From plants to birds: higher avian predation rates in trees responding to insect herbivory

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Introduction

• ‘Crying-for-help’ – tritrophic interaction between plants, herbivores and predators
• Feeding of larvae on a single branch can cause rapid systemic inducible responses in the tree
• Plant emissions can transmit herbivore-specific information that is detectable by e.g. parasitic wasps
  – volatile organic compounds (VOCs)
• Predators (birds, parasitic and predatory insects) can reduce densities of leaf-chewing insects and thus improve plant fitness
Introduction

• Previous studies in aviary
  – Birds (three species) more attracted to intact branches cut from herbivore trees than control trees
• How birds can find insect-rich trees?
  – Visual cues:
    • larvae and their faeces
    • holes in leaves
    • changes in reflectance (photosynthesis)
  – Olfactory cues:
    • VOCs

Experiment in nature

• Mountain birch (*Betula pubescens* ssp. *czerepanovii*) – autumnal moth larvae (*Epirrita autumnata*) – local insectivorous birds
  – at Kevo Subarctic Research Station in June 2007
  – 15 herbivore and 15 control trees
  – 3 × 20 larvae in each herbivore tree
• Plasticine larvae in both herbivore and control trees to study bird predation rate
  – 10 artificial larvae per tree
  – checked daily and replaced damaged for two weeks
• VOC emissions and net photosynthesis were measured from the same experimental trees
Mesh bags and plasticine larvae

Real and artificial larvae
Local passerine birds

- pied flycatcher (*Ficedula hypoleuca*)
- willow warbler (*Phylloscopus trochilus*)
- brambling (*Fringilla montifringilla*)
- great tit (*Parus major*)
- Siberian tit (*Parus cinctus*)
- common redpoll (*Carduelis flammea*)
- yellow wagtail (*Motacilla flava*)
- bohemian waxwing (*Bombycilla garrulus*)
- bluethroat (*Luscinia svecica*)
- fieldfare (*Turdus pilaris*)

Photos by Kalle Rainio

Plasticine larvae

- Bar chart showing the amount of damaged larvae over time. The chart compares herbivore and control treatments.
  - Treatment effect: $p = 0.0072$
  - Time effect: $p = 0.0007$
  - Time squared effect: $p = 0.0002$

Days since the start of defoliation

Amount of damaged larvae

0 5 10 15 20 25 30 35

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Plasticine larvae

Amount of damaged larvae

Days since the start of defoliation

VOCs

VOC emissions

VOC emission (ng cm$^{-2}$ h$^{-1}$)

VOC emissions

VOCs

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*
### VOC emissions × damaged larvae

<table>
<thead>
<tr>
<th>Compound</th>
<th>No.</th>
<th>Group</th>
<th>( r_s )</th>
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<tr>
<td>(E)-DMNT</td>
<td>#6</td>
<td>homoterpene</td>
<td>0.576**</td>
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<tr>
<td>( \beta )-ocimene</td>
<td>#4</td>
<td>monoterpene</td>
<td>0.454*</td>
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<tr>
<td>linalool</td>
<td>#5</td>
<td>monoterpene</td>
<td>0.454*</td>
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<tr>
<td>( \beta )-bourbonene</td>
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<tr>
<td>cis-3-hexen-1-ol+(E)-2-hexenal</td>
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<td>green leaf volatile</td>
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<tr>
<td>cis-3-hexenyl butyrate</td>
<td>#15</td>
<td>green leaf volatile</td>
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<tr>
<td>( \alpha )-pinene</td>
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<td>monoterpene</td>
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<td>( \alpha )-copaene</td>
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<td>cis-3-hexenyl acetate</td>
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<tr>
<td>(E)-( \beta )-caryophyllene</td>
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<td>limonene</td>
<td>#3</td>
<td>monoterpene</td>
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<tr>
<td>caryophyllene oxide</td>
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<td>sesquiterpene</td>
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<tr>
<td>( \alpha )-humulene</td>
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<td>sesquiterpene</td>
<td>-0.023</td>
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<tr>
<td>( \beta )-myrcene</td>
<td>#2</td>
<td>monoterpene</td>
<td>-0.107</td>
</tr>
</tbody>
</table>

### Plasticine larvae

- **VOCs**
  - Treatment \( (p = 0.0072) \)
  - Time \( (p = 0.0007) \)
  - Time\(^2\) \( (p = 0.0002) \)

- **photosynthesis**
Discussion

- Birds were more interested in birches that had hidden defoliation by autumnal moth larvae than in control trees with no herbivory.
- The first evidence that passerine birds in nature can use cues other than visual recognition of herbivore larvae, damaged leaves or larval faeces to locate insect-rich trees.
- Many VOCs here that may attract birds are the same compounds that are known to attract insect parasitoids of the herbivores.
Discussion

• Support for both vision and olfaction as the candidate mechanism behind bird attraction
  – vision: different reflection in herbivore and control trees due to differences in photosynthesis
  – olfaction: significant differences in emissions of several VOCs between herbivore and control trees, and significant correlation with predation rate and three VOCs [(E)-DMNT, β-ocimene and linalool]

• More research is still needed about the role of both vision and olfaction

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Photo by Toni Nikkanen