Potential Distributions of *Chinchilla chinchilla* and *Chinchilla lanigera*

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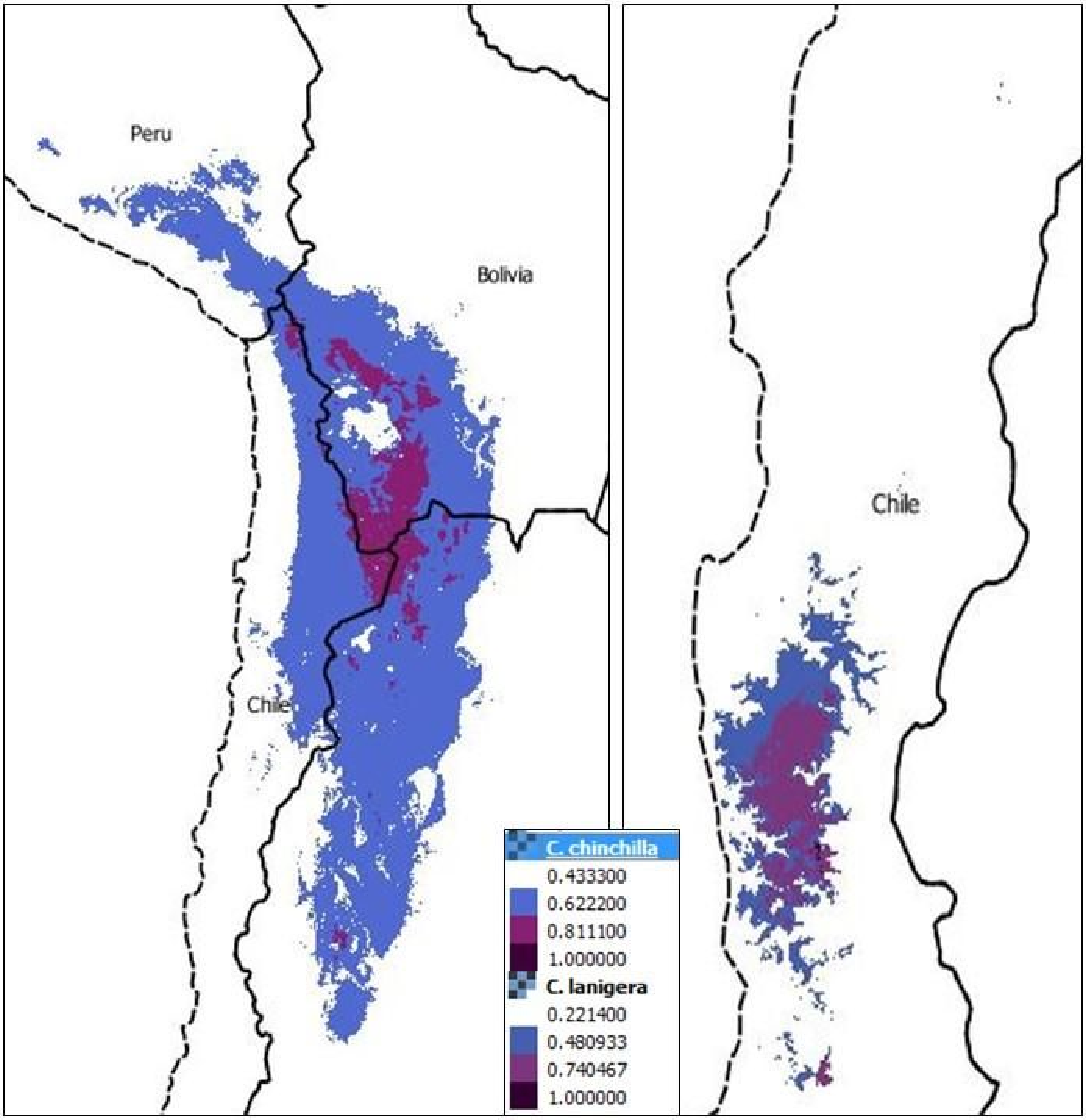
Save the Wild Chinchillas, IUCN, SSC, SMSG



Predicted distributions of *Chinchilla chinchilla (left)* and *C. lanigera (right)*

Abstract

Wild chinchillas were once thought to be extinct in the wild are listed as endangered. The current *in-situ* distribution of wild chinchillas exists in Bolivia and Chile. Short-tailed chinchillas (*Chinchilla chinchilla*) was rediscovered in Chile in 2001 and Bolivia in 2017 existing in the wild. The long-tailed species (*Chinchilla lanigera*) is endemic to Chile and wild colonies were found in the 1970's. This study utilizes known and historical species distributions, elevation and climate to predict the probability of suitable habitat in Maxent, a maximum entropy algorithm for each species. For *C. chinchilla,* the area with the highest potential to encounter colonies was above a predicted values of 0.81 in the high Andes. For *C. lanigera*, areas with a probability of above 0.74 are the most likely areas to contain colonies. For conservation, these areas should be of highest priority for search expeditions.

Introduction

Chinchillas are caviomorph rodents which once roamed the mountains and foothills of South America. Chinchillas are nocturnal and live together groupings called colonies. Both species of chinchillas and their range decreased dramatically as millions were exported during colonial South America for the fur trade (ALBERT 1900). Chinchilla are endangered because of hunting and trapping of the animals for its pelts. Between 1895 and 1921 over three million chinchilla pelts including a small number of live animals were exported from Chile. Some authors report that more than 21 million chinchillas were killed between 1840 and 1916 and only a fraction of those caught were able to be exported (JIMÉNEZ 1996).

Chinchilla chinchilla (brevicaudata), short-tailed chinchillas were believed extinct in the wild (JIMÉNEZ 1996). In 2001, Jimenez found remains of short-tailed chinchillas in fresh fecal material of foxes in northern Chile (JIMÉNEZ pers. comm 2001). Since then a few more colonies have been located in northern Chile. Copa et al. (2014) published research that mapped the probability of short-tailed chinchillas existing in Bolivia using once existing locations and MAXENT. In 2017, a wild colony was discovered in an area that was suggested as having a high probability. This was the first documented wild colony in Bolivia since 1939 (COPA pers. comm. 2017). Currently, *C. chinchilla* is listed as critically endangered (CE) in both Chile and Bolivia (ROACH and KENNERLEY 2016). Its native range included the Andes of Peru, Bolivia, Chile and Argentina.

C. lanigera, the long-tailed species, is endemic to Chile was thought to be extirpated from its original range which included the foothills of the Andes from northwest of Potrerillos south to Region IV (JIMENEZ 1996). Upon rediscovery of wild *C. lanigera* in central Chile, beginning in the mid-1970's, a series of studies on these endangered rodent populations have tried to understand chinchillas, their habitat and population dynamics. Wild long-tailed chinchillas are listed as endangered (EN) by the IUCN and Chilean government and are protected from international trade by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Appendix 1 (CONAF 1988; ROACH and KENNERLEY 2016).

Methods

Since 2001, four small colonies of *C. chinchilla* species were located in Chile and one colony in Bolivia. These locations, as well as eight other historical locations in Bolivia and Argentina, were used to extrapolate locations with the highest probability of suitable habitat for hosting short-tailed chinchilla colonies. Thirty-six known locations were utilized to identify possible area of habitat for long-tailed chinchillas based on current distribution. The majority of these points are clustered around Reserva National Chinchillas in the IV Region of Chile. All locations were entered into a database of a geographical spatial program and coded to the corresponding species. Locational data was exported as point locations to ascii format and loaded into the MAXENT program (PHILLIPS 2009).

To predict suitable habitat, point locations for each species were modelled with nineteen environmental variables. The variables were loaded into the modeling program consisting of a digital elevation model (USGS 2019) and climate data (WorldClim 2029). All data was downloaded in grid format in 30 arc second (approximately 1 km grid cells) resolution. The following climatic variables include:BIO1 = Annual Mean Temperature, BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)), BIO3 = Isothermality (BIO2/BIO7) (* 100), BIO4 = Temperature Seasonality (standard deviation *100), BIO5 = Max Temperature of Warmest Month, BIO6 = Min Temperature of Coldest Month, BIO7 = Temperature Annual Range (BIO5-BIO6), BIO8 = Mean Temperature of Wettest Quarter

BIO9 = Mean Temperature of Driest Quarter, BIO10 = Mean Temperature of Warmest Quarter, BIO11 = Mean Temperature of Coldest Quarter, BIO12 = Annual Precipitation, BIO13 = Precipitation of Wettest Month, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality (Coefficient of Variation), BIO16 = Precipitation of Wettest Quarter, BIO17 = Precipitation of Driest Quarter

BIO18 = Precipitation of Warmest Quarter, BIO19 = Precipitation of Coldest Quarter

MAXENT was run to create response curves for each environmental variable, create output maps images, and conduct a jackknife analysis to measure the importance of each variable in predicting probability locations. Only one location per species per grid cell was utilized by removing multiple locations if more than one point occurred within the grid cell. Random test percentage was run on 25% of the data points to test for validation of model. Threshold was set at 5% as the data is highly reliable. The model was replicated 15 times for each species. Files were saved in ascii format to aid in further analysis in QGIS and spreadsheets. Default output for MAXENT analysis is in logistic format. Values ranged from zero to one. Higher values correspond to locations whose variables most likely correlate with the known point locations for each species. For each species the average predicted suitable habitat layer was imported into QGIS to create user friendly maps.

RESULTS

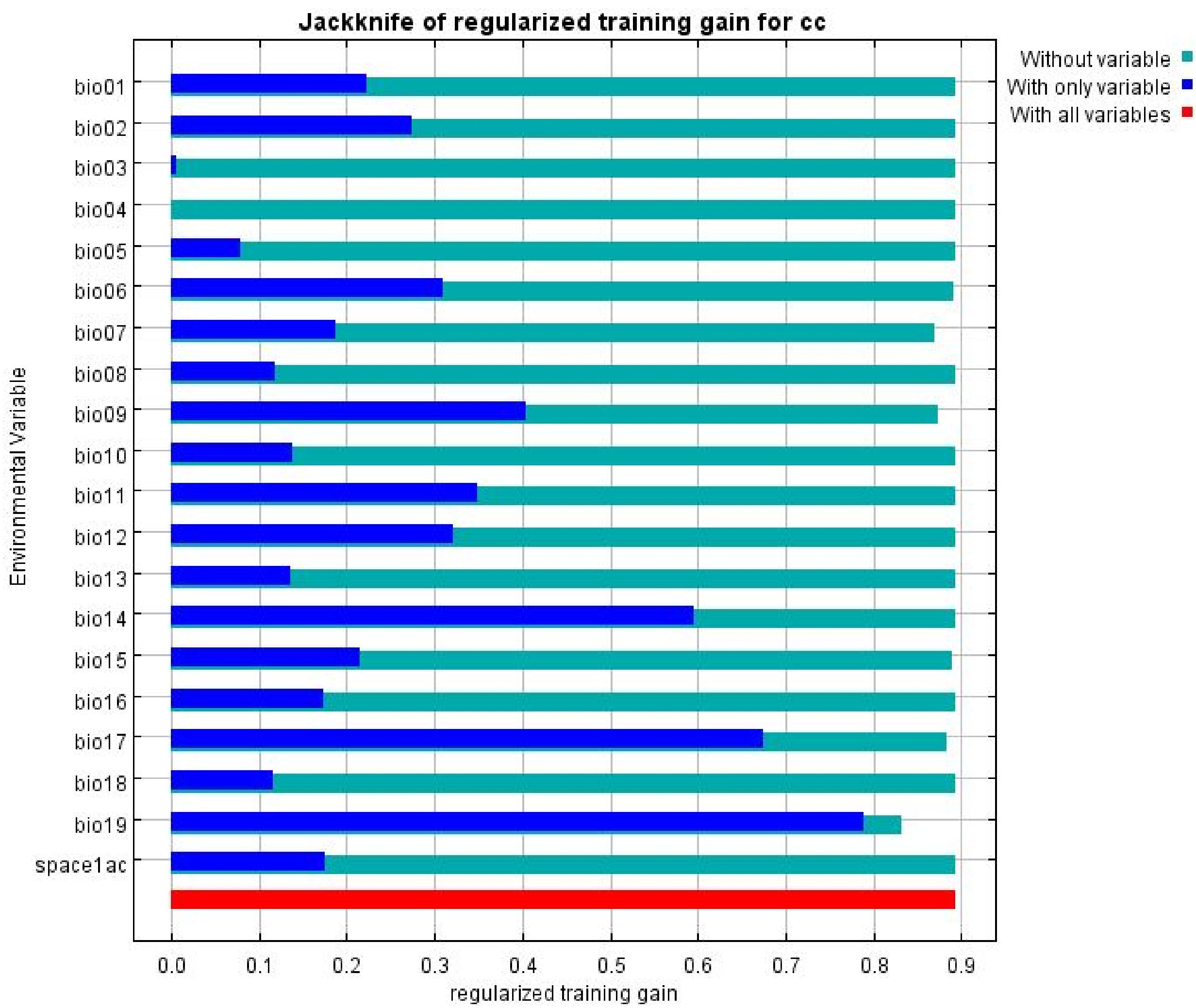
Chinchilla chinchilla

MAXENT split sample model used historic and current locations to identify areas of suitable habitat for *C. chinchilla*. For each replication, the model randomly selected ten sites as training locations and three as test points for each replica. Training data from short-tailed chinchilla locations had an AUC of 0.865 with a standard deviation of 0.045, while a random prediction was AUC=0.5. Based on the algorithm, the cutoff threshold was 0.4333. Thus, it is unlikely that this species exists in areas classified under this threshold. Bioclimatic factors that contributed most for the model for *C. chinchilla* are BIO19 = Precipitation of Coldest Quarter, and BIO9 = Mean Temperature of Driest Quarter. These two variables contributed 86.2% of the model results. Based on a jackknife analysis of variables, the bioclimatic layers with high variable importance are BIO19 = Precipitation of Coldest Quarter and BIO17 = Precipitation of Driest Quarter.

The table below displays the percent each variable contributed and its permutation importance (or feature importance) in deriving the spatial range probability distribution.

Variable	Percent contribution	Permutation importance
bio19	51.2	51.9
bio09	35	3.6
bio17	5.9	33.1
bio07	3.1	9.6
bio15	1.3	0.8
bio14	1.2	0
bio12	1	0
bio02	0.6	0
bio06	0.3	0.4
bio11	0.2	0
bio01	0.1	0
bio04	0	0.1
bio13	0	0.6
space1ac	0	0
bio05	0	0
bio03	0	0
bio08	0	0
bio16	0	0
bio18	0	0
bio10	0	0

Jackknife assessment of variable importance. Based on this graph, Bio19, Bio17 and Bio14 are the most important factors for model construction for *C. chinchilla*.



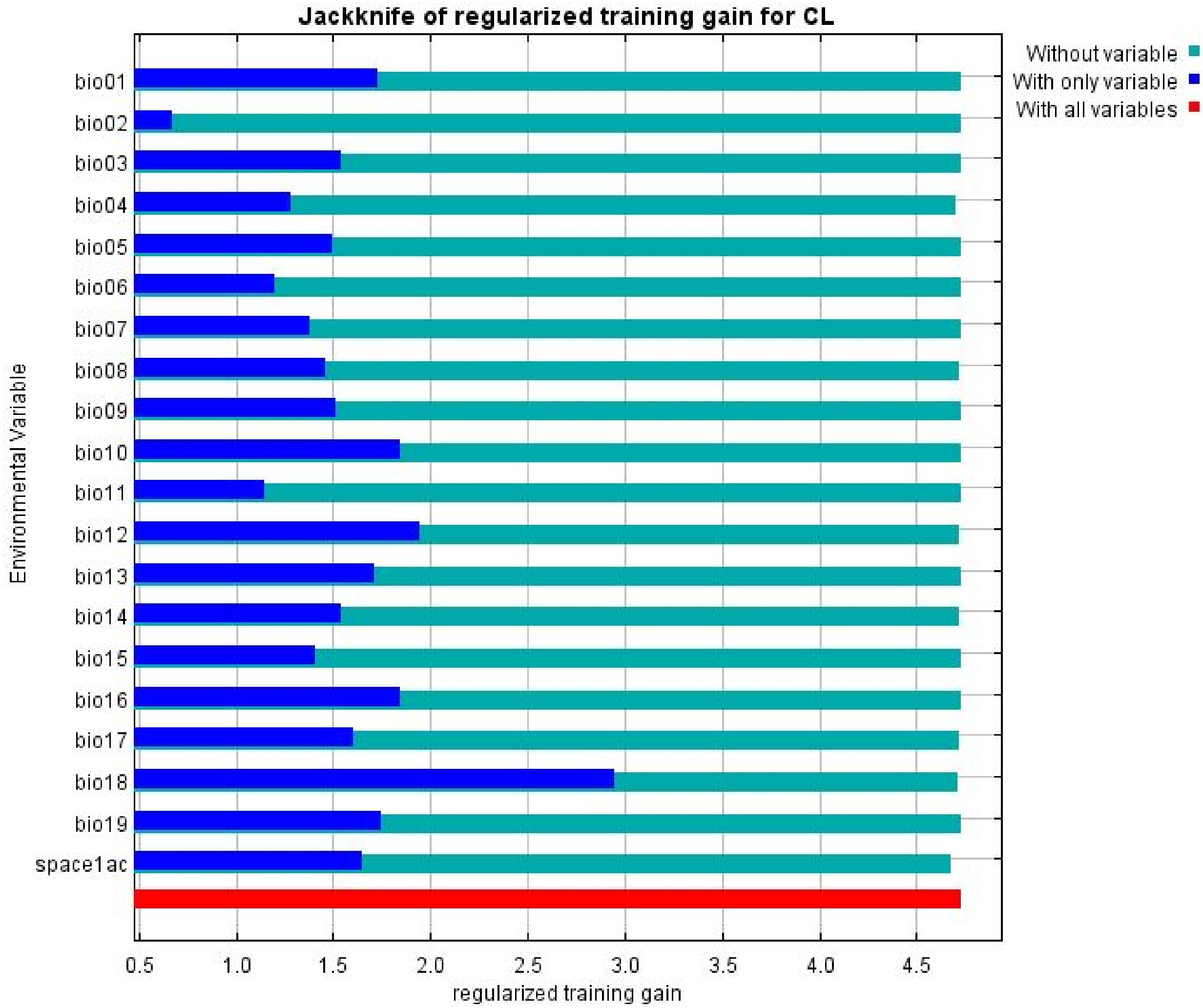
Chinchilla lanigera

MAXENT utilitzed 32 of the 36 known *C. lanigera* points in this investigation. Four locations were replicated spatially and excluded from this analysis. Each split sample model randomly chose 24 points for training and 8 for testing. Training data had an AUC of 0.994 with a standard deviation of 0.002, while a random prediction was AUC=0.5. Based on the algorithm, the cutoff threshold was 0.2214. Thus, it is unlikely that this species exists in areas classified under this threshold. According to the MAXENT program, the highest contributing bioclimatic factors affecting the distribution of suitable habitat for *C. lanigera* are BIO18 = Precipitation of Warmest Quarter and BIO19 = Precipitation of Coldest Quarter, which combined consist contribute 80.7% to the model. The bioclimatic features with the highest permutation importance are BIO17 = Precipitation of Driest Quarter at 23.6% and BIO14 = Precipitation of Driest Month at 17.7%. A jackknife test of variable importance shows BIO18 = Precipitation of Warmest Quarter was the most most useful layer in model construction.

Variable important in predicting suitable locations for *C. lanigera* are:

Variable	Percent contribution	Permutation importance
bio18	52.1	47
bio19	28.6	0
bio14	9.5	17.7
elevation	4.3	4.6
bio08	2.5	3.6
bio02	1	0
bio17	0.6	23.6
bio15	0.5	0
bio06	0.3	0.2
bio04	0.3	2.4
bio12	0.2	0.2
bio01	0.1	0
bio13	0	0.5
bio07	0	0
bio03	0	0.1
bio10	0	0
bio09	0	0
bio05	0	0.1
bio16	0	0
bio11	0	0

Jackknife test of variable importance.results for *C. lanigera:*



DISCUSSION

For species with small geographical ranges such as wild chinchillas the AUC levels reported are expected and acceptable for valid analysis (PHILLIPS 2009). As expected the model predicted the areas with highest probability for suitable habitat are in locations that currently host colonies. However, most currently known locations of short-tailed were not in areas with the highest probability. Also, the model did not determine that the northernmost and coastal colony of long-tailed chinchillas was in suitable habitat. It is interesting that elevation contributes little to the current predictions for *C. chinchilla* considering it consisted of 8.1% when Copa et al. (2014) used these same methods and model. In fact, elevation only contributed 2.4% to the model for *C. lanigera*. In Copa et al (2014) temperature extremes during the hottest and coldest portions of the year as well as altitude were the most important variables for predicting the distribution of the short-tailed chinchillas. However, this study found that winter precipitation and mean average temperature during the driest part of the year were the most important. It was not surprising that precipitation was the most important environmental factor based on the arid and mediterranean climate characteristic of much of the study area for *C. lanigera*. Winter or cold trimester is the seasonal period of the year with most precipitation in *C. lanigera's* natural habitat. One discrepancy is the lack of areas predicted near the northern most known location for *C. lanigera.* It is interesting to see the highest probability of some colonies of long-tailed chinchillas existing farther south than previously documented. These maps can guide expeditions in search of these endangered species.

REFERENCES

ALBERT, F. (1900): La chinchilla. Act. Soc. Scient. Chile. 10:379-407.

CONAF-Corporación Nacional Forestal. (1988): Brochure of endangered Chilean mammals. Santiago.

COPA ALVARO, M.E. et al. (2014): Distribución potencial de la chinchilla de colo corta (*Chinchilla chinchilla*, Rodentia) en el sudeste de Bolivia. Ecologia Bolivia, 49(2):65-76.

JIMÉNEZ, J.E. (1996): The extirpation and current status of wild chinchillas *Chinchilla lanigera and C. brevicaudata*. Biological Conservation, 77:1-6

MAXENT https://biodiversityinformatics.amnh.org/open_source/maxent/ Downloaded on 07 September 2019.

ROACH, N. & KENNERLEY, R. (2016): *Chinchilla chinchilla*. *The IUCN Red List of Threatened Species* 2016: e.T4651A22191157. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T4651A22191157.en. Downloaded on 01 October 2019.

ROACH, N. & KENNERLEY, R. (2016): *Chinchilla lanigera* (errata version published in 2017). *The IUCN Red List of Threatened Species* 2016: e.T4652A117975205. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T4652A22190974.en. Downloaded on 01 October 2019.

PHILLIPS, S.J. 2009. A Brief Tutorial on Maxent. Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History. Lessons in Conservation, Vol. 3, pp.

USGS *https://dds.cr.usgs.gov/ee-data/coveragemaps/shp/ee/gtopo30/gtopo30.zip* Downloaded on 07 September 2019.

Worldclim *https://www.worldclim.org/* Downloaded on 07 September 2019.