Water Quality
The Key to Good Fish Husbandry

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North Central Regional Aquaculture Center
Realism Rule #1

“"A Severely or Chronically Stressed Fish is a Dead Fish”

- Severe stress is typically caused by a sudden event, causing death within minutes or up to a day.
- Chronic stress is longer term exposure to poor living conditions, causing impairment to the immune system.
  - “A chronically stressed fish is a diseased fish and then eventually a dead fish”
Realism Rule #2

- Must closely match production goal (pounds) and subsequent feed use with the system’s ability to remove wastes!
  - In aerated Midwest ponds, a realistic production goal is 3000 pounds of fish per acre. Above that requires increasing the pond’s ability to digest additional wastes.
  - In RAS systems, production is based on gallons of water (living space) and the size of the filtration systems.
  - In flow-through systems, production is essentially based on gallons of water and exchange rate. Flushing of wastes.
An Interesting Insight

• A close aquaculture friend recently told me “A Successful Fish Culturist is not successful because he or she is a successful biologist, physiologist etc”;

• “No, he or she is successful in large part because he or she is a successful water quality and aquatic waste management specialist”.

• “If you successfully degrade generated fish wastes and uneaten food safely and therefore maintain excellent water quality, the fish will take care of themselves”.
A Real World Example (2012)

Daily Ave. Lbs. of Feed / Pond / Week

- May
- June
- July
- Aug.
- Sept.
Water Temperature?

Daily Ave. Lbs. of Feed / Pond / Week

May | June | July | Aug. | Sept.
--- | --- | --- | --- | ---
20 | 25 | 20 | 5 | 10

Ave. Water Temp. (°C)

May | June | July | Aug. | Sept.
--- | --- | --- | --- | ---
10 | 20 | 25 | 15 | 5
Low AM Oxygen?

Ave. Lbs. of Feed / Pond / Week

Ave. AM Oxygen (ppm)

May | June | July | Aug. | Sept.

Low AM Oxygen?
Un-ionized Ammonia?

Ave. Lbs. of Feed / Pond / Week

Ave. NH₃ (ppm)

May June July Aug. Sept.
Important to Monitor!

- Water temperature
- Dissolved oxygen
- pH
- Nitrogen compounds
  - Nitrite
  - Ammonia
  - Un-ionized ammonia
- Alkalinity
- Carbon dioxide
Water Temperature

- Each fish species has upper lethal thermal limits. Ex. Rainbow trout will start dying once water temps exceed 68 F.
- Elevated water temps can cause stress, leading to health issues.
- High water temps also negatively impact biological degradation of wastes. Bacteria less efficient!
- Needed to calculate un-ionized ammonia levels!
Dissolved Oxygen

- Less than 5 ppm can lead to chronic fish stress, less than 3 ppm can lead to fish deaths.
- Dissolved oxygen utilized by fish, plants, and bacteria.
- Bacteria most efficient in degrading wastes need oxygen! **Aerobic bacteria.**
- Strong pattern of daily and seasonal variation.
Oxygen: Growing Season Variation

6 AM Oxygen Conc. (mg/l)

May June July Aug. Sept.

Good

Bad
Factors Affecting Daily & Seasonal Oxygen Levels

- **Sunlight**
  - Sunlight produces oxygen, BOD uses oxygen at night.
  - Cloudy days lower daylight oxygen production, affecting night levels.
  - After June 21, losing daylight.

- **Water temperature**
  - Warm water holds less oxygen than cool water.

- **Amount of aquatic plants / algae / planktonic algae**
  - “Choked” greenery elevates daytime oxygen to very high levels but night levels are very low (BOD).
  - Sudden die-off of planktonic algae major cause for concern.
  - Aquatic plants / filamentous algae do not die-off suddenly unless you do it!
More Factors Affecting Daily & Seasonal Oxygen Levels

- **Feeding**
  - Lower oxygen levels during periods of heavy feeding.
  - Begin to elevate a pond’s BOD quickly once feeding exceeds 15 lbs per day per acre.
  - There is a feed / waste cumulative effect.

- **Fish size**
  - 2\textsuperscript{nd} year growout equals higher feed amounts in June, July, & August as compared to 1\textsuperscript{st} year fingerlings.

- **Aeration**
  - Nighttime oxygen levels can be raised with vigorous surface aeration.

- **Volume of oxygen-less water**
  - Increased volume of “hypolimnion” lacking oxygen lowers night levels.
Causes & Prevention of Low Oxygen Summer Fish Kills

Causes

- Summer Kills
  - Too much pond nighttime BOD, excessive plants
  - Sudden planktonic algae die-off
  - Poorly planned herbicide / algaecide treatments
  - Premature overturn or pond flip
Summer Overturn or “Flip” Explained

Summer Stratification

<table>
<thead>
<tr>
<th>warm</th>
<th>9 ppm</th>
<th>1 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 ppm</td>
<td>3 ft.</td>
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<table>
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<tr>
<th>cold</th>
<th>2 ppm</th>
<th>5 ft.</th>
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<tbody>
<tr>
<td></td>
<td>1 ppm</td>
<td>7 ft.</td>
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Rainstorm

| slightly cooler | 2 ppm  | 2 ppm  | 1 ft. |
|                | 2 ppm  | 3 ppm  | 3 ft. |
|                | 2 ppm  | 2 ppm  | 5 ft. |
|                | 2 ppm  | 2 ppm  | 7 ft. |
|                | 1 ppm  | 9 ppm  | 9 ft. |
Causes & Prevention of Low Oxygen Summer Fish Kills

**Causes**

- Summer Kills
  - Too much pond nighttime BOD, excessive plants
  - Sudden planktonic algae die-off
  - Poorly planned herbicide / algaecide treatments
  - Premature overturn or pond flip

**Prevention**

- Summer Kills
  - Realistic production expectations
  - Avoid herbicide treatments, remove plants manually
  - Prevent stratification
  - Aeration at the ready!
Causes & Prevention of Low Oxygen Winter Fish Kills

- **Causes**
  - **Winter Kills**
    - Opaque ice
    - Any ice with heavy snow on top
    - Oxygen lowers slowly, so may take weeks before fish are in trouble
Causes & Prevention of Low Oxygen Winter Fish Kills

Causes

- Winter Kills
  - Opaque ice
  - Any ice with heavy snow on top
  - Oxygen lowers slowly, so may take weeks before fish are in trouble

Prevention

- Winter Kills
  - Monitor oxygen
  - Remove snow or,
  - Aerate to open a hole
Aeration Insight

- **Bottom bubble systems**
  - Highly efficient at mixing the water column.
  - Prevents stratification, allowing oxygen in deep water.
  - Keeps “hole” open in winter
  - Not an effective method to quickly add oxygen to water.
  - Low cost to operate.

- **Surface agitation**
  - Very effective at adding oxygen to water, great low oxygen tool.
  - Not effective at preventing stratification, except in very shallow ponds.
  - Expensive to operate.
Most fish species tolerate 6.5 – 9.0 well, chronic exposure to lower & higher can become problematic. Avoid sudden changes!

Bacteria critical to waste degradation function best at levels between 7.0 and 8.5.

Needed to calculate un-ionized ammonia levels!

Can be done with a meter! Easy!

Higher pH in glacial Ohio, 8.5 -9.0 common. 7.0 – 8.0 in Eastern Ohio.

Strong daily variation due to carbon dioxide levels.
pH: Daily Variation

![Graph showing pH variation over 12 hours]

- **Good**: Blue line
- **Bad**: Orange line

**pH**
- 6
- 6.5
- 7
- 7.5
- 8
- 8.5
- 9
- 9.5
- 10

**Hour**
- 12
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
Factors Affecting pH Levels

- **Alkalinity**
  - Low alkalinity soils / well water cause initial pH to be lower.
  - High alkalinity soils / well water causes initial pH to be higher.
  - Western Ohio has higher alkaline soils, eastern Ohio the opposite.

- **Carbon dioxide levels (i.e plant / algae biomass)**
  - “choked” ponds have more daily pH variation caused by lower afternoon CO\(_2\) levels due to increased photosynthesis and CO\(_2\) uptake. Night pH levels lower due to high production of CO\(_2\) from high respiration by all the plants and algae.

- **Water temperature**
  - Higher water temperatures “rev” up photosynthesis and respiration, causing more daily variation in CO\(_2\) and thus pH.
Reducing High pH

- **Monitor** pH & un-ionized ammonia levels
  - Consider using methods to reduce pH once afternoon un-ionized ammonia levels exceed 0.10 mg/l.

- **Manually remove** “choked” plants / filamentous algae
  - 10-20% removal will lower afternoon uptake of CO$_2$ and lower pH.

- **Decay more organic matter**
  - Prevent stratification with bottom aeration – increases aerobic bacteria - enhances decay of bottom organic matter - increases CO$_2$ production and lowers pH. Probably best to operate 24/7 from May 15$^{th}$ onward.
  - Add soybean or cottonseed meal at a rate of 15 pounds per acre per day for a week. Uses oxygen! Be careful!
Nitrogen Compounds

Ammonia/Nitrogen Cycle

- Ammonia (NH₃)
- Fish Wastes, Uneaten Feed
- Nitrosomonas Bacteria
- Fish Feed
- Algae, Plants
- Nitrobacter Bacteria
- Nitrite (NO₂)
- Nitrate (NO₃)
Nitrogen Compounds

- **Nitrate (NO$_3$)**
  - Non-toxic up to 200 ppm. Aquatic plants / algae quickly uptake nitrates.

- **Nitrite (NO$_2$)**
  - Very toxic to fish at very low levels, causes brown blood disease.
  - Fortunately, quickly converted to nitrates by bacteria.

- **Total Ammonia (TAN)**
  - Ionized ammonia (NH$_4^+$)
    - Not toxic at typical pond levels
  - Un-ionized ammonia (NH$_3$)
    - Reduced feeding at 0.06 ppm, mortality above 0.6 ppm.
    - Levels increase with higher pH and water temperatures.
Factors Affecting Un-ionized Ammonia Levels

- pH has a large impact on un-ionized ammonia levels – water temperature less so.
- 0.25 ppm total ammonia

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<td>0.008</td>
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- 1.0 ppm total ammonia

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<td>0.166</td>
<td>0.222</td>
<td>0.287</td>
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<td>0.284</td>
<td>0.362</td>
<td>0.446</td>
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<td>0.442</td>
<td>0.531</td>
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Factors Affecting Un-ionized Ammonia Levels

- Total Ammonia Levels (no ammonia = no unionized ammonia!) Sources of total ammonia are:
  - Feed Eaten
    - Metabolism of consumed feed results in the discharge of ammonia via the gills and;
    - Decomposition of solid feces also produces ammonia.
  - Uneaten Feed
    - Decomposition of uneaten feed produces significant amounts of ammonia.
    - Note that fish retain 20-25% of feed nitrogen during metabolism, meaning 75-80% of feed nitrogen is discharged into the water as ammonia.
    - All of the nitrogen in uneaten feed ends up as ammonia.
Factors Affecting Un-ionized Ammonia Levels

- Aerobic bacteria efficiency
  - Oxygen-loving aerobic bacteria within the nitrogen cycle are very efficient at converting total ammonia to eventually nitrates. Again, no total ammonia = no un-ionized ammonia.

- Amount of oxygenated substrate for aerobic bacteria
  - Aquatic Plants – stems and leaves provide substrate
  - Pond bottom – aerobic bacteria form dense colonies on oxygenated pond bottom materials.
  - A lack of oxygen along the bottom can severely decrease the conversion of ammonia to nitrates, which could increase un-ionized ammonia levels under certain conditions.
  - Bottom oxygen needed 24/7.
Aquatic Plants .......

An absolutely critical component to pond aquaculture but too much, too little, or a monoculture can be problematic!
Pros of Aquatic Plants

- Produce the bulk of a pond’s oxygen. Critical!
- Algae excellent at up-taking ammonia directly, submerged plants fair.
- Submerged plants provide large attachment substrate for aerobic bacteria, enhancing conversion of ammonia into nitrates which are used by the plants.
- Submerged plants mitigate the water quality problems associated with crashes of algae populations.
- Aquatic plants produce aquatic invertebrates = free food.
Cons of Aquatic Plants

- Dense planktonic algae populations can crash, causing low oxygen levels and spikes in ammonia and nitrites.
- “Choked” aquatic plant & algae communities can lower AM oxygen levels to lethal levels due to high respiration. Expensive surface aeration needed.
- “Choked” aquatic plant & algae communities can raise afternoon pH levels above 9.0, causing un-ionized ammonia to potentially be a problem.
- Harvesting fish with seines can be problematic in the presence of aquatic plants.
Millcreek’s Aquatic Plants Goal

- A planktonic algae community that allows a secchi disk to be seen down to about 24 inches.
- A submerged plant community that provides about 25-30% coverage in shallow areas.
Millcreek’s Aquatic Plants Goal

- A planktonic algae community that allows a secchi disk to be seen down to about 24 inches.
- A submerged plant community that provides about 25-30% coverage in shallow areas.
- No cattails whatsoever—virtually impossible to keep a seine down along the bottom.
- Keep filamentous algae abundance low—seine collects this as you pull, causing harvest to be stressful to both the fish and you.
Set Realistic Production Goals!

- A pond’s waste management capability can support the feed required to grow about 3000 pounds of fish per acre.
- This equals about 22-25 pounds of feed per day per acre.
- Avoid the temptation to feed more to boost production. Eventually the pond’s bacteria & plant community will be unable to handle the wastes, water quality will degrade, fish will stop eating, and death could follow.
Water Quality BMP II

- Regularly monitor water quality parameters!
  - Oxygen / Temperature (AM)
    - Daily in ponds during warm weather and periods of heavy feeding. Once every 2-3 days otherwise.
  - pH, nitrites, ammonia
    - One every 2-3 days during warm weather and periods of heavy feeding. Weekly otherwise.
  - Carbon Dioxide
    - Weekly
  - Alkalinity
    - Monthly
Water Quality Goals (0.5 m)

- **Typical**
  - AM Oxygen > 4 ppm
  - pH 6.5 - 9.0
  - Hardness > 20 ppm
  - Alkalinity > 90 ppm
  - Nitrites < 0.05 ppm
  - Carbon dioxide < 20 ppm
  - Ammonia < 1 ppm
  - Un-ionized ammonia < 0.06 ppm

- **Millcreek Perch Farm’s**
  - AM Oxygen > 6 ppm
  - pH 7.0 – 8.5
  - Hardness > 80 ppm
  - Alkalinity > 150 ppm
  - Nitrites < 0.02 ppm
  - Carbon dioxide < 5 ppm
  - Ammonia < 0.5 ppm
  - Un-ionized ammonia = 0.02 ppm
Water Quality BMP III

- Religiously record water quality data!
  - Allows one to monitor trends, can be proactive in preventing a potential problem.
  - Provides a written historical record to look back over when similar concerns arise.
  - A fish health specialist / veterinarian will always ask to look at recent water quality data when problems arise.
Use Bottom Bubble Aeration!

- Prevents water column stratification.
- Better oxygen profile, including oxygen along the pond bottom.
- Improves aerobic bacteria abundance & efficiency. Slows muck build-up.
- Enhances conversion of ammonia into harmless nitrates.
- Keeps un-ionized ammonia levels at very low levels if not zero.
Water Quality BMP V

- Encourage / Tolerate a Diverse Aquatic Plant Community!
  - Combination of algae & submerged plants.
  - Mitigates seasonal and daily “boom & bust” oxygen levels prevalent in ponds dominated by planktonic algae.
  - Improves aerobic bacteria abundance & efficiency due to increased surface area on plant stems & leaves
  - Enhances conversion of ammonia into harmless nitrates.
  - Keeps un-ionized ammonia levels at very low levels if not zero.
Education! Education!

- Be a life-long learner!
- Use all sources of information on water quality, fish health, and fish husbandry.
  - State extension programs
  - Factsheets, bulletins, published articles, websites (SRAC)
  - Workshops
  - Other culturists!
- Create, review and re-work your own Water Quality & Fish Husbandry BMP – it is a living document.

Questions?