

# Aquaponics at the College of Tropical Agriculture and Human Resources (CTAHR)

Clyde S. Tamaru, Bradley “Kai” Fox, Harry Ako, Theodore Radovich, Jari Sugano, C.N. Lee, Kathleen McGovern-Hopkins and RuthEllen Klinger-Bowen

Master Gardener Conference

October 16, 2010

Ala Moana Hotel, Honolulu, Hawaii



# Who is Clyde Tamaru and Why is He Here?

- Royal Elementary
- Central Intermediate
- McKinley High School
- B.S. Biology, @ UH Mānoa
- M.S. Zoology, @ UH Mānoa
- Ph.D. Faculty of Agriculture, Dept. of Fisheries, University of Tokyo



# Who is Clyde Tamaru and Why is He Here?

Provide technical assistance to aquaculture stakeholders and now includes Aquaponic stakeholders.



# Who is Clyde Tamaru and Why is He Here?

Maintains a research and extension portfolio involving three institutions.



**C/T/A/H/R**

College of Tropical Agriculture and Human Resources  
University of Hawai'i at Mānoa



UNIVERSITY OF HAWAII  
**WINDWARD**  
COMMUNITY COLLEGE



**HAWAII INSTITUTE OF  
MARINE BIOLOGY**

AT COCONUT ISLAND



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University of Hawai'i at Mānoa

For over a thousand years ancient Hawaiians were completely isolated from the rest of the world.



Hawaii

Currently, over 80% of our food and 90% of our energy is imported

Image IBCAO  
Image © 2010 TerraMetrics  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image © 2010 DigitalGlobe  
28°29'04.70" N 164°27'33.91" W elev 0 ft

©2009

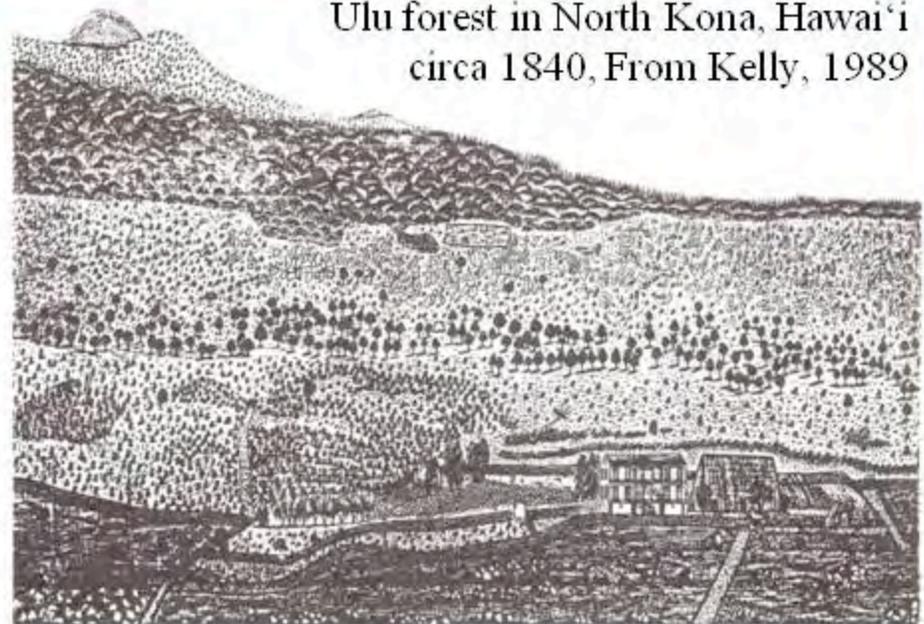
Eye alt

# The Ahupua'a : A Model of Resource Management

Waikalua  
Loko,  
Kaneohe  
Ahupua'a,  
1927



Ulu forest in North Kona, Hawai'i  
circa 1840, From Kelly, 1989



Heeia  
Loko,  
Heeia  
Ahupua'a,  
1940

# LIFE IN THE AHUPUA'A

## Food Was Gathered



933780 www.fotosearch.com



Copyright © 1991 Herb Kawainui Kane



# LIFE IN THE AHUPUA'A Food Was Grown



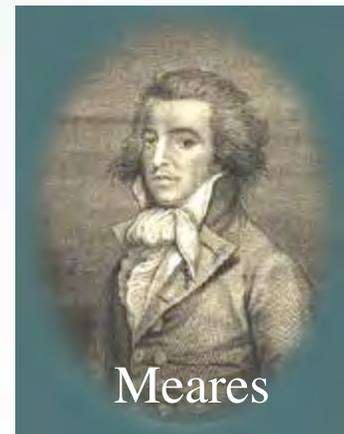
- “Some large ponds which appeared to be full of fish. He [the king] mentioned he had some others with a great quantity of turtle” - J. Meares – 1789
- “for industry of cultivation and agricultural improvements they could scarcely be exceeded in any country in the world” – Archibald Menzies - *Menzies' Journal of Vancouver's Voyage, April to October, 1792*



Vancouver



Menzies



Meares



# Who are We and Why are We Here?

Vision: CTAHR will actively help Hawai‘i diversify its economy, ensure a sustainable environment, and strengthen its communities, and will be the premier resource for tropical agricultural systems and natural resource management in the Asia-Pacific region.

“Producing more of Hawai’s food and fuel here in the islands is a vital step in creating a sustainable future”. [http://www.ctahr.hawaii.edu/downloads/2010\\_POW.pdf](http://www.ctahr.hawaii.edu/downloads/2010_POW.pdf)

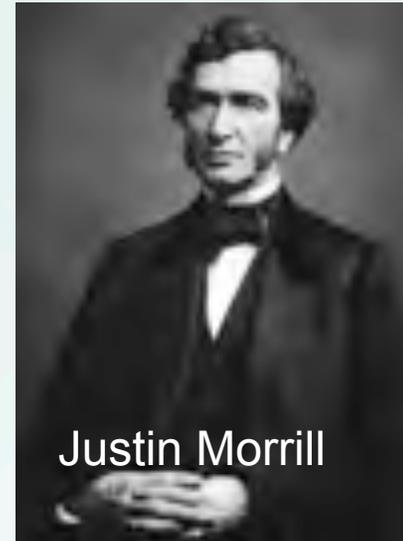


“Centennial” – white anthurium bred by UH scientists to celebrate 100<sup>th</sup> birthday

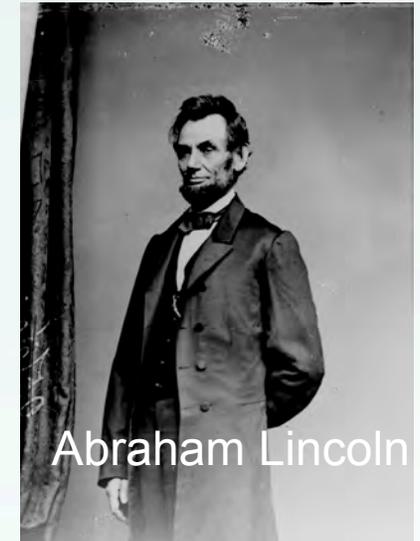


# Land Grant College System

- Universities or colleges that receives the benefits of the Morrill Acts of 1862 and 1890  
(Education)
- Hatch Act of 1887 allowed land grant colleges to create agricultural research stations to conduct practical research that would assist farmers (Research)
- Smith-Lever Act of 1914 results in the cooperative extension services and a mechanism for technology transfer (Extension)



Justin Morrill



Abraham Lincoln



# Classic Example of How a Land Grant College Program Works



**Drs. Haruyuki Kamemoto and Heidi Kuehnle with “Tropic Fire”. Since 1950 developing disease resistant and novel anthuriums for the flower industry, which helped anthuriums become the state’s most valuable cut-flower crop (farm-gate value of \$4.7 million in 2005)**



**Tropic Sunrise  
Society of American  
Florists/ 2007 Outstanding  
Varieties Competition.**

**Lavendar Lady  
Society of American Florists/  
2004 Outstanding Varieties  
Competition**

**Harold and Eric Tanouye  
Green Point Nurseries, Inc.**



# Scientists decipher papaya's genome

Research could pave  
way for transgenic  
fruit exports to Japan



An international consortium led by University of Hawaii researchers described the genetic code of the Sun Up papaya. It marks the first transgenic fruit crop to be deciphered.  
*Nature* **452**, 991-996 (24 April 2008)



# Why are we working with aquaponics?

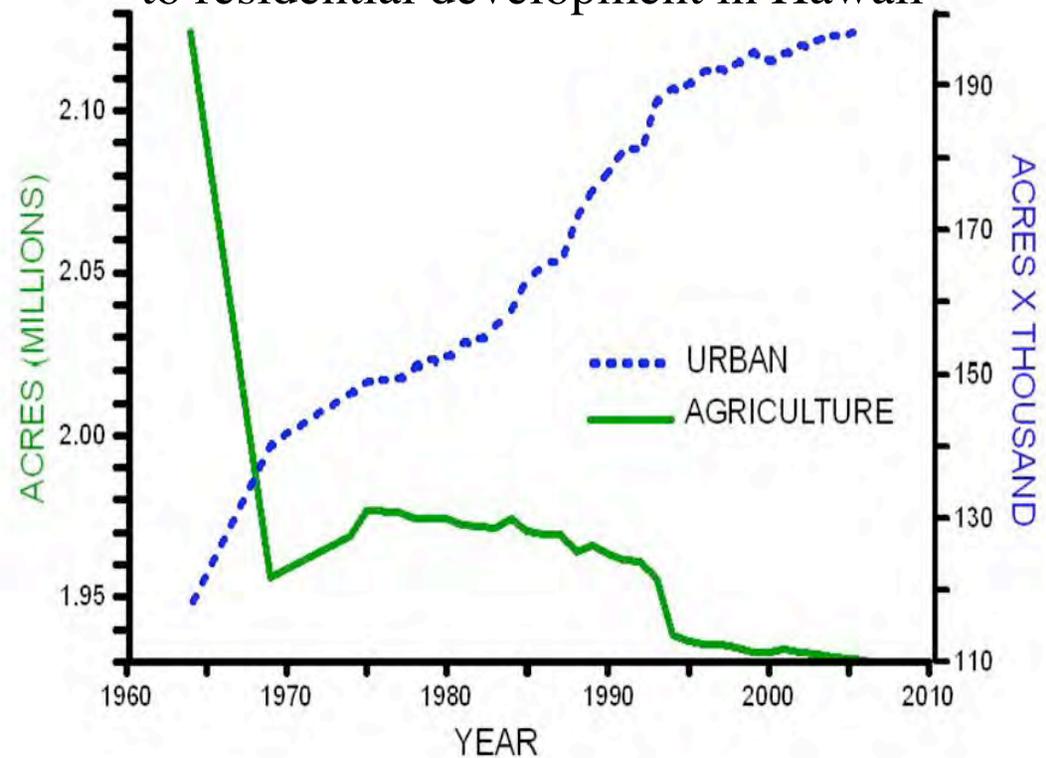
- Addresses several priority actions outlined in Hawai‘i 2050 Sustainability Plan such as:
  - Increase recycling, reuse and waste reduction strategies.
  - Develop a more diverse and resilient economy
  - Create a sustainability ethic.
  - Increase production and consumption of local foods and products, particularly agriculture.



# Justification for focusing on backyard aquaponic systems

Agricultural land lost

to residential development in Hawaii



Source: [http://hawaii.gov/dbedt/info/economic/databook/Data\\_Book\\_time\\_series/](http://hawaii.gov/dbedt/info/economic/databook/Data_Book_time_series/)



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# It is All About Expectations



**My first attempt at hydroponic production of lettuce.**



**Harry Ako and Adam Baker's hydroponic production of lettuce**



# Technology Transfer: Training the Trainers



1<sup>st</sup> Annual Statewide  
University of Hawaii Master Gardener Conference!

**GROWING**  
*together in*  
**HAWAII**

OCTOBER 15, 16, 17, 2010

Specialized Field Trips, High Quality Educational  
Sessions, Networking Opportunities!

For more details on registration, visit  
<http://www.ctahr.hawaii.edu/sustainag/MG>

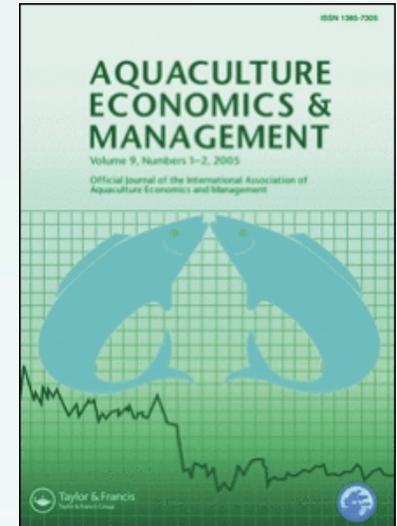
An equal opportunity/affirmative action institution



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# Providing the best information to make informed decisions: Are the economic benefits of integrating aquaculture and hydroponics real or perceived?

- Economic feasibility studies are few in number
- Investigation shows that Net Present Value (NPV) over a 10 year horizon is:
  - \$499,000 fish alone
  - \$18,397 lettuce alone
  - **\$522,000 integrated fish and lettuce (+ 4.6%)**
- Net benefits derived from:
  - Reduction in barramundi effluent disposal costs
  - Cost savings in water
  - Cost saving in nutrients for the lettuce system.

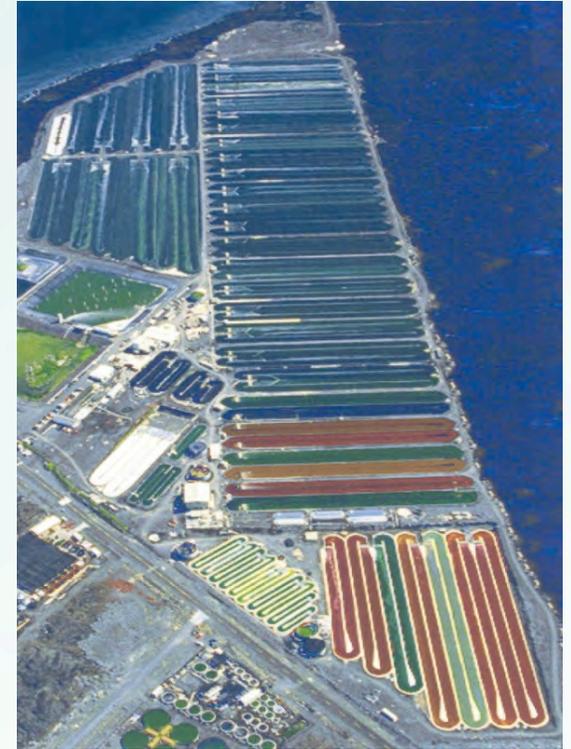


Rupasinghe and Kennedy, 2010. Economic benefits of integrating a hydroponic-lettuce system into a barramundi fish production system. *Aquaculture Economics Management*, 14: 2, 81-96.

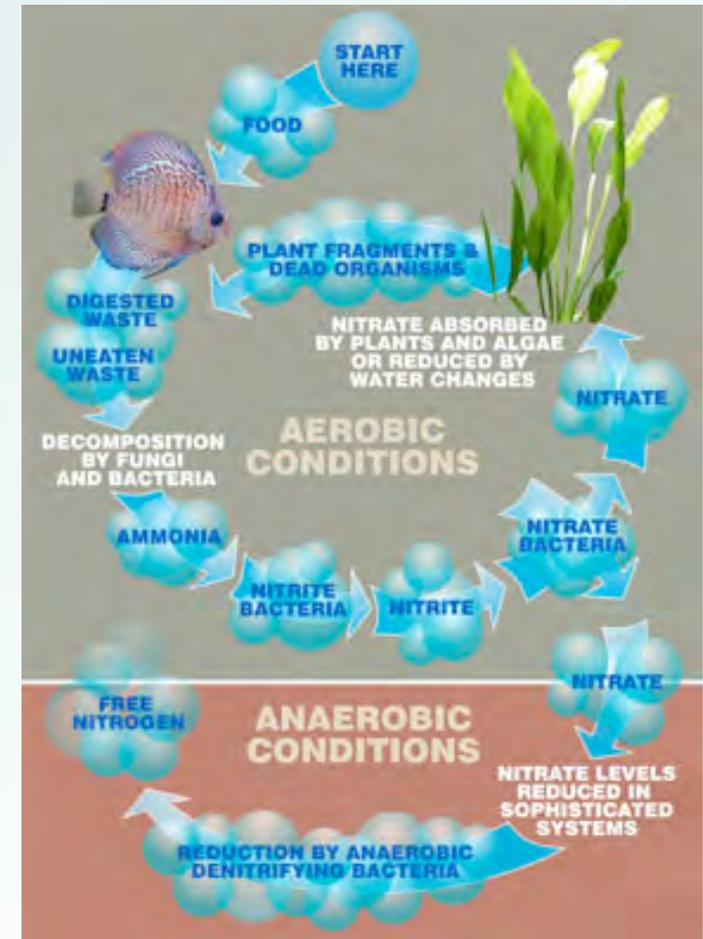
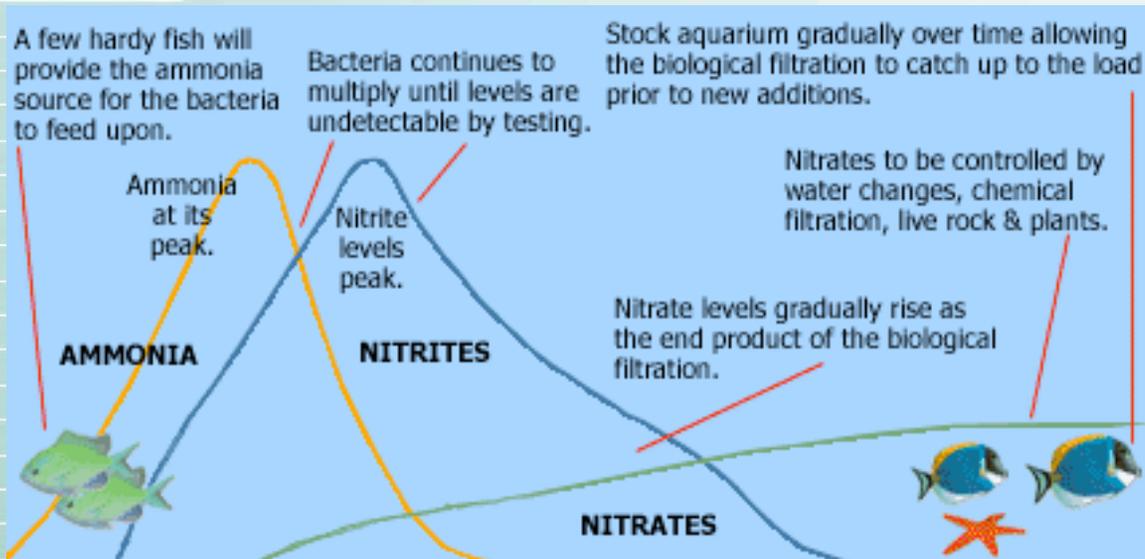


# What is **Aquaponics**?

- **Aquaculture**: farming of aquatic organisms under controlled conditions.



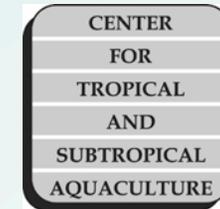
# Water Quality 101: Nitrogen Cycle in an Aquaculture Setting



Source: <http://www.liveaquaria.com/PIC/article.cfm?aid=78>



# ADAPTING AQUAPONICS SYSTEMS FOR USE IN THE PACIFIC ISLANDS



Mass balance of nitrogen. Of total nitrogen input into the system as feed, about 27% is captured as fish flesh, about 43% is captured as lettuce biomass, and a small fraction (30%) is lost as nitrogen gas or as solids used to fertilize garden plants.

Tank	Fish biomass (%)	Lettuce biomass (%)	Denitrification or solids (%)
T1	26	40	34
T2	32	41	27
T3	22	49	29
Mean	27	43	30

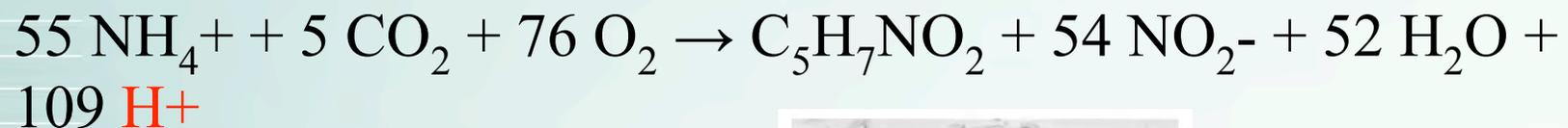


# Chemistry of the Nitrification Process



Photo credit: Stan  
Watson, Woods Hole  
Oceanographic Institute.  
2010

Nitrosomonas



Nitrobacter

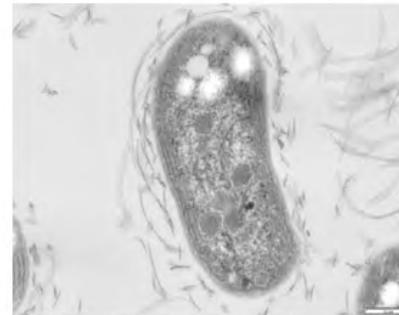


Photo credit: W.J.  
Hickey, University of  
Wisconsin-Madison,  
2006



From: Haug and McCarty, 1972



# Assessing the utility of vermicast tea for pH remediation and as a source of micronutrients



What is Aquaponics?:  
Hydroponics: Technique of growing plants (without soil) in water containing dissolved nutrients

Static hydroponic cucumbers in a trash can. (Kratky, 2003)



Commercial hydroponic lettuce farm on Maui



Static hydroponic watercress in 5 gallon bucket (Kratky, 2003)



# Types of Aquaponic Systems

- Ebb and flow (reciprocating)
  - Hydroponic support media (gravel, clay balls, cinder, etc.)
- Raft aquaponics
  - Polystyrene sheets
- Nutrient Film Technique (NFT)
  - Rain Gutters
  - Pvc pipe
- Three Components
  - Rearing tank
  - Biofilter
  - Hydroponic component



# Solid support media for ebb and flow systems



Black Cinder



Pea gravel

Expanded Clay Balls



A key part to an ebb and flow growbed is the bell siphon.

You will learn more about the bell siphon and have an opportunity to make one during the latter part of this workshop.





You can grow just about anything in an ebb and flow gravel bed!



# The most basic design



Submersible Pump inside of fish tank



## Magnetic Drive Water Pumps (Supreme©):

<b>Pump (gph)</b>	<b>Price</b>	<b>W</b>	<b>Wh/day</b>	<b>kWh/day</b>	<b>Operating Cost/day (\$)</b>
250	\$84.35	24	576	0.58	0.15
350	\$91.90	35	840	0.84	0.22
500	\$107.70	45	1080	1.08	0.28
700	\$121.45	60	1440	1.44	0.37
950	\$191.00	93	2232	2.23	0.58



Recycled HDPE Fish Tanks (Tuffstuff©):

Rectangle Tank

31"x46"x16"      75gal      \$75.90

Oval Tank

22"x28"x8"      15gal      \$20.75

20"x20"x11"      18gal      \$23.88

25"x35"x12"      30gal      \$28.88

27"x38"x13"      40gal      \$37.26

30"x41"x15"      50gal      \$46.38

35"x50"x18"      85gal      \$67.05

34"x51"x20"      110gal      \$75.52

38"x56"x20"      140gal      \$121.82

41"x58"x21"      160gal      \$130.00

40"x58"x24"      180gal      \$165.96



Recycled HDPE Grow Beds (Tuffstuff©):

Lg. Rectangle

36"x24"x8"      26gal      \$15.99

Contractor Sloped Ends

60"x36"x12"      90gal      \$103.30





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Darrel Tanaka,  
Kailua Elementary



Windward  
Community College,  
Aquaculture  
Complex



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WCC Aquaculture Complex

# Waimanalo Prototype(s)



Kawika Kahiapo



Leina'ala Bright



# Hawaii State Hospital Module



Rearing Tanks

Biofilter  
“Reciprocating  
Ebb and Flow”

Hydroponic  
Component



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# Commercial Scale Aquaponics

Mari's Garden  
Mililani, Oahu

[http://www.marisgardens.com/  
photo/aquaponics/](http://www.marisgardens.com/photo/aquaponics/)

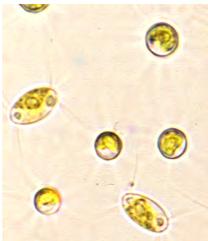


Friendly Aquaponics  
Hilo, Hawaii

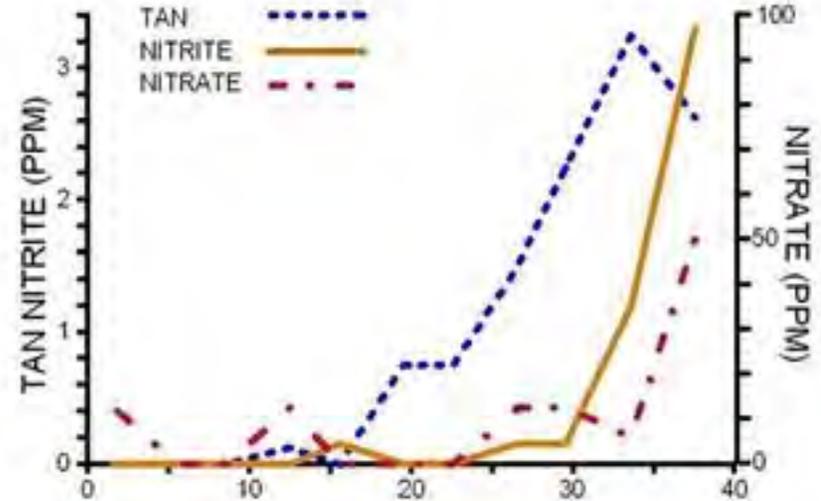
[http://  
www.friendlyaquaponics.com/](http://www.friendlyaquaponics.com/)



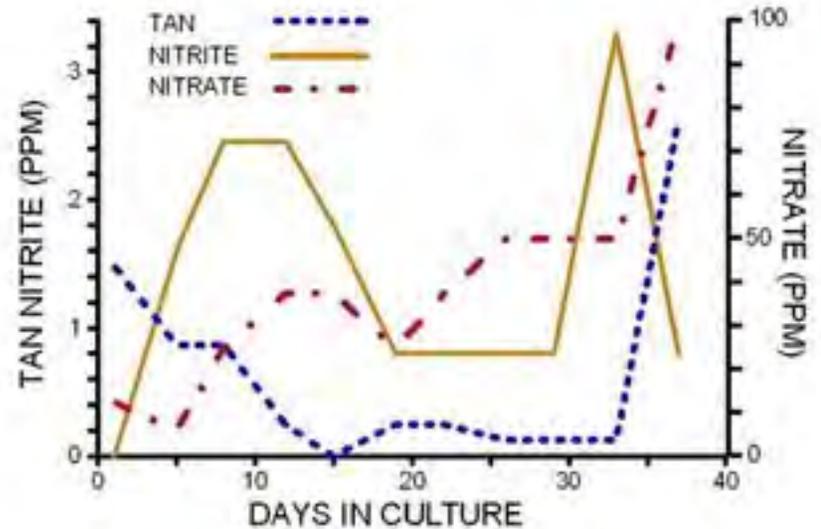
# Temporal Changes in TAN, Nitrite and Nitrate in Covered and Uncovered Fish Tanks



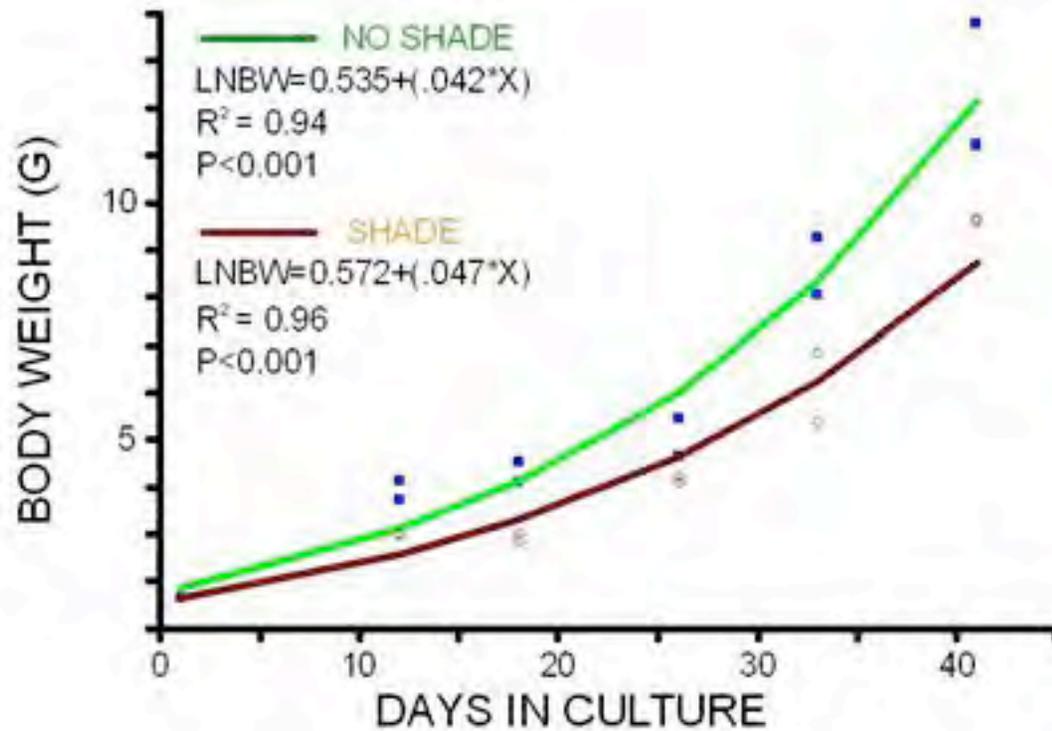
**Uncovered tank**



**Covered tank**



# Temporal changes in fish growth in covered and uncovered fish tanks



**No Shade**



**Shade**

Difference in growth between treatments is significantly ( $p<0.001$ ) different, ANCOVA, SYSTAT 1985

# Tilapia is the fish used exclusively in aquaponics operations in Hawaii.

- Tolerates low Dissolved Oxygen (DO) levels (e.g., 0.2 ppm)
- Tolerates high Total Nitrate levels (>400 ppm)
- Tolerates high Total Ammonia Nitrogen levels (e.g., >90 ppm) @ pH 6.0
- Tolerates low pH levels (< 5.0)



Smoked Tilapia

Alan Wong's  
RESTAURANTS



# Different Feed Treatments

- Rangen 350 Catfish Feed:
  - Crude Protein.....35.0%
  - Crude Fat.....5.0%
  - Crude Fiber.....5.0%
  - Ash.....10.0%
  - Phosphorus.....1.0%

**Retail Price**  
**\$ 0.63/ lb**

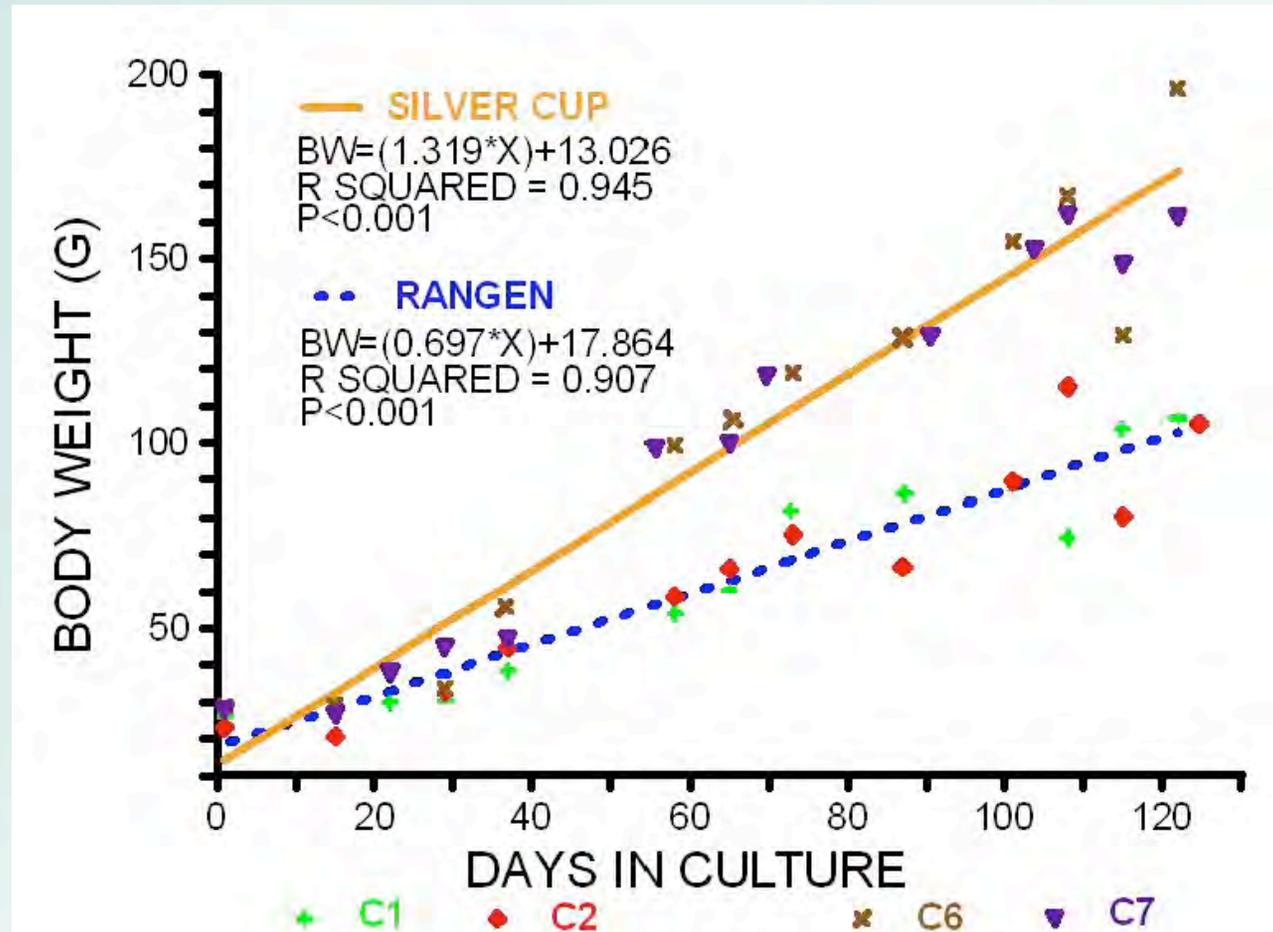


- Silver Cup Steelhead Feed:
  - Crude Protein.....45.0%
  - Crude Fat.....16.0%
  - Crude Fiber.....3.0%
  - Ash.....12.0%
  - Phosphorus.....1.2%

**Retail Price**  
**\$ 0.77/ lb**



# Growth of Tilapia Fed Two Different Feeds



**Fish being fed the Rangen feed will take an estimated 289 additional days to reach 450g (e.g, 1 lb)**



# Summary of effects of different feeds



	Rangen	Silver Cup
Net Gain (\$)	\$8.62	\$39.60
FCR	0.75	1.09
Harvest Density (kg/m <sup>3</sup> )	10.35	19.03
Survival (%)	98.5%	98.9%



**Fish Quality:** Significant ( $p < 0.05$ ) difference in whole carcass crude fat detected between treatments

**Rangen**

**Silver Cup**

26.1% Fat

33.2% Fat



**Tilapia Cakes**



**Steamed Tilapia**



**Baked Tilapia**

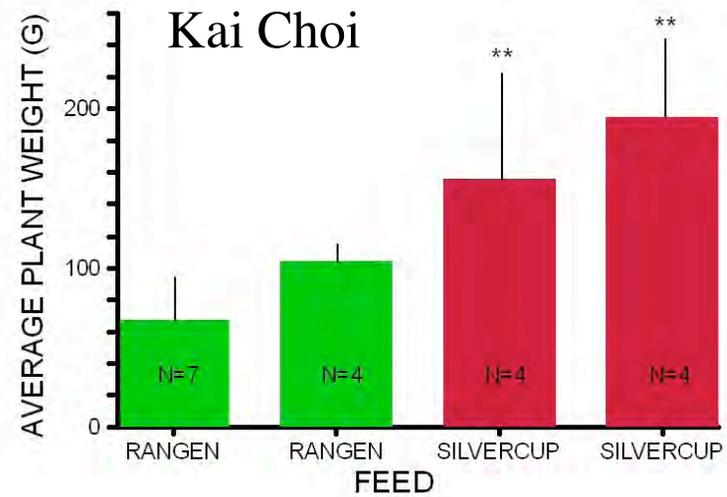
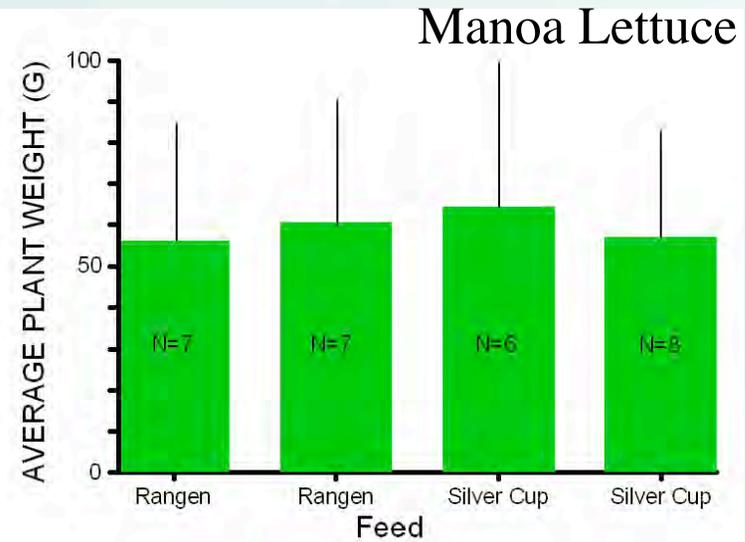
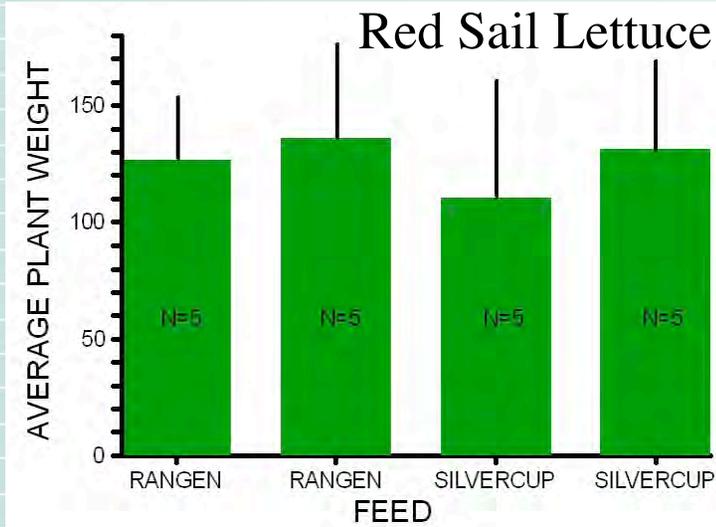


# Water Quality Parameters: Nutrients

	Rangen	Silver Cup	Statistics (p-value)
Total Nitrate (ppm)	31.9 ± 14.6	79.8 ± 30.9	<b>p&lt;0.01</b>
Total Nitrite- nitrogen (ppm)	0.6 ± 0.4	0.9 ± 0.4	0.4226
Total Ammonia – Nitrogen (ppm)	0.3 ± 0.5	2.0 ± 1.4	<b>p&lt;0.05</b>



# Growth Of Plants In Response To Two Fish Feeds



# Future Work: Replacement of Fish Food with home grown/produced food stuffs



Biopods at Windward Community College





WCC Aquaculture Complex

## Extension and Outreach

Strengthening  
Communities: Waimanalo  
Prototypes

Kawika Kahiapo



Leina'ala Bright





December 11, 2009



February 10, 2010  
June 22, 2010



December 11, 2009



CINDER

RAFT

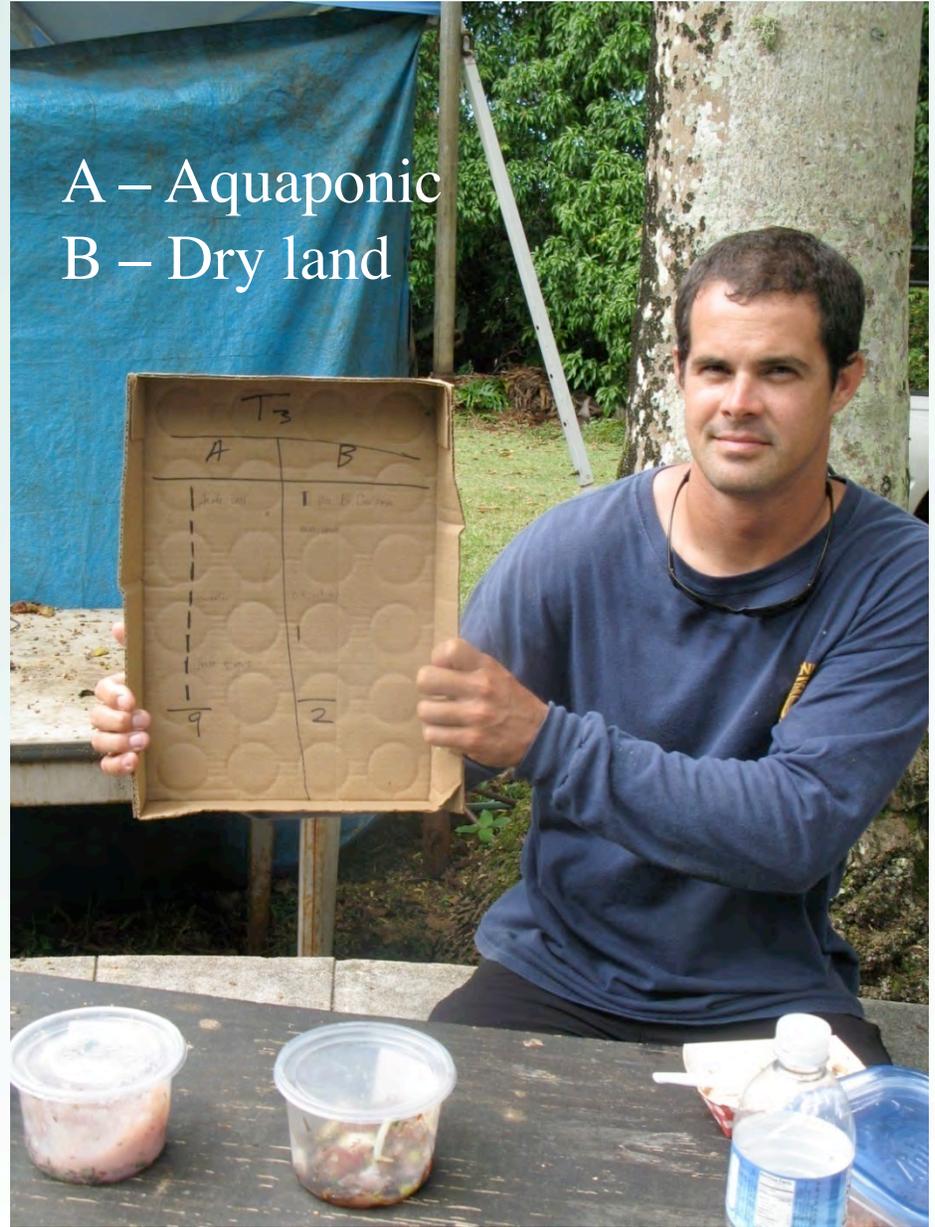


Preparation  
of kalo





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# Education: Mentoring the Next Generation of Scholars

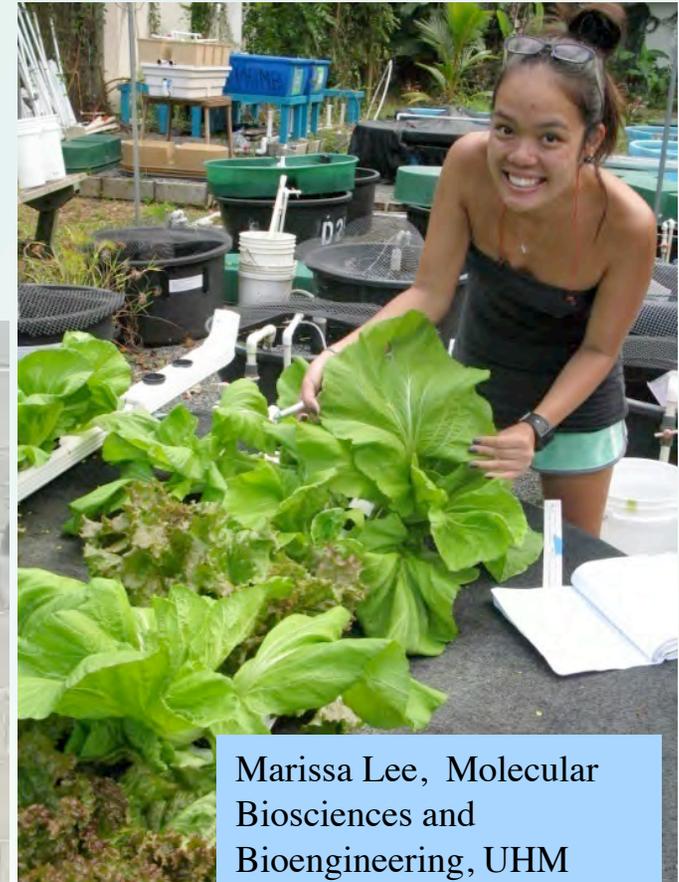


Kam School Fair 2010



Megan Talaro  
McKinley High School  
State Science Fair

UH Consortium 2010  
Science Fair Award



Marissa Lee, Molecular  
Biosciences and  
Bioengineering, UHM

Gamma Sigma Delta Award  
of Merit, 2010 CTAHR  
Student Symposium



# Education: Training the Trainers

## Pearl City Highlands Intermediate School

Principal: Ms, Amy Martinson  
Lynn Fujioka, ISIS Hawaii  
Hapa Farms



# Growing Food Mending Lives State Hospital Project



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