

Supplementary material for:

Decoding the functional adaptation of animal echolocation: A global macroevolutionary analysis

Authors

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Supplementary information includes the following items:

Figures S1 – S11

Tables S1 – S19

Supplementary References

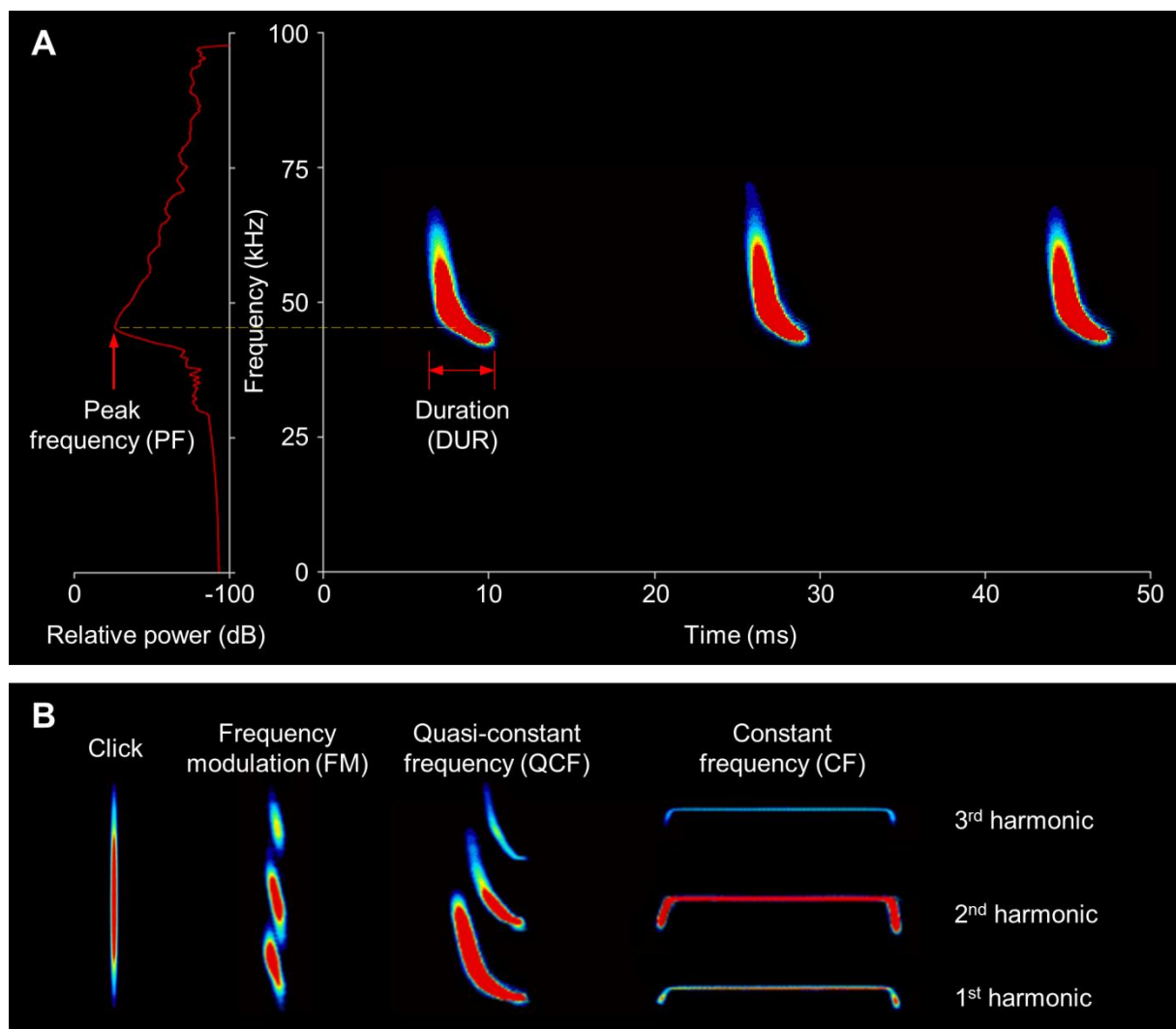


Figure S1. Schematic representations of selected echolocation call design properties. A, Representative composite diagram including a power spectrum (left) and a corresponding spectrogram (right) of echolocation pulses, highlighting peak frequency (PF, in kHz), measured at the peak amplitude of an entire pulse, and the duration (DUR, in ms), calculated as the length of the pulse. B, Spectrograms illustrate structural properties, such as call types and harmonics (see the “Metrics defining echolocation call design and data compilation” section in the Method Details for detailed descriptions). All schematics were created using Avisoft-SASLab Pro software v5.3.2 (Avisoft Bioacoustics, Berlin).

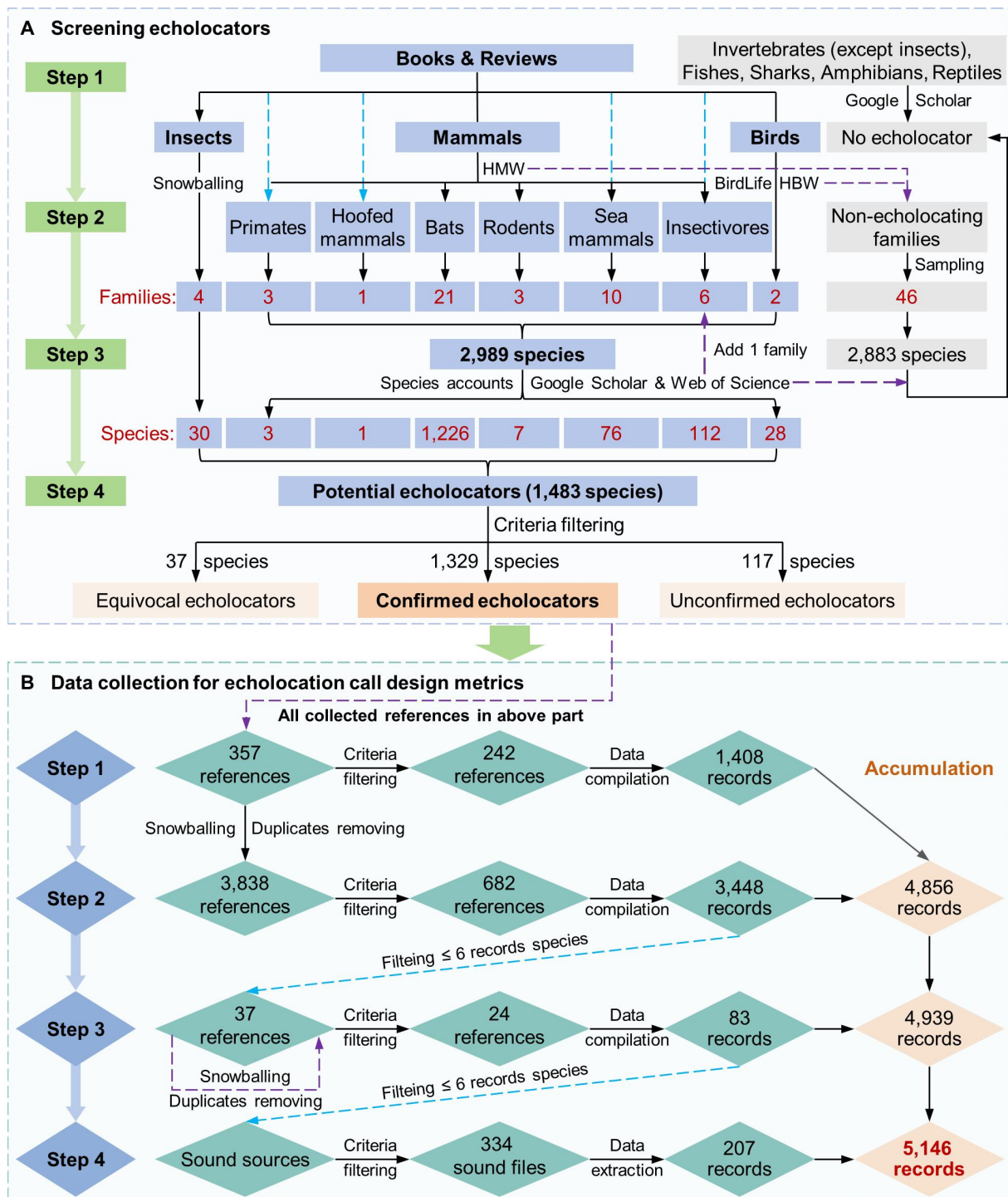


Figure S2. Workflow overview for screening echolocating species and collating echolocation call design data. A, A systematic structured four-step literature search and review procedure was conducted to identify confirmed, equivocal, and unconfirmed echolocators. B, The four-step target-capture approach used to compile data and information on echolocation call design properties from various data sources.

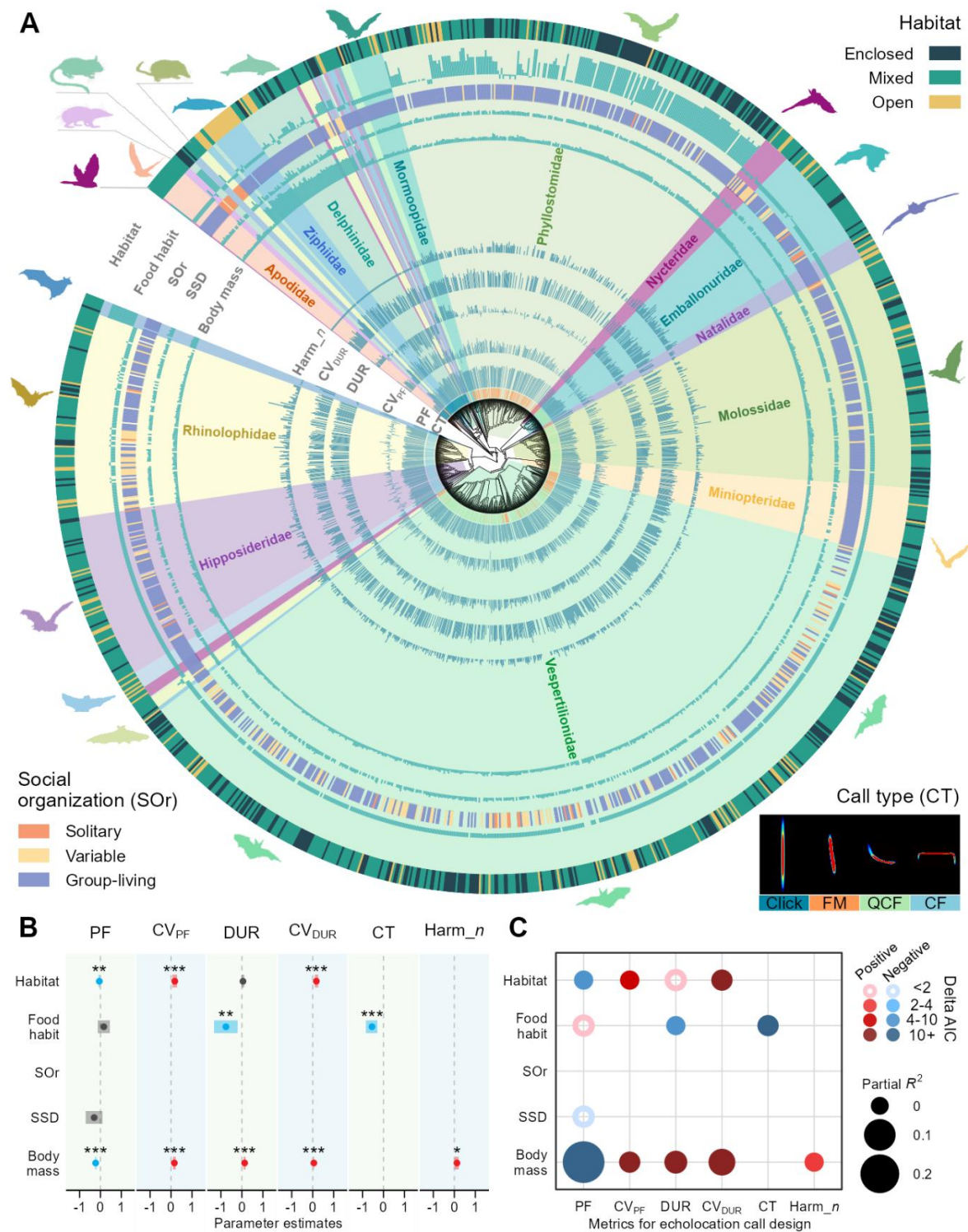


Figure S3. Links between echolocation call design and functional adaptation based on original data ($n = 1,013$ echolocating species). A, Species distribution across the phylogenetic supertree, with color scales depicting variations in species-specific mean values of echolocation call design properties and predictor variables used in PGLS analyses. For clarity, natural-log transformations were applied to body mass, peak frequency (PF) and duration

(DUR), while the coefficients of variation for peak frequency (CV_{PF}) and duration (CV_{DUR}) were deflated using the $\ln(x+1)$ transformations. Sexual size dimorphism (SSD) was inflated by subtracting the minimum value of 0.8. SOr, Harm_*n* and CT represent social organization, number of harmonics, and call type, respectively. Color shadings denote different families, with those having more than ten species named explicitly. Animal silhouettes are derived from PhyloPic (www.phylopic.org). Click, FM (frequency modulation), QCF (quasi-constant frequency) and CF (constant frequency) represent different call types in the inset. B, Standardized effect sizes (colored dots) with their 95% confidence intervals (shaded bars) based on PGLS models. Statistical significance is indicated by $P < 0.05$ (*), $P < 0.01$ (**), and $P < 0.001$ (***). Red denotes a positive significant relationship, while blue indicates a negative significant relationship. Grey represents significant effects in the univariate PGLS models but not in the multivariate PGLS models. C, Relative importance of predictor variables from PGLS models (see Method Details, and Tables S6 and S7 for details). Gaps indicate variables that were not significant ($P > 0.05$ and $|\Delta AIC| < 2$) in the univariate models and were therefore excluded from the multivariate models. Red and blue solid circles represent positive and negative effects of predictor variables. Hollow circles denote significant effects in the univariate PGLS models but not in the multivariate PGLS models. The size of each circle is proportionate to the relative change in importance (partial R^2 values) of variables, which were calculated using the “R2_lik” function in the “rr2” package⁶⁶.

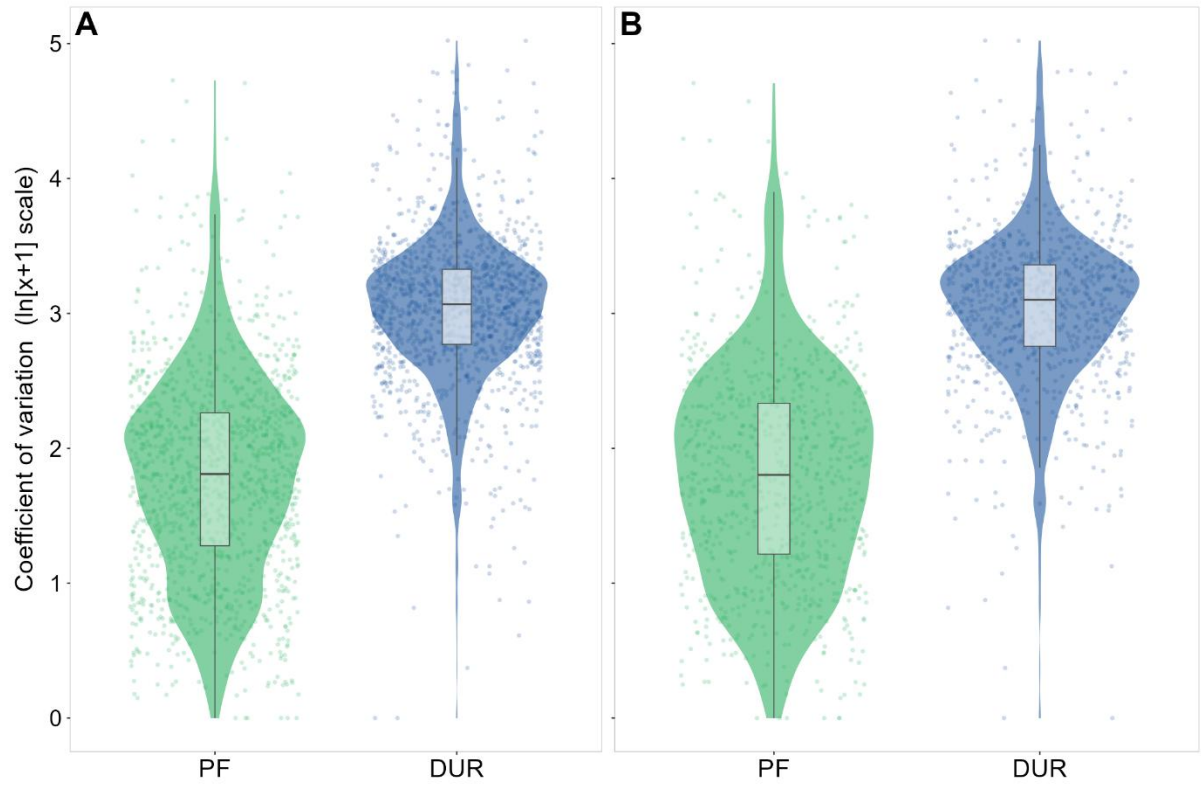


Figure S4. Distributions of the coefficients of variation for peak frequency (CV_{PF}) and duration (CV_{DUR}), based on complete data after imputation (A) and original data (B). For clarity data were deflated using an $\ln(x+1)$ transformation.

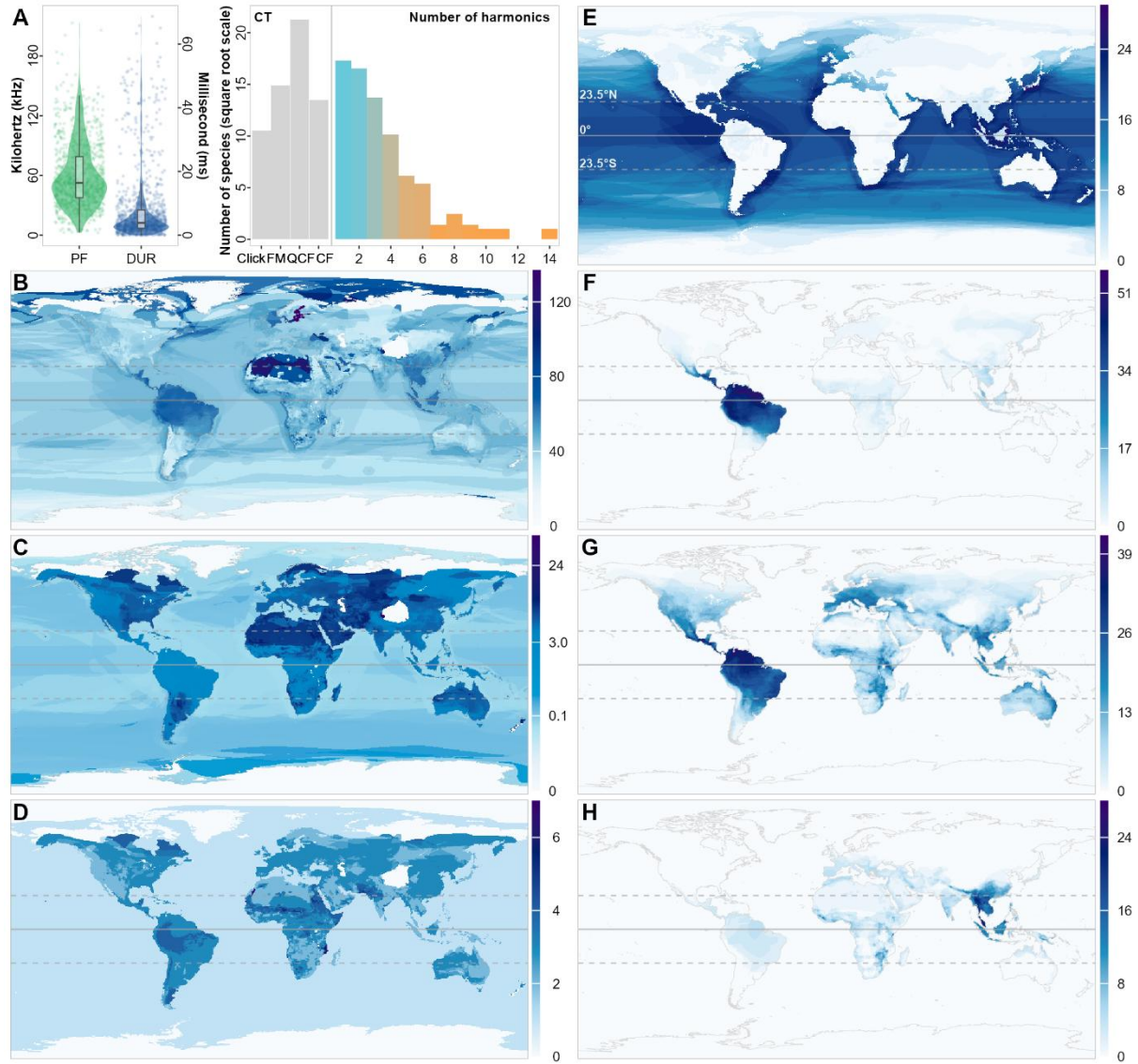


Figure S5. Variations in echolocation call design properties from original data. (A) Value distributions of peak frequency (PF, in kHz), duration (DUR, in ms), call type (CT) and number of harmonics (Harm_ n). For clarity, species numbers were deflated using square root transformation. (B to H) Geographic distributions of PF (B), DUR (C), Harm_ n (D) and CT (E to H) across species assemblages defined for 55×55 km ($\sim 0.5^\circ$ scale) areas. In (B) to (D), color scales depict variations in assembly median values. Panels (E) to (H) represent four call types: click, frequency modulation (FM), quasi-constant frequency (QCF), and constant frequency (CF), respectively. Color scales in (E) to (H) depict differences in the number of species assemblages.

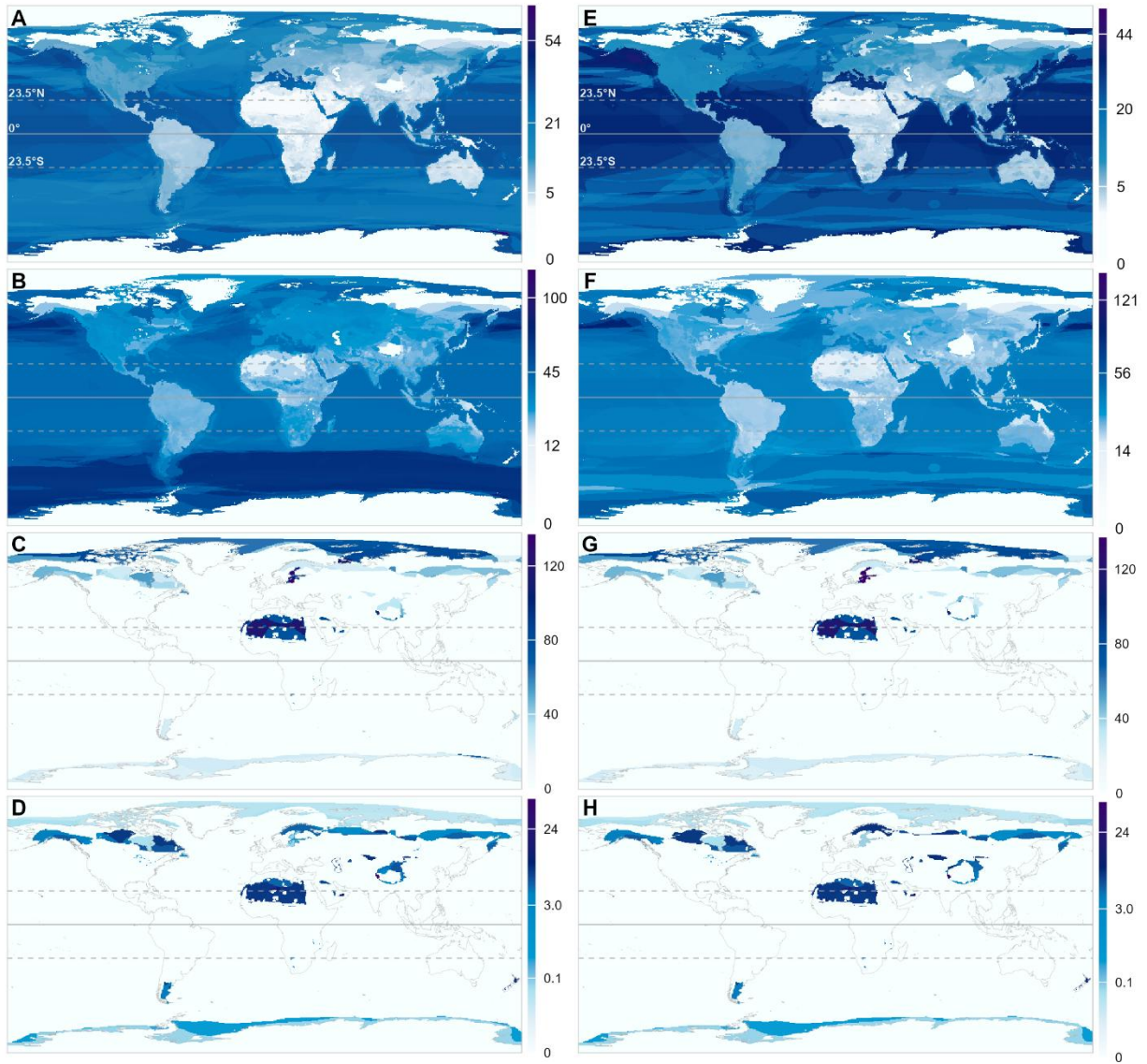


Figure S6. Global patterns of coefficients of variation for two numerical echolocation call design properties and geographic variations in these metrics for specific areas with up to two echolocating species, based on complete data after imputation (A-D) and original data (E-H). Panels (A) and (E) present the coefficients of variation for peak frequency (CV_{PF}). Panels (B) and (F) present the coefficients of variation for duration (CV_{DUR}). Panels (C) and (G) show specific distributions in peak frequency (PF) for grid cells including only up to two echolocating species. Panels (D) and (H) show specific distributions of duration (DUR) for grid cells including only up to two echolocating species. In (A) to (H), the spatial resolution is 0.5° latitude by 0.5° longitude (giving a cell size of c. 55×55 km at the equator).

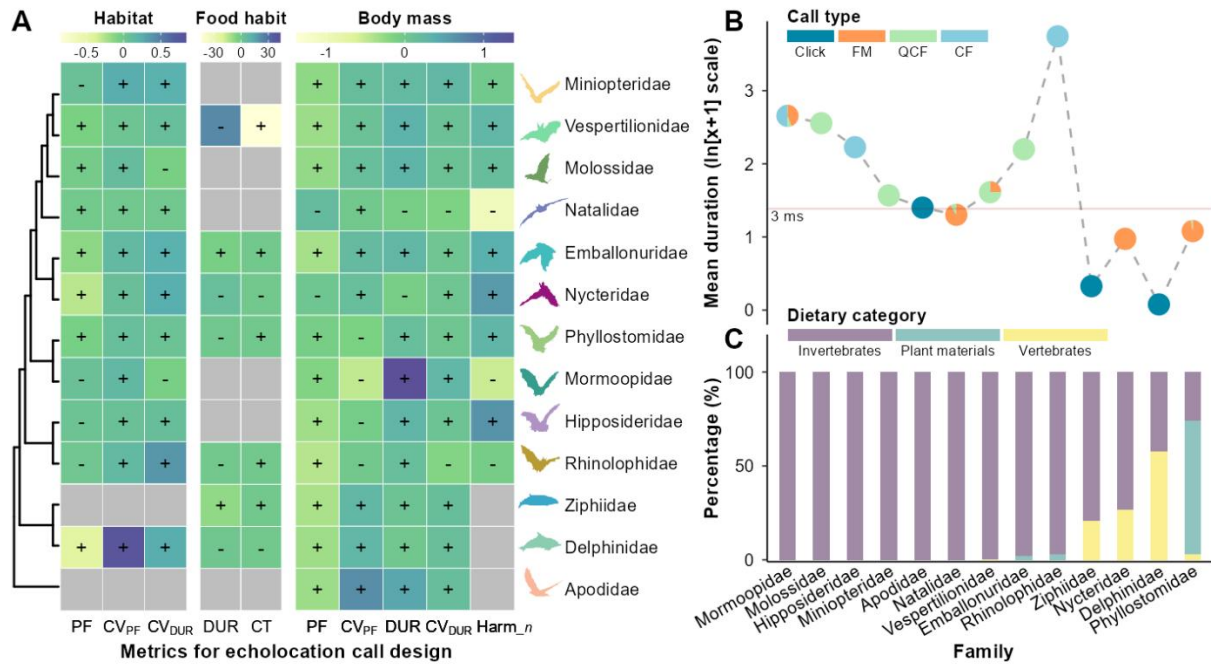


Figure S7. Associations between echolocation call designs and predictor variables at the family level. A, Three heatmaps illustrate relationships between echolocation call design and habitat type, food habit, and body mass based on univariate robust liner regressions (“rlm” function in “MASS” package⁶⁷, not corrected for phylogeny) (see Method Details) for each of the 13 families with more than ten echolocating species. “+” denotes consistency with the results in the PGLS multivariate models, while “-” denotes inconsistency. Positive slopes are shown in dark blue, negative slopes in light green, and zero (flat) slopes in gray. PF, DUR, Harm_n, CV_{PF} and CV_{DUR} represent peak frequency, duration, number of harmonics, coefficients of variation for peak frequency and duration, respectively. B, Call duration change as call “shape” transitions from horizontal to vertical (i.e., constant frequency [CF] to Click; see Figure S1B for detailed spectrogram) across the 13 families that including more than ten echolocating species. FM and QCF represent frequency modulation and quasi-constant frequency for different call types. For clarity, mean durations were deflated using the ln(x+1) transformations. (C) Food habits at the family level in relation to three assigned dietary categories (see Method Details for details). Panels (B) and (C) show that echolocating species that specialize on predating invertebrates (mostly insects or euphausiids) have a more horizontal call shape (i.e., CF and QCF) with long pulse duration, while echolocating species with high diet diversity emit calls with a more vertical shape (i.e., FM and click) with short duration, conforming with the “distance of focus” [DOF] theory^{5,6}. Notably, all four families with call durations of less than 3 milliseconds (ms) use click and FM calls, and exhibit substantial dietary diversity.

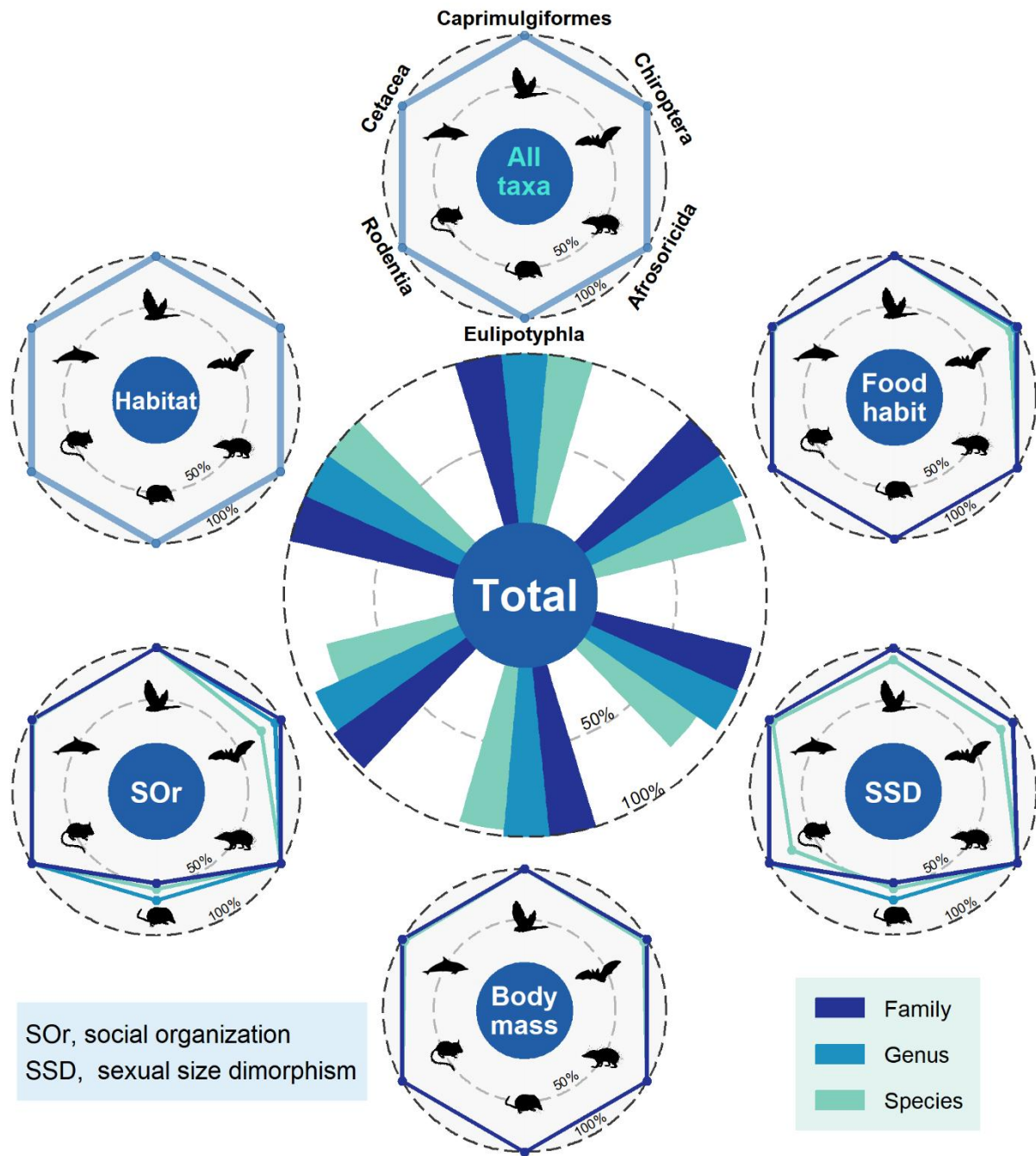


Figure S9. Overview of the original dataset relating predictor variables across all six orders of echolocators. Percentages of echolocating species that have acoustic records at the family-, genus-, and species-levels presented for all taxa and each variable, corresponding to the outer ring of the laser chart. Color scale in dark blue, light blue and green denote the family-, genus-, and species-level, respectively.

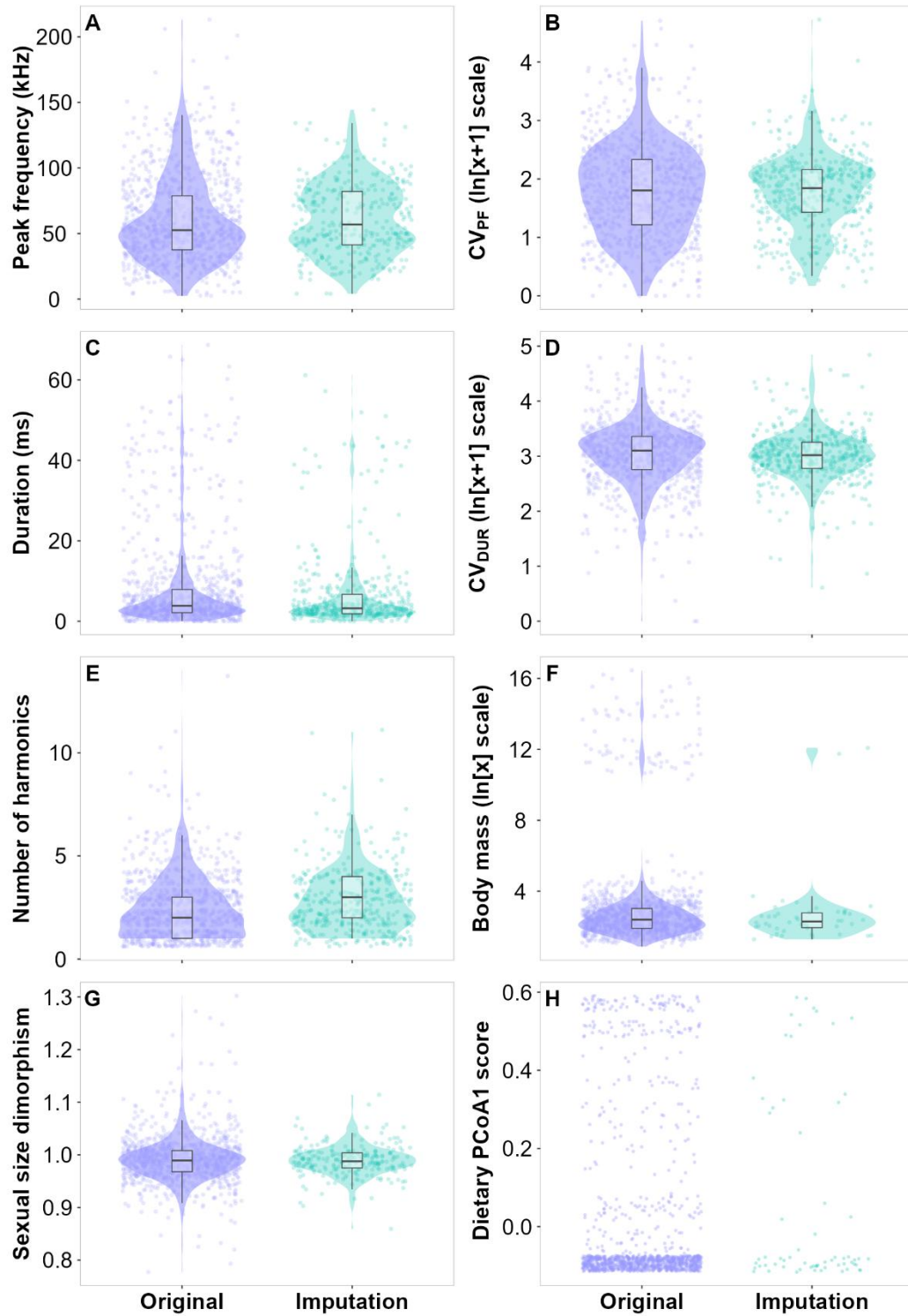


Figure S10. Graphical comparisons between original and imputed data for echolocation call design properties and predictor variables. For clarity, body mass, and coefficients of variation for peak frequency (CV_{PF}) and duration (CV_{DUR}) were deflated using an $\ln(x)$ or $\ln(x+1)$ transformation.

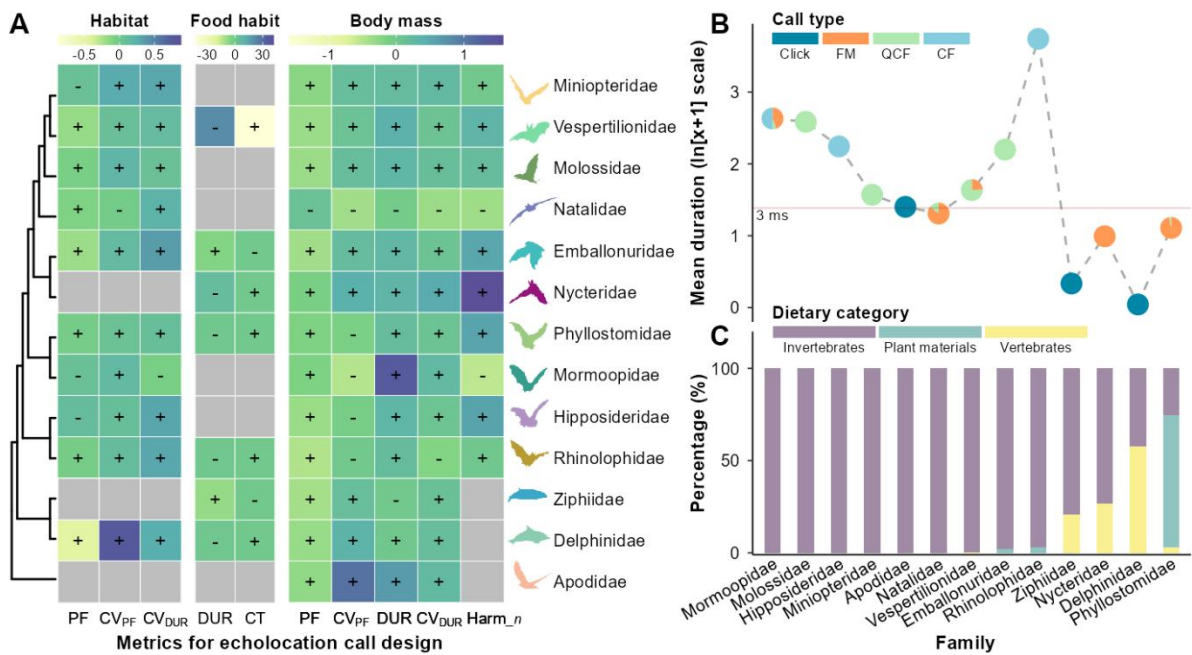


Figure S11. Associations between echolocation call designs and predictor variables at the family level, based on original data ($n = 1,013$ species). A, Three heatmaps illustrate relationships between echolocation call design with habitat type, food habits, and body mass, based on univariate robust liner regressions (“rlm” function in “MASS” package⁶⁷, not corrected for phylogeny) for each of the 13 families with more than ten echolocating species. “+” denotes consistency with the results in the PGLS multivariate models, while “-” denotes inconsistency. Positive slopes are shown in dark blue, negative slopes in light green, and zero (flat) slopes in gray. PF, DUR, Harm_n, CV_{PF} and CV_{DUR} represent peak frequency, duration, number of harmonics, coefficients of variation for peak frequency and duration, respectively. B, Call duration changes as call ‘shape’ transitions from horizontal to vertical (i.e., constant frequency [CF] to Click) (see Figure S1B for detailed spectrogram) across the 13 families which included more than ten echolocating species. FM and QCF represent frequency modulation and quasi-constant frequency for different call types. For clarity, mean duration was deflated using a $\ln(x+1)$ transformation. C, Dietary composition at the family level, based on three assigned dietary categories (see Method Details, and EltonTraits¹² for details). Panels (B) and (C) show that echolocating species specializing on predating invertebrates have a more horizontal call shape (i.e., CF and QCF) with a long pulse duration, whereas echolocating species with a high diet diversity emit calls with a more vertical shape (i.e., FM and click) with short duration, conforming with the ‘distance of focus’ [DOF] theory^{5,6}. Notably, all four families with call durations of less than 3 milliseconds (ms) use click and FM calls, and exhibit substantial dietary diversity.

Table S1. Descriptions and functional significances of echolocation call design properties.

Metric	Parameter	Description	Functional interpretation	Reference ID
Numerical	Peak frequency (PF)	Frequency with the maximum energy (amplitude) in the maximum energy harmonic (kHz).	Lower PF travels farther while higher PF gives greater resolution.	1, 2
	Duration (DUR)	Duration of the maximum energy harmonic (ms).	Shorter DUR gives better localization performance while longer DUR provides more temporal information.	1, 2
	Coefficients of variation for PF and DUR (CV_{PF}, CV_{DUR})	Variance of PF and DUR.	Lower CV enhances focus and concentration while higher CV enlarges the field-of-detection correction.	3, 4
Structural	Call type (CT)	Call classification, also called “sonotype”, based on sonic wave shape at the highest amplitude, including click, frequency modulation (FM), quasi-constant frequency (QCF), constant frequency (CF).	Following the “distance of focus” [DOF] theory, a more vertically-shaped sonotype is more effective at focusing large and less-mobile objects, while a more horizontally-shaped sonotype is more effective at detecting small objects over longer distances.	5, 6, 7
	Number of harmonics (Harm_n)	Number of the harmonic beams per pulse.	The more harmonics, the better the discrimination of target echoes from clutter echoes.	8

Table S2. Echolocation functions and predictor variables. Inclusion of predictor variables, along with morphological and evolutionary constraints on echolocation calls, where body size and species ancestry limitations on acoustic signals have been documented across various animal groups^{9–11}. SSD, sexual size dimorphism. Data sources are provided for each predictor variable: IUCN, www.iucnredlist.org; EltonTraits, EltonTraits 1.0 database¹²; HMW, “Handbook of the Mammals of the World”^{13–21}; AVONET, morphological, ecological and geographical data for all birds²²; Vertlife, www.vertlife.org^{23,24}.

Function/constraint	Predictor variable	Data sources
Spatial orientation	Habitat	IUCN and Global habitat type map ²⁵
Prey acquisition	Food habit	EltonTraits ¹² and various literatures
Social organization	Social organization	HMW ^{13–21} and various sources
Sexual size dimorphism (SSD)	SSD	HMW ^{13–21} , AVONET ²² and various sources
Morphological constraint	Body mass	HMW ^{13–21} and various sources
Evolutionary constraint	Phylogenetic signal	Vertlife ^{23,24}

Table S3. List of unconfirmed echolocating species. Taxonomic information and brief reasons for uncertainty for each unconfirmed species are provided. Details on the criteria for identifying echolocators can be found in the “Screening echolocators” section of the Method Details.

Class	Order	Family	Species	Reasons
Aves	Caprimulgiformes	Apodidae	<i>Cypseloides cherriei</i>	Click-like calls were recorded, but echolocation was uncertain ^{26,27} .
			<i>Cypseloides cryptus</i>	Click-like calls were recorded, but echolocation was uncertain ^{26,28} .
			<i>Aerodramus mearnsi</i>	
			<i>Aerodramus infuscatus</i>	
			<i>Aerodramus nuditarsus</i>	Inference from similar ecological habits with congeneric echolocators ^{26,29} .
			<i>Aerodramus orientalis</i>	
			<i>Aerodramus whiteheadi</i>	
			<i>Aerodramus pelewensis</i>	Informed speculation ^{26,29,30} , but no experimental evidence.
			<i>Aerodramus leucophaeus</i>	Informed speculation ^{26,29,31,32} , but no experimental evidence.
			<i>Schoutedenapus myoptilus</i>	Click-like calls were recorded, but echolocation was uncertain ^{26,33} .
Mammalia	Chiroptera	Pteropodidae	<i>Eonycteris spelaea</i>	Echolocation was proposed, but experimental evidence were insufficient ³⁴ .
			<i>Megaerops ecaudatus</i>	Click-like calls were recorded, but echolocation was uncertain ³⁵ .
			<i>Cynopterus brachyotis</i>	Click-like calls were recorded, but echolocation was uncertain ³⁵ .
			<i>Cynopterus horsfieldii</i>	Click-like calls were recorded, but echolocation was uncertain ³⁵ .
			<i>Macroglossus sobrinus</i>	Click-like calls were recorded, but echolocation was uncertain ³⁵ .
			<i>Stenonycteris lanosus</i>	Click-like calls were recorded but echolocation was uncertain ^{21,36} .
			<i>Boneia bidens</i>	Informed speculation ^{21,36} , but no experimental evidence.
			<i>Eidolon dupreanum</i>	Click-like calls were recorded, but echolocation was uncertain ³⁷ .
	Cingulata	Dasypodidae	<i>Dasypus novemcinctus</i>	Evolutionary prediction ³⁸ , but no experimental evidences.

Table S3. (Continued)

Class	Order	Family	Species	Reasons
Mammalia	Afrosoricida	Tenrecidae	<i>Hemicentetes nigriceps</i>	Inference from similar ecological habits with congeneric echolocator ³⁹ .
			<i>Nesogale talazaci</i>	Inference from similar ecological habits with congeneric echolocator ³⁹ .
			<i>Microgale longicaudata</i>	Informed speculation ⁴⁰ , but no experimental evidence.
		Potamogalidae	<i>Micropotamogale ruwenzorii</i>	Informed speculation ⁴⁰ , but no experimental evidence.
			<i>Potamogale velox</i>	Informed speculation ⁴⁰ , but no experimental evidence.
			<i>Cryptotis parvus</i>	Echolocation was proposed but experimental evidence was insufficient ^{20,40,41} .
	Eulipotyphla	Soricidae	<i>Neomys fodiens</i>	Informed speculation ⁴⁰ , but no experimental evidence.
			<i>Blarina hulophaga</i>	Inference from similar ecological habits with congeneric echolocator ²⁰ .
			<i>Blarina carolinensis</i>	Inference from similar ecological habits with congeneric echolocator ²⁰ .
			<i>Blarina peninsulae</i>	Inference from similar ecological habits with congeneric echolocator ²⁰ .
			<i>Blarina shermani</i>	Inference from similar ecological habits with congeneric echolocator ²⁰ .
			<i>Sorex</i> spp.*	Inference from similar ecological habits with congeneric echolocator ²⁰ .
		Talpidae	<i>Uropsilus aequodonta</i>	Informed speculation ³⁸ , but no experimental evidence.
			<i>Uropsilus andersoni</i>	Informed speculation ³⁸ , but no experimental evidence.
			<i>Uropsilus atronates</i>	Informed speculation ³⁸ , but no experimental evidence.
			<i>Galemys pyrenaicus</i>	Informed speculation ⁴⁰ , but no experimental evidence.
		Solenodontidae	<i>Solenodon paradoxus</i>	Informed speculation ^{20,39} and evolutionary prediction ³⁸ , but no experimental evidence.

Note: *The genus includes 86 species with similar ecological habits, and, of these, only four were experimentally verified to be echolocators.

Table S4. List of equivocal echolocating species. Taxonomic information and brief reasons for each equivocal species are provided. Details on the criteria used for identifying echolocators can be found in the “Screening echolocators” section of the Method Details.

Class	Order	Family	Species	Reasons
Mammalia	Primates	Hominidae	<i>Homo sapiens</i>	Very few blind people, after training, could use audible clicks and echoes to navigate their surroundings ^{42,43} , indicating that human beings are not typical echolocators.
		Daubentoniidae	<i>Daubentonia madagascariensis</i>	Mechanical vibration signals produced by digital percussion, but not a typical echolocation sound ^{44,45} .
		Tarsiidae	<i>Tarsius spectrumgurskyae</i>	Ultrasonic calls were recorded, but any function for navigation remains in doubt ^{46–48} .
	Artiodactyla	Hippopotamidae	<i>Hippopotamus amphibius</i>	Click calls were occasionally recorded in muddy water, but echolocation function remains in doubt ^{48,49} .
	Rodentia	Spalacidae	<i>Eospalax baileyi</i>	Mechanical seismic waves, but not a typical echolocation sound ⁵⁰ .
			<i>Nannospalax ehrenbergi</i>	Mechanical seismic waves produced by head drumming, but not a typical echolocation sound ^{51,52} .
		Muridae	<i>Rattus norvegicus</i> *	Ultrasonic calls were recorded, but their function for navigation remains in doubt ^{40,53,54} .
Insecta	Hymenoptera	Ichneumonidae**	<i>Pimpla instigator</i>	Substrate-borne mechanical vibration communication, but not typical echolocators ^{55–57} .
			<i>Pimpla turionellae</i>	
			<i>Xanthopimpla stemmator</i>	

Table S4. (Continued)

Class	Order	Family	Species	Reasons
Insecta	Hymenoptera	Orussidae**	<i>Orussus abietinus</i>	Substrate-borne mechanical vibration communication, but not typical echolocators ^{55–59} .
			<i>Orussus occidentalis</i>	
			<i>Orussus sayii</i>	
	Coleoptera	Gyrinidae**	<i>Dineutes carolinus</i>	Water waves produced by wing fanning, but echolocation function was controversial ^{60,61} .
	Lepidoptera	Noctuidae***	<i>Agrotis segetum</i>	Click signals possibly produced by wing fanning were recorded, but function for navigation remained doubtful ^{62–64} .
			<i>Aplecta nebulosa</i>	
			<i>Apamea fucosa</i>	
			<i>Amphipyra perflua</i>	
			<i>Archanara sparganii</i>	
			<i>Autographa gamma</i>	
			<i>Autographa pulchrina</i>	
			<i>Catocala nupta</i>	
			<i>Cerastis rubricosa</i>	
			<i>Diachrysia chrysitis</i>	
			<i>Enargia paleacea</i>	
			<i>Eurois occulta</i>	
			<i>Hypena proboscidalis</i>	
			<i>Hydraecia micacea</i>	
			<i>Ipimorpha subtusa</i>	
			<i>Mniotype satura</i>	

Table S4. (Continued)

Class	Order	Family	Species	Reasons
Insecta	Lepidoptera	Noctuidae***	<i>Mythimna turca</i>	Click signals possibly produced by wing fanning were recorded, but function for navigation remained doubtful ^{62–64} .
			<i>Phragmitiphila typhae</i>	
			<i>Plusia festucae</i>	
			<i>Scoliopteryx libatrix</i>	
			<i>Tholera popularis</i>	
			<i>Xestia baja</i>	
			<i>Xestia c-nigrum</i>	

Note: *This study referred to a blinded laboratory rat, identified by Thoms et al.⁴⁰ as *Rattus norvegicus*. **Members of these three families were speculated to use substrate-borne mechanical vibration communication⁵⁷; however, considering the vast number, only species whose acoustics have been directly described using the term “echolocation”, were included in this list. ***Noctuid moths (family Noctuidae) were recorded to emit click signals produced by wing fanning, but any function for navigation remained doubtful^{63,64}. Given the large number of species in this family, only those whose acoustics have been directly described using the term “echolocation”, were included in this list.

Table S5. The phylogenetic signal (Pagel's λ statistic) of each variable. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_*n*, number of harmonics per pulse; SSD, sexual size dimorphism. The statistical value of food habit is based on the PCoA1 score in the principal coordinates analysis (PCoA) for dietary categories. *P*-values in bold indicate significant differences ($P < 0.05$).

Parameter	Imputed	Pagel's λ	<i>P</i> -value
PF	Yes	>0.999	<0.001
	No	>0.999	<0.001
DUR	Yes	>0.999	<0.001
	No	>0.999	<0.001
CV _{PF}	Yes	0.999	<0.001
	No	0.999	<0.001
CV _{DUR}	Yes	0.999	<0.001
	No	0.998	<0.001
CT	Yes	>0.999	<0.001
	No	>0.999	<0.001
Harm_ <i>n</i>	Yes	0.999	<0.001
	No	0.998	<0.001
Habitat	Yes	0.996	<0.001
	No	0.996	<0.001
Food habit	Yes	>0.999	<0.001
	No	>0.999	<0.001
Social organization	Yes	0.999	<0.001
	No	0.998	<0.001
SSD	Yes	0.997	<0.001
	No	0.996	<0.001
Body mass	Yes	>0.999	<0.001
	No	>0.999	<0.001

Table S6. Statistical results from single-predictor (univariate) PGLS models for echolocation call designs. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_*n*, number of harmonics per pulse; SSD, sexual size dimorphism. The statistical value of food habit was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, whereas CV_{PF} and CV_{DUR} were transformed by using ln(*x*+1) transformations. *P*-values in bold indicate significant differences ($P < 0.05$).

Predictor	Parameter	Imputed	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Partial R^2
Habitat	PF	Yes	1329	-0.046	0.013	-3.478	0.001	10.062	0.999	0.785	0.009
		No	987	-0.067	0.019	-3.543	<0.001	10.5	0.999	0.733	0.013
	DUR	Yes	1329	0.052	0.022	2.422	0.016	3.861	>0.999	0.894	0.004
		No	916	0.088	0.035	2.491	0.013	4.198	0.999	0.847	0.007
	CV _{PF}	Yes	1329	0.12	0.033	3.654	<0.001	11.308	0.999	0.519	0.01
		No	876	0.202	0.052	3.875	<0.001	12.92	0.998	0.395	0.017
	CV _{DUR}	Yes	1329	0.099	0.026	3.842	<0.001	12.7	0.999	0.194	0.011
		No	864	0.206	0.04	5.196	<0.001	24.647	0.989	0.059	0.03
	CT	Yes	1329	0.008	0.011	0.694	0.488	1.517	0.999	0.922	<0.001
		No	968	-0.001	0.016	-0.061	0.952	1.996	0.999	0.916	<0.001
	Harm_ <i>n</i>	Yes	1329	-0.009	0.059	-0.161	0.872	1.974	0.999	0.389	<0.001
		No	941	0.012	0.08	0.15	0.881	1.977	0.997	0.282	<0.001
Food habit	PF	Yes	1329	0.285	0.124	2.29	0.022	3.243	0.999	0.783	0.004
		No	979	0.401	0.175	2.287	0.022	3.227	0.999	0.73	0.005
	DUR	Yes	1329	-0.569	0.211	-2.699	0.007	5.275	>0.999	0.893	0.005
		No	909	-0.862	0.296	-2.916	0.004	6.481	0.999	0.854	0.009

Table S6. (Continued)

Predictor	Parameter	Imputed	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Partial R^2
Food habit	CV _{PF}	Yes	1329	-0.182	0.304	-0.597	0.551	1.643	0.999	0.515	<0.001
		No	869	0.116	0.383	0.304	0.762	1.908	0.998	0.384	<0.001
	CV _{DUR}	Yes	1329	-0.005	0.223	-0.021	0.983	2	0.999	0.185	<0.001
		No	857	-0.012	0.219	-0.053	0.958	1.997	0.992	0.029	<0.001
	CT	Yes	1329	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.013
		No	960	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.016
	Harm_ <i>n</i>	Yes	1329	-0.856	0.527	-1.625	0.104	0.641	0.999	0.39	0.002
		No	934	-0.904	0.547	-1.651	0.099	0.728	0.997	0.282	0.003
Social organization	PF	Yes	1329	0.017	0.017	1.006	0.315	0.987	0.999	0.782	0.001
		No	873	0.038	0.024	1.597	0.111	0.554	0.999	0.709	0.003
	DUR	Yes	1329	0.009	0.028	0.33	0.741	1.891	>0.999	0.895	<0.001
		No	815	0.011	0.041	0.277	0.782	1.923	0.999	0.858	<0.001
	CV _{PF}	Yes	1329	0.028	0.042	0.661	0.508	1.562	0.999	0.515	<0.001
		No	786	0.055	0.06	0.925	0.355	1.143	0.998	0.385	0.001
	CV _{DUR}	Yes	1329	0.011	0.033	0.333	0.739	1.889	0.999	0.185	<0.001
		No	773	-0.014	0.044	-0.329	0.743	1.892	0.984	0.019	<0.001
	CT	Yes	1329	0.015	0.015	1.011	0.312	0.978	0.999	0.922	0.001
		No	859	0.011	0.019	0.561	0.575	1.684	0.999	0.919	<0.001
	Harm_ <i>n</i>	Yes	1329	0.112	0.075	1.488	0.137	0.215	0.999	0.39	0.002
		No	841	0.064	0.097	0.655	0.512	1.57	0.997	0.27	0.001

Table S6. (Continued)

Predictor	Parameter	Imputed	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Partial R^2
SSD	PF	Yes	1329	-0.624	0.191	-3.266	0.001	8.639	0.999	0.784	0.008
		No	885	-0.715	0.243	-2.944	0.003	6.647	0.999	0.722	0.01
	DUR	Yes	1329	-0.16	0.308	-0.519	0.604	1.73	>0.999	0.895	<0.001
		No	834	-0.201	0.412	-0.487	0.627	1.763	>0.999	0.857	<0.001
	CV _{PF}	Yes	1329	0.049	0.473	0.104	0.918	1.989	0.999	0.515	<0.001
		No	800	0.018	0.636	0.028	0.978	1.999	0.998	0.368	<0.001
	CV _{DUR}	Yes	1329	0.4	0.37	1.08	0.28	0.833	0.999	0.186	0.001
		No	791	0.339	0.511	0.663	0.508	1.56	0.973	0.012	0.001
	CT	Yes	1329	0.203	0.163	1.244	0.214	0.45	0.999	0.922	0.001
		No	873	0.095	0.192	0.493	0.622	1.756	0.999	0.912	<0.001
	Harm_ <i>n</i>	Yes	1329	-0.156	0.839	-0.186	0.852	1.965	0.999	0.389	<0.001
		No	857	-0.292	0.951	-0.307	0.759	1.906	0.998	0.293	<0.001
Body mass	PF	Yes	1329	-0.207	0.01	-20.029	<0.001	349.033	0.999	0.833	0.232
		No	974	-0.244	0.012	-19.668	<0.001	324.312	0.999	0.805	0.285
	DUR	Yes	1329	0.122	0.019	6.298	<0.001	37.146	>0.999	0.901	0.029
		No	905	0.139	0.025	5.673	<0.001	29.697	0.999	0.85	0.034
	CV _{PF}	Yes	1329	0.13	0.029	4.549	<0.001	18.563	0.999	0.521	0.015
		No	863	0.17	0.033	5.133	<0.001	24.017	0.998	0.399	0.03

Table S6. (Continued)

Predictor	Parameter	Imputed	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Partial R^2
Body mass	CV _{DUR}	Yes	1329	0.079	0.022	3.682	<0.001	11.51	0.999	0.193	0.01
		No	853	0.062	0.008	7.909	<0.001	58.509	<0.001	0.068	0.068
	CT	Yes	1329	-0.016	0.01	-1.558	0.119	0.43	0.999	0.922	0.002
		No	953	-0.019	0.012	-1.606	0.109	0.583	0.999	0.914	0.003
	Harm_ <i>n</i>	Yes	1329	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.004
		No	927	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.006

Table S7. Statistical results from multi-predictor (multivariate) PGLS for echolocation call designs. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_*n*, number of harmonics per pulse; SSD, sexual size dimorphism. The statistical value of food habit was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, while CV_{PF} and CV_{DUR} were transformed by using ln(x+1) transformations. *P*-values in bold indicate significant differences ($P < 0.05$).

Parameter	Imputed	Predictor	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Phylo R^2	Partial R^2
PF	Yes	Habitat	1329	-0.025	0.012	-2.111	0.035	2.467	0.999	0.834	0.819	0.003
		Food habit		0.176	0.11	1.609	0.108	0.595				0.002
		SSD		-0.312	0.168	-1.852	0.064	1.44				0.003
		Body mass		-0.202	0.01	-19.454	<0.001	332.136				0.222
	No	Habitat	871	-0.052	0.018	-2.886	0.004	6.338	0.999	0.799	0.784	0.01
		Food habit		0.16	0.15	1.067	0.286	0.855				0.001
		SSD		-0.301	0.211	-1.424	0.155	0.038				0.002
		Body mass		-0.229	0.013	-17.397	<0.001	259.05				0.259
DUR	Yes	Habitat	1329	0.036	0.021	1.69	0.091	0.861	>0.999	0.899	0.823	0.002
		Food habit		-0.469	0.212	-2.214	0.027	2.908				0.004
		Body mass		0.12	0.019	6.175	<0.001	35.707				0.028
	No	Habitat	898	0.052	0.036	1.465	0.143	0.154	0.999	0.853	0.735	0.002
		Food habit		-0.761	0.281	-2.711	0.007	5.354				0.008
		Body mass		0.132	0.025	5.353	<0.001	26.331				0.031

Table S7. (Continued)

Parameter	Imputed	Predictor	<i>n</i>	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Phylo R^2	Partial R^2
CV_{PF}	Yes	Habitat	1329	0.108	0.033	3.29	0.001	8.805	0.999	0.525	0.472	0.008
		Body mass		0.121	0.029	4.248	<0.001	15.965				0.013
	No	Habitat	863	0.176	0.052	3.355	0.001	9.225	0.998	0.407	0.344	0.013
		Body mass		0.156	0.033	4.684	<0.001	19.738				0.025
CV_{DUR}	Yes	Habitat	1329	0.091	0.026	3.517	<0.001	10.34	0.999	0.2	0.116	0.009
		Body mass		0.072	0.021	3.344	0.001	9.164				0.008
	No	Habitat	853	0.173	0.04	4.384	<0.001	17.075	<0.001	0.089	<0.001	0.022
		Body mass		0.056	0.008	7.034	<0.001	46.267				0.055
CT	Yes	Food habit	1329	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.905	0.013
	No	Food habit	960	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016
Harm_n	Yes	Body mass	1329	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004
	No	Body mass	927	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006

Table S8. Principal coordinates analysis (PCoA) results for food habit, based on original data and complete data after imputation. Dietary category descriptions are taken from in the EltonTraits 1.0 database¹². Percentage values represent the percentage of the total variation explained by each PCoA axis.

Dietary item	Original data		Complete data after imputation	
	PCoA1	PCoA2	PCoA1	PCoA2
	(78.28%)	(17.55%)	(79.25%)	(16.58%)
Invertebrates	-31.487	-8.668	-31.78	-8.58
Vertebrates	1.974	15.42	1.758	15.094
Plant material	29.514	-6.752	30.016	-6.513

Table S9. Comparative analysis between original data and complete data after imputation for each variable. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_*n*, number of harmonics per pulse; SSD, sexual size dimorphism. The statistical value of food habits was based on the PCoA1 scores in a principal coordinates analysis (PCoA) for dietary categories. Body mass included substantial variation from 2.4 g in Gervais's Funnel-eared bats (*Nyctiellus lepidus*) to 23,500 kg in sperm whales (*Physeter macrocephalus*), which was addressed using a natural-log transformation.

Parameter	Estimate	SE	<i>t</i> -value	<i>P</i> -value
PF	-0.256	1.344	-0.190	0.849
DUR	0.419	0.491	0.854	0.393
CV_{PF}	0.405	0.395	1.026	0.305
CV_{DUR}	0.772	0.686	1.126	0.260
CT	0.024	0.037	0.665	0.506
Harm_<i>n</i>	-0.046	0.027	-1.694	0.09
Social organization	0.039	0.022	1.785	0.074
Food habit	<0.001	0.008	<0.001	>0.999
SSD	<0.001	0.002	0.142	0.887
Body mass (log scale)	0.011	0.100	0.107	0.915

Table S10. Results from the variance inflation factor (VIF) analysis for all predictor variables. VIF value < 2 indicated that there was no multicollinearity across all predictors. The statistical value of food habits was based on the PCoA1 in a principal coordinates analysis (PCoA) for dietary categories (see the Method Details section for detailed descriptions). Body mass included substantial variation from 2.4 g in Gervais's Funnel-eared bats (*Nyctiellus lepidus*) to 23,500 kg in sperm whales (*Physeter macrocephalus*), which was addressed using a natural-log transformation.

Predictor	Imputed	VIF
Habitat	Yes	1.102
	No	1.118
Food habit	Yes	1.092
	No	1.101
Social organization	Yes	1.037
	No	1.023
Sexual size dimorphism (SSD)	Yes	1.055
	No	1.051
Body mass (log scale)	Yes	1.106
	No	1.101

Table S11. Phylogenetic covariance model comparison based on three evolutionary models (Brownian Motion [BM], Ornstein-Uhlenbeck [OU], and estimated Lambda [LA]) used in PGLS analysis. SOr, social organization; PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_*n*, number of harmonics per pulse; SSD, sexual size dimorphism. The statistical value of food habits was based on PCoA1 scores for dietary categories. Prior to analysis, body mass, PF, and DUR were log-transformed, and CV_{PF} and CV_{DUR} were ln(x+1) transformed.

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
Habitat	PF	Yes	BM	-526.619	1059.237	714.698	0
			OU	-504.167	1016.334	671.794	0
			LA	-168.27	344.539	0	1
		No	BM	-613.056	1232.113	706.692	0
			OU	-593.205	1194.409	668.988	0
			LA	-258.71	525.421	0	1
	DUR	Yes	BM	-1200.45	2406.9	769.391	0
			OU	-1177.872	2363.745	726.236	0
			LA	-814.755	1637.509	0	1
		No	BM	-1108.927	2223.854	691.933	0
			OU	-1087.78	2183.561	651.64	0
			LA	-761.96	1531.921	0	1
	CV _{PF}	Yes	BM	-1876.295	3758.589	1015.397	0
			OU	-1853.177	3714.354	971.161	0
			LA	-1367.596	2743.193	0	1
		No	BM	-1521.871	3049.741	952.143	0
			OU	-1501.83	3011.66	914.062	0
			LA	-1044.799	2097.598	0	1
	CV _{DUR}	Yes	BM	-1705.858	3417.717	1329.106	0
			OU	-1682.418	3372.837	1284.226	0
			LA	-1040.306	2088.611	0	1
		No	BM	-1406.054	2818.108	1219.282	0
			OU	-1384.603	2777.206	1178.379	0
			LA	-795.413	1598.826	0	1
	CT	Yes	BM	-350.287	706.575	769.938	0
			OU	-328.075	664.15	727.513	0
			LA	35.682	-63.363	0	1
		No	BM	-481.833	969.667	827.123	0
			OU	-459.836	927.672	785.128	0
			LA	-67.272	142.544	0	1
	Harm_ <i>n</i>	Yes	BM	-2880.948	5767.896	1491.185	0
			OU	-2857.412	5722.824	1446.113	0
			LA	-2134.355	4276.711	0	1
		No	BM	-2280.996	4567.992	1412.914	0
			OU	-2258.12	4524.24	1369.162	0
			LA	-1573.539	3155.078	0	1

Table S11. (Continued)

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
Food habit	PF	Yes	BM	-542.176	1090.352	737.302	0
			OU	-519.71	1047.419	694.37	0
			LA	-172.525	353.049	0	1
	DUR	No	BM	-636.334	1278.668	742.103	0
			OU	-616.472	1240.944	704.379	0
			LA	-264.282	536.565	0	1
		Yes	BM	-1199.467	2404.933	753.129	0
			OU	-1176.892	2361.784	709.98	0
			LA	-821.902	1651.804	0	1
	CV_{PF}	No	BM	-1100.239	2206.478	720.384	0
			OU	-1079.12	2166.241	680.146	0
			LA	-739.047	1486.095	0	1
		Yes	BM	-1874.003	3754.005	997.371	0
			OU	-1850.892	3709.785	953.151	0
			LA	-1374.317	2756.634	0	1
		No	BM	-1508.682	3023.363	921.96	0
			OU	-1488.698	2985.396	883.993	0
			LA	-1046.702	2101.403	0	1
	CV_{DUR}	Yes	BM	-1705.041	3416.081	1313.272	0
			OU	-1681.609	3371.218	1268.408	0
			LA	-1047.405	2102.81	0	1
		No	BM	-1398.408	2802.815	1185.774	0
			OU	-1376.99	2761.979	1144.938	0
			LA	-804.521	1617.042	0	1
	CT	Yes	BM	-348.966	703.932	801.831	0
			OU	-326.715	661.43	759.328	0
			LA	52.949	-97.898	0	1
		No	BM	-482.272	970.545	830.018	0
			OU	-460.256	928.512	787.986	0
			LA	-66.263	140.526	0	1
	Harm_n	Yes	BM	-2879.875	5765.749	1491.534	0
			OU	-2856.358	5720.716	1446.501	0
			LA	-2133.107	4274.215	0	1
		No	BM	-2267.274	4540.549	1405.392	0
			OU	-2244.438	4496.876	1361.719	0
			LA	-1563.579	3135.157	0	1

Table S11. (Continued)

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
SOr	PF	Yes	BM	-547.87	1101.74	744.227	0
			OU	-525.37	1058.739	701.226	0
			LA	-174.757	357.514	0	1
		No	BM	-546.664	1099.327	538.912	0
			OU	-527.156	1062.312	501.897	0
			LA	-276.208	560.415	0	1
	DUR	Yes	BM	-1200.762	2407.524	780.417	0
			OU	-1178.187	2364.373	737.267	0
			LA	-809.553	1627.106	0	1
		No	BM	-982.087	1970.175	603.47	0
			OU	-961.269	1930.539	563.834	0
			LA	-679.353	1366.705	0	1
	CV _{PF}	Yes	BM	-1875.376	3756.751	1000.87	0
			OU	-1852.269	3712.538	956.656	0
			LA	-1373.941	2755.881	0	1
		No	BM	-1366.707	2739.414	841.163	0
			OU	-1346.946	2701.893	803.642	0
			LA	-945.125	1898.251	0	1
	CV _{DUR}	Yes	BM	-1705.678	3417.355	1314.668	0
			OU	-1682.241	3372.481	1269.794	0
			LA	-1047.344	2102.687	0	1
		No	BM	-1268.126	2542.251	1119.244	0
			OU	-1246.945	2501.89	1078.883	0
			LA	-707.504	1423.007	0	1
	CT	Yes	BM	-348.911	703.822	766.206	0
			OU	-326.712	661.425	723.809	0
			LA	35.192	-62.384	0	1
		No	BM	-460.512	927.023	786.018	0
			OU	-438.723	885.445	744.441	0
			LA	-66.502	141.005	0	1
	Harm_ <i>n</i>	Yes	BM	-2880.837	5767.674	1493.099	0
			OU	-2857.303	5722.606	1448.03	0
			LA	-2133.288	4274.576	0	1
		No	BM	-2087.768	4181.535	1308.469	0
			OU	-2065.159	4138.317	1265.251	0
			LA	-1432.533	2873.066	0	1

Table S11. (Continued)

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
SSD	PF	Yes	BM	-545.52	1097.039	748.523	0
			OU	-523.014	1054.027	705.512	0
			LA	-170.258	348.516	0	1
		No	BM	-510.073	1026.146	512.647	0
			OU	-491.085	990.17	476.67	0
			LA	-252.75	513.499	0	1
	DUR	Yes	BM	-1200.756	2407.512	779.121	0
			OU	-1178.187	2364.374	735.983	0
			LA	-810.195	1628.391	0	1
		No	BM	-1031.965	2069.929	708.356	0
			OU	-1011.446	2030.893	669.319	0
			LA	-676.787	1361.574	0	1
	CV _{PF}	Yes	BM	-1876.789	3759.578	1003.192	0
			OU	-1853.674	3715.349	958.963	0
			LA	-1374.193	2756.386	0	1
		No	BM	-1336.476	2678.953	771.466	0
			OU	-1317.182	2642.364	734.878	0
			LA	-949.743	1907.486	0	1
	CV _{DUR}	Yes	BM	-1704.324	3414.648	1313.15	0
			OU	-1680.887	3369.774	1268.276	0
			LA	-1046.749	2101.498	0	1
		No	BM	-1283.378	2572.756	1120.735	0
			OU	-1262.574	2533.148	1081.126	0
			LA	-722.011	1452.022	0	1
	CT	Yes	BM	-350.364	706.729	770.548	0
			OU	-328.152	664.305	728.125	0
			LA	35.91	-63.82	0	1
		No	BM	-490.361	986.723	820.992	0
			OU	-468.889	945.777	780.047	0
			LA	-78.865	165.731	0	1
	Harm_ <i>n</i>	Yes	BM	-2880.689	5767.379	1490.674	0
			OU	-2857.153	5722.307	1445.602	0
			LA	-2134.352	4276.705	0	1
		No	BM	-2093.641	4193.282	1337.662	0
			OU	-2071.401	4150.801	1295.182	0
			LA	-1423.81	2855.62	0	1

Table S11. (Continued)

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
Body mass	PF	Yes	BM	-417.63	841.261	832.155	0
			OU	-395.244	798.488	789.382	0
			LA	-0.553	9.106	0	1
		No	BM	-502.707	1011.413	795.947	0
			OU	-483.093	974.187	758.72	0
			LA	-103.733	215.466	0	1
	DUR	Yes	BM	-1182.662	2371.325	828.494	0
			OU	-1160.168	2328.336	785.505	0
			LA	-767.415	1542.831	0	1
		No	BM	-1090.862	2187.725	693.616	0
			OU	-1069.811	2147.621	653.513	0
			LA	-743.054	1494.108	0	1
	CV _{PF}	Yes	BM	-1876.062	3758.125	1019.647	0
			OU	-1852.972	3713.944	975.466	0
			LA	-1365.239	2738.478	0	1
		No	BM	-1477.644	2961.287	912.115	0
			OU	-1457.679	2923.357	874.185	0
			LA	-1020.586	2049.172	0	1
	CV _{DUR}	Yes	BM	-1705.289	3416.578	1326.144	0
			OU	-1681.867	3371.734	1281.3	0
			LA	-1041.217	2090.435	0	1
		No	BM	-1390.954	2787.908	1217.731	0
			OU	-1369.529	2747.059	1176.882	0
			LA	-781.088	1570.176	0	1
	CT	Yes	BM	-346.444	698.888	761.018	0
			OU	-324.298	656.595	718.725	0
			LA	35.065	-62.13	0	1
		No	BM	-488.572	983.144	825.183	0
			OU	-466.642	941.283	783.323	0
			LA	-74.98	157.961	0	1
	Harm _n	Yes	BM	-2880.165	5766.331	1495.245	0
			OU	-2856.637	5721.275	1450.189	0
			LA	-2131.543	4271.086	0	1
		No	BM	-2238.839	4483.678	1373.103	0
			OU	-2216.006	4440.012	1329.437	0
			LA	-1551.287	3110.575	0	1

Table S11. (Continued)

Predictor	Parameter	Imputed	Covariance model	logLik	AIC	Delta AIC	AICw
Multi-predictor model	PF	Yes	BM	-384.822	783.644	781.56	0
			OU	-362.514	741.029	738.945	0
			LA	6.958	2.084	0	1
		No	BM	-301.709	617.418	395.418	0
			OU	-283.499	582.998	360.998	0
			LA	-103	222	0	1
	DUR	Yes	BM	-1179.493	2372.986	792.753	0
			OU	-1156.989	2329.978	749.745	0
			LA	-782.116	1580.233	0	1
		No	BM	-908.926	1831.852	605.707	0
			OU	-888.716	1793.432	567.287	0
			LA	-605.073	1226.145	0	1
	CV_{PF}	Yes	BM	-1871.634	3757.268	1021.777	0
			OU	-1848.543	3713.087	977.596	0
			LA	-1359.745	2735.491	0	1
		No	BM	-1189.923	2393.845	702.939	0
			OU	-1170.934	2357.869	666.962	0
			LA	-837.453	1690.906	0	1
	CV_{DUR}	Yes	BM	-1702.251	3418.502	1333.399	0
			OU	-1678.834	3373.668	1288.565	0
			LA	-1034.552	2085.103	0	1
		No	BM	-1174.161	2362.322	1138.024	0
			OU	-1153.549	2323.097	1098.799	0
			LA	-604.149	1224.298	0	1
	CT	Yes	BM	-341.435	696.871	788.321	0
			OU	-319.275	654.55	746	0
			LA	53.725	-91.451	0	1
		No	BM	-458.981	931.963	758.857	0
			OU	-437.761	891.521	718.415	0
			LA	-78.553	173.106	0	1
	Harm_n	Yes	BM	-2878.967	5771.934	1497.747	0
			OU	-2855.456	5726.912	1452.725	0
			LA	-2129.094	4274.187	0	1
		No	BM	-1914.401	3842.802	1242.379	0
			OU	-1892.368	3800.736	1200.313	0
			LA	-1292.211	2600.423	0	1

Table S12. Comprehensive summary of sensitivity analysis validation. ↑ represents fully validated PGLS results; ↗ represents partially validated PGLS results. Detailed statistical results can be found in Tables S13-S16 below.

Sensitivity analysis	Imputed	Parameter					
		PF	DUR	CV _{PF}	CV _{DUR}	CT	Harm_ <i>n</i>
(1) randomly selected records							
	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
(2) randomly selected species							
(i) sampling for all species							
50%	Yes	↑	↑	↑	↑	↑	↑
	No	↗	↑	↑	↑	↑	↑
75%	Yes	↗	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
90%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
95%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
(ii) sampling for each family							
50%	Yes	↑	↑	↑	↑	↑	↑
	No	↗	↑	↗	↑	↑	↑
75%	Yes	↗	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
90%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
95%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
(iii) sampling for each genus							
50%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
75%	Yes	↗	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
90%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑
95%	Yes	↑	↑	↑	↑	↑	↑
	No	↑	↑	↑	↑	↑	↑

Table S13. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²	
DUR	Yes	Habitat	30	0.034	0.023	1.451	0.152	0.356	>0.999	0.882	0.806	0.002	
				(0.004)	(0.001)	(0.159)	(0.04)	(0.349)	(0.001)	(0.004)	(0.012)	(0.001)	
		Food habit	72	-0.494	0.226	-2.19	0.031	2.825				0.004	
				(0.035)	(0.005)	(0.166)	(0.011)	(0.747)			(0.001)		
		Body mass	100	0.131	0.021	6.269	<0.001	36.889				0.029	
				(0.006)	(<0.001)	(0.29)	(<0.001)	(3.516)			(0.003)		
	No	Habitat	48	0.046	0.038	1.21	0.235	0.601	0.999	0.838	0.72	0.002	
				(0.008)	(0.001)	(0.198)	(0.076)	(0.349)	(<0.001)	(0.005)	(0.011)	(0.001)	
		Food habit	98	-0.74	0.314	-2.371	0.026	3.746				0.006	
				(0.09)	(0.017)	(0.354)	(0.028)	(1.604)			(0.002)		
		Body mass	100	0.154	0.027	5.74	<0.001	30.564				0.036	
				(0.011)	(0.001)	(0.304)	(<0.001)	(3.377)			(0.004)		
CV _{PF}	Yes	Habitat	100	0.095	0.037	2.548	0.017	4.627	0.999	0.477	0.427	0.005	
				(0.014)	(0.001)	(0.376)	(0.019)	(1.909)	(<0.001)	(0.013)	(0.014)	(0.001)	
		Body mass	100	0.124	0.032	3.866	<0.001	13.008				0.011	
				(0.011)	(0.001)	(0.341)	(<0.001)	(2.609)			(0.002)		
		No	Habitat	100	0.151	0.06	2.518	0.019	4.477	0.997	0.354	0.296	0.007
					(0.022)	(0.001)	(0.378)	(0.019)	(1.907)	(<0.001)	(0.014)	(0.014)	(0.002)
	Body mass		100	0.154	0.036	4.251	<0.001	16.026				0.021	
				(0.011)	(0.001)	(0.286)	(<0.001)	(2.378)			(0.003)		
	CV _{DUR}	Yes	Habitat	100	0.09	0.03	3.016	0.005	7.25	0.999	0.163	0.093	0.007
					(0.012)	(0.001)	(0.409)	(0.007)	(2.464)	(<0.001)	(0.012)	(0.015)	(0.002)
			Body mass	97	0.064	0.025	2.577	0.019	4.835				0.005
					(0.01)	(0.001)	(0.448)	(0.025)	(2.308)			(0.002)	
No		Habitat	100	0.157	0.046	3.424	0.001	9.806	<0.001	0.069	<0.001	0.014	
				(0.016)	(0.001)	(0.357)	(0.002)	(2.404)	(<0.001)	(0.006)	(<0.001)	(0.003)	
		Body mass	100	0.059	0.009	6.373	<0.001	37.967				0.046	
				(0.004)	(<0.001)	(0.417)	(<0.001)	(5.084)			(0.006)		

Table S13. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458	0.108	-4.229	< 0.001	15.79	0.999	0.924	0.905	0.013
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Food habit	100	-0.566	0.151	-3.769	0.001	12.324	0.999	0.906	0.88	0.015
				(0.053)	(0.006)	(0.45)	(0.001)	(3.242)	(<0.001)	(0.005)	(0.02)	(0.003)
		SOr	2	0.038	0.02	1.884	0.06	1.56				0.004
				(0.001)	(<0.001)	(0.013)	(0.001)	(0.047)				(<0.001)
Harm_n	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	45	0.029	0.011	2.745	0.02	6.299	>0.999	0.927	0.891	0.006
				(0.01)	(0.003)	(0.895)	(0.022)	(6.599)	(<0.001)	(0.054)	(0.052)	(0.005)
		Food habit	30	-0.349	0.157	-2.248	0.046	3.421				0.004
				(0.089)	(0.016)	(0.617)	(0.043)	(3.191)				(0.002)
		SOr	5	0.032	0.015	1.993	0.05	2.011				0.003
				(0.007)	(0.002)	(0.194)	(0.02)	(0.793)				(0.001)
	No	SSD	29	0.178	0.166	1.567	0.01	7.683				0.007
				(0.514)	(0.038)	(2.739)	(0.019)	(4.272)				(0.003)
		Body mass	80	0.045	0.012	3.664	0.005	12.376				0.011
				(0.018)	(0.002)	(1.016)	(0.011)	(7.802)				(0.006)
		Habitat	63	0.108	0.053	2.037	0.069	2.523	0.999	0.832	0.694	0.01
				(0.028)	(0.003)	(0.519)	(0.069)	(2.063)	(<0.001)	(0.019)	(0.05)	(0.005)
CV _{PF}	Yes	Food habit	85	-0.895	0.383	-2.345	0.033	3.717				0.013
				(0.163)	(0.024)	(0.446)	(0.04)	(2.057)				(0.005)
		SSD	9	-1.65	0.645	-2.556	0.014	4.636				0.016
				(0.222)	(0.041)	(0.297)	(0.01)	(1.542)				(0.004)
		Body mass	92	0.092	0.034	2.714	0.014	5.596				0.017
				(0.018)	(0.001)	(0.492)	(0.017)	(2.701)				(0.006)
	No	Habitat	64	0.056	0.023	2.35	0.025	4.896	0.999	0.715	0.663	0.005
				(0.025)	(0.003)	(1.184)	(0.032)	(3.081)	(<0.001)	(0.059)	(0.04)	(0.002)
		Food habit	4	0.551	0.237	2.288	0.042	8.209				0.008
				(0.61)	(0.007)	(2.582)	(0.076)	(7.345)				(0.005)
		SOr	3	-0.068	0.024	-2.883	0.005	6.344				0.006
				(0.004)	(0.001)	(0.234)	(0.003)	(1.365)				(0.001)
CV _{PF}	No	SSD	4	0.695	0.314	2.284	0.042	3.507				0.004
				(0.12)	(0.055)	(0.623)	(0.047)	(2.953)				(0.002)
		Body mass	78	0.09	0.021	4.293	0.003	17.883				0.015
				(0.028)	(0.002)	(1.269)	(0.01)	(9.447)				(0.007)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV_{DUR}	No	Habitat	67	0.164 (0.035)	0.074 (0.004)	2.212 (0.465)	0.046 (0.052)	3.133 (1.948)	0.998 (<0.001)	0.363 (0.031)	0.298 (0.031)	0.012 (0.005)
		Food habit	3	1.106 (0.161)	0.439 (0.021)	2.535 (0.483)	0.017 (0.015)	4.579 (2.548)				0.015 (0.006)
		SSD	2	0.95 (0.263)	0.837 (0.082)	1.156 (0.427)	0.27 (0.175)	0.701 (0.799)				0.004 (0.002)
		Body mass	100	0.155 (0.023)	0.042 (0.002)	3.727 (0.577)	0.001 (0.006)	12.058 (4.177)				0.032 (0.009)
	Yes	Habitat	84	0.054 (0.014)	0.018 (0.003)	2.965 (0.642)	0.012 (0.023)	7.187 (3.908)	0.999 (<0.001)	0.418 (0.058)	0.357 (0.064)	0.007 (0.003)
		Food habit	1	0.651	0.193	3.379	0.001	9.402	0.999	0.418	0.357	0.009
		SOr	2	-0.05 (0.009)	0.02 (0.002)	-2.378 (0.186)	0.019 (0.009)	3.675 (0.882)	0.999 (<0.001)	0.418 (0.058)	0.357 (0.064)	0.005 (0.001)
		SSD	17	0.514 (0.108)	0.225 (0.047)	2.361 (0.642)	0.036 (0.032)	3.958 (3.515)				0.005 (0.003)
	No	Body mass	89	0.055 (0.024)	0.016 (0.001)	3.366 (1.562)	0.009 (0.037)	11.709 (6.509)				0.01 (0.005)
		Habitat	100	0.172 (0.041)	0.056 (0.003)	3.058 (0.728)	0.012 (0.024)	7.819 (4.491)	<0.001 (<0.001)	0.09 (0.023)	<0.001 (<0.001)	0.023 (0.01)
		Food habit	11	0.309 (0.071)	0.156 (0.013)	1.978 (0.462)	0.067 (0.05)	2.127 (2.036)				0.01 (0.005)
		SSD	19	0.756 (0.413)	0.664 (0.05)	1.136 (0.599)	0.327 (0.235)	1.346 (0.913)				0.004 (0.004)
		Body mass	100	0.051 (0.008)	0.011 (0.001)	4.777 (0.794)	<0.001 (0.001)	20.92 (7.161)				0.053 (0.016)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458	0.108	-4.229	< 0.001	15.79	0.999	0.924	0.905	0.013
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	
	No	Food habit	100	-0.55	0.139	-3.965	< 0.001	13.627	0.999	0.917	0.901	0.016
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Harm_n	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006
				(<0.001)	(<0.001)	(<0.001)	(< 0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
(2) 75% random for all species												
PF	Yes	Habitat	96	-0.023	0.011	-2.166	0.058	3.149	0.999	0.853	0.842	0.004
				(0.006)	(0.001)	(0.598)	(0.069)	(2.926)	(<0.001)	(0.011)	(0.013)	(0.002)
		Food habit	71	0.191	0.104	1.849	0.088	1.788				0.003
				(0.04)	(0.003)	(0.403)	(0.093)	(1.141)				(0.001)
		SOr	7	0.022	0.013	1.749	0.215	2.723				0.003
				(0.012)	(0.001)	(1.027)	(0.346)	(2.821)				(0.003)
		SSD	91	-0.296	0.153	-1.941	0.097	2.472				0.003
				(0.096)	(0.013)	(0.626)	(0.113)	(2.308)				(0.002)
		Body mass	100	-0.165	0.01	-17.092	< 0.001	263.944				0.181
				(0.018)	(0.001)	(1.363)	(<0.001)	(36.056)				(0.023)
	No	Habitat	100	-0.055	0.021	-2.588	0.026	5.079	0.999	0.786	0.773	0.011
				(0.012)	(0.001)	(0.586)	(0.048)	(2.975)	(<0.001)	(0.012)	(0.014)	(0.005)
		Food habit	75	0.184	0.17	1.092	0.307	0.92				0.002
				(0.061)	(0.007)	(0.377)	(0.175)	(0.525)				(0.001)
		SOr	8	0.06	0.025	2.409	0.025	3.99				0.01
				(0.011)	(0.001)	(0.436)	(0.021)	(2.151)				(0.004)
		SSD	94	-0.378	0.247	-1.536	0.16	1.097				0.004
				(0.107)	(0.012)	(0.447)	(0.129)	(1.08)				(0.002)
		Body mass	100	-0.225	0.015	-14.999	< 0.001	192.705				0.258

(0.008) (<0.001) (0.672) (<0.001) (15.403) (0.016)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	69	0.039	0.019	2.131	0.065	3.131	0.999	0.91	0.845	0.004
				(0.01)	(0.003)	(0.706)	(0.066)	(4.037)	(<0.001)	(0.015)	(0.019)	(0.003)
		Food habit	75	-0.444	0.189	-2.357	0.033	3.817				0.004
				(0.087)	(0.005)	(0.468)	(0.049)	(2.104)				(0.002)
		SOr	3	0.035	0.019	1.786	0.082	1.248				0.003
				(0.006)	(0.001)	(0.267)	(0.05)	(0.918)				(0.001)
	No	SSD	11	0.249	0.225	1.584	0.01	7.487				0.007
				(0.659)	(0.044)	(2.773)	(0.012)	(5.378)				(0.004)
		Body mass	98	0.087	0.017	5.13	0.001	24.95				0.02
				(0.019)	(0.002)	(0.933)	(0.006)	(8.637)				(0.006)
CV _{PF}	Yes	Habitat	72	0.072	0.041	1.749	0.104	1.425	0.999	0.848	0.725	0.005
				(0.017)	(0.002)	(0.411)	(0.074)	(1.358)	(<0.001)	(0.009)	(0.016)	(0.002)
		Food habit	95	-0.797	0.329	-2.427	0.024	4.054				0.009
				(0.119)	(0.017)	(0.4)	(0.025)	(1.943)				(0.003)
		SSD	1	-1.501	0.548	-2.742	0.006	5.533	0.999	0.848	0.725	0.012
	No	Body mass	100	0.124	0.028	4.361	<0.001	17.061	0.999	0.848	0.725	0.028
				(0.015)	(0.001)	(0.468)	(<0.001)	(3.993)	(<0.001)	(0.009)	(0.016)	(0.006)
		Habitat	99	0.085	0.029	2.942	0.009	6.898	0.999	0.602	0.556	0.007
				(0.015)	(0.001)	(0.51)	(0.017)	(2.938)	(<0.001)	(0.019)	(0.021)	(0.002)
		Body mass	100	0.112	0.026	4.348	<0.001	17.175				0.014
				(0.015)	(0.001)	(0.62)	(<0.001)	(5.644)				(0.004)
	No	Habitat	100	0.164	0.061	2.716	0.016	5.609	0.998	0.392	0.329	0.012
				(0.03)	(0.002)	(0.5)	(0.025)	(2.704)	(<0.001)	(0.021)	(0.02)	(0.004)
		Body mass	100	0.155	0.037	4.258	<0.001	16.18				0.028
				(0.017)	(0.001)	(0.484)	(<0.001)	(4.181)				(0.006)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV_{DUR}	Yes	Habitat	99	0.074 (0.013)	0.023 (0.001)	3.211 (0.569)	0.005 (0.012)	8.608 (3.603)	0.999 (<0.001)	0.288 (0.026)	0.212 (0.03)	0.008 (0.003)
		SSD	4	0.674 (0.107)	0.322 (0.004)	2.091 (0.329)	0.043 (0.023)	2.458 (1.478)				0.004 (0.001)
		Body mass	97	0.067 (0.011)	0.02 (0.001)	3.397 (0.573)	0.003 (0.006)	9.836 (3.93)				0.009 (0.003)
	No	Habitat	100	0.172 (0.022)	0.046 (0.001)	3.735 (0.468)	0.001 (0.002)	12.071 (3.406)	<0.001 (<0.001)	0.089 (0.014)	<0.001 (<0.001)	0.022 (0.005)
		Food habit	10	0.284 (0.032)	0.133 (0.006)	2.139 (0.257)	0.039 (0.032)	2.646 (1.023)				0.007 (0.002)
		SSD	13	0.453 (0.172)	0.573 (0.02)	0.785 (0.28)	0.449 (0.155)	1.307 (0.485)				0.001 (0.001)
		Body mass	100	0.054 (0.006)	0.009 (<0.001)	5.977 (0.75)	<0.001 (<0.001)	33.395 (8.383)				0.054 (0.012)
	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)
		Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
(3) 90% random for all species												
PF	Yes	Habitat	100	-0.024	0.011	-2.093	0.045	2.486	0.999	0.843	0.83	0.003
				(0.004)	(0.001)	(0.31)	(0.03)	(1.339)	(<0.001)	(0.006)	(0.009)	(0.001)
		Food habit	85	0.18	0.108	1.67	0.108	0.986				0.002
				(0.03)	(0.003)	(0.292)	(0.061)	(0.916)				(0.001)
		SOr	1	0.022	0.014	1.587	0.113	0.525	0.999	0.843	0.83	0.002
		SSD	98	-0.284	0.163	-1.742	0.125	1.765	0.999	0.843	0.83	0.002
	No			(0.088)	(0.004)	(0.535)	(0.124)	(1.478)	(<0.001)	(0.006)	(0.009)	(0.001)
		Body mass	100	-0.19	0.01	-18.678	<0.001	308.969				0.209
				(0.005)	(<0.001)	(0.632)	(<0.001)	(18.572)				(0.011)
		Habitat	100	-0.052	0.019	-2.696	0.012	5.408	0.999	0.796	0.782	0.01
				(0.007)	(0.001)	(0.358)	(0.015)	(1.873)	(<0.001)	(0.007)	(0.008)	(0.002)
		Food habit	91	0.169	0.157	1.079	0.3	0.863				0.002
DUR	Yes			(0.043)	(0.005)	(0.288)	(0.135)	(0.445)				(0.001)
		SOr	17	0.05	0.022	2.26	0.03	3.212				0.008
				(0.006)	(0.001)	(0.297)	(0.019)	(1.377)				(0.002)
		SSD	95	-0.307	0.224	-1.369	0.195	0.755				0.003
				(0.08)	(0.006)	(0.351)	(0.103)	(0.752)				(0.001)
		Body mass	100	-0.229	0.014	-16.523	<0.001	233.292				0.262
	No			(0.005)	(<0.001)	(0.457)	(<0.001)	(11.902)				(0.01)
		Habitat	84	0.038	0.021	1.846	0.081	1.598	0.999	0.903	0.83	0.003
				(0.008)	(0.001)	(0.357)	(0.056)	(1.293)	(<0.001)	(0.007)	(0.013)	(0.001)
		Food habit	97	-0.46	0.204	-2.271	0.031	3.269				0.004
				(0.056)	(0.008)	(0.326)	(0.025)	(1.478)				(0.001)
		Body mass	100	0.109	0.019	5.838	<0.001	31.895				0.025
				(0.008)	(<0.001)	(0.401)	(<0.001)	(4.597)				(0.003)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV _{PF}	No	Habitat	90	0.057	0.037	1.546	0.138	0.817	0.999	0.854	0.737	0.003
				(0.011)	(0.001)	(0.298)	(0.073)	(0.68)	(<0.001)	(0.006)	(0.01)	(0.001)
		Food habit	100	-0.774	0.307	-2.525	0.015	4.45				0.008
				(0.069)	(0.016)	(0.269)	(0.012)	(1.343)				(0.002)
		Body mass	100	0.136	0.026	5.165	<0.001	24.483				0.032
				(0.011)	(0.001)	(0.351)	(<0.001)	(3.497)				(0.004)
	Yes	Habitat	100	0.1	0.031	3.175	0.003	8.22	0.999	0.553	0.503	0.008
				(0.012)	(0.001)	(0.398)	(0.004)	(2.497)	(<0.001)	(0.012)	(0.014)	(0.002)
		Body mass	100	0.118	0.028	4.258	<0.001	16.219				0.014
				(0.011)	(0.001)	(0.424)	(<0.001)	(3.476)				(0.003)
		Habitat	100	0.171	0.055	3.108	0.003	7.746	0.998	0.401	0.338	0.012
				(0.019)	(0.001)	(0.337)	(0.004)	(2.073)	(<0.001)	(0.011)	(0.012)	(0.003)
CV _{DUR}	No	Body mass	100	0.156	0.034	4.527	<0.001	18.413				0.026
				(0.011)	(0.001)	(0.348)	(<0.001)	(3.036)				(0.004)
		Habitat	100	0.085	0.025	3.44	0.001	9.93	0.999	0.236	0.157	0.009
				(0.009)	(0.001)	(0.356)	(0.002)	(2.441)	(<0.001)	(0.016)	(0.018)	(0.002)
		SSD	2	0.651	0.347	1.877	0.062	1.532				0.002
				(0.013)	(0.011)	(0.101)	(0.013)	(0.38)				(0.001)
	Yes	Body mass	99	0.066	0.021	3.115	0.005	7.931				0.008
				(0.01)	(0.001)	(0.497)	(0.007)	(3.131)				(0.002)
		Habitat	100	0.173	0.042	4.148	<0.001	15.166	<0.001	0.089	<0.001	0.022
				(0.012)	(0.001)	(0.296)	(<0.001)	(2.423)	(<0.001)	(0.008)	(<0.001)	(0.003)
		SSD	5	0.274	0.525	0.523	0.605	1.701				<0.001
				(0.088)	(0.009)	(0.172)	(0.121)	(0.17)				(<0.001)
	No	Body mass	100	0.055	0.008	6.614	<0.001	40.846				0.054
				(0.003)	(<0.001)	(0.413)	(<0.001)	(5.182)				(0.006)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)
	No	Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)
(4) 95% random for all species												
PF	Yes	Habitat	100	-0.025 (0.003)	0.012 (<0.001)	-2.124 (0.246)	0.04 (0.026)	2.58 (1.024)	0.999 (<0.001)	0.839 (0.003)	0.825 (0.006)	0.003 (0.001)
		Food habit	88	0.175 (0.019)	0.109 (0.001)	1.604 (0.177)	0.114 (0.037)	0.653 (0.539)				0.002 (<0.001)
		SSD	100	-0.319 (0.045)	0.166 (0.002)	-1.926 (0.271)	0.063 (0.042)	1.822 (0.984)				0.003 (0.001)
		Body mass	100	-0.197 (0.003)	0.01 (<0.001)	-19.129 (0.318)	<0.001 (<0.001)	322.315 (9.564)				0.217 (0.006)
		Habitat	100	-0.053 (0.005)	0.019 (0.001)	-2.807 (0.299)	0.007 (0.007)	5.979 (1.675)	0.999 (<0.001)	0.797 (0.005)	0.782 (0.006)	0.01 (0.002)
		Food habit	99	0.159 (0.028)	0.154 (0.004)	1.038 (0.186)	0.307 (0.094)	0.881 (0.365)				0.001 (0.001)
	No	SOr	11	0.049 (0.006)	0.022 (<0.001)	2.232 (0.244)	0.029 (0.014)	3.061 (1.151)				0.007 (0.002)
		SSD	100	-0.322 (0.056)	0.218 (0.005)	-1.478 (0.256)	0.152 (0.068)	0.586 (0.593)				0.003 (0.001)
		Body mass	100	-0.229 (0.003)	0.013 (0.001)	-16.892 (0.291)	<0.001 (<0.001)	244.141 (7.852)				0.26 (0.006)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	83	0.038	0.021	1.804	0.082	1.358	>0.999	0.901	0.827	0.003
				(0.007)	(0.001)	(0.284)	(0.044)	(1.05)	(0.001)	(0.006)	(0.011)	(0.001)
		Food habit	100	-0.462	0.208	-2.228	0.033	3.061				0.004
				(0.053)	(0.007)	(0.308)	(0.025)	(1.375)				(0.001)
		Body mass	100	0.114	0.019	6.007	<0.001	33.782				0.027
				(0.005)	(<0.001)	(0.288)	(<0.001)	(3.402)				(0.002)
	No	Habitat	90	0.054	0.036	1.509	0.143	0.627	0.999	0.857	0.743	0.003
				(0.009)	(0.001)	(0.248)	(0.063)	(0.573)	(<0.001)	(0.005)	(0.009)	(0.001)
		Food habit	100	-0.754	0.303	-2.496	0.016	4.292				0.007
				(0.059)	(0.016)	(0.234)	(0.014)	(1.144)				(0.001)
		Body mass	100	0.139	0.026	5.419	<0.001	27.088				0.034
				(0.01)	(0.001)	(0.309)	(<0.001)	(3.253)				(0.004)
CV_{PF}	Yes	Habitat	100	0.103	0.032	3.205	0.002	8.324	0.999	0.539	0.487	0.008
				(0.008)	(<0.001)	(0.262)	(0.001)	(1.712)	(<0.001)	(0.007)	(0.008)	(0.001)
		Body mass	100	0.12	0.028	4.28	<0.001	16.312				0.014
	No	Habitat	100	0.172	0.054	3.204	0.002	8.297	0.998	0.404	0.342	0.012
				(0.013)	(0.001)	(0.243)	(0.002)	(1.531)	(<0.001)	(0.007)	(0.007)	(0.002)
		Body mass	100	0.155	0.034	4.593	<0.001	18.946				0.025
CV_{DUR}	Yes	Habitat	100	0.087	0.025	3.455	0.001	9.992	0.999	0.217	0.135	0.009
				(0.008)	(0.001)	(0.295)	(0.002)	(1.98)	(<0.001)	(0.013)	(0.012)	(0.002)
		Body mass	100	0.069	0.021	3.219	0.003	8.51				0.008
				(0.008)	(<0.001)	(0.415)	(0.004)	(2.641)				(0.002)
	No	Habitat	100	0.172	0.041	4.236	<0.001	15.858	<0.001	0.088	<0.001	0.022
				(0.009)	(0.001)	(0.228)	(<0.001)	(1.894)	(<0.001)	(0.005)	(<0.001)	(0.002)
		SSD	1	0.331	0.497	0.666	0.506	1.554	<0.001	0.088	<0.001	0.001
		Body mass	100	0.055	0.008	6.816	<0.001	43.416	<0.001	0.088	<0.001	0.055
				(0.002)	(<0.001)	(0.307)	(<0.001)	(3.968)	(<0.001)	(0.005)	(<0.001)	(0.005)

Table S14. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)
	No	Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)

Table S15. Summary of statistical results from multi-predictor (multivariate) PGLS analysis testing echolocation call designs based on 100 random samplings of 50%, 75%, 90%, and 95% of species from each echolocating family. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_n, number of harmonics per pulse; SSD, sexual size dimorphism; SOr, social organization. N, the number of times the predictor was entered into the model. The statistical value of food habits was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, while CV_{PF} and CV_{DUR} were transformed by using ln(x+1) transformations. Statistical results represent the mean for each predictor entered into the model, with the standard error (SE) in parentheses. *P*-values in bold indicate significant differences ($P < 0.05$).

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
(1) 50% random for each family												
PF	Yes	Habitat	79	-0.02 (0.007)	0.008 (0.002)	-2.832 (1.246)	0.045 (0.072)	7.618 (8.496)	>0.999 (<0.001)	0.881 (0.017)	0.875 (0.019)	0.007 (0.006)
		Food habit	43	0.14 (0.332)	0.093 (0.006)	1.48 (3.536)	0.052 (0.094)	12.377 (17.352)				0.011 (0.013)
		SOr	22	0 (0.027)	0.01 (0.001)	0.032 (2.95)	0.053 (0.114)	6.53 (4.397)				0.006 (0.003)
		SSD	67	-0.276 (0.098)	0.119 (0.026)	-2.377 (0.867)	0.053 (0.068)	4.479 (5.13)				0.005 (0.004)
		Body mass	100	-0.099 (0.036)	0.008 (0.001)	-12.685 (3.011)	<0.001 (<0.001)	156.699 (66.493)				0.111 (0.044)
		No	Habitat	93	-0.055 (0.019)	0.026 (0.002)	-2.086 (0.71)	0.087 (0.129)	3.124 (2.805)	0.999 (<0.001)	0.767 (0.017)	0.756 (0.019)
	Food habit		37	0.216 (0.068)	0.193 (0.011)	1.128 (0.374)	0.29 (0.165)	0.895 (0.528)				0.003 (0.002)
	SOr		6	0.066 (0.021)	0.03 (0.001)	2.181 (0.684)	0.078 (0.147)	3.57 (1.705)				0.012 (0.005)
	SSD		91	-0.499 (0.198)	0.294 (0.018)	-1.7 (0.679)	0.16 (0.185)	1.998 (1.916)				0.007 (0.005)
	Body mass		100	-0.219 (0.013)	0.017 (0.001)	-12.688 (0.787)	<0.001 (<0.001)	137.495 (15.117)				0.26 (0.022)

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	54	0.031	0.011	2.882	0.018	7.005	>0.999	0.928	0.891	0.007
				(0.008)	(0.004)	(0.854)	(0.026)	(5.566)	(<0.001)	(0.043)	(0.043)	(0.004)
		Food habit	31	-0.433	0.162	-2.678	0.021	5.664				0.006
				(0.117)	(0.013)	(0.716)	(0.023)	(4.263)				(0.003)
		SOr	10	0.03	0.016	1.899	0.069	1.715				0.003
				(0.006)	(0.001)	(0.339)	(0.041)	(1.392)				(0.001)
	No	SSD	20	0.287	0.174	1.921	0.014	8.643				0.008
				(0.487)	(0.031)	(2.712)	(0.025)	(7.081)				(0.005)
		Body mass	80	0.048	0.013	3.85	0.005	14.189				0.012
				(0.018)	(0.002)	(1.219)	(0.01)	(10.515)				(0.008)
		Habitat	74	0.103	0.052	1.998	0.072	2.368	0.999	0.832	0.69	0.009
				(0.027)	(0.003)	(0.516)	(0.069)	(2.123)	(<0.001)	(0.011)	(0.029)	(0.005)
CV _{PF}	Yes	Food habit	83	-0.887	0.377	-2.354	0.032	3.761				0.012
				(0.172)	(0.02)	(0.442)	(0.038)	(2.046)				(0.004)
		SSD	6	-1.375	0.607	-2.265	0.034	3.292				0.012
				(0.254)	(0.031)	(0.408)	(0.027)	(1.882)				(0.004)
		Body mass	98	0.096	0.033	2.885	0.011	6.609				0.018
				(0.019)	(0.001)	(0.557)	(0.018)	(3.242)				(0.007)
	No	Habitat	75	0.062	0.025	2.486	0.032	4.659	0.999	0.687	0.64	0.005
				(0.016)	(0.002)	(0.666)	(0.071)	(3.124)	(<0.001)	(0.052)	(0.035)	(0.002)
		Food habit	1	0.223	0.234	0.954	0.34	1.087	0.999	0.687	0.64	0.001
		SOr	3	-0.02	0.03	-0.771	0.029	2.78	0.999	0.687	0.64	0.004
				(0.078)	(0.006)	(2.504)	(0.005)	(0.328)	(<0.001)	(0.052)	(0.035)	(0.001)
	No	SSD	2	0.644	0.356	1.809	0.074	1.297				0.002
				(0.055)	(0.008)	(0.196)	(0.03)	(0.709)				(0.001)
	No	Body mass	92	0.1	0.022	4.549	0.005	19.642				0.016
				(0.024)	(0.001)	(1.044)	(0.044)	(9.045)				(0.007)

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV _{DUR}	No	Habitat	69	0.152	0.072	2.106	0.059	2.768	0.998	0.365	0.301	0.01
				(0.04)	(0.003)	(0.546)	(0.055)	(2.539)	(<0.001)	(0.03)	(0.029)	(0.006)
		SOr	1	0.159	0.081	1.957	0.051	1.851	0.998	0.365	0.301	0.009
		SSD	2	1.015	0.827	1.216	0.235	0.533	0.998	0.365	0.301	0.004
				(0.332)	(0.064)	(0.308)	(0.117)	(0.654)	(<0.001)	(0.03)	(0.029)	(0.002)
	Yes	Body mass	100	0.159	0.041	3.901	0.001	13.368				0.033
				(0.024)	(0.001)	(0.584)	(0.003)	(4.378)				(0.009)
		Habitat	89	0.058	0.019	2.959	0.017	7.379	0.999	0.395	0.335	0.007
				(0.016)	(0.002)	(0.799)	(0.033)	(4.906)	(<0.001)	(0.046)	(0.055)	(0.004)
		Food habit	1	0.49	0.207	2.367	0.018	3.608	0.999	0.395	0.335	0.004
		SOr	1	-0.049	0.024	-2.056	0.04	2.233				0.003
		SSD	17	0.528	0.254	2.04	0.029	3.59	0.999	0.395	0.335	0.004
				(0.289)	(0.04)	(1.231)	(0.023)	(1.926)	(<0.001)	(0.046)	(0.055)	(0.001)
		Body mass	88	0.057	0.017	3.291	0.009	10.384				0.009
				(0.021)	(0.001)	(1.271)	(0.022)	(6.158)				(0.005)
CT	No	Habitat	99	0.177	0.055	3.21	0.006	8.585	<0.001	0.089	<0.001	0.024
				(0.033)	(0.002)	(0.587)	(0.012)	(3.715)	(<0.001)	(0.019)	(<0.001)	(0.008)
		Food habit	14	0.33	0.154	2.146	0.04	2.717				0.011
				(0.045)	(0.005)	(0.314)	(0.029)	(1.352)				(0.003)
		SSD	21	0.637	0.652	0.968	0.368	0.998				0.003
				(0.274)	(0.047)	(0.393)	(0.195)	(0.655)				(0.002)
	Yes	Body mass	100	0.052	0.011	4.841	<0.001	21.429				0.052
				(0.007)	(0.001)	(0.709)	(<0.001)	(6.615)				(0.014)
		Food habit	100	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.905	0.013
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Food habit	100	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
Harm_ <i>n</i>	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
(2) 75% random for each family												
PF	Yes	Habitat	99	-0.022	0.011	-2.069	0.065	2.676	0.999	0.854	0.844	0.003
				(0.005)	(0.001)	(0.514)	(0.083)	(2.065)	(<0.001)	(0.01)	(0.012)	(0.002)
		Food habit	65	0.181	0.105	1.733	0.141	1.97				0.003
				(0.08)	(0.004)	(0.739)	(0.179)	(4.035)				(0.003)
		SOr	5	0.011	0.013	0.822	0.28	1.034				0.001
				(0.015)	(0.001)	(1.22)	(0.295)	(0.669)				(0.001)
		SSD	86	-0.296	0.155	-1.91	0.1	2.315				0.003
				(0.092)	(0.008)	(0.594)	(0.112)	(2.016)				(0.002)
	Body mass	100	-0.17	0.01	-17.469	<0.001	274.24				0.187	
			(0.013)	(<0.001)	(1.136)	(<0.001)	(31.527)				(0.02)	
	No	Habitat	100	-0.052	0.021	-2.432	0.033	4.242	0.999	0.789	0.776	0.009
				(0.012)	(0.001)	(0.535)	(0.06)	(2.506)	(<0.001)	(0.011)	(0.012)	(0.004)
		Food habit	75	0.181	0.169	1.08	0.316	0.923				0.002
				(0.064)	(0.008)	(0.405)	(0.195)	(0.591)				(0.001)
		SOr	18	0.056	0.024	2.348	0.025	3.64				0.009
				(0.008)	(0.001)	(0.332)	(0.018)	(1.615)				(0.003)
SSD		92	-0.359	0.242	-1.481	0.191	1.285				0.004	
			(0.13)	(0.012)	(0.533)	(0.166)	(1.114)				(0.002)	
Body mass	100	-0.228	0.015	-15.379	<0.001	201.827				0.264		
		(0.007)	(0.001)	(0.605)	(<0.001)	(14.352)				(0.014)		

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	81	0.04	0.019	2.159	0.054	3.009	0.999	0.908	0.839	0.004
				(0.009)	(0.003)	(0.563)	(0.052)	(2.714)	(<0.001)	(0.008)	(0.016)	(0.002)
		Food habit	77	-0.453	0.19	-2.383	0.031	3.933				0.004
				(0.089)	(0.005)	(0.485)	(0.039)	(2.395)				(0.002)
		SOr	2	0.038	0.02	1.887	0.075	1.689				0.003
				(0.008)	(0.001)	(0.494)	(0.069)	(1.865)				(0.001)
	No	SSD	11	0.137	0.229	1.044	0.019	4.416				0.005
				(0.611)	(0.047)	(2.42)	(0.019)	(2.156)				(0.002)
		Body mass	100	0.091	0.017	5.281	0.001	26.467				0.021
				(0.019)	(0.001)	(0.917)	(0.004)	(8.715)				(0.006)
CV_{PF}	Yes	Habitat	77	0.071	0.041	1.73	0.113	1.461	0.999	0.849	0.726	0.005
				(0.019)	(0.002)	(0.451)	(0.085)	(1.459)	(<0.001)	(0.008)	(0.015)	(0.003)
		Food habit	98	-0.773	0.328	-2.368	0.027	3.763				0.008
				(0.114)	(0.018)	(0.386)	(0.027)	(1.846)				(0.003)
		SSD	3	-1.416	0.496	-2.856	0.005	6.194				0.013
				(0.124)	(0.017)	(0.234)	(0.004)	(1.296)				(0.002)
	No	Body mass	100	0.127	0.028	4.525	<0.001	18.497				0.029
				(0.015)	(0.001)	(0.481)	(<0.001)	(4.279)				(0.006)
		Habitat	99	0.088	0.029	3.005	0.008	7.283	0.999	0.591	0.544	0.007
				(0.015)	(0.001)	(0.517)	(0.013)	(3.1)	(<0.001)	(0.018)	(0.019)	(0.002)
	No	Body mass	100	0.114	0.026	4.386	<0.001	17.426				0.014
				(0.013)	(0.001)	(0.547)	(<0.001)	(4.822)				(0.004)
		Habitat	100	0.165	0.06	2.738	0.015	5.746	0.998	0.392	0.328	0.012
				(0.031)	(0.001)	(0.504)	(0.031)	(2.748)	(<0.001)	(0.016)	(0.015)	(0.004)
		Body mass	100	0.156	0.036	4.319	<0.001	16.643				0.028
				(0.015)	(0.001)	(0.42)	(<0.001)	(3.595)				(0.005)

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²		
CV _{DUR}	Yes	Habitat	100	0.078	0.023	3.364	0.003	9.614	0.999	0.278	0.2	0.009		
				(0.013)	(0.001)	(0.575)	(0.006)	(3.894)	(<0.001)	(0.022)	(0.021)	(0.003)		
		SSD	3	0.668	0.324	2.064	0.039	2.266				0.003		
				(0.008)	(0.01)	(0.045)	(0.004)	(0.187)				(<0.001)		
		Body mass	100	0.067	0.02	3.362	0.005	9.696				0.009		
				(0.013)	(0.001)	(0.654)	(0.013)	(4.311)				(0.003)		
	No	Habitat	100	0.175	0.046	3.832	<0.001	12.811	<0.001	0.091	<0.001	0.023		
				(0.023)	(0.001)	(0.487)	(0.001)	(3.71)	(<0.001)	(0.01)	(<0.001)	(0.006)		
		Food habit	6	0.266	0.127	2.093	0.039	2.417				0.007		
				(0.021)	(0.003)	(0.171)	(0.017)	(0.7)				(0.001)		
		SSD	14	0.391	0.549	0.707	0.497	1.416				0.001		
				(0.17)	(0.021)	(0.294)	(0.179)	(0.436)				(0.001)		
CT	Yes	Food habit	100	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.905	0.013		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)		
		Food habit	100	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)		
		No	Food habit	100	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016	
					(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	
	Harm_n		Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004	
					(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	
			Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006	
					(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	
		(3) 90% random for each family												
		PF	Yes	Habitat	100	-0.024	0.011	-2.107	0.046	2.583	0.999	0.843	0.831	0.003
(0.004)	(0.001)					(0.341)	(0.041)	(1.395)	(<0.001)	(0.006)	(0.009)	(0.001)		
Food habit	79			0.168	0.109	1.547	0.135	0.722				0.002		
				(0.027)	(0.003)	(0.263)	(0.079)	(0.545)				(0.001)		
SOr	3			0.021	0.015	1.472	0.244	1.842				0.002		
				(0.013)	(0.001)	(0.91)	(0.289)	(1.8)				(0.002)		

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	No	SSD	100	-0.296 (0.068)	0.163 (0.004)	-1.817 (0.41)	0.094 (0.096)	1.692 (1.169)				0.003 (0.001)
		Body mass	100	-0.19 (0.005)	0.01 (<0.001)	-18.628 (0.59)	<0.001 (<0.001)	307.458 (17.373)				0.208 (0.01)
		Habitat	100	-0.053 (0.007)	0.019 (0.001)	-2.734 (0.384)	0.011 (0.015)	5.629 (2.04)	0.999 (<0.001)	0.798 (0.005)	0.784 (0.007)	0.01 (0.002)
		Food habit	90	0.162 (0.035)	0.158 (0.006)	1.032 (0.23)	0.315 (0.119)	0.889 (0.419)				0.001 (0.001)
		SOr	14	0.049 (0.006)	0.022 (0.001)	2.203 (0.296)	0.035 (0.026)	2.957 (1.291)				0.007 (0.002)
		SSD	98	-0.32 (0.066)	0.221 (0.006)	-1.449 (0.296)	0.164 (0.085)	0.666 (0.635)				0.003 (0.001)
		Body mass	100	-0.228 (0.004)	0.014 (<0.001)	-16.551 (0.409)	<0.001 (<0.001)	234.394 (10.595)				0.26 (0.009)
		Habitat	75	0.038 (0.007)	0.021 (0.001)	1.806 (0.306)	0.083 (0.045)	1.369 (1.191)	0.999 (<0.001)	0.902 (0.007)	0.829 (0.013)	0.003 (0.001)
	Yes	Food habit	89	-0.456 (0.054)	0.204 (0.007)	-2.241 (0.312)	0.032 (0.024)	3.12 (1.405)				0.004 (0.001)
		Body mass	100	0.111 (0.008)	0.019 (<0.001)	5.907 (0.391)	<0.001 (<0.001)	32.68 (4.495)				0.026 (0.003)
		Habitat	85	0.054 (0.01)	0.036 (0.001)	1.471 (0.263)	0.155 (0.074)	0.624 (0.544)	0.999 (<0.001)	0.856 (0.006)	0.739 (0.01)	0.003 (0.001)
		Food habit	100	-0.737 (0.076)	0.31 (0.018)	-2.389 (0.293)	0.022 (0.02)	3.796 (1.371)				0.007 (0.002)
		Body mass	100	0.138 (0.011)	0.026 (0.001)	5.274 (0.349)	<0.001 (<0.001)	25.593 (3.555)				0.033 (0.004)

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²	
CV_{PF}	Yes	Habitat	100	0.101 (0.011)	0.032 (<0.001)	3.202 (0.346)	0.003 (0.007)	8.352 (2.159)	0.999 (<0.001)	0.549 (0.009)	0.499 (0.011)	0.008 (0.002)	
		Body mass	100	0.118 (0.008)	0.028 (<0.001)	4.246 (0.321)	<0.001 (<0.001)	16.047 (2.71)				0.013 (0.002)	
	No	Habitat	100	0.174 (0.017)	0.055 (0.001)	3.162 (0.298)	0.003 (0.003)	8.056 (1.862)	0.998 (<0.001)	0.4 (0.009)	0.338 (0.01)	0.013 (0.002)	
		Body mass	100	0.155 (0.008)	0.034 (<0.001)	4.522 (0.247)	<0.001 (<0.001)	18.321 (2.21)				0.025 (0.003)	
	CV_{DUR}	Yes	Habitat	100	0.084 (0.008)	0.025 (0.001)	3.398 (0.325)	0.001 (0.002)	9.625 (2.202)	0.999 (<0.001)	0.235 (0.015)	0.154 (0.016)	0.009 (0.002)
			Body mass	100	0.065 (0.009)	0.021 (0.001)	3.054 (0.434)	0.005 (0.007)	7.499 (2.653)				0.007 (0.002)
No		Habitat	100	0.171 (0.011)	0.041 (0.001)	4.151 (0.265)	<0.001 (<0.001)	15.176 (2.212)	<0.001 (<0.001)	0.089 (0.006)	<0.001 (<0.001)	0.022 (0.003)	
		Body mass	100	0.055 (0.002)	0.008 (<0.001)	6.721 (0.298)	<0.001 (<0.001)	42.147 (3.822)				0.055 (0.005)	
CT	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)	
	No	Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)	
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)	
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)	

Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
(4) 95% random for each family												
PF	Yes	Habitat	100	-0.025	0.012	-2.112	0.038	2.507	0.999	0.838	0.825	0.003
				(0.002)	(<0.001)	(0.195)	(0.021)	(0.809)	(<0.001)	(0.003)	(0.006)	(0.001)
		Food habit	86	0.175	0.109	1.608	0.113	0.677				0.002
				(0.018)	(0.001)	(0.165)	(0.042)	(0.44)				(<0.001)
		SOr	2	0.017	0.015	1.15	0.252	0.669				0.001
				(0.001)	(<0.001)	(0.088)	(0.036)	(0.201)				(<0.001)
	No	SSD	99	-0.307	0.166	-1.851	0.078	1.61				0.003
				(0.051)	(0.002)	(0.306)	(0.072)	(0.932)				(0.001)
		Body mass	100	-0.197	0.01	-19.162	<0.001	323.311				0.217
				(0.003)	(<0.001)	(0.33)	(<0.001)	(9.905)				(0.006)
		Habitat	100	-0.053	0.019	-2.82	0.006	6.007	0.999	0.799	0.785	0.01
				(0.004)	(0.001)	(0.216)	(0.005)	(1.195)	(<0.001)	(0.004)	(0.005)	(0.001)
DUR	Yes	Food habit	100	0.158	0.153	1.035	0.308	0.919				0.001
				(0.025)	(0.004)	(0.173)	(0.081)	(0.307)				(0.001)
		SOr	11	0.049	0.021	2.301	0.023	3.337				0.007
				(0.003)	(0.001)	(0.145)	(0.008)	(0.675)				(0.001)
		SSD	99	-0.307	0.216	-1.42	0.166	0.45				0.002
				(0.051)	(0.005)	(0.226)	(0.063)	(0.532)				(0.001)
	No	Body mass	100	-0.229	0.013	-17.01	<0.001	247.543				0.26
				(0.003)	(<0.001)	(0.332)	(<0.001)	(9.096)				(0.006)
		Habitat	84	0.035	0.021	1.693	0.097	0.932	>0.999	0.903	0.83	0.002
				(0.005)	(0.001)	(0.208)	(0.038)	(0.711)	(<0.001)	(0.006)	(0.01)	(0.001)
		Food habit	100	-0.461	0.211	-2.184	0.034	2.842				0.004
				(0.041)	(0.007)	(0.257)	(0.016)	(1.197)				(0.001)
	Yes	Body mass	100	0.114	0.019	5.968	<0.001	33.298				0.026
				(0.005)	(<0.001)	(0.243)	(<0.001)	(2.831)				(0.002)

No	Habitat	91	0.052 (0.006)	0.035 (0.001)	1.467 (0.169)	0.148 (0.046)	0.402 (0.358)	0.999 (<0.001)	0.857 (0.005)	0.742 (0.008)	0.002 (0.001)
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Table S15. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²			
CV _{PF}	Yes	Food habit	100	-0.761	0.302	-2.529	0.014	4.453	0.999	0.535	0.483	0.007			
				(0.045)	(0.017)	(0.229)	(0.009)	(1.159)				(0.001)			
		Body mass	100	0.14	0.026	5.45	<0.001	27.411				0.034			
				(0.01)	(0.001)	(0.299)	(<0.001)	(3.152)				(0.003)			
		Habitat	100	0.105	0.032	3.243	0.002	8.541				0.008			
				(0.007)	(<0.001)	(0.215)	(0.001)	(1.383)				(<0.001)	(0.006)	(0.007)	(0.001)
CV _{DUR}	No	Body mass	100	0.121	0.028	4.279	<0.001	16.267	0.998	0.403	0.34	0.014			
				(0.005)	(<0.001)	(0.202)	(<0.001)	(1.716)				(0.001)			
		Habitat	100	0.174	0.054	3.252	0.001	8.582				0.013			
				(0.01)	(0.001)	(0.187)	(0.001)	(1.193)				(<0.001)	(0.006)	(0.006)	(0.001)
		Body mass	100	0.156	0.034	4.646	<0.001	19.409				0.025			
				(0.005)	(<0.001)	(0.158)	(<0.001)	(1.438)				(0.002)			
CV _{DUR}	Yes	Habitat	100	0.088	0.025	3.452	0.001	9.946	0.999	0.214	0.131	0.009			
				(0.006)	(0.001)	(0.242)	(0.001)	(1.64)				(<0.001)	(0.01)	(0.011)	(0.001)
		Body mass	100	0.071	0.021	3.305	0.002	8.994				0.008			
				(0.006)	(<0.001)	(0.31)	(0.002)	(1.988)				(0.002)			
		Habitat	100	0.173	0.04	4.274	<0.001	16.167				<0.001	0.089	<0.001	0.022
				(0.008)	(0.001)	(0.192)	(<0.001)	(1.595)				(<0.001)	(0.004)	(<0.001)	(0.002)
CT	No	Body mass	100	0.056	0.008	6.902	<0.001	44.495	<0.001	0.089	<0.001	0.055			
				(0.001)	(<0.001)	(0.181)	(<0.001)	(2.378)				(0.003)			
		Food habit	100	-0.458	0.108	-4.229	<0.001	15.79				0.999	0.924	0.905	0.013
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)				(<0.001)	(<0.001)	(<0.001)	(<0.001)
		Food habit	100	-0.55	0.139	-3.965	<0.001	13.627				0.999	0.917	0.901	0.016
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)				(<0.001)	(<0.001)	(<0.001)	(<0.001)
Harm_ <i>n</i>	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004			
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)				(<0.001)	(<0.001)	(<0.001)	(<0.001)

No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)
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Table S16. Summary of statistical results from multi-predictor (multivariate) PGLS analysis testing echolocation call designs based on 100 random samplings of 50%, 75%, 90%, and 95% of species from each echolocating genus. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_n, number of harmonics per pulse; SSD, sexual size dimorphism; SOr, social organization. N, the number of times the predictor was entered into the model. The statistical value of food habits was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, while CV_{PF} and CV_{DUR} were transformed by using $\ln(x+1)$ transformations. Statistical results represent the mean for each predictor entered into the model, with the standard error (SE) in parentheses. *P*-values in bold indicate significant differences ($P < 0.05$).

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
(1) 50% random for each genus												
PF	Yes	Habitat	74	-0.023	0.008	-2.902	0.028	7.545	>0.999	0.863	0.856	0.007
				(0.007)	(0.002)	(1.054)	(0.053)	(7.089)	(<0.001)	(0.015)	(0.017)	(0.005)
		Food habit	48	0.303	0.102	2.944	0.078	11.359				0.01
				(0.23)	(0.005)	(2.183)	(0.092)	(18.778)				(0.014)
		SOr	24	-0.009	0.011	-0.87	0.223	4.865				0.004
				(0.024)	(0.001)	(2.28)	(0.327)	(3.472)				(0.004)
	No	SSD	83	-0.331	0.125	-2.655	0.022	5.457				0.006
				(0.094)	(0.025)	(0.646)	(0.032)	(3.771)				(0.003)
		Body mass	100	-0.116	0.008	-13.595	<0.001	178.081				0.125
				(0.04)	(0.001)	(3.138)	(<0.001)	(74.203)				(0.049)
		Habitat	100	-0.064	0.023	-2.722	0.017	5.69	0.999	0.766	0.745	0.013
				(0.012)	(0.001)	(0.519)	(0.029)	(2.751)	(<0.001)	(0.011)	(0.013)	(0.005)
PF	Yes	Food habit	88	0.2	0.166	1.217	0.241	0.614				0.003
				(0.04)	(0.006)	(0.271)	(0.117)	(0.454)				(0.001)
		SOr	7	0.06	0.028	2.154	0.044	2.82				0.009
				(0.012)	(0.001)	(0.42)	(0.034)	(1.886)				(0.004)
		SSD	100	-0.48	0.249	-1.92	0.075	1.946				0.007
				(0.106)	(0.01)	(0.406)	(0.064)	(1.514)				(0.003)
	No	Body mass	100	-0.224	0.015	-14.493	<0.001	178.832				0.266
				(0.007)	(0.001)	(0.437)	(<0.001)	(9.582)				(0.011)

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²	
DUR	Yes	Habitat	69	0.033	0.013	2.604	0.025	5.273	>0.999	0.918	0.863	0.005	
				(0.01)	(0.004)	(0.708)	(0.028)	(4.235)	(<0.001)	(0.017)	(0.025)	(0.003)	
		Food habit	64	-0.466	0.182	-2.547	0.032	5.052				0.005	
				(0.15)	(0.008)	(0.76)	(0.036)	(4.425)				(0.003)	
		SOr	12	0.035	0.018	1.911	0.082	2.003				0.003	
				(0.01)	(0.001)	(0.511)	(0.068)	(2.026)				(0.002)	
		SSD	31	0.469	0.191	2.477	0.055	4.857				0.005	
				(0.148)	(0.014)	(0.784)	(0.174)	(3.6)				(0.003)	
	Body mass	90	0.059	0.014	4.029	0.007	15.759				0.013		
			(0.023)	(0.002)	(1.285)	(0.016)	(10.269)				(0.008)		
	No	Habitat	93	0.086	0.044	1.965	0.073	2.176	0.999	0.856	0.697	0.007	
				(0.021)	(0.002)	(0.471)	(0.067)	(1.896)	(<0.001)	(0.007)	(0.018)	(0.003)	
Food habit		92	-0.685	0.323	-2.12	0.04	2.566				0.008		
			(0.082)	(0.013)	(0.249)	(0.027)	(1.031)				(0.002)		
CV _{PF}	Yes	Habitat	96	0.082	0.028	2.927	0.008	6.768	0.999	0.621	0.574	0.007	
				(0.014)	(0.001)	(0.463)	(0.012)	(2.696)	(<0.001)	(0.035)	(0.032)	(0.002)	
		SOr	2	0.09	0.036	2.444	0.015	3.984				0.005	
				(0.004)	(0.001)	(0.124)	(0.006)	(0.603)				(0.001)	
		Body mass	99	0.121	0.025	4.939	0.001	22.659				0.018	
				(0.016)	(0.001)	(0.676)	(0.007)	(6.11)				(0.005)	
		No	Habitat	100	0.178	0.064	2.775	0.012	5.9	0.998	0.371	0.287	0.014
					(0.03)	(0.002)	(0.468)	(0.015)	(2.595)	(<0.001)	(0.02)	(0.021)	(0.004)
	Body mass		100	0.168	0.037	4.547	<0.001	18.525				0.035	
				(0.012)	(0.001)	(0.35)	(<0.001)	(3.081)				(0.005)	

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV_{DUR}	Yes	Habitat	98	0.067 (0.012)	0.022 (0.001)	3.053 (0.55)	0.007 (0.011)	7.602 (3.404)	0.999 (<0.001)	0.326 (0.027)	0.25 (0.03)	0.007 (0.003)
		SOr	2	0.062 (0.009)	0.027 (<0.001)	2.333 (0.334)	0.023 (0.018)	3.503 (1.555)				0.004 (0.001)
		SSD	6	0.534 (0.041)	0.32 (0.012)	1.674 (0.162)	0.098 (0.032)	0.83 (0.547)				0.002 (<0.001)
		Body mass	100	0.075 (0.012)	0.019 (0.001)	3.972 (0.617)	0.001 (0.004)	14.087 (4.702)				0.012 (0.004)
	No	Habitat	100	0.191 (0.023)	0.048 (0.001)	3.983 (0.491)	<0.001 (0.001)	13.954 (3.832)	<0.001 (<0.001)	0.094 (0.012)	<0.001 (<0.001)	0.028 (0.007)
		SSD	20	0.453 (0.109)	0.551 (0.018)	0.824 (0.202)	0.419 (0.113)	1.276 (0.349)				0.001 (0.001)
		Body mass	100	0.05 (0.003)	0.009 (<0.001)	5.634 (0.342)	<0.001 (<0.001)	29.152 (3.673)				0.054 (0.006)
CT	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)
	No	Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)
(2) 75% random for each genus												
PF	Yes	Habitat	100	-0.023 (0.004)	0.011 (0.001)	-2.027 (0.365)	0.057 (0.049)	2.285 (1.43)	0.999 (<0.001)	0.845 (0.008)	0.832 (0.01)	0.003 (0.001)
		Food habit	92	0.185 (0.033)	0.107 (0.003)	1.732 (0.329)	0.101 (0.089)	1.277 (0.851)				0.002 (0.001)

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	No	SOr	3	0.028 (0.007)	0.013 (0.002)	2.255 (0.913)	0.061 (0.071)	3.648 (4.427)				0.004 (0.003)
		SSD	100	-0.345 (0.056)	0.161 (0.007)	-2.151 (0.377)	0.042 (0.032)	2.777 (1.781)				0.004 (0.001)
		Body mass	100	-0.183 (0.011)	0.01 (<0.001)	-18.218 (0.933)	<0.001 (<0.001)	295.727 (24.822)				0.201 (0.016)
		Habitat	100	-0.056 (0.007)	0.02 (0.001)	-2.838 (0.367)	0.008 (0.009)	6.193 (2.065)	0.999 (<0.001)	0.791 (0.008)	0.774 (0.009)	0.011 (0.003)
		Food habit	92	0.167 (0.04)	0.159 (0.006)	1.056 (0.271)	0.308 (0.14)	0.839 (0.469)				0.002 (0.001)
		SOr	7	0.054 (0.004)	0.023 (0.001)	2.368 (0.207)	0.02 (0.012)	3.667 (0.977)				0.008 (0.002)
		SSD	100	-0.364 (0.083)	0.223 (0.007)	-1.627 (0.363)	0.125 (0.08)	1.042 (1.04)				0.004 (0.002)
		Body mass	100	-0.228 (0.005)	0.014 (<0.001)	-16.087 (0.329)	<0.001 (<0.001)	221.092 (8.025)				0.262 (0.008)
		Habitat	87	0.041 (0.009)	0.021 (0.002)	1.996 (0.524)	0.068 (0.052)	2.286 (2.683)	0.999 (<0.001)	0.9 (0.006)	0.825 (0.01)	0.003 (0.002)
		Food habit	95	-0.499 (0.045)	0.197 (0.005)	-2.54 (0.244)	0.014 (0.011)	4.513 (1.231)				0.005 (0.001)
		SOr	1	0.031	0.021	1.487	0.137	0.22	0.999	0.9	0.825	0.002
		SSD	4	0.535 (0.078)	0.215 (0.001)	2.492 (0.357)	0.018 (0.016)	4.31 (1.769)	0.999 (<0.001)	0.9 (0.006)	0.825 (0.01)	0.005 (0.001)
		Body mass	100	0.104 (0.015)	0.018 (0.001)	5.683 (0.658)	<0.001 (0.001)	30.407 (6.316)				0.024 (0.005)

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV _{PF}	No	Habitat	84	0.064 (0.014)	0.039 (0.001)	1.665 (0.377)	0.117 (0.071)	1.161 (1.23)	0.999 (<0.001)	0.855 (0.006)	0.724 (0.013)	0.004 (0.002)
		Food habit	99	-0.719 (0.054)	0.304 (0.012)	-2.37 (0.192)	0.02 (0.011)	3.662 (0.896)				0.007 (0.001)
		Body mass	100	0.128 (0.009)	0.027 (0.001)	4.824 (0.308)	<0.001 (<0.001)	21.124 (2.927)				0.03 (0.004)
	Yes	Habitat	100	0.098 (0.013)	0.031 (0.001)	3.2 (0.41)	0.003 (0.004)	8.385 (2.649)	0.999 (<0.001)	0.568 (0.014)	0.519 (0.017)	0.008 (0.002)
		SOr	1	0.086	0.04	2.171	0.03	2.72	0.999	0.568	0.519	0.004
		Body mass	100	0.121 (0.011)	0.027 (0.001)	4.461 (0.418)	<0.001 (<0.001)	17.966 (3.683)	0.999 (<0.001)	0.568 (0.014)	0.519 (0.017)	0.015 (0.003)
	No	Habitat	100	0.18 (0.02)	0.057 (0.001)	3.154 (0.354)	0.003 (0.004)	8.043 (2.207)	0.998 (<0.001)	0.392 (0.011)	0.322 (0.013)	0.014 (0.003)
		Body mass	100	0.16 (0.009)	0.035 (<0.001)	4.629 (0.266)	<0.001 (<0.001)	19.271 (2.415)				0.029 (0.003)
CV _{DUR}		Yes	Habitat	100	0.078 (0.01)	0.024 (0.001)	3.259 (0.429)	0.003 (0.003)	8.779 (2.797)	0.999 (<0.001)	0.258 (0.017)	0.179 (0.019)
	SSD		1	0.572	0.353	1.624	0.105	0.643	0.999	0.258	0.179	0.002
	Body mass		99	0.069 (0.009)	0.021 (0.001)	3.275 (0.454)	0.003 (0.006)	8.906 (2.975)	0.999 (<0.001)	0.258 (0.017)	0.179 (0.019)	0.008 (0.002)
	No	Habitat	100	0.18 (0.014)	0.043 (0.001)	4.206 (0.344)	<0.001 (<0.001)	15.658 (2.854)	<0.001 (<0.001)	0.09 (0.006)	<0.001 (<0.001)	0.024 (0.004)
		SSD	1	0.3	0.528	0.569	0.57	1.675	<0.001	0.09	<0.001	<0.001
		Body mass	100	0.053 (0.002)	0.008 (<0.001)	6.411 (0.226)	<0.001 (<0.001)	38.176 (2.769)	<0.001 (<0.001)	0.09 (0.006)	<0.001 (<0.001)	0.054 (0.004)

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.905	0.013
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	
	No	Food habit	100	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Harm_n	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	No	Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
(3) 90% random for each genus												
PF	Yes	Habitat	100	-0.024	0.012	-2.067	0.046	2.359	0.999	0.84	0.825	0.003
				(0.003)	(<0.001)	(0.265)	(0.033)	(1.047)	(<0.001)	(0.005)	(0.007)	(0.001)
		Food habit	95	0.173	0.11	1.581	0.124	0.686				0.002
				(0.024)	(0.002)	(0.233)	(0.083)	(0.516)				(0.001)
		SSD	100	-0.312	0.165	-1.888	0.066	1.636				0.003
				(0.037)	(0.003)	(0.229)	(0.033)	(0.859)				(0.001)
		Body mass	100	-0.196	0.01	-19.02	<0.001	319.099				0.215
				(0.004)	(<0.001)	(0.428)	(<0.001)	(12.607)				(0.008)
	No	Habitat	100	-0.054	0.019	-2.887	0.005	6.394	0.999	0.798	0.783	0.01
				(0.004)	(0.001)	(0.233)	(0.004)	(1.337)	(<0.001)	(0.005)	(0.006)	(0.002)
		Food habit	100	0.158	0.153	1.035	0.308	0.91				0.001
				(0.024)	(0.004)	(0.171)	(0.086)	(0.291)				(0.001)
		SOr	9	0.047	0.021	2.203	0.029	2.889				0.007
				(0.002)	(0.001)	(0.118)	(0.009)	(0.52)				(0.001)
		SSD	100	-0.312	0.215	-1.455	0.154	0.445				0.003
				(0.047)	(0.005)	(0.212)	(0.053)	(0.532)				(0.001)
		Body mass	100	-0.229	0.013	-16.938	<0.001	245.494				0.26
				(0.003)	(<0.001)	(0.268)	(<0.001)	(7.246)				(0.005)

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
DUR	Yes	Habitat	84	0.034	0.02	1.669	0.103	0.875	>0.999	0.903	0.831	0.002
				(0.005)	(0.001)	(0.219)	(0.041)	(0.726)	(<0.001)	(0.004)	(0.008)	(0.001)
		Food habit	100	-0.459	0.213	-2.159	0.034	2.704				0.004
				(0.032)	(0.006)	(0.197)	(0.016)	(0.858)			(0.001)	
		Body mass	100	0.114	0.019	5.963	<0.001	33.232				0.026
				(0.004)	(<0.001)	(0.217)	(<0.001)	(2.525)			(0.002)	
	No	Habitat	96	0.053	0.036	1.475	0.149	0.495	0.999	0.856	0.735	0.003
				(0.008)	(0.001)	(0.206)	(0.056)	(0.435)	(<0.001)	(0.005)	(0.009)	(0.001)
		Food habit	100	-0.742	0.3	-2.483	0.015	4.197				0.007
				(0.028)	(0.017)	(0.169)	(0.007)	(0.83)			(0.001)	
		Body mass	100	0.138	0.026	5.38	<0.001	26.688				0.033
				(0.011)	(0.001)	(0.32)	(<0.001)	(3.342)			(0.004)	
CV _{PF}	Yes	Habitat	100	0.104	0.032	3.219	0.002	8.396	0.999	0.538	0.486	0.008
				(0.008)	(<0.001)	(0.229)	(0.002)	(1.461)	(<0.001)	(0.008)	(0.009)	(0.001)
		Body mass	100	0.122	0.028	4.32	<0.001	16.623				0.014
				(0.006)	(<0.001)	(0.225)	(<0.001)	(1.922)			(0.001)	
	No	Habitat	100	0.175	0.054	3.271	0.001	8.709	0.998	0.4	0.335	0.013
				(0.011)	(0.001)	(0.197)	(0.001)	(1.267)	(<0.001)	(0.007)	(0.007)	(0.002)
CV _{DUR}	Yes	Habitat	100	0.087	0.025	3.424	0.001	9.764	0.999	0.218	0.135	0.009
				(0.007)	(0.001)	(0.255)	(0.001)	(1.735)	(<0.001)	(0.013)	(0.013)	(0.001)
		Body mass	100	0.07	0.021	3.259	0.002	8.726				0.008
				(0.007)	(0.001)	(0.355)	(0.003)	(2.245)			(0.002)	
	No	Habitat	100	0.175	0.041	4.332	<0.001	16.654	<0.001	0.089	<0.001	0.023
				(0.007)	(0.001)	(0.189)	(<0.001)	(1.615)	(<0.001)	(0.004)	(<0.001)	(0.002)
	Body mass	100	0.055	0.008	6.844	<0.001	43.727				0.055	
			(0.001)	(<0.001)	(0.158)	(<0.001)	(2.057)			(0.002)		

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²		
CT	Yes	Food habit	100	-0.458	0.108	-4.229	<0.001	15.79	0.999	0.924	0.905	0.013		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)			
	No	Food habit	100	-0.55	0.139	-3.965	<0.001	13.627	0.999	0.917	0.901	0.016		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)			
Harm_n	Yes	Body mass	100	0.12	0.05	2.383	0.017	3.677	0.999	0.392	0.371	0.004		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)			
	No	Body mass	100	0.124	0.051	2.434	0.015	3.92	0.998	0.284	0.252	0.006		
				(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)			
(4) 95% random for each genus														
PF	Yes	Habitat	100	-0.024	0.012	-2.072	0.041	2.327	0.999	0.836	0.822	0.003		
				(0.002)	(<0.001)	(0.157)	(0.02)	(0.623)	(<0.001)	(0.002)	(0.005)	(0.001)		
		Food habit	90	0.179	0.109	1.633	0.105	0.692				0.002		
				(0.012)	(0.001)	(0.112)	(0.023)	(0.366)				(<0.001)		
		SOr	1	0.011	0.015	0.763	0.445	1.415	0.999	0.836	0.822	<0.001		
				SSD	100	-0.309	0.167	-1.842	0.067	1.412	0.999	0.836	0.822	0.003
						(0.017)	(0.001)	(0.1)	(0.015)	(0.37)	(<0.001)	(0.002)	(0.005)	(<0.001)
				Body mass	100	-0.2	0.01	-19.313	<0.001	327.847				
		(0.002)	(<0.001)			(0.167)	(<0.001)	(5.02)					(0.003)	
	No	Habitat	100	-0.052	0.018	-2.849	0.005	6.151	0.999	0.8	0.785	0.009		
				(0.003)	(0.001)	(0.155)	(0.003)	(0.852)	(<0.001)	(0.004)	(0.004)	(0.001)		
		Food habit	99	0.161	0.151	1.066	0.29	0.847				0.001		
				(0.016)	(0.003)	(0.115)	(0.058)	(0.219)				(<0.001)		
		SOr	7	0.046	0.021	2.164	0.031	2.709				0.006		
				(0.002)	(0.001)	(0.063)	(0.005)	(0.273)				(<0.001)		
		SSD	100	-0.298	0.212	-1.404	0.162	0.169				0.002		
				(0.018)	(0.003)	(0.083)	(0.026)	(0.156)				(<0.001)		
		Body mass	100	-0.229	0.013	-17.229	<0.001	254.055				0.259		
				(0.002)	(<0.001)	(0.204)	(<0.001)	(5.795)				(0.004)		

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²		
DUR	Yes	Habitat	100	0.034	0.021	1.628	0.105	0.666	>0.999	0.9	0.825	0.002		
				(0.002)	(<0.001)	(0.099)	(0.022)	(0.321)	(<0.001)	(0.001)	(0.002)	(<0.001)		
		Food habit	100	-0.466	0.213	-2.193	0.029	2.817				0.004		
				(0.009)	(0.001)	(0.052)	(0.004)	(0.229)			(<0.001)			
		Body mass	100	0.118	0.019	6.114	<0.001	34.982				0.027		
				(0.002)	(<0.001)	(0.082)	(<0.001)	(0.986)			(0.001)			
	No	Habitat	99	0.048	0.034	1.397	0.164	0.156	>0.999	0.86	0.747	0.002		
				(0.003)	(0.001)	(0.074)	(0.022)	(0.14)	(<0.001)	(0.004)	(0.007)	(<0.001)		
		Food habit	100	-0.747	0.313	-2.394	0.018	3.759				0.006		
				(0.013)	(0.015)	(0.151)	(0.005)	(0.758)			(0.001)			
		Body mass	100	0.148	0.026	5.711	<0.001	30.209				0.036		
				(0.007)	(<0.001)	(0.189)	(<0.001)	(2.041)			(0.002)			
CV _{PF}	Yes	Habitat	100	0.107	0.033	3.281	0.001	8.77	0.999	0.528	0.475	0.008		
				(0.005)	(<0.001)	(0.155)	(0.001)	(1.014)	(<0.001)	(0.004)	(0.005)	(0.001)		
		Body mass	100	0.121	0.028	4.267	<0.001	16.138				0.014		
				(0.004)	(0.001)	(0.129)	(<0.001)	(1.095)			(0.001)			
		Habitat	100	0.177	0.053	3.35	0.001	9.206	0.998	0.403	0.339	0.013		
				(0.007)	(<0.001)	(0.137)	(<0.001)	(0.925)	(<0.001)	(0.004)	(0.004)	(0.001)		
	No	Body mass	100	0.156	0.033	4.684	<0.001	19.749				0.025		
				(0.003)	(<0.001)	(0.093)	(<0.001)	(0.866)			(0.001)			
		CV _{DUR}	Yes	Habitat	100	0.09	0.026	3.483	0.001	10.118	0.999	0.204	0.119	0.009
						(0.003)	(<0.001)	(0.113)	(0.001)	(0.787)	(<0.001)	(0.003)	(0.003)	(0.001)
				Body mass	100	0.073	0.021	3.399	0.001	9.545				0.009
						(0.002)	(<0.001)	(0.111)	(<0.001)	(0.752)			(0.001)	
No	Habitat	100	0.175	0.04	4.382	<0.001	17.064	<0.001	0.09	<0.001	0.022			
			(0.004)	(<0.001)	(0.106)	(<0.001)	(0.915)	(<0.001)	(0.001)	(<0.001)	(0.001)			
	Body mass	100	0.056	0.008	7.02	<0.001	46.06				0.056			
			(<0.001)	(<0.001)	(0.041)	(<0.001)	(0.543)			(0.001)				

Table S16. (Continued)

Parameter	Imputed	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CT	Yes	Food habit	100	-0.458 (<0.001)	0.108 (<0.001)	-4.229 (<0.001)	<0.001 (<0.001)	15.79 (<0.001)	0.999 (<0.001)	0.924 (<0.001)	0.905 (<0.001)	0.013 (<0.001)
	No	Food habit	100	-0.55 (<0.001)	0.139 (<0.001)	-3.965 (<0.001)	<0.001 (<0.001)	13.627 (<0.001)	0.999 (<0.001)	0.917 (<0.001)	0.901 (<0.001)	0.016 (<0.001)
Harm_n	Yes	Body mass	100	0.12 (<0.001)	0.05 (<0.001)	2.383 (<0.001)	0.017 (<0.001)	3.677 (<0.001)	0.999 (<0.001)	0.392 (<0.001)	0.371 (<0.001)	0.004 (<0.001)
	No	Body mass	100	0.124 (<0.001)	0.051 (<0.001)	2.434 (<0.001)	0.015 (<0.001)	3.92 (<0.001)	0.998 (<0.001)	0.284 (<0.001)	0.252 (<0.001)	0.006 (<0.001)

Table S17. Summary of statistical results from multi-predictor (multivariate) PGLS analysis testing echolocation call designs based on 100 random sampling trees, excluding species not included in the original phylogenetic supertree. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration; CT, call type; Harm_n, number of harmonics per pulse; SSD, sexual size dimorphism; SOr, social organization. N, the number of times the predictor was entered into the model. The statistical value of food habits was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, while CV_{PF} and CV_{DUR} were transformed by using $\ln(x+1)$ transformations. Statistical results represent the mean for each predictor entered into the model, with the standard error (SE) in parentheses. *P*-values in bold indicate significant differences ($P < 0.05$).

Parameter	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R^2	Phylo R^2	Partial R^2
PF	Habitat	100	-0.044 (0.004)	0.02 (0.001)	-2.201 (0.164)	0.03 (0.01)	2.884 (0.754)	0.999 (<0.001)	0.777 (0.009)	0.764 (0.008)	0.006 (0.001)
	Food habit	70	0.197 (0.024)	0.146 (0.006)	1.355 (0.199)	0.184 (0.069)	0.439 (0.298)				0.002 (0.001)
	SSD	100	-0.365 (0.055)	0.23 (0.005)	-1.583 (0.218)	0.123 (0.068)	0.734 (0.398)				0.003 (0.001)
	Body mass	100	-0.219 (0.008)	0.014 (0.001)	-16.192 (0.307)	<0.001 (<0.001)	225.85 (7.513)				0.249 (0.007)
DUR	Habitat	72	0.049 (0.01)	0.037 (0.001)	1.308 (0.228)	0.202 (0.066)	0.595 (0.37)	0.999 (<0.001)	0.853 (0.005)	0.724 (0.01)	0.002 (0.001)
	Food habit	100	-0.594 (0.05)	0.287 (0.013)	-2.074 (0.237)	0.043 (0.023)	2.367 (1.013)				0.005 (0.001)
	Body mass	100	0.123 (0.013)	0.025 (0.001)	4.815 (0.423)	<0.001 (<0.001)	21.125 (3.922)				0.028 (0.005)
CV_{PF}	Habitat	100	0.149 (0.006)	0.055 (<0.001)	2.69 (0.115)	0.008 (0.002)	5.244 (0.625)	0.999 (<0.001)	0.381 (0.003)	0.314 (0.003)	0.009 (0.001)
	Body mass	100	0.146 (0.004)	0.033 (0.001)	4.406 (0.205)	<0.001 (<0.001)	17.289 (1.771)				0.024 (0.002)

Table S17. (Continued)

Parameter	Predictor	N	Estimate	SE	<i>t</i> -value	<i>P</i> -value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV_{DUR}	Habitat	100	0.167 (0.01)	0.04 (<0.001)	4.166 (0.199)	<0.001 (<0.001)	15.28 (1.656)	<0.001 (<0.001)	0.094 (0.003)	<0.001 (<0.001)	0.022 (0.002)
	Food habit	41	0.216 (<0.001)	0.114 (<0.001)	1.885 (<0.001)	0.06 (<0.001)	1.563 (<0.001)				0.005 (<0.001)
	Body mass	100	0.052 (0.001)	0.008 (<0.001)	6.766 (0.219)	<0.001 (<0.001)	42.701 (2.773)				0.057 (0.003)
CT	Food habit	89	-0.532 (0.117)	0.138 (0.009)	-3.909 (1.015)	0.002 (0.003)	14.159 (8.318)	>0.999 (<0.001)	0.92 (0.011)	0.887 (0.035)	0.019 (0.009)
	SOr	37	-0.034 (0.011)	0.012 (0.001)	-2.821 (0.651)	0.012 (0.01)	6.349 (4.064)				0.011 (0.005)
	Body mass	27	-0.035 (0.004)	0.012 (<0.001)	-2.905 (0.332)	0.006 (0.007)	6.531 (1.845)				0.01 (0.002)
Harm_n	Body mass	100	0.119 (0.009)	0.052 (0.001)	2.275 (0.156)	0.025 (0.01)	3.197 (0.703)	0.999 (<0.001)	0.281 (0.004)	0.245 (0.004)	0.006 (0.001)

Table S18. Summary of statistical results from multi-predictor (multivariate) PGLS analysis testing echolocation call designs based on 100 random sampling trees for all echolocating species. Full and partial R^2 values were calculated using the “R2_lik” function in the “rr2” package^{65,66}. PF, peak frequency; DUR, duration; CV_{PF} , coefficient of variation for peak frequency; CV_{DUR} , coefficient of variation for duration; CT, call type; Harm_ n , number of harmonics per pulse; SSD, sexual size dimorphism; SOr, social organization. N, the number of times the predictor was entered into the model. The statistical value of food habits was based on the PCoA1 score in a principal coordinates analysis (PCoA) for dietary categories. Prior to model analysis, natural-log transformation was performed for body mass, PF and DUR, while CV_{PF} and CV_{DUR} were transformed by using $\ln(x+1)$ transformations. Statistical results represent the mean for each predictor entered into the model, with the standard error (SE) in parentheses. P -values in bold indicate significant differences ($P < 0.05$).

Parameter	Predictor	N	Estimate	SE	t -value	P -value	Delta AIC	Pagel's λ	Full R^2	Phylo R^2	Partial R^2
PF	Habitat	100	-0.047 (0.004)	0.019 (0.001)	-2.535 (0.186)	0.013 (0.007)	4.471 (0.928)	0.999 (<0.001)	0.79 (0.006)	0.776 (0.009)	0.008 (0.001)
	Food habit	77	0.191 (0.027)	0.14 (0.009)	1.387 (0.311)	0.183 (0.069)	0.648 (0.836)				0.002 (0.001)
	SOr	4	0.045 (<0.001)	0.022 (<0.001)	2.103 (<0.001)	0.036 (<0.001)	2.445 (<0.001)				0.006 (<0.001)
	SSD	100	-0.342 (0.051)	0.218 (0.004)	-1.566 (0.238)	0.129 (0.072)	0.69 (0.527)				0.003 (0.001)
	Body mass	100	-0.225 (0.009)	0.013 (<0.001)	-17.247 (0.598)	<0.001 (<0.001)	255.163 (15.787)				0.256 (0.013)
DUR	Habitat	46	0.042 (0.008)	0.035 (0.002)	1.195 (0.165)	0.239 (0.071)	0.54 (0.367)	0.999 (<0.001)	0.856 (0.01)	0.747 (0.018)	0.002 (<0.001)
	Food habit	94	-0.659 (0.066)	0.279 (0.016)	-2.367 (0.285)	0.023 (0.016)	3.688 (1.373)				0.006 (0.001)
	Body mass	100	0.131 (0.026)	0.024 (0.001)	5.348 (0.984)	<0.001 (<0.001)	27.125 (10.517)				0.032 (0.011)

Table S18. (Continued)

Parameter	Predictor	N	Estimate	SE	t-value	P-value	Delta AIC	Pagel's λ	Full R ²	Phylo R ²	Partial R ²
CV_{PF}	Habitat	100	0.167 (0.005)	0.053 (<0.001)	3.183 (0.11)	0.001 (0.001)	8.117 (0.699)	0.998 (<0.001)	0.402 (0.004)	0.339 (0.004)	0.012 (0.001)
	Body mass	100	0.144 (0.006)	0.032 (0.001)	4.479 (0.203)	<0.001 (<0.001)	17.94 (1.784)				0.023 (0.002)
CV_{DUR}	Habitat	100	0.179 (0.01)	0.04 (<0.001)	4.487 (0.17)	<0.001 (<0.001)	18.001 (1.53)	<0.001 (<0.001)	0.09 (0.002)	<0.001 (<0.001)	0.023 (0.002)
	Food habit	27	0.216 (<0.001)	0.113 (<0.001)	1.907 (<0.001)	0.057 (<0.001)	1.647 (<0.001)				0.004 (<0.001)
	Body mass	100	0.055 (0.001)	0.008 (<0.001)	6.915 (0.197)	<0.001 (<0.001)	44.731 (2.539)				0.053 (0.003)
CT	Food habit	88	-0.622 (0.11)	0.134 (0.009)	-4.666 (0.858)	<0.001 (0.001)	20.265 (7.629)	0.999 (<0.001)	0.909 (0.013)	0.873 (0.04)	0.023 (0.007)
	SOr	9	-0.042 (<0.001)	0.014 (<0.001)	-2.909 (<0.001)	0.004 (<0.001)	6.46 (<0.001)				0.011 (<0.001)
	SSD	21	0.22 (0.039)	0.114 (0.001)	1.928 (0.315)	0.066 (0.045)	1.817 (1.184)				0.005 (0.002)
	Body mass	40	-0.033 (0.003)	0.012 (<0.001)	-2.77 (0.283)	0.008 (0.009)	5.742 (1.48)				0.008 (0.002)
	Food habit	6	-0.878 (0.001)	0.45 (<0.001)	-1.95 (0.001)	0.051 (<0.001)	1.81 (0.001)	0.998 (<0.001)	0.277 (0.007)	0.242 (0.007)	0.004 (<0.001)
Harm_n	Body mass	100	0.125 (0.014)	0.051 (0.001)	2.474 (0.251)	0.017 (0.012)	4.178 (1.228)				0.006 (0.001)

Table S19. The long-tailed distribution for continuous predictor variables and echolocation call design metrics. SSD, sexual size dimorphism; Harm_*n*, number of harmonics per pulse; PF, peak frequency; DUR, duration; CV_{PF}, coefficient of variation for peak frequency; CV_{DUR}, coefficient of variation for duration. The average (Mean) and standard deviation (SD) of these variables were calculated, and the long-tailed distribution was defined as SD/Mean ≥ 1 .

Parameter	Imputed	<i>N</i>	Mean	SD	SD/Mean
Food habit	Yes	1329	-8.48E-16	0.21	2.43E+14
	No	1266	6.72E-16	0.2	3.03E+14
SSD	Yes	1329	0.99	0.04	0.04
	No	1098	0.99	0.04	0.04
Body mass	Yes	1329	7.90E+04	7.04E+05	8.9
	No	1283	8.16E+04	7.16E+05	8.77
PF	Yes	1329	60.47	31.4	0.52
	No	987	60.22	32.73	0.54
DUR	Yes	1329	7.79	11.25	1.44
	No	916	8.21	11.7	1.42
CV_{PF}	Yes	1329	7.12	8.77	1.23
	No	876	7.53	9.51	1.26
CV_{DUR}	Yes	1329	23.11	15.19	0.66
	No	864	23.88	16.43	0.69
Harm_<i>n</i>	Yes	1329	2.56	1.54	0.6
	No	941	2.44	1.52	0.62

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