



The No.1 Aquaponics magazine  
for the backyard enthusiast.

**Issue 5**

Second Quarter 2009

Bringing Food Production Home

# Backyard Aquaponics

*Backyard Barra*  
with Neville Passmore

**Channel Catfish** – *Ictalurus punctatus*

**Soldier Flies** – growing your own fish food



# Welcome



**T**he fifth edition of the magazine sees us take things forward another step with a printed version of the current edition becoming available. From this edition onwards the magazine will be available either as an electronic subscription, or as a printed version.

A printed magazine is something we have always planned to make available one day, however it requires a certain level of interest to make the printing investment viable.

There are many positive environmental aspects to producing a magazine in an electronic format. However with a printed magazine we can reach

more people, and the more people who become empowered to grow their own food, the better off we all are. So it's a trade off, and we offer you the choice as to what best suits you, the reader.

For those who currently have electronic subscriptions and wish to upgrade to receiving printed editions, we will be making a "printed edition upgrade" available in the near future. ●

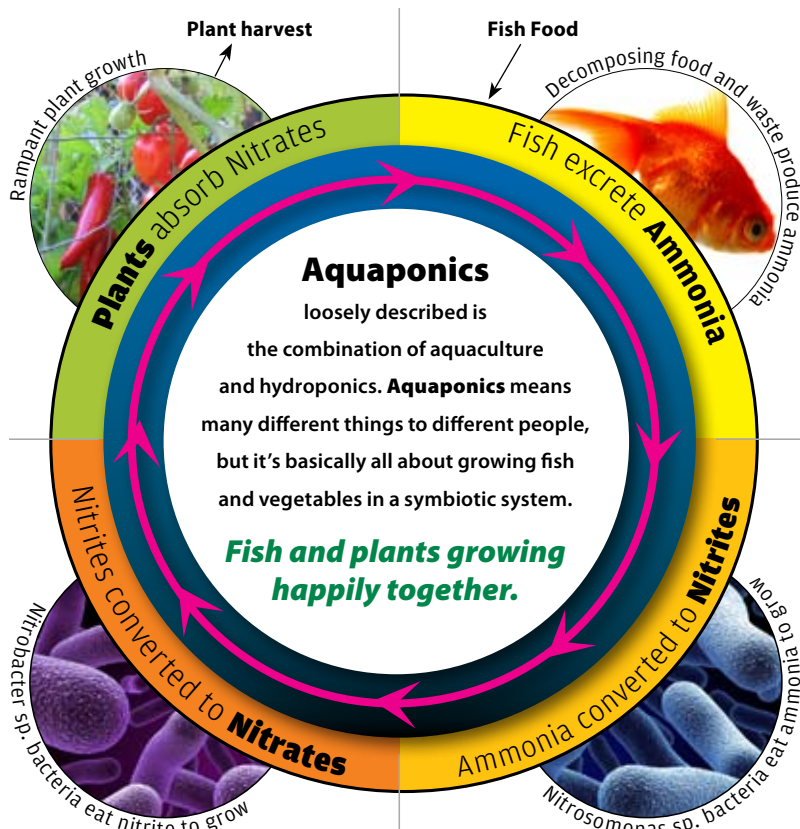
**Joel Malcolm, Editor**

## Backyard Aquaponics on the tube

There is a whole range of aquaponics videos that you can view on youtube, visit the link below and see us in action!  
<http://www.youtube.com/user/backyardaquaponics>



## The Nitrogen Cycle



# Backyard Aquaponics



Issue 5 • Second quarter • 2009

## Backyard Aquaponics Magazine

is a quarterly publication which aims to promote the ideas of Aquaponics and home food production coupled with healthy and sustainable living.

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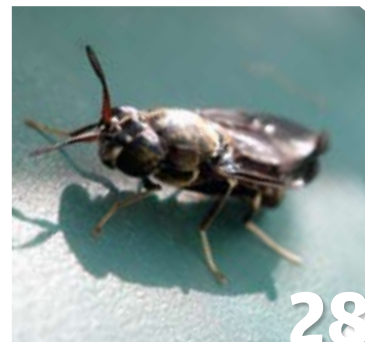
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# Brian's SYSTEM

By Brian Hobbs



Inside the greenhouse



every thread in the forum from start to finish. After a year of reading and thinking about "Aquaponics" it was time to start planning and building my own aquaponic system.

The first step was to decide how big the system was going to be. This was determined by how many fish per week our family wanted to eat. We have three people in our home and we wanted two fish meals each per week. This meant six fish per week for a total of 312 fish per year. I planned to grow the fish to plate size (about 500gms). Joel's book and the forum indicated that fish could be stocked at six kilograms per 100 litres of water. So, 60 fish weighing one kilogram each could be stocked in 1000 litres of water. Since my harvest size was only 500 grams I could stock 120 fish per 1000 litres. Doing the math, I determined that the minimum fish tank size I needed would be 2700 litres.

The next step was to figure out the volume of growbeds required to service 2700 litres of water. Again, reading Joel's book and the forum gave me the answer. I needed a ratio of 2:1, 5400 litres of growbeds, twice the amount of the fish tank (2700 litres).

**M**y Aquaponic journey really began way back in the mid 1970s. At that time I was looking through a magazine and found an article about growing fish at home using a biofilter.

Ever since that day I have always wanted to grow my own fish. Although I had thought about it from time to time, it never went past the thinking stage. Then one day I was

watching "Gardening Australia" and saw an episode about Joel Malcolm, growing fish and plants together in a suburban backyard. He called it "Aquaponics".

I was immediately hooked (no pun intended). Straight after the show I googled "Aquaponics" and found Joel's website and forum. Within a week I had ordered his book and DVD. I read

“We have three people in our home and **we wanted two fish meals** each per week. This meant six fish per week for a total of 312 fish per year.”



The next step to figure out was the space needed to accommodate this system. Fortunately, my backyard is large, so I was confident a large system would fit in (as well as receiving adequate sun light). Most of the systems I read about were under some kind of a shelter to prevent rain from flooding the systems and upsetting the balance, while at the same time letting in light.

To figure out exactly how much space would be needed for my system, I had to start looking for fish tanks and growbeds. The dimensions of the tanks and grow beds would help me settle on the size of the shelter needed to house everything.

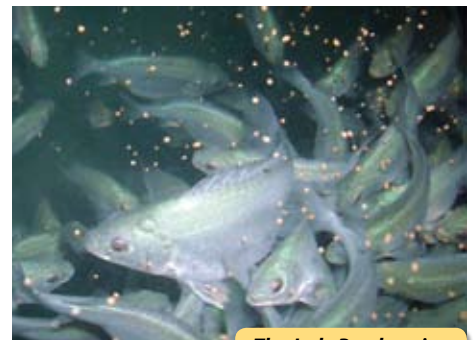
Specially made aquaponic tanks and growbeds are available here in Southeast Queensland. However, because my system was large and my budget small, buying specially made tanks and growbeds was, for me at the time, too expensive. I had to find cheaper options for these items.

I was able to source a couple of second hand aquaculture fish tanks from Gympie. One tank was square holding about 2500 – 3000 litres and with dimensions of two metres by 2 metres. The other tank is round and holds 1000 litres. The diameter of this tank is 1mtr. I went to Gympie with another forum member (Veggieboy) to pick up the tanks as he was buying several of the tanks as well. The three hour trip back home was a nightmare as the ropes kept moving and cutting. We almost lost one tank as it tried to fly away on the highway.

Next I needed to find growbeds. Scanning the Backyard Aquaponics forum I discovered EllKayBee's system and the growbeds he was using which would be perfect for my system. EllKayBee was using budget cattle troughs from a company called Tilkey. They were made of black polythene and were 2 x 1.8 metres x.300 millimetres deep. The price was good. At the time I purchased 10 troughs at \$130 each. They would need a little support for the sides and this was incorporated into the design of my system.

Having determined the fish tanks and growbed dimensions, I could calculate the size of the structure needed to house the whole system. Looking on the internet I finally

decided to buy a greenhouse with a waterproof roof and 50 percent shade cloth on the bottom half of the sides and fully on the ends. This greenhouse would be 12 metres x 4 metres. I purchased it in kit form through VP Structures at a cost of \$2,600 and erected it myself.



**The Jade Perch arrive**



**The first planting**



**Raising the grow beds**



**Cementing the foundation pipes**



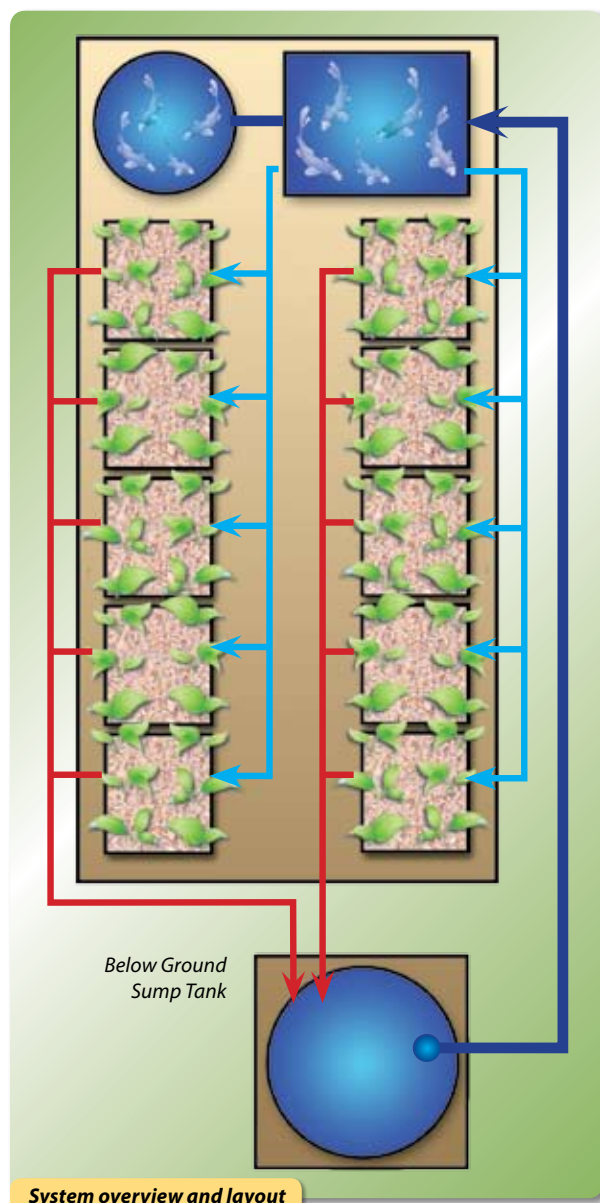
**Burying the sump tank**





## Our Favourite Tanks

“Many people can not believe the **size and the quality** of the veggies grown in this way”



**System overview and layout**

were positioned inside the structure. I played around with the placement of the tanks and growbeds until I was satisfied. Electricity

was run to the greenhouse for the pumps and lights. Besser blocks and fence palings were used to elevate the growbeds.

My system was going to be a “CHIFT PIST”, that is “Constant Height In the Fish Tank and Pump In the Sump Tank”. The aquaculture tank has a central pipe which is about 100 millimetres below the height of the tank, the idea being that the water will exit at the top of the pipe keeping the water at a constant level. This is different to the normal set up where the pump is in the fish tank and the water level falls and rises. The central pipe does pose a problem, though, because fish can fall down the pipe and block the water. To solve this, a larger and longer pipe was placed over the smaller central one. The length was higher than the level of the tank so I cut small holes in the bottom of the larger pipe and covered the holes

with gutter guard to prevent small fish from being expelled through the pipe. This also helps with the removal of solids which were rotated around the tank as the water from the sump was pumped in. The slope of the tank floor and the rotating water pushed the solids to the middle of the tank and were expelled through the central pipe into the growbeds.

This kind of system requires a large sump tank - I have 5400 litres of growbeds that need to be flooded. The growbeds were filled with 10 millimetre gravel. Unsure about how much water would be needed to flood the growbeds and to ensure there would be

enough water to do the job, a galvanized rainwater tank was purchased as my sump. It is 2.5 metres in diameter and 800 millimetres high. The sump tank is buried outside at the front of the greenhouse. This allows the growbeds to drain into the sump by gravity. This gave me approx 4500 litres of water for the growbeds. Combined with the water in the fish tank this gave me a total of about 7000 litres of water for the whole system.

The system was assembled using PVC pressure pipe for all the plumbing. I used 5 cubic meters of gravel in the growbeds. Using rain water from my 10000 litre rain tank I filled the sump and the fish tank. A friend donated some of his fish water so I could start the bacteria off. I added one cup of ammonia each week for six weeks to feed and multiply the bacteria. At the same time I planted the first crop and ordered 500 jade perch (125 for a friend for his dam and 75 for another friend's aquaponic system). This left me with 300 fish.

Unfortunately, my friend was unable to take his 75 fish so I kept them. This meant my system was overstocked. As the fish got larger I had to feed them according to the rate the ammonia in the water was being converted. The growth of the fish was slowed because they could not be fed at the optimum rate.

The aquaponic system has been operational for one year now and the fish are approaching plate size. Our family has enjoyed (and shared) a lot of vegetables produced by the system. Many people cannot believe the size and quality of the veggies grown in this way. Two school excursions have come to investigate my system as part of their science curriculum. Overall, I am very pleased at the small amount of regular maintenance required to keep my system fully operational, as well as it being a relaxing and rewarding past time. ●

A tree-lopper was hired to remove trees that were in the way of the greenhouse site. Next, the bobcat came to level the site. I wanted to cement in the footing pipes of the greenhouse but was not confident in my ability to make sure they were all square and level. So I asked a workmate of mine, Dirk, to help me. He was able to make sure all the footings were correct. It cost me a Thai food dinner for his help (very generous on his part).

After the footings were all in, the greenhouse was assembled. It was like a large Meccano set and went together easily. Before the cover was attached the fish tanks and the growbeds



# Chicken Caesar Salad

This Chicken Caesar Salad recipe is based on a method used by Jamie Oliver, it's a great way to produce some of the nicest croutons.

## Method

- Tear up bread into small chunks and place in a baking tray.
- Place chicken legs or pieces into the tray and garnish liberally with pepper, rosemary leaves and olive oil. Using your hands to mix it, **ensure that all pieces are well coated in oil and rosemary.**
- Arrange chicken pieces on top of the bread chunks, and place in the oven for 35-40 minutes or until the chicken is starting to brown.
- Place the bacon strips on top of the chicken and return to the oven for a further 15 minutes or until the bacon becomes crispy.
- Tear up the lettuce into rough pieces, remove the meat from the chicken legs using a fork if the chicken is still hot and break up the bacon or pancetta. Mix up the chicken, bacon and lettuce and drizzle with Caesar dressing. Shave some parmesan cheese over the top and add a few anchovies as well if you like.

## Ingredients

- 1 cos lettuce
- 4-5 chicken legs
- 1/4 loaf ciabatta bread or similar
- 4-5 rashers of pancetta or good quality bacon
- Fresh rosemary or other herb like sage, tarragon or thyme
- Parmesan cheese
- Caesar dressing (freshly made or bought)
- Anchovies (optional)
- Makes enough for 2

Enjoy!





By the Barbeque

Always a favourite at Thai restaurants, try these tasty Thai Fish Cakes and dipping sauce at home.

# Thai Fish Cakes

## *Fish cake ingredients*

500g white fish fillets  
3 teaspoons red curry paste  
2 tablespoons fish sauce  
½ teaspoon salt  
8 runner beans  
1 tablespoon coriander leaves,  
finely chopped  
2 kaffir lime leaves, finely chopped  
Oil for frying (peanut, vegetable or corn)

## *Method*

- Chop the fish into 2cm (¾ inch) pieces and place in a food processor until well blended.
- Add the red curry paste, fish sauce, salt and kaffir lime leaves and process for a further minute.
- Stir in finely sliced beans and coriander, and refrigerate for 10 minutes.
- Make fish cakes by taking a spoonful of mix and rolling into balls.
- Fry in hot oil until lightly browned on both sides, about 5 minutes.
- Place on paper towel to remove excess oil.
- Serve with wedges of lime, sprigs of coriander and dipping sauce.





Blend the fish in the processor



Stir in beans and coriander



Form into patties and fry



### Dipping sauce ingredients

- 50ml water
- 30ml white wine vinegar
- 3 tablespoons sugar
- ½ teaspoon salt
- 1 tablespoon fish sauce
- 2 spring onions
- 3 sprigs of coriander

### Method

- Combine water, vinegar, sugar, salt and fish sauce in a bowl and stir until sugar dissolves.
- Add finely chopped spring onion and coriander.
- Dipping sauce may be served hot or cold.



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By the Barbeque

# Fresh Basil Pesto



Bursting with fresh-from-the-garden colour and flavour, a drizzle of basil pesto brings simple dishes to life, and the homemade version puts shop-bought ones in the shade...

**O**riginating from Liguria, on the Mediterranean coast in Italy's north-west, pesto is one of the most versatile sauces to come from the country. The Ligurians are known for their independence and reliance on their own freshly grown products, and their recipes are dominated by the use of seafood, olive oil, herbs and vegetables. As well as using on pasta dishes, try stirring a tablespoonful into minestrone just before serving, for a delicious flavour.

## Ingredients

45g ( $\frac{1}{4}$  cup) pine nuts  
45g ( $\frac{1}{4}$  cup) unsalted cashew nuts  
3 cups fresh basil leaves  
4 small garlic cloves, halved  
120g ( $1\frac{1}{2}$  cups) shredded parmesan  
150 mls olive oil







## Method

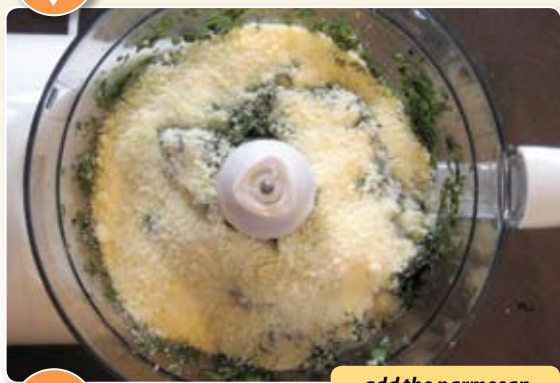
- Preheat oven to 180°C. Spread the pine nuts over a baking tray. Bake in oven for 5 minutes or until toasted. Remove from oven and set aside for 10 minutes to cool.
- Place the nuts, basil, garlic and parmesan in the bowl of a food processor and process until finely chopped.
- With the motor running, gradually add the oil in a thin steady stream until well combined.

## Tips & tricks

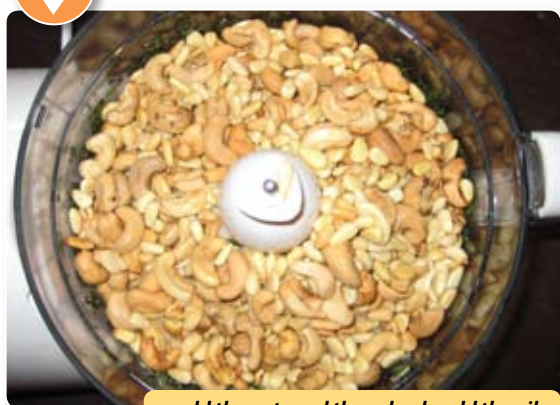
- **To freeze (for up to 4 months):** Transfer the pesto to a small airtight container and smooth the surface. Drizzle with olive oil to cover. Label, date and freeze.
- **To thaw:** Place in the fridge for 3-4 hours or until thawed. Stir to combine.



Blend the basil in the processor...



... add the parmesan...



... add the nuts and then slowly add the oil.

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By the Barbeque

# Roasted Capsicum *Sauce*

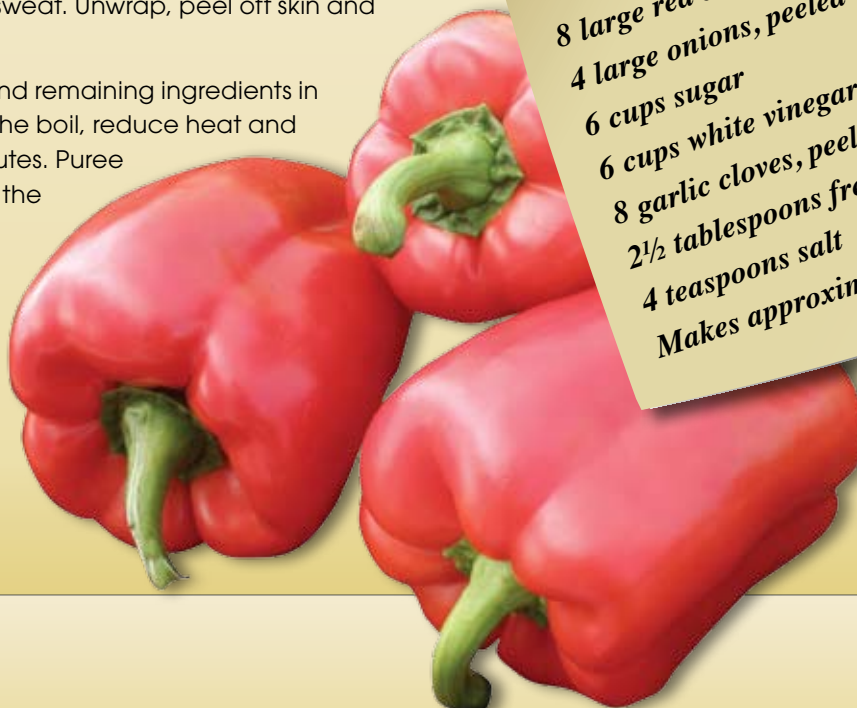
A tasty alternative to sweet chilli sauce, this capsicum sauce can be stored for up to a year.

## *Method*

- Remove seeds and core from capsicums, then cut in halves. Place under a hot grill until skin blisters and blackens. Wrap individually in cling wrap and leave for several minutes to sweat. Unwrap, peel off skin and chop the flesh.
- Combine capsicum and remaining ingredients in a saucepan. Bring to the boil, reduce heat and cook slowly for 40 minutes. Puree or sieve. Bring back to the boil and cook for 5 minutes more.
- **Pour into warm sterilised jars and seal immediately.** Store in a cool, dry and dark place for up to one year. The sauce can be eaten immediately.

## *Ingredients*

8 large red capsicums  
4 large onions, peeled and chopped  
6 cups sugar  
6 cups white vinegar  
8 garlic cloves, peeled and crushed  
2½ tablespoons fresh ginger, grated  
4 teaspoons salt  
Makes approximately 1600ml







# Aquaponics in *Mudgee*

By Shannida & Matt Herbert



**We** stumbled across aquaponics by chance in early 2006, after visiting an organic hydroponics farm as part of a case study for one of Shannida's university

subjects. Coming home after seeing this farm, we searched Google for more information, and found aquaponics. Our lives have not been the same since. With a whole new world of growing opened up to us we



*The mini jungle*

Shannida and Matt have written a book about aquaponics called "Aquaponics in Australia", and they run an online business "Aquaponics Pty Ltd", where they sell informational products and hardware. [www.aquaponics.com.au](http://www.aquaponics.com.au)

“We are located on a 100-acre bush property, with **no reliable water supply**, and no connection to electricity”

started building our own systems right away. We have not planted anything in our organic soil vegetable garden since, and it has now become a jungle of fruit trees and bamboos mixed with ponds of lilies and water chestnuts.

We are located in Mudgee, on a 100-acre bush property, with no reliable water supply, and no connection to mains electricity supply. We run on solar power for the house, shed and aquaponics systems. Our water for the house and systems is stored in tanks and comes from the roof of the house, shed and green-house. Hot water is created through solar in the hot months and through a fire coil system in the colder months.





## Our Favourite Tanks

“We even have an **apple tree** which is going strong and will hopefully flower and fruit next season”



Our main attraction to aquaponics was the water saving - as we were using up to 3000 litres a day on our garden during the hottest months our dam level was dropping very quickly! The fish aspect also had us excited as it was something that we thought would never be possible to do where we lived. Who would have thought that you could raise fish without a large continuous supply of fresh water?



*A welcome visitor*

We have currently operating seven media based systems, one NFT system, and one deep flow system. We have a mix of silver perch and goldfish in our systems, and we are about to add Australian native catfish to one of the systems. Our silver perch are in some of the systems located in the greenhouse, the goldfish located in the rest of the systems. We found that if the silver perch were in the tanks outside the greenhouse, they would struggle to survive and not eat, therefore not get any fatter.

This was presumably due to the extremes of temperature they experienced in a tank exposed to the elements.

Some of the plants currently being grown in our systems include basil, lettuce, onion, oregano, tomato, capsicum, parsley, lemongrass, thornless raspberry, beans, snow peas, Chinese cabbage, strawberries, tatsoi and chilli. We even have an apple tree which is going strong and will hopefully flower and fruit next season. Our deep flow system is overrun with peppermint currently, it was the best choice over the summer when everything else was being eaten by invading possums and wallabies, we now have bird netting covering



*Our media systems in the greenhouse*



the area so this problem will not occur again. The peppermint removal will be as simple as pulling out of the floating boards and scooping out roots from the water in channel. There will be no pop up peppermint next season, as happens in any soil garden with running rooted plants.

We also have a solar power business, which has kept us very busy in the last 12 months, and our aquaponics systems were left to their own devices during this time, with daily visits only to feed the fish and make sure pumps and aerators were still operational. We would also duck in each night to harvest some greens for dinner, and we tested the water in the systems every couple of months. At the beginning of autumn this year, we ventured into the greenhouse to do some pruning and culling of plants, and ended out with five piles more than 3 ft high to add to the compost heap. The one thing we noticed was that our backs were not hurting as they always had after doing the same job in the conventional vegetable garden, and there were no weeds. It was quite enjoyable to dig through the growth and find plants that had survived rather well considering they were growing in a mini jungle.

Over the three years that our systems have now been running we have had many ups and downs along the way and many incidents involving animals that should not have entered the aquaponics area. The latest has been a mouse plague which has been getting progressively worse in the last 4–5 months. Traps are set all over the greenhouse yet munching of the plants is still going on constantly and seedlings are often bitten off. During this last summer a goanna tried to make his home underneath one of the fish tanks, and we had visits from seven snakes. These have been the main problem with living in bushland; the animals' home is literally metres from our home!

We have also had many wanted animals in the greenhouse including praying mantis, spiders and bees. Walking around the growbeds at night with a torch reveals

just how many spiders are living amongst the greenery. Our systems have become an ecosystem of their own, with all of the elements for a continuing healthy existence (as long as water and fish food are added, of course!). Many of our beds are filled with second generation plants. We did not have to plant them as they merely grew from where the seed was left from the parent plant the season before.

Will our system keep going in its present state for years to come without too much adjustment? That is something that only time will tell. All we know at this three-year point, is that the systems are capable of



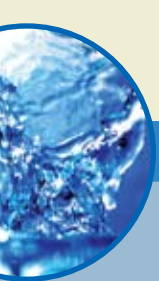
**The deep flow system and its peppermint**

continuing growth, and seem to produce much more lush growth now than when the systems were only 1-2 years old.

Aquaponics is definitely an art that needs to be understood to achieve the best from it. There is no defined right or wrong way to practice aquaponics; any system that keeps fish and plants healthy is a successful one. Once the principles are understood, there is an element of being able to be creative, which we find appealing in itself. We have loved learning about aquaponics, and think there will be always something new to learn as more people experiment with their own systems. ●







# Channel Catfish

*Ictalurus punctatus*

By Aleece B. Landis

## FACTS

**Channel catfish** are the most farmed aquaculture species in the USA. They occur naturally in central and eastern North America including central Florida. Since I am in central Florida, this species appeals as a native. They are well adapted to the climate and the species can survive much colder climates so I don't need to worry about keeping them warm in winter.

Two to four pounds (one to two kilograms) is the average size that anglers could expect to find in most waterways. A 20 lb (9 kg) specimen would be spectacular and even a 10 lb (4.5 kg) fish would be admirable, although channel catfish can reach 40-50 lbs. The world record for channel catfish is 64 lbs. They are classified as omnivores but are definitely on the more carnivorous side.

Channel catfish prefer slow to moderate currents and sand or gravel bottoms and grow fairly quickly but definitely not as fast as tilapia. They are more sensitive to dissolved oxygen levels than are

tilapia and do not like really high salt concentrations in their water.

Channel catfish mature between three and eight years of age. The male finds a cave or hollow to invite the female to lay her eggs. Then the male guards the eggs, using his tail to fan water over them to keep them oxygenated. I do not yet know how likely it is to get channel catfish to breed in a backyard aquaponics system.

## WHY CHANNEL CATFISH?

As noted above, they are a native fish to my location and therefore well adapted to

the climate. They are good eating and easy to acquire.

Our climate is subtropical (Central Florida, USA.) We are in a fairly hot humid climate but because we are surrounded by water in Florida, the heat is rarely too extreme, though the hot season is generally long. In winter we can get frosts, though the ground does not freeze and cold spells rarely last very long.

Water in an outdoor aquaponics system can easily drop below 50°F during a cold spell here but could be back up to 70°F in a week. During summer here it would be possible to get water over 90°F and having shade for the grow beds and fish tanks is a must.



“We harvested our biggest catfish so far on 10 December 2008. It weighed 3.5lbs (1.6Kg)”



Having an in-ground tank to couple with ground temperatures in this climate is very helpful for both summer and winter temperature modification. I've found that this isn't quite enough for keeping the tilapia happy but it is enough to support channel catfish.

#### WHAT IS THE MEAT LIKE?

Catfish is a really dense, oily but mild flavoured fish. I don't find them to have a "fishy" taste. The dense "meaty" or tough texture of catfish is a negative to some people while others prefer it.

#### WHAT ABOUT CLEANING THEM?

Cleaning catfish is a little different from cleaning fish with scales. Instead of scaling them, you skin or peel them. Our usual method is to net them out of the tank and quickly club them. Originally we tried the knife to the brain method but the skull was too hard and we bent the knife. Then we clip the barbs off for safety. To skin, cut around the head and grab the skin with a good pair of pliers and peel skin away. If lucky, the skin will peel off in large pieces. Once skinned, gut and remove the head and tail. Then we soak the fish in ice water before smoking or grilling.

Catfish can also be filleted without the steps of skinning or gutting but that takes a good knife and a fair bit of practice and even done well, misses out on some of the meat.

#### OUR CATFISH IN PARTICULAR

We got our first batch of channel catfish on 24 March 2008. There were 47 of them ranging from 4 to 10 inches in length. On 9 August 2008 we had our first catfish dinner. We harvested our biggest catfish so far on 10 December 2008. It weighed 3½ lbs (1.6 kg). I think we have cleaned a couple of smaller catfish but I would say our eating size range for catfish has been between 2½ and 3½ lbs.

#### *Smoked Catfish Dip*

Smoked catfish (skinless and de-boned)  
Onion (finely chopped)  
Pickle relish  
Lemon juice  
Sour cream  
Salt, pepper and cayenne pepper to taste

Mix ingredients together to taste. I found I really like smoked catfish dip but not everyone does.



We got more channel catfish fingerlings in December 2008 - 32 of them this time but we got smaller ones in the 3-5 inch size so I could quarantine them in the aquarium. As at 1 March 2009, we still have four of our original catfish living outside the tilapia cage in our big in-ground tank. They are the clean up crew to take care of food that escapes the tilapia cage.

We harvested the rest of the original batch as they were showing signs of stress illness after the previous harvesting. This is what I see as the biggest drawback with channel catfish, they are timid and stress can easily trigger illness in them. Since they have no scales, they can be particularly prone to skin infections when they scrape themselves on the tank, which tends to happen when they try to avoid being netted. This seems to become more prevalent as the fish grow larger.

It may be good practice to make sure the salt level in the system is around three parts per thousand when planning to harvest channel catfish by netting them. I have not tried fishing for the catfish with hook and line though it may be a less stressful way to harvest them. ●



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# Is the accepted view of Nitrification *a Myth?*

And might it change the way  
we understand aquaponics?

By John Burgess







## INTRODUCTION

**It has been a paradigm** in biology and the aquarium hobby that there are two bacteria responsible for nitrification. The first, called *Nitrosomonas europaea* oxidizes ammonia to nitrite, while the second, *Nitrobacter winogradskyi*, oxidizes nitrite to nitrate.

These organisms are called nitrifiers and are classified as belonging to the same family of bacteria. However, recent work on the phylogenetics of these organisms and their close relatives has shown that this classification is wrong and needs to be revised.

Nitrite is formed in aquarium systems from the oxidation of ammonia, the principal nitrogenous waste of teleosts, by autotrophic ammonia-oxidizing bacteria (AOB). Oxidation of nitrite to nitrate in aquaria is typically attributed to bacteria belonging to the genus *Nitrobacter*, which are members of the subdivision of the class *Proteobacteria*.

The oxidation of nitrite to nitrate in fish culture systems, ranging from home aquaria to commercial aquaculture systems, is an important process. The accumulation of high concentrations of nitrite, which is toxic to fish and other aquatic organisms, is prevented by active nitrite removal by nitrifying micro-organisms. (Nitrite-oxidising Bacteria {NOB}). Thus, closed aquatic filtration systems usually provide a solid substratum, which is termed a biological filter or bio-filter, to promote the growth of AOB and NOB.

A variety of materials can form the substratum of a bio-filter, ranging from gravel to specially engineered moulded plastics. Bio-filters can be submerged in the flow path of the filtration system or can be located such that the

water trickles or percolates through a medium situated in the atmosphere outside the aquarium, before flowing back into the tank.

## IMPLICATIONS OF THE NITRIFICATION PROCESS

High levels of nitrite lead to brown blood disease. Brown blood disease occurs in fish when water contains high nitrite concentrations. Nitrite enters the bloodstream through the gills and turns the blood to a chocolate-brown colour. Haemoglobin, which transports oxygen in the blood, combines with nitrite to form methemoglobin, which is incapable of oxygen transport.

Brown blood cannot carry sufficient amounts of oxygen and affected fish can suffocate despite adequate oxygen concentration in the water. This accounts for the gasping behaviour often observed in fish with brown blood disease, even when oxygen levels are relatively high. In humans high nitrite levels cause "blue baby" disease.

Sodium chloride (common salt; NaCl) is used to "treat" brown blood disease. Calcium chloride also can be used but is typically more expensive. The chloride portion of salt competes with nitrite for absorption through the gills and maintaining at least a 10 to 1 ratio of chloride to nitrite in a pond effectively prevents nitrite from entering the fish.

Where fish have bacterial and/or parasitic diseases, their sensitivity to nitrite may be greater, and a higher chloride to nitrite ratio may be needed to

afford added protection from nitrite invasion into the bloodstream.

As a general rule, strive to maintain at least to 50 to 100 ppm chloride in pond waters as "insurance" against high spikes of nitrite concentration. 1000 ppm of salt is equal to a 0.1% level.

Brown blood disease can be prevented, or at least minimized, by close monitoring of nitrite, chloride, and total ammonia nitrogen (TAN), and by maintaining the proper chloride to nitrite ratio. If brown blood disease does occur, adding salt to the water can reverse the condition. Fish surviving brown blood disease or nitrite stress are more susceptible to bacterial infections, anaemia (white-lip or no-blood), and other stress-related diseases. These secondary problems, such as *Aeromonas* or *Columnaris* infections, often occur 1 to 3 weeks after brown blood disease occurs.

### Remember:

**1 ppm of ammonia can lead to almost 3 ppm of nitrite because one Nitrogen atom in a molecule of ammonia (molecular weight of 17) forms one Nitrogen atom in a molecule of nitrite (molecular weight of 46), so 17 ppm of ammonia would lead to 46 ppm of nitrite. In other words, the ratio of the molecular weights (46/17) can potentially multiply the ammonia levels by 2.7 times.**

**1 ppm of nitrite can similarly lead to 1.35 ppm of nitrate (62/46).**

**1 ppm of ammonia can for the above reasons lead to 3.65 ppm of nitrate (62/17). (1)**

**“ You can completely destroy a great biological filter by rigorously cleaning it with chlorinated tap water ”**

## THE CURRENT POSITION AND PRACTICES

Traditionally, the bacteria responsible for the oxidation of ammonia and nitrite in





## In the Garage

aquaria were considered to be *Nitrosomonas europaea* and *Nitrobacter winogradskyi* or their close relatives, respectively. However, there is some indication that both *N. europaea* and *N. winogradskyi* may not be predominant components of actively nitrifying freshwater aquaria.

In seawater aquaria, however, *N. europaea* and close relatives did appear to comprise a significant proportion of the total eubacterial community, but *N. winogradskyi* was below detection limits. The most well studied members of this group of organisms (i.e., *N. winogradskyi* and close relatives) belong to the subdivision of the class *Proteobacteria*. Another NOB, *Nitrospira marina*, is phylogenetically affiliated with non-NOB such as *Leptospirillum ferrooxidans*.

Whether in pure culture or on bio-filters, NOB are slowly growing organisms with doubling times from 12 to 32 hrs. Therefore, in newly set up aquaria, ammonia and nitrite can reach concentrations toxic to fish before a sufficient biomass of AOB and NOB becomes established.

To reduce the length of time for the establishment of NOB on bio-filters, commercial preparations of these organisms, in various forms of preservation, are available to seed the aquarium environment. These preparations range from essentially pure cultures of *Nitrobacter* species, to mixed cultures of autotrophic AOB and NOB organisms, and to products, which combine autotrophic nitrifying bacteria with various species of heterotrophic bacteria. Past studies have generally shown these mixes to be ineffectual but have not elucidated specific reasons for their poor performance.

A combination of methods was used to investigate concurrently the appearance of NOB on bio-filters and the oxidation of nitrite to nitrate. In order to identify bacteria responsible for nitrite oxidation in aquaria, genes were developed from bio-

films of several freshwater aquaria. Analysis indicated the presence of nitrite-oxidizing bacteria closely related to other members of the genus *Nitrospira*.

Nucleic acid hybridisation from bio-films of freshwater aquaria demonstrated that *Nitrospira* comprised nearly 5% of SRNA extracted from the bio-films during the establishment of nitrification. Nitrite-oxidizing bacteria belonging to the subdivision of the class *Proteobacteria* (e.g., *Nitrobacter spp.*) were not detected in these samples.

Aquaria which received a commercial preparation containing *Nitrobacter* species did not show evidence of *Nitrobacter* growth and development, but did develop substantial populations of *Nitrospira*-like species. Time series analysis showed a correspondence between the appearance of *Nitrospira* and the initiation of nitrite oxidation.

In total, the data suggest that *Nitrobacter winogradskyi* and close relatives were not the dominant nitrite-oxidizing bacteria in freshwater aquaria. Instead, nitrite oxidation in freshwater aquaria appeared to be mediated by bacteria closely related to *Nitrospira moscoviensis* and *Nitrospira marina*. The commencement of nitrite oxidation coincided with the appearance of the putative nitrite-oxidizing *Nitrospira*-like bacterium.

The results lend support to the conclusion of an earlier study, which suggested that [*Nitrobacter* types] were not major components of nitrite oxidation bacterial populations in freshwater or marine aquaria. Results regarding the beneficial effects of the

addition of a bacterial additive containing *Nitrobacter* species were equivocal.

While nitrite levels in treated aquaria decreased earlier than those in untreated aquaria, there was no evidence that *Nitrobacter* species were actively growing in these aquaria. However, since *Nitrospira*-like bacteria were readily detected and that their establishment coincided with nitrite oxidation we postulate that *Nitrospira*-like organisms, and not *Nitrobacter* species, are the major nitrite oxidizers in the freshwater aquarium environment. (Hovanec, T. A. and E. F. DeLong. 1996. *Comparative analysis of nitrifying bacteria associated with freshwater and marine aquaria*. *Appl Environ Microbiol* 62:2888-2896.) (2)

The purpose of the first part of a recent study was to identify the actual nitrite-oxidizing bacteria in aquaria. Earlier results had shown that *Nitrobacter winogradskyi* are not present in measurable quantities in freshwater or saltwater aquaria.

The final test looked at the effects of adding a bacterial additive to aquaria during the start-up phase. Duplicate aquaria were set up and dosed with ammonium chloride. A commercially available bacterial additive was added to one set on a weekly basis as per the manufacturer's instructions. The other set did not receive any additive.

Water chemistry was measured three times a week and filter samples taken for bacterial analysis. Molecular probes for *Nitrobacter* and *Nitrospira*-like bacteria were used on these samples. *Nitrobacter* was not detected in either situation, but the tests did detect *Nitrospira*-like bacteria in both cases.

Thus, even when adding *Nitrobacter* to the system, these bacteria fail to become established. The only possible positive to adding the additive was that a greater percentage of the total bacteria DNA in the samples were from the *Nitrospira*-like bacteria in the tanks that received the

“Aquaponic systems should be maintained at pH levels between 6.5 and 7.5”





additive. While there are more tests to be performed, it seems that the additive did have a kind of "fertilization" effect.

What is surmised, is that there are nutrients in the additive that the *Nitrospira*-like bacteria can use to increase their numbers faster than in tanks without the additive.

Finally, the results of the many tests reported in the paper demonstrate that *Nitrobacter winogradskyi* and its close relatives are not the nitrite-oxidizing bacteria in aquaria. Rather, this task falls to the *Nitrospira*-like bacteria. (3)

It's time for hobbyists, technical people and writers of articles in the fish hobby press to call for the correct name to be used for the nitrite-oxidizing bacteria in aquaria - that is *Nitrospira*.

### WHY IS IT IMPORTANT TO KNOW THE BACTERIA?

A compelling reason is that there are fundamental physiological differences between *Nitrobacter* and *Nitrospira* spp., the most important of which may be the fact that the *Nitrobacter* spp. is not really an obligate aerobe (it would need to be in an environment that contains oxygen) and it can be grown, albeit slowly, hetero-trophically, (getting the carbon it needs from organic chemicals instead of just from carbon dioxide, which is called autotrophic growth).

On the other hand, so far *Nitrospira* spp. can only be grown auto-trophically and aerobically. This could be an important bit of information when trying to provide an optimal environment. Further, by knowing which bacteria play an important role in

the cycling of chemicals, such as nitrite, researchers can study and (hopefully) find out why sometimes things go wrong. For instance, a relatively common problem in saltwater aquaria is that it can take a long time for the nitrite to be completely oxidized to nitrate. It has been reported that the nitrite concentrations in newly set-up aquaria are often between 1 and 5 milligrams per litre for 10 to 14 weeks or longer. Why? By being able to target and count the bacteria responsible for nitrite oxidation we can now see whether there are substances that inhibit their growth by actually counting the number of bacterial cells over the course of time during the establishment of nitrification.

As nitrite becomes more evident, so do the populations of *Nitrospira marina* removing the nitrite from the system and changing it into nitrate (and energy for the bacteria).

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## In the Garage



As the populations grow, they gradually become able to reduce nitrite, as soon as *Nitrosomonas* acting on ammonia production creates it.

The bacteria that reduces nitrite to nitrate, *Nitrospira marina* is inhibited by a free concentration of ammonia in the water. This is the reason why the *Nitrospira marina* population is essentially kept at a zero level until Day 10 when the ammonia spike reaches the minimum level. Once the ammonia inhibition is removed, then (and only then) *Nitrospira marina* can begin to replicate. They are also lithotrophic so they require the same things that *Nitrosomonas* require - oxygen, their food source and clean hard places to attach and populate.

*Nitrospira* were confirmed as the dominant nitrite oxidizers via RNA slot blotting. *Nitrospira moscoviensis* were used for the pure culture trials. The results from this study suggest that free ammonia (NH<sub>3</sub>-N) concentrations of up to 10 mg/L were not inhibitory to *Nitrospira* either in situ or in pure culture. (4)

Generally it has been observed that the bacteria that convert the nitrite to nitrate don't show up until ammonia concentrations build up to high concentrations. So the *Nitrospira marina* doesn't start to show up or become effective until after the ammonia levels start to spike. Then it takes 4 to 8 weeks to become effective enough to level off and reduce the nitrite concentrations.

The *Nitrospira marina* is the second half of the biological filter and takes much longer to mature than the first half. Algae and plants then remove the nitrates, thus completing the nitrification process in aquaria and ponds. They also can be removed by frequent water change.

What is not well understood is you can completely destroy a great biological filter



by rigorously cleaning it with chlorinated tap water, and throwing out the media and replacing it with new media. Some chemical treatments can also destroy it.

Another recent study, with the benefit of the most modern technology, including DNA sequencing and analyses, also demonstrated that the actual converter of nitrite to nitrate in aquaria is *Nitrospira marina*. (Hovanec, T. A. and E. F. DeLong. 1996, "Comparative analysis of nitrifying bacteria associated with freshwater and marine aquaria", *Appl Environ Microbiol* 62:2888-2896 and Burrell, P. C., J. Keller and L.L. Blackall. 1998, "Microbiology of a Nitrite-Oxidizing Bioreactor", *Applied Env Microbiol* 64:1878-1883.)

The study was conducted to evaluate the role played by *Nitrospira*-like species on the oxidation of nitrite to nitrate in freshwater aquaria. Nucleic acid hybridization, time series analysis, and oligonucleotide probes were employed to sample the influence of the *Nitrospira*- and *Nitrobacter*-like species. Results revealed that bacteria related to *Nitrospira moscoviensis* and *Nitrospira marina* were the mediators in nitrite oxidation in freshwaters rather than *Nitrobacter winogradskyi*. (5)

Commercial companies have tried to market special preparations of ammonia-oxidizing and nitrite-oxidizing bacteria (the mixes included *Nitrobacter* instead of *Nitrospira*) that could be put into a new aquarium to establish a healthy nitrogen cycle. However, these mixes were inexplicably ineffective so tests were done to analyze the bacterial content of aquaria water.

While bacteria from the genus *Nitrobacter* are nitrite-oxidizing organisms and could theoretically fill the nitrite-oxidizing niche, the tests indicated relatively high numbers of *Nitrospira* and no *Nitrobacter* bacteria at all. Thus, *Nitrospira* is now considered the dominate nitrite-oxidizing bacterium in aquaria, (as well as in wastewater treatment systems and other reactors as shown by

other similar studies) (Hovanec et al.1998), though water that is too rich in ammonia or has a pH that is too low will inhibit *Nitrospira*'s nitrifying activity. (6)

Only recently cultivation-independent methods revealed that novel yet uncultured NOB are far more important than *Nitrobacter* in wastewater treatment plants (Burrell et al., 1998; Juretschko et al., 1998; Schramm et al., 1998). These bacteria belong to the genus *Nitrospira*, which is part of the bacterial phylum Nitrospirae (Ehrich et al., 1995), and are not related to *Nitrobacter*.

The findings indicate that *Nitrospira*-like bacteria can use inorganic as well as some organic carbon sources, and may benefit from the increased availability of organic carbon in wastewater or other habitats. (7)

Under aerobic conditions, the *Nitrospira*-like bacteria in bioreactor samples took up inorganic carbon (as  $\text{HCO}_3^-$  or as  $\text{CO}_2$ ) and pyruvate but not acetate, butyrate, and propionate, suggesting that these bacteria can grow mixotrophically in the presence of pyruvate. In contrast, no uptake by the *Nitrospira*-like bacteria of any of the carbon sources tested was observed under anoxic or anaerobic conditions. (8)

It was demonstrated in the experiments described above, that nitrite concentration affected the competition between *Nitrospira* and *Nitrobacter*. Transient-elevated nitrite concentrations stimulated the growth of *Nitrobacter*, while in the undisturbed chemostat control *Nitrospira* dominated.

These results were consistent with the abovementioned K/r-hypothesis.

*Nitrobacter*, as an r-strategist, through a rapid growth rate, takes over and dominates situations in which resources are temporarily abundant, while *Nitrospira*, which grows more slowly, characteristic of K-strategists, tend to be successful in resource-limited situations. (9)

#### IN SUMMARY – WHAT DOES IT ALL MEAN?

- It is *Nitrospira* that is responsible for the conversion of nitrites to nitrates, both during the initial cycling of a system and ongoing, not *Nitrobacter* as previously held.
- The reason for the nitrite "spike" typically seen around Day 10-14 in a cycling system, is due to the free ammonia concentration in the water, the ammonia "spike" and the inhibiting effect it has on *Nitrospira*.
- Once the inhibiting ammonia "spike" has been removed, nitrification by *Nitrospira* will commence immediately. This is evidenced by the almost simultaneous fall to zero of ammonia readings and sudden rise in nitrites.
- Commercial "starter" preparations containing *Nitrobacter* and *Heterotrophic* bacteria, are essentially useless.
- High ammonia readings or a pH reading that is too low will inhibit *Nitrospira*'s nitrifying activity.
- Under aerobic conditions *Nitrospira* will take up carbon (as  $\text{HCO}_3^-$ ), the bicarbonate ion. An effect that we observe as "buffering" against the acidification of ammonia breakdown.
- Uptake of bicarbonate buffering will not occur under anoxic or anaerobic conditions, leading to possible rapid rises in free ammonia and pH swings.
- *Nitrobacter* can assume a short term predominate population in a cycling system which experiences a "fleeting" Nitrite imbalance, due to its rapid growth rate.
- Once established, *Nitrospira* tends to dominate and maintain a balance in a mature system by limiting the Nitrite resource.





## In the Garage

I believe the points above have been observed in many AP systems as evidenced in occasional sudden "greening" of water, even in a mature system, due to a temporary imbalance of nitrites that encourages *Nitrobacter* and an associated algal bloom (both signs of imbalance), followed just as suddenly at times by a "clumping" of the algae as it effectively dies off, and a clearing of the water with a "brownish" tinge occurs as the *Nitrospira* re-assert dominance.

I postulate that the brownish colour and "stringy" algae and bio-film often seen in a stable, mature system is in fact evidence that the *Nitrospira* is the dominant nitrifying bacteria present and represents a stable system and explains the reason why AP systems running within a range of pH between 6.5 and 7.5 achieve both faster initial cycling and ongoing stability.

Similarly, I believe this goes a long way to explain why it is often difficult to both initially cycle and subsequently maintain an AP system with a pH of 8-9+, and why ammonia has such an increased toxicity at those pH levels. Both the normal "buffering" effects and nitrification processes are inhibited, unbalanced and become almost self-perpetuating, perhaps explaining why, even after cycling, some systems have great difficulty moving beyond pH 8 and why it often takes such systems significantly longer to cycle.

I believe it also goes some way in explaining sudden fish mortalities, often surmised, probably correctly, to be due to a combination of pH, ammonia, temperature and oxygen depletion.

I postulate that indeed this represents a significant difference between AP systems and pond-based systems, and some RAS systems, which employ techniques such as liming to lower and maintain pH to levels of

pH 8-9 and the associated management of algal blooms.

This is often done to encourage succession in the ponds, to provide natural food (zooplankton, rotifers etc) for fish stock as juveniles and as an aid to carbon dioxide/oxygen conversion.

Such practices, though, are always essentially at a pivot point of imbalance and require constant management. Of course in AP systems we rely on external bio-filtration from our growbeds, a practice which, in my opinion, results in greater stability. In my opinion, I believe it could be said that pond based systems never really "cycle" as such, and exist constantly on the edge of imbalance. This can be seen when the effects of temperature and feeding result in oxygen depletion and the normal phytoplankton algae die and the pond crashes into a toxic "blue-green algae" that rapidly depletes not only the oxygen but, I believe, combined with the pH effectively "kills" the *Nitrospira*, leading to a rapid rise in free ammonia, itself detrimental to nitrification by *Nitrospira* and rapid depletion of oxygen from the water body.

I believe this also represents an explanation as to why it is that AP systems tend to usually run quite happily with oxygen levels of about 4mg, whereas pond-based and RAS systems often employ significant supplementary oxygenation to raise levels to around 8+ mg.

It has also been a long-held view amongst koi-keepers and breeders that koi ponds (and the koi themselves) benefit from maintaining a pH around 8.5, a practice that leads to significant problems with both water quality and algae and demands for high levels of filtration.

Many koi exponents are now challenging such beliefs and maintaining healthy clear ponds and fish at pH levels of 6.5 – 7.5.

## CONCLUSION

I'm not a scientist and have neither the opportunities or resources to test these beliefs, but in my opinion;

- Aquaponic system source water should always be adjusted to a pH level between 6.5 and 7.5 before commencing the cycling process.
- Aquaponic systems should be maintained at pH levels between 6.5 and 7.5.
- Maintaining these pH levels will benefit nutrient uptake by plants, maximize nitrification by *Nitrospira*, minimize free ammonia toxicity, maximize oxygenation and maintain a level of stability with minimal stress to both the owner and the fish in the system. ●

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John Burgess runs an aquaponic business in N.S.W. Australia, [www.freshbynature.com.au](http://www.freshbynature.com.au)  
He's also a very active member of the Backyard Aquaponics online discussion forum.



# Backyard Barra

Neville Passmore, presenter of The Garden Gurus TV show, tells of his adventures with aquaponics and fish farming.



**N**ow I have the attention of every red-blooded fishing person in the country, I can say, yes, it is possible to grow your own barramundi in your backyard pond. I have a 1500-litre slit pond at the back of my house with more than 20 barra growing in it that will, with a bit of luck and good management, end up later in the season on my table ready to be eaten. I have already enjoyed trout from the farm, and the flavour of freshly caught and cooked freshwater fish is just better than my powers of description. My fish farming experience has been something of a journey, so allow me to walk you along the path.

I first caught the aquatic food-growing bug in Thailand, where I saw large ponds in rural areas where they grew kang kong or water morning glory as a surface crop and farmed fish under the water in large ponds. Then I was introduced to organic ponds by Jim Hoffman at Woodvale Fish and Lily Farm. Jim's daughter Calinda Anderson writes a regular water garden column in The Guru. Jim used a mix of aquatic herbs to strip nutrients from the water in his fish farm where he grew koi and goldfish for sale. All the water from the water lily and fish beds drains to the lowest point on the property where it is pumped through a series of channels, each of which

has a suite of water cress, reeds, Chinese water chestnuts and other aquatics to clean all the fish wastes from the water so it can be recirculated back through the nursery. A hidden factor in the water cleanup is the gravel in the base of the ponds, which acts as a base on which algae grow. The bacteria convert the ammonia from fish wastes into useable nitrogen-based fertiliser. The plants can then take this up as food and use it to fuel their own growth.

Now this idea of growing fish and plants together in one system started running around in my mind, and I wondered if it





## Our Favourite Tanks

might be possible to grow edible fish in such a system. I visited Rob Van Aurich, an expert in hydroponics at his business called Hydroponics Express. On one hand, I was completely disappointed; you see, I thought I had invented this backyard fish farming business. Rob pointed out that it had been in existence for years, and he even had a working hydroponic fish farm in the demonstration nursery for me to see. This certainly was a bonus, and my enthusiasm returned very quickly. On my next visit to his nursery, I met up totally by coincidence with Joel Malcolm, who was actively setting up hydroponic fish farms all around the country under the name Backyard Aquaponics, a combination of aquaculture and hydroponics.

I set up the hardware at home and picked up my first lot of trout from Rob. He pumped oxygen into the bags to keep the levels up for

the one-hour journey home. When I opened the boot at home, I was devastated to find all the babies were floating. Hoping against hope to revive them with a shot of cold pond water, I emptied the bags into the specially prepared trout home - to no avail.

My wife, Sandra, is a palliative care nurse and the sight of 25 deceased trout in my production pond turned into a story that was repeated to great amusement to colleagues, family and friends. Unfortunately, this was not the last tragedy.

The next lot of trout delivered direct to my garden by Joel Malcolm took off like rockets, tripling their size in eight weeks. These are such terrific fish to grow at home; they explode through the water when you toss some floating food pellets on the surface, and dart around at other times with great speed.

I had one meal of these elusive fish and it was sublime. The morning I was due to fly to Ireland to film our The Gurus Explore Northern Ireland show, I noticed the water level was a bit low in the pond so put the hose in the water to top it up. I forgot to turn it off, and found to my horror on my first phone call home that the entire school of plate-size trout has died as a result of exposure to the chlorine in drinking water, which had overflowed the pond edges and left many on the path. Devastation.

I managed on my return to get my hands on some black bream, a hardy but slower growing fish. One week after they went into the water, all had died from a spotting disease which attacked the weakened fish that were suffering from a change of water temperature, stopping them from feeding and hence affecting their ability to fight off disease. So my reputation was getting a new battering



**Neville and daughter Gabriella planting their new growbed**



“ I can’t wait to rev up the barbecue for my first **home-grown Spicy Barra in Banana Leaf** ”



with every batch entering the system. But determination is one of my strong points so I am forging ahead with another species of fish.

The aquaculture section of Fremantle TAFE supplied me with barramundi babies and loaned me an immersion heater to bring the water temperature up. Trout love cold conditions and are ideal fish for winter growing in Perth, whereas the summer water temperatures of over 25°C are way too hot for them to survive. The ideal temperature for tropical barramundi is 28°C so they are perfect to grow in summer.

The barra are looking good. While they are not anywhere as active as trout, it’s great to see them moving around in the shadows as they tend to do.

Above the pond are two growbeds filled with hydrocoral, also known as expanded clay. This is a furnace-cooked clay material that has thousands of tiny fissures inside of each granule, which make it highly absorbent and amazingly lightweight. These granules act as an inert soil substitute. Vegetable and strawberry plants grow in the hydrocoral. A small pump lifts the pond water up into the grow beds for 15 minutes of every hour to flood them. The water drains back into the pond after it has watered the plants by immersion.

I have planted the grow beds with a selection of broccoli, lettuce, tomato, coriander, Swiss chard, purple fennel, Chinese water chestnuts and red-

stemmed spring onions. At planting, I washed soil off the roots of the plants and placed them into the hydroponic growing system by plunging the roots into the clay media.

After a decidedly shaky start, I am in the backyard barramundi business with a vengeance. Every setback has been a learning experience and I can’t wait to rev up the barbecue for my first home-grown Spicy Barra in Banana Leaf. For further information on aquaponics, I suggest going to our website [www.thegardengurus.tv](http://www.thegardengurus.tv) and looking up aquaponics on the search engine to see a story we shot at Backyard Aquaponics, Joel Malcolm’s business, showing the whole process in moving pictures for *The Garden Gurus*. ●





By the Pool

# Larvae Land

*Grow your own fish food*

By Faye Arcaro







If you had told me a year ago that I would be breeding flies I would have said you were crazy. But for anyone who loves their worm farms, here is another link in the chain of sustainability.



**A**

s we begin to explore the underworld of bugs we develop an awareness that they are an integral part of our ecosystem. The more we understand the part they play, the greater respect we have for them and we begin to embrace their value. Here we have yet another article in our series of beneficial bugs as we uncover the often unrecognised Black Soldier Fly.

There are over 120,000 species of fly around the world today and they are often seen as vectors of disease. It is important to remember that flies can be beneficial as pollinators, reducing food waste, controlling other insects, as well as food for many birds, mammals and reptiles. *Hermetia illucens* or Black Soldier Fly as they are commonly known are not house fly pests as they do not regurgitate their food and rarely enter homes.

### Life Cycle

Adult soldier flies will only live for 5-8 days and during this time their sole purpose is to reproduce by finding a mate and laying up to 900 eggs. Perhaps one reason for their short adult life is they do not eat and therefore are unable to sustain themselves. They are most active in the warmer months of the year. Most adults are usually seen

as they first emerge or when the female returns to the food source/farm/biopod to deposit her clutch of eggs.

The female looks for the right environment such as a crevice above or close to a source of food rather than directly on it so that when the eggs hatch they either drop or crawl giving them a better chance of survival.

The eggs are about 1mm in size and hatch in around four days. The larvae are voracious feeders, and during this phase will have five instars (moult) and if environmental conditions are favourable they will reach maturity anywhere from 2-4 weeks depending on conditions and available food. The complete cycle can take as little as 38 days from egg to winged adult at temperatures of 29°C or 84°F.

As the grubs grow their colours change from white or creamy yellow, turning brown as they mature. Larvae can range in length from 3-19 mm ( $\frac{1}{8}$ " to  $\frac{3}{4}$ "). They are sensitive to light and when uncovered will burrow away in search of a dark hiding spot.

The mature brown larvae are known as prepupae and as they mature they leave the source of food and look for a dryer environment to hatch out.

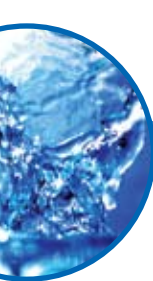
When shown the larvae of a Black Soldier Fly many people acknowledge they have seen them in their compost pile or worm farm and are delighted to have identified them.

### Uses

**Waste reduction:** BSFL have been found to reduce waste matter by an astonishing 95%. These biological bulldozers react to their food at an amazing rate and consume in a 24 hour period what worms would take days to process.

They will consume anything that will break down including meat, dairy, citrus and onions. They do not wait until the matter is undergoing its decomposition or decay and for that reason there is little if any smell.





*Black soldier flies lay their eggs in batches, with an average of about 900 per mass. The eggs hatch in 4 days at 24°C (75°F), and the larvae develop through five instars in 2 weeks or more.*

*The pupa is formed within the pupal case (puparium) formed by the integument of the last instar larva, and the pupal stage lasts 2 weeks or more. The adult emerges from the puparium through a T-shaped slit in the anterior.*

*The life cycle from egg to adult requires 38 days at 29°C (84°F) and 60 days at 20°C (68°F).*



### Interesting facts

- The adult fly has no mouthparts therefore does not bite or sting
- BSF avoid homes and are not known disease spreaders
- Mature larvae turn brown and harvest themselves cleanly up a ramp and into a bucket
- The presence of Black Soldier Flies deters and eliminates the common house fly
- The addition of fish offal to manure has been shown to increase the omega-3 fatty acid content of prepupae to approximately 3% (St-Hilaire et al 2007b)
- Food waste may be reduced by as much as 95%
- A one-metre square feeding surface of larvae is capable of reducing more than 15kg of food waste in 24 hours
- Excellent source of high protein feed for poultry, fish, reptiles and livestock
- In cool weather they will eat more and process more scraps but will mature later
- They increase the internal temperature of their habitat as they process the food wastes and without food the temperature drops markedly so it is a good idea to add food scraps regularly
- BSFL will keep for weeks at room temperature
- Calcium levels are higher in darker coloured pupae
- They can be heard chomping on the food waste
- BSFL tolerate higher temperature than worms



**Castings:** the castings left behind by the BSFL resemble coffee grounds and are said to make an ideal bedding for worm farms. The worms further process the BSFL castings making the worm castings richer in nutritional value.

In a pot study, plant growth was increased when the digested manure residue was added to either clay soil or clean sand. (*Larry Newton, Craig Sheppard, Dr Wes Watson, Gary Burtle Robert Dove.*)

**Live feed:** conversion of food waste to highly valuable feed suitable as bait for anglers, aquaculture industry, aquarium fish, poultry feed, reptiles and livestock. Commonly sold under the names phoenix worms or soldier grubs for marketing purposes as consumers react adversely to the label of fly maggots. They may be preserved by freezing.

### Part of an aquaponics system

Many people often question how they can close the loop in an aquaponics system and believe that costly inputs of commercial feeds make it unviable. Farming BSFL will compliment an existing worm farm and reduce waste, while producing a feed of 45% protein and 35% fat making it highly nutritious. As these grubs convert waste to quality feed they will reduce leaf matter, fruits, fish guts and waste into suitable fish food. Their castings can then be added to the worm farm and further broken down.

### How to start a soldier fly farm or biopod

We had already identified larvae from a worm farm and that was the catalyst for starting a bio-pod. We started adding the same bedding that we would start a worm farm with. This included aged compost, lupin mulch and the addition of leachate from a worm farm to moisten the area. Layers were created with organic food scraps, rotting fruit and layers of

cardboard soaked in worm leachate. We added about 30-50 yellow/cream coloured larva found in the worm farm as well as the surrounding bedding which was quite moist.

We have continued to find larvae in the worm farm and from time to time boost the supply in the bio-pod to help establish the colony. Within around 3-4 weeks we started to observe the mature larvae in the bucket. During the early stages we observed a few other insects were attracted to the pod which included fermentation flies, ants, small maggots as well as some worms. It was not long before we witnessed a female fly visiting to lay eggs. Not long after did we notice that there is little if any other activity other than the BSFL.

The ants were attracted to the food scraps and we have found that by supporting the legs in bowls of water they were prevented from climbing up the legs. Another way is to smear petroleum jelly (Vaseline), which they stick to and talcum powder renders them unable to move about also. The addition of juice which has leached may be sprayed under the lid to attract females as it gives off an odour undetectable to humans.

We add scraps to the biopod about twice a week and have been delighted to witness the collection of prepupae harvesting themselves. The biopod works by allowing the female to enter a space through

the lid where she lays her eggs above their source of food. When the eggs drop down the larvae have access to a ready supply of food. When the larvae mature they wriggle up the ramp in search of drier ground, fall down the chute and are clean, ready to feed to the fish.

### Diet

Meat, fish, dairy products, food scraps, citrus and onions.

**Not recommended** - Bones, egg shells, grass, garden refuse and paper.

### Useful links

[www.blacksoldierflyblog.com](http://www.blacksoldierflyblog.com)

[www.thebiopod.com/pages/resources](http://www.thebiopod.com/pages/resources)

[www.esrint.com/pages/bioconversion](http://www.esrint.com/pages/bioconversion) ●

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# Aquaponics *in Kenya*



By Travis Hughey

**I**n 2006 I was invited to help build a couple of barrel-ponics systems at a bible school in Karatina, Kenya. Randy Durden, a supporter of Antioch Bible School, had visited my aquaponics system while we were living in Awendaw, SC and wanted to see if it could be done in Kenya.

I took over the hardware kits and Randy supplied the travel and barrels needed, as well as the frame-work and gravel. My son T.J. travelled with me and helped put the systems together while at the school. The students were excited about the

new thing coming and asked many good questions both while building the system and at the lectures I held teaching the principles of aquaponics. We left them with a functioning barrel-ponics system which they harvested vegetables and fish from, before dismantling it and trying their hand at making things larger.

I revisited the system in 2007 to see what they had done and I was very impressed with the fact that they made it their own and believe this is what should happen. Unfortunately there were a few design problems. One was they had made a

growbed much too deep and were sacrificing surface area for cubic footage. In aquaponics it is not necessary to have deep beds because the plants are getting fed and watered on a very regular basis. I have grown fruit producing papaya trees 10ft. tall in 11" of gravel.

The second problem was they used two barrel-ponics flood tanks for this larger system. While this may sound reasonable on the outside, the system never flooded the beds very well as the two tanks seldom synchronized to completely flood the growbeds.





*Getting unpacked and started. I brought a good tool kit to assist in building the system quickly. Cordless drills are a wonderful thing!*



*Working on the flood valve under the watchful eye of one of the local boys.*



*One of the students helping to cut the barrel with a pull saw. I believe it was the first time he had used such a saw.*



*Using charcoal in a "Jiko" (pronounced gee-ko) to gently heat the suction tube so we can bend it.*



*Installing the top raft tank onto the flood tank of the system. The growbeds and fish tank are already almost completed.*



*Filling the growbeds with gravel. No soil required with this method of growing crops.*

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## Over the Back Fence

The third problem was their choice of fish. Located in the highlands, Karatina is mostly cool. They had chosen tilapia because they knew I raised them and thought they would be a good choice.

Tilapia are a good choice as long as the water temperature can get in the 70's

(°F) but where they had the system situated it just did not get warm enough. A much better choice would have been catfish or trout grown from a hatchery just down the road. They had to travel a long way just to get the tilapia.



**The larger system they built using components from the original system.**

Even with all these obstacles the system was still growing pumpkin and spinach and proves it's resiliency, once the bacterial culture that makes the system work is established. ●



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# Conversion tables

## Metric Length

1 millimetre [mm]		0.03937 in
1 centimetre [cm]	10 mm	0.3937 in
1 metre [m]	100 cm	1.0936 yd
1 kilometre [km]	1000 m	0.6214 mile

## Imperial Length

1 inch [in]		2.54 cm
1 foot [ft]	12 in	0.3048 m
1 yard [yd]	3 ft	0.9144 m

## Metric Volume

1 cu cm [cm <sup>3</sup> ]		0.0610 in <sup>3</sup>
1 cu decimetre [dm <sup>3</sup> ]	1,000 cm <sup>3</sup>	0.0353 ft <sup>3</sup>
1 cu metre [m <sup>3</sup> ]	1,000 dm <sup>3</sup>	1.3080 yd <sup>3</sup>
1 litre [l]	1 dm <sup>3</sup>	1.76 pt
1 hectolitre [hl]	100 l	21.997 gal

## Imperial Volume

1 cu inch [in <sup>3</sup> ]		16.387 cm <sup>3</sup>
1 cu foot [ft <sup>3</sup> ]	1,728 in <sup>3</sup>	0.0283 m <sup>3</sup>
1 fluid ounce [fl oz]		28.413 ml
1 pint [pt]	20 fl oz	0.5683 l
1 gallon [gal]	8 pt	4.5461 l

## USA Volume

1 fluid ounce	1.0408 UK fl oz	29.574 ml
1 pint (16 fl oz)	0.8327 UK pt	0.4731 l
1 gallon	0.8327 UK gal	3.7854 l

## Metric Mass

1 milligram [mg]		0.0154 grain
1 gram [g]	1,000 mg	0.0353 oz
1 kilogram [kg]	1,000 g	2.2046 lb
1 tonne [t]	1,000 kg	0.9842 ton

## Imperial Mass

1 ounce [oz]	437.5 grain	28.35 g
1 pound [lb]	16 oz	0.4536 kg
1 stone	14 lb	6.3503 kg
1 hundredweight [cwt]	112 lb	50.802 kg
1 long ton (UK)	20 cwt	1.016 t

## Temperature Celcius

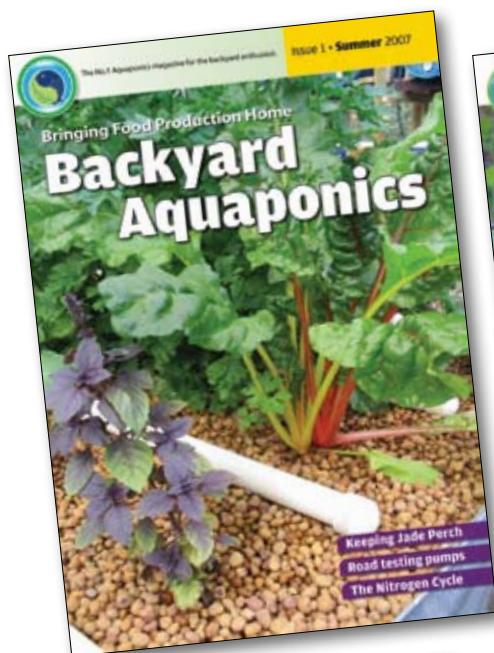
0°C		32°F
5°C		41°F
10°C		50°F
15°C		59°F
20°C		68°F
25°C		77°F

## Total Ammonia Nitrogen (TAN) - ppm

Use this table to find out when ammonia levels will start to become toxic to your fish

Temp (°C)	pH										
	6.0	6.4	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4
4	200	67	29	18	11	7.1	4.4	2.8	1.8	1.1	0.68
8	100	50	20	13	8.0	5.1	3.2	2.0	1.3	0.83	0.5
12	100	40	14	9.5	5.9	3.7	2.4	1.5	0.95	.61	0.36
16	67	29	11	6.9	4.4	2.7	1.8	1.1	0.71	0.45	0.27
20	50	20	8.0	5.1	3.2	2.1	1.3	0.83	0.53	0.34	0.21
24	40	15	6.1	3.9	2.4	1.5	0.98	0.63	0.4	0.26	0.16
28	29	12	4.7	2.9	1.8	1.2	0.75	0.48	0.31	0.2	0.12
32	22	8.7	3.5	2.2	1.4	0.89	0.57	0.37	0.24	0.16	0.1





**T**his edition of the **magazine** sees us take things forward another step with a printed version becoming available. The magazine will be available either as an electronic subscription, or in a printed format. For current subscribers who wish to receive printed editions, we will be sending out details of how to upgrade soon.

Work is well under way on the **sixth edition** of the magazine. We will continue to showcase systems belonging to members of the online discussion forum, there will be information on vegetables and plants well suited to aquaponics systems, plus lots of useful hints and tips.

*It's promising to be an exciting issue, packed full of information.*



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