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THE CHANGING FOREST FOR  
THE BIRDS: USING REMOTE  
SENSING TIME SERIES TO  
EXAMINE BIRD HABITAT,  
OCCURRENCE AND NICHE

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# ACKNOWLEDGEMENTS

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# OVERARCHING GOALS

**Ecological emphasis**

to enhance our understanding of habitat, occurrence and niche of four woodland bird species

**Remote sensing emphasis**

to enhance the contribution of remote sensing time series in bird habitat, occurrence and niche analyses

# STUDY SPECIES

Eurasian Blue Tit  
(*Cyanistes caeruleus*)



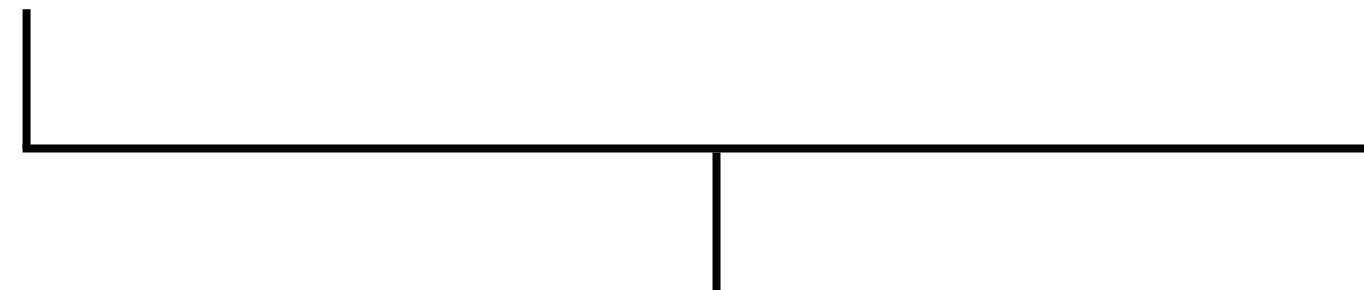
Common Chaffinch  
(*Fringilla coelebs*)



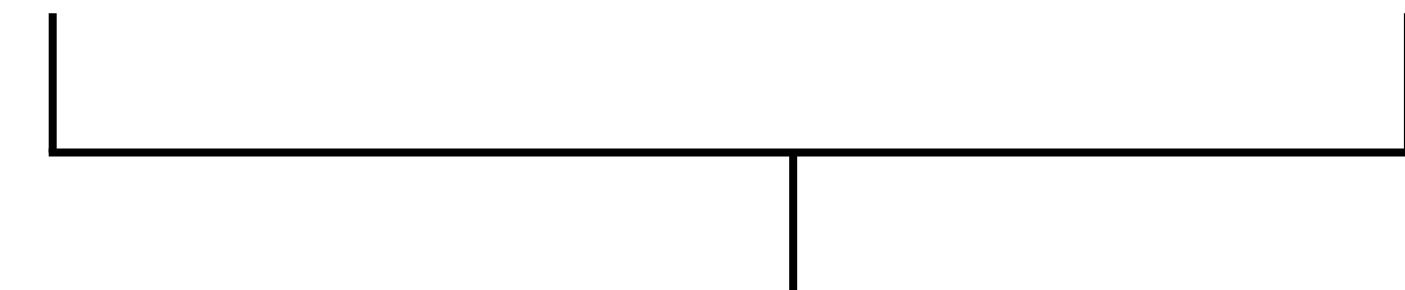
Common Chiffchaff  
(*Phylloscopus collybita*)



Willow Warbler  
(*Phylloscopus trochilus*)

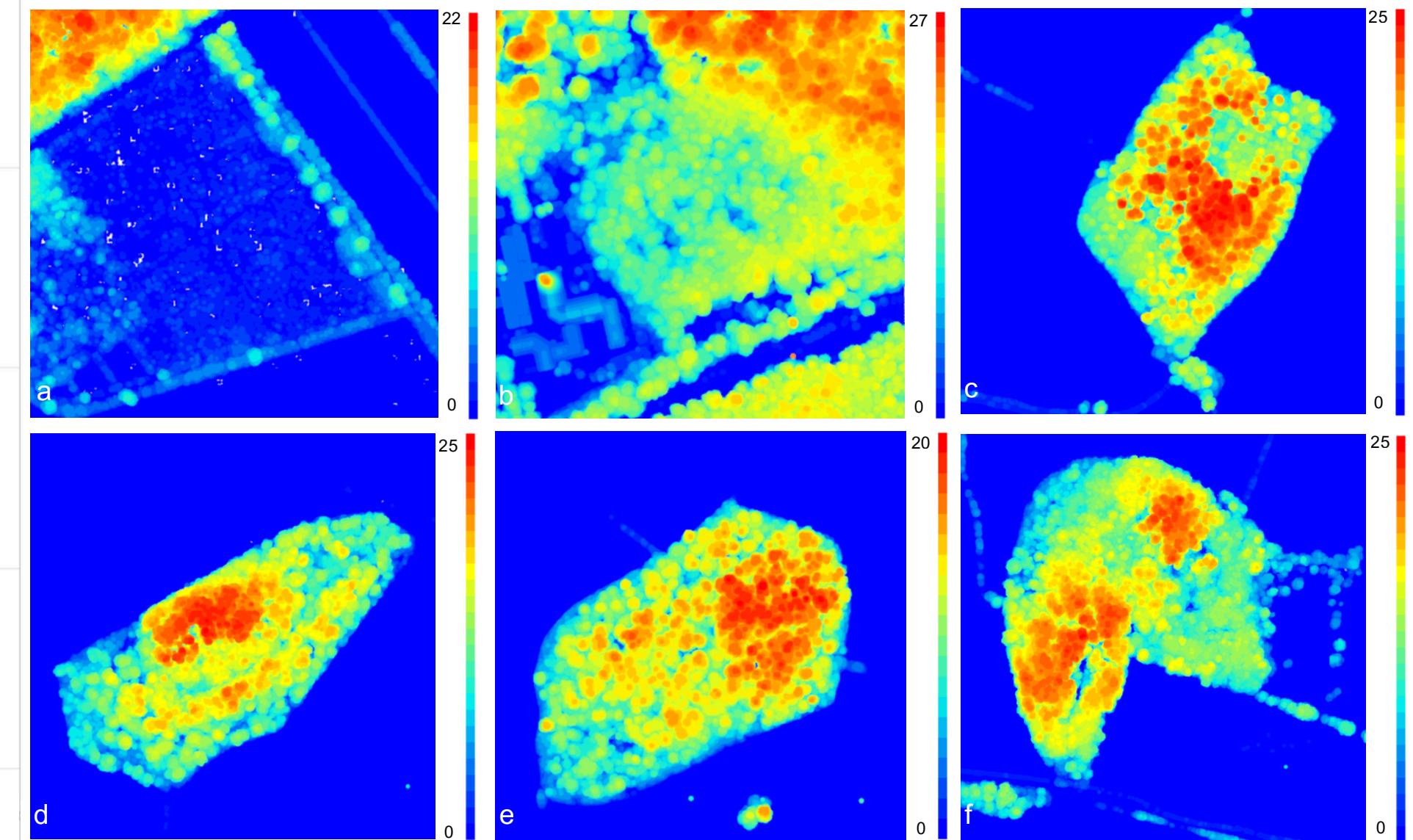


habitat generalists



habitat specialists

# STUDY SITES



**Passive rewilling plots:** a) New Wilderness (2.1 ha, abandoned in 1996), b) Old Wilderness (3.9 ha, abandoned in 1961)

**Ancient remnant woodlands:** c) Riddy (9.4 ha), d) Gamsey (4.9 ha), e) Lady's (8.4 ha), f) Raveley (7.2 ha)

# DATA

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Bird data	Airborne laser scanning (ALS) data	Landsat data	Study sites
2000-2002	2000-06-10	2000-06-18	Old Wilderness and New Wilderness only
2005-2007	2005-06-26	2005-06-09	all sites
2012-2014	2012-09-15	2013-07-17	all sites
2015-2017	2015-06-22	2015-08-08	Old Wilderness and New Wilderness only

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# PREPROCESSING

**Bird data:** remove juveniles, movement and overlapping observations within the same year

**ALS data:** quality control, terrain normalization (cloth simulation function, kriging, noise filtering)

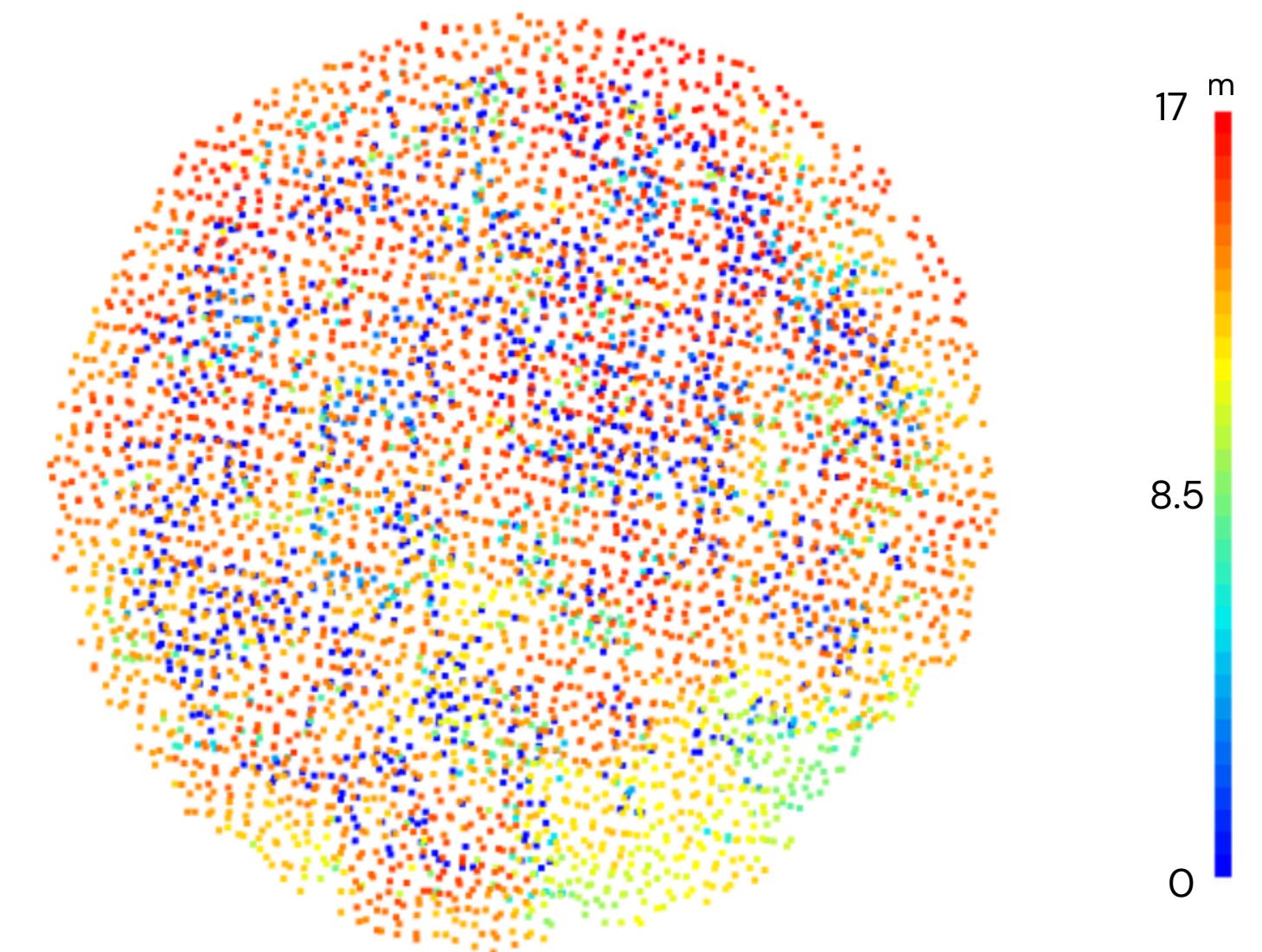
**Landsat data:** digital number to radiance to top-of-atmosphere reflectance, per band relative calibration

# M E T R I C   E X T R A C T I O N

All metrics extracted using a circular sampling plot with a 15-metre radius.

Why?

- potential errors due to registration or digitization inaccuracies
- approximates known travel distances
- consistent with previous studies



Sample ALS plot for one Blue Tit observation

# CHAPTER 2 → MANUSCRIPT 1

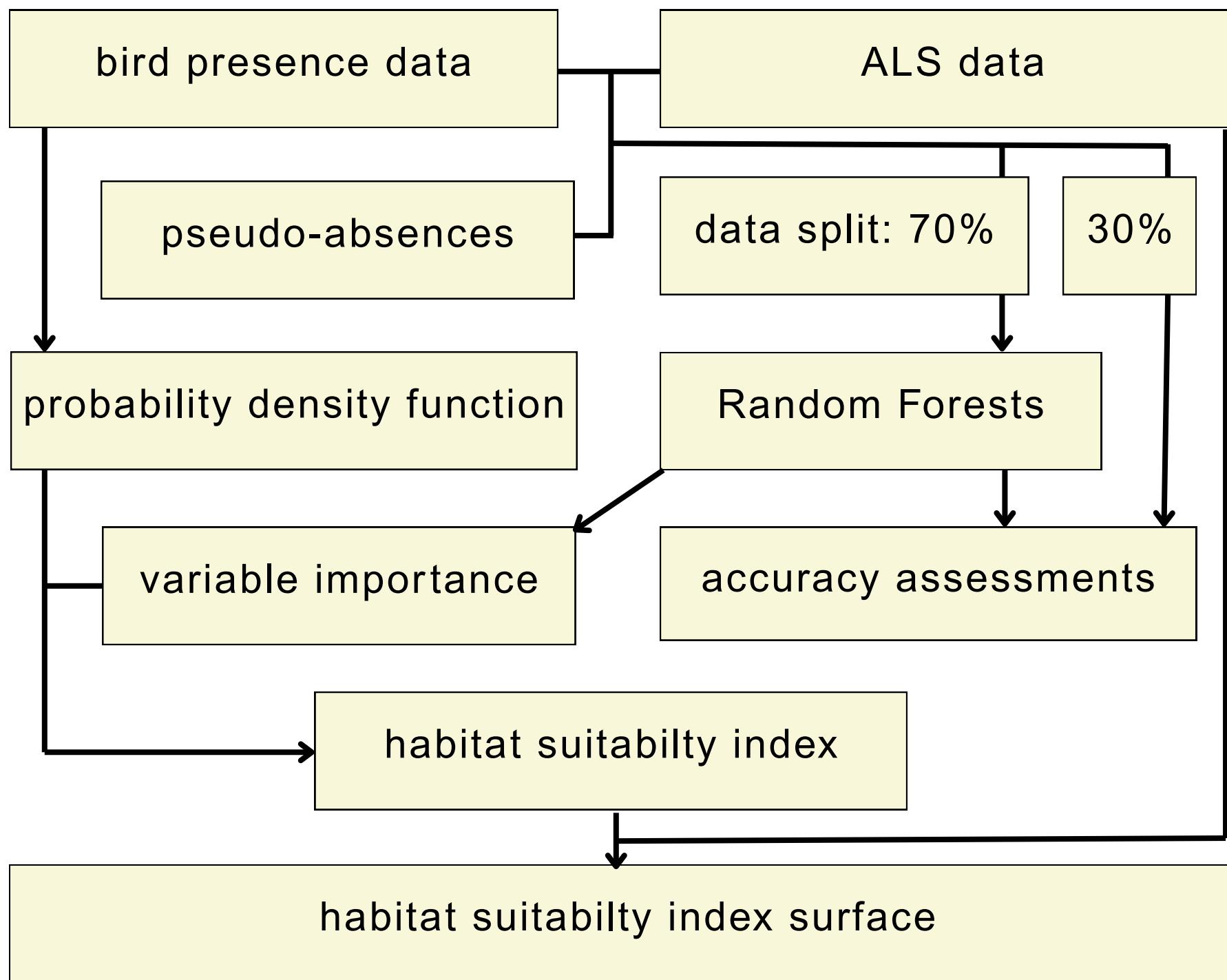
**Title:** Using airborne laser scanning time series data to model spatio-temporal patterns in bird habitat  
across multiple woodlands (in review at Ecological Informatics)

**Objective:** examine differences in habitat suitability across space, time and species



Gámsey Wood

# METHODS & METRICS



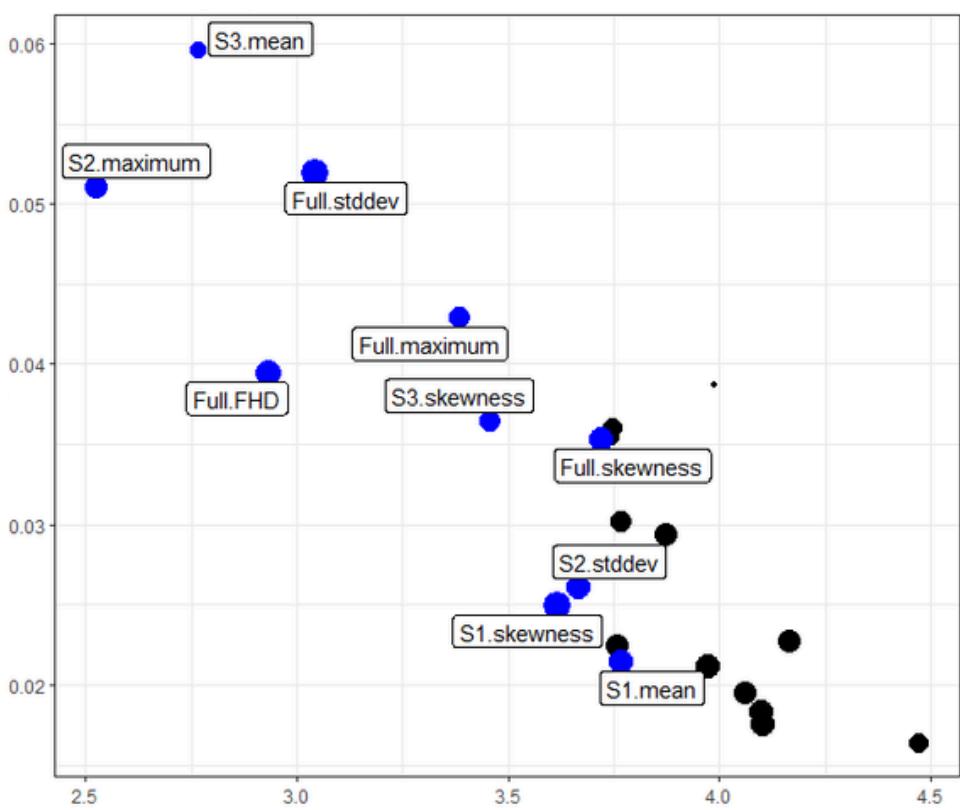
ALS variable	Strata
foliage height diversity	full
canopy closure	
maximum	
mean	full,
standard deviation	shrub (<2m),
skewness	understorey (2-8 m),
kurtosis	overstorey (>8m)

# RESULTS

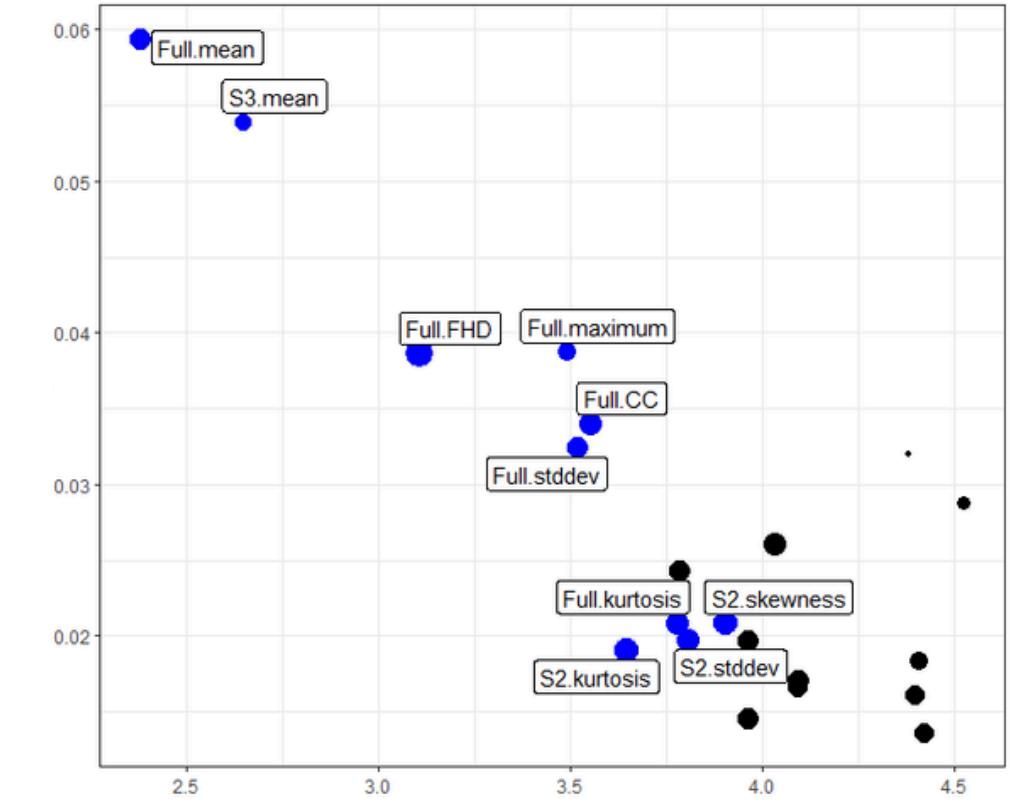
What variables are important?

- shrub for Chiffchaff and Willow Warbler
- full vertical profile for Chaffinch
- all strata for Blue Tit
- foliage height diversity among the top ten for three species

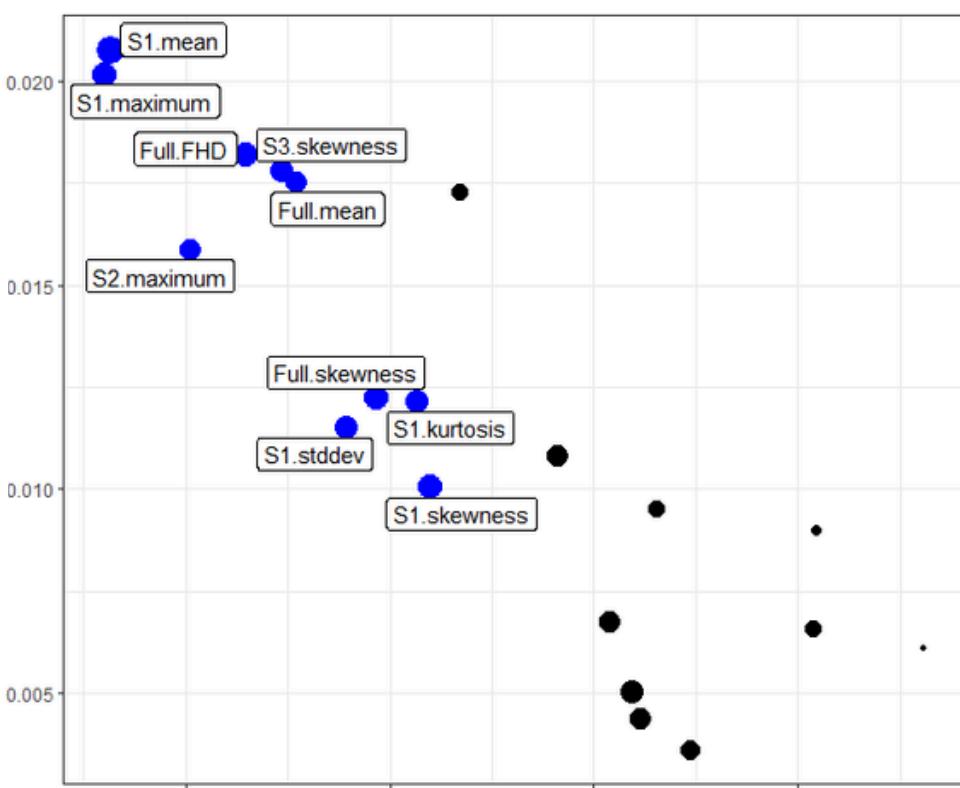
Blue Tit



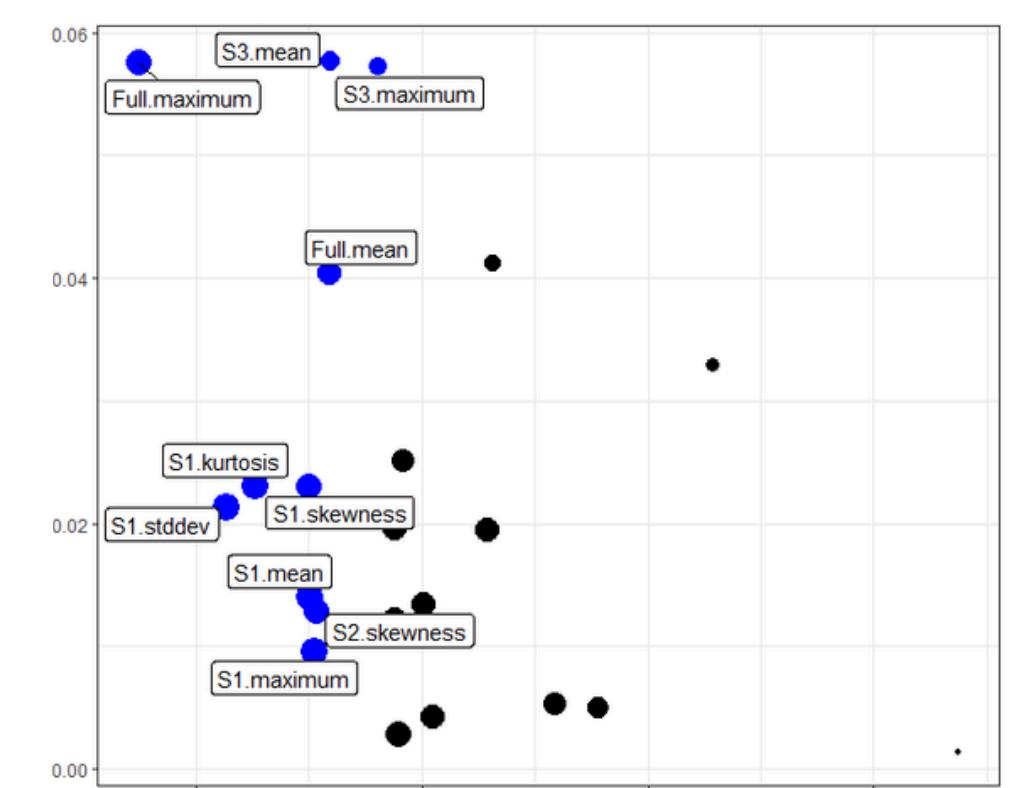
Chaffinch



Chiffchaff



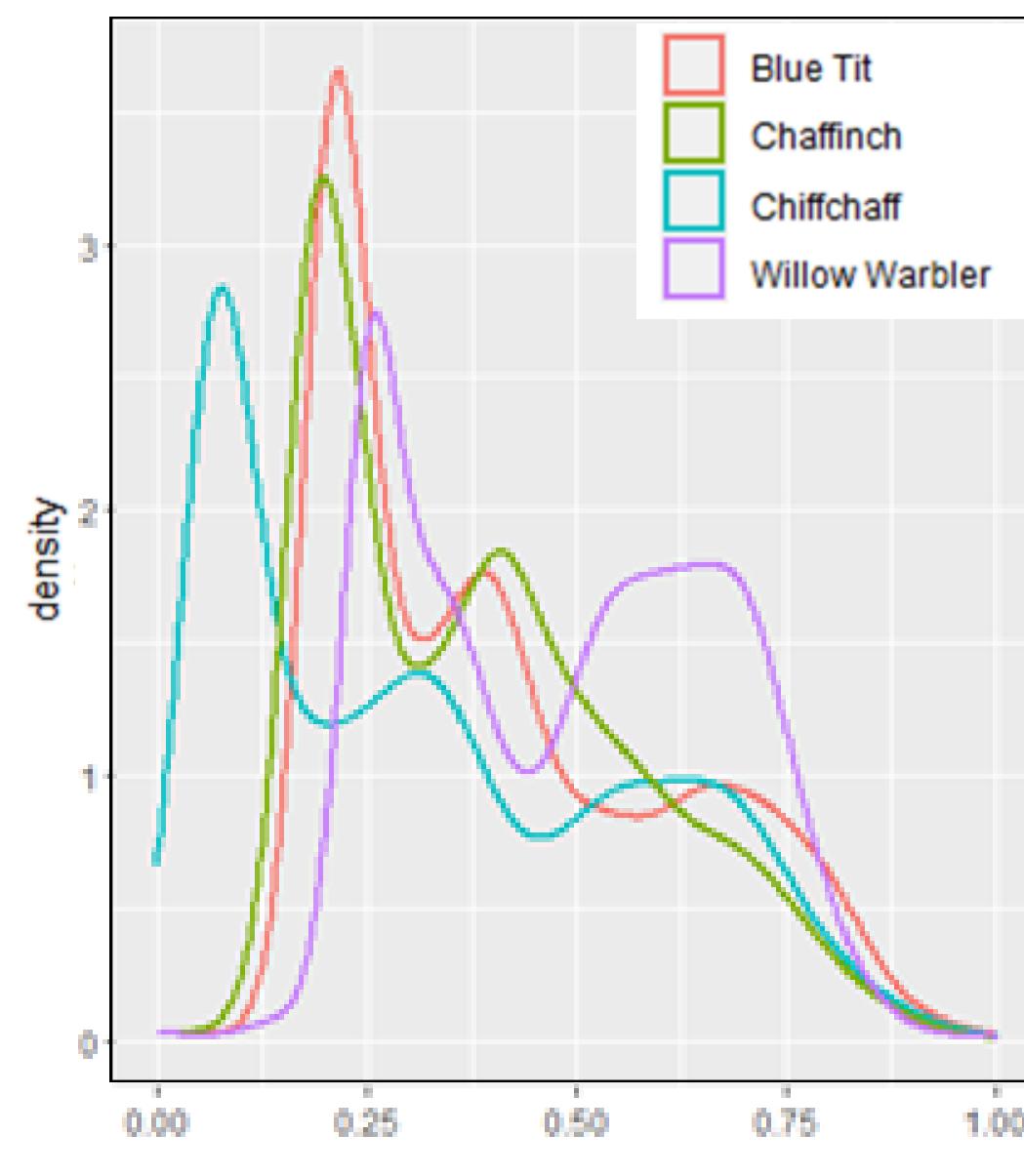
Willow Warbler



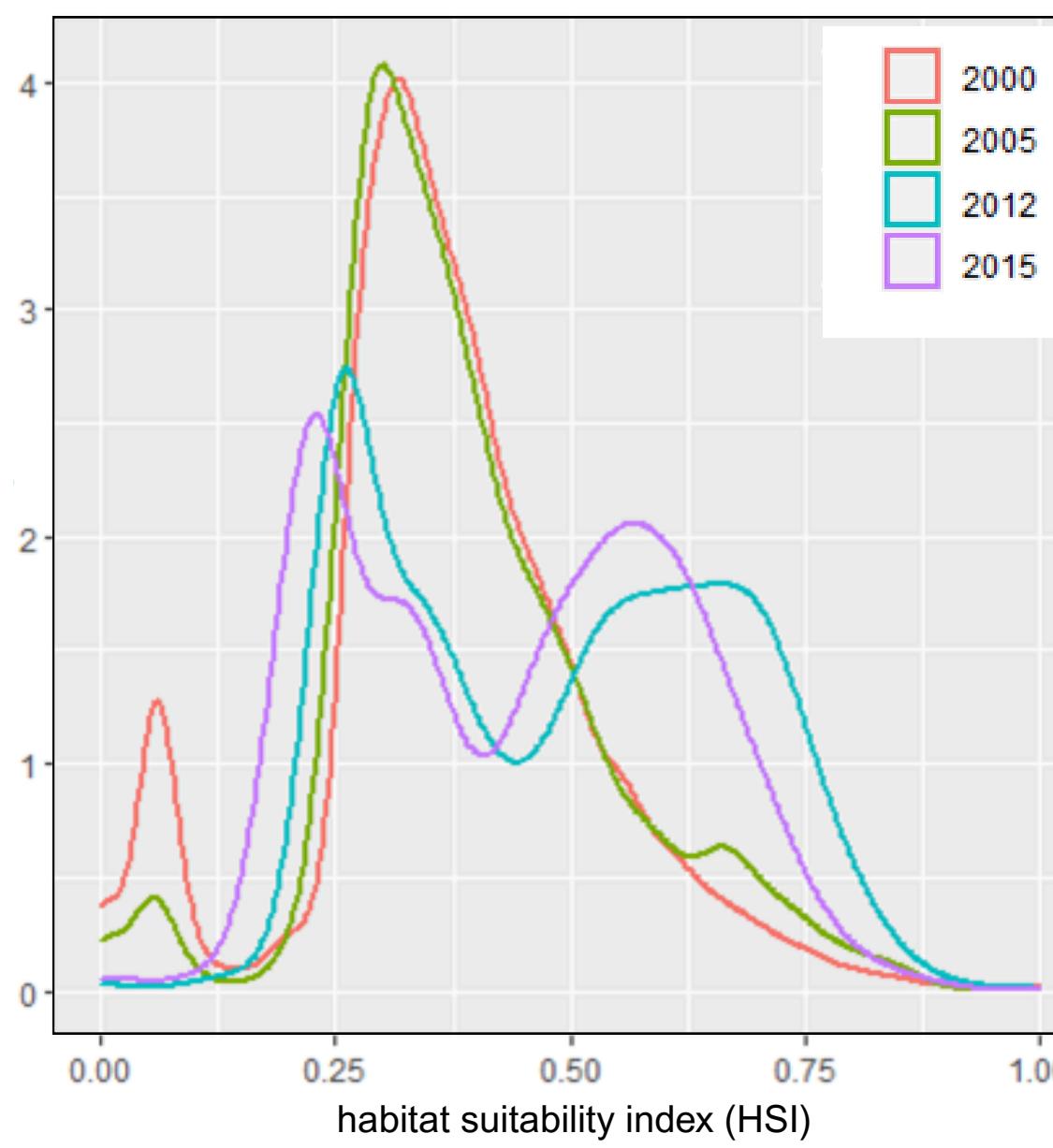
# RESULTS

Does habitat suitability vary by species, time and site?

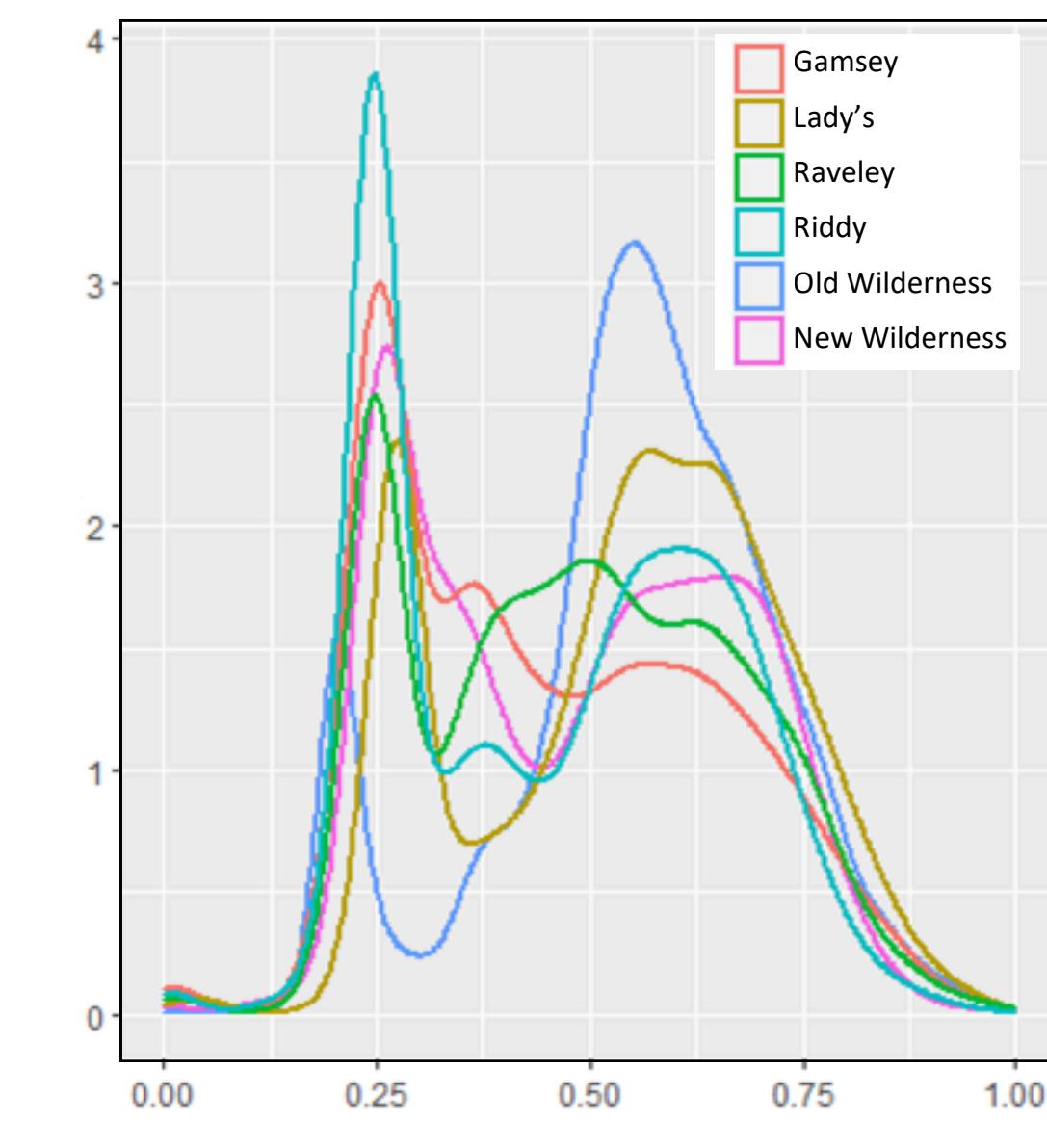
variation in HSI values by species  
at New Wilderness in 2012



variation in HSI values by year  
for Willow Warbler at New Wilderness

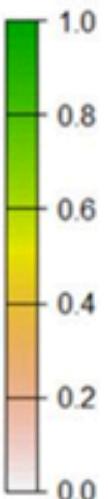
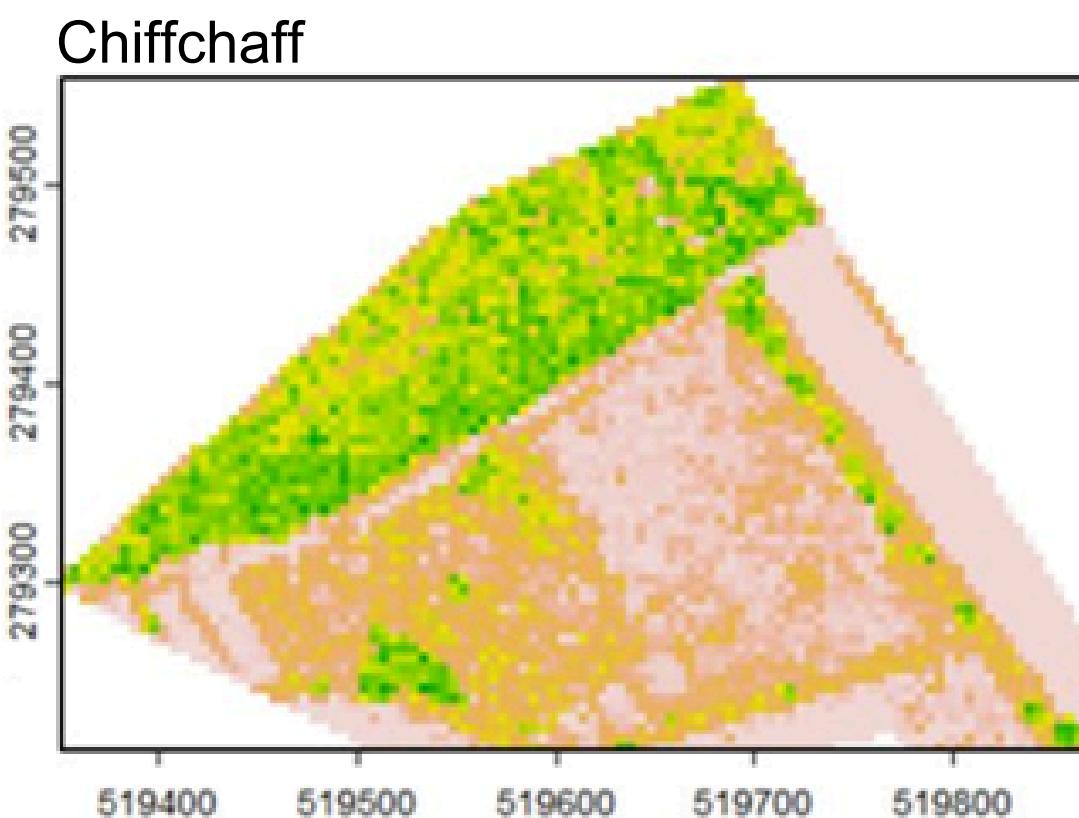
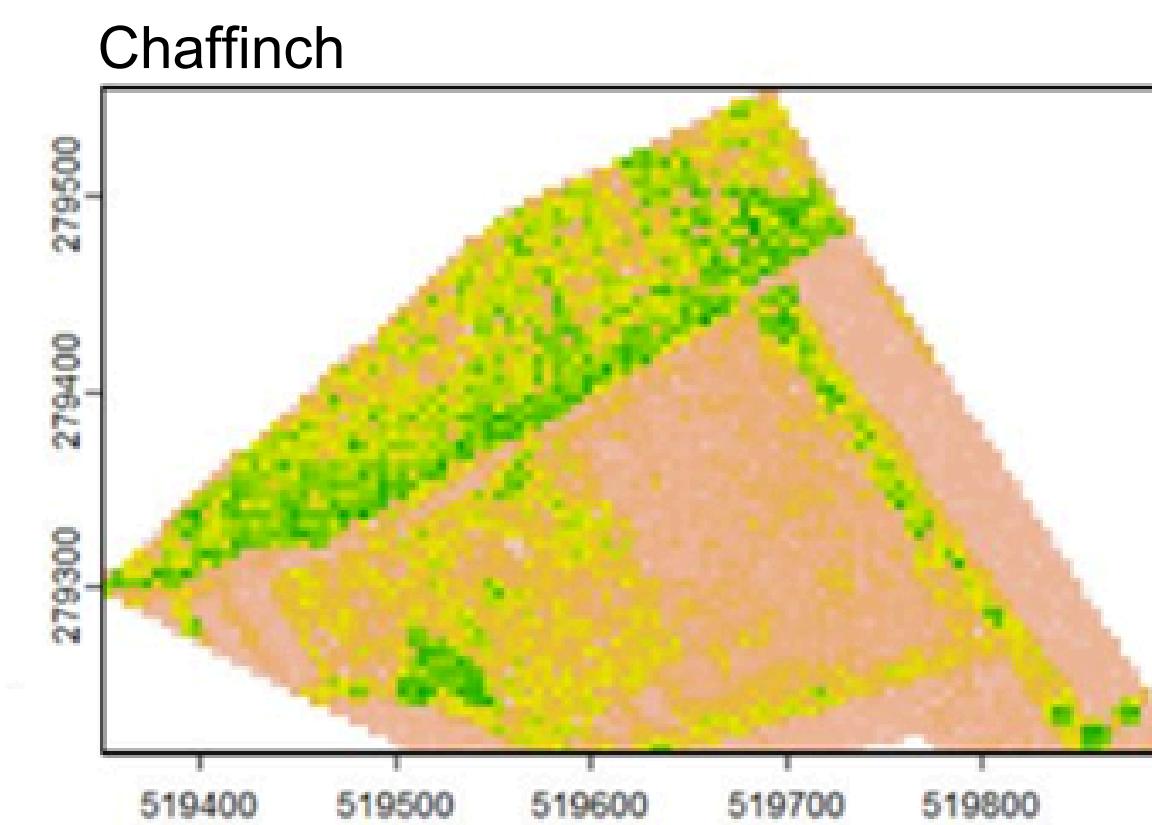
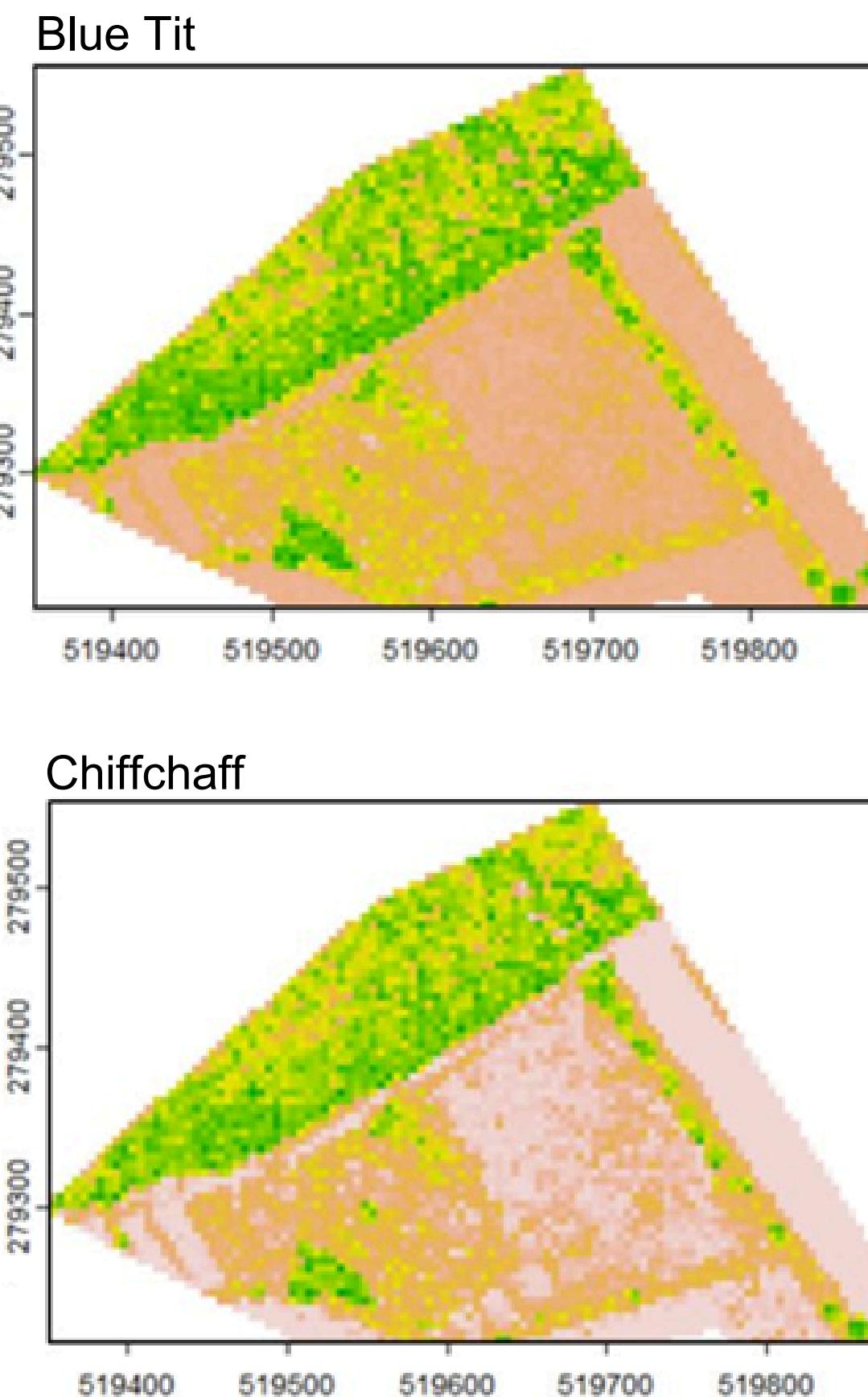


variation in HSI values by site  
for Willow Warbler in 2012



# RESULTS

Example of differences across species at New Wilderness in 2012.



# S U M M A R Y

- from highest to lowest accuracy: Willow Warbler, Blue Tit, Chaffinch, Chiffchaff •
- all ALS variables contributed to models, none were among the top 10 for all four species •
- variation in HSI values was greatest for specialist species and at New Wilderness •

## **Significance:**

- time series of ALS data provide an ecologically realistic characterization of habitat across space and time •

# CHAPTER 3 → MANUSCRIPT 2

**Title:** Predicting woodland bird species habitat with multi-temporal and multisensor remote sensing data

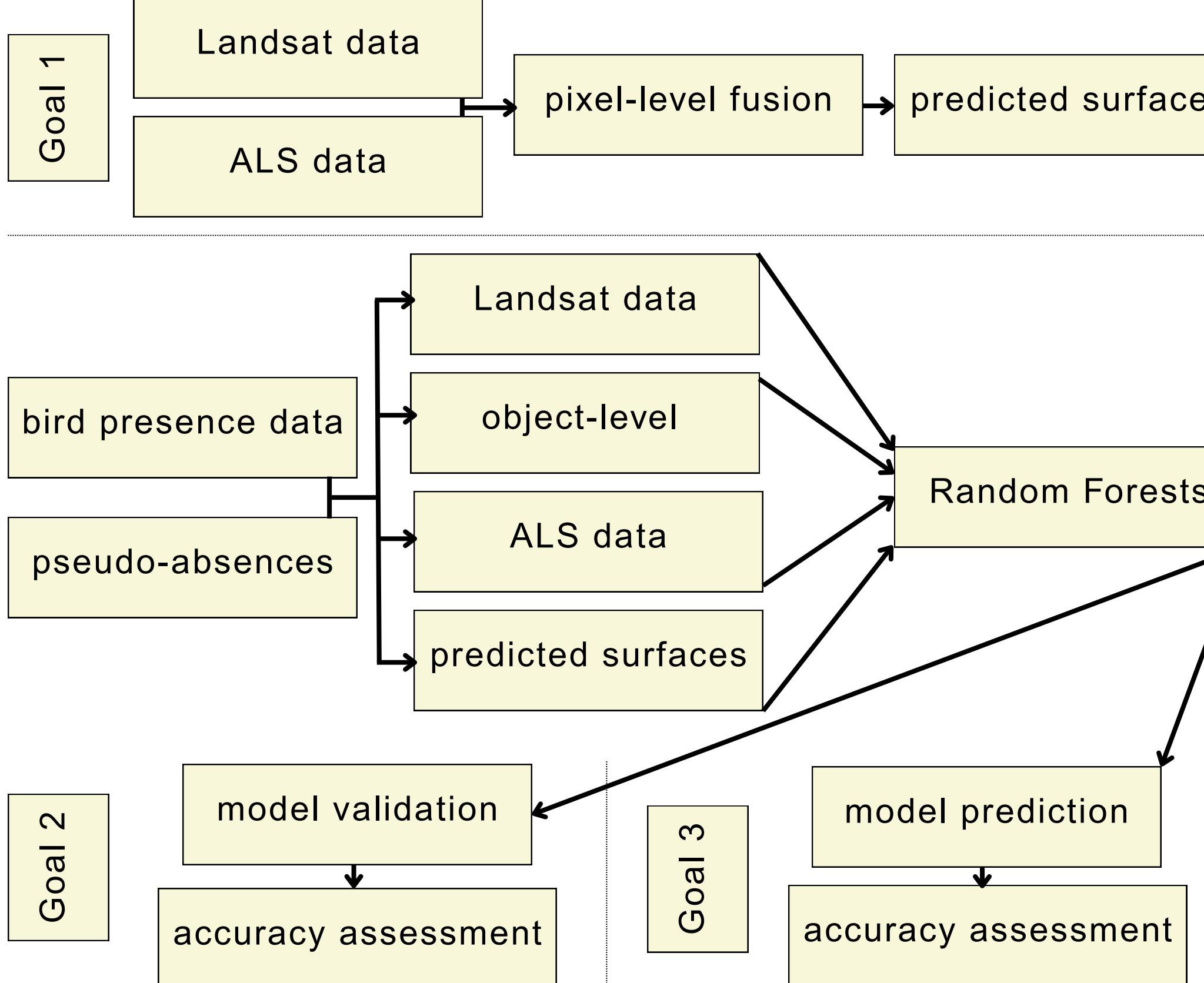
(in review at PloS One)

**Objective:** systematically assess multiple fusion methods for habitat modelling and prediction



Old Wilderness

# METHODS & METRICS



ALS variables	Landsat variables
foliage height diversity	blue
canopy closure	green
canopy relief ratio	red
maximum	near infrared
mean	shortwave infrared 1
standard deviation	shortwave infrared 2
entropy	normalized difference vegetation index
	normalized burn ratio
	tasseled cap transformation
	greenness, wetness, and brightness

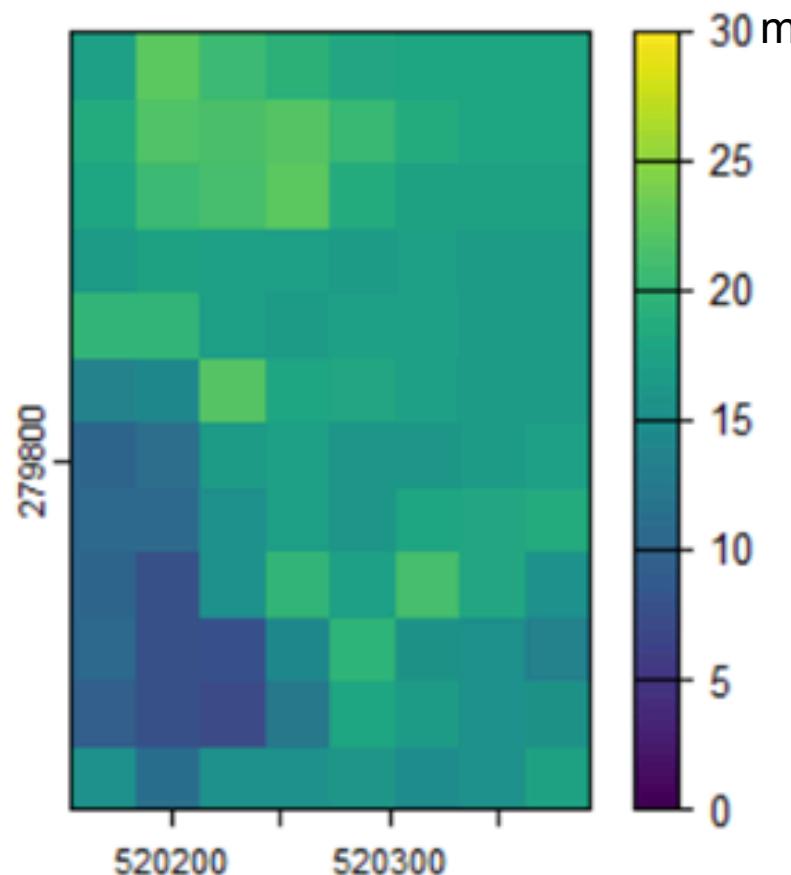
# RESULTS

Can spectral data be used to predict structural attributes?

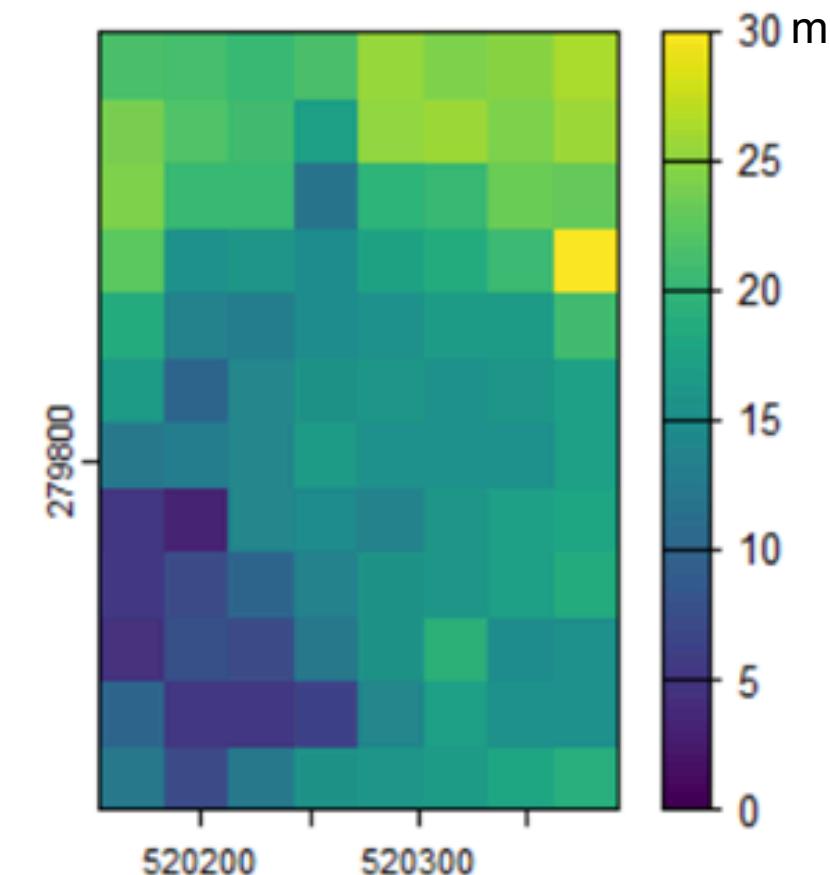
Yes, but...

- some better than others
- error greatest for high and low values
- green, red, SWIR 1 and NBR are important

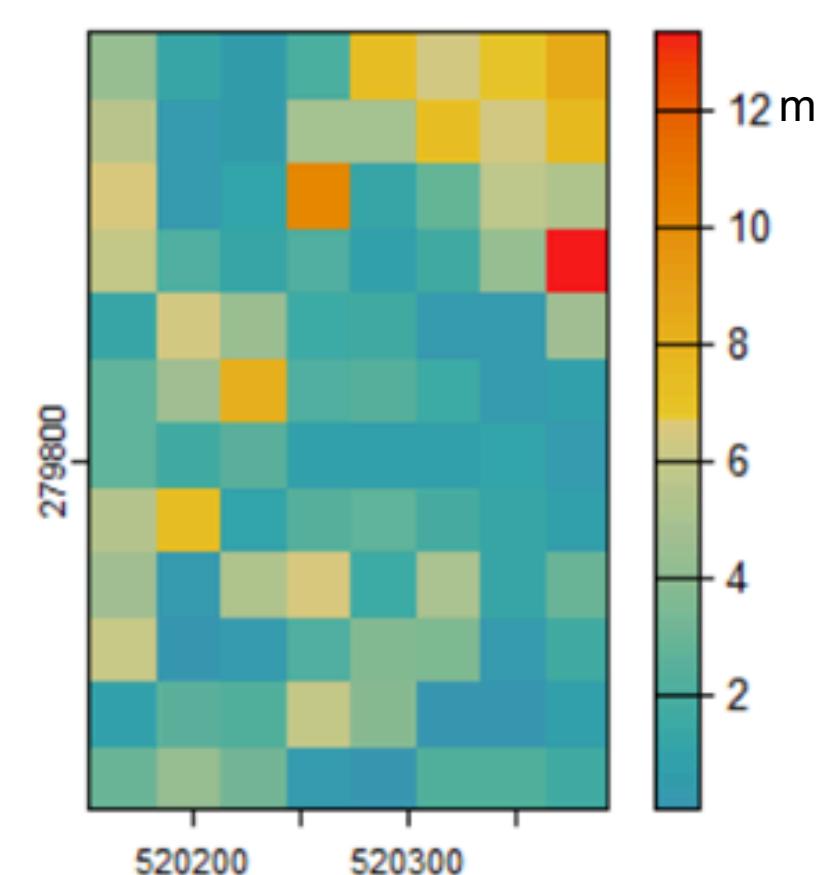
predicted max height



actual max height



difference

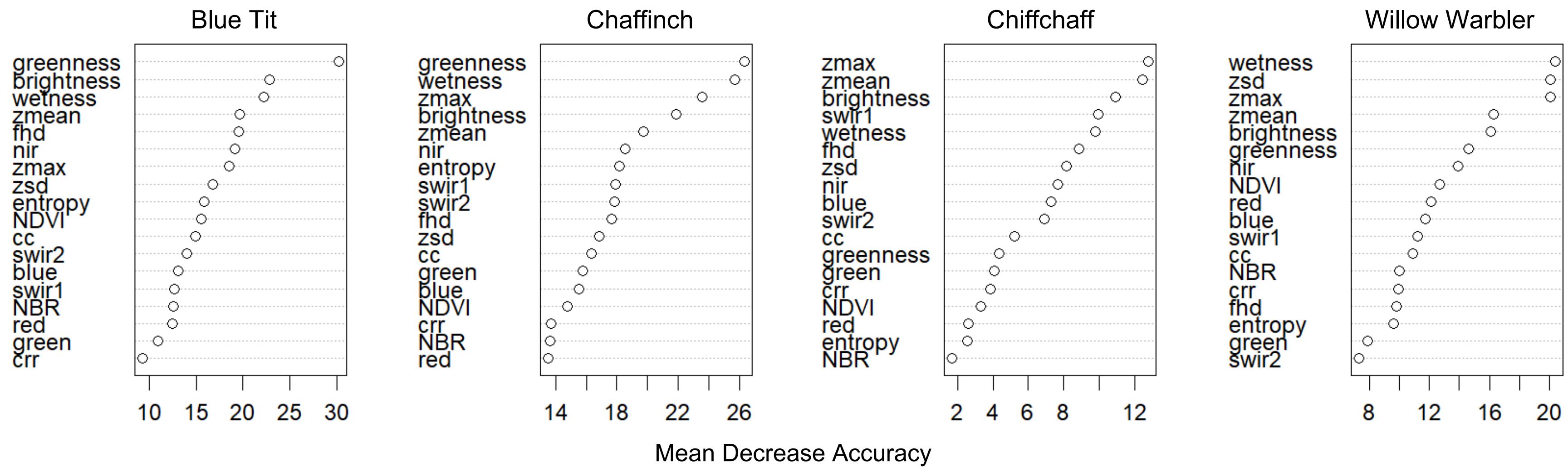


# RESULTS

Out-of-bag model error | error on validation dataset

	<b>ALS only</b>	<b>Landsat only</b>	<b>object-level fusion</b>	<b>predicted surface</b>
<b>Blue Tit</b>	0.22   0.23	0.13   0.22	0.15   0.09	0.24   0.33
<b>Chaffinch</b>	0.19   0.19	0.13   0.17	0.14   0.14	0.21   0.28
<b>Chiffchaff</b>	0.29   0.31	0.26   0.28	0.20   0.25	0.32   0.47
<b>Willow Warbler</b>	0.10   0.10	0.08   0.13	0.07   0.06	0.18   0.24

# RESULTS

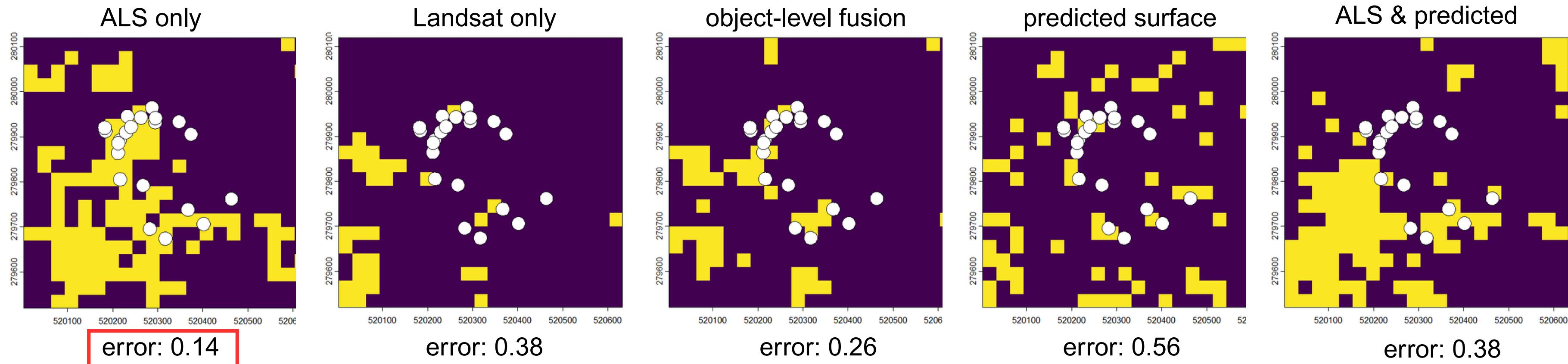


Which variables are important from the object-level fusion models?

- maximum and mean height (ALS)
- mixed results for foliage height diversity (ALS)
- tasseled cap transformation variables (Landsat)

# RESULTS

How well do these models predict presence?



Example of Chiffchaff, shown here at the Old Wilderness.

## S U M M A R Y

- spectral data can predict structural attributes, but errors matter when used to model or predict occurrence •
- ecologically informed variable selection expectations were not always supported •
- object-level fusion produced models with the lowest validation error, but not for prediction •

### **Significance:**

- methods integrating ecological knowledge and data-driven exploration may produce accurate models •

# CHAPTER 4 → MANUSCRIPT 3

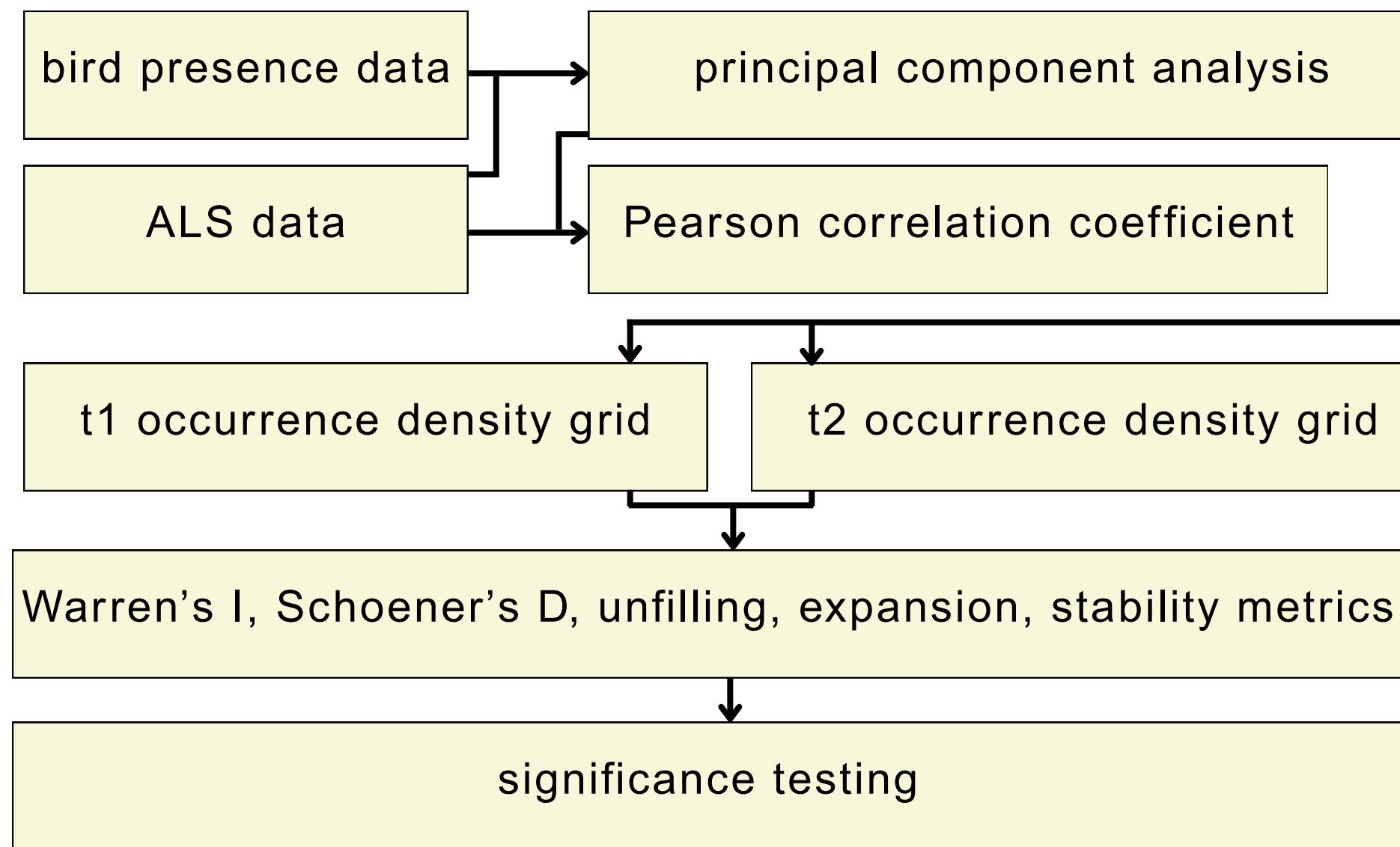
**Title:** Assessing woodland bird niche dynamics across successional time with airborne laser scanning  
(in review at Ibis)

**Objective:** examine niche dynamics (or lack thereof) through successional time



New Wilderness

# METHODS & METRICS



ALS variables	vegetation component
maximum	vertical distribution of vegetation heights
mean	
standard deviation	heterogeneity of vertical distribution of vegetation
foliage height diversity	
canopy relief ratio	relative position of canopy elements
canopy closure	heterogeneity of horizontal distribution of vegetation

# RESULTS

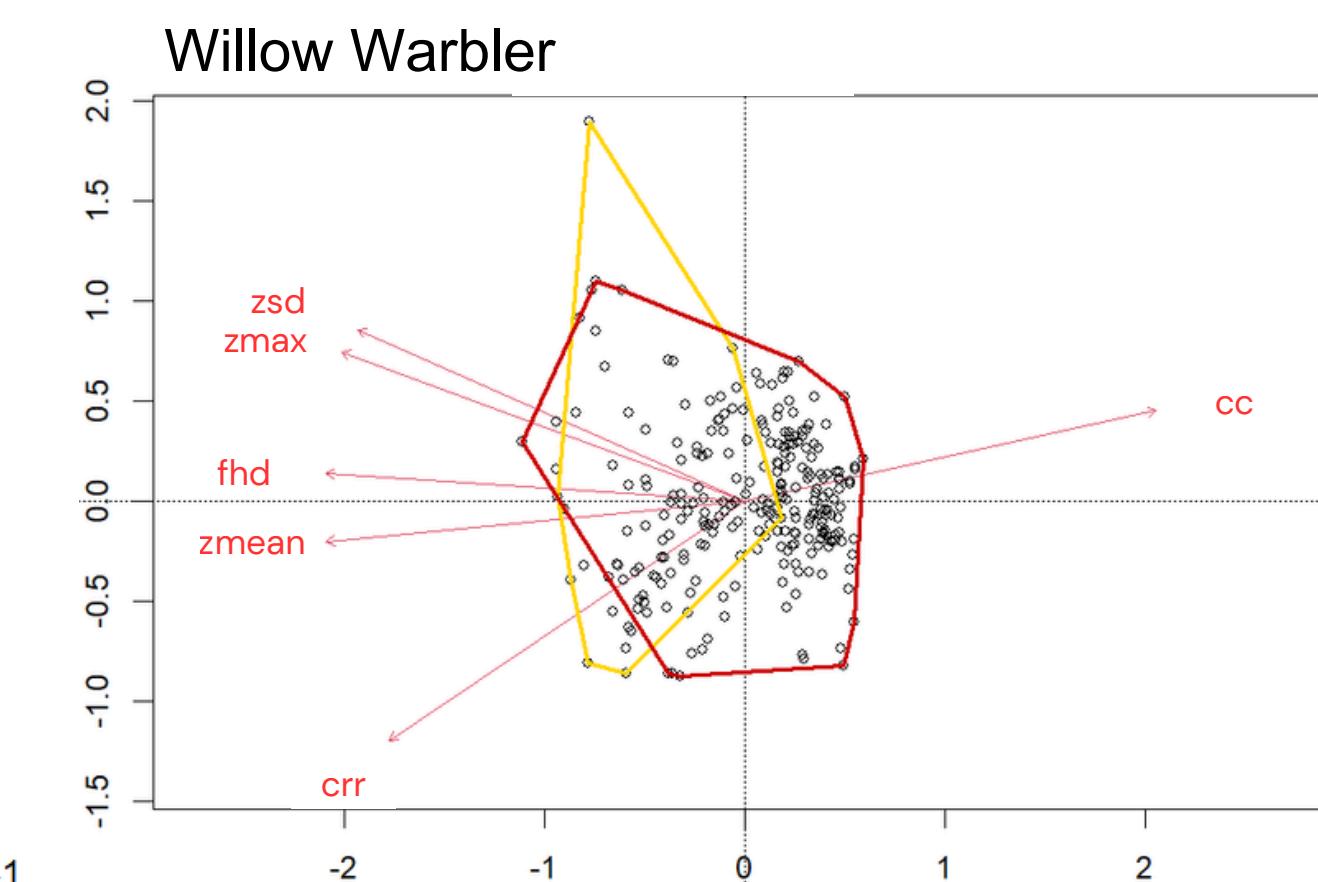
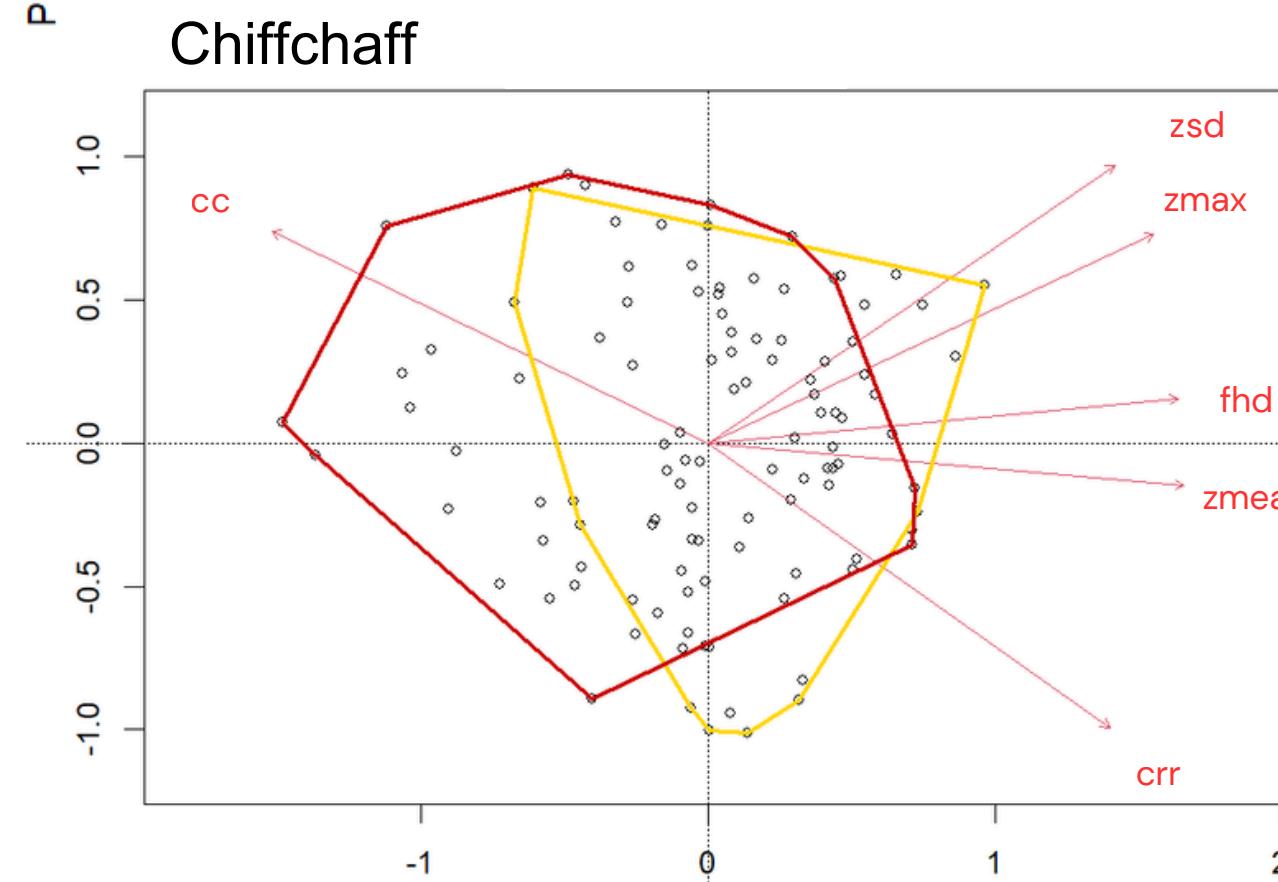
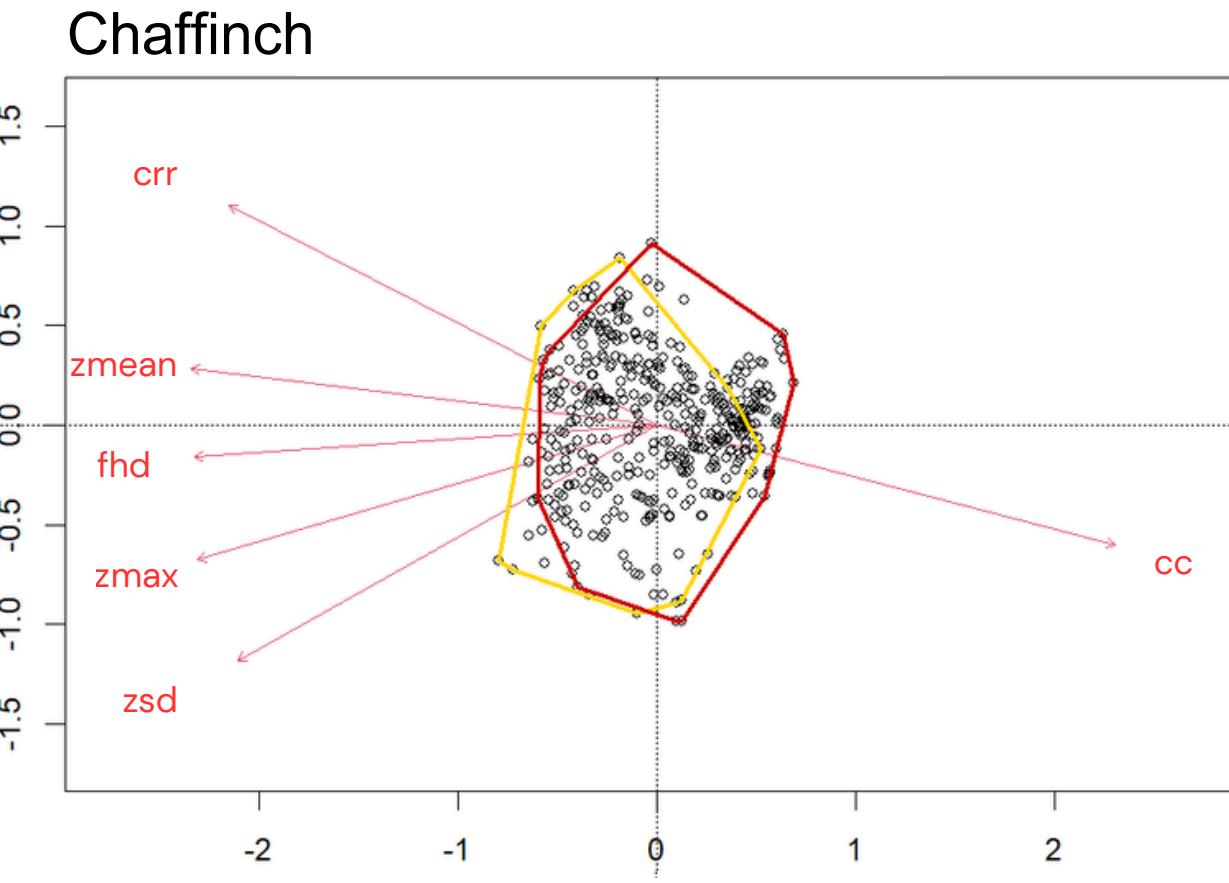
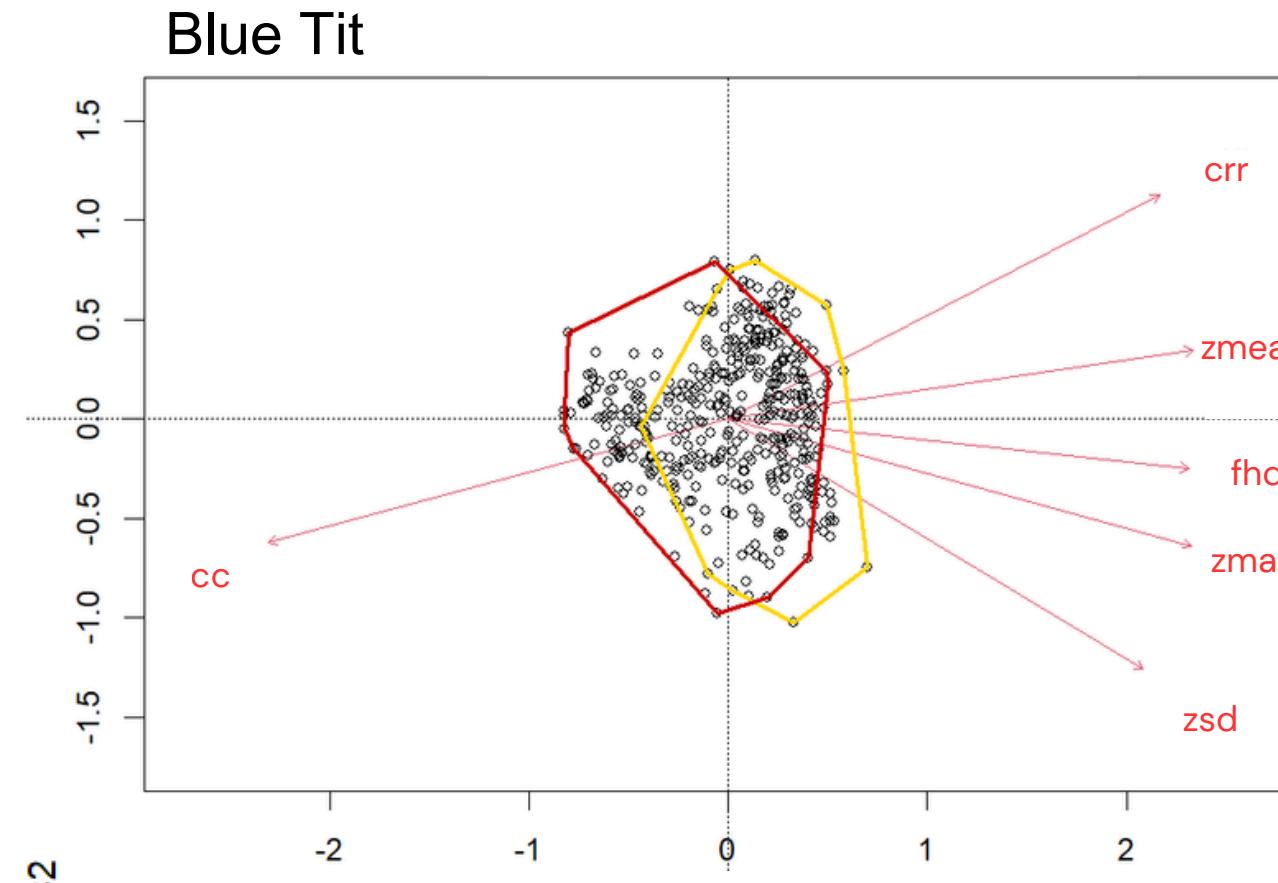
Cumulative proportion of variance explained

	PC1	PC2	PC3	PC4	PC5	PC6
<b>Blue Tit</b>	0.836	0.940	0.983	0.994	0.999	1.000
<b>Chaffinch</b>	0.847	0.946	0.982	0.994	0.999	1.000
<b>Chiffchaff</b>	0.769	0.935	0.980	0.993	0.999	1.000
<b>Willow Warbler</b>	0.846	0.952	0.980	0.993	0.998	1.000

PC1 represents a trade-off between canopy height (mean) and heterogeneity (foliage height diversity), with canopy closure

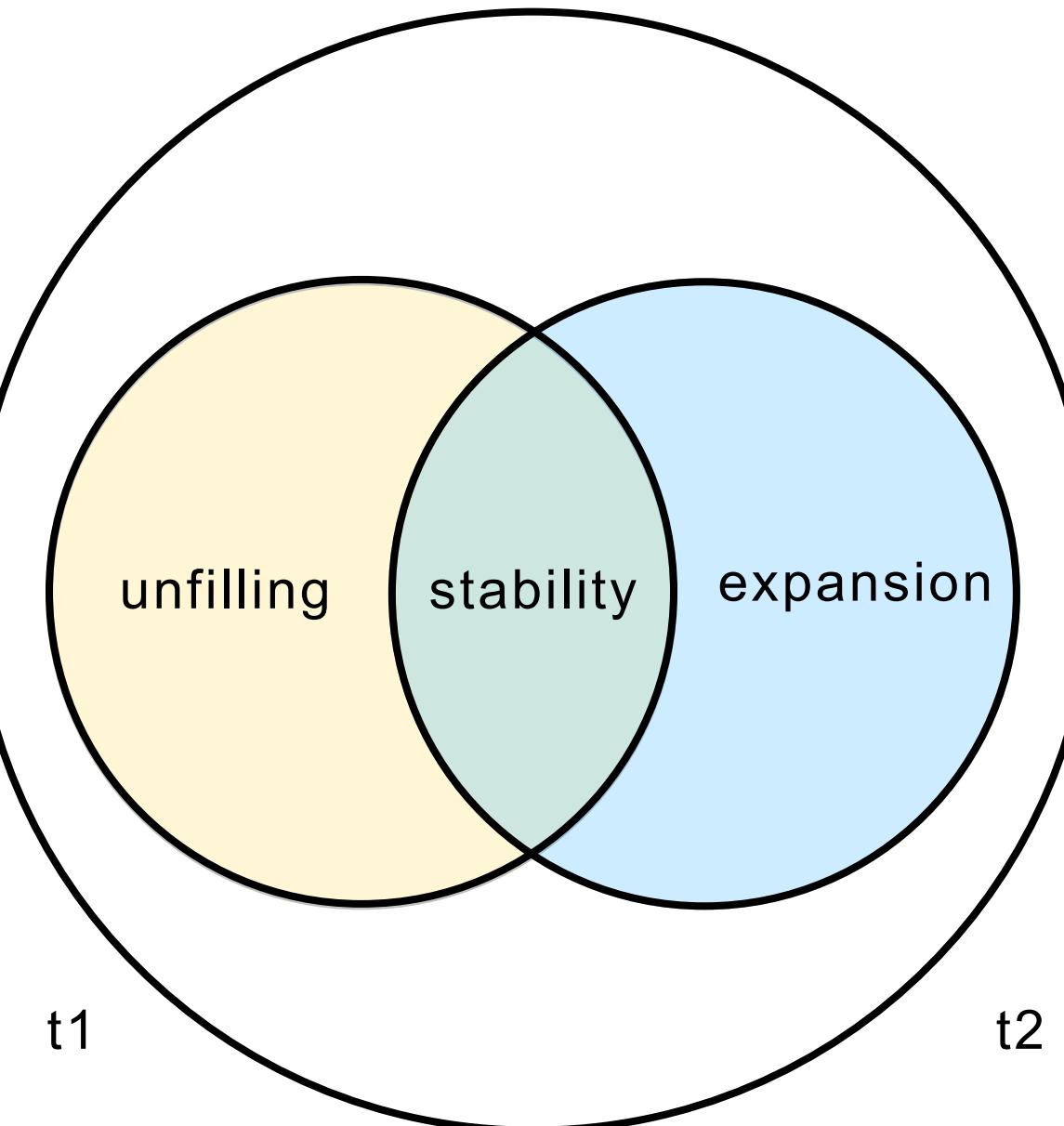
# RESULTS

Are species' niches  
the same or  
different across  
successional time?



—	herbaceous-shrub dominated stage (4-19 years since abandonment)
—	tree dominated stage (39-54 years since abandonment)

# RESULTS



Niche divergence mostly rejected by equivalency statistics (except Chiffchaff)

	<b>Blue Tit</b>	<b>Chaffinch</b>	<b>Chiffchaff</b>	<b>Willow Warbler</b>
<b>Schoener's D</b>	0.366 *	0.393 *	0.536 *	0.263 *
<b>Warren's I</b>	0.543 *	0.577 *	0.678 *	0.388 *
<b>Expansion</b>	0.133 *	0.179 *	0.073	0.234 *
<b>Stability</b>	0.867 *	0.821 *	0.927	0.766 *
<b>Unfilling</b>	0.339 *	0.254 *	0.179 *	0.597 *

# S U M M A R Y

- niche attributes are largely conserved across successional time •
- Blue Tit and Chaffinch niche shifts are aligned with structural changes of succession •
- Chiffchaff and Willow Warbler niche width was greater during the herbaceous-shrub seral phase •

## **Significance:**

- species-specific traits can modulate niche dynamics, different mechanisms likely make the same pattern •

# ECOLOGICAL AND REMOTE SENSING CONTRIBUTIONS

## Chapter 2 ➔ Manuscript 1:

species are associated with specific vegetation strata, which can be characterized with ALS •

## Chapter 3 ➔ Manuscript 2:

more data doesn't mean better models; balance data-driven exploration and ecological knowledge •

## Chapter 4 ➔ Manuscript 3:

succession and species traits contribute to niche dynamics, but similar woodland structure is used •

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**T H A N K   Y O U   F O R   Y O U R   T I M E  
&   F O R   A L L O W I N G   M E   T O  
S H A R E   M Y   R E S E A R C H   W I T H  
Y O U !**

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