Supporting information for

Geographical range area, habitat breadth and specialisation on natural habitats predict land-use responses and climate-change sensitivity more consistently than life-history and dietary traits in terrestrial vertebrates

April 20, 2022

S1 Compiling diet information

S1.1 Processing diet data from EltonTraits (Wilman2014) and AmphiBIO (Oliveira2017).

For mammals and birds, diet information was obtained from the EltonTraits database (**Wilman2014**). Before processing the data, the taxonomy was aligned to that of the trait datasets from (**Etard2020**). Primary diet was directly available for birds, but not for mammals. For both classes, diet was described as the percent use of different food items (namely: invertebrates, vertebrates –either ectotherms, endotherms, fish or unknown–, carrion, fruit, nectar, seed or other plant material). Therefore, we chose not to use the provided primary diet for birds, and instead we applied our own procedure to infer primary diet from recorded food items across birds and mammals. We first grouped the different vertebrate food items together with carrion to create a single 'vertebrate' food item category. We then used the percent uses of the food items to infer primary diet, classifying species' primary diet into the following categories: vertebrate eaters; invertebrate eaters; plant/seed eaters; fruit/nectar eaters; and omnivores [these categories are similar to those employed for birds primary diet in EltonTraits]. When all food items had a percent use below (or equal to) 50% percent, species were classified as omnivores. When a single food item had a percent use strictly above 50%, species were classified into the corresponding primary diet group. For each species, we calculated diet breadth as the number of consumed food items (regardless of the percent use of those items).

For amphibians, diet information was partly extracted from the AmphiBIO database (**Oliveira2017**), and partly compiled from the literature (see next section). In AmphiBIO, diet information was recorded as the consumption of six food items (leaves, flowers, seeds, fruit, arthropods and vertebrates), but the percent use of these items was not recorded. From AmphiBIO, we classified amphibians into the different diet categories, depending on the combinations of consumed food items.

S1.2 Diet data complements for amphibians and reptiles

To increase diet data coverage for amphibians, we compiled data from published papers and from the grey literature, targeting species occurring in the PREDICTS database. We were able to collect diet information for an additional 108 amphibians from 26 published sources (all found to be invertebrate eaters; see below for the list of sources). For reptiles, there was no readily available diet information (except for trophic level information, see **Etard2020**). Thus, we collected diet data from the literature, specifically targeting reptiles occurring in the PREDICTS database. From the literature, we added diet information for 239 reptiles. Finally, diet breadth was calculated across amphibians and reptiles from the recorded food items. The compiled diet data are available at: `https://figshare.com/articles/Reptile_Diet_csv/12024309` (DOI: 10.6084/m9.figshare.12024309.v1) and `https://figshare.com/articles/Untitled_Item/12024312` (DOI: 10.6084/m9.figshare.12024312.v4).

S1.2.1 Complementary data sources for amphibians

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- Yap, C.H. & Jaafar, I. (2011). Stomach Content Analysis of Tropical Forest Toads *Ingerophrynus parvus* and *Phrynoides aspera* (ANURA : BUFONIDAE) from Kedah, Malaysia. Taxonomist and Ecologist Conference 2011.

S1.2.2 Complementary data sources for reptiles

The 148 sources are listed in the dataset available from `https://figshare.com/articles/Reptile_Diet_csv/12024309` (DOI: 10.6084/m9.figshare.12024309.v1).

S2 Imputing missing trait values

S2.1 Trait data coverage

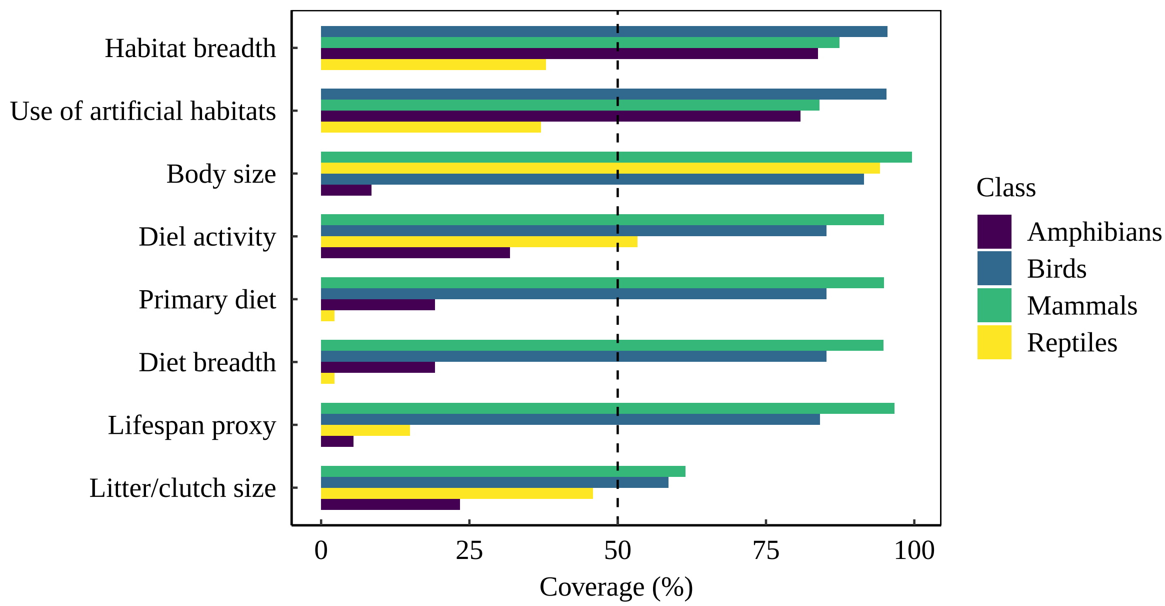

Figure S1: Trait coverage, including coverage for diet information, calculated as the proportion of species for which trait values are not missing. The dashed line represents 50% coverage.

S2.2 Phylogenetic signal in traits

We measured the phylogenetic signal in traits using Pagel's λ (for continuous traits) and Borges' δ (for categorical traits). We found evidence of phylogenetic conservatism in all the traits.

Table S1: Phylogenetic signal in continuous and categorical traits. BM: body mass; BL: body length; GL: generation length; MA: age at sexual maturity; ML: maximum longevity; L: longevity; LCS: litter/clutch size; HB: habitat breadth; DA: diel activity; UA: use of artificial habitats. Continuous traits were log-10 transformed to improve normality before estimating Pagel's λ – except for habitat breadth which was square-rooted. A star indicates a significant signal (p-value<0.05 for the log-likelihood ratio test in the case of λ; and a significant difference from the simulated null distribution of δ for categorical traits). 'NA' indicates traits that were not considered for a given class. All traits showed significant phylogenetic signal, with signals for BM, BL, L, GL, MA and LCS being particularly strong (above 0.8) across the four classes.

	Pagel's λ								**Borges' δ**		
Class	**BM**	**BL**	**GL**	**MA**	**ML**	**L**	**LCS**	**HB**	**Diet**	**DA**	**UA**
Amphibians	0.98*	0.94*	NA	0.85*	0.82*	NA	0.93*	0.99*	3.4*	3.4*	4.5*
Birds	0.99*	NA	0.97*	NA	NA	NA	0.95*	0.60*	6.4*	32e3*	1.8*
Mammals	0.99*	NA	0.97	NA	NA	NA	0.99	0.71	26*	52*	1.3*
Reptiles	1.0*	NA	NA	NA	0.94*	0.98*	1.0*	0.52*	2.2*	6.4*	1.4*

S2.3 Implementation of missing value imputations

We imputed missing trait values using random forest algorithms, as implemented in R with missForest (**Stekhoven2012**; **Stekhoven2016**). Phylogenetic relationships were included as additional predictors in the form of phylogenetic eigenvectors (**DinizFilho2012**), extracted from the phylogenies using the PVR package (**Santos2018**). Following **Penone2014**, we included the first ten phylogenetic eigenvectors as additional predictors of missing trait values in each class. As not all species were represented in the phylogenies, we also added taxonomic order as a predictor for all species. All traits in table S1 were included in the imputations, as well as diet breadth. Habitat & diet breadth were considered as categorical variables for the imputations (and so, discretised). Tuning parameters of missForest were set to ten maximum iterations and to one hundred trees grown in each forest.

S2.4 Imputation error & imputation congruence

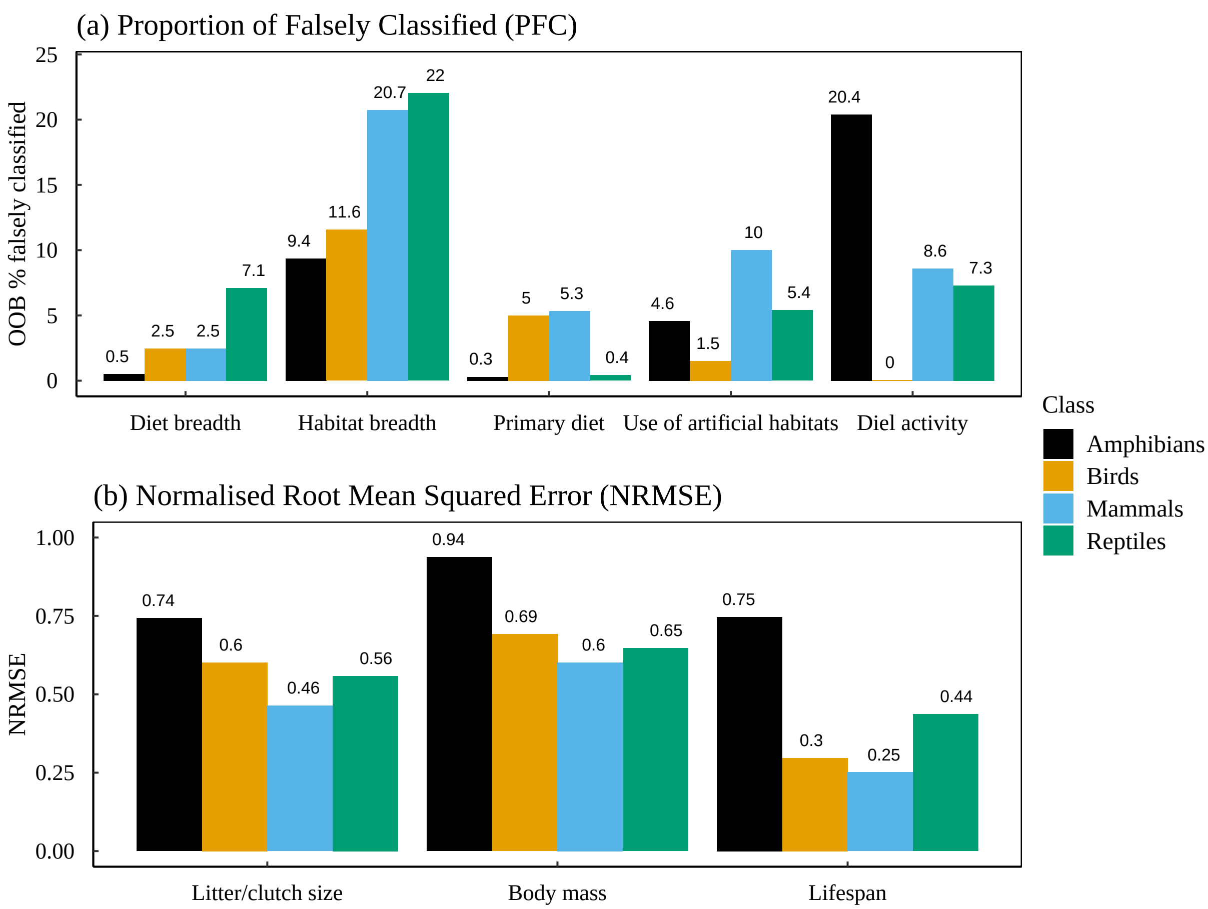

Figure S2: Estimation of imputation errors for the traits included in the analyses. (a) For the categorical traits, we show the proportion of falsely classified traits (‘PFC’, out-of-bag estimates); (b) For the continuous traits, we calculate the normalised root-mean-squared error from the mean square error (that we divide by the standard deviation of the known trait distribution).

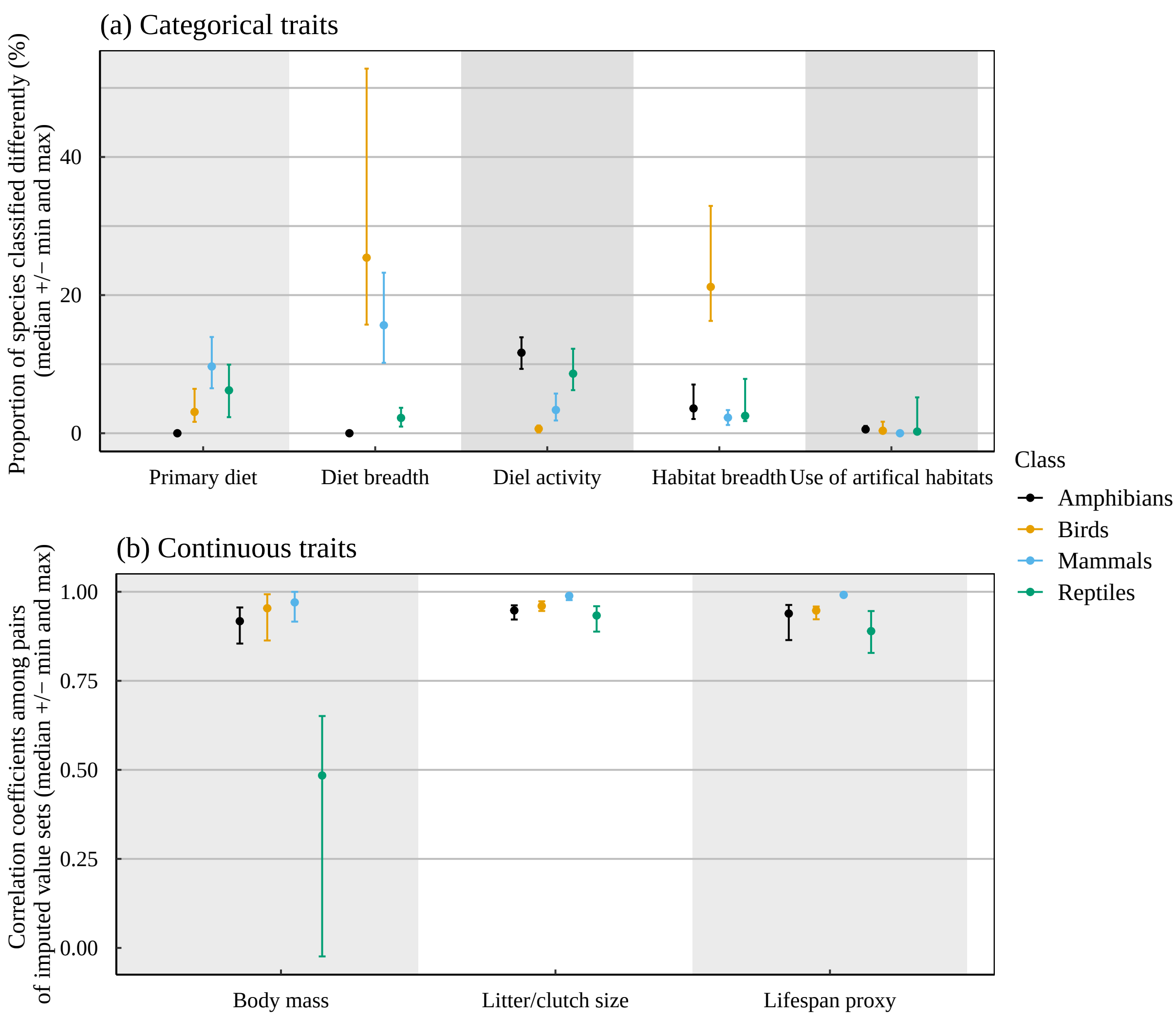

Figure S3: Imputation congruence among eight independent sets of imputed traits. (a) For the categorical traits, we show the median and the range of the proportion of species for which different imputation rounds yielded different imputed values. The proportion of species for which the estimated values were different between two imputed datasets was obtained for each pair of imputed sets (by obtaining pairwise comparisons among the eights sets of imputed datasets). (b) For the continuous traits, we show the range and median of the correlation coefficients among pairs of imputed sets, for each trait.

S3 Sample sizes: number of sampled sites across classes and land-use types

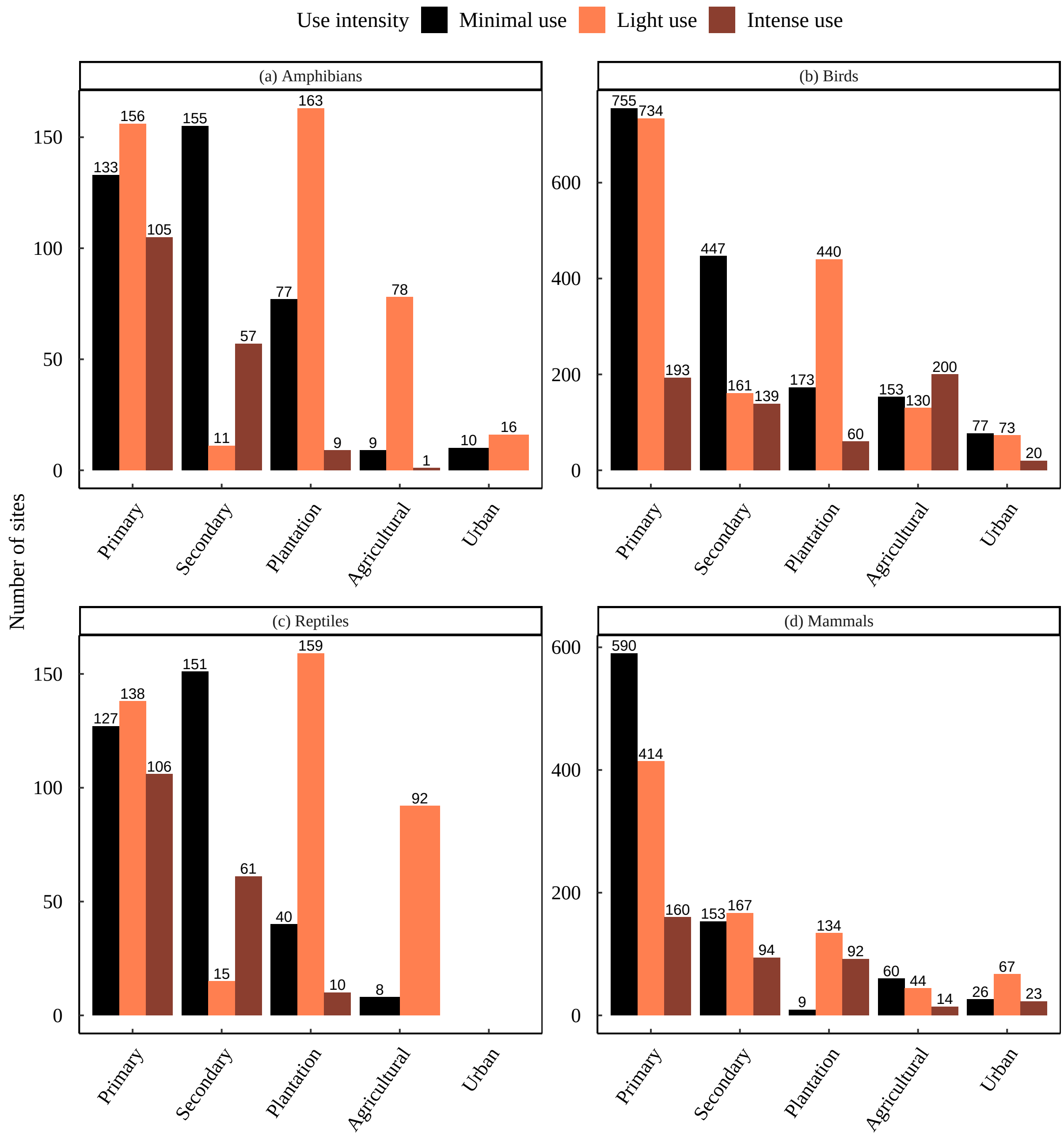

Figure S4: Sample sizes (number of PREDICTS sites) for the different land-use types, in each class.

S4 Land-use responses: multicollinearity checks among the predictors

Table S2: Generalised Variance Inflation Factors among the candidate species-level predictors for the mixed-effects model fitted across amphibians, ***prior to the exclusion of primary diet***. The model aimed at investigating the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.7
Lifespan proxy ($\log_{10}$)	1.8
Specialisation	1.8
Range area ($\log_{10}$)	2.0
Body mass ($\log_{10}$)	2.0
Land use	2.0
Litter/clutch size ($\log_{10}$)	2.5
Land-use intensity	2.6
Habitat breadth (square-root)	3.2
Diet breadth (square-root)	22.8
Primary diet	23.6

Table S3: Generalised Variance Inflation Factors among the species-level predictors for the mixed-effects model fitted across amphibians ***(after the exclusion of primary diet)***, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.6
Diet breadth (sqrt)	1.7
Lifespan proxy ($\log_{10}$)	1.8
Specialisation	1.8
Range area ($\log_{10}$)	1.9
Land use	2.0
Body mass ($\log_{10}$)	2.0
Litter/clutch size ($\log_{10}$)	2.4
Land-use intensity	2.6
Habitat breadth (square-root)	3.1

Table S4: Generalised Variance Inflation Factors among the species-level predictors for the mixed-effects model fitted across birds, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.1
Land use	1.2
Land-use intensity	1.2
Litter/clutch size ($\log_{10}$)	1.3
Range area ($\log_{10}$)	1.4
Diet breadth (square-root)	1.5
Specialisation	1.6
Lifespan proxy ($\log_{10}$)	1.7
Habitat breadth (square-root)	1.8
Body mass ($\log_{10}$)	1.9
Primary diet	2.3

Table S5: Generalised Variance Inflation Factors among the species-level predictors for the mixed-effects model fitted across mammals, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.2
Range area ($\log_{10}$)	1.2
Specialisation	1.4
Land-use intensity	1.4
Diet breadth (square-root)	1.7
Land use	1.8
Habitat breadth (square-root)	1.8
Litter/clutch size ($\log_{10}$)	2.7
Body mass ($\log_{10}$)	3.0
Lifespan proxy ($\log_{10}$)	3.4
Primary diet	4.4

Table S6: Generalised Variance Inflation Factors among the candidate species-level predictors for the mixed-effects model fitted across reptiles, *prior to the exclusion of primary diet*. The model aimed at investigating the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.1
Specialisation	1.3
Range area ($\log_{10}$)	1.3
Habitat breadth (square-root)	1.6
Lifespan proxy ($\log_{10}$)	1.9
Litter/clutch size ($\log_{10}$)	2.8
Land use	3.2
land-use intensity	3.5
Body mass ($\log_{10}$)	3.9
Diet breadth (square-root)	5.8
Primary diet	9.9

Table S7: Generalised Variance Inflation Factors among the species-level predictors for the mixed-effects model fitted across reptiles *(after the exclusion of primary diet)*, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability.

Predictor	GVIF
Diel activity	1.1
Diet breadth (square-root)	1.2
Specialisation	1.2
Range area ($\log_{10}$)	1.3
Habitat breadth (square-root)	1.6
Lifespan proxy ($\log_{10}$)	1.9
Litter/clutch size ($\log_{10}$)	2.7
Land use	3.2
Body mass ($\log_{10}$)	3.2
Land-use intensity	3.4

S5 Implementing Climate-niche Factor Analysis (CENFA; Rinnan2019) across terrestrial vertebrates

S5.1 Historical climate data: groups of intercorrelated variables

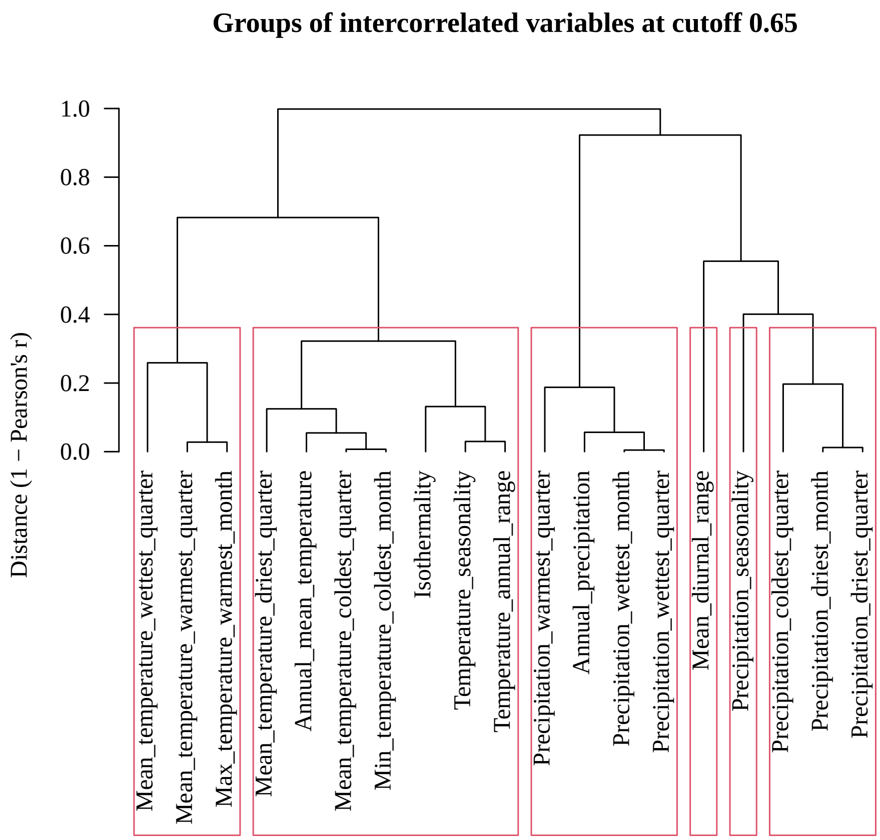

Figure S5: Groups of intercorrelated climatic variables at cutoff 0.65, obtained using the 'removeCollinearity' R function (virtualspecies R package, **virtualspecies**).

S5.2 CENFA estimation and resolution

We estimated climate change sensitivity across terrestrial vertebrates with the CENFA framework using three different resolutions for the species distribution files and the climatic variables: 50 km^2, 10 km^2 and 5 km^2. Indeed, the higher the resolution, the better species distribution is likely to be captured, particularly for the narrow-ranging species (Figure S6). When working with lower resolutions, the actual geographical distribution of a narrow-ranging species might be overestimated (Figure S6), such that the climatic niche breadth of the species, and consequently its climate-change sensitivity, might also be overestimated. However, higher resolutions are more computationally demanding, which can be limiting where working across several thousand species.

Thus, we looked for a resolution that provided the best estimations of climate-change sensitivity for the narrow-ranging species while requiring acceptable computational load. With a resolution of 50 km^2, climate-change sensitivity tended to be overestimated for more of the narrow-ranging species than at 10 km^2 (Figure

S7); and at 10 km^2, climate-change sensitivity tended to be overestimated for more of the narrow-ranging species than at 5 km^2 (Figure S7). Below 5 km^2, we deemed the computational load not acceptable for a global estimation of climate-change sensitivity across terrestrial vertebrates.

Hence, we chose to work with a resolution of 5 km^2. At this resolution, there were still some-narrow ranging species for which sensitivity was likely overestimated (Figure S7). To prevent any impact of such species on the analyses, we selected out species with the smallest range sizes, using a conservative threshold of 100 km^2 for range size (Figure S7).

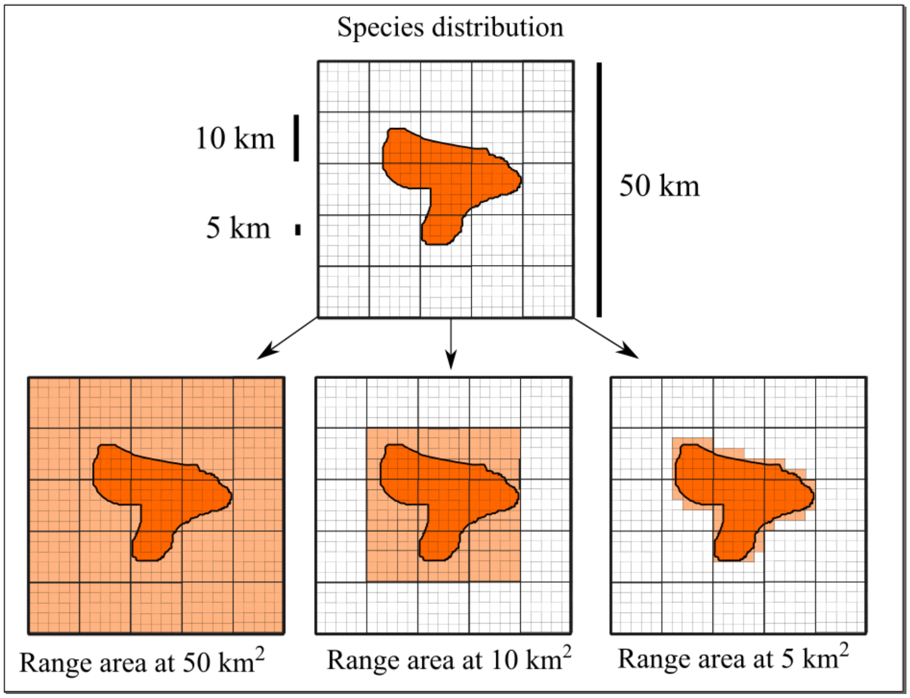

Figure S6: Possible impact of resolution choice on estimated geographical range area. We represent a virtual distribution for a species (orange shape). The species distribution is more accurately captured at higher resolution (e.g., 5 km^2) than at lower resolutions (e.g., 10 km^2 or 50 km^2), which can tend to overestimate the geographical range area because of the aggregation of grid cells at lower resolution which can artificially augment the amount of occupied area.

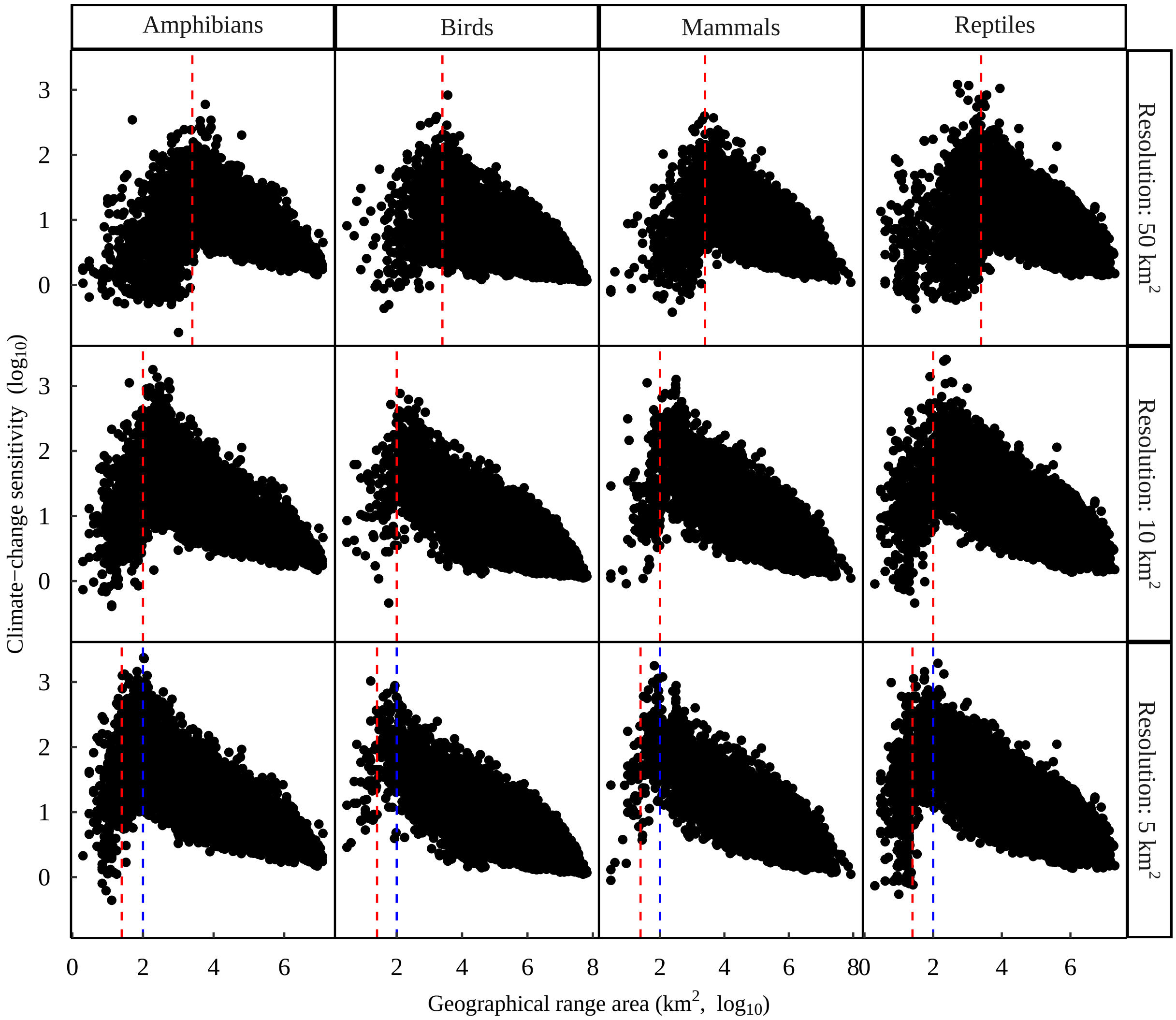

Figure S7: Climate-change sensitivity estimations at three different resolution (50 km^2, 10 km^2 and 5 km^2) against geographical range area (estimated at 1 km^2). With the red dashed lines, we highlight the range areas that correspond to the surface area of one grid cell (*i.e.*, 2,500 km^2, 100 km^2 and 25 km^2 respectively). Climate-change sensitivity was estimated using the CENFA framework (**Rinnan2019**). We chose to work at a resolution of 5 km^2 and we excluded species whose range area was $\leq$100km^2 (blue dashed line), that is, species whose distribution could intersect up to four grid cells.

S6 Climate-change sensitivity models: multicollinearity checks

Table S8: Generalised Variance Inflation Factors among the candidate species-level predictors for the phylogenetic least-square regression fitted across amphibians, *prior to the exclusion of diet breadth*. The model aimed at investigating the effects of the species-level predictors on species climate-change sensitivity.

Predictor	GVIF
Diel activity	1.1
Lifespan proxy ($\log_{10}$)	1.2
Range area ($\log_{10}$)	1.3
Body mass ($\log_{10}$)	1.4
Litter/clutch size ($\log_{10}$)	1.5
Specialisation	1.6
Habitat breadth (square-root)	1.9
Primary diet	17.1
Diet breadth (square-root)	17.1

Table S9: Generalised Variance Inflation Factors among the species-level predictors for the phylogenetic least-square regression fitted across amphibians, *after excluding diet breadth*. The model was fitted to investigate the effects of the species-level predictors on species climate-change sensitivity.

Predictor	GVIF
Diel activity	1.1
Primary diet	1.1
Lifespan proxy ($\log_{10}$)	1.2
Range area ($\log_{10}$)	1.3
Body mass ($\log_{10}$)	1.4
Litter/clutch size ($\log_{10}$)	1.5
Specialisation	1.6
Habitat breadth (square-root)	1.9

Table S10: Generalised Variance Inflation Factors among the species-level predictors for the phylogenetic least-square regression fitted across birds. The model was fitted to investigate the effects of the species-level predictors on species climate-change sensitivity.

Predictor	GVIF
Diel activity	1.1
Range area ($\log_{10}$)	1.2
Litter/clutch size ($\log_{10}$)	1.3
Diet breadth (square-root)	1.5
Specialisation	1.6
Habitat breadth (square-root)	1.8
Lifespan proxy ($\log_{10}$)	1.9
Body mass ($\log_{10}$)	2.0
Primary diet	2.1

Table S11: Generalised Variance Inflation Factors among the species-level predictors for the phylogenetic least-square regression fitted across mammals. The model was fitted to investigate the effects of the species-level predictors on species climate-change sensitivity.

Predictor	GVIF
Range area ($\log_{10}$)	1.2
Diel activity	1.3
Specialisation	1.3
Habitat breadth (square-root)	1.5
Diet breadth (square-root)	1.6
Body mass($\log_{10}$)	2.3
Litter/clutch size ($\log_{10}$)	2.4
Primary diet	2.7
Lifespan proxy ($\log_{10}$)	3.0

Table S12: Generalised Variance Inflation Factors among the species-level predictors for the phylogenetic least-square regression fitted across reptiles. The model was fitted to investigate the effects of the species-level predictors on species climate-change sensitivity.

Predictor	GVIF
Diel activity	1.1
Range area($\log_{10}$)	1.2
Specialisation	1.4
Habitat breadth (square-root)	1.5
Lifespan proxy ($\log_{10}$)	1.6
Litter/clutch size ($\log_{10}$)	2.0
Body mass ($\log_{10}$)	2.9
Diet breadth (square-root)	2.9
Primary diet	3.6

S7 Land-use responses: estimated effects from full (all-predictor) models

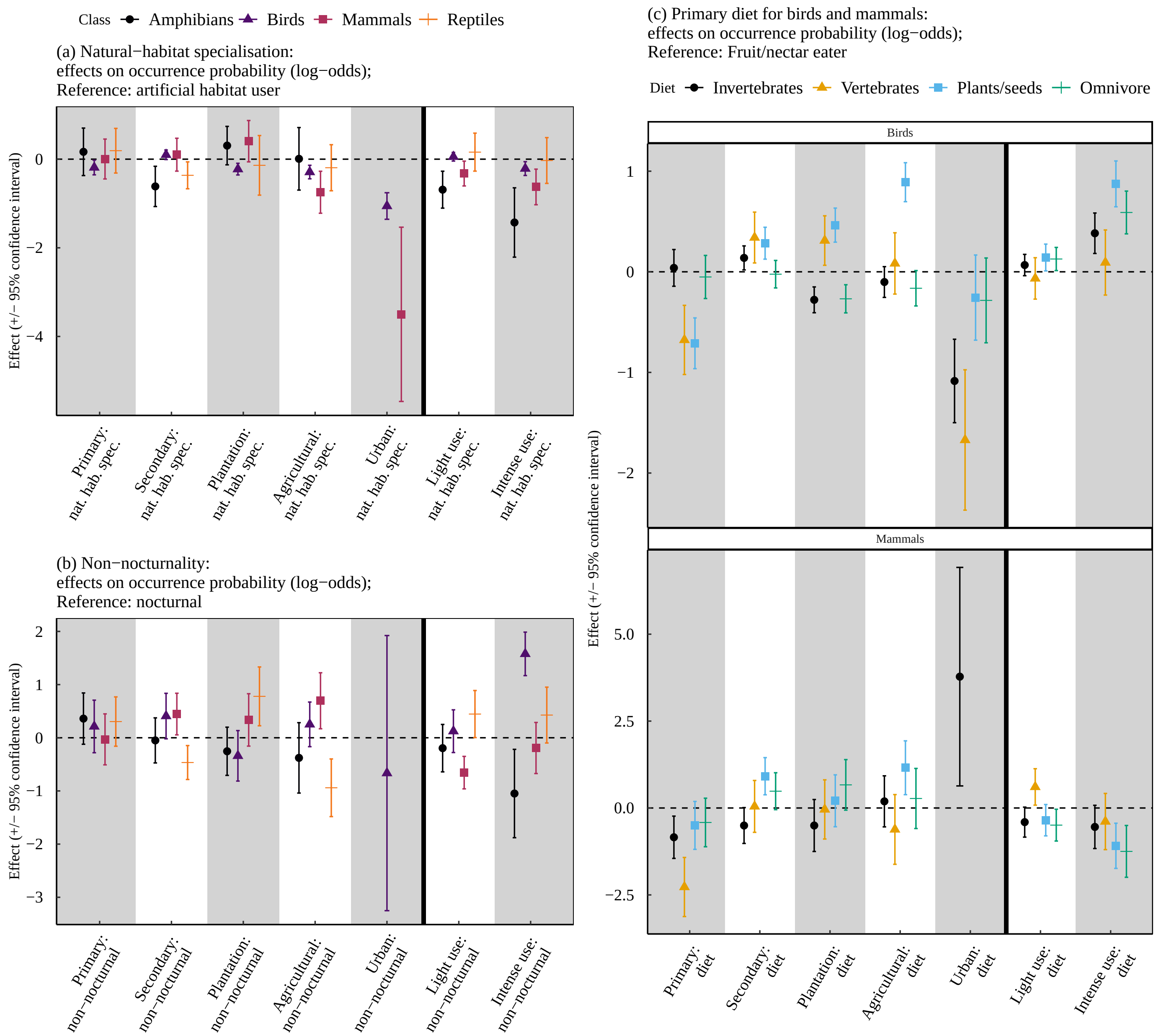

Figure S8: Effects of categorical traits on species probability of occurrence in the different land-use types, estimated from the full (all-predictor) models fitted in each class. The estimated effects correspond to those of the interaction terms between land use and each trait (as well as the interaction terms between land-use intensity and each trait). Hence, for each trait, the '0' baseline represents the reference level of the trait, and the effects show how any other trait level affects occurrence probability. For diet, we only show effects for mammals and birds because the full models did not include diet for reptiles and amphibians. Effects for urban reptiles could not be estimated are weren't any sampled sites. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

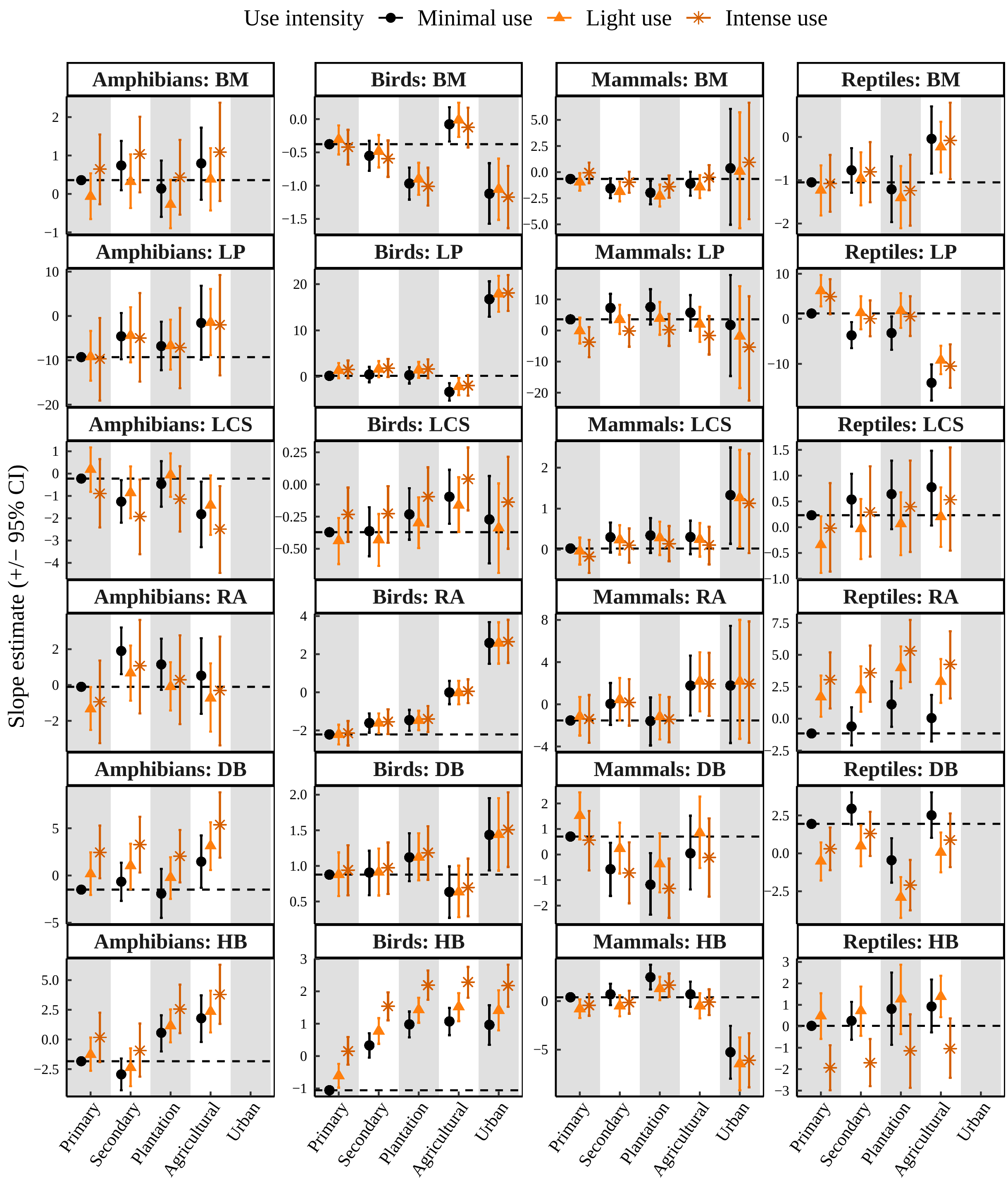

Figure S9: Effects of land use and land-use intensity on the slope of the relationships between occurrence probability and continuous predictors, for each class and each predictor. The slopes were estimated from the full (all-predictor) models fitted in each class. Each column corresponds to a class and each row corresponds to a predictor (BM=body mass; LP=lifespan proxy; LCS=litter/clutch size; RA=geographical range area; DB=diet breadth; HB=habitat breadth). We did not plot the effects for amphibians in urban land uses, and those for mammals in urban land uses (for diet breadth), because error bars were large (and all effects were null). Effects for urban reptiles could not be estimated are weren't any sampled sites. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

S8 Land-use responses: occurrence probability predictions from the partial models for artificial habitat use and diel activity

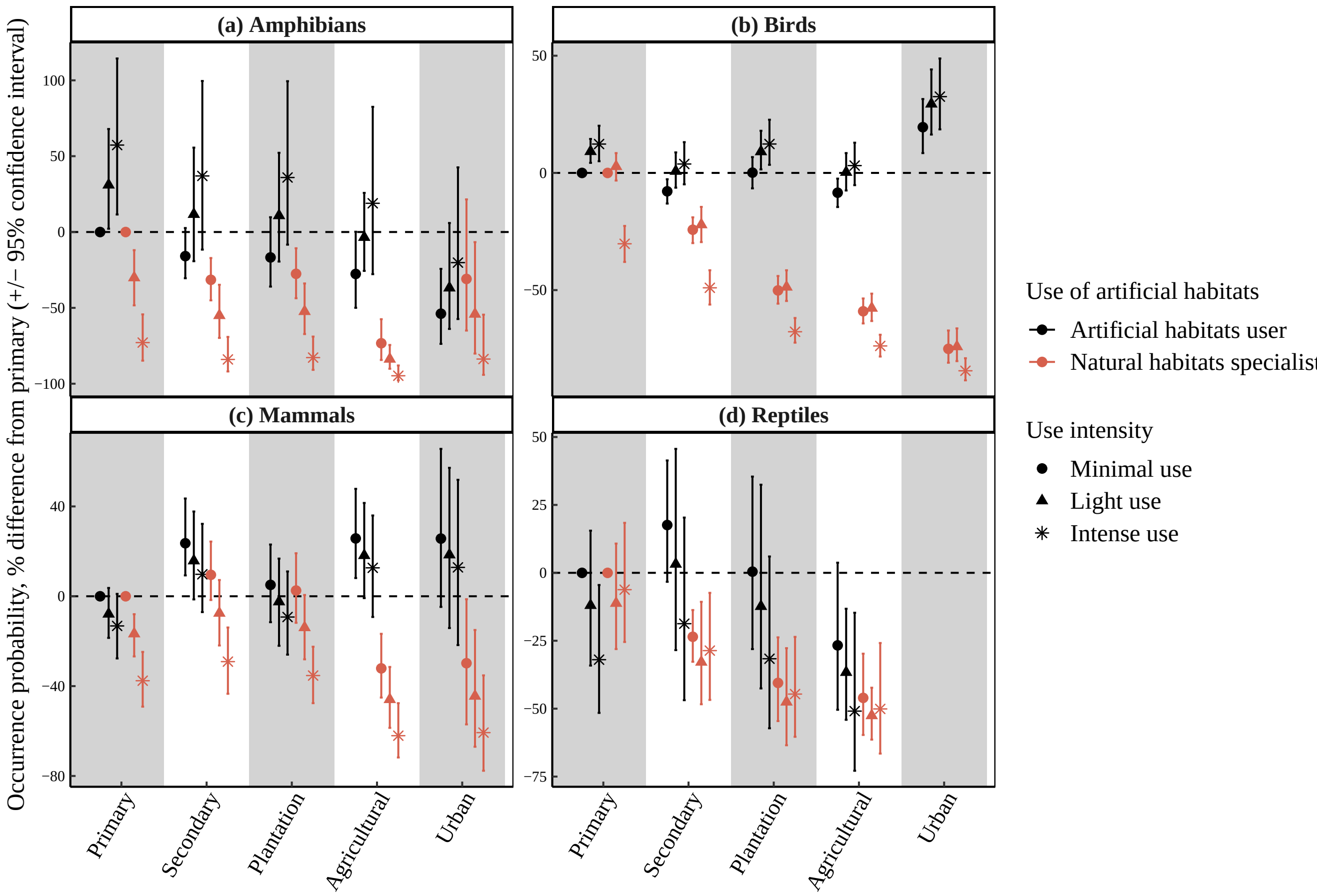

Figure S10: Predicted occurrence probability as a function of land use, land-use intensity, artificial habitat use and their interactions in each class. The predictions were obtained from the partial models fitted in each class for artificial habitat use. Effects could not be estimated for urban reptiles, as there weren't any sampled sites. The predictions are rescaled with reference to minimally-used primary vegetation. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

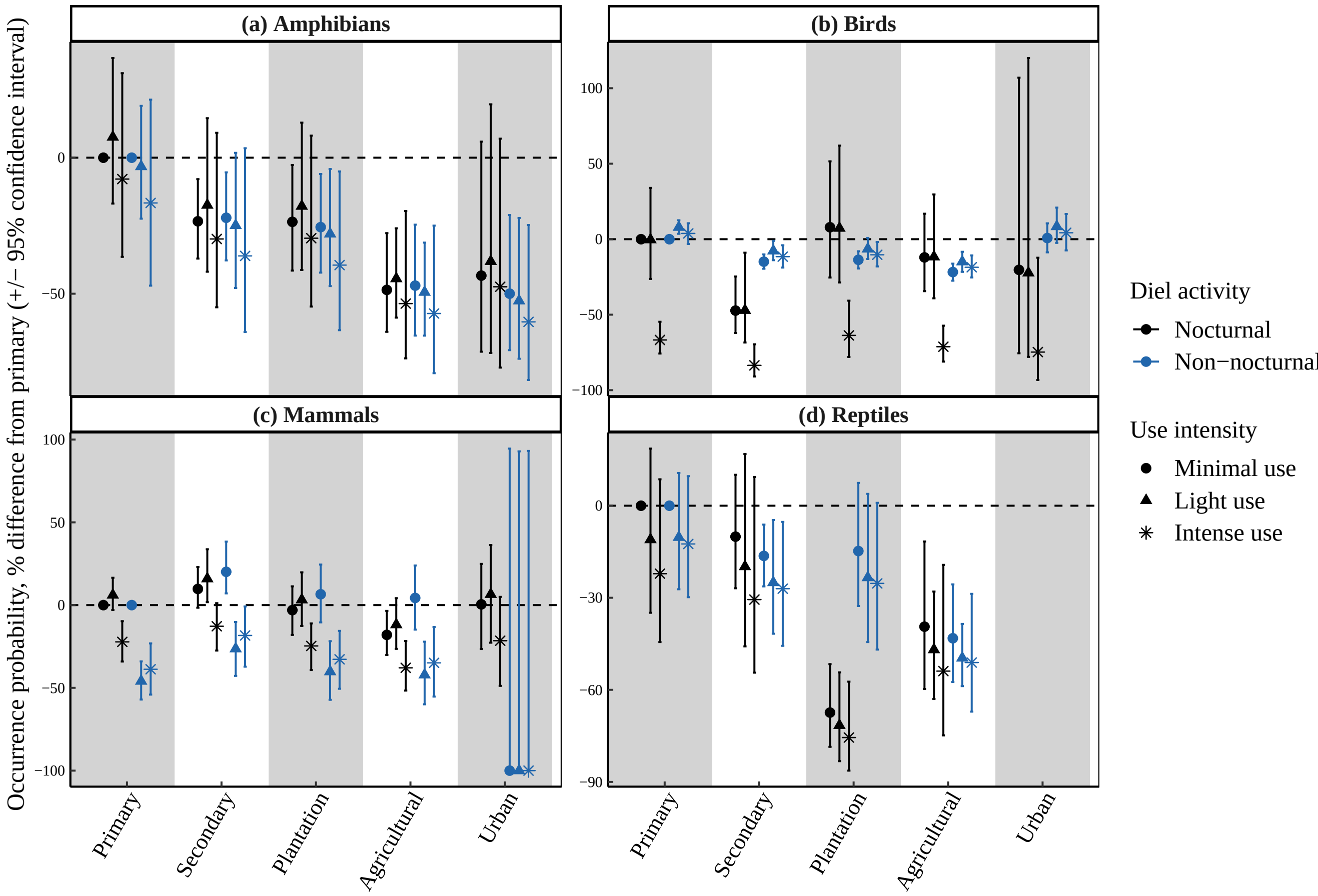

Figure S11: Predicted occurrence probability as a function of land use, land-use intensity, diel activity and their interactions in each class. The predictions were obtained from the partial models fitted in each class for diel activity. Effects could not be estimated for urban reptiles, as there weren't any sampled sites. Error bars are large for non-nocturnal urban mammals because there were very few sampled species (only five). The predictions are rescaled with reference to minimally-used primary vegetation. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

S9 Land-use responses: diagnostic plots for the full (all-predictor) models

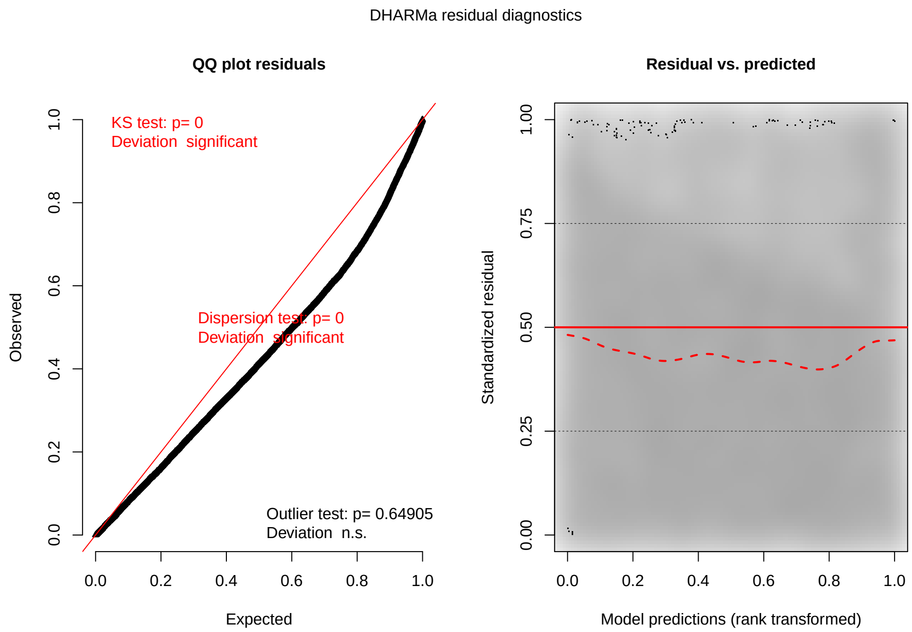

Figure S12: Diagnostic plots for the mixed-effects model fitted on amphibians, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability (all-predictor model). The diagnostic plots were obtained from the DHARMa R package (**DHARMa**).

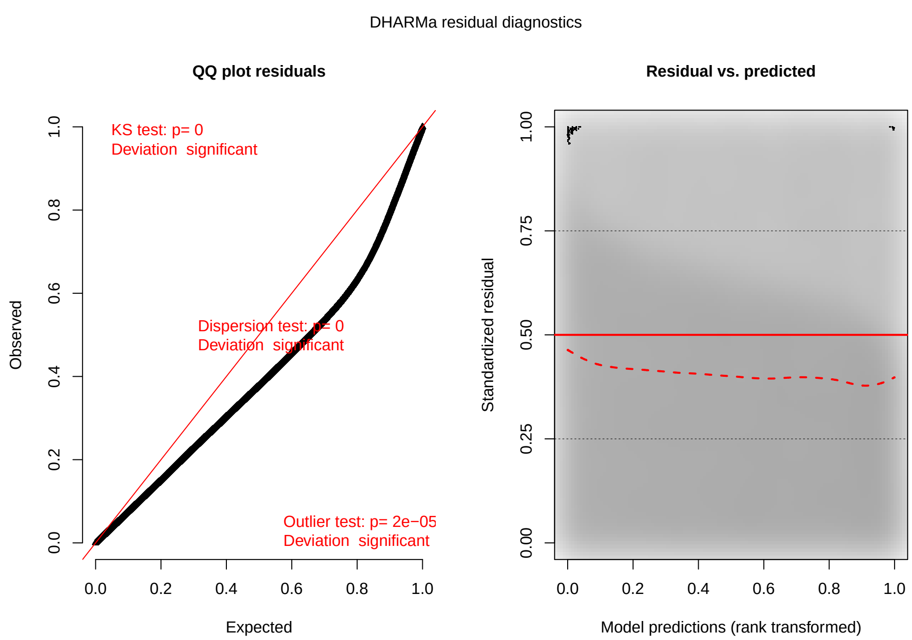

Figure S13: Diagnostic plots for the mixed-effects model fitted on birds, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability (all-predictor model). The diagnostic plots were obtained from the DHARMa R package (**DHARMa**).

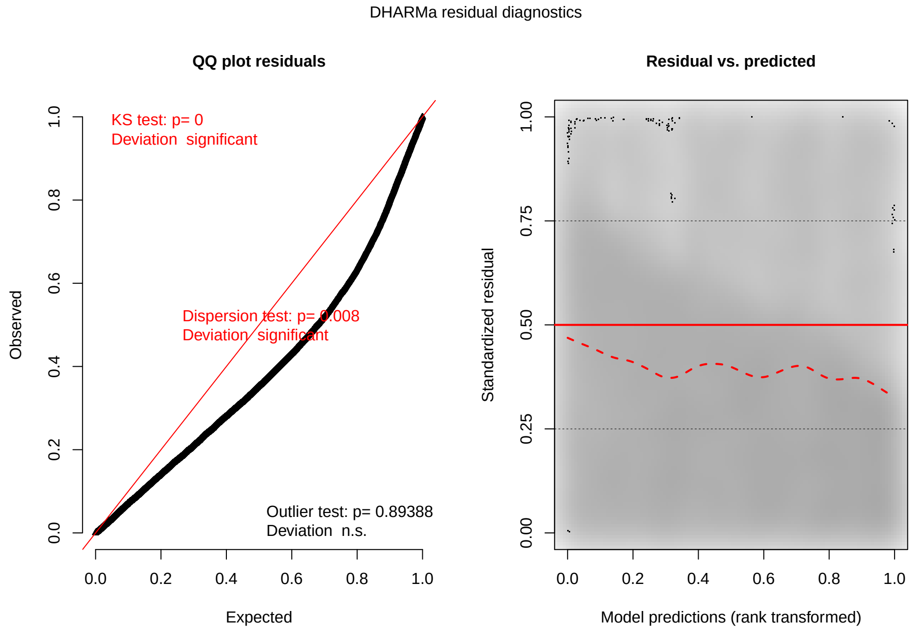

Figure S14: Diagnostic plots for the mixed-effects model fitted on mammals, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability (all-predictor model). The diagnostic plots were obtained from the DHARMa R package (**DHARMa**).

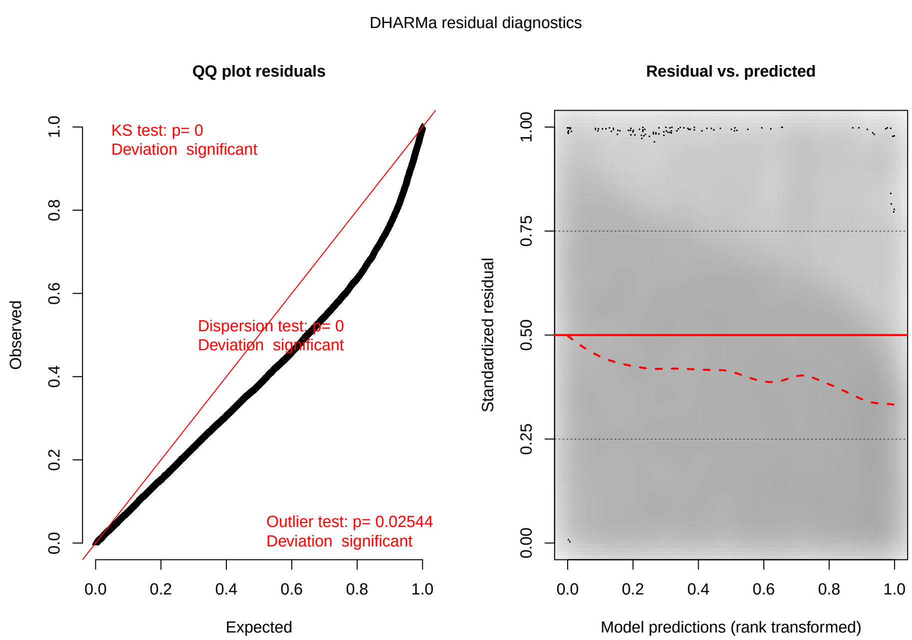

Figure S15: Diagnostic plots for the mixed-effects model fitted on reptiles, looking at the effects of land use, land-use intensity and the species-level predictors on species occurrence probability (all-predictor model). The diagnostic plots were obtained from the DHARMa R package (**DHARMa**).

S10 Land-use responses: estimated effects from a Bayesian framework (MCMCglmm, (MCMCglmm))

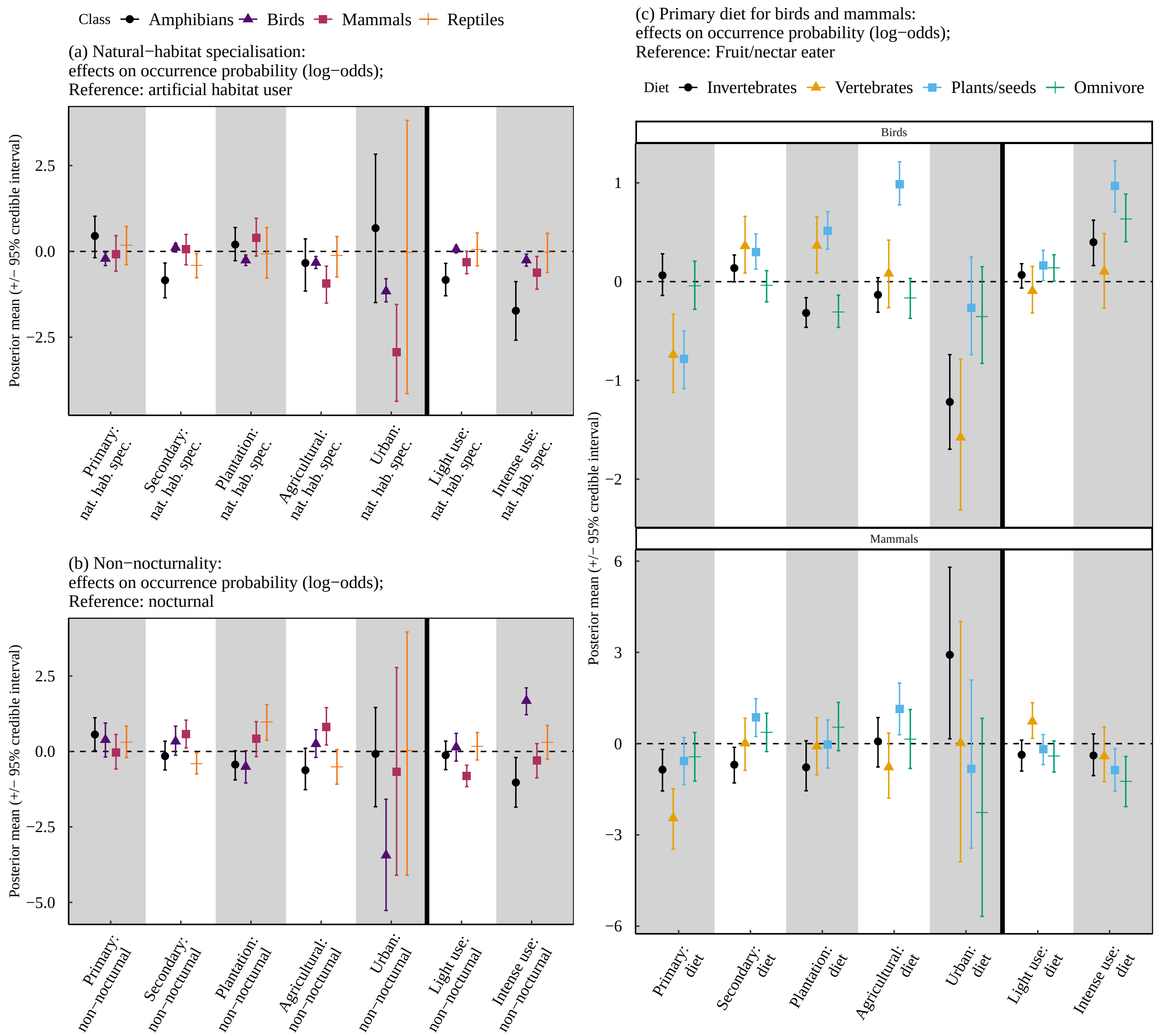

Figure S16: Effects of categorical traits on species probability of occurrence in the different land-use types, estimated from the full (all-predictor) models fitted in each class with a Bayesian approach, using MCMCglmm (MCMCglmm). The estimated effects correspond to those of the interaction terms between land use and each trait (as well as the interaction terms between land-use intensity and each trait). Hence, for each trait, the '0' baseline represents the reference level of the trait, and the effects show how any other trait level affects occurrence probability. For diet, we only show effects for mammals and birds because the full models did not include diet for reptiles and amphibians. Effects for urban reptiles could not be estimated are weren't any sampled sites. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

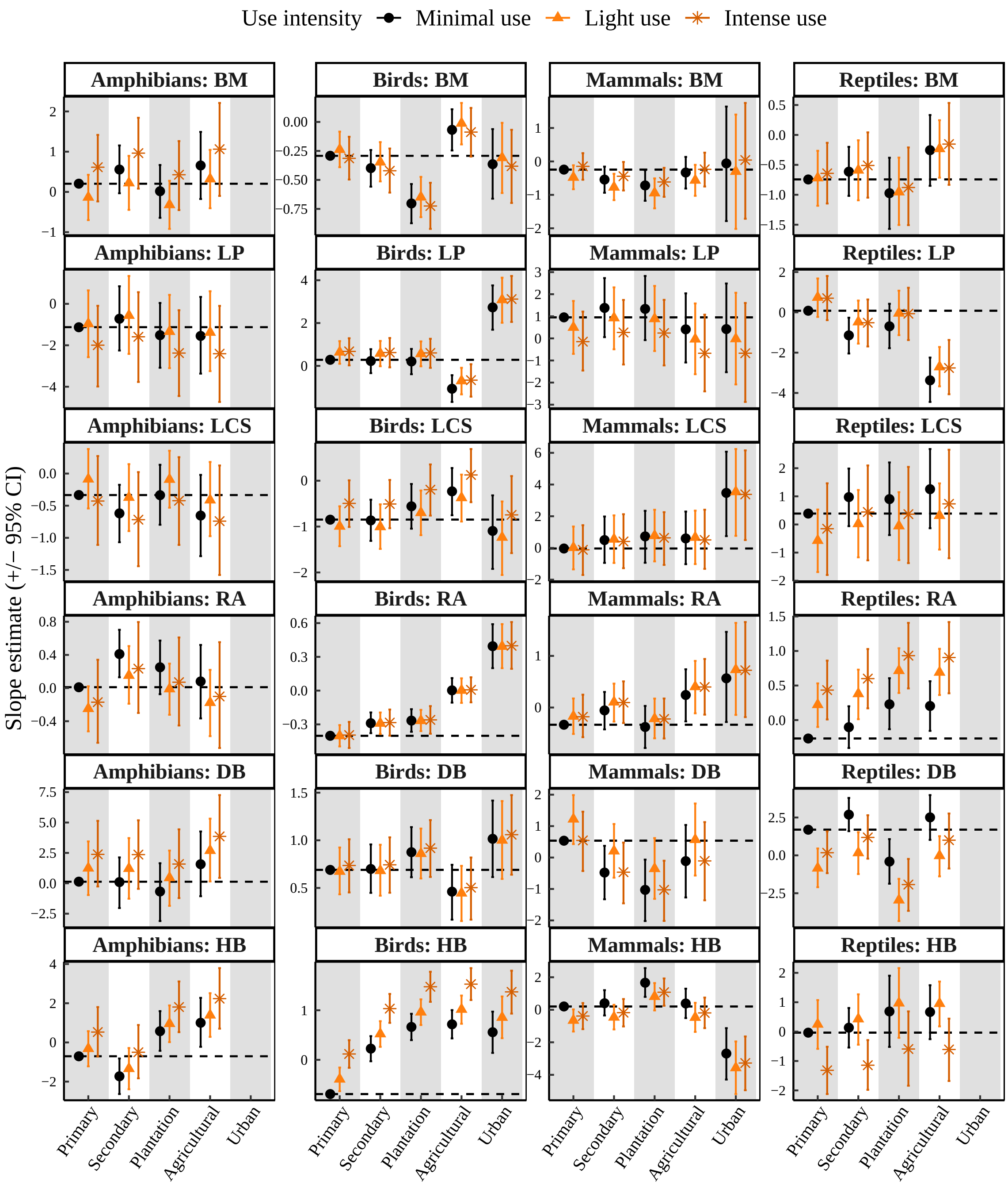

Figure S17: Effects of land use and land-use intensity on the slope of the relationships between occurrence probability and continuous predictors, for each class and each predictor. The slopes were estimated from the full (all-predictor) models fitted in each class with a Bayesian approach, using MCMCglmm (**MCMCglmm**). Each column corresponds to a class and each row corresponds to a predictor (BM=body mass; LP=lifespan proxy; LCS=litter/clutch size; RA=geographical range area; DB=diet breadth; HB=habitat breadth). We did not plot the effects for amphibians in urban land uses, and those for mammals in urban land uses (for diet breadth), because error bars were large (and all effects were null). Effects for urban reptiles could not be estimated are weren't any sampled sites. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

S11 Climate-change sensitivity: model summaries and diagnostic plots

S11.1 Summaries & diagnostic plots for models fitted on species with range area $>$100 km^2)

Table S13: Summary for the PGLS model fitted on amphibians, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=4,537).

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.15	0.21	5.49	< 0.001
$\log_{10}$(Body mass)	-1.97	0.61	-3.22	0.001
$\log_{10}$(Body mass)^2	-0.26	0.42	-0.60	0.55
$\log_{10}$(Body mass)^3	0.46	0.37	1.24	0.22
$\log_{10}$(Lifespan proxy)	-0.21	0.59	-0.36	0.72
$\log_{10}$(Lifespan proxy)^2	-0.14	0.43	-0.32	0.75
$\log_{10}$(Lifespan proxy)^3	0.58	0.35	1.66	0.10
$\log_{10}$(Litter/clutch size)	1.59	0.54	2.96	0.003
$\log_{10}$(Litter/clutch size)^2	-0.06	0.38	-0.16	0.87
$\log_{10}$(Litter/clutch size)^3	-0.74	0.31	-2.37	0.02
$\log_{10}$(Range area)	-26.60	0.34	-77.15	< 0.001
$\log_{10}$(Range area)^2	4.27	0.29	14.57	< 0.001
$\log_{10}$(Range area)^3	-1.65	0.28	-5.96	< 0.001
square-root(Habitat breadth)	-2.26	0.43	-5.32	< 0.001
square-root(Habitat breadth)^2	0.81	0.30	2.67	0.01
square-root(Habitat breadth)^3	-0.59	0.28	-2.10	0.04
Specialisation: Natural habitat specialist	0.02	0.01	1.85	0.06
Diel activity: Non-nocturnal	0.04	0.01	3.28	0.001
Primary diet: Omnivore	0.01	0.03	0.29	0.77
Primary diet: Plants/seeds	0.04	0.13	0.31	0.76
Primary diet: Vertebrates	0.13	0.15	0.87	0.39

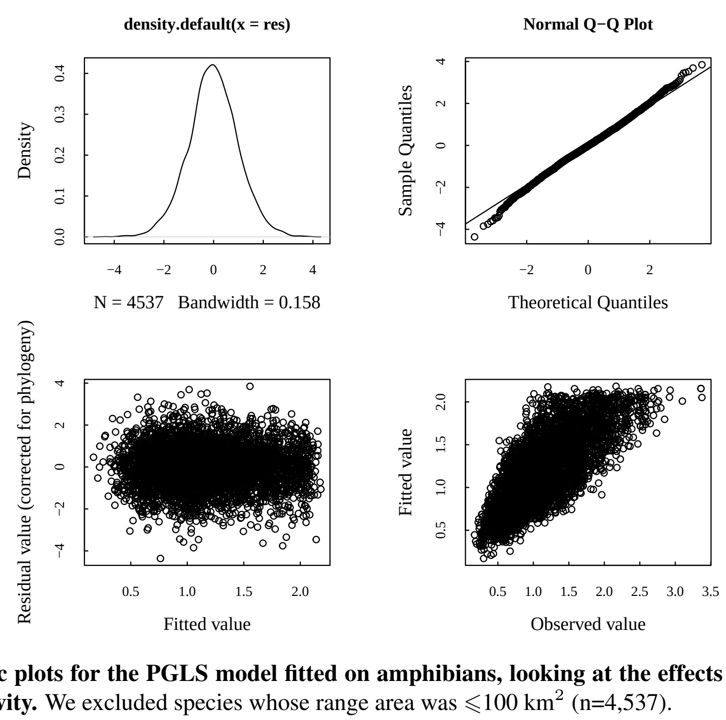

Figure S18: Diagnostic plots for the PGLS model fitted on amphibians, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=4,537).

Table S14: Summary for the PGLS model fitted on birds, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=10,198).

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.64	0.08	7.91	< 0.001
$\log_{10}$(Body mass)	2.24	0.67	3.36	0.001
$\log_{10}$(Body mass)^2	0.16	0.42	0.37	0.71
$\log_{10}$(Body mass)^3	-0.22	0.37	-0.60	0.55
$\log_{10}$(Lifespan proxy)	-0.23	0.59	-0.38	0.70
$\log_{10}$(Lifespan proxy)^2	-0.84	0.39	-2.16	0.03
$\log_{10}$(Lifespan proxy)^3	-0.10	0.28	-0.36	0.72
$\log_{10}$(Litter/clutch size)	3.72	0.39	9.46	< 0.001
$\log_{10}$(Litter/clutch size)^2	-0.42	0.33	-1.26	0.21
$\log_{10}$(Litter/clutch size)^3	-0.40	0.27	-1.47	0.14
$\log_{10}$(Range area)	-30.69	0.27	-113.09	< 0.001
$\log_{10}$(Range area)^2	7.22	0.24	29.92	< 0.001
$\log_{10}$(Range area)^3	-2.73	0.23	-11.74	< 0.001
square-root(Habitat breadth)	0.86	0.33	2.59	0.01
square-root(Habitat breadth)^2	-0.89	0.24	-3.63	< 0.001
square-root(Habitat breadth)^3	-0.22	0.23	-0.95	0.34
square-root(Diet breadth)	-0.50	0.31	-1.64	0.10
square-root(Diet breadth)^2	-0.11	0.25	-0.44	0.66
square-root(Diet breadth)^3	0.32	0.24	1.36	0.18
Specialisation: Natural habitat specialist	0.06	0.01	10.13	< 0.001
Diel activity: Non-nocturnal	-0.02	0.04	-0.66	0.51
Primary diet: Invertebrates	0.06	0.01	5.53	< 0.001
Primary diet: Omnivores	0.02	0.01	2.09	0.04
Primary diet: Plants/seeds	0.06	0.01	4.69	< 0.001
Primary diet: Vertebrates	0.01	0.02	0.83	0.41

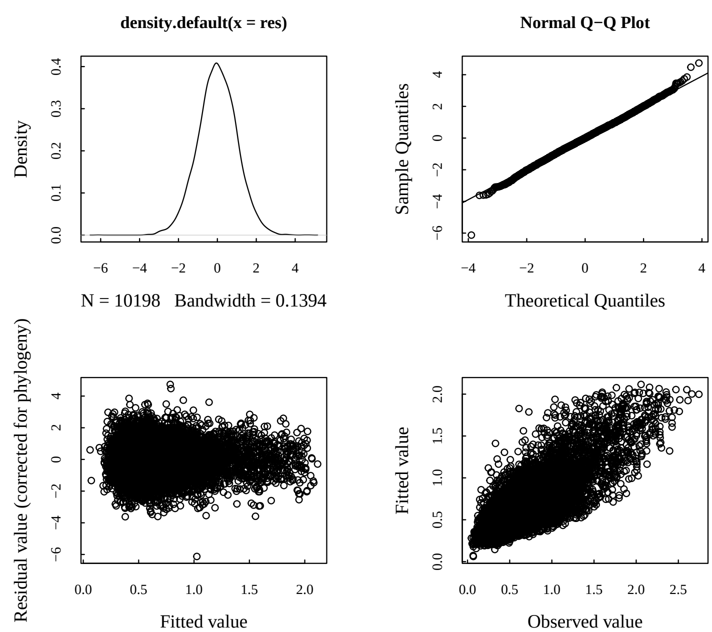

Figure S19: Diagnostic plots for the PGLS model fitted on birds, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=10,198).

Table S15: Summary for the PGLS model fitted on mammals, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=4,712).

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.84	0.16	5.37	< 0.001
$\log_{10}$(Body mass)	-4.62	0.94	-4.93	< 0.001
$\log_{10}$(Body mass)^2	0.40	0.56	0.72	0.47
$\log_{10}$(Body mass)^3	0.59	0.44	1.33	0.18
$\log_{10}$(Lifespan proxy)	1.60	1.03	1.55	0.12
$\log_{10}$(Lifespan proxy)^2	-0.79	0.49	-1.60	0.11
$\log_{10}$(Lifespan proxy)^3	-0.15	0.43	-0.35	0.73
$\log_{10}$(Litter/clutch size)	3.29	0.71	4.63	< 0.001
$\log_{10}$(Litter/clutch size)^2	0.06	0.42	0.14	0.89
$\log_{10}$(Litter/clutch size)^3	-0.16	0.33	-0.47	0.64
$\log_{10}$(Range area)	-24.17	0.31	-78.21	< 0.001
$\log_{10}$(Range area)^2	4.15	0.28	15.09	< 0.001
$\log_{10}$(Range area)^3	-0.90	0.26	-3.45	0.001
square-root(Habitat breadth)	-1.24	0.34	-3.60	< 0.001
square-root(Habitat breadth)^2	0.22	0.27	0.82	0.41
square-root(Habitat breadth)^3	-0.03	0.26	-0.10	0.92
square-root(Diet breadth)	-1.21	0.47	-2.55	0.01
square-root(Diet breadth)^2	0.33	0.36	0.91	0.36
square-root(Diet breadth)^3	0.11	0.34	0.33	0.74
Specialisation: Natural habitat specialist	0.04	0.01	3.22	0.001
Diel activity: Non-nocturnal	0.003	0.01	0.23	0.82
Primary diet: Invertebrates	-0.02	0.03	-0.62	0.54
Primary diet: Omnivores	-0.02	0.03	-0.77	0.44
Primary diet: Plants/seeds	0.03	0.02	1.32	0.19
Primary diet: Vertebrates	-0.04	0.04	-0.98	0.33

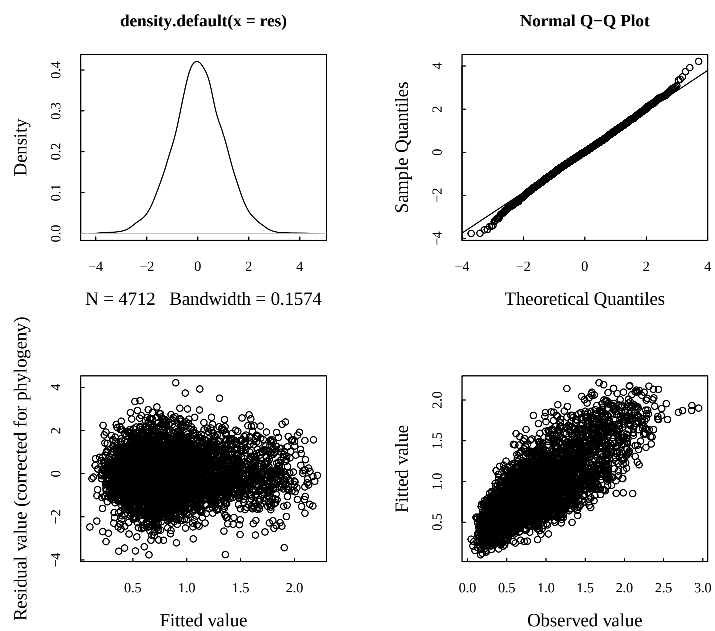

Figure S20: Diagnostic plots for the PGLS model fitted on mammals, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=4,712).

Table S16: Summary for the PGLS model fitted on reptiles, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=7,330).

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.02	0.13	7.70	< 0.001
$\log_{10}$(Body mass)	-4.62	0.62	-7.47	< 0.001
$\log_{10}$(Body mass)^2	0.97	0.41	2.35	0.02
$\log_{10}$(Body mass)^3	-0.96	0.33	-2.90	0.004
$\log_{10}$(Lifespan proxy)	0.89	0.51	1.74	0.08
$\log_{10}$(Lifespan proxy)^2	-1.27	0.39	-3.27	0.001
$\log_{10}$(Lifespan proxy)^3	-0.29	0.33	-0.88	0.38
$\log_{10}$(Litter/clutch size)	0.84	0.68	1.24	0.22
$\log_{10}$(Litter/clutch size)^2	-0.34	0.45	-0.76	0.45
$\log_{10}$(Litter/clutch size)^3	0.26	0.35	0.74	0.46
$\log_{10}$(Range area)	-31.88	0.31	-101.48	< 0.001
$\log_{10}$(Range area)^2	5.15	0.27	19.03	< 0.001
$\log_{10}$(Range area)^3	-1.97	0.26	-7.53	< 0.001
square-root(Habitat breadth)	0.56	0.35	1.59	0.11
square-root(Habitat breadth)^2	-0.67	0.27	-2.49	0.01
square-root(Habitat breadth)^3	0.05	0.26	0.21	0.83
square-root(Diet breadth)	-0.33	0.37	-0.90	0.37
square-root(Diet breadth)^2	-0.02	0.27	-0.08	0.94
square-root(Diet breadth)^2	0.31	0.26	1.22	0.22
Specialisation: Natural habitat specialist	0.10	0.01	8.50	< 0.001
Diel activity: Non-nocturnal	-0.02	0.01	-1.88	0.06
Primary diet: Omnivore	-0.03	0.03	-0.92	0.36
Primary diet: Vertebrates	-0.02	0.02	-1.05	0.30

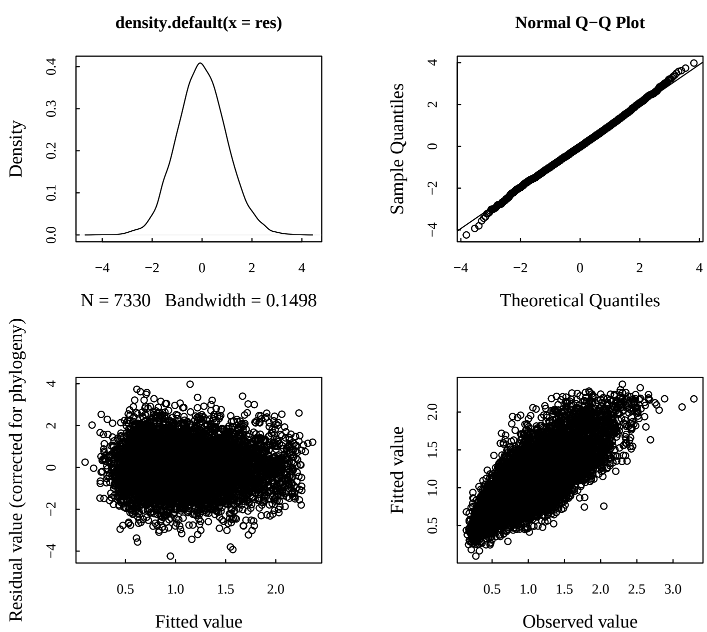

Figure S21: Diagnostic plots for the PGLS model fitted on reptiles, looking at the effects of species-level predictors on climate-change sensitivity. We excluded species whose range area was $\leqslant$100 km^2 (n=7,330).

S11.2 Summaries for the PGLS models fitted on all species (including those with range area $\leqslant$100 km^2)

Table S17: Summary for the PGLS model fitted on amphibians, looking at the effects of species-level predictors on climate-change sensitivity. We included species whose range area was $\leqslant$100 km^2 (n=5,197).

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.23	0.20	6.01	< 0.001
$\log_{10}$(Body mass)	-1.70	0.74	-2.29	0.02
$\log_{10}$(Body mass)^2	-0.56	0.52	-1.09	0.28
$\log_{10}$(Body mass)^3	0.12	0.44	0.27	0.78
$\log_{10}$(Lifespan proxy)	0.46	0.72	0.64	0.52
$\log_{10}$(Lifespan proxy)^2	0.21	0.53	0.40	0.69
$\log_{10}$(Lifespan proxy)^3	0.50	0.43	1.17	0.24
$\log_{10}$(Litter/clutch size)	0.95	0.64	1.48	0.14
$\log_{10}$(Litter/clutch size)^2	-0.34	0.45	-0.74	0.46
$\log_{10}$(Litter/clutch size)^3	-1.07	0.38	-2.79	0.01
$\log_{10}$(Range area)	-28.60	0.42	-67.90	< 0.001
$\log_{10}$(Range area)^2	-3.57	0.37	-9.76	< 0.001
$\log_{10}$(Range area)^3	8.78	0.34	25.56	< 0.001
square-root(Habitat breadth)	-2.55	0.52	-4.89	< 0.001
square-root(Habitat breadth)^2	0.46	0.38	1.21	0.23
square-root(Habitat breadth)^3	-1.26	0.35	-3.62	< 0.001
Specialisation: Natural habitat specialist	0.02	0.01	1.55	0.12
Diel activity: Non-nocturnal	0.03	0.01	2.46	0.01
Primary diet: Omnivore	0.001	0.04	0.02	0.99
Primary diet: Plants/seeds	-0.12	0.15	-0.80	0.42
Primary diet: Vertebrates	0.20	0.18	1.14	0.26

Table S18: Summary for the PGLS model fitted on birds, looking at the effects of species-level predictors on climate-change sensitivity. We included species whose range area was $\leqslant$100 km^2 (n=10,340).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.64	0.08	7.62	< 0.001
$\log_{10}$(Body mass)	2.07	0.70	2.94	0.003
$\log_{10}$(Body mass)^2	0.26	0.45	0.57	0.57
$\log_{10}$(Body mass)^3	-0.15	0.39	-0.39	0.70
$\log_{10}$(Lifespan proxy)	-0.47	0.62	-0.76	0.45
$\log_{10}$(Lifespan proxy)^2	-0.67	0.41	-1.64	0.10
$\log_{10}$(Lifespan proxy)^3	-0.07	0.29	-0.24	0.81
$\log_{10}$(Litter/clutch size)	3.25	0.41	7.84	< 0.001
$\log_{10}$(Litter/clutch size)^2	-0.64	0.35	-1.82	0.07
$\log_{10}$(Litter/clutch size)^3	-0.30	0.29	-1.04	0.30
$\log_{10}$(Range area)	-33.48	0.29	-116.96	< 0.001
$\log_{10}$(Range area)^2	6.56	0.25	25.72	< 0.001
$\log_{10}$(Range area)^3	1.56	0.24	6.39	< 0.001
square-root(Habitat breadth)	1.01	0.35	2.88	0.004
square-root(Habitat breadth)^2	-1.22	0.26	-4.75	< 0.001
square-root(Habitat breadth)^3	-0.38	0.24	-1.59	0.11
square-root(Diet breadth)	-0.44	0.32	-1.38	0.17
square-root(Diet breadth)^2	-0.27	0.26	-1.04	0.30
square-root(Diet breadth)^3	0.43	0.25	1.73	0.08
Specialisation: Natural habitat specialist	0.06	0.01	9.75	< 0.001
Diel activity: Non-nocturnal	-0.01	0.04	-0.35	0.73
Primary diet: Invertebrates	0.06	0.01	6.03	< 0.001
Primary diet: Omnivore	0.03	0.01	2.61	0.01
Primary diet: Plants/seeds	0.07	0.01	5.13	< 0.001
Primary diet: Vertebrates	0.02	0.02	0.85	0.39

Table S19: Summary for the PGLS model fitted on mammals, looking at the effects of species-level predictors on climate-change sensitivity. We included species whose range area was $\leqslant$100 km^2 (n=4,841).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.86	0.15	5.68	< 0.001
$\log_{10}$(Body mass)	-4.57	0.97	-4.69	< 0.001
$\log_{10}$(Body mass)^2	0.37	0.59	0.62	0.53
$\log_{10}$(Body mass)^3	0.67	0.47	1.44	0.15
$\log_{10}$(Lifespan proxy)	1.50	1.09	1.38	0.17
$\log_{10}$(Lifespan proxy)^2	-0.93	0.52	-1.79	0.07
$\log_{10}$(Lifespan proxy)^3	-0.05	0.46	-0.11	0.91
$\log_{10}$(Litter/clutch size)	3.28	0.75	4.35	< 0.001
$\log_{10}$(Litter/clutch size)^2	0.19	0.44	0.43	0.67
$\log_{10}$(Litter/clutch size)^3	-0.35	0.35	-0.99	0.32
$\log_{10}$(Range area)	-26.32	0.34	-78.41	< 0.001
$\log_{10}$(Range area)^2	2.16	0.30	7.26	< 0.001
$\log_{10}$(Range area)^3	3.80	0.29	13.28	< 0.001
square-root(Habitat breadth)	-1.24	0.37	-3.31	0.001
square-root(Habitat breadth)^2	0.10	0.29	0.34	0.73
square-root(Habitat breadth)^3	-0.15	0.28	-0.55	0.58
square-root(Diet breadth)	-1.57	0.50	-3.12	0.002
square-root(Diet breadth)^2	0.34	0.38	0.88	0.38
square-root(Diet breadth)^3	-0.03	0.36	-0.09	0.93
Specialisation: Natural habitat specialist	0.04	0.01	3.55	< 0.001
Diel activity: Non-nocturnal	-0.001	0.02	-0.07	0.95
Primary diet: Invertebrates	-0.03	0.03	-0.97	0.33
Primary diet: Omnivore	-0.03	0.03	-0.96	0.34
Primary diet: Plants/seeds	0.02	0.03	0.83	0.41
Primary diet: Vertebrates	-0.06	0.04	-1.59	0.11

Table S20: Summary for the PGLS model fitted on reptiles, looking at the effects of species-level predictors on climate-change sensitivity. We included species whose range area was $\leqslant$100 km^2 (n=7,945).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.08	0.14	7.79	< 0.001
$\log_{10}$(Body mass)	-4.04	0.72	-5.64	< 0.001
$\log_{10}$(Body mass)^2	0.22	0.48	0.46	0.64
$\log_{10}$(Body mass)^3	-0.84	0.39	-2.19	0.03
$\log_{10}$(Lifespan proxy)	0.72	0.61	1.18	0.24
$\log_{10}$(Lifespan proxy)^2	-1.42	0.46	-3.07	0.002
$\log_{10}$(Lifespan proxy)^3	-0.30	0.39	-0.77	0.44
$\log_{10}$(Litter/clutch size)	1.23	0.80	1.54	0.12
$\log_{10}$(Litter/clutch size)^2	-0.21	0.53	-0.40	0.69
$\log_{10}$(Litter/clutch size)^3	-0.23	0.41	-0.56	0.58
$\log_{10}$(Range area)	-32.18	0.37	-87.40	< 0.001
$\log_{10}$(Range area)^2	-6.51	0.32	-20.05	< 0.001
$\log_{10}$(Range area)^3	9.84	0.31	31.28	< 0.001
square-root(Habitat breadth)	1.05	0.42	2.53	0.01
square-root(Habitat breadth)^2	-0.91	0.32	-2.83	0.005
square-root(Habitat breadth)^3	-0.06	0.30	-0.20	0.84
square-root(Diet breadth)	-0.52	0.43	-1.20	0.23
square-root(Diet breadth)^2	0.02	0.32	0.07	0.95
square-root(Diet breadth)^3	0.24	0.31	0.77	0.44
Specialisation: Natural habitat specialist	0.10	0.01	7.07	< 0.001
Diel activity: Non-nocturnal	-0.02	0.01	-1.76	0.08
Primary diet: Omnivore	-0.01	0.04	-0.18	0.85
Primary diet: Vertebrates	-0.01	0.02	-0.64	0.52

S11.3 Models estimates for the PGLS models fitted on all species, against models estimates for the PGLS models fitted on species whose range area >100 km^2

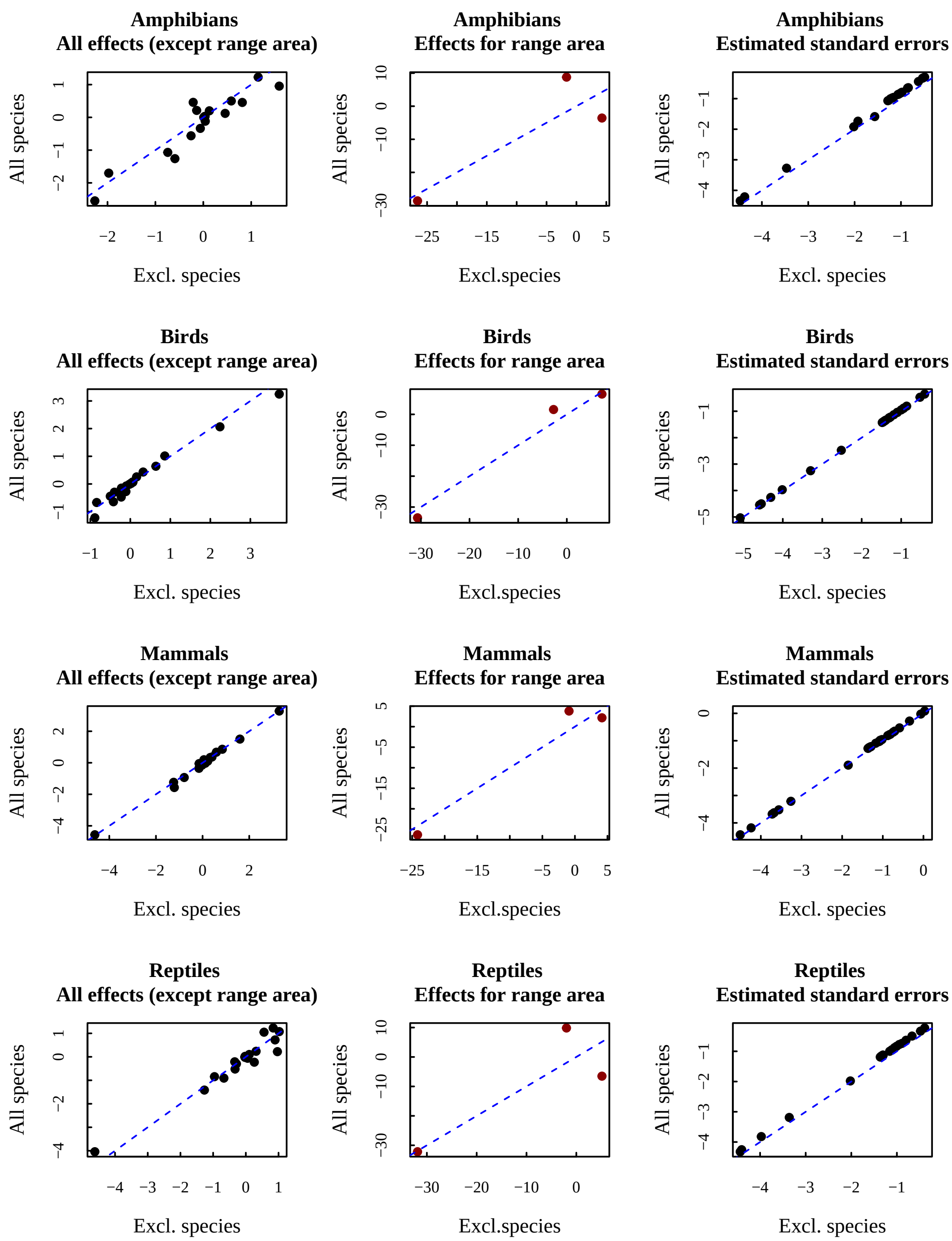

Figure S22: Estimates for the PGLS models looking at the effects of the species-level predictors on species climate-change sensitivity, either fitted on all species (y–axis), or fitted on the species whose range area was >100 km^2 (x–axis). Overall, the estimates from both sets of models were congruent, except for those estimated for geographical range area. Hence, we show the effects for range area separately from the effects of other predictors. Across all classes, the relationship between sensitivity and geographical range area was reversed between the two sets of models. We found that sensitivity was positively affected by geographical range area when including all species, likely because of the underestimation of sensitivity for the narrow-ranging species when working with a resolution of 5 km^2 (see Figure S7). The dashed line is the identity line (y=x).

S12 Validations on complete trait data subsets

S12.1 Synthesis table

(a) "Within land-use type" effects of the species-level predictors on occurrence probability − <=> more sensitive; + <=> less sensitive																Predictors		(b) Climate-change sensitivity: − <=> more sensitive + <=> less sensitive			
Secondary vegetation				Plantation forest				Agricultural				Urban									
0	−	0	0	0	−	0	0	0	−	−	+	+	−	0	NA	More narrowly-distributed	Habitat affinity	−	−	−	(−)
0	−	0	0	−	−	0	0	−	−	0	−	−	−	0	NA	Smaller habitat breadth		0	−	−	−
−	−	0	0	0	−	0	0	−	−	−	+	0	−	0	NA	Natural habitat specialist	Specialisa-tion	0	−	0	−
0	+	+	0	+	+	(+)	+	0	+	+	0	0	0	0	NA	Non-nocturnal		0	0	0	0
−	0	(+)	0	(−)	0	+	0	−	0	(+)	+	−	−	0	NA	Narrower diet breadth	Resource use	0	0	0	0
NA	(+)	+	NA	NA	+	+	NA	NA	−	0	NA	NA	+	0	NA	Smaller body mass		0	(+)	−	0
NA	0	0	−	NA	−	(−)	0	NA	−	(−)	0	NA	0	−	NA	Smaller litter/clutch size	Life-history	0	+	+	0
NA	0	0	−	NA	(−)	0	0	NA	+	0	+	NA	−	0	NA	Shorter-lived		(+)	0	0	0

Figure S23: Summary of the effects of the species-level predictors (all except primary diet) on (a) species responses to disturbed land uses (within land-use type effects) and on (b) species climate-change sensitivity, in each class, ***estimated from the models fitted on complete trait data subsets (excluding imputed trait values)***. The symbol **–** is drawn where a predictor is found to have a negative effect on occurrence probability within a disturbed land use, or where the predictor renders the species more sensitive to climate change. A **+** indicates a positive effect of a predictor on occurrence probability in a land-use type and also indicates significantly lower sensitivity to climate change. For the land-use effects, we report 'within land-use type effects' here, that is, given a disturbed land use, whether there were significant differences in occurrence probability for different trait values. These effects were derived from the interactive terms of the full, all-predictor models.

S12.2 Predicted occurrence probability as a function of land use, land-use intensity, diet and their interactions, in each class (validation on complete trait data subsets from partial models)

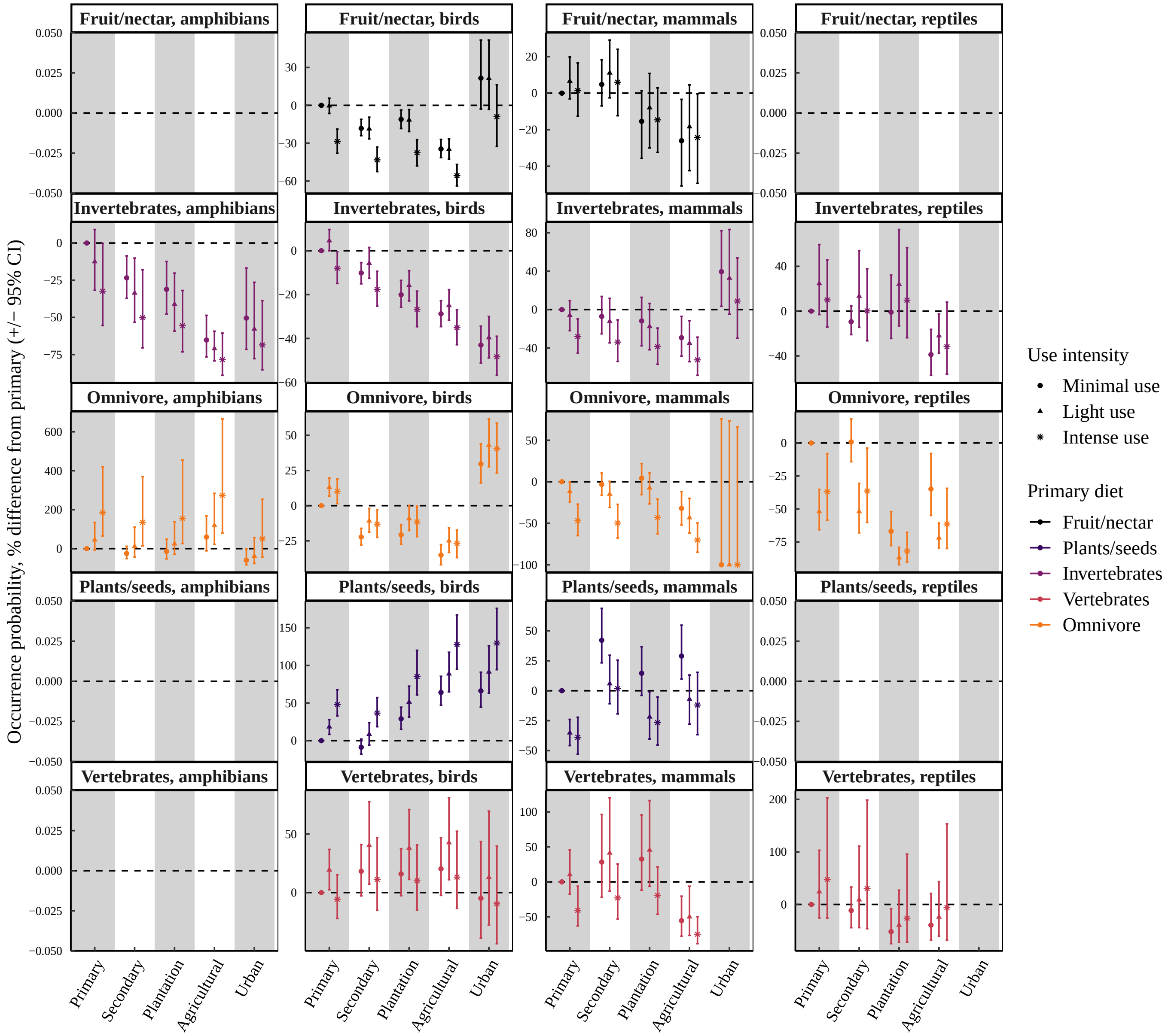

Figure S24: Predicted occurrence probability as a function of land use, land-use intensity, diet and their interactions in each class. The predictions were obtained from the partial models fitted in each class for diet, *estimated using complete trait data subsets (excluding imputed trait values)*. Empty plots are drawn where there were no data for a diet category in given class (e.g., amphibian fruit/nectar eaters). Effects could not be estimated for urban reptiles, as well as for urban vertebrate, fruit/nectar and plant/seed eaters for mammals because there were no sampled species. The predictions are rescaled with reference to minimally-used primary vegetation. Primary: primary vegetation; Secondary: secondary vegetation; plantation: plantation forest; agricultural: cropland and pasture.

S12.3 Validations on complete trait data subsets: PGLS model summaries

Table S21: Summary for the PGLS model fitted on amphibians, ***using the complete trait data subset (excluding imputed values)***, looking at the effects of the species-level predictors on climate-change sensitivity.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.825	0.342	5.344	< 0.001
$\log_{10}$(Body mass)	-0.030	0.035	-0.875	0.385
$\log_{10}$(Lifespan proxy)	0.180	0.103	1.742	0.086
$\log_{10}$(Litter/clutch size)	0.052	0.032	1.639	0.106
$\log_{10}$(Range area)	-0.261	0.024	-10.888	< 0.001
square-root(Habitat breadth)	-0.032	0.030	-1.078	0.285
square-root(Diet breadth)	-0.068	0.107	-0.635	0.527
Specialisation: Natural habitat specialist	-0.006	0.059	-0.095	0.925
Diel activity: Non-nocturnal	-0.009	0.044	-0.205	0.839

Table S22: Summary for the PGLS model fitted on birds, ***using the complete trait data subset (excluding imputed values)***, looking at the effects of the species-level predictors on climate-change sensitivity.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.551	0.143	10.875	< 0.001
$\log_{10}$(Body mass)	0.020	0.011	1.759	0.079
$\log_{10}$(Lifespan proxy)	0.047	0.036	1.308	0.191
$\log_{10}$(Litter/clutch size)	0.212	0.022	9.487	< 0.001
$\log_{10}$(Range area)	-0.230	0.003	-73.130	< 0.001
square-root(Habitat breadth)	-0.011	0.005	-2.319	0.020
square-root(Diet breadth)	0.015	0.011	1.319	0.187
Specialisation: Natural habitat specialist	0.044	0.007	6.586	< 0.001
Diel activity: Non-nocturnal	0.001	0.058	0.019	0.984
Primary diet: Invertebrates	0.047	0.014	3.330	0.001
Primary diet: Omnivore	0.016	0.014	1.144	0.253
Primary diet: Plants/seeds	0.048	0.016	2.993	0.003
Primary diet: Vertebrates	-0.005	0.022	-0.247	0.805

Table S23: Summary for the PGLS model fitted on mammals, ***using the complete trait data subset (excluding imputed values)***, looking at the effects of the species-level predictors on climate-change sensitivity.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	2.194	0.187	11.705	< 0.001
$\log_{10}$(Body mass)	-0.047	0.012	-3.865	< 0.001
$\log_{10}$(Lifespan proxy)	0.065	0.046	1.416	0.157
$\log_{10}$(Litter/clutch size)	0.147	0.034	4.293	< 0.001
$\log_{10}$(Range area)	-0.269	0.005	-54.621	< 0.001
square-root(Habitat breadth)	-0.042	0.010	-4.320	< 0.001
square-root(Diet breadth)	-0.030	0.020	-1.487	0.137
Specialisation: Natural habitat specialist	0.016	0.013	1.235	0.217
Diel activity: Non-nocturnal	0.012	0.015	0.792	0.428
Primary diet: Invertebrates	-0.038	0.031	-1.220	0.223
Primary diet: Omnivores	-0.031	0.027	-1.148	0.251
Primary diet: Plants/seeds	0.034	0.027	1.298	0.195
Primary diet: Vertebrates	-0.039	0.040	-0.995	0.320

Table S24: Summary for the PGLS model fitted on reptiles, ***using the complete trait data subset (excluding imputed values)***, looking at the effects of the species-level predictors on climate-change sensitivity.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.269	0.522	2.433	0.018
$\log_{10}$(Body mass)	-0.033	0.058	-0.570	0.571
$\log_{10}$(Lifespan proxy)	0.015	0.130	0.119	0.905
$\log_{10}$(Litter/clutch size)	0.095	0.128	0.739	0.463
$\log_{10}$(Range area)	-0.093	0.049	-1.878	0.066
square-root(Habitat breadth)	-0.094	0.045	-2.097	0.041
square-root(Diet breadth)	0.067	0.112	0.595	0.554
Specialisation: Natural habitat specialist	0.221	0.075	2.936	0.005
Diel activity: Non-nocturnal	-0.118	0.080	-1.486	0.143