Evaluation of collembolan trait performance as effect indicator of environmental change

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Outline

\begin{itemize}
  \item The concept of \textit{traits}
  \item A collembolan trait database
  \item The Vulcan project
  \item Empirical evidence from the VULCAN project
  \item Conclusions
\end{itemize}
The *trait* concept

- Taxonomic characters are functionally arbitrary and unrelated to responses to the environment
- Ecological and morphological traits are functionally related to the environment
- Traits can more easily be assigned to unidentifed species than taxonomic units
- The composition of traits may be stable across habitats while the species composition changes

Collembolan adaptations to climate

**Individual level**

- Cuticular properties
  - Scales
  - Thickness
- Behaviour
  - Vertical migration, diurnal and seasonal
  - Feeding
- Physiology
  - Heat and drought biochemical protectants

**Community level**

- Species composition
  - Species with traits tolerant to climate change should prevail
### Trait database v. 1.0: Morphological traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of ocelli</td>
<td>0 - 8</td>
</tr>
<tr>
<td>Body size (max.)</td>
<td>mm, to the nearest 0.1 mm</td>
</tr>
<tr>
<td>Body pigmentation level (max)</td>
<td>0 white, 1 lightly, 2 intensely</td>
</tr>
<tr>
<td>Body pigmentation pattern</td>
<td>0 absent, 1 present, 2 spotted</td>
</tr>
<tr>
<td>Modified hairs or scales</td>
<td>0 absent, 1 present</td>
</tr>
<tr>
<td>Furca development</td>
<td>0 absent, 1 reduced, 2 fully developed short, 3 f.d. long</td>
</tr>
<tr>
<td>Antenna estimated length</td>
<td>0 short, 1 medium, 2 long</td>
</tr>
<tr>
<td>Antenna: Head Ratio (max)</td>
<td></td>
</tr>
<tr>
<td>Antenna/ body ratio</td>
<td></td>
</tr>
</tbody>
</table>

### Ecological traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life form (morphological)</td>
<td>1 epedaphic; 2 hemiedaphic-xerophile; 3 hemiedaphic-mesophile; 4 hemiedaphic-hydrophilic; 5 euedaphic</td>
</tr>
<tr>
<td>Life form (Rusek 1989)</td>
<td>1 Atmobios; 2 Ba epigeonts; 3 Bb hemiedaphobionts; 4 Bc1a large euedaphobionts with furca; 5 Bc1b large euedaphobionts without or reduced furca; 6 Bc2a medium euedaphobionts with furca; 7 Bc2b medium euedaphobionts without or reduced furca; 8 Bc3a small euedaphobionts with furca; 9 Bc3b small euedaphobionts without or reduced furca</td>
</tr>
<tr>
<td>Vertical habitat preference</td>
<td>1 epedaphic; 2 hemiedaphic; 3 euedaphic</td>
</tr>
<tr>
<td>Habitat preference</td>
<td>1 plant, 2 soil surface, 3 soil 0-10 cm depth</td>
</tr>
<tr>
<td>Moisture preference</td>
<td>0 xeroresistant, 1 xero-mesophilic, 2 indifferent, 3 mesophilic, 4 meso-hydrophilic</td>
</tr>
<tr>
<td>Habitat width</td>
<td>0 steno, 1 steno/eury, 2 eury and eury/hydriphilo</td>
</tr>
<tr>
<td>Trophic position</td>
<td>1 microbivore, 2 herbivore/pollin. feeder, 3 predator and microbivore</td>
</tr>
<tr>
<td>Mode of reproduction</td>
<td>0 generally parthenogenetic, 1 bisexual, 2 both modes occur</td>
</tr>
<tr>
<td>Phenology</td>
<td>1 urivoltine, 2 bivoltine, 3 multivoltine</td>
</tr>
<tr>
<td>Mouthparts</td>
<td>1 sucking, 2 grinding, 3 piercing</td>
</tr>
<tr>
<td>Metabolic rate corrected for weight</td>
<td>1 low, 2 medium, 3 high</td>
</tr>
<tr>
<td>Weight of progeny relative to weight at maturity</td>
<td>Quantitative ratio</td>
</tr>
</tbody>
</table>
Hypothesis:
Collembolan life-forms respond in a *trait* manner to environmental impacts

Contrasting ecological properties of life forms

<table>
<thead>
<tr>
<th>Table 1. Contrasts between properties distinguishing edaphic and euedaphic Collembola. Modified from Petersen (1980)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>life form</strong></td>
</tr>
<tr>
<td>vertical distribution</td>
</tr>
<tr>
<td>size of specimens</td>
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<tr>
<td>reproduction</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>metabolic activity</td>
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<tr>
<td>food</td>
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</table>

PCA overview of traits

- Moisture preference
- Habitat width
- Trophic position
- Mode of reproduction
- Mouthparts
- No. of ocelli
- Body size
- Body pigmentation level
- Body pigmentation pattern
- Modified hairs or scales
- Furca development
- Antenna estimated length
- Antenna : head ratio

Location of VULCAN sites

Infrastructure of large scale experiments designed to study climate change effects on shrublands

Increase
The VULCAN experiment 2001-2004

Vulnerability assessment of shrubland ecosystems in Europe under climatic changes (VULCAN)

› A transect of six European shrubland locations
› Experimental climatic treatments of
   › Warming: 0.3 to 1.3 °C in April to June 2003
     Reflective curtains are drawn across the plots at night thus preventing heat loss.
   › Drought: Reduced precipitation between 9.9% and 92.6%.
     Plots are protected from rain by a rain cover for 1-2 months in the growing season

Seventeen collembolan species responded to the climate treatments according to statistical analyses

<table>
<thead>
<tr>
<th>Country</th>
<th>C</th>
<th>W</th>
<th>D</th>
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<tbody>
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<td>683</td>
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<td>3333</td>
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<tr>
<td>SP</td>
<td>1059</td>
<td>202</td>
<td>286</td>
</tr>
</tbody>
</table>

Petersen (2011) SOIL ORGANISMS Volume 83(3)
PCA plots of population abundances showing climate treatments and countries.

Traits separates European shrubland locations.

\[ T_m = \sum \log(p_i + 1) r_i \]
Trait distribution:
Species not responding and species responding to the climatic manipulations:

Distribution among the sampled layers: plant, soil surface and soil 0-10 cm

Gisin’s 3 lifeforms

PCA plot of the trait scores
All 21 trait scores differed significantly among European location

Consclusions

- Population densities of collembolan species responded to warming and drought manipulations

- Low performance of traits:
  Trait scores did not respond to VULCAN warming and drought manipulations, and therefore had no detectable predictive value for these environmental changes

- High performance of traits:
  Trait scores were dramatically different throughout the VULCAN shrubland locations and therefore reflects long-term climatic conditions
Acknowledgements

› Henning Petersen for inspiration on the life-form perception of collembolans and making data from VULCAN available for Department of Bioscience, Aarhus University

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› ECOMARG (Danish EPA)

› Colleagues at XVI ICSZ 😊