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Effects Of Environmental And Anthropogenic Factors On The Range Contraction Of Bird And Mammal Species

Patrice M. Betz
Fort Hays State University

EFFECTS OF ENVIRONMENTAL AND ANTHROPOGENIC

FACTORS ON THE RANGE CONTRACTION OF

BIRD AND MAMMAL SPECIES

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Patrice M. Betz

B.S., Fort Hays State University

Date______________________ Approved__________________________________
Major Professor

Approved__________________________________
Chair, Graduate Council

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Patrice M. Betz

Has Been Approved

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Chair, Supervisory Committee

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Supervisory Committee

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Supervisory Committee

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Supervisory Committee

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Chair, Department of Biological Sciences

PREFACE

This thesis has been formatted in the style of the journal *Conservation Biology*.

Keywords: range contraction, range loss, persistence, extinction, conservation, human influence

ABSTRACT

The largest contributor to biodiversity loss is habitat destruction caused by humans. A common consequence of habitat destruction is a reduction in the geographic range of a species. Little research has been done to separate the contribution of anthropogenic and environmental variables to the extinction or persistence of species that have experienced range contraction. In this thesis, I examined the relative effects of several variables (elevation, mean annual precipitation, mean annual temperature, human population density, distance from roads, and proportion of land converted to built-up land, cropland, and rangeland) on the geographic ranges of declining bird and mammal species from all continents except Antarctica. Species were examined separately to determine which variables might have influenced the contraction in the ranges of individual species. The results of each variable were compiled both by individual species and by continent. My results suggest environmental variables have a greater effect on species persistence and extinction than do the anthropogenic variables I tested. Mean annual precipitation was most often identified as having a positive or negative influence on species persistence. The findings of this study provide a comprehensive assessment of the effects of environmental and anthropogenic variables on the persistence of both individual species and all species from each of the 6 continents included in the analyses. These findings could allow conservation biologists to better predict areas where a declining species will persist, thereby enabling the prioritization of areas for the establishment of wildlife reserves.

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INTRODUCTION

Human Impact and the Biodiversity Crisis

Biodiversity is threatened. The current extinction rate is estimated to be between 1,000 and 10,000 times greater than the extinction rate expected without the contribution of humans (Wilson 1988). Because of this, it is believed we are in the throes of the sixth mass extinction event (Diamond et al. 1989, Chapin et al. 2000), one that will worsen as the global human population increases, along with its growing demand for natural resources (Erlich 1988).

Since the end of the Pleistocene (Alroy 2001), and especially since the onset of European exploration in the late 15th century (Heywood and Stuart 1992), mankind has been a major contributor to the extinction of numerous species. It is estimated that roughly 40% of the world's primary productivity is put towards human use—that is, towards the use of a single species (Mace and Reynolds 2001). That leaves only 60% available for the millions of other species that inhabit the planet. Because we are highly mobile and capable of making great changes to the landscape, it is easy to disrupt the natural world, both purposely for our own benefit, and accidentally. As put by Gretchen Daily (1997), "Virtually no place remains untouched—chemically, physically, or biologically—by the curious and determined hand of humanity. Although much more by accident than by design, humanity now controls conditions over the entire biosphere." It can be argued that humanity thus controls the fate of millions of species as well.

On Habitat Loss and the Risk of Extinction

Species become extinct for a multitude of reasons, and often a combination of them (Pimm et al. 1988, Diamond et al. 1989, Erlich and Daily 1993, Lomolino and Channell 1995, Owens and Bennett 2000). Some slip into extinction naturally, as a result of natural climactic fluctuations or geological processes, but recently many others have declined or become extinct as the direct or indirect result of human action (Mace and Reynolds 2001). The most common cause of species decline is habitat loss (Pimm and Raven 2000). If individuals of a species cannot find habitat adequate for survival and reproduction, the species will decline and eventually become extinct (Hanski and Ovaskainen 2002).

Certain species are more vulnerable to extinction than others based on a variety of factors, such as life history (i.e., fecundity, age of maturity, habitat specialization, diet specialization, etc.) (McKinney 1997), usefulness to humans (Rosser and Mainka 2002), and rarity (McKinney 1997). Island flora and fauna are particularly vulnerable to extinction due to their small geographic ranges, small population sizes, and lack of defenses against introduced species, both predators and competitors (Purvis et al. 2000). Endemics of oceanic islands also cannot typically disperse to new locations due to their insular nature.

A common consequence of habitat loss is habitat fragmentation (With and King 1999). Naturally caused by geographic processes and artificially caused by anthropogenic alteration of the landscape, habitat fragmentation occurs when portions of habitat are degraded or destroyed, leaving only pockets of habitat remaining. Depending on the life histories of the species inhabiting them, habitat fragments can become, in a sense, isolated "islands" of habitat, and thus rife with many of the problems associated with island biodiversity extinction risks (Diamond et al. 1976). If individuals in a population cannot move from one habitat fragment to another, the population becomes isolated from other populations. Small, isolated populations are more susceptible to stochastic events such as genetic drift, population crashes, or natural disasters (Pimm et al. 1988). If habitat fragmentation for a species is severe, the separated populations will become extinct over time, one by one, until there are no individuals of that species remaining.

Range Contraction Analysis and Its Use for Conservation

One of the indicators of decline in a species is a reduction in its geographic range. This reduction in a range occurs when a species has lost habitat within its historical range (Figure 1). I will refer to this range reduction as "range contraction."

The geographic ranges of species are dynamic, their boundaries naturally expanding and shrinking over time as a result of geological processes, natural fluctuations in climate, and interactions with other species (Gaston and He 2002). However, a large portion of the geographic range of a species can also be lost over time as a result of human activity (Lomolino and Channell 1995), most often habitat destruction (Pimm and Raven 2000). This habitat destruction is primarily due to land being converted from natural habitat to cropland, pastures, cities and towns, and roads by humans (Forester and Machlis 1996). My focus in this thesis is range contraction caused by habitat destruction, but it should be noted that range contraction can result from other types of anthropogenic disturbances as well, such as overexploitation, the spread of invasive species, and anthropogenic climate change (Groom 2006).

Research focused on range contraction can be beneficial to species conservation. Range contraction research can enable conservation biologists to more accurately predict where declining species will persist. Such areas of predicted persistence can be protected by establishing wildlife preserves or national parks to create refuges for these species. This research can also lead to more thorough and collaborative surveys which include better data on the changing range limits of species. Lastly, research on range contraction can simply provide conservation biologists with a better understanding of the complexity of the interactions between geographic ranges, threats to biodiversity, and species persistence.

The aim of this study is to examine the effect of several environmental and anthropogenic variables on the persistence of local populations of birds and mammals experiencing range contraction. I sought to determine if the effects of the variables tested differed by continent. I predicted the portion of range lost would coincide with areas of greater human influence. I also predicted species to persist in areas of higher elevation, colder temperatures, and lower precipitation because I expect human influence to be lower in these areas, and thus, the habitats in them less likely to have been altered.

METHODS

Species' Range Data

To conduct the analysis of effects of the environmental and anthropogenic variables on the geographic range contraction of species, range maps with both the remnant and historical ranges for species were required. The remnant range is the current area of the historical range within which a species persists, with the "current" date for this analysis being anywhere from 1970 to 2014. Unfortunately, range maps for species are not frequently updated, and for the majority of species in this analysis, the most recent range map is from 10-20 years ago. The historical range is the geographic range a species once occupied. The time period the historical range represents differs from species to species and is often not specified in the map sources. Typically in Australia and North America, this period is near the beginning of European settlement. The sources of species' ranges from the other continents, however, are not as explicit in dating the historical range.

Remnant and historical ranges of bird and mammal species from all continents except Antarctica were gathered for this analysis, yielding data for a total of 139 bird species and 148 mammal species (Table 1). Data sources included journal articles, field guides, online databases, and species management plans (Table 2). There were several specifications required for these ranges to be considered for analysis. Only those ranges that included both the historical and remnant ranges could be analyzed; thus, extinct species were excluded. I also excluded species that are, or had been, extinct in the wild or only exist in captive populations, such as the American bison (*Bison bison*), Arabian oryx (*Oryx leucoryx*), and black-footed ferret (*Mustela nigriceps*). Only native ranges of species were included in the analyses. Maps limited to subspecies were excluded. In species whose ranges included areas of reintroduction, those reintroduction sites were not included in the remnant range. For birds, only year-round and breeding ranges were considered for analysis; wintering ranges were excluded. If a map contained elements of uncertainty, such as points of "possible extralimital occurrence" or "presence uncertain," those elements were not included as part of either the remnant or historical ranges in the analysis. When more than one range map was available for the same species, the most recent map was used.

When maps were not available as shapefiles, they were georeferenced and digitized using ArcGIS 10.1 (ESRI 2014). Once digitized, they were converted from vector data to raster data with a cell size of 0.083333° to match the cell size of the environmental and anthropogenic layers. Raster ranges converted from a vector range comprised of multiple polygons often had to be reclassified so all cells in the range had the same value.

Environmental Data

Three environmental variables were used in this analysis: elevation (m) (Figure 2), mean annual precipitation (mm) (Figure 3), and mean annual temperature (°C) (Figure 4). Data for these variables came from Worldclim (Hijmans et al. 2005). Temperature and mean annual precipitation data were gathered that coincided as closely as possible with the time of contraction. The downloaded data were in raster form with a size of 5 arc-minutes (0.083333°), or roughly 10 km^2.

Because precipitation and temperature were only available as average monthly values, the values of each month for each variable were added together and divided by 12 to yield the mean annual temperature and mean annual precipitation.

Anthropogenic Data

Five measures of human disturbance were used in the analysis: distance from roads (Figure 5), human population density (Figure 6), and proportion of land converted to built-up land (Figure 7), cropland (Figure 8), and rangeland (Figure 9). All anthropogenic data were downloaded as raster GIS layers. Data for roads (CIESIN et al. 2011), human population density (Balk et al. 2006, CIESIN et al. 2011), cropland (Ramankutty et al. 2008, Ramankutty et al. 2010: Cropland), and rangeland (Ramankutty et al. 2008, Ramankutty et al. 2010: Pastures) were downloaded from SEDAC (SEDAC 2013). Built-up land was downloaded from Atlas of the Biosphere (Atlas of the Biosphere 2001).

These five anthropogenic layers had to be prepared for analysis. The largest cell size available for the human population density data was smaller than the cell size for the other layers. To resolve this issue, the aggregate function was used in ArcGIS to merge adjacent cells to form larger cells (cell size of 0.083333°) by using the mean of the aggregated cell values. Using ArcGIS, I constructed a distance to road raster layer from the road layer. Lastly, built-up land, cropland, and rangeland layers were obtained as percentages of the landscape and were divided by 100 to convert the values to proportions.

Separation of Continents

Because the results were compiled by continent, continents which are not geographically distinct from each other needed to be separated. The Ural Mountains and Caucasus Mountains were used as the boundaries to separate Europe and Asia. Four species (*Canis lupus*, Mammalia; *Castor fiber*, Mammalia; *Otis tarda*, Aves; and *Ursus arctos*, Mammalia) occurred in both Europe and Asia, and their ranges in the two continents were also split using the Ural and Caucasus mountain ranges as boundaries. Wallace's line (Lomolino et al. 2010) was used to separate Australia and southeast Asia. The islands of Sulawesi and New Guinea were therefore classified as part of Australia.

Analysis

A separate model was constructed for each species. In ArcGIS, the historical range of each species was converted to a point data layer. The values of the historical range point layer were coded to 1 for points where the species persists (within the remnant range) and 0 for the portion of the historical range where the species is extinct. For each point in the historical range the values of the 3 environmental and 5 anthropogenic layers were then extracted. Thus, for each point in the historical range I had recorded whether the species was persistent or extinct, and the value from each of the environmental and anthropogenic variables at that geographic location.

The attribute table of the point data layer was exported from ArcGIS to a text file. The text file was imported into Excel where it was prepared for statistical analysis. The large number of points recorded in the text file inflates the statistical power and causes very small differences to be statistically significant. To reduce this inflated power, a subset of 100 points from the historical range and 100 points from the remnant range were randomly selected for each species. Some species had very small ranges, resulting in less than 100 points in either their historical or remnant ranges (Table 3). For these species, an equal number of points were selected from each range type (historical or remnant) based on the range type which had the lowest number of points. This resulted in less than 200 total data points for analysis. For instance, the historical and remnant ranges of the Javan warty pig (*Sus verrucosus*, Mammalia, Asia) yielded a total of 204 historical points and 69 remnant points available for analysis. Thus, all 69 remnant points and only 69 randomly sampled historical points were used in the analysis of this species. Species with less than 50 historical or remnant points were excluded from analysis because the sample size was considered insufficient. Variables with a very low amount of variability, i.e., variables with fewer than 3 nonzero values, were deleted on a species-by-species basis. When two variables for a species were highly collinear ($r \geq 0.80$), one of the two collinear variables was removed from the model for that species. The values of all remaining variables were then z-score standardized (Urdan 2005).

Statistical analyses were conducted using the statistical program R (R Core Team 2014). Each species was analyzed separately. A logistic regression was conducted to predict species persistence by using the 3 environmental and 5 anthropogenic variables for each species. Because not all variables had a significant effect on persistence, it was unnecessary to include all variables in the model for each species; variables that had little or no effect were excluded from the models on a species-by-species basis. This was done by using a procedure similar to a forward stepwise regression. In this procedure, R built a model with no independent variables, then began an iterative process in which it built more models by subsequently adding independent variables that decreased the Akaike Information Criterion (AIC), a measure of model quality in which low values are desirable. This iterative process was stopped when a variable was added that increased the AIC. The model with the lowest AIC was then used for the subsequent analysis. Models with an AIC that differed from the previous model by less than 2.00 are not statistically different from each other, but the model with the lowest AIC was still used for the analysis (see "Best Model Not Sig. Different" column of Table 4).

Statistically significant coefficients from the final logistic regression model for each species were noted. These coefficients for a logistic regression are slope coefficients which represent a change in the logit in response to a change of one unit in the independent variable. Although the way in which a logistic regression coefficient is calculated is different from the way in which it is calculated for linear regression, the coefficients can still be interpreted as indicative of a positive or negative relationship between the independent and dependent variables (Hosmer and Lemeshow 2000). An independent variable with a significant coefficient indicates that variable has a significant effect (positive or negative) on the persistence of the species.

After conducting the logistic regression, all assumptions applicable to a logistic regression were tested for each species to ensure that none were violated. Any outliers were also identified and removed, and the logistic regression was repeated. Lack of fit was assessed for each model to ensure model validity. Fit of the model and error rate were also recorded for each species (Table 4).

For certain species, all *p* values from the logistic regression were close to or equal to 1 and therefore nonsignificant. In some cases, this problem was fixed by excluding a single variable from the model (see description of Table 4). When excluding a variable did not change the significance of the *p* values, a new model was manually created using two or three of the variables that had the largest effect on species when a logistic regression was conducted on those variables alone.

RESULTS

Overview

Of the 287 species analyzed, 11 species occurred on 2 or more continents, resulting in 300 separate range maps. However, results were compiled using species counts for both taxa (Aves and Mammalia) by continent (Table 5), so some species are counted more than once. Originally, I intended to compare the results of birds and mammals. However, lack of adequate sample sizes of both taxa for each continent made such comparisons untenable. Results for birds and mammals are therefore compiled together (Tables 4 and 5).

Variable coefficients (Table 4) and species counts (Table 5) were used to indicate relative influence of individual variables on species persistence. Species counts were used to determine the positive or negative effects of each variable on species persistence by continent. Only coefficient values that are significant are noted for each species. For example, in the logistic regression model for the Greater Sage-Grouse (*Centrocercus urophasianus*, Aves, North America), the coefficient value for proportion of land converted to rangeland is both significant and positive (Table 4). This indicates that, as the proportion of rangeland in an area increases, so does the chance that Greater Sage-Grouse persists there. In the case of this species, there is a positive relationship between persistence and rangeland. If, however, a coefficient value is negative, it indicates a negative relationship with species persistence. One of the significant negative coefficients for the Greater Sage-Grouse is proportion of cropland. As the amount of land converted to cropland increases, the chance that the Greater Sage-Grouse persists there decreases. This is unsurprising because agricultural lands do not meet the habitat requirements of this species (Aldridge et al. 2008).

Of the 287 species analyzed, 284 included at least one variable that significantly affected persistence; 3 species yielded no significant variables (Table 6). Of the 284 species that yielded at least one significant variable, lack of fit could not be assessed for 6 of the species (*Aviceda jerdoni*, Aves, Asia; *Conilurus penicillatus*, Mammalia, Australia; *Mesembriomys gouldii*, Mammalia, Australia; *Pseudomys bolami*, Mammalia, Australia; *Trichosurus vulpecula*, Mammalia, Australia; and *Alces alces*, Mammalia, North America) and for one of the two range maps used for *Gulo gulo* (Mammalia, North America). Because the analyses for these species are incomplete, their models are listed in the results of the logistic regression models by species (Table 4) but are not included in the summarized results by continent (Table 5). Similarly, lack of fit for several species was nonsignificant ($p < 0.05$), indicating that the model did not perform better than chance at predicting species persistence (denoted by an asterisk in the "L.O.F. $p < 0.05$" column of Table 4). However, these species and their associated values are included in the final results.

Although these results are listed comprehensively by continent, the effects of the independent variables on each species are also worthy of note; information about the effects of these variables on individual species can be important to the conservation of those species. The results are compiled comprehensively because the effects of the variables (Table 5) are perhaps more useful for multispecies conservation at a regional level.

Environmental Variables

Elevation

Elevation had a significant positive effect on the persistence of 17 of 39 (43.6%) African species, 47 of 122 (38.5%) Asian species, 18 of 66 (27.3%) Australian species, 1 of 10 (10.0%) European species, 11 of 47 (23.4%) North American species, and 3 of 9 (33.3%) South American species. Globally, this variable had a positive effect on 97 of 293 (33.1%) species.

Elevation had a significant negative effect on the persistence of 2 of 39 (5.1%) African species, 24 of 122 (19.7%) Asian species, 16 of 66 (24.2%) Australian species, 8 of 10 (80.0%) European species, 9 of 47 (19.1%) North American species, and 4 of 9 (44.4%) South American species. Globally, this variable had a negative effect on the persistence of 63 of 293 (21.5%) species.

Precipitation

Mean annual precipitation had a significant positive effect on the persistence of 16 of 39 (41.0%) African species, 36 of 122 (29.5%) Asian species, 28 of 66 (42.4%) Australian species, no European species 18 of 47 (38.3%) North American species, and 3 of 9 (33.3%) South American species. Globally, this variable had a positive effect on 101 of 293 (34.5%) species.

Mean annual precipitation had a significant negative effect on the persistence of 7 of 39 (17.9%) African species, 52 of 122 (42.6%) Asian species, 17 of 66 (25.8%)

Australian species, 1 of 10 (10.0%) European species, 9 of 47 (19.1%) North American species, and 2 of 9 (22.2%) South American species. Globally, this variable had a negative effect on the persistence of 88 of 293 (30.0%) species.

Temperature

Mean annual temperature had a significant positive effect on the persistence of 14 of 39 (35.9%) African species, 25 of 122 (20.5%) Asian species, 22 of 66 (33.3%) Australian species, 1 of 10 (10.0%) European species, 12 of 47 (25.5%) North American species, and 2 of 9 (22.2%) South American species. Globally, this variable had a positive effect on the persistence of 76 of 293 (25.9%) species.

Mean annual temperature had a significant negative effect on the persistence of 3 of 39 (7.7%) African species, 20 of 122 (16.4%) Asian species, 15 of 66 (22.7%) Australian species, 8 of 10 (80.0%) European species, 20 of 47 (42.6%) North American species, and 2 of 9 (22.2%) South American species. Globally, this variable had a negative effect on the persistence of 68 of 293 (23.2%) species.

Anthropogenic Variables

Distance from Roads

Distance from roads is interpreted differently than the other anthropogenic variables. Instead of indicating the severity of a human disturbance, it is comprised of distances from a human disturbance. Increasing distance from a road means a decrease in human disturbance. If species persistence is positively correlated with distance from roads, that species tends to persist in areas where fewer roads exist. If a species is negatively correlated with distance from roads, that species tends to persist in areas with more roads.

Distance from roads had a significant positive effect on the persistence of 8 of 39 (20.5%) African species, 20 of 122 (16.4%) Asian species, 8 of 66 (12.1%) Australian species, 1 of 10 (10.0%) European species, 5 of 47 (10.6%) North American species, and 4 of 9 (44.4%) South American species. Globally, this variable had a positive effect on the persistence of 46 of 293 (15.7%) species.

Distance from roads had a significant negative effect on the persistence of 3 of 39 (7.7%) African species, 7 of 122 (5.7%) Asian species, 7 of 66 (10.6%) Australian species, 1 of 10 (10.0%) European species, 8 of 47 (17.0%) North American species, and 2 of 9 (22.2%) South American species. Globally, this variable had a negative effect on the persistence of 28 of 293 (9.6%) species.

Human Population Density

Human population density had a significant positive effect on the persistence of no African species, 17 of 122 (13.9%) Asian species, 7 of 66 (10.6%) Australian species, no European species, 1 of 47 (2.1%) North American species, and no South American species. Globally, this variable had a positive effect on the persistence of 25 of 293 (8.5%) species.

Human population density had a significant negative effect on the persistence of 11 of 39 (28.2%) African species, 26 of 122 (21.1%) Asian species, 15 of 66 (22.7%) Australian species, 1 of 10 (10.0%) European species, 6 of 47 (12.8%) North American species, and 1 of 9 (11.1%) South American species. Globally, this variable had a negative effect on the persistence of 60 of 293 (20.5%) species.

Built-Up Land

Proportion of land converted to built-up land had a significant positive effect on the persistence of no African species, 8 of 122 (6.6%) Asian species, 1 of 66 (1.5%) Australian species, 1 of 10 (10.0%) European species, no North American species, and no South American species. Globally, this variable had a positive effect on the persistence of 10 of 293 (3.4%) species.

Built-up land had a significant negative effect on the persistence of no African species, 7 of 122 (5.7%) Asian species, no Australian species, no European species, 5 of 47 (10.6%) North American species, and no South American species. Globally, this variable had a negative effect on the persistence of 12 of 293 (4.1%) species.

Cropland

Proportion of land converted to cropland had a significant positive effect on the persistence of 3 of 39 (7.7%) African species, 33 of 122 (27.0%) Asian species, 10 of 66 (15.2%) Australian species, no European species, 4 of 47 (8.5%) North American species, and 1 of 9 (11.1%) South American species. Globally, this variable had a positive effect on the persistence of 51 of 293 (17.4%) species.

Cropland had a significant negative effect on the persistence of 13 of 39 (33.3%) African species, 25 of 122 (20.5%) Asian species, 9 of 66 (13.6 %) Australian species, 2 of 10 (20.0%) European species, 12 of 47 (25.5%) North American species, and 1 of 9

(11.1%) South American species. Globally, this variable had a negative effect on the persistence of 62 of 293 (21.2%) species.

Rangeland

Proportion of land converted to rangeland had a significant positive effect on the persistence of 4 of 39 (10.3%) African species, 21 of 122 (17.2%) Asian species, 6 of 66 (9.1%) Australian species, 3 of 10 (30.0%) European species, 9 of 47 (19.1%) North American species, and 3 of 9 (33.3%) South American species. Globally, this variable had a positive effect on the persistence of 46 of 293 (15.7%) species.

Rangeland had a significant negative effect on the persistence of 6 of 39 (15.4%) African species, 26 of 122 (21.3%) Asian species, 9 of 66 (12.9%) Australian species, 1 of 10 (10.0%) European species, 7 of 47 (14.9%) North American species, and 2 of 9 (22.2%) South American species. Globally, this variable had a negative effect on the persistence of 51 of 293 (17.4%) species.

DISCUSSION

Environmental Variables

Overview

The effects of the environmental variables on species persistence were split more evenly between positive influence and negative influence than expected based on species counts (Table 5). Precipitation positively affected persistence for the most species. Precipitation also negatively affected persistence for the most species. There was no environmental variable tested that could allow for the accurate prediction of persistence or extinction for all species included in this study.

Elevation

A positive relationship between elevation and species persistence indicates a higher probability that a species will persist at higher elevations. For those species that are affected by elevation in this way, this could be the result of an interaction between elevation and another variable included in this analysis. For example, temperature decreases with increasing altitude (Figures 2 and 4) and human population density tends to be lower at higher elevations (Figures 2 and 6). Some bird species included in this study that are endemic to southern Asia continue to inhabit the piedmont of the Himalayas in Nepal and northwest India, but have lost portions of their range in central and southern India where elevation is lower. This could be attributed to habitat loss brought about by the development of cities and villages, cropland, and rangeland in those areas. Certain other Asian species, such as the snow leopard (*Panthera unica*), have lost areas of their downslope range due to retaliatory hunting by local farmers and herders, as well as loss of natural prey due to both competition with livestock and hunting (Mishra et al. 2003). For species such as these, higher elevation areas could be refuges from human disturbance.

Conversely, the persistence of some species is negatively influenced by elevation. This result is counterintuitive when considering the relationship between elevation and human population density. As with the positive relationship between elevation and the persistence of certain species, this negative relationship is possibly the effect of an interaction between elevation and one or more of the other variables included in this study. For instance, elevation and temperature were often collinear in the logistic regression models of species in this analysis. One of these variables was excluded on a species-by-species basis if the correlation between the two variables was too high ($r \geq 0.80$), but both variables were kept in the analysis if they were not highly correlated ($r < 0.80$). Although the process used to build a model with the lowest AIC sometimes omitted one of the two variables that were still somewhat correlated, this omission did not always occur. Thus, the negative relationship seen between persistence and elevation could be caused by another environmental variable interacting with elevation.

Precipitation

Of all the variables tested, mean annual precipitation appeared to have the greatest effect on species persistence. Globally, it positively affected the persistence of more species than any other variable, and negatively affected the persistence of more species than any other variable. This indicates that precipitation is likely a very important factor for the ecological requirements of species, and therefore for their persistence.

The contradictory effects of precipitation between the species of this study are probably an overgeneralization of a complex pattern seen among differing environments within the continents, as well as combining results from a diverse assortment of species with different habitat requirements. In Australia, for instance, precipitation was the variable that positively affected persistence for the most species, and negatively affected persistence for the most species. It is unclear how to interpret this, because this importance of precipitation to species persistence is not seen among the other continents. It can be speculated the Australian species included in the study came from more varied habitats than the species from other continents, and the persistence of many of these

Australian species were either positively affected by precipitation or negatively affected by precipitation based on their differing habitat requirements. The cause of this result for Australia is still unclear, but these results suggest the persistence of Australian species appears to be more affected by precipitation than the persistence of species from other continents.

Temperature

Mean annual temperature did not have a positive relationship with persistence for the most species on any continent. It did, however exhibit a negative relationship with species persistence for the most North American species. Species in North America therefore tend to persist in cooler areas within their historical geographic range than in warmer areas. However, this pattern is probably more the result of a correlation between temperature and one or more human influence variables than the result of a direct relationship between temperature and persistence. For example, a continental climate dominates central North America (Bailey 1980), and this central portion of the continent is characterized by higher mean temperatures than on the coast. But the center of North America, particularly the center of the continental United States, has also been heavily impacted by agriculture and rangeland (Figures 8 and 9). This habitat loss via land use change is probably the driver of the negative relationship between temperature and species persistence.

Like mean annual precipitation, the differing responses of species persistence to mean annual temperature is probably also due to the differing ecological requirements of the species. Because temperature is correlated with elevation, it is also possible that some species that tend to persist in areas of higher elevation also tend to persist in areas with lower mean temperatures, or vice versa. This pattern is seen in only 5 of the species analyzed (Table 4), but this pattern could be obscured by the fact that elevation or temperature was often excluded from species models due to collinearity. Investigation into this possibility is recommended.

Anthropogenic Variables

Overview

The anthropogenic variables negatively affected the persistence of fewer species than expected. Contrary to prediction, the anthropogenic variables positively affected the persistence of many species. Cropland negatively affected persistence for the most species. Cropland also positively affected persistence for the most species. As with the environmental variables, there was no anthropogenic variable that could allow for the accurate prediction of persistence or extinction for all species included in this study.

Distance from Roads

More species persisted farther from roads than closer to roads. This is intuitive because roads can be a barrier to the movement of individuals of a species from one patch of habitat to another, and those individuals willing to attempt crossing a road incur risk. However, some species do persist closer to roads than farther from roads. This is interesting because there are few recorded instances of species using roads or roadside ditches as habitat or as corridors for movement (Forman and Alexander 1998). Further research is required to understand the possible causes of species persistence close to roads.

Human Population Density

Human population density had a negative effect on the persistence of a smaller number species than expected, and had a positive effect on the persistence of more species than expected. Like with built-up land, I expected the persistence of a much larger number of species to be negatively affected by population density. The reason for this is probably due to population density having a much lower contribution to species extinction than other variables associated with population density, such as the other anthropogenic variables included in this study. A large number of humans could exist in an area, but unless they destroy habitat or harm species directly, the number of humans itself has no effect.

It is surprising that human population density was positively correlated with the persistence of any species analyzed for this study. I expected a uniformly negative relationship between human population density and species persistence. As human population in an area increases, anthropogenic disturbance in that area is expected to increase, thereby causing more local extinctions. This was not the case for 25 species. Perhaps these species have adapted to coexist with humans, even in a highly disturbed environment. Or perhaps they are on the brink of extinction in those areas, and the "extinction debt" (Hanski and Ovaskainen 2002) has yet to be paid. However, the reasons for this positive relationship between species persistence and human population density are unclear and require further inquiry.

Built-Up Land

Built-up land was omitted from many of the species models in this study. Because the number of nonzero cells for built-up land was very low for the majority of species, the variable was often excluded due to lack of variation. This low number of nonzero cells is due to the fact that, although cities are numerous and continuing to grow with human population density, the actual land surface that urban areas cover is quite low (Figure 5). Thus, the number of cells containing portions of built-up land in the geographic ranges of most species is also low. When built-up land was left in the logistic regression models, it did not have an effect on many of the species included in this study. In fact, built-up land had a significant effect, positive or negative, on the persistence of only 22 species.

Some of these results for built-up land are counterintuitive because the more manmade structures that are in an area, the less habitat there is in that area. For those few species negatively affected by built-up land, it is possible that other factors are working in conjunction with built-up land to cause local extinctions. A city could be surrounded by many kilometers of cropland, such that the cropland plays a much larger role in local extinctions than the city does. Thus, built-up land itself might not be the direct cause of local extinctions, but other factors associated with built-up land, like the other anthropogenic variables included in this study, could be the main contributors.

Cropland

Of the anthropogenic variables included in this study, cropland had a negative effect on persistence for the most species across the world. The only continent on which cropland had a negative effect on persistence for the most species was Africa.
It is likely this variable has such a negative effect on the African species analyzed because many of those species are large-bodied with very large home range sizes. As such, they are more susceptible to habitat fragmentation and loss caused by agriculture than smaller-bodied species.

Africa is unique among the continents in terms of the nature in which cropland has manifested over time; unlike in Asia, Australia, and North America, where human disturbance has spread from one end of the continent to the other (Lomolino and Channell 1995), cropland in Africa has appeared around settlements that had already been established for thousands of years (Channell and Lomolino 2000), thus creating a pattern of severe fragmentation. Although this study contains analyses of only a sample of African mammals (and one bird), it is probably an accurate representation of the effects of cropland on the majority of extant, large-bodied African mammals.

Interestingly, of the anthropogenic variables, cropland also had a positive effect on persistence for the most species across the world. It is likely that most of the species whose persistence is positively affected by cropland reside in portions of remnant habitat adjacent to crop fields. However, a positive relationship between cropland and species persistence could also be attributed to the possibility that crops provide a food source for some species.

Rangeland

The effects of rangeland were split more evenly between positive and negative relationships with species persistence than the other human influence variables. Species whose persistence was negatively influenced by rangeland could include those whose habitat was lost in the development of rangeland itself, such as tropical species whose forests are being destroyed to make room for areas to graze livestock (FAO n.d.) Poor grazing practices might degrade grassland habitats within rangelands, thus damaging habitat for native species and making it impossible for them to adequately breed, nest, or forage there. Another possibility is that native grazing species that formerly foraged in areas which now have large amounts of rangeland have been persecuted by ranchers or herdsmen, or simply been outcompeted by livestock.

However, other species persist in areas of rangeland. This could be because areas of rangeland in which they persist are appropriately managed, maintaining the grassland habitat and the species that live there. In North America, for example, the pronghorn antelope (*Antilocapra americana*) can often be found grazing near cattle (Utah DWR 2009). Nests and lekking grounds of the Sharp-Tailed Grouse (*Tympanuchus phasianellus),* another North American species, are often found in rotationally grazed pastures (Kirby and Grosz 1995). If grazing practices are appropriate, then rangeland could potentially be a refuge for grassland-inhabiting species.

CONCLUSION

Conclusions for This Study

In general, the environmental variables tended to have a greater effect on species persistence than did the anthropogenic variables. I expected the anthropogenic variables to have a much greater negative effect on species persistence than they did. Although more species persisted in areas of higher elevation like I expected, more species also persisted in areas of greater precipitation and higher temperatures, contrary to my predictions.

The positive and negative effects of the variables on species persistence were also spread more evenly among species than I had anticipated. I expected persistence for the majority of species on each continent to be negatively affected by all the anthropogenic variables, but this was not always the case. Certain variables, such as human population density and built-up land, likely do not have direct effects on the persistence of species; other anthropogenic variables associated with human population density and built-up land might have a much greater effect. Similarly, the effects of one environmental variable on species persistence are likely not exclusive to that one variable, because environmental variables (such as elevation and temperature) tend to be correlated with each other. The causes and impacts of range contraction on species persistence are clearly complex, and the scope of this study is insufficient for understanding all of them.

Caveats and Future Research

Range contraction analysis is not yet well understood. There have been numerous studies focused on geographic range contraction and decline in species (Towns and

Daugherty 1994, Lomolino and Channell 1995, Channell and Lomolino 2000, Rodríguez and Delibes 2000, Erlich and Ceballos 2002, Rodríguez 2002, Hemerik et al. 2006), but none of them provide adequate understanding of the dynamics and interactions that lead to range contraction. This study, while unique in its approach, is likewise insufficient for generating a comprehensive view of the causes and consequences of range contraction. However, range contraction is still useful to the realm of conservation and is worthy of further study.

There is an element of artificiality to this study that is true of any range contraction analysis. The boundaries of a geographic range are dynamic, and thus inconstant. Species occurrence throughout its geographic range as printed on a map is unlikely, and the map is therefore a flawed metaphor. Range maps are also compiled by different researchers, many of whom use different methods. This would introduce inconsistency into the assumptions used when creating the different range maps. In addition, species detection is not perfect, and species occurrence in an area can be missed. The range maps used in this study should therefore be considered approximate.

The scale of this study was very large. Because of the size of the scale used here, it would have been difficult to use a grain that was small. The data points used in this study were roughly 10 km^2, a grain size in which small details are aggregated or summarized. A cell size of 1 km^2 would have been better, but the various GIS data layers used in this study were not always available at this resolution. A larger resolution had to be used across all variable layers for consistency.

These results are not comprehensive; only a small sample of bird and mammal species of the world was included in this study. This is a consequence of limited data availability due to the Wallacean shortfall (Lomolino et al. 2010). Were data on the geographic ranges of more species to be located and added to the analysis, the results might change. Another improvement to this study would be the inclusion of more taxonomic groups, terrestrial or aquatic. Similarly, inclusion of more variables in this study, such as those indicative of the biology and/or life history of the species, such as diet specificity, fecundity, average life span, and home range size, would also be beneficial. Inclusion of these variables would give us a more complete view of the threats imposed upon individual species and the factors that tend to make a species more vulnerable to losing portions of its geographic range.

Implications for Conservation

With biodiversity in peril and the degree of human disturbance increasing across the world, the research and application of conservation is becoming more important. Although this study is not comprehensive, my findings can still be useful to the conservation of biodiversity across the world. The broad results given here by continent and by variable can be valuable for multispecies conservation and the prediction of localities of persistence at a regional or continental scale. However, the results given for individual species that are in decline can also be helpful for single-species conservation; knowledge of the factors that have an effect on the persistence of a single species can assist conservation biologists in protecting that species from further decline. The findings of this study could also assist conservation biologists in predicting where a declining species will eventually persist, an ability which could prove vital to conservation in the future. Clearly, the development and implementation of studies such as this are essential to increasing our knowledge of the connections between range contraction, extinction, persistence, environment, and human disturbance.

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TABLES

Table 1. Bird and mammal species included in the range contraction analysis. A=Aves, M = Mammalia.

Continent	Taxon	Acronym	Species Name	Common name
Africa	A	ptex	*Pterocles exustus*	Chestnut-bellied sandgrouse
Africa	M	acju_af	*Acinonyx jubatus*	Cheetah
Africa	M	adna	*Addax nasomaculatus*	Addax
Africa	M	amcl	*Ammodorcas clarkei*	Dibatag
Africa	M	anma	*Antidorcas marsupialis*	Springbok
Africa	M	behu	*Beatragus hunteri*	Hirola
Africa	M	caau	*Canis aureus*	Golden jackal
Africa	M	casi	*Canis simiensis*	Ethiopian wolf
Africa	M	ceje	*Cephalophus jentinki*	Jentink's duiker
Africa	M	cesi	*Ceratotherium simum*	White rhino
Africa	M	ceel_af	*Cervus elaphus*	Red deer
Africa	M	dapy	*Damaliscus pygargus*	Bontebok
Africa	M	dibi	*Diceros bicornis*	Black rhino
Africa	M	eqaf	*Equus africanus*	African wild ass
Africa	M	eqgr	*Equus grevyi*	Grevy's zebra
Africa	M	eqqu	*Equus quagga*	Plains zebra
Africa	M	eqze	*Equus zebra*	Mountain zebra
Africa	M	feca_af	*Felis caracal*	Caracal
Africa	M	fese	*Felis serval*	Serval cat
Africa	M	gasp	*Gazella spekei*	Speke's gazelle
Africa	M	gica	*Giraffa camelopardalis*	Giraffe
Africa	M	hiam	*Hippopotamus amphibius*	Hippo
Africa	M	hybr	*Hyaena brunnea*	Brown hyena
Africa	M	koko	*Kobus kob*	Kob
Africa	M	kova	*Kobus vardoni*	Puku
Africa	M	loaf	*Loxodonta africana*	African elephant
Africa	M	lypi	*Lycaon pictus*	African wild dog
Africa	M	nada	*Nanger dama*	Dama gazelle
Africa	M	naso	*Nanger soemmerringii*	Soemmerring's gazelle
Africa	M	okjo	*Okapia johnstoni*	Okapi
Africa	M	orda	*Oryx dammah*	Scimitar-horned oryx
Africa	M	papa	*Pan paniscus*	Bonobo
Africa	M	pale	*Panthera leo*	Lion
Africa	M	papr_af	*Panthera pardus*	Leopard
Africa	M	paha	*Papio hamadryas*	Hamadryas baboon
Africa	M	pola	*Potamochoerus larvatus*	Bush pig
Africa	M	prcr	*Proteles cristata*	Aardwolf
Africa	M	tade	*Taurotragus derbianus*	Giant eland
Africa	M	taor	*Taurotragus oryx*	Common eland
Asia	A	acgi	*Acridotheres ginginianus*	Bank myna
Asia	A	aeni	*Aegithina nigrolutea*	Marshall's iora
Asia	A	aeti	*Aegithina tiphia*	Common iora

Asia	A	amam	*Amandava amandava*	Red avadavat
Asia	A	amph	*Amaurornis phoenicurus*	White-breasted waterhen
Asia	A	anme	*Anhinga melanogaster*	Oriental darter
Asia	A	anti	*Anorrhinus tickelli*	Brown hornbill
Asia	A	anco	*Anthracoceros coronatus*	Malabar pied hornbill
Asia	A	ansi	*Anthus similis*	Long-billed pipit
Asia	A	aqra	*Aquila rapax*	Tawny eagle
Asia	A	avje	*Aviceda jerdoni*	Jerdon's baza
Asia	A	avle	*Aviceda leuphotes*	Black baza
Asia	A	bamo	*Batrachostomus moniliger*	Sri Lanka frogmouth
Asia	A	buib	*Bubalcus ibis*	Cattle egret
Asia	A	bubi	*Buceros bicornis*	Great hornbill
Asia	A	buin	*Burhinus indicus*	Indian stone-curlew
Asia	A	bust	*Butorides striata*	Striated heron
Asia	A	capa	*Cacmantis passerinus*	Grey-bellied cuckoo
Asia	A	caas	*Caprimulgus asiaticus*	Indian nightjar
Asia	A	chma	*Chlamydotis macqueenii*	Asian houbara
Asia	A	chmc	*Chrysococcyx maculatus*	Asian emerald cuckoo
Asia	A	chfe	*Chrysocolaptes festivus*	White-naped woodpecker
Asia	A	clja	*Clamator jacobinus*	Jacobin cuckoo
Asia	A	coma	*Coracina macei*	Large cuckooshrike
Asia	A	cuce	*Culicicapa ceylonensis*	Grey-headed canary-flycatcher
Asia	A	cuco	*Cursorius coromandelicus*	Indian courser
Asia	A	diag	*Dicaeum agile*	Thick-billed flowerpecker
Asia	A	duae	*Ducula aenea*	Green imperial pigeon
Asia	A	ermo	*Eremopsaltria mongolica*	Mongolian finch
Asia	A	ergr	*Eremopterix griseus*	Ashy-crowned sparrow-lark
Asia	A	erni	*Eremopterix nigriceps*	Black-crowned sparrow lark
Asia	A	euor	*Eurystomus orientalis*	Dollarbird
Asia	A	fafa	*Falcipennis falcipennis*	Sharp-winged grouse
Asia	A	faju	*Falco jugger*	Laggar falcon
Asia	A	fape	*Falco peregrinus*	Peregrine falcon
Asia	A	frgu	*Francolinus gularis*	Swamp Francolin
Asia	A	fuat	*Fulica atra*	Eurasian coot
Asia	A	gade	*Garrulax delesserti*	Wynaad laughingthrush
Asia	A	gala	*Garrulax lanceolatus*	Black-headed jay
Asia	A	gala	*Garrulax lanceolatus*	Black-headed jay
Asia	A	glpr	*Glareola pratincola*	Collared pratincole
Asia	A	gran	*Grus antigone*	Sarus crane
Asia	A	gybe	*Gyps bengalensis*	White-rumped vulture
Asia	A	hasi	*Haematospiza sipahi*	Scarlet finch
Asia	A	hale	*Haliaeetus leucogaster*	White-bellied sea eagle
Asia	A	hain	*Haliastur indus*	Brahminy kite
Asia	A	haer	*Harpactes erythrocephalus*	Red-headed trogon
Asia	A	heca	*Hemicircus canente*	Heart-spotted woodpecker
Asia	A	hych	*Hydrophasianus chirurgus*	Pheasant-tailed jacana
Asia	A	keze	*Ketupa zeylonensis*	Brown fish owl
Asia	A	lasc	*Lanius schach*	Long-tailed shrike

Asia	A	lavi	*Lanius vittatus*	Bay-backed shrike
Asia	A	leso	*Leptopoecile sophiae*	White-browed tit warbler
Asia	A	loat	*Lonchura atricapilla*	Chestnut munia
Asia	A	loma	*Lonchura malacca*	Black-headed munia
Asia	A	lost	*Lonchura striata*	White-rumped munia
Asia	A	lubr	*Luscinia brunnea*	Indian blue robin
Asia	A	maab	*Malacocincla abbotti*	Abbott's babbler
Asia	A	meha	*Megalaima haemacephala*	Coppersmith barbet
Asia	A	meli	*Megalaima lineata*	Lineated barbet
Asia	A	meze	*Megalaima zeylanica*	Brown-headed barbet
Asia	A	mele	*Merops leschenaulti*	Chestnut-headed bee-eater
Asia	A	meor	*Merops orientalis*	Green bee-eater
Asia	A	mear	*Mesia argentaurius*	Silver-eared mesia
Asia	A	mein	*Metopidius indicus*	Bronze-winged jacana
Asia	A	moma	*Motacilla maderaspatensis*	White-browed wagtail
Asia	A	neco	*Nettapus coromandelicus*	Cotton pygmy-goose
Asia	A	nici	*Nisaetus cirrhatus*	Crested hawk eagle
Asia	A	ortr	*Oriolus traillii*	Maroon oriole
Asia	A	otta_as	*Otis tarda*	Great bustard
Asia	A	pacr	*Pavo cristatus*	Common Peafowl
Asia	A	peca	*Pelargopsis capensis*	Stork-billed kingfisher
Asia	A	peph	*Pelecanus philippensis*	Spot-billed pelican
Asia	A	peti	*Pellorneum tickelli*	Buff-breasted warbler
Asia	A	pefu	*Petrochelidon fluvicola*	Streak-throated swallow
Asia	A	phni	*Phalacrocorax niger*	Little cormorant
Asia	A	pifl	*Picus flavinucha*	Greater yellownape
Asia	A	pigr	*Pitta granatina*	Garnet pitta
Asia	A	prgr	*Prinia gracilis*	Graceful prinia
Asia	A	prso	*Prinia socialis*	Ashy prinia
Asia	A	psda	*Pseudibis davisoni*	White-shouldered ibis
Asia	A	pspa	*Pseudibis papillosa*	Red-naped ibis
Asia	A	ptin	*Pterocles indicus*	Painted sandgrouse
Asia	A	rhau	*Rhipidura aureola*	White-browed fantail
Asia	A	ryal	*Rynchops albicolus*	Indian skimmer
Asia	A	saca	*Sarcogyps calvus*	Red-headed vulture
Asia	A	same	*Sarkidiornis melanotos*	Knob-billed duck
Asia	A	safu	*Saxicoloides fulicatus*	Indian robin
Asia	A	stru	*Stachyridopsis rufifrons*	Rufous-fronted babbler
Asia	A	stac	*Sterna acuticaudata*	Black-bellied term
Asia	A	stal	*Sterna albifrons*	Little tern
Asia	A	stau	*Sterna aurantia*	River tern
Asia	A	sulu	*Surniculus lugubris*	Square-tailed drongo-cuckoo
Asia	A	tepa	*Tersiphone paradisi*	Asian paradise-flycatcher
Asia	A	tipi	*Timalia pileata*	Chestnut-capped babbler
Asia	A	trbi	*Treron bicinctus*	Orange-breasted green pigeon
Asia	A	trcu	*Treron curvirostra*	Thick-billed green pigeon
Asia	A	trph	*Treron phoenicopterus*	Yellow-footed green pigeon
Asia	A	tust	*Turdoides striata*	Jungle babbler

Asia	A	tusu	*Turdoides subrufa*	Rufous babbler
Asia	A	tual	*Turdus albocinctus*	White-collared blackbird
Asia	A	tyal	*Tyto alba*	Barn owl
Asia	A	urer	*Urocissa erythrorhyncha*	Red-billed blue magpie
Asia	M	acju_as	*Acinonyx jubatus*	Asiatic Cheetah
Asia	M	aime	*Ailuropoda melanoleuca*	Giant panda
Asia	M	bubu	*Bubalus bubalis*	Water buffalo
Asia	M	calu_as	*Canis lupus*	Gray wolf
Asia	M	caca	*Capreolus capreolus*	European roe deer
Asia	M	cafi_as	*Castor fiber*	Eurasian beaver
Asia	M	disu	*Dicerorhinus sumatrensis*	Sumatran rhino
Asia	M	elma	*Elephas maximus*	Asian elephant
Asia	M	eqhe	*Equus hemionus*	Onager
Asia	M	feca_as	*Felis caracal*	Caracal
Asia	M	mazi	*Martes zibellina*	Sable
Asia	M	pael	*Panolia eldii*	Eld's deer
Asia	M	papr_as	*Panthera pardus*	Leopard
Asia	M	pati	*Panthera tigris*	Tiger
Asia	M	paun	*Panthera unica*	Snow leopard
Asia	M	prgu	*Procapra gutturosa*	Mongolian gazelle
Asia	M	sata	*Saiga tatarica*	Saiga antelope
Asia	M	suve	*Sus verrucosus*	Javan warty pig
Asia	M	tain	*Tapirus indicus*	Malayan tapir
Asia	M	urar_as	*Ursus arctos*	Brown bear
Australia	A	paqu	*Pardalotus quadragintus*	Forty-spotted pardalote
Australia	A	peto	*Pedionomus torquatus*	Plains-wanderer
Australia	A	pefl	*Pezoporus flaviventris*	Western ground parrot
Australia	A	peoc	*Pezoporus occidentalis*	Night parrot
Australia	A	pewa	*Pezoporus wallicus*	Eastern ground parrot
Australia	A	piir	*Pitta iris*	Rainbow pitta
Australia	A	tume	*Turnix melanogaster*	Black-breasted buttonquail
Australia	M	acpy	*Acrobates pygmaeus*	Feathertail glider
Australia	M	aeru	*Aepyprymnus rufescens*	Rufous rat-kangaroo
Australia	M	bega	*Bettongia gaimardi*	Eastern bettong
Australia	M	bepe	*Bettongia penicillata*	Brush-tailed bettong
Australia	M	betr	*Bettongia tropica*	Northern bettong
Australia	M	ceco	*Cercartetus concinnus*	Southwestern pygmy possum
Australia	M	cope	*Conilurus penicillatus*	Brush-tailed rabbit-rat
Australia	M	dabl	*Dasycercus blythi*	Brush-tailed mulgara
Australia	M	dacr	*Dasycercus cristicauda*	Crest-tailed mulgara
Australia	M	daby	*Dasyuroides byrnei*	Kowari
Australia	M	dage	*Dasyurus geoffroi*	Western quoll
Australia	M	daha	*Dasyurus hallucatus*	Northern quoll
Australia	M	dama	*Dasyurus maculatus*	Tiger quoll
Australia	M	davi	*Dasyurus viverrinus*	Eastern quoll
Australia	M	gyle	*Gymnobelideus leadbeateri*	Leadbeater's possum
Australia	M	isau	*Isoodon auratus*	Golden bandicoot
Australia	M	isma	*Isoodon macrourus*	Northern brown bandicoot

Australia	M	isob	*Isoodon obesulus*	Southern brown bandicoot
Australia	M	laco	*Lagorchestes conspicillatus*	Spectacled hare-wallaby
Australia	M	lala	*Lasiorhinus latifrons*	Southern hairy-nosed wombat
Australia	M	maeu	*Macropus eugenii*	Tammar walalby
Australia	M	mapa	*Macropus parryi*	Whiptail wallaby
Australia	M	mala	*Macrotis lagotis*	Greater bilby
Australia	M	mego	*Mesembriomys gouldii*	Black-footed tree-rat
Australia	M	mema	*Mesembriomys macrurus*	Golden-backed tree-rat
Australia	M	noal	*Notomys alexis*	Spinifex hopping mouse
Australia	M	noaq	*Notomys aquilo*	Northern hopping mouse
Australia	M	noce	*Notomys cervinus*	Fawn hopping mouse
Australia	M	nofu	*Notomys fuscus*	Dusky hopping mouse
Australia	M	nomi	*Notomys mitchelli*	Mitchell's hopping mouse
Australia	M	onfr	*Onychogalea fraenata*	Bridled nail-tail wallaby
Australia	M	pegu	*Perameles gunnii*	Eastern barred bandicoot
Australia	M	peau	*Petaurus australis*	Yellow-bellied glider
Australia	M	pela	*Petrogale lateralis*	Black-flanked rock-wallaby
Australia	M	pepe	*Petrogale penicillata*	Brush-tailed rock-wallaby
Australia	M	pexa	*Petrogale xanthopus*	Yellow-footed rock-wallaby
Australia	M	phca	*Phascogale calura*	Red-tailed phascogale
Australia	M	phpi	*Phascogale pirata*	Northern brush-tailed phascogale
Australia	M	phta	*Phascogale tapoatafa*	Brush-tailed phascogale
Australia	M	phci	*Phascolarctos cinereus*	Koala
Australia	M	pogi	*Potorus gilberti*	Gilbert's potoroo
Australia	M	psmi	*Pseudantechinus mimulus*	Carpentarian antechinus
Australia	M	psoc	*Pseudocheirus occidentalis*	Western ringtail possum
Australia	M	pspe	*Pseudocheirus peregrinus*	Common ringtail possum
Australia	M	psal	*Pseudomys albocinereus*	Ash-grey mouse
Australia	M	psau	*Pseudomys australis*	Plains rat
Australia	M	psbo	*Pseudomys bolami*	Bolam's mouse
Australia	M	psch	*Pseudomys chapmani*	Western pebble-mound mouse
Australia	M	psde	*Pseudomys desertor*	Desert mouse
Australia	M	psna	*Pseudomys nanus*	Western chestnut mouse
Australia	M	psno	*P. novahollandiae*	New Holland mouse
Australia	M	pssh	*Pseudomys shortridgei*	Heath mouse
Australia	M	ptpo	*Pteropus poliocephalus*	Grey-headed flying fox
Australia	M	ratu	*Rattus tunneyi*	Pale field rat
Australia	M	ravi	*Rattus villosissimus*	Long-haired rat
Australia	M	sebr	*Setonix brachyurus*	Quokka
Australia	M	smgi	*Sminthopsis gilberti*	Gilbert's dunnart
Australia	M	suce	*Sus celebensis*	Sulawesi warty pig
Australia	M	thbi	*Thylogale billardierii*	Tasmanian pademelon
Australia	M	trvu	*Trichosurus vulpecula*	Common brushtail possum
Australia	M	wabi	*Wallabia bicolor*	Swamp wallaby
Australia	M	wysq	*Wyulda squamicaudata*	Scaly-tailed possum
Australia	M	zype	*Zyzomys pedunculatus*	Central rock rat
Europe	A	otta_eur	*Otis tarda*	Great bustard

Europe	A	tete	*Tetrao tetrix*	Black grouse
Europe	A	teur	*Tetrao urogallus*	Capercaillie
Europe	A	tett	*Tetrax tetrax*	little bustard
Europe	M	calu_eur	*Canis lupus*	Gray wolf
Europe	M	cafi_eur	*Castor fiber*	Eurasian beaver
Europe	M	gugl_eur	*Gulo gulo*	Wolverine
Europe	M	mica	*Microtus cabrerae*	Cabrera's vole
Europe	M	mulu	*Mustela lutreola*	European mink
Europe	M	urar_eur	*Ursus arctos*	Brown bear
North Am	A	amne	*Ammospermophilus nelsoni*	San Joaquin antelope squirrel
North Am	A	apco	*Aphelocoma coerulescens*	Florida scrub-jay
North Am	A	atcu	*Athene cunicularia*	Burrowing owl
North Am	A	boum	*Bonasa umbellus*	Ruffed grouse
North Am	A	busw	*Buteo swainsoni*	Swainson's hawk
North Am	A	ceur	*Centrocercus urophasianus*	Greater sage grouse
North Am	A	cybu	*Cygnus buccinator*	Trumpeter swan
North Am	A	elfo	*Elanoides forficatus*	American swallow-tailed kite
North Am	A	fafe	*Falco femoralis*	Aplomado falcon
North Am	A	gram	*Grus americana*	Whooping crane
North Am	A	gyca	*Gymnogyps californianus*	California condor
North Am	A	haha	*Harpia harpyja*	Harpy Eagle
North Am	A	icam	*Ibycter americanus*	Red-throated caracara
North Am	A	lalu	*Lanius ludovicianus*	Loggerhead shrike
North Am	A	lebo	*Leuconotopicus borealis*	Red-cockaded woodpecker
North Am	A	mega	*Meleagris gallopavo*	Wild turkey
North Am	A	paui	*Parabuteo unicinctus*	Harris' hawk
North Am	A	roso	*Rostrhamus sociabilis*	Snail kite
North Am	A	sapa	*Sarcoramphus papa*	King vulture
North Am	A	tycu	*Tympanuchus cupido*	Greater prairie chicken
North Am	A	typa	*Tympanuchus pallidicinctus*	Lesser prairie chicken
North Am	A	typh	*Tympanuchus phasianellus*	Sharp-tailed grouse
North Am	A	vech	*Vermivora chrysoptera*	Golden-winged warbler
North Am	M	alal	*Alces alces*	Moose
North Am	M	anam	*Antilocapra americana*	Pronghorn antelope
North Am	M	calu_na	*Canis lupus*	Gray wolf
North Am	M	caru	*Canis rufus*	Red wolf
North Am	M	ceel_na	*Cervus elaphus*	Elk
North Am	M	cylu	*Cynomys ludovicianus*	Black-tailed prairie dog
North Am	M	diel	*Dipodomys elator*	Texas kangaroo rat
North Am	M	erdo	*Erethizon dorsatum*	North American porcupine
North Am	M	gugl_na	*Gulo gulo*	Wolverine
North Am	M	lepa	*Leopardus pardalis*	Ocelot
North Am	M	loca	*Lontra canadensis*	North American river otter
North Am	M	lyca	*Lynx canadensis*	Canada lynx
North Am	M	maam	*Martes americana*	American marten
North Am	M	mapi	*Martes pennati*	Fisher
North Am	M	oram	*Oremnos americanus*	Mountain goat
North Am	M	ovmu	*Ovibos muschatus*	Muskox

North Am	M	ovca	*Ovis canadensis*	Bighorn sheep
North Am	M	ovda	*Ovis dalli*	Dall's sheep
North Am	M	paon_na	*Panthera onca*	Jaguar
North Am	M	puco_na	*Puma concolor*	Mountain lion
North Am	M	rata	*Rangifer tarandus*	Caribou
North Am	M	sytr	*Sylvilagus transitionalis*	New England cottontail
North Am	M	urwa	*Urocitellus washingtoni*	Washington ground squirrel
North Am	M	uram	*Ursus americanus*	Black bear
North Am	M	urar_na	*Ursus arctos*	Brown bear
North Am	M	vuve	*Vulpes velox*	Swift fox
South Am	A	gugu	*Guaruba guarouba*	Golden parakeet
South Am	M	chbr	*Chrysocyon brachyurus*	Maned wolf
South Am	M	hibi	*Hippocamelus bisulcus*	Patagonia huemul
South Am	M	lagu	*Lama guanicoe*	Guanacoe
South Am	M	paon_sa	*Panthera onca*	Jaguar
South Am	M	puco_sa	*Puma concolor*	Mountain lion
South Am	M	tror	*Tremarctos ornatus*	Spectacled bear
South Am	M	vivi	*Vicugna vicugna*	Vicuna
South Am	M	wioe	*Wilfredomys oenax*	Greater Wilfred's mouse

Table 2. Sources of species' range maps used in the range contraction analysis. A=Aves, M=Mammalia.

Continent	Taxon	Species	Source
Africa	A	*Pterocles exustus*	Johnsgard 1991
Africa	M	*Acinonyx jubatus*	Kingdon 1997
Africa	M	*Addax nasomaculatus*	Kingdon 1997
Africa	M	*Ammodorcas clarkei*	Kingdon 1997
Africa	M	*Antidorcas marsupialis*	Kingdon 1997
Africa	M	*Beatragus hunteri*	Kingdon 1997
Africa	M	*Canis aureus*	IUCN
Africa	M	*Canis simiensis*	Kingdon 1997
Africa	M	*Cephalophus jentinki*	Kingdon 1997
Africa	M	*Ceratotherium simum*	Kingdon 1997
Africa	M	*Cervus elaphus*	Kingdon 1997
Africa	M	*Damaliscus pygargus*	Burton 1987
Africa	M	*Diceros bicornis*	International Rhino Foundation
Africa	M	*Equus africanus*	Kingdon 1997
Africa	M	*Equus grevyi*	Kingdon 1997
Africa	M	*Equus quagga*	IUCN/SSC Equid Specialist Group
Africa	M	*Equus zebra*	Kingdon 1997
Africa	M	*Felis caracal*	Burton 1987
Africa	M	*Felis serval*	Kingdon 1997
Africa	M	*Gazella spekei*	Kingdon 1997
Africa	M	*Giraffa camelopardalis*	Kingdon 1997
Africa	M	*Hippopotamus amphibius*	Kingdon 1997
Africa	M	*Hyaena brunnea*	Burton 1987
Africa	M	*Kobus kob*	Kingdon 1997
Africa	M	*Kobus vardoni*	Kingdon 1997
Africa	M	*Loxodonta africana*	Kingdon 1997
Africa	M	*Lycaon pictus*	Kingdon 1997
Africa	M	*Nanger dama*	Kingdon 1997
Africa	M	*Nanger soemmerringii*	Kingdon 1997
Africa	M	*Okapia johnstoni*	Kingdon 1997
Africa	M	*Oryx dammah*	Kingdon 1997
Africa	M	*Pan paniscus*	Kingdon 1997
Africa	M	*Panthera leo*	Panthera 2009
Africa	M	*Panthera pardus*	Kingdon 1997
Africa	M	*Papio hamadryas*	Burton 1987
Africa	M	*Potamochoerus larvatus*	Ultimate Ungulate
Africa	M	*Proteles cristata*	Burton 1987

Africa	M	*Taurotragus derbianus*	Kingdon 1997
Africa	M	*Taurotragus oryx*	Kingdon 1997
Asia	A	*Acridotheres ginginianus*	Grimmett et al. 2012
Asia	A	*Aegithina nigrolutea*	Grimmett et al. 2012
Asia	A	*Aegithina tiphia*	Grimmett et al. 2012
Asia	A	*Amandava amandava*	Grimmett et al. 2012
Asia	A	*Amaurornis phoenicurus*	Grimmett et al. 2012
Asia	A	*Anhinga melanogaster*	Grimmett et al. 2012
Asia	A	*Anorrhinus tickelli*	Grimmett et al. 2012
Asia	A	*Anthracoceros coronatus*	Grimmett et al. 2012
Asia	A	*Anthus similis*	Grimmett et al. 2012
Asia	A	*Aquila rapax*	Grimmett et al. 2012
Asia	A	*Aviceda jerdoni*	Grimmett et al. 2012
Asia	A	*Aviceda leuphotes*	Grimmett et al. 2012
Asia	A	*Batrachostomus moniliger*	Grimmett et al. 2012
Asia	A	*Bubalcus ibis*	Grimmett et al. 2012
Asia	A	*Buceros bicornis*	Grimmett et al. 2012
Asia	A	*Burhinus indicus*	Grimmett et al. 2012
Asia	A	*Butorides striata*	Grimmett et al. 2012
Asia	A	*Cacmantis passerinus*	Grimmett et al. 2012
Asia	A	*Caprimulgus asiaticus*	Grimmett et al. 2012
Asia	A	*Chlamydotis macqueenii*	Johnsgard 1991
Asia	A	*Chrysococcyx maculatus*	Grimmett et al. 2012
Asia	A	*Chrysocolaptes festivus*	Grimmett et al. 2012
Asia	A	*Clamator jacobinus*	Grimmett et al. 2012
Asia	A	*Coracina macei*	Grimmett et al. 2012
Asia	A	*Culicicapa ceylonensis*	Grimmett et al. 2012
Asia	A	*Cursorius coromandelicus*	Grimmett et al. 2012
Asia	A	*Dicaeum agile*	Grimmett et al. 2012
Asia	A	*Ducula aenea*	Grimmett et al. 2012
Asia	A	*Eremopsaltria mongolica*	Grimmett et al. 2012
Asia	A	*Eremopterix griseus*	Grimmett et al. 2012
Asia	A	*Eremopterix nigriceps*	Grimmett et al. 2012
Asia	A	*Eurystomus orientalis*	Grimmett et al. 2012
Asia	A	*Falcipennis falcipennis*	Johnsgard 1983
Asia	A	*Falco jugger*	Grimmett et al. 2012
Asia	A	*Falco peregrinus*	Grimmett et al. 2012
Asia	A	*Francolinus gularis*	IUCN
Asia	A	*Fulica atra*	Grimmett et al. 2012
Asia	A	*Garrulax delesserti*	Grimmett et al. 2012
Asia	A	*Garrulax lanceolatus*	Grimmett et al. 2012

Asia	A	*Garrulax lanceolatus*	Grimmett et al. 2012
Asia	A	*Glareola pratincola*	Grimmett et al. 2012
Asia	A	*Grus antigone*	Grimmett et al. 2012
Asia	A	*Gyps bengalensis*	Grimmett et al. 2012
Asia	A	*Haematospiza sipahi*	Grimmett et al. 2012
Asia	A	*Haliaeetus leucogaster*	Grimmett et al. 2012
Asia	A	*Haliastur indus*	Grimmett et al. 2012
Asia	A	*Harpactes erythrocephalus*	Grimmett et al. 2012
Asia	A	*Hemicircus canente*	Grimmett et al. 2012
Asia	A	*Hydrophasianus chirurgus*	Grimmett et al. 2012
Asia	A	*Ketupa zeylonensis*	Grimmett et al. 2012
Asia	A	*Lanius schach*	Grimmett et al. 2012
Asia	A	*Lanius vittatus*	Grimmett et al. 2012
Asia	A	*Leptopoecile sophiae*	Grimmett et al. 2012
Asia	A	*Lonchura atricapilla*	Grimmett et al. 2012
Asia	A	*Lonchura malacca*	Grimmett et al. 2012
Asia	A	*Lonchura striata*	Grimmett et al. 2012
Asia	A	*Luscinia brunnea*	Grimmett et al. 2012
Asia	A	*Malacocincla abbotti*	Grimmett et al. 2012
Asia	A	*Megalaima haemacephala*	Grimmett et al. 2012
Asia	A	*Megalaima lineata*	Grimmett et al. 2012
Asia	A	*Megalaima zeylanica*	Grimmett et al. 2012
Asia	A	*Merops leschenaulti*	Grimmett et al. 2012
Asia	A	*Merops orientalis*	Grimmett et al. 2012
Asia	A	*Mesia argentaurius*	Grimmett et al. 2012
Asia	A	*Metopidius indicus*	Grimmett et al. 2012
Asia	A	*Motacilla maderaspatensis*	Grimmett et al. 2012
Asia	A	*Nettapus coromandelicus*	Grimmett et al. 2012
Asia	A	*Nisaetus cirrhatus*	Grimmett et al. 2012
Asia	A	*Oriolus traillii*	Grimmett et al. 2012
Asia	A	*Otis tarda*	Johnsgard 1991
Asia	A	*Pavo cristatus*	Grimmett et al. 2012
Asia	A	*Pelargopsis capensis*	Grimmett et al. 2012
Asia	A	*Pelecanus philippensis*	Johnsgard 1993
Asia	A	*Pellorneum tickelli*	Grimmett et al. 2012
Asia	A	*Petrochelidon fluvicola*	Grimmett et al. 2012
Asia	A	*Phalacrocorax niger*	Grimmett et al. 2012
Asia	A	*Picus flavinucha*	Grimmett et al. 2012
Asia	A	*Pitta granatina*	Lambert and Woodcock 1996
Asia	A	*Prinia gracilis*	Grimmett et al. 2012
Asia	A	*Prinia socialis*	Grimmett et al. 2012

Asia	A	*Pseudibis davisoni*	IUCN
Asia	A	*Pseudibis papillosa*	Grimmett et al. 2012
Asia	A	*Pterocles indicus*	Grimmett et al. 2012
Asia	A	*Rhipidura aureola*	Grimmett et al. 2012
Asia	A	*Rynchops albicolus*	Grimmett et al. 2012
Asia	A	*Sarcogyps calvus*	Grimmett et al. 2012
Asia	A	*Sarkidiornis melanotos*	Grimmett et al. 2012
Asia	A	*Saxicoloides fulicatus*	Grimmett et al. 2012
Asia	A	*Stachyridopsis rufifrons*	Grimmett et al. 2012
Asia	A	*Sterna acuticaudata*	Grimmett et al. 2012
Asia	A	*Sterna albifrons*	Grimmett et al. 2012
Asia	A	*Sterna aurantia*	Grimmett et al. 2012
Asia	A	*Surniculus lugubris*	Grimmett et al. 2012
Asia	A	*Tersiphone paradisi*	Grimmett et al. 2012
Asia	A	*Timalia pileata*	Grimmett et al. 2012
Asia	A	*Treron bicinctus*	Grimmett et al. 2012
Asia	A	*Treron curvirostra*	Grimmett et al. 2012
Asia	A	*Treron phoenicopterus*	Grimmett et al. 2012
Asia	A	*Turdoides striata*	Grimmett et al. 2012
Asia	A	*Turdoides subrufa*	Grimmett et al. 2012
Asia	A	*Turdus albocinctus*	Grimmett et al. 2012
Asia	A	*Tyto alba*	Grimmett et al. 2012
Asia	A	*Urocissa erythrorhyncha*	Grimmett et al. 2012
Asia	M	*Acinonyx jubatus*	Panthera
Asia	M	*Ailuropoda melanoleuca*	WWF
Asia	M	*Bubalus bubalis*	Burton 1987
Asia	M	*Canis lupus*	Burton 1987
Asia	M	*Capreolus capreolus*	IUCN
Asia	M	*Castor fiber*	Burton 1987
Asia	M	*Dicerorhinus sumatrensis*	International Rhino Foundation
Asia	M	*Elephas maximus*	Santiapillai and Jackson 1990
Asia	M	*Equus hemionus*	IUCN/SSC Equid Specialist Group
Asia	M	*Felis caracal*	Burton 1987
Asia	M	*Martes zibellina*	IUCN
Asia	M	*Panolia eldii*	Smithsonian National Zoological Park
Asia	M	*Panthera pardus*	Burton 1987
Asia	M	*Panthera tigris*	Panthera
Asia	M	*Panthera unica*	Panthera
Asia	M	*Procapra gutturosa*	Ultimate Ungulate
Asia	M	*Saiga tatarica*	Campos et al. 2010

Asia	M	*Sus verrucosus*	Semiadi and Meijaard 2006
Asia	M	*Tapirus indicus*	Medici E. P. et al. 2003
Asia	M	*Ursus arctos*	Serheen et al. 1999
Australia	A	*Pardalotus quadragintus*	Hermes 1990
Australia	A	*Pedionomus torquatus*	Hermes 1990
Australia	A	*Pezoporus flaviventris*	Hermes 1990
Australia	A	*Pezoporus occidentalis*	Hermes 1990
Australia	A	*Pezoporus wallicus*	Hermes 1990
Australia	A	*Pitta iris*	Lambert and Woodcock 1996
Australia	A	*Turnix melanogaster*	Johnsgard 1991
Australia	M	*Acrobates pygmaeus*	Strahan and van Dyck 2006
Australia	M	*Aepyprymnus rufescens*	Strahan and van Dyck 2006
Australia	M	*Bettongia gaimardi*	Strahan and van Dyck 2006
Australia	M	*Bettongia penicillata*	Strahan and van Dyck 2006
Australia	M	*Bettongia tropica*	Strahan and van Dyck 2006
Australia	M	*Cercartetus concinnus*	Strahan and van Dyck 2006
Australia	M	*Conilurus penicillatus*	Strahan and van Dyck 2006
Australia	M	*Dasycercus blythi*	Strahan and van Dyck 2006
Australia	M	*Dasycercus cristicauda*	Strahan and van Dyck 2006
Australia	M	*Dasyuroides byrnei*	Strahan and van Dyck 2006
Australia	M	*Dasyurus geoffroi*	Strahan and van Dyck 2006
Australia	M	*Dasyurus hallucatus*	Strahan and van Dyck 2006
Australia	M	*Dasyurus maculatus*	Strahan and van Dyck 2006
Australia	M	*Dasyurus viverrinus*	Strahan and van Dyck 2006
Australia	M	*Gymnobelideus leadbeateri*	Hermes 1990
Australia	M	*Isoodon auratus*	Strahan and van Dyck 2006
Australia	M	*Isoodon macrourus*	Strahan and van Dyck 2006
Australia	M	*Isoodon obesulus*	Strahan and van Dyck 2006
Australia	M	*Lagorchestes conspicillatus*	Strahan and van Dyck 2006
Australia	M	*Lasiorhinus latifrons*	Strahan and van Dyck 2006
Australia	M	*Macropus eugenii*	Strahan and van Dyck 2006
Australia	M	*Macropus parryi*	Strahan and van Dyck 2006
Australia	M	*Macrotis lagotis*	Strahan and van Dyck 2006
Australia	M	*Mesembriomys gouldii*	Strahan and van Dyck 2006
Australia	M	*Mesembriomys macrurus*	Strahan and van Dyck 2006
Australia	M	*Notomys alexis*	Strahan and van Dyck 2006
Australia	M	*Notomys aquilo*	Strahan and van Dyck 2006
Australia	M	*Notomys cervinus*	Strahan and van Dyck 2006
Australia	M	*Notomys fuscus*	Strahan and van Dyck 2006
Australia	M	*Notomys mitchelli*	Strahan and van Dyck 2006
Australia	M	*Onychogalea fraenata*	Strahan and van Dyck 2006

Australia	M	*Perameles gunnii*	Strahan and van Dyck 2006
Australia	M	*Petaurus australis*	Strahan and van Dyck 2006
Australia	M	*Petrogale lateralis*	Strahan and van Dyck 2006
Australia	M	*Petrogale penicillata*	Strahan and van Dyck 2006
Australia	M	*Petrogale xanthopus*	Strahan and van Dyck 2006
Australia	M	*Phascogale calura*	Strahan and van Dyck 2006
Australia	M	*Phascogale pirata*	Strahan and van Dyck 2006
Australia	M	*Phascogale tapoatafa*	Strahan and van Dyck 2006
Australia	M	*Phascolarctos cinereus*	Strahan and van Dyck 2006
Australia	M	*Potorus gilberti*	Strahan and van Dyck 2006
Australia	M	*Pseudantechinus mimulus*	Strahan and van Dyck 2006
Australia	M	*Pseudocheirus occidentalis*	Strahan and van Dyck 2006
Australia	M	*Pseudocheirus peregrinus*	Strahan and van Dyck 2006
Australia	M	*Pseudomys albocinereus*	Strahan and van Dyck 2006
Australia	M	*Pseudomys australis*	Strahan and van Dyck 2006
Australia	M	*Pseudomys bolami*	Strahan and van Dyck 2006
Australia	M	*Pseudomys chapmani*	Strahan and van Dyck 2006
Australia	M	*Pseudomys desertor*	IUCN
Australia	M	*Pseudomys nanus*	Strahan and van Dyck 2006
Australia	M	*Pseudomys novahollandiae*	Strahan and van Dyck 2006
Australia	M	*Pseudomys shortridgei*	Strahan and van Dyck 2006
Australia	M	*Pteropus poliocephalus*	Strahan and van Dyck 2006
Australia	M	*Rattus tunneyi*	Strahan and van Dyck 2006
Australia	M	*Rattus villosissimus*	Strahan and van Dyck 2006
Australia	M	*Setonix brachyurus*	Strahan and van Dyck 2006
Australia	M	*Sminthopsis gilberti*	Strahan and van Dyck 2006
Australia	M	*Sus celebensis*	Ultimate Ungulate
Australia	M	*Thylogale billardierii*	Strahan and van Dyck 2006
Australia	M	*Trichosurus vulpecula*	Strahan and van Dyck 2006
Australia	M	*Wallabia bicolor*	Strahan and van Dyck 2006
Australia	M	*Wyulda squamicaudata*	Strahan and van Dyck 2006
Australia	M	*Zyzomys pedunculatus*	Strahan and van Dyck 2006
Europe	A	*Otis tarda*	Johnsgard 1991
Europe	A	*Tetrao tetrix*	Johnsgard 1983
Europe	A	*Tetrao urogallus*	Johnsgard 1983
Europe	A	*Tetrax tetrax*	IUCN
Europe	M	*Canis lupus*	Burton 1987
Europe	M	*Castor fiber*	Burton 1987
Europe	M	*Gulo gulo*	Burton 1987
Europe	M	*Microtus cabrerae*	IUCN
Europe	M	*Mustela lutreola*	Burton 1987

Europe	M	*Ursus arctos*	Serheen et al. 1999
North Am	A	*Ammospermophilus nelsoni*	Hafner et al. 1998
North Am	A	*Aphelocoma coerulescens*	Jonshon et al. 2012
North Am	A	*Athene cunicularia*	Wellicome 2001
North Am	A	*Bonasa umbellus*	Schroeder et al. 2004
North Am	A	*Buteo swainsoni*	Johnsgard 2001
North Am	A	*Centrocercus urophasianus*	USFWS 2014
North Am	A	*Cygnus buccinator*	Leopold et al. 1981
North Am	A	*Elanoides forficatus*	Johnsgard 2001
North Am	A	*Falco femoralis*	Johnsgard 2001
North Am	A	*Grus americana*	CWS and USFWS 2007
North Am	A	*Gymnogyps californianus*	Howell and Webb 1995
North Am	A	*Harpia harpyja*	Howell and Webb 1995
North Am	A	*Ibycter americanus*	Ridgely et al. 2005
North Am	A	*Lanius ludovicianus*	Bird Studies Canada
North Am	A	*Leuconotopicus borealis*	Ridgely et al. 2005
North Am	A	*Meleagris gallopavo*	Leopold et al. 1981
North Am	A	*Parabuteo unicinctus*	Johnsgard 2001
North Am	A	*Rostrhamus sociabilis*	Johnsgard 2001
North Am	A	*Sarcoramphus papa*	Howell and Webb 1995
North Am	A	*Tympanuchus cupido*	The Grouse Partnership
North Am	A	*Tympanuchus pallidicinctus*	USFWS 2011
North Am	A	*Tympanuchus phasianellus*	Schroeder et al. 2010
North Am	A	*Vermivora chrysoptera*	Cornell Lab of Ornithology 2014
North Am	M	*Alces alces*	Leopold et al. 1981
North Am	M	*Antilocapra americana*	Leopold et al. 1981
North Am	M	*Canis lupus*	Montana Natural Heritage Program
North Am	M	*Canis rufus*	USFWS "Map"
North Am	M	*Cervus elaphus*	Laliberte and Ripple 2004
North Am	M	*Cynomys ludovicianus*	Reid 2006
North Am	M	*Dipodomys elator*	Reid 2006
North Am	M	*Erethizon dorsatum*	Reid 2006
North Am	M	*Gulo gulo*	Reid 2006
North Am	M	*Leopardus pardalis*	Reid 2006
North Am	M	*Lontra canadensis*	Laliberte and Ripple 2004
North Am	M	*Lynx canadensis*	Laliberte and Ripple 2004
North Am	M	*Martes americana*	Laliberte and Ripple 2004
North Am	M	*Martes pennati*	Canadian Geographic 2014
North Am	M	*Oremnos americanus*	Laliberte and Ripple 2004
North Am	M	*Ovibos muschatus*	Laliberte and Ripple 2004
North Am	M	*Ovis canadensis*	Canadian Geographic 2014

North Am	M	*Ovis dalli*	Laliberte and Ripple 2004
North Am	M	*Panthera onca*	Panthera
North Am	M	*Puma concolor*	Panthera
North Am	M	*Rangifer tarandus*	Leopold et al. 1981
North Am	M	*Sylvilagus transitionalis*	USFWS "Locations"
North Am	M	*Urocitellus washingtoni*	Hafner et al. 1998
North Am	M	*Ursus americanus*	Serheen et al. 1999
North Am	M	*Ursus arctos*	Serheen et al. 1999
North Am	M	*Vulpes velox*	Laliberte and Ripple 2004
South Am	A	*Guaruba guarouba*	IUCN
South Am	M	*Chrysocyon brachyurus*	Burton 1987
South Am	M	*Hippocamelus bisulcus*	Ultimate Ungulate
South Am	M	*Lama guanicoe*	Burton 1987
South Am	M	*Panthera onca*	Panthera
South Am	M	*Puma concolor*	Panthera
South Am	M	*Tremarctos ornatus*	Serheen et al. 1999
South Am	M	*Vicugna vicugna*	Burton 1987
South Am	M	*Wilfredomys oenax*	IUCN

Table 3. Species that did not meet the range contraction analysis target of 200 total data points. A data point for each species was comprised of a 10 km^2 GIS raster grid cell.

Continent	Taxon	Species	Common Name	Total Points Used
Africa	Mammalia	*Beatragus hunteri*	Hirola	186
Asia	Aves	*Aegithina tiphia*	Common iora	140
Asia	Aves	*Buceros bicornis*	Great hornbill	136
Asia	Aves	*Lanius schach*	Long-tailed shrike	126
Asia	Aves	*Megalaima zeylanica*	Brown-headed barbet	112
Asia	Aves	*Merops leschenaulti*	Chestnut-headed bee-eater	154
Asia	Aves	*Nisaetus cirrhatus*	Crested hawk eagle	154
Asia	Aves	*Oriolus traillii*	Maroon oriole	152
Asia	Aves	*Pavo cristatus*	Common Peafowl	158
Asia	Aves	*Picus flavinucha*	Greater yellownape	168
Asia	Mammalia	*Sus verrucosus*	Javan warty pig	138
Australia	Aves	*Pardalotus quadragintus*	Forty-spotted pardalote	156
Australia	Aves	*Pezoporus wallicus*	Eastern ground parrot	102
Australia	Mammalia	*Bettongia tropica*	Northern bettong	182
Australia	Mammalia	*Petaurus australis*	Yellow-bellied glider	154
Australia	Mammalia	*Potorus gilberti*	Gilbert's potoroo	134
Australia	Mammalia	*Pseudantechinus mimulus*	Carpentarian antechinus	102
Australia	Mammalia	*Wyulda squamicaudata*	Scaly-tailed possum	144
Europe	Mammalia	*Microtus cabrerae*	Cabrera's vole	108
North Am	Aves	*Ammospermophilus nelsoni*	San Joaquin antelope squirrel	124
South Am	Mammalia	*Wilfredomys oenax*	Greater Wilfred's mouse	104

Table 4. Results of logistic regression models by species. Variable coefficients resulting from the logistic regression for each species are listed in their respective columns. Red coefficient values indicate statistical significance ($p = 0.05$). Coefficient values that are black were included in the model recommended by the backward stepwise regression, but were not shown to be significant. A symbol in place of a coefficient value indicates omission of that variable for that species: ~ indicates variable omission by stepwise regression, ● indicates variable omission due to collinearity with another variable, ♦ indicates variable omission due to lack of nonzero values, † indicates variable omission due to extreme uniform variable nonsignificance prior to stepwise regression, and ■ indicates variable omission due to extreme uniform variable nonsignificance after stepwise regression.

Continent	Taxon	Species	Elevation	Mean Annual Precipitation	Mean Annual Temperature	Distance from Roads	Human Population Density	Proportion of Built-up Land	Proportion of Cropland	Proportion of Rangeland	AIC	Best Model Not Sig. Different	Fit of Model	Error Rate	L.O.F. p<0.05
Af	A	ptex	3.112	†	†	†	†	†	†	1.668	136.05	N/A	0.53	0.11	
Af	M	acju_af	1.095	0.447	1.036	~	-1.369	~	-0.783	0.281	237.38	*	0.19	0.21	
Af	M	adna	2.761	-1.962	4.711	~	~	~	♦	♦	179.46		0.38	0.15	
Af	M	amcl	●	-1.100	0.671	~	~	♦	0.388	~	243.92		0.15	0.21	
Af	M	anma	1.756	-2.883	2.979	0.746	~	♦	-2.386	-0.392	167.69	*	0.45	0.15	
Af	M	behu	~	~	~	~	-1.939	♦	~	-0.403	246.39		0.07	0.23	
Af	M	caau	4.620	-2.936	8.890	~	-11.527	~	~	~	34.28	*	0.91	0.02	*
Af	M	casi	1.312	~	●	~	-0.867	-0.334	0.312	-0.575	214.38	*	0.27	0.18	
Af	M	ceje	~	0.614	~	0.685	~	♦	~	-0.926	256.68		0.10	0.23	
Af	M	cesi	~	0.785	~	-0.312	0.502	♦	0.483	~	237.78	*	0.18	0.21	

Af	M	ceel_af	●	2.265	~	~	~	-0.369	~	-0.682	168.13		0.42	0.13	
Af	M	dapy	~	~	-4.674	~	~	-1.802	1.529	0.997	90.17	*	0.71	0.07	
Af	M	dibi	~	-0.261	●	~	~	♦	-0.407	0.319	266.22		0.06	0.24	
Af	M	eqaf	1.308	4.694	3.852	-0.791	~	♦	-1.223	~	89.34	*	0.72	0.08	
Af	M	eqgr	~	0.727	●	0.657	-5.347	♦	~		230.84		0.19	0.19	*
Af	M	eqqu	●	-0.870	-0.541	-0.447	~	~	~	~	239.94		0.16	0.20	*
Af	M	eqze	1.016	-1.090	1.286	~	~	~	~	~	216.93		0.25	0.18	*
Af	M	feca_af	~	3.606	~	~	~	~	-0.912	-1.003	158.29		0.46	0.13	
Af	M	fese	~	3.505	3.791	~	~	~	~	~	82.15		0.73	0.05	*
Af	M	gasp	~	-1.534	●	~	-1.159	♦	♦	~	188.36		0.33	0.15	*
Af	M	gica	1.648	0.456	1.433	~	-0.456	♦	~	0.699	229.80	*	0.21	0.20	
Af	M	hiam	●	~	~	~	0.335	♦	-0.376	~	276.61	*	0.02	0.25	
Af	M	hybr	2.676	0.438	2.798	1.541	~	~	~	~	140.91	*	0.53	0.11	*
Af	M	koko	0.546	-0.317	●	1.028	-3.245	♦	-0.593	0.296	202.63	*	0.32	0.17	*
Af	M	kova	-0.477	0.516	~	~	~	♦	-0.605	~	256.63		0.10	0.22	
Af	M	loaf	~	1.341	~	~	~	~	-0.370	~	216.59		0.24	0.18	
Af	M	lypi	●	0.631	~	~	~	♦	-0.776	~	255.14		0.10	0.23	
Af	M	nada	2.508	~	4.000	-0.288	-1.001	♦	~	~	196.01	*	0.33	0.17	
Af	M	naso	0.253	~	●	0.844	~	♦	0.570	~	251.47	*	0.12	0.23	
Af	M	okjo	0.331	~	~	0.656	~	♦	-1.327	-42.617	236.47	*	0.18	0.21	*
Af	M	orda	2.367	~	4.419	-0.456	~	♦	-17.090	-0.747	186.58		0.37	0.16	
Af	M	papa	-4.229	10.427	●	~	-1.148	~	-2.243	1.337	63.60	*	0.81	0.05	*
Af	M	pale	1.209	0.723	1.427	~	-0.723	♦	-1.130	0.333	228.78	*	0.23	0.20	
Af	M	papr_af	0.341	1.833	●	~	~	~	-0.352	~	195.03	*	0.33	0.16	
Af	M	paha	0.826	-0.568	●	-1.514	-0.508	♦	~	~	234.42	*	0.19	0.20	
Af	M	pola	0.881	-1.914	●	~	1.579	♦	~	0.453	149.91		0.50	0.12	

Af	M	prcr	●	-1.981	-4.802	~	1.495	♦	-1.478	-0.925	92.28	*	0.71	0.07	
Af	M	tade	1.063	~	●	0.959	-8.954	♦	~	~	139.69		0.53	0.11	
Af	M	taor	1.055	~	2.162	0.348	-5.342	~	~	~	202.53	*	0.31	0.17	
As	A	acgi	1.510	-1.392	~	1.310	~	0.363	0.786	~	174.39	*	0.41	0.15	*
As	A	aeni	●	4.941	1.854	-0.963	~	-10.585	-2.024	~	55.58	*	0.84	0.04	
As	A	aeti	-0.778	-1.006	~	~	~	0.729	0.387	-0.399	153.19	*	0.27	0.17	*
As	A	amam	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
As	A	amph	-1.163	-2.077	●	~	0.591	-0.662	~	-0.627	123.23	*	0.47	0.13	
As	A	anme	†	-4.017	-1.776	-1.655	~	~	-0.639	~	88.54	*	0.72	0.05	*
As	A	anti	2.924	4.949	●	~	2.181	~	~	-2.373	83.07	*	0.74	0.06	
As	A	anco	-2.484	~	●	~	-0.594	~	-1.218	0.885	148.42	*	0.50	0.10	*
As	A	ansi	6.124	-4.861	●	3.033	0.498	~	-1.937	~	55.26	*	0.84	0.03	
As	A	aqra	-4.282	12.146	●	~	~	~	0.902	~	44.58	*	0.87	0.04	
As	A	avje	139.513	1.6192	●	~	~	~	2.6675	-4.1971	25.515		0.94	0.02	N/A
As	A	avle	-1.570	0.538	●	~	-2.365	~	-0.742	4.014	146.25		0.52	0.12	
As	A	bamo	1.441	0.447	●	~	~	~	0.463	-2.991	157.85		0.47	0.12	*
As	A	buib	2.707	3.589	~	2.658	4.654	~	0.743	0.582	84.16	*	0.75	0.05	*
As	A	bubi	27.514	-0.717	●	~	♦	~	1.220	-2.751	44.24	*	0.82	0.04	*
As	A	buin	●	1.723	0.777	-0.429	~	~	1.385	-0.371	132.00	*	0.57	0.07	*
As	A	bust	~	-3.166	●	~	~	~	2.374	0.420	101.88	*	0.66	0.07	*
As	A	capa	4.422	1.694	5.210	~	-1.165	~	-0.666	~	89.06		0.72	0.06	
As	A	caas	†	6.397	4.356	-1.131	-2.736	-1.715	-1.473	~	58.84	*	0.84	0.05	
As	A	chma	2.789	-0.611	1.831	0.641	~	~	~	~	139.98	*	0.53	0.11	
As	A	chmc	2.450	~	●	~	0.515	~	0.573	~	202.59		0.30	0.17	
As	A	chfe	1.147	-1.314	●	-0.409	~	~	1.706	-0.910	130.73	*	0.57	0.09	*
As	A	clja	■	4.055	●	■	1.650	■	■	■	113.83	N/A	0.61	0.08	

As	A	coma	3.359	-1.827	0.914	-0.468	-2.858	1.073	1.262	~	110.03	*	0.66	0.08	
As	A	cuce	~	3.273	●	~	~	~	-0.514	0.648	168.44		0.42	0.14	
As	A	cuco	-3.323	~	-4.733	~	-1.779	~	1.150	~	127.68		0.58	0.10	
As	A	diag	0.552	-2.794	~	1.149	-1.088	~	~	-0.610	118.33		0.62	0.08	*
As	A	duae	~	0.107	●	~	~	~	1.821	-0.187	191.83		0.34	0.16	
As	A	ermo	-1.705	2.584	●	3.010	†	♦	~	35.075	61.04		0.82	0.04	*
As	A	ergr	3.815	-2.281	1.566	~	~	~	1.624	~	92.46		0.70	0.07	
As	A	erni	1.631	1.511	~	-1.660	~	~	-0.603	-1.265	169.87	*	0.43	0.12	*
As	A	euor	-1.272	-0.480	●	-0.303	~	-3.921	-0.761	1.357	205.81	*	0.31	0.16	*
As	A	fafa	-2.353	3.549	~	0.881	~	~	-0.400	~	137.23	*	0.54	0.12	
As	A	faju	●	-1.699	3.253	0.697	-3.692	~	-1.426	~	83.62		0.74	0.06	*
As	A	fape	●	-1.012	-2.722	0.512	~	~	0.820	-0.448	186.26	*	0.37	0.14	*
As	A	frgu	●	-0.917	-1.123	~	-0.860	~	0.822	~	239.16		0.17	0.21	
As	A	fuat	●	-0.666	-0.605	~	~	~	~	0.584	246.24		0.14	0.22	*
As	A	gade	0.504	-0.545	●	0.274	3.293	-0.913	~	-1.345	180.59	*	0.40	0.14	*
As	A	gala	~	~	~	0.398	~	~	-0.757	-0.516	252.48		0.12	0.22	
As	A	gala	~	~	●	0.398	~	~	-0.757	-0.516	252.48		0.12	0.22	
As	A	glpr	1.819	4.949	4.337	-3.525	-5.732	5.477	-1.414	~	86.52		0.74	0.08	
As	A	gran	-1.407	-3.058	-2.589	~	~	~	-0.417	0.595	157.95	*	0.47	0.12	*
As	A	gybe	●	0.788	†	~	-1.219	0.810	1.988	~	189.81		0.35	0.15	*
As	A	hasi	-2.470	●	●	1.089	-1.761	♦	-5.189	~	149.16		0.50	0.11	*
As	A	hale	●	-0.418	5.167	0.653	1.832	~	~	~	147.06	*	0.51	0.11	*
As	A	hain	-5.032	●	●	~	†	~	~	-3.010	33.93		0.90	0.02	
As	A	haer	~	1.726	●	0.401	-0.607	♦	-0.709	-0.609	177.37	*	0.40	0.15	
As	A	heca	1.642	-0.656	●	~	~	3.808	1.387	~	74.40		0.41	0.14	
As	A	hych	7.687	†	9.409	~	-2.572	~	1.776	~	39.09		0.89	0.02	*

As	A	keze	5.993	-1.263	3.200	-1.226	~	~	0.757	-0.740	91.10	*	0.72	0.05	*
As	A	lasc	†	-3.365	●	~	43.787	-5.790	5.409	~	53.29		0.75	0.04	*
As	A	lavi	●	-5.899	1.609	~	-1.253	~	~	~	73.94		0.76	0.05	
As	A	leso	1.050	3.610	●	-1.373	5.197	♦	-0.713	~	73.71		0.78	0.05	
As	A	loat	13.871	-1.002	●	~	~	~	0.403	-0.724	153.26	*	0.48	0.11	*
As	A	loma	-0.656	-2.300	●	0.569	-0.747	0.860	0.570	-0.363	127.63	*	0.60	0.10	*
As	A	lost	-0.398	0.244	●	0.413	-0.726	1.378	0.644	~	261.57	*	0.11	0.23	
As	A	lubr	7.570	-3.881	●	~	~	~	2.009	1.804	36.73	*	0.90	0.03	
As	A	maab	38.907	2.165	●	~	-2.714	~	1.460	-1.084	51.95		0.86	0.04	*
As	A	meha	●	-3.474	-0.556	34.903	-0.858	~	0.650	-0.459	99.75	*	0.69	0.08	
As	A	meli	●	-2.056	-10.109	-3.357	~	4.150	~	0.758	85.11	*	0.74	0.07	
As	A	meze	~	-2.754	0.652	~	1.029	5.784	1.091	0.560	68.55	*	0.65	0.09	*
As	A	mele	●	-0.559	0.480	0.869	~	1.104	-0.394	~	181.32	*	0.21	0.20	*
As	A	meor	●	-2.903	-2.709	1.780	~	~	2.349	-0.861	83.87		0.74	0.05	*
As	A	mear	1.824	2.279	●	~	-1.175	~	~	~	129.01		0.56	0.09	
As	A	mein	-3.655	1.160	-4.775	~	~	~	0.661	~	118.12		0.61	0.09	
As	A	moma	22.171	-4.047	~	~	~	~	2.050	-4.976	33.90		0.91	0.02	*
As	A	neco	5.739	~	2.196	-0.940	0.465	~	1.167	1.044	107.14	*	0.66	0.08	*
As	A	nici	-0.846	-2.077	●	0.336	~	1.714	~	~	114.47	*	0.51	0.11	
As	A	ortr	~	3.415	●	-0.974	~	♦	~	9.209	84.12		0.64	0.08	*
As	A	otta_as	~	~	~	~	~	~	~	0.374	274.46		0.02	0.24	
As	A	pacr	†	~	●	1.337	~	~	13.857	~	43.08		0.83	0.04	
As	A	peca	9.129	-1.549	~	~	-0.981	1.190	~	-0.952	90.71	*	0.71	0.06	
As	A	peph	●	0.824	0.898	-0.850	1.014	-0.573	-0.696	~	220.04	*	0.26	0.19	
As	A	peti	1.610	-0.523	●	0.406	0.586	~	~	-4.151	138.44	*	0.54	0.10	
As	A	pefu	4.196	1.583	~	0.773	0.948	~	~	-0.926	83.40	*	0.74	0.05	*

As	A	phni	-0.937	-2.385	●	0.518	~	~	~	~	123.85	*	0.58	0.08	*
As	A	pifl	0.743	†	●	0.677	5.230	~	-1.685	~	120.14		0.52	0.11	
As	A	pigr	~	-0.634	●	~	-3.745	~	-0.532	~	241.19		0.16	0.21	
As	A	prgr	5.456	†	6.287	4.596	~	~	1.227	~	92.82	*	0.70	0.07	*
As	A	prso	4.067	-3.845	1.537	~	~	2.825	~	~	43.88		0.88	0.03	
As	A	psda	~	1.242	●	~	-95.327	~	2.910	3.380	75.58		0.76	0.06	
As	A	pspa	†	15.060	-3.901	~	~	~	1.152	~	44.95		0.87	0.02	*
As	A	ptin	~	-2.691	●	†	~	5.300	~	3.043	96.71		0.68	0.08	
As	A	rhau	2.959	†	1.448	~	15.145	~	-0.733	~	92.71		0.70	0.07	
As	A	ryal	~	5.682	1.175	~	~	~	1.012	-1.348	66.13	*	0.80	0.04	*
As	A	saca	●	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
As	A	same	†	-2.857	~	~	-11.519	~	~	-0.685	49.15	*	0.85	0.04	
As	A	safu	1.188	†	~	0.878	11.475	-7.023	-1.464	0.687	112.33		0.65	0.09	
As	A	stru	6.282	~	~	~	~	~	-0.705	0.957	150.35		0.49	0.12	*
As	A	stac	-4.485	†	~	4.148	-6.659	4.120	~	5.324	73.19		0.78	0.05	
As	A	stal	-2.660	-4.323	-4.531	~	3.200	-1.735	~	~	56.96	*	0.84	0.05	*
As	A	stau	~	-3.180	4.718	~	~	1.187	~	0.719	61.78		0.81	0.05	
As	A	sulu	~	1.189	●	~	~	-0.467	-0.907	~	199.67		0.31	0.16	*
As	A	tepa	8.403	-1.621	~	~	-0.498	~	~	-0.705	137.73	*	0.54	0.10	*
As	A	tipi	~	-0.567	-4.963	0.530	-0.553	0.460	~	-1.003	157.08	*	0.48	0.12	
As	A	trbi	-2.198	-1.038	-1.963	-0.297	-6.061	0.309	~	-0.968	207.27	*	0.31	0.16	*
As	A	trcu	2.426	~	●	~	●	~	~	-0.851	193.83		0.32	0.15	*
As	A	trph	3.299	4.173	0.956	-10.447	~	-5.371	~	-2.468	53.25	*	0.86	0.04	*
As	A	tust	5.990	~	3.734	0.967	3.482	~	~	~	75.14		0.77	0.07	
As	A	tusu	0.384	-0.478	●	0.611	2.390	-2.387	~	~	214.26	*	0.27	0.18	
As	A	tual	6.593	-12.402	●	■	■	♦	■	■	18.99	N/A	0.95	0.01	N/A

As	A	tyal	6.731	-0.762	1.733	0.704	~	1.724	1.792	~	91.93		0.72	0.07	
As	A	urer	1.066	-3.130	●	~	~	~	1.604	2.476	119.68		0.60	0.09	*
As	M	acju_as	1.477	-13.687	-1.748	~	-22.459	~	~	-0.753	144.88		0.52	0.11	*
As	M	aime	1.798	-0.530	●	0.518	~	~	-0.676	-0.733	146.87	*	0.51	0.11	
As	M	bubu	●	0.519	-0.474	~	~	~	0.587	-0.812	256.15	*	0.11	0.23	
As	M	calu_as	-2.022	~	-3.511	~	-0.808	~	~	~	99.91	*	0.67	0.07	
As	M	caca	0.382	~	●	0.496	-0.464	-1.653	-0.240	~	231.66		0.21	0.20	
As	M	cafi_as	-0.847	1.317	1.069	~	0.493	~	0.352	-0.692	180.35	*	0.40	0.15	
As	M	disu	●	~	~	~	-1.968	~	0.622	~	252.94		0.11	0.22	*
As	M	elma	-1.106	0.776	●	~	-0.288	~	-0.304	-1.166	222.94	*	0.24	0.19	
As	M	eqhe	0.732	-1.472	~	~	~	0.426	~	-0.378	207.25		0.29	0.16	*
As	M	feca_as	~	~	●	-0.454	7.375	~	~	4.113	181.08		0.38	0.16	
As	M	mazi	-1.790	~	-11.117	~	1.505	~	~	~	42.01		0.88	0.03	*
As	M	pael	●	-0.242	-0.782	~	~	~	-0.961	-0.529	215.70	*	0.26	0.18	*
As	M	papr_as	~	3.396	-1.170	-0.497	~	~	0.867	~	123.05		0.59	0.09	
As	M	pati	~	1.017	1.161	~	-2.354	-1.607	-0.579	-1.336	165.20		0.45	0.14	
As	M	paun	2.190	-0.874	0.661	1.684	~	♦	-0.435	~	159.02	*	0.47	0.13	
As	M	prgu	-1.631	~	~	~	~	♦	-0.670	0.508	212.92	*	0.26	0.17	*
As	M	sata	~	0.424	0.977	-0.273	~	~	-0.936	0.534	227.31	*	0.22	0.19	*
As	M	suve	●	0.423	~	~	-0.304	~	~	~	187.33	*	0.05	0.25	
As	M	tain	-0.324	~	~	~	~	-22.509	-1.095	~	233.29		0.19	0.20	*
As	M	urar_as	-0.268	~	-1.805	1.275	~	~	~	~	177.12	*	0.39	0.15	*
Aus	A	paqu	-1.560	~	●	~	2.043	~	-0.603	-0.603	155.97		0.33	0.17	
Aus	A	peto	-1.577	-3.979	-6.412	1.299	~	♦	~	~	79.01		0.75	0.05	*
Aus	A	pefl	0.893	-0.388	†	~	-187.591	~	-2.423	~	131.88	*	0.56	0.10	
Aus	A	peoc	-0.354	-2.065	2.689	~	-11.906	♦	~	~	169.38	*	0.43	0.14	

Aus	A	pewa	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aus	A	piir	~	0.545	~	-2.587	92.301	♦	-3.930	-2.574	130.75	*	0.57	0.08	*
Aus	A	tume	~	1.138	-1.188	-0.038	~	0.634	~	~	203.80		0.30	0.16	*
Aus	M	acpy	~	10.670	5.834	~	-184.877	104.850	~	-0.033	63.94	*	0.81	0.06	
Aus	M	aeru	♦	-2.668	20.279	~	~	~	-2.741	~	23.74		0.94	0.01	*
Aus	M	bega	♦	-1.154	-4.003	~	~	~	~	-0.369	144.03	*	0.51	0.11	*
Aus	M	bepe	2.017	-4.620	-6.492	~	~	♦	4.795	1.529	61.78		0.82	0.04	*
Aus	M	betr	†	†	3.455	†	†	†	†	-2.345	107.82	N/A	0.60	0.09	
Aus	M	ceco	-0.642	3.910	2.134	1.018	-42.042	~	0.747	~	141.49		0.53	0.12	
Aus	M	cope	~	1.539	0.8302	0.5679	18.72	♦	~	234.9	170.23	*	0.42	0.14	N/A
Aus	M	dabl	2.610	-2.606	2.466	~	~	♦	♦	~	143.12		0.52	0.11	
Aus	M	dacr	~	-8.644	4.940	~	~	~	~	2.105	53.15		0.84	0.04	
Aus	M	daby	-3.249	~	0.713	0.427	-8.511	~	~	~	131.68		0.56	0.11	
Aus	M	dage	~	1.313	†	-0.870	66.018	♦	0.553	-0.549	144.95		0.52	0.12	
Aus	M	daha	0.440	~	1.052	~	40.871	~	~	~	245.93	*	0.14	0.21	*
Aus	M	dama	1.546	2.502	1.474	0.429	~	~	~	~	138.29	*	0.54	0.09	*
Aus	M	davi	-0.454	1.515	†	~	~	~	-0.419	~	217.43	*	0.24	0.18	
Aus	M	gyle	~	0.919	~	~	~	~	~	~	247.14		0.12	0.22	*
Aus	M	isau	4.840	†	14.102	1.305	5.112	♦	5.584	-1.197	52.35		0.86	0.03	*
Aus	M	isma	~	7.164	11.573	1.696	5.944	-2.240	~	-1.445	62.75	*	0.82	0.05	*
Aus	M	isob	-0.804	1.549	-0.888	~	1.874	~	-1.147	~	155.30	*	0.48	0.12	
Aus	M	laco	-0.755	13.804	~	~	5.031	~	-1.461	~	64.59		0.80	0.05	
Aus	M	lala	-1.329	-2.368	●	~	-52.279	~	~	~	68.78		0.78	0.05	
Aus	M	maeu	~	1.428	-2.790	~	-8.318	~	0.711	~	151.03		0.49	0.13	
Aus	M	mapa	-2.544	0.643	-0.948	~	~	~	~	-0.446	176.32	*	0.40	0.15	
Aus	M	mala	1.264	-0.879	6.058	~	-29.330	♦	~	~	105.46	*	0.66	0.08	

Aus	M	mego	1.3988	2.0901	●	~	47.8525	♦	84.0376	106.416	132.86		0.56	0.11	N/A
Aus	M	mema	~	0.720	●	1.354	~	♦	0.628	~	199.83		0.31	0.17	
Aus	M	noal	13.022	-6.184	1.390	1.709	114.859	♦	~	-2.430	57.11	*	0.84	0.04	
Aus	M	noaq	†	●	5.399	~	-1.497	♦	♦	♦	49.09		0.80	0.03	*
Aus	M	noce	~	-2.206	5.906	-0.898	-1.471	♦	♦	~	111.71		0.63	0.09	
Aus	M	nofu	-2.272	1.735	~	-2.992	2.597	♦	♦	~	158.19		0.47	0.13	
Aus	M	nomi	-9.355	~	~	~	~	~	1.702	1.893	63.54		0.80	0.04	
Aus	M	onfr	~	2.010	2.309	-0.089	~	0.493	~	~	157.55		0.47	0.12	*
Aus	M	pegu	~	2.803	●	~	~	~	-1.420	-0.326	143.49	*	0.51	0.12	
Aus	M	peau	-31.250	~	-9.000	~	~	~	~	~	19.77		0.94	0.01	
Aus	M	pela	-0.704	3.303	~	~	-2.241	♦	~	~	180.27	*	0.38	0.14	*
Aus	M	pepe	~	0.933	●	~	~	~	0.385	~	252.89		0.11	0.21	*
Aus	M	pexa	1.804	~	0.574	-0.468	3.316	♦	~	~	188.66		0.35	0.15	
Aus	M	phca	~	5.367	7.037	-5.130	-2.923	♦	1.474	1.280	51.97	*	0.86	0.04	
Aus	M	phpi	0.962	2.506	●	~	-2.340	♦	♦	♦	176.52		0.39	0.15	
Aus	M	phta	-0.650	0.878	-0.544	0.263	0.436	~	0.510	~	262.22	*	0.10	0.23	
Aus	M	phci	~	2.665	-1.675	~	~	~	~	0.415	153.94	*	0.47	0.12	*
Aus	M	pogi	■	-3.059	■	■	■	♦	1.219	■	69.59	N/A	0.64	0.08	
Aus	M	psbo	65.289	33.311	67.718	-5.363	~	♦	~	~	25.723		0.94	0.03	N/A
Aus	M	psmi	†	●	●	†	-2.963	♦	♦	●	55.08	N/A	0.64	0.06	*
Aus	M	psoc	-1.053	~	-1.786	~	~	~	-1.004	~	171.19		0.41	0.14	
Aus	M	pspe	-3.431	12.107	~	~	~	~	~	~	70.86		0.77	0.05	
Aus	M	psal	■	■	1.528	■	■	♦	-1.832	■	177.45	N/A	0.38	0.14	
Aus	M	psau	1.971	-12.684	-1.271	0.510	~	♦	~	0.726	104.15	*	0.67	0.08	
Aus	M	psch	3.739	-0.689	5.242	~	-0.777	♦	♦	~	127.56		0.58	0.09	
Aus	M	psde	0.786	0.436	2.192	0.384	~	♦	~	-0.784	157.32	*	0.48	0.12	*

Aus	M	psna	-1.254	†	†	7.037	†	♦	†	†	157.55	N/A	0.45	0.12	*
Aus	M	psno	2.365	~	3.450	~	-2.009	~	~	~	122.19		0.59	0.08	*
Aus	M	pssh	~	-1.553	-4.076	~	~	~	-0.998	-0.498	148.83		0.50	0.15	
Aus	M	ptpo	1.846	~	†	-0.804	0.328	~	~	-0.964	190.38	*	0.35	0.16	
Aus	M	ratu	~	0.613	0.850	0.678	40.399	♦	~	0.770	198.36		0.32	0.17	
Aus	M	ravi	6.496	-8.870	18.274	~	~	♦	~	~	35.34		0.90	0.03	
Aus	M	sebr	~	0.955	-2.300	~	~	~	0.390	~	196.97	*	0.32	0.17	*
Aus	M	smgi	3.017	■	-1.871	■	■	♦	■	■	118.87	N/A	0.59	0.08	*
Aus	M	suce	0.439	-1.708	●	0.617	-3.761	~	-0.465	~	174.18		0.41	0.13	*
Aus	M	thbi	~	2.138	~	~	~	~	~	-0.316	187.33	*	0.35	0.16	
Aus	M	trvu	-2.498	12.121	-3.427	~	294.358	♦	~	4.100	38.07		0.91	0.03	N/A
Aus	M	wabi	6.249	2.907	5.518	~	~	♦	~	~	39.01		0.89	0.02	*
Aus	M	wysq	†	2.049	●	†	†	♦	†	-1.083	96.48	N/A	0.55	0.10	
Aus	M	zype	7.604	-5.137	●	-1.494	21.914	~	♦	♦	78.70		0.75	0.05	*
Eur	A	otta_eur	1.889	-1.935	2.139	~	0.562	-0.557	~	~	146.44	*	0.52	0.12	
Eur	A	tete	-1.144	~	-4.852	~	-1.775	~	~	~	84.23	*	0.73	0.05	*
Eur	A	teur	-1.630	~	-3.052	1.398	~	~	-0.778	~	88.56	*	0.72	0.06	*
Eur	A	tett	-2.384	~	-1.007	~	-3.930	4.640	~	-0.844	117.13		0.62	0.09	
Eur	M	calu_eur	-2.602	~	-1.447	~	~	~	0.383	0.720	191.01	*	0.35	0.16	*
Eur	M	cafi_eur	~	~	-1.382	-0.764	~	~	~	~	233.86		0.18	0.20	
Eur	M	gugl_eur	-5.487	~	-5.373	1.332	5.783	~	~	6.081	65.21	*	0.81	0.06	
Eur	M	mica	-3.065	~	●	~	~	~	-1.665	~	71.37		0.58	0.12	
Eur	M	mulu	-3.072	●	-3.385	~	~	~	~	0.634	120.61		0.59	0.10	*
Eur	M	urar_eur	-0.494	~	-3.203	~	~	-0.450	~	~	121.45	*	0.59	0.08	*
NA	A	amne	~	~	-1.177	-1.228	~	~	~	1.507	116.58		0.37	0.16	
NA	A	apco	~	~	~	~	-0.369	●	~	~	275.68		0.02	0.25	

NA	A	atcu	3.304	-1.619	1.425	~	~	~	0.992	0.710	133.74		0.59	0.10	
NA	A	boum	1.080	1.332	-2.551	~	~	~	-1.330	-1.210	125.80	*	0.60	0.10	
NA	A	busw	1.700	0.497	-2.430	~	~	~	2.461	1.193	86.35	*	0.73	0.07	
NA	A	ceur	~	-0.626	-1.281	~	-0.516	~	-1.512	0.624	199.45	*	0.32	0.17	
NA	A	cybu	~	5.721	-3.223	-1.820	~	0.416	-1.115	1.032	138.95	*	0.55	0.12	
NA	A	elfo	4.439	6.243	12.673	-1.382	3.146	-1.389	-1.854	~	47.45	*	0.89	0.06	
NA	A	fafe	●	4.034	~	-0.834	1.268	-2.962	~	-1.118	131.57	*	0.57	0.11	
NA	A	gram	3.725	9.715	7.178	1.350	~	~	-2.460	~	49.04	*	0.87	0.03	*
NA	A	gyca	3.250	0.498	3.711	~	~	-0.252	0.895	~	176.95	*	0.41	0.14	*
NA	A	haha	0.616	0.719	~	-0.583	~	-0.685	-1.362	~	206.77		0.30	0.17	
NA	A	icam	~	1.039	~	-0.335	-1.649	~	-6.308	2.764	151.60	*	0.50	0.13	
NA	A	lalu	-1.352	0.560	-0.752	~	~	~	-0.878	0.250	216.67	*	0.26	0.18	
NA	A	lebo	-0.903	0.712	0.367	-0.381	~	~	-0.915	~	209.51		0.29	0.18	*
NA	A	mega	~	0.713	0.713	~	-2.326	~	0.713	~	205.68		0.29	0.18	*
NA	A	paui	~	5.049	~	-0.868	~	~	~	~	152.56		0.47	0.12	
NA	A	roso	7.001	~	8.746	~	~	~	~	~	27.22		0.92	0.02	
NA	A	sapa	~	1.687	1.660	~	-0.735	~	-0.555	-0.330	191.45	*	0.35	0.16	*
NA	A	tycu	~	-0.995	0.419	-0.303	~	-0.989	~	~	241.87	*	0.16	0.21	
NA	A	typa	~	0.657	-1.603	~	0.549	~	~	~	220.94		0.24	0.19	*
NA	A	typh	-3.686	~	-3.686	~	~	~	~	1.295	117.94		0.60	0.09	
NA	A	vech	0.700	~	-1.314	~	~	●	-0.660	~	196.36		0.32	0.16	
NA	M	anam	~	-0.540	-0.976	~	~	~	~	0.540	230.07		0.20	0.20	
NA	M	alal	~	1.320	-6.246	~	~	~	~	~	69.267	*	0.79	0.05	N/A
NA	M	calu_na	~	~	-12.697	~	~	~	~	-4.591	31.32		0.91	0.03	
NA	M	caru	~	2.081	5.171	0.343	~	-0.369	~	~	95.81		0.69	0.06	
NA	M	ceel_na	2.496	0.754	~	-0.492	~	~	-0.633	~	154.48	*	0.48	0.13	

NA	M	cylu	-9.716	1.794	-10.066	0.758	~	~	~	1.134	40.45	*	0.90	0.03	*
NA	M	diel	●	●	~	~	0.556	-0.823	~	-0.412	273.26		0.04	0.24	
NA	M	erdo	1.146	~	-8.070	21.918	~	~	~	11.291	47.19	*	0.87	0.04	
NA	M	gugl_na	~	~	-3.170	~	~	-149.200	~	-2687	105.92	*	0.65	0.08	N/A
NA	M	lepa	-31.361	~	~	1.144	~	~	1.438	~	49.81		0.85	0.03	*
NA	M	loca	-0.754	1.016	-2.172	-1.158	~	~	-1.926	-0.552	128.08		0.59	0.09	
NA	M	lyca	-1.050	~	-4.401	6.247	~	~	-0.689	-1.151	71.53		0.79	0.04	*
NA	M	maam	1.455	~	-0.550	~	~	~	~	-0.743	235.14		0.18	0.21	
NA	M	mapi	~	-0.537	0.583	~	-15.210	~	-0.731	-0.484	229.64	*	0.22	0.19	*
NA	M	oram	-1.820	-0.553	-2.210	2.805	~	~	~	~	119.27	*	0.61	0.08	
NA	M	ovmu	0.953	-2.421	-0.812	2.541	-87.530	♦	♦	♦	112.40	*	0.64	0.09	*
NA	M	ovca	~	-0.356	~	0.259	-0.327	~	-0.284	-0.791	255.75	*	0.12	0.23	
NA	M	ovda	1.025	~	-0.466	~	~	~	~	~	232.80		0.18	0.20	*
NA	M	paon_na	●	2.422	~	~	-1.382	~	-0.319	~	187.75	*	0.35	0.15	
NA	M	puco_na	5.344	~	2.535	0.712	~	~	-0.433	~	106.23	*	0.65	0.08	
NA	M	rata	~	-0.490	~	~	-6.646	~	-5.194	~	249.28	*	0.13	0.22	
NA	M	sytr	~	0.454	1.012	~	~	-0.771	~	~	239.27		0.17	0.21	
NA	M	urwa	-1.030	-0.592	●	~	~	-0.577	~	~	225.39		0.22	0.19	*
NA	M	uram	-0.384	0.700	-2.398	-0.929	-0.484	~	-1.340	~	152.18	*	0.50	0.12	
NA	M	urar_na	~	~	-3.671	~	~	~	~	-3.192	52.65		0.83	0.04	
NA	M	vuve	2.038	-0.613	4.778	~	~	~	~	~	101.42	*	0.66	0.09	
SA	A	gugu	3.899	~	~	1.676	-6.163	♦	~	~	89.62		0.71	0.07	
SA	M	chbr	1.744	~	2.176	-3.341	~	~	~	0.629	164.33		0.44	0.13	
SA	M	hibi	-0.546	~	-1.349	-1.255	~	~	-0.911	-0.711	212.68	*	0.28	0.18	
SA	M	lagu	-0.766	-0.591	-0.727	0.504	~	~	-1.610	0.473	194.74		0.35	0.15	*
SA	M	paon_sa	-0.844	2.088	●	5.034	-0.548	~	-0.463	~	133.36	*	0.56	0.11	

SA	M	puco_sa	0.916	0.708	1.540	~	~	-1.593	~	~	190.21	*	0.35	0.15
SA	M	tror	~	0.392	●	0.557	~	~	~	~	262.50		0.07	0.24
SA	M	vivi	-0.623	-2.950	●	-0.985	~	~	2.660	-8.027	142.39	*	0.53	0.13
SA	M	wioe	~	~	●	2.455	~	~	~	16.709	23.79		0.88	0.03

Table 5. Individual variable influences by continent. Numbers indicate the total number of species whose persistence was positively influenced (+) by each variable, and the number of species whose persistence was negatively influenced (-) by each variable. "Most Positive" indicates the variable that had a positive influence on persistence of the most species for that continent, and "Most Negative" indicates the variable that had a negative influence on persistence of the most species for that continent.

		Elevation	Precipitation	Temperature	Roads	Population	Built-Up Land	Cropland	Rangeland	Most Positive Environmental	Most Negative Environmental	Most Positive Human Influence	Most Negative Human Influence	Overall Most Positive Variable	Overall Most Negative Variable
Africa	+	17	16	14	8	0	0	3	4	Elev	Precip	Roads	Crop	Elev	Crop
	-	2	7	3	3	11	0	13	6						
Asia	+	47	36	25	20	17	8	33	21	Elev	Precip	Crop	Pop/ Range	Elev	Precip
	-	24	52	20	7	26	7	25	26						
Australia	+	18	28	22	8	7	1	10	6	Precip	Precip	Crop	Pop	Precip	Precip
	-	16	17	15	7	15	0	9	9						
Europe	+	1	0	1	1	0	1	0	3	Elev/ Temp	Elev/ Temp	Range	Crop	Range	Elev/ Temp
	-	8	1	8	1	1	0	2	1						
North America	+	11	18	12	5	1	0	4	9	Precip	Temp	Range	Crop	Precip	Temp
	-	9	9	20	8	6	5	12	7						
South America	+	3	3	2	4	0	0	1	3	Elev/ Precip	Elev	Roads	Range/ Roads	Roads	Elev
	-	4	2	2	2	1	0	1	2						
Global Totals	+	97	101	76	46	25	10	51	46	Precip	Precip	Crop	Crop	Precip	Precip
	-	63	88	68	28	60	12	62	51						

Table 6. Number of bird and mammal species used in the range contraction analysis for each continent. "Total Number" indicates the number of species from each taxon whose range contraction was statistically analyzed. "Number with Significant Variables" indicates the number of species whose persistence was significantly affected by at least one of the variables tested. "Number with No Assessing L. O. F." indicates the number of species whose analysis could not be completed due to an error in the data for those species.

Continent	Taxon	Total Number	Number with Significant Variables	Number with No Assessing L.O.F.
Africa	Aves	1	1	0
Africa	Mammalia	38	38	0
Asia	Aves	103	101	1
Asia	Mammalia	20	20	0
Australia	Aves	7	6	0
Australia	Mammalia	63	63	4
Europe	Aves	4	4	0
Europe	Mammalia	6	6	0
North America	Aves	23	23	0
North America	Mammalia	26	26	2
South America	Aves	1	1	0
South America	Mammalia	8	8	0
Totals		300	297	7

FIGURES

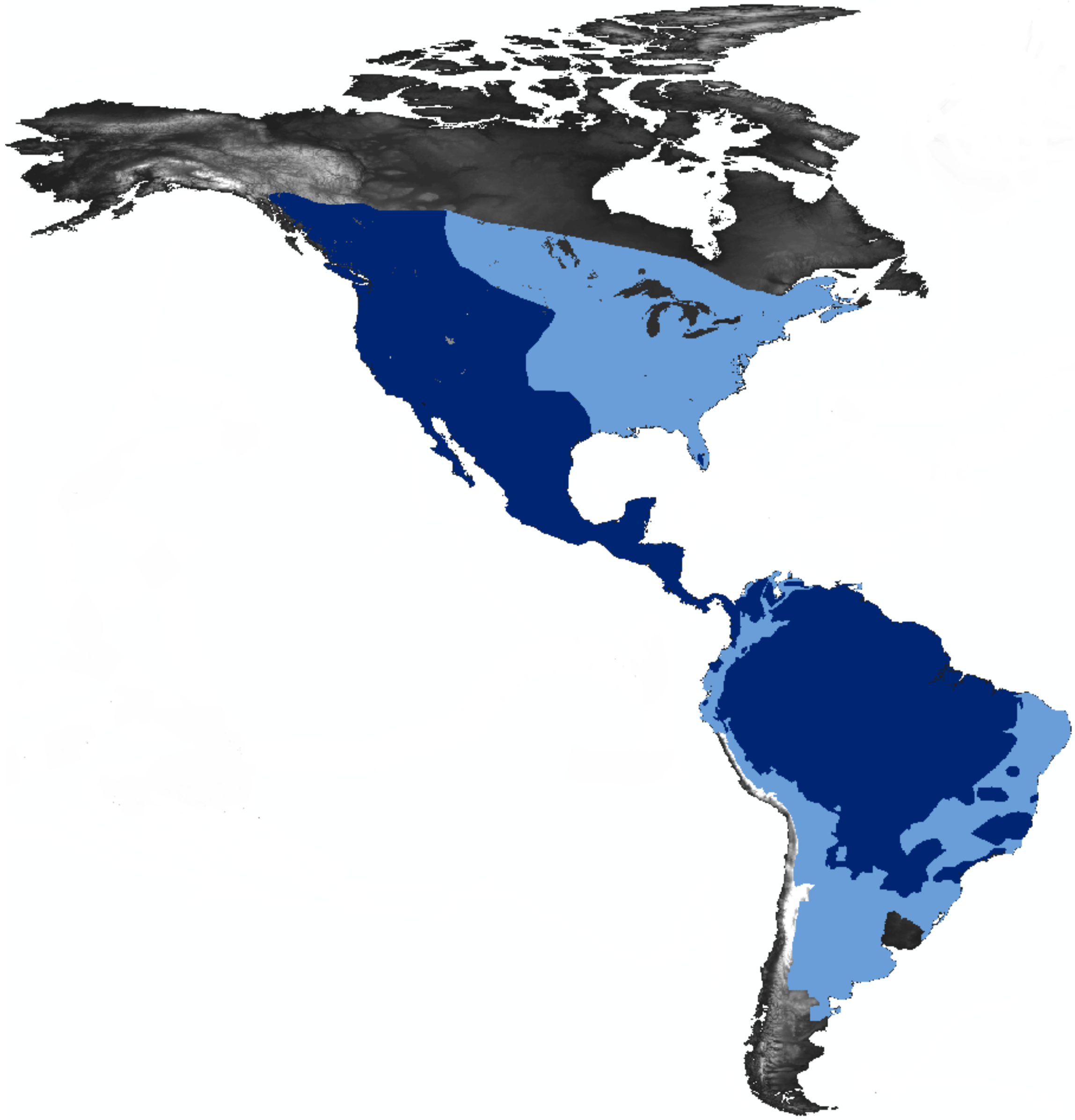

Figure 1. Range contraction of the mountain lion (*Puma concolor*) in North America and South America, overlaid onto the global elevation layer. The lighter shade of blue indicates historical range, and the darker shade of blue indicates remnant range.

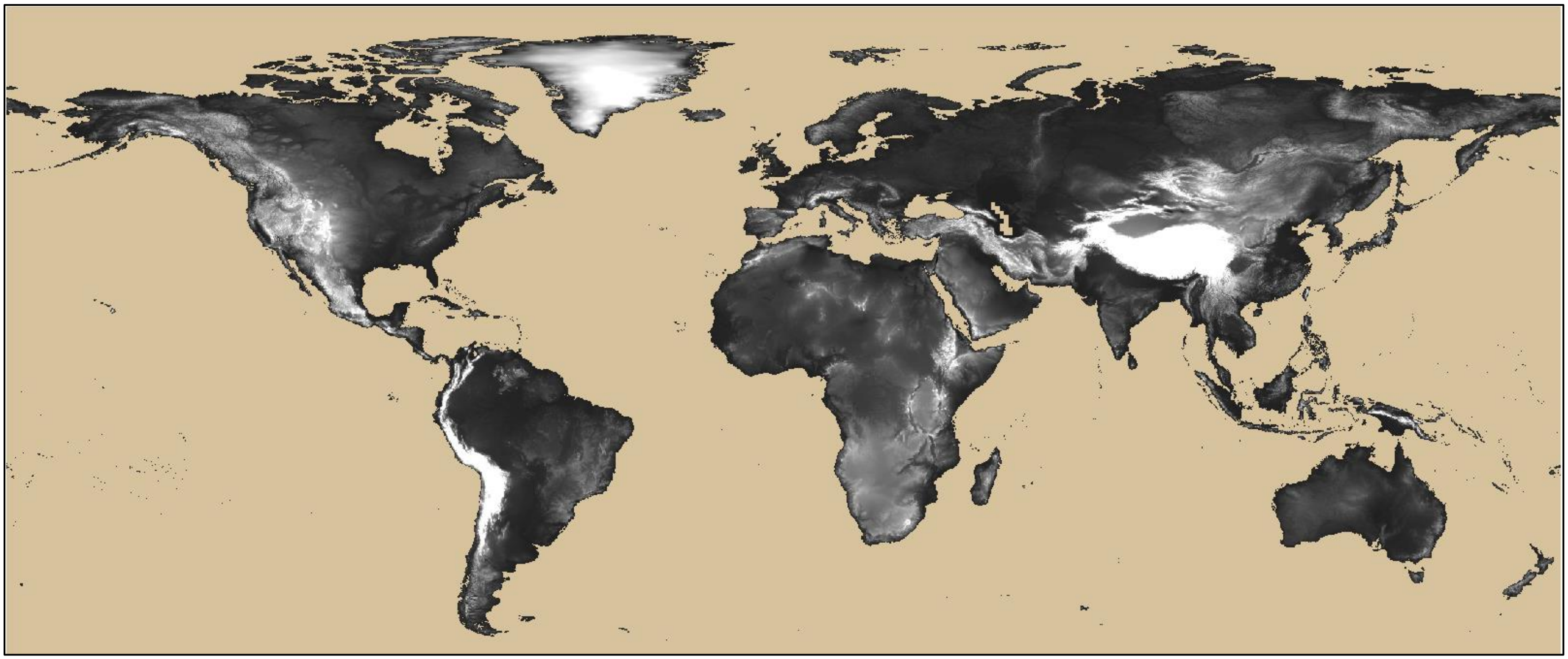

Figure 2. Global elevation. Areas lighter in color indicate areas of greater elevation.

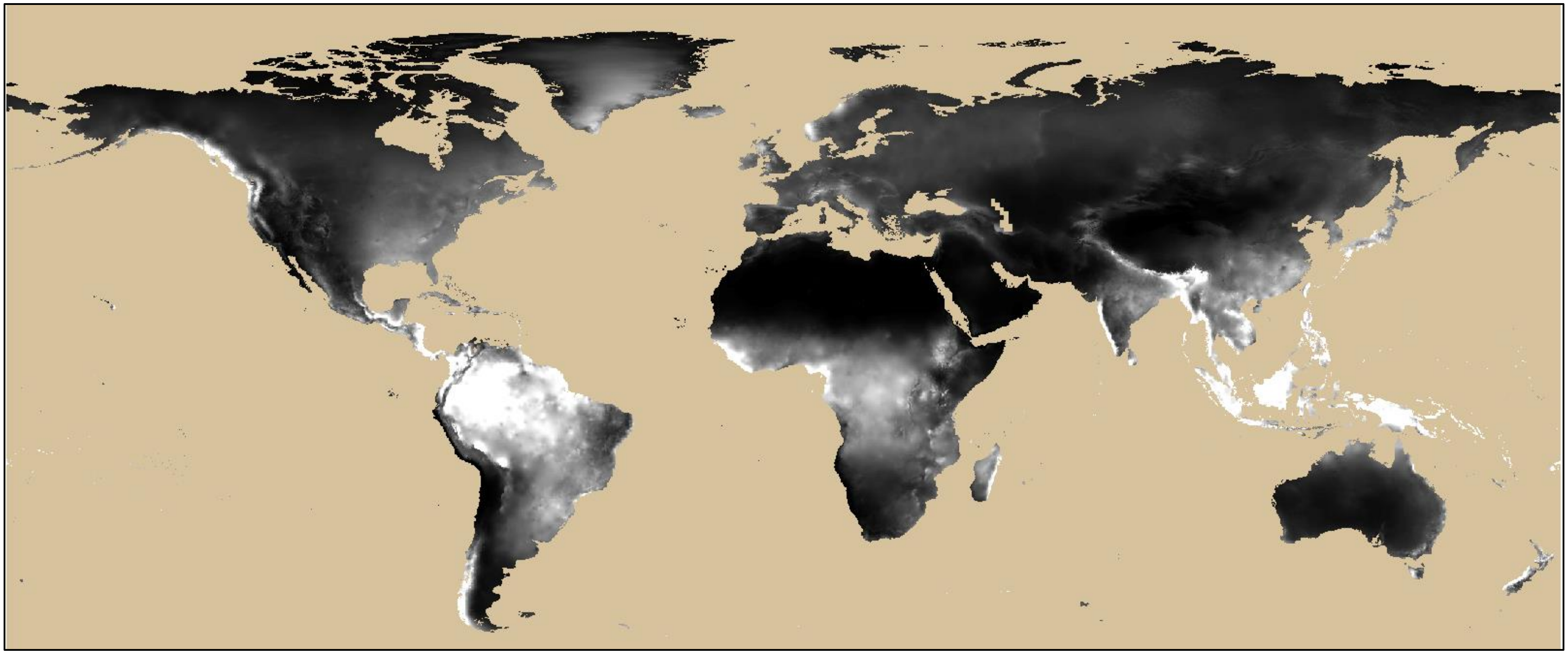

Figure 3. Global mean annual precipitation. Areas lighter in color indicate areas of higher mean annual precipitation.

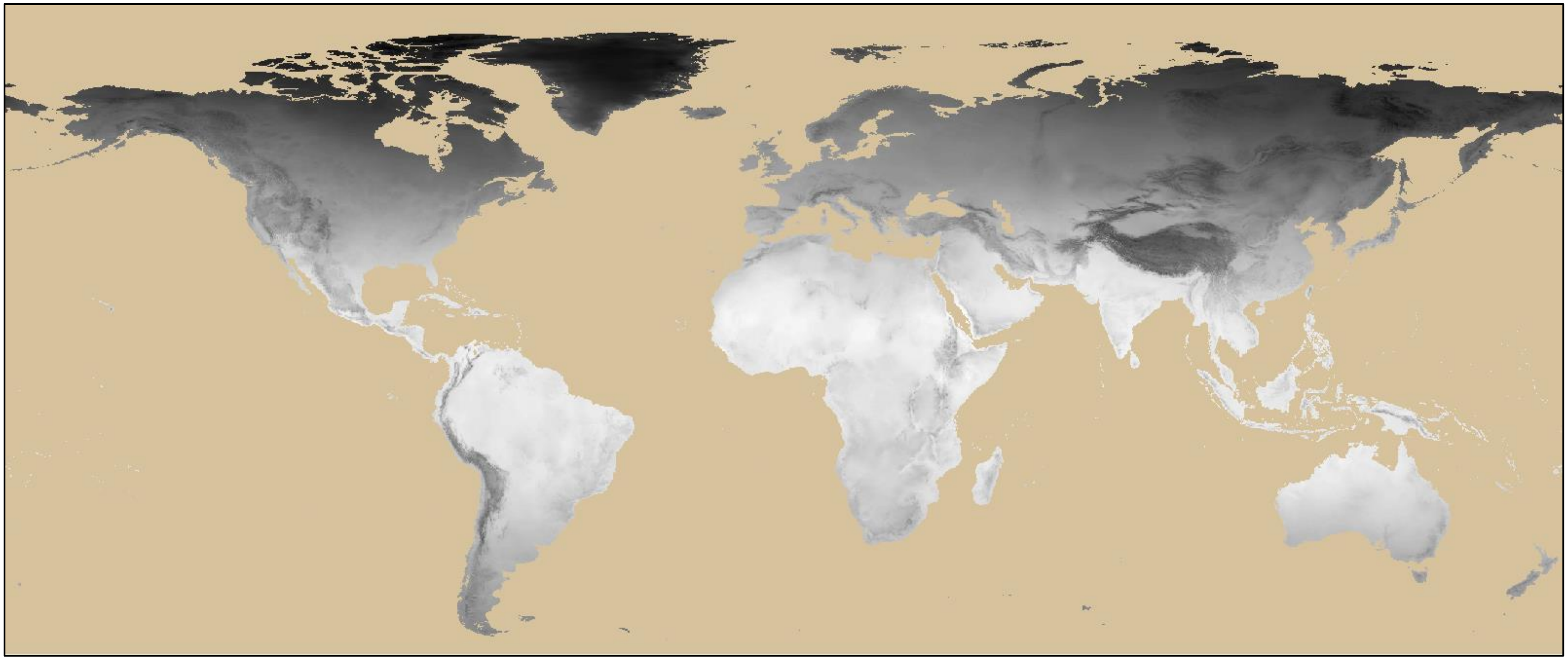

Figure 4. Global mean annual temperature. Areas lighter in color indicate areas of higher mean annual temperature.

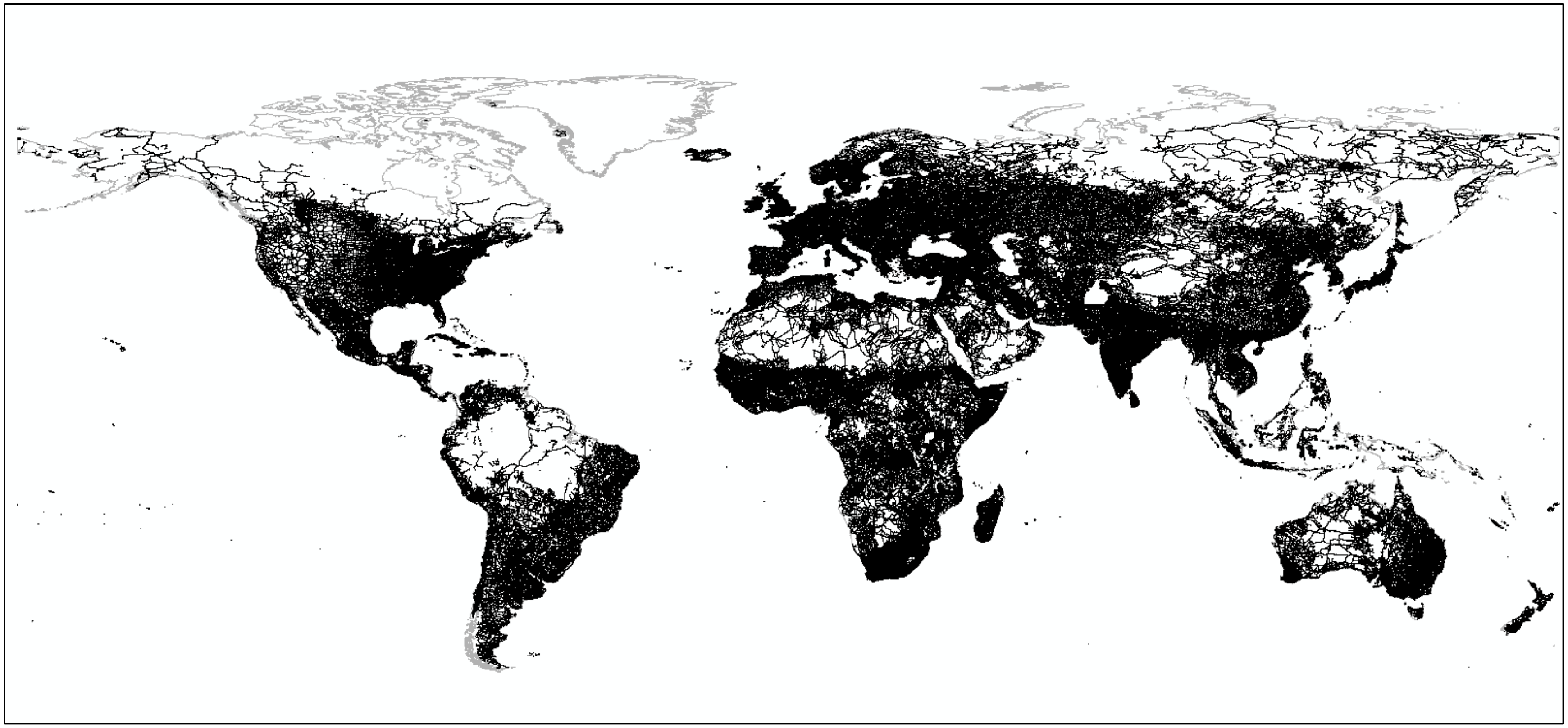

Figure 5. Global roads vector layer. Areas with a greater amount of black indicate a greater prevalence of roads.

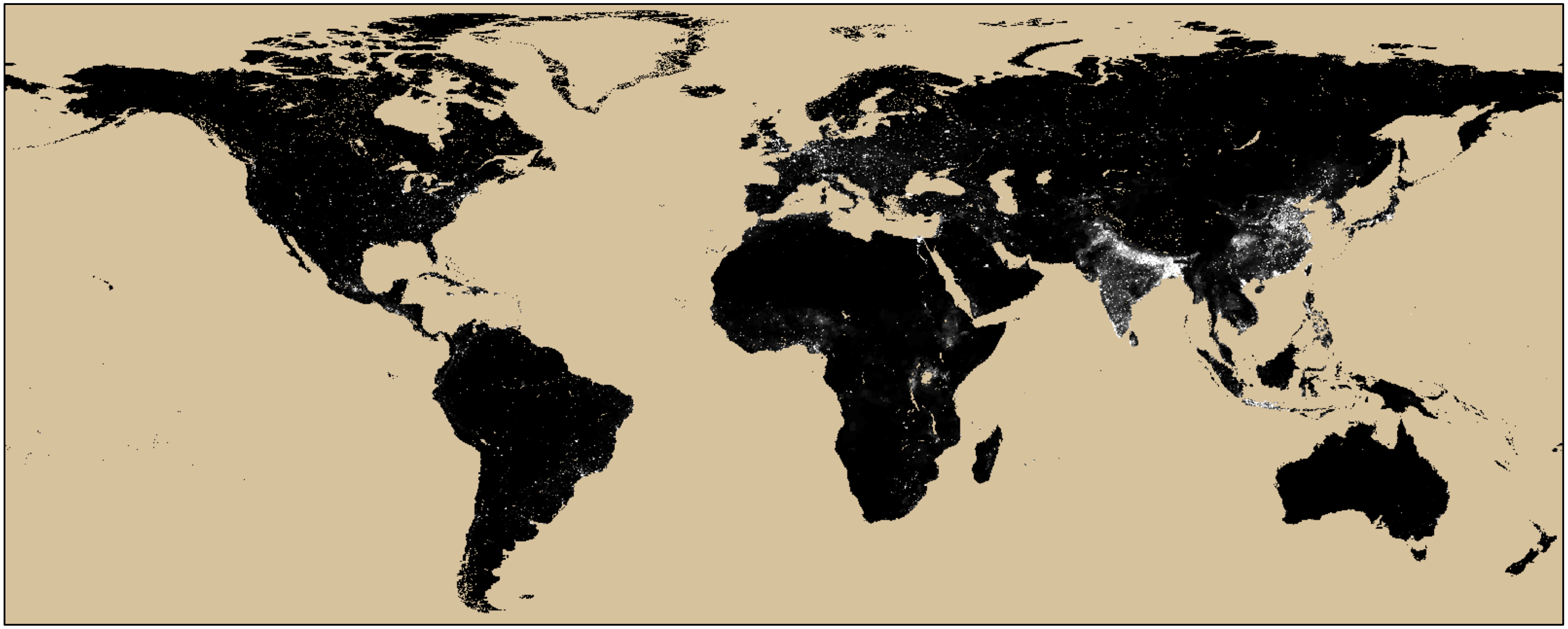

Figure 6. Global human population density. Areas lighter in color indicate areas of higher human population density.

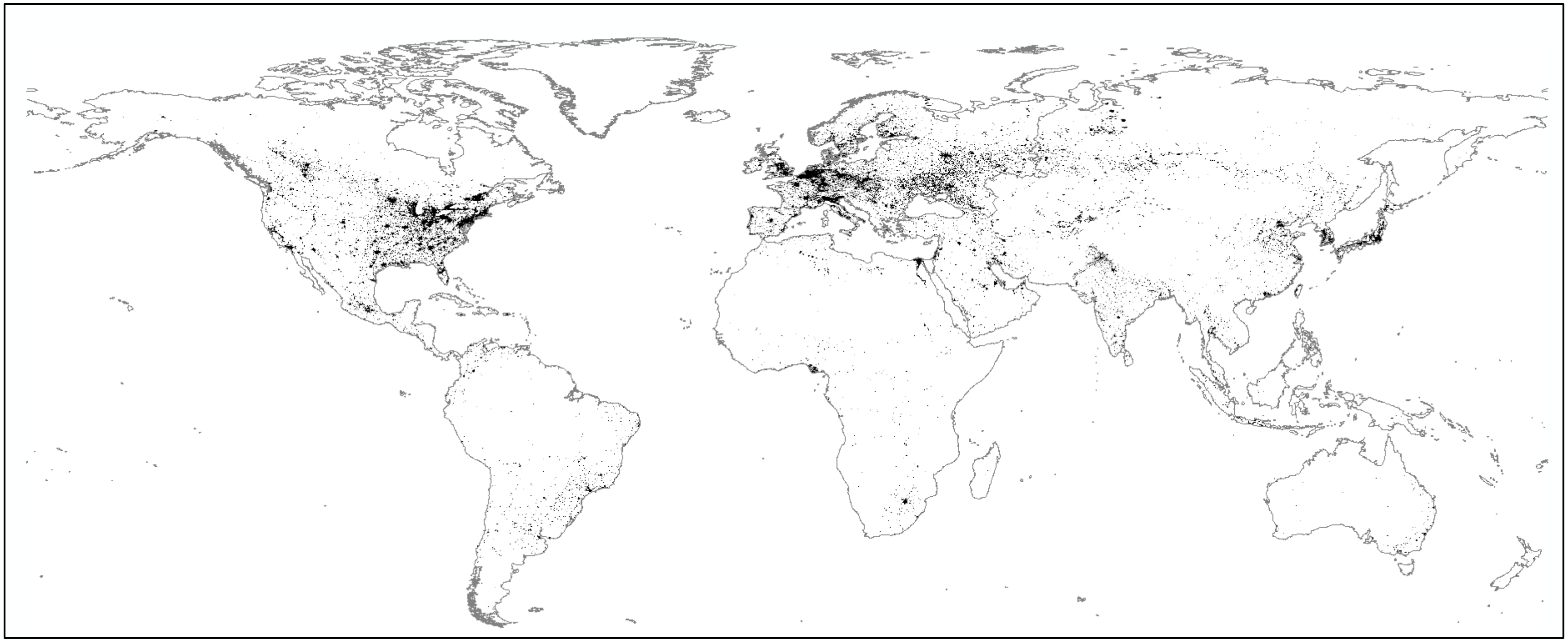

Figure 7. Global built-up land. Areas darker in color indicate areas with greater proportions of built-up land.

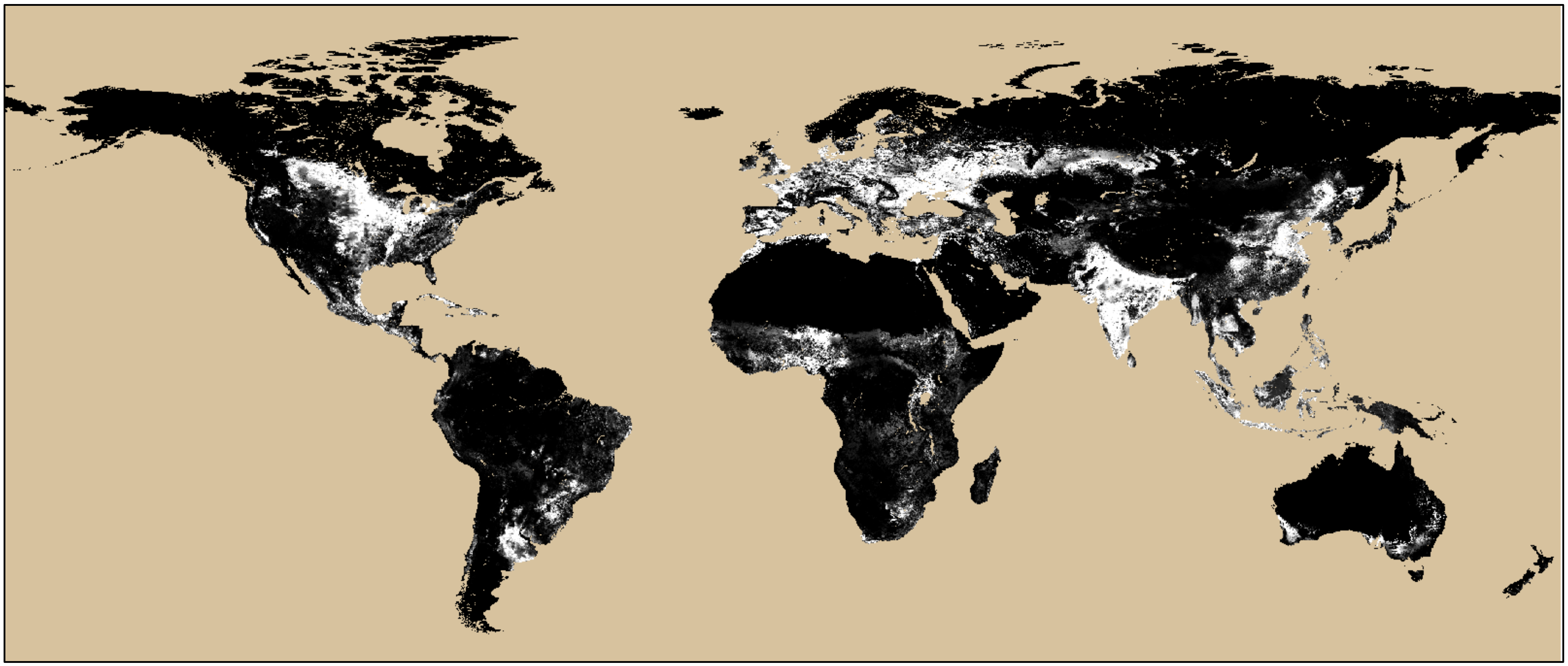

Figure 8. Global cropland. Areas lighter in color indicate areas with greater proportions of land converted to cropland.

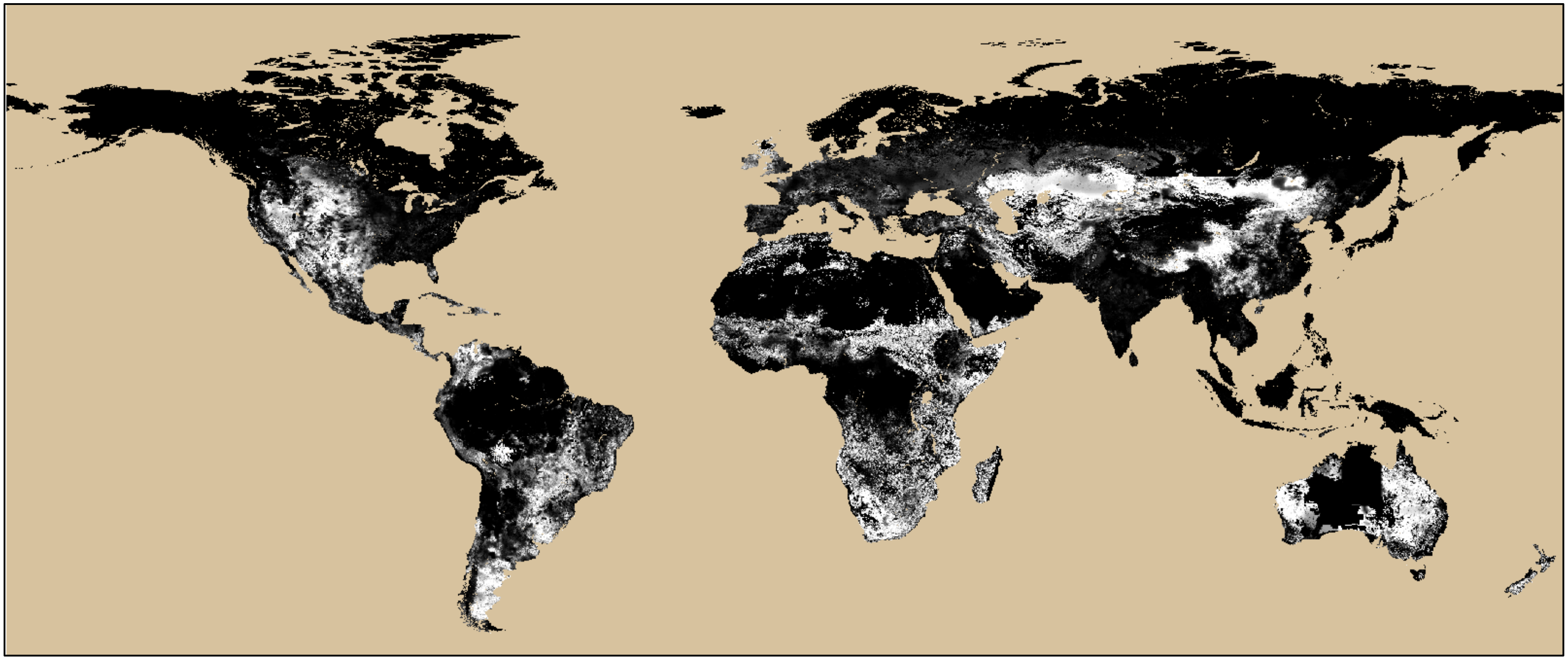

Figure 9. Global rangeland. Areas lighter in color indicate areas with greater proportions of land converted to rangeland.