

Climate effects on insect ecological stoichiometry

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Environmental conditions

- Organisms encounter many environmental conditions.
- Sometimes these conditions can have beneficial effects on the organisms.
- For example in ectothermic species, temperature increases could increase their growth rate (Nilsson-Örtman et al. 2012) or upregulate their immune function (Prokkola et al. 2013).



Ecological conditions

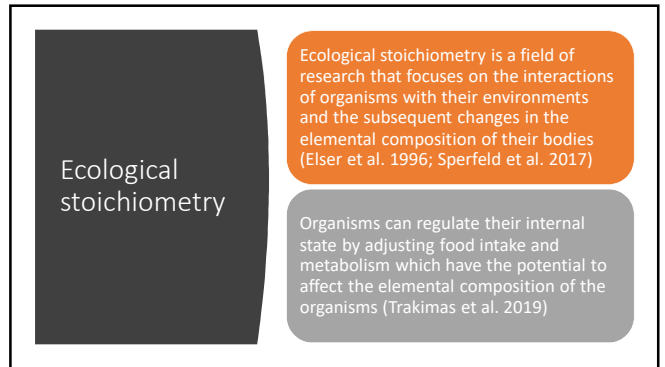
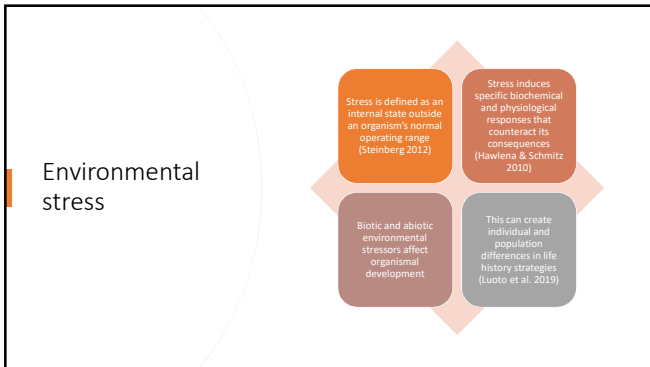
- Yet, environmental conditions can also be perceived as stressful.



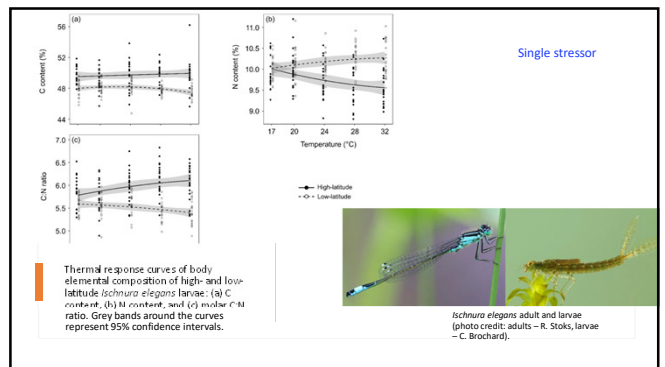
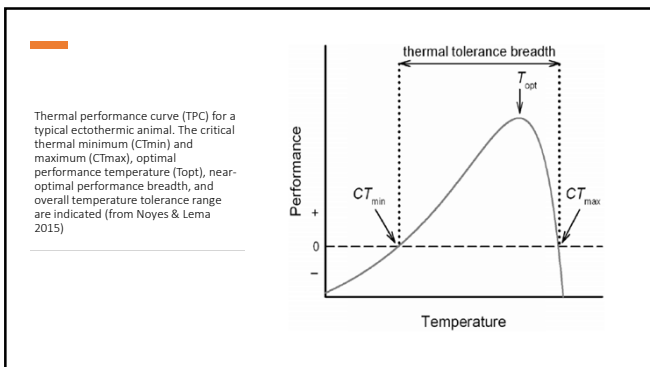
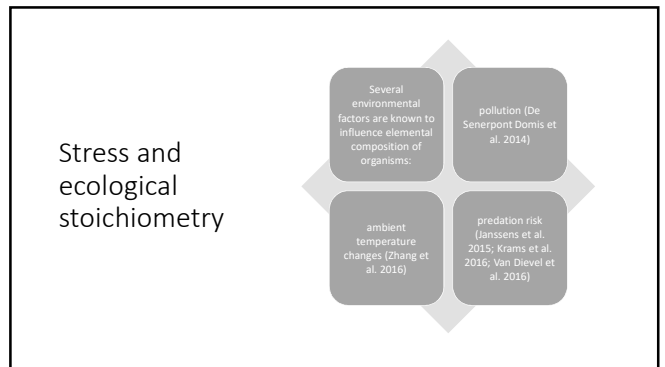
Stress in forest ecosystems

The importance of environmental stress

- In nature, organisms face many environmental conditions both in isolation and combined that are often stressful.
- Understanding and predicting how these environmental conditions and their interactions affect different levels of biological organization is a key challenge in stress research.
- This problem asks for an integrated approach in research including chemistry, medical aspects of adaptation, toxicology, ecology, agriculture, plant and animal physiology.



Examples of studies suggesting that stress (predators, climate change, pesticides) increases body C, lowers body N, increase the C/N ratio and affects other elements



The estimated elemental composition of macromolecules and the contribution of the macromolecules to the total body dry mass and the total body C and N contents.
Dm = dry mass per larva (Van Dievel et al. 2019)

Macromolecules	C (% of dm)	N (% of dm)	Dry mass (mg)	Contribution to C (%)	Contribution to N (%)
Proteins	46 - 53	17	1.00	16.5 - 19.0	29.9
Fat	54.2 - 70	1.6	0.06	1.7 - 2.3	0.3
Sugars	37 - 54.2	0	0.02	0.5 - 0.7	0
Cuticular chitin	41.4	6.9	0.02	0.4	0.3
Cuticular melanin	44.3 - 65.3	7.5 - 9.5	0.006	0.1 - 0.2	0.1 - 0.2



Hypothesized changes to elemental composition caused by predators

- Predator-induced stress generally increases metabolic rate (Hawlena & Schmitz 2010; Krams et al. 2013)
- Subsequently rising energetic demands increase the overall demand for carbohydrate-based fuel and lower the need for nitrogen-rich (N) proteins necessary for growth
- Under such circumstances, the body utilizes proteins to produce glucose (Hawlena & Schmitz 2010)

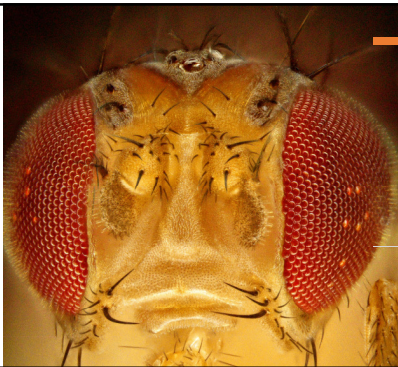
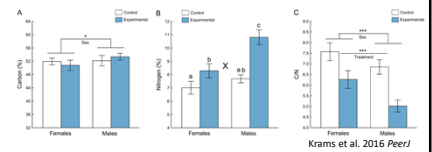


Photo: Enno Merivae

Single stressor



Predation risk and elemental composition in *D. melanogaster*

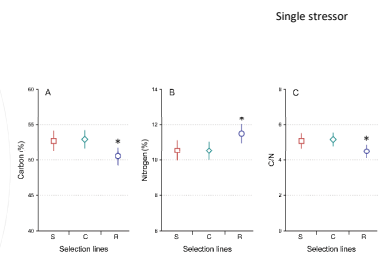
Gryllus integer

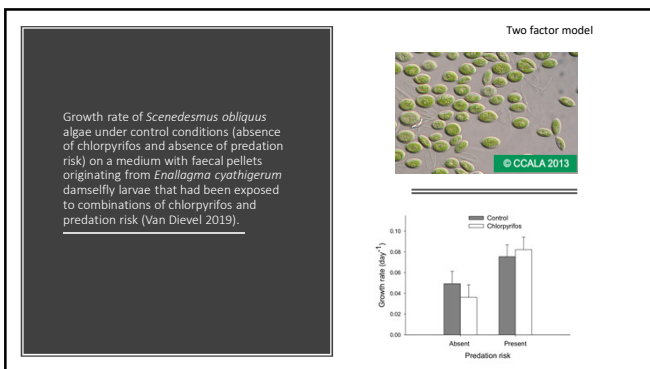
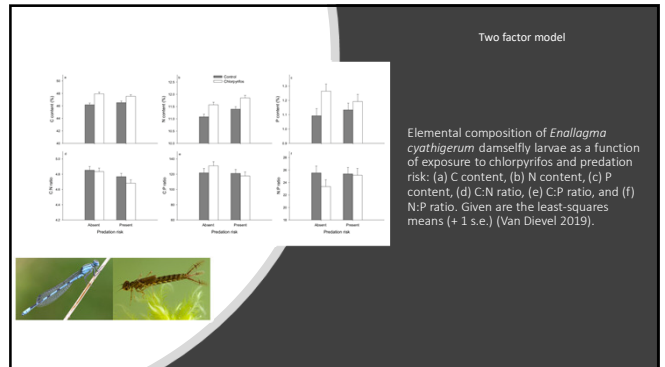
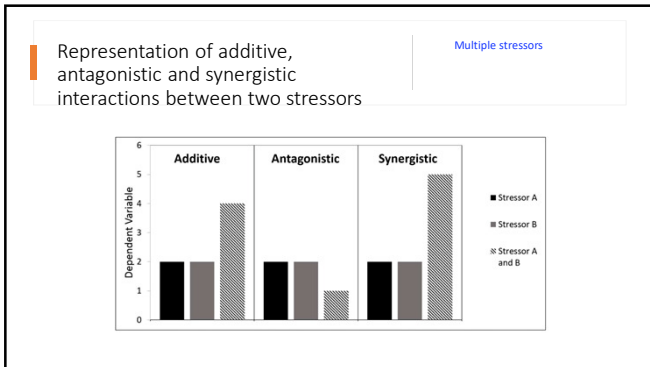
- After five generations of selection for developmental speed, developmental time (the average maturation time \pm SD) of crickets was:
 - rapidly developing individuals: 91.03 \pm 6.06 days
 - control group: 117.33 \pm 7.53 days
 - slowly developing crickets: 136.17 \pm 8.28 days.



Developmental speed and elemental composition

Average carbon percentage (A), nitrogen percentage (B) and carbon-to-nitrogen ratio (C) in *Gryllus integer* crickets selected for slow development (S, squares), rapid development (R, circles) and control developmental (C, diamonds) lines. Error bars: 95%CI. Asterisks indicate significant differences between the lines (* $P < 0.05$) (Trakimas et al. 2019)





The wolf: A key-species in the ecosystem of Yellowstone

Conclusions

- Predators, climate, pesticides can have single effects on prey individuals;
- These factors may have a number of combined additive or synergistic effects on insects in the agricultural and forest ecosystems;
- The direction and magnitude of the outcome of combined effects caused by climate, pesticides and predators are difficult to predict;
- Explicit focus on ecological stoichiometry has the potential to sharpen predictions and to move the whole general stress paradigm forward through a more holistic understanding of organismal responses to fluctuating selection pressures including climate change.

A key challenge for ecologists, agriculture and forestry scientists is to predict how single and joint effects of global warming, developmental stress, population density, pesticide use, other kind of pollution and predation risk translate from the individual level up to ecosystem functions. This is crucial to ensure sustainable development.

Thank you!

