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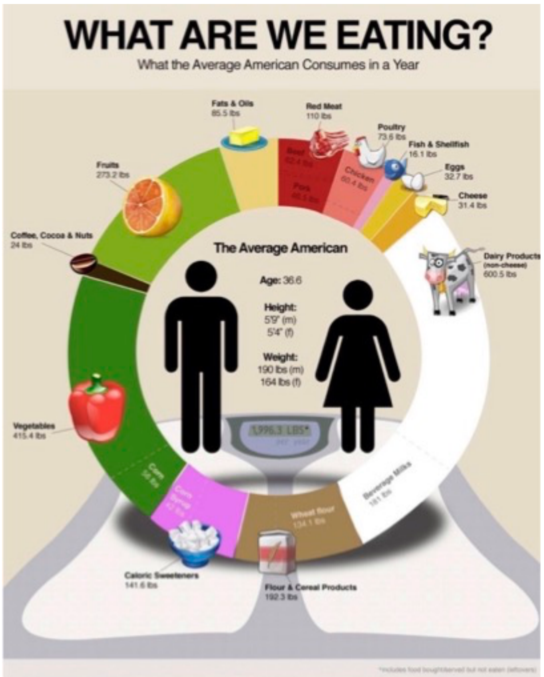
A Quick Operational Guide to Managing your NxT Aquaponics System in the Phoenix Backyard Garden Program

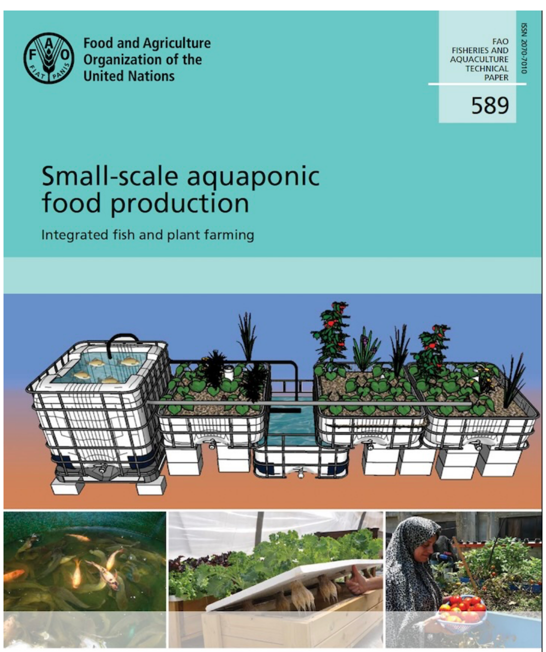


How to use this guide:

Integrated aquaculture (fish farming/agriculture) is an ancient technique for food production that keeps getting reinvented over and over again because it simply works. Credit for one recent application of this technology called Aquaponics that was developed in the late 1980's, is largely given to Dr. James Rakocy from the University of the Virgin Islands.

According to the USDA, the average American eats about 2,000 pounds of food annually (see graphic to the left). Given the right amount of time, expertise, good weather and equipment, nearly 40 percent (800) lbs., of that food could be produced in an average Phoenix backyard. A summary of standard operational procedures, the mission of this document is to help you and your family reach that goal using aquaponics.

Aquaponics can be complex:



Of the methods for growing food in a Phoenix Az. backyard, aquaponics is likely the most complex. But it can produce a wide variety of fruits, vegetables, freshwater fish and crustaceans year-round. Some of the processes can be a wee bit technical. For example, basic fish culture and plant nutrient deficiency management. To help, links are provided to detailed references that will aid in your understanding.

To begin, we suggest you download the document linked below. ("Small scale aquaponics food production" from the United Nations Food and Agriculture Organization.) This and related information will help you on your journey to productive aquaponics.

http://nxthorizon.com/PDF/SmallscaleaquaponicfoodproductionFAO.pdf

Pt. 1. Aquaponics: What is it and how does it work?

There are many definitions for aquaponics. The definition we will use here is "The farming and husbandry of plants and aquatic animals."

1.1. Aquaponics in the Phoenix Backyard Garden Program

First. The aquaponic systems you have been provided are not designed for commercial uses. Commercial systems have a very different design. Though similar to commercial Vertical Farms, the method used here is intended to work within the rules and regulations that govern farmers markets and back yards. It is called Cottage Law and you can find something about it at the link below.

https://www.maricopa.gov/DocumentCenter/View/93212/Cottage-food-FAQ_5-1-24

The goal is to grow enough food to feed a family in a small Phoenix Arizona backyard using low cost easy to find materials. The last time this was done successfully on a large scale were the War Gardens of World War 1 later called Victory Gardens during World War II. A small Victory Garden required an about of 400 ft^2 of land, a plot size too large for the normal Phoenix back yard.

1.2 Parts of your Aquaponics system:

The photo below is the standard NxT Horizon aquaponics system used within the Backyard Garden Program. To allow for easy and low-cost repair, the aquaponics system (farm) is specially constructed of low-cost materials available from many big box hardware stores or online.

1.2.1 Deep Water Culture

This method of aquaponics is called Deep Water Culture (DWC). There are many different ways to do this. This particular method was developed by NxT around 2012 and published in Brooks 2017. The design is very DIY (do it yourself) making it easy to repair. (http://nxthorizon.com/PDF/design1.pdf).

For ease in construction and low cost, the farm uses a 5 x 8-foot splash pool covered by a **fish safe plastic liner.** This creates a body of water where food plants float on **rafts** (see photo) with their roots extending down into the pool. The plant roots and the clarifier are where most of the microorganisms are found that convert the fish waste to plant nutrients. The fish tanks are made from **two readily available trash cans** made from **food safe High-density polyethylene (HDPE) plastic**. Water circulation is created through the use of Air Lift Pumps powered by compressed air. The **clarifier** is a simple device that collects the solid waste from the fish for later use.

30% and 70% shade screens (depending on time of year) are supported by a trellis structure and work to protect the plants from excess sunlight during Phoenix's increasingly hot summers. The level of the screen may be changed to adjust for time of year or any changes in the local environment. The trellis also provides structure where a wide variety of vining plants can grow. Finally, plants on the rafts and the fish in the enclosed internal tanks facilitates growth and harvesting and makes everything easier to manage. The following pages provide basic instructions on what must be done every day to keep things working. Basic care needs to be done daily and takes about ½ hour once you get good at it.

1.2.2 What kind of plants and fish can be grown in Phoenix?

Below is an abridged list of plants and animals that have been successfully grown in Phoenix with this particular type of aquaponics system:

Asian greens: Bok Choy, Joi Choi, Tokyo Bekana, Hon Tsai Tai, Komatsuna. (Medium to large in size)

American Greens: Collards, Mustard, Broccoli, Cauliflower, Red Mustard, Purple Kale. (Medium to large in size)

Tomatoes: Cherry, Grape, Boutique Cherry, Best Boy, Sweet 100s, Yellow Pear. (Very large plants)

Peas and Beans: Black Eyed Peas, Yard Long Beans, Lima, Pima Lima, Purple, Green Snap, Tepary Brown & White). (Medium sized plants).

Flowers: Nasturtium, Giant Zinnias, Celosia, Petunia, Marigold, Gazania, Cosmos, Lisianthus, Giant sunflower. Nasturtiums. (Most small to medium sized plants.)

Lettuce: Garden mix, Butter Crunch, Red Sails, Red Oak Leaf, Green Oak Leaf, Simpson, Romain. (Small plants)

Melons/Gourds/Cucumbers: Charentais. Luffa, Yellow Hybrid Melon, Cantaloupe, Honeydew, Classic Cucumber, Armenian Cucumber, Japanese Cucumber, Lemon Cucumber, Zucchini, Yellow Squash, Yellow Watermelon, Sugar Baby Watermelon. (Tend to be large plants)

Basils: Italian, Lemon, Thai, Cinnamon, Serata, Spicy Globe, Purple, African Blue. (Can be large and bush like)

Misc. Crops: Red Chard, Rainbow Chard, Celery, Sweet Potato (leaves used as greens), Oregano, Strawberries, Shiso Greens, Amaranth, Beets, Rutabagas, Purslane, Malabar Spinach, Red Radish.

Peppers: Explosive Ember, Habanero, Green Bell, Golden Bell, Anaheim Chili, Maxi Bell, Red Cherry, Tabasco, Jalapeno.

Aquatic Animal Species: Goldfish, Giant Freshwater Prawn (*Macrobrachium rosenbergii),* Tilapia (*Oreochromis niloticus* (Nile), *O. aureus* (Blue), *O. mossambicus* (Mozambique), *O. urolepis hornorum* (Wami)), Platyfish, Mollies, Endlers, Swordtails, Guppies, South American armored catfish.

1.2.3 One for All water quality requirements: High tech high production water-based farming systems often require a different nutrient quality for each type of crop produced. However, though different nutrient mixes could improve productivity, all the species and cultivars listed above have overlapping water quality and nutrient needs. When combined with the well aerated nearly two-foot-deep water in the plant grow bed, these conditions create a unique oxygen rich culture environment. This way a single farm can produce a wide variety of plants and fish all in one body of water thus allowing a family access to a broad-based diet.

1.2.4 "Winter" Crops

Seasonal cropping is when crops are grown that do well in that time of the year. Though with climate change and the resulting weather instability, growing seasons are somewhat fluid now. The following Winter (October – March) and Summer (April – September) crops were chosen not only because they will thrive during these seasons and produce a good amount of food. But also, so that if you can grow these you can also grow the hundreds of other crops that are available as listed later in the document.

1. Channel Catfish
2. Lettuce (Many different cultivars all related)
3. Greens (Collard Greens, Broccoli, Cauliflower: All *Brassica oleracea.)*
4. Onions
5. Chard
6. Tomatoes (Tomatoes would not normally be listed here but the climate is changing so they might do well)

Alt: Celery

1.2.5 "Summer" Crops

1. Tilapia (Normally a "Summer only" fish crop but the changing weather and increasing genetic cold tolerance is allowing for an expanded growing season into winter/fall.)
2. Cucumbers (These could actually be planted in March.)
3. Squash (Zucchini for example)
4. Musk Melons (Cantaloup, Honeydew, Armenian Cucumbers)
5. Peppers (Too many kinds to mention. Jalapeno and Yellow Banana are good to start with)
6. Sugar Baby Watermelon
7. Channel Catfish
8. Basil and Sweet Potato vine.

NOTE 1: With the changing weather, plants like Chard and Tomatoes may grow all year.

NOTE 2: There are many other opportunities that may be just as good as the ones chosen but we will start with these.

Preferred Water Quality Requirements for good growth of all 12 recommended beginner crops.

pH (A measure of how acid the water is) 6.5 to 6.8 NOTE: Tap water is about 8.0. Plants grow at about ½ as fast than at 6.8

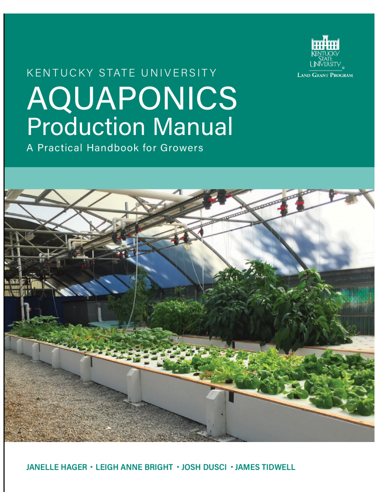
Ammonia: 0.25 ppm

Nitrite: 0 – 0.25 ppm

Nitrate 20 ppm

Temperature: "Winter" Ambient 40°F to 90°F (channel catfish prefer water around 75 to 85°F but do just fine at 40F but they don't grow.)

"Summer" Ambient 65°F to 90°F (Note, tilapia (blue/ Nile hybrid also prefer water 75 to 85°F but normally tend to die in 40F water.



References: Kentucky State University Aquaponics Production Manual (2021). **NOTE: 67 pages 3.7.1MB).**
https://www.ksuaquaculture.org/PDFs/Aquaponics%20Handbook%202021%20Updated%20.pdf

PS Aquaponics is also an amazing way to teach STEM (Science, Technology, Engineering and Math). There is some aspect of aquaponics that covers literally every discipline. Provided by **National Agriculture in the Classroom**, if you would like to spend some time in aquaponics with your children, behind this link is an excellent curriculum on aquaponics for children in 3rd – 5th grades: https://agclassroom.org/matrix/lesson/632/.

Don't let the age levels fool you. Though designed for grade schoolers, there are literally hundreds of pages of background information on aquaponics that are perfectly suitable for adults as well.

1.3 BASIC RULES OF THE WATER: AQUACULTURE

A good definition of aquaculture is "the farming and husbandry of aquatic animals and plants," which for the most part is also a good definition of aquaponics. In addition, aquaponics is regulated in the state of Arizona as aquaculture. In summary an aquaponics system is what is called a Recirculating Aquaculture System (RAS). As seen in the image this is where water flows in a closed loop. (NOTE: THE FAO AQUAPONICS MANUAL GOES INTO GREAT DETAIL ON THIS. FOR DETAILS PLEASE REVIEW)

Daily Management: To ensure a good crop, aquaponics systems act as well-oiled machines. All the parts need to be maintained in good running order. The following are a few of the things you must do on a daily basis to keep your system running and your plants and animals healthy. Aquaponics depends on what is called the Nitrogen Cycle. One of the processes that maintains life on earth, the Nitrogen Cycle is working in soils and water anywhere microbes metabolize ammonia from animals eventually into nitrate that is needed by plants as fertilizer. As seen in the photo below, some call it the Aquaponics Process:

Water Flow: Proper water flow is critical to provide oxygen to your plants and animals (Yes, your plant roots require oxygen) as well as moving fish waste and cleaned water to where they need to be. **Make sure the compressed air pumps are on and providing a lot of air.** Then make sure that bubbles are seen throughout the growing system and the fish tanks.

Checking Water Quality: You must know the quality of your water at all times. The API Master Freshwater Test Kit you have been provided, is what you will use to check important water quality parameters daily. These include the pH, the levels of Ammonia, Nitrite and Nitrate. For full instructions on using the test kit. Please review the following video:

https://www.youtube.com/watch?v=b0gH-6f41Uc&t=48s

pH: pH is the measure of how much acid is in the water. First, you want to keep the amount of acid in the water for good system health between 6.6 and 6.8. (7 is neutral) This is the amount of acid where nutrients are most available to the plants but also where the fish and the microorganisms, that condition the water will continue to grow well. Also maintaining this slightly acid water helps to prevent scale (called lime and Calcium Carbonate) from settling on all of the underwater surfaces in your system. (More on how to maintain your pH level is found later in the document.) **A recent discovery is though 6.8 pH is necessary for rapid plant growth, water straight from the tap with a pH of 8 still allows good growth though about 50% slower.**

1.4 Basic Aquaponics Process - Filtration, Cycling and Water Circulation

Cycling: As mentioned earlier, the water circulation system is dedicated to maintaining water quality by either removing dirt, solid fish waste and detritus from the water and converting toxic liquid fish waste (primarily ammonia) to plant food in the form of nitrate. This last but extremely important part of the process is called biofiltration and the process of getting it started is called cycling. **I cannot say this strongly enough. Successfully starting and maintaining biofiltration is the secret of successful aquaponics. If the ammonia is not converted to nitrate it builds of in the water and can kill the fish. Just as importantly if the ammonia is not converted to nitrate there is no food for the plants.**

1. Ammonia is released by your fish as they breakdown proteins from their food. When your garden's biofiltration is operating properly, the amount of Ammonia in the water should be between 0 and 0.25ppm. Ammonia is toxic so if levels start to rise stop feeding and contact a local expert on aquaponics or aquariums.

2. Nitrite is created as part of the Nitrogen cycle (see above) when bacteria breakdown the ammonia as a source of energy. It is also toxic and not normally in abundance (0.25 ppm or so). However, if its levels start to rise, it may mean something in your system is out of balance such as wasted feed or a dead fish which is why you should test for it every day. In general, to bring the level down, stop feeding.

3. Nitrate is created when bacteria break down Nitrite. It is what your plants use as food. Without it your system will not prosper. How much you see in the water depends on how much food you have given your fish, water temperature, what kind of plants you are growing and how "hungry" your plants are. When you test for Nitrate look for a level of about 20 ppm or so. If you do not see this your system may be out of balance, for example if you have not fed your fish enough.

For a full detailed explanation of cycling please review the FAO manual chapters 2 & 3
And the Kentucky State University Manual Page 26-27
https://www.ksuaquaculture.org/PDFs/Aquaponics%20Handbook%202021%20Updated%20.pdf

Bob Rob and well-respected aquaponics expert from Australia does a good job in this how-to video:
https://www.youtube.com/watch?v=kmxfl_fkmtc

Water level and water quality:

Naturally water is of critical importance to an aquaponics system. There are many possible sources of water for aquaponics, tap, rain, surface (river, lake, canal) well etc. In the case of the systems used here, of all the possible sources of water in Phoenix Metro, tap is the best:

Clean (filtered and then sterilized with chlorine)

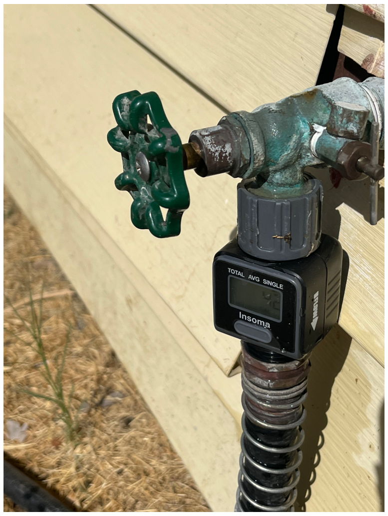
Always available (24/7)

Comparatively low in cost when used in small amounts. (At the moment about $0.012 per gallon at this writing (Winter 2024).

Abundant: In consideration of drought conditions, water in Phoenix is not to be wasted. Aquaponics is one of the most water efficient methods of agriculture. Depending on the skill of the operator, aquaponics allows more food to be produced per gallon of available water.

Filling and maintaining water levels: Using city tap water makes water management much easier. **Using your garden hose, fill the system from your backyard hose to about 3 inches below the inside edge (see photo on left).** No more. Every day some water will evaporate so every 3 (three) days or so, use your garden hose to fill it back up to the prescribed level.

RECORDING WATER USE: it is important to record using the hose water meter provided. There are a wide variety of hose water meters that are suitable for the task and are very similar in design and operation. This video provides basic how to use information on the of these brands of meter you may have been provided: https://www.youtube.com/watch?v=qJ0nF1KB-ws



Removing the chlorine from tap water: To keep your tap water free of pathogens, Phoenix uses chlorine to sterilize its water supply. Chlorine is also deadly to the fish and can damage the plants so it must be removed. There are several ways to do this but the easiest is to simply let it sit for 24 hours. In that time the chlorine will naturally gas out of the water. In general, don't worry about the chlorine in the small amounts of makeup water you will use to counter evaporation. There is not enough there to hurt your fish. Normally you can change up to 10% of your total water (about 60 gallons per day) safely. More is possible but getting more experience or expert help is recommended before attempting this. Finally, there are also some very effective and safe chemical means to remove chlorine from water. **Please talk to your aquaponics provider about these.**

Air: The oxygen in air is essential for all organisms in an aquaponics system. The fish, the plant roots and the microorganisms that filter the water all die without it or grow very slow if they don't get enough of it. Air is supplied by two compressed air pumps (brand may vary) and delivered to the aquaponics system through a series of air transport tubes that connect to air stones that break the air stream in to billions of bubbles and the air lift pumps in the fish tanks that are responsible for water circulation. The air pumps use commercial 120-watt electricity and plug into standard wall sockets. Though the system has been designed to allow fish and plant survival should air from the pumps be lost for a few hours, it is critical that these pumps must be on 24/7 for proper growth and use. Starting the air pumps is simple, if they are operating normally just plug them in. If the pumps do not activate and/or if you do not see an abundant almost jacuzzi like bubbling in the system check if your power is on and or the connections of the airlines to the valves and other distribution points (see section 1.7.3). If nothing is working ask for assistance immediately from the aquaponics program manager.

Care of your fish: As stated earlier, in aquaponics we grow three kinds of organisms. Fish, Microbes and Plants. As you feed the fish, they produce waste that contains beneficial microbes that clean the water to convert into plant food. Many aquaponics systems focus on the plants with the purpose of the fish being primarily to provide fertilizer. In the case of your system, the value the fish produced per pound is just as important as the value of the plants. It is important for the fish to be well cared for so they may provide a high protein nutrition source for the user. The goal in this case is to produce at least 30 lbs. of food fish per year. Even for those who do not wish to eat their fish, high value not normally eaten types of fish like Koi may be produced just as well.

1.5 What kind of fish can be grown?

Though there may be more species available in the near future, to meet Arizona Game and Fish department rules, there are currently two types of food fish that grow well in our systems, Channel Catfish and Tilapia (*Oreochromis sp*.). The Channel Catfish we use are native to the Mississippi river and all Tilapia are native to Africa. Though they taste very different, both are highly desired as food and can be found in the seafood shelves of most supermarkets.

Just as growing food crops outside is seasonal, so is growing fish. For example, Tilapia are warm water tropical fish and may be cultured when the water is over 70 degrees. (Late spring, summer, early fall). They die in water under 60 degrees. Catfish are considered "temperate water" fish. This means they take cold winter water (under 40 degrees F) and can be grown almost year-round in Phoenix. However, during the very hot summer of 2023-2024 tank water temperatures exceeded 90 degrees causing heat stress in some of the catfish produced.

Food safety is critical in the US food system. An excellent source of information on the food safety of these two fish is the Monterey Seafood watch. It is considered one of the best sources of this kind of information in the world. Simply click this link and then type in the name of the fish you wish to know about and it will take you to SCIENCE BASED information on that species. Here is the link: https://www.seafoodwatch.org.

Fish and pH. Fish are sensitive to pH (acidity). Some prefer a high pH like Tilapia (8.0 or so). Some a lower pH. Catfish for example like water that is a little acid at 6.5 or so. As will be discussed in some detail in the plant section, aquaponics needs a pH of about 6.5 to keep the plants happy. This makes a pH of 6.8 a sweet spot for all.

Feeding your fish: Feeding your fish is easy on the surface. Purchase fish feed from your local agriculture feed store or if necessary, a pet/aquarium store. Though there are many brands that provide different qualities, features (such as being all organic for example) and prices, for this purpose and to get you started, choose a food that is labeled to be good for a number of different types of fish with at least 20% protein. Preferably 35 to 40% Be sure the pellets float (When you use feed that sinks it is difficult to tell if your fish have eaten it.) and are small (3/32 inches) in size. If the pellets are too large, they can be difficult for small fish to ingest.

You want to feed your fish all they can eat; however, you can feed them only as much as they can consume in 30 minutes. Sounds contradictory but not really. In the first few days after you stock your fish they will be reluctant to eat. To get them started, twice a day (morning and evening) spread a few pellets of feed on the surface of the water, close the lid and wait. After 30 minutes open the lid and remove and discard the feed floating on the surface. (**Note: never leave the food in more than 30 minutes. Longer and it may get soggy, sink and clog the fish tanks internal filters. Many text say 10 to 15 minutes but 30 are needed so the catfish can get at them**) After a few days the fish should learn to come to the surface and eat.

After the fish learn to eat, continue the twice daily feeding of the same amount of food until all of it is eaten within the 30-minute period. At that time, you may increase the amount of food you provide them. The long-term need is to get them to eat as much as they can for best growth. Though the fish tanks look small they are sized to hold 10, 1.5-pound fish (15 pounds of fish per tank) at any one time and to allow you to grow them to this size over a season. Just to be careful however, start out with about ½ this number of fish until you gain more experience.

The following is a very complete primer on feeding your fish except you can leave the fish feed in the tank for 30 minutes instead of the 5 minutes recommended by the link:

https://gogreenaquaponics.com/blogs/news/a-full-guide-to-fish-feeding-in-aquaponics#:~:text=Conclusion,to%20use%20quality%20fish%20food.

Choosing the right kind of food fish: The kind of food fish you choose depends on your personal taste. Do you like tilapia? Do you like catfish? It may also depend on your cultural desires and restrictions. For example, some cultures restrict the kind of fish that can be consumed only to those with scales. Tilapia have scales while catfish do not. However, catfish do well in the cooler waters of fall and winter while tilapia tend to die when water temperatures drop below 60°F.

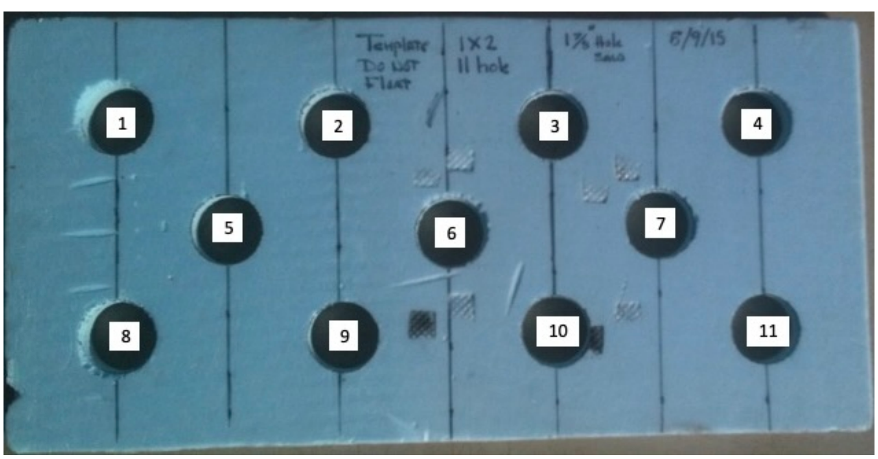
Nonfood fish: The aquaponics system can grow nonfood fish such as Koi, just as well as food fish. The same biological (temperature) rules apply to them just as food fish. One important point here. Koi is simply a common carp bred to display amazing color patters and gold fish are closely related and get big as well. Though they are not on the restricted fish lists as are channel catfish and tilapia, they are only considered inedible because there is not a clear culture in the US for a fish with a lot of bones. Beyond that they are just as edible as other food fish and can get very big. So big that in some parts of the world they are served as the center piece of a holiday meal instead of a large bird.

Breeding: When the conditions are right (time of year etc) some types of fish such a tilapia, gold fish and Koi breed very easily in the system. The presence of baby fish however can make managing somewhat difficult. For example, tilapia fry will eat your roots as will Koi and goldfish. Some easy to install design changes for the system are in the works. Catfish do not breed under the conditions found in your system.

Jumping: You must keep the lid on your fish tanks at all times. Both catfish and tilapia will jump out if you don't. Tilapia far more so than the catfish.

Integrated Pest Management (IPM) (Mosquito Eating Fish & Algae/Detritus Eating Fish): Mosquitos can carry disease and love bodies of open water and so do very well in aquaponics. To manage them we add small fish from a family called *Poeciliidae* (Live Bearers) that include: mosquito fish, mollies, platies, guppies (male and female in photo), red way platy fish, swordtails and a few others, to the water in the plant grow bed. Most of them have some degree of cold tolerance so some will overwinter. They eat the mosquito larvae but also clean the roots of certain encrusting microbes, that though beneficial can over grow. As long as there is food, they will reproduce allowing you to have a constant and self-regulating population of these fish.

Encrusting Algae and General Gunk: There are two basic types of algae. Planktonic algae and encrusting algae. Planktonic algae cause green water. Encrusting algae grow on the walls of your aquaponic systems. Not needed so much during the winter months, for spring, summer and fall, the algae is managed by introducing a sucker mouth catfish from south America commonly called Plecos. *Hypostomus plecostomus* is the common species used though there are a number of others that mostly look and act much alike. Their role in the aquaponics is to eat the encrusting algae of the walls and generally cleanup the organic gunk that can collect in the tank over time. They are purchased small but can grow to nearly a foot over a summer. The do a great job but are warm water only so must be removed in the winter.



Pt 1.6 Plant Care

Pt 1.6.1 How to plant (Rafts):

The first part of plant cultivation in DWC requires what are called floating rafts (Image to left). They can be made from a number of materials, one of the most common being 1-inch-thick extruded polystyrene provided by either for example, Lowes (Blue Board) or Home Depot (Pink Board). For our systems 1-inch-thick boards are normally cut into 1 x 2 ft or 2 x 2 ft sheets and drilled with 2-inch holes in the patterns shown below. This specific hole size is the accept the 2-inch net pots that will be used for your plants.

For ease of use, each panel is drilled with a standard number of holes. Two square foot rafts with 11 holes and 4 square foot rafts with 22 holes. As discussed in the book Square Food Gardening, each type of plant you use requires a certain amount of space. Lettuce for example, can be planted close together. Even as close as 5 per square foot of raft space. Conversely tomatoes require much more room so only can be planted at 1 plant per square foot. As an example, using the number places in 1ft x 2ft raft in the image

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When planting lettuce or onions, all 11 places may be used. When planting collards, and other large plants of its type, places 1, 4, 6, 8 and 11 would provide the necessary spacing and help to balance the raft in the water as the plants grow.

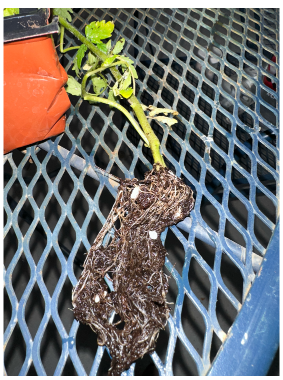
For Celery (a very big and heavy plant, only space 6 would likely be suitable.)

For Tomatoes only space 6 would be suitable and only when next to the north wall for proper light and so the trellis may support it (See section 1.2.2)

Planting in the aquaponics is a simple 5 step process.

Step 1. The most common way to plant is to use a starter plant. The often come in six pacts as seen in the photo to the left. In this case, tomatoes.

Step 2. Remove the plant from the packing container including the potting soil.



Step 3. Using a bucket with a little cool water in it or a slow stream from a garden hose, gently wash most of the potting soil off of the roots.

Step 4. Place the roots in the net pot and place some kind of LECA (Lightweight Expanded Clay Aggregate) around the roots to stabilize the plant. The type normally used for this system is called "Hydroton."

Step 5. Place the net pot in the raft and place the raft in the water.

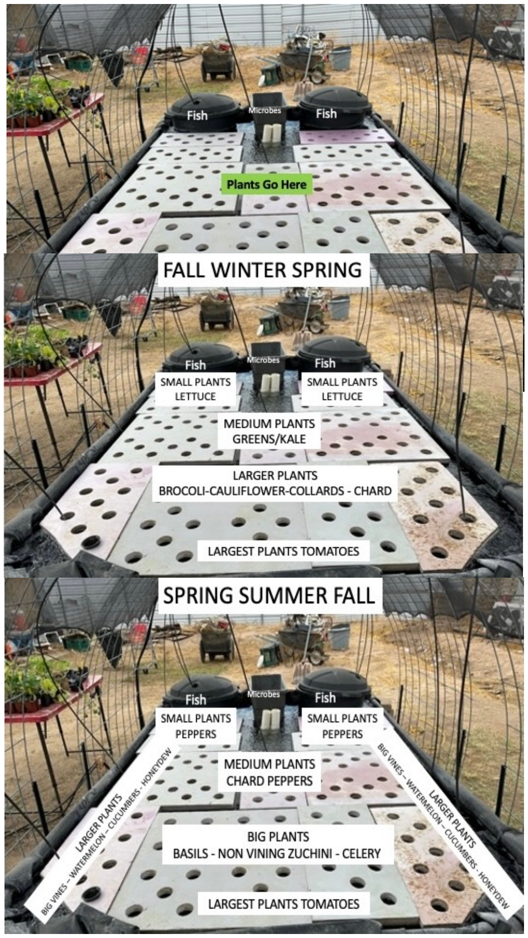
As the plant grows, its roots will extend out of the net pot into the water.

Daily check point: Make sure the air compressors are running and that effusive bubbles are seen coming from all 9 air stones. Plant roots need a lot of air and will not grow well without it.

Pt 1.6.2 Where to plant what?

A fully grown out aquaponics system can look somewhat like a food forest. However, to allow the growth of the greatest about of food planting is not haphazard. Certain types and sizes of plants go in certain locations. On page 2 there is a short list of vegetables and fruits that have been successfully grown in this type of aquaponic system. On the downside, 2023 was a wakeup call for many Valley of the Sun urban farmers. The extreme daytime and nighttime heat of the summer and the potential for continued warm weather perhaps in the late fall has thrown traditional planting schedules into question.

The data is still being gathered on how the changing climate will affect what and how we plant. However, for the short term, there are some basic rules on where to plant your crop.



Orientation: The sun always crosses to the south. The system in the photo is oriented North/South (South is to the top of the photo). So, you always place your smaller plants on the South side of your aquaponics and the biggest plants on the North side. As also discussed in section 1.2.1, how to plant rafts, this is so as they grow, no plants will be blocked from the sun because of being shaded out by bigger plants in front of them. The same planted method works for systems oriented east west. The small plants are still on the South side and the large plants on the North.

Since there are nearly 200 places for plants in the system, the temptation is to plant something in each one of them. Don't do it. For the small plants (lettuce, onions, radishes etc.) you can indeed plant them side by side. But the bigger plants must be given space. Each 5-hole space marks out 1 square foot. For some plants like smaller peppers, you can use 4 spaces per square foot. However, for larger plants like greens, they must be spaced out at 6 holes per large raft. In general, for the entire system, you only need two tomato plants. (see Section 1.2.1) This will leave your system looking a bit empty at first, but the space will quickly fill as the plants grow.

Pt. 1.6.3. Trees

Two of the byproducts of fish culture are fish sludge and compost "tea" water. Both are powerful fertilizers but are not "hot" thus potentially damaging to the plants. To make use of this fertilizer and to maximize the amount of food that can be produced, everyone gets a citrus tree. Since every month or so the clarifier must be empty of waste the trees are a great place to put the water for a few years until the producing fruit

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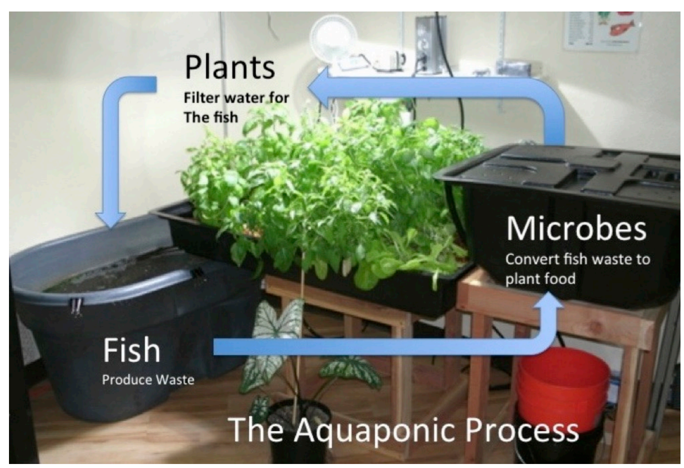
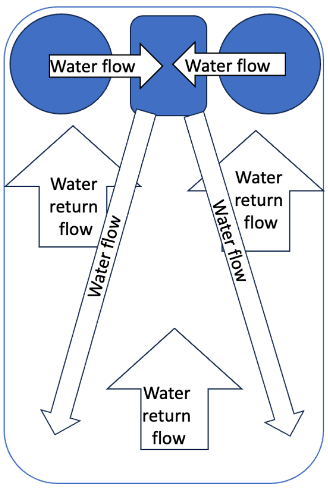
Pt. 1.7 The Water Recirculation System



Just a short recap. The type of aquaponics we use is a type of recirculating aquaculture system or RAS. As seen in the photo to the left, following the arrows, water carrying fish waste is driven to a tank called the clarifier where solid wastes are separated from the liquid waste and where microbes then convert the liquid waste to plant food (Nitrate). The water then flows to the plant grow bed where the nitrate is used by the plants as fertilizer. The water now scrubbed of nitrate is returned "cleaned" to the fish and the process starts over.

In the case of the system you are using, a more efficient recirculation method is used but the elements of the aquaponics process are the same. (Middle photo). In this case there are two fish tanks, one on each side. (Note: these tanks can all hold one kind of fish, or a different kind or age of fish in each side etc. The tanks are also easily removed to make harvesting easy. In each fish tank there are "air lift" water pumps that, following the arrows, push water and fish waste through pipe "A" to the clarifier tank. The airlift pumps are driven by the compressed air pumps mentioned in part 1., which are as safety feature, located some distance from the water in the aquaponics system.

The clarifier tank is where, as in the upper photo, solid waste is separated from the liquid waste and where microbes start to change the liquid waste (starting with ammonia), into nitrate for the plants. As discussed in Pt. 1, this process is called Biofiltration and it also takes place on the roots of the plants and any surface where the microbes can live.

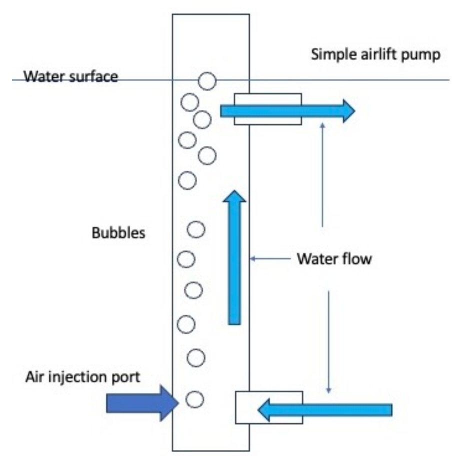


Continuing to follow the arrows, leaving the clarifier the water now flows (B) directly to the plant roots for the plants to uptake the Nitrate as a fertilizer. The water is then drawn back to the fish tanks by the action of the airlift pumps and the process starts over again. The third photo shows the rafts/floats the hold the plants. Plants, fish and microbes require a lot of oxygen. It is called Biological Oxygen Demand (BOD). Without the air, nothing in the system will thrive.

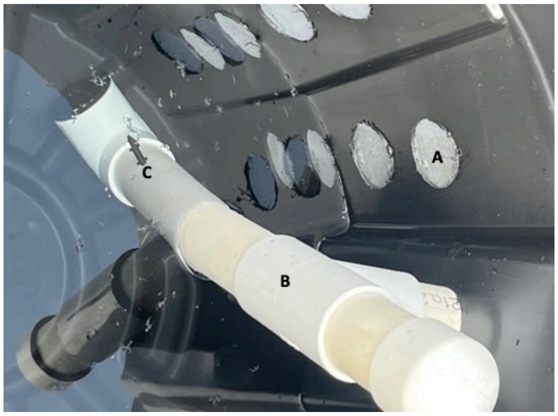
To provide the oxygen needed, the air compressors pump air through nine air stones (photo to left), strategically placed (one in each fish tank (2), one in each of the four corners of the main plant tank also called the grow bed (4), one in the center of the main tank (1), one on each long side of the main tank ½ way between each end). The bubble streams also completely mix the water every 15 minutes thus providing an even distribution of oxygen and nutients though all parts of the system.

Weekly check point: Make sure the air compressors are running and that effusive bubbles are seen coming from all 9 air stones.

Pt. 1.7.1 Fish Tank details:



(RECAP) To allow for easy and low-cost repair by the user, the aquaponics system is specially constructed of low-cost materials available from many big box hardware stores or online. This includes the 2 fish tanks. Externally each fish tank is drilled with 44 holes sized for 1.5-inch PVC connection, each covered by fiberglass window screen (Page 13 Photo at left A). The window screen in plastic welded to the fish tank. No glue is used. The screening over the holes allows for water to be pulled into the tank by the airlift pump (B) while

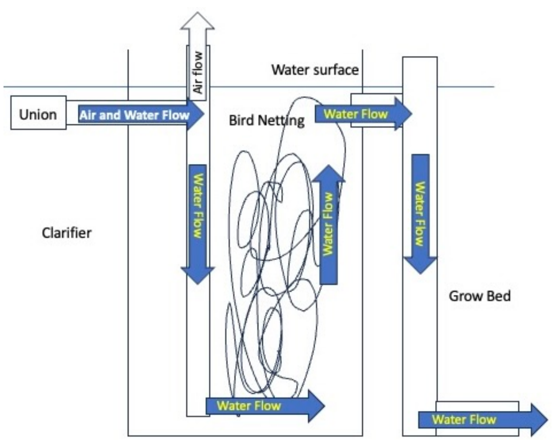


not allowing wasted feed and fecal matter to escape in to the grow bed. Airlift pumps are simple devices that use compressed air only to move the water. (see diagram) In each fish tank and made from 1.5-inch PVC, the airlift pump that creates the necessary water recirculation for the aquaponic system is attached to the wall of the tank. Compressed air is injected into the pump through an airline that is attached at point C (See photo).

Pt. 1.7.2. The Clarifier.

Using bird netting to disrupt water currents, the primary purpose of the clarifier is to capture solid waste before the water goes to the plant grow bed. This is a critical step to keep the plant roots free of detritus. The bird netting also provides a significant amount of additional biological surface area (BSA) for the bacteria that "eat" the ammonia and nitrite to live on. The clarifier is connected to both fish tanks (left tank shown for this example) through the use of an easy release threaded union. The union serves a dual purpose. Not only to allow the clarifier to be disconnected from the fish tank so it may be cleaned (monthly). But also, to release the fish tank so it may be easily removed to harvest the fish.

The air and water pumped from the fish tank separates with the air released upwards and out of the system and the water with fish waste flowing downward to the bottom. The water is then forced to pass through the bird netting which captures the solid waste. The water now cleared of solid waste can now pass into the grow bed.



Weekly check point: To confirm that the air lift pump is working properly look to the pipe in the clarifier and just right to the union as shown, that allows air to be released from the water stream. If the airlift pump is working properly this location should be bubbling vigorously. If not please call your aquaponics service provider for assistance asap.

1.7.3. The Gang Valves (also called manifolds).

Connected directly to the Air Compressors the Gang Valves are the series of small valves that individually control how much air goes to each need in the aquaponics system. The lines from the air compressors are normally placed underground coming to the surface at the aquaponics unit. The gang valves are located up on the hoop trellis on the left and the right. Each gang valve is fed by an individual air pump.

1.7.4. Game and Fish regulations.

In Arizona, aquaponics is regulated as aquaculture and requires a license for the fish. The program pays for stocking. You will be contacted by a program representative whenever it is time to restock your system with a regulated species of fish (tilapia and catfish are regulated while koi and goldfish are not.)

1.7.5. How many fish to stock?

How many fish to stock is one of the most common questions in aquaponics and also one of the most difficult. How many fish depends on how many plants in your grow bed, water temperature, water flow, kind of fish, shape of your fish tank and on and on and on. Based on taking all the above into account and more, the aquaponics system described here is designed to hold (carry) thirty pounds of fish at any one time when your grow beds are full planted out with big plants. For example, one could stock 11 6-inch catfish fingerlings in each tank. It is expected that 1 fish in each tank will die leaving you with 22 fish total. Successfully growing them all to 1.5 pounds would give you 30 pounds. But there is so much more too it. Once again Rob Bob provides a good introduction to the subject in this video.
https://www.youtube.com/watch?v=MeYtUfBKwNo

2.0. Plant Nutrient Deficiencies and Fish Diseases

2.1. Plant Nutrient Deficiencies:

Have you ever wondered why traditional land farms grow acres of only one kind of plant in individual fields? The answer is fairly simple. It is easier that way. Each kind of plant has its own set of environmental and nutritional requirements that are different from others. They are also almost always morphologically different as well, thus requiring its own method of harvest. However, "Man does not live by lettuce alone." As discussed in part 1, your aquaponics system is designed to grow a wide variety of plants quickly and with high quality. Nearly 100 different species or varieties of species so far, so it can feed a family. Growing all of these plants in the same body of water at the same time can be challenging because it forces some plants to compete with each other for nutrients, space and light. The temperature and pH (acidity) and TDS (total dissolved solids) levels also play critical roles. The first place you often see the results of this competition in your plants is in the form of various nutrient deficiencies.

The nutrients needed by the plants in your Aquaponics system include potassium, nitrogen, phosphorus, calcium sulfur, and magnesium. They also need small amounts of molybdenum, manganese, boron, copper, chloride, zinc and iron. Not getting them in the form they need, the amounts they needed and at the right times can affect their growth rates, taste and nutritional value. For example, in a perfect world all of the above are supposed to come from the fish waste. However, if these ingredients are not in the fish food, the plants can become malnourished.

2.2.2. So, what do you do?

There is a simple answer to this question and then there is the complex answer. First the basics.

1. Test the water. As we discussed in Pt 1.3. and 1.4, use the instructions from the link below to test your water for Nitrite, Ammonia and pH.

2. Examine your plants: Your plants will often tell you if they are short of nutrients and what kind. Learning what to look for and what it means can be challenging, complex and take some time to learn. However, after a few months, learn you will. To help you in the process please open this link and save it. It goes to one of the simplest and most complete explanations of 20 of the most common nutrient deficiencies you will see.
https://www.youtube.com/watch?v=9SotrCwqfHo&t=24s

3. Fix the problem: Now this is the hard part. For the beginner, the best path is prevention. To prevent many if not most nutrient deficiency problems from happening do the following:

A. Nitrogen: After cycling, stock your fish and plant your crops at the same time. Secondly feed your fish as much as you can without increasing the ammonia levels or clogging the filters (see cycling). The baby fish will not produce much nitrogen at first and your young plants will want to grow faster than the fish. However, the amount of nitrogen produced by the fish will allow the plants to stay even with the fish even though the plants will look a bit nitrogen short at times.

B. Phosphorous: This is the nutrient that promotes flowering, seeding and fruiting. The source is once again the fish. As before, feeding your fish as much as you can will normally provide sufficient phosphorus. Again, the plants will want to grow faster than the fish and will show some deficiency at first (medium to low numbers of flowers)

C. Potassium. Potassium helps facilitate the movement of water and the management of nutrients and carbohydrates in plant tissue. It's involved with enzyme activation within the plant, which affects protein, starch and cell energy production. Once again, using the easy planting schedule suggested above should provide enough potassium.

D. Magnesium: As demonstrated in the video linked above magnesium is necessary for the chlorophyll molecule to work in photosynthesis. If you don't have it your leaves will turn white and your plants will suffer and die. Fortunately, you can purchase it in the form of PURE (check the label carefully. NO FRAGRENCES) $MgSO_4$ otherwise known as Epsom Salt. Again, you must make sure it is pure. Added fragrances will kill your system. Adding a palm full of this to your aquaponics every month will provide more than enough to keep your plants happy.

E. Calcium. No problems here. Phoenix water is very hard and full of calcium.

F. Iron. Iron like Magnesium is needed for photosynthesis. Getting the iron the plants need is a bit more problematic. Primary because Iron is no longer in the fish feed. Also, when the iron is dissolved in the water it must be in the right form to be available. You can't simply through a rusty nail in the water to solve the problem. The iron must be what is called "chelated" to be available for the plants to use.

There are a number of different iron formulations available from the local nurseries and big box stores. One that we have found that provides the best form of chelation (FeDDHA) and will not hurt the fish is a product called Kerex. The recommended dosage is 6 table spoons full of powder every 3 weeks.

3.0. Emerging Issues

3.1 Fish Diseases

Epistylis:

Catfish are known to be disease prone. Last year it was ICH. This year something that on the surface looks just like ICH but is very different. Epistylis.

Epistylis is easily confused with ich. On the surface they look a lot alike. Epistylis is typically fuzzy and translucent. Some of our farmers say the fish looks like it is covered in jelly.

Treatment recommendation:

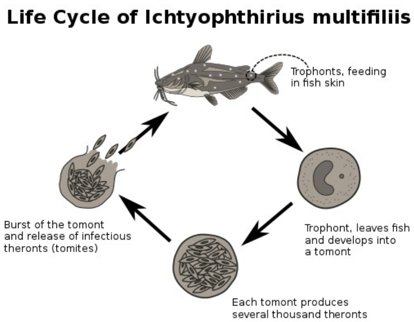
Ware still exploring this. While it quickly kills once the fish has it, it does not seem to easily spread. Something to do with how clean the water is perhaps. Unlike ICH, the literature suggests this disease can be treated by antibiotics. Also, unlike ICH, warm water does not have an effect.

ICH:

ICH Ich is a fish disease caused in fresh water by the parasite *Ichthyophthirius multifiliis*. It presents as fish covered with white cysts in which the organism is growing. It one of the most common diseases seen in catfish and has a high mortality rate. Outbreaks can be triggered by sudden drops in temperature as was seen at the beginning of February 2024 or by contaminated water or sick fish being added to your tank.

NOTE: Ich is a cold/temperature water disease. It cannot survive in waters over 82ºf. This suggests it would be better to sock catfish in warmer months to mitigate future concerns.

3.2. Fish kill due to power failure:



Some farmers have experienced fish kill due to power failure (often after dust storms for example). The cause was apparently a bad Ground Fault Interrupter (GFI) that cut off the electricity one night. Power failures are the bane of all aquaculture systems that use electricity to circulate water and to supply air. Professional farms go to considerable expense to provide the battery or diesel-powered electrical backup systems needed to protect the health of the fish. However, small scale aquaponics systems usually do not because the cost is greater than the benefit. Simply since the fish are only there to provide nutrients, it is less expensive to just replace them than protect them. Following the Fish Centric management philosophy however, requires the fish be protected so they may consistently reach a market size.

To accomplished this task, the fish management system is designed to provide the fish oxygen for approximately 5 hours after a power failure. The system is 100 % passive thus low in cost. It is not a panacea however. Normally fish die in 1 hour after the pumps stop. Five hours is a 500% improvement and is usually enough time for the farmer to take action after a loss of power. However, in this case it was still not enough time.

3.3 Fish taste

Fish taste like what they eat. Channel catfish are well known for often having a muddy taste. This is called off flavor. The causes of this are normally the presence of various chemicals, bacteria, algae etc in the water where they lived. Any wide spread application of aquaponics must manage flavor if the effort is to be successful. Judging taste is often difficult. The same fish can taste good or bad depending on the taster.

Recently however during the April 2nd 2024 Aquaponics Office Hours meeting one farmer provided an impassioned testimonial as to the flavor of her fish. An audio of her remarks is found at the beginning of the April 1 Office Hours video (see office hours section. If her thoughts are found to be a good representation of those of others, then there is great potential for Phoenix farm raised catfish in the local market, adding value to the farm

.

3.6. Trees and Fish Waste, Planting and Fertilization

The aquaponics + tree concept is based on the amount of fish waste (a powerful fertilizer) that will be produced over time and that using it to water a citrus tree would be a sustainable use for it that in turn would eventually produce more food.

3.7 Extreme Heat Impacts

As suggested by this paper, (https://bit.ly/3vGbKfn) developing site appropriate new agriculture technologies can take some time due to the need to experience as wide a variety of environmental and economic conditions as possible. So there is little that can be written at this time.

3.8. Harvesting Challenges.

3.8.1 Lost fruit

As suggested by the photo on the right, when properly done growth in an aquaponic system can be extremely productive. However, the luxuriant growth has proven to be a problem when it comes to harvesting. Often a ripe fruit is covered by the overgrowth of plants and not seen until it is too late. This is most often true when it comes to vining fruit like melons though it can happen just as well as stalked fruit such as peppers and okra.

Solution: Do not depend on your fruit being easily seen. Every day you must look through your system particularly on the outside and down the sides for the fruit that is not readily visible.

3.8.2. Need to harvest now

On occasion an aquaponic system may produce more fruit that is needed by the household. The temptation for some farmers has been to let the ripe fruit sit in the garden till needed in the house. DO NOT DO THIS. When the fruit is ripe, if left on the plant will continue to ripen until it is no longer edible. Always harvest the fruit when ripe and then store it in the refrigerator or perhaps give it away to friends.

3.8.3 When to harvest fish

Just like your plants your fish will not grow evenly. Some will grow faster than others some slower than others. Often the fast-growing fish can grow much faster than the slower. If so, as seen in the photo, the big ones will bully/fight the smaller ones on occasion, especially when the water gets up around 90 degrees or so, leading to death or even cannibalism.

It is extremely important to watch your fish. When they get crowded, harvest the big ones. Especially when they start to get around 1.5 pounds or so. This will leave space for the smaller ones to grow. This is true for Tilapia and Catfish.