Landscape diversity, food-web interactions, and the rapid evolution of pea aphids to parasitism

NSF/NASA Dimensions of Biodiversity

2013-2018

Anthony R. Ives, UW-Madison
Jason P. Harmon, North Dakota State University
Kerry M. Oliver, University of Georgia
Volker C. Radeloff, SILVIS Lab, UW-Madison
Likai Zhu, SILVIS Lab, UW-Madison
Landscape diversity, food-web interactions, and the rapid evolution of pea aphids to parasitism

NSF/NASA Dimensions of Biodiversity
2013-2018

Anthony R. Ives, UW-Madison
Jason P. Harmon, North Dakota State University
Kerry M. Oliver, University of Georgia
Volker C. Radeloff, SILVIS Lab, UW-Madison
Likai Zhu, SILVIS Lab, UW-Madison
How does global change affect food webs?
Global change and food webs
Global change and food webs
Global change and food webs
Global change and food webs
Global change and food webs
Global change and food webs

I. Landscape homogenization

II. Nighttime lights and warming

III. Global warming in winter
Global change and food webs

Landscape homogenization and synchrony
What is the effect of synchronous vs. asynchronous harvesting?

Simulated experiment for susceptible aphids

![Graph showing aphid numbers and percent parasitism over days for synchronous and asynchronous harvesting.](image-url)
Experiment

Contrast synchronous vs. asynchronous harvesting
Augment natural populations with 50% resistant (*H. defensa*) and 50% susceptible clones.
Augment natural populations of parasitoids to ensure at least moderate parasitism.
Results: ecological dynamics

[Graphs showing ecological dynamics with data points and trend lines for Async and Sync conditions, with axes labeled for date and log10 Aphids.]

aphid numbers
parasitism
## Results: evolutionary dynamics

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Assayed</th>
<th>Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>async</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>async</td>
<td>101</td>
<td>63</td>
</tr>
<tr>
<td>sync</td>
<td>101</td>
<td>6</td>
</tr>
<tr>
<td>sync</td>
<td>100</td>
<td>7</td>
</tr>
</tbody>
</table>
spatio-temporal variability

ecological dynamics

evolutionary dynamics

2015

2016
Spatio-temporal variability

Ecological dynamics

Evolutionary dynamics

Ecological-evolutionary dynamics

Async

Sync

Parasitism index

Aphid numbers

Parasitism
Spatially diverse agricultural landscape

Arlington Research Station

STARFM: Landsat + MODIS
Spatially diverse agricultural landscape

Likai Zhu

STARFM: Landsat + MODIS
Broad-scale view of disturbances
Broad-scale view of disturbances
Global change and food webs

I. Landscape homogenization

II. Nighttime lights and warming

III. Global warming in winter
Global change and food webs
Nighttime lights and warming
Global change and food webs
Nighttime lights and warming
C7
Visual hunter

Cmac
Hunts in the dark
Visual predator

Number of aphids

Control
Visual predator

Night warming

Number of aphids

Control  Warm

Visual predator
Visual predator

Light pollution

Number of aphids

Control  Warm  Light

0  50  100  150  200  250  300
Visual predator

Night warming

Light pollution

Number of aphids

PREDICTED

Control  Warm  Light  W/L exp

Night warming and Light pollution affect the number of aphids. A bar graph shows the predicted effect of Control, Warm, Light, and W/L exp treatments on the number of aphids.
Visual predator

Night warming

Light pollution

Number of aphids

Control  Warm  Light  W/L exp  W/L

PREDICTED

OBSERVED
C7
Visual hunter

Cmac
Hunts in the dark
Nighttime lights vs. nighttime warming in US croplands
Global change and food webs

I. Landscape homogenization

II. Nighttime lights and warming

III. Global warming in winter
Global change and food webs

Winter warming

Global Temperatures

- Annual Average
- Five Year Average

Temperature Anomaly (°C)

1860 1880 1900 1920 1940 1960 1980 2000
Wisconsin is getting less snow cover.
Wisconsin is getting less snow cover.
Less snow reduces parasitism and increases aphid density.
Snow cover (MODIS)
Frozen ground (AMSR-E)
Frozen ground with no snow
Introduction

- Whether frozen ground is covered by snow greatly affects biotic responses to climate change because the subnivean can provide an insulated and thermally stable refugium.
- Satellite data characterizing freeze/thaw cycles and snow cover are available, but have not been combined to map the subnivean.

Goal

To characterize global patterns of frozen ground with or without snow in order to provide a baseline to assess the effects of future climate change on organisms that overwinter.

Data and methods

- NASA MEaSUREs Global Record of Daily Landscape Freeze/Thaw Status data from AMSR-E: 2000-12
- 8-day MODIS Snow Cover product (MOD10A2) from 2000-12

Methods

- Daily AMSR-E freeze/thaw data
- 8-day MODIS snow cover data
- Filtering outliers
- Interpolating cloud pixels
- Defining the timing and duration of frozen season
- Duration of snow-covered frozen ground ($D_{WS}$) / Duration of uncovered frozen ground ($D_{WOS}$)
- The start of the frozen season: middle day of the first 15 consecutive days for which at least 8 days were frozen
- The end of the frozen season: middle day of the last 15 consecutive days for which at least 8 days were thawed
- The length of the frozen season: period between the start and end of the frozen season

Discussion and conclusions

- We developed a 500-m resolution dataset for 2000-12 that captured global patterns of snow-covered and uncovered frozen ground
- The mid-latitude areas were functionally colder than either northern or southern latitudes due to more days of uncovered frozen ground
- The $D_{WOS}$ at high latitudes may be more sensitive to climate change because of its shorter duration and greater temporal variability
- Climate warming may result in a counterintuitive trend of large areas in the north becoming functionally colder as snow cover diminishes

Fig. 1 Global pattern of the mean length of the snow season ($D_{WS}$, 2000-12) The Northern Hemisphere accounted for about 57% of all snow covered ground. The longest $D_{WS}$ occurred in mountainous regions and high latitudes.

Fig. 2 Global pattern of the mean length of the frozen season (2000-12). The pattern was similar to that of the $D_{WS}$ which indicated that the $D_{WS}$ became longer with an increase in the frozen season duration.

Fig. 3 Global pattern of the mean length of uncovered frozen ground ($D_{WOS}$, 2000-12). Cold constrained areas were at middle latitudes even though the frozen season was shorter than that at high latitudes.

Fig. 4 Variations of (a) $D_{WS}$ and (b) $D_{WOS}$ by latitude. We smoothed the data with a local polynomial regression fit.

Fig. 5 Global pattern of the percentage of $D_{WS}$ ($D_{WS}$ divided by the sum of $D_{WS}$ and $D_{WOS}$). The longest $D_{WS}$ mainly occurred at the mountainous regions and high latitudes.

Fig. 6 Global pattern of the CV of $D_{WS}$. The temporal variability of $D_{WS}$ was lower at higher latitudes.

Fig. 7 Global pattern of the CV of $D_{WOS}$. The temporal variability of $D_{WOS}$ was greater at higher latitudes.
Global change and food webs

I. Landscape homogenization

II. Nighttime lights and warming

III. Global warming in winter
Global change and food webs

I. Homogenization and synchronous mowing disrupts predator-prey cycles, and evolutionary dynamics

II. Interaction of nighttime lights and warming gives visual predators an unpredicted edge

III. Winter warming makes mid-latitudes functionally colder, preventing the overwintering of parasitoids wasps
Global change and food webs
Global change and food webs

Theory → Field experiment → Remote sensing
Global change and food webs

Loose scaling between experiments and satellite data can be both fruitful and fun!
Thank you!