STUDY TO REDUCE PARASITIC INFESTATIONS OF YELLOW PERCH IN FLOW-THROUGH OUTDOOR GROWOUT SYSTEMS

Prepared for

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By

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Section 1 – Executive Summary

Blue Iris Fish Farm, LLC was awarded a Wisconsin Agriculture Diversification and Development Grant (ADD Grant No. 24023) for the purpose of studying methods to reduce or eliminate parasitic infestations in yellow perch in outdoor ponds. The specific mechanism for conducting the study was to raise perch in pond-side tanks using water known to be infected with the larval stage of both yellow grub and black spot. Since these larval stages are only slightly mobile, the hypothesis is that pond-side tanks subjected to a continuous current would prevent infection of perch, i.e., the parasites could not overcome the continuous current provided to the tanks to be able to infect the fish.

In studies conducted in 2009 by Blue Iris, 1,500 perch contained in four pond-side tanks and one control net pen were tested to determine if the experimental design was adequate to conduct the test. Necropsies of approximately 25 percent of the perch indicated that no fish were infected over the three month window of the test (June through August). Flow rates through the pond-side tanks were between one and four exchanges per hour. Water was supplied using a vertical submerged perforated pipe providing tangential flow to the tank.

In the current study (June through August 2010) Blue Iris obtained an ADD Grant to further test the hypothesis. In 2010, two pond-side tanks were employed along with one net pen. The pond-side tanks were lower profile than those used in 2009, were configured to deliver water from a horizontal surface perforated pipe, and during the test period, flows to both tanks were significantly slower than in 2009 (flow rates of one exchange per one to two hours). At the lower flow rates, parasitic infection was observed in all three environments (tanks and control pen) as early as mid-July. Infections were multiple per infected fish and as high as 30 percent of the population by the end of August.

It is obvious that the infective stages of the parasites can withstand high velocity of water. Not all of the differences in test set up could be eliminated as a cause of infection in year two of the study, i.e., it is not certain that flow alone prevented (or encouraged) infection.

Further tests need to be conducted to identify the following:

1. What is the best configuration of plumbing to ensure complete tank mixing?
2. What is the minimum flow necessary to eliminate parasitic infections?
3. Does the plumbing need to be direct from pump to tank to prevent opportunities for secondary infestations?
4. Do temperature and oxygen concentration have any effect on the amount and degree of infestation?
5. Will the presence of water flow result in lower growth rates of perch?

Based on two years of testing, it appears that pond-side tanks can be used as a mechanism to reduce or eliminate parasitic infestation of perch with yellow grub and black spot. The amount of parasitic infestation is likely a function of water flow. If this is true, then fish farmers should be able to raise fish using a water source significantly smaller in footprint than the large expanses of water currently being used at fish farms. Small pond settings between one quarter acre to one acre in size will be sufficient to grow a significant amount of fish. Likewise, since these parasites are common to many fish species, other economically important fish such as sunfish, hybrid striped bass and other species which tolerate caged culture should perform equally as well under these conditions.

Section 2 – Background

Aquaculture of yellow perch in the Midwest has historically followed two schools of thought. Indoor recirculating aquaculture systems (RAS: where water is retained and recycled) have the advantage of containing perch in a managed environment. RAS systems however have very high initial capital costs as well as high operational costs. RAS systems have historically suffered from the inability to obtain adequate high quality feed trained fingerlings with which to stock the RAS system. Outdoor pond systems, on the other hand, are significantly less costly both in upfront capital investment and operations. However, outdoor systems are plagued by environmental factors including temperature control, weed problems, parasites and predation. These environmental conditions make it somewhat impractical, if not impossible, to estimate standing crop, establish feeding regimens, and harvest. Lack of the ability to have intimate control over these parameters has reduced the amount of fish that can be harvested from outdoor systems and the quality of outdoor grown fish is somewhat less than that of RAS counterparts. In terms of measurable parameters, indoor systems will outperform outdoor systems with respect to sheer numbers that can be grown per gallon of water, the health of indoor versus outdoor fish (parasitic infestation), and the fillet yield per fish (typically five to ten percent higher in an indoor system).

Neither the indoor nor outdoor systems can practically operate independent of one another in the upper Midwest where production is primarily pond-driven . That is, indoor systems rely on production of high quality fingerlings from pond settings throughout the year as a stocking source. Outdoor systems which are only capable of seasonal production (especially in the Midwest) rely on indoor systems to move production indoors for feeding and growth continuity. Maximum production and ensuring a steady supply of product are dependent on mating indoor and outdoor systems. A discussion on the benefits of mating these two systems was presented during the Midwest Perch Forum (West, 2006) and further described in *Feasibility Study to Evaluate the Economic Viability of a Perch-Based Grower and Marketing Cooperative in Wisconsin* (West, 2008). Instances of double and triple cropping a RAS system as described by West (2006) were demonstrated in Ohio as recently as 2007 (Lynch, personal communication).

As noted above, fish production in an outdoor system on a fish per gallon basis falls far short of what can normally be achieved indoors. There are several reasons for this but by and large, ponds will not significantly increase in production unless there is a complementary increase in energy input. Examples of costly energy inputs include increases in oxygen to satisfy the extra demand by fish, oxygen for effectuating wastewater treatment (treatment of fish waste, too much feed, and decaying organic matter) and possibly manipulating temperature and day length for maximum production. Pond operations have not cost nearly as much to run as RAS systems simply because pond operations are not energy driven.

There have been several studies which have shown that pond production can be significantly increased with some increase in energy input. These modified pond systems include partitioning

systems, in-line raceways, floating raceways, and pond-side tanks. While all of these systems do increase production, the best production for yellow perch seen in an outdoor system in the Midwest is approximately 18 months from egg to market size. However, this rate of production is predicated on the assumption that high quality feed trained fish can reach four inches the first year, will over winter in ponds, and can resume growth to maturity (approximately eight inches) in an outdoor production facility by the fall of the second year. This has to be achieved while at the same time the parasite burden does not influence early mortality, growth and flesh quality.

While pond production can be increased substantially, the question is whether or not it makes sense to encourage the development of intense outdoor aquaculture systems if the fish are still subject to parasitism and the attendant diseases and mortality. Two of the most common visible parasites, yellow grub and black spot (trematode worms), are typically found in outdoor pond systems and their presence in the flesh of fish severely reduces the value of final product (Figures 2.1 and 2.2). Infestations typically result in fish that cannot be sold in the food market, for which they were intended.

Figure 2.1 Observable yellow grub in an approximatge five inch yellow perch

Figure 2.2 The same yellow perch dissected to show the infestation which appears in the fillet

Photos by Andrew West, UW-Stevens Point

This study focuses on research to overcome the impact of these two parasites on outdoor aquaculture systems. The life cycle of these digenetic parasites is fairly well understood. Both parasites need three hosts including a bird for the adult stage, a snail for the intermediate stage, and finally the fish. There has been much research done on interrupting one or more of the host transfer stages. To date, most biological and chemical means of parasite control have had limited success. There has been a study conducted by the University of Wisconsin-Stevens Point (Stevens Point, WI) under a North Central Regional Aquaculture Center (NCRAC) grant which looked into non-traditional biological approaches to parasite control. The study described herein is an offshoot of the UW-Stevens Point study designed to test a specific hypothesis that “the current flow in pond-side RAS systems will prevent grub infestations.”

It is known that the infective stage of the parasite is a free swimming larva. While mobility of these free swimming organisms is adequate to accomplish infection, it has not been demonstrated that these free swimming forms can withstand water current. In general, ponds do not have significant current and tend to be ideal environments for parasitic infestation. However, it is not known if parasitic infestation can occur in flowing water and more importantly, in pond water that is flowing during the very brief period (hours) when larva are infective.

The question to be addressed by the study is whether pond water, which is known to be infected by these parasites, can be pumped into a pond-side RAS system without infecting the fish. If the fish do not take up the parasites, this will have a significant impact on raising fish outdoors. Beneficial impacts include being able to supply parasite free stock to indoor RAS systems, being able to provide a parasite free food fish product, and increased production of pond-based systems using a hybrid pond-side RAS approach in this region of the U.S.

Section 3 – Introduction

In 2009, Blue Iris Fish Farm, LLC received a Sustainable Agriculture Research and Extension grant (SARE Grant No: FNC08-731) to conduct studies on the use of pond-side tanks to eliminate or reduce parasitic infestations of yellow perch. To execute this grant, Blue Iris set up four 1000-gallon tanks. These were fed a continuous water supply from a three-acre pond. Water was directly pumped to each tank in tandem with the influent entering the tank via a vertical standpipe with flow tangent to the sidewall. All tanks were fitted with double drains (top and bottom). Flow was set between one and four tank volumes per hour. The tank setup is pictured in Figure 3.1. A single net pen was constructed and installed in the pond along a dock approximately 40 feet from shore. This pen was used for a control.

Figure 3.1 Seven-foot diameter tanks used in 2009. Feed pipe is a common manifold separately valved. Bottom drain is also a common manifold.

Three hundred parasite-free perch were stocked into each of the pond-side tanks and the control pen in June 2009. During each month for three months a necropsy was performed on a lot of fish from each tank and pen for the presence of parasitic infection (necropsies conducted by University of Wisconsin-Stevens Point). Of the 1,500 perch used for the study, none were observed to have parasitic infections by the end of August.

The 2009 study did have some limitations. It was observed that water conditions in late July and August were less than optimal. Water temperatures in August elevated to 27^0C. The elevated temperature coincided with lower than desired oxygen levels. Oxygen concentrations became a limiting factor for the study and needed to be overcome for a permanent design.

Blue Iris evaluated three scenarios which would require an oxygen backup system for emergency use. These are described below:

1. Emergency oxygen supply in the event of power outage. A generator could supply power in these emergencies but someone would have to be onsite to actuate the generator.
2. Emergency oxygen supply in the event of pump failure. Here a generator would do no good unless it was used to activate an air supply while the pump was repaired or replaced.
3. Emergency oxygen supply in the event of no flow or low pond oxygen levels. This actually happened. Neither the electricity nor the pump failed in 2010 but flow was restricted due to pipe blockages. The correction was to provide an oxygen sensor in the pond-side tank. The oxygen sensor would signal oxygen deficiency at a pre-determined minimum concentration e.g. 6.0 mg/L. When the oxygen concentration fell below 6.0, an actuator value would open allowing oxygen from an oxygen cylinder to feed each tank. Once the oxygen level was returned to an acceptable level, the actuator valve would close shutting off the oxygen. This configuration would solve the problem caused by any of the three emergency conditions. While one would expect the power to be restored or a failed pump repaired or replaced, at least oxygen would always be guaranteed while the oxygen supply lasted, and this could be for one to two days depending on the supply available.

If follow-up investigations were to be conducted, several limitations need to be addressed. As noted above, a backup system for oxygen needed to be installed. In addition, in the first study, the pond-side tanks were located along a shallow bay (3 to 4 feet of water) which stagnated in August. The chosen location made it impossible to obtain a quality water supply. High water temperatures were observed in August, heavy weed growth stagnated the water, algae clogged the plumbing, and biological demands in the pond reduced the oxygen in the supply water at the pump intake.

Irrespective of the limitations, the result was that no fish were observed to become infected with parasites.

In 2010, Blue Iris was awarded this current ADD grant to continue the parasite study. In this second year, Blue Iris was to increase the number of fish in each tank to reflect real farm production conditions. In addition, Blue Iris kept records of all the electrical usage associated with individual pumps so as to provide a general cost expectation for operations.

To accommodate the need for higher water quality, Blue Iris moved the tank setup to a more central location along the pond and relocated the water intake to the center of the pond thereby having the ability to pull water from any depth between the surface and eight feet.

Section 4 – Methods

Section 4.1 Equipment and Tank Setup

In May 2010, Blue Iris installed two 1000- gallon pond-side tanks. These tanks were standard stock tanks which were nine-feet in diameter and 32 inches deep. Each tank was fitted with top and bottom drains. The incoming water was supplied via a ¼ hp Superfalls Low Head Pump (Model KJ11000) capable of delivering 183 gpm. Water intake source was the middle of the pond with approximately 70 feet of run from the pump to the tanks. A 3000-gallon green tank was positioned between the pump and the pond-side tanks. The purpose of the green tank was to provide a water reservoir for the ability to gravity feed water to each fish tank and to pre-filter water of unwanted debris and larger predatory beetles. The overall value of the green tank will be discussed in Section 6.

Water was pumped to the green tank using four inch PVC. Water from the green tank was split into three lines, two three inch PVC lines and one two inch line. Each line contained separate shut off valves which allowed the system to operate with many flow options. The discharge of the pump was also fitted with a valve to control pump flow rate. Throughout the project, the pump was never run at maximum as the volume of flow was capable of feeding not only the test tank setup but also an additional six adjacent tanks used on the farm.

Each tank was fed water via a two inch PVC off the three inch delivery line. In contrast to the previous year, the incoming water line to the tank was delivered via a horizontally configured PVC pipe. The horizontal configuration may have caused some problem with the overall success of the project because it may have resulted in inadequate flow velocities in the tank top to bottom (see discussion in Section 6).

Each tank was fitted with a top canopy which covered a four by four foot section of the tank in the middle. Attached to the top and positioned immediately after the intake pipe was a belt feeder. Belt feeders were filled daily of an appropriate sized food (Silver Cup, slow sink), the quantity of which was determined weekly based on fish growth and tank mass. Each morning fish were also hand fed to determine feed response. Pictures of the tank setup are shown in Figures 4.1 and 4.2.

The outflow from both the top and bottom drains was discharged back into the pond. No attempt was made to filter the waste. As a practical approach and for a more permanent setup, waste filtration is recommended as it can be put to good use elsewhere. More importantly, there is no value and a strong disincentive for adding oxygen-demanding waste to a pond.

Figure 4.1 General tank setup with green tank in background
Intake is on dock in middle of the pond behind the green tank

Figure 4.2 Close up of tank showing influent pipe, top drain, and 4x4 cover to which shade cloth is attached. Intake pipe can be rotated to direct flow down or horizontal for more tank speed.

Section 4.2 Electrical Equipment

Blue Iris uses a number of electrical pumps to run the operation. These include a 2-hp pump for the well, a ¾-hp Gast rotary vane compressor for aeration, and up to four Sweetwater ¼-hp water pumps. The well is used sparingly and does not add water to this pond. The aerator is normally run 24 hours per day every day of the year. For this project, one line was used to provide aeration to the green tank. Sweetwater pumps are used in numerous places to pump water and there are backup pumps available for these. In 2010, each pump run time was recorded so that energy usage and costs per pump could be determined. With the Sweetwater pumps, energy usage is variable depending on the amount of throttling that is provided each pump.

Section 4.3 Fish Stocks

In June 2010, Blue Iris purchased approximately 1,500 parasite-free fish to be used for the project. These fish averaged 5.7 mm in length and weighed 7.8 grams. Once conditioned, these fish were added to one of the pond-side tanks and the net pen. A second batch of 1,000 fish was obtained. The average fish was 11.3 mm in length and weighed 9.9 grams. The second batch was observed to be slightly parasitized and was segregated in a second tank. An aliquot of fish from both batches was taken and a necropsy performed by UW-Stevens Point student interns. Necropsies were conducted under the direction of Dr. Todd Huspeni, parasitologist with the University of Wisconsin, Stevens Point. Data relative to the pre-study infection rates is provided in Section 5.

Section 4.4 Procedures and Record Retention

Records were kept daily relative to the operations. Fish were fed daily as noted above. Electrical usage was recorded as to the number of kilowatts used per day, which pumps were working and their hours of usage. Blue Iris maintains a separate power source which is independent of residential usage and is devoted to the farm operation.

Tanks were cleaned as needed and water chemistries were taken several times per week. In mid-July it was noted that the incoming water from the pond was low in oxygen so an aerator was added to the green tank and run continuously. Dissolved oxygen concentrations in the green tank and subsequent receiving tanks remained above 6.0 mg/L after the aerator was installed.

Each month, samples of 30 fish were taken from both pond-side tanks and the net pen. These samples were taken to UW-Stevens Point and a necropsy performed. The resultant data is provided in Section 5.

Section 4.5 Additional Studies

In an effort to determine exactly when parasitic infections occur in young of the year additional samples of free run perch were obtained in July and August 2010. For these investigations, approximately 130 perch (two inch or less) and 80 perch (two inch or less) were seined from the pond in July and August respectively. The reason for collecting only fish two inches or less is because these would most likely be young of the year. Aging the fish at UW-Steven Point indicated that these fish indeed were young of the year. Some fish of the July batch were placed in aquariums at the lab at Stevens Point while others were evaluated immediately. The purpose of retaining live specimens was to determine if perch which initially appeared free of parasites might actually be infected. An infectious stage may need an incubation period during which to manifest itself and become an observable infection. It is known that stress may contribute to the manifestation of black spot in perch. All of the fish were eventually evaluated. The fish obtained from the August seine were all tested earlier as some were already observed to have been infected by yellow grub. All data from these collections appears in Section 5.

Section 5 – Presentation of Data

5.1 Fish Data

In June 2010, approximately 2,300 fish were stocked in two pond-side tanks and one net pen. The stocking densities, stock identification, and initial average length and weight are noted in Table 5.1. Initial parasite densities of the primary stocks were also identified and included on Table 5.1. The fish in Tank 2 were noted to have a light infection. Of the 50 fish tested from Tank 2, seven had at least on grub while three fish had two grubs. This level of parasite infection is normally insignificant as they can be removed readily during the filleting process.

Table 5.1
Initial Fish Stocking Data

Parameter	Net Pen	Tank 1	Tank 2
Stock Density	300	1000	1000
Stock Derivation	Parasite free stock	Parasite free stock	Some infection noted
Average Length	78 mm	78 mm	99 mm
Average Weight	5.7 g	5.7 g	11.3 g
Initial (%)Parasite Presence	0	0	14

Fish were held in their individual tanks or pen from June through August. At monthly intervals, 30 individual fish from each treatment were collected and tested for the presence of parasites. Monthly data obtained from the fish is presented in Table 5.2.

Table 5.2

	Net Pen			Tank 1			Tank 2		
Date	Weight (g)	Length (mm)	#Infections	Weight (g)	Length (mm)	#Infections	Weight (g)	Length (mm)	#Infections
5-10-10	5.7	78	0	5.7	78	0	11.3	99	10
6-21-10	11.5	92.2	0	11.2	92.8	0	22.0	110.8	4
7-26-10	32.6	126.3	6	21.7	114.5	0	24.5	117.5	23
8-23-10	38.6	130.95	24	31.4	132.6	34	42.2	141.6	33

Fish lengths for the three treatments are plotted on Figure 6.1 while fish weights are similarly plotted on Figure 6.2. The number of parasitic infections observed in the necropsied fish is shown in Figure 6.3 with percent infections appearing in Figure 6.4. It is noted that in Tank 2, the number of infections decreased from May to June. The differences in Figures 6.3 and 6.4 are due to multiple infections for some of the fish, i.e., the total number of infections (Figure 6.3) is larger than the number of fish sampled (30 fish per treatment).

Figure 6.1
Length of Fish (May through June, 2010)

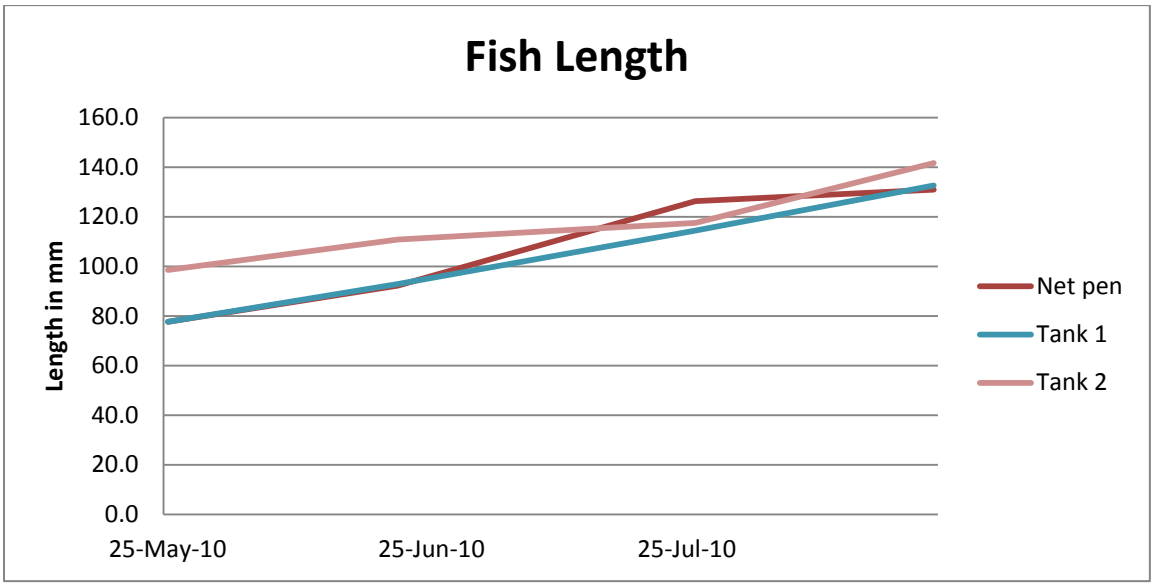


Figure 6.2
Weight of Fish (May through June, 2010)

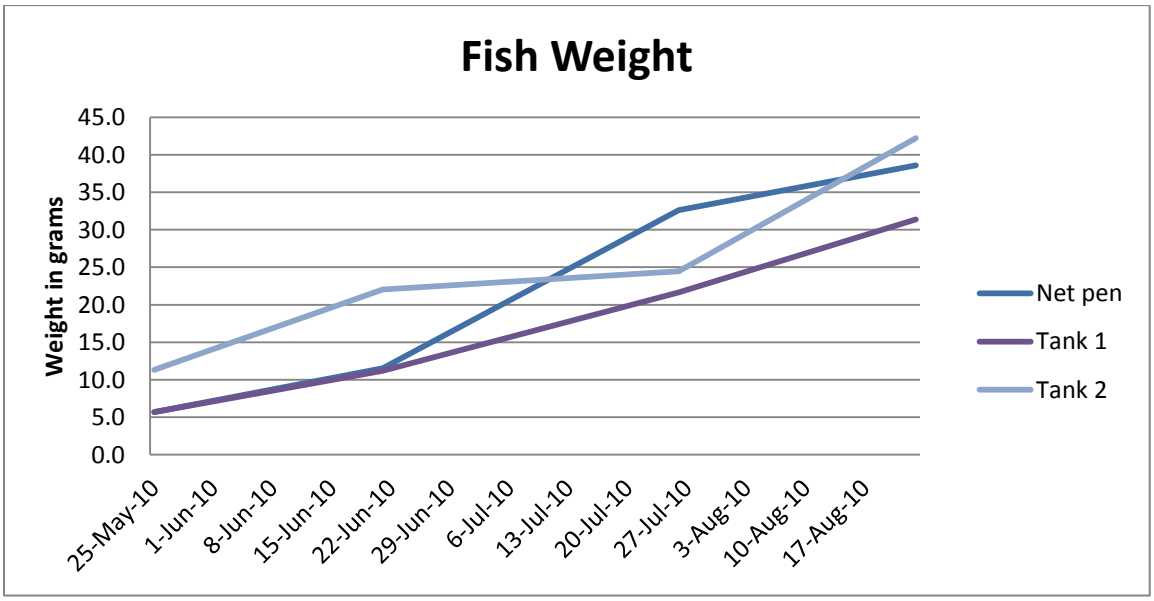
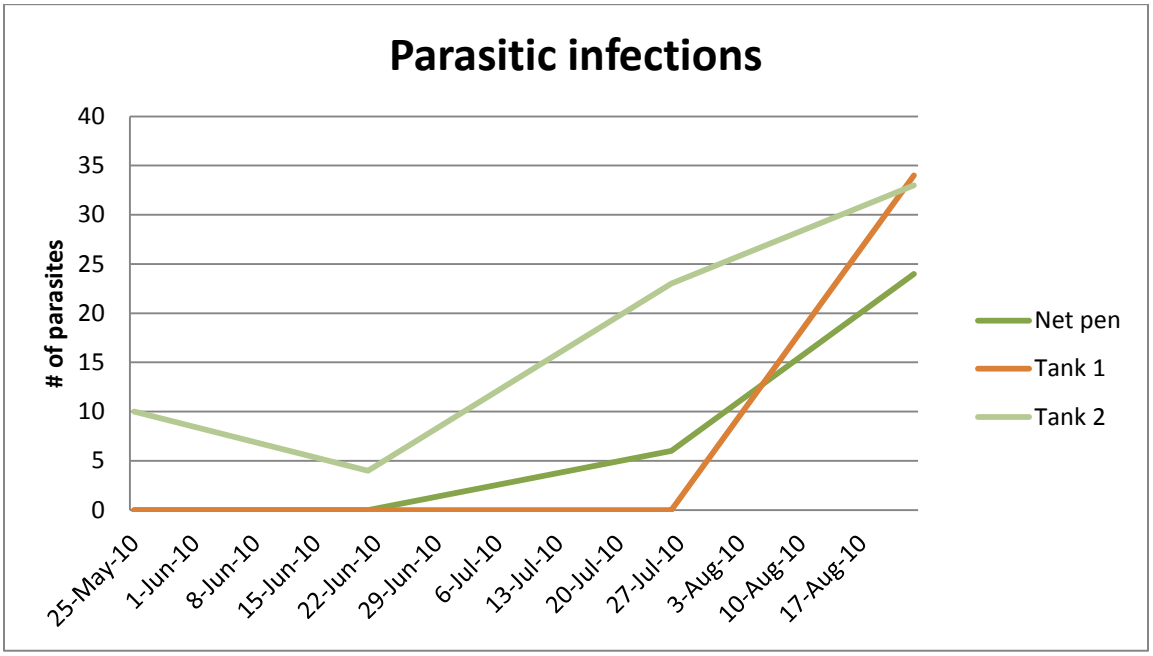
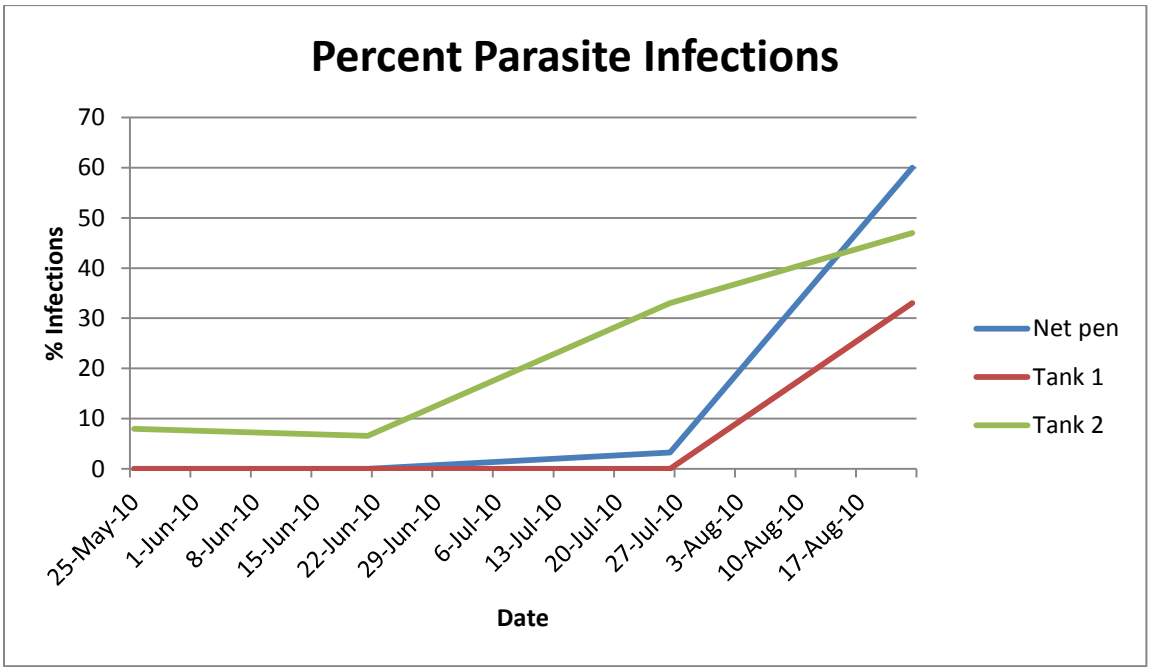


Figure 6.3
Number of Parasites per 30 Fish Sampled*
May through August, 2010



For Tank 2, the number of fish sampled was 50 in May but in all other sampling events per treatment the number sampled was 30 fish

Figure 6.4
Percent Parasitic Infections per Treatment
May through August, 2010



5.2 Electrical Use Data

Blue Iris used three types of pump systems including, pump for the well, aerator, and pumps for delivering water. Based on the data collected over a period of five months (April through September) Table 5.3 shows the electrical usage and cost associated with each pump.

Table 5.3
Electrical Consumption and Costs
Associated with Pumps

Pump	**Estimated KW hours**	**Estimated Cost**
Well (2HP)	88 kWh/24 hours	$0.1176/kWh = $10.35/day
Gast Aerator ¾-hp rotary vane	13.6 kWh /24 hours	$0.1176/kWh = $1.60/day
Superfalls #1 ¼- hp	8 kWh /24 hours	$0.1176/kWh = $0.94/day
Superfalls #2 ¼- hp	8 kWh /24 hours	$0.1176/kWh = $0.94/day
Superfalls #3 ¼- hp	8 kWh /24 hours	$0.1176/kWh = $0.94/day
Superfalls # 4 ¼- hp	8 kWh /24 hours	$0.1176/kWh = $0.94/day

Section 6 – Discussion of Data and Findings

6.1 Test Setup Differences between 2009 and 2010

In 2009, Blue Iris conducted the test study to obtain preliminary data to indicate whether or not pond-side tanks could be a tool for use by fish farmers to reduce or eliminate parasitic infections by yellow grub and black spot in yellow perch. The test duration in 2009 was from June through August and was terminated in late August when water quality problems limited growth of perch. Blue Iris was successful in demonstrating that pond-side tanks could be used to prevent parasitic infection of yellow perch as no infections were observed in the 1,500 fish exposed to infected pond water. Unfortunately, no infections were observed in the net pen control either.

The 2010 study herein described duplicated the 2009 efforts with the following exceptions:

1. Pond-side tanks were moved to an area of the pond where a water source from the center of the pond could be obtained.
2. Pond-side tanks were lower profile and wider than the 2009 tanks (9'wide X 28 inch versus 7.5'wide X 60 inch sidewall).
3. Pond-side tanks in 2010 had a horizontal surface influent distribution versus a vertical submerged influent distribution in 2009.
4. Pond-side tanks in 2010 were fed from a gravity tank versus direct pump in 2009.
5. Pond-side tanks in 2010 had a flow rate resulting in a water change every one to three hours versus one to four changes per hour in 2009.
6. Pond-side tanks in 2010 were stocked with about 1,000 fish per tank versus 300 in 2009.
7. All of the test fish used in 2009 were from parasite-free stock. Stocks of parasite-free fish were limited in 2010 so only one test tank and the control were stocked with parasite-free stocks. The second tank was stocked with fish that had a minor existing infection.

6.2 Discussion of Fish Data

Necropsies performed on delivered parasite-free fish indicated that the fish were in fact free of parasites at the onsite of the study. One thousand parasite-free fish were stocked into Tank 1 and 300 were similarly stocked into the net pen. An additional 1,000 fish containing minor parasite infections were stocked into Tank 2. Of these fish, the original 50 fish necropsies indicated that seven had grubs (4 with a single grub and 3 with two grubs). This level of infection is considered minor because these can be easily removed during processing and do not result in loss of marketable fish. As shown in Figures 6.3 and 6.4 there was actually a loss of observed infection in Tank 2 by the June assessment. The perceived loss was probably due to sample size.

By July all three treatments (both tanks and the net pen) were observed to have some parasitic infection and that number increased significantly by August ranging between 30 and 60 percent of the fish sampled. The range of infection (numbers of grubs per fish) was from zero to a maximum of nine. Infection rates greater than one or two become very costly to remove during processing unless they are associated with the gill or tail. During the necropsy, each grub found was measured for length and location of infection was noted, i.e., tail, gill, or muscle. With multiple infections, it was noted that usually all three locations on the fish were infected. The only difference between treatments was that Tank 1 did not have observable infections until August. Tank 2 had significantly more infections than the net pen until August when the net pen exceeded Tank 2 in the number of infections. Theoretically, the net pen should have had the most infections because the pen was located directly in infected water and exposure potential would have been high. However, since the infection(s) are due to the presence of an infected snail releasing parasites, the following scenario needs to occur:

1. The pen needs to become coated with algae,
2. The pen needs to be colonized with snails,
3. The snails have to be pre-infected or wait for a blue heron to provide the infection,
4. The infection needs to mature in the snail and be released,
5. The larvae released from the snail must infect the fish, and finally,
6. The infection in the fish must progress enough to be observed during the necropsy

Since this whole scenario takes time, it is probable that snails in the vicinity of the net pen were pre-infected so as to produce infections in fish by July (six weeks). It should be noted that all of the infections observed were of the yellow grub. No black spot was observed in any of the samples either year. The avian host for the black spot is the kingfisher and a different snail is involved.

There are a number of factors which might contribute to parasitic infection in 2009 versus 2010. These include:

1. Slower flow rates per tank in 2010 versus 2009
2. The use of a gravity flow (green tank) upstream of the fish tanks instead of directly pumped incoming pond water.
3. The use of horizontal feed (surface water distribution) in 2010 instead of a vertical feed (in-tank water distribution) in 2009.

In 2009, incoming water was purposely injected at a high rate. While the 2009 study did not detect problems with the fish because of the high rate of water feed, the incoming water rates were kept high in order to prevent infection. One of the side effects of high flow is that the fish are required to swim more and this could cause a reduction in growth, i.e., fish could be leaner due to their conversion of body fats to protein. This hypothesis was not tested as by the end of the test period, no fish were filleted to determine percent yield. Normally, in pond run farm

raised fish one will see fatty deposits in the body cavity which when filleted result in a lower percent return than would a leaner fish. One of the benefits of higher flow in a pond-side tank might be a conversion of fat to meat with a resultant higher fillet yield.

In 2010, the rate of incoming water to the pond-side tanks was purposely slower with the intention of finding a point at which an infection would occur. Therefore, slowing the rate of flow did accomplish its purpose.

Another possible contributor of infection however, might have been the installation of a green tank (gravity feed) between the pump and the pond-side tanks. The purpose of the green tank was to have additional water head in case of power outage and to have a common tank where filtration could take place and multiple feed lines could be derived. The green tank did allow pre-filter capabilities however; the resultant reservoir was somewhat similar to a pond in that snails did enter the green tank. While most of the snails were filtered, certainly any parasites associated with the snails were not filtered. Based on observations, the gravity feed option did not provide sufficient flow rates to prevent parasitic infestations.

Finally, though this was never tested, it is believed that a surface flow will not be sufficient to produce homogeneous flow top to bottom in the pond-side tanks. While the surface flow will be based on the rate of incoming water and direction of distribution arm, tank flow in the center and at the bottom can lag substantially. While the fish do not have to work as hard to maintain position in water, this aspect might provide an opportunity for infection. It was noted at the end of the season that most of the gravity fed plumbing had been colonized by what appeared to be bryozoans, in some cases severely limiting flow in gravity plumbing. This problem was not observed in 2009 when all tanks were directly filled from the pond water.

A review of the fish growth data suggests that there was a significant growth window in the first month to month and a half (see Figures 6.1 and 6.2). This is because many of the larger fish were harvested as they matured leaving a crop smaller in size albeit still growing at a fair rate. We do see that the net pen fish tended to gain weight a little better than the pond-side tank counterparts. Again, that is deemed to be attributable to a greater percentage of stored fat versus the leaner tank counterparts.

6.3 Discussion of Water Quality Findings

In both years, water quality issues became a problem in mid-July through August. The water quality issues could have been avoided by selecting a different pond (deeper, cooler); however, for this study there was a need to use a shallower pond with an active parasitic infection. At the onset of the study, pond water temperatures were in the mid to high teens (^{0}C) with oxygen concentrations between 8 and 10 ppm. By mid-July, pond temperatures had risen to 25 and as high as 27^{0}C with incoming water oxygen concentrations about 2 ppm. Heavy rains in July had moved a significant amount of water to the pond from an adjacent wetland. Most of the incoming water from the wetland had migrated to the lower strata of the pond thereby decreasing

the oxygen to 2 ppm. Surface water oxygen was maintained at 6 ppm throughout the summer. Due to the low oxygen concentrations, the water intake had to be moved from a near bottom location to a point between one and two feet from the surface. In addition, an air diffuser was placed in the green tank for all of July and August. While oxygen levels were never lower than 5 ppm in the pond-side tanks before supplemental aeration was provided, once aeration was provided, oxygen concentrations in the pond-side tanks always remained above 6 ppm. The temperature however might have been sufficiently high to lower the feed intake and therefore slow growth.

6.4 Additional Testing

Based on communications between Blue Iris and the UW-Stevens Point, it was decided to capture young of the year (YOY) perch from the main pond to try to identify an approximate date when regular pond-run fish might become infected with parasites. Fish are normally spawned in April and hatch in about seven to ten days. By July 1, the YOY are normally about one inch. By August these same fish can be between two and three inches.

Same sized perch usually travel in schools and these schools will theoretically travel through infected water (areas where infected snails are shedding parasite larvae). In July, Blue Iris seined a shallow bay of the pond and captured 140 fish that were less than two inches. This sized fish were thought to be YOY and approximately three months old. Scale samples were taken and aging was conducted by UW-Stevens Point. These fish were verified to be YOY. Some of the July batches were placed in an aquarium while the remaining batches were evaluated for the presence of grubs. Those in the aquarium were saved so that if a parasitic infection was not immediately observable due to immature stage of grub infestation, additional incubation in an aquarium may be sufficient for the grub to develop. A second batch of about 70 less than two inch perch were collected in August and also tested for parasitic infection.

Of the two batch collection efforts (July and August), parasitic infestations were observed at rates of 63 and 61 percent respectively. This infection rate is nearly identical to that which was observed in the net pen. This suggests that if a pond has a parasitic infection, perch will become infected and have a noticeable infection as early as three months of age. The number of parasites per individual did not exceed four for either of the YOY groups. By contrast, a similar collection of pond-run perch in 2009 saw parasitic infections numbering in the hundreds per individual when fish were of the four to five inch class (approximately one and a half years old). Figures 2.1 and 2.2 demonstrate highly infected specimens.

Section 7 – Significance of Findings

After two years of studying the use of pond-side tanks for rearing yellow perch, it appears that given proper flow rates, a fish farmer may be able to prevent yellow grub infections. More work needs to be conducted to identify specific flow dynamics and there also needs to be additional work done to determine if perch can attain or match optimal growth rates achieved in other grow-out systems. However, if parasite reduction or elimination can be achieved, then a host of other benefits accrue such as:

1. Pond-side tanks can reduce predation. This is true for fish that are subject to large predators such as otter, mink, herons, cormorant, and other predatory species of fish, as well as a host of small predators such as aquatic members of the Order Hemiptera and Coleoptera, and the larval stages of the Order Odonata.
2. Pond-side tanks save on food – there is a specific mass of fish in each tank and feed is rationed to the specific needs of the standing crop. Feeding rates and uptake by fish can be monitored so that waste is greatly reduced.
3. There is a reduction in waste that needs to be treated. While this study did not attempt to collect and treat waste discharged from the tanks, it is recommended that this be the practice. There will be fish waste and some waste food. This can be used for other purposes but the main issue here is that the waste should not be going back into the pond from which the water supply is derived.
4. There is a reduction in labor from the standpoint that there is no weed harvesting, no pond seining to harvest fish. Most of the labor associated with ponds is pond maintenance. Not only do weeds have to be harvested but dikes have to be maintained by mowing, possibly riprap (another big expense), or brush cutting as necessary. Without maintenance, unwanted weeds will colonize the banks and predators are invited. Muskrats too will colonize banks that are not maintained.
5. There is a reduction in the need to allocate money for nets, seines, and other fish harvesting equipment. Depending on the size of the ponds, if fish were grown in ponds, it would take hundreds of feet of nets to harvest the pond. If multiple fish sizes are grown, each size fish would require a different sized harvest net.
6. There is a significant reduction in the need for large volumes of water (acres) with which to raise fish. A large crop of fish can be grown with as little as ¼ acre of water. With the need for smaller ponds and/or a smaller number of ponds, a reduction in labor for pond maintenance is again achieved.
7. If pond-side tanks can successfully provide clean (parasite-free) fish then additional markets open up to fish farmers. Throughout this report most of the emphasis has been to raise fish that are free of parasites to be used in the fish food market. However, there is a significant demand for feed-trained fingerlings that are also parasite-free. Feed-trained fingerlings are usually marketable by the end of July and August. As shown by this study, parasitism occurs by the time feed-trained fingerlings would be ready to be shipped. Therefore, it is very important to be able to supply a guaranteed parasite-free stock to other fish farmers who want to grow out fish in ponds, tanks or RAS systems.
8. There are a number of other species that are economically important to Wisconsin fish farmers and neighboring states which are also affected by these same parasites. These

include all of the sunfish and hybrid striped bass. These too have been shown to be candidates for tank culture.

Section 8 – Summary

Studies conducted in 2009 and 2010 raising perch outdoors in pond-side tanks were conducted to determine if this method could reduce or eliminate parasitic infections of yellow perch by yellow grub and black spot. The study was undertaken using a three-acre pond as a water source which was known to be infected by both yellow grub and black spot. While perch from the pond were not known to be infected with black spot (resident sunfish were infected with black spot) many of the resident perch contained minor to heavy infections of yellow grub.

Tanks used in the 2009 study were 7.5 foot diameter with a 50 inch sidewall. Water was direct pumped into tanks which had a vertical tangential flow distribution. Of the 1,500 fish tested in 2009, none were observed to become infected with yellow grub.

Tanks used in the 2010 study were 9 foot diameter with a 30 inch sidewall. Water was indirectly pumped into the tanks which had a horizontal surface flow distribution. Of the 2,300 fish tested in 2010, between 30 and 60 percent became infected with yellow grub.

The hypothesis for the study was that flow rates were key to preventing (or allowing) parasite infestation of the yellow perch. Flow rates were significantly higher in 2009 versus 2010 and there were a number of tank set up conditions that favored parasitism to be promoted in 2010 versus 2009.

While the two years produced two distinct results, there are a number of questions that arise from the two years of study. The two studies did not identify an exact flow or range of flow which would be the breakpoint for parasitic infection. Additionally, the long term goal of this approach would be to determine the optimum growth which can be achieved at the most favored flow rates. Comparative studies still need to be conducted which would allow fish grown in pond-side tanks to be compared with weight/length ratios of yellow perch grown in other existing rearing settings as well as the need to obtain information relative to fillet yield per range of flow rates used.