Eavesdropping on Vineyards

Machine Learning Methods for Monitoring Birds in Viticultural Landscapes

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Introduction

Birds in Vineyards

Birds can be useful indicators of ecosystem health.

Changes in bird communities can reflect broader environmental conditions[1]

More biodiversity (nature) around the vineyard can be a good thing, but birds can cause significant financial loss [2]

Invasive species

Certain species may be less desirable, both for the grower and for nature.
Which factors influence the presence of pest vs beneficial species?

Common Blackbird

Common Starling

Common Myna

More birds in vineyards?

PEST SUPRESSION

More birds and bats can mean less chemicals and rodents

Insectivores can provide useful services, other species can consume rodents or chase away less desirable species

BIODIVERSITY ACCOUNTING

Incentivising best-practice

There is a growing global demand for biodiversity accounting and offsetting, with over 100 countries implementing biodiversity policies which incentivise landholders [6]

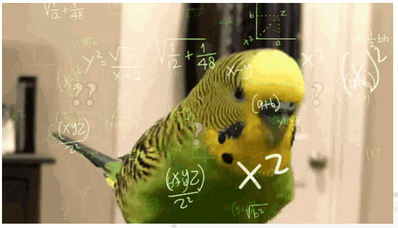
SUSTAINABILITY

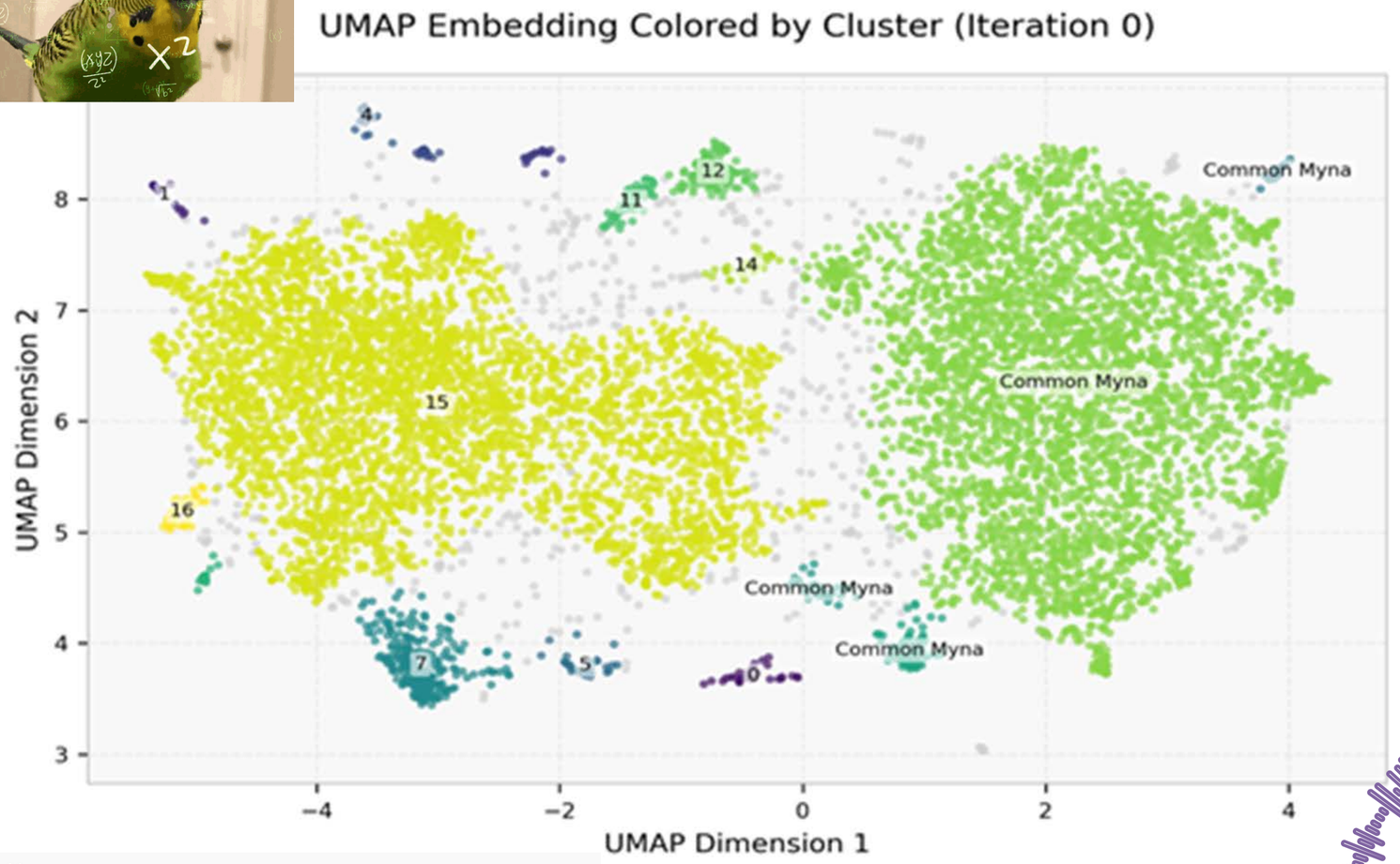
Informed Consumers + Ecotourism

Some consumers willing to pay a premium price for wine certification that takes biodiversity into account. Birdwatching is also a billion-dollar industry in Australia [7]

Passive Acoustic Monitoring

- Verifiable, cost effective data that can be used to guide policy & management [8]
- **Helps to mitigate seasonal and spatial biases and monitor invasive species** [9]
- Huge advances in automated processing methods
  - However:
    - Reliability concerns
    - Need for testing and adaptation to local conditions (domain shift) [10]

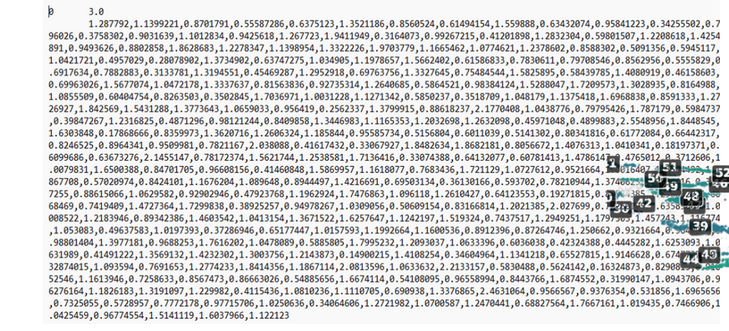


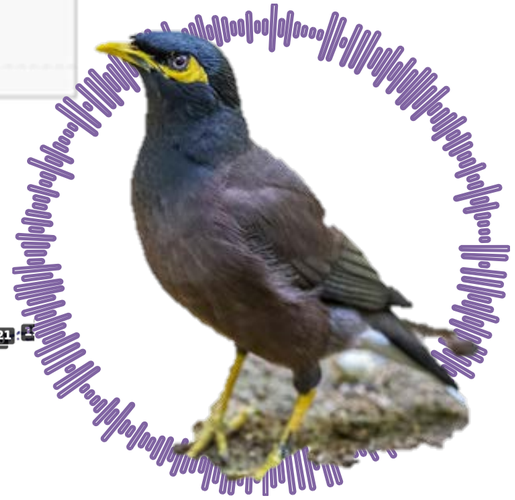


Chapter 3

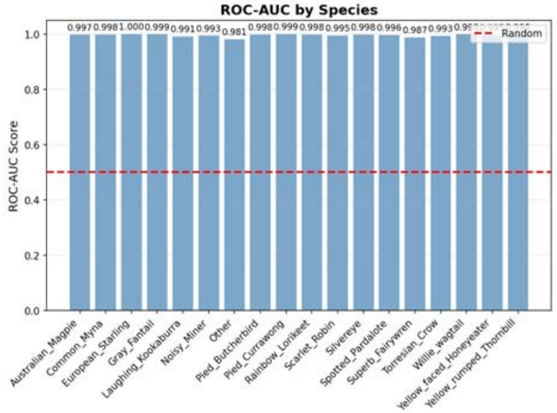
Machine learning

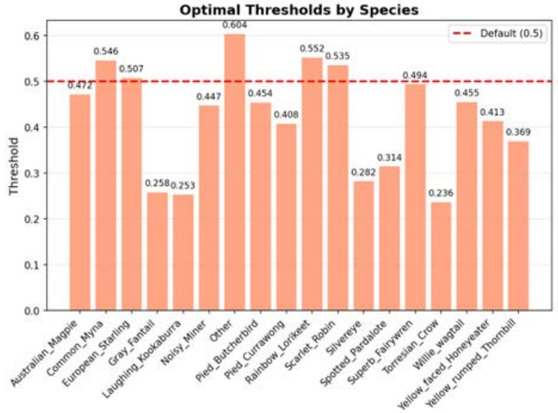
- Combined a range of machine learning (AI) approaches (supervised and unsupervised) using expert human validation
- Teaching the machine to accurately identify bird calls in the target region

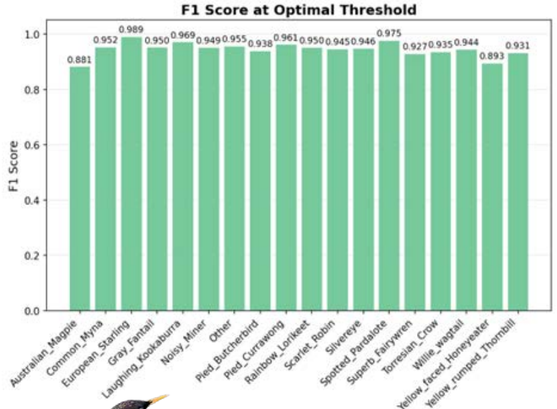


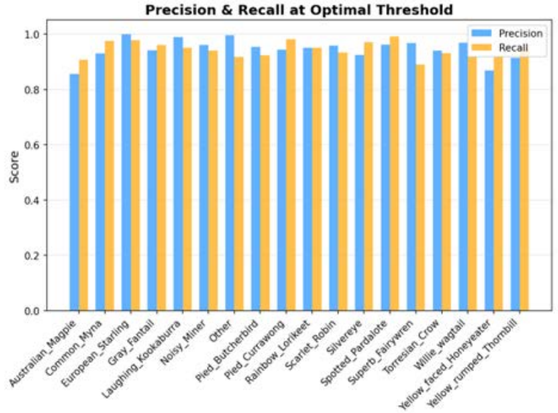


Custom Grower Classifier









Survey Approach

45
Vineyard sites

60
Acoustic Recorders

18
Months Monitored

Granite Belt Region, Queensland, Australia

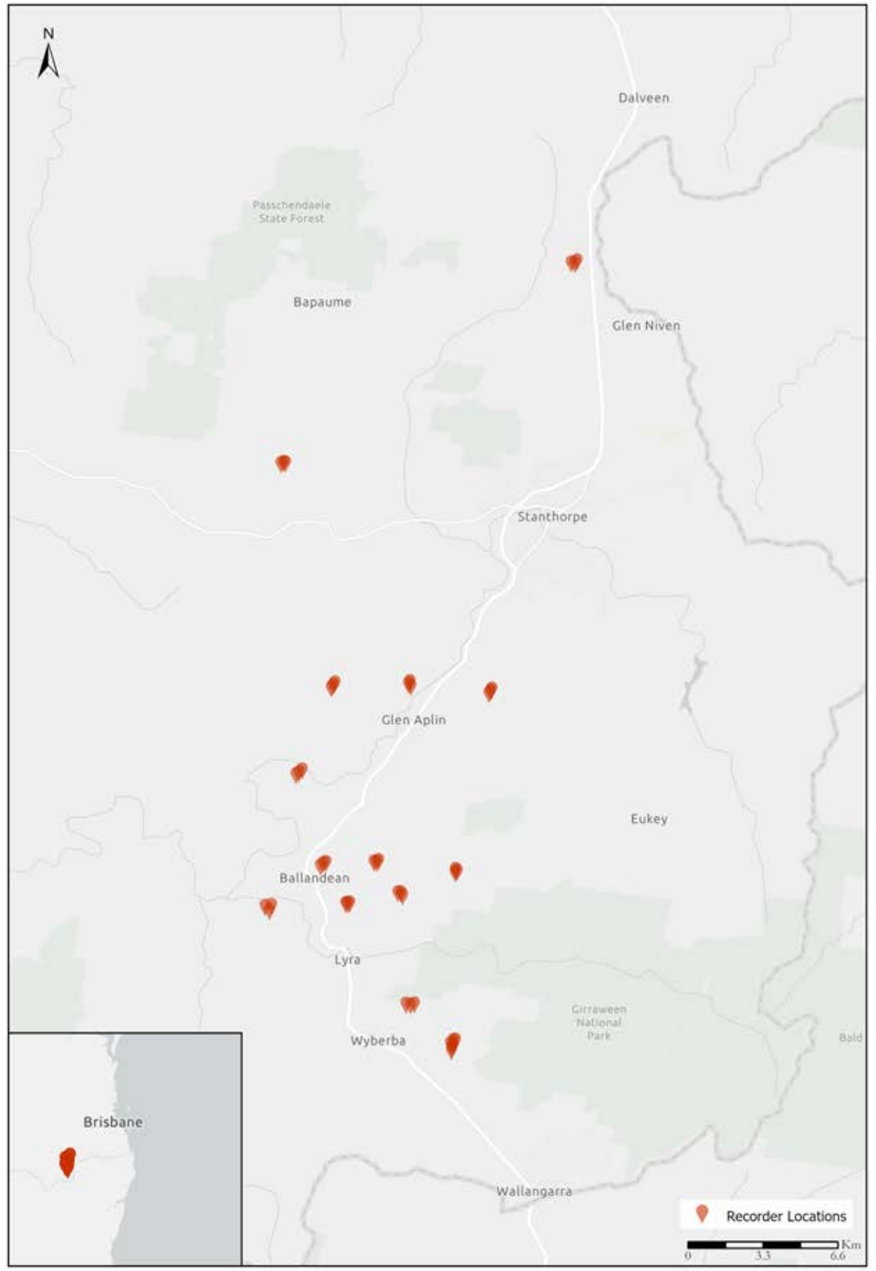
Region retains sufficient landscape heterogeneity & native vegetation to examine landscape effects while representing the production challenges faced by Australian viticulturists. Approx 80,000 hours of data/30tb

Acoustic Monitoring

Landscape Analysis

Camera Traps

Ground Surveys



Cafeteria Trials & Harvest Monitoring

- Camera traps observing feeding experiments and vines during harvest
- Automated camera bird detection

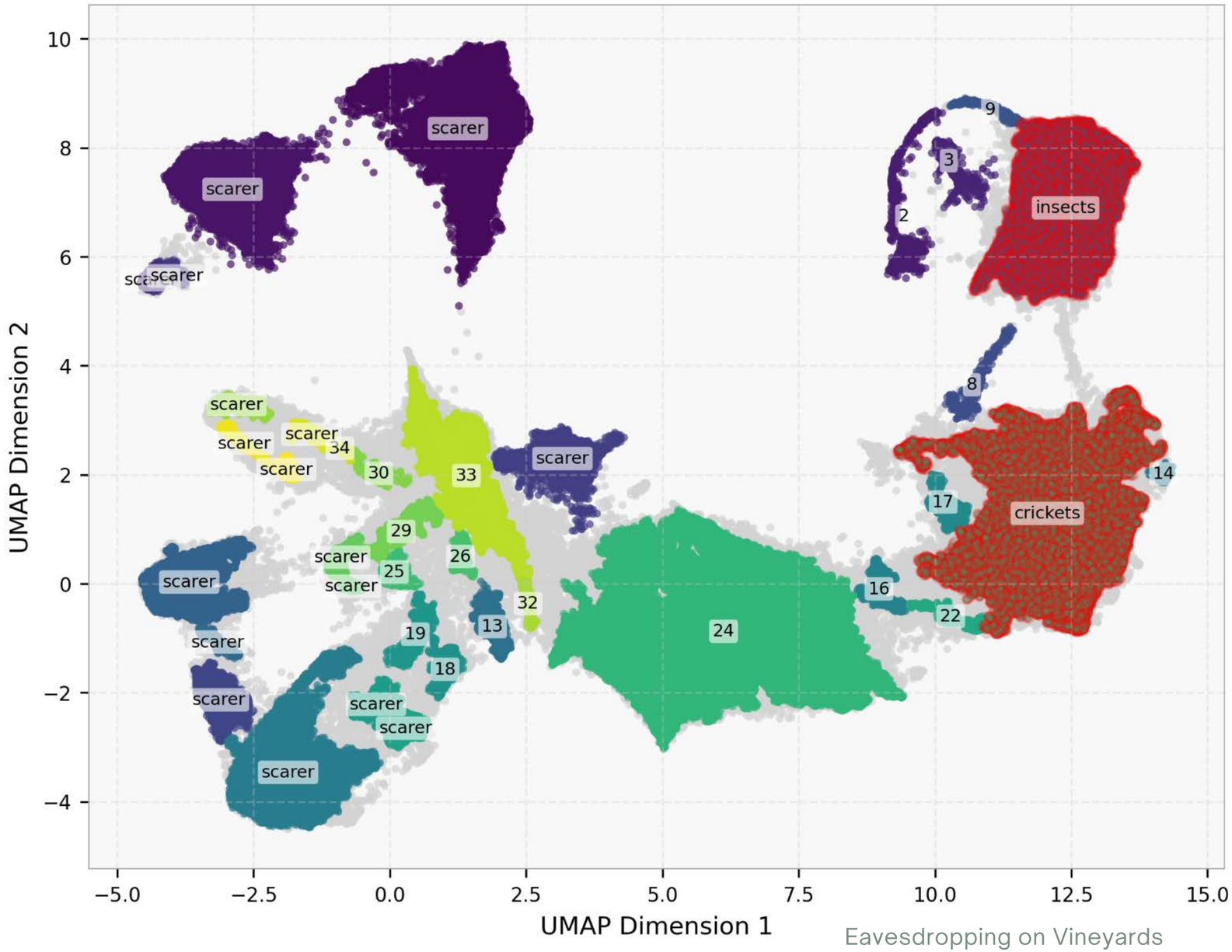
Testing deterrents

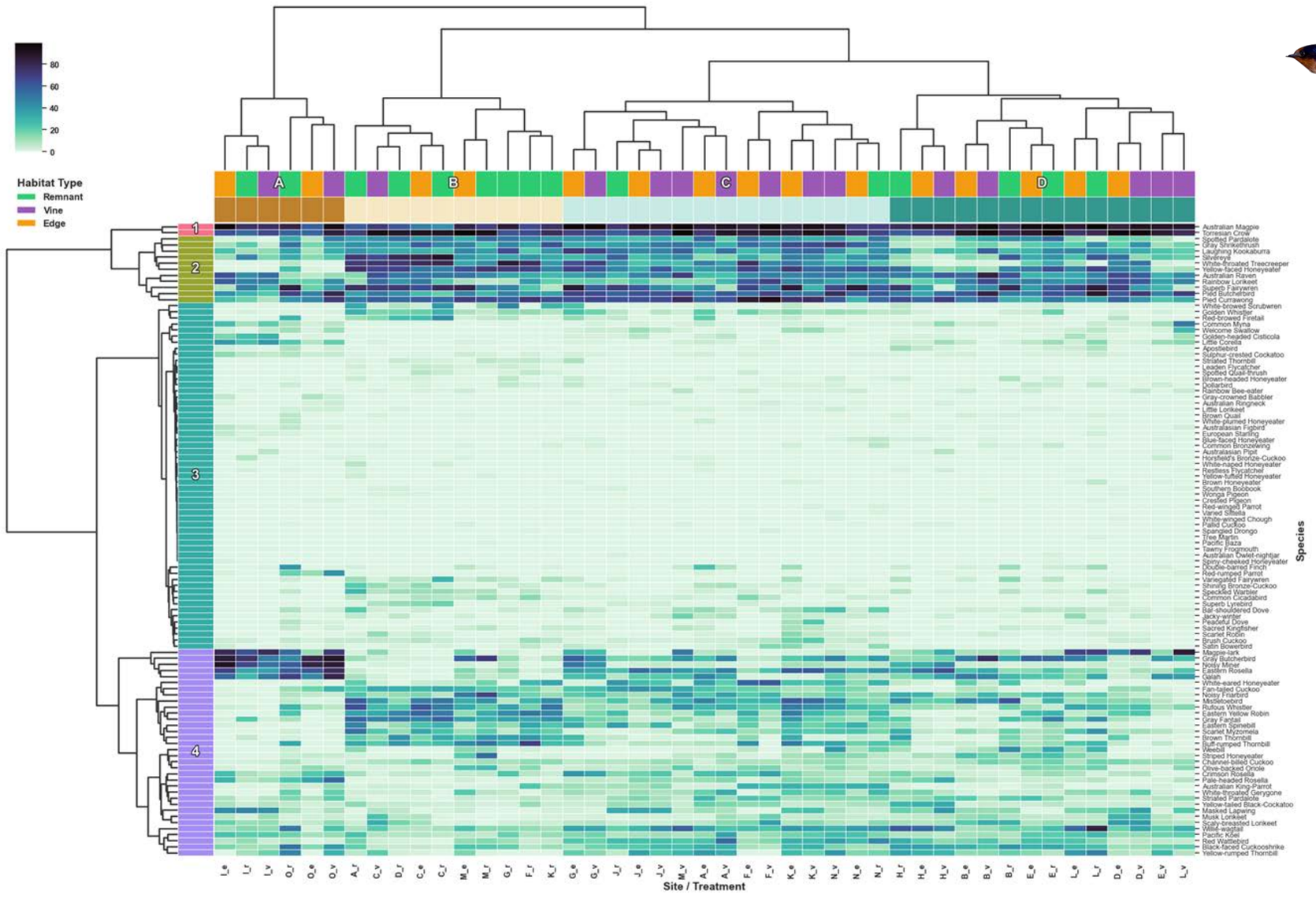
- Nearly one third of all bird species globally utilise agricultural habitats at least occasionally [13]
- Estimates suggesting that bird damage costs the Australian wine grape industry between AUD 20 and 300 million annually [14]
- Lasers, nets, acoustic deterrents, gas guns, lethal control

birdcontrolgroup.com

Sound classification

- Classify the amount of sound deterrents, insect and wind noise in a landscape so that we can factor these into our modelling

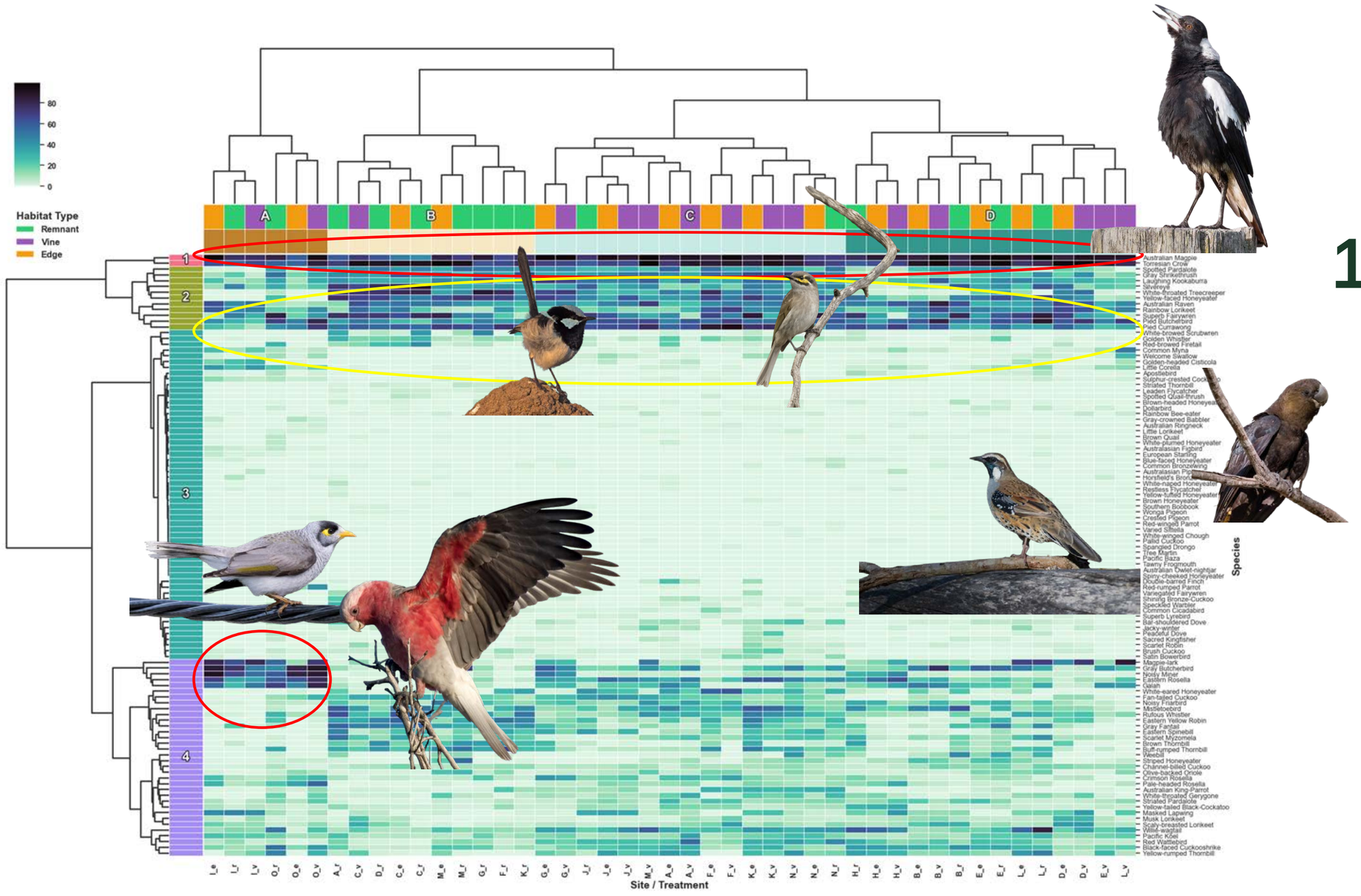




QUT

130 Species

Eavesdropping on Vineyards



130 Species

Eavesdropping on Vineyards

Chapter 4

High Impact Species

European Starling

Invasive

Common Myna

Invasive

Rainbow Lorikeet

Native Parrot

Pied Currawong

Native Generalist

Silvereye

Native Frugivore

Chapter 4

Common Friends

Superb Fairywren

Yellow-rumped Thornbill

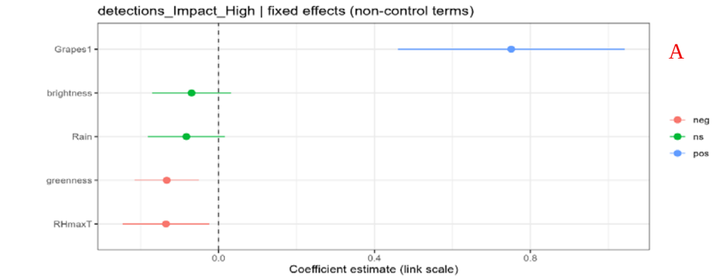
Laughing Kookaburra

Scarlet Robin

Willie Wagtail

Chapter 3

Results



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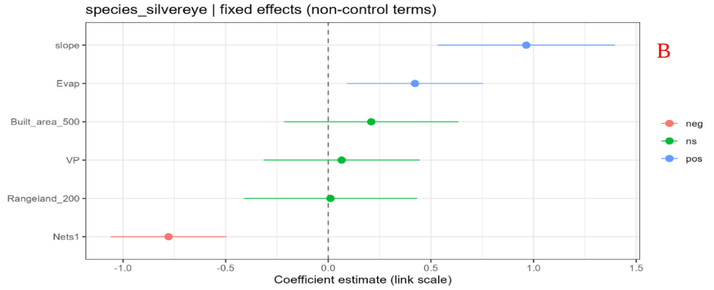

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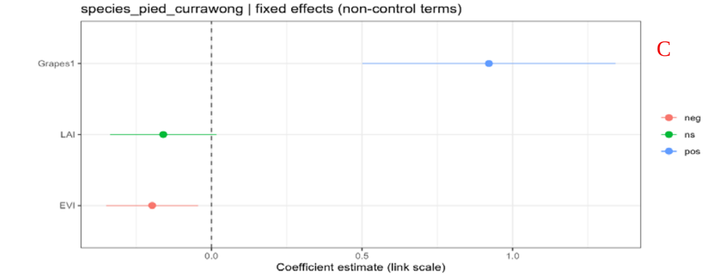

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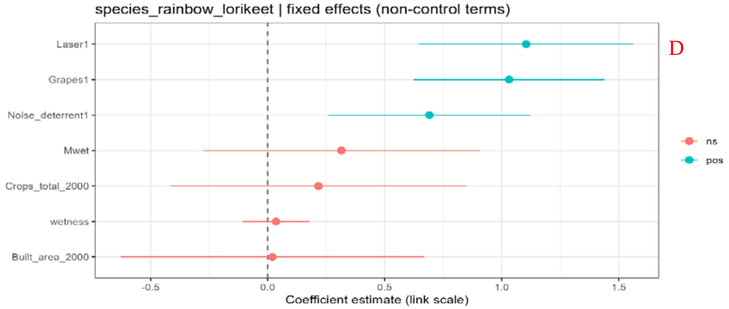

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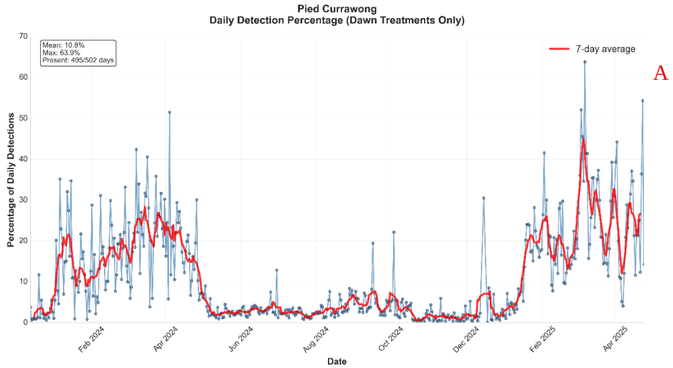

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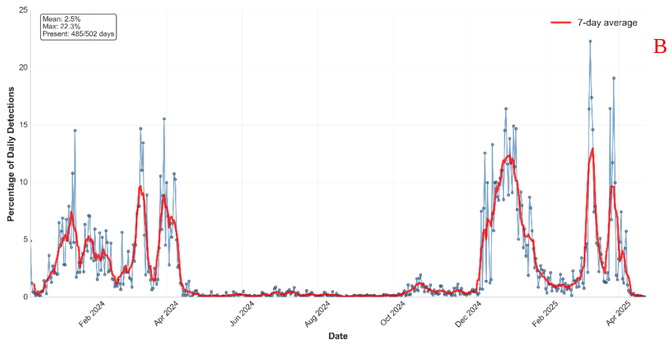

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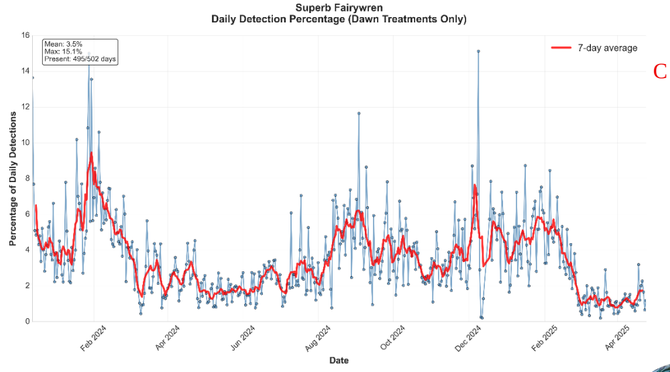

C

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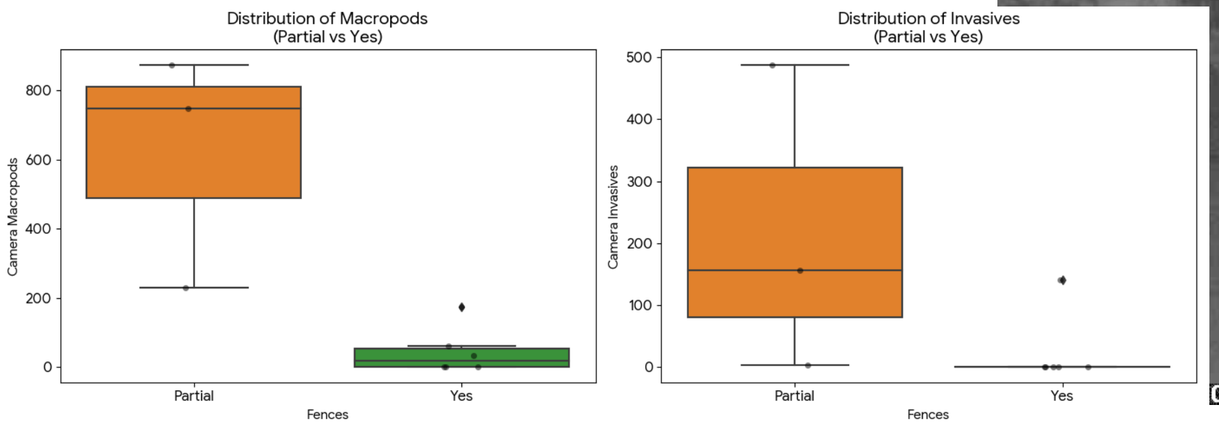
Chapter 4

Nocturnal Thieves

- Invasive mammals and rodents potentially responsible for a large amount of ‘unseen’ damage

Chapter 4

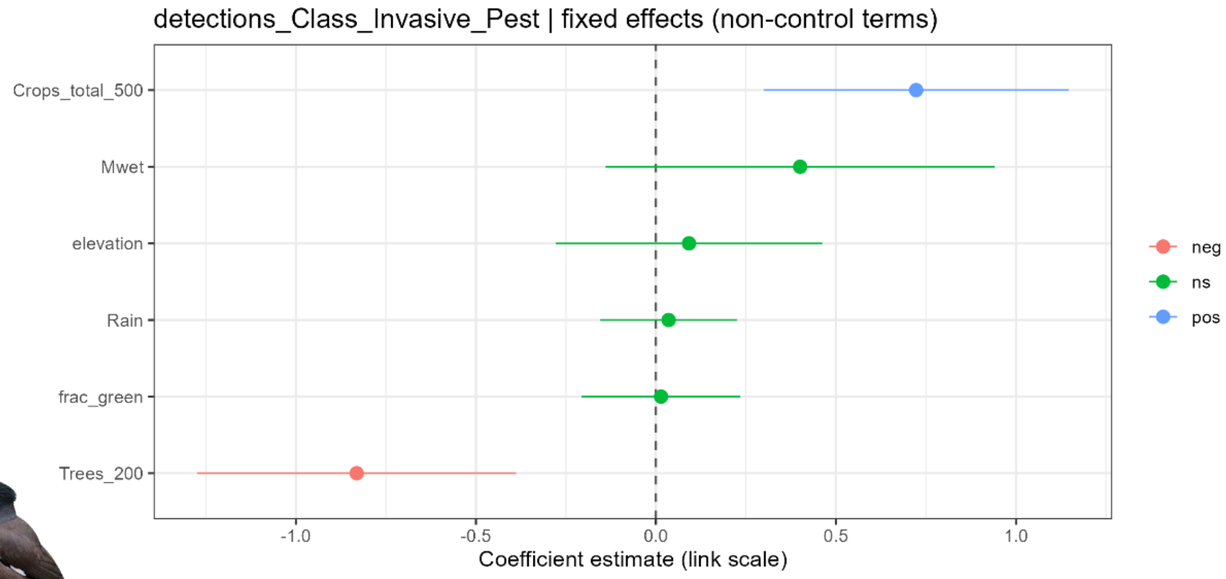
Nocturnal Thieves

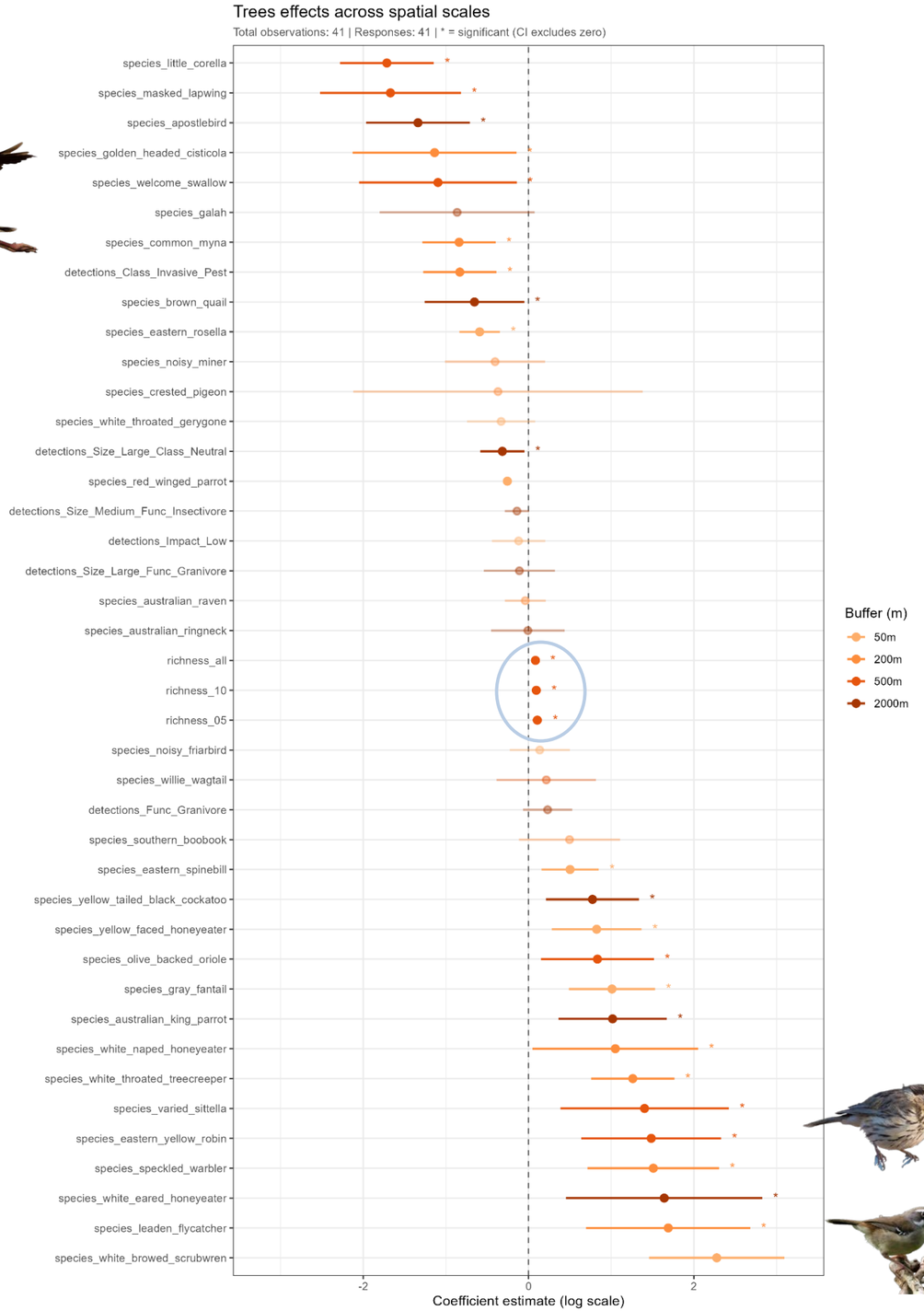


Chapter 3

Results

- Ratio between crop and native vegetation has the strongest influence on bird presence in the Granite Belt
- More complex than just more trees = more pests





Conclusions

- **Passive acoustic monitoring has the potential to provide cost-effective long-term bird data at scale**
  - Provides objective, provable data
  - Useful for monitoring invasive species & temporal trends
- **Gives us a tool to start trying to better answer some more complex questions**
- Generally more diverse vineyards provide better outcomes for avian and bat diversity (Muñoz-Sáez et al., 2021)

Acknowledgements

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Bird photos by Terence Alexander

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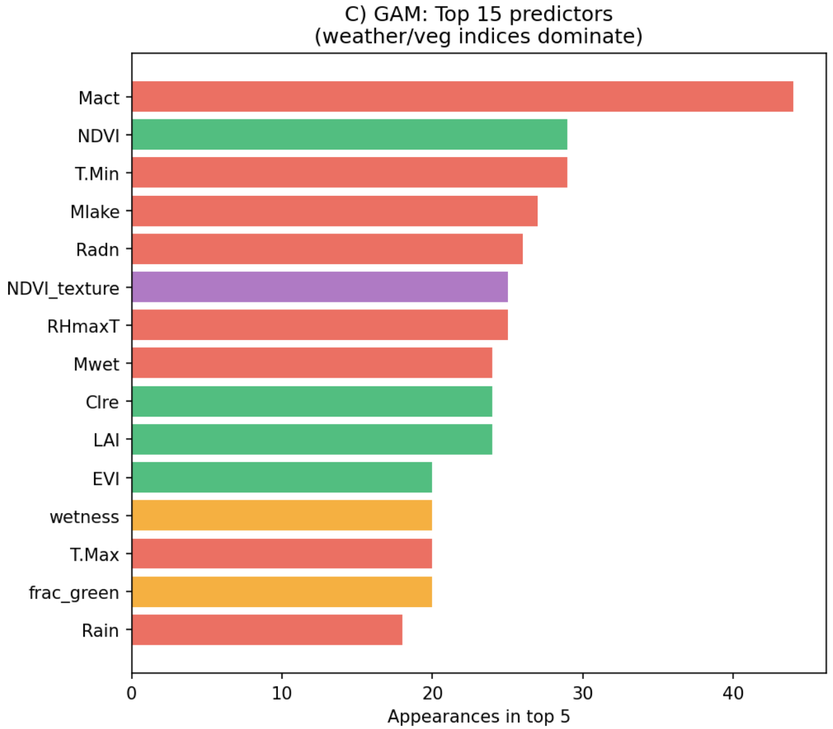
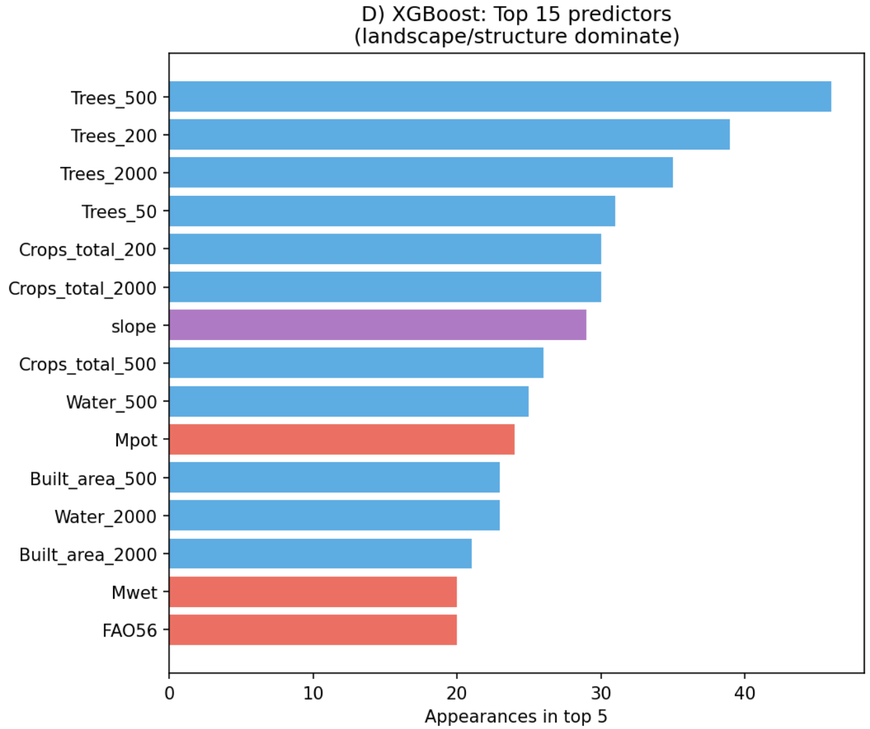
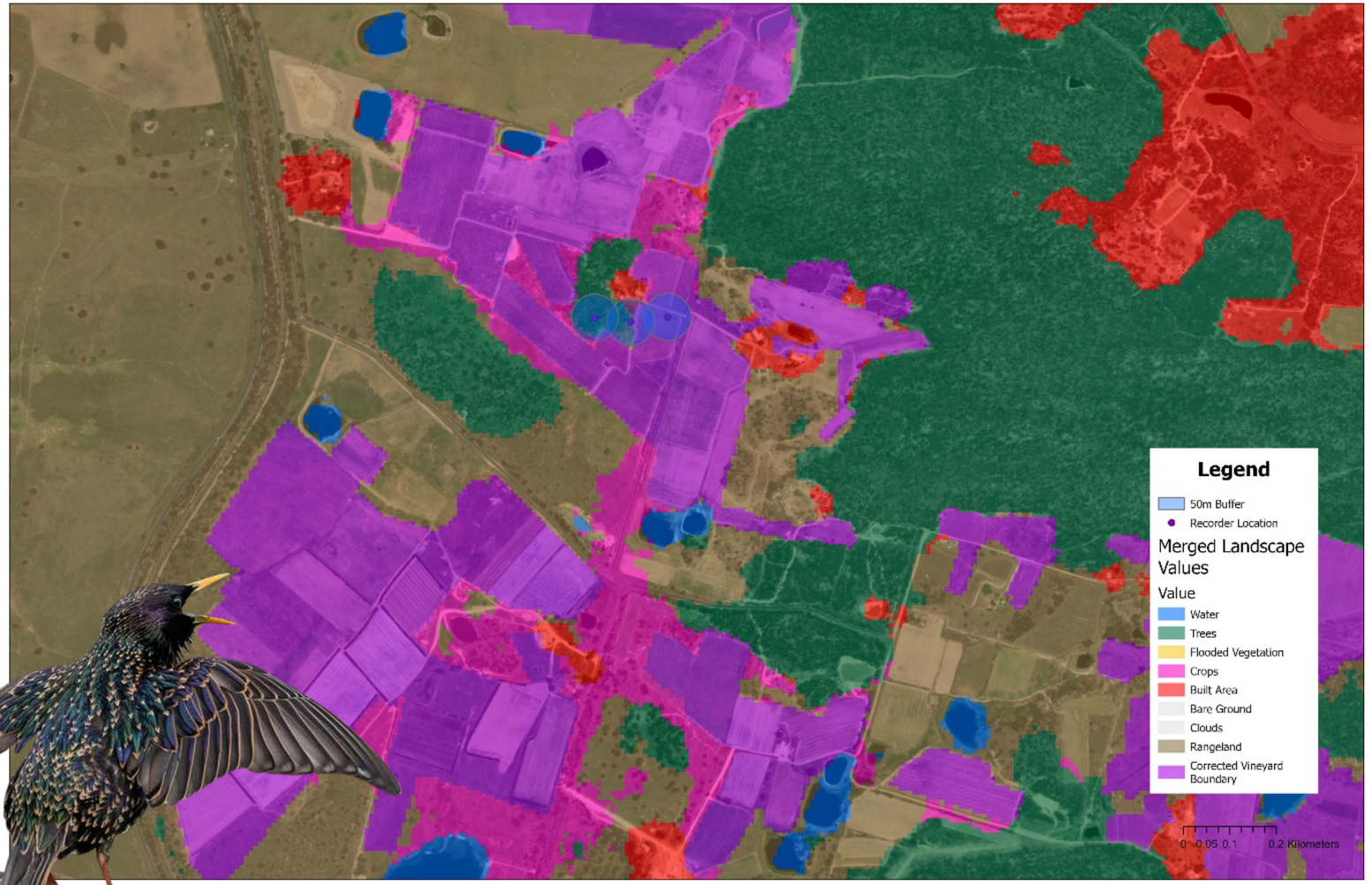
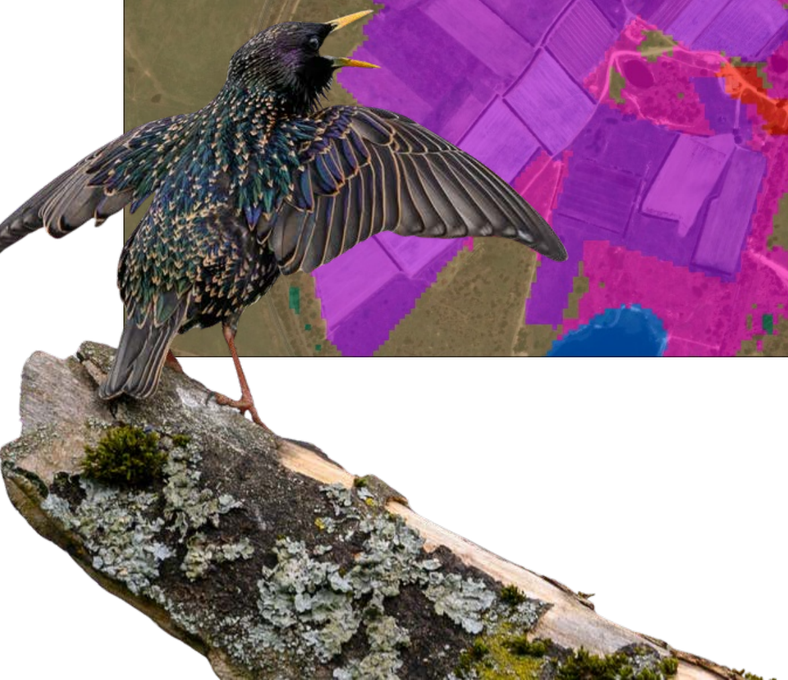
Modelling


C) GAM: Top 15 predictors
(weather/veg indices dominate)
Mact
NDVI
T.Min
Mlake
Radn
NDVI_texture
RHmaxT
Mwet
Clre
LAI
EVI
wetness
T.Max
frac_green
Rain
0
10
20
30
40
Appearances in top 5


D) XGBoost: Top 15 predictors
(landscape/structure dominate)
Trees_500
Trees_200
Trees_2000
Trees_50
Crops_total_200
Crops_total_2000
slope
Crops_total_500
Water_500
Mpot
Built_area_500
Water_2000
Built_area_2000
Mwet
FAO56
0
10
20
30
40
Appearances in top 5





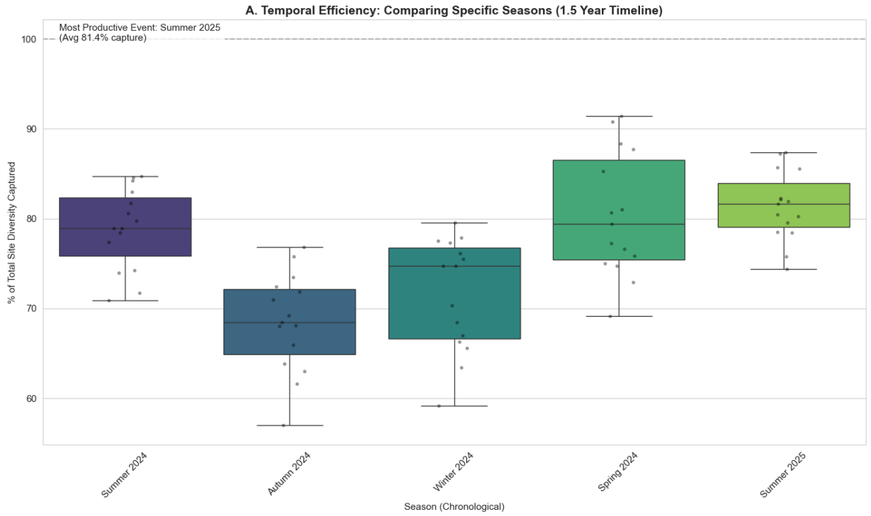
Which landscape variables are influencing bird communities?

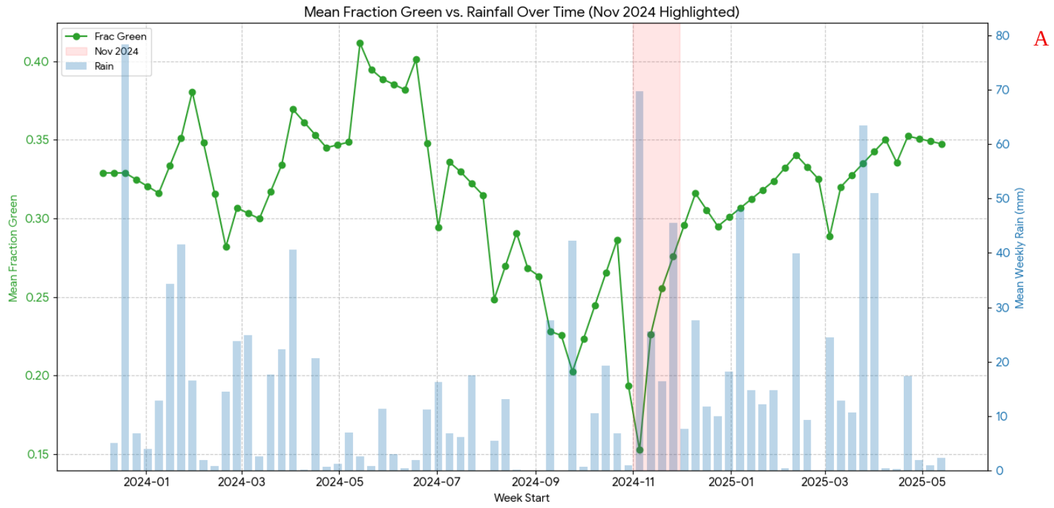
- Landscape composition at four spatial scales: 50m, 200m, 500m, and 2,000m.
- Satellite Indices & Fractional Cover
- Weather
- Deterrent Use
- Structure & Topography
- Management interventions
- Day of year, recording effort, site, season
- Presence of grapes
- Response variables: *Individual species, richness, functional groups, size*

Chapter 3

Temporal Influence

- **Seasonal trends across sites are guided by climate variables**
- Morton's Actual Evapotranspiration (transfer of water) is a strong predictor for bird activity but is consistent across sites [19]
- Seasonality needs to be taken into account in the modelling approach





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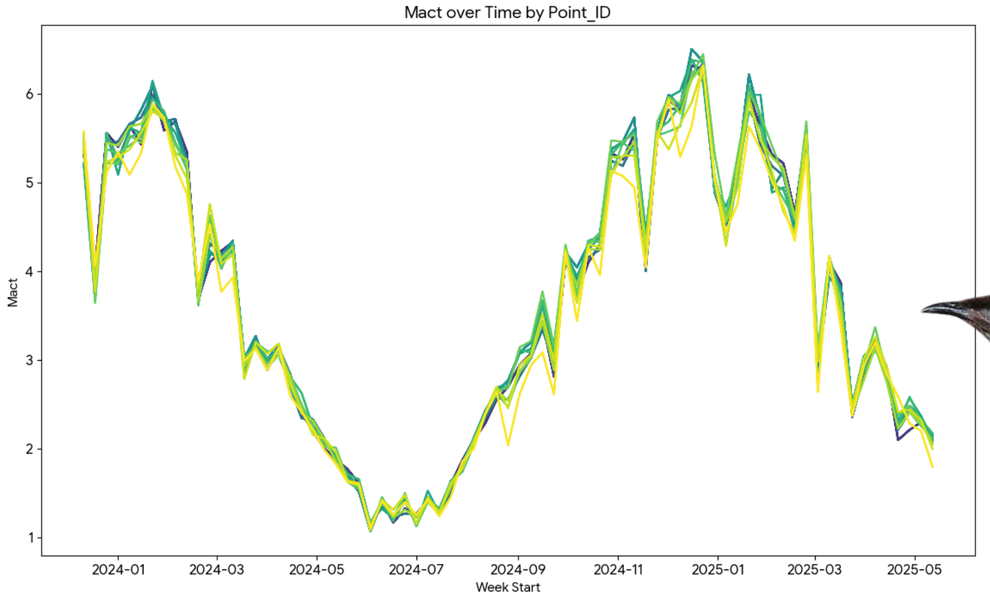

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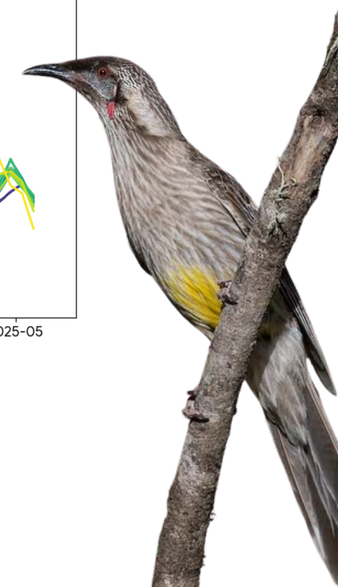
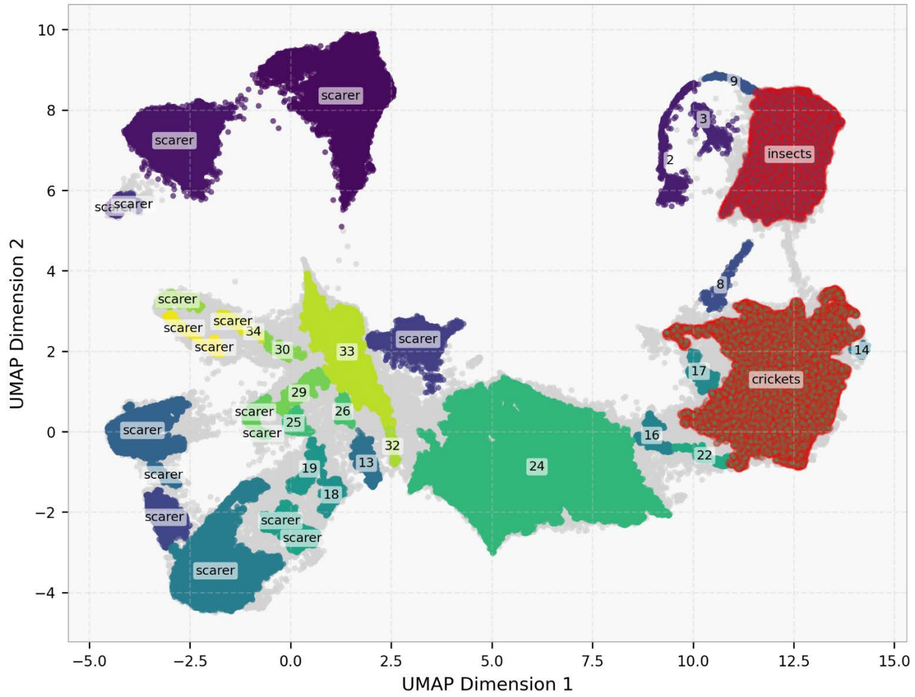
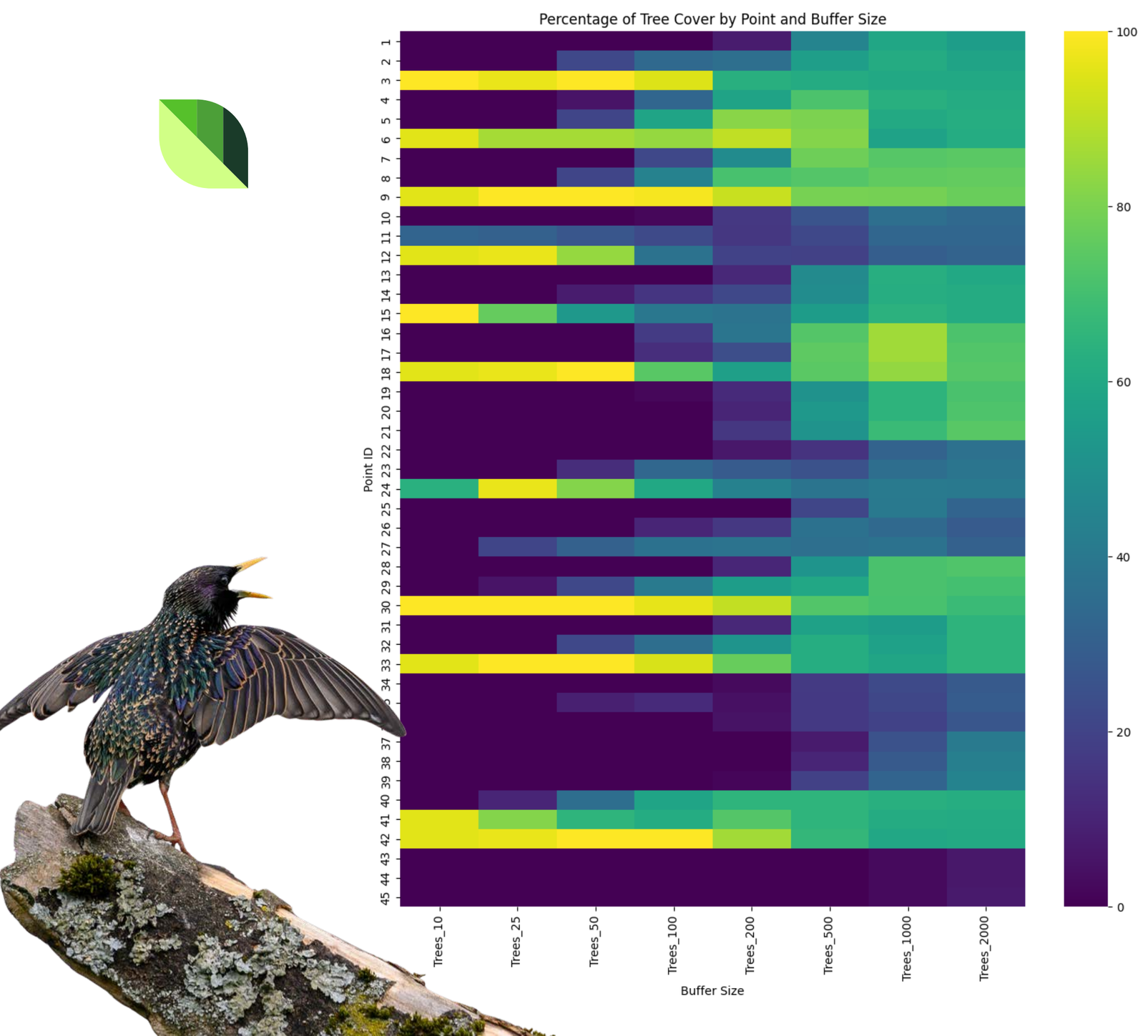


Chapter Conclusions

- Unsupervised learning provides useful utility in the birdsong detection pipeline
- **Reduces reliance on thresholds**
- Can also be used to classify soundscapes and quantify noise deterrent levels





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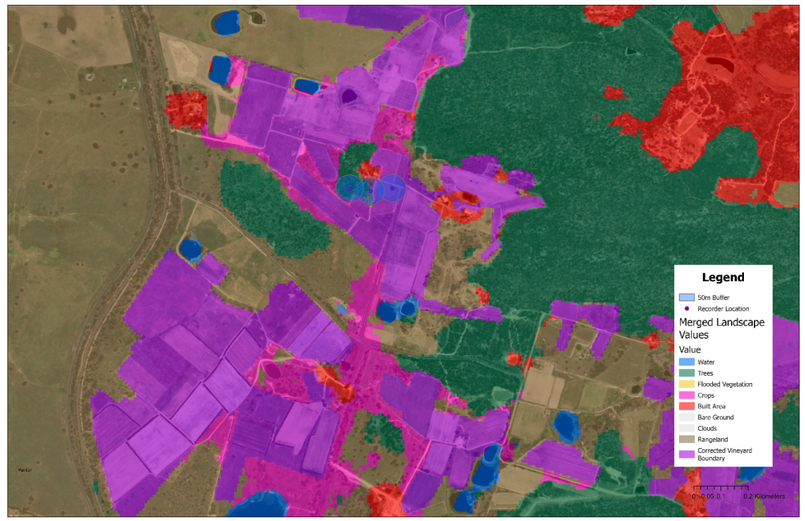
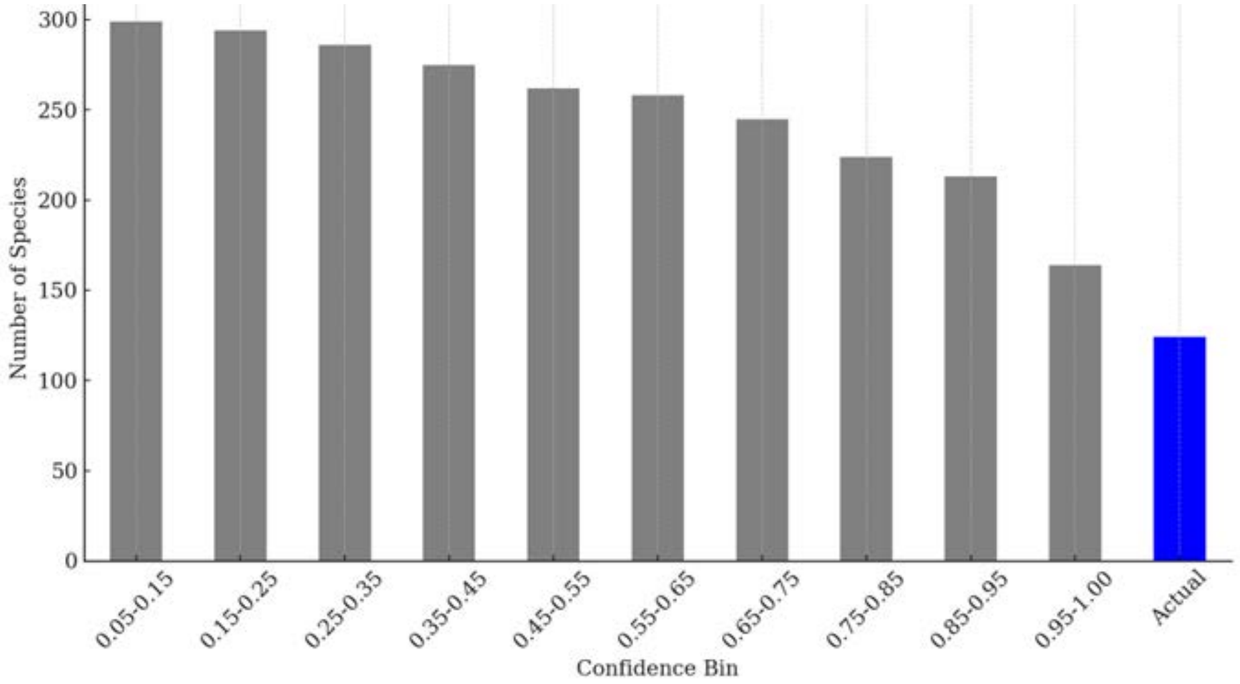


- A human ear in the loop is important if you want reliable data
- Species – specific thresholds outperform fixed thresholds

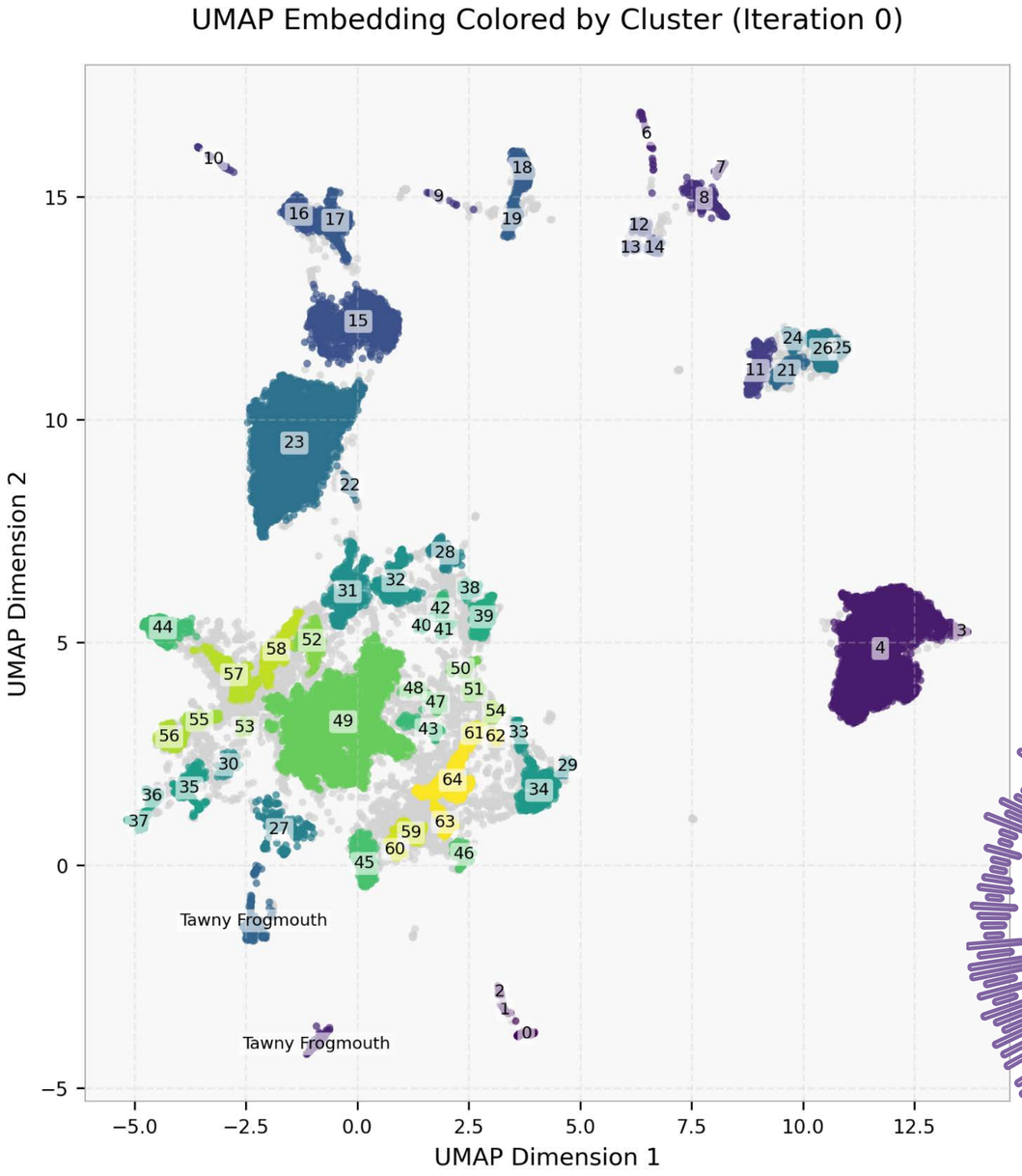


BirdNET Number of Species at each threshold vs validated (species confirmed in the Audio)

Chapter 2
Results

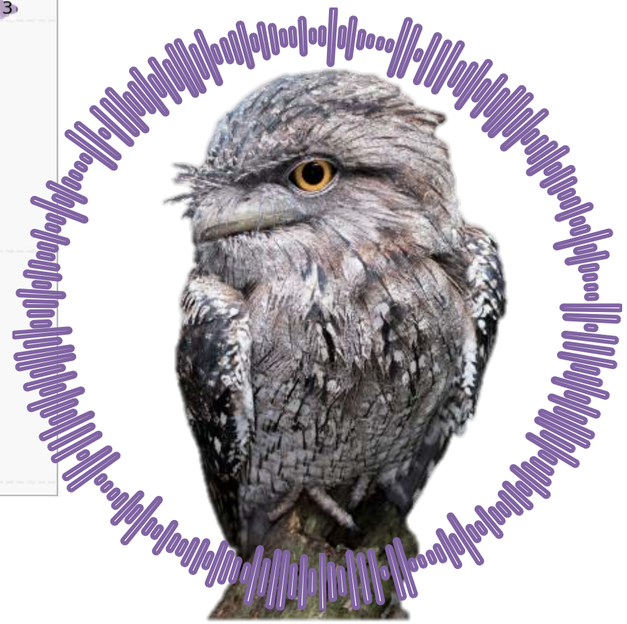
Threshold	*Precision*	*Recall*	*F1 Score*
0	0.185	0.92	0.308
0.1	0.755	0.639	0.692
0.2	0.837	0.497	0.623
0.3	0.892	0.415	0.566
0.4	0.938	0.347	0.506
0.5	0.948	0.294	0.449
0.6	0.962	0.25	0.397
Tuned (Varied/species-	**0.966**	**0.371**	**0.536**
0.7	0.971	0.201	0.333
0.8	0.976	0.165	0.282
0.9	0.981	0.101	0.183

Fixed vs Tuned Thresholds



Tawny Frogmouth

- Thousands of high confidence false positives
- Useful species for rodent control
- No detections in any validation bin using the approach in Ch. 2

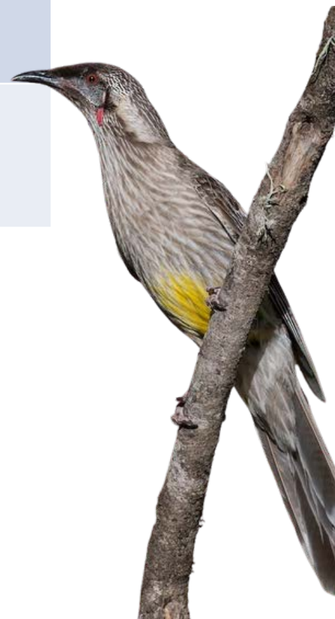


Chapter 3

Testing

- Tested the approach by manually validating every single point
- Outperforms the supervised model at any threshold
- Removes thousands of false-positives
- Locates detections that would otherwise have been missed

Species	Clustering F1	TP located	FP removed	BirdNET F1 (>0.2)	BirdNET F1 (>0.4)	BirdNET F1 (>0.6)	BirdNET F1 (>0.8)
Common Myna (Acridotheres tristis)	**0.973**	3976	4,994	0.563	0.395	0.222	0.079
Powerful Owl (Ninox strenua)	**1.000**	271	7,109	0.117	0.239	0.320	0.264
European Starling (Sturnus vulgaris)	**0.937**	1342	4,368	0.532	0.554	0.442	0.279
Tawny Frogmouth (Podargus strigoides)	**0.995**	594	30,794	0.056	0.105	0.154	0.137

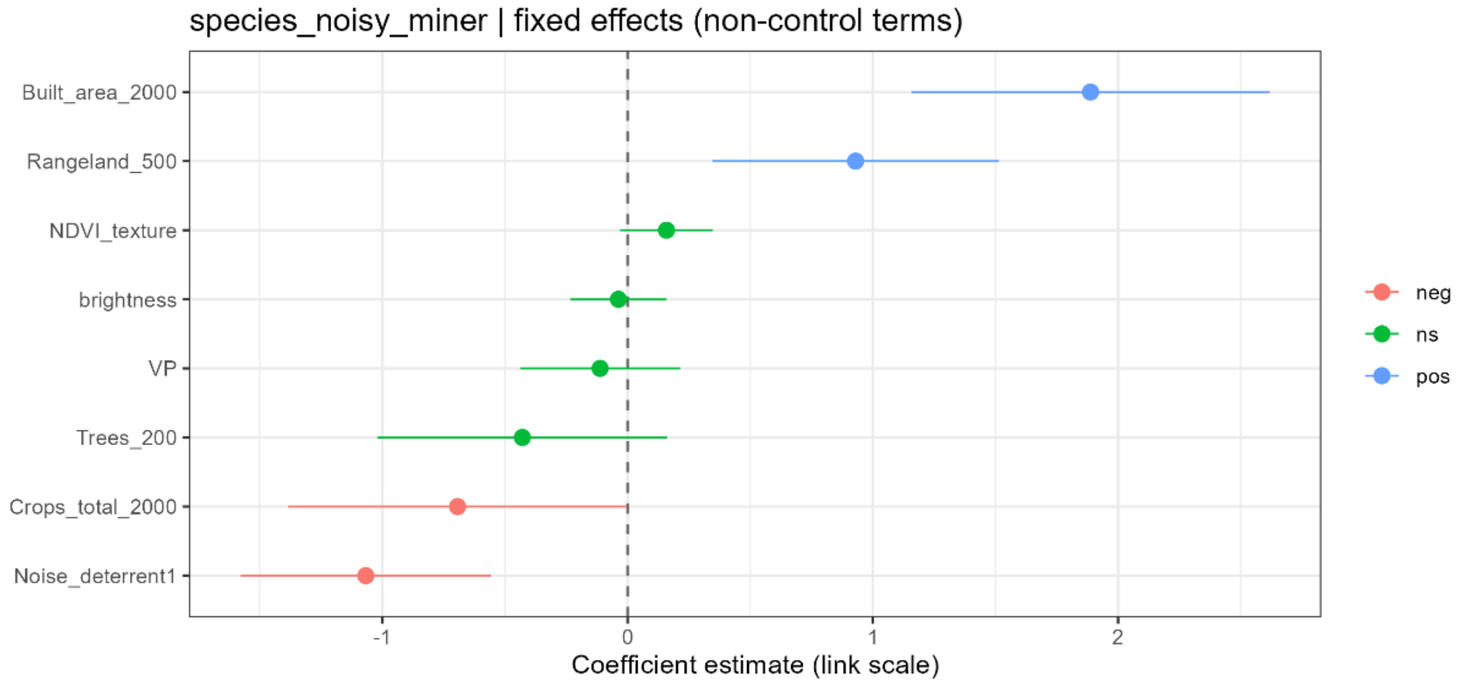


Birds as a biodiversity indicator

Finding appropriate indicators has been a key challenge for biodiversity accounting and results-based biodiversity schemes. [1]

Changes in avian communities reflect changes in broader biodiversity, environmental conditions and habitat. [2]

1 (Burton & Schwarz, 2013)
2 (Bibby, 1999; Doohan et al., 2019; Fraixedas et al., 2020; Gregory et al., 2003; Koleff et al., 2003; Koskimies, 1989).


species_noisy_miner | fixed effects (non-control terms)
Built_area_2000
Rangeland_500
NDVI_texture
brightness
VP
Trees_200
Crops_total_2000
Noise_deterrent1
-1
0
1
2
Coefficient estimate (link scale)
neg
ns
pos