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Species-specific traits mediate avian demographic responses under past climate change

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Supplementary Note 1: Geographic variation in demographic histories

At a global scale, close distributional and phylogenetic relationships of species experiencing similar geographic and climatic conditions (i.e., zoogeographic realms) are a cornerstone for macro-ecological studies[60,61]. Species occupying a common zoogeographic realm may experience similar levels of environmental variation, and thus may have similar demographic responses, compared to species with the same life-history strategies in other areas of the world[16]. Because geographic variation in the magnitude of changing climate may dictate the context and severity of selection acting on morphological and/or life history traits in different regions of the world[62,63], broad-scale studies of phylogenetically distinct groups native to differing geographic areas may facilitate tests of the mediating role of traits on demographic responses to climate change. We evaluated variation in species-specific demographic histories across zoogeographic realms to quantify the extent of possible geographic structure in our clustering of demographic patterns (Fig. 1, Supplementary Figure 21), and determine if species in certain zoogeographic realms exhibited atypical patterns of demographic change over the past one million years.

We assigned all 263 species in our analysis to one of the 11 main zoogeographic realms identified via multi-taxon species assemblages by Holt et al.[59] (Fig 3). Following this previous work, migratory species were assigned to the realm corresponding to their breeding range, and species with larger ranges extending across multiple realms were assigned to the realm where the individual sampled for whole-genome sequencing originated. To quantify whether realm-specific demographic patterns deviated from random expectations and if our designation of a given species to a given realm influenced our results, we performed a modified permutation test for the six realms that contained at least 19 species. For each of these six realms, we first generated a distance matrix among samples based on the focal realm and the remaining species. For instance, species in the Oceanian realm (n = 19) represent a subset of the 263*121 matrix of normalized N_e values generated as part of our analysis (see Materials and Methods – 'Demographic reconstruction over the past one million years'). We generated a distance matrix containing differences in the N_e fluctuations between each Oceanian sample and every remaining species using the 'distmat' function in the R package *pracma*[64]. Next, we calculated the overall variance among these distances, which represents the discrete distance in values between these 19 samples and all remaining species. If individuals within the Oceanian realm exhibited substantially different N_e trajectories compared to all remaining species (e.g., they formed a subtree of the cluster tree in Fig. 1), this process would produce distances with similar values, which would result in a smaller variance. Another scenario is that N_e trajectories of some species from the Oceanian realm are more similar than other Oceanian birds (e.g., they formed multiple subtrees). In this case, the variance increases as the intra-realm groupings are more visible. We then generated a background distribution of potential variances by randomly sampling 19 species from the 263*121 matrix, calculating the variance in distances between this subset and remaining species in the matrix (as above), and repeating this process 1,000 times. If the actual variance between N_e trajectories from the Oceanian realm and remaining species was found to be greater than or equal to the 95th percentile values generated from this background distribution, the demographic histories of species in the Oceanian realm would be considered to exhibit significant regionality. We repeated this process for the remaining five realms with n $\geq$19, using their respective sample sizes to generate the actual and background distance matrices. Results from the above analysis indicate little geographic variation in demographic trends among realms, and that assignment to a given geographic realm (i.e., among species with distributions spanning multiple realms) had no significant effect on our results and interpretations (Supplementary Figure 22).

Supplementary Note 2: Selection and measurement of morphological and life-history traits

Trait data for all species involved in our study were collected from a combination of live-caught individuals, museum specimens, and existing published databases following previous comparative studies of avian morphological and life-history variation[65–67]. Our initial set of potential morphological and life-history traits consisted of 17 traits typically found to exhibit links with demographic responses to climate change in contemporary studies (see Supplementary Table 11 for full description of all traits). Because equal observation numbers are required to compare AIC values among competing models[68], we used the *missForest* R package[69] to impute missing values (via a random forest algorithm) for some traits with less than 100% complete records across all species (mass = 98%, clutch size = 84%, egg mass = 74%, incubation duration = 64%, brain size = 57%, generation time = 96% [but see below]), based on phylogenetic relatedness among species[69–71]. Normalized root mean squared error for missing value imputation was 0.038, indicating high accuracy in estimating known trait values (where values closer to zero indicate good performance of the random forest algorithm and values close to 1 indicate low accuracy in estimating known trait values)[69]. Prior to imputing missing values, we excluded both maximum longevity and mortality rate from further analyses as each had less than 40% complete records, and generation time because species-specific generation times factored into our PSMC-based estimates of N_e over time (see Methods, main text). Further, we excluded range size and elevation min/max since these represent more fluid traits that are highly influenced by measurement under contemporary climate parameters, and may not represent the historic geographic and elevation niches used by species under past instances of climate warming and cooling across the globe. All remaining traits are assumed to remain consistent within these distinct species over the past million years, as this represents a relatively brief period in avian evolution[72]. Further, we have no *a priori* rationale to suggest that species have undergone directional changes in morphological or life-history traits over this period of cyclical climate warming and cooling, thus any trait changes over time may add additional noise but are unlikely to bias our results and interpretations.

We tested for multicollinearity among the remaining 12 traits using Pearson pairwise correlation analysis[73] and identified those which were co-linear at a level of $r \geq 0.7$. For these pairs of co-linear traits, we calculated univariate ANOVAs (with mean overall correlation coefficients between N_e and GAST during periods of *Climate Warming* and *Climate Cooling* [above] as response variables) and compared their F-values, retaining variables with the highest F-value while excluding those with lower F-values from downstream analysis[73–75]. Following this step, eight morphological and life-history traits remained: body mass, brain-body ratio, tarsus length, bill length, egg mass, clutch size, incubation duration, and hand-wing index (see Germain et al.[76] for further description of relationships among key traits and Principal Component Analysis). These eight traits were then incorporated into further variable selection analyses using linear mixed-effect models to identify the best suite of traits likely to influence demographic responses during *Climate Warming* and *Climate Cooling* (Results and Discussion, main text).

Supplementary Note 3: Contemporary latitudinal variation in key morphological/life-history traits

The key morphological and life-history traits related to survival/growth, reproduction, and dispersal that we identified as being associated with species-specific N_e responses to changing climate may also be reflected in how traits contribute to the contemporary distribution of species globally, given that the Earth's climate is currently undergoing a period of dramatic warming. Using a combination of trait data collected from museum specimens and the published literature for contemporary bird species distributed globally, we tested whether species currently distributed in tropical (i.e., warmer) latitudes express traits consistent with those species that exhibited increasing N_e under the most recent period of *Climate Warming* (~147-123 kya), under the assumption that such traits may be indicative of a warm-adapted life-history.

We first constructed an additional series of PPA models aimed at identifying the trait network distinguishing species which exhibited increasing N_e tendency under *Climate Warming* (n = 88 species) verses those with decreasing N_e tendency (n = 127) during this period without limiting the confidence level. Note that this PPA measures only the response to climate warming, not climate warming and cooling as measured in the Warming Positive and Warming Negative PPA models. We also performed this analysis at different confidence levels. Details of best performing models are presented in Supplementary Table 12. Results from the best supported and final averaged models for this analysis are presented in Supplementary Figures 11-20 (at differing confidence levels), and indicate that species which increased effective population size under *Climate Warming* were clearly differentiated from remaining species by lower HWI.

Next, we assembled morphological (i.e., body mass, bill length, and hand-wing index) and distributional (mean centroid longitude and latitude of breeding/resident range) data for all

10,950 contemporary bird species (example – Supplementary Figure 23), again from datasets compiled for previous avian comparative studies[65–67]. In addition, estimates of egg mass for species not included in our previous analyses were collected from Rotenberry and Balasubramaniam[77], incubation duration from Cooney et al.[78], and clutch size from Jetz et al.[79], Werner and Griebler[80], and Cooney et al.[78]. From these combined sources, complete data were available for 2,745 species in total. Using a linear model with absolute latitude as the response and our six key traits as (scaled) predictor variables, we found that all traits were indeed significant predictors of current global distribution (Supplementary Figure 24). Specifically, species currently centered at lower latitudes (i.e., warmer tropical regions) were found to have longer incubation durations and longer bills, but smaller clutch sizes, lighter eggs, lighter body mass, and lower hand-wing indexes.

Our results reveal some degree of concordance between the trait-mediated influences on demographic change under past climate warming and the contemporary distribution of species along a latitudinal gradient. Both sets of analyses revealed that less dispersive species appear better adapted (temporarily and spatially) to a ‘warmer’ life-history. Overall, these results from contemporary distributions conform to long-standing expectations (e.g., Bergmann’s rule[81,82]) where larger bodied species are more likely to adapt to and therefore be found in cooler latitudes, and also highlight the relationship between migration ability and latitudinal variation, where temperate species are more likely to be migratory (and thus have higher HWI values) than tropical species[67]. Likewise, these global data also confirm predictions of larger clutch sizes at higher latitudes both within and across species[83–86], that parental investment towards offspring development (e.g., egg mass) is greater in cooler temperate latitudes[87–89], and that species at lower latitudes tend to exhibit longer incubation durations[78]. Thus, while these findings provide additional support that the six key traits identified through our analyses play a central role in mediating demographic responses to warming global temperatures across both space (i.e., latitudinal variation) and time (i.e., response to climate warming), they indicate that historical responses to climate change alone are not fully indicative of contemporary distributions.

Supplementary Table 1 – List of 325 species (species names in italics) for which whole-genome sequencing data were constructed as part of the B10k Genomes Project Phase II (https://b10k.genomics.cn) by Feng et al.[19], including taxonomic order and assignment to one of the 11 major zoogeographic realms (where possible) identified by Holt et al.[59]. Species were assigned to the realm corresponding to their breeding range, and species present in multiple realms were assigned the realm corresponding to the sampling location. The 263 species which passed quality control checks for genome-wide coverage and missing data, as well as full demographic coverage over the focal time period (30 kya–1 mya) are identified as "Analyzed = YES", and demographic clustering groups (where k = 7 groups) are provided for each. *Warming* and *Cooling* (i.e. *Climate Warming* and *Climate Cooling* in-text) refer to demographic responses ("Increase", "Decrease", "Unrelated"; quantified by significant positive/negative correlations between N_e and Global Average Surface Temperature) during periods of warming (~147–123kya) and cooling (~122–65kya, Supplementary Figure 8). IUCN refers to current conservation status (LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered) according to the International Union for Conservation of Nature Red List (www.iucnredlist.org). The mean (±SD) of effective population size (N_e) estimates for each species from 30kya–1mya are given (x 10^4).

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Acanthisitta chloris	Australian	Passeriformes	Group 4	Increase	Increase	LC	YES	12.14 (4.76)
Acrocephalus arundinaceus	Palearctic	Passeriformes	Group 7	Increase	Decrease	LC	YES	11.09 (3.73)
Aegithalos caudatus	Palearctic	Passeriformes	Group 6	Decrease	Unrelated	LC	YES	6.8 (1.1)
Aegotheles bennettii	Oceanian	Caprimulgiformes	Group 6	Decrease	Decrease	LC	YES	26.95 (11.31)
Agapornis roseicollis	Afrotropical	Psittaciformes				LC	NO	3.04 (0.34)
Agelaius phoeniceus	Nearctic	Passeriformes	Group 6	Decrease	Decrease	LC	YES	23.73 (14.67)
Alaudala cheleensis	Sino-Japanese	Passeriformes	Group 6	Increase	Decrease		YES	63.14 (16.25)
Alca torda	Palearctic	Charadriiformes	Group 3	Increase	Unrelated	NT	YES	3.12 (0.53)
Aleadryas rufinucha	Oceanian	Passeriformes	Group 1	Increase	Unrelated	LC	YES	13.22 (2.66)
Alectura lathami	Australian	Galliformes				LC	NO	2.1 (0.46)
Alopecoenas beccarii	Oceanian	Columbiformes	Group 5	Decrease	Decrease	LC	YES	12.29 (1.66)
Amazona guildingii	Neotropical	Psittaciformes	Group 5	Decrease	Decrease	VU	YES	2.52 (1.58)
Anas platyrhynchos		Anseriformes	Group 6	Decrease	Decrease	LC	YES	13.49 (7.5)
Anas zonorhyncha		Anseriformes	Group 6	Decrease	Decrease	LC	YES	18.57 (8.28)
Anhinga anhinga	Nearctic	Suliformes	Group 6	Decrease	Decrease	LC	YES	5.34 (2.21)
Anhinga rufa	Afrotropical	Suliformes				LC	NO	2.94 (0.75)
Anser cygnoides		Anseriformes	Group 6	Decrease	Decrease	VU	YES	8.73 (3.43)
Anseranas semipalmata	Australian	Anseriformes	Group 4	Increase	Unrelated	LC	YES	16.54 (4.53)
Anthoscopus minutus	Afrotropical	Passeriformes	Group 4	Increase	Decrease	LC	YES	11.07 (3.49)
Antrostomus carolinensis	Nearctic	Caprimulgiformes	Group 6	Decrease	Decrease	NT	YES	21.41 (7.02)
Apaloderma vittatum	Afrotropical	Trogoniformes	Group 4	Unrelated	Increase	LC	YES	7.42 (3.12)
Aptenodytes forsteri		Sphenisciformes	Group 4	Decrease	Decrease	NT	YES	4.18 (0.59)
Apteryx australis	Australian	Apterygiformes				VU	NO	1.42 (0.44)
Apteryx owenii	Australian	Apterygiformes				NT	NO	1.25 (0.52)
Apteryx rowi	Australian	Apterygiformes	Group 5	Increase	Increase	VU	YES	1.83 (0.7)
Aquila chrysaetos	Nearctic	Accipitriformes	Group 7	Increase	Decrease	LC	YES	1.46 (0.25)
Aramus guarauna	Neotropical	Gruiformes	Group 4	Increase	Unrelated	LC	YES	48.84 (23.62)
Ardeotis kori	Afrotropical	Otidiformes	Group 5	Decrease	Unrelated	NT	YES	1.87 (0.56)
Arenaria interpres	Panamanian	Charadriiformes	Group 7	Increase	Decrease	LC	YES	21.8 (6.2)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Asarcornis scutulata	Nearctic	Anseriformes				EN	NO	2.91 (0.44)
Atlantisia rogersi	Palearctic	Gruiformes				VU	NO	1.14 (0.42)
Atrichornis clamosus	Australian	Passeriformes	Group 7	Unrelated	Decrease	EN	YES	9.95 (2.56)
Balaeniceps rex	Afrotropical	Pelecaniformes				VU	NO	0.34 (0.1)
Balearica regulorum	Afrotropical	Gruiformes	Group 7	Decrease	Decrease	EN	YES	3.53 (0.49)
Bombycilla garrulus	Nearctic	Passeriformes	Group 3	Decrease	Increase	LC	YES	17.73 (4.98)
Brachypteracias leptosomus	Madagascan	Coraciiformes	Group 5	Decrease	Decrease	VU	YES	3.49 (1.51)
Bucco capensis	Neotropical	Piciformes	Group 7	Decrease	Decrease	LC	YES	24.03 (10.92)
Buceros rhinoceros	Oriental	Bucerotiformes				VU	NO	0.82 (0.35)
Bucorvus abyssinicus	Afrotropical	Bucerotiformes	Group 6	Decrease	Decrease	VU	YES	3.25 (1.17)
Buphagus erythrorhynchus	Afrotropical	Passeriformes	Group 6	Decrease	Decrease	LC	YES	12.14 (4.97)
Burhinus bistriatus	Neotropical	Charadriiformes	Group 5	Increase	Increase	LC	YES	2.98 (0.69)
Cairina moschata		Anseriformes	Group 7	Decrease	Decrease	LC	YES	12.78 (3.97)
Calcarius ornatus	Nearctic	Passeriformes	Group 5	Decrease	Decrease	VU	YES	29.71 (6.35)
Callaeas wilsoni	Australian	Passeriformes	Group 4	Increase	Unrelated	NT	YES	19.43 (9.86)
Callipepla squamata	Nearctic	Galliformes	Group 7	Increase	Decrease	LC	YES	11.24 (2.13)
Calonectris borealis	Palearctic	Procellariiformes	Group 4	Decrease	Increase	LC	YES	4.68 (0.83)
Calypte anna	Nearctic	Caprimulgiformes	Group 4	Increase	Increase	LC	YES	10.47 (3.14)
Calyptomena viridis	Oriental	Passeriformes	Group 6	Decrease	Decrease	NT	YES	24.47 (10.54)
Campylorhamphus procurvoides	Neotropical	Passeriformes	Group 4	Increase	Decrease	LC	YES	7.41 (2.03)
Cardinalis cardinalis	Nearctic	Passeriformes	Group 4	Decrease	Increase	LC	YES	11.62 (4.78)
Cariama cristata	Neotropical	Cariamiformes	Group 6	Decrease	Decrease	LC	YES	4.11 (1.17)
Casuarius casuarius	Oceanian	Casuariiformes	Group 7	Increase	Unrelated	LC	YES	2.8 (0.71)
Cathartes aura	Nearctic	Cathartiformes	Group 7	Unrelated	Decrease	LC	YES	5.03 (0.67)
Catharus fuscescens	Nearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	34.47 (10.83)
Centropus unirufus	Oriental	Cuculiformes	Group 2	Increase	Decrease	NT	YES	12.96 (3.78)
Cephalopterus ornatus	Neotropical	Passeriformes	Group 4	Increase	Unrelated	LC	YES	5.95 (2.48)
Cepphus grylle	Nearctic	Charadriiformes	Group 3	Unrelated	Unrelated	LC	YES	4.65 (0.89)
Cercotrichas coryphaeus	Afrotropical	Passeriformes	Group 6	Decrease	Decrease	LC	YES	42.14 (16.4)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Certhia brachydactyla	Palearctic	Passeriformes				LC	NO	6.44 (0.41)
Certhia familiaris	Palearctic	Passeriformes	Group 7	Decrease	Decrease	LC	YES	6.63 (1.31)
Ceuthmochares aereus	Afrotropical	Cuculiformes	Group 6	Decrease	Decrease	LC	YES	11.8 (4.07)
Ceyx cyanopectus	Oriental	Coraciiformes				LC	NO	
Chaetorhynchus papuensis	Oceanian	Passeriformes	Group 7	Decrease	Decrease	LC	YES	38.03 (9.39)
Chaetura pelagica	Nearctic	Caprimulgiformes				VU	NO	3.34 (0.33)
Charadrius vociferus	Neotropical	Charadriiformes				LC	NO	4.02 (1.52)
Chauna torquata	Neotropical	Anseriformes	Group 6	Decrease	Decrease	LC	YES	6.74 (2.3)
Chionis minor	Afrotropical	Charadriiformes				LC	NO	0.68 (0.1)
Chlamydotis macqueenii	Saharo-Arabian	Otidiformes	Group 3	Increase	Unrelated	VU	YES	6.05 (1.45)
Chloroceryle aenea	Neotropical	Coraciiformes	Group 5	Decrease	Decrease	LC	YES	18.99 (6.36)
Chloropsis cyanopogon	Oriental	Passeriformes	Group 6	Decrease	Decrease	NT	YES	20.07 (12.06)
Chloropsis hardwickii	Sino-Japanese	Passeriformes	Group 3	Decrease	Decrease	LC	YES	9.6 (2.65)
Chordeiles acutipennis	Neotropical	Caprimulgiformes	Group 6	Decrease	Decrease	LC	YES	10.62 (2.17)
Chroicocephalus maculipennis	Neotropical	Charadriiformes	Group 4	Increase	Increase	LC	YES	7.65 (3.26)
Chunga burmeisteri	Neotropical	Cariamiformes	Group 2	Increase	Decrease	LC	YES	12.39 (4.87)
Ciccaba nigrolineata	Panamanian	Strigiformes	Group 5	Decrease	Increase	LC	YES	2.87 (1.07)
Ciconia maguari	Neotropical	Ciconiiformes	Group 1	Increase	Increase	LC	YES	1.43 (0.26)
Cinclus mexicanus	Nearctic	Passeriformes				LC	NO	3.16 (0.67)
Circaetus pectoralis	Afrotropical	Accipitriformes	Group 1	Increase	Increase	LC	YES	2.21 (0.16)
Cisticola juncidis	Sino-Japanese	Passeriformes				LC	NO	6.06 (2.18)
Climacteris rufus	Australian	Passeriformes	Group 4	Increase	Increase	LC	YES	10.83 (3.49)
Cnemophilus loriae	Oceanian	Passeriformes	Group 2	Decrease	Decrease	LC	YES	16.8 (6.74)
Cochlearius cochlearius	Neotropical	Pelecaniformes	Group 7	Increase	Decrease	LC	YES	32.03 (7.11)
Colinus virginianus	Nearctic	Galliformes	Group 6	Decrease	Decrease	NT	YES	25.03 (9.48)
Colius striatus	Afrotropical	Coliiformes	Group 5	Unrelated	Increase	LC	YES	8.36 (1.85)
Columba livia	Palearctic	Columbiformes	Group 7	Decrease	Decrease	LC	YES	12.63 (2.79)
Columbina picui	Neotropical	Columbiformes	Group 3	Unrelated	Increase	LC	YES	45.01 (11.38)
Copsychus sechellarum	Oceanian	Passeriformes				EN	NO	2.24 (0.73)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Corvus brachyrhynchos	Nearctic	Passeriformes				LC	NO	1.56 (1.27)
Corvus cornix	Palearctic	Passeriformes	Group 3	Decrease	Decrease	LC	YES	5.98 (3.28)
Corvus moneduloides	Oceanian	Passeriformes				LC	NO	1.49 (0.67)
Corythaeola cristata	Afrotropical	Musophagiformes	Group 3	Increase	Increase	LC	YES	4.95 (1.51)
Corythaixoides concolor	Afrotropical	Musophagiformes	Group 5	Increase	Increase	LC	YES	4.81 (0.88)
Coturnix japonica	Sino-Japanese	Galliformes	Group 6	Decrease	Decrease	NT	YES	79.27 (64.14)
Crotophaga sulcirostris	Panamanian	Cuculiformes	Group 4	Increase	Unrelated	LC	YES	18.2 (8.03)
Crypturellus cinnamomeus	Panamanian	Tinamiformes	Group 6	Decrease	Decrease	LC	YES	6.92 (2.66)
Crypturellus soui	Neotropical	Tinamiformes	Group 6	Decrease	Decrease	LC	YES	12.83 (5.43)
Crypturellus undulatus	Neotropical	Tinamiformes	Group 2	Decrease	Decrease	LC	YES	27.86 (14.92)
Cuculus canorus	Palearctic	Cuculiformes	Group 6	Decrease	Decrease	LC	YES	5.58 (1.29)
Daphoenositta chrysoptera	Australian	Passeriformes	Group 1	Increase	Unrelated	LC	YES	50.43 (5.49)
Dasyornis broadbenti	Australian	Passeriformes	Group 7	Decrease	Decrease	LC	YES	7.55 (3.05)
Dicaeum eximium	Oceanian	Passeriformes	Group 4	Decrease	Increase	LC	YES	26.44 (14.61)
Dicrurus megarhynchus	Oceanian	Passeriformes				NT	NO	5.52 (3.78)
Donacobius atricapilla	Neotropical	Passeriformes	Group 6	Decrease	Decrease	LC	YES	6.61 (2.05)
Dromaius novaehollandiae	Australian	Casuariiformes	Group 7	Decrease	Unrelated	LC	YES	3.92 (0.99)
Dromas ardeola	Afrotropical	Charadriiformes	Group 5	Decrease	Decrease	LC	YES	2.15 (0.85)
Drymodes brunneopygia	Australian	Passeriformes	Group 5	Increase	Decrease	LC	YES	6.8 (1.44)
Dryoscopus gambensis	Afrotropical	Passeriformes	Group 1	Increase	Increase	LC	YES	7.95 (0.69)
Dyaphorophyia castanea	Afrotropical	Passeriformes	Group 1	Increase	Increase	LC	YES	48.98 (76.27)
Edolisoma coerulescens	Oriental	Passeriformes	Group 7	Decrease	Increase	LC	YES	14.49 (1.27)
Egretta garzetta	Sino-Japanese	Pelecaniformes	Group 5	Decrease	Decrease	LC	YES	4.16 (0.34)
Emberiza fucata	Sino-Japanese	Passeriformes	Group 2	Unrelated	Decrease	LC	YES	21.72 (16.58)
Erpornis zantholeuca	Oriental	Passeriformes	Group 6	Decrease	Decrease	LC	YES	12.34 (7.66)
Erythrocercus mccallii	Afrotropical	Passeriformes	Group 3	Decrease	Unrelated	LC	YES	14.21 (3.7)
Eubucco bourcierii	Panamanian	Piciformes				LC	NO	5.29 (1.83)
Eudromia elegans	Neotropical	Tinamiformes	Group 7	Decrease	Decrease	LC	YES	8.54 (2.23)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Eulacestoma nigropectus	Oceanian	Passeriformes	Group 1	Decrease	Decrease	LC	YES	8.02 (0.46)
Eurypyga helias	Neotropical	Eurypygiformes	Group 7	Increase	Decrease	LC	YES	11.66 (2.42)
Eurystomus gularis	Afrotropical	Coraciiformes	Group 2	Increase	Decrease	LC	YES	16.29 (2.17)
Falco cherrug	Saharo-Arabian	Falconiformes	Group 1	Decrease	Unrelated	EN	YES	3.1 (0.94)
Falco peregrinus	Saharo-Arabian	Falconiformes				LC	NO	1.08 (0.05)
Falcunculus frontatus	Australian	Passeriformes	Group 3	Decrease	Increase	LC	YES	14.94 (4.09)
Formicarius rufipectus	Panamanian	Passeriformes				LC	NO	4.21 (1.82)
Fregata magnificens	Nearctic	Suliformes				LC	NO	0.78 (0.06)
Fregetta grallaria	Oceanian	Procellariiformes	Group 3	Unrelated	Decrease	LC	YES	14.15 (6.58)
Fulmarus glacialis	Palearctic	Procellariiformes	Group 3	Increase	Increase	LC	YES	2.14 (0.2)
Furnarius figulus	Neotropical	Passeriformes	Group 4	Increase	Decrease	LC	YES	6.66 (2.58)
Galbula dea	Neotropical	Piciformes	Group 4	Increase	Unrelated	LC	YES	11.22 (4.69)
Gallus gallus	Oriental	Galliformes				LC	NO	12.36 (6.29)
Gavia stellata	Palearctic	Gaviiformes	Group 7	Unrelated	Decrease	LC	YES	6.58 (1.09)
Geococcyx californianus	Nearctic	Cuculiformes				LC	NO	5.37 (1.29)
Geospiza fortis	Neotropical	Passeriformes				LC	NO	1.98 (0.34)
Glareola pratincola	Saharo-Arabian	Charadriiformes	Group 1	Increase	Increase	LC	YES	20.29 (3.73)
Glaucidium brasilianum	Neotropical	Strigiformes	Group 1	Increase	Increase	LC	YES	15.11 (13.93)
Grallaria varia	Neotropical	Passeriformes	Group 4	Decrease	Increase	LC	YES	7.17 (2.81)
Grantiella picta	Australian	Passeriformes	Group 7	Increase	Increase	VU	YES	19.62 (5.21)
Grus americana	Nearctic	Gruiformes				EN	NO	1.37 (0.28)
Gymnorhina tibicen	Australian	Passeriformes	Group 3	Decrease	Increase	LC	YES	22.01 (7.75)
Halcyon senegalensis	Afrotropical	Coraciiformes	Group 5	Decrease	Decrease	LC	YES	20.75 (8.9)
Haliaeetus albicilla	Palearctic	Accipitriformes	Group 4	Increase	Unrelated	LC	YES	0.93 (0.28)
Haliaeetus leucocephalus	Nearctic	Accipitriformes				LC	NO	
Heliornis fulica	Neotropical	Gruiformes	Group 5	Unrelated	Increase	LC	YES	8.91 (4.46)
Hemignathus wilsoni	Nearctic	Passeriformes				EN	NO	4.09 (1.6)
Hemiprocne comata	Oriental	Caprimulgiformes	Group 6	Decrease	Decrease	LC	YES	20.8 (6.94)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Herpetotheres cachinnans	Panamanian	Falconiformes	Group 6	Decrease	Decrease	LC	YES	8.5 (2.39)
Himantopus himantopus	Neotropical	Charadriiformes	Group 4	Increase	Increase	LC	YES	13.75 (4.38)
Hippolais icterina	Palearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	16.09 (3.5)
Hirundo rustica	Nearctic	Passeriformes	Group 3	Decrease	Decrease	LC	YES	26.49 (14.85)
Horornis vulcanius	Oriental	Passeriformes					NO	6.29 (1.54)
Hydrobates tethys	Nearctic	Procellariiformes	Group 6	Decrease	Decrease	LC	YES	14.18 (3.24)
Hylia prasina	Afrotropical	Passeriformes	Group 1	Increase	Increase	LC	YES	26.98 (16.97)
Hypocryptadius cinnamomeus	Oriental	Passeriformes				LC	NO	5.89 (1.65)
Ibidorhyncha struthersii	Sino-Japanese	Charadriiformes				LC	NO	1.59 (0.18)
Ifrita kowaldi	Oceanian	Passeriformes	Group 4	Decrease	Unrelated	LC	YES	10.26 (2.68)
Illadopsis cleaveri	Afrotropical	Passeriformes	Group 3	Unrelated	Decrease	LC	YES	48.98 (26.59)
Indicator maculatus	Afrotropical	Piciformes	Group 7	Decrease	Decrease	LC	YES	14.24 (3.37)
Jacana jacana	Panamanian	Charadriiformes	Group 6	Decrease	Decrease	LC	YES	11.92 (2.86)
Lanius ludovicianus	Nearctic	Passeriformes				NT	NO	6.12 (4.62)
Larus smithsonianus	Nearctic	Charadriiformes	Group 7	Unrelated	Decrease	LC	YES	3.53 (0.57)
Leiothrix lutea	Sino-Japanese	Passeriformes	Group 6	Decrease	Decrease	LC	YES	17.23 (7.62)
Lepidothrix coronata	Neotropical	Passeriformes	Group 2	Decrease	Decrease	LC	YES	51.28 (35.51)
Leptocoma aspasia	Oceanian	Passeriformes	Group 4	Increase	Increase	LC	YES	13.68 (11.7)
Leptosomus discolor	Madagascan	Leptosomiformes	Group 5	Increase	Increase	LC	YES	12.43 (1.9)
Leucopsar rothschildi	Oriental	Passeriformes				CR	NO	0.75 (0.19)
Limosa lapponica	Australian	Charadriiformes	Group 1	Decrease	Increase	NT	YES	6.27 (2.1)
Locustella ochotensis	Palearctic	Passeriformes	Group 2	Increase	Unrelated	LC	YES	19.04 (4.96)
Lonchura striata	Oriental	Passeriformes	Group 2	Increase	Decrease	LC	YES	21.43 (16.37)
Lophotis ruficrista	Afrotropical	Otidiformes	Group 5	Decrease	Unrelated	LC	YES	6.08 (1.96)
Loxia curvirostra	Nearctic	Passeriformes	Group 4	Decrease	Increase	LC	YES	8.34 (3.39)
Loxia leucoptera	Nearctic	Passeriformes	Group 4	Decrease	Increase	LC	YES	35.91 (23.13)
Machaerirhynchus nigripectus	Oceanian	Passeriformes	Group 3	Increase	Unrelated	LC	YES	31.55 (9.34)
Malurus elegans	Australian	Passeriformes	Group 3	Increase	Increase	LC	YES	6.77 (2.6)
Manacus manacus	Panamanian	Passeriformes	Group 7	Increase	Increase	LC	YES	10.46 (2.13)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Melanocharis versteri	Oceanian	Passeriformes	Group 3	Decrease	Decrease	LC	YES	37.28 (14.14)
Melopsittacus undulatus	Australian	Psittaciformes	Group 1	Increase	Increase	LC	YES	6.58 (1.49)
Melospiza melodia	Nearctic	Passeriformes	Group 4	Increase	Decrease	LC	YES	12.89 (6)
Menura novaehollandiae	Australian	Passeriformes	Group 7	Increase	Decrease	LC	YES	3.43 (0.76)
Merops nubicus	Afrotropical	Coraciiformes	Group 5	Increase	Increase	LC	YES	12.36 (4.45)
Mesembrinibis cayennensis	Panamanian	Pelecaniformes	Group 6	Decrease	Decrease	LC	YES	9.48 (3.68)
Mesitornis unicolor	Madagascan	Mesitornithiformes	Group 5	Decrease	Increase	VU	YES	3.63 (0.37)
Mionectes macconnelli	Neotropical	Passeriformes	Group 5	Increase	Decrease	LC	YES	13.08 (4.83)
Mohoua ochrocephala	Australian	Passeriformes	Group 7	Increase	Decrease	EN	YES	9.83 (3.4)
Molothrus ater	Nearctic	Passeriformes	Group 3	Decrease	Decrease	LC	YES	16.35 (9.42)
Motacilla alba	Palearctic	Passeriformes	Group 2	Decrease	Decrease	LC	YES	13.56 (7.82)
Mystacornis crossleyi	Madagascan	Passeriformes	Group 6	Decrease	Decrease	LC	YES	8.6 (3.64)
Neodrepanis coruscans	Madagascan	Passeriformes				LC	NO	6.29 (2.1)
Neopipo cinnamomea	Neotropical	Passeriformes	Group 5	Decrease	Decrease	LC	YES	7.17 (2.71)
Nesospiza acunhae	Palearctic	Passeriformes				VU	NO	0.67 (0.08)
Nestor notabilis	Australian	Psittaciformes	Group 5	Decrease	Unrelated	EN	YES	1.9 (0.25)
Nicator chloris	Afrotropical	Passeriformes	Group 7	Decrease	Decrease	LC	YES	10.53 (3.34)
Nothocercus julius	Neotropical	Tinamiformes	Group 7	Decrease	Decrease	LC	YES	4.73 (0.92)
Nothocercus nigrocapillus	Neotropical	Struthioniformes	Group 3	Increase	Increase	LC	YES	8.52 (2.01)
Nothoprocta ornata	Neotropical	Struthioniformes	Group 5	Unrelated	Decrease	LC	YES	12.18 (2.24)
Nothoprocta pentlandii	Neotropical	Struthioniformes	Group 7	Decrease	Decrease	LC	YES	16.71 (4.69)
Nothoprocta perdicaria	Neotropical	Struthioniformes	Group 3	Increase	Increase	LC	YES	16.06 (8.76)
Notiomystis cincta	Australian	Passeriformes				VU	NO	7.86 (2.83)
Numida meleagris	Afrotropical	Galliformes	Group 7	Increase	Decrease	LC	YES	15.61 (3.5)
Nyctibius bracteatus	Neotropical	Caprimulgiformes	Group 5	Decrease	Decrease	LC	YES	15.76 (4.09)
Nyctibius grandis	Neotropical	Caprimulgiformes	Group 5	Decrease	Increase	LC	YES	6.75 (1.79)
Nycticryphes semicollaris	Neotropical	Charadriiformes	Group 1	Increase	Increase	LC	YES	8.67 (3.24)
Nyctiprogne leucopyga	Neotropical	Caprimulgiformes	Group 5	Decrease	Increase	LC	YES	30.5 (8.88)
Oceanites oceanicus	Nearctic	Procellariiformes	Group 5	Decrease	Increase	LC	YES	4.59 (1.43)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Odontophorus gujanensis	Neotropical	Galliformes	Group 2	Decrease	Decrease	NT	YES	25.11 (23.23)
Oenanthe oenanthe	Palearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	19.71 (14.89)
Onychorhynchus coronatus	Panamanian	Passeriformes				LC	NO	5.21 (2.29)
Opisthocomus hoazin	Neotropical	Opisthocomiformes			LC	NO	0.23 (0.01)	
Oreocharis arfaki	Oceanian	Passeriformes		Group 4	Decrease	Increase	LC	YES 62.32 (
Origma solitaria	Australian	Passeriformes	Group 4	Increase	Increase	LC	YES	7.39 (3.8)
Oriolus oriolus	Palearctic	Passeriformes	Group 3	Decrease	Decrease	LC	YES	19.19 (11.47)
Orthonyx spaldingii	Australian	Passeriformes	Group 5	Increase	Decrease	LC	YES	4.77 (1.1)
Oxyruncus cristatus	Neotropical	Passeriformes	Group 3	Decrease	Decrease	LC	YES	34.37 (24.26)
Pachycephala philippinensis	Oriental	Passeriformes	Group 1	Increase	Increase	LC	YES	16.7 (5.62)
Pachyramphus minor	Neotropical	Passeriformes	Group 7	Decrease	Decrease	LC	YES	50.29 (16.55)
Pandion haliaetus	Nearctic	Accipitriformes				LC	NO	1.08 (0.18)
Panurus biarmicus	Palearctic	Passeriformes				LC	NO	7.54 (2.55)
Paradisaea raggiana	Oceanian	Passeriformes	Group 7	Decrease	Decrease	LC	YES	6.42 (1.83)
Pardalotus punctatus	Australian	Passeriformes	Group 3	Decrease	Increase	LC	YES	56.96 (23.48)
Parus major	Palearctic	Passeriformes	Group 4	Increase	Increase	LC	YES	7.23 (3.1)
Passer domesticus	Palearctic	Passeriformes	Group 7	Unrelated	Decrease	LC	YES	14.85 (5.63)
Passerina amoena	Nearctic	Passeriformes	Group 6	Decrease	Decrease	LC	YES	42.64 (26.2)
Patagioenas fasciata		Columbiformes	Group 2	Increase	Decrease	LC	YES	13.3 (6.3)
Pedionomus torquatus	Australian	Charadriiformes	Group 4	Increase	Increase	CR	YES	16.63 (9.04)
Pelecanoides urinatrix	Neotropical	Procellariiformes	Group 6	Decrease	Decrease	LC	YES	10.1 (3.37)
Pelecanus crispus	Saharo-Arabian	Pelecaniformes				NT	NO	0.8 (0.05)
Penelope pileata	Neotropical	Galliformes	Group 5	Increase	Increase	VU	YES	6.07 (1.61)
Peucedramus taeniatus	Nearctic	Passeriformes	Group 3	Unrelated	Increase	LC	YES	24.53 (5.23)
Phaethon lepturus	Afrotropical	Phaethontiformes	Group 6	Decrease	Decrease	LC	YES	3.77 (1.52)
Phalacrocorax auritus	Nearctic	Suliformes	Group 2	Increase	Unrelated	LC	YES	2.68 (0.55)
Phalacrocorax brasilianus	Neotropical	Suliformes	Group 7	Increase	Unrelated	LC	YES	9.63 (1.17)
Phalacrocorax carbo	Palearctic	Suliformes	Group 3	Decrease	Decrease	LC	YES	2.53 (0.39)
Phalacrocorax harrisi	Neotropical	Suliformes				VU	NO	0.48 (0.05)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Phalacrocorax pelagicus	Nearctic	Suliformes	Group 7	Increase	Decrease	LC	YES	2.5 (0.29)
Phasianus colchicus	Sino-Japanese	Galliformes	Group 3	Increase	Increase	LC	YES	24.11 (8.62)
Pheucticus melanocephalus	Nearctic	Passeriformes	Group 2	Decrease	Decrease	LC	YES	19.45 (8.48)
Phoenicopterus ruber		Phoenicopteriformes	Group 7	Decrease	Decrease	LC	YES	8.17 (1.75)
Phylloscopus trochilus	Palearctic	Passeriformes	Group 7	Increase	Unrelated	LC	YES	25.23 (8.82)
Piaya cayana	Neotropical	Cuculiformes	Group 6	Decrease	Decrease	LC	YES	17.63 (7.13)
Picathartes gymnocephalus	Afrotropical	Passeriformes				VU	NO	1.69 (0.15)
Picoides pubescens	Nearctic	Piciformes				LC	NO	4.99 (1.19)
Piprites chloris	Neotropical	Passeriformes	Group 1	Increase	Increase	LC	YES	32.94 (59.32)
Pitta sordida	Oriental	Passeriformes	Group 6	Decrease	Decrease	LC	YES	12.81 (5.38)
Ploceus nigricollis	Afrotropical	Passeriformes	Group 3	Decrease	Decrease	LC	YES	36.23 (14.06)
Pluvianellus socialis	Neotropical	Charadriiformes				NT	NO	1.54 (0.34)
Podargus strigoides	Australian	Caprimulgiformes	Group 6	Decrease	Decrease	LC	YES	19.63 (6.59)
Podiceps cristatus	Nearctic	Podicipediformes	Group 3	Decrease	Decrease	LC	YES	5.62 (1.24)
Podilymbus podiceps	Neotropical	Podicipediformes	Group 4	Increase	Increase	LC	YES	10.06 (2.97)
Poecile atricapillus	Nearctic	Passeriformes	Group 2	Increase	Decrease	LC	YES	20.99 (8.28)
Polioptila caerulea	Nearctic	Passeriformes	Group 1	Decrease	Increase	LC	YES	63.55 (25.38)
Pomatorhinus ruficollis	Sino-Japanese	Passeriformes	Group 7	Increase	Decrease	LC	YES	31 (13.92)
Pomatostomus ruficeps	Australian	Passeriformes	Group 7	Increase	Decrease	LC	YES	7 (1.13)
Promerops cafer	Afrotropical	Passeriformes	Group 3	Decrease	Decrease	LC	YES	10.75 (3.23)
Prunella fulvescens	Palearctic	Passeriformes	Group 4	Increase	Increase	LC	YES	7.87 (1.16)
Prunella himalayana	Palearctic	Passeriformes	Group 3	Decrease	Increase	LC	YES	35.7 (14.15)
Psilopogon haemacephalus	Oriental	Piciformes				LC	NO	5.96 (4.05)
Psophia crepitans	Neotropical	Gruiformes	Group 2	Increase	Decrease	NT	YES	17.35 (6.43)
Pterocles burchelli	Afrotropical	Pterocliformes	Group 5	Decrease	Unrelated	LC	YES	11.78 (8.54)
Pterocles gutturalis	Afrotropical	Pterocliformes	Group 1	Decrease	Increase	LC	YES	4.84 (0.94)
Pteruthius melanotis	Sino-Japanese	Passeriformes	Group 3	Unrelated	Decrease	LC	YES	16.02 (5.76)
Ptilonorhynchus violaceus	Australian	Passeriformes	Group 2	Increase	Decrease	LC	YES	2.94 (0.6)
Ptilorrhoa leucosticta	Oceanian	Passeriformes	Group 7	Unrelated	Decrease	LC	YES	22.93 (7.47)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Pycnonotus jocosus	Nearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	17.81 (2.22)
Pygoscelis adeliae		Sphenisciformes	Group 4	Increase	Increase	LC	YES	2.88 (0.94)
Quiscalus mexicanus	Panamanian	Passeriformes				LC	NO	4.97 (1.96)
Ramphastos sulfuratus	Panamanian	Piciformes	Group 5	Unrelated	Increase	LC	YES	5.8 (1.09)
Regulus satrapa	Nearctic	Passeriformes	Group 3	Decrease	Increase	LC	YES	25.2 (8.68)
Rhabdornis inornatus	Oriental	Passeriformes	Group 1	Decrease	Increase	LC	YES	5.84 (0.32)
Rhadina sibilatrix	Palearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	55.92 (25.37)
Rhagologus leucostigma	Oceanian	Passeriformes	Group 3	Decrease	Decrease	LC	YES	20.68 (6.62)
Rhea americana	Neotropical	Rheiformes	Group 4	Increase	Increase	NT	YES	5.61 (2.07)
Rhea pennata	Neotropical	Rheiformes	Group 3	Increase	Decrease	LC	YES	3.01 (0.72)
Rhinopomastus cyanomelas	Afrotropical	Bucerotiformes	Group 6	Decrease	Decrease	LC	YES	6.66 (3.08)
Rhinoptilus africanus	Afrotropical	Charadriiformes	Group 4	Increase	Increase	LC	YES	21.35 (5.37)
Rhipidura dahli	Oceanian	Passeriformes				LC	NO	4.29 (3.45)
Rhodinocichla rosea	Panamanian	Passeriformes				LC	NO	4.03 (0.94)
Rhynochetos jubatus	Oceanian	Eurypygiformes	Group 3	Decrease	Decrease	EN	YES	9.16 (2.45)
Rissa tridactyla	Nearctic	Charadriiformes	Group 6	Decrease	Decrease	VU	YES	4.19 (2.04)
Rostratula benghalensis	Oriental	Charadriiformes	Group 7	Decrease	Increase	LC	YES	4.54 (0.49)
Rynchops niger	Neotropical	Charadriiformes	Group 3	Unrelated	Increase	LC	YES	5.9 (1.39)
Sakesphorus luctuosus	Neotropical	Passeriformes	Group 7	Decrease	Decrease	LC	YES	7 (1.18)
Sapayoa aenigma	Panamanian	Passeriformes	Group 4	Increase	Increase	LC	YES	7.4 (3.92)
Sclerurus mexicanus	Neotropical	Passeriformes	Group 4	Increase	Increase	LC	YES	7.21 (2.17)
Scopus umbretta	Afrotropical	Pelecaniformes				LC	NO	2.88 (0.24)
Scytalopus superciliaris	Neotropical	Passeriformes	Group 3	Decrease	Decrease	LC	YES	8.46 (2.09)
Serilophus lunatus	Oriental	Passeriformes				LC	NO	4.32 (0.69)
Setophaga coronata	Nearctic	Passeriformes	Group 7	Increase	Increase	LC	YES	14.59 (4.28)
Setophaga kirtlandii	Nearctic	Passeriformes	Group 1	Increase	Increase	NT	YES	14.98 (9.28)
Sinosuthora webbiana	Palearctic	Passeriformes	Group 7	Increase	Unrelated	LC	YES	20.15 (5.75)
Sitta europaea	Palearctic	Passeriformes				LC	NO	3.38 (0.87)
Smithornis capensis	Afrotropical	Passeriformes	Group 7	Increase	Unrelated	LC	YES	11.49 (3.29)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Spizaetus tyrannus	Neotropical	Accipitriformes	Group 1	Decrease	Increase	LC	YES	2.1 (0.51)
Spizella passerina	Nearctic	Passeriformes				LC	NO	7.17 (1.3)
Stercorarius parasiticus	Panamanian	Charadriiformes	Group 1	Decrease	Increase	LC	YES	4.09 (2.55)
Sterrhoptilus dennistouni	Oriental	Passeriformes	Group 4	Increase	Increase	NT	YES	8.27 (2.63)
Strix occidentalis	Nearctic	Strigiformes				NT	NO	0.66 (0.19)
Struthidea cinerea	Australian	Passeriformes	Group 6	Decrease	Decrease	LC	YES	15.28 (7.21)
Struthio camelus	Afrotropical	Struthioniformes				LC	NO	0.49 (0.21)
Sturnus vulgaris		Passeriformes	Group 2	Increase	Decrease	LC	YES	7.48 (2.87)
Sylvia atricapilla	Palearctic	Passeriformes	Group 3	Increase	Increase	LC	YES	16.73 (4.78)
Sylvia borin	Palearctic	Passeriformes	Group 3	Decrease	Decrease	LC	YES	27.61 (12.37)
Sylvietta virens	Afrotropical	Passeriformes	Group 1	Decrease	Decrease	LC	YES	6.29 (3.52)
Syrrhaptes paradoxus	Palearctic	Pterocliformes	Group 5	Decrease	Decrease	LC	YES	12.61 (4.72)
Tachuris rubrigastra	Neotropical	Passeriformes				LC	NO	10.19 (3.44)
Tauraco erythrolophus	Afrotropical	Musophagiformes	Group 6	Decrease	Decrease	LC	YES	6.27 (1.45)
Thinocorus orbignyianus	Neotropical	Charadriiformes	Group 1	Increase	Increase	LC	YES	25.51 (14.64)
Thryothorus ludovicianus	Nearctic	Passeriformes	Group 1	Increase	Increase	LC	YES	21.19 (4.67)
Tichodroma muraria	Palearctic	Passeriformes				LC	NO	1.27 (0.03)
Tinamus guttatus	Neotropical	Tinamiformes	Group 3	Decrease	Decrease	NT	YES	11.24 (3.62)
Todus mexicanus	Panamanian	Coraciiformes	Group 6	Decrease	Decrease	LC	YES	9.83 (2.63)
Toxostoma redivivum	Nearctic	Passeriformes				LC	NO	3.13 (0.93)
Tricholaema leucomelas	Afrotropical	Piciformes	Group 3	Decrease	Decrease	LC	YES	6.43 (1.1)
Trogon melanurus	Neotropical	Trogoniformes	Group 7	Increase	Decrease	LC	YES	29.15 (4.87)
Turnix velox	Australian	Charadriiformes	Group 4	Decrease	Decrease	LC	YES	21.41 (8.32)
Tyrannus savana	Neotropical	Passeriformes	Group 1	Increase	Increase	LC	YES	57.2 (17.53)
Tyto alba	Nearctic	Strigiformes	Group 7	Decrease	Increase	LC	YES	5.11 (0.58)
Upupa epops	Sino-Japanese	Bucerotiformes	Group 7	Increase	Decrease	LC	YES	17.54 (2.04)
Uria aalge	Palearctic	Charadriiformes	Group 1	Decrease	Increase	LC	YES	3.71 (0.46)
Uria lomvia	Nearctic	Charadriiformes	Group 5	Increase	Unrelated	LC	YES	10.16 (3.82)
Urocolius indicus	Afrotropical	Coliiformes	Group 1	Increase	Increase	LC	YES	11.01 (6.6)

Species	Realm	Order	Cluster	Warming	Cooling	IUCN	Analyzed	Mean (SD) N_e x 10^4
Urocynchramus pylzowi	Sino-Japanese	Passeriformes	Group 4	Increase	Increase	LC	YES	11.57 (3.89)
Vidua chalybeata	Afrotropical	Passeriformes				LC	NO	4.41 (1.32)
Vidua macroura	Afrotropical	Passeriformes	Group 2	Increase	Decrease	LC	YES	11.43 (3.76)
Vireo altiloquus	Nearctic	Passeriformes	Group 2	Decrease	Decrease	LC	YES	13.33 (3.34)
Xiphorhynchus elegans	Neotropical	Passeriformes	Group 7	Decrease	Decrease	LC	YES	9.6 (0.85)
Zapornia atra	Oceanian	Gruiformes				VU	NO	4.93 (7.53)
Zonotrichia albicollis	Nearctic	Passeriformes	Group 5	Decrease	Increase	LC	YES	8.55 (2.68)
Zosterops hypoxanthus	Oceanian	Passeriformes	Group 1	Decrease	Decrease	LC	YES	18.38 (7.54)

***Species names (binomial nomenclature) presented in italics**

Supplementary Table 2. Robustness values represented by the average of the consistency ratios at five different values of clustering groups (k).

Number of clusters	**3**	**4**	**5**	**6**	**7**
Robustness (%)	0.7189	0.7803	0.7874	0.7999	0.8349

Supplementary Table 3. Two-sided Chi-square test to determine whether the clustering pattern (k=7) could be explained in part by when species within each cluster group reached their maximum effective population size. The first value in the brackets represent the observed number of species reaching the maximum N_e values in that period, while the second value represents the number of species reaching the maximum N_e values outside that period. Underlined observed values represent significant differences from the background expectations (*: *p-value* < 0.05, **: *p-value* < 0.01, ***: *p-value* < 0.001).

	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Background
Upper Pleistocene (30–129kya)	(30, 4)*** $p = 1.78 \times 10^{-5}$	(14, 6) $p = 0.16$	(32, 10)** $p = 0.001$	(40, 0)*** $p = 1.95 \times 10^{-10}$	(0, 35)*** $p = 8.33 \times 10^{-11}$	(0, 43)*** $p = 1.75 \times 10^{-13}$	(22, 27) $p = 0.31$	(138, 125)
Middle Pleistocene (129–774kya)	(5, 29)*** $p = 4.08 \times 10^{-11}$	(16, 4) $p = 0.27$	(33, 9) $p = 0.09$	(5, 35)*** $p = 2.79 \times 10^{-14}$	(27, 8) $p = 0.2$	(43, 0)*** $p = 7.36 \times 10^{-7}$	(45, 4)*** $p = 5.26 \times 10^{-5}$	(174, 89)
Lower Pleistocene (774–1,000kya)	(3, 31) $p = 0.54$	(0, 20) $p = 0.13$	(0, 42)* $p = 0.01$	(0, 40)* $p = 0.01$	(16, 19)*** $p = 1.54 \times 10^{-8}$	(7, 36) $p = 0.77$	(10, 39) $p = 0.2$	(36, 227)

Supplementary Table 4. Summary of three types of demographic responses (“Increase”, “Decrease”, “Unrelated”; quantified by significant positive/negative correlations between N_e and Global Average Surface Temperature) at different confidence levels (confidence level ≥0; confidence level ≥95%; confidence level ≥90%; confidence level ≥85%; confidence level ≥80%) during periods of warming (~147–123kya) and cooling (~122–65kya; see Supplementary Figure 8).

	Confidence level	**Number of species showing increase response**	**Number of species showing decrease response**	**Number of species showing unrelated response**
Climate Warming	0	108	136	19
	95%	80	109	1
	90%	85	113	1
	85%	86	115	2
	80%	88	117	3
Climate Cooling	0	91	142	30
	95%	71	124	4
	90%	74	129	4
	85%	76	132	7
	80%	81	133	9

Supplementary Table 5. Overall demographic responses to focal periods of past warming (147–123kya) and cooling (122–65kya; see Supplementary Figure 8) at different confidence levels. For both the *Climate Warming* and *Climate Cooling* responses, "Increase" and "Decrease" indicate the direction of significant correlations (Pearson's correlation coefficient) between N_e and Global Average Surface Temperature (GAST; data from[50]), where detected. The number of species exhibiting the combined responses during *Climate Warming* and *Climate Cooling* are given, as well as the categorization label used throughout our study.

Climate Warming	**Climate Cooling**	**Number of species (Confidence level > 0)**	**Number of species (Confidence level ≥ 95%)**	**Number of species (Confidence level ≥ 90%)**	**Number of species (Confidence level ≥ 85%)**	**Number of species (Confidence level ≥ 80%)**	**Categorization label**
Increase	Decrease	33	10	14	16	18	Warming Positive
Decrease	Increase	29	10	12	13	16	Warming Negative
Increase	Increase	55	40	43	44	47	Consistent N_e Increase
Decrease	Decrease	98	80	82	84	84	Consistent N_e Decrease
Demographic change not related to changing GAST during *Climate Warming* or *Climate Cooling*		48	4	4	8	10	N_e independent of climate change

Supplementary Table 6. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for four comparison groups of combined demographic responses to *Climate Warming* and *Climate Cooling* (see Supplementary Table 5) without limiting the confidence level. “Model Group” refers to core model categories depicted in Supplementary Figure 10), “p” represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), “CICc” is the size-corrected C-statistic Information criterion, “ΔCICc” is the difference in CICc between the focal model and the top-ranked model, “l” is the relative likelihood, and “w” represents the CICc weights.

Model Group	**p**	**CICc**	**ΔCICc**	**l**	**w**
“Warming Positive” responses (n = 33) versus all remaining species (n = 230)					
D	**0.223**	**63.199**	**0.000**	**1.000**	**0.158**
D	0.186	64.224	1.025	0.599	0.094
D	0.156	65.095	1.896	0.388	0.061
“Warming Negative” responses (n = 29) versus all remaining species (n = 234)					
D	**0.208**	**63.575**	**0.000**	**1.000**	**0.076**
D	0.192	64.012	0.437	0.804	0.061
D	0.190	64.116	0.541	0.763	0.058
D	0.182	64.320	0.745	0.689	0.052
D	0.173	64.580	1.005	0.605	0.046
K	0.169	64.691	1.117	0.572	0.043
D	0.158	65.050	1.475	0.478	0.036
Species sensitive to *Climate Warming* and *Climate Cooling* (n = 33 + 29) versus species with consistent N_e increase or decrease (n = 98 + 55)					
N	**0.768**	**52.891**	**0.000**	**1.000**	**0.062**
L	0.712	53.991	1.100	0.577	0.036
F	0.723	54.272	1.381	0.501	0.031
L	0.696	54.287	1.395	0.498	0.031
M	0.717	54.388	1.497	0.473	0.030
M	0.686	54.464	1.573	0.456	0.028
M	0.680	54.578	1.687	0.430	0.027
I	0.696	54.756	1.865	0.394	0.025

Model Group	p	CICc	ΔCICc	l	w
Species which exhibited consistent N_e decrease (n = 98) versus all remaining species (n = 165)					
L	**0.222**	**63.222**	**0.000**	**1.000**	**0.049**
I	0.213	63.399	0.177	0.915	0.045
N	0.211	63.410	0.188	0.910	0.044
L	0.202	63.689	0.467	0.792	0.039
I	0.191	64.093	0.871	0.647	0.032
D	0.185	64.212	0.989	0.610	0.030
F	0.181	64.345	1.122	0.571	0.028
K	0.180	64.356	1.133	0.567	0.028
K	0.176	64.479	1.256	0.534	0.026
F	0.174	64.550	1.327	0.515	0.025
F	0.170	64.678	1.455	0.483	0.024
F	0.170	64.685	1.462	0.481	0.023
I	0.168	64.722	1.500	0.472	0.023
D	0.168	64.732	1.510	0.470	0.023
D	0.168	64.743	1.520	0.468	0.023
I	0.163	64.904	1.682	0.431	0.021
I	0.160	64.985	1.763	0.414	0.020
L	0.161	64.997	1.775	0.412	0.020
L	0.160	64.998	1.776	0.411	0.020
L	0.157	65.127	1.904	0.386	0.019
I	0.155	65.168	1.946	0.378	0.018

*For each comparison, the top-ranked model is given in bold.

Supplementary Table 7. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for four comparison groups of combined demographic responses to *Climate Warming* and *Climate Cooling* (see Supplementary Table 5) when setting the confidence level as 95%. "Model Group" refers to core model categories depicted in Supplementary Figure 10), "p" represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), "CICc" is the size-corrected C-statistic Information criterion, "ΔCICc" is the difference in CICc between the focal model and the top-ranked model, "l" is the relative likelihood, and "w" represents the CICc weights.

Model Group	p	CICc	ΔCICc	l	w
"Warming Positive" responses (n = 10) versus all remaining species (n = 134)					
F	**0.568**	**58.481**	**0.000**	**1.000**	**0.073**
L	0.530	58.549	0.069	0.966	0.071
D	0.600	58.593	0.113	0.945	0.069
D	0.619	58.999	0.519	0.772	0.057
F	0.567	59.108	0.627	0.731	0.054
F	0.559	59.246	0.766	0.682	0.050
L	0.467	59.681	1.200	0.549	0.040
F	0.518	59.909	1.428	0.490	0.036
L	0.474	60.069	1.588	0.452	0.033
D	0.584	60.251	1.771	0.413	0.030
"Warming Negative" responses (n = 10) versus all remaining species (n = 134)					
L	**0.784**	**55.470**	**0.000**	**1.000**	**0.164**
F	0.731	57.240	1.770	0.413	0.068
Species sensitive to *Climate Warming* and *Climate Cooling* (n = 10 + 10) versus species with consistent N_e increase or decrease (n = 80 + 40)					
F	**0.651**	**58.690**	**0.000**	**1.000**	**0.134**
F	0.582	59.030	0.340	0.843	0.113
D	0.623	59.890	1.200	0.549	0.074
D	0.541	60.352	1.662	0.436	0.058
F	0.497	60.404	1.714	0.424	0.057

Model Group	p	CICc	ΔCICc	l	w
Species which exhibited consistent N_e decrease (n = 80) versus all remaining species (n = 64)					
I	**0.781**	**56.387**	**0.000**	**1.000**	**0.099**
I	0.709	56.809	0.422	0.810	0.080
L	0.694	57.055	0.668	0.716	0.071
I	0.589	58.123	1.736	0.420	0.042

244 *For each comparison, the top-ranked model is given in bold.

Supplementary Table 8. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for four comparison groups of combined demographic responses to *Climate Warming* and *Climate Cooling* (see Supplementary Table 5) when setting the confidence level as 90%. "Model Group" refers to core model categories depicted in Supplementary Figure 10), "p" represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), "CICc" is the size-corrected C-statistic Information criterion, "ΔCICc" is the difference in CICc between the focal model and the top-ranked model, "l" is the relative likelihood, and "w" represents the CICc weights.

Model Group	p	CICc	ΔCICc	l	w
"Warming Positive" responses (n = 14) versus all remaining species (n = 141)					
D	**0.624**	**58.480**	**0.000**	**1.000**	**0.073**
M	0.517	58.486	0.006	0.997	0.072
F	0.566	58.740	0.260	0.878	0.064
D	0.640	58.949	0.469	0.791	0.057
N	0.457	59.565	1.085	0.581	0.042
D	0.591	59.651	1.171	0.557	0.040
L	0.450	59.699	1.219	0.544	0.039
D	0.501	59.791	1.311	0.519	0.038
D	0.616	60.039	1.558	0.459	0.033
D	0.519	60.075	1.595	0.450	0.033
F	0.449	60.160	1.680	0.432	0.031
F	0.474	60.225	1.745	0.418	0.030
F	0.470	60.295	1.815	0.404	0.029
F	0.501	60.347	1.867	0.393	0.029
F	0.493	60.480	2.000	0.368	0.027
"Warming Negative" responses (n = 12) versus all remaining species (n = 143)					
F	**0.820**	**53.578**	**0.000**	**1.000**	**0.102**
L	0.795	54.111	0.533	0.766	0.078
L	0.833	54.114	0.536	0.765	0.078
M	0.728	54.725	1.147	0.564	0.058
L	0.706	55.140	1.562	0.458	0.047
F	0.779	55.188	1.610	0.447	0.046

Model Group	p	CICc	ΔCICc	l	w
F	0.803	55.554	1.976	0.372	0.038
Species sensitive to *Climate Warming* and *Climate Cooling* (n = 14 + 12) versus species with consistent N_e increase or decrease (n = 82 + 43)					
D	**0.727**	**57.011**	**0.000**	**1.000**	**0.070**
D	0.768	57.184	0.173	0.917	0.065
F	0.668	57.231	0.219	0.896	0.063
D	0.680	57.768	0.757	0.685	0.048
K	0.566	58.288	1.277	0.528	0.037
F	0.544	58.657	1.646	0.439	0.031
D	0.658	58.864	1.853	0.396	0.028
D	0.565	58.889	1.878	0.391	0.028
F	0.606	58.906	1.895	0.388	0.027
F	0.650	58.977	1.966	0.374	0.026
Species which exhibited consistent N_e decrease (n = 82) versus all remaining species (n = 73)					
I	**0.823**	**55.172**	**0.000**	**1.000**	**0.142**
L	0.681	56.882	1.710	0.425	0.060

*For each comparison, the top-ranked model is given in bold.

Supplementary Table 9. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for four comparison groups of combined demographic responses to *Climate Warming* and *Climate Cooling* (see Supplementary Table 5) when setting the confidence level as 85%. "Model Group" refers to core model categories depicted in Supplementary Figure 10), "p" represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), "CICc" is the size-corrected C-statistic Information criterion, "ΔCICc" is the difference in CICc between the focal model and the top-ranked model, "l" is the relative likelihood, and "w" represents the CICc weights.

Model Group	p	CICc	ΔCICc	l	w
"Warming Positive" responses (n = 16) versus all remaining species (n = 149)					
D	**0.589**	**58.065**	**0.000**	**1.000**	**0.069**
D	0.612	58.310	0.245	0.885	0.061
I	0.538	58.374	0.309	0.857	0.059
D	0.601	58.478	0.413	0.813	0.056
D	0.636	58.621	0.556	0.757	0.052
F	0.513	58.789	0.724	0.696	0.048
F	0.505	59.420	1.355	0.508	0.035
D	0.569	59.576	1.511	0.470	0.032
D	0.616	59.604	1.539	0.463	0.032
D	0.564	59.649	1.584	0.453	0.031
D	0.483	59.778	1.713	0.425	0.029
L	0.432	59.793	1.728	0.421	0.029
K	0.444	59.993	1.928	0.381	0.026
D	0.497	60.064	1.999	0.368	0.025
"Warming Negative" responses (n = 13) versus all remaining species (n = 152)					
L	**0.852**	**52.597**	**0.000**	**1.000**	**0.098**
L	0.858	53.254	0.657	0.720	0.071
F	0.811	53.511	0.914	0.633	0.062
L	0.766	53.746	1.148	0.563	0.055
F	0.796	53.825	1.227	0.541	0.053
L	0.750	54.064	1.466	0.480	0.047
F	0.798	54.516	1.919	0.383	0.038

Model Group	p	CICc	ΔCICc	l	w
M	0.726	54.526	1.929	0.381	0.037
L	0.723	54.592	1.994	0.369	0.036
Species sensitive to *Climate Warming* and *Climate Cooling* (n = 16 + 13) versus species with consistent N_e increase or decrease (n = 84 + 44)					
K	**0.730**	**55.284**	**0.000**	**1.000**	**0.063**
D	0.857	55.350	0.065	0.968	0.061
F	0.754	55.579	0.295	0.863	0.055
D	0.789	55.731	0.447	0.800	0.051
D	0.764	56.164	0.880	0.644	0.041
F	0.763	56.182	0.898	0.638	0.040
M	0.635	56.372	1.088	0.581	0.037
I	0.666	56.425	1.141	0.565	0.036
D	0.701	56.481	1.196	0.550	0.035
F	0.694	56.606	1.321	0.517	0.033
D	0.762	57.027	1.743	0.418	0.026
K	0.661	57.147	1.863	0.394	0.025
Species which exhibited consistent N_e decrease (n = 84) versus all remaining species (n = 81)					
K	**0.687**	**55.850**	**0.000**	**1.000**	**0.049**
I	0.714	56.023	0.173	0.917	0.045
D	0.756	56.044	0.194	0.908	0.044
N	0.637	56.148	0.298	0.862	0.042
I	0.664	56.249	0.399	0.819	0.040
I	0.725	56.543	0.693	0.707	0.034
K	0.639	56.678	0.828	0.661	0.032
F	0.667	56.809	0.960	0.619	0.030
D	0.662	56.894	1.045	0.593	0.029
D	0.649	57.102	1.253	0.535	0.026
F	0.612	57.122	1.272	0.529	0.026
D	0.728	57.254	1.404	0.495	0.024
L	0.638	57.278	1.428	0.490	0.024
L	0.553	57.617	1.767	0.413	0.020
D	0.615	57.649	1.799	0.407	0.020
F	0.580	57.664	1.814	0.404	0.020

262 *For each comparison, the top-ranked model is given in bold.

Supplementary Table 10. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for four comparison groups of combined demographic responses to *Climate Warming* and *Climate Cooling* (see Supplementary Table 5) when setting the confidence level as 80%. "Model Group" refers to core model categories depicted in Supplementary Figure 10), "p" represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), "CICc" is the size-corrected C-statistic Information criterion, "ΔCICc" is the difference in CICc between the focal model and the top-ranked model, "l" is the relative likelihood, and "w" represents the CICc weights.

Model Group	p	CICc	ΔCICc	l	w
"Warming Positive" responses (n = 18) versus all remaining species (n = 157)					
D	**0.620**	**57.308**	**0.000**	**1.000**	**0.072**
F	0.614	57.397	0.090	0.956	0.068
D	0.640	57.578	0.271	0.873	0.063
D	0.639	57.603	0.296	0.863	0.062
D	0.679	57.650	0.343	0.842	0.060
F	0.589	58.360	1.053	0.591	0.042
F	0.524	58.369	1.062	0.588	0.042
D	0.675	58.424	1.116	0.572	0.041
D	0.614	58.600	1.292	0.524	0.038
D	0.591	58.919	1.612	0.447	0.032
F	0.519	58.926	1.618	0.445	0.032
I	0.480	59.117	1.810	0.405	0.029
F	0.504	59.177	1.870	0.393	0.028
F	0.533	59.209	1.901	0.387	0.028
D	0.529	59.271	1.964	0.375	0.027
F	0.566	59.279	1.971	0.373	0.027
"Warming Negative" responses (n = 16) versus all remaining species (n = 159)					
I	**0.854**	**53.081**	**0.000**	**1.000**	**0.088**
I	0.808	53.348	0.267	0.875	0.077
L	0.787	53.765	0.684	0.710	0.063
I	0.799	54.238	1.157	0.561	0.050
L	0.724	54.360	1.279	0.528	0.047

Model Group	p	CICc	ΔCICc	l	w
F	0.744	54.584	1.503	0.472	0.042
F	0.726	54.917	1.836	0.399	0.035
F	0.759	54.970	1.889	0.389	0.034
Species sensitive to *Climate Warming* and *Climate Cooling* (n = 18 + 16) versus species with consistent N_e increase or decrease (n = 84 + 47)					
F	**0.895**	**52.331**	**0.000**	**1.000**	**0.126**
F	0.902	53.076	0.745	0.689	0.087
D	0.883	53.547	1.216	0.544	0.068
F	0.826	53.967	1.636	0.441	0.055
F	0.862	54.029	1.698	0.428	0.054
D	0.893	54.283	1.951	0.377	0.047
Species which exhibited consistent N_e decrease (n = 84) versus all remaining species (n = 91)					
F	**0.816**	**53.889**	**0.000**	**1.000**	**0.047**
K	0.778	53.938	0.049	0.976	0.046
M	0.742	54.013	0.125	0.940	0.044
F	0.763	54.229	0.340	0.844	0.040
D	0.835	54.286	0.398	0.820	0.039
L	0.706	54.699	0.811	0.667	0.031
F	0.728	54.886	0.997	0.607	0.029
I	0.715	55.118	1.229	0.541	0.025
F	0.746	55.212	1.323	0.516	0.024
D	0.741	55.302	1.414	0.493	0.023
F	0.779	55.345	1.456	0.483	0.023
K	0.698	55.415	1.526	0.466	0.022
L	0.688	55.598	1.709	0.426	0.020
M	0.657	55.600	1.712	0.425	0.020
L	0.651	55.690	1.801	0.406	0.019
D	0.713	55.778	1.889	0.389	0.018

*For each comparison, the top-ranked model is given in bold.

Supplementary Table 11. List of morphological and life-history traits initially selected for analysis of trait-based influences on long-term demographic responses to climate change, based on links between each trait and population responses to climate change over ecological time scales from contemporary data.

Category	Trait		Predicted response to climate change	Reference
Survival/Growth				
	Body mass		smaller species less sensitive to climate change (particularly warming)	25,90,91
	Body size	*measured as:*	small-bodied species better able to exploit shelter/micro-climate under changing temperature	25,92
		tarsus length		
		wing length		
		bill length/width/depth		
	Relative brain size		Problem solving and flexible resource use allow increased ability to cope with environmental change	93,94
	Generation time		Influence of demographic and environmental stochasticity on population dynamics decreases with longer generation time	95–98
	Maximum longevity		longer-lived species respond slowly to selective pressure, higher extinction probability	96,98
	Mortality Rate		longer-lived species respond slowly to selective pressure, higher extinction probability	96,98

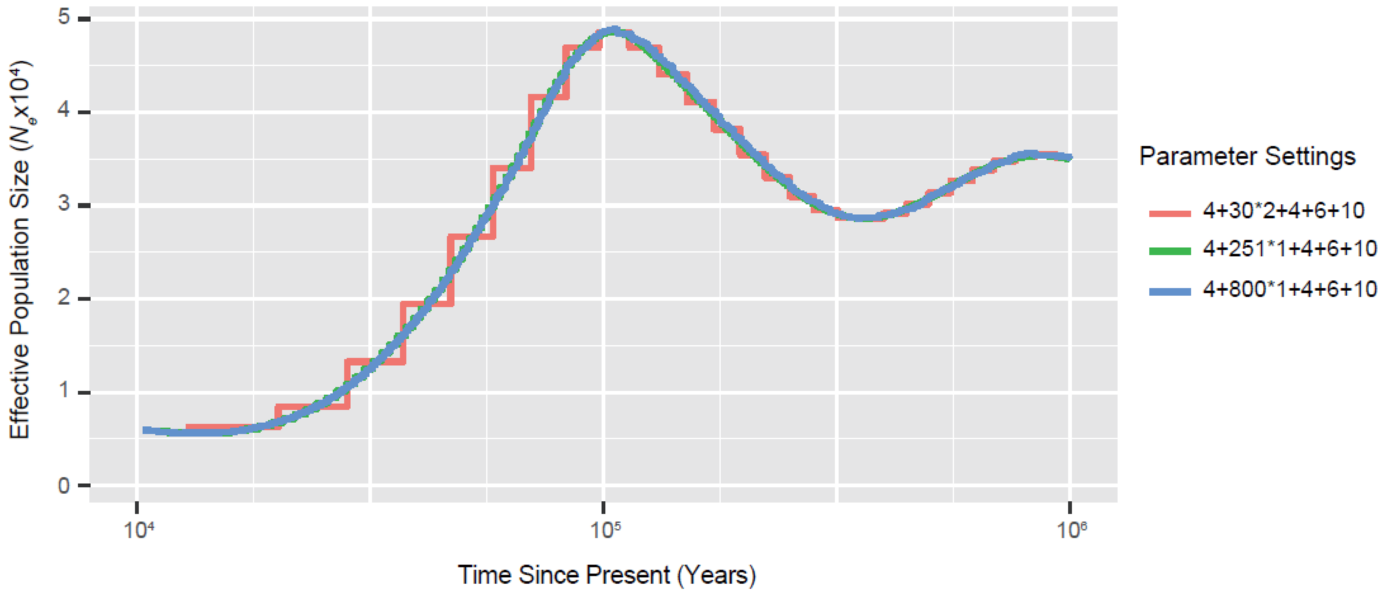
Category	Trait		Predicted response to climate change	Reference
Fecundity				
	Clutch size		Higher reproductive rate linked to increased colonization opportunity under climate change	24,99
	Egg mass		Higher energetic investment in eggs favorable under warm conditions	24,100,101
	Incubation duration		Longer incubation periods typical of species with slow responses to selective pressure, higher extinction probability	96–98,102
Movement/Dispersal				
	Elevational range	*measured as:*	High-elevation species already near climatic and geographic limit, more likely to decline under climate change	13,25
		elevation (min)		
		elevation (max)		
	Movement ability	*measured as:*	Allows for spatial shifts under adverse climate, particularly given phenological changes on breeding grounds	15,91,103,104
		Kipps distance		
		hand-wing index		

Supplementary Table 12. Details of best performing Phylogenetic Path Analysis (PPA; two-sided) models (ΔCICc ≤ 2 from top-ranked model) for comparison between species which exhibited increasing N_e tendency under *Climate Warming* verses those with decreasing N_e tendency under *Climate Warming* at different confidence levels. “Model Group” refers to core model categories depicted in Supplementary Figure 10), “p” represents the p-value (where $p < 0.05$ indicates that the available evidence rejects the model), “CICc” is the size-corrected C-statistic Information criterion, “ΔCICc” is the difference in CICc between the focal model and the top-ranked model, “l” is the relative likelihood, and “w” represents the CICc weights.

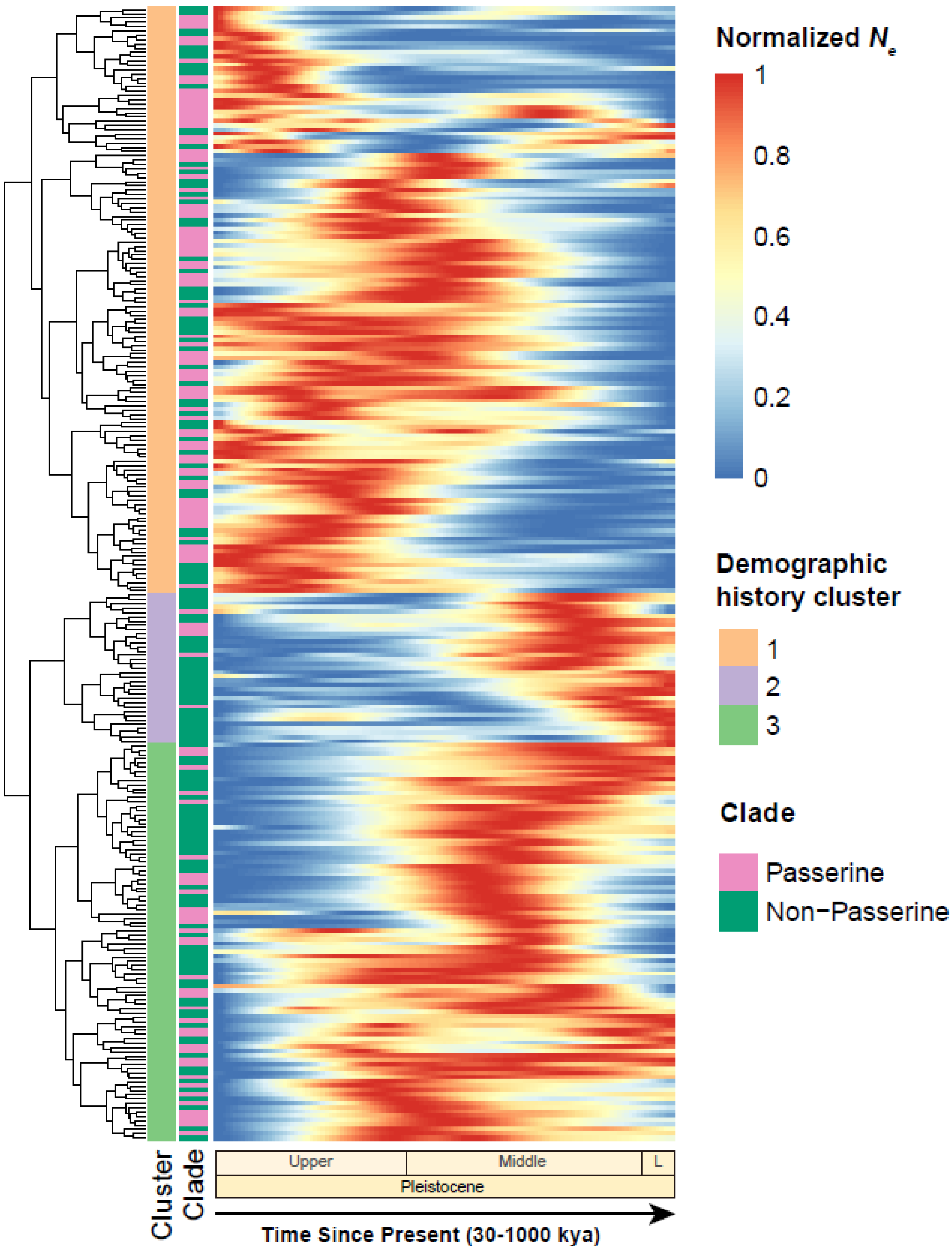
Model Group	**p**	**CICc**	**ΔCICc**	**l**	**w**
Confidence level > 0: species with increasing Ne tendency (n = 108 species) verses those with decreasing Ne tendency (n = 136) under Climate Warming					
N	**0.231**	**63.023**	**0.000**	**1.000**	**0.076**
I	0.225	63.267	0.244	0.885	0.068
I	0.197	64.034	1.011	0.603	0.046
L	0.185	64.352	1.329	0.515	0.039
K	0.184	64.405	1.382	0.501	0.038
D	0.184	64.475	1.452	0.484	0.037
I	0.180	64.589	1.566	0.457	0.035
D	0.169	64.914	1.891	0.389	0.030
Confidence level ≥ 95%: species with increasing Ne tendency (n = 80 species) verses those with decreasing Ne tendency (n = 109) under Climate Warming					
N	**0.456**	**58.906**	**0.000**	**1.000**	**0.130**
Confidence level ≥ 90%: species with increasing Ne tendency (n = 85 species) verses those with decreasing Ne tendency (n = 113) under Climate Warming					
N	**0.409**	**59.636**	**0.000**	**1.000**	**0.117**
I	0.362	60.834	1.198	0.549	0.064
L	0.321	61.431	1.794	0.408	0.048
I	0.331	61.445	1.808	0.405	0.047

Model Group	p	CICc	ΔCICc	l	w
Confidence level ≥ 85%: species with increasing Ne tendency (n = 86 species) verses those with decreasing Ne tendency (n = 115) under Climate Warming					
I	**0.471**	**58.795**	**0.000**	**1.000**	**0.078**
N	0.414	59.514	0.720	0.698	0.055
K	0.408	59.909	1.114	0.573	0.045
I	0.396	60.130	1.336	0.513	0.040
D	0.387	60.608	1.814	0.404	0.032
I	0.387	60.614	1.819	0.403	0.032
I	0.385	60.636	1.841	0.398	0.031
Confidence level ≥ 80%: species with increasing Ne tendency (n = 88 species) verses those with decreasing Ne tendency (n = 117) under Climate Warming					
N	**0.402**	**59.681**	**0.000**	**1.000**	**0.067**
I	0.401	59.980	0.298	0.861	0.058
I	0.393	60.425	0.744	0.689	0.046
D	0.367	60.904	1.222	0.543	0.036
I	0.360	61.023	1.342	0.511	0.034
I	0.346	61.037	1.355	0.508	0.034
K	0.344	61.071	1.390	0.499	0.034
K	0.325	61.469	1.788	0.409	0.028
D	0.330	61.615	1.934	0.380	0.026

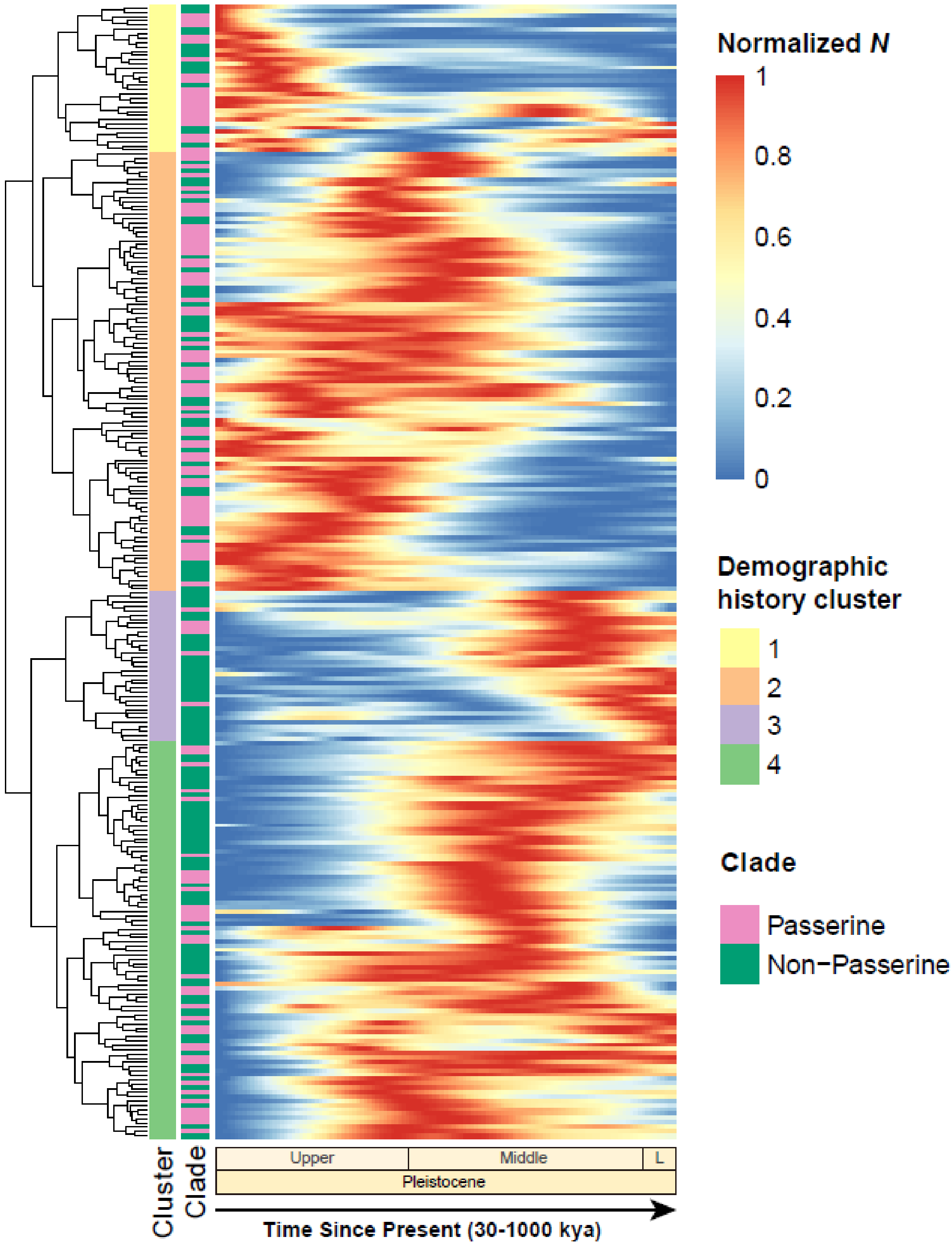
*For each comparison, the top-ranked model is given in bold



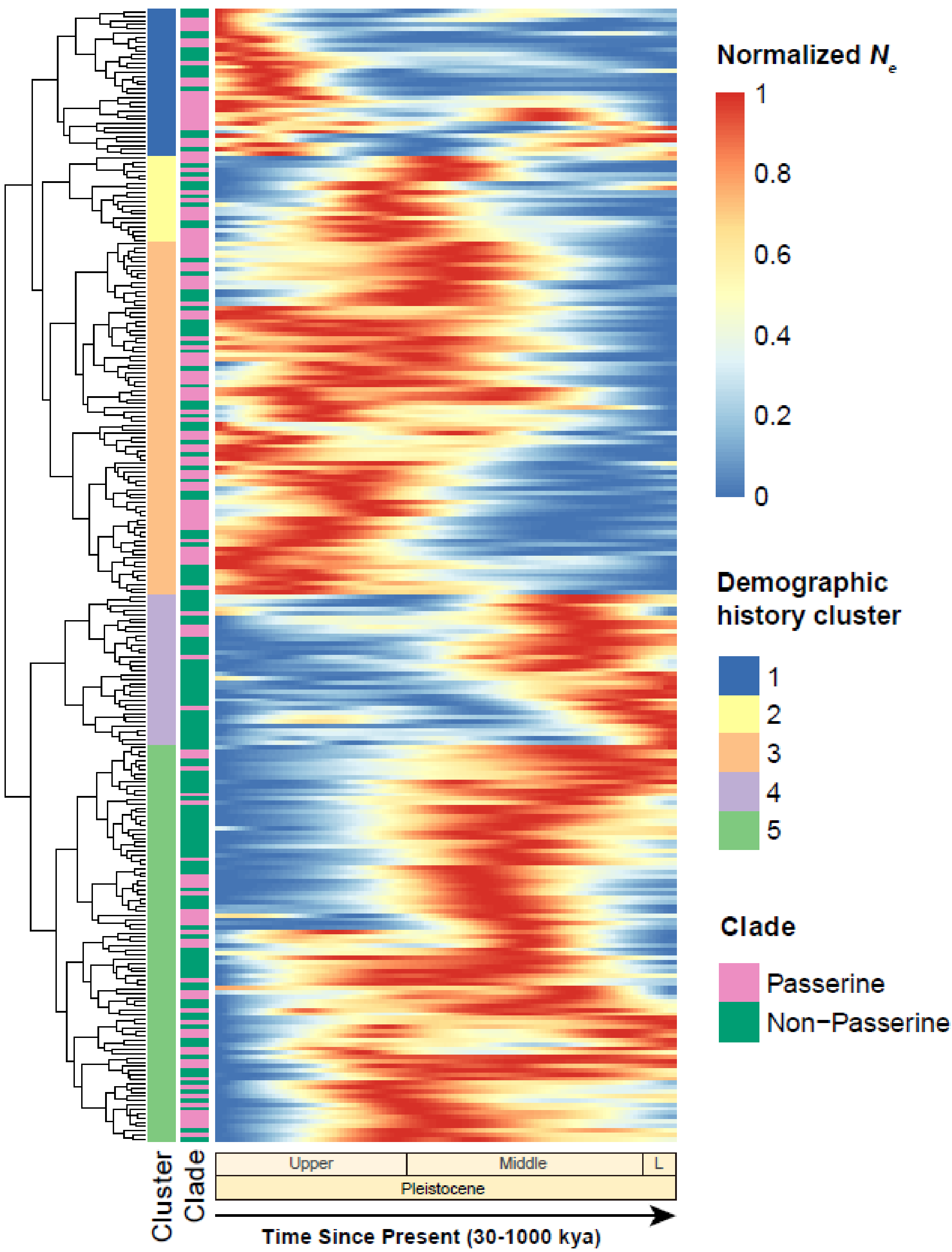
Supplementary Figure 1. PSMC curves of *Menura novaehollandiae* under three parameter settings: 1) -N30 -t5 -r5 -p 4+30*2+4+6+10; 2) -N30 -t5 -r5 -p 4+251*1+4+6+10; and 3) -N30 -t5 -r5 -p 4+800*1+4+6+10.



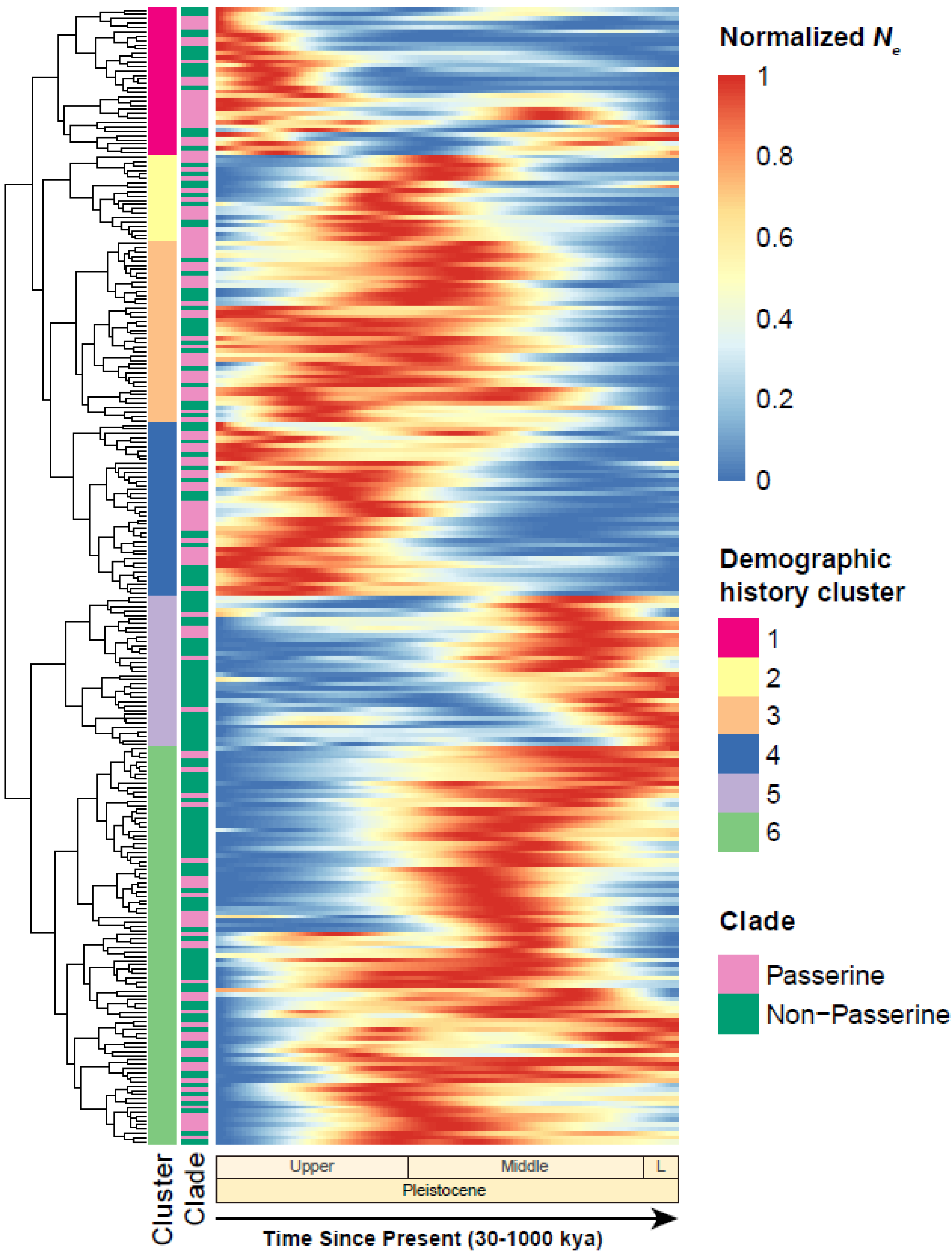
Supplementary Figure 2. Demographic histories of 263 avian species from 30,000 to 1 million years ago (all x-axes presented on the log10 scale), when splitting the clustering dendrogram into 3 groups based on the overall similarity of long-term N_e patterns during the Upper/Middle/Lower(L) Pleistocene.



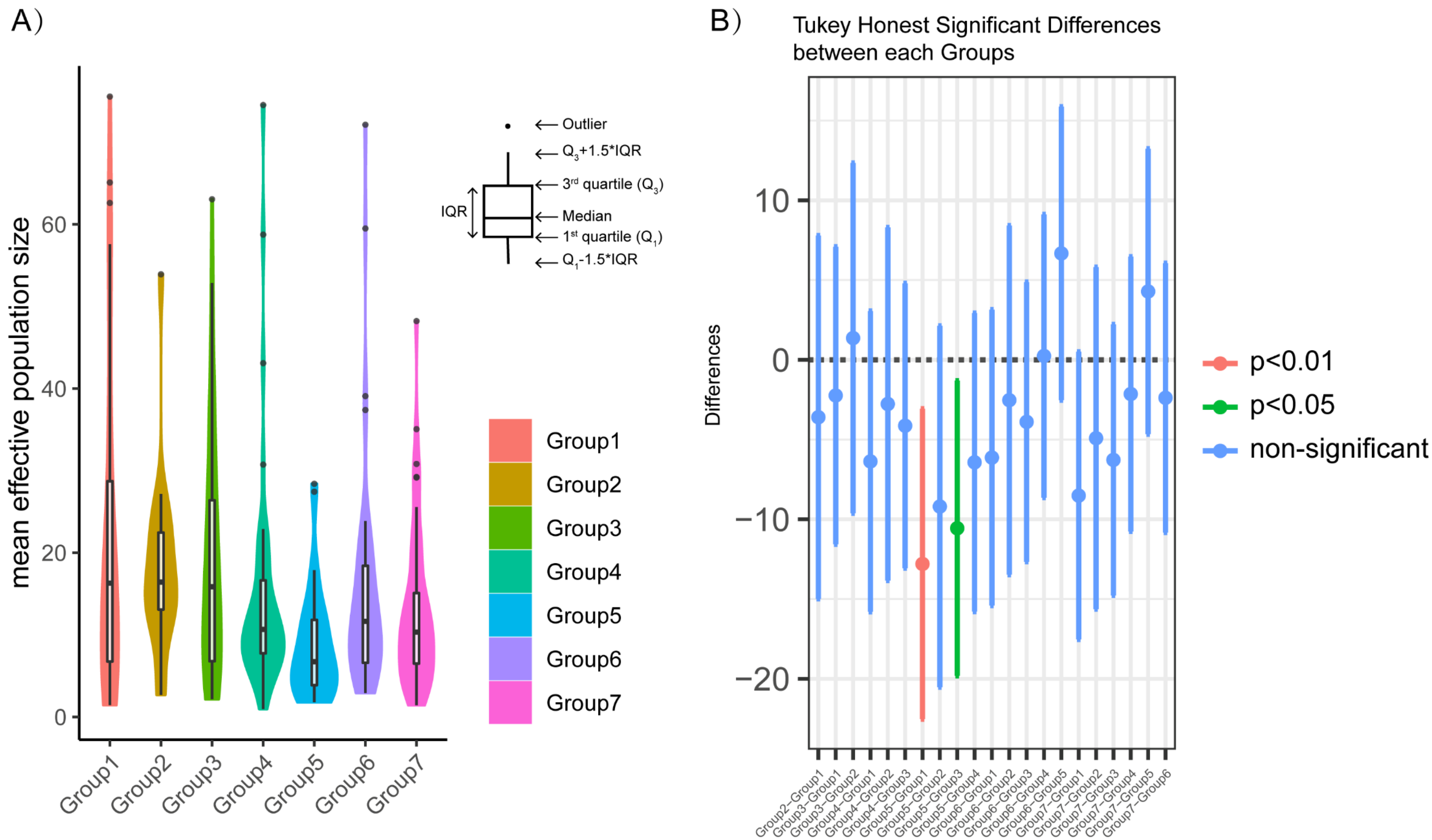
Supplementary Figure 3. Demographic histories of 263 avian species from 30,000 to 1 million years ago (all x-axes presented on the log10 scale), when splitting the clustering dendrogram into 4 groups based on the overall similarity of long-term N_e patterns during the Upper/Middle/Lower(L) Pleistocene.



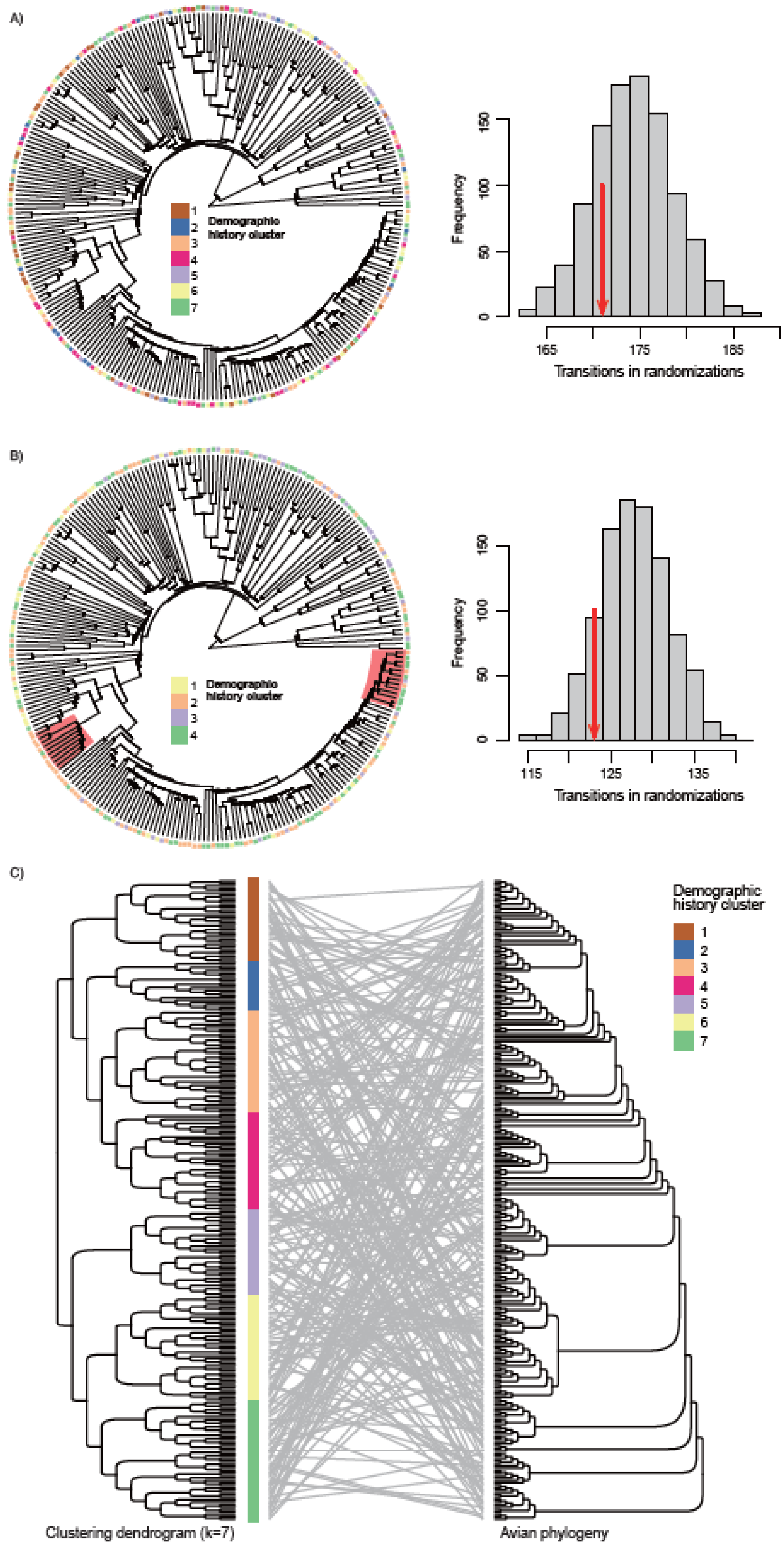
Supplementary Figure 4. Demographic histories of 263 avian species from 30,000 to 1 million years ago (all x-axes presented on the log10 scale), when splitting the clustering dendrogram into 5 groups based on the overall similarity of long-term N_e patterns during the Upper/Middle/Lower(L) Pleistocene.



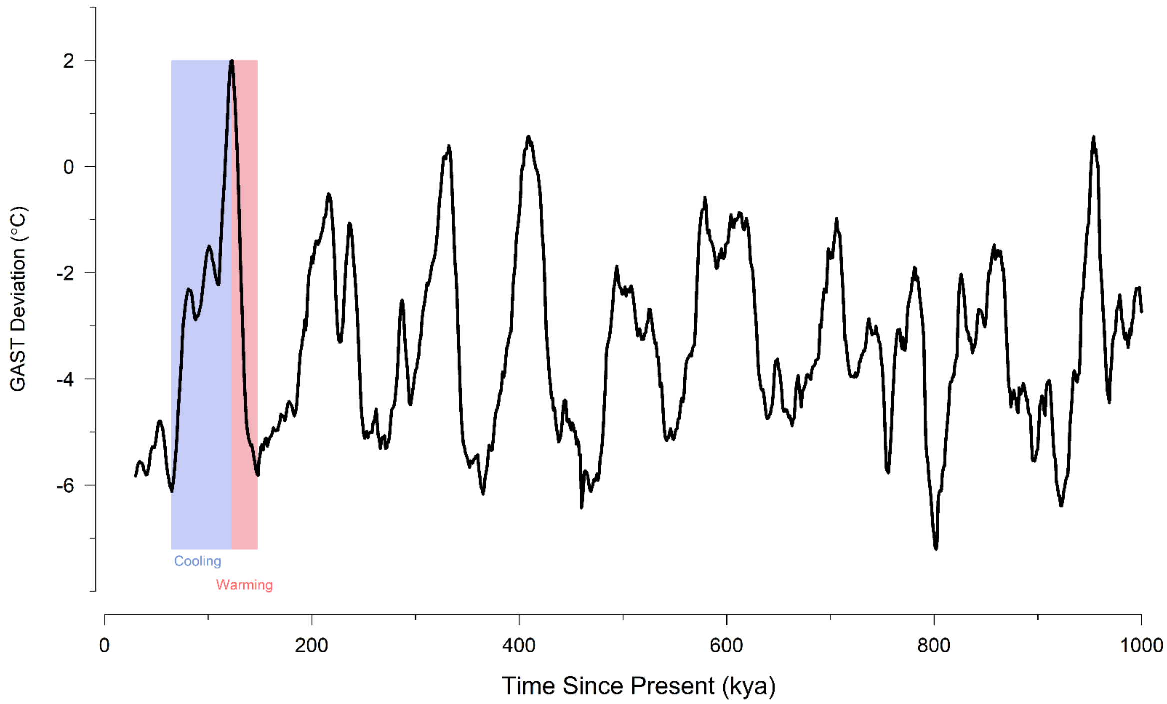
Supplementary Figure 5. Demographic histories of 263 avian species from 30,000 to 1 million years ago (all x-axes presented on the log10 scale), when splitting the clustering dendrogram into 6 groups based on the overall similarity of long-term N_e patterns during the Upper/Middle/Lower(L) Pleistocene.


A)
mean effective population size
0
20
40
60
Outlier
Q3+1.5*IQR
3rd quartile (Q3)
IQR
Median
1st quartile (Q1)
Q1-1.5*IQR
Group1
Group2
Group3
Group4
Group5
Group6
Group7
B)
Tukey Honest Significant Differences
between each Groups
Differences
10
0
−10
−20
p<0.01
p<0.05
non-significant
Group2−Group1
Group3−Group1
Group3−Group2
Group4−Group1
Group4−Group2
Group4−Group3
Group5−Group1
Group5−Group2
Group5−Group3
Group5−Group4
Group6−Group1
Group6−Group2
Group6−Group3
Group6−Group4
Group6−Group5
Group7−Group1
Group7−Group2
Group7−Group3
Group7−Group4
Group7−Group5
Group7−Group6

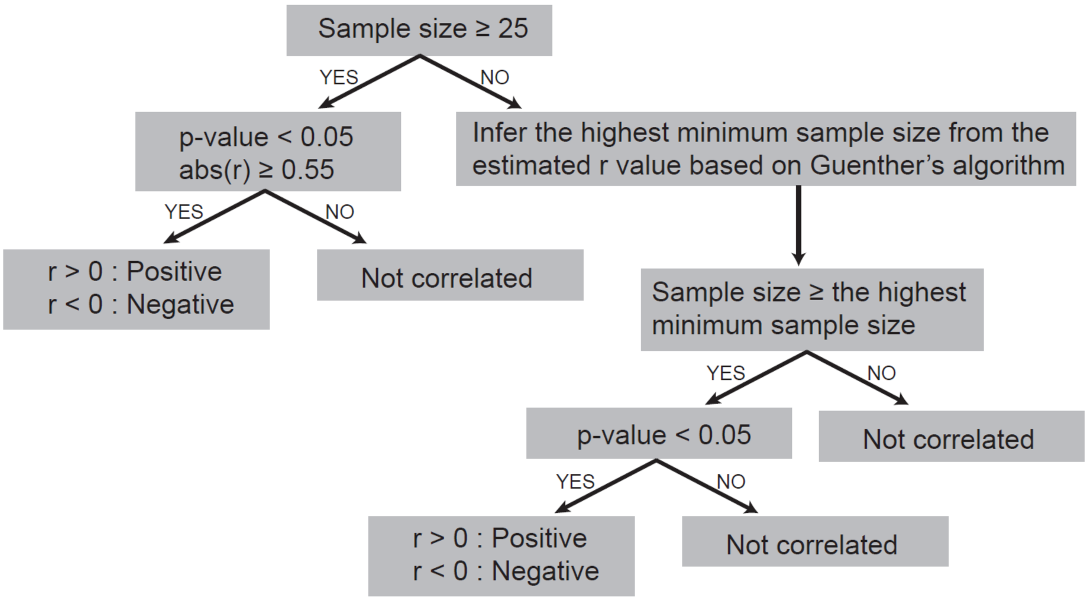
Supplementary Figure 6. Analysis of variance (ANOVA; two-sided) comparing intra-group and inter-group differences of mean N_e values for the k=7 demographic history clusters (Groups 1–7, *n* for each group = 34, 20, 42, 40, 35, 43, 49, respectively). A) Box lines represent the median, 1st quartile (Q1) and 3rd quartiles (Q3), whiskers demarcate ×1.5 the interquartile range (IQR). B) One-sided Tukey Honest Significance test, where dots represent mean inter-group differences and lines represent standard error for each inter-group comparison. Orange and green lines represent significant differences between Group 5 and Group 1 ($p = 0.002$), and Group 5 and Group 3 ($p = 0.02$), respectively.


A)
Demographic history cluster
1
2
3
4
5
6
7
Frequency
0
50
100
150
165
175
185
Transitions in randomizations
B)
Demographic history cluster
1
2
3
4
Frequency
0
50
100
150
115
125
135
Transitions in randomizations
C)
Demographic history cluster
1
2
3
4
5
6
7
Clustering dendrogram (k=7)
Avian phylogeny

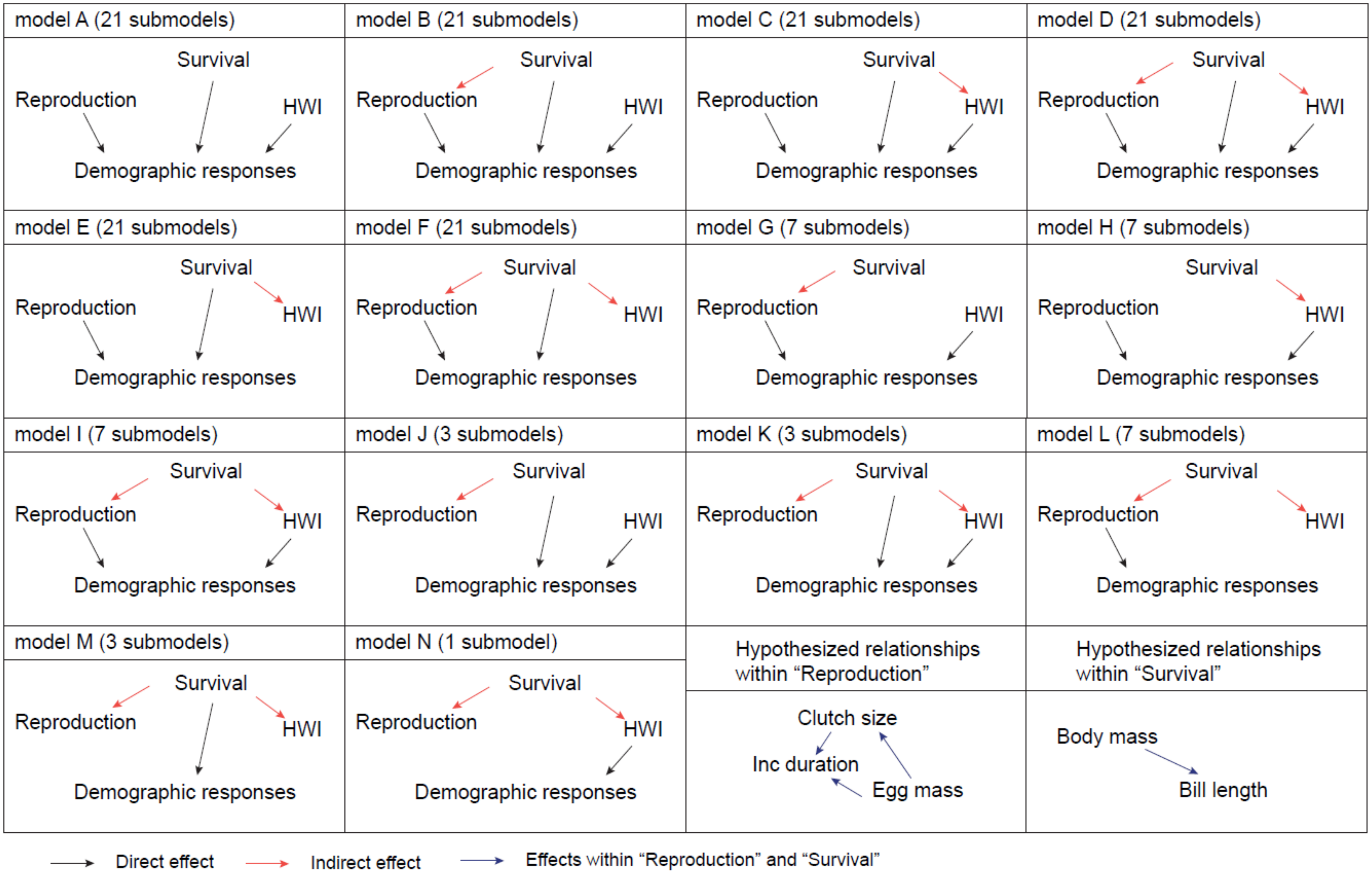
Supplementary Figure 7. Phylogenetic signals of the overall demographic clusters. A) The demographic cluster (k=7) mapped, as a categorical variable, within the phylogeny on the left. The null model of evolutionary transitions is shown in the right histogram with an arrow highlighting the number of observed transitions of clustering labels. B) The demographic cluster (k=4) mapped within the phylogeny on the left. Some phylogenetically related lineages showing the similar N_e trajectories are labeled by the red background. The null model of evolutionary transitions is shown in the right histogram with an arrow highlighting the number of observed transitions of clustering labels. C) Comparison of the position of the species on the clustering dendrogram (k=7) and the most up-to date avian phylogeny developed using B10k resources (Stiller et al., in prep).



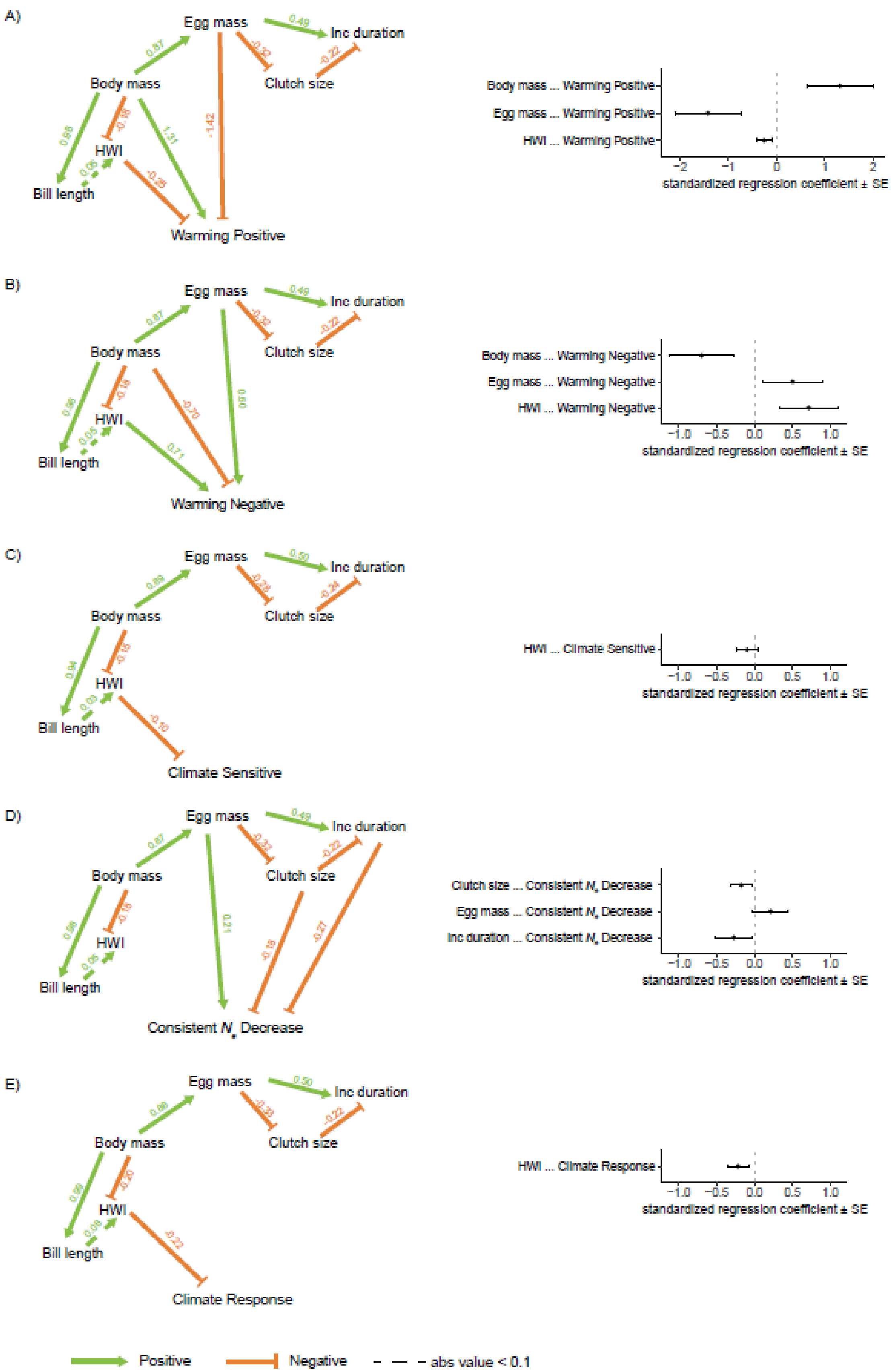
Supplementary Figure 8. Estimated deviation of global average surface temperature (GAST, °C) from present levels (black line, data from Snyder[50]). Blue and red bars depict focal periods of abruptly increasing (~147–123kya) and decreasing (~122–65kya) temperatures, used to calculate species-specific demographic responses during *Climate Warming* and *Climate Cooling*.



Supplementary Figure 9. Flow chart depicting the criteria used in quantifying demographic responses (“Increase”, “Decrease”, and “Unrelated”) to changing climate. *r* represents Pearson's correlation coefficient from two-sided linear correlation test.

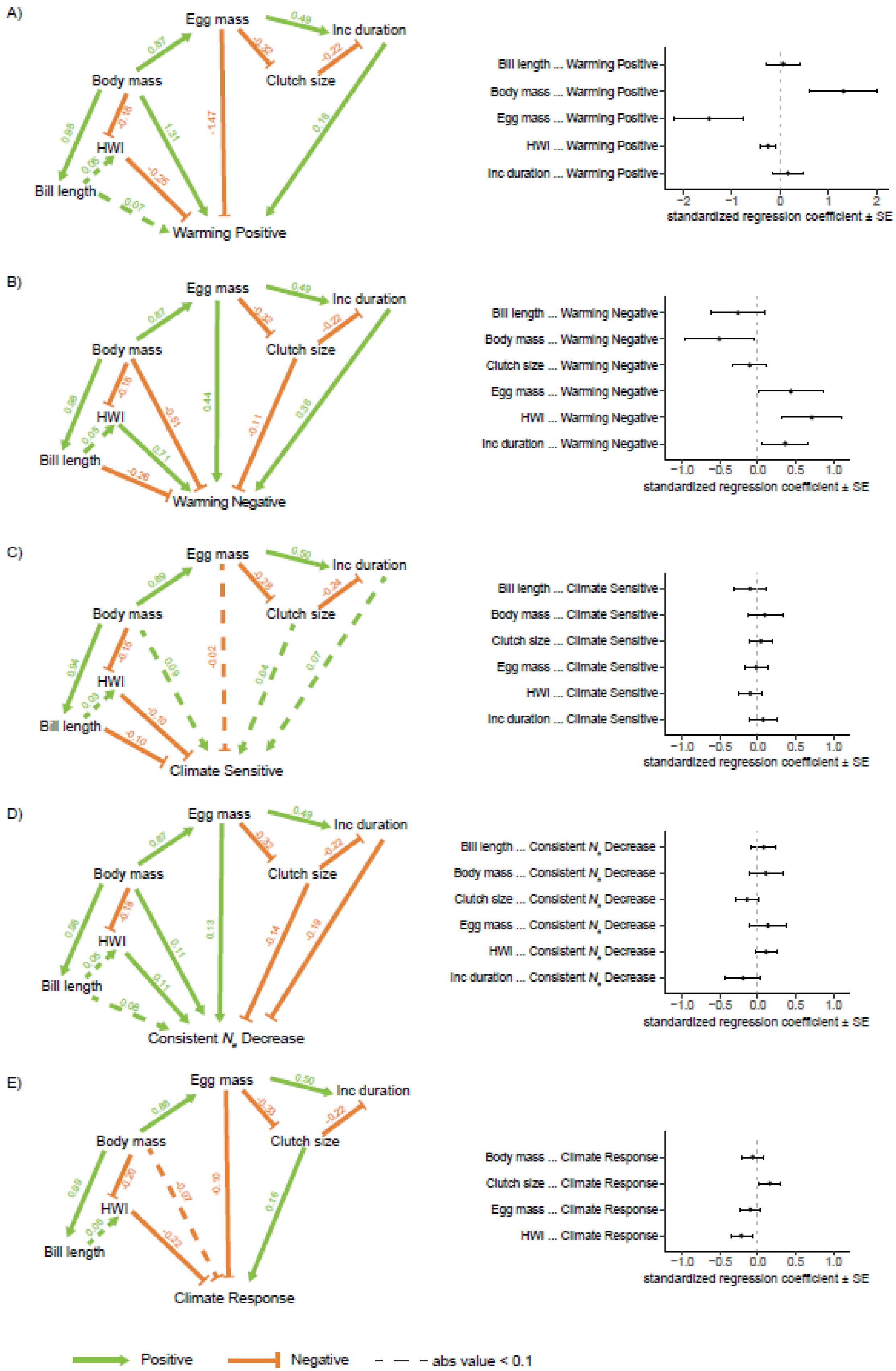

model A (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model B (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model C (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model D (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model E (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model F (21 submodels)
Survival
Reproduction
HWI
Demographic responses
model G (7 submodels)
Survival
Reproduction
HWI
Demographic responses
model H (7 submodels)
Survival
Reproduction
HWI
Demographic responses
model I (7 submodels)
Survival
Reproduction
HWI
Demographic responses
model J (3 submodels)
Survival
Reproduction
HWI
Demographic responses
model K (3 submodels)
Survival
Reproduction
HWI
Demographic responses
model L (7 submodels)
Survival
Reproduction
HWI
Demographic responses
model M (3 submodels)
Survival
Reproduction
HWI
Demographic responses
model N (1 submodel)
Survival
Reproduction
HWI
Demographic responses
Hypothesized relationships within “Reproduction”
Clutch size
Inc duration
Egg mass
Hypothesized relationships within “Survival”
Body mass
Bill length
Direct effect
Indirect effect
Effects within “Reproduction” and “Survival”

Supplementary Figure 10. 14 core models (164 models in total) shown as Directed Acyclic Graphs (DAGs) were tested in Phylogenetic Path Analysis. The "*Reproduction*" category contains three traits (egg mass, clutch size, and incubation duration) and the "*Survival*" category contains two traits (body mass and bill length), each of which have their hypothesized relationships labeled in blue. A direct effect (black) means a trait is directly causally linked to the demographic responses. An indirect effect (red) means a trait is a causal parent of other traits. Since the "*Reproduction*" and "*Survival*" categories contain multiple traits, the number of derived sub models is given in the heading next to the name of each core model.



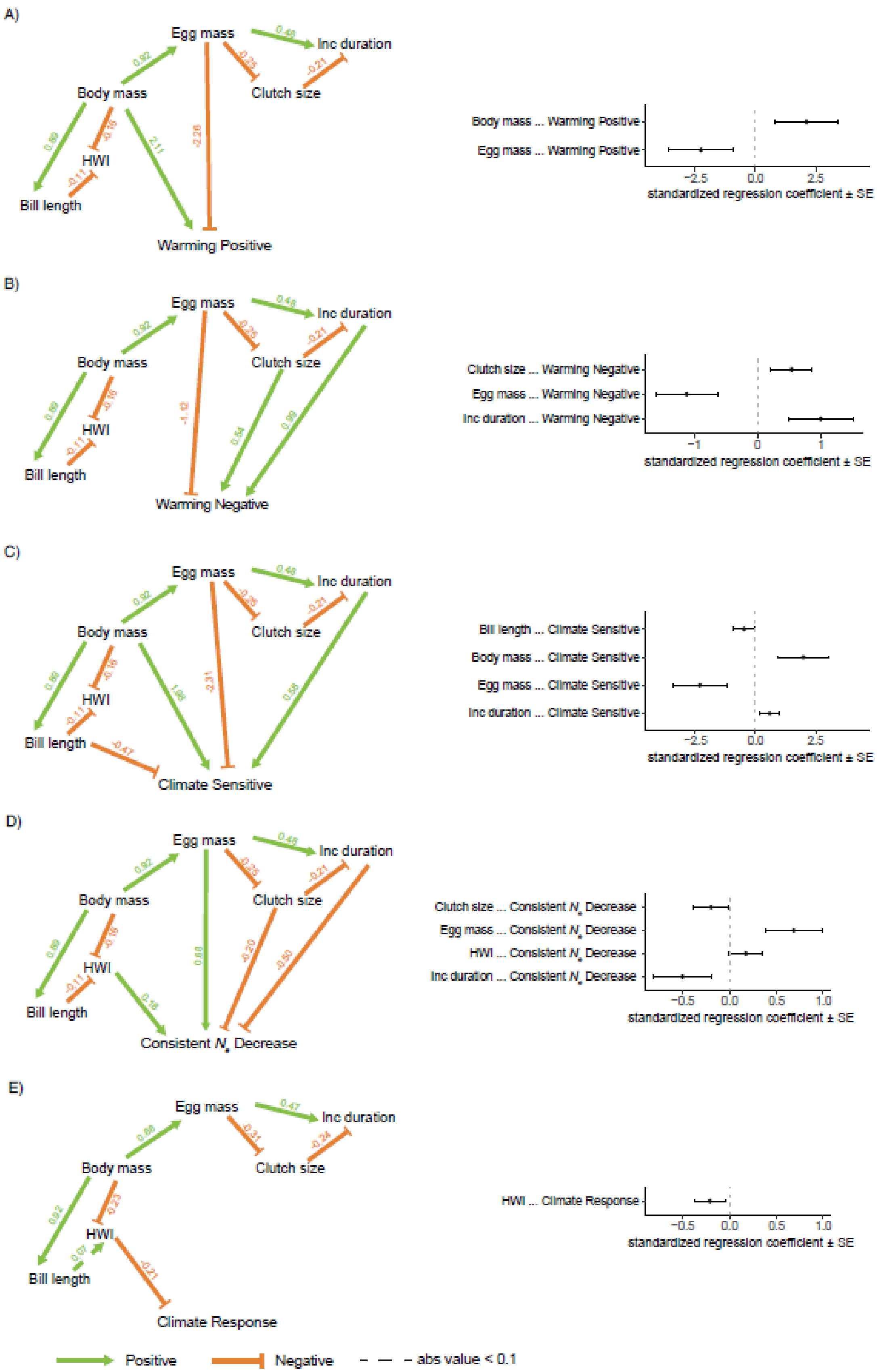
A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Body mass ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Negative
Body mass ... Warming Negative
Egg mass ... Warming Negative
HWI ... Warming Negative
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Sensitive
HWI ... Climate Sensitive
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Response
HWI ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

Supplementary Figure 11. Directed acyclic graphs and corresponding standardized regression coefficients (± standard error) for the top-ranked models of five comparisons implemented via Phylogenetic Path Analysis without limiting the confidence level. A) "Warming Positive" (n = 33) responses versus all remaining species (n = 230). B) "Warming Negative" (n = 29) versus all remaining species (n = 234). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 33 + 29) versus species with consistent N_e increases or decreases (n = 98 + 55). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 98) versus all remaining species (n = 165). E) species with increasing N_e tendency (n = 88) versus species with decreasing N_e tendency (n = 127) under *Climate Warming* (see Supplementary Note 3). Positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. See Supplementary Table 6 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.

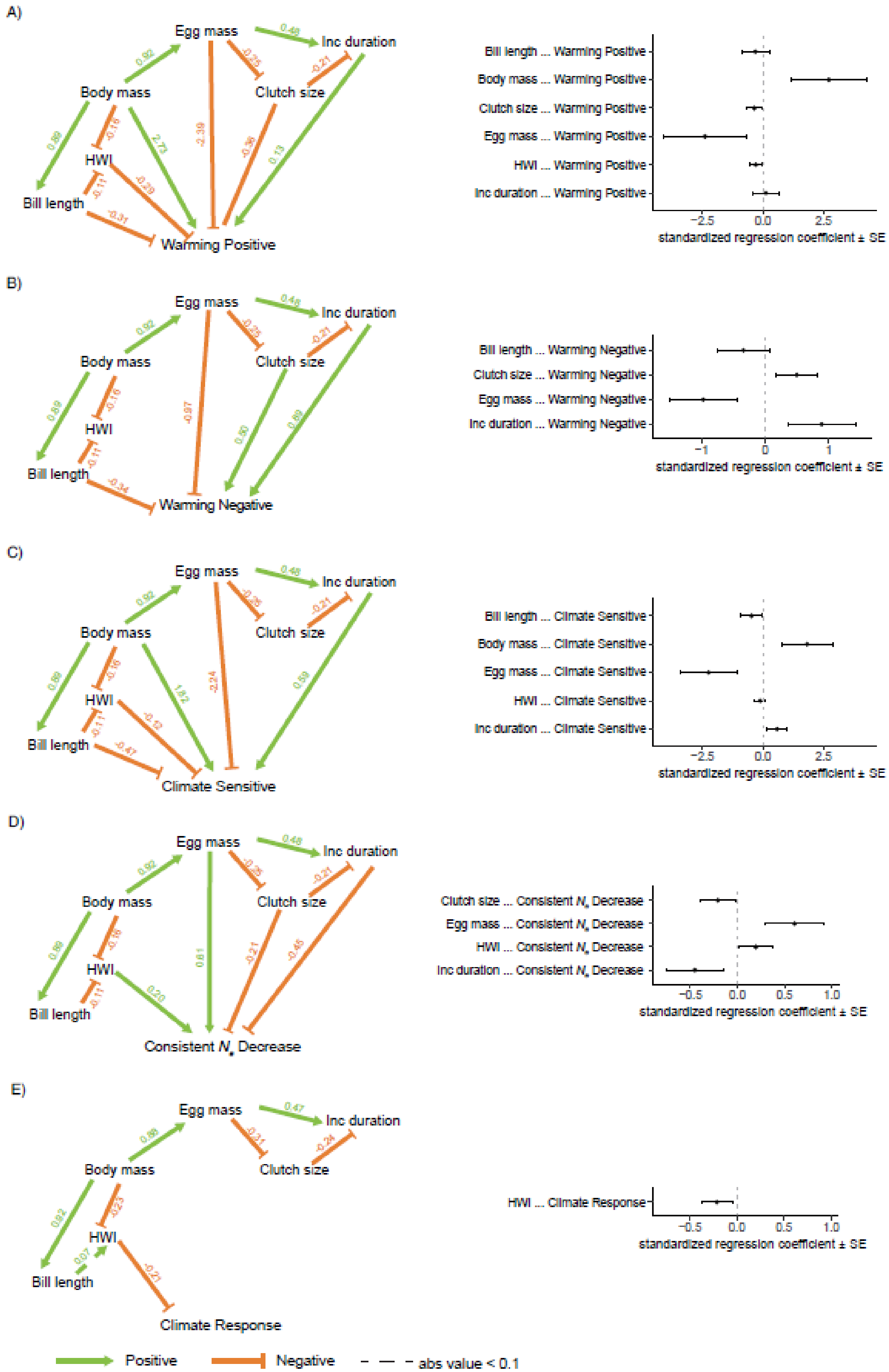


A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Bill length ... Warming Positive
Body mass ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
Inc duration ... Warming Positive
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Negative
Bill length ... Warming Negative
Body mass ... Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
HWI ... Warming Negative
Inc duration ... Warming Negative
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Clutch size ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Consistent N_e Decrease
Bill length ... Consistent N_e Decrease
Body mass ... Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Response
Body mass ... Climate Response
Clutch size ... Climate Response
Egg mass ... Climate Response
HWI ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

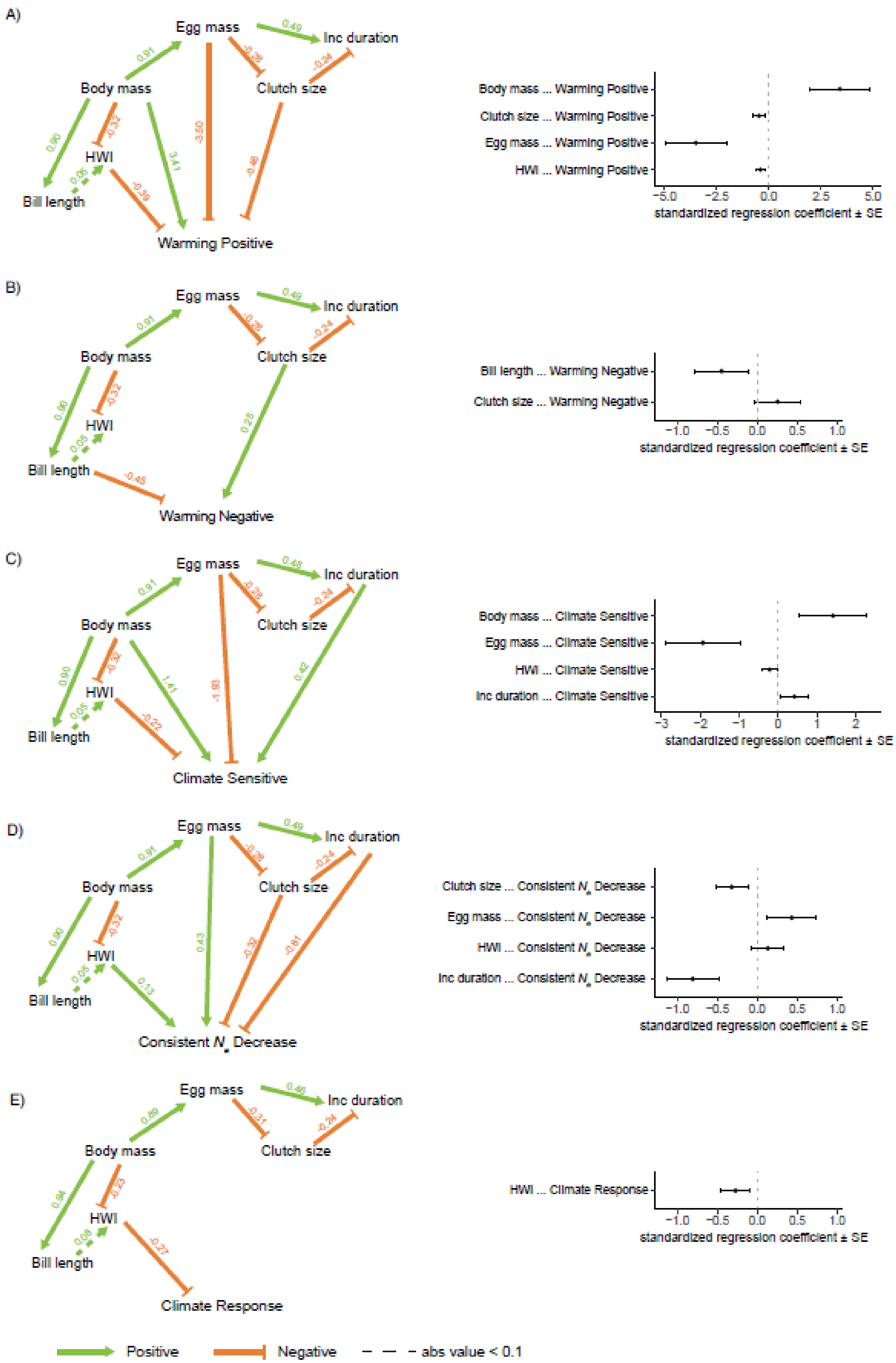
Supplementary Figure 12. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the average best performing models (ΔCICc ≤2 from top-ranked model) of five comparisons implemented via Phylogenetic Path Analysis without limiting the confidence level. A) "Warming Positive" (n = 33) responses versus all remaining species (n = 230). B) "Warming Negative" (n = 29) versus all remaining species (n = 234). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 33 + 29) versus species with consistent N_e increases or decreases (n = 98 + 55). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 98) versus all remaining species (n = 165). E) species with increasing N_e tendency (n = 88) versus species with decreasing N_e tendency (n = 127) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 6 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.


A)
Egg mass
Inc duration
Clutch size
Body mass
HWI
Bill length
Warming Positive
Body mass ... Warming Positive
Egg mass ... Warming Positive
−2.5
0.0
2.5
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Clutch size
Body mass
HWI
Bill length
Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
Inc duration ... Warming Negative
−1
0
1
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Clutch size
Body mass
HWI
Bill length
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Egg mass ... Climate Sensitive
Inc duration ... Climate Sensitive
−2.5
0.0
2.5
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Clutch size
Body mass
HWI
Bill length
Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
−0.5
0.0
0.5
1.0
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Clutch size
Body mass
HWI
Bill length
Climate Response
HWI ... Climate Response
−0.5
0.0
0.5
1.0
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

Supplementary Figure 13. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the top-ranked models of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 95%. A) “Warming Positive” (n = 10) responses versus all remaining species (n = 134). B) “Warming Negative” (n = 10) responses versus all remaining species (n = 134). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 10 + 10) versus species with consistent N_e increases or decreases (n = 80 + 40). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 80) versus all remaining species (n = 64). E) species with increasing N_e tendency (n = 80) versus species with decreasing N_e tendency (n = 113) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 7 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.

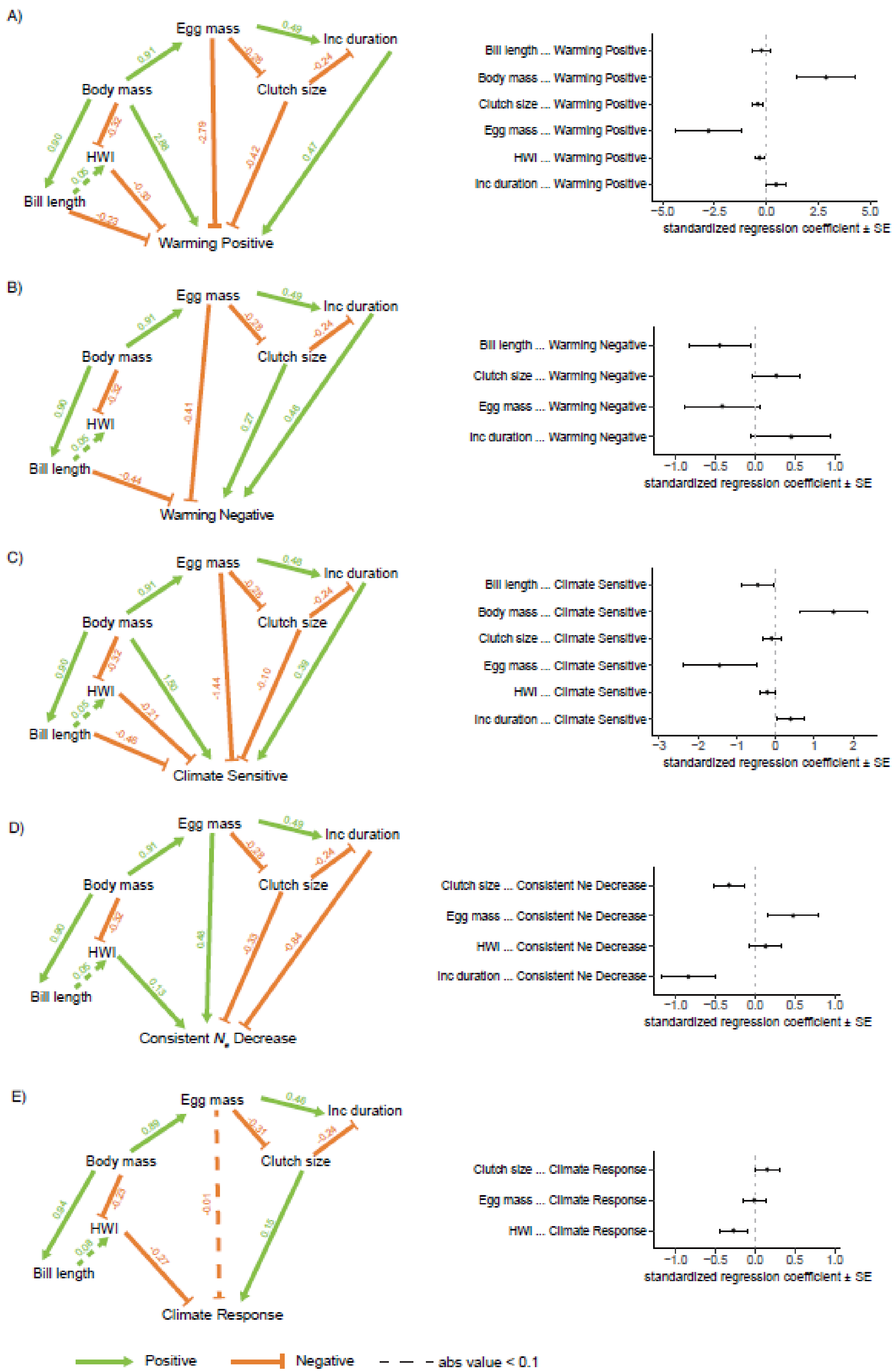

A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Bill length ... Warming Positive
Body mass ... Warming Positive
Clutch size ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
Inc duration ... Warming Positive
−2.5
0.0
2.5
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Negative
Bill length ... Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
Inc duration ... Warming Negative
−1
0
1
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
−2.5
0.0
2.5
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
−0.5
0.0
0.5
1.0
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Response
HWI ... Climate Response
−0.5
0.0
0.5
1.0
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

Supplementary Figure 14. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the average best performing models (ΔCICc ≤2 from top-ranked model) of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 95%. A) “Warming Positive” (n = 10) responses versus all remaining species (n = 134). B) “Warming Negative” (n = 10) responses versus all remaining species (n = 134). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 10 + 10) versus species with consistent N_e increases or decreases (n = 80 + 40). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 80) versus all remaining species (n = 64). E) species with increasing N_e tendency (n = 80) versus species with decreasing N_e tendency (n = 113) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 7 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.


A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Body mass ... Warming Positive
Clutch size ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
standardized regression coefficient ± SE
B)
Warming Negative
Bill length ... Warming Negative
Clutch size ... Warming Negative
C)
Climate Sensitive
Body mass ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
D)
Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
E)
Climate Response
HWI ... Climate Response
Positive
Negative
abs value < 0.1

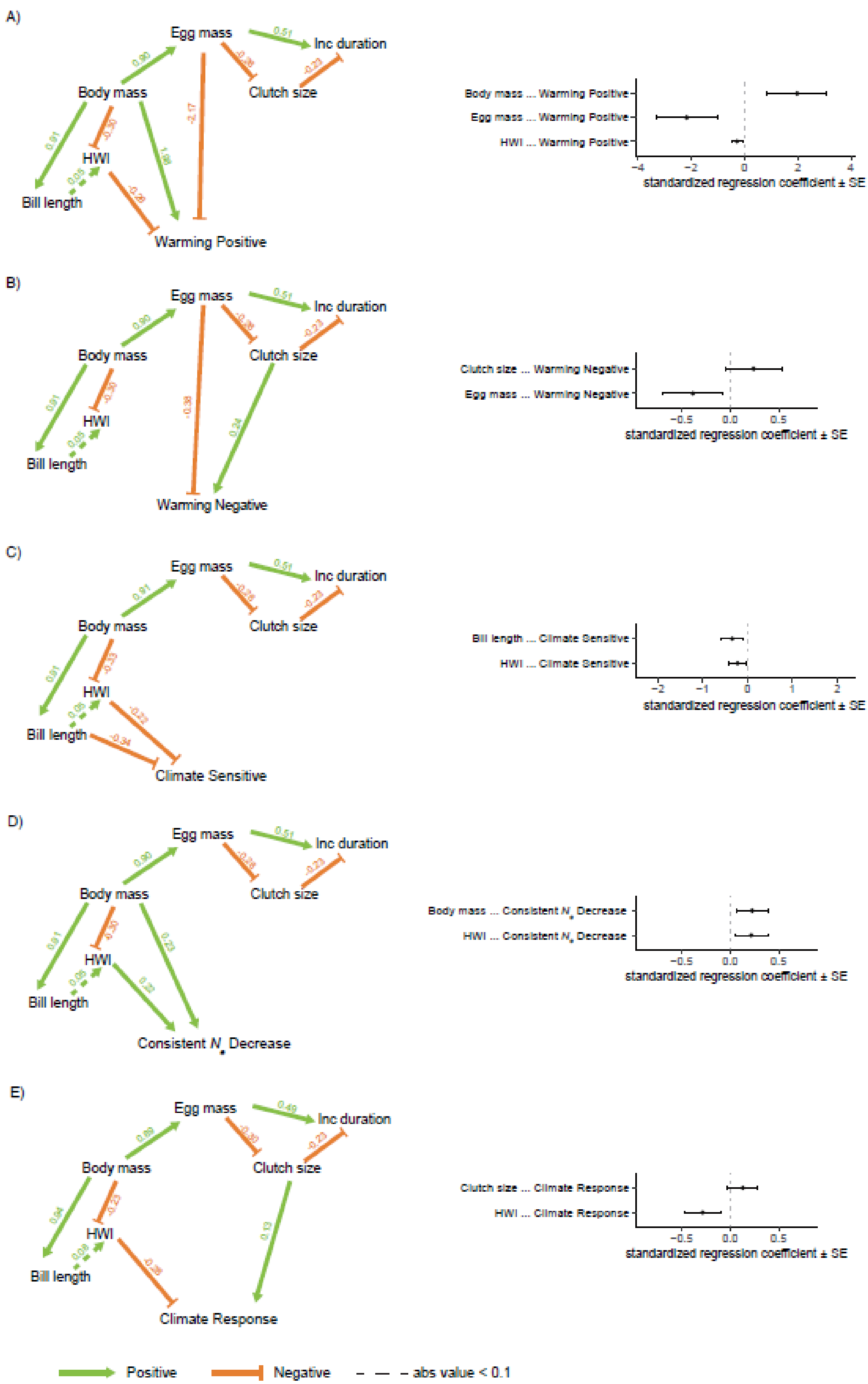
413

Supplementary Figure 15. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the top-ranked models of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 90%. A) "Warming Positive" responses (n = 14) versus all remaining species (n = 141). B) "Warming Negative" responses (n = 12) versus all remaining species (n = 143). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 14 + 12) versus species with consistent N_e increases or decreases (n = 82 + 43). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 82) versus all remaining species (n = 73). E) species with increasing N_e tendency (n = 85) versus species with decreasing N_e tendency (n = 113) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 8 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.

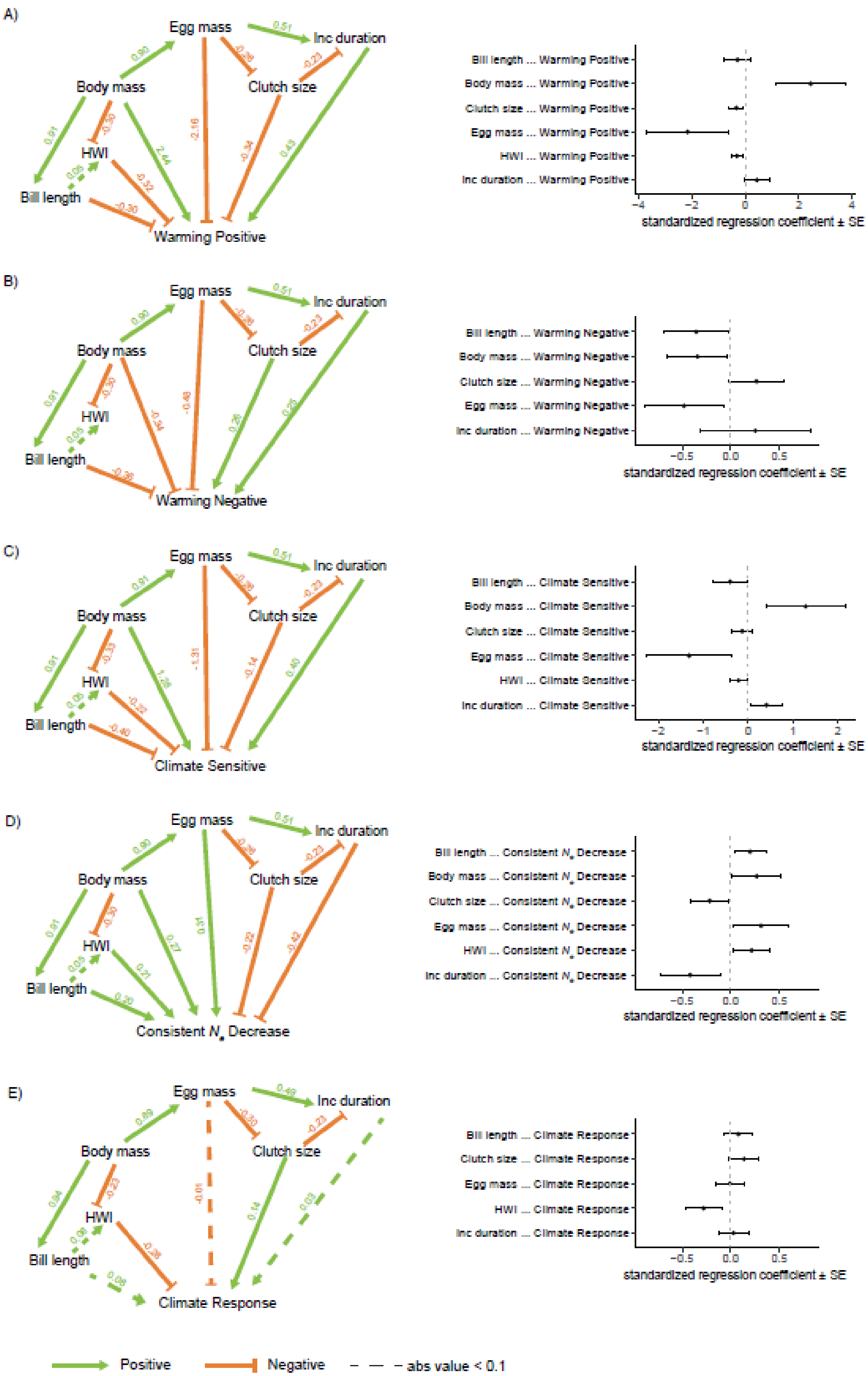

A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Bill length ... Warming Positive
Body mass ... Warming Positive
Clutch size ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
Inc duration ... Warming Positive
standardized regression coefficient ± SE
B)
Warming Negative
Bill length ... Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
Inc duration ... Warming Negative
C)
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Clutch size ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
D)
Consistent N_e Decrease
Clutch size ... Consistent Ne Decrease
Egg mass ... Consistent Ne Decrease
HWI ... Consistent Ne Decrease
Inc duration ... Consistent Ne Decrease
E)
Climate Response
Clutch size ... Climate Response
Egg mass ... Climate Response
HWI ... Climate Response
Positive
Negative
abs value < 0.1

429

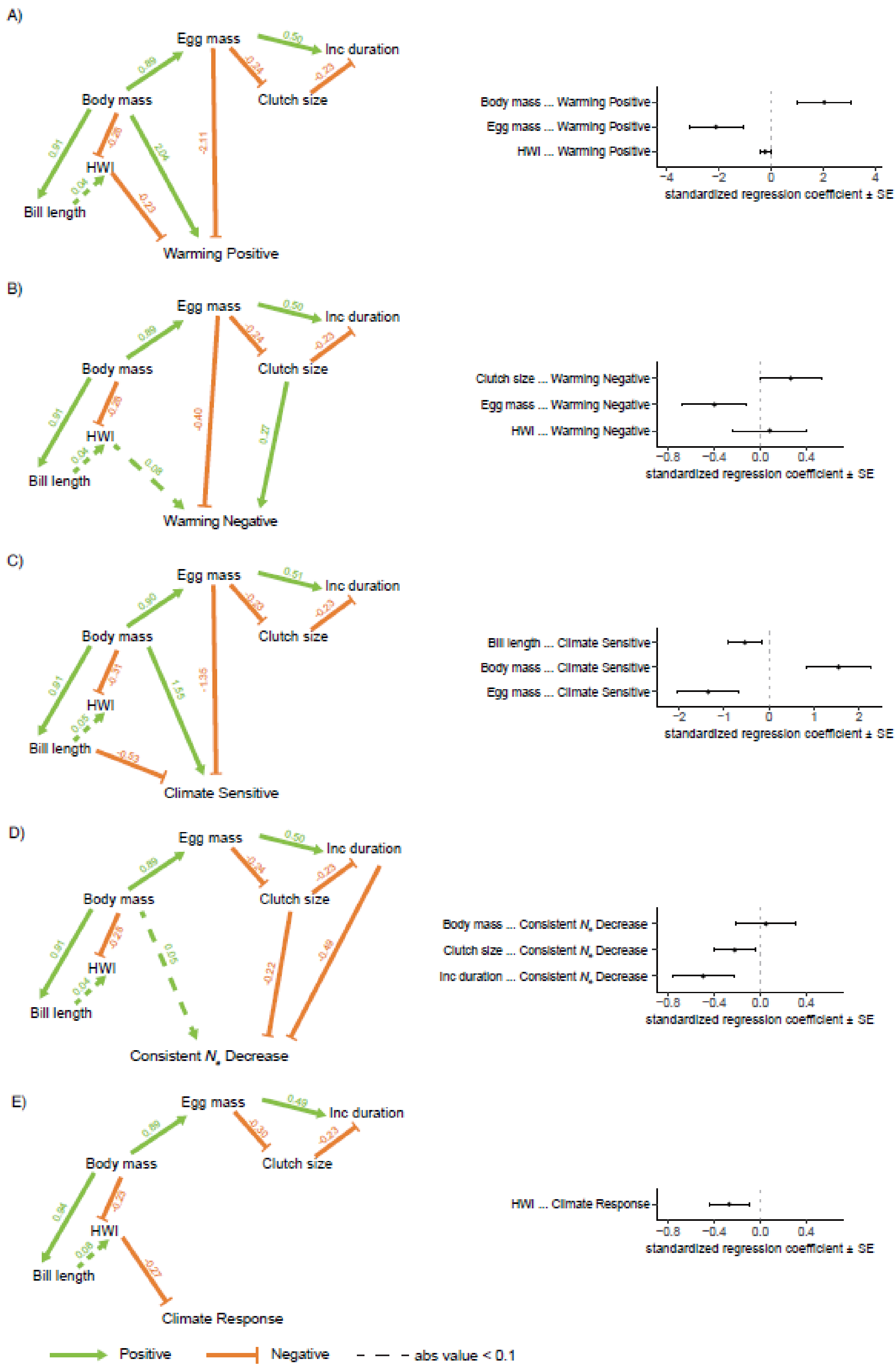
Supplementary Figure 16. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the average best performing models (ΔCICc ≤2 from top-ranked model) of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 90%. A) "Warming Positive" responses (n = 14) versus all remaining species (n = 141). B) "Warming Negative" responses (n = 12) versus all remaining species (n = 143). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 14 + 12) versus species with consistent N_e increases or decreases (n = 82 + 43). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 82) versus all remaining species (n = 73). E) species with increasing N_e tendency (n = 85) versus species with decreasing N_e tendency (n = 113) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 8 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.


A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Body mass ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Sensitive
Bill length ... Climate Sensitive
HWI ... Climate Sensitive
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Consistent N* Decrease
Body mass ... Consistent N* Decrease
HWI ... Consistent N* Decrease
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Response
Clutch size ... Climate Response
HWI ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

Supplementary Figure 17. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the top-ranked models of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 85%. A) “Warming Positive” responses (n = 16) versus all remaining species (n = 149). B) “Warming Negative” responses (n = 13) versus all remaining species (n = 152). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 16 + 13) versus species with consistent N_e increases or decreases (n = 84 + 44). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 84) versus all remaining species (n = 81). E) species with increasing N_e tendency (n = 86) versus species with decreasing N_e tendency (n = 115) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 9 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.

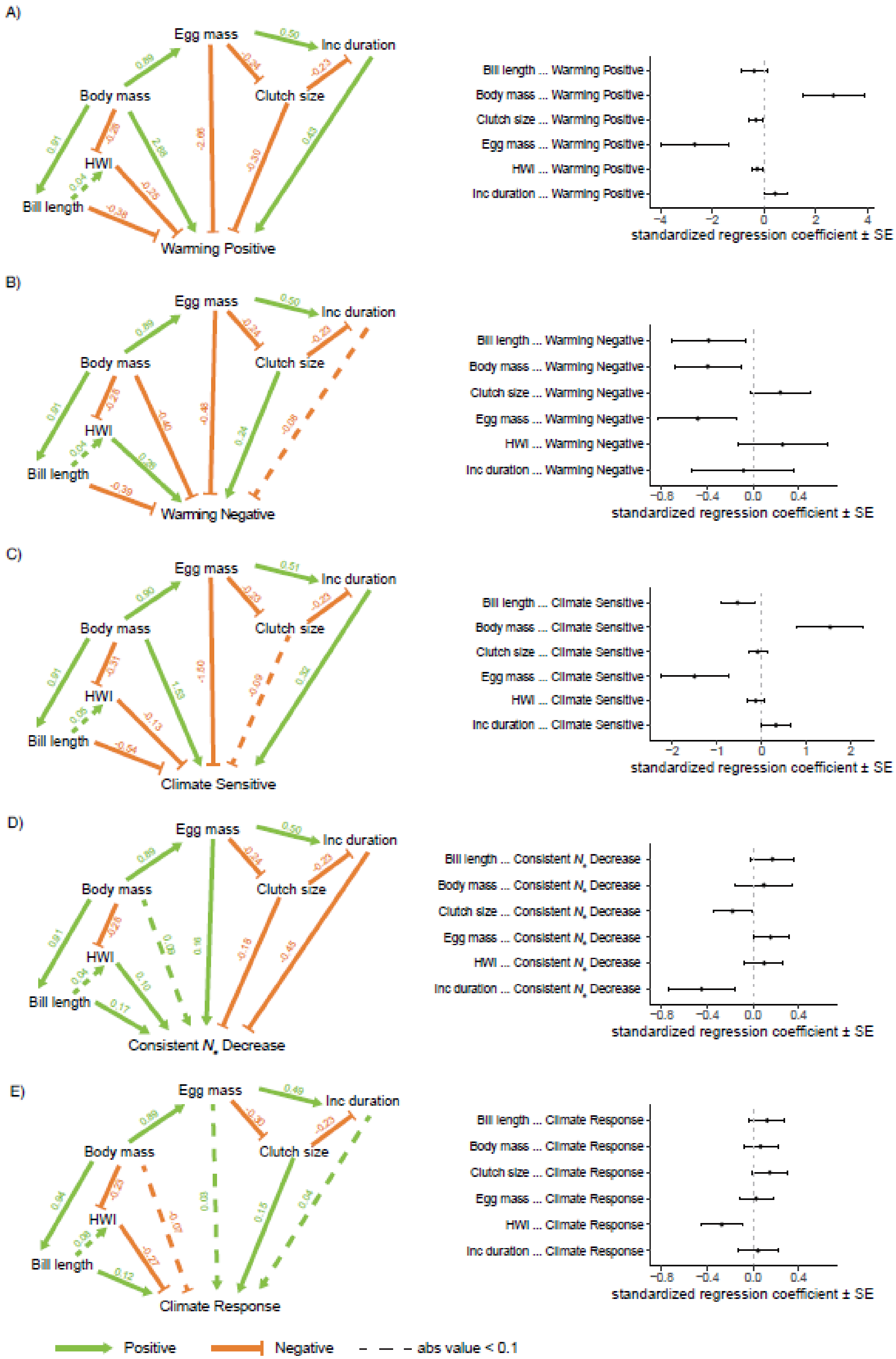

A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Bill length ... Warming Positive
Body mass ... Warming Positive
Clutch size ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
Inc duration ... Warming Positive
standardized regression coefficient ± SE
B)
Warming Negative
Bill length ... Warming Negative
Body mass ... Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
Inc duration ... Warming Negative
standardized regression coefficient ± SE
C)
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Clutch size ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
standardized regression coefficient ± SE
D)
Consistent N_e Decrease
Bill length ... Consistent N_e Decrease
Body mass ... Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
standardized regression coefficient ± SE
E)
Climate Response
Bill length ... Climate Response
Clutch size ... Climate Response
Egg mass ... Climate Response
HWI ... Climate Response
Inc duration ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

Supplementary Figure 18. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the average best performing models (ΔCICc ≤2 from top-ranked model) of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 85%. A) “Warming Positive” responses (n = 16) versus all remaining species (n = 149). B) “Warming Negative” responses (n = 13) versus all remaining species (n = 152). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 16 + 13) versus species with consistent N_e increases or decreases (n = 84 + 44). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 84) versus all remaining species (n = 81). E) species with increasing N_e tendency (n = 86) versus species with decreasing N_e tendency (n = 115) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 9 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.

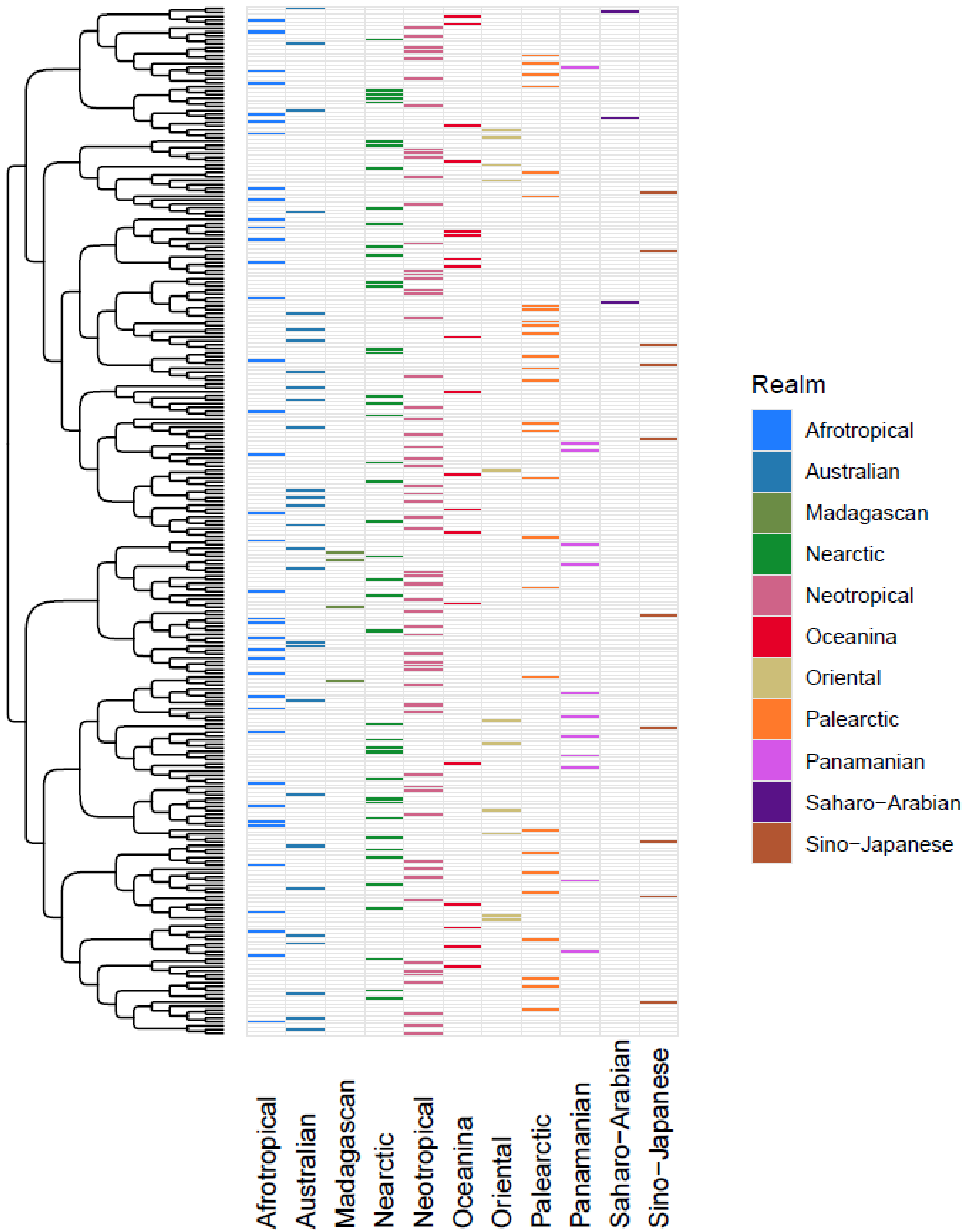


A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Body mass ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
standardized regression coefficient ± SE
B)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
HWI ... Warming Negative
standardized regression coefficient ± SE
C)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Egg mass ... Climate Sensitive
standardized regression coefficient ± SE
D)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Consistent N_e Decrease
Body mass ... Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
standardized regression coefficient ± SE
E)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Climate Response
HWI ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

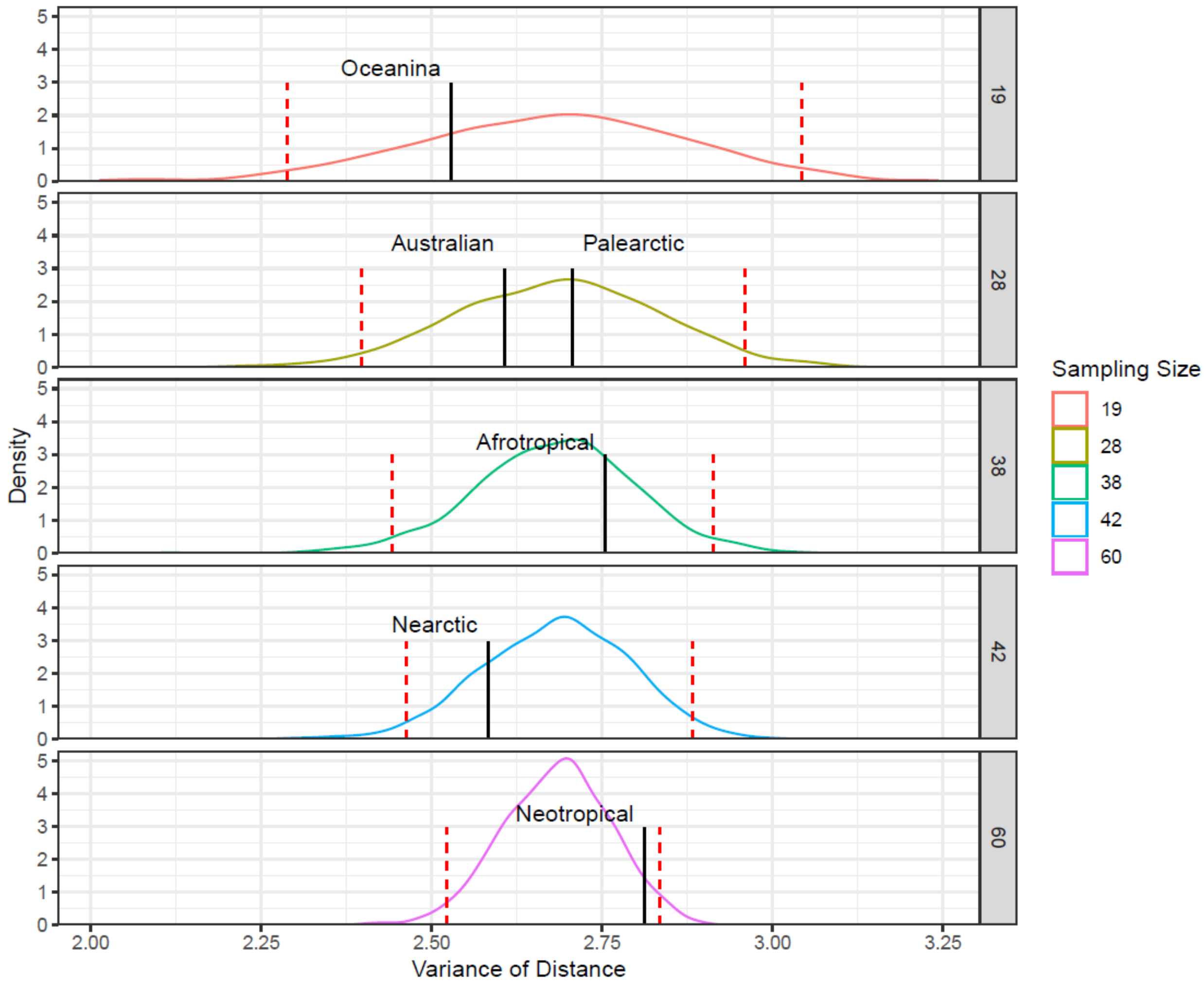
Supplementary Figure 19. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the top-ranked models of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 80%. A) “Warming Positive” responses (n = 18) versus all remaining species (n = 157). B) “Warming Negative” responses (n = 16) versus all remaining species (n = 159). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 18 + 16) versus species with consistent N_e increases or decreases (n = 84 + 47). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 84) versus all remaining species (n = 91). E) species with increasing N_e tendency (n = 88) versus species with decreasing N_e tendency (n = 117) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 10 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.


A)
Egg mass
Inc duration
Body mass
Clutch size
HWI
Bill length
Warming Positive
Bill length ... Warming Positive
Body mass ... Warming Positive
Clutch size ... Warming Positive
Egg mass ... Warming Positive
HWI ... Warming Positive
Inc duration ... Warming Positive
standardized regression coefficient ± SE
B)
Warming Negative
Bill length ... Warming Negative
Body mass ... Warming Negative
Clutch size ... Warming Negative
Egg mass ... Warming Negative
HWI ... Warming Negative
Inc duration ... Warming Negative
standardized regression coefficient ± SE
C)
Climate Sensitive
Bill length ... Climate Sensitive
Body mass ... Climate Sensitive
Clutch size ... Climate Sensitive
Egg mass ... Climate Sensitive
HWI ... Climate Sensitive
Inc duration ... Climate Sensitive
standardized regression coefficient ± SE
D)
Consistent N_e Decrease
Bill length ... Consistent N_e Decrease
Body mass ... Consistent N_e Decrease
Clutch size ... Consistent N_e Decrease
Egg mass ... Consistent N_e Decrease
HWI ... Consistent N_e Decrease
Inc duration ... Consistent N_e Decrease
standardized regression coefficient ± SE
E)
Climate Response
Bill length ... Climate Response
Body mass ... Climate Response
Clutch size ... Climate Response
Egg mass ... Climate Response
HWI ... Climate Response
Inc duration ... Climate Response
standardized regression coefficient ± SE
Positive
Negative
abs value < 0.1

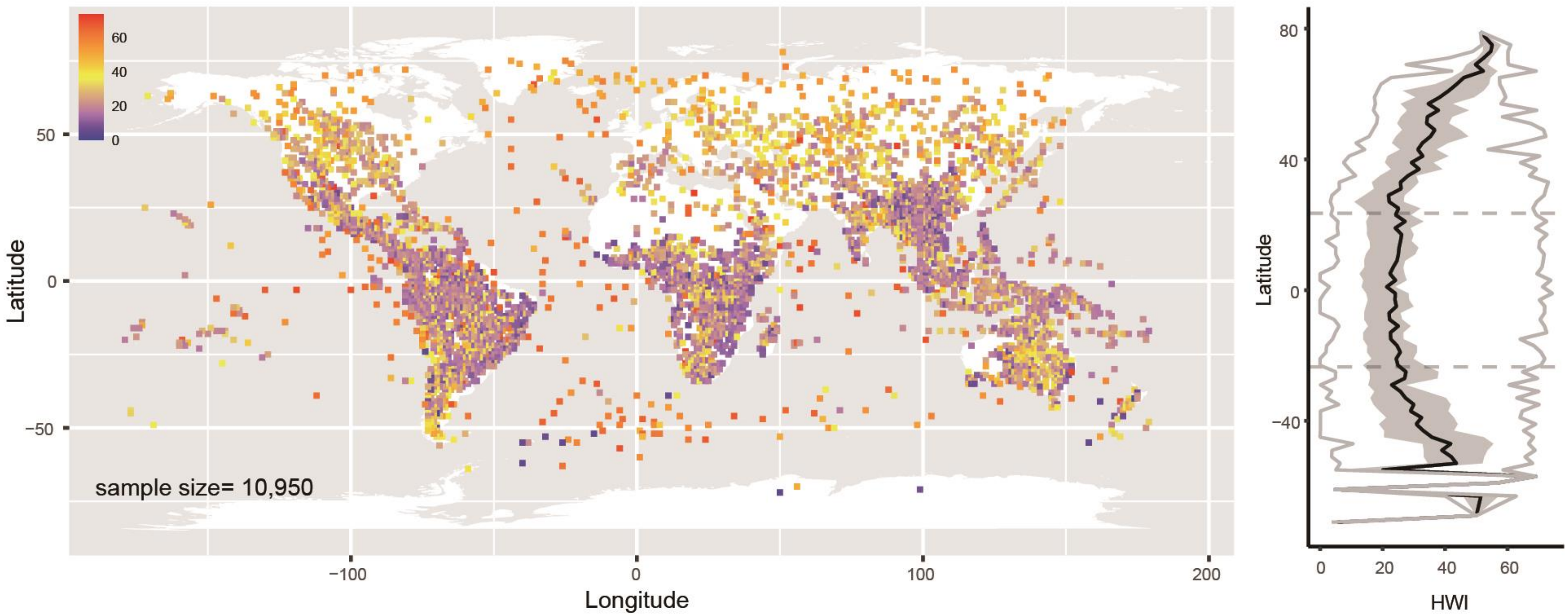
Supplementary Figure 20. Directed acyclic graphs (left panels) and corresponding standardized regression coefficients (right panels) for the average best performing models (ΔCICc ≤2 from top-ranked model) of five comparisons implemented via Phylogenetic Path Analysis when setting the confidence level as 80%. A) “Warming Positive” responses (n = 18) versus all remaining species (n = 157). B) “Warming Negative” responses (n = 16) versus all remaining species (n = 159). C) species sensitive to *Climate Warming* or *Climate Cooling* (n = 18 + 16) versus species with consistent N_e increases or decreases (n = 84 + 47). D) species with consistent N_e decreases under *Climate Warming* and *Climate Cooling* (n = 84) versus all remaining species (n = 91). E) species with increasing N_e tendency (n = 88) versus species with decreasing N_e tendency (n = 117) under *Climate Warming* (see Supplementary Note 3). For left panels, positive paths are depicted with green arrows, while negative paths are given in orange and values above the line depict corresponding standardized regression coefficients. Dotted lines represent standardized regression coefficients less than 0.1. Right panels depict the standardized regression coefficients (center dot) and corresponding standard error bars. See Supplementary Table 10 for details of model outputs of Panels A-D and Supplementary Table 12 for details of model outputs of Panel E.


Realm
Afrotropical
Australian
Madagascan
Nearctic
Neotropical
Oceanina
Oriental
Palearctic
Panamanian
Saharo−Arabian
Sino−Japanese

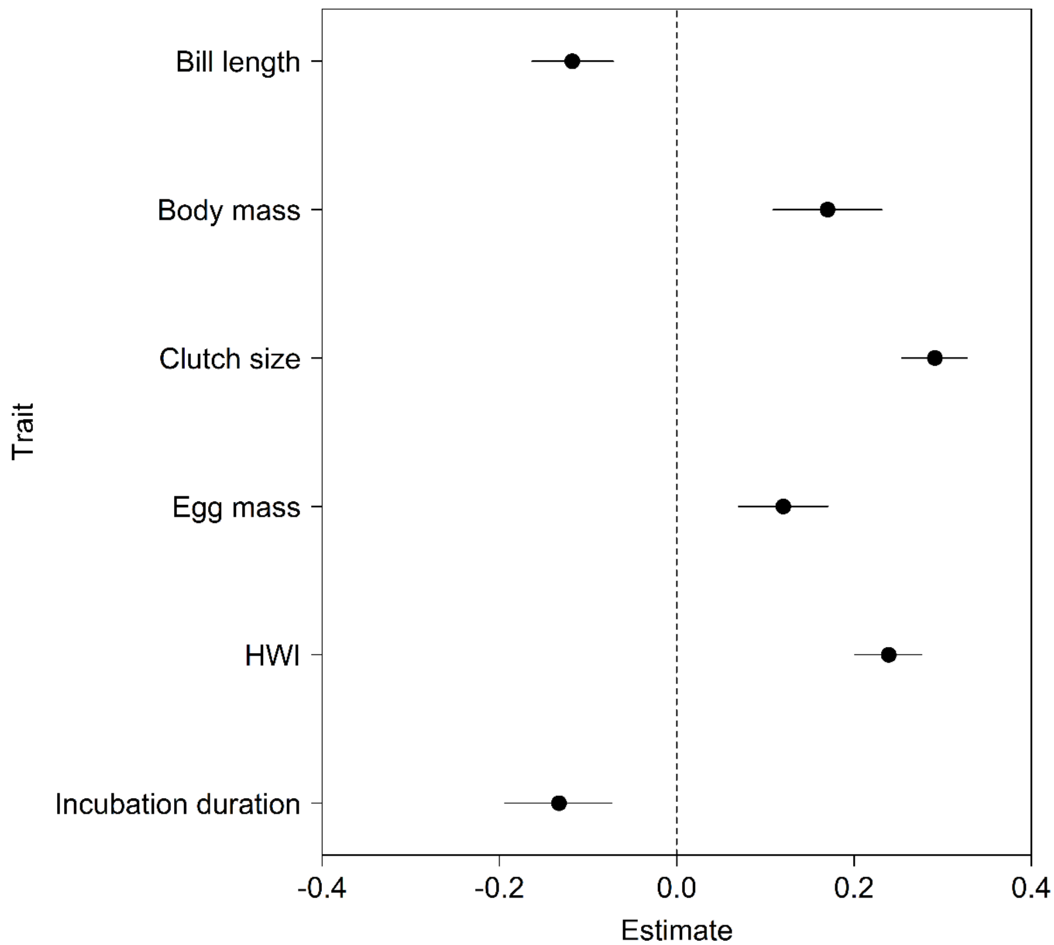
Supplementary Figure 21. The clustering dendrogram presented in Fig 1 (at k = 7), with each species' zoogeographic realm identified. Each column along the bottom represents one of the 11 major zoogeographic realms[59], and species belonging to each realm are indicated in the corresponding color.



Supplementary Figure 22. The observed variance of distance values for six realms with n ≥ 19 species (black vertical lines) and background variances generated via randomly sampling the same number of species. For each panel, curves represent the distribution of variances generated from 1000 sampling permutations, and red dotted lines represent the 95th percentiles.



Supplementary Figure 23. Contemporary global distribution of HWI for n = 10,950 avian species. Left: the median HWI of species within each grid cell (1° scale). Right: the HWI for each species within latitudinal bands (5° scale). The black line represents the median value, while the grey shading represents the interquartile range, and two grey lines represent the minimum and maximum of values. The dashed horizontal lines are S23.5° and N23.5°, representing the regional boundaries of the tropics.



Supplementary Figure 24. Effects plot from linear model quantifying the relative influence of each key morphological/life-history trait on the latitude (absolute mean geographic centroid of breeding/resident range) of 2745 avian species. All possible combinations of the six predictor variables were tested, but results from the global model (R^2 = 0.17) was unequivocally the most parsimonious (all other models ΔAIC > 16) and so are presented here. Points represent parameter estimates while whiskers depict 95% CIs. The dotted line represents a parameter estimate of zero, and effects are considered significant if CIs do not overlap zero.

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