NASA Biodiversity Project

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

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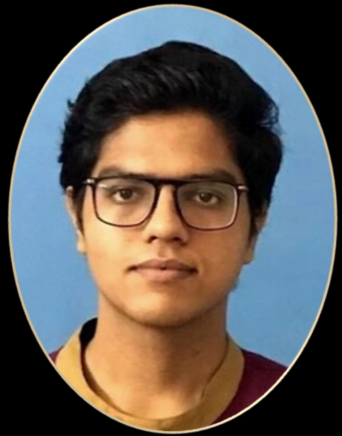

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UAV and ISS Remote Sensing Analysis

Jingjing Liang

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

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Overarching 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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Hypotheses

Hypotheses. We will use a variety of space-based, UAV-based and *in situ*-based sensors to characterize the relationship between habitat features (structure, composition, and condition) and animal biodiversity across space, time and disturbances at eleven acoustic study locations as well as tree species diversity survey data within nine Köppen-Gieger climate zones:

H1: **Habitat structure** moderates animal acoustic diversity across all time frames (hourly, daily, seasonal and annual) and in all biomes, and, in particular,

- H1.1 Habitat loss (i.e., area) correlates strongly with animal acoustic diversity across all time frames (hourly, daily, seasonal and annual) and in all biomes
- H1.2 Fragmentation of habitat does not correlate with animal acoustic diversity as measured across all time frames and in all biomes
- H1.3 Vertical habitat structural complexity positively correlates with animal acoustic diversity

H2: Animal acoustic diversity is positively correlated with diversity of **vegetation composition**

- H2.1 That an array of space-based platforms strongly predicts tree diversity from in situ measurements
- H2.2 That animal acoustic diversity strongly correlates with tree diversity
- H2.3 That animal acoustic diversity strongly correlates with space-based vegetation composition measures

H3: **Vegetation condition** drives animal activity patterns, and, in particular,

- H3.1 Peak greening of vegetation during the year is synchronized with peak of acoustic activity of all animals for all biomes
- H3.2 Across any landscape where vegetation stress is variable, the greatest animal acoustic activity will be located in areas of least vegetation stress
- H3.3 In ecosystems that are characterized by brief rainfall events (e.g., deserts, grasslands, mangroves), the peak animal acoustic activity will occur after the rainfall event and when plant stress is low

H4: **Biogeographic trends** in plant and animal diversity, using regional to global scale comparisons, will be consistent with a variety of known global patterns:

- H4.1 Species richness for animals and plants will be greatest in equatorial regions and decline as one moves to higher latitudes
- H4.2 Activity patterns of animals will be greatest in reference habitats and decline with increasing human activity
- H4.3 Vegetation composition spectral signatures and acoustic signals will follow the well-known species area curve

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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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)

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)

Major Highlights of Last 12 Months

1. Two published, three papers in review, many more coming
2. Have DESIS-based habitat species diversity model ✓
3. Preliminary GEDI habitat structural complexity model ✓
4. Moved to using CNN-based BirdNET to identify all bird calls
5. Using transfer learning, we now have OrthopteraNET, FrogNET, and ChimpNET built
6. Preliminary avian acoustics phenology models ✓
7. Assembling all of these tools into package called TidyAcoustics ✓

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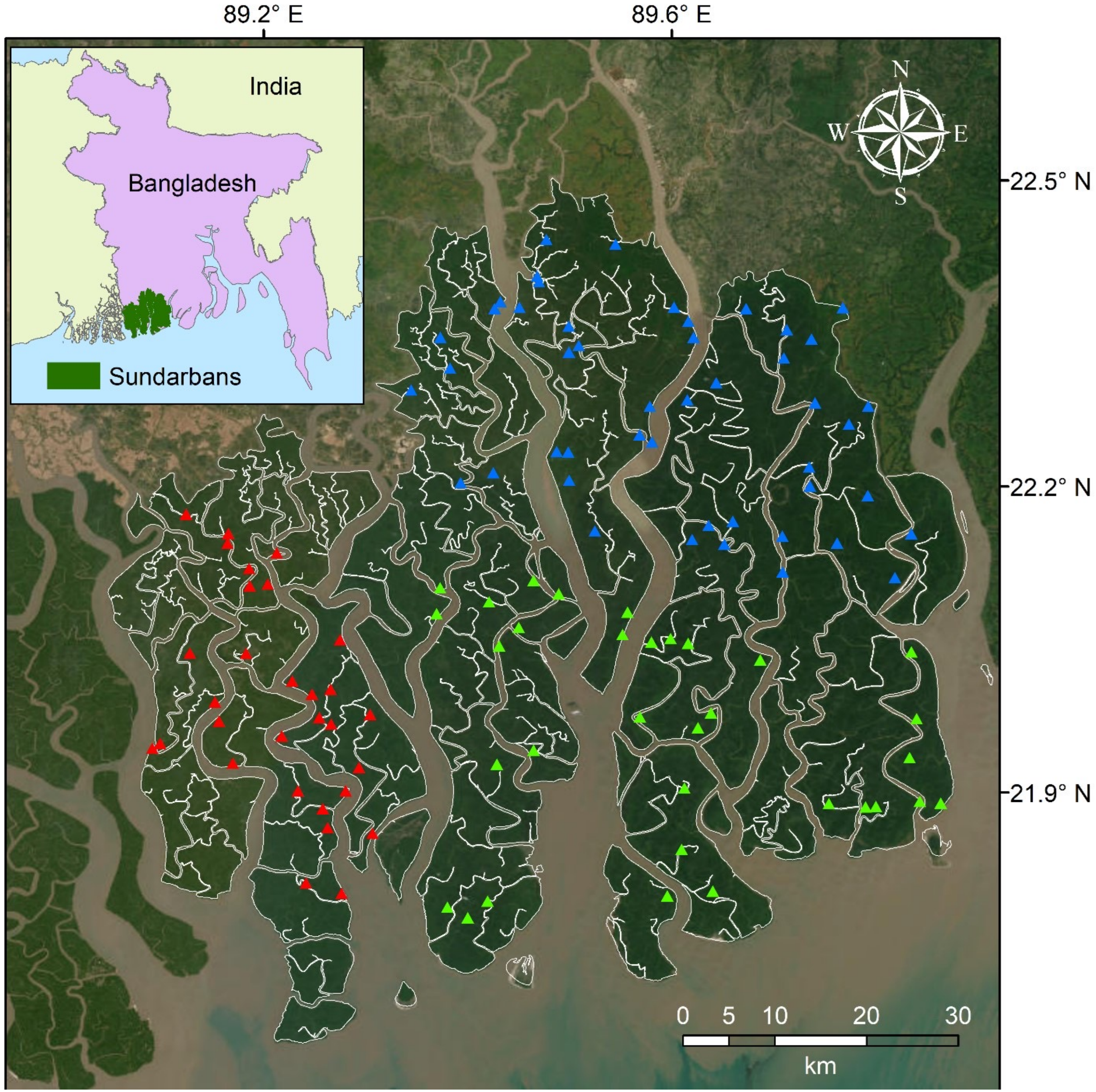
1. DESIS MODEL FOR MANGROVES IN BANGLADESH



Mangroves of the Sundarbans Protected Area

110 Permanent Survey Plots

Data collected at each plot (10m x 110m)
Tree species, dbf and abundances
Condition of tree (healthy, diseased, dying, dead)
Canopy height
Soil salinity
Taken every 5 years since 1983

Blue = hyposaline (low salinity)
Green = mesosaline (medium salinity)
Red = hypersaline (high salinity)

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Spectral Species Model Using DESIS, Landsat and Sentinel-2

Reducing the dimensionality of the Hyperspectral Data using Principal Component Analysis

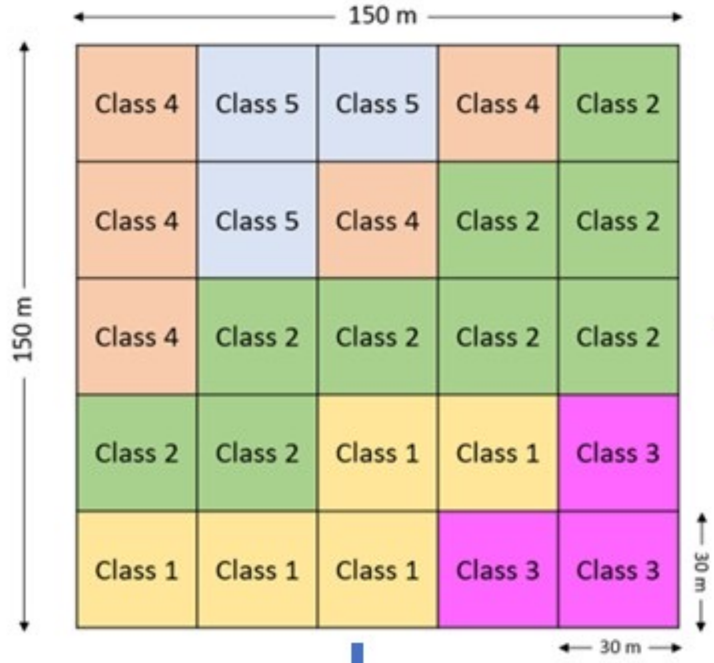
→ Unsupervised k-means clustering on the first three Principal Components

→ Determine Optimal number of Clusters (Spectral Species) using heuristic elbow method

↓ Every image pixel (30 meters) is assigned to one Spectral Species Class

← Create Spectral Spaces of 150-m x 150-m that consist of 25 image pixels of 30-m

←



↓ Compute Spectral Species Diversity of Spectral Spaces using Shannon Entropy Equation

→ Generate Spectral Species Diversity map of Study area at 150-m spatial resolution

→ Extract Spectral Species Diversity values for the Permanent Sampling Plots

Analysis of Spectral Species Model

- Spectral species → Species Richness (q=0) → Shannon's Diversity (q=1) → Simpson's Diversity (q=2)
- Coefficient of variation of band values → Species Richness (q=0) → Shannon's Diversity (q=1) → Simpson's Diversity (q=2)
- Examined these relationships also in three salinity zones

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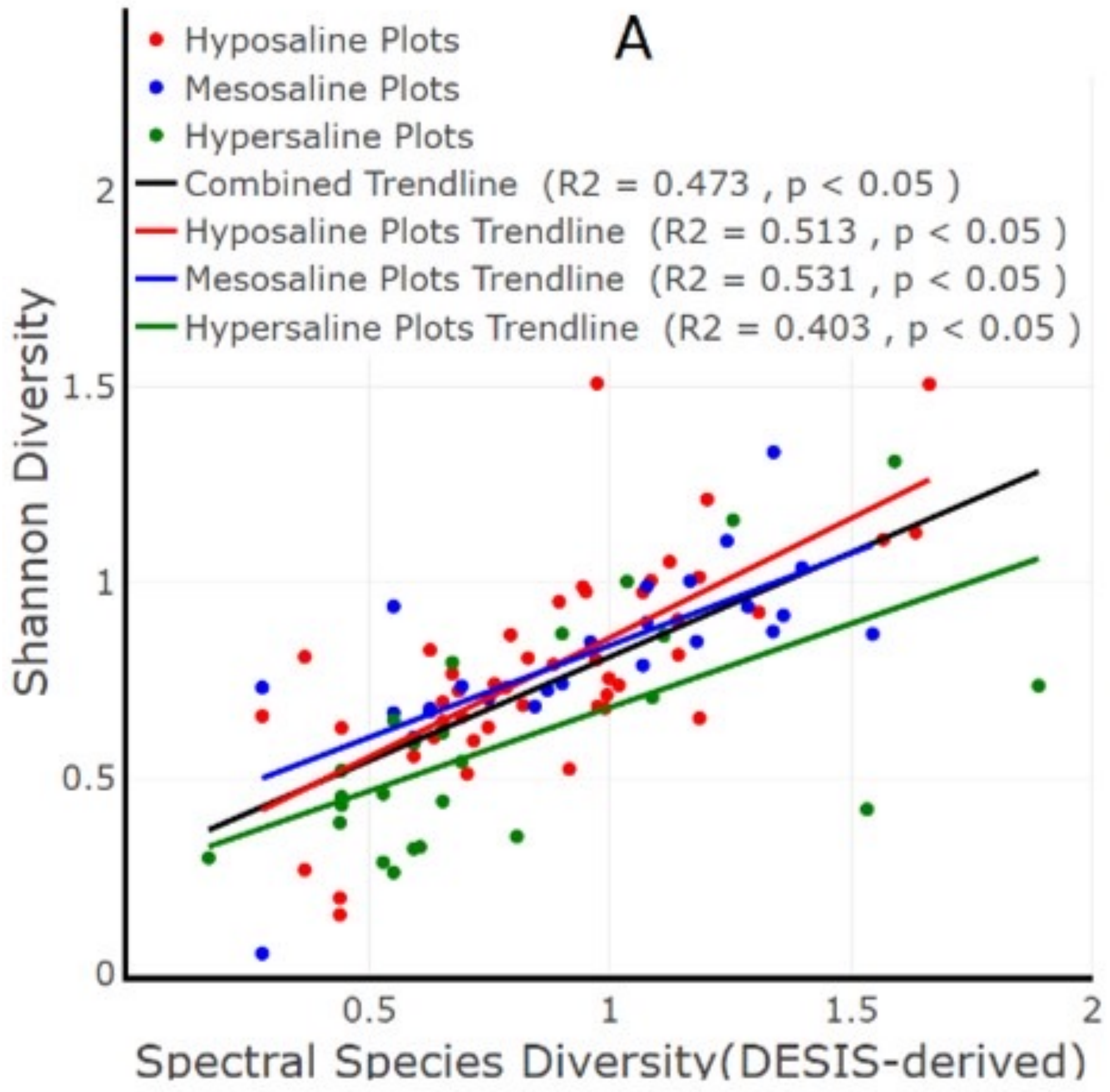

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Hypothesis 1.1 was that there should be a positive relationship between Spectral Species Diversity and Plant Survey Diversity (shown here as Shannon Diversity, q=1)

Cannot reject

Hypothesis 1.2 that hyposaline should have greater values (red line), followed by mesosaline (blue line) and then hypersaline (green line)

Cannot reject

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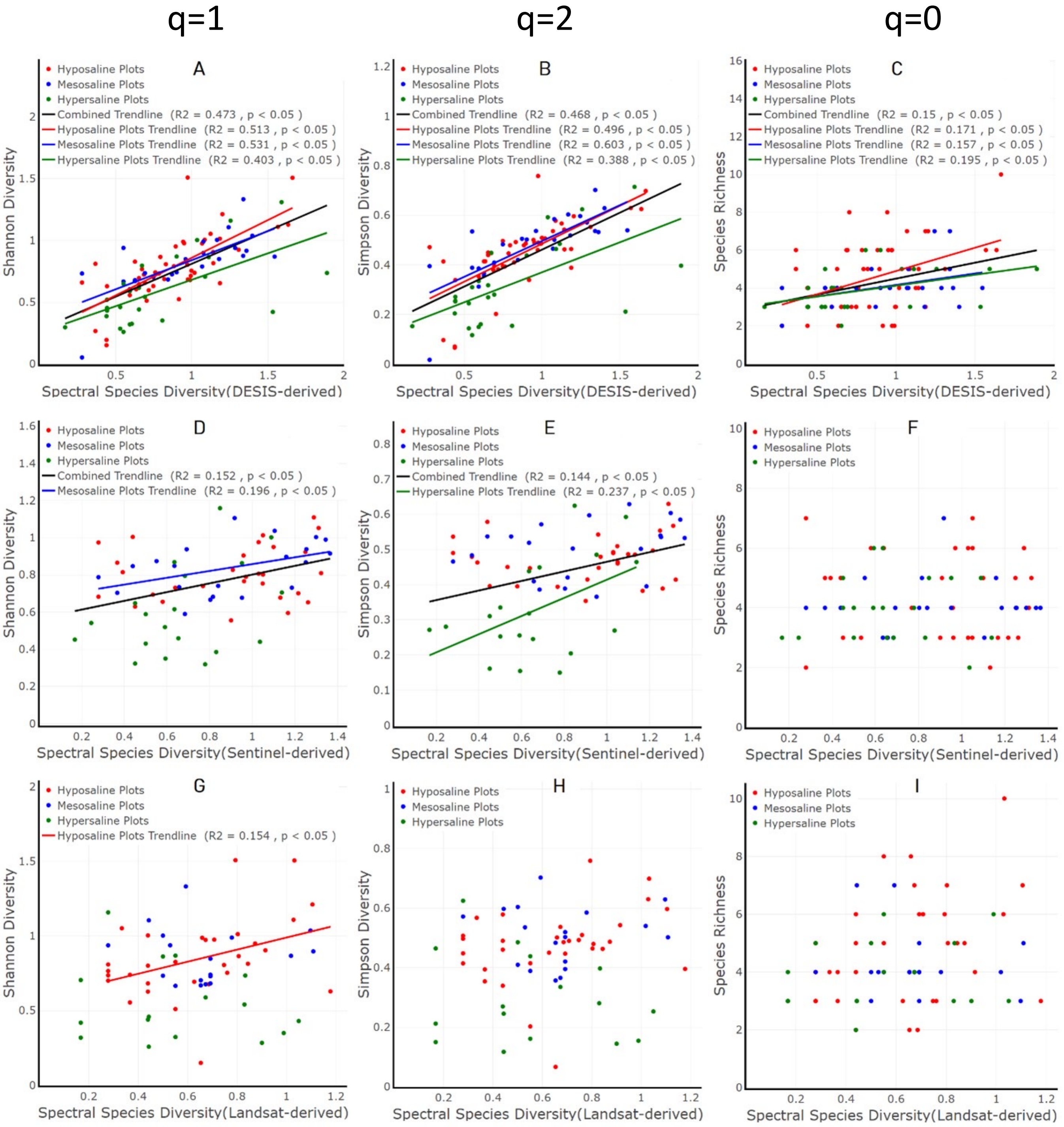

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Hypothesis 1.3 was greater Hill numbers for measures of species diversity should provide more power.

Cannot reject

Hypothesis 1.4 that hyperspectral imagery should perform better than multispectral imagery

Cannot reject

Hill numbers are designated as q

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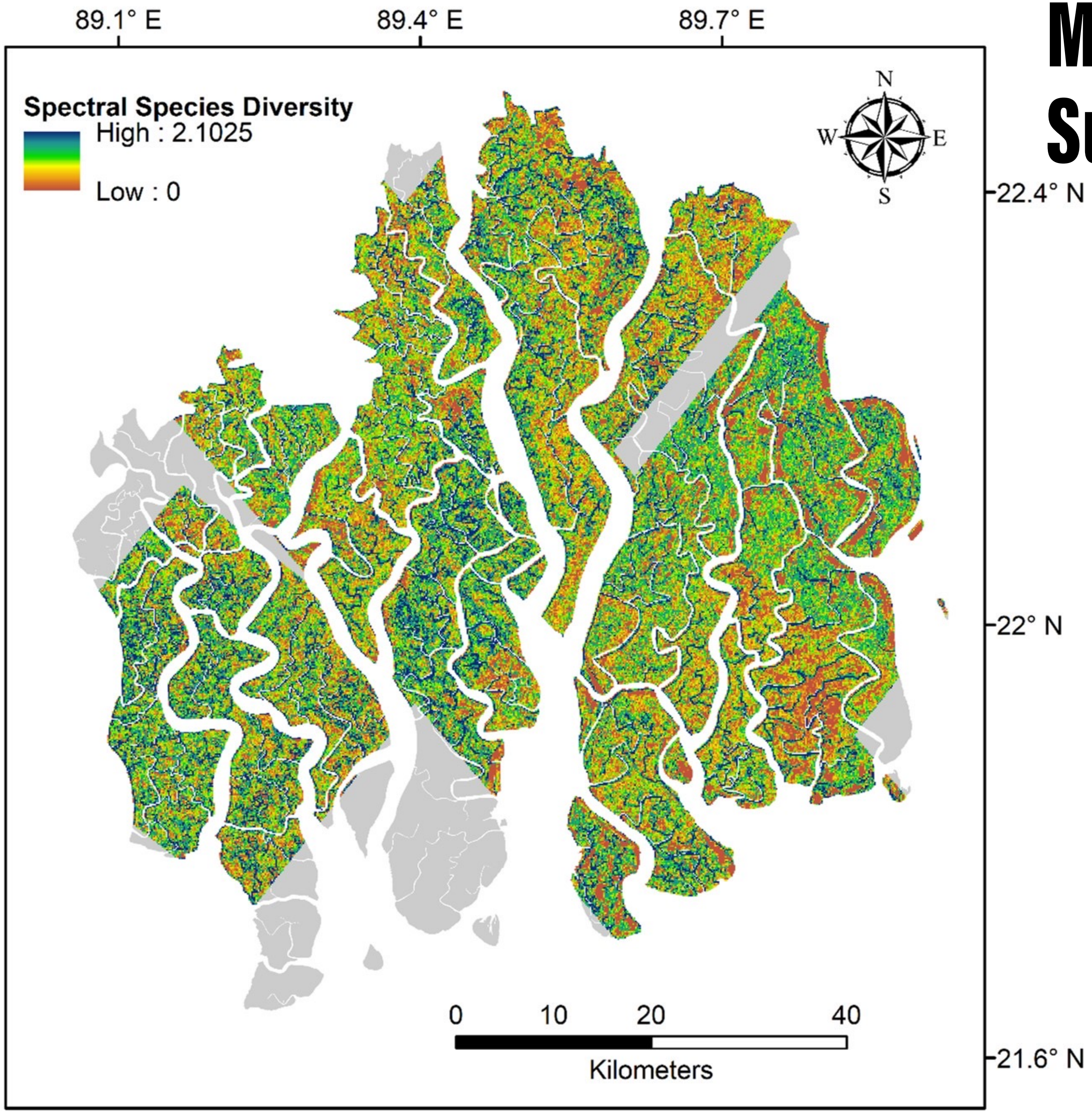

Map of Spectral Species Diversity shows complex patterns across the mangroves with the greatest diversity in areas with the highest level of protection (wildlife sanctuaries)

Spectral Species Diversity does not follow a east to west gradient which was expecte

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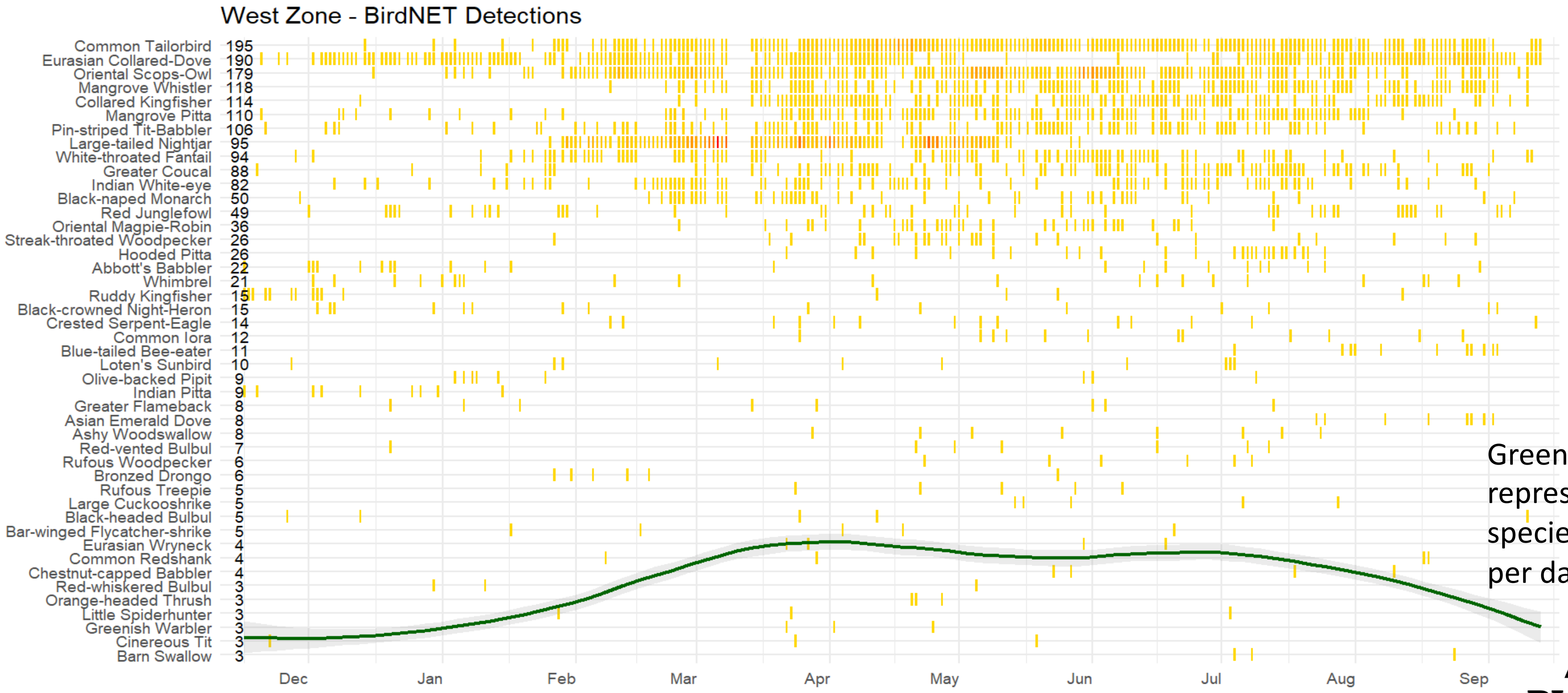
2. BIRDNET RESULTS FOR BANGLADESH

Mangroves of the Sundarbans Protected Area



Green line represents avian species richness per day

Fig 1: Temporal Trend in Avian diversity in West zone (high salinity) from November 2022 to September, 2023

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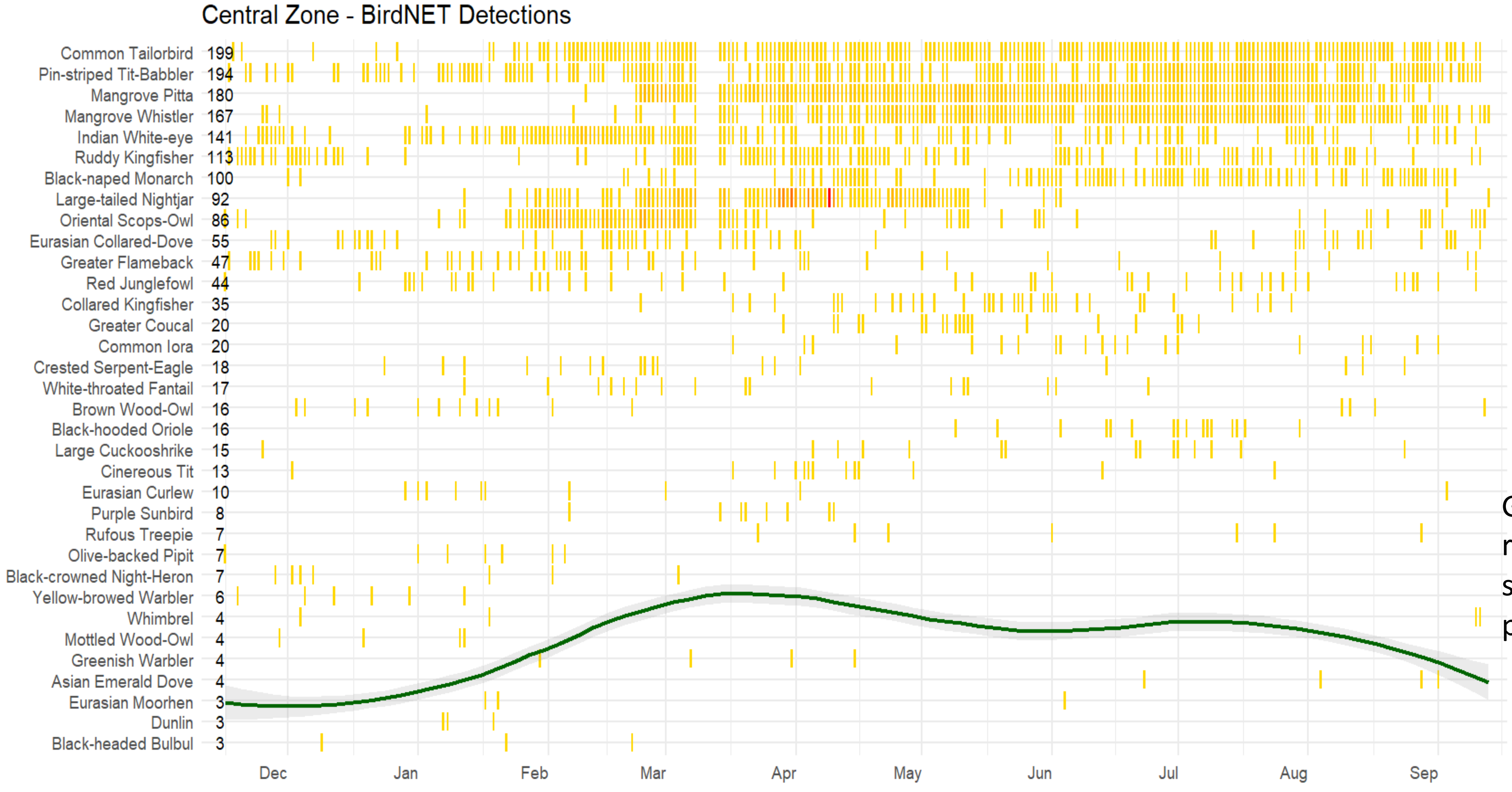
Mangroves of the Sundarbans Protected Area



Green line represents avian species richness per day

Fig 2. Temporal Trend in Avian diversity in Central zone from November 2022 to September, 2023

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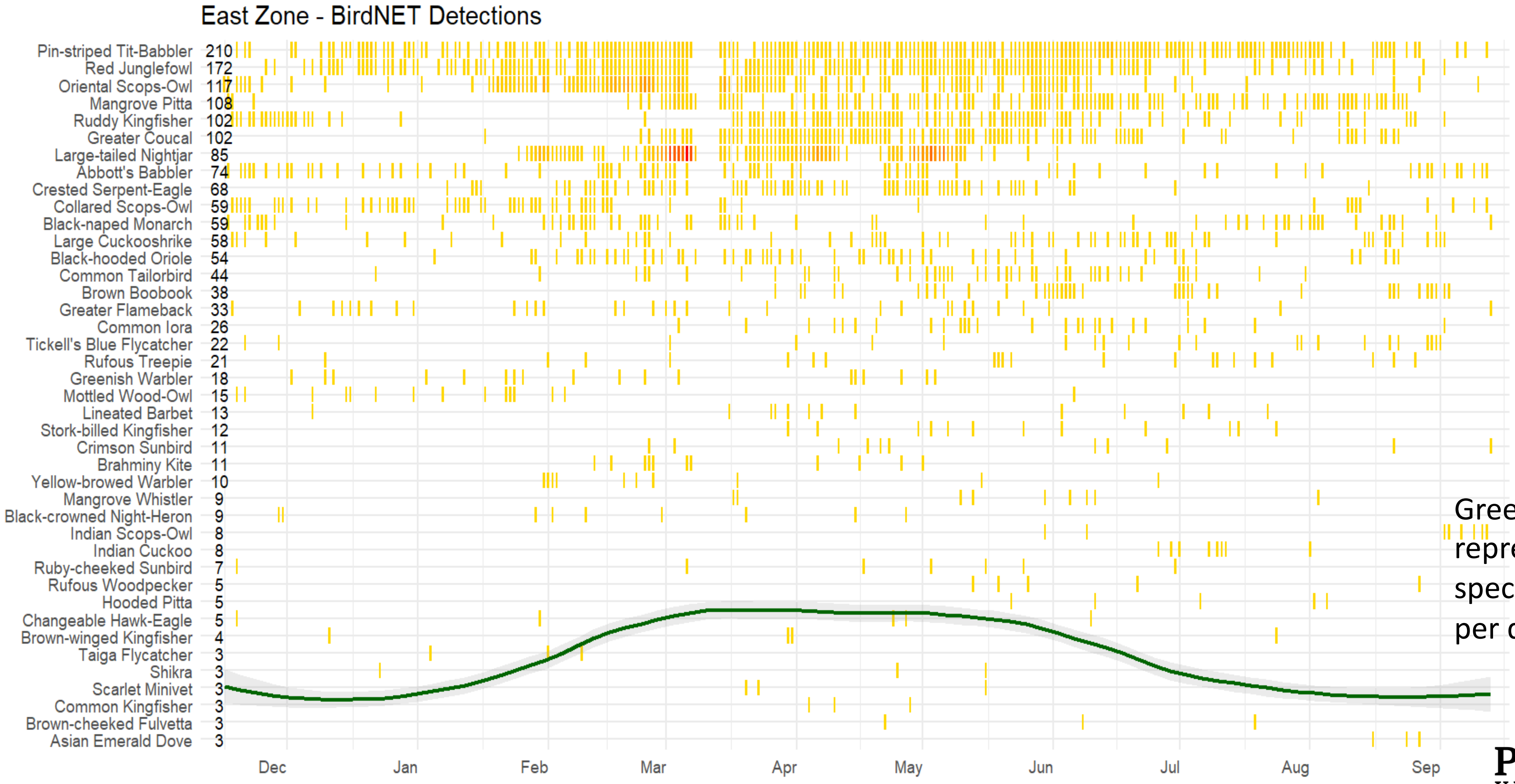
Mangroves of the Sundarbans Protected Area



Green line represents avian species richness per day

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Fig 3 Temporal Trend in Avian diversity in East zone (low salinity) from November 2022 to September, 2023

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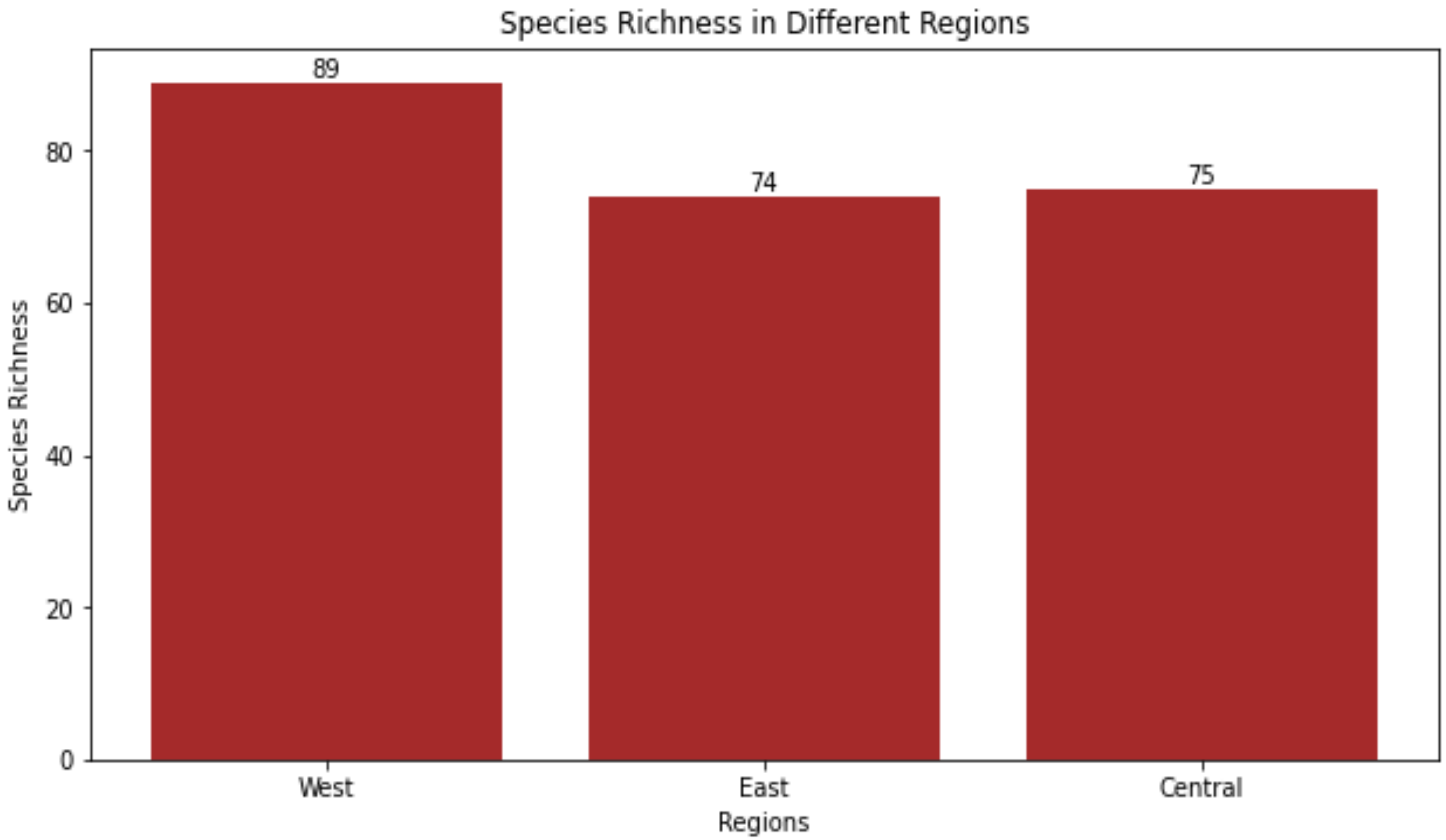

Fig 4: Species richness in salinity zones

Hypothesis 1.5 is that due to high stress in the west and high levels of top dying disease, bird species richness should be the lowest.

Preliminarily rejecting hypothesis

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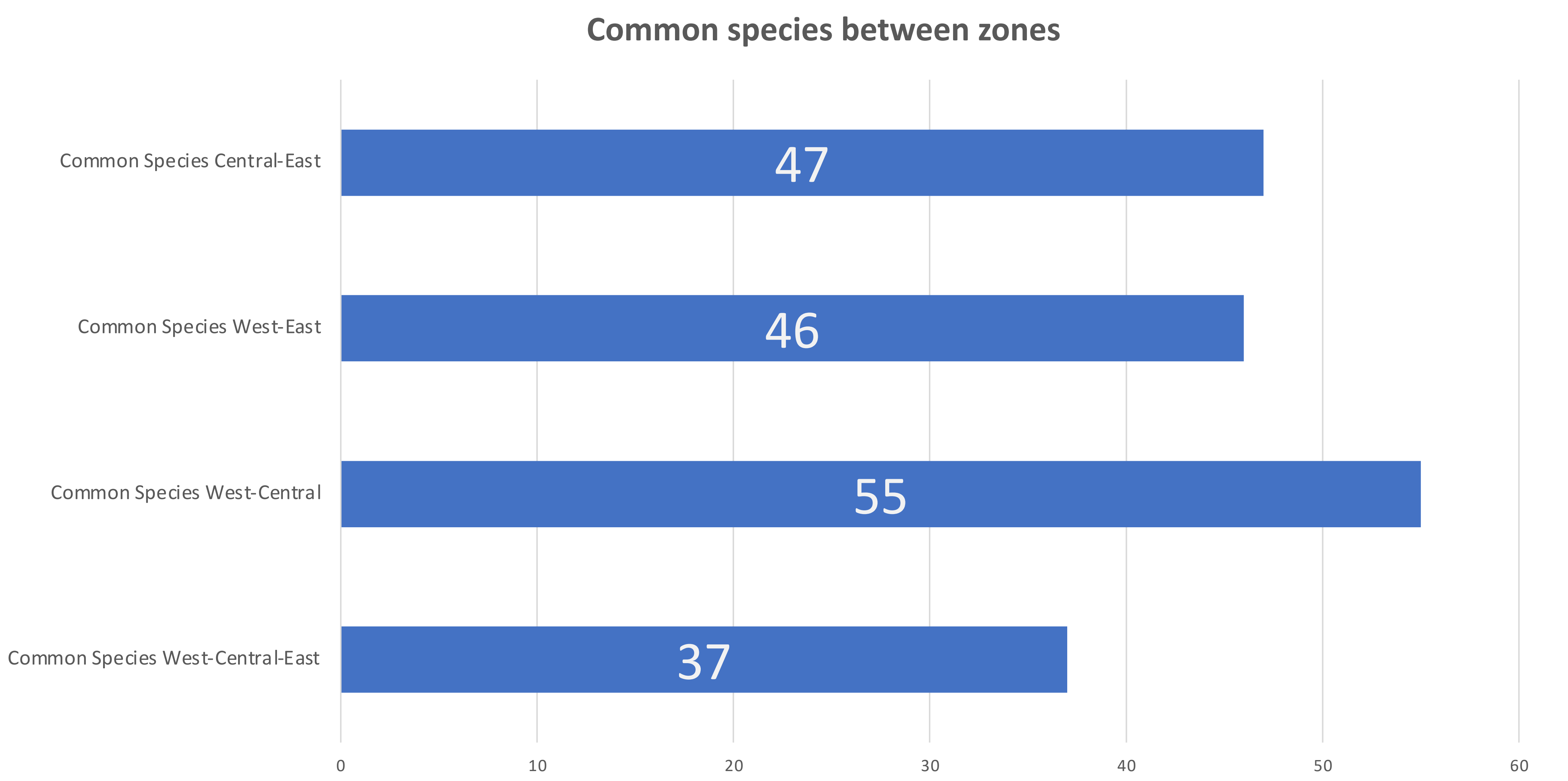

Fig 5: Number of common species between zones

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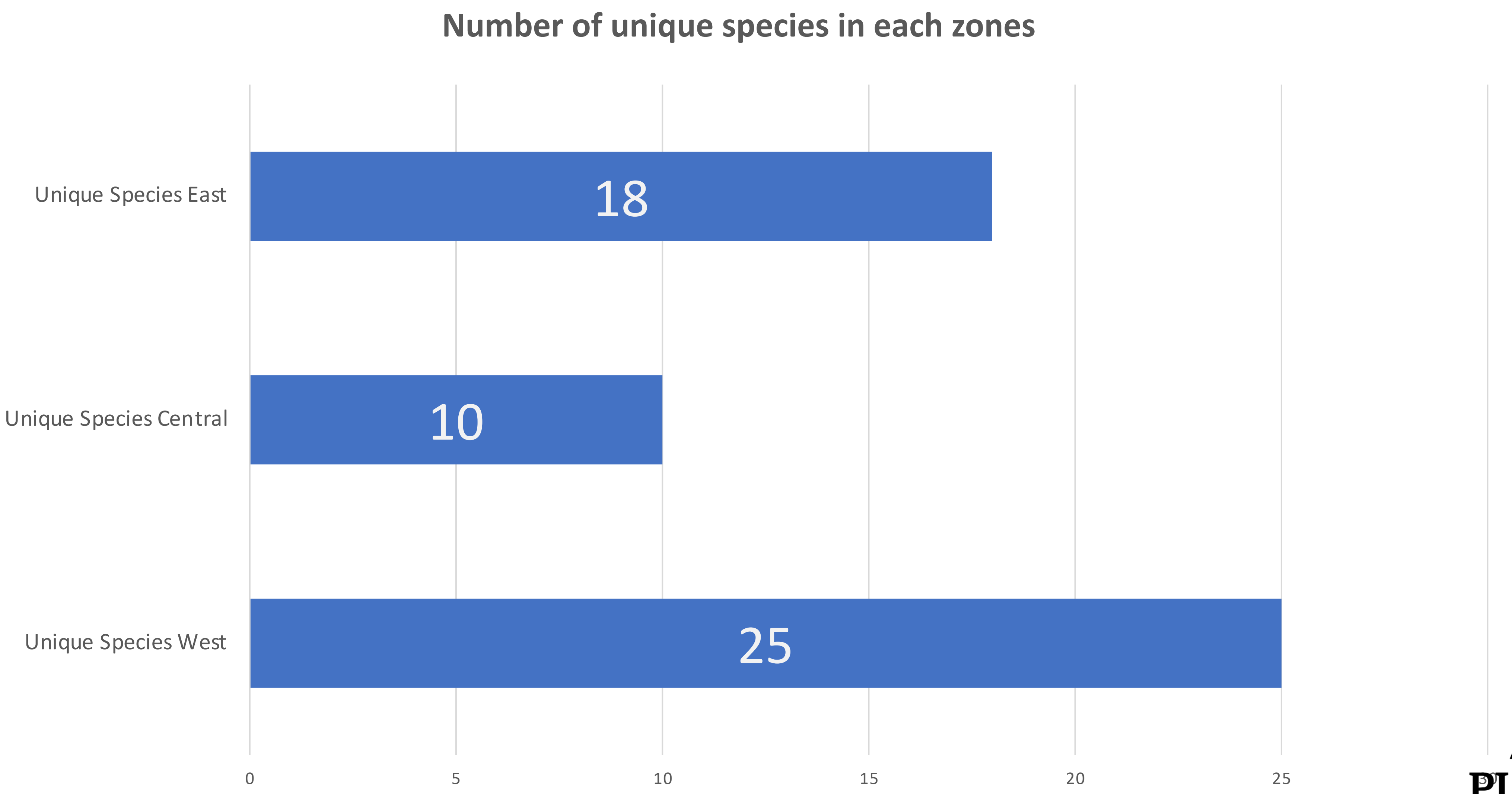

Fig 6: Number of unique species in each zone

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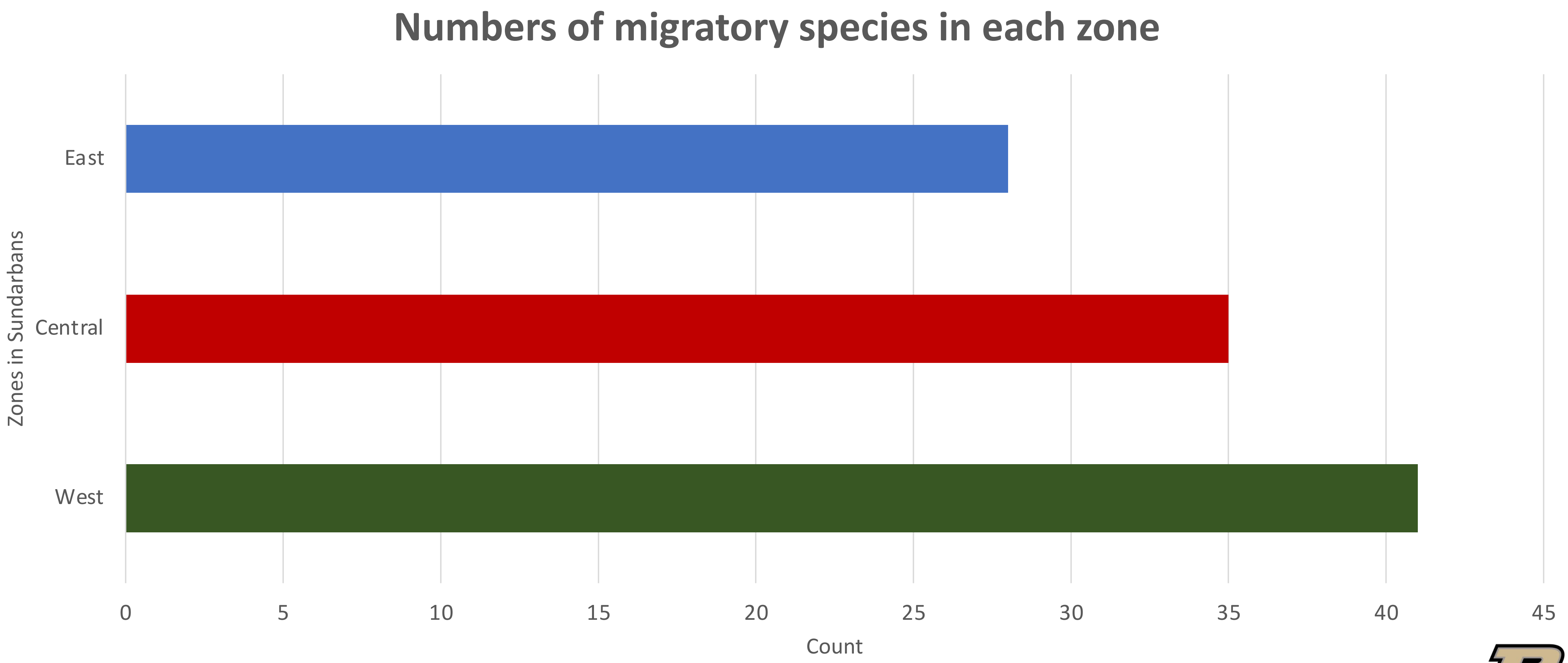

Fig 6: Number of Migratory species in each zone

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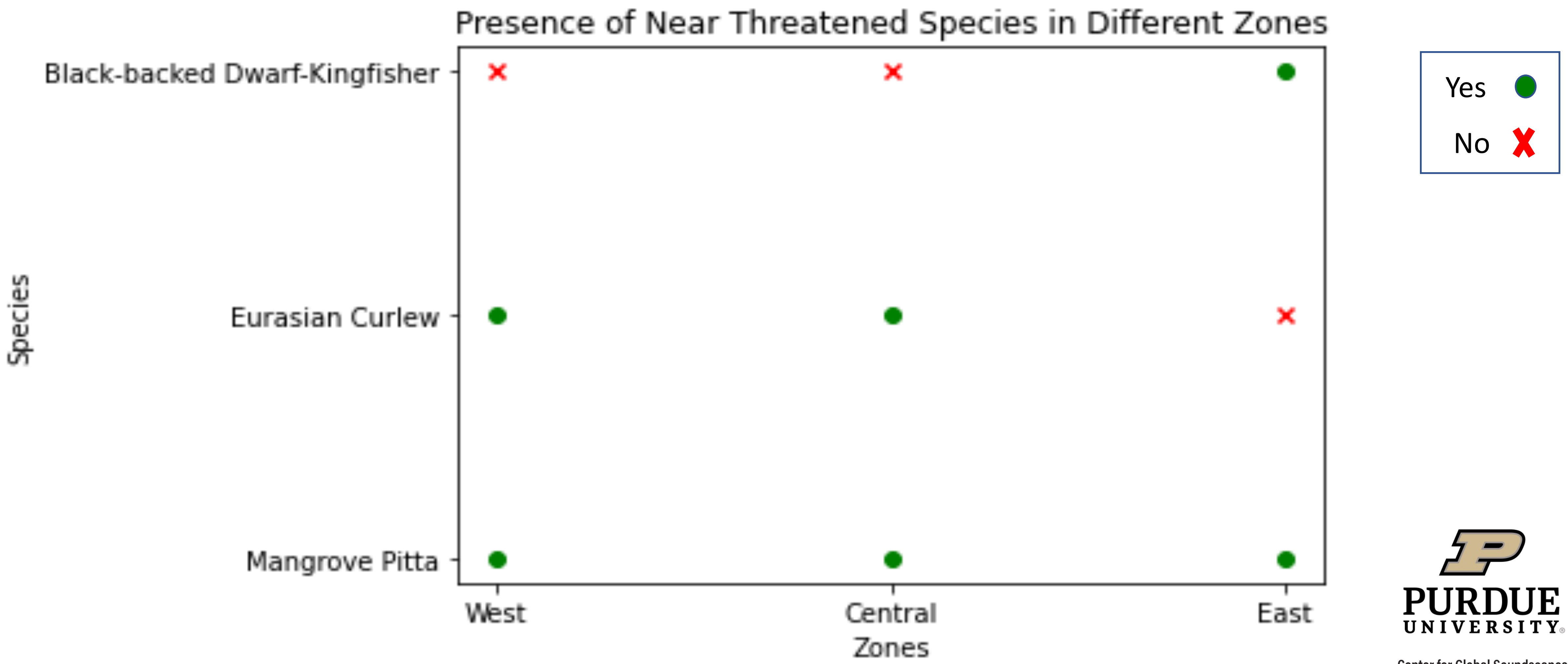

Fig 7: Near Threatened species according to IUCN in each zones

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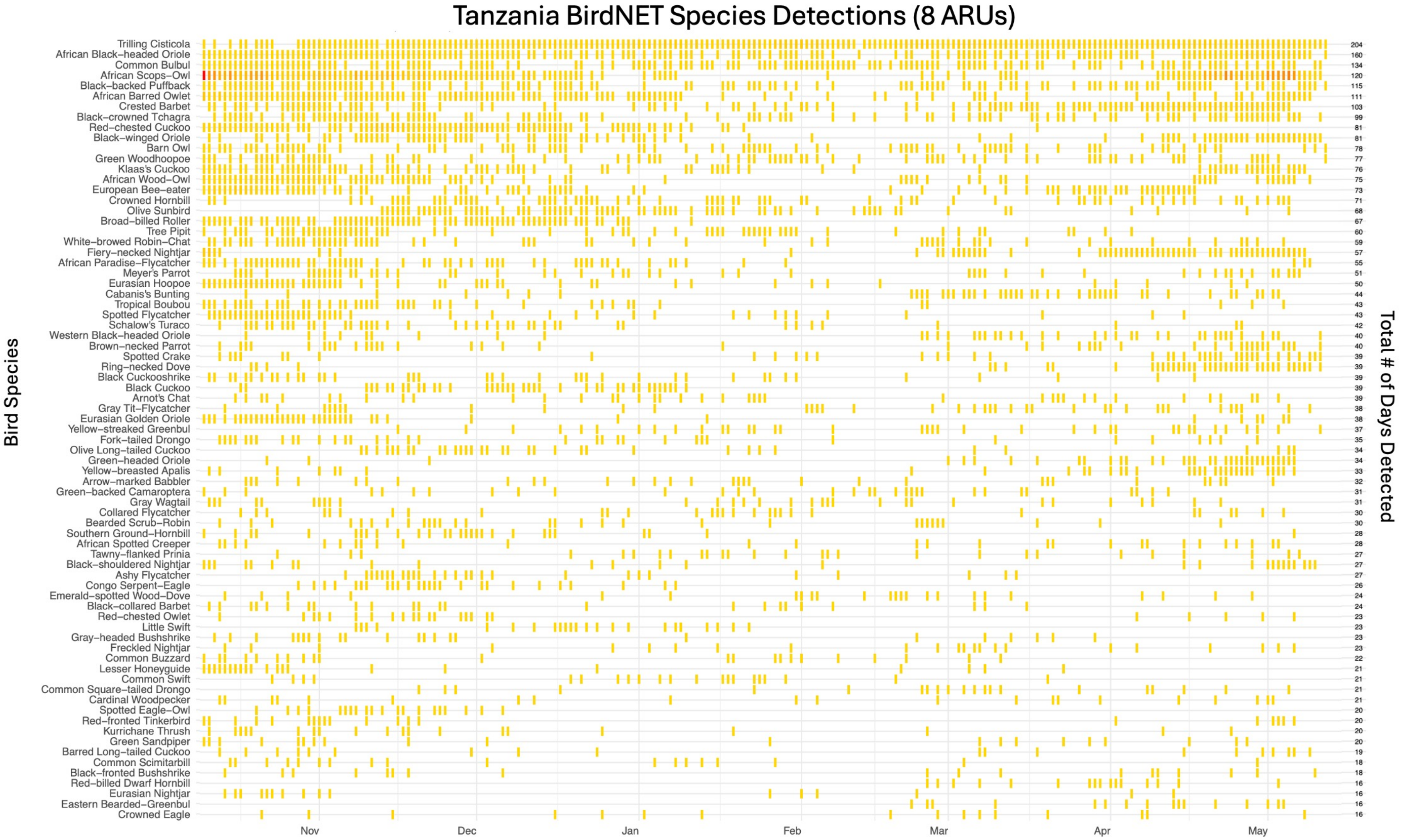
3. BIRDNET RESULTS FOR TANZANIA



2022 2023

Preliminary Analysis of Acoustic Data from Tanzania and Plant Survey Results

Daily call rate averages (per hour)

Over 120 species of birds detected during 7 months of recording

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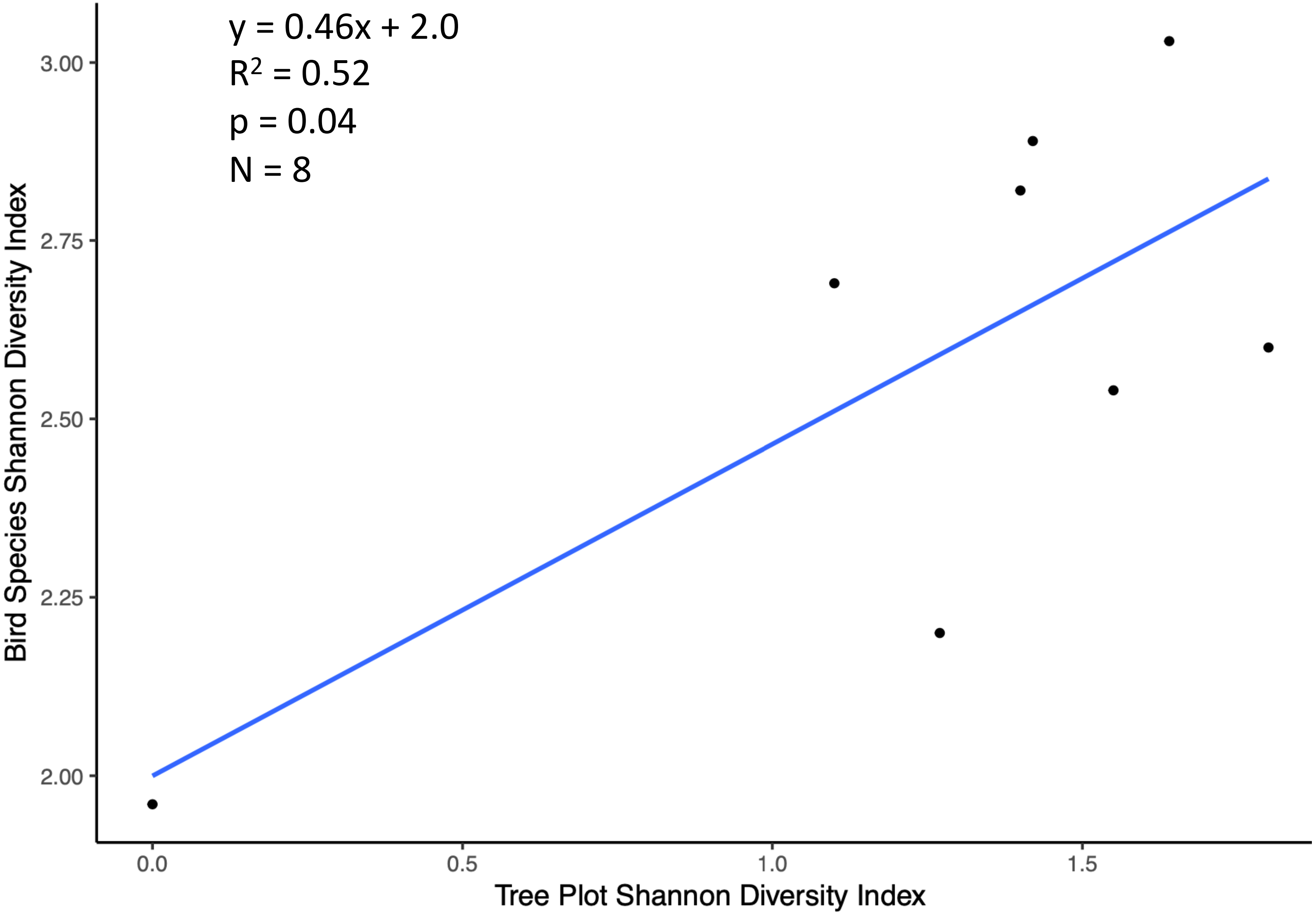
Tree Plot Shannon Diversity vs. BirdNET Species Shannon Diversity

(Preliminary Results for 8 ARUs)



Hypothesis 1.6 is that avian species call rate diversity should be positively correlated with plant species diversity

Cannot reject

Bird Species Shannon Diversity = species richness times detection number (as proxy for abundance)

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4. TECHNOLOGY DEVELOPMENTS

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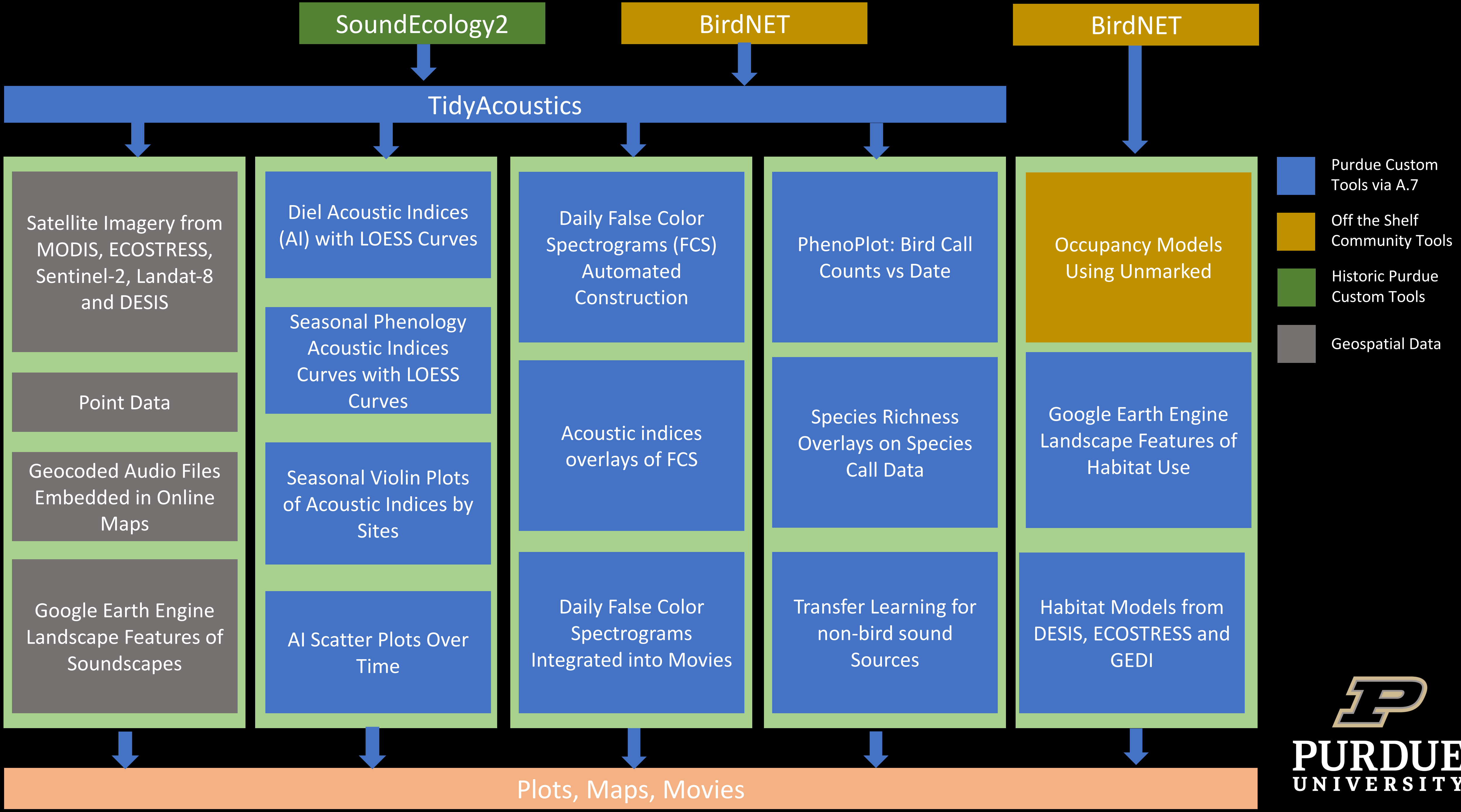

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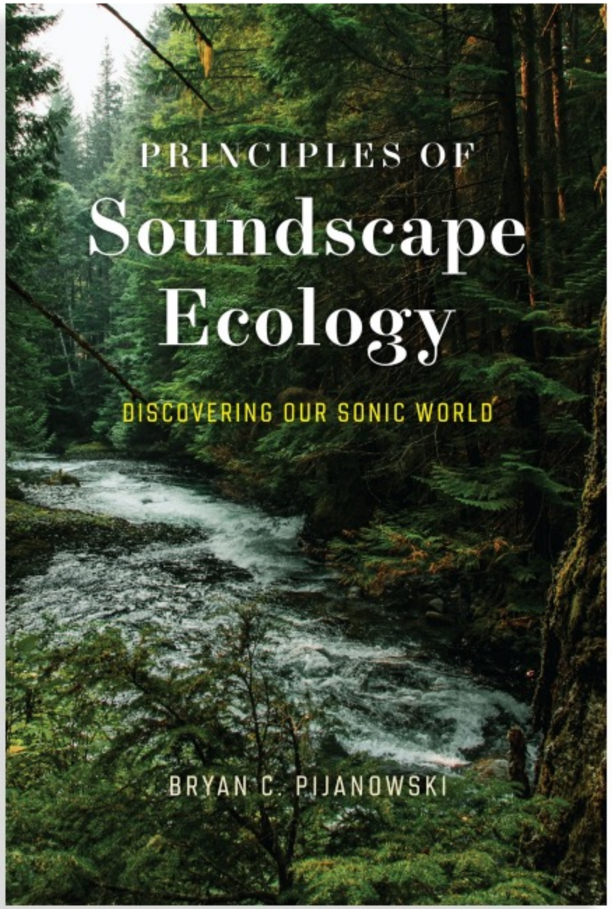

Principles of Soundscape Ecology

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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