Aquaculture – A Continuum Tracking Single Species Progress Based on SARE Support

Introduction

This species summary is based on research efforts which occurred between 2008 and 2020 during which support from six Sustainable Agriculture Research and Extension (SARE) grants was provided. While the target species was yellow perch, many of the results and outcomes can be applicable to other species including members of the genus Lepomis as well as other percids. The author, Bill West of Blue Iris Fish Farm, Black Creek, WI was either the administrator of the grants herein referenced or a major participant of same. The SARE grants referenced were all conducted within the North Central Region of SARE and include the following:

FNC08-731 Study to Reduce Parasitic Infestations of Yellow Perch in Flow-Through Outdoor Grow-out Systems

FNC14-955 Increase Sustainability on Fish Farms with the Development of Value- Added Products from Fish and Fish Waste

FNC16-1064 Developing a Self-Funded Aquaculture Program for High Schools

FNC17-1105 Increasing Farm Income and Diversification by Converting Abandoned Manure Pits into Aquaculture Production Facilities

FNC18-1132 Developing a "Cold Banking" system for perch which would provide an available supply of fish for indoor grow-out facilities throughout winter.

FNC19-1166 Developing a Production and Distribution Mechanism for Feed Trained Perch Fingerlings for Use in Aquaculture Grow-out Facilities

It is not the intent of this summary to redo these project reports however, where new information has been learned since project termination, these aspects will be shared. As will be shown by this report, there are many facets that need to be addressed to result in the successful process of taking a species from "egg to market" and each completed grant advanced our knowledge of specific details in the process.

The "Big Picture" premise is that while indoor aquaculture (typically known as recirculating aquaculture systems or RAS) is promising and can be achieved, most small to medium sized fish culture operations remain outdoor operations. Regardless of the economic incentives to conduct outdoor aquaculture, two main drawbacks will always remain including biosecurity (weather, predation, biological vectors (disease and parasitism), weed management etc., and the fact that outdoor culture remains seasonal. While RAS systems are capital intensive, there are several drawbacks to indoor culture (specifically perch) which have nothing to do with money. These include:

1. Indoor culture demands the availability of feed trained fingerlings which must be available to optimize indoor production for up to three stocking/harvests per year to maintain production. Currently there is no consistent supply for a single stocking event much less three.
2. No one has put together a production model which optimizes what we know on feed, grow-out potential, husbandry, fish health etc. When Blue Iris first entered this field typical grow-out for perch from egg to market was between 1.5 to 2 years. Now with mating outdoor hatching and feed training with indoor finishing, we have achieved 10-month markets.

Again, "Big Picture," it matters not whether you are outdoor or RAS, neither option has a supply of feed trained fingerlings nor a precise recipe for success.

To summarize the previous referenced SARE projects we find that the first project was to obtain a product that was free of visible parasites (significant outdoor problem). One project dealt with creating value-added products that would supplement or enhance production. Two projects (working with high schools and farmers with manure pits) were specifically designed to make use of existing water and systems to increase production options. Finally, two other projects were meant to specifically address the shortfalls of the industry i.e., provide a source of thousands of feed trained fingerlings and show how this could be achieved for a market that needed the supply several times a year.

Chapter 1. Updating Project FNC08-731 With Twelve Years of Experience Using Pond-side Tanks

As noted right from the beginning, the whole purpose of attempting to raise perch (or other susceptible species) in pond-side tanks was to eliminate or prevent the fish from getting either yellow grub or black spot. In that effort the project was successful. There are few options available to the farmer to accomplish this without completely draining ponds each year and/or completely remove infected snails from the water source. The pond-side tank option was the least cost option especially when considering this is essentially a one-man operation.

As an overview, this statement is the most accurate assessment of the pond-side tank operation. "The pond-side tank operation is functionally similar in production potential to an indoor system while maintaining the cost requirements at or below that of a comparable outdoor system." If this is true, and it very well could be, then we have the best of both worlds – high production of indoor and low cost of outdoor. Why is this so? Over the years, several benefits of pond-side tank production have become obvious and are listed below.

Benefits of Pond-side Tanks

1. Just like indoor systems, we know exactly how many fish are in the tank and can provide the exact amount of feed needed daily.

2. Because we provide water from a pond to feed the tanks, the water exchange rate is one tank every one to two hours – a 1000-gallon tank will get from 500 to 1000 gallons per hour. Because of the exchange rate, there is no need to aerate any of the tanks i.e., the mass of the fish cannot deplete the oxygen in the supplied water. There is a need for emergency backup but that may never need to be used.

3. Continuous feeders provide 100% of the daily requirements.

4. Water spin spreads out the slow sink feed both vertically and horizontally so that even less aggressive fish are fed.

5. Tanks are automatically cleaned daily and manually cleaned weekly if needed.

6. A single pump can supply 3-6 1000-gallon tanks at about $1.00 per day electrical usage. Over the twelve years this has gone up about $0.20 per day.

7. Fish tested so far (perch and bluegill) both have achieved one inch per month growth and increased fillet yields (to 50% in perch).

8. There is no pond maintenance for weed control.

9. A one to three tank system can be purchased and installed for under $10,000.

10. Trials indicate that as many as 1500 perch can be raised in a single tank at 8 inches. If it is assumed that there are about 3.5 perch to the pound, 1500 perch is equivalent to about 430 pounds of fish per tank (can be scaled for bluegill or saugeye).

11. Blue Iris has operated a six-tank system which operates using water supplied by a quarter acre pond. This system significantly reduces the footprint necessary to operate comparable open pond grow-out systems.

12. In a typical pond, water temperatures in July and August can reach high 70s and low 80s. This time window has been known to cause fish to go off feed. There may be several factors at play here, but we know that oxygen transfer is reduced and becomes a limiting factor. This causes a window of reduced growth for the fish which may last from three to five weeks. In the pond-side tank system, we have not seen any reduction in feed uptake during this time and it may be because of the continuous water recirculation.

One might say that this is more than operating on a shoestring. And well it may be. It would be remiss if the downside of "lean" operations is not also discussed. Some problems have been encountered and these are discussed below.

One obvious drawback is the fact that we rely heavily on a single pump to drive the system. True but over the years we have learned where backups are warranted. There are three ways to keep a pump from getting water into a tank. These include:

1. Electrical power outage
2. Plenty of electricity but pump fails
3. Plenty of electricity, pump runs but line clogs, breaks, or becomes disconnected

Supplying dual backup pumps is okay but if it does not automatically switch itself from one source to another there is still someone on call. We have installed a 10KW all house generator to service the operation. The second backup was to install a high/low dissolved oxygen meter which automatically powers on and off at pre-determined setpoints. That way regardless of electrical failure, pump failure or just diurnal water quality fluctuations, water quality is optimal for the fish.

Principles of Operation

There is a major difference in the way we culture fish using pond water when we use pond-side tanks versus just having fish in the pond. Conceptually, we must look at fish culture as one big experiment in wastewater treatment. If we solve the wastewater treatment issue, the fish will be just fine. In a pond setting, we really have no control over (nor way to measure accurately) the mass of organic matter in the water. Organic matter includes not only all the fish but all other critters in the water plus all the plants, all the feed we throw in each day, as well as all the detritus (including fish waste solid and dissolved) in the water column and on the bottom. We can take an educated guess as to how much aeration is needed and production is limited or accentuated on our ability to aerate and/or reaerate to maintain the needs of the system.

In pond-side tanks we are working with a pond which has no fish in it. In fact, we hope to have a pond with no oxygen consuming entities or as few as possible. The principle of operation relies on a dependence of stable oxygen concentrations in the pond. As noted previously the objective is to avoid aeration in the tank that houses the fish. This sounds like heresy! But, if all systems are functioning as planned, we move water in and out of the tank in one hour – way before fish have an opportunity to consume all the oxygen. Standby oxygen is always available regardless.

There is a significant benefit to not aerating in the tank. In wastewater treatment, it is always easier to treat waste as a solid when it is a solid. If we aerate (and we have seen some operations where fish culture tanks are boiling with air), then by definition we have just turned all discreet solids into dissolved solids. Dissolved solids are many times more expensive to treat. So do not beat up the solids. Set up the tanks to have a continuous removal of solids and transfer the solids to a drop tank, clarifier, or hydro sieve as a preliminary treatment practice. Then in a secondary step you can reaerate to remove dissolved wastes including gaseous fish waste.

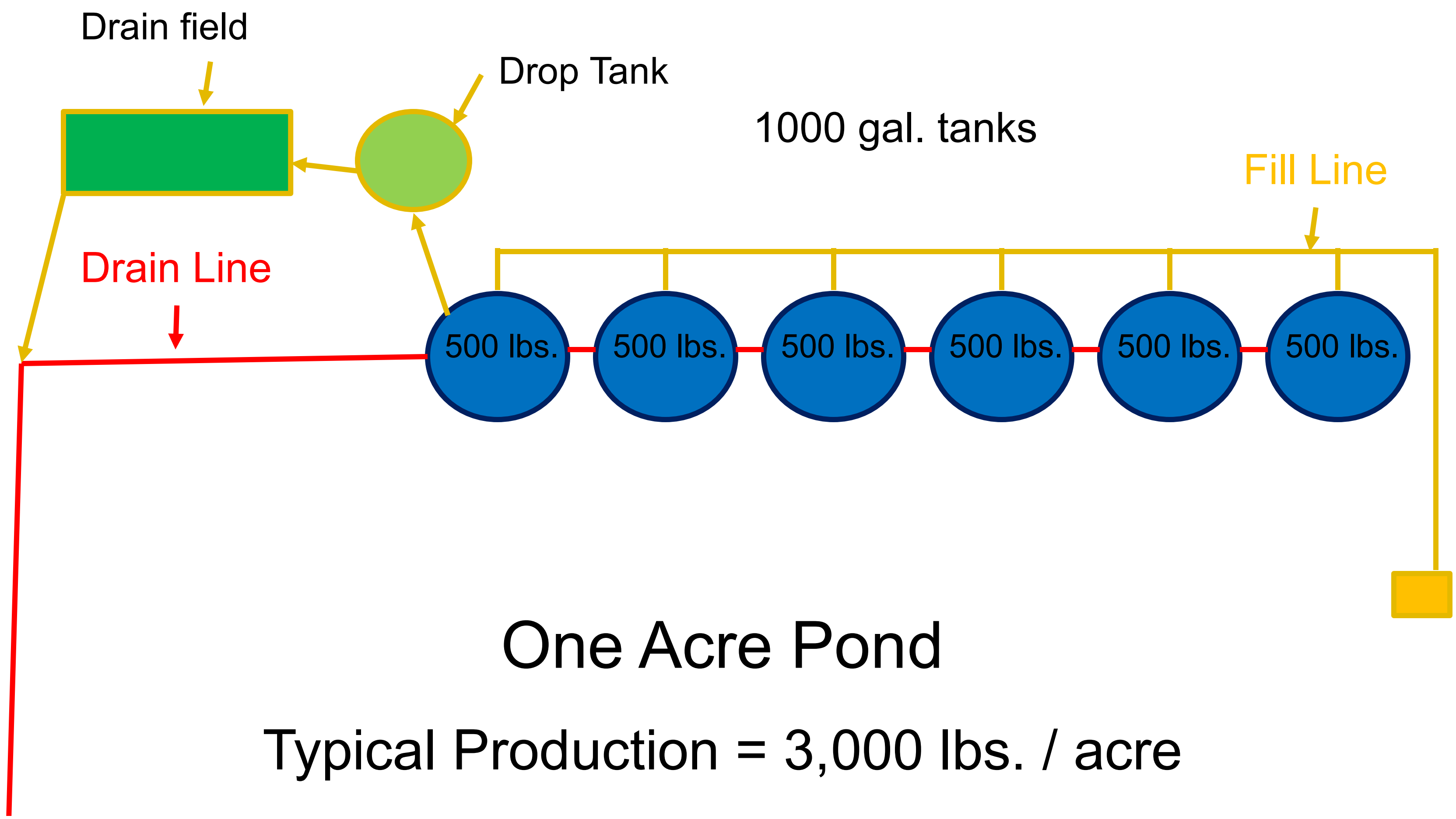
In an attempt to boost oxygen in pond-side tanks, aeration was added to the tanks in 2020. As predicted, solids were beat up quite a bit, but the ramifications of increased dissolved solids (including more available nutrients) were not predicted. Aeration resulted in an explosion of in-tank algae growth which resulted in daily maintenance and cleaning and an increase in odor. The take on this is if you need aeration, do it in the pond.

Below is a conceptual schematic of a pond-side tank system which has been tweaked over the years. The fill line is a single pump, and the setup is designed to flow by gravity from the fish tanks to the clarifier/hydro sieve/drop tank then to a sand/gravel filter prior to returning to the pond. The red line is a discharge from the fish tanks without any treatment. The green tanks assume some treatment.

Conceptually, one can keep adding tanks depending on capacity of the pump (current pumping capacity is about 160 gallons per minute). With an effective tank capacity of 1000 gallons, 160 gpm will provide 9600 gph minus friction and head loss but still enough to serve 9 – 1000-gallon tanks at one change per hour. Not shown in the schematic is the discharge of the clear water from the fish tanks. Typically, we run about 80% of the flow as a tank overflow directly back to the pond. The remaining 20% is the below grade flow carrying the solids to the drop tank.

The drop tank is still under development. We use the treatment concepts of drop tank, hydro sieve, clarifier interchangeably but this stage must be engineered to incorporate expansion. In wastewater treatment we would go from a primary settling tank to a mixed liquor (highly aerated) tank then further clarification and off to the discharge. Small systems do not need all of this unless the receiving pond is small. Larger systems must accommodate a higher level of waste treatment and it is preferable to do it prior to going to the pond than in the pond.

As noted in the schematic, the goal of a pond is 3000 pounds per acre. Here, we have six tanks with 3000 pounds stationed alongside a ¼ acre pond for comparison.


Drain field
Drop Tank
1000 gal. tanks
Fill Line
Drain Line
500 lbs.
500 lbs.
500 lbs.
500 lbs.
500 lbs.
500 lbs.
One Acre Pond
Typical Production = 3,000 lbs. / acre

Production Parameters

As first stated, one of the confounding issues with production is the lack of quality feed trained fingerlings. Blue Iris produces its own feed trained fingerlings, so this does not hamper production on a year-to-year basis. However, there are some elements to consider when setting up tanks for initiating production each year.

First, you will need feed trained fingerlings with which to stock your tanks. We are looking at a growing season of about 4.5 months in central Wisconsin. Feed trained fingerlings will come from an overwintered pond setting or possibly from a cold banked supply (discussed in another chapter). Fish raised in pond-side tanks can grow about one inch per month and therefore need to be about four inches in May – larger is better.

At Blue Iris we typically seine a pond for overwintered fish. When doing so, we will end up with fish of several sizes but prefer to harvest fish from four to six inches. As we stock tanks assuming a rate of 1500 per tank, we generally sort fish by size classes. For each three-tank set, we stock 1500 six-inch fish in one tank, 1500 five-inch fish in the second tank, and 3000 four-inch fish in the last tank. Based on experience, we know that the six-inch fish will be on the table in late June or early July. When this is achieved, we clean the tank and refill it then split the fish from the four-inch tank into two groups. So now we have three tanks with 1500 fish again and in essence are double cropping one tank each year. In actuality we are literally full harvesting four tanks.

It is possible that there might be some shorts (undersized fish) on the final harvest day. You must make a decision to either take them to market, hold them over for a second year or even sell them as premium stockers. It is well to know that perch start putting on eggs as early as August. Therefore, trying to obtain fillet weight going into September or October usually does not work as fish eat less and mass gain goes into eggs. Know when to wind down operations if you are outdoors.

Future Production Operations

Pond-side tanks are ideal for small to medium sized operations especially those limited by water resources. In the past twelve years several small operations have added tanks to small ponds and have increased production without damaging their water resource. Two other options that have been evaluated include putting a pond-side tank system in conjunction with a Community Supported Ag (CSA) setup. Here, a small water source could easily be sufficient to add fish to the weekly vegetable basket. In this case though, fish might be a seasonal harvest at the end of a fish production run and available in the fall but still part of the CSA. But as shown above, it is possible to harvest fish from an outdoor setting from June through September.

A second option, and considered highly possible, is the conversion of abandoned manure pits to fish production operations. Here, pond-side tanks can be used as described prior or in many cases, tanks can be set up in an adjacent building. Re-purposing manure pits for aquaculture has the potential to establish new sources for grow-out of food fish, fish for stocking, and operations for handling fry and fingerlings. These options are discussed in another chapter.

Chapter 2: Exploring Value-Added Products Beyond Those Discussed in FNC14-955.

There were two aspects to completing FNC14-955 including one, development of a fish hydrolysate for use as an organic plant feed and two, explore the potential for using the protein derived from fish waste as a substitute for wild-caught fish protein (fish meal) in fish feeds.

The final report for FNC14-955 indicated that fish hydrolysate could be produced quite simply and indeed could be sold for a price comparable to that of the fish fillets. In actuality, the value for hydrolysate is inversely proportional to the value of the fish.

The project was able to develop protein extracts for use as a feed supplement but were unable to find a feed manufacturer that could make a small run of fish feed for the cost of the grant. At this time there are other large university projects underway investigating this very project.

In the last six years, we have been aware of an increasing amount of need to find more uses of our fish products. The fortunes of domestic fish production have ebbed and flowed.

Chapter 3: Developing a Self-Funded Aquaculture Program for High Schools, Beyond FNC16-1064

Blue Iris Fish Farm has continued to work with the same high schools as in the original project and has added more schools as the supply of fish allows. Each of the existing schools has been successful to the point where there is an annual harvest of fish. However, since this is a school setting, the school curriculum is set to provide the most exposure of students to a wide variety of aquaculture/aquaponics experiences. This aspect alone makes it difficult to plan a single stream line of fish, plants, or a combination thereof which is conducive to generating a marketable commodity.

Given the limitations with working with schools, it should be pointed out that it is the combination of Blue Iris Fish Farm and at least one high school which proved that it is possible to complete an entire perch egg to market life cycle in less than one year. That is, we can spawn, hatch, and feed train perch at a farm setting and transfer them indoors at the end of the growing season (August/September) and have them market ready between February and March – between 9 and 11 months.

The one point that should be emphasized is that the supplier of fish should be encouraged to provide quality fish, ones that will likely offer the program an opportunity to succeed. There is no benefit to “dump” fish seconds on a high school program. The teachers will be less successful, the students will not learn how to be successful, and the fish farmer will get no eager trainees back into the work force.

Chapter 4: FNC17-1105 Increasing Farm Income and Diversification by Converting Abandoned Manure Pits into Aquaculture Production Facilities – beyond FNC17-1105.

At the beginning of FNC17-1156 we started with three farms. One farm dropped out of the program before much data could be collected, one farm ran through the entire data collection process, and one with a leaky manure pit had to be rebuilt prior to evaluation. We did find out that over the years of use, a significant amount of nutrients accumulated in the bottom of the manure pit such that we could not overcome their contribution to the ecosystem in summer. This is similar to lake dynamics where we witness lake turnover twice a year followed by a nutrient enhanced bloom.

Since the time of the project the two remaining farms did get their manure pits in workable condition and at this time are prepared to move forward. A number of options exist for a working converted manure pit. However, we will continue to discuss options relative to use in the perch industry.

One major omission in the original document was a discussion of options. From an overview, there appears to be a single pond to work with – the converted manure pit. In the perch industry this is limiting because it prevents the owner from capitalizing on the multiple aspects of the industry. Ideally, a perch operation needs three ponds – one for each major stage of development. This assumes that the operation wants to deal with all the stages of perch growth and development.

The three major stages of perch development are:

1. Hatch through about two inches and may even be used until the end of the first summer. Here the eggs are collected and incubated and held until hatch. After hatch, the fry are either tanked for feed training or released to a fertilized pond for initial feeding on zooplankton then feed trained. These ponds or tanks can be shallow – three to six feet but there needs to be sufficient water volume to maintain the water quality and house the expanding size demand of the crop for the first year.
2. The second stage is grow-out. If the facility is intending to grow-out fish for the food fish market or even extended growth stockers, there needs to be a separate pond than the first pond which holds all the fry. The second pond is for grow-out which is essential in the upper Midwest where you need two years to reach market size.
3. The third stage is the adult stage. In this pond one would typically hold brood stock. This pond needs to be of sufficient size and water quality to hold hundreds of brood stock over winter. Brood stock typically run larger than 10 inches. Prime brood stock run 12 to 15 inches and some prime females can provide over 100,000 eggs.

There is no requirement for each operation to conduct all stages of perch development. If all you want to do is provide eggs, then one brood stock pond is all you need, and your operation will have a three-week operation each spring.

The original project summary did not address other options other than dealing with a single pond. It would be remiss to ignore additional options and other strategies. Obviously, land is a huge commodity that a farmer already in most cases owns. Depending on the lay of the land, there may be an opportunity to construct multiple ponds, raceways, basins, etc. But for this discussion let us not suggest additional capital expense alternatives.

Most farms do not just have a manure pit remote from other operations. The pit, depending on size is situated near a barn, cattle staging area, or other animal holding area. Because they are adjacent to farm buildings, the manure pit is generally fed by subsurface plumbing and usually has an electrical source fairly close. These features are also required once the manure pit is converted to an aquaculture operation.

Above we have talked about using the main pond as a potential brood stock pond. We can add a second stage of the perch life cycle by converting the barn to an indoor aquaculture facility. Here we merely install flowthrough tanks. To accomplish this, we reverse the flow of the water by using water from the pond to flow through the indoor tanks. The tanks will be set up in one of several scenarios:

1. As a Stage 1 Operation – Here the tanks are set up as a hatching station. The number of eggs to be hatched is designed to match the gallons of water needed (tank space) to complete hatch, feed training, and first summer growth. Graded fish up to five inches can be either sold to other perch farmers or held into winter where this operation becomes a cold banking facility.
2. As a Stage 2 Operation – Here the tanks are set up as a grow-out station. The perch will likely start in spring (usually about May) as feed trained 4+ inch fish and will be grown out to 8.5 to 9 inches by fall. The tanks will be flow through using water from the pond as the water source.
3. As a Cold Banking Operation – Here fish are brought into the system as fish that are feed trained, and the intent is store them indoors at ambient water temperature (34 – 44 degrees F) beginning in September of each year. These fish are on a minimum maintenance diet and are sold on an as needed basis to facilities who have indoor facilities which need stocking over winter (high schools, aquaponic facilities etc.).

The idea here is to provide the farmer with additional sources of income. These three scenarios can be accomplished in addition to carrying broodstock in the pond and selling eggs in the spring. However, it should be obvious that Scenarios 1 and 3 can be conducted together as can Scenarios 2 and 3. Scenarios 1 and 2 cannot be done at the same time unless there are sufficient tanks for each scenario. The calculation of how many tanks are needed (total water volume) is based on the size of the fish (mass) at the end of the particular cycle that is in progress.

The second critical calculation to be conducted here is what to do with fish waste. We have multiple fish waste sources, and we have one pond. Typically, we can run adult brood stock in the pond and aeration needs will be based on the number of fish, fish feed needed (may have natural feed) and total volume of water (each manure pit is different in size, and some may run into the millions of gallons). Adding waste from the three scenarios could add a significant amount of waste to the pond, or it could add very little. Fish waste will be variable based on the following considerations:

1. Egg mass carries quite a bit of waste as ammonia but the sheer volume of mass even for a million eggs is insignificant with respect to the mass of the pond.
2. If fry are feed trained using live feeds, this will be inconsequential. Fry being feed trained from formulated feeds will add an insignificant amount of waste. Typically, at this stage one should be siphoning off waste from the bottom of the tanks, flows should be slow and water temperatures at ambient (likely little if any oxygen demand that cannot be satisfied by the system)
3. Once fry are trained onto pelleted feeds, waste in the form of fish waste and feed waste will need to be removed. The extent of the removal needed will be dependent on the total mass loading of the system. At some point, there will be sufficient waste that you will want to pull from the system prior to the water going back to the pond. A number of waste treatment options exist including mechanical solids separation, gravity separation and other methods for treatment of dissolved solids and gasses. The key is to continuously remove waste which would otherwise contaminate the pond. Based on experience, growing fish from four inches to market size will be the most waste intensive for two reasons. First, the fish stage of development is the largest and will generate the most waste (both fish waste and feed waste) and second, this grow-out window will occur when the pond temperature is the highest.

One limiting factor which is common to all fish farms in the upper Midwest is the fact that we have a limited growing season. Typically, our fish growing season will start in May and be nearly finished by the middle of September. We can extend the growing season to some degree by heating the water. One thing that we need to be mindful of is integrating existing systems with the aquaculture operation. Some farms are generating waste heat be it in animal heating units or methane generation. On one particular farm there was a parlor holding several hundred animal units. That farm had a problem getting rid of air in excess of 80 degrees. A heat recovery unit might have been used to dump waste heat into the aquaculture operation from September to April. These are considerations that should go into an overall plan to incorporate aquaculture onto an existing farm.

Chapter 5: Developing a "Cold Banking" system for perch which would provide an available supply of fish for indoor grow-out facilities throughout winter – developments beyond FNC18-1132

With respect to perch, cold banking is relevant for a number of reasons. First, perch only spawn once a year. Therefore, unless you manipulate the spawning cycle to have perch spawn out of cycle, e.g., as demonstrated by Milwaukee School of Freshwater Sciences, there will be only one chance to obtain eggs from perch each year. That said, there are ways to extend the perch spawning season by taking advantage of spawning cycles within the United States which may begin at the end of February and not be completed until June. However, if one only considers local fish, the spawning season usually lasts from two to three weeks – the length being highly dependent on weather conditions, particularly the onset of warm or cold spells. Cold banking is somewhat of a compromise to developing an out of season spawning program. That is, it is designed to have fish ready for culture and/or harvest outside of the normal window of growth.

Which leads to the second reason for cold banking – having fish available for culture when there are tanks which need to be filled. This points to the real reason for cold banking – the development of sustained indoor aquaculture or recirculating aquaculture systems (RAS). Those who grow perch in ponds generally follow the cycles of perch which leads to a two-year grow-out harvest. However, by transferring the perch cycle indoors into an RAS, that grow-out cycle can be nine to ten months from hatch to table. Additionally, if an RAS concentrated on initiating grow-out of perch beginning at a four-inch size, the RAS could produce three crops per year. And here is the dilemma. Who has four-inch fish available for stocking an RAS tank three times per year if it were not for cold banking or out of season spawning?

Since the time of the original grant, what has transpired in the industry? Based on the results of the Project FNC12-1132, we know we can succeed with cold banking. Do we need to? Not currently. Why? The need for cold banking reserves is mostly dependent on RAS industry demands. Currently there are three sectors that use or could use feed trained fingerlings at the four-inch size. These include high school RAS systems, small to medium sized aquaponics systems, and larger RAS systems which would actually be classified as production systems.

High schools generally use one or more tanks which could be housing one or more species. They are generally not big enough to set up a program around a single species and are more in tuned with teaching aquaculture concepts. However, they many times lose a first batch of fish and are in need of more fish or, they may require additional fish for the second half of the year.

Aquaponics systems are for the most part focusing on the plant side of production. It is rare to see perch as the fish species but that is slowly changing. Heretofore few if any tried to make money on the fish side using perch.

Large RAS facilities would actually need perch several times a year. However, to date there is not a single major RAS system producing perch (this is slowly changing as there are some startups beginning at the time of this writing).

Given the poor demand for off season feed trained fingerlings, there may no need to push cold banking at present. That said, in 2021 we saw a huge demand for feed trained fingerlings, and it is believed that if that demand could have been satisfied, that might have generated a demand for replacement feed trained fingerlings. So the industry is gaining momentum.

More discussion on feed trained fingerlings is provided in Follow-up to FNC19-1166 found in Chapter 6.

Chapter 6: Developing a Production and Distribution Mechanism for Feed Trained Perch Fingerlings for Use in Aquaculture Grow-out Facilities – developments beyond FNC19-1166.

Understanding what the term "feed trained" fingerling is half the battle. One would think that after millions of years perch would not need to be trained to feed. And they don't. However, if we want fish to eat at the rate where they can be profitably grown and do it in a controlled environment they have to be weaned off of natural feeds and "trained" to eat nutritionally prepared diets.

Perch have an even greater requirement since their mouth size is extremely small. First diets must match the small mouth size and in addition, since perch are carnivores, the protein source usually has to be a meat source (original non-fish meal diets have resulted in very poor if not disastrous results).

A survey of the industry suggests that there are perhaps three procedures for feed training perch. These include:

1. Move either fertilized eggs or newly hatched fry into pre-fertilized ponds. Allow fry to begin initial feeding on plankton up until the fry are about one inch. At that time fry should be harvested, transferred to holding tanks and be introduced to a size appropriate feed (fry feeds at this stage usually run at a high protein concentration (60-80%) and are fed up to 6% body weight). Feed training at this stage should be continued no less than two weeks, three more appropriate. Trained fish can be put back into the pond for resumption of feeding on formulated diets or fish can be retained in tanks for continued rearing or transfer offsite.
2. An all-indoor system relies on some live feeds initially but migrates through various feed sizes in 20 to 30 days. Between days 15 and 30, formulated feeds are introduced and completely replace natural feeds by day 30.
3. The third option is more a composite of the first two. Here one may use pond water (indoor or outdoor) and it is likely that there is reliance on at least some natural feeds as a first food. The introduction of formulated diets can occur as early as five days post hatch but certainly within 15 days post hatch. In the beginning, the ratio of live/formulated diet may be 90/10 but that quickly goes to 50/50 then 10/90 within a month. Since perch fry are attracted to light, a useful option is to use natural feeds during the day then feed formulated diets via belt feeder and solar lights at night.

There are pros and cons to each feed training strategy. Here is what we know:

1. Perch are capable of growing one inch per month – even from hatch
2. Perch grown in a pond will take about six weeks to get to one inch
3. Perch grown in a pond using today's numbers (2021) can achieve about 90% survival
4. Perch grown in an indoor system can achieve one inch in one month

5. Perch grown in an indoor system using today's numbers (2021) can achieve about 20% survival (that number is climbing as we get better at preparing and administering fry feeds)
6. Perch are attracted to light as fry. This aspect can be used for feed training and other situations such as harvesting.
7. Perch fry as many other fish are also attracted to flow. This aspect can be used for feeding and harvesting.

Additional perch points:

1. Perch need to be continuously size graded up to three to four inches to eliminate cannibalism and ensure even growth for a size-graded cohort
2. After a perch gets to about four inches there appears to be very little maintenance (just feeding and growing)
3. Perch exhibit sexual dimorphism – females grow much faster than males. At the end of August of the first growing season, one should have six or more size cohorts. This is the most important point for the perch grower who wants to make the most cost-effective decisions on perch grow-out. You must learn the value of each cohort and determine if a cohort is a food fish, a stocker or even future broodfish and how much labor and capital you can afford to spend on each cohort.

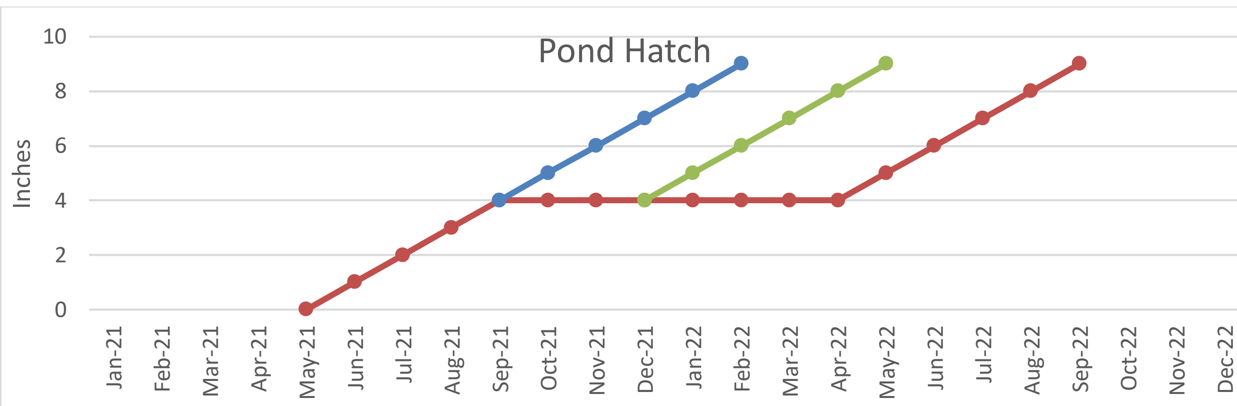
FNC19-1166 was to develop a mechanism for getting a number of perch culturists trained. The training was to essentially include information on early-stage culture because as was indicated previously, once perch are three to four inches, they are on their way. So, if perch can get from the hatch through the two-inch window, and a number of culturists have succeeded in doing so, we have made a significant jump start on the perch industry.

As was discussed in the beginning, the whole bottleneck in the perch industry is the lack of quality feed trained fingerlings. And, as was also discussed, the outdoor perch grow-out industry has very different needs than the indoor grow-out industry. The outdoor industry in the upper Midwest necessarily takes a hiatus from culture from September to April while the indoor industry has culture continue twelve months a year. For the outdoor industry, there really is no need for "out of season" spawning of perch nor for that matter the need for "cold banking" perch fry – unless the outdoor culturists are storing perch for the indoor culturists.

While there has been much research done (20-30 years) on out of season spawning, genetically manipulated all-female perch, and cold banking among other strategies, as of 2020 none of these manipulations has resulted in jump starting the industry. Over the same 30 years significant strides have resulted in much more success in the use of recirculating aquaculture systems (RAS or indoor aquaculture). But that said, perch aquaculture remains over 90% outdoors and for the most part, perch sales have been in stockers not for food fish. With the price for food fish on the rise, it is anticipated that the percent of perch grown out as food fish will increase. Parallel to that development, the increase in numbers of feed trained fingerlings will result in a more saturated supply of stockers reducing the price for that market making it more viable to grow fish out as food fish.

In the following figures we see the likely scenario of a normal hatch distribution. Figure 1 is based solely on a typical pond hatch and following only the cohort of fish that we wish to take to market as food fish. In the Midwest we should start getting eggs in late March through mid-April. Eggs could hatch by the first of May, so May is charted as zero inches. A good cohort grows at one inch per month, and you can track the progress of the cohort through the first year, over winter and a resumption of growth next spring to a harvest by the following September at 9 inches. The red line shows that progress as if we overwintered under the ice in a pond. However, if we had the cold banking capabilities, we could hold the cohort at ambient with a maintenance diet, and literally choose when to resume grow-out. The blue line and green lines show two events where some subsets of the original cohort were possibly sold offsite for stocking perhaps an aquaponics facility or maybe a high school.

Figure 1



The maximum number of fish available from a pond hatch will be in the fall of the first year. It is well to remember however that fish growth is based on light and temperature and there will be a balance in fish growth as fish start slowing down by September. To maintain continuity of growth i.e., maintain the one inch per month growth rate, you want to move fish indoors before they become too impacted by shorter days and cooler water temperatures. In addition, light and water temperature has a lot to do with sexual maturity in fish and keeping both temperatures and daylength at summer conditions reduces sexual advancement. Normally adult perch will start putting on egg mass as early as August.

From Figure 1 it is shown that used in conjunction with cold banking, given sufficient number of fish available by September there are quite a few facilities which could be stocked through winter and into May of the following year. The main question is how viable the cold banked fish would be.

Figure 2 ignores the normal pond hatch for the time being and assumes there is Out of Season spawning being done. From our work, we know that we can produce perch at any month of the year but by charting the information, it appears that an indoor facility at best can produce three separate batches of fish per year. An indoor facility may not harvest an entire tank each time a batch is completed but assume that is the case. Then an entire batch will need replacement three times per year.

Figure 2

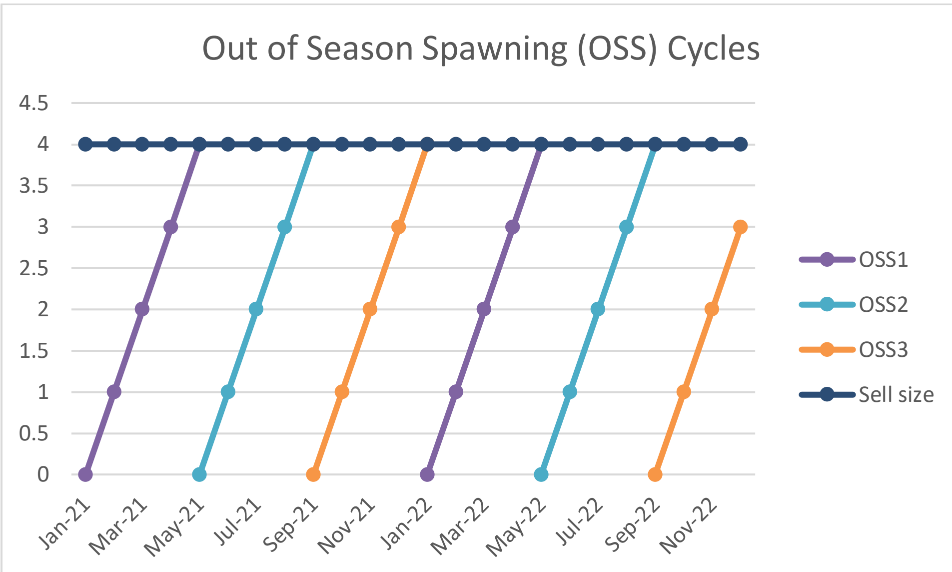


Figure 2 looks fairly busy, but it is not really. All that is portrayed is repetitive three out of season spawning events. The important part of this chart is to pay particular attention to the spawn date and the sell date. With out of season spawning, we assume that there is not going to be an attempt to grow the fish to market size. These fish will assume to be ready for sale at four inches. This facility is truly in the business of providing feed trained fingerlings in an out of season spawning setting.

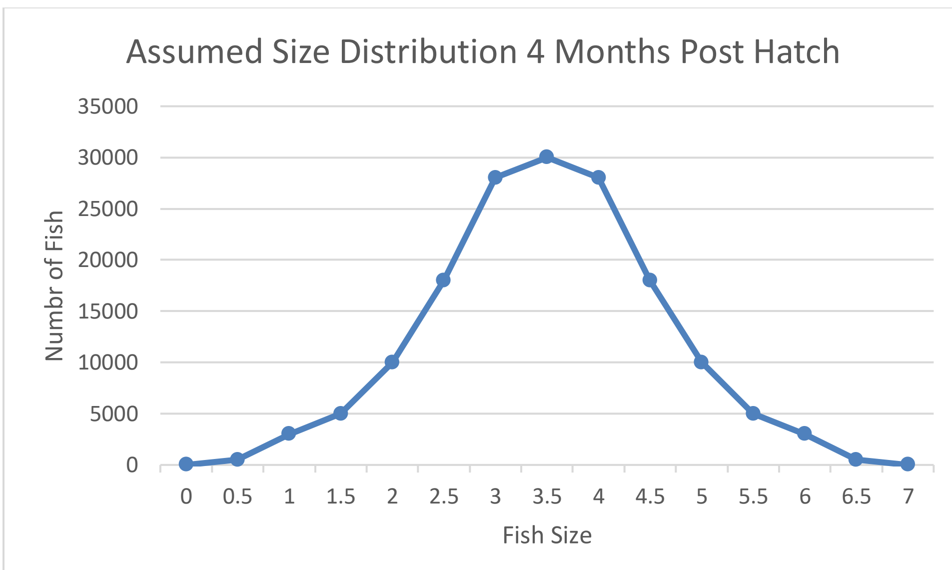
Important items to note:

1. A January spawn will provide the most available feed trained fingerlings to industry when they most need them. Why? As noted elsewhere, most perch are still grown outdoors. If this is true, then the most need for four-inch fingerlings for grow out is at the beginning of the open water season – about the middle of May. True, there are likely to be thousands of perch fingerlings held over from the previous year under the ice but for anyone short in the spring, this is the time to have the most fingerlings available. And, it also coincides with a likely window where many indoor facilities are going to need fish.
2. The second spawning cycle is in May but that lands right on top of the normal spawning cycle. This will load a batch of fish on top of the outdoor batch all at the same time. Until market demand doubles the hatch by September, it is not logical to conduct indoor spawning currently.
3. A September spawn might be the second best out of season spawn cycle. Here it is anticipated that anyone who has an indoor facility should have stocked up in September

but should have most of the fish market ready by January/February and ready to restock the tanks. Additionally, most culturists would want their tanks market ready to satisfy the demand in Lent.

One final consideration that should be taken into account both by the buyer and seller of feed trained fingerlings is the impact that sexual dimorphism has on growth rates and how soon you can expect to get an individual cohort to market. Figure 3 is a standard bell-shaped curve showing potential population densities at each inch cohort. Actual densities might not resemble this at all because we may actually have two peaks (one for each sex) and in reality, most of the really big females may have eaten a good portion of the males. In an indoor system we have to account for the 80% who have perished prior to being feed trained – where on the curve do they come from? Regardless, let us assume that there is a normal bell-shaped curve and male and female densities are distributed based on what we know of their growth rates. The rule of thumb is that out of each lot of fish, 20% are premium females that you can use for grow-out.

Figure 3



Normally when we start selecting candidates for grow-out we ignore the top five percent. These are what we call the shooters, those that grow really fast and may have done so at the expense of the males. This top five percent could be used for grow-out, but they are already one to two inches larger than the average premium females. They may be better candidates for future brood stock.

The premium stock used for grow-out should be at least four inches and probably as large as five and a half inches. If we select down as far as three and a half inches, we will have two groups of fish 3.5-4.5 and 4.5-5.5 which will encompass about 20-30 percent of the lot. By straying below 4.5 inches, we likely include most of the fastest growing males of the lot.

By selecting the top group (4.5-5.5 inches) grow-out should be complete within four to five months. The second group (3.5-4.5 inches), one would expect to add between two and four months. In total, start to finish the premium fish could be on the table in nine to ten months from hatch. A second cohort can follow the first but more likely to reach market size in ten to twelve months.

If you are a buyer of feed trained fingerlings, you have to know what size a fish should be at the appropriate age. What is presented here is rather ideal. There are a number of conditions which skew the growth rate to less than optimal including poor water quality, less than optimum temperature, tank densities (if indoor), predators (if outdoors), etc. But what is presented herein is achievable.