Applying Sustainable Development Goals to the Conservation of Winter Environments and Cold-adapted Species in a Warming World

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Project: 18-SLSCVC18-0001

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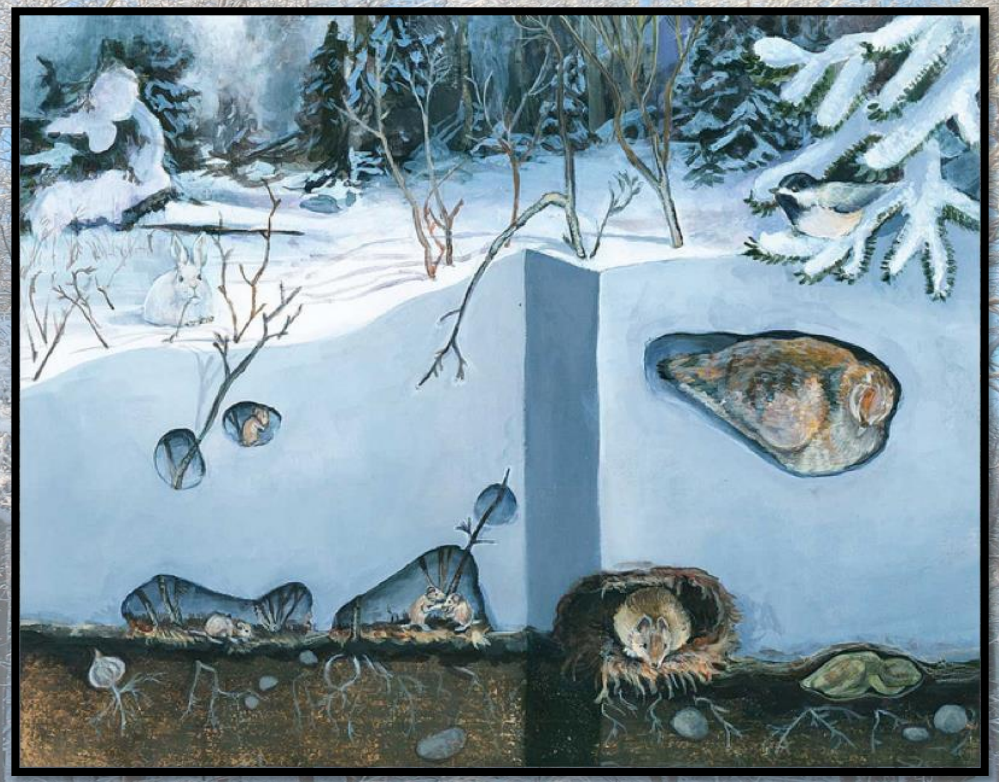
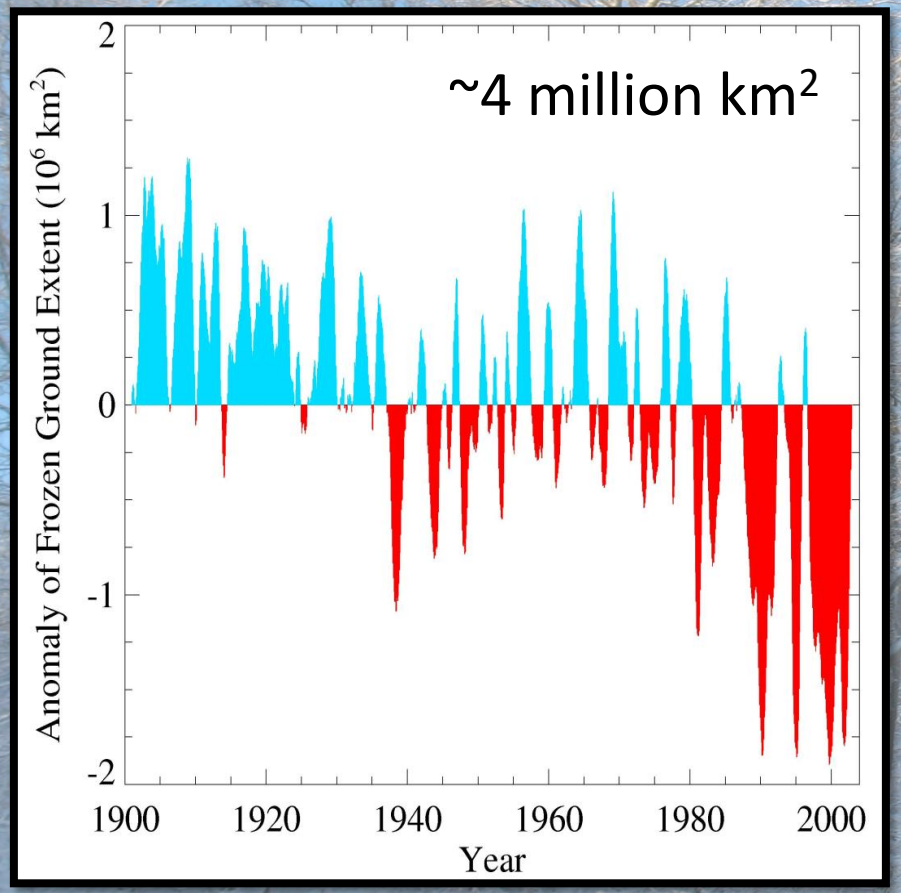
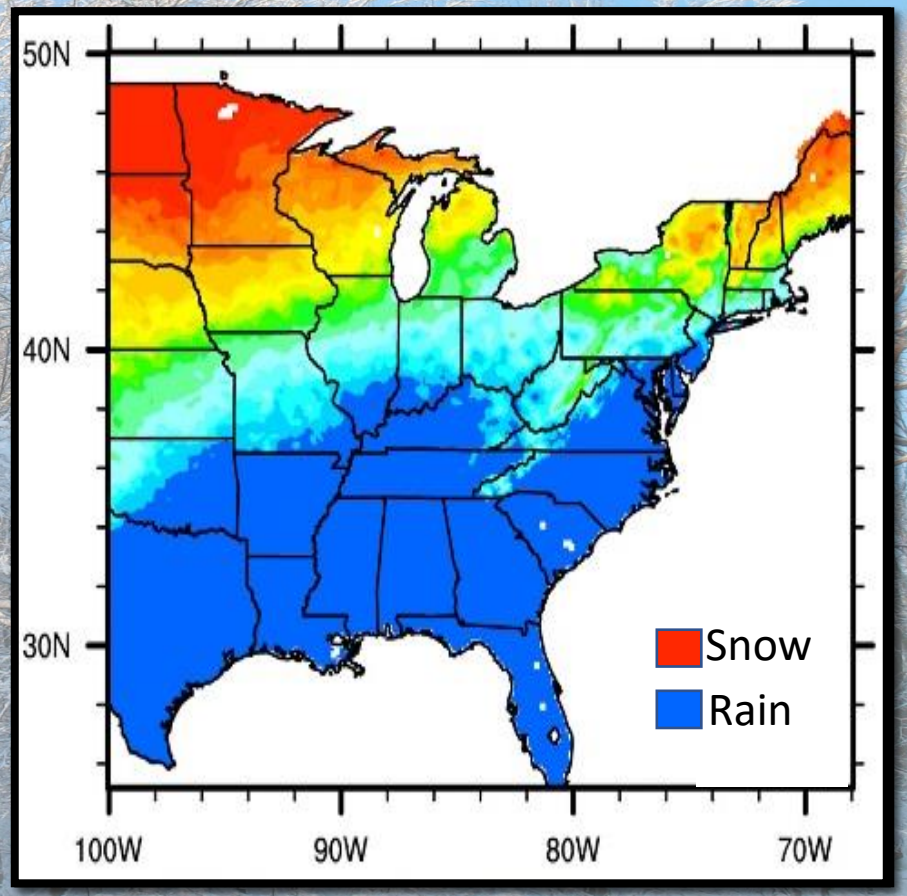
Winter: More than meets the eye



Pauli et al. 2013; Zuckerberg and Pauli 2018

Snow loss in a warming world





Brown and Robinson 2011; Ning and Bradley 2015

Addressing UN Sustainable Development Goals

SDG 15 – ‘Life on Land’

Proportion of important sites for terrestrial biodiversity that are covered by protected areas (15.1.2)

Assessing protect areas coverage for important winter biodiversity

Our Questions

Can we develop ecologically-relevant metrics to capture snow cover dynamics using existing remotely sensed data?

❄

Does information on winter climate and snow improve distribution modelling of vertebrate communities?

❄

Are we doing a good job of protecting winter biodiversity “hotspots”?

Winter Habitat Indices

Snow – optical multispectral sensors

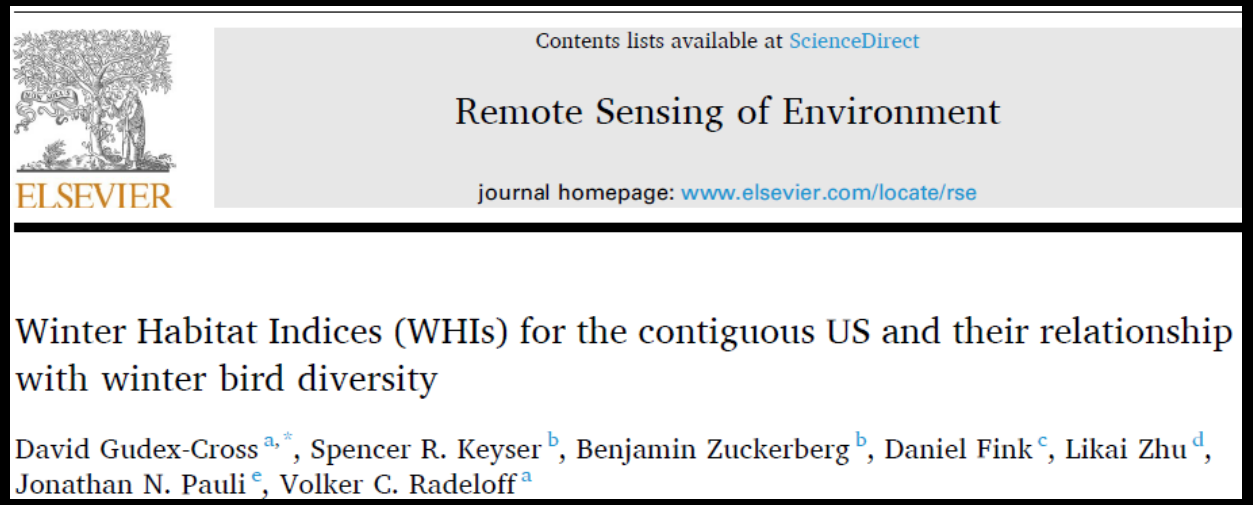
Satellite/Sensor	Spatial Resolution	Imaging Frequency	Data Record
MODIS*	500m	Daily	2000-On
Landsat (all sensors)	30m	16 days	1985-On
Landsat 8	30m	16 days	2013-On
Sentinel 2	10-30m	5 days	2017-On
Harmonized L8-S2	30m	2-3 days	2017-On

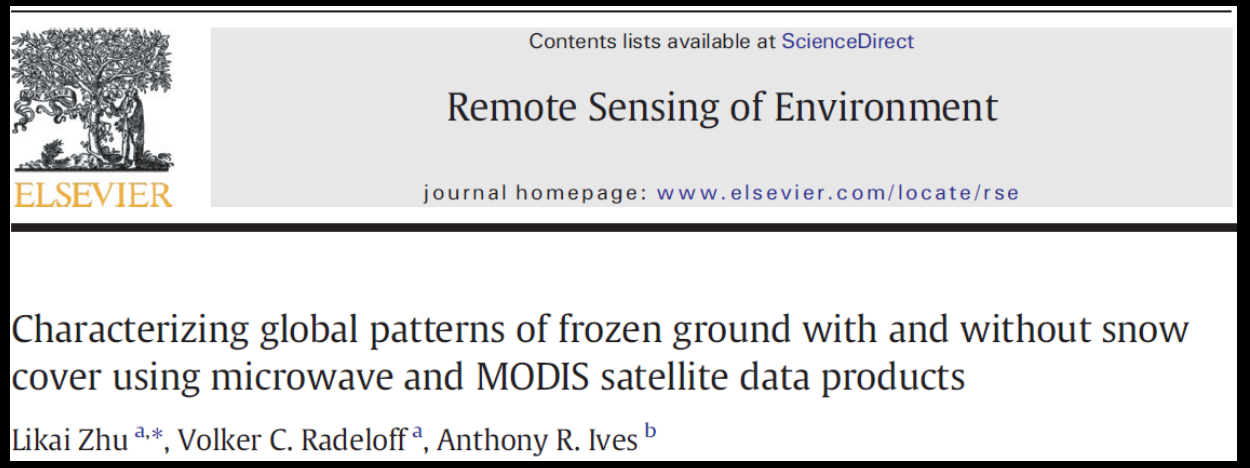
*Data from both MODIS sensors (Aqua & Terra) begin in 2002

Frozen ground – microwave sensors

Data Product	Spatial Resolution	Image Frequency	Data Record
MEaSUREs Freeze/Thaw	6-25km**	Daily	1979-2018*

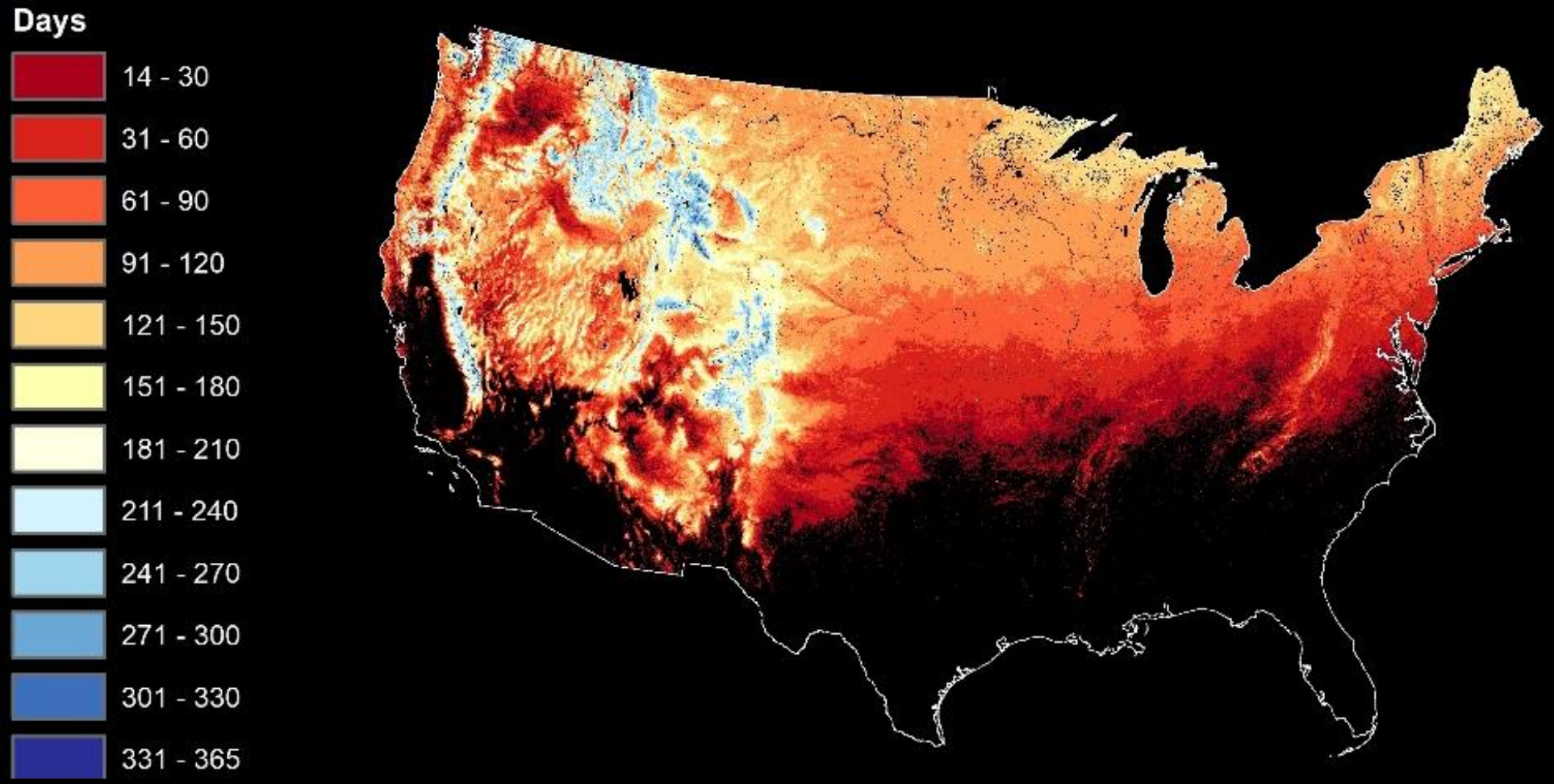
**6 km data only available for the Northern Hemi from 2002-2018





Snow Season Length

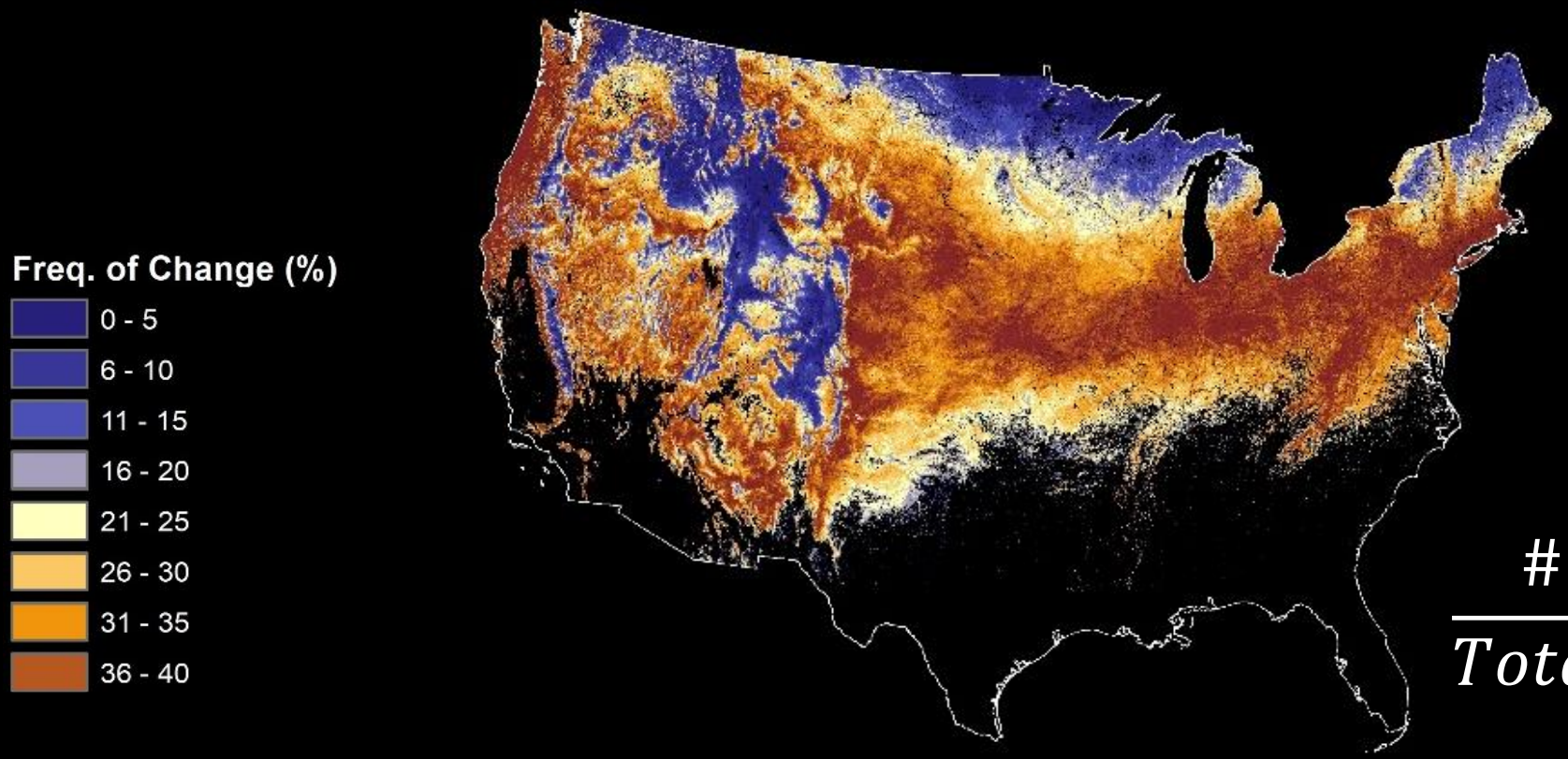
 # days between first & last snow



Snow Cover Variability

Example Time-Series:

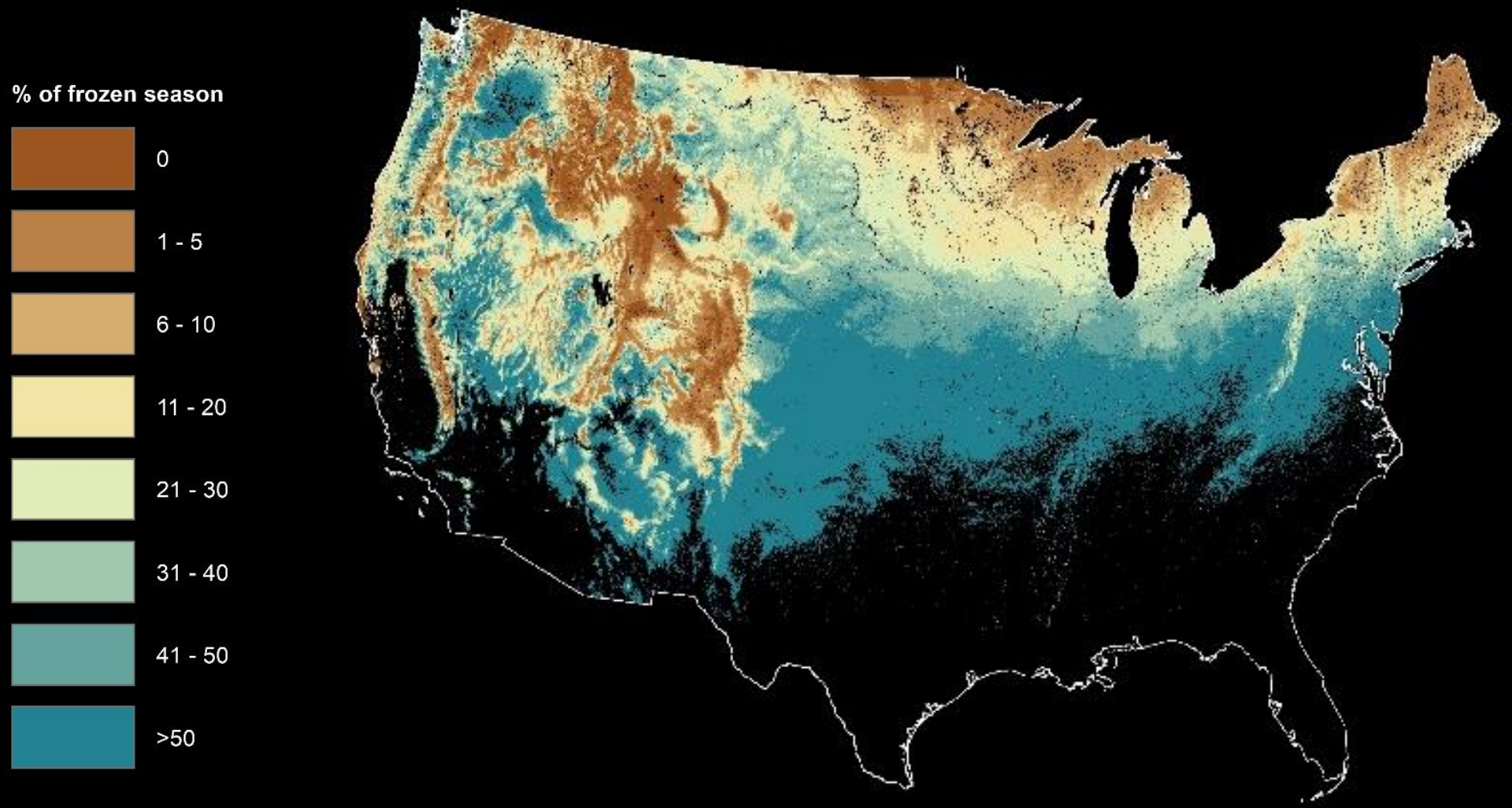
	no snow	no snow	snow	snow	snow	no snow	no snow	snow	snow	no snow	
State	0	0	1	1	1	0	0	1	1	0	= 10 total obs
Abs(Change)		0	1	0	0	1	0	1	0	1	= 4 change events
											SCV = 40%

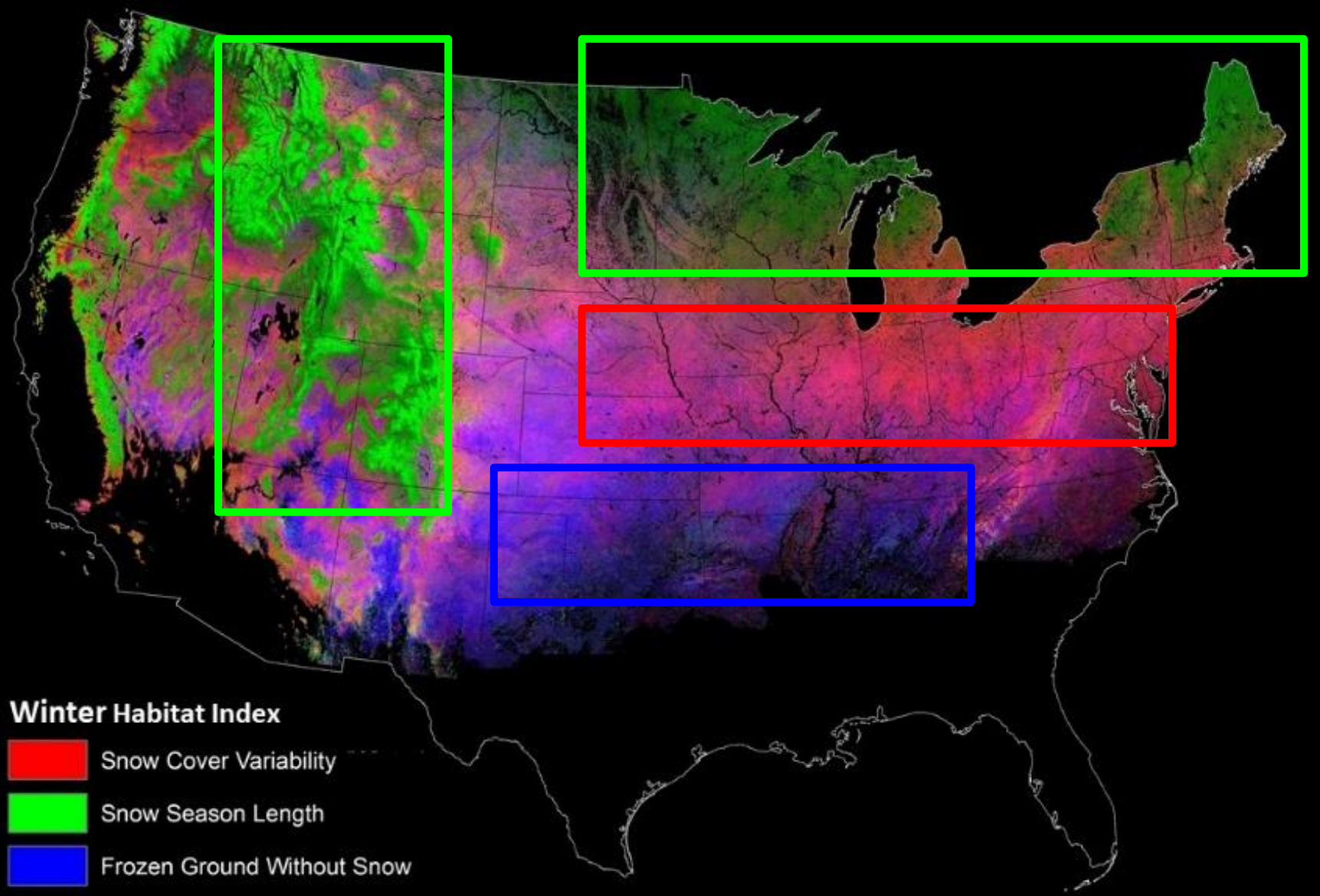


$$\frac{\#\ of\ Change\ Events}{Total\ \#\ of\ Observations}$$

Frozen Ground without Snow

# of frozen ground w/o snow days ÷ total # frozen days

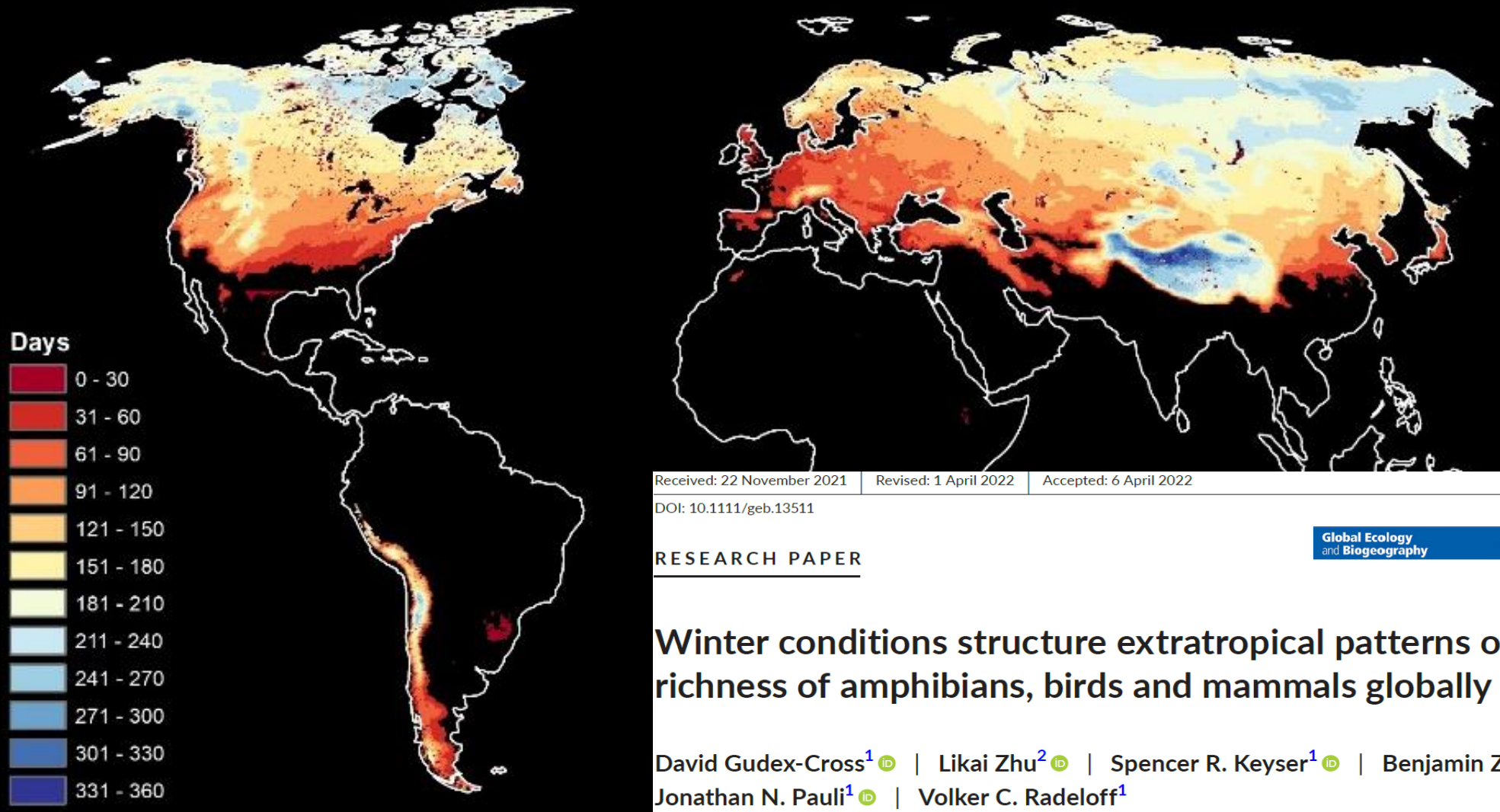



Winter Habitat Index
Snow Cover Variability
Snow Season Length
Frozen Ground Without Snow

Winter Vertebrate Data Sources

Data Source	Occurrence/ Abundance	Spatial Extent/Resolution	Temporal Extent/Resolution	Taxa Included
eBird	☑ ☑	Global/3 km neighborhoods	2004-2020/Weekly	
Furbearer Harvest Database	☑ ☑	U.S. Wide/Varying Spatial Units	1900-2020/Annual	
IUCN Range Maps	☑ ☒	Global/~110 km	NA	

Global Winter Habitat Indices



Received: 22 November 2021 | Revised: 1 April 2022 | Accepted: 6 April 2022

DOI: 10.1111/geb.13511

RESEARCH PAPER

Global Ecology and Biogeography | A Journal of Macroecology | WILEY

Winter conditions structure extratropical patterns of species richness of amphibians, birds and mammals globally

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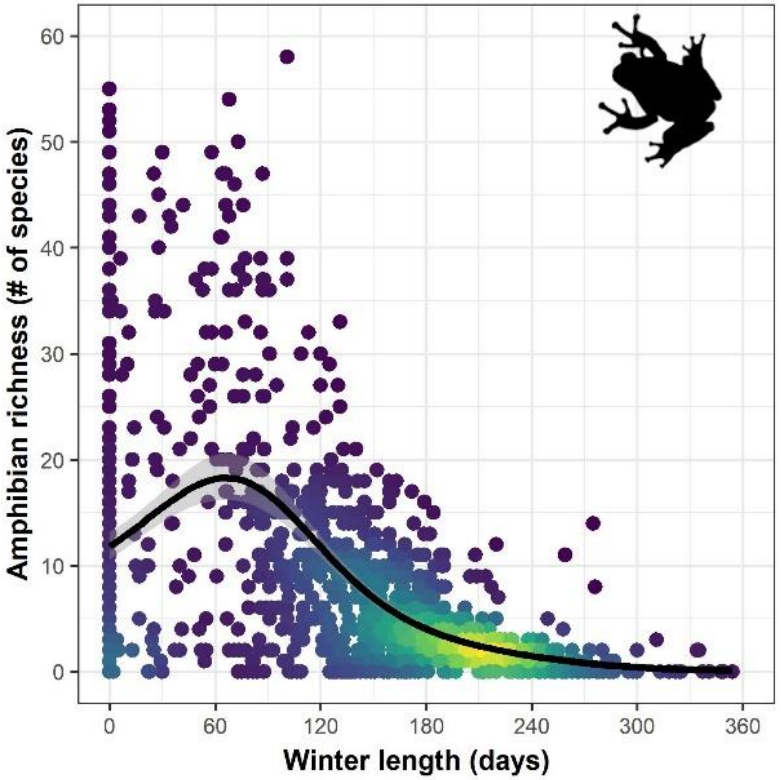
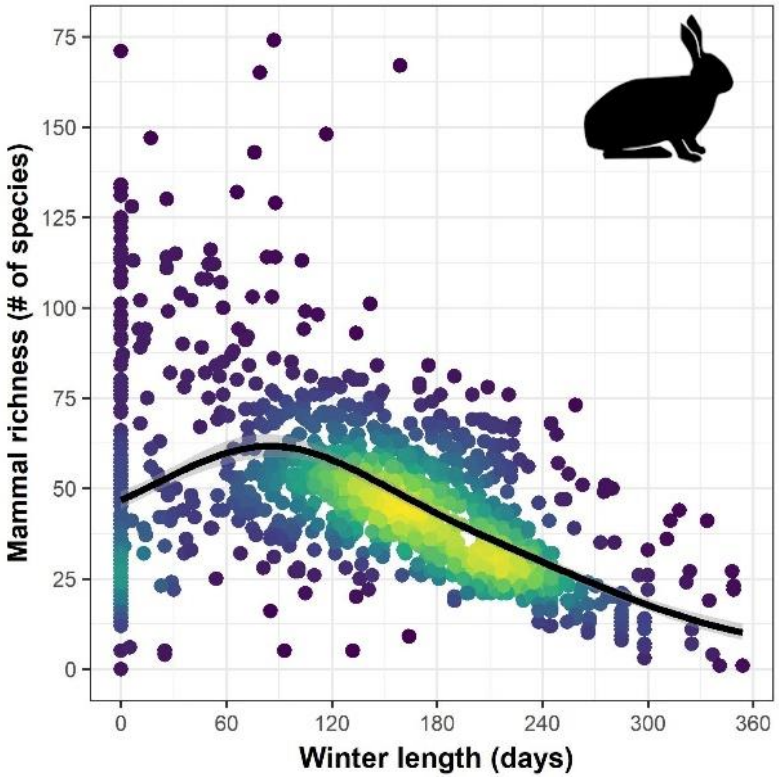
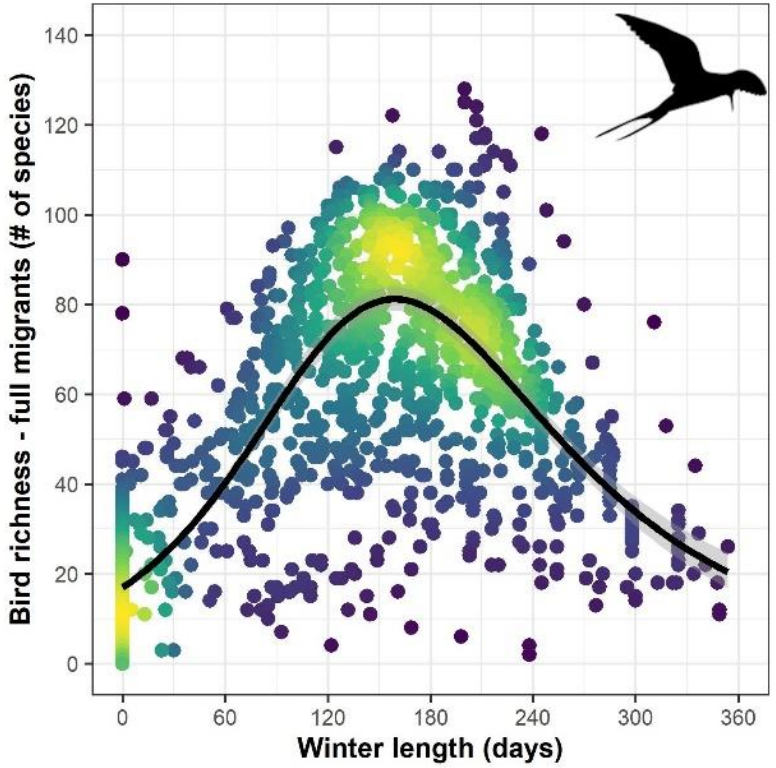
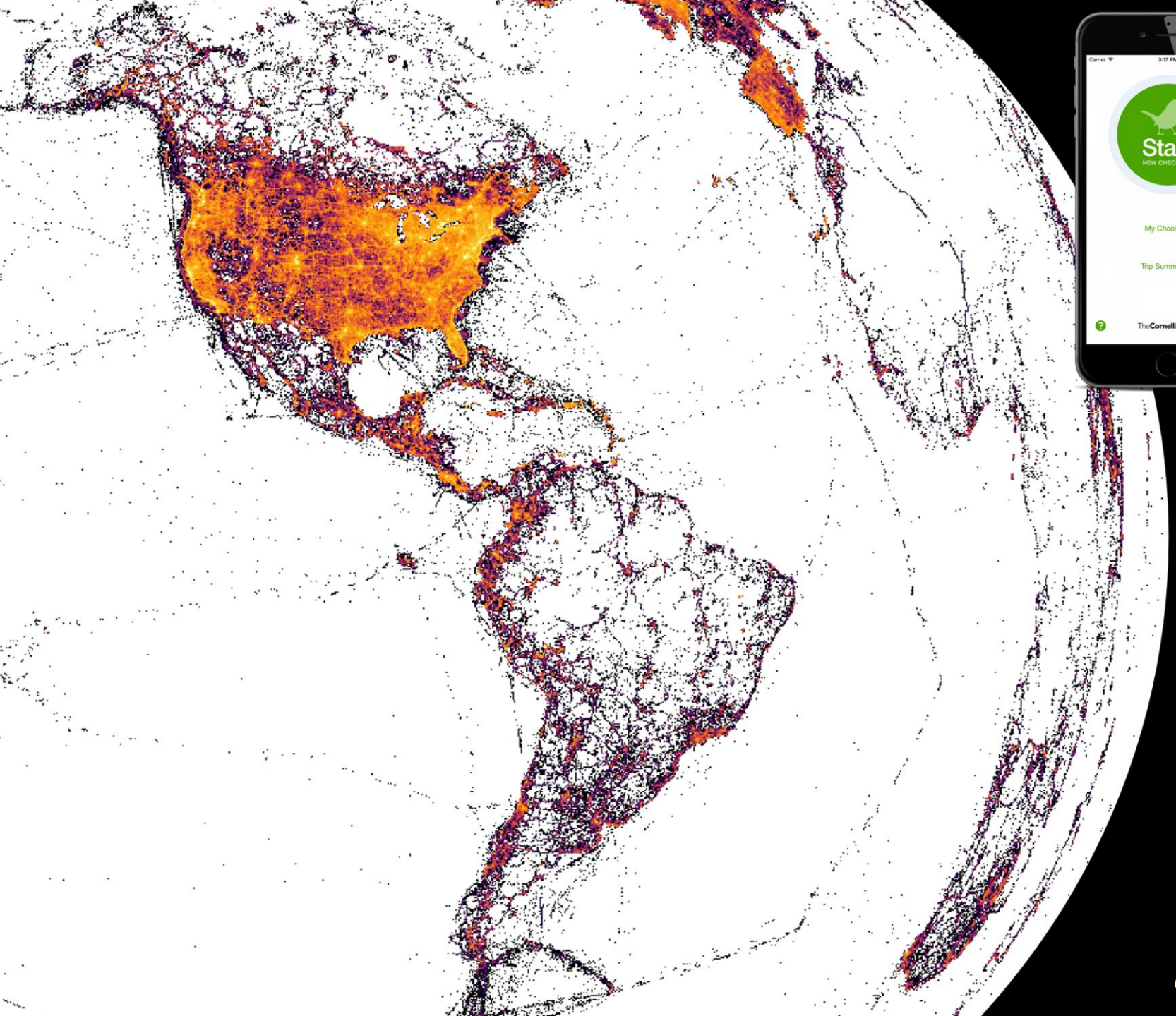
Winter climate is a strong determinant of extratropical diversity gradients

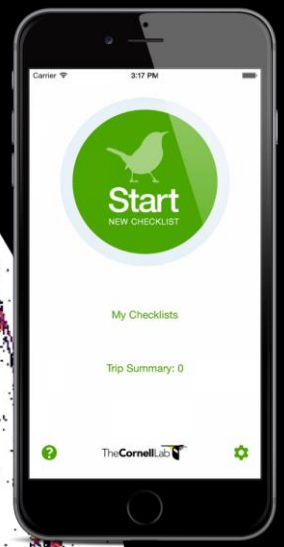






Gudex-Cross et al. 2022. Global Ecology and Biogeography





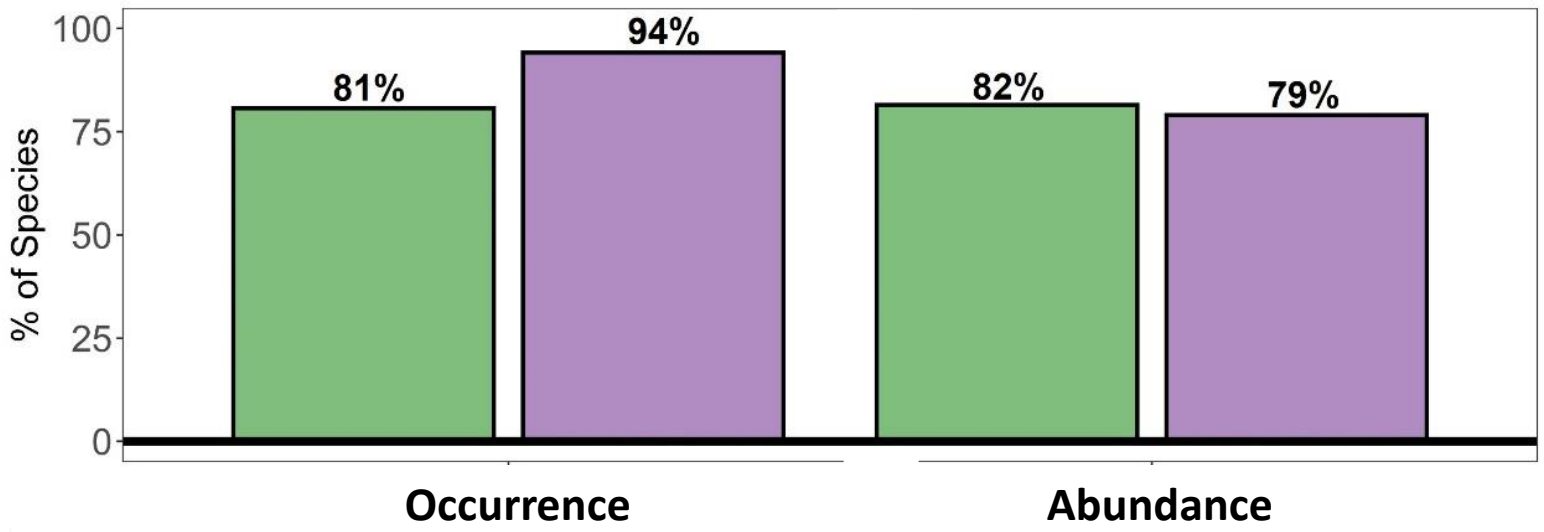
eBird

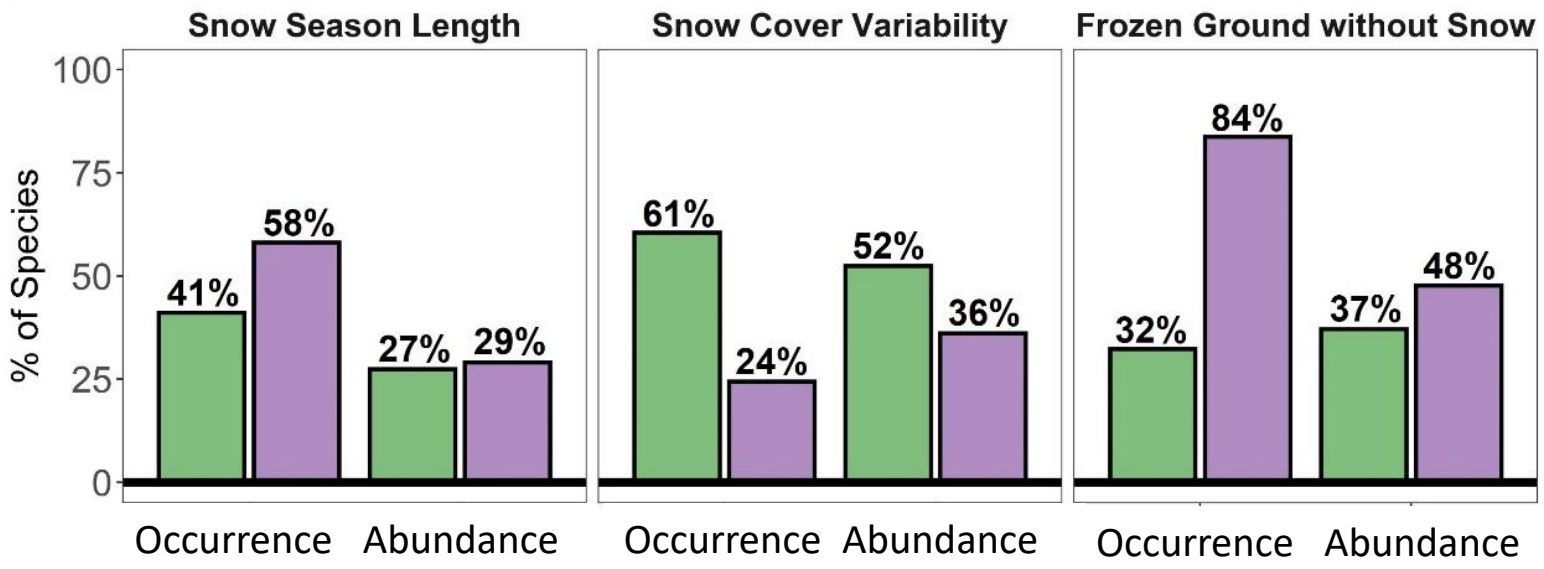
2004 – 2022
26M Checklists
6.5M Locations

Occurrence
Abundance

Dynamic Species Distribution Modeling

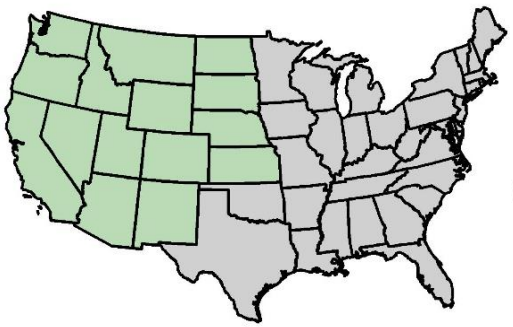
WHIs and bird distributions

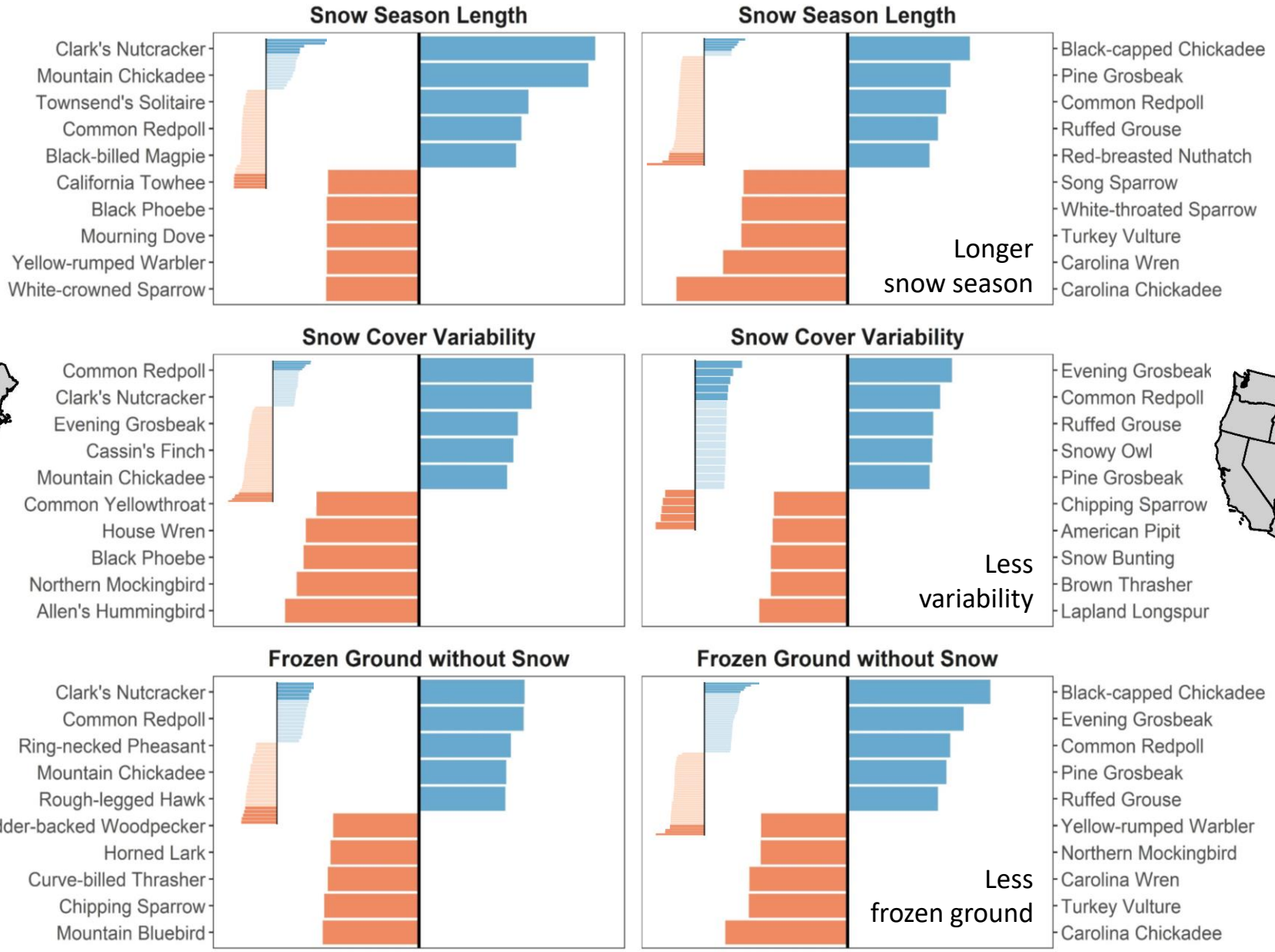


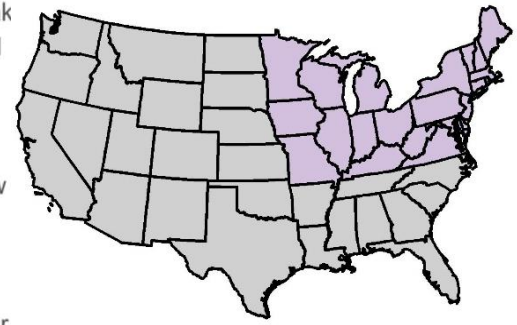


East
West

Keyser et al., In-Review





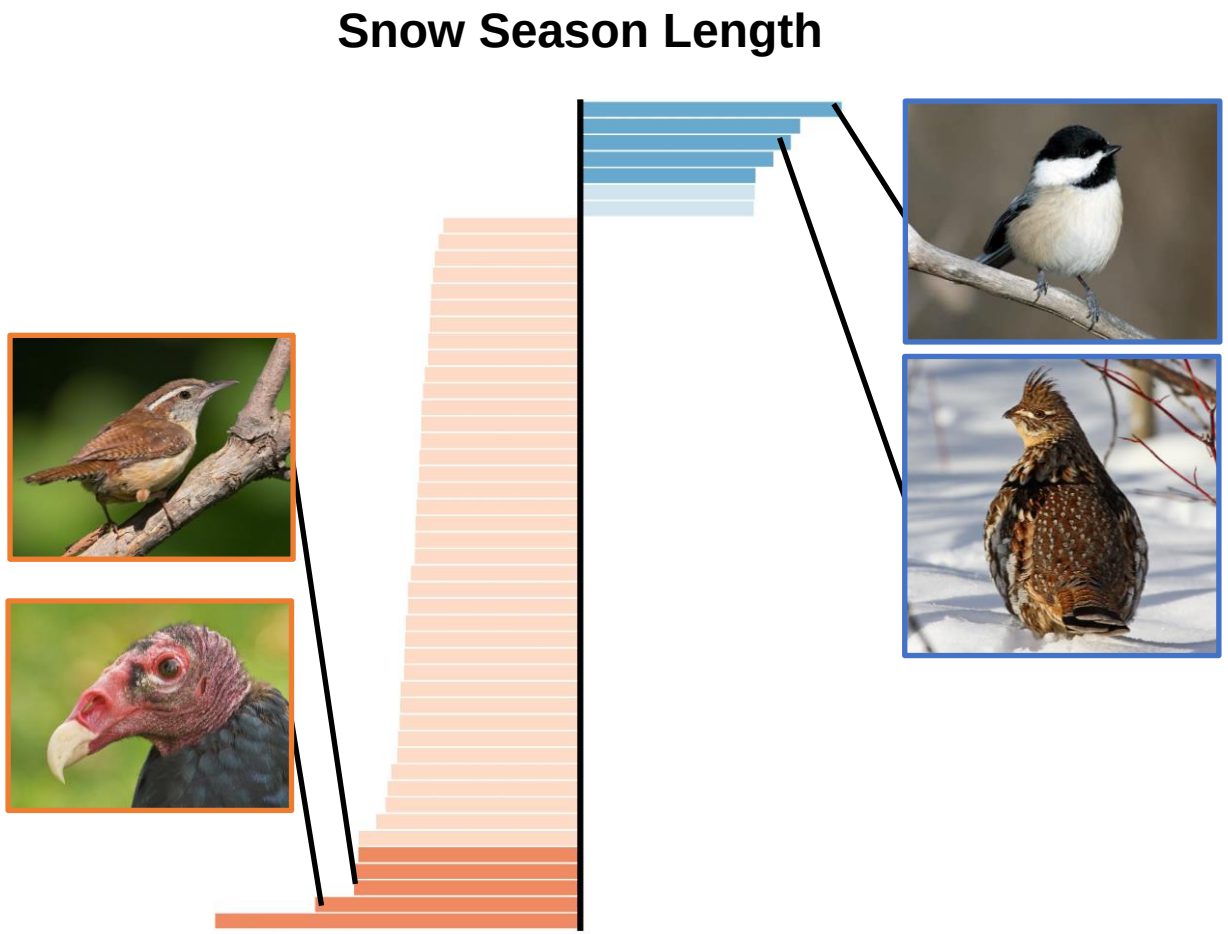


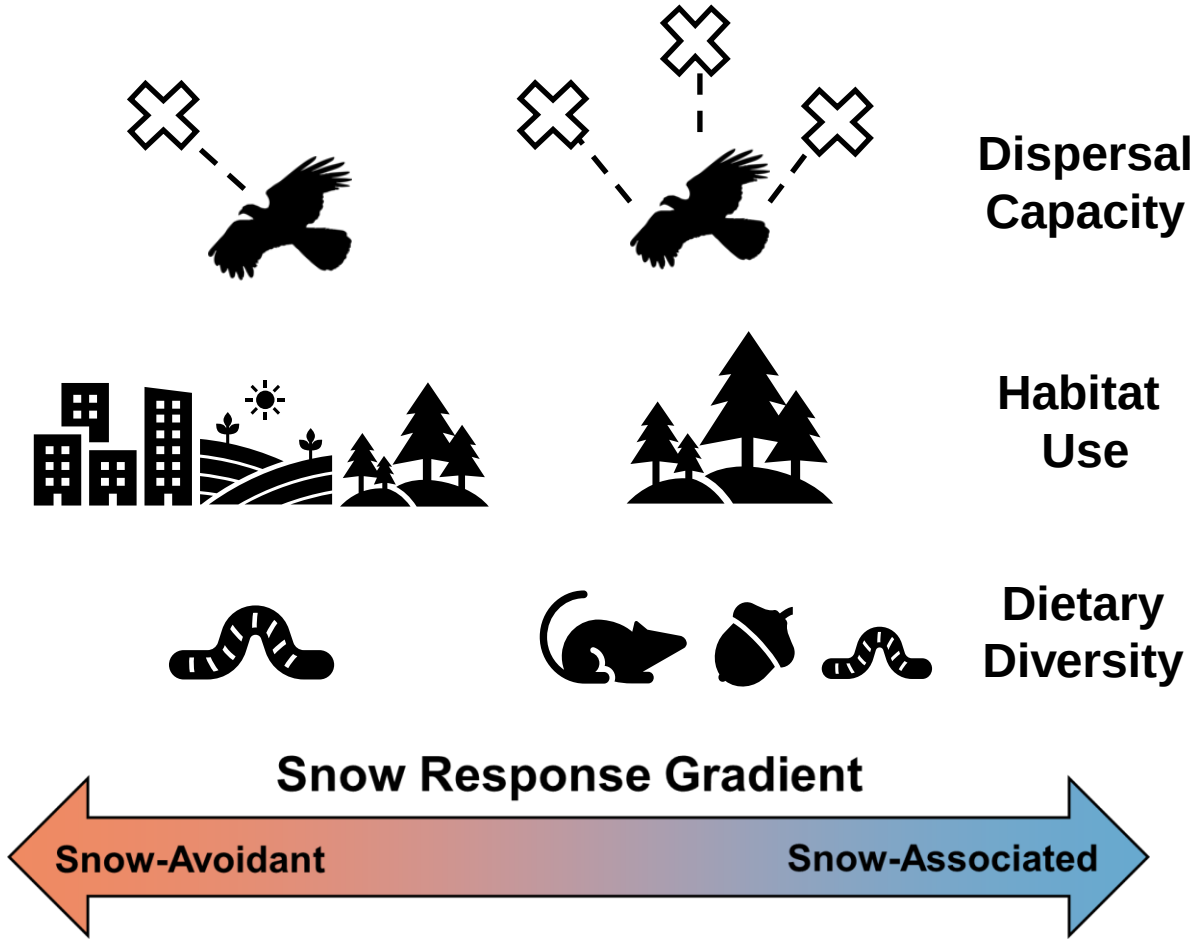
Predictor Importance

Snow-Avoidant ⟷ **Snow-Associated**

Keyser et al., In-Review

Winter-adapted Traits





Keyser et al., In-Review

Conserving winter biodiversity

Total Winter Species Richness

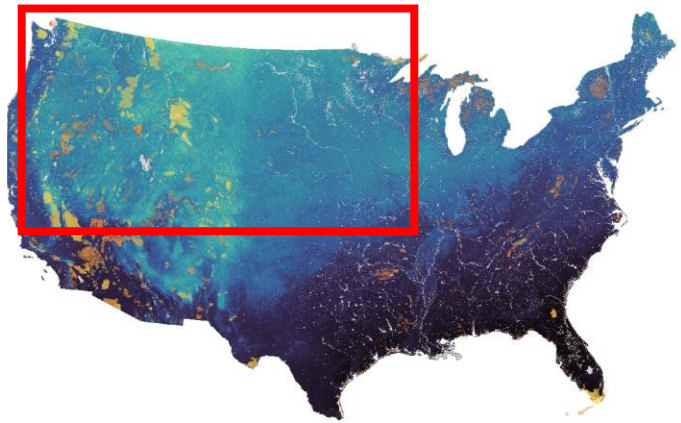
Snow-associated Species Richness

Less Vulnerable

Winter Climate Change Vulnerability

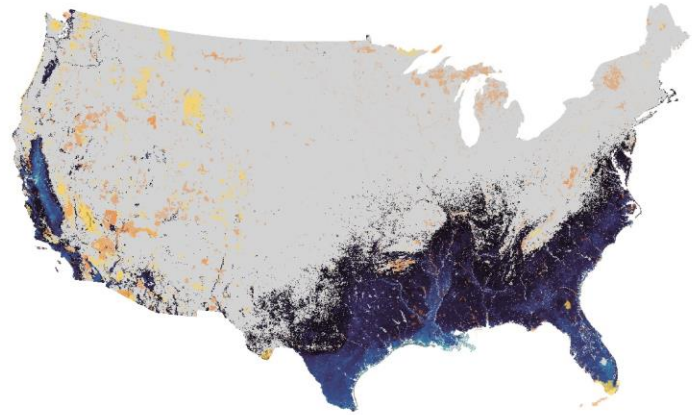
More Vulnerable

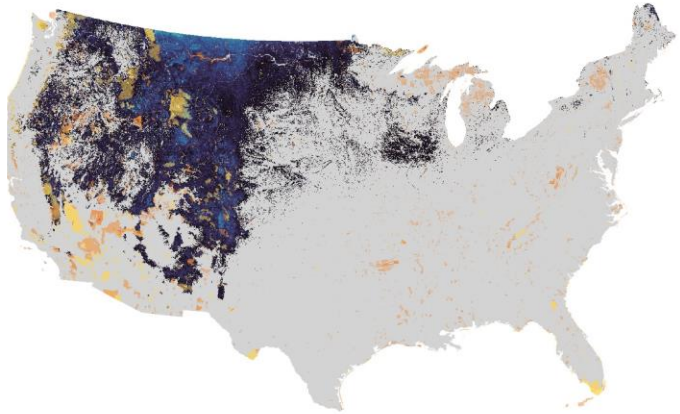
Full Winter Bird Richness



Snow-associated Bird Richness

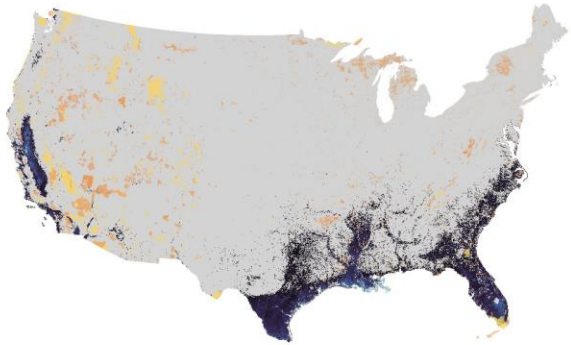
75th Percentile Winter Richness Hotspots

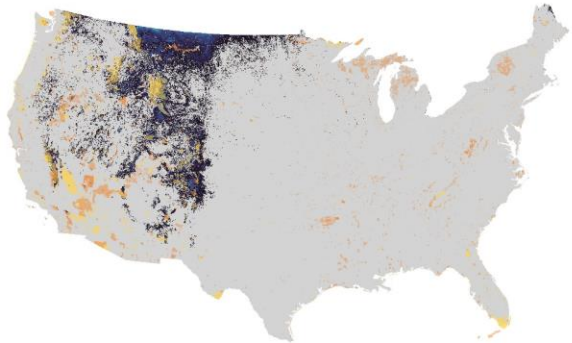




75th Percentile Snow-Associated Hotspots

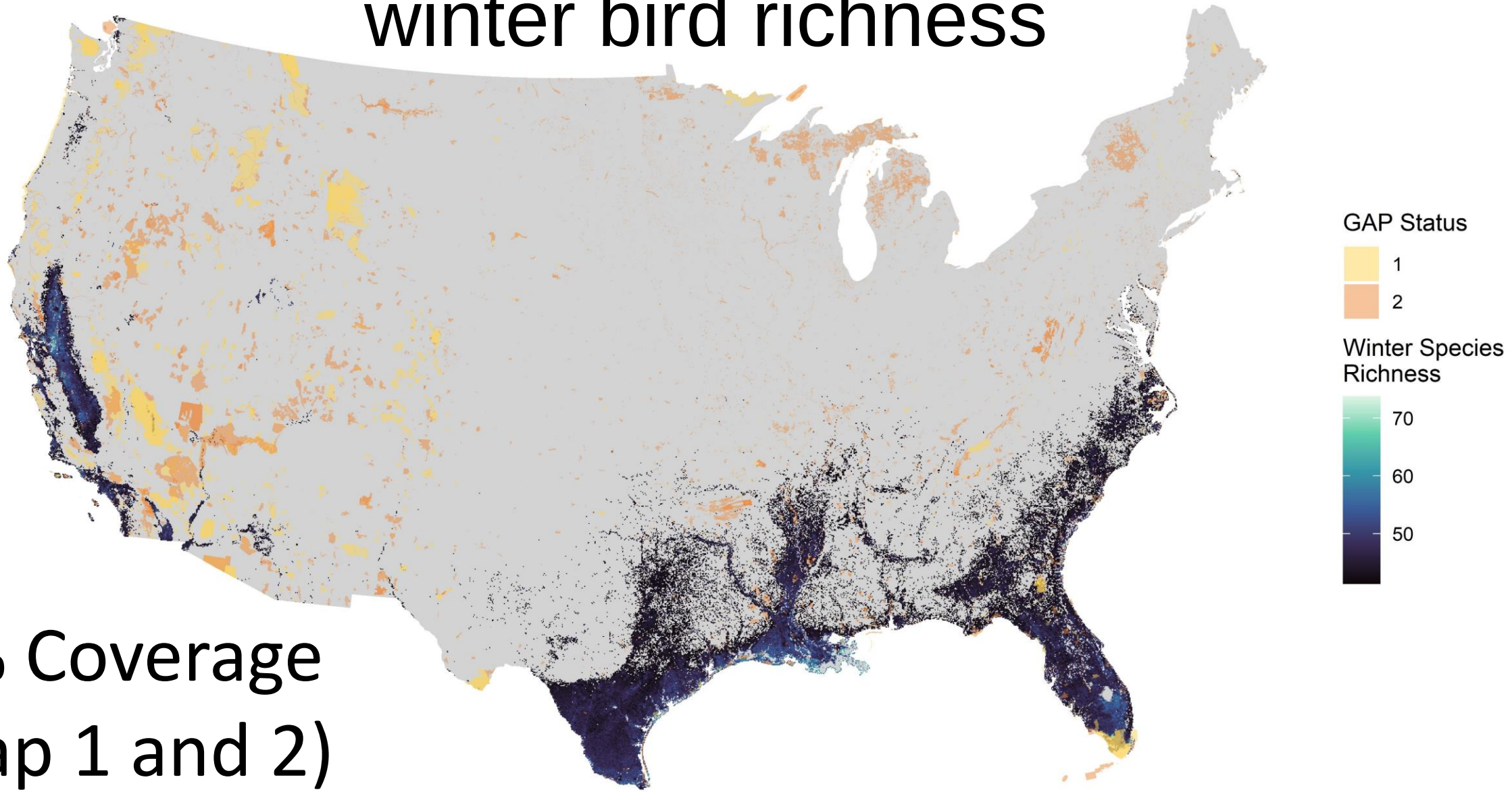
90th Percentile Winter Richness Hotspots





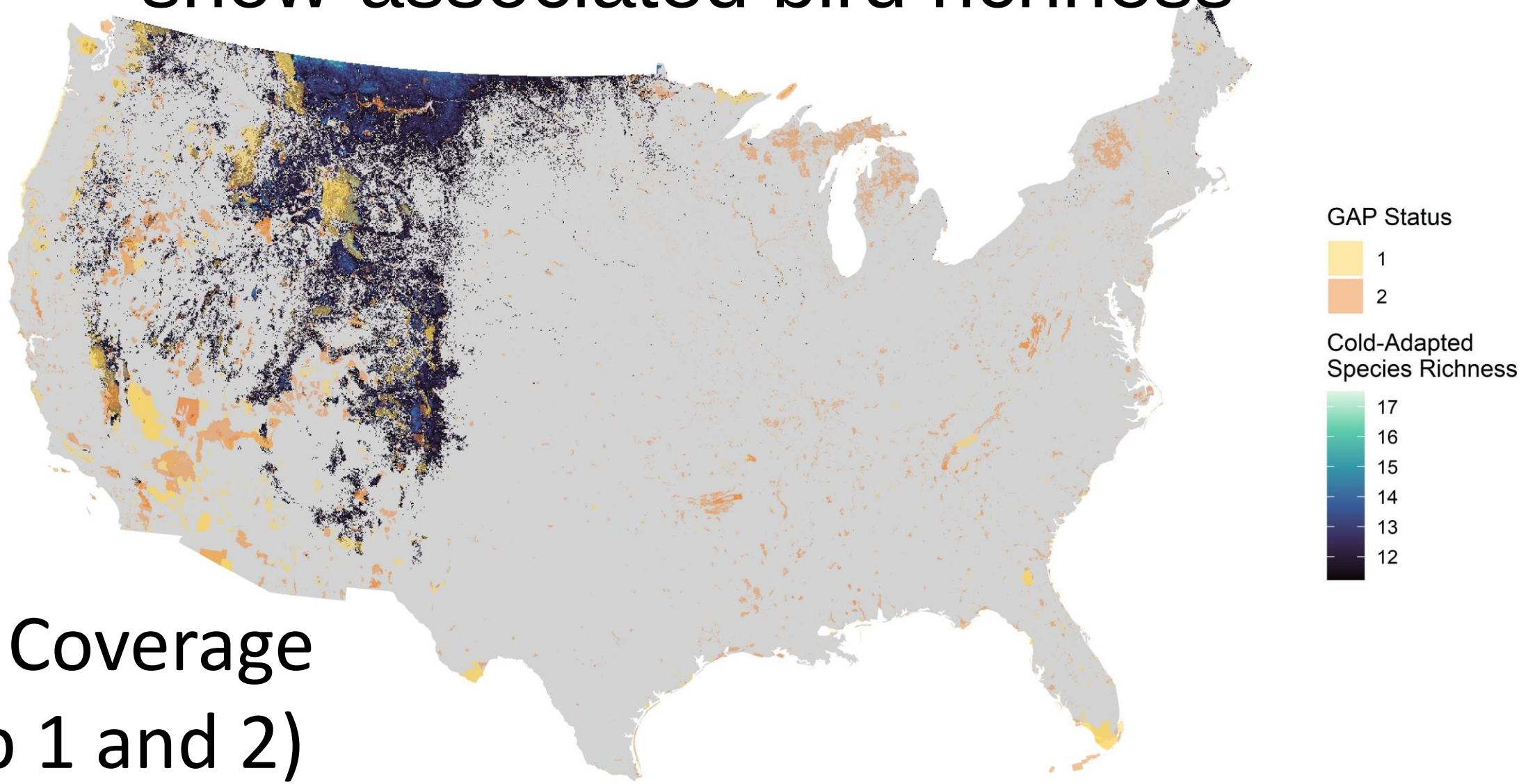
90th Percentile Snow-Associated Hotspots

Protected Areas for 90th percentile of total winter bird richness



5% Coverage (Gap 1 and 2)

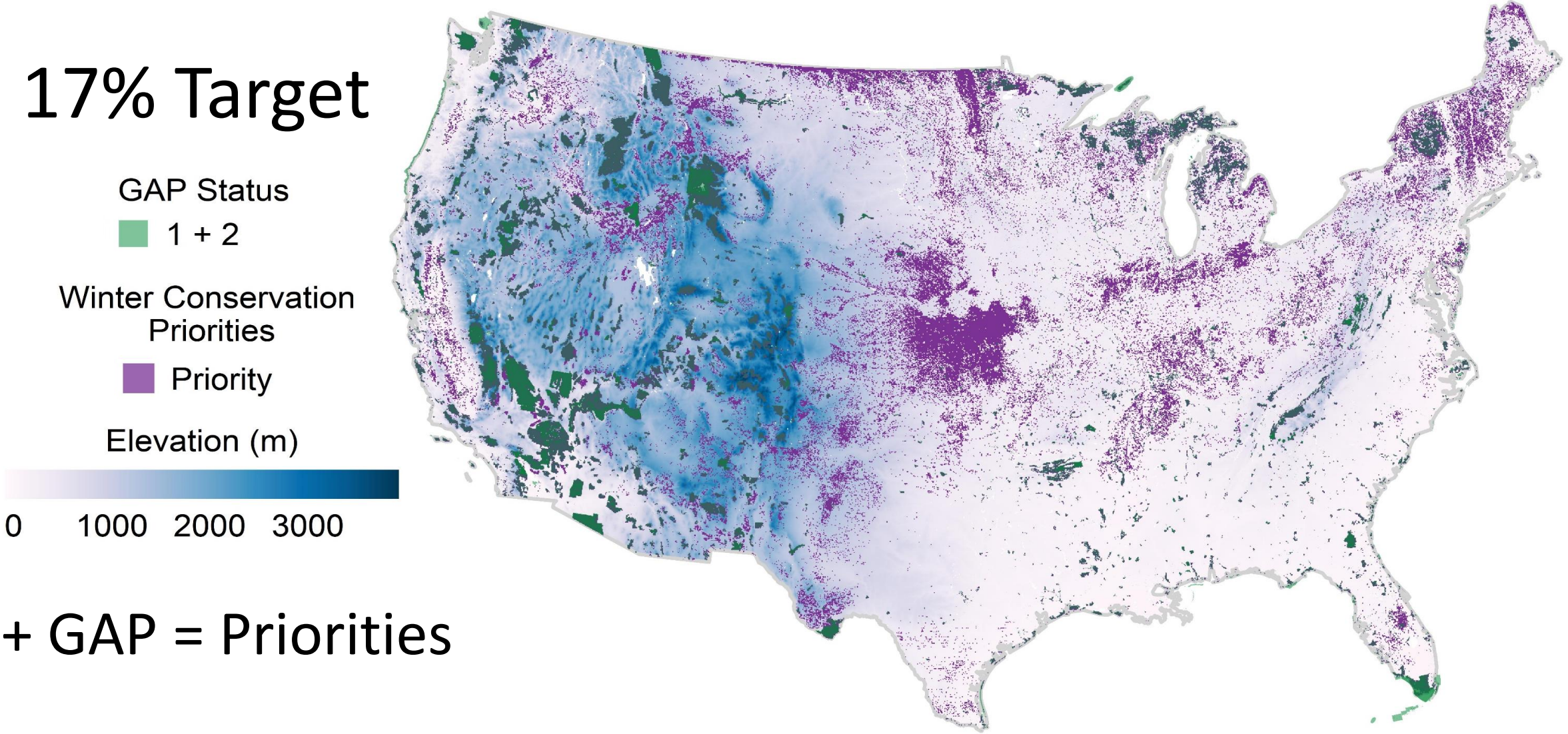
Protected Areas for 90th percentile of snow-associated bird richness



13% Coverage (Gap 1 and 2)

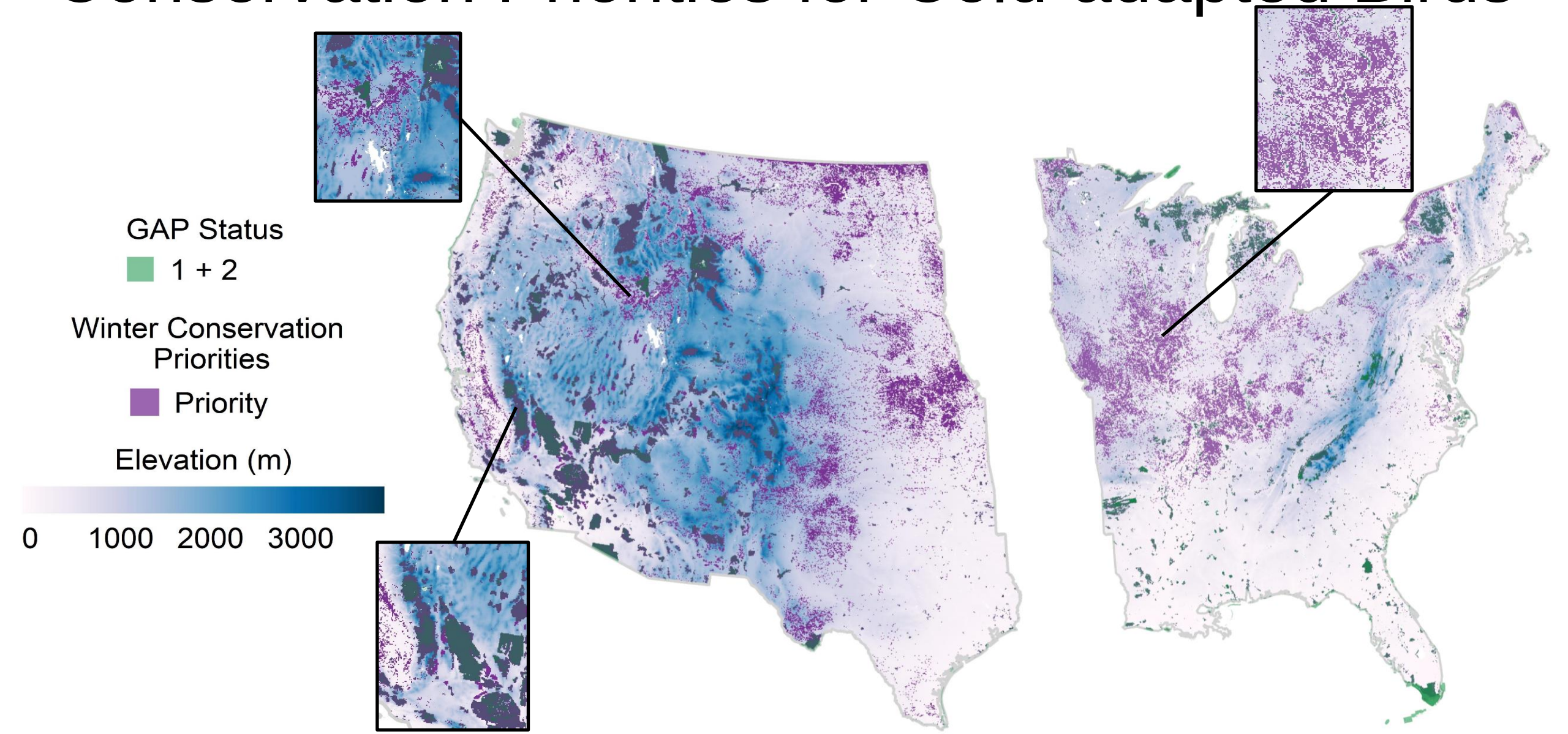
Conservation Priorities for Winter-adapted Birds

17% Target



$ + GAP = Priorities

Conservation Priorities for Cold-adapted Birds



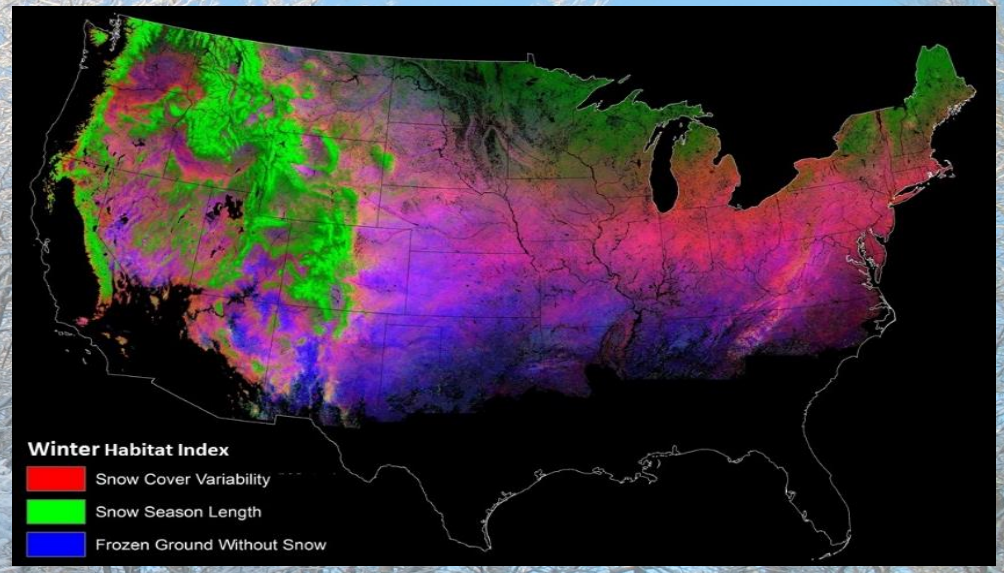
Winter Biodiversity

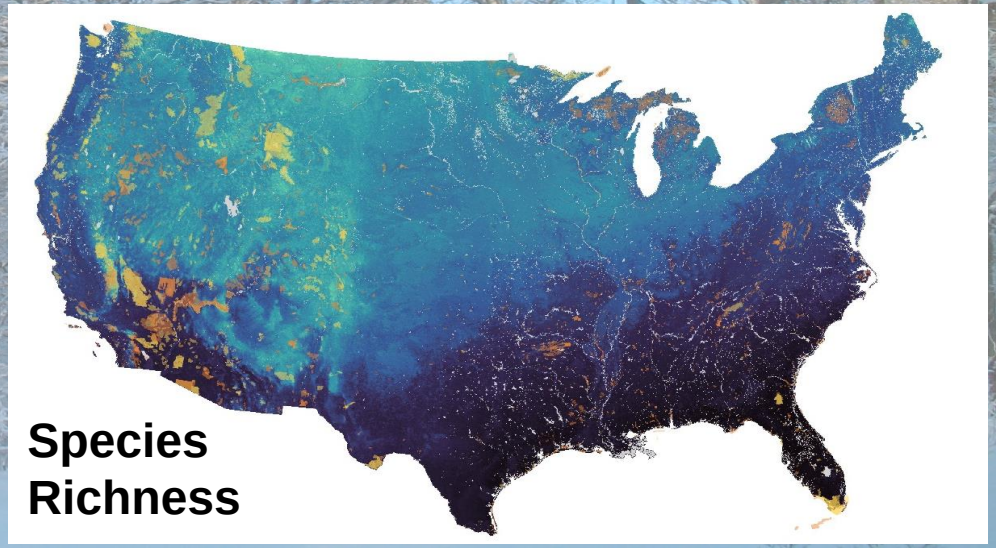
Snow is habitat!

WHIs for conservation planning

Winter diversity lacks protection

Varies geographically





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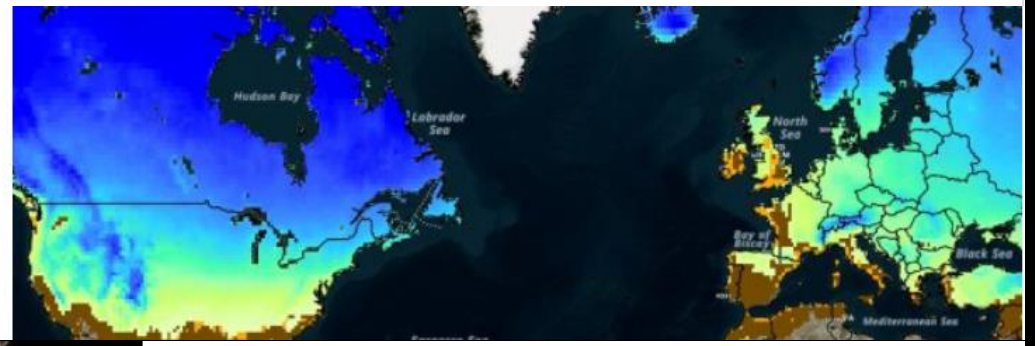
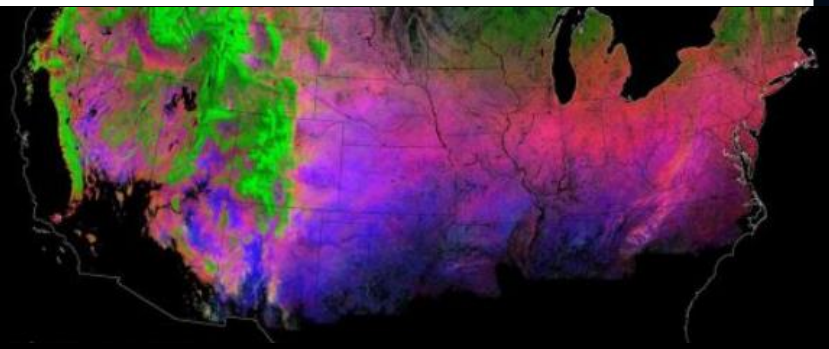
GLOBAL SUBNIVIUM DATA

Snow Cover & Snow Free Duration

Start/End/Length of Frozen Season

Global Subnivium Data »





WINTER HABITAT INDICES (WHIS)

WHIs based on Snow Cover Variability, Snow Season Length, and Frozen Ground without Snow duration.

WHIs Data & Maps »