Aquaponics for Teaching and Demonstration

Duval County Florida

University of Florida

Department of Agriculture Education and Communication

Masters Project

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Introduction:

School gardens have become extremely popular within the United States in recent years. Gardens are a wonderful tool to teach youth responsibility, promote healthy eating, and build self-esteem and confidence, (Story, 2009). Students in public schools come from very diverse backgrounds; gardening can increase communication and build common interpersonal relationships. These gardens can consist of raised bed or container gardens, traditional in ground gardens, hydroponics, and aquaponics. Aquaponics is a technique that combines hydroponic gardening and aquaculture and can be used as an education tool in many disciplines, allowing students to learn through experience. Aquaponic systems are a fun way to incorporate education on local food systems and environmental sustainable practices into the science classroom. Recirculating aquaponic systems use much less water than traditional in-ground farming. The following program uses miniature aquaponic and barrel aquaponic systems as a teaching tool for students to learn science, math, engineering, and technology. This system is small enough to be set up in any classroom setting to teach adults (teachers and youth volunteers) and youth plant growing techniques, water quality, the nitrogen cycle, aquaculture techniques and recycling practices, while increasing awareness of environmental issues facing Florida. The program can be used as presented or modified to suit the needs of your classroom setting.

Aquaponic systems in science classrooms can be invaluable education tools, allowing students to learn aquaculture, horticulture and sustainability. Hands-on activities provide students with an opportunity to experience what they are learning. Experiential learning opportunities with aquaponic systems lead to increased knowledge retention, promote positive behavior change, and increase appreciation and awareness of fresh, locally grown food, which increases participation in local food systems and awareness of food security. Adults and youth exposed to educational activities using sustainable practices are more likely to adopt environmentally-friendly practices and have greater appreciation and awareness for local food systems.

The Duval County Extension Office has designed this program to prepare students, teachers, and youth leaders techniques to build their own aquaponic systems and engage students in STEM curricula. By incorporating aquaponics into daily classroom activities teachers can increase nutrition education opportunities and address childhood obesity. Aquaponic systems can be expensive and time-consuming, but this program shows participants how to build an inexpensive and user-friendly system which will produce plants and fish simultaneously.

Teachers as Adult Learners

The program participants in the "Aquaponics for Teaching and Demonstration" workshop consisted mostly of public school teachers and master gardener volunteers. Knowles (1980) explains that there are four basic assumptions associated with the adult learning theory. First, adults are competency based learners in that they would like to apply new skills and knowledge to their current situation. Second, adults usually have many experiences that they can relate new knowledge too and use as a resource for learning. Next, adults have specific learning needs based on real life problems or situations; lastly, adults become more self-directed as they mature. Many teachers have little or no budget, but have tons of creativity; therefore, by providing participants with the knowledge resources to build an aquaponic system they can put their limited resources to best use. Merriam (1999) states it is important to recognize and acknowledge the previous knowledge and experiences of adult learners, including their ability to recognize their own skills as lifelong learners. Teachers are looking for opportunities and unique projects to engage their students while also providing them with life skills. While, providing the background knowledge to enable these adult learners to build their own aquaponic systems, it is important to acknowledge the differences among individuals, their backgrounds and learning styles.

Purpose and Objectives

Objectives: Two objectives of the Aquaponics for Teaching and Demonstration Program are to provide teachers, master gardeners and volunteer leaders with clear instructions to build their own aquaponics system using primarily recycled materials and provide supportive materials for system maintenance and education materials for incorporation into classroom curricula.

Definition of Terms and Acronyms

Aquaponics- a system of aquaculture in which waste produced by fish or an aquatic species provides nutrients for hydroponically grown plants which assist in cleaning the water ammonia and nitrogen from the system.

Hydroponics- the process of growing plants in a soilless environment.

IFAS- Institute of Food and Agricultural Sciences; a federal, state and county partnership established to increase knowledge in agriculture, natural resources, and life sciences to improve quality of life for individuals.

STEM Education- Science, Technology, Engineering, and Math; an approach to teaching and learning that integrates the content and skills of science, technology, engineering, and mathematics. These behaviors include engagement in inquiry, logical reasoning, collaboration, and investigation. The goal of STEM education is to prepare students for post-secondary education and the workforce.

Sustainability- using methods that do not deplete natural resources.

Limitations of the Study

Limitations of this research include:

1. The study was limited to participants in Duval County Florida in the Northeast region of the University of Florida Extension District.
2. Participants may have certain characteristics that may predispose them to specific outcomes (experience, education).
3. Participants may not answer all answer all of the questions on the assessment or evaluation.

Basic Assumptions

1. All participants will understand evaluation instruments and will not be misled.
2. Participants will answer survey instruments honestly.

Significance of Problem

Aquaponics for Teaching and Demonstration provides simple examples of aquaponic systems that are inexpensive to build and require little previous knowledge to successfully grow plants and aquatic species. Teachers and homeowners frequently spend large amounts of money on systems that are not designed for small spaces and require large amounts of maintenance and care. The content taught in this workshop provides background knowledge to successfully establish and maintain a new aquaria-ponic or barrel-ponic system in a classroom or backyard environment. Safety is another significant portion of this training; first, it is essential when working with students to ensure physical hazards do not exist (tripping, cuts or electricity), and secondly, food safety (proper hand washing, harvesting, and processing techniques). It is important for educators, students and volunteers to have a positive experience and success when establishing a new system to create a positive learning environment and provide motivation to continue sustaining the aquaponic system.

This workshop also provides a new creative method for teachers to engage students in the classroom through experiential learning. By using STEM education, students are provided hands on experience that will assist them in gaining life skills as well as obtain a deeper comprehension and application of science, math, and engineering content.

Theoretical Framework

Knowles' (1980) Adult Learning Theory states adults learn from their experiences, new information must be significant to their current situation, and real life issues generate the need to learn new information. Teachers are in a constant search for new curricula and activities to engage their students, while still meeting state and national standards. Aquaponics for Teaching and Demonstration fits this need by providing a flexible list of activities, readymade curricula sources, and an easily constructed, real- life aquaculture production system. The adult learning theory is based on problems not content; and with aquaponics there are a multitude of issues that can be simplified through training.

The adult learning theory also blends well with the constructivist approach is a learning theory that draws from the students existing knowledge, beliefs and skills. "Constructivism contends that students are not sponges ready to absorb and use transmitted knowledge; the knowledge already written on their mental slates affects how they interpret new observations and how they accommodate newly constructed knowledge. If, during the course of instruction, teachers are not cognizant of students' prior knowledge, then the message offered by the teacher likely will not be the message constructed by the student" (Mestre 1991).

Methods

The program uses a miniature aquaponic system as a tool to enhance students' experience in science, technology, engineering and math. The model system is small enough to be set up in any classroom setting, can be built with little cost, and can easily be assembled and disassembled. It can be used to teach plant growing techniques, the nitrogen cycle, aquaculture techniques and recycling practices, while increasing awareness of environmental issues facing Florida. Participants gain knowledge on basic principles of aquaponics, Florida rules and regulations, and instructions for constructing a small aquaponics system. The workshop provides information on types of aquaponic systems and how to construct them; water quality considerations for plants and fish; basic fish health care; food safety considerations, and current curricula available.

Topics also include information on successfully plant and aquatic species for specific systems, plant growing techniques, the nitrogen cycle, aquaculture techniques and recycling practices, rules and regulations, while increasing awareness of current environmental issues facing Florida. Participants will receive lesson plans to be used in the classroom, aquatic system requirements and design, information on food safety and hygiene, plant selection and nutrient requirements, and an introduction to fish nutrition and health. Participants also have the opportunity to participate in modeling exercises demonstrating how an aquaponics system works.

Population and Sample

The population for this study included Duval County Public School teachers and volunteers of the University of Florida Duval County Extension Office. The workshop occurred in June of 2014 at the Duval County Extension Office. The program was posted and advertised though email list serves through the Duval County Extension Office and the Duval County Public Schools. There were approximately 45 teachers and volunteers that attended the training. Class sizes generally range between 15 and 50 participants; however, because of the restricted schedule of the Duval County Public School teachers, the participant registration was set for one session during their break from classes.

Research Design

This study used quantitative research techniques and was administered via a pre and posttest. The assessment tool consist of a multiple choice pre and post and the evaluation instrument utilized a Likert scale that can be statistically analyzed. The survey instrument was created, pilot tested and revised by the research to ensure validity and reliability. The pre-test evaluation was provided at the beginning of the workshop during the registration period and was collected prior to introduction of workshop materials. Participants provided their name (or could use a fictitious name to provide anonymity) on both the pre and posttest to enable the researcher to compare and evaluate knowledge gain.

A follow up evaluation will also be sent out six months from the date of the workshop to evaluate the implementation of new systems and environmentally friendly gardening procedures.

Training Description

The Aquaponics for Teaching and Demonstration workshop provides participants with knowledge to build and implement an aquariaponic or barrel-ponic system in their classroom. The materials presented will off teachers the basic knowledge and skills to startup a simple aquaponic system and create a sustainable environmentally friendly experiential learning opportunity for their students. The program was designed to cover the most essential components of system design, water quality, fish health, food safety, and available K-12 educational curricula to meet Next Generation Science Standards and Common Core Standards.

The workshop is designed to assist teachers that are interested in building or are currently using an aquaponics system for purposes of teaching K-12 students STEM, agriculture, horticulture, and nutrition education. These systems can be simple and inexpensive or elaborate and extremely costly. The purpose of the workshop is to provide background knowledge and resources to assist Duval County Public School's teaching faculty with the needed resources to successfully rear and harvest aquatic species and vegetable crops simultaneously with few resources and little space.

There are four broad subject areas that are covered, aquaculture, horticulture, food safety and educational curricula. Aquaculture encompasses many different species, types of equipment, and techniques. The rationale behind this module is to break this broad spectrum industry into a suitable, user friendly, applicable teaching tool for K-12 teachers. There are several primary concerns, first and foremost human safety; followed closely by animal welfare and life support. Safety concerns in the classroom can stem from the combination of water, electricity, moving parts, tripping hazards, and biological concerns (bacterial or fungal infections). Life support and animal welfare is where most people fail in aquaculture. There are many factors that lead into life threatening hazards for fish and aquatic species, and many of these can occur quickly. Unlike many animal species that may be alright if left in a dirty cage over a weekend, a fish's environment or tank provides them all of their life support including oxygen (fish breathe too!). The fish's gills filter everything that enters its body (good and bad), and this is where the importance of water quality measurements, filtration, equipment, and the nitrogen cycle are essential for success.

Next, horticulture is the process of growing plants for human use; this is limitless as to what plants, techniques, or environments this includes. For purposes of this workshop, we will specifically focus on growing plants in aquatic environments. Note that this course will only discuss fresh water systems; however, salt water environments are also suitable, the equipment and processes are nearly identical; salt water systems function well as part of environmental science or habitat restoration projects. Because this workshop focuses on the use of aquatic systems to grow plants, it is necessary to determine what plant types will thrive in this environment, when to plant them and how to determine when they should be harvested. Along with general plant knowledge, it is important to understand the risks involved both as a teaching professional and to students. Food safety is a huge concern if growing edible crops. Lastly, there are many gardening curricula available; therefore there is no need to write custom curricula in most cases. The final task will include identifying the sources of current curricula and how to adapt them into fitting lesson plans for your school district.

Course/ Workshop Understandings

Learners will understand that:

1. Aquaponics is a great method to incorporate biotechnology into today's classroom environment.
2. School gardens are a wonderful teaching tool for any subject area.
3. Educational curricula are available for any grade level.
4. There are regulations through FWC on certain species of fish.
5. The most important factors in successful aquaponic systems are water quality

and stocking density.

Essential Questions

1. What is aquaponics?

   Objective 1: Describe system requirements

   Objective 2: Review plants that will work well in small systems

2. What are the major concerns with water quality?

   Objective 1: Nitrogen cycle and stocking density

   Objective 2: Alkalinity, chlorine and dissolved oxygen

3. Why is fish health important?

   Objective 1: Describe normal fish behavior and signs

   Objective 2: Fish diseases

4. Why is food safety important?

   Objective 1: Important bacterial, fungal and viral infections

   Objective 2: Preventative management

5. How do I incorporate aquaponics into my classroom?

   Objective 1: Aquaculture and aquaponics curricula

   Objective 2: Agriculture and gardening curricula

Cornerstone Tasks

1. General principles of aquaculture:

Assist participants in understanding the importance of water quality; participants will measure several water samples and identify problematic parameters and their potential causes.

Participants will learn how to calculate fish stocking density for various scenarios. Individuals will learn permitting requirements for their County and which regulatory district your county is in; this will also cover USDA annual inspections.

2. Growing seasons and horticulture:

Teach participants how to select the best plants for their system, determine when vegetables will grow, how long it takes to harvest, and nutritional requirements coming from the aquaculture system. Participants will also review the water cycle and the importance of the nitrogen cycle in Aquaponics system to both the fish and plants.

Assessment and Evaluation

This workshop will use a multiple choice pre and posttest format to determine if participants have improved their knowledge base. A six month follow up survey using a Likert scale will also be conducted to evaluate the long term success of applicable knowledge of aquaponic system use in the classroom. The data collection process will be concluded on June 16, 2014. At this time, pre and posttest data will have already been tabulated and the survey data will be obtained in January 2015. From this point a quantitative analysis will be performed and the summative evaluation compiled. The evaluation will include demographic information on participants, pre and post knowledge based questionnaire answer, and then data from the follow up survey to analyze how the workshop participants implemented the materials. At the completion of the evaluation a complete cost analysis and return on investment will be available to plan for future workshops. The program evaluation will be made available in the extension office's annual report and will also be shared with stakeholders that may be interested receiving training, providing future support or providing training or materials to assist teachers in future workshops. These stakeholders will include the Florida Department of Agriculture, County School Boards and City commissioners, and corporations such as Verti-Gro, Black Cow, and Pentair.

The Aquaponics for Teaching and Demonstration training will use Stufflebeam's CIPP Evaluation Model. CIPP stands for context, input, process, and product, all of which are different types of evaluation but can be used together. One of the largest challenges to using aquaponics in a school environment are logistics, tight teaching schedules, and readymade curricula. Most teachers' look at aquaponic and hydroponic systems as expensive and complex, but there are many ways to build a system that is neither.

Next, input will be evaluated by looking at available resources. There are many available resources for startup and maintenance of any type of school garden. These can include government grants from the US Department of Agriculture or Florida Department of Agriculture and Consumer Services or other government agencies. Input can include donation of materials from Home Depot, other local hardware stores, or plant and soil companies. Lastly, there are unlimited numbers of third party companies and non-profit organizations that are happy to assist with materials, cost and often labor at schools. The only input that may not be easy to fix at specific schools is a place to put a large aquaponic system. Often, there are ways to downsize to make it more reasonable for the area available; but there are rare occasions where there is simply not an appropriate or safe space to implement an aquaponics system on school grounds.

Process is the third part of our evaluation tool. This will include how the knowledge gained at the Teacher's Guide to Aquaponics is implemented. This refers to teachers who have made improvements to existing systems at their school, teachers who have built (or attempted to build) new systems, and teachers that do not have the commitment to build a full size system but have scaled it back to allow the students design a model system similar to the activity in the workshop. This part of the evaluation will be exceptionally usefully for planning future workshops and ensuring that they fit the needs of a wide spread versatile teacher audience. If the workshop concludes and teachers do not take the processes back to their classrooms there may not be a demand for the program in the future.

The last part of Stufflebeam's model is the product evaluation. For this initial workshop, I would like to 1) evaluate the effectiveness, cost, and logistics of the aquaponics model that teachers put together in the workshop; and 2) evaluate the cost effectiveness and return on investment of the workshop as a whole. This component of the CIPP model is the equivalent of a summative evaluation and therefore will be conducted from the beginning until the end. This is an important evaluation process because it examines all of the previous variables as well as the end product. For this process to be complete, it is important to look at the needs assessment, the entire environment, the funding sources and other resources, the processes that were followed and implemented, and the finished product.

By using Stufflebeam's CIPP model, you can complete formative and summative evaluations nearly simultaneously or the formative leads to the summative evaluation. This is useful in many cases, such as this teacher workshop. It is specifically useful because there is always room for improvement, and by using a formative evaluation from the beginning of the program you can easily make the needed improvements while planning for the next step. It is always necessary to evaluate the program itself and its objectives; without this information you may be teaching the right information to the wrong audience or the wrong information to the appropriate audience. For purposes of this workshop, the primary objective is to enable teachers to design their own aquatic systems without being concerned with spending thousands of dollars, and empowering them with the basic knowledge to keep their students safe, and aquatic plants and animals alive. This may seem simple, but it only takes a few small things to go wrong and they compound into large problems equating to a major headache for an already busy teacher. This workshop is also intended to assist teacher in implementing new engineering practices to meet the Next Generation Science Standards without having to write their own curricula. The implementation of the Next Generation Science Standards is coming within the next two years to be fitted into the Common Core Standards which began this year. NGSS will be focused on STEM education, encouraging all lessons to use Science Technology Engineering and Mathematics regardless of the subject area.

The assessment and evaluation instruments are as follows:

Aquaponics for Teaching and Demonstration

Pre/ Posttest for June 16, 2014

1. What is the proper stocking density for fish in an aquaponic system?
    a. 2 fish per gallon of water
    b. 1 inch of fish per gallon of water
    c. 1 inch of fish per 2 gallons of water
    d. 30 fish per system
2. What is the first key to controlling a pest?
    a. Look for beneficial insects
    b. Spray pesticides

    c. Apply IPM methods
    d. Identify pests
3. What is the proper amount of time to wash your hands for?
    a. 20 seconds
    b. 30 seconds
    c. 1 minute
    d. 15 seconds
4. Which of the following is the best source for a safe water supply?
    a. Rain barrel
    b. Well water
    c. Pond water
    d. Public water source
5. What is the most critical component of fish health?
    a. Recognizing normal behavior
    b. Not bringing in new fish
    c. Monitoring fish tank water
    d. All of the above
6. Which water quality parameter is most deadly to fish when not correct?
    a. Ammonia
    b. Nitrite
    c. pH
    d. Alkalinity
7. What biological cycle helps the plants convert fish waste into nutrients?

a. Carbon cycle
b. Photosynthesis
c. Nitrogen cycle
d. Dissolved oxygen

8. What is the primary food safety concern with aquaponic systems?
    a. Plants are fed water that contains animal feces
    b. There are live animals in the system
    c. Water sources might not be safe
    d. Additional pests may be present
9. Why are harvesting and food processing techniques important?
    a. Temperatures must be correct before harvesting
    b. Each time the product goes through a process, it is exposed to an infection point
    c. Harvesting techniques can be harmful
    d. All products should be washed immediately after harvest
10. What subject areas can aquaponics be used to teach?
    a. Agriculture
    b. Math and science
    c. Engineering
    d. All of the above

Aquaponics for Teaching and Demonstration

Evaluation for June 16, 2014

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1. Attending training today was worth my time?					
2. Presenters were knowledgeable?					
3. Did you learn new information?					
4. Will you share this information with others?					

5. As a result of this program:
   _______ I am more knowledgeable about creating a safe environment for growing edibles at my school.
   _______ I plan to make changes to my school garden program.
   _______ I learned new techniques to incorporate hydroponics and aquaponics into my program.
   _______ I learning how to identify sick fish in my system.

6. What will you do or change as a result of this program?

7. What did you like best about this program?

8. What did you like least?

9. What other training would be helpful for you to be successful with aquaponics?

10. How many students at your school will be impacted by this training?

Comments:

Results

A total of 46 participants attended the training on June 16th, 2014. Two of the participants had aquaponics systems that were being implemented into their classroom curricula.

The participant results of the evaluation survey are listed below.

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1. Attending training today was worth my time?	**83%**	**15%**	**2%**	**0**	**0**
2. Presenters were knowledgeable?	**91%**	**9%**	**0**	**0**	**0**
3. Did you learn new information?	**85%**	**13%**	**2%**	**0**	**0**
4. Will you share this information with others?	**74%**	**11%**	**15%**	**0**	**0**

Participants answered that 91% thought they were more knowledgeable about creating a safe environment for growing edibles at my school. 93% plan to make changes to their school garden program, and 89% stated that they learned new techniques to incorporate hydroponics and aquaponics into their program. 93% also felt they learned how to identify sick fish.

The pre and post test data shows a 67% knowledge gain in water quality; 13% knowledge gain in food safety and an overall increase in knowledge of 26%.

It is evident that most of the information covered in the workshop was new information for the attendees. This provides the instructors with a challenge because of the amount of information that needs to be covered in a short period of time to assist attendees in being successful in future aquaponic endeavors. It is essential to provide the critical life support information for both aquatic species and plants for the participants to sustain a new system.

Participant evaluations show that attendees were satisfied with the content of the material as well as with the presenters. Suggestions were also made to increase hands on participation, and also hold a class to build the systems. An emphasis was placed on modeling systems in this training environment due to restrictions on time and space, but it is evident that participants would be interested in attending future advanced training sessions.

Conclusions

In conclusion, Aquaponics for Teaching and Demonstration provides useful strategies to implement aquaponic systems that are inexpensive to build and require only basic knowledge of aquaculture and horticulture to successfully grow plants and aquatic species. Teachers and homeowners frequently spend large amounts of money on systems that are not designed for small spaces and require large amounts of maintenance and care. The content taught through this training provides background knowledge to successfully establish and maintain a new aquaria-ponic or barrel-ponic system in a classroom or backyard environment. Knowledge of adequate water quality parameters, basic fish health and stocking densities will also initiate success when building a new aquaponic system. Food safety (proper hand washing, harvesting, and processing techniques) is essential for any successful school garden, but especially when working with live animals. Prevention and risk mitigation is the key to any hazard or safety risk, food safety is no different. It is important for educators, students and volunteers to have a positive experience and success when establishing a new system to create a positive learning environment and provide motivation to continue sustaining the aquaponic system. Adults and youth exposed to environmental education activities are more likely to adopt environmentally-friendly landscape practices and have greater appreciation and awareness for local food systems.

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Appendix

Aquaponics for Teaching and Demonstration

Many teachers do not feel that they have the time, space, or expertise to have an aquaponics system in their classroom. However, the truth is it does not have to be a large system to create an excellent learning opportunity.

An aquaponics system can be used for many youth science experiments in the classroom and can be built from materials that you may already have laying around.

This free class will teach the basics of setting up a tank and how to incorporate it into your current lesson plans.

June 16th, 2014, 1 to 4 p.m.

Duval County Extension Office
1010 N McDuff Avenue

Jacksonville, FL 32254

Register via email: maxine32666@ufl.edu

Aquaponics for Demonstration and Teaching Agenda

Duval County Extension Office

1010 N McDuff Ave Jacksonville, FL 32254

June 16, 2014 1-4PM

1:00 p.m. Introduction to Aquaponics

1:30 p.m. Aquaponic System Design

2:00 p.m. Introduction to Fish Health

2:30 p.m. Break

2:45 p.m. Water Quality

3:15 p.m. Food Safety in Aquaponic Gardening

3:45 p.m. Available Classroom Curricula

4:00 p.m. Closing Remarks and Questions

Power Point Presentation:

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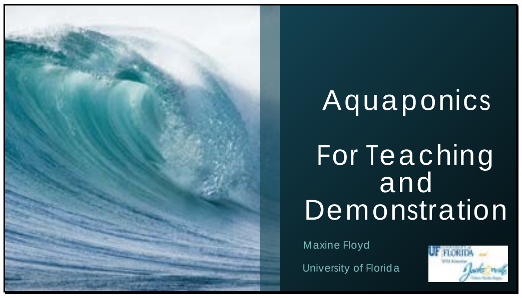

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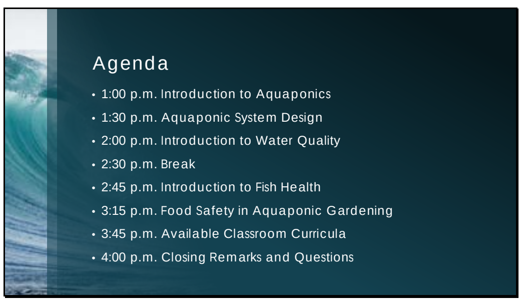

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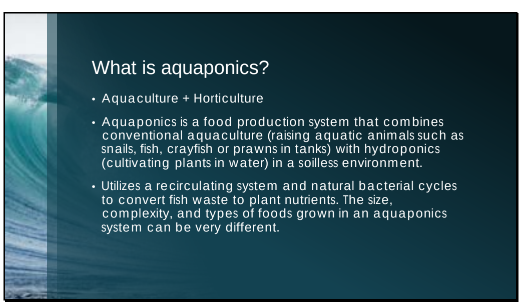

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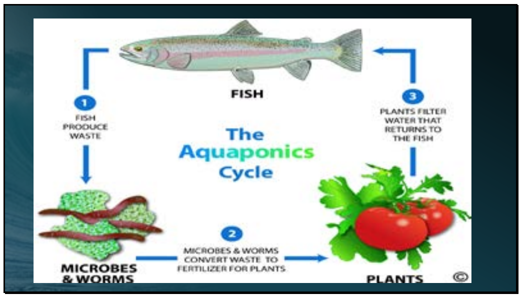

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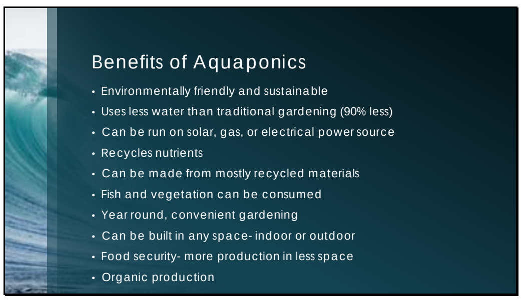

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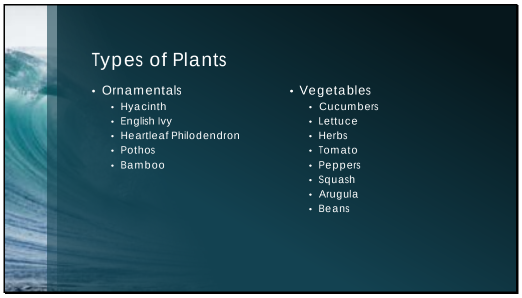

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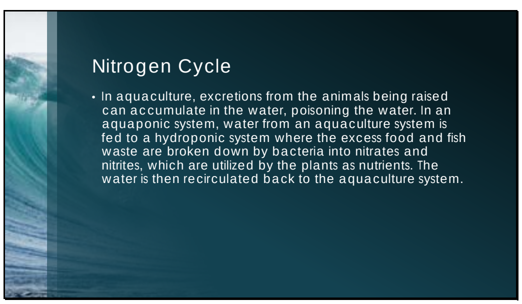

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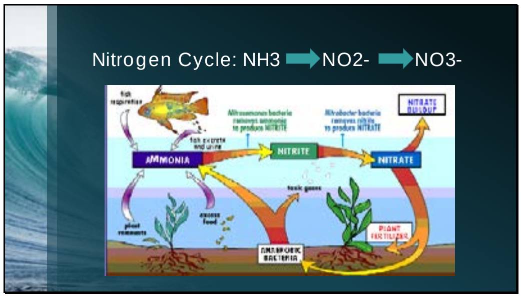

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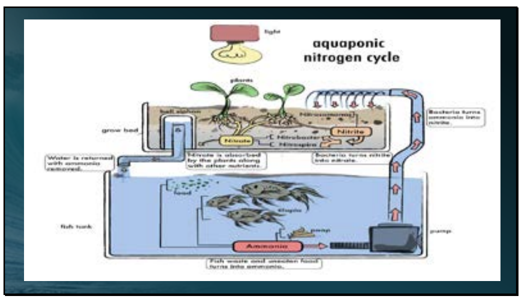

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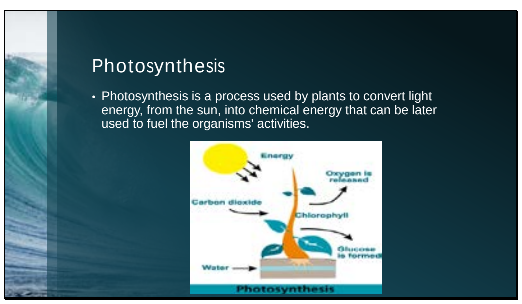

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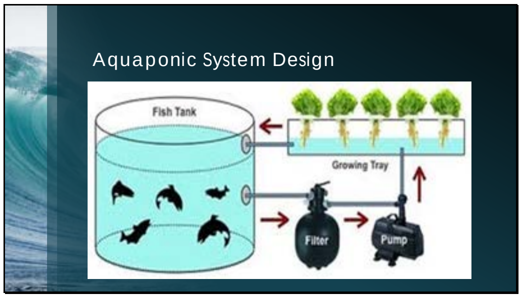

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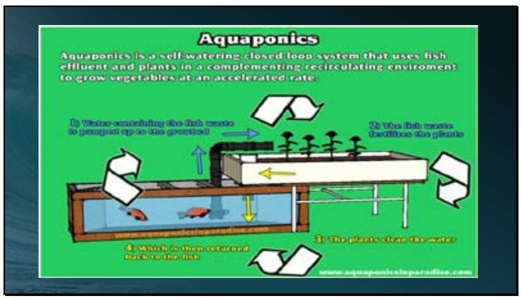

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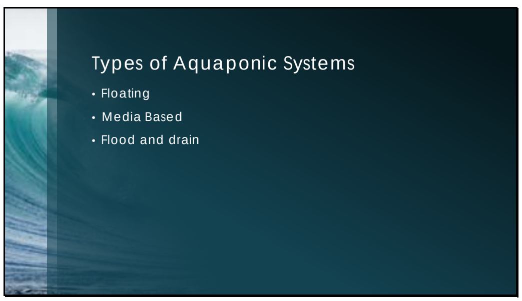

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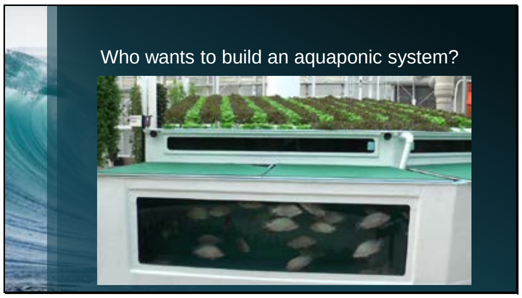

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References:

- Bernstein, S. (2011). *Aquaponic Gardening: A Step-by-step Guide to Raising Vegetables and Fish Together*. New Society Publishers.
- Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006). Recirculating aquaculture tank production systems: aquaponics—integrating fish and plant culture. *SRAC Publication*, *454*, 1-16.
- Veludo, M., Hughes, A., & Le Blan, B. Introduction to Aquaponics: A Key to Sustainable Food Production.
- Yamamoto, J., & Brock, A. A Comparison of the Effectiveness of Aquaponic Gardening to Traditional Gardening Growth Method.
- http://www.aces.edu/dept/fisheries/education/documents/barrel-ponics.pdf

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UNIVERSITY OF FLORIDA IFAS EXTENSION

Introduction to Water Quality: *Fish vs Plants*

Ruth Francis-Floyd, DVM, MS, DACZM
University of Florida

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"Normal Parameters" for Fish Culture

	Fresh Water	Salt Water
Dissolved Oxygen:	saturation (Pond: > 5 mg/L)	saturation
Carbon Dioxide:	<20 mg/L	< 20 mg/L
pH:	6.5 – 9.0	7.8 – 8.3
Total Ammonia Nitrogen:	< 1 mg/L	< 0.5 mg/L
Unionized Ammonia Nitrogen:	< 0.05 mg/L	<0.05 mg/L
Nitrite:	0 mg/L	0 mg/L
Nitrate:	< 20 mg/L	< 50 mg/L
Total Alkalinity:	> 100 mg/L	> 250 mg/L
Total Hardness:	> 20 mg/L	> 250 mg/L

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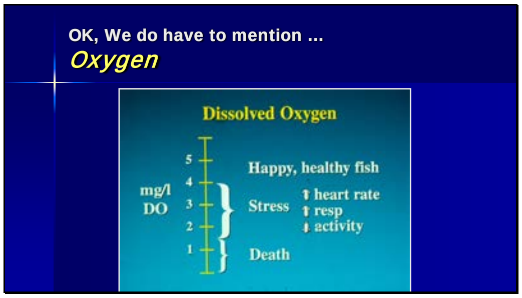

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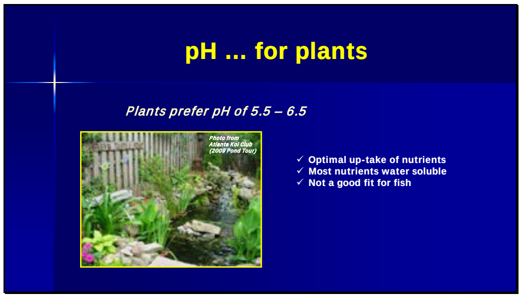

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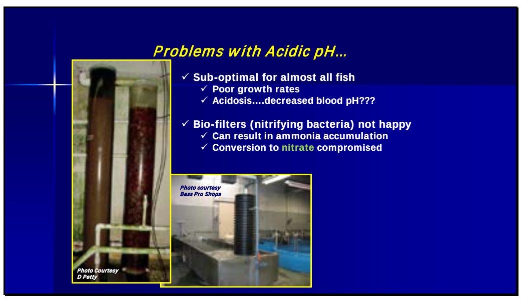

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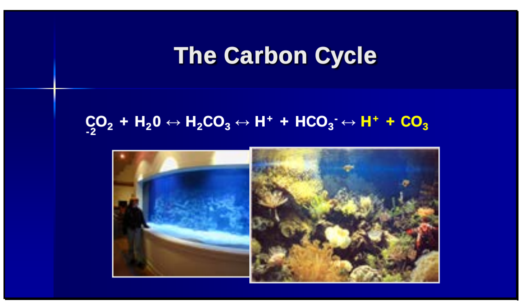

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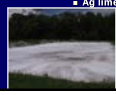
Total Alkalinity

- Total Alkalinity
  - Measures carbonate
  - Indicative of buffering capacity
  - ≥ 100 mg/L desirable in most systems
  - To increase TA add
    - Baking soda ($Na_2(CO_3)_2$)
    - Dolomite
    - Ag limestone

✓ Alkalinity is required for biofilter!

✓ Buffers acids produced by all this biology!

✓ Probably worthy of consideration for aquaponic mangement



NEVER USE LIME (CaO)!!!

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Total Hardness

- Measure of divalent cations (Ca, Mg etc)
- Typically of greater importance in hatcheries.
- As long as minimal amount of minerals present (>20 mg/L), should be minimal concern for aquaponics systems.
- To increase
  - Dolomite ($Ca(CO_3)_2$ and Mg $(CO_3)_2$
  - Ag limestone ($Ca(CO_3)_2$
- To decrease
  - Reverse osmosis, use of distilled water, etc.

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The Nitrogen Cycle

- Thanks to http://www.pondenterprises.com/filter/nitrogen.html for the picture.

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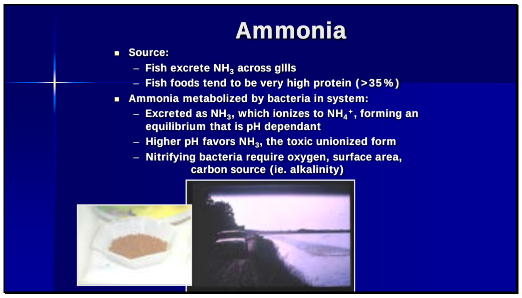

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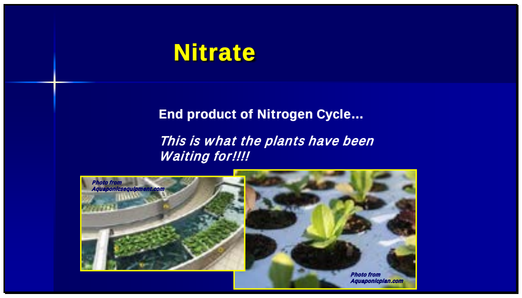

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Toxins in City Water….

- **Chlorine**
  - Highly toxic to fish
    - 0.02 mg/L clinical disease
    - 0.04 mg/L lethal
  - Sublethal exposure common
    - Signs include excess mucus, flashing, agitation and chronic mortalities
- **Chloramine**
  - Ammonia used to stabilize chlorine molecule
  - Dechlorination can result in significant levels of ammonia being released

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Sublethal Chlorine Toxicity

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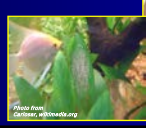
Let's Talk About the Fish….

Target Species for Aquaponic Production:

Channel Catfish
Tilapia
Koi
Other????



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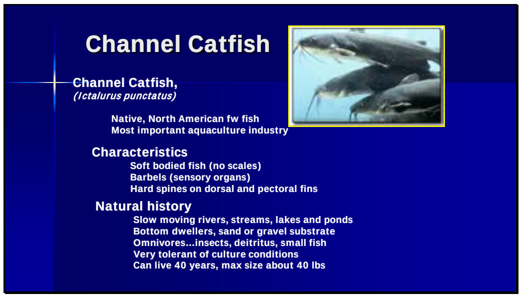

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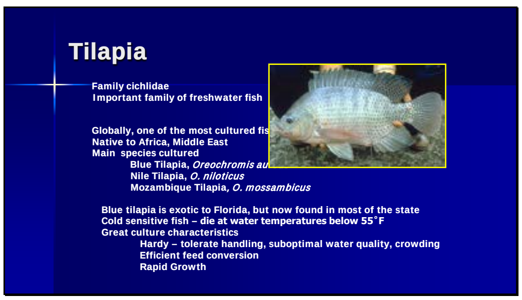

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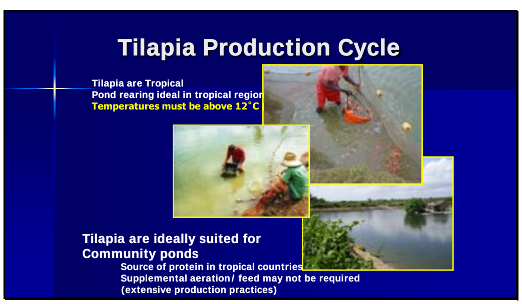

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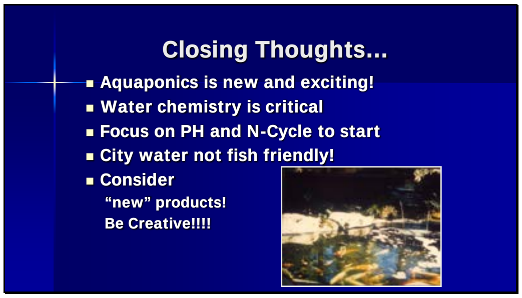

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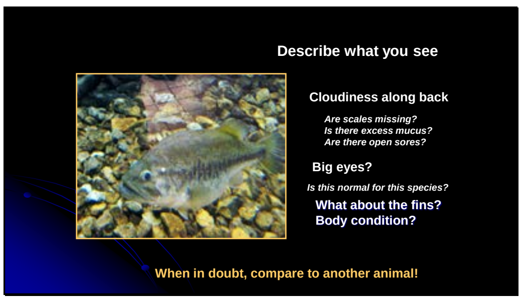

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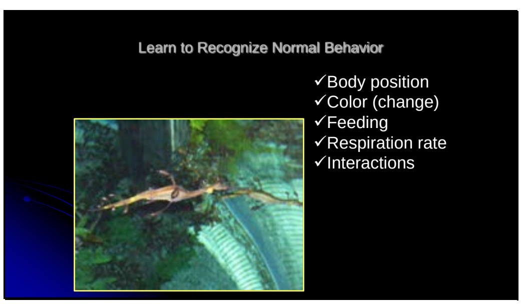

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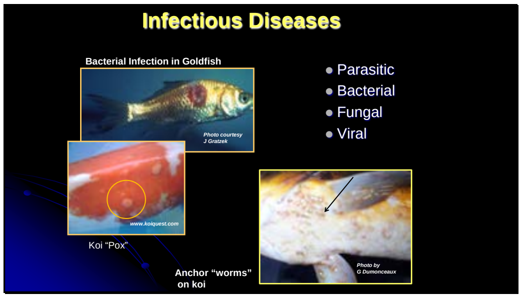

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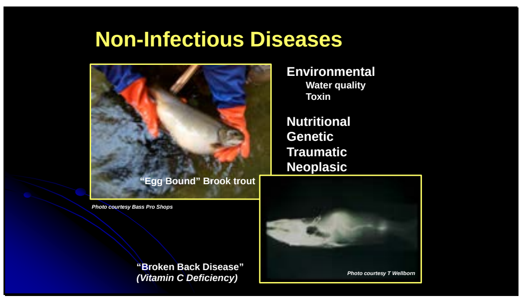

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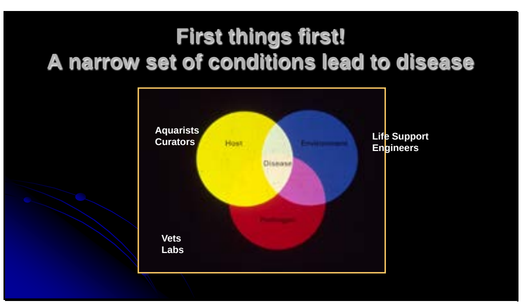

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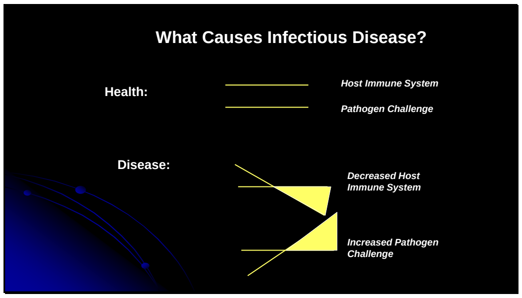

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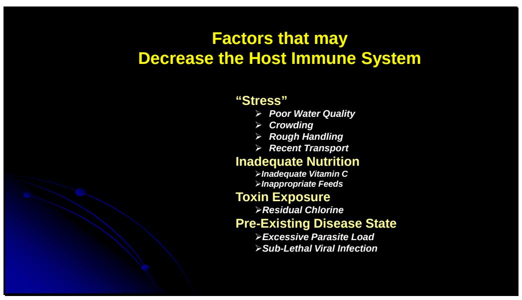

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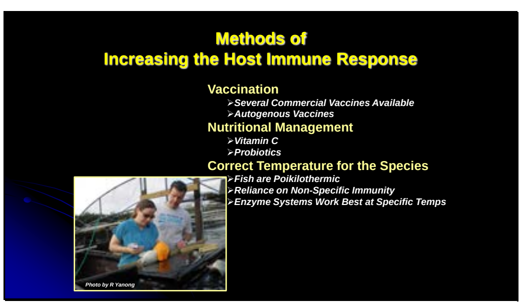

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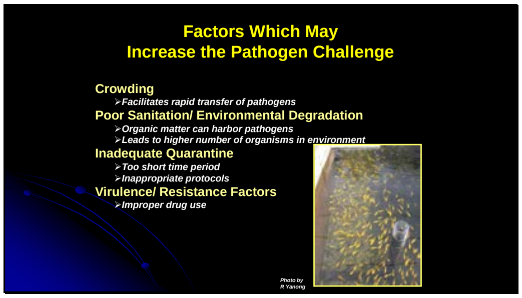

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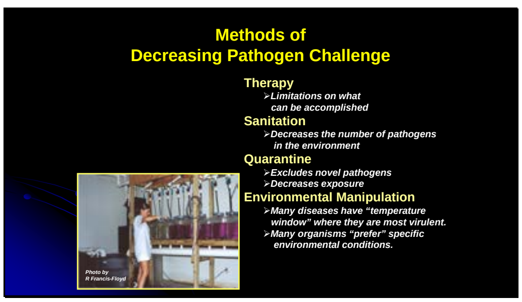

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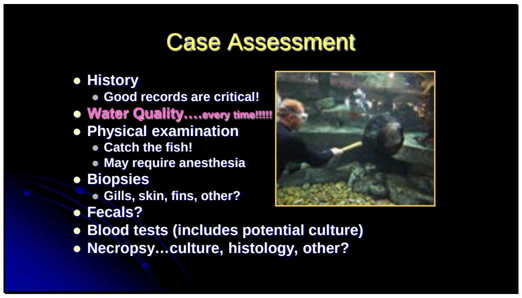

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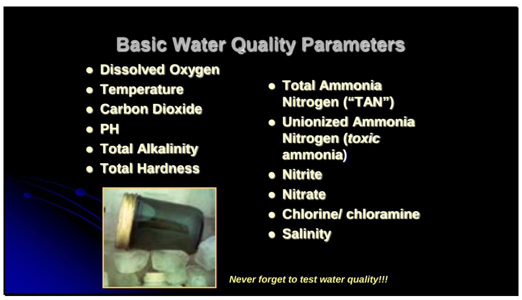

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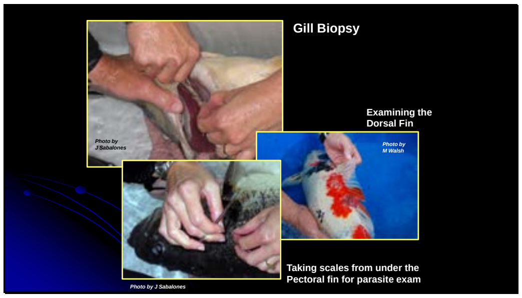

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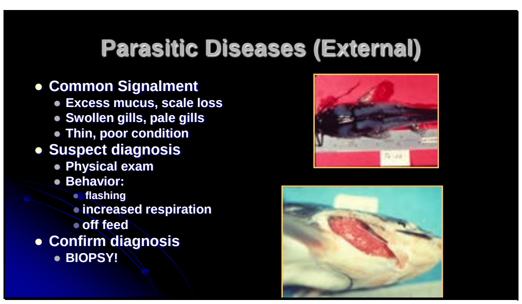

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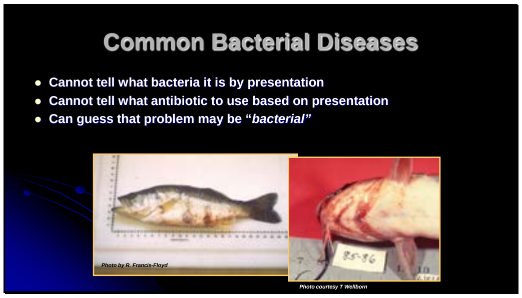

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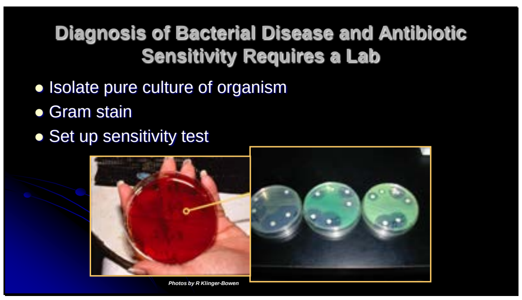

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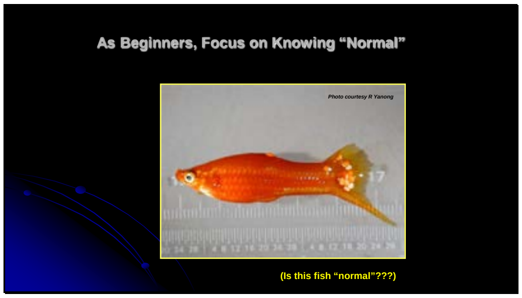

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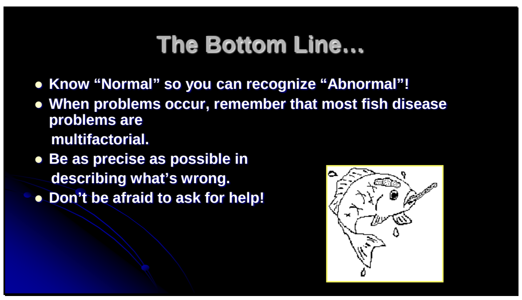

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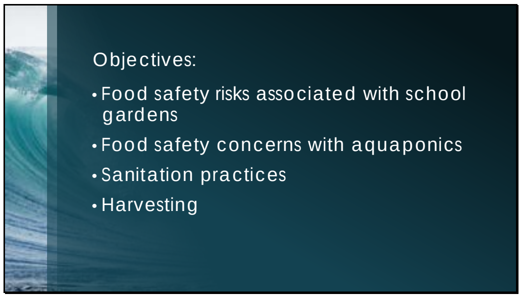

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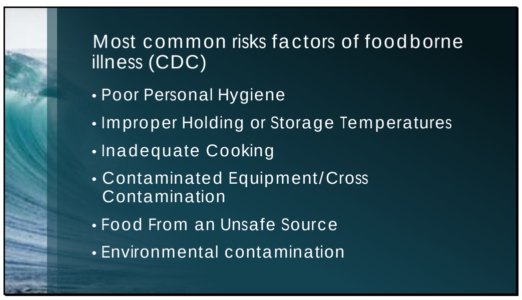

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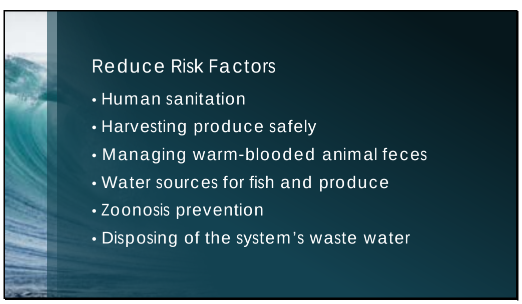

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Human sanitation

- Before and After Anything you Touch
- Wash hands for 20 seconds

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Handling produce

GOOD

BAD

UH-CTAHR On-Farm Food Safety: Aquaponics, July 2009

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References

- On Farm Food Safety: Aquaponics http://www.ctahr.hawaii.edu/oc/freepubs/pdf/FST-38.pdf
- Chalmers, G. A. (2004). "Aquaponics and Food Safety ". *Lethbridge, Alberta April.* http://www.fastonline.org/images/manuals/Aquaculture/Aquaponic_Information/Aquaponics_and_Food_Safety.pdf

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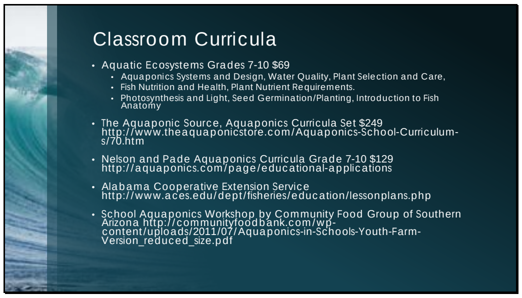

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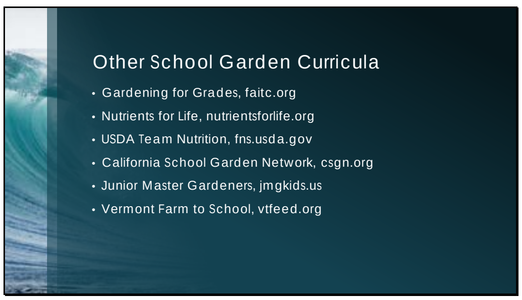

Workshop Handouts:

Aquariaponics materials list:	Cost:
10 Gallon Aquarium (or larger)	$10-50
Fish or Invertebrates: 1-2 inches of fish per gallon of water	Variable
Hydroponic Pump	$10-25
Aerator	$10
Air Stones	$4
Soil- less media: i.e. River rock or clay pebbles	$5
Container for soil-less media	$5
2 foot of ¾ inch PVC	$3
3 foot of vinyl tubing	$2
Fresh Non Chlorinated Water	Variable
Total Cost:	

Barrel-ponics materials list:	Cost:
3- 35 or 55 Gallon Drums	Free - $30 Each
Fish or Invertebrates: 1-2 inches of fish per gallon of water	Variable
Hydroponic Pump	$10-25
Aerator	$10
Air Stones	$4
Soil- less media: i.e. River rock or clay pebbles	$5
4 foot of ¾ inch PVC	$4
2.5 foot 2" PVC	$3
3- 2" Male adapters	
3- 2" Female adapters	
1- ½" - ¾" Male adapters	
1- ¾" Male adapter	
1- ¾" Female adapter	

1- 2” Elbow

Fresh Non Chlorinated Water

Total Cost:

Building materials equipment needed:

Drill

1” Paddle Drill Bit

2 1/4 ” Hole saw Drill Bit

Caulking gun with Silicone

Access to power

Suggested Classroom Activities:

Aqauponics Vocabulary Matching Game:

Instructions: Each student or pair of students is handed either a term or its definition. The students then find the person who has the match to each given term.

HABITAT	**Area where a particular species of plant, animal, or other organism lives.**
SOLUBLE	**Capable of being dissolved in some solvent (usually water).**
AQUACULTURE	**Raising aquatic animals or cultivating aquatic plants for food.**
FOOD SYSTEM	**Includes all processes involved in feeding a population.**
NUTRIENT	**Any substance that can be metabolized by an animal to give energy and build tissue.**
SUSTAINABLE	**Able to be maintained or upheld. This is how biological systems continue to exist and remain diverse and productive.**
MICROORGANISM	**A single or multi- celled that is microscopic.**

BACTERIA	**Microscopic living organisms, usually one-celled, that can be found everywhere. They can be dangerous when they cause infection, or beneficial, as in the process of decomposition.**
DECOMPOSE	**To break down, decay or remove.**
HYDROPONICS	**Method of growing plants without soil.**

<u>Water Quality Assessment Worksheet</u>

Group # ___________

Date: _____________

Names of group members:

____

____

Sample #_________

1. Temperature___________________
2. Dissolved oxygen_______________
3. pH___________________________
4. Alkalinity_____________________
5. Total Ammonia Nitrogen_________
6. Total Hardness_________________
7. Chlorine ______________________
8. Water clarity___________________

Sample #_________

1. Temperature___________________
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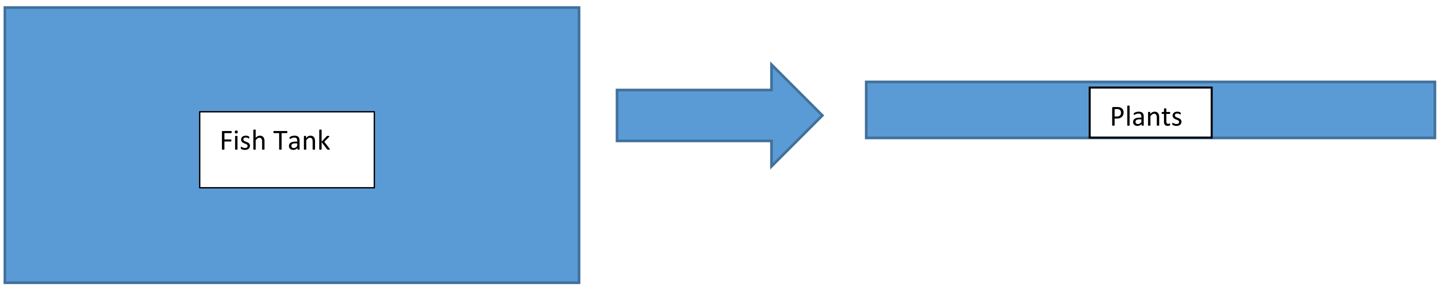
8. Water clarity___________________

<u>Design Your Own Aquaponic System Activity</u>

Group # ___________

Names of group members____

Note: This activity can also be modeled using Styrofoam cups, tooth picks and goldfish crackers.



1. Draw your own system on the back of this page. Use arrows to show how will pipe or direct the water from the fish tank to the plants and back. Label all parts and equipment you choose to use.

2. What size fish tank did you choose?

3. What size pump should you use? Gallons per hour?

4. Is aeration necessary, if so where did you add air?

5. Did you use gravity to move the water from one point to another?

6. Did you choose to use solar power or other sources of energy to power your pump?

7. Will you flood your plant beds or have continuous flow through?

Aquaponics in Your Classroom Pre and Posttest

1. What is the volume of your aquaculture tank? Grow bed?
    a. ____
    b. ____
2. What website should you go to find fish regulations for your County?

    ____

3. List three crucial parts to an aquaculture system.

____

4. What is the best average pH for an aquaponics system? _____________________________
5. Circle three daily/ weekly fish health requirements.

Feeding	Water changes	Water quality testing
Change filters	Scrub tanks	Count fish

6. List three potential hazards for students working around aquaculture systems.
    a. ____
    b. ____
    c. ____
7. Circle best crops for aquaponics.

Kale	Lettuce	Basil	Chives	Tomato
Tangerines	Cucumbers	Celery	Peas	Parsley

8. What is more dangerous to fish ammonia, nitrite or nitrate? __________________________
9. List three food safety concerns.
    a. ____
    b. ____
    c. ____
10. What is a beneficial insect?
    ____

Additional Curricula:

Alabama Cooperative Extension Service

http://www.aces.edu/dept/fisheries/education/lessonplans.php

Aquatic Ecosystems Grades 7-10, $69. www.aquaticeco.com.

Brooks, Meredith. (2010). Aqua Curricula. Center for Tropical and Subtropical Aquaculture.

http://pacificaqua.org/a-q-u-a-youth/curriculum/

Nelson and Pade Aquaponics Curricula Grade 7-10 $129.

http://aquaponics.com/page/educational-applications

School Aquaponics Workshop by Community Food Group of Southern Arizona

http://communityfoodbank.com/wp-content/uploads/2011/07/Aquaponics-in-Schools-Youth-Farm-Version_reduced_size.pdf

The Aquaponic Source, Aquaponics Curricula Set $249.

http://www.theaquaponicstore.com/Aquaponics-School-Curriculum-s/70.htm

University of Florida Teach Aquaculture. http://irrec.ifas.ufl.edu/teachaquaculture/

Sample Lesson Plan from Stonehurst Elementary:

Lesson: Build your own Aquaponics Garden
Marissa Blanco- Johnson, Liam Conner, Hazel Krane, Kylie Rostad, Tallulah Shepherd, Wildon Uyeda
Grades: K - 2
Subject area: Ecology
Time required: 30 minutes per class
State Curriculum Standards:
Kindergarten
Life Sciences
2. Different types of plants and animals inhabit the earth. As a basis for understanding this concept:
c. Students know how to identify major structures of common plants and animals (e.g. stems, leaves, roots, arms, wings, legs).
Investigation and Experimentation
4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
a. Observe common objects by using the five senses.
b. Describe the properties of common objects.

First Grade
Life Sciences
2. Plants and animals meet their needs in different ways. As a basis for understanding this concept:
a. Students know different plants and animals inhabit various kinds of environments and have external features that help them thrive in different kinds of places.
b. Students know both plants and animals need water, animals need food, and plants need light.
c. Students know animals eat plants or other animals for food and may also use plants or even other animals for shelter and nesting.
e. Students know roots are associated with the intake of water and soil nutrients and green leaves are associated with making food from sunlight.

Second Grade
Life Sciences
2. Plants and animals have predictable life cycles. As a basis for understanding this concept:
e. Students know light, gravity, touch, or environmental stress can affect the germination, growth, and development of plants.
Earth Sciences
3. Earth is made of materials that have distinct properties and provide resources for human activities. As a basis for understanding this concept:
e. Students know rock, water, plants, and soil provide many resources, including food, fuel, and building materials, that humans use.

Content:

Students will be taught about the newly constructed aquaponics garden in their greenhouse by creating a small, take home system, that the students can keep. As they construct their scaled system, they will be taught about the integral components of aquaponics, and how each part sustains the plants and the fish. To conclude, they will then apply the knowledge acquired through a tour of their large scale greenhouse aquaponic system.

Prerequisites:

Students must have basic knowledge concerning living things (fish need water and food to live), be capable of following directions given to them by an authoritative source, and basic health and safety knowledge concerning glass tanks and live animals. They must understand that all organisms have requirements for life and produce waste products.

Background:

Aquaponics is the combination of conventional hydroponics and aquaculture in a new way. Hydroponics is a method of growing plants in nutrient rich water, without soil in an enclosed area. Fish farming, or aquaculture is the farming of aquatic organisms i.e. fish. Aquaponics is a sustainable system that combines both methods, by filtering the water between plants and fish continuously. Aquaponics was created to combat the issues and complications of conventional fish farming. Problems such as: the used harmful chemicals and pesticides to control the health of the fish, waste released into the surrounding environments, and uncontrollable nitrates. Combining it with hydroponics solves these problems by creating a healthier environment for the fish to live in, due to the nutrients released by the plants, and it becomes completely sustainable. The waste is cycled between the fish and the plants, creating a symbiotic relationship, leaving few additional pollutants. The plants will take in carbon dioxide and release oxygen, which will combat the ammonia released by the fish waste in a process called nitrification. The modern developments of aquaponics is generally attributed to the works of the New Alchemy Institute and Dr. Mark McMurty of North Carolina State University, but information and papers about the topic have been found from nearly a decade before. These papers lead other people, such as Tom and Paula Speraneo, to create their own aquaponics greenhouses, and make their own adjustments to edit the theory. In 1997, the Aquaponics Journal publication was initiated by John S. Pade and Rebecca L. Nelson, in order to bring together research and application from people around the world.

Objective:

1. Students will understand the components of an aquaponics system, and how they function together.
2. Students will understand the differences between oxygen and carbon dioxide and understand the basic principles of photosynthesis and respiration.
3. Students will understand the basics of plant and fish life, including waste products and needs.
4. Students will obtain the ability to secure and maintain a healthy aquaponics system in their own homes, and will be part of the team taking care of the larger scale system at school.

Materials (per student):

• Clear plastic bottles (2 liter, with tops cut off)
• Gravel (1 handful)
• Chlorine free water
• Fish (Minnows, Goldfish)
• One vine of Pothos containing at least 4 leaves.

Preparation:

Three stations must be set up, on separate tables. One with gravel of various colors, one with purified water and fish, and the last with plants, fish food, and fish care guides. The tanks must be clean and healthy, any damaged plants or fish removed before the laboratory is begun. Some of the plants must be on a bucket on the table, so as to be visible to the students, and the rest must be in a box underneath the table, so they will stay healthy and ready for use. The bottles, given that they will be used to carry the fish and plants the students will take home, must be washed out thoroughly, so no contaminating traces can remain. The gravel must be rinsed through again, to get rid of any dirt, or unhealthy bacteria, or waste.

Procedure:

Step 1: To set up for our lesson, we arrived at the school thirty minutes early, to check in with the offices, and to alert the teachers that we would be starting soon. We had to set up and clean off tables, to make the environment safe for children. {One station for gravel, one for water and fish, and one for plants, fish food, and care guides}

Step 2: We set up a station for our teacher to cut the tops from the plastic bottles the students would be using for their habitats. The first presenter placed the freshly rinsed gravel in separate plastic cases, to make it easier for the class to reach. The second presenter filled a large crate with water from a tap, and released two tablespoons of water purifier into the mixture. After waiting for it to be safe, and checking the respective temperatures of the waters, we released the fish into the crate, and cleaned the nets to be ready for use. The third presenter filled one bucket with plants, and placed it on the table, to be more visible, and placed the rest under the table to protect it from the sun. The presenter then went on to cut out damaged or unhealthy leaves from the plants, before the students arrived. A presenter was also sent to check on the greenhouse, to make sure it was safe and ready for students.

Step 3: We began the lesson by introducing ourselves, and our teacher explained to the students what QuikSCience was, and what we were planning to teach them. Then each respective presenter went by explaining and asking the students questions about their own sections. The included questions were such as ‘Do plants breathe?’ and ‘What are the waste products of fish?’

Step 4: We continued to ask questions while our teacher cut the tops from their bottles, and the students began to set up their habitats.

Step 5: At the first station, a student would have to answer a question correctly in order to collect their gravel for their habitat. Questions such as, ‘Why do we need gravel in the system?’ The question would have to be answered correctly before the student could proceed to the next station.

Step 6: They would then continue to the next station, where they would answer a question asked to them by the second presenter, before they would fill their bottles up with the purified water. Questions such as ‘Do fish breathe?’ and ‘What are some of the fish’s waste products?’ They would then take a net, and pick out a fish they wanted, with help from the presenter. The presenter then would transfer the fish from the crate, into their bottle, and the students would be allowed to continue to the next station.

Step 7: At the next station, they would answer questions such as ‘Do plants breathe?’ and ‘What is the element plants let out, and what’s the compound they breathe in?’ They would each receive four plant leaves to place in their bottle and pick up a package of fish food and a care guide.

Step 8: They would then continue to the greenhouse, in which they would take a tour, and wait for the rest of their class to be finished. They would then briefly go over proper care for their plants and fish, before going back to class.

Step 9: Clean up included giving several example systems away to the office, and recycling any extra bottles at the school's recycling bins. We placed the fish back into their small tank, and put the remaining gravel and plants into a box, and left any extra fish food with the class teachers.

Evaluation:

To determine if our lesson was successful, and to see if the students were paying attention, at each station, the students would answer a question about the lecture, and if they got it right, they are allowed to get their materials, and proceed to the next section. The presenter handing out fish would ask questions pertaining to fish and their functions, and so on. The final check was a tour of their own aquaponics greenhouse, and their teachers will be checking up on the students to see if they have been able to retain enough information to successfully continuously take care of the fish.

Follow-Up Activities:

The follow-up activities will be taking their aquaponics systems home, transferring them into a more permanent habitat, and maintaining the health to keep the fishes alive and functioning for as long as possible.

Lesson Outline:

I. Asks students to choose an aquatic problem and come up with a solution.
II. Our Plan
A) Our Problem: Aquaculture
1) Also known as fish farming.
2) Fish farming can be good.
a) They don't take fish from the wild.
b) Forms are cheaper and easier to maintain than commercial ocean fishing operations.
3) But they can also be bad.
a) Greater need for pesticides or other harmful chemicals.
b) If a fish accidentally gets loose, it will be in competition with native species for food and space.
c) Produces a high quantity of waste, and no natural ways to use or get rid of it.
d) Has no way of dealing with the ammonia released from the fish, which poisons the water.
B) Our Solution: Aquaponics
1) Aquaponics is a system combining conventional hydroponics and aquaculture
a) Hydroponics means cultivating plants in nutrient rich water
b) Aquaculture is fish farming.
2) Pros:
a) The waste produced by one is used by the other, creating a mutually beneficial or symbiotic relationship.
b) You can raise both plants and fish simultaneously
c) It's healthier for the environment, and creates a healthier cycle within the systems.
d) The oxygen released by the plants combats the nitrates (Ammonia) and stops the tank and food from being poisoned.
e) Much less chemical waste.
3) Cons:
a) More expensive than conventional fish farming.
b) Harder to maintain on a large scale.
c) Diseases will spread more easily due to the continuous water cycling between the plants and the fish.

III. Building the systems
A) Habitat
1) A habitat is a place for the plants and fish to live and grow.
2) We will be using a clear plastic bottle, so light can be let into the system.
3) Remove the lid of the bottle, and cut it open. Keep the top to the side.
4) Why is it important?
1) Provides light and a place to live.
B) Gravel
1) Used to stabilize the bottle, ground the plants, and retain the good bacteria.
2) Students must take one handful of gravel of their own color choice for their bottle.
3) Why is it important?
1) Good bacteria that lives on the gravel will turn waste into fertilizer for the plants.
C) Water
1) All living things need water to live.
2) Make sure the water is chlorine free because chlorine will kill the fish.
3) Why is it important?
a) *Everything* needs water to live.
D) Fish
1) Students must take one fish.
2) Why do we need fish?
a) In a larger scale system, the fish raised can be eaten.
b) They complete the relationship, and will create a healthy tank.
c) They can be ornamental due to their color.
2) Do fish breathe?
a) Yes. They don't breathe air, they breathe oxygen from the water through a process called respiration.
b) When they exhale they produce carbon dioxide, which is then absorbed by the plants.
3) Waste.
a) Chemicals inside their waste (ammonia) will poison the fish, unless it is filtered out.
b) The fish takes oxygen out of the water, and puts waste and carbon dioxide into it.
4) Why is it important?
a) It maintains the balance of the tank.
b) They will be kept as pets.
E) Plant
1) The plants we will be using are called Pothos.
2) Turn the top of the bottle upside down and place it inside of your bottle.
3) Pick four leaves of the plant, and let them sit inside the hole at the top, making sure the bottom of the roots touch the water.
4) About the plant:
a) Plants are alive.
b) What do they need to live?
i) Light.
ii) Water.
iii) Fertilizer, which they will get from the fish waste, and bacteria in the gravel.
iv) Carbon Dioxide, which the fish release.
c) The process of absorbing carbon dioxide and releasing oxygen is called photosynthesis.

5) Why is it important?
a) To clean the water for the fish.
IV. Taking care of your miniature ecosystem
A) When the students take the structure home, they should transfer the fish and plants into a larger glass vessel as soon as possible.
B) Keep the aquaponics garden inside the house next to a window, so the plant can be exposed to a normal light cycle.
C) Feed the fish 1-2 flakes of food a day.
a) If a student forgets to feed a fish, the fish can also eat plant roots, so do not overfeed the day after missing a feed. This can cause disease or even death for the fish.
D) Add water that is chlorine free. You can either:
a) Buy chlorine free water.
b) Use a filter to clean tap water.
c) Use dechlorinating drops sold at the pet store.
d) Just leave tap water out for 24 hours, the exposure makes the chlorine evaporate into the surrounding environment.
V. Learn more by visiting the QuikScience website or http://teamaquaponics.webstarts.com for information about the project.