NASA Biodiversity Project

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Soundscapes – Animal Diversity & Assist with Silent Remote Sensing + Develop Framework

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Biodiversity Metrics for Plants and Animals + *in situ* Forest Diversity Data

UAV and ISS Remote Sensing Analysis

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Overaching Objective

Our vision is to use three ISS sensor platforms (GEDI, DESIS and ECOSTRESS), a variety of space-based remote sensing platforms (e.g., MODIS, Landsat, ICESat 1/2), *in situ* acoustic sensor data, and an assortment of other "silent" in situ data (field surveys, national and regional forest inventory data, UAV data, and meteorological data) to build a multi-sensor biodiversity modeling framework that is applied to major terrestrial global biomes.

- Animal + Plant Biodiversity Model

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ISS-based Sensor Habitat Models

ECOStress

Habitat Condition Model (ECOStress vs. stressor/condition)

DESIS

Plant Species Diversity Model (DESIS vs. survey data)

GEDI

Structure (GEDI vs. survey data/drone point cloud)

Dynamic Habitat Model

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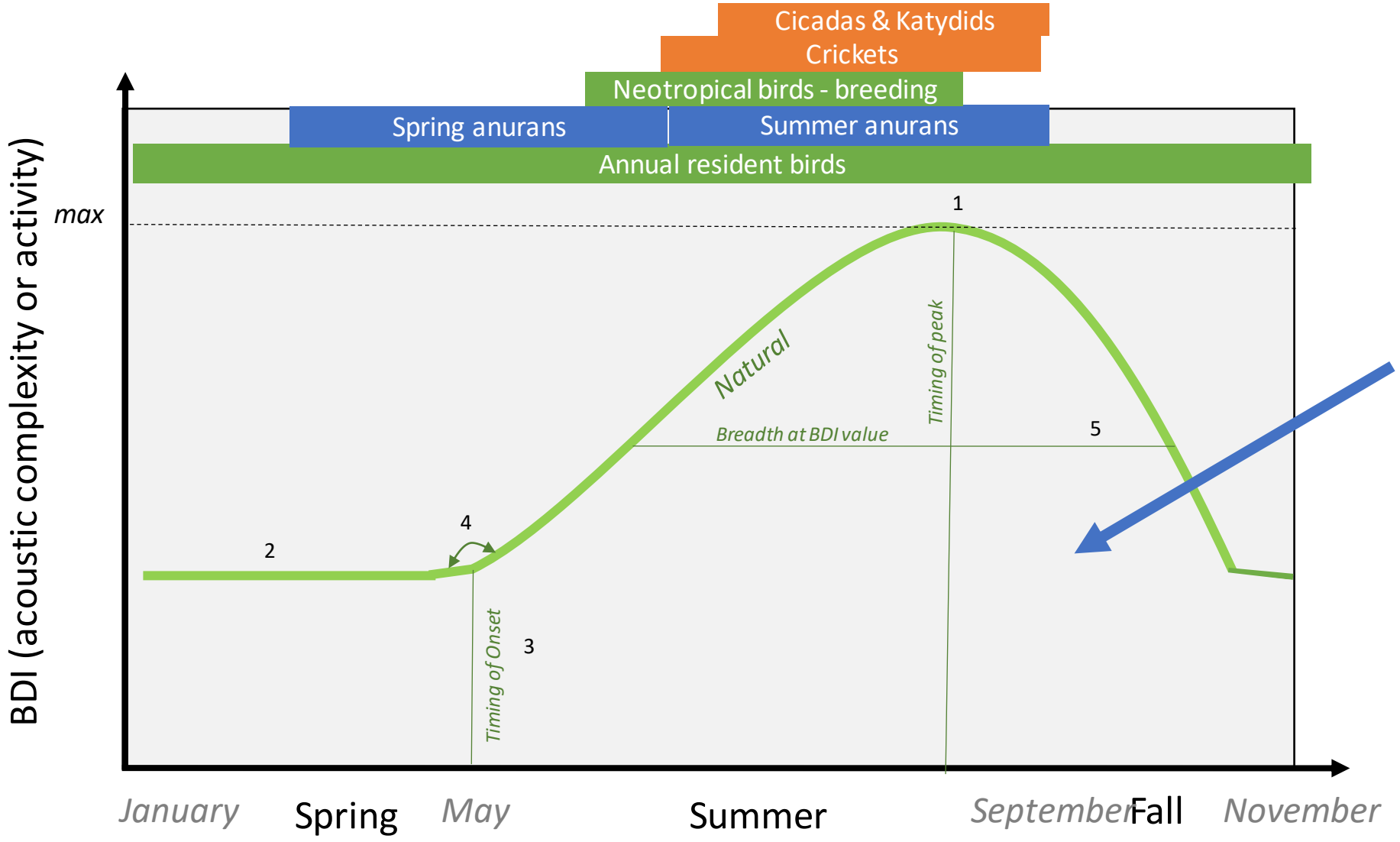
Animal-Habitat Biodiversity Framework

Conceptual Model for Acoustic Phenology (Temperate Forest)

A. Seasonal Changes of a Biophonic Diversity Index (ACI, ADI, H, BI)



Area under the curve is the site annual acoustic diversity

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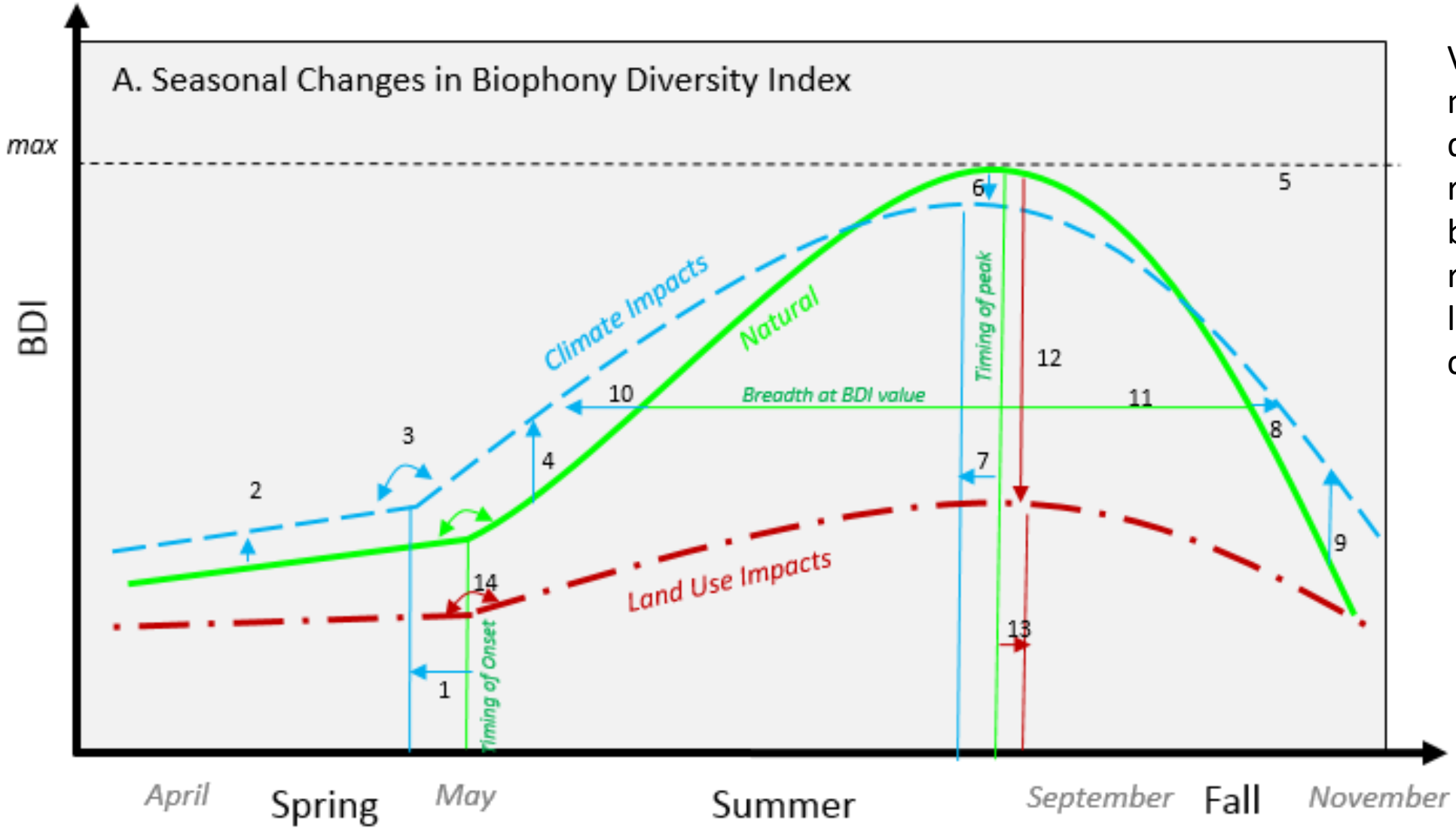
Animal-Habitat Biodiversity Framework

Conceptual Model of Stressor-Response in a Soundscape



Values 1-13 are measures of departures from reference or baseline and represent impacts of land use or climate change

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Sites

Tippecanoe Soundscape Study (TEMPERATE FOREST)

7 sites at Purdue properties that have been recording since 2008

Sites include old growth forest, secondary forest, urban forest, two ag sites, wetland and one old orchard

Need to expand this to 25 locations strategically placed
(2 year long study)

Tanzania Miombo Woodland Study (WOODLANDS)

7-9 sites at UCL's Issa Valley Miombo woodlands that have been recording since Feb 2017

Sites include marginal woodlands (< 50% canopy cover) and riparian woodlands (> 80% cover)

Need to expand this to 25 locations strategically placed
(1-2 month long study)

Sites

Mongolia Forest-Steppe Study (ASIAN STEPPE)

Interfaces to an NSF Coupled Natural Human Systems 2 project in the central highlands and the western mountain regions.

Collecting data on herder practices as it relates to coupling of sonic-silent variables important to their lifeways and lived experiences

Ethnographic study on sonic practices.

Bangladesh Sundarbans Mangrove Study (MANGROVES)

7 sites at Swapan Kumar's 200+ mangrove forest 20 year inventory study in the Sundarbans (UNESCO site)

Sites span low to high tree diversity based on his long-term data over a very large area

Need to expand this to 25 locations strategically placed
(1 month long study)

Major Highlights of Last 3-6 Months

1. Acoustic (seasonal and diel) phenologies for all sites as function of ecosystem dynamics and environmental stressors (Sundarbans and Mongolia)
2. Building of ISS-based plant models (focusing on DESIS and ECOStress)
3. Collection of tools for perceptualizing acoustic, drone-based and ISS-based data
4. Increased communication with local natural resource decision makers

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1. Acoustic Phenologies

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Omnidirectional Mics
Omnidirectional Mics
S4A03848
PROPERTY OF
PURDUE UNIVERSITY
wildlife
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UNIVERSITY
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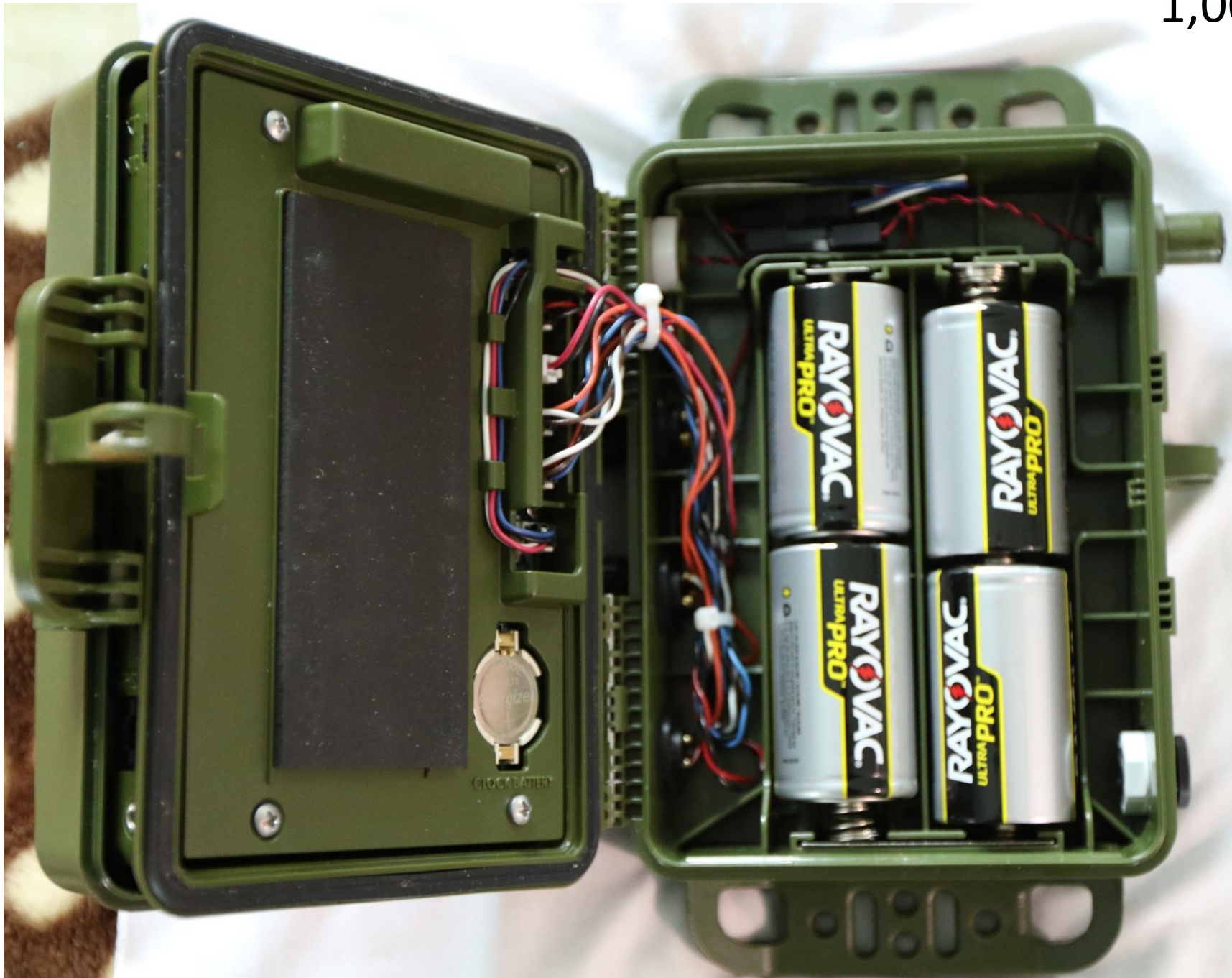
S4A17568
wildlife

1,000,000 recordings



4 D-cell sized batteries. Program sensors to record using a duty cycle of 1 min on, 9 mins off.
Will last 4 months.

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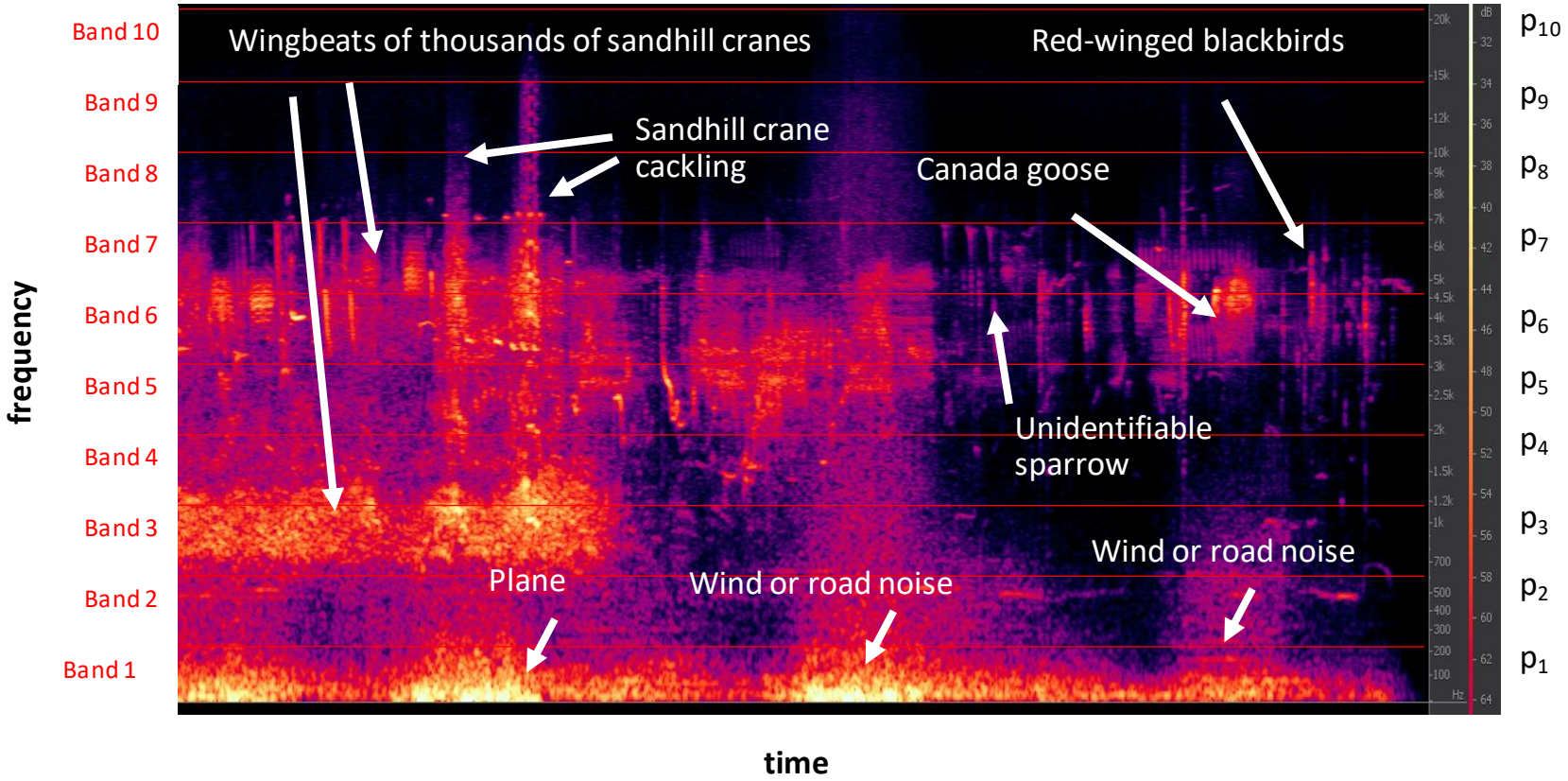
Use Four Approaches to Calculate Animal Diversity Using Acoustic Data

1. Acoustic Indices: Spectrogram Discretization

A. Frequency Band Discretization of a Spectrogram



B. Indices based on Frequency Band Discretization

Acoustic Diversity Index (Frequency Band Entropy)

$$\beta_{t,l} = \sum_{i=1}^{N} p_i * \ln p_i$$

Others Include

H (spectral and temporal entropy)
ACI (Acoustic Complexity Index)
BI (Bioacoustic Index)
NSDI (normalized spectral difference index)

Use SoundEcologyR

Zhao, Zhao, Zhi-yong Xu, Kristen Bellisario, Rui-wen Zeng, Ning Li, Wen-yang Zhou, and Bryan C. Pijanowski. "How well do acoustic indices measure biodiversity? Computational experiments to determine effect of sound unit shape, vocalization intensity, and frequency of vocalization occurrence on performance of acoustic indices." *Ecological Indicators* 107 (2019): 105588.

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Acoustic Indices

Acoustic Diversity Index (ADI)

Diversity of sound across all frequency bands and expressed as entropy measure

Acoustic Complexity Index (ACI)

Number of modulated events in frequency and amplitude dimensions per minutes

Bioacoustic Index (BI)

Measure of the amount of activity in frequencies for birds (2-8 kHz)

Number of Events (EVN)

Number of acoustic events per second

H (Spectral Entropy)

Entropy measured across time and frequency bins segmented by FFT per recording

Signal to Noise Ratio (SNR)

Measure of acoustic activity and intensity per minute

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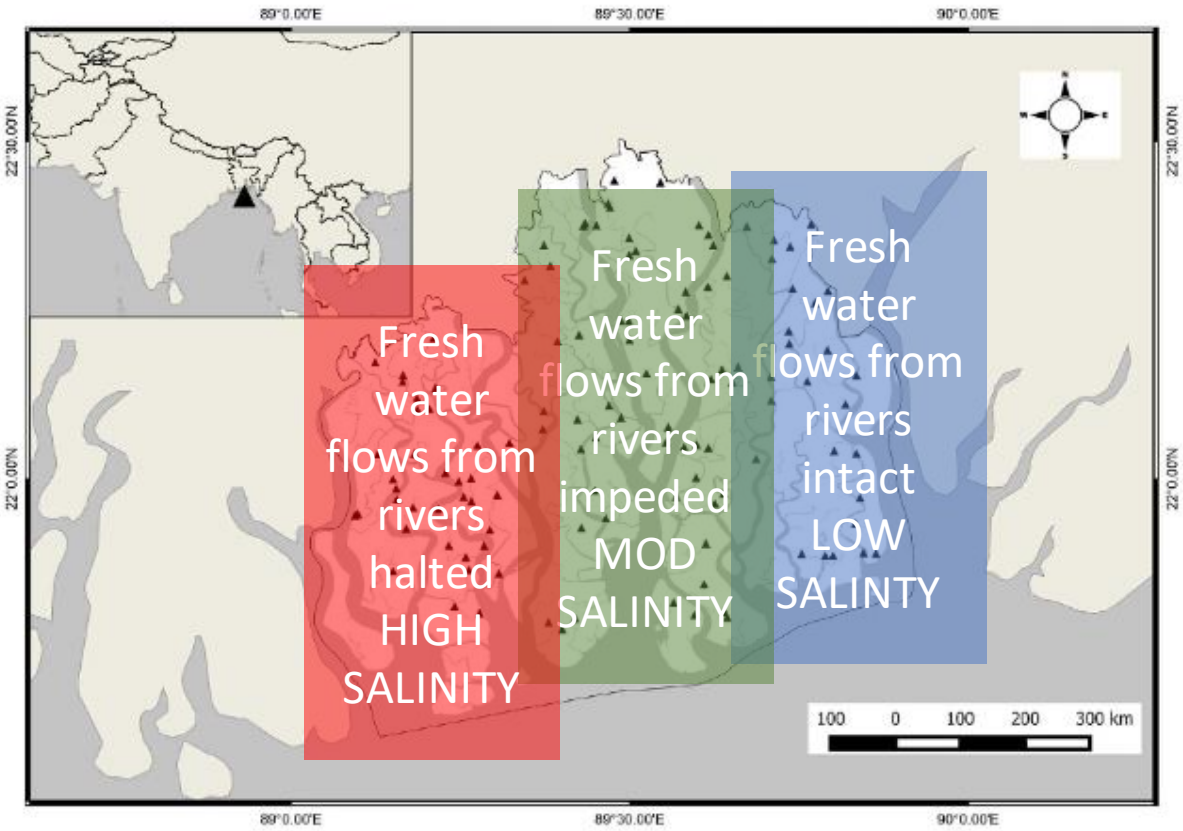
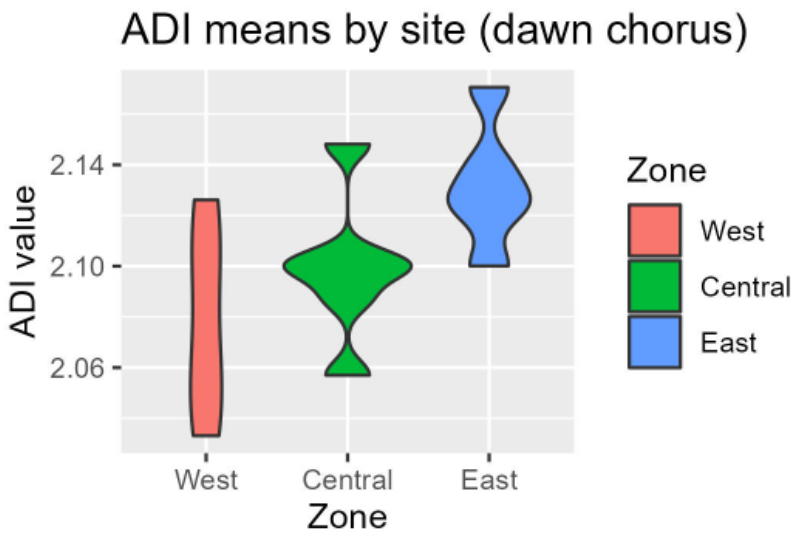
Sundarbans – UNESCO World Heritage Site in Bangladesh and India and Largest Intact Mangrove System in the World

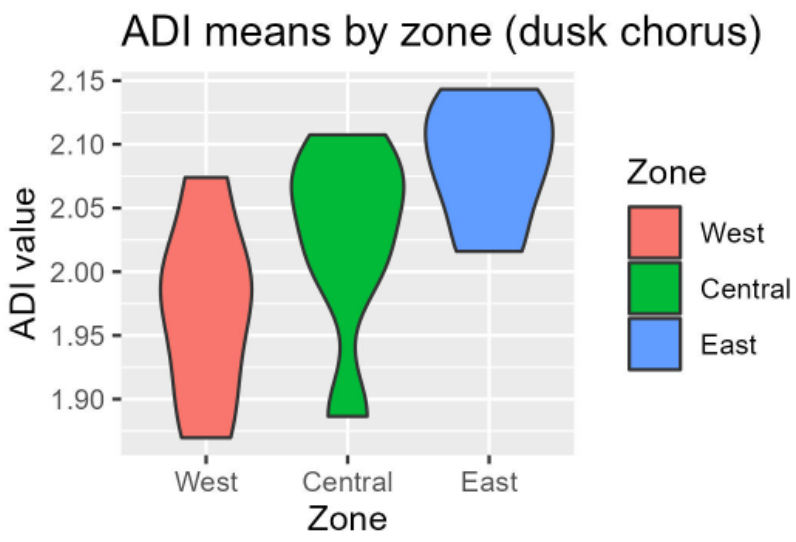


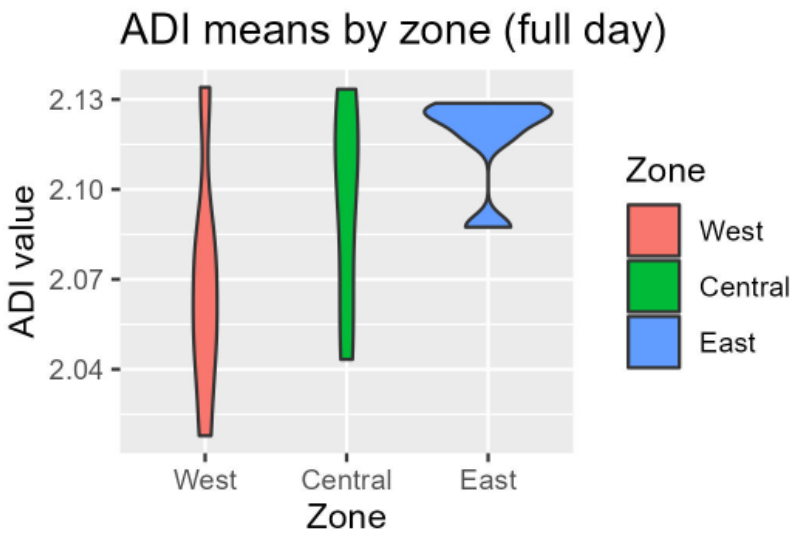
Forest Department, Bangladesh mangrove tree monitoring sites (N=110). Number of trees, species, dbh, crown height, # diseased, # cut.

Also shown is research vessel and an endangered Ganges River dolphin breaching, upper left of boat

Acoustic Indices







West is most highly stressed due to higher than normal salinity and thus has reduced ADI values likely reflecting fewer birds and insects

Dawn reflects mostly avian species richness whereas dusk chorus is mostly insects with a few crepuscular and nocturnal birds

Central zone remain high and might reflect consistency with the Intermediate Disturbance Hypothesis of Connell

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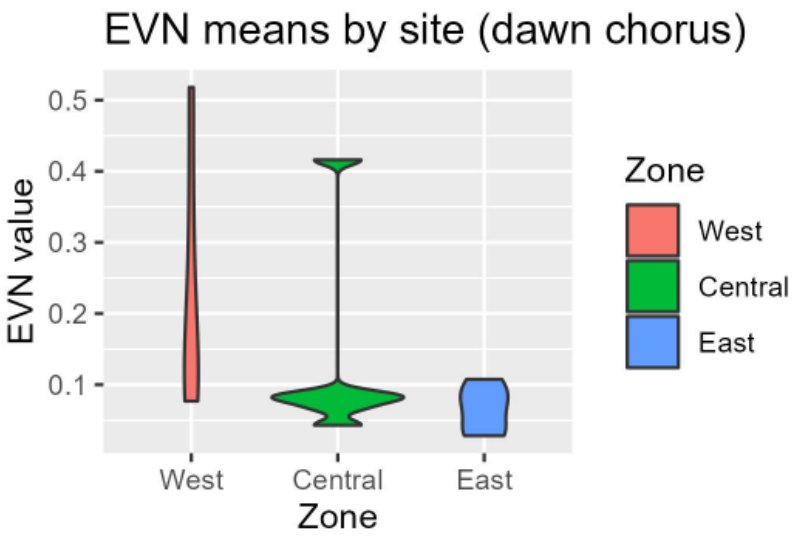
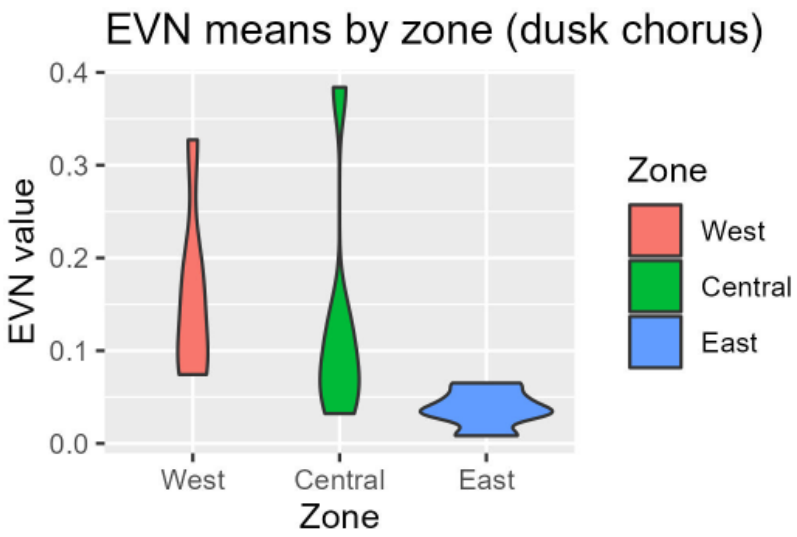
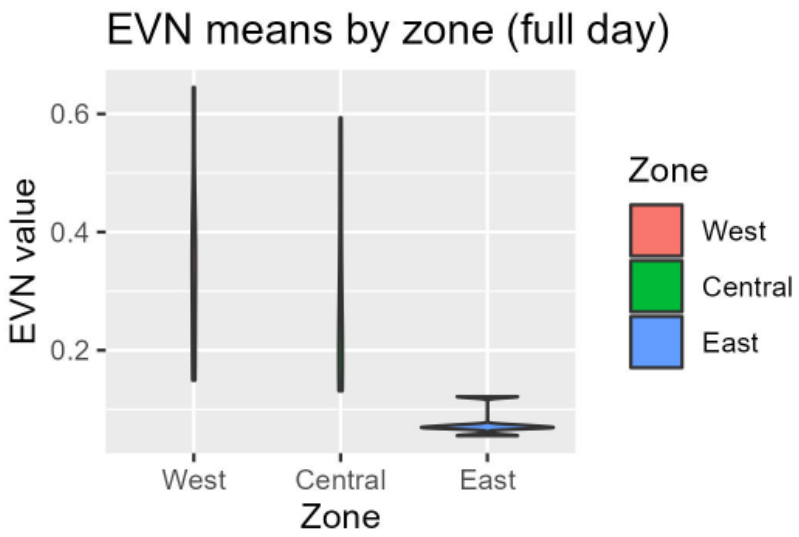
Acoustic Indices







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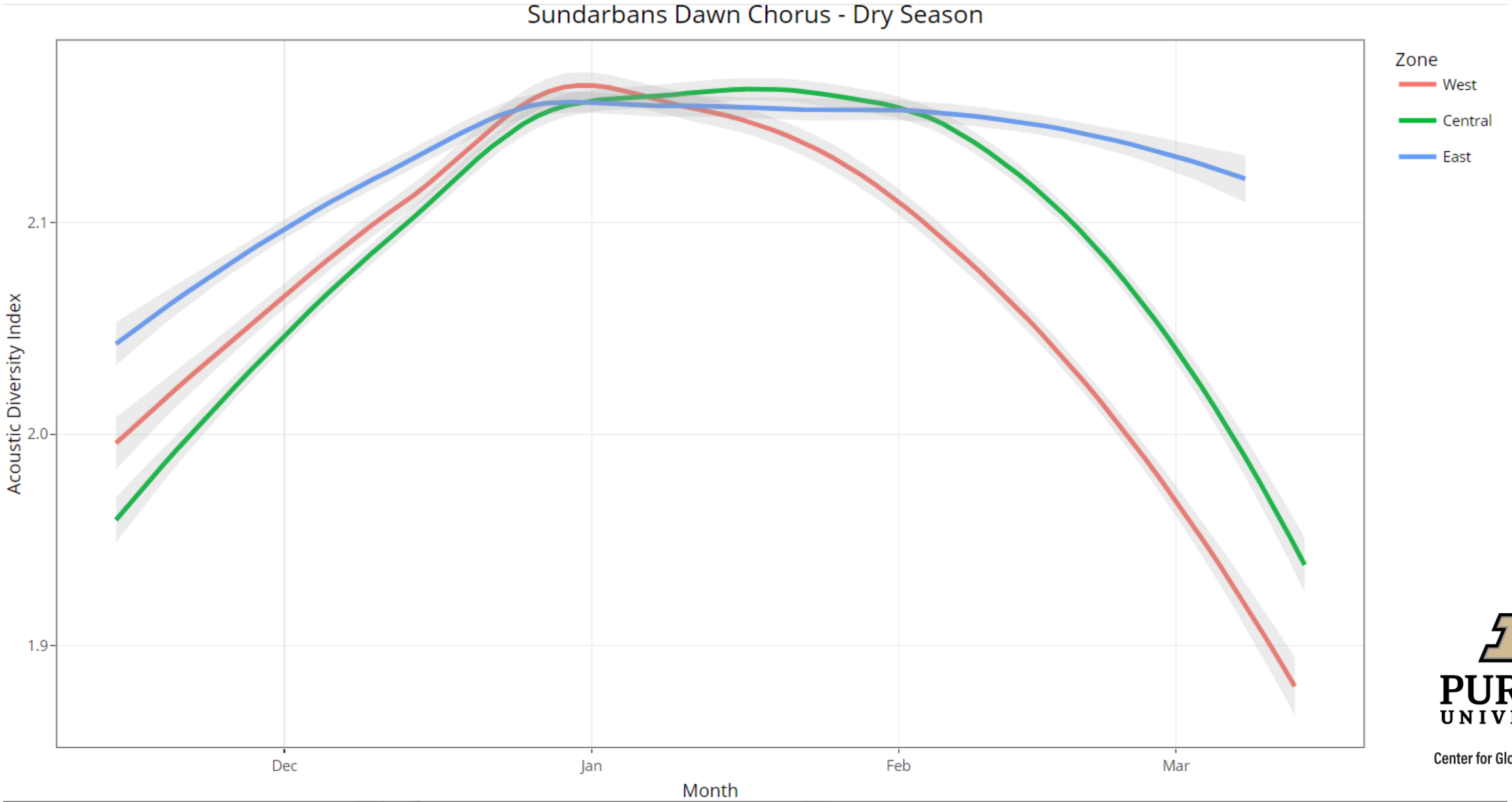
Acoustic Indices (ADI) – Phenology Model



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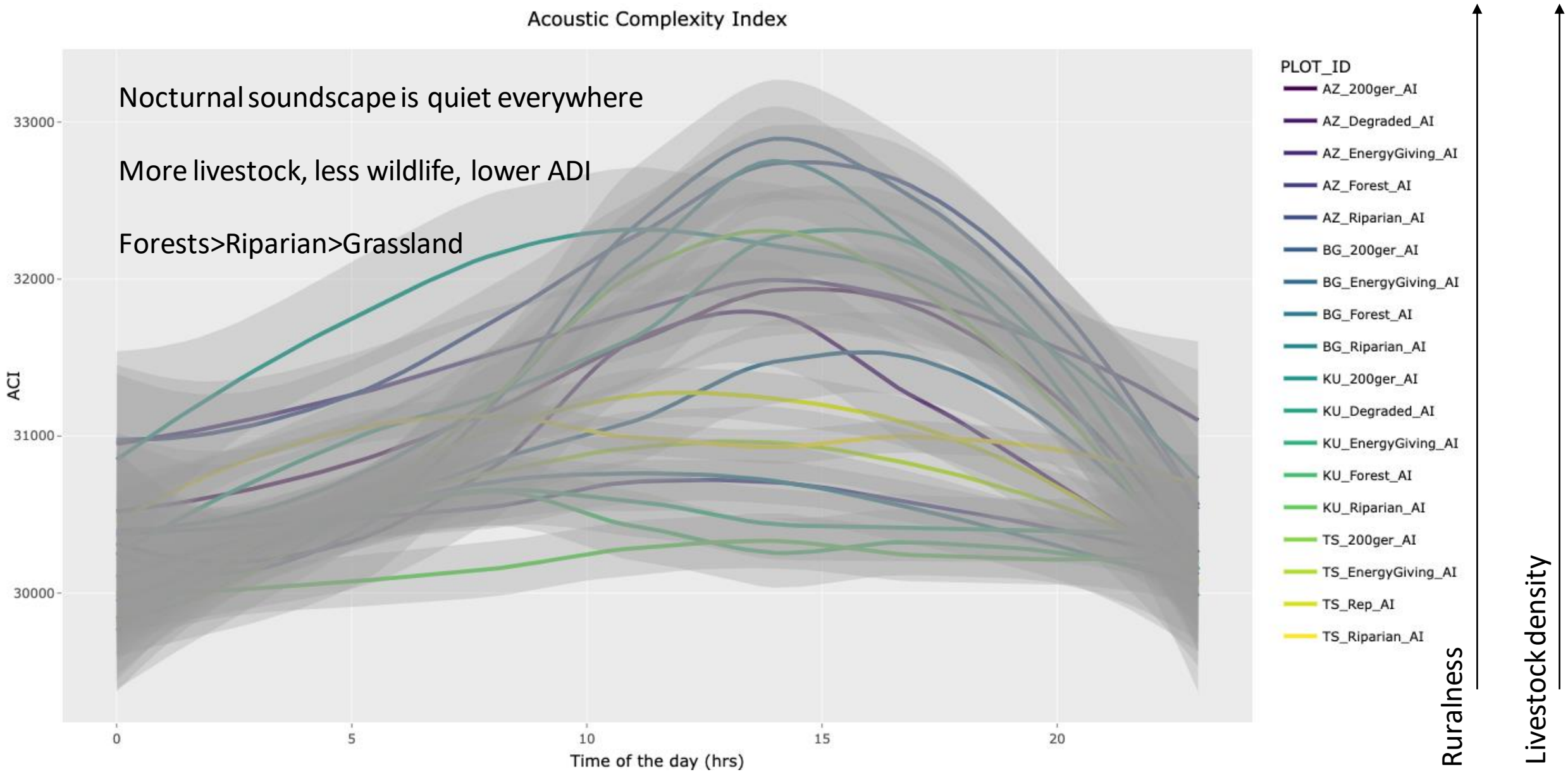
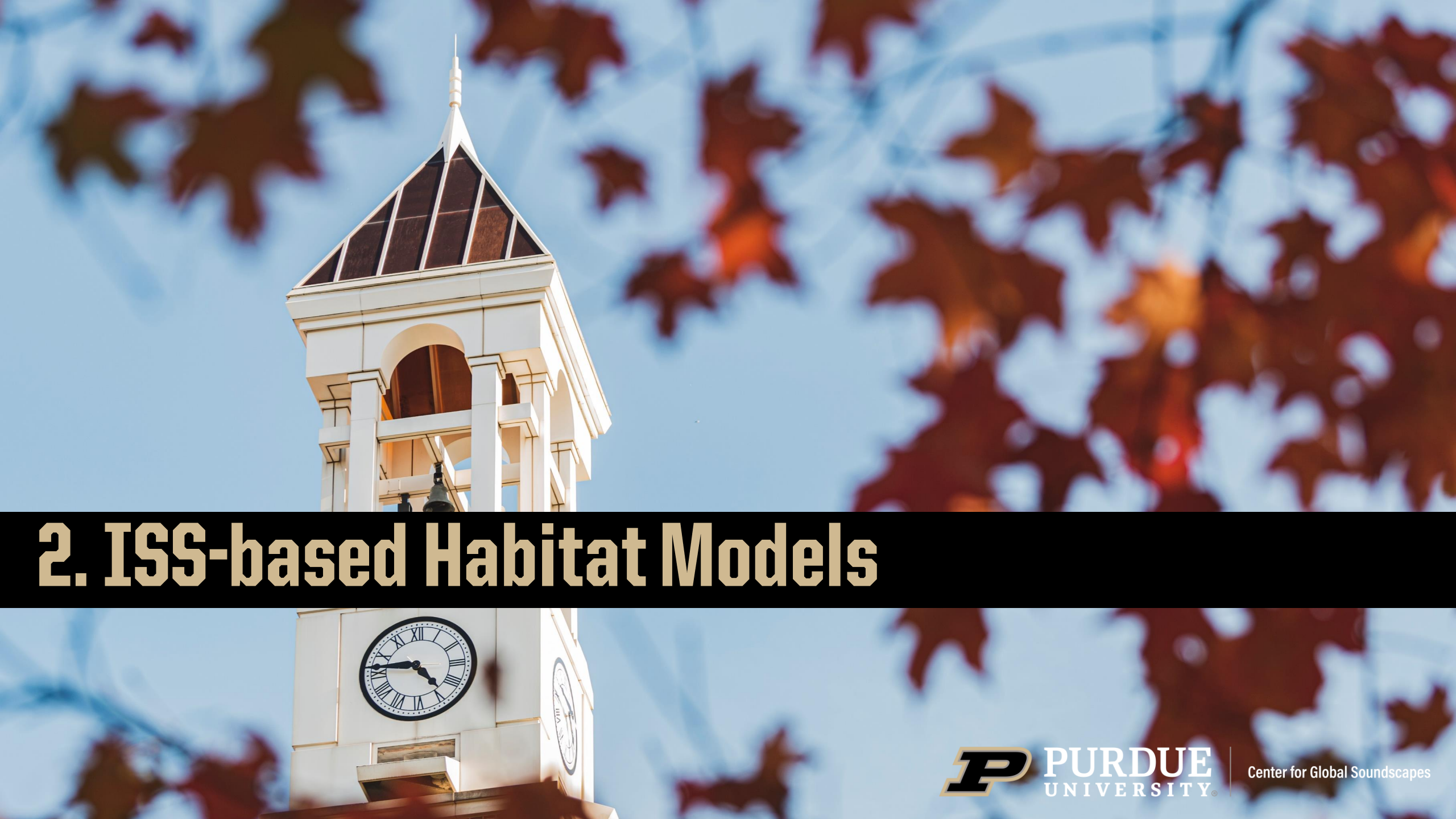
Acoustic Indices (ADI) – Phenology Model for Mongolia





2. ISS-based Habitat Models

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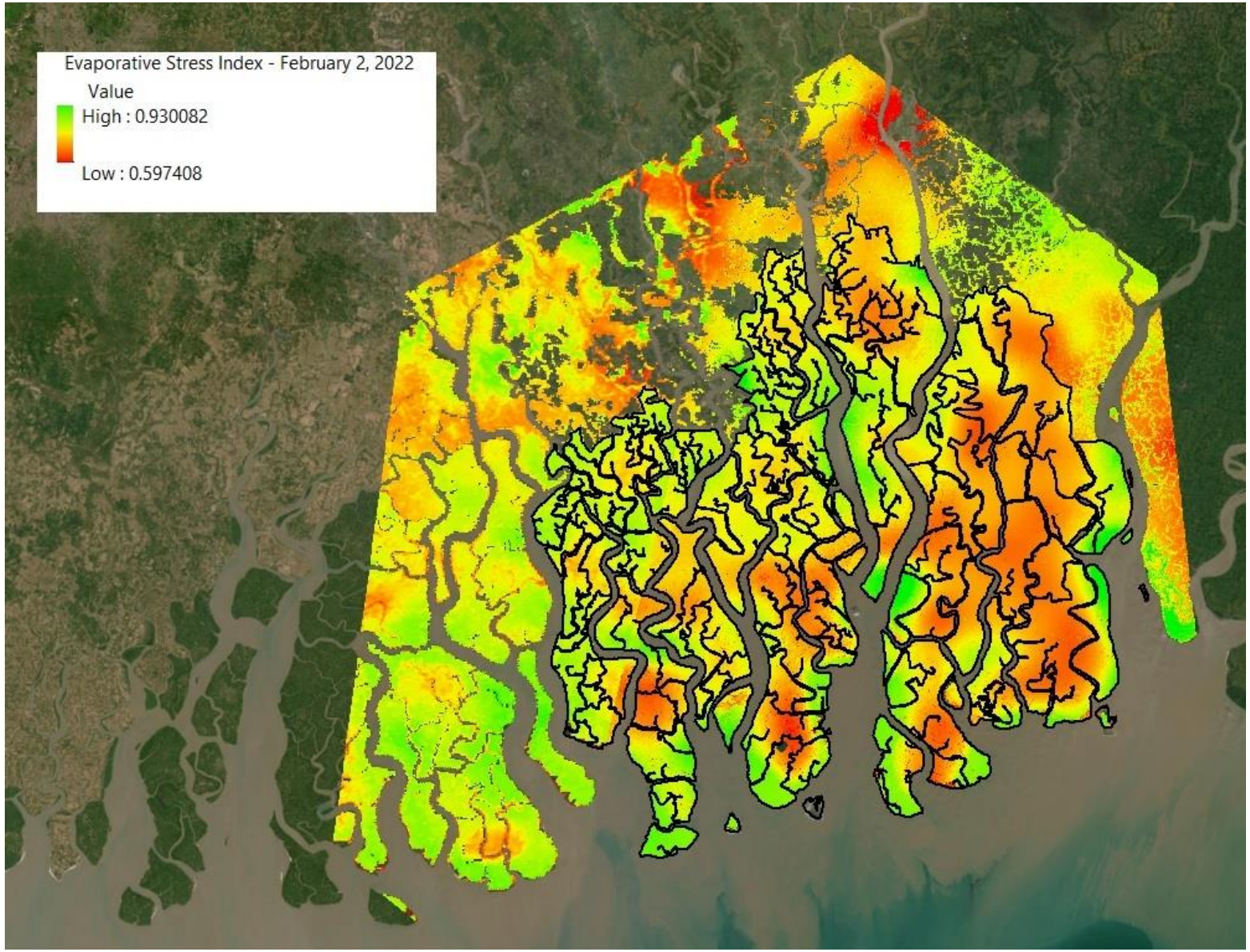
ECOStress for Sundarbans



Have now compiled over 100 ECOStress scenes for ESI and LST

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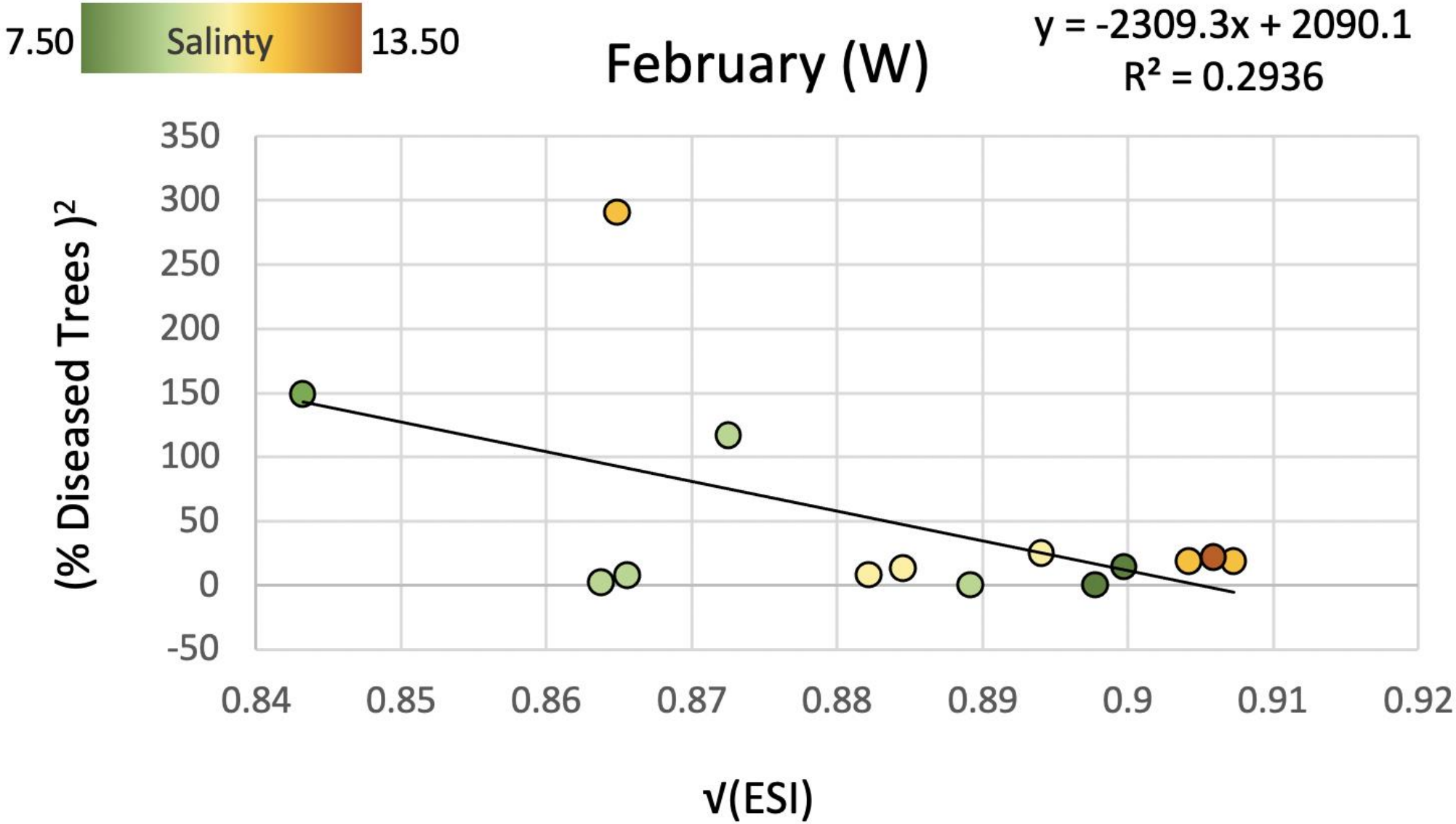
ECOStress ESI and % diseased trees (top dying)



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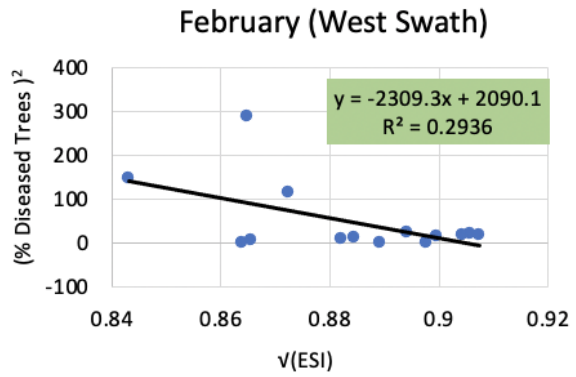
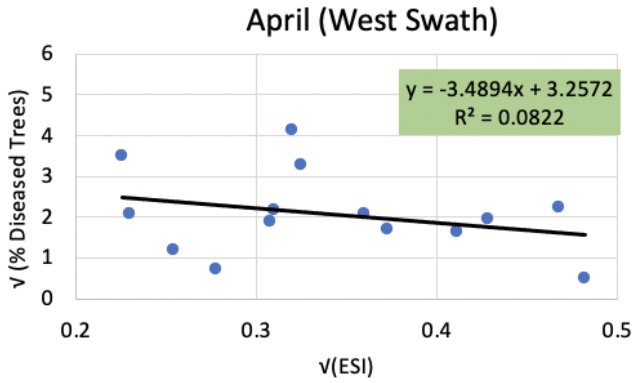
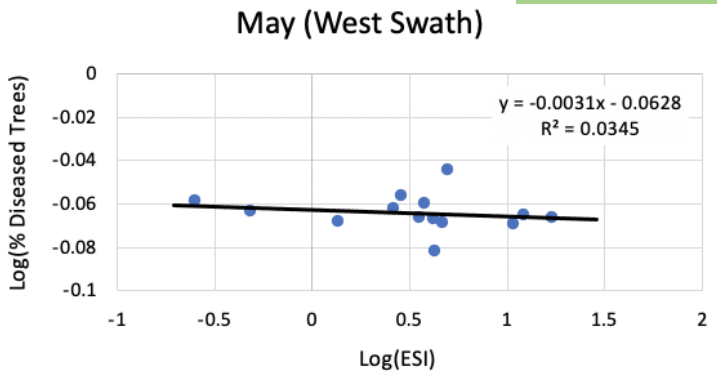
ECOStress ESI and % diseased trees by Zone and Month

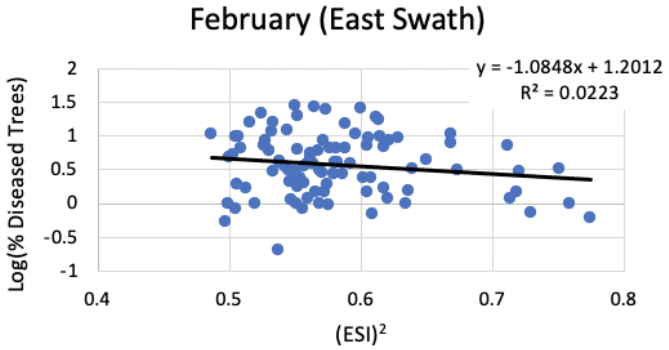
Mean ESI within 300m Buffer

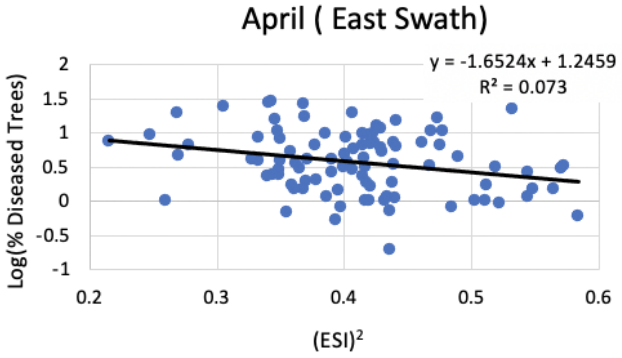
Indicates larger R^2 value between monthly swath comparisons

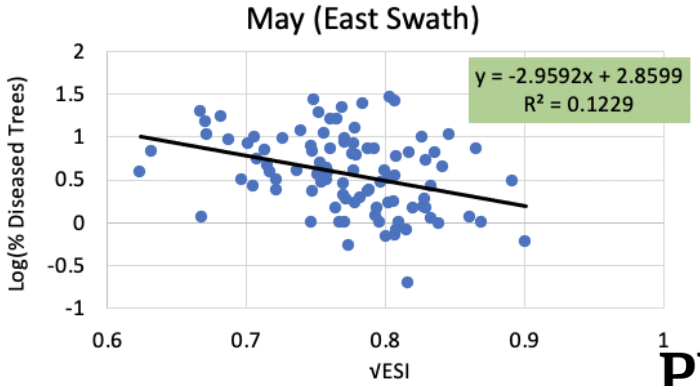












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DESIS Spectral Diversity Model: We propose to calculate the spectral features using entropy

$$DESIS\ Shannon\ Entropy_x = \sum_{i=1}^{150} P(x_i) \log_e P(x_i)$$

Where, $$P(x_i) = \frac{Surface\ Reflectance\ Value\ of\ the\ i{-}th\ band\ for\ Pixel\ X}{Sum\ of\ Surfacee\ Reflectance\ Values\ of\ all\ the\ bands\ for\ Pixel\ X}$$

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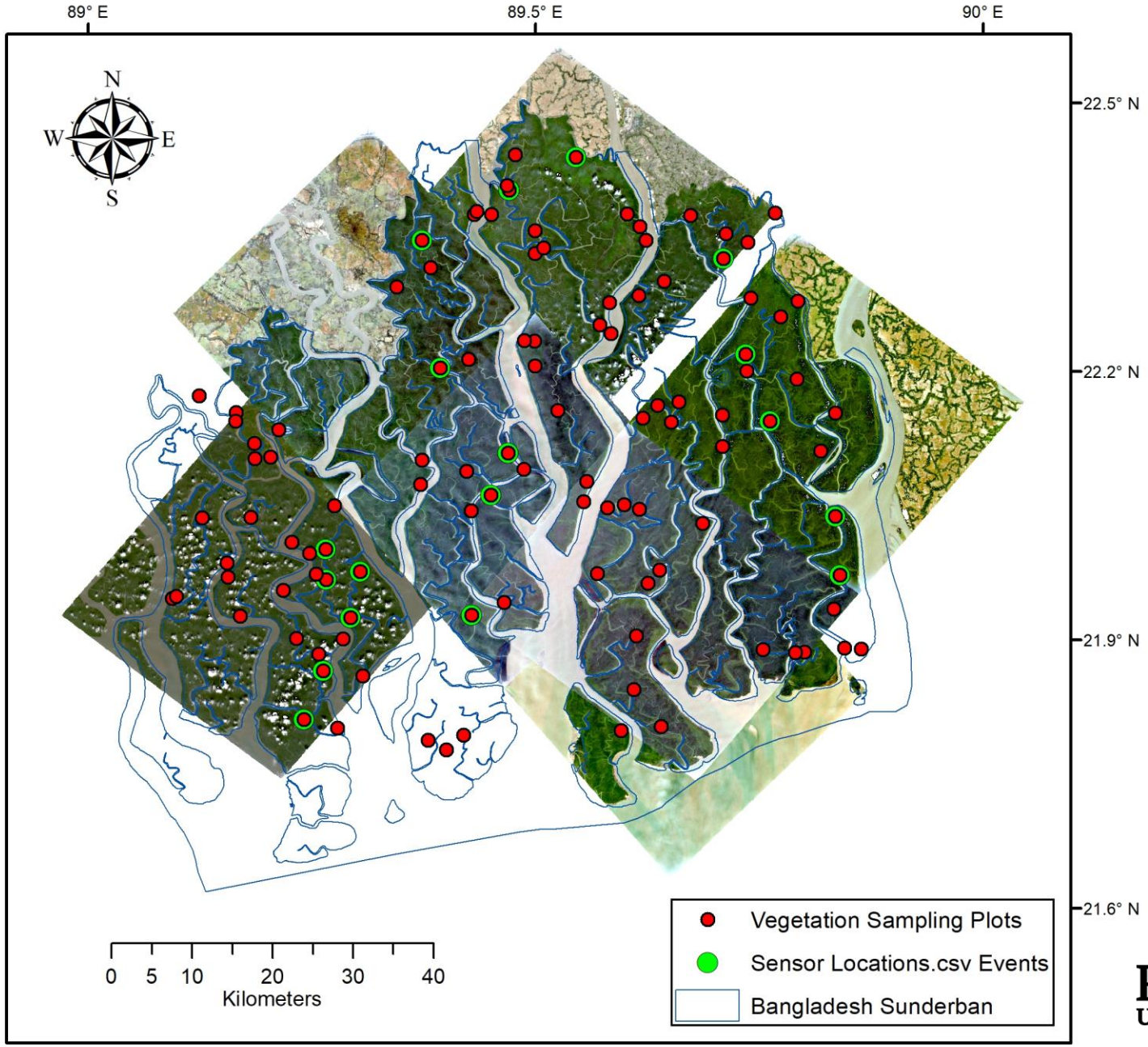
DESIS Images for Bangladesh Sundarbans



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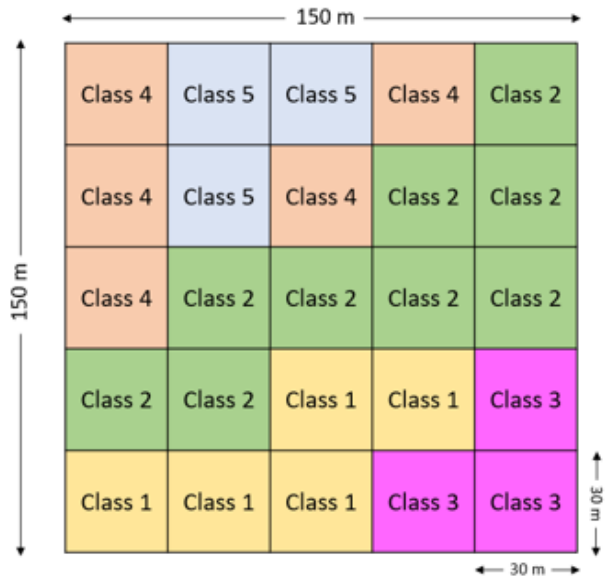
Second-order Spectral Diversity Index Computation

Reduce the dimensionality of Multispectral/ Hyperspectral Data using PCA/CCA/PLS

Generate new spectral bands with the initial PCA axes values., e.g. – PCA1 Raster

Perform Unsupervised Classification with few PCA Bands (30m Resolution)

Classified map of 30m resolution is projected to 150m with 25 sub-pixels



Calculation of Shannon Entropy on the 150m pixel with count value of classes

Second-order Spectral Diversity Index with150m Spectral Resolution

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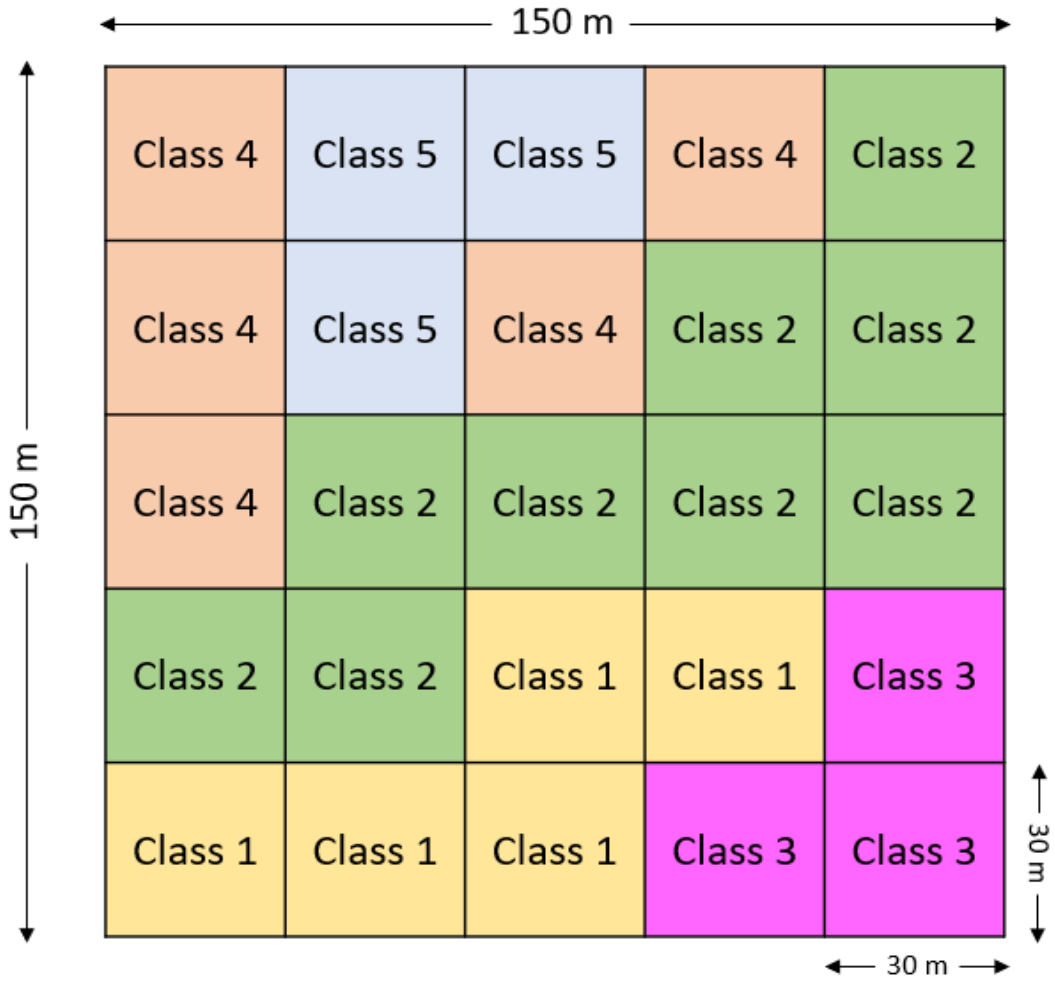
Second-order Spectral Diversity Index Computation



Exemplary 150m Pixel with 25 sub-pixels. Here the frequencies of Class 1 to Class 5 are 5, 9, 3, 5 and 3 respectively. So the Shannon Entropy value for this pixel is 1.52.

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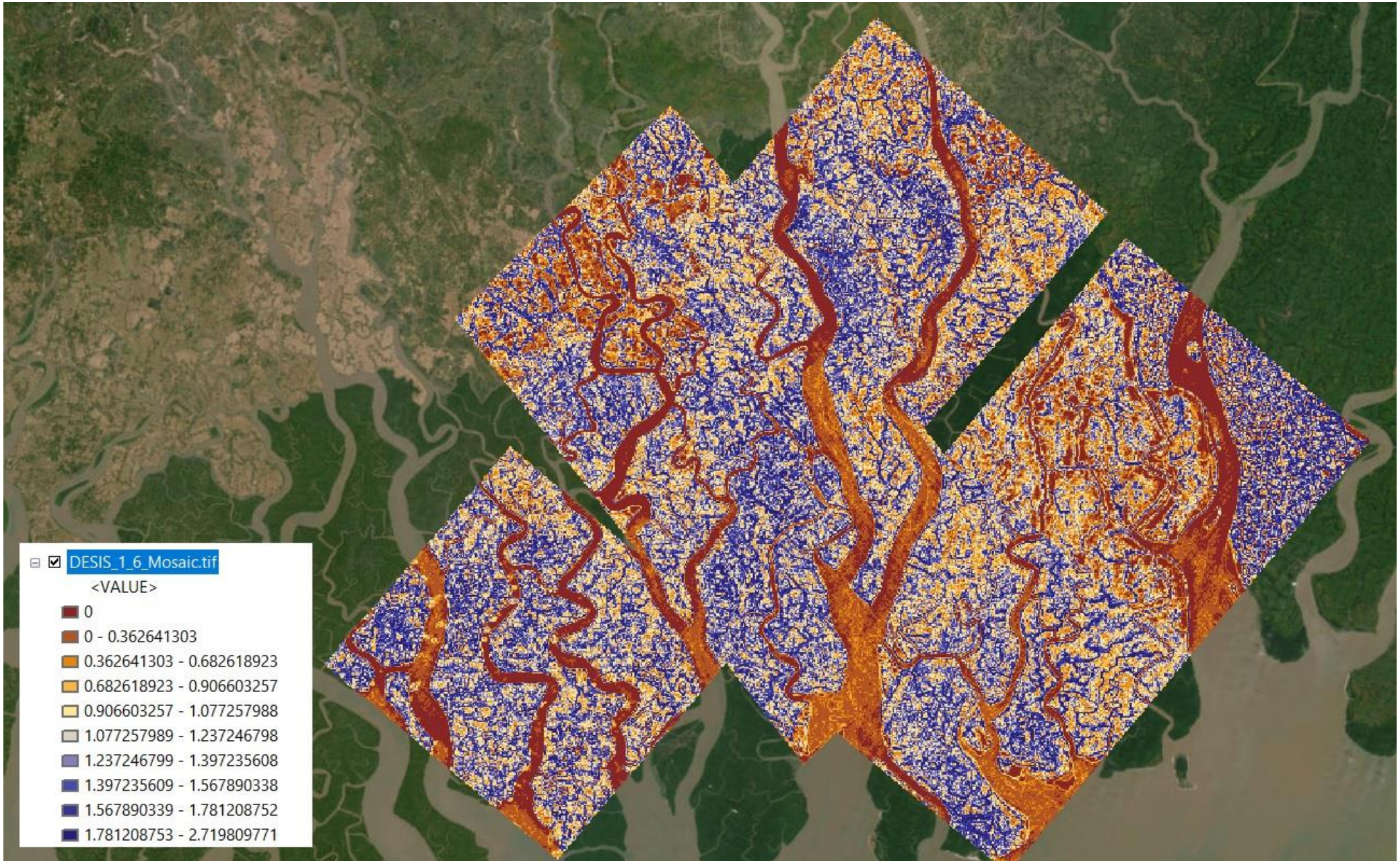
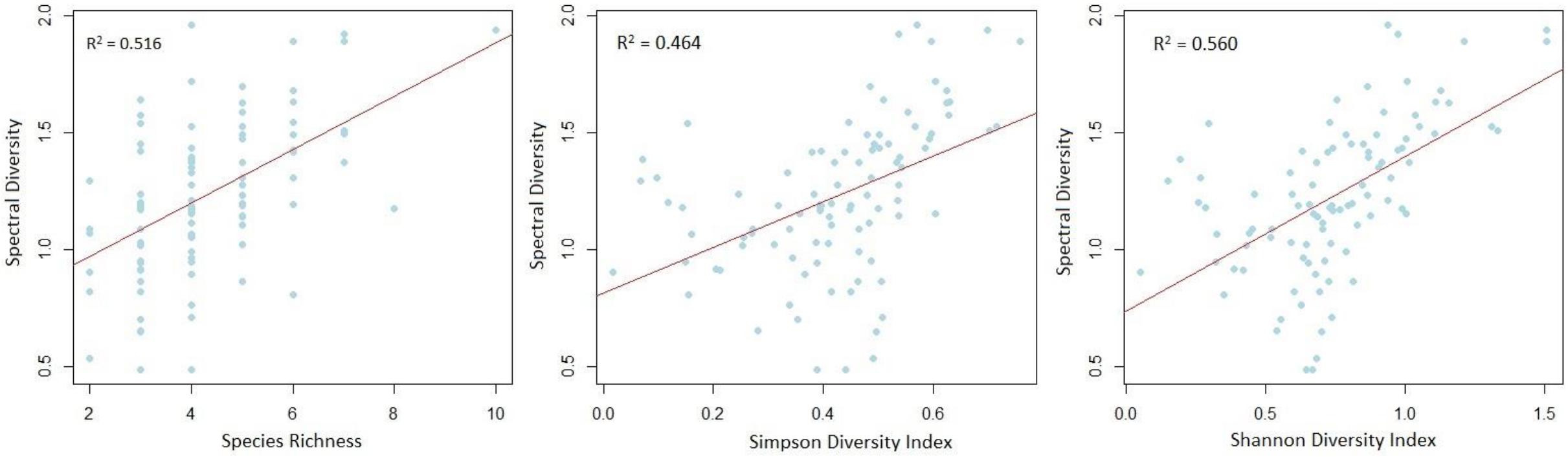
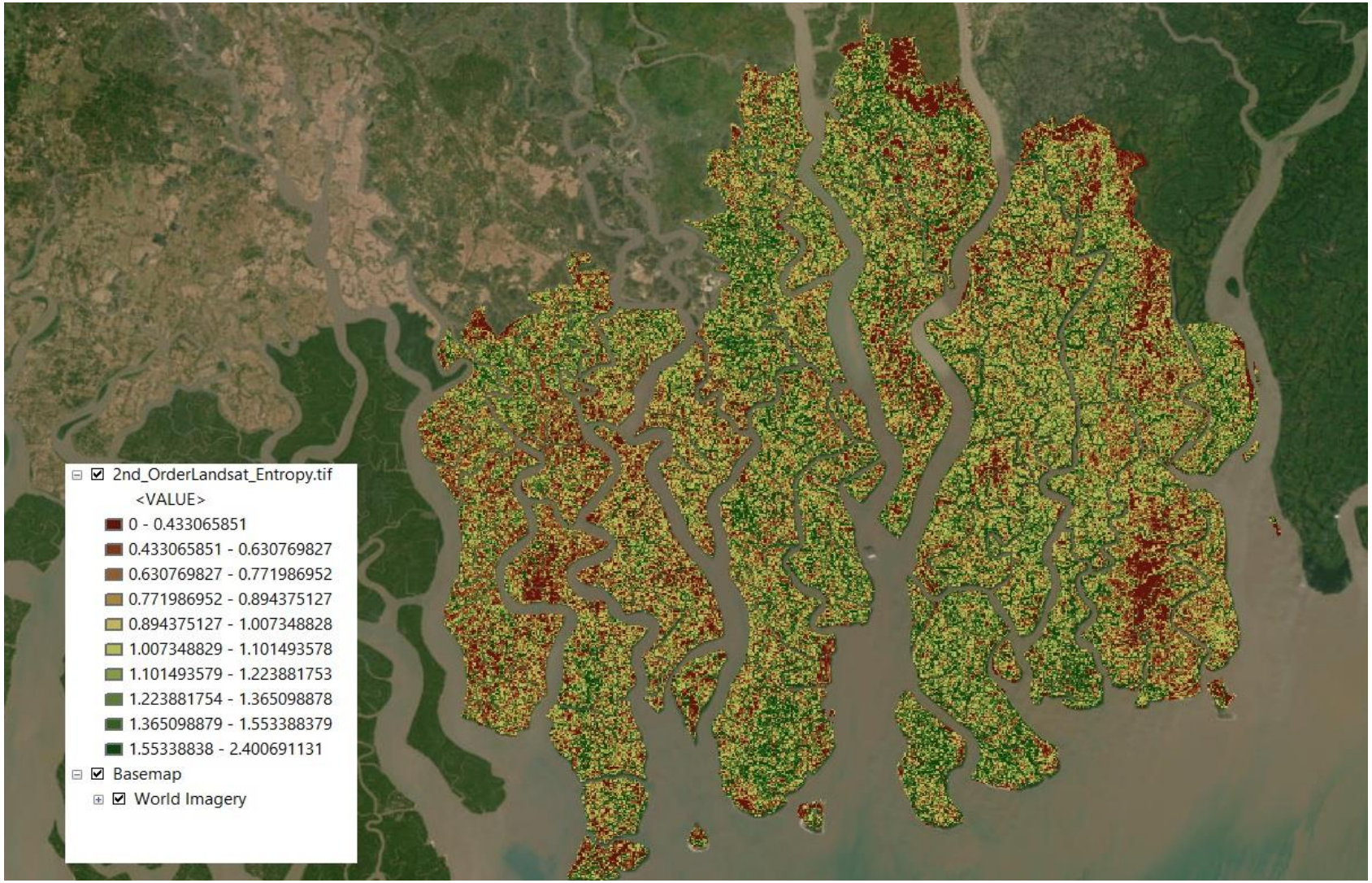
Second-order Spectral Diversity Index Computation with DESIS



Correlation between Plant Diversity and Second-order Spectral Diversity Index (Computed with DESIS) (95 Plots)



First-order Spectral Diversity Index Computation with LANDSAT-9



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3. TidyAcousticsR

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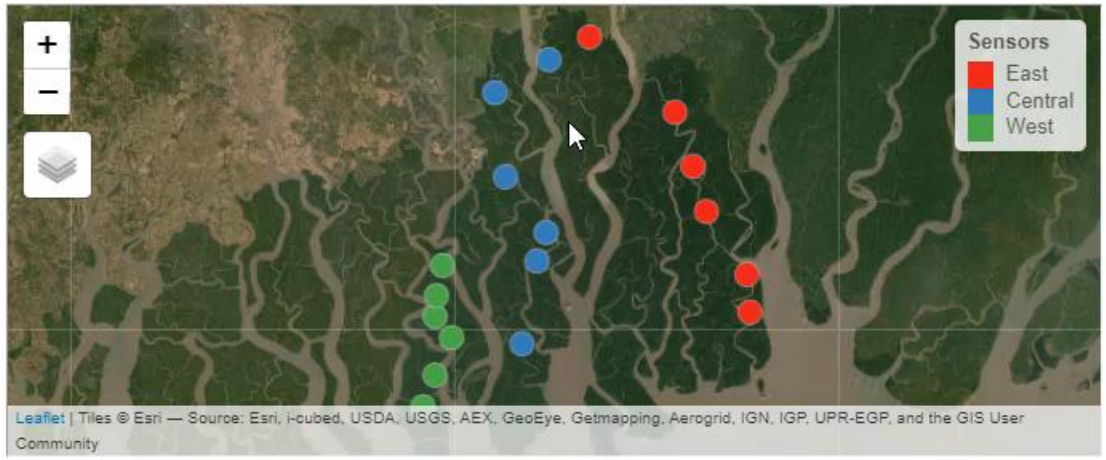
File | C:/Users/bpijanow/Desktop/TidyAcousticsR_site/website.html

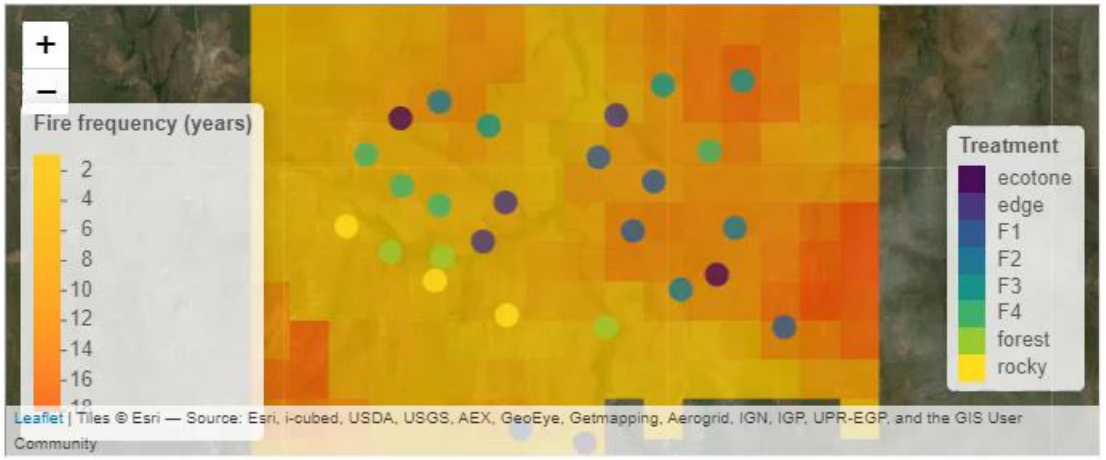
Spatial-Acoustic Interactive Visualization Tools

Interactive map - Sundarbans, Bangladesh



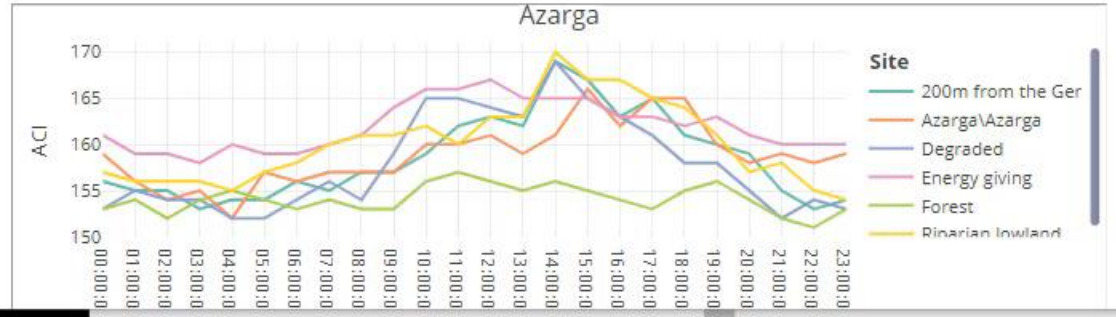
On the left panel, select one of the available data layers. Zoom in and click on the sample points to display metadata and listen to the underwater recordings.

Interactive map - Issa Valley, Tanzania

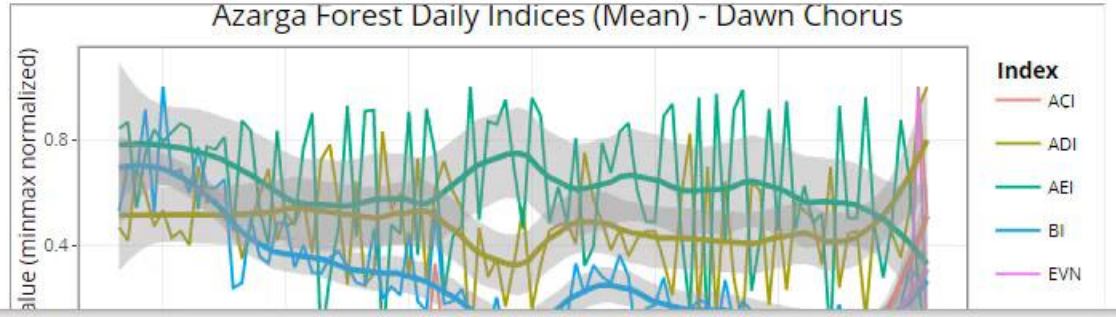


Click on a point to see a time-lapse video of the soundscape at that sensor. Please note that not all the sensors have time-lapse videos associated to them.

Diel soundscape acoustic indices plot - Mongolia



Dawn chorus time-series plot - Mongolia



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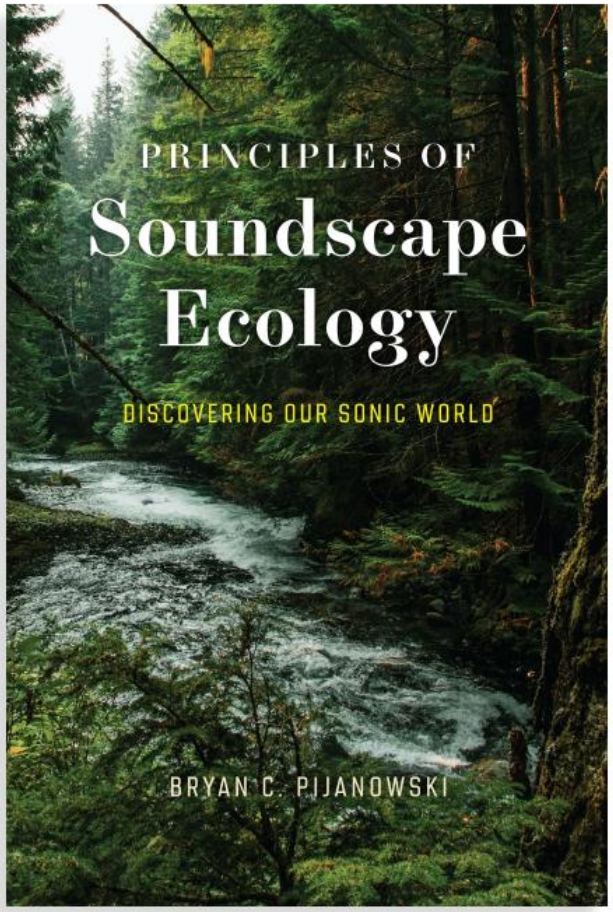

Principles of Soundscape Ecology

Discovering Our Sonic World

Bryan C. Pijanowski

From a founding figure in the field, the definitive introduction to an exciting new science.

What do the sounds of a chorus of tropical birds and frogs, a clap of thunder, and a cacophony of urban traffic have in common? They are all components of a soundscape, acoustic environments that have been identified by scientists as a combination of the biophony, geophony, and anthrophony, respectively, of all of Earth's sound sources. As sound is a ubiquitous occurrence in nature, it is actively sensed by most animals and is an important way for them to understand how their environment is changing. For humans, environmental sound is a major factor in creating a psychological sense of place, and many forms of sonic expression by people embed knowledge and culture. In this book, soundscape ecology pioneer Bryan C. Pijanowski presents the definitive text for both students and practitioners who are seeking to engage with this thrilling new field. *Principles of Soundscape Ecology* clearly outlines soundscape ecology's critical foundations, key concepts, methods, and applications.

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- Fulbright Program