Answering questions about milfoil physiology, spread, and growth in our lakes:

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1. The role of drying during transport
2. The role of changing water temperatures

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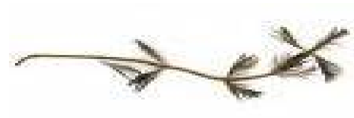
Mechanisms of milfoil spread



- Both vegetative and sexual reproduction are possible
  - seeds are thought to be a relatively unimportant means of dispersal (Madsen and Smith 1997)
- Autofragmentation in mid-late summer
  - some nodes develop rootlets and begin to abscise from the plant below
- Allofragmentation occurs from disturbance such as boat motors, paddles, wind etc.
  - breaks fragments free from rooted stems

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Long distance dispersal of fragments

Appears to be mainly by the transfer of fragments on water craft and watercraft trailers

iisgcp.org

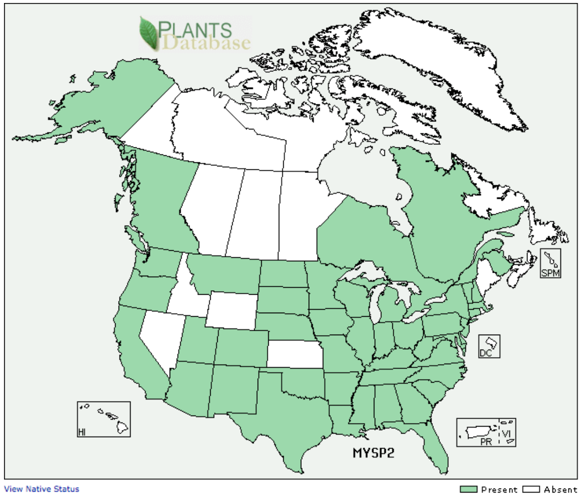
dec,ny.gov

New Zealand study: Inter-lake movement of boats was almost exclusively the cause of the transfer of aquatic weeds (Johnstone et al. 1985) .

Eurasian Watermilfoil (*Myriophyllum spicatum* L) (EWM)

- Invasive Species
- Introduced & Spread across N. America
- Among the most troublesome aquatic plants in N. America

  - (Madsen et al., 1991; Smith & Barko, 1990)



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What happens to EWM during overland transport?

- Our watershed stewards regularly pull fragments of aquatic plants off of boats and trailers.

- Stewards at our boat launches removed:
  - 21 EWM fragments in 2008
  - 12 EWM fragments in 2009

from boats and trailers preparing to launch into lakes without EWM populations (Watershed Stewardship Program 2008 and 2009).

- **These fragments were in various stages of desiccation.**

Very little is known about how drying affects the viability of EWM

So we asked:

1) **How fast does EWM dry out under out laboratory conditions?**

2) **How does drying affect the probability of new growth and rootlet development**

In the Laboratory

Weighed, measured, and dried fragments in a lab at room temperature for **0, 3, 6, 18, 24, 48 hours** (10 replicate strands per treatment)

- Fragments were placed into bins in the lab under grow lights (16 hours on / 8 hours off)

- in lake water that was changed every 4-5 days.

- Strands were examined and data collected on the incidences of new growth and rootlet development for 5 weeks.

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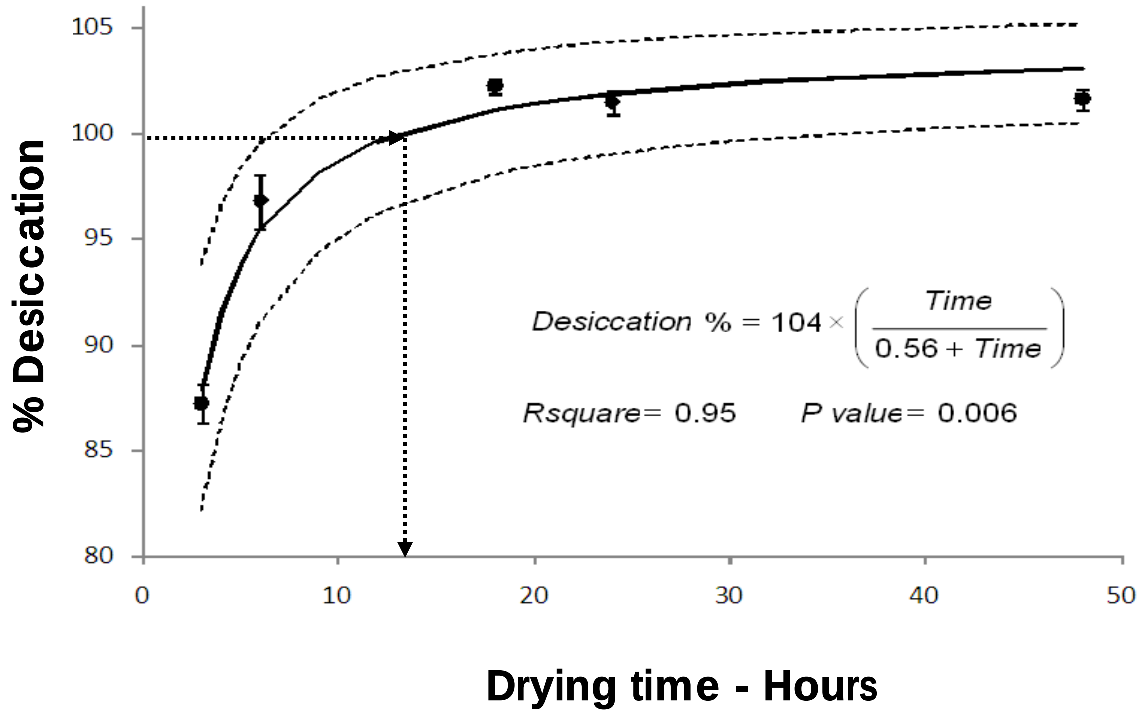
What we examined.....

- How fast does milfoil dry?
- How does drying a fragment affect new growth and rootlet development?
- What does this mean for the spread management of Eurasian watermilfoil?

Desiccation rate



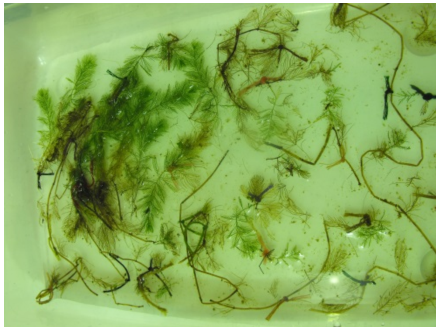
3 hrs = 88% desiccated

6 hrs = 96% desiccated

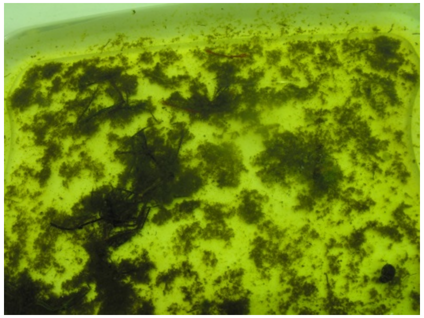
13 hrs = 100% desiccated

Barnes et al (2009) reported 70% desiccation after 1 hr and 90% after 3 hours

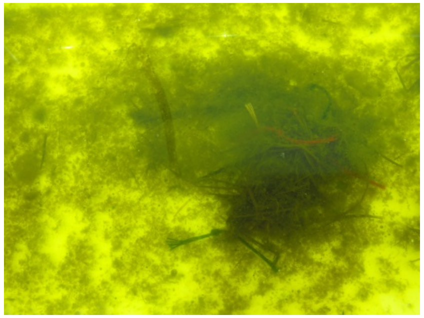
Visual Observations of fragments:



Control



6 hour



48 hour

- Control fragments remained buoyant
- 3 hr fragments were initially buoyant and then began to sink after several days
- All other treatments were not buoyant and fragments began to disintegrate after one week

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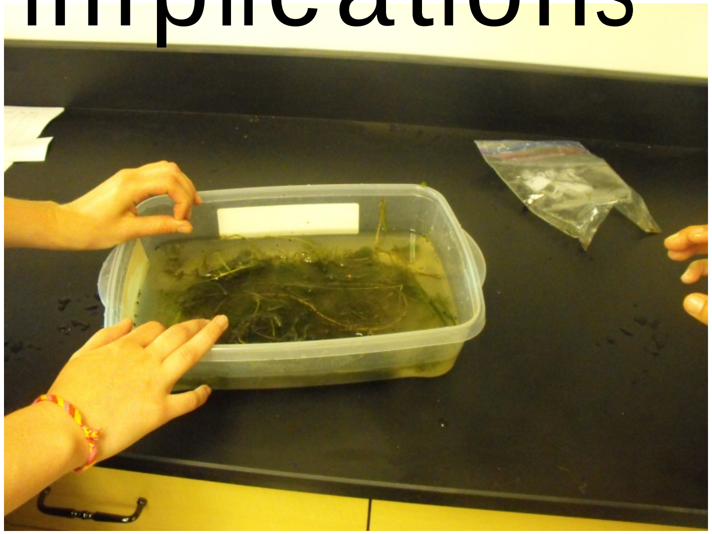
Statistical Probability of new growth after drying? (logistic regression analysis)

Desiccation %	Probability	95% Confidence	
		Lower	Upper
0	0.98	0.89	1.00
87	0.06	0.00	0.72
96	0.03	0.00	0.61
100	0.02	0.00	0.55

Fragments in the control treatment had a 98% likelihood producing new growth

Fragments in the 100% desiccated treatments had a 2% likelihood of producing new growth

Management implications



- EWM fragments dry quickly
- **Drying significantly reduces the chances** that a fragment will grow when reintroduced into a new lake
- …. **a new infestation only takes one strand**…..

- **This is a good news/bad news story.**

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The boating population has the most control over the spread of aquatic invasives

- High pressure boat washing and visual inspection reduced the amount of macrophytes introduced to water bodies by boats by 88%,
- Only about 1/3 of registered boaters always take these precautions (Rothlisberger et al. 2010).
- Johnstone et al. (1985) reported that none of the 5 invasive species they were studying were found in lakes with no boating or fishing activity

Story number 2

Growth of invasive and native watermilfoil species across a range of water temperatures:

What are the implications for aquatic plant communities under climate change scenarios?

Invasive species and Climate change

Invasives :

- reduce native plant diversity
- alter sediment and nutrient processing
- disturb natural habitats and communities
- interfere with recreational activities
- decrease property values

(Pimentel, Lach, Zuniga and Morrison, 2000).

- **A rise in invasive species globally has been observed to be causing a decline and even extinction in many indigenous species populations (Lovell and Stone, 2005).**

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Climate change

- Northeastern winters are predicted to shorten by half, providing for a longer growing season and earlier first-leaf and first-bloom dates for terrestrial plants (Frumhoff, McCarthy, Melillo, Moser and Wuebbles, 2007).

- **Changes in growing season length will also be reflected in lakes with earlier ice out and warmer spring water temperatures along with higher summer peaks** (Bornette and Puijalon, 2011).

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Research objective:

- **Examine the physiological responses of fragments of milfoil species over a range of water temperatures that are predicted due to global change scenarios**

- Eurasian watermilfoil (*Myriophyllum spicatum* – **EWM**)
- variable leaf milfoil (*Myriophyllum heterophyllum*- ***VLM***)
- northern watermilfoil (*Myriophyllum sibericum* - ***NWM***)

Northern Watermilfoil

(*M. sibiricum* Komarov) (NWM)

- Native species
- Close relative of EWM
- Range reduced due to EWM
- NWM & EWM prefer similar habitats, rarely coexist

(Aiken et al.,1980; Smith & Barko, 1990)

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Variable leaf milfoil (*M.heterophyllum*) (VLM)

- Able to form dense mats at a lake's surface, blocking sunlight

- Dense mats tend to reduce circulation in shallow waters, causing an increase in temperature (Argue et al., 2005).

- Considered invasive to the Adirondacks in northern New York, but is native to southwestern Quebec, North Dakota, New Mexico and Florida

What we wanted to know

- **Does growth and rootlet development of fragments increase of decrease or stay the same at different water temperatures?**

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Lab methods

- Six replicate water baths at each of the 5 target temperatures **(14C, 21C, 24C, 26C, 31C).**
- Thirty fragments (**6 reps X 5 temps) of each milfoil species** were placed into individual glass containers with **water collected from Lower St. Regis Lake** and one container of each species was placed into each water bath (**water topped up as needed, changed weekly**).
- Fragments were initially each **8 to 10 cm long** and **all had intact apical meristems and were unbranched**.

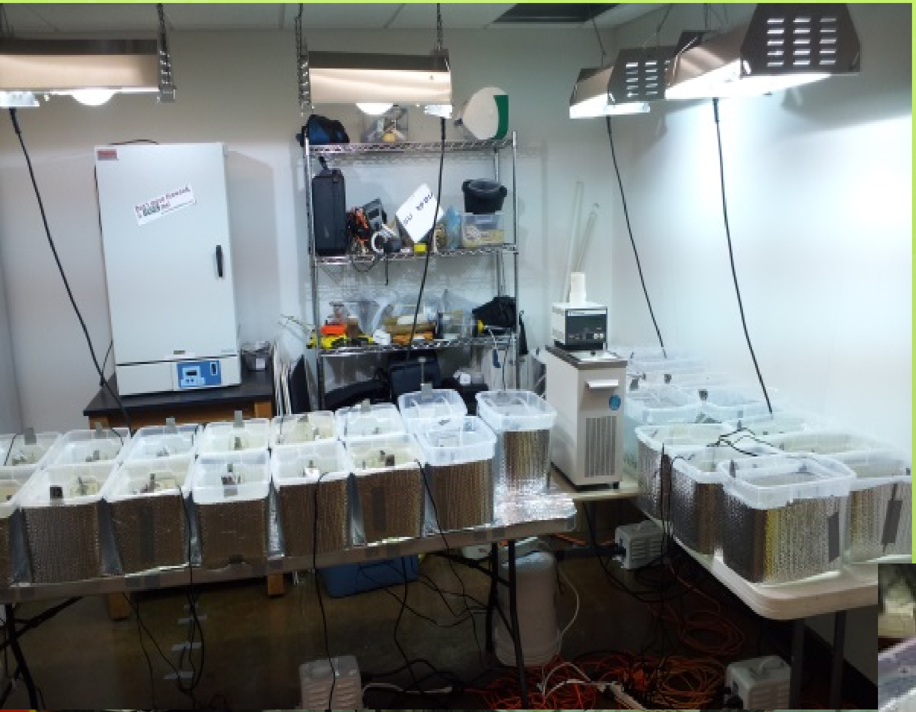

Figure 1. Images of experimental set up for 6 week milfoil temperature response experiment.

What we measured

- Final length, lateral and total growth
- Final fresh total biomass
- Final fresh viable biomass
- Final number of nodes with rootlets
- Final dry biomass

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Results: Average water temperatures for 6 week experiment

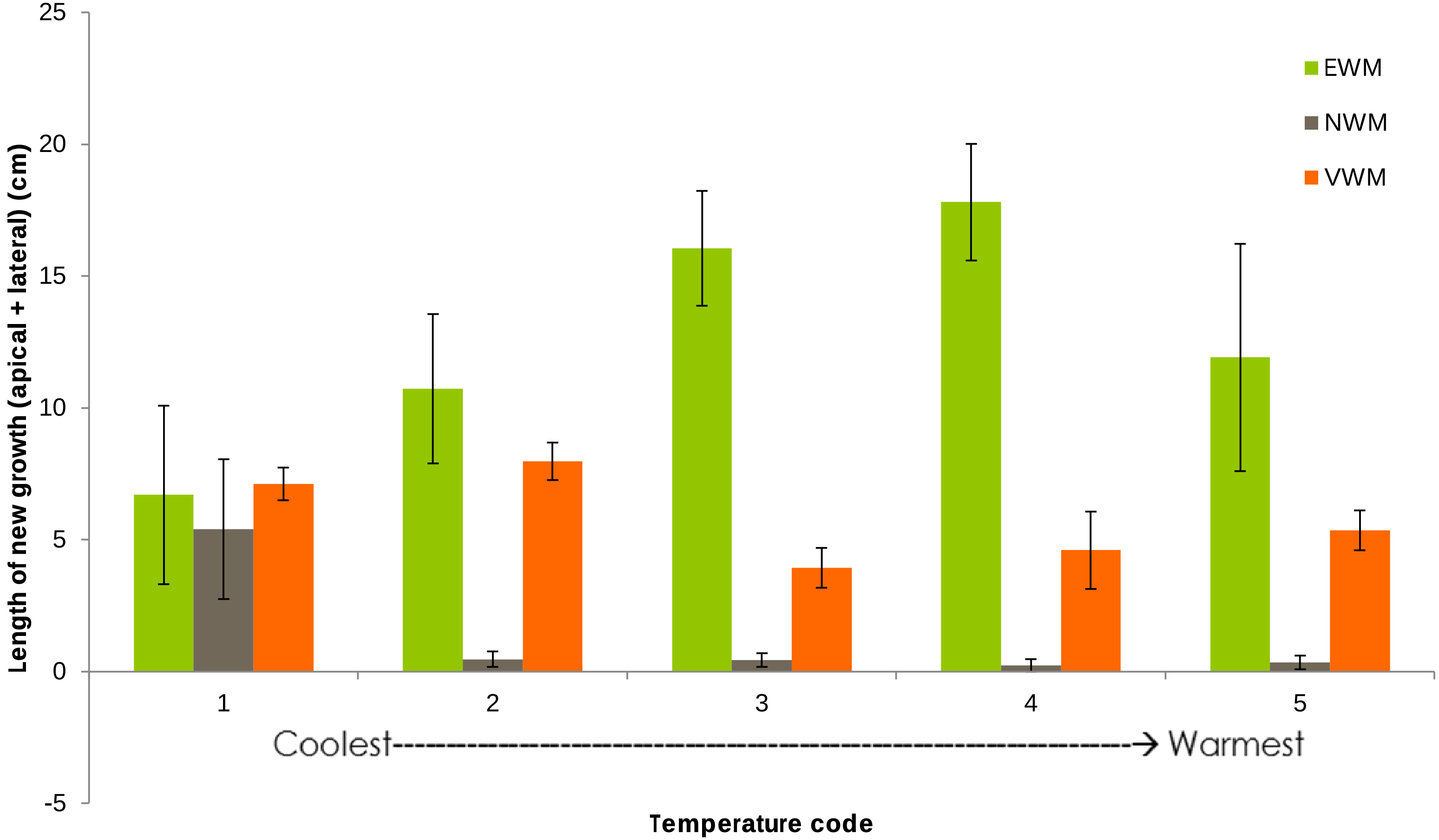
Temp. treatment	EWM	NWM	VLM	Control
Highest	32.15 ± 0.86	32.48 ± 0.88	32.38 ± 0.79	32.25 ±0.79
High	28.44 ± 1.0	28.41 ± 1.03	28.44 ± 0.87	28.45 ± 0.92
Medium	25.11 ± 0.96	25.24 ± 0.72	25.14 ± 0.67	25.18 ± 0.73
Medium Low	20.05 ± 0.34	20.23 ± 0.26	20.13 ± 0.40	20.16 ± 0.38
Low	14.09 ± 0.46	13.78 ± 0.22	13.86 ± 0.42	13.89 ± 0.28

Temperatures were consistently similar within a treatment and across species fragments

What we found

- **Looking at differences in species response to temperature**
- **Looking at interactions: Did species respond differently to temperature**
- 2 factor ANOVA

Total length growth significant species X temperature interaction (p = 0.006)



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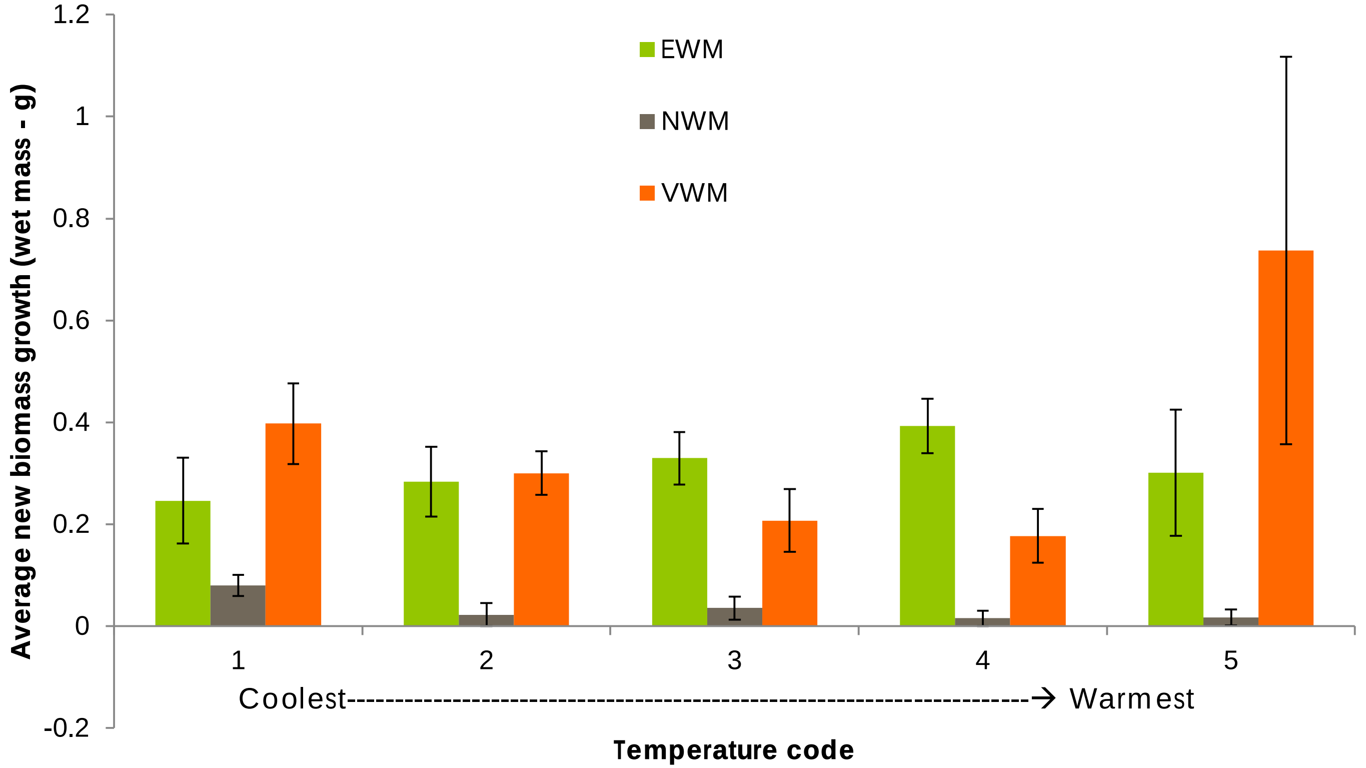
Total Biomass new growth(fresh mass)

no significant effect of species or treatment



Some of this tissue is non-viable, and so a different picture emerges when you examine remaining viable biomass....

Different life history / carbon allocation strategies

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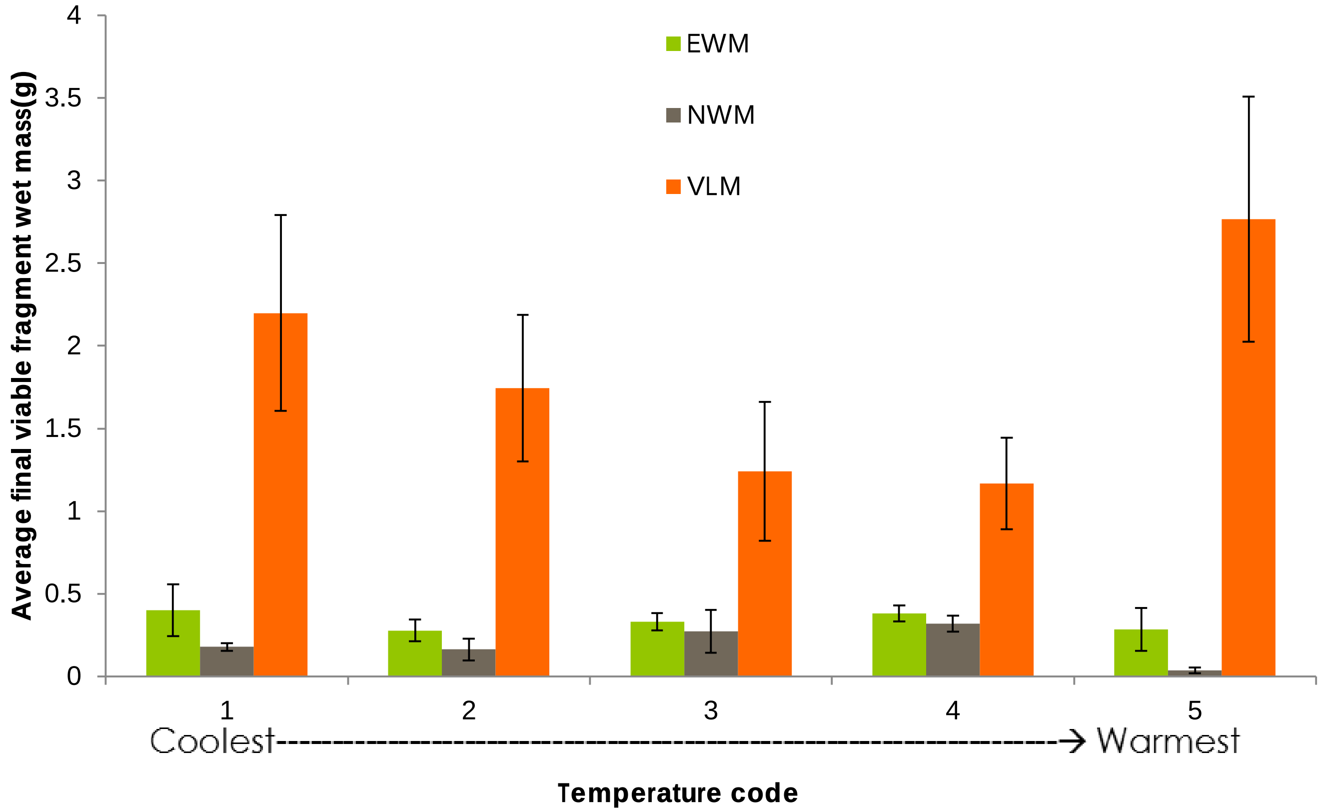
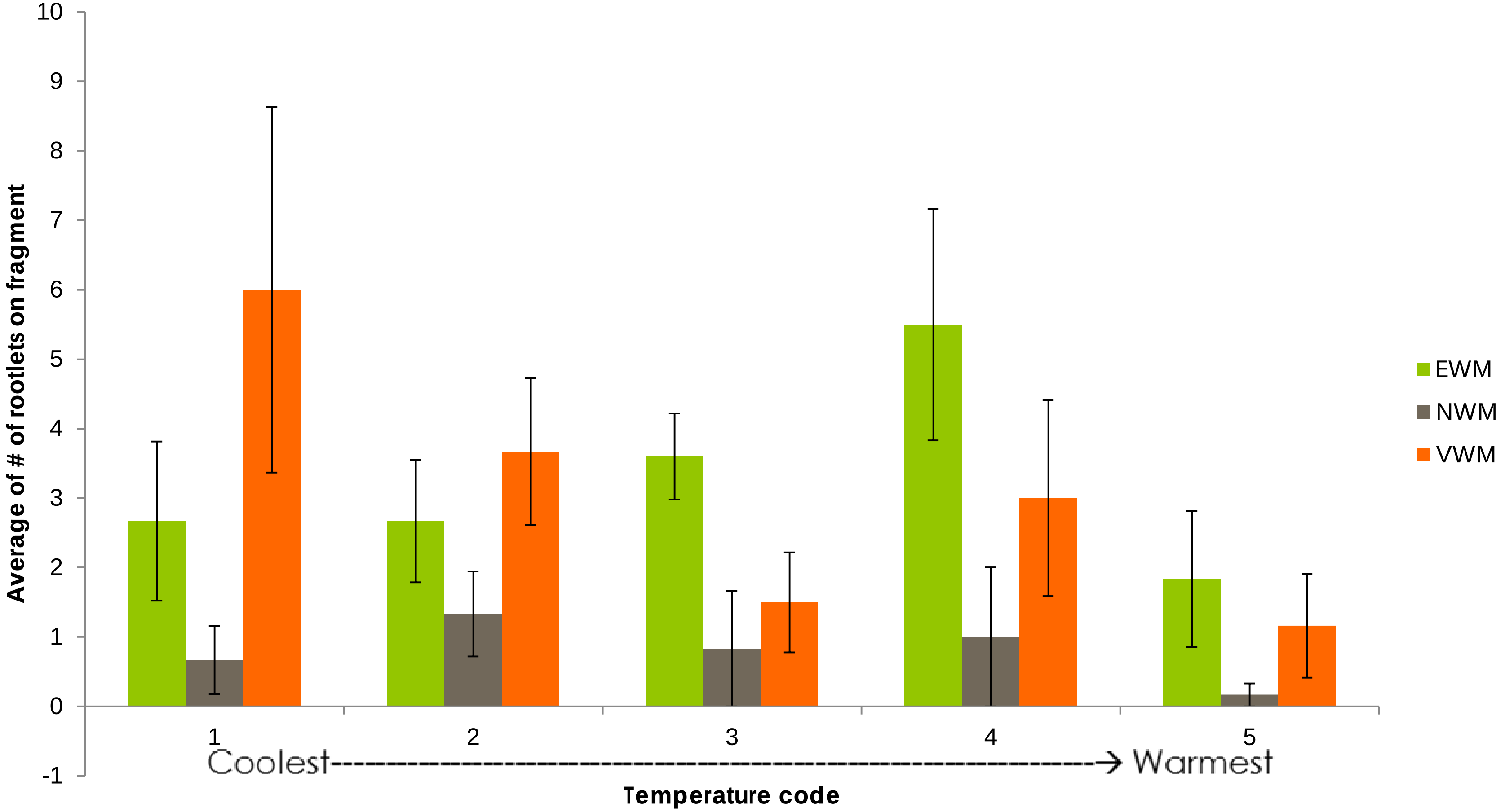
Total final viable biomass

significant effect of species (p<0.0001



VLM ends the experiment with significantly more viable biomass per fragment than the other two species

Rootlet production



Looks like an interaction between temperature and species…(TBD)

Take home messages..

- Native NWM grew significantly less than the invasive species regardless of temperature, and was negatively affected in higher water temperature.
- Invasive EWM and VLM fragments added about the same amount of new biomass over the experiment, however they had distinctly different response curves to temperature increases.
- The fragments of different species grow very differently while they float

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Conclusions so far……

- ~~northern watermilfoil (*Myriophyllum sibericum* - ***NWM***)~~

- Eurasian watermilfoil (*Myriophyllum spicatum* - **EWM**
- variable leaf milfoil (*Myriophyllum heterophyllum*- ***VLM***)

we can only hypothesize at this point about competition between the two invasive species…….

Implications for natural aquatic communities?

- **Ecosystems are complex…**
  - Controlled laboratory studies are the first step in developing hypotheses about competition outcomes in warming summer water temperatures.
  - Establishment studies needed
  - Actual competition experiments needed
- **These outcomes clearly suggest that the slow growing, native NWM will be negatively affected by warmer spring and summer water temperatures, while the invasives will benefit.**

Acknowledgements

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  - Paul Smith's College