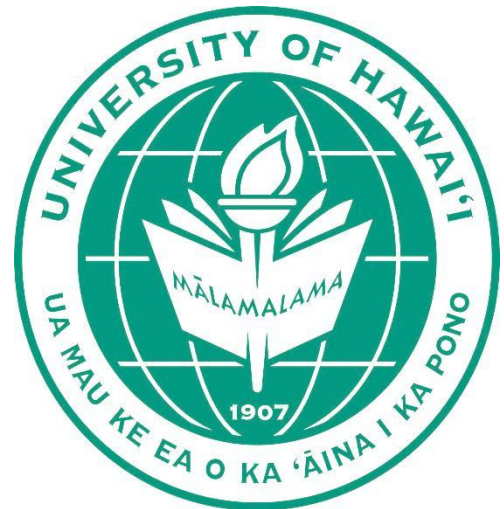


# Research into technologies for Commercial Aquaponics

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# Background

- Aquaponics systems receive attention. However, in many cases their capital and operating costs are too high to have an impact on food security or sustainability.
- Our purpose is to sustainably improve food security so that Hawaii can grow more of its own food.
- This said, aquaponics is well suited for island environments where land is at a premium and there are limited fresh water supplies.
- I will describe some of the **technical details** we have worked on to make aquaponics commercially practical.

# Sizing, the Nutrient Flux Hypothesis. No one knew how to balance fish feed, fish, and plants.

- We first figured out how many nutrients plants need (48 of them). We did hydroponics experiments shown in the first row.
- We then figured out how many metabolite fish produced if eating 40 g feed/day in the second row.

	N (g)	K (g)	Ca (g)	Mg (g)	P (g)	Fe (mg)	Zn (mg)	Cu (mg)	B (mg)
Needed/48 plants	31	46	15	5	6	58	30	25	133
Produced/40 g feed	47	105	34	21	11	38	94	59	79

## Bottom line recipe

2.5 kg or 5 lb fish

50 gal or 200 L water

40 g or 0.088 lb fish food/day

48 plants

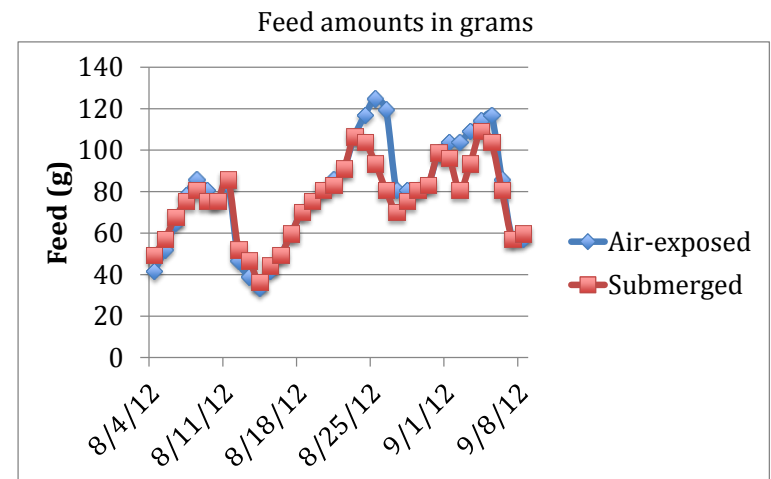
Extension: Farms often feed too little and fish and plant growth is suboptimal. Iron must be added. Making too little money is **not** okay to us.



# Biofilter

- We began with biofilters submerged in water for simplicity sake.
- Air exposed cinder should be better. Oxygen for bioremediation should be drawn from air not water. Results are shown on right.
- Cinder biofilter acts as a physical filter and red worms in the cinder eat solids (not shown).
- Biofilter was allowed to overload. Overloading occurred as judged by the fact that  $\text{NH}_3$  rose to 0.3 mg/L and feeding dropped. Roughly the capacity is 50-60 g feed/L cinder biofilter. We are not sure of this number.
- It is **not** okay to waste money on aeration bioremediation electricity.

Replicate	Submerged	Air-exposed
1	5.3	6.3
2	5.4	5.9
3	4.8	5.8
4	4.4	5.1
5	5.2	5.4
6	5.2	5.4
7	6.3	6.8
Mean	5.2	5.8
P-value	0.003	



# Airstones, what did Claude Boyd really say? Electricity used for aeration is the highest operational cost item for aquaponics.

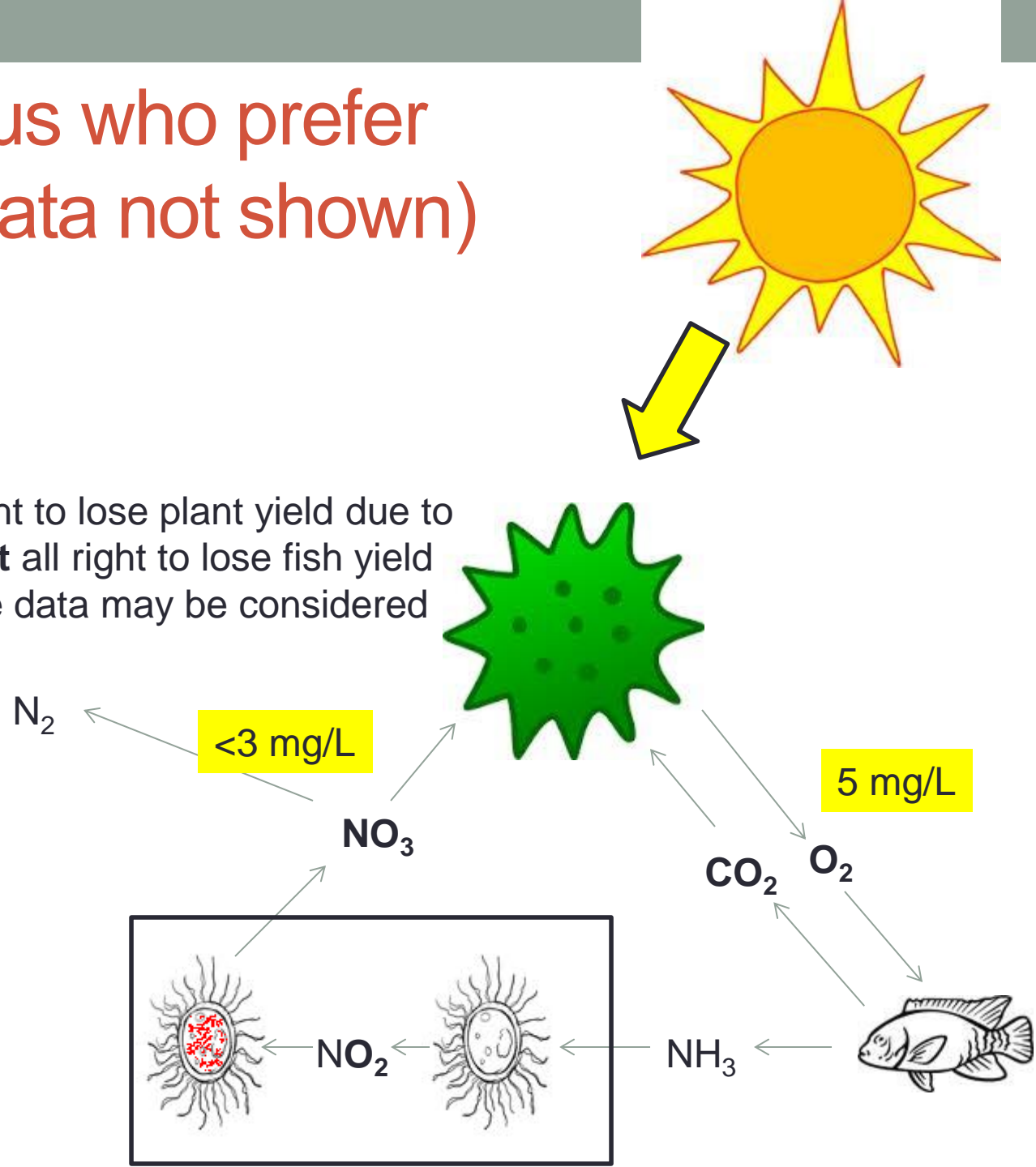
- Following and adapting the work of Boyd and Moore to aquaponics, relative to 0.8 cfm air and 200 L water volume three diffusers are best.
- It was a tough read. P.I. had to do the reading.

	1 Diffuser	2 Diffusers	3 Diffusers	4 Diffusers
Replicate	D.O.	D.O.	D.O.	D.O.
1	4.8	6.6	7.1	7.8
2	5.3	5.8	7.1	6.3
3	4.8	6.0	7.0	7
4	5.1	-		
Mean	5.0 <sup>a</sup>	6.1 <sup>b</sup>	7.1 <sup>c</sup>	7.0 <sup>c</sup>

- Each airstone 6 inches long for 200 L water at recommended heavy fish biomass loads. Scale this up and you can buy and run the smallest air pump.
- Impact: Electrical use is highest operating expense in aquaponics unlike traditional aquaculture where feed costs are the largest expense. It is **not** all right to lose profit to electricity.

# For those of us who prefer cartoons... (data not shown)

Impact. It is **not** all right to lose plant yield due to denitrification. It is **not** all right to lose fish yield due to low DO. These data may be considered operating minima.



# Media. We should have done this ahead of farmers but didn't.

- We investigated several types of media in a controlled setting. In the background, our best. The data are as follows

Plant roots need oxygen  
May or may not prefer  
structure but very current  
experiments question this.  
Raft with air gap may be  
okay if run properly.

Medium	Lettuce harvest weights
Cinder trickle air exposed	128a
Cinder ebb and flow	131a, 139a
Raft with air gap	58c, 68c, 73c, 101b, 80c, 119b
Raft with no air gap	9.7d, 84c*

\*heavily (non-economically) aerated

## Media. The exception.

- We investigated cinder trickle versus raft with air gap except that we cleaned the systems of suspended solids before the trial.
- There was no significant difference in size between cleaned systems.

Medium	Pak choy harvest weights
Cinder trickle air exposed	236a
Raft with air gap	194a



# Feed, being cheap can cost you more

- For Samoa, 4 cans flour, 2.5 cans fishmeal, 1 can starch, 1 can water, 5 spoonfuls cooking oil, 1 vitamin and mineral packet.
- 28% protein compared with 41% protein of Silver Cup trout feed.
- Fish adjusted to the lower protein Samoa feed by eating more.
- Growth rates were similar but FCRs were not.

Treatment	days	Specific growth rate	Total feed eaten	Mean feed/day (g)	FCR*
Silver Cup Trout 1	28	0.019	1.62	58	1.1
Samoa 1	28	0.015	2.15	77	2.0
Silver Cup Trout 2	49	0.015	2.68	55	0.96
Samoa 2	49	0.014	4.19	85	1.55

\*weight gained/feed eaten

- Take home lesson: Don't be too cheap with your feed, the fish will just eat more.

# Breeding and rearing fish for farmers

- We listen to what Clyde tells us. We had 10 males and 20 females in a tank. (We do not have much space.) They breed in the summer when it is warm.
- Every two or three weeks we move the fish. They get scared and the babies which are in the females' mouths are spit out.
- We then harvest them. We generally have more babies than we can handle.
- We followed water chemistry. We discovered that greenwater is good because the greenwater does some water maintenance for us. Algae provides some oxygen.
- Impact: Instead of 1 change/24 hr, 50% change per week at densities of about 10-20 kg/m<sup>3</sup>.

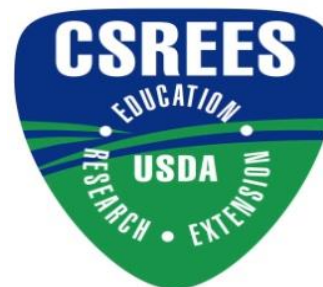
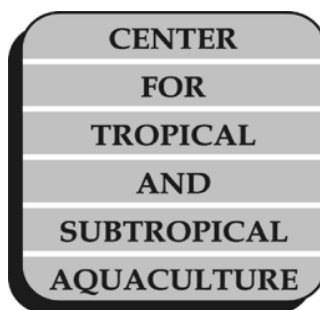


# Accomplishments, we wished we had finished everything before people started.

- Matching: fish:feed:water volume. Nutrient flux hypothesis.
- Biofilter sizes and configurations.
- Airstones. Decreased electrical usage due to proper investment in airstones.
- Denitrification and fish well being criteria for dissolved oxygen levels.
- Began work on various set ups for aquaponics, gravel or raft with air gap. Solids removal.
- Tested aquaponics feeds.
- Learned to become more efficient using greenwater.
- Our system may be called PAS (pake aquaponics system)

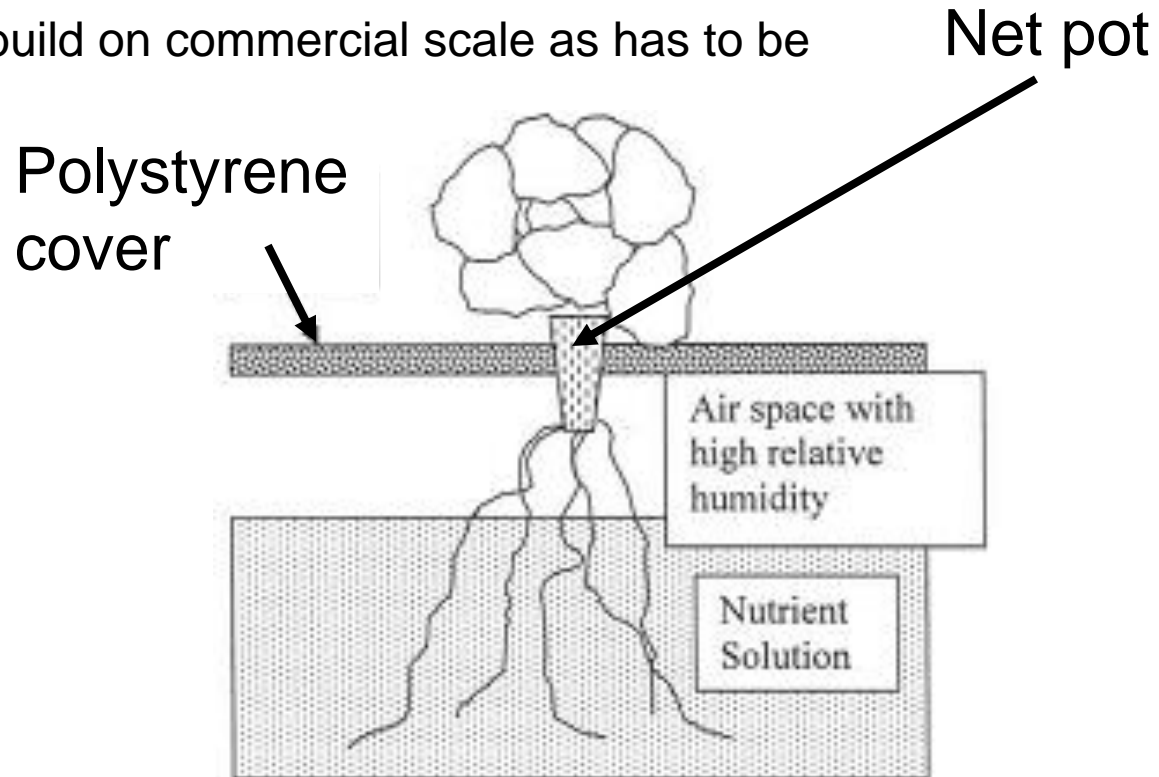
# Acknowledgements

- Thank you to the following organizations for support.



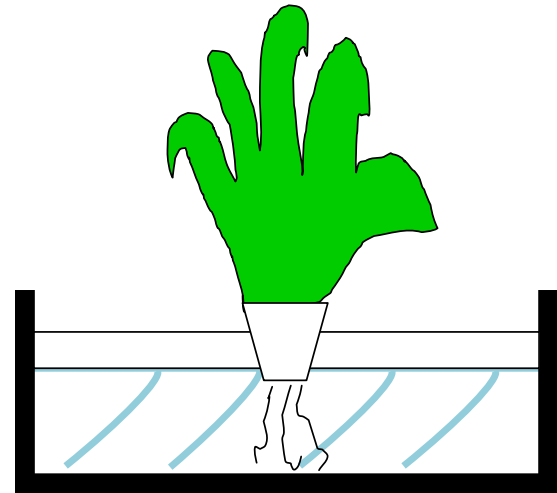
# Media – we had not originally investigated

- Kratky design
- Note air space for roots
- Worked well for us
- Very difficult to build on commercial scale as has to be very level.



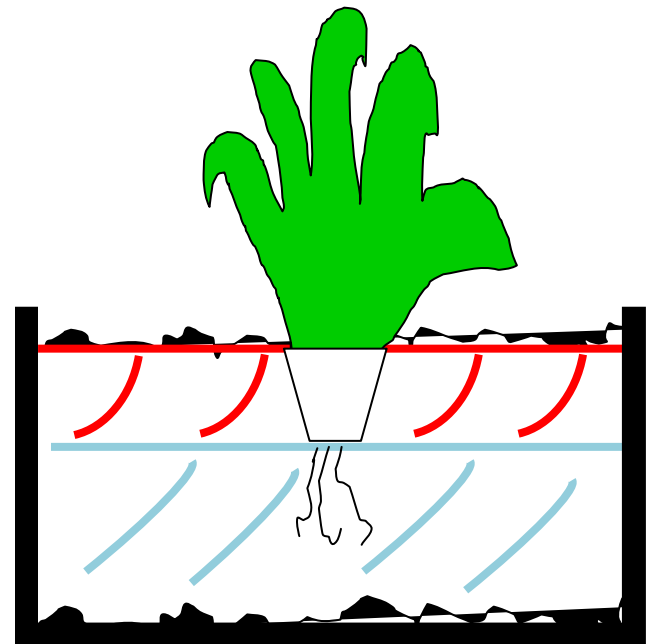
# Media - Raft

- In polystyrene board floating in water.
- No air for roots.
- In our work, no raceway aeration. In original version, 230 airstones per raceway with no consideration of the electrical cost.
- Easy to construct. Leveling not critical.



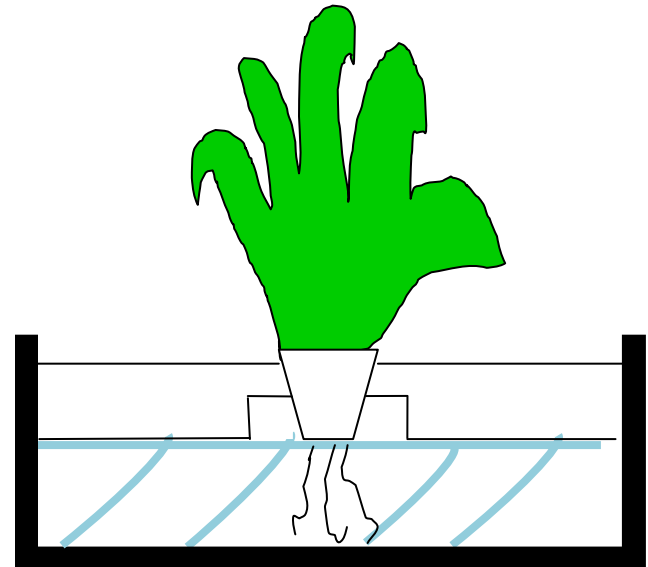
# Media-volcanic cinder

- Run either as ebb and flow or as a trickle filter. Allow air to roots.
- Mari's Garden, Otsuji Farms, and we have good luck with this.
- Trick. Have to buy gravel in bulk (\$100/cubic yard).



# Media – another idea – raft with air pockets

- Easy to construct. Polystyrene floats on water. No need for careful leveling.
- Has air pocket for roots.
- No need for expensive aeration.





## Media - results

- Cinder systems run in either the trickle mode or ebb and flow mode outperformed rafts systems
- Rafts with air gaps outperformed raft
- Raft with vigorous (and expensive) aeration performed better than plain raft

medium	Lettuce harvest weights (56 days)
Cinder, trickle	128a
Cinder, ebb and flow	131a, 139a
Raft with air gap	58c, 68c, 73c, 101b, 80c, 119b
Raft *(with vigorous aeration)	9.7d, *84c