Development of a Polyculture System

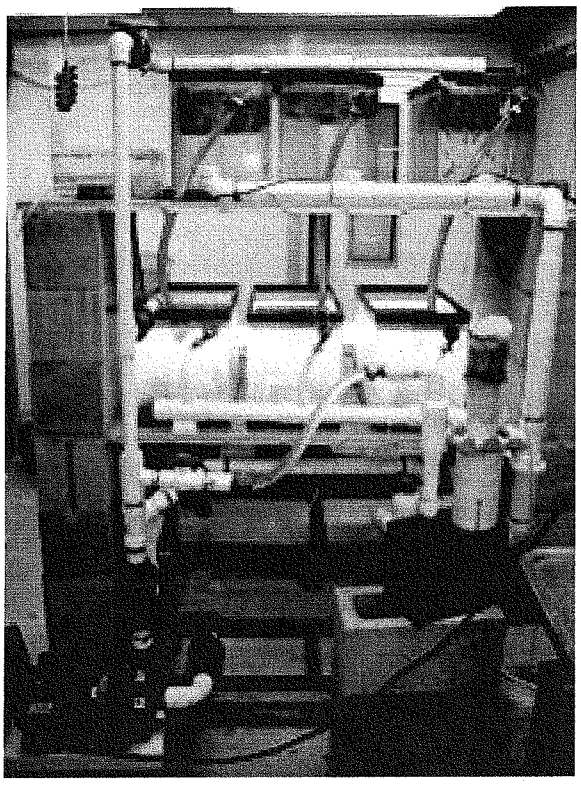

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Table of Contents:

Abstract

Our group constructed a three tiered, cascading, recirculating system for use in polyculture. Observation of short-term survivability of *Nereis virens*, *Strongylocentrotus droebachiensis* and *Ulva lactuca* in the system were positive. To optimize survivability and growth rates, further studies on flow rates, organism density, temperature, salinity and water quality are needed.

Introduction

Traditional aquaculture involves single species culture. The development of efficient polyculture systems will make aquaculture more profitable. The idea is that in a polyculture system you have multiple species that benefit from one another, but that each species is profitable as well. The organisms used in the polyculture system designed for this project were *Nereis virens*, *Strongylocentrotus droebachiensis*, and *Ulva lactuca*. These organisms were chosen because they have all been successfully cultured in the past, they have similar tolerances to temperature and salinity, and they all have good market value.

Nereis virens is a marine polychaete that is used by shore and small boat fishermen as bait; it is also used as a highly nutritious feed in fish and shrimp broodstocks (www.seabait.com, 2008). *N. virens* is an omnivore and will eat live or dead organic material. *N. virens* is found on the shores of North America and Northern Europe (www.seabait.com, 2008), and has been produced commercially both in New England and in Europe (Olive, 2005).

Strongylocentrotus droebachiensis fecal matter has been shown to be a possible food source for benthic detritivores (Mamelona and Pelletier, 2005). *S. droebachiensis* gonads are a popular food in Asia and populations have been in decline requiring alternative harvesting methods (Harris et al, 2003). A study by Shpigel et. al in 2005 showed that a combined diet of *Ulva lactuca* and a commercial feed optimized gonad quality in the sea urchin, *Paracentrotus lividus*. *U. lactuca* has also been shown to effectively remove nitrogenous waste from recirculating aquaculture systems (Wang at al, 2007). Thus, the three organisms *N. virens*, *S. droebachiensis*, and *U. lactuca* all benefit from the association that occurs in a polyculture environment; *N. virens* are fed by *S. droebachiensis* fecal matter, the *S. droebachiensis* feed on the *U. lactuca* and in turn the *U. lactuca* utilize nitrogenous waste as a source of nutrients.

The objectives for this study were to design and build a single system that would be capable of holding all three organisms. The system needed to be durable, flexible, easy to scale up to commercial size and easy to build, use and maintain. All parts of the system needed to be corrosion resistant. For the sake of this study, future studies and potential commercial operations, the system needed to be in use continuously for months or years without breakdowns of the pump, filters, tanks or plumbing. The system could be used for future experiments that change flow rates, or other parameters. Ultimately, the design of the system may be used by a commercial aquaculture business that would need to operate on a larger scale, with more organisms than the system used in this experiment. Excess expenses with building and maintaining the system needed to be avoided. These expenses included building material and labor to build and maintain the system. Building materials needed to be cheap, durable, readily available and easy to

assemble and repair. Once finished, the system needed to require minimal maintenance, as most effort was concentrated on growing the organisms.

Methods

The system was built in an air conditioned wet lab in the Spaulding Life Science building on the Durham campus of the University of New Hampshire. For this experiment the temperature of this room was controlled by a household air conditioner that was set to 60 degree Fahrenheit. This air conditioner was installed on cinder blocks in one of the door of the room. The door was left open and two layers of two mm plastic drop cloth were taped to the door frame and covered the open doorway for insulation.

The system consisted of six ten-gallon glass aquaria and one 50-gallon glass aquarium. The aquaria rested on pultruded fiberglass gratings, which were supported by cinder blocks. Fiberglass grating was used to the support the aquaria because of its strength and corrosion resistance. Cinder blocks were used to support the gratings because they were readily available and easy to assemble into three tiers. The aquaria and cinder blocks were donated by Dr. David Berlinsky and the fiberglass gratings were purchased from American Grating.

The top row of three ten-gallon aquaria held the *S. droebachiensis* suspended in ¼ inch plasticized wire baskets over a layer of sediment, which contained the *N. virens* (Fig.1). This design allowed the fecal matter of *S. droebachiensis* to fall through the wire baskets to the *N. virens* without any effort. The wire baskets kept the *S. droebachiensis* and the *N. virens* from physically interacting with each other in any other way. The wire baskets were designed to be easy to install and remove. The baskets also allowed

monitoring of both the *S. droebachiensis* and *N. virens* without removing either organism from the system.

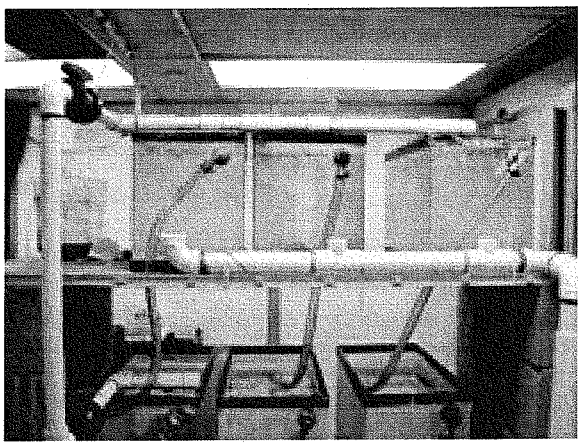

Figure 1. Image of the top tier without the plasticized wire baskets.

The second row of ten-gallon aquaria contained the *U. lactuca.* This row of aquaria was illuminated from the side by a 48" GE Plant and Aquarium F40T12 wide spectrum bulb (Fig. 2). This bulb was cheap and provided a spectrum and intensity of light that was sufficient for the *U. lactuca* to grow.

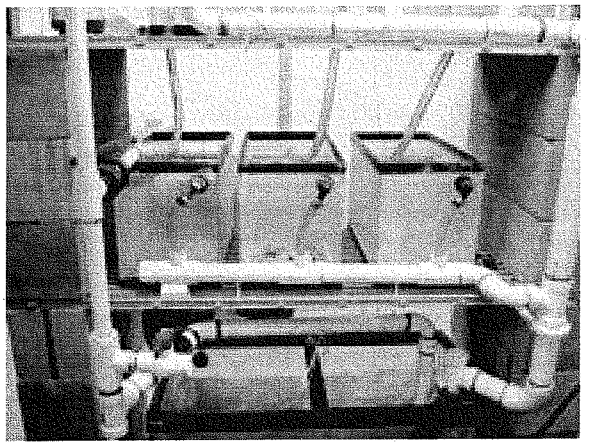

Figure 2. Image of the second tier without the Aquarium light.

Plasticized wire grates (1/4 inch mesh) were placed over the outlet for each aquarium with *U. lactuca* to prevent any large pieces from flowing out of the second tier of aquaria.

The bottom tier consisted of the 50-gallon aquarium, which acted as a reservoir (Fig. 3).

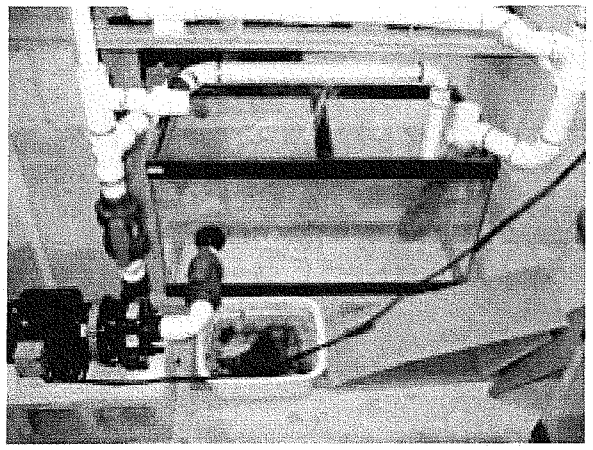

Figure 3. Image of the bottom tier (reservoir) and the Reeflo Barracuda pump.

A Reeflo Barracuda pump was used to circulate water through the aquaria and filters (Fig. 3). PVC piping was used to transport the water form the reservoir to the pump, and from the pump to the top tier of tanks. Clear plastic tubing was used to drain each top tank tier tank individually into the second tier tank directly below it and to drain each second tier tank individually. PVC piping was used to drain the second tier of tanks as a whole.

A protein skimmer was custom built for the system, and was plumbed so that it would filter water leaving the reservoir and recirculate the filtered water back into the reservoir. A 100-micron filter bag was placed over the input from the second tier of tanks into the reservoir to remove particulate waste. This bag was rinsed regularly. The *N. virens* were fed (Sera) Granumarin fish food and small pieces of *U. lactuca* whenever there was no extra food on the surface of the sediment. The *S. droebachiensis* were fed *Palmaria palmata*, which was replaced when it was totally consumed. The water level in the reservoir was monitored regularly and fresh water or seawater was added to the

system whenever necessary to prevent the pump from pumping air. No physical or chemical properties of the water in the system were measured. No quantitative measurements of survivability or growth rates were taken.

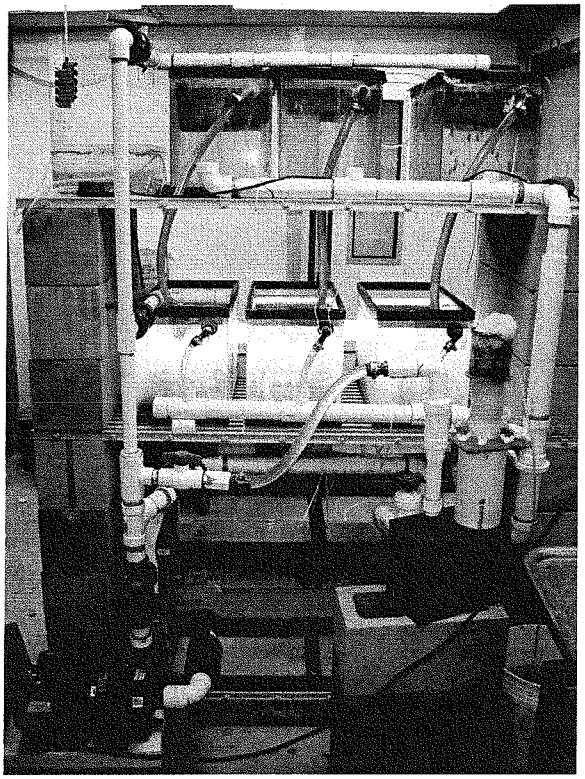

Figure 4. Image of the completed setup.

Results

The three tiered system that was built was durable and easy to build and maintain. The system and an identical system that was not used in this experiment were built over the course of several weeks during the winter of 2007-2008. The *N. virens* were

collected from the sunken forest next to Odiorne State Park in Rye, NH. The *S. droebachiensis* were donated by the Portsmouth (NH) Urchin Hatchery. The *U. lactuca* was collected from Hilton Park in Dover, NH. All three organisms were able to survive together in the system for several weeks. Some of the *S. droebachiensis* died, but their deaths coincided with a problem that caused the air conditioner that was being used to cool the room where the system was to turn off. This may have caused the temperature of the water in the system to rise to a level that was too hot for the *S. droebachiensis.*

Discussion

The small scale system that was built for this experiment should be fairly easy to scale up to commercial size. This could be done either by increasing the number of tanks in each tier, or by increasing the size of the tanks in each tier. The glass aquaria that were used are probably not ideal. They are deeper than they need to be and are fragile compared to the fiberglass troughs used in some culture systems of *S. droebachiensis.* The design of the baskets could also be improved; the baskets are difficult to remove from the tanks.

The design of the system makes it very easy to adjust. Flow rates can be varied for an individual aquarium, or for the entire system. This would make future experiments that seek to optimize flow rates very easy to conduct. Other experiments could include changing the relative biomass of the three organisms. *N. virens* and *S. droebachiensis* have different optimum temperatures, and a compromise would have to be made to optimize growth rates for both organisms. Nutrient levels must also be adjusted to

optimize the growth rate of *U. lactuca,* without decreasing the growth rates of the other two organisms.

The room where the system was built is designed to have its own air conditioning system that can be adjusted down to five degrees Celsius. This air conditioner broke early in the fall and has still not been repaired. For much of the year, the temperature in the room was too high for the urchins to survive. The household air conditioner was installed in March, after it was donated by Dr. Larry Harris of the University of New Hampshire.

S. droebachiensis can be cultured at temperatures ranging from four to ten degrees Celsius (Daggett et al, 2006). *N virens* can be cultured at temperatures as high as 18 degrees Celsius (Olive et al, 1998). *U. lactuca* can grow at a range of temperatures from 10 to 20 degrees Celsius (Taylor et al, 2001). An ideal temperature for the system could be found by measuring growth rates of all three species over a temperature range of five to 15 degrees Celsius. The ideal temperature would probably be somewhere between 10 and 15 degrees, as the *N. virens* are the most valuable product and it is that growth rate that should be maximized.

References

1) Caron A, Desrosiers G, Olive PJW, Retiere C, Nozais C. (2004) Comparison of diet and feeding activity of two polychaetes, Nephtys caeca (Fabricius) and Nereis virens (Sars), in an estuarine intertidal environment in Quebec, Canada. JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY 304-2, 225-242

2) Harris L.G., Madigan P. & Waters K. (2003) A hatchery system for green sea urchin aquaculture in the Gulf of Maine. World Aquaculture 34, 32-36

3) Mamelona J, Pelletier E (2005) Green urchin as a significant source of fecal particulate organic matter within nearshore benthic ecosystems. JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY 314-2, 163-174

4) Olive, PJW. (1999) Polychaete aquaculture and polycheate science: A mutual synergism. HYDROBIOLOGIA 402, 175-183

5) www.Seabait.com. 2005-2008. Seabait Ltd. 24 April. 2008 <http://www.seabait.com>

6) Shpigel M, McBride SC, Marciano S, Ron S, Ben-Amotz A (2005) Improving gonad colour and somatic index in the European sea urchin Paracentrotus lividus. AQUACULTURE 245; 1-4 , 101-109

7) Wang H (Wang, Hua), Liu CF (Liu, Chang-Fa), Qin CX (Qin, Chuan-Xin), Cao SQ (Cao, Shu-Qing), Ding J (Ding, Jun). (2007) Using a macroalgae Ulva pertusa biofilter in a recircultaing system for production of juvenile sea cucumber Apostichophs japonicus. AQUACULTURAL ENGINEERING; 36-3, 217-224

8) Daggett, T. L., Pearce, C. M. and Robinson, S. M. (2006) A comparison of three land-based containment systems for use in culturing green sea urchins, *Strongylocentrotus droebachiensis* (Müller) (Echinodermata: Echinoidea). Aquaculture Research; 37-4, 339-350

9) Olive, P. J. W., Rees, S. W. and Djunaedi, A. (1998) Influence of photoperiod and temperature on oocyte growth in the semelparous polychaete Nereis (Neanthes) virens. Marine Ecology – Progress Series; 172, 169-183

10) Taylor, R., Fletcher, R. L. and Raven, J. A. (2001) Preliminary studies on the growth of selected 'Green tide' algae in laboratory culture: Effects of irradiance, temperature, salinity and nutrients on growth rate. Botanica Marina; 44-4, 327-336