# Association Between Competition and kin discrimination in GIFT strain, Nile tilapia (Oreachromis nilotics)


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The World Food Prize Foundation

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WorldFish

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## ***Abstract***

Many animals including zebrafish, juvenile brook trout, and species of salmonid have shown the ability to recognize kin. With the ability to recognize their own kin these animals have shown better social behavior towards their kin, such as increased food sharing and reduced aggressiveness. According to some published evidence, fish are able to discriminate kin based on chemosensory cues (e.g. Brook trout by Hiscock and Brown, 2000; Atlantic salmon by Olsen *et al.,* 2004; Zebrafish by Gerlach *et al.,* 2007, 2008). The study conducted by Gerlach *et al.* (2007) even showed that when juvenile zebrafish reared in kin group grew 33% more compared to the non-kin group. In that the study the authors concluded that because zebrafish raised with kin experienced less competition and a less stressful environment, they had a better growth rate.

Kin recognition has been observed in zebrafish, juvenile brook trout, and species of salmonid, but has yet to be observed in tilapia. This is the focus of the experiment. We want to know if tilapia have the ability to recognize their kin. Obviously, tilapia or any animal for that matter can't tell us that they know which of their fellow species are their kin or not. So, in order to figure out if tilapia can recognize their kin we will employ the use of coefficient of variation (CV) of body weight to measure the results of the experiment. CVs are cheapest and simplest way to measure the appearance or degree of competition in fish. Predominantly, an increase in CV indicates aggressive behavior and more competition (Jobling, 1995; McCarthy et al., 1992; Adams et al., 2000). On the contrary, a low CV suggest that there is less competition and a good social environment (Jobling, 1995; Mambrini et al., 2006). According to the studies stated above, when zebrafish were raised with kin they experienced less competition and a less stressful environment. So, we can conclude that CVs should be able to indicate (although indirectly) if tilapia can recognize their kin. So, this bring us to our hypothesis. Our hypothesis is that tilapia do have the ability to recognize their kin and we will see lower CVs if the fish are raised with their kin. Our hypothesis was chosen because that since many other species of fish have the ability to recognize their kin, tilapia should also have this ability.

The question that comes up next is how will this help people who are food insecure? When it comes down to it, the reason that this experiment is significant is uniformity. Typically, when fish are harvested in a third- world or developing country there are many fish that are too small to be eaten. The farmer has wasted their time and money to raise an inferior fish that is not the correct size when it is harvest time. If it is true that tilapia can recognize their kin and there are lower CVs when tilapia is raised with their kin, this means that more fish will be uniform in size at harvest time.

The design of the experiment is simple. Thirty black round plastic tanks with stocking density of 50-70 fish will be used. The families of fish are organized into two treatments. Treatment 1 has

fingerlings from a single family. Treatment 2 has fingerlings from two unrelated families. The weight of the fish will be measured once a month. Weighing the fish will also help us examine the growth rate and degree of competition in each test group. At the end of four months the experiment will be terminated and the final weight and sex of the fish will be recorded. The date will be analyzed using the SAS statistical software package (SAS Institute Inc., 1997). If the experiment works as designed, we anticipate that we can clearly conclude if our hypothesis is proven or disproven. We will know if the hypothesis is correct if we will see lower CVs in treatment 1 then treatment 2.


## *Acknowledgements*

This internship was the experience of a lifetime and it wouldn't have been possible without a whole list of people. The first person I would like to thank would be the late **Dr. Norman Borlaug**. Unfortunately, I was not able to meet him before he passed away in 2009. The only way I have to get to know the amazing person that was Dr. Norman Borlaug is through stories. I absolutely love hearing stories about him. Every time I attend an event that is hosted by the World Food Prize, I hear another incredible story about Dr. Borlaug and every time the story makes me wish even more that I could have met him. He touched so many lives in his lifetime, and he has touched just as many lives in his death. His ability to make an impact on people's lives, even after he died, is something that is truly unbelievable. Thank you, Dr. Borlaug.

The second person that I need to thank is the second person that the Borlaug-Ruan International Internship is name after and that person is **John Ruan**. Known as the person that "rescued" the World Food Prize, he is one person that truly deserves gratitude. I cannot thank him enough for his generosity. I also would like to thank him for his idea to move the World Food Prize to Des Moines, Iowa. The World Food Prize is one of the many reasons that makes me proud of my home state and every time I see a semi-truck with name Ruan on it, I turn to person next to me and tell them, "The guy who started that company is one of the people that made my internship possible."

I also would like to thank **Ambassador Kenneth Quinn**, **Lisa Fleming**, and the **entire staff at the World Food Prize**. The amount of work that these people put into the Borlaug-Ruan International Internship is astonishing. I don't know many organizations that have the boldness to send twenty-three high school age students by themselves to a foreign country for two months. I am still impressed on how smoothly the staff of the World Food Prize run this internship, plus on top of that they can flawlessly execute multiple youth institutes and programs, a three-day symposium with hundreds of attendants, and an international award that honors the people who have made great strides involving the world food supply. There is no amount of gratitude I could give that would fully show my appreciation for the World Food Prize and the people who run it.

My heartfelt thanks also go to the **staff at WorldFish**. Specifically, I would like to thank **Sharon Suri** and her husband **Asaad** for allowing me to stay in their home and for being such welcoming hosts, **Hooi Ling** who was my supervisor, and **Khairul Rizal Abu Bakar** and **John Benzie** for allowing me to work on the recirculating aquaculture systems.

Finally, I would like to thank the teachers that inspired me to apply for this internship. These teachers include **Dawn Guritz**, **Sarah DeBour**, and **Jane Halladay**. Teachers tend to be some of the first people in life that can recognize your talents and inspire you to do great things. So, I would like to thank these three teachers for doing just that.

## ***Introduction***

### Personal Introduction

If I was told five years ago, that I would be working in agriculture and even pursuing a career in agriculture, I wouldn't have believed it. Even though I was born and raised in Iowa, I didn't give agriculture much thought. I guess that changed when I moved from where I was born, Clinton, Iowa, to Alexander, Iowa. Alexander is an extremely small town and with only one hundred seventy-five people. It is truly one of those towns that if you blink while driving past, you will miss it. As you could imagine, the school I went to was also small. It was at that school, CAL Community School, that my passion for agriculture developed.

I took an agriculture class based only on the fact that I needed a class to fill up my schedule. One of the requirements for taking that class was joining the FFA chapter. After a month or two of taking the class and being a member in the FFA chapter, I started to notice various opportunities. That year the FFA chapter was building a new greenhouse and one day as I walking into class I noticed an intriguing system sitting in the classroom. That system was a hydroponics system. I showed interest in it and my agriculture teacher, Sarah DeBour, told me that if I fixed it I could do some experiments with it. I did just that and for the latter half of my freshman year and most of the summer I did some experiments growing tomatoes, peas, lettuce, and peppers hydroponically.

Then during the beginning of my sophomore year my FFA chapter received a grant to obtain an aquaponic system. This changed my life and sparked an enormous interest in aquaponics. I learned everything I could about it. Every book, article, or video I could find on the subject I read or watched to learn as much as I could. Since I knew the most about aquaponics, I was put in charge of the system. I can still remember how ecstatic I was when the delivery truck came in with the system. I assembled the system as fast as humanly possible. Working with the system turned my theoretical knowledge into hands-on experience. I made plenty of mistakes while in charge of the system. For example, at one point I managed to kill five hundred dollars' worth of koi because the nitrite levels in the system were too high. However, I did not let these mistakes deter me. I turned my missteps into positive learning experiences. When working with aquaponics, errors are guaranteed to happen because the system can be very fragile, especially in the beginning stages of starting the system. Running an aquaponics system opened my eyes to how much fun I could have in agriculture and to the possibility of persuading a career in ag.

My sophomore year also happened to be the first year I attended the Iowa Youth Institute. My agriculture teacher was the one who wanted me to write the paper. I wrote it on sustainable agriculture in Egypt. I must admit that the paper I wrote was not my best paper, but I would get another chance at writing the paper. Because during my junior year, my English teacher Mrs. Guritz made my whole class write the paper. This time I knew what I was doing and what mistakes I made with my last paper. This second paper was on malnutrition in Haiti. Naturally, my solution to malnutrition in Haiti was aquaponics. With this paper, I attended the Global Youth Institute in October of 2015.

I absolutely loved the atmosphere of the Global Youth Institute. Having hundreds of people who share the same passion as you is definitely exciting. Attending the three-day event further increased my passion for agriculture. I was not sure if I wanted to apply for the Borlaug-Ruan Internship going into the Global Youth Institute, but after it was over I was dead set on applying for and receiving the internship. I wanted to help more with food insecurity issues and use my knowledge of aquaponics to teach and help people. So, not even a day after my experience at the 2015 Global Youth Institute ended, I started on the application process. I used my experience with aquaponics as a huge selling point as why the World Food Prize Foundation should pick me as one of the 2016 Borlaug-Ruan Interns. I believe this paid off because in April of 2016, I learned I was going to WorldFish in Penang, Malaysia.

## Going the Distance- Iowa to Malaysia

June 21, 2016 was the day that I eagerly waited for. It was the day I would leave for an adventure of a lifetime. In the time before leaving for my internship, I started preparing for it. I started to do research on Malaysia and the organization I would intern at for two months, WorldFish. I did not know anything about either of these subjects, but after a few hours of reading countless articles I had a basic understanding of what Penang, Malaysia was like. From what I could tell, Penang looked like many large American cities and after spending two months there, I can say that there are many similarities.

In no time, June 21st arrived. I was expected to arrive in Penang on June 23rd, so to say that it was a long journey to Malaysia is an understatement. Not only was it a long trip, but it was also my first time flying on a plane. So, after two long days of traveling I finally landed in Penang. I wandered around for a bit before I found the person who was supposed to pick me up. His name was Maniam. One of the first things I noticed as I walked out of the airport was how beautiful Penang was. The mountains in the background were simply breathtaking. The second thing I noticed about Penang was less picturesque and that was the traffic. I have been in big cities before and the traffic was bad, but in Penang it was insane. The main reason for this was because of the motorcycles and scooters. It seemed like there were hundreds of them and they did not seem to follow many traffic laws. They were always driving too fast and would drive in between cars while going down the freeways. I'm not going to lie, there were times I was generally scared for my life, but by some miracle we made it to the apartment where I would stay safely.

## A Short History Lesson-WorldFish

The research center that I would work at for two months has been around in one form or another since the 1970s. In fact, it was not originally known as WorldFish. It started off as the International Center for Living Aquatic Resources Management (ICLARM). ICLARM was established at the University of Hawaii in 1975 and was a Rockefeller-funded program. It became fully operational as an independent center two years later in 1977 and put its first headquarters in Manila, Philippines.

Throughout the years ICLARM slowly grew and extended it reach. It opened offices in the Pacific, Solomon Islands, and Bangladesh in 1985, 1986, and 1989, respectfully. It became a member of the highly-respected Consortium of International Agricultural Research Centers (CGIAR) in 1992. Then in 1998 ICLARM once again expanded. The Egyptian government made the Abbassa Research Center available to the organization.

Perhaps one of the best gifts that ICLARM made available to the human population came in 1997. This was the GIFT tilapia or the Genetically Improved Farmed Tilapia. ICLARM and its partners, the Institute for Aquaculture Research, Norway (AKVAFORSK, now Nofima) and national fisheries institutions in the Philippines (the Bureau of Fisheries and Aquatic Resources, the Freshwater Aquaculture Center of Central Luzon State University, and the Marine Science Institute of the University of the Philippines) started the GIFT project in 1988. The GIFT tilapia has provided many small-scale farmers with a source of food and nutrition. This tilapia is currently in sixteen countries and on it 15th generation (Hooi Ling,2016).

ICLARM moved its headquarters to Penang, Malaysia in 2000. In 2002 ICLARM adopted its current name, WorldFish. WorldFish expanded its reach again, by putting offices in Cambodia and Zambia and starting program work in East Timor and Myanmar. In 2012 CGIAR selected WorldFish to the CGIAR Research Program on Aquatic Agricultural Systems. Looking ahead in the future, it is guaranteed that WorldFish will continue to expand and help thousands of people through its many programs.

### Mentors and Supervisors

While working at WorldFish I had the great honor of working with many wonderful people. My supervisor for the kin discrimination experiment was Hooi Ling. She is a quantitative geneticist who specializes in aquatic species. She has over twelve years of experience in breeding fish. I also worked with John Benzie, who is the head of the genetics department at WorldFish. He was the one who allowed me to design and build the recirculation aquaculture system at WorldFish. John has authored many research publications. His research is primarily in the development of aquaculture and natural resource management and the application of genetics.

## ***Research Project***

### Background

The goal of the research project that I helped with was to find the association between competition and kin discrimination in GIFT strain, Nile tilapia (*Oreochromis niloticus*). In short it has been shown that many animal will show better social behavior towards their siblings or relatives then compared to unrelated conspecifics. These "better" social behaviors include reduced aggression and increased food sharing among relatives (Kareem and Barnard, 1982; Hiscock and Brown, 2000; Wahaj *et al.*, 2004; Gerlach *et al.*, 2007). According to published evidence, the mechanisms that allow fish to discriminate kin is based on chemosensory cues. Fish such as Brook trout (Hiscock and Brown, 2000), Atlantic salmon (Olsen *et al.*, 2004), and zebrafish (Gerlach *et al.*, 2007, 2008) have all shown that they can distinguish kin based on chemosensory cues.

We want to know if tilapia, specifically Nile tilapia, (*Oreochromis niloticus*), have the capacity to recognize their own kin because of uniformity. As stated earlier, when some species of animals are raised with their kin, they show less aggression and increased food sharing. This means that the animals will be about the same size. This is important, especially in the aquaculture industry. The market demands a certain size of fish and when a farmer can only sell a few large fish, which often are the ones that are the most aggressive, he or she loses money. That is what we are trying to negate with this experiment. If tilapia can recognize their kin and are more uniform in size when raised with their kin, this will hopefully lead to more fish that can be sold when harvest time comes; thus increasing the profits of the small-scale farmer.

## Method and Materials

The execution of this experiment is straight forward. Brood fish from the eighth generation of GIFT (Genetically Improved Farmed Tilapia) will be used to spawn the fish for the experiment. In total, there was ten males and twenty females transferred to WorldFish's fish tank facility from Jitra Aquaculture Extension Center.

For the brood fish to reach spawning, they were condition in fiberglass tanks with optimum feeding. The mating was carried out in big fiberglass tanks where mating hapas were installed. The mating ratio was one male per two females. Once the fertilized eggs were collected from the mouth of the females, they were transferred to incubators. Eggs were kept with their full sib-family and placed into two different incubators.

Once the fry absorbed the yolk-sac, they were transferred to two nursery hapas for nursing until the tagging size of 5 grams has been reached. Before being released into the nursery hapas, total weight and number fry of each family was recorded. A total of six hapas will be placed into the same fiberglass tank. Doing this will reduce any environmental differences that can occur during the nursing period. This will also allow for the exchange of chemical cues between different families (Hiscock and Brown, 2000). Thus, non-relatives or relatives would have been familiar with all the chemical cues in the same tank.

Once the fingerlings reach the size of grams, they were individually identified with PIT (Passive Integrated Transponder) tags. Initial weight and date of tagging were recorded. What these tags allow us to do, is identify each fish and track it growth individually. The tanks used to raise the fish in this experiment were 30 black round plastic tanks. The stocking density per tank was about 50-70 pieces. The families were organized into two different treatments according to their relationship. Treatment 1 consisted of fingerlings from one full-sib family. Treatment 2 consisted of fingerlings from two unrelated families (one of the families if from T1.

The fish used in the experiment were stocked in the tanks on the same day and the date was recorded. Every month the body weight of the fish was measured. Using the body weight, the CV of body weight for each family could be calculated (CV, % = 100 x standard deviation x mean$^{-1}$). Mortality was recorded daily. When the fish were fed, the feed was place at one spot to stimulate competition. Fish were fed twice daily (3-5% of their body mass) with commercial pellet feed containing 40% protein. The experiment ran for 4 months. The reason being is that four months is equivalent to the grow-out period in ponds). The weight, length, width, and sex of each fish was taken a week before the experiment was terminated.

One of the benefits of the benefits of using tilapia that were related to those in the main stream GIFT breeding program is that a comparison can be made between the breeding program where all the fish were grown out in a communal pond and the CVs collected in this experiment.

## Responsibilities

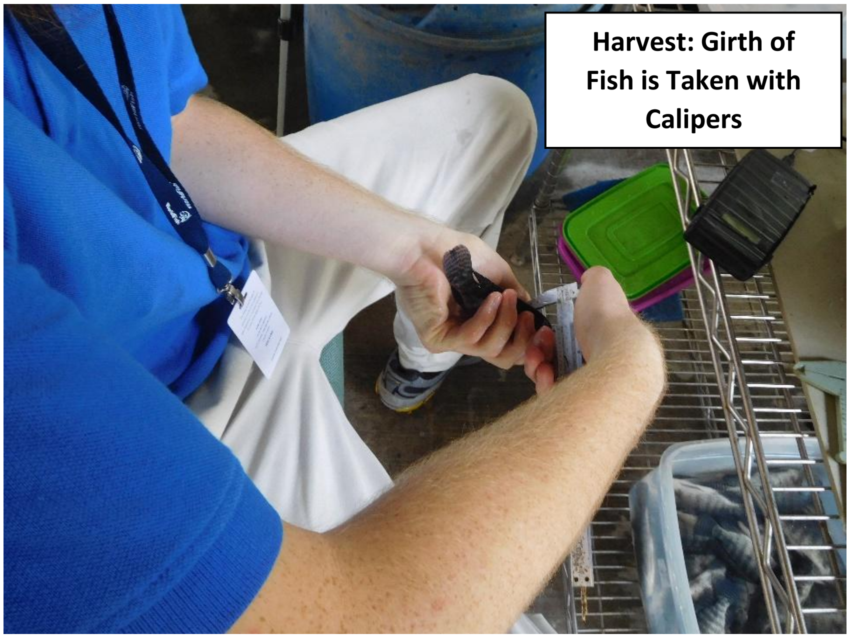
For the most part my responsibilities for the experiment were simple. Every day I would feed the fish twice, once when I got to work and once before I left work. While feeding the fish, I would check for mortalities and record them. I also oversaw the cleaning of the tank filters. I did this about once a week.

**Feeding the Fish**

Another important task I performed was assisting with the data recording for the experiment. This was done once during July and then when we harvested the fish in August. The data recording took three to four days to complete. For the first data recording, only the weight in grams was taken for all the fish. Over a thousand fish needed to be weighed.

**Data Collection: Scanning the Fish for PIT Tag**

The procedure for weighing the fish is as following: First we would completely drain the water in the tank. This allowed us to collect the fish and gave us a chance to do a complete water change in the tanks. Once the fish were collected, we would sedate them. Then an electronic reader was use to read the PIT tags in the bellies of the fish. A scale was then used to find the weight. Finally, the fish were returned their respective fish tanks. For the harvest the same procedure was followed, expect the length, width, and girth were measured and then the fish were put into an ice bath to euthanize them. Then the fish were dissected to determine sex.



**Harvest: Girth of Fish is Taken with Calipers**

**Harvesting the Fish**

## Results

Unfortunately, as of the writing of this paper the data is still being analyzed. So, the official results are unknown, but based on observations the fish raised with their full-sib family were more uniform in size then the fish raised with unrelated conspecifics. If the actual data concurs with this observation, then this trial would be a success and then subsequent trials will take place to show with 100% certainty that tilapia can discern kin. Below is the data for the whole experiment.

**Kin recognition experiment – second batch – April to August 2016**

*Summary for harvest data*

Table 1 Number of observations (N), simple mean, minimum, maximum, standard deviation and coefficient of variation of harvest body weight (g), body width (cm) and duration of experiment (days).

| Variable | N | Mean | Minimum | Maximum | Standard deviation | Coefficient of variation |
|---|---|---|---|---|---|---|
| Body weight | 1058 | 54.9 | 8.4 | 191.2 | 24.2 | 44.0 |
| Body width | 1058 | 1.9 | 1.0 | 3.3 | 0.3 | 17.8 |
| Duration of experiment | 1058 | 118 | 117 | 119 | 0.8 | 0.7 |

Table 2 Number of observations (N), simple mean, minimum, maximum, standard deviation and coefficient of variation of harvest body weight (g), body width (cm) and duration of experiment (days) by sex.

| Variable | Sex | N | Mean | Minimum | Maximum | Standard deviation | Coefficient of variation |
|---|---|---|---|---|---|---|---|
| Body weight | Female | 485 | 47.0 | 8.4 | 142.1 | 17.9 | 38.2 |
| | Male | 551 | 62.5 | 12.6 | 191.2 | 26.4 | 42.2 |
| Body width | Female | 485 | 1.8 | 1.0 | 3.0 | 0.3 | 16.9 |
| | Male | 551 | 2.0 | 1.1 | 3.3 | 0.3 | 17.1 |
| Duration of experiment | Female | 485 | 118 | 117 | 119 | 0.8 | 0.7 |
| | Male | 551 | 118 | 117 | 119 | 0.8 | 0.7 |

A total of 1,500 pcs of fry were stocked on 11$^{th}$ April 2016. Four months later, 1058 pcs of fish were harvested. This yielded an overall survival rate of 70.5%.

## ***Recirculating Aquaculture System (RAS) Project***

### Introduction

While at WorldFish, I took on another project. This project originated from a conversation Khairul, a research assistant at WorldFish, and I were having one. He was showing me the recirculating aquaculture system that WorldFish had. In my opinion, this system was not well designed. It was too confusing and complex. The system was also having trouble with cloudy water due to solids not being properly filtered.

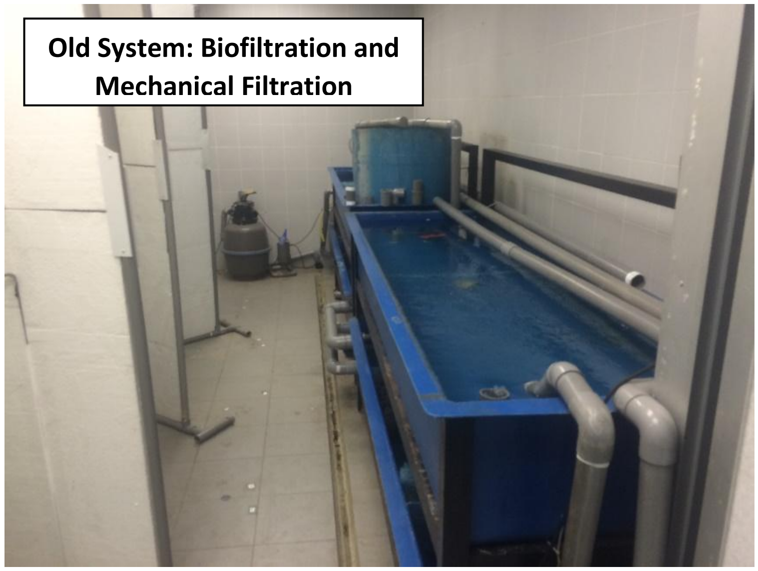
After showing me the system, Khairul told me about the system that WorldFish wanted to build and showed me the plans for it. After looking at the plans I noticed something wrong. The biofiltration in the system was before the mechanical filtration and this can cause a lot of problems. When biofiltration is before mechanical filtration, the biofilter media will get clogged up with solids. This causes a giant mess in the biofilter and potentially can cause the system to crash. I took this concern to John Benzie, head of the genetics division at WorldFish, and explained why this design could cause a problem. I told him I would be willing to redesign the system and even build it. He graciously let me do just that.

Old System: Sump Tanks

Definition: "Recirculating aquaculture systems (RAS) operates by filtering water from the fish (or shellfish) tanks so it can be reused within the tank. This dramatically reduces the amount of water and space required to intensively produce seafood products. The steps in RAS include solids removal, ammonia removal, Co2 removal awhat is biofiltration in aquaculturend oxygenation." ("What Is Recirculating Aquaculture?", 2017).

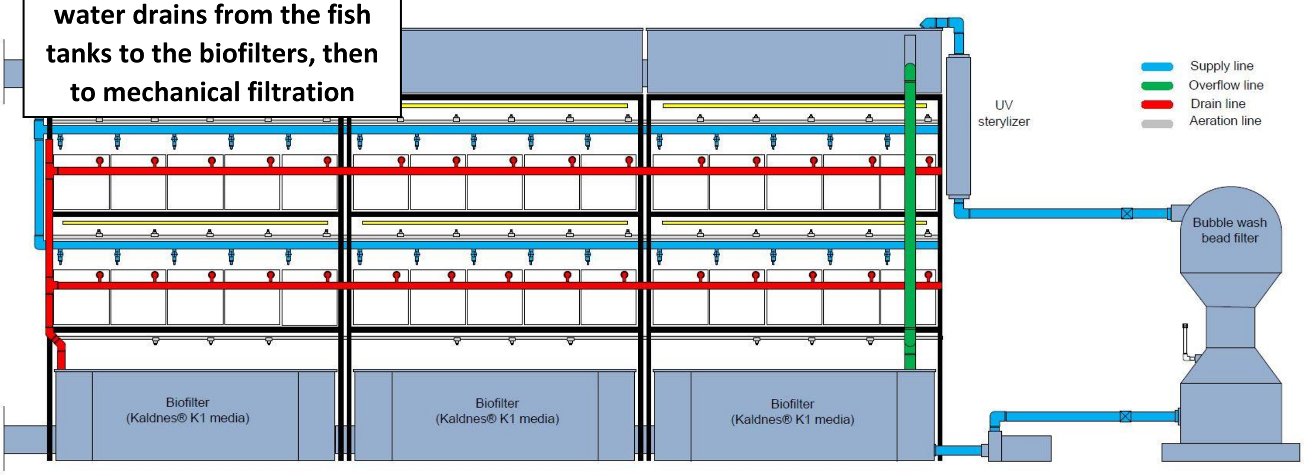
Definition: Biofiltration- the process of using bacteria to turn ammonia ($NH_3$) into nitrite ($NO_2$) then into nitrate ($NO_3$).

Mechanical filtration- the process of using a media to physically trap solids



**Old System: Biofiltration and Mechanical Filtration**

**Old System: Fish Tanks**




**Original Design: Notice the water drains from the fish tanks to the biofilters, then to mechanical filtration**

## Design

To redesign the system, I used the 3D model software, SketchUp. Since WorldFish had already bought the fish tanks, the filter tanks, and the sand filter, I had a good start to designing the system. The first step I took to redesign this system was to do some calculations. All my calculations are on the conservative side. This system is designed to be able to support a commercial stocking density. The stocking density is how many grams of fish per liters of water are in the tanks. Most commercial recirculating aquaculture run their stocking density around 50g/L. Designing the system with such a high stocking density is one of safety mechanisms I implemented to add a level of safety to the system.

With stocking density in mind, I could figure out the maximum kilograms of fish that the system can support. That number is 139 kg of fish and with the fish spread throughout sixty fish tanks, each fish tank can support 2315 g.

The next step was to figure out the total amount of biofilter media that is needed to filter out the ammonia produced by the fish. Ammonia is toxic to fish in concentrations 3.0mg/L or more. In this system, I wanted the ammonia concentration to be maintained at 1.0mg/L or less. Therefore, to figure out the volume of biofilter needed, I had to use a fairly complex formula. First, I needed to figure out was the TAN or Total Ammonia Nitrogen. The formula (Losordo, 2015) I used is as following:

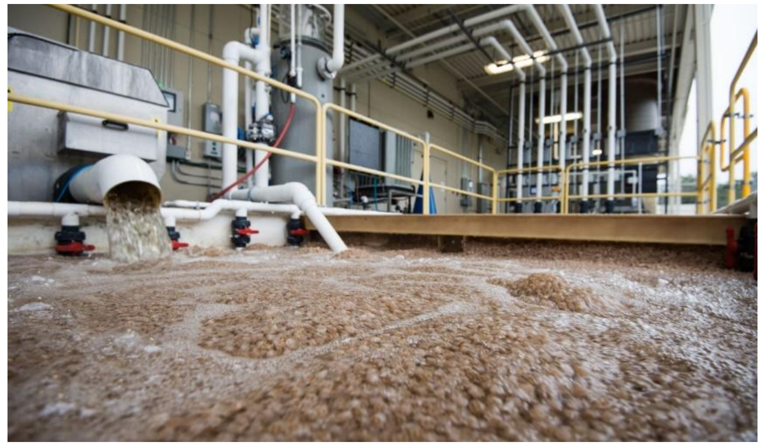
TAN Produced= 7.17kg feed/ day **x** 40% x 50% Nitrogen Wasted **x** 0.16g Nitrogen/ g Protein **x** 1.2g TAN/ g Nitrogen= 0.160128 kg TAN/ day

What does all this mean? Well, 7.17kg feed/day is the maximum amount of feed that will be fed per day. The 40% is the protein content of the feed. There is 50% nitrogen wasted. Then you have 0.16g Nitrogen/ g Protein. This is how many grams of nitrogen are produced per gram of protein in the feed. Finally, there is the number of grams of total ammonia nitrogen per gram of nitrogen. Hence, the TAN produced in this system will be 0.160128 kg TAN/day or 160.13g TAN/day.

Once the TAN was calculated, I could go onto the volume of biofilter media needed to filter this amount of ammonia. But first a little background on the type of biofiltration used in this system. The type is called a Moving Bed Biofilm Reactor (MBBR). MBBRs employ a high-surface area, polyethylene media that bacteria colonialize. Thousands of pieces of this media are put into a tank that is well aerated, causing them take on fluid-like properties.

Media Used in MBBRs

Credit: Pentair AES



MBBR in Action

Credit: Pentair AES

Then I found the total volume of media needed using the following calculations:

Biological Media: A MBBR can filter out 300g TAN/ cubic meter/ day (source) (also known as VTR)

> Biofilter media volume (cubic meter) = TAN Production (160.13g TAN/ day) ÷ VTR (300g TAN/ Cubic meter/day) = 0.53 cubic meters

Another type of filtration needed in a RAS is mechanical filtration. I didn't have to do much thinking on what type of mechanical filtration I would use, because WorldFish had already bought sand filters. A sand filter uses sand or another media to trap solids and other debris. The solids and other debris is removed from the sand filter by backwashing with water.

A Typical Sand Filter

Credit: Pentair AES

Once the biofiltration and mechanical filtration needs were met, I found the amount of aeration needed in the system. Both fish and bacteria require oxygen for many of their biological processes. Using some general figures, I could calculate how many liter per minute the system required (source). Aeration requirements:

Liters/Minute of air needed for one tank: 5.66L/min

Liters/Minute of air needed for all tanks: 339.6L/min

Liters/Minute of air needed for biofilter: 65L/min

Total air needed for system: 535.19L/min

The air would be provided by an air blower, which is basically a glorified air compressor, and air stones (Timmons, 2007).

Finally, I had to figure out the water exchange rate for the system. This is used to find correctly sized water pump. The water exchange rate is the amount of water that needs to flow through a system for biological and mechanical filtration to properly take place. The typical water exchange rate for most systems is the whole system volume turned over in one hour. I decided to have a water exchange rate of 1.5x's/hr. In order to calculate how many liters of water that needed to be pump in an hour, I needed to find the total system volume.

System Volume: Fish Tanks = 2778L

46.7L/ Tank

Biofiltration Tanks (Top Tanks) = 2453.46L

408.91L/ Tank

Bottom Tanks= 1500L

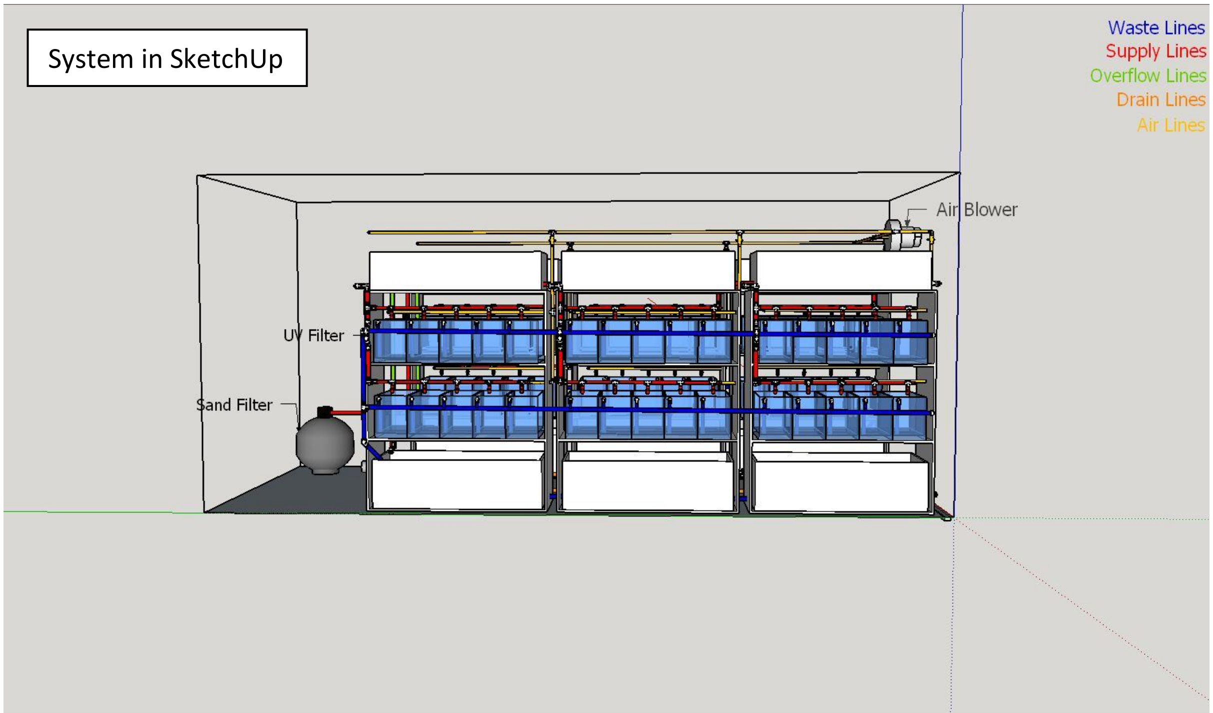
250L/ Tank

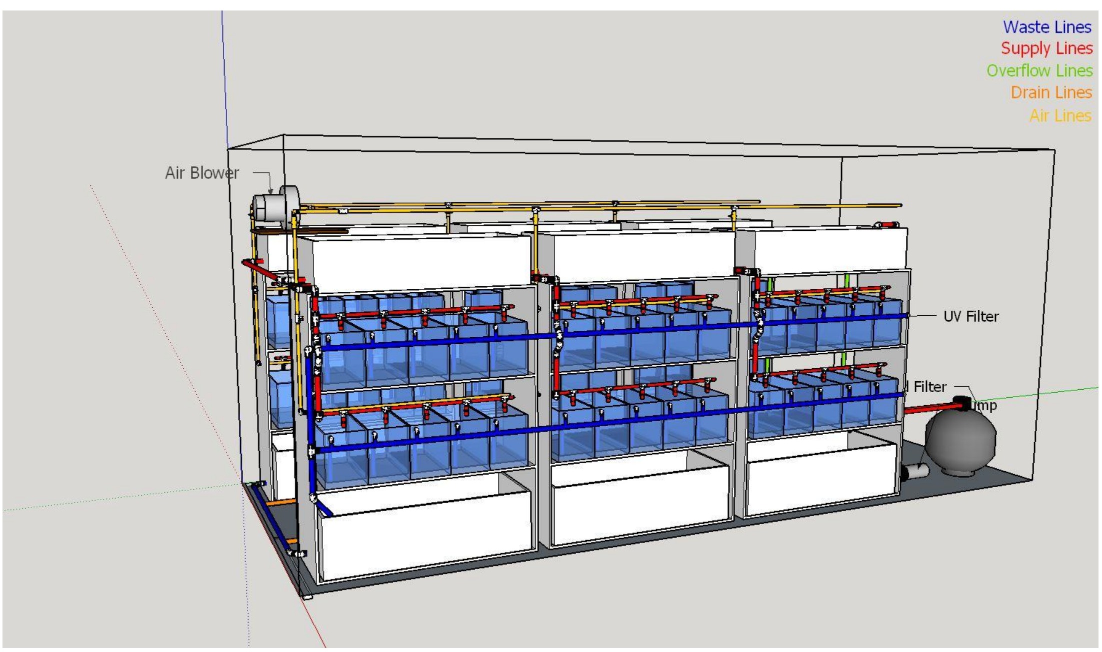
Biofiltration Tank

Total System Volume = 6731L

Water Exchange Rate: 1.5x's/hr

Water that needs to be pump in one hour: 10,096.5L or 168L/ min


System in SketchUp
Waste Lines
Supply Lines
Overflow Lines
Drain Lines
Air Lines
Air Blower
UV Filter
Sand Filter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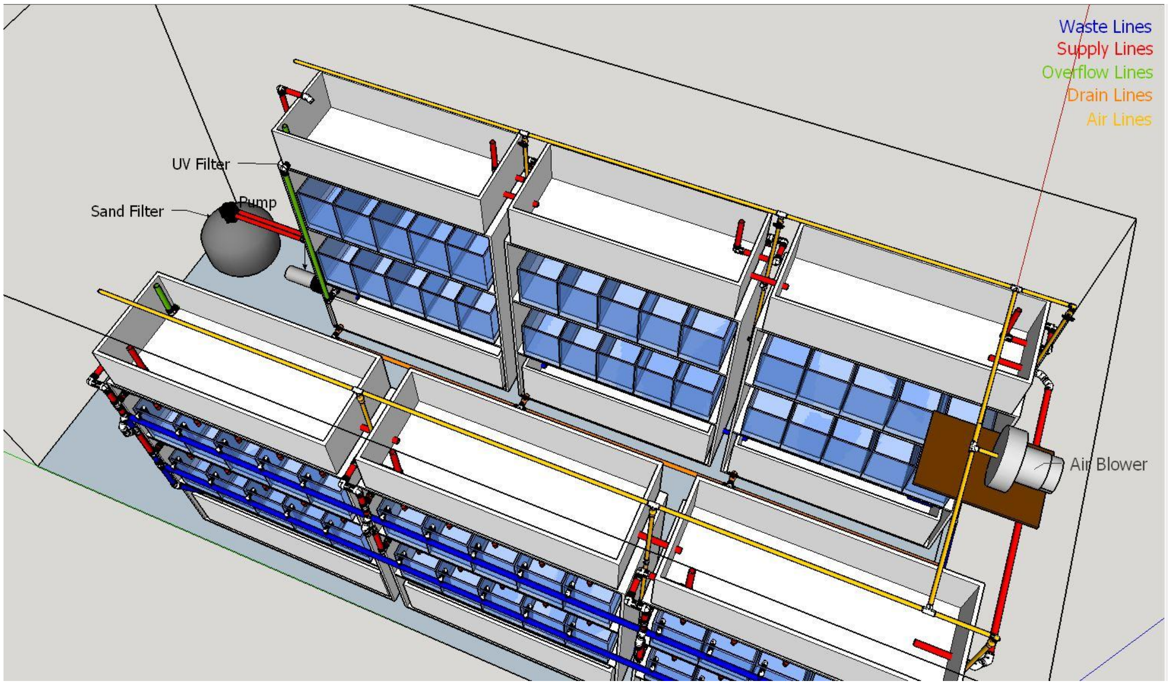
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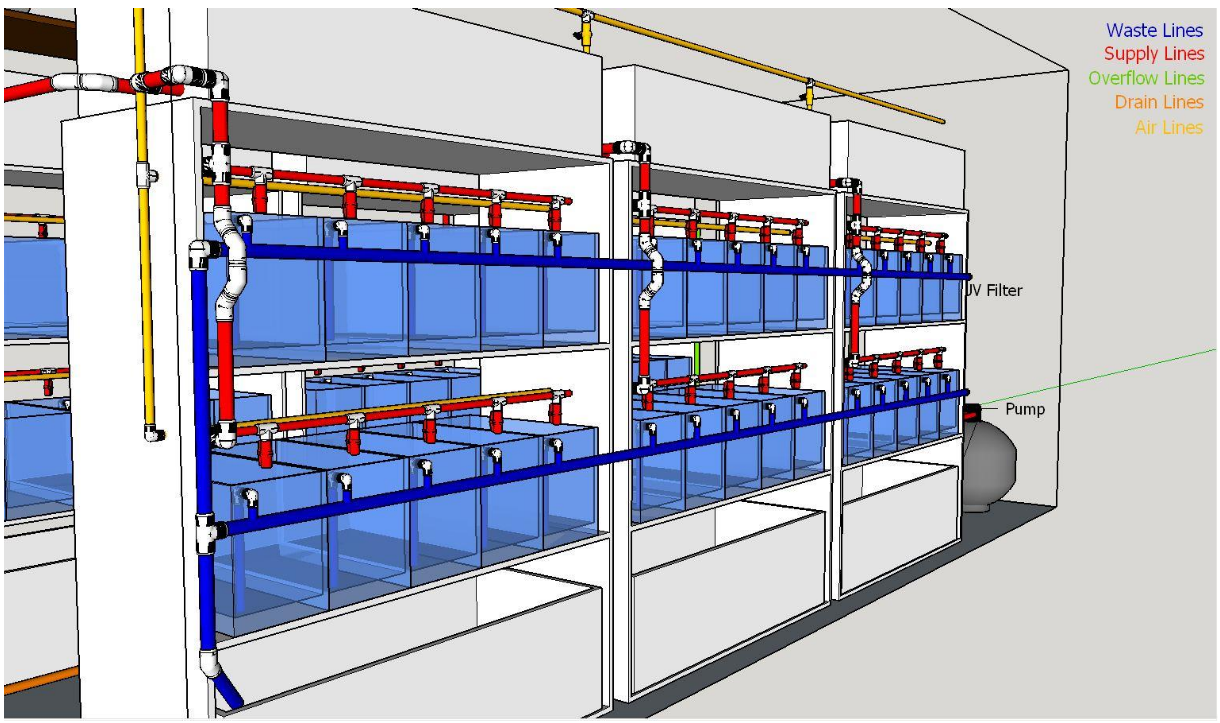
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UV Filter
Pump

## Construction

I must say that Khairul and I built this system extremely fast and I am quite proud of that. There were many components of the system that were the same. This made construction easier. Using an assembly-line approach we measured, cut, and assembled the PVC components in an efficient manner.

Khairul helped the process of construction by getting materials fast. It can be difficult to get materials needed for an aquaculture system in Malaysia, but Khairul was able to get the bulk of materials without any trouble. The specialized equipment like the air blower, biological and mechanical filtration media, water pump, and some other small components we could not get locally. As a result, we had to order from an international aquaculture dealer called Pentair Aquatic Ecosystems. Unfortunately, I had to leave before these components arrived, but we finished about 94% finished with the system before I left. There will be a total of four of these systems built. Khairul will build the other three systems, therefore I made sure to thoroughly teach him the construction process..

## *Conclusion*

I still believe that going on this internship was one of the best adventures that I have ever had. I cannot describe in words how much fun it was to live in Malaysia, help with a research project, and build a recirculating aquaculture system. Helping with kin discrimination project has showed me what it is like to be a part of something that has the potential to help many people. It too early to tell how this project will impact food security, but if it is true that tilapia can recognize their kin then the implications could save thousands if not millions of dollars.

The implications of the recirculating aquaculture system I designed built could help improve food security. Not only is recirculating aquaculture more efficient than traditional growing methods, but it has the potential to be extremely sustainable. Sustainability is vital to solving food insecurity problem, because environmental issues causes more problems and can force people deeper into poverty. We must be able to feed an ever-growing population sustainably and I believe RAS could play a role in that.

Not only did I grow as a young scientist, but I grew as a person. I am now an international traveler and a global citizen.  I have seen and learned about a new culture. An unforeseen impact of this internship is my current inspiration to obtaining a private pilot's license. Idespise airports, particularly because I got stuck at the Dallas-Fort Worth airport on my return trip because of weather. However, I discovered that I love to fly.

One of Dr. Borlaug's most famous quotes is, "Food is the moral right of all who are born into this world." After my internship, I truly understand this quote. After going to another country and working with an organization that has the goal of ending food insecurity, I now have a new perspective on one of biggest issues facing our world today. I would also like add to Dr. Borlaug's quote, because then it will reflect even more on what I want to do with my life. "**Nutritious** food is the moral right of all who are born into this world."

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