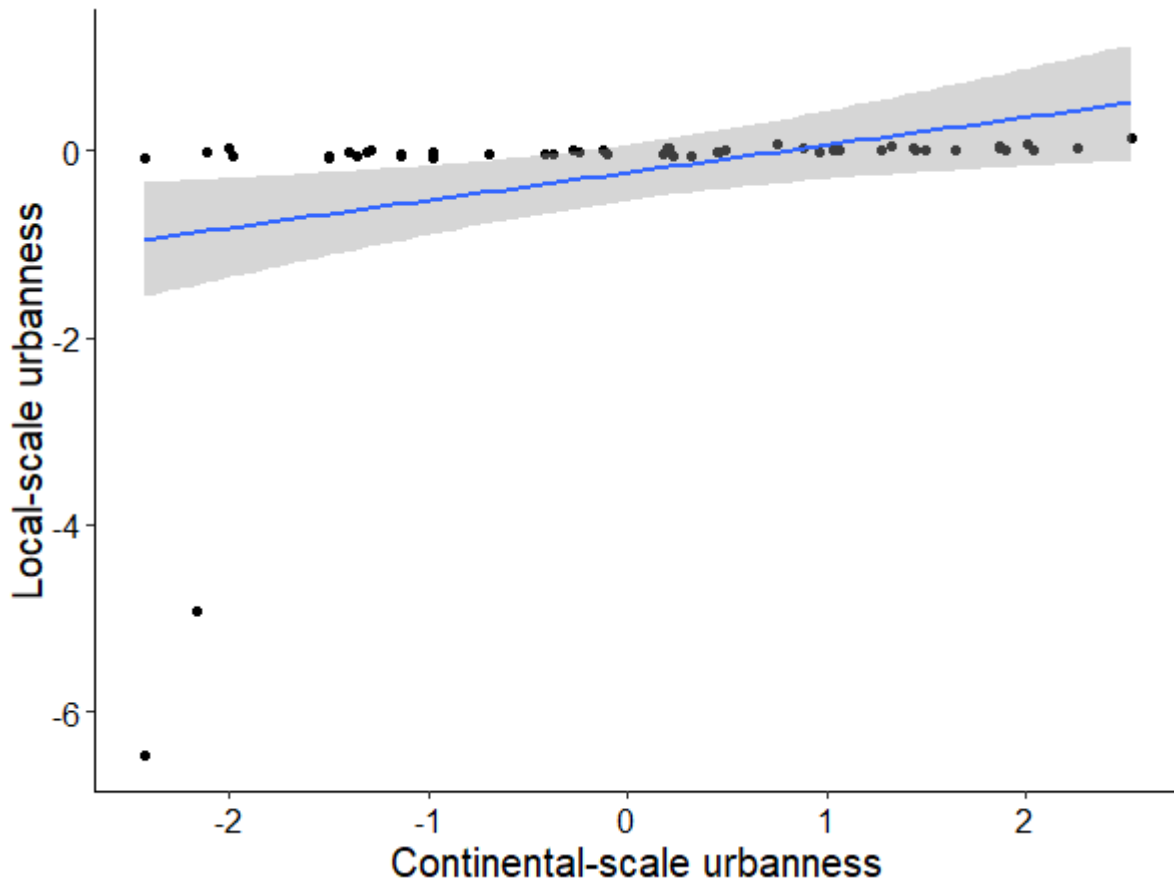
Brown Goshawk	<i>Accipiter fasciatus</i>	1	9918	No
Buff-rumped Thornbill	<i>Acanthiza reguloides</i>	1	7033	No
Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>	1	4270	No
Common Bronzewing	<i>Phaps chalcoptera</i>	1	15076	No
Fuscous Honeyeater	<i>Ptilotula fusca</i>	1	4085	No
Horsfield's Bronze-Cuckoo	<i>Chrysococcyx basalis</i>	1	8035	No
Little Lorikeet	<i>Glossopsitta pusilla</i>	1	4865	No
Peregrine Falcon	<i>Falco peregrinus</i>	1	2960	No
Red-capped Robin	<i>Petroica goodenovii</i>	1	4299	No
Rufous Fantail	<i>Rhipidura rufifrons</i>	1	10113	No
Spotted Quail-thrush	<i>Cinclosoma punctatum</i>	1	423	No
Varied Sittella	<i>Daphoenositta chrysoptera</i>	1	4854	No
White-headed Pigeon	<i>Columba leucomela</i>	1	4069	No
Willie-wagtail	<i>Rhipidura leucophrys</i>	1	106114	No
Yellow Thornbill	<i>Acanthiza nana</i>	1	12237	No

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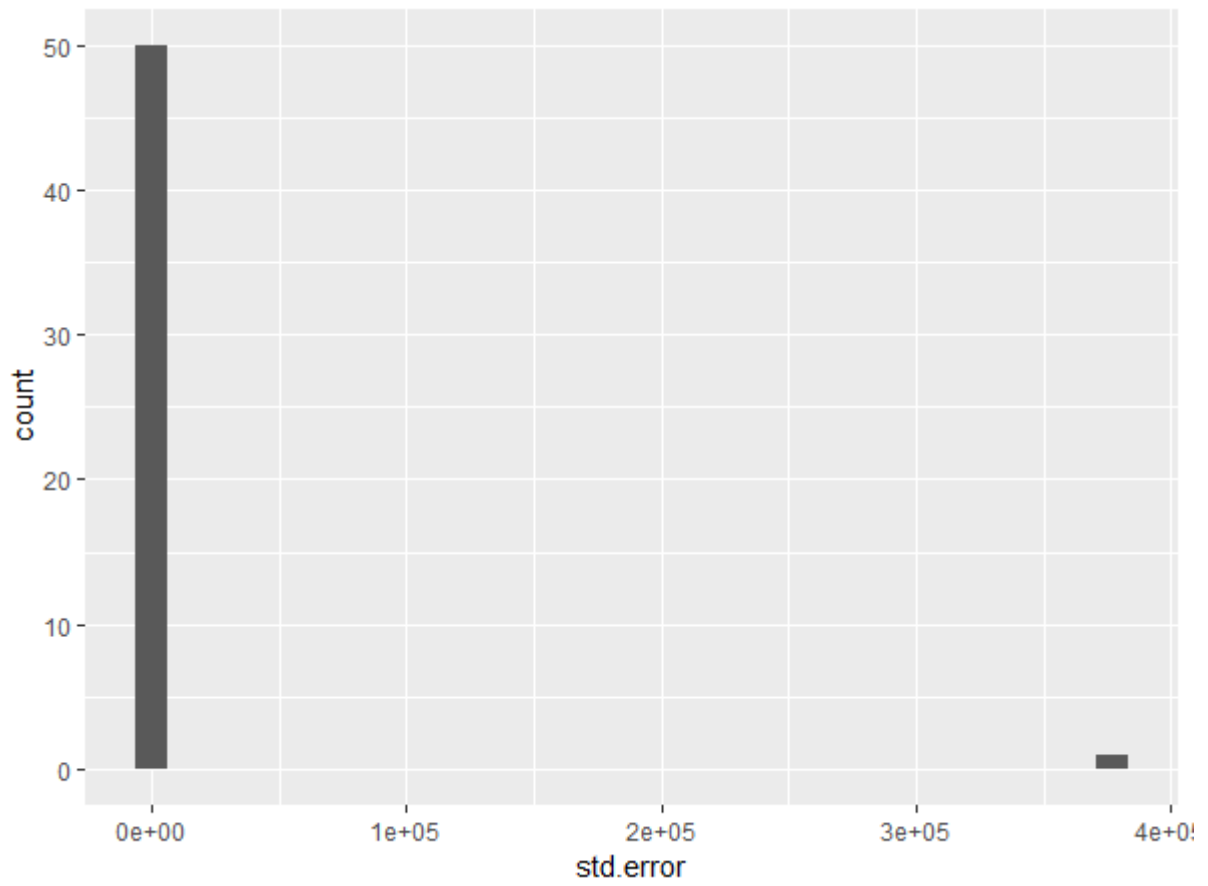
## Appendix 2.

**Derivation A1.** Methods used to identify and eliminate outliers from analyses. Outliers were for species which had poor model-fit at the local-scale, and only considered species at the local-scale, based on GLMM model fits.

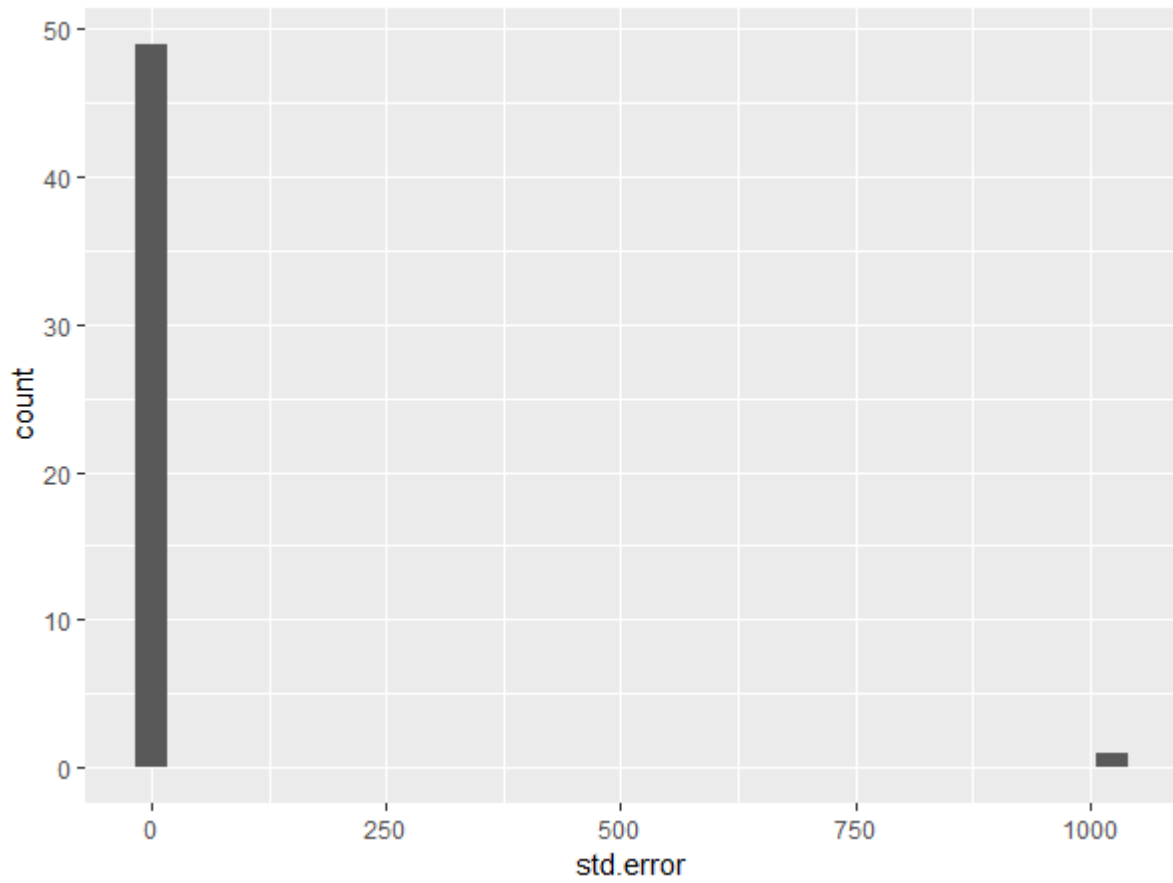
- 1.) Investigated relationship between all 51 species' parameter estimates and their continental-scores – 51 species had > 10 observations, meeting our a priori cut-off for modelling consideration.



2.) Then investigated the outliers, using a histogram of their standard error for the 51 species included in the analysis.

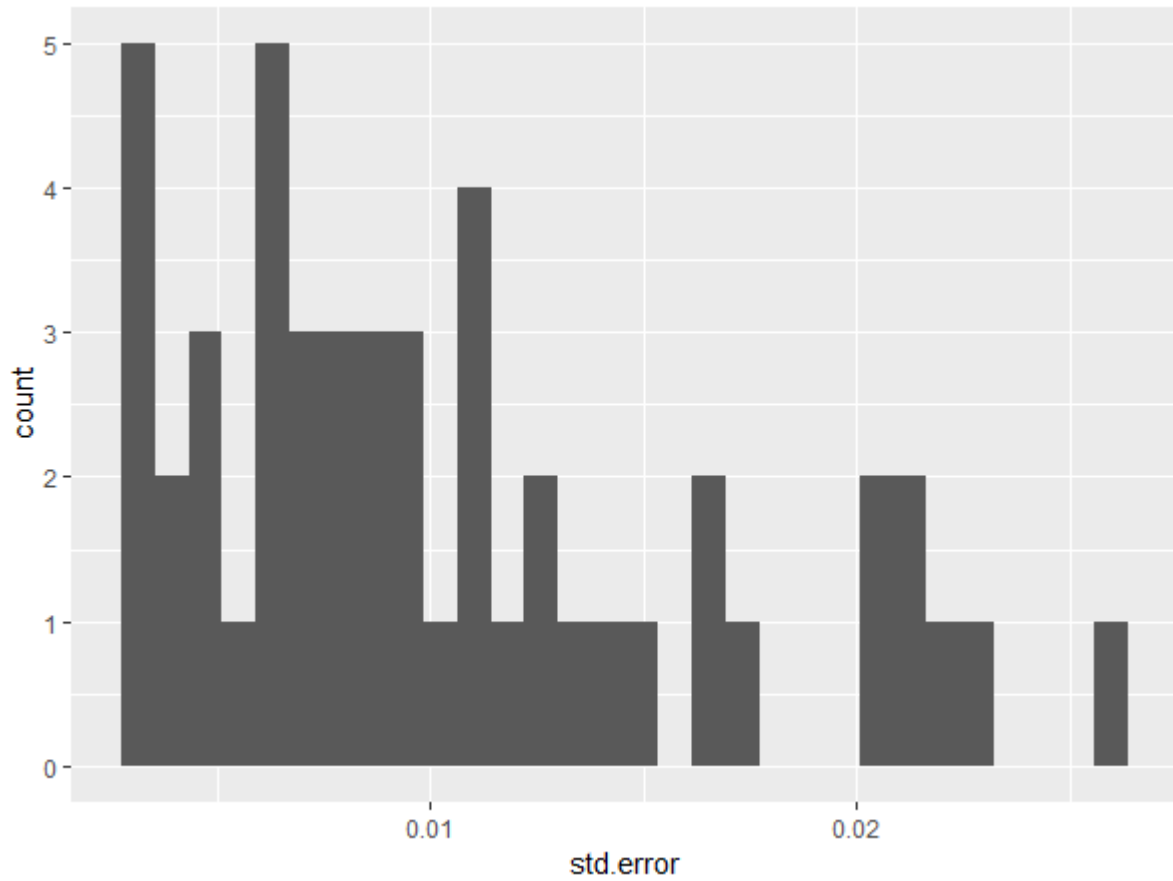


3.) Then identified any species which were greater than 0.95 outlier, using the 'scores' function from the outliers package in R. This identified one species which was an outlier – Pilotbird. We then re-plotted the histogram.





- 4.) We repeated step 3 and found that there was one individual outlier still present, obvious from the histogram. Thus, we removed White-eared Honeyeater from the analysis. We were then satisfied with the statistical spread of standard errors associated with GLMMs.

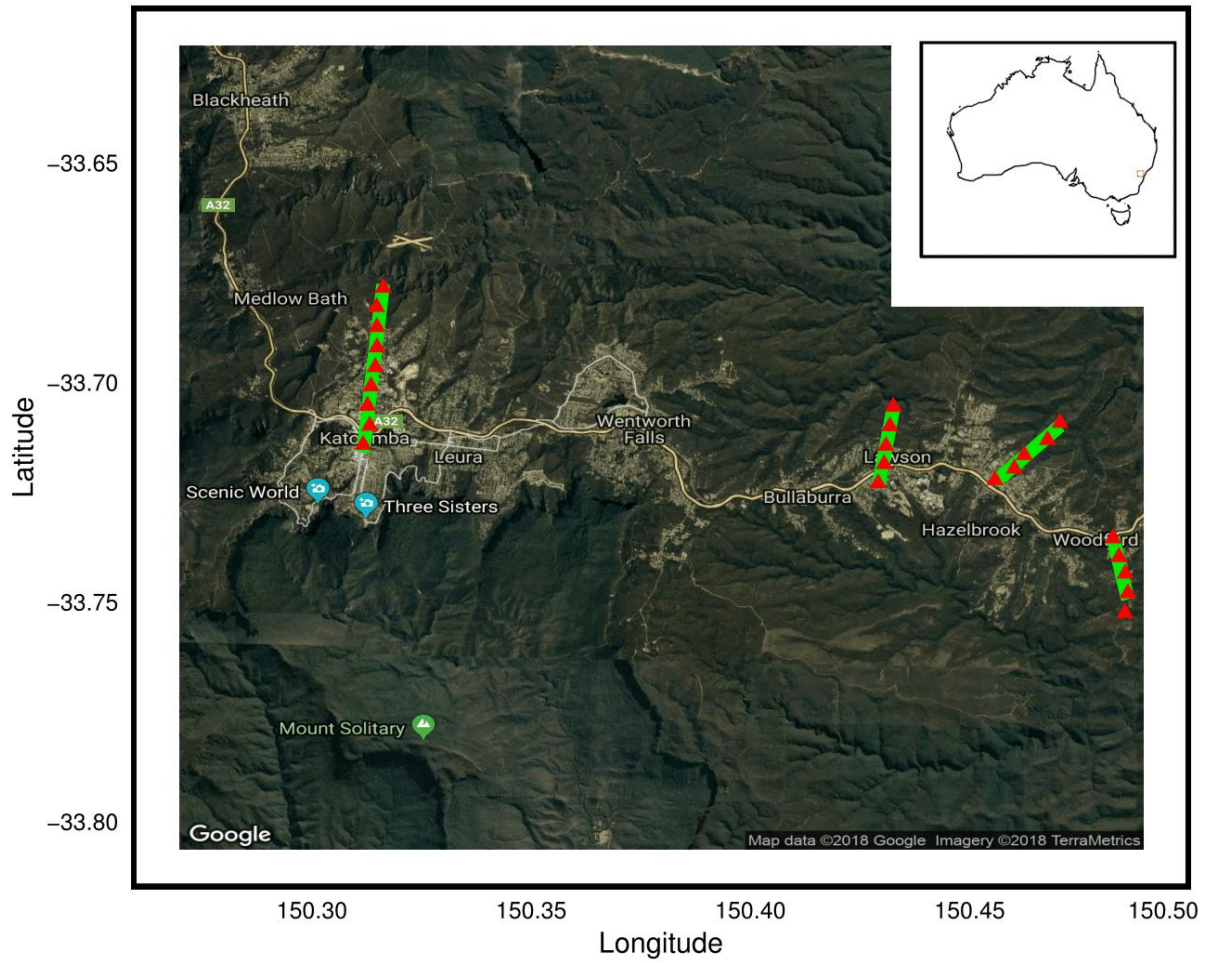


**Table A2.** The results of the modelled relationships of the local-scale responses to urbanization, for the 49 species included in the final analysis. Bolded p-values represent significance at the  $\alpha=0.05$  level.

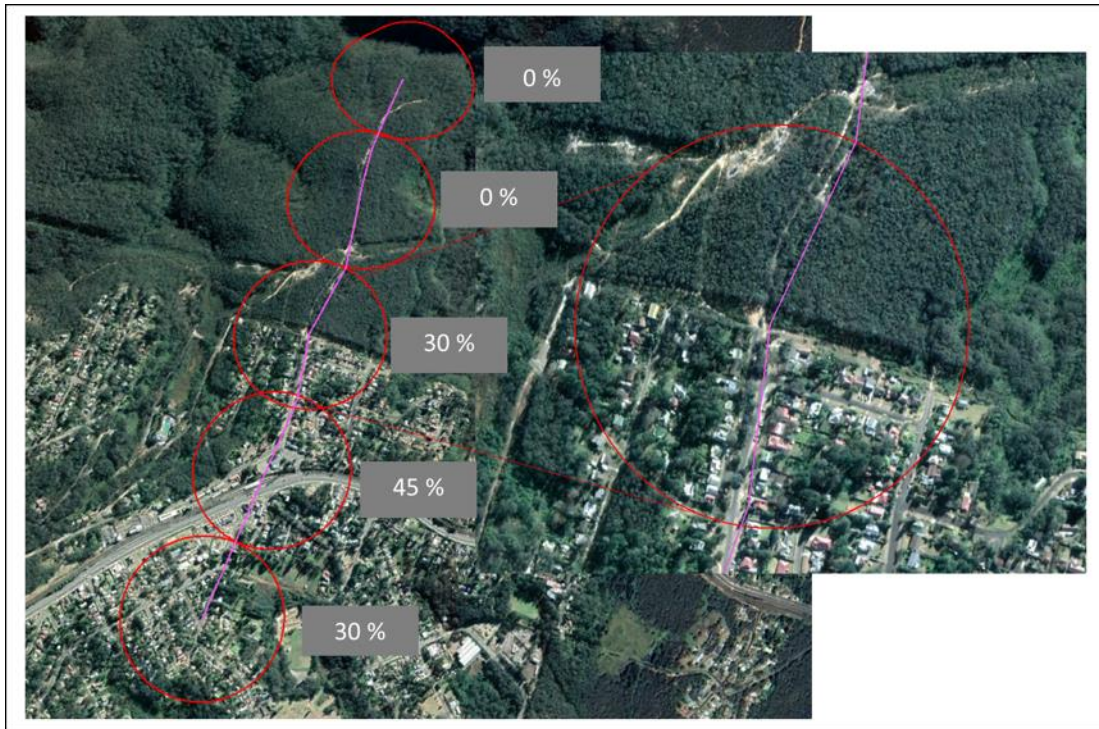
Species	Parameter estimate	Standard error	Statistic	p-value	Deviance	Continental urban score
Australian King-Parrot	0.005	0.005	1.039	0.299	49.236	1.217
Australian Magpie	0.011	0.003	3.804	<b>0.000</b>	106.265	2.807
Australian Raven	-0.005	0.006	-0.733	0.463	28.513	2.607
Black-faced Cuckooshrike	-0.035	0.015	-2.383	<b>0.017</b>	30.899	1.193
Brown Thornbill	-0.037	0.006	-5.902	<b>0.000</b>	22.951	0.903
Common Myna	0.033	0.007	4.562	<b>0.000</b>	37.714	9.588
Crested Pigeon	-0.001	0.010	-0.100	0.920	35.677	4.471
Crimson Rosella	0.000	0.003	0.069	0.945	42.610	0.761
Eastern Spinebill	-0.015	0.003	-4.603	<b>0.000</b>	39.544	0.784
Eastern Whipbird	-0.059	0.014	-4.068	<b>0.000</b>	37.225	0.319
Eastern Yellow Robin	-0.049	0.010	-4.902	<b>0.000</b>	20.013	0.224
Eurasian Blackbird	0.043	0.011	3.919	<b>0.000</b>	35.554	6.489
Fan-tailed Cuckoo	-0.023	0.009	-2.631	<b>0.009</b>	34.617	0.269
Galah	0.027	0.014	1.994	<b>0.046</b>	24.625	1.217
Golden Whistler	-0.072	0.020	-3.553	<b>0.000</b>	19.413	0.377
Gray Butcherbird	0.003	0.004	0.812	0.417	104.344	5.178
Gray Fantail	-0.027	0.006	-4.597	<b>0.000</b>	22.647	0.663
Gray Shrikethrush	-0.054	0.011	-4.791	<b>0.000</b>	37.411	0.223
House Sparrow	0.040	0.010	4.067	<b>0.000</b>	20.147	3.771
Laughing Kookaburra	0.004	0.009	0.431	0.666	38.574	0.879
Lewin's Honeyeater	-0.011	0.011	-1.025	0.305	33.769	0.377
Little Wattlebird	0.010	0.004	2.236	<b>0.025</b>	22.663	2.882
Magpie-lark	0.021	0.011	1.965	<b>0.049</b>	36.199	4.189
Masked Lapwing	0.010	0.013	0.781	0.435	39.177	1.635
Mistletoebird	-0.053	0.023	-2.318	<b>0.020</b>	16.692	0.256

New Holland Honeyeater	-0.054	0.008	-6.587	<b>0.000</b>	50.585	1.369
Noisy Friarbird	-0.035	0.021	-1.716	0.086	11.444	0.688
Noisy Miner	0.014	0.013	1.091	0.275	44.768	7.661
Pacific Koel	0.015	0.008	2.017	<b>0.044</b>	27.592	3.575
Pied Currawong	0.007	0.003	2.355	<b>0.019</b>	55.863	4.232
Rainbow Lorikeet	0.032	0.007	4.429	<b>0.000</b>	63.526	6.489
Red Wattlebird	0.011	0.003	3.150	<b>0.002</b>	101.945	6.636
Red-whiskered Bulbul	0.065	0.026	2.516	<b>0.012</b>	20.904	7.431
Rock Pigeon	0.145	0.022	6.542	<b>0.000</b>	8.875	12.490
Rufous Whistler	-0.083	0.017	-4.830	<b>0.000</b>	19.095	0.224
Satin Bowerbird	0.020	0.006	3.346	<b>0.001</b>	68.313	0.134
Scarlet Myzomela	-0.034	0.016	-2.114	<b>0.034</b>	28.946	0.499
Silver-eye	-0.007	0.007	-0.955	0.339	39.141	1.564
Spotted Pardalote	-0.022	0.005	-4.444	<b>0.000</b>	25.003	1.585
Striated Thornbill	-0.024	0.008	-3.014	<b>0.003</b>	34.102	0.247
Sulphur-crested Cockatoo	0.018	0.004	4.553	<b>0.000</b>	71.695	2.401
Superb Fairywren	0.029	0.017	1.706	0.088	21.647	1.227
Superb Lyrebird	-0.072	0.021	-3.382	<b>0.001</b>	17.221	0.088
Welcome Swallow	0.060	0.021	2.858	<b>0.004</b>	9.857	2.107
White-browed Scrubwren	-0.051	0.012	-4.171	<b>0.000</b>	37.141	1.260
White-naped Honeyeater	-0.023	0.009	-2.384	<b>0.017</b>	26.121	0.121
White-throated Treecreeper	-0.055	0.006	-8.702	<b>0.000</b>	47.739	0.138
Yellow-faced Honeyeater	-0.027	0.005	-5.176	<b>0.000</b>	28.974	0.321
Yellow-tailed Black-Cockatoo	0.007	0.009	0.789	0.430	30.263	0.275

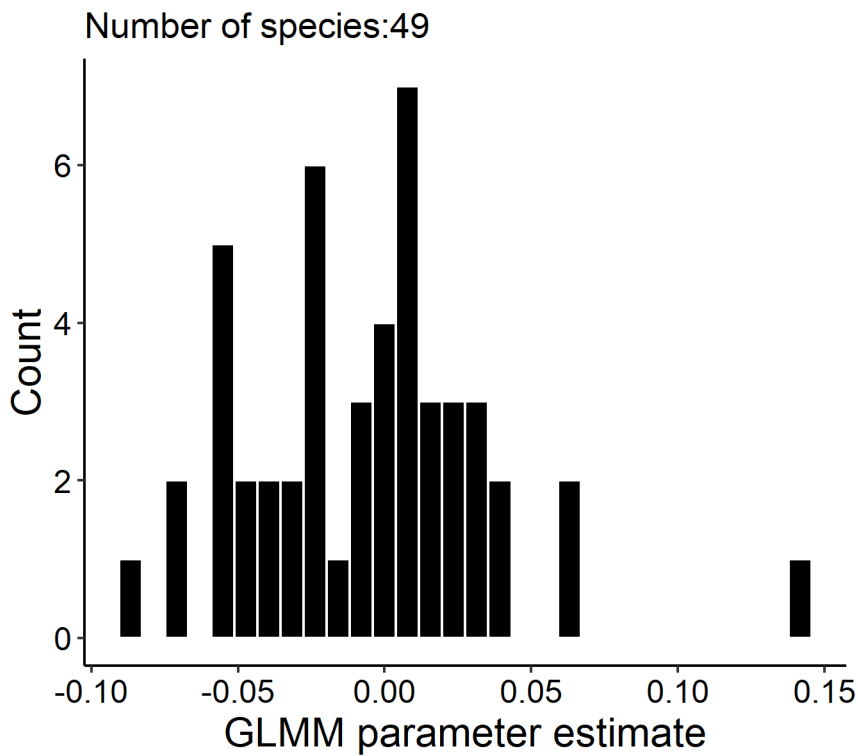
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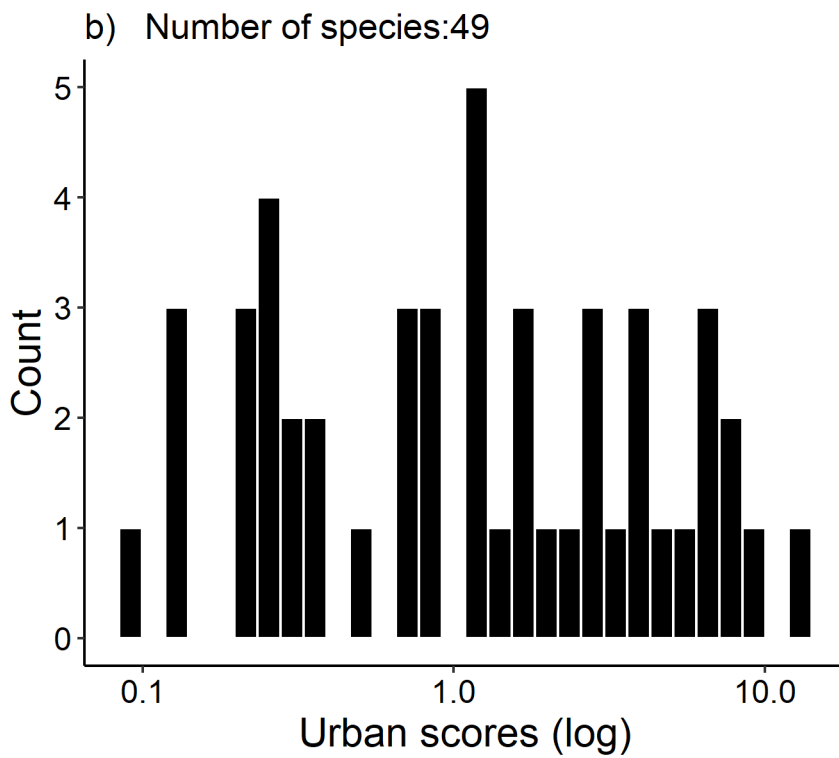
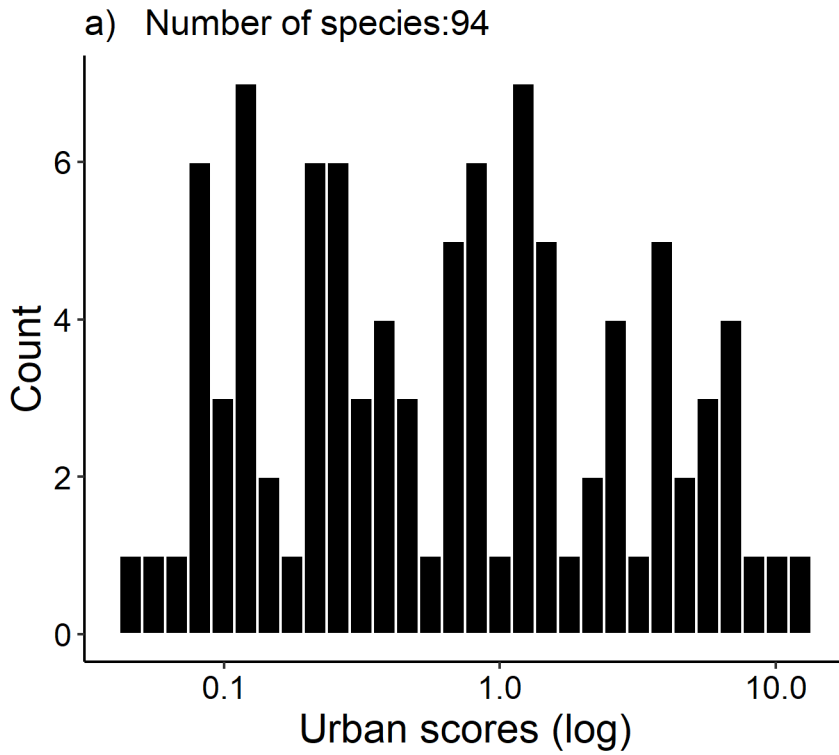
**Figure A1.** A map of the study area, located in the Blue Mountain World Heritage area, ~ 180 km west of Sydney, New South Wales, Australia.



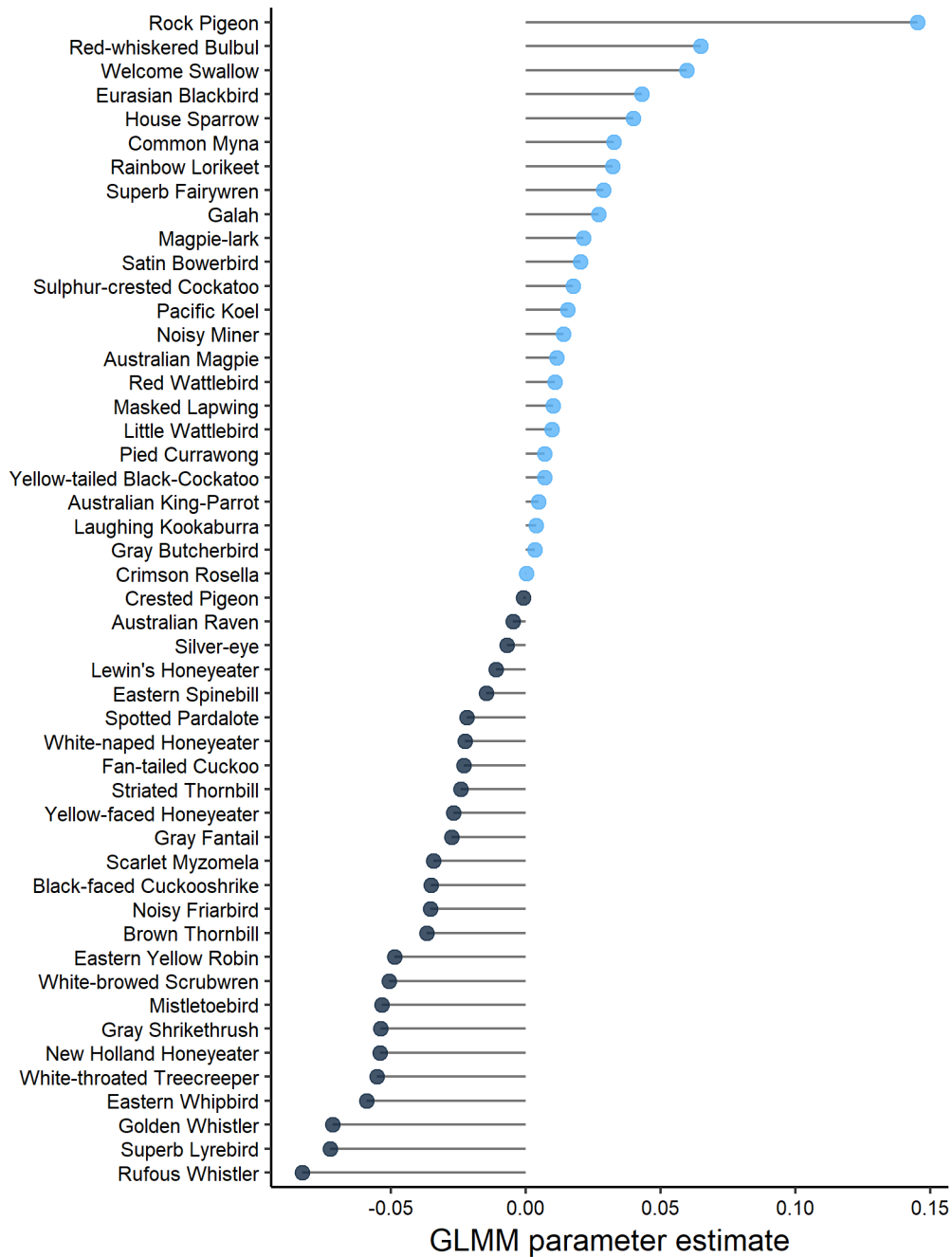
**Figure A2.** An example of how urbanization was calculated at a given point, showing the Lawson transect. The percent impervious surface was estimated within a 250 m buffer, and is shown in the gray boxes for each of the transect points. The circle on the right is an enlarged version of point C from the Lawson Transect.



**Figure A3.** Histogram of the parameter estimates from Generalized Linear Models fitted for each species, representing the local-scale response to urbanization. Species with a parameter estimate  $> 0$  are responding positively to urbanization, while species with a parameter estimate  $< 0$  are responding negatively to urbanization. Model results, including p-values, can be found in Table S2.

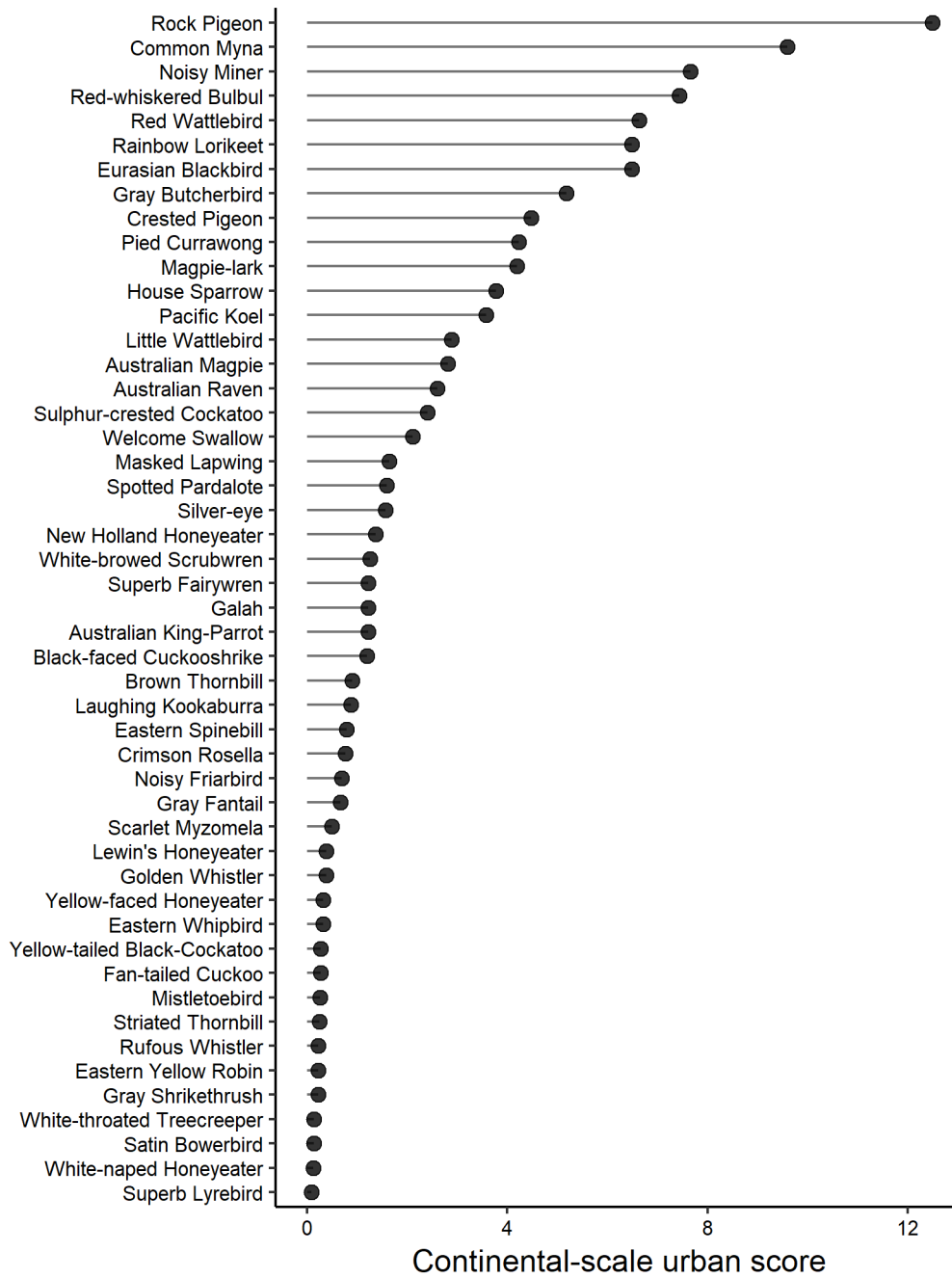


**Figure A4.** Histogram of the continental-urban scores for the 94 species (a) and for the 49 species included in the analysis (b). The urban-scores are measures of a species-specific distributional response to VIIRS night-time lights, gleaned from eBird data (Callaghan et al. 2019).



**Figure A5.** The 49 species included in the study, ranked by their local-scale urban score (i.e., GLMM parameter estimate). Values on the right (light blue) are positively associated with urbanization while values on the left (dark blue) are negatively associated with urbanization.





**Figure A6.** The 49 species included in the study, ranked by their continental-scale urban scores, showing the species most associated with urbanization (Rock Pigeon) to the least (Superb Lyrebird). Compare with Figure S5.