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Title: Response to climate change is related to species traits in the Lagomorpha

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Abstract: Climate change during the last five decades has impacted on natural systems significantly and the rate of current climate change is of great concern among conservation biologists. Here, we assess the projected change in the bioclimatic envelopes of all 87 species in the mammalian order Lagomorpha under future climate using expertly validated species distribution models. Results suggest that climate change will impact more than two-thirds of Lagomorphs, with leporids (rabbits, hares and jackrabbits) likely to undertake poleward shifts with little overall change in range extent, whilst pikas are likely to show extreme shifts to higher altitudes associated with marked range declines, including the likely extinction of Kozlov's Pika (*Ochotona koslowi*). Species traits were associated with predictions of change, with smaller-bodied species more likely to exhibit range contractions and elevational increases, but showing little poleward movement. Lagomorphs vulnerable to climate change require urgent conservation management to mitigate range declines and/or extinctions.

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Main Text: The Lagomorpha is one of the most important mammalian orders economically and scientifically; as a major food resource, laboratory animals, valued game animals, pests of agricultural significance and the base of many predator/prey relationships providing insights into entire trophic systems (*1*). Species Distribution Models (SDMs) are widely used in ecology and relate species occurrences at known locations to environmental variables to produce models of environmental suitability, which can be spatially or temporally extrapolated to unexplored areas or into past or future conditions (*2*, 3). Lagomorphs are native or introduced on all continents except Antarctica, occur from sea level to >5,000m and from the equator to 80°N spanning a huge range of environmental conditions. Whilst other studies have modelled large numbers of species (*4*) or, for example, a few key species within each mammalian order (*5*), Lagomorphs due to their restricted diversity provide an opportunity to examine the response of every species yielding a detailed picture of change within an entire order for the first time. Furthermore, the small number of Lagomorph species, compared to other mammalian groups, means that datasets can be verified in detail, modelled individually and outputs expertly validated.

We assessed projected change in the bioclimatic envelopes of all 87 lagomorph species under future climate change using a combination of climatic, topographical and environmental variables (*6*). The taxonomy of the group is in constant flux but all belong to just two families: the Ochotonidae and the Leporidae. The Ochotonidae consists of one monotypic group in the genus *Ochotona* containing 25 species of small, social, high-altitude pikas. The Leporidae has 32 species of large, solitary, cursorial hares and jackrabbits in the genus *Lepus* and 30 species of medium-sized, semi-social, fossorial rabbits from 10 genera (*1*). A quarter of Lagomorphs are listed in the IUCN

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Red List of Threatened Species (www.iucnredlist.org) with a notable number of highly range-restricted species, for example, the Tres Marias cottontail (*Sylvilagus graysoni*) and black jackrabbit (*Lepus insularis*) which occupy islands <500km^2 and ~80km^2 respectively in the Gulf of California. In addition, pikas as high-altitude specialists are extremely susceptible to changes in their environment (*7*) with only small changes in temperature leading to heat stress (*8*).

We used a framework for model validation based jointly on subjective expert evaluation and objective model evaluation statistics (Fig. S1). Expert validation, whereby an acknowledged expert on each species judges model predictions for current and past distributions (*9*), can be a useful tool prior to making future extrapolations. Forty-six Lagomorph experts, including 20 members of the Lagomorph Specialist Group (LSG) of the IUCN Species Survival Commission (SSC), were paired to one or more species and asked to assess whether model projections accurately, roughly or did not capture the current and past range of each species (good, medium and poor respectively) (*6*). There was a high degree of agreement between expert classification and model Kappa (k) values (Fig. S2). k is an objective measure of prediction accuracy based on input species records and background points adjusted for the proportion of correct predictions expected by random chance (*10*). Fifty-eight species (67%) were deemed 'modellable' with expert validation classed as medium or good and k>0.4 and 29 species (33%) rejected as 'unmodellable' with expert validation classed as poor and/or k<0.4. Unmodellable species were 4 times more likely to be listed by the IUCN as Data Deficient than modellable species, with 8 unmodellable species (28%) listed as threatened. Hereafter, all results are for modellable species only and, therefore, are a conservative estimate of the impact of climate change on the order as a whole.

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Changes in climate are predicted to have strong influences on the ecology and distribution of species (*11, 12*) with pronounced impacts on terrestrial biodiversity (*4*). Global changes in predicted Lagomorph species richness suggest that almost a third of the Earth's terrestrial surface (31.5 million km^2) is predicted to experience loss of Lagomorph species by 2080 (Fig. 1). The desert regions of North Eastern China and hills of Sichuan become increasingly unsuitable, losing up to 10 species by 2080, including the woolly hare (*Lepus oiostolus*) and Glover's pika (*Ochotona gloveri*); which are predicted to undergo dramatic movements to higher elevations. In contrast, species gains were notable across: (a) northern Eurasia, due to poleward movements of the mountain hare (*Lepus timidus*) whose boreo-alpine niche is highly sensitive to changes in temperature (*13, 14*) and (b) North America, where some regions e.g. the Upper Missouri catchment of Montana and North Dakota gain up to 5 species including the desert and eastern cottontails (*Sylvilagus audubonii* and *S. floridanus* respectively) which are predicted to exhibit strong poleward movements. The majority of Lagomorph species in Africa were classed as unmodellable and as such Figure 1 is data deficient for this continent. Parts of Africa are expected to become drier and warmer under future climate, with large increases in arid land (*15*) leading to negative consequences for Lagomorphs. Nevertheless, the results for modellable species suggest species gains in Southern Africa, due to a latitudinal shift in the range of the African savannah hare (*Lepus microtis*).

Species are predicted to adapt their bioclimatic niche to future conditions, migrate to maintain their current niche, or become range restricted and undergo population decline, local extirpation or total extinction under future scenarios (*16*). Thirty-six Lagomorph species exhibited range loss (63%), 48 poleward movements (83%) and 51 elevational

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increases (88%). Thirty-five species (60%) exhibited range declines *and* either poleward movements *or* elevational increases. On average, all three groups of Lagomorphs exhibited significant poleward shifts ($F_{df=1,228}$= 30.1, p<0.001) and elevational increases ($F_{df=1,228}$= 19.7, p<0.001) by 2080 (Fig. 2, Table S1). The average poleward shift for the Order was 1.1° and elevational shift 165m; these values are much higher than averages calculated in a recent meta-analysis collating information on a wide variety of taxonomic groups (*17*). Pikas exhibited the most substantial mean increase in elevation becoming increasingly isolated on mountain summits (e.g. the Rockies in North America and the Tibetan Plateau and high Himalayas) resulting in a significant 31% range contraction ($F_{df=1,228}$ =5.0, p=0.03). Pikas are known to be extremely susceptible to heat stress (*8*); thus, increases in temperature or unpredictable seasonality are likely to induce elevational rather than latitudinal shifts in these high-altitude specialists.

The leporids, typically being lowland species, exhibited less substantial increases in elevation but greater poleward shifts. As global temperatures increase, northern latitudes will become more climatically suitable for southern leporids and, therefore, species bioclimatic envelopes will track poleward to match. Thus, rabbits, hares and jackrabbits all exhibited little overall change in the total extent of their ranges. The majority of the modellable rabbit species were from the genus *Sylvilagus* inhabiting south and eastern USA and Mexico, which are projected to become generally drier (*18*) inducing latitudinal shifts in species to track suitable habitats or vegetation. Thus, by shifting their ranges poleward, leporids are predicted to be able to maintain or increase their range extent suggesting they are considerably less sensitive to projected climate change than pikas.

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Recent studies have found that species' morphological and life history traits can be good predictors of climate change responses (*19*). Phylogenetic generalised least squares (PGLS) regressions estimated lambda (λ) to be close to zero (p>0.05) for changes in range, poleward movement and elevation indicating that observed trends were independent of phylogeny (*20*). Generally, the members of each group were capable of showing a variety of responses i.e. species of pika, rabbits, hares or jackrabbits exhibited both increases and decreases in each response variable within each group (Fig. 2). There was a significant positive relationship between range change and adult body mass (β=0.258, $F_{df=4,52}$=2.308, p=0.021) with hares and jackrabbits generally increasing their range by 2080 and pikas exhibiting range contraction (Table S2; Fig. S3). This could occur due to a relationship between adult body mass and dispersal distance, which was used to clip model projections, but a Spearman's Rank correlation suggested no correlation between these variables in the dataset used. Adult body mass was positively associated with poleward movement (β=0.196, $F_{df=5,49}$=1.989, p=0.047) and inversely related to elevational change (β= -0.183, $F_{df=2,50}$=2.019, p=0.043). Smaller species, principally pikas and some rabbits, were typically more capable of elevational shifts in range whilst larger species, principally hares and jackrabbits, had a greater tendency for poleward shifts. This relationship is probably due to the large number of small-bodied species that dwell in mountainous regions (n=24) which have more opportunity to shift altitudinally. The average adult body mass for Lagomorphs living in mountainous regions was 836g, compared to 1.8kg in lowland areas. A 1m elevational shift is equivalent to a 6km latitudinal shift (*11*), so it is easier for smaller species to shift altitudinally. The number of litters a species produces per year was positively related to latitudinal and maximum elevational shifts (β=0.215, $F_{df=5,49}$=2.731, p=0.006

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and β=0.160, $F_{df=2,53}$=1.746, p=0.081 respectively) with more fecund species being capable of more extreme upward or poleward shifts, as in Moritz *et al*. (2008) (*21*). There was also a positive relationship between species dietary niche and the degree of poleward shift predicted (β=0.181, $F_{df=5,\ 49}$=2.190, p=0.029).

The uncertainties in SDM using projected future climate scenarios are well described[6]. Models are vulnerable to sampling bias (*22*), spatial scale issues (*23*), lack of data for rare species (*24*), uncertainty regarding future climate conditions (*25*) and insufficient independent evaluation (*23*). We have tackled these explicitly by accounting for sampling bias by restricting the set of background points used, using data with the highest spatial resolution available (30 arc-second) and selecting species records to match, bootstrapping models for rare species with few records, averaging climatic data from five global circulation models and using a framework of joint expert and metric-driven model validation to segregate outputs into those that were modellable and unmodellable before subsequent analysis.

Regardless of individual model outcomes (see Supplementary Materials), the overall trends observed across the order Lagomorpha as a whole are compelling. This study did not take account of shifts in habitats, vegetation or human impact in response to climate change, but we have shown that adaptation to future climate conditions may be possible as some species were predicted to exhibit poleward movements, with only modest shifts in range or elevation e.g. snowshoe hare (*Lepus americanus*) and Appalachian cottontail (*Sylvilagus obscurus*).

The predicted changes in climate conditions are likely to have greater impacts on isolated Lagomorph populations, i.e. those on islands and in high-altitude systems. Lagomorph species occupying islands (n=6) will, on average, lose 8km^2 of their ranges

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compared to 0.2km^2 gain for continental species (*n*=52), whilst mountain dwelling species (*n*=24) will lose 37km^2 of their ranges compared to 25km^2 gain for lowland species (*n*=34). If changes continue at the rate currently predicted until the 2080s, then there may be no climatically suitable range available for some montane or isolated species e.g. the Tres Marias cottontail (*Sylvilagus graysoni*), black jackrabbit (*Lepus insularis*) or Gansu pika (*Ochotona cansus*). Conservation strategies, such as assisted migration, could be the only option for these highly range-restricted species. Furthermore, conservation management will need to focus on small-bodied mammals as these are predicted to show more dramatic responses to changing climate. Small mammals are key in food webs sustaining predator populations, impacting plant communities by grazing and soil biology and hydrology by burrowing. Thus, fundamental shifts in Lagomorphs globally will cause trophic cascade effects, especially in northern latitudes such as the cyclic systems of the Arctic. The advancing knowledge of past extinction rates for Lagomorphs (*26*), along with significantly better bioclimatic envelope modelling, could aid the prediction and prevention of future extinctions. Our models suggest that Kozlov's pika (*Ochotona koslowi*) may become extinct by the 2080s as the elevational increases required to maintain its current bioclimatic envelope disappear as it reaches the maximum elevation available. Assessment of vulnerability to climate change is needed urgently to identify how and to what extent species, taxa, communities and ecosystems are susceptible to future changes, taking into account likely changes to vegetation, human pressures and interspecific interactions, and to direct conservation management in an efficient and effective manner. Multi-species approaches are likely to lead to more effective mitigation measures and contribute to

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our understanding of the general principles underpinning the biogeographical and ecological consequences of climate change impacts.

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Acknowledgments: This project was funded by *Quercus*, Northern Ireland's Centre for Biodiversity and Conservation Science. We thank all Lagomorph experts for validating models, namely (in alphabetical order of surname): Pelayo Acevedo, Francesco Angelici, Penny Becker, Sabuj Bhattacharya, Rudy Boonstra, Arturo Carillo-Reyes, Youhua Chen, Nishma Dahal, John Flux, Jennifer Frey, Sumiya Ganzorig, David Gray, Thomas Gray, David Happold, Robert Kissell, Paul Krausman, Charles Krebs, Hayley Lanier, Daniel Lew, John Litvaitis, Consuelo Lorenzo, Gopinathan Maheswaran, Jose Antonio Martinez-Garcia, Bob McCleery, Tamera Rioja Pardela, Jorge Salazar-Bravo, Jan Schipper, Koji Shimano, Chelmala Srinivasulu, Andrew Tilker, Jorge Vazquez, Alejandro Velasquez, Eric Waltari, Hariyo Wibisono, Julia Witczuk and Fumio Yamada. Particular thanks to Michael Barbour (Auburn University, USA), Kai Collins (University of Pretoria) and Christy Bragg (Endangered Wildlife Trust, South Africa), Deyan Ge (Chinese Academy of Sciences, China), David Hik (University of Alberta, Canada), Dana Lee (Oklahoma State University, USA), Andrey Lissovsky (Zoological Museum of Moscow State University, Russia), Andrew Smith (Arizona State University, USA), Franz Suchentrunk (Research Institute of Wildlife Ecology, Austria), Zelalem Tolesa (Addis Ababa University, Ethiopia) and Weihe Yang (Chinese Academy of Sciences, China) for contributing data, taxonomic expertise and also validating models.

The authors declare no competing financial interests. N.R. designed the study, K.L. conducted the analysis and all of the authors contributed to initial planning, discussion of results and preparation of the manuscript.

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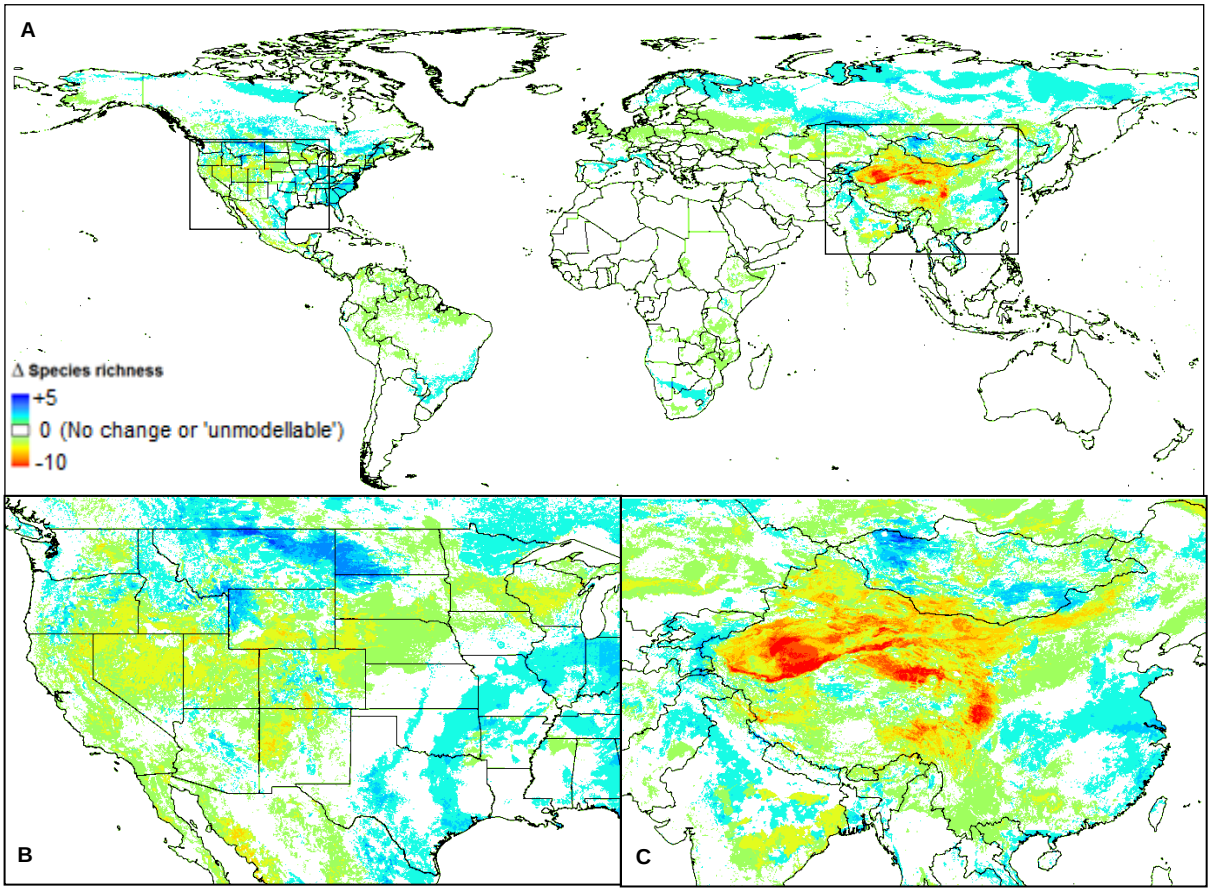

Figure 1. Change in predicted Lagomorph species richness from the 1930s to 2080s. A, Global patterns in predicted species loss and gain showing details in **B**, North America and **C**, Asia. White areas indicate no change in species richness or areas that are occupied by unmodellable species with uncertain outcomes (i.e. data deficient).

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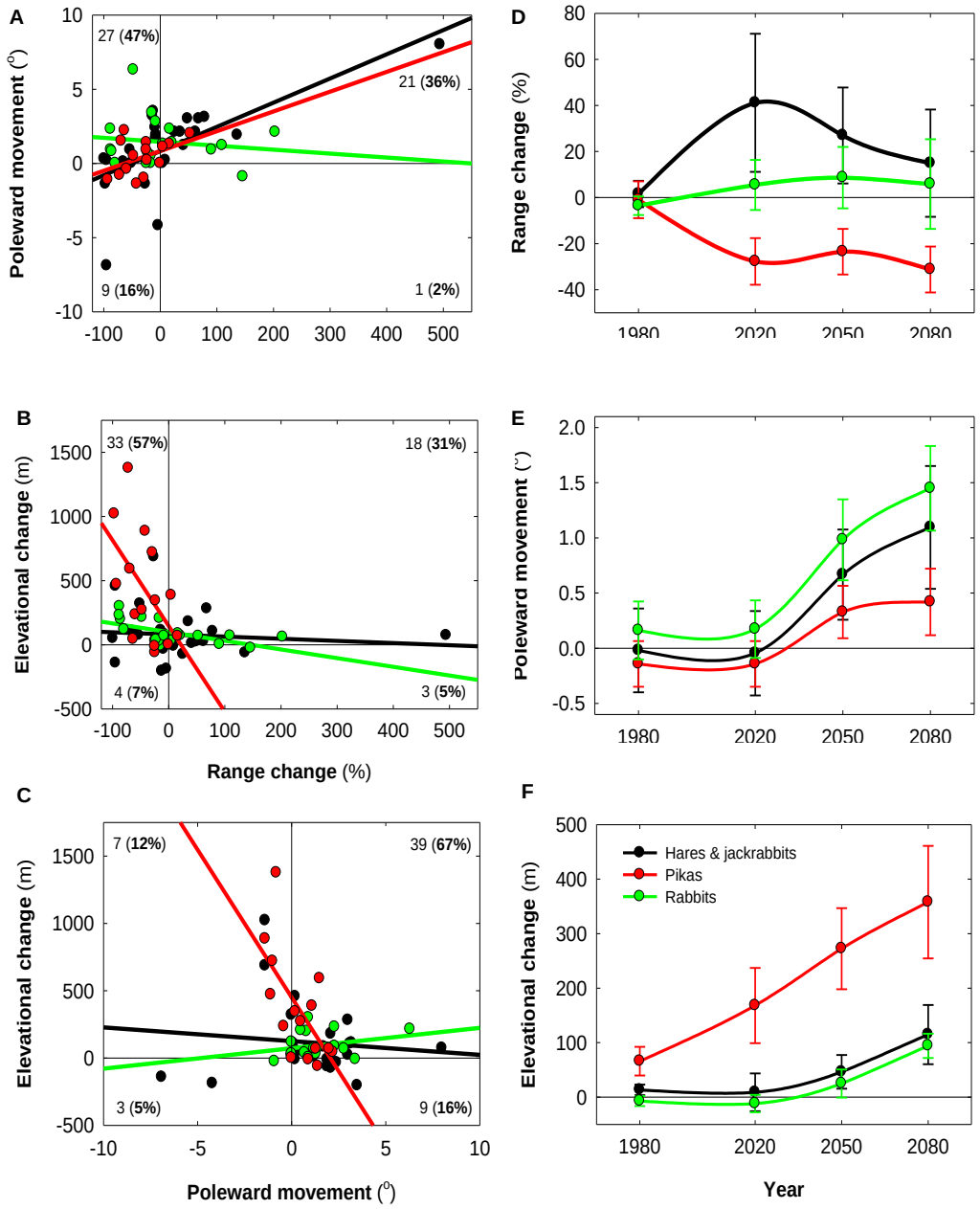

Figure 2. Characterisation of predicted Lagomorph bioclimatic envelope change. Scatterplots show the linear relationship between range change (%) and **A**, poleward movement (°), **B**, elevational change (m) and **C**, poleward movement and elevational change. The numbers of species in each quadrant that exhibited positive or negative change on each axis are shown in plain text with percentages in bold parentheses. Temporal trends for **D**, range change, **E**, poleward movement and **F**, elevational change

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± 1 standard error for each species group; pikas (red), rabbits (green) and hares and jackrabbits (black).

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Supplementary Materials:

Materials and Methods

Figures S1-S3

Tables S1-S2

References (*27-49*)

Species accounts (89 x 1 pages)

Supplementary Materials:

Materials and Methods:

Species data

A total of 139,686 records including all 87 Lagomorph species were either downloaded from the Global Biodiversity Information Facility (GBIF) Data Portal (data.gbif.org), collated from species experts or members of the IUCN Lagomorph Specialist Group and/or searching the literature. Taxonomic, spatial and temporal data accuracy and sampling bias issues were dealt with leaving 41,874 records of which 3,207 were pre-1950 and 38,667 were post-1950. All records were checked against the latest IUCN taxonomy, if names did not match after studying taxonomic synonyms and previous names they were rejected, and if records for the target species fell outside the extent of the IUCN geographic range polygon they were also rejected. Records with spatial error estimates >2km were removed and duplicates were eliminated unless they occurred in different temporal periods (pre-1950 and post-1950). To remove spatial bias the background data was only selected from sites at which any lagomorph had been recorded, and to remove temporal bias the background data (10,000 points) had the same proportion of past to current points as there were past to current species records.

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Environmental parameterisation

Empirical climate data were downloaded from WorldClim and the CCAFS GCM Data Portal at 30 arc-second resolution (≈1km grid cells). Records pre-1950 were associated with mean climate data from 1900-1949 and those post-1950 were associated with mean data from 1950-2000. Projected future climate data were obtained from the IPCC 4th Assessment Report using the A2 emissions scenario. Although the A2 future climate change scenario was originally described as 'extreme climate change' it now appears to best represent the trend in observed climate. Pierce *et al.* (2009) (*27*) report that using data averaged across five global circulation models (GCMs) is substantially better than any one individual model and significantly reduces model error. We used the following five GCMs: CCCma-CGCM3.1/T47, CNRM-CM3, CSIRO-Mk3.0, HadCM3 and NASA-GISS-ER. Future projections adopted the time periods: 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099).

Fifteen environmental variables were used in their raw format: mean annual temperature (°C), temperature seasonality (°C), mean temperature of the hottest month (°C), mean temperature of the coldest month (°C), mean annual precipitation (mm), mean precipitation of the wettest month (mm), mean precipitation of the driest month (mm) and precipitation seasonality (mm). Further composite variables were calculated including: annual evapotranspiration (mm), annual water balance (mm), the number of months with a positive water balance, mean annual Normalised Difference Vegetation Index (NDVI), human influence index, solar radiation and surface roughness index.

Evapotranspiration was calculated using the Hargreaves equation (*28*):

$$\text{Evapotranspiration} = 0.0023 \times (T_{mean} + 17.8) \times (T_{max} - T_{min})^{0.5} \times R_a$$

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where,

$R_a = ((24 \times 60)/\pi) \times G_{sc} \times d_r [(\omega_s \times \sin\varphi \times \sin\delta) + (\cos\varphi \times \cos\delta \times \sin\omega_s)]) \times 0.408$

G_{sc} = solar constant = 0.0820 MJ m-2 min-1

d_r = inverse relative distance Earth-Sun = $1 + 0.033 \cos((2\pi/365) \times J)$

ω_s = sunset hour angle [rad] = $\arccos[-\tan(\varphi)\tan(\delta)]$

φ = latitude [radians] (grid file in decimal degrees converted to radians (multiply by $\pi/180$))

δ = solar decimation [rad] = $0.409 \sin(((2\pi/365) \times J) - 1.39)$

J = number of days in the year. J at the middle of the month is approximately given by J = INTEGER (30.4 Month – 15) = 15 on average.

Annual evapotranspiration was taken as the sum of all monthly values. Annual water balance was calculated by subtracting annual evapotranspiration from mean annual precipitation. The number of months with a positive water balance was calculated by subtracting each monthly evapotranspiration from its corresponding monthly precipitation, and then converting these into a binary format, where a value greater than zero was given a value of one and a value less than zero was kept at zero (*29*). The twelve binary files were then summed to calculate the number of months with a positive water balance.

Mean annual Normalised Difference Vegetation Index (NDVI) was calculated from monthly values which were downloaded from the EDIT Geoplatform (http://edit.csic.es/Soil-Vegetation-LandCover.html). NDVI is commonly used to measure the density of plant growth and is obtained from NOAA AVHRR satellite

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images. A negative value indicates snow or ice, a value around 0 indicates barren areas, values between 0.2 and 0.3 indicate grassland, and values near 1 indicate rainforests (*30*). Human influence index was downloaded from the SEDAC website (http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-influence-index-geographic). This was a composite of human population density, railways, roads, navigable rivers, coastlines, night-time lights, built-up areas and agricultural and urban land cover. Values within the index range from 0 to 64, where zero equalled no human influence and 64 represented maximum human influence (*31*). Solar radiation was calculated using the Spatial Analyst function in ArcGIS 10.1 (ESRI, California, USA). Solar radiation is defined as the total amount of incoming solar insolation (direct and diffuse), or global radiation, and was measured in watt hours per square meter or WH/m^2 (*32*). An index of surface roughness was also calculated by finding the difference between maximum and minimum gradient values, based on a global Digital Elevation Model at 30 arc-second resolution downloaded from WorldClim (*33*). Altitude was not included as a variable independently because organisms perceive climatic and habitat variables as proxies for altitude (*34*).

Species distribution modelling

SDMs were run using MaxEnt (version 3.3.3k) (*35*, *36*). Models used two different sets of input data: i) pre- and post-1950s data, or, ii) post-1950s data only. For some species, the set of input data used affected the model outcome substantially. The ‘species with data’ (SWD) format was used for data entry pairing pre-1950 records with mean climatic variables from 1900-1949 and post-1950 records with mean data from 1950-2000. The models were validated using either 10 replicate bootstrapping for species

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with low numbers of records (<30) or 4-fold cross-validation for species with high numbers of records (≥30). Linear, quadratic and product feature types were used. The 10 percentile threshold was applied to define likely presence and absence of each species. Records for each species were associated with global land cover data downloaded from the ESA GlobCover 2009 Project and any land class not occupied by the target species was marked as unsuitable. Thus, two sets of model outputs were created: i) showing suitable bioclimatic space (i.e. model predictions), and, ii) bioclimatic space restricted to occupied habitat (i.e. model predictions clipped to suitable habitats). Outputs were then clipped to a minimum convex polygon of the species occurrence records, buffered by a distance value specific to each species which was verified by experts from the IUCN Lagomorph Specialist Group, to remove areas of over-prediction. This meant that the suitable area within reach of each species was predicted, and led to much more realistic outputs than just simply predicting suitable area.

Introduced ranges for the European hare (*Lepus europaeus*) and rabbit (*Oryctolagus cuniculus*) were not modelled due to lack of records (common species are frequently under-recorded). Mountain hare (*Lepus timidus*) populations in Ireland and mainland Eurasia were modelled separately due to the distinct ecological differences between the two (*37*) but the outputs were subsequently combined to reflect the current classification of the Irish hare (*L. t. hibernicus*) as a sub-species of *L. timidus*.

Model evaluation

A bespoke website (lagomorphclimatechange.wordpress.com) was created to allow each expert to review the output of their allocated species. Experts selected either: i) pre- and

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post-1950 input data showing the suitable bioclimatic envelope, ii) pre- and post-1950 input data showing the suitable bioclimatic envelope restricted to suitable habitat, iii) post-1950 input data only showing the suitable bioclimatic envelope, or, iv) post-1950 input data only showing the suitable bioclimatic envelope restricted to suitable habitat. Experts selected the model perceived as optimal in describing the known pre-1950 and post-1950 range of species overlaid by the current IUCN range extent polygon. Expert evaluation classed each model as 'good', 'medium' or 'poor' according to the criteria in Anderson *et al.* (2003) (*9*). In addition to expert evaluation, models were assessed using Kappa as calculated in R (version 3.0.0). The 'accuracy' function in the SDMTools package (*38*) was used to calculate the Area under the Curve (AUC) value, omission rate, sensitivity, specificity, proportion correct, Kappa and True Skill Statistic (TSS). Models that had a Kappa >0.4 and those that were ranked as either 'good' or 'medium' by expert evaluation were defined as modellable and were carried forward for analysis, whilst those that had a Kappa <0.4 or were ranked as 'poor' by expert evaluation were defined as unmodellable and were rejected from further analysis (see Fig. S1). Kappa was used because it utilises commission and omission errors (*39*), and although it does not take into account prevalence like TSS (*40*), it has widely accepted thresholds (*41, 42, 43*) which make it best suited for use in this study. The optimum threshold for Kappa was taken as 0.4 (*40, 41, 42*). The model settings selected as providing the optimal outcome were used to predict species bioclimatic envelopes under future climate during the 2020s, 2050s and 2080s. Future predictions were clipped to the buffered minimum convex polygon of the target species further buffered by the dispersal distance (kilometres/year) of each species multiplied by the number of years elapsed from the present (1950-2000) taken as 1975. Annual dispersal distances were

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elicited from each species expert during the model evaluation procedure or taken from the literature. For some species where no data were available, the average for specific groups (i.e. Asian pikas or African hares) was used. Predicted range size, mean latitude and minimum, mean and maximum elevation for each species and each time period were calculated. Model outputs for each species can be found in the Supplementary Materials.

Species traits

Species trait data were downloaded from the PanTHERIA database (*44*) and updated by searching the literature. Correlated traits were removed to reduce collinearity and the final set of traits used to describe each modellable species were: activity cycle (nocturnal only, diurnal only, mixed), adult body mass (g), diet breadth (number of dietary categories eaten from: vertebrates, invertebrates, fruit, flowers/nectar/pollen, leaves/branches/bark, seeds, grass and roots/tubers), gestation length (days), habitat breadth (above ground-dwelling, aquatic, fossorial and ground-dwelling), home range (km^2), litters per year, litter size, population density (n/km^2) and age at sexual maturity (days).

Statistical analysis

To illustrate global change in the distribution of Lagomorphs, the difference in predicted species richness per cell was calculated between the 1930s (1900-1949) and 2080s (2070-2099). The difference in model output metrics (range size, mean latitude and minimum, mean and maximum elevation) was calculated between the 1930s and 2080s. Change in range size was expressed in percentage change but change in latitude

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was represented as degree movements towards poles and change in elevation in metres. GLMs were used to test the differences in temporal trends for range change, poleward movements and elevation between lagomorph groups: pikas, rabbits and hares and jackrabbits. PGLS regressions were then performed using the 'caper' (*45*) package in R to test whether changes in model predictions varied with species traits. A lagomorph phylogeny was extracted from the mammalian supertree provided by Fritz *et al.* (2009) (*46*). Likely clade membership for five species not included in this phylogeny was determined from Ge *et al*. (2013) (*26*) and the literature, and then missing tips were grafted on using an expanded tree approach (*47*). Outliers were removed prior to analysis identified as those with a studentized residual >3 following Cooper *et al.* (2012) (*48*). All subsequent models exhibited normally distributed residuals tested using Shapiro-Wilk. The scaling parameter lambda (λ) varies from 0, where traits are independent of phylogeny, to 1, where species' traits covary in direct proportion to their shared evolutionary history (*20*). We estimated λ for the overall model and tested its significance during the PGLS analysis. All subset regressions were run using the 'dredge' function in the 'MuMIn' (*49*) package in R and model averaging was used to describe the effect of each variate.

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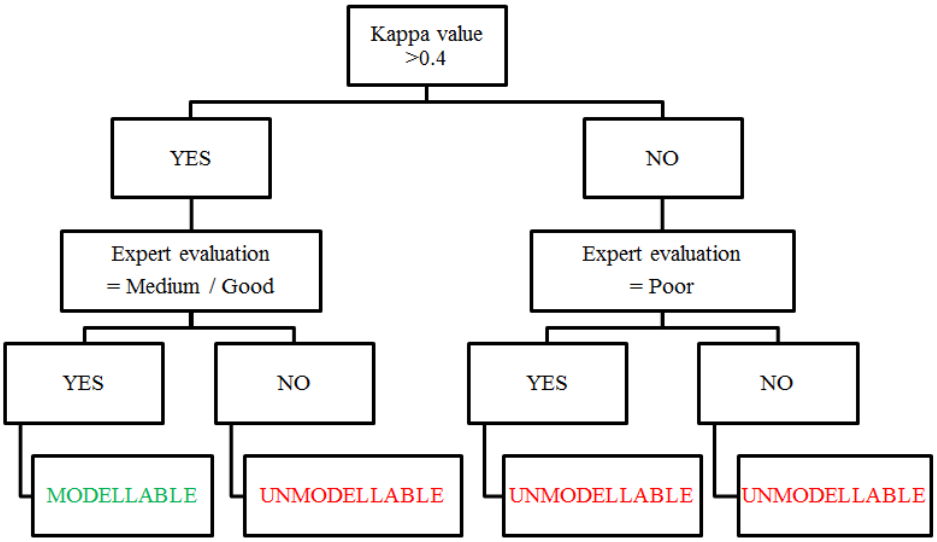

Figure S1. Framework for assessing whether species were modellable or unmodellable based on Kappa values and expert evaluation classification. The optimum threshold for Kappa was taken as 0.4 (*40*, *41*, *42*). Expert evaluations were classified according to Anderson *et al* (2003) (*9*).

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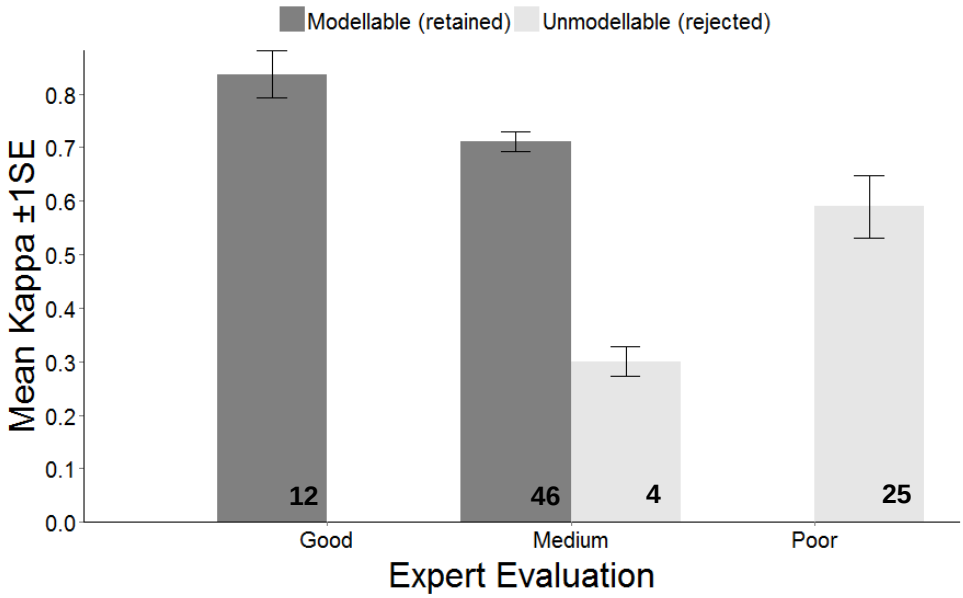

Figure S2. Agreement between expert evaluation and model accuracy. Mean Kappa ±1 standard error within the categories assigned by expert evaluation. Dark grey bars indicate species that were deemed modellable and retained for further analyses, whereas light grey bras indicate unmodellable species that were rejected. Sample sizes (i.e. numbers of species) are shown in the bars.

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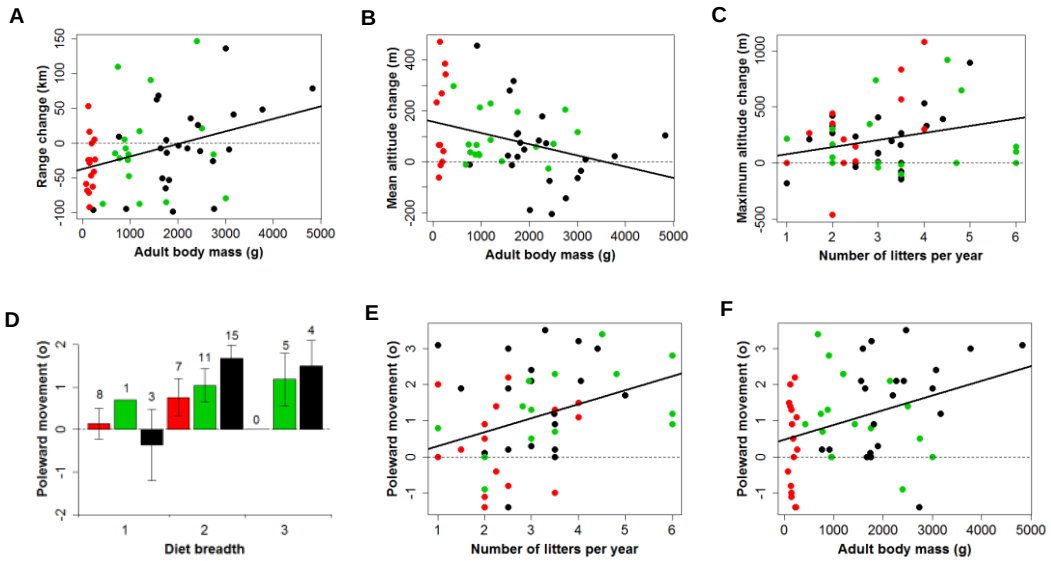

Figure S3. Relationships between species traits and responses to future climate change. The ability of species' traits to predict changes in **A**, range **B**, mean elevation **C**, maximum elevation and **D**, **E**, **F**, poleward movement under future climate (between ~1930s and ~2080s) for each group; pikas (red), rabbits (green) and hares and jackrabbits (black). Diet breadth is a categorical variable and is therefore represented as a bar plot (±1 standard error) with sample sizes (i.e. numbers of species) shown above the bars. Only significant predictors of change are shown here. The dashed line at zero indicates no change in the response variable.

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Table S1. Results of GLMs characterising predicted Lagomorph bioclimatic envelope changes. Significant *p* values are in bold. Group refers to Lagomorph taxonomy, i.e. pikas, rabbits and hares & jackrabbits.

Response variable	**Term**	***Deviance***	***Residual Deviance***	***F***	***Df***	***p***
Range change (km)	Group	0.217	4.334	6.467	2,229	**0.002**
	Year	0.085	4.249	5.033	1,228	**0.026**
	Group: Year	0.055	4.195	1.639	2,226	0.196
Mean latitudinal change (^{o})	Group	<0.001	<0.001	0.000	2,229	1.000
	Year	<0.001	<0.001	30.102	1,228	**<0.001**
	Group: Year	<0.001	<0.001	8.375	2,226	**<0.001**
Mean elevation change (m)	Group	1442316	9159926	19.856	2, 9	**<0.001**
	Year	716859	8443066	19.737	1, 8	**<0.001**
	Group: Year	234776	8208290	3.232	2, 6	**0.041**

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Table S2. Results of phylogenetically controlled generalised least square regressions. Significant *p* values for model-averaged coefficients are in bold. *F* and *p* values for the top model are listed under each response variable; asterisks (*) indicate traits in the top model. Lambda (λ) confidence intervals and significance from 0 and 1 are also shown.

Response variable	Trait	β ± s.e.	*F*	*p*
Range change (km)	Adult body mass (g)*	0.258 ± 0.112	2.308	**0.021**
$F_{df=4, 52}$=4.28, *p*=0.005	Diet breadth	0.137 ± 0.088	1.552	0.121
	Gestation length (days)	-0.154 ± 0.121	1.269	0.204
Lambda 95%CI=0, 0.147	Litters per year	0.090 ± 0.084	1.073	0.283
N.S. from 0, *p*<0.01 from 1	Litter size	-0.062 ± 0.098	0.634	0.526
	Home range size (km^2)	-0.069 ± 0.099	0.698	0.485
	Population density (n/km^2)	-0.079 ± 0.090	0.878	0.380
	Age at sexual maturity	-0.062 ± 0.089	0.694	0.488
	Activity cycle	0.020 ± 0.134	0.151	0.880
	Habitat breadth	0.050 ± 0.101	0.493	0.622
Mean latitudinal change (°)	Adult body mass (g)*	0.196 ± 0.099	1.989	**0.047**
$F_{df=5, 49}$=6.10, *p*<0.001	Diet breadth*	0.181 ± 0.082	2.190	**0.029**
	Litter size*	0.128 ± 0.097	1.320	0.187
Lambda 95%CI=0, 0.209	Litters per year*	0.215 ± 0.079	2.731	**0.006**
N.S. from 0, *p*<0.01 from 1	Activity cycle	0.097 ± 0.124	0.787	0.431
	Age at sexual maturity	-0.106 ± 0.084	1.254	0.210
	Home range size (km^2)	-0.088 ± 0.113	0.787	0.438
	Gestation length (days)	0.147 ± 0.132	1.112	0.266
	Habitat breadth	0.028 ± 0.093	0.304	0.761
	Population density (n/km^2)	0.027 ± 0.084	0.318	0.750
Mean elevation change (m)	Adult body mass (g)*	-0.183 ± 0.091	2.019	**0.043**
$F_{df=2, 50}$=5.92, *p*=0.005	Gestation length (days)	0.099 ± 0.106	0.932	0.351
	Diet breadth	-0.110 ± 0.079	1.386	0.166
Lambda 95%CI=0, 0.205	Home range size (km^2)	0.074 ± 0.075	0.986	0.324
N.S. from 0, *p*<0.01 from 1	Litters per year	-0.057 ± 0.070	0.813	0.416
	Age at sexual maturity	0.055 ± 0.075	0.731	0.324
	Activity cycle	0.075 ± 0.105	0.708	0.479
	Population density (n/km^2)	0.064 ± 0.071	0.902	0.367
	Litter size	0.019 ± 0.079	0.235	0.814
	Habitat breadth	-0.005 ± 0.085	0.058	0.953
Max. elevation change (m)	Litters per year *	0.160 ± 0.092	1.746	0.081
$F_{df=2, 53}$=3.54, *p*=0.036	Gestation length (days)	-0.136 ± 0.116	1.169	0.242
	Habitat breadth	0.095 ± 0.102	0.934	0.351
Lambda 95%CI=0, 0.384	Age at sexual maturity	-0.098 ± 0.096	1.020	0.308
N.S. from 0, *p*<0.01 from 1	Activity cycle	0.041 ± 0.118	0.348	0.728
	Litter size	0.014 ± 0.104	0.137	0.891
	Population density (n/km^2)	0.054 ± 0.091	0.596	0.551
	Adult body mass (g)	0.034 ± 0.121	0.280	0.780
	Home range size (km^2)	-0.003 ± 0.107	0.029	0.977
	Diet breadth	0.004 ± 0.093	0.047	0.962

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Species accounts (#1-89)

Key for response curves

Abbreviation	Description
HII	Human Influence index
Hilliness	Surface Roughness index
MaxPrec	Maximum precipitation
MaxTemp	Maximum temperature
MinPrec	Minimum precipitation
MinTemp	Minimum temperature
PrecSea	Precipitation seasonality
RealMAR	Mean annual precipitation
RealMAT	Mean annual temperature
TempSea	Temperature seasonality
etpsum	Annual evapotranspiration
ndvi	Normalised difference vegetation index
radiation	Solar radiation
wbann	Annual water balance
wbpos	Number of months with a positive water balance

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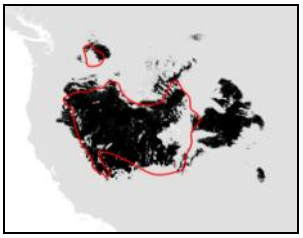
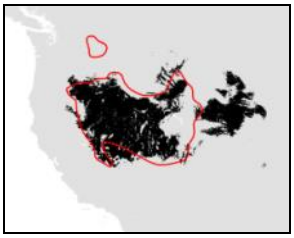
Species account #1 - Pygmy rabbit (*Brachylagus idahoensis*)
n = 39
Expert: Penny Becker, Washington Dept. of Fish & Wildlife, USA
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 15km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	1.00
Proportion correct	1.00
Kappa	**0.75**
True Skill Statistic	0.90

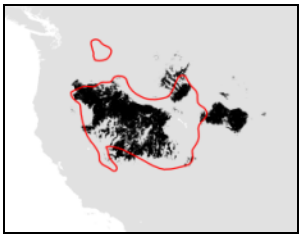
Summary: The Pygmy rabbit's bioclimatic envelope is predicted to decline by 87% with a 1° mean latitudinal poleward shift and mean increase in elevation of ~300m driven predominately by an increase in mean minimum elevation (>600m) with little change in mean maximum elevation (~50m). 95% of the permutation importance of the model was contributed to by mean annual temperature (64.5%), maximum temperature (25.2%) and annual water balance (5.9%).



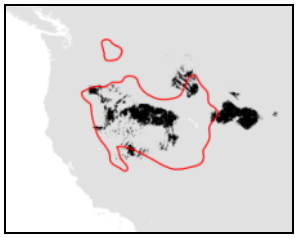
a) ~ 1930s (1900-1949)



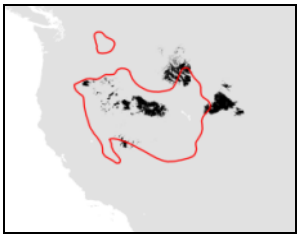
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



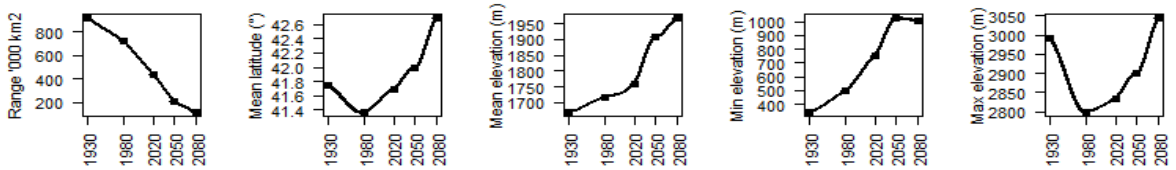
d) ~ 2050s (2040-2069)

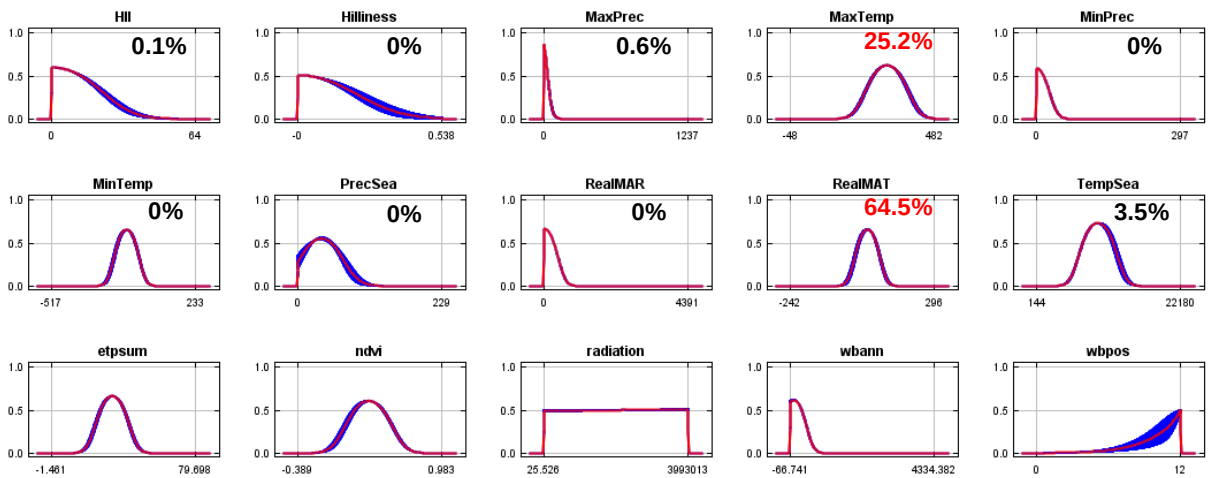


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Beauvais GP, *et al*. 2008)





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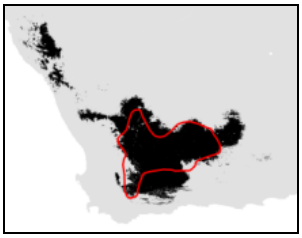
#2 - Riverine rabbit (*Bunolagus monticularis*)

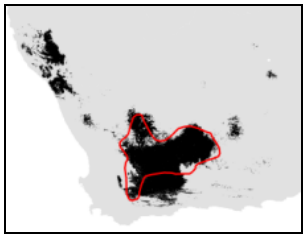
n = 109
Status: Kai Collins, University of Pretoria, South Africa
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.98
Omission rate	0.03
Sensitivity	0.97
Specificity	1.00
Proportion correct	1.00
Kappa	**0.85**
True Skill Statistic	0.97

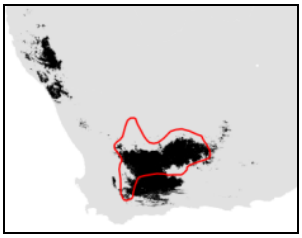
Summary: The Riverine rabbit's bioclimatic envelope is predicted to decline by 85% with a ~1° mean latitudinal poleward shift and mean increase in elevation of ~200m driven by similar increases in both minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by minimum temperature (33.1%) and precipitation (22.5%), temperature seasonality (22.3%), mean annual temperature (6.7%) and precipitation (5.0%), annual evapotranspiration (4.3%) and precipitation seasonality (2.6%).



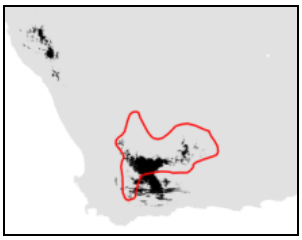
a) ~ 1930s (1900-1949)



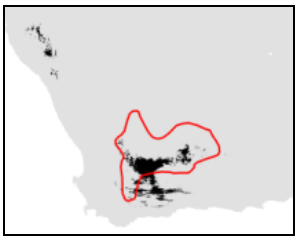
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



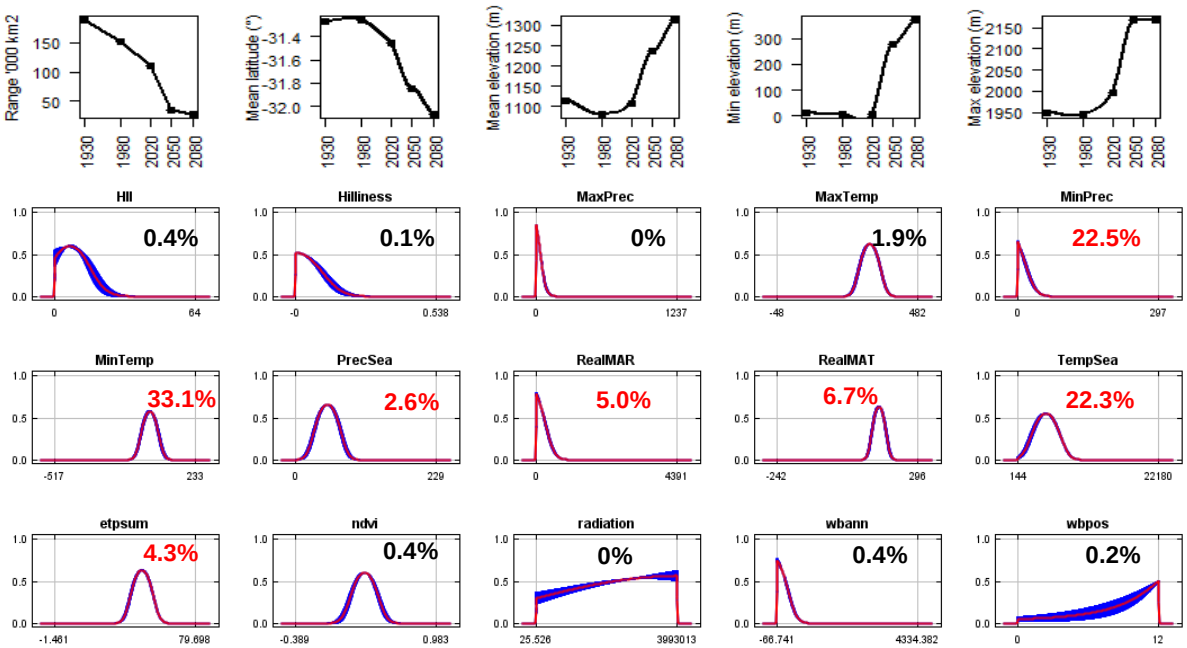
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Beauvais GP, *et al*. 2008)



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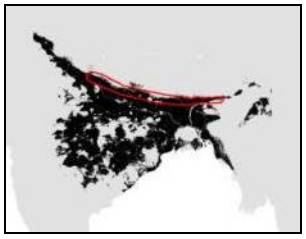
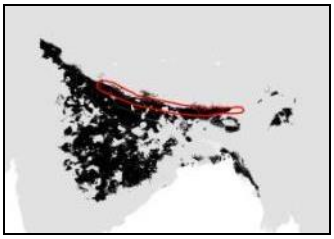
#3 - Hispid hare (*Caprolagus hispidus*)
n = 18
Expert: Gopinathan Maheswaran, Zoological Survey of India
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 5km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.97
Omission rate	0.06
Sensitivity	0.94
Specificity	0.99
Proportion correct	0.99
Kappa	**0.81**
True Skill Statistic	0.94

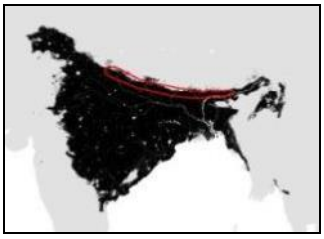
Summary: The Hispid hare's bioclimatic envelope is predicted to increase by 21% with a ~1.5° mean latitudinal poleward shift and mean increase in elevation of ~70m driven by increases in maximum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (52.7%), precipitation seasonality (29.0%), annual evapotranspiration (6.6%), number of months with a positive water balance (2.9%), maximum precipitation (2.2%) and minimum temperature (1.7%).



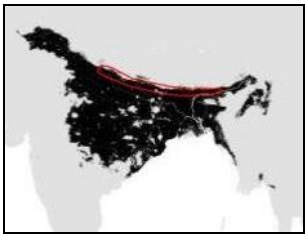
a) ~ 1930s (1900-1949)



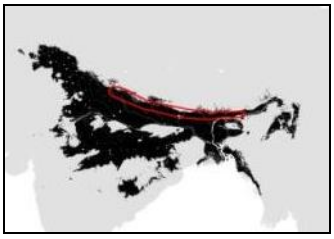
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



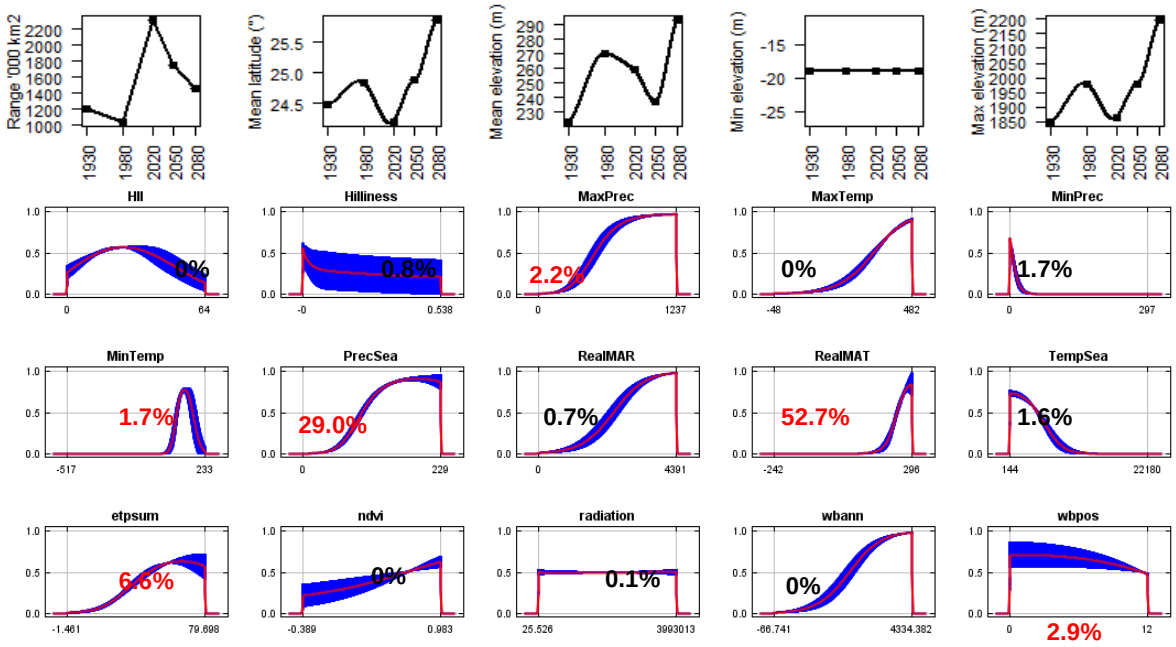
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Maheswaran, G. & Smith, A.T. 2008)



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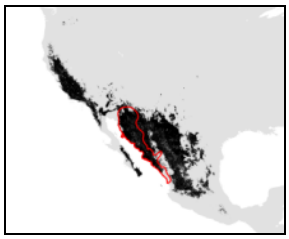
#4 – Antelope jackrabbit (*Lepus alleni*)

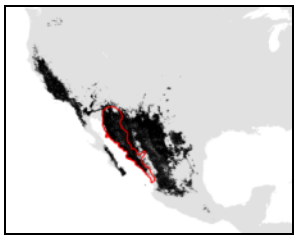
n = 32
Expert: Paul Krausman, University of Montana
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 25km/year (Expert)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.91
Omission rate	0.16
Sensitivity	0.84
Specificity	0.99
Proportion correct	0.98
Kappa	**0.26**
True Skill Statistic	0.83

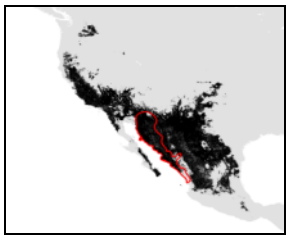
Summary: The Antelope jackrabbit's bioclimatic envelope is predicted to increase by 172% with a ~3° mean latitudinal poleward shift and mean increase in elevation of ~20m driven by increases in maximum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (24.8%), minimum precipitation (21.1%), annual water balance (16.3%), minimum temperature (13.0%), temperature seasonality (7.3%), normalised difference vegetation index (5.8%), annual evapotranspiration (5.2%) and human influence index (3.7%).



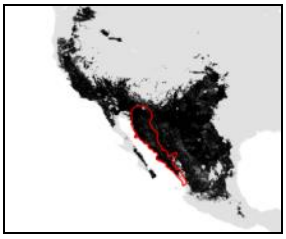
a) ~ 1930s (1900-1949)



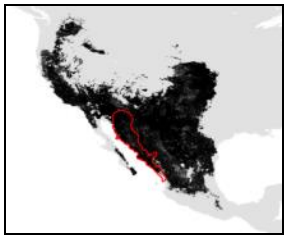
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



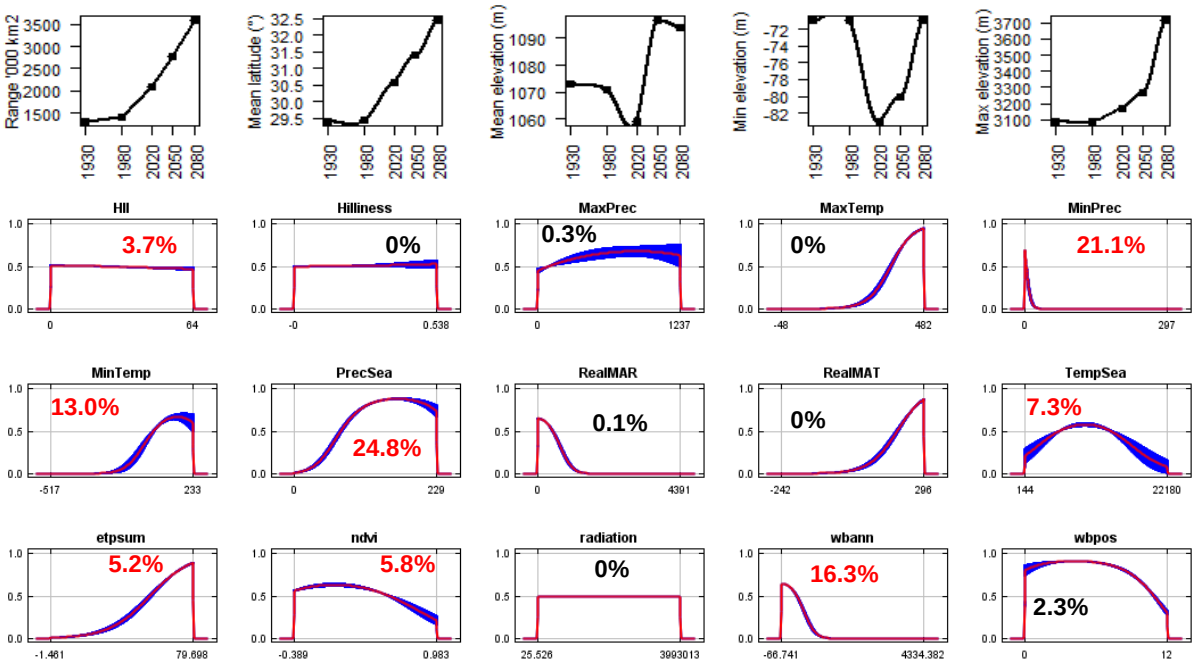
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Malpica, F.J. & Rangel Cordero, H. 2008)



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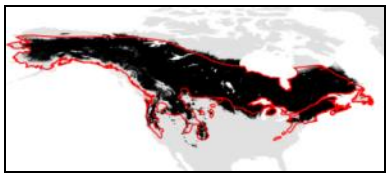
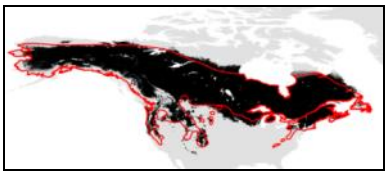
#5 – Snowshoe hare (*Lepus americanus*)
n = 506
Expert: Charles Krebs, University of British Colombia & Rudy Boonstra, University of Toronto
Expert evaluation: Good
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 24km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.07
Sensitivity	0.93
Specificity	0.97
Proportion correct	0.97
Kappa	**0.72**
True Skill Statistic	0.90

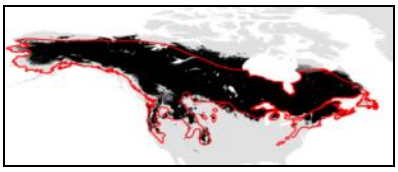
Summary: The Snowshoe hare's bioclimatic envelope is predicted to decline by 7% with a ~2° mean latitudinal poleward shift and mean decrease in elevation of ~10m, but with increases in both minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (83.1%), maximum temperature (7.2%), normalised difference vegetation index (2.1%), mean annual precipitation (1.5%) and annual evapotranspiration (1.2%).



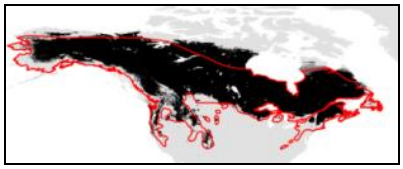
a) ~ 1930s (1900-1949)



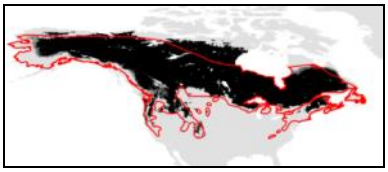
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



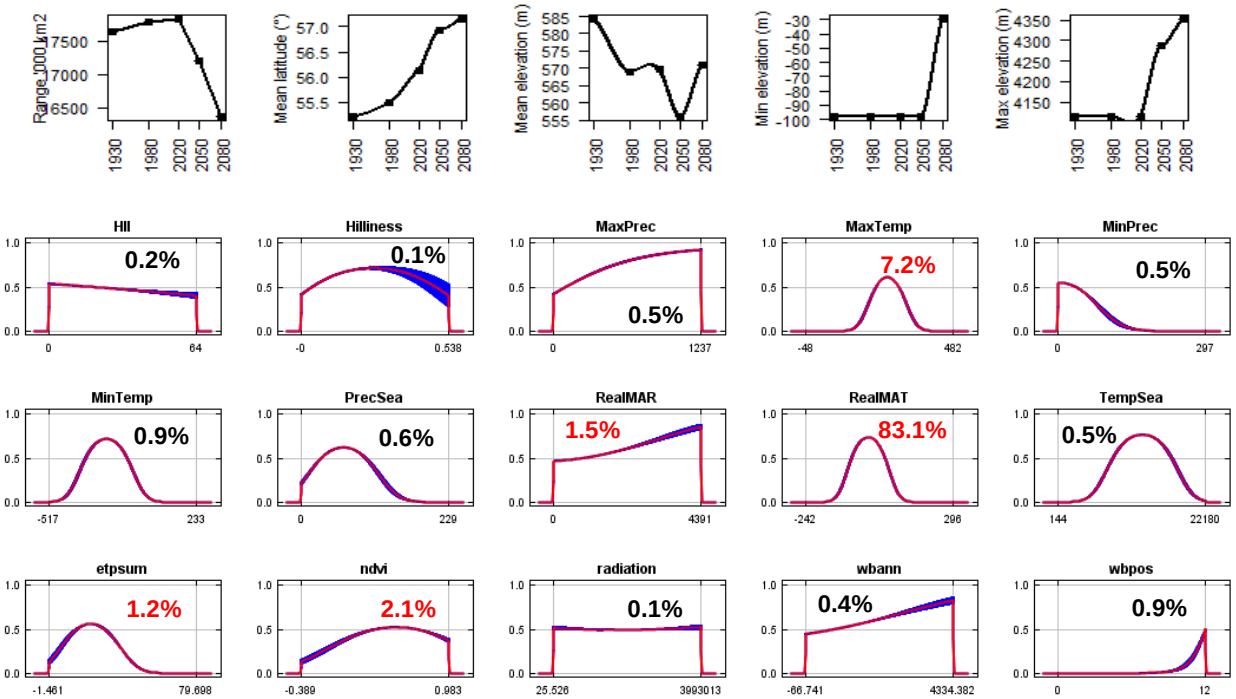
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Murray, D. & Smith, A.T. 2008)



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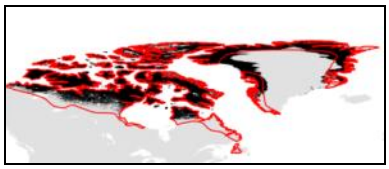
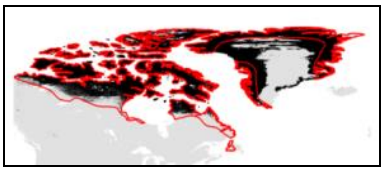
#6 – Arctic hare (*Lepus arcticus*)
n = 18
Expert: David Gray, Grayhound Information Services
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Chapman & Flux, 1990)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.97
Omission rate	0.06
Sensitivity	0.94
Specificity	0.99
Proportion correct	0.99
Kappa	**0.36**
True Skill Statistic	0.94

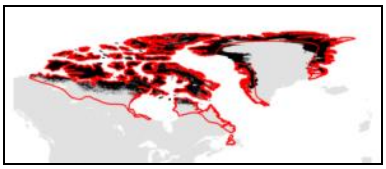
Summary: The Arctic hare's bioclimatic envelope is predicted to decline by 30% with a ~2° mean latitudinal poleward shift and mean decrease in elevation of ~10m driven by decreases in maximum elevation. 95% of the permutation importance of the model was contributed to by maximum temperature (34.0%), annual evapotranspiration (15.4%), surface roughness index (14.4%), human influence index (10.1%), normalised difference vegetation index (9.2%), mean annual temperature (4.4%), precipitation seasonality (1.5%), mean annual precipitation (1.5%), maximum precipitation (0.3%), minimum precipitation (0.3%), solar radiation (0.3%), minimum temperature (0.1%) and number of months with a positive water balance (0.1%).



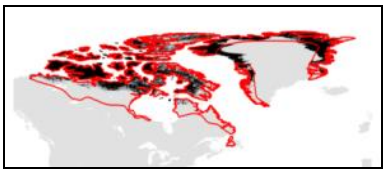
a) ~ 1930s (1900-1949)



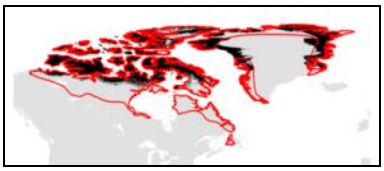
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



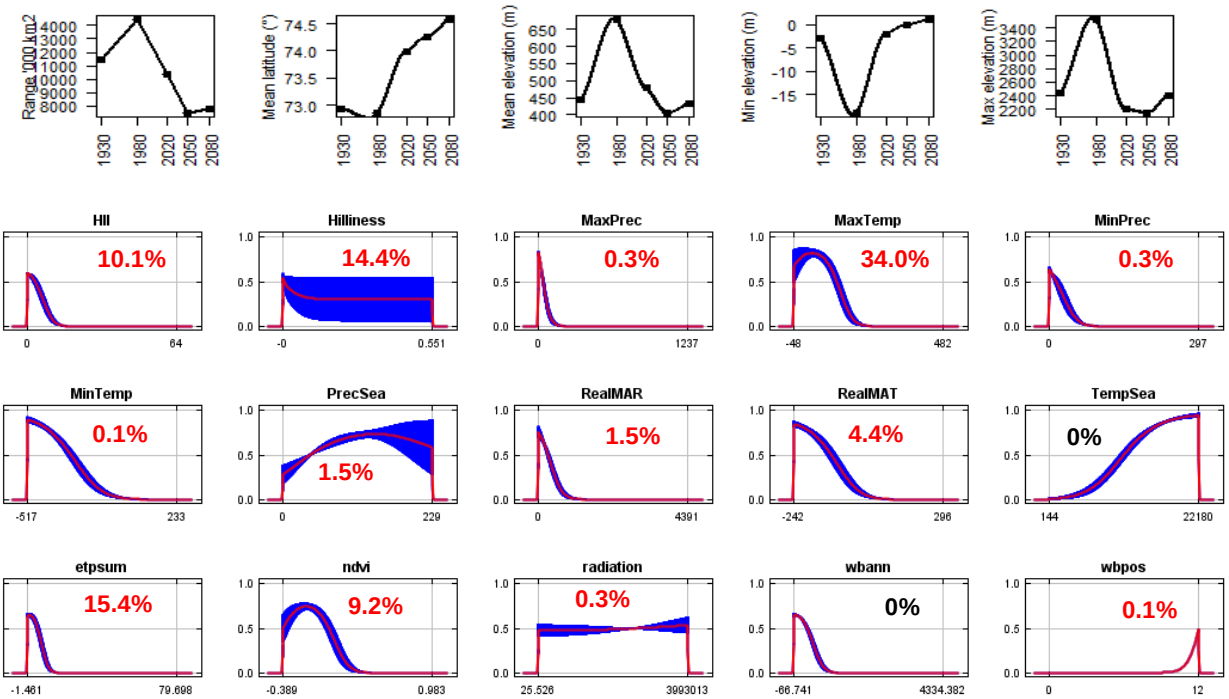
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Murray, D. & Smith, A.T. 2008)



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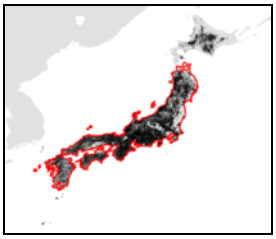
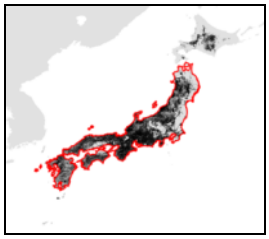
#7 – Japanese hare (*Lepus brachyurus*)
n = 9
Expert: Koji Shimano, Shinshu University, Japan
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.43**
True Skill Statistic	0.99

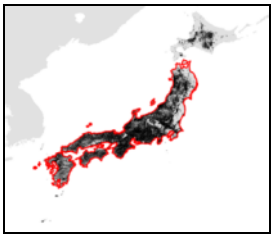
Summary: The Japanese hare's bioclimatic envelope is predicted to increase by 9% with no latitudinal poleward shift and a mean increase in elevation of ~10m driven by a decrease in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (31.8%), annual water balance (20.6%), human influence index (13.5%), mean annual precipitation (8.9%), maximum precipitation (6.2%), precipitation seasonality (5.4%) and minimum precipitation (4.4%).



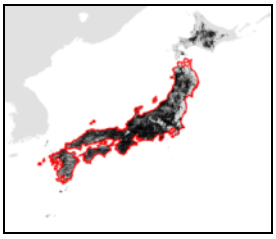
a) ~ 1930s (1900-1949)



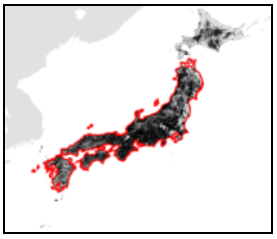
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



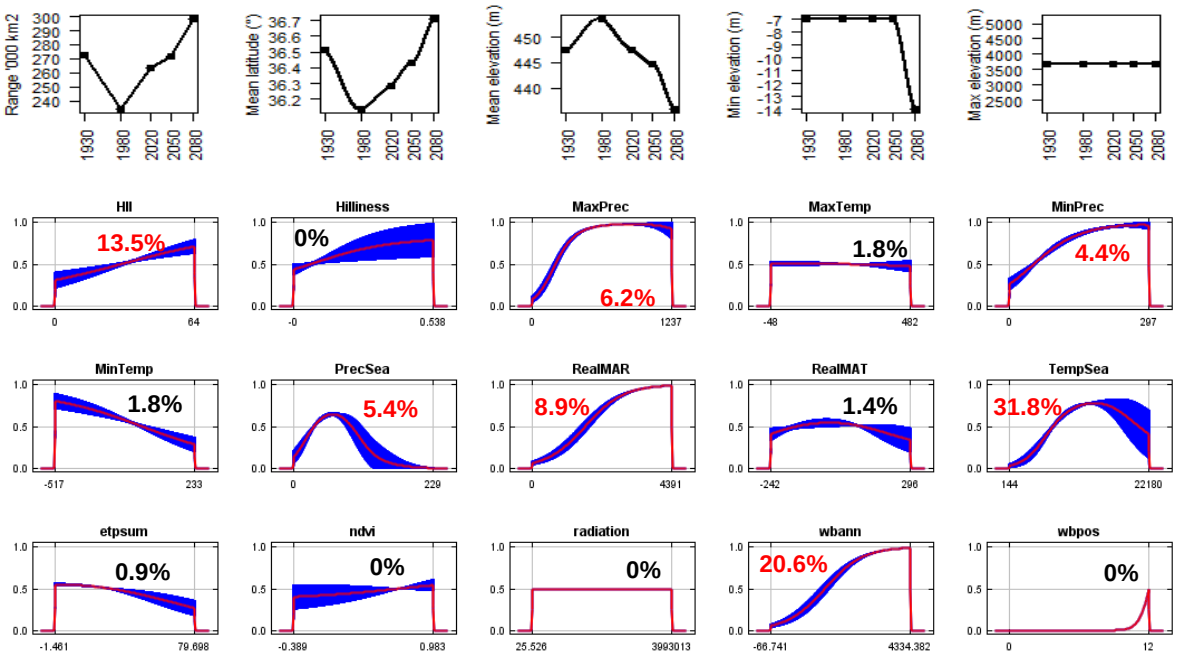
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Yamada, F. & Smith, A.T. 2008)



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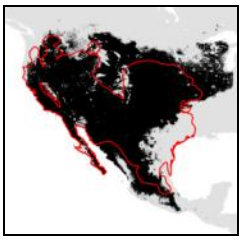
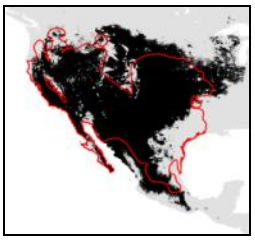
#8 – Black-tailed jackrabbit (*Lepus californicus*)
n = 970
Expert: Alejandro Velasquez, UNAM-Canada
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1.5km/year (Average for NA leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.93
Omission rate	0.07
Sensitivity	0.93
Specificity	0.94
Proportion correct	0.94
Kappa	**0.69**
True Skill Statistic	0.87

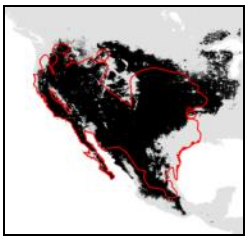
Summary: The Black-tailed jackrabbit's bioclimatic envelope is predicted to decline by 25% with a ~2° mean latitudinal poleward shift and mean decrease in elevation of ~75m, but with increases in both minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (31.8%), annual evapotranspiration (18.5%), maximum temperature (17.0%), mean annual temperature (8.9%), minimum temperature (8.0%), minimum precipitation (4.0%), human influence index (3.9%) and temperature seasonality (3.5%).



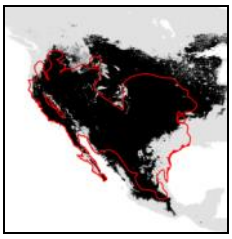
a) ~ 1930s (1900-1949)



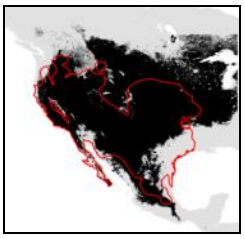
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



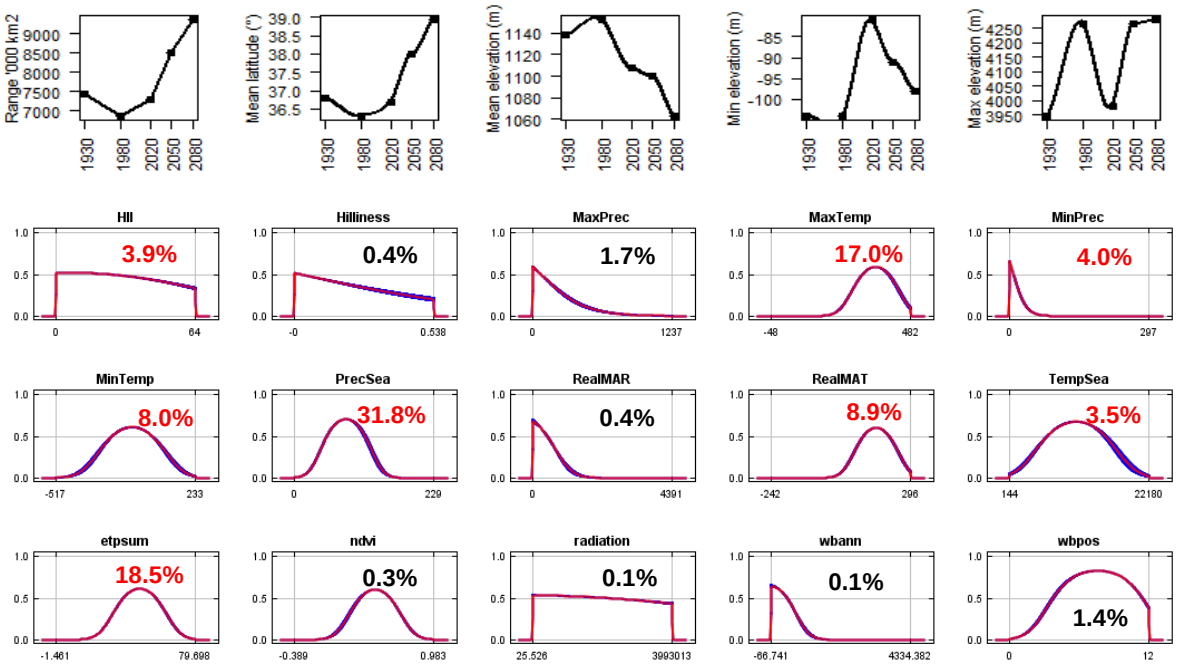
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)



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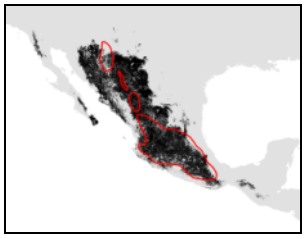
#9 – White-sided jackrabbit (*Lepus callotis*)

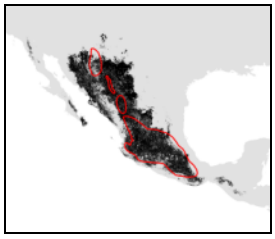
n = 37
Expert: Jennifer Frey, New Mexico State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 18.9km/year (Average for NA leporids)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.97
Omission rate	0.05
Sensitivity	0.95
Specificity	0.99
Proportion correct	0.99
Kappa	**0.36**
True Skill Statistic	0.93

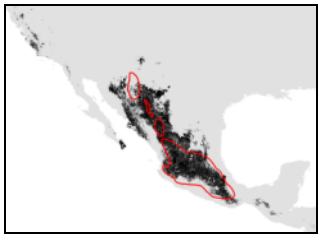
Summary: The White-sided jackrabbit's bioclimatic envelope is predicted to increase by 3% with a ~1° mean latitudinal poleward shift and a mean increase in elevation of ~150m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (35.4%), annual evapotranspiration (22.3%), minimum temperature (17.0%), mean annual temperature (10.5%), minimum precipitation (6.5%), maximum precipitation (6.5%), surface roughness index (3.0%) and number of months with a positive water balance (2.7%).



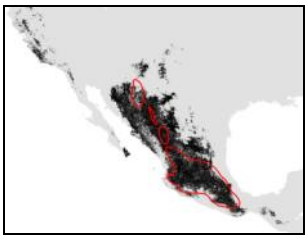
a) ~ 1930s (1900-1949)



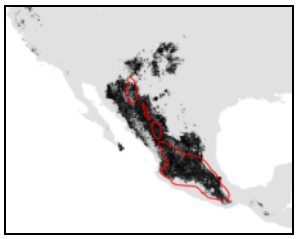
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



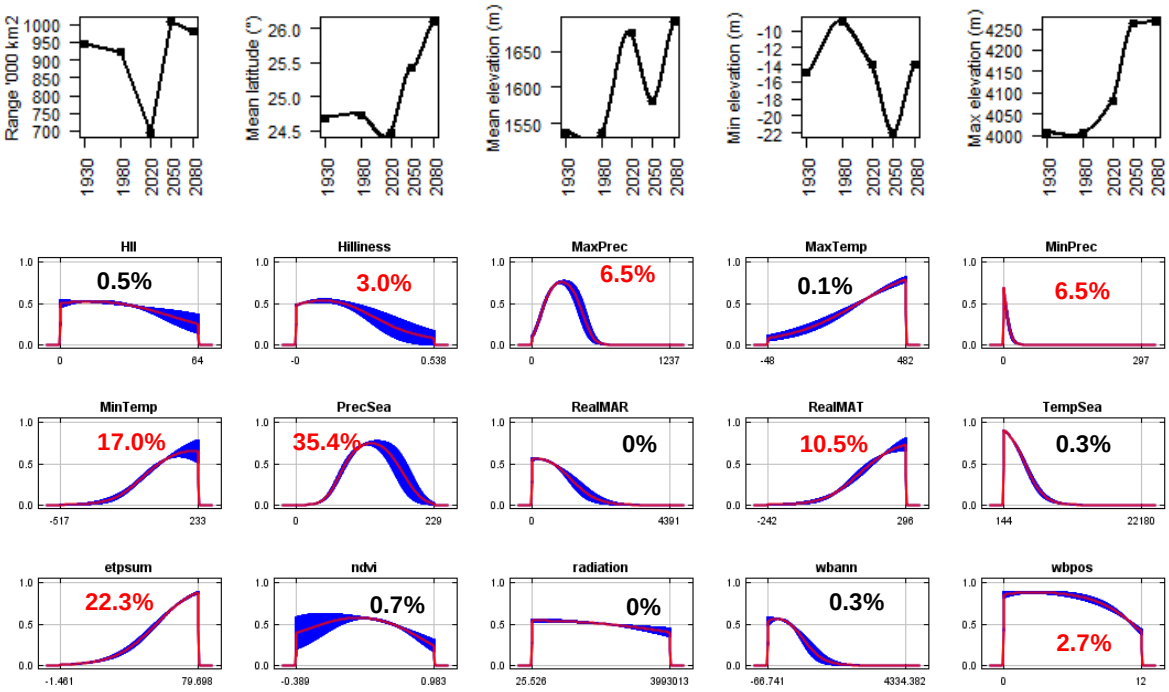
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)



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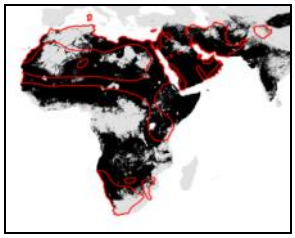
#10 – Cape hare (*Lepus capensis*)

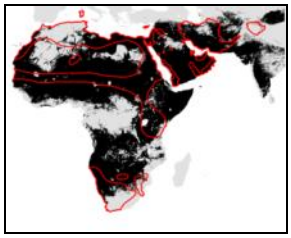
n = 231
Expert: John Flux, IUCN Lagomorph Specialist Group
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 35km/year (Expert)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.93
Omission rate	0.10
Sensitivity	0.90
Specificity	0.97
Proportion correct	0.97
Kappa	**0.56**
True Skill Statistic	0.87

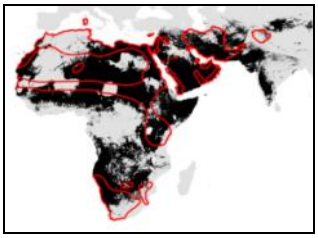
Summary: The Cape hare's bioclimatic envelope is predicted to decrease by 45% with ~2° mean latitudinal shift towards the Equator and a mean increase in elevation of ~330m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (33.1%), minimum precipitation (29.6%), maximum temperature (9.7%), human influence index (7.2%), normalised difference vegetation index (4.6%), minimum temperature (3.2%), number of months with a positive water balance (2.9%), maximum precipitation (2.2%), mean annual precipitation (2.1%) and precipitation seasonality (2.0%).



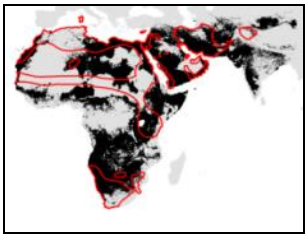
a) ~ 1930s (1900-1949)



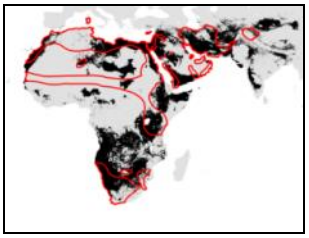
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



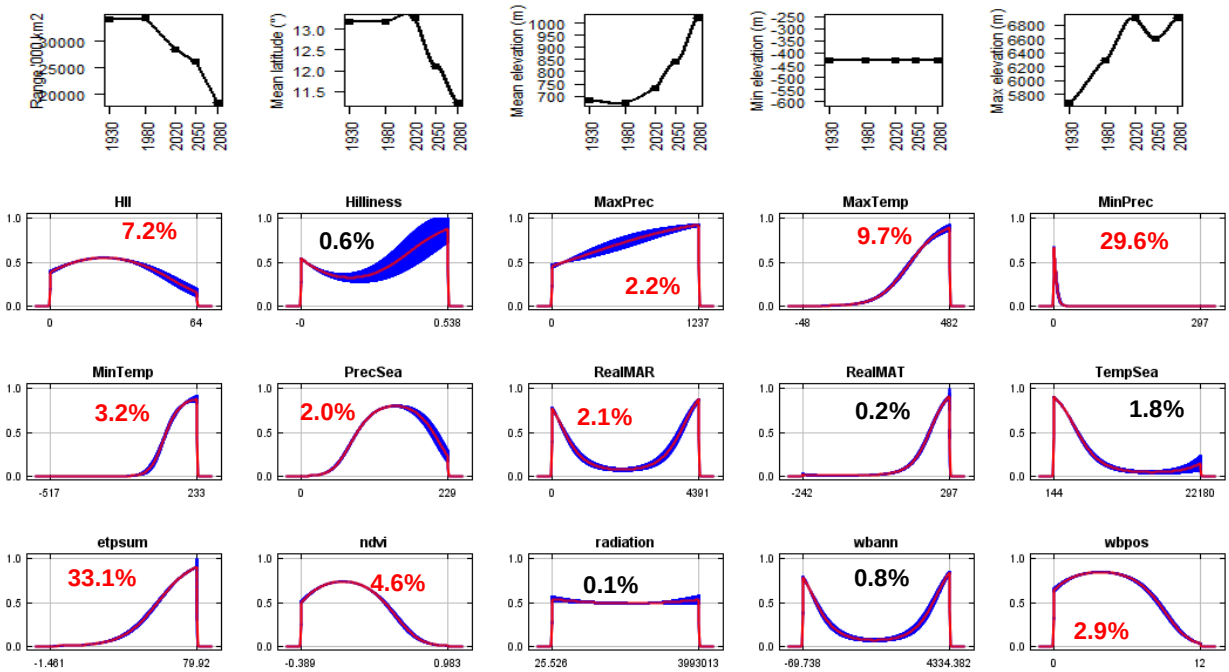
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Drew, C., *et al*. 2008)



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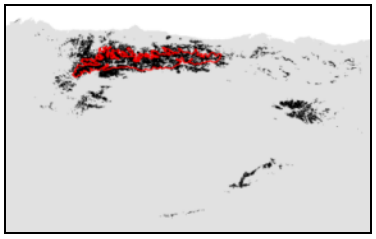
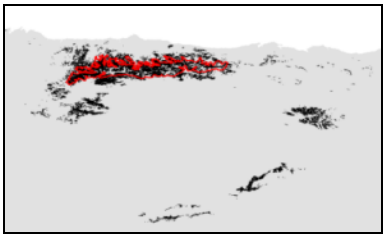
#11 – Broom hare (*Lepus castroviejoi*)
n = 164
Expert: Pelayo Acevedo, University of Porto
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Average for European leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.80**
True Skill Statistic	0.89

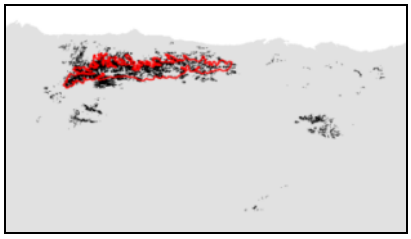
Summary: The Broom hare's bioclimatic envelope is predicted to decrease by 90% with a ~0.2° mean latitudinal poleward shift and a mean increase in elevation of ~450m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (62.0%), maximum temperature (20.6%), temperature seasonality (10.9%) and surface roughness index (3.8%).



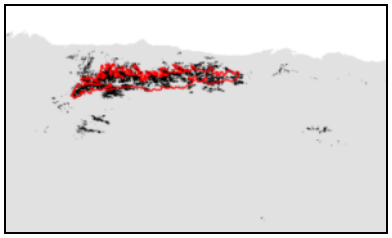
a) ~ 1930s (1900-1949)



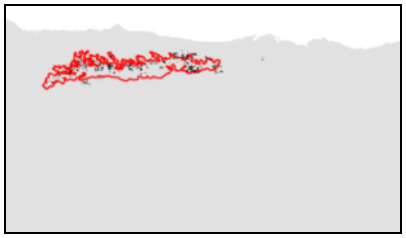
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



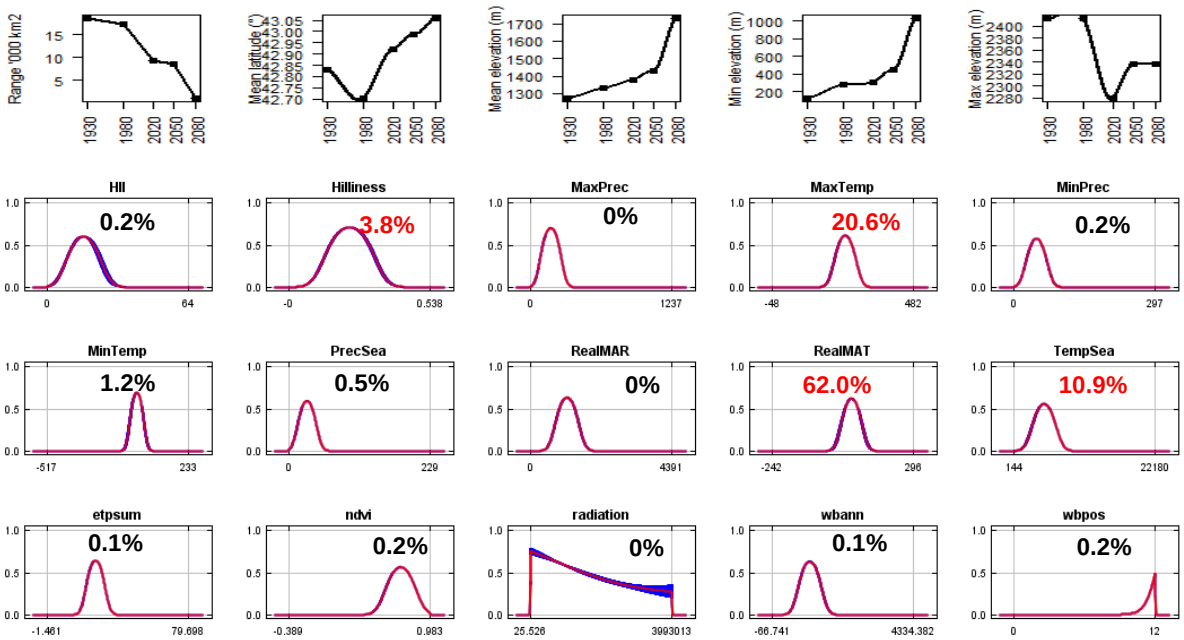
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

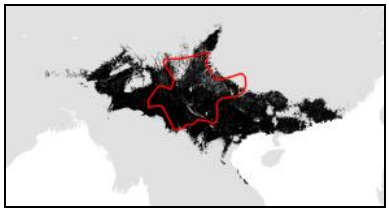
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



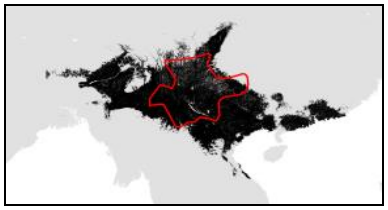
#12 – Yunnan hare (*Lepus comus*)
n = 59
Expert: Weihe Yang, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.92
Omission rate	0.15
Sensitivity	0.85
Specificity	0.99
Proportion correct	0.99
Kappa	**0.67**
True Skill Statistic	0.84

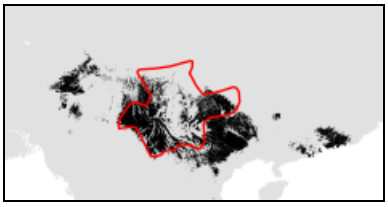
Summary: The Yunnan hare's bioclimatic envelope is predicted to decrease by 65% with a ~0.1° mean latitudinal poleward shift and a mean increase in elevation of ~100m driven by both increases in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (59.9%), maximum temperature (26.8%), temperature seasonality (2.9%), number of months with a positive water balance (2.6%), annual evapotranspiration (2.0%) and mean annual temperature (1.7%).



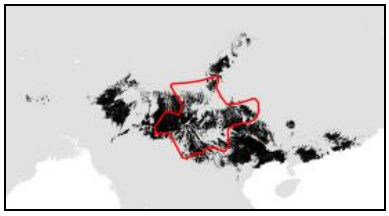
a) ~ 1930s (1900-1949)



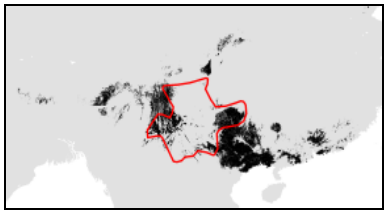
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



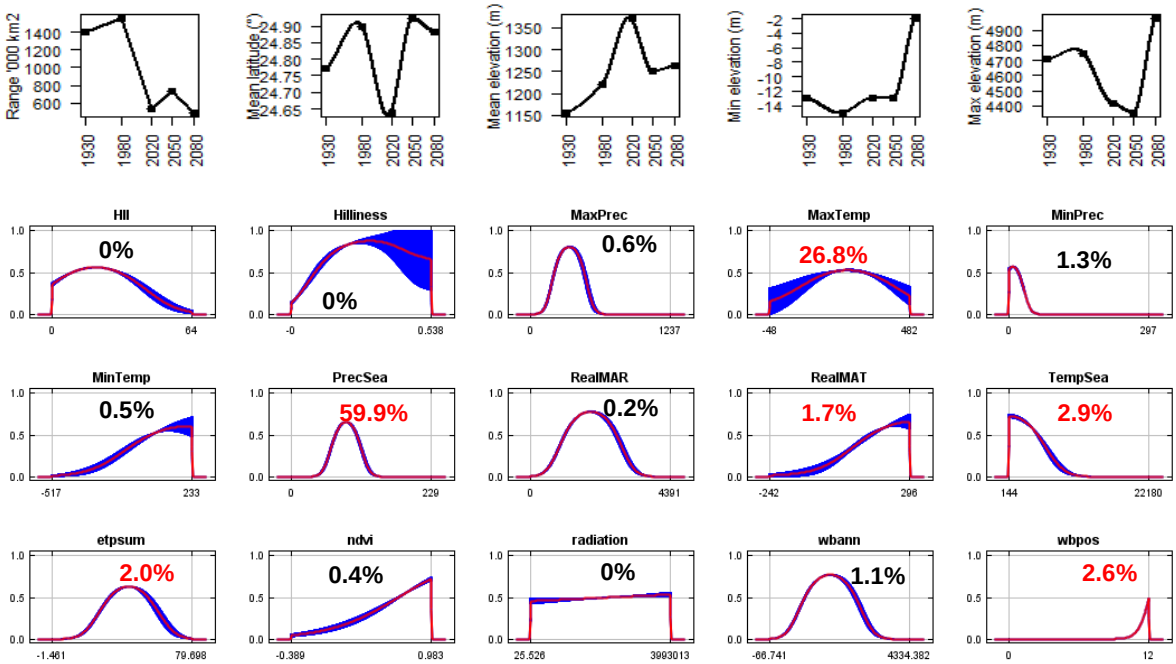
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

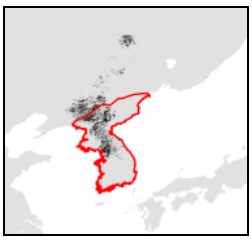
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

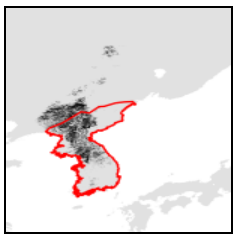


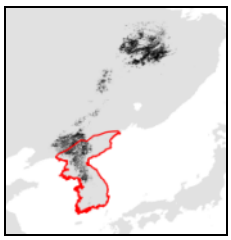
#13 – Korean hare (*Lepus coreanus*)
n = 6
Expert: Weihe Yang, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

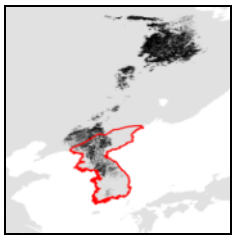
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.86**
True Skill Statistic	0.99

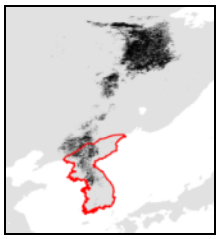
Summary: The Korean hare's bioclimatic envelope is predicted to increase by 500% with a ~8° mean latitudinal poleward shift and a mean increase in elevation of ~70m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (27.2%), mean annual precipitation (25.6%), minimum temperature (17.7%), annual water balance (13.1%), normalised difference vegetation index (4.7%), precipitation seasonality (4.5%) and human influence index (2.4%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

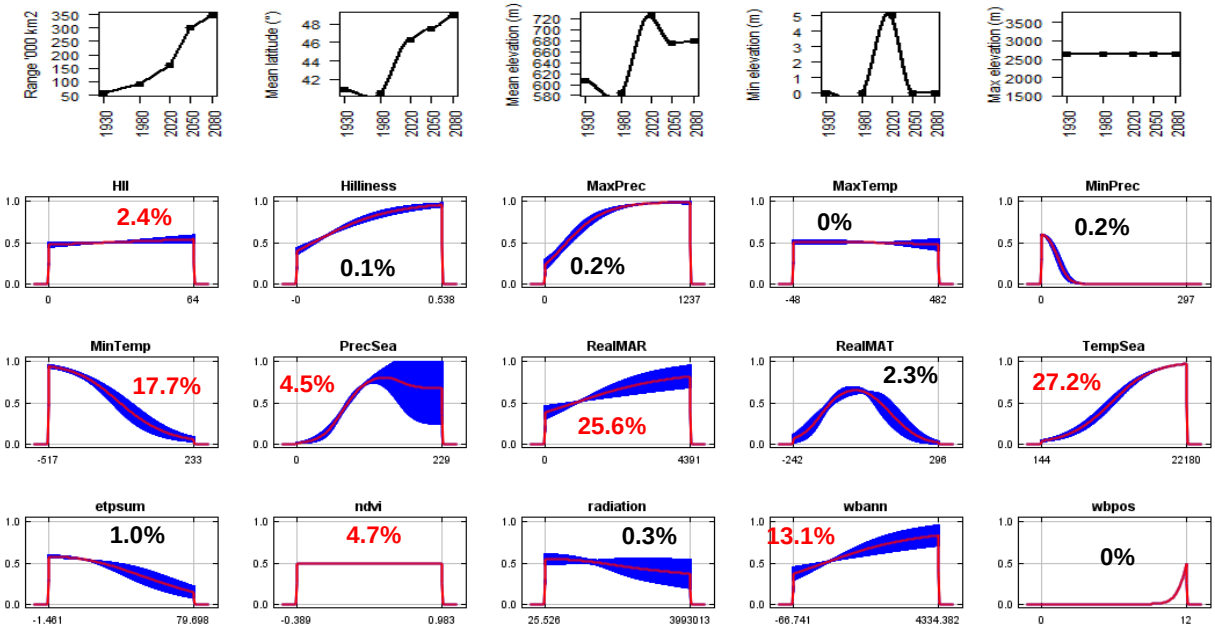

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

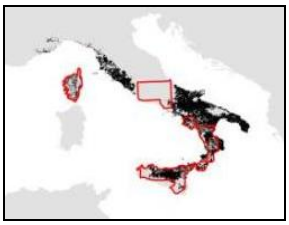
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

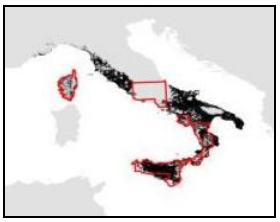


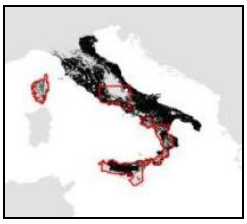
#14 – Apennine hare (*Lepus corsicanus*)
n = 59
Expert: Francesco Angelici, Italian Foundation of Vertebrate Zoology
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Expert)
Status: MODELLABLE

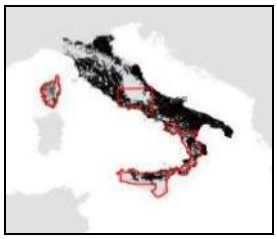
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.53**
True Skill Statistic	0.99

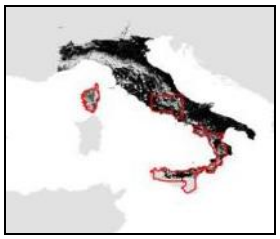
Summary: The Apennine hare's bioclimatic envelope is predicted to increase by 125% with a ~2° mean latitudinal poleward shift and a mean decrease in elevation of ~60m. 95% of the permutation importance of the model was contributed to by minimum temperature (37.9%), annual evapotranspiration (34.3%), temperature seasonality (11.4%), minimum precipitation (11.1%) and maximum temperature (2.8%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

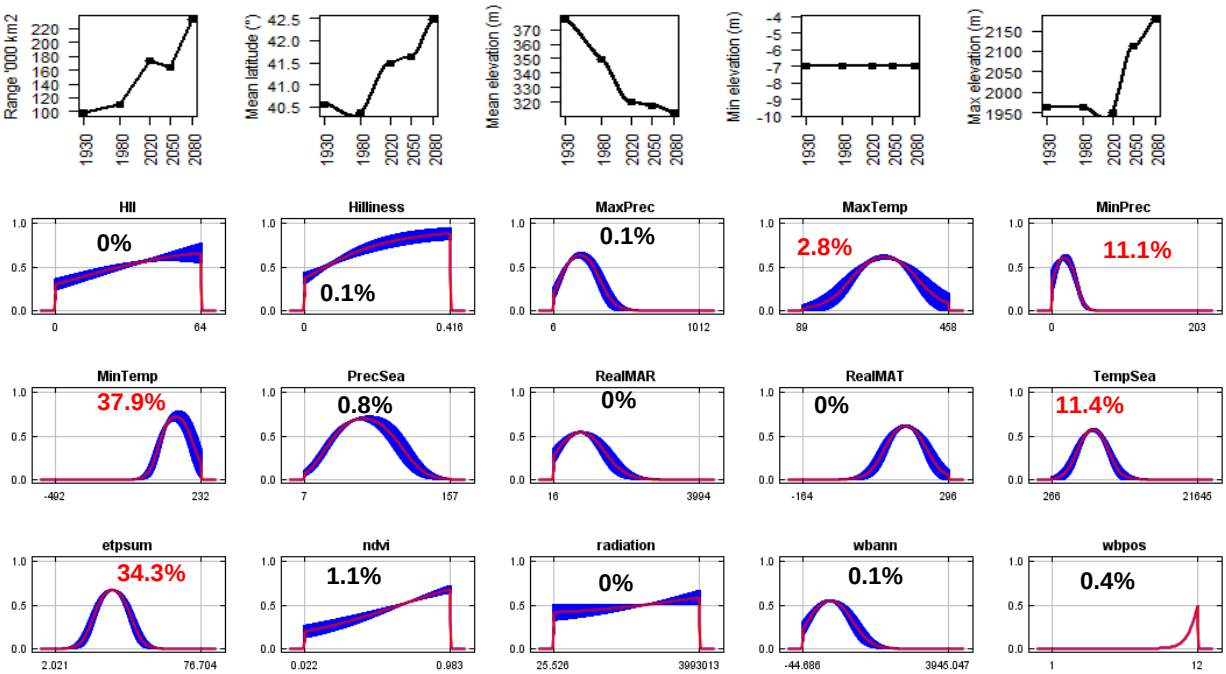

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

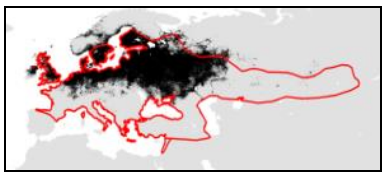
Red polygon = IUCN range (Angelici, F.M., Randi, E., Riga, F. & Trocchi, V. 2008)



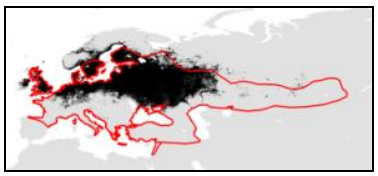
#15 – European hare (*Lepus europaeus*)-native range only
n = 6,186
Expert: Neil Reid, Queen's University Belfast
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Chapman & Flux, 1990)
Status: MODELLABLE

Model evaluation metric	
AUC	0.81
Omission rate	0.07
Sensitivity	0.93
Specificity	0.69
Proportion correct	0.78
Kappa	**0.57**
True Skill Statistic	0.62

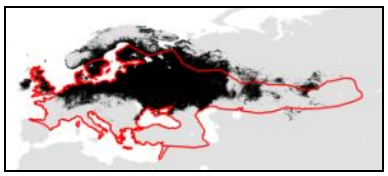
Summary: The European hare's bioclimatic envelope is predicted to increase by 50% with a ~3° mean latitudinal poleward shift and a mean increase in elevation of ~20m driven by an increase in both maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (58.0%), minimum temperature (9.0%), temperature seasonality (7.3%), surface roughness index (5.5%), human influence index (5.1%), precipitation seasonality (3.3%), annual water balance (3.3%), minimum precipitation (3.0%), normalised difference vegetation index (2.4%) and mean annual temperature (1.5%).



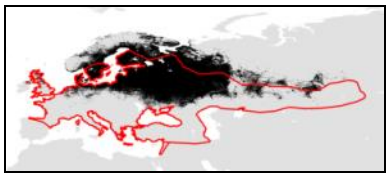
a) ~ 1930s (1900-1949)



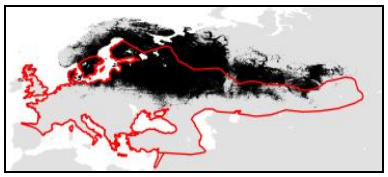
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



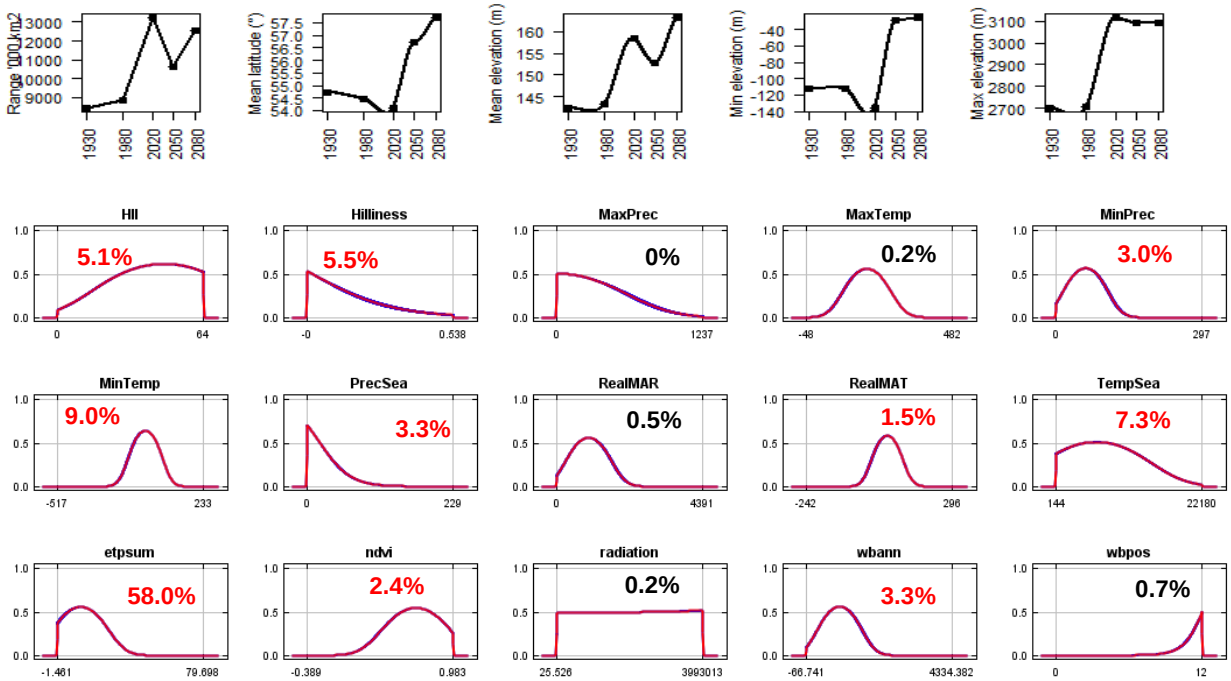
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

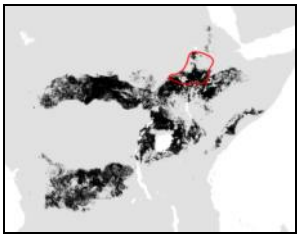
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

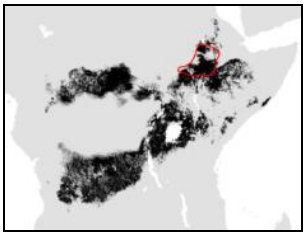


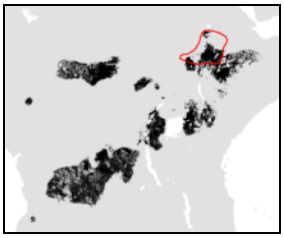
#16 – Ethiopian hare (*Lepus fagani*)
n = 9
Expert: Zelalem Tolesa, Addis Ababa University
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 8km/year (Average for African leporids)
Status: UNMODELLABLE

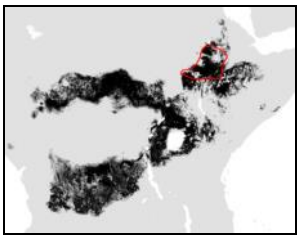
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.56**
True Skill Statistic	0.99

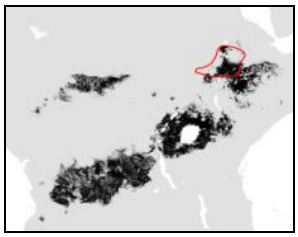
Summary: The Ethiopian hare's bioclimatic envelope is predicted to decrease by 15% with no latitudinal poleward shift and a mean increase in elevation of ~200m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (92.7%) and annual evapotranspiration (5.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

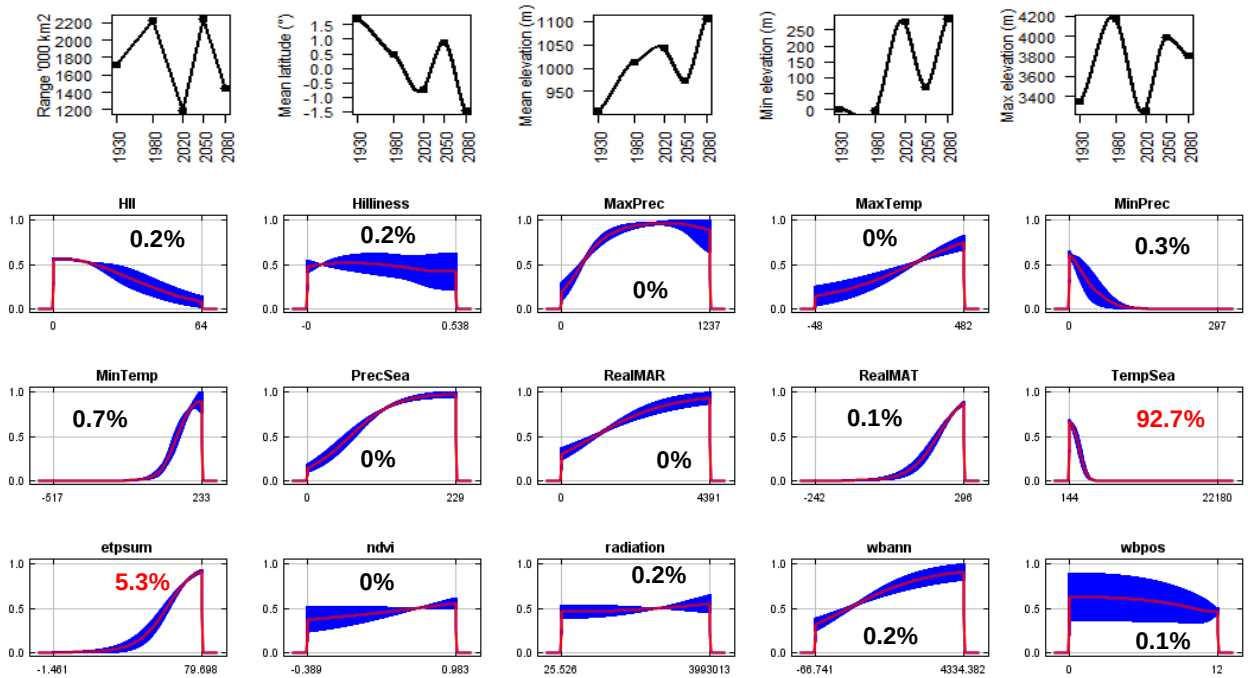

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

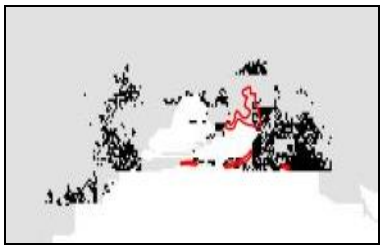
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



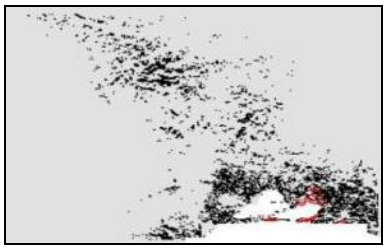
#17 – Tehuantepec jackrabbit (*Lepus flavigularis*)
n = 8
Expert: Arturo Carillo-Reyes, Universidad de Ciencias y Artes de Chiapas
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Expert)
Status: UNMODELLABLE

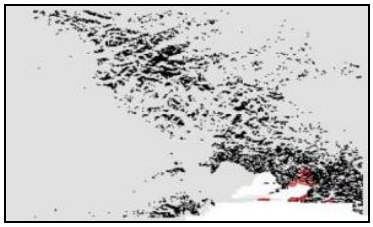
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.95**
True Skill Statistic	0.99

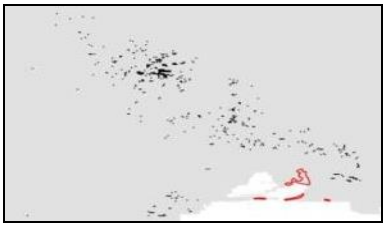
Summary: The Tehuantepec jackrabbit's bioclimatic envelope is predicted to decrease by 45% with a ~1° mean latitudinal poleward shift and a mean increase in elevation of ~450m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (81.7%), mean annual temperature (2.7%) and normalised difference vegetation index (1.7%).


a) ~ 1930s (1900-1949)

b) ~ 1980s (1950-2000)

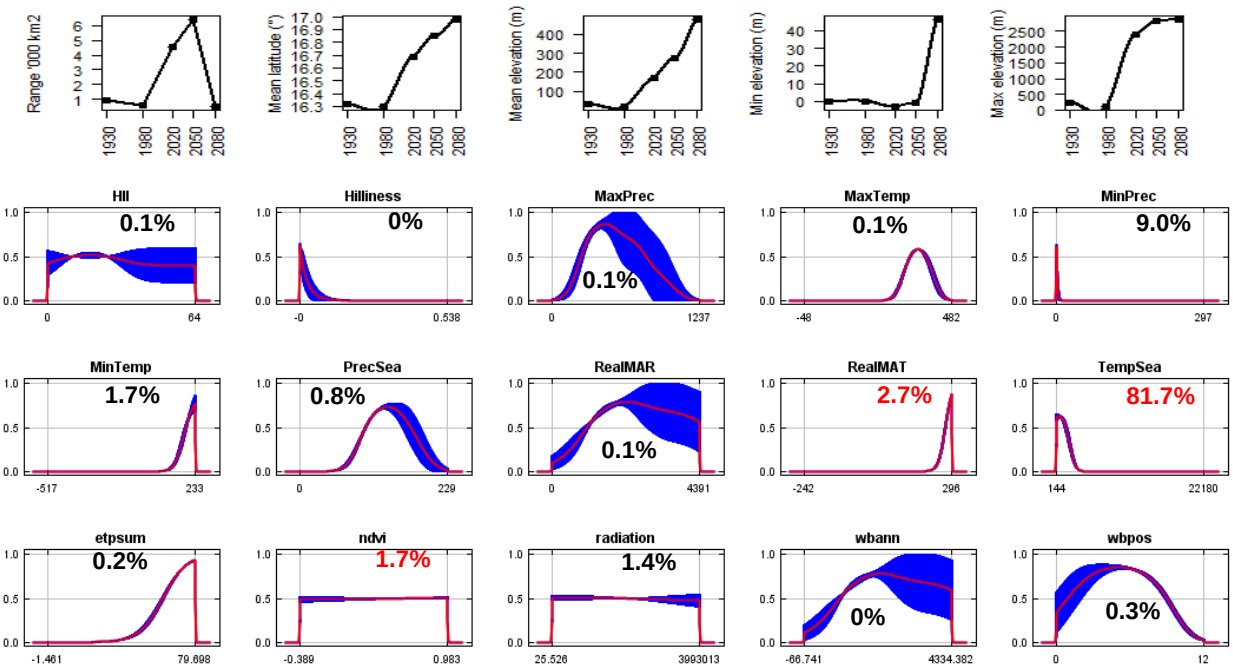

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

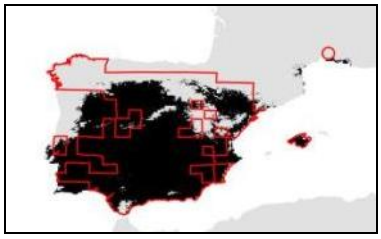
Red polygon = IUCN range (Cervantes, F.A., *et al*. 2008)

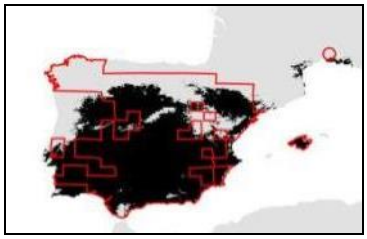


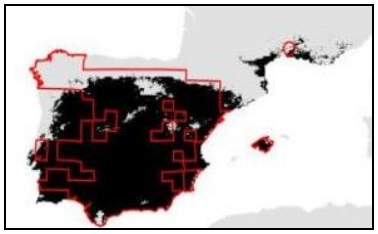
#18 – Iberian hare (*Lepus granatensis*)
n = 1675
Expert: Pelayo Acevedo, University of Porto
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7km/year (Expert)
Status: MODELLABLE

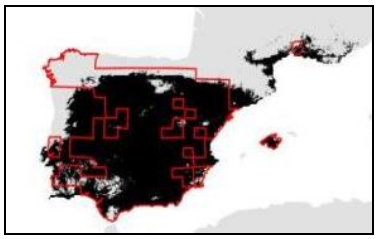
Model evaluation metric	
AUC	0.94
Omission rate	0.08
Sensitivity	0.92
Specificity	0.95
Proportion correct	0.95
Kappa	**0.81**
True Skill Statistic	0.87

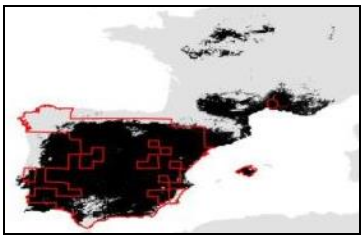
Summary: The Iberian hare's bioclimatic envelope is predicted to increase by 40% with a ~1° mean latitudinal poleward shift and a mean increase in elevation of ~10m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by maximum precipitation (39.0%), annual evapotranspiration (38.0%), minimum temperature (15.0%) and maximum temperature (3.0%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

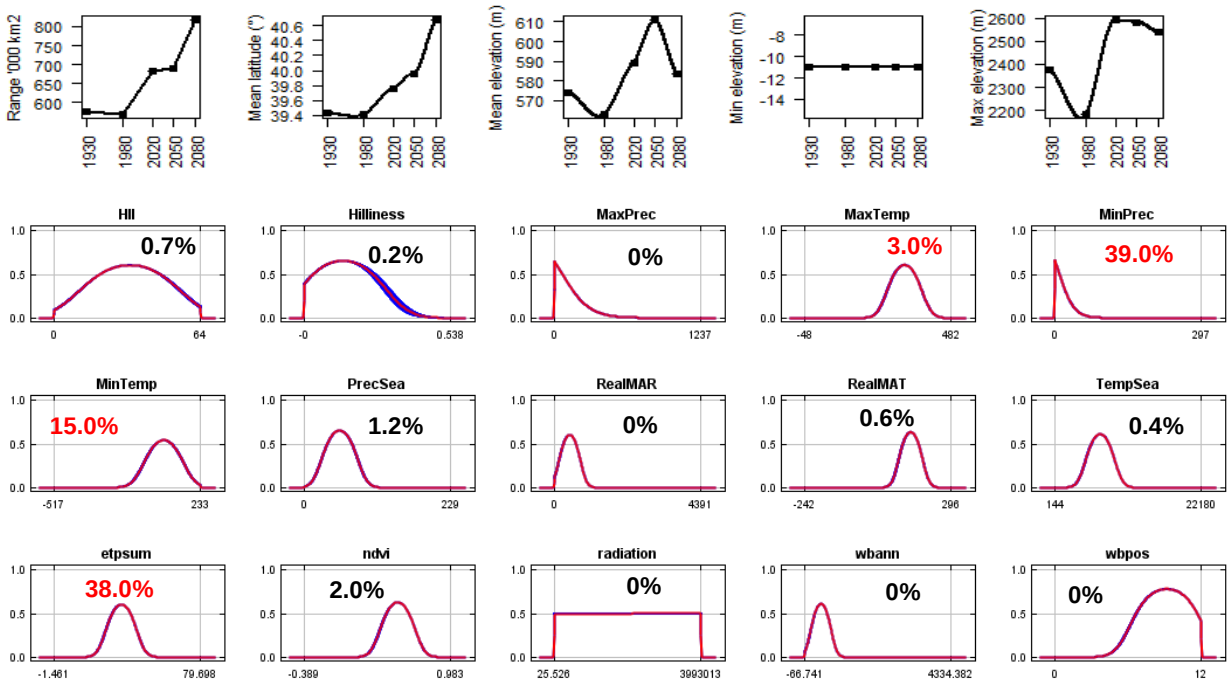

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

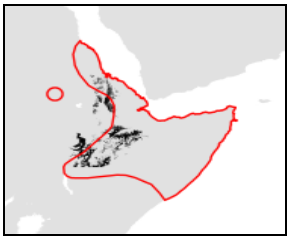
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

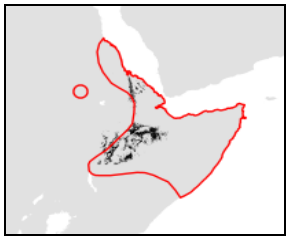


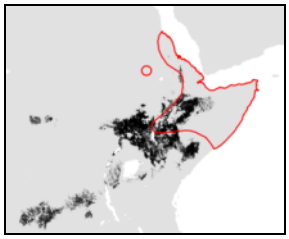
#19 – Abyssinian hare (*Lepus habessinicus*)
n = 7
Expert: Zelalem Tolesa, Addis Ababa University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 25km/year (Average for African leporids)
Status: MODELLABLE

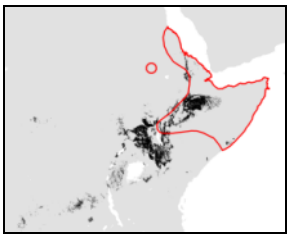
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.82**
True Skill Statistic	0.99

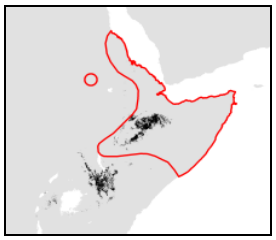
Summary: The Abyssinian hare's bioclimatic envelope is predicted to decrease by 4% with a ~4° mean latitudinal shift towards the Equator and a mean decrease in elevation of ~200m driven by an decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (87.6%), annual evapotranspiration (4.9%) and minimum precipitation (4.1%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

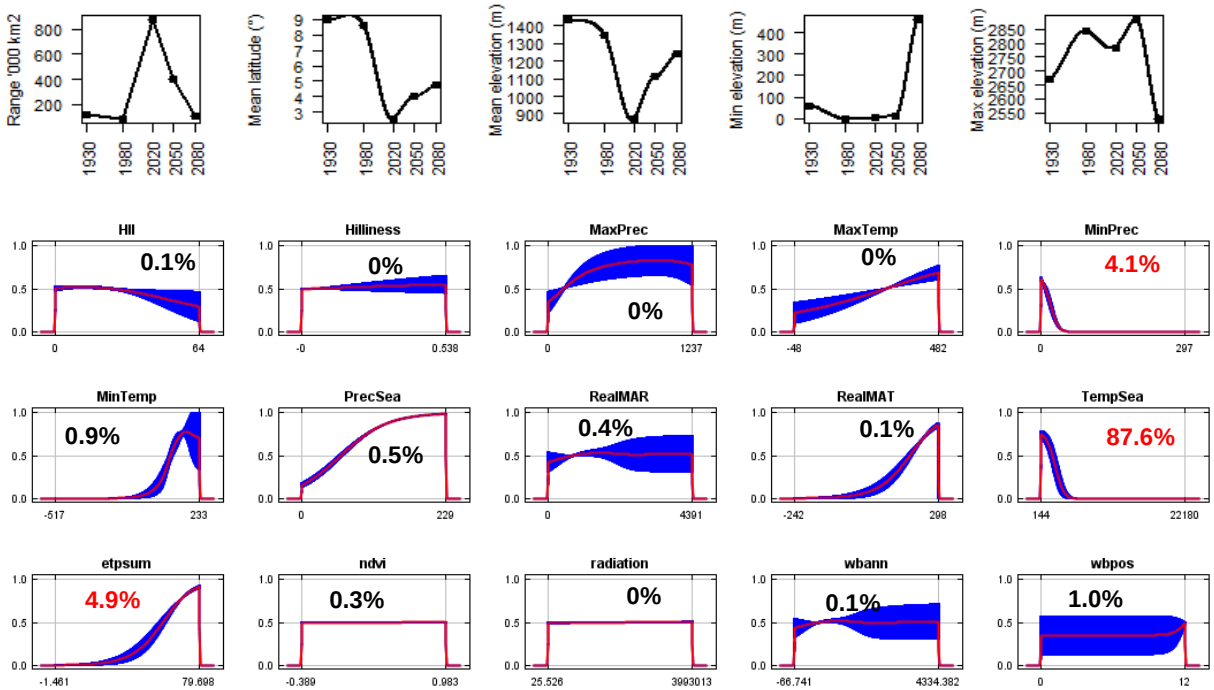

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

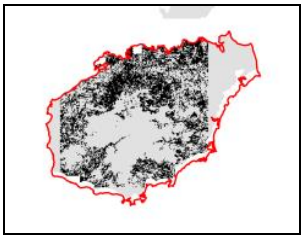
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

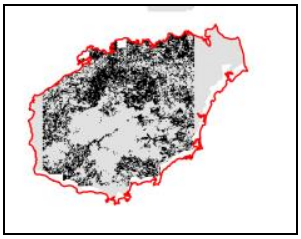


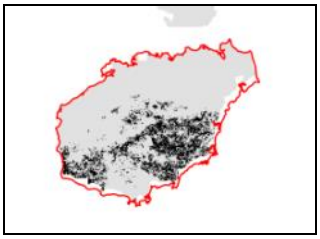
#20 – Hainan hare (*Lepus hainanus*)
n = 9
Expert: Youhua Chen, Wuhan University, China
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Average for island leporids)
Status: MODELLABLE

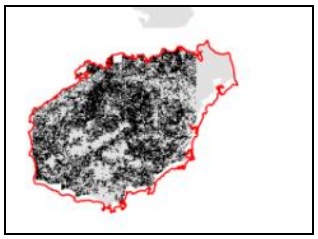
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.86**
True Skill Statistic	0.99

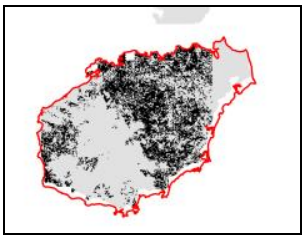
Summary: The Hainan hare's bioclimatic envelope is predicted to increase by 4% with no latitudinal poleward shift and a mean increase in elevation of ~20m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum temperature (71.0%), mean annual temperature (22.8%) and temperature seasonality (5.4%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

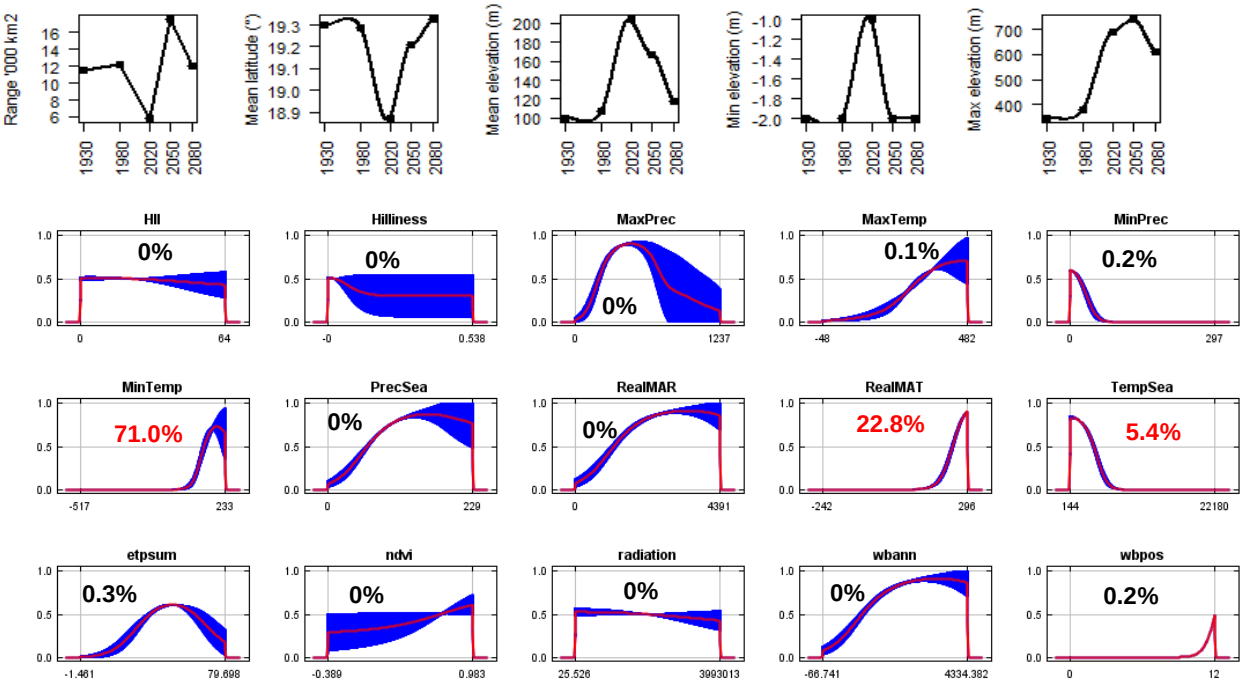

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

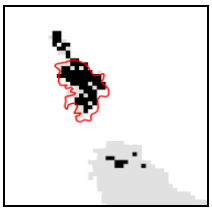
Red polygon = IUCN range (Lazell, J.,*et al*. 2008)

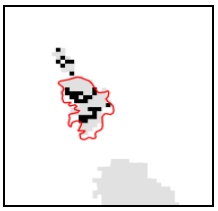


#21 – Black jackrabbit (*Lepus insularis*)
n = 3
Expert: Tamara Rioja Pardela, Universidad de Ciencias y Artes de Chiapas, Mexico
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Average for island leporids)
Status: MODELLABLE

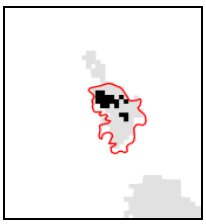
Model evaluation metric	
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

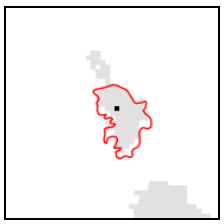
Summary: The Black jackrabbit's bioclimatic envelope is predicted to decrease by 100% with a ~0.3° mean latitudinal polewards shift and a mean increase in elevation of ~50m driven by an increase in both minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (28.6%), minimum precipitation (16.5%), annual water balance (13.3%), minimum temperature (12.9%), mean annual temperature (7.1%), temperature seasonality (5.5%), surface roughness index (5.0%) and normalised difference vegetation index (3.2%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

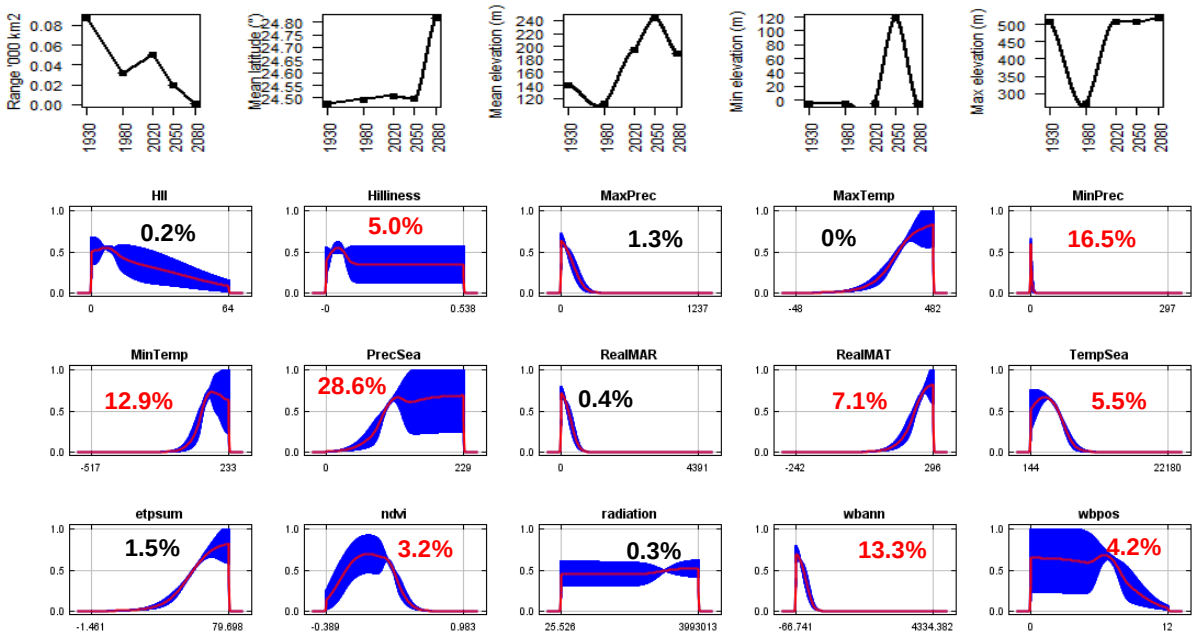
c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

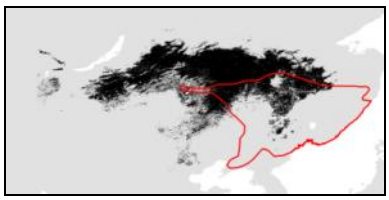
Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)



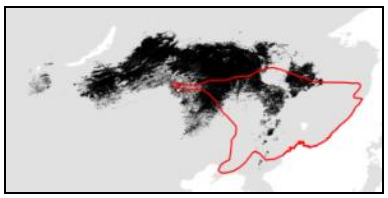
#22 – Manchurian hare (*Lepus mandshuricus*)
n = 36
Expert: Deyan Ge, Institute of *Zoology*, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Sokolov, V.E. *et al*., 2009)
Status: MODELLABLE

Model evaluation metric	
AUC	0.96
Omission rate	0.08
Sensitivity	0.92
Specificity	0.99
Proportion correct	0.99
Kappa	**0.78**
True Skill Statistic	0.92

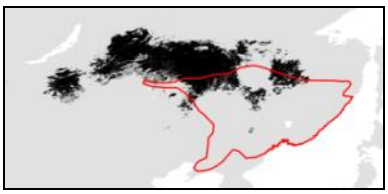
Summary: The Manchurian hare's bioclimatic envelope is predicted to decrease by 50% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~70m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (77.3%), mean annual temperature (10.4%), minimum temperature (4.5%), normalised difference vegetation index (2.6%) and annual evapotranspiration (2.4%).



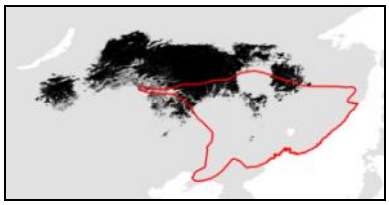
a) ~ 1930s (1900-1949)



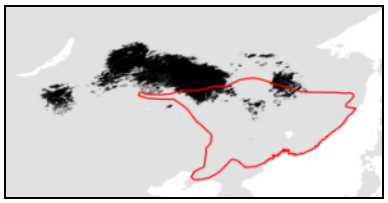
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



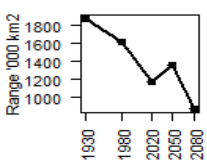
d) ~ 2050s (2040-2069)

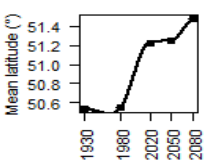


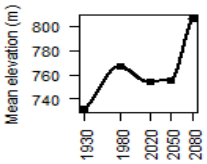
e) ~ 2080s (2070-2099)

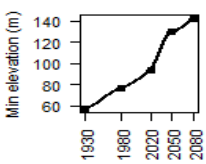
Black = predicted suitable envelope

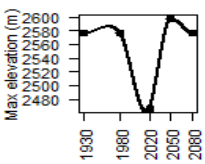
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

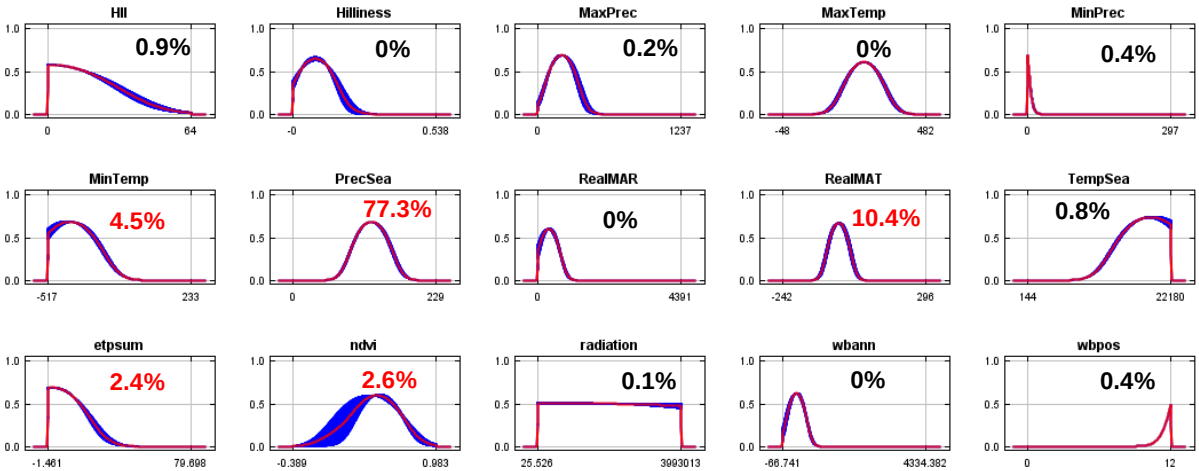








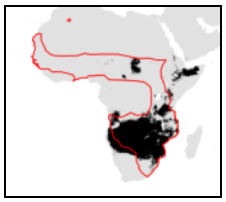




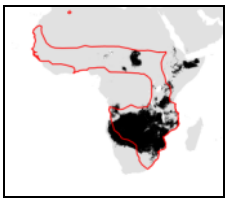
#23 – African savannah hare (*Lepus microtis*)
n = 82
Expert: John Flux, IUCN Lagomorph Specialist Group
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic only
Dispersal distance: 15km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.93
Omission rate	0.13
Sensitivity	0.87
Specificity	0.99
Proportion correct	0.99
Kappa	**0.62**
True Skill Statistic	0.86

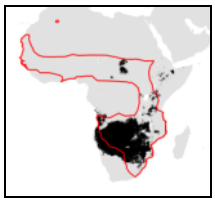
Summary: The African savannah hare's bioclimatic envelope is predicted to decrease by 15% with a ~3° mean latitudinal polewards shift and a mean increase in elevation of ~100m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (40.9%), maximum temperature (18.5%), annual evapotranspiration (9.2%), minimum precipitation (6.2%), temperature seasonality (5.4%), mean annual precipitation (5.4%), minimum temperature (4.9%), precipitation seasonality (4.1%) and annual water balance (1.7%).



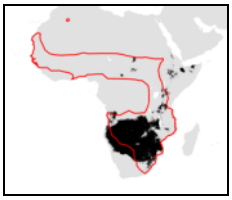
a) ~ 1930s (1900-1949)



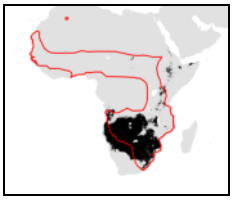
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



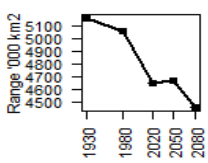
d) ~ 2050s (2040-2069)

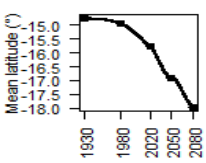


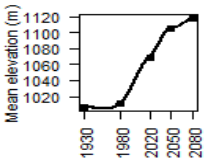
e) ~ 2080s (2070-2099)

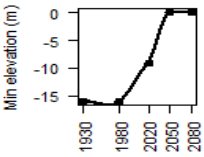
Black = predicted suitable envelope

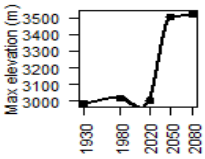
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

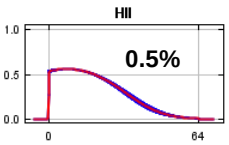


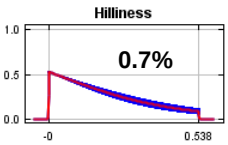


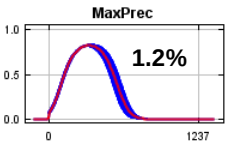


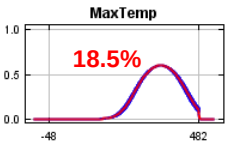


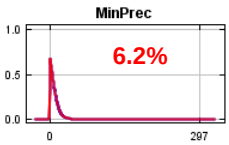


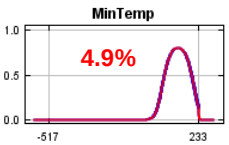


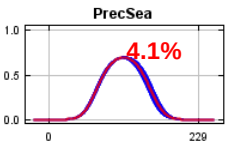


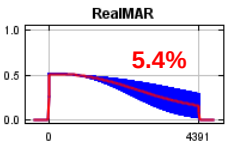


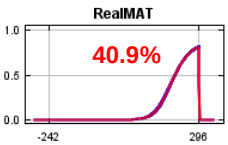


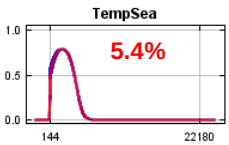


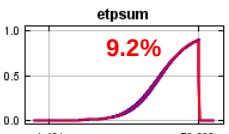


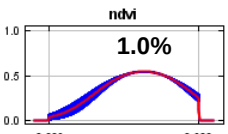


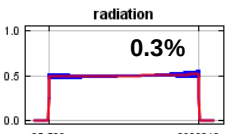


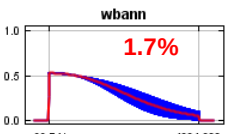


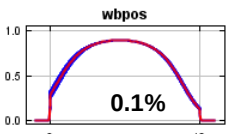








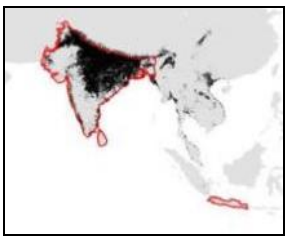


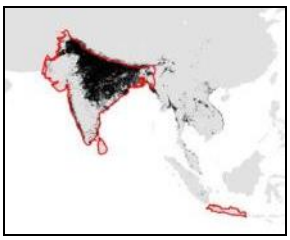


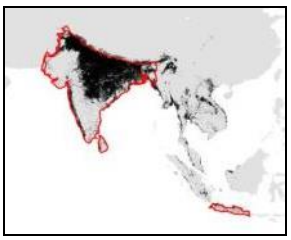
#24 – Indian hare (*Lepus nigricollis*)
n = 17
Expert: Gopinathan Maheswaran, Zoological Survey of India
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 6km/year (Expert)
Status: MODELLABLE

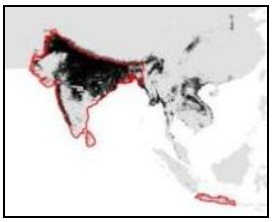
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.59**
True Skill Statistic	0.99

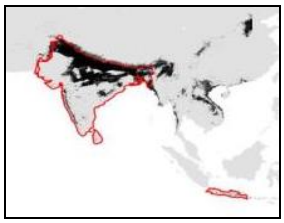
Summary: The Indian hare's bioclimatic envelope is predicted to decrease by 10% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~80m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (48.0%), mean annual temperature (14.9%), human influence index (11.9%), minimum temperature (10.3%), temperature seasonality (7.0%), number of months with a positive water balance (2.8%) and minimum precipitation (1.5%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

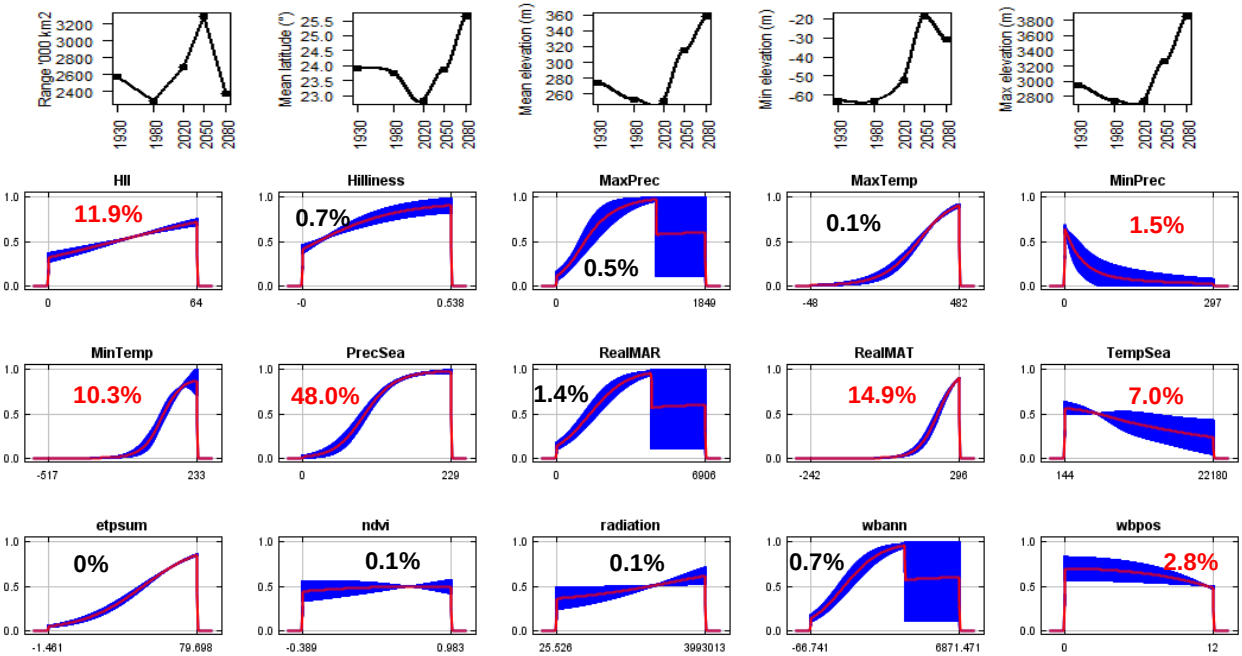

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

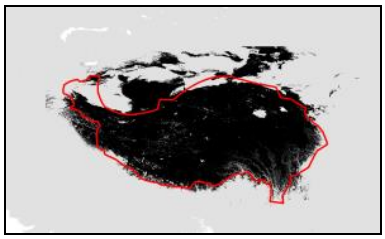
Red polygon = IUCN range (Maheswaran, G. & Jordan, M. 2008)



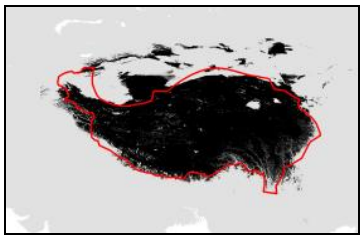
#25 – Woolly hare (*Lepus oiostolus*)
n = 84
Expert: Weihe Yang, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.63**
True Skill Statistic	0.89

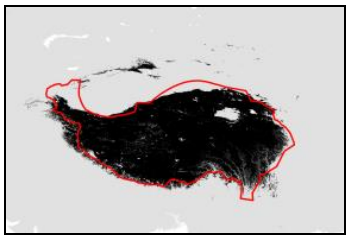
Summary: The Woolly hare's bioclimatic envelope is predicted to decrease by 25% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~680m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (82.1%), maximum temperature (5.0%), minimum temperature (4.6%) and annual evapotranspiration (3.8%).



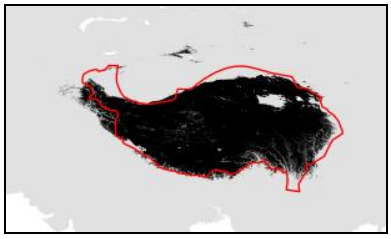
a) ~ 1930s (1900-1949)



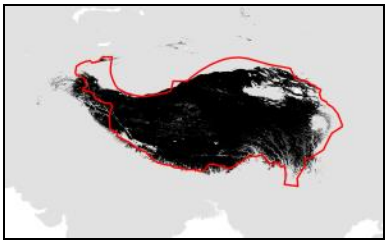
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



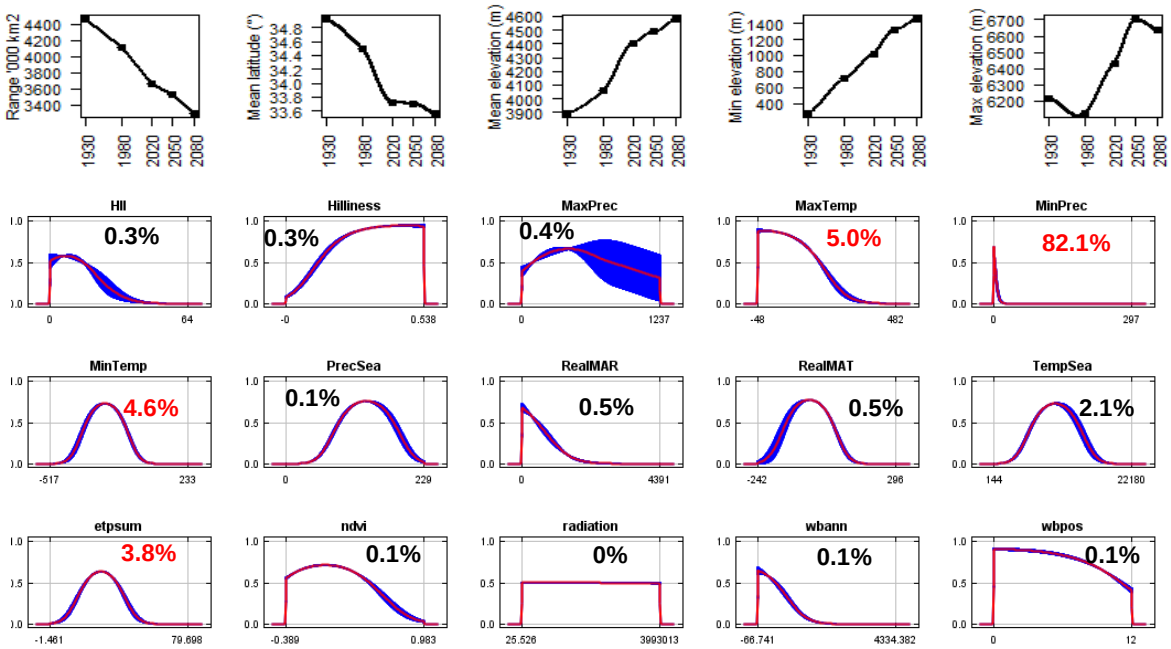
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

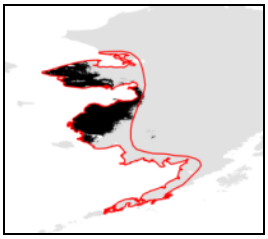
Red polygon = IUCN range (Indian CAMP Workshop & Johnston, C.H. 2008)

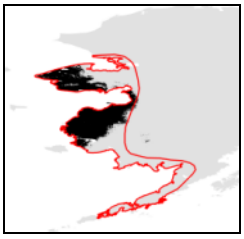


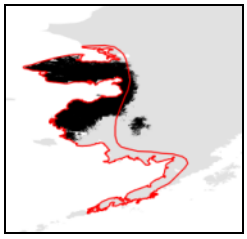
#26 – Alaskan hare (*Lepus othus*)
n = 8
Expert: Eric Waltari, City University of New York
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic only
Dispersal distance: 2km/year (Average for Arctic leporids)
Status: MODELLABLE

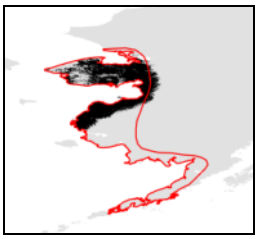
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.89**
True Skill Statistic	0.99

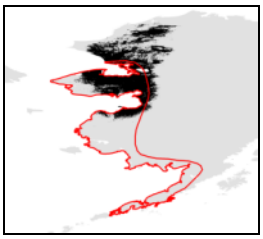
Summary: The Alaskan hare's bioclimatic envelope is predicted to increase by 80% with a ~3° mean latitudinal polewards shift and a mean increase in elevation of ~100m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (52.8%), mean annual temperature (26.4%), precipitation seasonality (11.3%) and mean annual precipitation (5.0%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

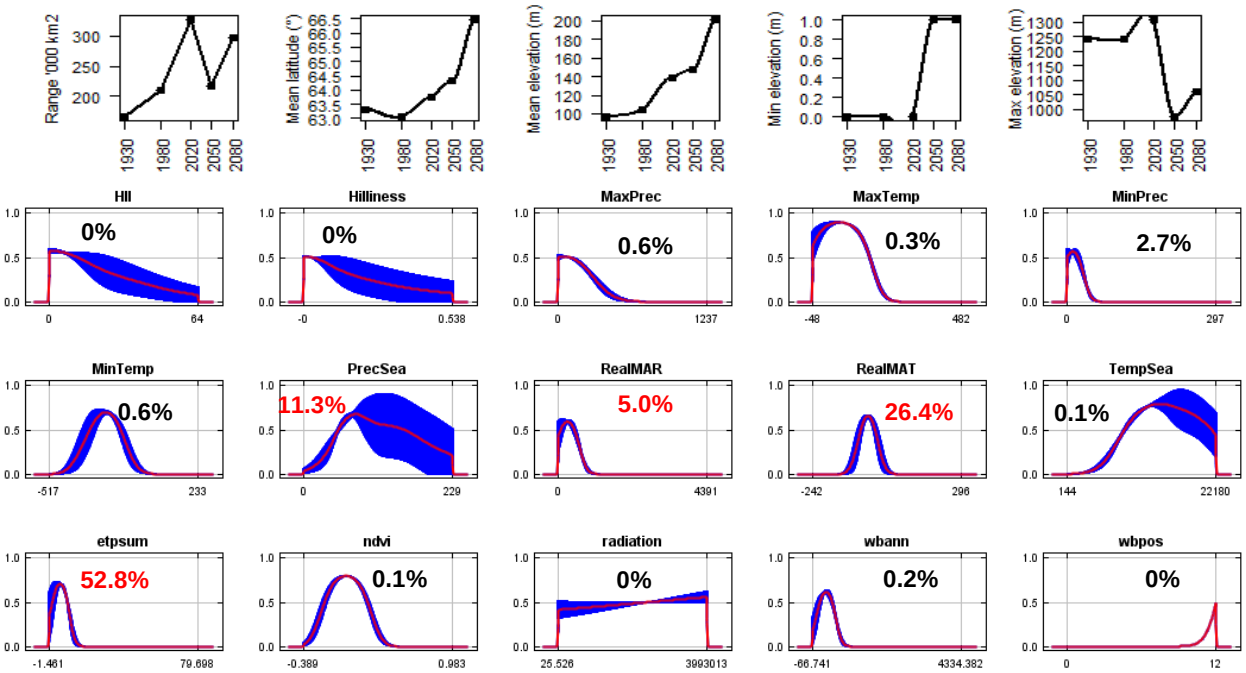

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Murray, D. & Smith, A.T. 2008)

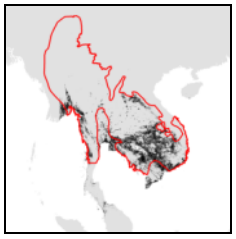


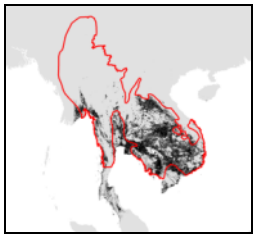
#27 – Burmese hare (*Lepus peguensis*)
n = 7
Expert: Thomas Gray, WWF Greater Mekong
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

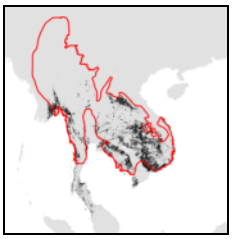
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.58**
True Skill Statistic	0.99

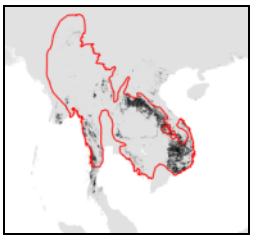
Summary: The Burmese hare's bioclimatic envelope is predicted to increase by 40% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~180m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (52.6%), minimum precipitation (32.9%), solar radiation (6.5%) and mean annual temperature (4.3%).

a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

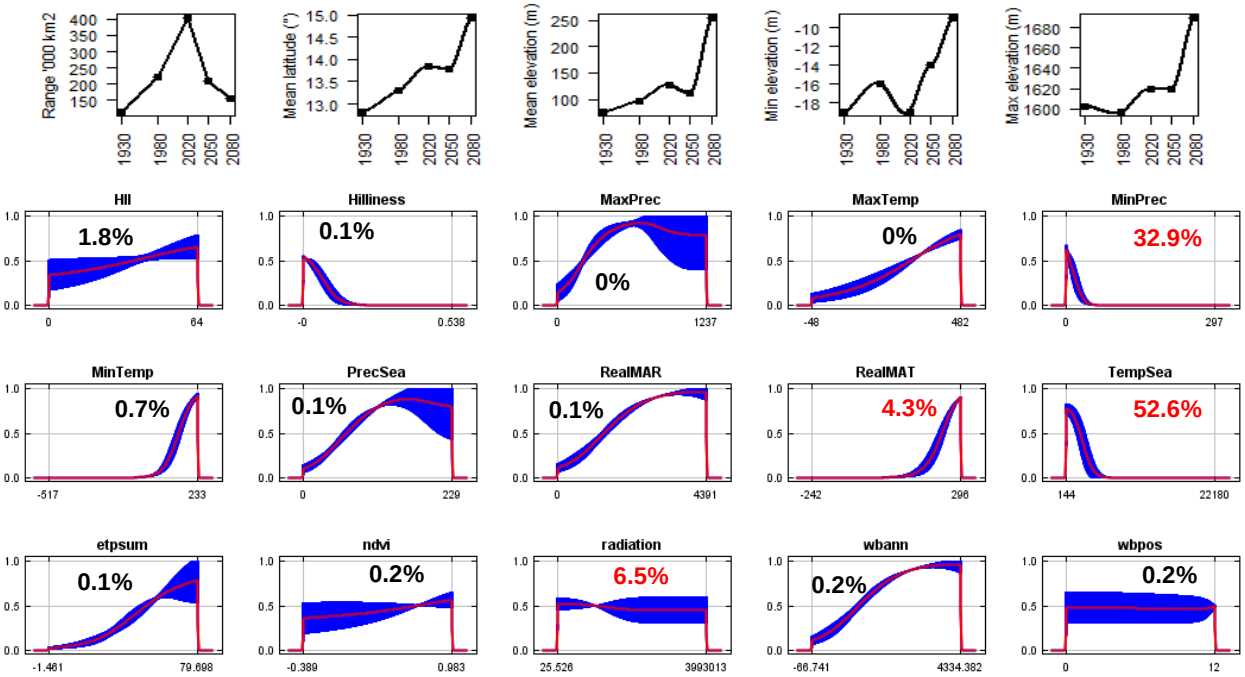

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

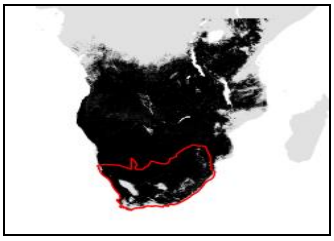
Red polygon = IUCN range (Duckworth, J.W., *et al*. 2008)



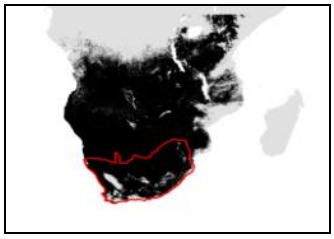
#28 – Scrub hare (*Lepus saxatilis*)
n = 39
Expert: Kai Collins, University of Pretoria
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 25km/year (Average for African leporids)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.08
Sensitivity	0.92
Specificity	0.97
Proportion correct	0.97
Kappa	**0.18**
True Skill Statistic	0.89

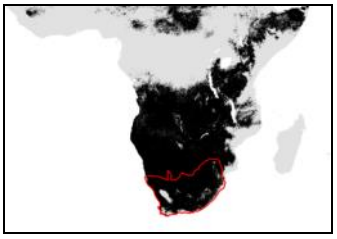
Summary: The Scrub hare's bioclimatic envelope is predicted to decrease by 15% with a ~2° mean latitudinal shift towards the Equator and a mean increase in elevation of ~65m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (52.8%), mean annual temperature (26.4%), precipitation seasonality (11.3%) and mean annual precipitation (5.0%).



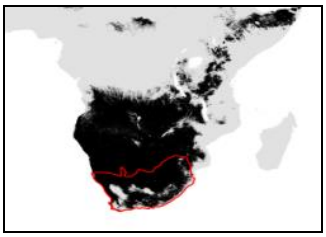
a) ~ 1930s (1900-1949)



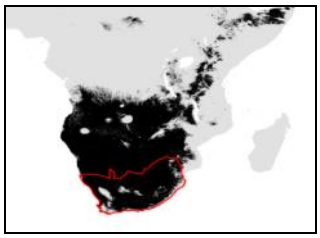
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



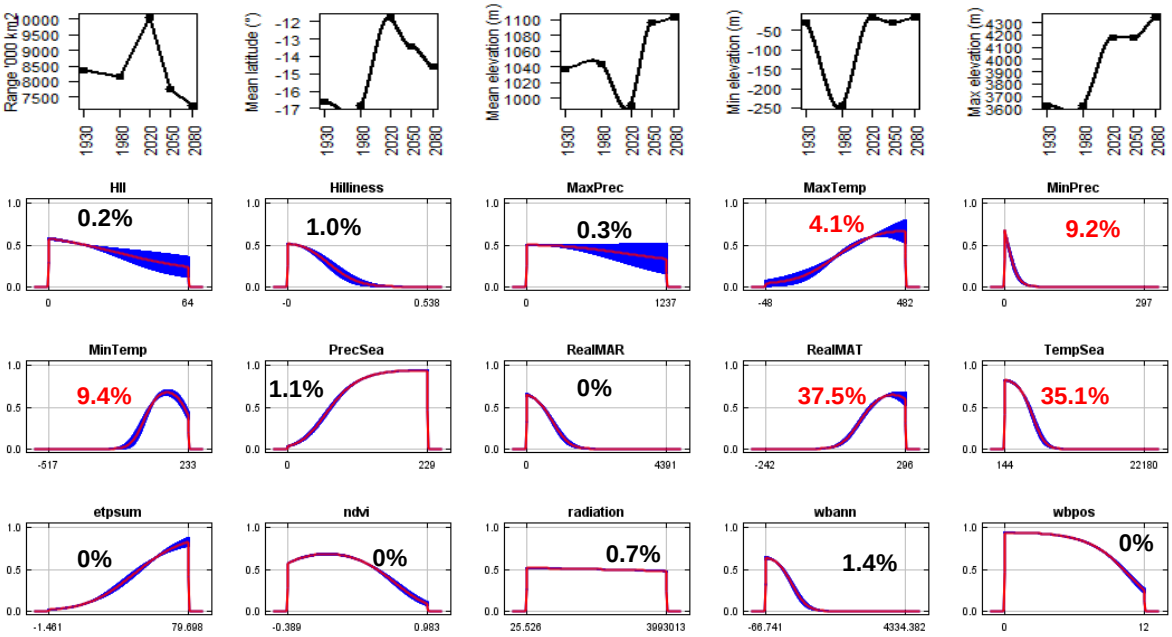
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

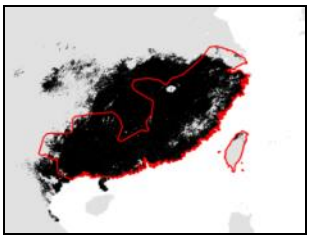
Red polygon = IUCN range (Collins, K., *et al*, 2008)

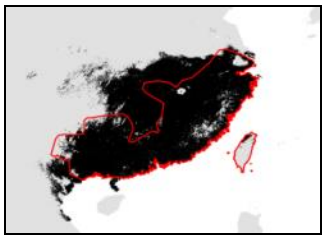


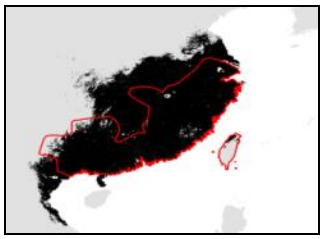
#29 – Chinese hare (*Lepus sinensis*)
n = 141
Expert: Weihe Yang, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

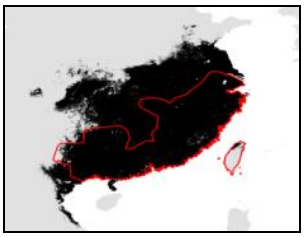
Model evaluation metric	
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.81**
True Skill Statistic	0.89

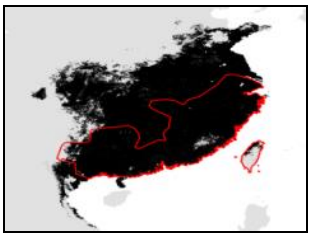
Summary: The Chinese hare's bioclimatic envelope is predicted to increase by 60% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~25m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (56.5%), temperature seasonality (22.9%), precipitation seasonality (8.0%), mean annual precipitation (5.4%) and annual evapotranspiration (3.5%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

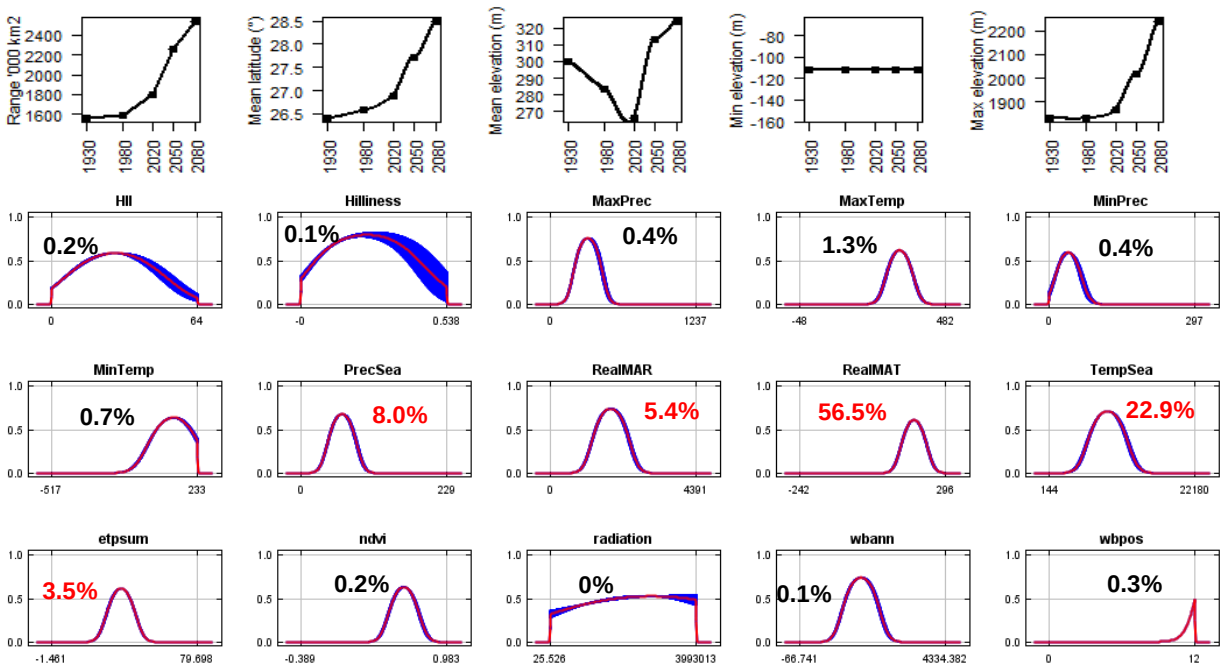

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

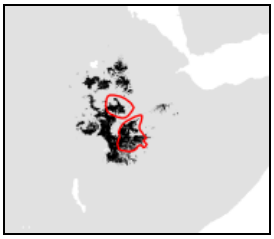
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

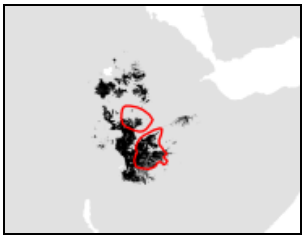


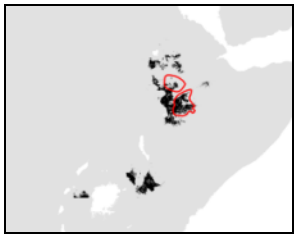
#30 – Ethiopian highland hare (*Lepus starcki*)
n = 13
Expert: Zelalem Tolesa, Addis Ababa University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 8km/year (Average for African leporids)
Status: MODELLABLE

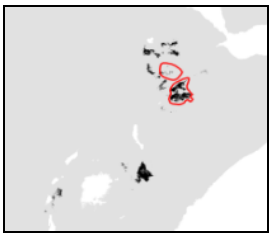
Model evaluation metric	
AUC	0.96
Omission rate	0.08
Sensitivity	0.92
Specificity	0.99
Proportion correct	0.99
Kappa	**0.86**
True Skill Statistic	0.92

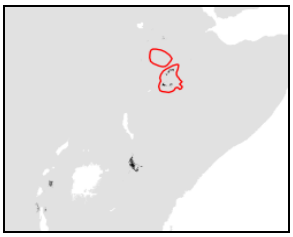
Summary: The Ethiopian highland hare's bioclimatic envelope is predicted to decrease by 90% with a ~7° mean latitudinal shift towards the Equator and a mean decrease in elevation of ~140m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (80.6%) and minimum temperature (18.5%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

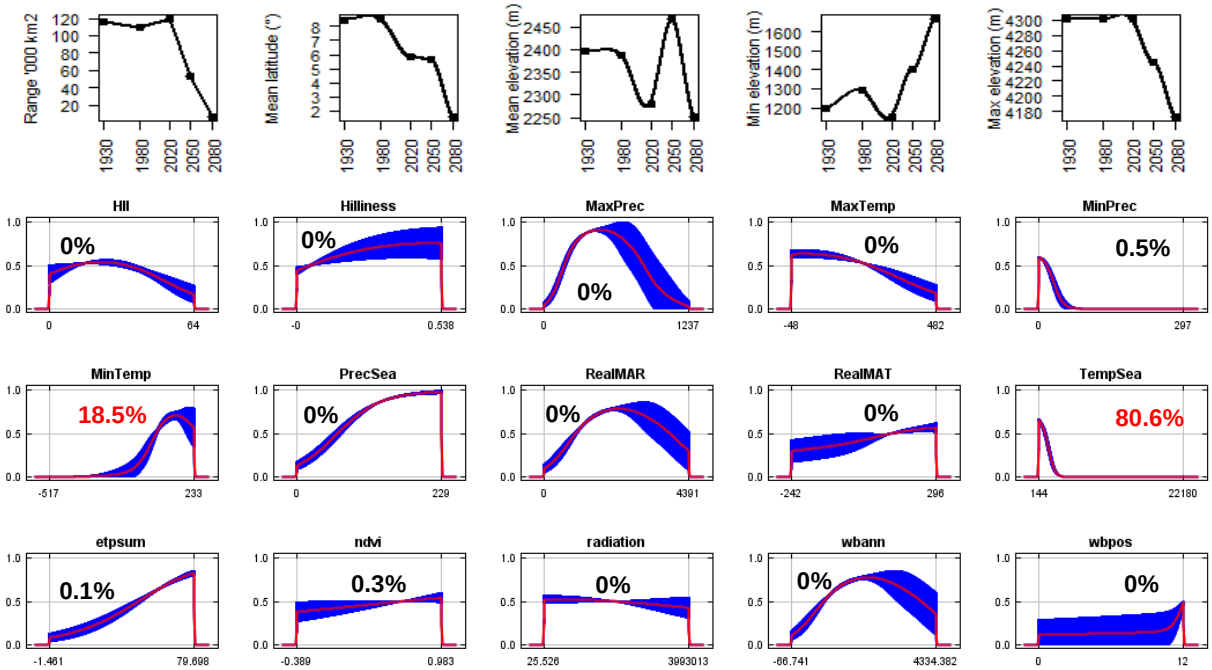

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

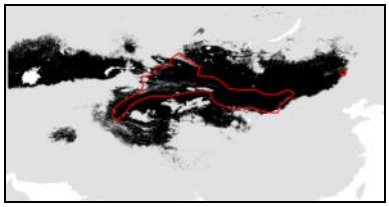
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



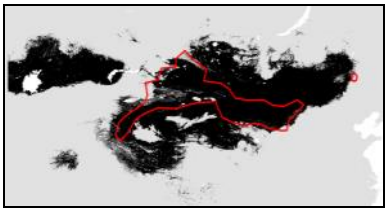
#31 – Desert hare (*Lepus tibetanus*)
n = 55
Expert: Chelmala Srinivasulu, Osmania University, India
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.92
Omission rate	0.15
Sensitivity	0.85
Specificity	0.99
Proportion correct	0.99
Kappa	**0.57**
True Skill Statistic	0.85

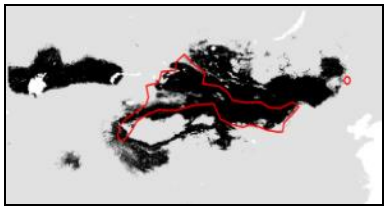
Summary: The Desert hare's bioclimatic envelope is predicted to decrease by 50% with no latitudinal shift towards the Equator, but a mean increase in elevation of ~320m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (54.5%), minimum temperature (19.3%), maximum precipitation (17.3%), annual evapotranspiration (2.8%) and human influence index (1.7%).



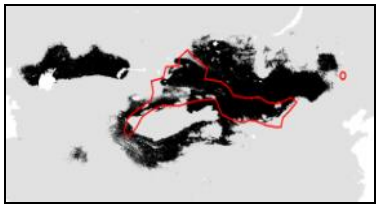
a) ~ 1930s (1900-1949)



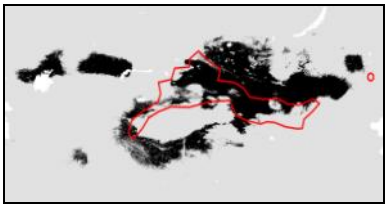
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



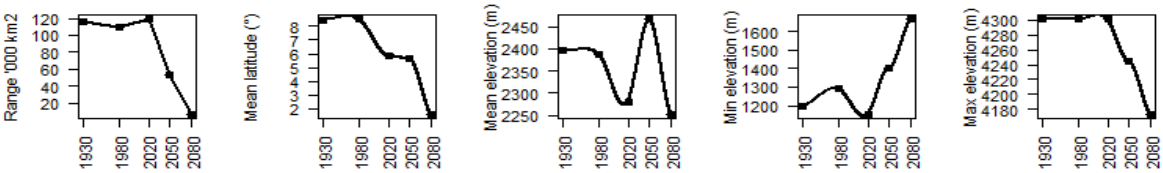
d) ~ 2050s (2040-2069)

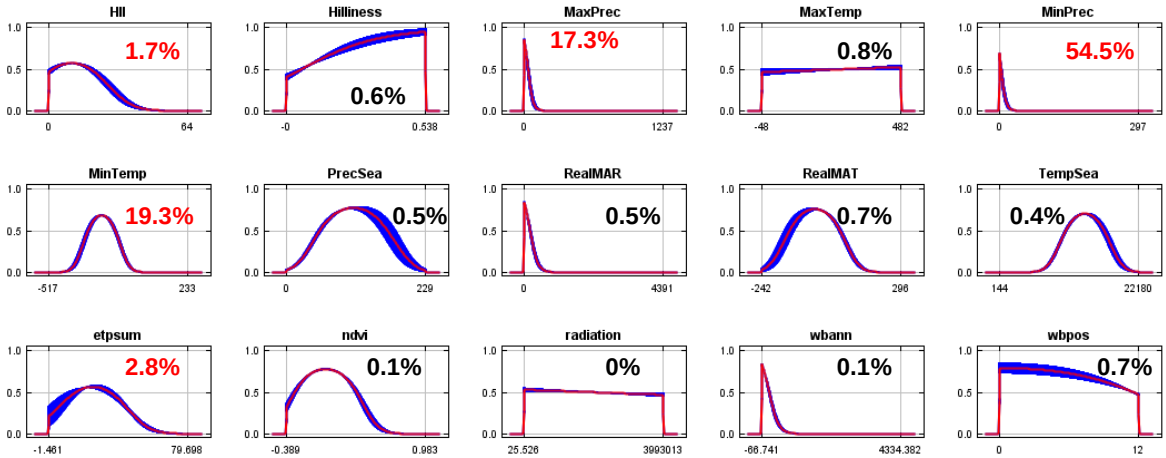


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (China Red List & Johnston, C.H. 2008)

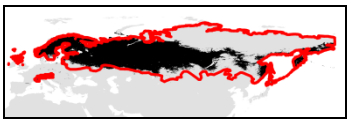




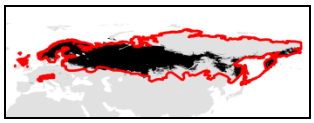
#32 – Mountain hare (*Lepus timidus*) – Eurasian populations
n = 2,460
Expert: Neil Reid, Queen's University Belfast
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.91
Omission rate	0.08
Sensitivity	0.92
Specificity	0.90
Proportion correct	0.91
Kappa	**0.74**
True Skill Statistic	0.82

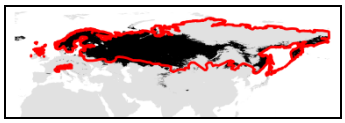
Summary: The Mountain hare's bioclimatic envelope is predicted to decrease by 10% with a ~4° mean latitudinal polewards shift and a mean decrease in elevation of ~10m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (87.9%), temperature seasonality (3.9%), minimum precipitation (2.1%) and minimum temperature (1.6%).



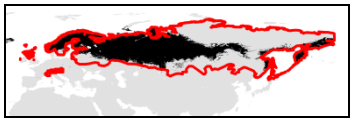
a) ~ 1930s (1900-1949)



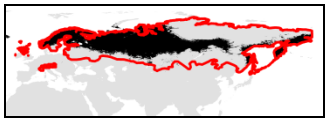
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



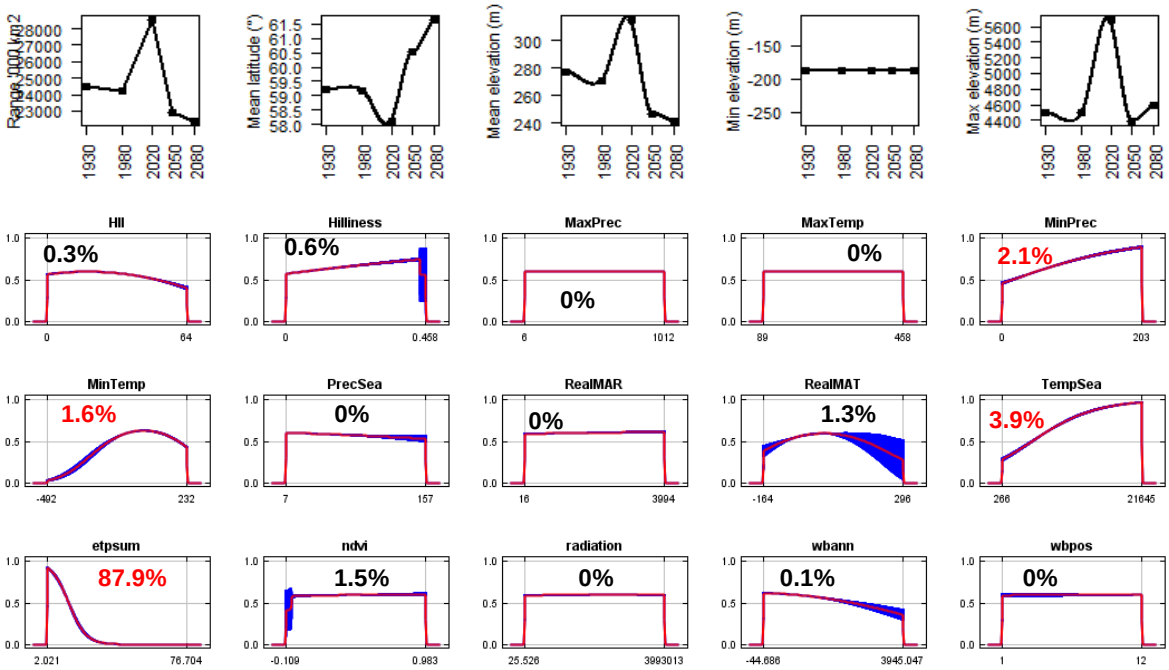
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

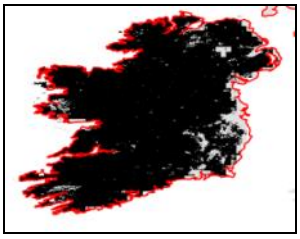
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

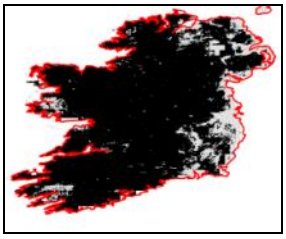


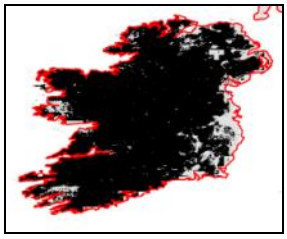
#33 – Irish hare (*Lepus timidus hibernicus*)
n = 706
Expert: Neil Reid, Queen's University Belfast
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Expert)
Status: MODELLABLE

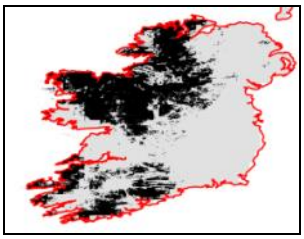
Model evaluation metric	
AUC	0.94
Omission rate	0.08
Sensitivity	0.92
Specificity	0.97
Proportion correct	0.96
Kappa	**0.75**
True Skill Statistic	0.88

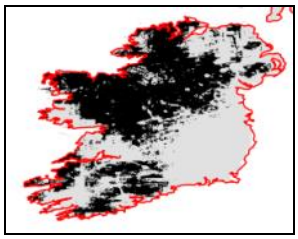
Summary: The Irish hare's bioclimatic envelope is predicted to decrease by 50% with a ~0.5° mean latitudinal polewards shift and a mean decrease in elevation of ~10m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (44.6%), annual evapotranspiration (41.5%), normalised difference vegetation index (6.4%), precipitation seasonality (3.6%) and maximum precipitation (2.5%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

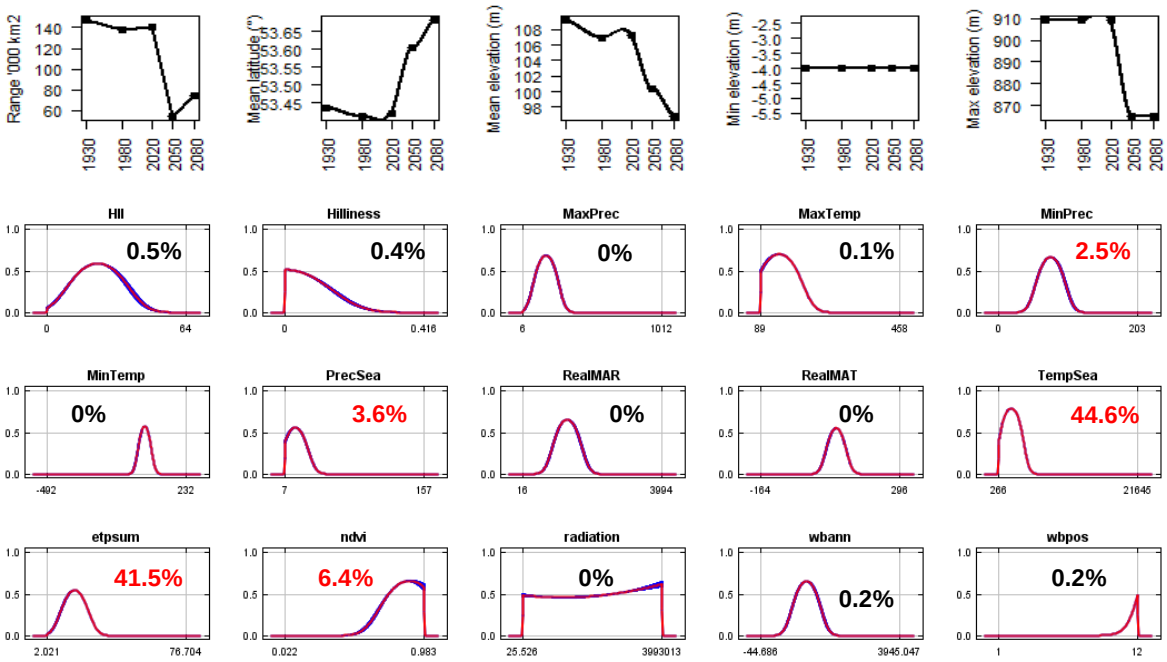

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

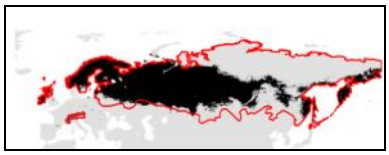
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



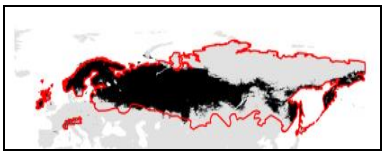
#34 – Mountain hare (*Lepus timidus*)
– Eurasian & Irish populations combined
n = 3,166
Expert: Neil Reid, Queen's University Belfast
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.92
Omission rate	0.07
Sensitivity	0.93
Specificity	0.91
Proportion correct	0.91
Kappa	**0.78**
True Skill Statistic	0.84

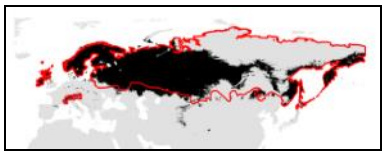
Summary: The Mountain hare's bioclimatic envelope is predicted to decrease by 10% with a ~2° mean latitudinal polewards shift and a mean decrease in elevation of ~40m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (87.6%), temperature seasonality (4.1%), minimum precipitation (2.1%) and minimum temperature (1.6%).



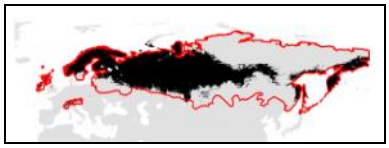
a) ~ 1930s (1900-1949)



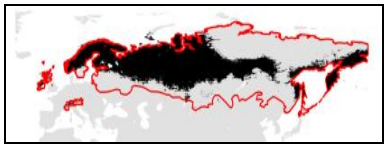
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



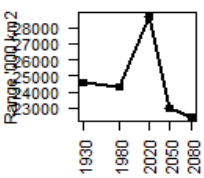
d) ~ 2050s (2040-2069)

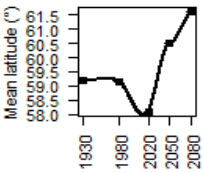


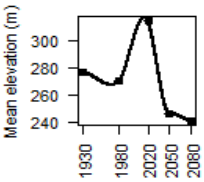
e) ~ 2080s (2070-2099)

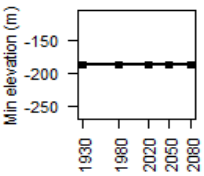
Black = predicted suitable envelope

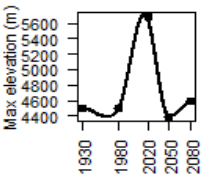
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

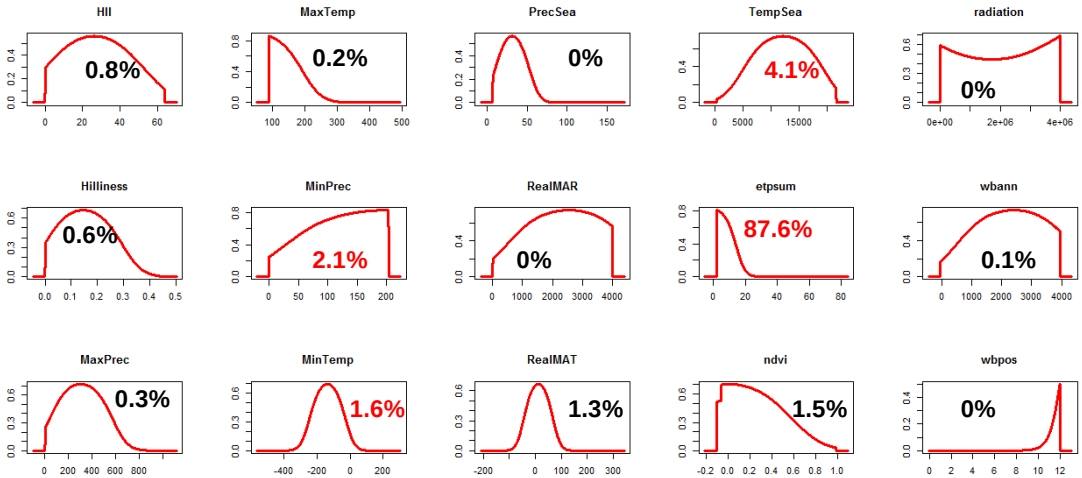








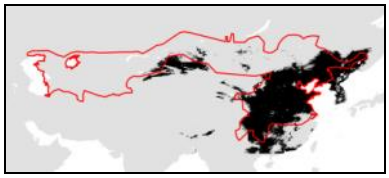




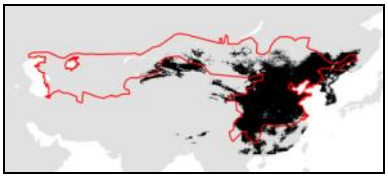
#35 – Tolai hare (*Lepus tolai*)
n = 316
Expert: Chelmala Srinivasulu, Osmania University, India
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2.5km/year (Average for Asian leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.98
Kappa	**0.76**
True Skill Statistic	0.88

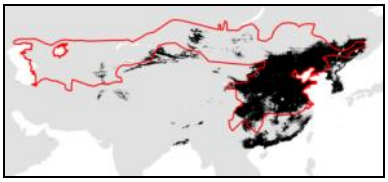
Summary: The Tolai hare's bioclimatic envelope is predicted to increase by 70% with a ~3° mean latitudinal polewards shift and a mean increase in elevation of ~280m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (43.5%), maximum temperature (17.3%), mean annual temperature (15.2%), precipitation seasonality (9.6%), annual evapotranspiration (4.6%), mean annual precipitation (3.7%) and minimum precipitation (1.8%).



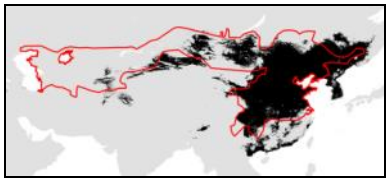
a) ~ 1930s (1900-1949)



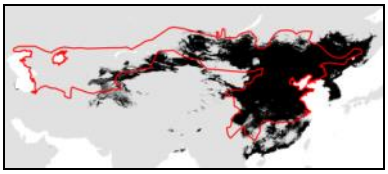
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



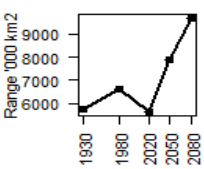
d) ~ 2050s (2040-2069)

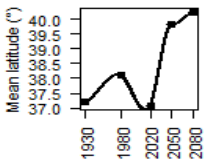


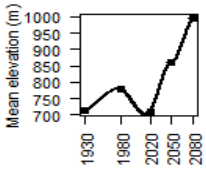
e) ~ 2080s (2070-2099)

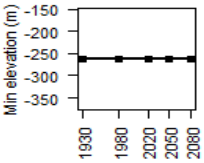
Black = predicted suitable envelope

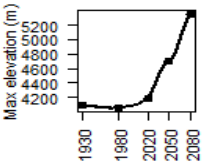
Red polygon = IUCN range (China Red List & Johnston, C.H. 2008)

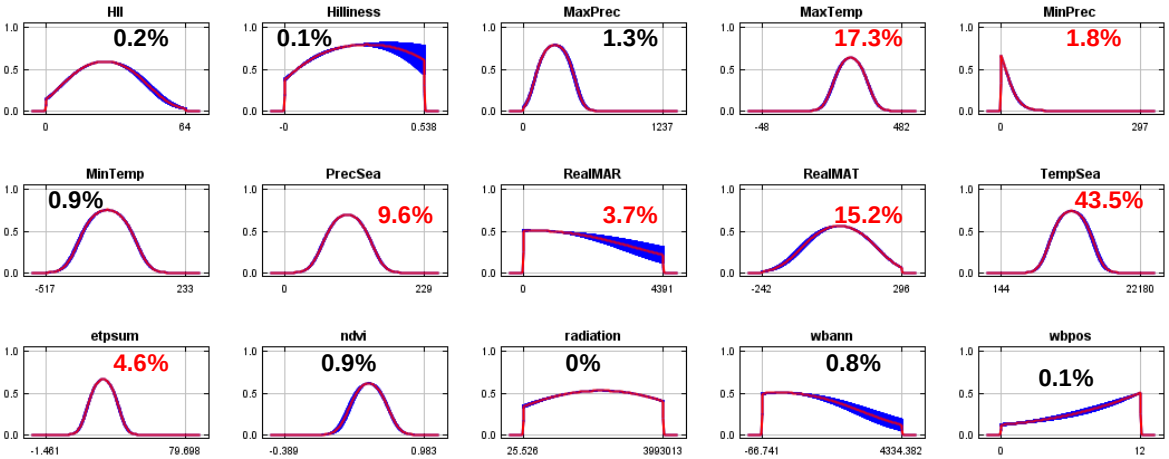








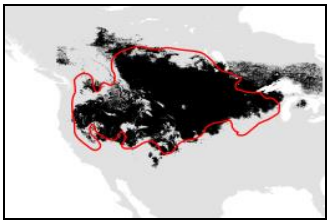




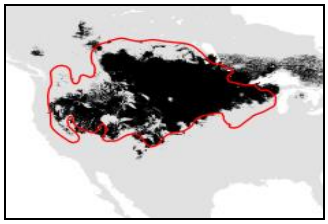
#36 – White-tailed jackrabbit (*Lepus townsendii*)
n = 275
Expert: Eric Waltari, City University of New York
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 18.9km/year (Average for NA leporids)
Status: MODELLABLE

Model evaluation metric	
AUC	0.94
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.76**
True Skill Statistic	0.89

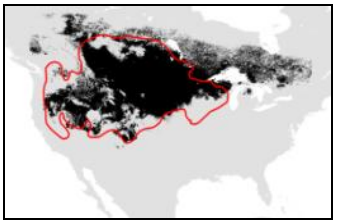
Summary: The White-tailed jackrabbit's bioclimatic envelope is predicted to decrease by 10% with a ~4° mean latitudinal polewards shift and a mean increase in elevation of ~200m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (62.5%), maximum temperature (28.5%), temperature seasonality (3.4%) and annual evapotranspiration (1.6%).



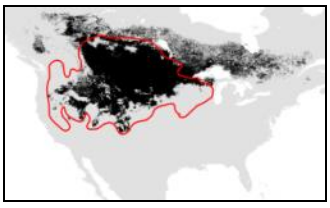
a) ~ 1930s (1900-1949)



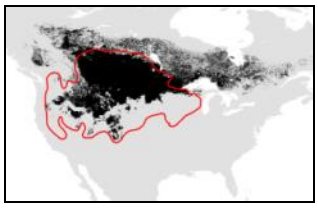
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



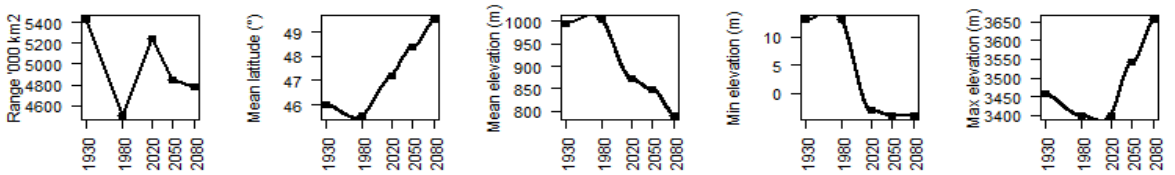
d) ~ 2050s (2040-2069)

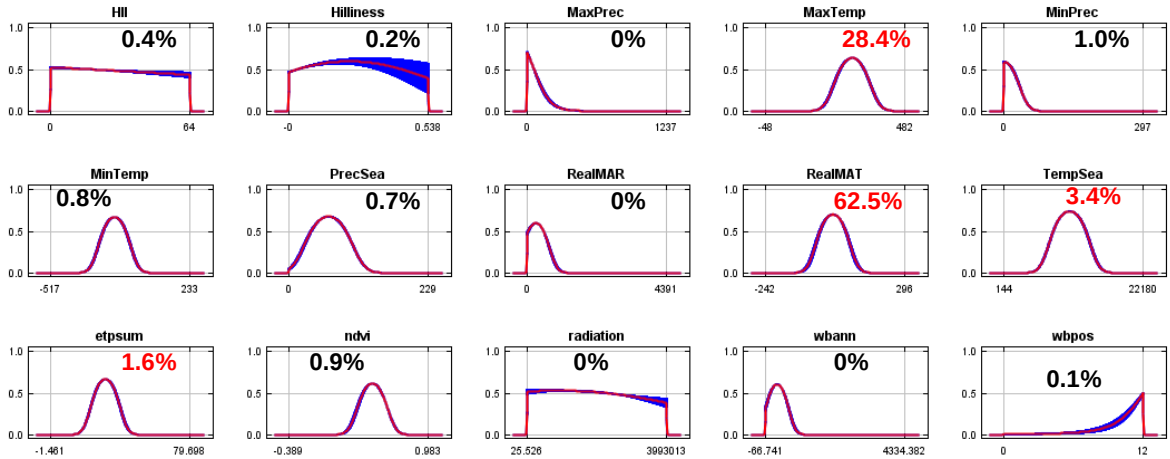


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

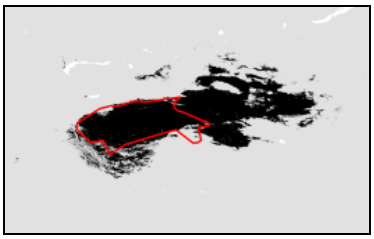




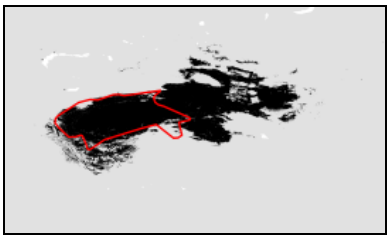
#37 – Yarkand hare (*Lepus yarkandensis*)
n = 49
Expert: Weihe Yang, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Smith & Xie, 2008)
Status: MODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.74**
True Skill Statistic	0.90

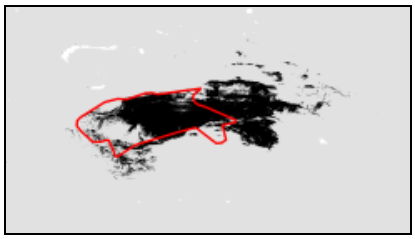
Summary: The Yarkand hare's bioclimatic envelope is predicted to decrease by 100% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~1000m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (58.8%), maximum precipitation (16.3%), mean annual precipitation (11.9%) and minimum temperature (11.7%).



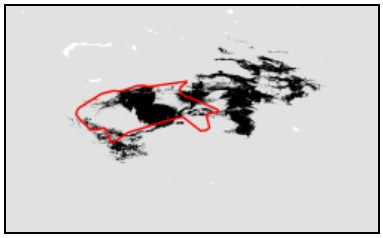
a) ~ 1930s (1900-1949)



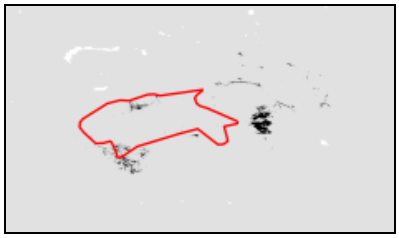
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



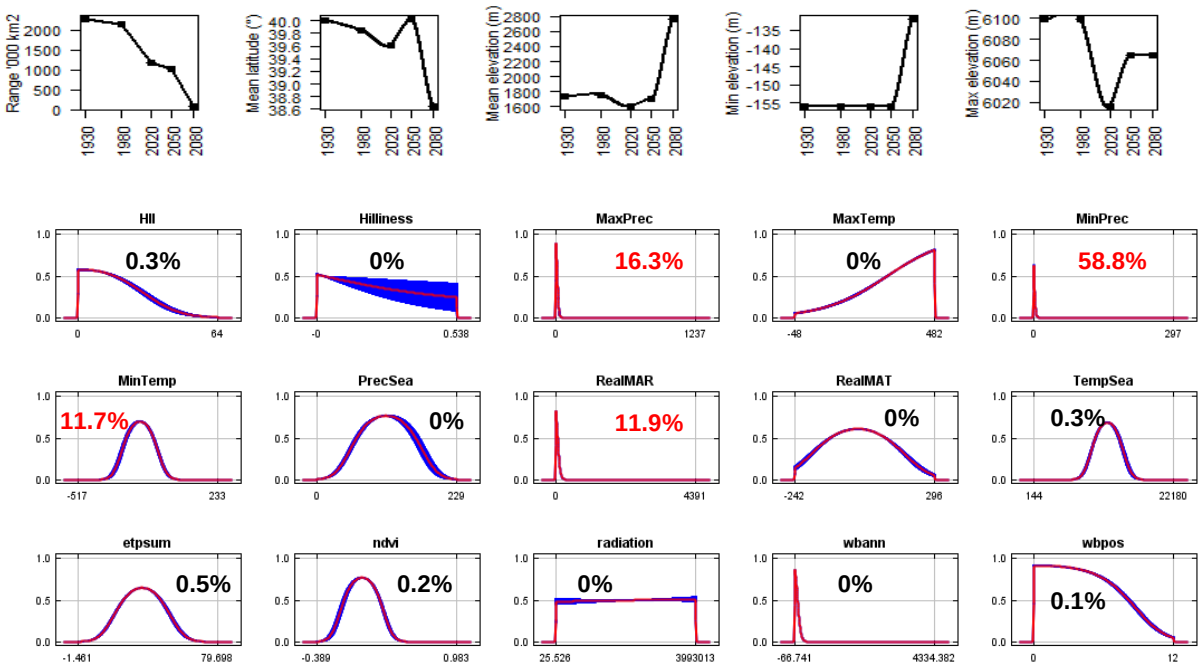
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

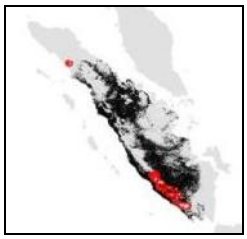
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



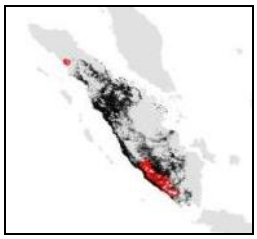
#38 – Sumatran striped rabbit (*Nesolagus netscheri*)
n = 11
Expert: Hariyo Wibisono, Wildlife Conservation Society, Indonesia
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Expert)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.95**
True Skill Statistic	0.99

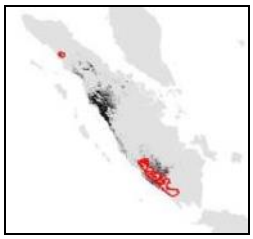
Summary: The Sumatran striped rabbit's bioclimatic envelope is predicted to decrease by 91% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~330m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (99.3%).



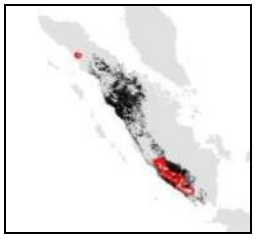
a) ~ 1930s (1900-1949)



b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)

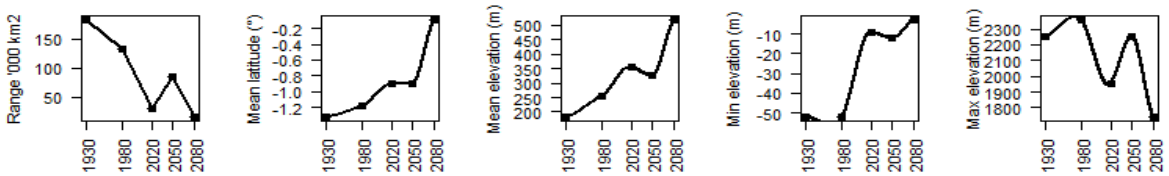


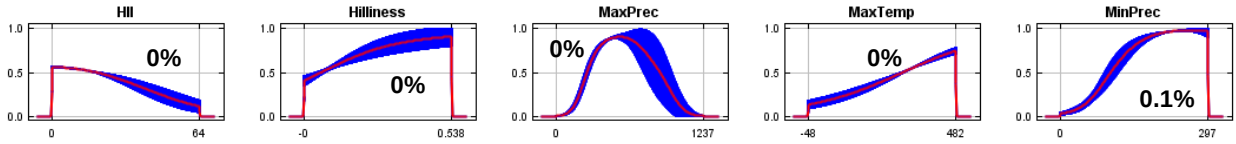
d) ~ 2050s (2040-2069)

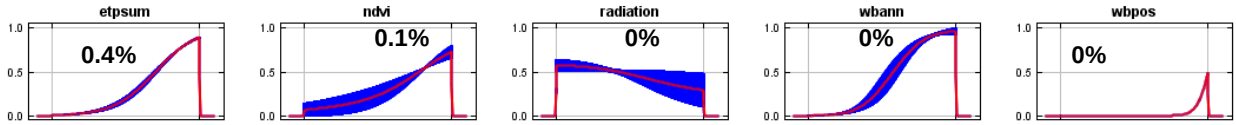
e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Meijaard, E. & Sugardjito, J. 2008)



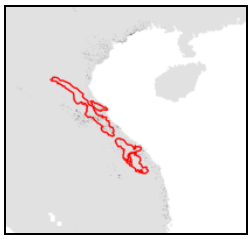


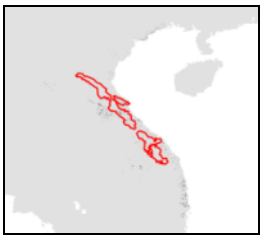


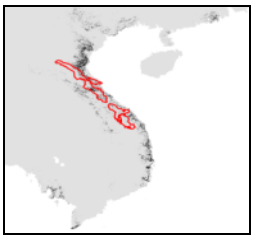
#39 – Annamite striped rabbit (*Nesolagus timminsi*)
n = 4
Expert: Thomas Gray, WWF Greater Mekong & Andrew Tilker, University of Texas Austin
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 10km/year (Expert)
Status: UNMODELLABLE

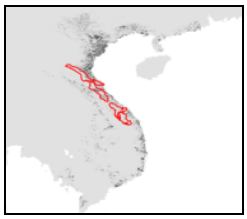
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.50**
True Skill Statistic	0.99

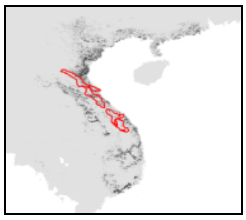
Summary: The Annamite striped rabbit's bioclimatic envelope is predicted to decrease by 1500% with a ~0.3° mean latitudinal shift towards the Equator and a mean decrease in elevation of ~20m driven by an decrease in minimum elevation. 95% of the permutation importance of the model was contributed to by solar radiation (43.3%), minimum temperature (30.0%), mean annual temperature (14.1%), human influence index (6.4%) and annual evapotranspiration (2.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

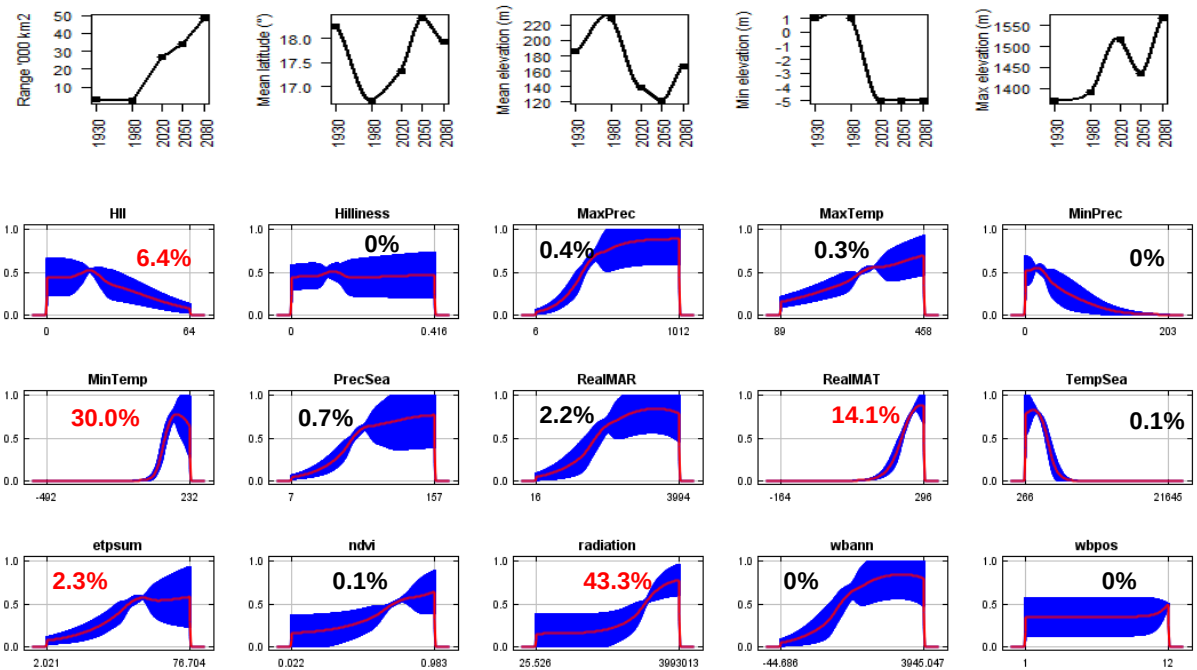

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

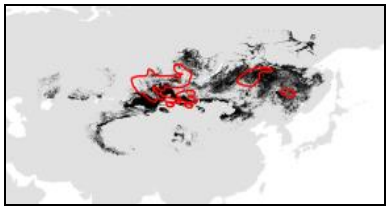
Red polygon = IUCN range (Abramov, A., *et al*. 2008)



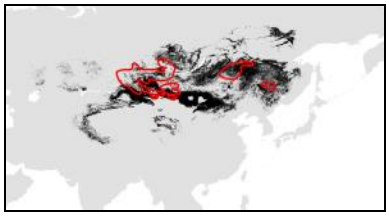
#40 – Alpine pika (*Ochotona alpina*)
n = 16
Expert: Sumiya Ganzorig, Hokkaido University
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 10km/year (Similar ecology to *O.pallasi*)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.29**
True Skill Statistic	0.99

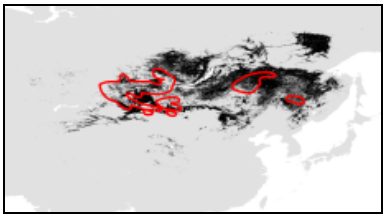
Summary: The Alpine pika's bioclimatic envelope is predicted to decrease by 10% with a ~4° mean latitudinal polewards shift and a mean decrease in elevation of ~80m. 95% of the permutation importance of the model was contributed to by minimum precipitation (50.1%), mean annual temperature (31.1%), number of months with a positive water balance (10.9%), minimum temperature (2.3%) and annual evapotranspiration (1.3%).



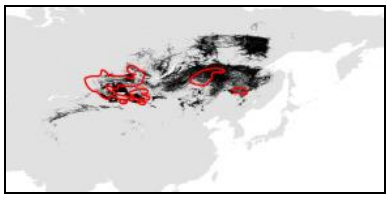
a) ~ 1930s (1900-1949)



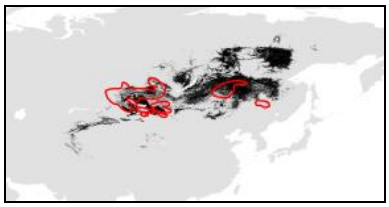
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



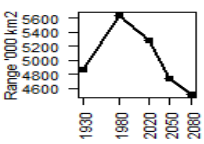
d) ~ 2050s (2040-2069)

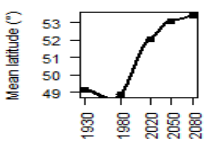


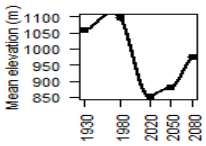
e) ~ 2080s (2070-2099)

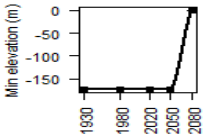
Black = predicted suitable envelope

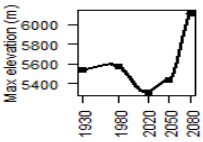
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

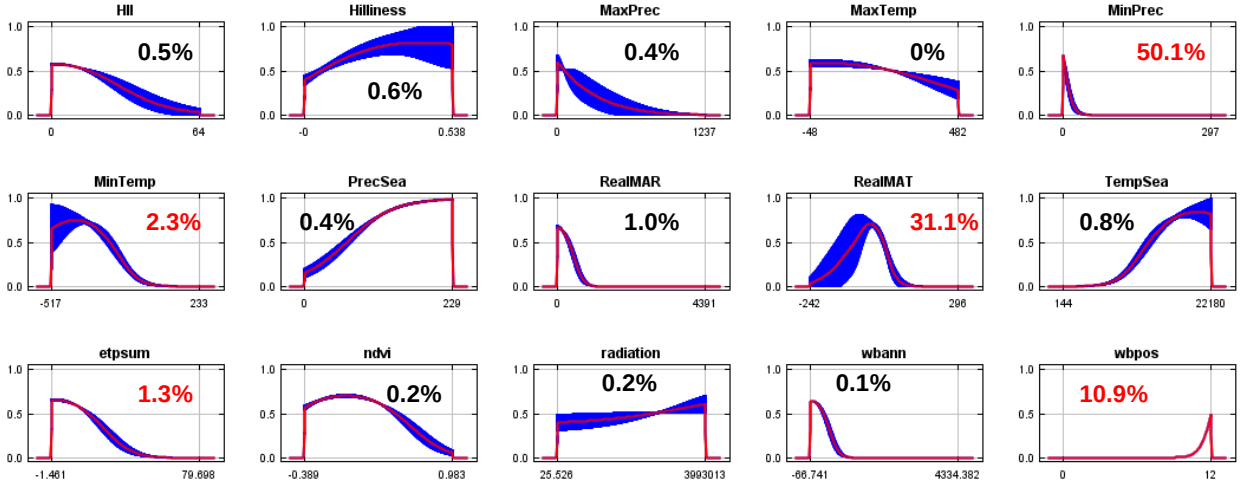








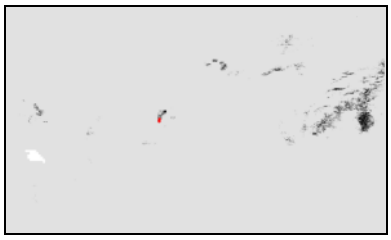




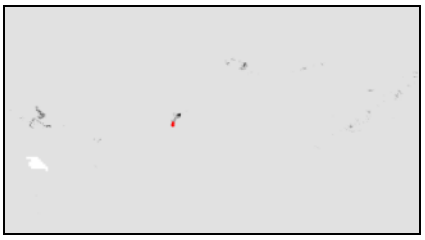
#41 – Silver pika (*Ochotona argentata*)
n = 4
Expert: Andrew Smith, Arizona State University
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: UNMODELLABLE

Model evaluation metric	
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

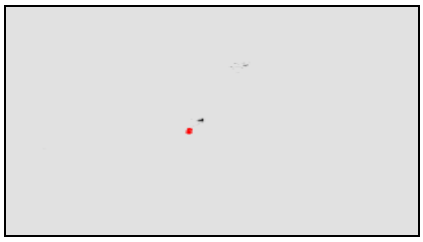
Summary: The Silver pika's bioclimatic envelope is predicted to decrease by 80% with a ~4° mean latitudinal polewards shift and a mean increase in elevation of ~360m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (62.7%), human influence index (17.1%), mean annual precipitation (8.6%), minimum temperature (5.4%) and annual evapotranspiration (1.8%).



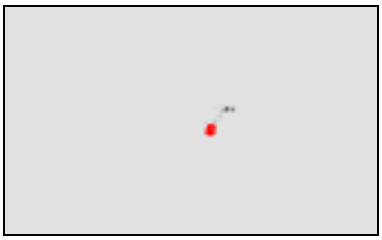
a) ~ 1930s (1900-1949)



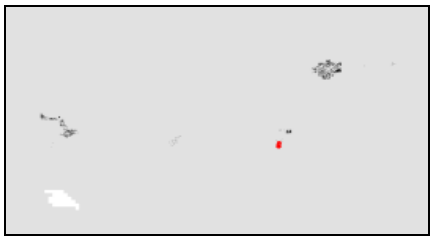
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



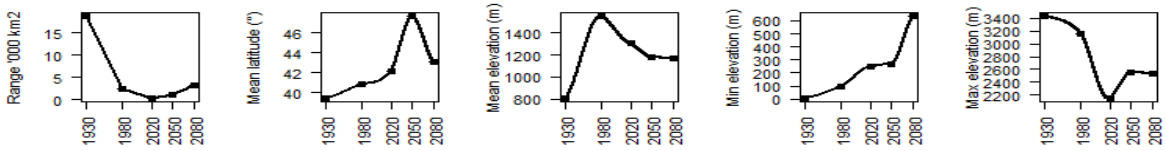
d) ~ 2050s (2040-2069)

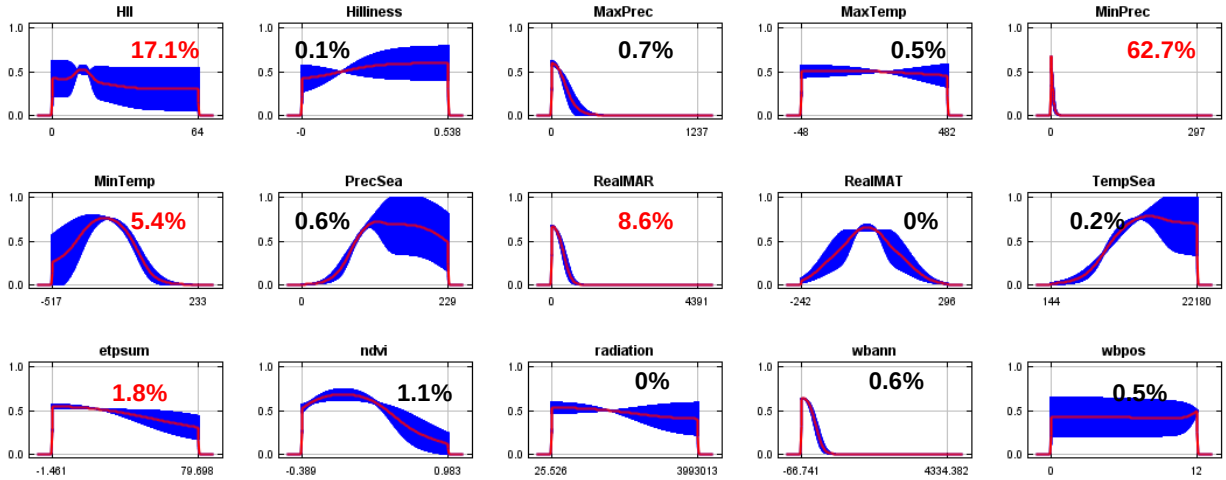


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

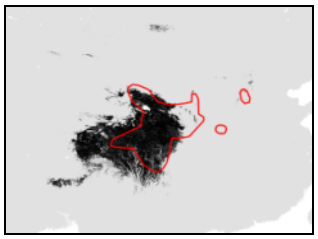


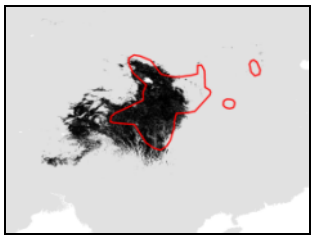


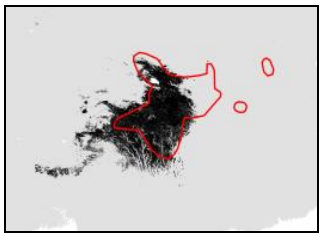
#42 – Gansu pika (*Ochotona cansus*)
n = 38
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1.5km/year (Similar ecology to *O.roylei*)
Status: MODELLABLE

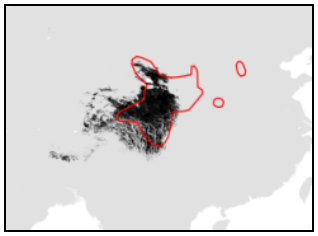
Model evaluation metric	
AUC	0.95
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.61**
True Skill Statistic	0.89

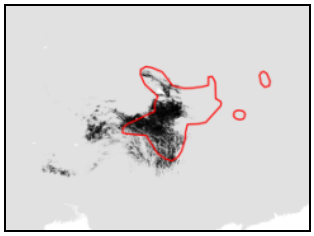
Summary: The Gansu pika's bioclimatic envelope is predicted to decrease by 60% with a ~0.4° mean latitudinal shift towards the Equator and a mean increase in elevation of ~230m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (89.8%) and minimum temperature (6.9%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

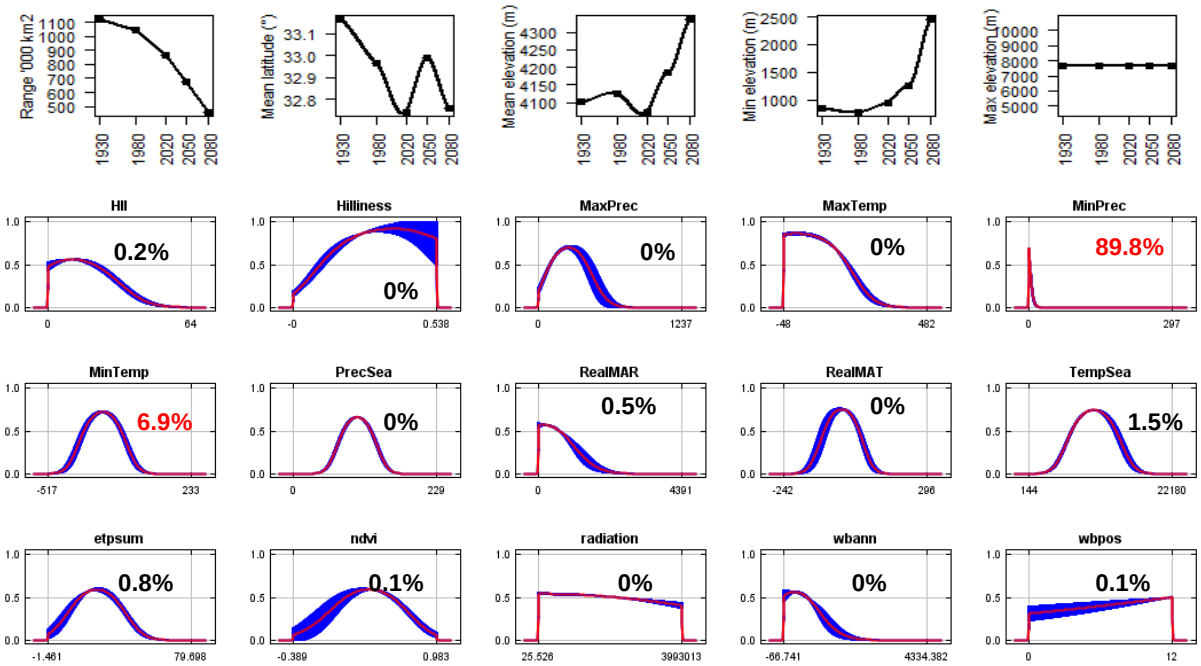

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

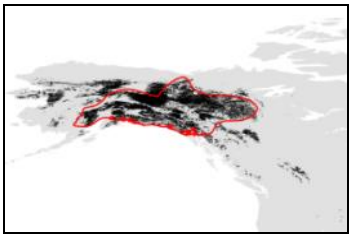
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

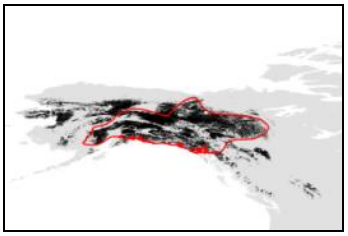


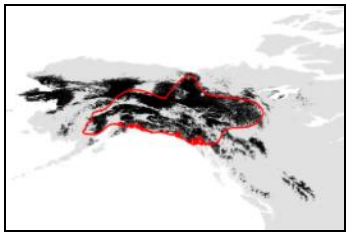
#43 – Collared pika (*Ochotona collaris*)
n = 193
Expert: Hayley Lanier, University of Michigan & David Hik, University of Alberta
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Expert)
Status: UNMODELLABLE

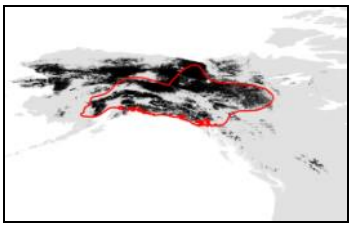
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.86**
True Skill Statistic	0.90

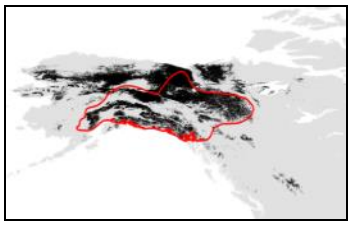
Summary: The Collared pika's bioclimatic envelope is predicted to increase by 20% with a ~2° mean latitudinal polewards shift and a mean decrease in elevation of ~140m. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (86.7%), mean annual temperature (3.3%), normalised difference vegetation index (3.2%) and maximum temperature (2.0%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

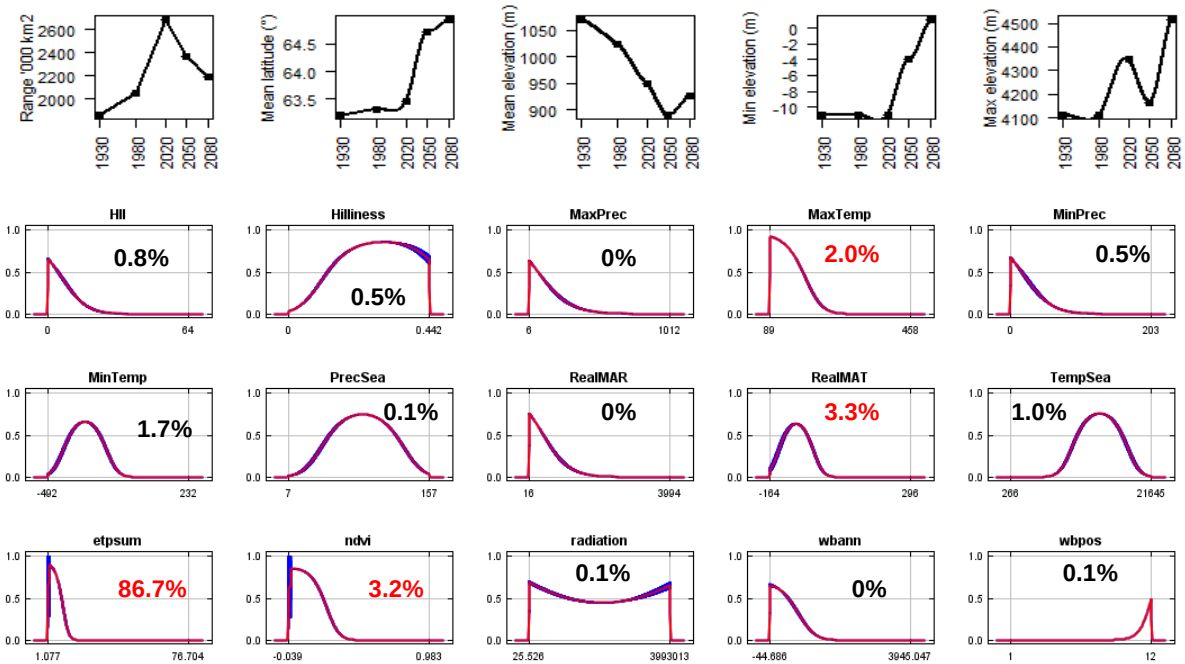

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

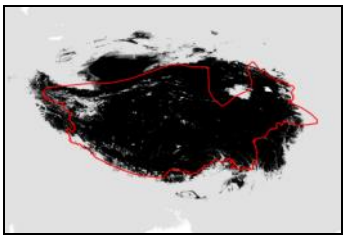
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



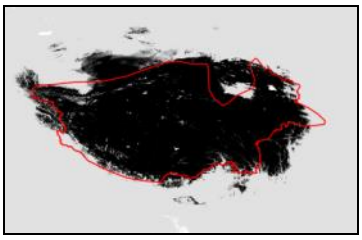
#44 – Plateau pika (*Ochotona curzoniae*)
n = 131
Expert: Andrew Smith, Arizona State University
Expert evaluation: Good
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.1km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.76**
True Skill Statistic	0.88

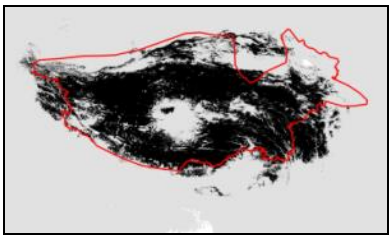
Summary: The Plateau pika's bioclimatic envelope is predicted to decrease by 30% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~700m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (48.0%), maximum temperature (42.0%) and annual evapotranspiration (6.8%).



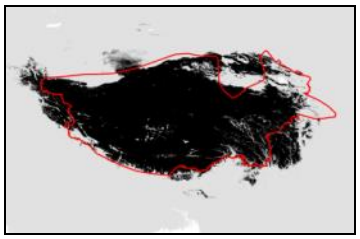
a) ~ 1930s (1900-1949)



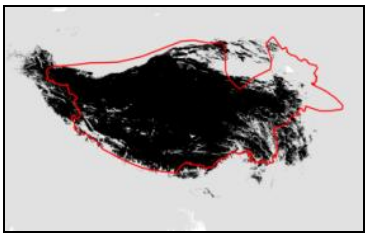
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



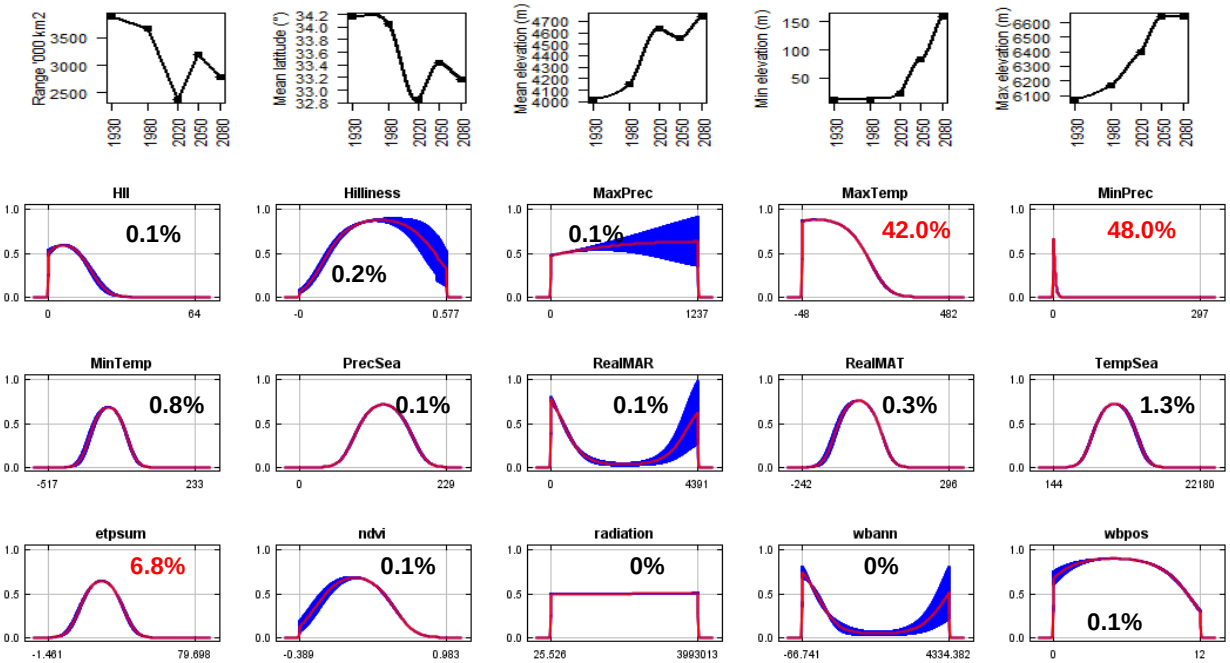
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

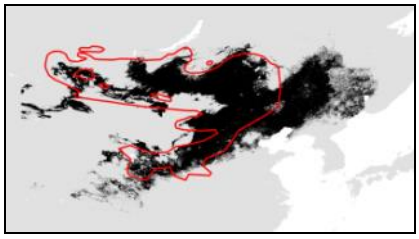
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



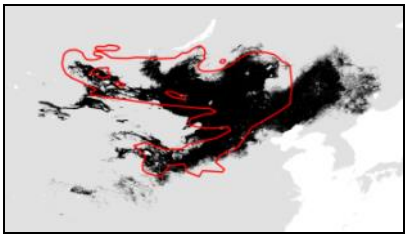
#45 – Daurian pika (*Ochotona dauurica*)
n = 131
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.1km/year (Similar ecology to *O.curzoniae*)
Status: MODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.66**
True Skill Statistic	0.89

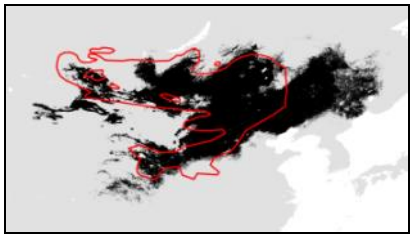
Summary: The Daurian pika's bioclimatic envelope is predicted to decrease by 25% with a ~1° mean latitudinal polewards shift and a mean decrease in elevation of ~60m. 95% of the permutation importance of the model was contributed to by minimum precipitation (92.3%) and number of months with a positive water balance (2.7%).



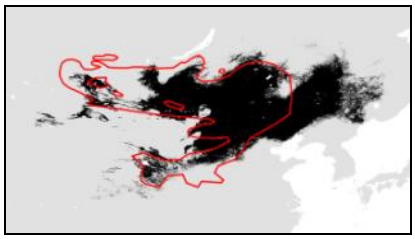
a) ~ 1930s (1900-1949)



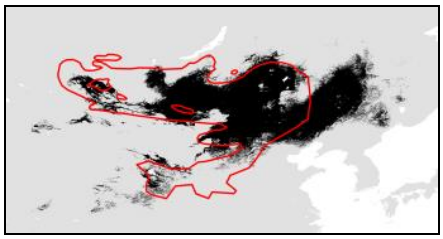
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



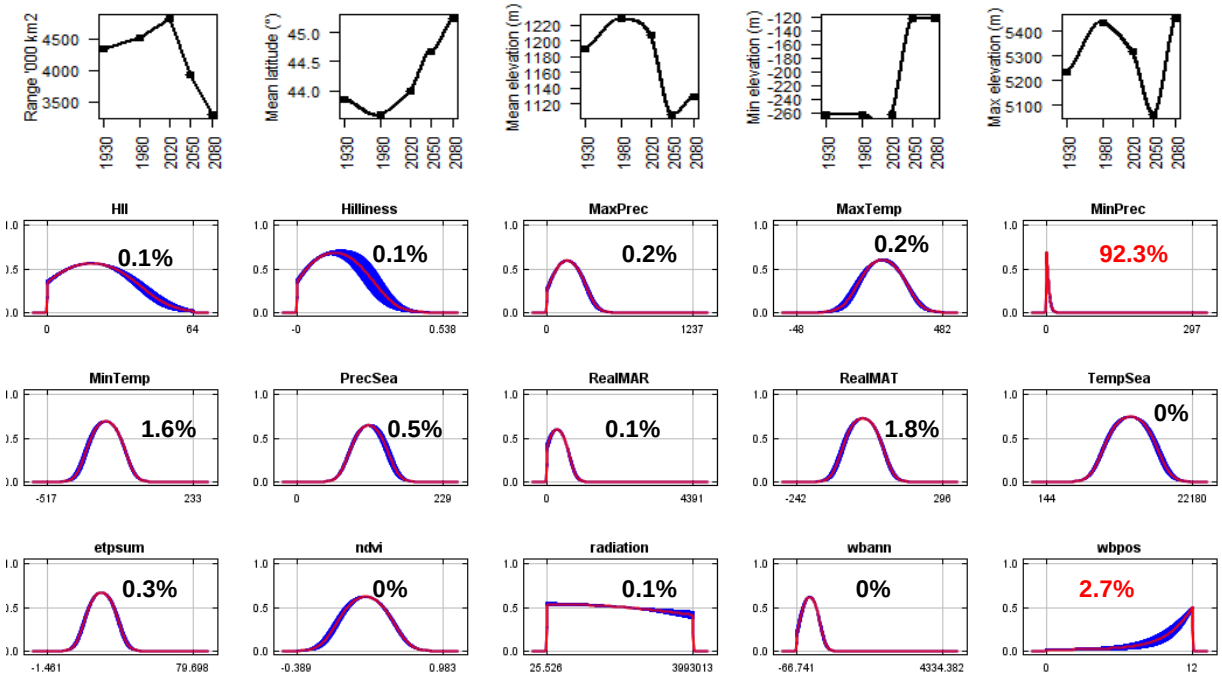
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

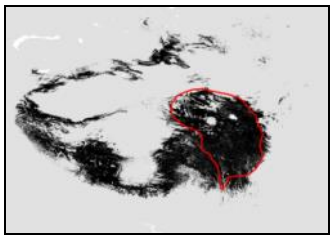
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



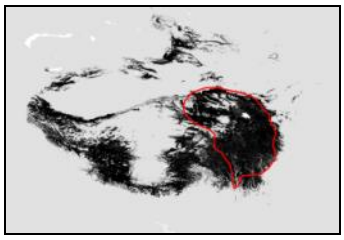
#46 – Chinese red pika (*Ochotona erythrotis*)
n = 39
Expert: Andrew Smith, Arizona State University
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.53**
True Skill Statistic	0.89

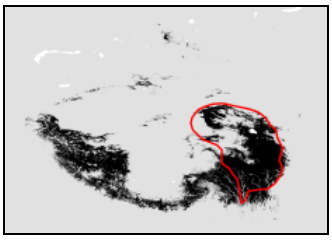
Summary: The Chinese red pika's bioclimatic envelope is predicted to decrease by 20% with a ~3° mean latitudinal polewards shift and a mean decrease in elevation of ~2400m driven by a decrease in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (87.2%), minimum temperature (7.2%) and mean annual temperature (2.9%).



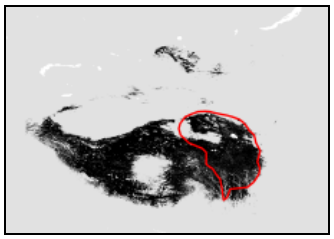
a) ~ 1930s (1900-1949)



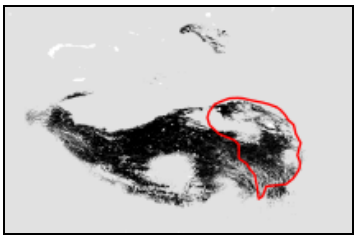
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



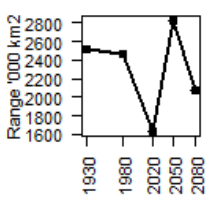
d) ~ 2050s (2040-2069)

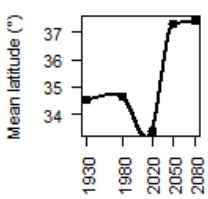


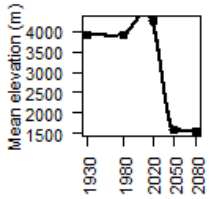
e) ~ 2080s (2070-2099)

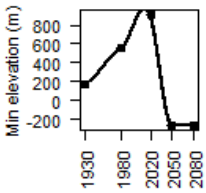
Black = predicted suitable envelope

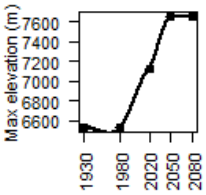
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

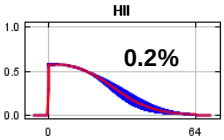


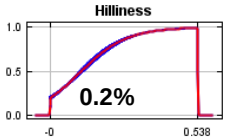


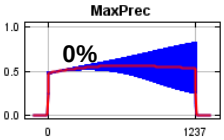


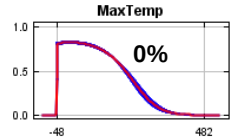


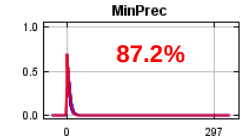


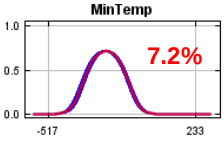


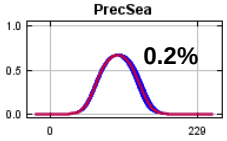


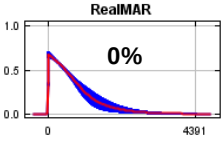


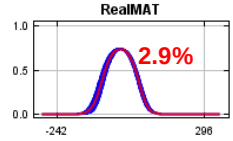


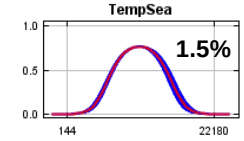


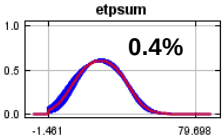


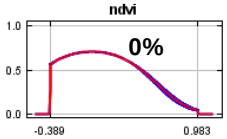


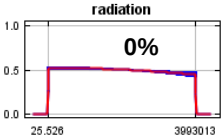


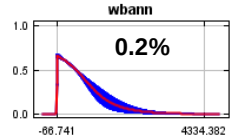


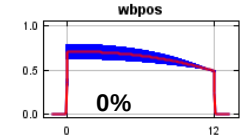








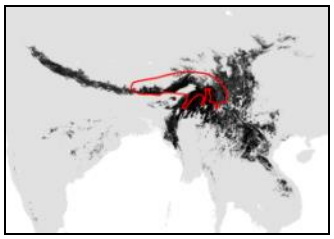


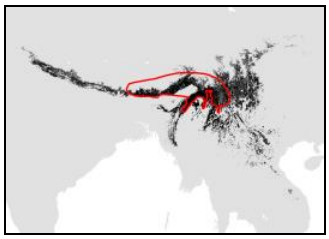


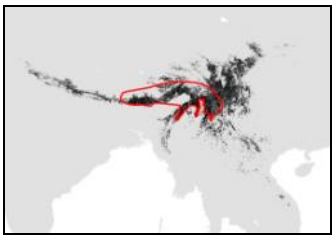
#47 – Forrest's pika (*Ochotona forresti*)
n = 9
Expert: Andrew Smith, Arizona State University
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: UNMODELLABLE

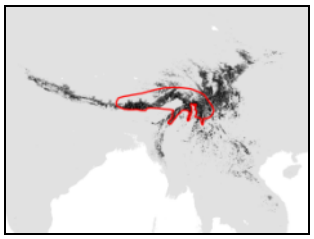
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.53**
True Skill Statistic	0.89

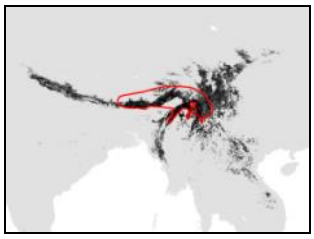
Summary: The Forrest's pika's bioclimatic envelope is predicted to decrease by 40% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~600m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (36.8%), temperature seasonality (20.6%), normalised difference vegetation index (12.1%), maximum temperature (9.3%), precipitation seasonality (7.6%), human influence index (6.2%) and surface roughness index (4.2%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

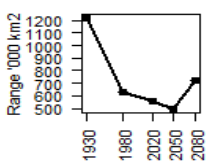

c) ~ 2020s (2010-2039)

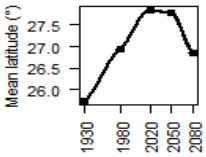

d) ~ 2050s (2040-2069)

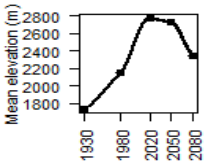

e) ~ 2080s (2070-2099)

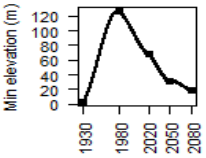
Black = predicted suitable envelope

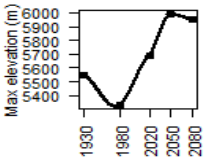
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

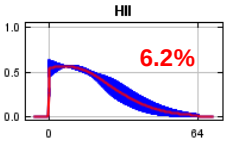


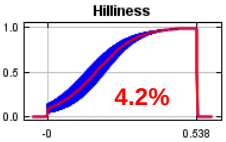


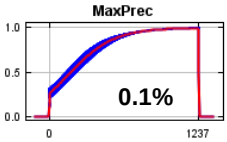


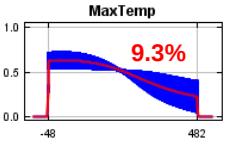


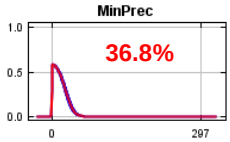


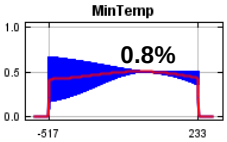


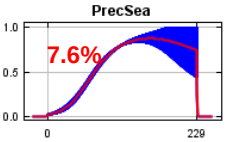


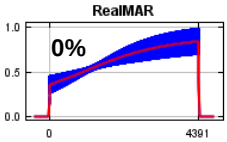


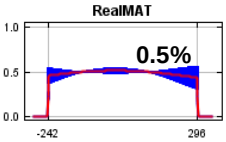


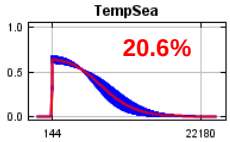


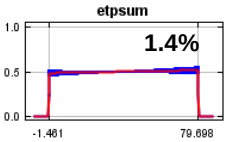


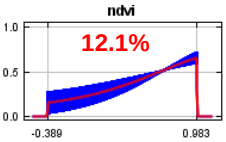


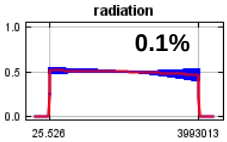


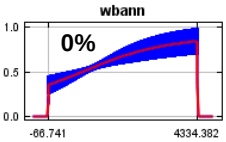


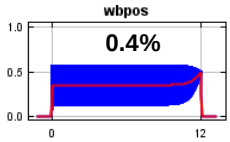








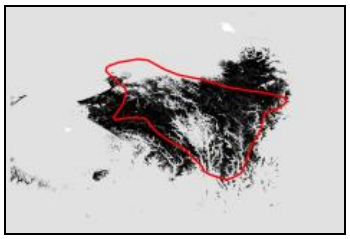




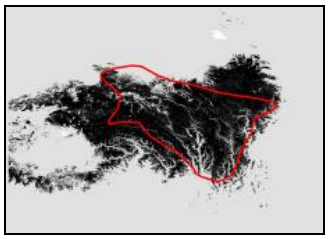
#48 – Glover's pika (*Ochotona gloveri*)
n = 22
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.65**
True Skill Statistic	0.99

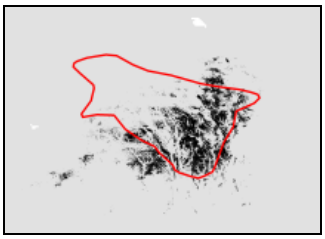
Summary: The Glover's pika's bioclimatic envelope is predicted to decrease by 50% with a ~0.5° mean latitudinal polewards shift and a mean increase in elevation of ~270m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (46.3%), minimum temperature (28.8%), mean annual temperature (12.7%), human influence index (3.8%), temperature seasonality (3.1%) and precipitation seasonality (1.8%).



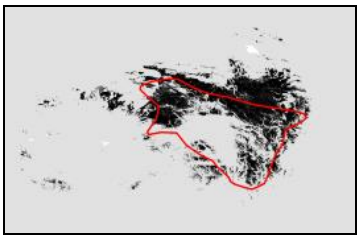
a) ~ 1930s (1900-1949)



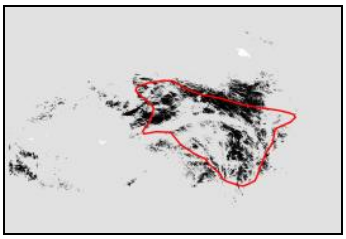
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



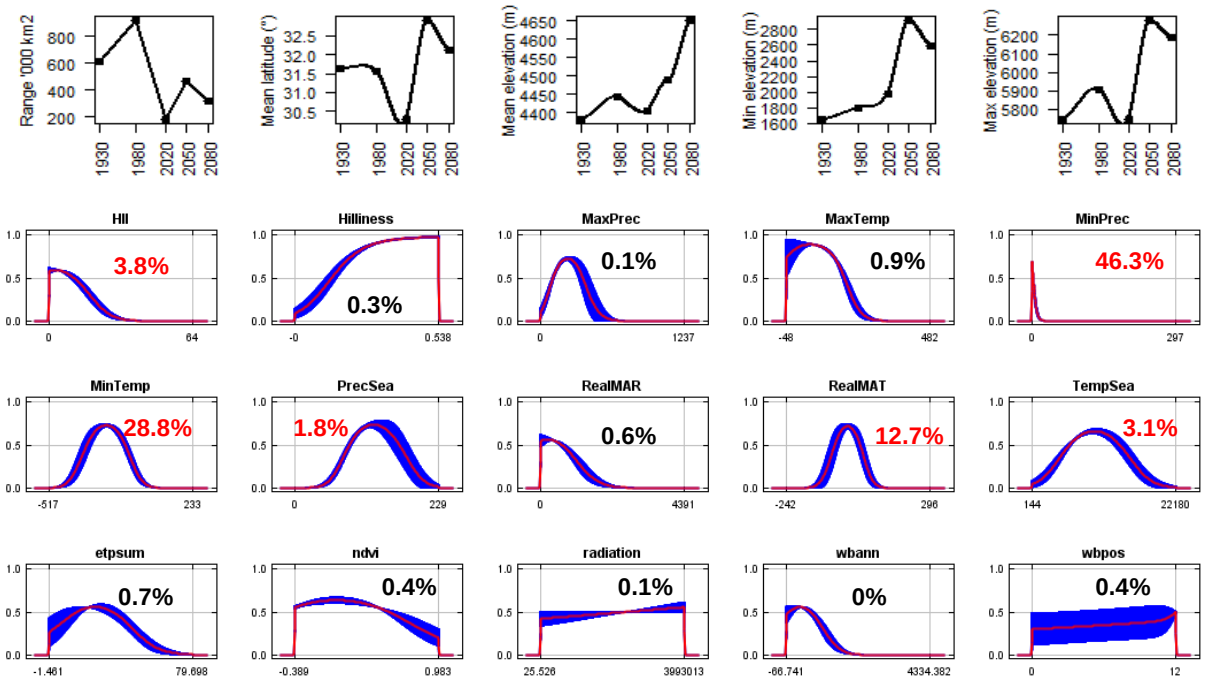
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

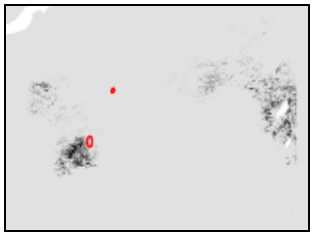
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

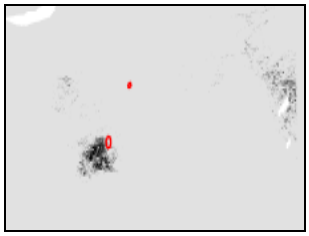


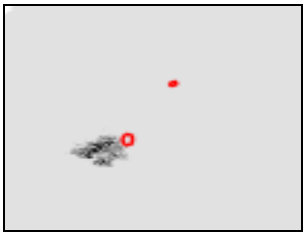
#49 – Hoffmann's pika (*Ochotona hoffmanni*)
n = 5
Expert: Andrey Lissovsky, Zoological Museum of Moscow State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: MODELLABLE

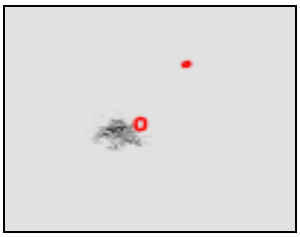
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.91**
True Skill Statistic	0.99

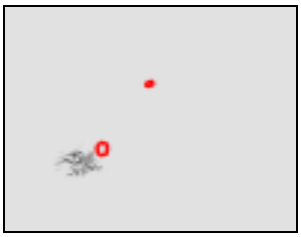
Summary: The Hoffmann's pika's bioclimatic envelope is predicted to decrease by 90% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~470m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (73.2%), mean annual temperature (12.6%), minimum temperature (6.5%) and minimum precipitation (5.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

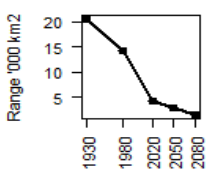

c) ~ 2020s (2010-2039)

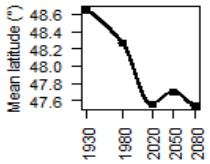

d) ~ 2050s (2040-2069)

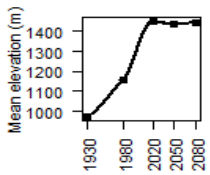

e) ~ 2080s (2070-2099)

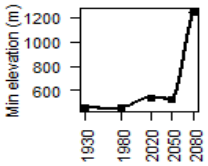
Black = predicted suitable envelope

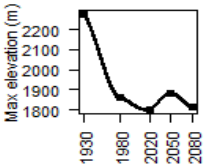
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

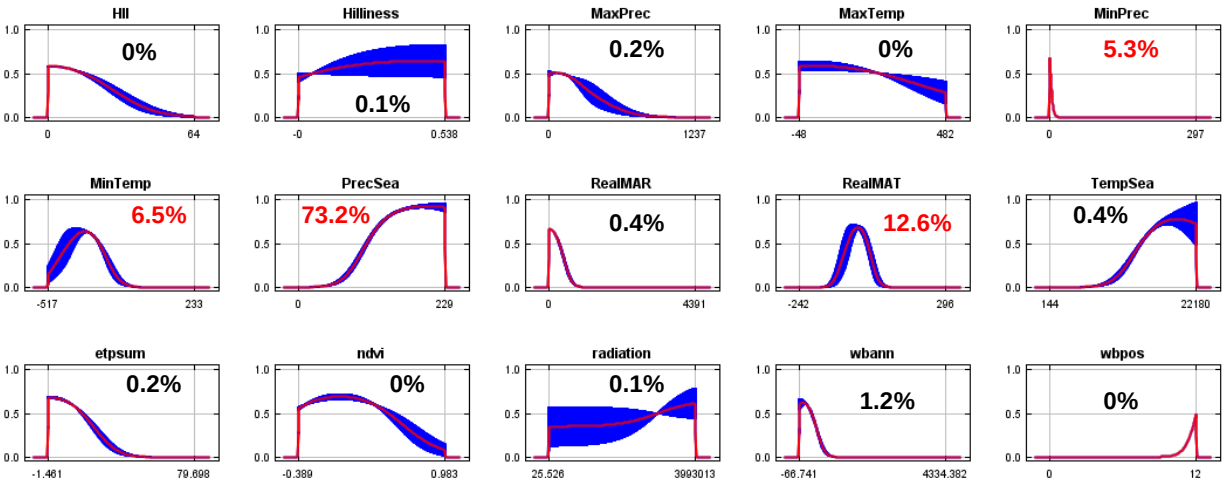








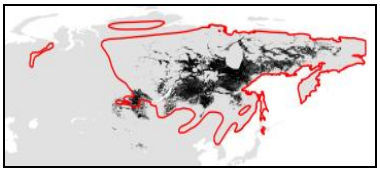




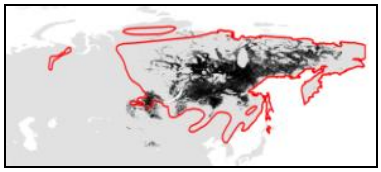
#50 – Siberian pika (*Ochotona hyperborea*)
n = 16
Expert: Julia Witczuk, Warsaw Agricultural University, Poland
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 10km/year (Similar ecology to *O.alpina*)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.97
Omission rate	0.06
Sensitivity	0.94
Specificity	0.99
Proportion correct	0.99
Kappa	**0.40**
True Skill Statistic	0.93

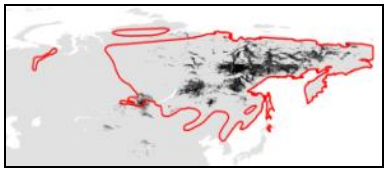
Summary: The Siberian pika's bioclimatic envelope is predicted to decrease by 100% with a ~5° mean latitudinal polewards shift and a mean increase in elevation of ~200m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (72.5%), annual evapotranspiration (10.4%), minimum precipitation (6.4%), human influence index (2.8%), normalised difference vegetation index (2.6%) and annual water balance (1.8%).



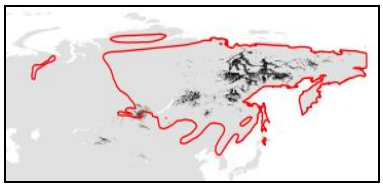
a) ~ 1930s (1900-1949)



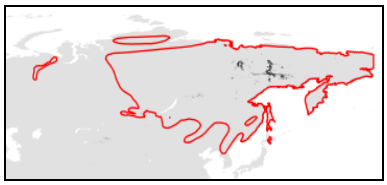
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



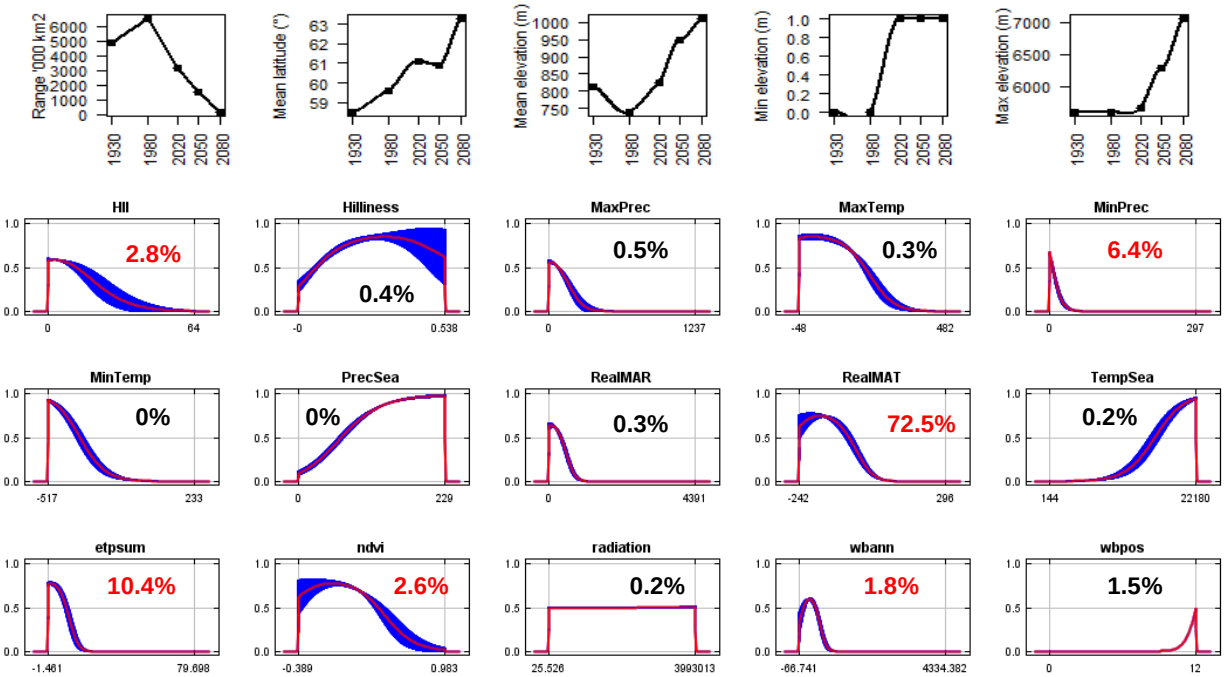
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

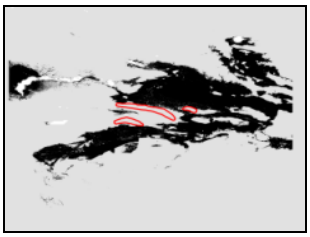
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



#51– Ili pika (*Ochotona iliensis*)
n = 11
Expert: Andrew Smith, Arizona State University
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Similar ecology to *O.koslowi*)
Status: UNMODELLABLE

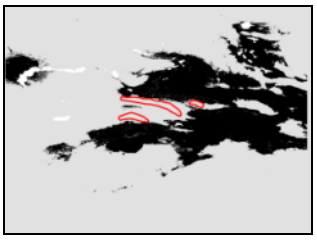
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.55**
True Skill Statistic	0.99

Summary: The Ili pika's bioclimatic envelope is predicted to decrease by 20% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~80m. 95% of the permutation importance of the model was contributed to by minimum precipitation (52.7%), minimum temperature (22.2%), mean annual temperature (8.8%), maximum precipitation (6.5%), temperature seasonality (3.0%) and human influence index (2.2%).

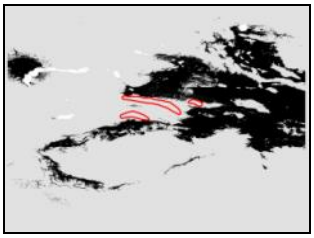


a) ~ 1930s (1900-1949)

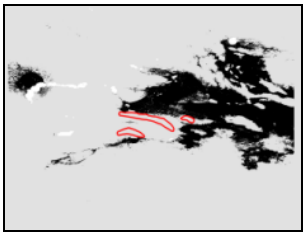
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



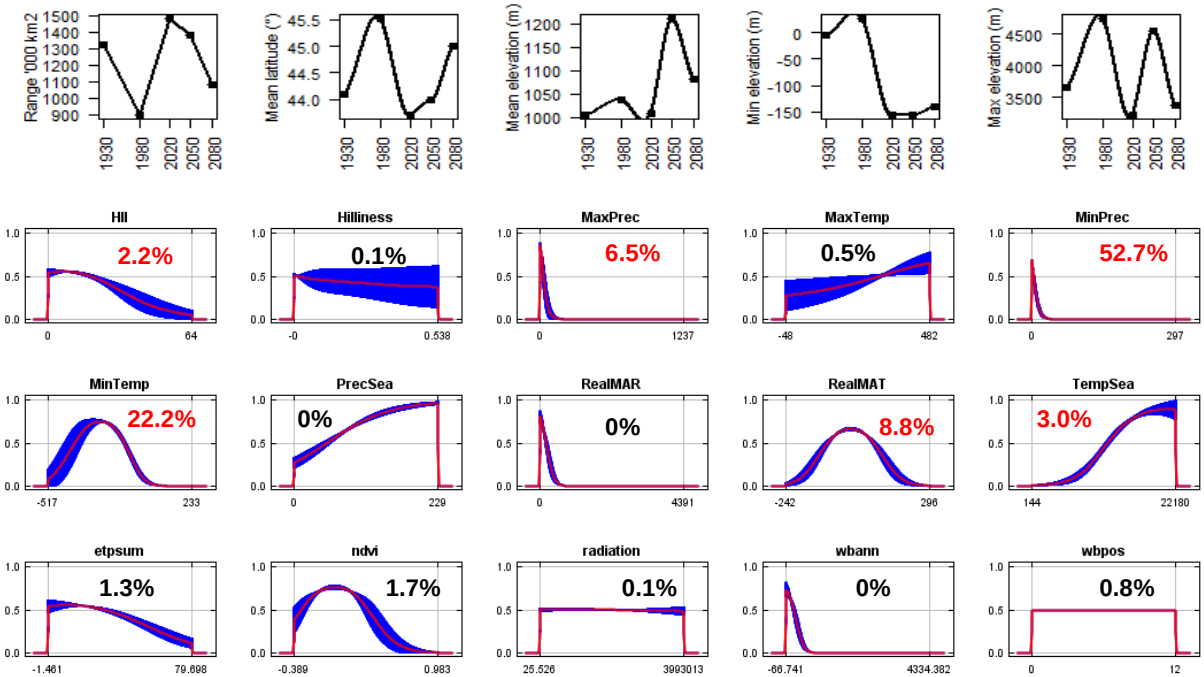
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

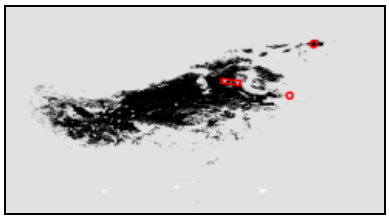
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



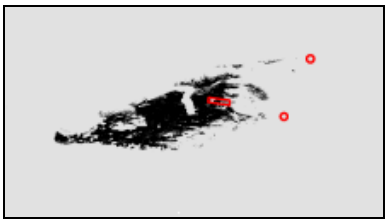
#52 – Kozlov's pika (*Ochotona koslowi*)
n = 5
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.86**
True Skill Statistic	0.99

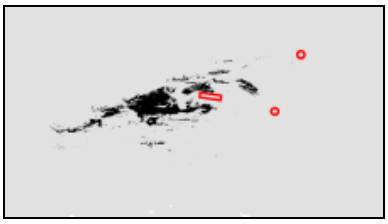
Summary: The Kozlov's pika's bioclimatic envelope is predicted to decrease by 100% (total extinction). 95% of the permutation importance of the model was contributed to by mean annual precipitation (66.8%), minimum precipitation (24.2%) and human influence index (5.8%).



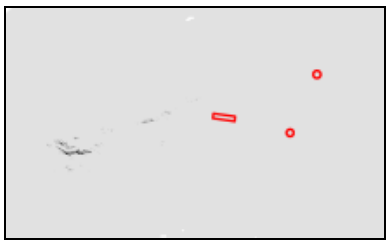
a) ~ 1930s (1900-1949)



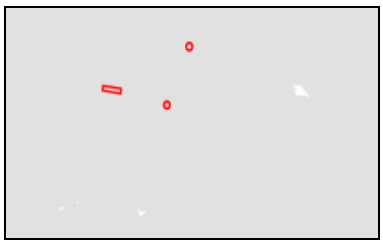
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



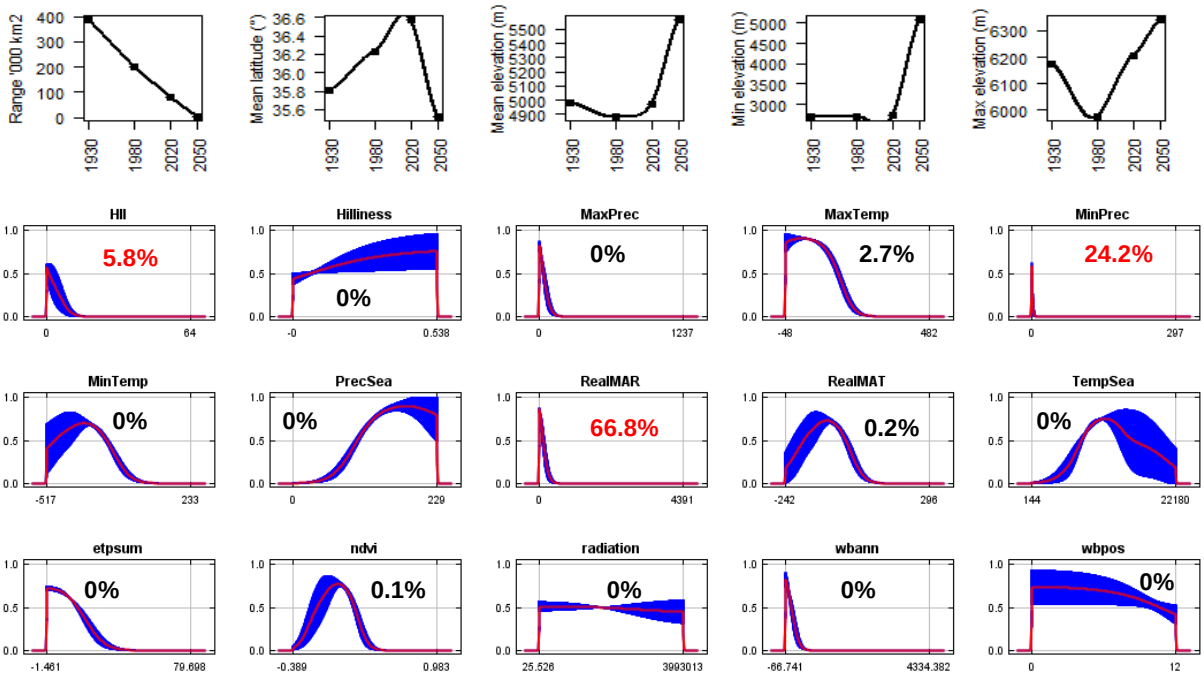
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

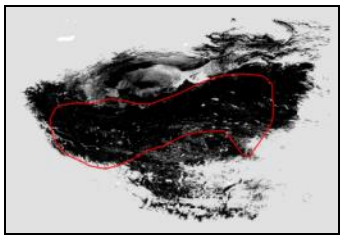
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



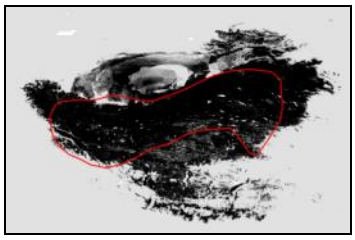
#53 – Ladak pika (*Ochotona ladacensis*)
n = 18
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.05km/year (Similar ecology to *O.curzoniae*)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.63**
True Skill Statistic	0.99

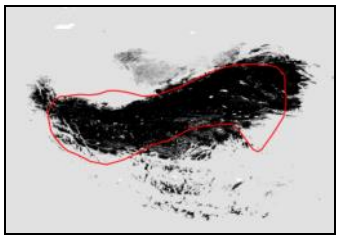
Summary: The Ladak pika's bioclimatic envelope is predicted to decrease by 70% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~1400m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by mean annual precipitation (47.9%), minimum precipitation (41.7%) and minimum temperature (5.7%).



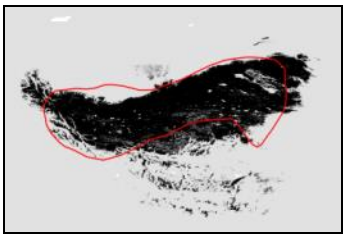
a) ~ 1930s (1900-1949)



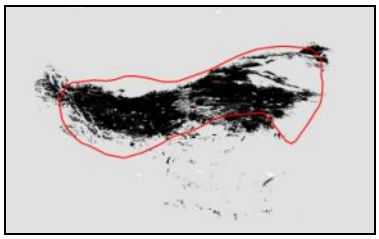
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



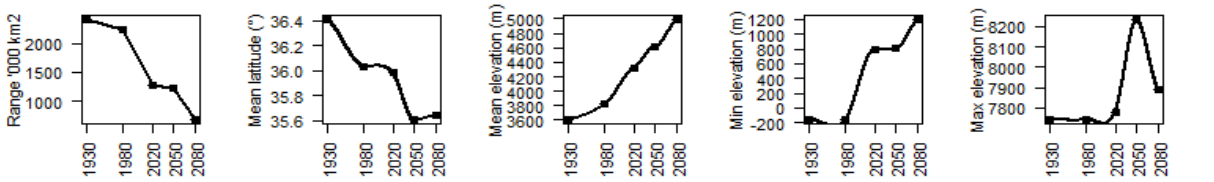
d) ~ 2050s (2040-2069)

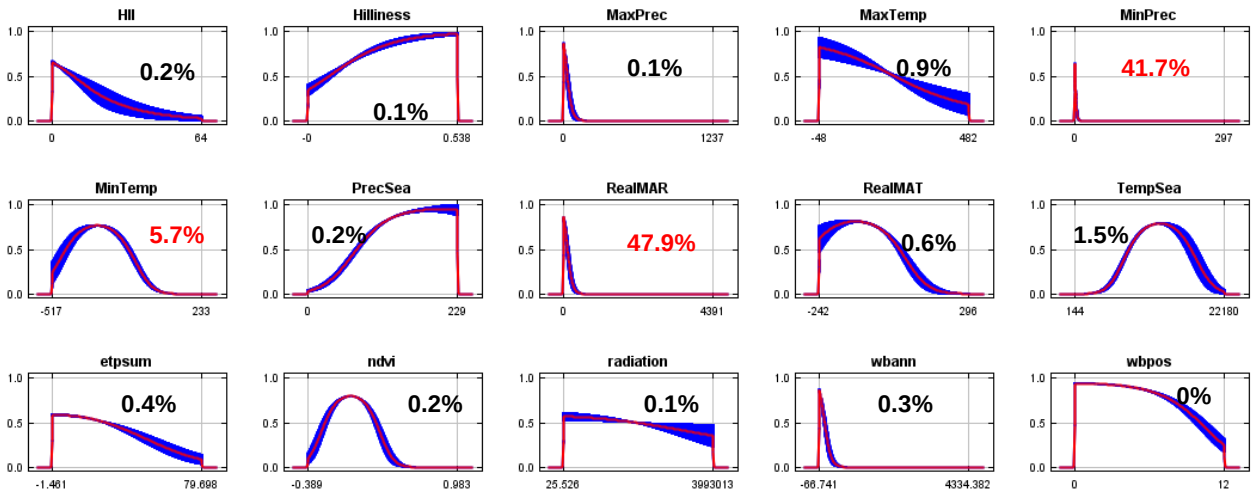


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

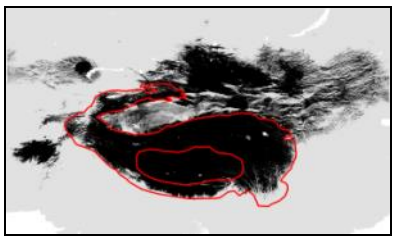


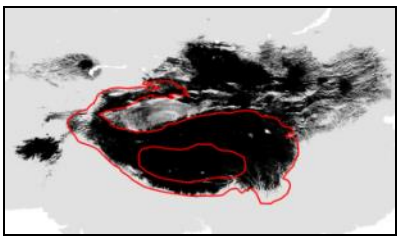


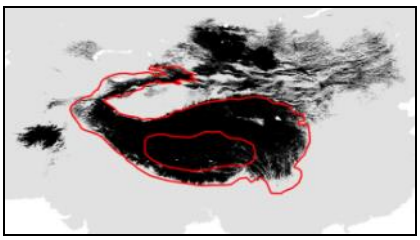
#54 – Large-eared pika (*Ochotona macrotis*)
n = 49
Expert: Nishma Dahal, National Centre for Biological Sciences, India
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Similar ecology to *O.roylei*)
Status: MODELLABLE

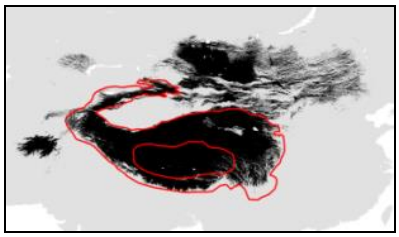
Model evaluation metric	
AUC	0.94
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.43**
True Skill Statistic	0.89

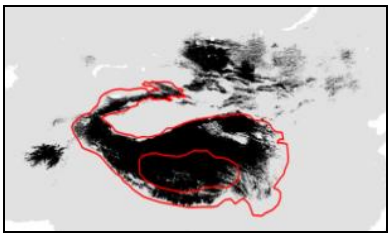
Summary: The Large-eared pika's bioclimatic envelope is predicted to decrease by 40% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~880m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (87.3%), minimum temperature (5.8%) and mean annual temperature (2.1%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

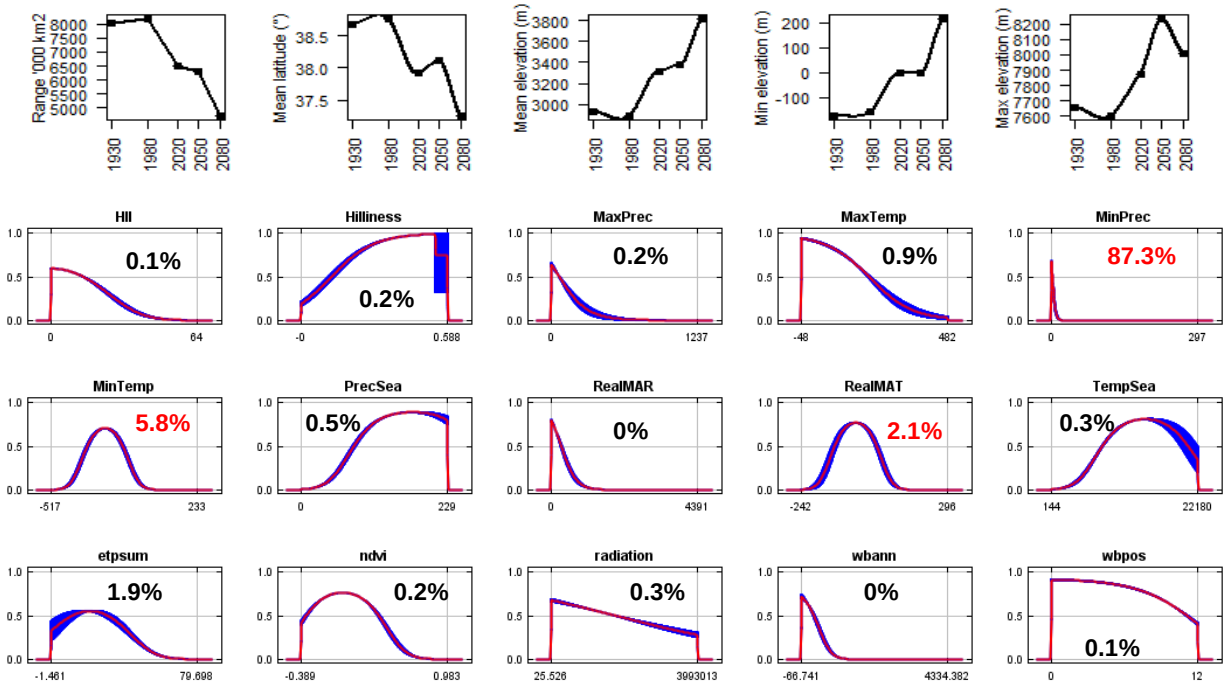

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

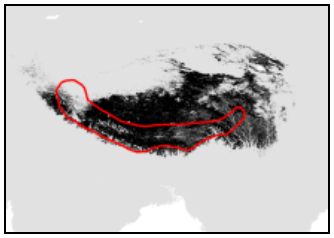
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

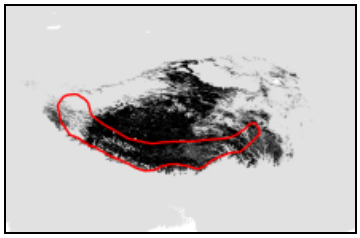


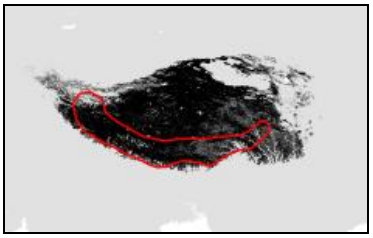
#55 – Nubra's pika (*Ochotona nubrica*)
n = 13
Expert: Nishma Dahal, National Centre for Biological Sciences, India
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.05km/year (Similar ecology to *O.curzoniae*)
Status: UNMODELLABLE

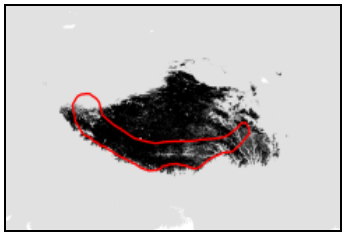
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.35**
True Skill Statistic	0.99

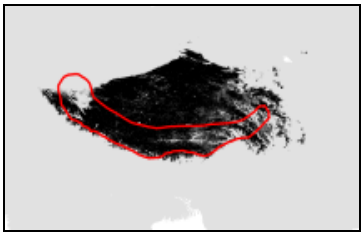
Summary: The Nubra's pika's bioclimatic envelope is predicted to increase by 1% with no latitudinal polewards shift, but a mean increase in elevation of ~200m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (76.1%) and mean annual temperature (20.9%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

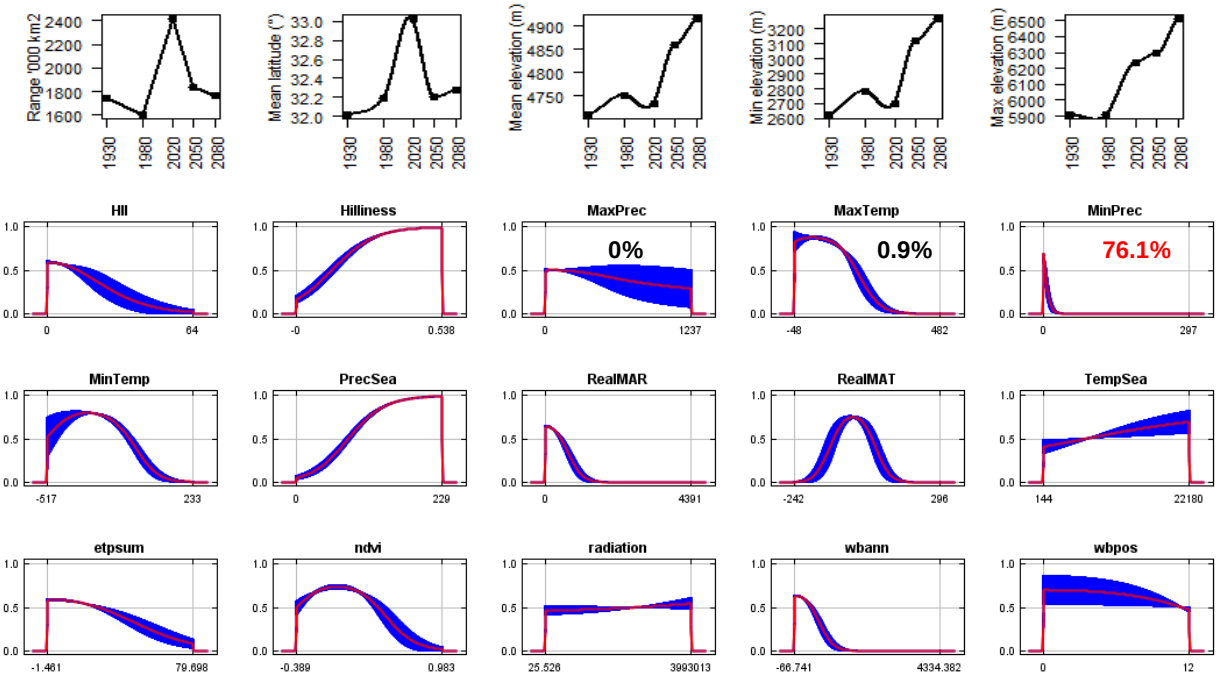

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

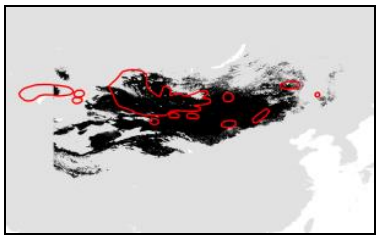
Red polygon = IUCN range (Smith, A.T. & Boyer, A. F. 2008)



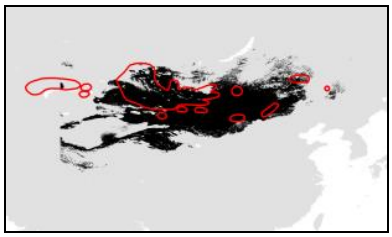
#56 – Pallas's pika (*Ochotona pallasi*)
n = 19
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 10km/year (Sokolov, V.E. *et al*., 2009)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.46**
True Skill Statistic	0.99

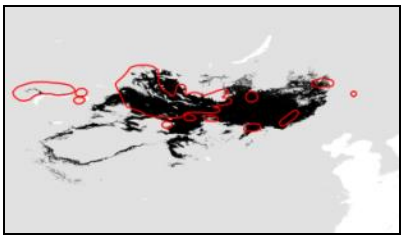
Summary: The Pallas's pika's bioclimatic envelope is predicted to decrease by 60% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~40m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (46.1%), mean annual precipitation (35.5%), mean annual temperature (9.4%) and minimum temperature (6.7%).



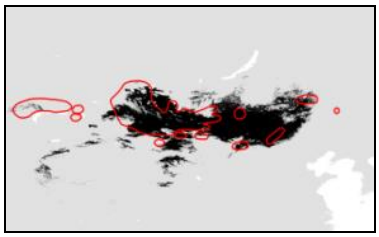
a) ~ 1930s (1900-1949)



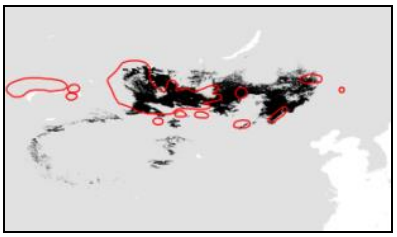
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



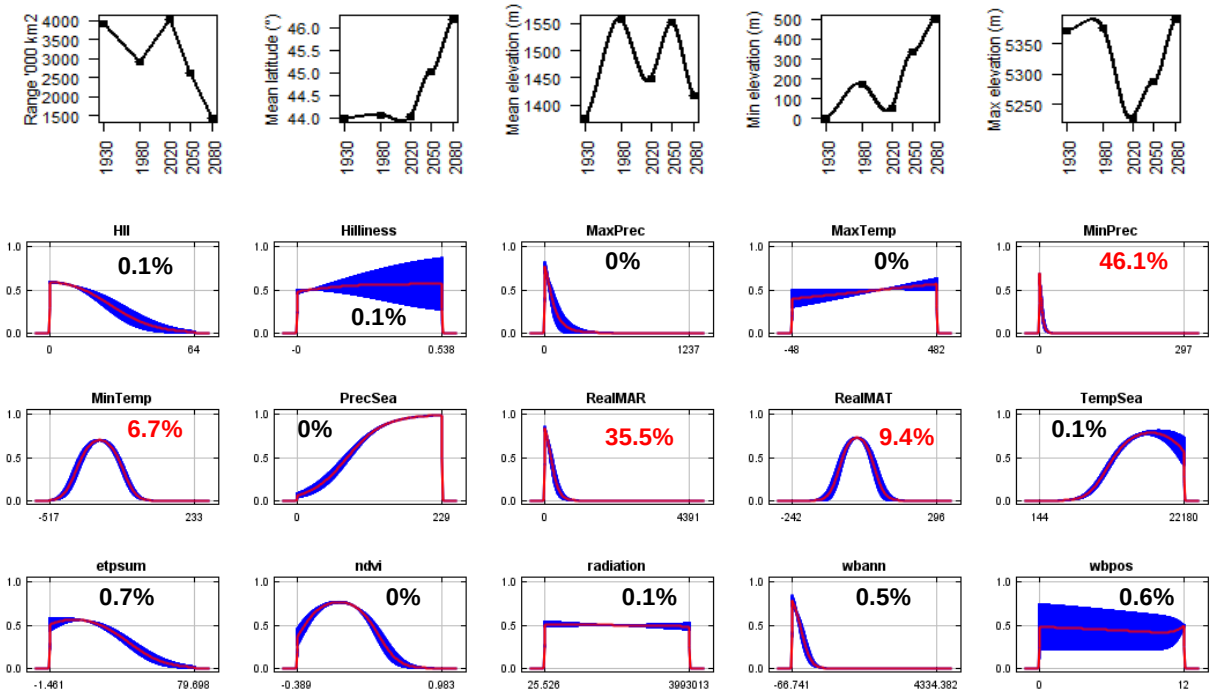
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

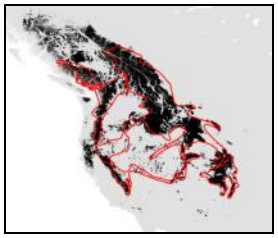
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

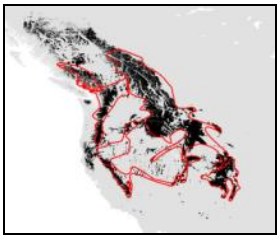


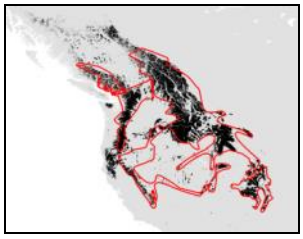
#57 – American pika (*Ochotona princeps*)
n = 670
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 16.1km/year (Expert)
Status: MODELLABLE

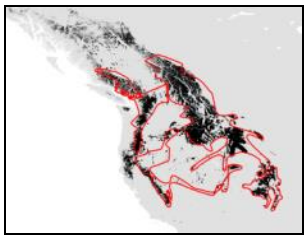
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.9
Specificity	0.99
Proportion correct	0.98
Kappa	**0.87**
True Skill Statistic	0.89

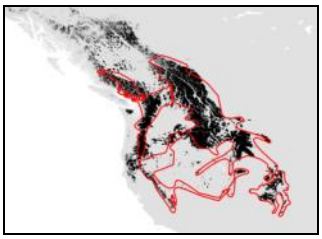
Summary: The American pika's bioclimatic envelope is predicted to decrease by 25% with a ~1° mean latitudinal polewards shift and a mean decrease in elevation of ~10m driven by an decrease in minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (88.1%), annual evapotranspiration (5.0%) and maximum temperature (2.8%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

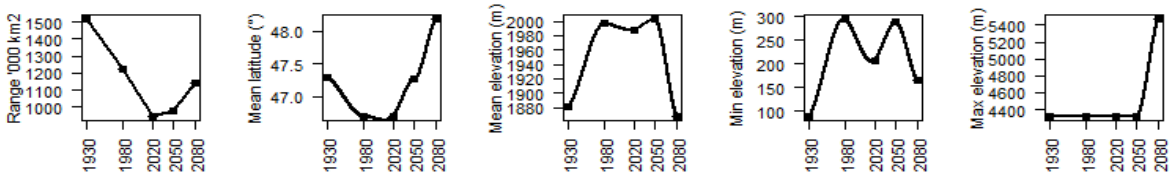

c) ~ 2020s (2010-2039)

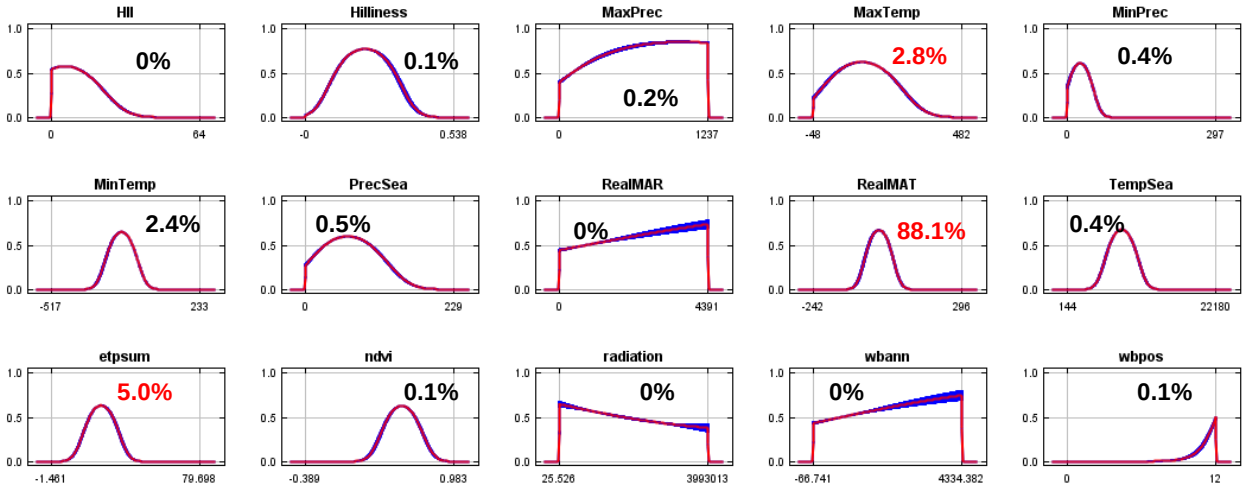

d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Beever, E. & Smith, A.T. 2011)

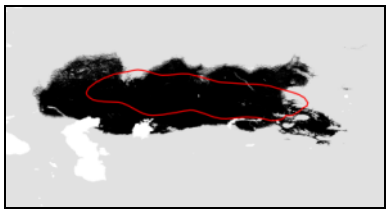




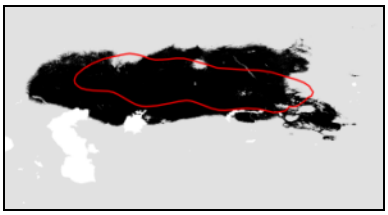
#58 – Little pika (*Ochotona pusilla*)
n = 30
Expert: Andrew Smith, Arizona State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 4km/year (Sokolov, V.E. *et al*., 2009)
Status: MODELLABLE

Model evaluation metric	
AUC	0.93
Omission rate	0.13
Sensitivity	0.87
Specificity	0.99
Proportion correct	0.99
Kappa	**0.58**
True Skill Statistic	0.86

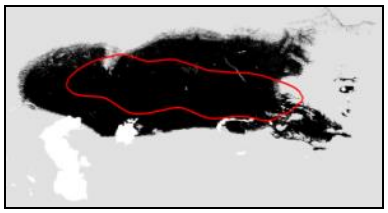
Summary: The Little pika's bioclimatic envelope is predicted to increase by 20% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~70m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (70.2%), annual water balance (13.3%), mean annual temperature (10.2%) and minimum temperature (4.5%).



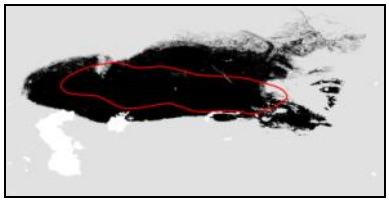
a) ~ 1930s (1900-1949)



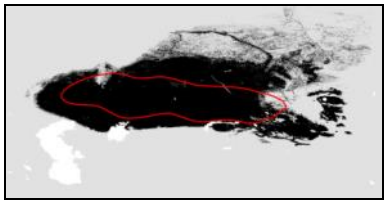
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



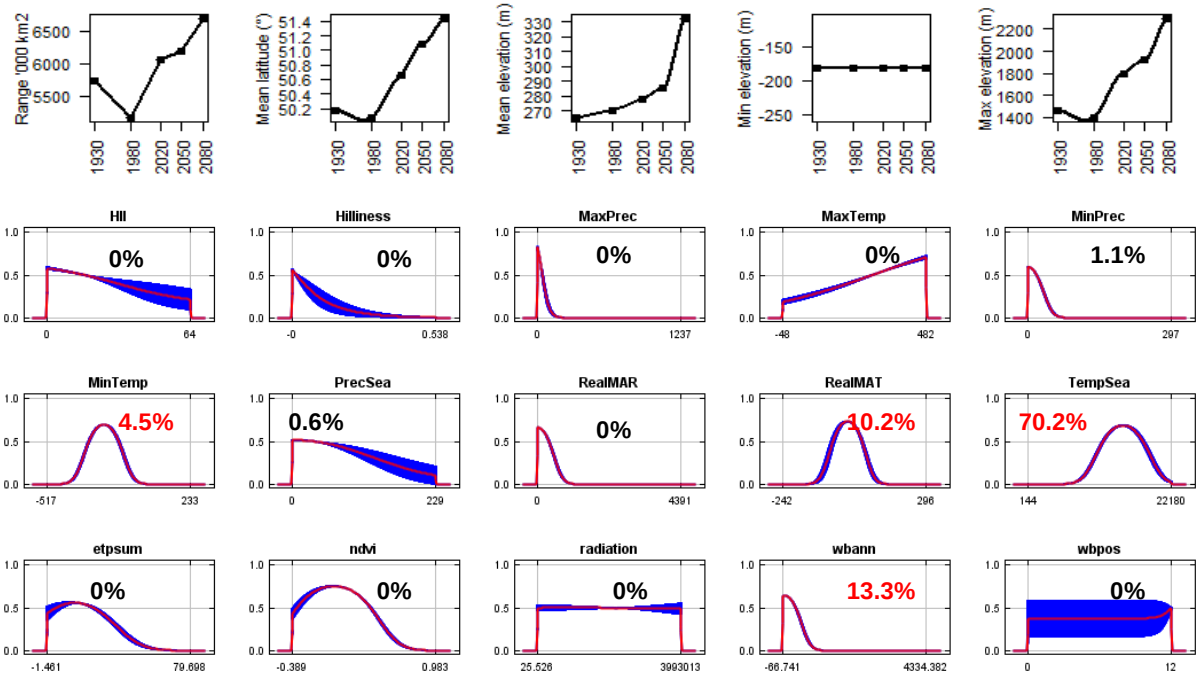
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

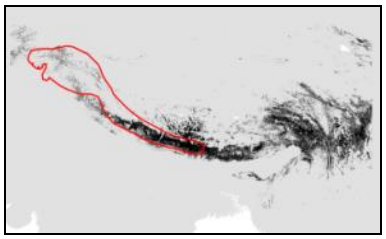
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



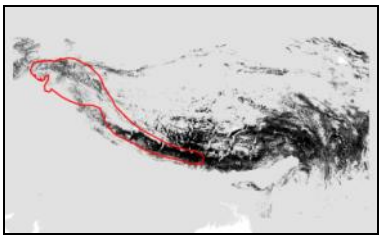
#59 – Royle's pika (*Ochotona roylei*)
n = 22
Expert: Sabuj Bhattacharya, Wildlife Institute of India
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.98
Omission rate	0.05
Sensitivity	0.95
Specificity	0.99
Proportion correct	0.99
Kappa	**0.76**
True Skill Statistic	0.95

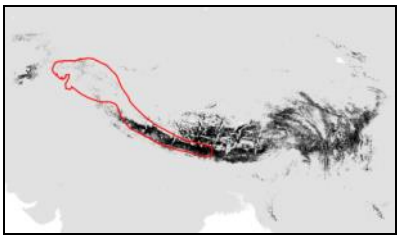
Summary: The Royle's pika's bioclimatic envelope is predicted to decrease by 20% with no latitudinal polewards shift and a mean increase in elevation of ~340m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (53.2%), maximum temperature (20.4%), temperature seasonality (10.2%), human influence index (5.5%), surface roughness index (4.2%) and precipitation seasonality (3.2%).



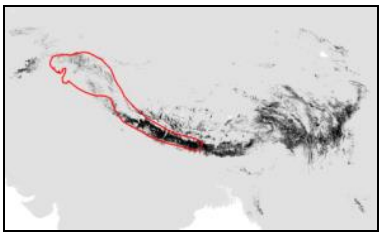
a) ~ 1930s (1900-1949)



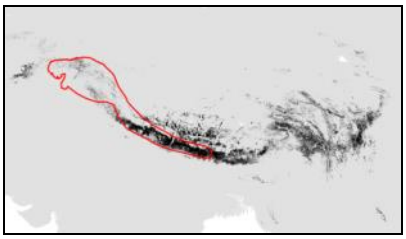
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



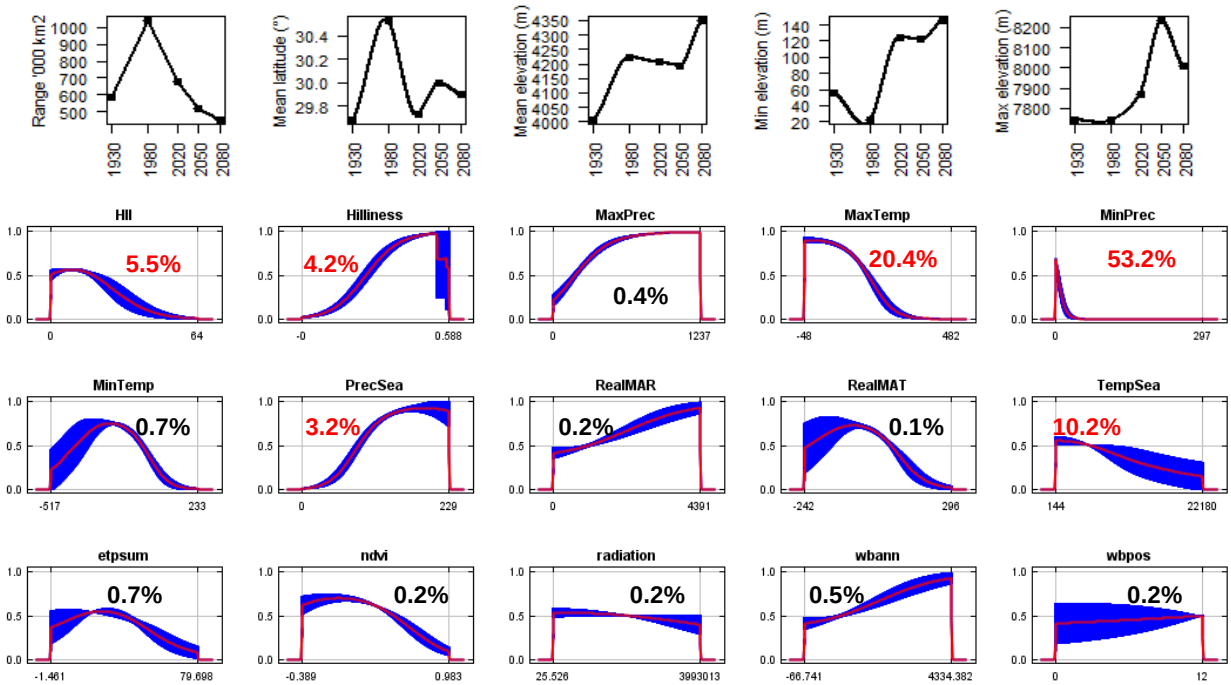
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

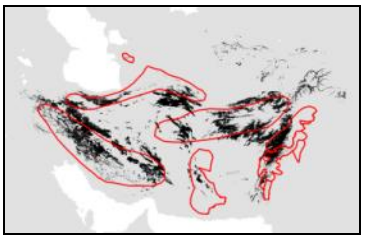
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

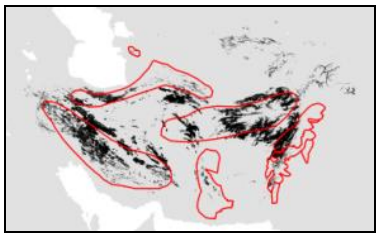


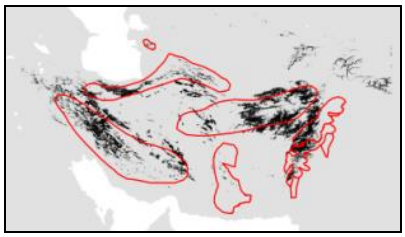
#60 – Afghan pika (*Ochotona rufescens*)
n = 17
Expert: Chelmala Srinivasulu, Osmania University, India
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: MODELLABLE

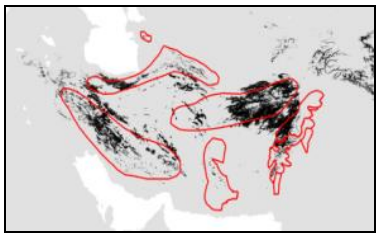
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.74**
True Skill Statistic	0.99

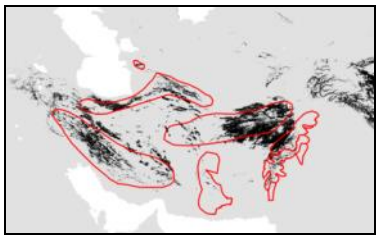
Summary: The Afghan pika's bioclimatic envelope is predicted to increase by 5% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~380m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (89.2%), minimum temperature (5.5%) and normalised difference vegetation index (2.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

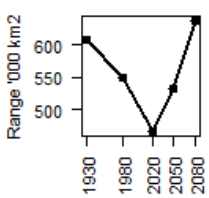

c) ~ 2020s (2010-2039)

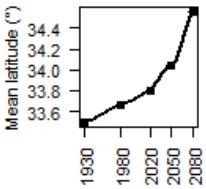

d) ~ 2050s (2040-2069)

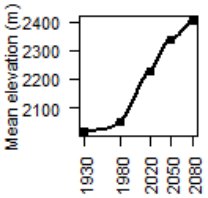

e) ~ 2080s (2070-2099)

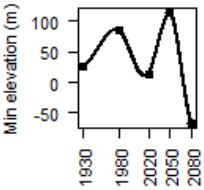
Black = predicted suitable envelope

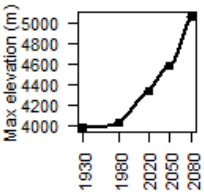
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

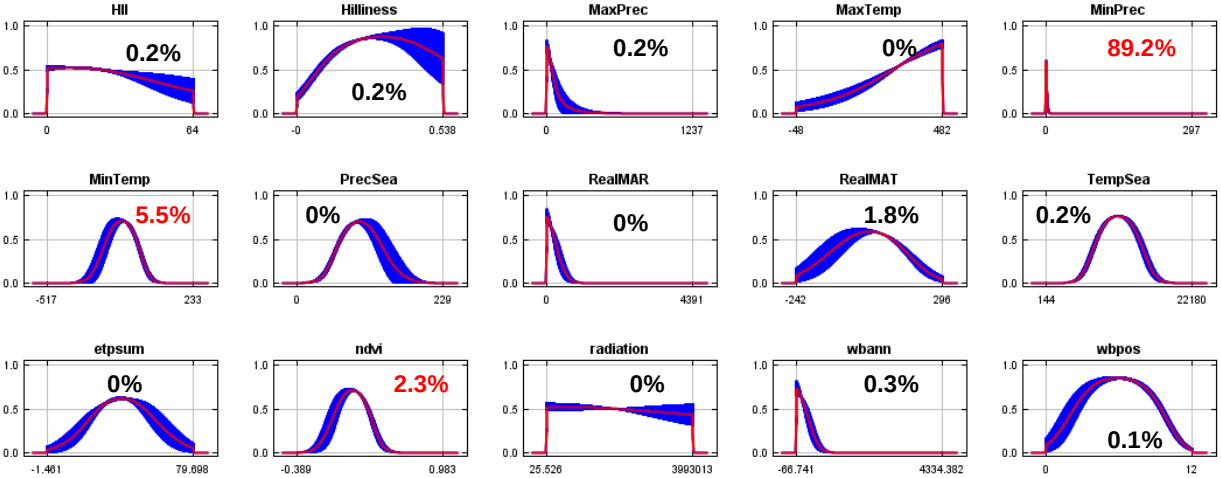








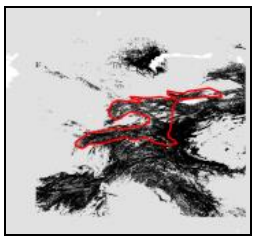


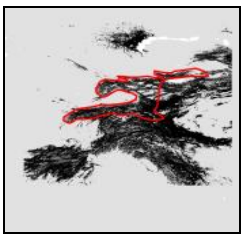


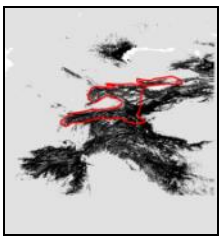
#61 – Turkestan red pika (*Ochotona rutila*)
n = 13
Expert: Andrey Lissovsky, Zoological Museum of Moscow State University
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Average for Asian pikas)
Status: UNMODELLABLE

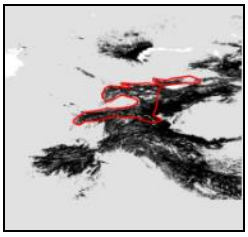
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.25**
True Skill Statistic	0.99

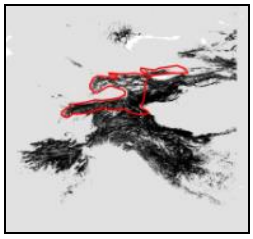
Summary: The Turkestan red pika's bioclimatic envelope is predicted to decrease by 10% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~630m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (82.5%), minimum temperature (5.9%), human influence index (3.0%), precipitation seasonality (2.5%) and surface roughness index (1.7%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

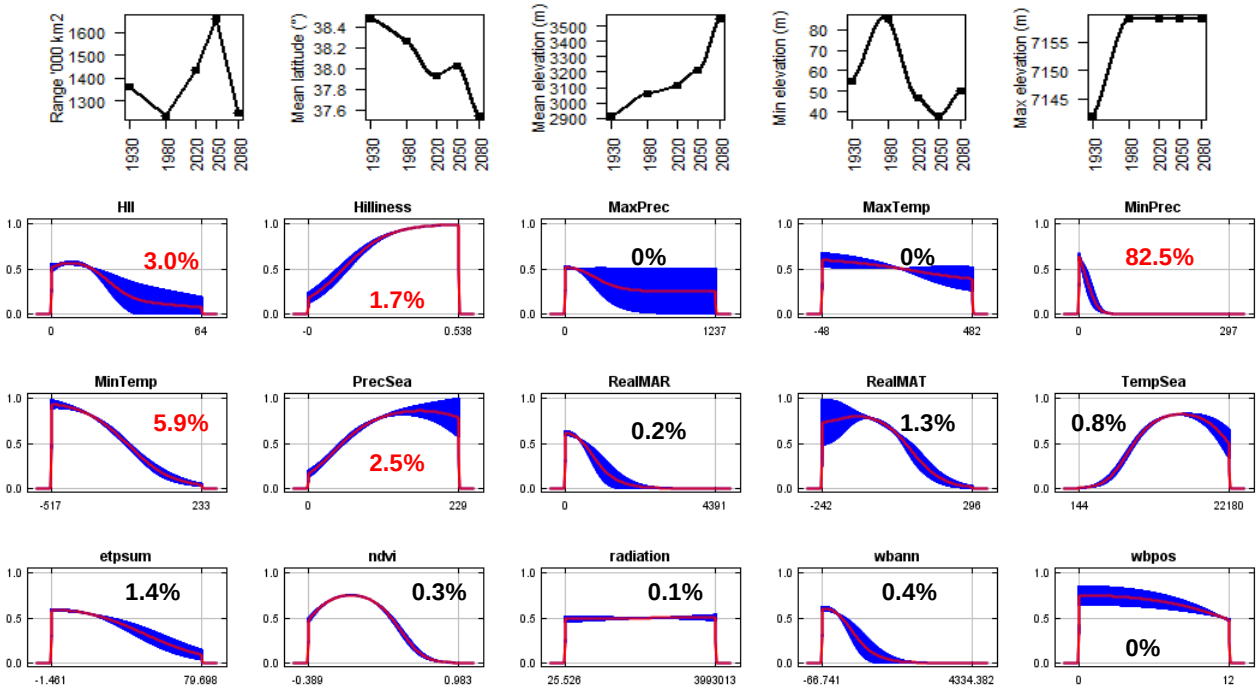

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

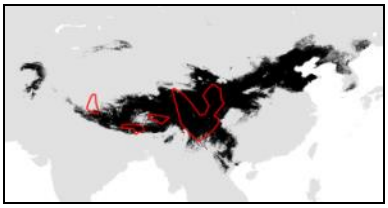


#62 – Moupin pika (*Ochotona thibetana*)
n = 95
Expert: Deyan Ge, Institute of Zoology, Chinese Academy of Sciences
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Similar ecology to *O.roylei*)
Status: UNMODELLABLE

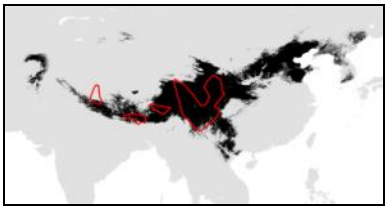
Model evaluation metric	
AUC	0.93
Omission rate	0.13
Sensitivity	0.87
Specificity	0.99
Proportion correct	0.99
Kappa	**0.52**
True Skill Statistic	0.86

Summary: The Moupin pika's bioclimatic envelope is predicted to increase by 10% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~370m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (43.5%), maximum temperature (38.5%), temperature seasonality (7.7%), annual evapotranspiration (3.7%) and mean annual precipitation (3.1%).

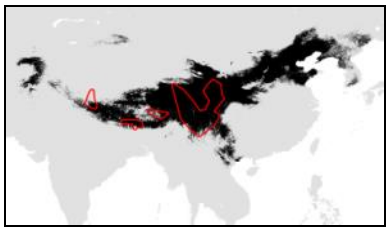
a) ~ 1930s (1900-1949)



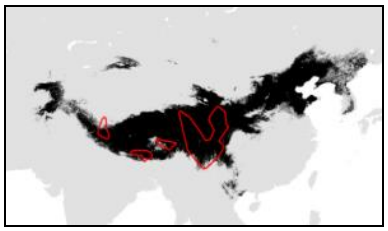
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



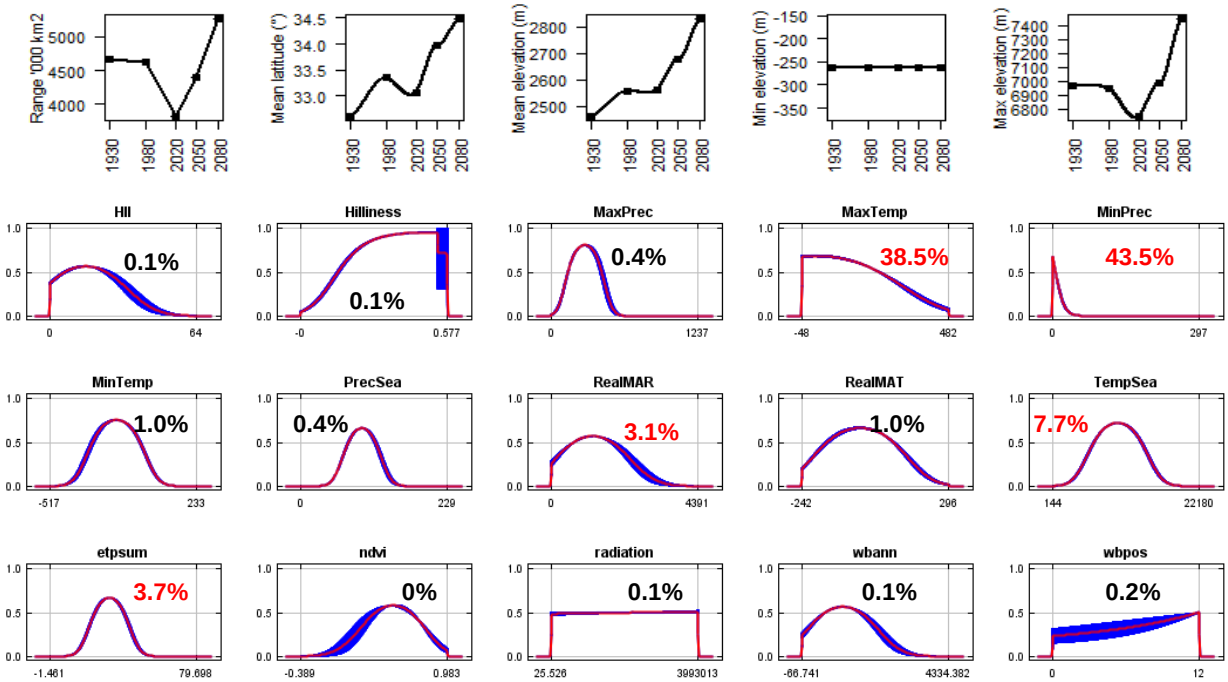
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

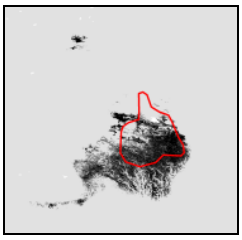
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

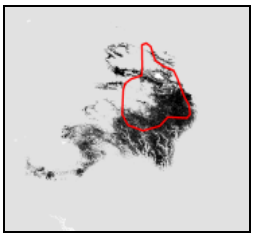


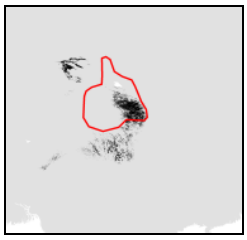
#63 – Thomas's pika (*Ochotona thomasi*)
n = 16
Expert: Andrew Smith, Arizona State University
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Similar ecology to *O.koslowi*)
Status: MODELLABLE

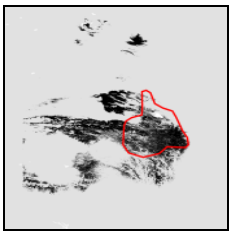
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.58**
True Skill Statistic	0.99

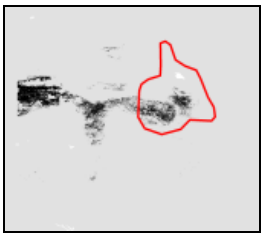
Summary: The Thomas's pika's bioclimatic envelope is predicted to decrease by 70% with a ~1.5° mean latitudinal polewards shift and a mean increase in elevation of ~590m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by minimum precipitation (56.6%), mean annual temperature (23.4%), minimum temperature (14.2%) and evapotranspiration (2.8%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

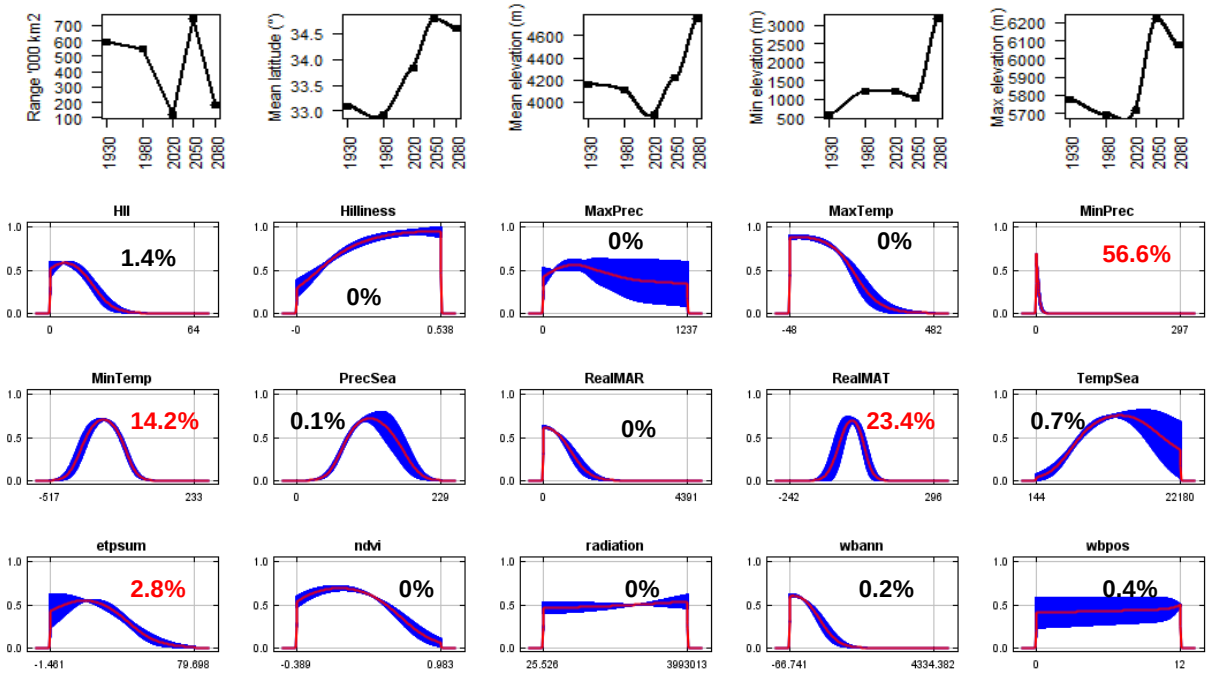

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

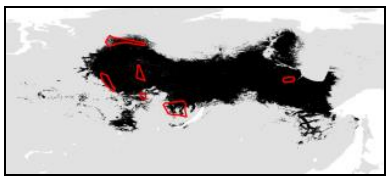
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)



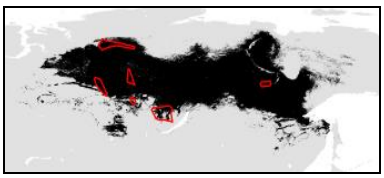
#64 – Turuchan pika (*Ochotona turuchanensis*)
n = 30
Expert: Andrey Lissovsky, Zoological Museum of Moscow State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 15km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.93
Omission rate	0.13
Sensitivity	0.87
Specificity	0.99
Proportion correct	0.99
Kappa	**0.50**
True Skill Statistic	0.86

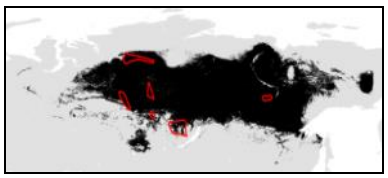
Summary: The Turuchan pika's bioclimatic envelope is predicted to increase by 50% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~70m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by minimum temperature (21.6%), minimum precipitation (19.9%), human influence index (15.2%), annual evapotranspiration (10.9%).



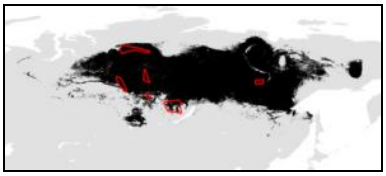
a) ~ 1930s (1900-1949)



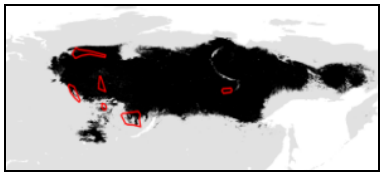
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



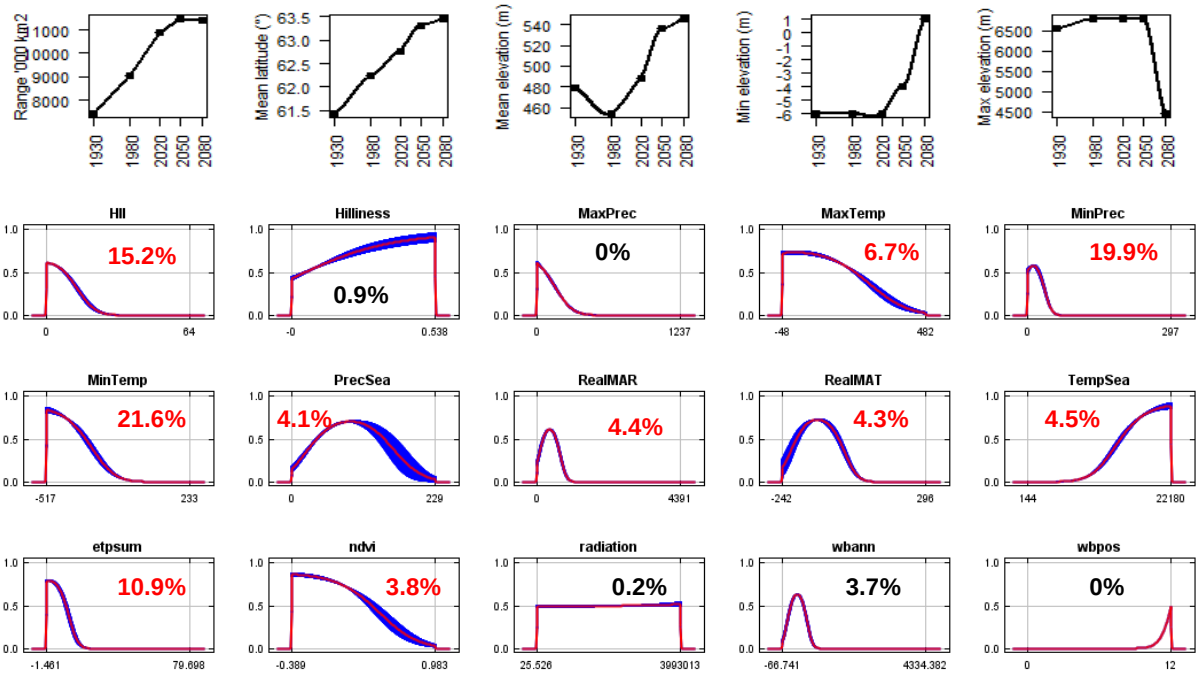
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

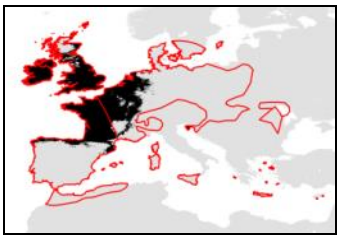
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)



#65 – European rabbit (*Oryctolagus cunciculus*)
n = 22,712
Expert: Neil Reid, Queen's University Belfast
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 1km/year (Expert)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.62
Omission rate	0.16
Sensitivity	0.84
Specificity	0.39
Proportion correct	0.62
Kappa	**0.23**
True Skill Statistic	0.23

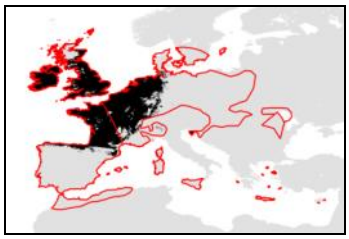
Summary: The European rabbit's bioclimatic envelope is predicted to increase by 30% with a ~2° mean latitudinal polewards shift and a mean decrease in elevation of ~10m. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (21.1%), mean annual temperature (19.0%), minimum temperature (13.9%), annual water balance (12.3%), mean annual precipitation (11.2%), human influence index (9.8%), precipitation seasonality (7.6%) and normalised difference vegetation index (2.9%).



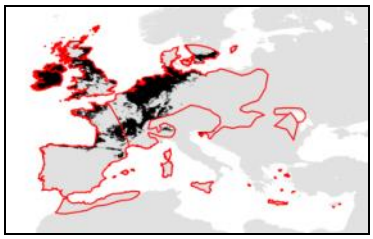
a) ~ 1930s (1900-1949)

b) ~ 1980s (1950-2000)

c) ~ 2020s (2010-2039)



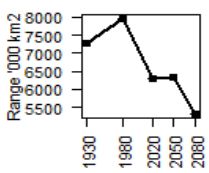
d) ~ 2050s (2040-2069)

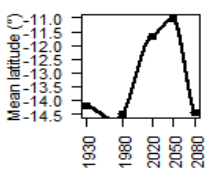


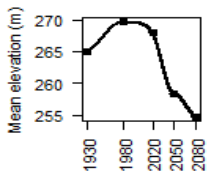
e) ~ 2080s (2070-2099)

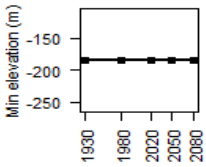
Black = predicted suitable envelope

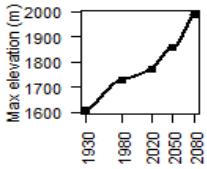
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

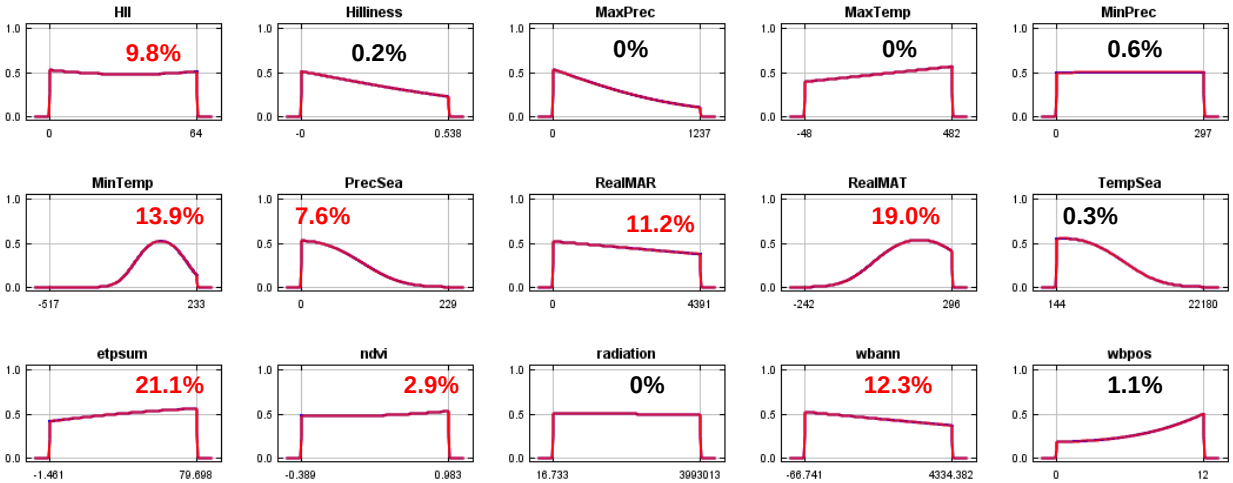








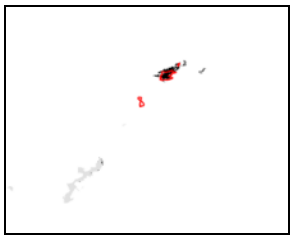


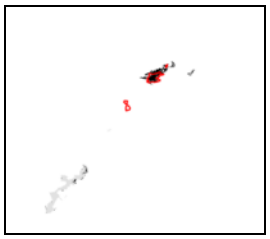


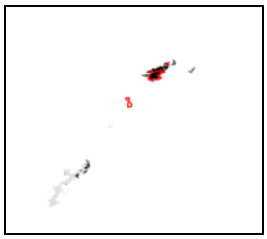
#66 – Amami rabbit (*Pentalagus furnessi*)
n = 9
Expert: Fumio Yamada, Forestry and Forest Products Research Institute, Japan
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Expert)
Status: MODELLABLE

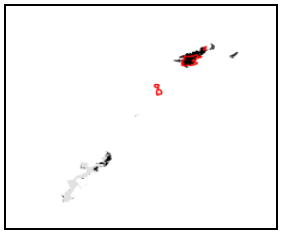
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	0.99
Specificity	0.99
Proportion correct	0.99
Kappa	**0.95**
True Skill Statistic	0.99

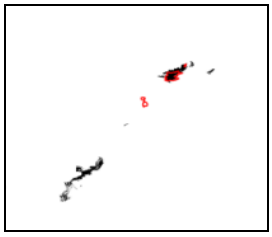
Summary: The Amami rabbit's bioclimatic envelope is predicted to increase by 150% with a ~1° mean latitudinal shift towards the Equator and a mean decrease in elevation of ~25m. 95% of the permutation importance of the model was contributed to by minimum temperature (97.3%), temperature seasonality (1.7%) and annual evapotranspiration (0.8%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

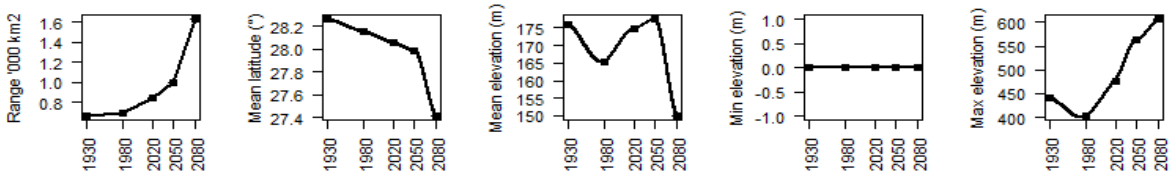

c) ~ 2020s (2010-2039)

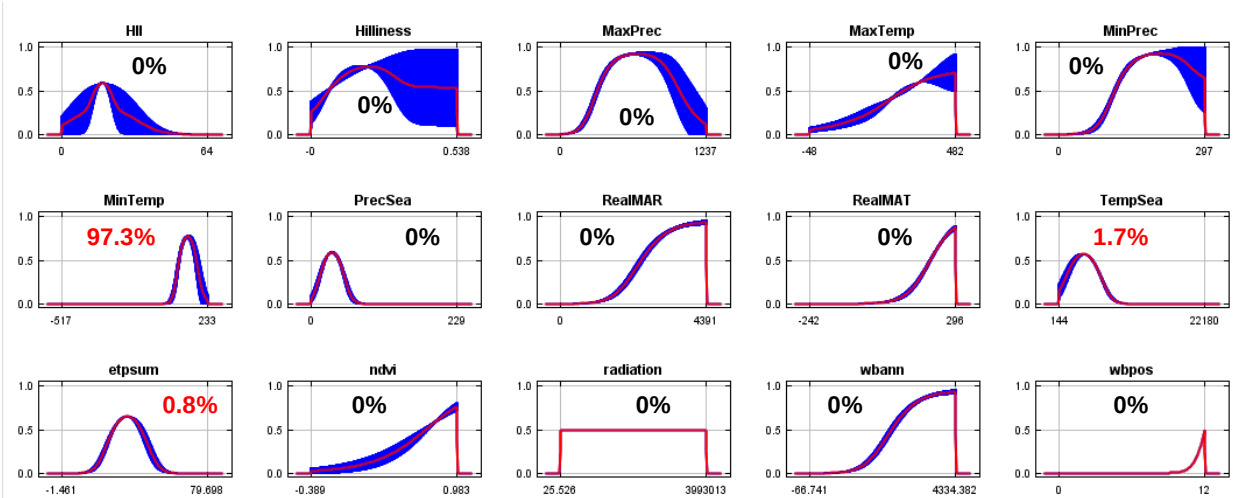

d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Yamada, F & Sugimura, K. 2008)

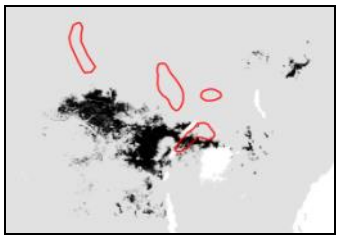


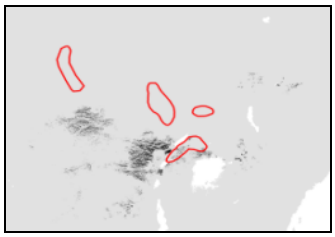


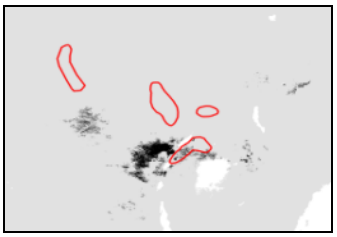
#67 – Bunyoro rabbit (*Poelagus marjorita*)
n = 8
Expert: David Happold, Australian National University
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Similar ecology to Pronolagus sp.)
Status: UNMODELLABLE

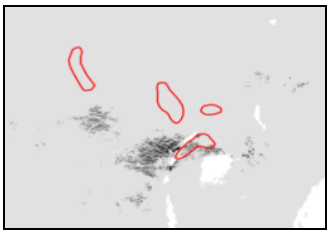
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.89**
True Skill Statistic	0.99

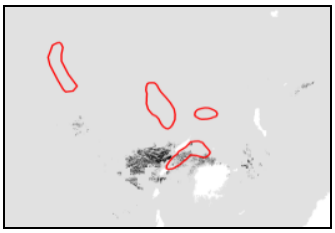
Summary: The Bunyoro rabbit's bioclimatic envelope is predicted to decrease by 90% with a ~1° mean latitudinal shift towards the Equator and a mean increase in elevation of ~200m driven by an increase in minimum elevation.. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (61.7%), temperature seasonality (31.4%) and number of months with a positive water balance (6.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

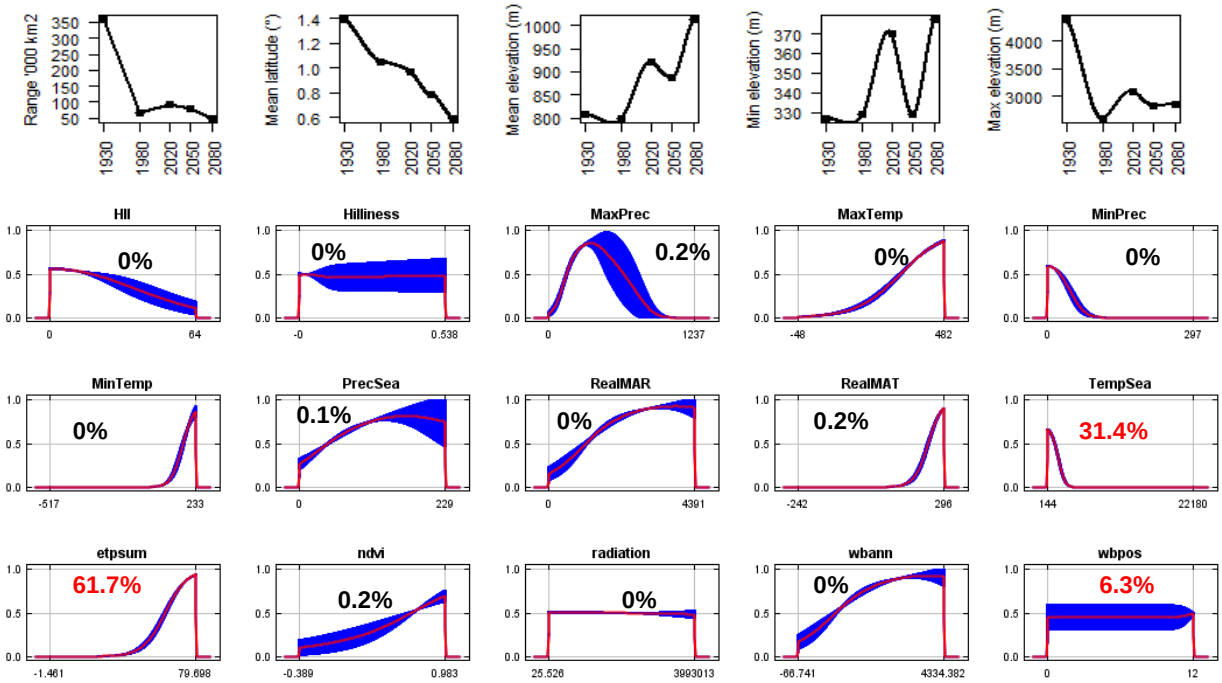

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

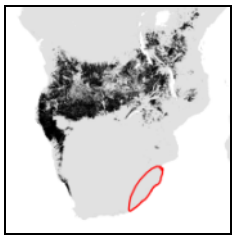
Red polygon = IUCN range (Collins, K. & Smith, A.T. 2008)

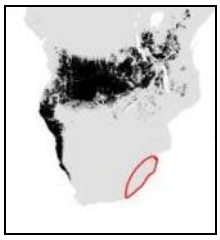


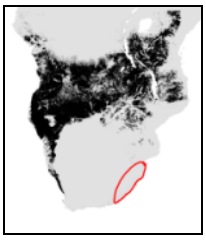
#68 – Greater red rock hare (*Pronolagus crassicaudatus*)
n = 7
Expert: Kai Collins, University of Pretoria
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Similar ecology to *P.randensis*)
Status: UNMODELLABLE

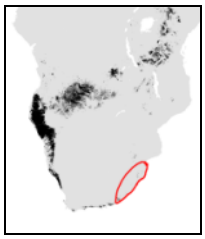
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.98
Proportion correct	0.98
Kappa	**0.06**
True Skill Statistic	0.98

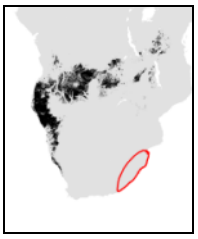
Summary: The Greater red rock hare's bioclimatic envelope is predicted to decrease by 65% with a ~3° mean latitudinal polewards shift and a mean decrease in elevation of ~20m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by human influence index (31.7%), temperature seasonality (29.3%) solar radiation (16.9%) and minimum precipitation (18.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

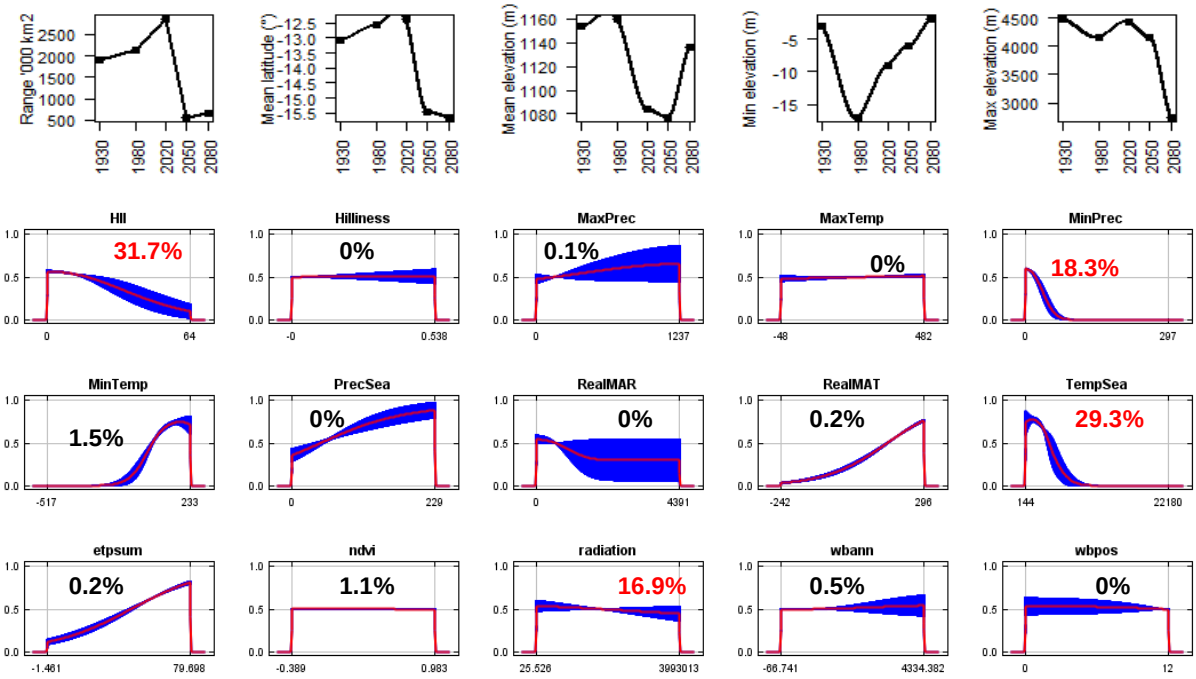

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

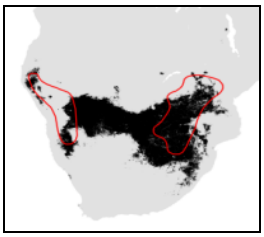
Red polygon = IUCN range (Matthee, C., *et al*. 2008)

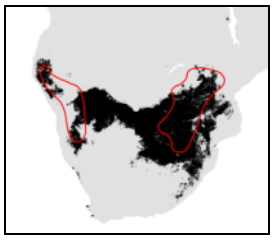


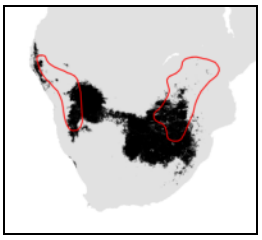
#69 – Jameson's red rock hare (*Pronolagus randensis*)
n = 27
Expert: Kai Collins, University of Pretoria
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Expert)
Status: UNMODELLABLE

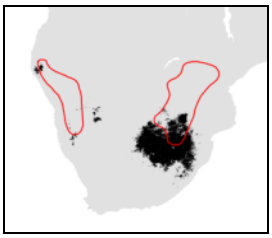
Model evaluation metric	
AUC	0.98
Omission rate	0.04
Sensitivity	0.96
Specificity	0.99
Proportion correct	0.99
Kappa	**0.55**
True Skill Statistic	0.96

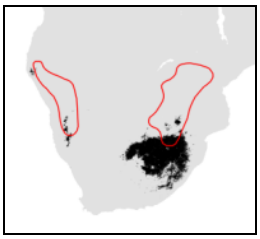
Summary: The Jameson's red rock hare's bioclimatic envelope is predicted to decrease by 70% with a ~5° mean latitudinal polewards shift and a mean increase in elevation of ~325m driven by an increase in maximum and minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (46.2%), maximum temperature (23.3%), minimum precipitation (16.3%), minimum temperature (7.0%) and temperature seasonality (1.4%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

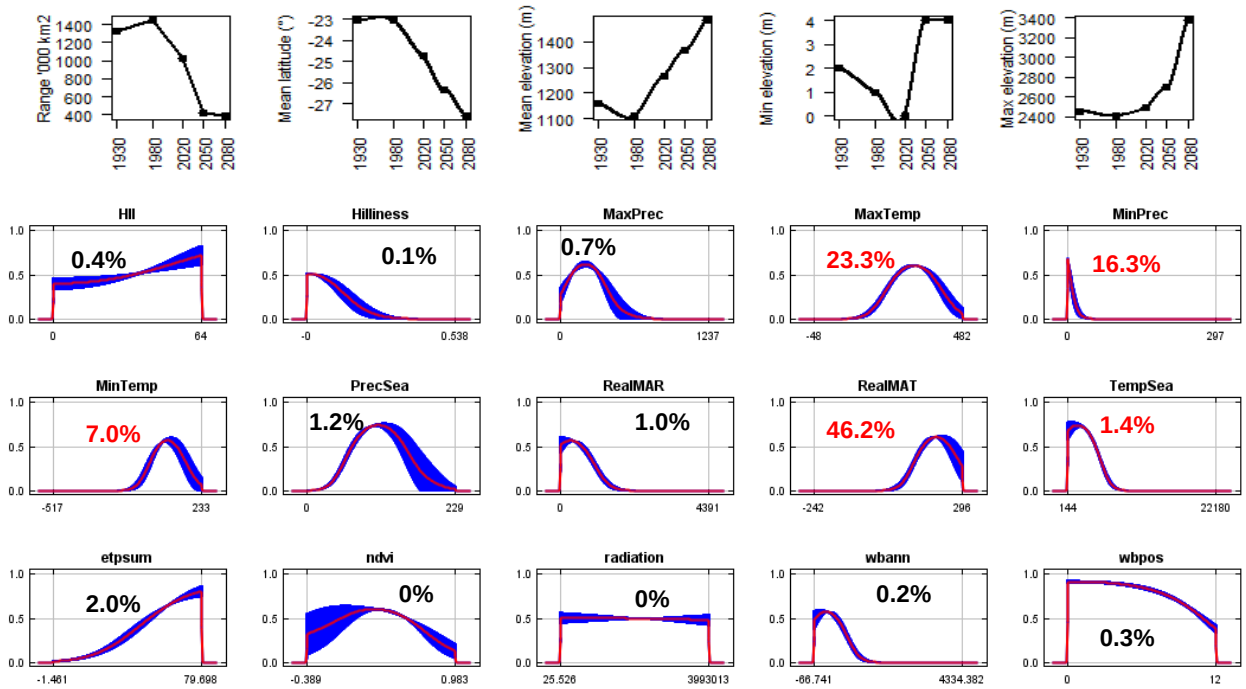

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

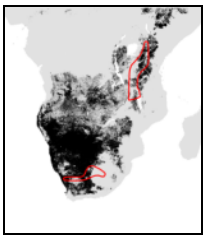
Red polygon = IUCN range (Matthee, C., *et al*. 2008)



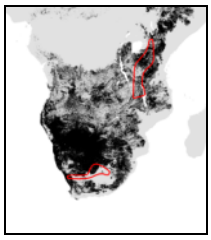
#70 – Smith's red rock hare (*Pronolagus rupestris*)
n = 9
Expert: Kai Collins, University of Pretoria
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Similar ecology to *P.randensis*)
Status: UNMODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.98
Proportion correct	0.98
Kappa	**0.07**
True Skill Statistic	0.98

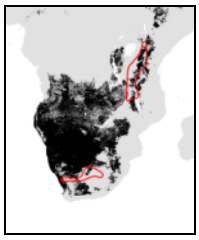
Summary: The Smith's red rock hare's bioclimatic envelope is predicted to decrease by 60% with a ~5° mean latitudinal polewards shift and a mean decrease in elevation of ~60m. 95% of the permutation importance of the model was contributed to by temperature seasonality (44.0%), minimum precipitation (18.5%), mean annual precipitation (18.3%), normalised difference vegetation index (6.3%), human influence index (5.2%) and minimum temperature (3.4%).



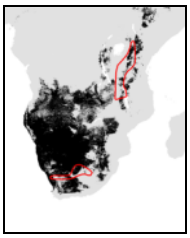
a) ~ 1930s (1900-1949)



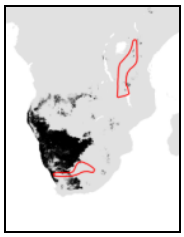
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



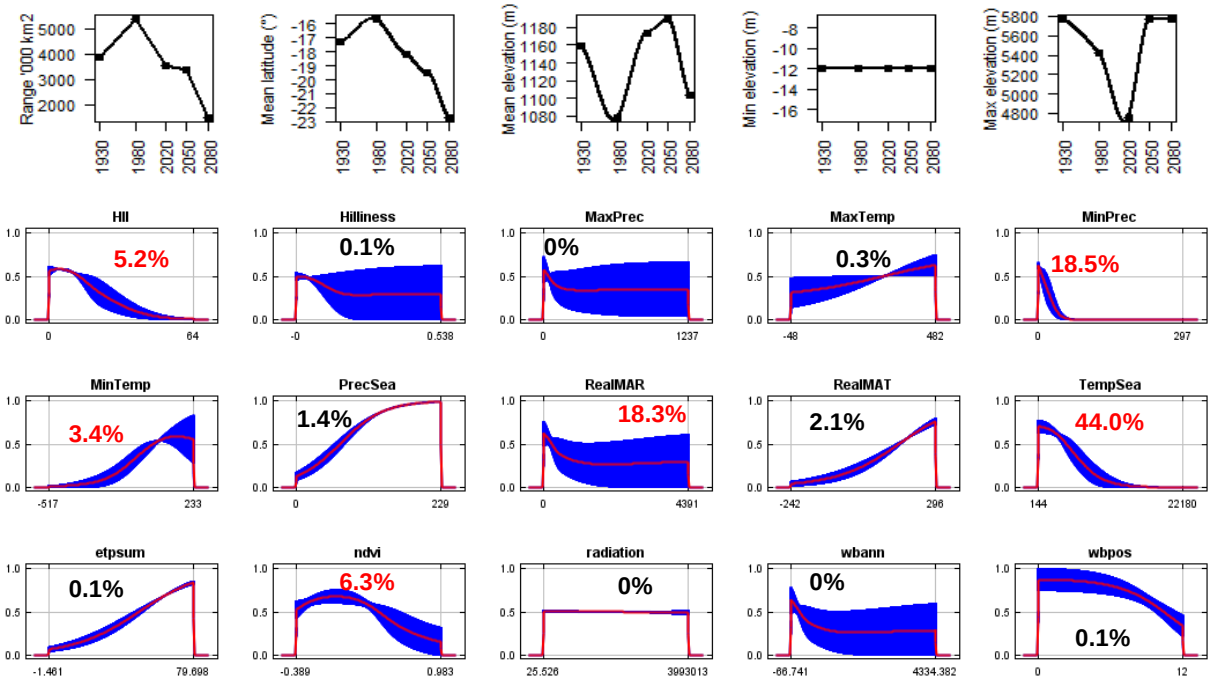
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

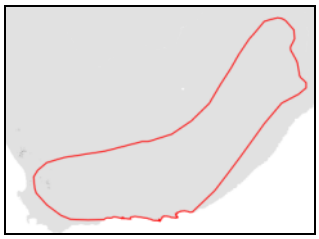
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)



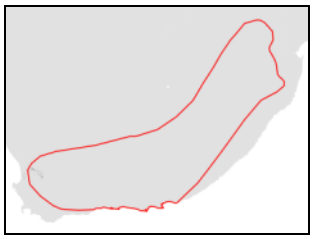
#71 – Hewitt's red rock hare (*Pronolagus saundersiae*)
n = 9
Expert: Kai Collins, University of Pretoria
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 2km/year (Similar ecology to *P.randensis*)
Status: UNMODELLABLE

Model evaluation metric	
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

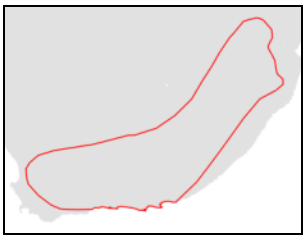
Summary: The Hewitt's red rock hare's bioclimatic envelope is predicted to decrease by 100% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~15m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (28.7%), precipitation seasonality (24.3%), maximum temperature (18.0%), annual evapotranspiration (16.0%), human influence index (5.6%), minimum temperature (1.9%) and minimum precipitation (1.6%).


a) ~ 1930s (1900-1949)

b) ~ 1980s (1950-2000)

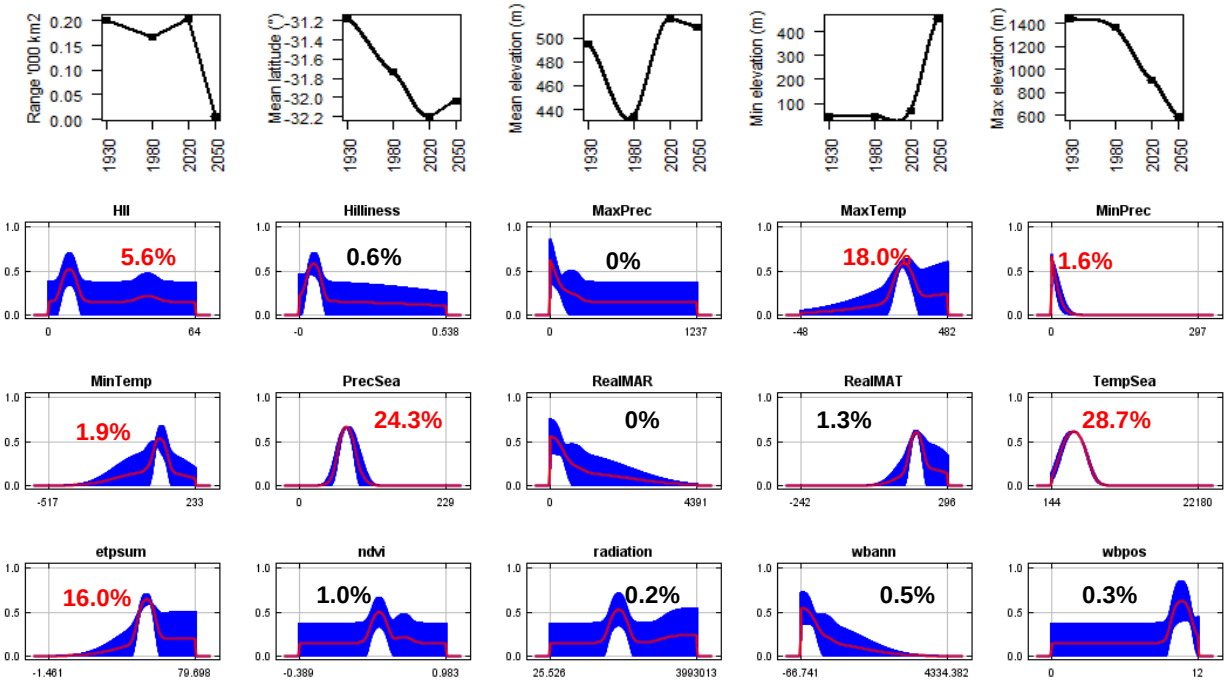

c) ~ 2020s (2010-2039)

d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

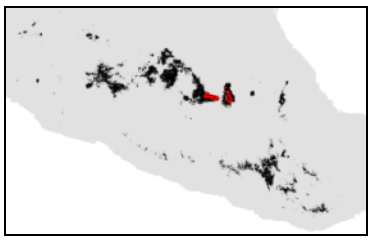
Red polygon = IUCN range (Smith, A.T. & Johnston, C.H. 2008)

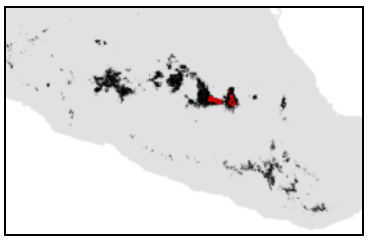


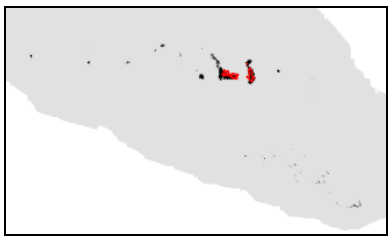
#72 – Volcano rabbit (*Romerolagus diazi*)
n = 31
Expert: Jose Antonio Martinez-Garcia, Universidad Autónoma Metropolitana, Mexico
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Average for island species)
Status: UNMODELLABLE

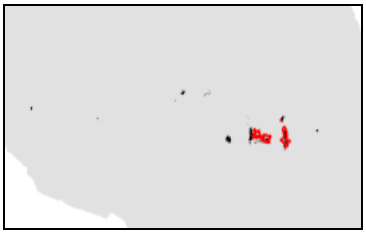
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.79**
True Skill Statistic	0.90

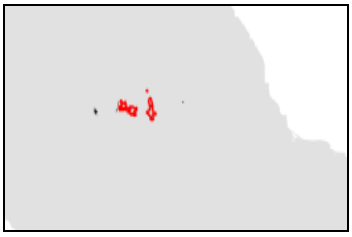
Summary: The Volcano rabbit's bioclimatic envelope is predicted to decrease by 100% with a ~0.2° mean latitudinal polewards shift and a mean increase in elevation of ~1500m driven by increases in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (75.2%), precipitation seasonality (16.2%) and minimum temperature (6.8%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

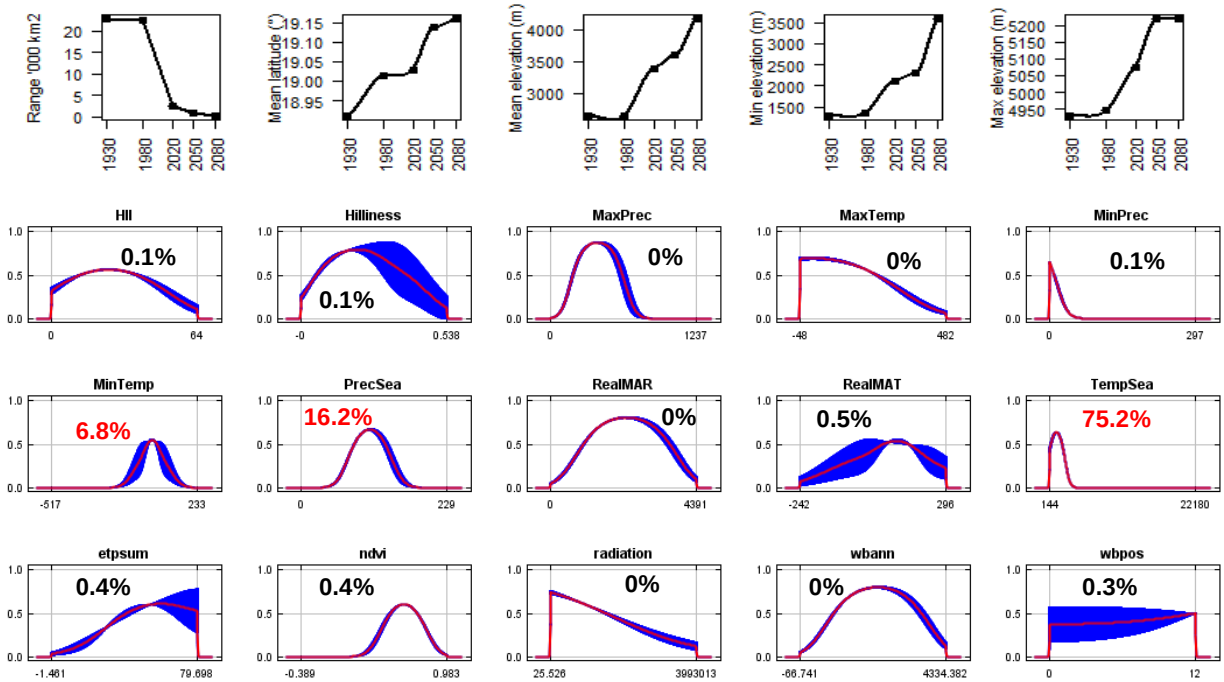

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

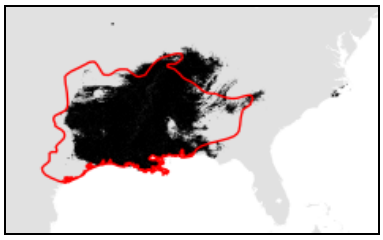
Red polygon = IUCN range (Malpica, F.J.,*et al*. 2008)



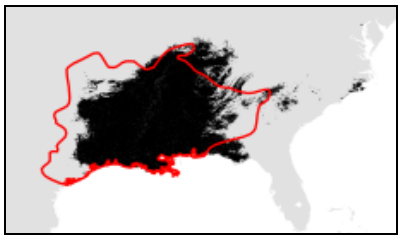
#73 – Swamp rabbit (*Sylvilagus aquaticus*)
n = 66
Expert: Robert Kissell, Memphis State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 25km/year (Expert)
Status: MODELLABLE

Model evaluation metric	
AUC	0.95
Omission rate	0.09
Sensitivity	0.91
Specificity	0.99
Proportion correct	0.99
Kappa	**0.76**
True Skill Statistic	0.91

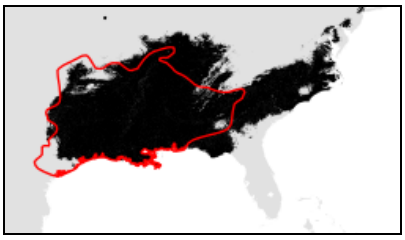
Summary: The Swamp rabbit's bioclimatic envelope is predicted to increase by 200% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~60m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (38.1%), mean annual temperature (36.7%), mean annual precipitation (12.7%), precipitation seasonality (4.7%) and minimum precipitation (3.6%).



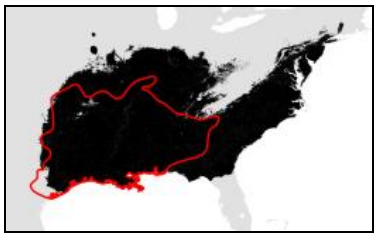
a) ~ 1930s (1900-1949)



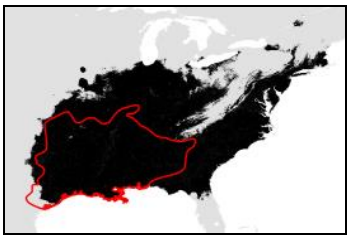
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



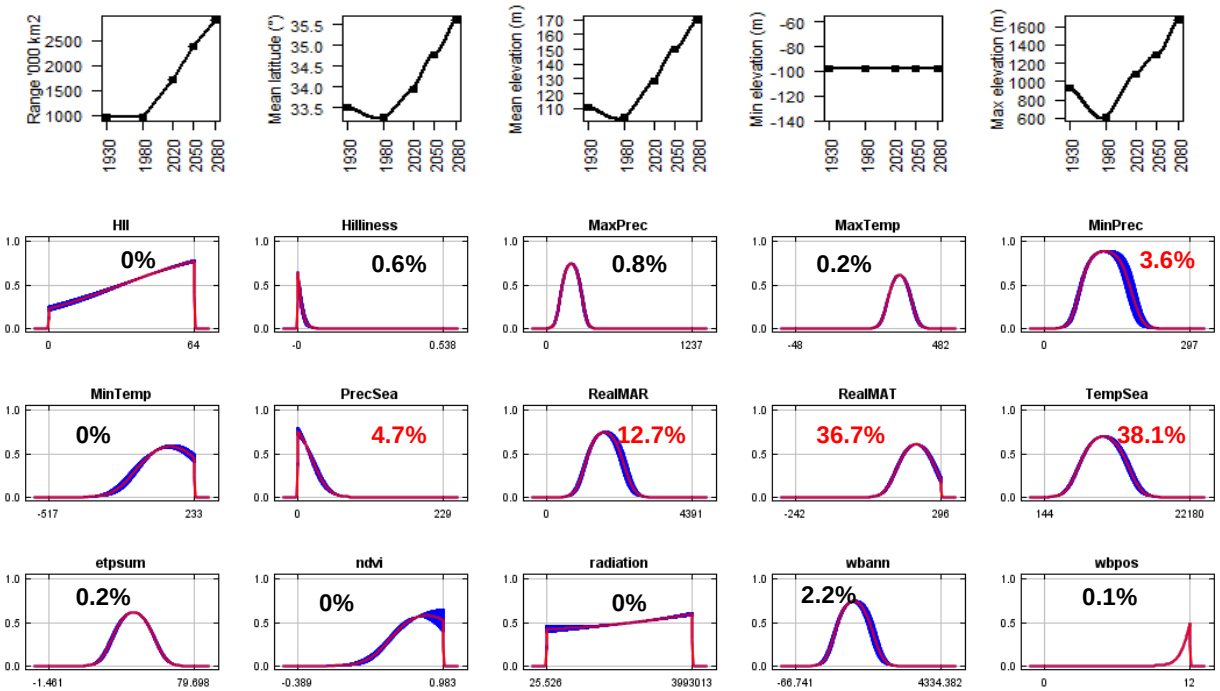
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

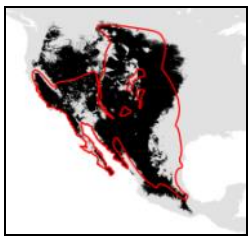
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

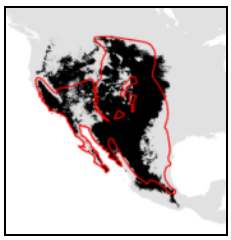


#74 – Desert cottontail (*Sylvilagus audubonii*)
n = 1040
Expert: Consuelo Lorenzo, Departamento Conservación de la Biodiversidad, Chiapas
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Similar ecology to *S.palustris*)
Status: MODELLABLE

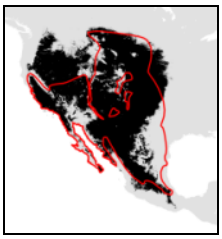
Model evaluation metric	
AUC	0.94
Omission rate	0.08
Sensitivity	0.92
Specificity	0.96
Proportion correct	0.96
Kappa	**0.78**
True Skill Statistic	0.88

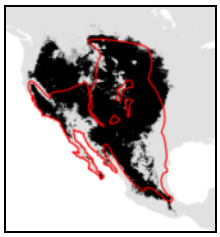
Summary: The Desert cottontail's bioclimatic envelope is predicted to increase by 5% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~30m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (36.6%), annual evapotranspiration (27.1%), mean annual temperature (13.6%), minimum temperature (9.1%), maximum temperature (3.0%), annual water balance (2.1%), minimum precipitation (1.9%) and human influence index (1.7%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

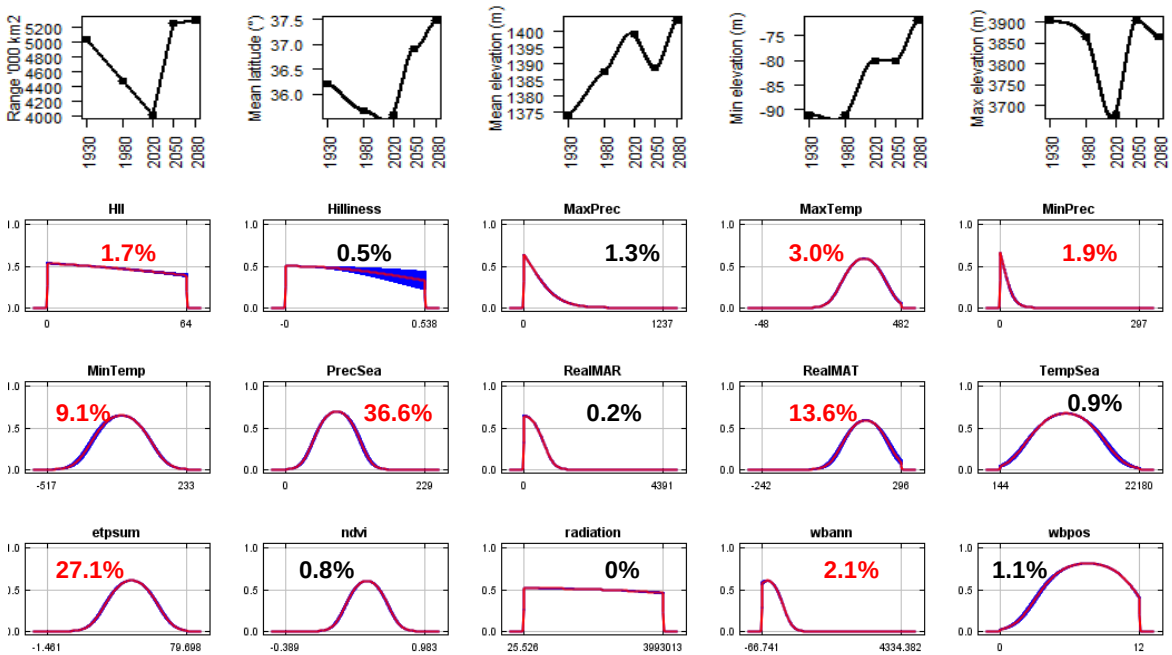
c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

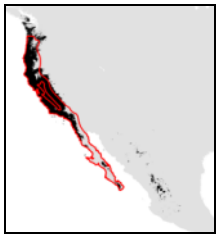
Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)

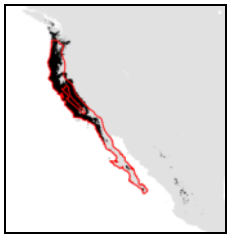


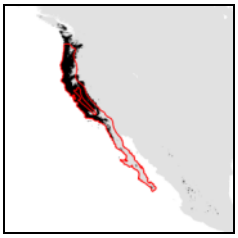
#75 – Brush rabbit (*Sylvilagus bachmani*)
n = 263
Expert: Consuelo Lorenzo, Departamento Conservación de la Biodiversidad, Chiapas
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Similar ecology to *S.transitionalis*)
Status: MODELLABLE

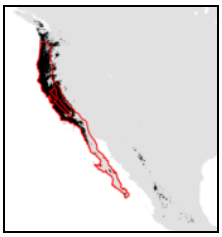
Model evaluation metric	
AUC	0.96
Omission rate	0.08
Sensitivity	0.92
Specificity	0.99
Proportion correct	0.99
Kappa	**0.89**
True Skill Statistic	0.91

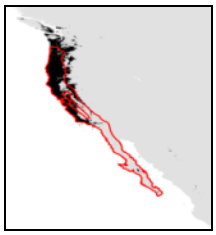
Summary: The Brush rabbit's bioclimatic envelope is predicted to decrease by 15% with a ~3° mean latitudinal polewards shift and a mean decrease in elevation of ~10m. 95% of the permutation importance of the model was contributed to by mean annual temperature (31.5%), minimum precipitation (24.5%), precipitation seasonality (14.4%), mean annual precipitation (7.1%), annual water balance (6.4%), minimum temperature (5.1%), normalised difference vegetation index (4.1%) and temperature seasonality (2.7%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

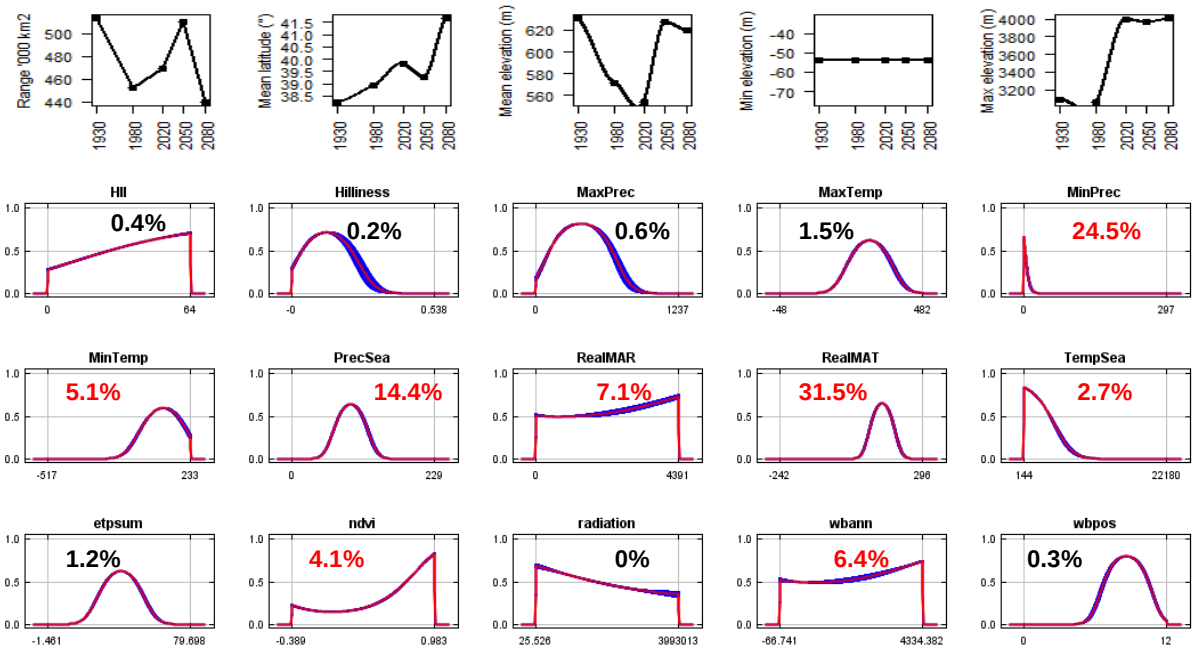

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

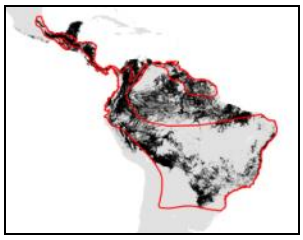
Red polygon = IUCN range (Romero Malpica, F.J.*et al*. 2008)

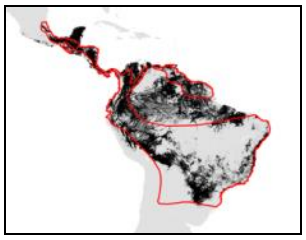


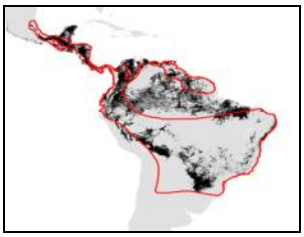
#76 – Forest rabbit (*Sylvilagus brasiliensis*)
n = 181
Expert: Jorge Salazar-Bravo, Texas Tech University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Similar ecology to *S.palustris*)
Status: MODELLABLE

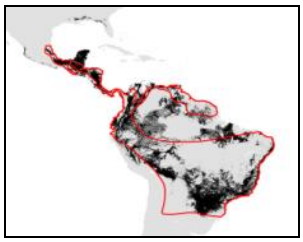
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.73**
True Skill Statistic	0.89

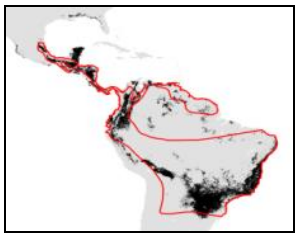
Summary: The Forest rabbit's bioclimatic envelope is predicted to decrease by 50% with a ~6° mean latitudinal polewards shift and a mean increase in elevation of ~210m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (71.4%), temperature seasonality (11.6%), normalised difference vegetation index (4.9%) and minimum temperature (4.6%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

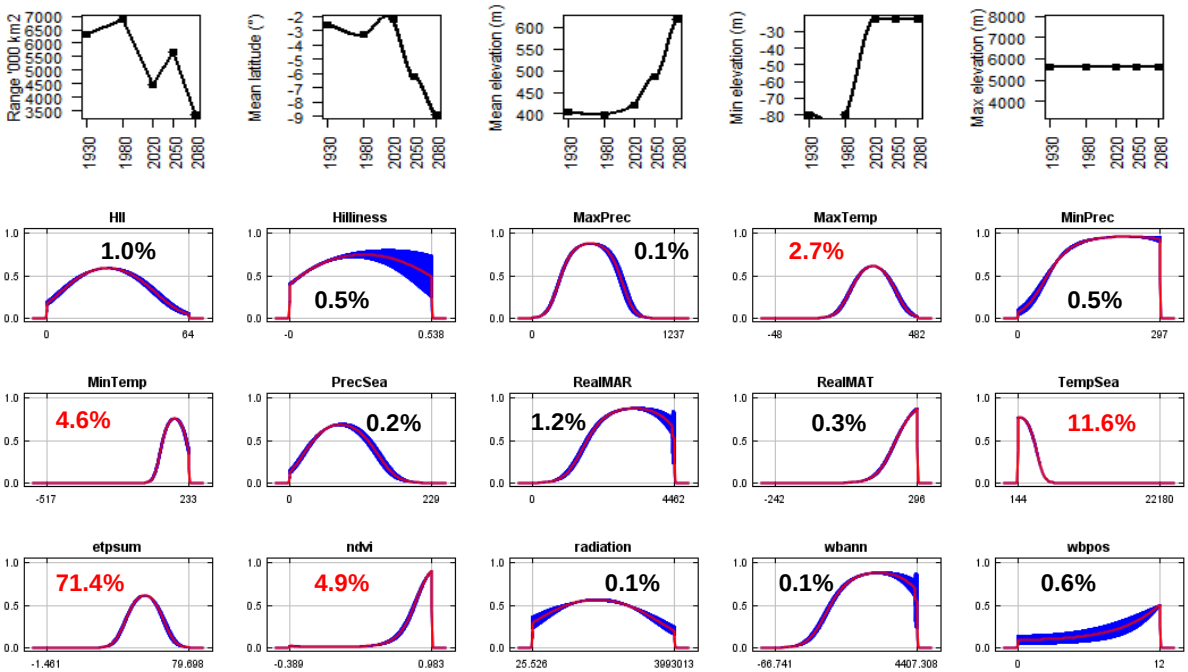

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

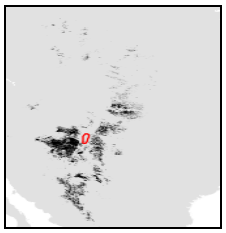
Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)



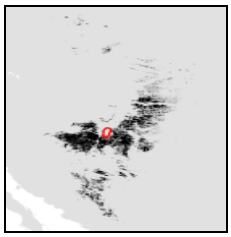
#77 – Manzano mountain cottontail (*Sylvilagus cognatus*)
n = 7
Expert: Jennifer Frey, New Mexico State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Similar ecology to *R.diazi*)
Status: MODELLABLE

Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.52**
True Skill Statistic	0.99

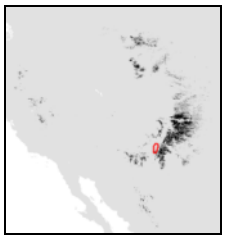
Summary: The Manzano mountain cottontail's bioclimatic envelope is predicted to decrease by 90% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~230m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by annual water balance (40.8%), minimum temperature (21.7%), precipitation seasonality (11.3%), mean annual temperature (8.2%), temperature seasonality (6.1%), minimum precipitation (4.3%) and mean annual precipitation (2.6%).



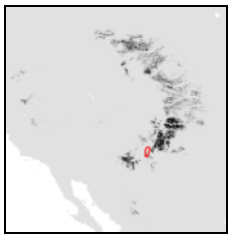
a) ~ 1930s (1900-1949)



b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)

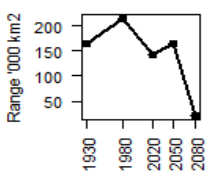


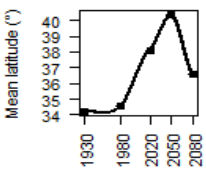
d) ~ 2050s (2040-2069)

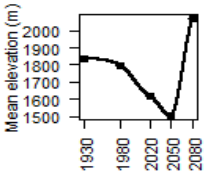
e) ~ 2080s (2070-2099)

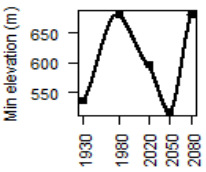
Black = predicted suitable envelope

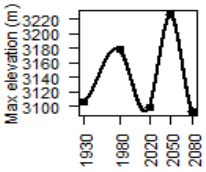
Red polygon = IUCN range (Smith, A.T. & Boyer, A. F. 2008)

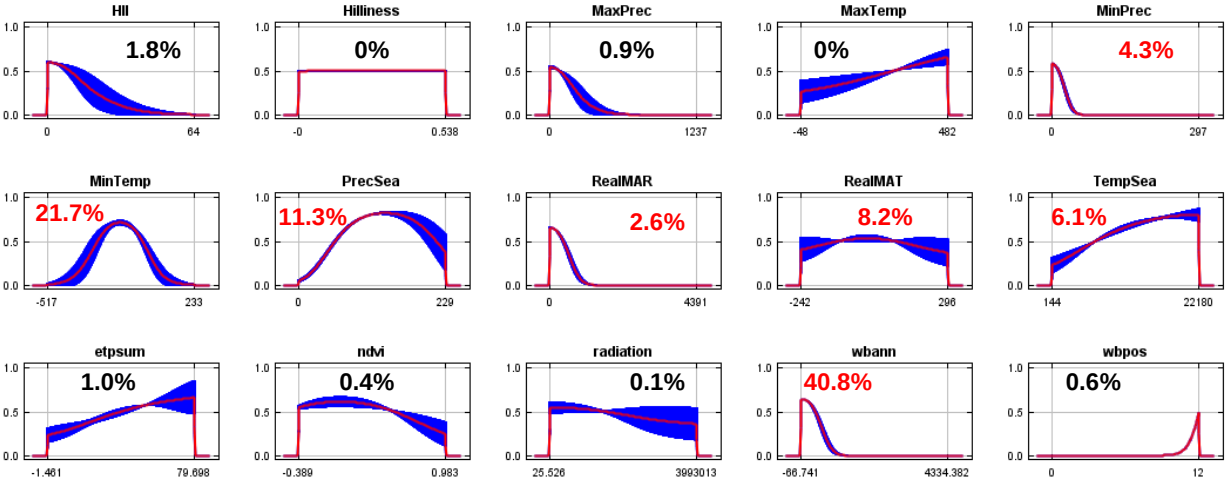








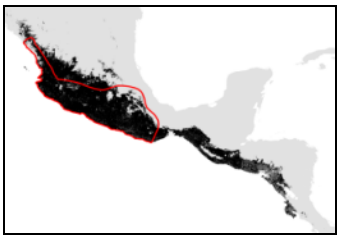


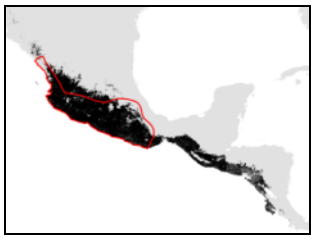


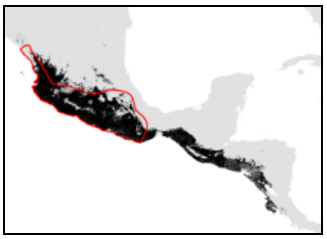
#78 – Mexican cottontail (*Sylvilagus cunicularius*)
n = 76
Expert: Jorge Vazquez, Laboratorio de Ecología del Comportamiento, UAT-UNAM
Expert evaluation: Medium
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Similar ecology to *S.palustris*)
Status: MODELLABLE

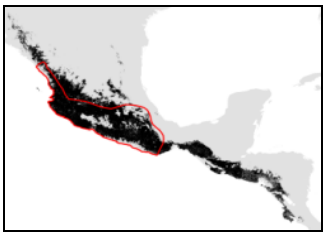
Model evaluation metric	
AUC	0.95
Omission rate	0.10
Sensitivity	0.90
Specificity	0.99
Proportion correct	0.99
Kappa	**0.73**
True Skill Statistic	0.89

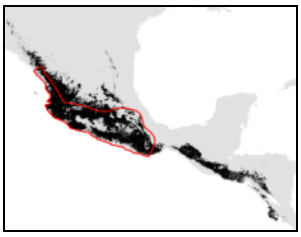
Summary: The Mexican cottontail's bioclimatic envelope is predicted to decrease by 15% with a ~0.5° mean latitudinal polewards shift and a mean increase in elevation of ~200m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (48.3%), precipitation seasonality (42.8%), normalised difference vegetation index (3.5%) and minimum temperature (2.2%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

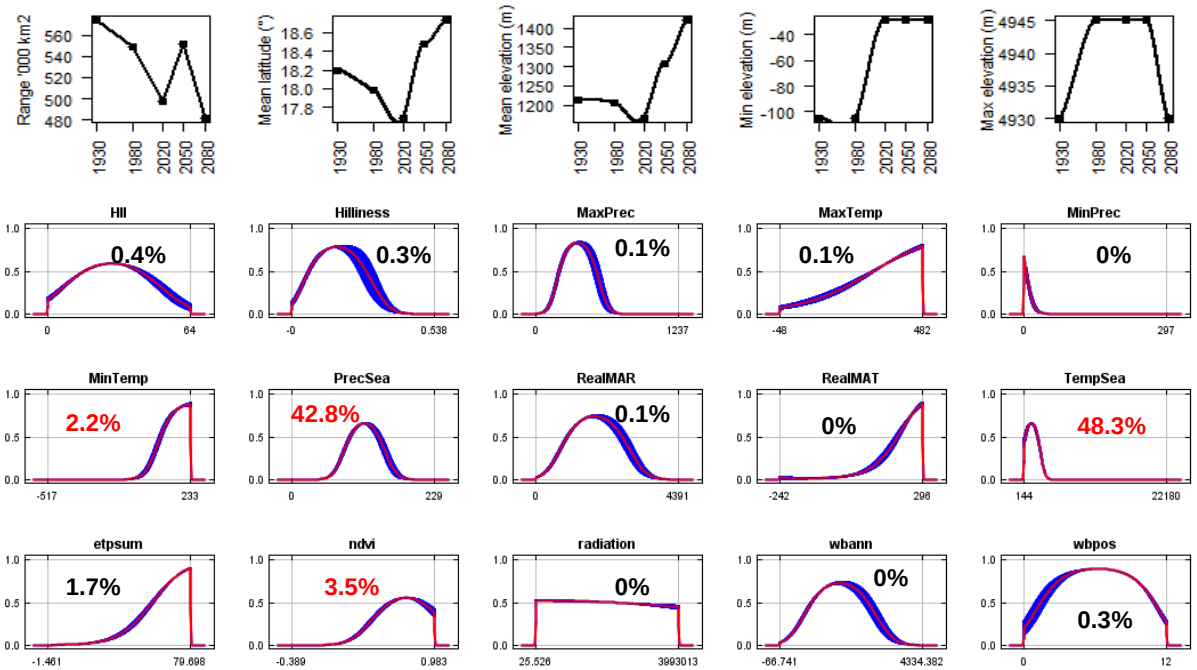

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

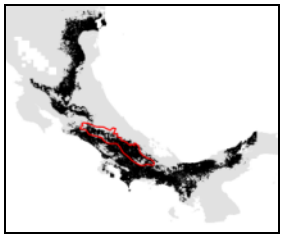
Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)

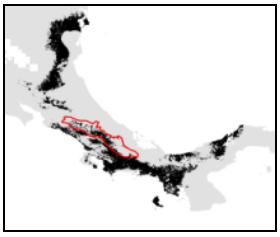


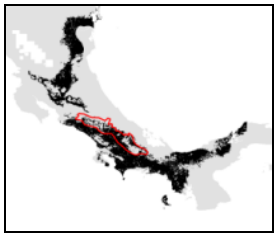
#79 – Dice's cottontail (*Sylvilagus dicei*)
n = 8
Expert: Jan Schipper, Arizona State University
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Similar ecology to *S.cognatus*)
Status: UNMODELLABLE

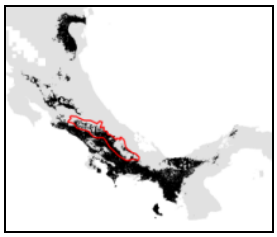
Model evaluation metric	
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.73**
True Skill Statistic	0.99

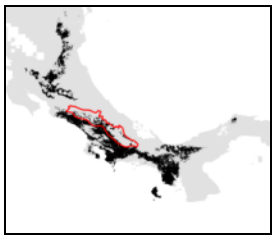
Summary: The Dice's cottontail's bioclimatic envelope is predicted to decrease by 50% with a ~1° mean latitudinal shift towards the Equator and a mean decrease in elevation of ~50m driven by a decrease in maximum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (93.7%) and annual water balance (2.6%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

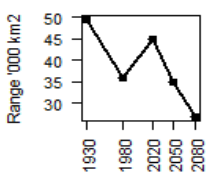

c) ~ 2020s (2010-2039)

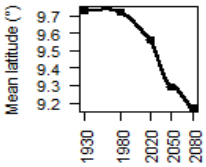

d) ~ 2050s (2040-2069)

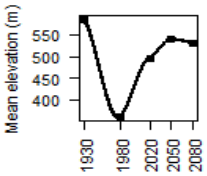

e) ~ 2080s (2070-2099)

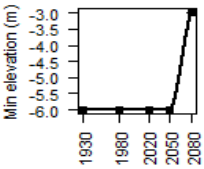
Black = predicted suitable envelope

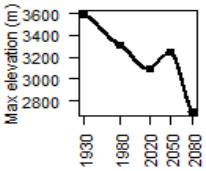
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)

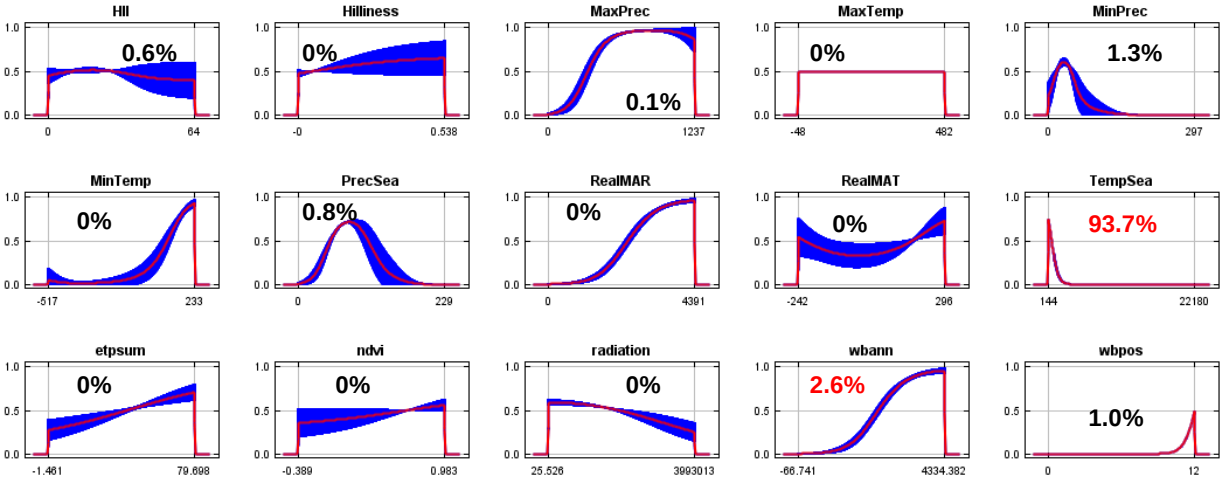








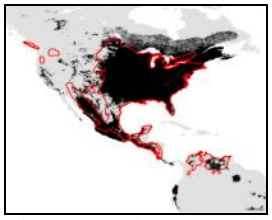


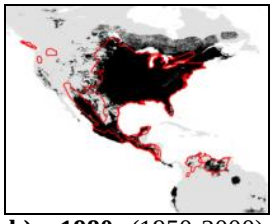


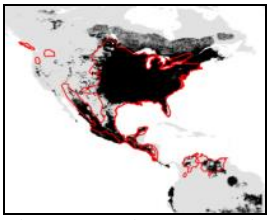
#80 – Eastern cottontail (*Sylvilagus floridanus*)
n = 1104
Expert: Jorge Vazquez, Laboratorio de Ecología del Comportamiento, UAT-UNAM
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Similar ecology to *S.palustris*)
Status: MODELLABLE

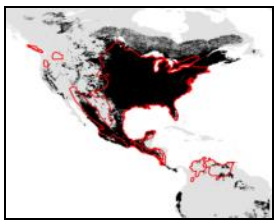
Model evaluation metric	
AUC	0.92
Omission rate	0.09
Sensitivity	0.91
Specificity	0.93
Proportion correct	0.93
Kappa	**0.69**
True Skill Statistic	0.84

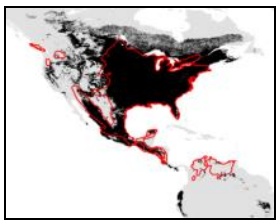
Summary: The Eastern cottontail's bioclimatic envelope is predicted to increase by 20% with a ~2° mean latitudinal polewards shift and a mean increase in elevation of ~90m driven by an increase in minimum and maximum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (29.5%), precipitation seasonality (26.2%), minimum temperature (11.5%), temperature seasonality (8.5%), minimum precipitation (8.1%), maximum temperature (3.3%), normalised difference vegetation index (2.9%), maximum precipitation (2.8%) and annual water balance (2.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

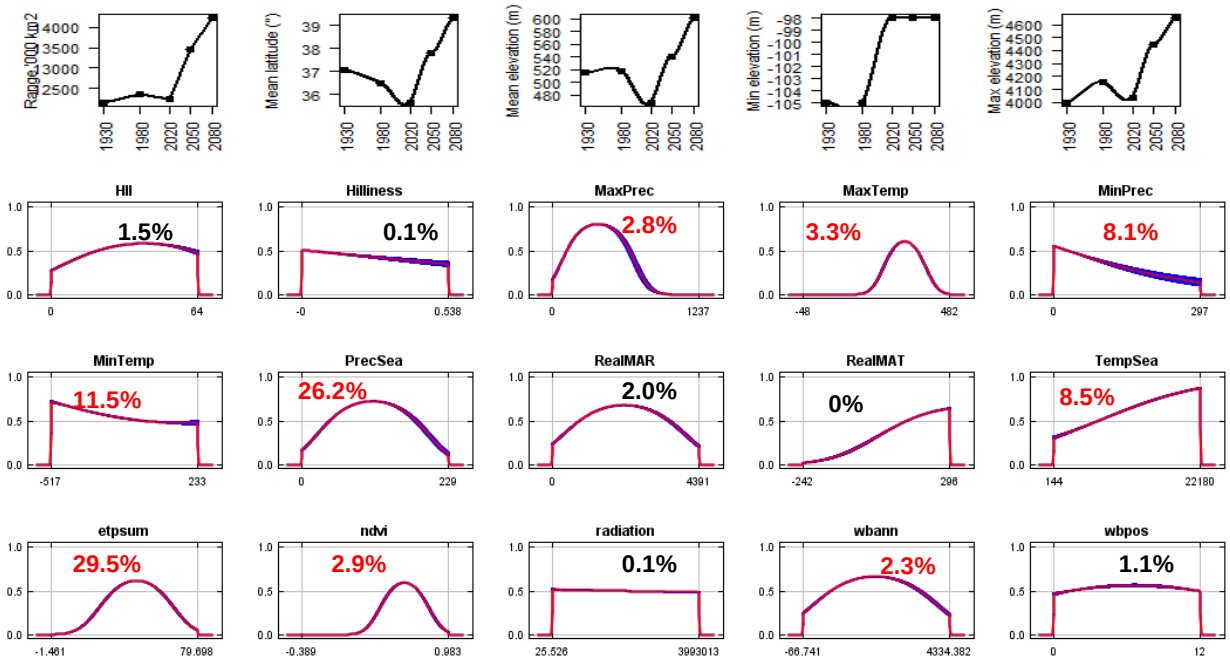

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)

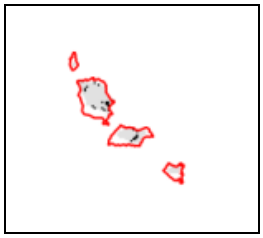


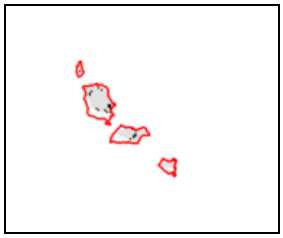
#81 – Tres Marias cottontail (*Sylvilagus graysoni*)
n = 6
Expert: Consuelo Lorenzo, Departamento Conservación de la Biodiversidad, Chiapas
Expert evaluation: Good
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Average for island species)
Status: MODELLABLE

Model evaluation metric	
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

Summary: The Tres Marias cottontail's bioclimatic envelope is predicted to decrease by 20% with a no latitudinal polewards shift and a mean increase in elevation of ~25m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by human influence index (56.0%), minimum precipitation (32.4%), precipitation seasonality (5.2%) and annual evapotranspiration (3.2%).

a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

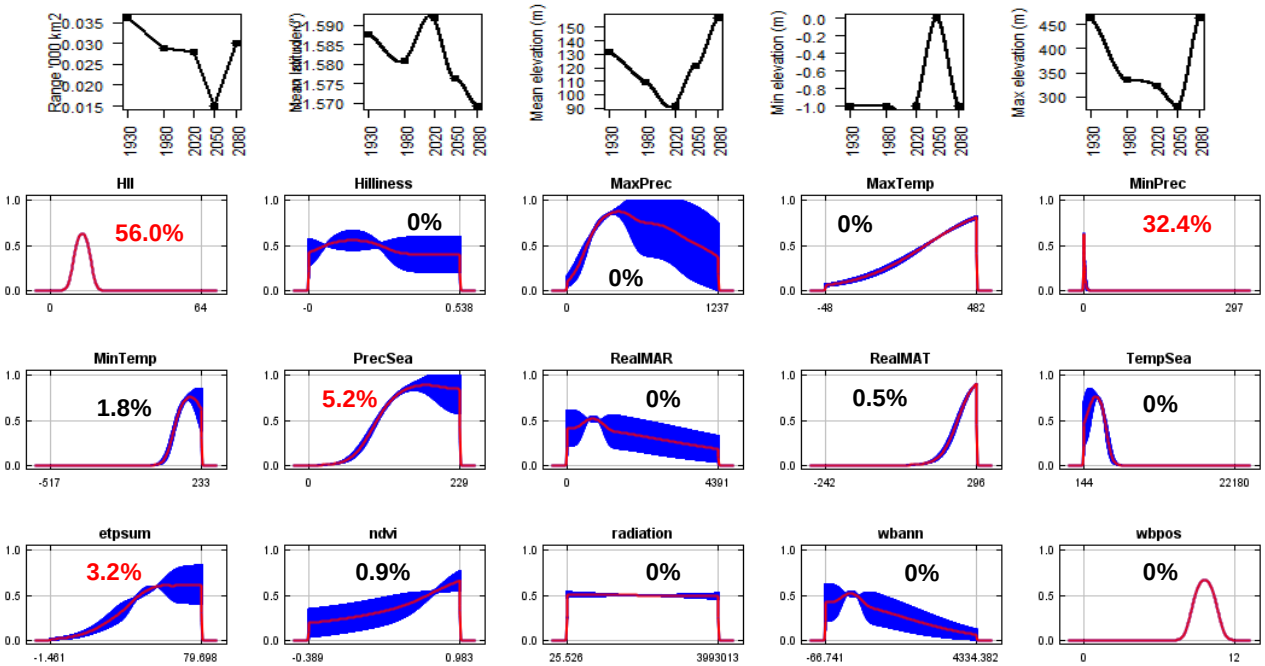

c) ~ 2020s (2010-2039)

d) ~ 2050s (2040-2069)

e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

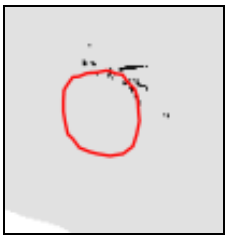
Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)

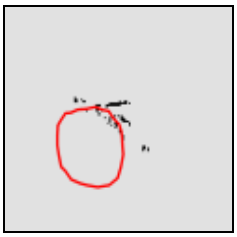


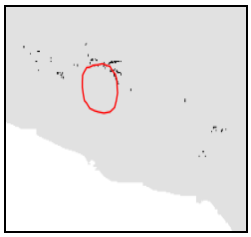
#82 – Omilteme cottontail (*Sylvilagus insonus*)
n = 3
Expert: Alejandro Velazquez, UNAM-Canada
Expert evaluation: Good
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Similar ecology to *S.dicei*)
Status: MODELLABLE

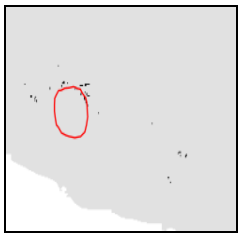
Model evaluation metric	
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

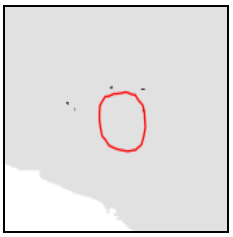
Summary: The Omilteme cottontail's bioclimatic envelope is predicted to decrease by 80% with a no latitudinal polewards shift and a mean increase in elevation of ~120m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by normalised difference vegetation index (78.5%), precipitation seasonality (11.3%) and temperature seasonality (5.3%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

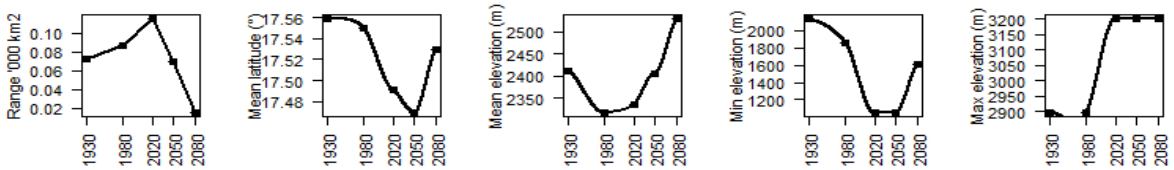

c) ~ 2020s (2010-2039)

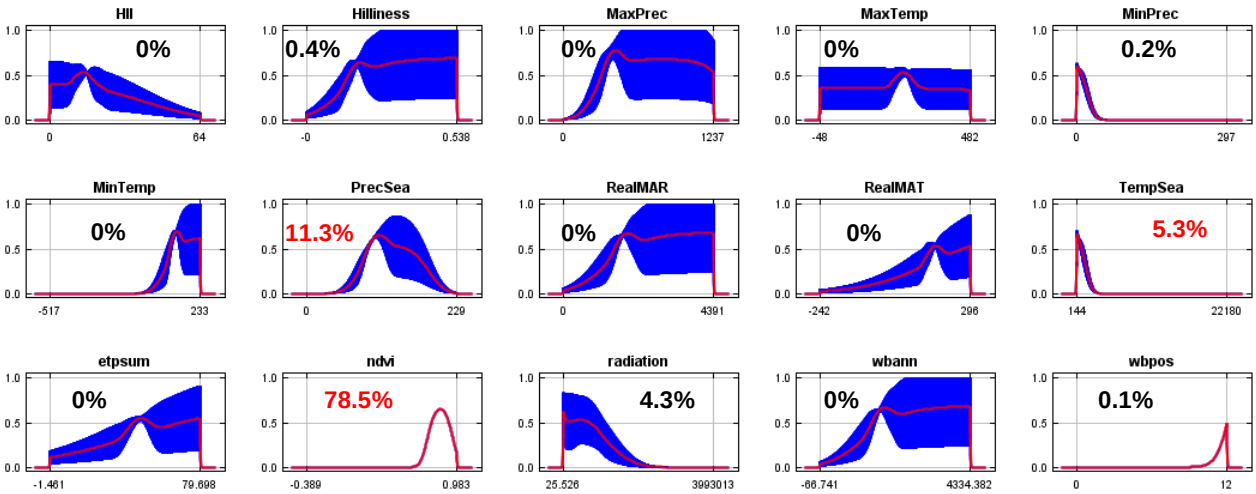

d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Romero Malpica, F.J. & Rangel Cordero, H. 2008)





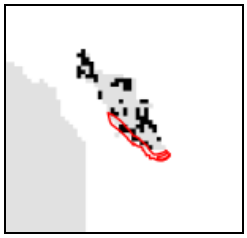
#83 – San Jose brush rabbit (*Sylvilagus mansuetus*)
n = 9
Expert: Tamara Rioja Pardela, Universidad de Ciencias y Artes de Chiapas, Mexico
Expert evaluation: Good
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Average for island species)
Status: MODELLABLE

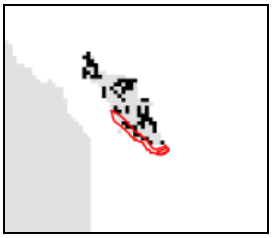
AUC	1.00
Omission rate	0.00
Sensitivity	1.00
Specificity	1.00
Proportion correct	1.00
Kappa	**1.00**
True Skill Statistic	1.00

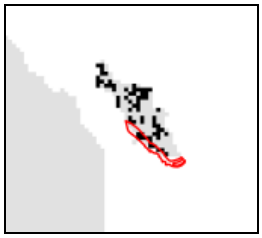
Summary: The San Jose brush rabbit's bioclimatic envelope is predicted to decrease by 25% with a no latitudinal polewards shift and a mean increase in elevation of ~30m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (36.7%), human influence index (34.0%), minimum precipitation (21.8%) and precipitation seasonality (3.2%).

a) ~ 1930s (1900-1949)

b) ~ 1980s (1950-2000)

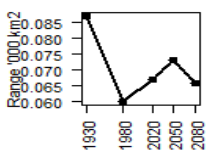

c) ~ 2020s (2010-2039)

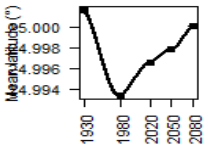

d) ~ 2050s (2040-2069)

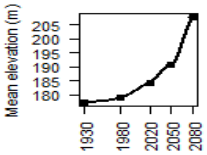

e) ~ 2080s (2070-2099)

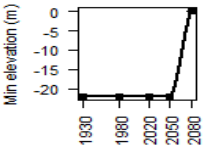
Black = predicted suitable envelope

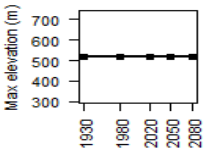
Red polygon = IUCN range (Lorenzo, C. & Álvarez-Castañeda, S. 2011)

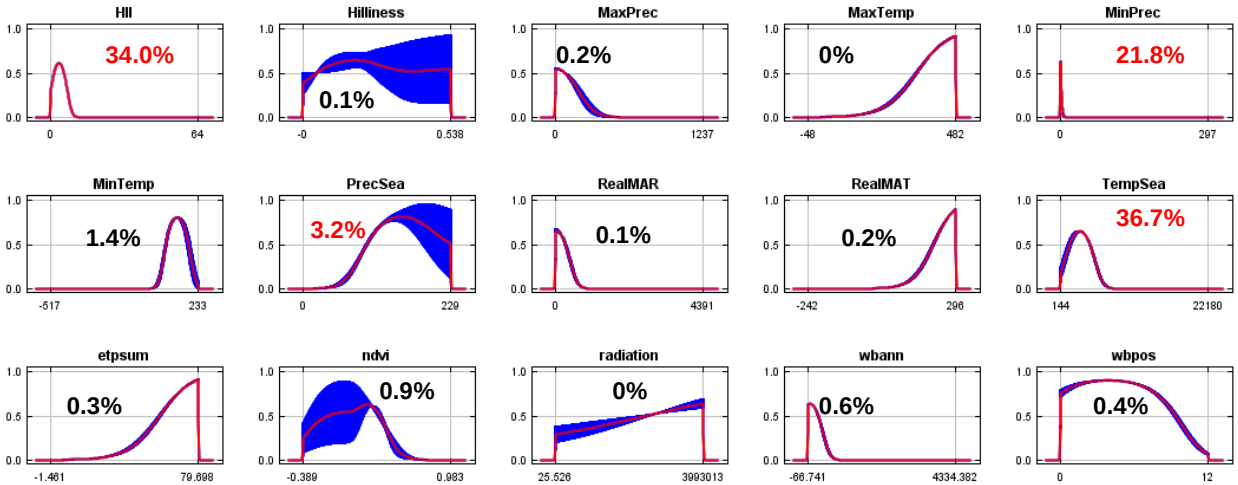








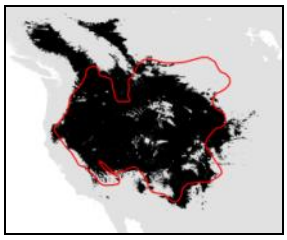


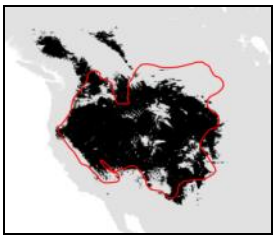


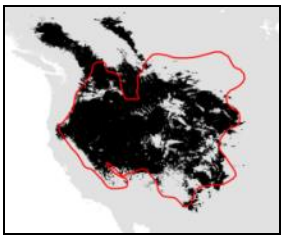
#84 – Mountain cottontail (*Sylvilagus nuttallii*)
n = 290
Expert: Jennifer Frey, New Mexico State University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Similar ecology to *S.palustris*)
Status: MODELLABLE

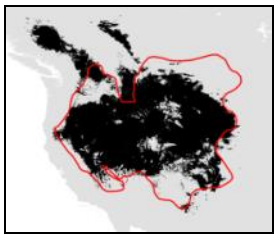
AUC	0.95
Omission rate	0.09
Sensitivity	0.91
Specificity	0.99
Proportion correct	0.99
Kappa	**0.78**
True Skill Statistic	0.90

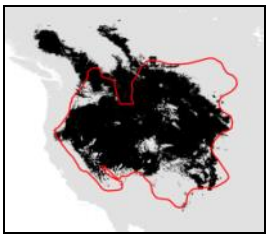
Summary: The Mountain cottontail's bioclimatic envelope is predicted to decrease by 20% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~40m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by mean annual temperature (64.0%), maximum temperature (26.9%), temperature seasonality (2.8%) and minimum precipitation (1.4%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

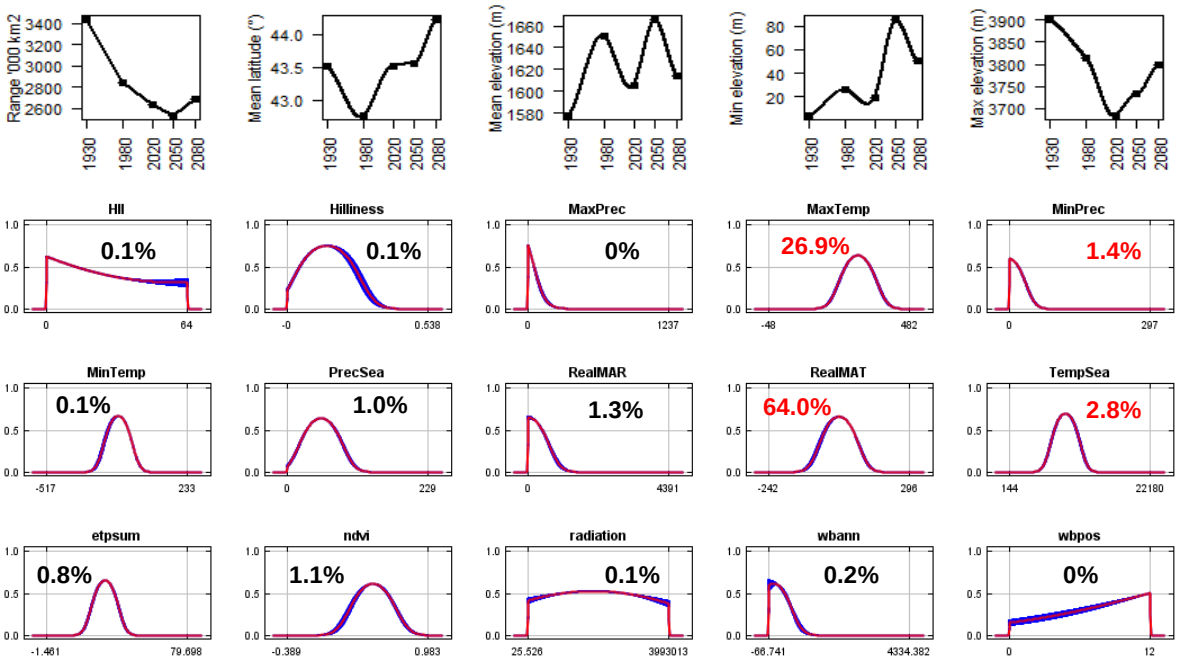

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

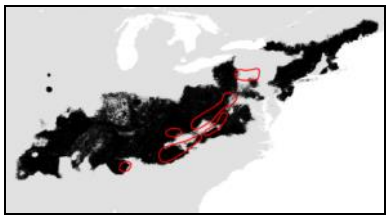
Red polygon = IUCN range (Smith, A.T. & Boyer, A.F. 2008)



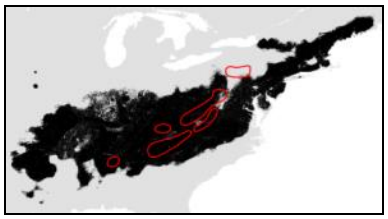
#85 – Appalachian cottontail (*Sylvilagus obscurus*)
n = 39
Expert: Michael Barbour, Auburn University
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic only
Dispersal distance: 0.01km/year (Similar ecology to *S.dicei*)
Status: MODELLABLE

AUC	0.97
Omission rate	0.05
Sensitivity	0.95
Specificity	0.99
Proportion correct	0.99
Kappa	**0.73**
True Skill Statistic	0.95

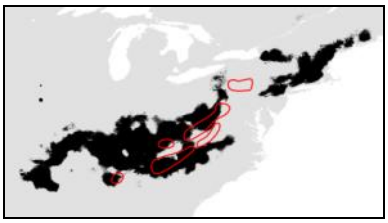
Summary: The Appalachian cottontail's bioclimatic envelope is predicted to decrease by 10% with a ~3° mean latitudinal polewards shift and a mean increase in elevation of ~70m. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (42.0%), minimum temperature (24.2%), minimum precipitation (18.8%) and precipitation seasonality (10.0%).



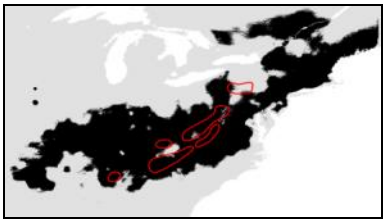
a) ~ 1930s (1900-1949)



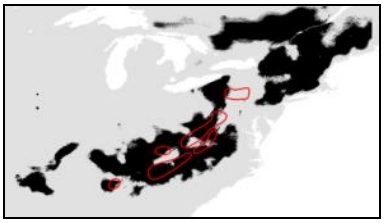
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



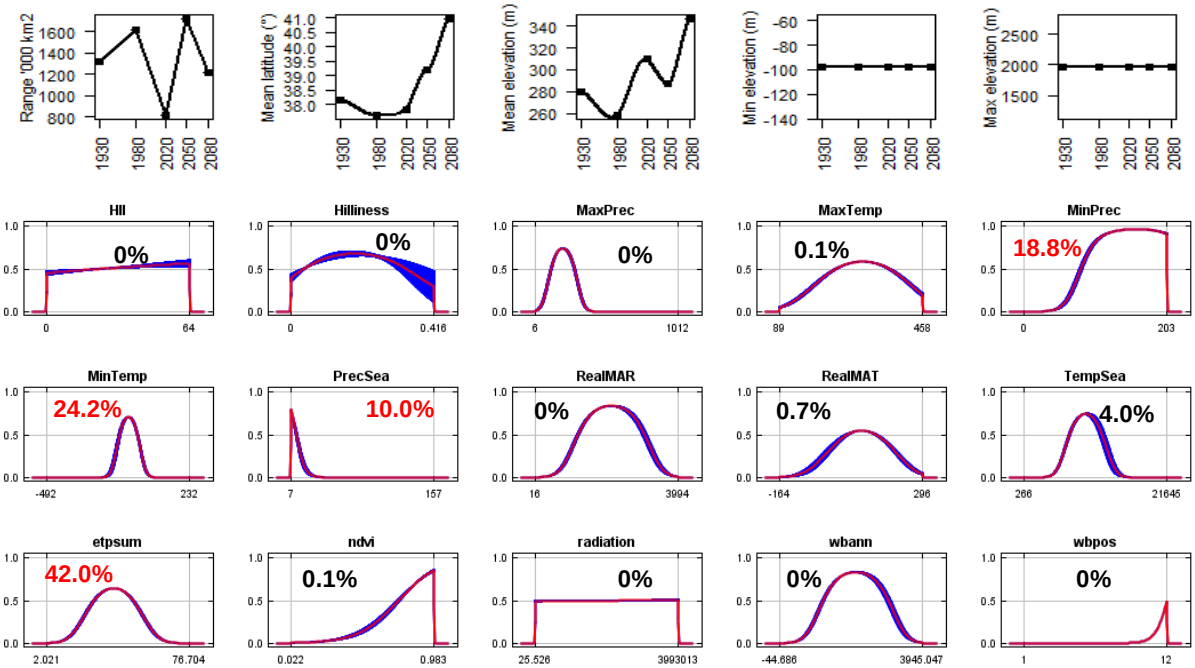
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

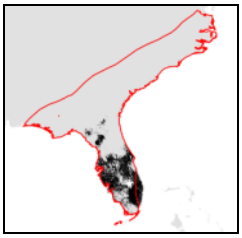
Red polygon = IUCN range (Barry, R. & Lazell, J. 2008)

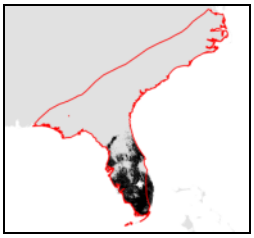


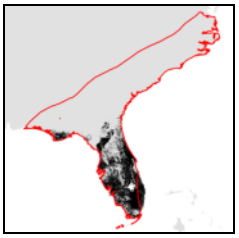
#86 – Marsh rabbit (*Sylvilagus palustris*)
n = 25
Expert: Bob McCleery, University of Florida
Expert evaluation: Good
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 7.5km/year (Expert)
Status: MODELLABLE

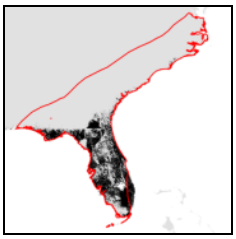
AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.75**
True Skill Statistic	0.99

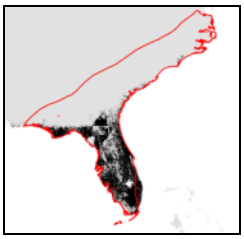
Summary: The Marsh rabbit's bioclimatic envelope is predicted to increase by 90% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~2m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by surface roughness index (73.1%), minimum precipitation (18.3%) and precipitation seasonality (4.9%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

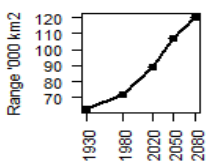

c) ~ 2020s (2010-2039)

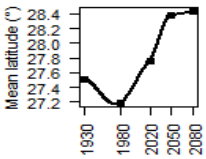

d) ~ 2050s (2040-2069)

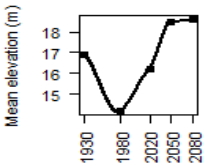

e) ~ 2080s (2070-2099)

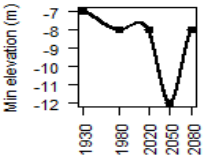
Black = predicted suitable envelope

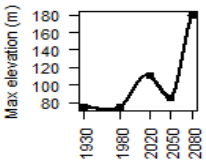
Red polygon = IUCN range (Faulhaber, C.A. & Smith, A.T. 2008)

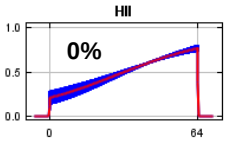


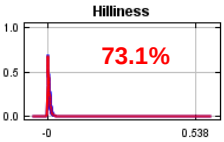


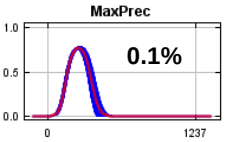


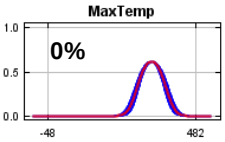


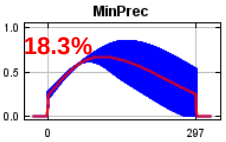


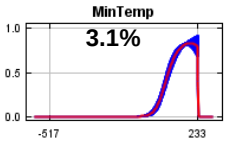


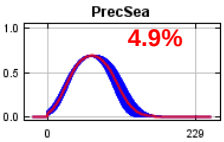


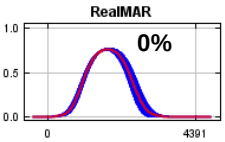


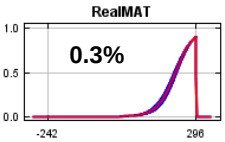


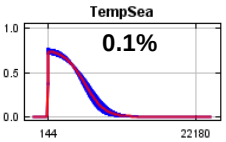


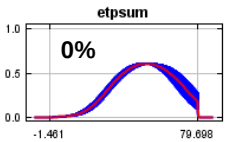


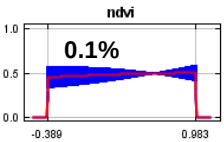


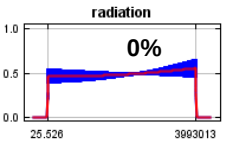


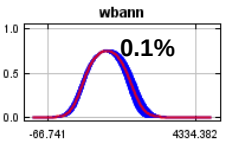


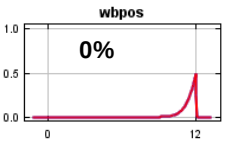








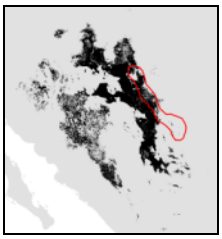


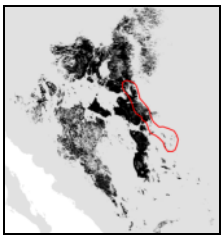


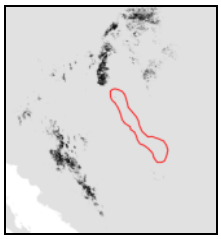
#87 – Robust cottontail (*Sylvilagus robustus*)
n = 9
Expert: Dana Lee, Oklahoma State University
Expert evaluation: Poor
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 0.01km/year (Similar ecology to *S.dicei*)
Status: UNMODELLABLE

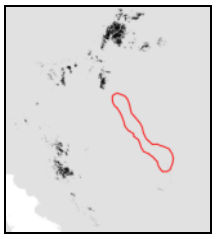
AUC	0.94
Omission rate	0.11
Sensitivity	0.89
Specificity	0.99
Proportion correct	0.99
Kappa	**0.27**
True Skill Statistic	0.88

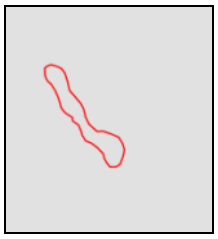
Summary: The Robust cottontail's bioclimatic envelope is predicted to decrease by 90% with a ~4° mean latitudinal polewards shift and a mean increase in elevation of ~480m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by precipitation seasonality (68.5%), minimum precipitation (8.2%), temperature seasonality (7.1%), minimum temperature (4.5%), mean annual precipitation (3.6%), annual water balance (2.6%) and number of months with a positive water balance (1.6%).


a) ~ 1930s (1900-1949)


b) ~ 1980s (1950-2000)

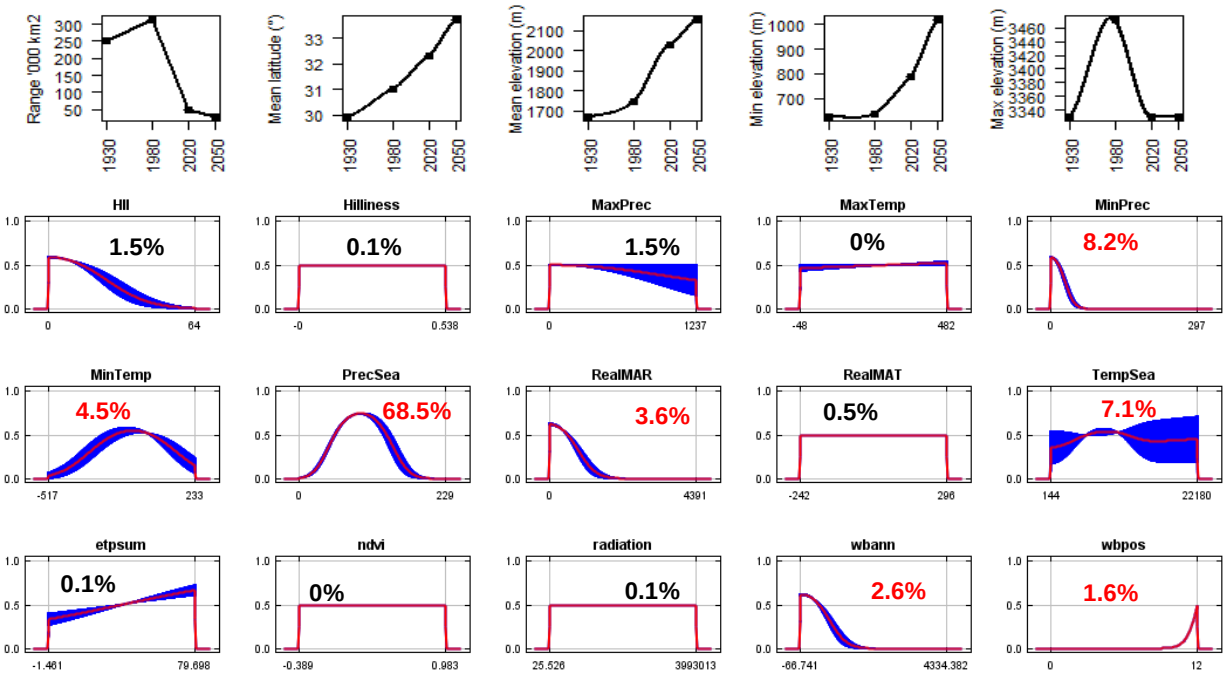

c) ~ 2020s (2010-2039)


d) ~ 2050s (2040-2069)


e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

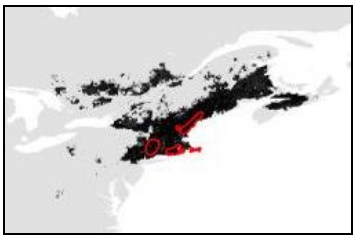
Red polygon = IUCN range (Ruedas, L. & Smith, A.T. 2008)



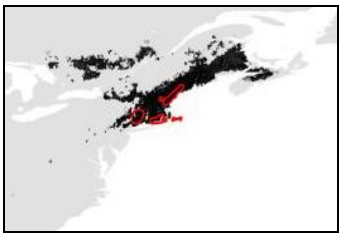
#88 – New England cottontail (*Sylvilagus transitionalis*)
n = 18
Expert: John Litvaitis, University of New Hampshire
Expert evaluation: Medium
Data: Modern and historic
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Expert)
Status: MODELLABLE

AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.68**
True Skill Statistic	0.99

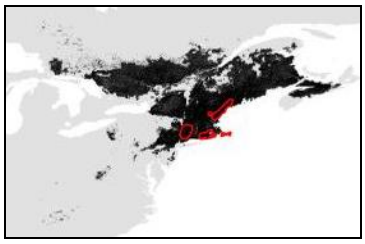
Summary: The New England cottontail's bioclimatic envelope is predicted to increase by 110% with a ~1° mean latitudinal polewards shift and a mean increase in elevation of ~70m driven by an increase in maximum elevation. 95% of the permutation importance of the model was contributed to by annual evapotranspiration (23.5%), temperature seasonality (22.2%), minimum temperature (17.4%), normalised difference vegetation index (16.0%), mean annual temperature (8.6%), maximum temperature (5.9%) and minimum precipitation (5.9%).



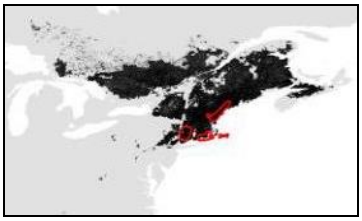
a) ~ 1930s (1900-1949)



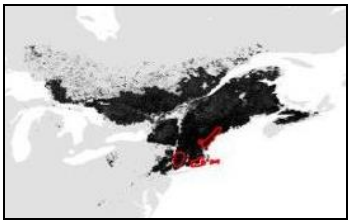
b) ~ 1980s (1950-2000)



c) ~ 2020s (2010-2039)



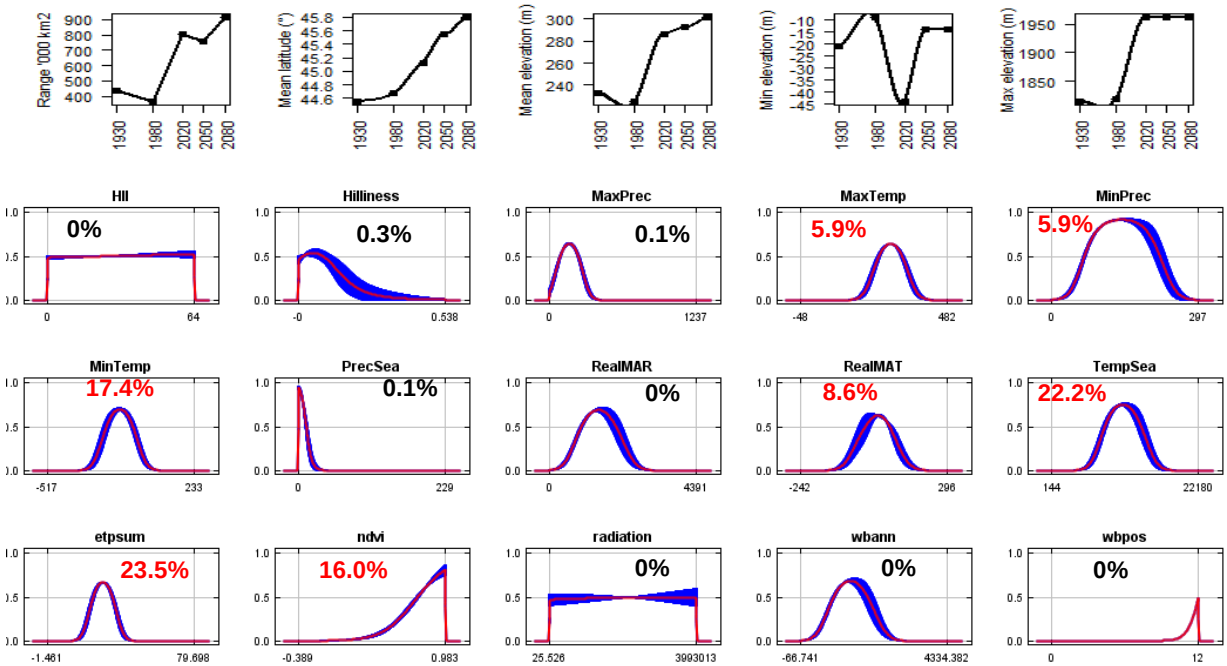
d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

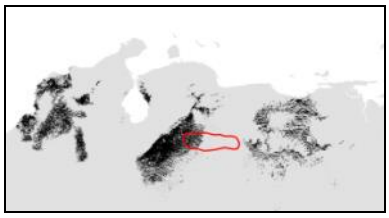
Red polygon = IUCN range (Barry, R., *et al*. 2008)



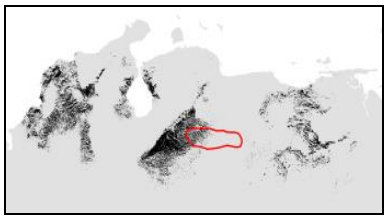
#89 – Venezuelan lowland rabbit (*Sylvilagus varynaensis*)
n = 6
Expert: Daniel Lew, Venezuelan Institute of Scientific Research, Ecology Centre, Biodiversity Unit
Expert evaluation: Poor
Data: Only modern
Envelope: Climatic and habitat
Dispersal distance: 3km/year (Similar ecology to *S.transitionalis*)
Status: UNMODELLABLE

AUC	0.99
Omission rate	0.00
Sensitivity	1.00
Specificity	0.99
Proportion correct	0.99
Kappa	**0.92**
True Skill Statistic	0.99

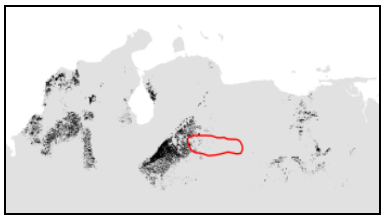
Summary: The Venezuelan lowland rabbit's bioclimatic envelope is predicted to decrease by 100% with a ~1.5° mean latitudinal polewards shift and a mean increase in elevation of ~275m driven by an increase in minimum elevation. 95% of the permutation importance of the model was contributed to by temperature seasonality (97.7%).



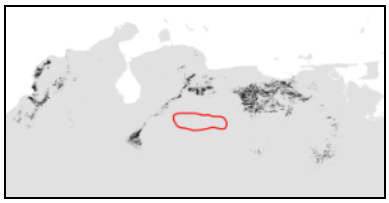
a) ~ 1930s (1900-1949)



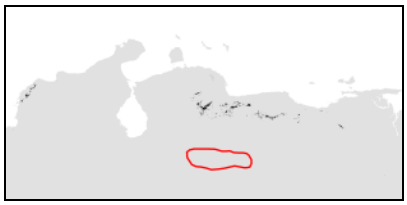
b) ~ 1980s (1950-2000)



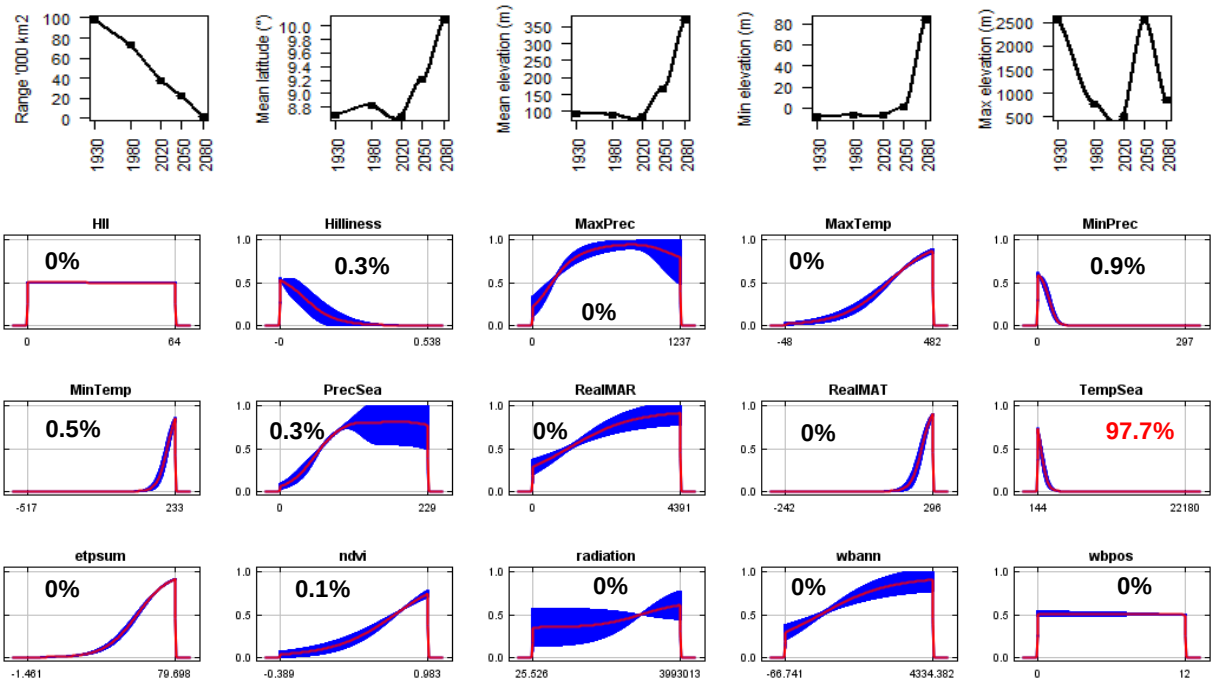
c) ~ 2020s (2010-2039)



d) ~ 2050s (2040-2069)



e) ~ 2080s (2070-2099)

Black = predicted suitable envelope

Red polygon = IUCN range (Durant, P. & Guevara, M.A. 2008)