Modeling the Growth and Sustainable Control of Invasive Watermilfoil

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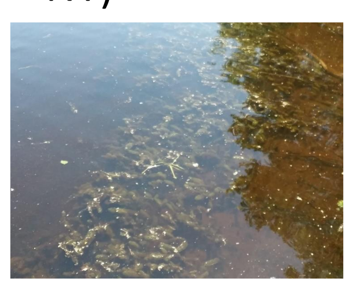
Motivation

Eurasian Water Milfoil (EWM) and Variable-leaf milfoil (VLM) are two of the most invasive species aquatic plants, found throughout the US and Canada. Invasive characteristics include:

- Outcompetes native plants (and grows fast!)
- Grows into dense mats forming monocultures
- Grows in eutrophic (nutrient rich) and oligotrophic (few nutrients) conditions (it's versatile!)
- Preferred habitat is 3-13 ft. deep (viable up to 33 ft. if water clear enough)
- Can reproduce by fragmentation

Project site: We aim to study the growth and control of VLM in Norwood Lake (a dammed reservoir on the Raquette River in Upstate NY)



Picture: White 2018

Fig: (a) VLM growing in Raquette River (Upstate NY)
(b) VLM close up

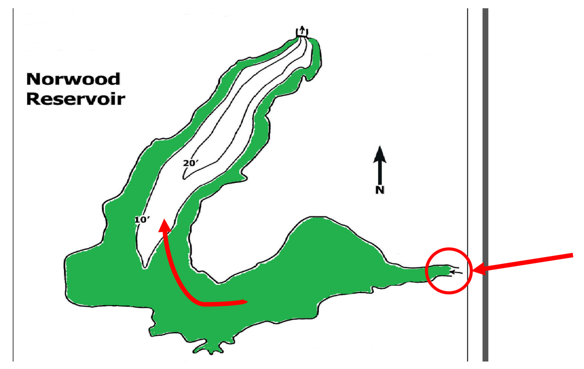


Fig: Area of Norwood lake predicted to be Invaded by VLM if nothing done (Twiss 2015). Fragments can (and do) come from upstream

Objectives

- Derive a growth model for EWM biomass growing in a single patch
- Determine which parameters are most sensitive (how do model parameters affect end of season total biomass?
- Study
- Explore spatial models to determine how EWM spreads (via fragmentation). Such models are conducive to testing control stratifies like:

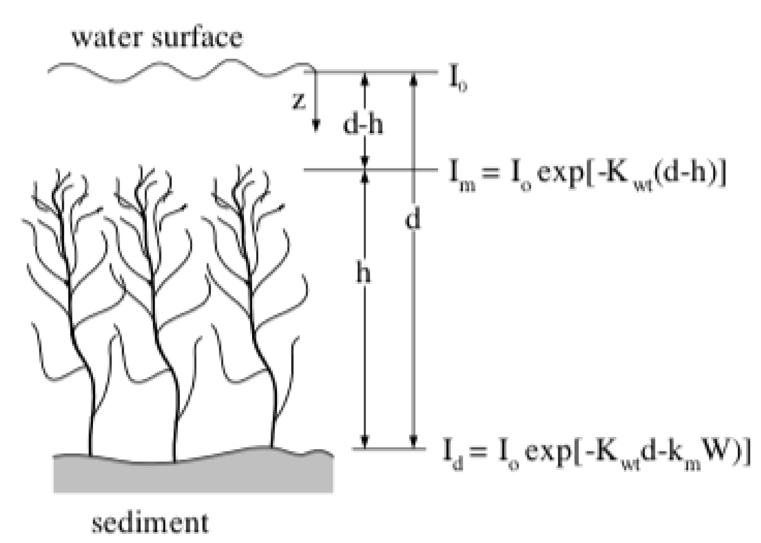
- (1) Benthic mats
- (2) Hand pulling
- (3) Biocontrol (the milfoil specialist – the milfoil weevil)

(1) Benthic Mats constructed by Twiss (similar, but not shown here) are 10 x 20 feet, made of black tarp and weighe down with rebar.

(2) White hand-pulling milfoil During 2017 drawdown on Norwood Lake. Hand pulling more difficult in water.

(3) Weevil known to feed on milfoil (specialist) (adult milfoil lay eggs in meristem of plant, and larvae and pupa feed on tissue in meristem, halting growth.

Milfoil ODE Patch Model [1]



Assumptions

- Only one biomass peak per season.
- Growth μ is a function of temperature and incident light.
- Nutrients and dissolved carbon to explicitly included (lumped into parameter μ_T).
- Uniform biomass density over depth (plant leaf structure is the same over depth) - $P(z,t) = P_o(t)$.
- Reproduction and multi-seasonal growth not modeled.

Model parameters:

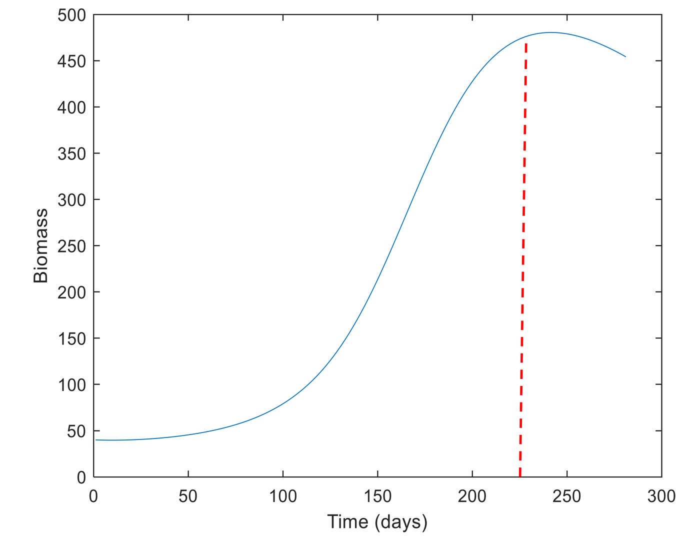
W	Biomass (kg/m^2)
μ_T	Light saturated growth rate (day^-1)
k_m, K_{wt}, k_1	Light attenuation coefficients

Model Equations:

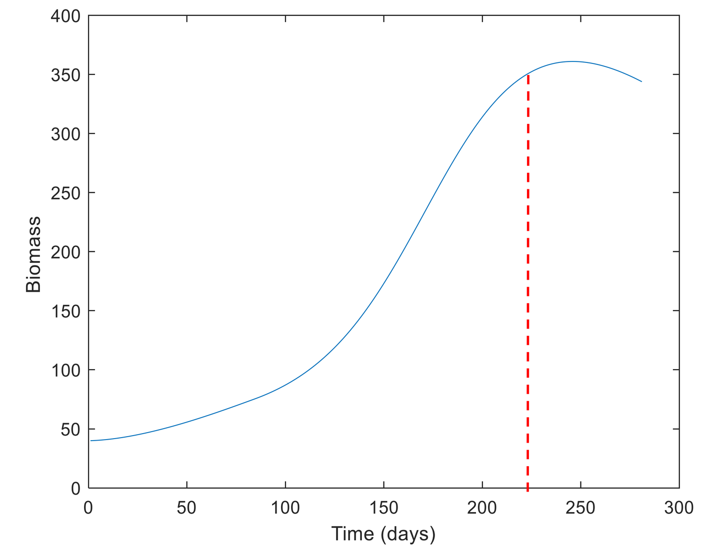
$$\frac{dW}{dt} = \int_0^d [\mu(z) - \lambda] P(z)\, dz$$

$$\frac{dW}{dt} = \underbrace{\frac{\mu_T}{k_m} \frac{k_m W}{K_{wt} h + k_m W} ln(\frac{k_1 + I_m}{k_1 + I_d})}_{\text{Plant growth depends on irradiance, temperature, water attenuation, and biomass.}} \underbrace{- \lambda_T W}_{\text{Plant decay due to respiration}}$$

Results for parameter set in [1]

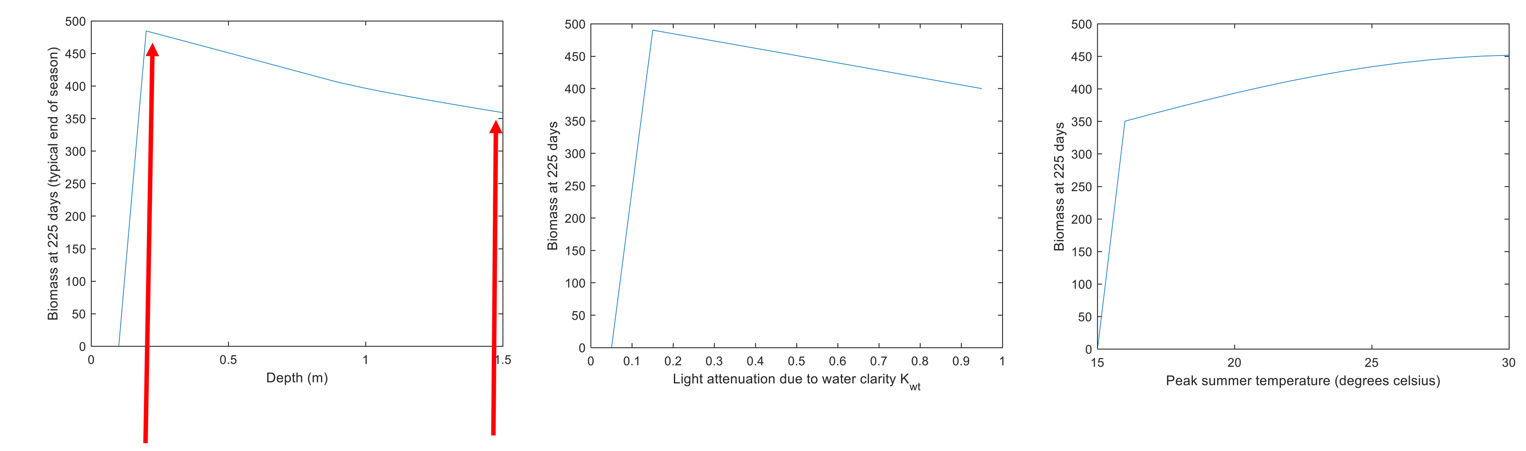


Smaller depth d = 0.2 m: Peak biomass is Higher (and end of season biomass at 225 days is higher)



Greater depth d = 1.2 m: Peak biomass is Lower (and end of season biomass at 225 days is lower)

Parameter Sensitivity



(1) Plant biomass (model output W) at day 225 is more sensitive at low depth: This is consistent with VLM and EWM growing faster at shallow depth.

(2) Plant biomass at 225 days more sensitive in clear water conditions: VLW and EWM grows faster in clearer water.

(3) Plant biomass at day 225 sensitivity increases with increasing temperature.

Sustainability

- Here, we aim to not only describe the growth (and eventual spread) of VLM and EWM, but we also hope to model it's control.
- Once our model includes a spatial component, we can explicitly model the placement of benthic mats as well as small-scale (local) hand pulling.
- These control mechanisms combined will help to define a sustainable control strategy that can be utilized by the general public in other lake communities (one that is time and cost efficient).

Future Work

- Make model Norwood Lake specific (already collected many parameters which include lake characteristics, and VLM growth characteristics).
- Explore spatial models (to study spread via fragmentation)
- Determine overwintering characteristics
- Create year to year model (now just 1 growing season)
- Explore control strategies outline in **objectives**.

Contact

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References:

[1] William R Herb. and Heinz G. Stefan. Ecological Modelling, 168(2003):77–100, May 2003.

[2] Elly et al P.H.Best. Ecological Modelling, 168(2003):77–100, May 2003