PROJECT FOR THE UNIVERSITY OF HAWAI'I AT HILO
MARINE OPTION PROGRAM

Hawaiian Near Shore Ecosystem Display Aquarium Biological Filtration System Support

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Introduction:

Physical water circulation, mineral deposition, and nutrient cycling driven by organism metabolisms, environmental conditions, and natural processes influence water chemistry. All of these factors are what make an aquatic or marine ecosystem habitable for life. The nitrogen cycle in particular is composed of several stages in which organisms are capable of metabolizing and producing different forms of nitrogen compounds (Harrison 2014). Without these processes occurring abundantly and naturally, such as in a closed aquarium system, nutrients can build up to toxic levels and organic debris may cloud the water. If measures are not taken to ensure an aquarium system properly mimics the natural environment of its residents, the organisms will not survive. Aquarium hobbyists have continuously developed countless methods for simulating these crucial processes, and if the techniques are implemented properly they will help maintain an aquarium system at desirable conditions, and allow it to support healthy comfortable marine or aquatic life.

Keeping an aquarium system healthy and functioning is an ongoing process that requires constant monitoring and adjustment. Fish excretion, uneaten food, and decaying organic matter are all naturally occurring sources of nitrogenous waste production within an aquarium containing an organism population, or bioload, of any size (Harrison 2014). Nitrate is the most threatening toxin that builds up easily over time as bacteria break down organic nitrogenous compounds. Nitrate build up, even at minor concentrations, can be toxic to many marine invertebrates and fish and will fuel unwanted algal growth (Foster and Smith 2014). While doing frequent water changes helps to reduce buildup of these nutrients and replenish the ecosystem, a filtration component that includes a large mechanism for denitrification is essential to keeping up with the waste output in an aquarium.

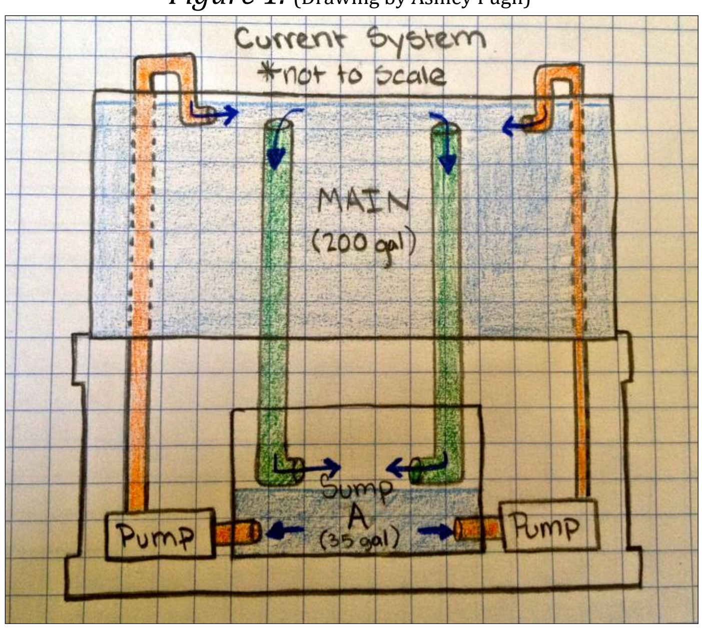
The 300-gallon aquarium on display in the Marine Science Building (MSB) at the University of Hawaii at Hilo (UHH) is a demonstration of a Hawaii Island near shore ecosystem, and a window into the local field environment where many marine science students of the university study and learn skills for research. The MSB aquarium system was designed, constructed, and is now maintained entirely by UHH students. This makes it more than just a hallway attraction for students, staff, and visitors to the campus, because it is additionally an opportunity for students to learn and showcase their acquired skills for aquarium maintenance. The display houses a number of native invertebrates, and *limu* (algae), but because of the previously minimal filtration system, this aquarium was incapable of supporting many additional organisms such as fish. It required a great deal of manual labor to control algal growth, as well as frequent water changes to prevent accumulation of toxic and unwanted nutrient build up. To solve this problem, a *Jaubert Plenum* biological filter system housing anaerobic bacteria within a fine grade aragonite sand bed with capability of eliminating nitrate and improving alkalinity of a system (Toonen and Wee 2005) was implemented. The outcomes of this project was assemblage of a 55-gallon *Jaubert Plenem* biological filtration refugium, construction of a stand for the refugium that is capable of housing a second sump and a protein skimmer, and creation of an effective flood-proof method for water circulation through the entire system. In doing so, an understanding of the components of an aquarium system was obtained, and a complete aquarium manual for this specific aquarium system was composed to be used by future student and staff caretakers. The intent behind the execution of this project was to create a healthier and more attractive aquarium display capable of housing fish, and prepare the system for the addition of a protein skimmer.

Methods & Materials:

Background

The aquarium system as it previously functioned (see image below) consisted of a 300-gallon acrylic main display tank from which water would fall through two centrally located PVC pipe overflow tubes (green) and into a 35-gallon sump (sump A) that remains located within the stand of the main display. The water would flow through filter socks (Figure 1) as it exited the overflow PVC and entered the sump. Water from the sump was then pumped through PVC pipes (orange) that transport it back in to the main display, creating a surface current where it enters. This created vital water movement within the tank, oxygenated the water and performed bulk filtration of debris (Brown T, Pers. Com. 2013). Because this basic system for water flow is such an important base for bulk filtration of debris, it remains in place with a few alterations and redirections of water to incorporate water flow through the refugium and additional sump that were added.

Figure 1. (Drawing by Ashley Pugh)



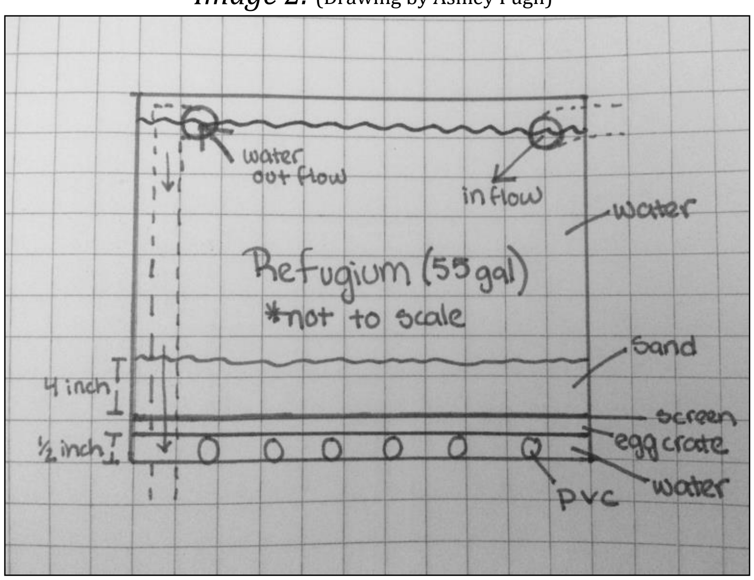
Overview

The biological filtration system assembled for this project is comprised of a 55-gallon aquarium containing a Jaubert Plenum biological filtration system. This type of filtration system contains a live sand bed that is suspended roughly a half inch above the aquarium floor. This water filled cavity encourages diffusion through the denitrifying bacteria rich sand bed producing excellent nitrate elimination. This biological filter refugium is a smaller aquarium, and mere 55-gallons in comparison to the 300-gallon main display, housing solely algae and live sand to be undisturbed by herbivorous predators. It sits on its own stand next to the main display, which is built to accommodate a protein skimmer. The second stand does not have cabinet doors in order to allow for educational viewing of the new system components.

Biological Filter Construction

The Jaubert Plenum model based system was assembled in a 55-gallon acrylic aquarium. The half-inch high water filled space under the sand bed was created using PVC pipe, egg crate grid, and window screen to create a permeable barrier between the sand bed and the aquarium floor. Sections of quarter-inch PVC pipe rest on the aquarium floor running from the back wall to the front, evenly spaced to support the egg crate grid, atop which window screen was placed to support a 4 inch sand bed (see diagram bellow for front view). Holes were drilled through the sides of the PVC segments to allow unobstructed water movement within the bottom chamber. Egg crate grid (.375 inch height) was cut to snugly fit the measurements of the aquarium floor. Between the sand and the grid are two layers of window screen; a barrier essentially impermeable to the sand and able to allow water diffusion through the sand bed and into the bottom, which will pull nutrients through the sand bed. The 4" sand bed houses anaerobic bacteria and acts as the mechanism for denitrification. (diagram below).

Image 2. (Drawing by Ashley Pugh)



Stand

A wooden stand for the refugium was built from 2x6" pieces of wood that were first cut in half to create 2x3" pieces. Four 46-inch long segments were then cut to provide the verticals of the stand and 48-inch and 24-inch pieces were used to build and top and bottom frame. Quarter-inch plywood was secured in place as the platform for the top and lower shelf of the stand. The Lower shelf is supported by three 24-inch long, 2x3-inch beams. This creates an extra vertical lift to the floor that the sump will be resting on. This was done to make the floors of sump B at a slightly elevated level to the floor of sump A, located under the main display, in order to encourage flow from sump B to sump A (see figure 4). This stand has over all dimensions of a 46-inch height, 48-inch width, and 24-inch depth, (see figure 3) and it extends in the space to the left of the original 300-gallon display and stand.

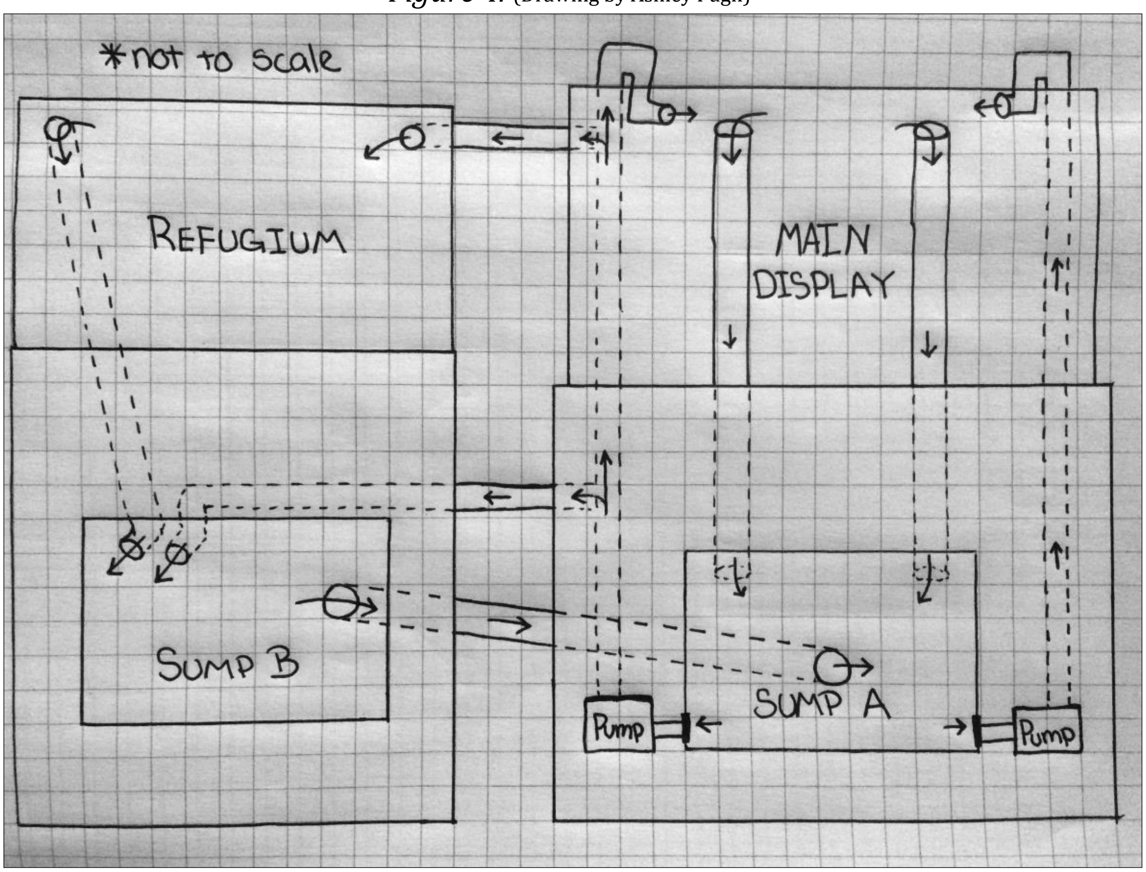
Figure 3. (Photo by Ashley Pugh)

Whole System Assembly and Water Flow:

The system is flood proof in the case of a pipe clog, pump burn out, or a power outage. In the case that such an event does occur, water will drain from both the large display and the refugium until water levels drop below the exit pipes of both the upper tanks. Once the water level is below the draining points it will no longer drain down into the sumps as it can no longer exit the upper tanks. The sumps will take in some extra water as the aquariums drains but will be able to accommodate this additional volume as long as water lever are maintained at the safe functioning water level. The safe water level was determined by trial runs that ensured the system had enough water for pumps to run wet and for sumps to accommodate extra water when pumps were shut off and upper tanks were drained. This safe water level, for when pumps are running, is marked by a black ink line on the side of sump A for easy reference.

The overall flow of water throughout the entire system can be described beginning in the main display. Water drains from the main display, runs through filter socks attached at the entrance into sump A as it did prior to the addition of the biological filtration system (figure 1). Water is pumped from sump A back into the main display without any obstruction on the right side (see Figure 4) and on the left side the pvc pipe running from the pump and back to the main display is diverted at two places. A tee was added to the line to allow flow from that line into sump B and also from that line into the refugium (figure 4). Water flows into the refugium at relatively slow rate and drains from the refugium into sump B by a gravity overflow on the left side of the back wall of the 55-gallon tank. Water in sump B is filtered by a protein skimmer that draws water from the sump and releases it back into the sump in the direction of the sump outflow; the line running from sump B to sump A. From sump A the cycle begins again as the filtered water is pumped up into the main display.

Figure 4. (Drawing by Ashley Pugh)



General Maintenance

Weekly aquarium cleanings will be performed and will include; wiping down the inner walls of the display with an acrylic-safe sponge, thoroughly washing the filter socks located at the bottom of the drain from the main display into sump A. Adding fresh de-ionized water to offset the natural evaporation that occurs will be required on a weekly basis. Water changes of 10-20% will be done periodically to restore nutrients and trace minerals. Water conditions and nutrient levels will be tested on a regular basis during the project as well. Such tests will include: pH, alkalinity, nitrate levels, and others compound concentrations as seen fit.

Manual

A detailed manual was composed with instructions for maintaining the aquarium and detailed explanations of the newly added components This was written as part of the project to assist students and staff responsible for the MSB aquarium's care in the future (full text in Appendix I).

Conclusion:

Previously, the MSB aquarium contained a modest population of invertebrates, a few small fish and multiple species of soft corals, which make up a healthy and interesting, but a somewhat un-energetic aquarium display. While the aquarium possessed space to add more organisms the filtration system could not support an increase of waste production that would be brought by a larger bioload. The addition of this *Jaubert Plenum* biological filter system and a protein skimmer create a more efficient system for water filtration and will allow more organisms to live comfortably in the near shore ecosystem display. This type of filtration system can serve as an educational demonstration for individuals interested in aquarium maintenance or chemical processes of marine environments.

References:

Brown T, (2013) Mokupapapa Discovery Center Aquarist. Personal Communication February 17, 2013

Goemans B. (2012) *The Living Marine Aquarium Manuel: Basic and Advanced Husbandry for The 'Modern' Marine Aquarium.* Retrieved from: http://www.saltcorner.com/LMAM/TOC.php?showsection=1

Harrison J PhD (2014) "Nitrogen Cycle of Microbes and Men" *Vision Learning Inc.* retrieved from" http://www.visionlearning.com/en/library/Earth-Science/6/The-Nitrogen-Cycle/98/reading

Toonen R, Wee C PhD (2005) "An Experimental Comparison of a Sandbed and Plemun-based System." *Advanced Aquarist*: volume IV

Appendix I

Marine Science Building Aquarium Manual

By Ashley Pugh

January 2016

Table of contents

INTRO:

Keeping an aquarium system healthy and functioning is an ongoing process that requires constant monitoring and adjustment of the system when necessary. The Marine Science Building's 300-gallon aquarium has been built and maintained by motivated UH Hilo students with all levels of experience as aquarium hobbyists. Being involved with the upkeep of the MSB aquarium is an excellent resume builder and a fun way to learn about ecosystem chemistry and the contributions and requirements of various organisms. It is also gratifying work to maintain a display that so many students, staff, and visitors to MSB enjoy on a daily basis.

Tips for Success:

1. **Keep an aquarium log.** Write down and date all the cleaning, water testing, organism addition and removal, ect… that are done to the aquarium. Science is all about data collection! These records are useful to reference for comparison as changes and development occurs over time.
2. **Do some research.** The more we understand things the more we tend to enjoy them so take some time to do some aquarium related research digging. It would be good to figure out the kinds of aquarium systems that exist, how they work, and what kinds of organisms each system best supports.

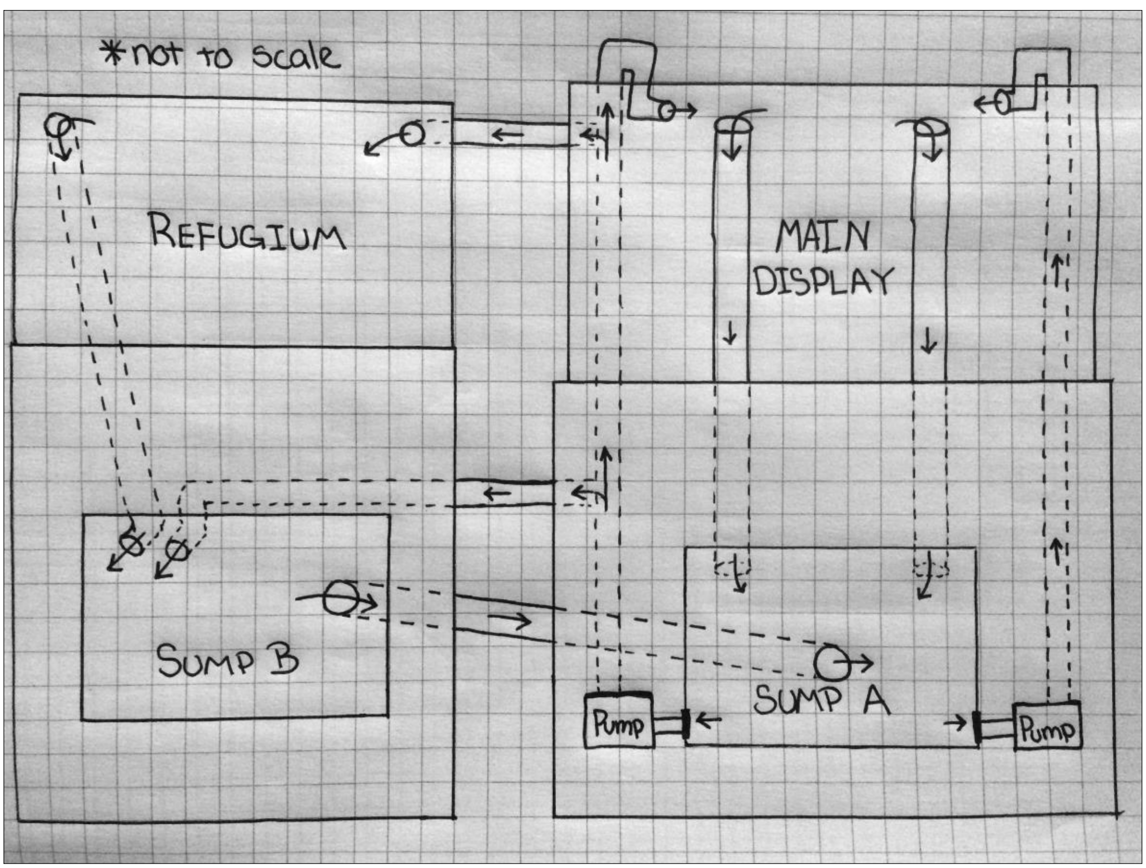
   Listed in appendix I are a few online sources that may be useful for expanding your aquarium knowledge!

MSB Aquarium Set up

System water flow:

The system is flood proof (***as long a safe water level is maintained!***) in the case of a pipe clog, pump burn out, or a power outage. In the case that such an event does occur, water will drain from both the large display and the refugium until water levels drop below the exit pipes of both the upper tanks. Once the water level is below the draining points it will no longer drain down into the sumps as it can no longer exit the upper tanks. The sumps will take in some extra water as the aquariums drains but will be able to accommodate this additional volume as long as water lever are maintained at or below safe levels. The safe water level was determined by trail runs that ensured the system had enough water for pumps to run wet and for sumps to accommodate extra water when pumps were shut off. This **safe water level**, for when pumps are running, is marked by a black ink line on the side of sump A and B.

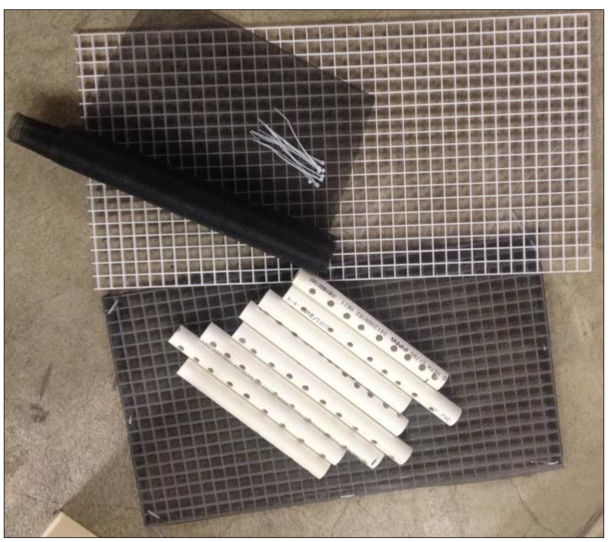
The overall flow of water throughout the entire system can be described beginning in the main display. Water drains from the main display, runs through filter socks attached at the entrance into sump A as it did prior to the addition of the biological filtration system. Water is pumped from sump A back into the main display without any obstruction on the right side (image below) and on the left side the PVC pipe running from the pump and back to the main display is diverted at two places. A tee was added to the line to allow flow from that line into sump B and from that line into the refugium (image below). Water flows into the refugium at relatively slow rate and drains from the refugium into sump B by a gravity overflow on the left side of the back wall of the 55-gallon tank. Water in sump B is filtered by a protein skimmer that draws water from the sump and releases it in the direction of the sump outflow; the line running from sump B to sump A. From sump A the cycle begins again as the filtered water is pumped up into the main display.

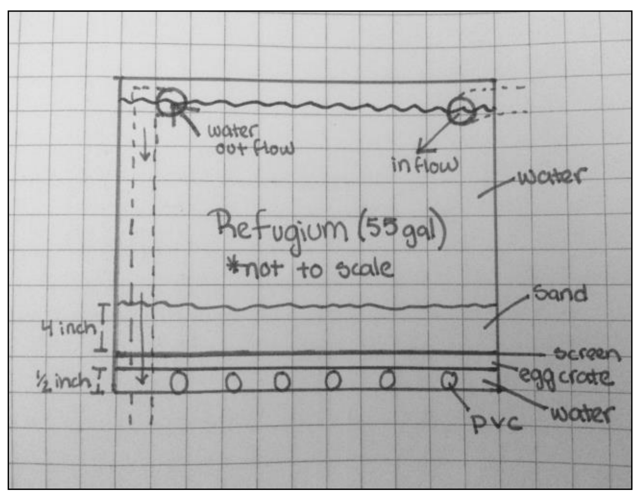


Biological Filter:

The biological filtration system assembled for this project is comprised of a 55-gallon aquarium containing a Jaubert Plenum biological filtration system. This type of filtration system contains a live sand bed that is suspended roughly a half inch above the aquarium floor (Figure 1). This water filled cavity encourages diffusion through the denitrifying bacteria rich sand bed producing excellent nitrate elimination. This biological filter refugium is a smaller aquarium, and mere 55-gallons in comparison to the 300-gallon main display, housing solely algae and live sand to be undisturbed by herbivorous predators. It sits on its own stand next to the main display, which is built to accommodate a protein skimmer. The second stand does not have cabinet doors in order to allow for educational viewing of the new system components.

The half inch space bellow the sand is created by a layer of egg crate grid resting on top of sections of PVC pipe running from the back wall to the front across the aquarium floor (image below). They are evenly spaced to support the weight of the sand bed and have holes drilled through the sides to allow unobstructed water movement within the bottom chamber. Egg crate grid (.375 inch height) snugly fits the measurements of the aquarium floor and rest on top of the PVC. On top of the grid are two layers of window screen, which is a barrier impermeable to the sand but will allow water diffusion into the bottom, pulling nutrients through the sand bed.





(Drawing by Ashley Pugh)

Testing water nutrient levels

There is a test kit for nutrients (nitrite, nitrate, ammonia), pH and alkalinity kept bellow the aquarium with directions for each test. The directions are simple and easy to follow as they all consist of adding a specified amount of aquarium water to a test tube and then adding drops of one or two successive indicator solutions. The indicator will change the watercolor so it can be compared to a color matching chart that will indicate the approximate nutrient concentration of the water in that vial. Every time the nutrient levels are tested it should be recorded in the aquarium log.

Desirable Nutrient Levels:

- Nitrate (NO_3) level < 10 ppm (Alken Murray Corp. 2006)
- Ammonia (NH_4) < 0.02 ppm (Alken Murray Corp. 2006)
- Nitrite (NO_2^-) levels are ideal between 0.01-0.04 ppm. Levels above 0.55 ppm are considered toxic and can cause disease in marine organisms (Alken Murray Corp. 2006).

Sources of nitrogen input include aquarium food, fish waste, and decaying organic matter. (A good reason to be careful not to overfeed!) The levels of these nutrients should be tested on a weekly basis and more frequently when adding organisms to the aquarium.

A brief summary of the Nitrogen cycle:

Nitrogen in fixed by bacteria from its low reactive form (N_2) into ammonium (NH_4) and exists as a part of organic compounds in all living organisms. When organisms die and are broken down by bacteria, an oxygen requiring process called nitrification occurs. During this process bacteria convert ammonium and ammonia into nitrite (NO_2) and then nitrate (NO_3) in the presence of oxygen. Nitrate is toxic to aquarium occupants even in small concentrations. Anaerobic bacteria (living mainly in the sand bed!) convert nitrate to N_2 under anoxic conditions. This eliminates the nitrogen from the system permanently.

Alkalinity

- Alkalinity is a measure of the system's buffering capacity, which is important to offset changes to the pH.
- The acceptable range for most fish is **20-200 ppm** (Alken Murray Corp. 2006)

pH

- The pH of a solution is a measure of the concentration of Hydrogen ions (H^+). The ideal pH for this aquarium is around **7.9** because this is what Hilo waters tend to be measured at. As a result of the amount of fresh water run off that occurs on the Hilo of the island (rainy side) the pH is a little lower than what is said to be ideal for marine environments. A low pH is indicative of carbon dioxide (CO_2) build up from organism respiration and a high pH is not desirable because it allows for ammonia build up (Alken Murray Corp. 2006). Most marine fish and invertebrates can tolerate pH levels of 8.0-8.5 (Premier Aquatics 2014).

Calcium (Ca)

- Calcium level should ideally mimic that of seawater, **400 ppm** (Premier Aquatics 2014). This nutrient is used for growth by corals and invertebrates with calcium carbonate shells.

Magnesium (Mg)

- Mgnesium concentration should mimic sea water in a marine aquarium system, at levels between **1250-1350 ppm** (Holmes-Farley 2008). The levels of magnesium can be restored through frequent water changes. Mg helps to stabilize carbonate and allow it to be present in higher concentrations, which creates a buffer for maintaining the ideal pH of about 8-8.5.

Phosphate

- Being a products of organism waste and breakdown of organic mater, phosphate builds up within a closed system. High levels of Phosphate (PO_4) aid algal growth so it is ideally kept at a concentration **bellow 0.10 ppm** (Alken Murray Corp. 2006).

Dissolved Oxygen

- Dissolved oxygen should be kept at or near saturation (Premier Aquatics 2014).
- The way the MSB system in designed allows for lots of water flow into the sump that creates bubbles, so as long as the pumps are running, the dissolved oxygen in the aquarium should remain at a desirable level.

Cleaning:

Several tools are located under the aquarium to be used for cleaning. They are listed below for inventory purposes though this list may change over time as tools are added or are worn out and discarded.

Tools:

Sponge(s)

White Algae Scrapper

Rubber (red) tip Algae Scrapper

Bucket

Hose

Microfiber towel (use with fresh water for cleaning outside of the glass only)

Squeegee

Miscellaneous towels and wash clothes

Step 1: Don't Scratch the Tank

The advantages of having an acrylic aquarium include; lighter weight, easy to drill into for filtration construction purposes, its ability to hold a stable temperature, it is not as pressure point sensitive towards the stand, and it has great viewing clarity (as long as it remains unscratched!). **The major disadvantage of acrylic is that it scratches easily**. When cleaning acrylic it's important to only use acrylic safe cleaning sponges, algae scrapers, and other cleaning tools. The product should specify that it is acrylic safe. If it does not specify please do not use it. Bear in mind that even if the materials are acrylic safe they can easily become harmful if sand gets caught between the tool and the aquarium walls during the cleaning process. Be careful not to stir up sand or brush the sponge on the sand while cleaning the bottom of the walls, as this will cause sand to get trapped on and in the pores of the sponge. If sand does happen to make contact with the sponge, please shake it out well and inspect it before continuing.

<u>Step 2</u>: Aquarium Wall Scrub

Scrub the front and sidewalls with sponge and algae scrapper when necessary. The algae on the back wall can be left alone. Please take note of precautions listed in step 1.

<u>Step 3</u>: Filter socks rinse

I. Remove the filter socks by un-looping the string hooked around the screws on the back wall under the stand and carefully pulling the sock off from around the PVC drain tube coming from the main display.
II. (NOTE: There are almost always snails caught in the socks. You will need to check for them and put them back up into the main display. Some may not survive depending on how long they have been in the filter sock and that is okay. They can be dropped in anywhere, though they tend to have an easier time turning over on the rocks)
III. Place the socks in a bucket available for transportation to avoid water dripping onto the floor.

IV. There is a blue hose for rinsing the filter socks that can be hooked to the nozzle on the side of the marine science building and the socks can be cleaned at the sink. The socks should be thoroughly rinsed both inside and out.

V. After the rinsing in done they need to been rung as dry as possible and then flung to remove as much remaining tap water as possible to avoid contamination to the system.

Note: **Ordering new filter socks**… There is come a point when the filter socks wear out. They may begin to feel thin or the fabric begins to become loose and fuzzy. They point at which they need be replaced is your judgment. They may be replaced with an identical set. You will want to order **200 Micron - Aquarium Felt Filter Bags - 7 Inch Ring by 16 Inch Long Made In The USA by *Aquatic Experts.***

Step 4: Top it off

Water evaporates from the aquarium each day but leaves the salt and other dissolved particles in place. Overtime the water level will go down, and the salinity will go up if the lost water is not compensated for by the addition of de-ionized water. Typically at least one 5–gallon jug of de-ionized water needs to be added each week. It is important that the sump water level stays at a constant and safe level for the functioning of the pumps and for flood prevention (reference "MSB Aquarium Set Up" for ideal sump water level). This safe water level, for when pumps are running, is indicated by a black Sharpie line marked on the side of the sump under the main display. De-ionized water may be obtained from the analytical lab located in MSB but **closed toed shoes must be worn in the lab at all times**.

Step 5: Empty Protein Skimmer

The collection cup at the top of the skimmer fills with foam and debris and should be emptied on a weekly basis. This upper compartment of the skimmer is removable. The black lid at the top of the compartment can come off as well. This can be removed and rinsed in the sink in the wet lab with tap water to remove all debris. Before re installing the entire compartment should be rinsed down with DI water (same water used for topping off aquarium) to ensure there is no contamination to the system. The compartment can then be replaced on the skimmer.

Step 6: Wipe down/ squeegee outside

There is a blue microfiber cloth that is stored draped over a PVC pipe under the aquarium. It can be saturated with drinking fountain water and used to wipe down the outside of the aquarium (and nothing else please). It is used to remove fingerprints and smudges and any salt-water drips from the top openings. It is favorable to save this step for last and once you are done accessing the inside of the tank and have the plastic cover back in place to avoid more salt water from in the tank dripping down after the wipe down.

Step 6: Put Everything Back Under the Tank

The squeegee should be stored rubber side up and so it does not touch anything and the blue microfiber cloth should be draped over the PVC where it was found, away from dirt. Other cleaning tools such should be dried as much as possible before being put back.

Changing lights

- The kinds of bulbs in the light fixture of the 200-gallon main display are ***48 inch T5 HO Reef White 10000K 54W by Aqua Medic***.
- Poor lighting can promote algal growth. The bulbs should be replace one at a time as not to shock the system. Each bulb should last a little over a year before it begins to lose intensity (Foster and Smith 2014). It may be helpful to number the bulbs with a sharpie and include the date replaced both directly on the bulb and in your aquarium journal.

Cleaning pumps

- The pumps themselves need to be checked for snails every so often just in case they get past the filter sock and sucked into the exit valves in the sump. Plastic diffuser grid squares are meant to stay in place over the exit PVC pipe but can sometimes be bumped out of place. You will need to reach inside the sump and check this these are in place on a routinely basis. There is a guard to prevent the snail from actually getting to the spinning piece within the pump but if too many snails get stuck in here, or something larger like a sea cucumber or starfish, it can clog the whole pump and cause it to burn out or the organism to die and spread it's decay through out the whole system which can potentially offset the chemistry enough to bring the whole system down.
- To check the pump you will need to have some towels on hand as it is impossible to take the pump off with out at least a small water spill.
- Pump Check Procedure:
    - I. Turn the pump off.
    - II. Place one towel under the pump to catch the water.
    - III. Secure vales on either side of the pump into the off position to prevent water flow.
    - IV. Unscrew the unions on either side of the pump. Some water will come out at this time but it should stop once the region between the pump and the valve that you put in off position has drained.
    - V. Pull the pump out and peak down into the PVC where water enters the pump. If you see snails in there, carefully remove them without pushing them past the guard and further into the pump. A butter knife of a pencil can be a helpful aid for reaching down into the PVC tube and get them lose. It may be helpful to angle the PCV down and allow gravity to assist them out once you knock them lose. If something larger such as a sea cucumber and starfish is caught (hopefully you noticed this immediately!), it will be necessary to thoroughly clean the pump with an alternate water source before putting it back into place.

VI. Once the snail check and cleaning in done, put the pump back into place and screw the top union completely tight while screwing the bottom union only partially tight, creating allowance for a leak from the bottom union.
VII. With one hand ready to tighten the bottom union as soon as water begin to leak out slowly unlock the top valve (should be on the opposite side of the pump from the look union.). This will allow water to flood back in to the pump and the loose union will allow air to exit while water takes its place. Tighten the bottom union as soon as water begins to spill out.
VIII. Finally, twist both valves into complete on position and turn the pump back on. Do one last check that it is functioning well, moving water though it was it was before, and nothing is leaking.

Water change

- Most likely will need to turn pumps off
- 10-15% (40-60 gallons) at least once a month, ideally bi-monthly
- The purpose of a water change is to purge the system of toxins and nutrients that are building up and not getting eliminated through the active filtration components. It's different than "topping off" the with deionized water, which is required each week to compensate for evaporation that occurs.

Carbon change

- There is a white bag for carbon that goes in the sump. Ideally carbon should be replaced every 8 weeks. The type of carbon can be either pelletized or granulated aquarium activated carbon. Pelletized tends to be preferable because it is easier to deal with during the rinsing process.

- **Carbon Change Procedure:**

1st. Remove the white mesh bag from the sump, dump the old carbon, and replace it with new carbon. New carbon is very dusty and will need to be rinsed before being placed into the aquarium system.

2nd. Rinse a few times under the running sink water- you'll see the black dust come off. When its running a little clearer have a couple buckets filled with DI water and very gently rinse the carbon bag in the DI buckets until the water looks clear. It is a touchy process until you get the hang of it since you can essentially keep rinsing it forever if you grind the granules against one another and keep making more dust.

3rd. VERY IMPORTANT!! Where you place the carbon in the sump: if the bag gets sucked into the pump inlet- it will either clog the pump and break it or shoot carbon granules all into the aquarium or both. There should be a white plastic diffuser grid in the sump that is used to protect the carbon bag from getting sucked into the pump inlet. Care should be taken to make sure the bag stays in the middle of the sump. A weight can be added to the back to ensure it stays put.

Appendix

I. Helpful Sources to Reverence:

The Living Marine Aquarium Manuel: Basic and Advanced Husbandry for The 'Modern' Marine Aquarium (2012)

http://www.saltcorner.com/LMAM/TOC.php?showsection=1

(This a an awesome resource that gives very accurate detail on all types of aquarium systems. Reference the section on the Jaubert Plenum biological filter to get an overview of the functions of the MSB aquarium's system.)

The nitrogen cycle is described well by Dr. Harrison in this article

http://www.visionlearning.com/en/library/Earth-Science/6/The-Nitrogen-Cycle/98/reading

(Build up of nitrate, NO_3, is toxic to fish and common in closed systems, so it's something that is important to have a good understanding of how it occurs.)

Algal growth prevention measures by Drs. Foster & Smith Educational Staff (2014)
http://www.liveaquaria.com/PIC/article.cfm?aid=4
(This particular link leads to an article on controlling algal growth and the role that light and nutrient build up play in facilitating it. LiveAquarium.com is a useful resource to explore or reference to answers other questions that may arise for you.)

Interpreting Water Analysis Test Results by Alken Murray Corp., 2006
http://www.alken-murray.com/TESTS01.htm
(This article explains what acceptable levels or nutrients are within a salt water system and details on why it is important to keep them at such levels. A summary of these acceptable levels is given in this manual under "Testing Water Nutrient Levels")

Ideal Water Conditions by Premier Aquatics: aquarium specialists, 2014
http://marinefish.net/html/ideal_water_conditions.html
(This articles gives explanation of ideal water parameters for both marine and fresh water aquariums.)

Reef Aquarium Water Parameters by Randy Holmes-Farley, 2008
http://reefkeeping.com/issues/2004-05/rhf/
(This articles gives explanation a number of nutrients that can be tested in a marine aquariums aquarium system. It's another good source to reference what the ideal concentrations of various nutrients should be within the system)