The Feasibility of Integrating Aquaponics Into the FoodCycles Urban Farm

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FOODCYCLES

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Aquaponics

Aquaponics systems are recirculating aquaculture systems that incorporate the growth of plants without soil. Both vegetables and fish are grown and the recycling of nutrients and water filtration are linked. There are three key roles in this system: the fish that produce the waste, bacteria that turn that waste into nitrates, and the plants that consume the nitrates thus purifying the water for the fish. There are three main system designs for aquaponics: Media-Filled Beds, Nutrient Film Technique, and Deep Water Culture.

Media-filled beds are the simplest form of aquaponics and are most commonly used in personal backyard setups. The system gets its name from its grow beds which are filled with a growing medium such as pea gravel or expanding clay. Water from the fish tank is pumped into the beds either continuously or on a timed flood and drain.

Figure 1: Media Filled System (backyardaquaponics.com)

Nutrient film technique is a very common approach to hydroponic growing, but less common in aquaponics. Enclosed gutters are used as grow beds with a thin film of water passing through from the fish tank. Plant roots hang down from suspended net pots allowing for nutrient uptake as the water passes through the gutters. These systems are generally used for leafy greens and require a familiarity in hydroponic production.

Figure 2: NFT System (thefishfarm.com.au)

Deep water culture is the most common method for aquaponics production. This system employs rafts that float on top of framed grow beds. Typically, water from the fish tank is continuously circulated through the grow beds where the plants are floating in the rafts. As the water flows through the grow bed, the plant roots take up the nutrients and the water returns to the fish tank.

Figure 3: Deep Water Culture (Sweet Water Organics)

Fish Farming in Canada

Aquaculture

There are aquaculture operations in every Canadian province. Over 70 species are raised and exported to over 20 countries worldwide.

In Ontario, rainbow trout account for over 80% of aquaculture production. This is primarily due to legislative restrictions on farmed fish. The Game and Fish Act of Ontario was changed in 1997 to allow more (over three dozen) species to be farmed in Ontario. There are only a few farms in the province that raise multiple species of fish. These farms generally supply fish for stocking ponds around the province. Up until the summer of 2010 there was one tilapia farm using a recirculating system in Lindsay, Ontario, but they were forced to move and have not yet relocated. One other recirculating system of note is in Kingsville. They raise yellow perch in ponds and then transfer them into an indoor recirculating system.

Aquaponics

There is currently no commercial aquaponic production happening in Ontario. A number of small aquaponic hobbyist and demonstration models are active in different cities, including Toronto, but no one is producing fish and plants for public consumption. Alberta is the leading province in aquaponics research and production. Dr. Nick Savidov has been doing aquaponic research for many years and has been pioneering a new system for greenhouse-based aquaponics. Two fish farms in Alberta (MDM farms and Greenview farms) started off as aquaponic enterprises, but eventually switched their primary focus to aquaculture. Circle M Trout Farm, which is also in Alberta, raises trout and fruiting vegetables in a non-recirculating system. Cultures Aquaponiques M.L. Inc, in Quebec has been one of the most successful aquaponic ventures in Canada. Established in 2005, they raise rainbow trout and floating Boston lettuce in a greenhouse environment. Floating Gardens is a new aquaponic venture in Saskatchewan. They plan to grow tilapia and various vegetables for the Saskatchewan market.

Aquaponics as an Addition to the Farm

FoodCycles is looking to introduce aquaponics as a means to diversify their urban farm's production and increase annual revenue, meaning that the focus and success of the farm does not rest solely on aquaponics production. Aquaponic vegetable production can be incorporated into the current market streams of the farm and the harvested fish will be sold to a niche market. Growing Power in Milwaukee, Wisconsin has successfully modeled this type of approach. They started with a smaller-scale system, raising tilapia and a mixture of leafy and fruiting vegetables and have gradually and sustainability increased their capacity, diversified their production and developed they expertise.

System Design

The most appropriate style of system for an urban farm is the deep water culture system. Typically this system includes a rearing tank, clarifier, biofilter or mineralizing tank, hydroponic raft tank and sump. The rearing tank is where the fish are raised. The clarifier removes solids from the system including fecal waste, uneaten feed and some organisms. The biofilter or mineralizing tank aid in the process of nitrification (conversion of ammonia into nitrates). Often this tank is filled with a netting material that provides plenty of surface area for helpful bacteria to thrive. The hydroponic raft tanks are the grow beds of the system. These beds are typically framed out of lumber and lined with an aquaculture grade EPDM liner. Styrofoam boards float on top of the grow beds with numerous holes drilled through for the plants to sit in. The sump is the lowest point in the system and contains the pump. Water in the system flows by gravity to a sump tank and is pumped back up into the rearing tank starting the cycle again.

The most common version of the deep water culture system was developed at the University of the Virgin Islands. Their model resembles a recirculating aquaculture system with four long outdoor grow beds. Nelson and Pade, Inc. (www.aquaponics.com) developed and now distribute an array of these systems in all different sizes. These systems include four rearing tanks for staggered fish production and come with all the plumbing.

Figure 4: University of Virgin Islands's System

Figure 5: Nelson and Pade System

While these systems can be very productive they require a lot of floor space and may not be the best configuration for an aquaponics system meant to augment a small urban farm's production. Growing Power uses a different configuration of the deep water culture system. They stack their grow beds on top of their rearing tanks. This system can be productive but requires a lot of labour and experienced attention to maintain. Sweet Water Organics have taken Growing Power's system and added on a clarifier and biofilter for better production rates and less intensive maintenance.

Figure 6: Growing Power's System

Figure 7: Sweet Water Organics' System

System Inputs

Fingerlings

Choosing and sourcing fingerlings is one of the most challenging aspects of small-scale aquaponics in Toronto. The main reason for this challenge lies in the gap between the typical aquarium hobbyist, who is raising a few fish a year, and the large-scale fish farms, who raise thousands of fish a year. If you are interested in purchasing and raising 300 fingerlings, your order is too large for a local pet store, who rarely supply edible fish, and too insignificant for most fish farms. Also, the majority of fish farms in Ontario raise trout, a species that is nearly impossible to raise in a small-scale recirculating aquaponics system.

Purchasing fingerlings from outside of Ontario is possible, but it will increase the input costs. Fish must be shipped in a substantial amount of water and be courier over night. Economies of scale are a factor as the cost of fingerlings will increase as the order size decreased. All of these factors can lead to expensive start up.

Seedlings

Plants should be started from seed in a simple germination system. If you bring in seedlings from outdoors you risk introducing disease and insects. Plan to over-seed by 15% to allow for the selections of the biggest and healthiest seedlings.

Growing Medium

Growers can use peat moss, coir, perlite or rockwool to start their seedlings. Of these, rockwool works the best for this type of production. Seeds are places directly in the cubes and when the seedling reaches 2 to 3 inches the cube is transplanted into the floating rafts. Rockwool can be purchased in bulk from Grow It All Hydroponics (www.growitall.ca).

Fish Feed

A feed conversion ratio (FCR) is used in animal husbandry to quantify the efficiency of converting feed mass into body mass. While fish have the lowest ratio compared to other farmed animals (between 1:1 and 2:1), it is essential that feed management be a priority in aquaponics. This is due to the fact that, aside from staffing, feed can be the largest input cost in raising fish, accounting for up to half of the variable cost of production. Feeding practices influence waste production, feed conversion, health, growth rate and ultimately financial return to the farmer.

Commercial fish feed can be purchased and picked up at Martin Feeds in Elmira, Ontario. The recommended feed for both tilapia and yellow perch is the Classic Floating Fish Feed, which comes in 20 kg (44.1 lbs) bags. It is important that feed be stored in sealed containers to prevent rodents from getting into it.

Nutrient Supplements

To increase plant production some growers will add major and minor nutrients in small doses. The most commonly added nutrients are potassium, calcium and iron. These supplements can be purchased at Grow It All Hydroponics in Toronto (www.growitall.ca).

Electricity

Power is needed for the system’s water pump, air pumps, heater and optional grow lights. Currently, the utilities are included in the rent cost of FoodCycles greenhouse space. So the addition of a small-scale system would not increase the cost of utilities.

Water

Water needs to be added to the system on a weekly basis. Evaporation, transpiration and water lost when flushing the clarifier are the main reasons for water loss.

Legislation

Aquaculture is the shared responsibility of the federal and provincial government. The role of the federal government involves research and development, inter-provincial and export trade, and environmental sustainability including water quality studies. The key federal agencies are Fisheries and Oceans Canada; Agriculture and Agri-Food Canada; Health Canada and Environment Canada.

The provinces and territories have the responsibility for the majority of site approvals and for overseeing the industry's day-to-day operations. The key provincial government agencies involved in the regulation and administration of aquaculture in Ontario are: the Ontario Ministry of Natural Resources, the Ontario Ministry of the Environment, and the local Conservation Authority.

For a small-scale aquaponics system the main legislation involves receiving an aquaculture licence. This licence permits the holder to culture, purchase, sell and transport the species specified in the licence. The granting of an aquaculture licence depends upon recommendations by the Local Ontario Ministry of Natural Resources District Office (Toronto falls in the Aurora District Office). The process involves an application form (appendix 1) and a site visit from a specialist who assess the potential ecological impacts of the proposed fish farm. The entire process can take up to three months and the licence is valid for five years at a cost of $247.66. An aquaculture licence is renewable or transferable, providing the licence conditions are complied with.

Fish Selection

There are many species of fish that can be grown in aquaponic systems. The main factors to consider when choosing which fish to raise are: experience, suppliers, climate, local market and size of the system. Two species in particular are appropriate for the FoodCycles system: tilapia and yellow perch.

Tilapia

The most commonly raised fish in aquaponics is tilapia. This is because they are so hardy, have rapid growth rates, can be stocked densely and can tolerate a range of water conditions. They are a warm water fish, thriving in temperatures between 17ºC and 32ºC. They will die if the water temperature drops below 10ºC for an extended time. Most farmers aim to keep their systems around 23ºC, which is compromise between the needs of the plants and the fish.

Tilapia are generally omnivores and will feed on commercially available pelleted feed at a FCR of 1.7:1. Some growers use a combination of duckweed, plants and worms as a protein supplement. This diet will keep the fish alive, but will not be effective in quickly raising the fish to marketable size of 600 to 900 grams (1.3 to 1.9 pounds). Using a commercial feed with 0.5 lbs/gallon stocking density, an experienced farmer can raise a fingerling to market size in six to eight months.

All of the Canadian production of tilapia is sold live to local markets, where premium prices are obtained for fresh, live fish. The current market price is around $2.50/lbs for live sales. Toronto is the single largest market for live tilapia in North America.

Yellow Perch

This species is a relative newcomer to the world of aquaponics. A native fish to the great lakes, their populations have decreased rapidly in the past two decades. They are a fairly hardy fish and can tolerate higher levels of ammonia and nitrite then both trout and salmon. Perch can also handle high volume stocking; a well maintained system can handle 10 to 15 fish per cubic foot of rearing tank. Ideal temperatures for growth fall in the range of 21ºC to 24ºC, but unlike tilapia the yellow perch can survive water temperatures down to freezing. Fish growth will stop when temperatures fall below 10ºC and fish should not be handled in temperatures over 26ºC because they are more susceptible to disease.

The growth rate of the yellow perch is slower than other cultured species. However, their whole fish market size of 110 to 150 gram (0.25 to 0.3 pounds) is smaller than that of most other cultured food fish. Perch will need to consume 2 to 3 percent of their body weight per day. The time required to rapidly rear perch from small fingerlings to harvestable size is approximately 12 to 14 months. Fingerlings must be purchased after they have been trained to feed on commercial pellet feed. The mortality of fingerlings drops to almost nil (with good husbandry) when the fish reach 3” in length.

The yellow perch has great potential for niche markets in the city of Toronto. Because yellow perch have been part of the local market for decades, the appeal of locally raised, mercury-free yellow perch is very high for restaurants. Generally, yellow perch need to be processed into fillets for sale, but whole fish sale may be possible when selling small volumes to local restaurants. The current market value of live perch is $3.00/lbs and $9.00/lbs for fillets.

Plant Selection

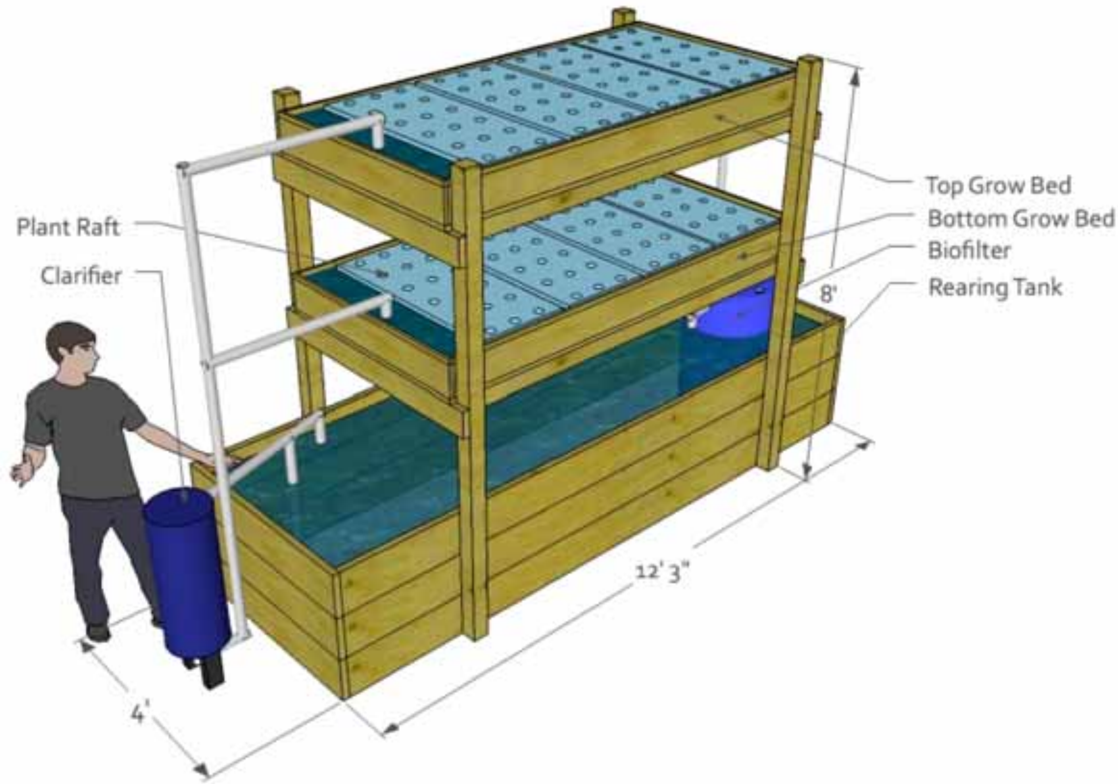
As with fish species, there are many types of vegetables that can be grown in aquaponics systems. Crops that have the greatest return should selected for production. Generally, culinary herbs like basil, cilantro, chives, parsley and mint will generate much more income compared to fruiting vegetables. Lettuce is another great crop for aquaponics. This is primary due to its quick seed-to-harvest time (approximately 40 days). Watercress has also been demonstrated to bring a great return.

A compromise must be made between the needs of the plants and the need of the fish. Both optimal water temperature and pH differ for plants and fish. Most fish will thrive in a pH between 7-8, while plants do best in pH levels 6-7. A system kept around 6.8 is a good comprise for aquaponics. Plants generally do better in a cooler water then what warm water fish with thrive in, so a comprised temperature of 21ºC to 23ºC.

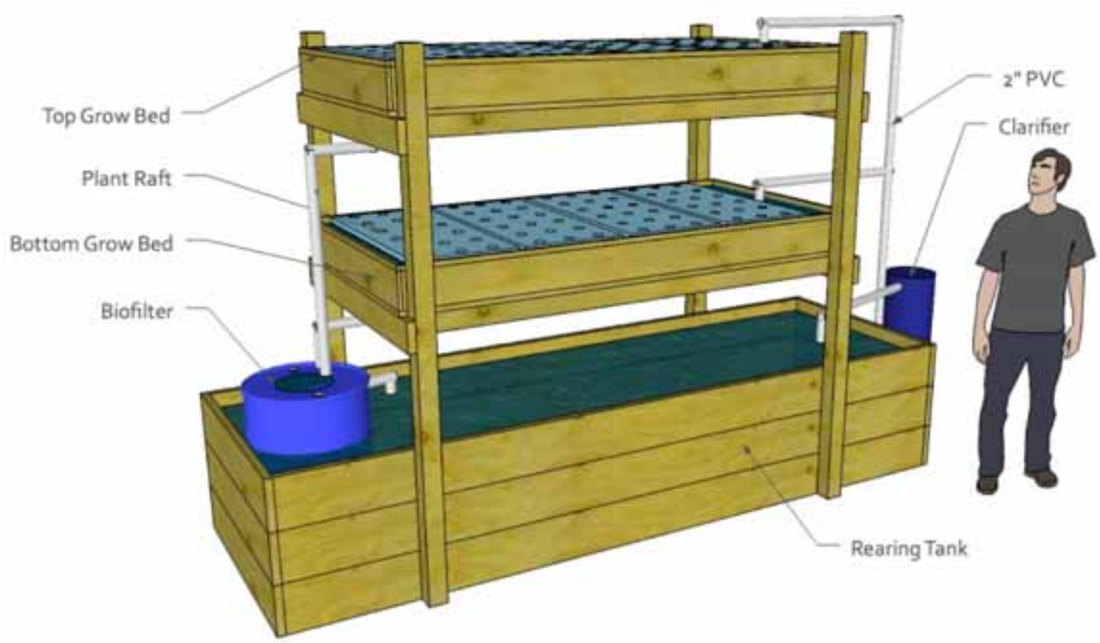
A staggered cropping production can be effectively employed in the deep water cycle system. A staggered crop production is one where groups of plants are started at different times to allow for a regular harvest. This approach allows for continuous uptake of nutrients and keeps the system at a fairly steady state.

FoodCycles Aquaponics System

The ideal aquaponics system for FoodCycles is a deep water cycle system with stacked grow beds. The scale of the system was chosen so that it would be manageable for those learning aquaponics and require minimal maintenance. A materials list and estimated budget is attached as Appendix 2. The following two images show the general layout and size of the system.



Plant Raft
Clarifier
Top Grow Bed
Bottom Grow Bed
Biofilter
Rearing Tank
8'
12' 3"
4'

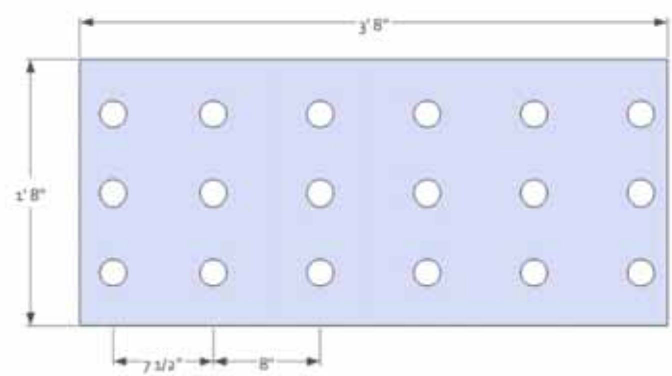


Top Grow Bed
Plant Raft
Bottom Grow Bed
Biofilter
2" PVC
Clarifier
Rearing Tank

The Rearing Tank and Grow Beds

The rearing tank of this system is approximately 720 gallons (2725 litres). The tank is constructed using lumber, ridged board insulation and 45 mil EPDM pond liner. The insulation is key in maintaining the ideal water temperature in the system during the colder months. The floor of the tank is graded towards one end where the pump is located. This is done to encourage the solids in the tank to move towards the pump where they will be pumped out into the clarifier.

Four wooden post hold up the two identical grow beds. These are also constructed out of lumber and 45 mil EPDM pond liner and are attached to the posts with a gradual slope for the water to flow. A layer of smooth river stone lines the bottom of the bed to provide more surface area for helpful bacteria. The plant rafts are made from 1” thick board insulation (2’x8’). The boards are cut into 20” x 44” sections for easier handling. Each grow bed can support four of these mini rafts and each raft can support 18 plants. The following image shows the general layout of a mini raft.



All lumber, insulation, fasteners and river stone can be purchased from a local hardware store. The EPDM must be pond grade, and can be purchase at Clarke Koi Ponds (www.clarkekoi.com).

Water Pump

A 1/3 Hp submersible water pump is ideal for this system. The pump should be suited for continuous use and be able to handle a fairly high level of solids. Scarboro Pump (www.scarboropump.com) is the ideal place to find such a pump in the city.

Air Pump

Two 115 volt (51 watts) air pumps are required to maintain ideal levels of dissolved oxygen. One pump services the rearing tank and the other services the two grow beds. In the rearing tank there are four lines with four-inch air stones. In the grow beds there are six to eight lines (three or four in each bed) with four-inch air stones evenly spaced.

A back up battery-powered air pump should also be purchase in the event of a long-term power outage.

Air pumps of this size can be purchased from larger aquatic stores like Big Al's (www.bigalsonline.ca). Tubing, fittings, valves and air stones can also be purchased from this store.

Clarifier

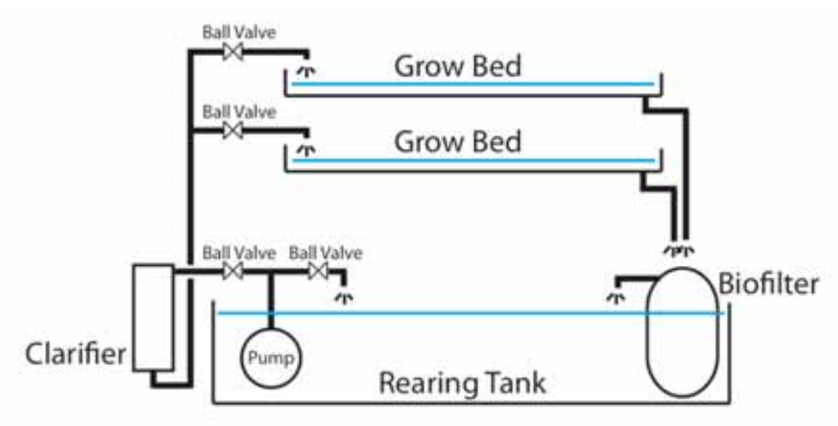
In terms of daily operations and system health, the clarifier is the most important piece. One commercial option is a bag filter system. Water is pumped from the rearing tank into the top of the bag filter vessel. Set into the vessel is a mesh bag that captures the solids as the water passes out the bottom and up into the grow beds. Every day the bag in the vessel is switched out with an extra bag that was emptied and rinsed the day before. This system can be purchased from Fish Farm Supply (www.fishfarmsupply.ca).

Biofilter

The biofilter is made using a 55-gallon food grade screw top plastic barrel. The barrel can be purchased from RIN Enterprises (OTPD-220-STR at www.rinenterprises.com). If a used barrel is acquired it should be thoroughly cleaned but no soaps should ever be used for any part of the system. The barrel is filled with bird control netting commonly used in orchards (www.duboisag.com). In this system the biofilter is placed after the grow beds to accommodate only using one pump. To avoid possible flooding, the barrel is placed in the rearing tank.

Plumbing

All the piping in the system is 2" schedule 40 PVC. Ball valves are used to control the flow rate and shut down certain lines in case of a problem. The following flow diagram shows the layout of the plumbing. All pipes, elbows, tees, and ball valves can be purchased at Elite Plumbing & Heating Supplies in Toronto.



Additional Equipment

The follow is a list of additional equipment that will need to be acquired:

- Two water heaters (800 watts)
  Needed to keep the temperature between 21º C and 24º C.
- A Freshwater Masters Test Kit
  For water quality testing
- Fish nets
  It is best to have two fish nets: one smaller picking net and one larger drip net
- Scale
  A scale and basket to weight fish
- Grow lights
  This is an optional component and dependent on start up capital. Grow lights could be set up under the top grow bed to increase production in the lower bed. Two 4’x2’ ballasts containing eight T5 fluorescents would keep up production levels through the late fall to early spring.
- Cooler
  For transportation of fish on ice.
- 12’ to 16’ articulated ladder
  An articulated ladder is ideal for use in tending and harvesting the top grow bed.
- Germination table
  A 2’x1’ table with an array 2’ long T5 grow lights and a germination heat mate.

Initial Start Up

Once your system is set up it is best to fill it with water and allow it to recirculate for a day. This will allow the grower to monitor the system, check for leaks and allow the chlorine content in the municipal water to dissipate.

Next it is time to add the fish. Fingerlings usually arrive in a large plastic bag filled with water. In order to safely transfer the fish into rearing tank you will need bring the temperature of the water in the bag up or down to the temperature of the tank. This can take up to 30 minutes, and is done by placing the bag in the fish tank and slowly exchanging the water. Wait at least a few hours before feeding them. Seedlings can be started once the fish are put into the tank.

Once the fish are established, the levels of ammonia will begin to rise and the system will begin the cycling process. Over the next 30 days, the ammonia levels will begin to lower as the nitrosomonas bacteria begin to increase. Next the level of nitrite will begin to rise and will lower as the nitrobacter bacteria arrive and convert the nitrites to nitrates. Once the levels of ammonia and nitrite are near 0 ppm (mg/L) the system is cycled. From this point the system will only become more productive and will reach its maximum potential in 6 to 9 months.

Daily Operation and Maintenance

The main daily tasks involved in aquaponics include feeding the fish, starting seedlings, transplanting, harvesting plants, water testing, adding water, cleaning and recording pertinent data. With a system this scale, the daily time investment would be between 30 minutes to an hour. An additional hour will need to be spent on one day for weekly maintenance.

A daily routine could look like this:

- Arrive at farm
    - Check that the system is running properly (5 -10mins)
    - Feed fish (5 – 10mins)
    - Test water quality and record conditions (10 -15mins)
    - Clean clarifier and compost solids (5-10mins)
- One hour before leaving
    - Feed fish (5 – 10mins)
    - Check plants (5 – 10mins)
- Once a week
    - Add new water to the system and fill up reservoir (10-15mins)
    - Harvest, package and refrigerate plants (25 -30mins)
    - Transplant seedlings into system (5- 10mins)
    - Start seedlings (10-15mins)

Feeding the Fish

Fish should be fed several times daily, ideally at the same times each day. A general rule of aquaculture is to feed as much as the fish can eat in 20 to 30 minutes. To be more precise, you can base your amount of feed on the average weight of the fish. This involves weighing one average sized fish a week and multiplying that weight by 1.5 to 2%. Be very careful not to overfeed your fish, as it will lead to water quality issues, possible disease and an increase in input costs. Automatic feeders can be purchased, but it best for the grower to hand feed the fish in order to monitor their health and habits.

Tending to the Plants

Seedlings need to be started in a simple germination setup. A heating mat can be used to accelerate the process of germination. Nutrient rich water from the aquaponics system can be used to water the seedlings as they grow. Once they are around 2 to 3 inches in height they can be transplanted into the rafts. Lettuces can be harvests with their roots in tact. This will prolong their shelve life, but make sure they are refrigerated as soon as possible.

Diseased plants should be removed immediately to avoid the spread of disease. If an insect infestation occurs special care must be taken as some pest solutions could kill the fish. Pesticides should never be used in an aquaponics system.

Water Testing

Water must be tested regularly to monitor the levels of pH, ammonia, nitrite, nitrate and temperature. Electrical conductivity, dissolved oxygen and alkalinity can also be monitored, but with a small-scale production system this will not be necessary.

PH is the most important factor and should be checked every day. Ideal levels lie between 6.5 and 7. If pH gets to high (too basic) the plants will not be able to absorb all the nutrients required for healthy production. If the pH drops below 6.5 (too acidic) the process of nitrification will slow and the system will suffer. To rasie the pH you can alternatively add calcium and potassium in small amounts. To lower the pH, add nitric phosphoric or acetic acid in very small quantities.

Ammonia, nitrite and nitrate can be measured weekly using a Freshwater Mater Test Kit. Ammonia (total ammonia NH_3/NH_4^+) levels need to stay below 3.0 mg/L. Nitrite is also very toxic to fish and must be kept below 1.0 mg/L. Nitrate, which is relatively nontoxic to fish, is the main nutrient for the plants in the system.

Adding Water

Water levels need to be topped up around once a week or as needed. If municipal water is being used it will need to be to de-chlorinated before added to the system. This can be achieved by allowing the water to sit out in open containers for at least 24 hours.

Removal of Solids

Fish fecal matter and uneaten feed make up most of the solids in the system. The clarifier should capture the majority of these solids. If not removed these solids will depress dissolved oxygen levels, decompose anaerobically, and hinder the plant roots from effective nutrient uptake. The clarifier should be monitored and cleaned once a day. These solids can be composted. Finer solids will be captured in the mesh of the biofilter tank, and should be cleaned every month or so.

Recording Data

Creating a log sheet for recording data can help the grower stay in tune with the system. A simple sheet can include the date, the weather conditions, amount of food fed, comments and each water quality parameter that is tested. An additional sheet can be made to track and plan seed starting and plant harvest times.

Harvesting Fish

Once the fish reach market size they can begin to be harvested. The less the fish are disturbed the better and the temperature of the tank should be between 21º C and 24º C. It is best practice to take the harvested fish off of their feed for three days before being sold to a restaurant or at a market. This is done by harvesting the number of fish selected for market that week, weighing them and placing them in a large barrel full of water with an air stone from the rearing tank in it.

Restaurant Survey

Seventeen Toronto restaurants were surveyed to find out about their interest in both tilapia and yellow perch, as well as a variety of crops that are typically produced in an aquaponic systems (Appendix 3). These restaurants currently order produce that is delivered by FoodCycles to their kitchen. Of these seventeen, 10 were interested in tilapia and 15 were interested in yellow perch. There were 12 chefs willing to pay more for fillets and 9 chefs who would prefer their fish whole. Only one restaurant said they would be willing to pick up the fish at the farm gate.

The restaurant Parts and Labour on Queen Street West said they would be willing to pay up to $4.00/lbs for yellow perch and would welcome 20lbs a week (60 to 70 fish). If the harvest was stretched out over two months, they could purchase around 530 fish. Brockton General on Dundas Street West said they would be willing to pay up to $5.00/lbs for yellow perch and would welcome 10 to 15 lbs a week (35 to 50 fish). However, they have a revolving menu and would only be able to buy for a few weeks.

Twelve crops were also selected for the survey. All 17 restaurants indicated interest in receiving fresh basil, 13 are interested in watercress and 11 are interested in heads of leafy lettuce.

Fixed and Variable Costs

Fixed Costs

The fixed costs of this project include: aquaculture licence, building materials, tanks, pumps, equipment and the rent for the greenhouse. Since the rent includes the cost of utilities, all power and water costs are not considered as variable costs. Using the footprint of the system as a fraction of the greenhouse floor space and multiplying that fraction by the annual rent (90 ft^2 / 3000 ft^2 x $10,116/year), a total of $304 dollars can be calculated and added to the annual expense of the operation.

- Aquaculture Licence (5 years): **$247.66**
  Purchased from the Local Ontario Ministry of Natural Resources District Office.
- Aquaponics System and equipment: **$4500 - $5200**
  Details of system are included under *FoodCycles System Design.* Range of price accounts for shipping costs, possible system add-ons and backups.
- Greenhouse Rent (footprint): **$304**

Total Fixed Costs: $5,050 - $5750

Variable Costs (Annual)

The main variable costs of this project include, fingerlings, freight, fish feed, seeds, growing medium, bags for produce, ice and staff time. Transportation of the produce can be integrated into the current FoodCycles model of using public transit and bicycles, and farm gate CSA, but the transportation of fish may require an automobile.

- Fingerlings: *tilapia (300)* **$260** *or Yellow Perch (1000)* **$1050**
  Details below.
- Freight: *tilapia* **$130** *or yellow perch* **$80**
- Fish Feed: *tilapia* **$720** *or yellow perch* **$450**
- Seeds: **$75 - $100**
  A selection of leafy lettuce seeds and kitchen herbs can be purchase from Urban Harvest (www.uharvest.ca).
- Growing Medium: **$250 - $300**
  Sheets of 98 - 1" Rockwool cubes can be purchase in bulk at Grow It All Hydroponics (www.growitall.ca). This cost could be lowered if the rockwool can be reused. It must first be soaked in hydrogen peroxide and water to kill off and harmful bacteria or fungi. Purchase a few sheets to experiment with reuse and if it does not work make a bulk order.
- Produce Bags: **$25**
  Bags can be purchased as part of the larger farm order.
- Ice for Fish Transport: **$30**
- Staff Time (farm time): **$5,824**
  At a rate of $14/hr for 8 hours a week.
- Staff Time (sales and trouble shooting): **$952**
  Sales and delivery will be teamed with current farm deliveries. For two months, an additional 10 hours will be added to each month for harvesting the fish, packaging and sales. An additional 4 hours per month is added for troubleshooting.

Total Variable Costs: $8,300 - $8,800

Cost to Raise Tilapia

Until Northern Tilapia relocates there is no local source of tilapia fingerlings. MDM Aqua Farms in Alberta purchase their fingerlings from a hatchery in Iowa. Sweet Water Organics orders theirs from Americulture in New Mexico (www.americulture.com). Both of these places order fingerlings in the magnitude of thousands, which brings their cost per fingerling down by over 5 times compared to an order in the hundreds. A quote received from Americulture estimated the cost of packaging and shipping at $130 and the price for 300 fingerlings at $260. Using this quote:

- Cost per fingerling: $260 / 300 fish + $ 130 / 300 fish = **$1.30/fish**
- With a FCR of 1.7:1 and a market weight of 1.5 lbs, each fish with require 2.55 lbs of feed in their lifespan (1.7 x 1.5 = 2.55).
- Martin Mills feed is $40 (after tax) for a 44.1 lbs bag of feed, or $0.90/lbs
- Each fish will cost (2.55 lbs x $0.90/lbs) = **$2.30/fish** to feed

Bringing the total cost to **$3.60 per tilapia**.

Cost to Raise Yellow Perch

Fish You Can Trust (www.fishyoucantrust.com) in Kingsville is the only producer of yellow perch in Ontario. A cost of $0.35/inch was given for an order of 1000 fingerlings. They also recommended that a 3" fingerling is the best size to start with when learning how to rear fish. A cost of approximately $80 would cover the overnight delivery of the fish. The price per inch drops by $0.10/inch at the follow order sizes: 5000, 10,000 and 25,000.

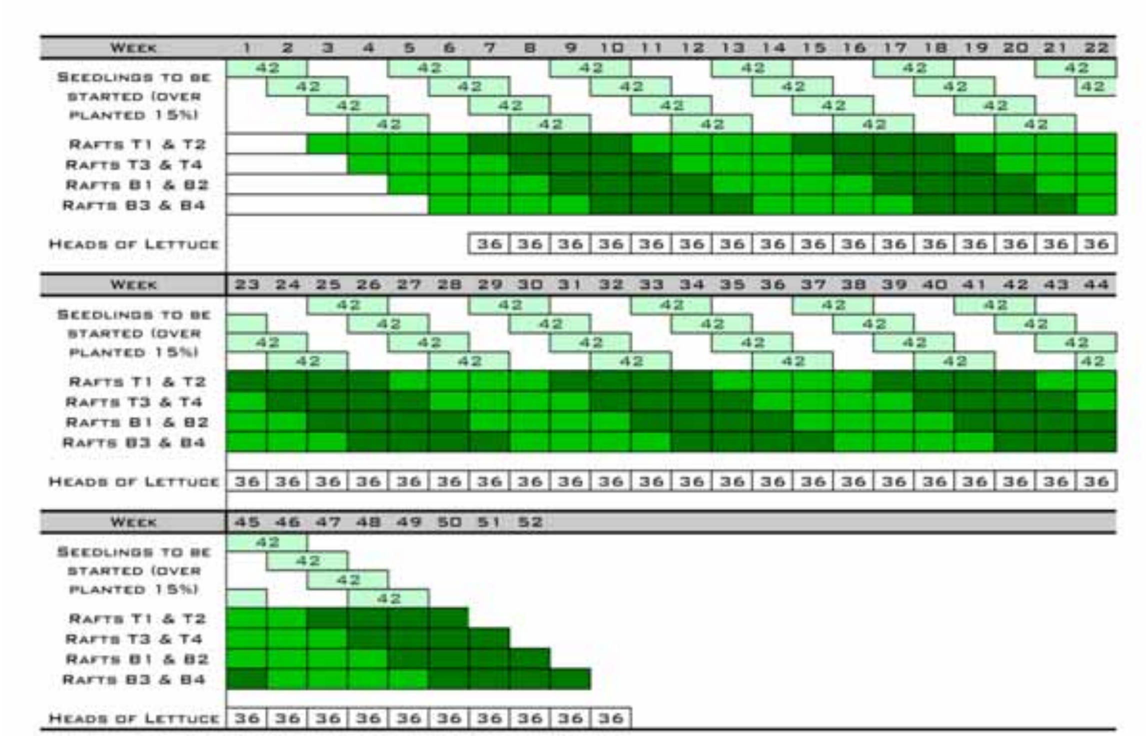
- Cost per fingerling: $0.35/inch * 3inch + $80 / 1000 fish = **$1.13/fish**
- With a FCR of 1.7:1 and a market weight of 0.3 lbs, each fish with require 0.5 lbs of feed in their lifespan (1.7 x 0.3 = 0.5).
- Martin Mills feed is $40 (after tax) for a 44.1 lbs bag of feed, or $0.90/lbs
- Each fish will cost (0.5 lbs x $0.90/lbs) = **$0.45/fish** to feed

Bringing the total cost to **$1.58 per yellow perch**

Projected Production

Crop Production

Over a span of one year, with effective staggered crop production, this system could produce between 1500 to 1600 heads of leafy lettuce. The following chart shows a sample crop production with leafy lettuce.



A seed-harvest time of 6 weeks (42 days) was used. The rafts refer to the eight mini plant rafts in the system (T: Top Bed, B: Bottom Bed). Each one has a capacity of 18 plants and two are planted in unison. Seedlings are started and given two weeks to reach the stage to be moved from the germination table to the raft. Once in the rafts, the lettuce will mature to harvest size in four weeks. Once the raft is harvested the seedlings started two weeks prior are transplanted. Using the $2.50 as a standard price for lettuce, a return of between **$3,750** and **$4,000** can be made during the year.

Fish Production

With good husbandry and a bit of luck, a harvest of 300 tilapia or 1000 yellow perch is expected. According to standard market value: $2.50/lbs for whole tilapia and $3.00/lbs for whole yellow perch, a revue of **$1,125** for tilapia (1.5lbs x $2.50/lbs x 300 fish), and **$900** for yellow perch (0.3lbs x $3.00/lbs x 1000). However, serving a niche market with an extra local food, we can expect to slightly mark up these prices.

If the cost of the system, aquaculture licence, additional equipment, fingerlings, freight, feed and growing supplies are all paid for using a capital grant (**$7,300**), leaving the staff time and rent to be covered (**$7080**). Sales from the produce are projected to be around **$3,750**, leaving **$3,330** to be made up by the fish. For tilapia that is **$11.10/fish** ($7.40/lbs) and for yellow perch it is **$3.33/fish** ($11.10/lbs). In both cases this is three times higher than the standard market price.

Conclusion and Recommendations

Aquaponics at this scale is not financially viable. However, starting at this smaller scale is a necessary stage to both build up experience and expertise in this method of food production and to develop markets for fresh fish. This scale of system is also fairly portable, and can be moved with the organization or be passed on to another organization. As experience increases, staff hours will decrease and volunteers can be brought in and trained to help with daily operations. It is also important that at least one staff member is committed to learning how to run the system and is set on staying with the project for at least a few years.

Because of their appeal to the niche markets in Toronto, the yellow perch is the recommended fish to rear. Having a fingerling source in Ontario is also an added bonus. Depending on where Northern Tilapia Fish Farm (previously in Lindsay, Ontario) relocates, it may be a feasible option to raise both yellow perch and tilapia in two separate systems.

A staggered crop production of leafy lettuce will bring in the best return for staff time. Growing 74 basil plants in the top grow bed over the summer months, when the temperature may be too hot for lettuce, is another option.

The sale and distribution of fish is the complex part of this new endeavor. A focus on a few restaurants as pilot projects in the first year will bring about a lot of learning for future expansion into more restaurants. Developing a fundraising fish fry event could be an effective way to make a return on the input costs and foster greater interest in FoodCycles. Supplying a large order of fish for a special events hosted by a partner organization may also be a good way to make a return.

The tipping point of financial viability depends mainly on two factors: the scale of production and staff time. If the system can be scaled up by five times (3740 gallons, 4’x4’x40’ rearing tank), with the staff hours only doubled, the system could be financially sustainable.

This system could support over 5000 yellow perch, at a stocking density of 10 fish/ft^3. If 5300 2” fingerlings are ordered at $0.25/inch (the 300 extra to account for potential loss), the cost per fish, transport and feed would be under a dollar. If 5000 fish are sold at $3.00 - $4.00/lbs, a return on the costs incurred can be made. This leaves the sale of produce to cover the cost of the staff time and greenhouse rent of $14,523 ($13,552 + $970). With an estimated production of 7000 heads of lettuce over the year, a return of $17,500 can be expected.

This approach would require a higher level of commitment from FoodCycles. The main factors being:

- Commitment to staying at the current greenhouse for at least 4 years
- One key staff member dedicated to learning and eventually training volunteers
- Finding alternative staff funding to cover the costs incurred from producing a lower volume in the first year
- Investigation and expansion into new markets
- Dedication of a significant portion of the greenhouse floor space

There is no question that aquaponics is an ingenious way of growing both fish and produce on a small footprint. A thriving system will not only increase and diversify the farm's production, but also generate lots of attention for a growing non-profit. The feasibility of integrating it into FoodCycles depends the commitment level of the organization, dedicated staff, and creative planning around finding alternative markets for fresh local fish.

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Appendix 1: Application for an Aquaculture Licence

Ontario

Ministry of Natural Resources
Ministère des Richesses naturelles

Application for an Aquaculture Licence
Demande de permis de pisciculture

☐ **New licence application / Nouvelle demande de permis**
☐ **Licence renewal / Renouvellement de permis** → Current Licence No. / Nº de permis actuel

Personal information contained on this form is collected under the authority of the *Fish and Wildlife Conservation Act, 1997* and will be used for the purpose of licencing, identification, enforcement, resource management and customer service surveys. Please direct further enquiries to the District Manager of the MNR issuing district.

Les renseignements personnels dans ce formulaire sont recueillis conformément à la *Loi sur la protection du poisson et de la faune*, 1997, et ils seront utilisés aux fins de délivrance de permis, d'identification, d'application des règlements, de gestion des ressources et de sondage sur les services à la clientèle. Veuillez communiquer avec le chef du district du MRN qui délivre le permis si vous avez des questions.

Please print
Veuillez écrire en caractères d'imprimerie

Name of Applicant / Nom du demandeur

Last Name / Nom de famille — ☐ Mr./M. ☐ Mrs./Mme ☐ Ms./Mlle | First Name / Prénom | Middle Name / Second prénom

Name of Business/Organization/Affiliation (if applicable) / Nom de l'entreprise/de l'organisme/de l'affiliation (le cas échéant)

OR / OU ▸ Name of Corporation / Indian Band / Nom de la société/bande indienne | Corp. # (if applicable) / Nº de société (le cas échéant)

Name of Corporation's/Indian Band's Contact Person / Nom de la personne-ressource de la société/bande indienne: Last name / Nom de famille | First name / Prénom | Contact phone # / Nº de tél. de la personne-ressource: Area Code / Code rég. | Tel. # / Nº | Ext. / Poste

Mailing address of Applicant / Adresse postale du demandeur

Street Name & No./PO Box/RR#/Gen. Del. / Nº, rue/C.P./R.R./poste restante

City/Town/Municipality / Ville/village/municipalité | Province/State / Province/État | Postal Code/Zip Code / Code postal/Zip

Physical address of applicant (if different from mailing address) / Adresse physique du demandeur (si elle diffère de l'adresse postale)

Street Name and No., Lot, Conc. / Nº, rue, lot, conc.

City/Town/Municipality / Ville/village/municipalité | Province/State / Province/État | Postal Code/Zip Code / Code postal/Zip

Phone numbers / Nºs de téléphone

Home telephone / Résidence: Area Code / Code rég. | Tel. # / Nº | Ext. / Poste
Business telephone / Bureau: Area Code / Code rég. | Tel. # / Nº | Ext. / Poste
Fax / Télécopieur: Area Code / Code rég. | Tel. # / Nº

Individuals to appear on licence (if any) / Autres noms à inscrire sur le permis (le cas échéant)

	Last name / Nom de famille	First name / Prénom	Middle Name / Second prénom
1			
2			
3			
4			

Location(s) of facility(ies) where fish will be kept / Emplacement de l'installation ou des installations où les poissons seront gardés

(Attach list, if insufficient space) (Joignez une liste si vous manquez d'espace)

Lot, Conc., Township, Municipality, Waterbody / Lot, conc., canton, municipalité, étendue d'eau	Species to be kept at the location / Espèces qui seront gardées à cet endroit

Security measures / Mesures de sécurité

Yes/Oui ☐ No/Non ☐ Plans attached / Plans ci-joints

Note: Additional approvals may be required from other agencies including but not limited to the Coast Guard, the Federal Department of Fisheries and Oceans and the Ontario Ministry of the Environment.

Remarque : Il faudra peut-être obtenir l'approbation d'autres organismes, y compris mais non exclusivement la Garde côtière, le ministère fédéral des Pêches et Océans et le ministère de l'Environnement de l'Ontario.

I certify that the information provided in this application is true.
Je certifie que les renseignements fournis dans cette demande sont véridiques.

Signature of Applicant / Signature du demandeur

Date of application / Date de la demande: Y/A Y/A Y/A Y/A | M M | D/J D/J

FW1014 (02/99)

Appendix 2: System Materials and Estimated Costs

Item	Quantity	Unit Price	Cost	Notes
2"x12" @ 12'	6	30.98	185.88	Home Hardware - Downtown Lumber
2"x12" @ 8'	3	20.69	62.07	Home Hardware - Downtown Lumber
2"x10" @ 8'	1	13.97	13.97	Home Hardware - Downtown Lumber
2"x6" @ 10'	1	8.79	8.79	Home Hardware - Downtown Lumber
2"x6" @ 8'	3	6.99	20.97	Home Hardware - Downtown Lumber
2"x4" @ 8'	5	4.49	22.45	Home Hardware - Downtown Lumber
4"x4" @ 8'	4	8.99	35.96	Home Hardware - Downtown Lumber
3/4" ply @ 4'x8'	3	25.28	75.84	Home Hardware - Downtown Lumber
1" rigid blue insulation @ 2'x8'	12	13.99	167.88	Home Hardware - Downtown Lumber
1/2" carriage bolt @ 10"	20	3.99	79.80	Home Hardware - Downtown Lumber
1/2" washer	20	0.28	5.60	Home Hardware - Downtown Lumber
1/2" nut	20	0.36	7.20	Home Hardware - Downtown Lumber
45 mil EPDM @ 15' wide	450	0.77	346.50	Clarke Koi Ponds
3" deck screws (250)	2	6.99	13.98	Home Hardware - Downtown Lumber
1/3 HP submersible water pump	1	$300.00	$300.00	Scarboro Pump
115V Linear Air Pump and accessories	2	$180.00	$360.00	Big Al's
Clarifier: Bag Filter and 5 micro Bags	1	$580.00	$580.00	Fish Farm Supply
Biofilter	1	$120.00	$120.00	RIN Ent/Dubois Agrinovation
Water Heaters (800 Watt)	2	$100.00	$200.00	Big Al's or other Online source
Masters Test Kit	1	$130.00	$130.00	Fish Farm Supply
Fish Net	2	$20.00	$40.00	Fish Farm Supply
Plumbing		$400.00	$400.00	Elite Plumbing
Grow Lights	2	$350.00	$700.00	Grow It All
River Rock	1		$80.00	Rona
Scale	1		$80.00	Rona
Cooler	1		$50.00	Rona
Articulated Ladder	1		$200.00	Rona

Sub Total	$4,286.89
Tax	$643.03
Total	**$4,929.92**

Appendix 3: Restaurant Survey

FISH

Are you interested in locally grown **Tilapia**?	**Y (10)**	**Y/N**	**N (7)**	**Ø (1)**
Are you interested in locally grown **Yellow Perch**?	**Y (15)**	**Y/N**	**N (3)**	**Ø (0)**
Would you buy it whole?	**Y (9)**	**Y/N (1)**	**N (6)**	**Ø (1)**
Or would you pay more to have it in fillets?	**Y (12)**	**Y/N**	**N (5)**	**Ø (1)**
Would you pick it up from this location: 70 Canuck, Toronto (the Foodcycles Greenhouse at Downsview Park)?	**Y (1)**	**Y/N (1)**	**N (15)**	**Ø (1)**

LEAFY GREENS

Does your store sell the following leafy greens? Please circle.

Basil (18)	**Water Cress (13)**	**Arugula (16)**
Spinach (12)	**Salad Mix (11)**	**Lettuce head (11)**
Chard (13)	**Callaloo (4)**	**Kale (11)**
Sorrel (8)	**Orach (2)**	**New Zealand Spinach (4)**

Would you be interested in locally grown leafy greens? **Y (15)** **Y/N (1)** **N (0)** **Ø (2)**

If so, which one(s)? all, tasty ones, bitter endives, puntarella, kale, lettuce, salad mix, as long as they're hearty, assorted lettuce, watcha got?

The Foodcycles Team would like to thank you for your time
647-453-FOOD
www.foodcycles.org

Appendix 4: Key Contacts

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