Inferring blue tit reproductive phenology using SPOT4 imagery

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Evolutionary Ecology:
Evolution takes place in an ecological context

How do animals adapt to their environment?
Can birds adapt to a heterogeneous environment?

**Process**
- Habitat heterogeneity
  - Environmental data, GIS

**Material for evolution**
- Genetic Diversity
  - Next Generation Sequencing

**Response**
- Dispersal?
  - Pgi gene
  - Multi-state models
- Adaptation?
  - Genome-wide signatures of selection *Clock, Pgi gene*
  - Quantitative genetics of the timing of breeding
Animal phenology:

- Variable in time & space
- Timed to its ecological environment
Parallel populations monitored in contrasted habitats

Study sites:

Cyanistes careuleus caeruleus
& C. c. ogliastrae

“D” Deciduous: Downy Oak
(Quercus pubescens)

“E” Evergreen: Holm Oak
(Quercus ilex)

Bird phenotype:
1 month difference in breeding time depending on oakwood morphotype.
Vegetation Indexes for Remotely Sensed phenology

NDVI: Normalized Difference Vegetation Index

- Measures green plant spectral reflectance using measurements acquired in red and near-infrared (NIR) regions

Can we use winter NDVI to differentiate deciduous and evergreen oaks?

“La Rouviere” study site: 80% deciduous, 20% evergreen
Research Aims

Can satellite imagery generate biologically relevant information regarding habitat heterogeneity and blue tit phenology?

• Validate satellite imagery with ground data

• Investigate the predictive power of remotely sensed vegetation indexes to explain variation in animal reproductive success

• Explore start of season (SOS) statistics and test their predictive power in explaining:
  • caterpillar peaks
  • blue tit timing of breeding
Collaborators

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Remote sensing in avian ecology research

Phenology

- Leaf Development Index
- Caterpillar biomass / frass

Remote sensing of phenology: satellite imagery

- MODIS – 2000
- LANDSAT – 1970s
- AVHRR – 1970s
- SPOT 4 (Take 5) - 2013

Vegetation indexes based on spectral reflectance

Data not always available
Remote sensing in avian ecology research

Satellite sensors to monitor phenology

- MODIS: 250 m. resolution, once a day acquisition
- LANDSAT: 30 m. resolution, every 16 days
- SPOT: 20 m. resolution, every 5 days

• Resolution vs frequency of image acquisition
Available satellite data

MODIS cloud fraction, Feb-June, 2000-2011
Remote sensing in avian ecology research

Cloudiness & bird long-term studies

monthly means & SDs of MODIS-derived cloud fraction (2000-2011):
Spot4 Take 5, Languedoc region. In yellow: “La Rouviere” site
20 images (2A) from 2\textsuperscript{nd} of February to 17\textsuperscript{th} of June 2013
Cloud-free / snow-free pictures: 14 /20
SPOT image of the La Rouviere site (1 pixel=20m)

Winter

Summer

Deciduous oak       Evergreen Oak
SPOT imagery + 194 nestboxes + 194 oak estimates in 50m radius
**SPOT NDVI & oak ground data**

- SPOT imagery explains up to 55% of variance in oak number measured in the field.

- Spot imagery in good agreement with ground data.
SPOT NDVI & bird reproductive data

Winter NDVI

Evergreen oaks

Deciduous oaks
• NDVI explains meaningful variation in bird reproduction
• It is a valuable proxy when ground vegetation data is not available
SPOT NDVI filter size

- How many pixels to sample around the nestbox to best capture biologically relevant ecological and reproductive data?

<table>
<thead>
<tr>
<th>Filter size:</th>
<th>1*1 pixel (10m radius)</th>
<th>3*3 pixels (30m radius)</th>
<th>5*5 pixels (50m radius)</th>
<th>7*7 pixels (70m radius)</th>
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- Pixel colours reflect contrasted NDVI values
SPOT NDVI as a proxy for oak ground data in 50m radius from nestbox

- NDVI filters between 30 and 50 meter radius best explain variance in the number of oaks as measured on the ground in a 50m radius
Can we use NDVI filters of increasing size to infer realised blue tit foraging distance when feeding offspring in the nest?

NDVI radius important at the fledging stage peaks at 50m
SPOT imagery accurately predicts NDVI signatures of deciduous and evergreen oaks along the season.

MODIS analyses are scheduled to infer pixel-based start of season statistics across several phenological cycles.
Summary

• SPOT imagery explains up to 55% of variance in [deciduous] oak number as measured in the field and is thus in good agreement with ground data.

• It is a valuable proxy when ground vegetation data is not available.

• NDVI explains meaningful variation in bird reproductive success.

• The potential of remote sensing data for evolutionary ecological studies at the animal individual level has been very little explored; these results suggest great potential for further analysis.

• Further analyses of phenological times series with additional MODIS and Landsat input are scheduled.