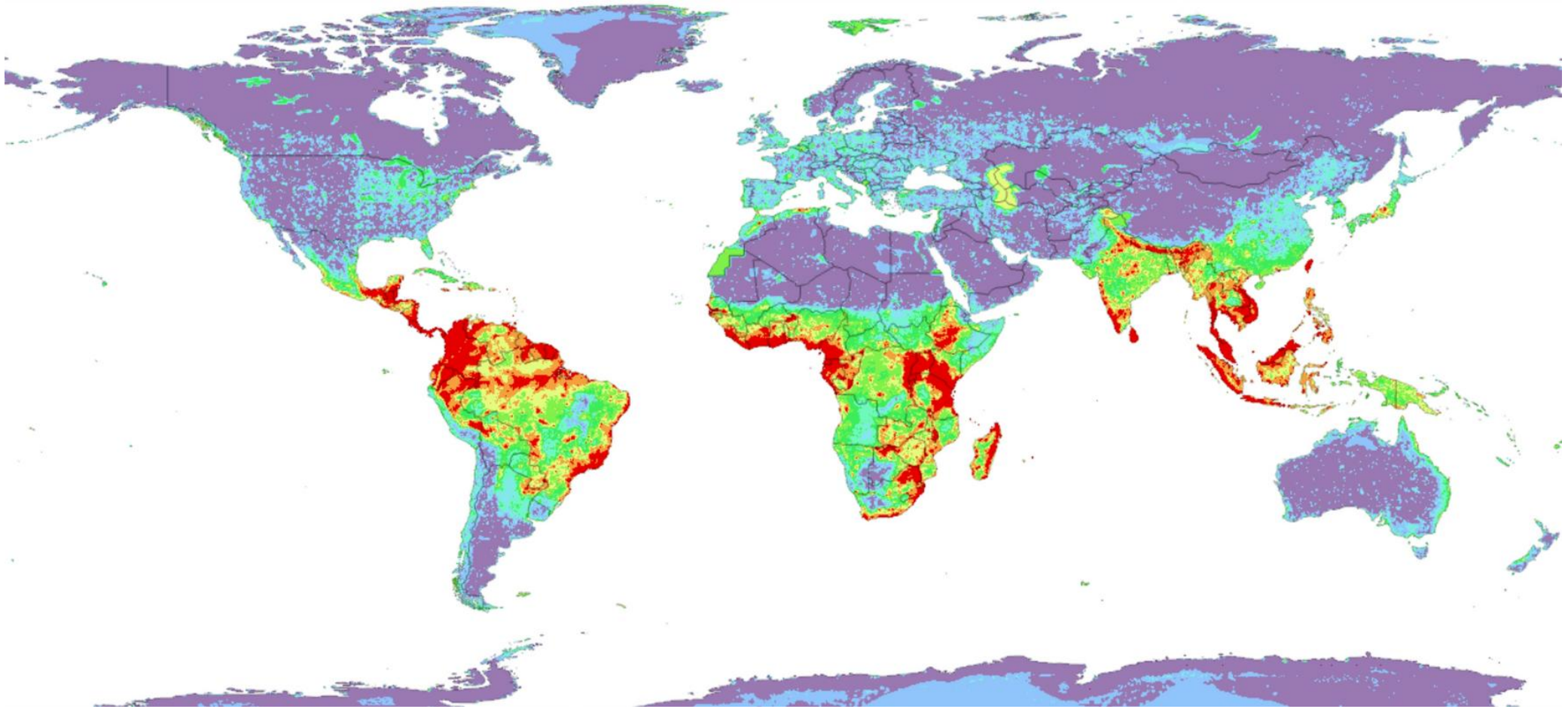


Moriz Steiner (he/him) | stein166@msu.edu | Manly Miles 202A

GEO409-FS2026: Ecosystem Modeling for Wildlife

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Topics covered:

- What is Ecosystem Modeling for Wildlife, and why is it used?

- Why is it vital for the entire planet, including humans? Wildlife conservation is essential but not high on the agenda in capitalist societies

Special

- Case study: Alaska in a changing climate

- Case study: Future Species Distribution Modeling for informing Climate Policy for Wildlife Conservation

- Applications in disease modeling & invasive species/ zoonotic diseases

What is ecosystem modeling?

- A model is a simplified representation of an ecosystem.
- It describes how organisms interact with their environment.
- We use models to explore which characteristics describe ecosystems and how they might change in the future under rapidly changing climate change.

Why model wildlife?

- Field observations cover limited places and times.
- Models help us explore changes beyond those observations.
- They support decisions about habitat protection and restoration.

How do species distribution models work?

- Record where a species occurs.
- Relate those locations to environmental variables (climate, habitat, socio-ecological, and landscape).
- Predict where suitable conditions occur today.
- Explore where those conditions could occur in the future.

Input data provisioning

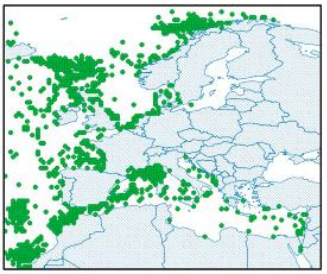
Ecological Niche Models

Trained and projected models

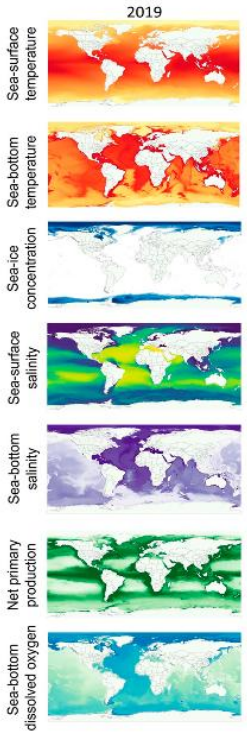
Ensemble model construction

Physeter macrocephalus

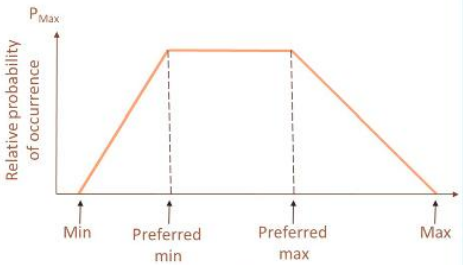




Presence locations



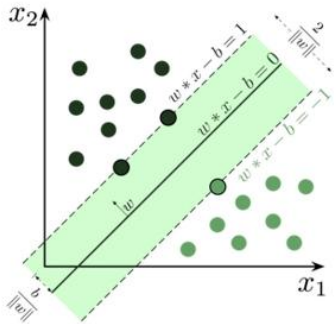
Environmental Variables



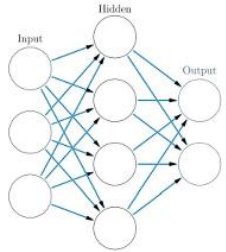
AquaMaps

$$\mathrm{H}(X) = -\sum_{i=1}^{n} p(x_i) \log_b p(x_i)$$

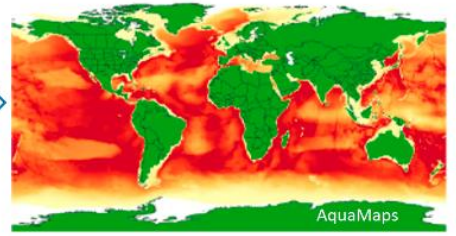
Maximum Entropy

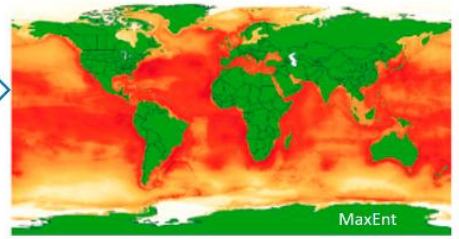


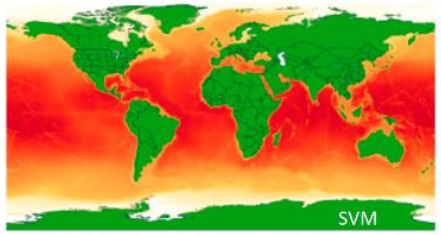
Support Vector Machines

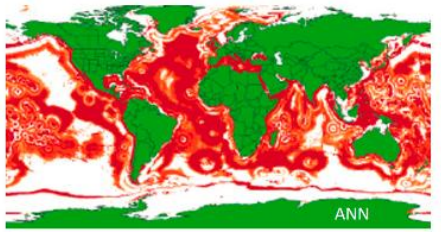


Artificial Neural Networks



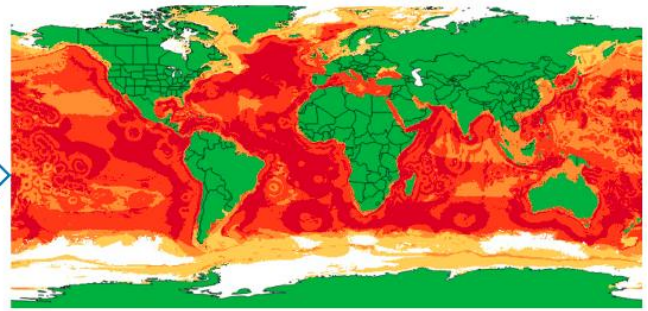


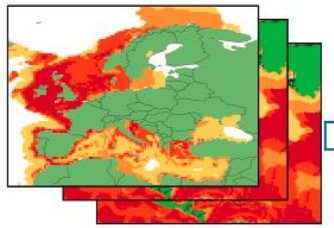




Coro, G., Sana, L., & Bove, P. (2025). An open science automatic workflow for multi-model species distribution estimation. *International Journal of Data Science and Analytics*, 20(2), 1131-1150. https://link.springer.com/article/10.1007/s41060-024-00517-w

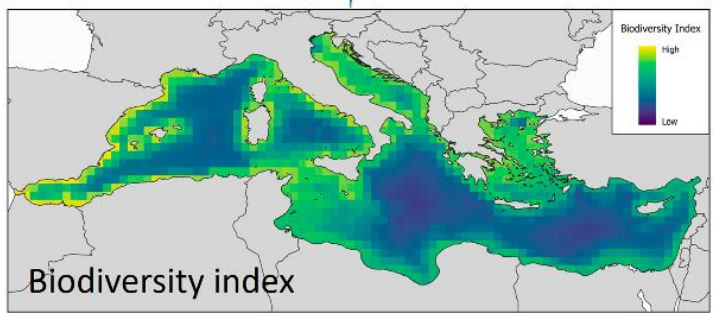
Ensemble model





Other ensemble models

Biodiversity index construction

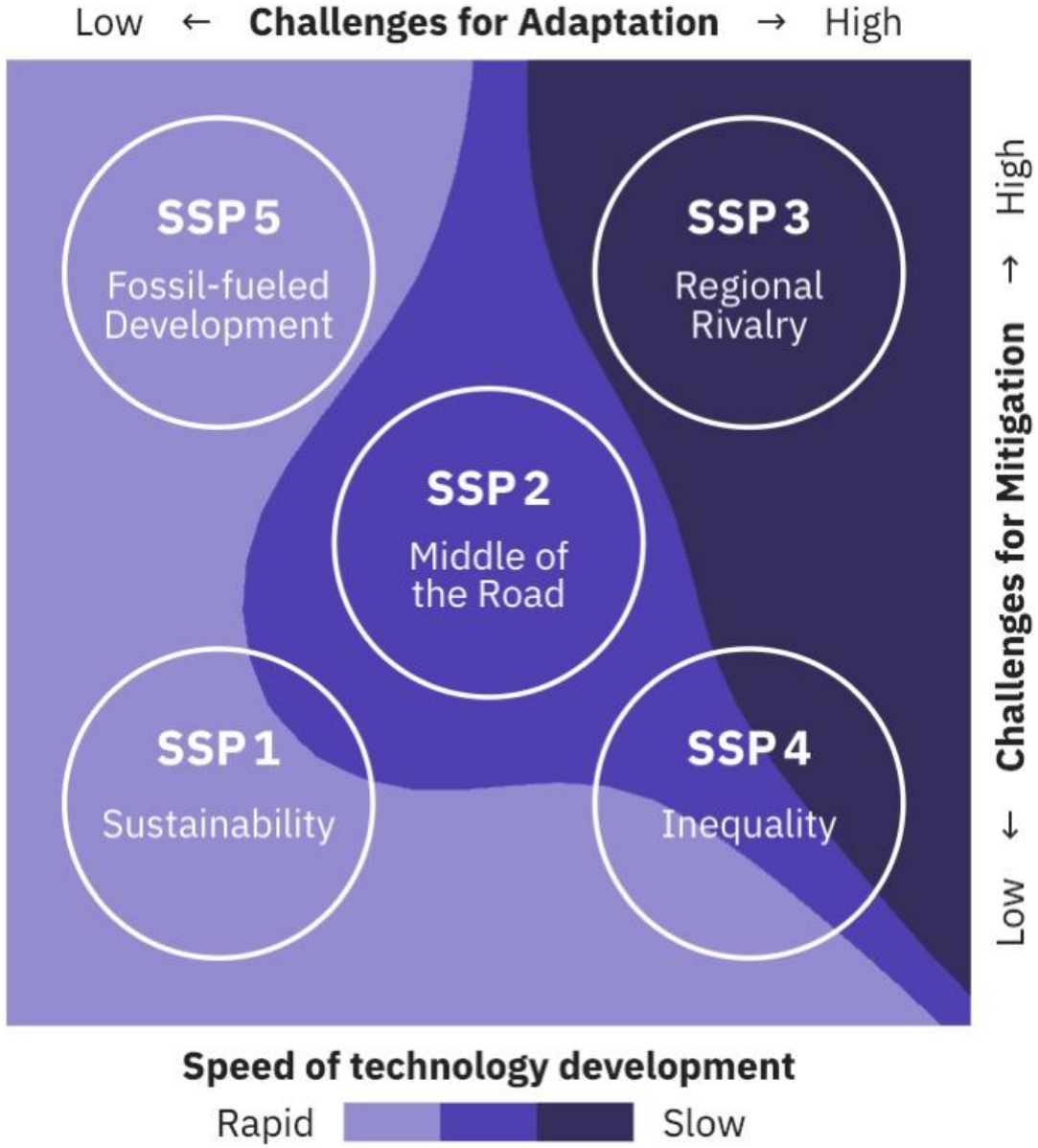


Wildlife modeling in the context of a changing climate

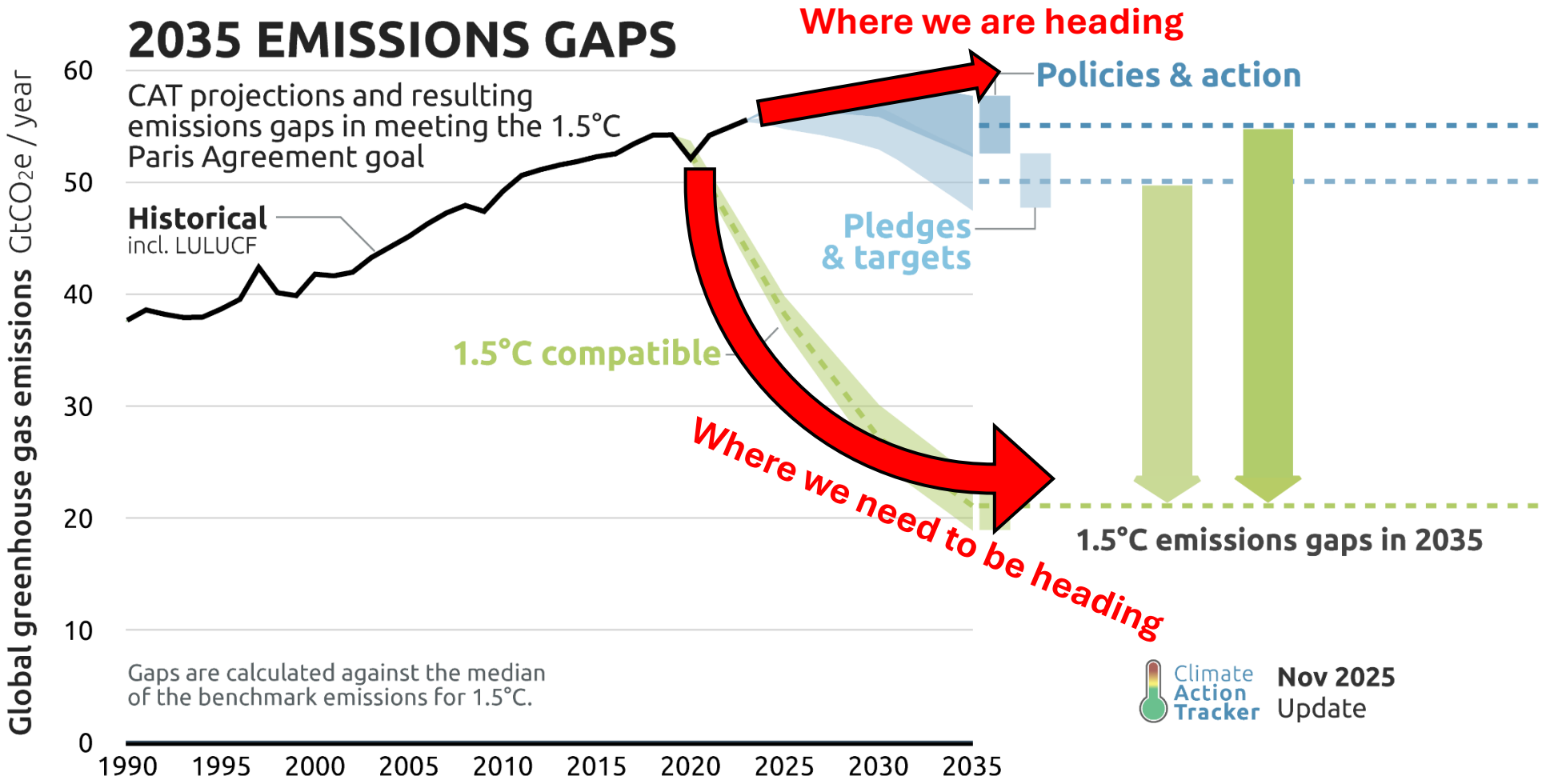
Predict where suitable habitat conditions could occur in the following potential future climate scenarios:

Comparing how difficult it would be to reduce climate change (mitigation) and cope with its effects (adaptation).

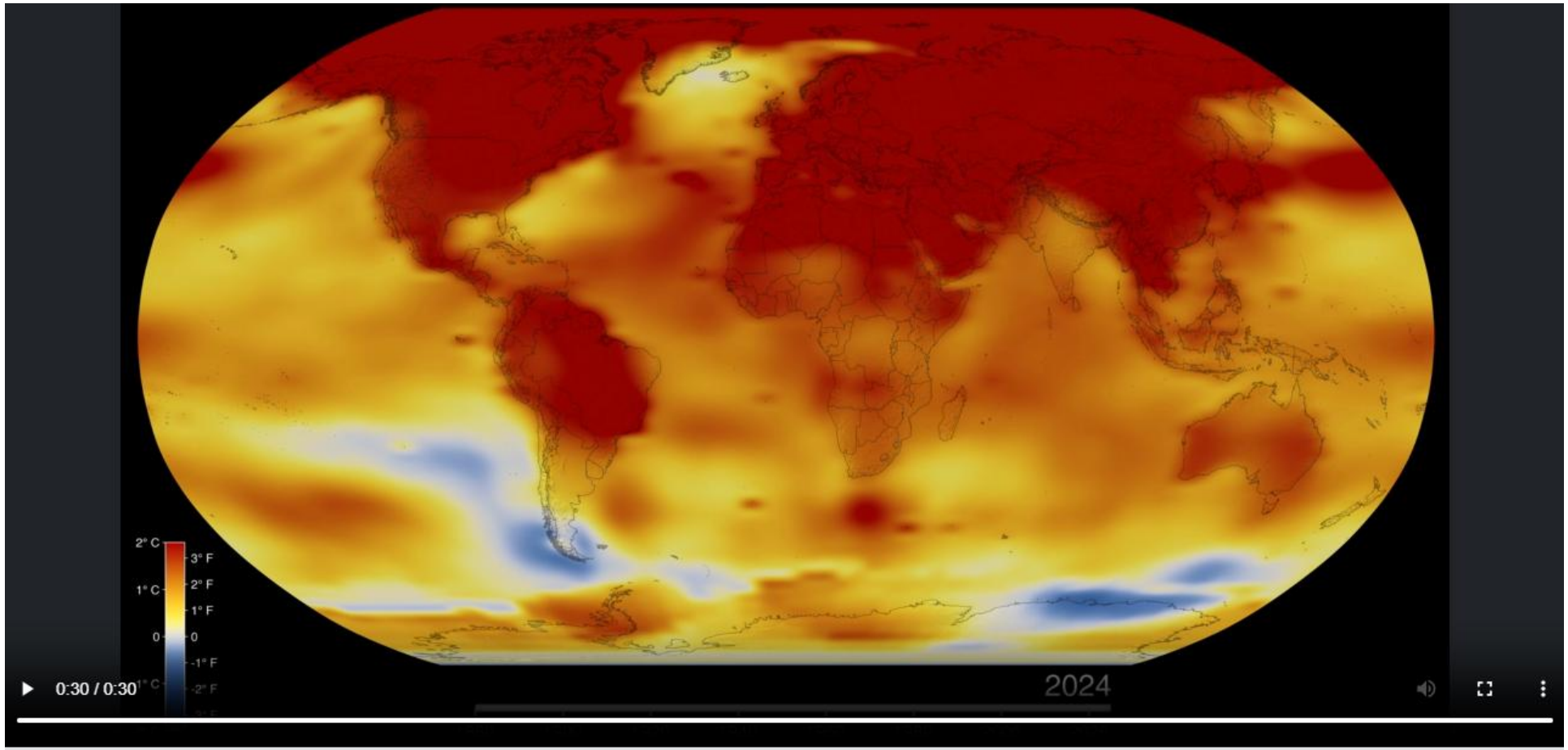
Sustainability (SSP1) makes both easier, regional rivalry (SSP3) makes both harder, inequality (SSP4) makes coping harder, fossil-fuel dependence (SSP5) makes reducing climate change harder, and SSP2 falls in the middle.



https://climatescenarios.org/primer/socioeconomic-development/



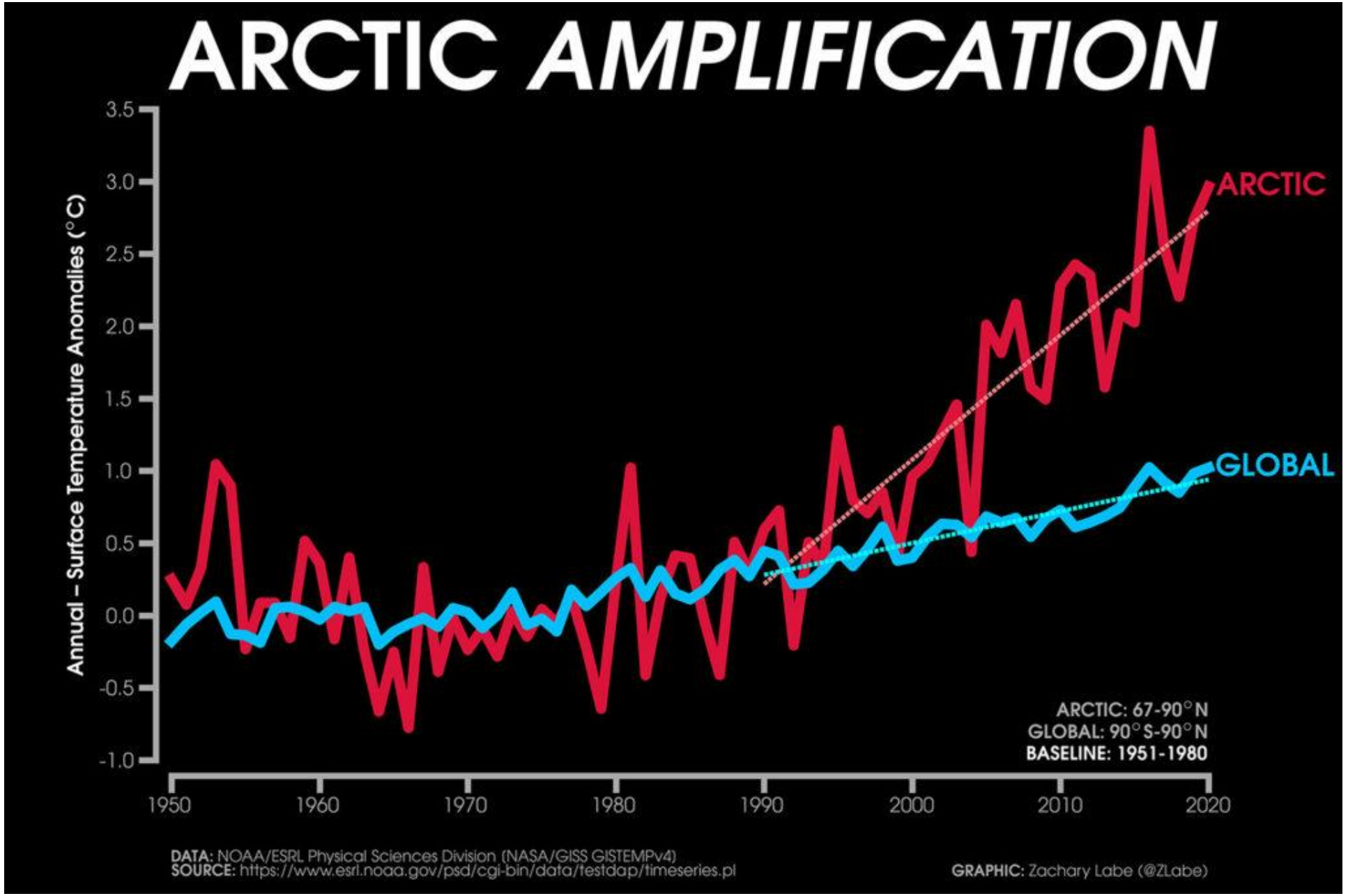
How is global climate change distributed across the planet?

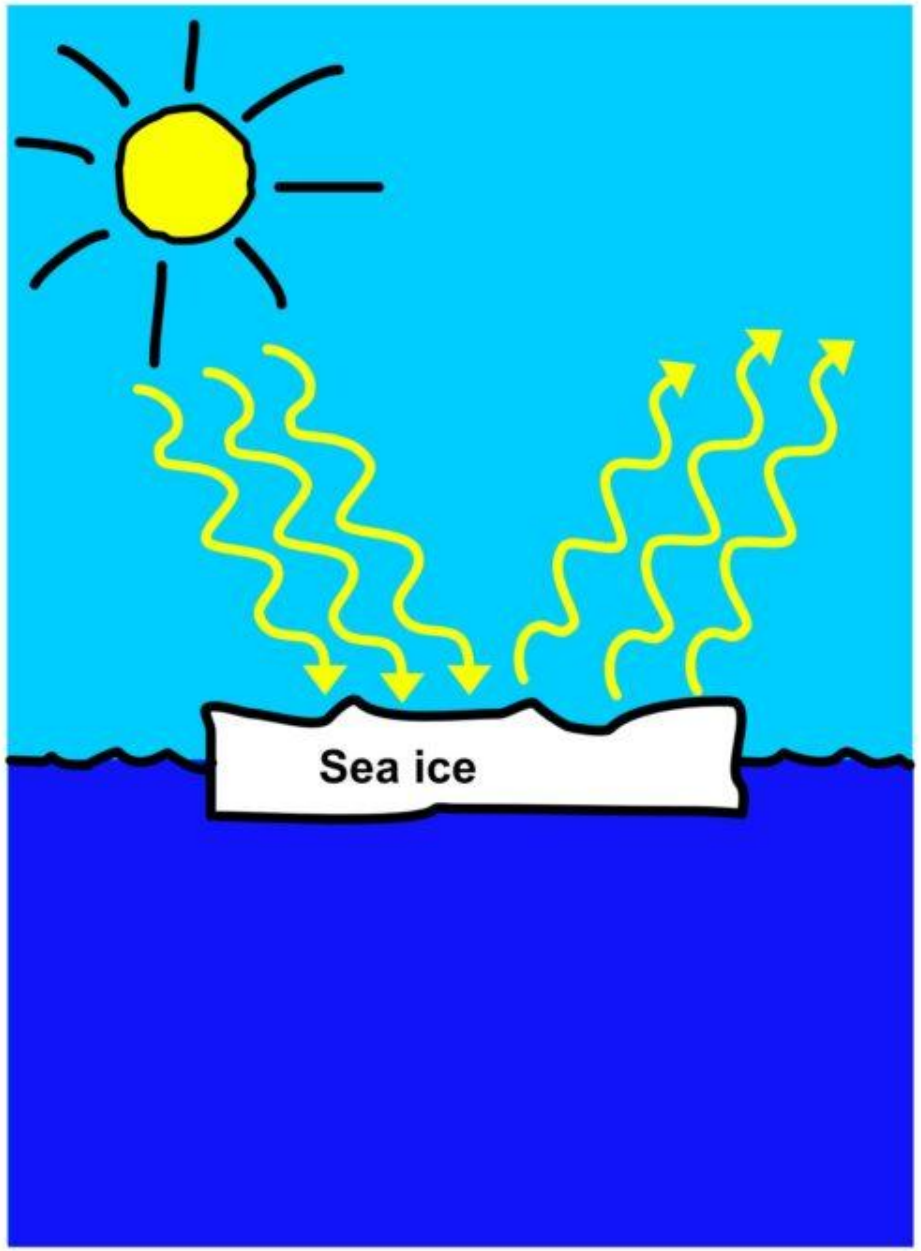


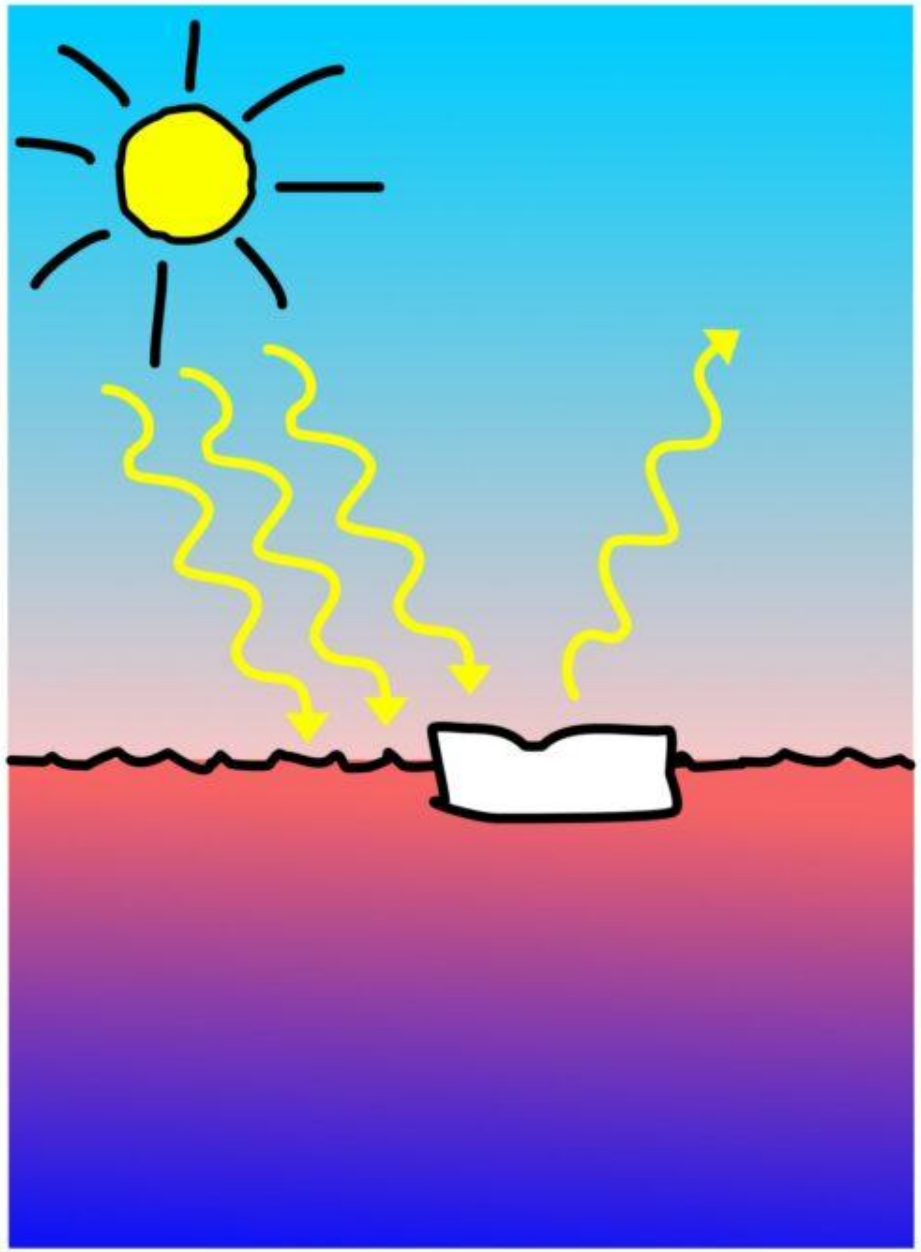
This color-coded map in Robinson projection displays a progression of changing global surface temperature anomalies. Normal temperatures are shown in white. Higher than normal temperatures are shown in red and lower than normal temperatures are shown in blue. Normal temperatures are calculated over the 30 year baseline period 1951-1980. The maps are averages over a running 24 month window. The final frame represents global temperature anomalies in 2024.

Download

https://svs.gsfc.nasa.gov/5450/


ARCTIC AMPLIFICATION
Annual – Surface Temperature Anomalies (°C)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1950
1960
1970
1980
1990
2000
2010
2020
ARCTIC
GLOBAL
ARCTIC: 67-90° N
GLOBAL: 90° S-90° N
BASELINE: 1951-1980
DATA: NOAA/ESRL Physical Sciences Division (NASA/GISS GISTEMPv4)
SOURCE: https://www.esrl.noaa.gov/psd/cgi-bin/data/testdap/timeseries.pl
GRAPHIC: Zachary Labe (@ZLabe)


Sea ice



Albedo;
Remember the lecture by C. Lei?

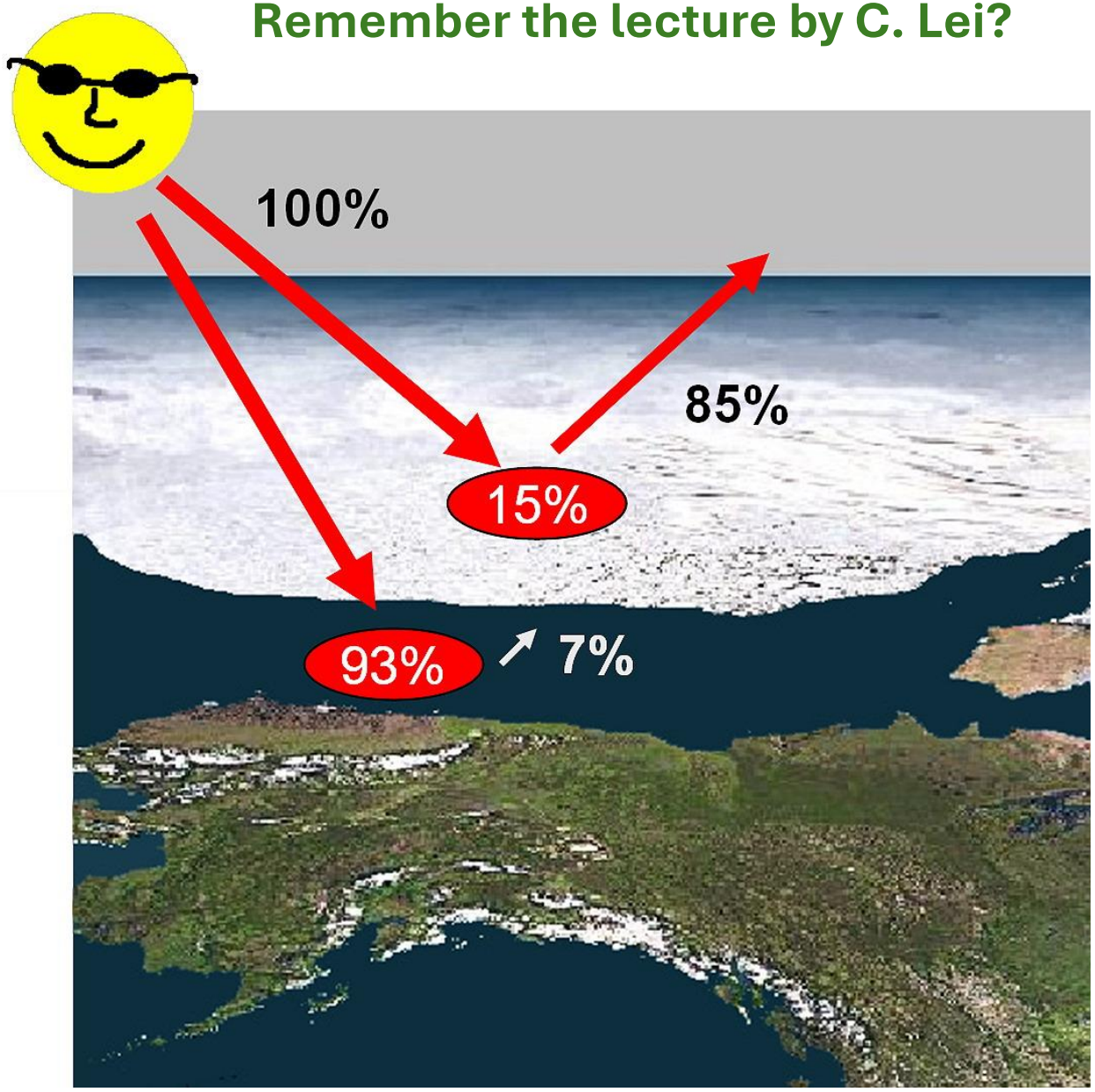


Figure 1. Sea ice reflects as much as 85% of solar radiation hitting the surface, hence absorbing only 15%. Ocean water, by contrast, reflects only about 7% of solar radiation, absorbing 93%. (Courtesy Don Perovich, CRREL)
https://www.pmel.noaa.gov/arctic-zone/essay_serreze.html

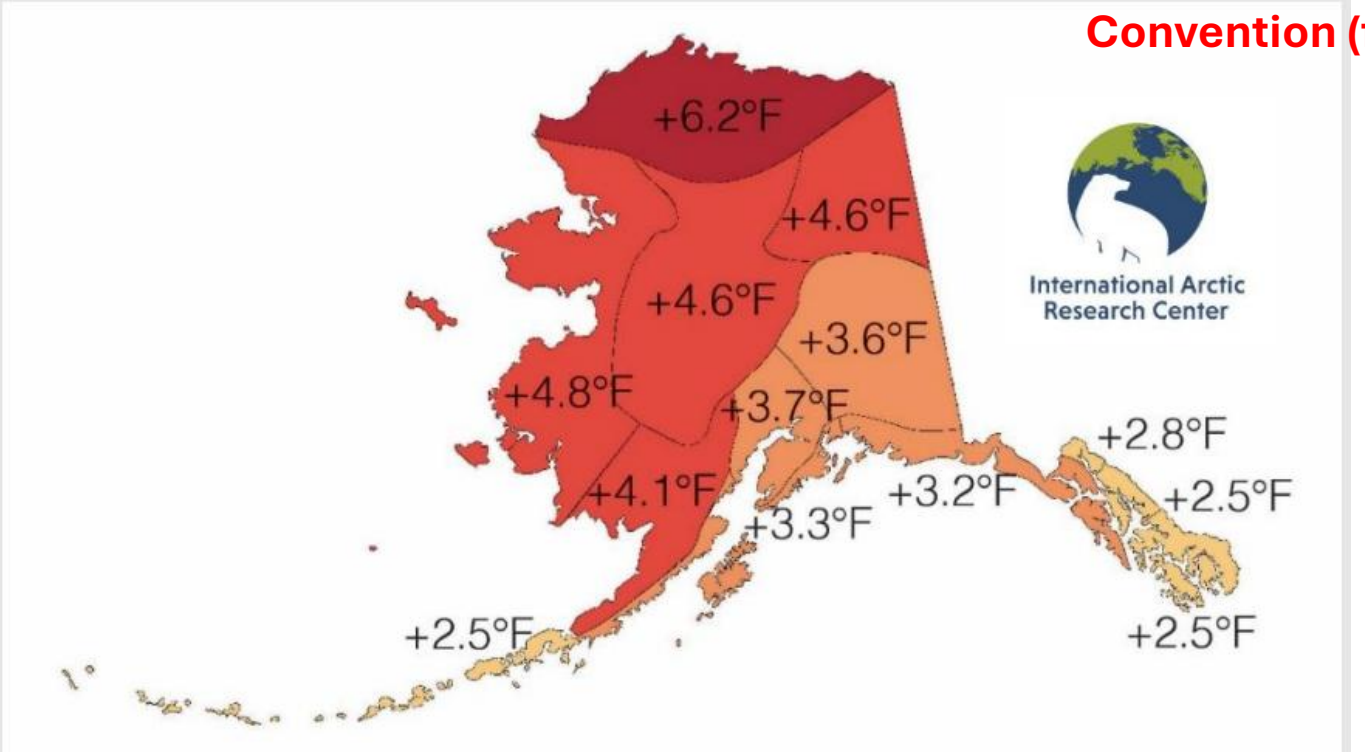
Case study: Alaska

Figure 1. Alaska's Annual Temperature Trend

Annual temperature trends in Alaska since 1970 show significant warming, with more extreme increases in the northern part of the state. Arctic warming is associated with a range of changes including loss of summer sea ice, permafrost degradation, and coastal erosion.

+2.7 deg F = Paris Agreement Convention (for 2100)

Annual temperature trend, 1970-2019. *Credit: Thoman, R. (2020). Summer's getting hotter.* Alaska's Changing Wildfire Environment, *Grabinski, Z. & H. R. McFarland, www.frames.gov/afsc/acwe. Data source: NOAA/NCEI & NWS.*

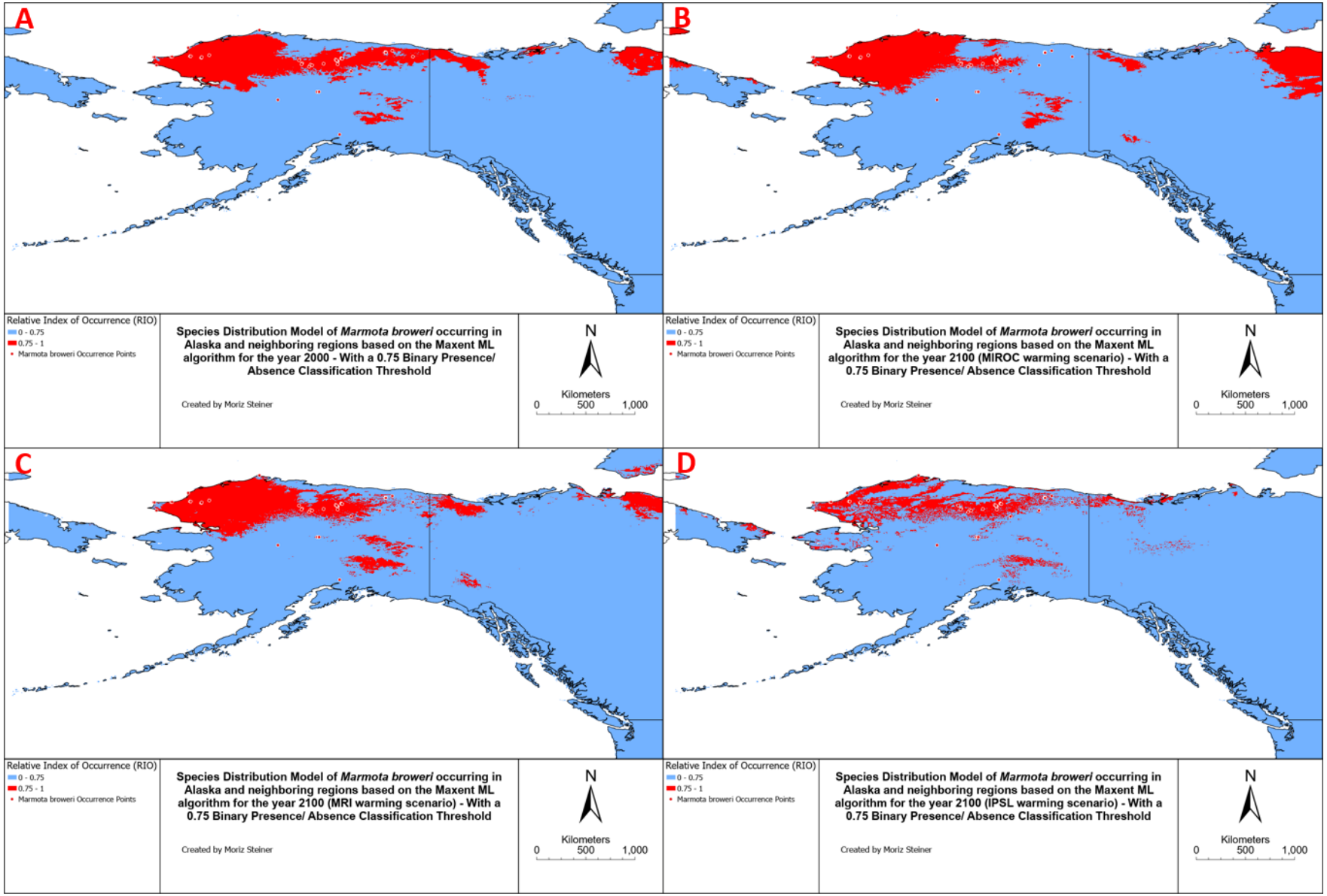



Alaska
Shishmaref
Arctic Lagoon




ARCTIC OCEAN
170° W
70° N
60° N
Bering Strait
Shishmaref
Tin Creek
Arctic Circle
Nome
ALASKA
(UNITED STATES)
CANADA
Gulf of Alaska
PACIFIC OCEAN
0 200 400 miles
0 200 400 kilometers
Conformal Conic Projection
Area of Main Map
UNITED STATES

Case study: Future Species Distribution Modeling for informing Policy



Steiner, M., Morton, JM., Huettmann, F. (in print). Holistic species conservation assessment in a changing climate: A shifting paradigm from conserving biodiversity to minimizing species extinction in squirrels. In *Climate Change Indicators and the Three Poles: Biological Indicators, Human Dimension: Vol III* (ISBN: 9781394264636). Chapter 61.

“Invasive” species

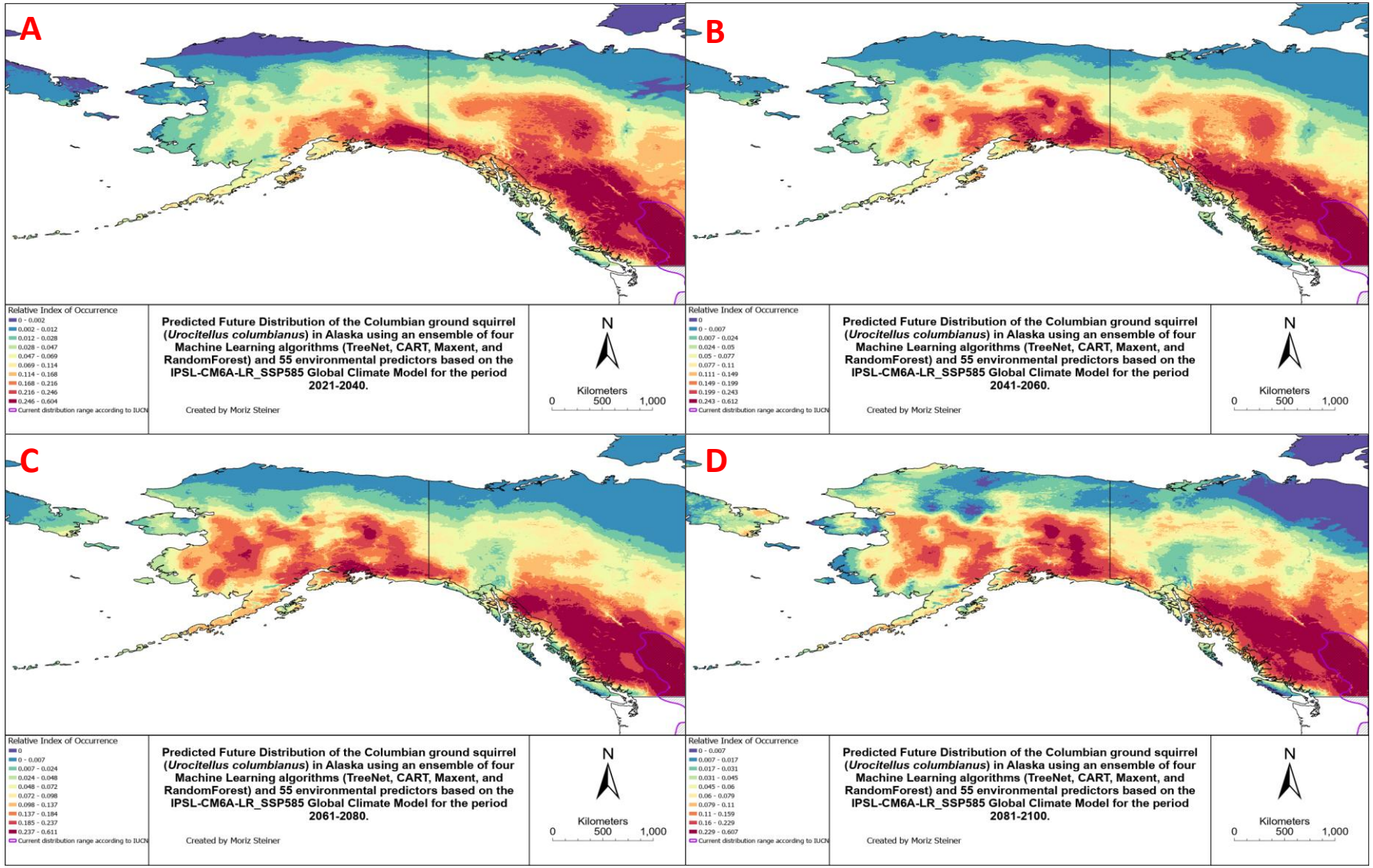
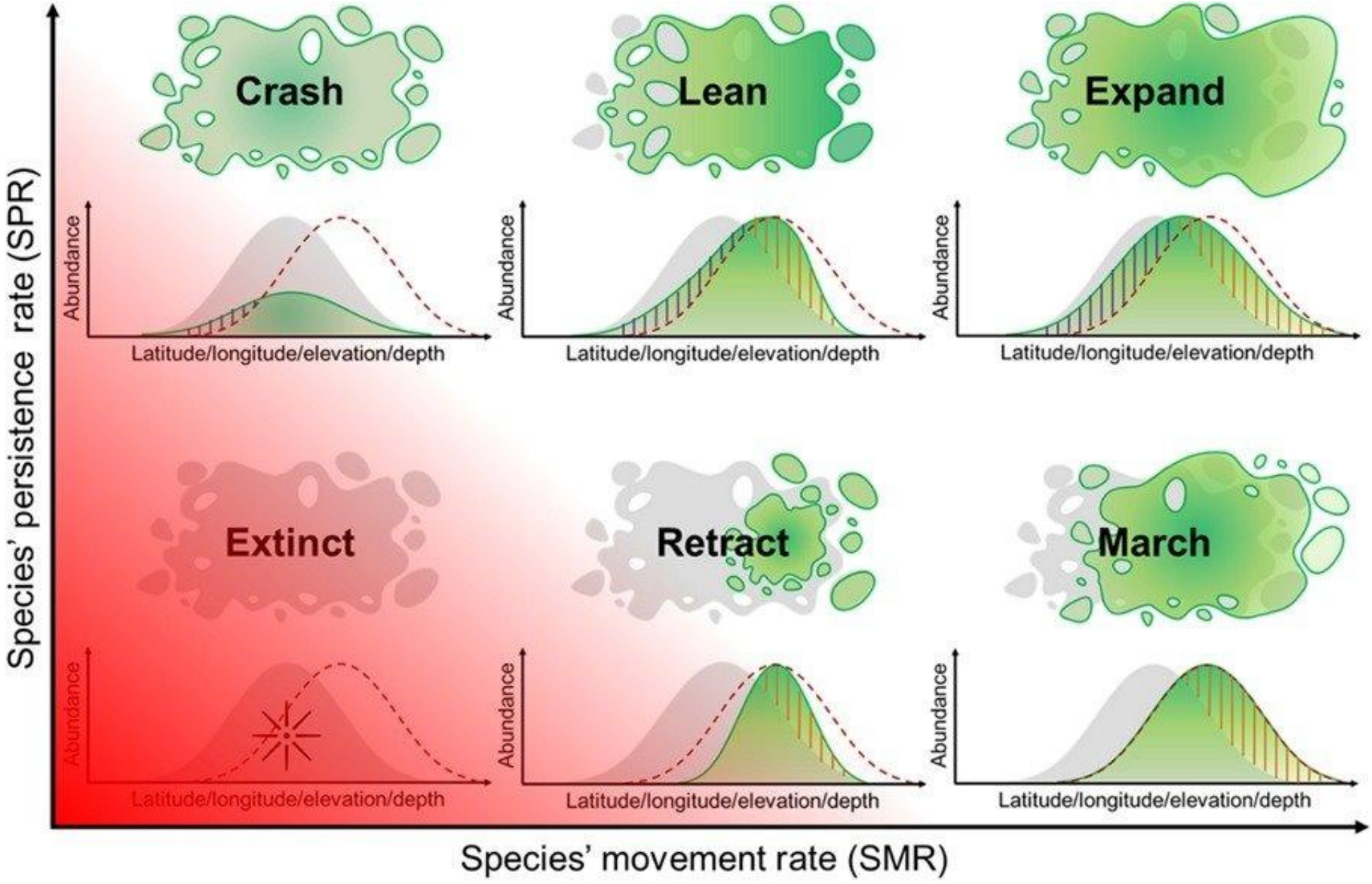


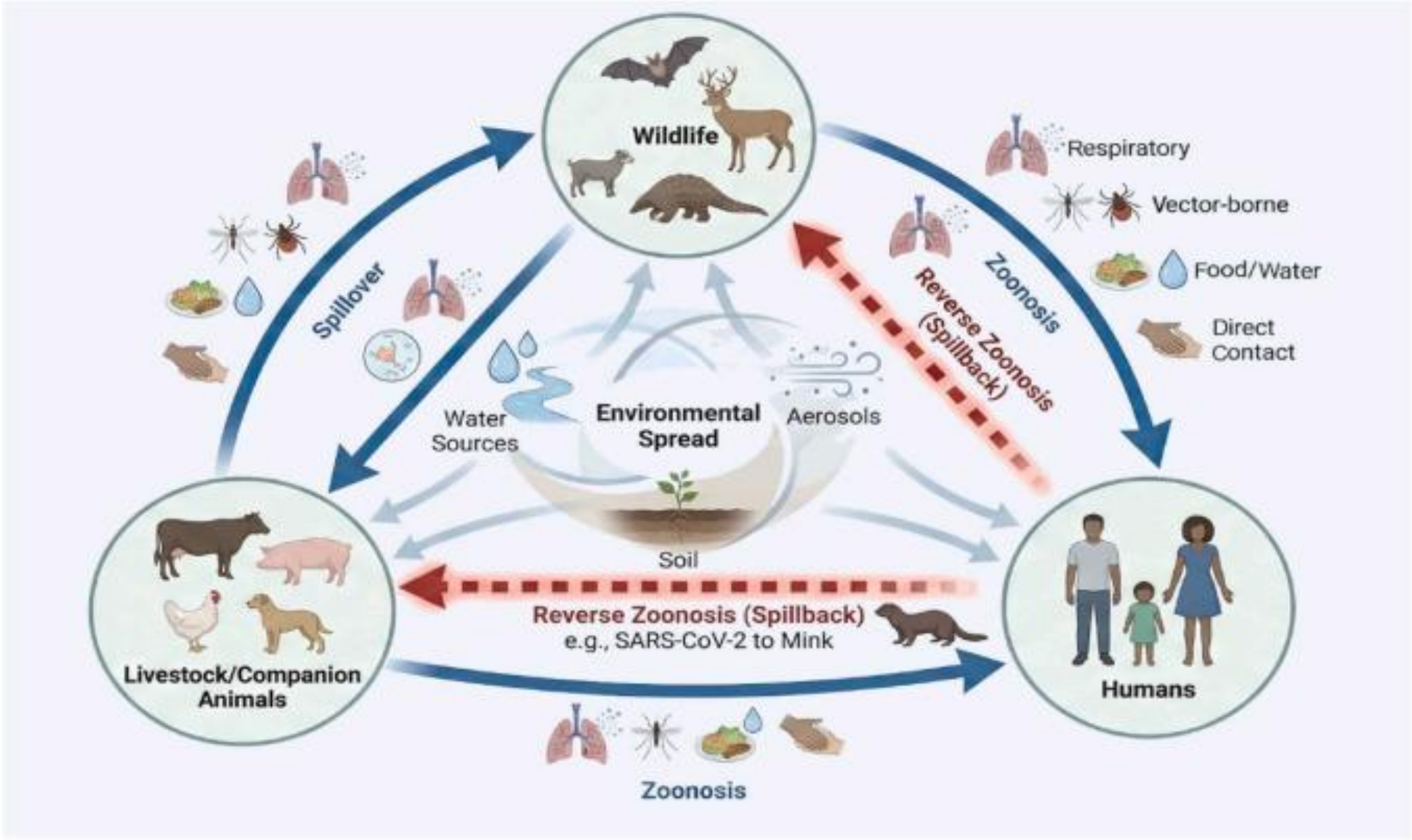
Figure 61.4: Predicted Future Distribution of the Columbian ground squirrel (*Urocitellus columbianus*) in Alaska using an ensemble of four Machine Learning algorithms (TreeNet, CART, Maxent, and RandomForest) and 55 environmental predictors based on the IPSL-CM6A-LR_SSP585 Global Climate Model for the period: A) 2021-2040, B) 2041-2060, C) 2061-2080, D) 2081-2100.

Steiner, M., Morton, JM., Huettmann, F. (in print). Holistic species conservation assessment in a changing climate: A shifting paradigm from conserving biodiversity to minimizing species extinction in squirrels. In *Climate Change Indicators and the Three Poles: Biological Indicators, Human Dimension: Vol III* (ISBN: 9781394264636). Chapter 61.

Species movement

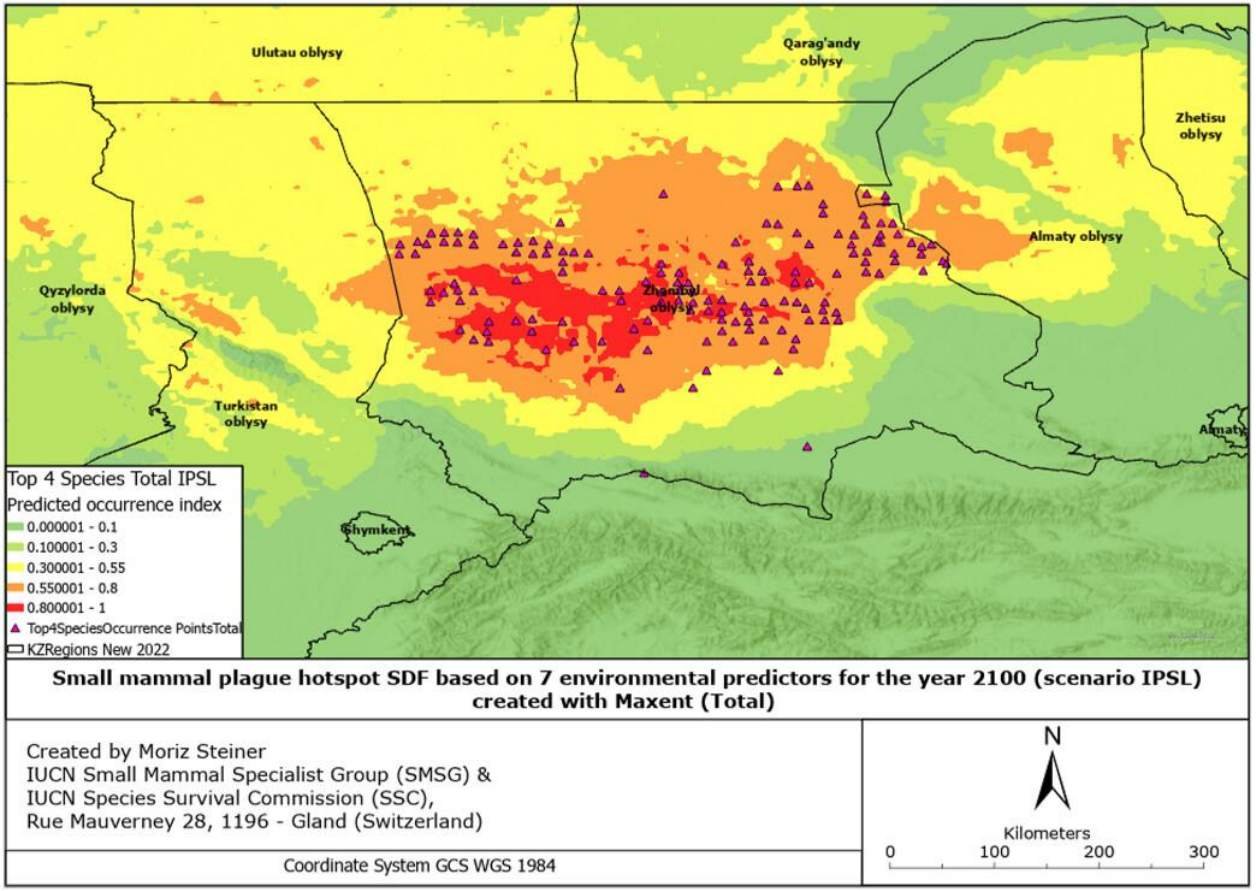


Zoonotic Diseases

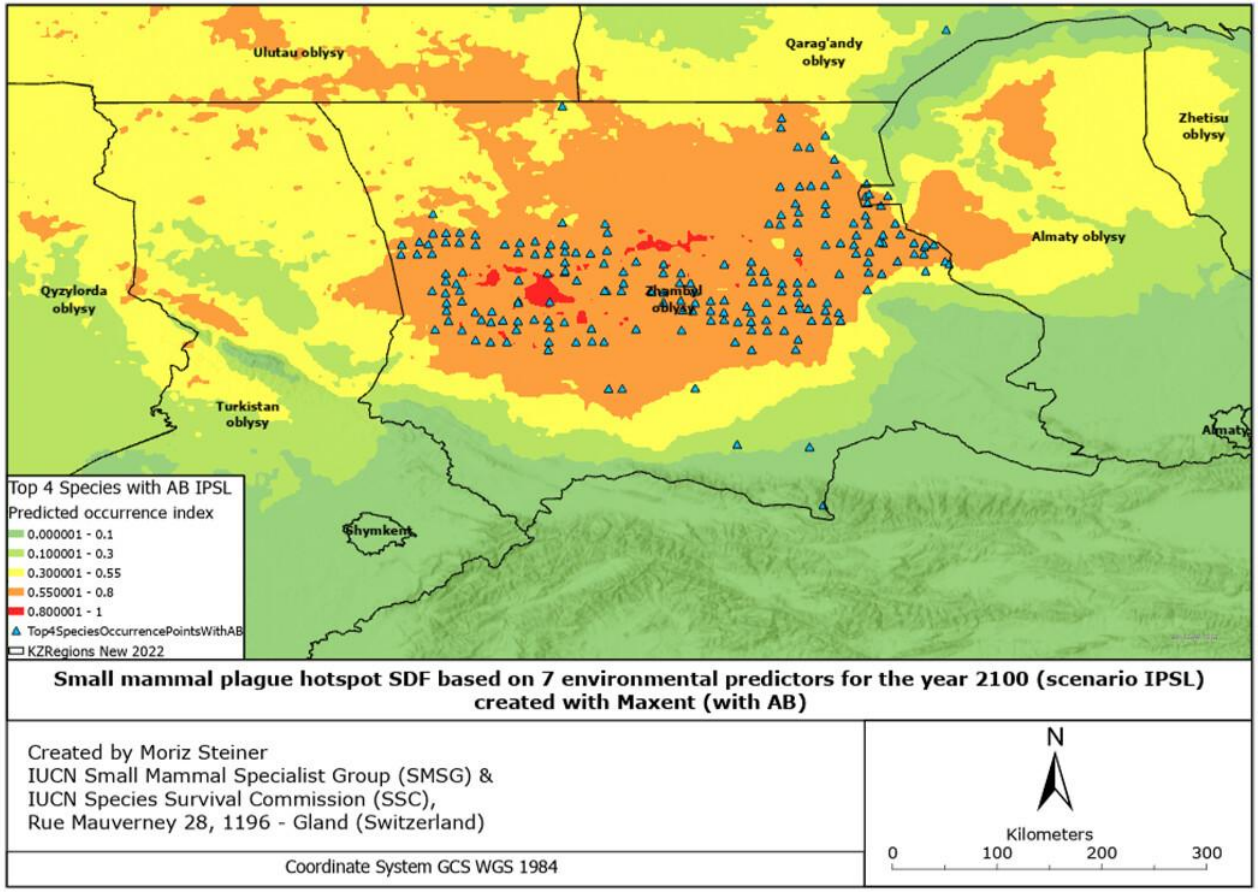


Guo, J., & Jin, N. (2026). Zoonotic diseases (zoonoses): Definitions, classifications, hazards, and prevention strategies. Animals and Zoonoses. Volume 2, Issue 1, Pages 1-6, ISSN 2950-2489, https://doi.org/10.1016/j.azn.2026.01.004.

An example of disease transfer predictions



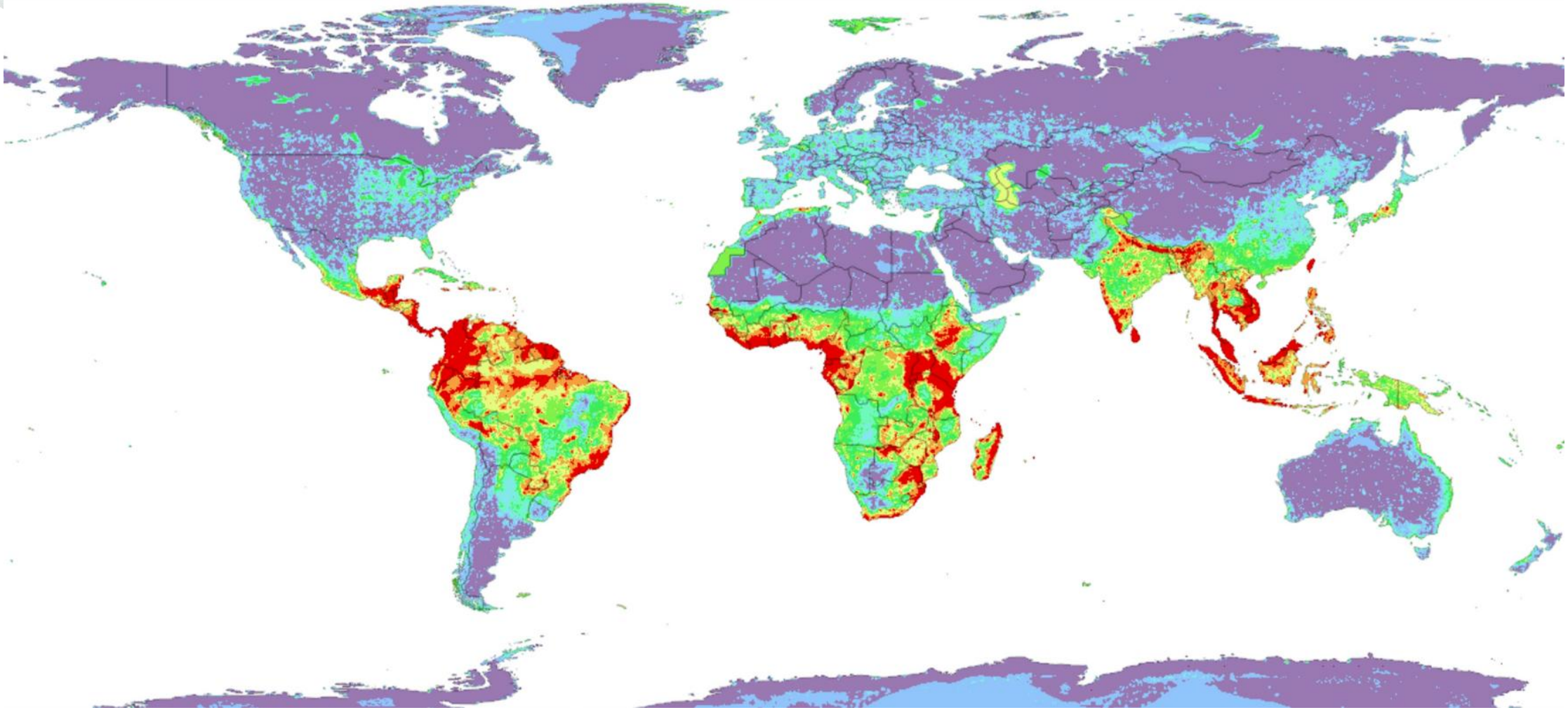
A



B

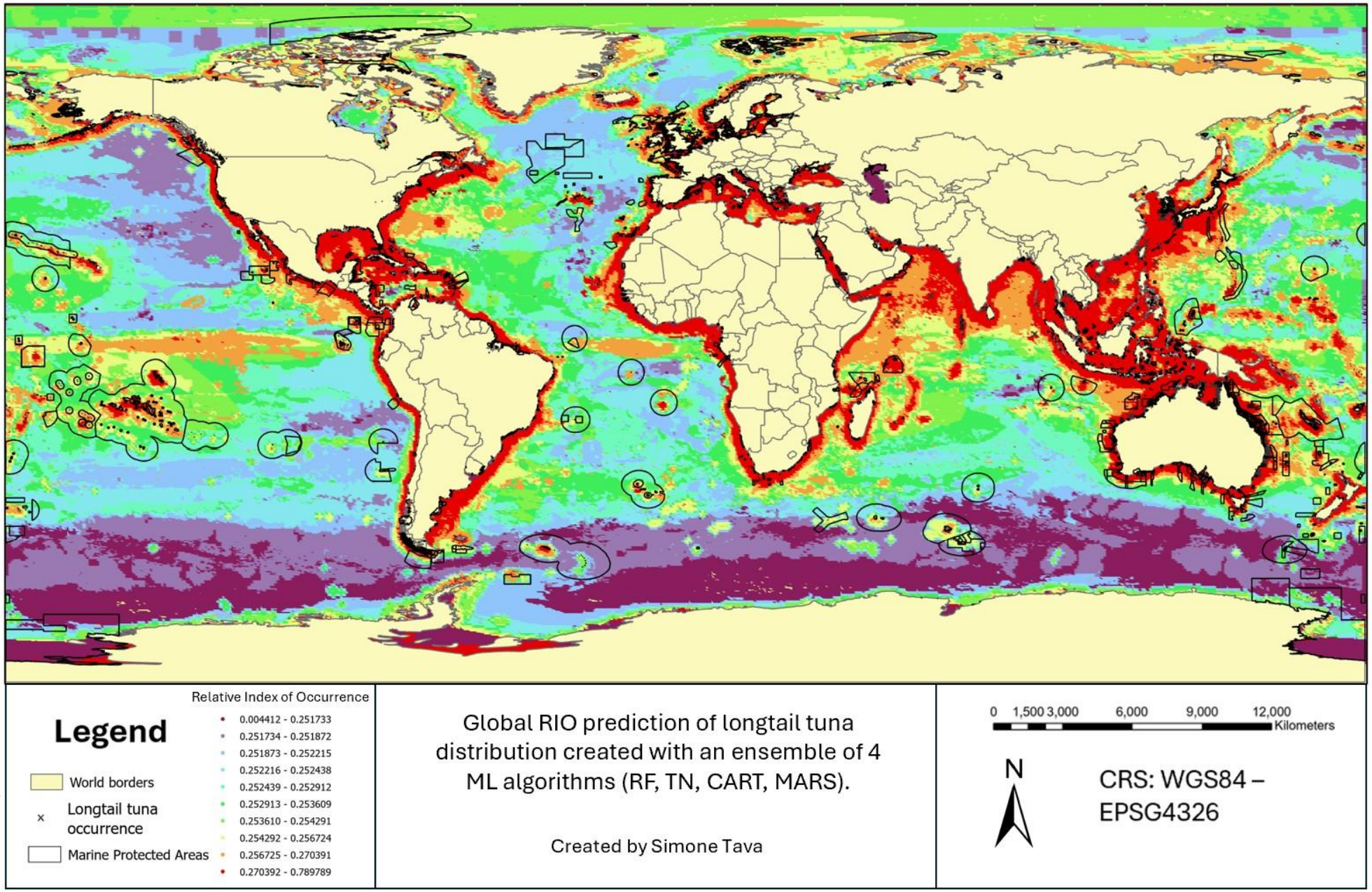
Rametov, N. M., Steiner, M., Bizhanova, N. A., Abdel, Z. Z., Yessimseit, D. T., Abdeliyev, B. Z., & Mussagalieva, R. S. (2023). Mapping plague risk using super species distribution models and forecasts for rodents in the Zhambyl Region, Kazakhstan. GeoHealth, 7(11), e2023GH000853.
https://doi.org/10.1029/2023GH000853

Another example: All global primates



Steiner, M., & Huettmann, F. (2025). Progress on the world's primate hotspots and coldspots: modeling ensemble super SDMs in cloud-computers based on digital citizen-science big data and 200+ predictors for more sustainable conservation planning. Ecological Processes, 14(1), 52. https://doi.org/10.1186/s13717-025-00614-z

A marine fish (tuna) example



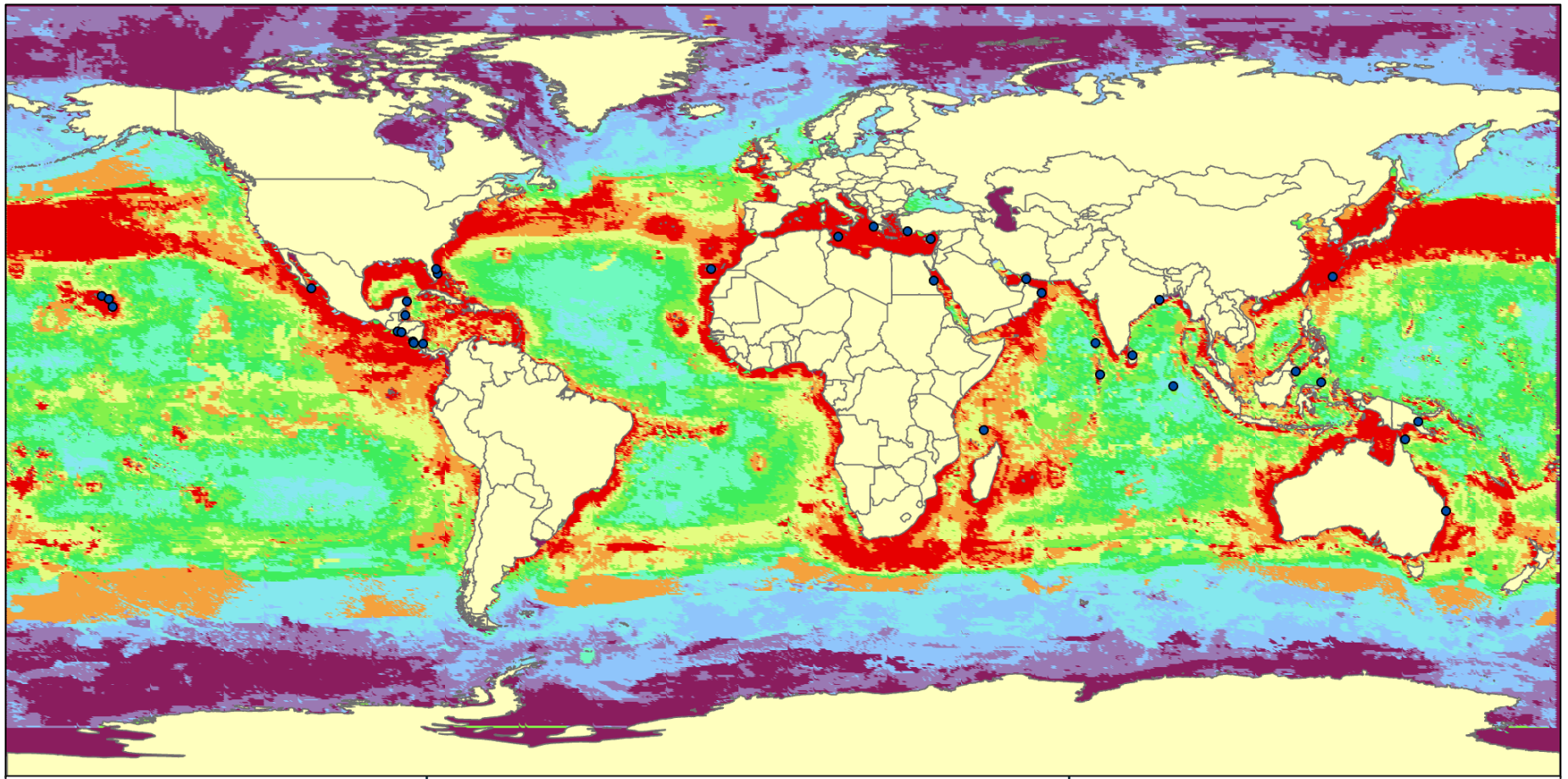
Tava, S., Steiner, M., Huettmann, F. (*Under review*). Tuna cannot be managed for species diversity and ecology: Inference from A First Global Community-Open Access BIG DATA Mining for Multi-Species Tuna Predictions Using a 'DIGITAL TWIN' hindcasting with Machine Learning Ensembles.

A marine reptile (turtle) example

Photo by Moriz Steiner



Tava, S., Steiner, M., Huettmann, F. (*Under review*). First Pooled Global Assessment of Marine Turtles Hot-and Coldspots from a DIGITAL TWIN as a New Frontier for Global Ocean Conservation with Open Access Data, GIS and Machine Learning Ensembles.



Factors affecting suitable habitats and species movement and underlying models

- A suitable area may remain unoccupied.
- Roads, cities, and other barriers can limit movement.
- Movement barriers, food, competitors, and disease influence where species can survive.
- Independent observations, data quality checks, and comparisons across scenarios help assess predictions.

How much should we trust a prediction model?

Stay critical!

- Check predictions against observations the model has not used.
- Ask where and how data are obtained, and whether they are missing or biased.
- Compare results across models and future scenarios.
- Use uncertainty to guide monitoring and decisions.

Practical wildlife movement examples: Moose & Beaver

Predictions can provide pre-event scenarios and guide land & wildlife management decisions





Photos by Moriz Steiner

Beaves to mitigate climate change effects (droughts)



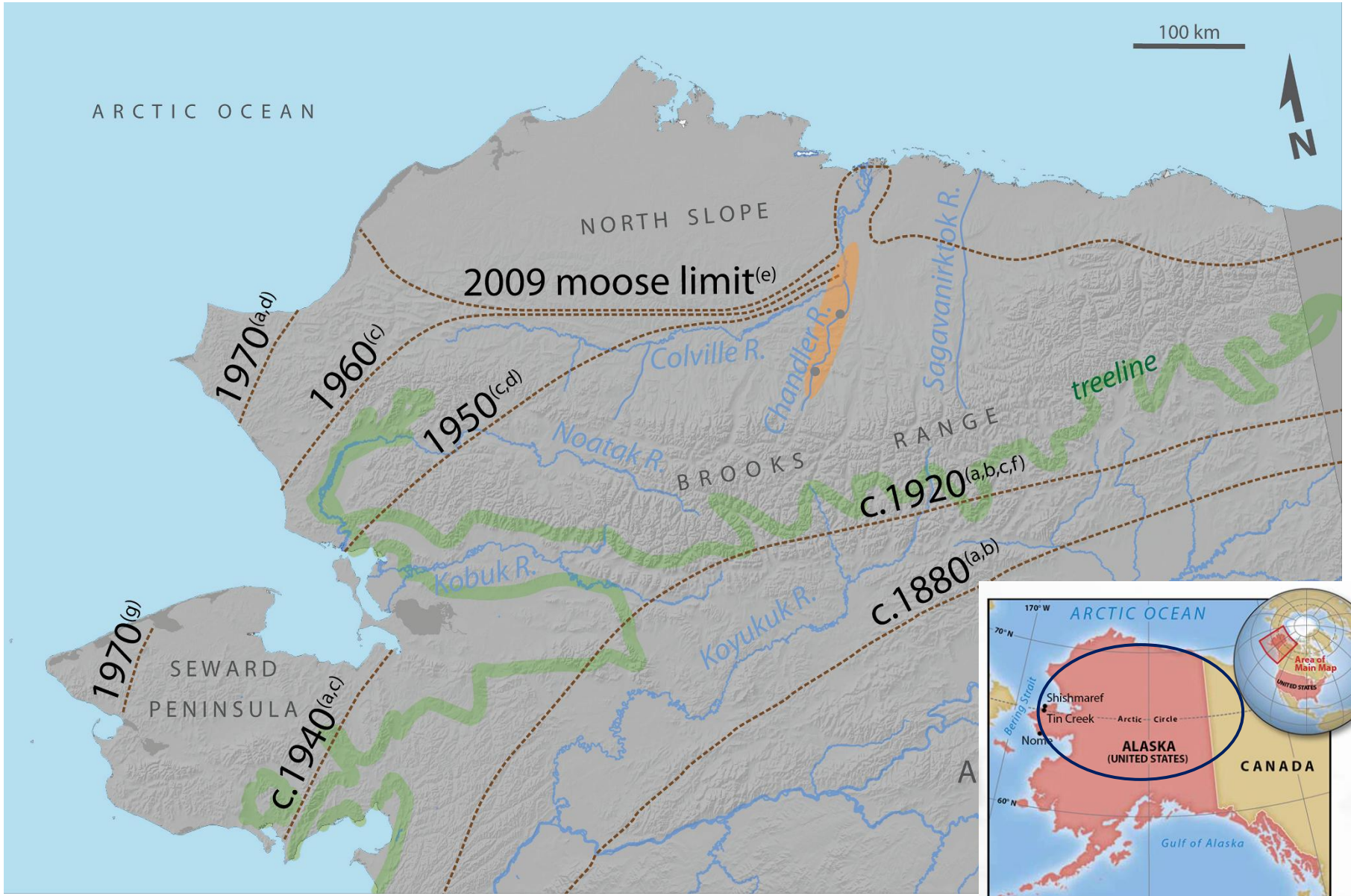
Beaver Drop



Relocation for sustainable land management

https://www.youtube.com/watch?v=rrOE-m7sX9E

Moose in Alaska



Tape KD, Gustine DD, Ruess RW, Adams LG, Clark JA (2016) Range Expansion of Moose in Arctic Alaska Linked to Warming and Increased Shrub Habitat. *PLoS ONE* 11(4): e0152636. https://doi.org/10.1371/journal.pone.0152636

RAD – Wildlife Management Framework

RESIST

Some changes can be resisted. Managers will work to maintain ecosystem processes, function, and composition without experiencing dramatic, threshold-crossing changes.

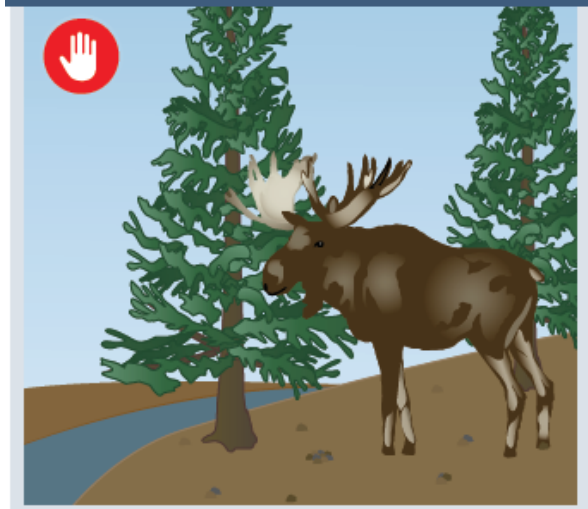
ACCEPT

Many changes can be accepted, perhaps because they cannot feasibly be resisted or because they are acceptable to—or even desirable by—society. Managers will work to ease the transition.

DIRECT

A few changes can be directed toward a different state, either because resistance is unrealistic or there is an opportunity to direct the change to a more desirable future state. Managers will face a new frontier in overseeing this process.

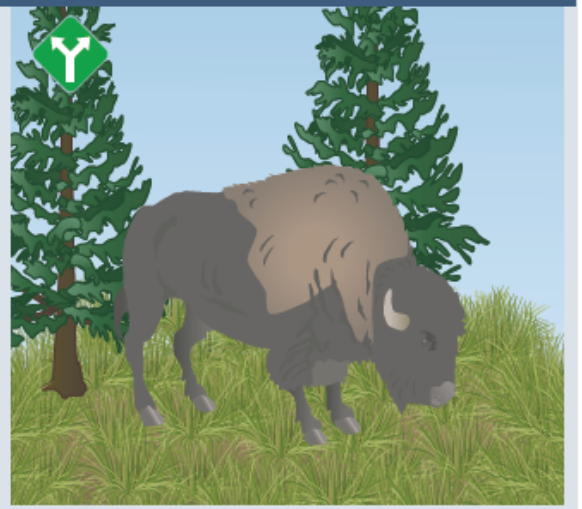
Kenai Peninsula, Alaska: A Case Study



Stream banks are restored, the most feasible and deleterious invasive species are eradicated, fire is managed progressively, and landscape connectivity is maintained through fish and wildlife passages under or over highways. Non-native species are monitored for escapement as climate changes.



Glaciers are melting, non-glacial streams are warming, tree line is rising, and wetlands are drying. Many invasives are not managed either due to a lack of feasibility or perceived threat. Society has accepted the changes in fish and wildlife communities, even with higher costs to ecosystem services.



A spruce bark beetle epidemic and human-caused fire have shifted white spruce forests into a novel grassland ecosystem. Non-native trees from neighboring regions are being planted, and the introduction of large grazers is being considered to stabilize the new grasslands and related communities.

https://www.akwildlife.org/radframework

Comments on Open Access, data quality, and citizen science data

- **Open access:** Share publications, data, inputs & outputs, metadata, and code.
- **Data quality:** Verify records, address biases, and report uncertainty.
- **Citizen science:** Expand biodiversity monitoring through public participation.
- **Conservation action:** Turn transparent, reproducible data and science into better decisions for sustainable biodiversity conservation.

My conservation-oriented take-home message

While human-driven climate change has and is continuously expected to have a significant impact on global biodiversity, the flora, fauna, and funga can help us mitigate climate change, and hence necessitate long-term sustainable biodiversity conservation initiatives!