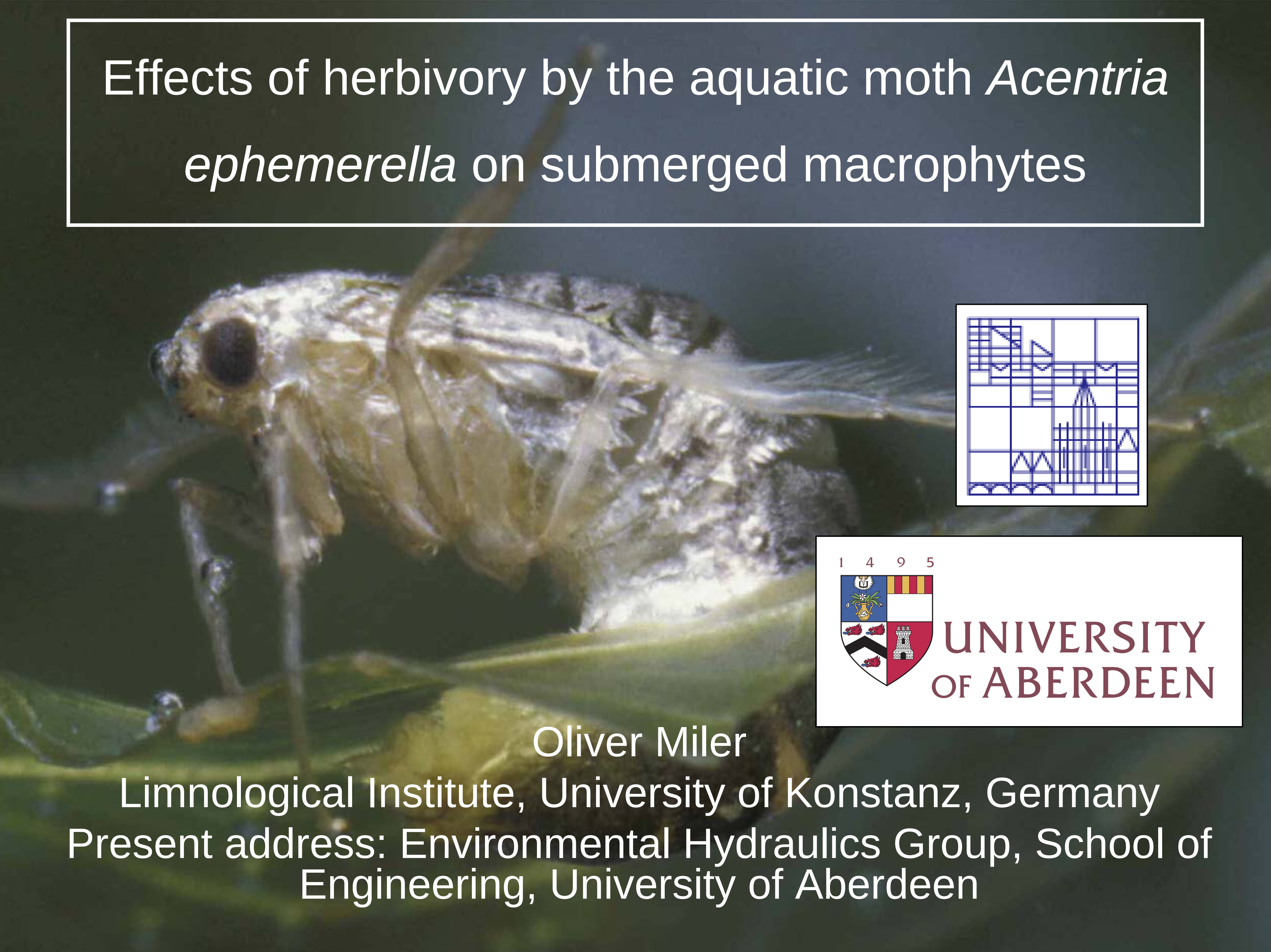

Effects of herbivory by the aquatic moth *Acentria ephemerella* on submerged macrophytes

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Macrophytes have an important structuring role in lakes !

Influence on:

- nutrient dynamics
- sedimentation and resuspension
- microbial communities
- carbon dynamics
- water turbidity
- physical complexity of the littoral zone → foraging and refuge habitat for fishes and macroinvertebrates

Grazing on freshwater macrophytes

Grazing by

- waterfowl (swans, ducks, coots)
- mammals (manatees)
- fish (grass carp)
- invertebrates
  - omnivorous Decapoda (e.g. the crayfish *Orconectes limosus*)
  - insect larvae: Lepidopera (Crambidae), Coleoptera (Curculionidae), Diptera (Ephydridae, Chironomidae)
  - Gastropoda
- the role of insect larvae as grazers of macrophytes has long been underestimated
- recent studies show an important role of insect larvae as herbivores feeding on submerged macrophytes

Agrawal & Fishbein (2006): three plant defence syndromes in a study on milkweeds

– Low nutritional quality syndrome → e.g. low N content, low water content, high toughness, digestibility reducing compounds

– Tolerance/escape syndrome → fast growth in high resource environments: high N content, low chemical defences and toughness, phenological strategies

– Nutrition and defence syndrome → high edibility (high N, high water content, high SLA, low toughness), but toxic defences

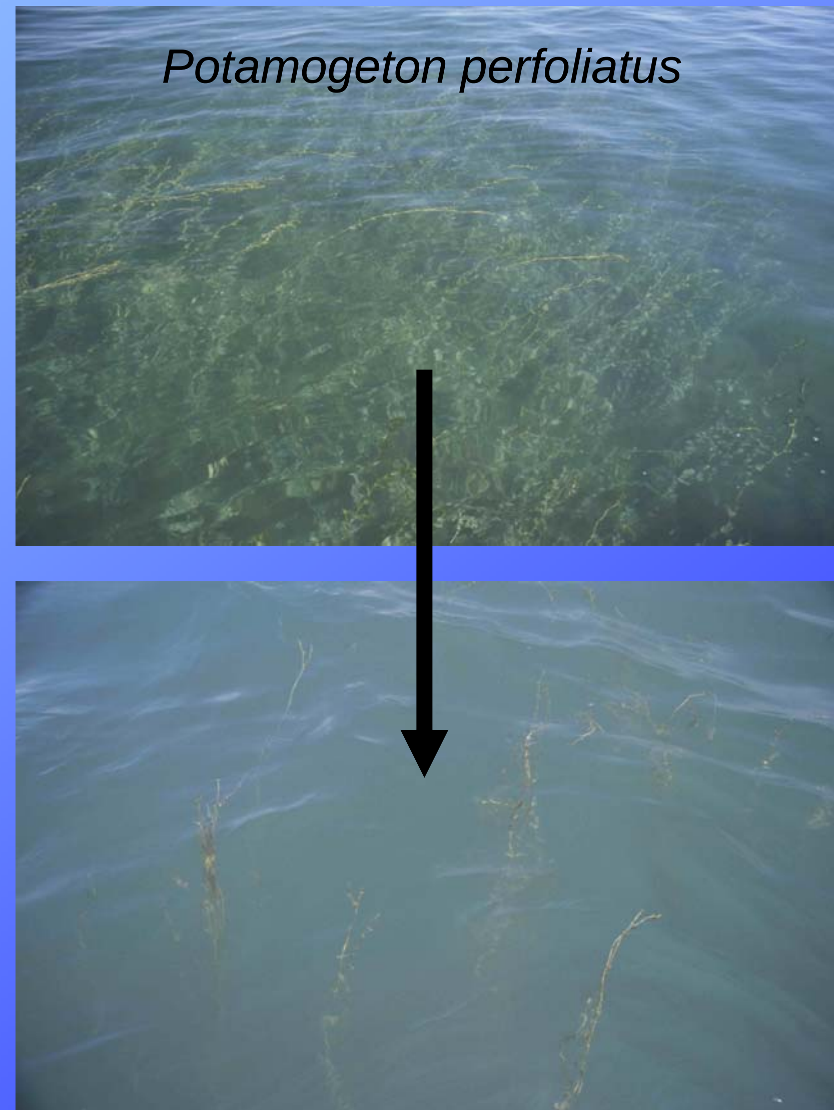
Agrawal, A.A. & Fishbein, M. 2006. Plant defense syndromes. *Ecology* **87,** 132-149.

Grazing on *Potamogeton* species

species of the genus *Potamogeton* often form large, mono-specific patches in lakes
→ important structuring role

strong grazing effects on macrophyte patches in lakes:

- no morphological defences
- no chemical defences
- high edibility for herbivores

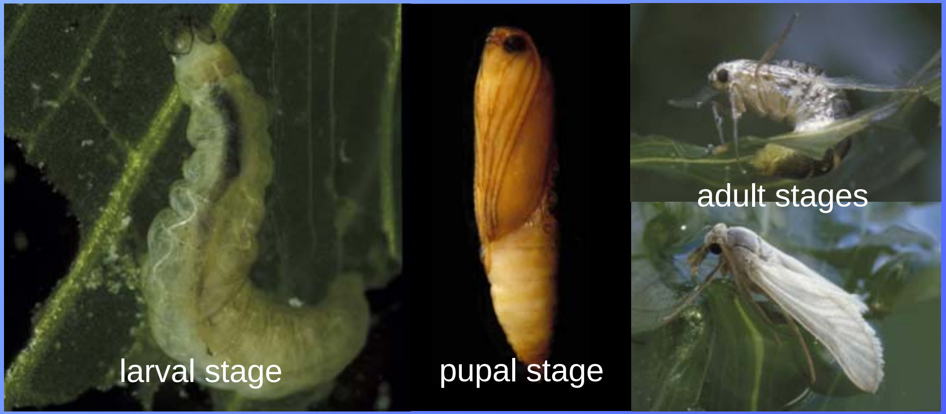


Do anti-herbivore strategies exist for *Potamogeton* species ?

If yes, what are these anti-herbivore strategies?

The study system

The herbivore: the aquatic moth *Acentria ephemerella*

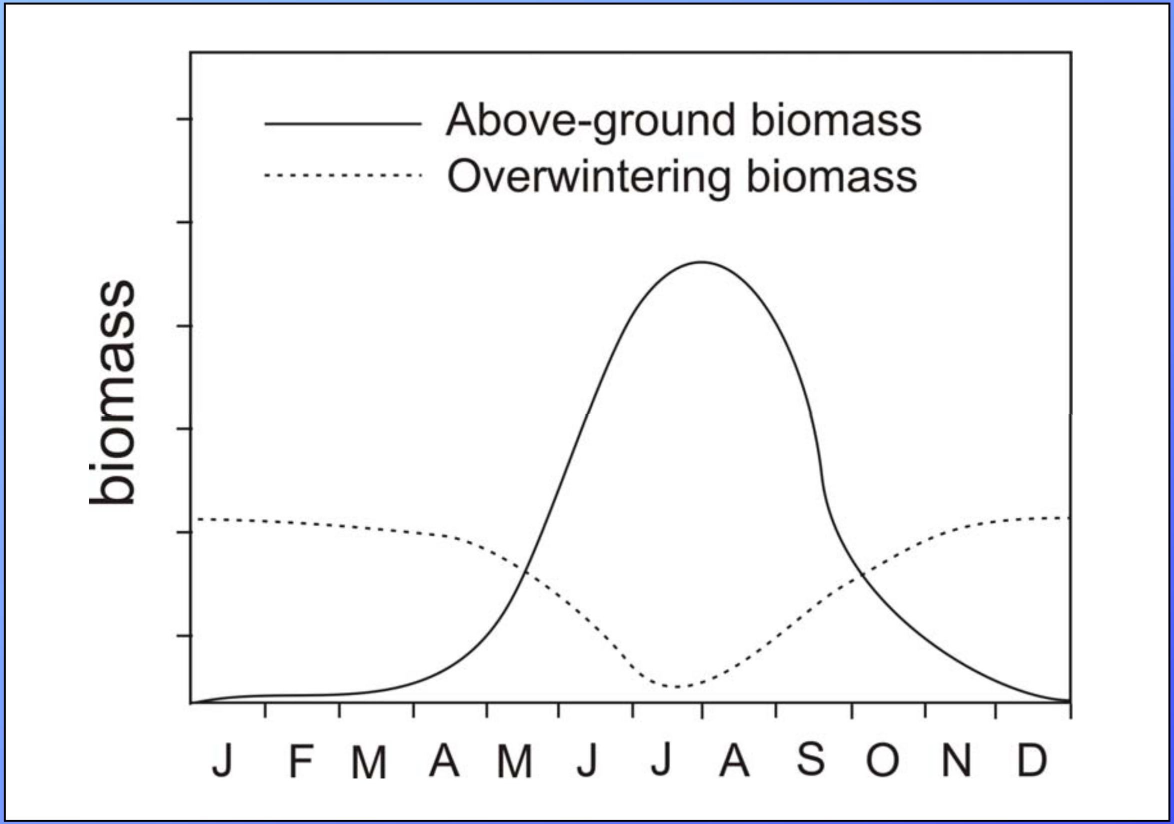


The plant: the submerged macrophyte *Potamogeton perfoliatus*

The water moth *Acentria ephemerella*

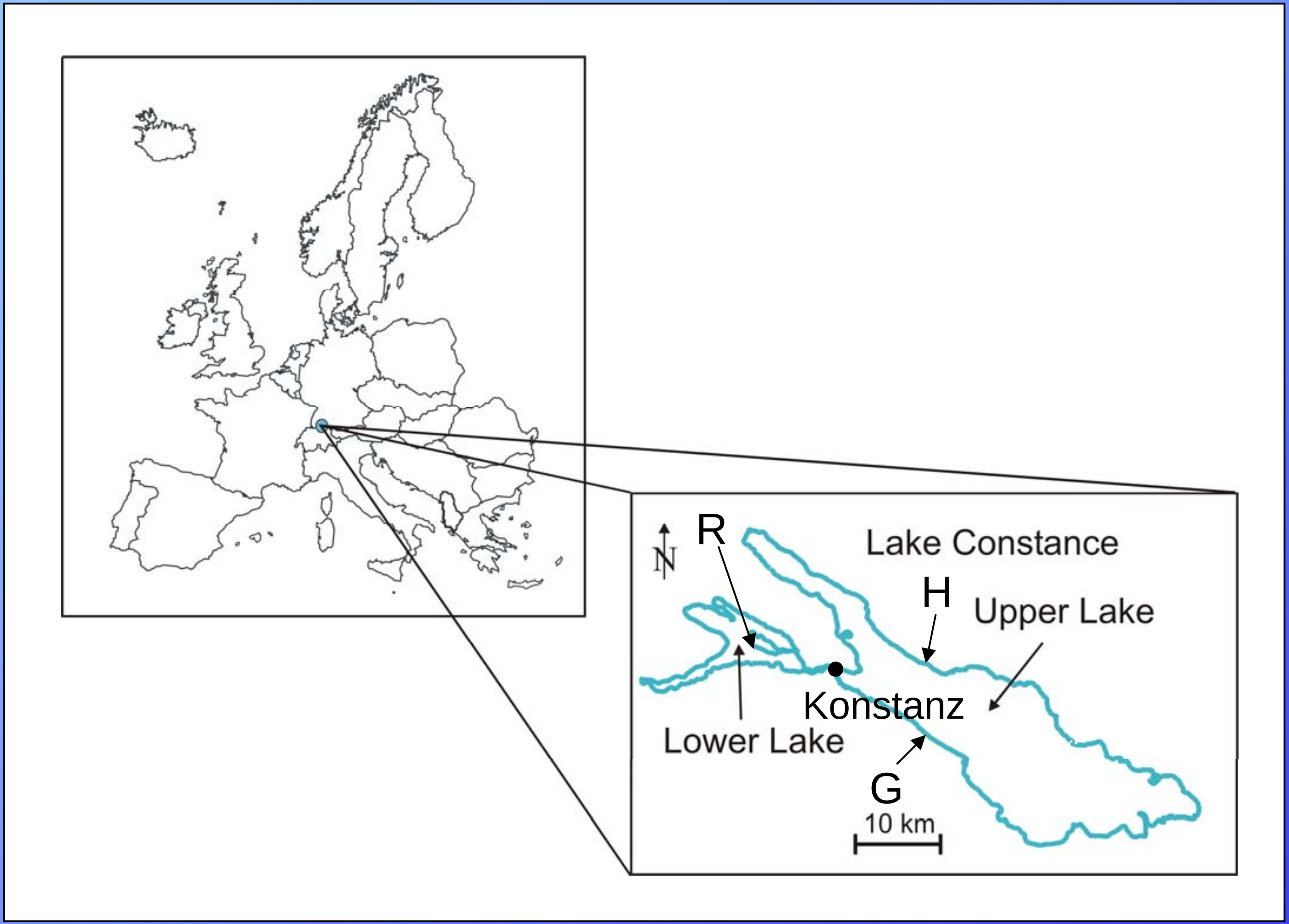
- aquatic stages: larvae, pupae and brachypterous females
- „terrestrial“ stages: macropterous males (and females (< 1 %))
- Wing dimorphism
- multivoltine (2-3 generations per year)
- short adult live span (2-4 days)
- Capital breeder
- clutch size: 120 – 550 eggs
- larval diapause from September - May

Life-cycle of *Potamogeton perfoliatus*



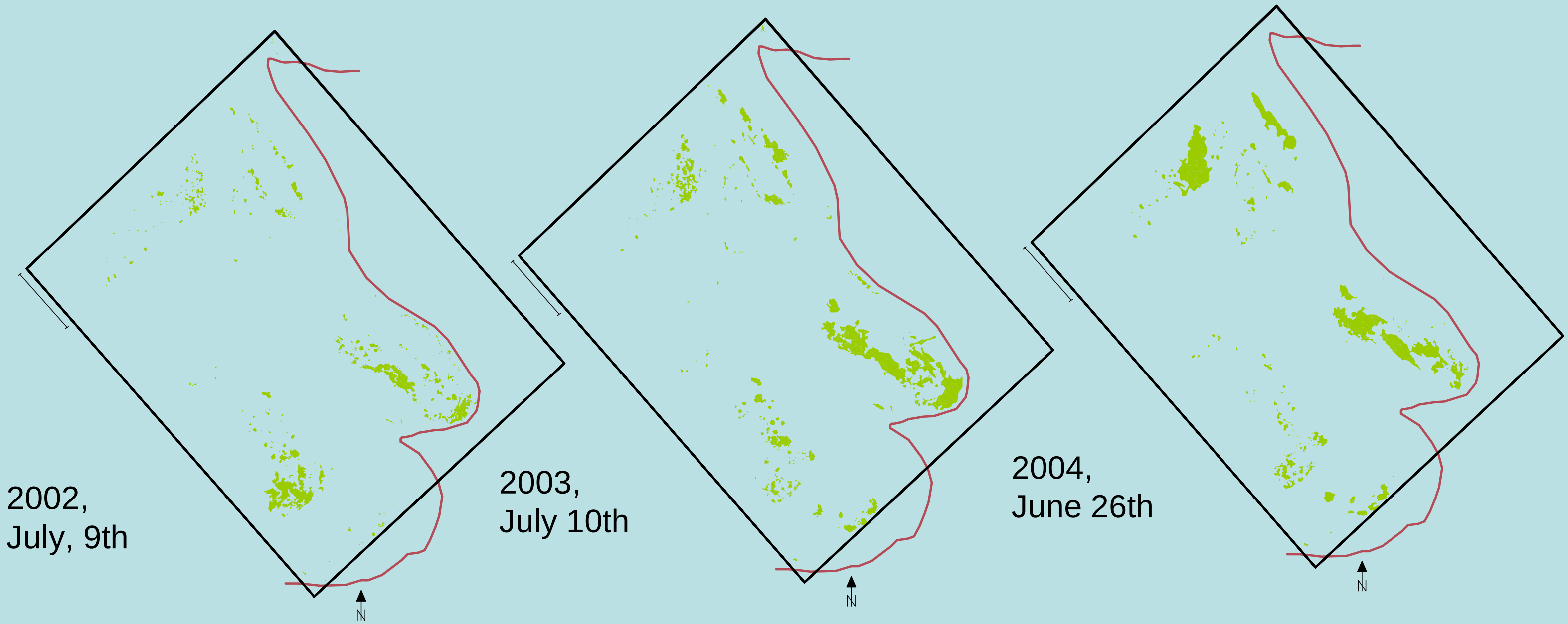
Strong seasonal biomass changes in the summer
Highest above-ground and lowest below-ground (overwintering) biomass

Sampling Sites



Sampling in two regions of Upper Lake Constance (Güttingen and Hagnau = G and H, respectively) and one region of Lower Lake Constance (Reichenau = R)

Patch dynamics of *Potamogeton perfoliatus*

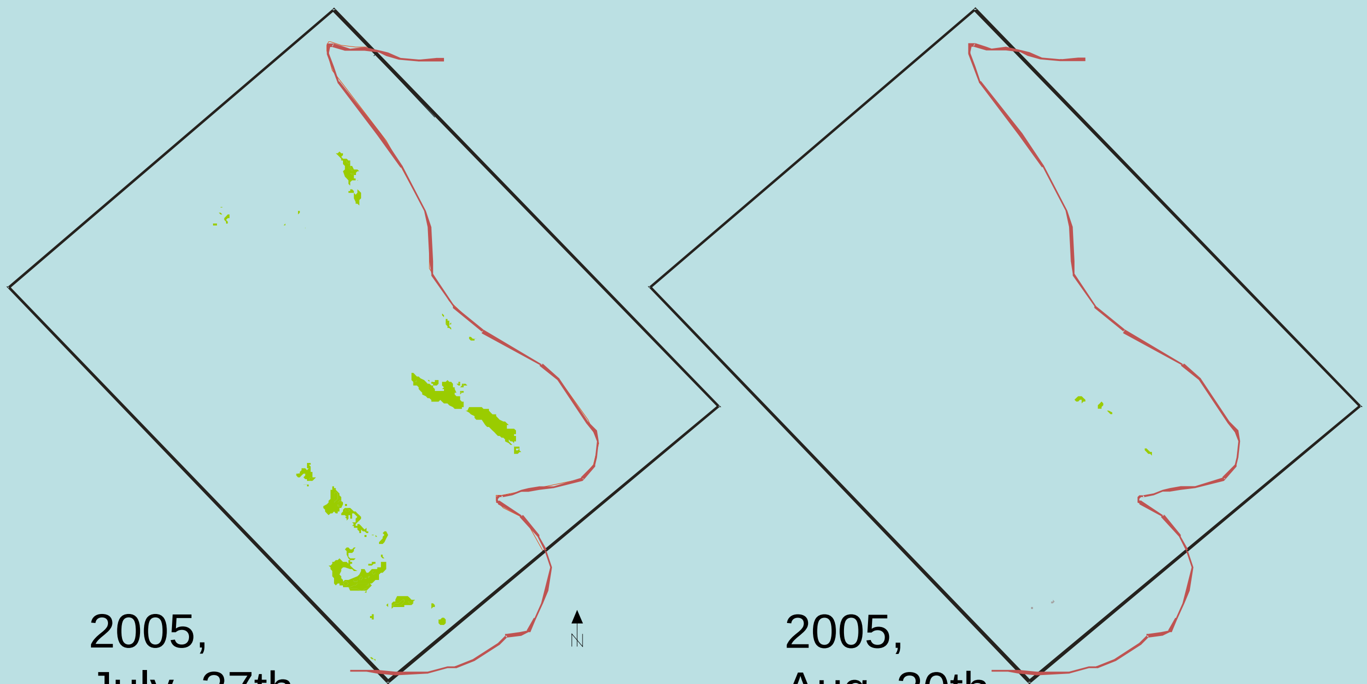


Patch area: 6100 m^2 **10 700 m^2** **10 600 m^2**

Sampling site Güttingen

Aerial photos: Thomas Heege, Deutsches Zentrum für Luft- und Raumfahrt (DLR), München
Digitising: Michael Dienst, Universität Hohenheim

Patch dynamics of *Potamogeton perfoliatus*



2005,
July, 27th

2005,
Aug, 30th

Patch area: 4 900 m^2

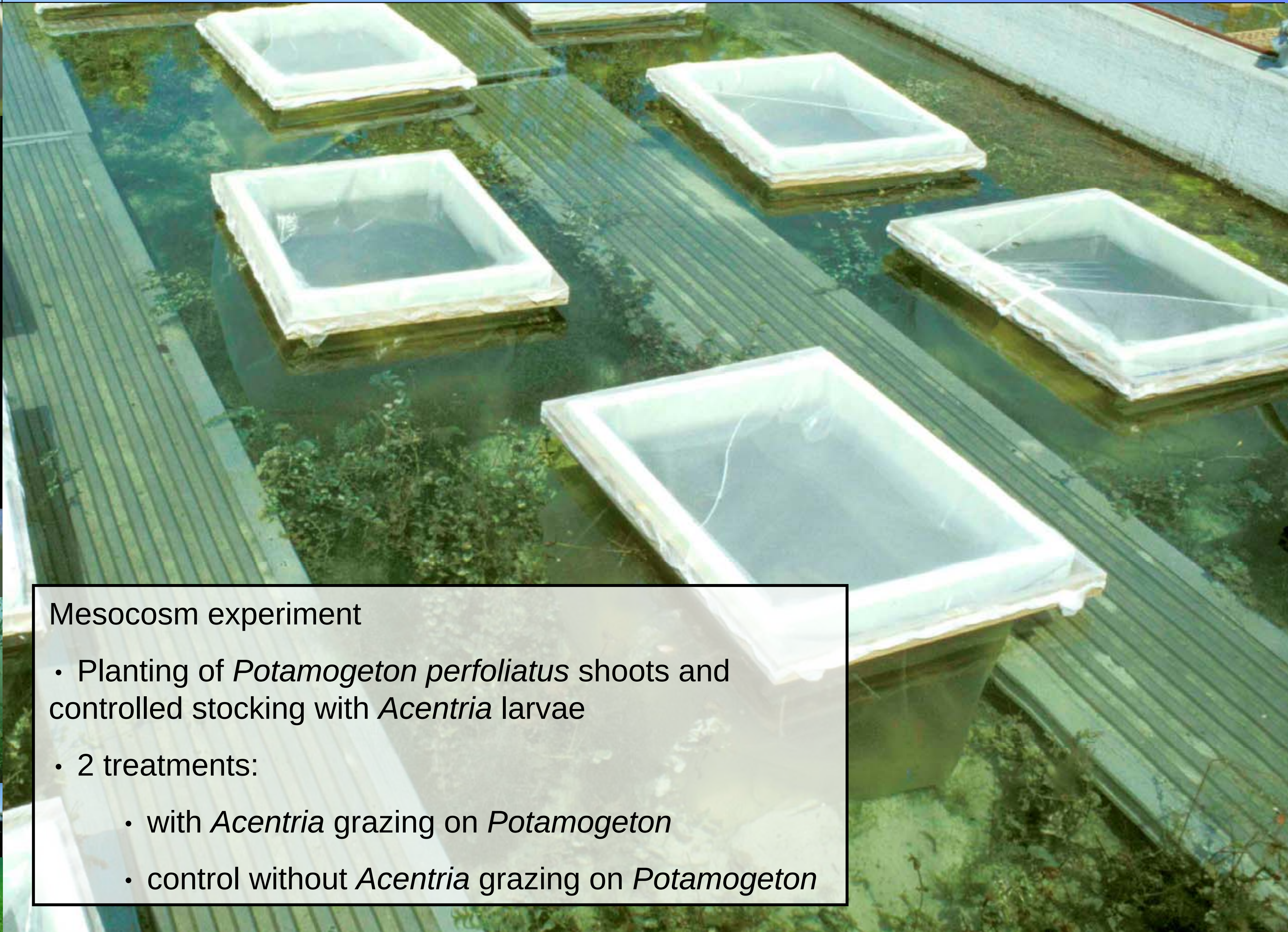
100 m^2

Sampling site Güttingen

Aerial photos: Thomas Heege, Deutsches Zentrum für Luft- und Raumfahrt (DLR), München

Digitising: Michael Dienst, Universität Hohenheim

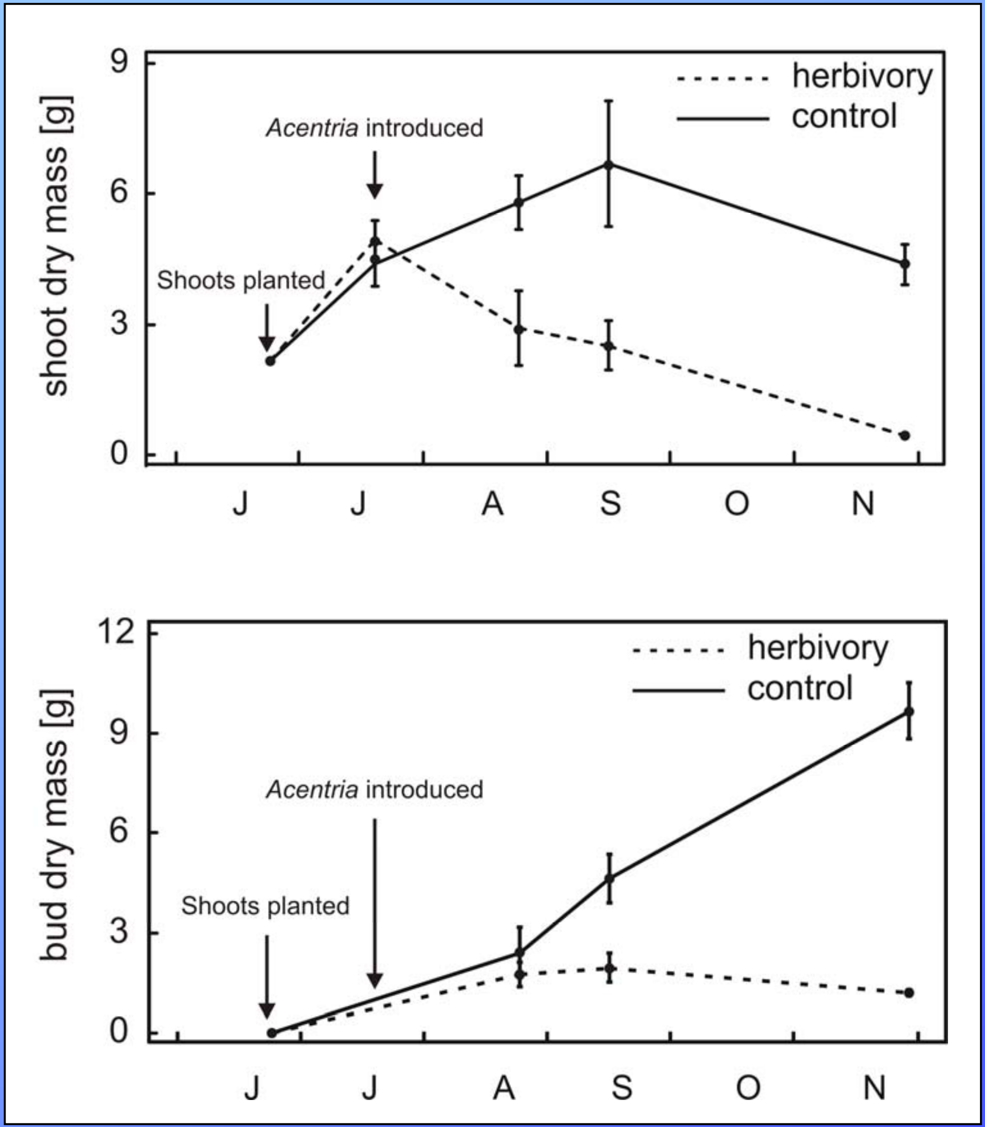
Experimental Design



Mesocosm experiment

- Planting of *Potamogeton perfoliatus* shoots and controlled stocking with *Acentria* larvae
- 2 treatments:
    - with *Acentria* grazing on *Potamogeton*
    - control without *Acentria* grazing on *Potamogeton*

Herbivory effects on *Potamogeton* biomass



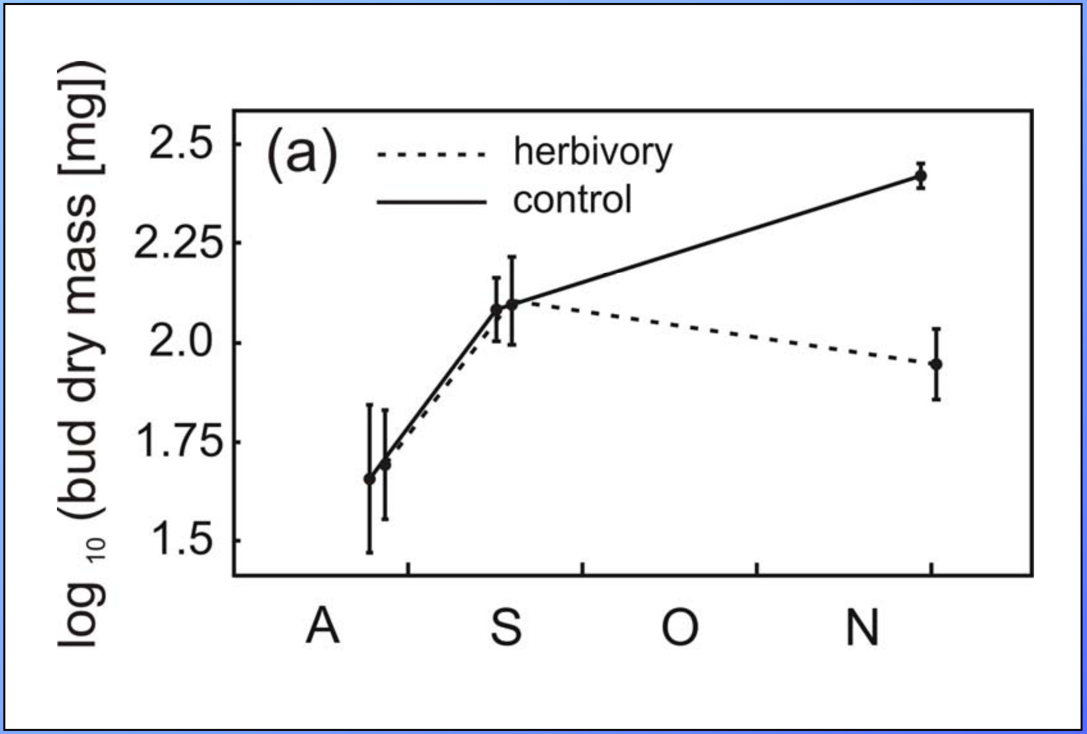
ANOVA, Interaction *Acentria** month: $F_{3,33} = 5.34$, $p = 0.0047$

Acentria herbivory reduces the above-ground biomass of *Potamogeton perfoliatus*

ANOVA, Interaction *Acentria** month: $F_{2,21} = 23.49$, $p < 0.0001$

Build-up of overwintering biomass was strongly reduced under herbivory

Effects on the overwintering organs of *Potamogeton*



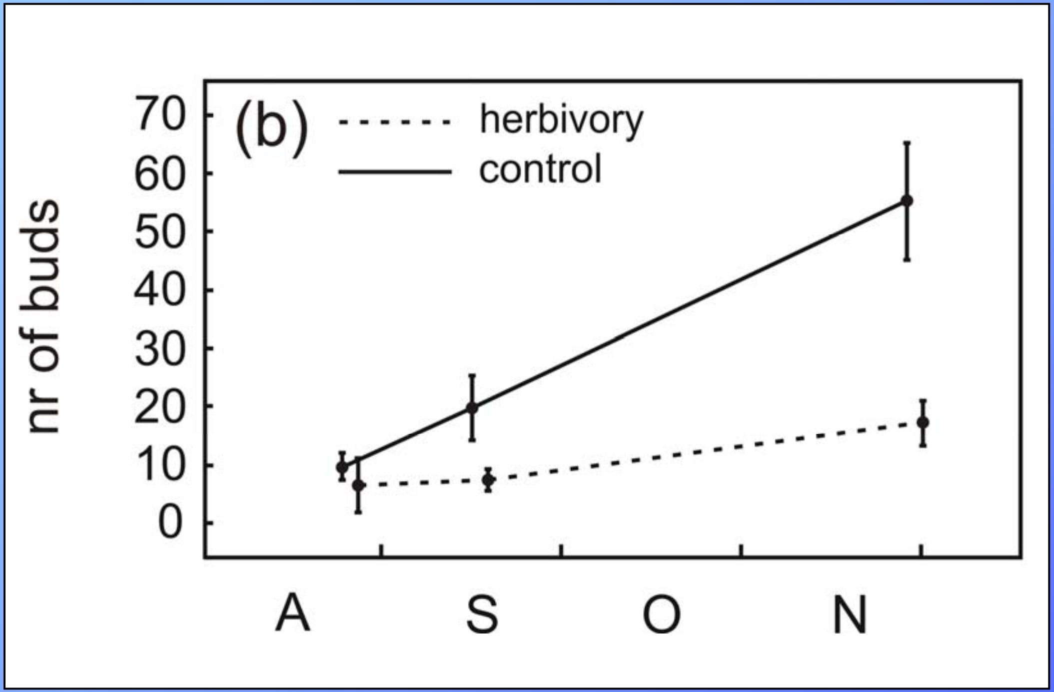
16 September to 29 November, ANOVA, factor month, $F_{1,12} = 783.68$, $p < 0.0001$, factor *Acentria*, $F_{1,12} = 10.04$, $p = 0.0081$, interaction month **Acentria*, $F_{1,12} = 11.53$, $p = 0.0053$

Mean biomass of overwintering organs

→ increase until September in the control and *Acentria* treatment

→ from September to November only increase in the control, but not in the *Acentria* treatment

Effects on the overwintering organs of *Potamogeton*



ANOVA, factor month, $F_{2,16} = 61.18$, $p < 0.0001$, factor *Acentria*, $F_{1,16} = 65.67$, $p < 0.0001$, interaction month **Acentria*, $F_{2,16} = 22.39$, $p < 0.0001$

Mean number of overwintering buds: strong increase until November in the control

Minimum size of overwintering buds during herbivory → first growth in size, then increase in number

Senescence

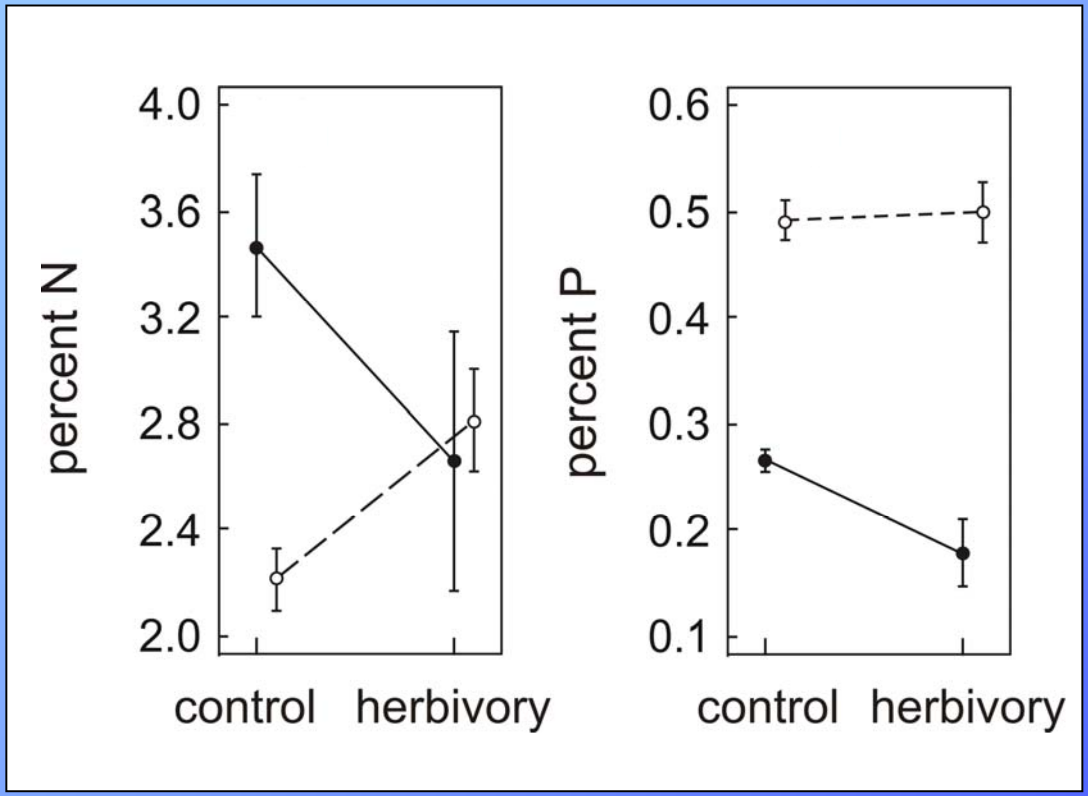
Control: little senescence

Acentria Treatment: strong senescence

→ defence strategy: Induction of an induced senescence

→ reduced food quantity and quality for *Acentria*

Nutrient translocation of *Potamogeton perfoliatus*



above-ground biomass

below-ground biomass

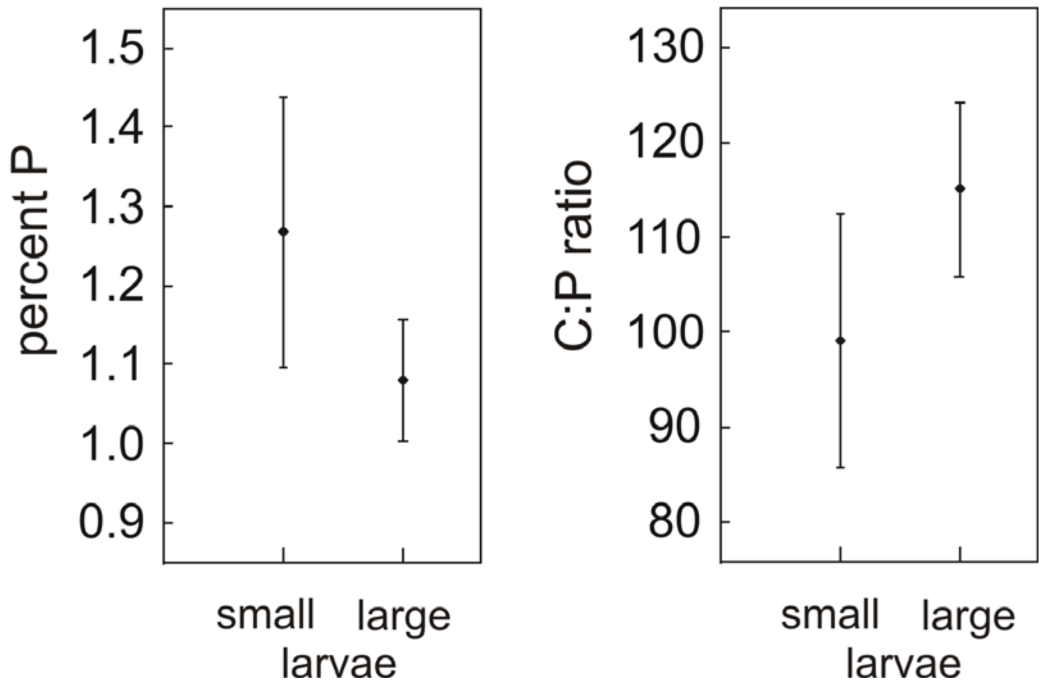
% N, ANOVA, interaction *Acentria**plant organ, $F_{1,12} = 5.56$, $p = 0.036$

% P, ANOVA, factor plant organ, $F_{1,12} = 131.86$, $p < 0.0001$, factor *Acentria*, $F_{1,12} = 2.92$, $p = 0.11$, $p < 0.0001$

N translocation from the shoots to the overwintering buds

Already high P content of the overwintering buds → primary reduction of the above-ground P content

Nutritial needs of *Acentria ephemerella*



Head capsule width: small larvae 245 µm
large larvae 1000 to 1170 µm

P limitation:

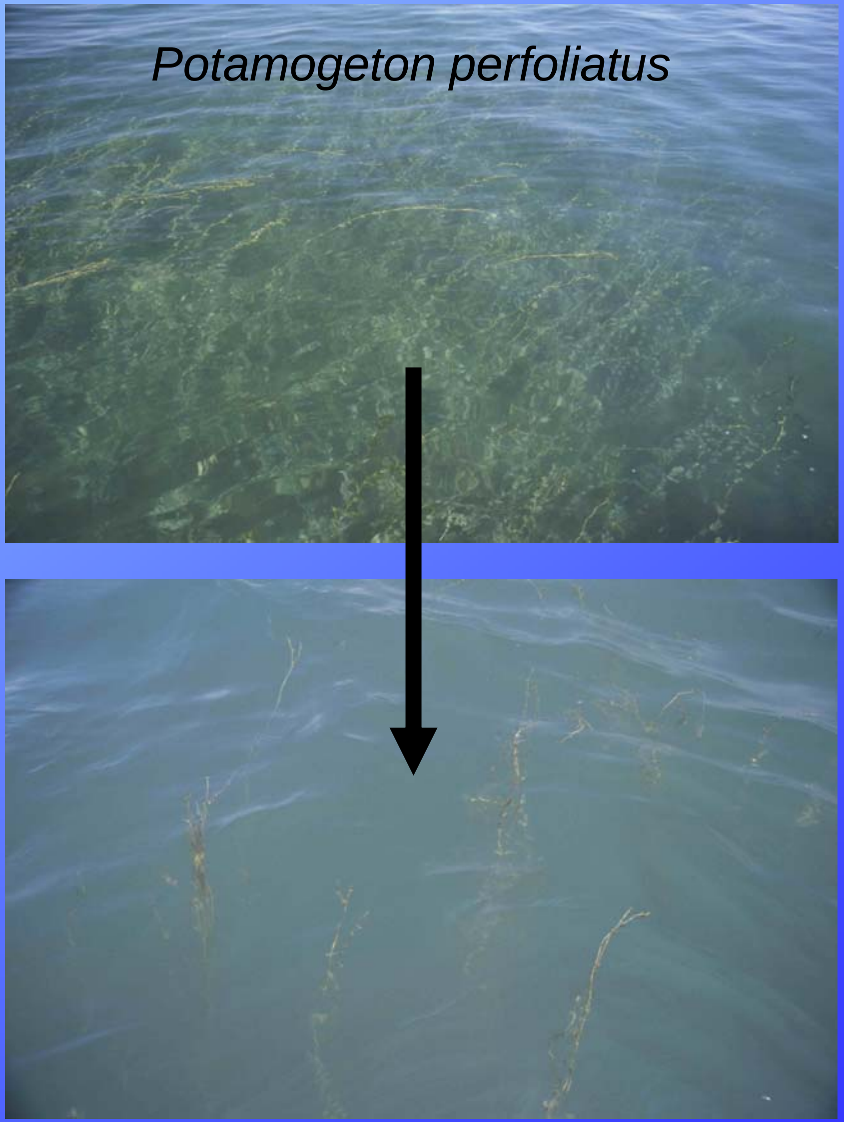
- early *Acentria* larval stages (C:P 90:1 - C:P 110:1), *Potamogeton* leaves (C:P 380:1 (control) und C:P 550:1 (herbivory))
- *Manduca sexta* (C:P 160:1), food plant (C:P 628:1)
- *Daphnia* (C:P ~ 80:1), food algae (C:P 200:1 bis 300:1)

Reduction of the above-ground P content → reduced food quality for *Acentria*
→ increase of the P limitation of *Acentria*

Conclusions

Potamogeton perfoliatus shows the „tolerance/escape syndrome“:
• fast growth during the summer
• from August on increased senescence of above-ground plant parts and biomass translocation to overwintering buds, translocation of N in overwintering organs, reduction of above-ground P

→ reduction of nutrients, energy and habitat for *Acentria*
→ early senescence as an anti-herbivore strategy and an adaptation against *Acentria* outbreaks



Further effects of herbivory-induced senescence

Herbivory-induced senescence changes the macrophyte patch structure, which affects the suitability as a foraging and refuge habitat for juvenile fishes

Juvenile perch in Lake Constance show a preference for patches that show a light senescence. Light senescence provides habitat conditions with a medium complexity

→ high invertebrate food availability
→ high manoeuvrability of juvenile fishes during food search
→ refuge against piscivorous predators

→ herbivory-induced senescence as a plant defence strategy is influencing the physical structure of macrophyte patches as a habitat for other organisms

Biophysics of flow-plant interactions

The Leverhulme Trust

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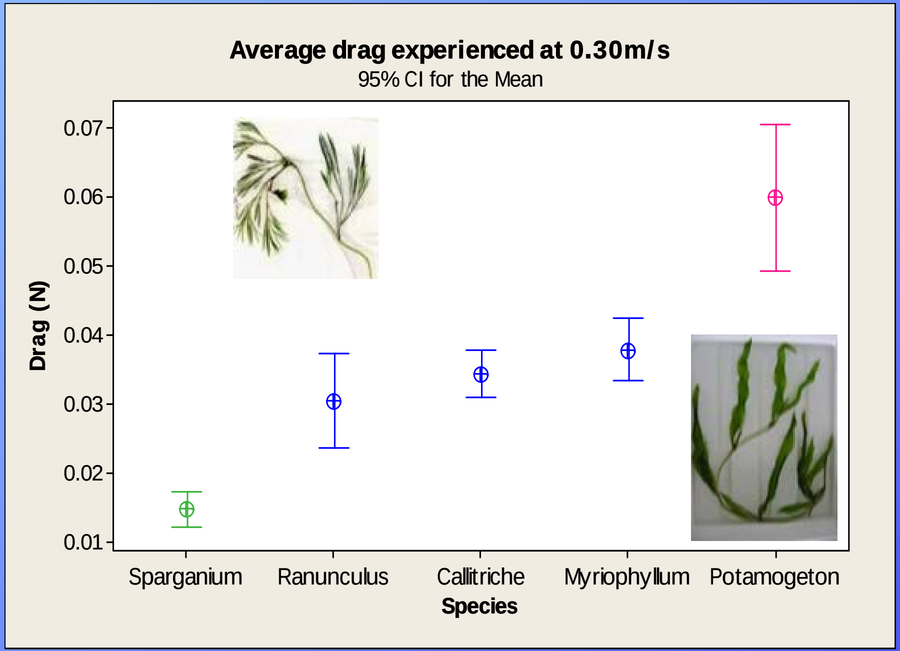

- Flow characteristics: multi-scale turbulence, viscous and diffusion boundary layers at plant surfaces
- Drag force measurements
- Light penetration into the canopy
- Plant morphology and biomechanics

Special thanks go to....

my supervisor Dietmar Straile and the Population and Food Web Ecology Group of the University of Konstanz

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SFB 454 Bodenseelitoral

Deutsche Forschungsgemeinschaft DFG

Thank You for Your attention !