Testing the climate-niche paradigm

for predicting global amphibian extinction risk

Claus Sarnighausen[1,2], Maximilian Kotz[2], Leonie Wenz[2] and Sanam Vardag[1]

[1]*Institute of Environmental Physics, University of Heidelberg, Germany*

[2]*Department of Complexity Science, Potsdam Institute for Climate Impact Research, Germany*

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Objective

Measuring the influence of climate change on species' **extinction risk** remains complex and lacks the appropriate tools [1]. We test the suitability of the **climate niche** for predicting the risk status of 3151 amphibian species, using the IUCN **Red List Category** as a proxy.

Main Questions

1. **Which climate variable has the most impact?**
2. **What is the role of the climate niche in predicting extinction risk?**

Data

IUCN Red List assessment

Categories and range maps

[8,011 amphibian species: 1980, 2004, 2022] [5]

ERA5 climate data

5 Bioclimatic variables and fractions of range within historical niche, derived from Temperature, Precipitation

[1940 – today, monthly; 0.25° x 0.25° global] [3, 7]

Human Pressure variables

Cropland*, Rangeland, Pasture*, Urban areas*, Human population density*, Mean Human accessibility†

***[1980, 2004, 2021; 0.5° x 0.5° global] [2, 4]**

†[2000, 2015; 0‘00'30° x 0‘00‘30° global] [6]

Biological traits

Habitat, Realm, Order, Body size, Breeding Type, Present geographic range

[Per species] [5, 8]

Contact

claus.sarnighausen@iup.uni-heidelberg.de

Climate Niche

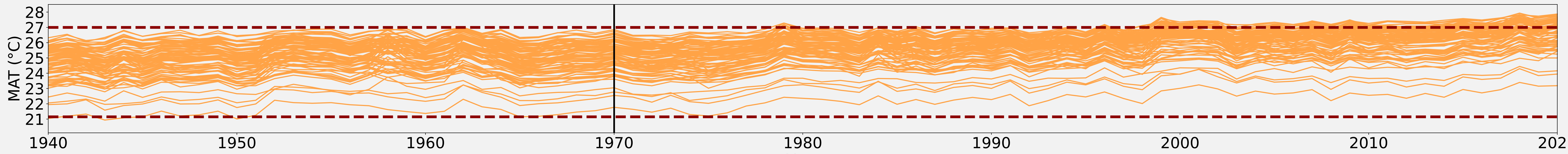


Fig. 1: **Mean annual temperature in geographic range of New Guinean Frog**. Each line refers to one grid cell (orange), some of them exceeding the thermal limit between 2000 and 2020 (red dotted)

The climate niche describes the climatic conditions for a population required to sustain. We define it following Pigot et al. (2023):

Thermal limit: most extreme monthly temperature experienced by a species across its geographical range in historical reference period (1940 - 1970)

The climate niche is locally exceeded for an individual climate variable if it exceeds the species' limit in at least 5 years within past two decades (Fig. 1)

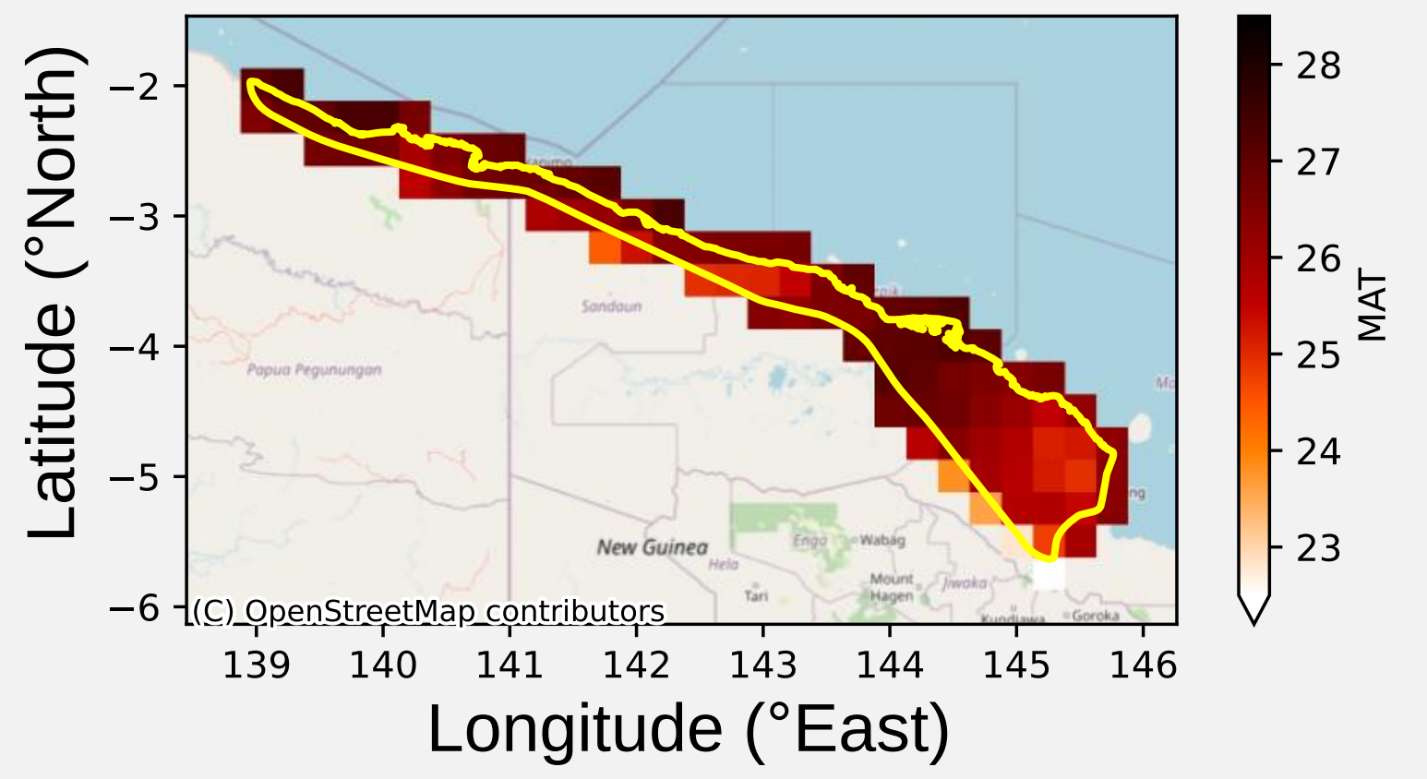


Fig. 2: **Spatial gridding** of mean annual temperature (MAT) data over the geographic range map of a New Guinean Frog (yellow line)

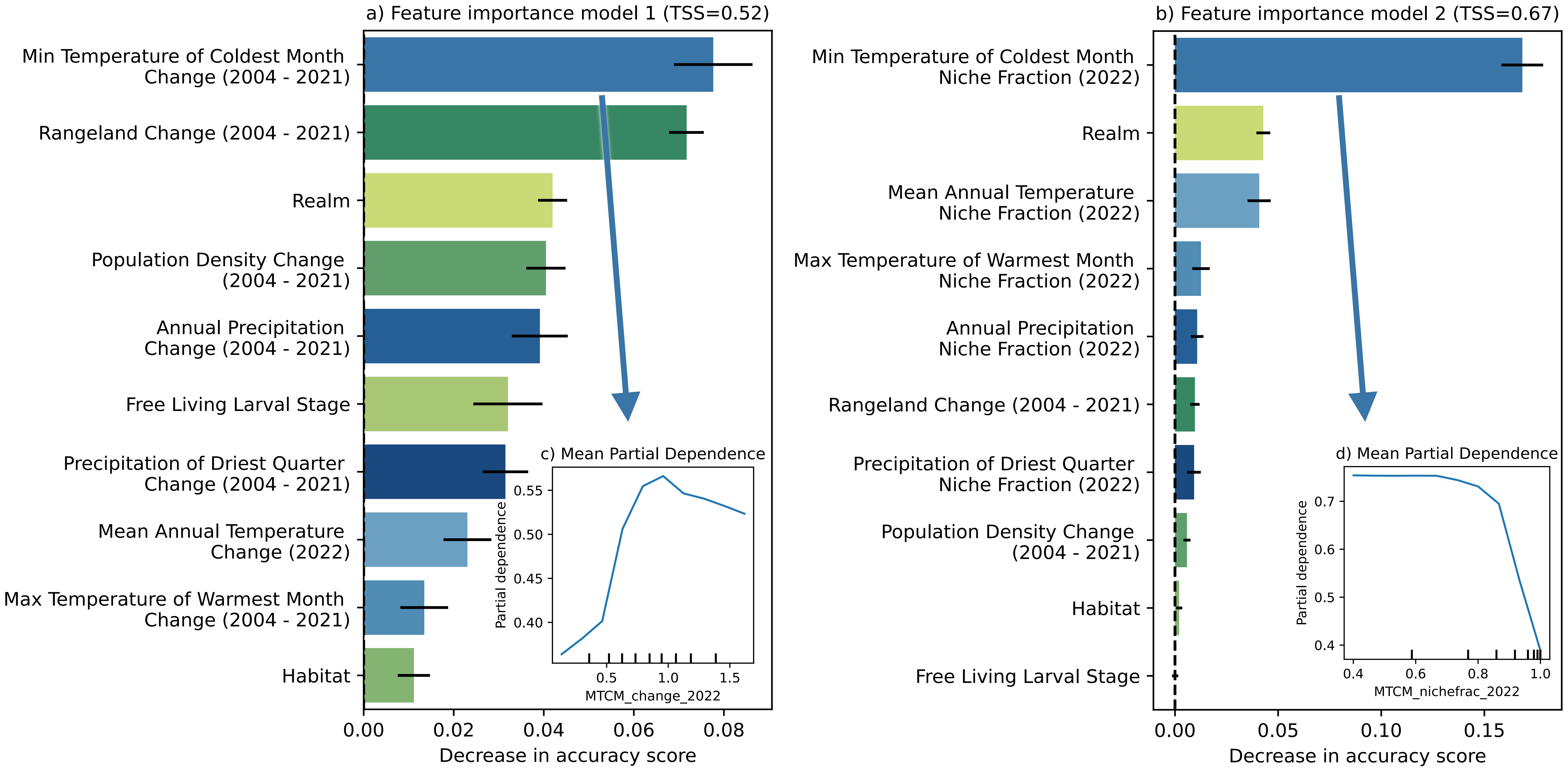


Fig. 3: **Two random forest modes with different selected variables, trained on predicting the red list changes between the 2004 and 2022 acescents.** The bar plots **(a, b)** show the relative feature importance calculated on the test set. The model performance is given by the true skill statistic (TSS = sensitivity + specificity – 1). In a), the climate variables are included as average changes across geographic range (2002 – 2022). In b), the climate variables are included as fraction of geographic range within climate niche. The nested plots **(c, d)** show partial dependence (mean model response between low risk 0 and high risk 1) for the most important variable **MTCM**: Min Temperature of Coldest Month

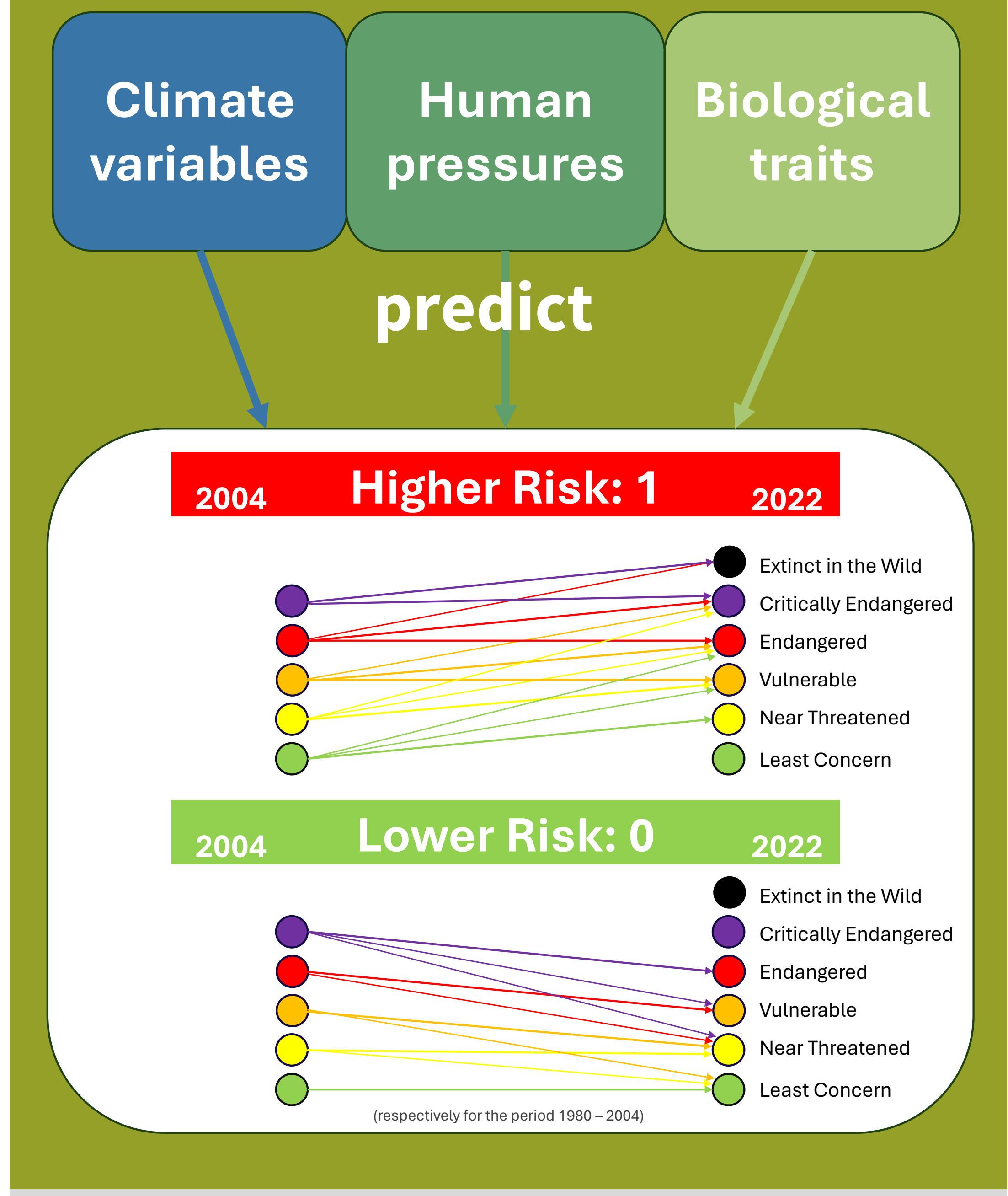
Key Messages

1. **Minimal Temperature of the coldest month** is consistently the most important climate variable (Fig. 3)
2. **The climate niche** is a more relevant predictor than human pressure and the respective climate change variables (Fig. 3b)

Limitations

- Estimating climate niches from today's geographic ranges may underestimate a species' true climate niche
- Possible adaption is not accounted for

Random Forrest Model



(respectively for the period 1980 – 2004)

References

1. Cazalis, V., Di Marco, M., Butchart, S. H., Akçakaya, H. R., González-Suárez, M., Meyer, C., ... & Santini, L. *et al.* Bridging the research-implementation gap in IUCN Red List assessments. *Trends in Ecology & Evolution* (2022). https://doi.org/10.1016/j.tree.2021.12.002
2. Di Marco, M., Venter, O., Possingham, H.P. *et al.* Changes in human footprint drive changes in species extinction risk. *Nat Commun* **9**, 4621 (2018). https://doi.org/10.1038/s41467-018-07049-5
3. Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J-N. (2023): ERA5 monthly averaged data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). https://doi.org/10.24381/cds.f17050d7
4. Klein Goldewijk, K., Beusen, A., Doelman, J., and Stehfest, E. Anthropogenic land use estimates for the Holocene – HYDE 3.2, *Earth Syst. Sci. Data* **9**, 927–953 (2017). https://doi.org/10.5194/essd-9-927-2017
5. Luedtke, J.A., Chanson, J., Neam, K. *et al.* Ongoing declines for the world's amphibians in the face of emerging threats. *Nature* **622**, 308–314 (2023). https://doi.org/10.1038/s41586-023-06578-4
6. Nelson, A., Weiss, D.J., van Etten, J. *et al.* A suite of global accessibility indicators. *Sci Data* **6**, 266 (2019). https://doi.org/10.1038/s41597-019-0265-5
7. O'Donnell, M.S., and Ignizio, D.A. Bioclimatic predictors for supporting ecological applications in the conterminous United States. *U.S. Geological Survey Data Series* **691** (2012).
8. Oliveira, B., São-Pedro, V., Santos-Barrera, G. *et al.* AmphiBIO, a global database for amphibian ecological traits. *Sci Data* **4**, 170123 (2017). https://doi.org/10.1038/sdata.2017.123
9. Pigot, A.L., Merow, C., Wilson, A. *et al.* Abrupt expansion of climate change risks for species globally. *Nat Ecol Evol* **7**, 1060–1071 (2023). https://doi.org/10.1038/s41559-023-02070-4