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What makes tree pests more successful?

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Abstract

Have you ever noticed tiny bumps on the branches of a tree? These may have been scale insects. These small insects feed on tree *sap*. Scale insects on urban trees are notably more *abundant* than those on rural trees. As a result, urban trees suffer from heavy infestations, and are often unhealthy or die. To protect and restore urban tree health, we needed to determine the factors that make these tree pests more successful in urban habitats.

Living organisms interact closely with each other and their environment. For this reason, we investigated the combined effects of urban warming and drought on trees and their insect pests. We measured drought stress in trees, counted the number of insects on each tree, the *embryos* developing inside female insects, and measured their body sizes.

The warmer, more drought-stressed trees harboured more successful pests than cooler, less drought-stressed trees. Our data suggest that as cities and natural habitats become hotter and drier, damaging scale insects will become more abundant.

Introduction

More than half of the world's population lives in cities. Across the globe, people are moving into cities at a faster rate than ever. Rapid growth may turn cities into places with harsh conditions that contain few nature-filled spaces. However, healthy plants and wildlife can help cities manage the challenges they face.

Although cities are primarily made of buildings, roads, parking lots, and vehicles, there are still plants in them. The trees within a city are referred to as the urban forest (Fig.1). Urban forests offer tremendous benefits to human and environmental health. They improve air and water quality, provide habitat for wildlife, cool down temperatures, reduce stormwater flooding, and beautify our environment. They make cities livable.

However, being a city tree is not easy. Urban forests have to combat a number of stressors:

- Heat released by human activities, concrete, and steel is trapped in cities. As a result, temperatures in urban areas are often warmer than their surrounding rural areas. We call this urban warming or the *urban heat island effect*.

Figure 1:
Trees within urban forests are valuable economically, aesthetically, and for the environmental sustainability of the region.

- Urban habitats are mostly made of *impermeable* surfaces (asphalt, concrete, packed soil). These surfaces reduce the amount of rainwater that reaches tree roots and causes drought stress.

Urban forests are often more heavily infested with *herbivorous arthropod* pests than plants in surrounding rural areas. These pests reduce tree health and the benefits trees provide for people and the environment.

In order to maintain and improve the health of our urban forests, we need to understand the complex relationships between the urban environment, plants, and pests. In this study we focused on two environmental factors that are common across nearly all urban landscapes to see how they affect herbivore *fitness* and *abundance* on urban trees.

We tested the *hypothesis* that urban warming and drought stress will combine to increase *fertility*, body size, abundance, and population growth of scale insects - pests that damage trees.

Methods

We studied the gloomy scale insect (*Melanaspis tenebricosa*) on red maple trees (*Acer rubrum*) in Raleigh, North Carolina (Fig. 2). The gloomy scale is an *armored scale* insect. It uses its pierce-sucking mouthparts to feed on tree sap. Red maple is a widely spread native tree in North America and the most commonly planted urban tree species in the southeastern U.S. Gloomy scale insects love red maples - especially those that live in cities.

To select our study sites, we created a grid and divided the city into equal *quadrants*. After randomly selecting three grid squares from each quadrant, we picked four trees in each selected grid.

For each tree, we measured:

1. Tree canopy temperature: We recorded the temperature within each tree's canopy every two hours during the summer months when gloomy scales are most active and developing.

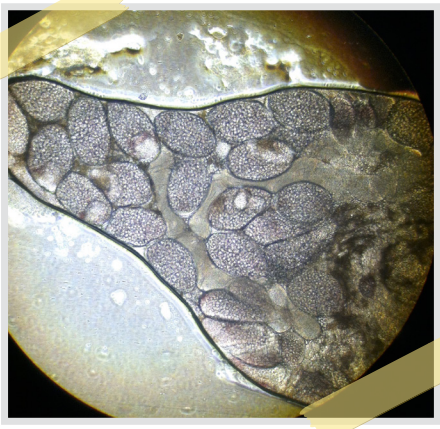
2. Drought stress: For two years, from May through August, we watered half of the trees twice a week and did not water the other half (Fig.3). To determine the level of drought stress, we periodically measured the amount of pressure in the tree's *xylem* (vascular system).

3. Gloomy scale fitness: We collected adult female gloomy scales, measured their body size, dissected them, and counted the number of embryos they had inside (Fig. 4).

Figure 2:
Red maple tree and its gloomy scale insect pests. (*Their name is "gloomy". It has nothing to do with their mood!*) A heavy infestation like this causes a tree to lose its branches and eventually die.

Figure 3:
Irrigation bag on a red maple.

Figure 4:
A microscope image of embryos recently dissected from a female gloomy scale insect.



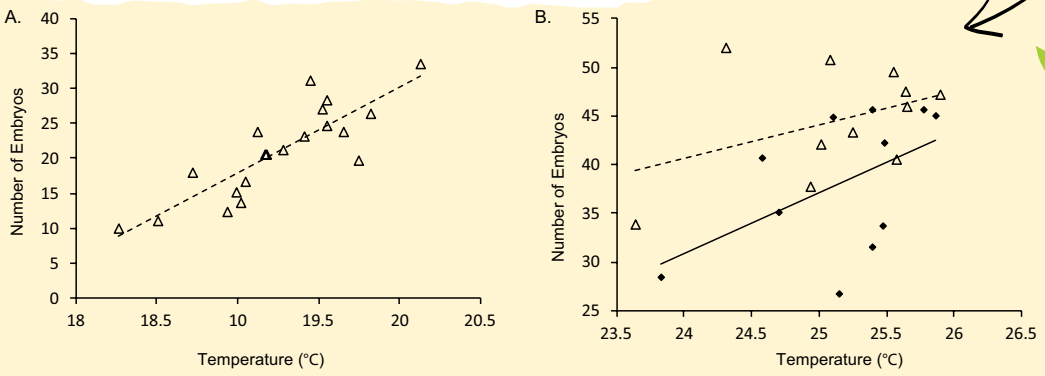
Results

The combined effect of drought stress and heat increased gloomy scale fitness and abundance on urban red maple trees. The warmer and drier the tree got, the bigger, more fertile, and more abundant the gloomy scale insects became (Fig. 5).

Figure 5:
Effects of temperature and watering on embryo production.

A) In a previous experiment, we found a relationship only between temperature and gloomy scale embryo production.

B) In this study, we found a relationship between two variables (temperature and watering) and embryo production.



A.) Dale, AG, Frank, SD. 2014. Urban warming trumps natural enemy regulation of herbivorous pests. Ecological Applications.

Discussion

Plants, insects, and the environment are intimately associated. They interact and respond to changes among each other. Because of this connectedness, when we search for answers to complex questions like the effects of *urbanization* or *climate change*, we need to consider multiple mechanisms. Here, we show that the combined effects of drought and urban warming benefit the fitness of a plant-feeding insect.

How are all these connected? Previous research has shown that when a tree is under drought stress, sugar and nitrogen concentrations within its vascular system increase. In addition, plants may become less able to defend themselves against pests. This means delicious and unprotected food for sap-feeding insects like the gloomy scale insect. As a result, these pests increase their body size, the number of offspring they produce (embryo production), and their abundance.

All of this doesn't sound too good for the trees. But here is the good news: Watered trees have less drought stress and smaller insects compared to the unwatered trees. This means that if we can reduce drought stress on urban trees, we may be able to effectively reduce damaging insect pest abundance.

Conclusion

Cities are the most rapidly expanding ecosystems on the globe. As cities continue to grow, factors like urban warming and drought stress may increase plant pest fitness. As a result, urban forests may suffer, which can negatively affect people and the environment.

What can we do to restore urban forests?

- Regular irrigation (watering) when possible may help keep herbivorous pest populations under control.
- Planting tree species that are better equipped than red maples to handle heat and drought stress would also reduce the occurrence of insect pest outbreaks.
- Take action to reduce urban heat islands. Visit the U.S. Environmental Protection Agency (epa.gov/heat-islands) website for some cool ideas.
- Make an effort to incorporate nature into your city life. Plant more trees and other vegetation to increase biodiversity and environmental sustainability in urban areas.

Glossary of Key Terms

Abundance – number of individuals in a given area. *There is an abundance of gloomy scale insects on heavily infested trees.*

Armored scale – a sap-feeding insect with a waxy, protective body covering. *Armored scale insects have a shell to protect their body.*

Arthropod – an invertebrate animal with an exoskeleton (external skeleton), segmented body, and jointed appendages (legs). This group includes insects, spiders, scorpions, millipedes and shrimp.

Biodiversity – diversity of all living organisms in an ecosystem, biological variety. *Rainforests support the greatest biodiversity on Earth.*

Embryo – an organism at any time before birth or hatching. *A human embryo develops for 40 weeks before it is ready to be born.*

Environmental sustainability – the interaction with the environment where the needs of present generations are met without compromising the needs of future generations. *Maintaining enough resources for everyone.*

Fertility (Synonym: Fecundity) – ability to reproduce. Animals with higher fertility produce more offsprings.

Fitness – how well an organism can survive and reproduce in an environment. *Survival of the fittest.*

Herbivorous – an animal that eats only plants. *Goats are herbivorous.*

Hypothesis – a prediction scientists make (usually based on observation or previous scientific knowledge) which can be tested.

Impermeable – a material that prevents fluids from passing through. *An impermeable coat will prevent rain from passing through and keep your clothes dry.*

Quadrant – dividing an area into four equal parts, each part is called quadrant.

Sap – carries water and nutrients to all the parts of the tree. Sap is like the blood of the tree. *The sap of maple tree is sugar-rich and used to make maple syrup.*

Urban heat island effect – an urban area that is significantly warmer than its surrounding rural areas due to human activities. Buildings, roads, asphalt and concrete in cities absorb the sun's heat during the day causing surface temperatures to rise. After sunset, while rural areas cool of rapidly, trapped heat in the infrastructures of a city keeps it warm. In the evening, the difference between urban and rural areas can be as high as 22°F (12°C).

Urbanization – people moving from rural to urban areas (cities) and developing rural or natural land into man-made structures. *Urbanization may result in smaller natural areas close to where people live.*

Xylem – one of the two major types of transport tissue in vascular plants (e.g. trees). *The main function of xylem is to transport water from the roots to the leaves of the plant.*

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Meineke EK, Dunn RR, Sexton JO, Frank SD. (2013) *Urban warming drives insect pest abundance on street trees.* PLOS One.
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0059687

United States Environmental Protection Agency
https://www.epa.gov/heat-islands

Check your understanding

1 How do urban forests make cities more livable?

2 What are some factors that make an urban tree's life not so easy?

3 What is the urban heat island effect and what causes it?

4 How can we reduce the urban heat island effect?

5 What are some factors that make pests more fit in cities?

6 Why is it important to analyze an ecosystem as a whole instead of individual organisms or environmental factors? What is the evidence in this article?