



# ALGAE GROWTH EXPERIMENTS USING DELTA WINGS

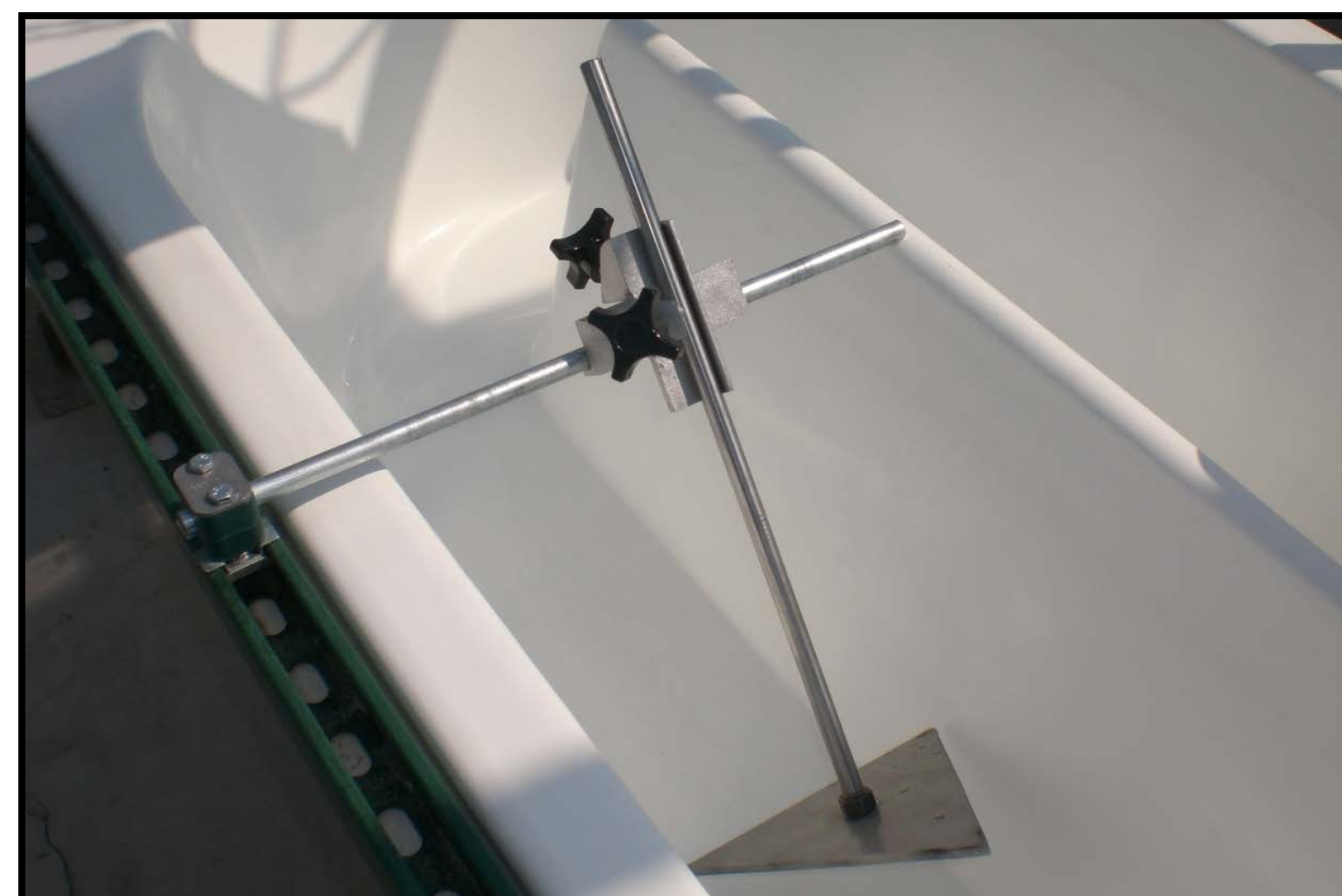
GARRETT VAUGHAN<sup>1</sup>, JUSTIN HUNT<sup>1</sup>, BYARD WOOD<sup>1</sup>,

<sup>1</sup>DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING, UTAH STATE UNIVERSITY, LOGAN, UT



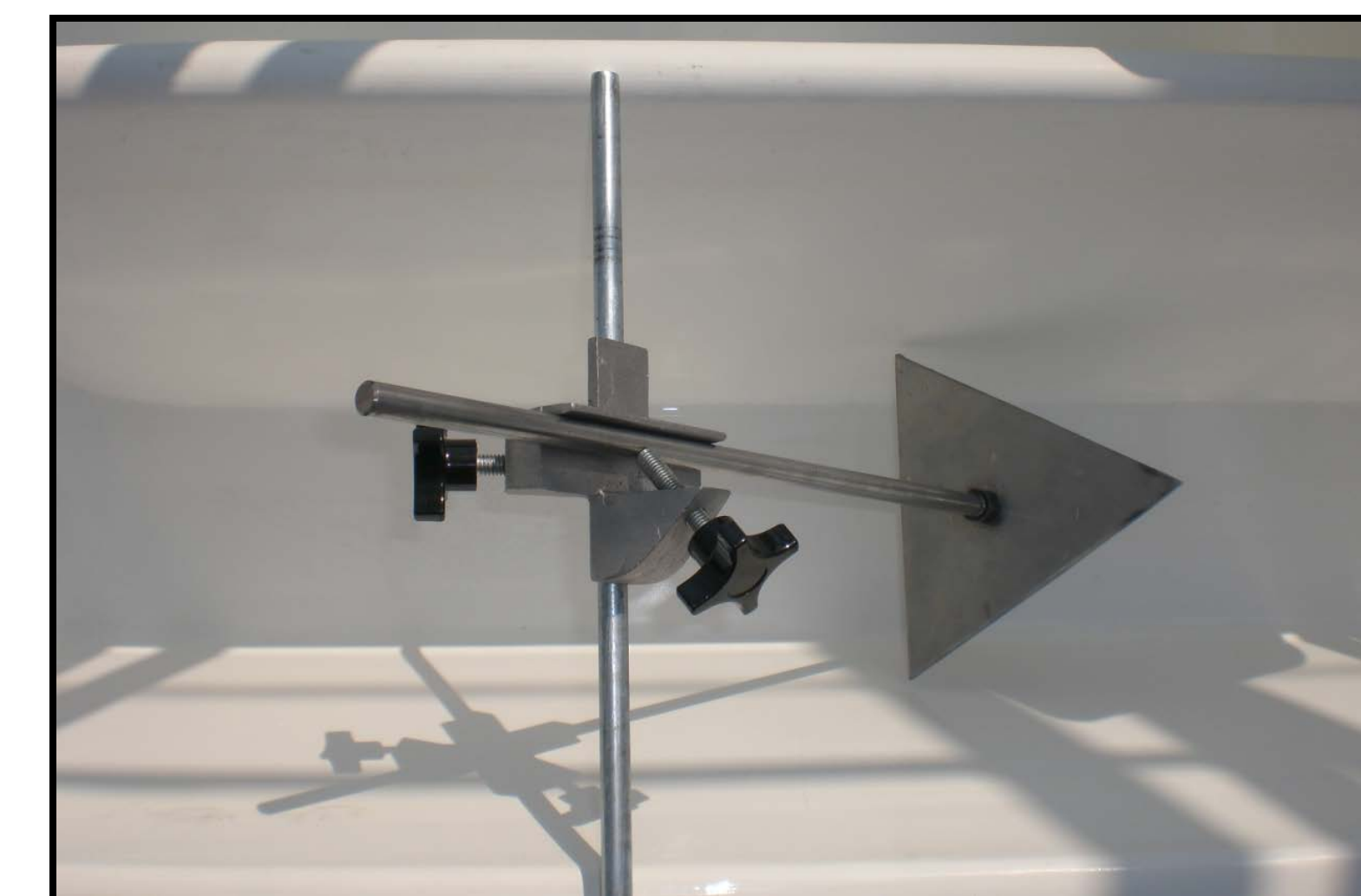
BioEnergy Center

## ABSTRACT



Delta Wing installed in raceway

Utah State University has been heavily involved in research regarding increasing vertical mixing in open channel raceways using delta wings with the hopes of increasing biomass production. Proper analysis of the mixing effects of the delta wing have been verified through CFD, ADV, and PIV efforts, but **does this increased vertical mixing help improve the overall growth of the algae?** Preliminary experimentation of these delta wings in commercially built raceway ponds to grow algae has been tested and proven to increase algal production in a *Chlorella Vulgaris* strain by **25-30%**. These results are very encouraging as research is pushed along to optimizing this production method.



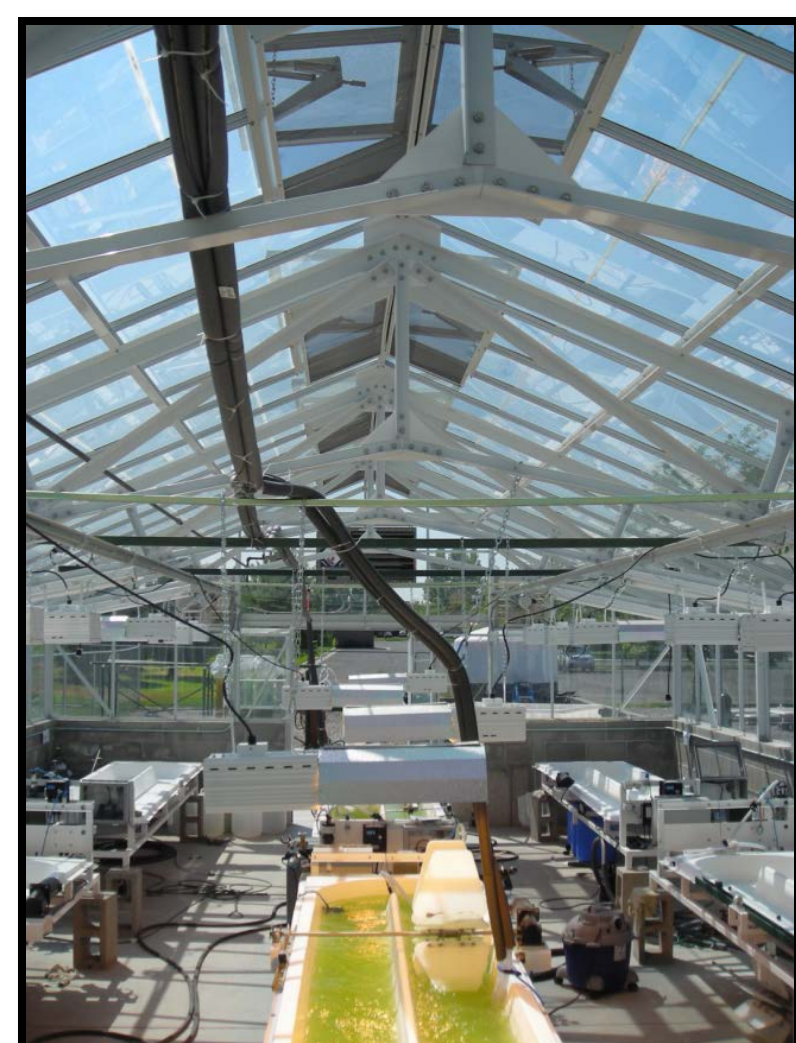
Top view of Delta Wing

## EXPERIMENTAL SETUP

Algal growth experiments were conducted in the research greenhouse at the Solar BioInnovations Center located on Utah State University's Innovation Campus. This environment allowed operation of well-controlled experiments. The facility has a chilling system that was used to regulate the raceway water temperature, via cooling coils, amidst the wide range of temperature variation within the greenhouse.



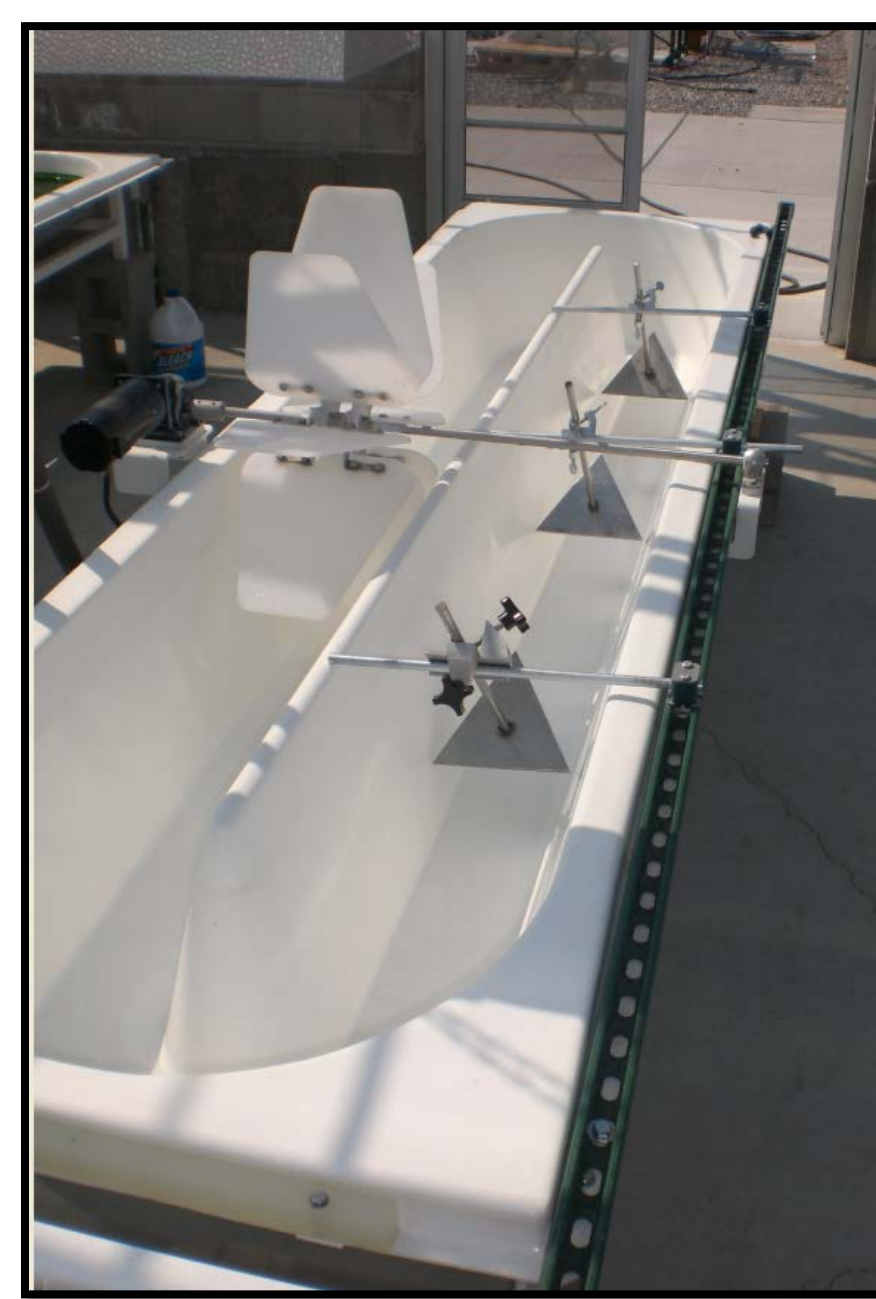
Outside the Solar BioInnovations Center Research Greenhouse



Inside view of Greenhouse with cooling coils

Two professionally manufactured raceways were used for side-by-side growth experiments. One raceway contained three delta wings and the other did not have delta wings. The main parameters are as follows:

- Greenhouse temperature range: 60 – 100 °F
- Raceway water temperature range: 70 – 75 °F
- Water depth: 10 in.
- Average velocity of water: 25 cm/s
- Number of delta wings: 3
- Delta wing spacing: 1.5 ft from bend, 2.5 ft, 2.5 ft, 1.5 ft from bend
- Algae strain: *Chlorella Vulgaris*

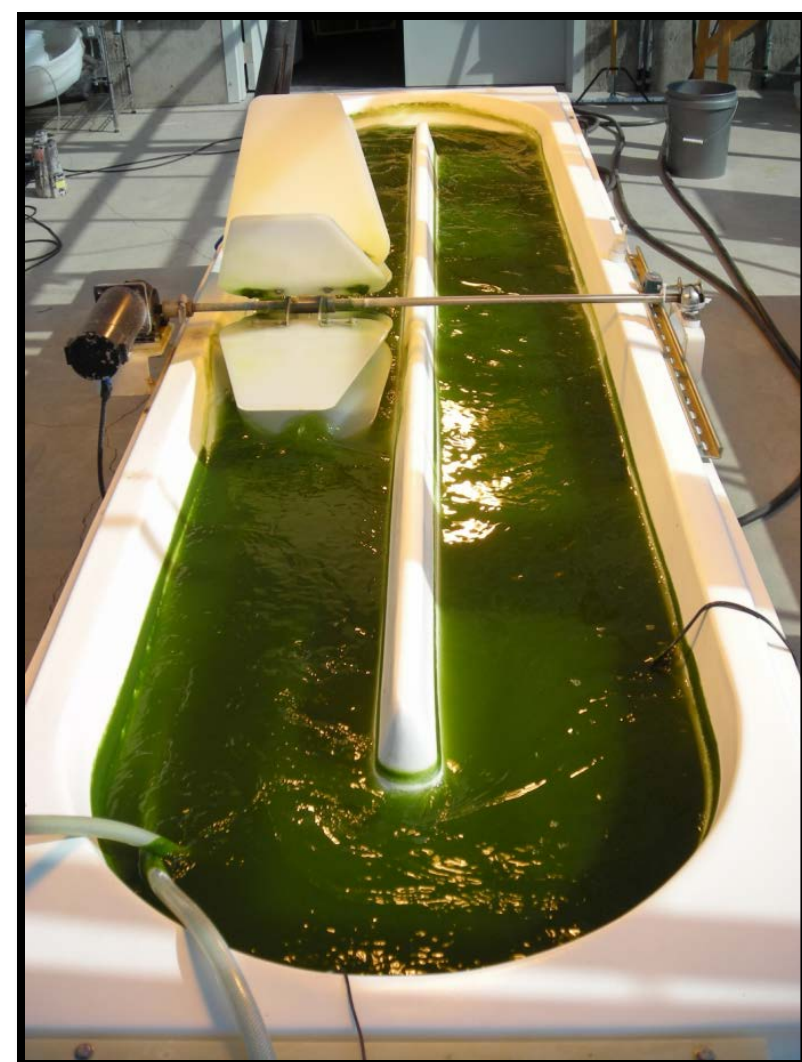


Delta wing experimental set-up

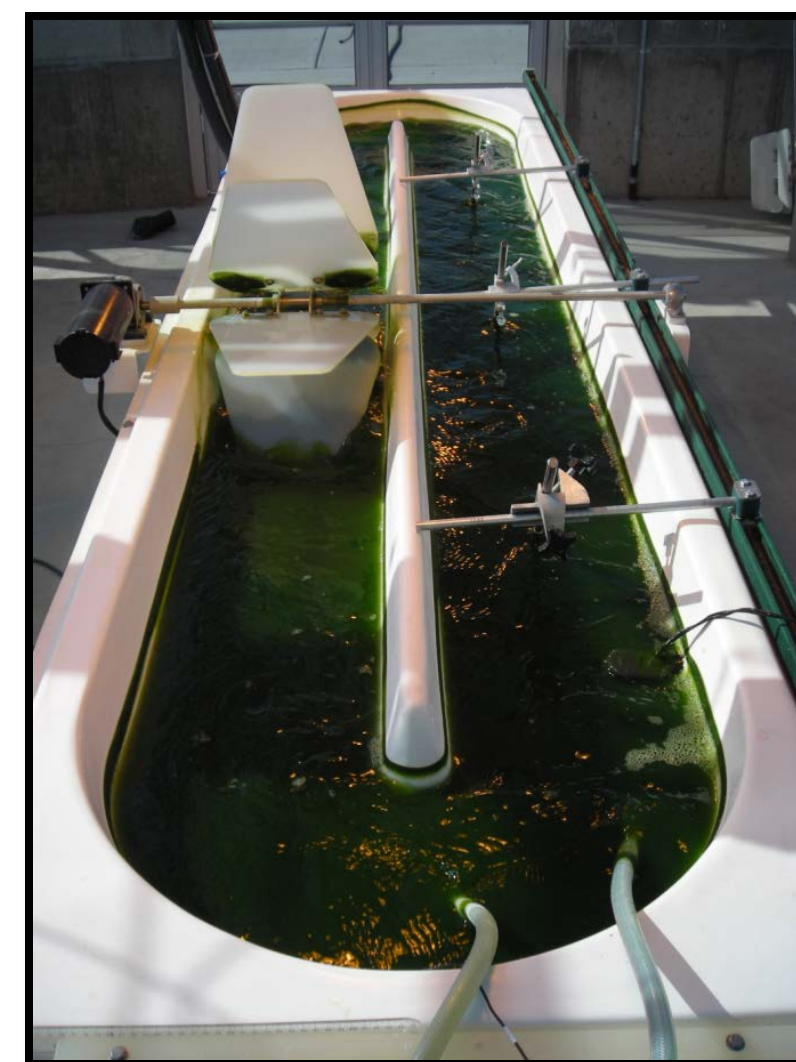


Tube used to grow *Chlorella* inoculum

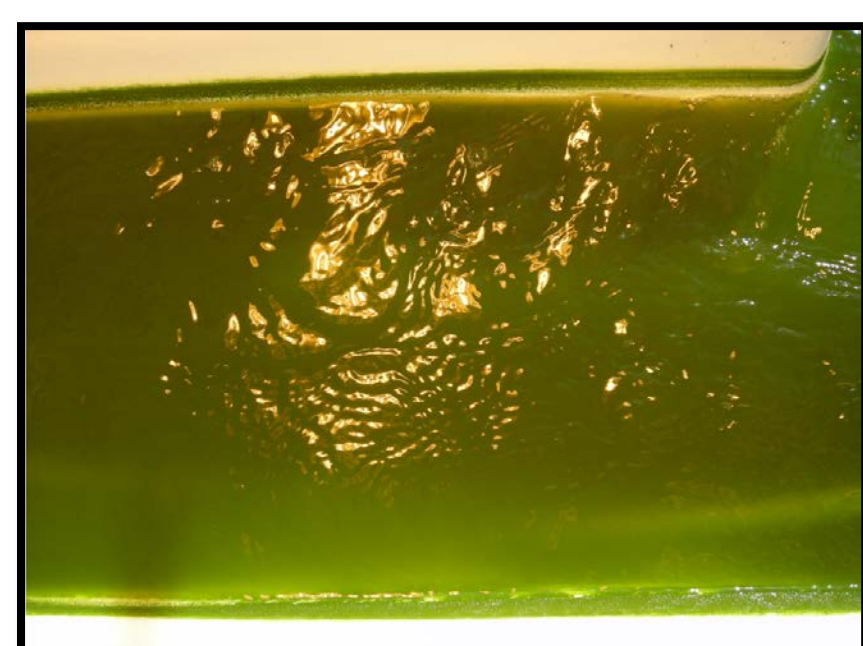
For comparison purposes, it can be seen that the raceway with the delta wings lead to denser algal biomass. In the results section, how much a difference the delta wings make is shown.



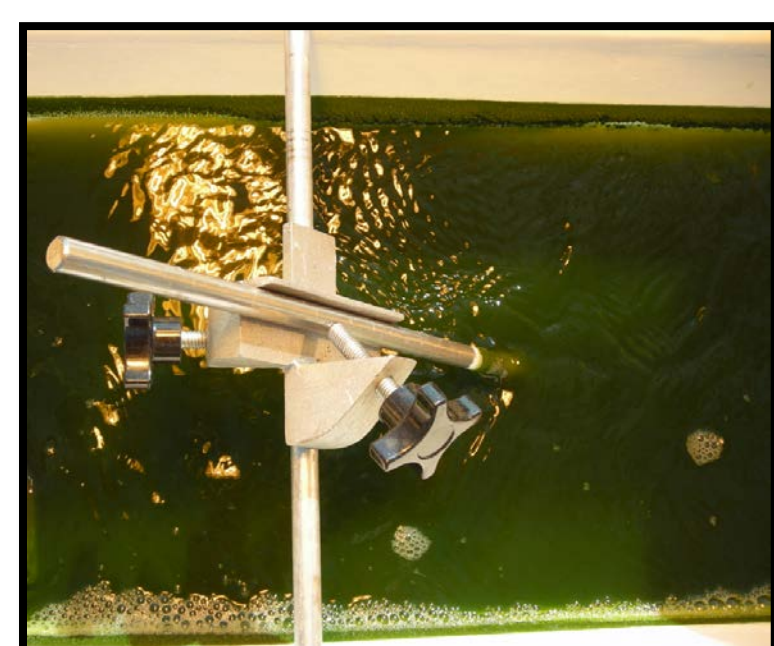
Raceway without delta wings



Raceway with delta wings

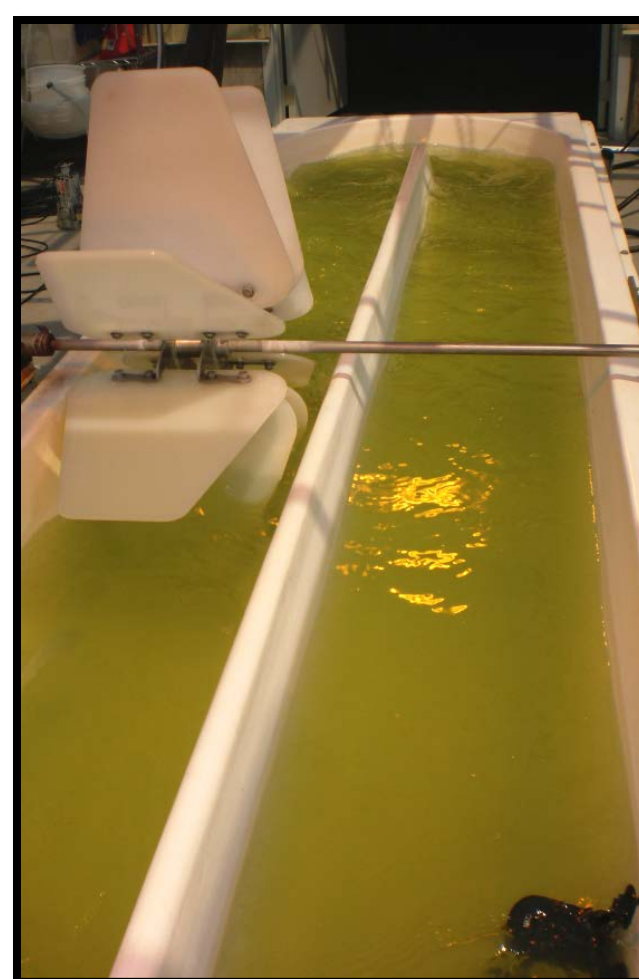


Raceway without delta wings



Raceway with delta wings

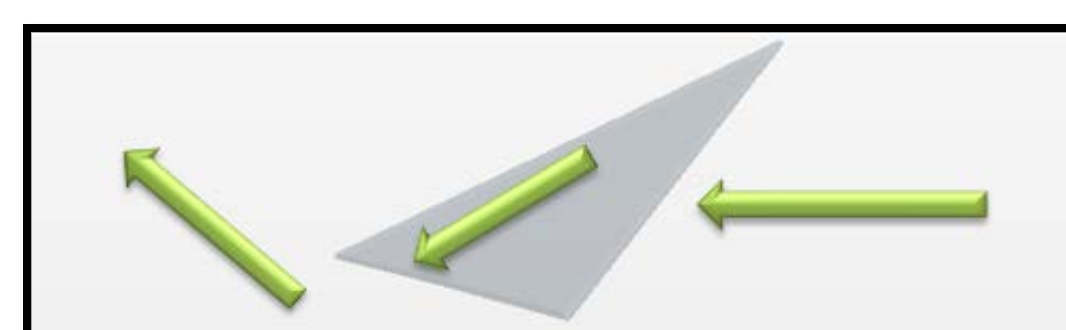
## RESEARCH PROBLEM DEFINED



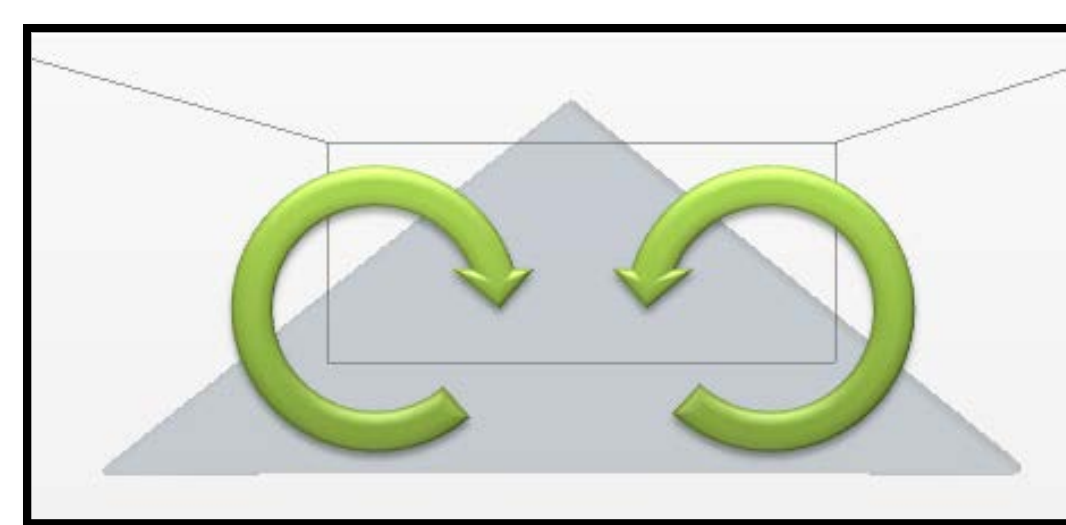
Channel laminar flow

In conventional raceways, the long straight channel sections experience a state of laminar or steady flow. This phenomenon leads to possible settling of algae which prevents them from receiving much needed sunlight at the free surface. Delta wings increase vertical mixing in these laminar channel regions and circulate algae from the bottom to the free surface for necessary photosynthetic exchange. **However, does the addition of delta wings in these laminar regions positively help the growth or diminish it?**

## DELTA WING CONCEPT

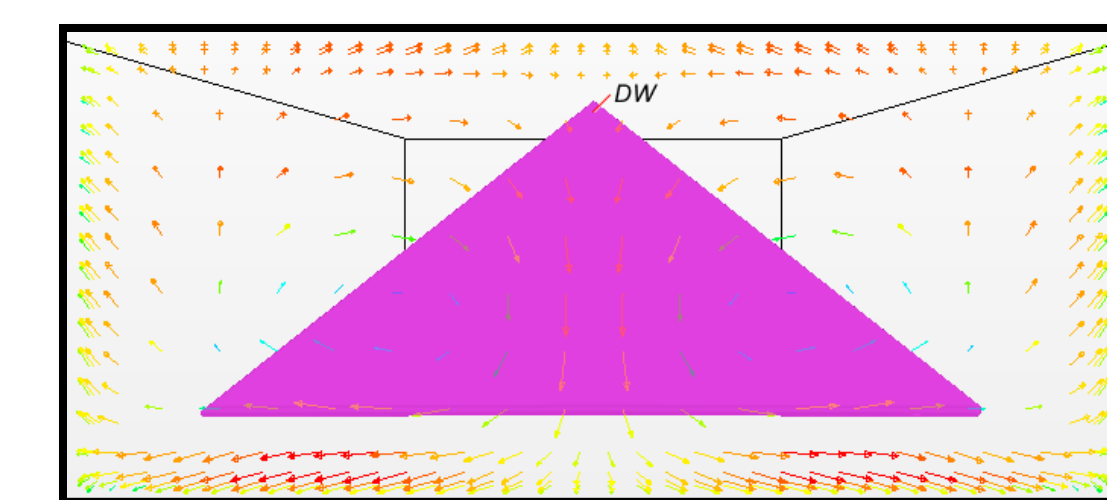


Side view of flow over delta wing

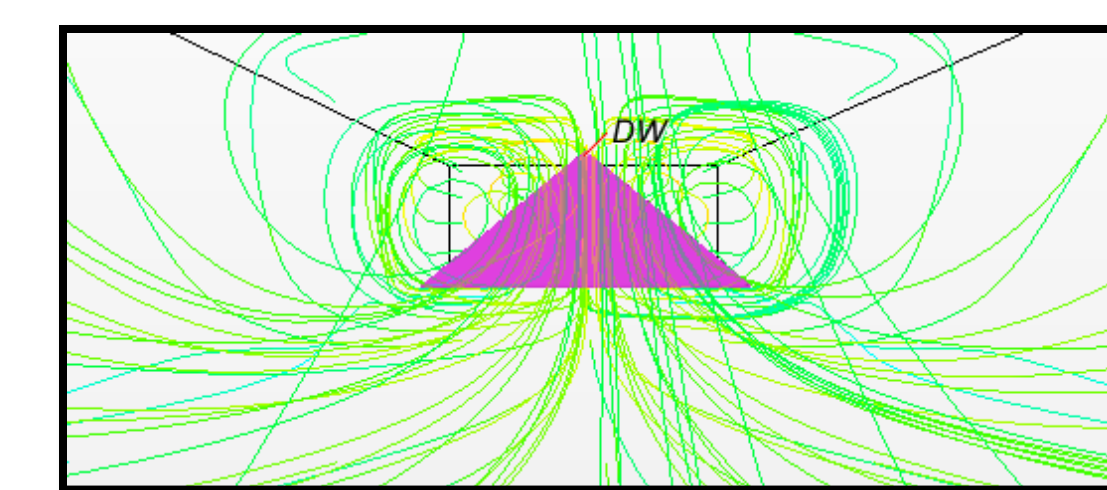


Downstream view of vortex generation

In order to increase vertical mixing in the raceway delta wings are placed in the flow at a certain angle of attack. As the flow passes the delta wing, a high pressure region below and low pressure region above create two vortices or swirling motions that propagate downstream. These vortices help to circulate the algae from the bottom to the free surface for necessary photosynthetic exchange.



Vector plot of vortex generation

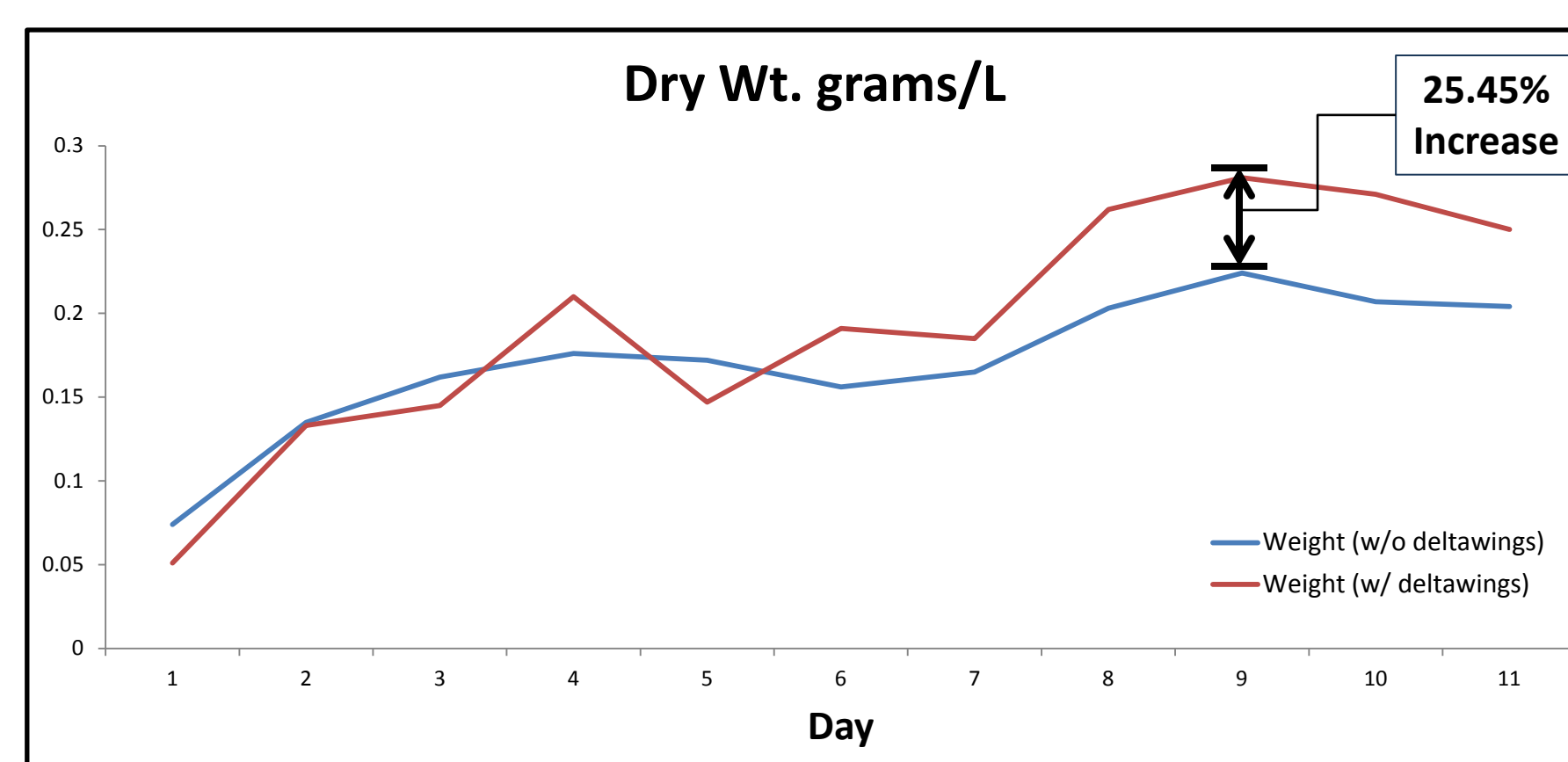


Streamlines of delta wing vortices

## RESULTS

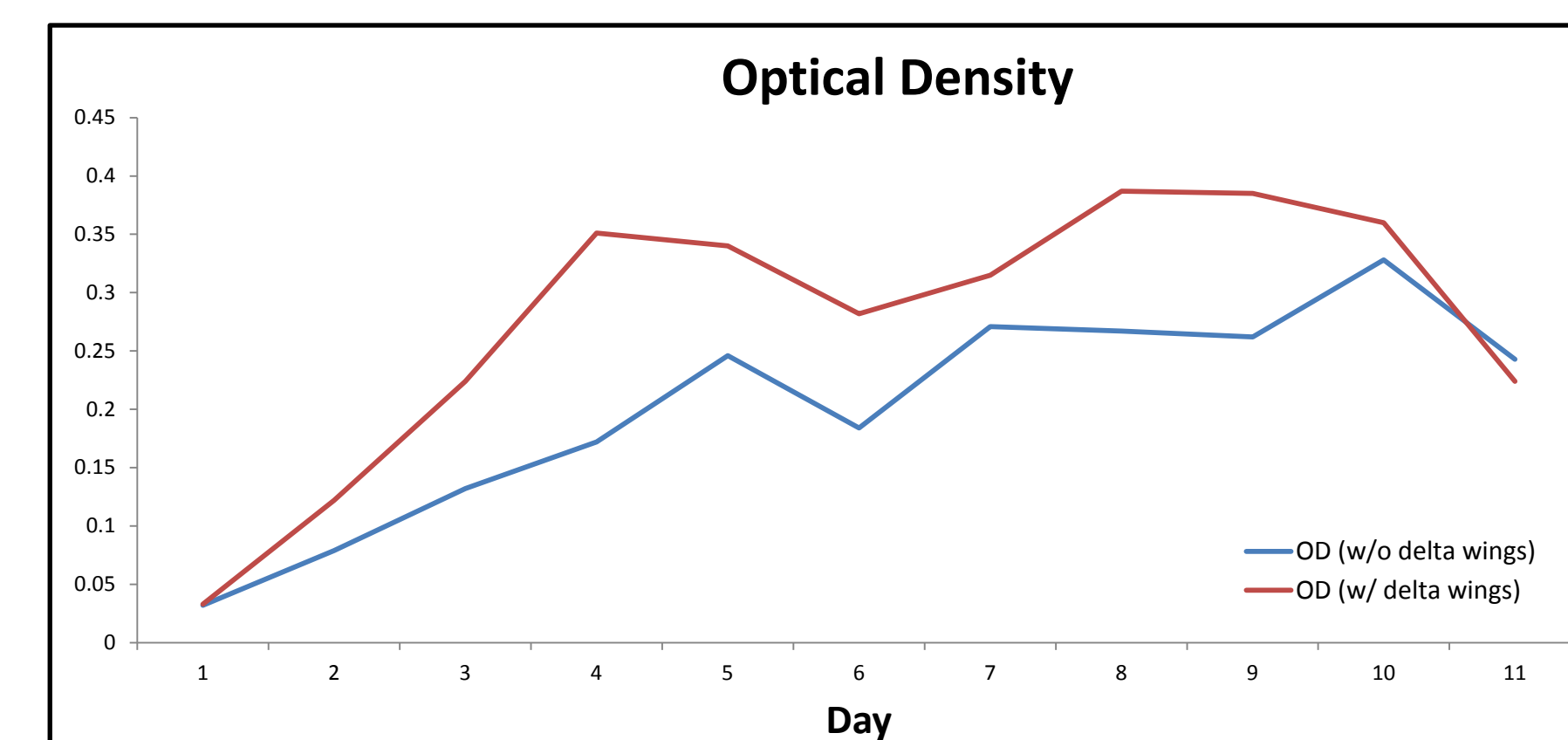
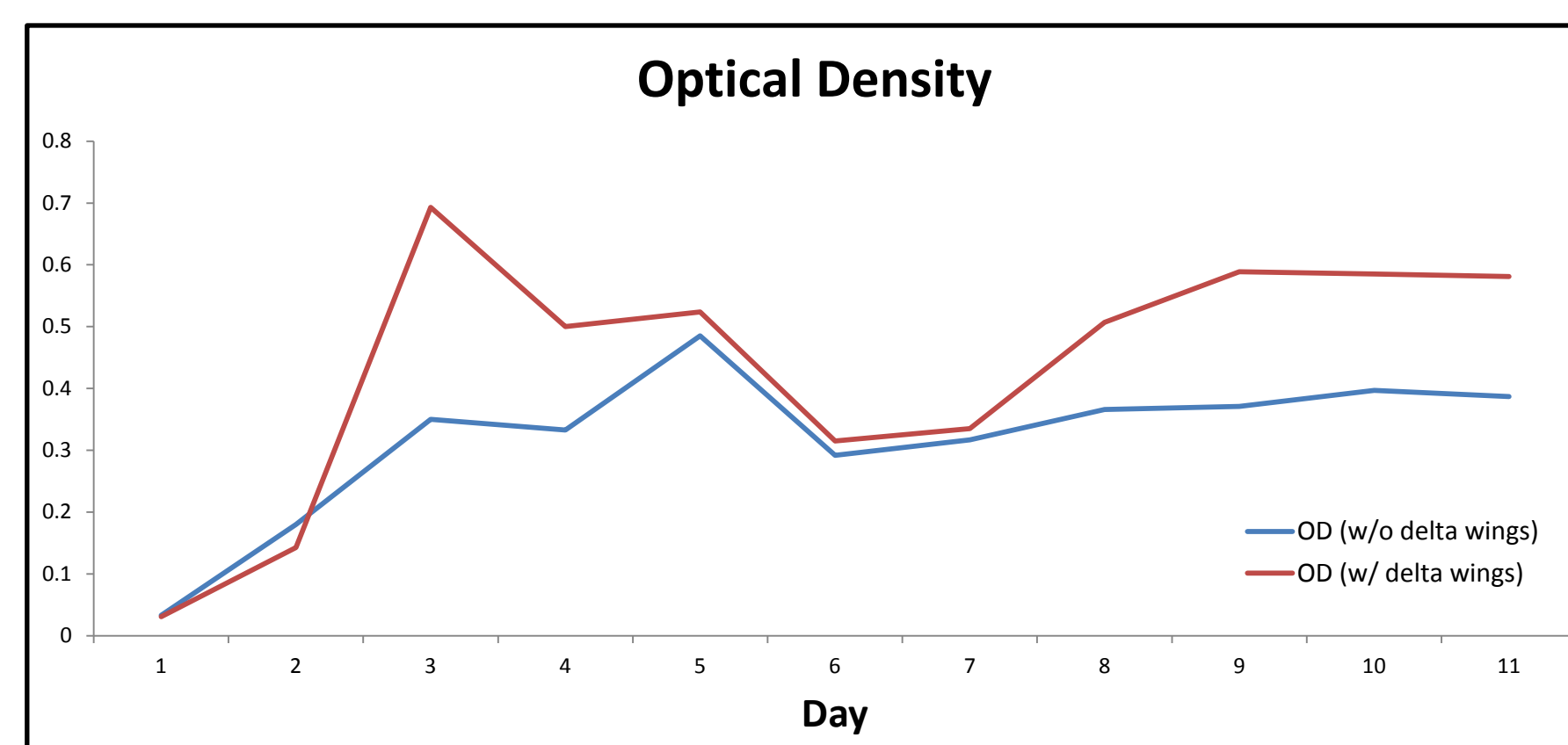
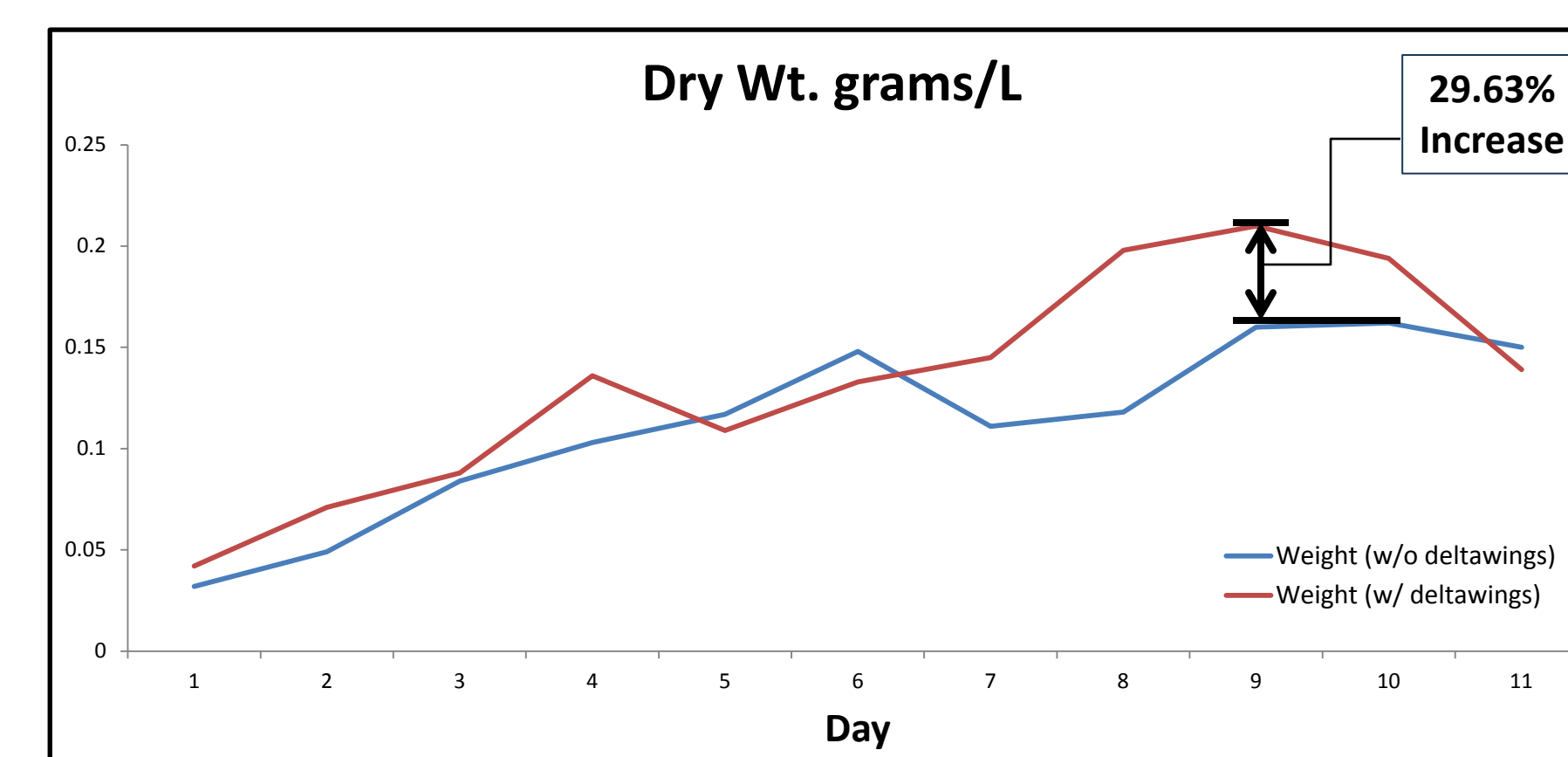
### Experiment 1

Date: 8/13/12 – 8/23/12



### Experiment 2

Date: 8/24/12 – 9/3/12



## CONCLUSIONS & FUTURE WORK

After the conduct of these experiments, it is shown that **the delta wings increase algal productivity** when using a *Chlorella Vulgaris* strain **by 25-30%**. Seeing as these are promising results, further experimental studies will be done to optimize algal productivity per energy consumption. In order to better understand the effectiveness in increasing algae growth using delta wings, multiple growth experiments will be designed to test the overall efficiency of this production method.

## ACKNOWLEDGMENTS

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