The role of taxonomic, functional, genetic, and landscape diversity in food-web responses to a changing environment

NSF/NASA Dimensions of Biodiversity

Tony Ives, UW-Madison
Aphid population dynamics, evolution, and environmental changes at large spatial scales

parasitic wasp attacking an aphid
Aphid population dynamics, evolution, and environmental changes at large spatial scales

Jason P. Harmon, North Dakota State University
Kerry M. Oliver, University of Georgia
Volker C. Radeloff, UW-Madison
Remote sensing and muddy boots

1. When and where are the results of micro-scale experiments relevant?

2. When are spatial covariances in remotely sensed variables relevant?

3. How will faster and finer remote sensing change what ecologists can do?
Messages

Combine remote sensing with experiments.

NEON is nice, but there is a lot more out there (muddy boots).

Incremental changes in technology can lead to step changes in applications.

Improving current products is not just more of the same.
Remote sensing and muddy boots

1. When and where are the results of micro-scale experiments relevant?

2. When are spatial covariances in remotely sensed variables relevant?

3. How will faster and finer remote sensing change what ecologists can do?
1. When and where are the results of microscale experiments relevant?

Likai Zhu

Brandon Barton
Snow is an insulator
What is the effect on aphids the following spring?
Less snow reduces predation and increases aphid density.
Snow matters: less snow could increase pest abundances.

- **Predators surviving winter**
  - Shallow: 0.1
  - Deep: 0.5

- **Aphids surviving predators in spring**
  - Shallow: 9
  - Deep: 9

- **Aphids survived parasitized**
  - Shallow: 3
  - Deep: 2
1. When and where are the results of micro-scale experiments relevant?

   Experiment done during 1 winter in 48 m²

Has snow cover changed through the years?

If so, at what spatial scale?
1. When and where are the results of micro-scale experiments relevant?

   Experiment done during 1 winter in 48 m$^2$

Has snow cover changed through the years?

If so, at what spatial scale?

   Remote sensing contains a lot of historical evidence.
Frozen days without snow are common at mid latitudes

MODIS Snow Cover
Landscape Freeze/Thaw Status: SMMR, SSM/I, and SSMIS
Rate of change in the number of days with frozen ground but no snow, 1982-2014
Predicted change from the RCP8.5 high emission scenario, 2041-2070
Global warming over decades will make large areas of the world functionally colder in winter.

This magnifies the consequences of the experiment.
Snow is important for many plants and animals.

This magnifies the relevance of remote sensing.
Interfacing remote sensing with experiments

For ecology: Provides broader context for the experiment.

For remote sensing: Provides motivation for integrating different products in biologically informative ways.
Remote sensing and muddy boots

1. When and where are the results of micro-scale experiments relevant?

2. When are spatial covariances in remotely sensed variables relevant?

3. How will faster and finer remote sensing change what ecologists can do?
2. When are spatial covariances in remotely sensed variables relevant?

Interactive effect of light pollution and nighttime temperature on predation of aphids

Colleen Miller
Experimentally manipulate light crossed with temperature
Visual hunter

Hunts in the dark
Visual predator

Night warming

Light pollution

Number of aphids

PREDICTED
Visual predator

Night warming

Light pollution

Number of aphids

Control | Warm | Light | W/L exp | W/L

OBSERVED

PREDICTED

Visual predator

Night warming

Light pollution

Number of aphids

Control | Warm | Light | W/L exp | W/L

OBSERVED

PREDICTED
Visual hunter

Hunts in the dark
Interfacing remote sensing with experiments

For ecology: Provides broader context for the experiment.
Co-occurrence of nighttime irradiance and decadal change in temperature

Map for US cropland
Positive covariance in light pollution and nighttime warming
Positive covariance in light pollution and nighttime warming

![Graph showing the relationship between change in temperature (C/decade) and light pollution (nw/cm²/sr) in Area. The graph includes lines for different light pollution categories: <0.25, 0.25-1, 1-10, >10. The x-axis represents Change in temperature (C/decade), and the y-axis represents Area/Expected.]
Night warming → Light pollution → Area

Observed/Expected

30% increase in effect

Light (nw/cm²/sr)

- <0.25
- 0.25-1
- 1-10
- >10

Change in temperature (°C/decade)
If there were no interaction between light pollution and increasing temperature in the biological system, spatial covariance would be irrelevant.
Interfacing remote sensing with experiments

For ecology: Provides broader context for the experiment.

We are not trying to forecast.

Experiments show what is possible, not what is.

For remote sensing: Provides justification for investigating spatial covariances among variables.
Remote sensing and muddy boots

1. When and how are the results of micro-scale experiments relevant?

2. When are spatial covariances in remotely sensed variables relevant?

3. How will faster and finer remote sensing change what ecologists can do?
3. How could faster and finer remote sensing change what ecologists can do?

Likai Zhu

Fusion of Landsat + MODIS
Understanding biological control in a temporally varying agricultural landscape.
Trying to reconstruct harvesting patterns by remote sensing
Spatial resolution from MODIS wasn’t fine enough when ground truthed.
It worked fine in Arizona
Projects from my lab that could use Sentinel 2a/2b or Landsat 7/8

Harvesting mosaic of alfalfa

Alfalfa mosaic virus

Algae blooms in Myvatn

Phil Townsend
What about other ecological studies?

Review of 348 randomly selected observational studies (Estes et al. 2018, Fig. 2)
Reviewed the 284 articles in the journal *Ecology* in 2017

no apparent application for RS

used RS at a single time point

used RS at multiple time points

could use RS at a single time

could use RS at multiple times

could use high frequency RS (≤ 7 day interval)
2% used remote sensing, but 20% could have used temporally replicated remote sensing data.
Ecological uses of multiple, repeated images

<table>
<thead>
<tr>
<th>Disturbance</th>
<th>Yearly</th>
<th>Monthly</th>
<th>Weekly</th>
<th>Daily</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Logging, Fire in forests</td>
<td>Drought, Wind damage</td>
<td>Fire in grasslands, Insect defoliation, Frost damage</td>
<td>Fire spread, Heat waves, Flooding</td>
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<tr>
<td>Movement</td>
<td>Range expansion</td>
<td>Migration</td>
<td>Human encroachment</td>
<td>Foraging, Migration</td>
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<tr>
<td>Ecosystem processes</td>
<td>Trends in GPP</td>
<td>Variance in GPP</td>
<td>Nutrient flushing</td>
<td>Nutrient loading</td>
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<tr>
<td>Population dynamics</td>
<td>Fragmentation</td>
<td>Plague insects</td>
<td>Plant disease, Animal survival</td>
<td>Phenologies, Algal blooms, Insect emergence</td>
</tr>
</tbody>
</table>

Show ecological uses of remote sensing
Show remote sensing applications in ecology
Incremental changes in technology can lead to step changes in applications.

Improving current products is not just more of the same.

Combine remote sensing with experiments.

The answers to my questions have always seemed to be at the next-larger scale.
## Remote sensing products, past and future

<table>
<thead>
<tr>
<th>Spatial scale (m)</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
<th>Currently</th>
<th>Near future</th>
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<tbody>
<tr>
<td>1–5</td>
<td>Frequency Satellites</td>
<td>Occasionally</td>
<td>3–5 days</td>
<td>Daily</td>
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<tr>
<td></td>
<td></td>
<td>Commercial</td>
<td>PlanetLabs</td>
<td>PlanetLabs</td>
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<tr>
<td>10</td>
<td>Frequency Satellites</td>
<td>Occasionally</td>
<td>Weekly</td>
<td>Weekly</td>
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<tr>
<td></td>
<td></td>
<td>SPOT</td>
<td>Sentinel 2a, 2b</td>
<td>Sentinel 2a, 2b</td>
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<tr>
<td>30</td>
<td>Frequency Satellites</td>
<td>Bi-weekly</td>
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<tr>
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<td>Landsat</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>3–5 days</td>
<td>3–5 days</td>
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<td></td>
<td>Landsat 7, 8; Sentinel 2a, 2b</td>
<td>Landsat 7, 8; Sentinel 2a, 2b</td>
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<tr>
<td>250–1000</td>
<td>Frequency Satellites</td>
<td>2x daily</td>
<td>4x daily</td>
<td>MODIS, VIIRS, NPOESS</td>
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<tr>
<td>8000</td>
<td>Frequency Satellites</td>
<td>AVHRR</td>
<td>AVHRR</td>
<td>AVHRR</td>
<td>Geostationary</td>
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