Collembola's role in regulating mass fluxes in soil and the effects of contrasting life histories

T. Larsen[1,2]*, P.H. Krogh[2], J. Magid[1], E. Hobbie[3], M. Ventura[4]

1) Plant Nutrition and Soil Fertility Laboratory, Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 FC, Denmark
2) Department of Terrestrial Ecology, National Environmental Research Institute, Vejlsøvej 25, DK-8600 Silkeborg, Denmark
3) University of New Hampshire, Terrestrial Ecology, 39 College Road, Durham, NH 03824, USA
4) Department of Freshwater Ecology, National Environmental Research Institute, Vejlsøvej 25, DK-8600 Silkeborg, Denmark

*Corresponding author: +45 8920 1572, Fax +45 8920 1414. E-mail: thl[α]dmu.dk (Thomas Larsen)

Introduction

To understand mass fluxes in the soil ecosystem it is important to understand the contribution of its biotic components. For soil microarthropods, fluxes have mostly been based on crude estimates because traditional means of measuring respiration or excretion are methodologically challenging (Filser 2002; Petersen and Luxton 1982). In this study, excretion of metabolites was quantified by following growth, oviposition and isotopic change of ^{13}C and ^{15}N in two Collembola species, *Proisotoma minuta* and *Protophorura armata*. In addition, the stoichiometry of the elements C, N and P were followed to investigate the physiology that contributes to the acquisition, incorporation and release of energy and elements. Understanding the linkage between stoichiometry, physiology and life history strategies is important for identifying requirements and potential responses to nutrient constraints.

Results and discussion

The two species have contrasting life history strategies. The smallest of the species, *P. minuta*, had a low adult growth but high fitness while the larger, *P. armata*, had a lower fitness and continued to grow considerably even after sexual maturity (**Table 1**). While body C of *P. armata* was significantly higher than *P. minuta*, it had significantly less N and P. Consequently, C/N and C/P was higher for *P. armata* than *P. minuta* (**Fig. 1**). This indicates that *P. armata* possessed more storage compounds such as lipids but less protein, nucleotides or nucleic acids than *P. minuta*. *P. minuta* eggs had about twice the amount of P than *P. armata*, either due to higher nucleotides or nucleic acids, which corresponds with the faster reproductive cycle of *P. minuta*. There were no significant differences between C/N of *P. armata* and its diet contrary to *P. minuta* (**Fig. 2**). The need of *P. minuta* for a lower dietary C/N and higher P for oviposition indicates that it requires a higher quality diet (Vrede *et al.* 2004). The half-lives were shortest for *P. minuta*, which was also expected from the life history data (**Table 1**). Excreted metabolites were for P. minuta equivalent to 10 to 12% of the elemental body content per day and 7–10% for *P. armata* (**Fig. 3**). This agrees well with the assumption made from the stoichiometry and life history data where *P. minuta* is the most active and fittest of the two species.

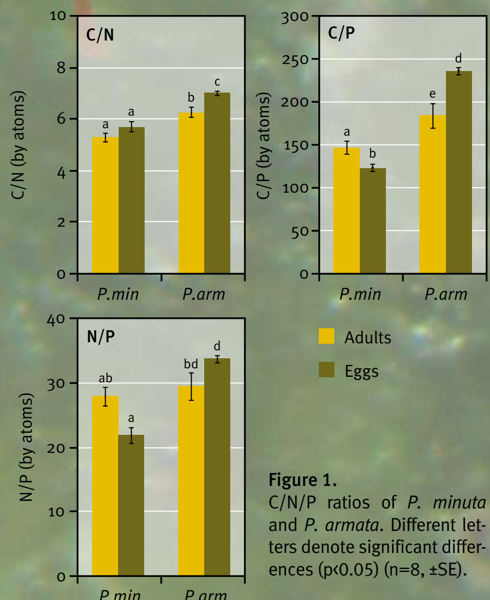

Figure 1.
C/N/P ratios of *P. minuta* and *P. armata*. Different letters denote significant differences (p<0.05) (n=8, ±SE).

Table 1. Life history parameters (means ±SD, n=4).

Species	Age (days)	W_i (μg ind^{-1})	W_f (μg ind^{-1})	$k_{intrinsic}$
P. minuta	[23-51]	9.7±0.9	12.2±0.7	0.008±0.001
P. armata	[29-57]	36.0±0.8	56.3±1.3	0.016±0.001

Species	Fecundity (no. eggs ind^{-1} day^{-1})	Fitness (% edw adw^{-1} day^{-1})	Elemental turnover $t_{½}$ C (days)	Elemental turnover $t_{½}$ N (days)
P. minuta	1.16±0.13	6.13±0.20	4.34±0.23	4.82±0.15
P. armata	0.39±0.06	1.45±0.09	6.10±0.47	6.56±0.43

W_i = initial dry weight, W_f = final dry weight, edw = egg dry weight, adw = adult dry weight, $k_{intrinsic} = \ln(W_f/W_i)/t$

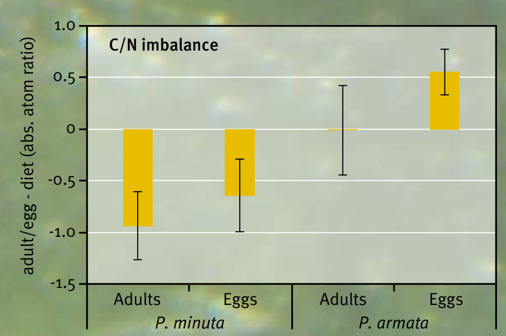

Figure 2.
C/N imbalances of *P. minuta* and *P. armata* in relation to the labelled diet (n=4, ±SE).

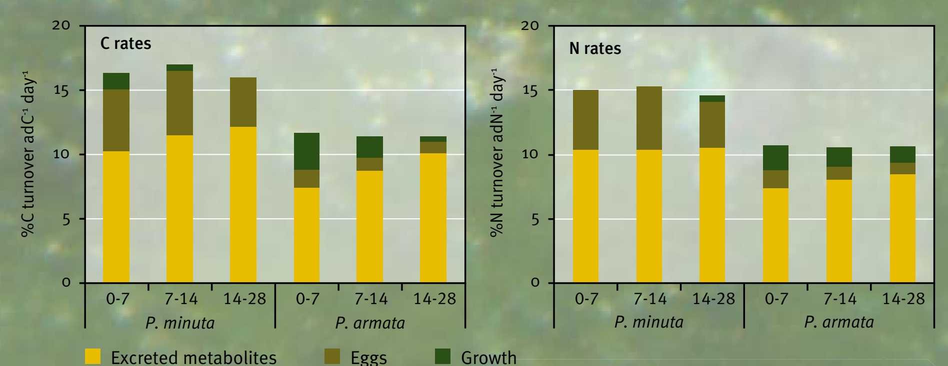

Figure 3.
C and N rates for metabolic excretion, growth, and oviposition for *P. minuta* and *P. armata*. adC and adN signify the body DW content of C and N, respectively. (n=4, ±SE).

Material and methods

Juvenile *P. minuta* and *P. armata* were raised on unlabelled yeast until they reached sexual maturity, when the diet was changed to yeast labelled with ^{13}C and ^{15}N. The controls were fed unlabelled yeast during the entire study. Animals living on the labelled yeast for two generations were used as a reference for isotopic equilibrium values. Ovipostion, growth, isotopic composition, and the content of the elements C, N and P were followed weekly or biweekly. Gypsum substrates were changed weekly to avoid inhibitory effects of info-chemicals on fecundity. An exponential asymptotic model $S_i=S_n-S_d*e^{(-c*t)}$ was fitted to the isotopic change values, where $S_i=\delta^{13}C$ or $\delta^{15}N$ at time t (days), S_n=asymptotic value of S, $S_d=S_n$ minus the value at intercept, and c=the turnover rate. The separation of the processes contributing to isotopic change or turnover, that is growth (k), oviposition (f), and excreted metabolites, (m) was done according to the method described by Hesslein *et al.* (1993): $S_i=S_n+(S_{[i=0]}-S_n)e^{-(k+f+m)t}$

Conclusions

The study determined metabolic rates and elemental pools for two Collembola species with contrasting life histories. The fittest of the two species, *P. minuta*, excreted the equivalent of 10–12% of the elemental body content per day, and *P. armata* 7–10%. Most elements are lost to excretion (CO_2 and N-waste). These figures in combination with stoichiometry and life histories indicate that the cost of *P. minuta*'s better fitness is a requirement for a higher quality diet than *P. armata*. The data produced in this study can be used to estimate the collembolan contribution to C and N fluxes in the soil.

References

Filser, J. 2002. The role of Collembola in carbon and nitrogen cycling in soil. Pedobiologia 46, 234–245.

Hesslein, R. H., Hallard, K. A. and Ramlal, P. 1993. Replacement of Sulfur, Carbon and Nitrogen in Tissue of Growing Broad Whitefish (Coregonus-Nasus) in Response to a Change in Diet Traced by Delta-S-34, Delta-C-13 and Delta-N-15. Canadian Journal of Fisheries and Aquatic Sciences 50, 2071–2076.

Petersen, H. and Luxton, M. 1982. A comparative analysis of soil fauna populations and their role in decomposition processes. In Quantitative ecology of microfungi and animals in soil and litter. Edt. Petersen, H. pp 287–388. Oikos.

Vrede, T., Dobberfuhl, D. R., Kooijman, S. and Elser, J. J. 2004. Fundamental connections among organism C:N:P stoichiometry, macromolecular composition and growth. Ecology 85, 1217–1229.