ONLINE SUPPLEMENTARY MATERIAL

Supplementary Methods

Red List Indices

We examined trends in extinction risk during 1988-2012 for parrots (*Psittaciformes*) and comparable high profile species-groups with similar numbers of species using Red List Indices. These groups included waterbirds (including species from families *Anseriformes, Podicipediformes, Phoenicopteriformes, Gruiformes, Gaviiformes, Ciconiiformes, Pelecaniformes, Suliformes, Charadriiformes*), seabirds (*Anseriformes, Podicipediformes, Phaethontiformes, Gaviiformes, Sphenisciformes, Procellariiformes, Pelecaniformes, Suliformes, Charadriiformes*), raptors (*Accipitriformes, Cathartiformes, Falconiformes*), each of which comprises multiple orders. Other groups included the largest bird orders (i.e. with more than 250 species) like pigeons (*Columbiformes*) and gamebirds (*Galliformes*), except the orders *Passeriformes*, *Caprimulgiformes*, and *Piciformes*. Cases where species were re-categorized owing to improved knowledge or revised taxonomy are excluded. We used data from the comprehensive assessments of all bird species in 1988, 1994, 2000, 2004, 2008 and 2012, updated to 2014 (Tittensor et al. 2014).

Database and variables

We assembled a database of the biological and geographic attributes of all 398 extant parrot species using the 2014 version of BirdLife International and IUCN's database which underpins the IUCN Red List assessments for birds on the BirdLife Data Zone (BirdLife International 2014) and IUCN Red List website (IUCN 2014). We added further data including the socio-economic and demographic attributes of the countries the parrots occur in, from various external sources (Table 1).

We used the IUCN Red List extinction risk categories of all extant species of parrots (BirdLife International 2014; IUCN 2014) as the response variables in our analyses. In tables and graphs we use the standard IUCN abbreviations for Red List categories as follows: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered (IUCN 2014). We analyzed the traits of 16 extinct species separately, and exclude hypothetical taxa that have not been confirmed as valid species (Hoyo et al. 2014). For all analyses we followed the taxonomy of BirdLife International (2014).

Because of the large number of explanatory variables we initially divided the potential explanatory variables into four groups and performed analyses separately for each. We then combined all significant variables from each sub-analysis into a final model (see below). The groups were: (A) geographical and distributional attributes of each species; (B) biological, ecological and life history variables; (C) type of utilization by humans; and (D) socio-economic and demographic attributes of the countries where the species occur. For detailed descriptions, source of data and values of each variable see Table 1.

We used spatial analyses on the digital distribution files from BirdLife International and NatureServe (2014). ArcGIS 10.2 was used to calculate the median latitude of the distribution of each species. We calculated historical distribution size (i.e. current plus extirpated or historical ranges) from the species' shape-files. We used historical distribution size instead of current distribution sizes in order to avoid possible circularity as current extent of occurrence is a parameter used in the IUCN Red List criteria. For the same reason population size and trend were not used, to avoid circularity (IUCN 2014).

We defined whether each species was an island endemic (yes/no) depending on whether it was restricted to an island smaller than 110 000 km^2. Under this arbitrary definition, parrots of larger islands such as Borneo (743 330 km^2), Sumatra (473 481 km^2), or New Guinea (452 860 km^2) were not considered island endemics; the largest island that qualified was Cuba

(109 820 km^2) (see description in Table 1). We tested the validity of this assumption by varying our definition of the island size (including larger island cutoffs) that qualified and found this made no difference to the results.

We determined the type of utilization by people (group C) from the IUCN Red List Use Classification Scheme (http://www.iucnredlist.org/technical-documents/classification-schemes) assigned into binomial variables (yes/no). Pets are defined as those species recorded as being kept in captivity, either as personal pets, or for display in zoos, collections etc.

To assess socioeconomic and demographic attributes, we used The World Economic Outlook Database (IMF 2013), The World Factbook (CIA 2013), and the database of the Food and Agriculture Organization of the United Nations (FAOSTAT 2013) as sources, and calculated the mean values of each parameter for all countries in which a species occurred (excluding vagrant records; Table 1).

Historical distribution size and body size were normalized using a $\log_e$ transformation.

Threats, conservation actions, and priority countries

To understand the specific threats associated with high extinction risk in parrots, we extracted data from BirdLife International (2014) who classify threats using the IUCN-CMP Unified Classification of Direct Threats (Salafsky et al. 2009, updated at http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme). We analyzed threats at level 1, apart from Biological Resource Use and Natural System Modifications, which we analyzed at level 2 given the fundamentally distinct processes these classes aggregate. We assessed how many parrot species are affected by each threat type globally and at the regional scale. We also considered the overall threat impact scores (which are calculated from the timing, scope and severity of each threat to each species:

http://www.iucnredlist.org/documents/Dec_2012_Guidance_on_Threat_Impact_Scoring.pdf), and excluded past and unknown threats and those with no/negligible impacts.

We analyzed data from BirdLife International (2014) on the most important conservation actions needed to improve the status of threatened parrots; these are coded against the IUCN-CMP Unified Classification of Actions (Salafsky et al. 2009, updated at http://www.iucnredlist.org/documents/Dec_2012_Guidance_Conservation_Actions_Needed_Classification_Scheme.pdf).

We used two methods to highlight important countries for parrot conservation. (1) We followed Croxall et al. (2012) to prioritize countries according to the sum of their ranks for the total numbers of their (a) parrot species, (b) globally threatened species, and (c) single country endemic species, and referred as 'country priority'. (2) In order to determine which countries had the highest proportion of unexplained extinction risk we calculated the mean for each country of the residuals from the combined linear logistic regression (see below) and used this to rank them in terms of the magnitude of unexplained variation remaining once all known significant causes of threatened status have been removed. We refer to this as 'unexplained extinction risk'.

Statistical analysis

We conducted our analyses of the likely determinants of the status of parrots at two levels, one designed to identify the broad covariates of whether a parrot species is threatened or not, and the other designed to evaluate in more detail the covariates of the degree of threat faced by parrot species. To test variables at the broader scale we assigned all species a binary response variable of 0 (Least Concern and Near Threatened) or 1 ('Threatened', i.e. Vulnerable, Endangered or Critically Endangered), and analyzed possible explanatory variables using linear logistic regression with appropriate controls for non-independence due to phylogenetic effects (see below).

To examine the possible causes of threat in further detail, we assigned numerical values corresponding to the extinction risk faced by each threatened species as follows: Vulnerable = 1, Endangered = 2, Critically Endangered = 3. We used ordinal regression models to analyze these values because of their directional numerical nature.

Linear logistic regression and ordinal regression models were initially computed using each set of variables (A-D above) separately. This was to avoid statistical issues associated with multicollinearity. The final universal model was computed by combining the variables found to be significant in each of the sub-models.

We used correlation matrices to determine whether variables within each group were correlated, and initially avoided using correlated variables in the same analysis. The following variables were excluded on this basis: mean body mass and clutch size (correlated with body size, Table S1a) and forest area of each country (correlated with area of agriculture, Table S1b). Because generation time was significantly positively correlated with body size (Table S1a), we calculated and used the residual values from the simple linear regression of generation time versus body size and referred this variable as 'residual generation time' following Owens and Bennett (2000). Similarly, we calculated residual values for industrial production growth rate, unemployment rate, human population density, urban population, human population growth rate, and agriculture area because they were significantly correlated with per capita GDP (Table S1b).

All linear logistic regressions and ordinal regression models were computed using GenStat 13.7 (Payne 2009). Akaike information criteria (AIC) and Bayesian information criteria (BIC) were used to determine the best parsimonious models containing all significant terms. Models were selected with the lowest AIC values and simultaneously having the lowest BIC values (Table S2). We also report *P*-values for each significant variable determined by its exclusion from the full models selected above. We also controlled for phylogenetic relatedness between species using phylogenetic generalized least squares (PGLS) regression.

Supplementary Results

Table S1. Correlation matrices. Correlation coefficients (Pearson's) are shown below diagonal, two-sided test of correlations different from zero above diagonal.

(a) Number of species: 337

Variables	Body Size	Body Mass	Clutch Size	Generation Time
Body Size	-	<0.001	<0.001	<0.001
Body Mass	0.8447	-	<0.001	<0.001
Clutch Size	-0.2214	-0.3011	-	<0.001
Generation Time	0.6533	0.7552	-0.2535	-

(b) Number of species: 378

Variables	Per capita GDP	Industrial Production Growth Rate	Unemployment Rate	Human Population Density	Urban Population	Human Population Growth Rate	Agriculture Area	Forest Area
Per capita GDP	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Industrial Production Growth Rate	-0.5775	-	0.5399	0.1514	<0.001	<0.001	<0.001	<0.001
Unemployment Rate	-0.2218	0.0316	-	0.5357	0.0343	<0.001	<0.001	0.0019
Human Population Density	-0.373	0.0739	0.032	-	<0.001	0.0189	0.9509	0.0068
Urban Population	0.6685	-0.6265	-0.1089	-0.5035	-	<0.001	<0.001	<0.001
Human Population Growth Rate	-0.3382	0.4275	0.3233	0.1207	-0.55	-	0.7567	0.0039
Agriculture Area	0.4914	-0.5284	0.2471	-0.0032	0.4027	-0.016	-	<0.001
Forest Area	-0.5472	0.3489	-0.1589	-0.139	-0.2195	-0.1481	-0.8451	-

Table S2. AIC (Akaike information criterion) and BIC (Bayesian information criterion, also referred to as Schwarz information criterion) values for best parsimonious models containing all significant terms for each variable group (ranked by AIC values).

Model	Linear Logistic Regression		
	AIC	BIC	d.f.
Threats	249.23	273.15	6
A - Geographical and distributional attributes	281.64	304.29	6
Final combined model	292.42	324.29	8
B - Biological, ecological and life history variables	327.60	354.02	7
D - Socio-economic and demographic attributes	375.71	391.45	4
C - Type of utilization by humans	452.62	468.55	4

Model	Ordinal Regression		
	AIC	BIC	d.f.
B - Biological, ecological and life history variables	358.22	664.74	96
A - Geographical and distributional attributes	360.82	670.54	97
D - Socio-economic and demographic attributes	382.42	719.01	103
Final combined model	432.68	822.95	115
Threats	436.95	828.26	115
C - Type of utilization by humans	440.57	824.05	113

Table S3. Significant variables in the linear logistic regression models run separately for each variable group (A-D) predicting the likelihood of a parrot species being threatened (VU, EN, CR). λ values for the phylogenetic generalized least squares model (PGLS) are given in the table for each model. We give mean ± standard deviation (SD).

Group	Variable	Wald statistic	d.f.	*P* (χ^2)	Estimate ± SD (PGLS)	*P* (PGLS) ± SD	λ ± SD
A	Historical Distribution Size ($\log_e$)	71.64	1	<0.001	-0.246 ± 0.004	<0.001 ± <0.001	0.087 ± 0.083
	Median Latitude	8.67	1	0.003	0.025 ± 0.004	0.260 ± 0.080	
	Region	30.41	3	<0.001	-0.175 ± 0.027	0.032 ± 0.038	
	Median Latitude * Historical Distribution Size ($\log_e$)	5.18	1	0.023	-0.001 ± <0.001	0.581 ± 0.058	
B	Body Size ($\log_e$)	12.59	1	<0.001	0.529 ± <0.001	<0.001 ± <0.001	<0.001 ± <0.001
	Forest Dependency	50.31	3	<0.001	0.492 ± <0.001	<0.001 ± <0.001	
	Residual Generation Time	10.10	1	0.001	0.492 ± <0.001	0.006 ± <0.001	
C	Used for Pets	9.15	1	0.002	-1.162 ± 0.013	<0.001 ± <0.001	0.269 ± 0.049
	Used for Food	11.47	1	<0.001	0.353 ± 0.017	0.029 ± 0.008	
	Used for Sport	4.55	1	0.033	0.423 ± 0.019	0.242 ± 0.021	
D	Residual Human Population Density	3.90	1	0.048	0.196 ± 0.007	0.006 ± 0.001	0.324 ± 0.067
	Residual Urban Population	26.98	1	<0.001	-0.275 ± 0.013	0.006 ± 0.002	
	Single Country Endemic	26.44	1	<0.001	0.755 ± 0.011	<0.001 ± <0.001	

Table S4. Significant variables in ordinal regression models run separately for each variable group (A-D) predicting the likelihood of a species being more endangered among threatened (VU, EN, CR) parrot species. λ values for the phylogenetic generalized least squares model (PGLS) are given in the table for each model. We give mean ± standard deviation (SD).

Group	**Variable**	**Deviance**	**d.f.**	P (χ^2)	**Estimate ± SD (PGLS)**	P **(PGLS) ± SD**	**λ ± SD**
A	Region	14.42	3	0.002	0.147 ± <0.001	0.015 ± <0.001	<0.001 ± <0.001
	Island Endemic	10.45	1	0.001	-0.250 ± <0.001	0.210 ± <0.001	
	Historical Distribution Size (loge)	5.15	1	0.023	-0.016 ± <0.001	0.621 ± <0.001	
B	Main Diet	10.04	4	0.040	0.094 ± <0.001	0.078 ± <0.001	<0.001 ± <0.001
C	Used for Pets	4.55	1	0.033	-0.495 ± <0.001	0.025 ± <0.001	<0.001 ± <0.001
D	Per capita GDP	8.79	1	0.003	<0.001 ± <0.001	0.030 ± <0.001	<0.001 ± <0.001
	Single Country Endemic	5.60	1	0.018	0.404 ± <0.001	0.007 ± <0.001	

Table S5. (a) Significant variables in the combined linear logistic regression model predicting the likelihood of a parrot species being threatened (VU, EN, CR). λ value for the phylogenetic generalized least squares model (PGLS) was <0.001 ± <0.001. We give mean ± standard deviation (SD).

Variable	**Wald statistic**	**d.f.**	***P*** **(χ^2)**	**Estimate ± SD (PGLS)**	***P*** **(PGLS) ± SD**
Historical Distribution Size (log_e)	64.89	1	<0.001	-0.245 ± <0.001	<0.001 ± <0.001
Body Size (log_e)	13.18	1	<0.001	0.474 ± <0.001	<0.001 ± <0.001
Residual Generation Time	16.82	1	<0.001	0.200 ± <0.001	<0.001 ± <0.001
Urban Population	28.71	1	<0.001	0.014 ± <0.001	<0.001 ± <0.001
Forest Dependency	29.47	3	<0.001	0.332 ± <0.001	<0.001 ± <0.001

(b) Significant variables in combined ordinal regression model predicting the likelihood of a species being more endangered among threatened (VU, EN, CR) parrot species. λ value for the final phylogenetic generalized least squares model (PGLS) was <0.001 ± <0.001. We give mean ± standard deviation (SD).

Variable	**Deviance**	**d.f.**	***P*** **(χ^2)**	**Estimate ± SD (PGLS)**	***P*** **(PGLS) ± SD**
Per capita GDP	8.47	1	0.004	0 ± <0.001	0.024 ± <0.001
Single Country Endemic	5.60	1	0.018	0.360 ± <0.001	0.015 ± <0.001
Used for Pets	4.75	1	0.029	-0.526 ± <0.001	0.016 ± <0.001

Table S6. (a) Significant threat variables in linear logistic regression model predicting the likelihood of a parrot species being threatened (VU, EN, CR). λ value for the phylogenetic generalized least squares model (PGLS) was 0.009 ± 0.018.

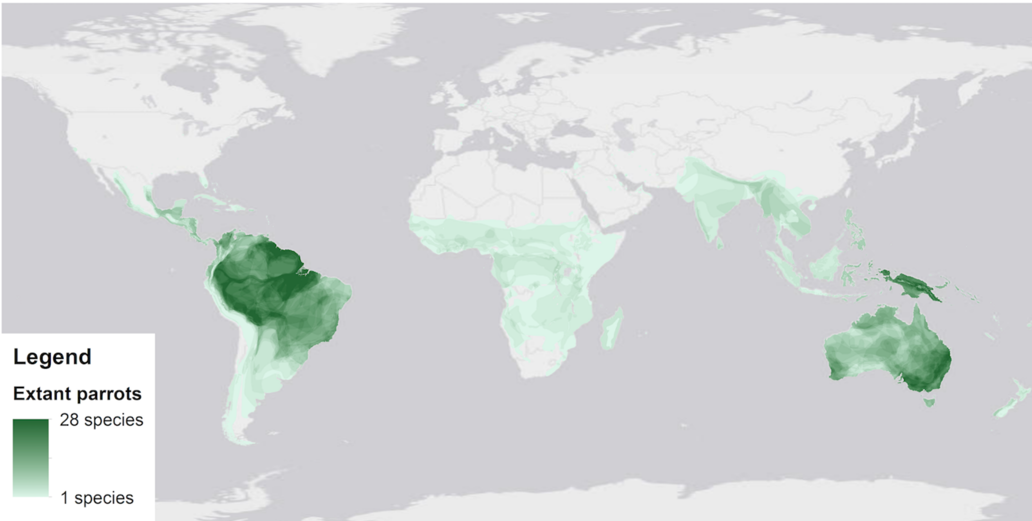
Variable	**Wald statistic**	**d.f.**	***P* (χ^2)**	**Estimate ± SD (PGLS)**	***P* (PGLS) ± SD**
Invasive Alien Species	32.65	1	<0.001	1.734 ± 0.004	<0.001 ± <0.001
Agriculture	28.97	1	<0.001	1.132 ± 0.008	<0.001 ± <0.001
Hunting & Trapping	19.88	1	<0.001	1.383 ± 0.002	<0.001 ± <0.001
Residential & Commercial Development	7.13	1	0.008	0.452 ± 0.009	<0.001 ± <0.001
Energy Production & Mining	4.71	1	0.030	0.397 ± 0.010	0.009 ± 0.002
Agriculture * Hunting & Trapping	7.39	1	0.007	-0.772 ± 0.012	<0.001 ± <0.001
Hunting & Trapping * Invasive Species	6.46	1	0.011	-1.178 ± 0.002	<0.001 ± <0.001

(b) Significant threat variables in ordinal regression model predicting the likelihood of a species being more endangered among threatened (VU, EN, CR) parrot species. λ value for the final phylogenetic generalized least squares model (PGLS) was <0.001 ± <0.001.

Variable	**Deviance**	**d.f.**	***P* (χ^2)**	**Estimate ± SD (PGLS)**	***P* (PGLS) ± SD**
Invasive Alien Species	14.41	1	<0.001	0.598 ± <0.001	<0.001 ± <0.001
Agriculture	5.85	1	0.016	0.332 ± <0.001	0.063 ± <0.001

Figure S1. Global density maps of (A) all extant parrot species, and (B) threatened parrots (Vulnerable, Endangered, and Critically Endangered). Color intensities indicate the number of parrot species.

(a)



(b)

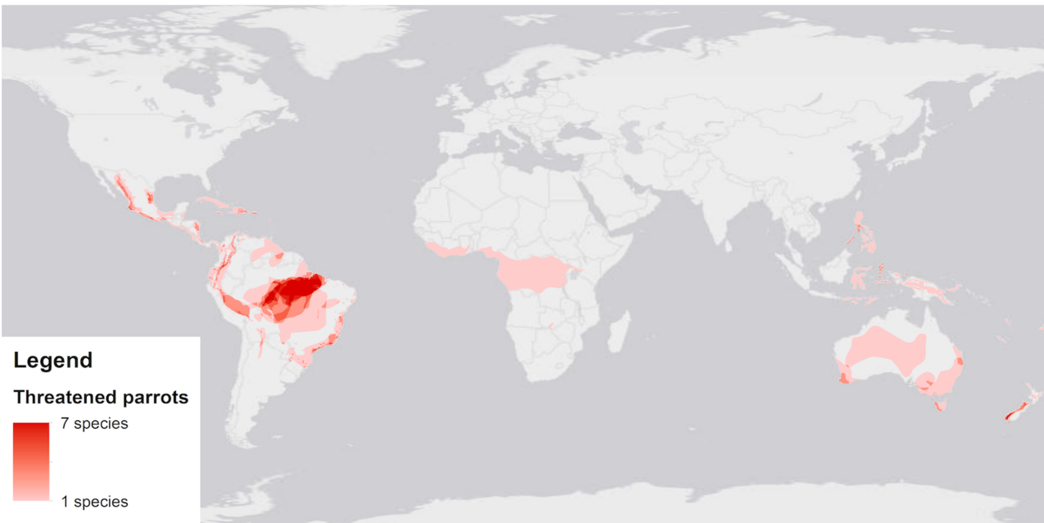


Figure S2. Predicted effect of significant variables on the probability of being threatened for parrot species according to: (a) Log_e (Historical Distribution Size, km^2), (b) Log_e (Body Size, cm), (c) Residual Generation Time (years), (d) Forest Dependency, and (e) Percentage of the human population living in urban conditions. Error bars represent standard errors.

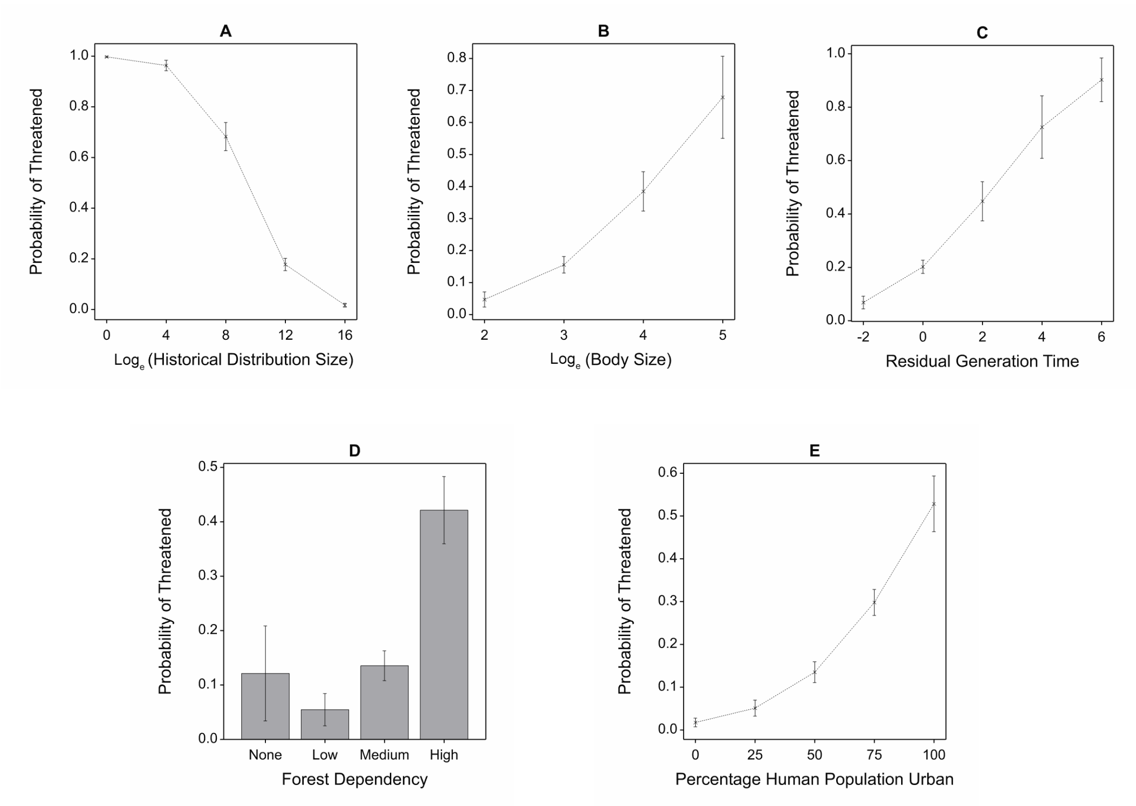
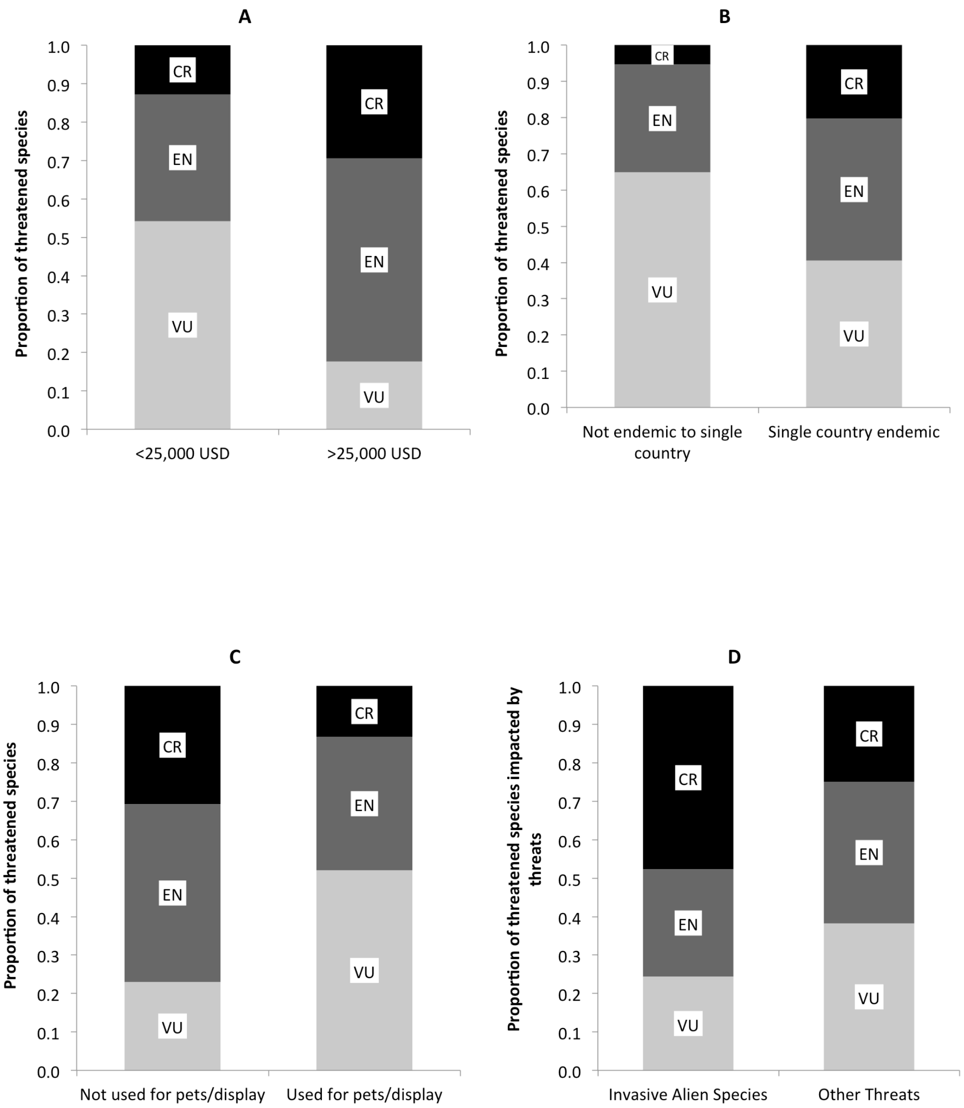


Figure S3. Proportion of threatened species in each category (VU, EN, CR) for each significant variable in ordinal regression models: (a) Per capita GDP, (b) Single Country Endemic, (c) whether Used for Pets/Display, and (d) whether threatened by Invasive Alien Species or other threats.



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