AGRI 519/CIVE 519 Sustainable Development Plans

Baird's Village Aquaponics Project

Final Report

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Presented to:
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McGill University – Bellairs Research Institute, Holetown, St. James, Barbados
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Thank You Note

McGill

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Dear Damian Hinkson,

We would like to extend to you our warm thanks for welcoming our participation into this innovative and notable project of yours. The project has been very educational and rewarding for all of us and we know that it will successfully achieve its important goals.

We thank you for acting both as our mentor, providing your technical expertise and influence on all matters and as a friend who helped enhance and ameliorate our experience in Barbados. Through the internship specifically, we were able to take part in many things that not everyone visiting Barbados has the opportunity to enjoy. Our relationship helped improve the internship and ensured that we achieved the highest levels of success.

We are grateful for the opportunity to have helped you in any way we could and look forward to hearing of the successes of the BVAA in the near future. We hope that we were able to further the aims and benefit the BVAA. We will all surely be back to visit Barbados at some point in the future and look forward to seeing the progress and accomplishments of the project.

Sincerely,

_________________ Margot Bishop

_________________ Simone Bourke

_________________ Keith Connolly

_________________ Tatjana Trebic

_________________ Susan Mahon
Internship Co-ordinator

_________________ Dr. Inteaz Alli
Program Director

Acknowledgements

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BAIRD'S VILLAGE AQUAPONIC PROJECT

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And

Baird's Village Aquaponic Association (BVAA)

"The project outlines the development of the role of aquaponics in Barbados and the expansion and development of the Baird's Village Aquaponic Association and its position in the burgeoning industry"

Aquaponic systems, community or individual sized, provide a viable option for Barbadians seeking to grow their own vegetables and ensure adequate nutrient consumption. The closed circuit system produces both vegetables and protein and reduces dependencies on other variables such as land, water and fertilizers. The Baird's Village Aquaponic Association (BVAA) has designed an aquaponic system that has proven to be effective in the tropical climate of Barbados; it is productive and has low maintenance costs. Additionally, the association has designed a simple system that is easily implemented and sustainable for the average Barbadian home.

The primary goal of our internship has been to assist our mentor, Damian Hinkson and the BVAA, to further develop the alternate agriculture method of aquaponics in Barbados and to assist the Baird's Village Aquaponics (BVAA) in becoming the leading retail and production aquaponics company in the country.

The bulk of our research of Aquaponics came from scientific journals and other literature published on the subject. Because the agricultural method is relatively new with not as much research as other processes, we emphasized the results from other existing systems such as the facility at the University of the Virgin Islands. Additionally, much of our knowledge came from our mentor, our own tests, research and experiences.

We assisted in the construction of grow beds and the Baird’s Village Community project. We also participated in agricultural fairs to increase publicity about the BVAA and disseminate information about aquaponics itself. Materials to further the brand of the BVAA were developed as well as publicity deliverables to increase exposure, such as: pamphlets, posters, business cards and newsletters.

We implemented a system at Bellairs Research Institute in order to conduct a controlled experiment testing and monitoring the water quality, the plant and fish output and any challenges that might occur in the system. Our aquaponic system contained tilapia in the fish tank and basil and okra in the crop bed. Water quality was tested bi-weekly, fish growth was monitored by several weigh-ins and the total plant biomass was calculated to find the total grow bed output. Additionally, a nutrient balance was calculated to ensure water was maintained at a safe level Our findings and outputs from this project include:

- The need to implement an aeration system in the fish tank to remedy the shortage of dissolved oxygen in the water
- To enhance fish growth, the fish feeding frequency must be increased.
- The crop bed must be maintained parallel and level to the ground to ensure that equitable nutrient distribution occurs ensuring a relatively uniform plant growth.
- To significantly lower production costs, crop bed can be made from the same material as the fish tank, a PVC cylindrical bed.

The information compiled in this result provides an understanding of the role played by the BFSS 2009 Aquaponics internship group in assisting the BVAA in further developing their brand and publicity as well as providing technical and scientific recommendations in order to maximize their system design. It will be a valuable source of information and deliverables for the BVAA in their continual development into a successful aquaponic system and organic produce retailer.

Introduction

Aquaponics is the combination of aquaculture, the raising of fish in synthetic tanks, and hydroponics, the growing of plants without a soil medium. The plants are grown in grow beds above the soil, which reduces the surface area required to grow vegetable crops. Toxic waste products from fish are removed by treating the water. This allows the recirculating system to raise large quantities of fish in relatively small volumes. (Rakocy et al, 2006) Plants have the potential to grow very quickly when they use the dissolved nutrients from fish excretions, and from the nutrients generated from the microbial breakdown of fish wastes. Fish excrete waste nitrogen through their gills, in the form of ammonia, directly into the water. The bacteria in the water and in the growing medium will then convert ammonia to nitrite and then to nitrate. Nitrate is relatively harmless to fish, while ammonia and nitrite are toxic; therefore nitrate is the preferred form of nitrogen for growing higher plants such as fruiting vegetables. (Rakocy et al, 2006)

There are several benefits to the owner of a backyard aquaponics system. Firstly, the waste produced by the fish is recovered by the plant instead of being expelled to the environment. Water exchange is minimized since the growing medium and plants act as biofilters, cleaning and returning the clean water to the fish tank. The surface area of the grow bed provides the area for bacterial growth, and is related to the treatment capacity of the system. (Graber A. et al, 2008) The treatment capacity has a unit of mass removal per unit time. Secondly, high-value vegetable crops, such as tomato, lettuce, cucumber and sweet basil, have cultured in hydroponic media. It is more desirable to grow high priced produce such as herbs to get the best profit per unit area of hydroponic bed. (Ghaly A.E. et al, 2004)

Fish species is an important consideration when setting up an aquaponics system. Trout, perch Arctic char, tilapia and bass are just a few of the warm and cold water fish suitable for recirculating aquaculture systems. However, most commercial aquaponic systems in North America are based on tilapia. (Diver, 2006) For our experiment, tilapia was chosen since they are a highly adaptable to fluctuations in temperature, pH and nutrient concentrations in the water. Many crops can be grown in an aquaponic system, but for the experiment being conducted this semester, okra and basil were the two crops selected to study. This is due to the ease of growth and relatively short growth period. Since the experiment was conducted over only two months, rapid growth was needed for best results.

The Baird's Village Aquaponic Association

The Baird's Village Aquaponic Association (BVAA) is a community organization that was founded on March 23rd, 2009 by our mentor, Mr. Damian Hinkson. It is a cooperation of farmers in the community of Baird's Village, in the parish of St. George, who are interested in capitalizing on the absence of an aquaponics industry in Barbados. Besides Damian, its members include: Robert Saul, Wendy Hinkson, Andy Brathwaite , Charles Paris, Cleveland Hinkson, Carmelia Hinkson and Conan Straker.

The BVAA is the only organization developing aquaponics in Barbados and was the recipient of a notable grant from the Global Environment Facility, of United Nations Development Programme, and their Small Grants Programme this past year. Their initial project proposal was to develop a community project which would produce a complete organic meal and then eventually develop the concept into a business venture selling both organic produce and aquaponic systems.

The BVAA has fostered a relationship with the Inter-American Institute for Cooperation on Agriculture (IICA) in order to achieve their current and future aims.

Goals and Objective

Project Goal: To optimize the mechanical, biological and socio-economical processes of aquaponics, and to promote public awareness and knowledge of aquaponics in Barbados.

Over the course of our three month internship with the Baird's Village Aquaponic Association (BVAA), we look forward to assisting our mentor with his innovative project which we hope will become an integral part in enhancing the livelihood of the average Barbadian. In order to attain our overlying goal and optimize our contribution to the BVAA's development over the course of our involvement, a certain set of objectives and a corresponding methodology was defined. We achieved our project goal by concentrating on the following four main objectives:

- Generating awareness of aquaponics and the BVAA's capacity to be the Barbadian resource for aquaponics.
- Assisting our mentor in developing the infrastructure and logistical capability to expand his business plan.
- Providing technical expertise to maximize the efficiency of the system.
- Conducting water quality assessment of the circulating fish tank water to ensure Damian's product meets all standards for the cultivation of fish.

Background

Barbados is the 15^{th} most water scarce country in the world where the freshwater withdrawal per capita is 333 m^3/yr. Its economy is heavily dependent on sugar, rum and molasses production throughout the 20^{th} century. The gradual introduction of social and political reforms in the 1940s and 1950s led to the complete independence from the UK in 1966. In the 1990s, tourisms and manufacturing surpassed the sugar industry in economic importance. (CIA World Factbook, 2009)

Barbados is one of the most densely populated countries on earth with an average 627 people/km^2. Barbados has an area of 430km^2 of which 37.21% is arable land and only 2.33% is allocated to permanent crops. The island is situated in a tropical climate where the rainy season commences in June and finishes in October. The terrain is relatively flat with a slight increase in elevation from the coast to inland. (CIA World Factbook, 2009)

Economic Context

The tourism and services industries account for three quarters of Barbados' GDP while only six percent comes from agriculture. Ten percent of the country's labour force is involved in agricultural activities. Growth in the country has rebounded since 2003 by means of increases in construction projects, housing and tourism revenues. (CIA World Factbook, 2009) The addition and increase of small scale farming initiatives is sure to increase the country's food security. Small scale farming is a food production system where food grown is mixed crops as well as small livestock. These small scale farms are quite abundant in the developing world since small scale operations are more practical. They do, however, tend to experience varying levels of efficiencies given local conditions and constraints. New technologies are often needed for the producer to meet the demands and competition in a market economy. This can sometimes be challenging since the small scale farm is usually run by a family in which labour and capital are issues that need to be overcome. (Zavodska, 2009)

Aquaponics has the potential to aid and soften the challenges posed by small scale farming in the Caribbean. The system does not require soil and uses minimal land. A household system can be set up in a family's backyard. Having access to one's own vegetables increases a family's food security and decreases its dependence on market food, of which some is imported produce. Consuming the fish being raised in the tank would also decrease a family's dependence on the market for fish. Meat on the island is quite expensive and most Barbadians diets have high percentages of protein in the form of fish. Owners of small scale farms develop a certain amount of independence and allow them to have food security, a main problem in the developing world. In developing nations, food security and poverty are intimately connected. (Zavodska, 2009)

Tilapia

The reasons why we chose tilapia as the fish to raise in the tank are simple. Tilapia is a tropical fish that prefers to live in waters between 28 and 30 degrees Celsius. They are highly adaptable to varying temperatures, pH and dissolved oxygen. For the proper performance and growth of tilapia, dissolved oxygen should be in the range of 5-8 mg/l. According to Winfree (1981), rapid growth is desired for raising tilapia and this can only be achieved by feeding the fish intensively. For the purposes of a backyard aquaponics system, emphasis is not placed on how fast the fish are growing. The growth rate of the fish is largely dependent on how many fish are being cultivated

Figure 1: Tilapia fish

and how often the consumer eats the fish. For aquaponics as a hobby, the growth of the fish needs only to be monitored by sight. If the fish are to be sold commercially, more emphasis is placed on how much food is given to the fish and how fast the fish are growing. (Winfree R.A. 1981)

In terms of the fish feed we are using, tilapia are known to grow well even with low cost fish feed. The feed used in our experiment is a low cost feed high in protein. The optimum amount of feed to be given is equal to the amount of feed fish eat in 15 minutes. The fish have responded well to this feed and it is consistently consumed within 15 minutes of giving it to them. The protein content is very important when choosing a fish feed. The growth rate of fish increases with increased protein in the fish feed. The feed we are using contains 32% protein. Therefore one third of their diet is protein which can go straight towards increasing the biomass of the fish.

Tilapia has been raised for aquaculture for over 50 years now. The dietary requirements for this species has unfortunately not been extensively studied as of yet. Excess energy may produce fatty fish, reduce feed consumption and inhibit proper utilization of other feedstuffs. It is therefore important to not feed to fish too much either. Damian Hinkson, our mentor, likes to feed his fish just enough to keep them satisfied, but no more. He likes to keep his fish slightly hungry so they will consume all the feed given to them and grow into full, lean fish.

Okra

Figure 2: Okra Plant

Okra is an annual tropical vegetable which is cultivated in the Southern United States, the Caribbean and Africa. The fruits are harvested when immature and eaten as a vegetable. The plant does not grow in cool areas or high altitudes. The production and agronomic characteristics of the plant has not been extensively studied or documented. However, this plant was chosen to be grown in the aquaponics grow bed because of its relatively short growth period and suitability to varying temperatures and climate. (Sionit, 1981)

Basil

Figure 3: Basil Plant

Basil is one of the most popular herbs in the spice cabinets of North and South America as well as the Caribbean. It is sold fresh-cut and dried in both supermarkets and farmers's markets. Over 40 different cultivars are known, but the most commercial cultivar belongs to the species *O. basilicum*. Basil is not just used for culinary needs; it can also be used as an ornamental herb, and the extracts are used in traditional medicines and essential oils. Herbs, such as basil, are of high value in the marketplace and using these herbs in the aquaponics system can maximize the profit per area of grow bed.

Literature Review

"Update on Tilapia and Vegetable Production in the UVI Aquaponic System" by Rackocy et al.

A commercial scale aquaponics system was developed at the University of the Virgin Islands in St. Croix. No major changes in the system have been implemented since 2000, and in 2002 and 2003, trials were conducted to evaluate the production of basil and okra. Batch and staggered production of basil in the aquaponic system was compared to field production of basil using staggered production technique. There were four harvests of the basil in batch production with an average yield of 2.0 kg/m^2. Initially there were a reservoir of nutrients; however by the fourth harvest evidence of nutrient deficiency was obvious. The cropping system was therefore changed to a staggered production to moderate nutrient uptake. In the staggered production trial, the plants were cut once (1.2 kg/m^2) and allowed to regrow for a final second harvest (2.4 kg/m^2). A second trial was conducted where the staggered production procedure was followed for basil seedlings that were planted in an adjoining field. The yield was 0.6 kg/m^2. Three varieties of okra seedlings were planted (North-South, Annie Oakley, and Clemson Spineless) were grown hydroponically at a low density (2.7 plants/m^2) and a high density (4.0 plants/m^3) and also in an adjoining field at the same low density. Production was greater per unit area at the higher density (2.89 kg/m^2) than the lower (2.54 kg/m^2), but lower per plant (710 g/plant for high and 940 g/plant for low). Production of okra in the field setting was 0.15 kg/m^2 and required much more intensive procedures. This low production may have been due to wet conditions and alkaline soils. A longer establishment time was thought to be needed. (Rakocy, Bailey, Shultz, & Thoman, 2004)

"Aquaponic Systems: Nutrient Recycling from Fish Wastewater by Vegetable Production" by Graber and Junge

In an aquaponic system the potential of three crop plants was assessed to recycle nutrients from fish wastewater. A trickling filter, using light-expanded clay aggregate (LECA system was used for nitrification of the wastewater providing surface for biofilm growth and area for crop plants. Nutrient input and removal rates were calculated through mass balance over a specified time, by the addition of nutrient input in the form of fish fodder, nutrient removal in the form of fruit and plant biomass, change in nutrient reservoir in the water, and nutrient losses by water exchange. Input was calculated using fertilizer coefficients determined through a separate experiment were fish were fed tilapia feed and build-up of nutrients was measured after 14 days. All water quality parameters measured (NH_4, NO_2, NO_3, pH, electrical conductivity, DO) were within tolerable limits except sometimes nitrite, which was above 0.2 mg N/L during one phase. Results were compared to controls of a traditional hydroponics systems and crop grown in soil. The highest nutrient removal rates by fruit harvest were achieved by during tomato culture: over a period of more than three months, fruit production removed 0.52, 0.11, 0.8 g/ m^2-d for N, P, and K in hydroponic and 0.43, 0.07, and 0.4 g/m^2-d for N, P, and K in aquaponic. The nutrient recycle rates were similar to those postulated in an earlier study of 100-200 g N/m^2-a and 10-20 g P/m^2-a and it was concluded that the trickling filter aquaponic system was able to adequately treat the fish wastewater. (Graber & Junge, 2009)

"Effect of Method and Scheduling of Irrigation on Water and Nitrogen Use Efficiencies of Okra" by Home et al.

Nitrogen use efficiency (NUE) and N uptake in plants are very significant components in determining water quality of aquaponic systems. In agricultural fields, excessive leaching takes place when high rates of water and N are applied in combination. This leaching makes most of the nitrate unavailable to the plant and can also contribute to ground water contamination. In an aquaponic system, however, this is not the case since the water is being recycled and the N stays confined in the closed system. NUE and N uptake were studied by P.G. Home, R.K. Panda and S. Kar in a sandy loam Okra field in Kharagpur, India. The experiment was carried out on a coarse textured sandy loam soil under subhumid sub-tropical conditions at an experimental farm. The results found suggested the maximum yield was obtained with a high nitrogen uptake and 30% maximum allowable depletion (MAD) irrigation scheduling. Maximum allowable depletion is the percentage of moisture drop from field capacity. A 30% MAD still keeps the soil quite moist. Yield and N uptake of vegetable crops have been found to increase when irrigation schedules are applied that keep soil water at or near field capacity. This type of soil conditions is similar to the grow bed being used by our mentor, Damian Hinkson, for his aquaponic system. Although there is no soil, the coconut husk serves as a growing medium and since the water is being pumped continuously through the grow bed, field capacity or near field capacity conditions are maintained. In the Home, Panda and Kar experiment, the N uptake was averaged to be 73.3 kg ha^{-1}, while the NUE was averaged to be 89%. These numbers will be used to compare the nitrate content being supplied to the fish via fish food and the resulting concentration of nitrate in the circulating water. (Home, Panda, & Kar, 2001)

<u>"Effect of Flow Rate on Water Quality Parameters and Plant Growth of Water Spinach (Ipomoea aquatic) in an Aquaponic Recirculating System" by Endult et al.</u>

Aquaponics systems were designed to provide an artificial, controlled environment that optimizes the growth of fish and soil-less plants, complete control over water quality, the production schedule and the fish product, while conserving water resources. Five different water flow rates (0.8, 1.6, 2.4, 3.2, and 4.0 L/min) were tested in order to relate nutrients removal, water quality and plant growth. It was found that the highest plant growth rate was at 1.6 L/min and that high growth rates and yields were generally seen when the major growth limiting nutrient, nitrogen, was delivered as a combination of ammonium and nitrate. In terms of fish growth rate, there were no significant differences in the feed conversion ratio (amount of food given vs. Weight gained) at various at flow rates. The results showed that the aquaponic system removed BOD_5 (47-65%), total suspended solids (67-83%), NH_3-N (64-78%), NO_2-N (68-89%), and demonstrated positive correlation with flow rates. NO_3

removal ranged from 42-65%, but decreased proportionately with flow rate after 1.6 L/min. It was suggested that the higher flow rates resulted in less contact time between nitrate and denitrifying bacteria, thus decreasing the system's denitrifying performance. Total phosphorous concentration ranged between 42.8% and 52.8%, and again had highest removal rates at 1.6 L/min. It was concluded that both plant growth and fish production were better at a flow rate of 1.6 L/min.

Promoting Aquaponics in Barbados

Construction of the System

In the first weeks of our internship, emphasis was placed on setting up the community scale aquaponics system in Baird's Village. All four group members traveled to Baird's Village to look at the current system to potentially offer design suggestion for future systems. The original system Damian had installed was quite rudimentary with only one grow bed and one fish tank. The plants growing were of varying species, including onion, lettuce, tomatoes and cabbage. One of the first problems we addressed was the depth of the grow bed. Damian felt the depth of the grow bed was too shallow and did not allow for proper drainage for the plants. Therefore we took apart the system and increased the depth by adding wood to the existing walls. We then relined the system with plastic to ensure no leaks would occur.

Figure 4: Aquaponic system at the beginning of our internship

The next time we joined Damian in Baird's village, it was to build three more grow beds to join the first one in order to complete a system. The concept of one system is to have four grow beds for one fish tank and have the water circulating throughout the system. The first grow bed was made from scrap material while the three new grow bed were constructed from plywood. It was therefore much lighter material, easier to handle and less individual pieces were needed to nail together. We then painted the outside for a more aesthetically pleasing system. The new grow beds were then lined with plastic and were ready to be hooked up together.

Another innovation was discovered at this time. Damian was originally placing the coconut husk in the grow beds as it came, and this was difficult to handle when it came to moving the system. We then thought it would be a good idea to first bag the coconut husk in a permeable net bag before placing it in the grow beds. This way, instead of having a pile of coconut mass to maneuver, we simply had net potato sacks full of coconut husk which could easily be carried. The bags were placed on the bottom of the grow bed and a small layer of husk was placed on top for the plants' direct growing medium. See the figure below for a schematic diagram.

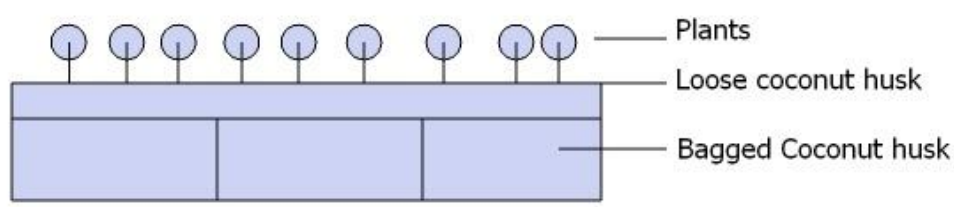

Figure 5: Cross-section of an aquaponic grow bed

The aquaponics system for Bellairs Research Institute was the next step in the construction phase of the internship. One of the grow beds that had been previously constructed would be used for housing the plants, while a new rectangular fish tank was built. The fish tank Damian built for our experiment is rectangular in shape and is made from ceramic kitchen counter material. One of the sides was a pane of glass so as to act as an aquarium. This way we could monitor the growth of the fish more effectively. A support for the grow bed was needed to raise the bed from the ground and away from ants and termites. This support was built using steel rods. We drilled holes through the steel for brace support and a nice frame was established for the Bellairs system. See the figure below for details.

Figure 6: The Bellairs aquaponic setup

The design of the grow beds has changed in the last few weeks of the internship. It seems less expensive to do away with wood as a material for the grow beds and simply have the grow beds the same material as the fish tanks. The fish tanks are large PVC cylinders which are cut down to size by Damian. This material can also be used for the grow beds, resulting in round grow beds as opposed to the rectangular grow beds we started with at the beginning. See figure below.

Figure 7: The most recent aquaponics setup at Damian Hinkson's house

Participation in Agricultural Fairs

An effective means of interacting with the public and promoting aquaponics in Barbados has been by attending agricultural and environmental fairs and expos. Aquaponics is still largely an unfamiliar means of agricultural production to most people in Barbados and by being present at these events we are able to offer the public a firsthand opportunity to see the system up and running. This also makes it possible for those interested in the system to talk to a member of the BVAA or one of the McGill BFSS students.

On September 26th the National Conservation Commission (NCC) held the 3rd Annual Arbor Expo at Queen's Park in Bridgetown, an event whereby the NCC promoted such themes as the importance of trees and plant life, soil conservation, and sustainable living. Damian Hinkson and the BVAA were asked to participate in the Arbor Expo to demonstrate the concept of aquaponics to the public. A complete aquaponics system was reconstructed at Queen's Park for the fair, as well as a table with informative posters and displays. The fair was well attended and, as BVAA interns, we were relied upon to give the public accurate information pertaining to aquaponics, including how the system worked, what the benefits of it were, and how they could go about setting up their own system at home. We also offered information regarding the history, purpose and objectives of the BVAA. People interested in the BVAA and aquaponics could also leave with an information pamphlet with a short explanation about the concept, the BVAA, and contact information (see Appendix B).

Local media, including the Barbados Advocate, the Nation News, and the Caribbean Broadcasting Corporation (CBC), were all in attendance and did stories on the BVAA and aquaponics, further serving the purpose of the BVAA's public awareness objectives (see Appendix B).

On October 3rd, Mr. Hinkson and the BVAA interns attended the Environment Expo in St. John Parish, with the theme of 'Climate Change'. Again, this was a great opportunity for the public to be introduced to aquaponics and the potential it holds for backyard agriculture. The exposition also served to increase the exposure of the BVAA. At this particular fair, the Minister of Agriculture and Rural Development was in attendance. He met with Mr. Hinkson and a valuable contact was acquired. The

Advocate and the Nation covered the event and again the BVAA and aquaponics received media attention. (See Appendix B)

The BVAA, being in its infancy, will rely on events such as these to promote itself and the concept of aquaponics. If aquaponics is to have a place in Barbados agriculture, the public must see that it is viable, sustainable, and simple enough for local Barbadians to operate. The BVAA will continue to attend these events, including AgroFest in February 2010, the premier agricultural expo hosted by the Barbados Agricultural Society, in an effort to make itself a prevalent fixture on the Barbados agricultural scene.

Promotional Materials

In order to disseminate information about Aquaponics and the BVAA around the island of Barbados, our group undertook a multifaceted approach consisting of publicity and brand development as well as technical development and research.

BVAA Posters

For the aforementioned agricultural and environment expos, we constructed simple yet informative posters in order to draw more visitors to our system. Both posters that we designed were on brightly coloured Bristol board with attractive images and fonts to ensure that passing foot traffic diverted their routes to the aquaponic system. One of the posters provided basic information of aquaponics and the system itself and the other poster focused on the Baird's Village Community Project, displaying images of the site and outlining future plans.

A purpose that these posters served was to attract the kind of person that isn't interested enough to come and approach someone or is intimidated of the seemingly complicated system. By putting out posters, we allowed for visitors to experience and understand the system for themselves which often lead to interaction and questions later. The concise information on the posters ensured that if the reader was interested they would need to interact with one of the group members, Damian or Robert Saul who could promote the BVAA itself.

Newsletters

A newsletter was developed to provide people with updates on the progress of the BVAA and spread further information about aquaponics around Barbados to both notable contacts, such as the Minister of Agriculture and Rural Development, and interested citizens. The two page newsletter is the template for future bi-monthly or monthly newsletters which will be published online and sent to special contacts at the discretion of the BVAA.

The two-paged newsletter (see Appendix B) contains information and content written and designed by the group members and Damian. The final configuration of the newsletter was formatted in a simple and clean outline with detailed images and text which complemented the earth tones reflective of other agriculture publications.

Content included in the newsletter is an overview of the community project up in Baird's Village and its development, status and anticipated end date. Also, because it is the fist volume of a series of newsletters, there is an explanation about aquaponics and its benefits in the context of Barbados. On the back page of the newsletter is an article written by Damian which expands on the simple concept of vegetable production. It discusses heirloom seeds, which are natural alteration to simple crops that produce output like French pumpkins and black tomatoes, which the BVAA has expressed interest in developing and eventually selling. Finally, the newsletter contains information about the BVAA and their associated partnerships. This includes member and contact information about the organization as well as where they are located in reference to a map of Barbados. The newsletter contains the new logo of the BVAA.

BVAA Logo

In order to further the development of the Baird's Village Aquaponic Association as a company and future brand a logo was designed and produced to be included on newsletters, posters, flyers and future products. The logo emerged from a series of colour and black and white sketches which were presented to the BVAA for their input and selection. With Damian's consultation, the logo was finalized and then digitalized with the help of a fellow Barbados Field Study Semester student, Ashley Parks. Ms. Parks' experience in design was very beneficial in the production of the final output, assisting in colour selection and final font and style of the logo and the final product of a professional and appealing logo that which the BVAA will likely become known for. Group members, along with the help of Ms. Parks, came up with two logos which will be used on future products and publications. (see Appendix B)

Business Cards

Business cards have been designed for Damian Hinkson further formalizing his role as chairman of the BVAA (see Appendix B). During the environment and agriculture fairs, it was apparent that many people were so receptive to his design and project that they sought further contact. In all of these situations if Damian had his own business cards it would have made the BVAA appear even more professional and would have led to exchanges with formal future business partners. These cards are designed in a similar style as the logo; in the same shades of blue and green as well as in a simple format. They will be ordered for Damian Hinkson, with his position labeled as chairman, and likely for other BVAA members in the future.

Pamphlet

Further deliverables for the agriculture and environment fairs were produced to further circulate information about the BVAA. We produced and printed pamphlets which people could take from the expo and fair. The pamphlet has many portions that provide concise and basic information about the BVAA, the agriculture method of aquaponics, the system itself, the system inputs and outputs produced and, contact information of the BVAA. (see Appendix B)

Due to the high cost of colour printing, we were limited in producing a large amount of pamphlets but found that the fifty we printed were very well received. When we did run out, people were still asking for a pamphlet or information sheet. This suggests the importance of providing people with a tangible object that can remind and maintain their interest. The pamphlet file has been shared with the BVAA who will likely, having also seen the response at public events, print more for future events.

Business Template

In order to assist with one of the primary short-term goals of the BVAA- of writing a business plan- a detailed business template was prepared for Damian. The template was extracted from four existing business which were thoroughly researched, with permission, to develop a form which was complimentary to the goals and visions of the BVAA. The internship group members felt it was not appropriate to write a complete business plan until some details had been obtained by the BVAA. These details include: the production price of a single system, the output capabilities of an individual and group system, the planned retail cost of produce and so on.

With the detailed business plan template, the Baird's Village Aquaponic Association members will be only required to fill in sections which are contextualized for the organization's future business plans.

Standards

Because aquaponics is a relatively new agriculture technology, many countries have not yet established any regulation or standardization for the processes and system requirements. Through communication with the Barbados National Standards Institute (BNSI) and the Inter-American Institute for Cooperation in Agriculture (IICA), we found that no such standards exist for Barbados. As a result of this, Mr. Hinkson has placed emphasis on the influential role that the BVAA would like to play in their creation. Because the BVAA is on the forefront of aquaponics in Barbados, they play a crucial role in how the researched method will function in the context of Barbados. IICA approached the BVAA to assist the BNSI writers in constructing an all-encompassing list of standards to be formalized in the future.

Using the Barbados National Standards on organic production as a template, we developed pertinent categories which would be necessary for customer protection in the future. Standard categories were developed based on areas of food/personal/fish safety, crop and tank bed construction, water quality, input and component ratios and so on. Standards were developed based on literature research and from the experience accrued over trials and time by the BVAA. With our assistance, the BVAA has compiled a list of draft standards which will compliment the standards developed from the officials at the BNSI and will ensure that both future customers and the Aquaponics method itself will be protected in Barbados.

The Experiment

An aquaponic system was set up at Bellairs Research Institute in Holetown, St. James, Barbados (see Figure 8) with the help of our mentor, Damian Hinkson. Twelve seedlings of basil and twelve seedlings of okra were planted on October 20th in four rows, in a grow bed 117 x 180 cm in area and 30.5 cm in depth.

Figure 8: Aquaponic system at Bellairs Research Institute

A fish tank was filled with a volume of 0.26 m^3 of tap water and 26 young tilapia fish were added on October 22nd. After multiple leak situations, the system finally came to a relative equilibrium and laboratory experiments on the quality of the fish tank water began on November 9th, 2009. The goal of this experiment was to provide our mentor with information regarding the quality of fish tank water over time in an aquaponic system as it pertains to fish growth and health. This scientific approach to aquaponics will allow the BVAA and Mr. Hinkson to use the information obtained in our experiment as part of the company's future publications about the maintenance, efficiency and potential problems associated with the technical components of an aquaponic system.

Objectives

1) To determine the water quality in an aquaponics system over time with regards to seven parameters (temperature, pH, salinity, phosphate, nitrate, ammonia and dissolved oxygen).
2) To determine whether an aeration system is necessary to keep the dissolved oxygen at a desirable level.

3) To determine how the nitrification process is affecting the aquaponics system and particularly to observe the efficiency of the breakdown of ammonia in the system.
4) To determine the amount of biomass produced by an aquaponic system in six weeks.

Several experiments were performed in order to complete these objectives. The wet and dry weights of seedlings and of the grown plants were taken at the beginning and end of the growing period, respectively. The initial and final weights of the tilapia fish were taken on October 27th and December 3rd, respectively. Lab analysis consisted of measurements for temperature, pH, salinity, nitrate, ammonia and dissolved oxygen, twice a week for three weeks at approximately the same time of day. Measurements for phosphate were taken on three different occasions during the experimental period. The significance of each parameter and the lab procedures followed for each test are described below.

Temperature

At a temperature range of 27 to 29 °C, tilapia grow at optimal rates. A wider range of 25 to 32 °C gives acceptable growth rates and is easily maintained under the Barbadian climate. Temperatures on the higher end of this range will however reduce the solubility of oxygen in the water and may therefore result in the lowering of dissolved oxygen concentrations. (DeLong et al., 2009) Below 20 °C, reproduction in tilapia does not occur, while temperatures above 26.7 °C ensure the best rates of reproduction. (Popma and Masser, 1999) Thermal trauma in fish may be caused by rapid changes in temperature or by temperatures out of the survival range of the species. This may result in disruption of the cardiovascular system, nervous system, reduction of enzymatic activities, permanent impairment of body functions or death. (Post, 1998)

Temperature measurements of the water must be taken on site and preferably at the centre of the fish tank, not near the fish tank walls whose temperature may be significantly different. Measurements taken at the same time of day each time will be most easily comparable.

Materials

- Hanna Instruments HI 9828 Multiparameter Probe and Monitor

Procedure

1. A HI 9828 Multiparameter Probe was connected to the Hanna Instruments monitor and inserted into the centre of the aquaponic fish tank.
2. Readings were taken and recorded for temperature in °C.

pH

pH is a dimensionless value corresponding to the negative $\log_{10}$ of the H^+ ion concentration in a given solution. In a solution where the $[H^+]$ and $[OH^-]$ are in balance (each have a value of 10^{-7} mol/L), the pH is 7 and the solution is said to be neutral. Pure water has a pH of 7 and self-ionizes in the following way;

$$H_2O \rightleftharpoons H^+ + OH^-$$

When other compounds are introduced to pure water, the concentrations of hydrogen and hydroxide ions change. A solution whose pH is below 7 is said to be acidic, while one with a pH above 7 would be basic.

Tilapia can withstand a large pH range; from 5 to 10. However, ideal values are pH 6 to 9. The dissolution of carbon dioxide from the air into tank water results in the formation of carbonic acid and therefore reduces tank water pH. In tanks with water reuse, low pH is generally not encountered as a problem as the lower limit is pH 6.8 for the nitrifying bacteria in the plant bed biofilter – in aquaponic systems, the coconut husk. Values of water pH that are excessively high or low result in stresses and damage to fish skin and gills, inability to excrete bicarbonate ion or absorb oxygen, and rupturing of capillaries on fins and skin. The pH of the tank water also affects the solubility of other substances, some of which are toxic to fish. At very high or very low pH, the toxicity of some of these substances to fish increases greatly.

Measurements of pH are measured by an ion-selective electrode that detects hydrogen ion activity in aqueous solutions through small potential differences across its pH sensory membrane.

Materials

- Hanna Instruments HI 9828 Multiparameter Probe and Monitor

Procedure

1. A HI 9828 Multiparameter Probe was connected to the Hanna Instruments monitor and inserted into the centre of the aquaponic fish tank.
2. Readings were taken and recorded for pH.

Salinity

Salinity is a measure of the concentration of dissolved salts in a sample of water. Tilapia fish in general can survive in brackish water and some species grow well in salinities close to that of seawater even though they are a freshwater fish. Some types of tilapia display reduced reproductive performance in waters with salinity above 10 to 15 ppt. (Pompa and Masser, 1999) Since tilapia is a freshwater fish and the water in an aquaponic system is being circulated through a plant bed with crops that are not particularly salt-resistant, we would like to keep the dissolved salts to a minimum. This is assumed to be achieved since the original water used to fill the tank was fresh tap water coming from an outside tap. The units used to compare salinities are usually milligrams per liter (mg/l) or parts per thousand (ppt).

In our experiment, the salinity unit provided by the instrument used was the practical salinity unit (PSU), which is similar to parts per thousand.

Materials

- Hanna Instruments HI 9828 Multiparameter Probe and Monitor

Procedure

1. A HI 9828 Multiparameter Probe was connected to the Hanna Instruments monitor and inserted into the centre of the aquaponic fish tank.
2. Readings were taken and recorded for salinity in PSUs.

Phosphate

Phosphate (PO_4^{3-}) is often considered a limiting reagent in environments and can determine the rate of growth of organisms in a system. It is a major component of water quality and is environmentally highly relevant. Most fish require relatively high levels of phosphorus which can be obtained from the food they are fed or from the phosphates dissolved in the water they are cultured in. Some natural waters have extremely low concentrations of phosphates and may require the addition of phosphorus supplements. Deficiency in phosphorus has been associated with various conditions among several fish species including reduced skull growth, body growth and food conversion. (Post, 1983)

Phosphate is generally not a problem in terms of fish health, but is an environmental contaminant when wastewaters are disposed of in natural waters. Wastewaters that are released without any treatment contain a phosphate concentration of 2 to 20 mg/l. Typical phosphate concentrations in treated wastewaters are usually about 2-10 mg/l. (Rowe and Abdel-Magid, 1995) When disposing of the water in an aquaponic fish tank, phosphate concentrations should meet requirements set out in disposal guidelines. The Canadian Water Quality Guidelines for the Protection of Aquatic Life state that phosphate concentrations in bodies of water should be kept below 50 micrograms per liter (µg/l) in order for hypoxic conditions to be avoided. Hypoxic conditions imply an insufficient amount of dissolved oxygen for use by aquatic life.

In this experiment, Hach Company's Test 'N Tube pre-prepared reagents reacted with the phosphates in the fish tank water samples to form a blue colour for detection in the spectrophotometer. Measurements were taken on triplicates of the same water sample each time to reduce the level of error.

The test performed was called the PhosVer 3 Test 'N Tube Procedure. (Hach Company) It has a range of detecting phosphate from 0.00-5.00mg/l PO_4^{3-}.

Materials

- TenSette Pipette
- Water Sample
- Reactive Phosphorus Test 'N Tube Dilution Vial
- DR/2010 Spectrophotometer
- PhosVer 3 Phosphate Powder Pillow
- Kimwipes

Procedure

1. A TenSette Pipette was used to measure 5ml of sample to the Reactive Phosphorus Test 'N Tube Dilution Vial. The solution was capped and mixed.
2. The solution was cleaned with a Kimwipe and placed in the DR/2010. The DR/2010 was then zeroed.
3. The vial was removed from the machine and the content of one PhosVer 3 Phosphate Powder Pillow was added. The solution was mixed and a two minute reaction time was started.
4. The vial was once again cleaned with a Kimwipe and placed in the DR/2010. The phosphate concentration was read from the display in mg/l.

Nitrate

Nitrate (NO_3^-) is a form of nitrogen found in water and is a source of nutrients for plant uptake. It is formed as a product of the microbial degradation and oxidation of ammonia nitrogen (NH_3 – N and

NH_4^+ - N) and organic nitrogen. Nitrate concentration is an important parameter in water quality testing. For tilapia fish, the tolerance limit for nitrate is 150 mg/l. (Graber and Junge, 2008) In water reuse systems such as in an aquaponic system, toxicity from nitrates can occur when concentrations reach 300-400 mg/l. The filtration mediums in these systems, however, can usually control nitrate concentrations and keep them at much lower levels. (DeLong et al., 2009)

The chromotropic acid added to each sample vial in this experiment reacts with nitrate under strongly acidic conditions, creating a yellow product that absorbs light best at a wavelength of 410 nanometers. A higher concentration of nitrate corresponded to a higher ability of the solution to absorb light at this wavelength. Measurements were taken on triplicates of the same water sample each time to reduce the level of error.

The test performed was called the Chromotropic Acid Method. (Hach Company) It has a range of detecting nitrate concentrations of 0.00-30.00 mg/l NO_3^- -N.

Materials

- NitraVer X Reagent A vial
- Water Sample
- DR/2010 Spectrophotometer
- NitraVer X Reagent B Powder Pillow

Procedure

1. 1ml of sample was added to the NitraVer X Reagent A vial. The vial was inverted ten times to mix.
2. The vial was cleaned with a Kimwipe and placed in the DR/2010 and zeroed.
3. The content of one NitraVer X reagent B powder pillow was added to the vial. The vial was inverted to mix and a five minute reaction time was started.
5. The vial was then placed in the DR/2010 and a nitrate concentration was read from the display in mg/l.

Ammonia

Ammonia nitrogen consists of nitrogen in the ammonium ion form or in the following equilibrium:

$NH_4^+ \rightleftharpoons NH_3 + H^+$

Ammonia nitrogen is also used to a degree by plants as a nutrient source and is found in wastewaters as a product of animal waste. The unionized form of ammonia (NH_3) is highly toxic to fish and other aquatic life, while the ammonium ion (NH_4^+) is much less toxic. (DeLong et al., 2009) At values of pH typically found in aquaponic systems (values around 7), the majority of ammonia nitrogen is in the ammonium ion form. High pH values increase the proportion of ammonia nitrogen that is in the toxic unionized ammonia. (Droste, 1996) When fish are suddenly exposed to waters with unionized ammonia concentrations greater than 2 mg/l, most will die. When the concentration increases gradually to about 3 mg/l, about half of the fish will die within 3 or 4 days, therefore, NH_3 concentrations should be kept as low as possible. Chronic exposure to concentrations above 1 mg/l will cause gill disease and result in fish loss, particularly juvenile tilapia. Mortalities begin to occur at concentrations as low as 0.2 mg/l, when exposure is prolonged and food consumption decreases at 0.08 mg/l NH_3. (Popma and Masser, 1999) Thus, a concentration of NH_3 that is as close to zero as possible is ideal. Concentrations of the ionized form of ammonia should be kept below 1 mg/l NH_4^+. (Graber and Junge, 2009)

In the test used for this experiment, ammonia compounds react with chlorine to produce monochloramine which reacts with the salycylate in the pre-prepared solutions to form 5-aminosalicylate. The 5-aminosalicylate oxidizes with the presence of a sodium nitroprusside catalyst, forming a blue compound. The excess yellow reagent used turns this blue colour green and prepares the sample vial for a reading in the spectrophotometer. The intensity of the green colour is directly related to the concentration of total ammonia (NH_3 + NH_4^+) present in the sample. Measurements were taken on triplicates of the same water sample each time to reduce the level of error.

The test performed was called the ‘N tube Salicylate Method. (Hach Company) It has a range of 0.00-50.00 mg/l of ammonia (NH_3 + NH_4^+).

Materials

- 2 High Range AmVer Diluent Reagent vials
- 2 ammonia Salicylate reagent powder pillows
- 2 ammonia Cyanurate reagent powder pillows
- DR/2010 spectrophotometer

Procedure

1. 0.1ml of sample was added to one vial and 0.1ml of distilled water was added to another AmVer Diluent vial.
2. An ammonia salicylate reagent powder pillow was added to each vial.
3. An ammonia cyanurate reagent powder pillow was added to each vial.
4. The vials were capped and inverted to dissolve the powder. A 20 minute reaction time was started.
5. At the 20 minute mark, the vials were cleaned with Kimwipes and the blank vial was placed in the spectrophotometer. The instrument was zeroed.
6. The sample vial was placed in the spectrophotometer and the total ammonia (NH_3 + NH_4^+) concentration reading was taken in mg/l.

Dissolved Oxygen

Dissolved oxygen analysis measures the amount of gaseous oxygen (O2) dissolved in an aqueous solution. Oxygen enters bodies of water by dissolution from the surrounding air, by aeration (rapid movement along the water-air interface), and as a waste product of the photosynthetic processes of aquatic plants. Dissolved oxygen (DO) is an important parameter when testing for water quality for aquaculture. Fish may show signs of partial suffocation; surfacing, gulping of air, crowding into areas where water spills in and agitates the surface and reduction of activity. (Post, 1998) There are recognized optimal concentrations of DO for fish health and tolerance limits for survival that can be used to make conclusions and improvements regarding the oxygen levels available to fish before they reach a critically low level. The DO should not be lower than 3mg/l. If this is the case, fish growth may be stumped and health is reduced. (PBS 1998) The optimum DO for fish growth is at 5.0 – 7.5 mg/l. (DeLong et al., 2009)

When performing the dissolved oxygen test, only grab samples (samples taken of a homogeneous material in a single vessel) should be used and the analysis should be performed immediately. Therefore, this field test should be performed as close to the site of sampling as possible.

Materials

- Hanna Instruments HI 9828 Multiparameter Probe and Monitor

Procedure

3. A HI 9828 Multiparameter Probe was connected to the Hanna Instruments monitor and inserted into the centre of the aquaponic fish tank.
4. Readings were taken and recorded for DO concentrations in mg/L.

Results

Five data points were obtained between November 16th and December 3rd, 2009 for temperature, pH, salinity, nitrate, ammonia and dissolved oxygen. Three data points were collected for phosphate concentrations. The values obtained may be compared against values provided in scientific literature regarding the tolerance levels of each parameter for tilapia fish. Table 1 summarizes the results of this experiment.

Table 1: Summary of Results

Parameter		Range found in fish tank	Optimal range
Temperature		27.05-29.73 °C	27-29 °C
pH		7.38-7.65	6.8-9
Salinity		0.37-0.43 PSU (ppt)	< 10 ppt (PSU)
PO_4^{3-}		9.15-9.17 mg/l	50 µg/l
NO_3^-		0.77-1.23 mg/l	<150 mg/l
Ammonia	NH_3	0.002-0.0045 mg/l	<0.08 mg/l
	NH_4^+	0.098-0.220 mg/l	<1.0 mg/l
DO		2.31-2.94 mg/l	5.0-7.5 mg/l

Temperature

The temperature in the fish tank ranged from 27.05 to 29.73 °C. This falls nearly within the ideal temperature range for the cultivation of tilapia fish, with two of the measured temperatures being less than one degree Celsius above the optimal range for growth. Temperatures in Barbados range from the lowest average daily low temperature of 23.44 °C (74.2 °F) to the highest average daily high temperature of 29.89 °C (85.8 °F) over the course of a year. (Grantley Adams International Airport – see Table 17 in Appendix C) This temperature range should generally not represent any problems in terms of heating or cooling the water in a fish tank such as the one required in an aquaponics system to any significant or problematic degree. Figure 9 on the next page shows the changes in fish tank water temperature over the duration of the experiment.

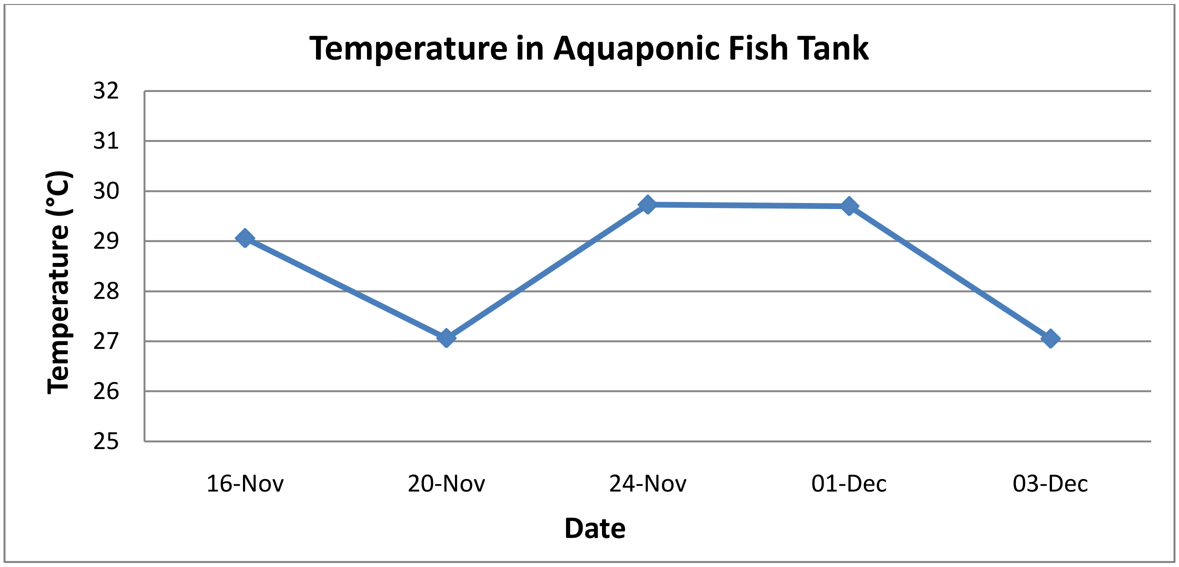

Figure 9 : Water temperature over time

pH

The pH values over the experimental period varied between 7.38 and 7.65, with the average pH value being 7.51. These values fall within the range of ideal pH for tilapia and for the biofilter microorganisms in the grow bed. Figure 10 below displays the relatively stable trend of pH values found over the course of the experimental period.

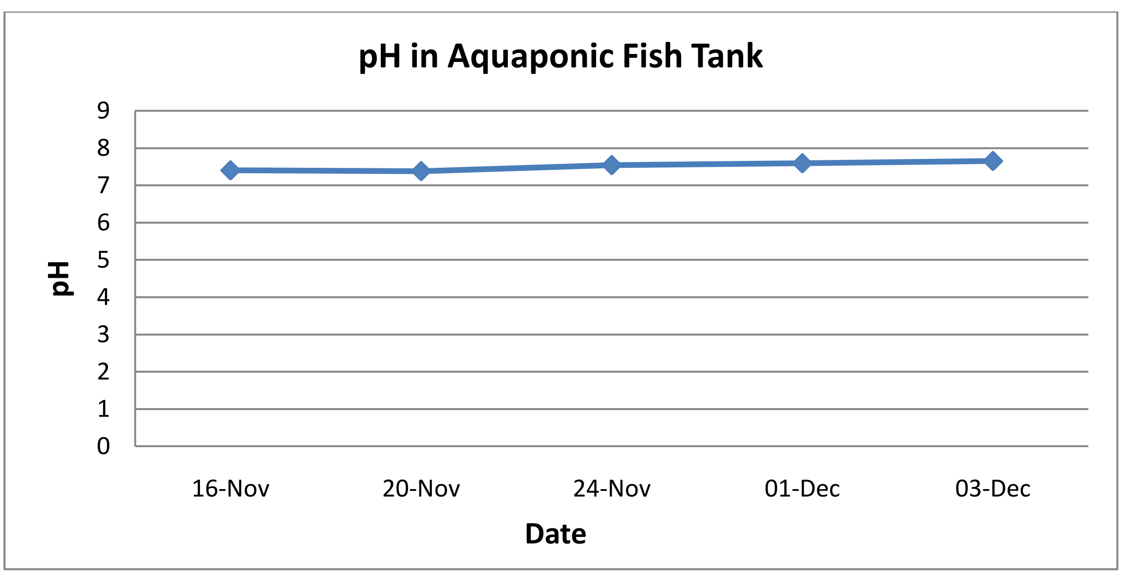

Figure 10: pH of fish tank water

Salinity

Salinity in the aquaponic fish tank remained well below tolerance limits for tilapia. The 0.37-0.43 PSU (or parts per thousand) range found in the fish tank is far below the 10 to 15 ppt range above which reproductive rates decline. Since the water in the fish tank was obtained from the tap and any additions were from rainwater, these low salinity numbers are appropriate. The salinity values measured are plotted below in Figure 11.

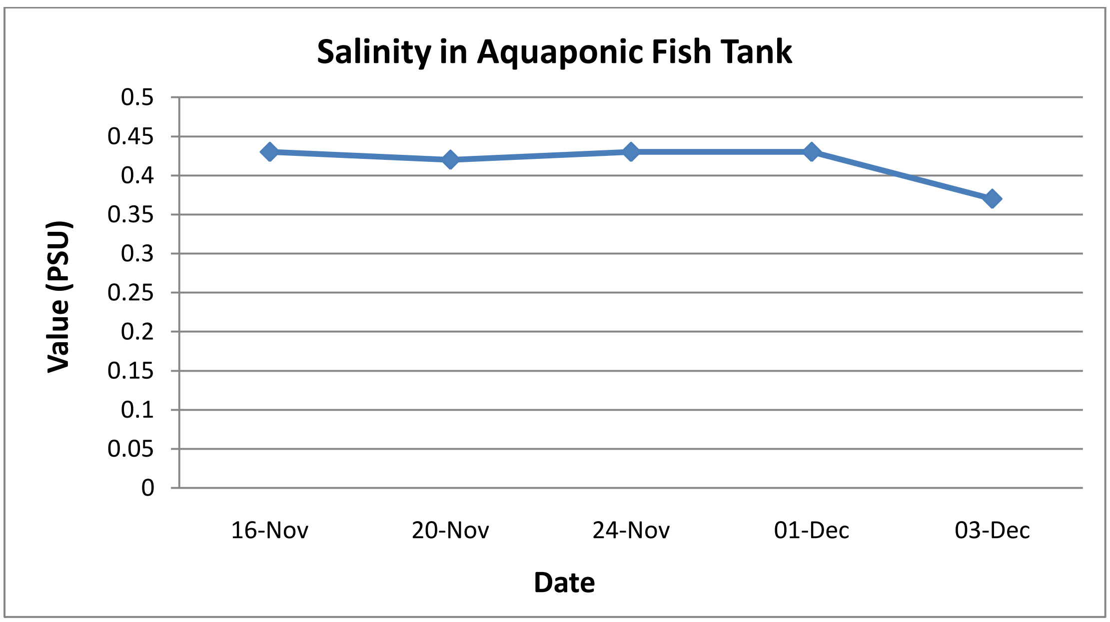

Figure 11: Salinity of fish tank water

Phosphate

The two phosphate measurements taken yielded concentrations of 9.17 and 9.15 mg/l PO_4^{3-}. These values are higher than the recommended values for the protection of aquatic life. The effects of high phosphate concentrations will be addressed in the discussion.

Nitrate

A range of 0.77 to 1.23 mg/l NO_3^- was found in the fish tank water. These numbers are far lower than the tolerance limit of 150 mg/l and therefore do not pose a problem in terms of fish health.

Figure 12 shows a plot of the concentration of nitrates over time in the fish tank.

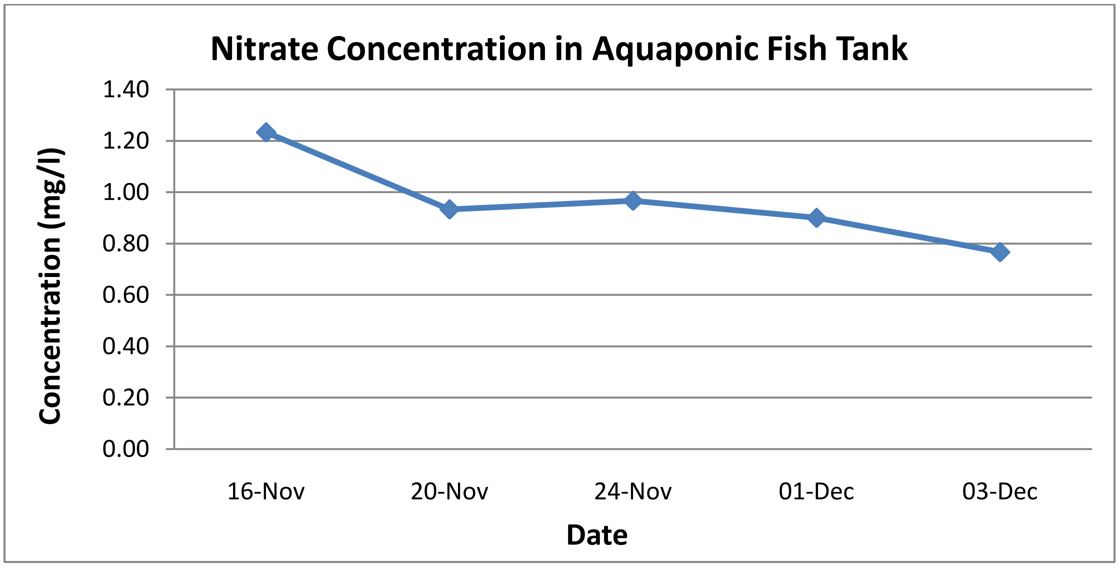

Figure 12: Nitrate concentration in water

Ammonia

The concentrations of total ammonia (NH_3 + NH_4^+) in the fish tank varied from 0 to 0.27 mg/l. Negative concentration values presumably obtained due to experimental error were considered to represent 0 mg/l of total ammonia. The changes in concentration over time are plotted in Figure 13 .

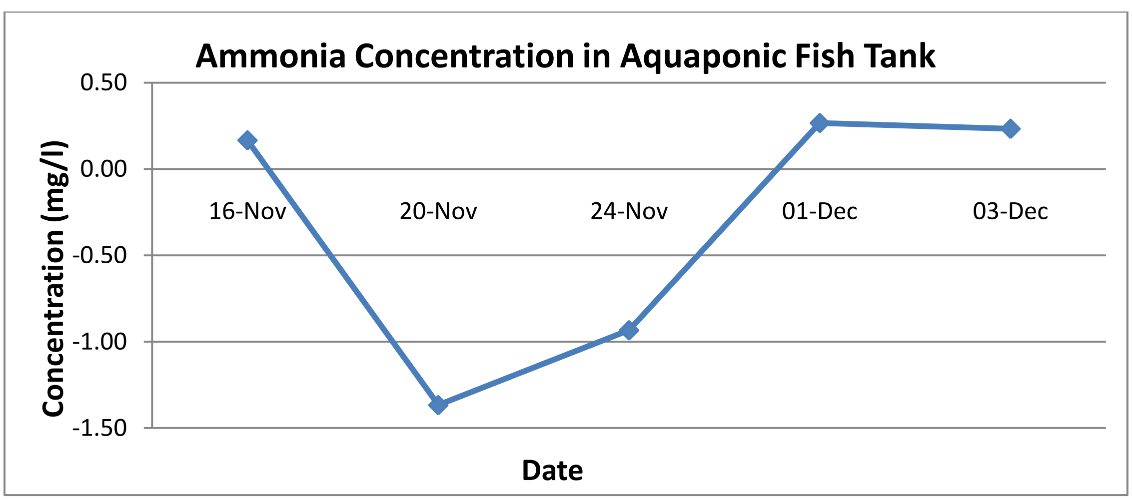

Figure 13: Ammonia concentration in fish tank water

In order to compare these values to published tolerance levels for tilapia, total ammonia concentrations had to be converted to unionized ammonia (NH_3) concentrations and ammonium ion (NH_4^+) concentrations. At the average pH value of 7.51 for the fish tank, NH_3 and NH_4^+ concentrations were determined using the relationships in Figures 14 and 15.

NH_3

Figure 14 (Droste, 1996) was used to convert the total ammonia (NH_3 + NH_4^+) concentrations (values along the curves in the plot) to unionized ammonia concentrations (values on the y-axis), at a pH value of 7.51. This resulted in an NH_3 concentration range of 0.002-0.0045 mg/l, which is well below the 0.08 mg/l concentration at which food consumption in tilapia declines.

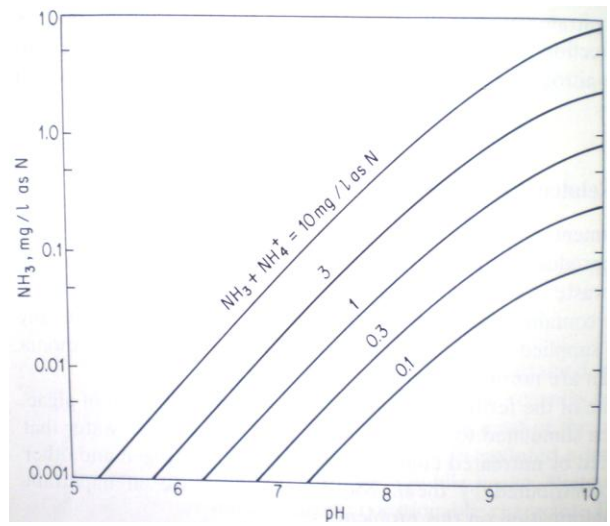

Figure 14: Relationship between total ammonia, pH and unionized ammonia

NH_4^+

Figure 15 (Post, 1983) was used to convert unionized ammonia concentrations to ammonium ion concentrations through the relationship shown in the figure, also using the average pH value of 7.51. This resulted in an NH_4^+ concentration range of 0.098-0.220 mg/l. These numbers are below the tolerance limit of 1 mg/l for tilapia health.

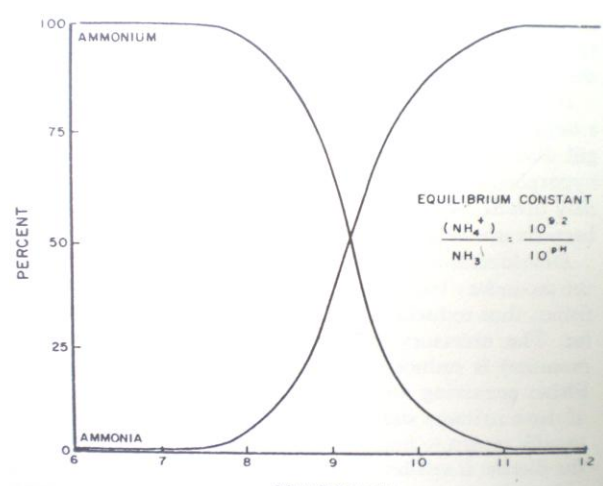

Figure 15: Relationship between pH and proportion of ammonium in total ammonia

Dissolved Oxygen

The dissolved oxygen content in the fish tank varied from 2.31 to 2.94 mg/l over the experimental period, with an average value of 2.72 mg/l. Recommended concentrations are 5.0-7.5 mg/l, in other words; at least twice the concentration that was found in our tank. Figure 16 displays the change in DO concentration over time.

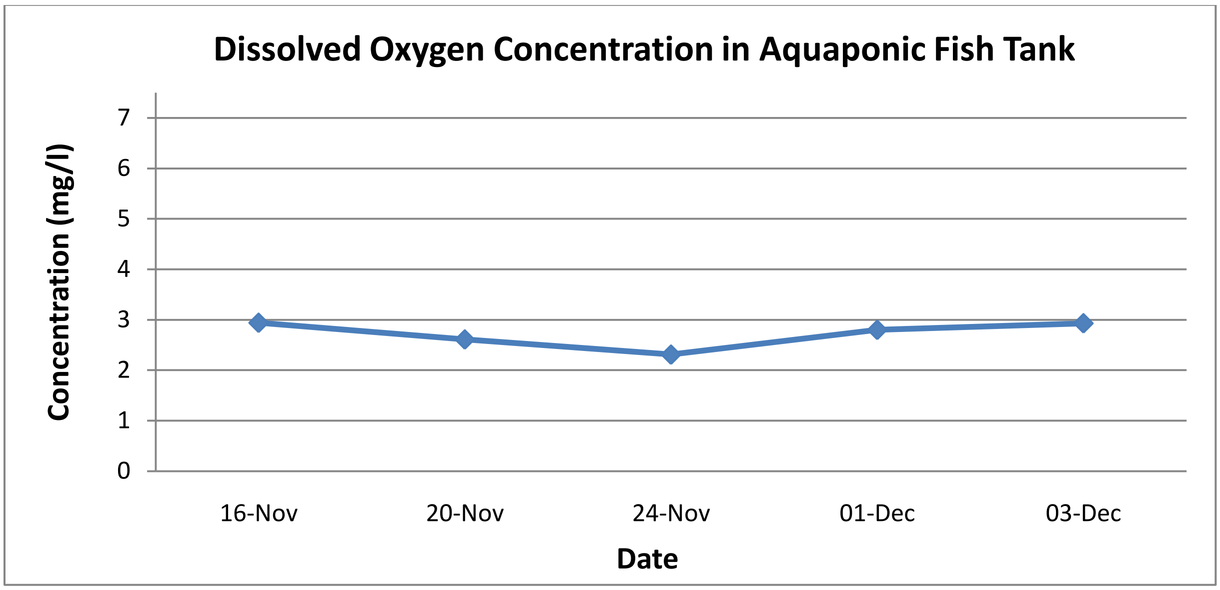

Figure 16: Dissolved oxygen in fish tank water

Biomass

Plants

Table 2 presents the original average weights of the okra/basil seedlings before they were planted and the final average weights of okra and basil plants at the time of harvest. The average okra plant increased in weight by 784% and the average basil plant increased in weight by 1031% over the six weeks.

Table 2: Average initial and final weights of okra and basil

Species	Average Dry Weight Seedling	Average Dry Weight Grown Plant	Percent Change in Weight
Okra	0.096	0.848	783.617
Basil	0.096	1.086	1030.833

In terms of total biomass of plants in the grow bed, 0.48 grams of okra were planted at the beginning of the growing period and 9.33 grams were harvested at the end. For basil, 0.48 grams in seedlings were planted and 5.43 grams were harvested. This corresponds to a total increase of 1437% in plant biomass over the six weeks of the experimental period. (see Table 3)

Table 3: Total initial and final biomass

Species	Total Dry Weight Seedlings	Total Dry Weight Grown Plants	Percent Change in Weight
Okra	0.48	9.331	1843.96
Basil	0.48	5.428	1030.83
Total	0.96	14.759	1437.40

Two of the okra plants had grown pods by the time of harvest. Their individual and total weights are tabulated in Table 4 below.

Table 4: Weight of okra pods

Okra Pod	Dry Weight of Pod
1	0.471
2	0.257
Total	0.728

Fish

Table 5 : Tilapia weights over course of experiment

Initial Weight		1154.7	g
Final Weight		1329.2	g
Total increase		174.5	g
Initial Average weight		46.188	g
Final Average weight		53.168	g
Average increase in fish weight		6.98	g

The weight of each individual fish was taken at the start and at the end of the experiment. This was to quantify the increase in mass of the fish during the experimental period. We can see that over the course of 6 weeks, each tilapia increased its biomass by almost 7 grams. The total increase in biomass was 174.5 grams (see Table 5). This increase is much smaller than what can be read from the literature. This will be addressed further in the discussion.

Discussion of Experiment

The overall quality of the aquaponic fish tank water was relatively high throughout the three weeks of laboratory testing. Temperature, pH, salinity, nitrates and ammonia (unionized and ionized) values were all in the ranges ideal for tilapia cultivation. The parameters for which values did not meet ideal conditions for aquaculture were dissolved oxygen and phosphate concentrations.

Low DO may be a result of the absence of an aeration system in the tank, the presence of high levels of organic matter (fish waste, leaves and other plant matter entering from the environment) whose degradation process requires the use of oxygen, the algae beginning to grow and decay on the tank sides and on the pipes, high water temperatures which lower the solubility of oxygen in water and high phosphate concentrations which may lead to hypoxic conditions. To improve the level of DO in aquaponic systems, an aeration system will need to be incorporated into the design of each fish tank. As oxygen levels are one of the most important water quality parameters that pertain to fish health, measures need to be taken to address this issue for the improvement of aquaponic systems before they are made available on the market.

The HACH Company prepared reaction vials that were used for phosphate, nitrate and ammonia may not have been the most precise and effective method of measuring the concentrations of these substances due to the age of the chemicals. Also, the HI 9828 Multiparameter Probe provided fluctuating values and may not have been perfectly calibrated. Other methods for measuring these water quality parameters should be explored.

Figure 17: After 6 weeks, okra is almost ready to harvest

The biomass of the plants in the grow bed increased by 1437% in total. However, out of the 24 plants originally placed in the grow bed, 16 survived and grew. The plants that were lost either wilted or were consumed by pests. Planting the seedlings to a higher density would have been a possibility. Plant growth also would likely have been great if the grow bed was not partially in the shade and had better access to sunlight.

Some speculations as to why the fish biomass didn’t increase as much as in the literature are that the experiments in the articles were more extensive and a greater degree of control was maintained over experiment parameters. In these experiments the fish were fed multiple times per day and were kept highly stocked in a small volume of water. This was clearly not the same for our experiment where feeding was once per day and the stocking density was quite small.

Ideally, this experiment would have been conducted over a much larger portion of our internship period and under more stringent conditions. Due to logistical complications, only three weeks of sampling were possible. A longer set of data would have given values that are more representative of an aquaponic system over time.

Conclusion to Laboratory Experiment

The four objectives of this experiment were met. The water quality parameters pertinent to fish health were monitored and all were found to be appropriate except for dissolved oxygen and phosphate concentrations. It was determined that an aeration system in the fish tank is necessary to elevate the DO concentration. The nitrification process and breakdown of organic matter proved not to pose any problems in terms of ammonia toxicity. The increase in biomass of the plants and fish over the six weeks of growth was determined and discussed. Further tests performed on aquaponic systems for longer periods of time would be an asset to the technical expertise of the BVAA

Cost Benefit Analysis

To assess the viability of housing a system a cost benefit analysis was performed. Cost benefit analyses are useful tools to determine the financial feasibility of a venture. The cost of all inputs to the system are tallied and weighed against the value of the system's outputs. In our case there are several inputs, including initial material costs, electricity, and fish feed. Our outputs are in the form of vegetable and tilapia production. Many assumptions must be made in order to make reasonable estimations for many of the inputs and outputs. A thorough explanation the systems components will be explored in this section.

Initial Material Costs

The cost of the materials used for the initial system setup was obtained by our mentor, Damian Hinkson, from the BVAA's financial records and were as follows in Table 6. A more detailed breakdown of some of the materials, such as the grow bed stands and distribution network can be found in Appendix C.

Table 6: Initial System Setup Material Costs ($BDS)

Materials	**Cost**
PVC Grow Bed	264.94
Grow Bed Stand	376.78
PVC Fish Tank	291.65
Pump	200
Distribution Network	269.56
Extension Cord	100
Grow Media	10
Media Bags	10
Seedlings	10
Tilapia fish	50
Total	1,582.94

Annual Costs

An additional input to the system cost of electricity used to run the water pump that circulates the water. The cost of electricity was assumed to be $0.21/kWh, which falls in line to what Barbados Light & Power charges (Barbados Light and Power). The calculations assume that a 0.5 horse power (373 Watts) pump that run 24 hours a day is used for the system. The annual electricity costs then become:

$$Annual\ Electricity\ Cost: \quad \frac{\$0.21}{kWh} * \frac{8760\ hr}{yr} * 0.373\ kW = \$\ \mathbf{686.17/year}$$

Finally, the annual cost of fish feed needs to be calculated. It was assumed that a fish tank would hold 50 tilapia fish with an average initial weight of 20 grams. Feeding rates, growth rates, and growth periods were all taken from publications of the Southern Regional Aquaculture Center (SRAC) and were as follows in Table 7. More detailed calculations of the can be found in Appendix C.

Table 7: Fish Feed Required for Tilapia Life Cycle

Weight Cagegory (g)	Growth Rate (g/day)	Feeding Rate (as % bodyweight)	Growth Period (days)	Feed Required (g)
20 - 50	1	5.5	30	2846.25
50 - 100	1.75	4	30	4522.5
100 - 250	3	2.5	50	5381.25
250 - 475	3.25	1.5	70	6685.313
		TOTALS	180	19435.31

The above table shows that the fish have four growth stages, each with a specific feeding and growth rate. Once the total amount of food was determined for a 180 day life cycle, it was assumed, for simplicity that there would be two life cycles per year and that a 22.5 kg bag of fish feed could be purchased for $51.75, as was indicated in the BVAA's financial records. This would therefore give the following annual fish feed costs:

$$Annual\ Fish\ Feed\ Cost: \quad \frac{19.435\ kg}{Life\ Cycle} * \frac{2\ Life\ Cycle}{year} * \frac{bag}{22.5\ kg} * \frac{\$51.75}{bag} = \$\mathbf{89.40\ /year}$$

Outputs

Fish production for the year is resultant from two full tilapia life cycles being completed. Fish prices were estimated looking at local supermarket prices. In the case of tilapia, it was assumed the monetary value to be taken as a whole fish, as opposed to just the fillets, at the price of $20/kg. With 50 fish in each cohort, harvested at approximately 475 g, the monetary value of all fish produced in the year is as follows:

$$Fish\ Production\ (kg) = \frac{50\ fish}{cohort} * \frac{2\ cohorts}{year} * \frac{0.475\ kg}{fish} * \frac{\$20}{kg} = \$950/year$$

To estimate vegetable production it was assumed that a plant density of 12 plants/m^2 was used. This is an empirical figure determined from the experiences of our mentor. For the sake of the cost benefit exercise it was assumed that a system uses half of its area to grow okra and the other half to grow basil. In reality systems can be used to a number of different crops, all with different yields and market prices, but for the sake of simplicity, and because of the information available, okra and basil were used as characteristic crops. Again, prices for okra and basil were determined by looking at local supermarket prices and were decided to be $ 6.75/kg for okra and $ 53.55/kg for basil. A grow bed of 1.824 m^2 will be assumed to hold 12 basil plants and 12 okra plants. Per plant production values, which were taken taken from Dr. James E. Rakocy's work with aquaponics at the University of the Virgin Islands, were found to have an average of 700 g for okra and 250 g. According to the UWI study, okra is harvested once every 3 months and basil, once a month. Table 8 summarizes the financial gains from the two crops on the next page.

Table 8: Annual Financial Gains from Okra and Basil

Crop	# of plants	harvests/year	weight/plant (kg)	total weight (kg)	market price ($BDS)	Annual value ($BDS)
Okra	12	4	0.7	33.6	6.75	226.8
Basil	12	12	0.25	36	53.55	1927.8

Table 9 summarizes the cost benefit analysis. See Appendix C for a more detailed table.

Table 9: Cost benefit analysis for single family aquaponics system for 1st and 2nd year

1st Year Inputs		Outputs	
Startup Materials	$1,582.94	Okra	$226.80
Electricity	$686.17	Basil	$1,927.80
Fish Food	$89.40	Tilapia	$950.00
Total	$2,358.51		$3,104.60

2nd Year Inputs		Outputs	
Electricity	$686.17	Okra	$226.80
Fish Food	$89.40	Basil	$1,927.80
		Tilapia	$950.00
Total	$775.57		$3,104.60

The tables make the distinction between the first and second year of production because initial start-up costs, which are quite significant, are only incurred in the first year. For this reason financial gains subsequent to the first year ($2329.03) are significantly higher than those experienced in the initial year of production ($746.09).

At this point it should be reiterated how much this analysis relies on the stated assumptions. Basil is obviously much more profitable than okra, which makes the system very profitable. If a family were to just use the system to produce for their own consumption, not much of area would be devoted to herbs, which is much more profitable. Planting densities, production plant weights, and material costs are all values that can vary and will affect a cost benefit. Nevertheless, the system seems to be quite financially worthwhile.

Self-Evaluation

The BFSS internship was an exciting opportunity to gain hands-on experience in an unfamiliar country with a challenging new social structure. We chose to work with Damian because he seemed to have a solid project which would help the Baird's Village community as a whole as well as aid in the growth of Damian's goals and objectives. We generally had a wonderful time working with him and are quite pleased with the internship chosen and the results and experience obtained in the past three months.

It was quite clear that we have all improved our practical skills. Construction was a big component of the internship; we were often outside working with power tools. Practical skills are a very important asset in the working world where a conceptual framework of structures and construction is necessary to make the right choices in the field.

We also gained experience with handling media attention. Participating in the agricultural shows attracted lots of people who may be interested in starting an aquaponics system in their backyard. We met the Minister of Agriculture and Rural Development, Senator the Honorable Haynesley Benn. We had a short discussion with him at the Enviro Expo in Saint John and he is now aware of aquaponics as a viable agricultural production system. The Advocate and The Nation, the local Barbadian newspapers, have featured two articles on the agricultural fairs with aquaponics being the highlight for both. We are now familiar with the media processes as a result of being interviewed by these newpapers. Mr. Hinkson has also become less camera-shy.

An original requirement for the choice of project was that it had to have a significant design component for Keith and Tatjana to be able to use the project for an engineering course. Since the beginning of the semester, however, plans have changed and it turned out that they will now take those engineering credits next semester since communication with the professors in Montreal has proven to be more challenging than originally anticipated. Since a specific design component was no longer required, we were free to conduct a water quality experiment in the lab instead and a huge weight has lifted from our shoulders. We think it would have been too much work if we had to design an aeration system or another component as well as all the other requirements and deliverables for this semester.

Lab access was a difficult problem to overcome during the semester. We only gained access to the lab when the Water Resources class commenced. This was approximately one month into the program, and we did not know these facilities existed and were potentially at our disposal. Using the lab was not a problem so long as a professor was using it. When the Water Resources class finished, however, lab access was denied due to liability issues. It took much persuasion and letter writing to finally allow access to the lab. If we had easier access to the laboratory we would have been able to obtain better results and more data points to show on our graphs. Since it was pretty much impossible to get into the lab every day, the fish feed could not be weighed and lab analyses were only performed twice a week for 3 weeks. Not weighing the fish feed made it impossible to perform a nutrient balance for the system and our experimental procedure had to be altered. A recommendation for next year would be to notify the students in the first week that these facilities are here and available and proper measures are taken as to assure lab analyses can be performed sooner, on a regular basis and with less resistance from the administration at Bellairs Research Institute.

Our relationship with Damian was quite positive. We learned a lot in a short amount of time and were able to help him with the documentation portion of his requirements for the UNDP grant program. We also produced a logo and newsletter to promote his vision and company in Barbados. Hopefully with these tools, he will be better equipped as a young entrepreneur and partnerships with other organizations like the UNDP will be successful.

In retrospect, Damian probably wanted more to have been done by the time we left. This is unfortunately due to the fact that materials for the construction of the community scale system did not arrive on time. We would definitely have been there to help set up this system, but we did have a hand in improving Damian's own demonstration system.

Conclusion

During the course of the semester, the overlying goal of our project and its four accompanying objectives acted as a means of focus and were met successfully. We were able to contribute to the amelioration of the BVAA's aquaponic system design as well as assist in promoting the concept of aquaponics in Barbados.

Generally, the introduction of aquaponics to the Barbadian public was well received. Many of the people we encountered at the promotional events we attended expressed interest in obtaining an aquaponic system in their own backyard. The media coverage generated by the cooperation between our group and the members of the BVAA has helped anchor the association in its future role as the premier voice for aquaponics for Barbados. The promotional materials and BVAA branding that were developed over the course of the semester will serve Mr. Hinkson and the BVAA as a strong base for future promotional endeavours. A rudimentary skeleton of standards for aquaponics in Barbados was drawn up in cooperation with BVAA members. These standards will further be edited and supplemented by the knowledge and expertise of the BVAA and the Barbados National Standards Institute.

The business infrastructure and logistical capabilities of the BVAA were discussed with Mr. Hinkson and the future aspirations of the association were considered. A business template catered to the needs of the BVAA was therefore formulated and made available to the association for use when they are ready to develop a full business plan.

In terms of improving the current aquaponics systems that the BVAA has, we were able to conduct experiments and make observations whose outputs will serve the association as preliminary scientific backing of the efficiency of their systems. The laboratory experiments conducted provided insight into the quality of water circulating through an aquaponic system over time and will serve as an example of the kinds of tests that will benefit the BVAA in further perfecting the setups that they will be selling to Barbadian households.

The four months of this internship have allowed us to play a small, yet significant role in promoting small-scale, sustainable agriculture in Barbados. The progress in aquaponic agriculture that we were privileged to witness during our stay on the island leads us to believe that Mr. Hinkson and the work of the BVAA will make a powerful and lasting contribution to increasing food security in the country and providing Barbadian citizens with the opportunity and tools to produce their own highly nutritious food crops with a small impact on the country's valuable and limited resources.

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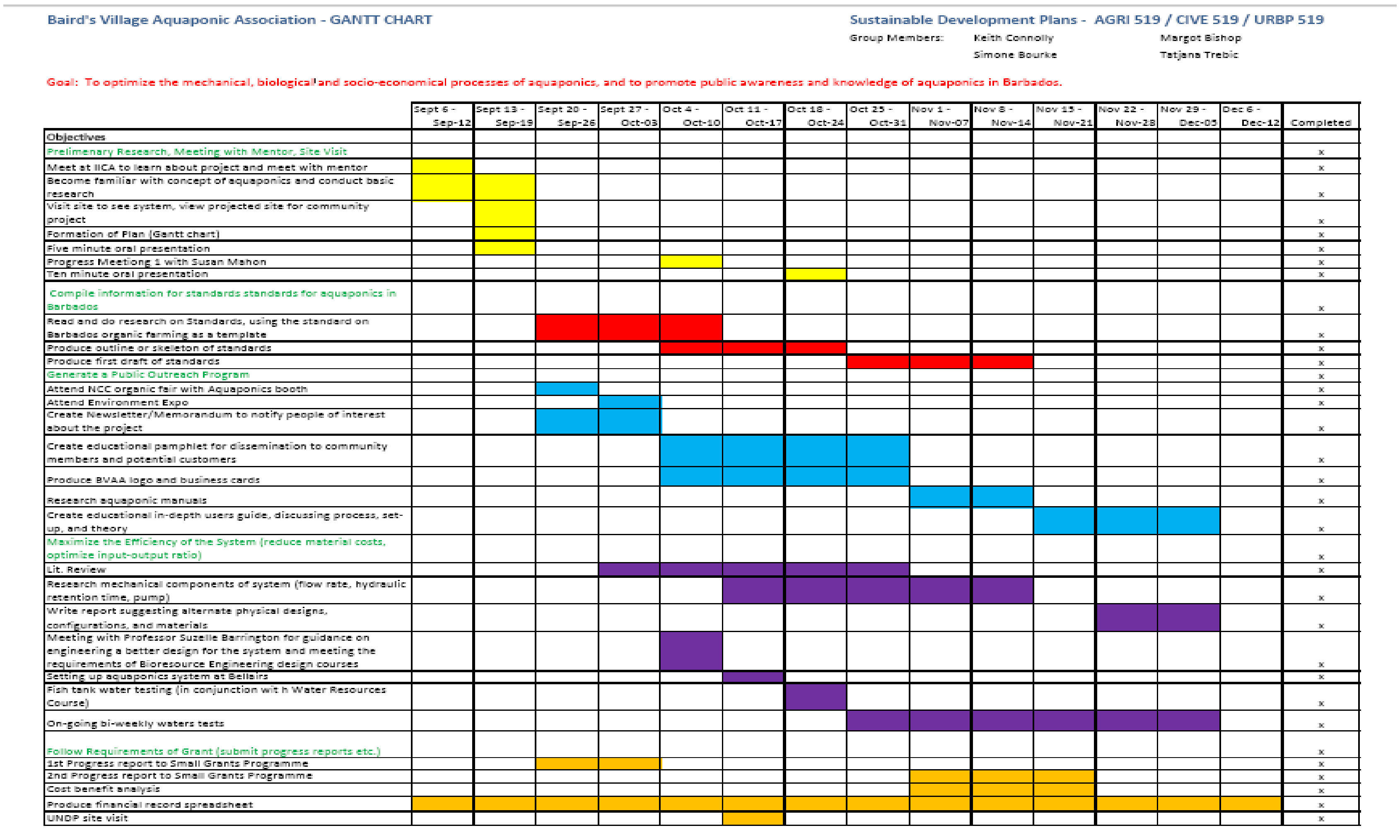
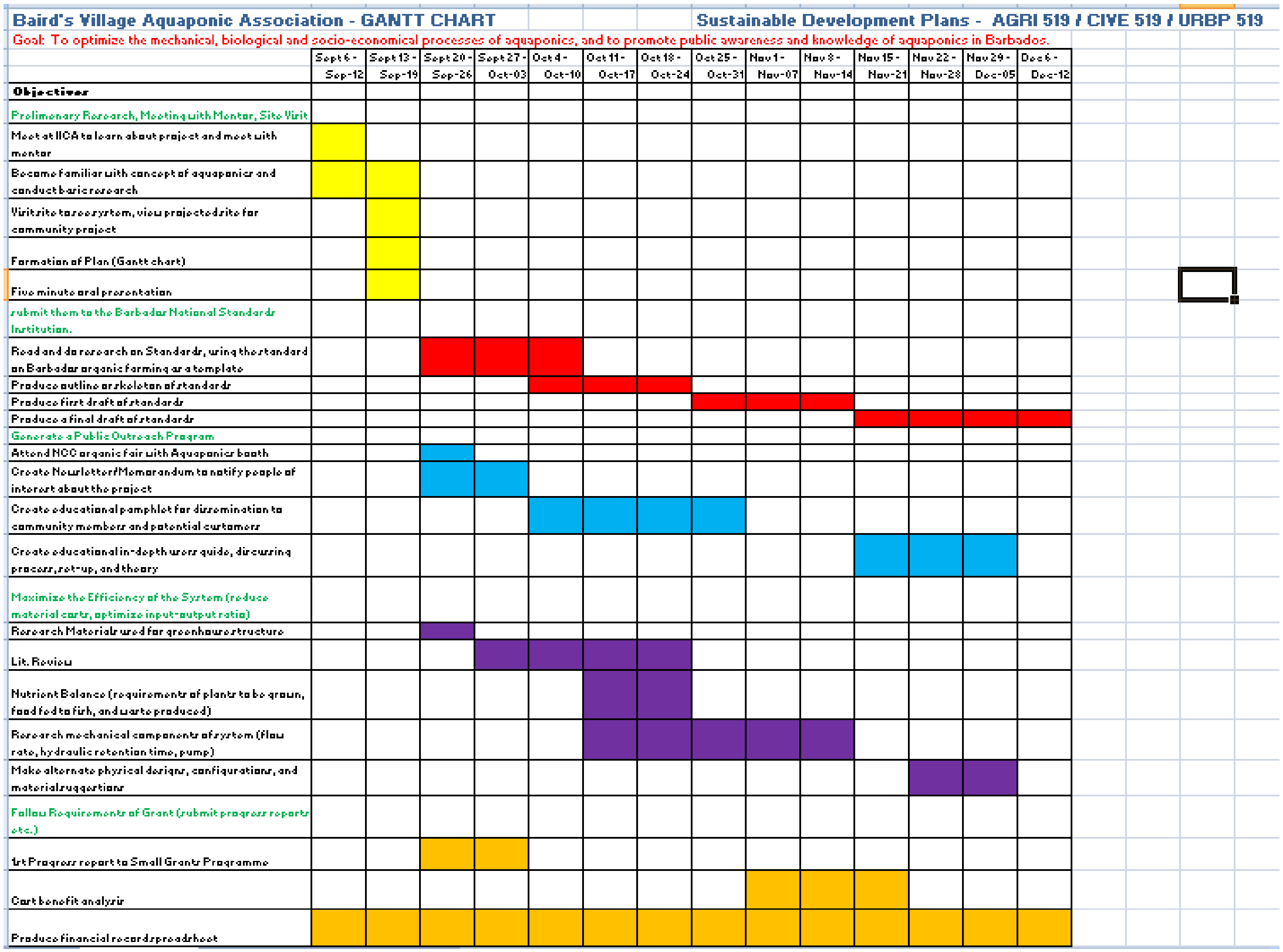
Appendix A: GANTT Charts



Original GANTT Chart



Appendix B: Promotional Documents

Business Card Design

BVAA
Baird's Village Aquaponics Association

Baird's Village Aquaponic Association

Damian Hinkson
Chairman

St. George, Barbados
Landline. 246.433.6137
Mobile. 246.830.1266
Email: BV.AA@hotmail.com

Logos

BVAA
Baird's Village Aquaponics Association

B.V.A.A.
Baird's Village Aquaponics Association

Educational Pamphlet

How can Aquaponics Affect me?

Aquaponics systems can be easy and cheap to set up and maintain, giving any individual the opportunity to grow fruits, vegetables, and fish in their backyard.

The move to subsistence agriculture can give families and communities the independence that comes with providing an economical and renewable food source.

Environmentally, aquaponics is an efficient use of valuable resources, does not affect the health of the soil, reduces land needed to produce crops, and therefore produces a smaller carbon footprint.

Eat local food. Eat healthy food.

Baird's Village Aquaponics Association
Baird's Village
St. Georges
Barbados

Damian Hinkson can be reached at:

Phone: (246) - 433 - 6137
Email: ancihydro1@hotmail.com

Baird's Village Aquaponics Association

In Partnership with:

United Nations Development Project (UNDP)
Inter-American Institute for Cooperation on Agriculture (IICA)
McGill University
Global Environmental Facility/Small Grants Programme (GEF/SGP)

What is Aquaponics?

Aquaponics is the symbiotic cultivation of plants and aquatic animals in a recirculating system. It combines aquaculture, the raising of fish, with hydroponics, growing plants in a nutrient rich solution without soil .

The fish produce waste which makes the water nutrient rich. This water is then circulated through hydroponic beds that use the waste as fertilizer to grow plants and crops.

Aquaponics in Barbados—The Story of the Baird's Village Aquaponics Association (BVAA)

Damian Hinkson has been largely responsible for aquaponics' emergence in Barbados. It started over five years ago in his backyard when he set up a simple, rudimentary system. Today his 1m x 2m grow bed is part of a refined, but still elegantly simple aquaponics system that grows tomatoes, lettuce, sweet potato and a number of other crops.

In 2009 Damian and a group from Baird's Village formed the Baird's Village Aquaponics Association. The BVAA applied for and received a grant from the Global Environmental Facility/Small Grants Programme to undertake a community scale aquaponics project.

Project plans include 36 1m x 2m grow beds with nine fish tanks, each housing 250 tilapia fish.

The BVAA hopes to create a viable aquaponics business that produces fresh produce and sells aquaponics equipment across Barbados, as well as to promote aquaponics as a sustainable means of agriculture for Barbadians.

The Baird's Village Aquaponics Association's mission is to provide a recognised superior brand of organic produce island wide and in doing so promote healthier eating habits, a healthier environment and contribute to solving the problem of food security in Barbados.

Newsletter

MONTHLY NEWSLETTER

BAIRD'S VILLAGE
Aquaponics Association

VOL 1

October, 2009

Aquaponics in Barbados, Volume 1, Issue 1

Special points of interest:

- The BVAA is the only organization developing aquaponic systems in Barbados.
- The aquaponic system has effectively produced many vegetables, including: watermelon, tomato, okra and various herbs.
- The hydroponic bed, raised on a system, acts as a biofilter and fixes the nutrients to the plant's biomass.

Inside this issue:

Aquaponics in Barbados: What the BVAA can do

In many countries the two most important inputs needed to grow nutritious fruits and vegetables are exactly two of the factors that many people lack; access to arable land and clean water. With the growing world population, more pressure is put on natural resources, increasing the problem of access. It is with these problems in mind that the agriculture community has led to the development of innovative and resourceful ways to produce food crops. One of the most important and emerging methods is the usage of aquaponics.

Aquaponics is the combination of two fields of cultivation; aquaculture, the breeding of fish, and hydroponics which is the growth of plants without any soil. This system offers a solution to the aforementioned problem that the average person, commercial farmer and the industrial produce face. Aquaponics reduces the emphasis placed on fertile soil and irrigation that is routinely used in crop growth, making it possibly for anyone to produce nutrient rich fruits and vegetables at lower costs. Additionally, the fish being bred offer a delicious source of protein right from a self-cleaning tank, removing a large burden of the work in fish farming.

A large social trend has been moving many communities in the world towards the fashion of producing and interacting with the earth in a more sustainable and organic way. The popularity of unaltered vegetables from the soil is supplemented by the feeling felt from eating something that you yourself grew from the soil. Aquaponics has made it easier to enjoy healthier produce from the earth, enriching diets and connecting normal people to the peaceful pursuit of agriculture. In a short time, Barbadians will have greater access to aquaponics systems that can be put into action in their own backyards.

Through the use of plastic frame, a simple plastic cover can be thrown over the system to protect it from excessive rain or

Baird's Village Community Project

The BVAA is in the process of expanding the backyard aquaponics system into a community sized project in Baird's Village, St. George. The 8 members of the BVAA, led by Mr. Damian Hinkson, will undertake the large scale system implementation shortly. The project, including site clearing, began August 24th, 2009 and expects to be open to the public and fully complete by February 27th, 2010.

The site will house 8 fish tanks, with 4 respective raised crop beds. There will be 250 Tilapia per tank, producing the natural fertilizer found in their waste, which will be distributed amongst the crop beds.

This pilot project will examine the potential for aquaponics to serve as a large scale output of produce and fish. Additionally, the Baird's Village Community Project will produce healthy, organic produce that has typically is expensive, to many families in the community.

Baird's Village Site

B.V.A.A.

Supplying the products & expertise required to make aquaponics the farmers technology of choice throughout the Caribbean."

Where is Baird's Village?

The Baird's Village Aquaponic Association (BVAA) was funded on March 23rd, 2009 by Mr. Damian Hinkson. The BVAA is cooperation of farmers interested in developing an aquaponics industry in Barbados. The members include: Robert Saul, Wendy Hinkson, Andy, Charles, Carmellia Hinkson, Conan Straker and Cleavland Hinkson. The BVAA is the only aquaponics organization in Barbados and hopes to provide organic produce for Barbadians at affordable prices and supply customers with their own backyard aquaponic systems.

BVAA contact:

- 246-433-6137/8301266
- enancihydro@hotmail.com
- BV.AA@hotmail.com
- Baird's Village, St George, Barbados

New Seeds by Damian Hinkson

The appeal of gardening at home is made much more enjoyable when you have different varieties to experiment with. Why grow the same tomato that you could purchase off the shelf at any supermarket when you can cultivate a French pumpkin tomato or a black cherry tomato instead.

Heirloom varieties are regaining their rightful popularity in the agriculture community, as people worldwide are shunning genetically altered crops in exchange for natural food- and heirlooms are as natural as they get. A heirloom is a plant of the *'true breeding'* variety, meaning that seeds will produce plants like the parent plant. They have been passed on from generation to generation, usually kept for a desirable, unique trait.

BVAA has begun trialing many heirloom vegetables to select seeds to bed used their breeding programs. The most notable so far is the jinn orange okra from Thailand which produces lively orange colored pods in four weeks. Though not practical for commercial growing because of the short growing season, it was crossed with the 'old time' okra to improve the crop yields.The commitment to enhancing product base and fostering a deeper understanding of biological growth capabilities of certain plants reflects the BVAA's commitment to innovative agriculture.

The system has a simple pipe network dispersing the nutrient-rich water around the plant bed. After the nutrients have been extracted, the water is returned into the fish tank.

Media Coverage

SEPTEMBER 27, 2009 — Habitat — SUNDAY SUN, 23A

Oasis in the Park

IT WAS a nature lover's oasis.

That's what the **Queen's Park** was transformed into yesterday as the National Conservation Commission's (NCC) week of activities in celebration of **Arbor Day** came to a close.

Plant lovers, environmentalists, agriculturists, herbalists, even artists and designers who are inspired by the natural environment, all found their penchant in the 100-year-old park.

When the **SUNDAY SUN** visited the park's shaded alcove there were only a few people visiting the dozen or so booths and exhibitions.

For those who came early, they were able to have first choice pickings of decorative household plants, local vegetables, herbs and their medicines as well as juices pressed and squeezed from indigenous fruits.

Those in the NCC tent said while sales had been slow but steady during the week, they anticipated a large crowd later yesterday afternoon at their plant sale.

Another crowd assembled in the Soil Conservation Unit's tent, which was primarily a display tent, showcasing some of the local trees that patrons could plant on their own lots, for shade, food, to help prevent soil erosion, and just for the pleasure of being surrounded by greenery.

One of the highlights was an exhibit of "aquaponics" which combined the techniques of aquaculture and hydroponics. This project was developed by Damian Hinkson who is getting ready to develop the backyard hobby into a commercial venture.

Herbal educator Annette "Obianuju" Maynard-Watson was also on-hand to discuss with the curious which locally grown herb, weed, leaf, flower or tree bark would cure which ailment.

The Coleridge & Parry 4-H Club also had an impressive stall with indigenous produce and their byproducts. This year's NCC celebrations revolved around the theme **Trees The Circle of Life.** (MS)

AQUAPONICS DEVELOPER Damian Hinkson (second right) **chatting with McGill University student Simone Bourke** (right). **Also pictured are Eston Lowe** (second left) **and Keith Connolly, also from McGill University.**

HERBAL EDUCATOR Obianuju (right) **pointing out healing-palm balm she made from local herbs to Patricia Bowen** (second left) **and Waveney Greaves.** Inset, **Esmay Johnson** (in hat) **from the Soil Conservation Unit explains the technique of budding to two plant enthusiasts.** (Pictures by Michelle Springer.)

Benefit of trees highlighted

IN addition to the environmental benefits of trees in mitigating the impact of global warming and soil erosion, the third annual Arbor Expo demonstrated *that trees have a lot more to offer than just shade.*

Barbadians made their way to Queen's Park yesterday to see the expo which featured a range of furniture, jewellery, fresh fruits and vegetables as well as plants and herbs.

National Conservation Commission (NCC) Special Projects Officer, Ricardo Marshall, told the ***Barbados Advocate*** that as part of the Arbor Day activities, which was officially celebrated worldwide on September 22, the expo is being held by the NCC to heighten the consciousness of Barbadians to the social benefits of trees.

He noted that the NCC, *in an effort to mitigate issues relating to soil erosion,* has embarked on the Capacity Building for Youth in Sustainable Land Management, which includes the 4 H movement and Soil Conservation Unit, and they have also planted approximately 1 500 trees in the Scotland District which is prone to land slippage.

Marshall explained that the NCC also invited a number of agencies, including the Sustainable Barbados Recycling Centre (SBRC) and the Soil Conservation Unit, to the expo.

"These other agencies may not have a direct link with trees, but because of their environmental component, we widened the scope of the expo to include other environmental issues," he said.

(JH)

The aquaponics display was very well received by visitors to the Arbor Expo.

6 • Sunday October 4, 2009 — The Barbados Advoca

Minister of Agriculture, Senator the Hon. Haynesley Benn looks on at this Aquaponics system by the Bird's Village Aquaponics Association headed by Damian Hinkson (third from left). Also present are Chairman of the St. John Parish Independence Committee, Damien Mascoll (first from left), Parish Ambassadors Ramona Downes and Kevin St. Hill, and EnviroCop Gail Riley (to right of ambassadors).

St. John Parish Independence Committee launches Environmental Expo

THE St. John Parish Independence Committee officially launched their Environmental Expo yesterday on the hardcourt in front of the St. John Polyclinic, Gall Hill, St. John with an aim to sensitise residents and Barbadians as a whole about the importance of preserving and protecting their environment.

Present at the Expo were representatives of the St. John DEO, the Ministry of Health, while there were a number of exhibits by Earth Mother Botanicals, the Bird's Village Aquaponics Association and the Association of Women in Agriculture (AWIA) who showcased their Jams, Jellies and a number of goodies, to name a few. Also present was Agrochem who displayed their range of environmentally safe line of pesticides and sprays.

Speaking at the launch, Minister of Agriculture, Senator the Hon. Haynesley Benn congratulated the Committee as well as the Community Independence Celebration Secretariat "for their choice of the parish project [titled 'Our land, our Treasure – Reducing our Carbon Foot Print'] which focuses on a 'Greener Environment' ... by encouraging residents to continually practice the 3 Rs – Reduce, Reuse and Recycle".

He moved that he wished that through the project title, "not only the people of St. John, but the entire country of Barbados will recapture with pride those words of the National Anthem 'these fields and hills beyond recall are now our very own'", urging "let us live the project title, Our land, Our Treasure".

Benn pointed out that in order to achieve success in reducing our Carbon Foot print, "we have to work closely with our neighbours who take pride in burning everything they need to get rid of ... [and] pay closer attention to those vehicles which emit smoke". He voiced his pleasure at the fact that the youth of St. John "are the ones leading the fight, accepting the challenge", noting that it gives him "hope and confidence that the future of this parish and of the country is assured".

"I want to use this occasion to assure you that this Government is totally committed to providing the necessary support to the youth of this nation and to the Agricultural sector" urged Benn, adding that the time is "at hand for us to expand Agriculture and food production and to increase investments in the sector and agri-business".

"We have been examining and developing ways to improve agricultural education in all our schools. We have more than doubled our financial support to the 4-H movement and it has paid dividends as the number of 4-H clubs have also more than doubled in the last year and a half. There are ongoing discussions with the Ministry of Education and Human Resource Development regarding the development of more effective, technology-driven agriculture curriculа to be instituted at Government's tertiary educational institutions" he furthered.

Benn also revealed that plans are to be undertaken for a similar project to the pilot project for the youth at the Home Agricultural station in St. Philip, for the parish of St. John as well at the Bath plantation. He stated that "under this program there will be an irrigation component to ensure the effective utilisation and availability of water. A number of green houses will be constructed which will be leased to young persons who are interested in agricultural activities. These young farmers will receive training in post harvest technology, agro-processing, farmer group dynamics as well as production techniques such as green house management and hydroponics".

He promised that the availability of investment capital "to encourage greater involvement in the development of small and micro-enterprises in rural districts as well as the training of small business persons will continue" as he commended the efforts of entrepreneurs present at the Expo, urging them to "pursue excellence in all of their endeavours".

(KH)

4A SUNDAY SUN — News — OCTOBER 4, 20

$500m food import bill

WHILE THE DOLLAR FIGURE attached to Barbados' food import bill may not be reducing, the actual number of items being imported is.

The island's food import bill for last year was almost $500 million, an increase of about $82 000 from 2007.

Minister of Agriculture Senator Haynesley Benn yesterday said the "quantities have reduced, but prices have gone up" and he is lauding local farmers for their efforts so far this year in maintaining levels of production.

Benn, who could not reveal figures, said: "This year even if the value of the food import bill remains the same or shows a slight reduction, I can safely say that the quantities have been reduced."

"Because of the economic downturn in many countries, the cost of production and shipping has gone up. When people hear about the food import bill, they immediately think about carrots and beans, but the import bill contains a number of raw materials and even the food items that hotels use and the prices of those commodities have increased," Benn said.

Production levels

Benn was speaking to reporters after an **Environmental Expo** organised by the St John Parish Independence Committee at Gall Hill, St. John, where he also spoke to production levels across the agriculture sector.

"This year I can report without any fear of contradiction that there has been more food produced than in previous years. Many households are producing food, the dairy farmers have been able to maintain their levels of production as well as the sheep farmers, and even food crop farmers have supplied the market well. We've not seen the type of shortages we experienced around this same time last year," he said.

(PCA)

FROM LEFT, Minister of Agriculture Senator Haynesley Benn, chairman of the St John Parish Independence Committee, Damian Mascoll, and former Ambassador Gail Riley, and current Ambassadors Kevin St. Hill and Ramona Downes observing an aquaponics display. (Picture by Charlie Pitt.)

Gibson petition for PM soon

by MELISSA ROLLOCK

THE Ian Gibson Policy Against Bullying And Harassment should be completed by the end of the month.

That along with a petition of what is hoped to be thousands of names will be presented to Prime Minister David Thompson by Gibson's father Victor Cadogan.

His neighbour Joy-Ann Haigh is drawing up the policy.

Gibson, a first former at Princess Margaret Secondary School, died on September 20 at the Queen Elizabeth Hospital after being struck by a car two days earlier on Sunbury Road, St Philip. He was allegedly running from a group of boys when he was hit.

Haigh is seeking to mobilise Barbadians to take a stand against bullying.

She said principals of two schools – Alexandra and Garrison Secondary – had instructed students to write letters speaking out against bullying, which Haigh will collect by Friday.

"As of next week Tuesday, the petitions will be out and we will notify people to let them know where they will be; they will be at several business places.

"By October 30 when the policy is completed, I'm handing it over to Mr Cadogan so he can take it to the Prime Minister. ...," she said.

Haigh said the policy stated that once a report has been made, the matter – from assessment to punishment – should be dealt with within ten school days.

■ Please see Pages 12A and 13A.

Teen gir sent to Dodd

A 15-YEAR-OLD SCHOOLGIRL was remanded to Summerville while two others received ba when they appeared in court yesterday, charged with inflicting serious bodily harm on a 15-year-old girl.

The girls – all stude of Parkinson Memorial Secondary School – we charged with the offen following an incident a the school which resul in the 15-year-old girl receiving multiple stal wounds. They were not allowed to plead since the offence is indictabl

Police Public Relatio Officer Sergeant Davi Welch said the victim was hospitalised at the Queen Elizabeth Hosp in serious but stable condition. She receive stab wounds to the he chest, hands and back. A knife was allegedly used. Up to press time the student was in ser but stable condition at Queen Elizabeth Hosp

The three accused, who appeared before Magistrate Christophe Birch at the District "5 Traffic Court, will retu to court on October 14

(MB)

Appendix C: Raw Data

Table 10: Raw data for weights of fish

Fish #	Initial Fish Weight (g)	Fish Weight (g)+ strainer	Final Fish weight (g)
1	98.5	198.5	46.5
2	96.7	202.5	50.5
3	53.5	253.5	101.5
4	45.2	212.2	60.2
5	32.7	263	111
6	18.2	214	62
7	27.8	184	32
8	29.7	235	83
9	25.9	199	47
10	13.8	189.5	37.5
11	23.2	176	24
12	18.7	236	84
13	79.2	211	59
14	83.8	168	16
15	62.1	245	93
16	31.8	217	65
17	76.2	185	33
18	32.7	221	69
19	46.7	187	35
20	55.5	208	56
21	41.1	205	53
22	37.1	184	32
23	40.6	174	22
24	46.3	177	25
25	37.7	184	32
Total Weight (g)	**1154.7**	**total (g)**	**1329.2**
Mean Weight (g)	**46.188**	**Average (g)**	**53.168**
weight of strainer (g)	**152**	**Average increase in fish weight (g)**	**6.98**

Table 11: Raw data for temperature, pH, salinity, ammonia, nitrate, and dissolved

Date	Temperature (°C)	pH	Salinity (PSU)	DO (mg/l)	Ammonia (mg/l)			Average	Standard Deviation	Nitrate (mg/l)			Average	Standard Deviation	Observations (Weather, water conditions, fish...)
					1	2	3			1	2	3			
16-Nov	29.06	7.4	0.43	2.94	0.3	0	0.2	0.17	0.15	1.8	0.9	1	1.23	0.49	Water level full, fish active, a little waste and leaves on bottom
20-Nov	27.06	7.38	0.42	2.61	0.2	-0.4	-3.9	-1.37	2.21	0.7	1.2	0.9	0.93	0.25	Water level full, fish active, large amount of waste and leaves on bottom, algae beginning to form on sides
24-Nov	29.73	7.54	0.43	2.31	0.5	-4.3	1	-0.93	2.93	1.1	0.9	0.9	0.97	0.12	Water level full, fish active, tank bottom cleaned, pump cleaned for better pumping performance
01-Dec	29.7	7.59	0.43	2.8	0.3	0.2	0.3	0.27	0.06	1	1	0.7	0.90	0.17	Water level below full mark, fish active, a little waste and leaves on tank bottom
03-Dec	27.05	7.65	0.37	2.93	0.5	0.2	0	0.23	0.25	0.7	1.1	0.5	0.77	0.31	Water level below full mark, fish active, a little waste and leaves on tank bottom
Average	28.52	7.512	0.416	2.718	0.36	-0.86	-0.48	-0.33	1.12	1.06	1.02	0.8	0.96	0.27	

Table 12: Raw data for phosphorus concentrations

Day	Phosphate - Diluted 5 times (mg/l)				Corrected Values - Diluted 5 times			Diluted Average	Corrected Values - Undiluted			Actual Average	Standard Deviation
	Blank	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3		Sample 1	Sample 2	Sample 3		
1	0.03	1.82	1.9	1.87	1.79	1.87	1.84	1.83	8.95	9.35	9.20	9.17	0.20
2		1.84	1.89	1.85	1.81	1.86	1.82	1.83	9.05	9.30	9.10	9.15	0.13

Table 13: Total ammonia concentrations and conversions to NH_3 and NH_4^+

Average Ammonia (mg/l)	From Figure	From Figure ....
	NH3 (mg/l)	NH4+ (mg/L)
0.17	0.002	0.0980
-1.37	0	0
-0.93	0	0
0.27	0.0045	0.2204
0.23	0.004	0.1959

Table 14: Initial weights of okra/basil plants

Okra/Basil Seedlings					
Total Plant Weight (g)	Weight of Dish (g)	Wet Weight with Dish (g)	Dry Weight with Dish (g)	Wet Weight (g)	Dry Weight (g)
1	2.086	3.052	2.173	0.966	0.087
2	2.106	3.094	2.202	0.988	0.096
3	2.103	3.103	2.186	1	0.083
4	2.102	3.059	2.203	0.957	0.101
5	2.103	3.212	2.216	1.109	0.113
Average (g)	2.1	3.104	2.196	1.004	0.096
Total (g)	10.5	15.52	10.98	5.02	0.48

Table 15: Final weights of basil plants

Basil					
Total Plant Weight (g)	Weight of Dish (g)	Wet Weight with Dish (g)	Dry Weight with Dish (g)	Wet Weight (g)	Dry Weight (g)
1	2.092	15.812	3.486	13.72	1.394
2	2.101	11.765	3.245	9.664	1.144
3	2.094	5.224	2.465	3.13	0.371
4	2.103	14.69	3.744	12.587	1.641
5	2.103	7.875	2.981	5.772	0.878
Average (g)	2.0986	11.0732	3.1842	8.9746	1.0856
Total (g)	10.493	55.366	15.921	44.873	5.428

Table 16:: Final Weights of Okra Plants and Pods

Okra					
Total Plant Weight (g)	Weight of Dish (g)	Wet Weight with Dish (g)	Dry Weight with Dish (g)	Wet Weight (g)	Dry Weight (g)
1	2.067	8.678	2.946	6.611	0.879
*2	2.069	12.577	2.887	10.508	1.289
3	2.101	8.068	3.015	5.967	0.914
4	2.072	9.578	3.016	7.506	0.944
5	2.083	12.503	3.63	10.42	1.547
6	2.082	3.652	2.383	1.57	0.301
7	2.082	6.576	2.877	4.494	0.795
8	2.068	7.605	2.92	5.537	0.852
*9	2.075	9.972	2.708	7.897	0.89
10	2.067	6.785	2.745	4.718	0.678
11	2.066	3.36	2.308	1.294	0.242
Average (g)	2.0756364	8.123090909	2.857727273	6.04745455	0.8482727
Total (g)	22.832	89.354	31.435	66.522	9.331

Pod					
Pod Weight (g)	Weight of Dish (g)	Wet Weight with Dish (g)	Dry Weight with Dish (g)	Wet Weight (g)	Dry Weight (g)
*2	7.78	12.216	8.251	4.436	0.471
*9	7.786	11.467	8.043	3.681	0.257
Average (g)	7.783	11.8415	8.147	4.0585	0.364
Total (g)	15.566	23.683	16.294	8.117	0.728

Table 17: Monthly Low and High Daily Temperatures for Barbados (Grantley Adams International Airport)

Month	Average Daily High Temperature	Average Daily Low Temperature
January	82.1 °F	74.2 °F
February	82.3 °F	74.3 °F
March	83.1 °F	75.0 °F
April	84.0 °F	76.4 °F
May	85.3 °F	78.0 °F
June	85.5 °F	78.7 °F
July	85.2 °F	78.2 °F
August	85.7 °F	78.3 °F
September	85.8 °F	77.9 °F
October	85.2 °F	77.6 °F
November	84.3 °F	77.0 °F
December	82.9 °F	75.0 °F

Table 18: Fish Feed Calulations

Day 1-30	Number of Fish:	50
	Initial - Final Weight (g):	20 - 50
	Growth Rate (g/day):	1
	Feeding Rate (% bodyweight):	5.5

Day	Average Weight (g)	Total Weight (g)	Food (g)
1	20	1000	55
2	21	1050	57.75
3	22	1100	60.5
4	23	1150	63.25
5	24	1200	66
6	25	1250	68.75
7	26	1300	71.5
8	27	1350	74.25
9	28	1400	77
10	29	1450	79.75
11	30	1500	82.5
12	31	1550	85.25

Day 31-60	Number of Fish:	50
	Initial - Final Weight (g):	50-100
	Growth Rate (g/day):	1.75
	Feeding Rate (% bodyweight):	4

Day	Average Weight (g)	Total Weight (g)	Food (g)
31	50	2500	100
32	51.75	2587.5	103.5
33	53.5	2675	107
34	55.25	2762.5	110.5
35	57	2850	114
36	58.75	2937.5	117.5
37	60.5	3025	121
38	62.25	3112.5	124.5
39	64	3200	128
40	65.75	3287.5	131.5
41	67.5	3375	135
42	69.25	3462.5	138.5

13	32	1600	88
14	33	1650	90.75
15	34	1700	93.5
16	35	1750	96.25
17	36	1800	99
18	37	1850	101.75
19	38	1900	104.5
20	39	1950	107.25
21	40	2000	110
22	41	2050	112.75
23	42	2100	115.5
24	43	2150	118.25
25	44	2200	121
26	45	2250	123.75
27	46	2300	126.5
28	47	2350	129.25
29	48	2400	132
30	49	2450	134.75
		Total:	2846.25

43	71	3550	142
44	72.75	3637.5	145.5
45	74.5	3725	149
46	76.25	3812.5	152.5
47	78	3900	156
48	79.75	3987.5	159.5
49	81.5	4075	163
50	83.25	4162.5	166.5
51	85	4250	170
52	86.75	4337.5	173.5
53	88.5	4425	177
54	90.25	4512.5	180.5
55	92	4600	184
56	93.75	4687.5	187.5
57	95.5	4775	191
58	97.25	4862.5	194.5
59	99	4950	198
60	100.75	5037.5	201.5
		Total:	4522.5

Day 61-110	Number of Fish:	50
	Initial - Final Weight (g):	100-250
	Growth Rate (g/day):	3
	Feeding Rate (% bodyweight):	2.5

Day	Average Weight (g)	Total Weight (g)	Food (g)
61	100	5000	125
62	103	5150	128.75
63	106	5300	132.5
64	109	5450	136.25
65	112	5600	140
66	115	5750	143.75
67	118	5900	147.5
68	121	6050	151.25
69	124	6200	155

Day 111 - 180	Number of Fish:	50
	Initial - Final Weight (g):	250 -400
	Growth Rate (g/day):	3.25
	Feeding Rate (% bodyweight):	1.5

Day	Average Weight (g)	Total Weight (g)	Food (g)
111	250	12500	187.5
112	253.25	12662.5	189.9375
113	256.5	12825	192.375
114	259.75	12987.5	194.8125
115	263	13150	197.25
116	266.25	13312.5	199.6875
117	269.5	13475	202.125
118	272.75	13637.5	204.5625
119	276	13800	207

70	127	6350	158.75	120	279.25	13962.5	209.4375
71	130	6500	162.5	121	282.5	14125	211.875
72	133	6650	166.25	122	285.75	14287.5	214.3125
73	136	6800	170	123	289	14450	216.75
74	139	6950	173.75	124	292.25	14612.5	219.1875
75	142	7100	177.5	125	295.5	14775	221.625
76	145	7250	181.25	126	298.75	14937.5	224.0625
77	148	7400	185	127	302	15100	226.5
78	151	7550	188.75	128	305.25	15262.5	228.9375
79	154	7700	192.5	129	308.5	15425	231.375
80	157	7850	196.25	130	311.75	15587.5	233.8125
81	160	8000	200	131	315	15750	236.25
82	163	8150	203.75	132	318.25	15912.5	238.6875
83	166	8300	207.5	133	321.5	16075	241.125
84	169	8450	211.25	134	324.75	16237.5	243.5625
85	172	8600	215	135	328	16400	246
86	175	8750	218.75	136	331.25	16562.5	248.4375
87	178	8900	222.5	137	334.5	16725	250.875
88	181	9050	226.25	138	337.75	16887.5	253.3125
89	184	9200	230	139	341	17050	255.75
90	187	9350	233.75	140	344.25	17212.5	258.1875
91	190	9500	237.5	141	347.5	17375	260.625
92	193	9650	241.25	142	350.75	17537.5	263.0625
93	196	9800	245	143	354	17700	265.5
94	199	9950	248.75	144	357.25	17862.5	267.9375
95	202	10100	252.5	145	360.5	18025	270.375
96	205	10250	256.25	146	363.75	18187.5	272.8125
97	208	10400	260	147	367	18350	275.25
98	211	10550	263.75	148	370.25	18512.5	277.6875
99	214	10700	267.5	149	373.5	18675	280.125
100	217	10850	271.25	150	376.75	18837.5	282.5625
101	220	11000	275	151	380	19000	285
102	223	11150	278.75	152	383.25	19162.5	287.4375
103	226	11300	282.5	153	386.5	19325	289.875
104	229	11450	286.25	154	389.75	19487.5	292.3125
105	232	11600	290	155	393	19650	294.75
106	235	11750	293.75	156	396.25	19812.5	297.1875
107	238	11900	297.5	157	399.5	19975	299.625
108	241	12050	301.25	158	402.75	20137.5	302.0625

109	244	12200	305
110	247	12350	308.75
		Total:	5381.25

159	406	20300	304.5
160	409.25	20462.5	306.9375
161	412.5	20625	309.375
162	415.75	20787.5	311.8125
163	419	20950	314.25
164	422.25	21112.5	316.6875
165	425.5	21275	319.125
166	428.75	21437.5	321.5625
167	432	21600	324
168	435.25	21762.5	326.4375
169	438.5	21925	328.875
170	441.75	22087.5	331.3125
171	445	22250	333.75
172	448.25	22412.5	336.1875
173	451.5	22575	338.625
174	454.75	22737.5	341.0625
175	458	22900	343.5
176	461.25	23062.5	345.9375
177	464.5	23225	348.375
178	467.75	23387.5	350.8125
179	471	23550	353.25
180	474.25	23712.5	355.6875
		Total:	6685.313

Table 19: Cost Benefit Analysis

Inputs						**Outputs**				
Materials					Cost	*Vegetable Production*		kg/year	Price ($/kg)	Value
PVC Grow Bed					264.94					
Grow Bed Stand							Okra	33.6	6.75	226.8
	Piece	Price	Amount	Total			Basil	36	53.55	1927.8
	2in tee	5.17	26	134.42						
	2in bend	5.17	8	41.36		*Fish Production*		47.5	20	950
	2in pipe	57	3	171.00						
	labor			30.00	346.78					
PVC Fish Tank					291.65					
Pump					200.00					
Distribution Network										
	Inflow	Price	Amount	Total						
	tee	5.8	1	5.80						
	bends	5.8	2	11.60						
	ball valve	27.7	1	27.70						
	pump to pip	3.4	1	3.40						
	bucket	12	1	12.00						
	2in pipe	57	1	57.00						
	Outflow									
	1.5 male ad	1.4	1	1.40						
	union	27.7	1	27.70						
	1.5.2in	3.4	1	3.40						
	tees	2.9	1	2.90						
	bends	2.35	4	9.40						
	plugs	3.3	2	6.60						
	female ada	1.9	1	1.90						
	1.5n ball va	19	1	19.00						
	1.5 pipe	45.53	0.5	22.77						
	2" pipe	57	1	57.00	269.57					
Extension Cord					100.00					
Grow Media					10.00					
Media Bags					10.00					
Seedlings					10.00					
Tilapia fish					50.00					
Anual Costs										
Electricity					686.17					
Fish Food					89.40					
	TOTAL				2,328.51					3104.60