Urban Ecology of Orb-weaving Spiders

The effect of noise pollution on the foraging behaviour of *Zygiella x-notata*

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Introduction

Urbanisation is one of the side effects of rapid global population growth and development. With increased urban development comes an **increase in noise pollution**.

These can interact with the auditory cues and signals that many animals employ by masking,distracting or misleading them.

Spiders particularly seem to offer an abundance of research interest in bioacoustics, having evolved to effectively pick up surrounding vibrations. **Webs have evolved to act like an antenna**- receiving and processing vibrations beyond what the individual could do by themselves.

How are spiders affected by increased anthropogenic noise?

Research Aims

1. How does the way spiders **construct their webs** change between different habitat noise levels?
2. How does **foraging behaviour** differ when exposed to different **prey stimuli** based on habitat noise levels?

Methodology

Experiment 1: Measuring web attributes

Webs act a **frozen snapshot** of the **foraging decisions** made by spiders. Orb webs have specific characteristics that can be reliably measured and compared. *Z x-notata* has a unique "missing sector" web, as shown below in Figure 1.

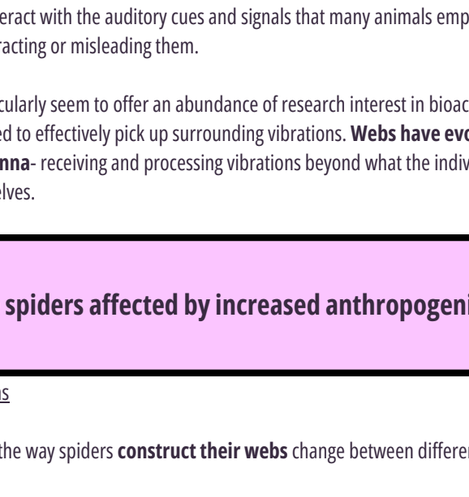

Figure 1: Modified picture of a slightly damaged *Z. x-notata* web (PMC03) taken by me near Port Meadow, Oxford. Counted and measured constituents labelled. ST = Signal thread, S = Spiral threads, H = Hub, R = Radius, AT = Anchor thread, dv = vertical diameter, dh = horizontal diameter, ru = Upper radius, rd = Lower radius.

These attributes were measured at almost 100 different webs across Oxford. Further calculations were made from these base measurements. **Comparing** characteristics between **different background noise levels** can show if that background noise is considered during web construction.

Experiment 2: Measuring reactions to prey frequencies

Tuning forks have been used for years in lab settings to **measure spider responses to prey wing beat frequencies**, but recently their proficiency for field experiments was shown by Davies and Hesselberg. I recorded videos of myself conducting tuning fork experiments at 34 different webs and used video processing software to find the **reaction times** and classify **different response types.**

440 Hz	256 Hz	128 Hz	32 Hz
• Small prey • e.g flies, mosquitoes	• Larger prey • e.g bees • Previously used to induce escape responses	• Large prey or predators • e.g parasitic wasps	• Experimental frequency • May stimulate traffic vibrations
 Photo by Erik Karits	 Photo by Jason Leung	 Photo by Gordon Woodcock	 Photo by Mike Bird

Figure 2: A table outlining the four tuning forks used for this experiment and their intended simulations.

Figure 3: A screenshot from a video showing the behavioural experiment in progress. A tuning fork is held to the bottom of a web, and a spider is seen at the hub as a result

Every spider was treated with **all four tuning forks**, but the **order** of which they were presented to the spider was **randomised**. Forks were assigned numbers from 1 to 4, and a random number generator was used to determine the order of use for each trial. This fork was then **held against the bottom of the web as it vibrated**. I removed the fork after the spider had come towards it, or the fork had stopped vibrating.

Results

In total, 98 different webs were measured and 34 behavioural experiments were conducted. I split these sites into **Urban and Park sites** based off distance to roads and abundance of greenery.

The **difference in decibels** between Urban and Park sites was shown to be **significant** ($p = 0.0002$), as was expected from my assumptions based off proximity to and amount of road and foot traffic in the area. This allows me to assume that **difference in background noise could be a possible factor for spiders to consider during web construction**.

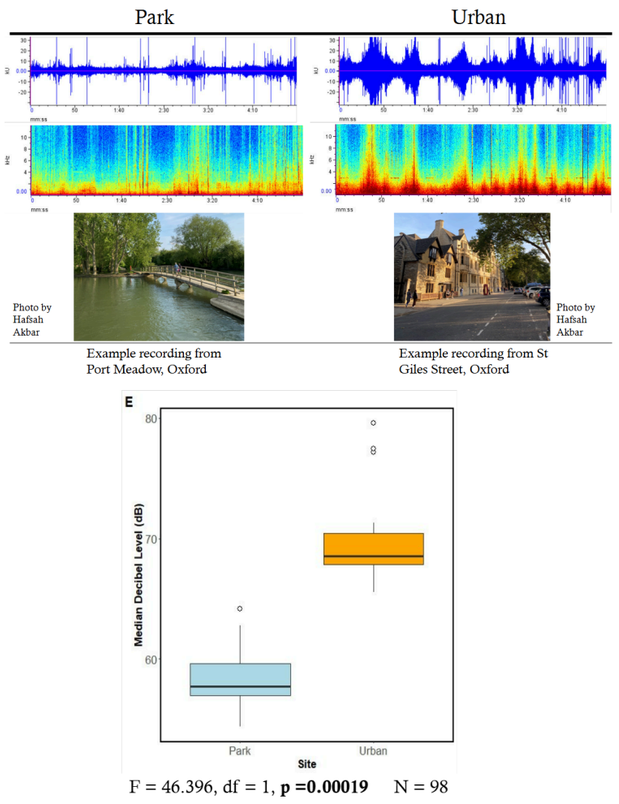

Figure 3: Waveforms and spectrograms of two sample noise recordings from a Park and Urban site (top). Bar graph showing the difference in medican decibel levels (dB) between Park and Urban sites (bottom).

In Experiment 1, 46 of the webs measured were defined as Park sites and 52 were classed as Urban. There was **no significant difference** between any measured or calculated **web characteristics** between Park and Urban sites.

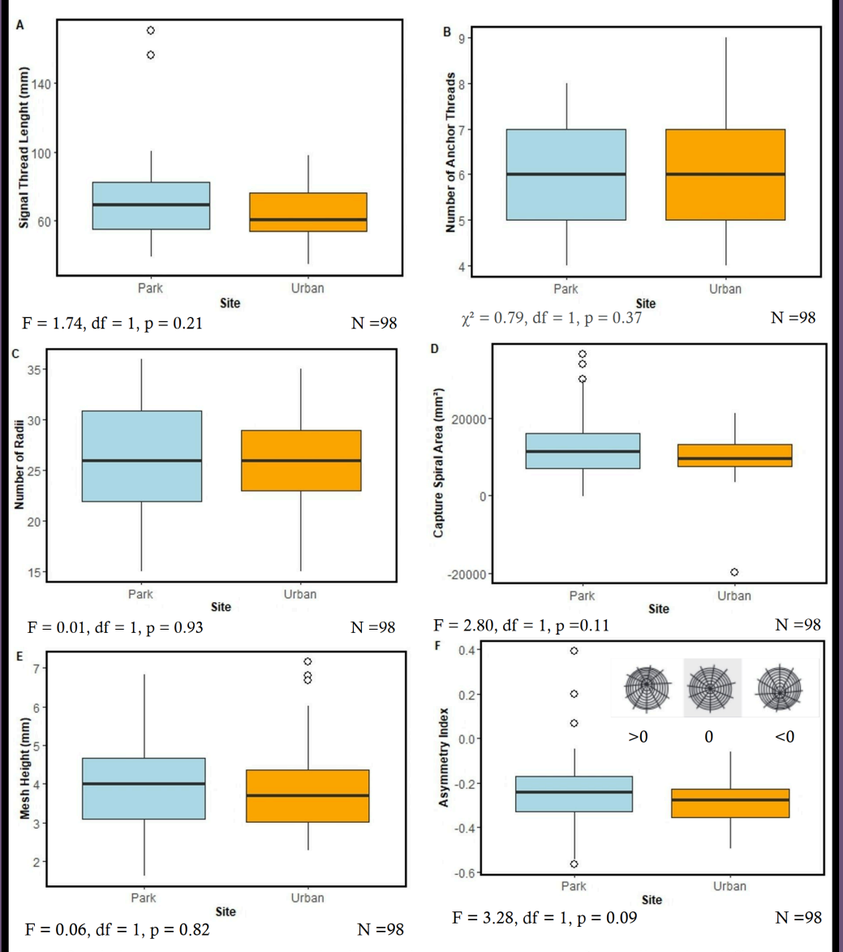

Figure 4: Compilation of comparative boxplots showing differences in measured values between Park and Urban sites. (A) Signal thread length, (B) Anchor thread count, (C) Radii count, (D) Capture spiral area, (E) Mesh height, (F) Asymmetry.

Of the 34 tuning fork experiments, 17 were from Urban sites and 17 were from Parks. The categories with the lowest occurrence of responses were grouped together into one category called "**Non-attack responses**". This category included "Moved away", describing how a spider seemed to retreat further back in response to a tuning fork and "Left retreat", which is when an individual did leave the retreat but did not make it to the Hub. The response "Leg movement" was also included in "Non-attack responses", which is when a spider's legs were seen to move but the actual body of the spider stayed within the retreat. The other remaining categories included "**Went to Hub**" and "**Attacked Fork**", which describe the finishing position of the spider at the end of the tuning fork experiment.

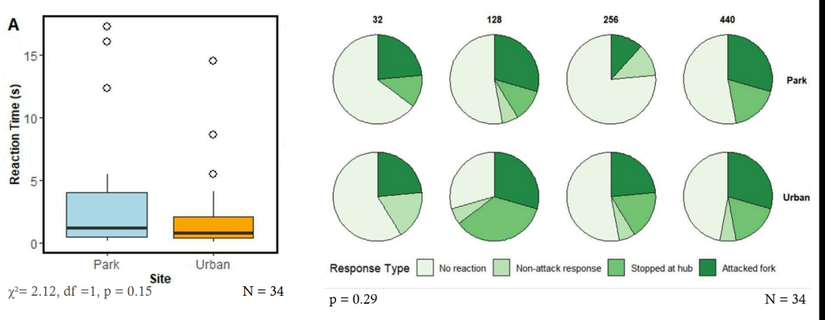

Figure 4: Box plot showing difference in reaction times (s) between Park and Urban sites (left). Compilation of pie charts showing the proportion of reaction types between fork frequencies and sites.

Discussion

No difference in web construction depending on the amount of noise in their environments

- **Other factors** may have **more influence** on web construction
  - Spiders living in roadside locations are not only subject to more noise, but also more **stress and pollution.**
- Future directions
  - **increasing** study **scale**
    - conducting these experiments in bigger cities
    - including "Rural" sites outside of the city
    - including more species like *Araneus diadematus* to compare between species

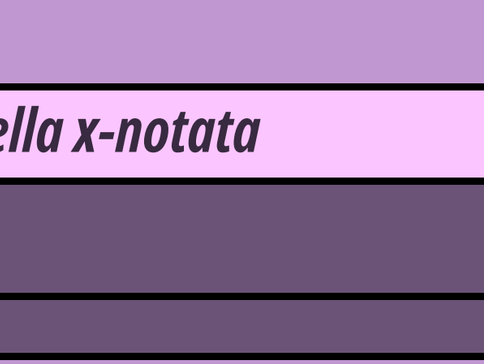

Figure 5: Map of Oxford and points showing where data was collected from, colour coded by whether it was classified as Park or Urban.

  - measuring **prey and predator abundance** and sizes.
    - prey and predator species may be less abundant in roadside locations

No difference in reaction times or response types to tuning fork stimuli **between Sites.**

- However, some trends can be observed
  - **Park sites had a higher proportion of No Reactions and Non-attack responses.** This could be due to:
    - **Abundance of prey**
      - Less prey species by the road because of the "windshield effect"
      - Spiders in Urban areas may have more scarcity of food, so are more likely to react to the tuning forks than Park spiders
    - **Increased predation risk**
      - More predator species, like parasitic wasps, likely to be found in greener locations
        - This could mean more hesitation to leave the safety of the retreat.

No difference between responses and reaction times **between different forks** at either site

- This was an unexpected result, considering previous results by Davies and Hesselberg (2022).
  - They found a difference in response types between 256 Hz and 440 Hz.
    - More "Escape" responses seen in response to 256 Hz tuning fork
    - More "Attack" responses seen in response to 440Hz tuning fork
- This could be because this is the **first experiment of it's kind to be conducted on *Zygiella x-notata***
- Future directions
  - Conducting **species specific tuning fork analyses**

Conclusion

Even in noisier urban habitats, *Zygiella x-notata* builds its webs and responds to vibrations in ways that are remarkably consistent with its park-dwelling counterparts. The lack of clear differences raises new questions: **is anthropogenic noise less disruptive to spiders than expected**, or **are other urban pressures—like prey scarcity or predation risk—shaping their behaviour** instead?

These findings suggest that *Z. x-notata* may already be well-equipped to cope with the challenges of the Anthropocene. As cities continue to expand, **exploring how and why some spiders thrive while others decline will be key to understanding the broader ecological consequences of urbanisation.**

What can this tell us about our impact on the animals around us?

References

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Thank you to Dr Thomas Hesselberg for his supervision on this project.