Bats and habitat fragmentation in Nicaragua: A country-wide multi-scale landscape analysis

José G. Martínez-Fonseca, Erin P. Westeen, Ho Yi Wan, Arnulfo Medina-Fitoria, Octavio Saldaña, Samuel A. Cushman, and Carol L. Chambers.

NAU
NORTHERN ARIZONA UNIVERSITY
School of Forestry

Artibeus lituratus

Introduction

- Worldwide: A global review of landscape-scale analyses in bats reveals geographic and taxonomic biases and opportunities for novel research. 2024 *In Press*

- Country level: This talk

- Species: *Vampyrum spectrum* (Phyllostomidae) movement and prey revealed by radiotelemetry and DNA metabarcoding. 2022

Introduction

- Selection of habitat is influenced by morphological and behavioral traits

- Allow species to respond to their environment across a range of spatial and temporal scales

Introduction

- Habitat fragmentation, degradation, and loss is recognized as one of the biggest threats to biodiversity

- Impede access to resources, demographic exchange, and gene flow

Introduction

Landscape structure can be quantified by metrics of:

Composition: diversity of patch types

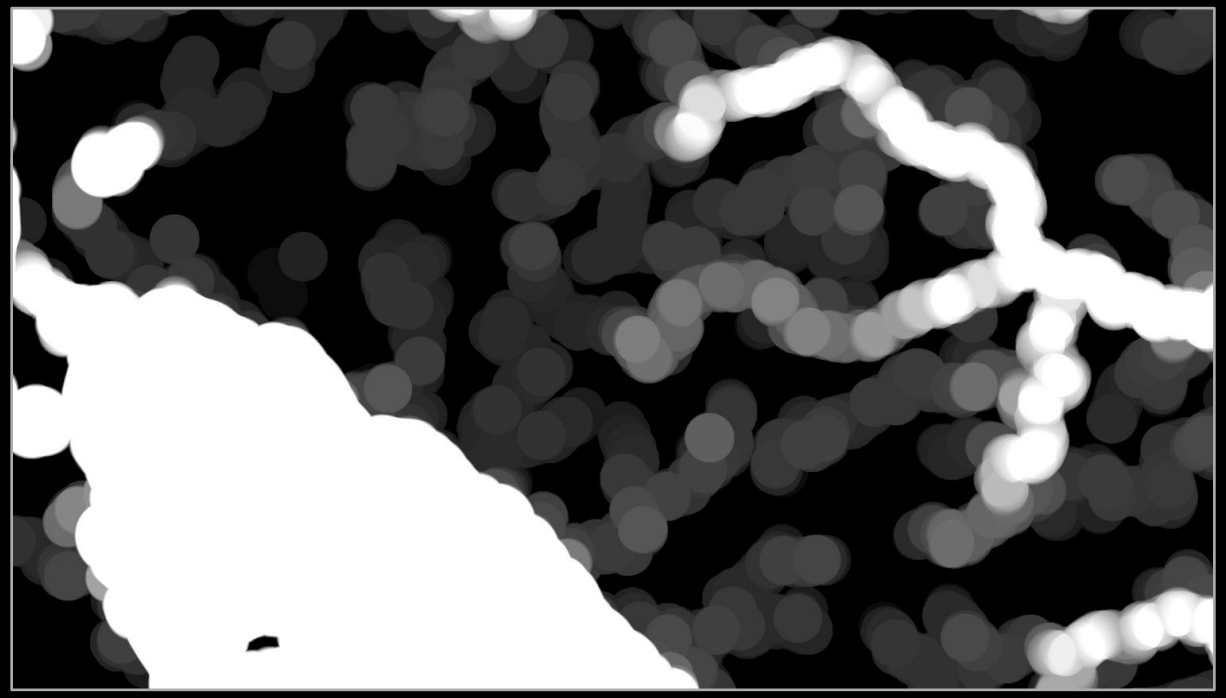
e.g., rainforest vs chaparral

Configuration: arrangement of the patches

e.g., number of patches, connectivity, edge effects

Introduction What is [spatial] scale?

Water at 150m scale



Water at 5000m scale

Introduction

BATS!

Vampyrodes caraccioli

Introduction

Bats are a challenging group for research:

- Nocturnal
- Slow reproductive cycles
- Taxonomy
- Diverse behaviors and functional groups
- Small size
- Detectability

Molossus alvarezi

Introduction

- Phyllostomids (“leaf-nosed”)
- Endemic to tropical and subtropical regions of the American continent
- ~200 species and equally diverse ecological traits

Lonchorhina aurita

Introduction

Diverse feeding guilds:

- Fruit-eating habitat generalists
- Gleaning insectivore and carnivore species often regarded as habitat specialists

Gardnerycteris keenani

Introduction

- We do not know much about these landscape-species interactions

Chrotopterus auritus

Introduction

- Landscape-scale effects on bats will improve our inferences for species habitat modeling

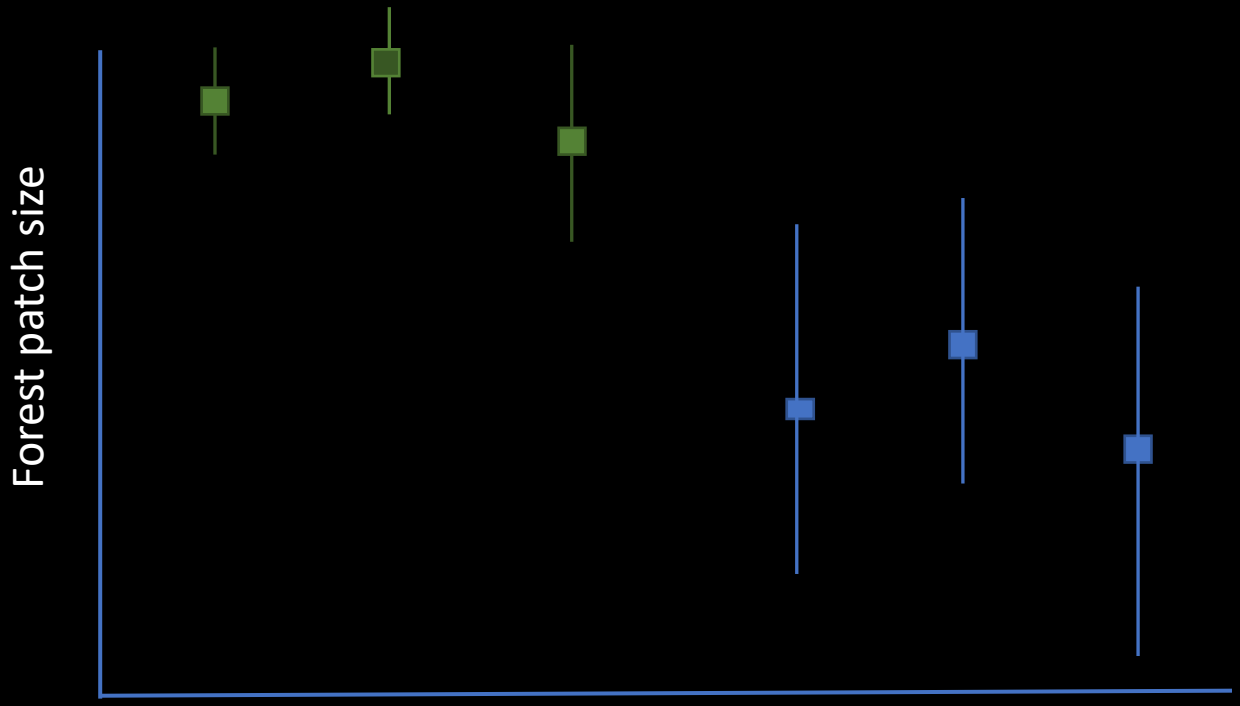
- Implications for management to preserve ecosystem functionality and for species conservation efforts

Introduction

Effects of landscape metrics at different scales will vary between species

Lophostoma silvicolum

“Habitat specialist”



Uroderma convexum

“Habitat generalist”

Research questions

- How do bat species tolerate forest fragmentation?

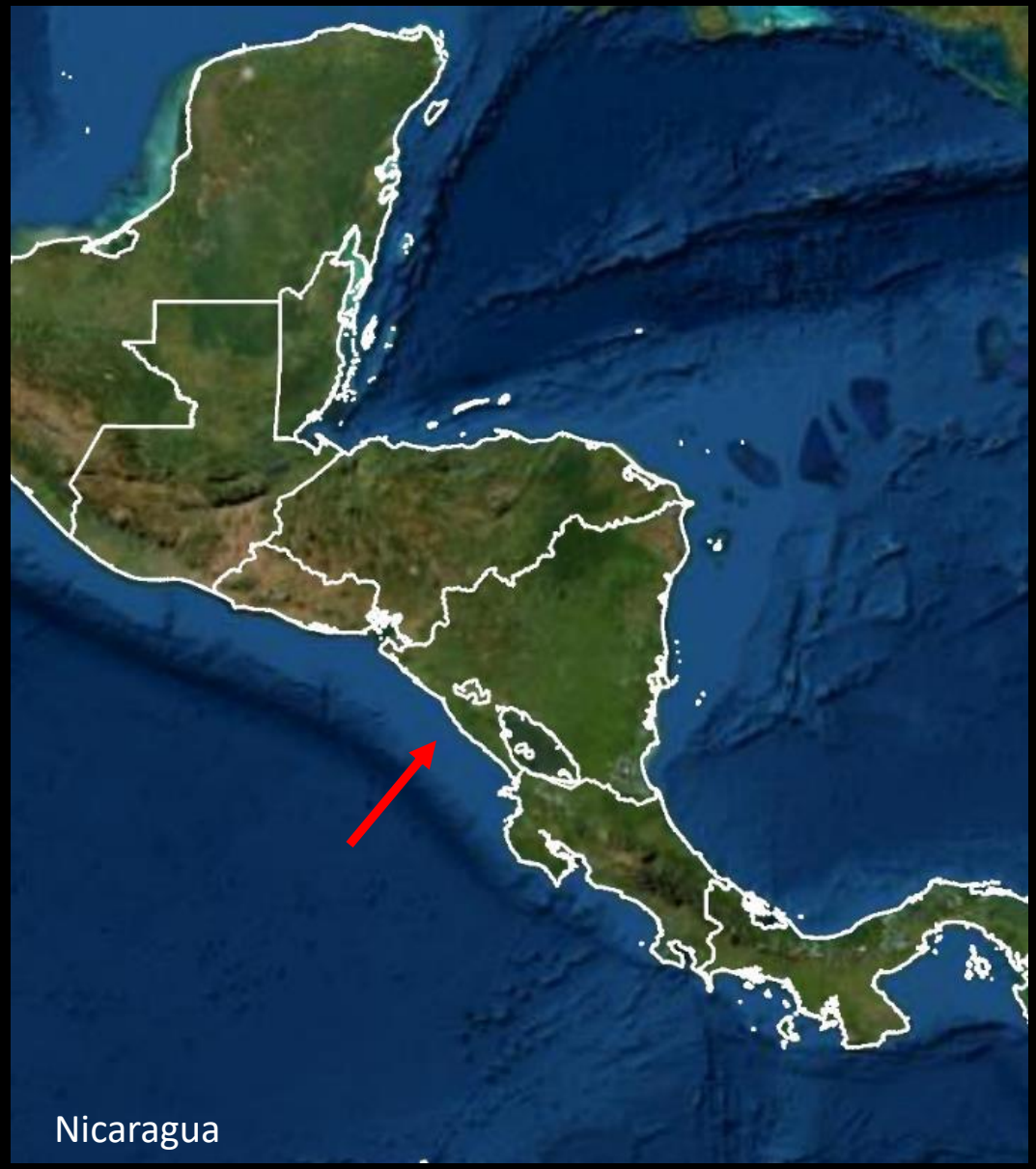
Quantify and describe the relative importance of landscape classes, metrics, and spatial scales that favor the occurrence of each species

Methods

Study area:

Nicaragua

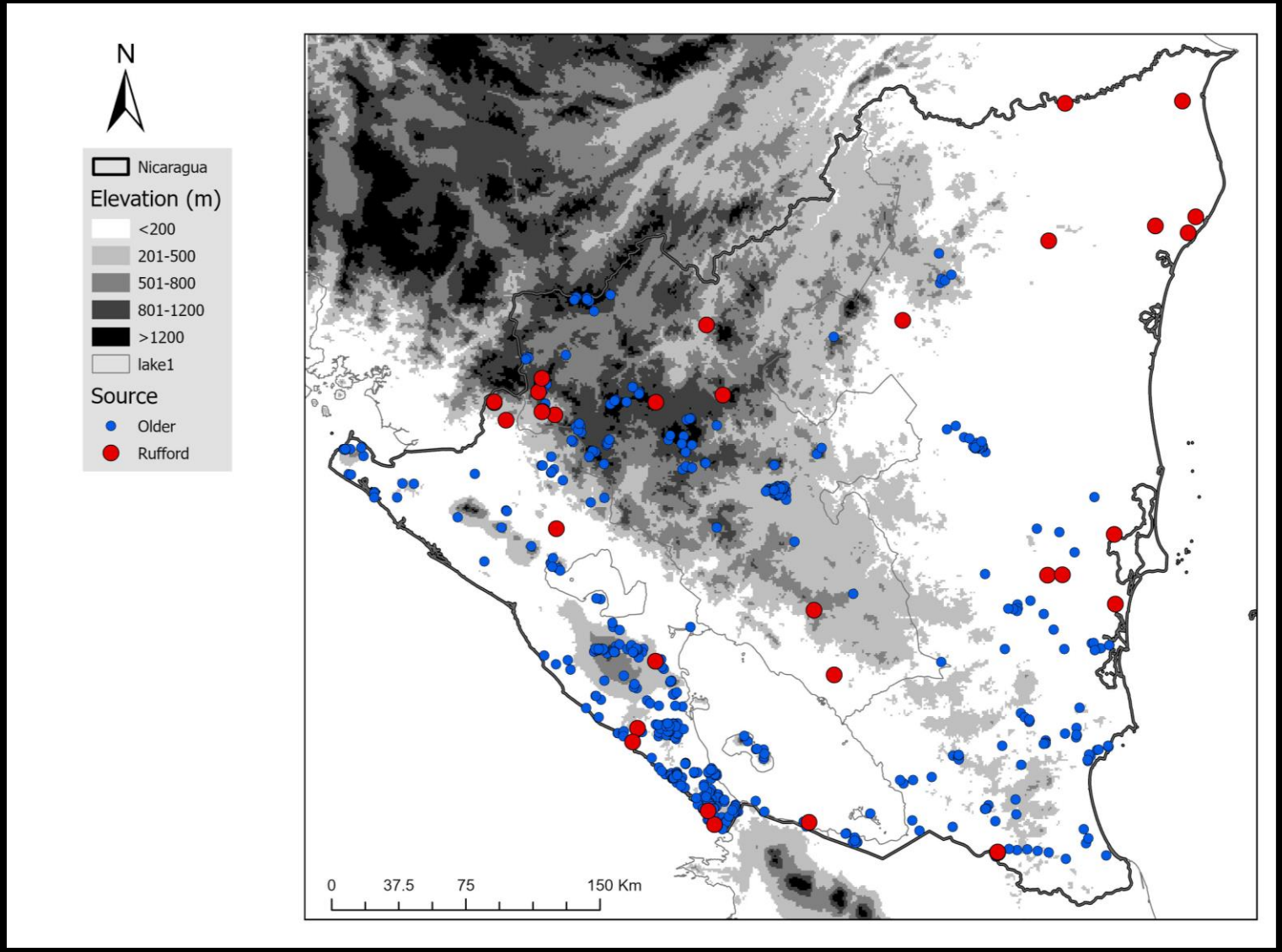
- 130 000 km^2
- 111 bat species



Methods

Data occurrence source:

20,000+ live captures
(850 nights, 660 sites)

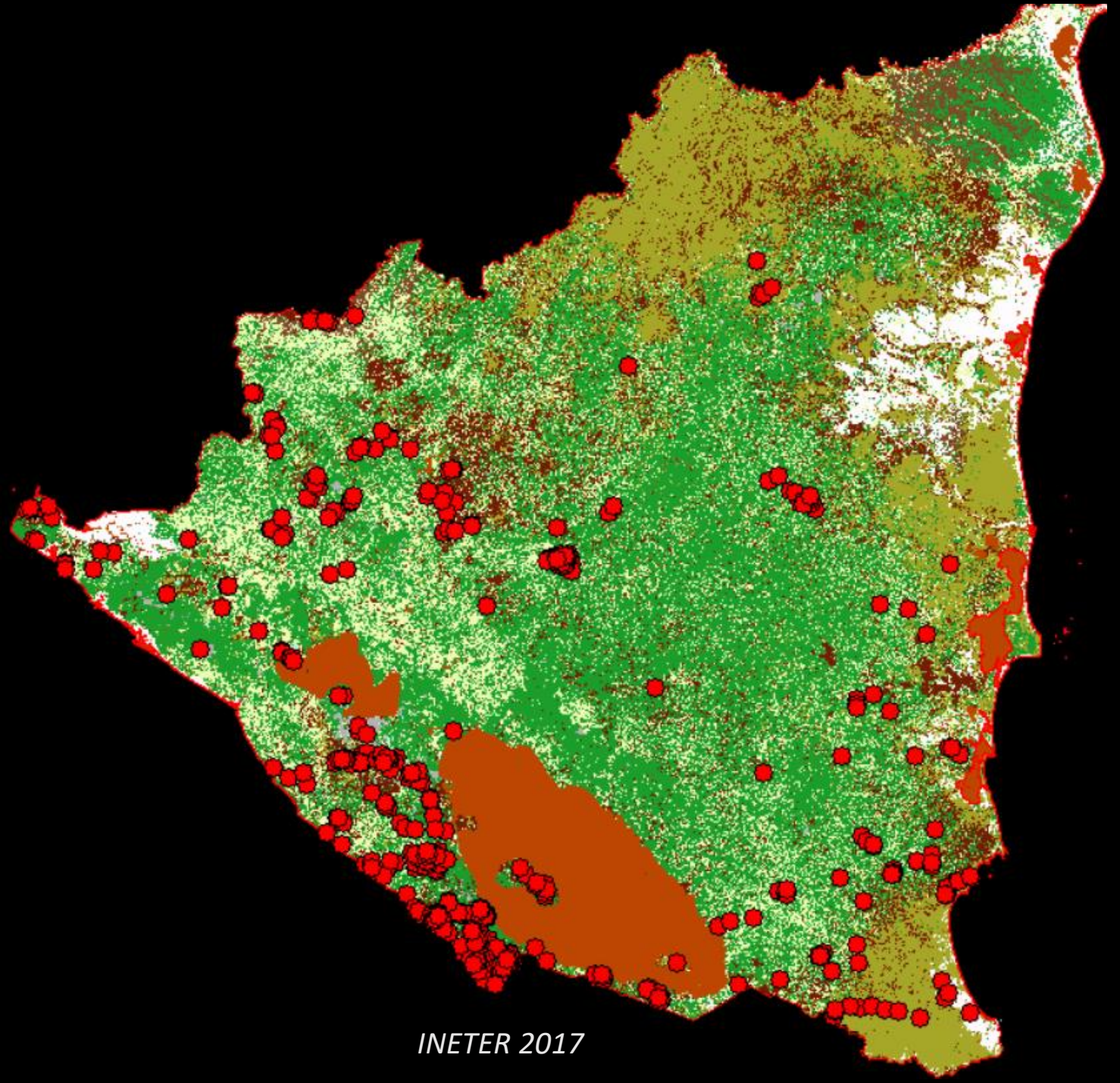


Methods

INETER (2017)
Land use

Hansen et al. (2017)
Tree cover

12 Land cover classes
(60 m raster resolution)



INETER 2017

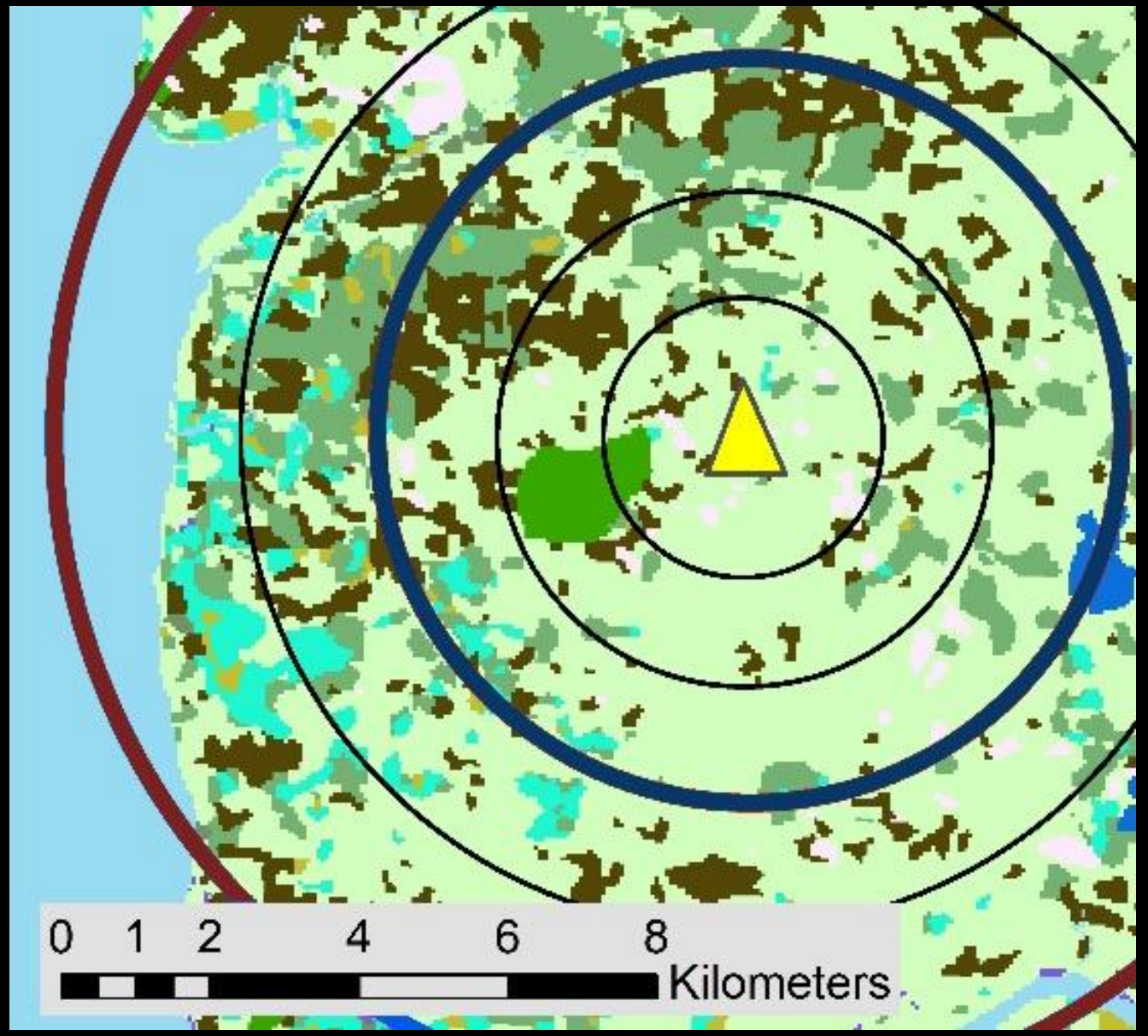
Methods

- 7 spatial scales

  small (150, 300, 600 m)

  medium (1200, 2400 m)

  large (4800, 6000 m)



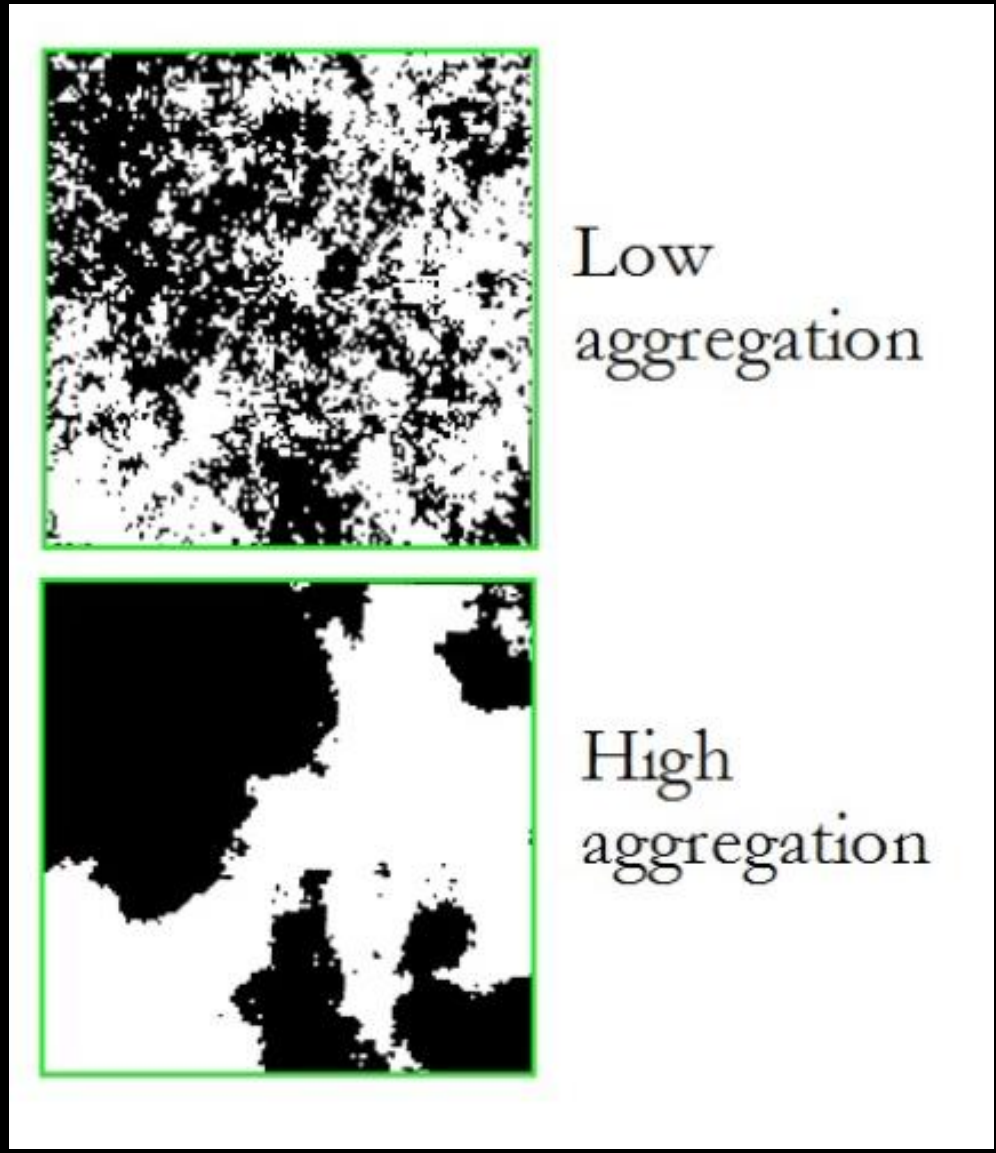
Methods

Landscape metrics

FRAGSTATS 4.2

13 landscape metrics

- Contagion
- Gyrate-Am (Correlation length)
- Largest Patch Index
- Patch & Edge Density
- Percentage of Landscape
- Simpson Diversity Index
- Contrast Weighted Edge Density

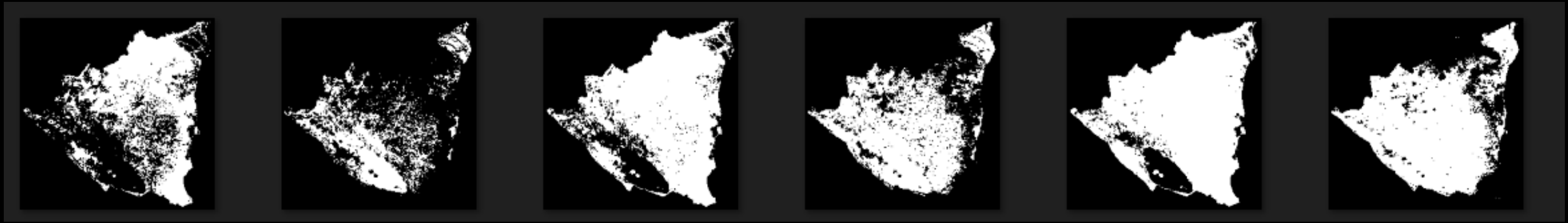


McGarigal et al. 2013

945 variables

metric/land cover/scale
combinations

patch density/Pine Forest/4800 m



Landscape variable layers' preview

Methods

Habitat generalists (Stenodermatinae)

Frugivores

Tree/leaf roosters

Artibeus lituratus (ARLI)
Mass: 53-73g
n= 305

Artibeus jamaicensis (ARJA)
Mass: 29-51g
n= 417

Chapter 3: Methods

Habitat specialists (Phyllostominae)

Phyllostomus discolor

Omnivore
Mass: 35-38g
n= 100
PHDI

Phyllostomus hastatus

Omnivore
Mass: 80-120g
n= 33
PHHA

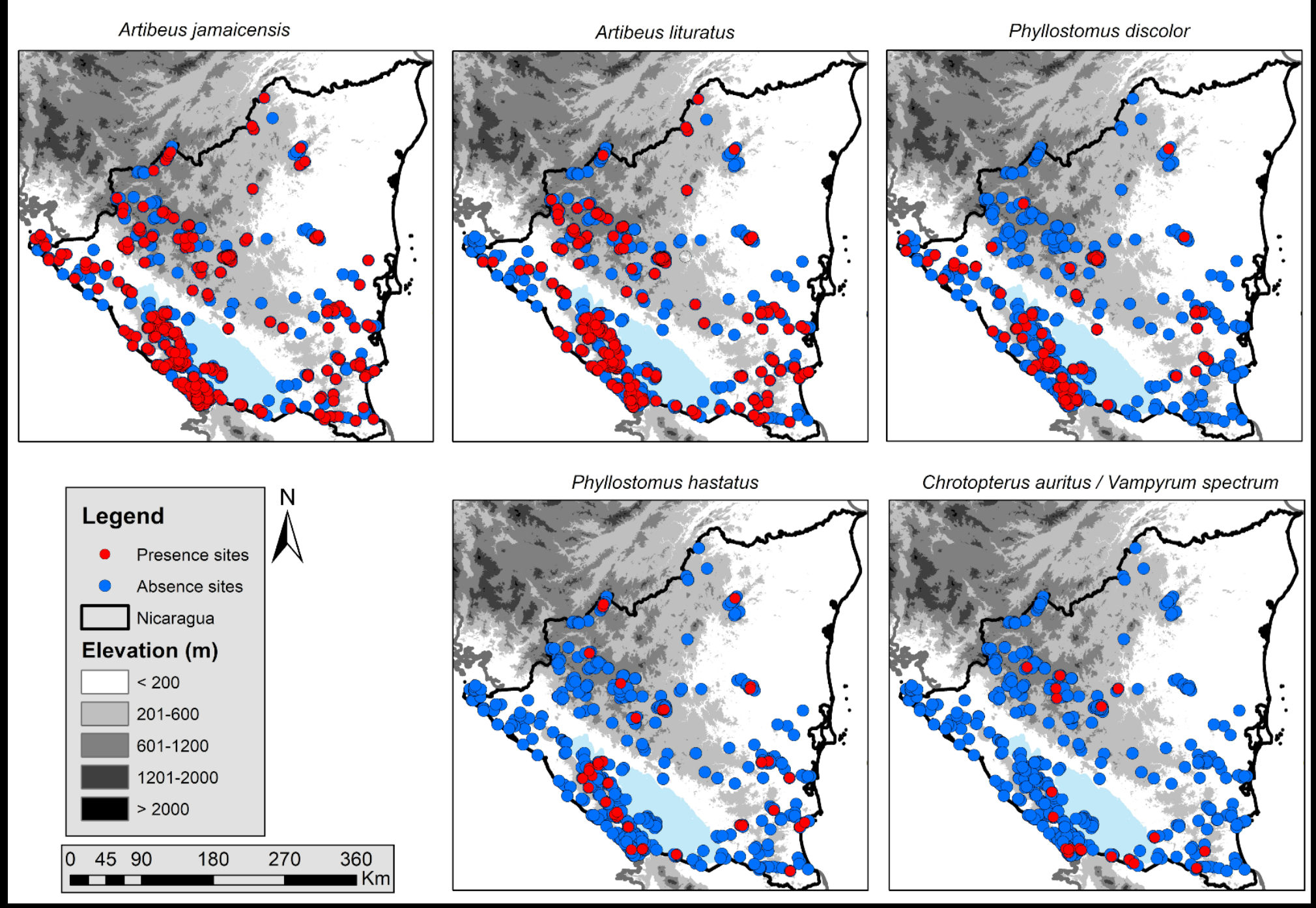
Chrotopterus auritus

Carnivore
Mass: 79-96g

Vampyrum spectrum

Carnivore
Mass: 170-180g

n= 23
CHAU/VASP


Artibeus jamaicensis
Artibeus lituratus
Phyllostomus discolor
Phyllostomus hastatus
Chrotopterus auritus / Vampyrum spectrum
Legend
Presence sites
Absence sites
Nicaragua
Elevation (m)
< 200
201-600
601-1200
1201-2000
> 2000
N
0 45 90 180 270 360
Km

Chapter 3: Methods

Random Forest Analysis

945 variables -> Scale optimization -> Multicollinearity check -> variable subset

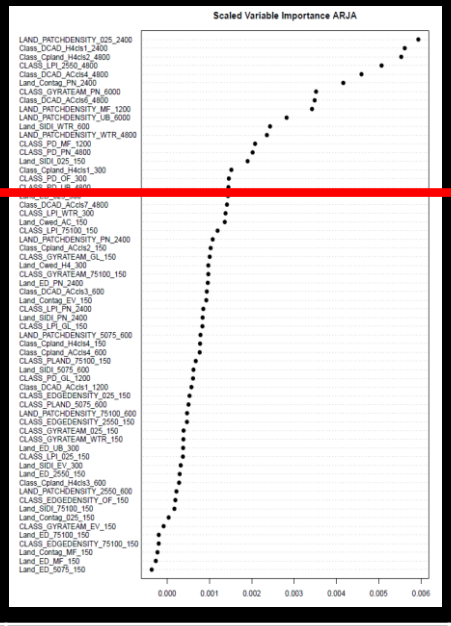
-> Model Improvement Ratio (MIR) -> Cross-validation / Model fit performance

randomForest and rfUtilities R packages

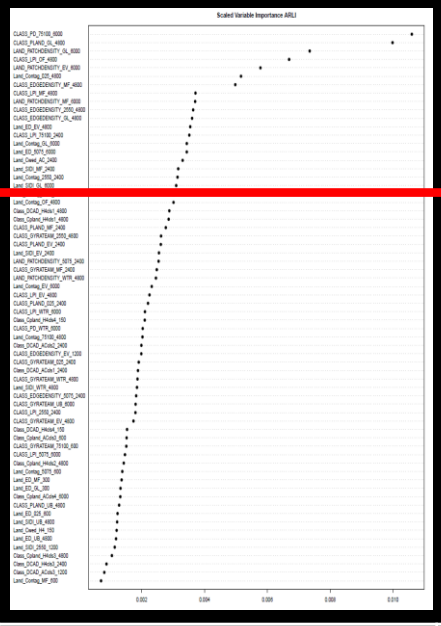
(Evans & Murphy, 2019; Breiman, 2021; Breiman & Cutler, 2022)

Chapter 3: Results

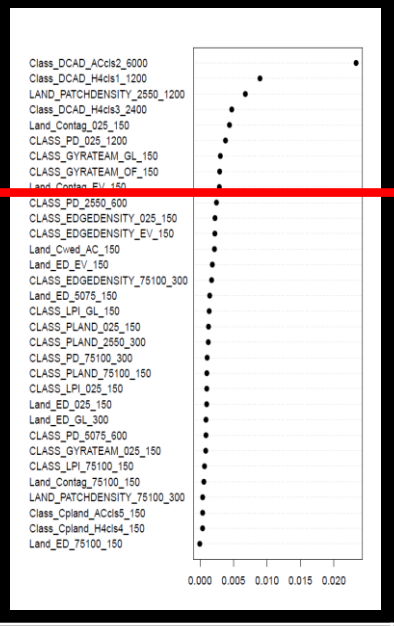
A. jamaicensis



A. lituratus

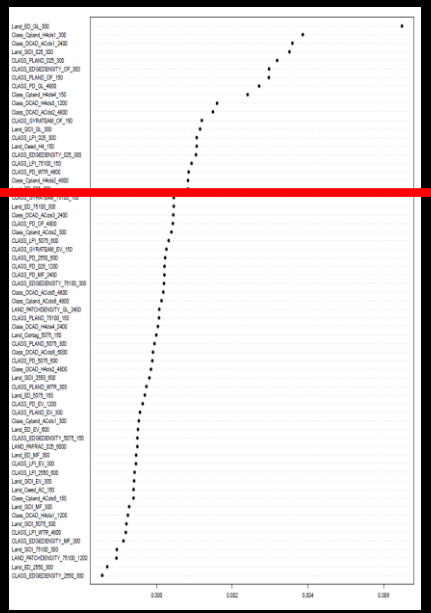


P. discolor



P. hastatus

V. spectrum/C. auritus

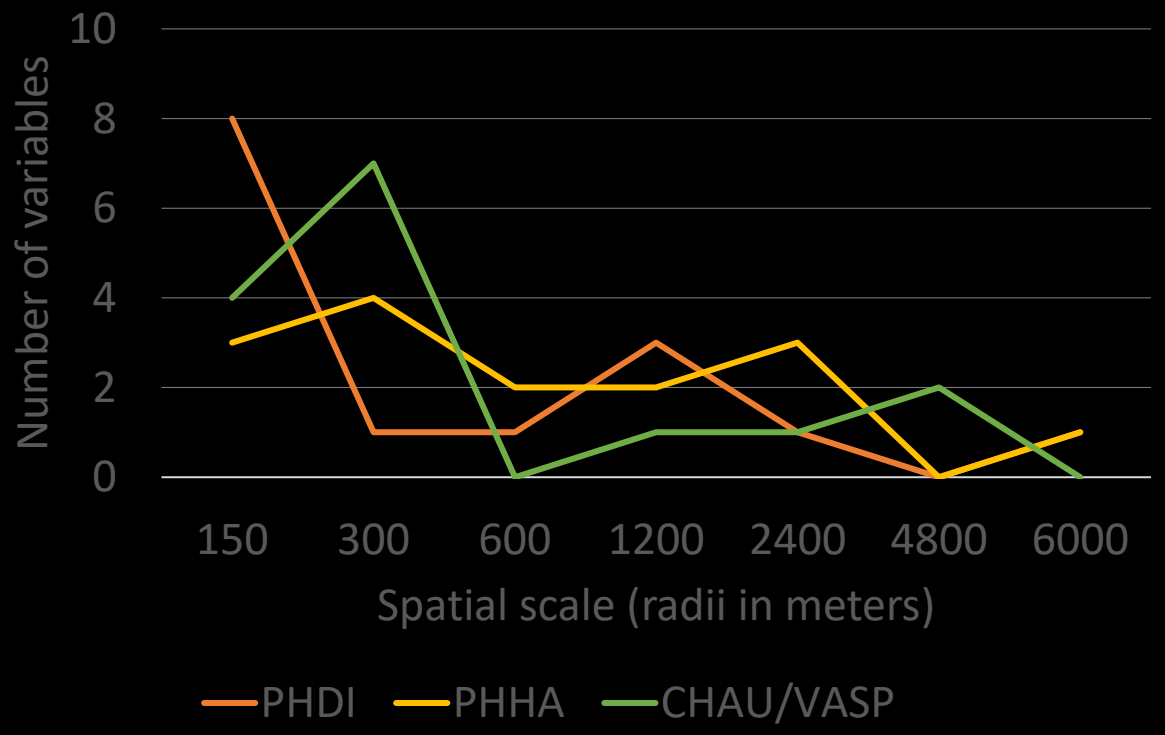


# Variables*	62	66	32	33	65
PCC	61.7	63.8	71	56	62
Cohen's Kappa	0.23	0.27	0.42	0.21	0.21
AUC	0.61	0.63	0.71	0.56	0.62

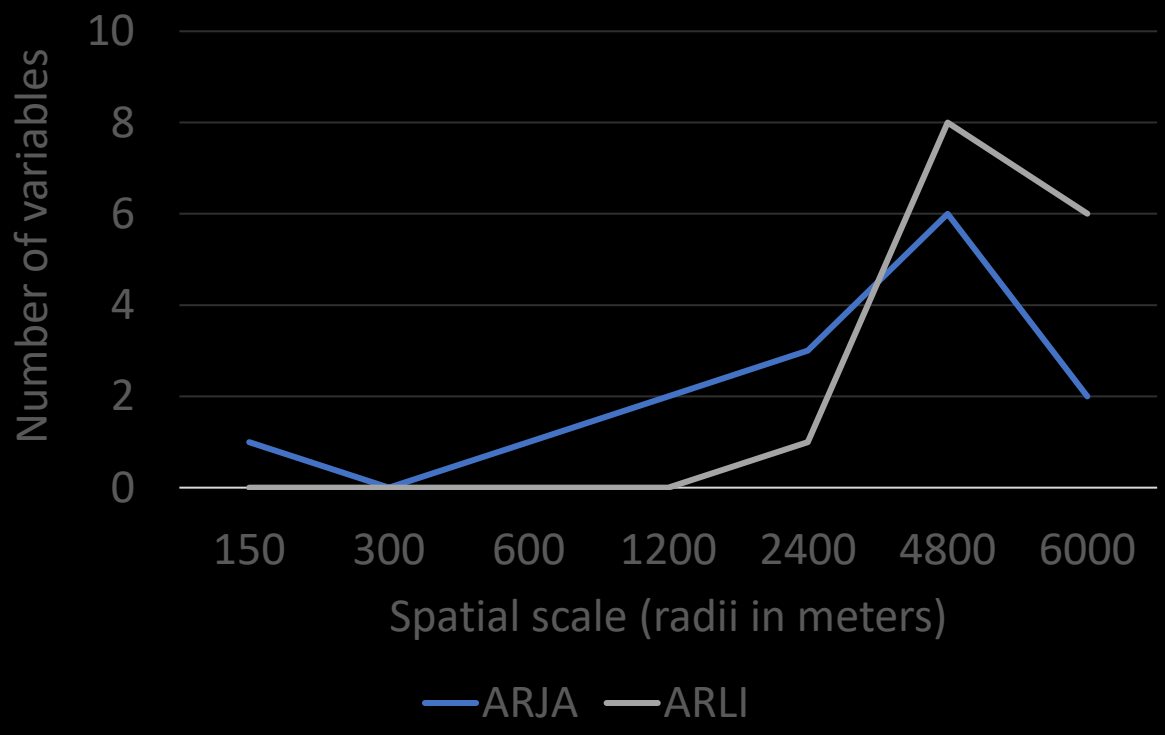
*In final model

Chapter 3: Results

Phyllostominae



Stenodermatinae



*Summary for top 15 variables in models (Scaled Variable Importance)

Chapter 3: Results

Habitat generalists

Responded positively to:

- Low density tree cover at large scale
- Dense tree cover at medium scales
- Urban areas

Responded negatively to:

- Pine forest amount
- Dense tree cover at small scales

Artibeus lituratus

Chapter 3: Results

Habitat specialists:

Responded positively to:

- Higher tree cover classes
- Mature forest

Responded negatively to:

- Low tree cover classes

Phyllostomus hastatus

Chapter 3: Discussion

- Important similarities between species in the two subfamilies but also a gradient in the tolerance to disturbance within

Continuous forest
Low mobility
High tree cover
Mature forests

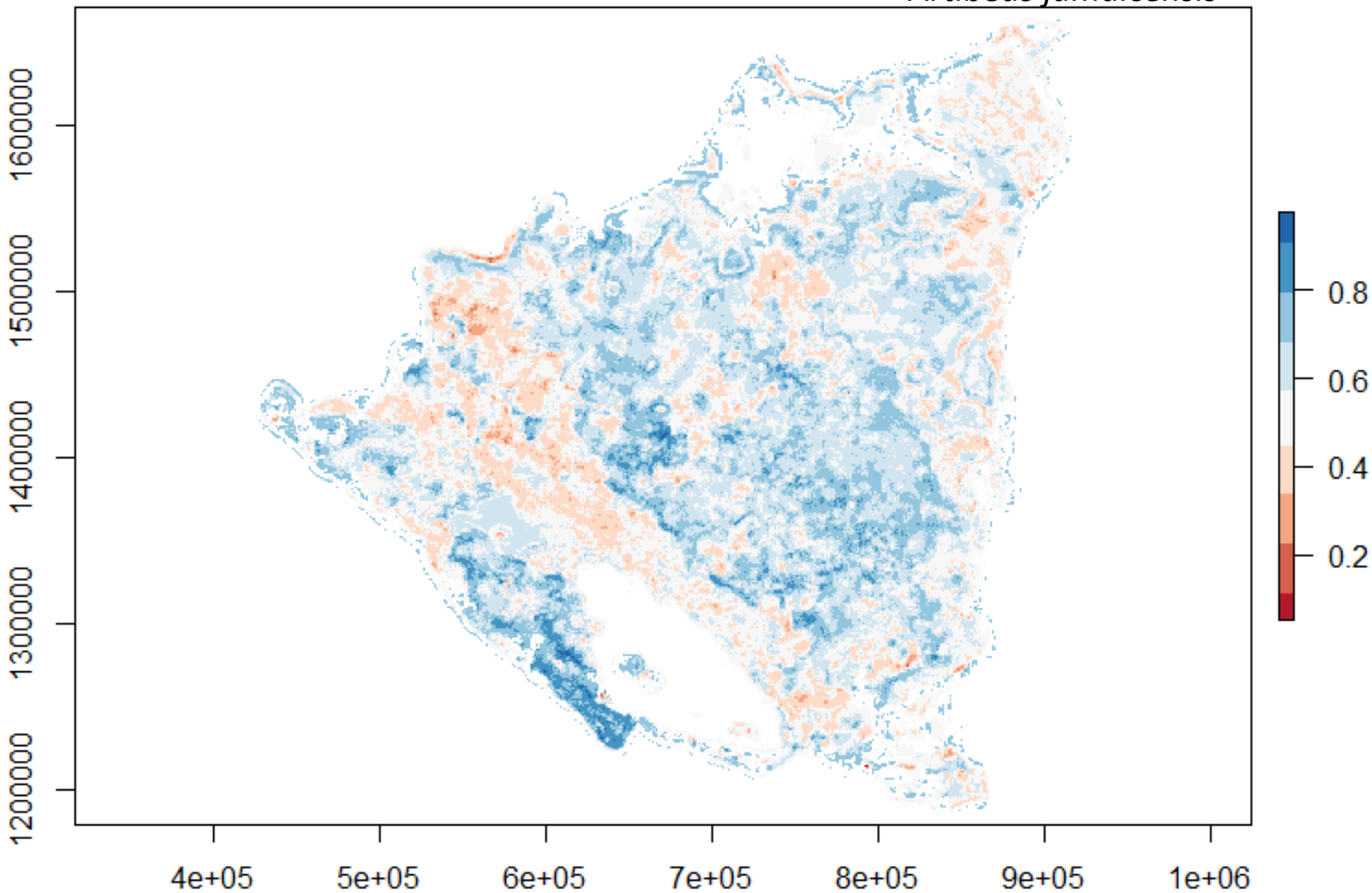
Tolerance to forest fragmentation

Highly fragmented forest
Great mobility
Low tree cover
Secondary forests

(Phyllostominae)

(Stenodermatinae)

Artibeus jamaicensis



Chapter 3: Discussion

- Correspond with empirical knowledge about both groups
- Anthropogenic changes affect closely related species in different ways

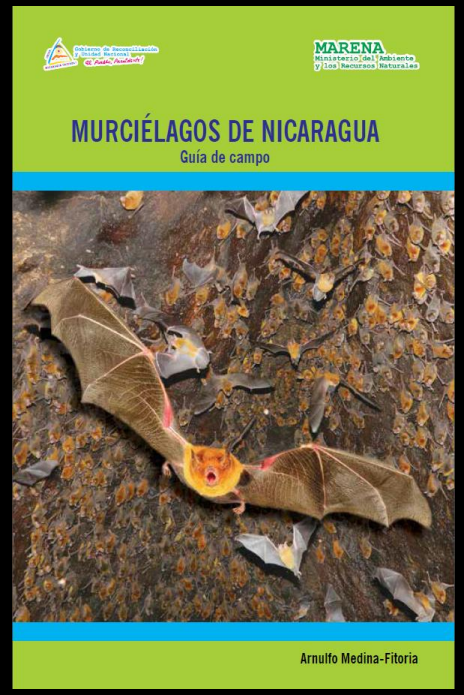
Chapter 3: Discussion

Research and management implications:

- There was no single landscape configuration that supported all the diversity of bat species in an area
- We need to manage for a diversity of landscapes, patch sizes, and connectivity for different vegetation types
- Inference should rely on more than one metric

In memoriam

Arnulfo Medina-Fitoria



Acknowledgements

Committee members:
Carol L. Chambers, Faith Walker,
Peter Fulé, Tad Theimer

NAU professors and mentors:
Dave Auty, Paul Beier, Chris Corben, Samuel A. Cushman, Mary DeJong, Jeff Jenness, Rebecca Mau, Arnulfo Medina-Fitoria, Bill Noble, Rodrígo Medellín, Bernal Rodríguez-Herrera, Octavio Saldaña, Javier Sunyer, Ho Yi Wan, Kimberley Williams-Guíllen, and Kei Yasuda

Mammal watching community:
Janell Cannon, Jon Hall, Abbey and Charles Hood, Fiona Reid, and Jon Swenson

Data collection:
Cristian Bonilla, Marlón F. Chávez-Velásquez, Hector Espinosa-Acevedo, Julio Loza, Maynor Fernández-Mena, Kiara Ruíz, and Luis E. Gutiérrez-López

Friends, colleagues, and lab mates:
Gabrielle Ayres, Frank J. Bonaccorso, Austin Dikeman, Jeff Foster, Jordyn Gladden, Samuel Ebright, Diny Hartiningtias, Samantha Hershauer, Jacquie Lyman, Tyler Mockta, Brianna Mann, Lenin Obando Matt Parker, Charlotte Rozanski, Daniel E. Sanchez, Audrey Sohikian, and Colin Sobek, Clarissa Starbuck, Luis Trujillo-Sosa, Jordyn Upton, Matt Voorhees, Jennifer Zahratka

Fieldwork in Nicaragua, 2017

Family:
Erin P. Westeen, Debra and William Westeen, José A. Martínez, Yamilet Fonseca, Francisco J. Martínez-Fonseca, Gabriela Schwizer

Acknowledgements

Northern Arizona University
(Center for International Education, School of Forestry,
Bat Ecology and Genetics Lab)

Paso Pacífico
The Rufford Foundation
Bat Conservation International (BCI)

Members of the Programa para la Conservación de Murciélagos de Nicaragua (PCMN) and the Red Lationamericana para la Consevacíon de Murciélagos (RELCOM)

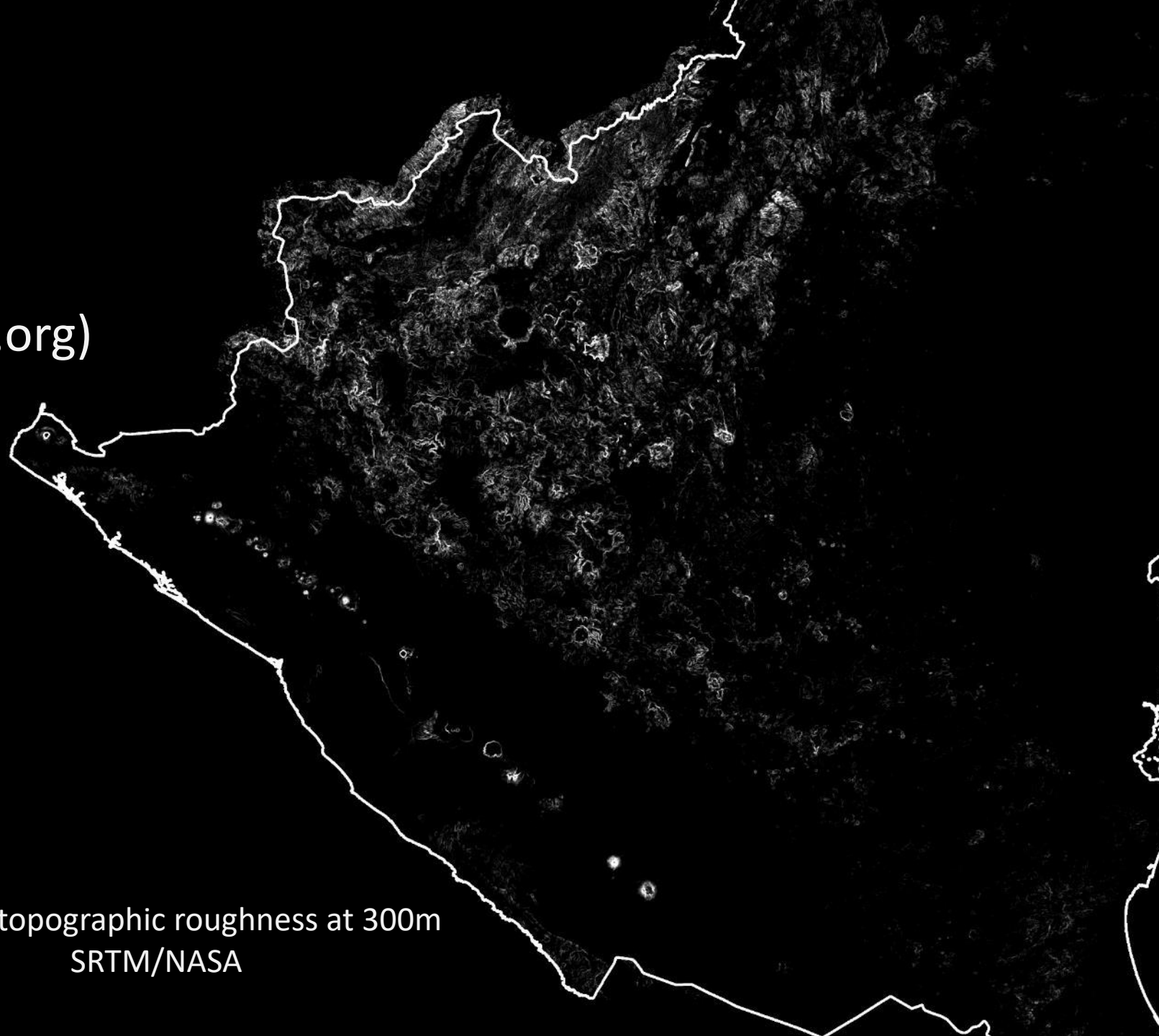
Questions? Preguntas?

Contact info:
jm3934@nau.edu
josegabrielwildlife.com

Methods

10 topographic (SRTM) and climatological data (bioclim.org)

- Annual temperature
- Annual precipitation
- Elevation
- Topographic roughness
- Heat Load Index (HLI)



Nicaragua topographic roughness at 300m
SRTM/NASA

Chrotopterus auritus

Chapter 3

Aspects to improve:

- Grain resolution
- Thematic resolution
- Sample size

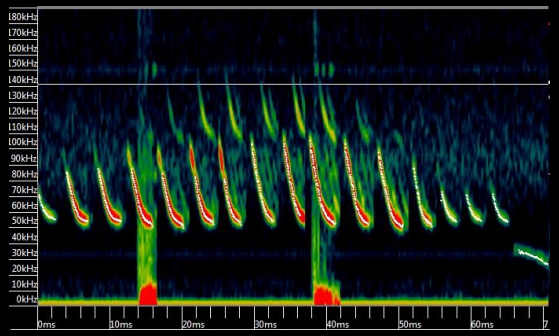
Introduction

Vespertilionidae

Emballonuridae

Molossidae

Phyllostomidae



Acoustics

Captures