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
  - $3 \times 20$ 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*)
Plasticine larvae

Days since the start of defoliation

Amount of damaged larvae

- Treatment ($p = 0.0072$)
- Time ($p = 0.0007$)
- Time squared ($p = 0.0002$)
Plasticine larvae

Amount of damaged larvae

Days since the start of defoliation

VOCs

treatment ($p = 0.0072$)
time ($p = 0.0007$)
time$^2$ ($p = 0.0002$)

herbivore control

Days since the start of defoliation

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

0 5 10 15 20 25 30 35
VOC emissions

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

- herbivore
- control

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### VOC emissions × damaged larvae

<table>
<thead>
<tr>
<th>Compound</th>
<th>No.</th>
<th>Group</th>
<th>$r_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E)-DMNT</td>
<td>#6</td>
<td>homoterpene</td>
<td>0.576*</td>
</tr>
<tr>
<td>β-ocimene</td>
<td>#4</td>
<td>monoterpene</td>
<td>0.454*</td>
</tr>
<tr>
<td>linalool</td>
<td>#5</td>
<td>monoterpene</td>
<td>0.454*</td>
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<tr>
<td>β-bourbonene</td>
<td>#11</td>
<td>sesquiterpene</td>
<td>0.242</td>
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<tr>
<td>cis-3-hexen-1-ol+(E)-2-hexenal</td>
<td>#13</td>
<td>green leaf volatile</td>
<td>0.224</td>
</tr>
<tr>
<td>cis-3-hexenyl butyrate</td>
<td>#15</td>
<td>green leaf volatile</td>
<td>0.162</td>
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<tr>
<td>α-pinene</td>
<td>#1</td>
<td>monoterpene</td>
<td>0.160</td>
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<tr>
<td>α-copaene</td>
<td>#7</td>
<td>sesquiterpene</td>
<td>0.147</td>
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<tr>
<td>cis-3-hexenyl acetate</td>
<td>#12</td>
<td>green leaf volatile</td>
<td>0.142</td>
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<tr>
<td>(E)-β-caryophyllene</td>
<td>#10</td>
<td>sesquiterpene</td>
<td>0.093</td>
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<tr>
<td>nonanal</td>
<td>#14</td>
<td>green leaf volatile</td>
<td>0.080</td>
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<tr>
<td>limonene</td>
<td>#3</td>
<td>monoterpene</td>
<td>-0.012</td>
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<tr>
<td>caryophyllene oxide</td>
<td>#9</td>
<td>sesquiterpene</td>
<td>-0.015</td>
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<tr>
<td>α-humulene</td>
<td>#8</td>
<td>sesquiterpene</td>
<td>-0.023</td>
</tr>
<tr>
<td>β-myrcene</td>
<td>#2</td>
<td>monoterpene</td>
<td>-0.107</td>
</tr>
</tbody>
</table>
Plasticine larvae

Days since the start of defoliation

Amount of damaged larvae

VOCs

herbivore control
treatment \( (p = 0.0072) \)
time \( (p = 0.0007) \)
time^2 \( (p = 0.0002) \)

photosynthesis
Net photosynthesis rate (+ 95% CL)

\[ p = 0.0024 \]

\[ \text{μmol m}^{-2} \text{s}^{-1} \]

Comparison between herbivore and control treatments.
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
Acknowledgements

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Thank you for your attention!