Can forests take the heat? Managing pests and ecosystem services in a warming climate

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Another feature of their distribution is that they are of very rare occurrence in the country, while they become excessively abundant in cities and towns. I may further say I have never seen them upon the soft maple, or any other tree while growing in a state of nature, with the possible exception of one single individual ever found on a wild grape vine. Its known occurrence is in Iowa, and to Minnesota, specifically.
Ecology of Herbivorous Arthropods in Urban Landscapes

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Abstract
Herbivorous arthropods are a major component of insect diversity across urbanized landscapes. Because many urbanized landscapes are dominated by non-native grasses, the composition of herbivores shifts from native, grass-associated species to generalist, non-grass species. The decline of diverse herbivore communities can have important impacts on the primary productivity of urban forests and the maintenance of ecosystem services such as nutrient cycling, pollination, and seed dispersal. This review examines the factors influencing herbivory in urban landscapes, including the persistence of native herbivorous arthropods, the proliferation of non-native herbivores, and the role of human activities in shaping urban herbivory patterns. It also explores potential management strategies for enhancing the diversity and abundance of herbivores in urban environments.
Hypothesis: Heat increases pest abundance on urban plants

Photo: E. Youngsteadt
‘Native’ chronic herbivores

- Armored scales
- Soft scales
- Caterpillars
- Mites
Gloomy scale, *Melanaspis tenebricosa*

- Pest of red maple
- Native to US
- Univoltine
Oak lecanium scale, *Parthenolecanium quercifex*

- Pest of oak trees
- Native to US
- Univoltine
Gloomy scale abundance increases at hotter sites

\[ R^2 = 0.4163 \]

7-month Mean Temperature

Meineke et al. 2013 PLoS One

- **Mean 1st instar scales**
  - $t_{38} = 2.90; P = 0.006$

- **Mean 2nd instar scales**
  - $t_{9} = 2.46; P = 0.036$

- **Mean ovisacs**
  - $X_{1}^{2} = 6.53; P = 0.011$
Are these native species invasive?

- No evolutionary history with ecosystem ✓
- High reproductive rate ✓
- Sexual and asexual reproduction ✓
- High dispersal ✓
- Reduce species richness ✓
- Have net negative effects on human interests ✓
- Phenotypic plasticity or adaptation to new environment ?
- Disconnect with local natural enemies ?
Are these native species invasive?

- No evolutionary history with ecosystem
- High reproductive rate

Hypothesis: Native scale insects become invasive in cities due to warming

- Have net negative effects on human interests
- Phenotypic plasticity or adaptation to new environment
- Disconnect with local natural enemies
Do native species become invasive with warming?

• Does warming cause phenotypic changes that increase scale fitness and abundance
• Does warming decouple scales from local natural enemies

Do cities predict which herbivores become invasive – Cities as Sentinels Hypothesis?

How do pests and warming affect tree health and services?
Do native species become invasive with warming?

- Does warming cause phenotypic changes that increase scale fitness and abundance
- Does warming decouple scales from local natural enemies

Do cities predict which herbivores become invasive –Cities as Sentinels Hypothesis?

How do pests and warming affect tree health and services?
Gloomy scale fitness
Body size increases with temperature

$R^2 = 0.44$  
$P = 0.0008$

Dale & Frank. 2014. *Ecological Applications*
Egg production increases with temperature

$R^2 = 0.72$

$P < 0.0001$

Egg production increases with temperature.

Dale & Frank. 2014. *Ecological Applications*
Effects of origin and greenhouse temperature on lecanium scale abundance and survival

- 40 Willow Oak Saplings
- 40 small branches with 2 scale ovisacs
- Placed on branches with elastic ties
- Counted scale insects every 2 weeks
Effects of origin and greenhouse temperature on scale abundance and survival

<table>
<thead>
<tr>
<th></th>
<th>22/18°C</th>
<th>30/26°C</th>
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<tbody>
<tr>
<td>Eggs from</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Cold site</td>
<td>+</td>
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<tr>
<td>Eggs from</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hot site</td>
<td>+</td>
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</tr>
</tbody>
</table>
Effects of origin and greenhouse temperature on oak lecanium abundance and survival

Do native species become invasive with warming?

- Does warming causes phenotypic changes that increase scale fitness and abundance ✓
- Does warming decouple scales from local natural enemies

Do cities predict which herbivores become invasive –Cities as Sentinels Hypothesis?

How do pests and warming affect tree health and services?
Life Cycle of lecanium scale
Do native species become invasive with warming?

- Does warming cause phenotypic changes that increase scale fitness and abundance? ✔
- Does warming decouple scales from local natural enemies? ✔

Do cities predict which herbivores become invasive – Cities as Sentinels Hypothesis?

How do pests and warming affect tree health and services?
Do native species become invasive with warming?

- Does warming cause phenotypic changes that increase scale fitness and abundance? ✔
- Does warming decouple scales from local natural enemies? ✔

Do cities predict which herbivores become invasive – Cities as Sentinels Hypothesis?

How do pests and warming affect tree health and services?
Determine if cities simulate climate change – Sentinel Cities Hypothesis

Elsa Youngsteadt, Research Assoc.  

Gloomy scale response to warming is congruent across urban and historical datasets.

Gloomy scale abundance responds to natural climate variation.
Revisit 20 sites to document current gloomy scale abundance
Do native species become invasive with warming?

- Does warming cause phenotypic changes that increase scale fitness and abundance? ✓
- Does warming decouple scales from local natural enemies? ✓

Do cities predict which herbivores become invasive – Cities as Sentinels Hypothesis? ✓

How do pests and warming affect tree health and services?
Do native species become invasive with warming?

- Does warming cause phenotypic changes that increase scale fitness and abundance? ✓
- Does warming decouple scales from local natural enemies? ✓

Do cities predict which herbivores become invasive –Cities as Sentinels Hypothesis? ✓

How do pests and warming affect tree health and services?
How do temperature and scales affect tree condition?
The Effects of Urban Warming on Herbivore Abundance and Street Tree Condition

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Abstract

Trees are essential to urban habitats because they provide services that benefit the environment and improve human health. Unfortunately, urban trees often have more herbivorous insect pests than rural trees but the mechanisms and consequences of these infestations are not well documented. Here, we examine how temperature affects the abundance of a scale insect, *Melanaspis tenebricosa* (Comstock) (Hemiptera: Diaspididae), on one of the most commonly planted street trees in the eastern U.S. Next, we examine how both pest abundance and temperature are associated with water stress, growth, and condition of 26 urban street trees. Although trees in the warmest urban sites grew the most, they were more water stressed and in worse condition than trees in cooler sites. Our analyses indicate that visible declines in tree condition were best explained by scale-insect infestation rather than temperature. To test the broader relevance of these results, we extend our analysis to a database of more than 2700 Raleigh, US street trees. Plotting these trees on a Landsat thermal image of Raleigh, we found that warmer sites had over 70% more trees in poor condition than those in cooler sites. Our results support previous studies linking warmer urban habitats to greater pest abundance and extend this association to show its effect on street tree condition. Our results suggest that street tree condition and ecosystem services may decline as urban expansion and global warming exacerbate the urban heat island effect. Although our non-probability sampling method limits our scope of inference, our results present a gloomy outlook for urban forests and emphasize the need for management tools. Existing urban tree inventories and thermal maps could be used to identify species that would be most suitable for urban conditions.

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df = 9, \chi^2 = 3.90, P = 0.048

Number of hot and cool trees in poor or excellent condition

\[ \chi^2 = 65.383 \]

\[ P = 0.0001 \]

Tree Functions

Tree Services

- Use city database of all willow oaks
- Surface temperature maps
- Allometric equations + magic

Warming reduces city-wide carbon sequestration by willow oaks 12%

Some natives become invasive with warming

- Climate change alters insect physiology, behavior, interactions
- Cities may be Sentinels that predict which chronic herbivores become invasive with climate warming
‘Native’ chronic herbivores could be invasives of the future

- Armored scales
- Soft scales
- Caterpillars
- Mites
• Heat and pests combine to affect carbon sequestration
• How does this affect earth system models?
Collaborators and Cooperators

- Rob Dunn
- Barbara Fair
- Vince D’Amico
- Adam Terando

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Raleigh Parks, Recreation and Cultural Resources

- Sally Thigpen
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Post doc and grad student positions available.
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