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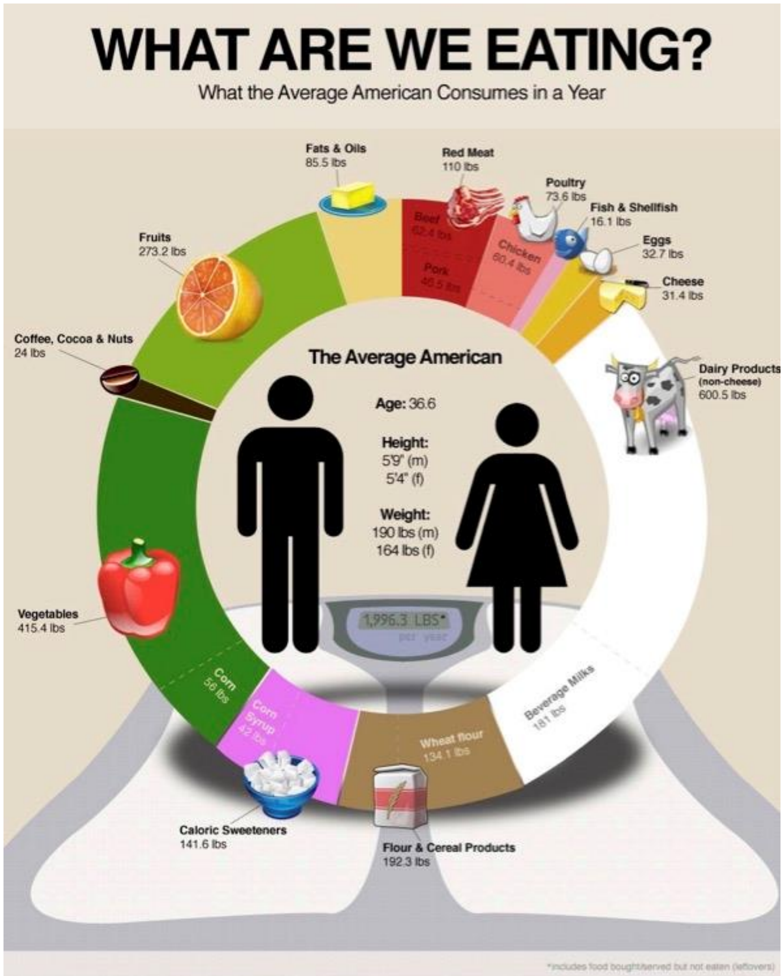
12 Crops to a Healthy Diet. A Quick Operational Guide to Starting your Aquaponics in the Phoenix Backyard Garden Program

According to the USDA, the average American eats about 2,000 pounds of food annually (see graphic below). Given the right amount of time, expertise, good weather and equipment nearly 40 percent (800) lbs., could be produced in an average Phoenix backyard. A summary of the standard operational procedures. Using a simple 6 crop winter and 6 crop summer mix of plant and animals the mission of this document is to help you and your family reach that goal using aquaponics.



No way around it, aquaponics is complex. In the Backyard Garden Program, we have made it less so thus bringing the concepts of agriculture technology to your back yard.

What is Aquaponics?

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

Aquaponics in the Phoenix Backyard Farming Program

The basic goal is to grow enough food for 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 the Victory Gardens during World War II. Victory Gardens required an average of 1,600 ft^2 of land, a plot size too large for the normal Phoenix back yard. However, by harnessing a little 21st century Agri-Food Tech science to reduce size, scale and cost, it was possible to create a comparatively low cost aquaponics system that can produce many desired local food staples including lettuce, kale, chard, broccoli, collard greens, tomatoes, peppers, cantaloups, honeydews, watermelons, catfish and much, much more. All of this using simple splash pools as the farms foundation and can be prefabricated and installed in less than 3 hours.

Parts of your Aquaponics system:

At times called an Aquaponic Victory Garden, the photo on the next page is the standard NxT Horizon aquaponics system used within the Backyard Garden Program. 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.

How does it work?

The method is called Deep Water Culture (DWC). The technique to allow Deep Water Culture in a splash pool was first developed around 2012 and published in Brooks 2017 (http://nxthorizon.com/PDF/design1.pdf).

The splash pool covered by a **fish safe plastic liner** creates a body of water where food plants are floating on **rafts** (see photo) with their roots extending down into the tank. The plant roots and the clarifier are where most of the microorganisms are found the convert the fish waste to nutrients. To hold the fish **two readily available trash cans** made from **food safe High-density polyethylene (HDPE) plastic** are used to support and grow fish. Water circulation is created through the use of an Air Lift Pump powered by compressed air. The **clarifier** is a simple device that collects the solid waste from the fish for later use.

A shade screen held up by a trellis structure works to protect the plants from excess sunlight during Phoenix's increasingly hot summers. The trellis also provides structure where a wide variety of vining plants can grow. Finally, plants on the rafts and the fish in an enclosed external tank 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. It can be done using about ½ hour of time.

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

Below is a short 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 (Tend to be small plants though Nasturtiums can grow very large)

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 bushey)

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, Super Chili.

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.

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. These overlapping environmental needs when combined with the well aerated nearly two-foot-deep water in the plant grow bed creates a unique oxygen rich culture environment that enhances root growth in both small and large plants as well as their access to nutrients. This way a single farm can produce a wide variety of crops including vines, large leafy greens, lettuce and fish all in one body of water thus allowing a family access to a more broad-based diet.

The 6 "Winter" Crops

Seasonal cropping is when crops are grown that do well in that season of the year. Though with climate change and the resulting weather instability, growing seasons are somewhat fluid now. The crops we are using the basic designations of Winter (October – March) and Summer (April – September) to describe the seasons. These crops were chosen not only because they will thrive during these seasons and produce a good amount of food. Basically, if you can grow these you can also grow the hundreds of other crops that are available 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

The 6 Summer Crops

1. Tilapia (Normally a "Summer" fish crop but the changing weather and increasing genetic cold tolerance is allowing for an expanded growing season.)
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

Alt: 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.

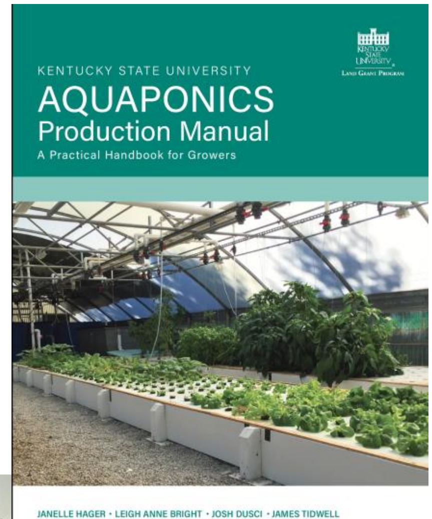
Preferred Water Quality Requirement for good growth of all 12 recommended beginner crops.

pH	6.5 to 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 do not do well in 40F water.

References: Here are the links to two great references. First is the **Kentucky State University Aquaponics Production Manual** (2021). **NOTE: 67 pages 3.7.1MB).**
https://www.ksuaquaculture.org/PDFs/Aquaponics%20Handbook%202021%20Updated%20.pdf

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.

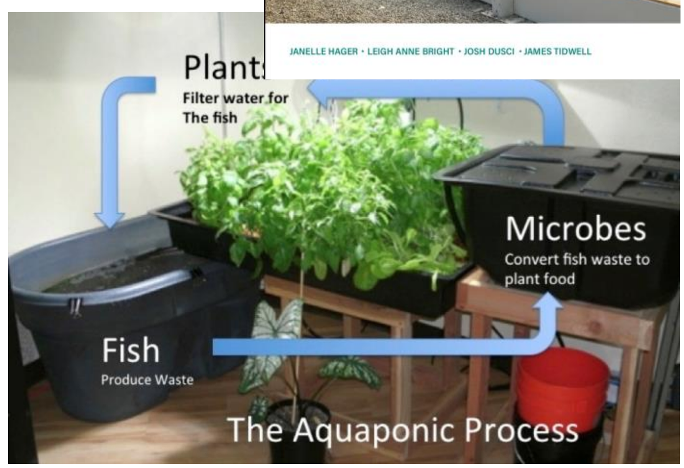
BASIC RULES OF THE WATER



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 needed by plants as fertilizer. As seen in the photo on the next page, 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 checked 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 conditions help to prevent scale (also 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.)

BIOFILTRATION

Biofiltration is the process that converts fish waste into plant food. There are basically 3 steps to the process:

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 to wait to contact your program aquaponic manager.

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 food fish which is why you should test for it every day. Also, when this happens for Nitrite or ammonia, please contact your aquaponics manager as soon as possible.

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. Once again contact the manager for advice.

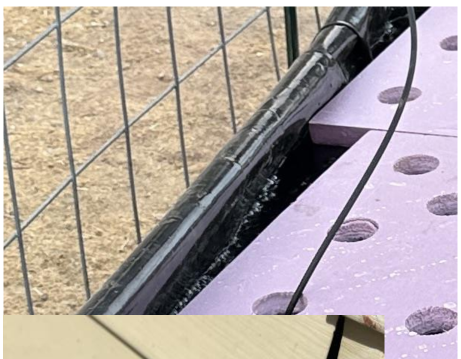
Water level and water quality:

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)

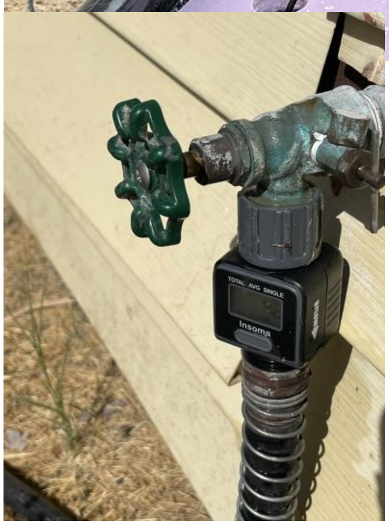
Always available (24/7)

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. Please record the data and transmit to the city of Phoenix using the link they will send you every month. 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 the system 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 is 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) 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 but we will leave that discussion for another day.

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 1.3.3). 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, Microorganisms 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 our program, 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.

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 and our goals of 10 crops, 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 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 that many consider 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 little acid at 6.6-6.6 or so. As will be discussed in some detail in the plant section, aquaponics needs a pH of about 6.6 to keep the plants happy. As long as the fish are given the opportunity to adapt slowly to any changes, they also do well at this 6.6 or so level.

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. 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 they can consume in 30 minutes. Sounds contradictory but not really. In the first few days after you stock your fish (how to stock fish is a subject we will explore later) 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**) 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. 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.

The following is a very good and very complete primer on feeding your fish:
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: Of 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 bread 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 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.

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.

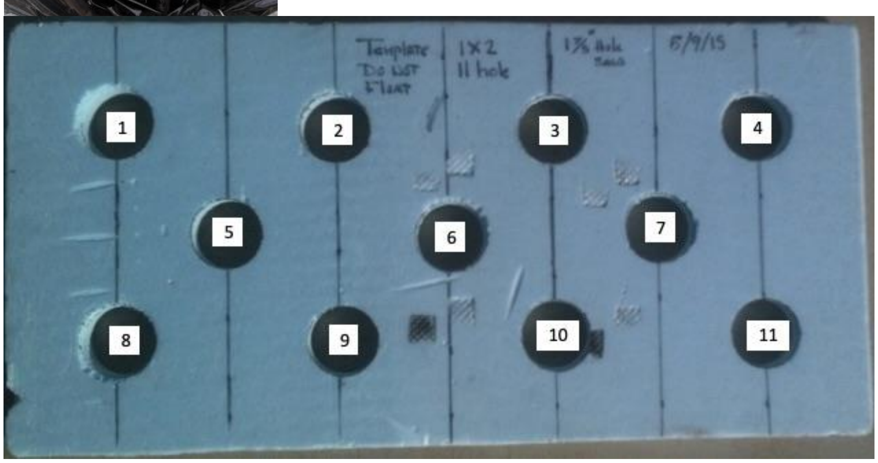
Maintaining fish health: Fish get sick from time to time. This subject will be discussed in detail in a later edition of this SOP

Integrated Pest Management (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 <u>Poeciliidae</u> (Live Bearers) that include: mosquito fish, mollies, platies, guppies, 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 causes green water and will be discussed in part 2 of this document. 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 1.2 Plant Care

Pt 1.2.1 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 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 requires little for example so can be planted close together. Even as close as 5 per square foot of raft space. Conversely tomatoes require much more 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 above:

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 grew.

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 1.2.2 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 location. 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.

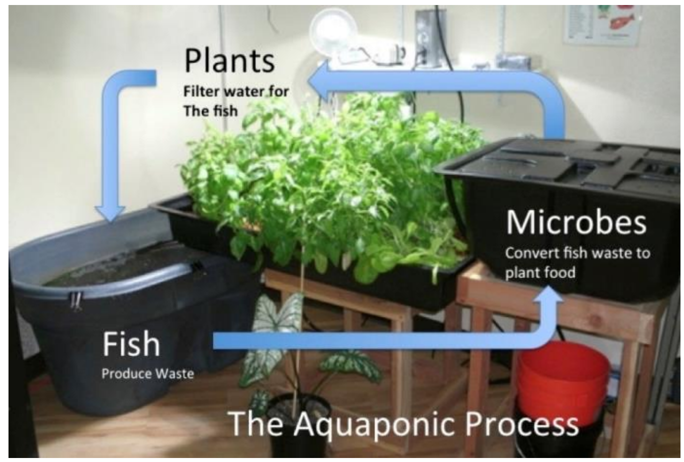
Orientation: The sun always crosses to the south. The system in the photo is oriented North (top of photo) South. So, you always place your smaller plants on the South side of your aquaponics and the biggest plants on the North side. As also discussed in section 1.2.1, how to plant rafts, this is so 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, 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. 1.2.3. Trees

Two of the byproducts of fish culture are fish sludge and compost "tea" water. Both which 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 but a better place to put the water on a. few years should start producing hundreds of pounds of fruit.

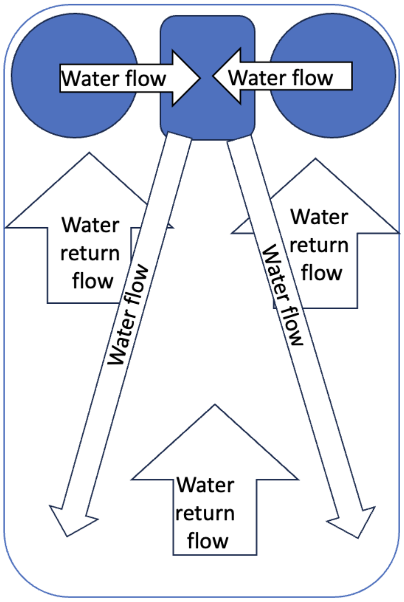
Pt. 1.3. The Water Recirculation System



Just a short recap. The type of aquaponics we use is a type of recirculating aquaculture system or RAS. As seen in the upper 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 the process is the same with some details changed to make it more efficient. (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 separate 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.

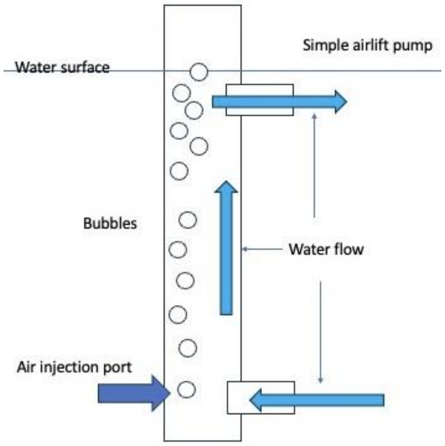


Continuing to follow the arrows, leaving the clarifier the water now flows (B) directly to the plant roots for the plants to uptake the Nitrate as a fertilizer. The water is then drawn back to the fish tanks by the action of the airlift pumps and the process starts over again. The third photo shows the 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 though 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) to completely mix the water every 15 minutes thus providing an even distribution of oxygen 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. 1.3.1 Fish Tank details:

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.

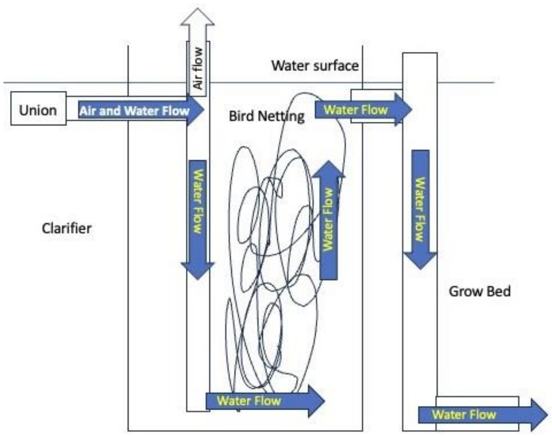


Externally each fish tank is drilled with 44 holes sized for 1.5-inch PVC connection, each covered by fiberglass window screen (Photo at left A). The window screen in plastic welded to the fish tank. No glue is used. The screening over the holes allows for water to be pulled into the tank by the airlift 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 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. 1.3.2. The Clarifier.

Through to use of bird netting to disrupt water currents, the primary purpose 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 populate. 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 elease 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 steam. If the airlift pump is working properly this location should bubbling furiously. If not please call your aquaponics service provider for assistance asap.

1.3.3. The Gang Valves (also called manifolds).

Connected directly to the Air Compressors the Gang Valves are the series of small valves all connected that individually connect to and control how much air goes to each need in 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 on up on the hoop trellis on the left and the right. Each gang valve is fed by an individual air pump.

1.3.4. 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.)

End of Pt. 1. Part 2 will consist of detail on how to use mosquito eating, fish, plant nutrient deficiencies, Integrated Pest Management for Fish and Plants.

Part 3 will discuss harvesting including what to harvest on plants, when to harvest and how information. Related information will also be available for the fish.