

## Aquaponics Workshop

Presented by  
Montgomery County Master Gardeners

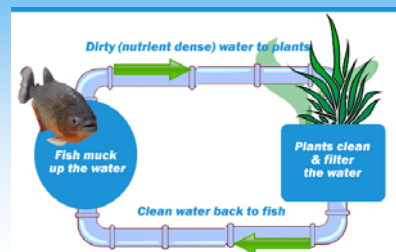
In conjunction with  
Texas AgriLife Extension Service



February 20, 2014  
Jim Bundscho

## Basic Concept

We have a pretty good idea of what we are trying to do ...  
*the devil is in the details*

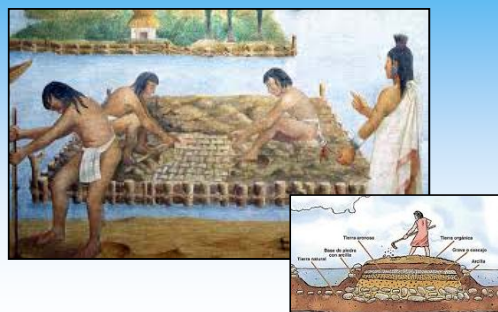


## Historical Perspective

The Aztec Indians may have been one of the first groups to practice what we now refer to as "Aquaponics". Before becoming a great empire in Central America ... the Aztecs were a nomadic people living near the shores of Lake Tenochtitlan. One of the ways they found for raised plants was by building floating rafts on the surface the lake.

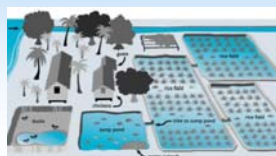
The Aztecs constructed large rafts out of reeds and rushes found near the lake, and covered them with soil which was dredged up from the bottom of the lake. They planted their vegetable crops on these floating mats called chinampas. When the plants matured, their roots grew through the soil and dangled in the water. Some remnants of chinampas can still be found today in Central Mexico.

## Aztec Indians - Lake Tenochtitlan



## Historical Perspective

For centuries, the Chinese have used a system of integrated aquaculture in which fish, ducks and plants co-existed in a symbiotic relationship. The ducks were housed in cages over the fish ponds. Finfish processed the wastes from the ducks. In a lower pond, catfish lived on the wastes that flowed from the finfish pond. The water from the catfish ponds was used for irrigated rice and vegetable crops.



## Some of the Pioneers in Aquaponics

The **New Alchemy Institute** was a research center that did investigation into organic agriculture, aquaculture, and bioshelter between 1969 and 1991. It was founded by **John Todd**, **Nancy Jack Todd**, and **William McLarney**.

In 1973 **Dr. James Rakocy** received his M.S. degree in environmental biology from the University of North Carolina. In 1980 he began 30 years of employment at the University of the Virgin Islands (UVI) where his focus was to develop aquaponic technology and directed research on the culture of tilapia in aquaponic systems.

In the mid 1980's, **Mark McMurtry** (a graduate student at North Carolina University) and **Professor Doug Sanders** created a closed loop aquaponic system. Effluent from fish tanks was used to trickle-irrigate tomatoes and cucumbers in sand grow beds which also functioned as bio-filters. As the water drained from the sand grow beds it was recirculated back into the fish tanks.

In the early 1990's, Missouri farmers **Tom and Paula Speraneo** modified the NCSU system and introduced their *Bioaponics* concept. They grew herbs and vegetables in ebb and flow gravel grow beds irrigated by the nutrient rich water in which they raised Tilapia.

## What are we really talking about?

- In its most basic form ... Aquaponics is really a “waste water treatment plant”
- Fish waste comes in ... plants grow and help to clean the water ... we eat the fish and the plants
- There are YEARS of data on how to treat waste water ... YEARS of data with Hydroponics ... and CENTURIES of experience with agriculture. We are just beginning to understand how small scale integrated Aquaponic systems for homeowners might be sized and managed properly.

## Aquaponics vs. Hydroponics

- Hydroponics uses a nutrient solution based on specific chemical compounds to optimize plant growth in a soil-less medium
- Aquaponics also “uses”, or more accurately “creates” a nutrient solution based on fish waste and microbial activity that more closely resembles natural processes in a healthy ecosystem



## Why do we really want to do it?

- Once you get past the “Wow, that’s neat!” Why do we really want to do it?
- The most rapidly growing segment in Aquaponics is the homeowner “back yard” system.
- The “Hydroponic” growers have acres of production for tomatoes, lettuce, etc. There are very few Aquaponic systems over 1 acre ... and most are single operator, home based market gardeners, or “backyard” gardeners.
- Why?  
You can get 2 crops ... fish and vegetables.  
There is no weeding.  
Water consumption is less than conventional row crops. Production can be as good as or better than Hydroponics.

## Why do we really want to do it?

There are challenges however –

High startup costs ... similar to Hydroponics

Bank financing is somewhat limited based on lack of proven financial history

Fish need care ... these are live animals!

On the other hand –

You can set this up on an abandoned parking lot or a rooftop

Protected environments mean lower weather risks

Niche markets can be established

## Aquaponic realities

- Plants need a robust supply of nutrients
- Nutrients are supplied primarily as a result of fish waste and mineralized waste
- Addition of Calcium, Magnesium and small amounts of Iron is common
- Nitrifying bacteria and fish both need oxygen to survive and work properly
- Solids removal and system management is needed

## System Types

- Raft – Deep water culture
  - UVI type systems
    - Constant flow – proven success when managed properly
    - Market gardener or Commercial scale
- Nutrient Film Technique – NFT
  - Commonly used in Hydroponics
  - Narrow channels of pipe
    - Shallow stream of nutrient circulated through troughs
- Media beds –
  - Flood and drain (ebb and flow)
  - Plants rooted into gravel or other media

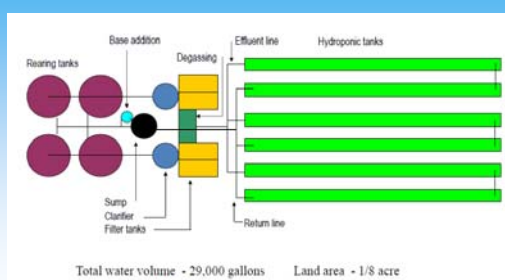
### Raft type systems

- Long beds ... up to 100' ... lined with rubber membrane
- Beds must be level and plumbed back to sump
- Floating styrofoam sheets with planting holes spaced for maximum plant density
- Root cups support transplants until root system develops
- Air stones approximately every 4 ft. are required to maintain dissolved oxygen levels within raft beds

### Raft type systems



### UVI System Model



### UVI Early Design Prototype

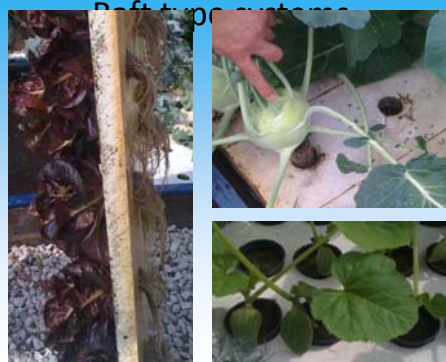


### Nelson & Pade – Family System



Nelson & Pade F5 Home package ...\$2,995  
(1) 110 Gallon fish tank, (2) 3' x 5' grow beds  
(2) Rafts, Water pump and air pump, etc...

### Raft type systems



## NFT (Nutrient Film Technique)

- Long sloping channels of PVC or other material – 3" to 4" deep
- Removable top for easy cleaning
- Planting holes spaced for maximum planting density
- Root cups hold plants while root system develops
- Shallow stream of nutrient rich water in trough

## NFT (Nutrient Film Technique)



Commercially available troughs ...  
PVC pipe may be an option ...



## Media beds – flood and drain

- Deep media beds – approximately 12"
- Material used varies by preference
  - Washed river gravel (heavy but inexpensive)
  - Hydroton (lightweight expanded clay – expensive)
  - Expanded shale – (lightweight – moderate cost in bulk)
- Flood and drain cycle is important to maintain oxygen rich environment for plants
- Can have problems with suspended solids and bio-film clogging the media if not sized properly
- Extra weight requires good support structure

## Media beds – flood and drain



Barrelponics - Travis Hugley

## Media beds – flood and drain



[www.cropking.com](http://www.cropking.com) 200 gallon system ... \$2695.00

## Hybrid Systems

- Raft plus Media systems
  - Rafts for shallow rooted plants
  - Media beds for deeper rooted plants and bio-filtration
- Shallow gravel and soil based systems
  - Growing Power – Milwaukee, WI.
  - Montgomery County - Texas
- Air tubes and vertical grow walls
  - Mostly for experimentation or demonstration





Murray Hallam - <http://practicalaquaponics.com/blog/>

Dr. Wilson Lennard – Cook Island Project  
Media Beds, Fish tanks, sump, bio-filter.

# Hybrid Systems



- Most aquaponic systems can be designed to be “hybrid” systems ... the nutrient flow and water quality remain the same. In fact, many of the new designs are utilizing a combination of grow beds to assist in mineralization and solids removal.
- The nutrient solution can be pumped or circulated some distance from the fish tank environment.

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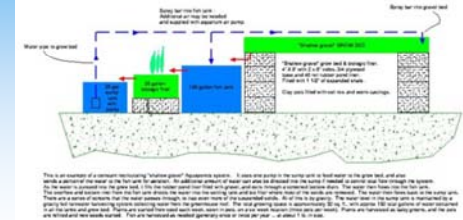
# Hybrid Systems



The top image shows a vertical garden with multiple layers of plants growing in a structured, tiered arrangement. The middle image shows a hydroponic system with plants growing in a nutrient solution, supported by a white structure. The bottom image shows a fish tank with a white structure, likely a filter or aeration system, integrated into the setup.

[illegible]

Constant Recirculating Aquaponic System  
Montgomery County Master Gardeners - 2013



## Keep an open mind in design

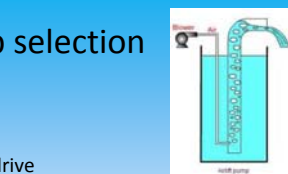


## Flow rates and system capacity

- General guidelines
  - 1 full exchange of water in fish tank per hour
  - 30 minute flow rate (or longer) through settling tank(s)
  - Constant flow & aeration high surface media (bio-filter)
  - 10 to 15 minutes per flood cycle in media beds
  - 30 minutes or longer for deep raft circulation
- Plan for flow rate loss due to clogging of media beds or filters
- Plan for flow rate loss due to “head height”

## Pump selection

- Flow rates (GPH or GPM)
- Head height
- Magnetic drive vs. shaft drive
- Power consumption
- Duty rating



## System component flow rates

- Fish tank exchange
  - At least once per hour
    - Example - 150 gallon fish tank requires 3 GPM or 150 GPH flow rate from pump, including loss of flow due to head pressure or clogging
- Bio filter and solids filter
  - Approximately once every 30 minutes or longer
    - This is related to size of filter vs. size of fish tank. Sediment filter capacity is approximately 1/2 that of fish tank
- Grow bed exchange
  - Approximately once every 30 minutes
    - This is a separate water line from the main line in the sump tank ... flow controlled by a ball valve
    - In raft systems ... flow rates can be 2 to 3 hours per cycle

## Solids and flow rates

- Solids removal
  - Solids cannot be consumed by plants
  - Plants get nutrients directly from solution
- Mineralization
  - Secondary treatment of bio solids in separate tank
  - Clarified liquid is returned to the system via sump
  - Un-dissolved solids are added to worm beds
    - Media beds can act as a mineralization tank
    - Must be sized appropriately to handle solids
    - Clogging may occur



## Sedimentation and Mineralization



Dr. Wilson Lennard –  
Swirl Filter, Screen filters,  
Mineralization Tank

## UVI System Components



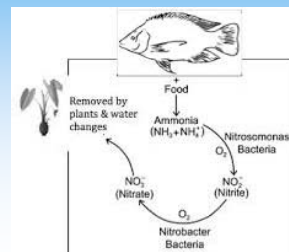
UVI System Components –  
Sludge pit, sediment, degassing and  
filter tanks.

## The Nitrogen Cycle in Aquaponics

- Fish consume food – excrete waste
- Ammonia is present in the water as a result of the fish waste and the breakdown of organic material and uneaten food

Beneficial bacteria living on the surface of gravel or other media convert Ammonia to Nitrite then to Nitrate

Hydrogen ions are released during this process which in turn lowers pH



## Macro and Micro Nutrients

### Macro nutrients –

- Nitrogen
- Phosphorous
- Potassium (Potash)
- Calcium
- Magnesium
- Sulfur

### Micronutrients –

- Copper, Boron, Iron, Manganese, Zinc, Chloride

## Nutrients and mineralization

- Solids and organic matter are important sources of nutrients – the fish food is limited in some ways
- Water dissolves these solids allowing the nutrients to be available to plants
- pH is important for these processes
- Typically, calcium and magnesium are limited in sufficient quantities for optimum plant growth
- Commercial systems add buffers such as Calcium Hydroxide or Potassium Carbonate, to the system to raise pH and add Calcium and Magnesium

## Vermiculture and Aquaponics

- Vermiculture (worm culture) has become a topic of discussion for many reasons -
- Do worms effectively remove solids from the Aquaponics system?
- Do worms aid in mineralization of solids?
- What added benefits are obtained from worm castings?



## Fish selection

Tilapia has been used in Aquaponic systems for many reasons

- Rapid growth
- High degree of tolerance to poor water quality
- Omnivores – primarily vegetable matter but can be carnivorous
- Accepted in the market as a mild edible fish
- Published data for feed rates and vegetable production – UVI model shows 1.7 lbs. of food will yield 1 lb. fish weigh gain.



## Other fish choices

- Ornamental fish – Koi  
Potential for higher prices per fish
- Blue gill or Sunfish  
Not herbivores ... will not clean algae from tank
- Catfish  
Cold water tolerant ... slower growing
- Crawfish / prawns  
Limited published data for economic models
- Barramundi  
Similar to Tilapia ... unknown sources for fry
- **Be careful of license requirements and invasive species**

## Feeding and health

### Stocking density

- Typically ¼ to ½ lb per gallon ... some systems stock at higher rates

### Feed quality

- A well balanced 32% protein floating pellet is most common.
- Some addition of Duckweed, or Fly larva, or other protein is often used ... a truly closed loop would grow the food the fish need

### Feed quantity –

- Typically you will feed as much as the fish will consume in 15 minutes. Several small feedings per day is preferred.
- Published data suggests 60 -90 grams of food per square meter of growing area (UVI system)
- Or – 1-1.5% or total fish biomass in terms of weight (Dr. Wilson Lennard)

## Feeding and health

You can calculate feed rates based on weight of fish, or total growing area ... The UVI model and others have published data for plant production based on feed rates.

### UVI Example –

**60 – 90 grams per square meter of growing area**

1 meter = 3.28 ft.

1 sq. meter = 3.28 x 3.28 ft. = 10.75 sq. ft.

28 grams = 1 ounce

60 grams / 28 = 2.14 oz. per 10 sq. ft.

or –

**Dr. Wilson Lennard (1% body weight)**

20 lbs fish in 100 gallons (.2 lb / gallon stocking density)

1 lb = 16 oz X 20 lbs. = 320 oz.

320 x 1% = 3.2 oz

## Feeding and health

### Proper aeration

- Dissolved oxygen levels ... as temperature increases more oxygen is needed ... fish respire more ... warm water cannot hold as much oxygen as in cooler water. The general rule of thumb in smaller systems is to watch the fish behavior and look for signs of stress (gasping at surface) Air stones and cascades of water will provide sufficient oxygen in the water.

### Water temperature

- Ideal temperature for Tilapia is 80 degrees F – fish stop eating at about 55 degrees, and chance of death at about 45 degrees F

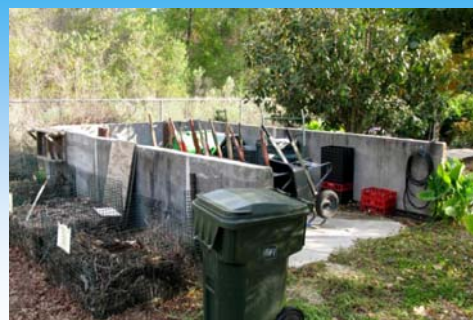
### Water quality –

- pH levels of 6.5 – 7.0 are optimum ... Available plant nutrients and fish health are related to pH.

## In summary

- Aquaponic systems must be managed to be effective
- Solids removal and re-mineralization are important for water quality and plant health
- Fish health drives the conversion of fish food to plant available nutrients
- Think in terms of “permaculture” ... integrated systems that create “layers” of benefits ... often greater than the single benefit each layer could provide
- Aquaponic systems not only provide nutrients for plants and protein for humans ... but they provide joy and beauty and a sense of connection to our food supply

## Montgomery County





Montgomery County



Montgomery County



Montgomery County



Montgomery County



Montgomery County



Montgomery County



## Montgomery County



## Montgomery County



## Montgomery County

Montgomery County Aquaponics Project

Beginning Values –

System Startup	10/30/12
Water Temp:	56 F
Air Temp:	60 F
pH	8.2 (tank)
	7.6 (transfer water)
Ammonia	3.0 ppm (transfer)
	.25 ppm (tank)
Nitrates	.50 ppm (tank)

## Montgomery County



## Montgomery County



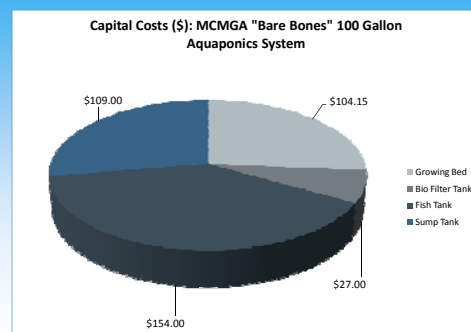
## Montgomery County



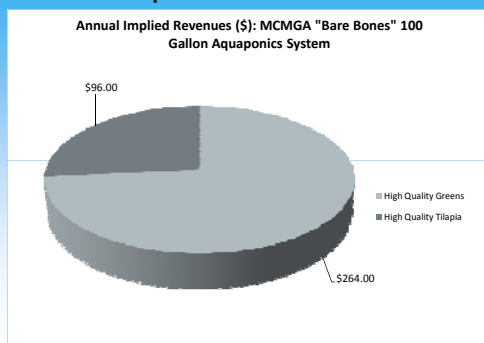
## Economic review - MCMGA

- When we started this project, we wanted to document the costs, and make some reasonable projections for revenue.
- The figures that are presented are for the system that we are building today, with the estimated production based on our data collected for the past 4 months.
- Please be aware that this is a demonstration system, and we continue to seek ways to improve upon design as well as economic data collection.
- If you are interested in Market Gardening ... the business model becomes much more complex.
- There are opportunities for increasing the scale of systems of this type, as well as using existing designs such as the UVI model. Before you invest in these systems as a potential business ... do the marketing and economic research just as you would for any other business.

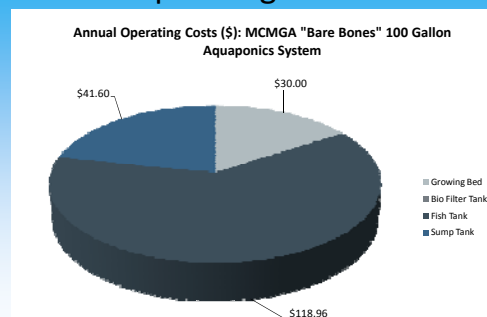
## Capital Costs



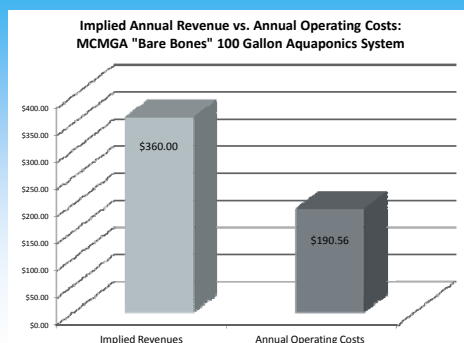
## Implied Revenues



## Operating Costs



## Revenues vs. Costs



## Resource list

Southern Regional Aquaculture Center (SRAC)  
<https://srac.tamu.edu/index.cfm>

University of Virgin Islands  
<http://www.uvi.edu/sites/uvi/Publications/UVAAquaponicSystem.pdf>

Dr. Wilson Lennard  
[www.aquaponic.com.au](http://www.aquaponic.com.au)

Additional reading and documents:  
 Friendly Aquaponics  
 Murray Hallam  
 Nelson and Pade  
 Backyard Aquaponics

A significant amount of quality material is available as PDF's on Dr. Lennard's website ... for FREE ...