SEASONAL RESOURCE SELECTION BY INTRODUCED MOUNTAIN GOATS IN THE SOUTHWEST GREATER YELLOWSTONE AREA

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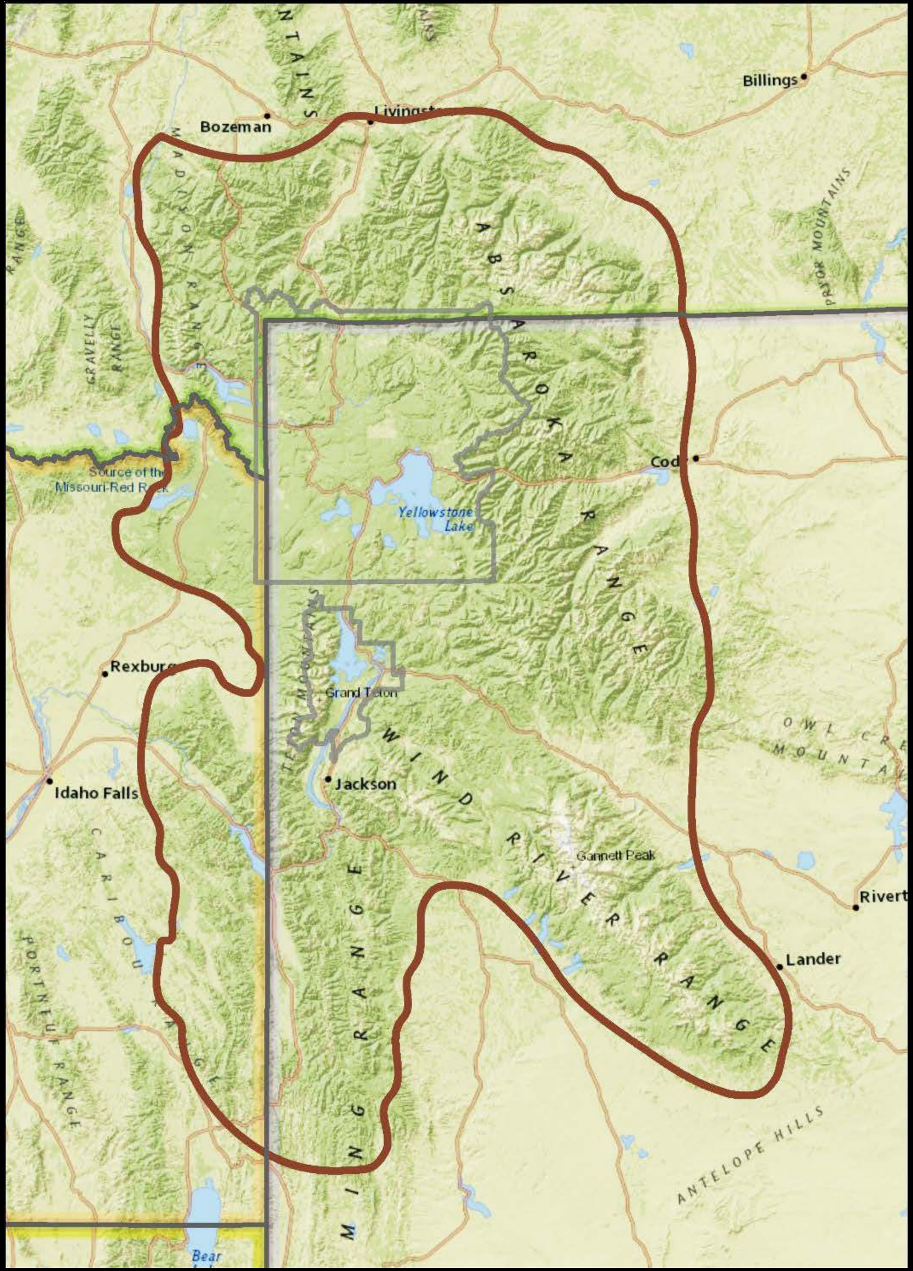
The Greater Yellowstone Area Mountain Ungulate Project

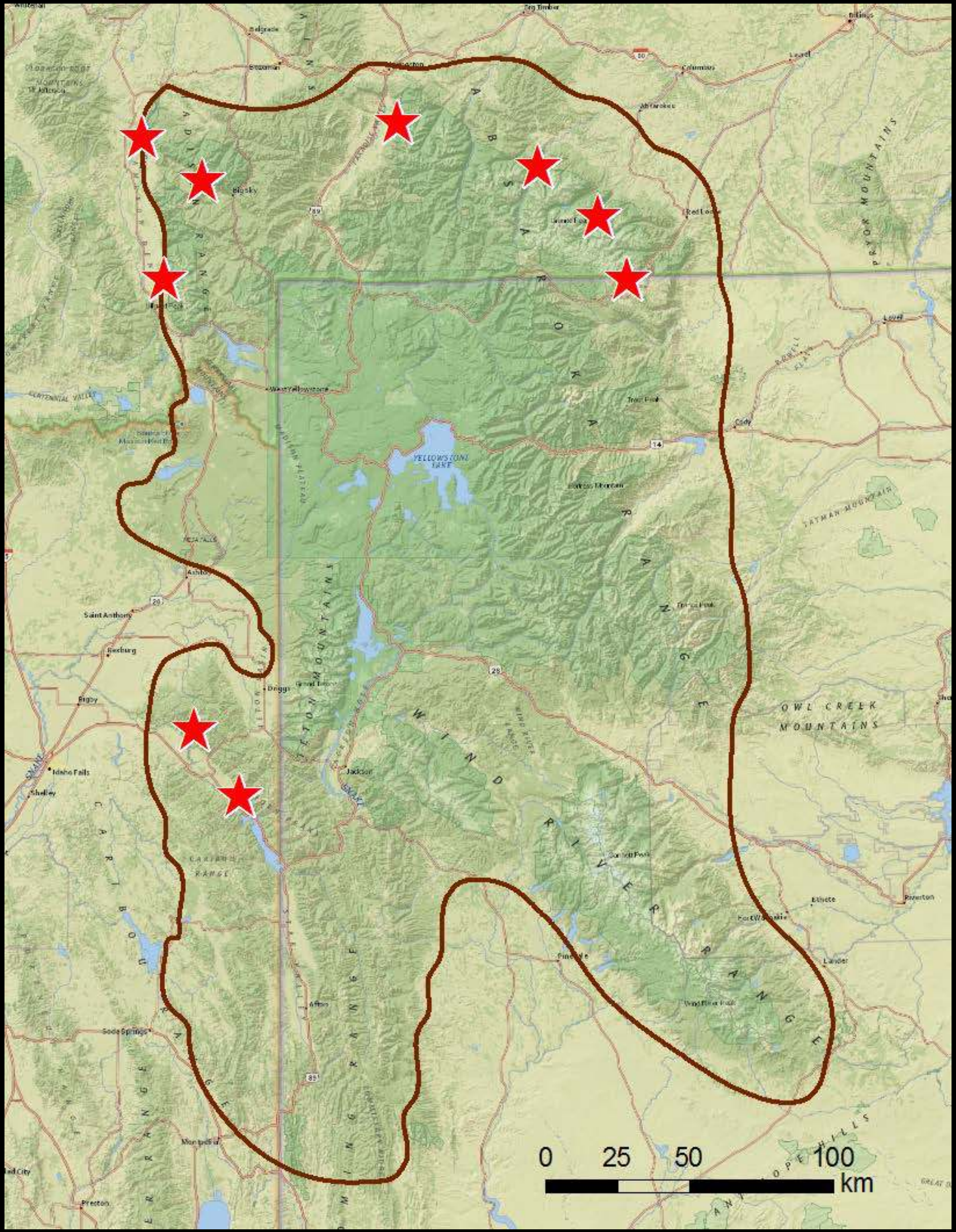
Initiated in 2009

Large-scale collaborative research effort

Project Goal

Develop and implement comparative studies of sympatric and allopatric mountain ungulates within the GYA.





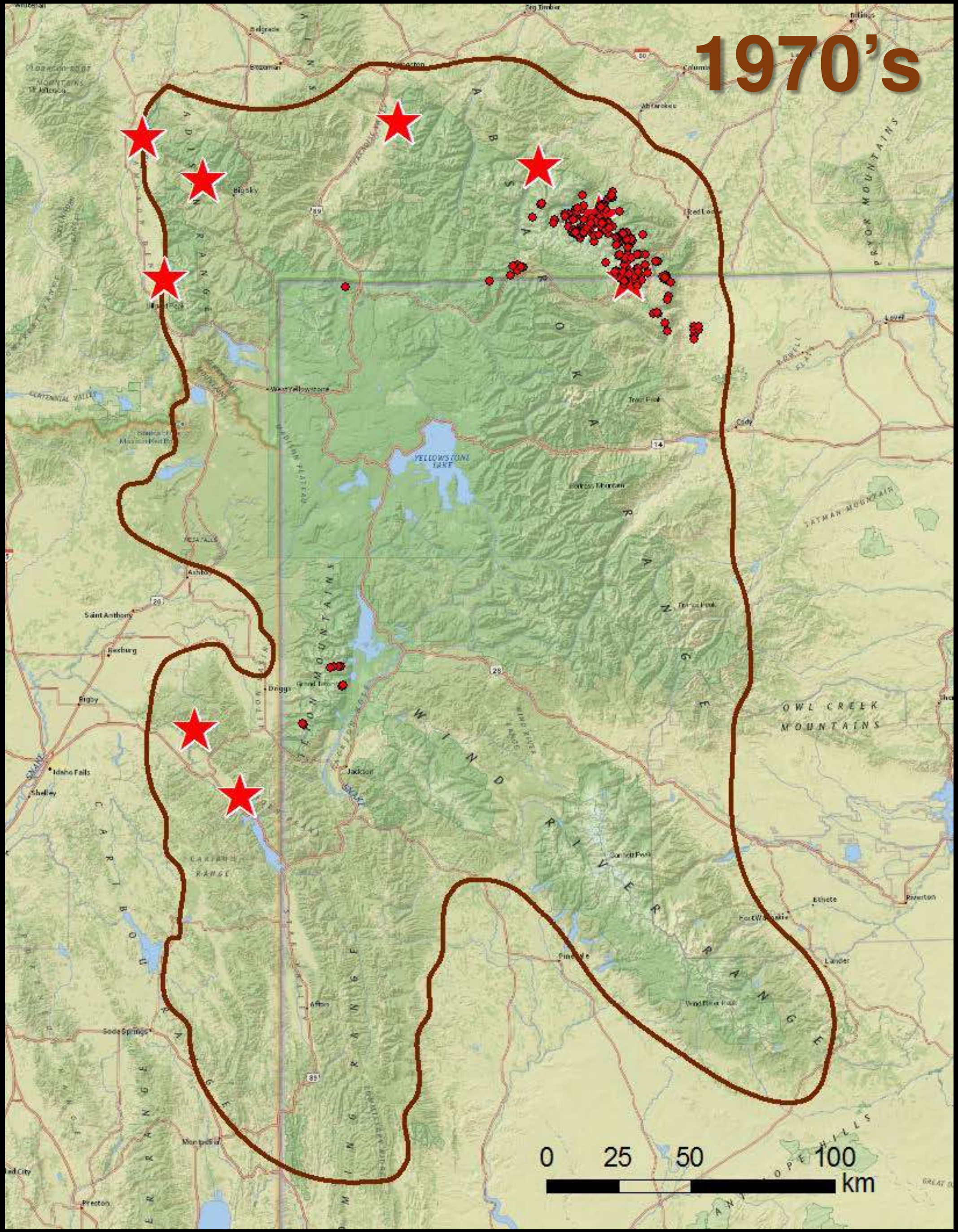
Mountain Goats in the GYA

Non-Native

Nine Introduction Sites

Introduced Montana 1942-1959
Introduced Idaho 1969-1971

Mountain Goats in the GYA



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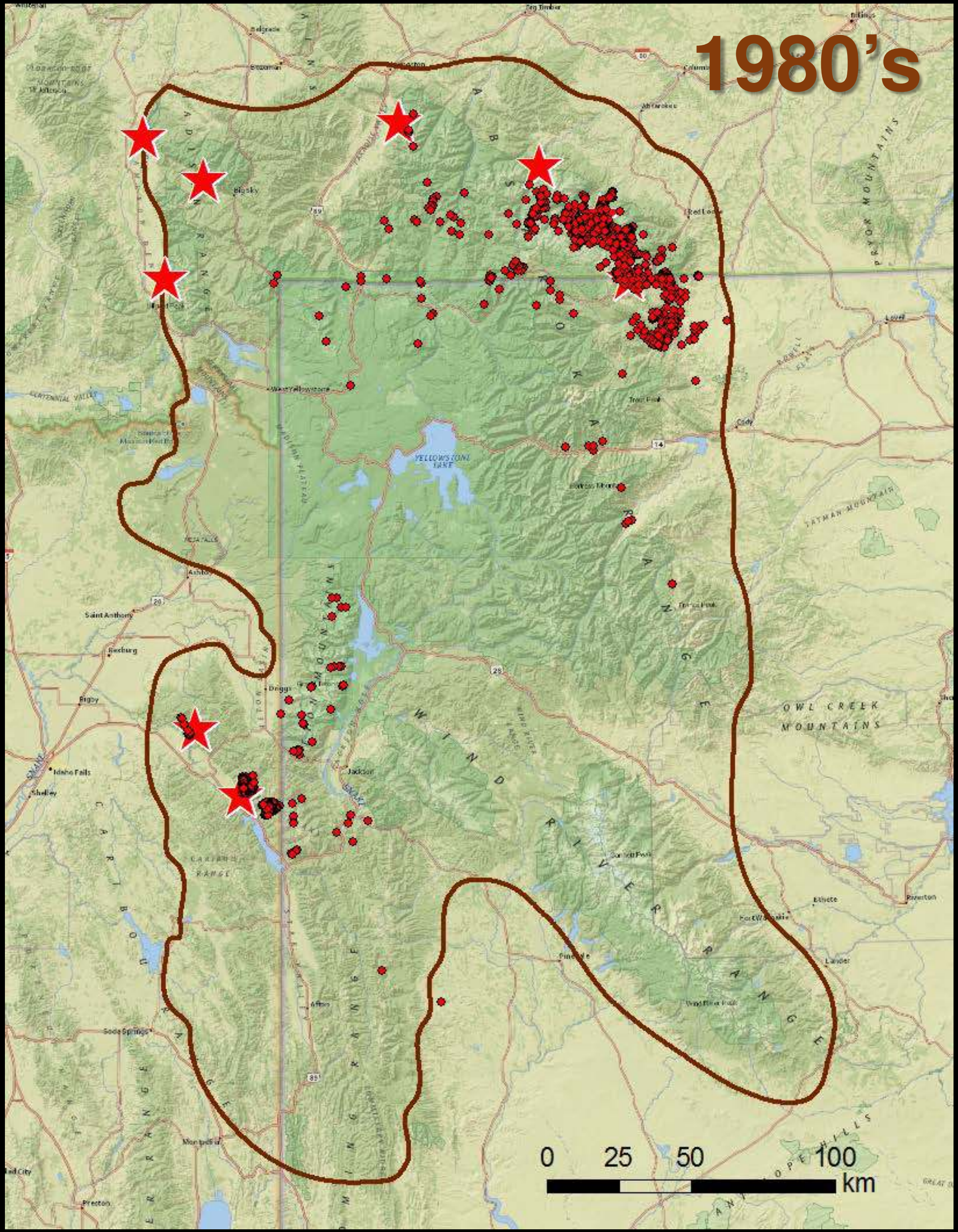

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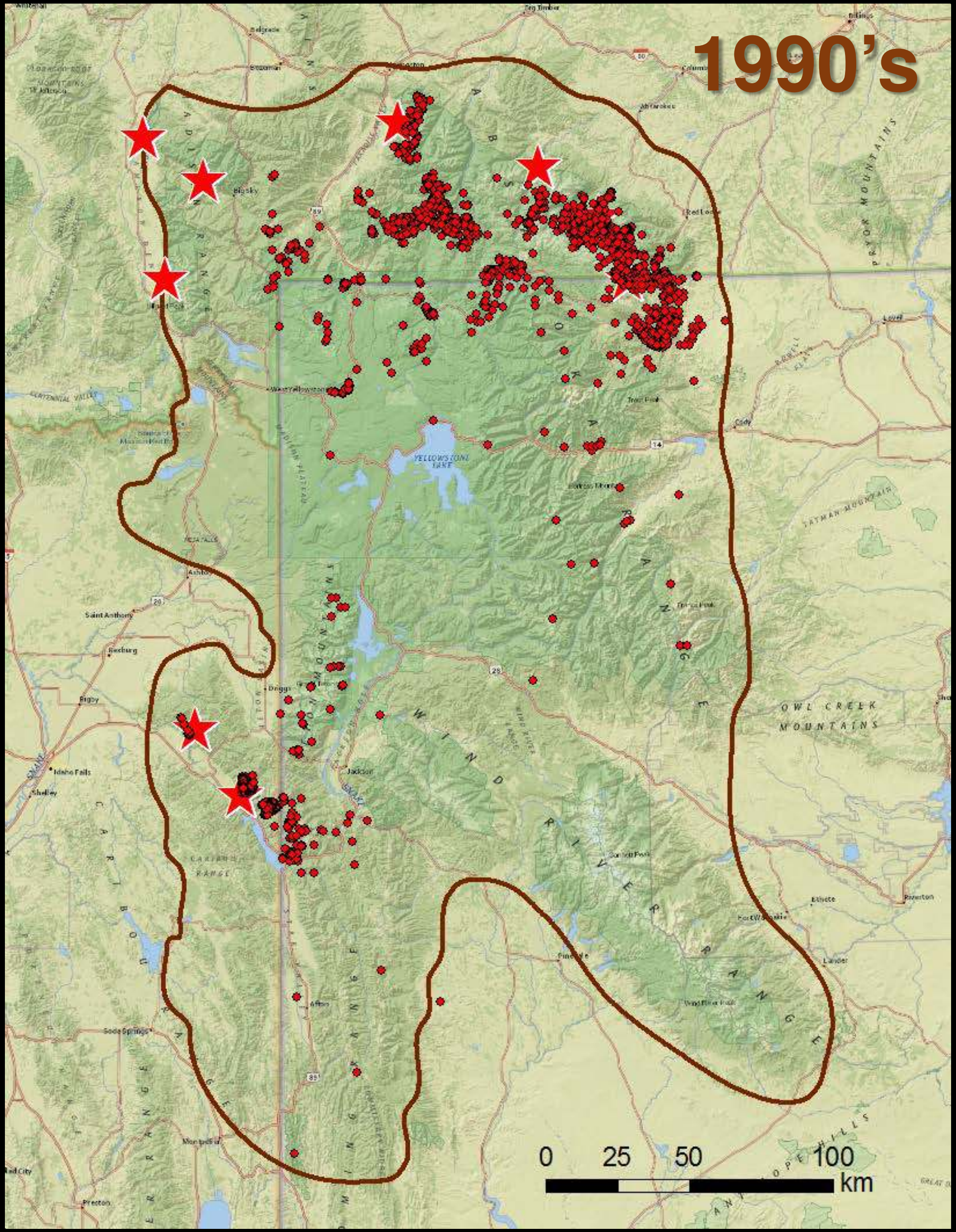

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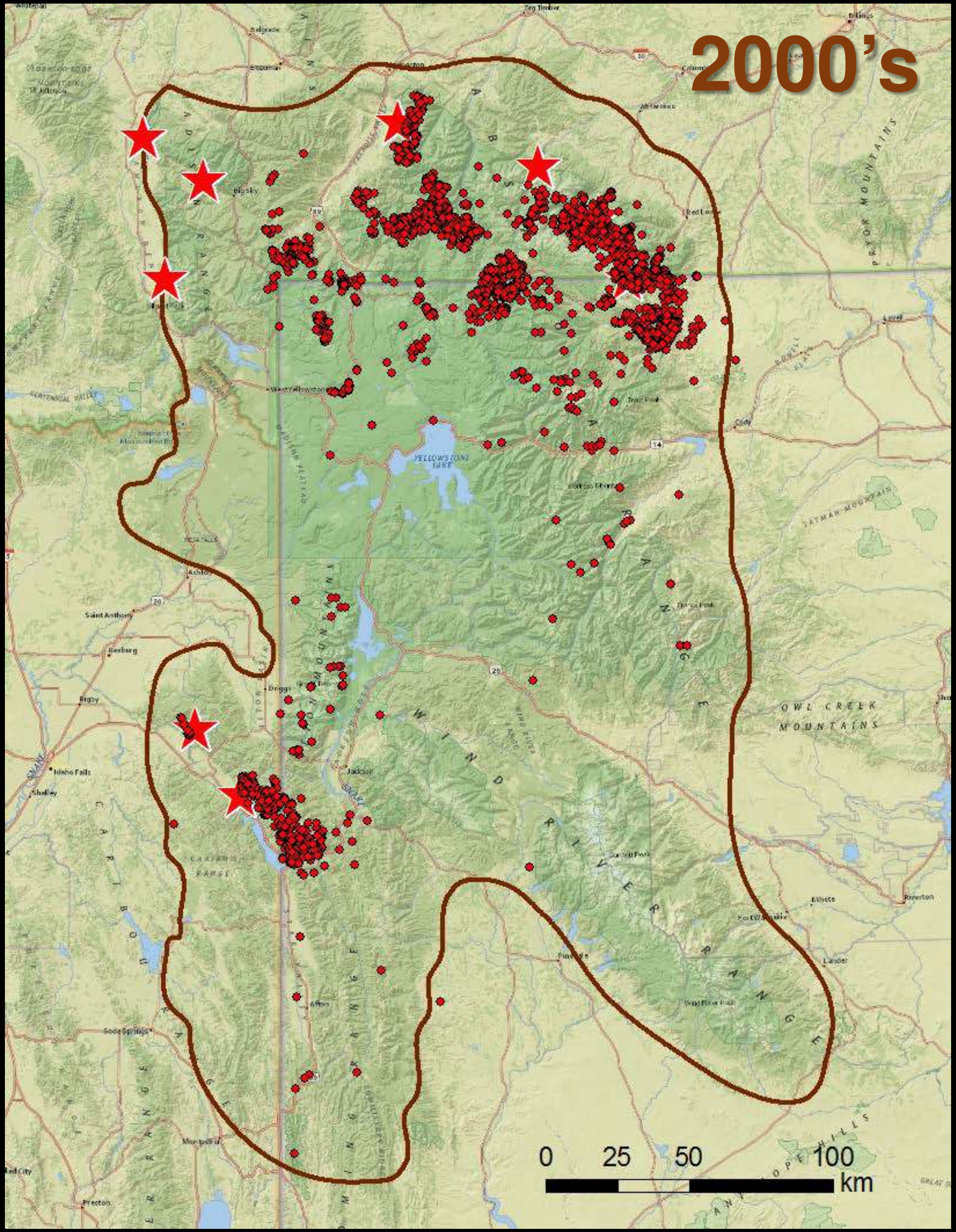

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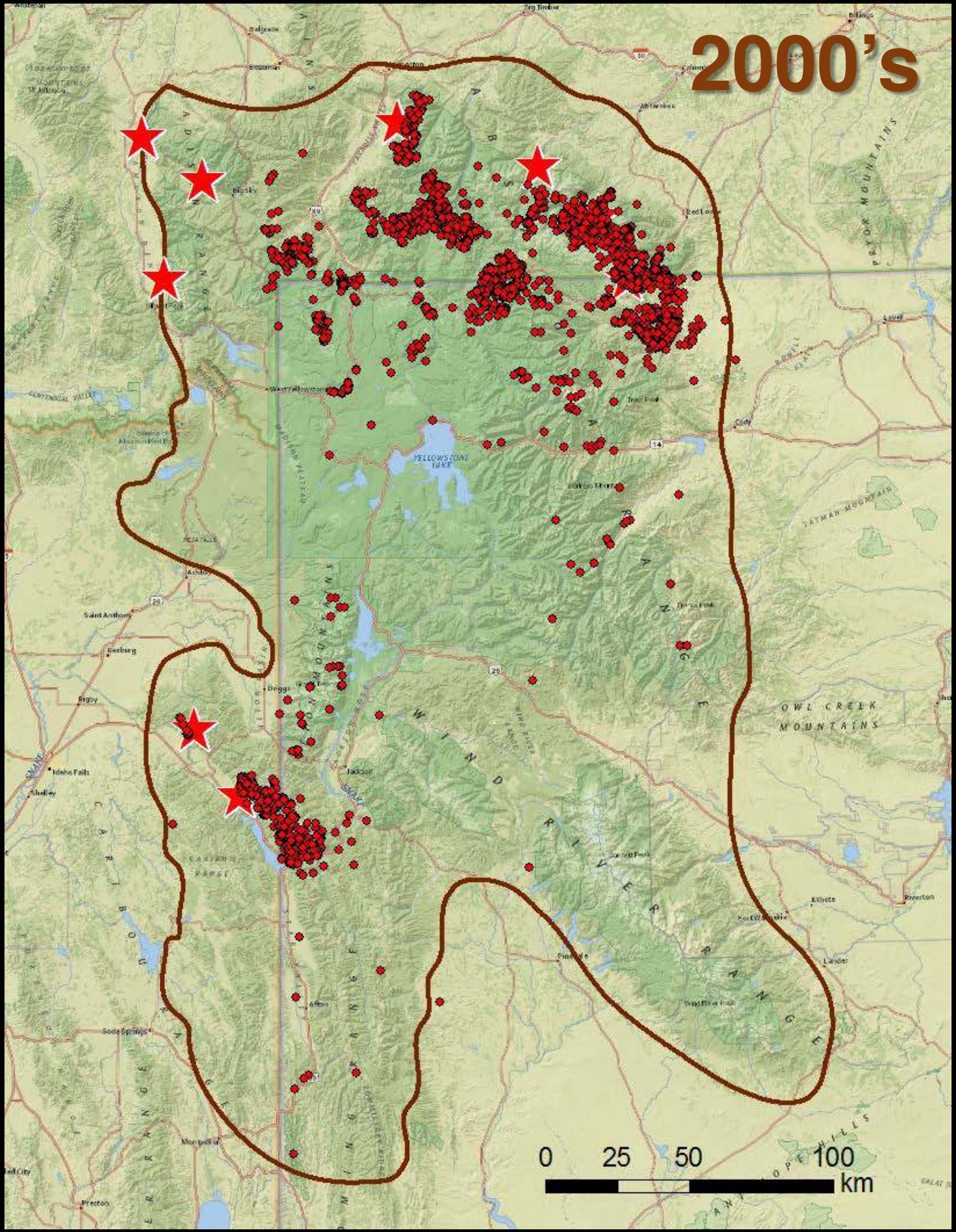
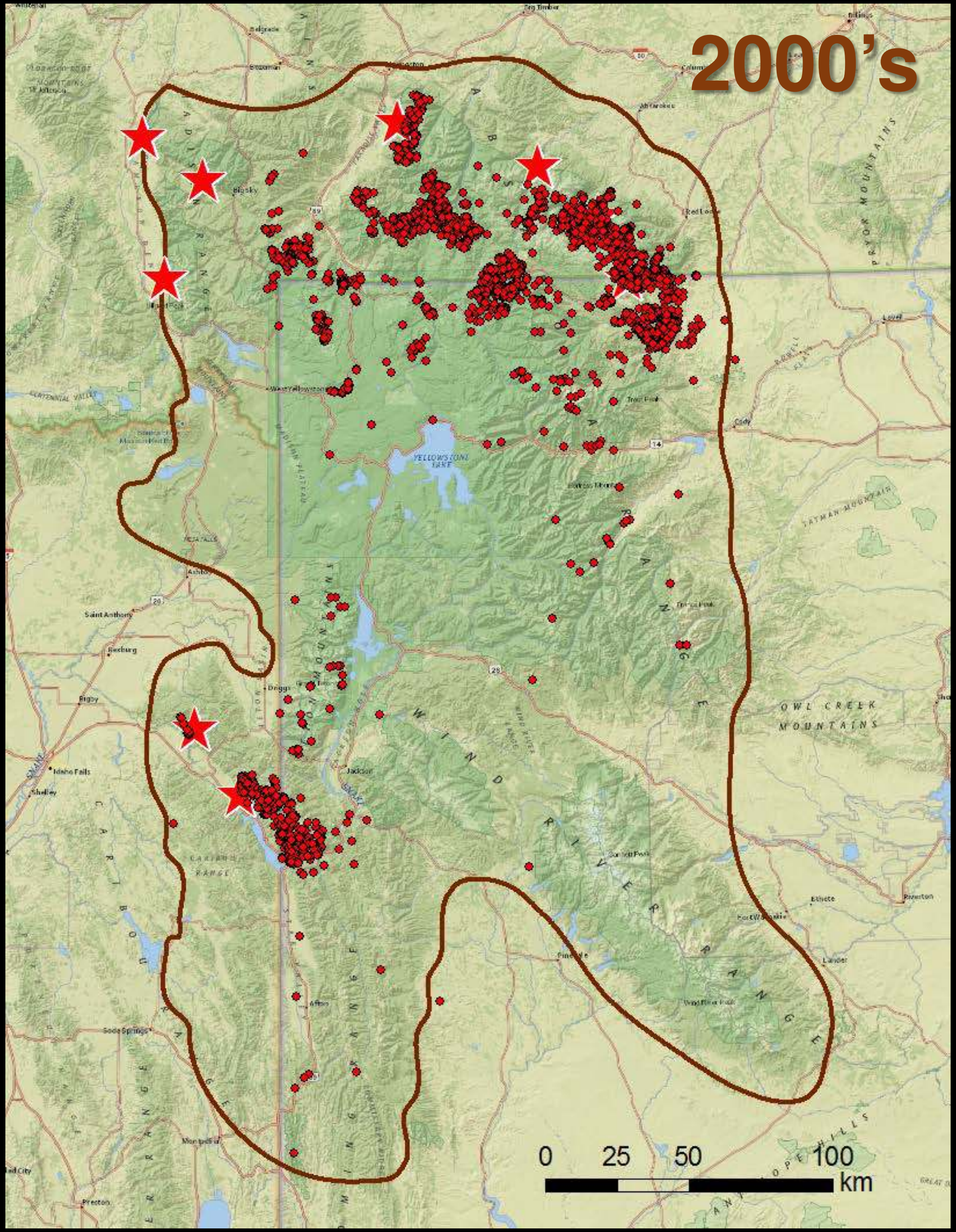


Mountain Goats in the GYA

Limited data available to inform management



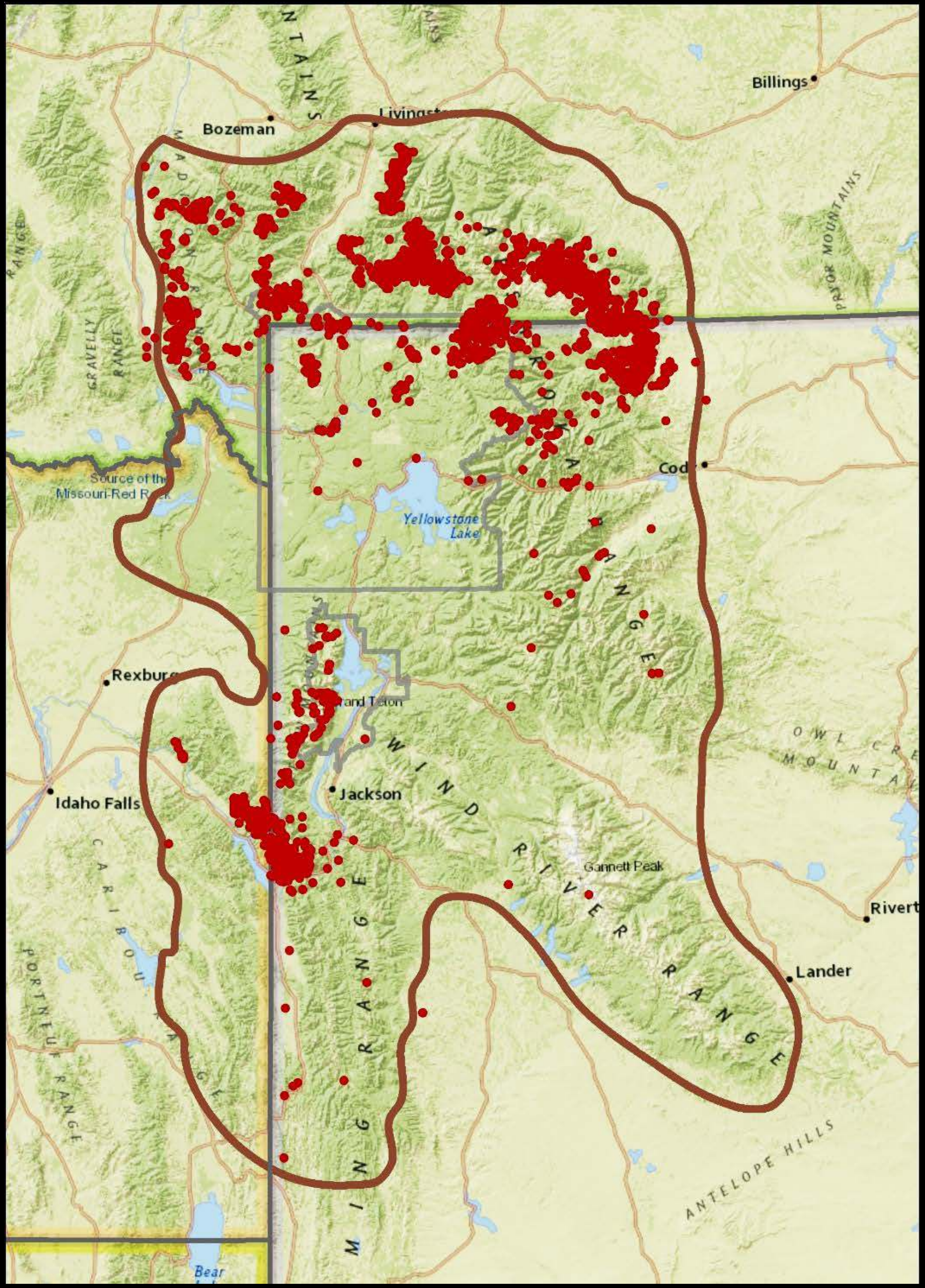
Mountain Goats in the GYA

Limited data available to inform management

- Identify seasonal ranges and habitat preferences
- Document seasonal movement strategies
- Assess the prevalence of respiratory pathogens
- Document population vital rates

Mountain Goats in the GYA

Broad scale trends



Mountain Goats in the GYA

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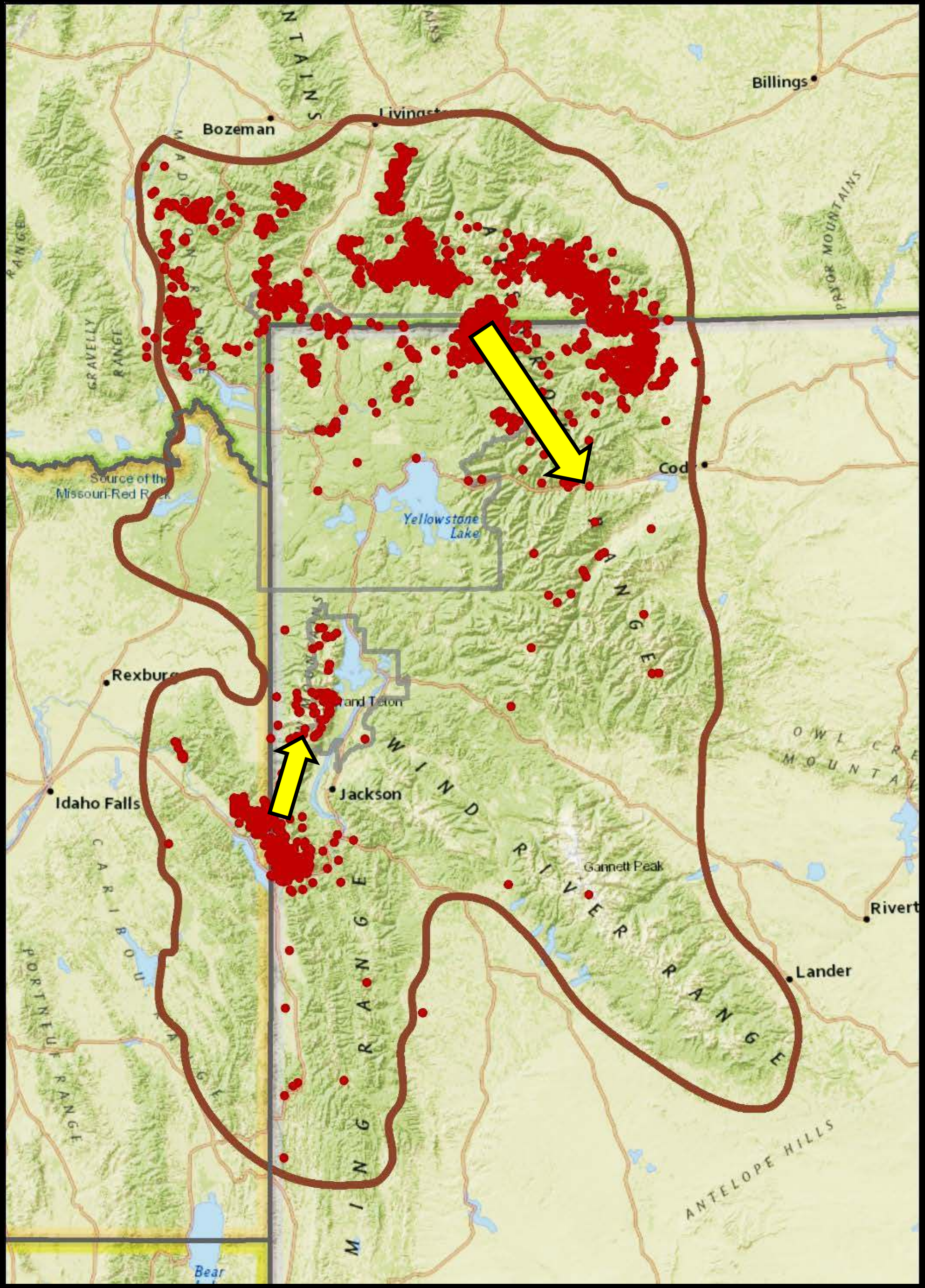
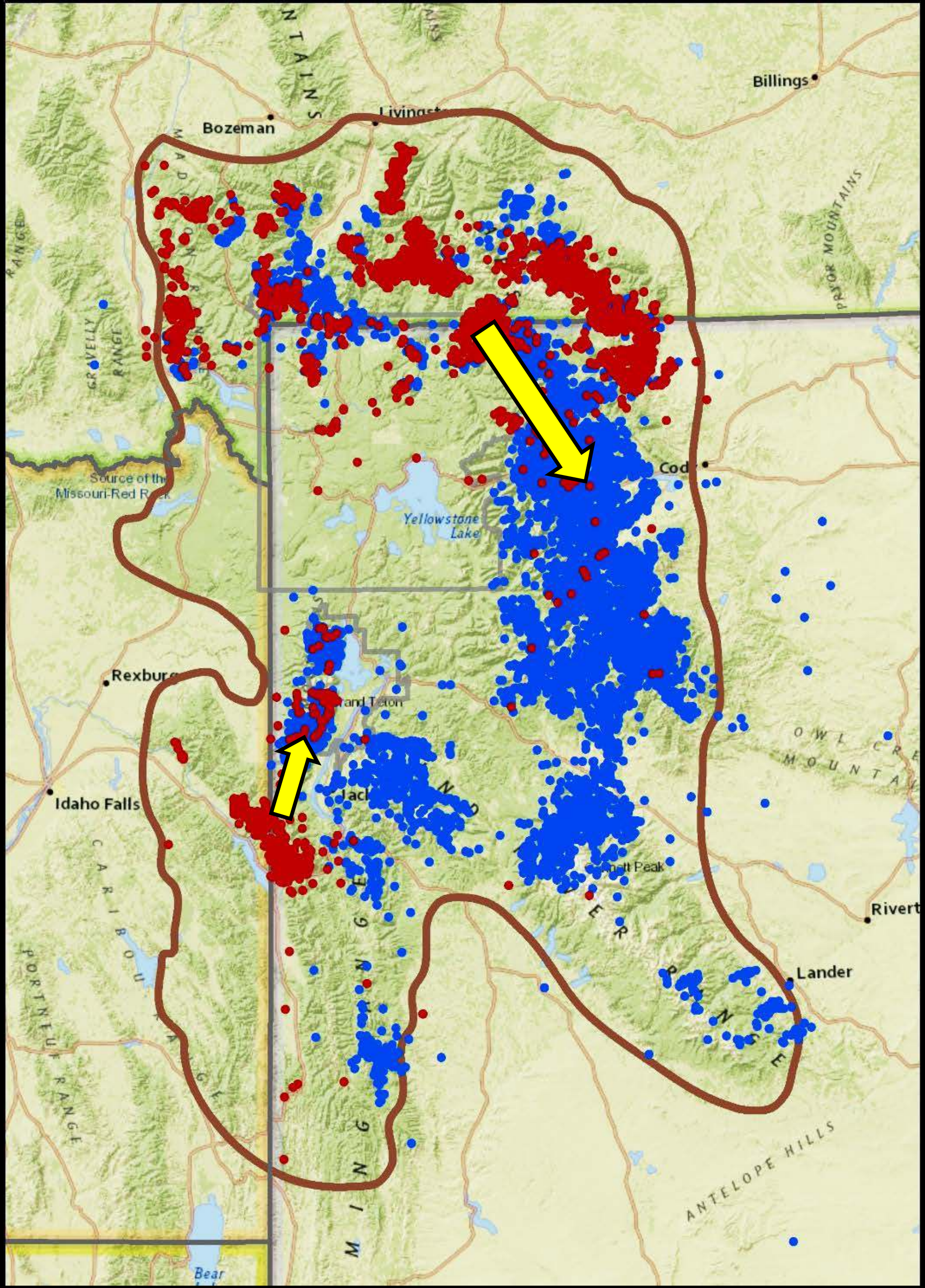


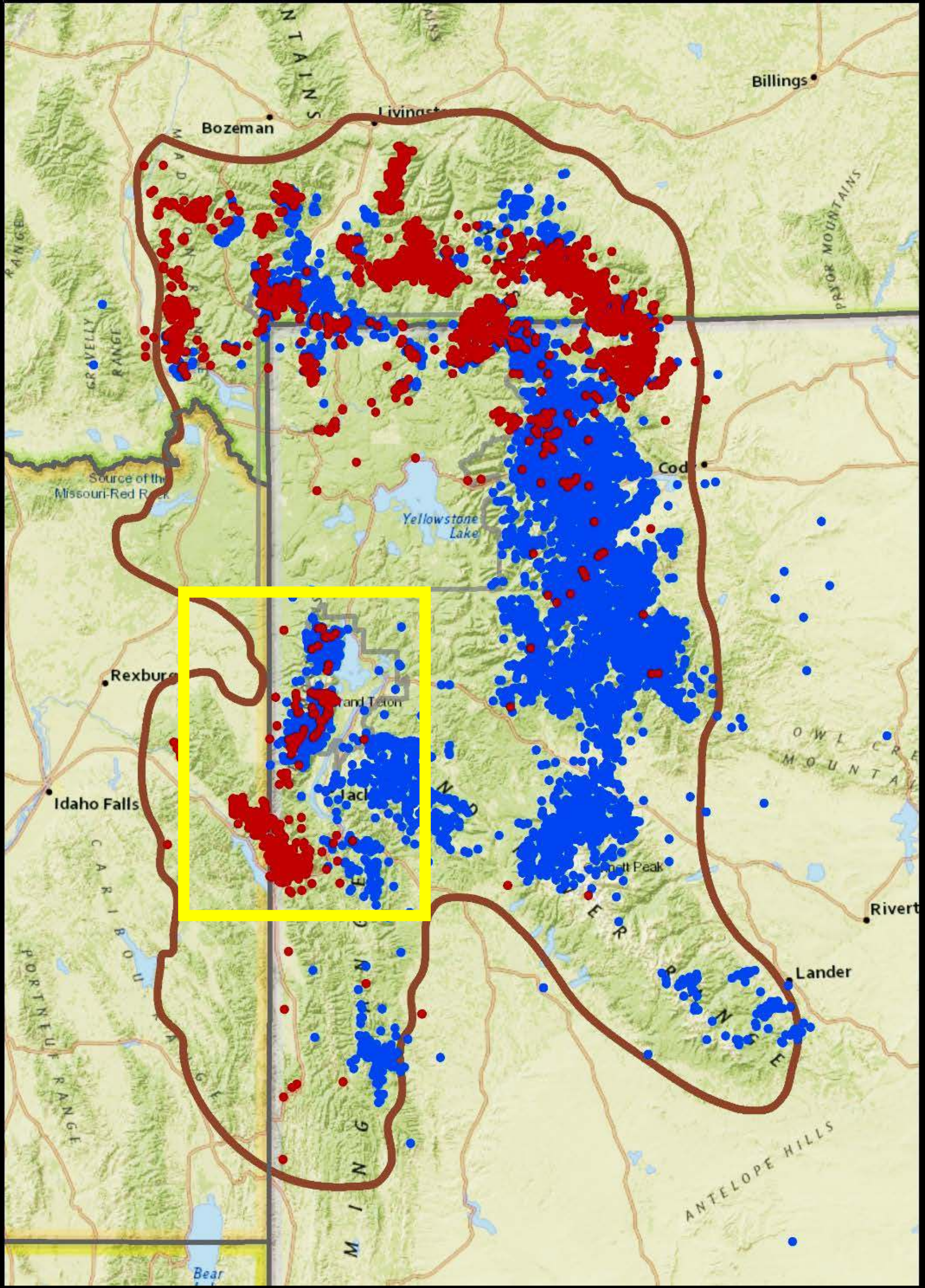
Mountain Goats in the GYA

Potential for increased competition with native bighorn sheep

Additional vectors for respiratory pathogens



Mountain Goats in the GYA

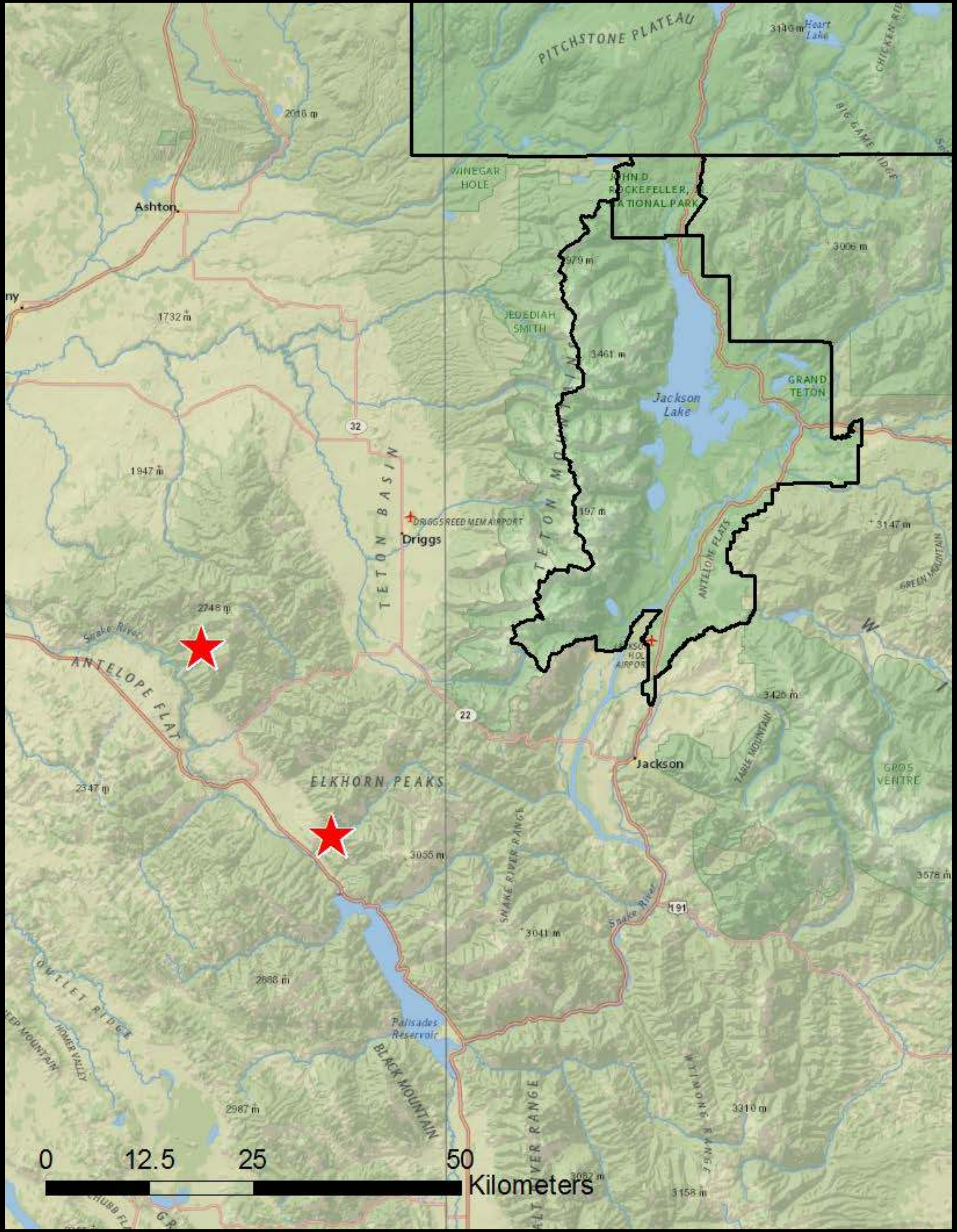


Potential for increased competition with native bighorn sheep

Additional vectors for respiratory pathogens

Snake River Range, ID and WY

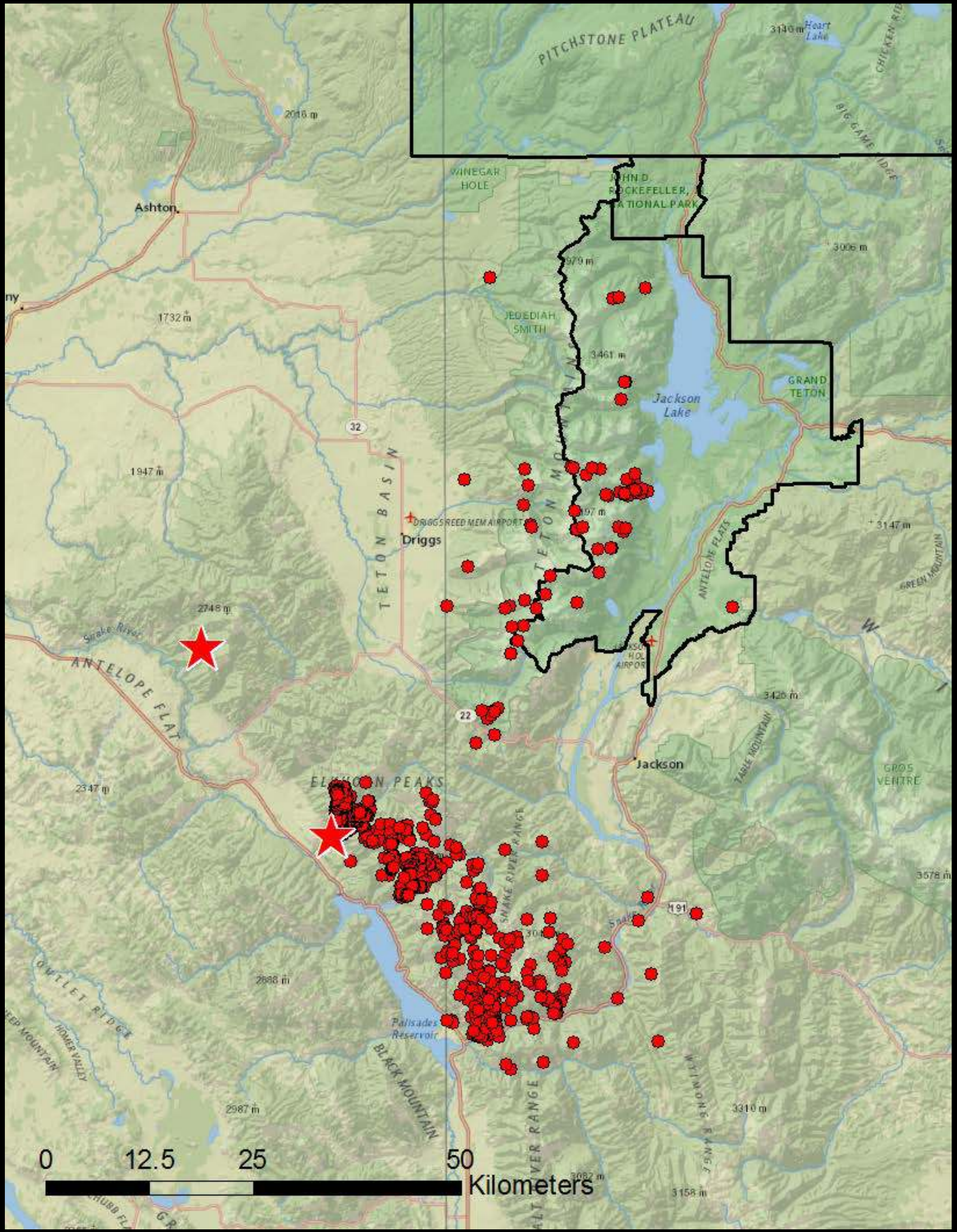
- Palisades Creek 1969 – 5 individuals
- Black Canyon 1970 – 7 individuals



Snake River Range, ID and WY

- Palisades Creek 1969 – 5 individuals
- Black Canyon 1970 – 7 individuals

300 individuals in 2014



Mountain Goats in the Teton Range

- Sporadic observations from 1970's to 2008
- Since 2008 nannie and kid groups have been documented every year
- 20-40 mountain goats in 2014
- 40-60 estimated currently

Mountain Goats in the Teton Range

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Concern of spatial overlap and competition with native bighorn sheep

Research Objectives

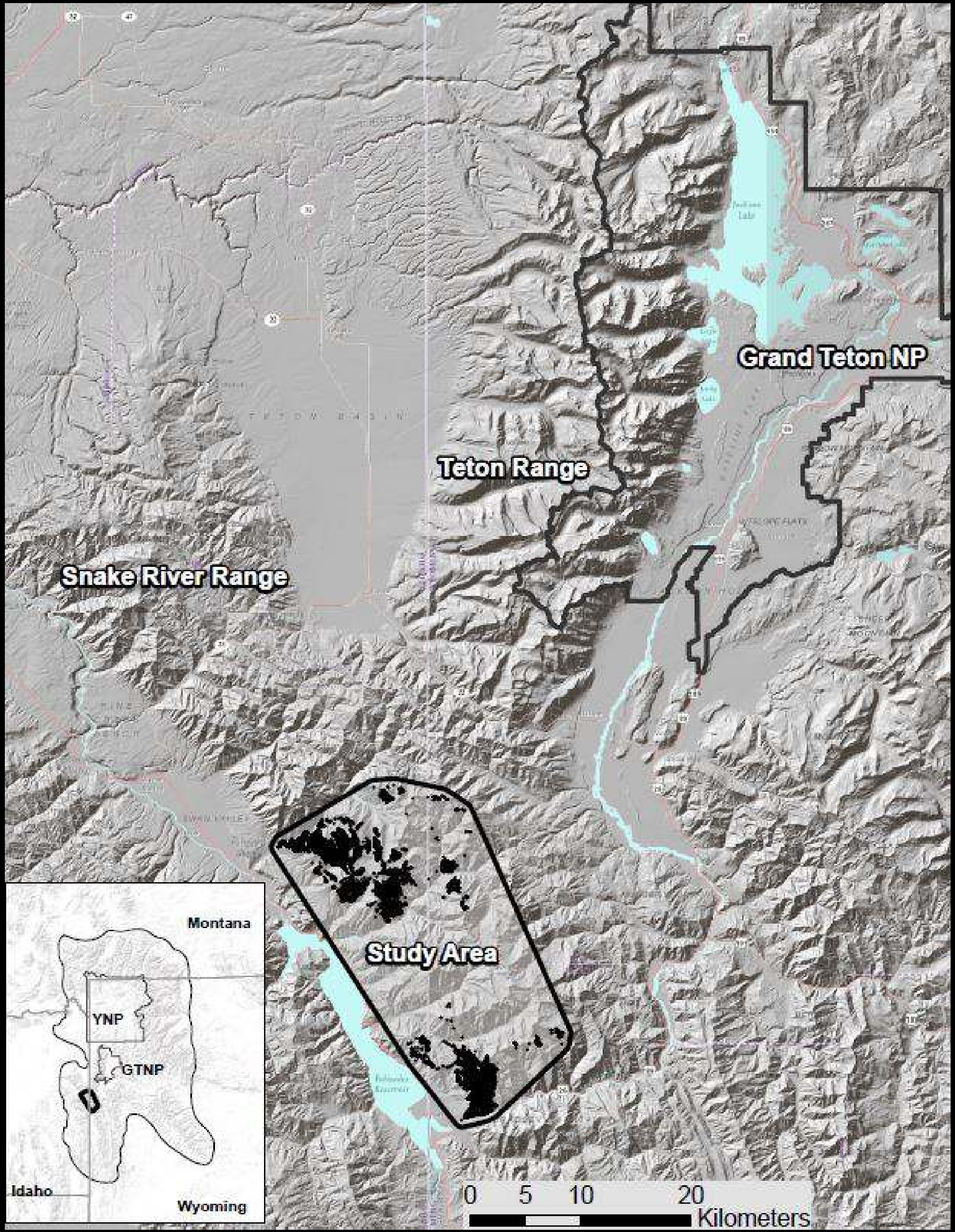
Describe mountain goat seasonal resource selection within the southwest GYA

1) Describe seasonal movement strategies.

2) Identify the terrain and environmental characteristics most strongly associated with seasonal ranges.

3) Extrapolate predictive models to examine the potential of mountain goats to expand throughout the region.

Study Area


Grand Teton NP
Teton Range
Snake River Range
Study Area
Montana
YNP
GTNP
Idaho
Wyoming
0 5 10 20
Kilometers

Capture and Handling

- Captures began in 2011
- Ground darting and helicopter net gunning
- Deploy GPS/VHF collar pairs
- Biological samples

Study Design and Sampling Framework

- Evaluated population-level resource selection
- Availability extent
  - Buffered population MCP
- Generated random samples of points at a ratio of 1:10 (used:available)
- Generalized linear mixed-effect models (GLMM)

(Manly et al. 2007, Gillies et al. 2006, Fieberg et al. 2010)

Landscape Covariates

Covariate		
Terrain		
Solar		
Vegetation		
Snow		

Landscape Covariates

Covariate		
Terrain		
Elevation		
Slope		
Standard deviation of slope curvature (CurvSD)		
Slope variance (SlopeVar)		
Terrain ruggedness (VRM)		
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Vegetation		
Canopy cover		
NDVI amplitude		
Time integrated NDVI		
Snow		
Snow water equivalent		
Snow depth		

Landscape Covariates

Covariate	Functional Form	
Terrain		
Elevation	Li	
Slope	Li, Sq	
Standard deviation of slope curvature (CurvSD)	Li, Ps	
Slope variance (SlopeVar)	Li, Ps	
Terrain ruggedness (VRM)	Li, Ps	
Solar		
Solar radiation	Li	
Aspect (NE to SW, -1 to 1)	Li	
Vegetation		
Canopy cover	Li	
NDVI amplitude	Li	
Time integrated NDVI	Li	
Snow		
Snow water equivalent	Li	
Snow depth	Li	

(DeVoe et al. 2015)

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Snow		
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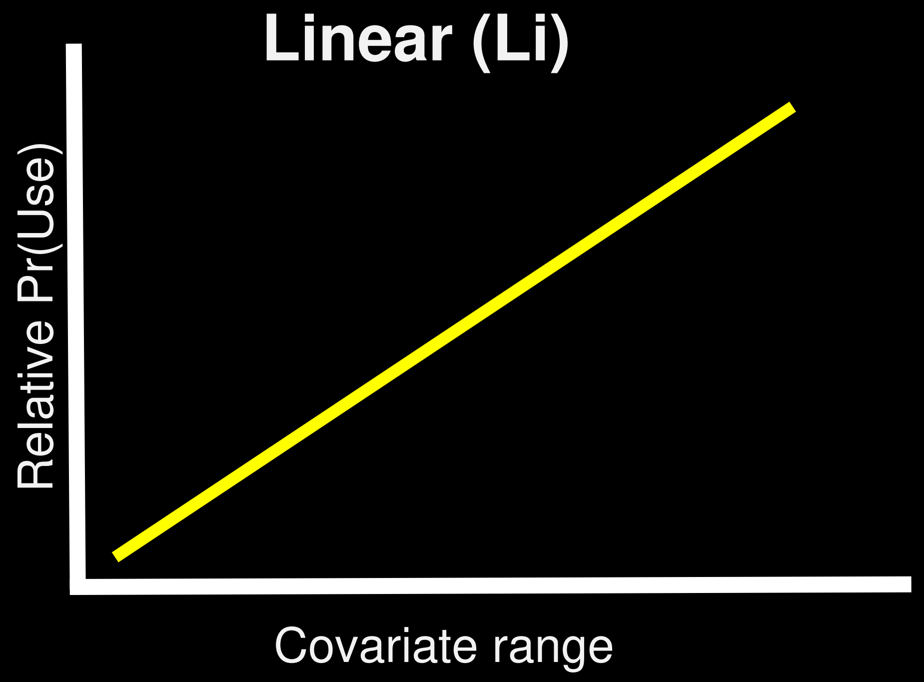
Snow depth	Li	



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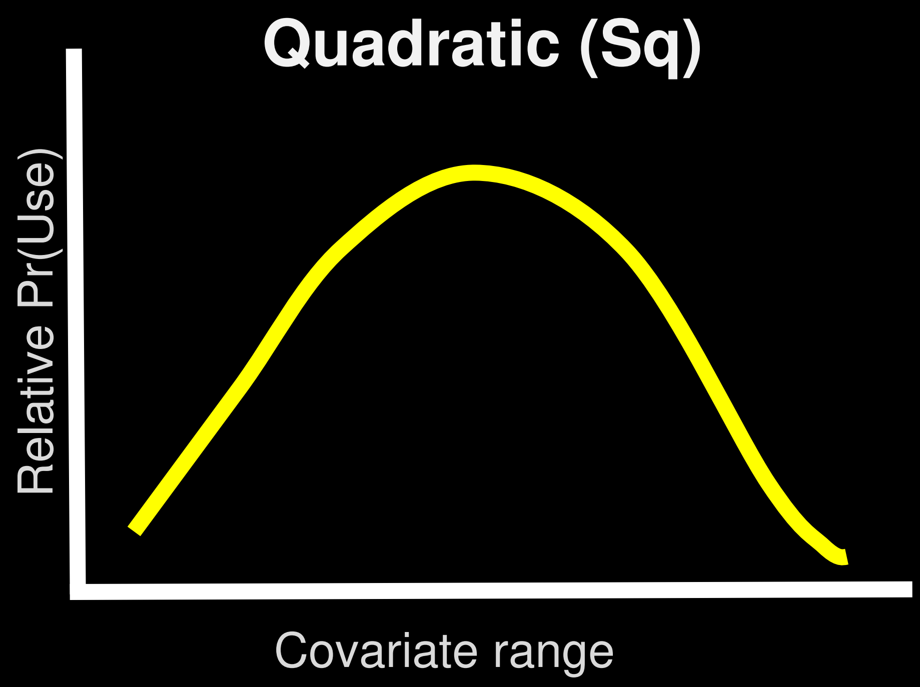

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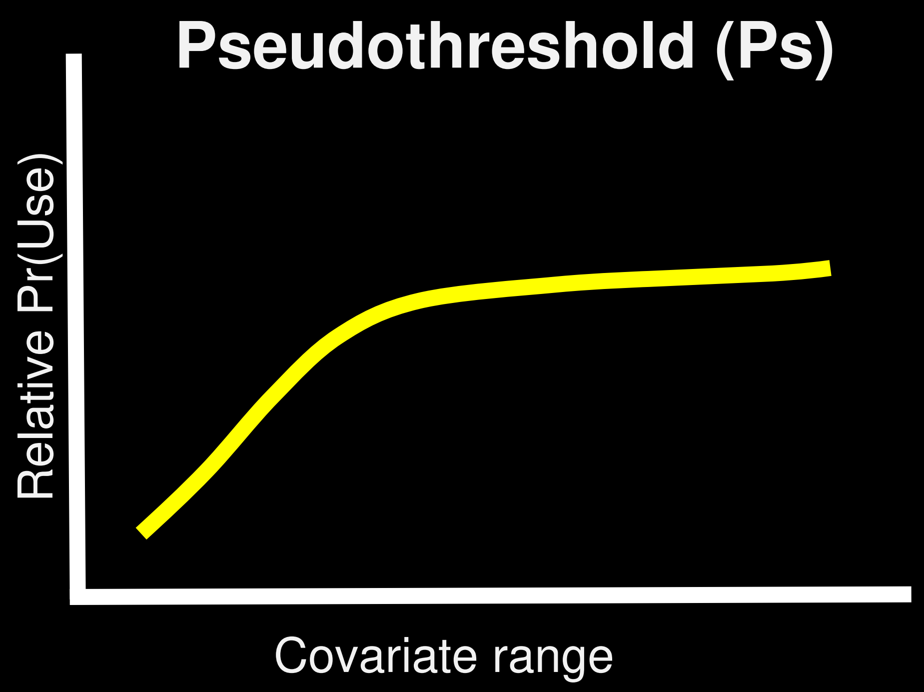

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Landscape Covariates

Covariate	Functional Form	Spatial Grains
Terrain		
Elevation	Li	30
Slope	Li, Sq	30, 100, 500, 1000
Standard deviation of slope curvature (CurvSD)	Li, Ps	30, 100, 500, 1000
Slope variance (SlopeVar)	Li, Ps	30, 100, 500, 1000
Terrain ruggedness (VRM)	Li, Ps	30, 100, 500, 1000
Solar		
Solar radiation	Li	30
Aspect (NE to SW, -1 to 1)	Li	30
Vegetation		
Canopy cover	Li	30, 100, 500, 1000
NDVI amplitude	Li	500, 1000
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Snow		
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(Meyer and Thuiller 2006, DeVoe et al. 2015, Laforge et al. 2015)

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Vegetation		
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NDVI amplitude	Li	500, 1000
Time integrated NDVI	Li	500, 1000
Snow		
Snow water equivalent	Li	1000
Snow depth	Li	1000

Spatial Grains

The size of an area surrounding a point (or pixel) within which ecological data are measured

(Meyer and Thuiller 2006, DeVoe et al. 2015, Laforge et al. 2015)

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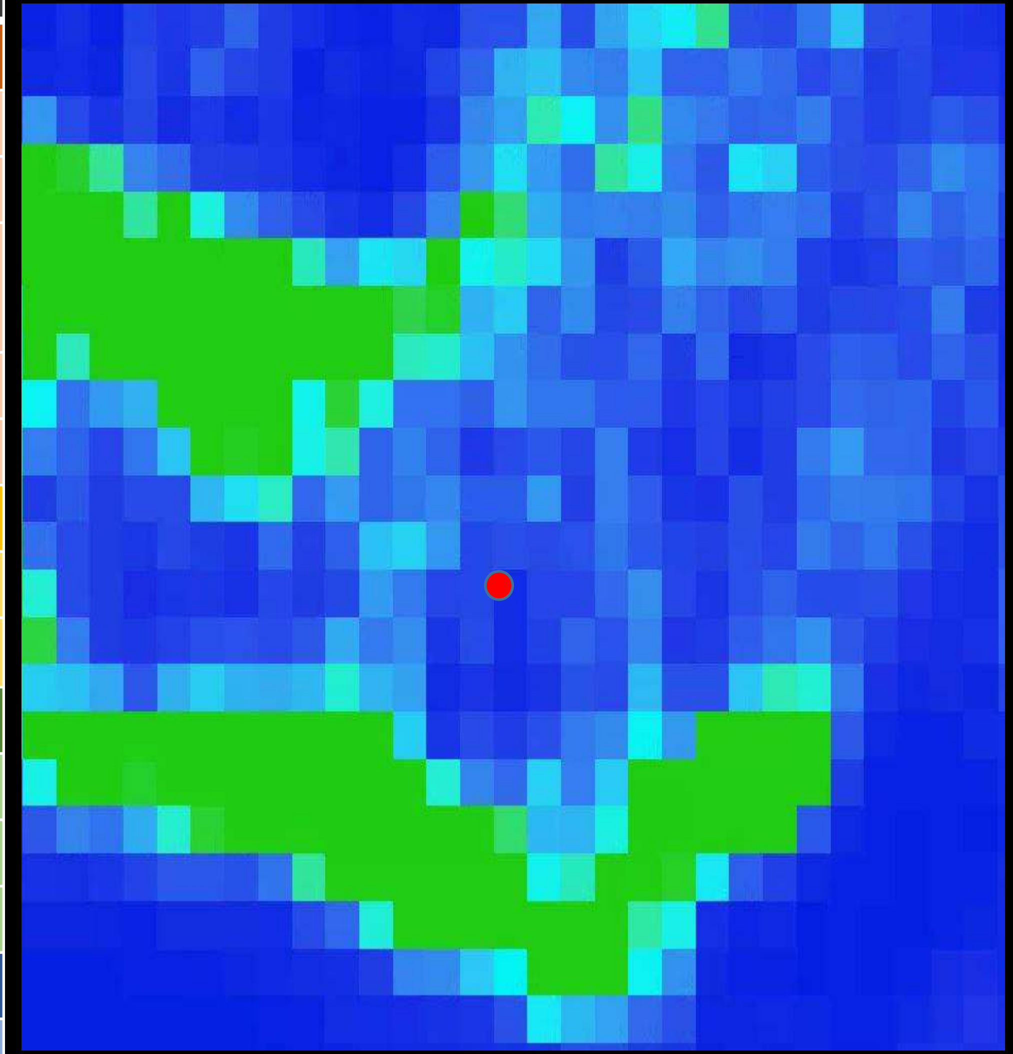

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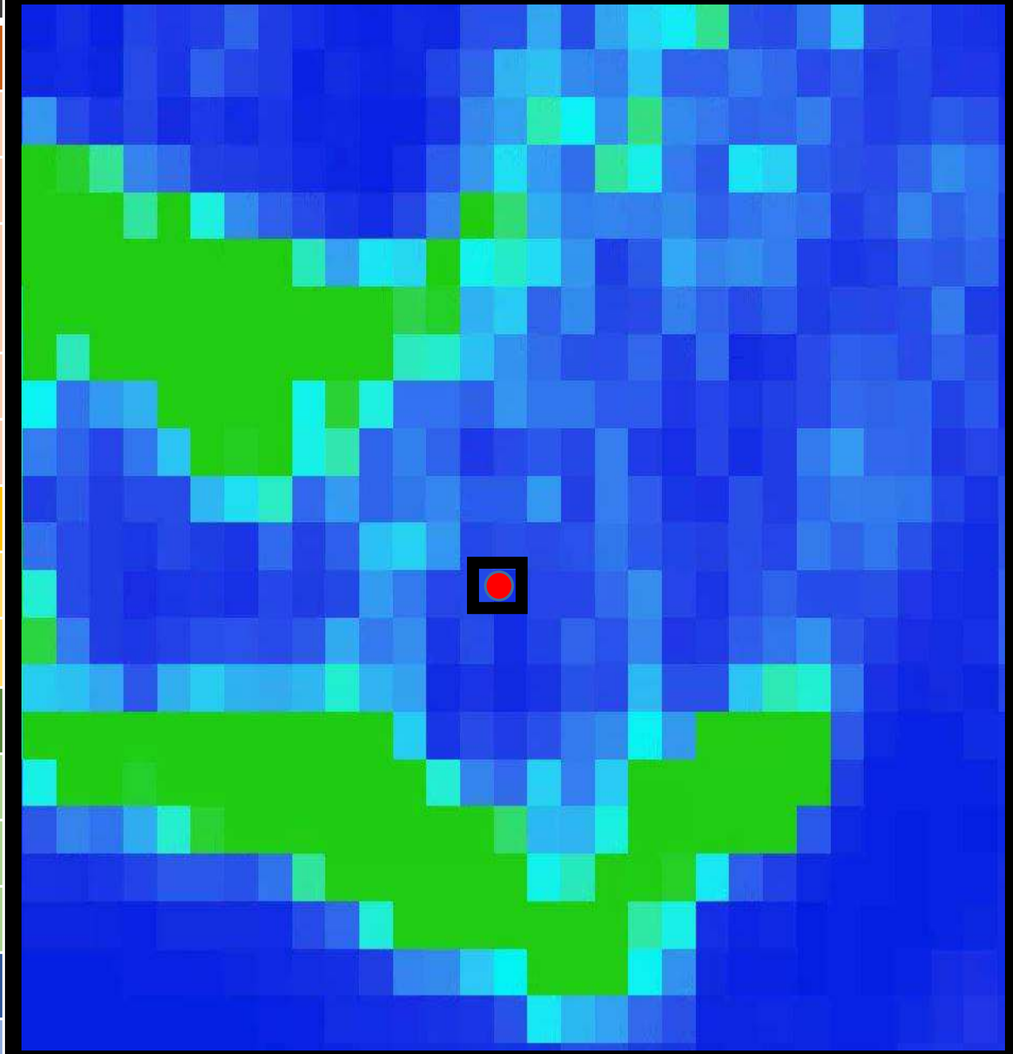

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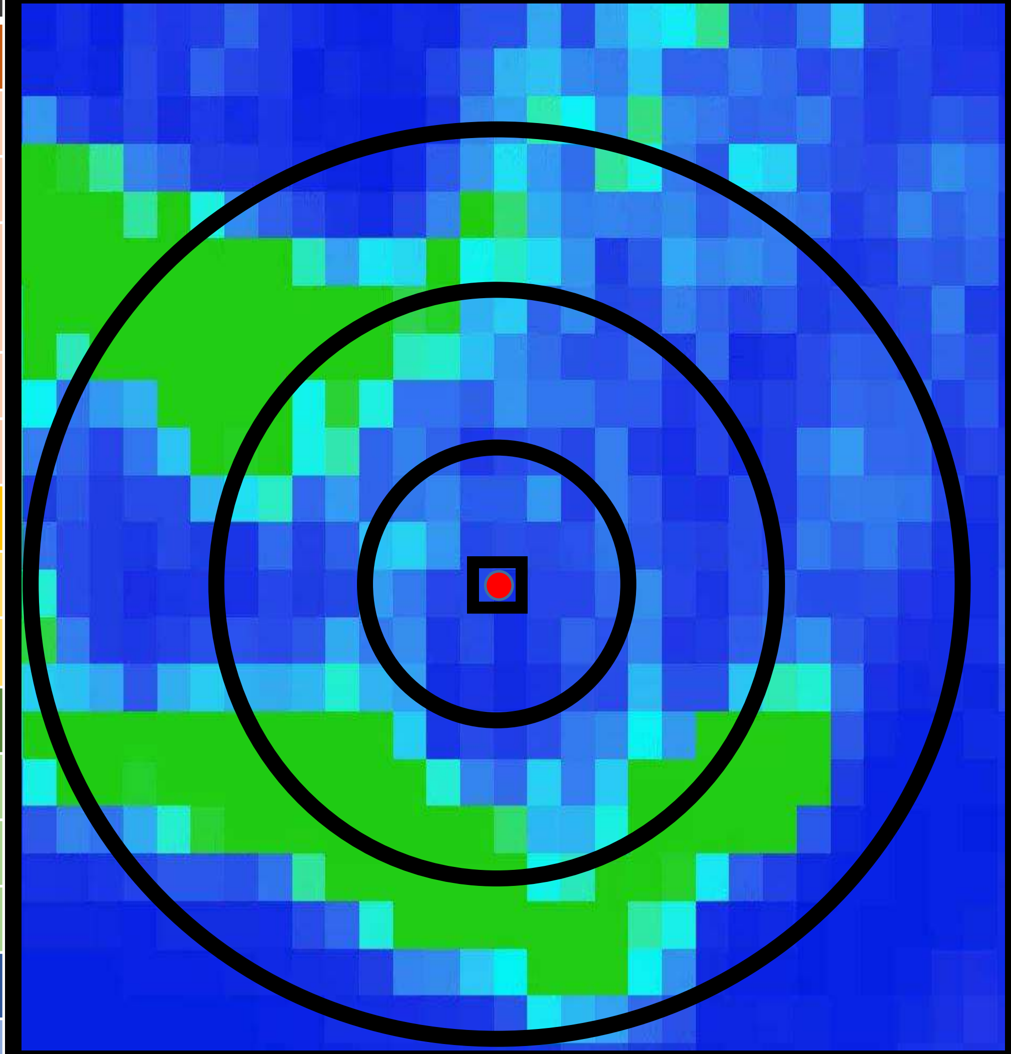

(Meyer and Thuiller 2006, DeVoe et al. 2015, Laforge et al. 2015)

Model Selection and Validation

- Tiered approach to model selection

Univariate

Functional Form
Spatial Grain

(Boyce et al. 2002, Burnham and Anderson 2002, Vaida and Blanchard 2005, Gillies et al. 2006, Fieberg et al. 2010)

Model Selection and Validation

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Univariate

Functional Form
Spatial Grain

→

Multivariate

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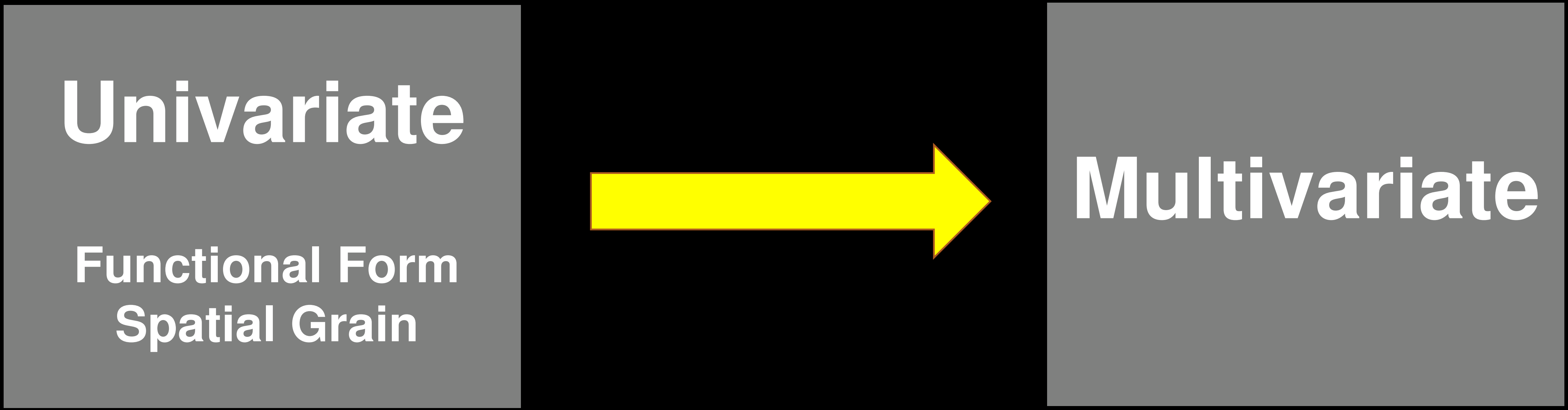


- Model ranking was conducted using AICc
- Preformed model validation using *k*-folds cross-validation
- Teton extrapolations were validated with independent data

(Boyce et al. 2002, Burnham and Anderson 2002, Vaida and Blanchard 2005, Gillies et al. 2006, Fieberg et al. 2010)

Results

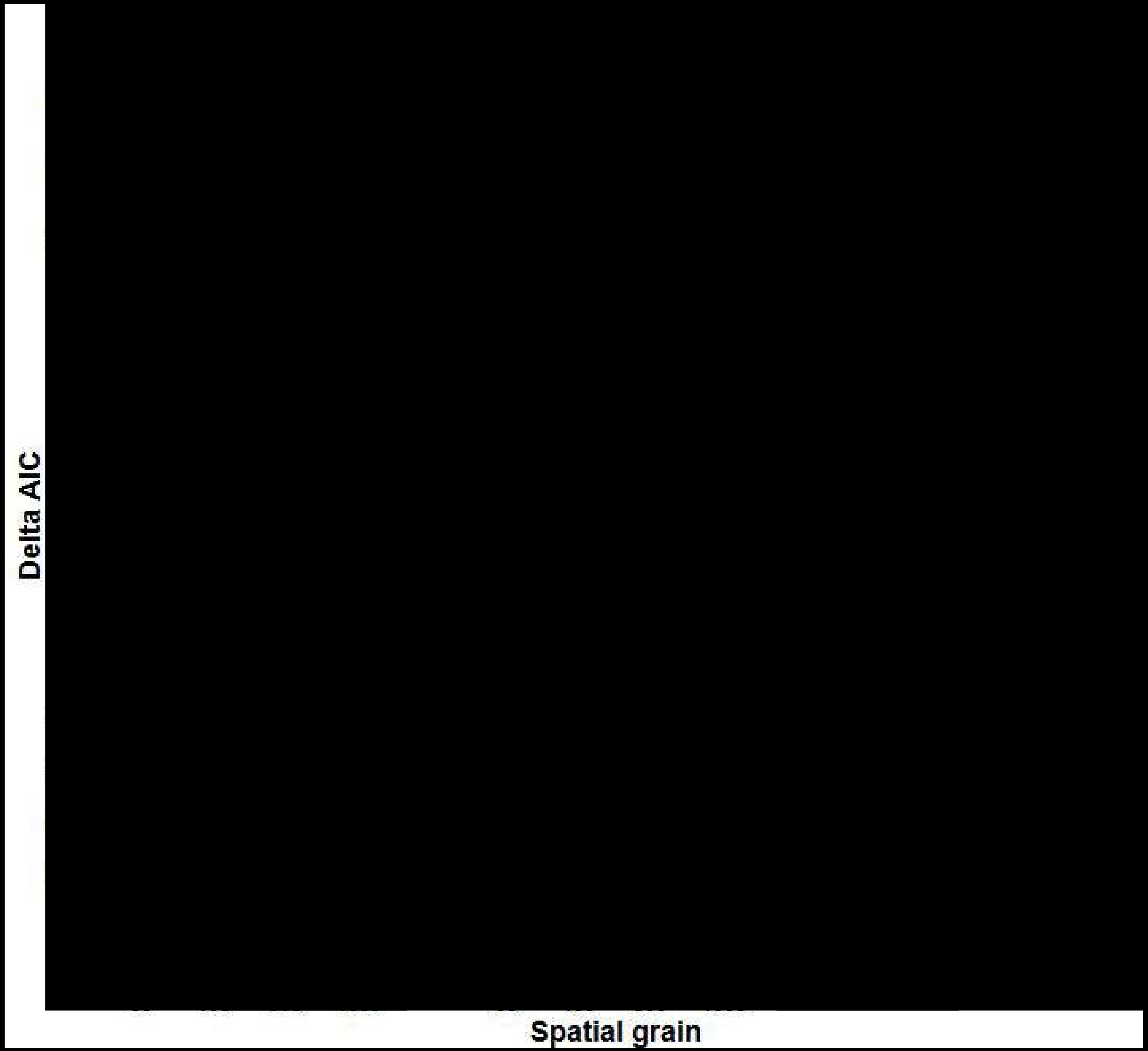
Results

- **Recovered data**: 18 GPS collars
  - 14 females
  - 4 males

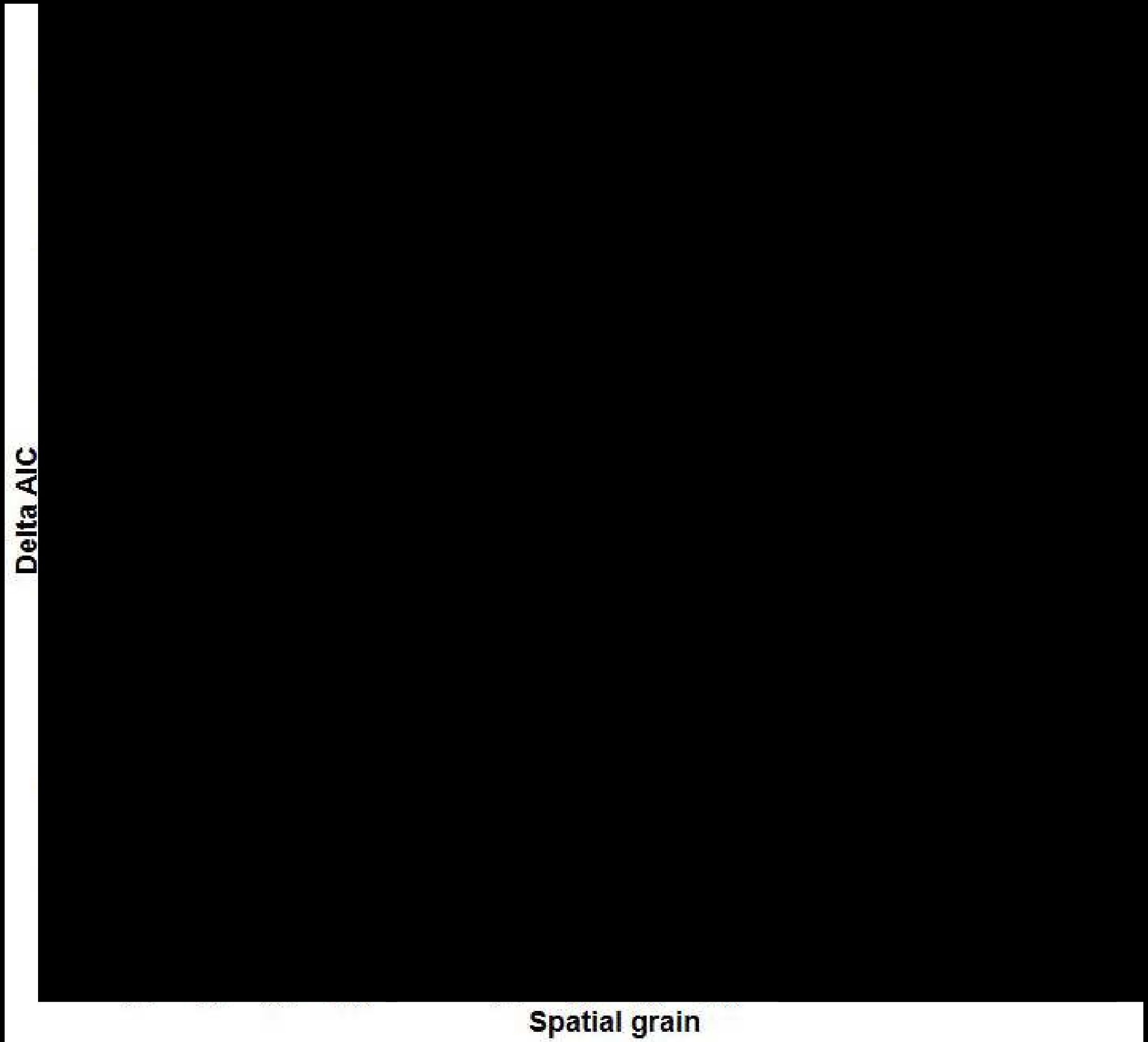
Univariate Models

Univariate Models

Summer



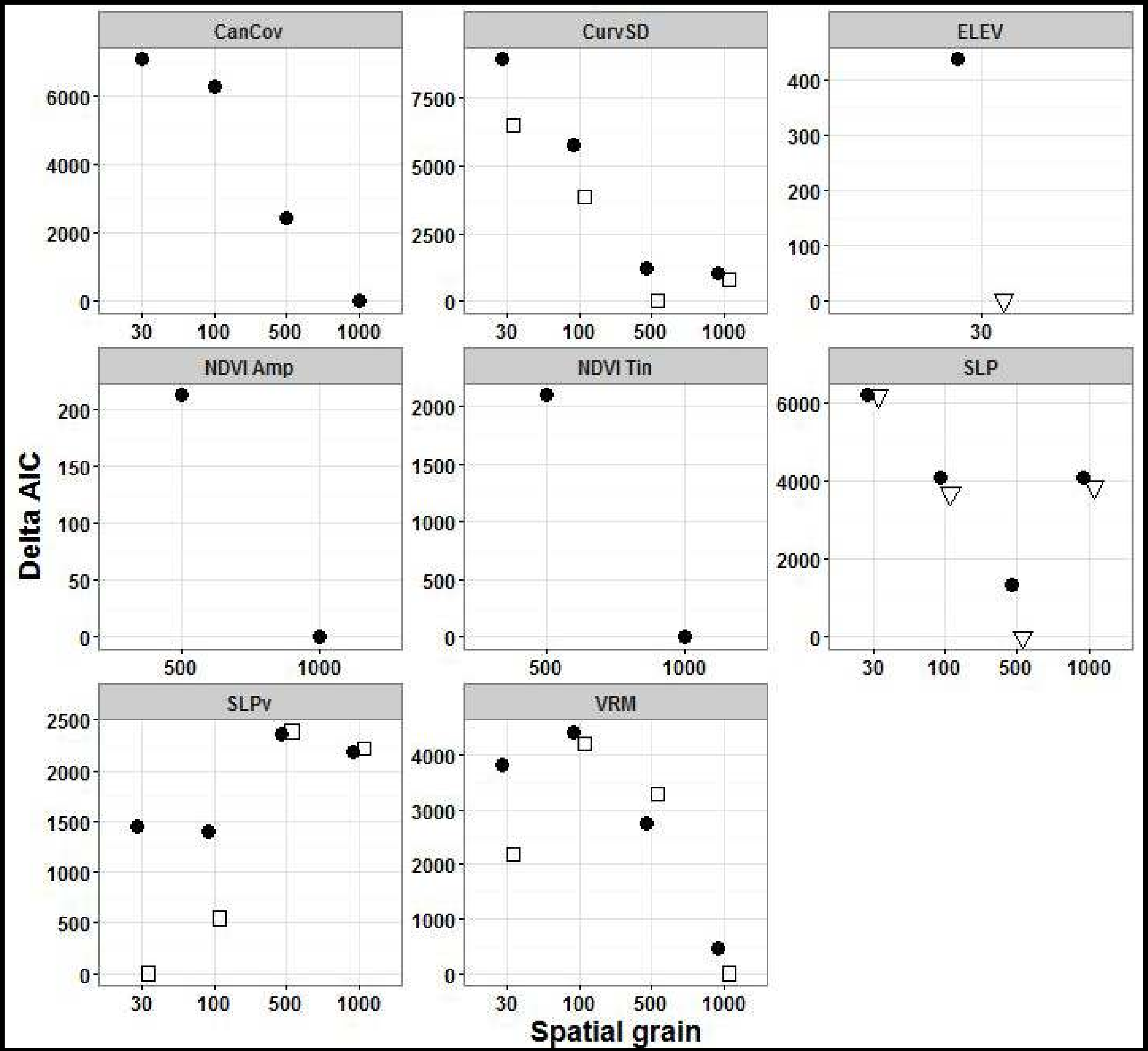
Winter



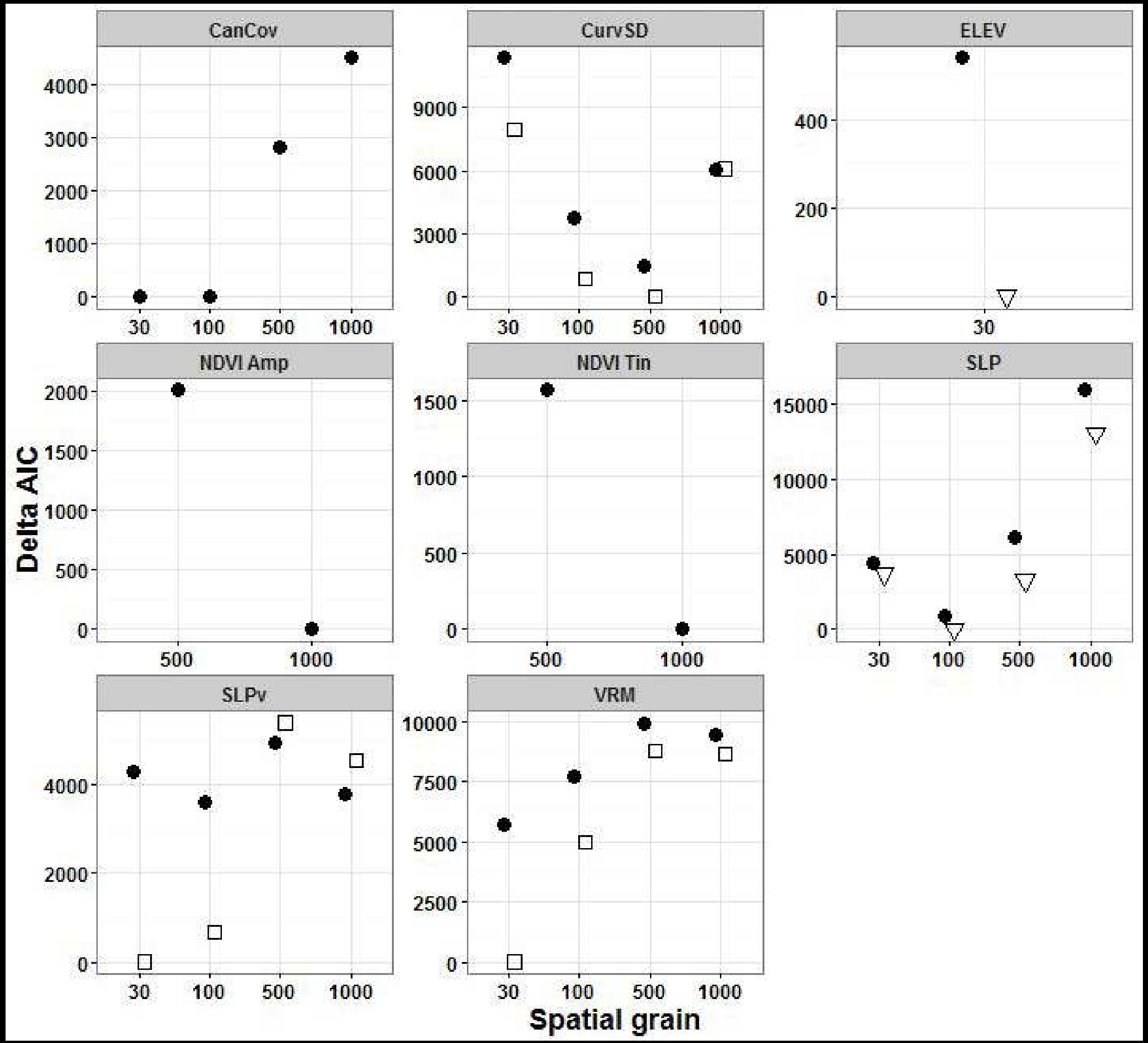
● Linear ■ Pseudothreshold ▲ Squared

Univariate Models

Summer



Winter



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Univariate Models

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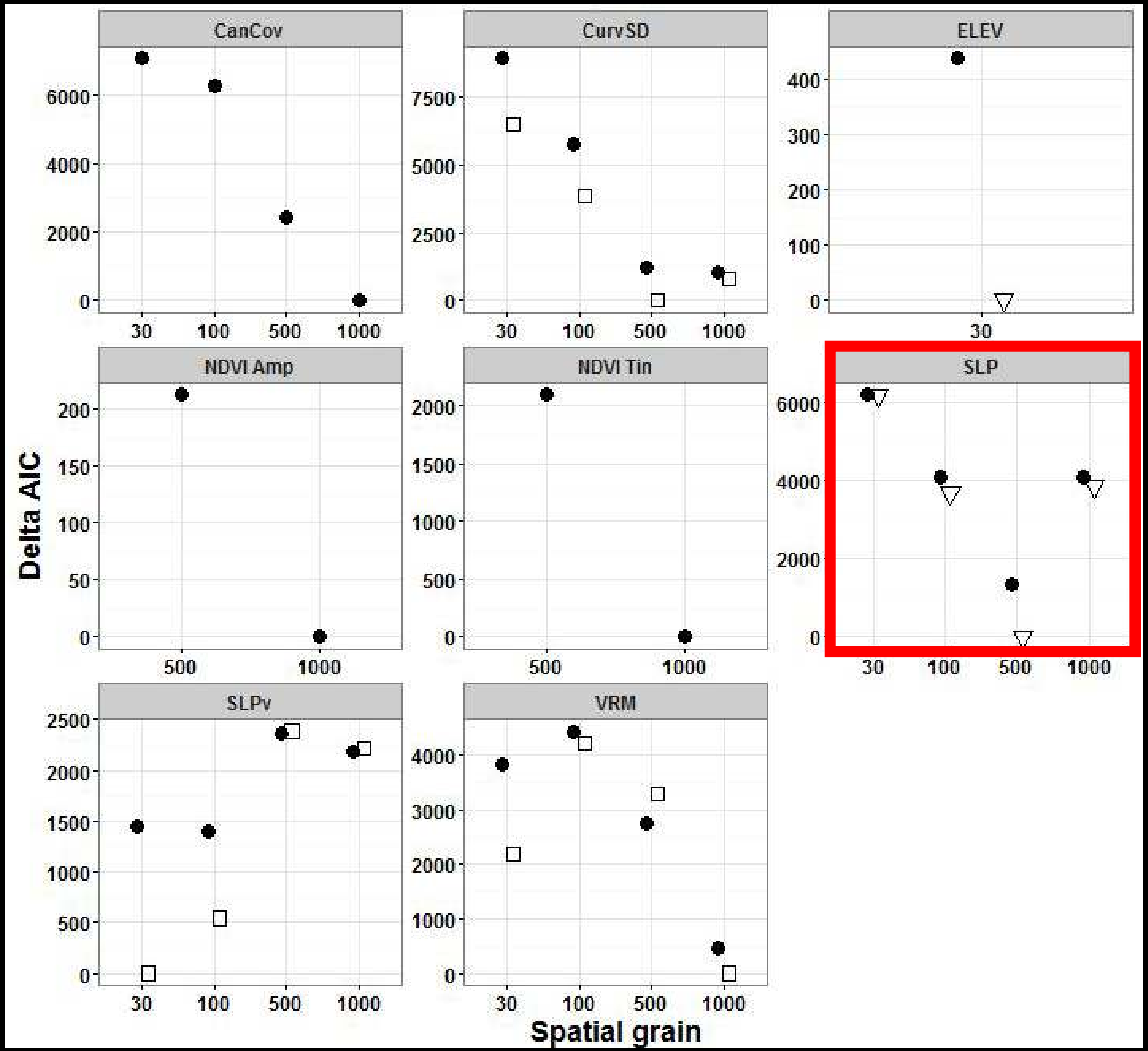
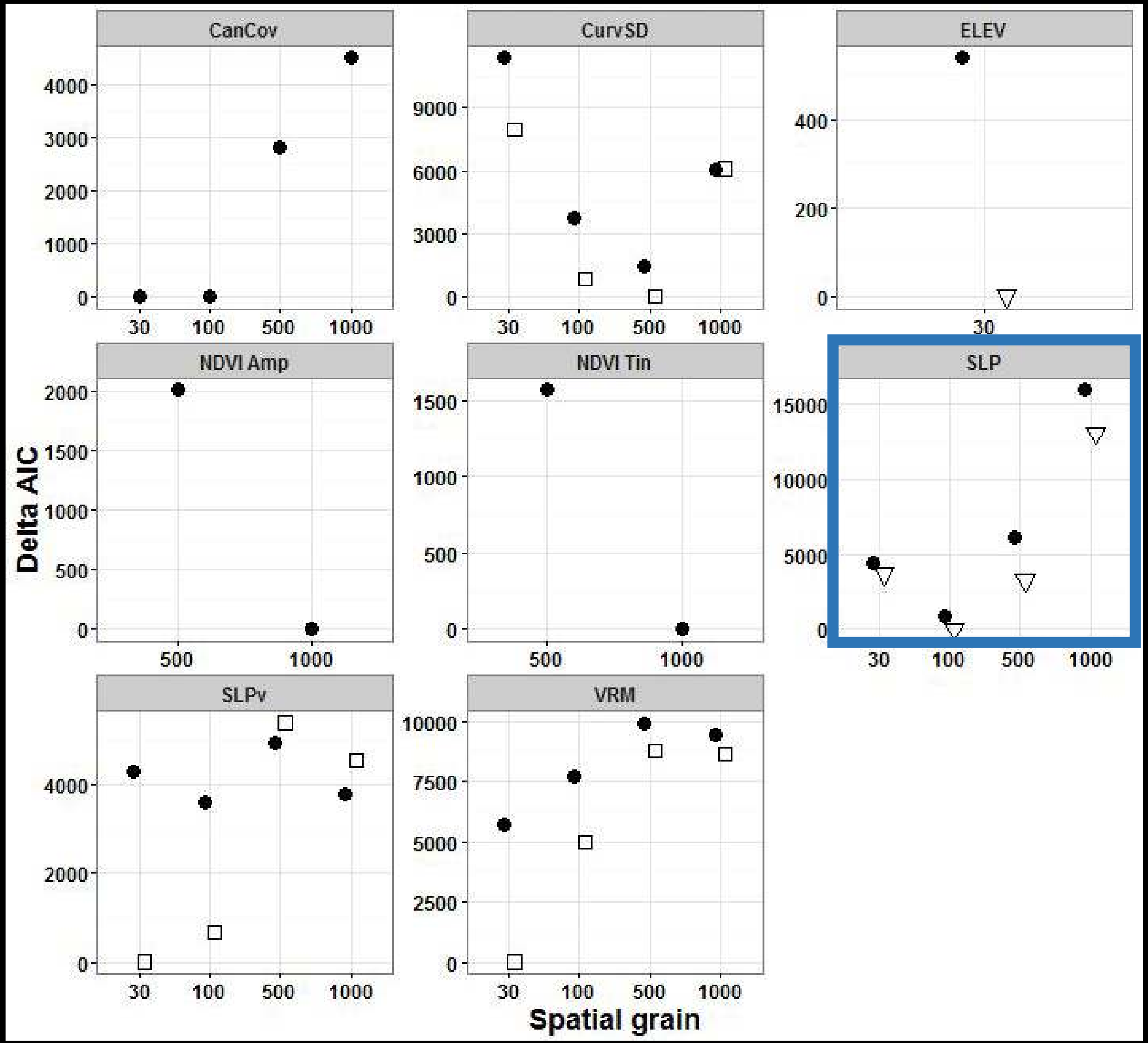


Winter



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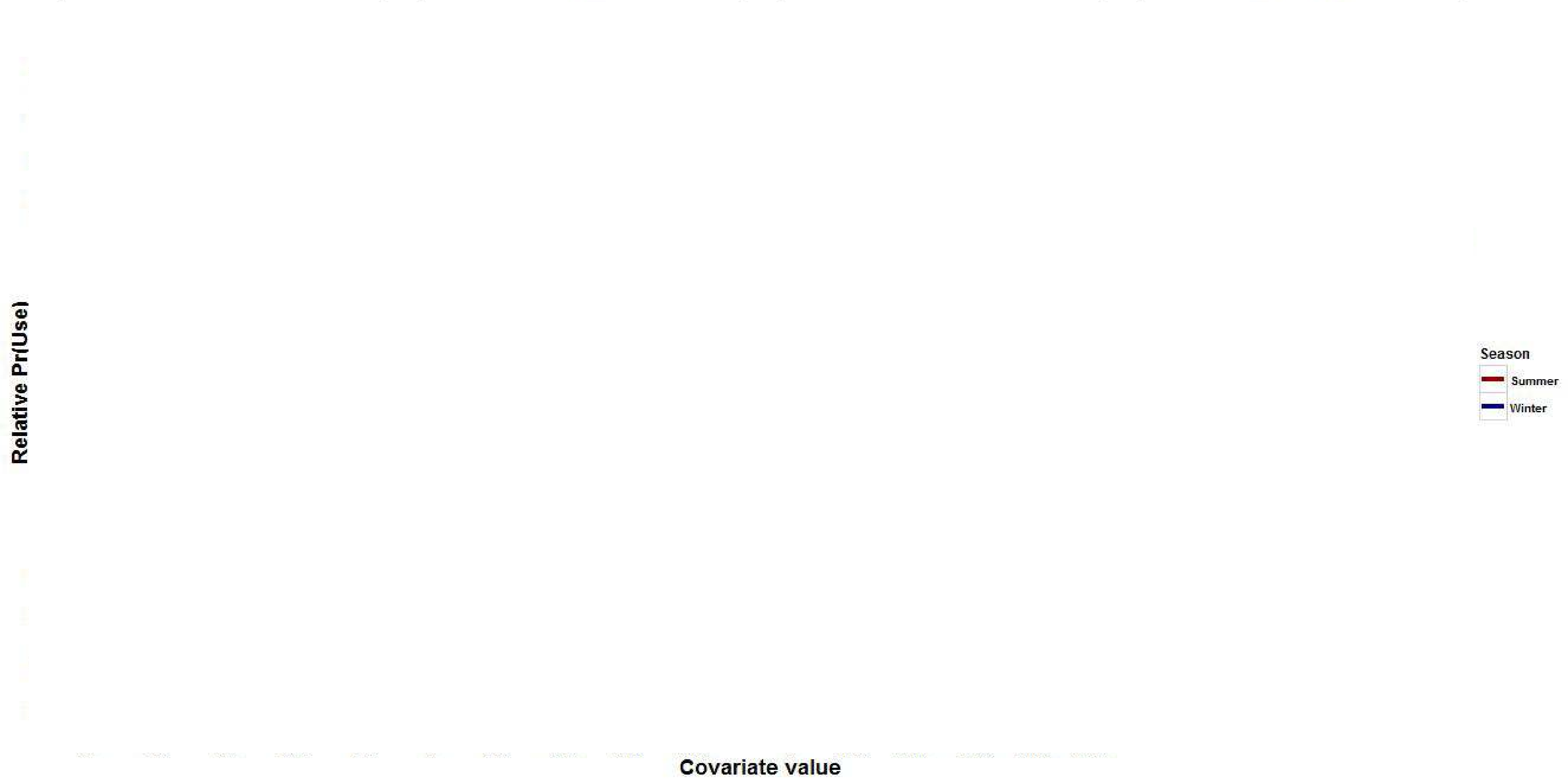
Habitat Relationships



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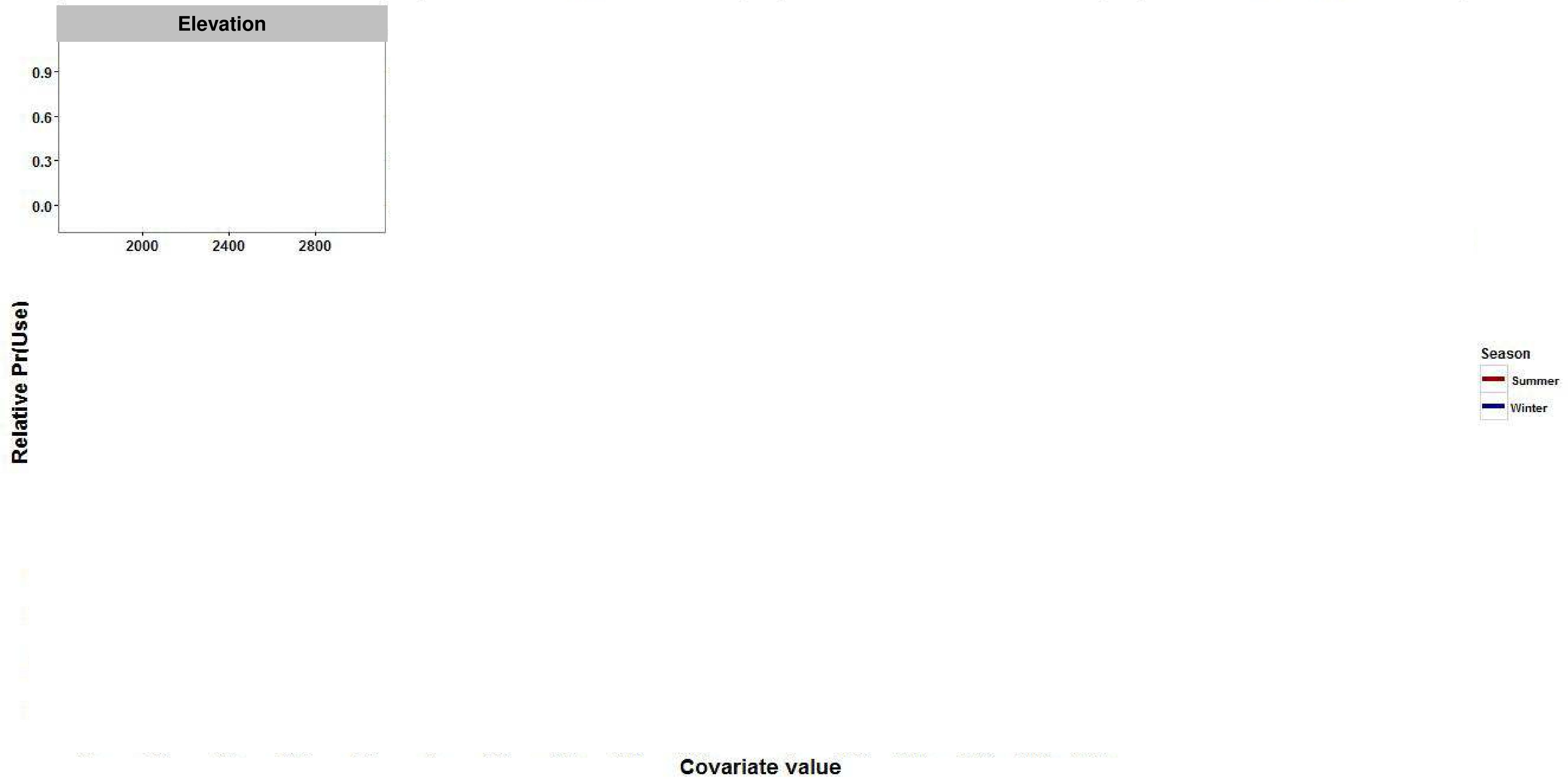

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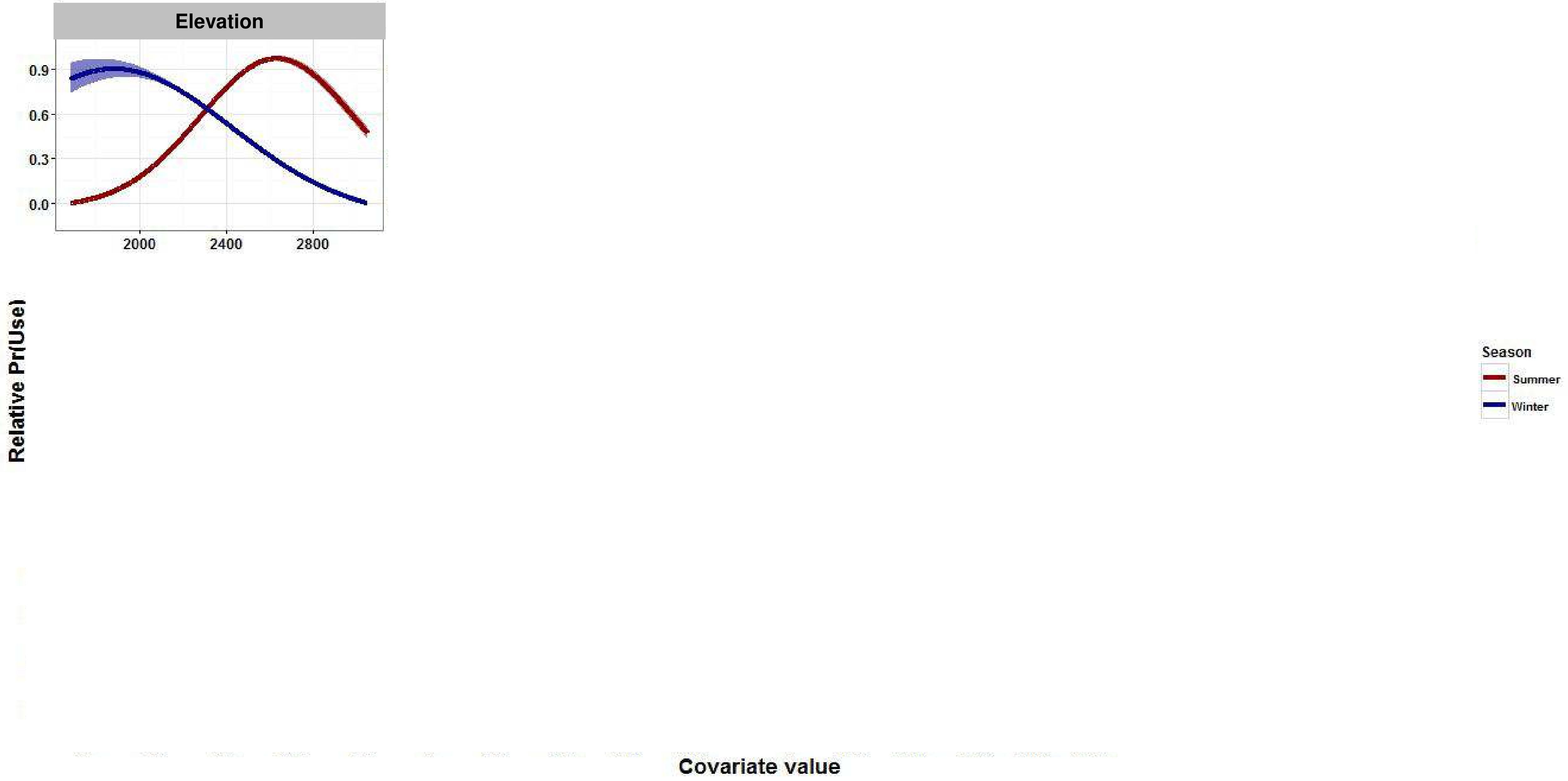

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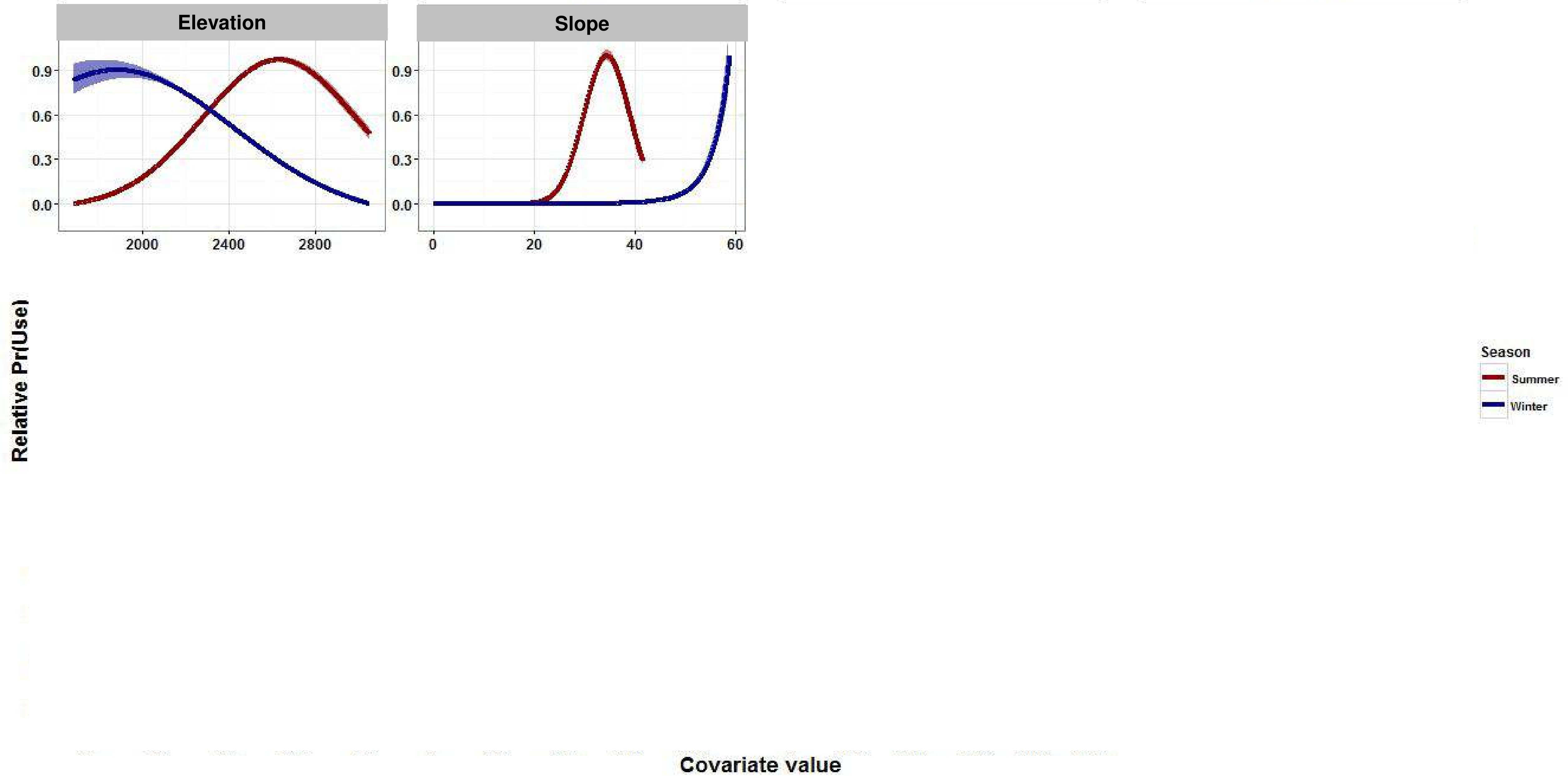

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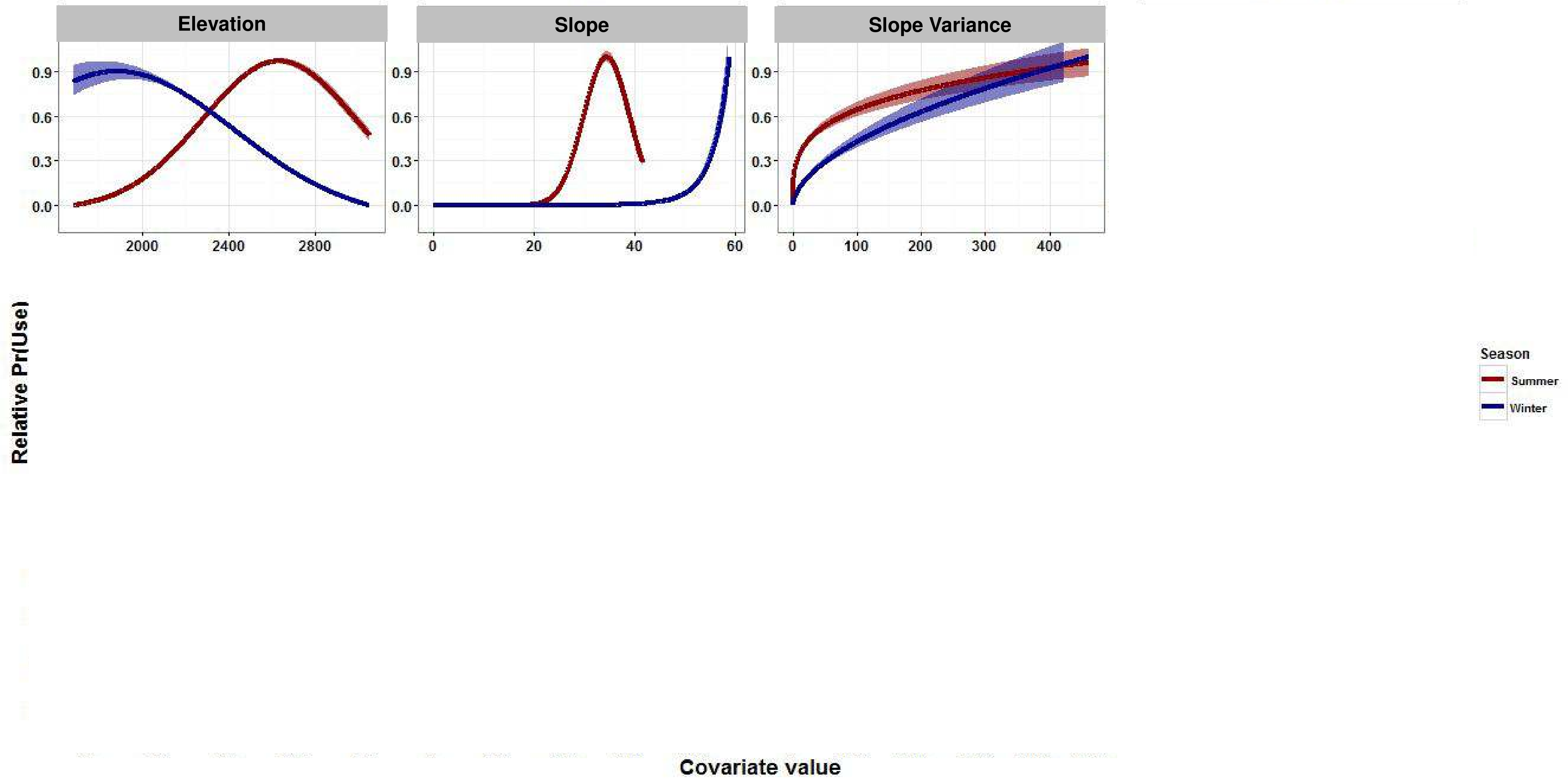

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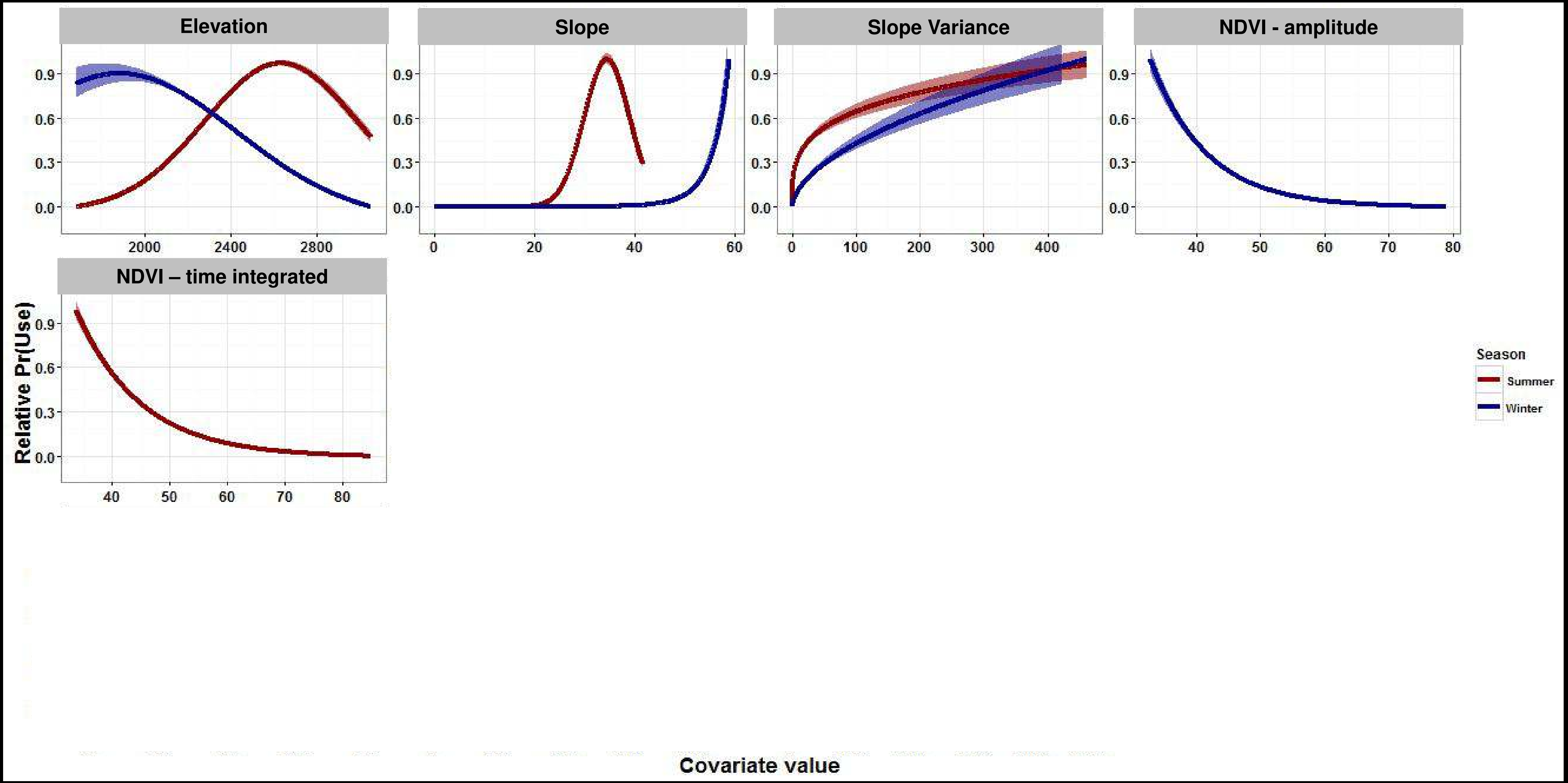

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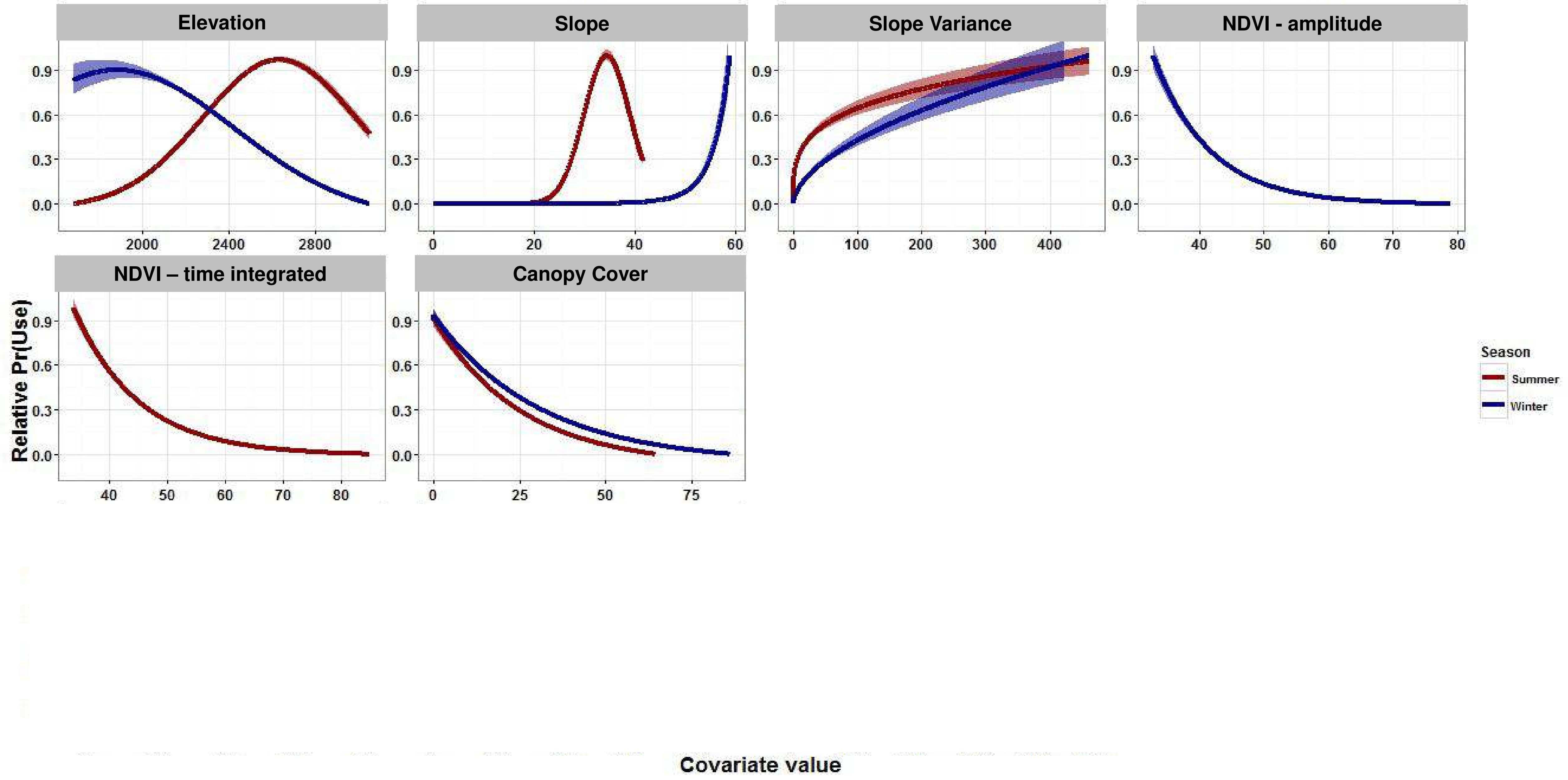

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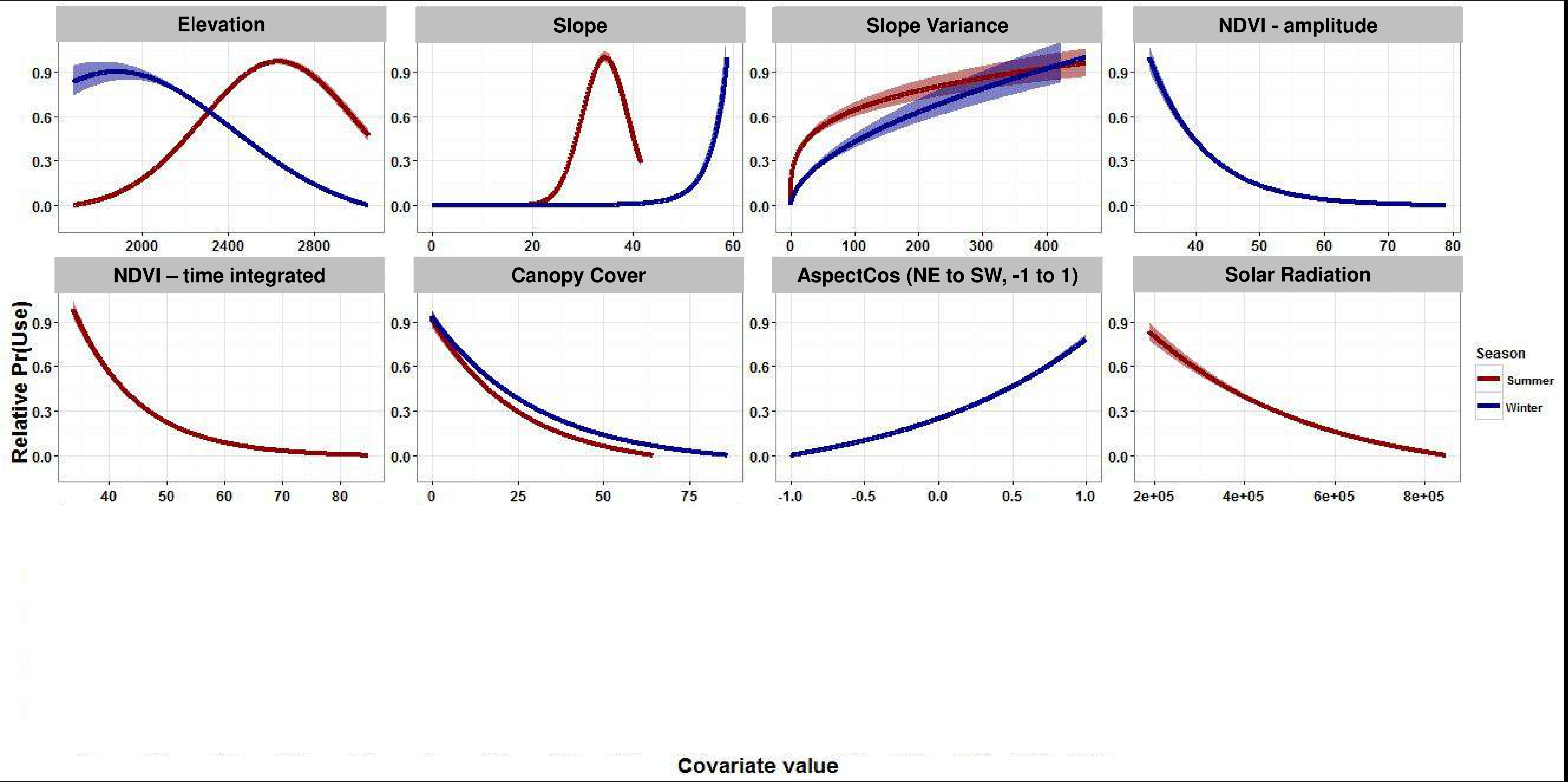

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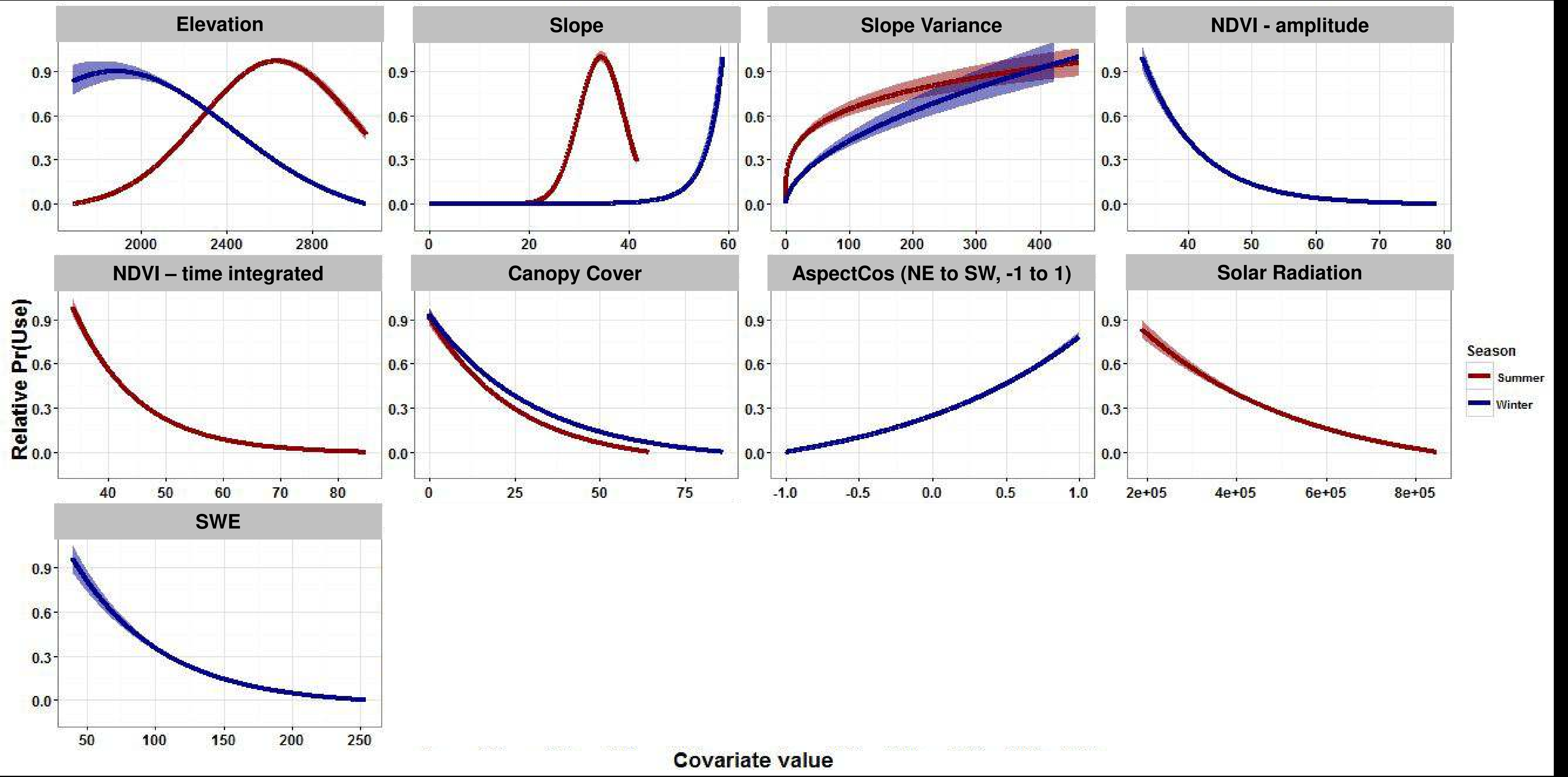
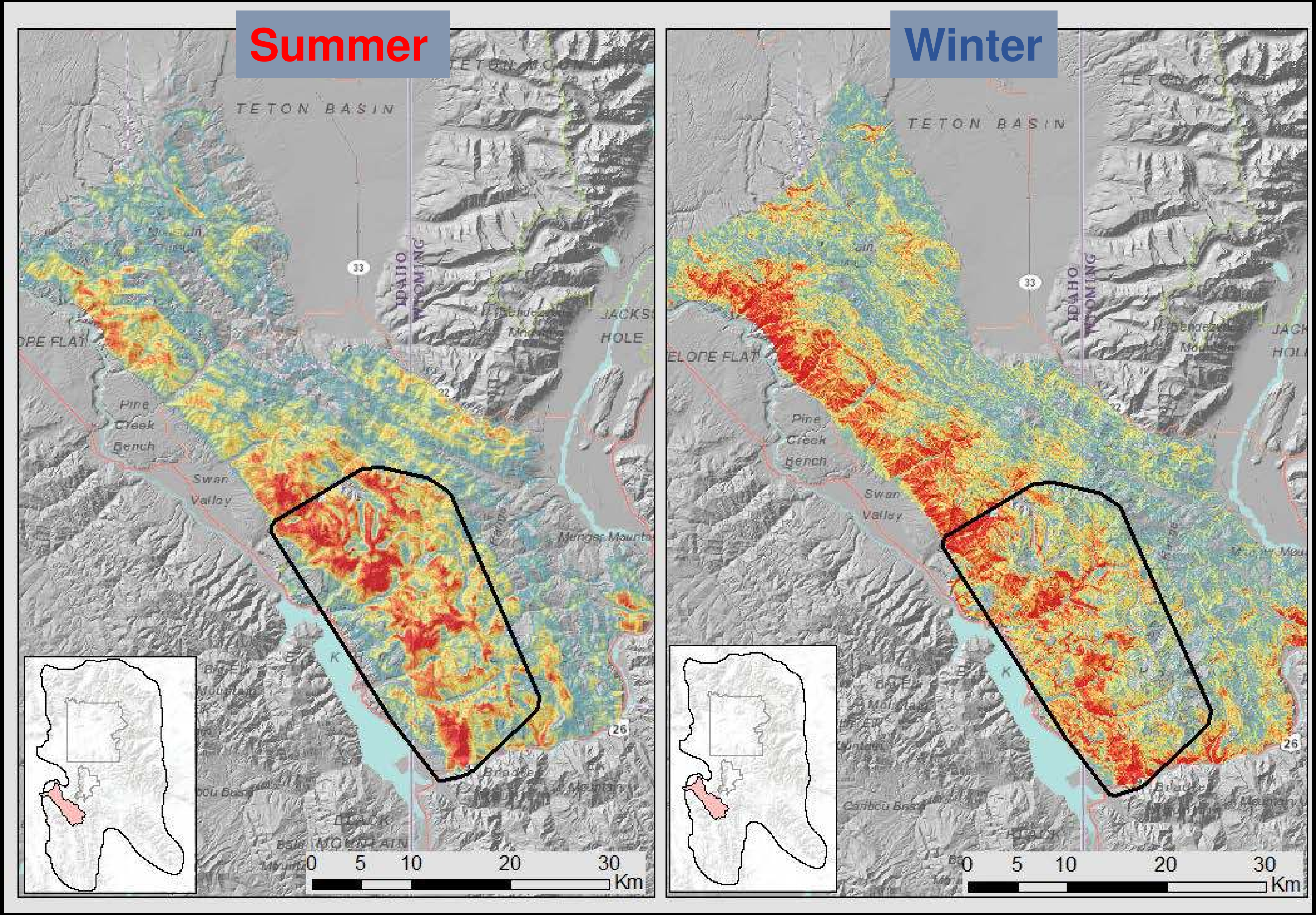
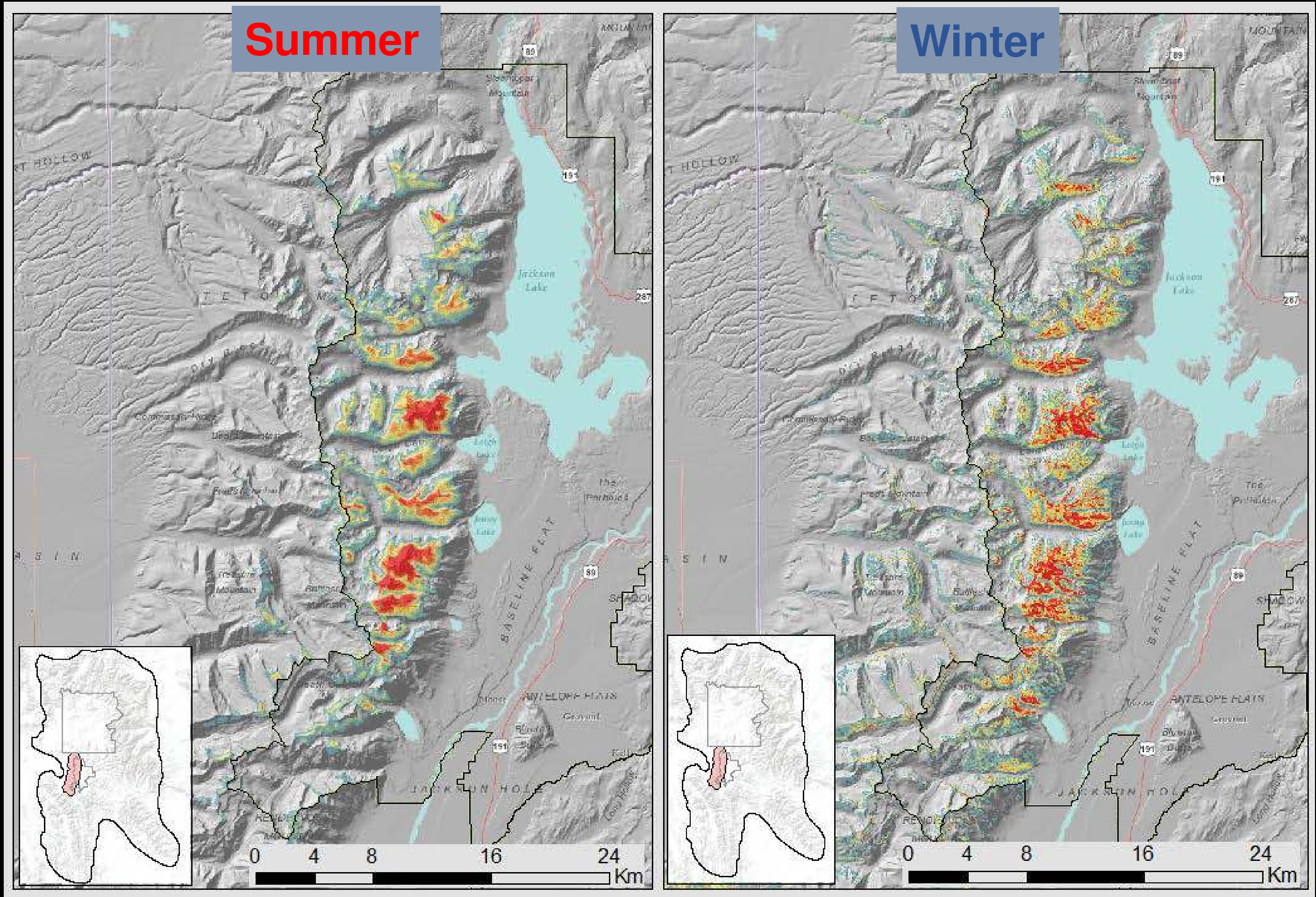


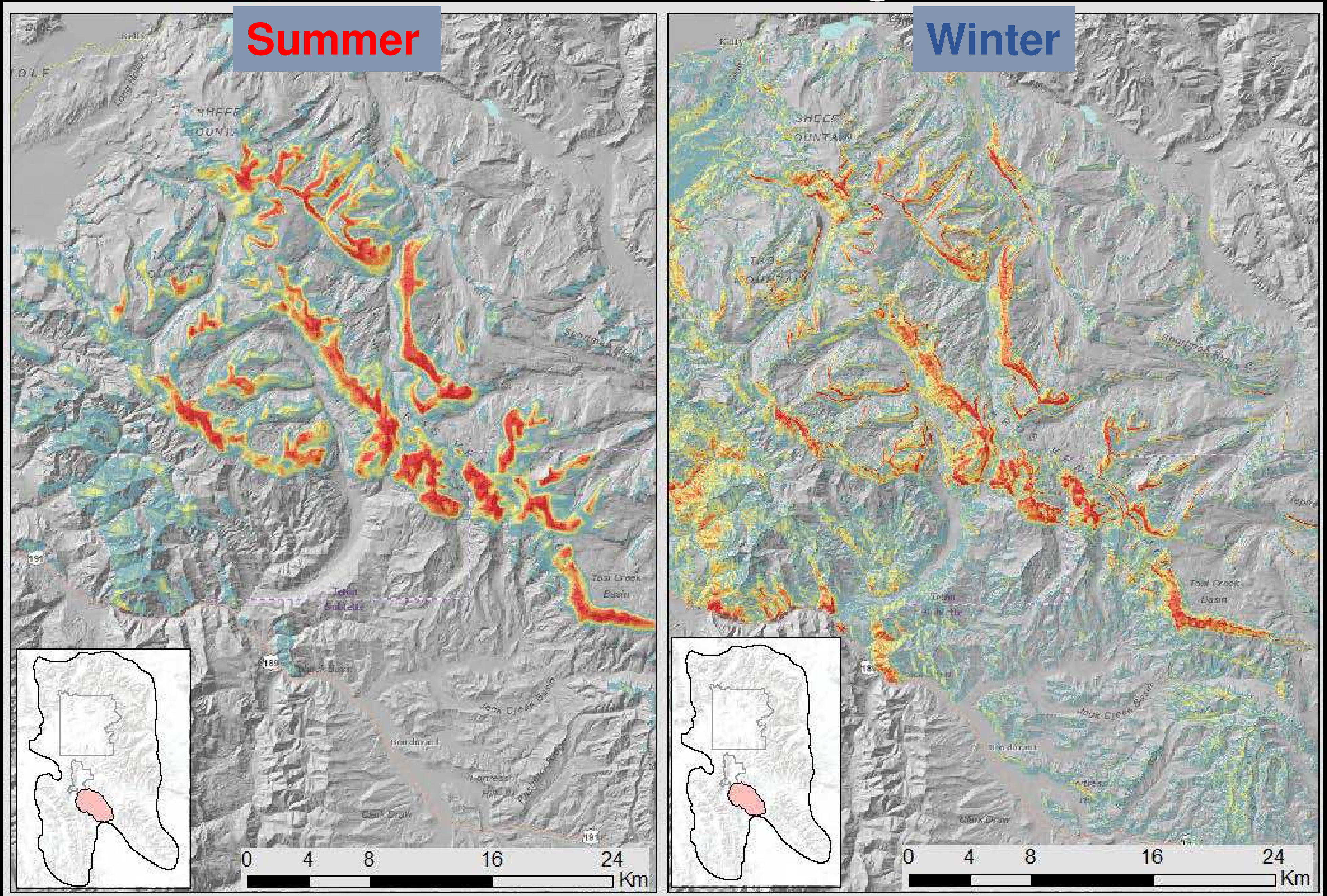
Snake River Range



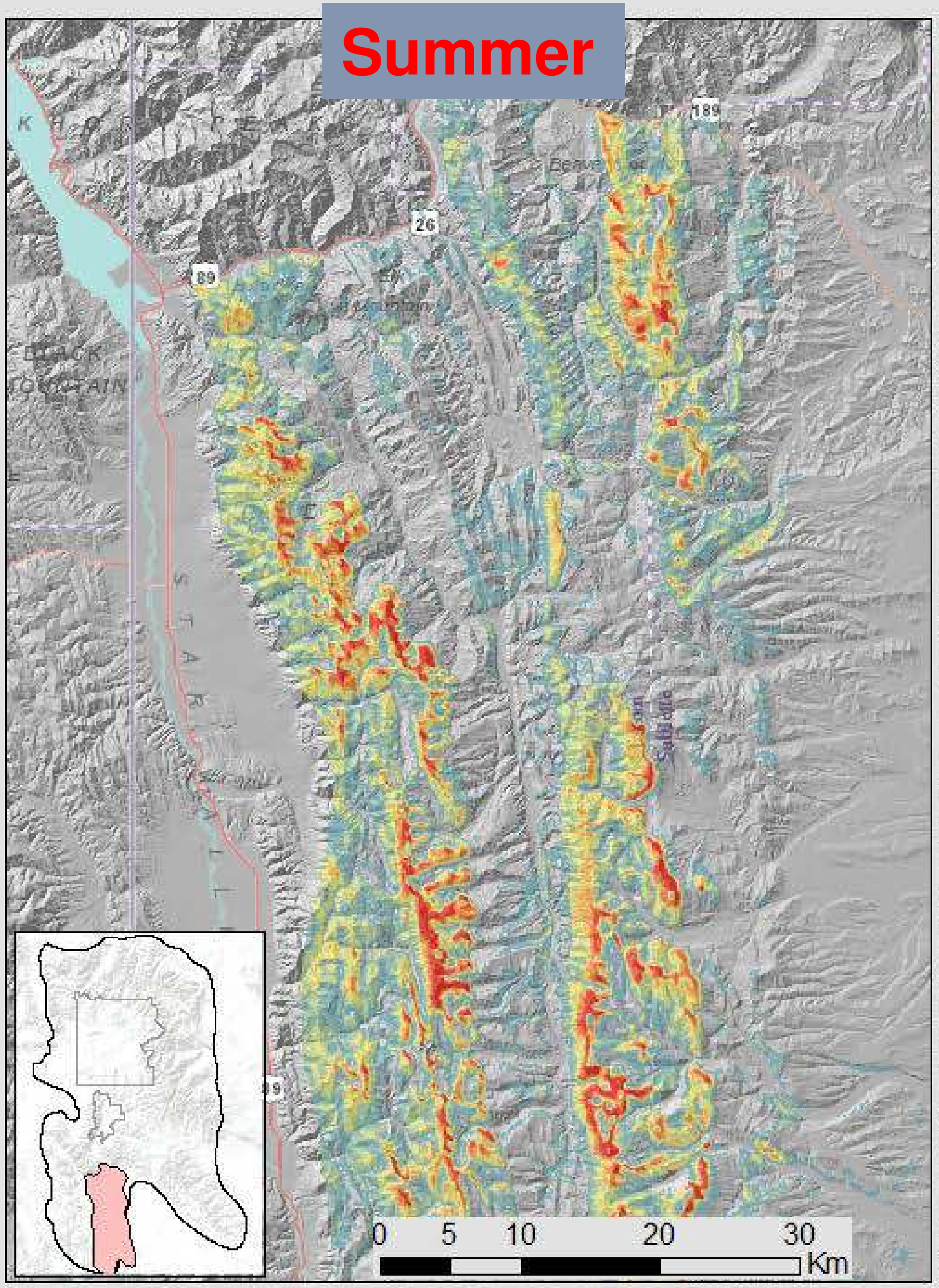
Teton Range

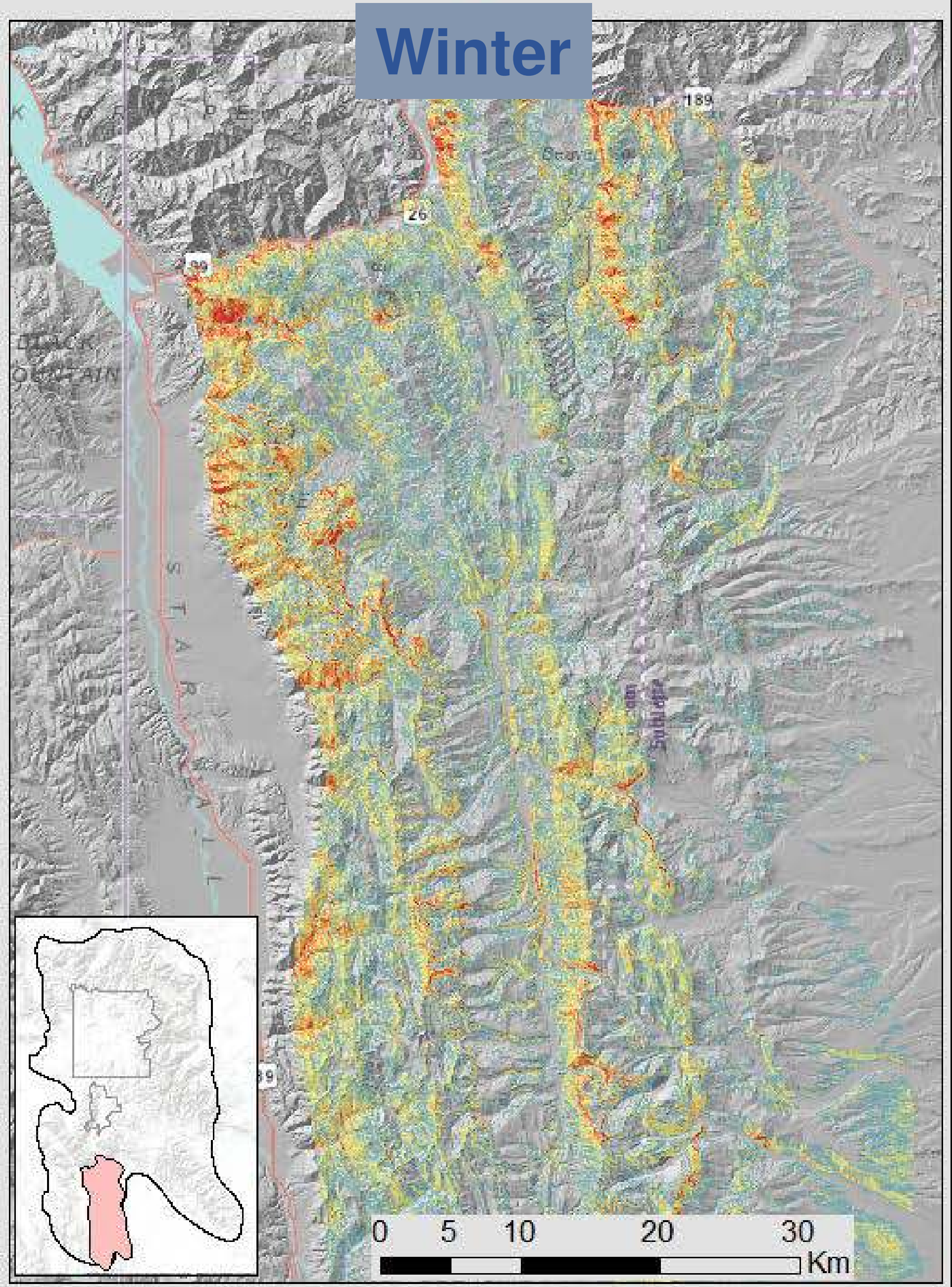

Summer
Winter
Jackson Lake
Leigh Lake
Jenny Lake
BASELINE FLAT
ANTELOPE FLATS
0 4 8 16 24 Km

Gros Ventre Range



Wyoming and Salt Ranges





Conclusions

- Terrain features drive resource selection in both seasons
  - Positive associations with steep and rugged terrain
  - Have lower elevation winter ranges

- Seasonal response to solar radiation
  - + in winter
  - - in summer

- Generally avoid vegetation indices and deep snow

Conclusions

Regional extrapolations:

- Core mountain goat summer range centered around high elevation rugged terrain.
- Broad range contraction in winter.
- Winter range generally consists of the most steep areas within a more broadly distributed summer range
- Preference for steep cliff slopes in winter patchily distributed across mid-elevations.

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Provide a predictive tool to help anticipate and manage for continued mountain goat expansion

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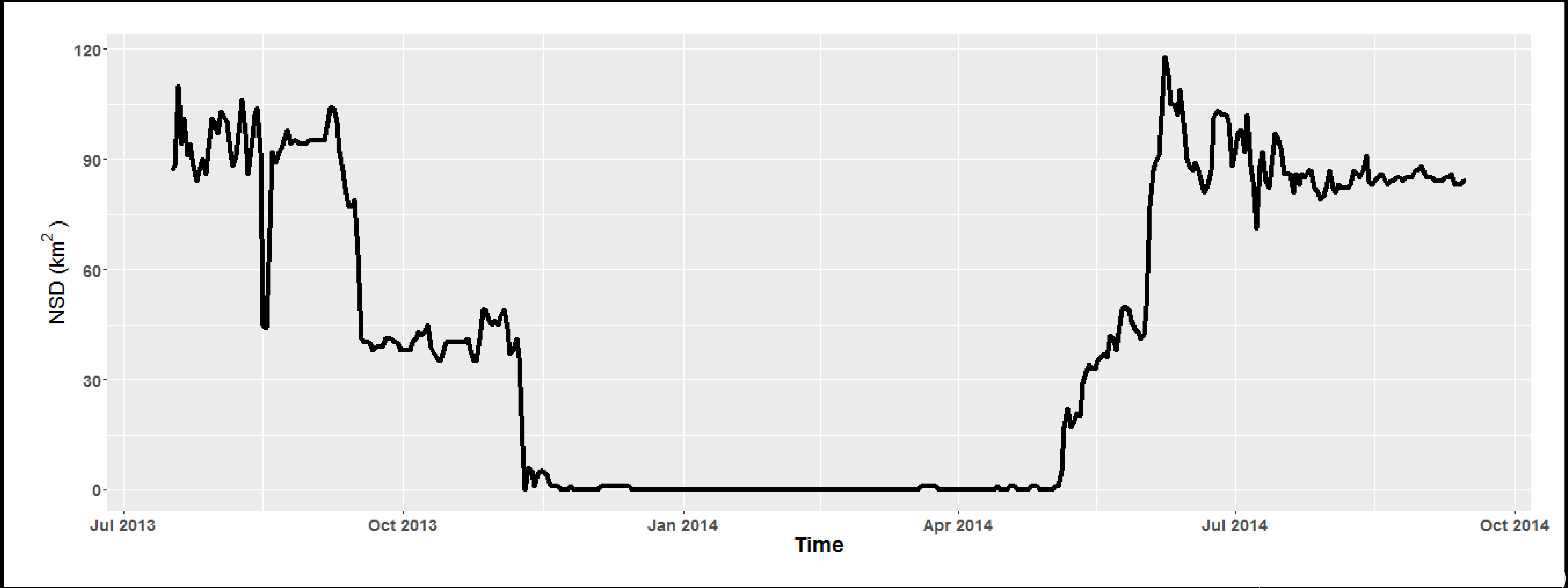
Keven Hurley Wild Sheep Biology Award

Delineating Seasons

- Individual variation in response to seasonal environmental conditions
- Net squared displacement



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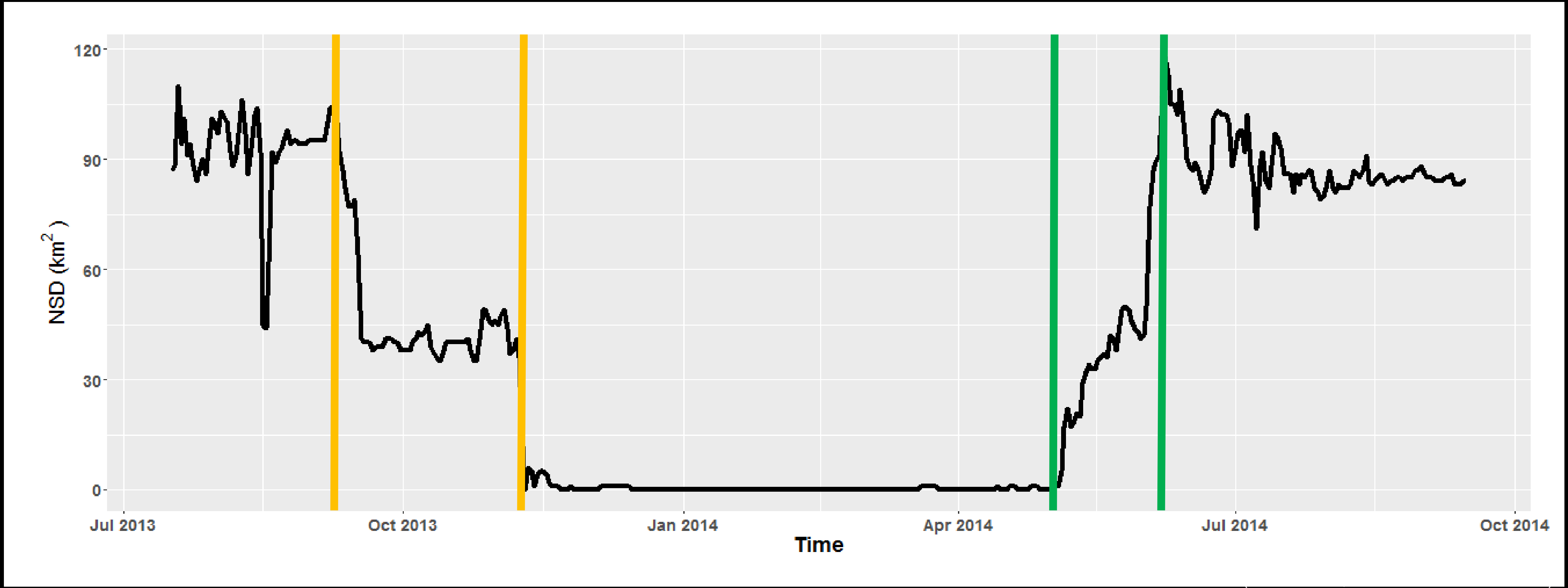

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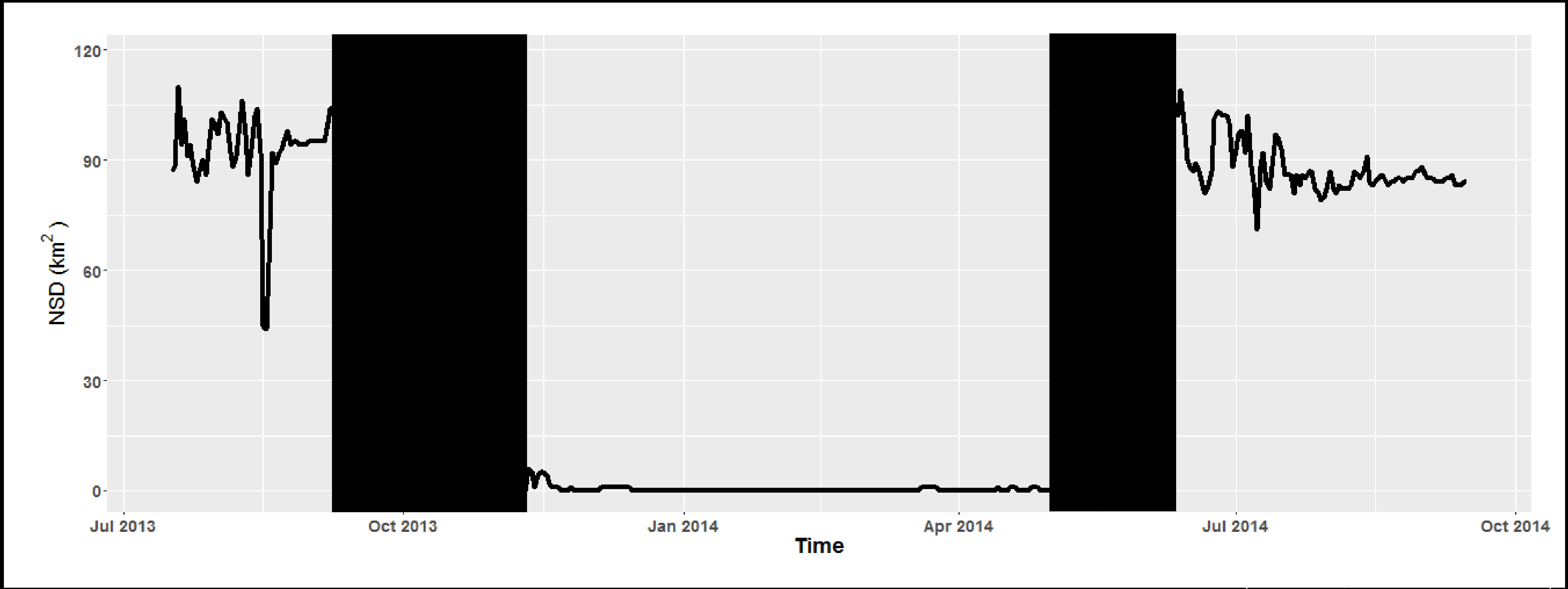

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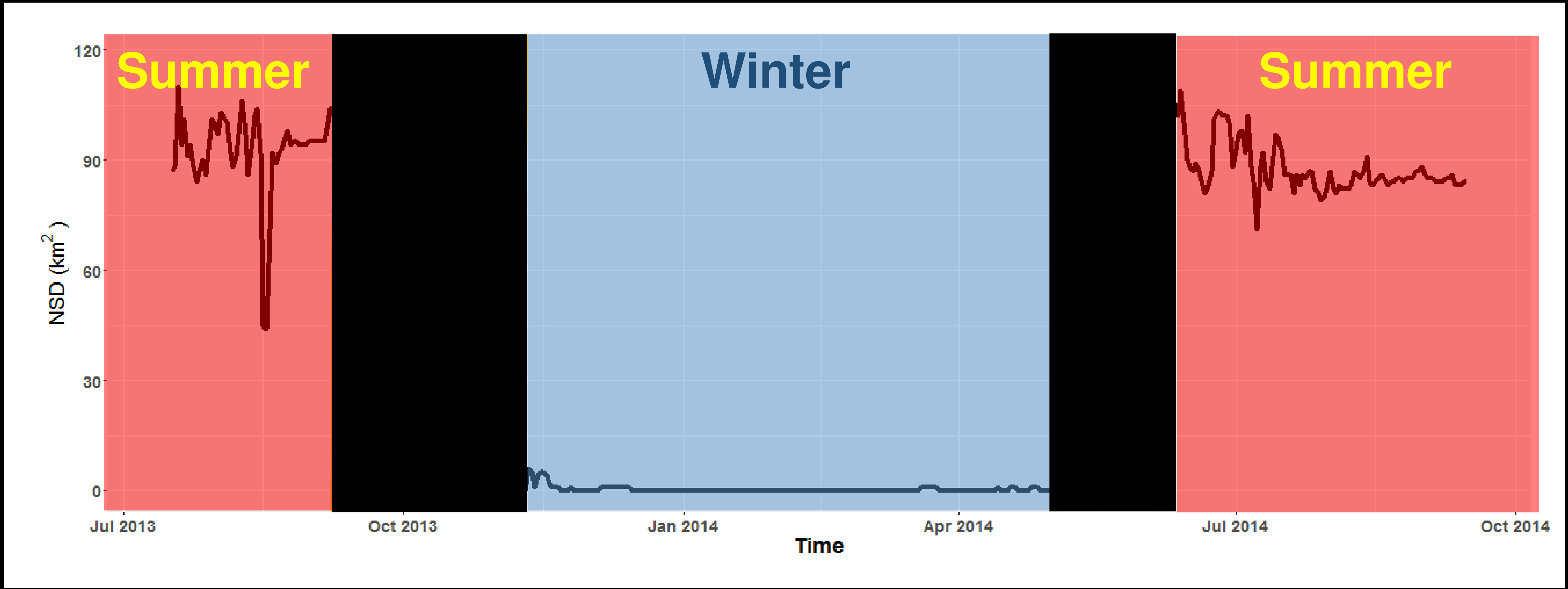


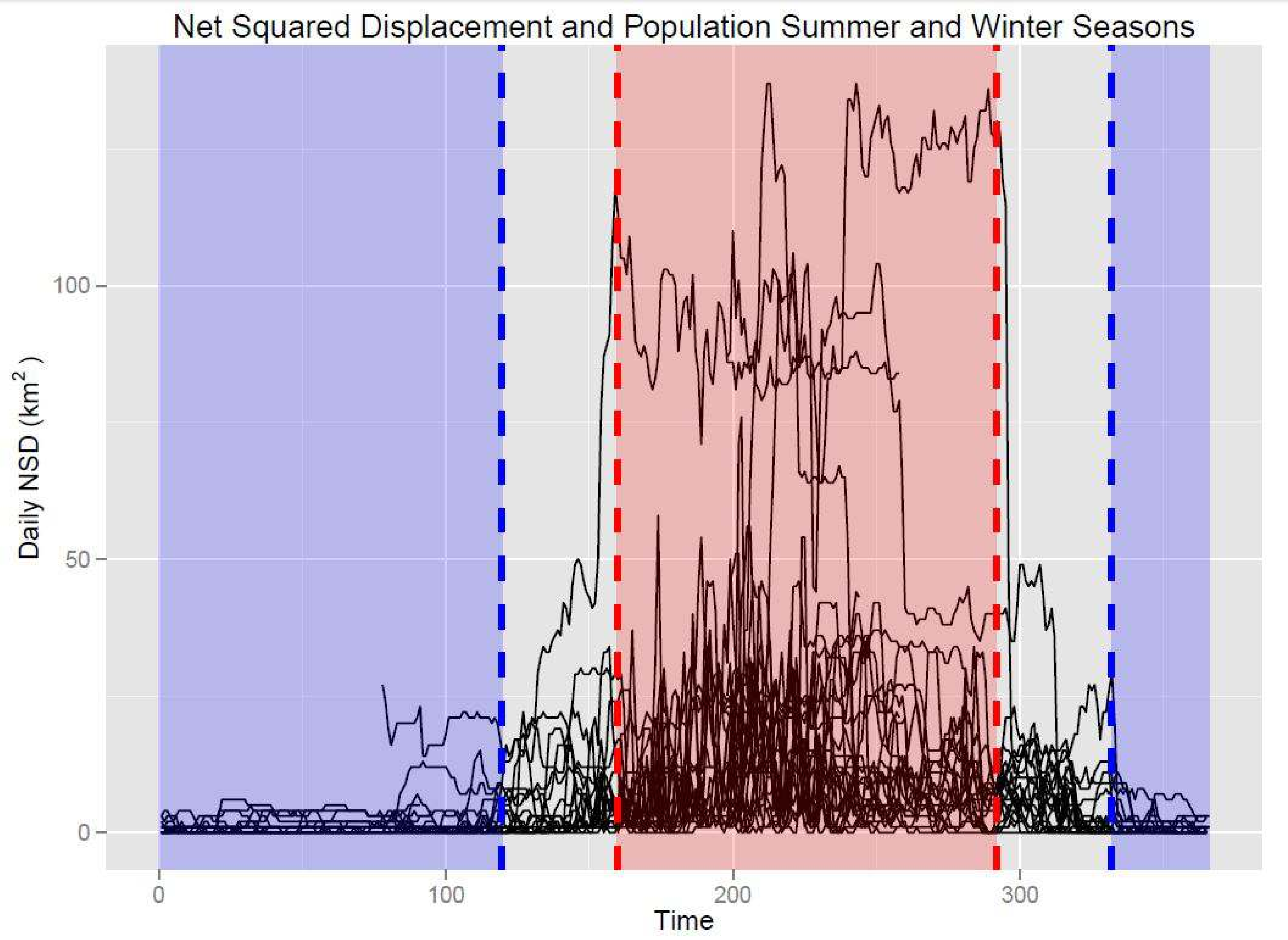
Seasons

Summer

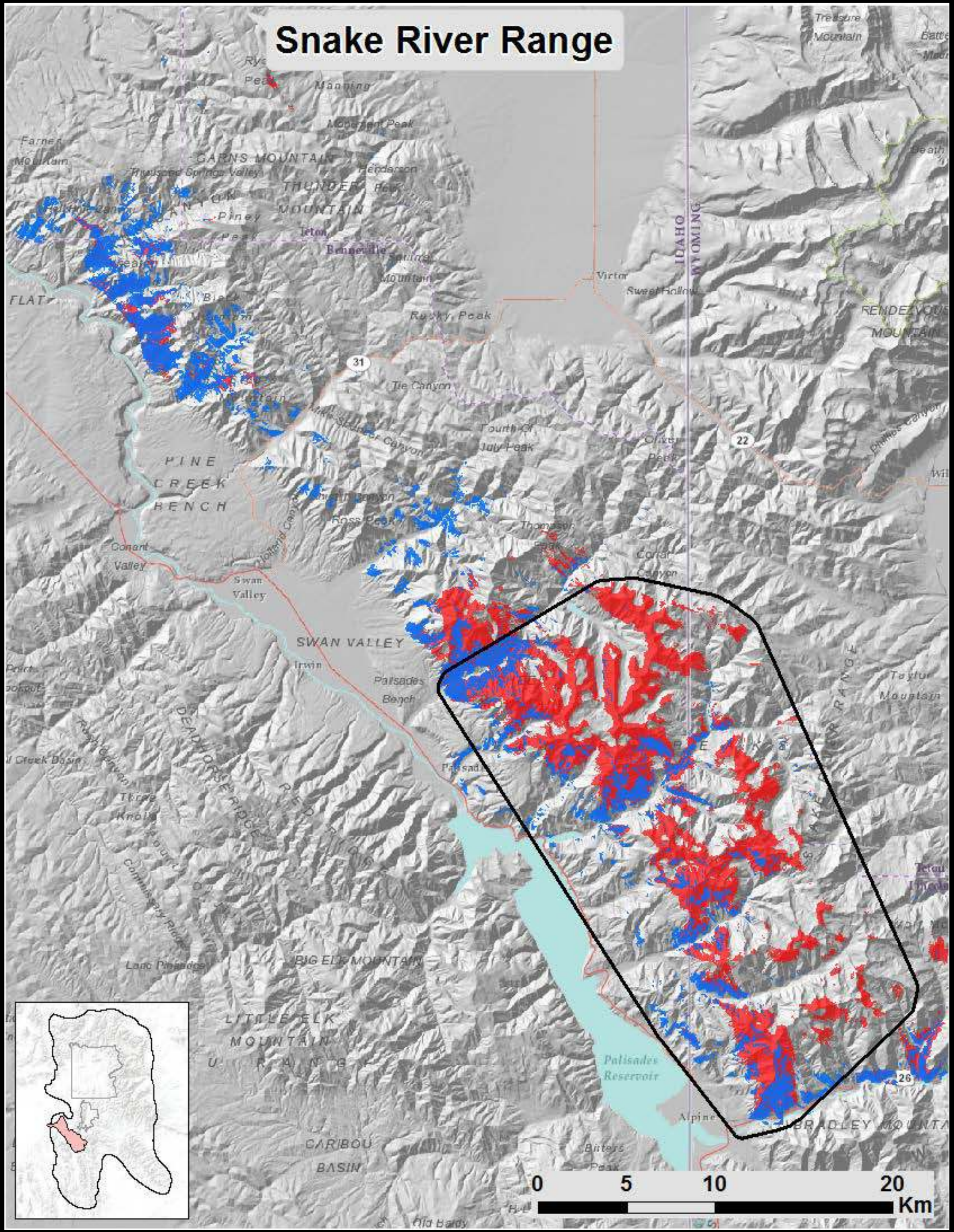
June 8th – October 18th

Winter

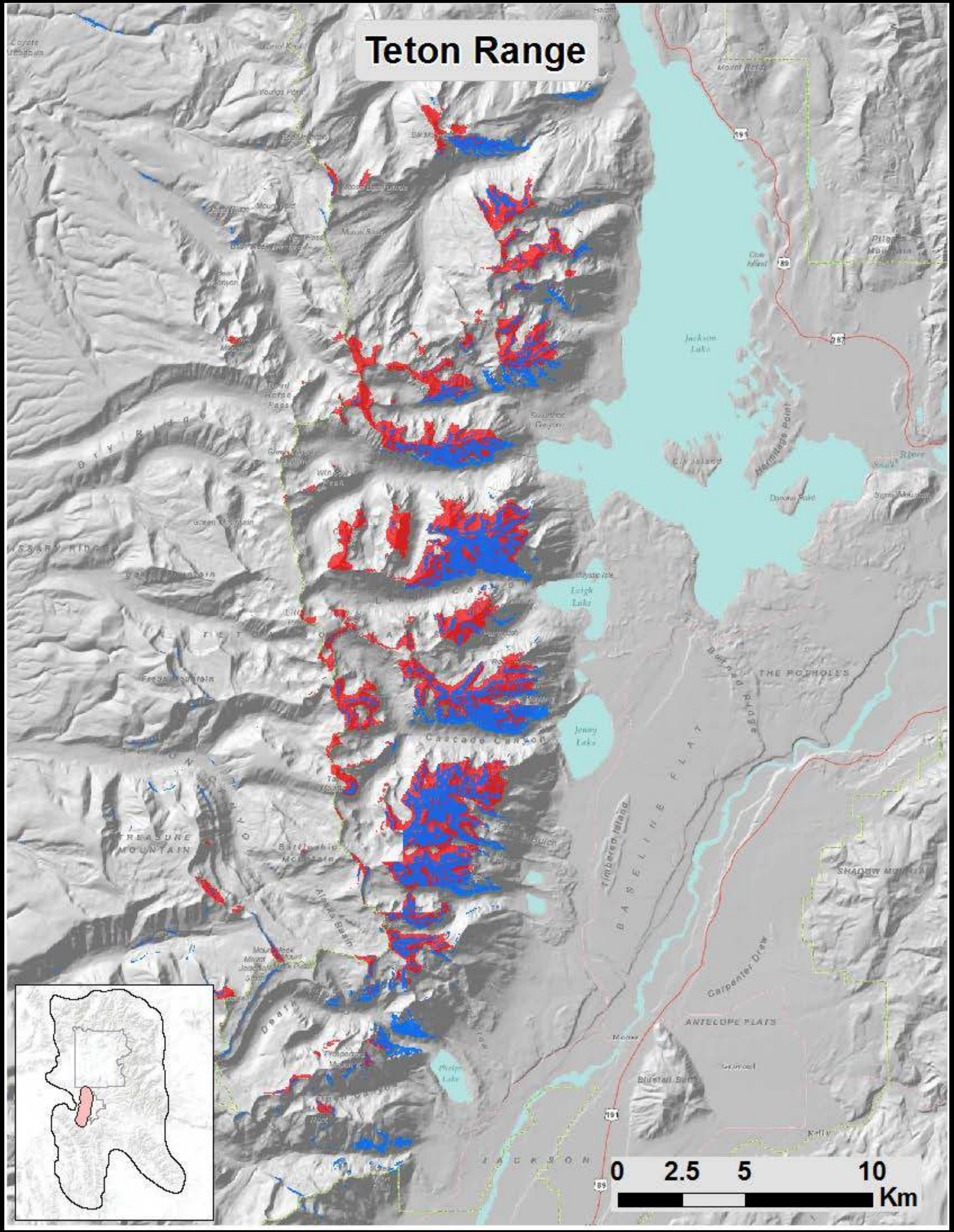
November 27th – April 29th



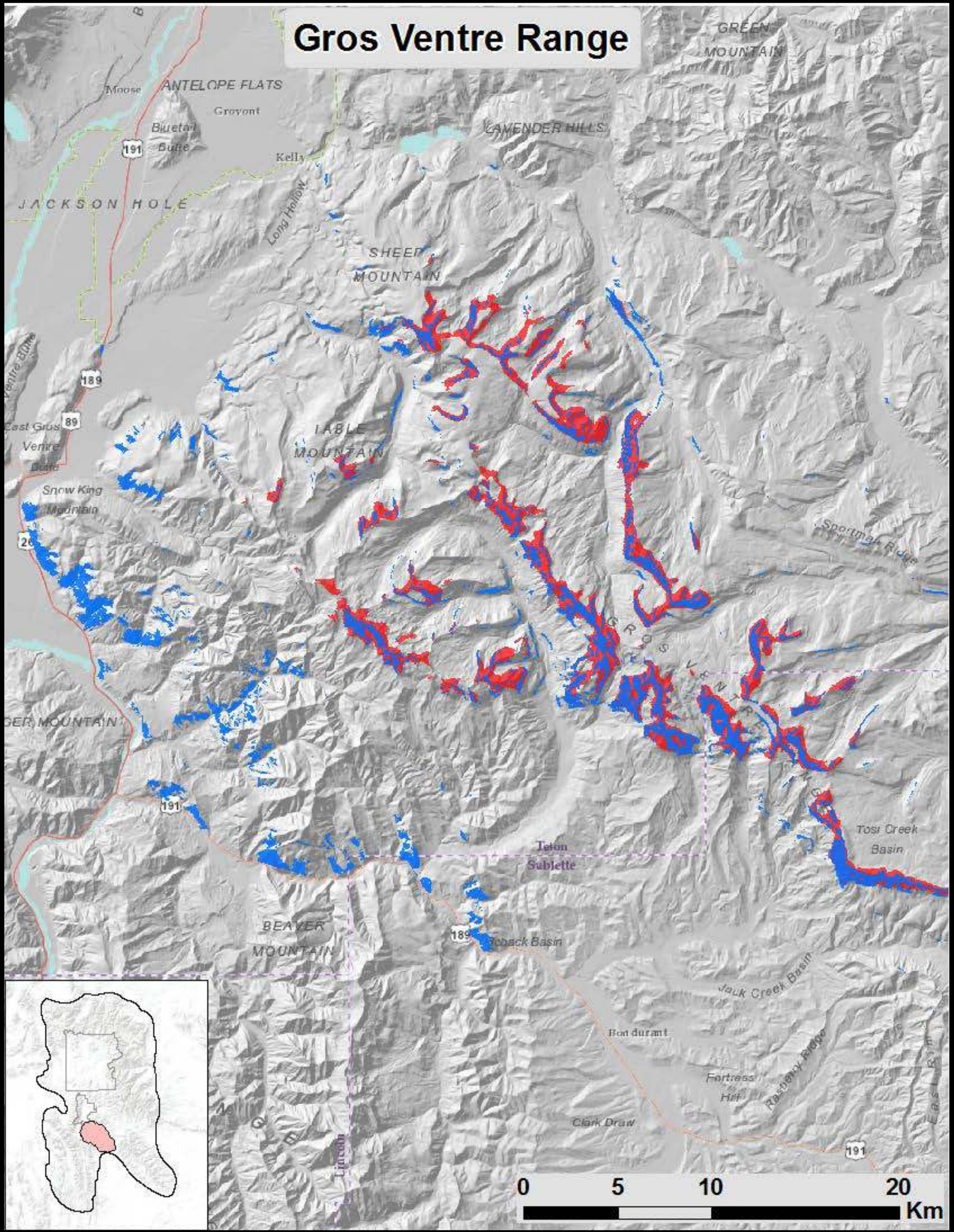
Snake River Range



Teton Range


Teton Range
Jackson Lake
Leigh Lake
Jenny Lake
Cascade Canyon
THE POTHOLES
ANTELOPE FLATS
SHADOW MOUNTAIN
0
2.5
5
10
Km

Gros Ventre Range



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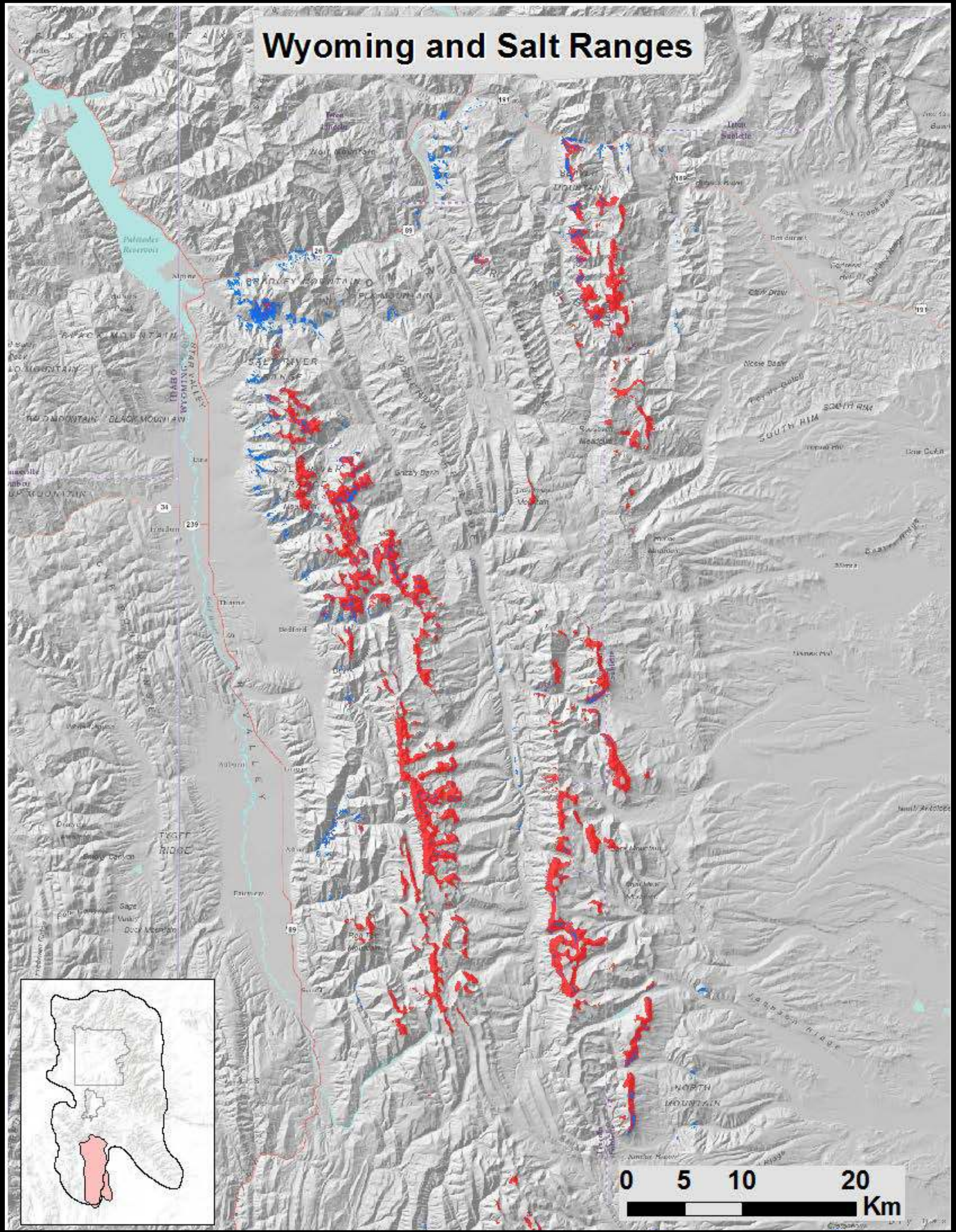
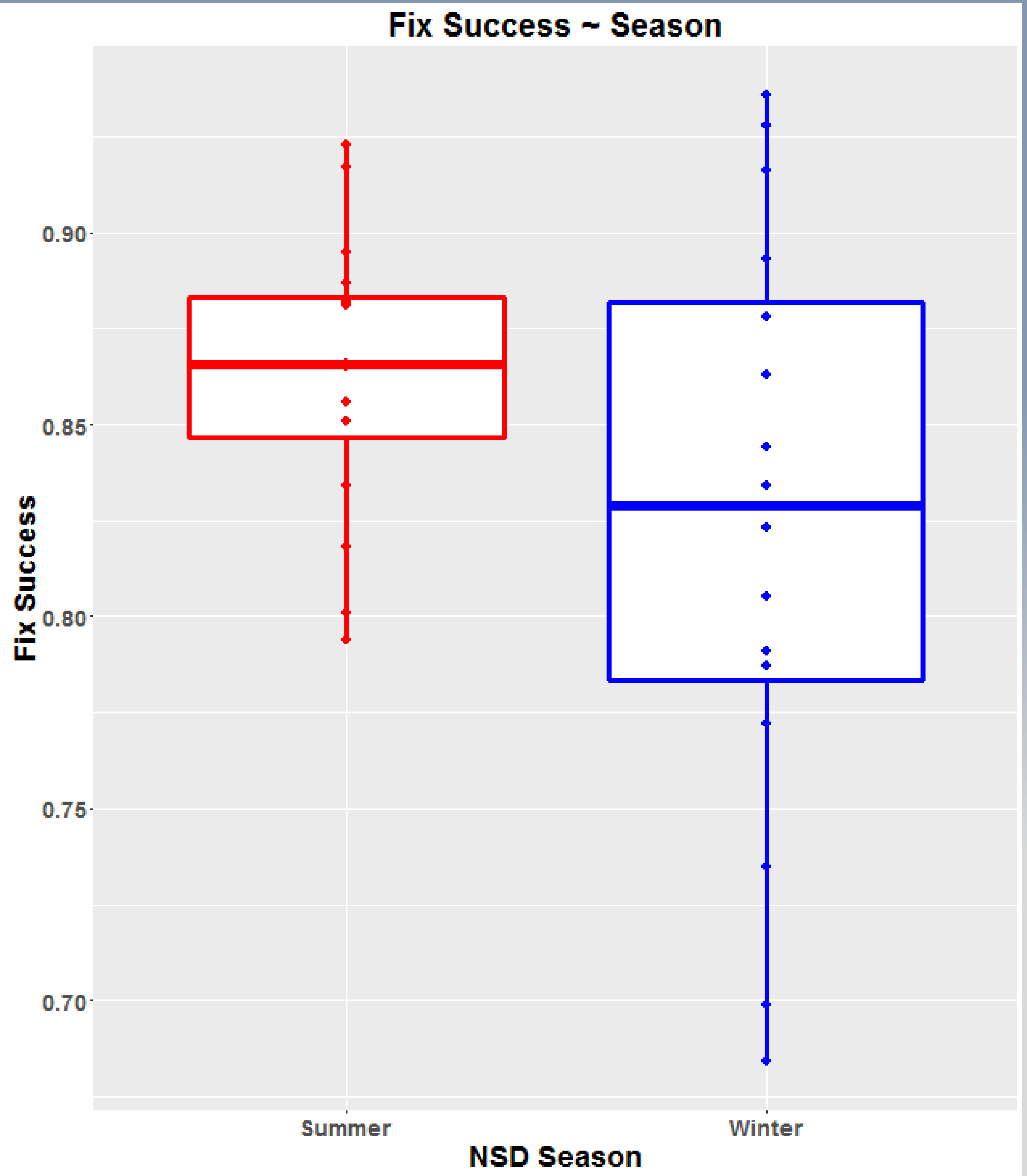


Data Screening

Spatial Impression

- 24 locations > 10 HDOP
- 88 locations > 60 meter horizontal error



(D'eon and Delparte 2005, Frair et al. 2010)

Model Selection and Validation

- Tiered approach to model selection

Univariate	**Tier One:**	Identified a functional form and spatial grain for each covariate
	Tier Two:	Competed similar covariate indices
Multi-variate	**Tier Three:**	1) Selected a base model within the terrain suite 2) Evaluated all combinations of the remaining covariates from other suites

- Model ranking was conducted using AICc
- Preformed model validation using *k*-folds cross-validation

(Boyce et al. 2002, Burnham and Anderson 2002, Vaida and Blanchard 2005, Gillies et al. 2006, Fieberg et al. 2010)