Test Results of ER 1 Prototype

1. Nitrifying Bacteria

This information was researched to help me better understand my test results. I was particularly interested in learning about the effect of temperature, pH and mineral content on the behavior of Nitrosomonas and Nitrobactor bacteria.

"Nitrifying bacteria are classified as obligate chemolithotrophs. This simply means that they must use inorganic salts as an energy source and generally cannot utilize organic materials. They must oxidize ammonia and nitrites for their energy needs and fix inorganic carbon dioxide (CO_2) to fulfill their carbon requirements. They are largely non-motile and must colonize a surface (gravel, sand, synthetic biomedia, etc.) for optimum growth. They secrete a sticky slime matrix which they use to attach themselves.

Species of Nitrosomonas and Nitrobacter are gram negative, mostly rod-shaped, microbes ranging between 0.6-4.0 microns in length. They are obligate aerobes and cannot multiply or convert ammonia or nitrites in the absence of oxygen.

Nitrifying bacteria have long generation times due to the low energy yield from their oxidation reactions. Since little energy is produced from these reactions they have evolved to become extremely efficient at converting ammonia and nitrite. Scientific studies have shown that Nitrosomonas bacterium are so efficient that a single cell can convert ammonia at a rate that would require up to one million heterotrophs to accomplish. Most of their energy production (80%) is devoted to fixing CO_2 via the Calvin cycle and little energy remains for growth and reproduction. As a consequence, they have a very slow reproductive rate.

Nitrifying bacteria reproduce by binary division. Under optimal conditions, Nitrosomonas may double every 7 hours and Nitrobacter every 13 hours. More realistically, they will double every 15-20 hours. This is an extremely long time considering that heterotrophic bacteria can double in as short a time as 20 minutes. In the time that it takes a single Nitrosomonas cell to double in population, a single E. Coli bacterium would have produced a population exceeding 35 trillion cells.

None of the Nitrobacteraceae are able to form spores. They have a complex cytomembrane (cell wall) that is surrounded by a slime matrix. All species have limited tolerance ranges and are individually sensitive to pH, dissolved oxygen levels, salt, temperature, and inhibitory chemicals. Unlike species of heterotrophic bacteria, they cannot survive any drying process without killing the organism. In water, they can survive short periods of adverse conditions by utilizing stored materials within the cell. When these materials are depleted, the bacteria die.

There are several species of Nitrosomonas and Nitrobacter bacteria and many strains among those species. Most of this information can be applied to species of Nitrosomonas and Nitrobacter in general., however, each strain may have specific tolerances to environmental factors and nutriment preferences not shared by other, very closely related, strains. The information presented here applies specifically to those strains being cultivated by Fritz Industries, Inc.

The temperature for optimum growth of nitrifying bacteria is between 77-86° F (25-30° C).

- Growth rate is decreased by 50% at 64° F (18° C).
- Growth rate is decreased by 75% at 46-50° F.
- No activity will occur at 39° F (4° C)
- Nitrifying bacteria will die at 32° F (0° C).
- Nitrifying bacteria will die at 120° F (49° C)

Nitrobacter is less tolerant of low temperatures than Nitrosomonas. In cold water systems, care must be taken to monitor the accumulation of nitrites.

The optimum pH range for Nitrosomonas is between 7.8-8.0.

The optimum pH range for Nitrobacter is between 7.3-7.5

Nitrobacter will grow more slowly at the high pH levels typical of marine aquaria and preferred by African Rift Lake Cichlids. Initial high nitrite concentrations may exist. At pH levels below 7.0, Nitrosomonas will grow more slowly and increases in ammonia may become evident. Nitrosomonas growth is inhibited at a pH of 6.5. All nitrification is inhibited if the pH drops to 6.0 or less. Care must be taken to monitor ammonia if the pH begins to drop close to 6.5. At this pH almost all of the ammonia present in the water will be in the mildly toxic, ionized NH_3^+ state.

Maximum nitrification rates will exist if dissolved oxygen (DO) levels exceed 80% saturation. Nitrification will not occur if DO concentrations drop to 2.0 mg/l (ppm) or less. Nitrobacter is more strongly affected by low DO than NITROSOMONAS.

All species of nitrifying bacteria require a number of micronutrients. Most important among these is the need for phosphorus for ATP (Adenosine Tri-Phosphate) production. The conversion of ATP provides energy for cellular functions. Phosphorus is normally available to cells in the form of phosphates (PO_4). Nitrobacter, especially, is unable to oxidize nitrite to nitrate in the absence of phosphates.

Sufficient phosphates are normally present in regular drinking water. During certain periods of the year, the amount of phosphates may be very low. A phenomenon known as "Phosphate Block" may occur. If all the above described parameters are within the optimum ranges for the bacteria and nitrite levels continue to escalate without production of nitrate, then phosphate block may be occurring. In recent years, with the advent of phosphate-free synthetic sea salt mixes, this problem has become prevalent among marine aquarists when establishing a new tank.

Minimal levels of other essential micronutrients is often not a problem as they are available in our drinking water supplies. The increasing popularity of high-tech water filters for deionizing, distilling, and reverse osmosis (hyper-filtration) produce water that is stripped of these nutrients. While these filters are generally excellent for producing high purity water, this water will also be inhibitory to nitrifying bacteria. The serious aquarist must replenish the basic salts necessary to the survival of the aquariumís inhabitants. These salts, however, usually lack these critical micronutrients.

All species of Nitrosomonas use ammonia (NH_3) as an energy source during its conversion to nitrite (NO_2). Ammonia is first converted (hydrolyzed) to an amine (NH_2) compound then oxidized to nitrite. This conversion process allows Nitrosomonas to utilize a few simple amine compounds such as those formed by the conversion of ammonia by chemical ammonia removers.

All species of Nitrobacter use nitrites for their energy source in oxidizing them to nitrate (NO_3).”

Information extracted from Fritz Industries internet article

2. ERIC Two Startup

In August of 2012 a 610 gal quarantine tank was started up with an ERIC Two filter containing EMat media. The tank was started with a relatively large fish load. My entire stock of fish were placed in the tank to allow the rebuild of the main pond.

The fish load was estimated to be 7,879 gr or 12.9 gr/gal. The filter did not seem to be able to cope with this load. It is possible better results would have been obtained if water treatments were not used to reduce ammonia and nitrite or if a more conservative feeding plan had been used. It is also possible that water changes were made too frequently.

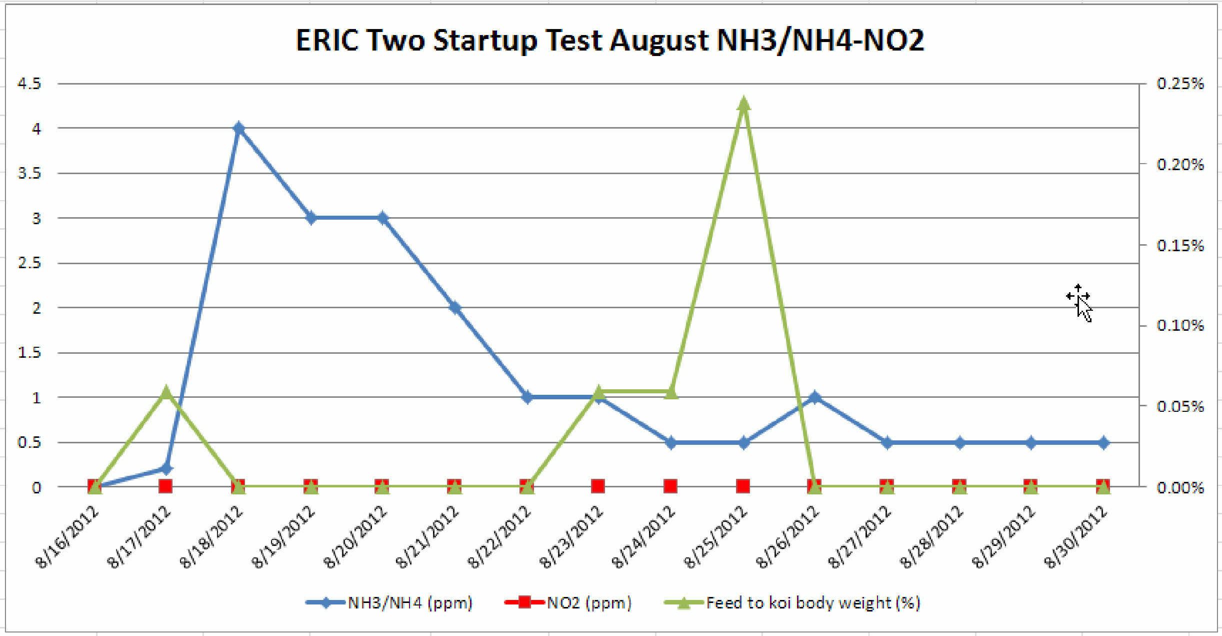
However, the results were not as good as expected. A number of the fish were finally removed to help reduce the load to a point where the filter could handle it.

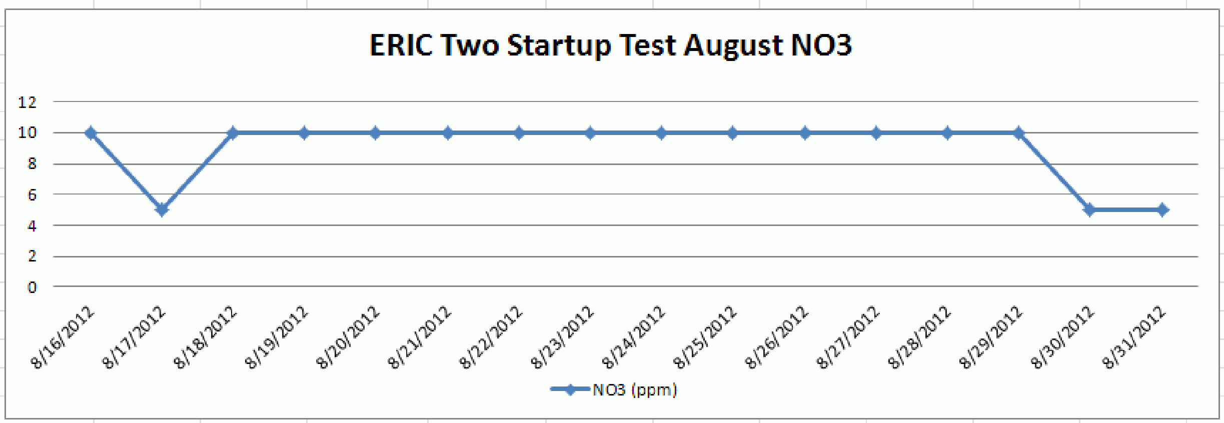
Nitrite was not reduced to zero consistently while feeding until the fish were relocated back into the pond in early February, 2013. Test results are shown below.

Fish Load: 8,407 gr
18.8 gr/gal

Range : End of Period
NH3/NH4: 0-4 : .3 ppm
NO2: 0 : 0 ppm
NO3: 5-10 : 5 ppm
Temp: 66-70 : 66°F
Wtr Chg: 0-44.09%

Feed, % of Body Wgt:
0-.06%

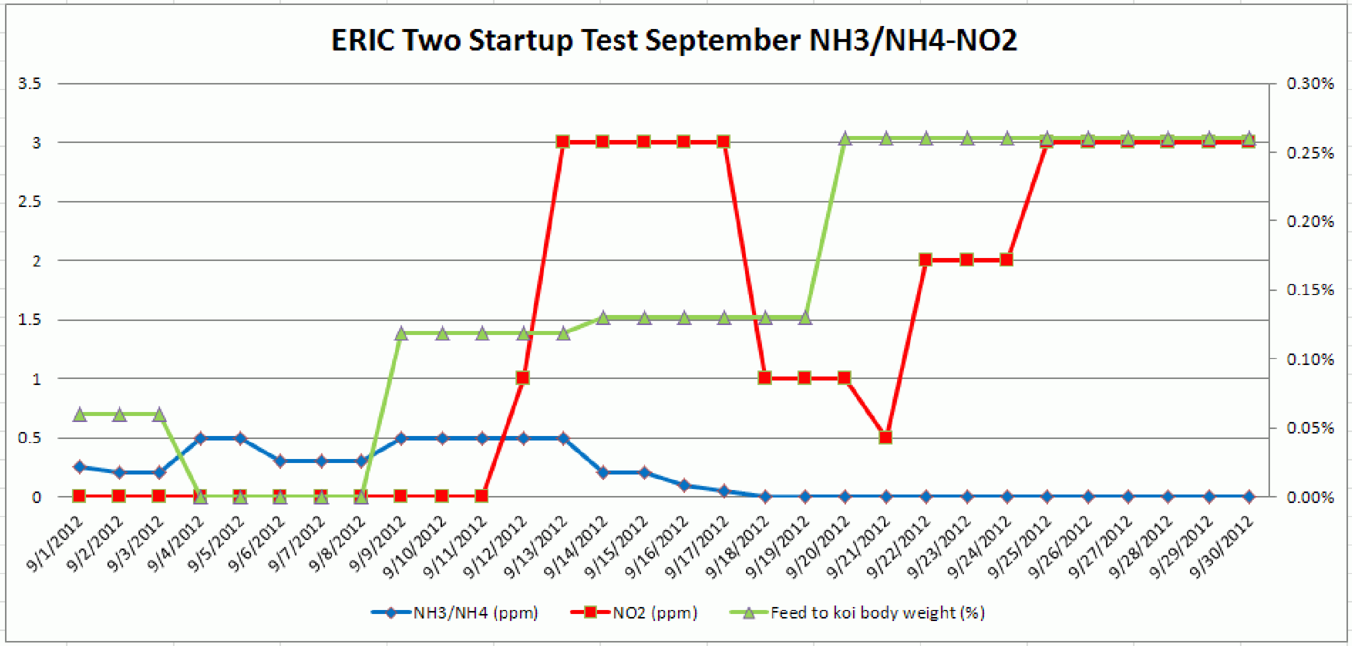


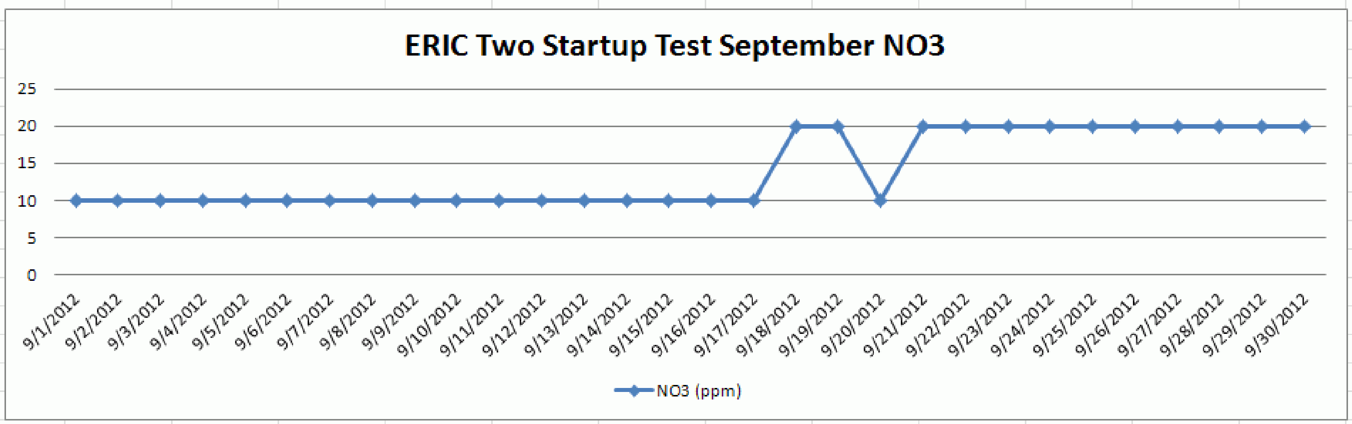


Fish Load,
9/1-13: 8,407 gr
13.8 gr/gal
9/14-31: 7,679 gr
12.6 gr/gal

Range : End
NH3/NH4: 0-.5 :
0 ppm
NO2: 0-3 : 3 ppm
NO3: 10-20 : 20 ppm
Temp: 62-71 :
67°F
Wtr Chg: 11.02-
33.07%

Feed, % of
Body Wgt:
0-.26%

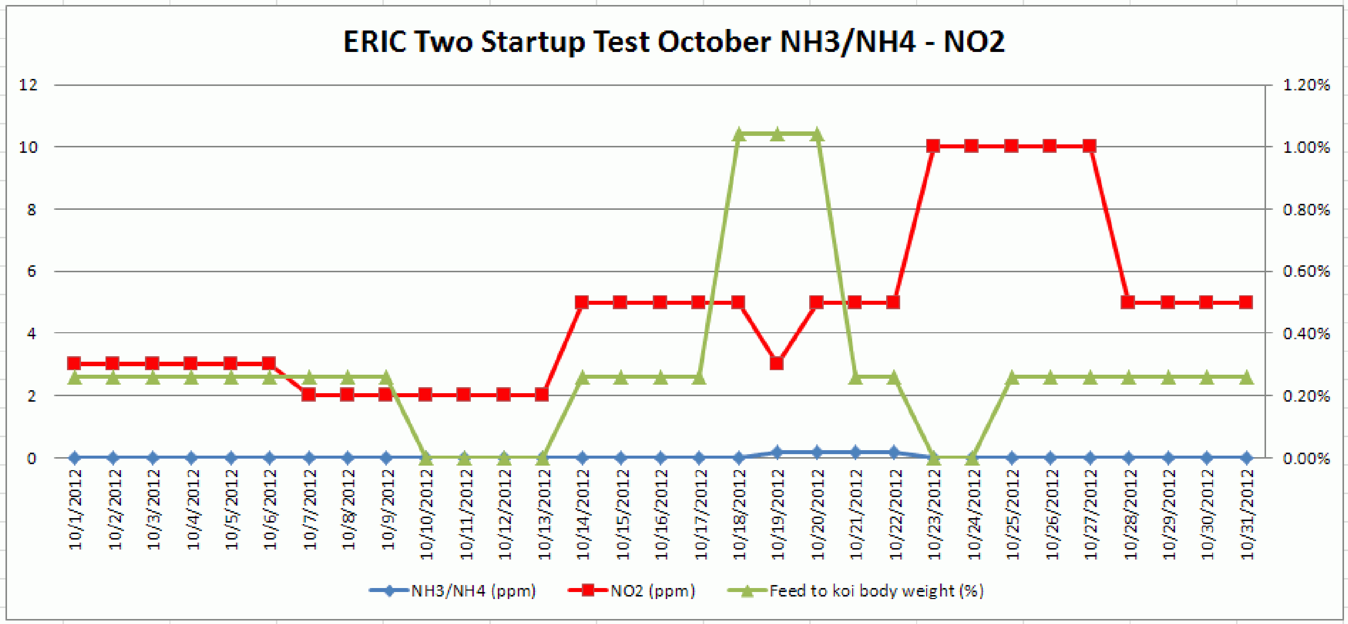


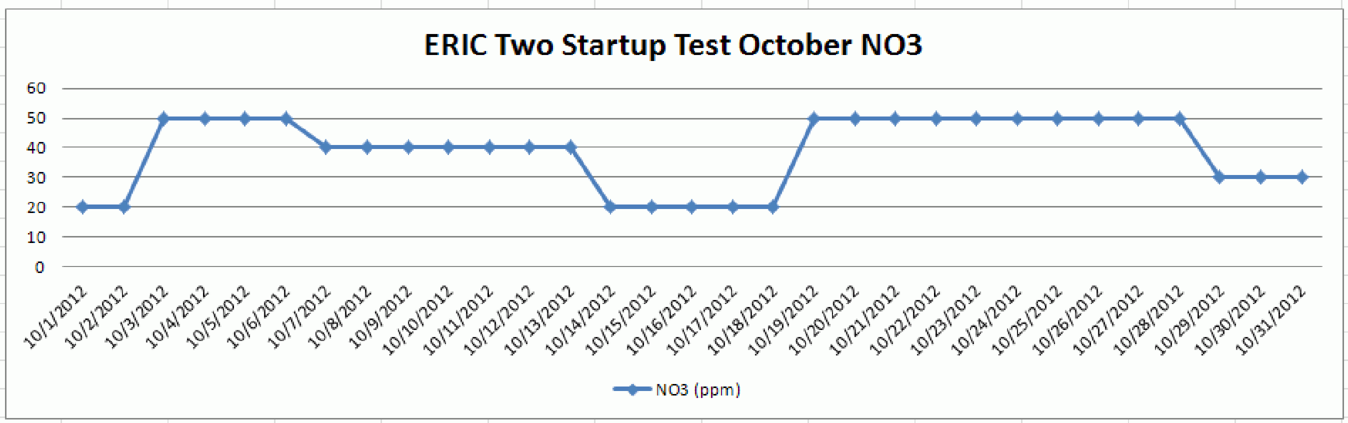


Fish Load, 7,679 gr
12.6 gr/gal

Range : End
NH3/NH4: 0-.2 : 0 ppm
NO2: 2-10 : 5 ppm
NO3: 20-50 : 30 ppm
Temp: 52-72 : 60°F
Wtr Chg: 11.02%

Feed, % of Body Wgt: 0-1.04%



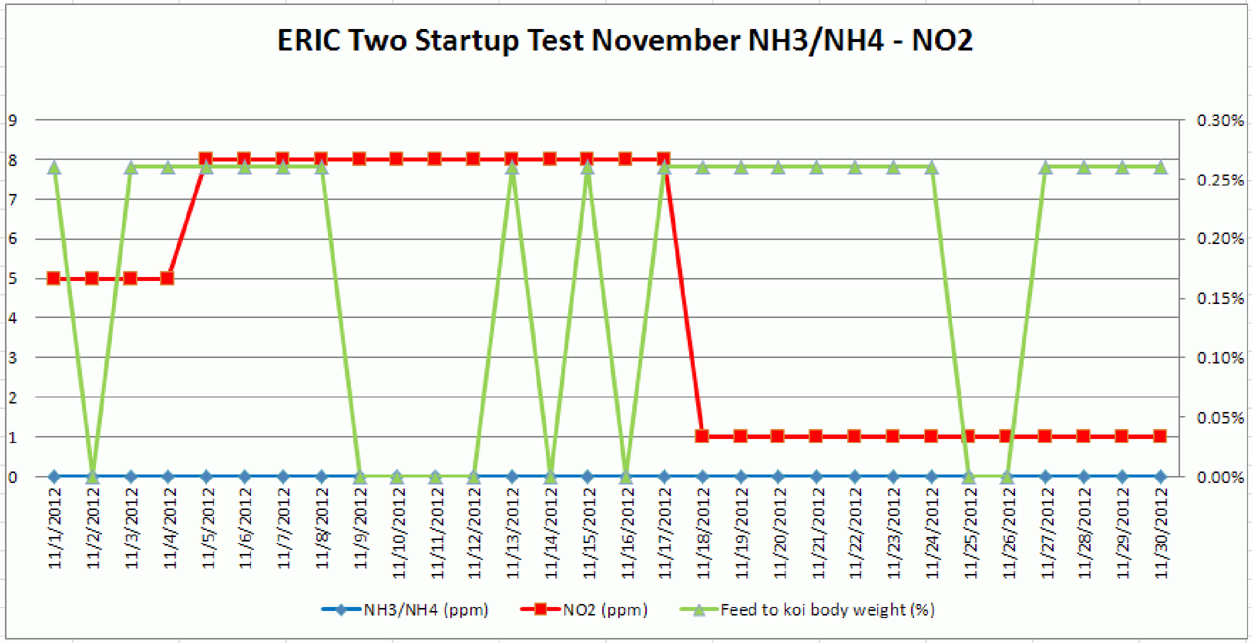


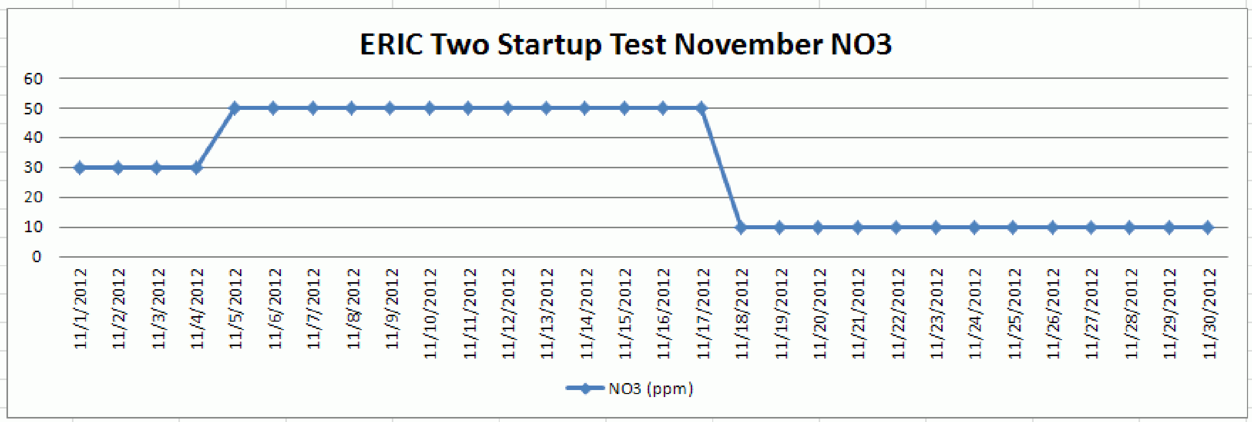
Fish Load, 7,679 gr
12.6 gr/gal

Range : End
NH3/NH4: 0 ppm

NO2: 1-8 : 1 ppm
NO3: 10-50 : 10 ppm
Temp: 44-60 : 60°F
Wtr Chg: 11.02%

Feed, % of Body Wgt: 0-.26%



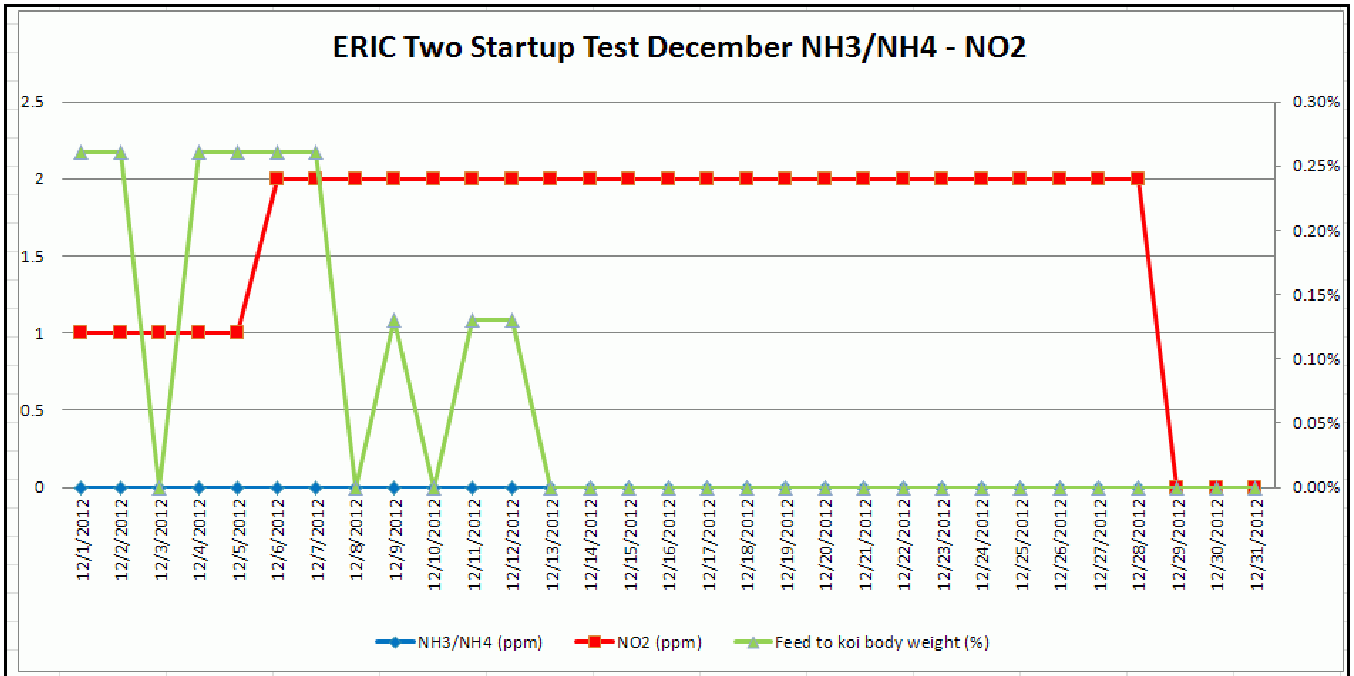


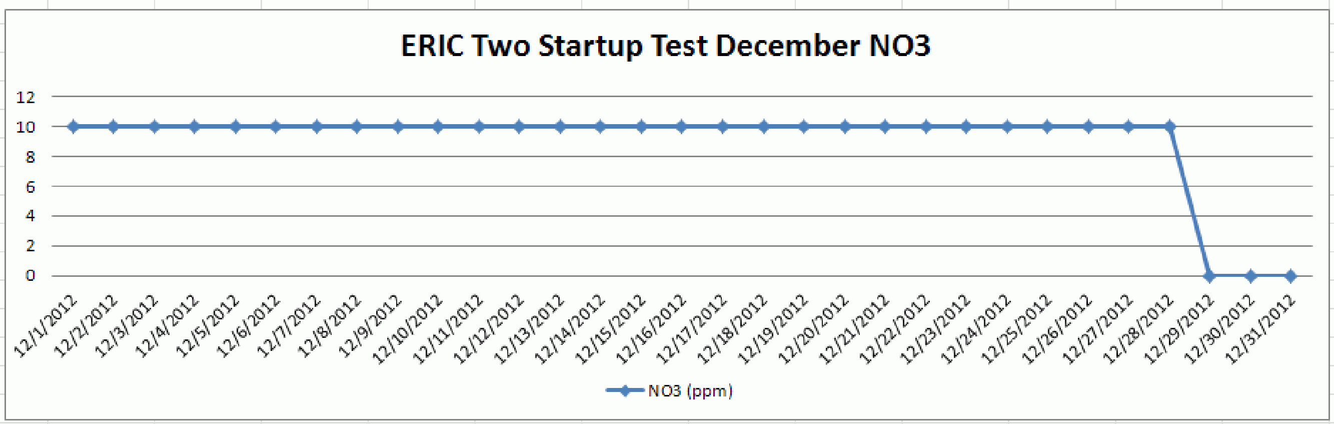
Fish Load, 7,679 gr
12.6 gr/gal

Range : End
NH3/NH4: 0 ppm

NO2: 0-2 : 0 ppm
NO3: 0-10 : 0 ppm
Temp: 42-62 : 42°F
Wtr Chg: 11.02-22.05%

Feed, % of Body Wgt: 0-.26%



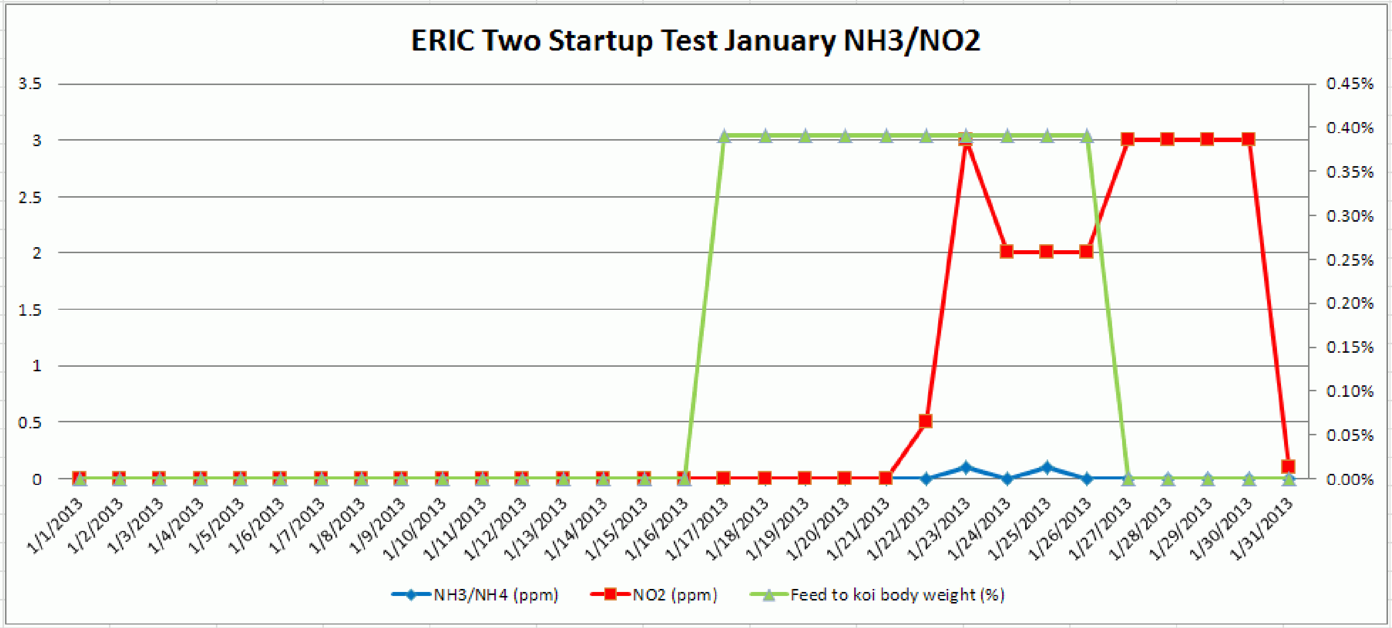


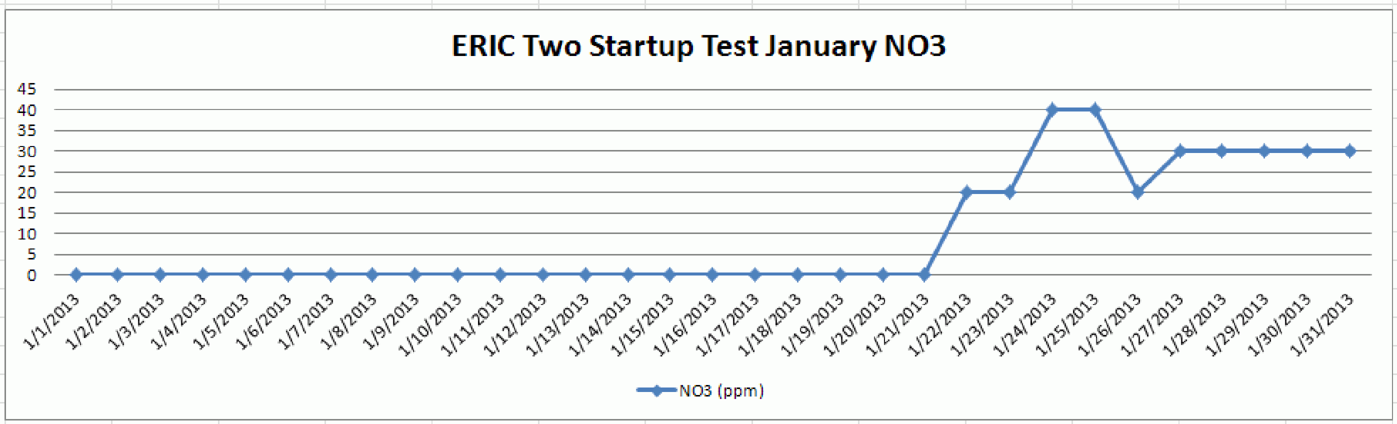
GreatWave Engineering
US Manufacturer of ERIC Pond Filters

Fish Load, 7,679 gr
12.6 gr/gal

Range : End
NH3/NH4: 0-.1 : 0 ppm
NO2: 0-3 : .1 ppm
NO3: 0-40 : 30 ppm
Temp: 44-55 : 44°F
Wtr Chg: 0-11.02%

Feed, % of Body Wgt: 0-.39%





2.1. Summary

- August

  All fish placed in QT. Ammonia immediately peaked and then began to reside. NO2 levels did not increase as expected. This could have been due to use of pond conditioner since system was refilled immediately with tap water after flushing and as many as 4 flushes were performed a day.

  On 8/21 the flow rate was reduced to approximately 300 gph as recommended by Peter Waddington.

- September

  Continued to flush two or three times per day. Gradually began to increase feed. Ammonia decreased, but NO2 increased dramatically. I reached conclusion that the filter could not handle the fish load. On 9/13 removed 7 small nisai and 2 adults, reducing the fish load to 7,679 gr or 12.6 gr/gal.

  On 9/19 started flushing once a day. Continued feeding .25% of body weight. NO2 steady at 3 ppm and ammonia now at 0 ppm.

- October

  Attended NAJGA conference 10/10-14, filter was not serviced during this period. Increased feeding on 10/18 followed by increase of NO2 to 10 ppm. Feeding was then reduced to previous level.

- November

  Continued feeding small amount. NO2 reached 8 ppm. Began adding MicrobeLift Nite-Out II in effort to control it. As temperatures fell stopped feeding. By end of month NO2 reduced to 1 ppm.

- December

  Intermittent feeding depending on temperature. On 12/15 stopped feeding when water temperature dropped below 50°F. Water readings were not taken until 12/29 when NO2 and ammonia were 0 ppm. Graph is misleading since readings were not taken immediately after feeding stopped.

- January

  By mid month was preparing new pond for habitation. When temperature in QT reached 57°F on 1/17 started feeding 30 gr, .39% of body weight. NO2 increased to 3 ppm. Stopped feeding on 1/27 in preparation for moving the fish to the new pond. NO2 reduced to .1 ppm by end of month. Five koi moved to the pond on 2/2/13.

GreatWave Engineering
US Manufacturer of ERIC Pond Filters

3. Introduction of ERIC One

Near the end of 2012 Peter Waddington announced availability of the ERIC One for testing. Three systems were shipped to enthusiasts in the UK. These individuals Vince Goodall (twizzle746), Ian Brassington (brasso) and unknown (mark6465).

They posted the results of their testing on the Them There Koyas Forum and are reproduced in graphical form here.

3.1. Vince Goodall's ERIC One Test

Vince Goodall, screen name twizzle746, started his test the day before Christmas, 2012. Data on fish load and feeding rate is sketchy, but it is clear that at some points during the test both the fish load and feeding rates were very high.

Vince's system holds 811 gallons. At the start of test the fish load was estimated to be 5,000 gr or 6.2 gr/gal. Initial feeding was reported to be light, but on January 10, 2013 was increased to approximately 134 gr/day or 2.68% of body weight assuming the fish load remained constant.

While ammonia and nitrite levels were never reduced to zero during the testing, Vince was very pleased with the results and purchased the filter before the test was completed. His koi appeared to be in excellent shape throughout the test.

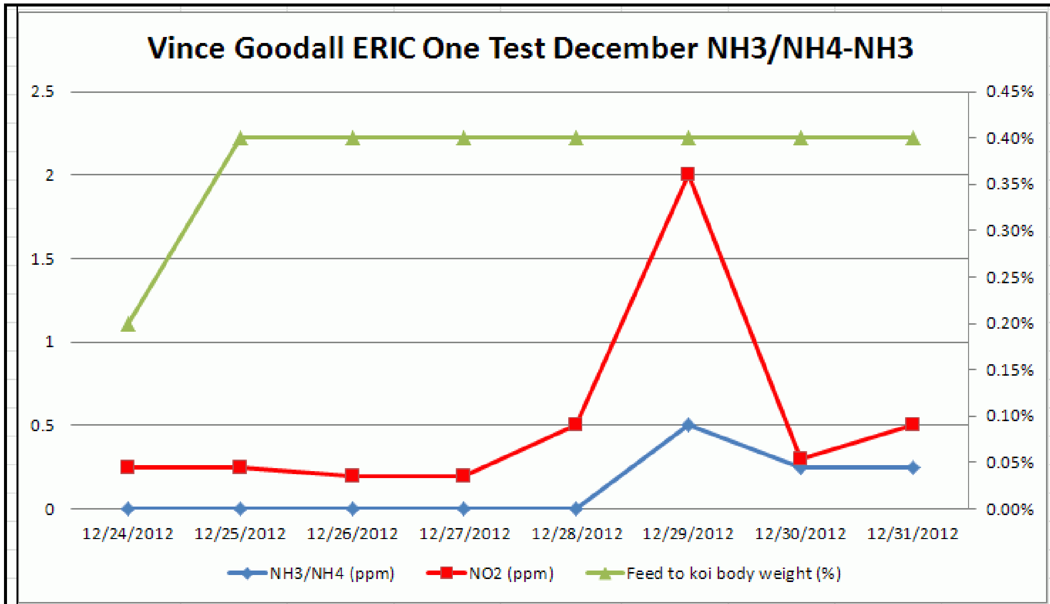
Fish Load, 5,000 gr, 6.2 gr/gal

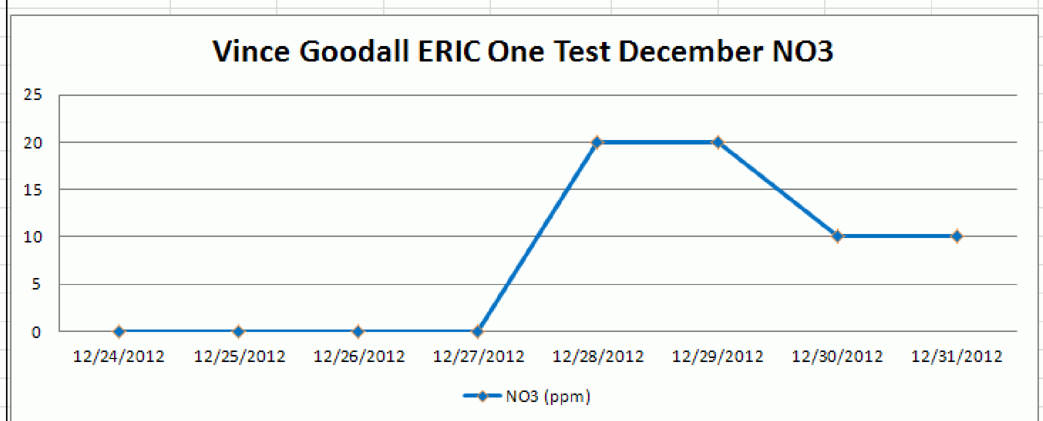
Range : End
NH3/NH4: 0-.5 : .25 ppm

NO2: .25-2 : .5 ppm
NO3: 0-20 : 10 ppm
Temp: 59°F

Wtr Chg: 0-3.26%

Feed, % of Body Wgt: .2-.4%



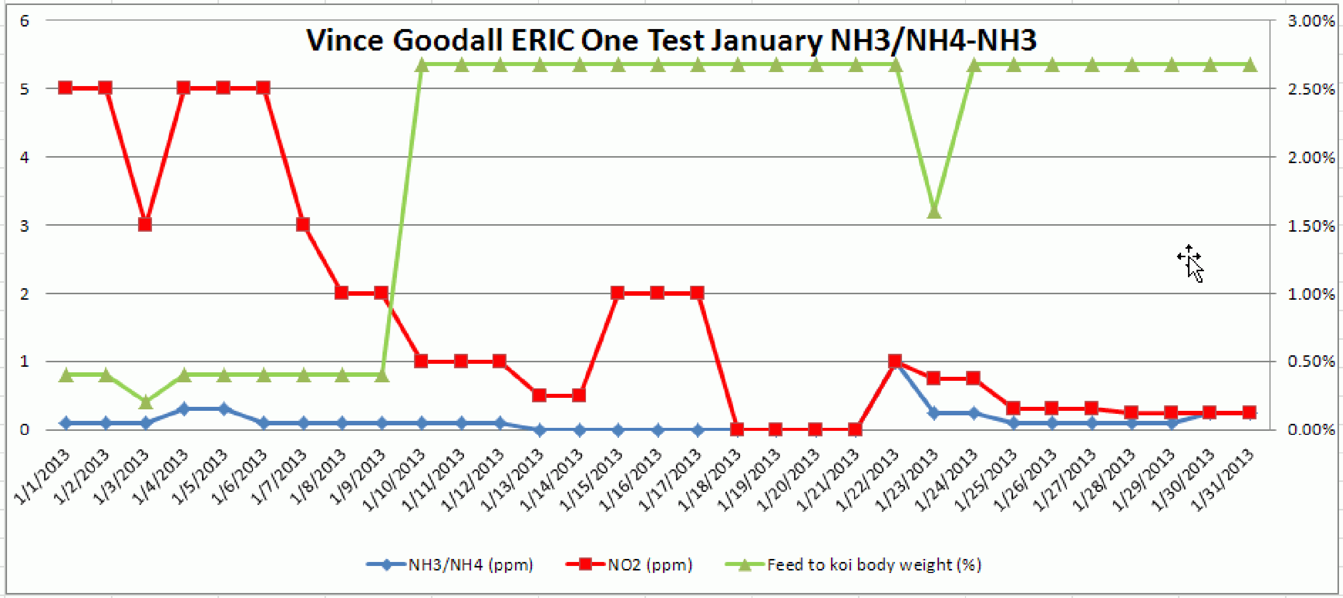


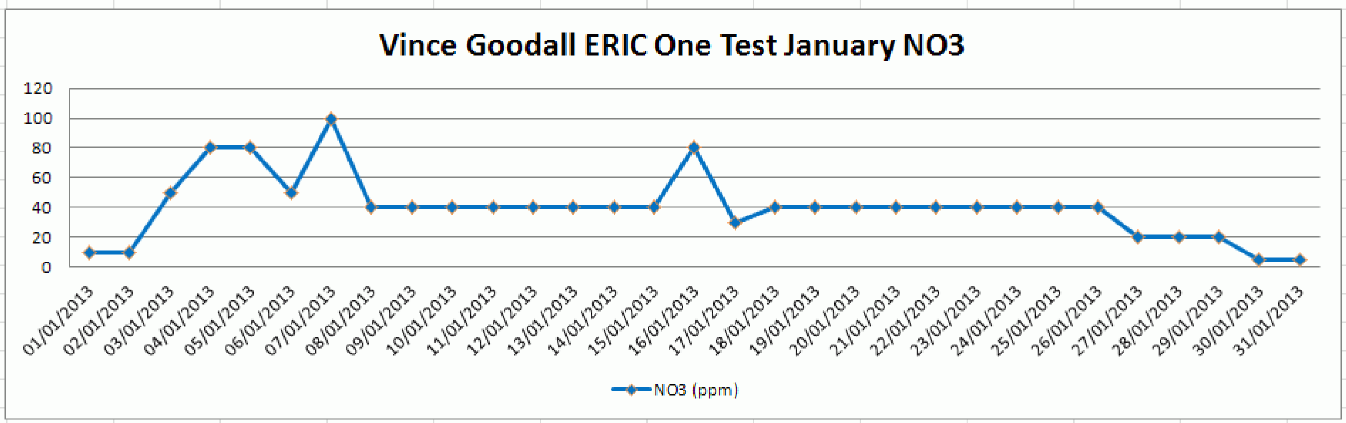
Fish Load, 5,000 gr
6.8 gr/gal

Range : End
NH3/NH4: 0-.3 : .25 ppm
NO2: .25-5 : .25 ppm
NO3: 10-100 : 5 ppm
Temp: 59°F

Wtr Chg: 0-3.26%

Feed, % of Body Wgt: .4-2.68%





3.2. Ian Brassington's ERIC One Test

Ian Brassington, screen name brasso, started his test on December 26, 2012. Ian's system holds 1,553 gals. His fish load was approximately 12,000 grams or 7.8 gr/gal. During the test he fed pretty aggressively.

Considering this, his results were extremely impressive.

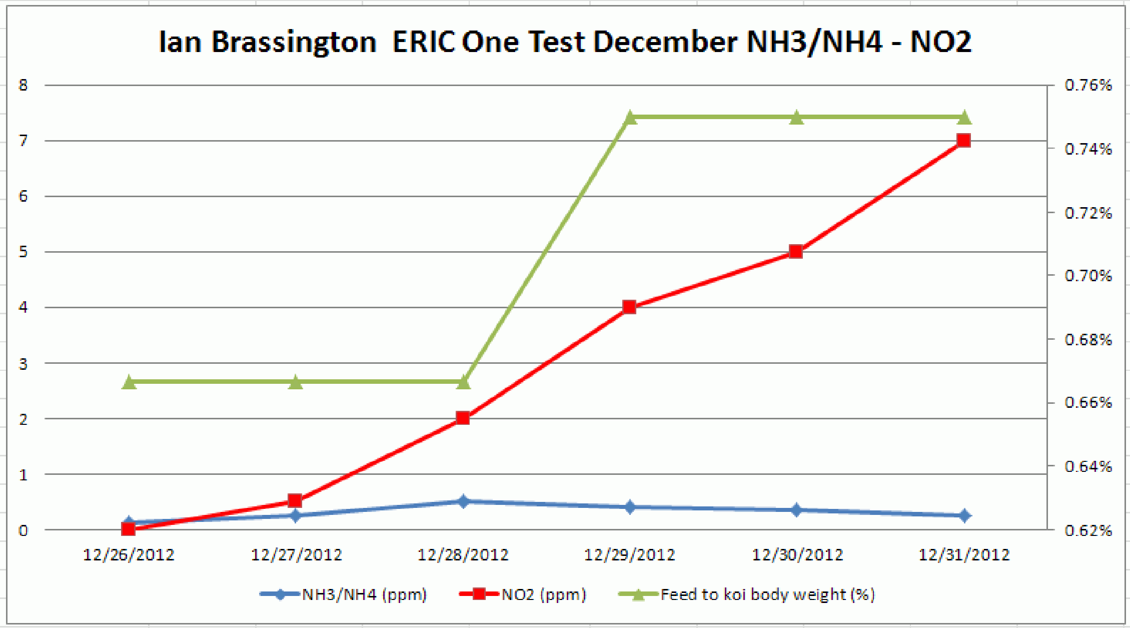
Fish Load, 12,000 gr, 7.8 gr/gal

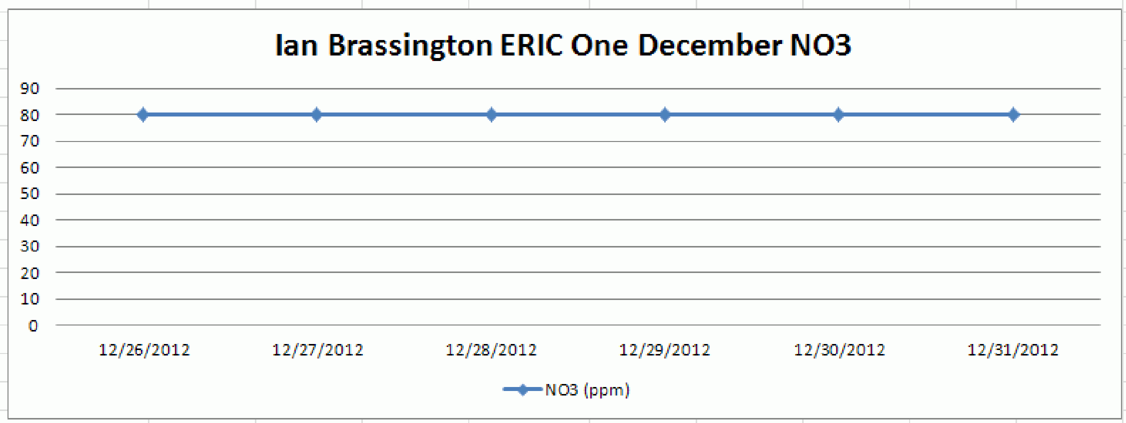
Range : End
NH3/NH4: .12--.5 : .25 ppm

NO2: 0-7 : 7 ppm
NO3: 80 ppm
Temp: 61°F

Wtr Chg: 1.7%

Feed, % of Body Wgt: .67-.75%





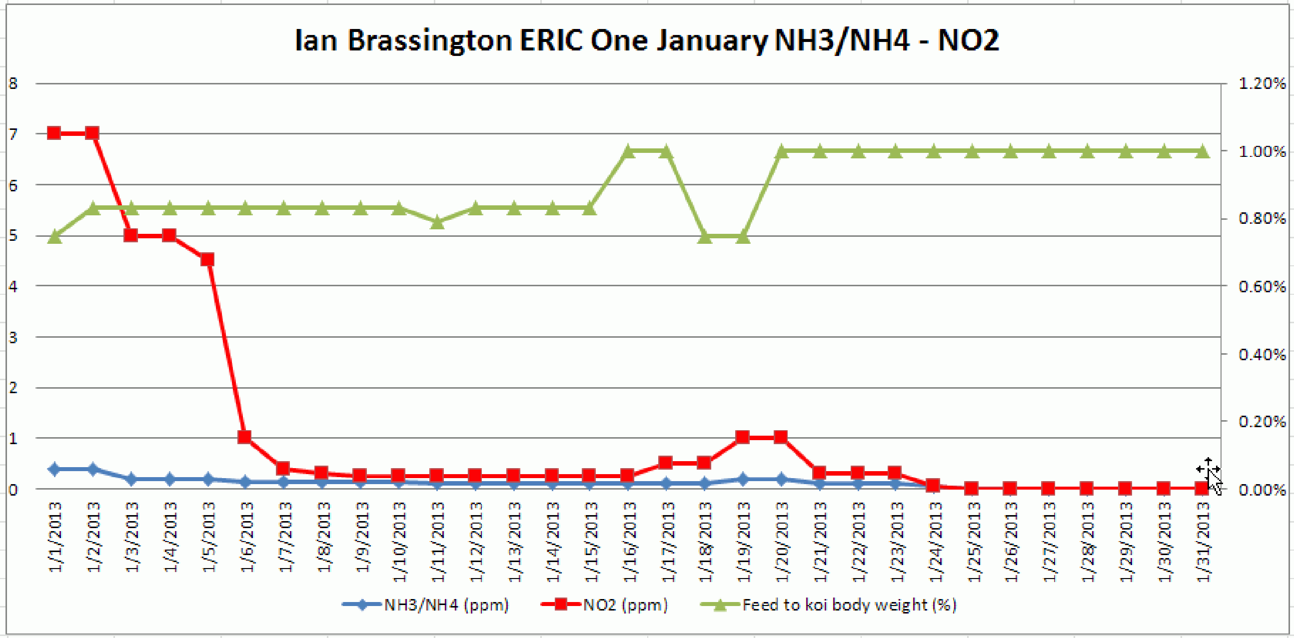
Fish Load, 12,000 gr
7.8 gr/gal

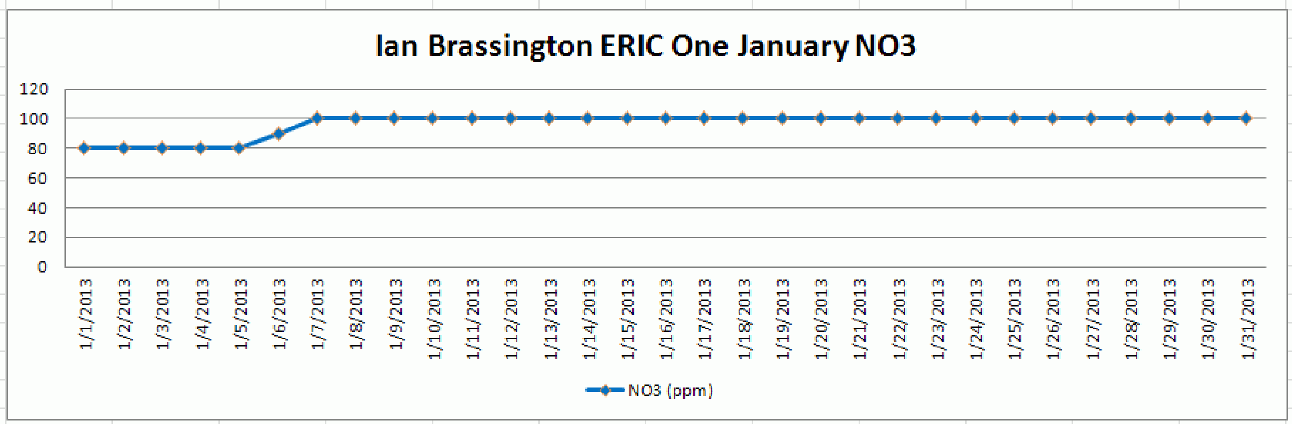
Range : End
NH3/NH4: 0-.1 : .01 ppm

NO2: 0-7 : 0 ppm
NO3: 80-100 : 100 ppm
Temp: 61°F

Wtr Chg: 1.7%

Feed, % of
Body Wgt:
.75-1%





3.3. Mark6465's ERIC One Test

Mark started testing January 20, 2013. While the first two ERIC Ones were pump fed, Mark's unit was gravity fed. His system holds 754 gallons. His fish load was 3,140 grams or 4.2 gr/gal.

Mark's results were also very good. The filter matured and NH_3/NH_4 and NO_2 readings were reduced to nearly zero in a relatively short amount of time. The koi were reported to be in excellent condition during the entire length of the test.

The results of this test suggest the practical limits of fish load and temperature that will support feeding up to 3% of body weight.

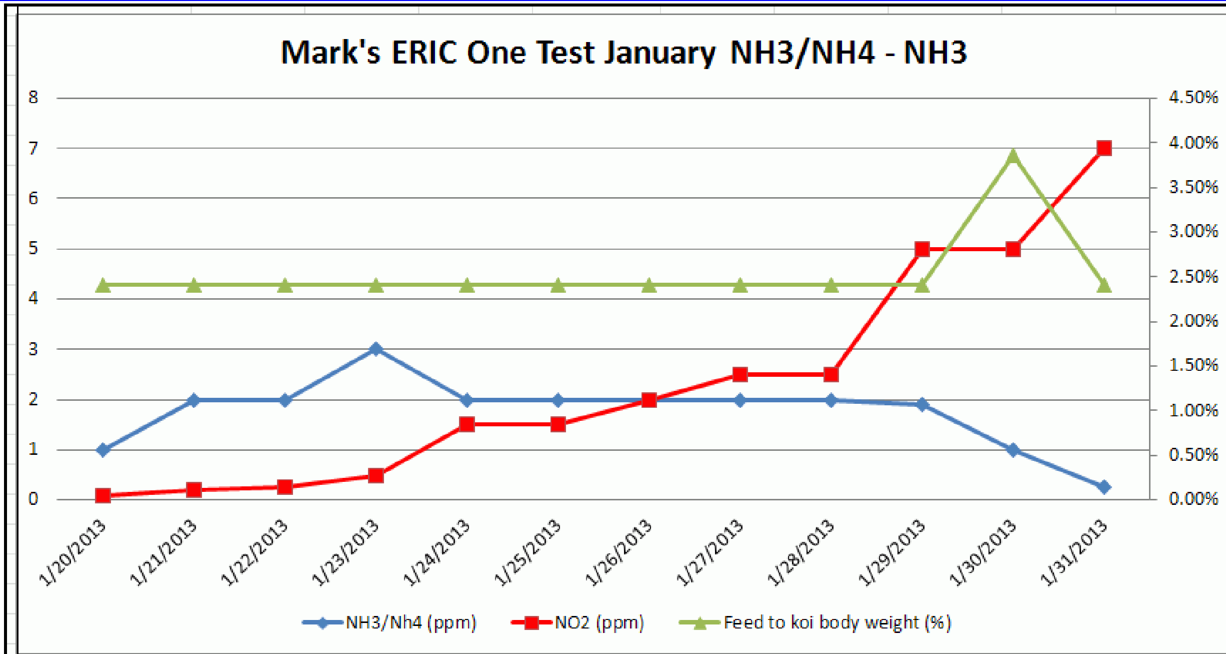
Fish Load, 3,140 gr,
4.2 gr/gal

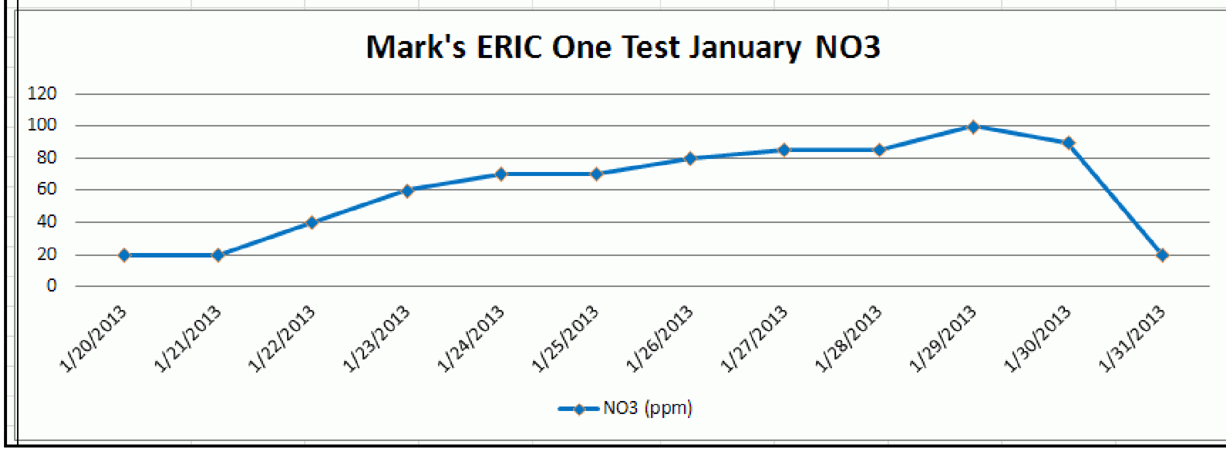
Range : End
NH3/NH4: 1-3 : .25 ppm

NO2: .1-7 : 7 ppm
NO3: 20-100 : 20 ppm
Temp: 73°F

Wtr Chg: 4.8-9.6%

Feed, % of Body Wgt:
2.42-3.86%

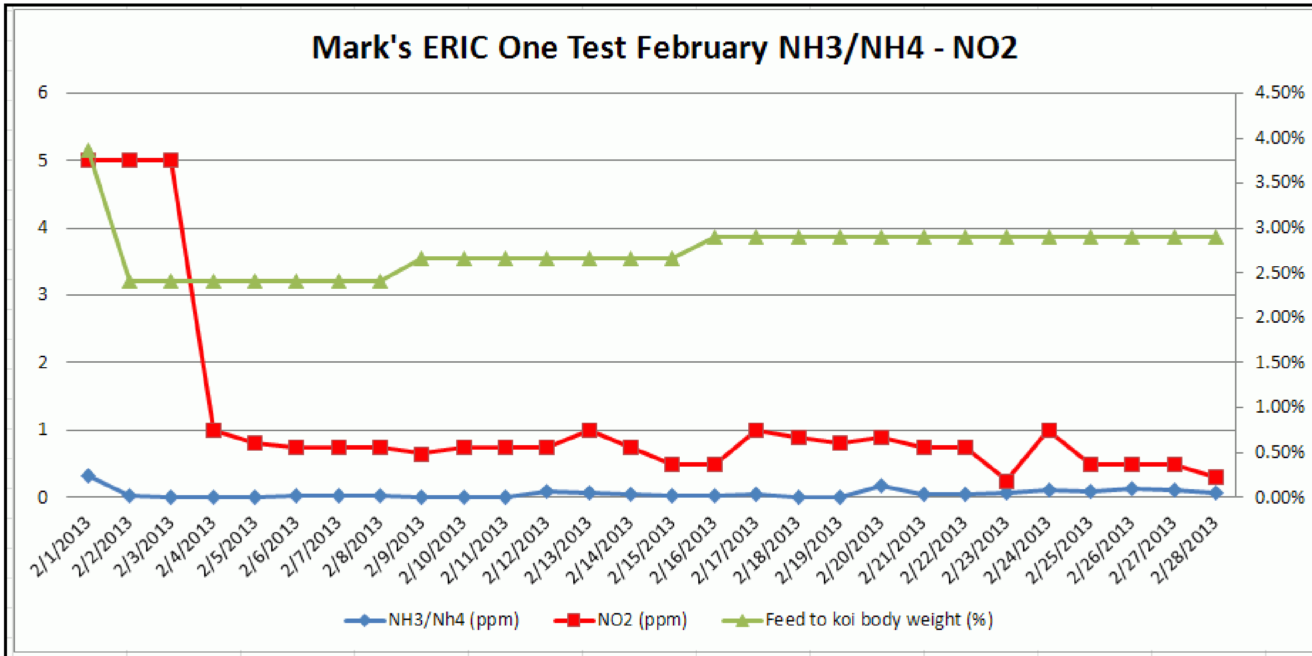


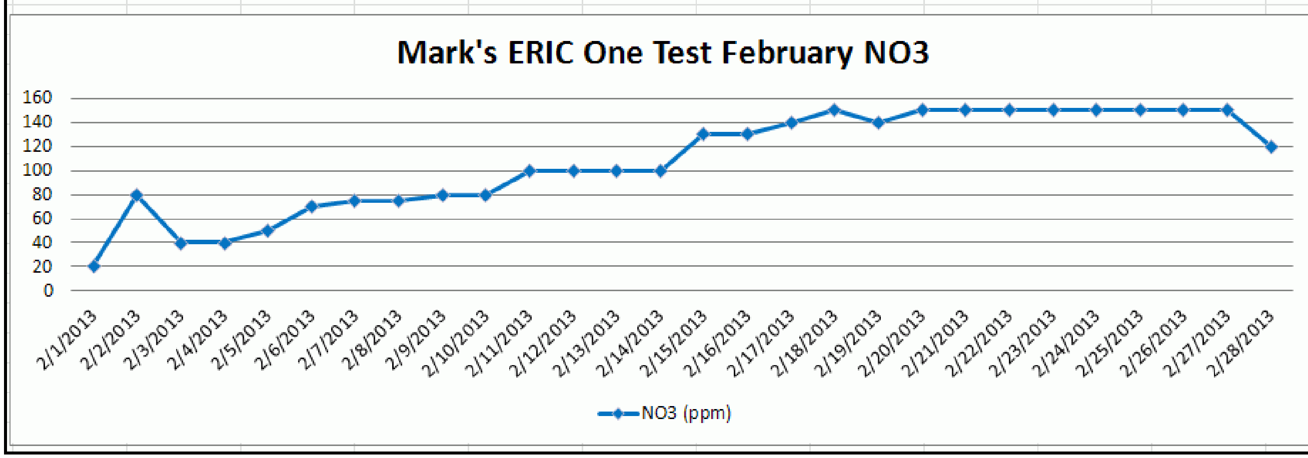


Fish Load, 3,140 gr, 4.2 gr/gal

Range : End
NH3/NH4: 0-.33 : .07 ppm
NO2: .3-5 : .3 ppm
NO3: 20-150 : 120 ppm
Temp: 73°F
Wtr Chg: 4.8-9.6%

Feed, % of Body Wgt: 2.42-3.86%





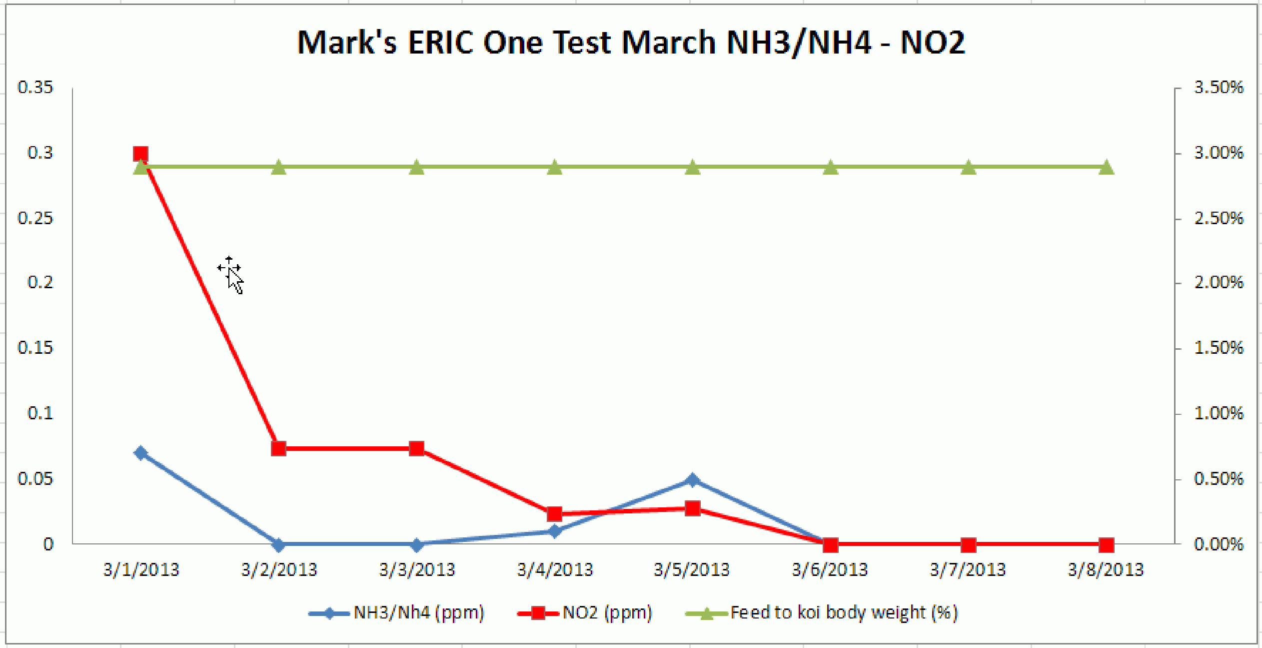
Fish Load, 3,140 gr, 4.2 gr/gal

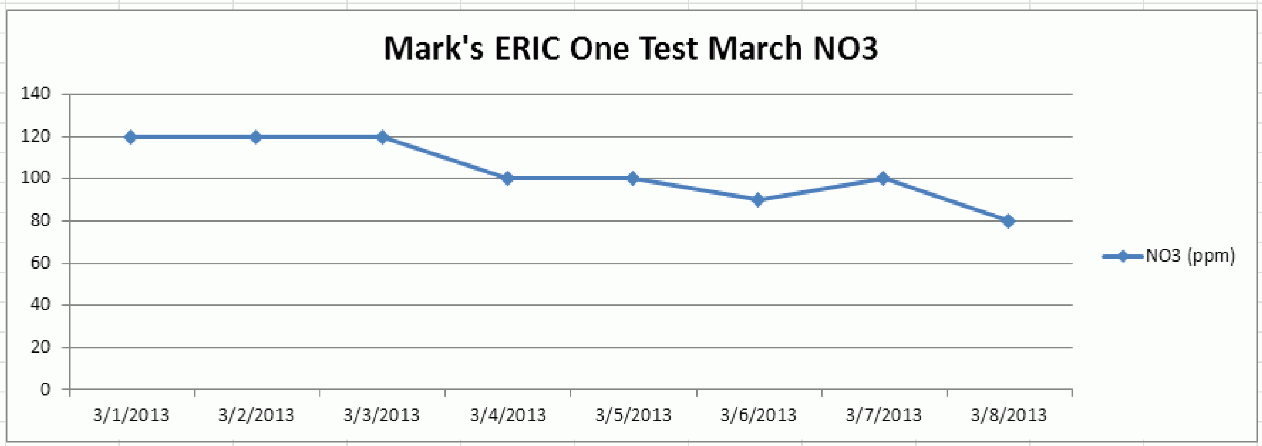
Range : End
NH3/NH4: 0-.07 : 0 ppm

NO2: 0-.3 : 0 ppm
NO3: 80-120 : 80 ppm
Temp: 73°F

Wtr Chg: 4.8%

Feed, % of Body Wgt: 2.9%





4. ERIC Two Baseline Test

In preparation for testing the ER 1 Prototype, a short baseline test was performed on the ERIC Two installed on the QT. In June, 2013 there were 6 nisai in the QT. I moved two of my largest koi into the QT to achieve the fish load that I wanted to test the ER 1 at. The estimated fish load was 7,842 gr or 12.8 gr/gal.

The test was only conducted for a short period. Feed rate was relatively high ranging from .52 to .87% of body weight per day. Results were good. NH3/NH4 increased slightly when the larger koi were introduced, quickly returned to zero and then increased slightly again when the feed rate was increased, but once again quickly returned to zero. Nitrite remained at zero throughout the test.

The test was then terminated having demonstrated that the ERIC Two could handle a very large fish load with a moderate feeding rate. Results are illustrated below.

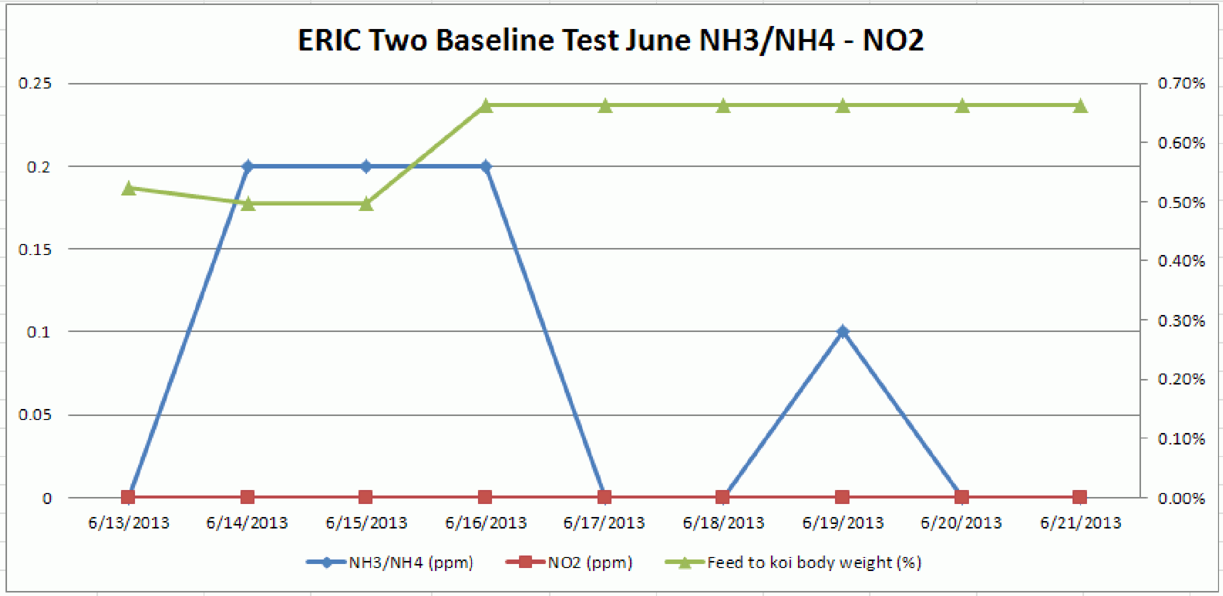
Fish Load, 7,842 gr,
12.8 gr/gal

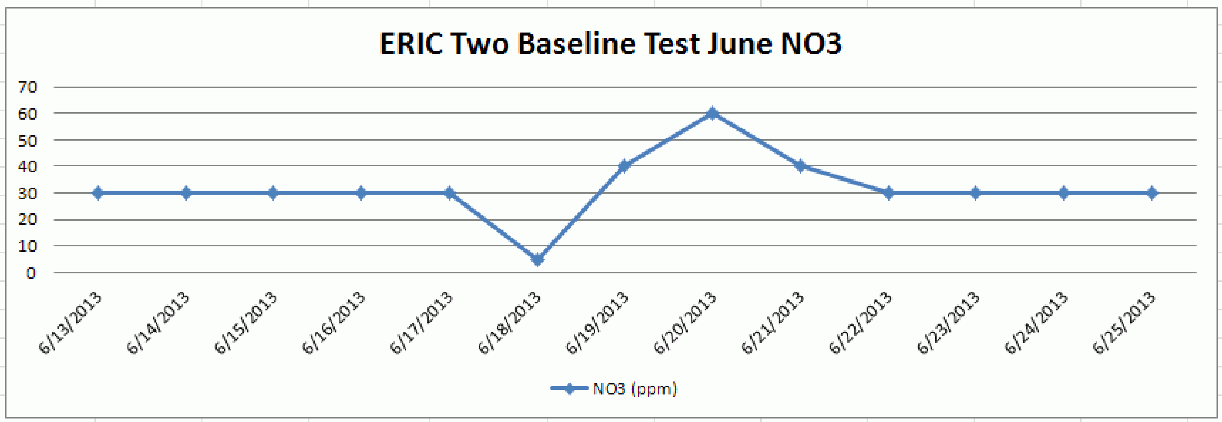
Range : End
NH3/NH4: 0-.2 : 0 ppm

NO2: 0 ppm
NO3: 80-120 : 80 ppm
Temp: 72-77°F

Wtr Chg: 11.02%

Feed, % of Body Wgt:
.52-.87%





5. ER 1 Prototype Test 1

After repairing the hole in the liner on the bottom of the QT and installing the ER 1 in place of the ERIC Two, the fish from the Baseline Test were returned to the QT to begin testing effectiveness of the ER 1. The fish load was 10,756 gr, 18.7 gr.

For the first couple of days the test proceeded normally. NH3/NH4 and NO2 began increasing slowly and the koi were eating well and acting normally. However, by the fourth day one of the larger koi was not eating well.

NH3/NH4 and NO2 were now at alarming levels. Levels this high had been observed in the ERIC One tests and the koi continued to eat well.

I was disappointed, but when I reviewed the ERIC One test results I realized that I was subjecting the ER 1 to a much higher fish load. The highest fish load recorded in the ERIC One testing was 7.2 gr/gal by Ian Brassington.

I planned to remove the two largest koi and continue testing with a fish load of 8.2 gr/gal, but then I realized that the RubberizeIt liner on the end of the QT under the waterfall was bulging alarmingly and could fail at any moment. Therefore, the test was suspended and the QT was drained for repairs.

Test 1 results are shown below.

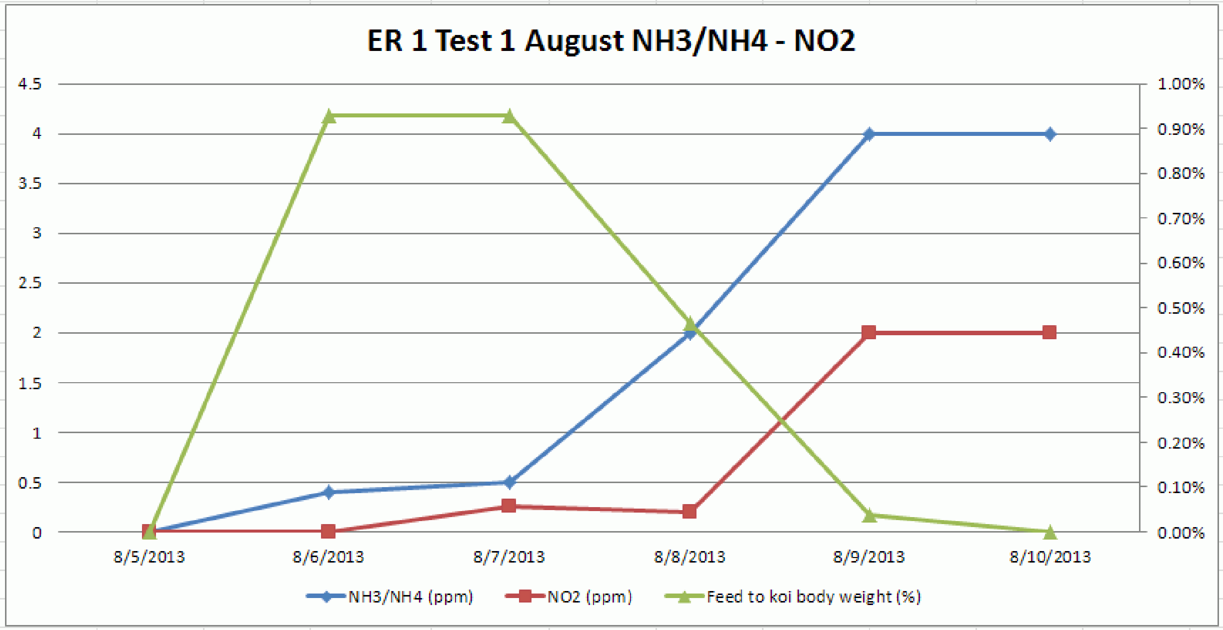
Fish Load, 10,756 gr,
18.7 gr/gal

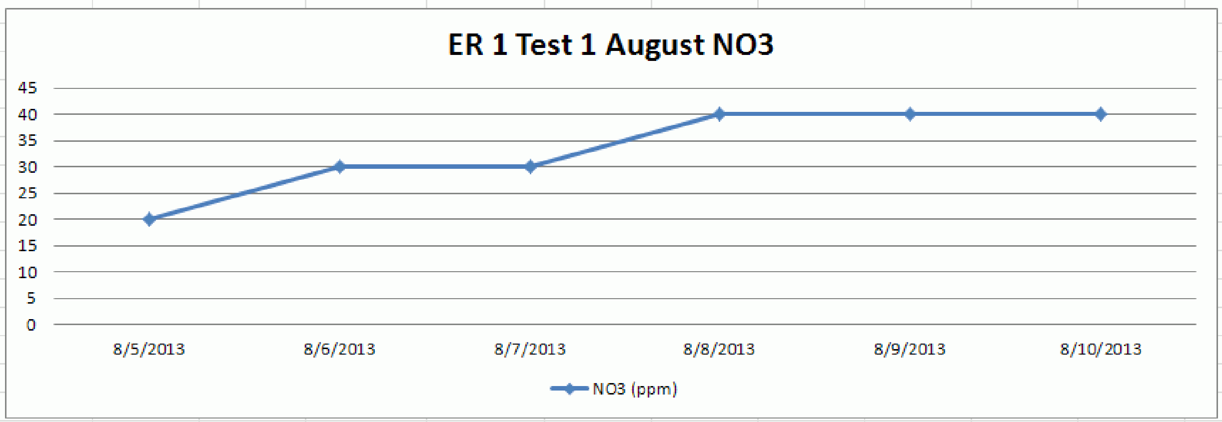
Range : End
NH3/NH4: 0-4 : 4 ppm

NO2: 0-2 : 2 ppm
NO3: 20-40 : 40 ppm
Temp: 69-76°F

Wtr Chg: 3.82%

Feed, % of Body Wgt:
0-.93%





6. ER 1 Prototype Test 2

Based on the claim that the BioMotion media was significantly more effective than EMat, I produced the ER 1 Prototype with significantly less biological filter volume than the ERIC One. The ERIC One utilizes three EMat Modules.

We had originally explored firing panels that appoximated the size of the EMat panels, but it quickly became clear that this was not practical. Instead we decided to use the existing spherical shaped BioMotion media. I fabricated a perforated enclosure to enclose this material that was approximately the same size as the ERIC One EMat Module, 10 1/2” x 7 1/2” x 11 1/8”.

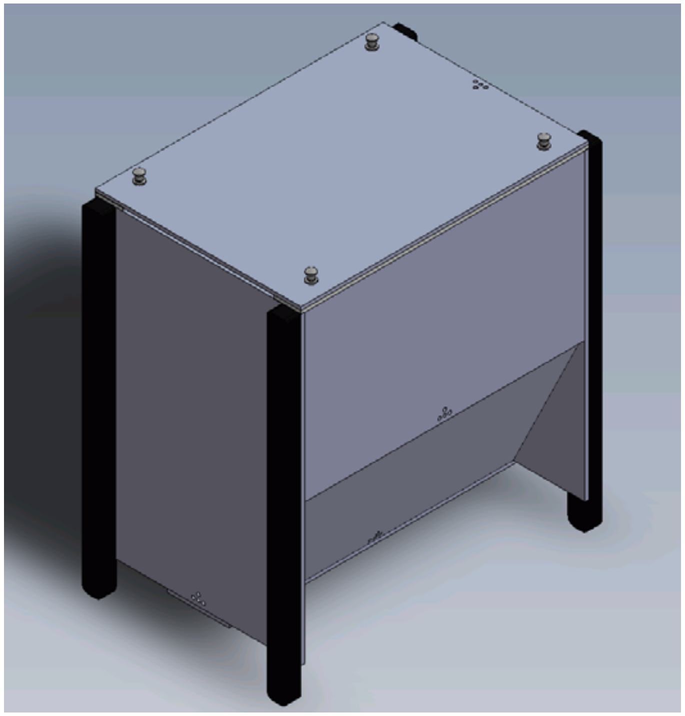


Figure 1. BioMotion Module

This enclosure holds 10 liters of BioMotion. Only two of these Modules were installed in the ER 1 Prototype so the volume of biological filter media was approximately 2/3 that of the ERIC One. The overall length of the filter is therefore somewhat shorter than the ERIC One, measuring only 39” in length inside the box.

In September an opportunity arose to obtain several koi that needed to be rescued from a pond where they were no longer wanted. Temporary repairs were performed on the QT to allow it to be used again for testing.

On Sept 6, 2013 I moved 7 fairly large koi into the tank. I was hoping for a fish load of approximately 8 gr/gal, but the koi were larger than I expected. The estimated load turned out to be 16,312 gr, 28.3 gr/gal.

I was very concerned that the extremely small ER 1 would not be able to handle this load under any circumstance. I expected I would need to move some of the koi out of the QT and into another tank, but I began Test 2 without feeding and taking water readings every morning.

I was very pleased to see that NO2 was being produced after one day of operation. Ammonia and NO2 increased steadily over the next three days and then ammonia began decreasing. NO2 remained nearly constant at 2 ppm.

Ammonia reached 0 on the 10th day. Regular feeding began on 17th day. Ammonia remained at 0 as feeding was increased to .05% of body weight.

By the 25th day NO2 began to decrease and quickly fell to zero. Feeding was gradually increased to .29% of body weight at which time NO2 increased to .2 ppm.

Test results are shown below.

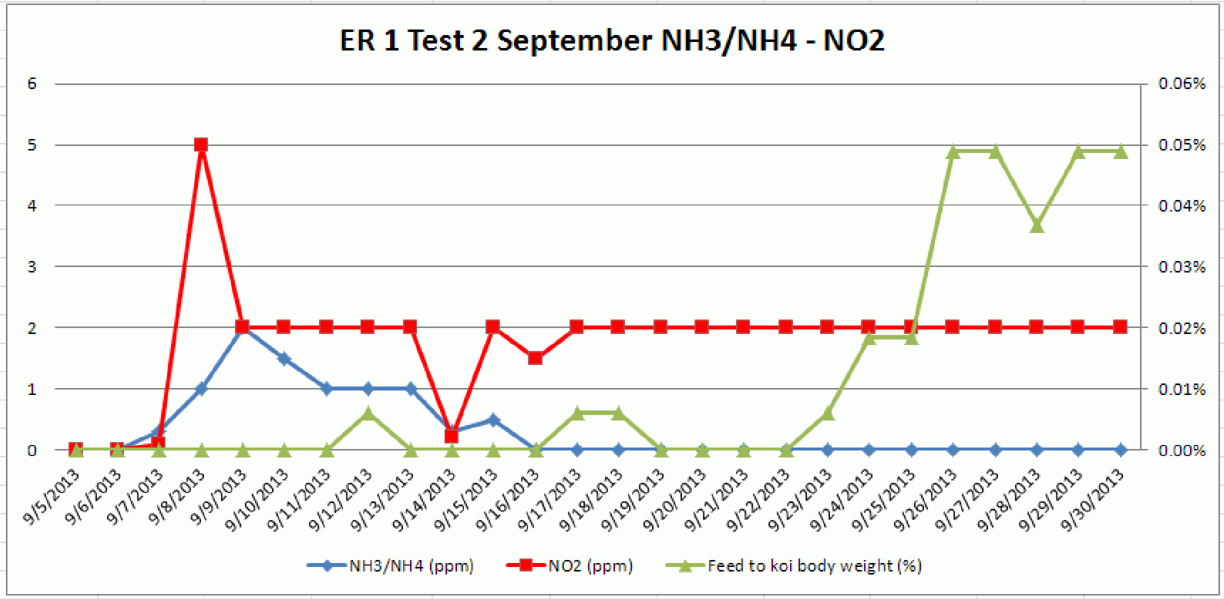
Fish Load, 16,312 gr, 28.3 gr/gal

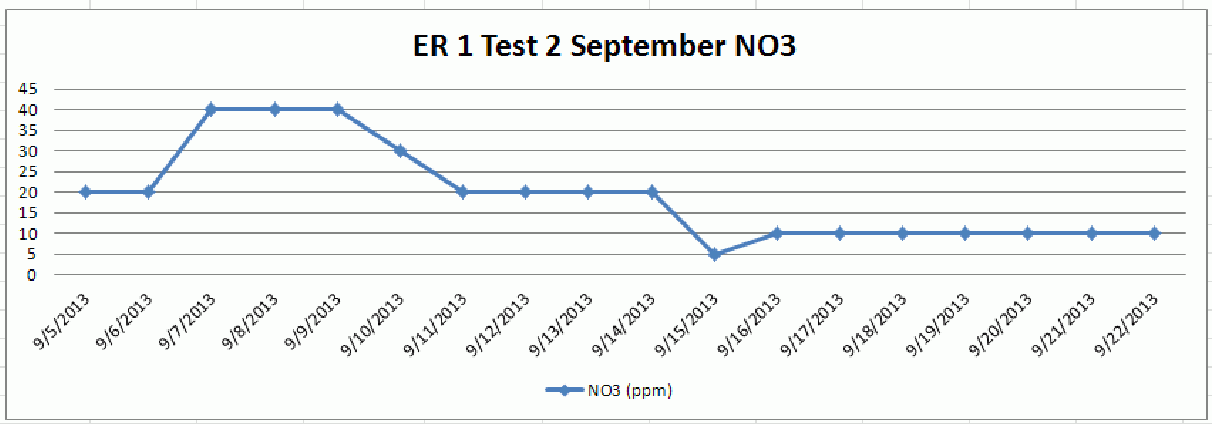
Range : End
NH3/NH4: 0-2 : 0 ppm

NO2: 0-5 : 2 ppm
NO3: 10-80 : 80 ppm
Temp: 67-75°F

Wtr Chg: 11.02-22.05%

Feed, % of Body Wgt: 0-.05%





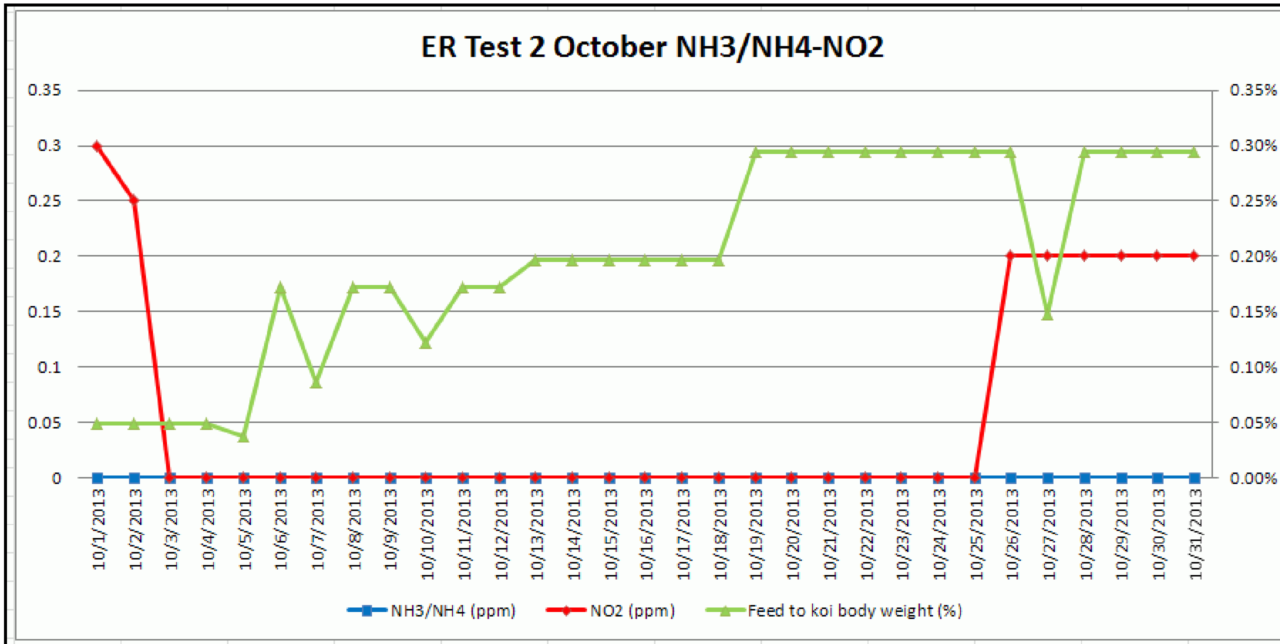
Fish Load, 16,312 gr, 28.3 gr/gal

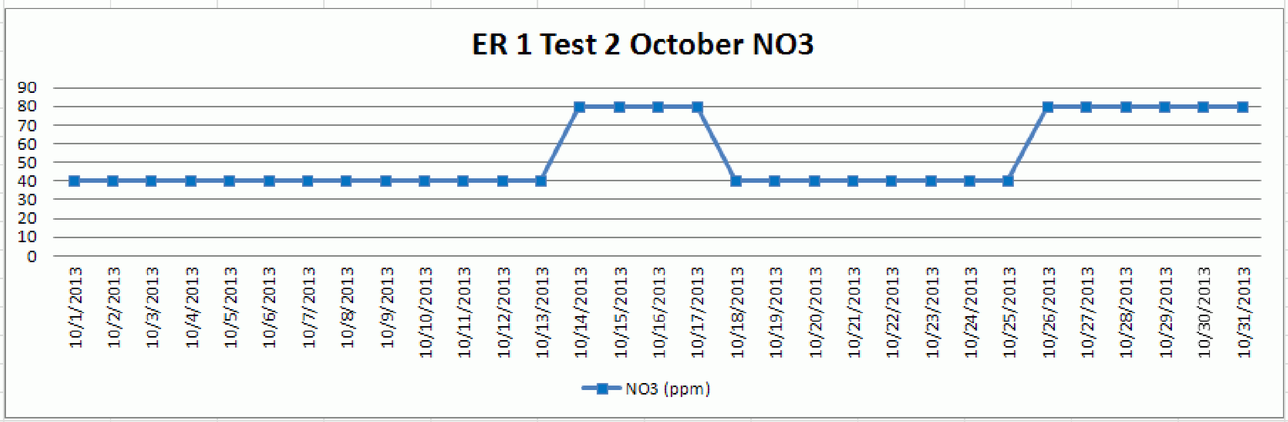
Range : End
NH3/NH4: 0 ppm

NO2: 0-.2 : .2 ppm
NO3: 40-80 : 80 ppm
Temp: 64-75°F

Wtr Chg: 11.02%

Feed, % of Body Wgt: .05-.29%





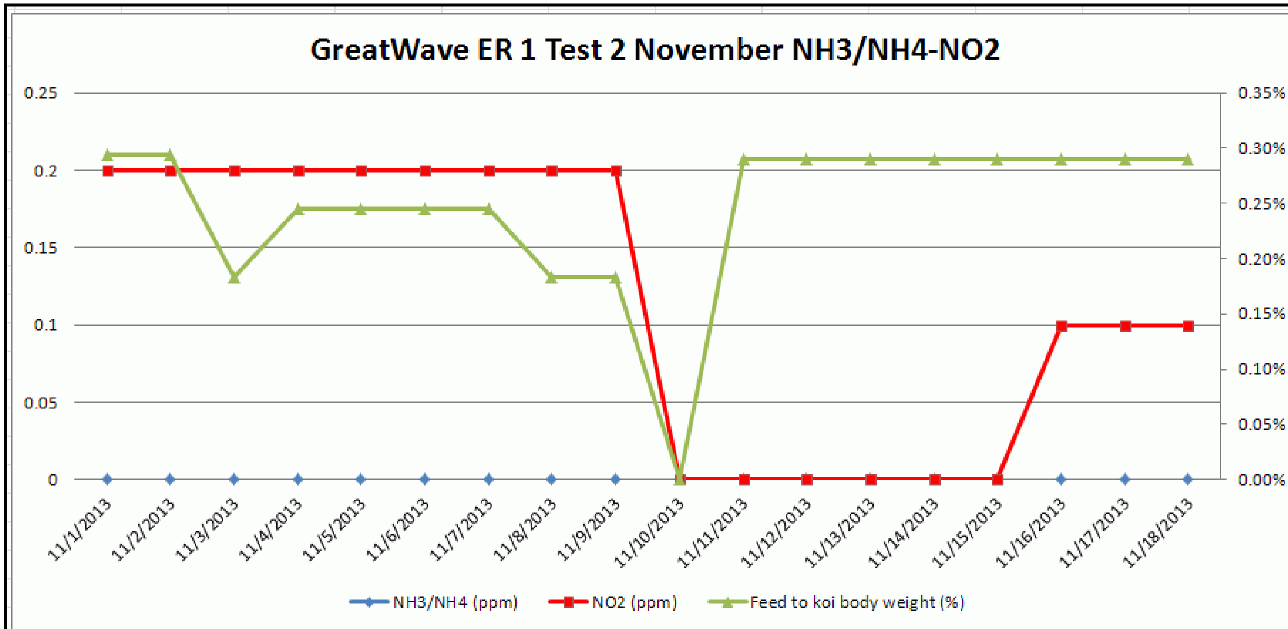
Fish Load, 11/1-9
16,312 gr, 28.3
11/10-
13,808 gr, 23.7 gr/gal

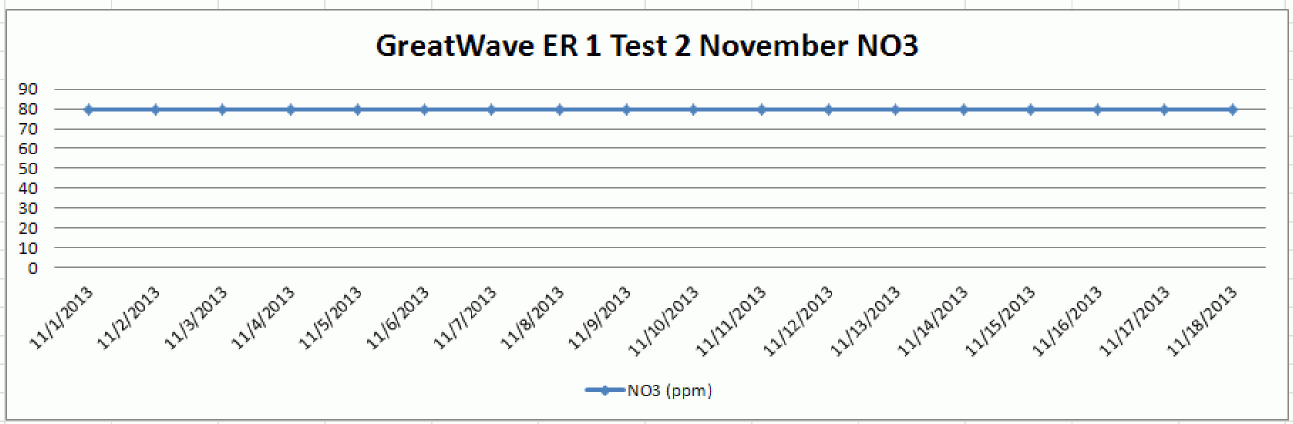
Range : End
NH3/NH4: 0 ppm

NO2: 0-2 : 0-.2 ppm : .1 ppm

NO3: 80 ppm
Temp: 63-68°F
Wtr Chg: 11.02%

Feed, % of Body Wgt: .18-.29%





7. Lessons Learned

- Results of Test 2 of the ER 1 Prototype Were Much Better Than I Expected

  The filter became active immediately after sitting idle and dry for nearly a month.

  The filter matured extremely quickly, reducing ammonia and nitrite to zero within a few days while subjected to an extremely large fish load.

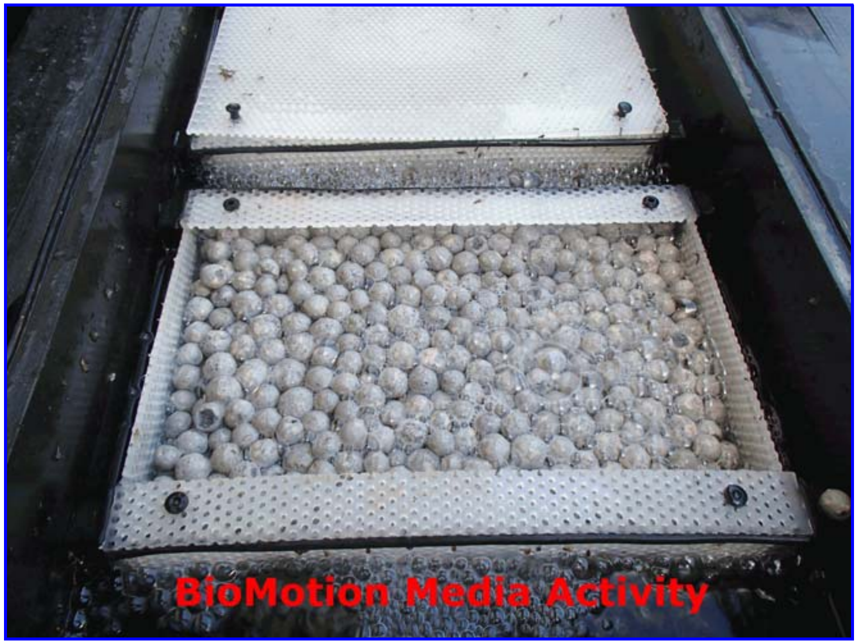
- Filter Effectiveness is Heavily Dependent Upon Water Temperature and Feeding

  My pond serviced by two ERIC Three filters began to show nitrite (.25 ppm) when feeding reached .46% of body weight and temperature dropped to 70°F.

  The ER 1 began to show nitrite (.2 ppm) when feeding reached .29% of body weight and temperature reached mid 60s.

- The GreatWave BioMotion Module Design Provides Adequate Media Motion

  When inspected on 11/21, after 77 days of operation, the media appears very clean. As advertised there is no evidence of biofilm forming on the media.



When viewed in a movie you can see slight motion of the media. A couple of weeks prior to this photo I had placed a nylon spacer on top of the media. It is now no where in sight and digging through the media I was unable to find it, indicating that individual pieces of media move significant distances over time.

This mild motion serves to keep the surface of the media extremely clean.

Unfortunately the quality of my camera image at this magnification is poor, so that it is difficult to tell from this photo that there is no film on the media.

- Like Other Biological Supporting Media BioMotion Hosts Various Nuisance Larvae

  The enclosure displays a number of fly larvae suggesting that it will need to be cleaned periodically. However, it will be easier to remove these from the openings in the enclosure that it would be to remove them from any sort of matting.

8. Where Do We Go From Here

Because the BioMotion media offers the possibility of equivalent filtration in a smaller package, GreatWave is designing a new line of filters, ER 1 - 4. All of these filters will have the same form factor. They will be larger in width and height than the current ERIC One, but considerably smaller than the current Twos thru Four.

The ER 1 will have a single BioMotion Module holding 12 liters of BioMotion Media. The remaining models will house BioMotion Modules equal to their model numbers, 2, 3 and 4. We believe adoption of the BioMotion media will improve on Peter's original ERIC concept and attract new customers to this excellent filtration system.