Algae Testbed
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Modeling and Optimization of *Nannochloropsis oceanica* Growth in Seasonal Algae Testbed Unified Field Studies

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- We need to be able to optimize algae growth and lipid production in large commercial scale systems
- Commercial scale tests are time consuming and expensive
- A computational model facilitates faster and cheaper optimization
- We apply our validated model to outdoor raceway ponds during multi-season, multi-location unified field studies (UFS) of *Nannochloropsis oceanica* (KA32 – Cellana) growth.
- This study shows our model's ability to predict growth and optimize parameters of interest like depth and harvesting rates.

– Models algae growth based on constitutive relations

- ***B*** – biomass concentration (g/m³)
- ***P*** – growth rate (1/d)
- ***B_M*** – metabolism rate (1/d)
- ***P_R*** – predation rate (1/d)
- ***P_M*** – max growth rate (1/d)
- ***f*** – growth limiting constitutive relations ($0 \le f \le 1$)

$$\frac{\partial}{\partial t}B(\mathbf{x},t) = \left(P - B_M - P_R\right)B(\mathbf{x},t) + \frac{B_L}{V}$$

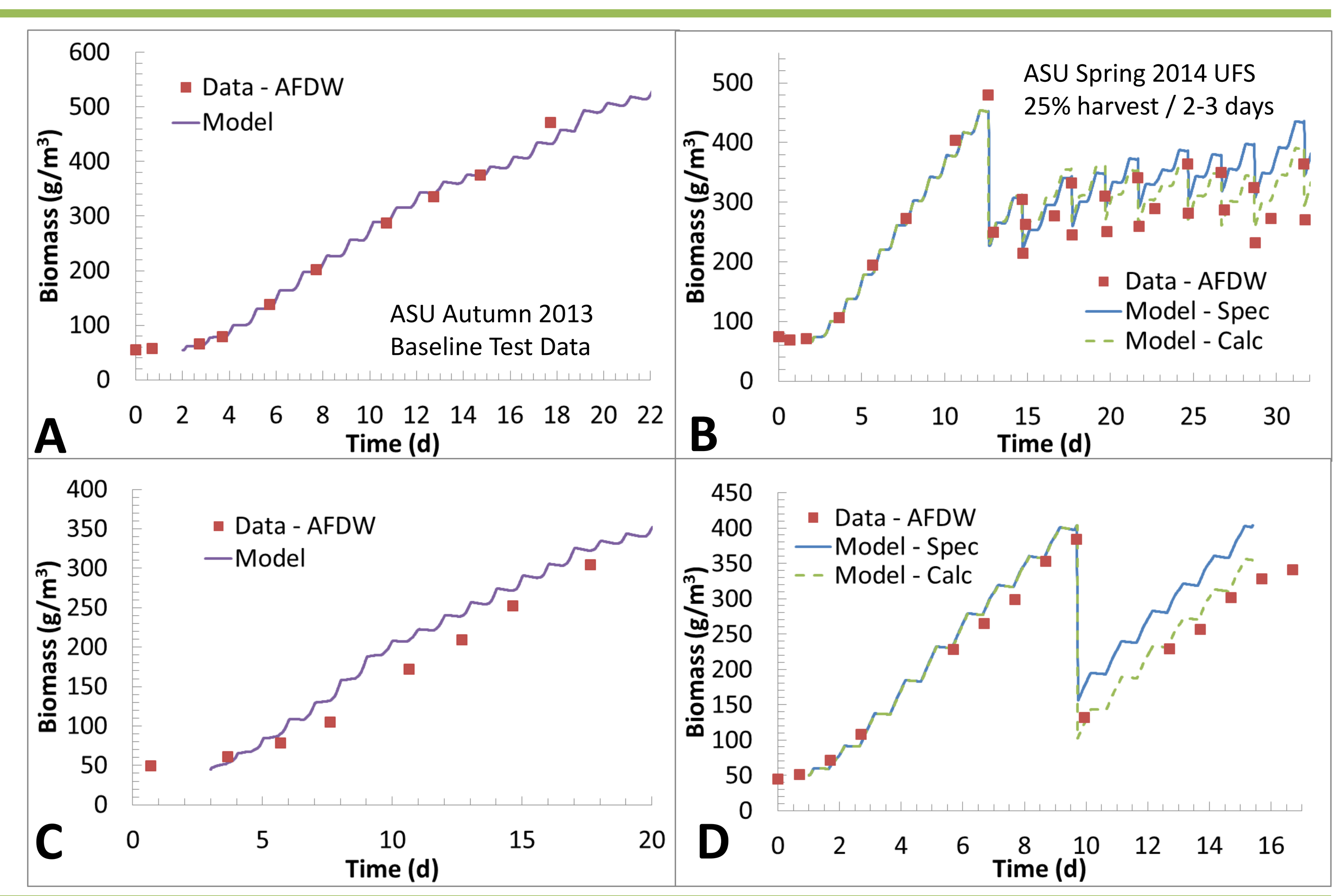
$$P = P_M \cdot \left[f_1(N)\, f_2(I)\, f_3(T)\, f_5(S)\right]$$

– Tracks nutrients, salinity, temperature, light, CO_2 and O_2

– Allows for sources and sinks of parameters (B_L)

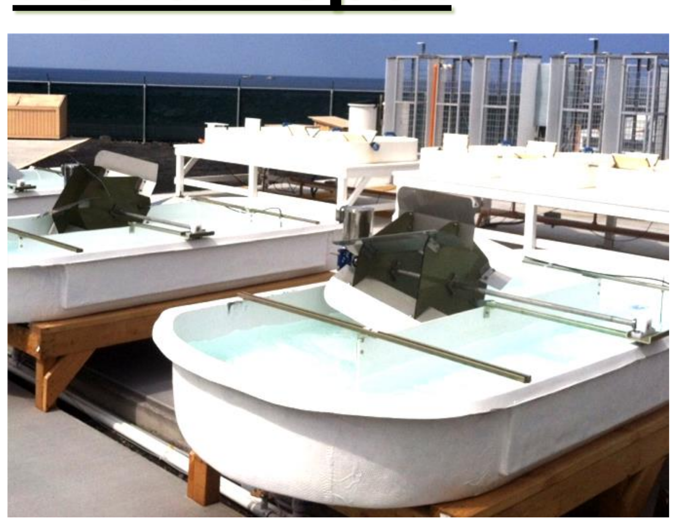
Calibration and Validation

- Max growth rate and limitation functions are calibrated using data from ASU autumn 2013 baseline study.
- Same calibration applied to all cases.
- Harvest modeled using biomass quantities from the data and dilutions and frequencies for verification.
- Calculated harvest fits model better.
- All cases had a lag time between inoculation and exponential growth.
- Model showed good agreement over different locations and seasons.



Comparisons of model results and measured data are plotted to show breadth of locations and seasons: A) Data used for calibration from ASU in autumn 2013, B) ASU spring 2014 with harvesting, C) CalPoly in autumn 2013, D) Cellana in spring 2014 with harvesting. Harvesting is modeled by either specifying the biomass removed based on data or calculating based on the planned frequency and dilution rate.

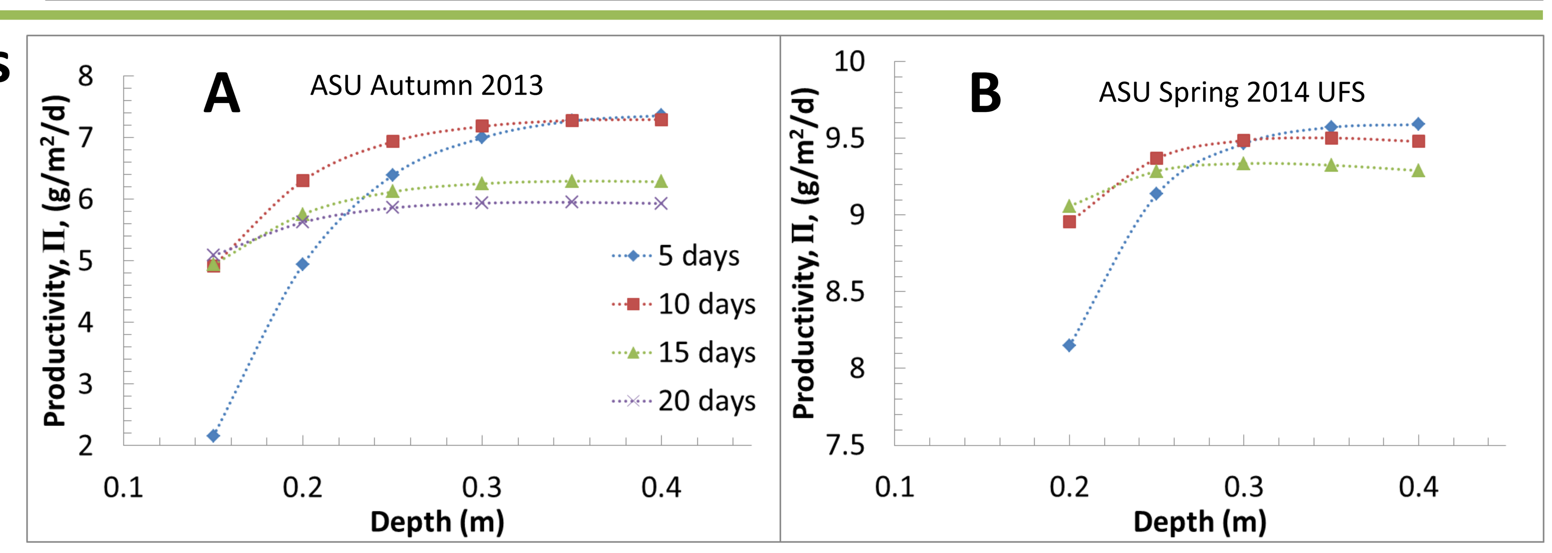
Pond Depth



- Depth of the modeled pond is varied for two seasons at the ASU location.
- The productivity is calculated after lag time with:

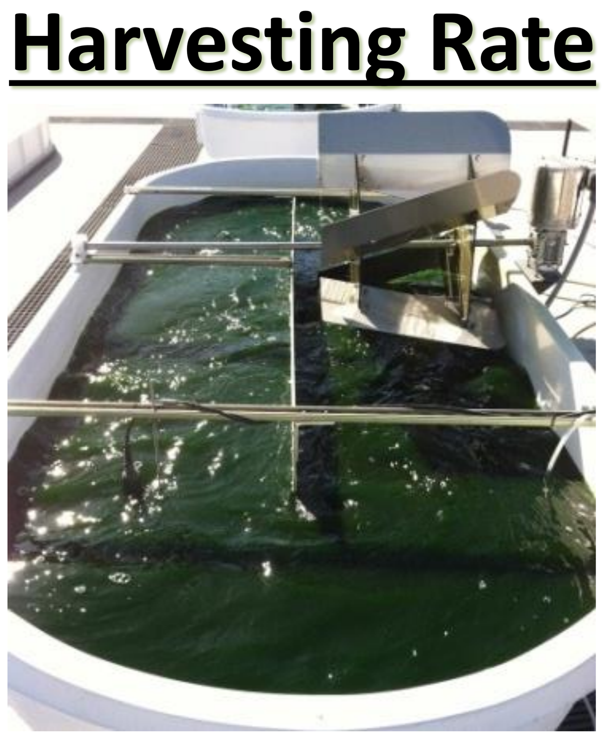
$$\Pi = \frac{(Biomass\ Growth)}{(Volume)(Time)} \times depth$$

- The calculated productivity is plotted versus depth for various harvesting frequencies.
- Depth has a greater impact with faster harvesting.
- Little improvement was seen for ponds deeper than 25 cm at all harvesting frequencies.

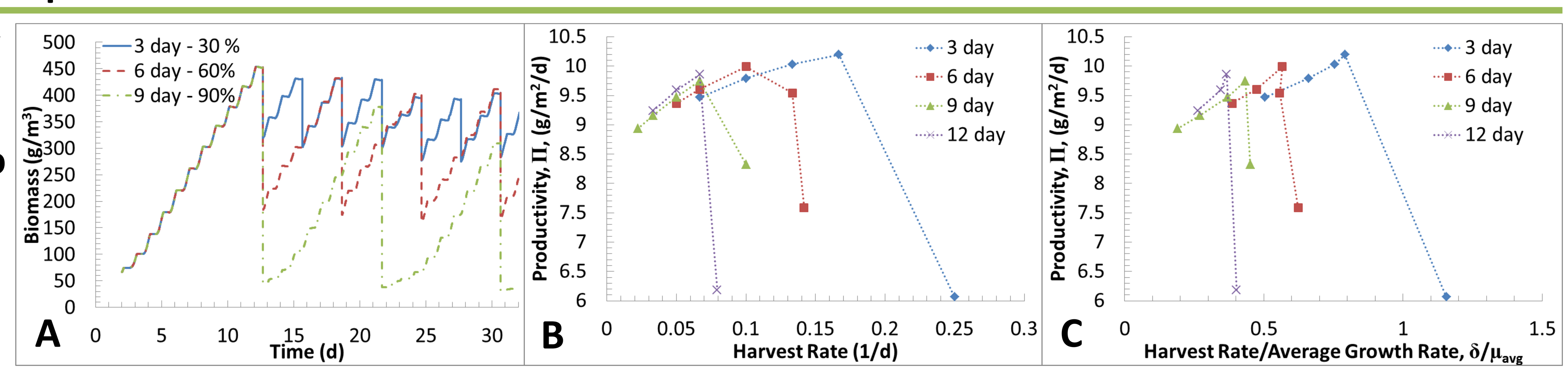


Modeled pond productivity as a function of pond depth for ASU location in: A) autumn 2013, and B) spring 2014.

Harvesting Rate

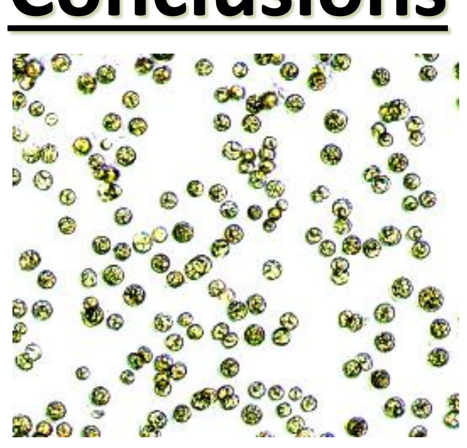


- Harvesting rate is varied by adjusting both the dilution and frequency of harvests.
- Productivity is compared to the harvesting rate and the ratio of harvesting rate to growth rate.
- The ideal harvesting rate depends on the harvesting frequency.
- When the concentration goes too low, the productivity is reduced due to the low population numbers.
- When the concentration is allowed to increase, the productivity slowly reduces due to self shading effects.



A) Modeled algae concentration over time for a harvest rate of 0.1/d at various harvest periods. B) Modeled productivity versus harvest rate for various harvest periods. C) Modeled productivity versus ratio of harvest rate to average growth rate for various harvest periods.

Conclusions



- Our algae growth model has been validated for use over multiple seasons and locations for a given strain calibration.
- A minimum optimal depth of 25 cm for the cases studied has been identified.
- The ideal harvesting rate depends on the harvesting frequency.
- More frequent harvesting allowed for a greater overall harvesting rate and productivity.
- This study shows the potential of this model to optimize cultivation and harvesting processes and parameters to increase the productivity of algae biomass cultivation.
- This model can be utilized for pond design optimization, strain selection, and process optimization for improved algal yields and productivities.

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