Alfcon's Aquaponics

An alternative way to grow vegetables and fish

www.alfconsaquaponics.com.au

Beginners Aquaponics

Workbook

Alfio & Leisa Contarino

Welcome to the Beginners Aquaponics Workbook!

We designed this workbook as a step-by-step guide to help people who are interested in setting up their own aquaponics system in the backyard. The workbook was created to work as a guide for beginners by providing detailed explanations of how to design, build and maintain an aquaponics system. Each section features exercises that complements the information provided and to help get the creative thinking flowing. We also developed the workbook so it could also act as a reference and resource book into the future.

Alfcon started his aquaponics business so that he could share his passion and belief in aquaponics as the future of food production. We both believe in the benefits of sustainable and ethical food practices and want to see people do it for themselves in their own backyards. We believe that this kind of self-sufficiency will help individuals, families, communities and ultimately the world.

We hope that you enjoy this workbook and always appreciate constructive feedback as well as stories from people about their designs and set-ups. Please visit us at the website: http://alfconsaquaponics.com.au/ or on Facebook: http://www.facebook.com/alfconsaquaponics and share your stories with us!

Leisa Contarino

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Introduction to aquaponics

What is aquaponics?

Aquaponics is a symbiotic food production system that combines aquaculture; which is the raising of aquatic animals such as fish, crayfish or prawns in a controlled environment, with hydroponics; which is growing plants in controlled water conditions. [1]

The combination of aquaculture and hydroponics results in fish water being passed through the plant bedding material. This makes aquaponics a 'closed system' and one where water will not be wasted.

In traditional aquaculture and hydroponics systems water is constantly replaced. This practice is ultimately unsustainable. In a world of growing water shortages, water wastage is a major environmental and social issue that requires immediate critical attention.

Water issues

Disposal offish waste in aquaculture is the most critical issue for this industry. Once the levels of waste get too high, even with bio filters, the water becomes toxic for the aquatic life. The only solution is to remove and replace approximately 20% of the water. In commercial freshwater aquaculture there are methods where fish waste is filtered and recirculated, but the need for water changes remain.

Joe Lencioni, shiftlngplxel.com

In hydroponics, the plants grow in water, but water alone is not enough and mineral nutrients, such as nitrate, sulphate and phosphate, need to be added to the water for the plants to grow. Although hydroponics can reduce water consumption up to 80% of traditional soil-based food production, the biggest single issue is maintaining water quality. Plants can deplete nutrient solutions in different spans of time, meaning that water can become saturated with certain nutrients or salt very quickly. This can happen in as little as 5 days. A water change process is often used to counteract this situation.

Aquaponics is called a symbiotic process because the waste from the fish is processed within the system and then relocated to feed the plants. The end result is that the water that is passed back to the fish tank is cleaned. This brings together the best parts of aquaculture and hydroponics to create a sustainable fish and vegetable garden in your very own backyard.

The process is simple, but there is still a vital need for maintenance so that the system remains stable and balanced. This course shows the step-by-step approach to create and maintain a balanced system from fish to plants in a backyard aquaponics system.

History of aquaponics

http://www.greenpeace.org

Aquaponics has been around for ages. The ancient Aztecs had agricultural islands known as 'chinampas', where plants were raised on stationary (and sometimes movable) islands in lake shallows. Waste materials collected in the chinampa canals and surrounding cities were then used to manually irrigate the plants.

In South China and Thailand, rice was (and still is) cultivated and farmed in paddy fields in combination with fish. This 'polycultural' type of farming involves using multiple crops in the same space, much in the same way as a natural ecosystem. These types of ecosystem farming practices existed in many Asian countries and used fish such as the oriental loach, swamp eel, common and crucian carp, as well as pond snails in the paddies. [1]

New and more complex ways of adding nutrients to crops was further developed and refined in China. Farmers added land livestock waste, such as pig or chicken manure, to their fields or ponds to increase production of vegetables and fruit bearing plants. However, the fish were in danger of receiving too much of these additional nutrients, so the farmers needed to be careful about balancing their system for maximum yield and minimum fish loss. [2]

The results were a complex system with chickens being raised in pens above pigs. The pigs lived in pens over a pond of carp. The water from the carp ponds was then directed to another pond with a different variety of fish such as catfish and other aquatic animals. Other systems included using ducks caged in houses over finfish ponds. The finfish processed the duck waste in the water and the water was then moved into a lower pond with catfish. Finally, after the catfish pond the water would be used to irrigate rice and other vegetable crops. [3]

These structures were called 'flow-through' systems, where water, once used through the ponds, which also grew edible plants, was released to the local paddies for further use as nutrient-rich water. The nutrient-rich mud from the bottom of the ponds was also used on the fields. At the end of the process, the water would also be released to streams, lakes or the ocean. [2].

The rice farmers in Southern China still use these kinds of eco-friendly systems to grow rice and fish today. According to research from Zhejiang University in China, the rice fish system requires 68% less pesticide use and 24% less chemical fertilizer than the regular monoculture rice system. [4]

The aquaponics system

Requirements & management

Before building or buying an aquaponics system, it is recommended to investigate carefully the intended space for the system, such as your backyard, balcony or patio, as well as think about intended plant use, proximity to power, as well as willingness to spend time and/or money to manage the system.

During this course, you will learn more about why these requirements are necessary. This will help you figure out what you really want to get out of your aquaponics system.

Some of the questions you might like to ask yourself are:

1. Do you want to have a small, simple system for growing micro-plants or herbs inside your house?
2. Do you want to replace your existing garden or supplement it?
3. Do you want to grow vegetables and fish in an apartment or on a small balcony?
4. Are you intending to reduce your shopping for vegetables and fish?
5. Are you looking to sell vegetables and fish for profit?
6. Is the space you intend to set up your aquaponics system close to power?
7. Are you interested in solar power for your system?
8. Are you going to build your own system or buy one ready-made?
9. Is the environment going to be suitable for the type of fish you want to stock your system with?
10. Do you intend to eat the fish you grow?
11. Is fish food easily obtainable?
12. Do you have the time to test and maintain the water regularly?
13. Do you have time to maintain a small system or large one or several systems?

Exercise 1

Read the above questions and then share your own ideas and requirements. You can start to write down your requirements on the next page and come back to these pages to write down more ideas anytime during or after the course.

The three elements of aquaponics

An aquaponics system actually contains three vital living parts; fish, plants and bacteria. The system relies on each of these living organisms to be balanced to be successful. This means that each is as important as the other and all must be maintained to create a balance.

Aquaponics is a 1- 2 - 3 closed system.

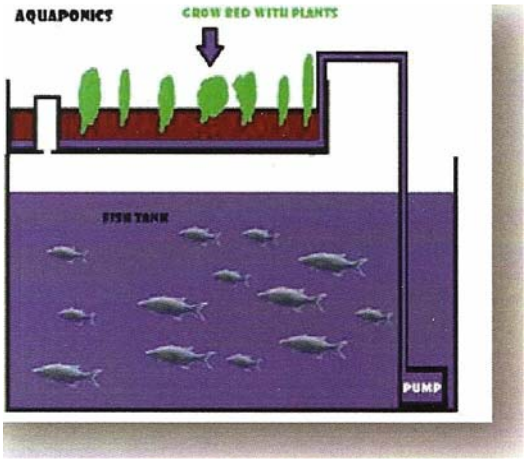
1. Fish grow and produce waste and ammonia. The bigger the fish grow, the more waste is produced.
2. The bacteria, usually found in the bedding material or growing material of the plants, convert the fish waste and ammonia into nitrites and then nitrates.
3. Plants absorb the nitrates to grow strong and healthy. By absorbing these trace elements, the plants clean the water as it goes back to the fish.

This process is very simple and natural. It is what happens in nature every day. Fish in the rivers eat insects, bugs and algae. They produce waste that is broken down by bacteria in the mud banks and submerged trees and even in the river bed. The nitrate rich water is then used by the plants that grow along side and near the river. This is why plants that grow near rivers are always green and healthy.

Understanding this 1- 2 - 3 process is vital to setting up and maintaining a balanced aquaponics system.

The 1 - 2 - 3 closed system

Fish - Bacteria - Plants



The 1 - 2 - 3 system is a symbiotic system between fish, bacteria and plants. The basic process starts with the fish in the tank producing waste. The fish water is pumped up to the grow bed, where the bacteria transform it into nutrients for the plants. The plants absorb the nutrients and then the clean water is passed back to the fish.

This process is called, *the Nitrogen Cycle.*

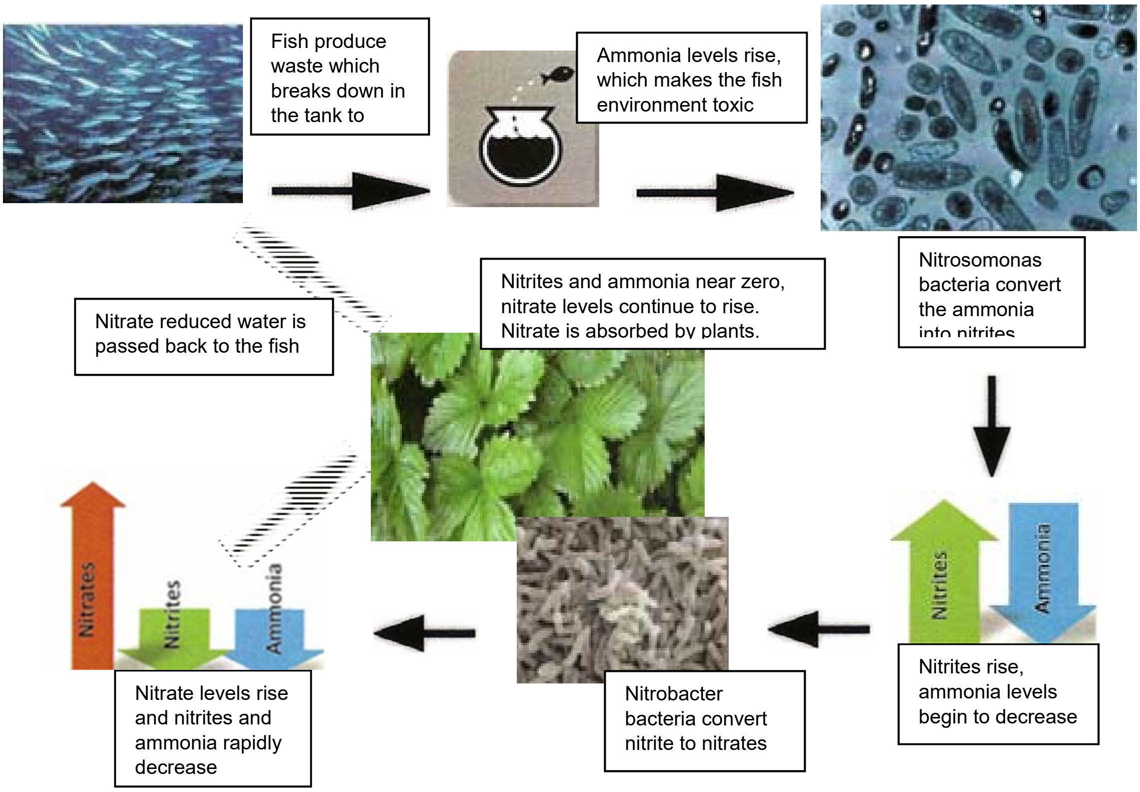


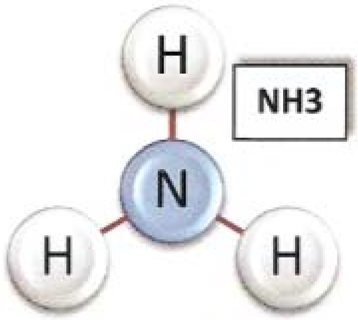
Figure 1: The Nitrogen Cycle

The nitrogen cycle is a continual loop. **However, there are many details that need to be maintained to make sure the entire system is balanced. If nitrate levels rise to beyond 100ppm (parts per million) it is dangerous for fish.**

The Nitrogen Cycle - in detail

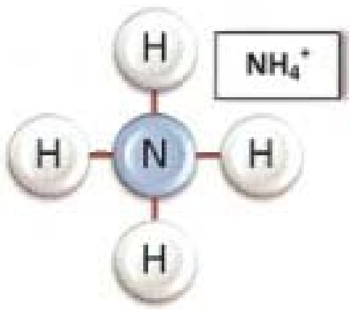
The three elements of an aquaponics system each have their part to play in the nitrogen cycle. This section looks more closely at the chemicals and process created as the water passes through each element of the system.

Fish & the Nitrogen Cycle



Waste excreted from the fish, as well as uneaten food that remain inside the aquaponics tank. If nothing eliminates these waste products, the fish in the aquaponics system will die.

Waste is quickly broken down into either ionized or un-ionized ammonia. The ionized form, ammonium (NH/)' is present if the pH is below 7 and is not toxic to fish. The un-ionized form, ammonia (NH3) is present if the pH is 7 or above and is highly toxic to fish. Any amount of un-ionized Ammonia (NH3) is dangerous, however once the levels reach 2 ppm (parts per million), the fish are in grave danger.



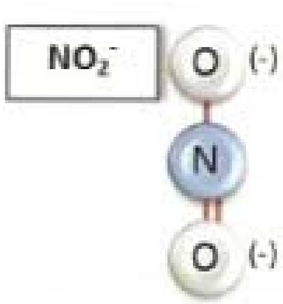
Water tests actually check the ammonia levels by checking for NH/and NH3 and so it is really these two types in combination that affects the quality of the water.

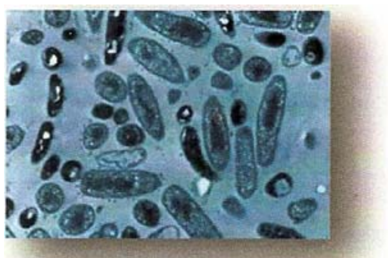
Ammonia usually begins rising by the third day after introducing fish into your system.

Bacteria & the Nitrogen Cycle

As mentioned in the diagram above, there are two types of bacteria in an aquaponics system. These bacteria live in the growing material that supports the plants. Bacteria require very specific temperatures in order to form and develop to be effective and successful in an aquaponics system.

Nitrosomonas





http://i608.photobucket.com/albums/tt163

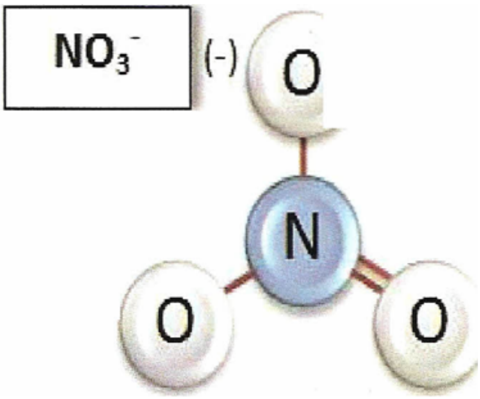
Nitrosomonas bacteria oxidize the ammonia. The result is that the ammonia is eliminated. However, the by-product of ammonia oxidation is nitrite (N0$_2$-), which is also highly toxic to fish.

Nitrites levels as low as 1 mg/l can be lethal to some fish.

Nitrite usually begins rising by the end of the first week after introducing fish.

Nitrosomonas prefer an optimum pH of 6.0-9.0.

Nitrobacter



In the last stage of the nitrogen cycle, Nitrobacter bacteria convert the nitrites (NO_2^-) into nitrates (NO_3^-)

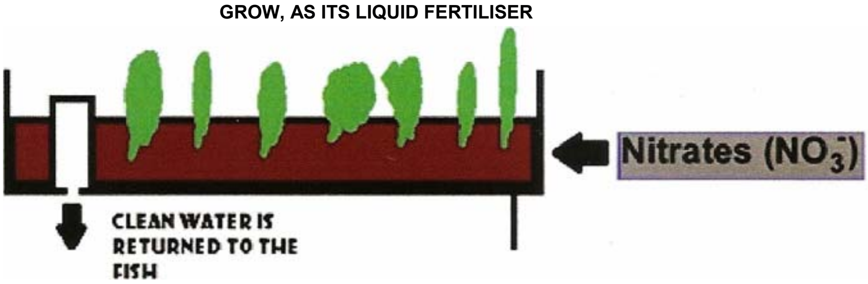
Nitrates are not highly toxic to fish in low to moderate levels. However, if nitrate levels rise to beyond 100ppm (parts per million), it is dangerous for fish.

Nitrobacter grow in a pH range of 5.8 -8.5 and has a pH optima between 7.6 and 7.8.

Plants & the Nitrogen Cycle

In an aquarium, regular water changes are required to reduce the NO_2- & NO_3-levels in the tank. However, in an aquaponics system, the nitrogen cycle is completed through the process of passing water onto the plants. By supplying plants the nitrate (NO_3-) rich water, they obtain a majority of the nutrients needed to grow. Most common fertilizers used in cultivating vegetables contain nitrates.

THE PLANTS ABSORB THE NITRATES TO GROW, AS ITS LIQUID FERTILISER



THE WATER IS PUMPED INTO THE GROW BED WHERE IT IS BROKEN DOWN INTO THE NITRATE FOR THE PLANTS

Figure 2: Plants in the nitrogen cycle

In an aquaponics system, after the plants absorb the nitrates the clean water is then passed back to the fish. This effectively eliminates the need to do water changes and therefore reduces the need for water replacement in fish tanks. In addition, it reduces the amount of water that plants need to grow because aquaponics is a closed system.

Compared to conventional vegetable-growing processes in the ground, aquaponics uses about 1/10th the water. There is some water lost in an aquaponics system, but this is generally through evaporation and transpiration.

Exercise 2

Discuss the importance and implications of the nitrogen cycle. One of the most vital, yet the least visible elements of the nitrogen cycle are the bacteria. Discuss what you think might happen when you put fish into a new aquaponics system without the bacteria present.

To help the discussion you might like to think about these questions:

- Where do bacteria come from? Can you help grow bacteria in your system?
- How long do you think it takes for the bacteria to develop?
- How long is the optimal time before adding fish to a new system?
- What temperatures are needed for bacteria?
- What might happen to bacteria during summer or winter?
- Where are the different places bacteria might develop in an aquaponics system?

Types and styles of aquaponics systems

There are three types of systems that are used in contemporary aquaponics ..

1. Gravel bed systems
2. Floating raft
3. NFT (Nutrient Film Technique)

All three systems have one common element, the fish tank. The difference is in the place where the vegetables grow.

The gravel bed system

Figure 3: Gravel bed System

In this system the vegetables grow in a bed of gravel, clay pebbles, rice husks, etc. The media acts as a place the vegetables can grow in and have support.

Sludge and waste from the fish tank gets pumped into the grow bed with the media. In the grow media the bacteria processes the waste, thereby acting as a biofilter and eliminating the need to remove the solids in a separate system.

These systems are known as "Flood and Drain" (also known as Ebb and Flow), and as the name suggests the water slowly fills up the grow bed and then a syphon drains it out to the fish tank or sump.

Some small systems do not need a syphon and the water can just flow out to the fish tank.

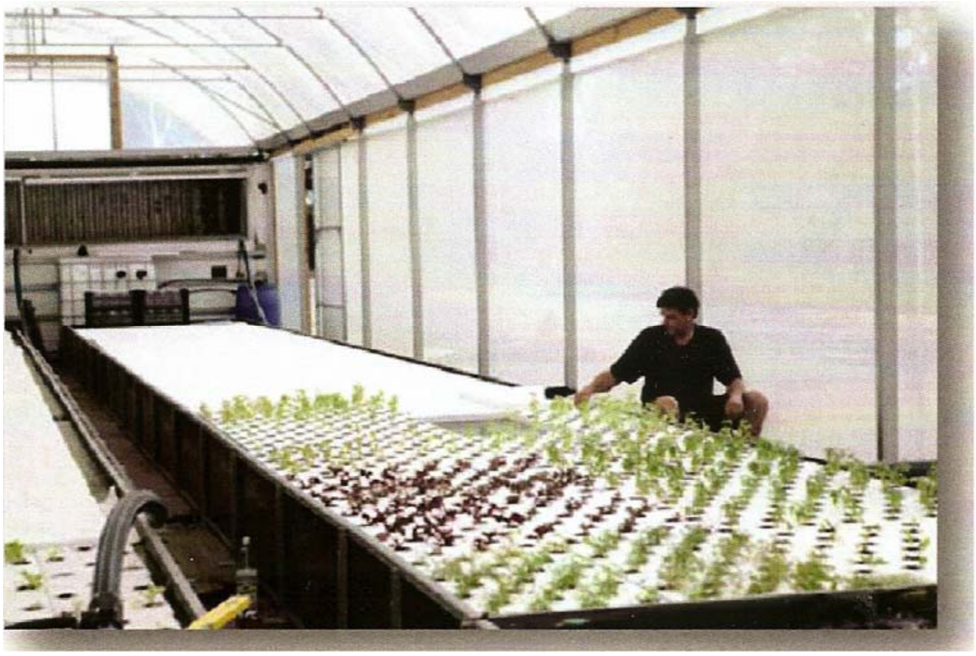
The important things to remember in selecting the media are:

- Is it easy to handle?
- Is it easy to clean?
- Does it have enough surface area for the bacteria to develop on?
- Does it allow for easy drainage?
- Is it expensive?
- Will it affect the pH?
- Will it introduce elements to the water that will affect the fish and or plants?
- Will it block the system?

The gravel bed does three major jobs:

1. It acts as a solids separation filter by removing solids particles from the water via mechanical screening
2. It acts as a solids mineralization area whereby solids are broken down into nutrients
3. It acts as the bio filter whereby dissolved ammonia is converted to nitrite then to nitrate

The floating raft system



(CERES Aquaponics System) http://wwwJlickr.com/photos/ceresgreentech/sets/72157625982336819/showl

In this system the vegetables float on a styrofoam raft. The rafts have small holes cut in them where plants are placed into net pots. The roots hang free in the water and allow the uptake of nutrients to occur.

The water level beneath the rafts is anywhere from 25 to 50 cm deep and as a result the volume of water is approximately four times greater than other systems. This higher volume of water results in lower nutrient concentrations and so higher feeding rate ratios are used. Bacteria form on the bottom surface of the rafts but generally, a separate biofilter is needed.

The NFT (Nutrient Film Technique) system

(Challenger Institute of Technology Aquaponics installation)

NFT consists of the plant roots sitting in a thin layer of nutrient water that runs through a PVC pipe. The shallow flow of nutrient water only reaches the bottom of the roots that develop in the trough. The top of the root mass is exposed to the air, therefore the plants receives adequate oxygen supply. Channel slope, length and flow rate must all be calculated to make sure the plants receive sufficient water, oxygen and nutrients. If properly constructed, an NFT system can sustain very high plant densities. In aquaponics NFT systems, a separate biofilter is crucial as there is no large surface area whereby bacteria communities can develop.

Pros and cons of the three systems

- NFT and media beds absorb lot of heat and transfer it to the water.
- Floating raft systems have a constant flow of water that tends to regulate temperature.
- NFT and raft styles require pre-filtration of solids and additional aeration
- Grow Beds have a higher volume water return and/or oxygen draw down through the media.
- Grow bed media can move through the system and block pipes.
- NFT and floating raft systems require a separate biofilter as an additional cost.

Exercise 3

Assess the above pros and cons list and determine which ones are cons and which are pros and which might be both? Also discuss if there might be other benefits or issues for the three system types?

Building your own system

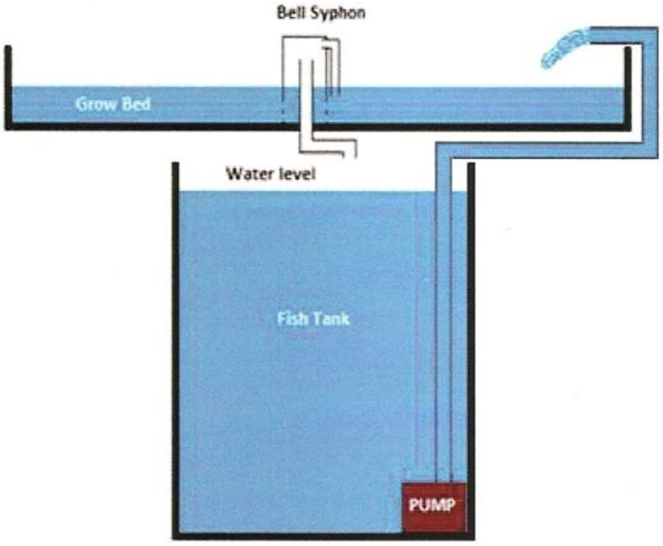


Figure 4 A gravel bed system

There are some basic elements common to all systems:

1. Fish Tank

The size of the tank will depend on the number of fish in the system. Fish tank size also defines the volume of area for the plants in the grow bed. e.g. generally a 500L fish tank will allow for a 500L grow bed. The smaller the tank, the less area for the grow bed.

A fish tank and/or grow bed can be easily built using an IBC (Intermediate Bulk Containers). IBCs often live their first life as a container of motor oil, glycerin, detergents, molasses or other substances used in commercial processes. It is imperative to clean the IBC thoroughly. It is also recommended to find out what the IBC contained previously, if you can. Any chemical residue left in an IBC can be fatal to fish and plants.

Other ideas for fish tanks are:

- Old bath tubs
- Drums
- Ponds
- Any container that can hold a volume of water

2. Pump

A 500L fish tank with a 500L grow bed needs to have water pumped at a rate of 500L per hour. The volume of the water in the fish tank needs to cycle through the system every hour.

Pumps can be obtained from aquarium stores, as well as Bunnings, pond shops, boating stores and aquaponics stores online. A Google search of pumps will provide many results.

The things to always remember are:

- Head level of the pump is how high it can pump water and at what rate it can pump at that height. Information about pump capacity can be in per hour or per minute. To calculate 500L moved in 60 minutes is 500/60 = 8.33L per min. So, the pump must do at least 8.33L per min to the height of your grow bed for it to be effective.
- Always try and get a pump that uses less wattage. The pump runs 24/7, so if the pump is 200W then the electricity used is 0.2 kW per hour. This is 4.8 kW per day, 33.6 kW per week and 1747.2 kW per year. This can cost approximately $380/year at current electricity prices. Pond pumps can range from as low as 10W:

3. Pipes, hoses and connectors

Pipes, hoses and connectors are used to allow for the movement of water through the system.

Pipe and fitting kits can be obtained from Bunnings or a local hardware store. However, it is important to make sure the pipes and hoses are safe for drinking water. Some PVC pipes contain lead, although almost all PVC pipe sold in Australia are lead free. However, the connectors might not be. Check first.

Other elements of an aquaponics system

In a gravel bed system other elements required are:

- Gravel bed using hydroton ŧ or other grow media
- Bell syphon or other type of syphon

A floating raft system needs:

- Polystyrene sheets
- Net pots
- Biofilter
- Aerator

The NFT system needs:

- Lots of PVC pipes
- Biofilter
- Aerator

* I use a pump that does 4500lt at 60W. Over 1 year the use is 524.16 kW or about $115.

ŧ Hydroton is a clay based media that allows bacteria to grow in it. Available from hydroponics stores.

Using a sump

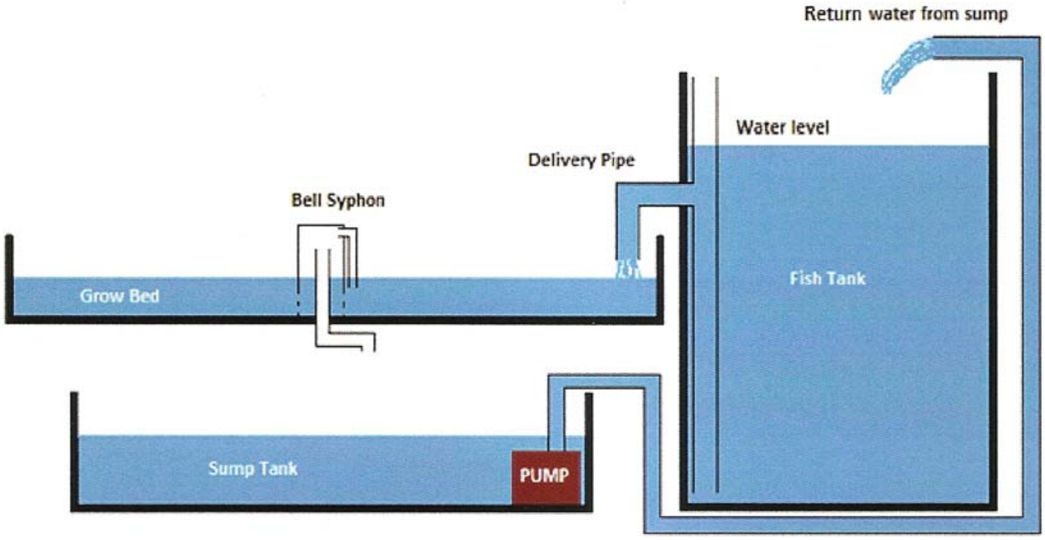


Figure 5 A sump system

Some systems are designed with a sump because the sump can be used to collect water from multiple grow beds. This system is mainly used in NFT and floating raft systems where the sump is used as the place where waste is broken down rather than in the grow bed.

The only difference from the basic system when using a sump is that the pump is in the sump.

You can buy an aquaponics systems from a few places:

- Alfcon's Aquaponics
- Backyard Aquaponics
- Practical Aquaponics for Everyone
- Sunshine Coast Aquaponics

Some suppliers do not provide the expanded clay or hydroton. These supplies can be sourced from hydroponics stores.

Some suppliers also include bacteria starter liquid/nutrient starter. These are only needed to kick start the system quickly. Compare the prices to that of aquarium and hydroponics stores before buying.

An aerator kit with tube and air stones can be sourced from aquarium stores. The aerator adds extra oxygen into the system. Plants and fish require oxygen.

2.

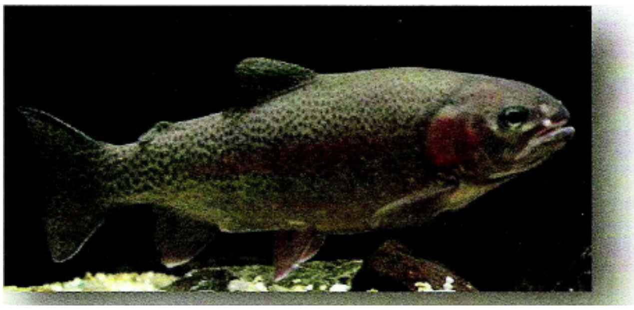
Exercise 4

Name 10 types of containers that could be used to build an aquaponics system. i.e. bathtub, bucket. Then use your imagination and design a system for caravan, or a balcony of a high rise flat, or a steep hill or even a system built into a wall in a house. Think of an inspired place for aquaponics and draw the most ideal system that utilizes some of the containers you have identified in your list.

Adding fish

An aquaponics system is nothing without fish. There is one important question to answer before stocking the tank with fish:

"Will the fish be for eating or not?"



Rainbow Trout (opencage.info)

Most people stock the tank with fish that can be eaten. However, in real terms, any fish that will live in fresh water will do. Vegetarians, vegans and others who do not want to eat the fish in their systems often stock with goldfish or Koi. The following section discusses the types of and factors relating to eating fish that are good in aquaponics systems. These fish can also be used for ornamental aquaponics systems.

Choosing a type of fish

The choice of fish is dependent on two factors, namely:

1. The temperature, i.e. time of year
2. What you want to eat?

Below is a standard list offish used in aquaponics:

Barramundi	Catfish
Carp‡	Jade Perch
Murray Cod	Silver Perch
Trout	

Fish have different tolerances for temperature. For optimal production of waste, as well as good eating, the preference for aquaponics is to stock different fish at different times of the year. In spring, it makes sense to stock fish that require warmer water such as barramundi or jade perch. In autumn barramundi can be harvested and it would be the ideal season to stock trout.

An alternative to rotation of fish stock is keep fish that can survive the cold as well as the hot weather, such as silver perch or jade perch. However, this practice is not without its troubles, particularly in climates where there are more extreme seasons, such as in Victoria and Tasmania in winter and Queensland and Western Australia in summer.

Each type of fish has its optimal conditions. A list of these conditions can be found in Appendix A.

‡ Also known as common, European, German, Great and Chinese carp. In Victoria carp is considered a noxious pest. According to some sources it is illegal to hold live carp, regardless of whether it is in an aquarium or not. See: http://www.biotechnologyoniine.gov.au/enviro/carp.htmi

When to add fish to the system

Many people new to aquaponics are new to fish and expect fish to do well in a new, clean tank. However, this is not the case. The fresh water eating fish are actually not as hardy as people might think.[§] Preparing a tank for fish is a vital part of the process of setting up a system. There are many stories out there about dead fish in new systems.

Preparing a new tank for fish is called 'seeding' and there are four basic ways to do it:

1. Add bacteria starter liquid to the system

This will kick start the bacteria and nitrogen cycle in the system. Using this method can mean it can take as little as 24 hours for the system to be ready for fish. However, the water also needs to also be at the correct chemical levels. This quick and easy start is not often the most ideal and can still result in higher fatalities.

2. Add a fish straight away when it dies

This solution is good if you already have fish. What happens is the fish decomposes in the water and it kick starts the nitrogen cycle. However, this solution is slow 'wait and see' as it takes about 4- 6 weeks for the bacteria to develop.[#]

3. Add small amounts of fish food every two days

Adding fish food also helps kick start the nitrogen cycle. Fish food provides nutrients for the bacteria to start growing. But, as with the solution above, it still takes a long time for the tank to be ready for fish. Approximately 4-6 weeks.

4. Add media and/or water from another aquaponics system

This is the fastest and safest way to get a new system up and running. In reality, a fish tank can be stocked with fish when ammonia and nitrite is at zero after adding a starter culture. The starter culture can be the liquid, dead fish or fish food. Check the water every two days with an aquarium test kit to see if the numbers are right. As soon as they are, add fish!

How to add fish to the system

When introducing new fish into a tank, place the fish still in their transport bag, into the tank unopened. This is to allow the temperature of the water in the bag to adjust to the water of the tank. After about 15 to 30min add some water from the tank into the bag; which helps the fish to get adjusted to the water conditions of the tank. Repeat this process every 5 minutes at least another two times and then release the fish.

[§] Goldfish and Koi are a little more hardy, but it is still possible to endure fatalities if the water is not prepared.

[#] Although it seems like a long time to wait to get a system at optimal before stocking it with fish, it is worth the wait. Small, non-flowering plants, such as lettuce can be grown in a system without fish in the meantime.

Where can I get fish from?

Fish can be purchased as fingerlings. Sometimes larger fish are also for sale at hatcheries. Another alternative is to catch fish in the wild and milk them for eggs, but this is not as easy as it sounds. Buying fingerlings from fisheries in Victoria is the recommended option and there is a list of fisheries and the types of fish they stock in Appendix B.

Water quality

The best way to test the quality of the water in an aquaponics system is to buy a water test kit. There is a master test kit for about $45 that will do over 800 tests.

There are also individual kits that test for specific things such as pH. These basic tests should be conducted weekly to ensure the major elements of the nitrogen cycle are running smoothly.

The basic tests are:

- pH value (pH)
- ammonium/ammonia (NH4/NH3)
- nitrite (N02)
- nitrate (N03)

More detailed tests are recommended when maintaining water quality where both fish and plants are involved:

- pH value (pH)
- Nitrite (N02)
- Nitrate (N03)
- Ammonium/ammonia (NH4/NH3)
- DO (Dissolved Oxygen)
- Total hardness (GH)
- Carbonate hardness (KH)
- Phosphate (P04)
- Iron (Fe) d
- Chlorine (Cl)

Water tests

pH

There is a delicate balance needed for pH as often what plants and bacteria need are not what fish like. Added to this, above a pH of 7 (neutral), nutrients often get locked out. (See figure 6)

Plants prefer a pH of around 6 so that they can take up certain nutrient (with a range from 4.5-7.0). Fish often prefer a pH of around 7 (with a range from 6.8-7.2). Bacteria prefer a range from 6.0-8.0.

pH testing is one of the most essential and regular checks for an aqua panics system. The

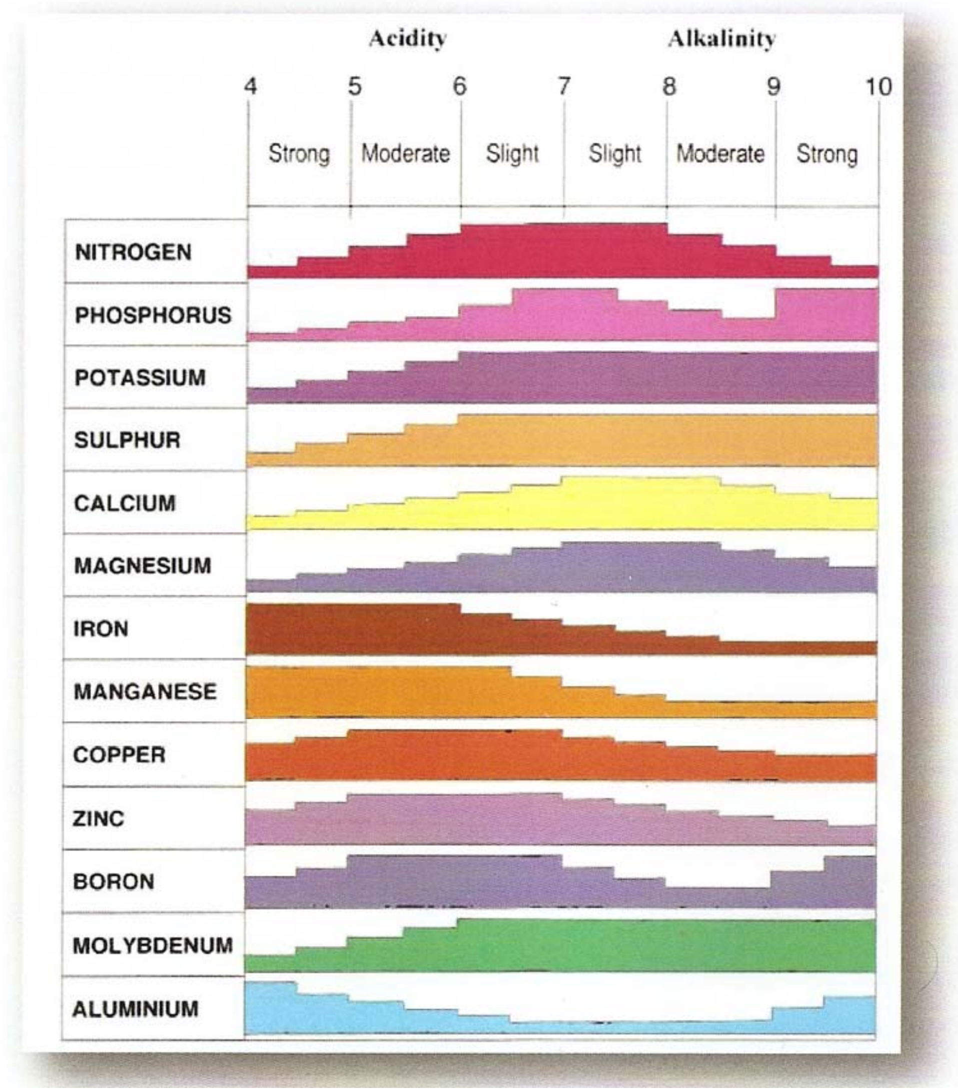


Figure 6 pH nutrient uptake chart http://aquaponicscommunity.com/profiles/blogs/chelated-iron

DO (Dissolved Oxygen)

Obviously, fish need oxygen to breathe; plants need oxygen at night and the beneficial bacteria need oxygen to break down (oxygenate) waste. Basically, everything that dies off or decays in the aquarium requires and therefore depletes oxygen. Unhealthy or dead plants, decaying live rock and live sand and uneaten food all suck oxygen out of the water. Organic acids, proteins and carbohydrates can also reduce the oxygen level in the aquarium.

Oxygen enters the water through gas exchange via surface agitation in aquaponics systems. The amount of oxygen that can be dissolved (saturated) in the water is dependent on the water temperature. Increasing temperatures decreases oxygen saturation.

The following table shows saturation levels at different temperatures.

C	0	C	0	C	0
0	14.60	**16**	9.85	**30**	7.54
1	14.19	**17**	9.65	**31**	7.41
2	13.81	**18**	9.45	**32**	7.28
3	13.44	**19**	9.26	**33**	7.16
4	13.09	**20**	9.07	**34**	7.05
5	12.12	**21**	8.90	**35**	6.93
8	11.83	**22**	8.72	**36**	6.82
9	11.55	**23**	8.56	**37**	6.71
10	11.27	**24**	8.40	**38**	6.61
11	11.01	**25**	8.24	**39**	6.51
12	10.76	**26**	8.09	**40**	6.41
13	10.52	**27**	7.95	**41**	6.31
14	10.29	**28**	7.81	**42**	6.22
15	10.07	**29**	7.67	**43**	6.13

Figure 7 Dissolved Oxygen Chart

For example, a freshwater aquarium with a temperature of 24 C can dissolve 8.4 ppm of oxygen.

Low oxygen levels in the fish tank will result in fish attempting to 'breathe' faster than normal resulting in chronic stress and eventual fish deaths. Different fish require different amounts of dissolved oxygen in the water. Adequate aeration is essential for the fish tank at all times and especially during warmer summer months as the water temperature rises.

Total hardness (GH) & Carbonate hardness (KH)

Water hardness is about dissolved minerals. The total hardness is usually regarded as consisting of two components: general hardness (GH) and carbonate hardness (KH).

General hardness (GH) is primarily caused by calcium and magnesium; which are divalent (which means a molecule that has a valence of two) metal ions.

Carbonate hardness (KH) represents the main 'buffering capacity' of the water, i.e. its ability to resist pH changes. Carbonate hardness is due to carbonate/bicarbonate ions (CaC03). KH is the term often used to describe the amount or degree of carbonate hardness.[††] Because carbonate hardness helps the water to resist pH changes, KH and pH is closely inter-related, i.e. if KH is high, the pH will be very stable. If KH is low then the pH will be less stable. Generally, less than 3 degrees KH means the pH will be less stable.

Degrees of Hardness	mg/l $CaC0_3$	Described as:
0- 4 dH	0- 70 ppm	very soft
4 - 8 dH	70 - 140 ppm	soft
8 -12 dH	140 - 210 ppm	medium hard
12-18dH	210 - 320 ppm	fairly hard
18 - 30 dH	320 - 530 ppm	hard

Figure 8 Water Hardness Chart

General hardness (GH) is the more important of the two in biological processes. When a fish or plant is said to prefer "hard" or "soft" water, this is referring to GH. Incorrect GH will affect the transfer of nutrients and waste products through cell membranes and can affect growth.

Decreasing hardness can be done through dilution, such as adding rain water to tap water. Increasing hardness can be done through adding limestone rock or coral gravel. For both cases there are chemical additives available.

Phosphate (P04)

Phosphate deficiencies impact on effective root growth and bud development and can result in poor seed development, fruit quality and size. These symptoms can be a result of other nutrient deficiencies, such as lack of nitrogen and potassium.

Excess phosphorus can also cause a deficiency in other nutrients, in particular iron and zinc and also induce potassium (K) deficiency.

Iron (Fe)

Yellowing leaves on plants means iron (Fe) needs to be added to the system. Iron deficiency is often a caused by high pH; which means pH balance is essential to the system. The way to add iron to a fish tank is by adding chelated iron from a garden supply shop. Others swear that worm tea has enough micronutrients, including iron, and add that to the fish tank. However, there are some issues with worm tea.

Chlorine (Cl)

Chlorine is often added to tap (drinking) water to kill bacteria and ensure that it is safe for human consumption. However, chlorine is not desirable in aquaponics systems for two

[††] KH or the degrees of hardness is often measured differently in different places around the world. Carbonate hardness is temporary and can be changes fairly easily, particularly through boiling of the water, where the carbonates disappear in the steam.

reasons. Firstly, it damages the gills of the fish which ultimately kills them. Secondly it is fatal for beneficial bacteria (which is why chlorine is used in drinking water remember?).

Chlorine must be removed from the water before adding it to the aquaponics system. Chlorine is added to drinking water in one of two ways; either as chlorine gas, or chloramine.

Standing water into a bucket or container for a couple of days will dissipate chlorine gas. Chloramine needs to be removed using store bought water conditioners or neutralizers.

If a water conditioner or chlorine neutralizer is purchased, it is essential to ensure that it is suitable for use with fish intended for human consumption.

When to add plants

In this course, it is recommended to add plants to the system when the nitrate levels are at about 30 - 40ppm. At lower levels, there are not enough nutrients in the water to constantly sustain the plants. Plants added too early begin to yellow and suffer a slow growth rate and sometimes develop diseases.

Adding plants to a system is also a consideration during harvesting. It is recommended in this course to not remove all plants at once when harvesting, but rather to harvest when needed and make sure to replace the harvested plants with a new seedling. Removal of too many plants at once could result in a nitrate increase that could kill the fish.

The same advice applies to fish; after removing fish ensure to replace them with fingerlings or other fish as soon as possible. This practice will ensure the system is in constant production and is balanced. Removal of most of the fish might result in not enough nutrients for the plants.

Remember: aquaponics is about a balanced eco system.

What types of plants?

This simple question is one that many people in aquaponics tend to argue the most about. Basically, leafy green vegetables, vine plants, fruit and fruit trees, and some root vegetables can all grow in an aquaponics system. It just depends on the system. Below is a list of plants that thrive in aquaponics systems:

Simpson's Curled (Lettuce)
Oregon Sugar Pod (Peas)
Bloomsdale Savoy (Spinach)
White Bunching (Onion)
Tomato (Grosse Lisse)
Tomato (Beefsteak)
Rainbow Chard
Numerous tomato varieties (the only tomato variety that hasn't grown well was pineapple)
Watercress
Chives (normal and garlic variety)
Celery
Cicoria Variegata
Capsicum (Californian wonder, Yolo wonder, Long sweet yellow)
Bok Choy
Broccoli
Rocket
Garlic
Sage
Yarrow

Cucumber (Lebanese)
Silver Beet (Giant Fordhook)
Lettuce (Cos)
Lettuce (All seasons)
Basil (Sweet green, purple, curly leaf and Thai)
Snow peas
Parsley (Flat leaf and curly leaf)
Yugoslavian watercress (also known as Lebanese watercress or Bulgarian watercress)
Chillies, many varieties
Kohl Rabi (Purple vienna)

Eggplant (Black beauty)
Cucumber (Burpless, Armenian)
Rockmelon
Cabbage
Mizuna
Coriander
Dwarf beans (Butter beans)
is I^{2}S Lemongrass
Comfrey

How to prepare plants and grow from seed

In an ebb and flow system, it is possible to sprinkle the seeds on the hydrotron and wait for seedlings (the birds will be waiting too). However, a higher rate success rate is more likely when using a seeding material.

Horticubes, a small oasis-like material for seed sprouting, or rock wool cubes are very good seedings materials used for seed sprouting, planting and growing in gravel.

Some seeds are more successfully sprouted indoors and then transplanted outdoors when they have started to produce leaves. Indoors provides a much more controlled environment for hard to sprout seeds where it is easier to control temperature, moisture and fertility. Growing seeds inside also means being able to get a jump start on the season. This means that more mature seedlings can be planted as soon as the weather is right. Plants that do with being moved are broccoli, Brussels sprouts, cabbage, cauliflower, celery, eggplant, leeks, onions, parsley, peppers, and tomatoes.

However, some vegetables do not like to be transplanted. Generally, these are root vegetables, such as carrots, beets, turnips and parsnips. Other more delicate plants include corn, beans, and peas.

Exercise 5

Discuss the following:

- What type of fish and plants are you thinking of growing?
- Can you transport the fish?
- What are the pros and cons for buying fish fingerlings as opposed to fish eggs?
- What might you need to transport fish long distances (over an hour)?
- Which system is better to grow plants from seed?

System maintenance

Water temperature

Different species of fish require different water temperatures and conditions. Information about fish requirements are in Appendix A. Water temperature fluctuations need to be kept at a minimum. A larger volume of water of 1,000L and more will offer stability and reduce sudden temperature changes in your system.

In summer on hot days the grow bed can heat up and the heat is then transferred to the water, when that water is passed back to the fish it can affect some fish.

In winter on cold days the grow bed can cool down and the water becomes colder, when that water is passed back to the fish it can affect some fish.

Water quality

Ammonia

High ammonia levels, from 2ppm, are toxic to fish. If the system is new or not fully cycled, or the fish are overfed, sudden spikes in ammonia levels, especially when temperature conditions are warmer than normal, can kill fish very quickly. Test for ammonia regularly if the system is new or if the fish have been overfed. Many people tend to overfeed their fish. Fish can actually go for a number of days without food.

Nitrate

Although high nitrate levels won't kill the fish, they will feel the impact of nitrates by the time the levels reach 100ppm, particularly if levels remain there for some time. Some fish can survive in higher levels of nitrate, but its best to research the nitrate levels the fish can tolerate. The resulting stress leaves the fish more susceptible to disease. A high nitrate reading means either to reduce the number of fish in the tank, or add more grow-beds and increase your number of plants to suck up the excess nutrients.

An aquaponics system in balance has low to nil nitrate readings and is a picture of lush vegetation. Plant growth will give a good indication of the health of the system.

pH level

An aquaponics system is a trade-off between the ideal pH range that the fish prefer (7-7.5) and the ideal range that the plants prefer (mid 6's). A pH around the mid 6.4 to 7 is the ideal range to keep both fish and plants happy. Outside these parameters, the fish health will begin to strain a little and the plants ability to take up the range of nutrients will be severely diminished. Monitor pH regularly to ensure the system is running at peak capacity.

On an established system, the water should be tested once every week to ensure any issues are caught before it kills fish, plants or bacteria.

Fish stress

Maintaining happy fish means an aquaponics system is in balance. Stress will kill fish or reduce their life span and also cause disease.

Poor water quality

Poor water condition is often due to lack of good filtration. Filtration that can handle the volume of fish waste and uneaten food in the fish tank is essential.

More is always better then less when it comes to filtration and the volume of water pumped through the filtration. Inadequate filtration meant that there is an inadequate volume of bacteria to convert the waste and uneaten food. This leads to an increase in ammonia or nitrite, this can be seen at extreme levels as murky or cloudy water. At this point water changes become necessary if the levels of water impurities rise too high. Stop feeding the fish and do partial water change.

Bad smells mean there are problems in the tank, and fast action is required otherwise fish will die. Remove uneaten food from the bottom of the tank as it will start to decompose and result in a build-up of ammonia in the system.

Transportation

Fish do not enjoy travelling. Transporting large numbers of fish can have a drastic effect on their slime coat, leading to weakening their immune system.

Handling Fish

Fish do not like to be handled or moved by force. Leaving them undisturbed is better for their health. When catching them for eating or moving, ensure to use the proper weave of net to prevent the fish from being snared.

Salt baths alleviate stress

Salt baths are can be used as a tonic to treat parasites that may be lurking on fish.

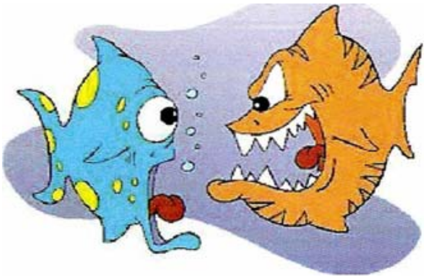
Salt is also used to de-stress fish. Fish actually contain levels of sodium in their systems. When fish are stressed they react by excreting minerals into the water. If this continues, then the salt loss can prove fatal. The treatment is to add a little salt to fish tank water. The concentration of salt in the water is related to the continued excrement of minerals by the fish, so increasing the water salinity reduces salt excretion and stress for the fish. Recommended salinity levels are in the range of 0.5-3 ppt.

However, be aware that adding salt into a system can affect other parts of the system. Some plants, such as strawberries, will not tolerate salt levels beyond 3 ppt. Do not dose higher than recommended as this will also kill both the fish and plants.

Low oxygen levels

Low oxygen levels in the water can cause chronic stress and eventual fish fatalities because the fish are trying to breathe faster than normal to get more oxygen. Different fish require different amounts of dissolved oxygen in the water. Trout requirements are 6ppm of dissolved oxygen. Other ‘hardier’ fish require less. Adequate aeration of the fish water is essential at all times, but especially during warmer summer months as dissolved oxygen is more difficult to saturate the water as the water temperature rises.

Harassment from other fish



Some fish are predatory and territorial and will attack and/or eat other fish in the tank. However, mixing of some compatible fish species can work out. It is recommended in this course to stock the tank with only one type of fish species for maximum ease of management. Choosing fish food and monitoring feeding is easier if only once species is stocked in the tank.

Overstocking of tank

Overstocking results in increasing poor water quality as the fish mature. Also as the fish mature there is a much greater demand on oxygen and this will place a limit to the system's capacity to meet that need.

Disturbance of the tank

It is recommended to keep the fish tank as protected from light and noise as much as possible. Fish have been known to kill themselves by leaping against the sides or even out ofthe tank when disturbed by light and/or noise. A lidded tank is ideal.

Lack of enough fish to provide schooling

Fish generally feel happier in a large group where they can be close together. Schooling fish are happy fish. The tank needs to have enough fish to ensure that the fish can feel safe in their group.

Moving plants around

Some people say that moving plants around the grow bed is fine. Others say that this puts undue stress on the plants. When the roots of a plant are disturbed they broken off in the gravel beds or the side of the walls in raft and NFT systems. This will allow for the chance for disease to occur in the plant.

Best not to move them once they are in the system. Plan ahead as to the best place to plant the different plants as to the direction of the sun, the height of the plants so you do not have to move them.

Growing and harvesting

When can I harvest fish?

If there are 20 fish in a 600L tank some fish will grow faster than others; there will always be some fish that feed more food and grow faster. This is good news because it means that the fish can be harvested over time; usually a month. It is best to harvest fish at eating at plate size; 300 - 500grams. To grow to this size, it can take 9 to 12 months, depending on the type of fish.

Remember when re-stocking that some species are aggressive and will eater smaller fish.

How do I kill fish humanely?

According the RSPCA (see: http://kb.rspca.org.au/What-is-the-most-humane-way-to-kill-a-fish-intended-for-eating_ 451.html) the most humane way to kill fish for human consumption is to strike them a fatal blow and then bleed them out.

On their website, they describe the process in detail, but the overall idea is to stun the fish as soon as it is out of the water either with percussive stunning, which involves hitting the fish just above the eyes with a blunt instrument; or spiking, which is using an ice pick or sharpened screwdriver into the brain of the fish. After stunning or spiking the fish needs to be immediately bled out by cutting the gill rakers or main artery.

Exercise 6

Think back on all discussions you have had before about design, type and requirements. Have you changed your mind about anything? How much time do you think is needed to maintain an aquaponics system? How scalable do you think they are? How many beds would you need to feed your family? You might want to think about greenhouses and if you want to use one and how it might work.

Summary - aquaponics basics

- Hot water drives oxygen out of the water.
- Most plants prefer the temperature of the water to be less than 20 degrees.
- Fish cannot regulate their body temperature; whatever the temperature is of the tank water is the temperature of the fish.
- Fish require 75% less energy than what humans do to feed.
- The level for oxygen for an aquaponics system is always set by the fish as they require the most oxygen (10mg per litre at 8 degrees Celsius)
- In a gravel bed system when the water is pulled out by the action of the syphon, it pulls the air in to the system and brings oxygen down to the roots of the plants.
- When bubbles come out of an air stone, it's not the bubbles that add oxygen to a system; it's when the bubbles break the surface.
- pH is important because if the water is too acid or too alkaline, it will affect the fish and plants and bacteria.
- A sick fish means a sick tank.
- It is important to start with high quality seeds as this leads to efficient germination and high quality plants
- Plants require 13 nutrients for growth. Generally, calcium, potassium and iron will need to be added to aquaponics systems.
- Design the system so that it only needs one pump and let gravity do most of the work.
- It is very easy to over feed fish and although uneaten fish food can contribute to the nitrogen cycle, it can also cause serious problems. Observation is the best method to ensure that fish are not overfed. If there is uneaten food after 20 minutes, then the fish have been fed too much. Continue to observe as the fish grow.
- Uneaten food should be removed from the tank.

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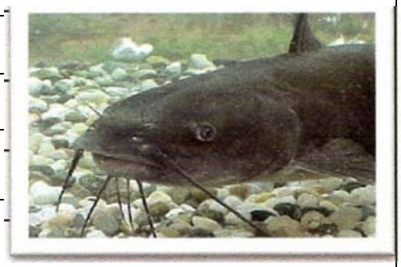
Appendix A

Goldfish	
Size:	40-50 cm
Weight:	Up to 1kg
Life span:	10 years+
Optimum water temp:	16°C - 24°C
Will survive in water:	>8°C
Fish stops feeding:	<6°C
Fish die:	<6°C
pH ideal:	7.0-7.5
pH tolerant:	6-8
Hardness:	>150ppm
Food:	Goldfish will consume almost anything. The kind of food goldfish will eat includes flakes, cooked peas, and insect larvae. Flake food often is preferred over pellet food due to the fact that they are easier for the goldfish to see and to clean after.
Habitat:	Goldfish live in ponds, or small lakes of fresh water

Murray Cod	
Size:	Up to 100cm
Weight:	Up to 130kg
Life span:	70 years or more
Optimum water temp:	24°C
Will survive in water:	2°C - 30°C
Fish stops feeding:	
Fish die:	
pH ideal:	5.8-6.5
pH tolerant:	5.5-9.0
Hardness:	20 - 400ppm
Food:	Murray cod have a varied diet of other fish, spiny freshwater crayfish, Yabbies. Shrimp, freshwater mussels, frogs, water fowl, small mammals, tortoises and other reptiles. Virtually anything within its realm that moves and is small enough to fit in its cavernous mouth is considered fair game! (Top Predator)
Habitat:	Murray cod are remarkable by any ecologist's standards in their adaptability and the diversity of habitats they occupy. Murray cod habitat varies greatly, from quite small clear, rocky, upland streams with riffle and pool structure on the upper western slopes of the Great Dividing Range to large, meandering, slow-flowing, often silty rivers in the alluvial lowland reaches of the Murray-Darling Basin.

Koi	
Size:	Up to 2m long
Weight:	Up to 90.9 kg
Life span:	47 years
Optimum water temp:	20°C - 25°C
Will survive in water:	10°C - 30°C
Fish stops feeding:	12°C
Fish die:	2°C
pH ideal:	7.5
pH tolerant:	6.5 - 9.0
Hardness:	75 -150 ppm
Food:	Omnivorous Will eat a wide variety of foods, including peas, lettuce, and watermelon. In the winter, their digestive systems slow nearly to a halt, and they eat very little, perhaps no more than nibbles of algae from the bottom.
Habitat:	Koi are a domestic variety of fish, so they don't really have a "natural" habitat. Koi normally live in ponds, and sometimes lakes, with moderate to strong water current. Koi normally live in fairly cool water, but they can tolerate warm water for part of the year.

Catfish	
Size:	Up to 3 m but growing smaller in captivity
Weight:	Up to over 150 kg
Life span:	30 years
Optimum water temp:	29.5°C
Will survive in water:	20°C - 35°C
Fish stops feeding:	10°C
Fish die:	8°C
pH ideal:	Best at a pH between 5.0 and 7.0 - slightly acidic
pH tolerant:	
Hardness:	
Food:	Catfish are carnivores which follow the food sources. Generally, they are a bottom species but will quite happily feed at the surface if food is available there. Generally, they eat a broad range of food, Yabbies and shrimp are the main ones, but worms, fish, insect larvae, tadpoles, frogs and snails etc are all consumed.
Habitat:	Wide natural distribution in the Murray-Darling River system, also found in streams along the NSW north coast, south to the Shoalhaven River. Prefers sluggish or still waters of rivers, creeks and billabongs. Spawning takes place from late spring until mid-summer following complex courtships, usually in nests up to 200 cm in diameter built of pebbles or gravel. Fertilised eggs are guarded by one of the parents and aerated by fanning with their tail. Generally, bottom feeders, taking molluscs, crustaceans, insect larvae and small fishes.

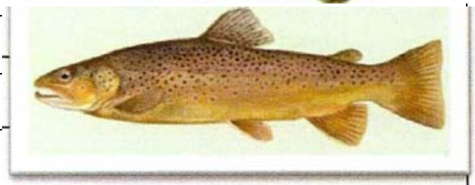


Jade Perch	
Size:	36cm -40cm
Weight:	1kg - 2kg
Life span:	3 years
Optimum water temp:	22°C - 28°C
Will survive in water:	15°C - 40°C
Fish growth stops below	18°C
Fish stops feeding:	16°C
Fish die:	10°C
pH ideal:	6.5 - 8.5
pH tolerant:	6.0 - 9.0
Hardness:	>80ppm
Food:	Omnivorous. Jade Perch are omnivores which survive on a wide variety of foods, such as zooplankton, small crustaceans, aquatic insects, molluscs, algae, duck weed and other plant material.
Habitat:	Typically found in large permanent and semi-permanent waterholes in the major rivers and their larger tributaries. In captivity they are omnivorous.

Barramundi	
Size:	Up to 150 cm
Weight:	400 - 600g within 12 months (3 kg within 18-24 months)
Life span:	They start living their lives as males and become females around 3-5 years.
Optimum water temp:	28°C
Will survive in water:	18°C - 38°C
Fish growth stops below	18°C
Fish stops feeding:	18°C
Fish die:	15°C
pH ideal:	7.0 - 8.5
pH tolerant:	
Hardness:	>100ppm
Food:	Omnivorous. They feed on live mullets, prawns and some other small live fishes.
Habitat:	They can be found in estuaries, near mangroves and coastal waters usually close to the shore. They live between fresh and saltwater preferring warmer brackish waters. Sometimes they can be found moving upstream into freshwater streams and rivers, especially the young of about 6 - 8 months.

Silver Perch	
Size:	40cm
Weight:	1kg to 2kg
Life span:	6 - 12 years
Optimum water temp:	24°C
Will survive in water:	12°C - 35°C
Fish growth stops below	15°C
Fish stops feeding:	15°C
Fish die:	5°C
pH ideal:	6.5 - 8.0
pH tolerant:	
Hardness:	>150ppm
Food:	Omnivorous. The importance of vegetative matter in the diet of silver perch is still debated. Silver perch appear primarily to be a low-order predator of small aquatic invertebrate prey, with occasional intakes of small fish and vegetative matter.
Habitat:	Schools in large numbers sometimes seen near the surface. In summer often congregates below rapids and weirs. Prefers warmer sluggish waters with debris cover. Shows a preference for fast-flowing waters, especially where there are rapids. Also found in lakes, lagoons and impoundments. Prefers open waters rather than heavily snagged areas. Often congregates in summer in large numbers below rapids and weirs. Is not reported in inhabit cool, high, upper reaches of streams.

Rainbow & Brown Trout	
Size:	60.0 cm **TL** male/unsexed
Weight:	25.4 kg
Life span:	7 - 12 years
Optimum water temp:	15°C
Will survive in water:	4°C - 19°C
Fish growth stops below	19°C
Fish stops feeding:	19°C
Fish die:	24°C
pH ideal:	5.0 - 8.0
pH tolerant:	
Hardness:	>320ppm
Food:	Carnivore. Trout generally feed on other fish, and soft bodied aquatic invertebrates, such as flies, mayflies, caddisflies, stoneflies, molluscs and dragonflies. In lakes, various species of zooplankton often form a large part of the diet. In general, trout longer than about 300 millimetres (12 in) prey almost exclusively on fish, where they are available. Adult trout will devour smaller fish up to 1/3 their length. Trout may feed on shrimp, mealworms, bloodworms, insects, small animal parts, and eel.
Habitat:	Trout can only be produced in rivers where habitat conditions are suitable. Extensive local and overseas research has identified the types of habitat preferred by trout and which give the best spawning success and survival, as well as fast growth rates, resulting in good numbers of larger fish. The ideal trout stream should have spawning areas of gravel, with water depths 20-100 cm deep and fast flowing water, 30-100 cm per second (cm/sec).



Appendix B

Where you can buy fingerlings in Victoria

Glenwaters Native Fish
Break-O-Day Road, Glenburn 3717
Phone: (03) 5797 8384; Mobile: 0428 580 633
Owner: John Main
Species: golden perch, silver perch, Murray cod, Australian bass, catfish, brown trout, rainbow trout, yabbies'
http://glenwatersnativefish.com.au/
Email: glenwaters@westnet.com.au
Sell food: Yes

Wartook Native Fish Culture
RMB,7389A, Roses Gap Rd, Wartook, VIC, 3401,
Phone: 03 5383 6306
Fax: 03 5383 6246
Species: Golden perch, Silver perch, Estuary perch, Australian Bass, Eel-tailed catfish, Murray Cod, Macquarie Perch

Email: n/a
Sell food: n/a

The Ballarat Trout Hatchery
401 Gillies Street North, Victoria, Australia (Opposite the Ballarat Aquatic & Lifestyle Centre)
Species: Rainbow and Brown Trout
Phone: 0419 156 474, 03 5334 1220
http://www.ballaratfishhatchery.com.au
Email: sales@ballaratfishhatchery.com.au
Sell food: Yes

Buxton Trout & Salmon Farm
2118 Maroondah HWY Buxton, Victoria, 3711
Phone: 03 5774 7370
Species: Rainbow Trout
http://buxtontrout.com.au/
Email: info@buxtontrout.com.au
Sell food: Yes

Central Victoria Freshwater Fish
Phone: Ben on 0414 221 114
Species: Rainbow and Brown Trout, Golden perch, Silver perch, Catfish, Murray Cod, Australian Bass
http://www.centralvicfreshwaterfish.com.au/index.htm
Email: info@centralvicfreshwaterfish.com.au
Sell food: Yes

Appendix C

Water quality & how to adjust

There are four main tests that can be done easily, pH, Ammonia, Nitrite and Nitrate.

pH

Ideally, in and Aquaponics system the pH should be in a range from 6.8 to 7.2 It is not uncommon for the pH in a new system to be at 7.5 or even higher. Once a system has completely cycled, the pH then should gradually drift downwards (become more acid).

Adjusting pH in your Aquaponics system needs to be done in small increments. Large or rapid changes can be detrimental to your fish health and in some cases, lead to fish deaths. Very low pH, say 5.5 can be very detrimental to the health of your fish. Fish have a mucous all over their body which is part of their health defence system. In low pH conditions this protective membrane can be damaged or destroyed. This will result in sick or dead fish. I view a pH of 6.0 as the very lower limit for my systems. Ideally, I try to keep the pH in the range of 6.6 to 7.2

In a mature Aquaponics system, the pH tends to drift down over time. This is as a result of the acid by product of the action of the beneficial bacteria in the AP system. It is a natural part of the process. Therefore, expect pH to gradually move down.

I have observed pH to drop from 6.8 down to 5.8 in less than a month due to this natural process.
If your new system reads at, say, 7.5 or higher, then perhaps a little help to bring the pH down would be in order.

Adjusting pH down

The easiest and safest way is to use the juice of a lemon. It will depend on the total litres or gallons of water in your AP system as to how many lemons will be needed.

In a system of 1000 L (250 gallons) the juice of half a lemon would be added initially. Wait for 24 hours then measure the pH. If a small fall is observed then repeat the process until you have the system down to just below 7.0 in the ideal range.

I have also used lemon juice concentrate from the supermarket. In my Aquaponics system there is a total of 500L of water in the system. I added 200 ml of the lemon concentrate per day for 4 days. This reduced the pH from 7.5 on day one to a reading of 6.8 on day 5. The system has drifted up a little to 7.0 on day 6, but appears to be holding at 7.0 for now. As the system gets more age I expect to see the pH slowly come down further all by itself.

Adjusting pH upwards

The tenancy is for pH to continue to drift down so regular pH readings should be taken, say, once a week.

Aquaponics systems tend to be low on 3 compounds, Iron, Calcium and Potassium.
It just so happens that Calcium and Potassium can be supplied to your system in the form of very convenient pH adjusters.

Builders Lime, known as hydrated lime in some states, provides calcium and Eco Rose, a product sold as an organic mildew control, provides potassium in the form of potassium bicarbonate.

In a 1000 litre system I use one table spoon of hydrated lime dissolved in water for one treatment, and on the next treatment one table spoon of Eco Rose dissolved in water.

Pour the dissolved mixture into the grow bed and allow it to circulate throughout your aquaponics system. Next day take a pH reading to assess the result. Re treat if necessary.

Remember, make adjustments over time. Do not go all out with one heavy treatment.

Ammonia

Ammonia will appear under the following conditions.

1. First cycling the tank. When you first start a tank to kick start the bacteria process (Nitrogen Cycle) needed in Aquaponics you need to either add a sacrificial fish to die and start the process or add a tea spoon of fish food every day for a week to kick start the bacteria process (Nitrogen Cycle).

    a. Sacrificial Fish

    In this situation as the fish dies and decomposes there is an ammonia spike in the system, and this is what started the bacteria process (Nitrogen Cycle) spoken about at the beginning

    b. Fish Food

    As the fish food breaks down there is a gradual ammonia increase in the system, and this is what started the bacteria process (Nitrogen Cycle) spoken about at the beginning

2. If you over feed the fish, the fish food breaks down there is a gradual ammonia increase in the system. STOP feeding the fish for a day or two and reduce the amount your feeding them

3. If a fish Dies and decomposes there is an ammonia spike in the system. REMOVE the dead fish, this can cause an ammonia spike that can kill the other fish and cause a domino effect.

Nitrite

Nitrite poisoning follows closely on the heels of ammonia as a major killer of Aquaponics fish. Just when you think you are home free after losing half your fish to ammonia poisoning, the nitrites rise and put your fish at risk again. Any time ammonia levels are elevated, elevated nitrites will soon follow. To avoid nitrite poisoning, test when setting up a new tank, when adding new fish to established a tank, when the filter fails due to power or mechanical failure, and when medicating sick fish.

Symptoms:

- -Fish gasp for breath at the water surface
- -Fish hang near water outlets
- -Fish is listless
- -Tan or brown gills
- -Rapid gill movement

Nitrate

The significance of nitrates in the Aquaponics is arguably less understood by fish keepers than the effect of ammonia and nitrites. Although nitrates are not directly lethal in the way ammonia or nitrites are, over time high levels of nitrate have a negative effect on fish, plants and the aquarium environment in general.

Effect on Fish

Fish will feel the impact of nitrates by the time the levels reach 100 ppm, particularly if levels remain there. The resulting stress leaves the fish more susceptible to disease and inhibits their ability to reproduce.

High nitrate levels are especially harmful to fry and young fish, and will affect their growth. Furthermore, conditions that cause elevated nitrates often cause decreased oxygen levels, which further stress the fish.

Nitrates and algae

Elevated nitrates are a significant contributor to undesirable algae growth. Nitrate levels as low as 10 ppm will promote algae growth. Algae blooms in newly setup tanks are usually due to elevated nitrate levels.

Although plants utilize nitrates, if nitrates rise faster than the plants can use them, the plants can become overgrown with algae, ultimately leading to their demise.

Where do nitrates come from?

Nitrates are a by-product of nitrite conjugation during the latter stages of the nitrogen cycle, and will be present to some degree in all aquariums. Detritus, decaying plant material, dirty filters, over-feeding, and over-stocking the tank, all contribute to increased production of nitrates.

Water used to fill the aquarium often has nitrates in it. In the United States, drinking water may have nitrates as high as 40 ppm. Before adding water to your tank test, it for nitrates so you know if the levels are unusually high in your water source. If nitrates are above 10 ppm, you should consider other water sources that are free of nitrates.

Appendix D

Plants nutrient deficiency

Nitrogen deficiency:

- Leaves to show effects first: Old plant
- Entire plant turns yellow green, and the older leaves become more yellowish than the younger.
- Older leaves do not die unless deficiency is extreme.

Phosphorus:

- Leaves to show effects first: Old plant
- Plant stops growing and becomes darker green or stays green.
- Some species may become purple with excess anthocyanin pigments building up.
- Other species do not produce excess anthocyanins and just stay green and small.
- Premature leaf drop-off.
- Similar to nitrogen deficiency.

Potassium:

- Leaves to show effects first: Old plant
- Small dead areas appear in older leaves. These can start like little pinpoints and grow. In some species, like Ceratopteris, the older leaves stay green while the little dead spots grow. The new leaves are reduced in size and leaf area, looking a bit 'singed'. In other species the older leaves can turn yellow before they die, but they do not have green persisting along the major veins as in magnesium deficiency.
- Yellow areas, then withering of leave edges and tips.

Sulphur:

- Leaves to show effects first: New plant
- Similar to nitrogen deficiency

Calcium:

- Leaves to show effects first: New plant
- Mild deficiency: Smaller, distorted new leaf growth. Reduced leaf tissue, with the central vein persisting.
- Leaves often cupped, rather than flat
- Moderate deficiency: Often sudden bends or twisting of leaf, which is now much reduced in size.
- White streaks or white edges in new growth. Roots are stubby and twisted. Root tips may die.
- Leaves of Vallisneria are strongly crinkled as though they have tried to grow and got jammed in a small space.
- Severe deficiency: New growth almost entirely white. Leaves are tiny deformed stumps. Growing points for both shoot and root die.

- Damage and die off growing points.
- Yellowish leaf edges.

Magnesium:

- Leaves to show effects first: Old plant
- In dicots: Yellowing of older leaves that starts from the edges inwards. The mid rib may remain
- green while the edges are yellowed or whitish and dying (I don't know what this deficiency looks like in monocots like Vallisneria, but it should involve death of the older leaves.)
- Yellow spots.

Iron:

- Leaves to show effects first: New plant
- Reduced chlorophyll in new growth. Leaves and stem are about the same shade. Growing tips of Ceratophyllum become pinkish and then white. Egeria densa tips become greenish yellow to yellow with the leaves small and clasped close to the stem. The new leaves of swords are smaller with patches or broad streaks extending lengthwise that are paler than the rest of the leaf (in mild deficiency). In more severe deficiency in most plants chlorophyll is lacking completely in the new growth which soon dies.
- Leaves Turn Yellow.
- Greenish nerves enclosing yellow leaf tissue.
- First seen in fast growing plants.

Manganese:

- Dead yellowish tissue between leaf nerves.

Boron:

- Leaves to show effects first: New plant
- Very similar to calcium deficiency. New growth is distorted and smaller, and then the growing tips of both roots and shoots die. In mild deficiency in Crypts, the leaves are cupped and the roots are shorter and distorted.
- Dead shoot tips, new side shoots also die.

Copper:

- Dead leaf tips and withered edges.

Zinc:

- Leaves to show effects first: Old plant
- Yellowish areas between nerves, Starting at leaf tip and edges.

Molybdenum:

- Leaves to show effects first: Old plant
- Yellow spots between leaf nerves, then brownish areas along edges.
- Inhibited flowering.

Appendix E

Some basic questions asked about aquaponics

Home Built vs. Manufactured

The best way to work out if you want a home built system or a manufactured system is to ask yourself two questions:

1. Do you want to spend money on having a system ready to go and knowing it will just work?
2. Do you want to build and know how every aspect works and have the time to build it?

Personally, I would go for the kit system to start with; so that way you know it should work if you assemble it correctly, this way you will know exactly want is needed to create a system and how every aspect of it works. But if you don't have the time to build a system buying one off the self can still work for you and you can take it apart and see how it works. Aquaponics systems are basic and simple from small systems to large systems.

Hobby vs. Commercial Scale Production Systems

The main difference with Hobby systems and commercial system is the size and construction.

With a hobby system, you might set it up like a commercial system, have the system in a green house, but the real difference is in maintaining the system, for example if you have 10,000L tank of water at 20 degrees the temperature would have to be very high and over several days to change that volume of water to the point where it is too hot for the fish and plants. In a smaller system like 500L it can change within a few days.

In a larger system if a fish dies, the ammonia it produces will not affect the system too dramatically, but in a smaller system it can cause a domino effect and kill another fish and then it cascades exponentially killing all the fish within hours.

But in smaller system you have the advantage of seeing the issues straight away; in a larger system you might not see any problems until it's too late. In a 500L system you can see if . there is a dead fish, in a 10,000L system you might not see dead fish and if there is an issue you could lose them all at once.

A smaller system can be run on a solar panel to run the pump, and you only need to check a lower number of pipes for blockages and issues. Commercial system needs more attention and work to maintain.

Fish Priority Designing vs. Plant Priority Designing

In designing a system, you can spend time and money making it perfect for both fish and plants. For the fish, you can make it as close to its natural environment, e.g. for silver perch the Murray river having shallow areas on the sides and deep in the middle, having areas of fast and slow moving water, having the waters levels rise and fall to match the seasons, and the temperature to match the seasons, etc ...

For plants, it's a bit easier you just have to adjust the water levels and temperature to match the plants you're growing, ensuring the amount of nutrients that are required for the plants you have is correct with a nutrient dispenser, etc.

The truth is the simple things to remember is the grow bed should be about 20 - 30 cm tall to allow the plants to expand their root system allowing stability of the plant so it can hole itself up and the water should never reach the top the media as this will cause algae.

The fish tank should have either an air stone or water flowing back into the system to re-oxygenate the water, never over stock the system best way to calculate it is 1 fish every 20lts of water. Have the fish tank covered and leave them alone as much as possible.