

Supplementary Information

Supplementary information for Guzman et al.: Using historical data to estimate bumble bee occurrence: Variable trends across species provide little support for community-level declines. *Biological Conservation*.

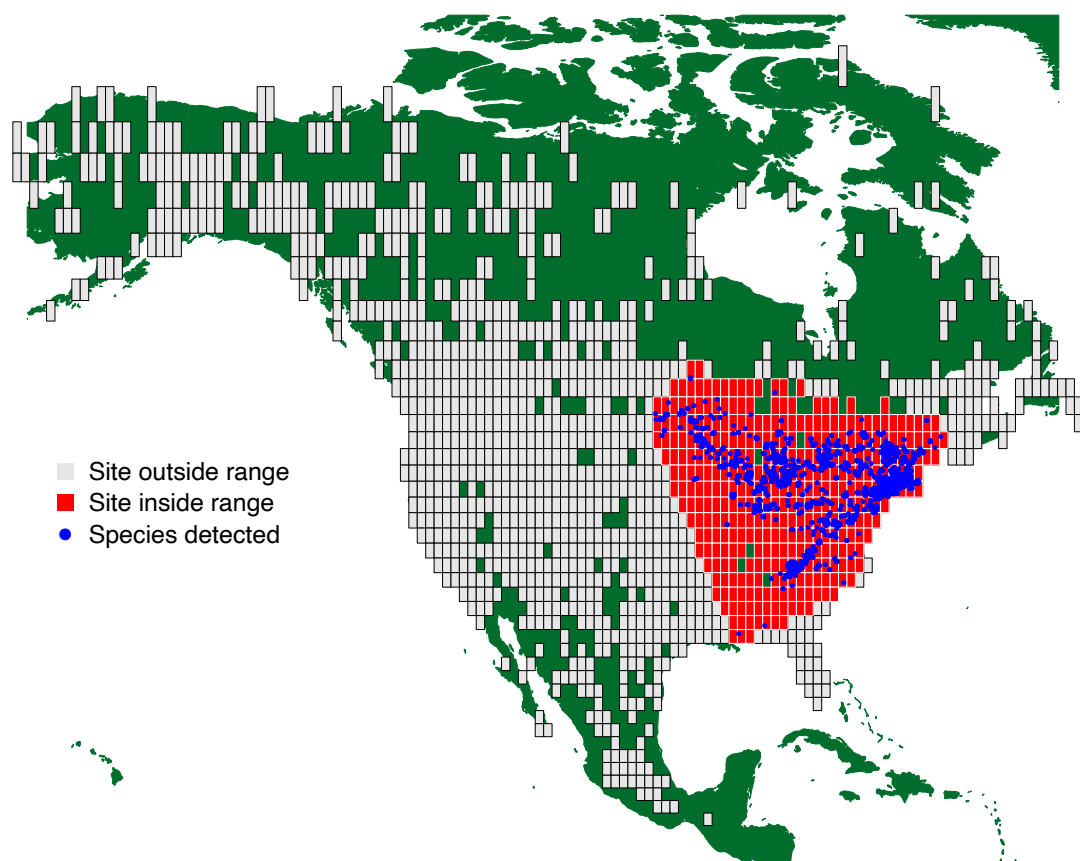


Figure S1: Sample inferred range map for *Bombus affinis* in North America. All sites for North America are shown as boxes, with sites in the range for *B. affinis* highlighted in red. Blue dots indicate actual detections of that species.

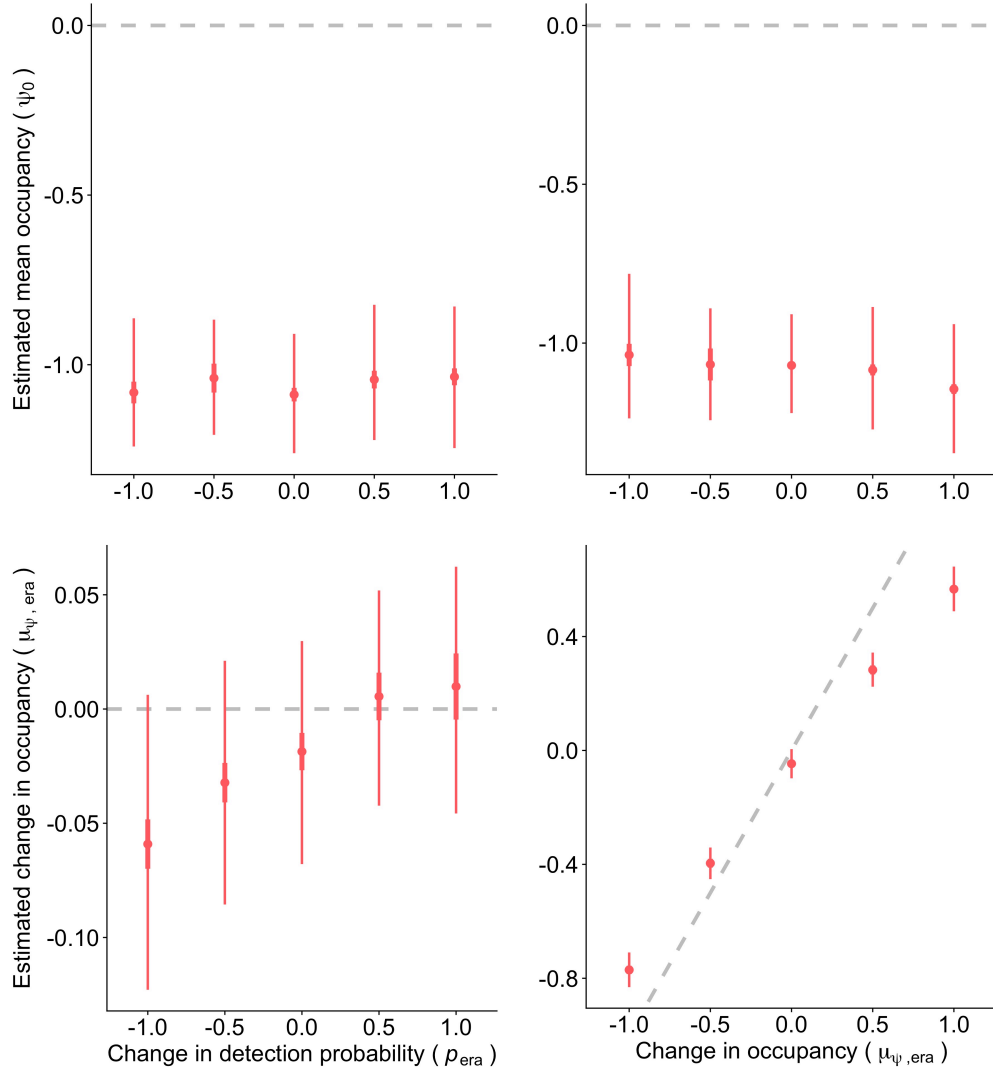


Figure S2: Estimated mean occupancy (top) and change in occupancy (bottom) when species are modelled across all sites and all time intervals ($MS_{all,all}$). The model underestimates mean occupancy (top), but produces comparatively less biased estimates of change or no change in occupancy (bottom) when detection changes through time. Data-sets correspond to the same parameters as used in Fig. 2 with no missing visits (red points in that figure). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets.

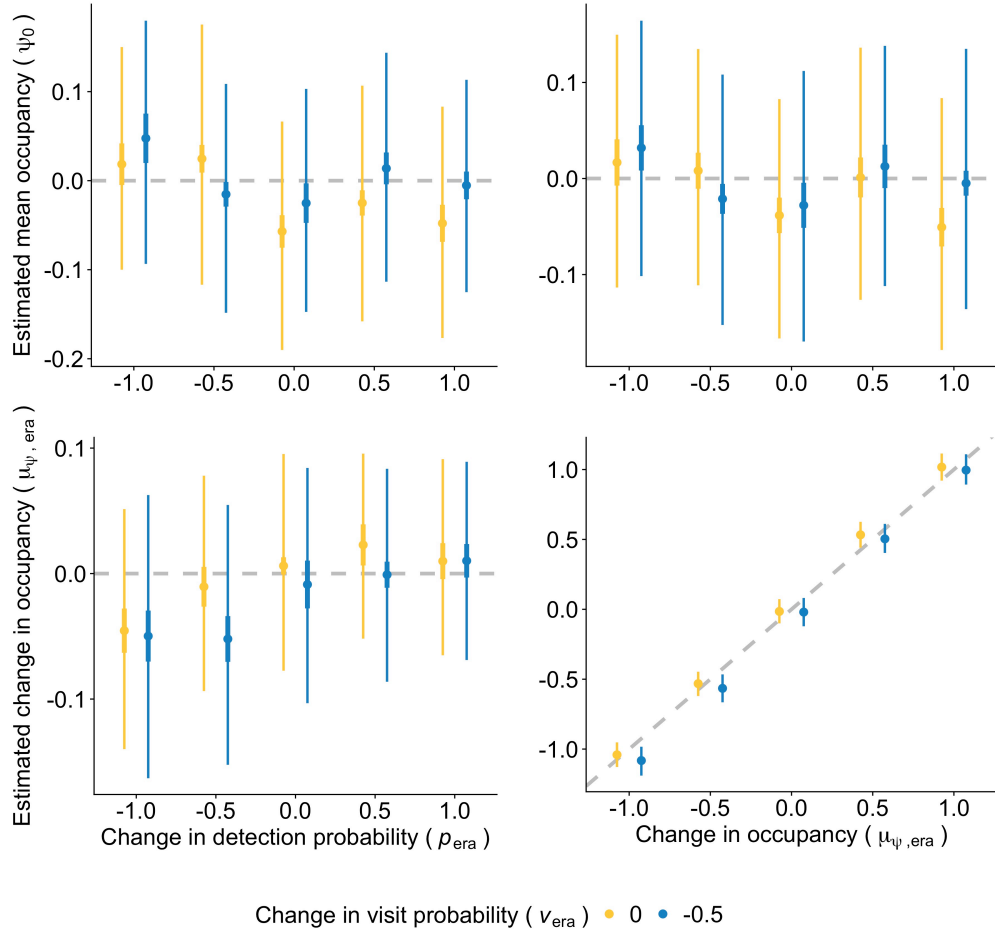


Figure S3: Estimated mean occupancy (top) and change in occupancy (bottom) when species are modelled only across sites in their range and only the time intervals where at least one species was detected using multi-species occupancy models ($MS_{range,detected}$). The model correctly estimates mean occupancy (top) and change or no change in occupancy through time (bottom), even when detection and visitation probability change through time. Data sets used here are the same as those used in Fig. 2 with proportion missing visits set at 0.5 ($v_0 = 0$). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets. Values on the x-axis can be converted to mean change on the probability scale as $\text{expit}(p_0 + x) - \text{expit}(p_0)$ (left) or $\text{expit}(\psi_0 + x) - \text{expit}(\psi_0)$ (right).

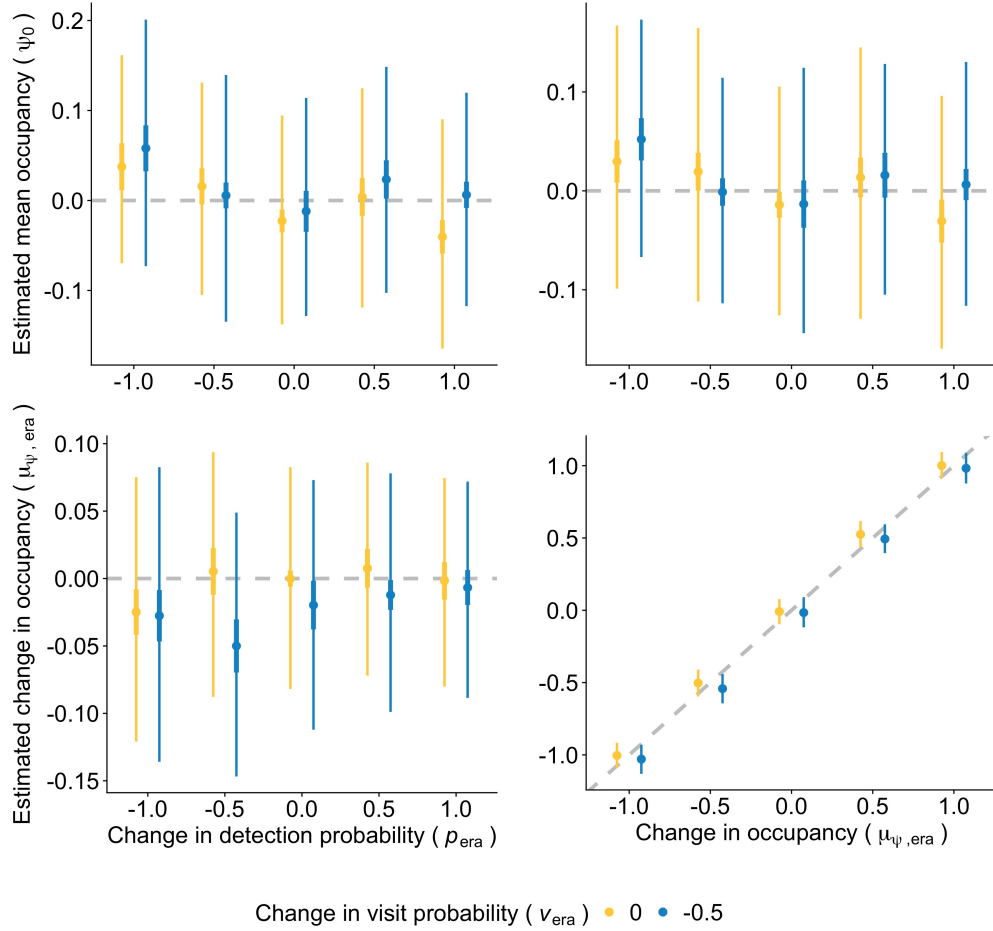


Figure S4: Estimated mean occupancy (top) and change in occupancy (bottom) when species are modelled only across sites in their range and only time intervals where visits actually occurred using multi-species occupancy models ($MS_{range,visits}$). The model correctly estimates mean occupancy (top) and change or no change in occupancy through time (bottom), even when detection and visitation probability change through time. Data sets used here are the same as those used in Fig. 2 with proportion of the time intervals missing visits set at 0.5 ($v_0 = 0$). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets.

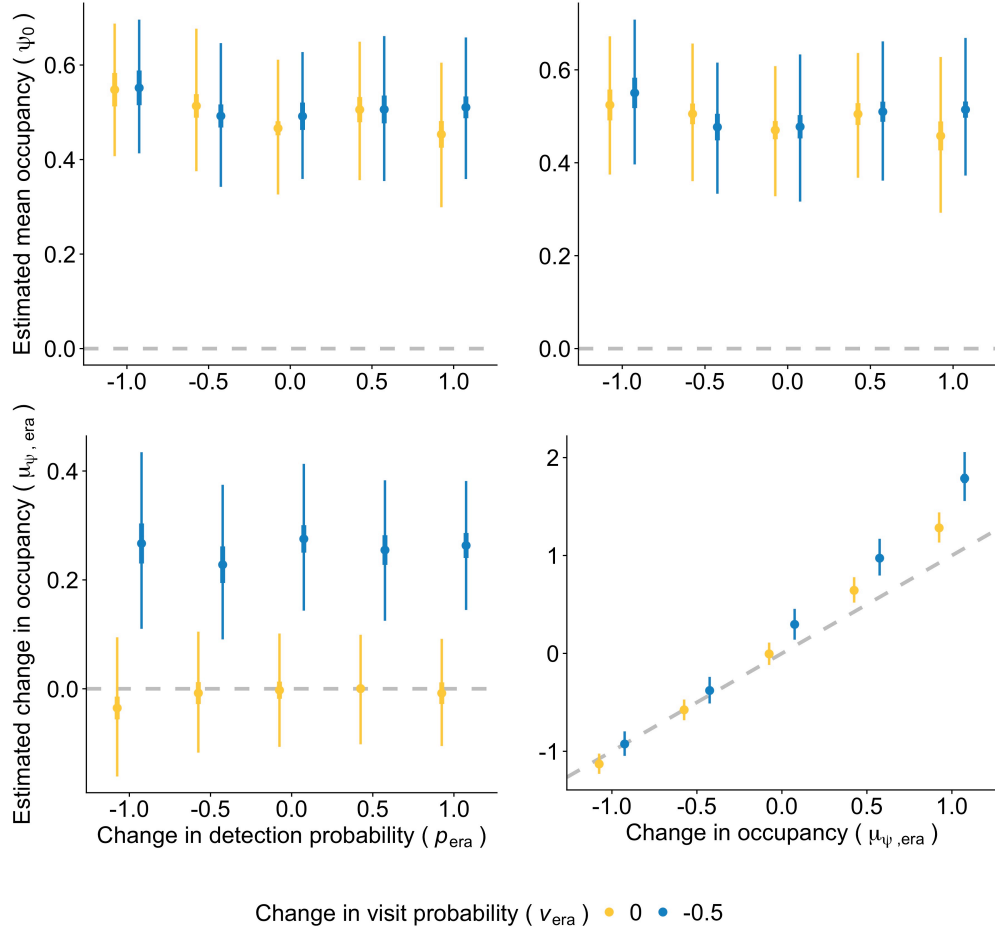


Figure S5: Estimated mean occupancy (top) and change in occupancy (bottom) when species are modelled only across sites in their range and all possible time intervals using multi-species occupancy models ($MS_{range,all}$). The model incorrectly estimates mean occupancy (top) and change in occupancy when occupancy changes through time (bottom right) or when visitation probability changes through time (bottom left). Data sets used here are the same as those used in Fig. 2 with proportion of time intervals that are missing visits set at 0.5 ($v_0 = 0$). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets.

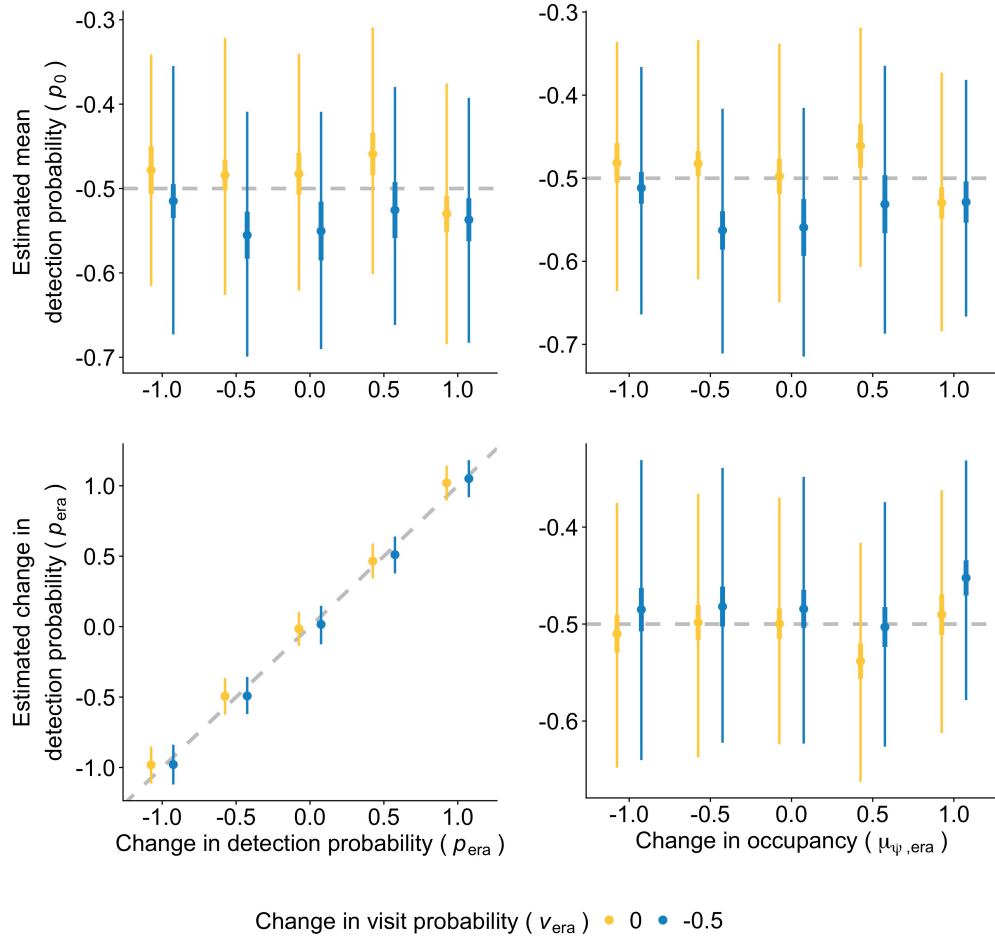


Figure S6: Estimated mean detectability (top) and change in detectability (bottom) when species are modelled only across sites in their range and only time intervals where visits actually occurred using multi-species occupancy models ($MS_{range,visits}$). The model correctly estimates mean detection probability (top) and change or no change in detection probability through time (bottom). Data sets used here are the same as those used in Fig. 2 with proportion of time intervals that are missing visits set at 0.5 ($v_0 = 0$). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets.

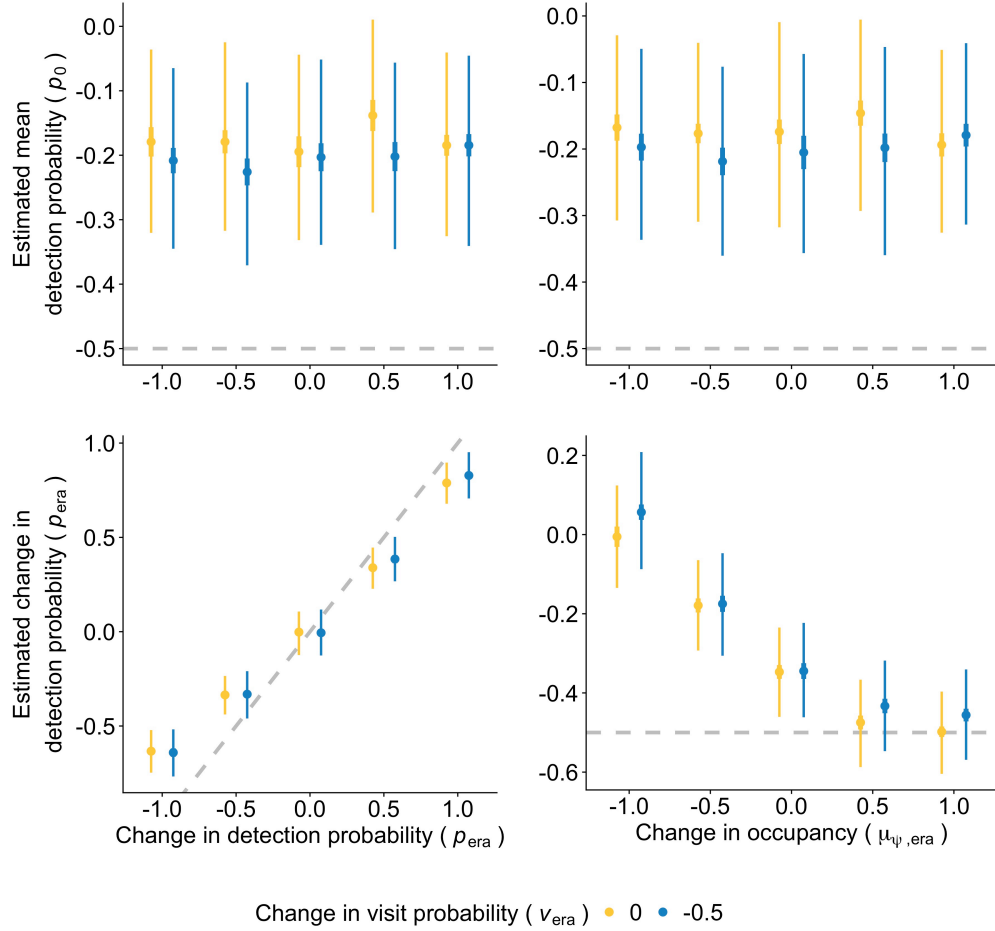


Figure S7: Estimated mean detectability (top) and change in detectability (bottom) when species are modelled only across sites in their range and only the time intervals where at least one species was detected using multi-species occupancy models ($MS_{range, detected}$). The model incorrectly estimates mean detection probability (top) and change in detection probability through time (bottom). Data sets used here are the same as those used in Fig. 2 with proportion of time intervals that are missing visits set at 0.5 ($v_0 = 0$). Points, thick vertical bars, and thin vertical bars show means, standard errors, and mean 95% BCI, respectively, across 10 simulated data sets.

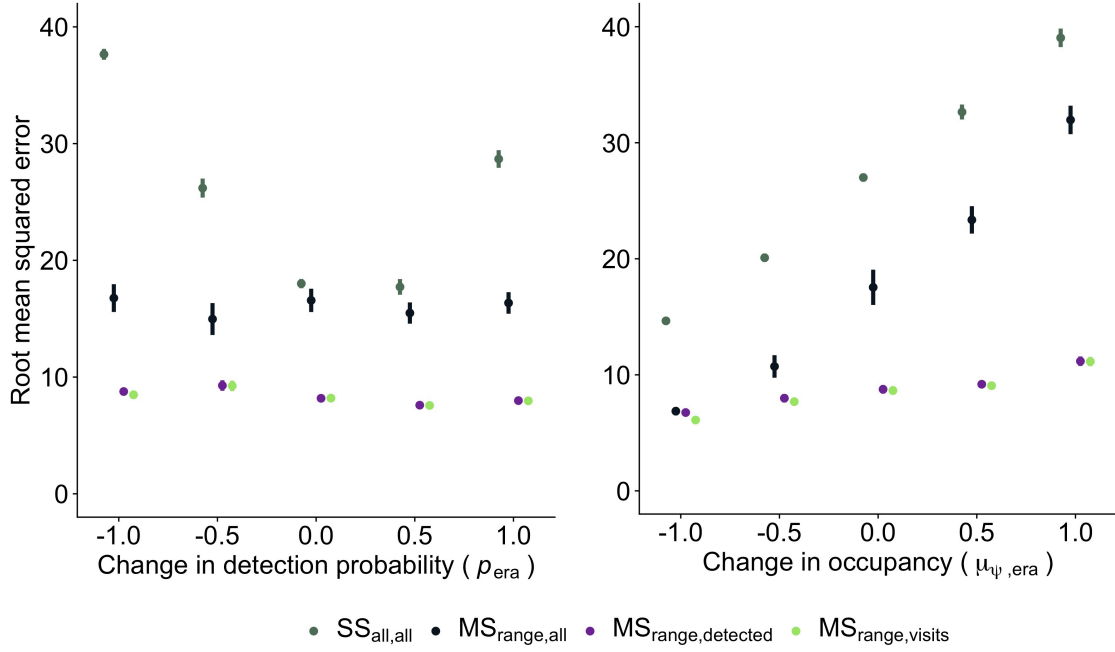


Figure S8: Error in model-estimated species-specific temporal changes in occupancy is lowest when species are modelled only across the sites in their ranges and across time intervals where actual visits took place ($MS_{range,visits}$) or time intervals where at least one species was detected ($MS_{range,detected}$). Modelling species across all time intervals in either a multi-species framework ($MS_{range,all}$) or using the single-species framework of Soroye et al. (2020) ($SS_{all,all}$) exhibits high error. Points and vertical bars show means and standard errors across 10 simulated data sets. Results here are for the same simulated data sets as used in Fig. S3 with proportion of time intervals that are missing visits set at 0.5 ($v_0 = 0$) and declining visitation through time ($v_{era} = -0.5$). Patterns when some visits are missing ($v_0 = 0$), but visitation is constant through time ($v_{era} = 0$), are similar.

		North America		Europe	
Parameter		Mean	95% BCI	Mean	95% BCI
Occupancy	ψ_0	0.267	[-0.052,0.618]	2.963	[2.129,3.834]
	$\sigma_{\psi,sp}$	0.913	[0.676,1.212]	2.205	[1.578,3.093]
	$\mu_{\psi,era}$	-0.11	[-0.455,0.274]	-0.745	[-1.765,0.373]
	$\sigma_{\psi,era}$	0.967	[0.714,1.31]	2.71	[1.89,3.812]
Detection	p_0	-0.835	[-1.115,-0.549]	-1.025	[-1.339,-0.719]
	$\sigma_{p,sp}$	0.747	[0.569,0.988]	0.863	[0.676,1.116]
	p_{era}	-0.047	[-0.181,0.091]	0.388	[0.187,0.588]
	$\sigma_{p,site}$	1.031	[0.98,1.086]	1.403	[1.327,1.482]

Table S1: Parameter estimates from $MS_{range,detected}$ when applied to the 66 species presented in Soroye et al. (2020) for North America and Europe.