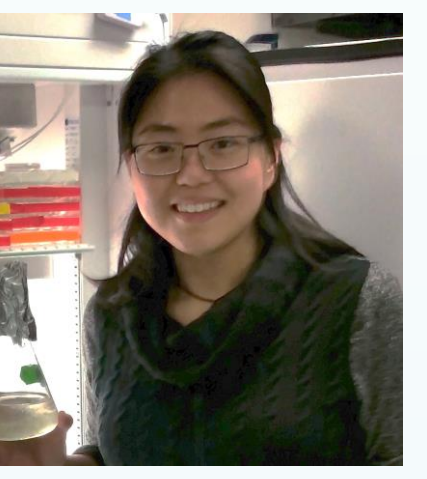


#197 Bacterivory enhances the phototrophic capabilities of an obligate phototrophic *Ochromonas* sp. (Chrysophyta)



Introduction

- Phagotrophic phytoflagellates are mixotrophic algae that can obtain carbon and energy through both photosynthesis and phagotrophy (bacterivory).
- There is a spectrum of mixotrophic strategies ranging from predominantly phototrophic to predominantly phagotrophic.
- Knowledge of different nutritional strategies and metabolism of mixotrophs will enable a better understanding of the functional roles of mixotrophs in communities.
- *Ochromonas* is a genus of mixotrophic chrysophytes. Many species are predominantly bacterivores, but *Ochromonas* sp. strain CCMP1393 is obligately phototrophic.
- This study investigates the gene expression of *Ochromonas* sp. strain CCMP1393 under different light regimes and bacteria availability.

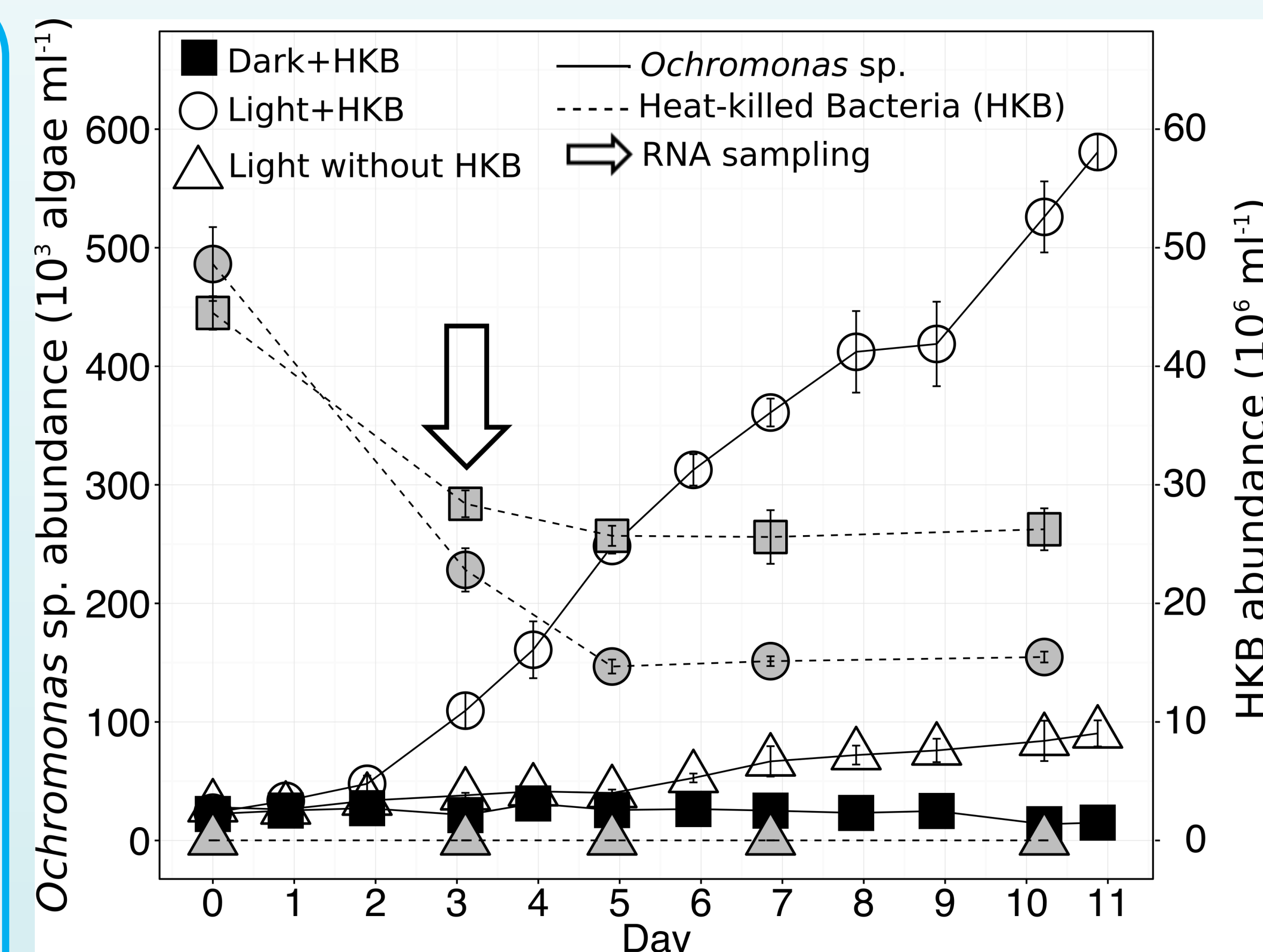


Fig. 1. Average abundance ($\pm$ SD) of *Ochromonas* sp. and heat-killed bacteria (HKB).

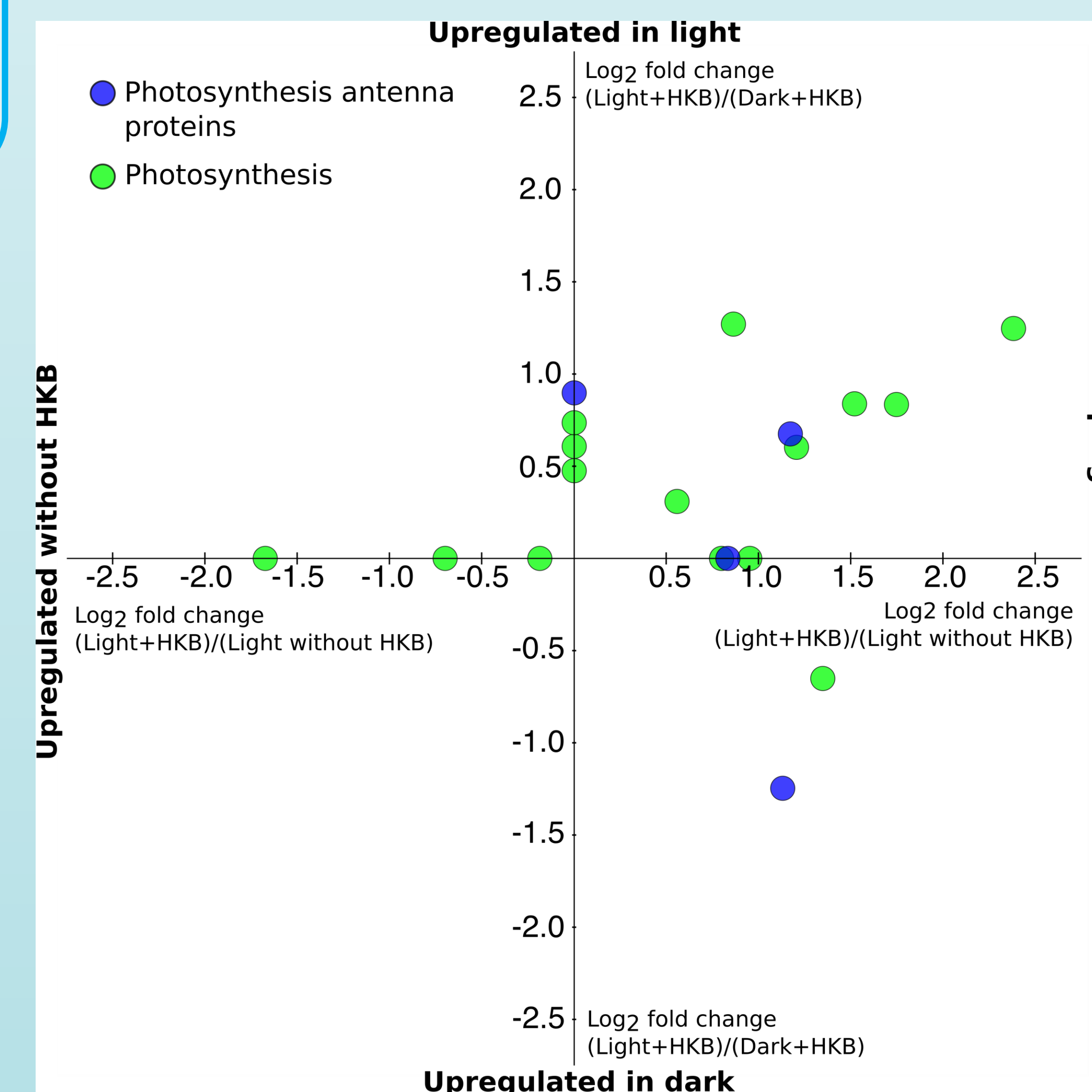


Fig. 2. Average $\log_2$ fold-change of differentially expressed genes related to photosynthesis and antenna proteins in the Light+HKB vs. Dark+HKB (y-axis) and Light+HKB vs. Light without HKB (x-axis) comparisons. A fold-change of 0 indicates that the gene is not differentially expressed in the comparison represented by the axis.

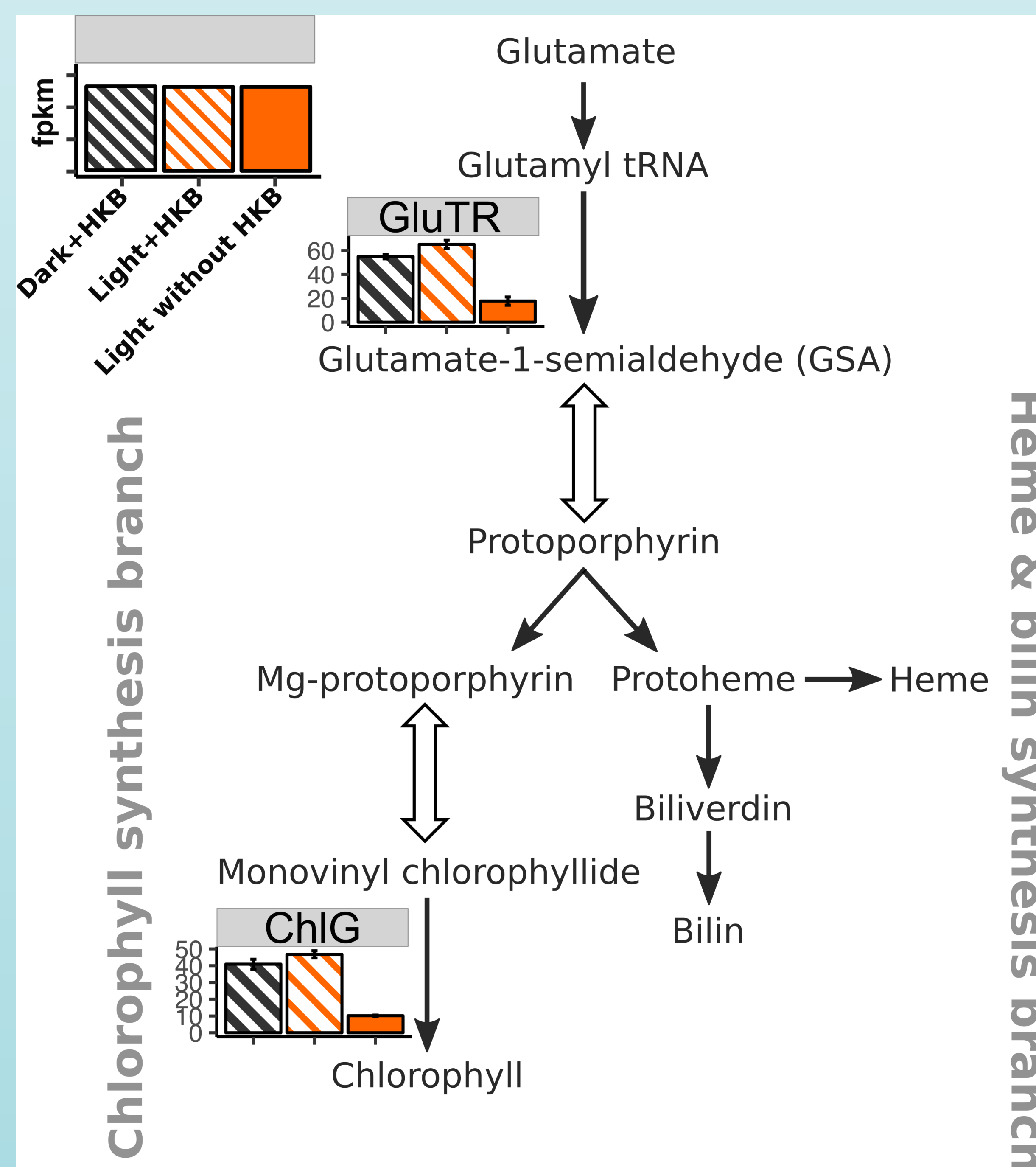


Fig. 3. Tetrapyrrole synthesis pathway with the average fragment per kilobase of transcript per million reads (fpkm; $\pm$ SD) of genes coding for glutamyl tRNA reductase (GluTR) and chlorophyll synthase (ChlG). Block arrows indicate pathways with multiple enzymes.

Material & Methods

- Axenic cultures of *Ochromonas* sp. strain CCMP1393 were grown in either constant dark with heat-killed bacteria (HKB; $\sim 5 \times 10^7$ HKB ml^{-1}), light with HKB, or light without HKB. Cultures were sampled for RNA on day 3 (Fig. 1).
- Extracted RNA was sequenced on Illumina NextSeq 500 (75 bp paired-end). Transcriptome was assembled using Trinity. Differentially expressed genes were identified using edgeR.
- Genes related to photosynthesis and light harvesting were identified by their annotations.

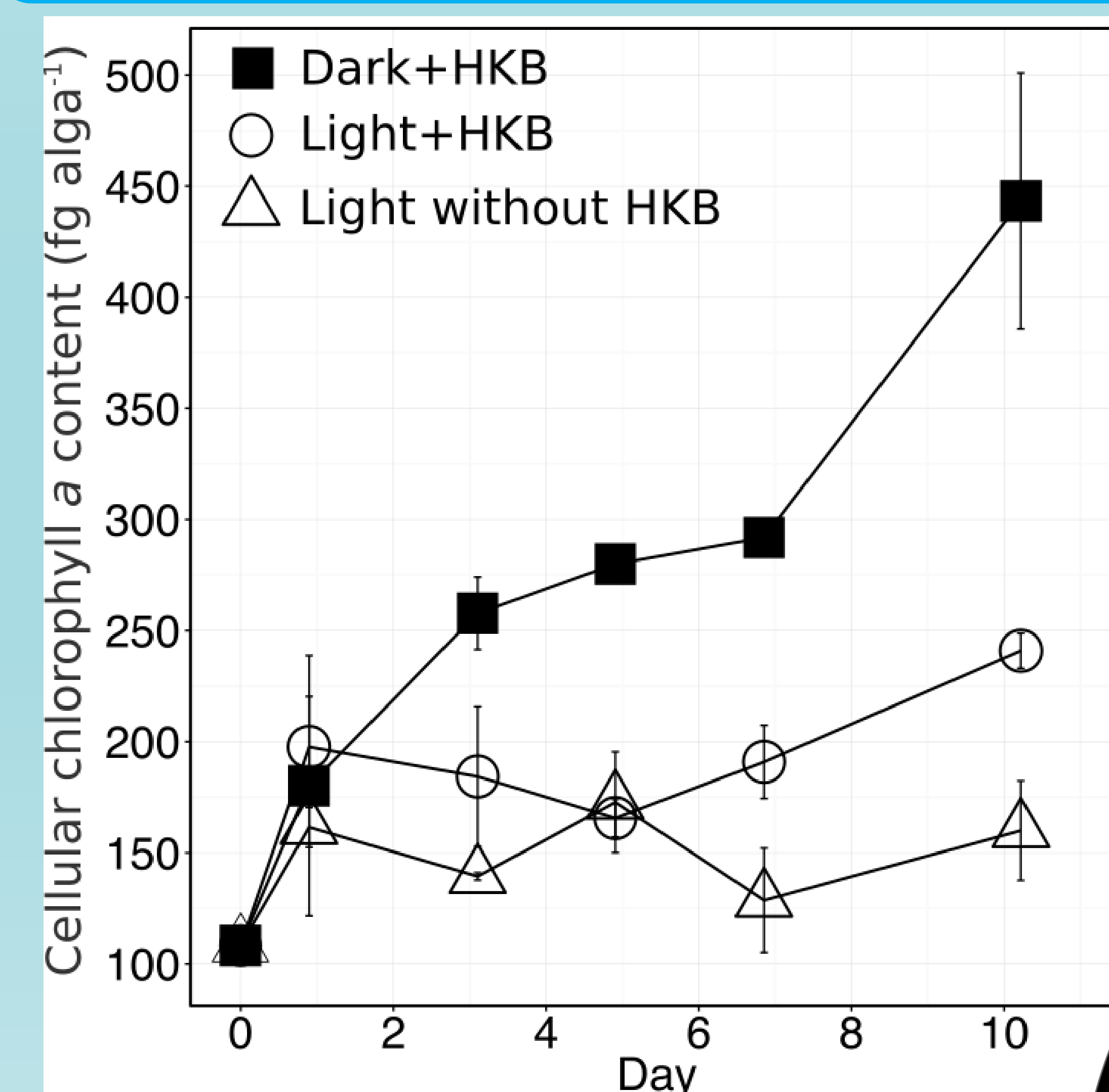


Fig. 4. Average cellular chlorophyll content ($\pm$ SD) of *Ochromonas* sp. Chlorophyll measurements were made on a Trilogy® Laboratory Fluorometer from Turner Designs.

Alle A.Y. Lie, Zhenfeng Liu, Ramon Terrado, Avery O. Tatters, Karla B. Heidelberg, David A. Caron

Department of Biology, University of Southern California, Los Angeles, CA 90089

Results

- *Ochromonas* sp. strain CCMP1393 had maximal growth rate (0.40 d^{-1}) in the presence of both light and HKB. Cultures with only light had a reduced growth rate (0.11 d^{-1}), and cultures placed in dark with only bacteria did not increase in abundance (-0.03 d^{-1}) (Fig. 1).
- The availability of light and HKB yielded a differential expression of 36% and 54% genes respectively.
- 57% genes related to photosynthesis and light harvesting (antenna proteins) were upregulated in the presence of HKB (Genes to the right side of the y-axis in Fig. 2).
- Genes important to chlorophyll synthesis (i.e. glutamyl t-RNA reductase (GluTR) and chlorophyll synthase (ChlG)) were upregulated in the presence of HKB (Fig. 3).
- Cellular chlorophyll content was significantly higher in cultures with both light and HKB (Light+HKB) compared to those with only light and no HKB (Light without HKB; Two-way ANOVA $p < 0.05$; Fig 4).

Discussion

- HKB had a considerable effect on the gene expression of *Ochromonas* sp. strain CCMP1393 even though the alga does not require it to increase in population abundance.
- Bacterivory appeared to enhance photosynthesis as $>50\%$ of genes related to photosynthesis were upregulated in the presence of HKB.
- Bacterivory also promoted the light harvesting capability of *Ochromonas* sp. strain CCMP1393 as genes related to antenna proteins and chlorophyll synthesis was upregulated in the presence of HKB, and yielded actual increase in chlorophyll content of algae supplied with HKB.
- In contrast, the presence of prey did not result in the upregulations of such genes related to photosynthesis and light harvesting in a predominantly phagotrophic *Ochromonas* sp. strain BG-1 (Lie et al. in press). Cellular content of this species decreased in the presence of HKB.
- *Ochromonas* sp. strain CCMP1393 relies on photosynthesis even in the presence of bacteria. Thus it has a functional role of both producer and consumer.

Reference

Lie, AAY, Z Liu, R Terrado, AO Tatters, KB Heidelberg, DA Caron. (in press) Effect of light and prey availability on the gene expression of the mixotrophic chrysophyte, *Ochromonas* sp. BMC Genomics.

Acknowledgements

The authors would like to thank the MOORE foundation for providing funding to the research project, as well as Turner Designs for providing travel funding for this conference.