Introduction to Aquaponics Part 1
November 15, 2014
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Morningstar Fishermen
American InterContinental University
Our Mission

- Give a man a fish and he eats for a day, teach a man how to raise fish and grow vegetables and the whole community eats for a lifetime

Our Motto

- Helping Others Help Themselves
Agenda

- Introduction to Aquaponics
- Systems
- Water Quality
- Fish
Who is this for?

- Extension Agents
- Students
- Teachers
- Gardening Clubs
- FFA Clubs
- Individuals
Uses of Aquaponics

- Water Quality and Water Conservation
- Growing fish food - duckweed
- Growing supplemental crop
- Ornamentals
- Food fish - tilapia
- *Spartina, Gracilaria*, sea purselane, and saltwort
- Marine – red drum
- Education for classroom
- Livestock Waste Treatment
Aquaponics

- Synergy between Hydroponics and Aquaculture
- Aquaponics is the integration of animal and plant culture in an aquatic media.

**IN-WATER FARMING**

- Fish waste becomes nutrition for plants.
- Water transports the nutrients to the plants.
Advantages of Aquaponics

• **Reduced Water Utilization** - Abundant high-quality water is usually the single most crucial resource for agriculture and aquaculture enterprises.
  
  • Aquaponics only use 1% to 3% of the water needed for traditional land based agriculture. (water loss due to evaporation and transpiration by the plants)
  
  • Traditional Aquaculture recirculating systems discharge 5 to 10% of their water daily to maintain water quality. (Reduced water heating cost in heated greenhouses)
  
  • Today agriculture utilizes 70% of the freshwater available in the world, and future population growth will continue to stress water availability.
# Water use efficiency in agriculture

## Water required per $100 of Produce

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<th>Liters</th>
<th>Gallons</th>
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<td>Sugar</td>
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<td>Beef Cattle</td>
<td>81,200</td>
<td>21,500</td>
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<td>Vegetables and fruits</td>
<td>37,900</td>
<td>10,000</td>
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<tr>
<td>Wheat and grain</td>
<td>24,500</td>
<td>6,500</td>
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<tr>
<td>Hydroponic crops</td>
<td>As low as 600</td>
<td>160</td>
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<tr>
<td>Aquaponic crops</td>
<td>As low as 200</td>
<td>60</td>
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Disney World - EPCOT - The Land

• 30,000 guests a day learn about hydroponics, aquaponics, aquaculture, tilapia, and advanced farming techniques

• Products are served in the Good Turn Restaurant
Development trials for Biosphere 2

- Biosphere 2 – A one hectare greenhouse. Completely sealed, with eight people living inside for two years.
Early trials for Biosphere 2

- University of Arizona provided overall technical support and designed the food system.
- Intensive food production
- Healthy foods with minimal need for external inputs
- Replicated trials with tilapia and lettuce
Aquaponics in the Classroom

- Micro-ecosystems
- Nitrogen Cycle
- Water Quality Chemistry & Testing
- Fish & Vegetable Growing Techniques
- Reproduction Cycles of Plants & Animals
Nicaragua, National Agrarian U.
St. Leo University 1-Day Training
• Simple, innovative and efficient system of food production combining aquaculture and hydroponic growing techniques

• Uses the natural cycle of nutrients to produce safe, chemical-free food

• Locally produced food - minimum carbon footprint, optimum freshness and maximum nutritional value
TWO ORGANISM OF DIFFERENT SPECIES WORKING TOGETHER

- Each benefiting from the relationship
- Each thriving in their environments
In addition to aquaponics (fish & plants), there are many kinds of aquaculture (fish culture) systems;

- Low intensity.
- High intensity.
- Green water.
- Polyculture.

There are many ways to raise tilapia including ponds, cages, in rice fields, tanks, or high intensity fish hatcheries.

Each tries to balance the needs of the fish with cost, available materials, labor and purpose (personal, commercial, community, education, etc.).
MSF Facility
Morning Star Fishermen - Aquaponics System

60,000 gallons (230,000 liters)
Only 24,000 (90,000 liters) used for fish grow-out

1,800 sq ft (170 m³) plant growing surface area

1,800 sq ft (170 m³) plant growing surface area
Raft Aquaponics

Thin Film Aquaponics
THE FISH TANK
THE CLARIFIER TANK
THE BIOFILTER TANK
UVI’S CILINDRO CONICAL CLARIFIER

1,000 gal. capacity
50 gal. / min. flow rate
20 min. resident time
Removes 50% of the solids

45º Upward Inlet
Effluent from Fish Grow-out

45º Cone Bottom

Baffle
Stand Pipe Drain

Effluent to Bio-filter

5%-10% Sludge
A gravity clarifier is the most economical method of removing solids from liquid because natural gravity is the source of energy and it is free.

A non-turbulent zone where solids, suspended by turbulence, are given sufficient time to settle to the bottom.

Baffles make the water stay longer in the clarifier - increasing the time available for settling.

Use gravity to move the water out from the fish grow-out tanks to the clarifier.

Using a water pump or airlift will destroy the waste particles, dissolving them or making them smaller and harder to remove.
• Tilapia produce solid and liquid waste

• The liquid waste, ammonia, is toxic to fish

• Solid waste is similar to manure and can be used to fertilize gardens

• Waste must be removed to keep your fish healthy

• Waste can be converted into nutrient for plants
Collar pipe with intake slits on bottom to force water to come from the bottom, pick up solid waste and flow down into the stand pipe and clarifier.

Directional flow to produce a circular motion which helps move sludge to the center to be picked up and deposited in the clarifier.

98 sq ft/cu ft

259 sq ft/cu ft

Artificial Bio-Substrates
**BIO FILTER TRICKLE TOWER ABOVE THE TANK**

Water is dispersed evenly at the surface and trickles through the wet bio-media.

Directional flow to produce a circular motion which helps move sludge to the center to be picked up and deposited in the clarifier.

Note pump is located above the sludge particle baffles.
Air-lift pumps are limited in their ability to lift water above 6” (15 cm) from the water surface.

Pipe diameter and the depth the air is injected controls optimal flow rates.

Bigger diameter pipes does not mean larger flows but depends on the air available.

Rising air lifts the water up and out of the tank. Large air bubbles lift more water than fine bubbles.
DISSOLVED OXYGEN – AIRLIFTS
(Move Water – Provide Aeration Remove CO2 Gas)
YOUR ABILITY TO CULTIVATE FISH WILL DEPEND ON 8 CHARACTERISTICS OF LIVING THINGS

- Light
- Water
- Respiration (Oxygen)
- Food
- Growth
- Reproduction
- Waste
- Responds to Changes
Water Source

- Lakes, Ponds, Creek, or Rivers – needs to be filters with a sock filter to keep out fish and invertebrate eggs and fry.
- Reclaimed Water (Gray water) – allot of drugs, chemicals
- Potable water – chlorine or chloramines
- Wells - shallow or deep
**WATER QUALITY PARAMETERS**

- Water Temperatures for Optimum growth: 28-32 °C (82-90 °F)
- Optimum spawning and embryo development: 25-30 °C (77-86 °F)
- Dissolved Oxygen (DO): above 3.0 mg/l
- Carbon Dioxide: below 15 mg/l
- Salinity: 0-28 ppt
- Turbidity: 25-100 mg/l
- pH: 6.0-8.5
- Alkalinity: 50-700 mg/l
- Total Ammonia Nitrogen (TAN): 0.5-1 mg/l
The Nitrification Process

Nitrosomonas

Nitrosospira

Nitrospira

Nitrobacter

Ammonia (NH₃)

Nitrite (NO₂⁻)

Nitrate (NO₃⁻)

Ammonia Oxidizing Bacteria (AOB)

Nitrite-Oxidizing Bacteria (NOB)

 amo = ammonia monooxygenase enzyme
Other Nitrifying Organisms

- Until recently (2005) nitrification was considered to be a bacterial process.
- Now we know that other microbes can cause nitrification.
- One group is Ammonia Oxidizing Archaea (AOA) affiliated with non-thermophilic Crenarchaeota.
- Some microbiologists have found that fungi, some algae, and certain heterotrophic bacteria also carry out nitrification.
Nitrogen Cycle

- Decomposition by fungi and bacteria
- Uneaten food/rotting veg.
- Ammonia (NH₃/NH₄)
- Oxidation by nitrobenzene bacteria
- Oxidation by nitrifying bacteria
- Nitrites (NO₃⁻)
- Nitrates (NO₃⁻)
- Absorbed by plants
NITRIFICATION

- An aerobic process - requires $O_2$ (consumes) oxygen

- Acid producing process releases $H^+$ - lowers pH

- pH 7.5 - Optimum pH for nitrification

- Below pH 6.0 nitrification stops
AMMONIA (NH₃) AND AMMONIUM (NH₄)

• A dissolved waste: colorless, odorless gas quickly dissolves, comes in two forms

• Free or unionized ammonia (NH₃) is TOXIC

• Ammonium (NH₄) ion is HARMLESS

• The amount of ammonia/ammonium depends on temperature and pH - for every pH unit increase the ammonia level increases 10x

• High temperature and high pH = danger to fish
Nitrite is toxic to fish because it makes the hemoglobin less capable of transporting oxygen
  - (Brown blood disease)

Nitrite concentration should be kept below 27 ppm

Tilapia are more tolerant of nitrite than many cultured freshwater fish

Fish gulping at the surface of the tank could indicate high Nitrite concentration (like low $O_2$)

Nitrite problems are typically more likely in closed, intensive culture systems due to insufficient, inefficient, or malfunctioning filtration systems
Nitrate is formed by bacteria in the water, on the walls of the tanks and in bio filters.

Nitrate is a natural fertilizer, used by plants to make protein.

Nitrate is non-toxic to tilapia in levels up to 800 ppm.
SEEDING BIO FILTER

• In order to process the ammonia from a large number of fish it is necessary to first establish or seed the bacteria into your bio filter

• Acclimation - this is done by placing a small number of fish in the system for 2 weeks prior to introducing the full amount of fish

• This establishes a healthy population of bacteria capable of handling the increased load of ammonia from the fish

• You may also add an active filter from another all ready established system
TIME REQUIRED FOR BIOFILTER TO MATURE

Ammonia (mg/l)

Nitrites & Nitrates (mg/l)

Time in Days

NH₃  NO₂  NO₃
The pH of a solution affects the solubility of nutrients, especially trace metals.

Essential nutrients such as iron, manganese, copper, zinc and boron are less available to plants at a pH higher than 7.0.

The solubility of phosphorus, calcium, magnesium and molybdenum sharply decreases at a pH lower than 6.0.

Compromise between nitrification and nutrient availability is reached in aquaponic systems by maintaining pH close to 7.0.

Higher pH levels, up to pH of 8, will still “work”, but only if all ammonia is converted to nitrate.
**pH RANGE**

LOG 10 SCALE (A pH VALUE OF 2 IS 10x HIGHER THAN pH OF 1)

- battery acid
- lemon juice
- pure rain (H₂O in equilibrium with atmospheric CO₂)
- freshly distilled water
- seawater
- baking soda (NaHCO₃ solution)
- household ammonia (NH₃)
- household bleach (NaClO solution)
- household lye (NaOH solution)
- gastric fluid
- carbonated beverages
- vinegar
- orange juice
- beer
- coffee
- egg yolks
- milk
- blood
- milk of magnesia (Mg(OH)₂) solution
- Plants
- Bacteria
- MSF well
- Tilapia

Stephen Lower
Tilapia are tropical fish, and as such require warmer waters to survive and thrive.

Ideal temperature range is between 78°F and 86°F Fahrenheit. 25°C to 30°C Celsius.

Temperatures below 70°F (21°C) slows feeding and growth.

Temperatures below 60°F (15°C) Tilapia will stop feeding and at 55°F (13°C) will begin to die.
Fish require oxygen to live.

Oxygen in the atmosphere is 20 ppm whereas in the water it ranges from 0 to 10 ppm.

Tilapia need at least 3 ppm to do well, and 5 ppm is ideal.

Tilapia can survive for short periods of time in levels as low as 0.5 ppm by gulping air, but this is not ideal.

Fish gulping at the surface of the tank sometimes indicate low Oxygen.

Oxygen can be measured chemically or electronically.
DISSOLVED OXYGEN (DO)
REQUIREMENTS IN PARTS PER MILLION (ppm) FOR FISH
10 Minute Break
When choosing which fish species to grow consider

- Toleration of marginal water quality
- Supply of fingerlings
- Acceptance of a commercial pelleted diet
- Fast growth at local temperature ranges
- Resistance to culture disease problems
- Marketability
FISH THAT DO WELL IN AQUAPONICS:

- Tilapia
- Hybrid Striped Bass
- Sunfish
- Bream
- Crappie
- Koi
- Carp
- Pacu
- Almost any ornamental fish such as angelfish, guppies, tetras, gouramis, swordfish, mollies
## What are Americans Eating?

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<th>2009</th>
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<td>Shrimp</td>
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<td>3.5 lbs</td>
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<td>3</td>
<td><strong>Cod</strong></td>
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<td>Salmon</td>
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<tr>
<td>1</td>
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Adapted from FDACS Florida Seafood Study Survey Overview 2007
Tilapia contains all nine essential amino acids; therefore, it is an excellent choice for meeting our daily protein needs.

Highly digestible protein and more readily broken down and absorbed than the protein in red meats and poultry.

### Nutritional Value per 100g (3.5 oz.) Serving

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<th>Protein g</th>
<th>Fat g</th>
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<tr>
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<tr>
<td>Tuna (belly)</td>
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ADVANTAGES OF FARMING TILAPIA

- Feeds low on the food chain
- Accepts wide range of feeds
- Good feed conversion rate (1.7).
- Resistant to poor water quality, disease, overcrowding and handling
- Good flesh quality
- Fingerlings are easy to produce year round
RESPONSE TO CHANGE

- Tilapia grow faster and larger if proper conditions are provided.

- Tilapia respond to water temperature, pH, dissolved oxygen, and changes in water quality.

- The health of your water determines the health of your fish.

- Understanding & watching tilapia behavior enables you to know if something is wrong & needs to be addressed quickly.
Blue tilapia (*Oreochromis aureus*)
- Interrupted bands on its caudal fin
- Male max. length of 20 in. and 8 pounds.
- Reaches 1 pound body wt. in 10 to 12 months.
- Greatest resistance to cold temp. - 46°F min.
- Breeds in water temperature as low as 70°F

Nile tilapia (*Oreochromis niloticus*)
- 7 to 12 vertical stripes found on the caudal fin
- Max. length of 2 feet in length and 10 pounds.
- Fast growing reaching harvest maturity of 2 to 3 pounds in 10 to 12 months.
- Top three most farmed fish in the world (together with salmon and carp) - two billion pounds per yr.

Mozambique tilapia (*O. mossambicus*)
- Weak or no bands on its caudal fin
- Max. length - 18 inches, 7 pounds
WHICH KIND OF TILAPIA TO STOCK?

• Nile tilapia grow fast and are able to obtain the largest size

• Red tilapia are the second fastest growing species and grown throughout the world

• Blue tilapia (Tampa Bay strain) grow well and are more tolerant to lower water temperatures as low as 55 °F. (13 °C) and can spawn at lower temperatures. No special permit required in Florida
BLUE TILAPIA
Tilapia in tank
Distribution of blue tilapia
• We all require food to live

• Tilapia diet changes as it grows

• Fry, fingerlings, and juveniles are omnivorous (will eat plants and animal material) and require more protein in their diet, while adults are primarily herbivores (plant eaters)

• They feed off of micro algae suspended in the water (green water) as well as aquatic plants and plant material
NUTRITIONAL REQUIREMENTS

• All animals require 5 basic food components;
  • Protein
  • Fat
  • Carbohydrate,
  • Vitamins & Minerals

• Fish eat to fulfill energy needs, not protein needs

• Fish need fewer energy calories than terrestrial animals because they are cold blooded and do not burn calories to stay warm

• Growth, disease, reproduction and higher water temperatures all increase energy requirements

• Carbohydrates, proteins, and fats combined supply 100% of the energy requirement for fish
NUTRITIONAL REQUIREMENTS

- As sources of energy, carbohydrates, proteins, and fats are interchangeable. Fats contain twice the calories for energy production as either proteins or carbohydrates.

- For juveniles, a diet high in fat may meet the energy need before sufficient protein has been ingested.

- Proteins not used for tissue production are utilized as energy. The metabolism of these proteins to sugars results in the release of highly toxic ammonia.

- For adults, a diet with a higher protein content than required puts an additional load on the filtration system and deteriorates water quality.
Tilapia are omnivores, with diet changing as they grow

Younger tilapia feed on a variety of food sources including microscopic animals and insect larvae, as well as algae, and plant detritus

Fry and juvenile fish need a minimum of 42-45% protein in their diet for growing body mass

Protein requirement tapers down as they grow

Older, larger tilapia feed mainly on algae and plant detritus, grazing constantly like cows
GILL RAKES

- Gill rakes are small structures that support the gills.

- In tilapia, gill rakes are specially adapted to filter the water and retain microscopic plants and animals (in Green Water) that are food for the fish.

  Natural food - 50 to 60% protein

- This is how females eat when brooding, but all fish used this method to eat, allowing them to survive when feed is not present.
COMMERCIAL FISH FOOD

• Tilapia fry can eat commercial fish food, provided it is small enough to fit in their mouths

• The higher the protein content the better.
  - Fry & fingerling require >45% protein content

• Grinding fish food into smaller pieces depending on the size of the fish allows you to use one type of food throughout the life stages of the fish
In high density indoor systems or cage culture, fish cannot forage freely on natural feeds, they must be provided a complete diet. (some diets are not complete - only supplemental diet)

With high quality complete feeds, one pound of fish body mass is produced by 1.5 to 2 pounds of feed

Typical tilapia Feeding Conversion Ratio; 1.7
1 lb. of growth / 1.7 lb. of feed or 0.59 (59%)
TILAPIA FEEDING IN TANK SYSTEMS

• The most important rule in fish nutrition is to avoid overfeeding
• Floating pellets are best for adults, 32% protein
• Can supplement with duckweed and other vegetable matter
• Quick to feed, quick to stop feeding, don’t ever over feed
• If food is left over, remove it from the tank before it sinks, turns into ammonia, and contaminates tank
**FEEDING PROCEDURES**

- Very Important: Use a test amount, or handful and observe behavior first
- Then feed modest amounts continually
- And slow as the fish slow down
- Feed all they will eat in 10-15 minutes
- Fry eat almost constantly (every 1 - 2 hr.)
- Fingerlings every 3 - 4 hr
- Adults three times a day
Feeding Tilapia
Once they absorb the yolk they begin eating microscopic plants and animals.
Micro algae is too small to see with the naked eye
Add gelatin

Chicken egg yolk powder

Roe (fish eggs)

Copepods, *Daphnia*

Rotifers (zooplankton)

Insects, worms, and larvae

Duckweed - Dry wt. 35% to 45% protein
• Vegetative reproduction - exponential growth
• Can double their mass in less than two days in warm, nutrient-rich water. 60 - 80 tons/ha2/yr. of solid material
• 92% to 94% water
• Under ideal conditions and harvested regularly protein content of 35% to 45% is possible
• Duckweed protein has higher concentrations of the essential amino acids, lysine and methionine, than most plant proteins - more closely resembles animal protein.
• High concentrations of trace minerals and pigments, beta carotene and xanthophylls, vitamin A precursors, that makes duckweed meal especially valuable.
Protein Content of Selected Foodstuffs

Figure 5.
- Start to reproduce at the juvenile phase (3 months old)

- Females protect eggs and fry for up to 2 weeks following fertilization

- Mother holds eggs and fry in her mouth, constantly pumping fresh water to provide oxygen (This is called Mouth Brooding)

- Female can produce a new clutch every 3-4 weeks
Tilapia have several distinct growth phases:

- Egg (3-5 days) in mothers mouth
- Larval fry (7-10 days) in mothers mouth
- Free swimming fry (4 weeks)
- Fingerlings (2 months)
- Juveniles (3 - 6 months)
- Adults
FERTILIZATION AND BROODING

- Female lays egg
- Male puts milt over eggs
- Female puts eggs into her mouth
- Males mate with several females
- Females mouth brood
- Eggs hatch in two to four days
- Brood for a further ten days
Food grown in tanks or fertilized ponds (plankton, green water) is often a good source of nutrition, but for maximal growth and health supplemental feeding is required.

Commercial feed tends to be a little low in Protein for fry (32% rather than the 45% needed for fry) some creative solutions have been found.
HOW MANY SHOULD I STOCK?

• Decide the weight you want them to be at harvest, (1/4, 1/2, 1 lb?)

• Decide the density you feel your system will sustain (1/8, 1/4, 1/2 lb of fish/gal. of water)

• At beginning stages we suggest using a density of 1/8 to 1/4 lb/gallon of water

\[
\text{Actual water volume} \times \text{Density} = \text{Weight of fish at harvest} \times \text{Fish needed}
\]

\[
\frac{400 \text{ gallons} \times 1/8 \ (0.125)}{1 \ lb. \ Fish} = 50 \text{ fish}
\]
HOW MANY SHOULD I STOCK?

- Rule of thumb per Dr. James Rakocy, U. of Virgin Islands:
  - Per Gravel Hydroponics Media – 1 cubic meter of fish (35.31 cubic feet) tank volume to 2 cubic meters of hydroponics media (70.62 cubic foot)
  - 57 g (2.01 oz) of fish feed per day square meter (10.76 square foot) of plants growing area for the staggered production of leaf lettuce.
  - 11.5 to 1 ratio of plant beds to fish tank surface area in high density fish systems (120 kg/cubic meter or 11.9 lbs/cubic foot).
• The key is to **balance the system** ratios so that the nutrient level stays relatively constant.

• Plant:Fish Ratios vary from 2:1 to 10:1

• Water:Fish Ratios vary from 1:1 to 10:1
GULPING AIR

- Gulping air at the surface can be an indication of low oxygen levels
- If it occurs in the early morning or during or after several cloudy days it may be a temporary problem
- If it continues during the day, then the problem is more serious
- First make sure the aerators are working
- If ok, then look at the micro-algae and see if the water is turning brown and clearing which indicates it is dying. Make water exchange if this is the case
JUMPING OUT OF TANK

• Jumping out of the tank is fairly common for Tilapia

• To help prevent jumping put netting over the top or along the sides or reduce water level 6” to 8” from the tank edge

• When water is clear they may become frightened by sudden movements

• If a lot of fish jump out, or you see them swimming erratically may indicate a water quality problem

• Stop feeding the fish for a day or so, check nitrite and ammonia levels, clean the bio-filter and make a 30% water exchange, turn up aeration level
• *Spartina alterniflora*
• On June 11, 2013 marked the one millionth marsh grass harvested from SERF
• Since 1997, *Spartina* harvested from SERF has been replanted at 90 locations in Tampa Bay
• 2 yr Sea Grant Marine Aquaponics Production of Marine Fish and Sea Vegetables (2014-15).
• Red Drum
• *Gracilaria*
• Sea purselane
• saltwort
• Offer 1-day, 5-day; 4, 8 or 12 week Courses; 2-day advanced course; and 1-day Online course.
• MSF has averaged 17 students per month.
• Students have come from 42 states & 9 countries.
• 858 have completed training since 2002.
• Internships with Hillsborough Community College, Pasco-Hernando Community College, Clearwater Christian College, and St. Leo University.
• Internships with Walt Disney World’s Epcot’s Land Exhibit (60 interns).
• Over 100 internships completed & 40 were from Central America.
• Since January 2012 MSF has given away over $24,000 in scholarships to students from around the world.
10 Minute Break
Part 2 - Phil Reasons

Thank You!
Plants