Aquasafra Tilapia grow-out suggestions. This document is a draft of an ongoing project to provide a grow-out manual for Aquasafra customers. It is currently in just two parts, but more will be added over the next few months.

<u>Section 1:</u>

1.1, Water quality is a critical factor when culturing any aquatic organism. Optimal water quality varies by species and must be monitored to ensure growth and survival. The quality of the water in the production systems can significantly affect the organism's health and the costs associated with getting a product to the market. Water quality parameters that are commonly monitored in the aquaculture industry include temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia, and nitrites. Depending on the culture system, carbon dioxide, chlorides, and salinity may also be monitored. Some parameters such as alkalinity and hardness are fairly stable, but others like dissolved oxygen and pH fluctuate daily. It is important to establish a standardized water quality testing protocol for your particular situation. Know the tolerance range for your culture species, establish critical levels, and be prepared to act if a problem occurs. The document below indicates the water quality Standards for Aquasafra's Tilapia.

<u>Aquasafra Water Quality Standards for Tilapia (*Table 1*)</u>

1. **Temperature** - Ideal **growth at 82º**

90+	Stressed – expect beginning of mortalities over 95º if in this range for several days.
85 to 89	Slower growth- Limit handling/ moving of fish in this range.
81F to 83F	**Ideal for grow out,** 82 is optimal.
80 to 75	Slower growth- Limit handling/ moving of fish in this range.
60 to 55	Stressed – expect beginning of mortalities if in this range for several days.

2. Ammonia – Ideally less than 0.03 ppm NH3
0.04 to 0.05 – reduce feed by 1/4
0.05 to 0.06 – reduce feed by 1/2
0.07 or higher – stop feeding
0.09 or higher – danger!!! lower pH to 7.0 by adding phosphoric acid or other available acid

3. Nitrite - ideally less than 0.4 ppm (if Chloride /Cl^-/ is below 10ppm**)**
0.5 to 0.6 ppm – reduce feed by 1/4
0.6 to 0.7 ppm – reduce feed by 1/2
1 ppm – danger!!! Stop feeding

If nitrite level does not decrease to 0.6 ppm after 5 days at 1/2 feed – salt to 100 ppm NaCl (if no plants in system**) as a temporary fix, and resume feeding at a rate that will keep nitrite below 2 ppm**
Check that O2 is above 6, pH has been at least 7.4 or higher, Check carbonate – should be above 200 ppm. Check Biofilter is circulating properly (no stagnant dead zones)**– add more beads/biomedia if everything else has been tried.**

4. **pH – OK range between 7.2 to 7.7,**
   Optimum level is 7.6, - unless biofilter and NH3 levels are Unstable,
   ("Unstable" = NH3 levels testing above 0.05, or spiking up and down every few days)
   If unstable, desired pH level is 7.3
   If NH3 above 0.09 to 0.1 – lower pH to 7 (or as low as 6.5 to get NH3 to safe level)

<u>For RAS systems:</u> If pH is Lower than 7.4 **–** Raise the pH by Adding lime/bicarb/ (CAOH/ CAO) or some form of Hydroxide (OH) to the biofilter bead area at the rate of ~1/8 lb. of lime per pound of the total daily amount of feed fed. If one treatment keeps pH in desired range after one day then stop adding lime. If pH keeps dropping each day, keep adding each day until the pH rises to a pH of 7.6

7.4 to 7.5 - cut lime/bicarb by 1/2 (add 1/8th lb. of lime / pound of daily total of feed)
7.6 or above - stop adding lime/bicarb.
7.7 or higher add enough phosphoric acid (or equivalent) to the beginning of the Biofilter, to bring the pH back to 7.4

If amount of buffer needed to keep pH constant is increasing relative to feed rate, likely is a CO2 problem.
If the amount of buffer needed to keep pH constant is decreasing, generally means biofilter is deactivating.

(When adding acid – put 50 mL ~ ¼ cup, in five gallons of water mix well, and then pour this acidified water slowly into the biofilter, add ¼ of bucket, wait 15 minuets, check pH, add another ¼ of the bucket, wait 15 more minutes. Keep checking pH and adding acid until pH is in desired range.)
CAUTION: WHEN ADDING ACID – ALLWAYS ADD ACID TO WATER NEVER WATER TO ACID!! <u>Put water in bucket first, then put in the acid</u>.
When handling acid: ***Always wear safety goggles and acid proof gloves.***

5. **Carbon Dioxide** (when O2 is at saturation ~7.5 to 8PPM O2 for 80º water),
   Ideally keep below 6 but up to 15 PPM is OK if dissolved CO2 is at saturation.
   Over 15 ppm – reduce feed by 1/4
   Over 30 ppm or higher – reduce feed by 1/2
   Over 40 PPM – Stop feeding
   If O2 is below saturation, (less than 8.2 ppm at 78 degree's) reduce upper level of CO2 range by % O2 levels are below O2 saturation.
   i.e. If O2 = 6 PPM, reduce CO2 maximum levels by 25% - Max CO2 = 11 PPM
   If CO2 is consistently high, *improve aeration to improve CO2 stripping* / or increase size of stripping tower. If high CO2, Don't use Calcium Carbonate as a buffer, as it adds CO2.

6. **Electrical Conductivity (EC)**
   A conductivity meter makes it straightforward to monitor water salinity and levels of total dissolved solids, TDS or total dissolved salts, measured in PPM or Mg/L.
   Ideal EC levels are different for RAS vs flow through tank or pond systems.
   For RAS systems, generally the higher the better, and levels as high as 300 to 1000 can be OK. Hi EC in RAS is generally reflecting the buildup of NO3 or Nitrate. In RAS systems EC is best used as an indicator of other issues, watching how EC behaves relative to other parameters. Over time EC can be an early indicator of trouble, but since each RAS system can be very different, the ideal EC scale needs to be calibrated for each system. Very Generally a dropping EC level can indicate that a Biofilter is deactivating. (The lowering of the amount of buffer additions needed to keep pH constant is another indication of a deactivating Biofilter.)
   For Flow Through tank systems with clear water and no to low algae, EC can be a rough way of determining if TAN levels are getting high without having to do a TAN test and conversion to NH3.
   For fresh water flow-through tanks (with no salt added, and low salinity well's)
   EC Below 330 to 350 will generally mean TAN is below 1 PPM
   EC Above 360 to 380 will generally mean TAN is above 1 PPM *<u>and a NH3 test should be done</u>*.
   EC Above 400 will almost always mean TAN is above 1 PPM and likely in the 2 to 8 PPM range.

There are many other tests that can be done. The next most productive is ORP, or Oxidative Reduction Potential – and like EC needs to be monitored with other factors, but generally a higher OPP, the healthier a system. Others are Alkalinity, Hardness, P, K, Mg, Cl, Na and others to numerous to get into in this short guide.

Most test kits are clear and simple, testing Ammonia/ NH3 needs a bit of explaining:

1.2 Testing Ammonia:

A common mistake in measuring Ammonia NH3/ Ammonium NH4 in fish tanks is assuming the test kits used are reading out as the toxic form of Ammonia / NH3. (Ammonia is sometimes referred to as *'un-ionized* ammonia.) The kits are measuring a total of TAN or Total Ammonical Nitrogen, which is a combination of several nitrogen compounds.

A common practice when measuring Ammonia is to assume the TAN # can tell you toxic Ammonia. You can't unless you know the pH. For example a TAN of 2 with a pH of 6.5 is not toxic, but a TAN of 2 with a pH of 8 is very toxic. Some folks get away with just using the TAN # from their basic test kits, if their pH is constant, and have mentally calibrated TAN readings with how their fish are acting. This works to a degree, but they are often putting their fish under small to medium stress levels just using TAN. And remember that Stress is accumulative. A little here, a little there, it adds up to causing disease outbreaks. So, it is important to keep lots of little stresses from adding up to collectively large amounts of stress, that can cause (on good days) slower growth, poor FCR's and (on bad days) disease outbreaks.

One needs to know just the NH3 levels to know the toxicity and potential stress on ones fish. NH4 is not toxic in levels as high as 50 ppm and higher, however NH3 starts being toxic at 0.06 PPM, I.e. a really small tinny amount. NH3 is quite toxic, which is why it is used as a bathroom/ kitchen cleanser to kill bacteria. (And used as a gas to kill people in war as nitrogen mustard gas.) You need to know your NH3 levels! Not just TAN. All test kits provide a TAN level, and you then need to know the pH to determine what part of the TAN reading is the toxic part as NH3.

The toxicity of Nitrogen as TAN is in equilibrium between NH3 (ammonia – toxic) and NH4 (ammonium – not toxic). I.e., some part of TAN is NH3, and some part is NH4. The equilibrium that controls the % that is NH3 and the % that is NH4 is pH. The higher the pH the higher the % of TAN is toxic NH3.

How to Convert a TAN Reading into Ammonia/NH3:

Start by following the directions in the Ammonia test kit to calculate TAN (Total Ammonical Nitrogen). As an example, let's say you get a TAN reading of 2. Then using the pH and temperature look up on Table 2. what is the % of TAN that is NH3. Multiply TAN times the % to get NH3.

For example, assuming a TAN of 2, and temperature for the day was 79.1 and pH 7.5 you would use the top row on table 2., look for the closest temperature to 79.1. You will see the closest value is 82.4 for the top temperature column on (rounding up from 79.1 to the next highest reading on the temperature scale which is 82.4). Then go down to the side pH column. Again, you will see there is not a 7.5, so use 7.6 the next highest number (always round up). The intersecting row of 7.6 with column of 82.4 you will see gives you the number 0.271. This is the % of TAN that is NH3 reported as a decimal. I.e. 27% is the %, since the number is given as a decimal to make it easier to do math with. (Some tables report in %, and then you need to divide by 100 to convert to a decimal).

Now, this will give you the value as NH3-N, but does not account for the weight of the Hydrogen Ions, to account for pure Ammonia as NH3, one needs to multiply by 1.2 to account for the weight of the H ions. If this is confusing, as it gets into a bit of real chemistry, just know you need to multiply by 1.2 for most test kits. If you aren't sure ask the manufacture of your test kit if this is needed. If the agent you get on the phone does not know about this 1.2 correction factor, ask for someone that knows enough chemistry to explain it.

The formula is:

TAN times % Ammonia/NH3 times 1.2 to = NH3
or TAN X %NH23 X 1.2

Putting in some numbers:

TAN X 0.271   Or in this example 2 X 0.271 = .542
.542 X 1.2 = **0.65 NH3** – (*this is quite high, NH3 should be below 0.06 !)*

If TAN was 1:   1 X 0.271 X 1.2 = **0.33**   (*this better but still above 0.06*)

If TAN was 1, and the pH was 7 then:
Looking up on the table with a temperature of 82.4 and pH of = the percent TAN = 0.0069
TAN of 2 times % of 0.0069 times 1.2 = NH2
2 X 0.0069 X 1.2 = **0.017** (not rounding up it is 0.01656) 0.017 This is quite good, *well below the limit of 0.06*

Table 2.:

pH	Temperature													
	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

Table 3.
Table 3 is a less accurate, but faster way to calculate NH3 levels. It's color coding also give a good visual indication of how pH impacts the toxicity of TAN as NH3.
This is simplified chart that does the calculations converting TAN into NH3. It is a bit less accurate, (*and #'s disagree by a little bit with Table 2.*) but unless you are using very accurate test kits, (like a HACH or equivalent reagents, not lower quality API reagents or equivalent) the error/ difference between Table 2 and Table 3, is not worth the accuracy Table 2. provides. But if using good reagents use Table 2.

Table 3:

TOTAL AMMONIA CONCENTRATION (ppm NH_4, N)											
pH	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	
6.0	.001	.001	.002	.002	.003	.003	.004	.005	.005	.006	
6.2	.001	.002	.003	.004	.005	.005	.006	.007	.008	.009	*A
6.4	.002	.003	.004	.006	.007	.009	.010	.011	.012	.014	
6.6	.002	.005	.007	.009	.011	.014	.016	.018	.020	.022	
6.8	.004	.007	.011	.014	.018	.021	.025	.028	.032	.035	
7.0	.006	.011	.017	.022	.028	.034	.039	.045	.050	.056	*B
7.2	.009	.018	.027	.035	.044	.053	.062	.071	.080	.088	
7.4	.014	.028	.042	.056	.070	.084	.098	.112	.125	.139	
7.6	.022	.044	.066	.088	.110	.131	.152	.175	.197	.219	*C
7.8	.034	.069	.103	.137	.171	.206	.240	.274	.308	.343	
8.0	.053	.107	.160	.213	.266	.320	.373	.426	.479	.533	
8.2	.082	.194	.246	.327	.409	.419	.573	.655	.737	.818	
8.4	.124	.248	.371	.495	.619	.743	.866	.999	1.114	1.238	
8.6	.183	.366	.549	.732	.915	1.098	1.281	1.463	1.646	1.829	*D
8.8	.262	.524	.786	1.048	1.310	1.571	1.833	2.095	2.357	2.619	
9.0	.360	.720	1.08	1.44	1.80	2.160	2.52	2.88	3.24	3.599	

*A = SAFE   *B = STRESS   *C = SLOW DEATH   *D = RAPID DEATH

Chart of fish ammonia toxicity

In Table 3, the top row (#'s 1 through 10) is you TAN number. The side column is pH.
Using the above example of a TAN of 2 and a pH of 7.6 this chart says NH3 = 0.44. Not the same as Table 2, but still good enough to say your NH3 is too high (*it's above 0.06*)

You can use Table 3 to see how pH impacts toxic NH3. Look at the TAN column of 2, at pH of 7, the NH3 is reported as 0.011 – which is good *It's below 0.06,* and it is shaded as light Blue – OK.
But if you continue down the pH Column, look at when pH is 7.6, with TAN at 2 NH3 is now 0.044 – just barley OK, but is shaded in a darker blue (*Table 3 chart is more conservative as it is for aquarium fish, not Tilapia, so they have a lower standard for toxic NH3 than 0.06*) At a pH of 7.8, with TAN at 2, Table 3 shows NH3 as 0.69, Shaded as dark blue – *Stressed!* At a pH of 8, NH3 is 0.107, now light purple - *Slow Death!*

Play with the chart – look at different TAN's and pH and see the range you need to keep your system/ tanks in. Sometimes people will have TAN levels at 8, which means, to not be killing your fish, you need to have the pH be no higher than 6.8 to not be stressed, or below 7.4 to not be in the "Slow Death" zone.

This should clearly show why one of the easiest ways to prevent a system that has a high NH3, is to lower the pH. If you have a TAN of 8, and a pH of 7.6, (Slow Death) you should put some acid in your tanks to lower the pH down to the range of 7.2, to quickly get out of Slow Death, and just into a zone of Stressed.

Putting in Acid will solve the immediate problem of high NH3, but not why the TAN was high in the first place. TAN will be high because either not enough water is being flushed through tanks, or for a RAS the Biofilter is not handling the amount of feed being fed. It is best to calculate NH3 each day to at least three times a week, and not let it spike by reducing feed or increasing flushing before NH3 is at a Stressed level (*NH3 above 0.06 ppm*).

In a RAS system (over the long-run, other than an emergency) it is counterproductive to lower the pH because biofilters perform much less efficiently at lower pH. So, by putting in Acid to lower the pH to reduce NH3 toxicity one is making the sort term problem better (reducing high NH3) but making the long term issue worse, making the filter less efficient there will be more NH3. The long-term solution is to reduce the pH for a temporary fix and reduce feeding until TAN comes down to well below 0.06 ppm. Then raise the pH back up to a level just below pushing NH3 into the Stressed zone (below 0.06). Then start raising feed levels back up until NH3 starts getting close to 0.06 ppm. Established biofilters can adjust to higher feed within 3 to 6 days. So raise feed every 4 to 5 days to allow the biofilter bacteria to grow to higher densities to handle more NH3 the additional feed will generate. The higher the pH the more efficient a biofilter will run, can handle more feed. But if at an ideal pH of 7.4 to 7.6, the TAN keeps spiking and NH3 exceeds 0.06 then the biofilter needs more media to make more surface area. (And lots of other areas could be causing issues like to many solids/ poor drum filter performance, two low of a tank water turnover rate to name just a few.)

For flow-through tank systems, Lowering the pH is less effective because often the flushing rate flushes out the acid to quickly to be effective, or alkalinity in well water counteracts/ neutralizes the acid requiring a lot of acid. In pond systems with algae, the algae will drive the pH up, requiring a huge amount of acid until the sun goes down. In the case of tanks or ponds, the best option is to just not let the TAN/ NH3 get too high in the first place by not over feeding. But in an emergency, if NH3 is in the Rapid Death zone, and fish are visibly stressed and dying, then throwing in lots of acid to lower the pH is worth trying.

In any of the above cases – having some quantity of inexpensive acid on hand can be essential to stop an NH3 stress or slow death event, until NH3 can drop to a safe, non-stressed level. The best acid/ most effective is Phosphoric Acid (H3PO4), but it is expensive. The next best is Hydrochloric Acid / HCL, or less pure, commercial forms of HCL, or Muriatic acid. Having a few 35 to 55 gallon barrels around, just in case, can be a life saver.

One other comment: Tilapia are tough, and often can handle high NH3 for some time, sometimes months or years (if they get that old before harvest), and not show any visible signs of stress. But they are stressed! And this stress will show up in other non-visible ways like slower growth, and lower feed utilization (higher FCR). They can handle this stress over a long time, but if other stressors are added, like low O2, or low Temperatures, or high NO2 or high dissolved CO2, then the stressors add up, and the rate of Mort's can slowly or rapidly increase. In worst cases other diseases like strep and a range of parasites can become much larger problems. It can seem like these issues 'came out of nowhere', but they were building all along, and if the NH3 is kept below 0.06 then at least toxic Ammonia/ NH3, will not be part of the problem.

Additional Conversion Factors Table 2.2.

The Conversion needed for some TAN to NH3 calculations of multiplying by 1.2, is often needed for other tests like Nitrite, or NO2. In the case of NO2/ Nitrite, many test kits require results to be multiplied by 3.3 to be accurate. Be sure to check with the manufacturer of your Nitrite reagents to see if this is necessary.

Table 2.2 **Summary of water quality equations**

Equation 1: Un-ionized ammonia (NH_3) from total ammonia ($NH_3 + NH_4^+$)
Total ammonia (from test) × fraction of un-ionized ammonia (from Table 2.1) = NH_3
Equation 2: Un-ionized ammonia (NH_3) from total ammonia nitrogen (NH_3^--N + NH_4^+-N)
Total ammonia nitrogen (from test) × fraction of un-ionized ammonia (from Table 2.1) × 1.2 = NH_3
Equation 3: Nitrite-nitrogen (NO_2^--N) to nitrite (NO_2^-)
NO_2^--N × 3.3 = NO_2^-
Equation 4: Nitrate-nitrogen (NO_3^--N) to nitrate (NO_3^-)
NO_3^--N × 4.4 = NO_3^-
Equation 5: Equivalency of gr/gal to mg/L
1 gr/gal = 64.79891 mg/gal ÷ 3.785 L/gal = 17.1 mg/L
Equation 6: Total alkalinity in gr/gal (drops) to mg/L
Drops of titrant (= gr/gal) × 17.1 = Total alkalinity in mg/L
Equation 7: Total alkalinity in dKH to mg/L
Drops of titrant (= dKH) × 17.86 = Total alkalinity in mg/L
Equation 8: Total hardness in gr/gal (drops) to mg/L
Drops of titrant (= gr/gal) × 17.1 = Total hardness in mg/L
Equation 9: Total hardness in dGH to mg/L
Drops of titrant (= dGH) × 17.86 = Total hardness in mg/L
Equation 10: Calculation of % N_2
$\%N_2 = [\%TGP - (\%DO \times 0.2095)] \div 0.7808$

Section 2: Stocking, Feeding, and Grading

SECTION 2.1 Data collection & Charts:
In order to manage Feeding, as well as good water quality for good growth and good profits three simple sets of data need to be tracked using three simple charts.

This process is designed to be as simple and fast as possible to not create any additional work in the already busy day of an aquaculture farm manager that is not absolutely necessary. But it does take some time, but the time is an investment that will have large return in faster fish growth, lower input costs and higher profits. Not doing this work will cost the farmer more money. The investment in time will definitely be paid back with better profits.

The core goal is to collect daily and weekly data to fill in a long-term chart or “log Chart” over time. The Log Chart is the most critical chart, as it shows over time the performance of fish, and water quality management techniques. It will guide decisions on how to best operate the farm to be more profitable.

The Log Chart is filled out with three critical sets of data that comes from three charts.
These three data sets are:

A. Water Quality
B. Feeding optimum amounts of feed
C. FCR (food Conversion Ratios) & fish growth in Grams/ day

A. Water quality clearly needs to be maintained to eliminate any stress on fish, which prevents disease, or the need for any medications, as well as slower or faster growth.

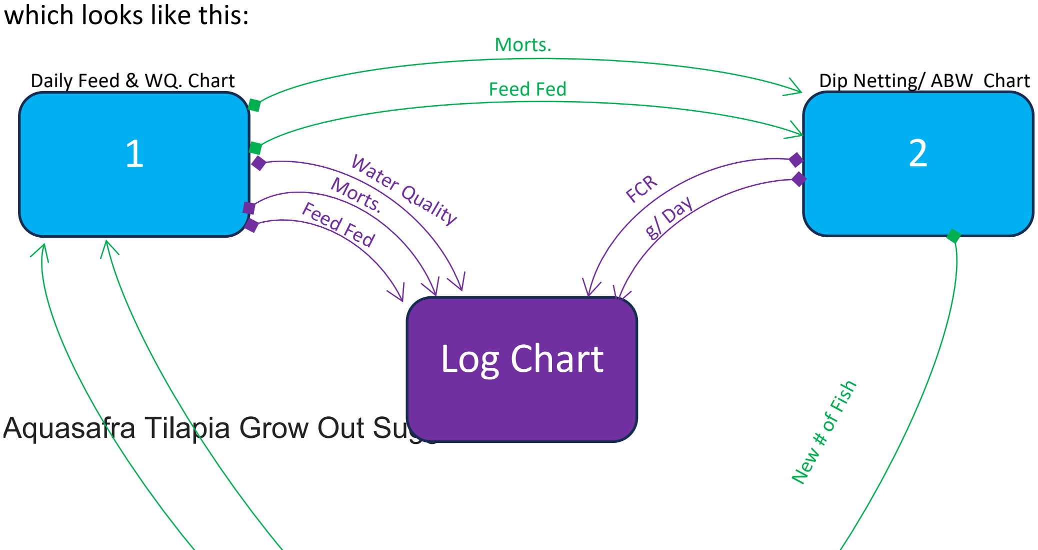
B. After water quality, Feed optimization has the largest impact on profitability since feed costs are 60% to 80% of most farms cost. Wasting labor, or other inputs is not nearly as costly as wasting feed. One can feed too much, or not enough - both will make the farm less profitable.

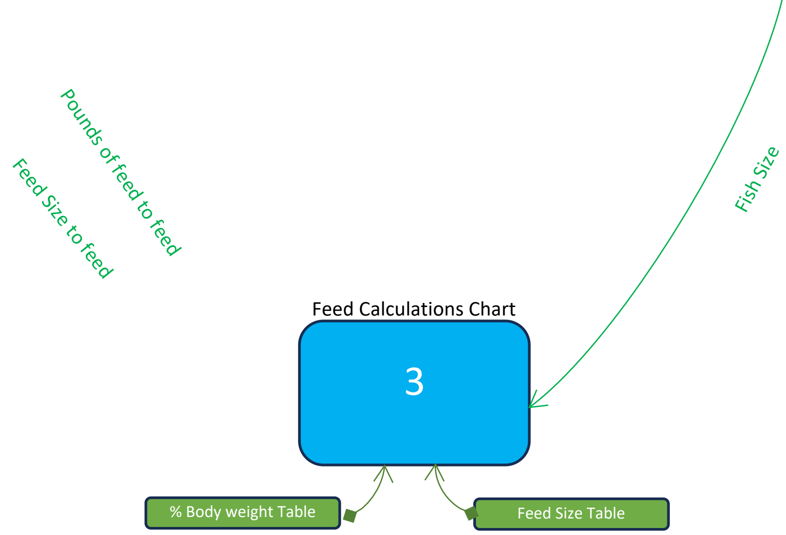
C. Knowing the Food Conversation Ratio or FCR allows the optimization of feed use, (maximizing profits) and knowing the growth rate in Grams per day or g’s/Day is important to know how to optimize the FCR. Details about FCR and g/day growth are described in more detail in Section XX

To fill out the Log Chart there are three charts that need to be kept:

1. Daily water quality and feed chart – (record; water quality, fish mortality and feed fed)
2. Dip Netting or measuring Average Body Weight (ABW) of fish in each Tank, Cage or Pond ~every 2 weeks
3. Feed Calculations – based on the charts 1 & 2 the amount of feed to feed per day is set.

The three sets of data, collected on three charts – that fill out the Log Chart can be thought of as a cycle which looks like this:





Filling in the Charts:

1.) Daily Feed and Water Quality Chart.

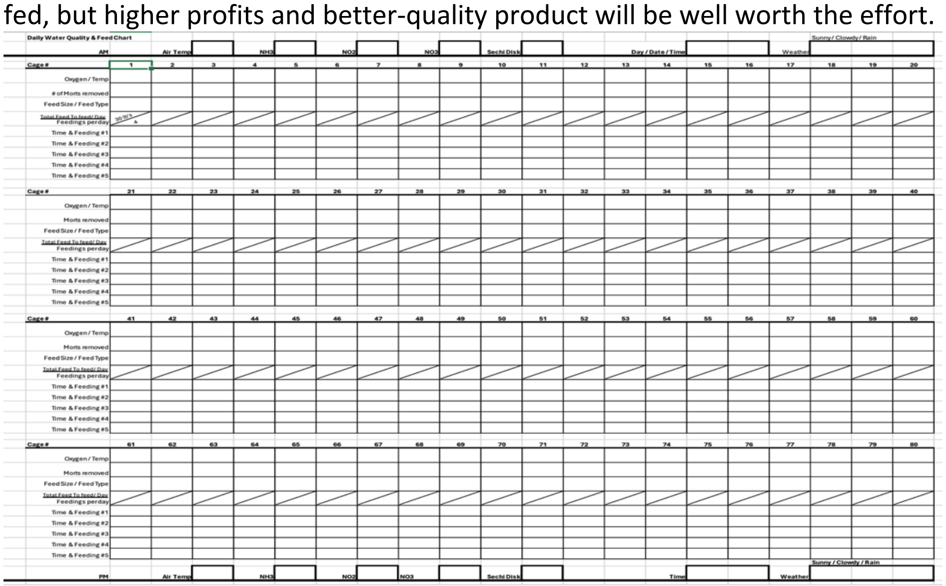
The process starts by filling in the Daily Feed and Water Quality Chart.

A. First – complete water quality numbers, at least Temp, and O2, but ideally NH3 & NO2. Water quality is needed to know if feeding should be started – *see above section on water quality to know if feed should be reduced by ½, ¼, or not fed at all.*

B. Next - remove and *Record* the number of Morts. or dead fish in each tank/ cage/ pond.

C. Last -Record the amount of feed that was fed in weight (lb.'s Kg's) for each time of feeding

This is a critical process – it can take a bit more time to do water quality, and record the amount of feed fed, but higher profits and better-quality product will be well worth the effort.



Daily Water Quality & Feed Chart

AM | Air Temp | NH3 | NO2 | NO3 | Sechi Disk | Day / Date / Time | Weather | Sunny / Cloudy / Rain

Cage #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Oxygen / Temp																				
# of Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings perday	30 lb's / 4																			
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				

Cage #	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings perday																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				

Cage #	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings perday																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				

Cage #	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings perday																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				

PM | Air Temp | NH3 | NO2 | NO3 | Sechi Disk | Time | Weather | Sunny / Cloudy / Rain

2.) Dip Netting / ABW Chart.

The Dip Netting / Average Body Weight (ABW) Chart determines how fast fish are growing and how well they are eating and digesting the feed they are fed. This is also essential information for calculating how much feed should be fed each day used in the Feed Calculations Chart.

This involves "Dip-Netting" or collecting one net full of fish in a given tank, cage or pond. Weigh the net, and then count the # of fish in the net. Dividing the weight by the number of fish calculates the average body weight of each fish. Do this three times to create a more accurate average ABW. More on this process is explained below in <u>Section XX</u>

Ideally this should be done at least once every two weeks. But on farms with lots of tanks, cages or ponds, it can be time intensive. So, a general trick is to sample several tanks cages or ponds that are in a given group. Many farms have tanks cages or ponds in groups of fish with the same age and size. For example a farm may have eight groups each with eight cages. One group of 8 cages is harvested and then restocked with new fingerlings each month. So, there are 8 groups, each with 8 cages, or a total of 64 cages. Since there are 8 cages in each group, one only needs to dip net 2 or 3 cages in each group. So instead of dip netting 64 cages every 2 weeks, only 16 cages need to be dip netted every two weeks. To make this even easier, one could do dip netting every week, dip netting half the groups one week and the other half the next week. This means only 8 cages need to be dip-netted each week.

Dip Netting / Average size Calculations

Cage #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total weight at last dip netting																				
Total Feed fed Fed since Last Dip netting																				
# of Days since last sample																				
# of fish in Cage																				
Weight #1																				
Count / # fish																				
Average size																				
Weight #2																				
Count / # fish																				
Average size																				
Weight #3																				
Count / # fish																				
Average Size																				
Average fish size																				
Total Weight																				
Total Growth in Grams growth																				
Growth in Grams/ Day																				
Food Conversion Ratio / FCR																				

With this ABW information you can then calculate Growth in Grams per day, and the Food Conversion Ratio.

To calculate the growth of fish in grams/ day one subtracts the ABW of the last dip-netting or sampling from the ABW of the most resent dip-netting to ABW sampling. This is calculated by Subtracting ABW From the last week's sampling from this week's sampling of ABW, divided by the number of days between the samplings. (See other examples in below sections.)

(ABW-This week's sampling) – (ABW Last sampling) / (Days between samplings)
= (Total Weight Gain per Day).

Divide Total Weight Gain/ Day by the number of fish in the cage, and you get the Average Body Weight gain of each fish over that last sampling time.

(Total Weight Gain per day) / (Number of fish per cage**) = ABW of each fish

Generally, ABW is calculated in Grams, so you can calculate the grams of growth per day. Then there are charts you can compare the growth in grams per day, to see if fish are growing well or growing poorly. Over time you will build your own charts of good or slower growth. Then you can use this information to adjust feed rates and other factors.

** Knowing the Number of fish in each cage is essential. The only way to know this is know the # of fish stocked into a tank, cage or pond, and subtract each week the # of fish that were removed as morts that week. This is why putting the number of Morts on the Daily Feed and WQ chart is essential. This is also important to know how many fish will be available to sell at harvest time.

Next is to calculate the Food Conversion Ratio. This is done by adding up all the feed fed since the last sampling session (why it is essential to record feed fed/ day). Divide total feed fed by total growth of that sampling period, and divide that by the # of fish = FCR.

(Total Feed Fed in grams) / (Total growth in grams) / (Number of fish)
= (Food Conversion Ratio).

Similarly, as in calculating growth, there are charts that show what a good FCR is for a given size of fish. You can then see if you are converting more feed fed into fish, (good) or converting less feed fed into fish – (bad). I.e. a poor FCR means you are using more feed that needed to grow your fish which means you are spending more money in feed than is needed.

Over time you can then compare the FCR you get each sampling with the weather, water quality, type of feed, and the amount of feed that has been fed. Using this information you can maximize your profits.

3.) Feed Calculation Chart

In order to calculate how much feed should be fed to each tank, cage or pond, you need to know the ABW calculated earlier in the Dip Netting and multiply this by the Percent of feed to feed a given size of fish. (See below charts for the % of body weight to feed.)

As a quick example for batch of 50g fish, you should feed 5% of their body weight per day.
Multiply 50g times 5% = grams to feed each fish or g/fish.
Then
Multiply g/fish times the # of fish in the batch (tank, cage or pond) = total grams to feed/ day

(ABW) * (% of Body weight to feed) / (total # of fish)
= (Grams to feed/ day).

Divide Grams/ 454 g's/ lb. = Pounds to feed per batch per day. Next look at the chart to see the recommended number of times to feed that batch per day. Smaller fish need to be fed more often 5 to 6 times/ day. Larger fish only need to be fed 3 times per day.

Also on the chart is the size of feed that should be fed that size of fish.

Put the amount to feed, the size of feed and the number of feedings per day on the Daily Feed chart for each batch (tank, cage or pond).

Feed per cage Calculation chart																				
Cage #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
# Fish in cage previous dip netting																				
Morts since last dip netting																				
Curent # of Fish in cage	3000																			
Average Weight	1																			
Total biomass in cage	3000																			
% o f Body weight to feed	0.015																			
Total Amount of feed to feed/ day	45																			
Total # of Feedings / day	3																			
Feed to feed per feeding	15																			
Size & % protiene to feed to feed																				

<u>The Log Chart</u>

Each week take the data from the seven (one per day) Feed & WQ charts and combine into the Log chart. This is the Morts, Feed fed, Water Q FCR & g/day growth. Each week this will grow with more and more data. Each week look back at the trends – maybe graph the data – and trends (good and bad) will show up. Based on the trends now you know the status of your farm, and you can make a range of decisions based on what the data is telling you .

Water Quality, FCR & G/Day - Trends Log:															
Average **Water Quality**		**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**
	NH3														
	NO2														
	NO3														
	Sechi														
	O2 At surface														
	O2 At 8'														
	O2 At 20'														
	O2 At 40'														
	Temp at Surface														
	Temp at 8'														
	Temp at 20'														
	Temp at 40'														
Cage #		**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**	**Date**
1															
	FCR														
	G/ Day														
	Morts														
2															
	FCR														
	G/ Day														
	Morts														
3															
	FCR														
	G/ Day														
	Morts														
4															
	FCR														
	G/ Day														
	Morts														
5															
	FCR														
	G/ Day														
	Morts														
6															
	FCR														
	G/ Day														
	Morts														

<u>The Cycle of charts.</u>

- Daily, collect data needed on the Feed & WQ chart.
    - Check if WQ is OK if good, feed according to the noted amounts & times.
- Once a week – do the needed dip nettings, calculate FCR & g/day growth.
- Once a week use data on Dip Netting ABW chart to calculate feed rates.
- Once a week create seven new Feed & WQ charts with the up dated feed amounts
- Once a week put all the collected data on the Log Chart.

Managing the cycle of the charts will take some time, but over the weeks and months, the process will get fast and simple. It is best to collect and calculate the data by hand but over time the process can be automated in a series of excel spreadsheets that can do the math automatically. There are many other ways to make the data collection easier and faster over time. The essential part is to start doing it each day, and each week tabulating the data and creating new feed charts for that week.

NEED TO UPDATE THE CHART EXAMPLES – MAKE THEM EASIER TO READ
ALSO NEED TO PUT A SET OF CHARTS BELOW WITH AROWS POINTING FROM EACH CELL TO THE NEXT WITH MATH AND SAMPLE EXAMPLES.
ALSO NEED TO PUT IN % OF BODY WEIGHT CHARTS / FEED SIZING CHART AND CHART THAT SAYS HOW MANY TIMES TO FEED/ DAY BASED ON AGE & BODY SIZE.

Put in Conclusion.
To clear up one important issue. The importance of calculating the amount of feed fed and feeding that amount each day, as opposed to "Feeding to saturation" (feeding as much feed until the fish stop eating)
Feeding to saturation is one simple way to feed that does not need the above 3 charts and all the work collecting data and doing math. Feeding to saturation is commonly done. But feeding to saturation can waste as much as 20% of the feed fed. Putting the work to feed a calculated amount of feed is more profitable.

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Also: Note keeping the 3 charts also does not know how many fish are in a tank, cage or pond leading to surprises at harvest time, and one cannot know how well the fish are growing to make improvements while the fish are growing, also {*possibly*} leading to disappointments at harvest time. To maintain even and consistent harvests, with consistent amounts of fish being ready to sell, keeping buyers happy, one needs to keep theses 3 charts.

There is no "Voodoo" in Aquaculture – there are no mysteries. Everything that happens or does not happen has a fairly simple reason. Keeping theses 3 charts to know the 3 sets of data, allows proper management to ensure there are no mysteries or surprises. This allows the best / maximum profitability.
~~~~~~~~~~~~~~~~~~~~~~

One needs to start doing Dip-Netting of Tanks or Cages at least every two weeks.
Or if there are many tanks/ cages for a given batch then measure at least 3 tanks/ cages in each batch, and average them together to get that batches growth, and each week sample a different set of tanks/cages in a batch.

While this is simple, it does require a commitment in time and planning. It will add around 1 hour a day in daily work to gather the data, and around two hours at the end of each week to tabulate the data and roughly one day of additional work every 2 weeks.

SAMPEL CHARTS:
SAMPLE CALCULATINS / AROWS WHAT INFO GOES WHERE…

Water Quality, FCR & G/Day - Trends Log:

Average Water Quality		Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date
	NH3														
	NO2														
	NO3														
	Sechi														
	O2 At surface														
	O2 At 8'														
	O2 At 20'														
	O2 At 40'														
	Temp at Surface														
	Temp at 8'														
	Temp at 20'														
	Temp at 40'														

Cage #		Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date
1															
	FCR														
	G/ Day														
	Morts														
2															
	FCR														
	G/ Day														
	Morts														
3															
	FCR														
	G/ Day														
	Morts														
4															
	FCR														
	G/ Day														
	Morts														
5															
	FCR														
	G/ Day														
	Morts														
6															
	FCR														
	G/ Day														
	Morts														

Dip Netting Chart:

Dip Netting / Average size Calculations

Cage #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total weight at last dip netting			#																	
Total Feed fed Fed since Last Dip netting																				
# of Days since last sample																				
# of fish in Cage																				
Weight #1																				
Count / # fish																				
Average size																				
Weight #2																				
Count / # fish																				
Average size																				
Weight #3																				
Count / # fish																				
Average Size																				
Average fish size																				
Total Weight																				
Total Growth in Grams growth																				
Growth in Grams/ Day																				
Food Conversion Ratio / FCR																				

Put examples of math showing arrows of what goes in which cell, etc.

Make it very clear and simple to understand.

Based on information calculated in the Dip netting chart, input # of fish in each tank or cage, to calculate the amount of feed needed for each tank/ cage.

Feed per cage Calculation chart

Cage #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
# Fish in cage previous dip netting			#																	
Morts since last dip netting																				
Curent # of Fish in cage	3000																			
Average Weight	1																			
Total biomass in cage	3000																			
% o f Body weight to feed	0.015																			
Total Amount of feed to feed/ day	45																			
Total # of Feedings / day	3																			
Feed to feed per feeding	15																			
Size & % protiene to feed to feed																				

Based on amount of feed calculated in the feed-calculation chart fill in the amount of feed, and number of feedings to each cage/ tank per day Into the Daily Water Quality & Feed chart .

Daily Water Quality & Feed Chart

Sunny/ Clowdy/ Rain

AM — Air Temp: ____ NH3: ____ NO2: ____ NO3: ____ Sechi Disk: ____ Day / Date / Time: ____ Weather: ____

Cage #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Oxygen / Temp																				
# of Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings per day	30 lb's / 4																			
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				
Cage #	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings per day																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				
Cage #	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings per day																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				
Cage #	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
Oxygen / Temp																				
Morts removed																				
Feed Size / Feed Type																				
Total Feed To feed/ Day / Feedings per day																				
Time & Feeding #1																				
Time & Feeding #2																				
Time & Feeding #3																				
Time & Feeding #4																				
Time & Feeding #5																				

Sunny / Clowdy / Rain

PM — Air Temp: ____ NH3: ____ NO2: ____ NO3: ____ Sechi Disk: ____ Time: ____ Weather: ____

Daily Water Quality & Feed chart is what is given to the individuals who are feeding each day.

A new Daily Water Quality & Feed chart, needs to be created for each day.
This tells the individuals feeding how much to feed each cage, and now many times to feed/ day.

It is also where the information from daily feeding Is recorded. First most important detail is just recording what was fed each day.

Secondly, water quality needs to be tested twice a day. The first tests should be done before feeding. The second test at the end of the day.

Morts and other details are recorded here as well for putting back into the Dip Netting chart.

The Dip Netting chart, besides providing the #' fish to input to the Feed Calculation chart – it is also where the Grams per day (G/Day) and Food Conversion Ratio (FCR) are calculated.

G/Day, FCR, Morts, and whether the fish are eating are the key metrics that the farm manager uses to see how well the fish are growing. This is the growth performance data – it is a way that a farm manager "listens to the fish" – They are speaking to you, but you can't hear them unless you have this data. One can of course look at the fish – color/ striping, activity, appetite – but those are surface level indicators. They are important, but only say so much. The Key metrics are G/Day and FCR.

Based on the grow performance data is looking – the farm manager can start to tune their feed charts over time. For example, if one is seeing the G/Day is low and increasing the % of body weight fed form 1.5% to 1.7% works better then up-date the feed chart. Over time one can dial in the best operating metrics for each farm's particular environmental conditions.

2.1: Recommended Feeding Rate Based on % of Body Weight:

Multiply % feeding range for the size of fry times the # of fry in a tank.

Example: For a tank with 10,000 fry, that are 5 grams in size are fed at 15% of their body weight. So, for a tank with 10,000 fry = 10,000 X 5 X 0.15= 7,500 grams of feed fed per day

7,500g divided by 454 to convert from grams to pounds. 7,500g / 454 = 16.5 pounds. This should be split up by at least 3 feedings / day, ideally 5 or 6 feedings/ day.

The range of 15% to 10% is based on size range noted on the chart, feed less to the smaller size, more to the larger sizes

Fish size should be sampled at least every month but ideally every 2 weeks to determine average size of fish. ** See description below on ways to sample fish size

Stocking Rate (Number/m3)	Weight (grams) Initial	Weight (grams) Final	Growth Period (days)	Feeding Rate (%)
8,000	0.02	0.5-1	30	20 to 15
3,200	0.5-1	5	30	15 to 10
1,600	5	20	30	10 to 7
1,000	20	50	30	7 to 4
500	50	100	30	4 to 3.5
200	100	250	50	3.5 to 1.5
100	250	450	70	1.5 to 1
55	450 (1 lb.)	700 (1.5 lbs.)		1.5 to 1

Fish should be graded into different batches at least twice but ideally three times as they grow.

Best times to grade are at the 5g size and again at the 60g size. Ideally a third grading at 1/2 lb. or 227 grams.

2.2 RECOMMENDED GRADER WIDTHS:

- 25/64 of an inch for tilapia greater than 5 grams
- 32/64 of an inch for tilapia greater than 10 grams
- 44/64 of an inch for tilapia greater than 25 grams
- 89/64 of an inch for tilapia greater than 250 grams/.55 lbs

Sampling fish in a tank to determine average size:

Using an average size net - 2'X1' - sneak up on tank and net out as many fish as possible - ideally 20 fish or more

Weigh the net (excluding the weight of the net)

Count the # of fish in the net as you through them back into the tank one by one

Divide weight of Net by number of Fish = average fish size. Use this number to calculate feed amount for tank.

Do this for at least three nets per tank

Do this at least every month, ideally every 2 weeks.

2.3 Example of Tilapia Tank Volumes & Stocking Density:

	Cubic Foot (ft3)	**Gallons (gal)**	**Cubic Meter (m3)**	**Liters (l)**	**# Fish to Stock to 1.5**
40 ft x 80 ft x 4 ft	12,800	95,750	363	362,455	20,000-21,000
53 ft x 97 ft x 4 ft	20,564	153,829	582	582,307	32,000-34,000

Stocking Densities:

- 1 lb. of tilapia will need 3 gallons of water
- 1.5 lb. tilapia will need 4.5 - 5 gallons of water
- 3 to 5 gallons of water for 1 lb. - 1.5 lbs. of tilapia

Feeding fundamentals.
1) How much feed to use per day?

In order to understand how much feed is required for your system, we must first know two (2) things: 1) How many fish are in your tank/cage? 2) What size are they?

To answer the first question, we need to know how many fish were stocked in each tank/cage. It is always critically important to know how many fish are stocked in each cage and the farmer should always record this number for future consultation. We also need to know how many (if any) fish have died in that tank/cage. A farmer should always record how many fish have been removed from the tank/cage and keep a running tally over time.

To answer the second question, we need to know what the average size of the fish in each cage/tank are. To do this, a farmer must take a sample of ten (10) fish three (3) different times in each tank once per week. It is critically important to know how the biomass is changing week to week in a tank/cage to know how well the fish are growing. Let's use the following example.

Tank A was stocked with 10,000 fish. However, 100 fish have died. The remaining fish have an average weight of 60g.

Calculation: $\frac{(number\ of\ fish\ x\ average\ weight\ of\ fish\ (g))}{454}$ = Biomass of tank/cage (pounds) *there are 454 grams in 1 pound)*

Example: $\frac{(9,900\ fish\ x\ 60g)}{454}$ = 1,308 pounds of fish in the tank/cage

We now know the amount of total biomass in our example tank/cage was 1,308 pounds. But how much feed do we throw in?

Using the chart below, we can know what percent biomass to feed the tanks. Since the fish in our example were 60g, we can see that we should be feeding 4% biomass per day.

Fish Size (g) <5
>5
>20

>50 >100 >250

Percent Biomass to Feed (%) 12
9
6

4 2.5 1.5

To calculate the amount of feed in this example per day, we need to use an additional equation.

$(^{Percent\ Biomass\ (\%)}/_{100})\ X\ Total\ pounds\ of\ fish\ in\ tank/cage$ 4

$(\ /_{100}) X$ 1,308 pounds of fish = 52.32 lbs of feed.

We now know that we should be feeding our example tank 52.32 pounds of feed. 2) What size feed to use for each size of fish?

Knowing how much feed to use is great, but the information is meaningless if the feed size used is incorrect. Optimizing the pellet size is a critical component to feeding efficiently. Please use the following chart to determine feed size.

FOOD PARTICLE CHART WAS NOT COPYABLE --- PLEAE INSERT

Using our example above, we can see that a 60g fish should be fed a 3mm pellet. In conclusion, our example tank should be fed 52.32 pounds of 3mm pellet feed.