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

Steven D Frank, Emily Meineke, Adam Dale, Elsa Youngsteadt

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North Carolina State University
ecoipm.org

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 possibl on a wild grape vine. unknown. Its known t, to Minnesota, Iowa, a

NO

JOSEPH DUNCAN

I. PULVINARIA INNUM
II. ASPIDIOTUS ANCYL

From Proceedings of Davenport Academy of

DAVENPORT, IOWA:
February, 1880.
Gazette Company, Printers.

Ecology of Herbivorous Arthropods in Urban Landscapes

Michael J. Raupp,[1] Paula M. Shrewsbury,[1] and Daniel A. Herms[2]

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0066-4170/10/0107-0019$

Key Words

urbanization gra
biodiversity, ecos

Abstract

Hypothesis: Heat increases pest abundance on urban plants

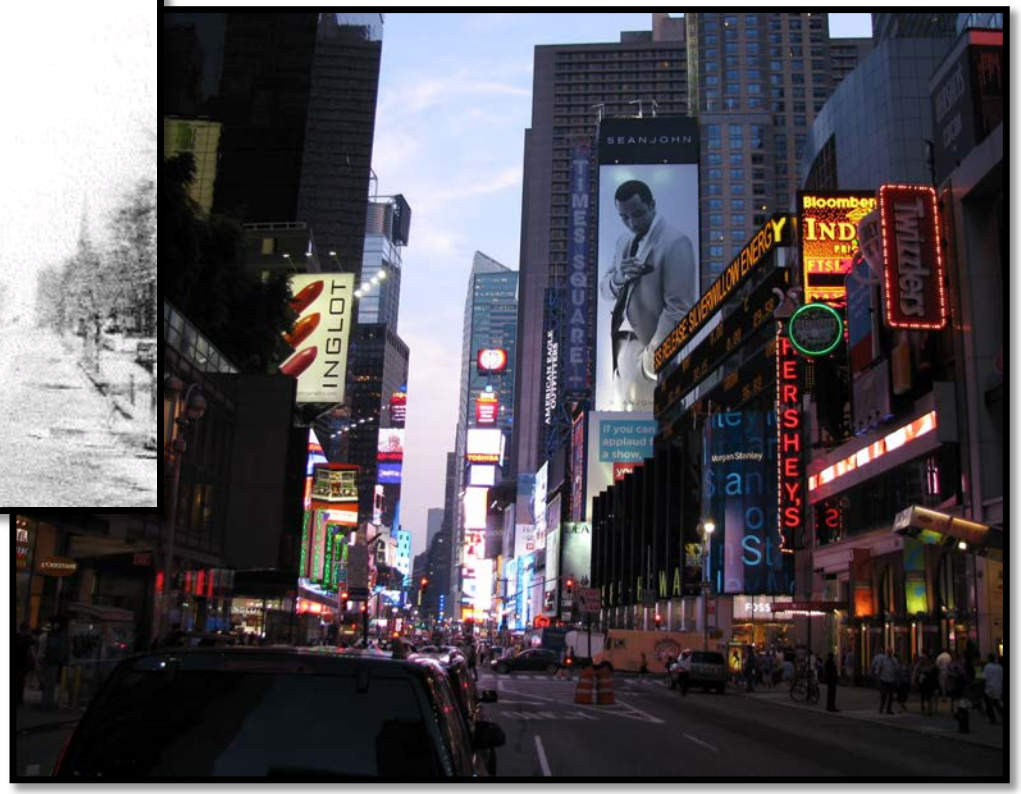


Photo: E. Youngsteadt

‘Native’ chronic herbivores

- Armored scales
- Soft scales
- Caterpillars
- Mites

Gloomy scale, *Melanaspis tenebricosa*

- Pest of red maple
- Native to US
- Univoltine

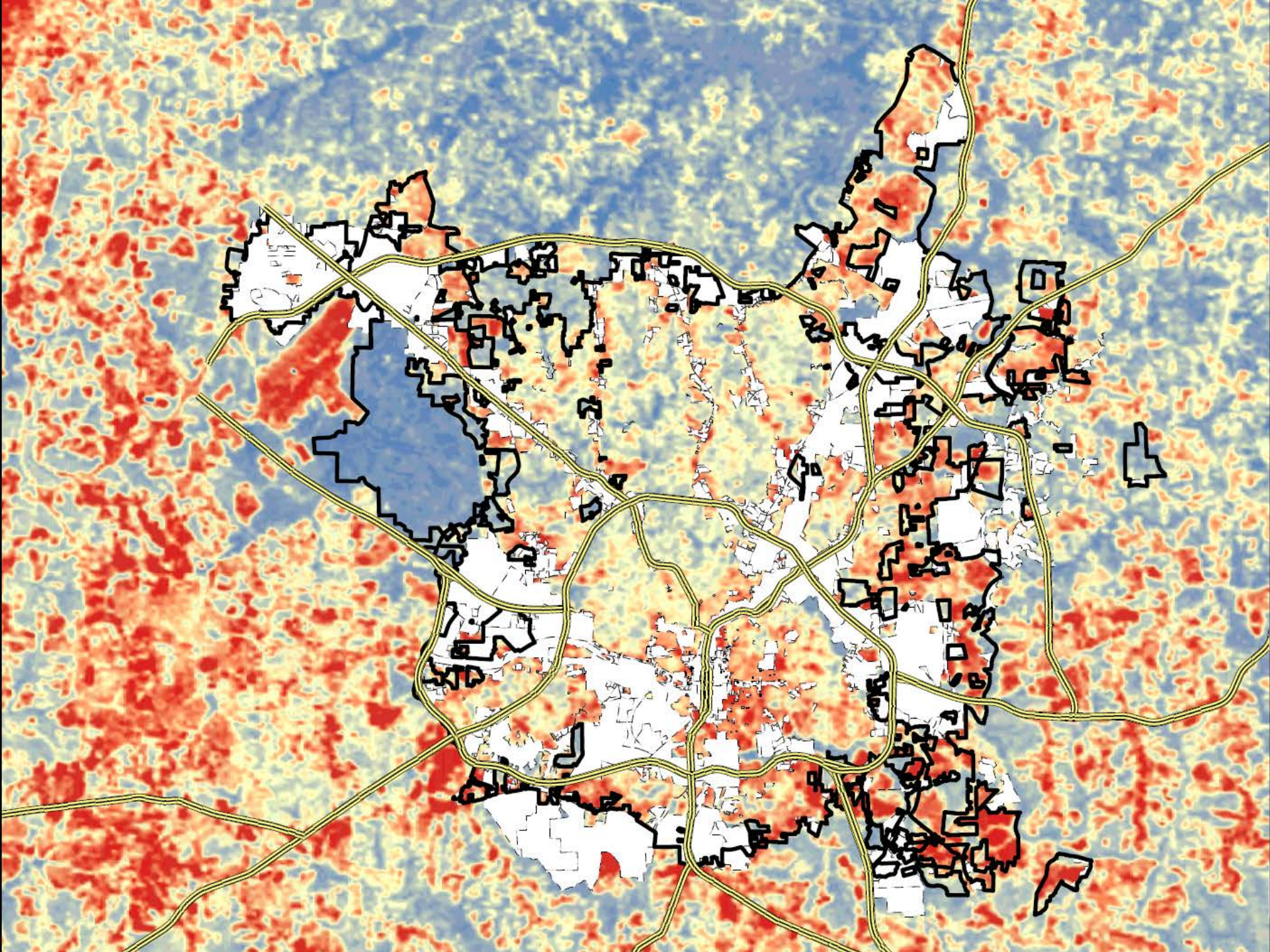
Adam Dale, University of Florida

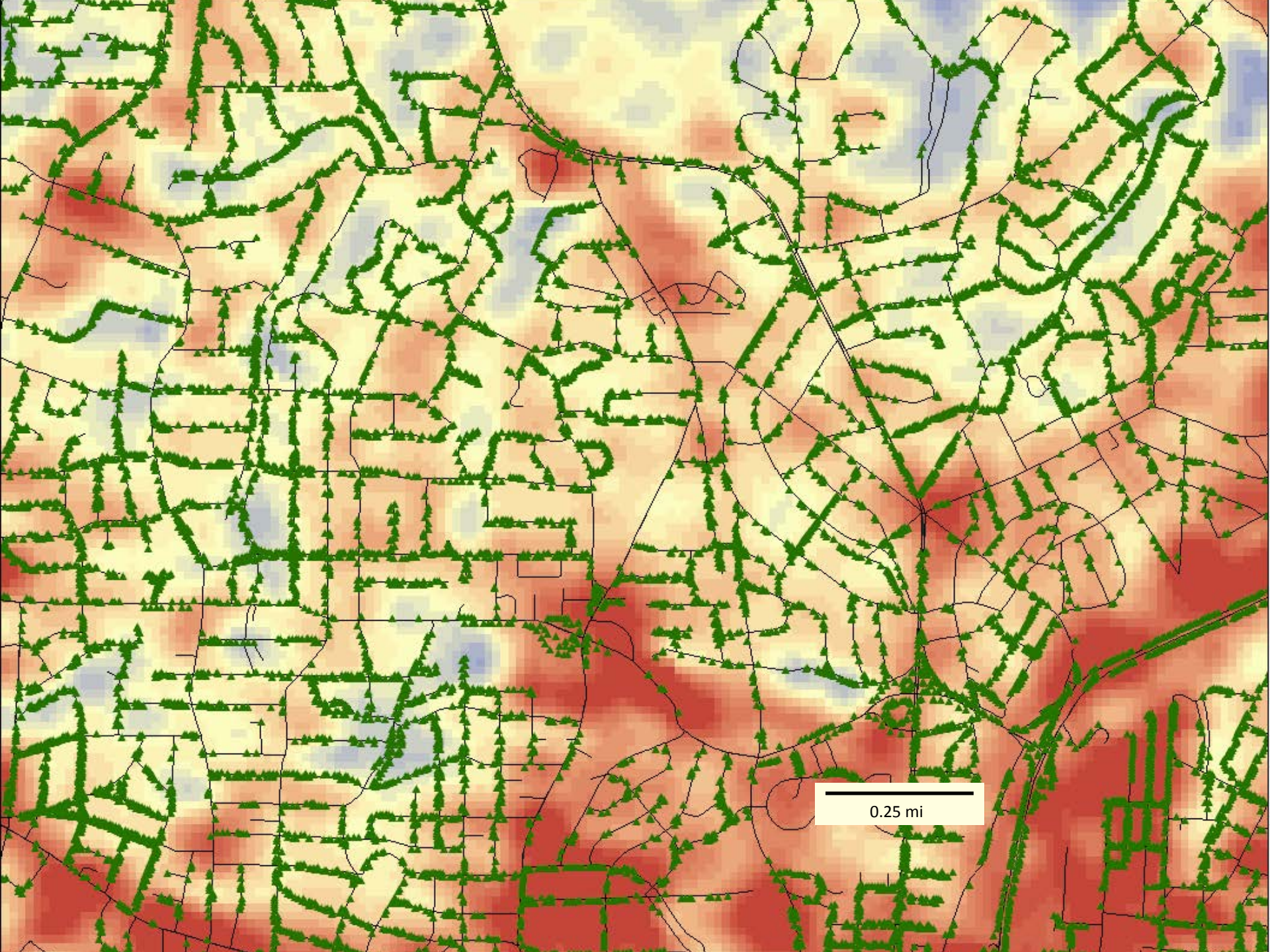
Oak lecanium scale, *Parthenolecanium quercifex*

- Pest of oak trees
- Native to US
- Univoltine

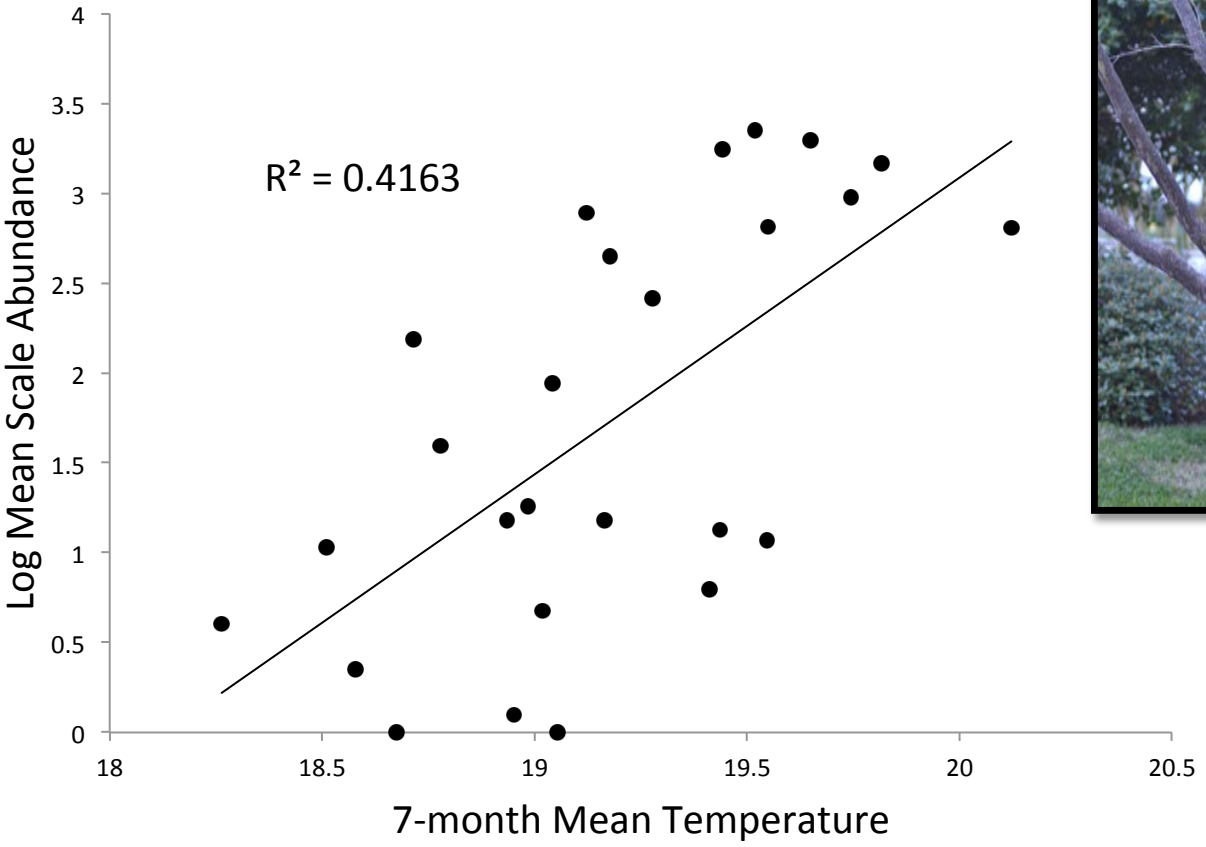
Clyde Sorenson

Emily Meineke, Harvard University

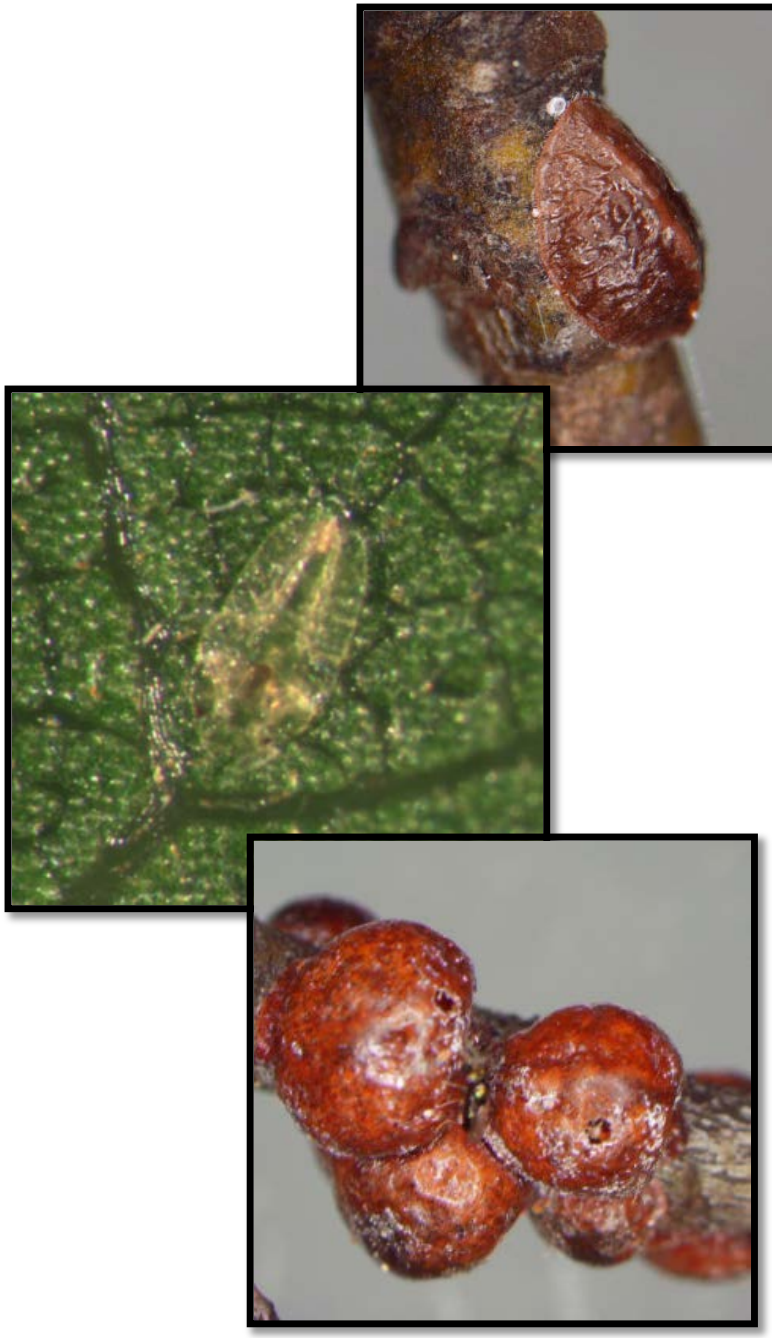


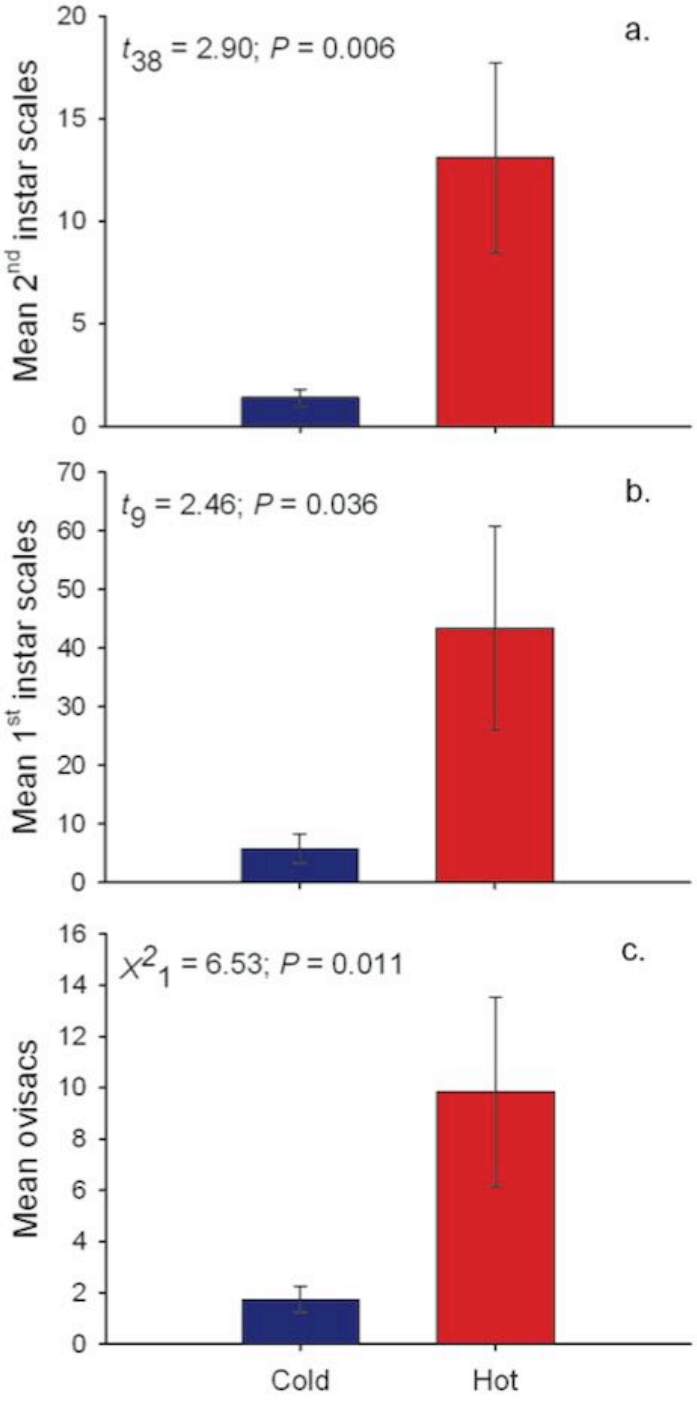

0.25 mi

Gloomy scale abundance increases at hotter sites



Dale & Frank. 2014 *Ecological Applications*; Dale et al. 2014 *PLoS One*





Meineke et al. 2013 *PLoS One*

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 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?

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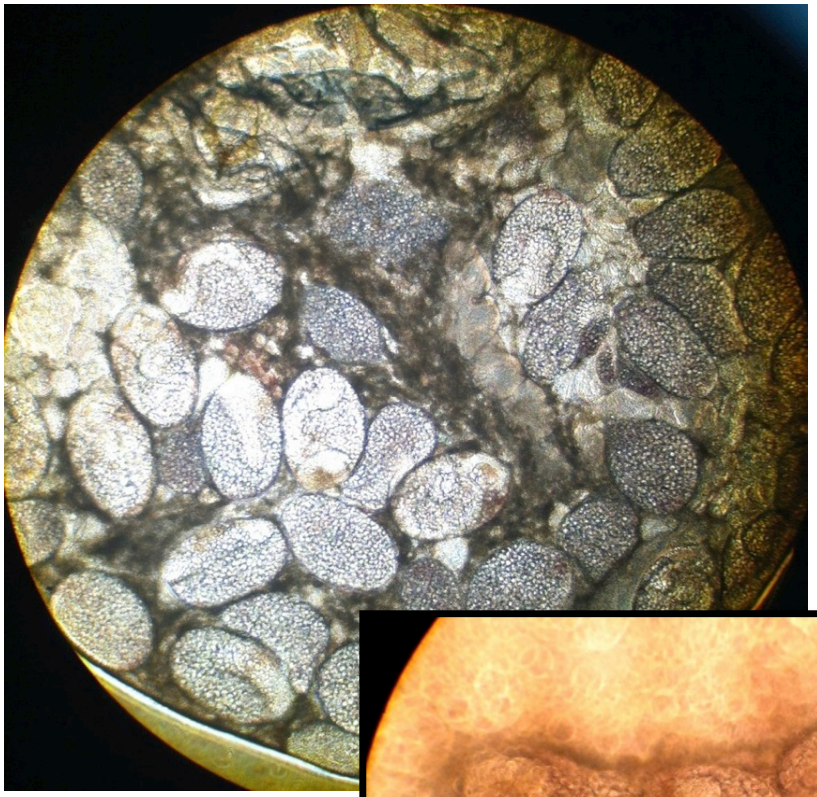
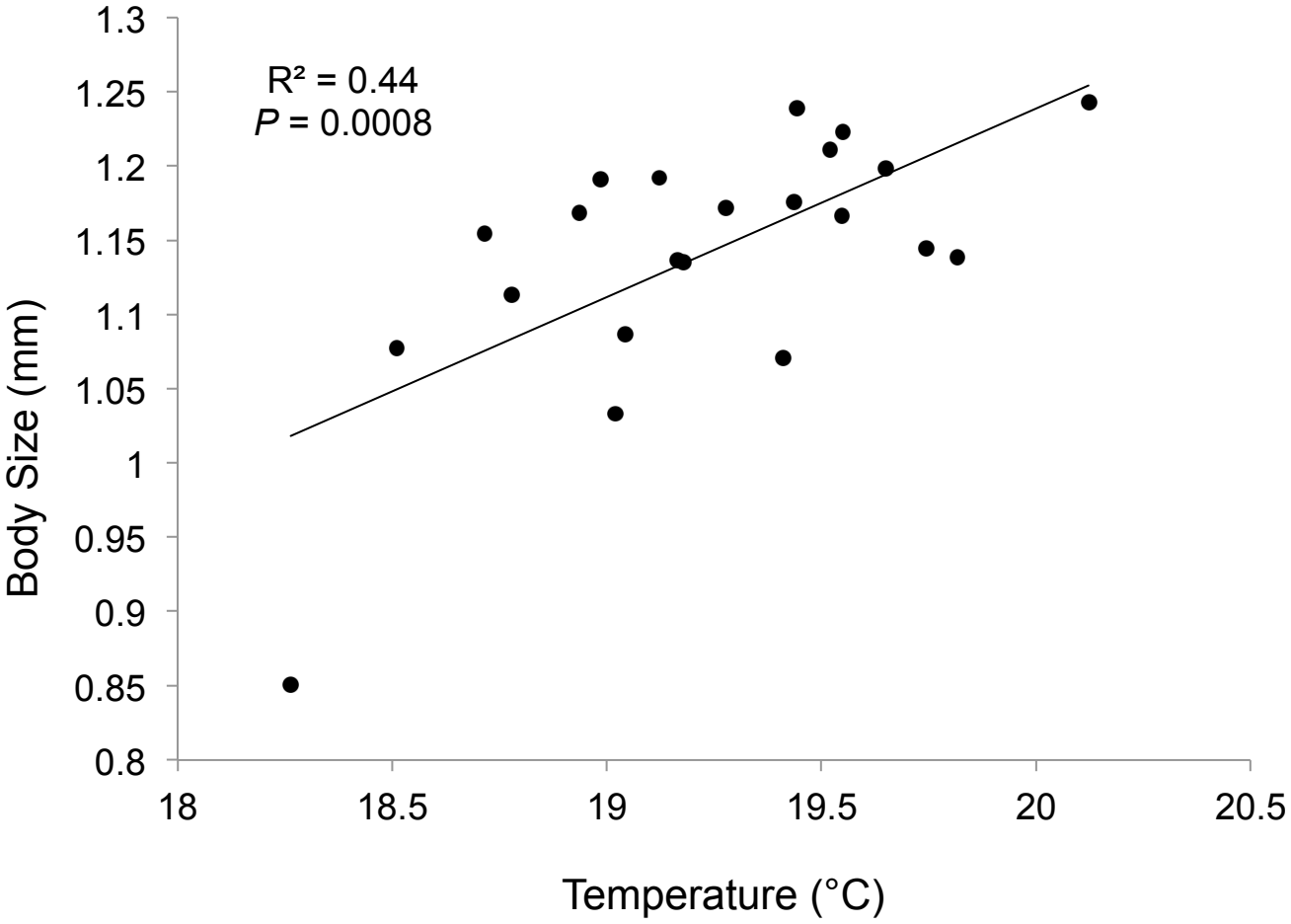
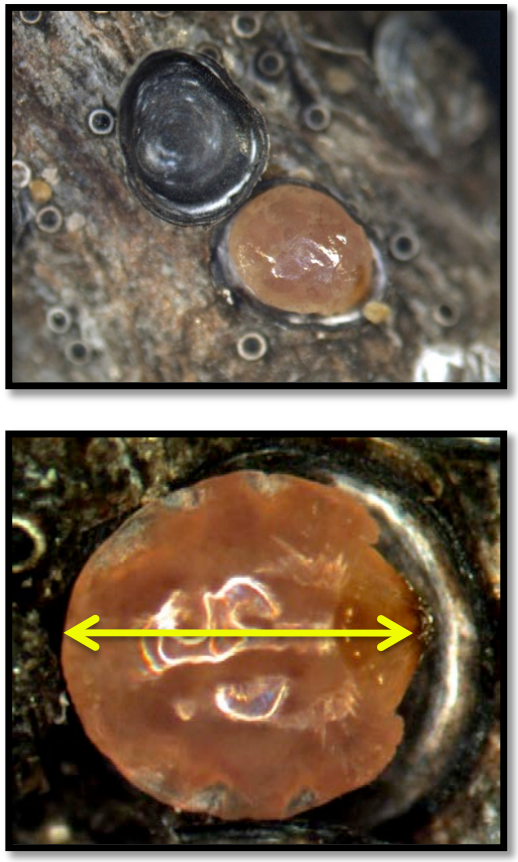
Gloomy scale fitness



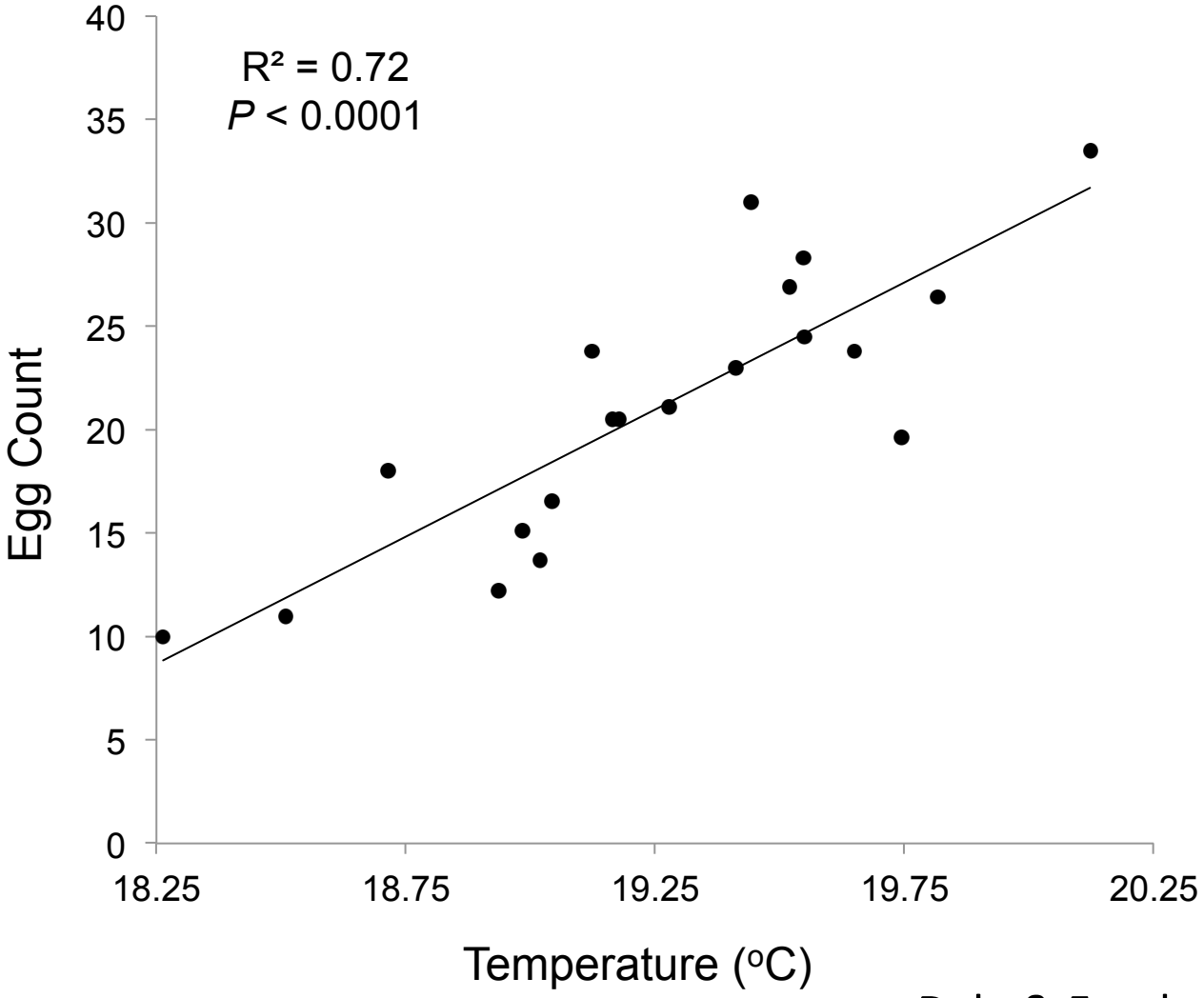
Body size increases with temperature

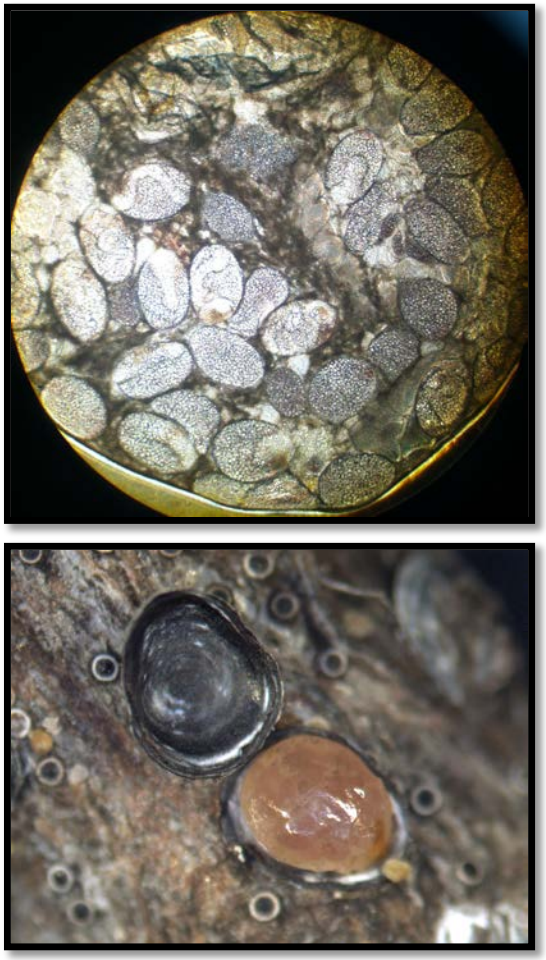




Dale & Frank. 2014. *Ecological Applications*

Egg production increases with temperature



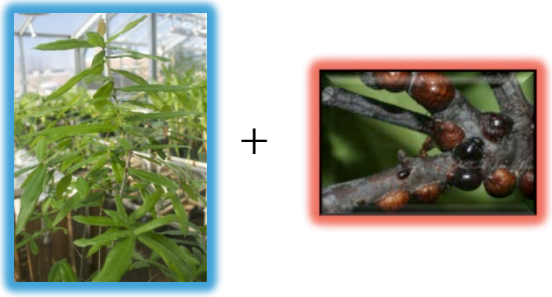


Dale & Frank. 2014. *Ecological Applications*

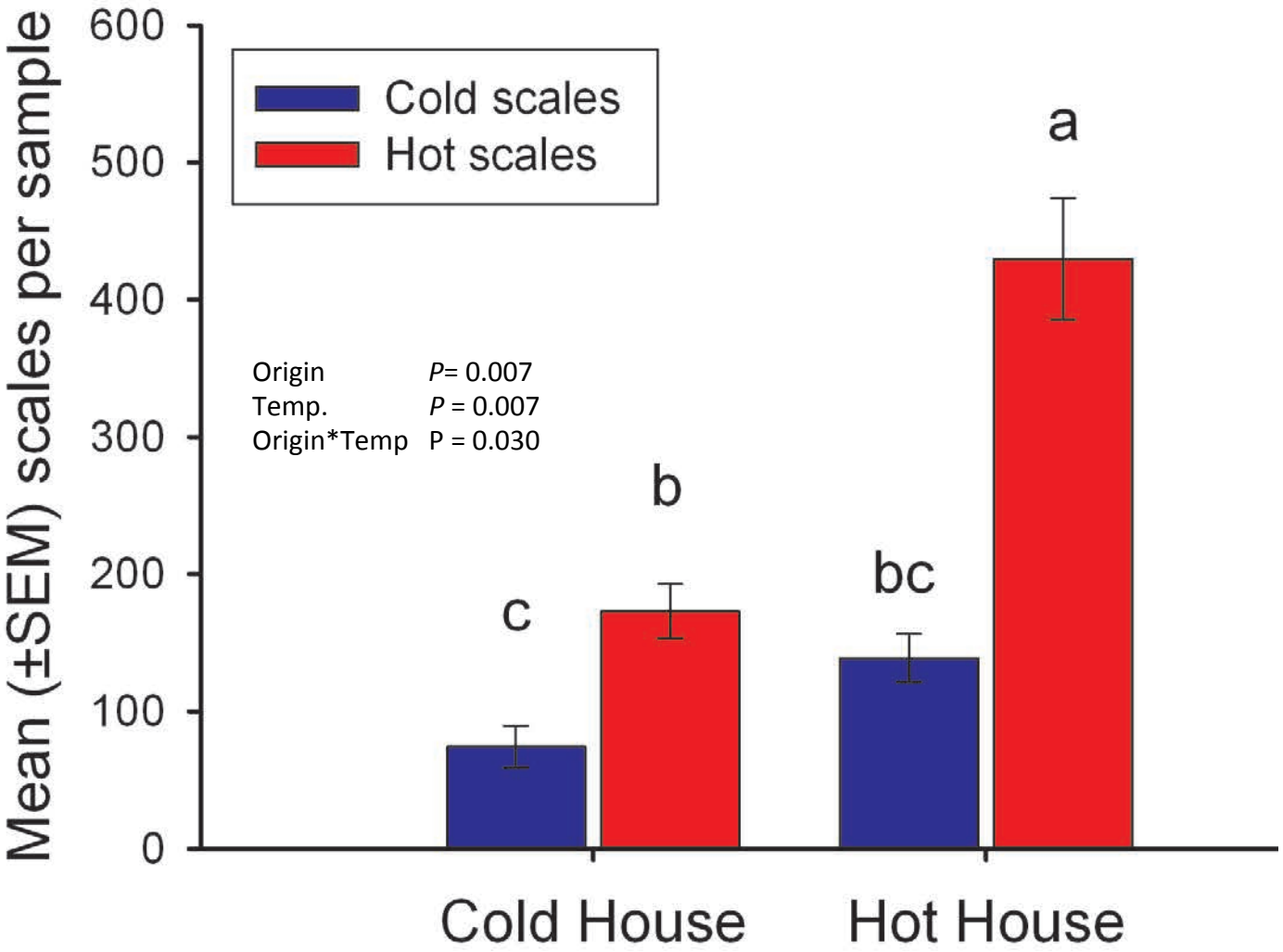
Effects of origin and greenhouse temperature on lecanium scale abundance and survival

- 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

	22/18° C	30/26° C
EGGS FROM COLD SITE		
EGGS FROM HOT SITE		

Effects of origin and greenhouse temperature on oak lecanium abundance and survival



Meineke et al. 2013. *PLoS One*

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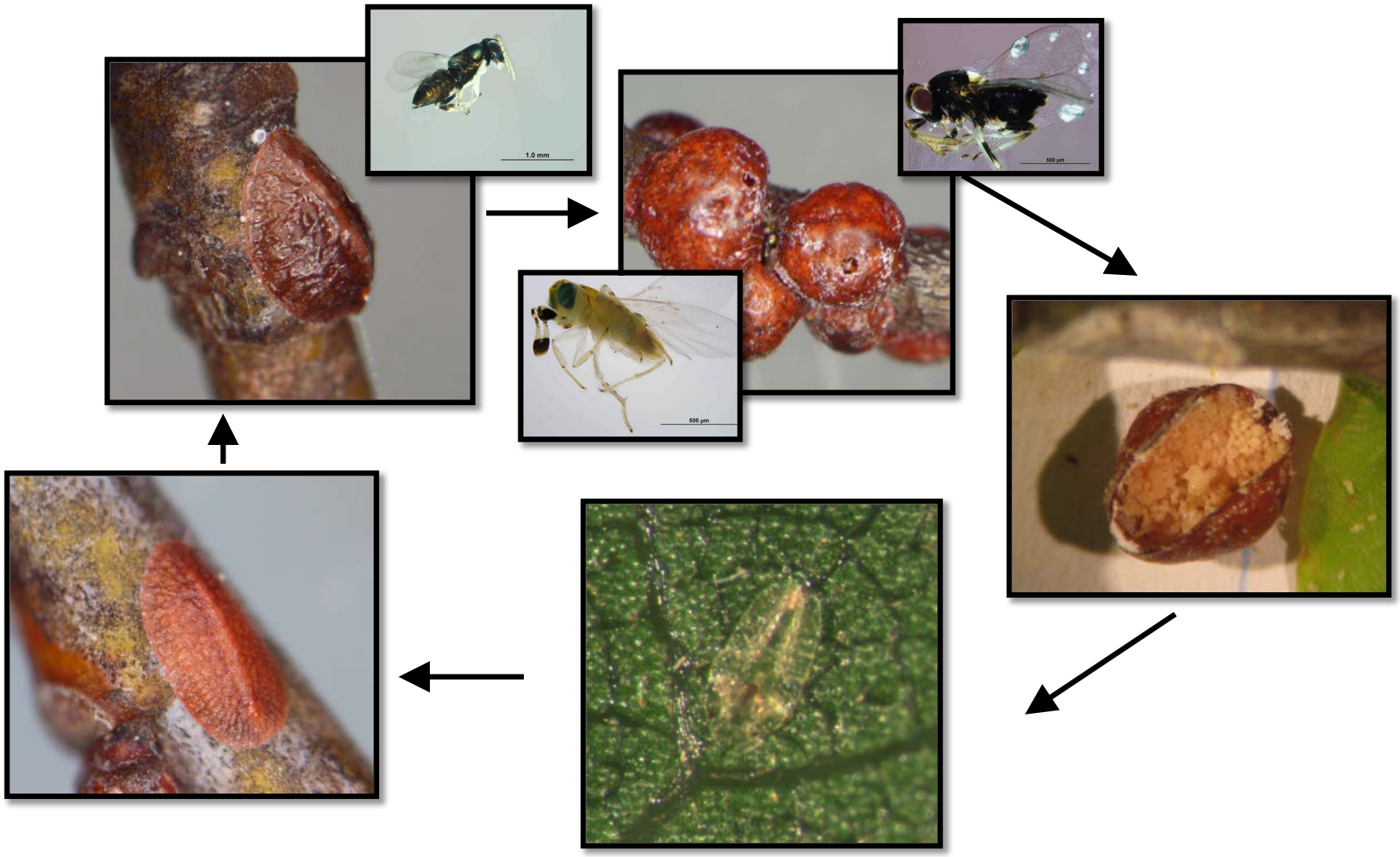
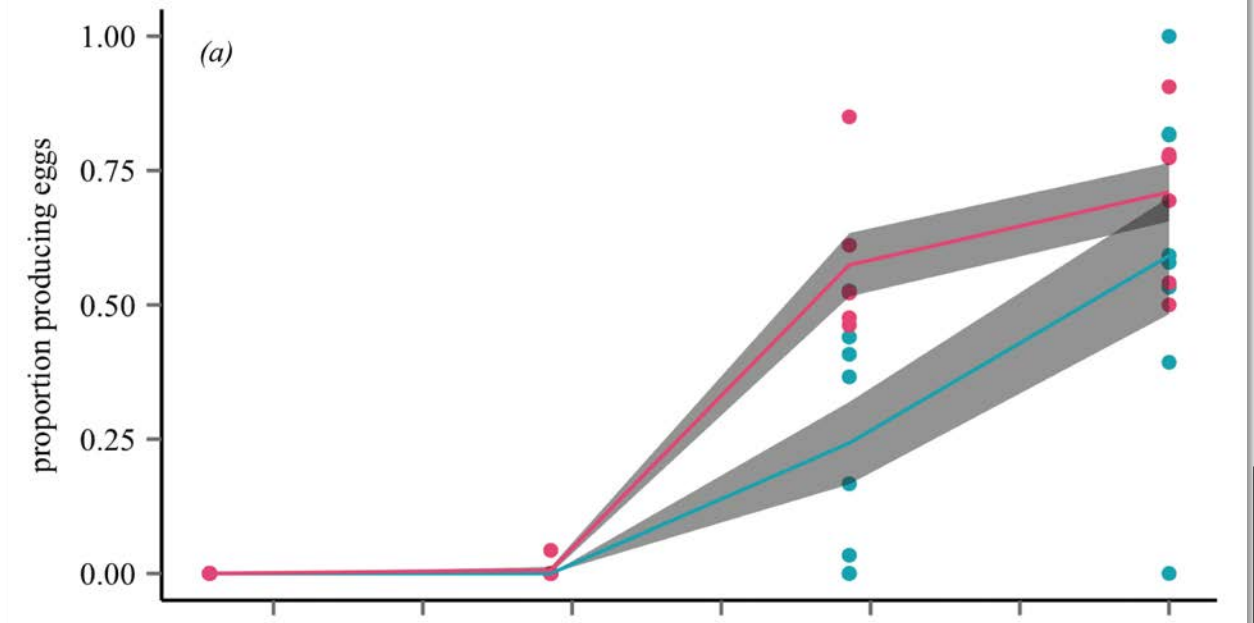
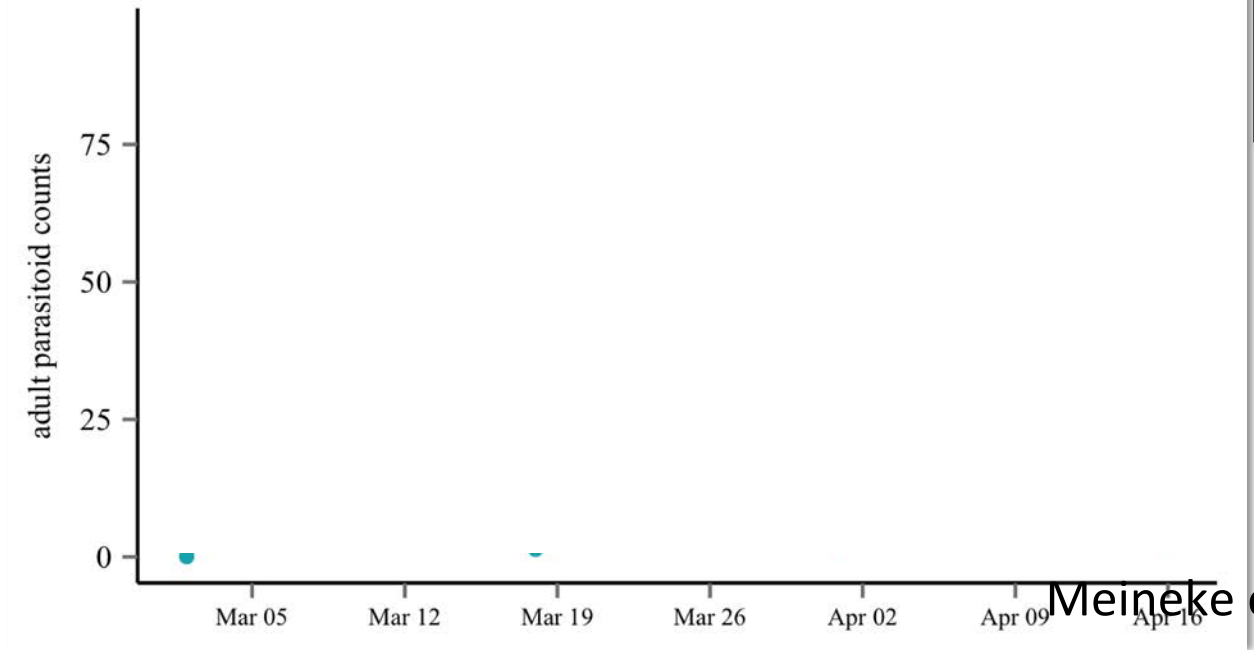
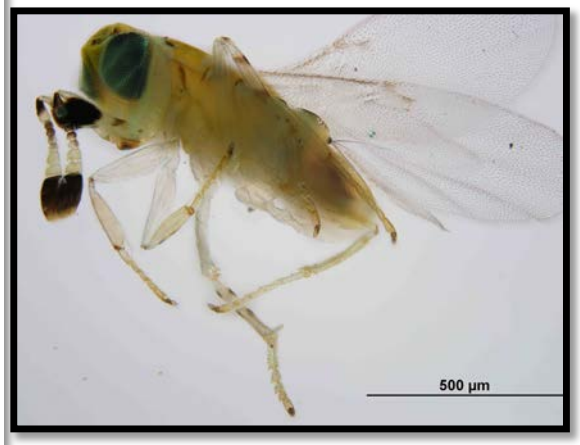
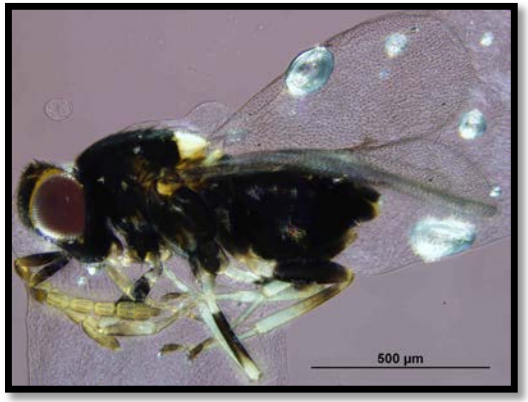
Life Cycle of lecanium scale











Meineke et al. 2015. *Biology Letters*

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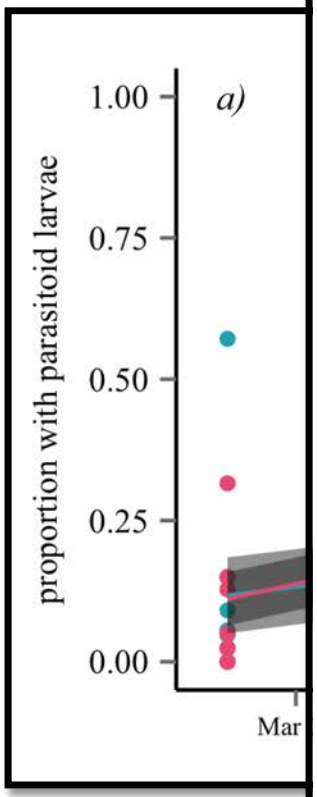

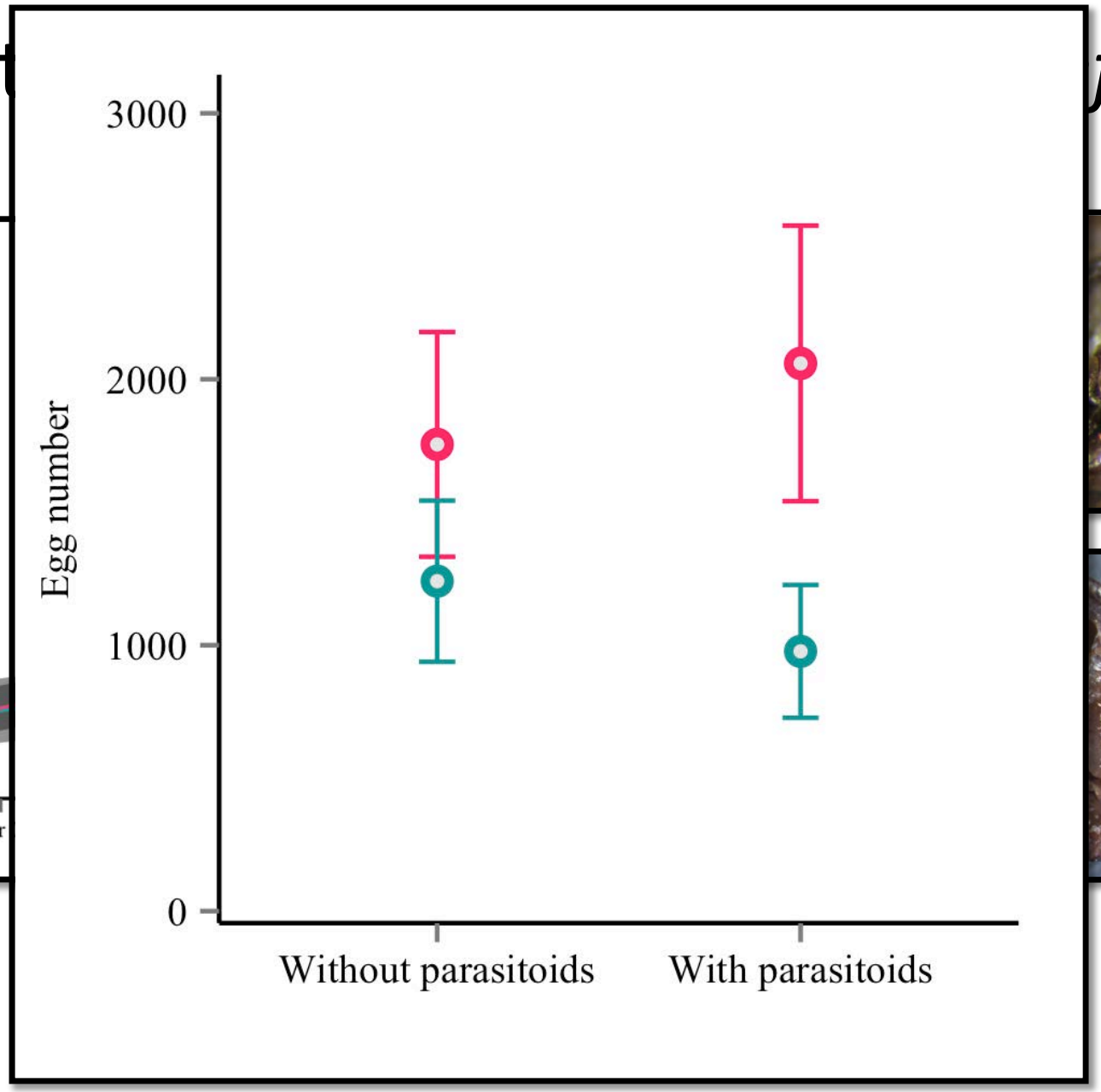

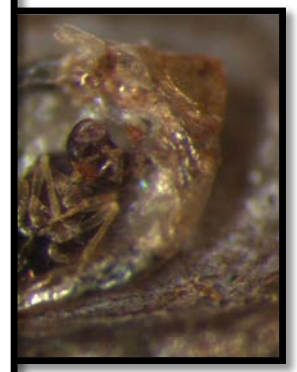

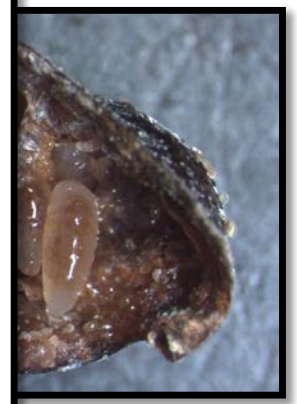

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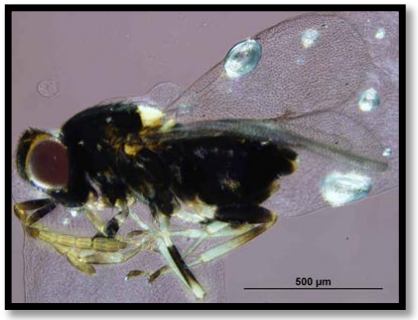

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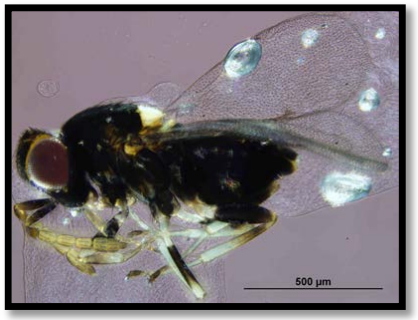


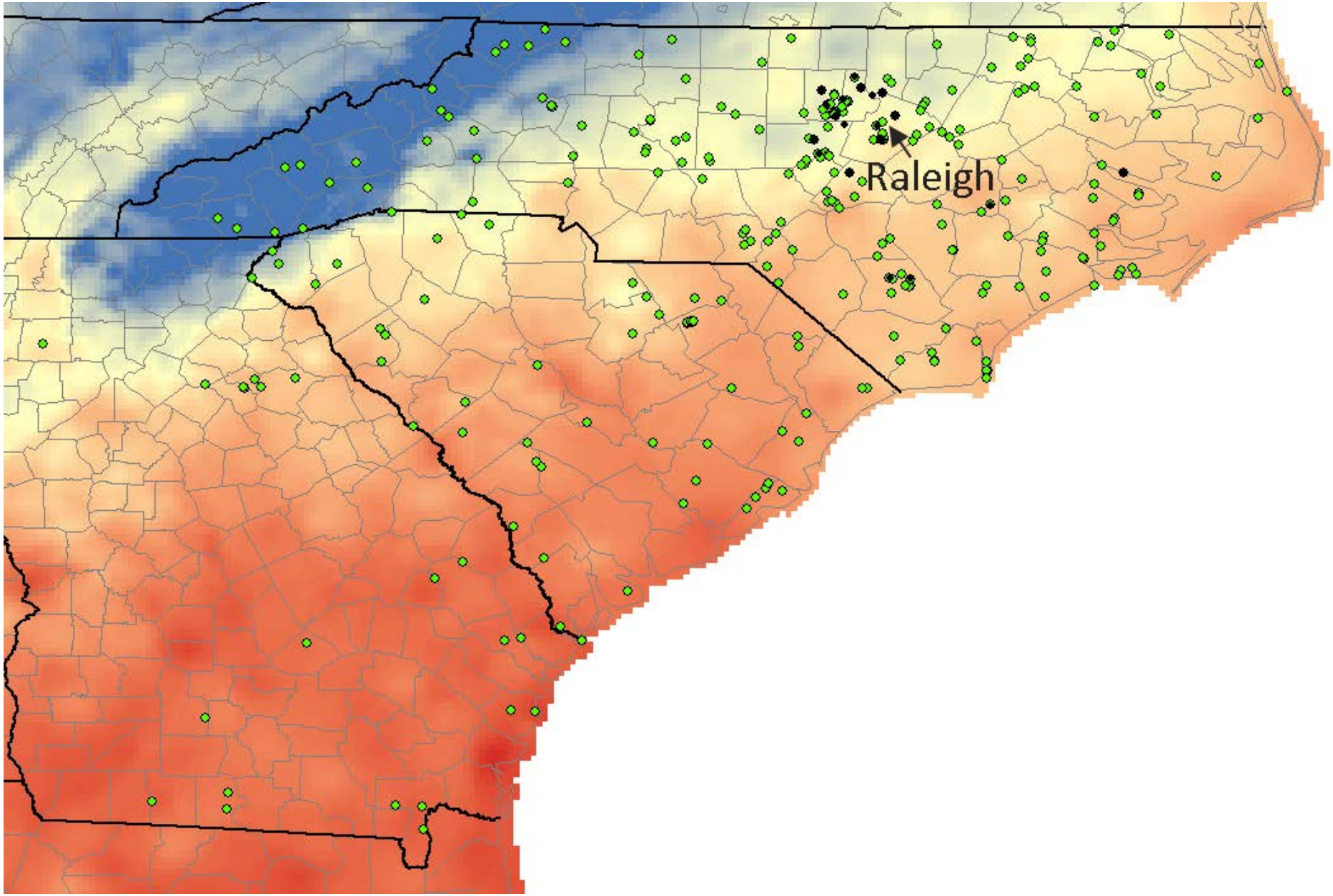
Determine if cities simulate climate change – Sentinel Cities Hypothesis

Elsa Youngsteadt, Research Assoc.

Youngsteadt et al. *2014. Global Change Biology*.

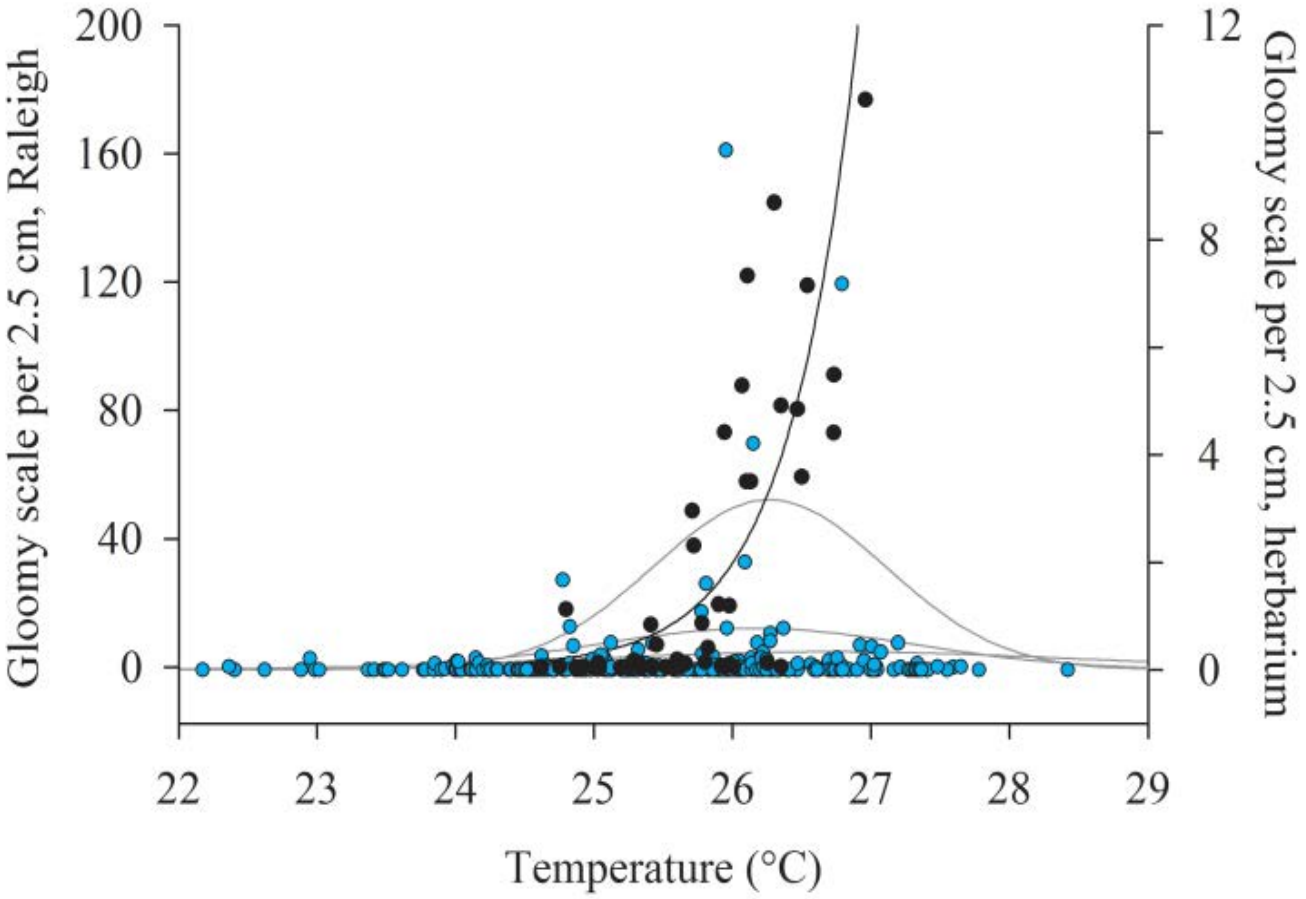

a


b
Acer rubrum L.
A. saccharinum L.
A. x freemanii E. Murray
annotation by
H. S. Forest 06/
THE UNIVERSITY OF TENNESSEE
Acer rubrum L.
var. rubrum
WILLIAM H. ELLIS
May, 1963
Ex Herb. Gray.
SOUTH CAROLINA
Berkeley County
Acer rubrum L.
Cleared strip along logging railroad through floodplain forest, Santee River, 3 miles northeast of Pineville
R.K. Godfrey and R.M. Tryon, Jr., No. 649 July 14, 1939
Seen in preparation of Congruent effects of urban warming and climate change on an insect herbivore
Inspected for evidence of gloomy scale insect Melanaspis tenebricosa (Comstock). Scale insect remains present.
E. Youngsteadt 2013 (NCSU)
NEW YORK BOTANICAL GARDEN



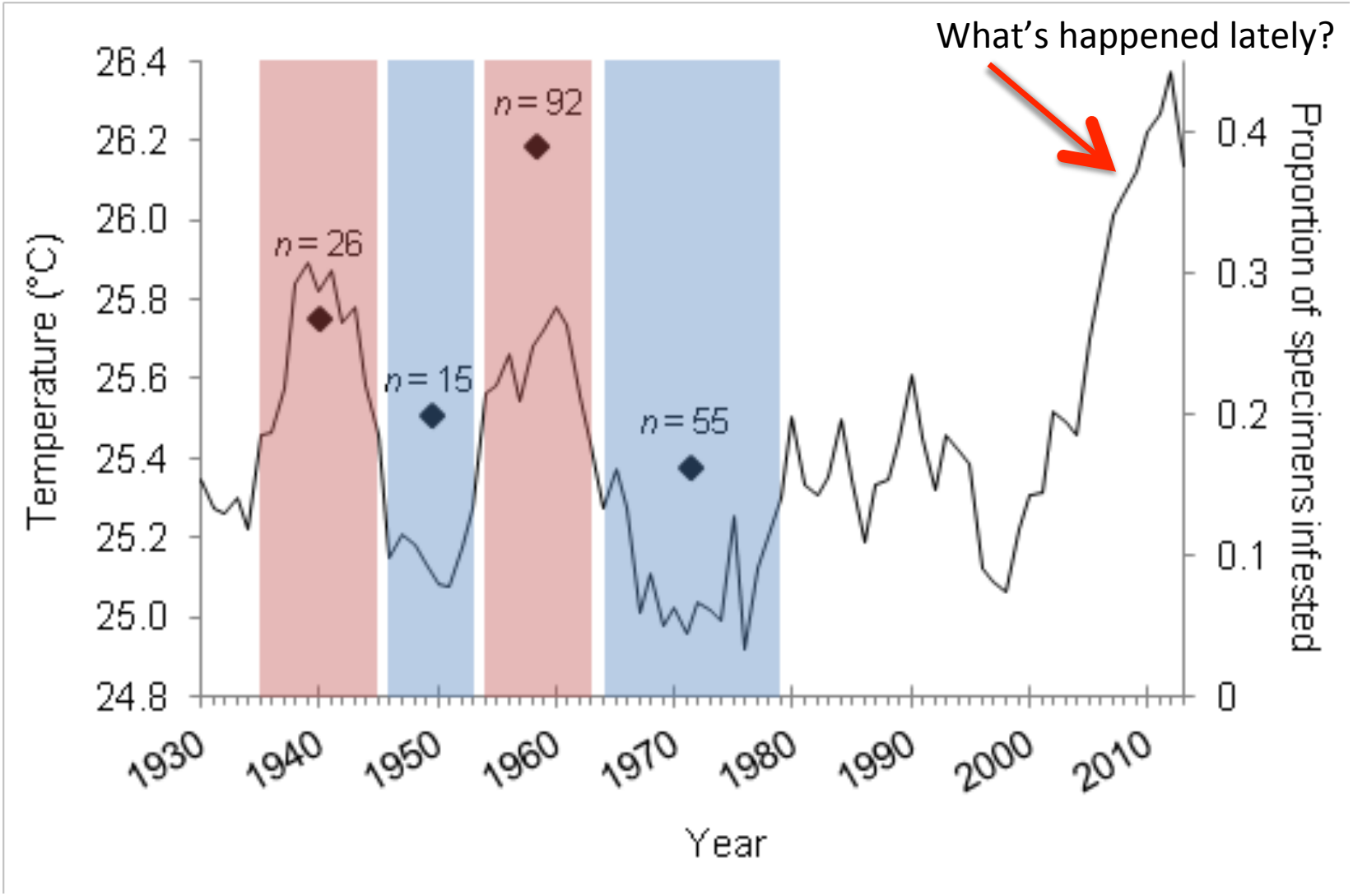
Youngsteadt et al. *2014. Global Change Biology*.

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



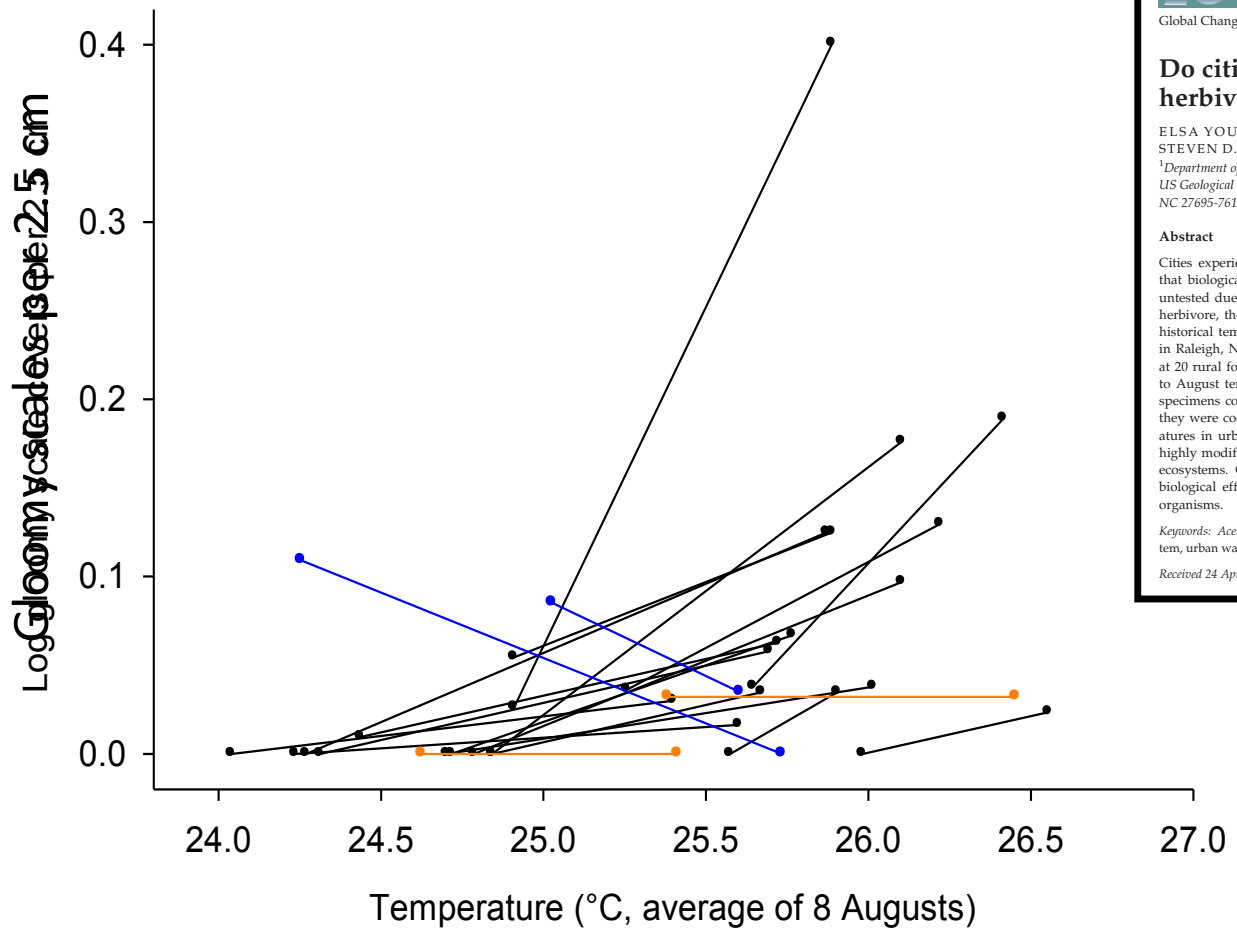
Youngsteadt et al. *2014. Global Change Biology*.

Gloomy scale abundance responds to natural climate variation



Youngsteadt et al. *2014. Global Change Biology*.

Revisit 20 sites to document current gloomy scale abundance



Global Change Biology

Global Change Biology (2014), doi: 10.1111/gcb.12692

Do cities simulate climate change? A comparison of herbivore response to urban and global warming

ELSA YOUNGSTEADT[1], ADAM G. DALE[1], ADAM J. TERANDO[2,3], ROBERT R. DUNN[4] and STEVEN D. FRANK[1]

[1]*Department of Entomology, North Carolina State University, Raleigh, NC 27695-7613, USA,* [2]*Southeast Climate Science Center, US Geological Survey, Raleigh, NC 27695-7617, USA,* [3]*Department of Applied Ecology, North Carolina State University, Raleigh, NC 27695-7617, USA,* [4]*Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695-7617, USA*

Abstract

Cities experience elevated temperature, CO_2, and nitrogen deposition decades ahead of the global average, such that biological response to urbanization may predict response to future climate change. This hypothesis remains untested due to a lack of complementary urban and long-term observations. Here, we examine the response of an herbivore, the scale insect *Melanaspis tenebricosa*, to temperature in the context of an urban heat island, a series of historical temperature fluctuations, and recent climate warming. We survey *M. tenebricosa* on 55 urban street trees in Raleigh, NC, 342 herbarium specimens collected in the rural southeastern United States from 1895 to 2011, and at 20 rural forest sites represented by both modern (2013) and historical samples. We relate scale insect abundance to August temperatures and find that *M. tenebricosa* is most common in the hottest parts of the city, on historical specimens collected during warm time periods, and in present-day rural forests compared to the same sites when they were cooler. Scale insects reached their highest densities in the city, but abundance peaked at similar temperatures in urban and historical datasets and tracked temperature on a decadal scale. Although urban habitats are highly modified, species response to a key abiotic factor, temperature, was consistent across urban and rural-forest ecosystems. Cities may be an appropriate but underused system for developing and testing hypotheses about biological effects of climate change. Future work should test the applicability of this model to other groups of organisms.

Keywords: *Acer rubrum*, climate change, global warming, herbivory, historical comparison, *Melanaspis tenebricosa*, urban ecosystem, urban warming

Received 24 April 2014 and accepted 8 July 2014

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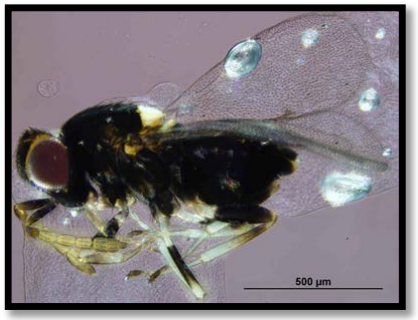

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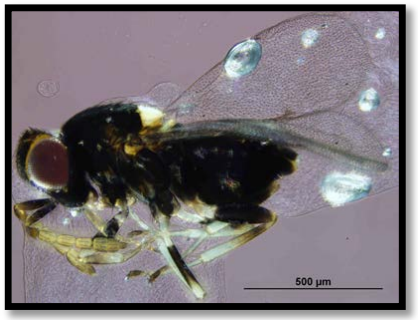
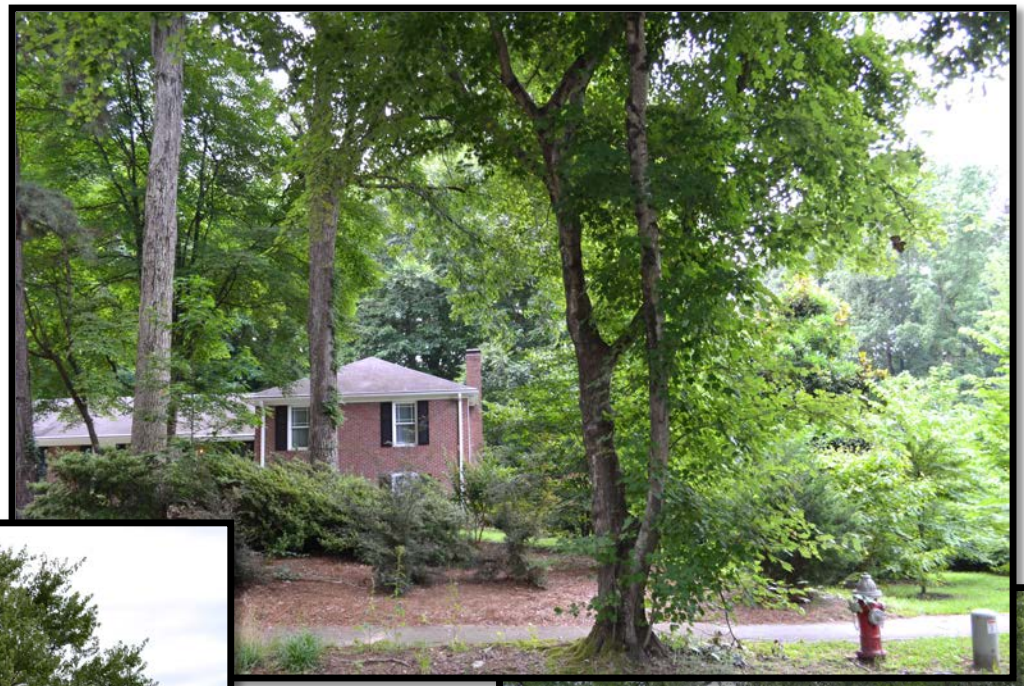
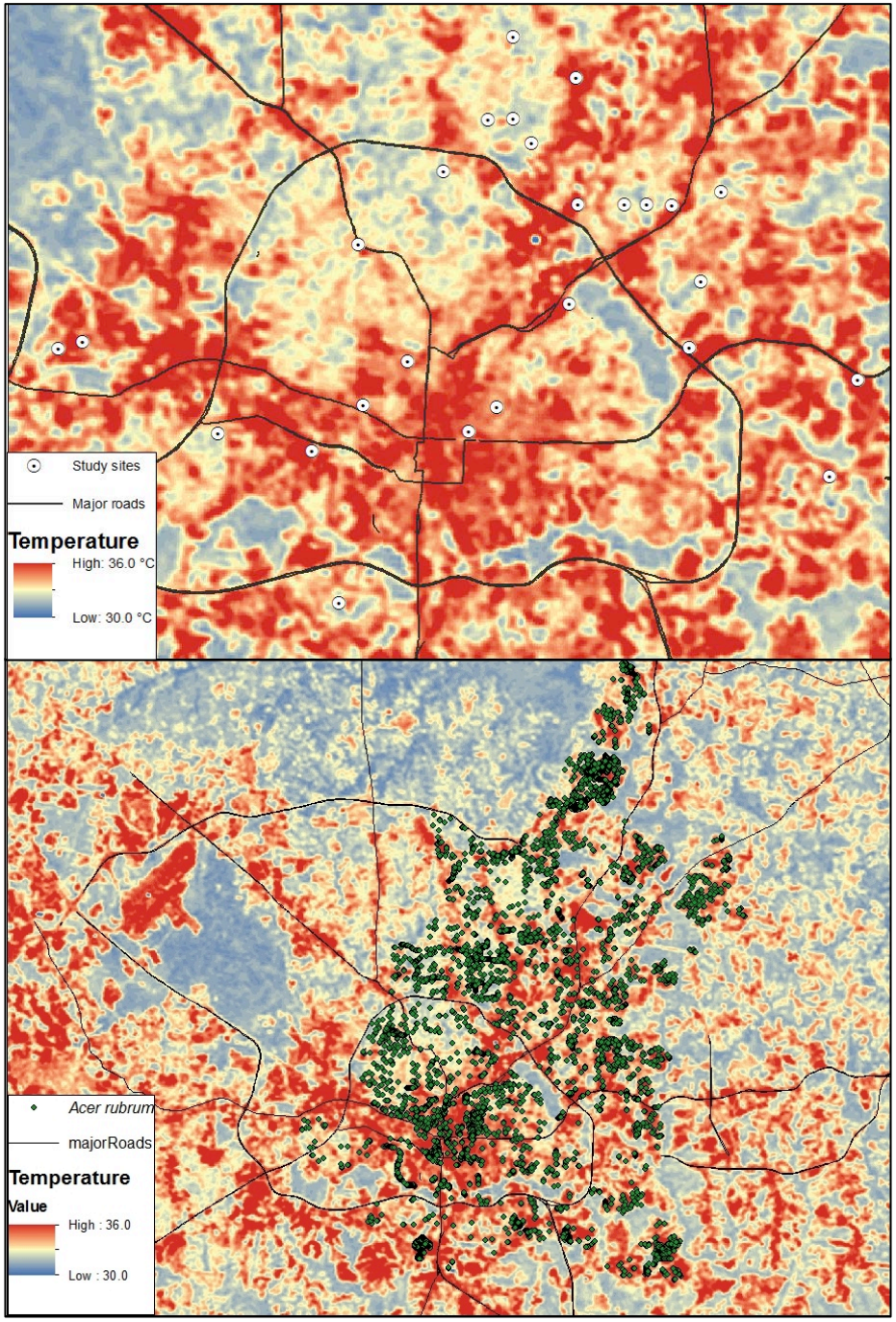


How do temperature and scales affect tree condition





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PLOS ONE

The Effects of Urban Warming on Herbivore Abundance and Street Tree Condition

Adam G. Dale*, Steven D. Frank

North Carolina State University, Raleigh, North Carolina, United States of America

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.

Citation: Dale AG, Frank SD (2014) The Effects of Urban Warming on Herbivore Abundance and Street Tree Condition. PLoS ONE 9(7): e102996. doi:10.1371/journal.pone.0102996

Editor: Ben Bond-Lamberty, DOE Pacific Northwest National Laboratory, United States of America

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Data Availability: The authors confirm that all data underlying the findings are fully available without restriction. Data are available on Figshare at: 10.6084/m9.figshare.1083873.

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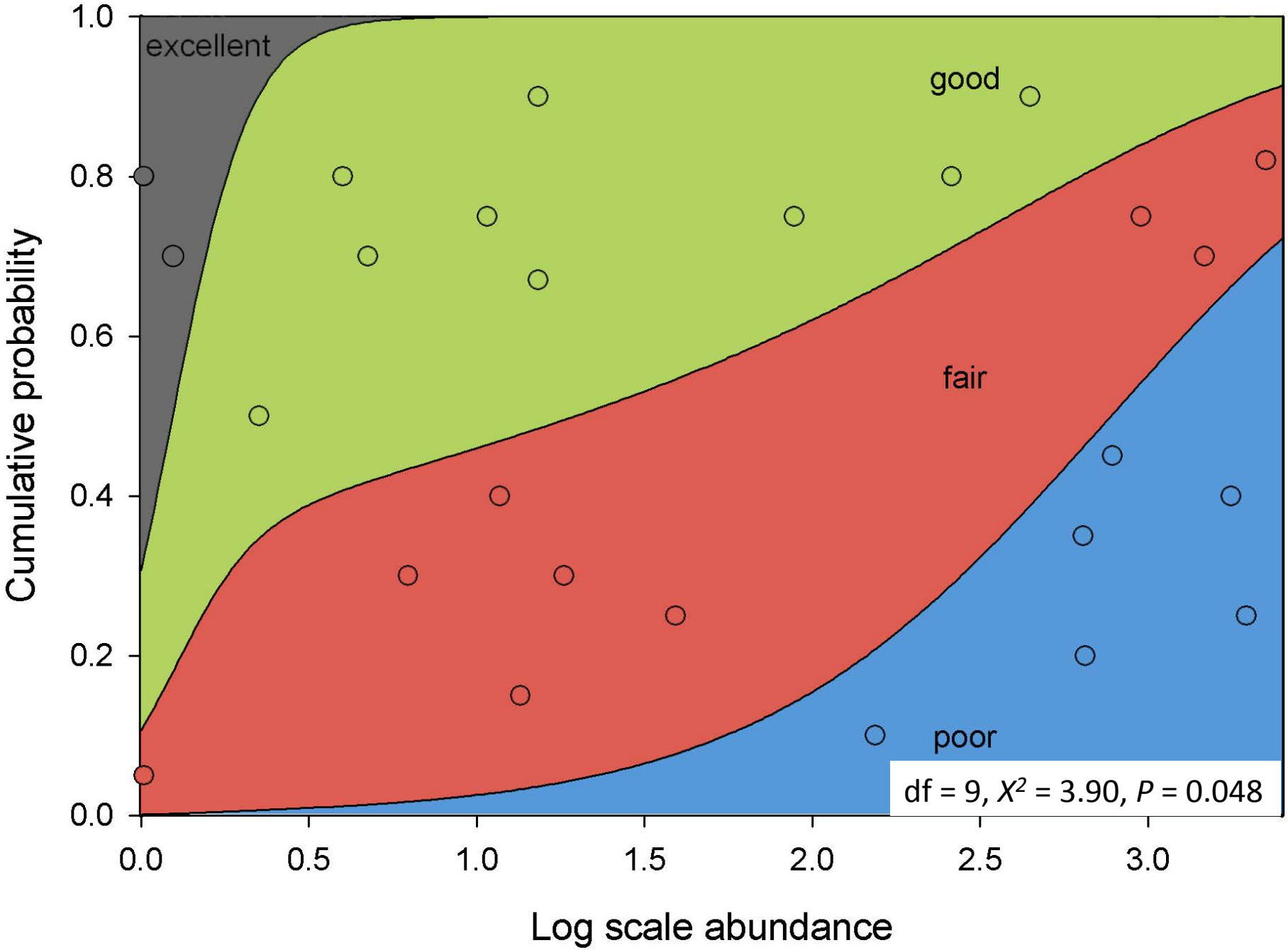
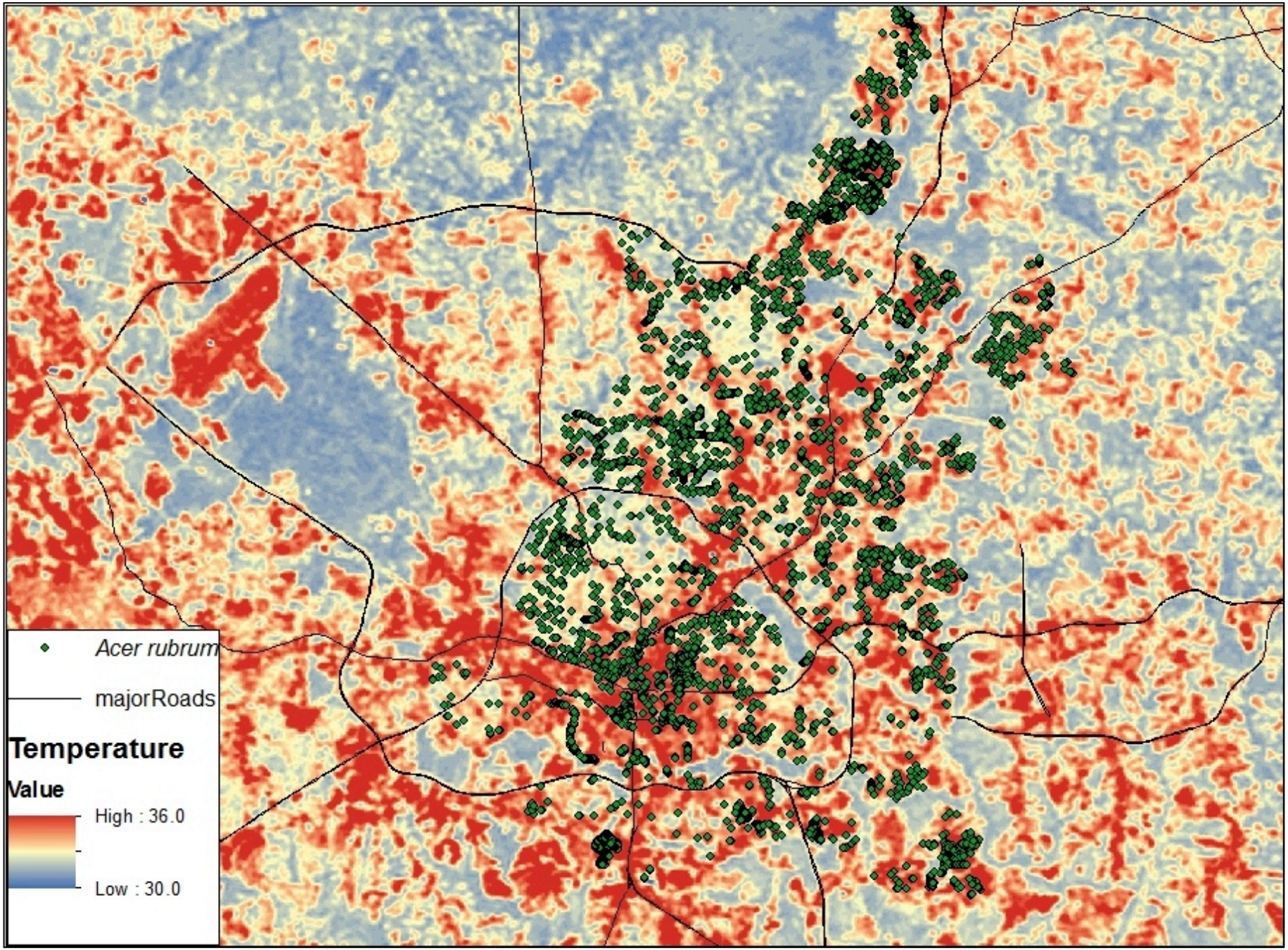
Competing Interests: The authors have declared that no competing interests exist.

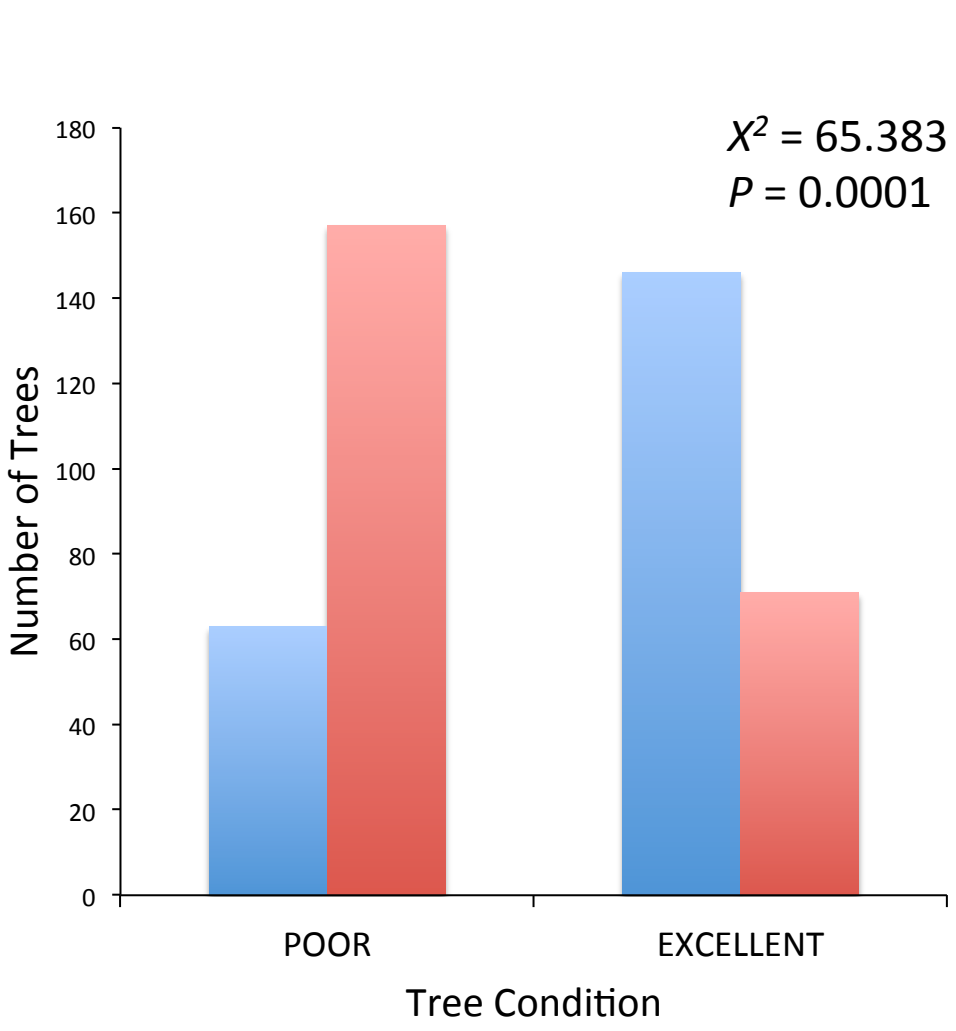
* Email: agdale2@ncsu.edu



Dale & Frank. 2014. *PLoS One*.

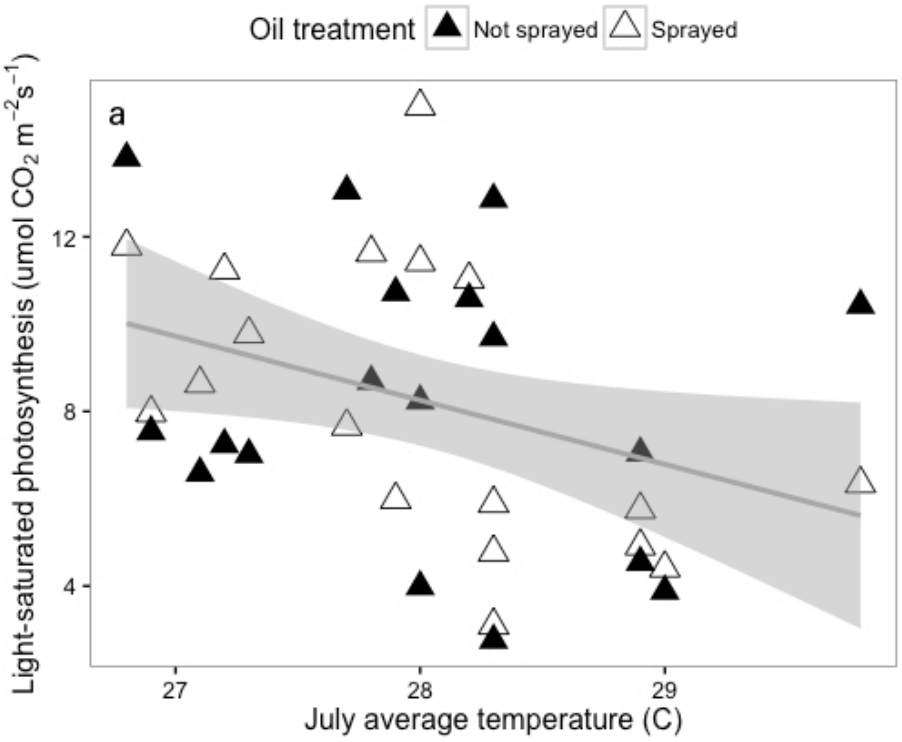

Acer rubrum
majorRoads
Temperature
Value
High : 36.0
Low : 30.0

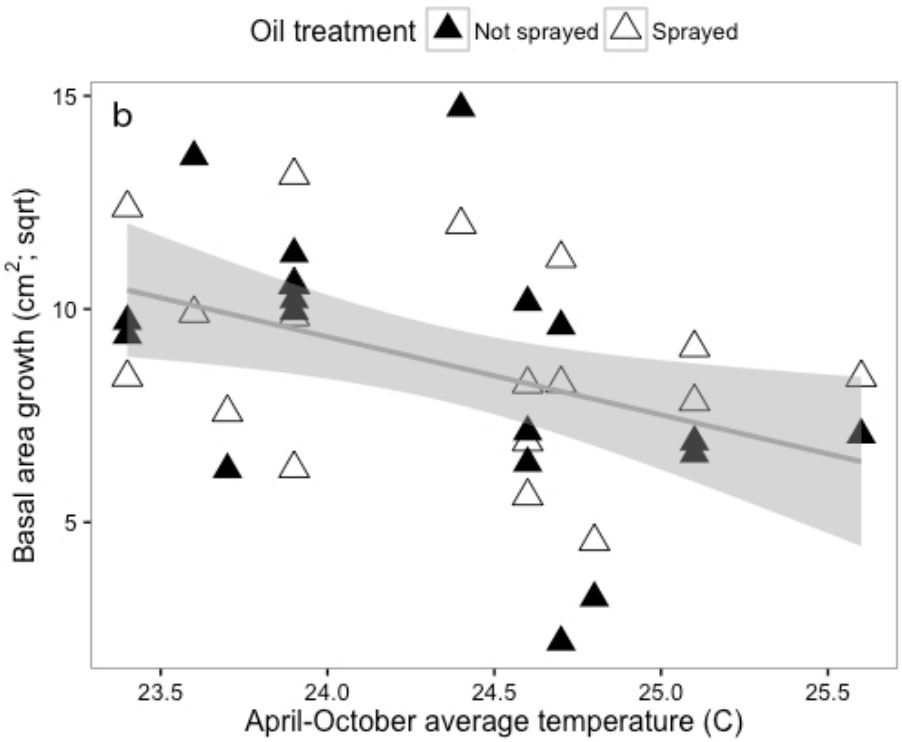
Number of hot and cool trees in poor or excellent condition



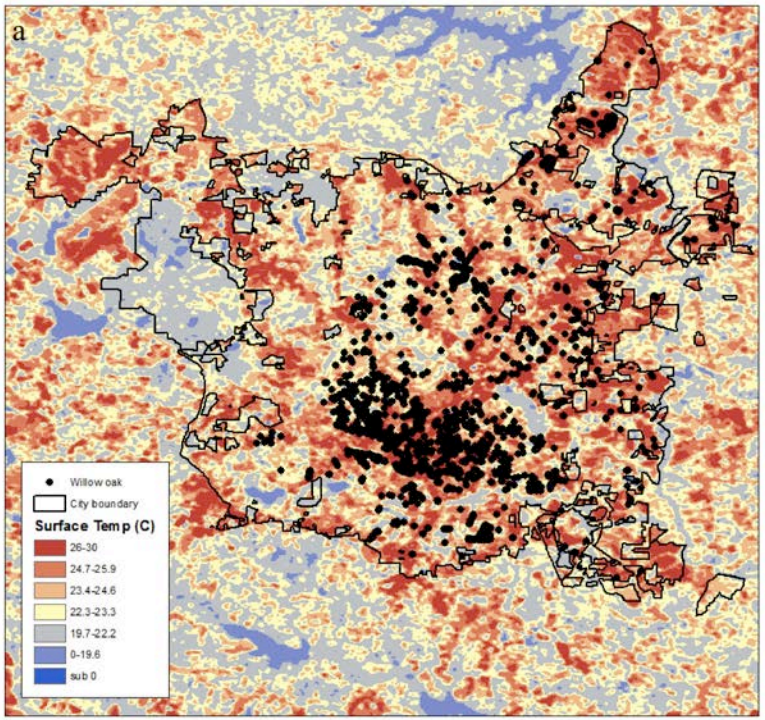
Dale & Frank. 2014. *PloS One*.

Tree Functions





Meineke et al. 2016. *Proceedings of the Royal Society-B*.



Tree Services

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

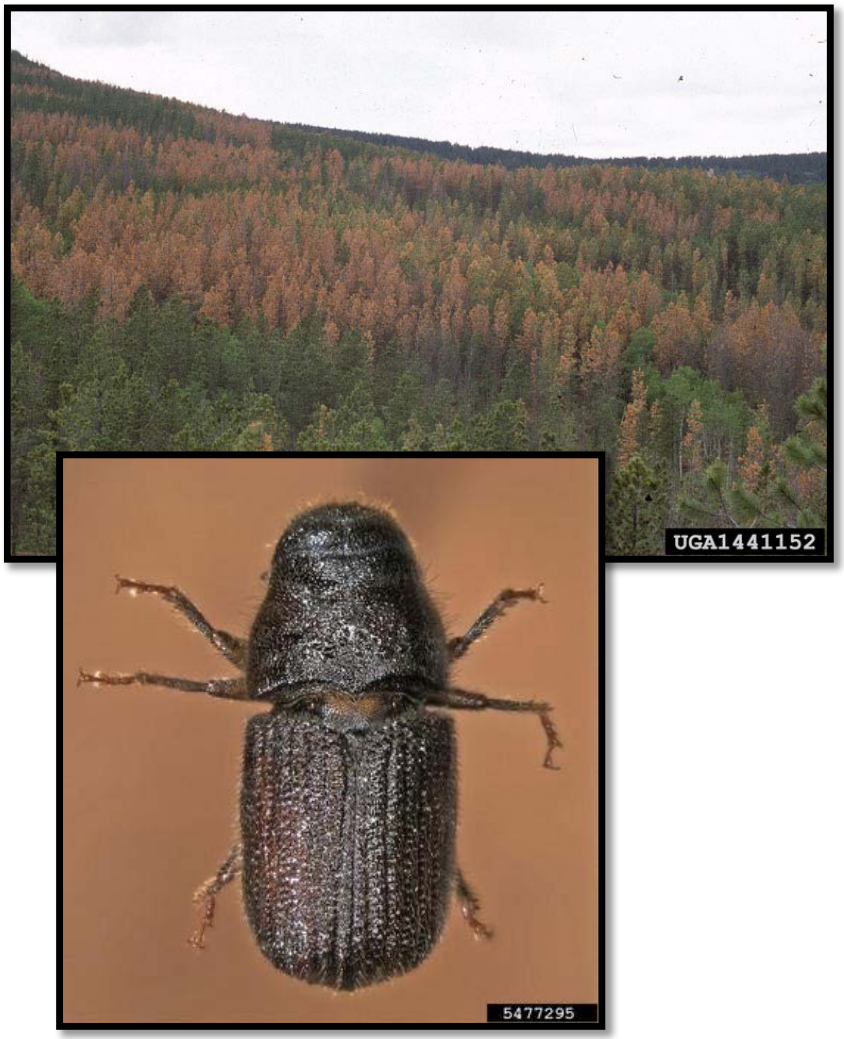
Warming reduces city-wide carbon sequestration by willow oaks 12%

Meineke et al. 2016. *Proceedings of the Royal Society-B*.

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

  Southeast Climate Science Center

  Raleigh Parks, Recreation and Cultural Resources
  - Sally Thigpen
  - Zach Manor

Field and Lab Help

Andrew Ernst, George Washburn, Cat Crofton, Daniel Schmidt, Anna Holmquist, Nicole Bissonette, Caitlin Melvin, Bobby Noukoun, Greg Bryant, Eric Archer, Allie Stewart, Uchenna Nwoko, Morgan Duncan, Laura Daly, Annemarie Nagle

Post doc and grad student positions available.

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