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Attached Algae Cultivation for Sustainable Bioenergy Production and Environmental Remediation

Sungwhan Kim[1], Ryan W. Davis[1]

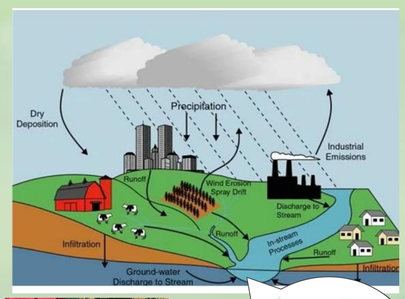
[1]Bioresource and Environmental Security Dept., Sandia National Laboratories, 7011 East Ave., Livermore, CA 94550, United States

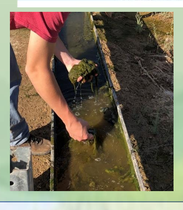
Problem Statement

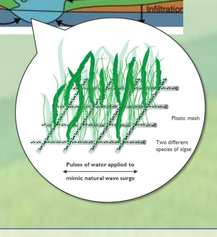
- Sustainable production of biomass as a feedstock for biofuel is needed.
- The conventional suspended cultivation method suffers from low biomass concentrations (0.1~1% of solid).
- Wasted nutrients in the agricultural runoff should be removed, otherwise can cause harmful algal blooms.
- Low biomass quality: high ash and low lipid contents.

Objectives

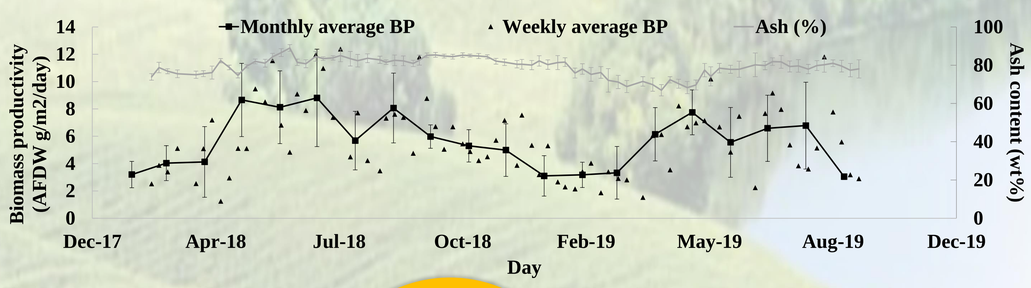
- Improve footprint biomass productivity through optimization of design and operation of the attached algae flow-way
- Improve quality of biomass through the understanding of algae-associated microbial community dynamics and domination of key algal strains

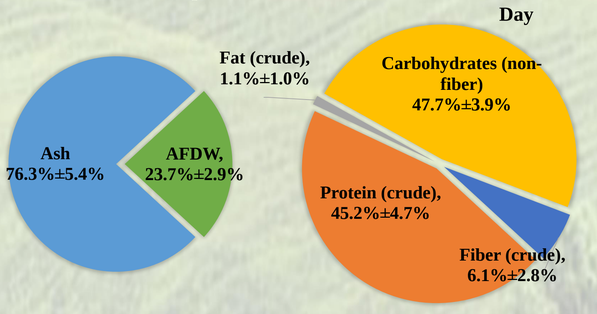






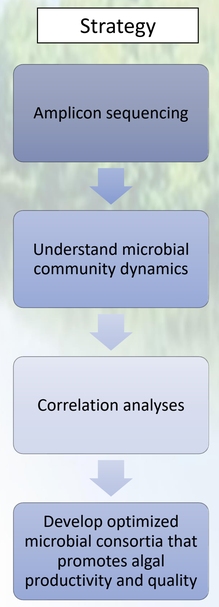
Productivity of biomass generation was measured over 2 years



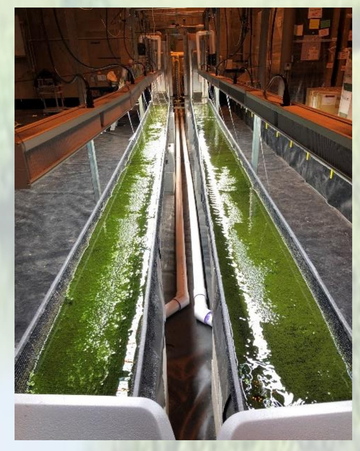


- Persistent algal ash-free biomass production at 2 to 12 g/m^2/day over two years (no crash).
- Nitrogen and phosphorous recovery at 300~800 mg/m^2/day and 5~30 mg/m^2/day, respectively.

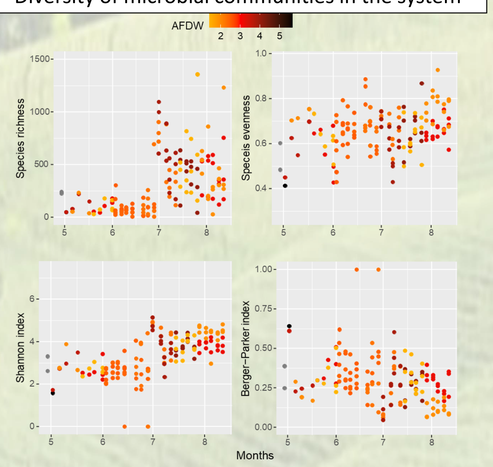
Strategy



Photographs of indoor pilot system

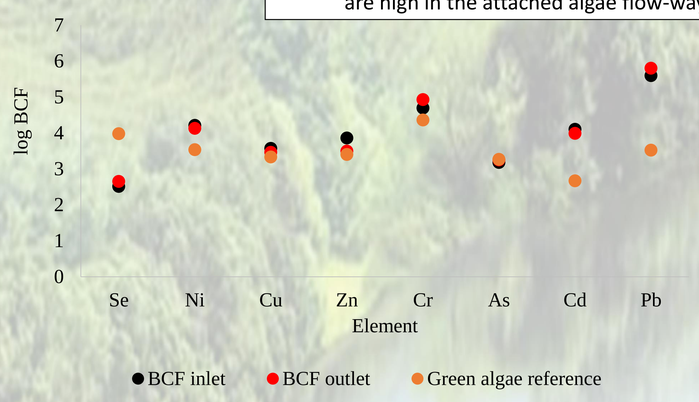


Diversity of microbial communities in the system



- Diversity of bacterial community increased over time along with their richness and evenness.
- No significant effect of biomass productivity and position of flow-way on diversity changes.

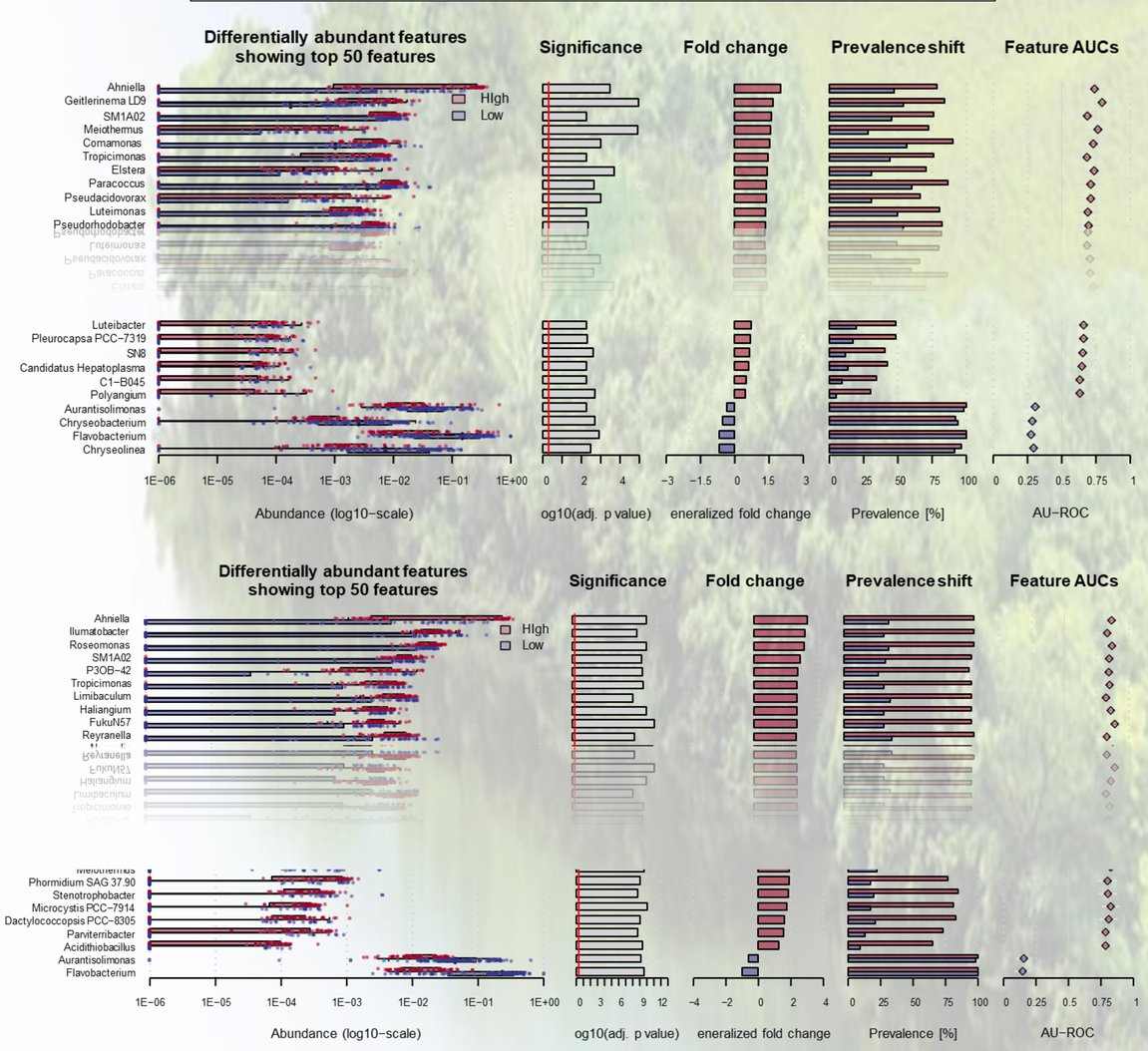
Bioconcentration Factors for various metals (for remediation) are high in the attached algae flow-way system



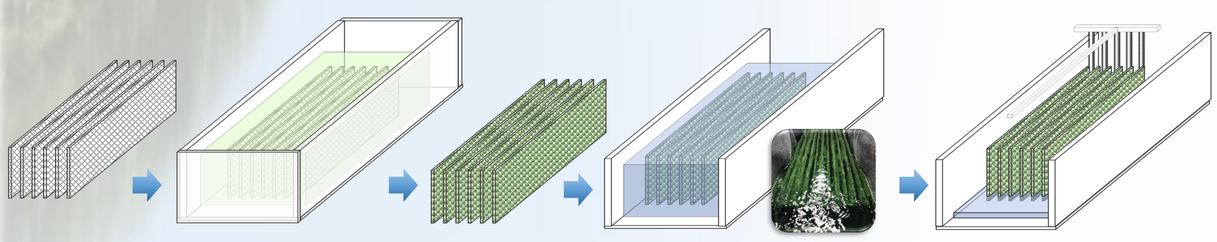
- Bioconcentration factor (BCF): $BCF = \frac{C_{algae}}{C_{water}}$
- log BCF<3: non accumulative, 3< log BCF<3.7: accumulative, 3.7<log BCF: very accumulative.
- Green algae reference: *Cladophora Prolifera* (L. Losada, 2020)

- Principal Component Analysis (PCA) shows that biomass productivity has a stronger positive correlation with weather conditions (high solar irradiation and warm temperature) than with concentrations of key nutrients
- A relatively weaker correlation with nutrient concentration offers the algae flow-way independence from the changes in nutrient availability
- Bioaccumulation of metal contaminants enables the algae flow-way a unique benefit to local ecosystem remediation.

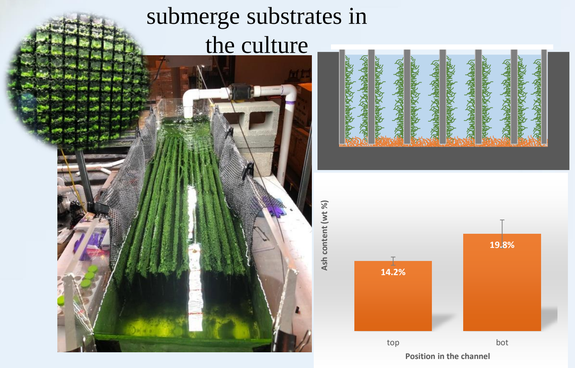
Microbial community members as they relate to biomass productivity & sloughing



A Multi-channel flow-way system



1. Unseeded substrates
2. Seeding target algal strain: submerge substrates in the culture
3. Seeded substrates
4. Implementation: Place seeded substrates on the flow-way
5. Harvesting the biomass



- Hydraulic retention time (HRT) will be optimized to maximize direct air capture of CO_2.
- Higher carbon utilization rate = higher growth rate
- There is a trade-off with a water treatment rate
- Another new design is under development

- Relative abundance of microbiome between two group (high (>3 g/m^2/day) and low ash-free biomass productivity) was assessed.
- Abundances of top 50 features across two different groups (high vs. low) have shown significantly different.
- Cross-validation accuracy is high with AUC = 0.837 (AUC>0.6 is typically considered accurate)
- Relative abundances of 27 bacterial genera collectively associated with ash-free biomass productivity of the flow-way with 17 of them positively associated and 10 of them negatively associated.

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2. Hennequin, L.M.*, Kim, S.*, Monroe, E.A., Eckles, T.P., Beck, N., Mays, W.D., Fennell, P.S., Hallett, J.P., George, A., Davis, R.W. 2022. Reclamation of nutrients, carbon, and metals from compromised surface waters fated to the Salton Sea: Biomass production and ecosystem services using an attached periphytic algae flow-way. Algal research.
3. Davis, R.W., Monroe, E., **Kim, S.** Algal Harvesting and Water Filtration. U.S. Patent and Trademark Office Application No. 16/904202, Jun 17, 20