Spatiotemporal analysis of *Apis mellifera* foraging in a *Brassica juncea* field using bioacoustics

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Introduction

- Compounds in mustard (*Brassica juncea*) pollen may reduce incidence of nosema spores in honey bees (*Apis mellifera*) (Ugolini 2021)
- To study this, we may want to monitor honey bee foraging in mustard fields
    - Existing methods can be:
        - Expensive
        - Time-consuming and time-constrained
        - Inaccurate (Portman 2020)
    - Alternative: **bioacoustics**

Background

- Bioacoustics is the study of how animals produce, transmit and receive sound
- Machine learning can be used for species identification
    - Analysis of birdsong recordings has been automated (Rivera 2023)
    - Zhang 2017 proposed insect classification by machine learning models trained on wingbeat signals
    - Kawakita 2019 automated classification of honey bees, bumblebees and hornets

Aims

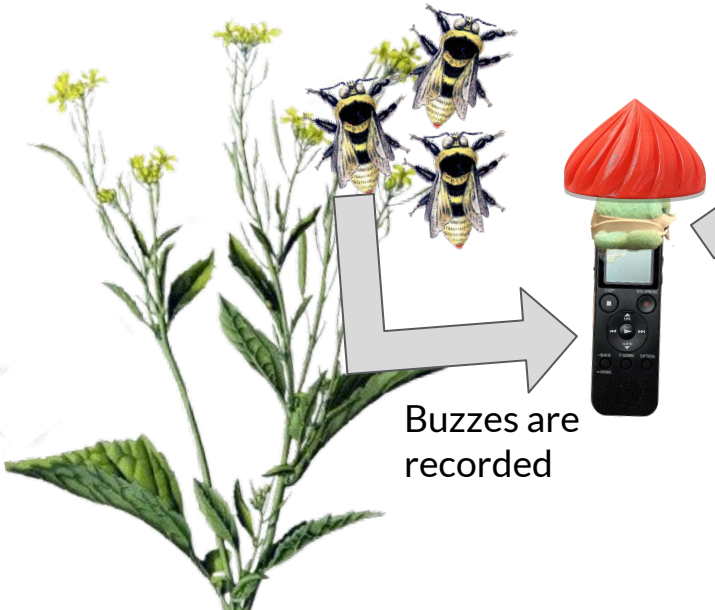
- Observe honey bee foraging rate in a mustard field:
  - throughout the day
  - throughout space
  - after the introduction of bumblebees

Methods

- 54 recorders placed in a 18 x 3 grid in a mustard field adjacent to four honey bee colonies
- After three days, bumblebee colonies were introduced

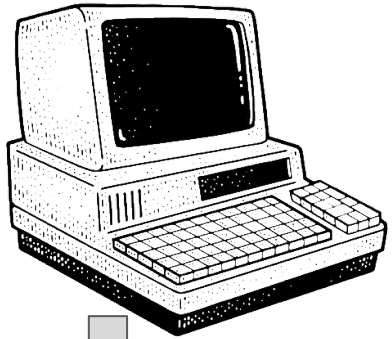
54 recorders placed
More than 10 ½ months of audio collected
27,900,000 data points

Data pipeline



Buzzes are recorded

Recordings are fed through buzzdetect



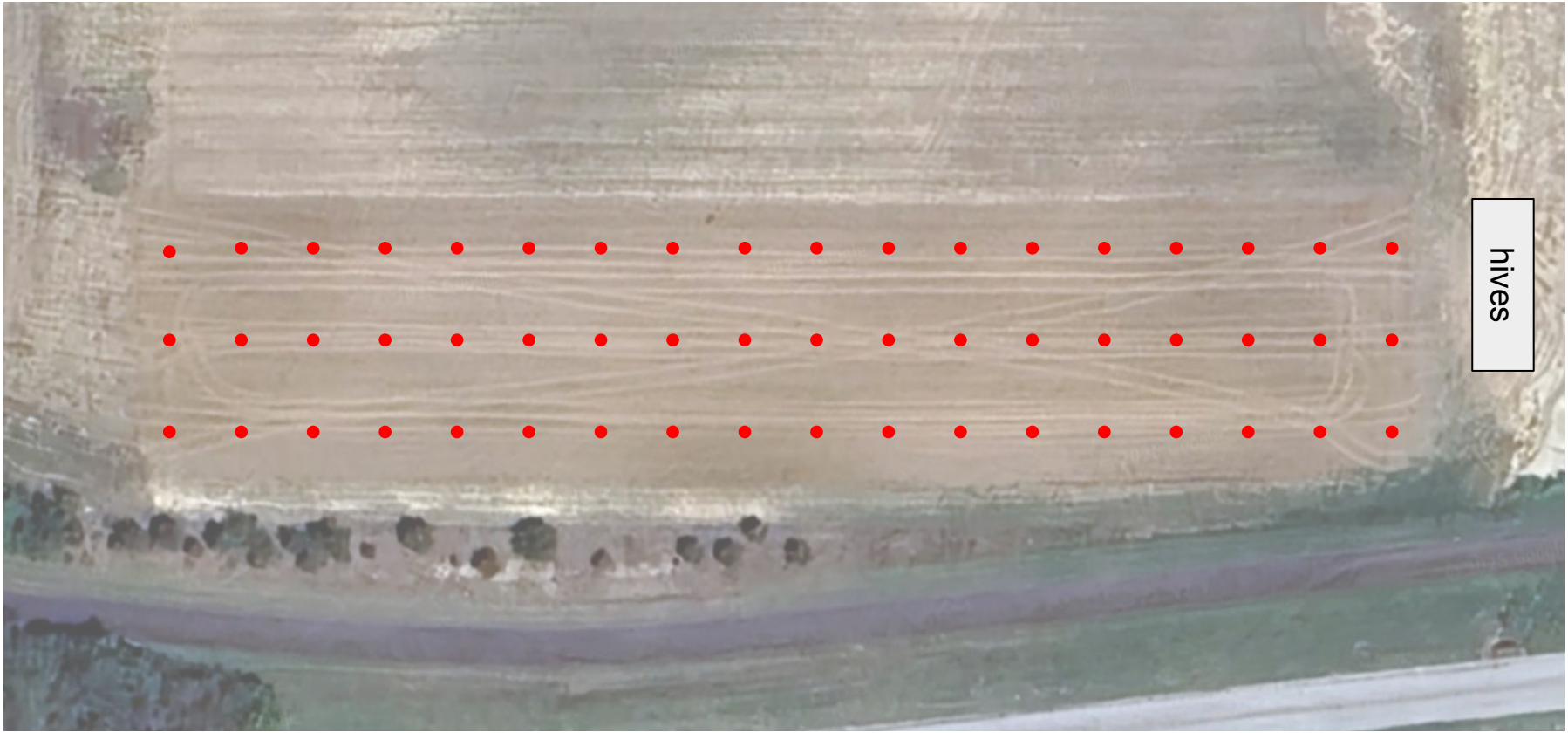
Binned detection rates are generated

start_bin	detections_neg1	detections_0	frames_total
2024-09-03 13:35:00 EDT	24	11	313
2024-09-03 13:40:00 EDT	48	38	312
2024-09-03 13:45:00 EDT	109	77	313
2024-09-03 13:50:00 EDT	103	63	312
2024-09-03 13:55:00 EDT	84	44	313
2024-09-03 14:00:00 EDT	76	57	312
2024-09-03 14:05:00 EDT	67	45	313

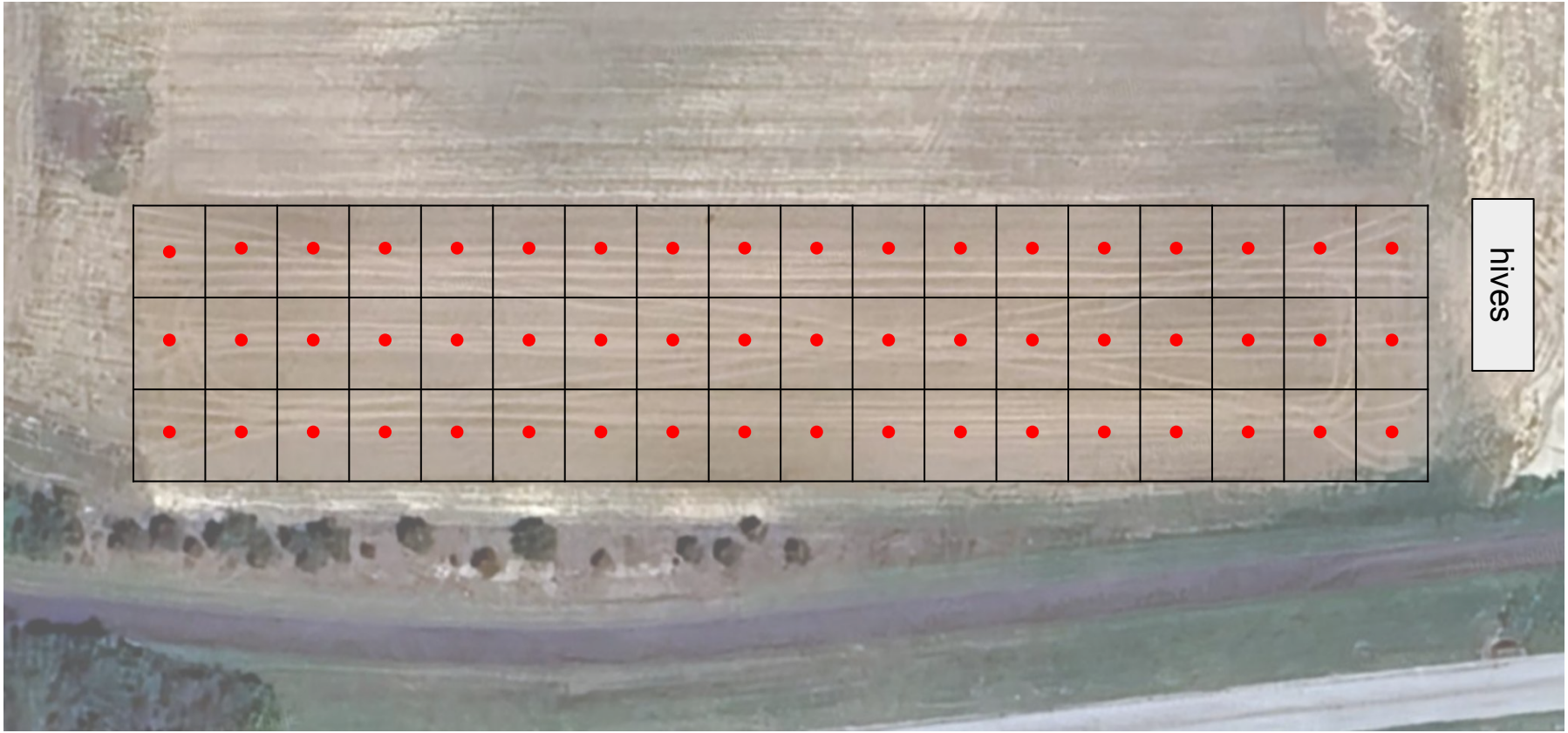
Analysis

Six days of bee activity

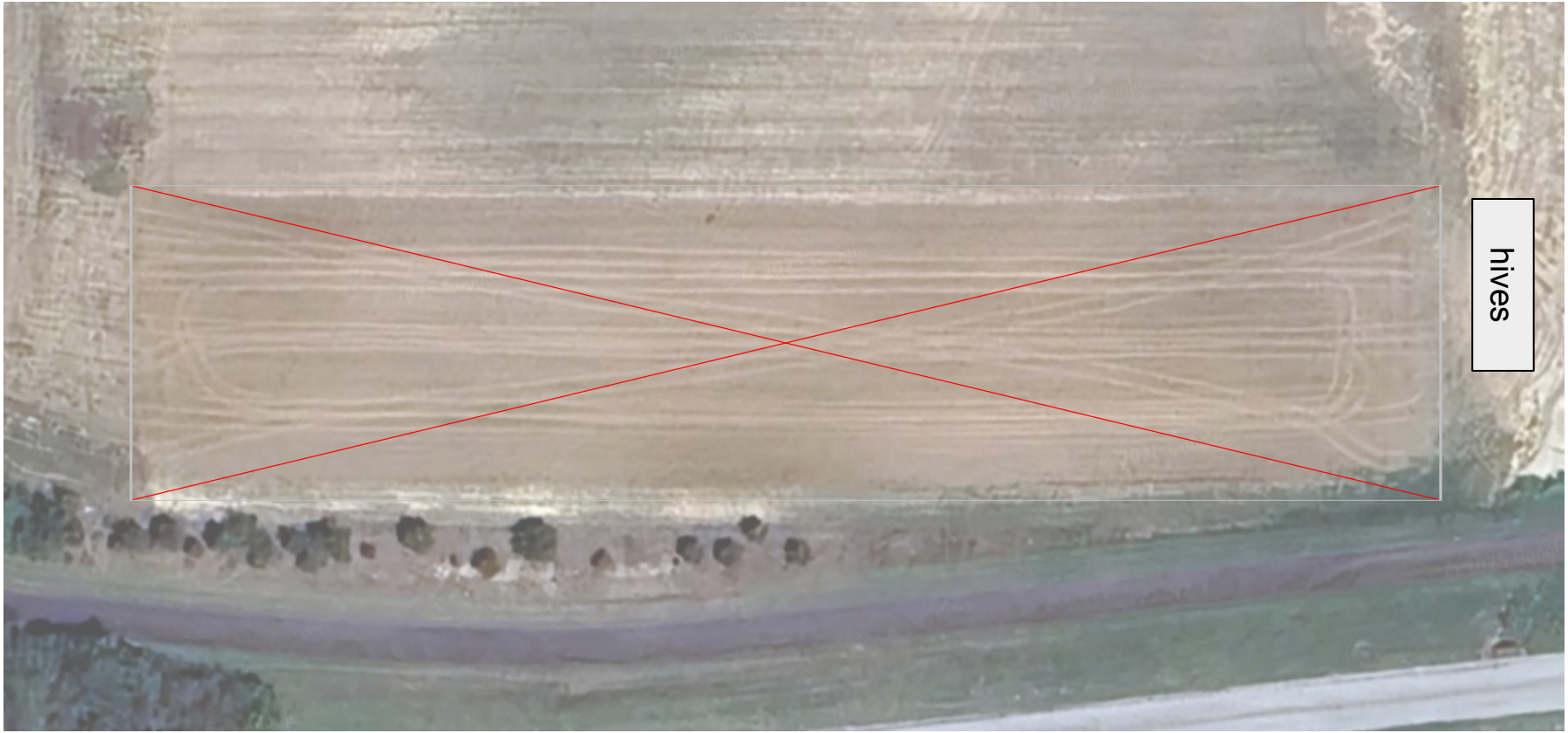
Six days of bee activity



Six days of bee activity



Six days of bee activity



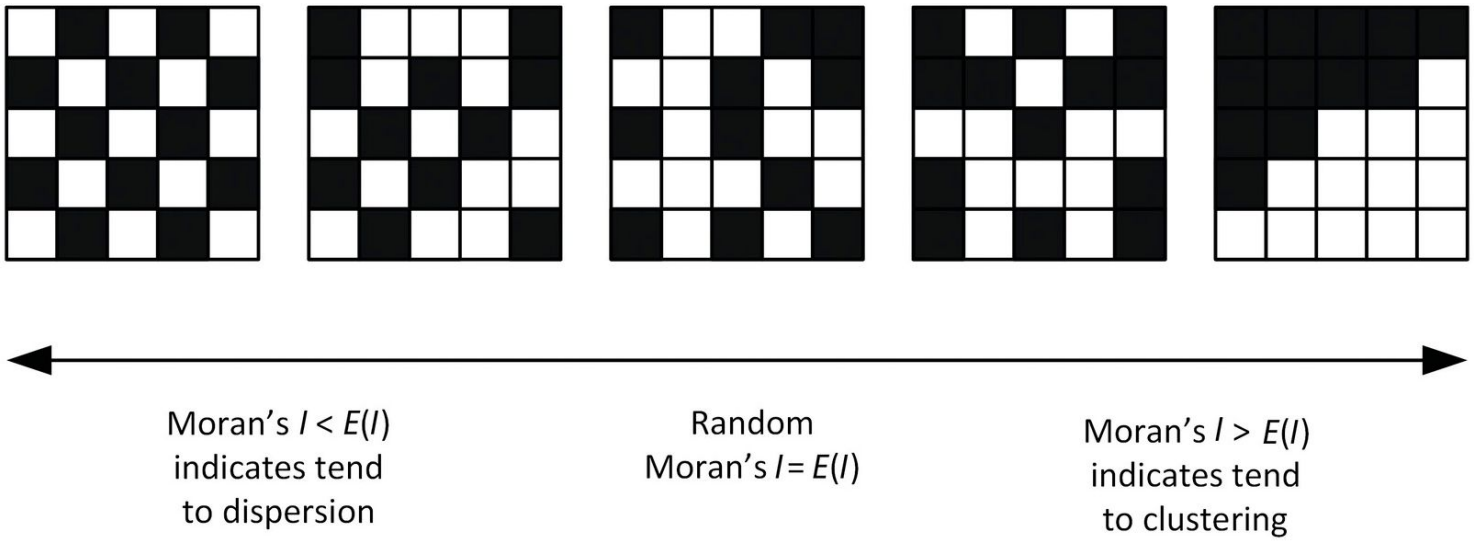
Spatial Analysis

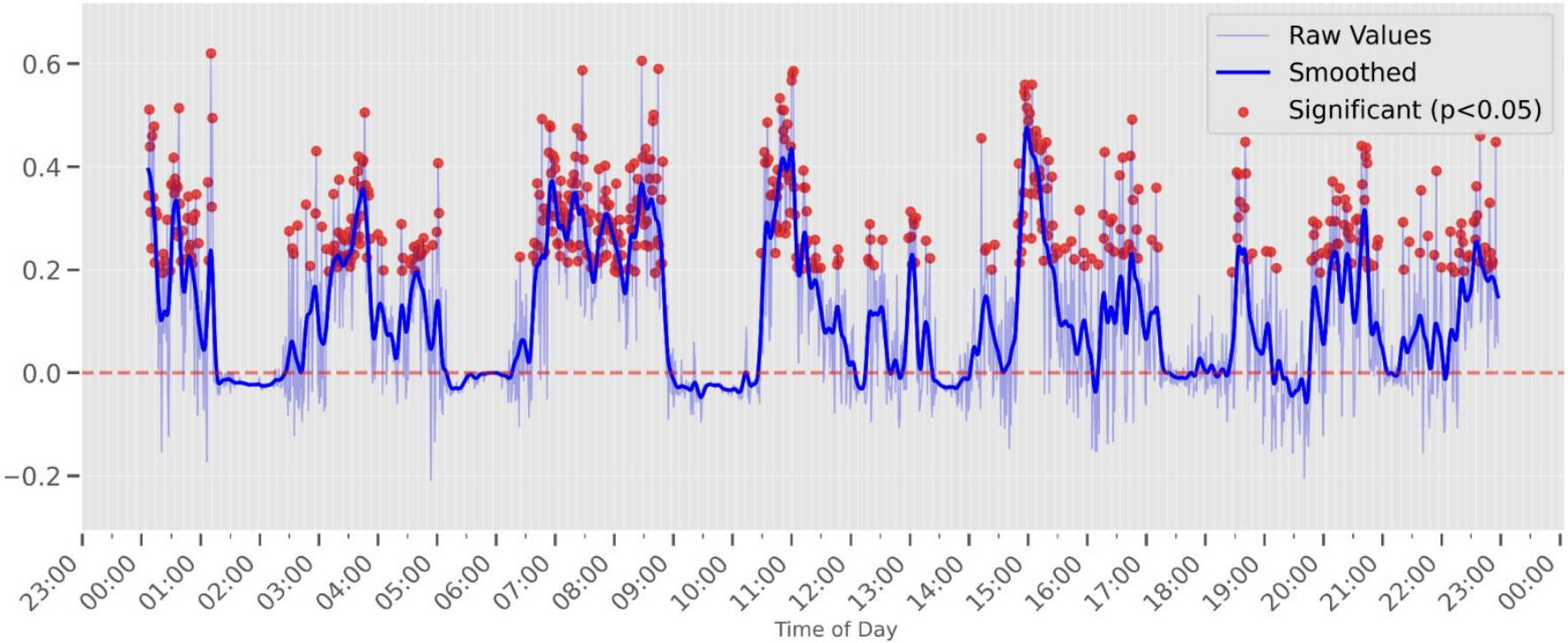
Moran's I

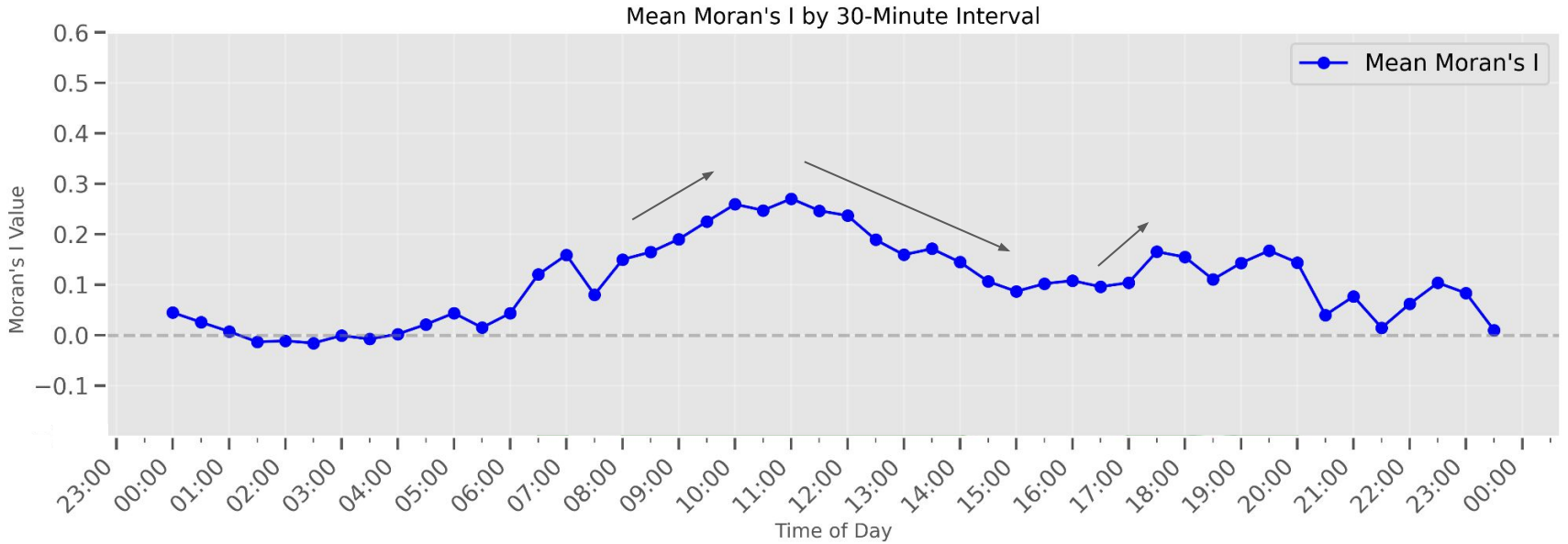
$$I = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (x_i - \bar{x})^2}$$

- Measure of spatial autocorrelation

Fan (2024)




Raw Values
Smoothed
Significant (p<0.05)
0.6
0.4
0.2
0.0
−0.2
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
Time of Day


Mean Moran's I by 30-Minute Interval
Mean Moran's I
Moran's I Value
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
Time of Day

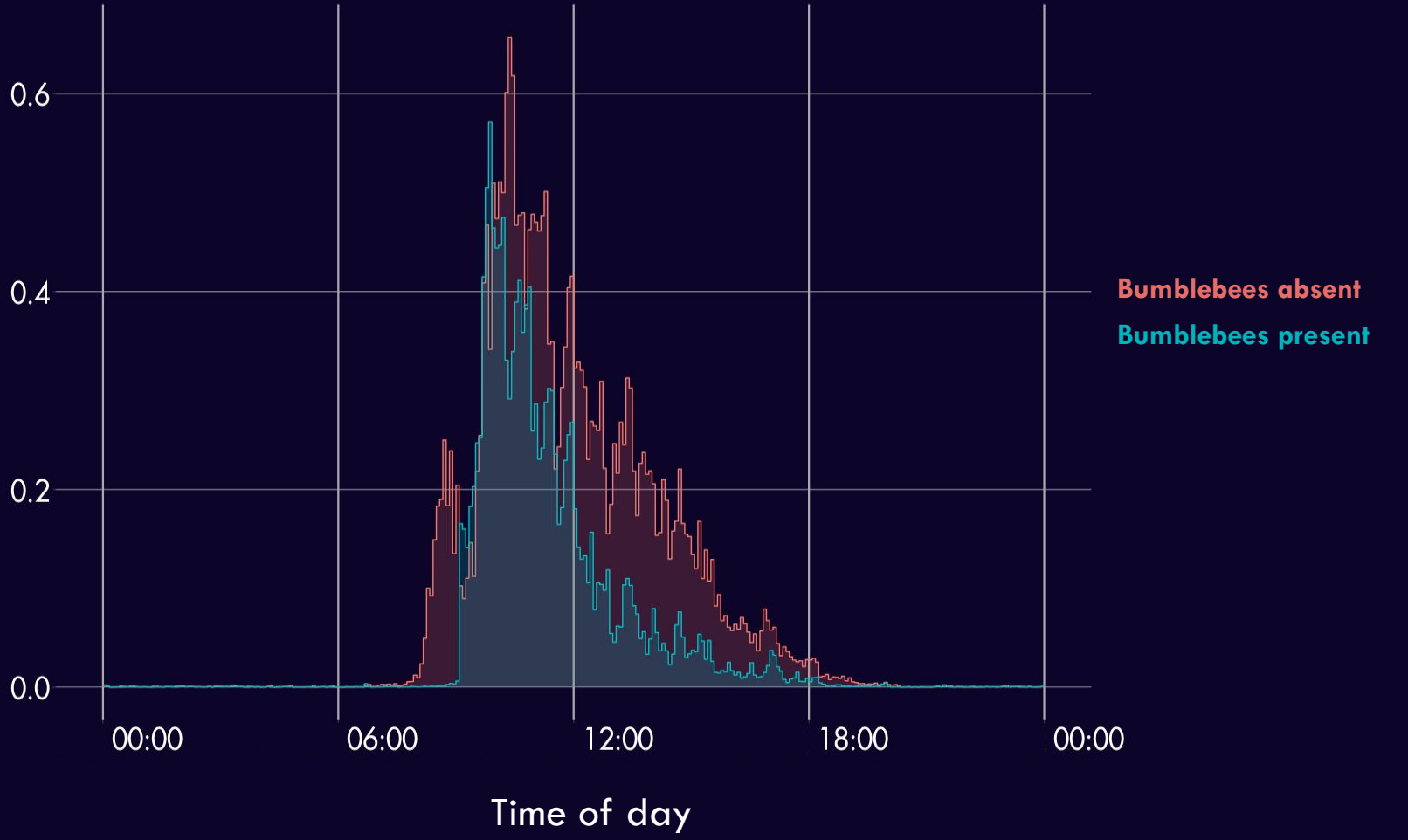
2024-09-05 17:55:00 EDT
0.6201

2024-09-05 17:55:00 EDT
0.6063

Temporal Analysis

Bumblebees

- Bumblebees placed after three full days
- Will bumblebees affect honey bee foraging?
- Answer: probably not
    - Bumblebees not witnessed in field
    - Pollen was not found to include mustard pollen


0.6
0.4
0.2
0.0
00:00
06:00
12:00
18:00
00:00
Time of day
Bumblebees absent
Bumblebees present

Findings

- Honey bee *Brassica juncea* foraging rates peaked shortly before noon
- Overall honey bee foraging rates decreased after the introduction of bumblers and became more temporally concentrated
    - Weather can be a confounding variable

Questions?

buzzdetect
GitHub

Acknowledgements

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