Actual and potential impact of insect pests on forests of the Barents region

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Introduction

- Climatic changes of past decades (reviewed by IPCC, 2001) have already caused detectable effects on different organisms and ecosystem processes.
- Increases of both atmospheric CO₂ and temperature are expected to further affect ecosystem structure and functions.
Insect-plant relationships, insect herbivore outbreaks and forest damage

- Modified interactions between herbivores and their host plants may have important consequences for forestry and agriculture.
- As a result, possible changes in noxiousness of herbivores have recently received considerable attention.
But…

- The number of *speculations* (‘*What if?’’) nearly exceeds the amount of data.
- Studies are restricted to *individual species* and does not allow ecosystem approach.
- In experimental studies, investigations of CO$_2$ effects dominate over research on the *combined* effect of CO$_2$ and temperature elevation.
Study goal

To provide a first approximation of the integration of different data and approaches in order to provide realistic prediction on potential changes in the impact of insect pests on forests of the Barents region during the nearest decades.
Input data

- Past data on pest outbreaks
- Studies linking pest performance and abundance with annual climate fluctuations
- Field data on foliage losses due to ‘background’ insect damage
- Meta-analysis of the combined effect of elevated CO$_2$ and temperature on herbivores
Brief survey of field-collected data

Past forest damage by eruptive insects

Effects of climatic variation on herbivores

Geographical variation in endemic herbivory
Past forest damage by eruptive insects: Definitions

‘Pest’ is a pejorative given to organisms that compete with humans for valued resources.

An outbreak: population density of a pest exceeded the ‘normal’ density by $\geq 100$, and/or the resulting damage significantly decreased functions of trees or stands.

Intensity of damage: 1, weak ($<30\%$ leaves damaged; plants are slightly weakened); 2, moderate ($31-70\%$, strongly weakened); 3, strong ($>70\%$, depressed or killed).
Data collection

- Study period: 1956-1998
- Study area: the Russian part of the Barents Sea region, within 61-69° N and 31-57° E limits.
- Data sources: official documents, scientific journals, and 'grey' literature, including unpublished technical and scientific reports.
- Altogether we screened 1200+ information sources, 248 of which contained relevant data.
- Information was cross-checked, and its reliability was evaluated through intensive consultations with local experts.
Data summary

- We received information on 135 outbreaks of 41 species.
- Most of records concern pests of Scots pine (74 outbreaks) and Norway spruce (31 outbreaks).
- The most extensive damage (an average outbreak area >5,000 ha) was imposed by European pine sawfly *Neodiprion sertifer* Geoffr. (12 outbreaks), autumnal moth *Epirrita autumnata* Bkh. (8 outbreaks), larch bud moth *Zeiraphera diniana* Gn. (3 outbreaks), and European spruce sawfly *Gilpinia hercynia* Htg. (3 outbreaks).
Past outbreaks of insect pests

The index of total forest damage (product of outbreak number, area, and intensity) in 1989-1998 was 4.9 times as high as in 1956-1965.
Differences between ecological groups

- The detected increase in incidence of pest insects was predominantly due to changes in population behaviour of species hibernating above snow cover.
- In this group (16 species, 55 outbreaks) both the annual number of outbreaks and intensity of forest damage steadily increased between 1955 and 1998, while the species which overwinter below the snow did not show significant changes.
Climatic effects on herbivores

Willow feeding leaf beetle
Chrysomela lapponica L.
(Coleoptera: Chrysomelidae)
Larval survival of *C. lapponica* in relation to temperature

\[ r = 0.77 \]

\[ P = 0.005 \]

\[ n = 11 \text{ years} \]

Survival increase:

7% with 1°C
Performance of *C. lapponica* in relation to host plant vigor

Higher summer temperatures may improve herbivore fitness by enhancing growth of host plants.
Geographical variation in endemic herbivory

Data on foliage losses due to “background” insect damage have been intensively searched for, but only some 20 data points were found, and no pattern emerged.

Conclusion based on published information: Foliage losses at the regional scale are <1% for conifers and <10% for birches, aspen and willows.
Foliage losses in birches due to endemic herbivory

Late summer of 2004
90 study sites
Variables:
- Proportion of damaged leaves
- Leaf area consumed
Losses of foliage in white birch due to endemic herbivory in relation to latitude.
Correlation of foliar damage in birches with climatic variables

<table>
<thead>
<tr>
<th>Birch species</th>
<th>Response variable</th>
<th>Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T (Jan)</td>
</tr>
<tr>
<td>B. pubescens</td>
<td>Leaves damaged</td>
<td>0.60*</td>
</tr>
<tr>
<td>(60 plots)</td>
<td>Loss of leaf area</td>
<td>0.64*</td>
</tr>
<tr>
<td>B. pendula</td>
<td>Leaves damaged</td>
<td>0.10</td>
</tr>
<tr>
<td>(25 plots)</td>
<td>Loss of leaf area</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*P<0.01
Foliage losses in birches: Conclusions

- Foliar damage in *B. pubescens* in Fennoscandia increased from 1-2% at 70°N to 5-7% at 60°N, mostly in terms of increase in proportion of damaged leaves.
- This pattern was best explained by temperatures of July.
- No pattern was revealed in foliar damage of *B. pendula* in Central Europe; losses were ≈5% between 60° and 48°N.
- Damage of northern birch forests by chewing and mining insects may double with the expected climatic warming, while in southern taiga forests the effects on birch foliar losses will be small or even negligible.
Meta-analysis of experimental data

Combined effects of elevated CO$_2$ and temperature on insect herbivores
Study method: Meta-analysis

Meta-analysis: statistical synthesis of the results of separate studies (quantitative research synthesis)

Effect size: a statistical measure of the magnitude of effect of interest

Meta-analysis provides more objective, informative and powerful way of summarising the results from individual studies as compared to narrative/qualitative reviews
Procedure of meta-analysis

- Data from different studies are transformed into a ‘common currency’ – **effect size** (ES)
- ES’s from individual studies are combined into a common estimate of the **magnitude** of the effect
- The **significance** of overall effect is computed
- The **homogeneity** of ES is calculated to check whether all studies share a common effect size
- Studies are grouped and the ES’s are **compared between groups**
Primary studies and data extraction

- Database: 42 publications (1987-2005) describing effects of elevated CO$_2$ and T both alone and in combination in controlled experiments.

- Response variables: (i) plant traits which may affect herbivore performance and (ii) herbivore performance and consumption rates (total of 224 effect size values).

- Concentration of CO$_2$ in most studies doubled, temperature increased by 3-6$^\circ$C relative to ambient.
Objects of primary studies: Plants

- Total of 31 species: 15 woody (7 gymnosperms and 8 angiosperms) and 16 herbaceous.
- Plant chemistry (all parts used by herbivores): nutritional value (nitrogen, C/N ratio) and defensive compounds (phenolics and terpenoids).
- Mechanical traits reflecting physical defences: leaf toughness, thickness, specific leaf area, resin droplets.
Objects of primary studies: Herbivores

Total of seven insects from three feeding guilds (chewers, miners, sap-feeders)
# Summary of effects

<table>
<thead>
<tr>
<th>Object</th>
<th>Variable (N)</th>
<th>CO₂</th>
<th>T</th>
<th>CO₂ +T</th>
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</thead>
<tbody>
<tr>
<td>Plants</td>
<td>Plant quality (45)</td>
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<td>(ns)</td>
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<tr>
<td></td>
<td>nitrogen (33)</td>
<td><img src="image" alt="↓" /></td>
<td>(↓ns)</td>
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<td>Defense (96)</td>
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<td>(ns)</td>
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<td></td>
<td>phenolics (50)</td>
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<td><img src="image" alt="↓" /></td>
<td>(ns)</td>
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<td></td>
<td>terpenoids (6)</td>
<td>(ns)</td>
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<tr>
<td>Herbivores</td>
<td>Performance (11)</td>
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<td><img src="image" alt="↑" /></td>
<td>(ns)</td>
</tr>
<tr>
<td></td>
<td>Consumption (12)</td>
<td>(ns)</td>
<td>(↑ns)</td>
<td>(↓ns)</td>
</tr>
</tbody>
</table>
Conclusions of meta-analysis

- Combined effects of CO$_2$ and T differ from the effects of these two factors acting separately.
- Plant traits that affect herbivore performance change respond differently to CO$_2$ and T, and therefore the resulting effects on herbivores are difficult to predict.
- CO$_2$ elevation reduces positive effects of T increase on herbivore performance.
- Combined effects of elevated CO$_2$ and T most likely would be detrimental for herbivores feeding on deciduous plants but negligible for feeding on evergreen plants.
We detected an overall increase in damage imposed by insect pests on the forests of the Barents region.

This increase was best expressed in species hibernating above snow cover, suggesting that elimination of low winter temperatures may explain this pattern.

Increase in summer temperatures is likely to improve performance of the pests that preferentially damage vigorously growing plants.

In long-term perspective, effects of temperature increase are likely to be mitigated by CO₂ elevation.