Climate Change and Wildlife Movements in the Himalaya

Sathyakumar Sambandam
Professor, WII

भारतीय वन्यजीव संस्थान
Wildlife Institute of India





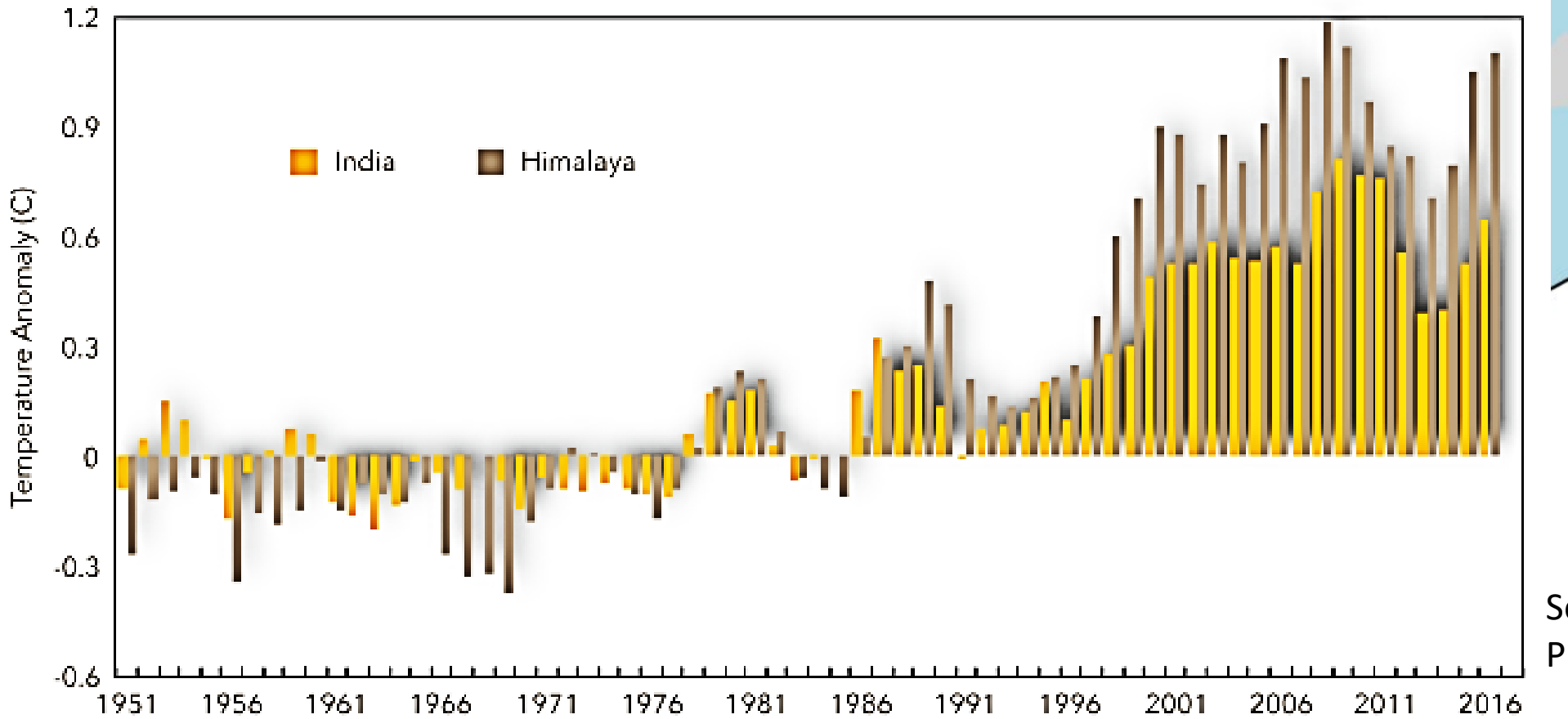






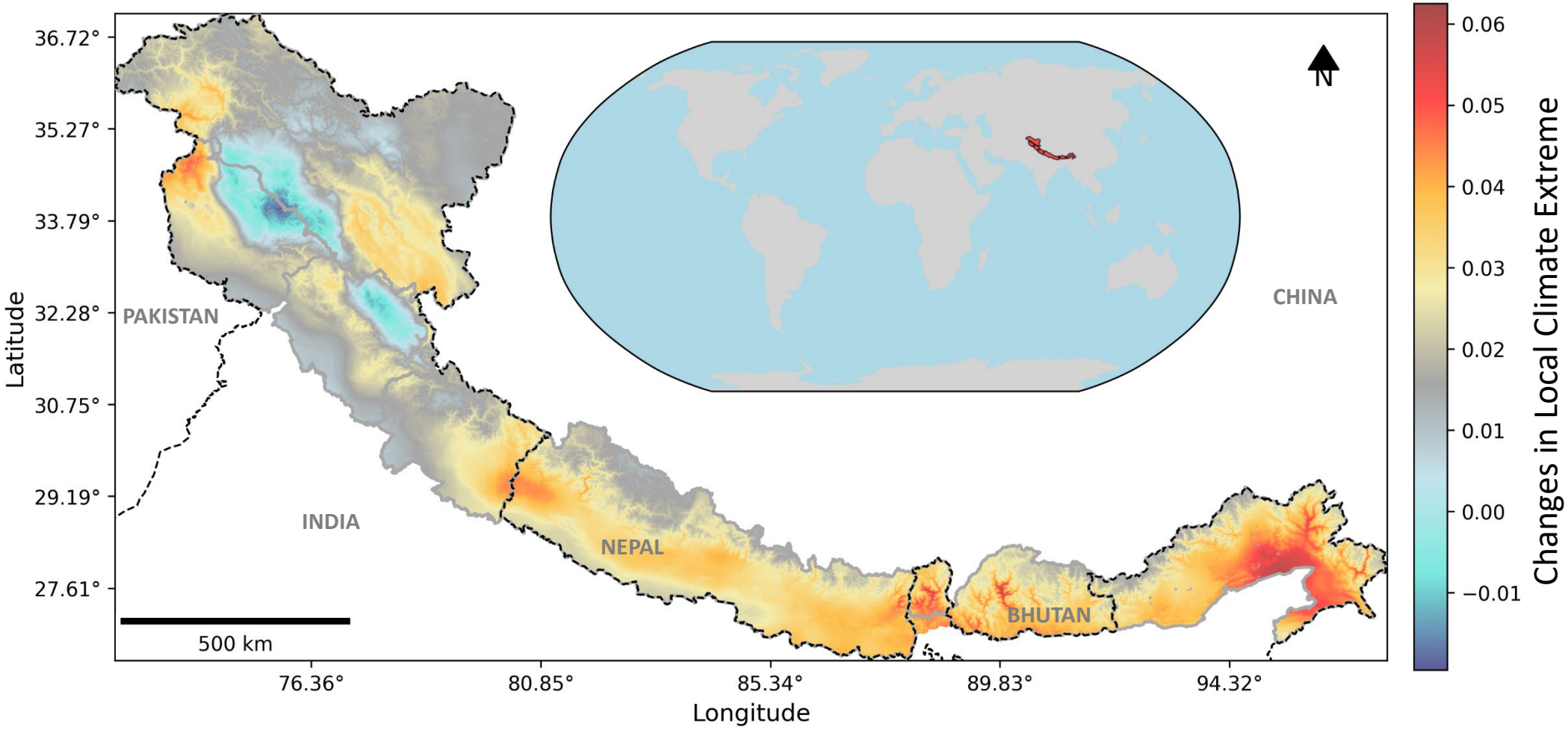
A Rapidly warming Himalaya…

- Moderate rising of mean temperature from 1901 to the early 1940s
- Falling trend between 1940 and 1970
- Continuous and rapid rising after 1970



Source: IITM, Pune

Changes in Probability of Local Climate Extremes

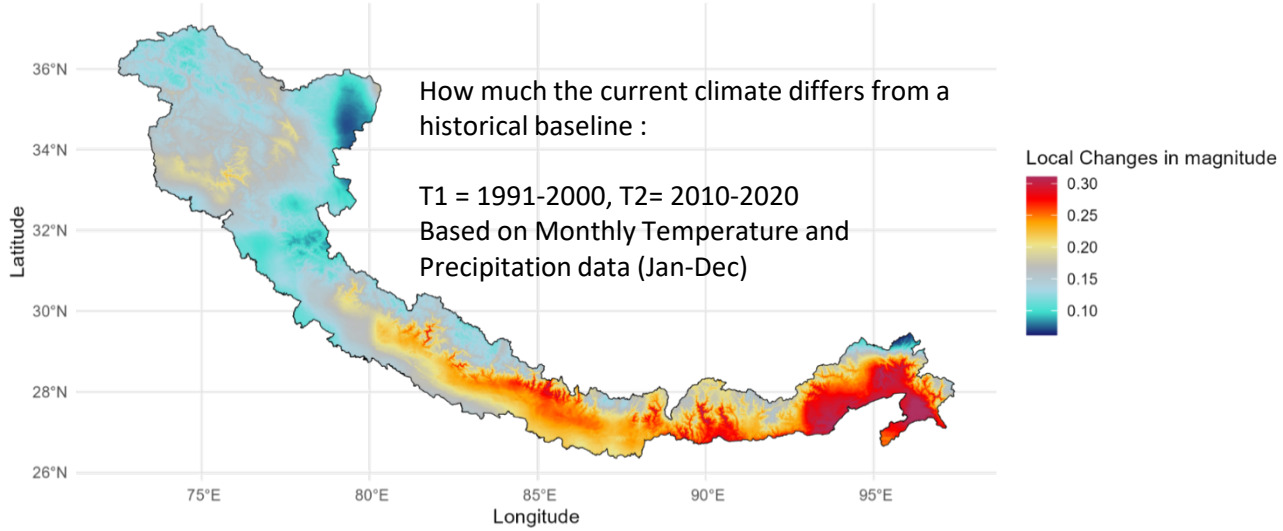


Probabilities shift between two periods:

T1 = 1991-2000, T2= 2010-2020
Based on Monthly Climate Data (Jan-Dec)

- **Blue and Light Blue Areas**: Represent areas where there has been a **decrease in the probability of extreme climate events**.
- **Yellow, Orange, and Red Areas**: Indicate areas with an **increase in the probability of extreme climate events**.

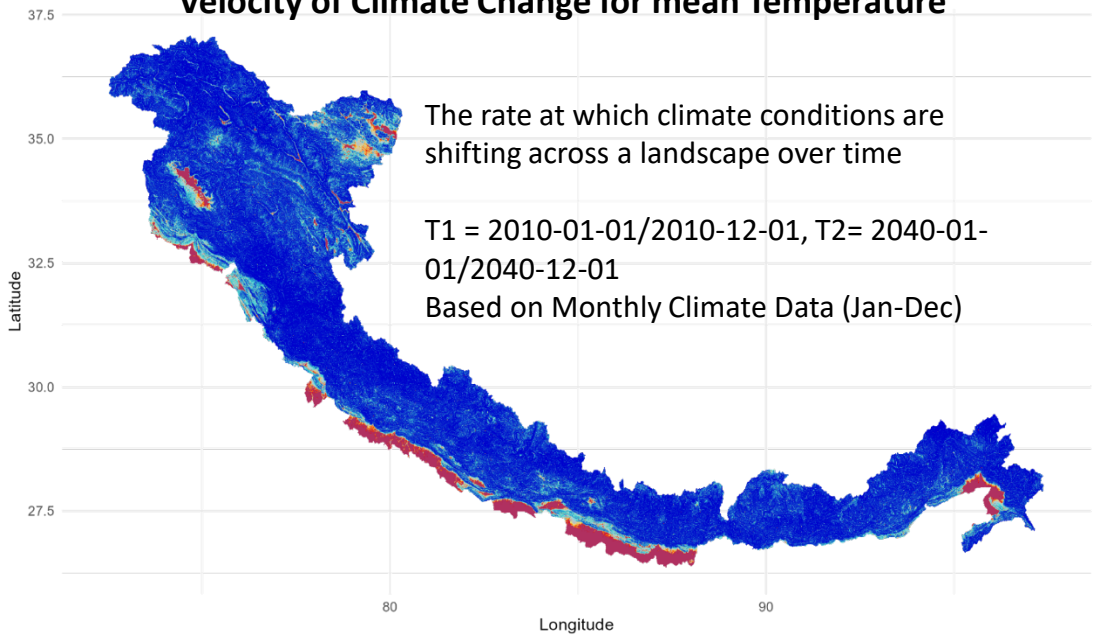
Standardized Local Anomalies in the Himalaya



How much the current climate differs from a historical baseline :

T1 = 1991-2000, T2= 2010-2020
Based on Monthly Temperature and Precipitation data (Jan-Dec)

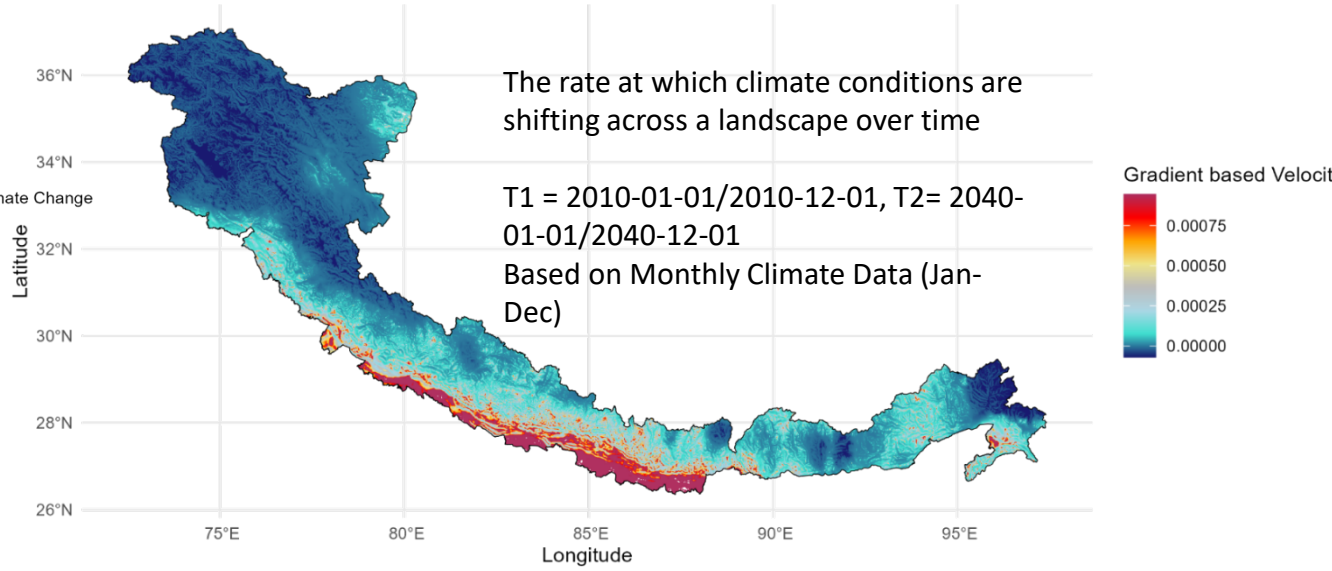
Velocity of Climate Change for mean Temperature



The rate at which climate conditions are shifting across a landscape over time

T1 = 2010-01-01/2010-12-01, T2= 2040-01-01/2040-12-01
Based on Monthly Climate Data (Jan-Dec)

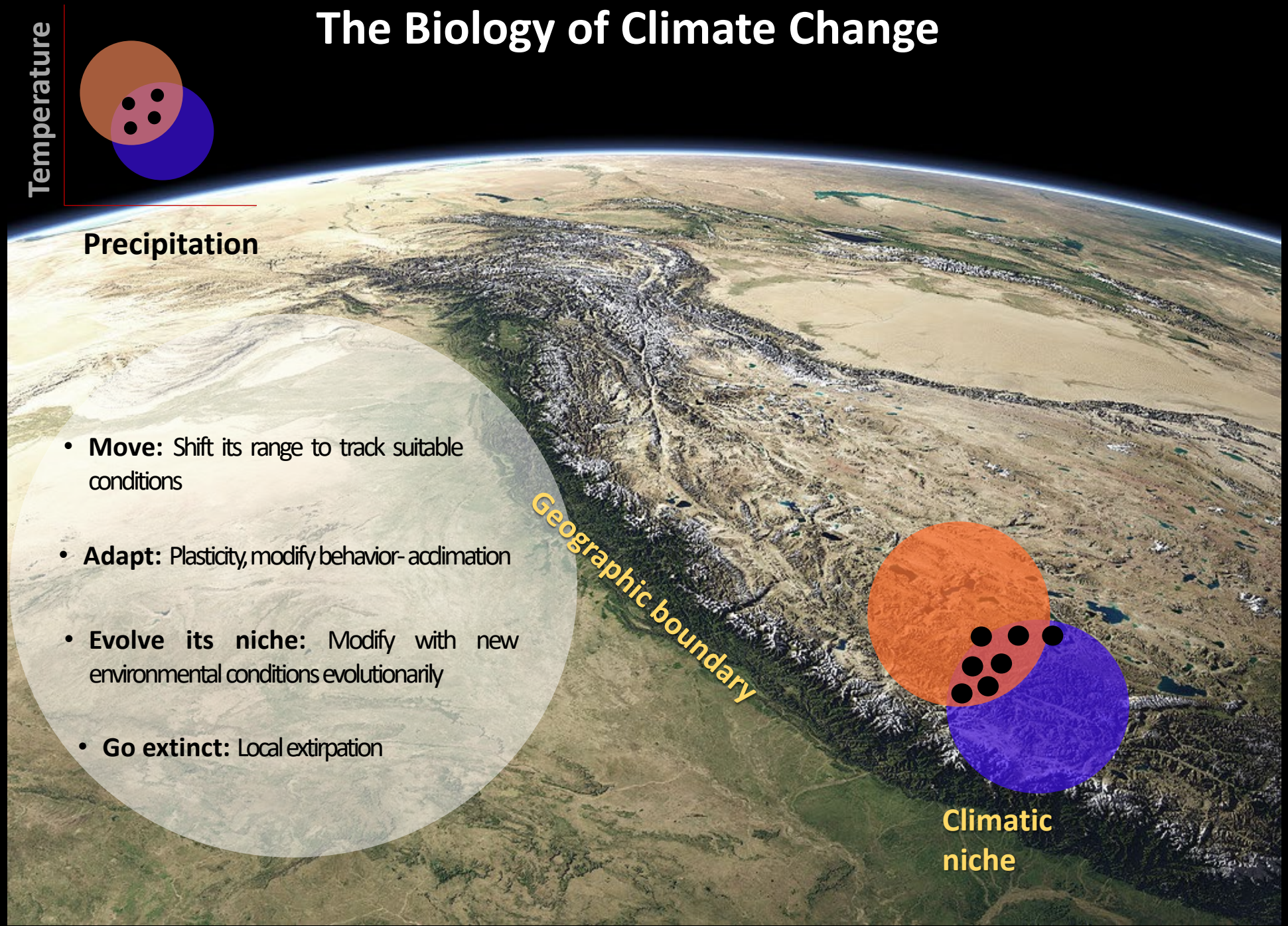
Velocity of Climate Change for Precipitation



The rate at which climate conditions are shifting across a landscape over time

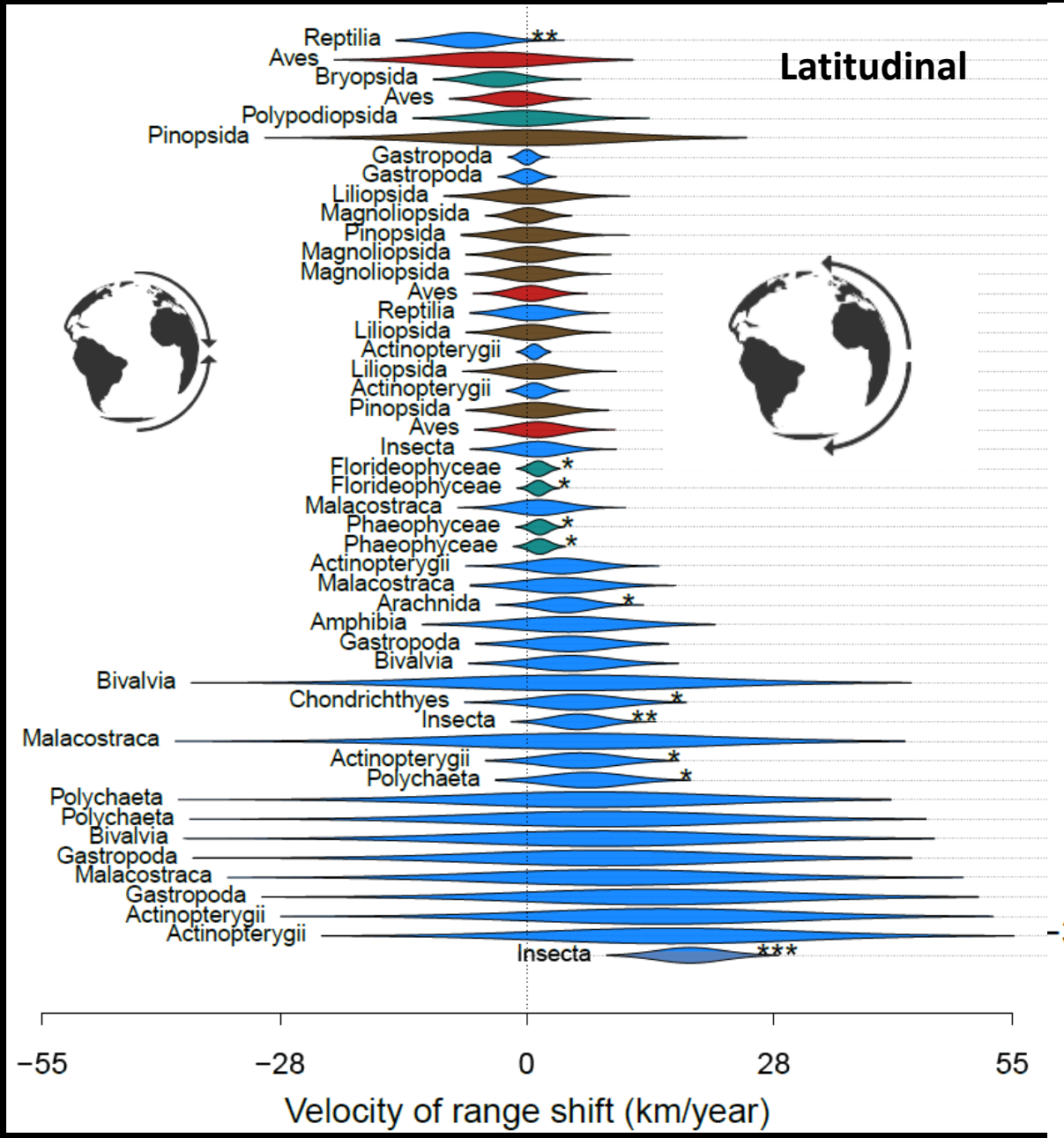
T1 = 2010-01-01/2010-12-01, T2= 2040-01-01/2040-12-01
Based on Monthly Climate Data (Jan-Dec)

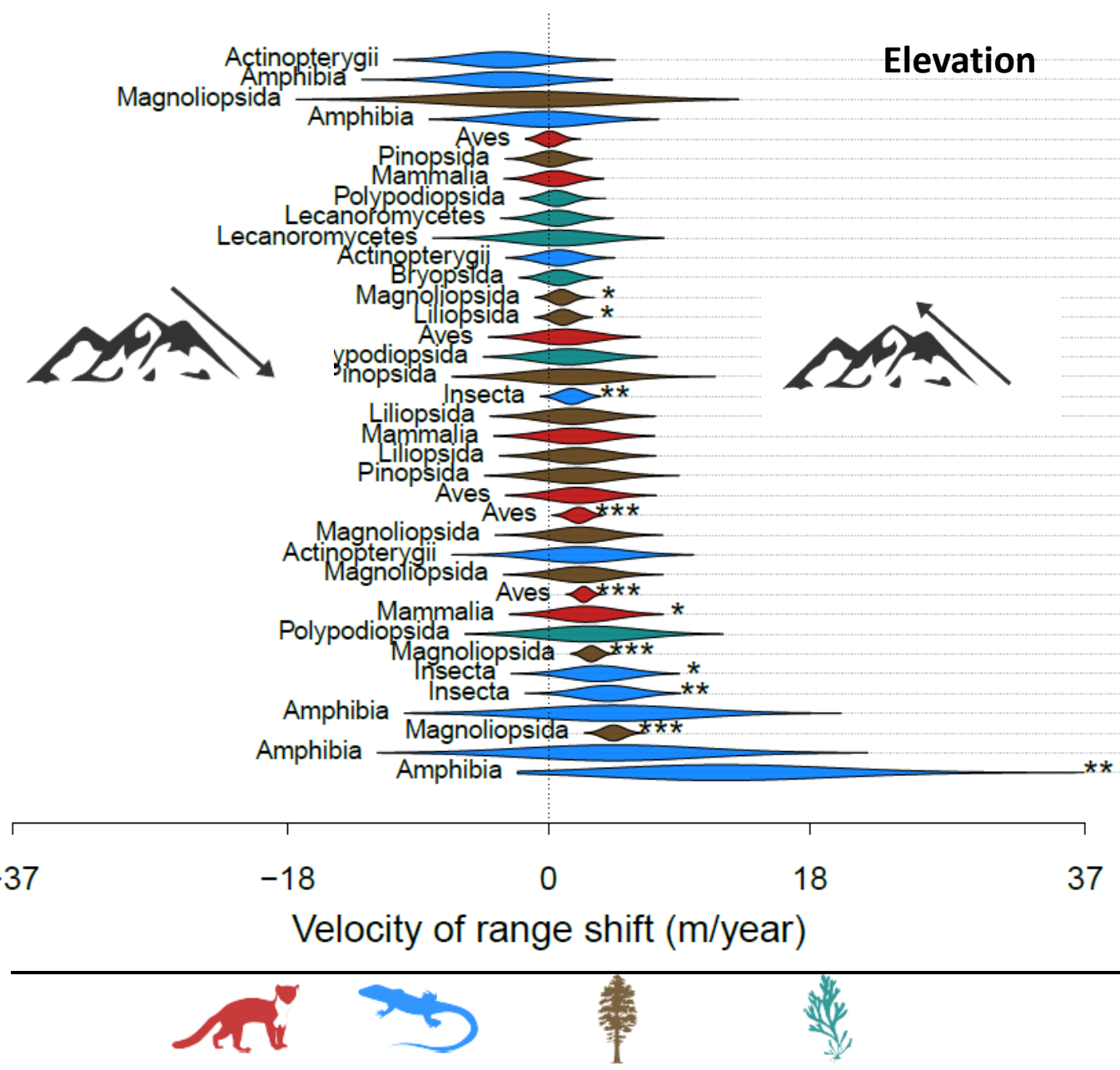
The Biology of Climate Change



- **Move:** Shift its range to track suitable conditions
- **Adapt:** Plasticity, modify behavior- acclimation
- **Evolve its niche:** Modify with new environmental conditions evolutionarily
- **Go extinct:** Local extirpation

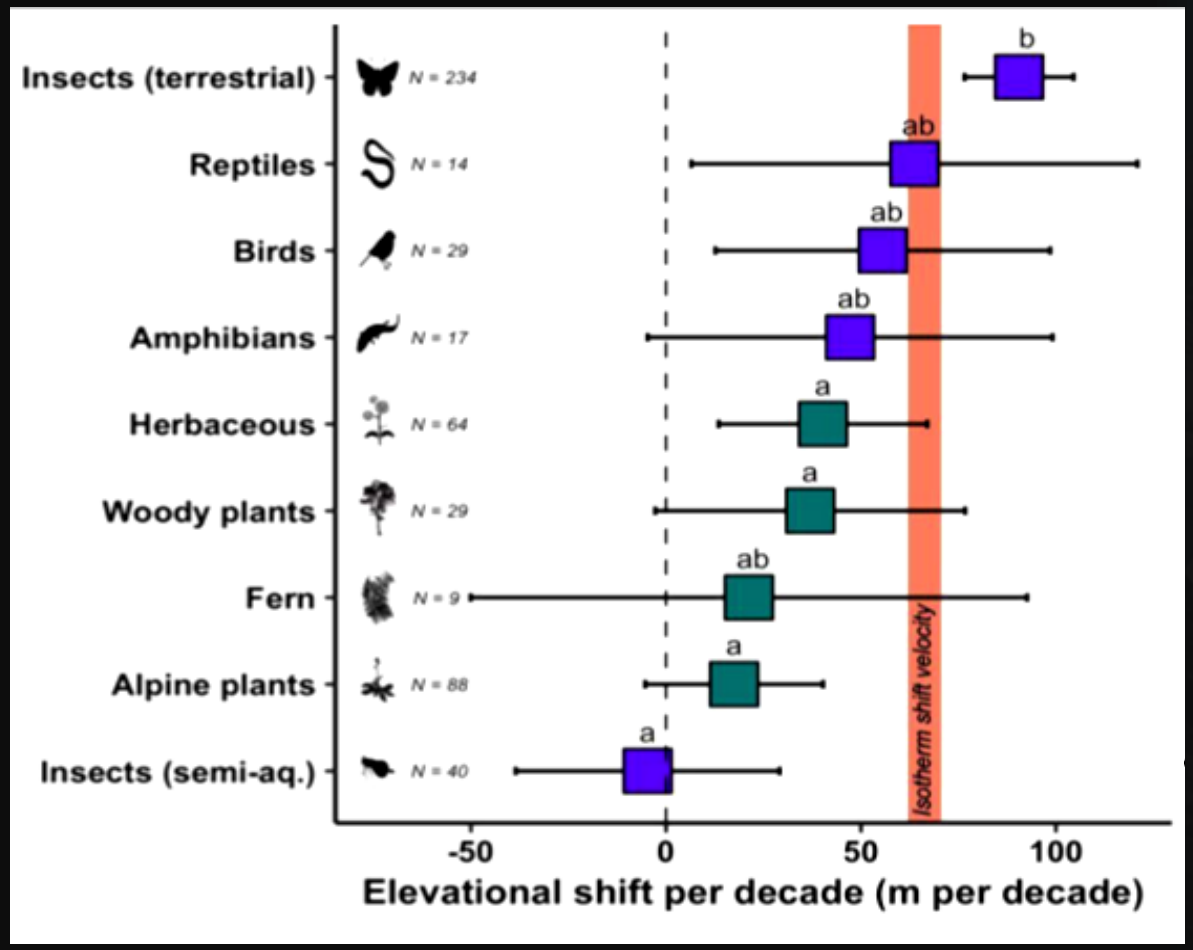
Species are now tracking climate change





Lenoir et al. 2020

Empirical evidences for elevational range shifts



Data of the European Alps (1980–2020)

Vitasse et al. (2021) Biological Reviews

Empirical evidences for elevational range shifts

Birds Available Baseline Data

June 16th, 1985

N = 10 nests with eggs

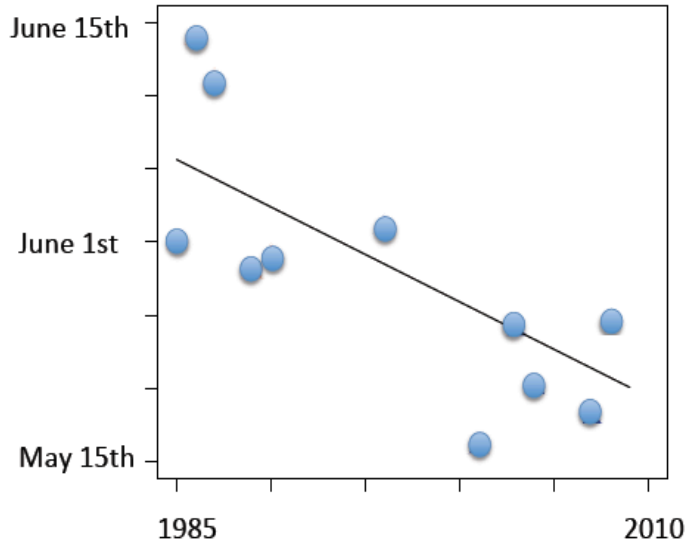
June 16th, 2009

N = 20 nests with chicks

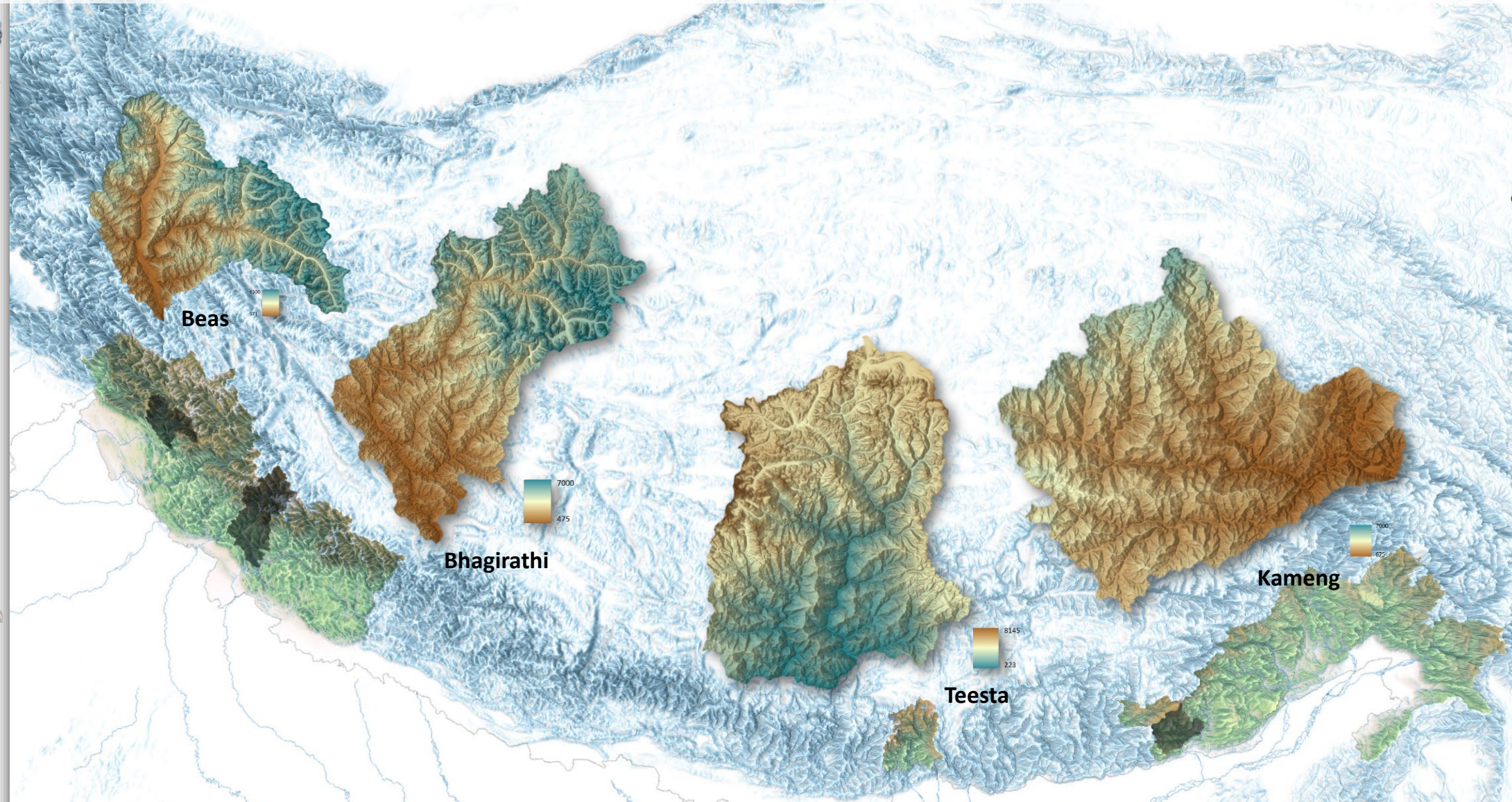
Price et al. (2017)

Elevational Distribution Data
WII-University of Chicago Project
Dr. Price's work in Western Himalaya

Laying date is advancing



Study Across Longitudinal & Elevation Gradients in the Indian Himalaya



Assessment and Monitoring of Climate Change Effects on Wildlife Species and Ecosystems for Developing Adaptation Strategies in the Indian Himalayan Region- National Mission on Sustaining the Himalayan Ecosystem (NMSHE)

Predicted Impacts of Climate Change on Selected Mammals in Uttarakhand

Data collection

NMSHE Phase I (2015-19) & II (2023 onwards)

Uttarakhand State Wildlife Population Estimation (UWPE 2021-23)

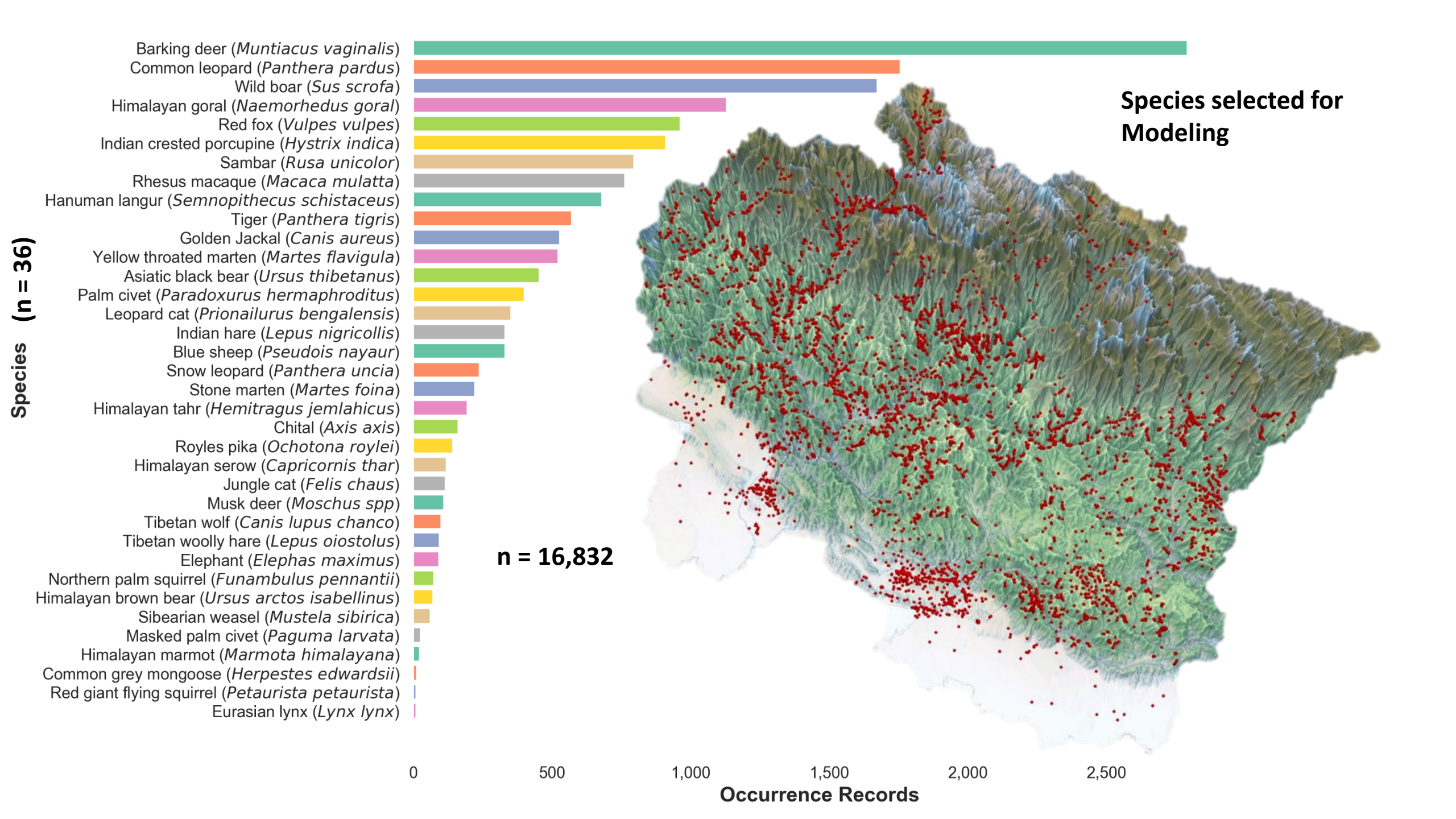
Snow Leopard Population Estimation (2022-23)

Literature and online resources (GBIF)

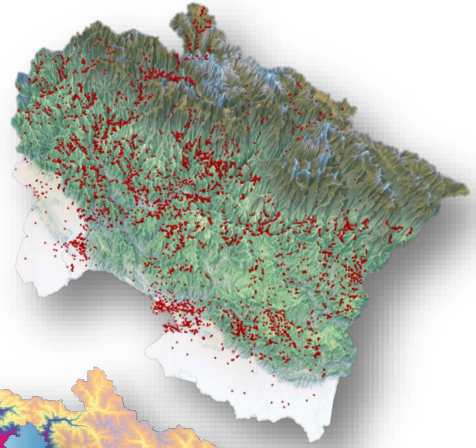
Removed ambiguous records

Spatial thinning

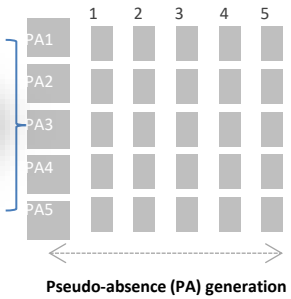
Total records collated : 16, 832

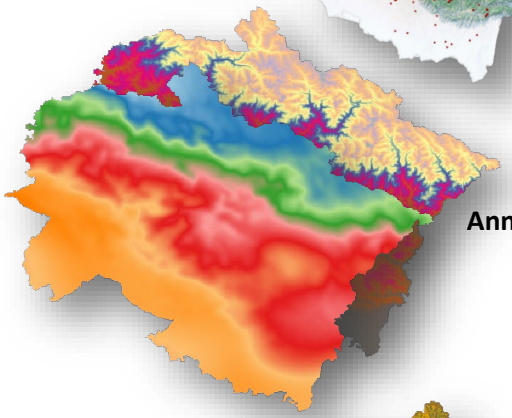

Species (n = 36)
Barking deer (Muntiacus vaginalis)
Common leopard (Panthera pardus)
Wild boar (Sus scrofa)
Himalayan goral (Naemorhedus goral)
Red fox (Vulpes vulpes)
Indian crested porcupine (Hystrix indica)
Sambar (Rusa unicolor)
Rhesus macaque (Macaca mulatta)
Hanuman langur (Semnopithecus schistaceus)
Tiger (Panthera tigris)
Golden Jackal (Canis aureus)
Yellow throated marten (Martes flavigula)
Asiatic black bear (Ursus thibetanus)
Palm civet (Paradoxurus hermaphroditus)
Leopard cat (Prionailurus bengalensis)
Indian hare (Lepus nigricollis)
Blue sheep (Pseudois nayaur)
Snow leopard (Panthera uncia)
Stone marten (Martes foina)
Himalayan tahr (Hemitragus jemlahicus)
Chital (Axis axis)
Royles pika (Ochotona roylei)
Himalayan serow (Capricornis thar)
Jungle cat (Felis chaus)
Musk deer (Moschus spp)
Tibetan wolf (Canis lupus chanco)
Tibetan woolly hare (Lepus oiostolus)
Elephant (Elephas maximus)
Northern palm squirrel (Funambulus pennantii)
Himalayan brown bear (Ursus arctos isabellinus)
Sibearian weasel (Mustela sibirica)
Masked palm civet (Paguma larvata)
Himalayan marmot (Marmota himalayana)
Common grey mongoose (Herpestes edwardsii)
Red giant flying squirrel (Petaurista petaurista)
Eurasian lynx (Lynx lynx)
0
500
1,000
1,500
2,000
2,500
Occurrence Records
Species selected for Modeling
n = 16,832

Data Collection



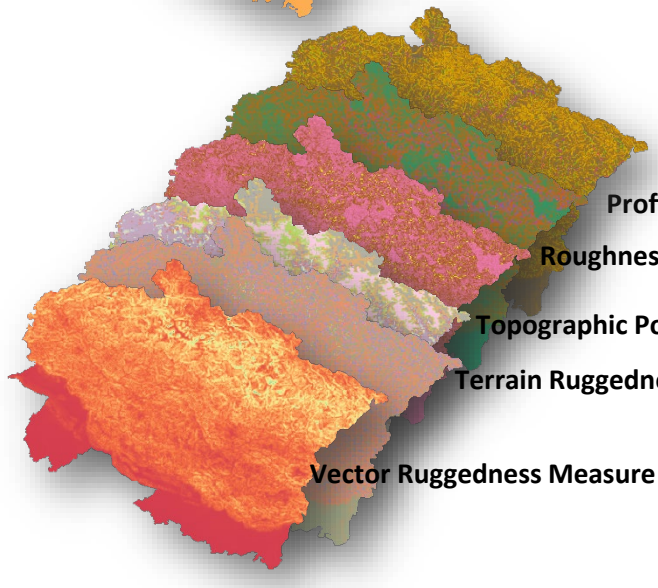
Random
Barbet-Massin et al. (2012)





Annual Mean Temperature: Bio 1

Annual Precipitation: Bio 12



Land-cover

Profile curvature (Min - Max)

Roughness (Min – Max)

Topographic Position Index (Min-Max): TPI

Terrain Ruggedness Index (Mean): TRI

Vector Ruggedness Measure (Mean): VRM

Algorithm

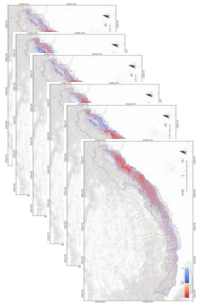
GBM

SVM

RF

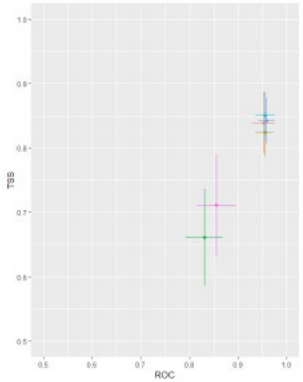
MAX-ENT

GLM



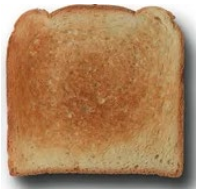
5 cross- validations
5 pseudo- absences samplings
Model evaluations (TSS, ROC)

Construction of ensemble model



Shared Socio-economic Pathways

SSP-126



1.5°C to 2°C

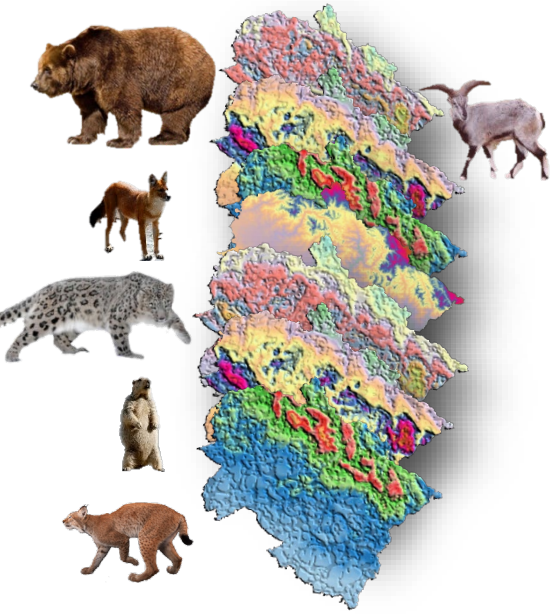
SSP-370

3.5°C to 4°C

SSP-585

4.3°C to 5.0°C

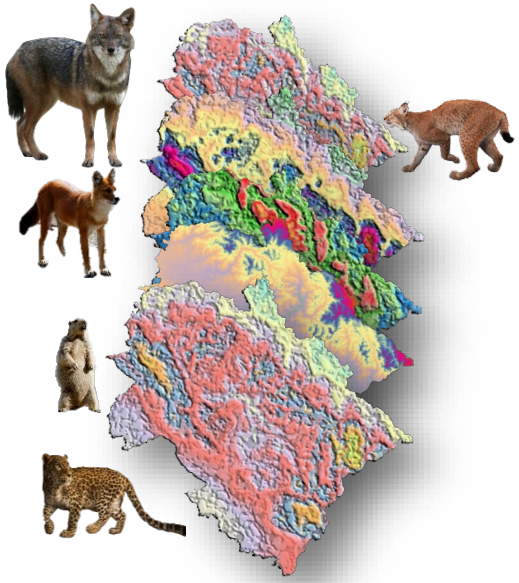
Model Projection



Current projection

CMIP-6

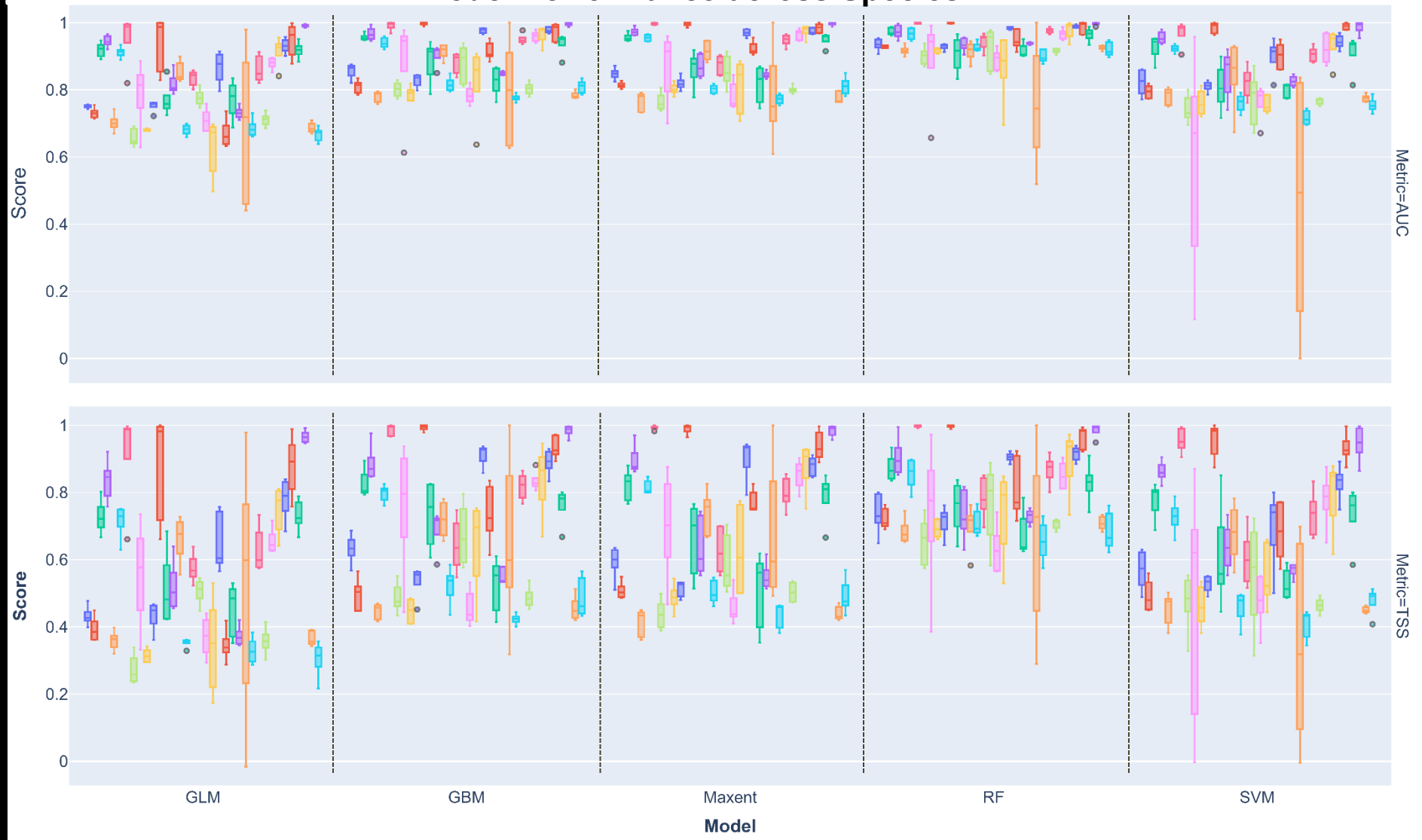
GFDL Earth System Model Version 4 (GFDL-ESM 4)



SSP-126, 370, 585
Year 2041-70

Future projection

Model Performance across Species

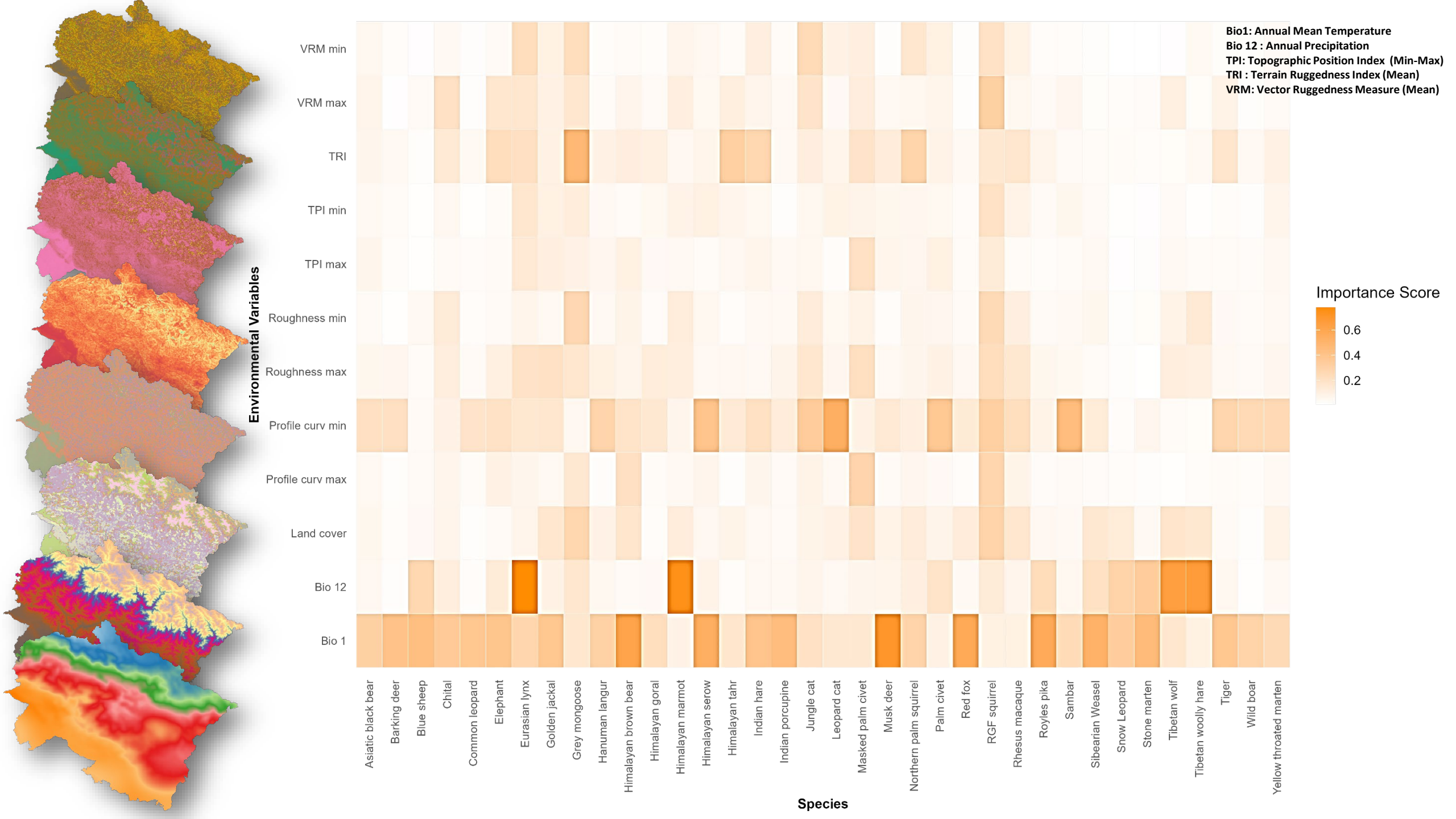


Species

- Asiatic black bear
- Barking deer
- Blue sheep
- Chital
- Common leopard
- Elephant
- Eurasian lynx
- Golden jackal
- Grey mongoose
- Hanuman langur
- Himalayan goral
- Himalayan marmot
- Himalayan serow
- Himalayan tahr
- Himalayan brown bear
- Indian porcupine
- Indian hare
- Jungle cat
- Leopard cat
- Masked palm civet
- Musk deer
- Northern palm squirrel
- Palm civet
- Red fox
- Red giant flying squirrel
- Rhesus macaque
- Royles pika
- Sambar
- Sibearian weasel
- Snow leopard
- Stone marten
- Tibetan wolf
- Tiger
- Tibetan woolly hare
- Wild boar
- Yellow throated marten

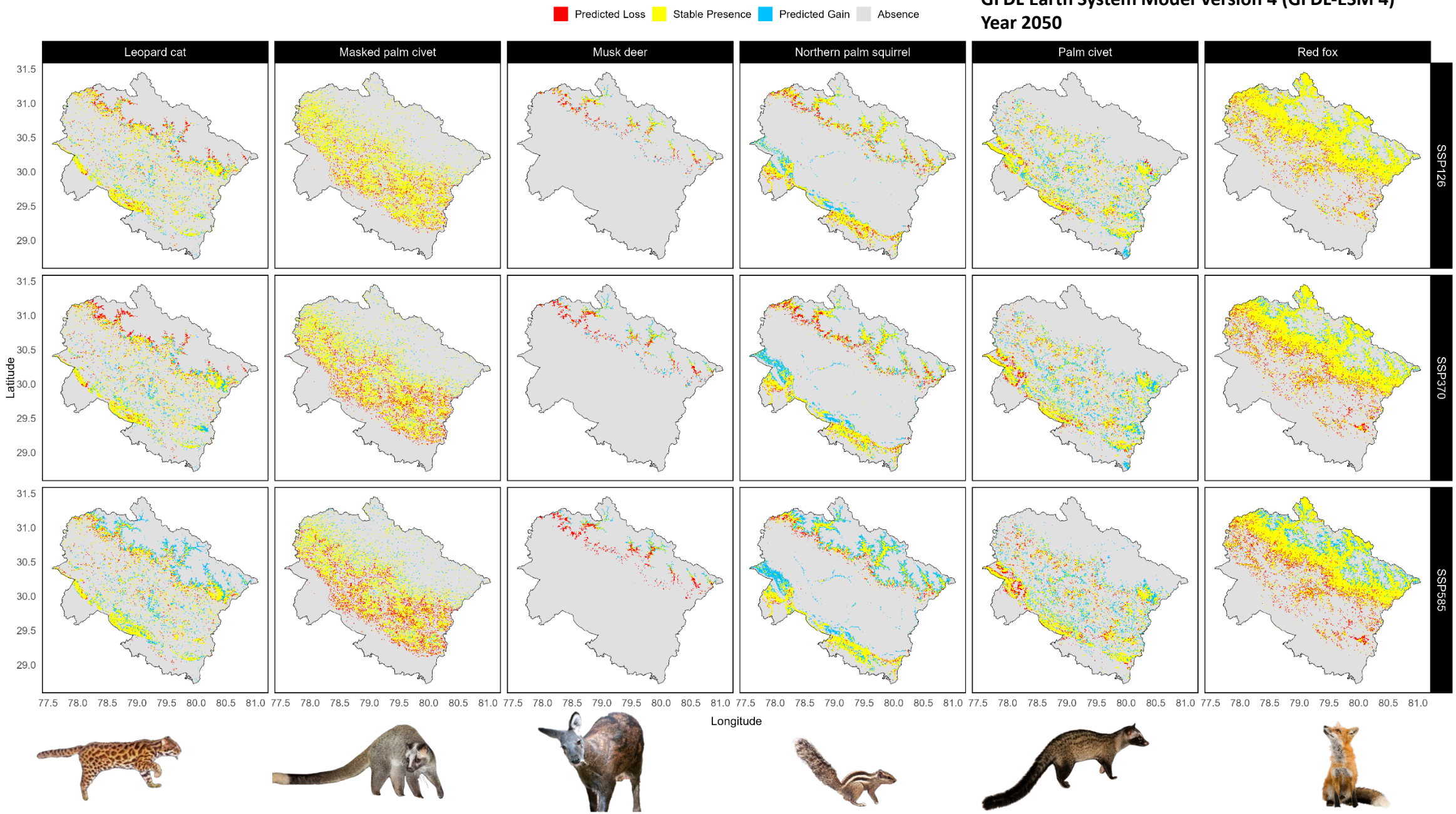
Variable Importance Scores

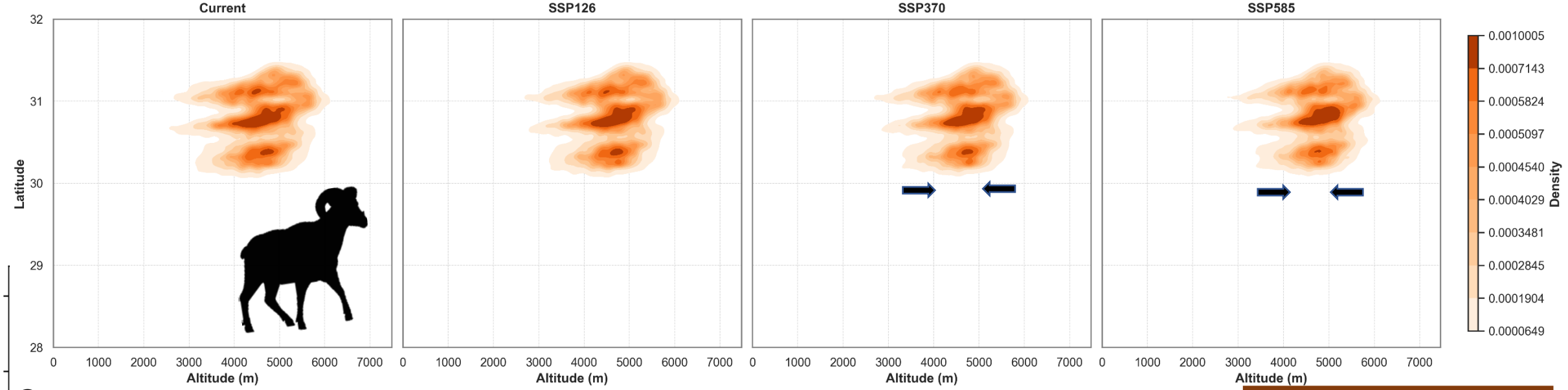
Bio1: Annual Mean Temperature
Bio 12 : Annual Precipitation
TPI: Topographic Position Index (Min-Max)
TRI : Terrain Ruggedness Index (Mean)
VRM: Vector Ruggedness Measure (Mean)


Bio1: Annual Mean Temperature
Bio 12 : Annual Precipitation
TPI: Topographic Position Index (Min-Max)
TRI : Terrain Ruggedness Index (Mean)
VRM: Vector Ruggedness Measure (Mean)
Importance Score
0.6
0.4
0.2
Environmental Variables
VRM min
VRM max
TRI
TPI min
TPI max
Roughness min
Roughness max
Profile curv min
Profile curv max
Land cover
Bio 12
Bio 1
Asiatic black bear
Barking deer
Blue sheep
Chital
Common leopard
Elephant
Eurasian lynx
Golden jackal
Grey mongoose
Hanuman langur
Himalayan brown bear
Himalayan goral
Himalayan marmot
Himalayan serow
Himalayan tahr
Indian hare
Indian porcupine
Jungle cat
Leopard cat
Masked palm civet
Musk deer
Northern palm squirrel
Palm civet
Red fox
RGF squirrel
Rhesus macaque
Royles pika
Sambar
Sibearian Weasel
Snow Leopard
Stone marten
Tibetan wolf
Tibetan woolly hare
Tiger
Wild boar
Yellow throated marten
Species

Predicted Loss and Gain Across Scenarios

GFDL Earth System Model Version 4 (GFDL-ESM 4)
Year 2050





Modeled Density of Presences

Literature based Elevation Ranges & Modeled Density of Presences

5000
4500
4000
3500
3000
2500
2000
1500
1000

Alpine-Subalpine (3300-3800m)
Temperate (1500-3000m)
Subtropical (<1500)

Snow-free slopes preference
avoid more open alpine slopes

△ 1000-3500
▲ 1500-2500

Goral

Alpine meadows (spring/summer), subalpine scattered tree/scrub habitats (autumn/winter)

△ 1500-4400
▲ 2000-3500

Himalayan tahr

Dense scrub undergrowth (day), alpine meadows (night)

△ 2500-4000
▲ 2700-3500

Musk deer

Steep, open grassy slopes with cliffs and forest cover

△ 2000-4000
▲ 2500-3700

Serow

Alpine steppe vegetated mountain pastures/subalpine slopes

△ 2500-5000
▲ 2800-4200

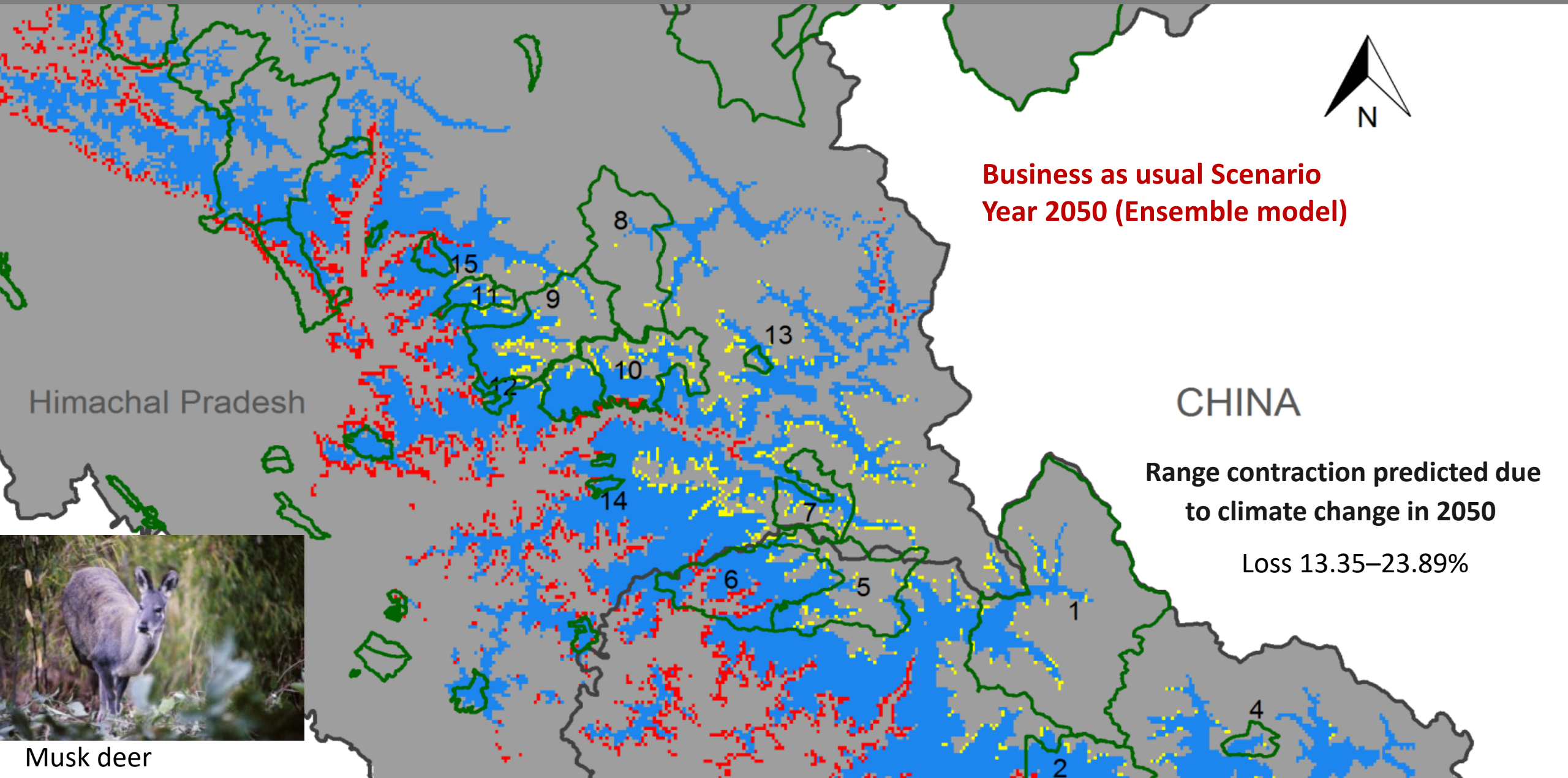
Blue sheep

Literature based Elevation Ranges

△ Elevation Range

▲ Optimal Elevation Range

Landscape Assessments for Habitat Connectivity in the Himalaya

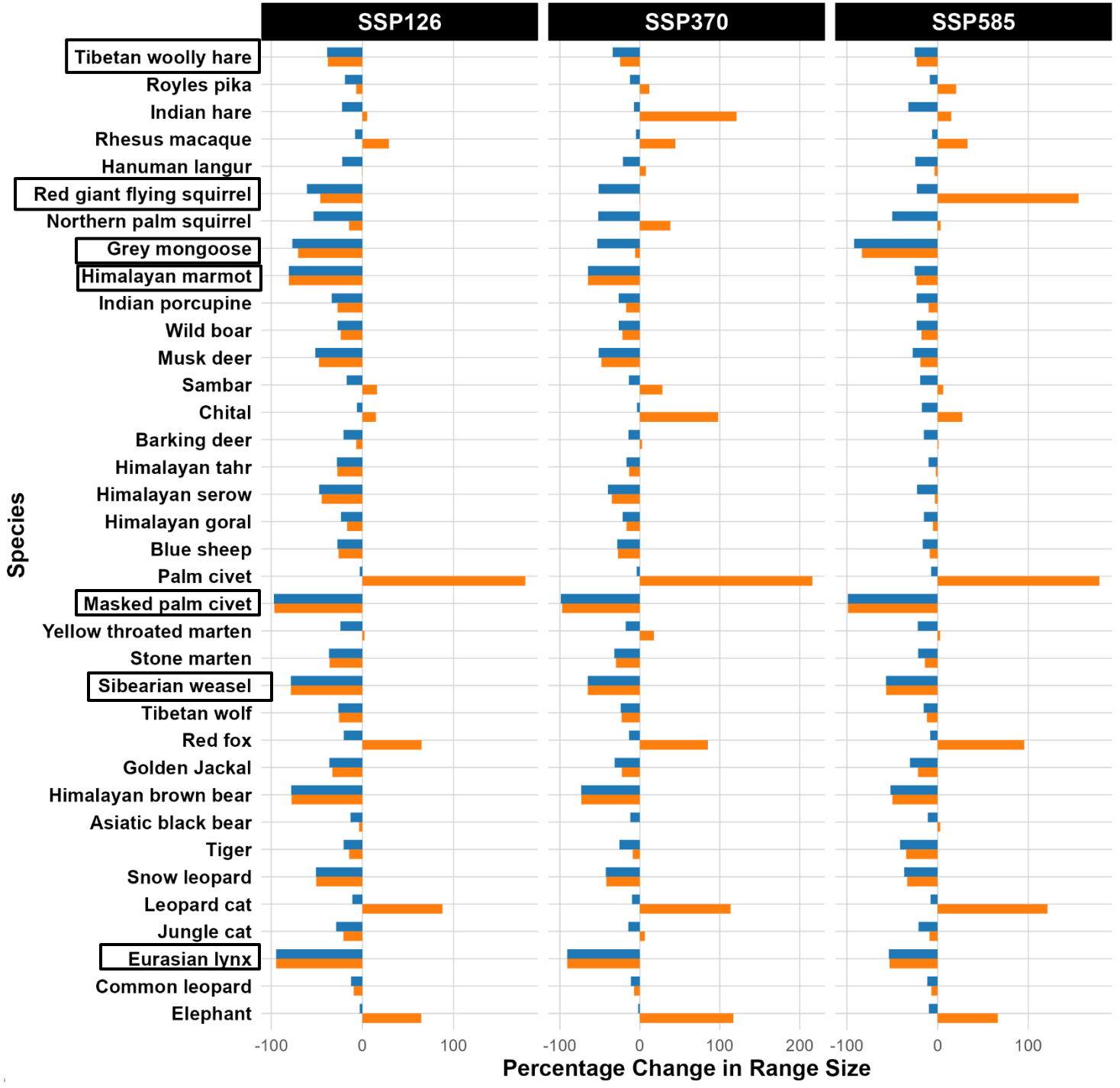


Musk deer

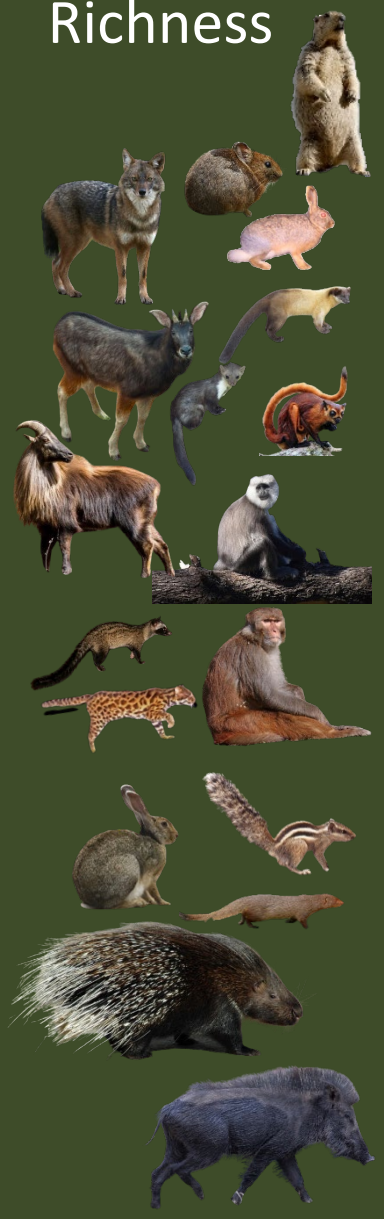
Staying Small is a Risky Business !

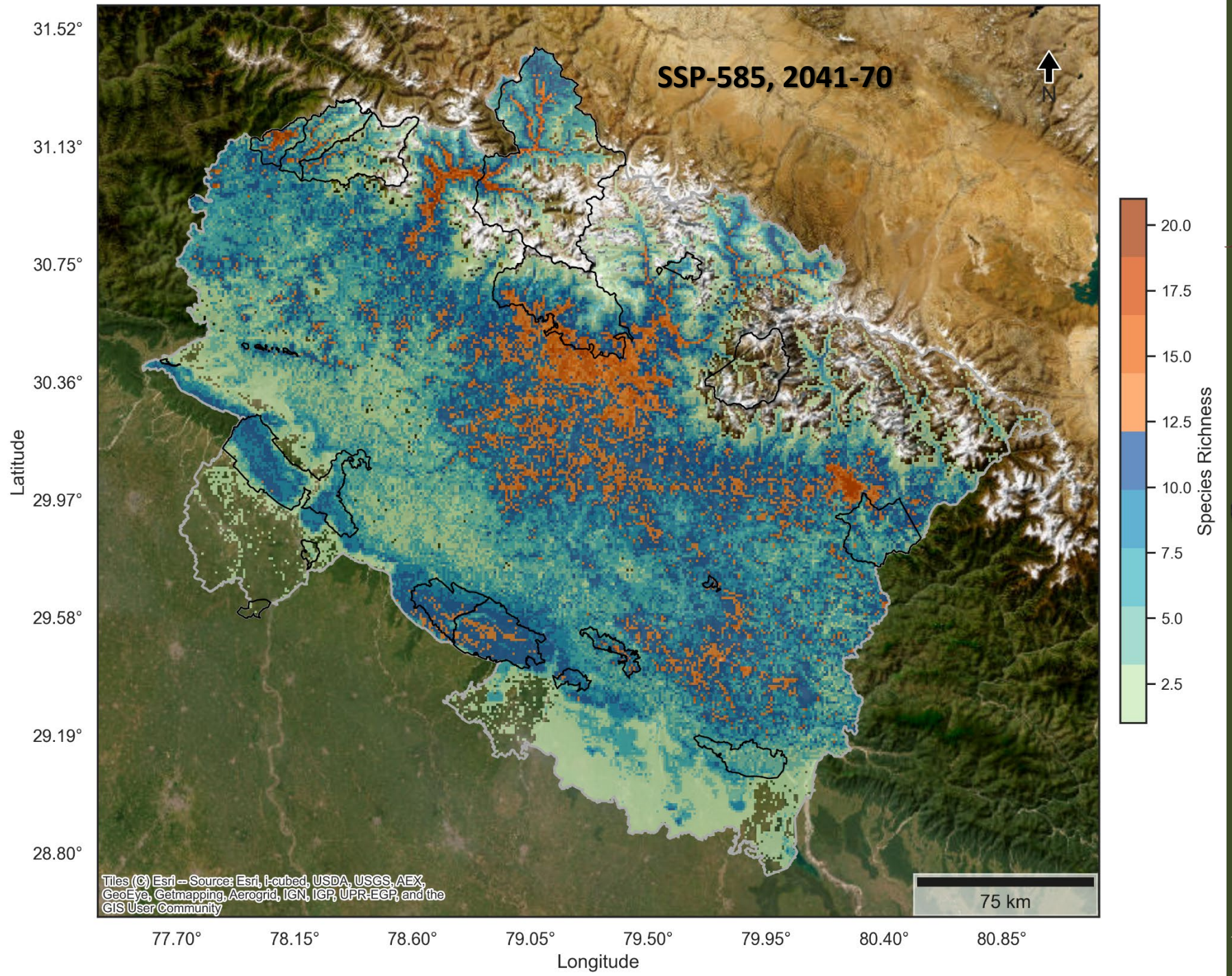




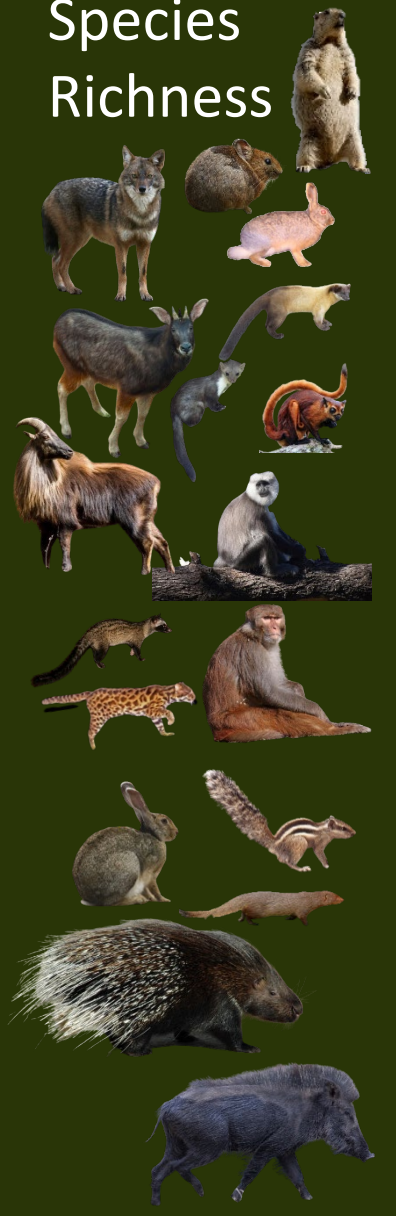
Shift in Species Richness

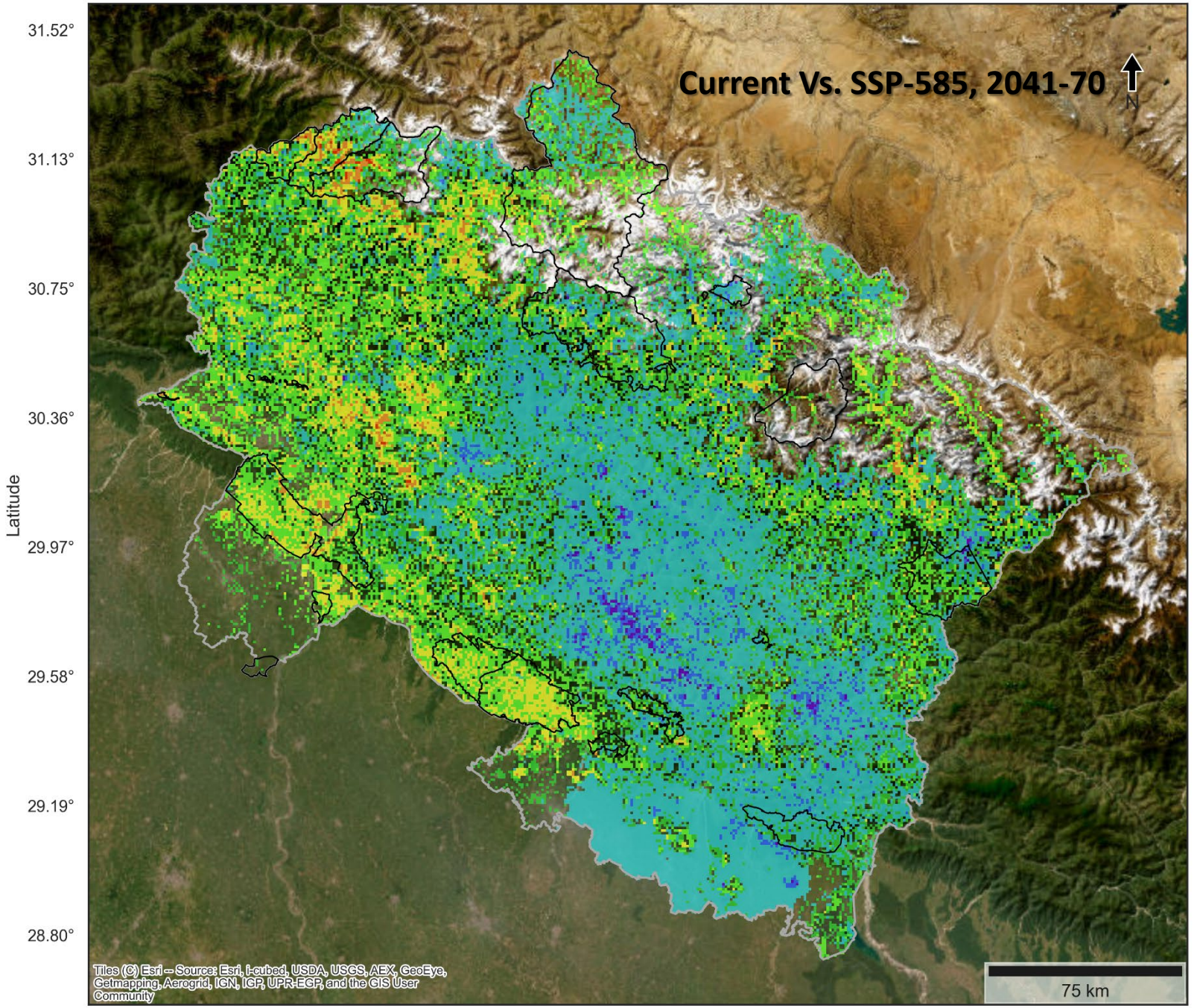




CMIP-6
GFDL Earth System Model Version 4 (GFDL-ESM 4)
Year 2050

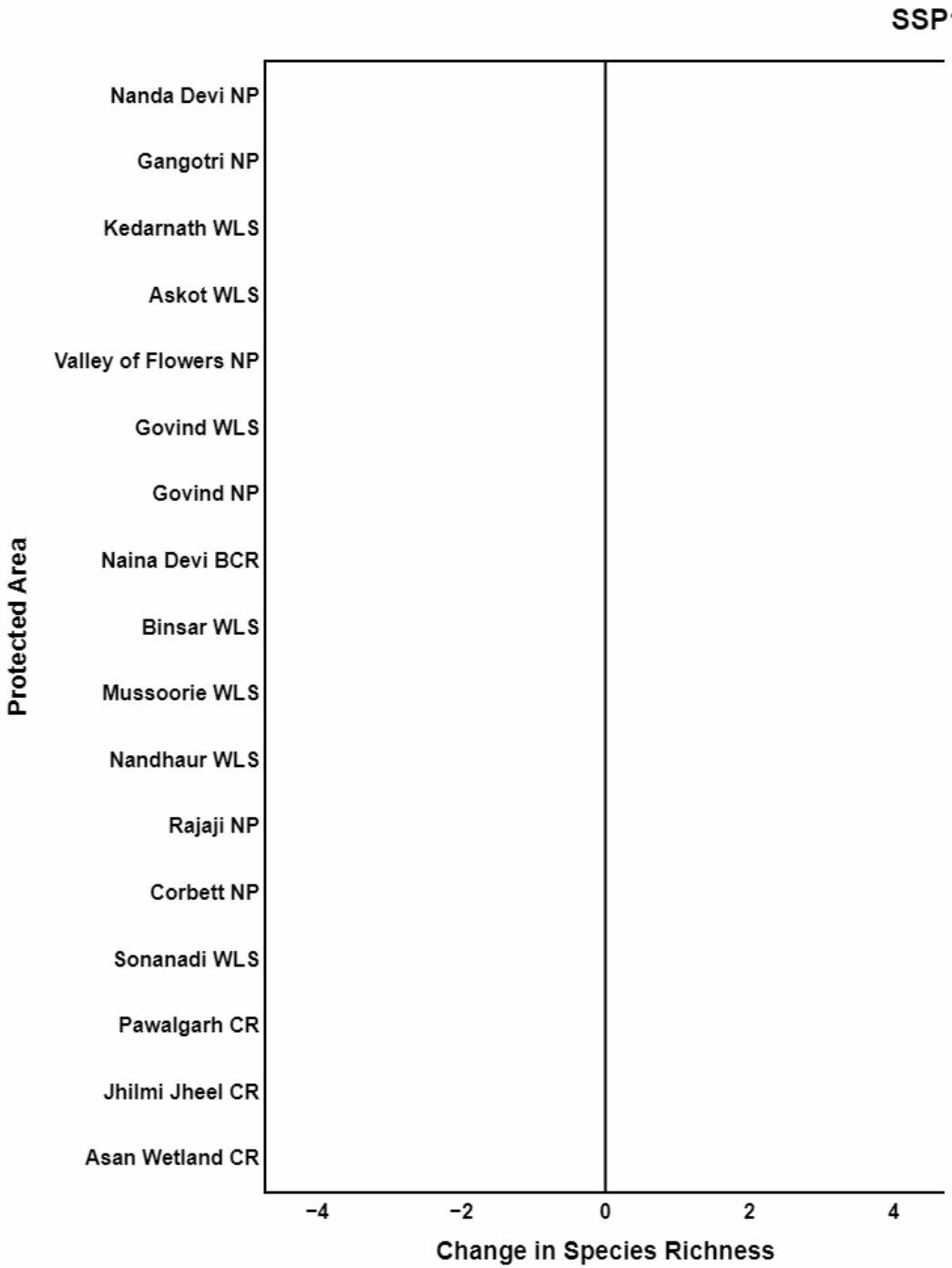
Loss & Gain in Species Richness

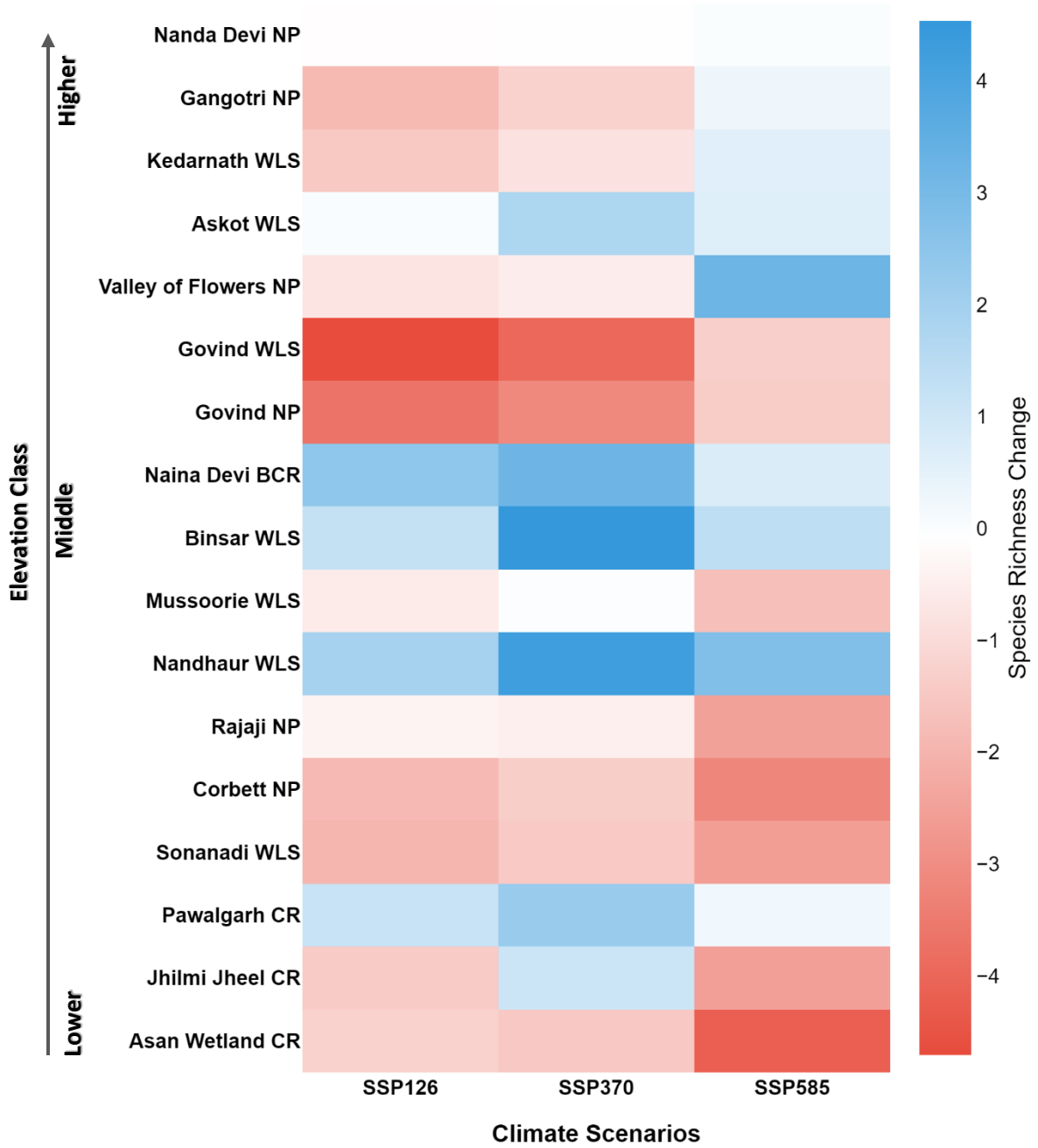


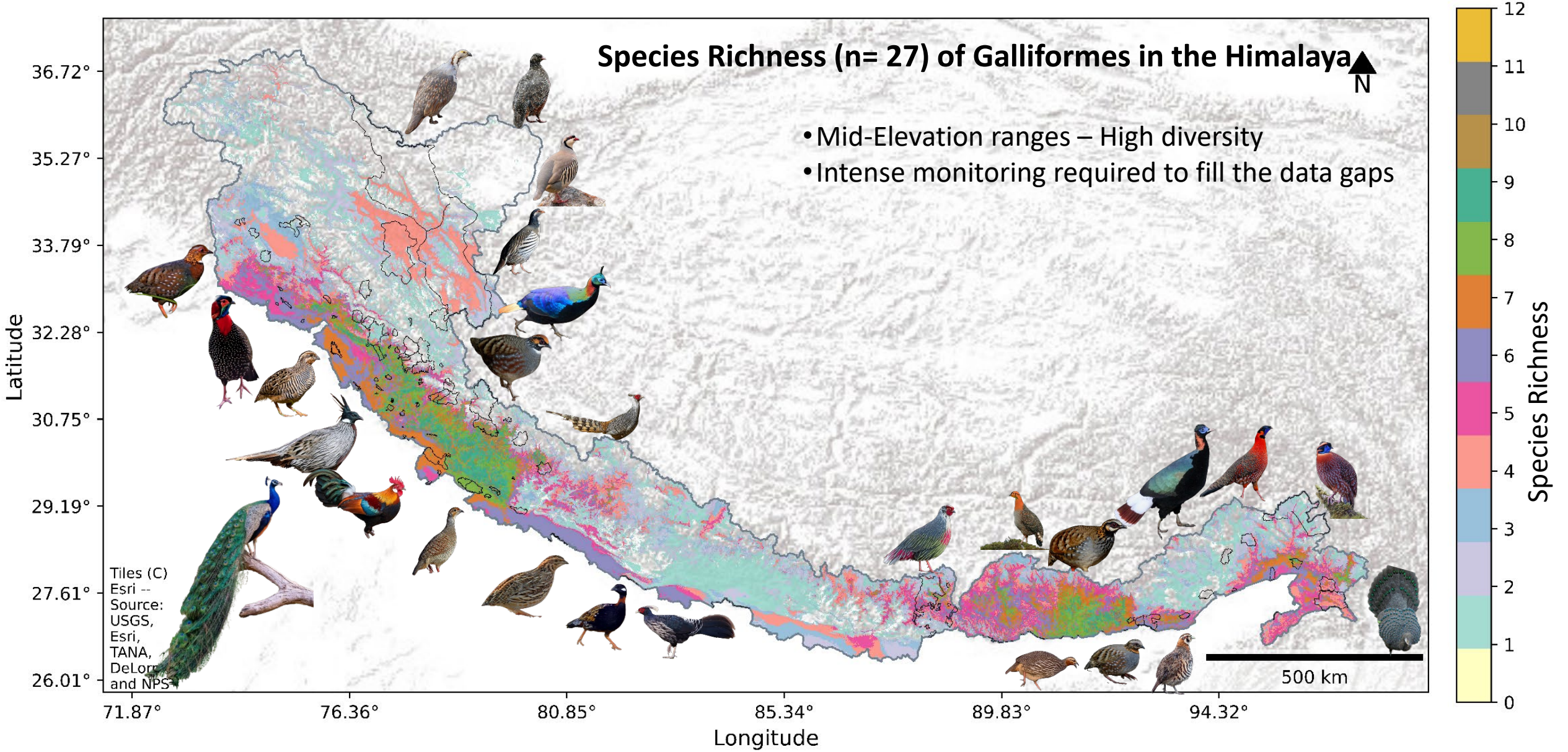


CMIP-6
GFDL Earth System Model Version 4 (GFDL-ESM 4)
Year 2050

Protected Areas Predicted to Buffer the Impact of Climate Change



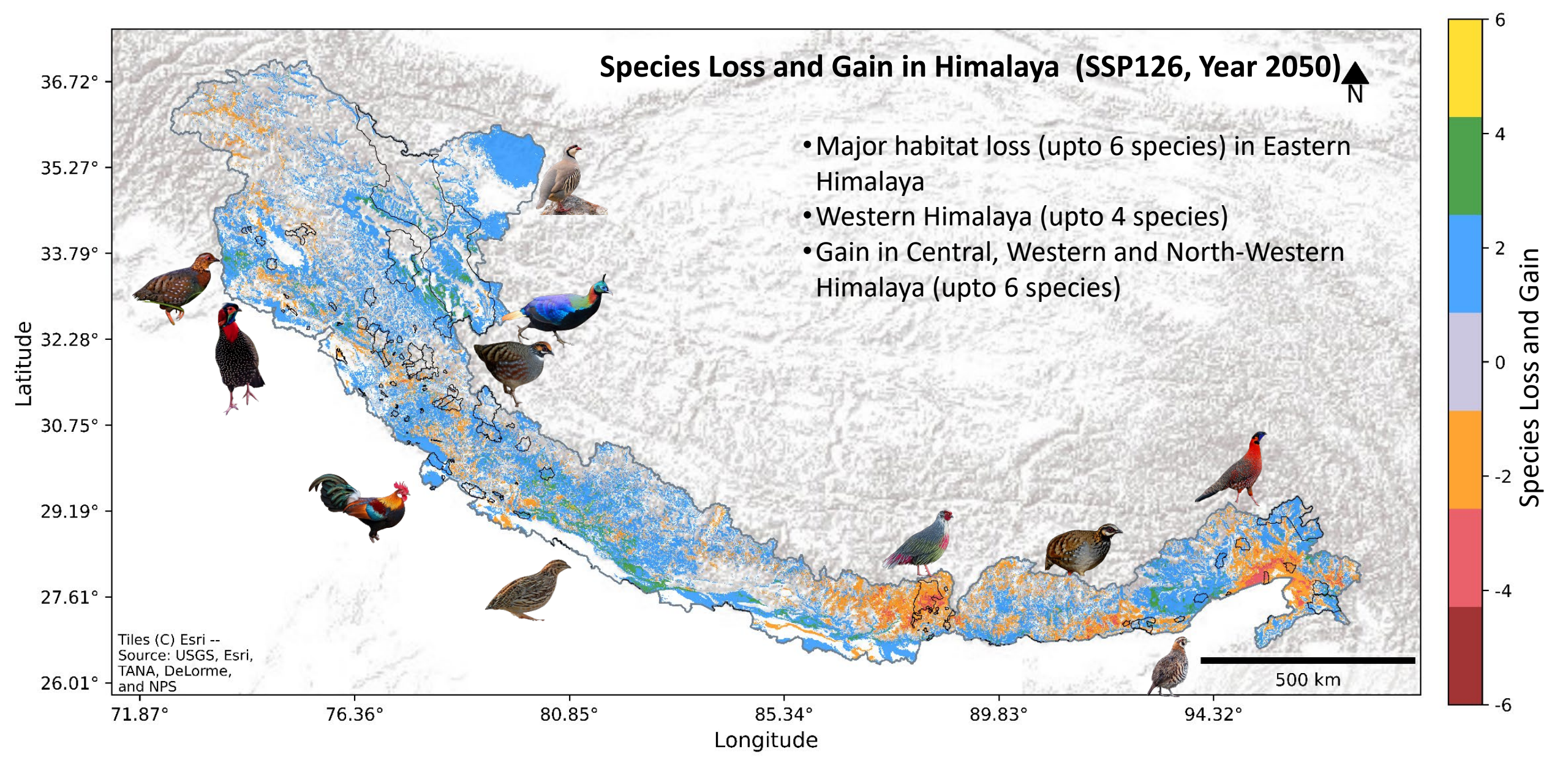




Input variables:
Monthly temperature and Precipitation (Jan – December)

Predictions based on ensemble modeling approach:

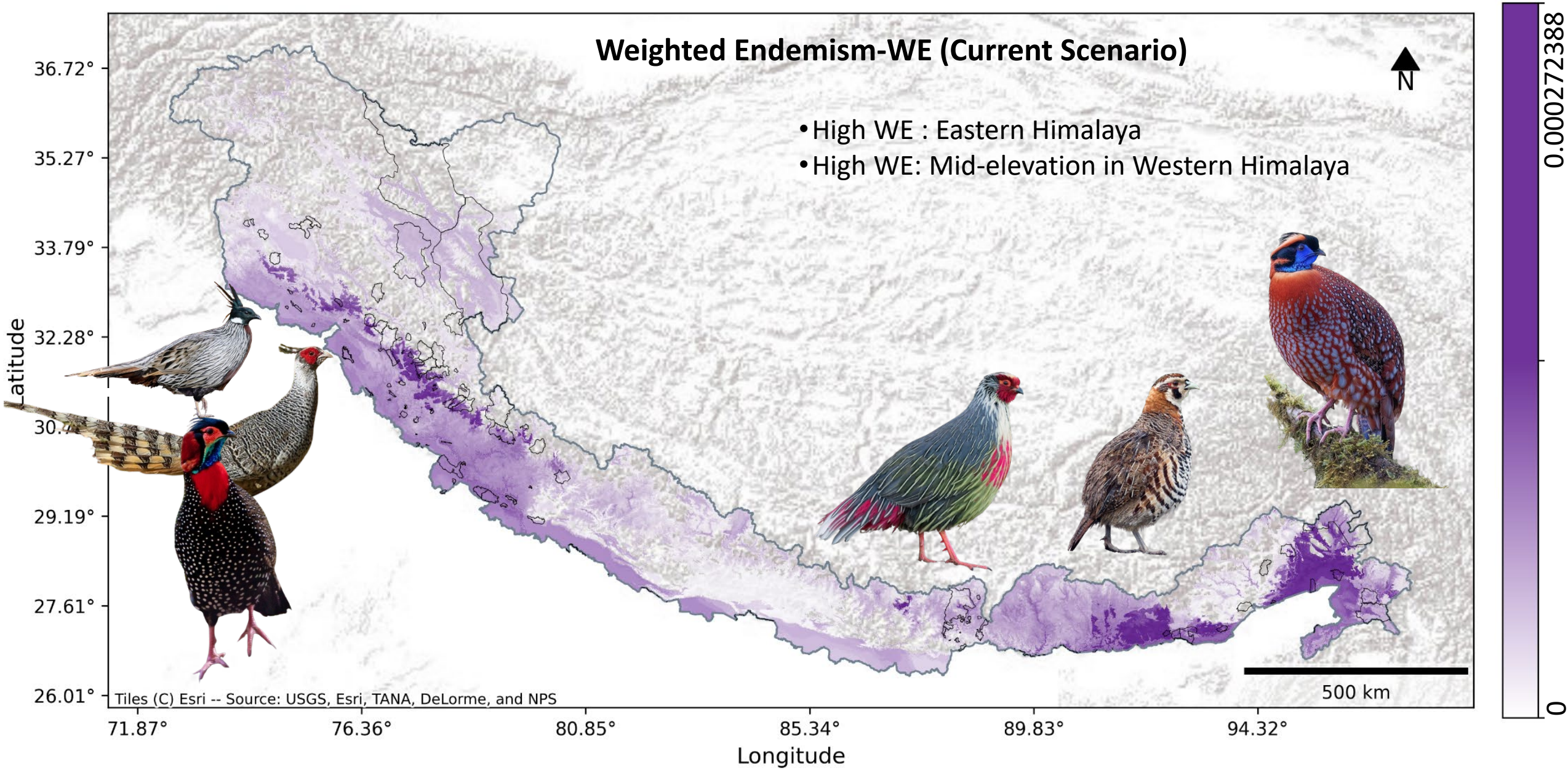
GBM | SVM | RF | MAX-ENT | GLM



Input variables:
Monthly temperature and Precipitation (Jan – December)

Predictions based on ensemble modeling approach:

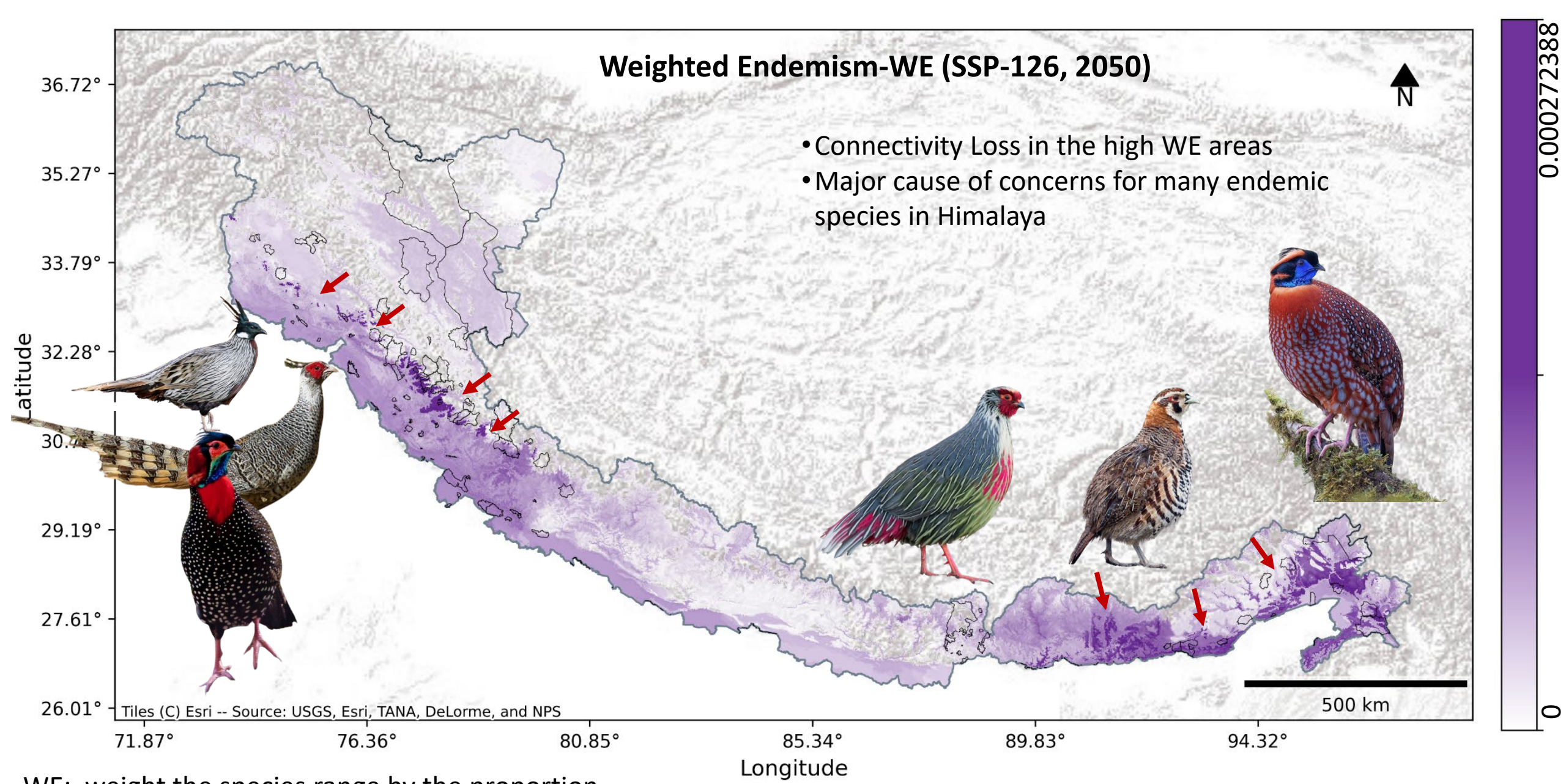
GBM | SVM | RF | MAX-ENT | GLM



WE: weight the species range by the proportion of the range of each species present in a given region

$$\mathrm{WE} = \sum_{\{c \in C\}} \frac{r_c}{R_c}$$

where *r* is the local range (in our case, the cell area) of taxon *c*, *Rc* is the total range size of the taxon *c* and *C* is the subset of taxa that occur in a given region



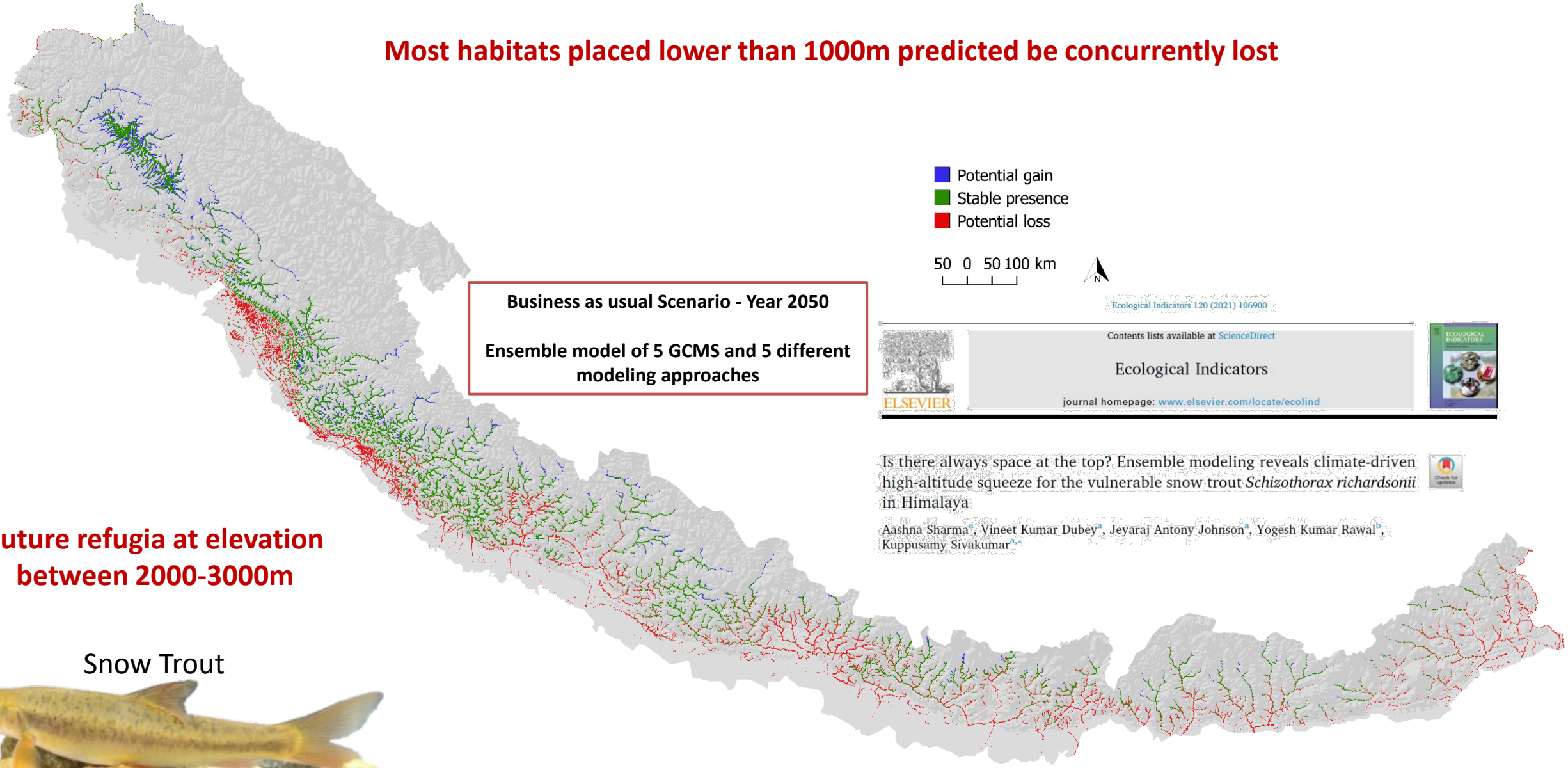
WE: weight the species range by the proportion of the range of each species present in a given region

$$\mathrm{WE} = \sum_{\{c \in C\}} \frac{r_c}{R_c}$$

where *r* is the local range (in our case, the cell area) of taxon *c*, *Rc* is the total range size of the taxon *c* and *C* is the subset of taxa that occur in a given region

Modeling the Future Range Shifts of Migratory Snow trout

Most habitats placed lower than 1000m predicted be concurrently lost



Business as usual Scenario - Year 2050

Ensemble model of 5 GCMS and 5 different modeling approaches

Ecological Indicators 120 (2021) 106900

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Is there always space at the top? Ensemble modeling reveals climate-driven high-altitude squeeze for the vulnerable snow trout *Schizothorax richardsonii* in Himalaya

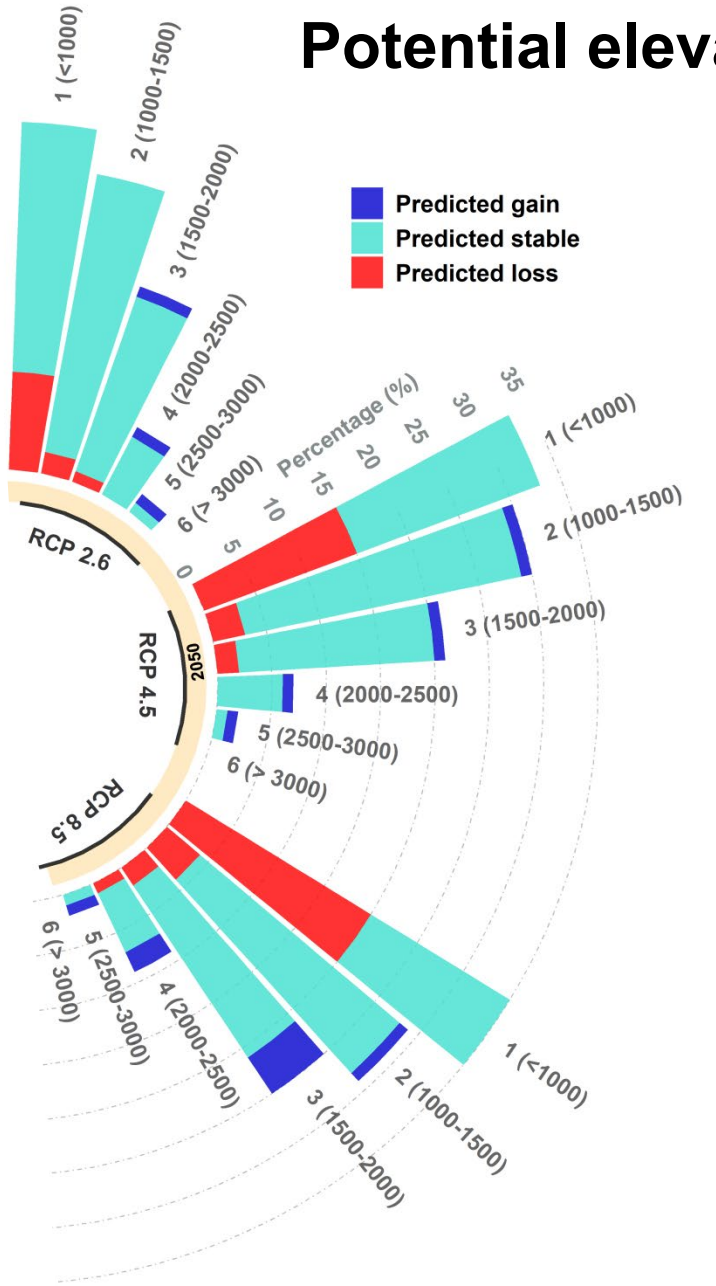
Aashna Sharma[a], Vineet Kumar Dubey[a], Jeyaraj Antony Johnson[a], Yogesh Kumar Rawal[b], Kuppusamy Sivakumar[a,*]

Future refugia at elevation between 2000-3000m

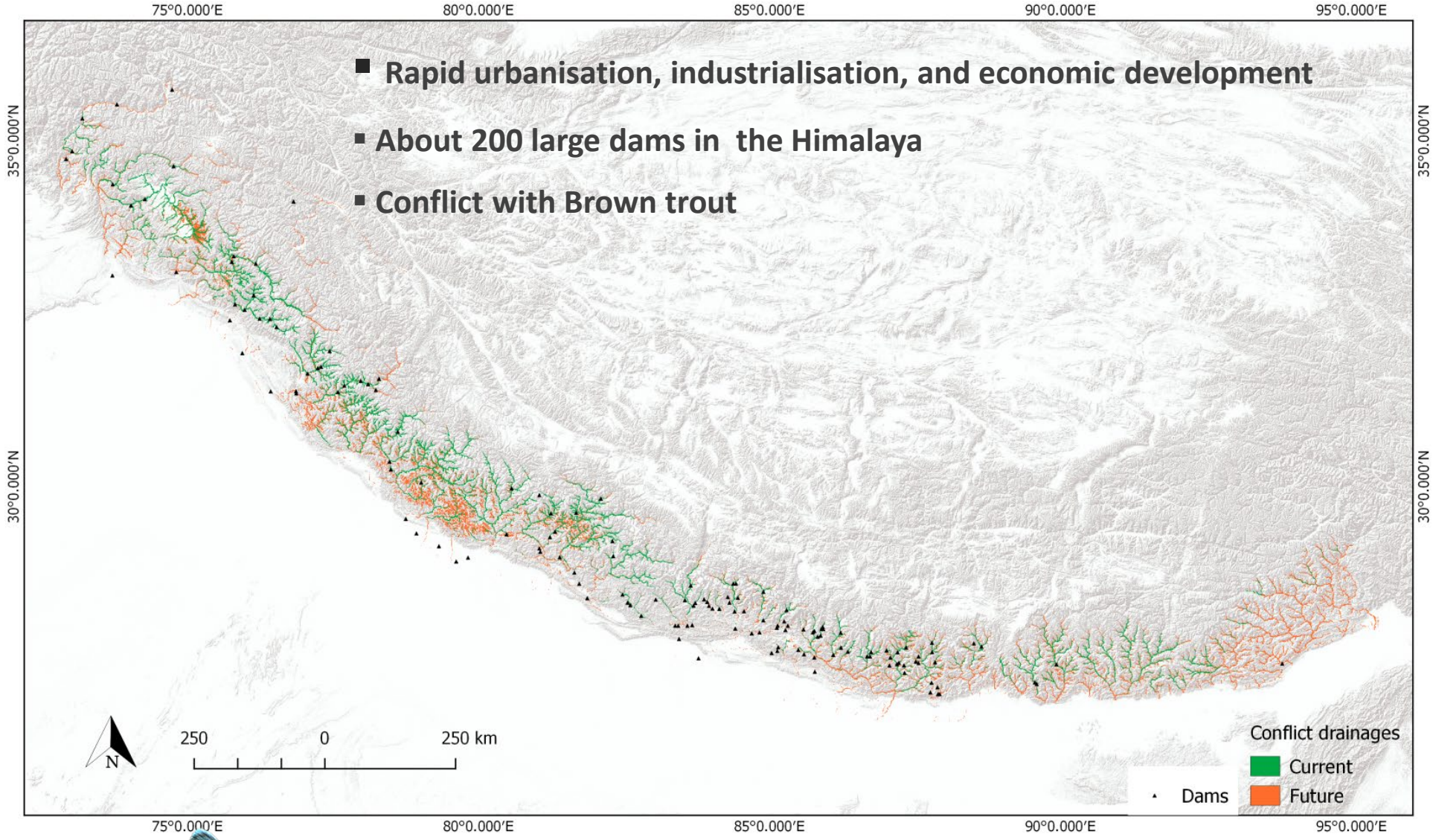
Snow Trout

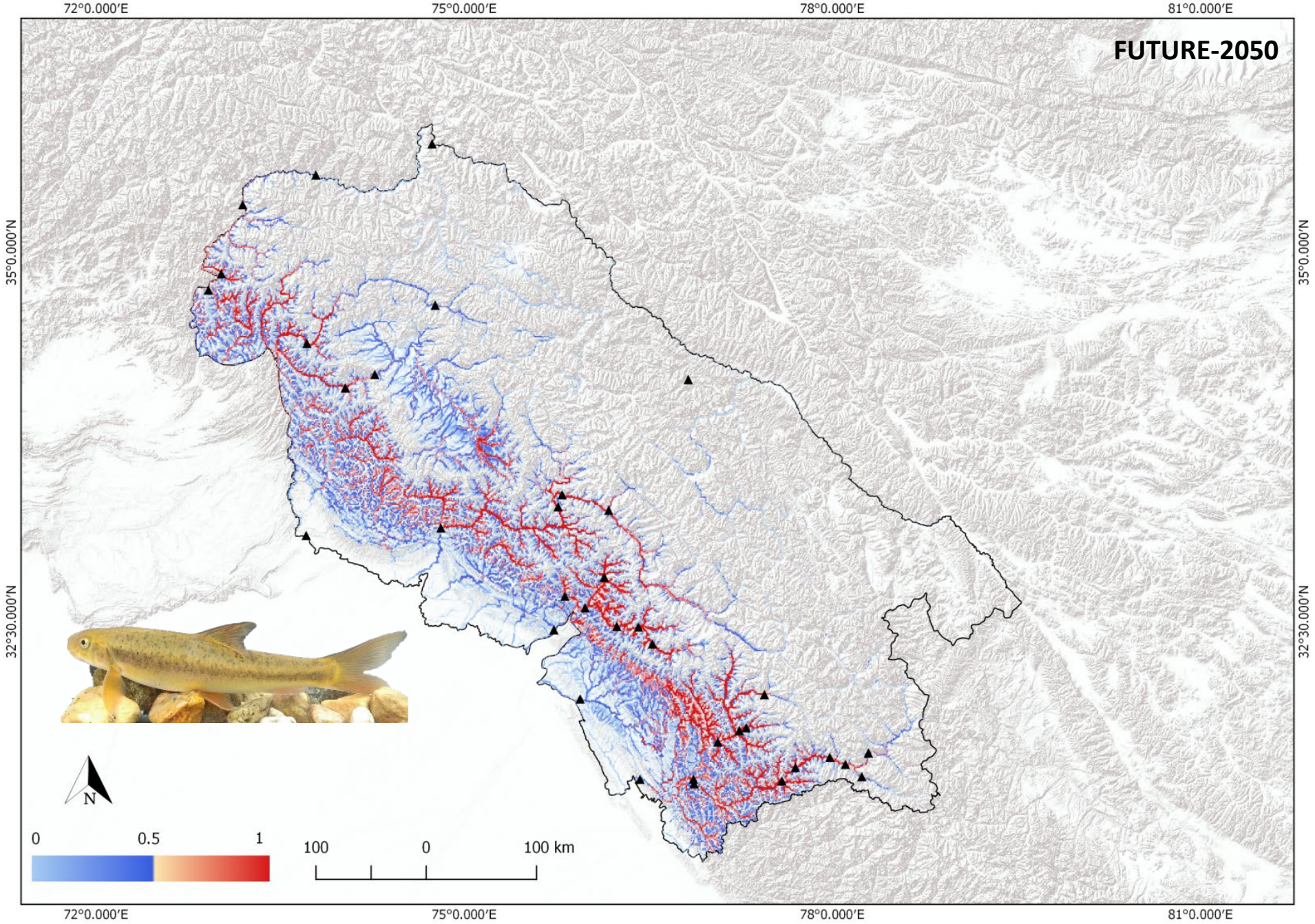
Sharma et al. (2020) Ecological Indicators

Potential elevational shifts



Loss of Connectivity and Conflict with Invasive




FUTURE-2050
72°0.000′E
75°0.000′E
78°0.000′E
81°0.000′E
35°0.000′N
32°30.000′N
N
0
0.5
1
100
0
100 km

Summary

- **High-altitude Protected Areas (PA) may buffer climate change impacts, but many areas outside PAs also have potential as climate *refugia*. Adequate landscape connectivity and expansion of PAs will be required for protecting wildlife in the face of climate change.**
- **Many species will need to move to track changing conditions, potentially leading to a dramatic reorganization of biodiversity.**
- **Conservation efforts should focus on securing movement corridors, habitat islands, and climate *refugia* where climate change impacts are expected to be less severe.**
- **While predicting future species movements remains challenging, habitat models can provide insights into species-specific connectivity needs**
- **Moving forward: refining our models, intensive sampling, integration of downscale data, physiological and evolutionary response**


Thank You