Water Quality

The Key to Good Fish Husbandry

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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

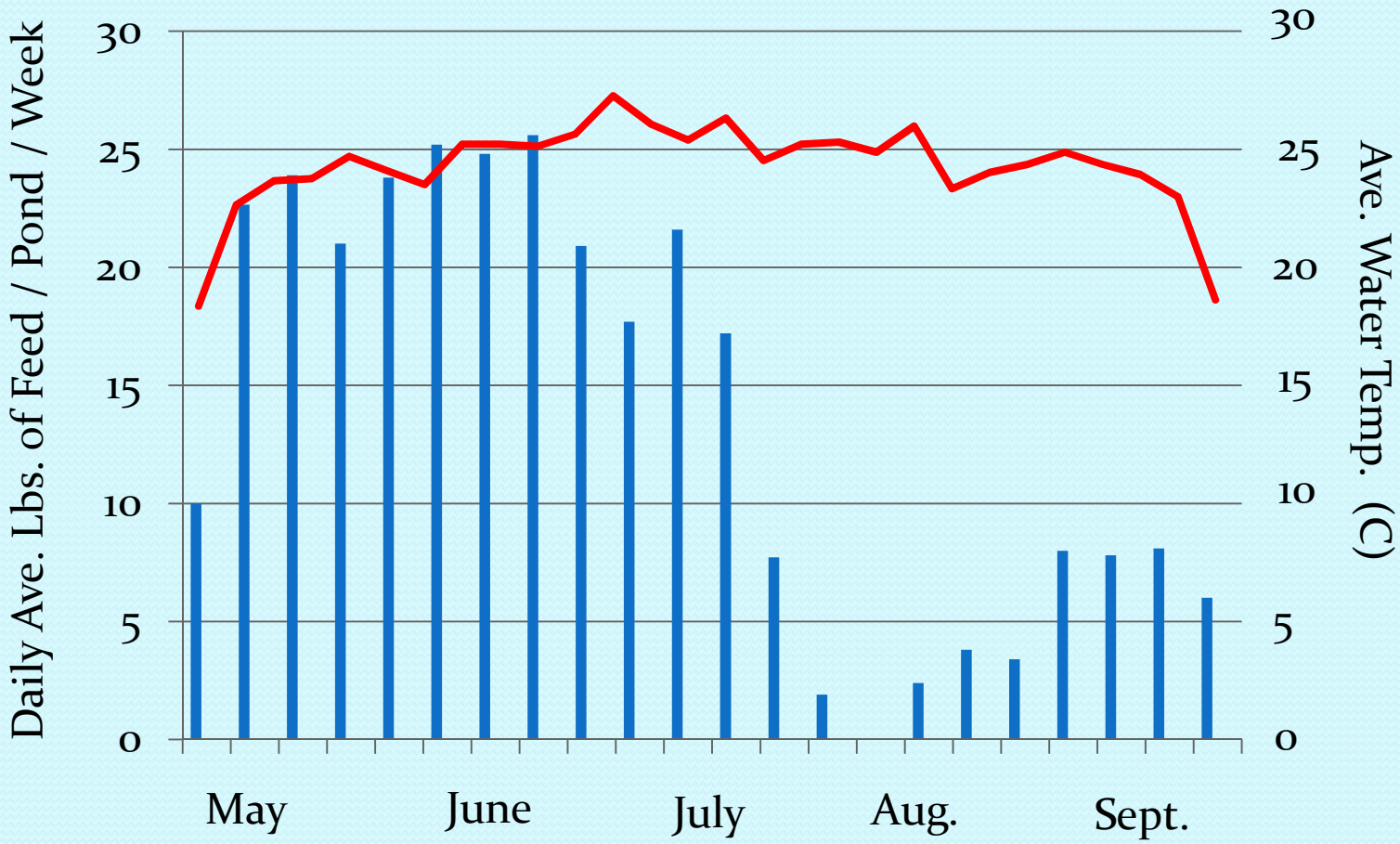
- Must closely match production goal (pounds) and subsequent feed use with the system's ability to remove wastes!
  - In aerated Midwest ponds, a realistic production goal is 3000 pounds of fish per acre. Above that requires increasing the pond's ability to digest additional wastes.
  - In RAS systems, 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

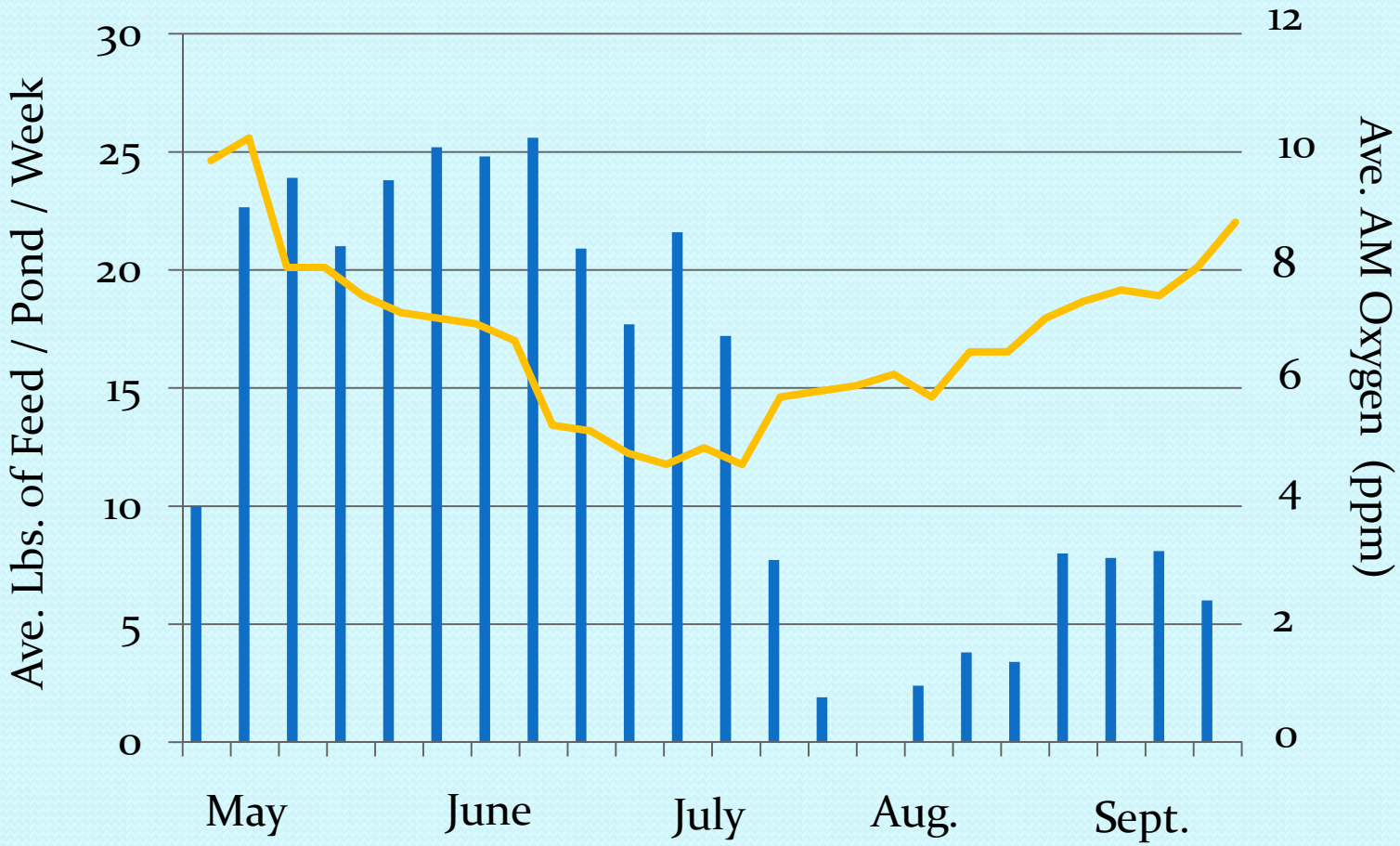
- A close aquaculture friend recently told me “A Successful Fish Culturist is not successful because he or she is a successful biologist, physiologist etc”;
- “No, he or she is successful in large part because he or she is a successful water quality and aquatic waste management specialist”.
- “If you 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)

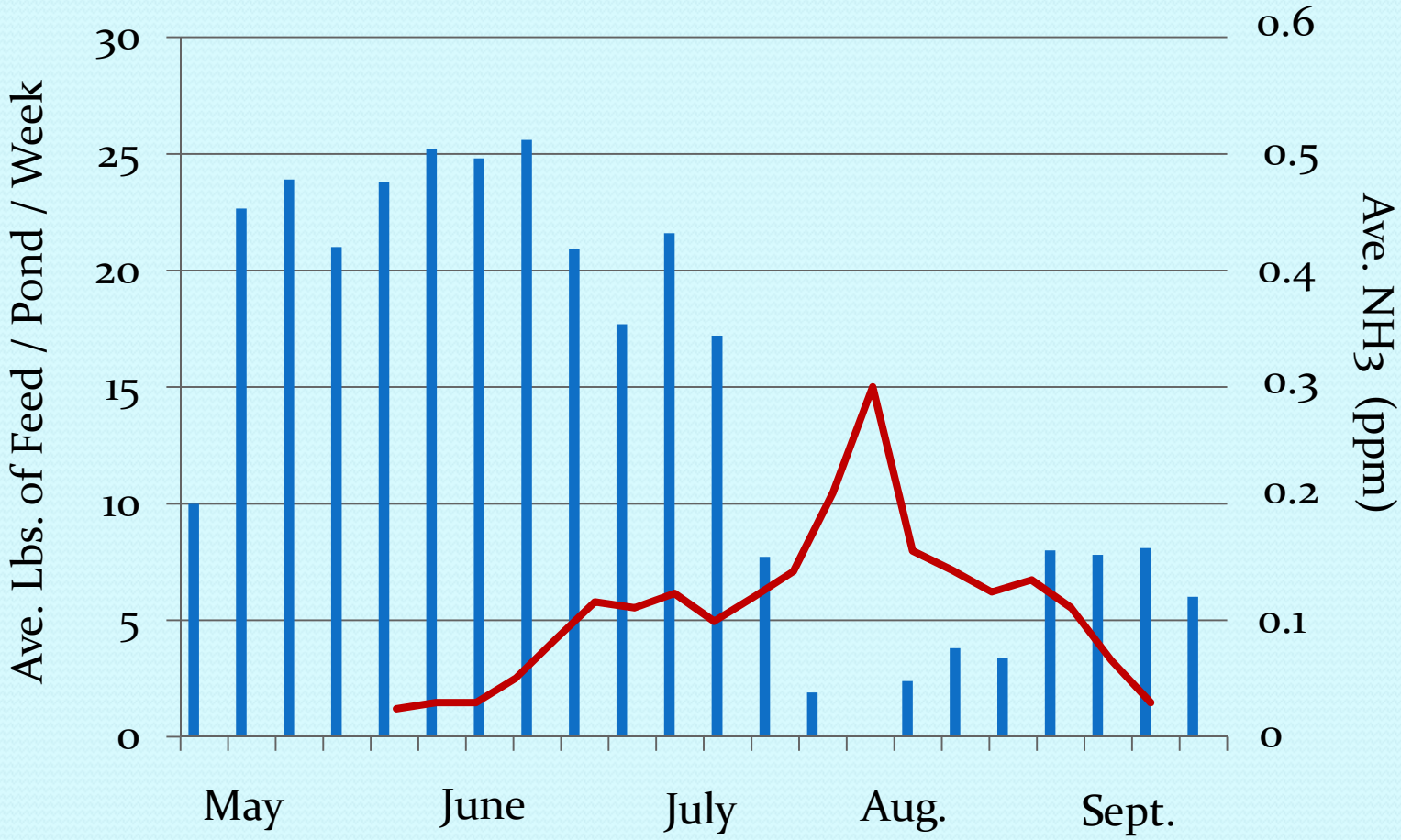
Water Temperature?



Low AM Oxygen?



Un-ionized Ammonia?



Important to Monitor!

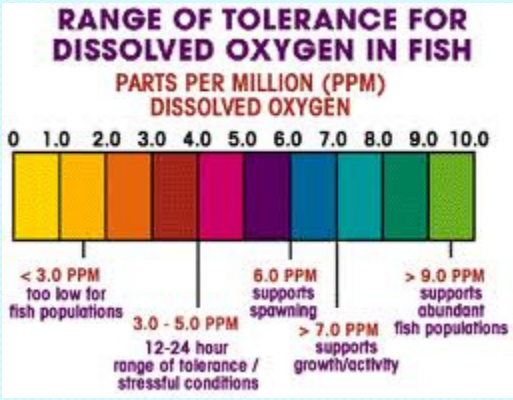
- Water temperature
- Dissolved oxygen
- pH
- Nitrogen compounds
  - Nitrite
  - Ammonia
  - Un-ionized ammonia
- Alkalinity
- Carbon dioxide

Water Temperature

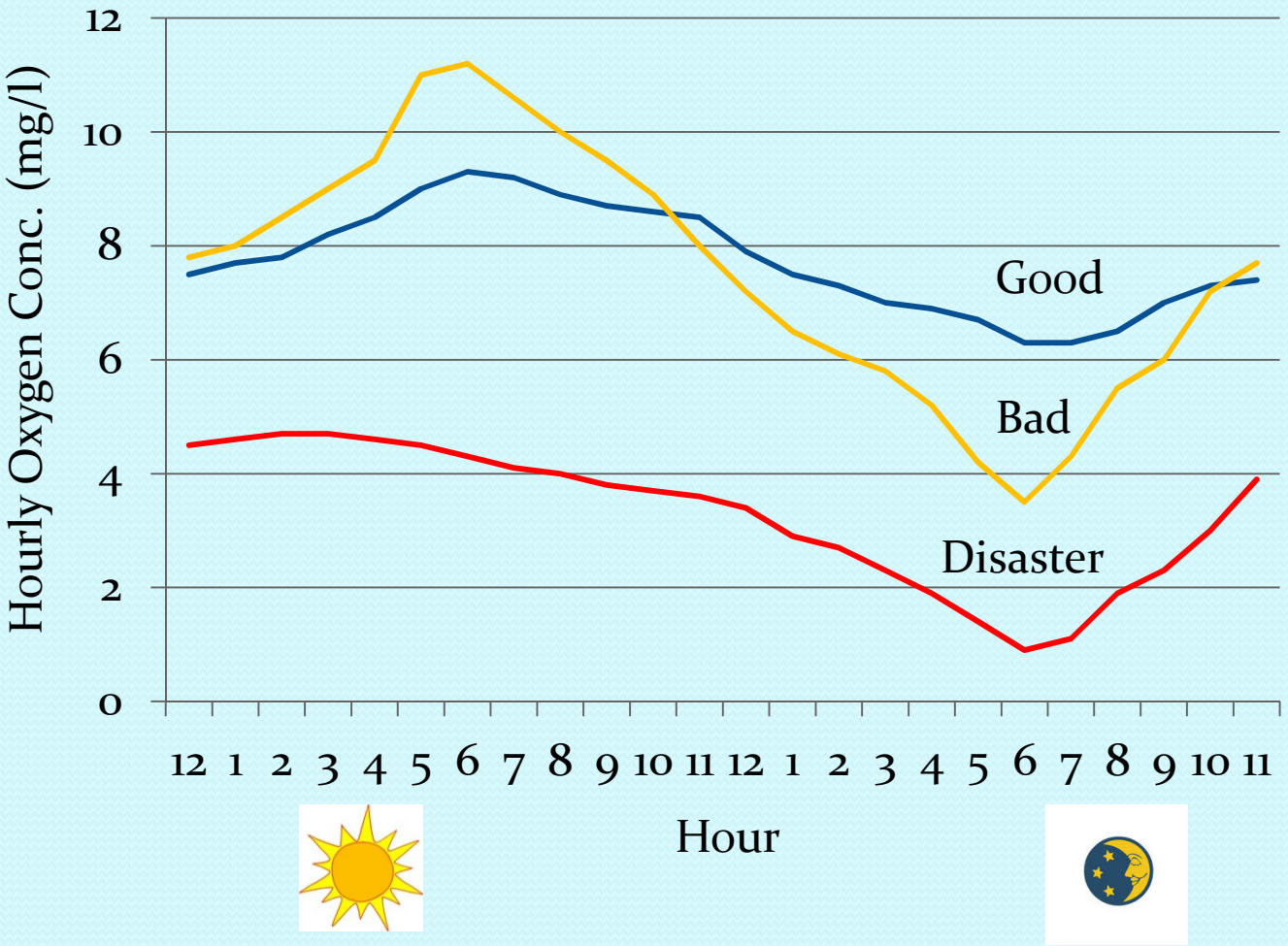
- Each fish species has upper lethal thermal limits. Ex. Rainbow trout will start dying once water temps exceed 68 F.
- Elevated water temps can cause stress, leading to health issues.
- High water temps also negatively impact biological degradation of wastes. Bacteria less efficient!
- Needed to calculate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

Dissolved Oxygen

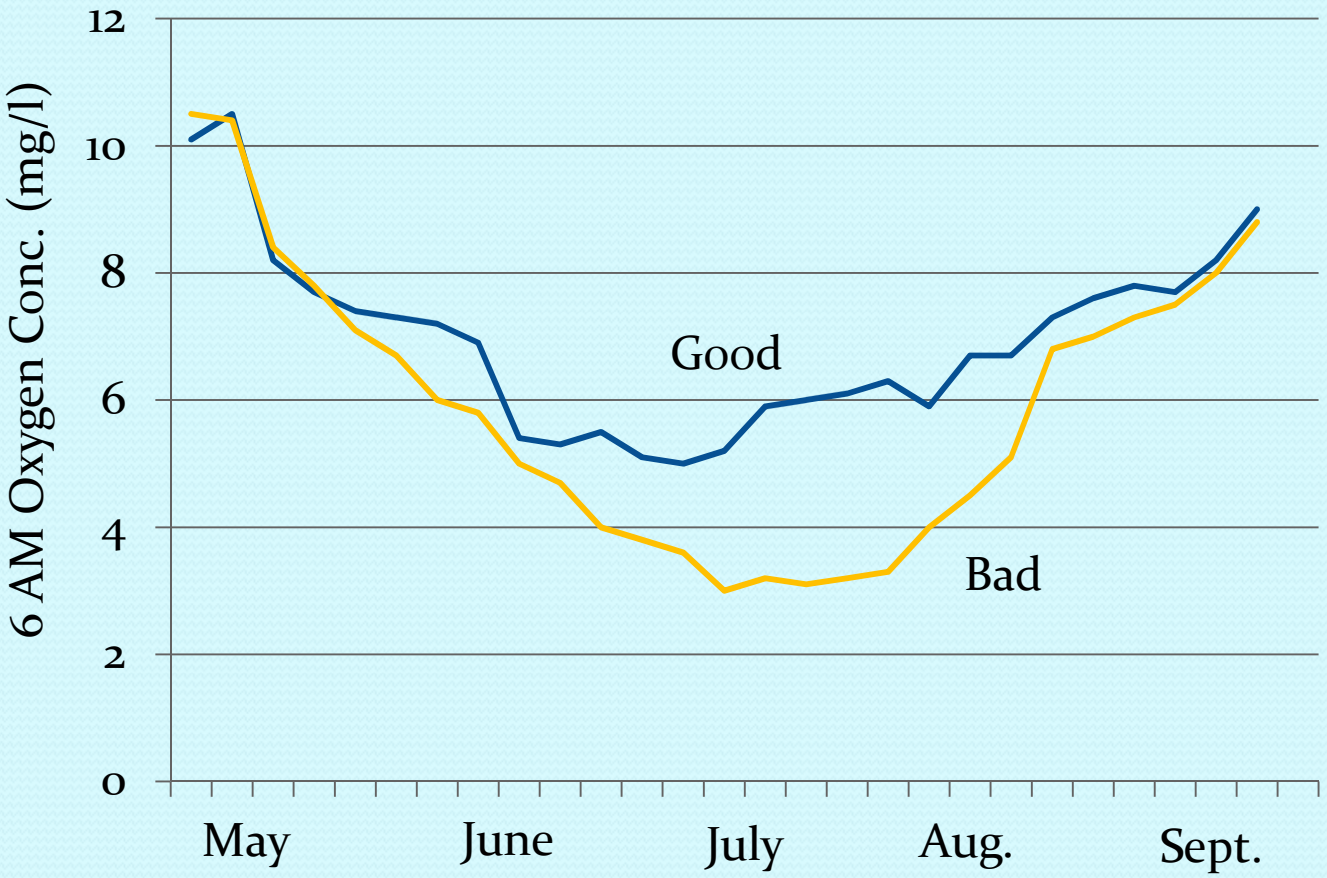
- Less than 5 ppm can lead to chronic fish stress, less than 3 ppm can lead to fish deaths.
- Dissolved oxygen utilized by fish, plants, and bacteria.
- Bacteria most efficient in degrading wastes need oxygen! Aerobic bacteria.
- Strong pattern of daily and seasonal variation.



Oxygen: Daily Variation



Oxygen: Growing Season Variation



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

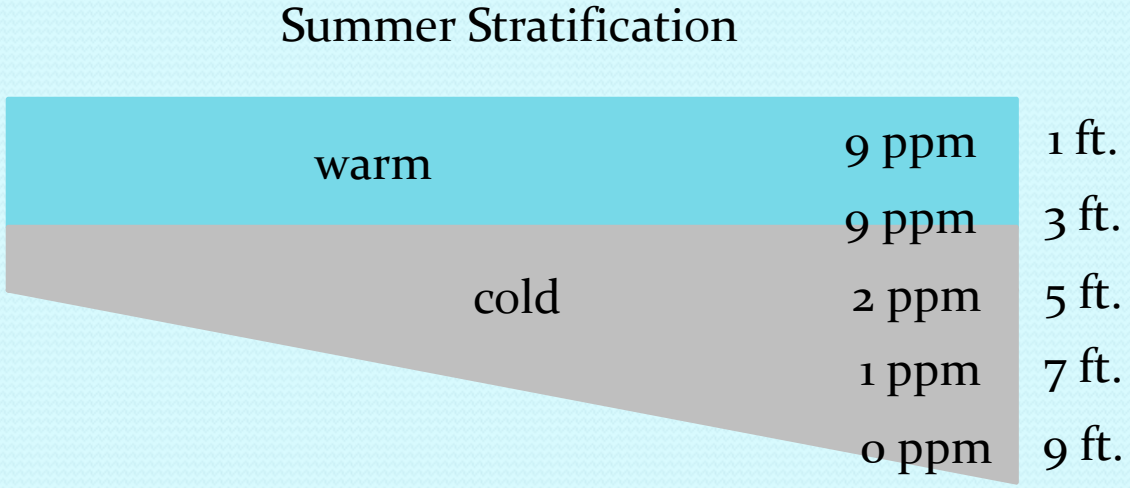
- Feeding
  - Lower oxygen levels during periods of heavy feeding.
  - Begin to elevate a pond's BOD quickly once feeding exceeds 15 lbs per day per acre.
  - There is a feed / waste cumulative effect.
- Fish size
  - 2nd year growout equals higher feed amounts in June, July, & August as compared to 1st 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



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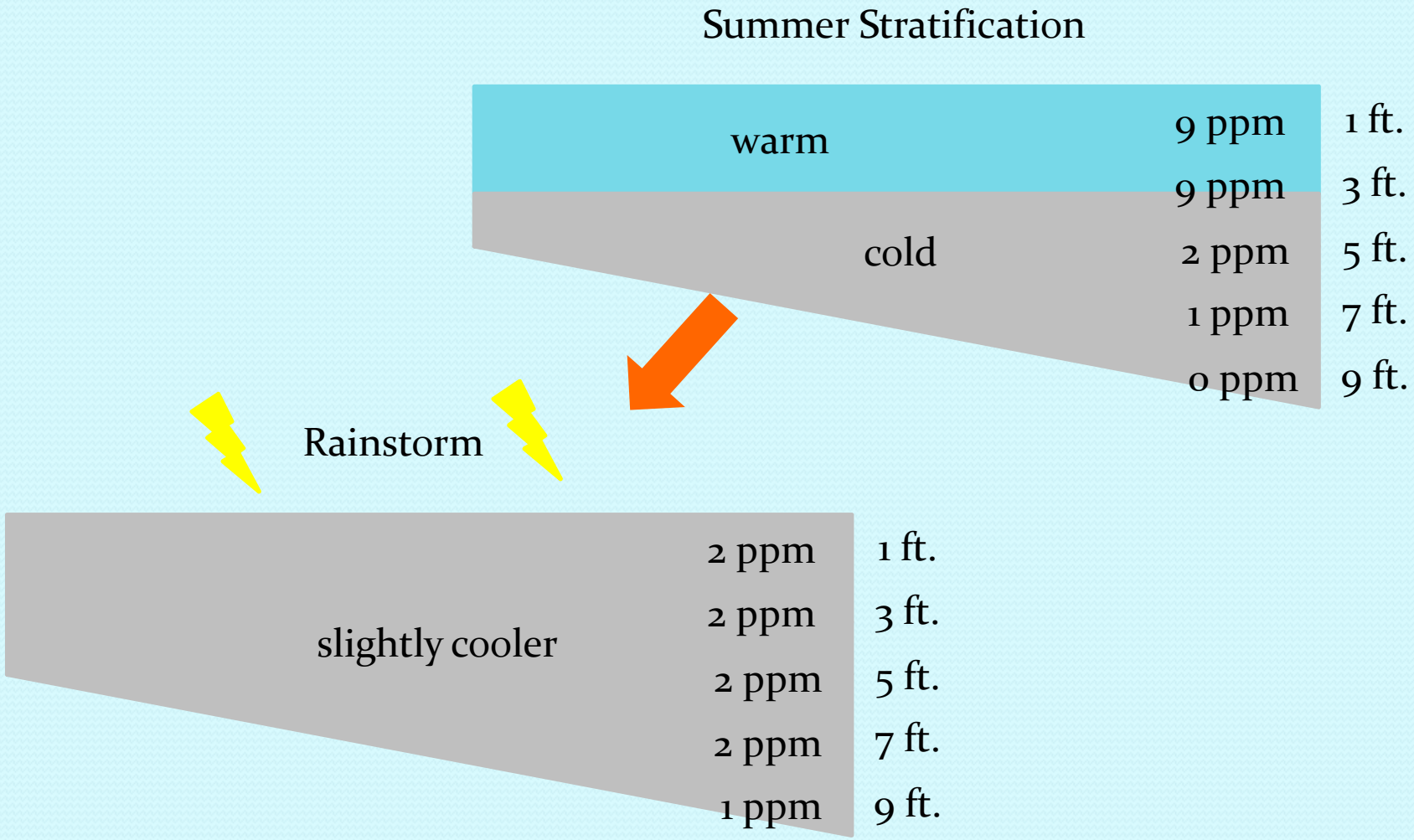

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Prevention

- 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

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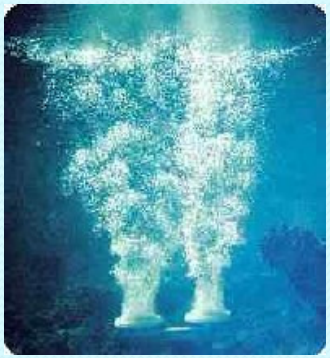
Prevention

- 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.

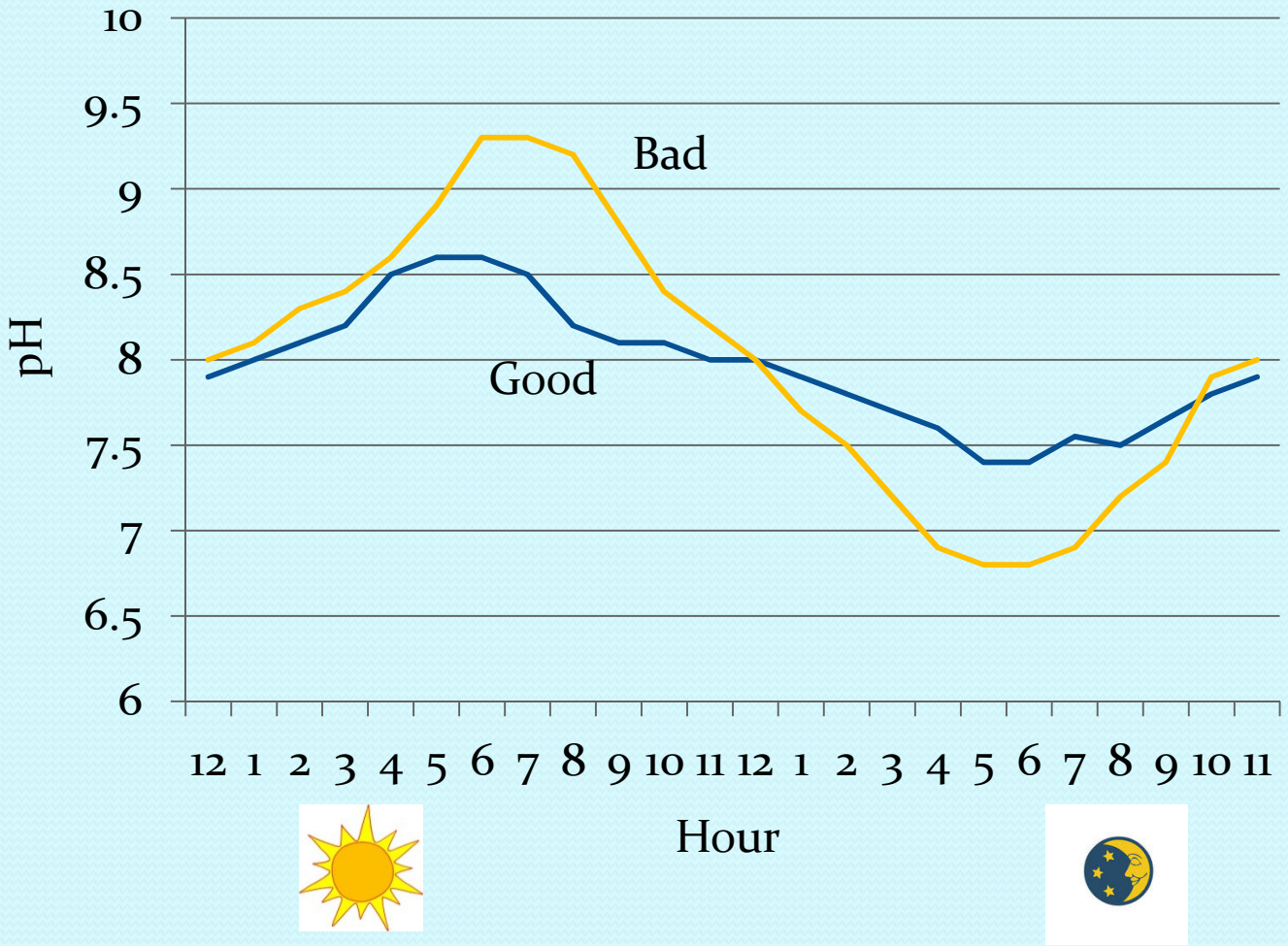


- Surface agitation
  - Very effective at adding oxygen to water, great low oxygen tool.
  - Not effective at preventing stratification, except in very shallow ponds.
  - Expensive to operate.

pH

- 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 glaciated Ohio, 8.5 -9.0 common. 7.0 – 8.0 in Eastern Ohio.
- Strong daily variation due to carbon dioxide levels.

pH: Daily Variation



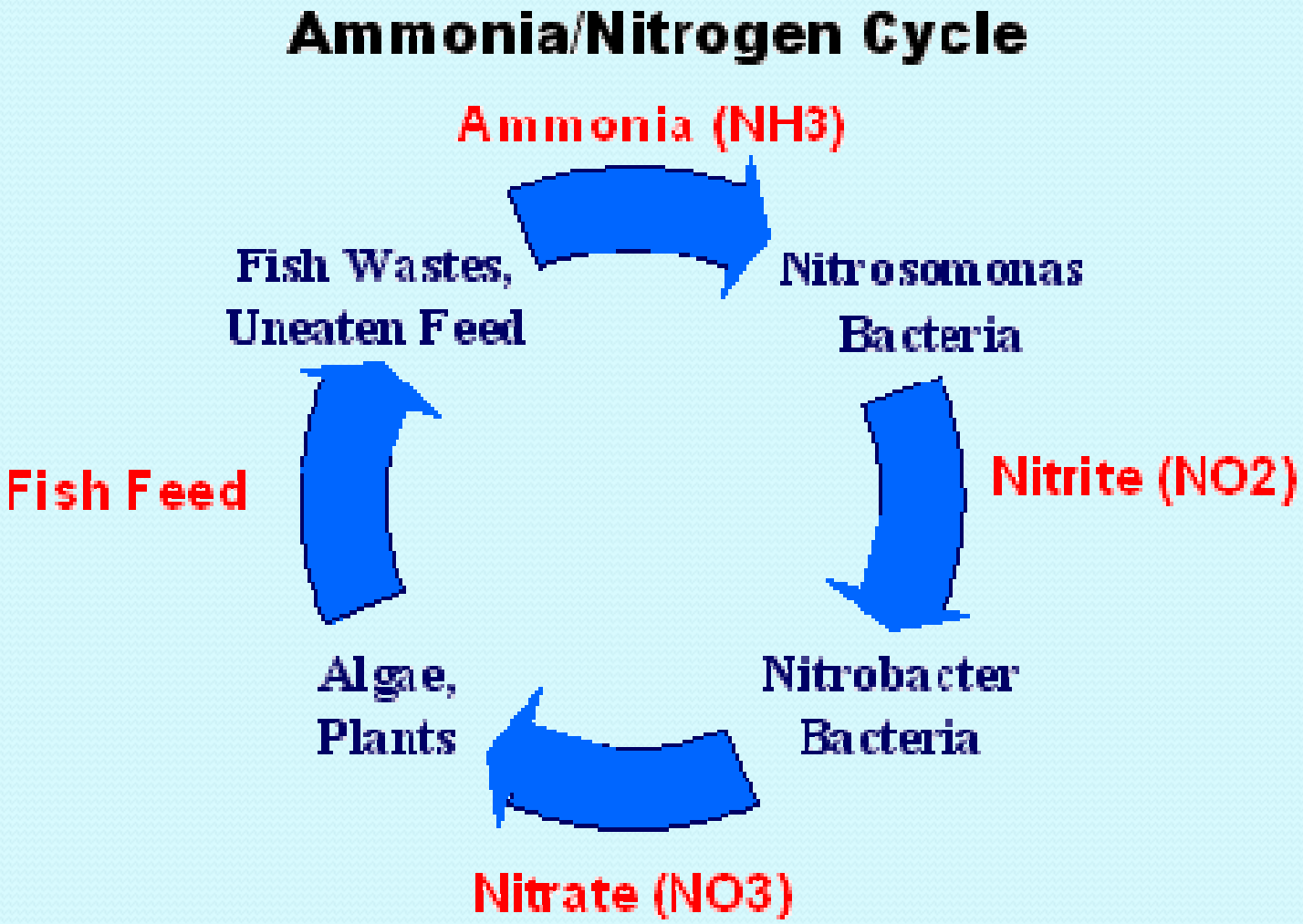
Factors Affecting pH Levels

- 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 15th 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



Nitrogen Compounds

- Nitrate (NO_3)
  - Non-toxic up 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

pH	20 C	25 C	30 C
7.5	0.003	0.004	0.006
7.8	0.006	0.008	0.012
8.1	0.012	0.017	0.023
8.4	0.023	0.031	0.042
8.7	0.041	0.055	0.072
9.0	0.071	0.090	0.131
9.3	0.110	0.133	0.154

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8.7	0.041	0.055	0.072
9.0	0.071	0.090	0.131
9.3	0.110	0.133	0.154

1.0 ppm total ammonia

pH	20 C	25 C	30 C
7.5	0.012	0.018	0.025
7.8	0.024	0.035	0.048
8.1	0.047	0.067	0.092
8.4	0.090	0.125	0.168
8.7	0.166	0.222	0.287
9.0	0.284	0.362	0.446
9.3	0.442	0.531	0.616

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

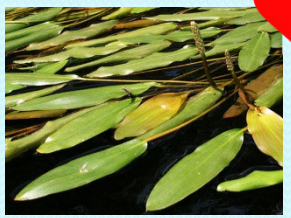
- Produce the bulk of a pond's oxygen. Critical!
- Algae excellent at up-taking ammonia directly, submerged plants fair.
- Submerged plants provide large attachment substrate for aerobic bacteria, enhancing conversion of ammonia into nitrates which are used by the plants.
- Submerged plants mitigate 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.

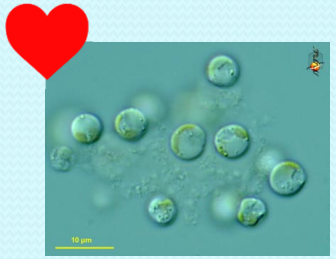
Millcreek's Aquatic Plants Goal

- 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.



Water Quality BMP I

- 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

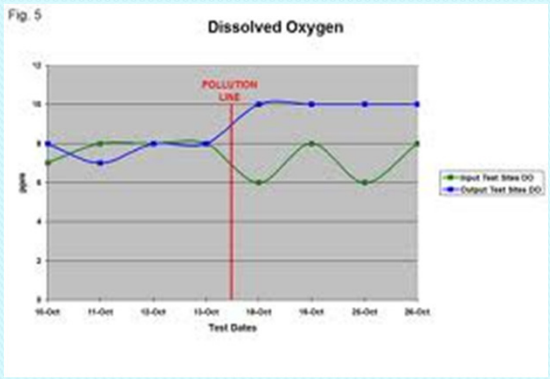
- Regularly monitor water quality parameters!
  - Oxygen / Temperature (AM)
    - Daily in ponds during warm weather and periods of heavy feeding. Once every 2-3 days otherwise.
  - pH, nitrites, ammonia
    - One every 2-3 days during warm weather and periods of heavy feeding. Weekly otherwise.
  -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



Water Quality BMP IV

- 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?