2018 Project Abstract
For the Period Ending June 30, 2021

PROJECT TITLE: Install and evaluate an invasive carp deterrent for Mississippi River locks and dams
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art.4, Sec. 2., Subd. 06E

APPROPRIATION AMOUNT: $998,000
AMOUNT SPENT: $968,643
AMOUNT REMAINING: $29,356

Sound bite: This project discovered that even when equipped with a sound-light deterrent, Lock and Dam 8 has little promise to stop invasive carp but that Lock and Dam 5 could stop over 99% of all carp if equipped with a sound-light deterrent that includes a bubble curtain.

Project outcome and results:

The purpose of our project was to determine how to stop invasive carp. Because all carp must pass through locks-and-dams we focused on these structures, focusing on Lock and Dam 8 (LD8) near the Iowa border. We specifically examined whether and how carp could be stopped at LD8 by adjusting its spillway gates, installing a sound-light deterrent in its lock, and managing native fish predators in its vicinity. While we found that this combination has little promise at LD8, nearly all carp could be stopped upstream at LD5 using a variant of it, sparing Lake Pepin and most of the state. Insight came from several aspects of our research. First, by releasing acoustically-tagged common carp at biweekly intervals and tracking their movements upstream through LD8, we discovered that carp passage through spillway gates only occurs at high discharges as predicted by a fish passage model -- proving that LD8 is a poor location to stop carp because its gates open infrequently, but that LD5 is an excellent location because its gates do. Second, we found that carp passage through locks is predictably low, meaning that the lock at LD5 is an excellent location to install a deterrent because of this LD's low spillway passage rates. Third, while we found that a sound-light deterrent was ineffective at blocking carp, a sound-light-bubbling system (BAFF) is. An engineering analysis supported using a BAFF at LD5. Fourth, when we examined whether native predatory fishes might control invasive carp, we discovered no support: no common predator feeds on fish (carp) eggs and floodplain predators do not favor their young. Finally, we created a numeric model which showed that a BAFF at LD5, coupled with spillway optimization, and carp removal at that site would stop 99.6% of all carp in Minnesota – a solution has been identified.

Results use and Dissemination

Our findings on carp deterrents are being used by the US Fish and Wildlife Service to test a bioacoustic fish fence. Our findings have been widely disseminated. A recent summary of the project was presented at a carp forum: Carp Forum. In addition, we presented our findings at several public (ex. 2019 Stop Carp Forum), scientific (ex. Midwest Fish and Wildlife meetings) and agency level meetings (ex. annual Mississippi River ANS Task Force Meetings). We have published 3 scientific peer-reviewed articles and have 2 in review. The *StarTribune* covered our project twice in front page articles as did *Minnesota Outdoors.*

Today's Date: August 8 2021

Final report

Date of Work Plan Approval: March 4, 2018

Project Completion Date: June 30, 2021

PROJECT TITLE: Install and evaluate an invasive carp deterrent for Mississippi River locks and dams

Project Manager: Peter Sorensen

Organization: University of Minnesota

College/Department/Division: College of Food, Agriculture and Natural Resource Sciences, FWCB, MAISRC

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Location: Statewide

Total Project Budget: $998,000

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Appropriation Language:

$998,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the United States Army Corps of Engineers and the United States Fish and Wildlife Service to install, evaluate, and optimize a system in Mississippi River locks and dams to deter passage of invasive carp without negatively impacting native fish and to evaluate the ability of predator fish in the pools above the locks and dams to consume young carp. The project must conduct a cost comparison of equipment purchase versus lease options and choose the most effective option. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

I. PROJECT STATEMENT:

Untold millions of invasive Silver and Bighead carp (together known as Bigheaded carp - a variety of Asian carps that is also known as "invasive carp" by the state of Minnesota) presently inhabit the Mississippi River below the Iowa border from where they are moving north. This project seeks to solve this problem by conducting a proof-of concept study using state-of-the-art fish deterrent technologies at the most southern lock and dam structure in Minnesota. The work promises to protect the entire state from these carp and has two components:

1) Activity #1 will install a new, state-of-the-art acoustic carp deterrent system in the lock at Lock and Dam #8 while guiding efforts to enhance velocity fields through its spillway gates to selectively stop carp moving through this structure. Overall efficacy of this integrated deterrent system will be evaluated by monitoring passage rates of common carp (a surrogate for bigheaded carp) and several native fishes (walleye, etc.) while adjustments are made to improve system function. Recommendations for purchase or improvement will be rendered at the end of the project.
2) Activity #2 will quantify predatory fish populations in the pool above Lock and Dam #8 to determine if, and how, these populations might be naturally enhanced to suppress survival of any possible young carp that might be spawned if a few adult still happen to pass through the Lock and Dam. Predator populations from several river sites, with, and without carp, will be compared. Recommendations will be made to the MN DNR and USFWS at project end.

At present, the only impediment to the upstream invasion of Bigheaded carp into the Upper Mississippi River and its tributaries including the Minnesota and St. Croix Rivers are the lock and dams maintained by the US Army Corps of Engineers (USACE). Each lock and dam contains a lock chamber to permit navigation and a series of gated spillways that regulate velocity flow-fields (depth), both of which can be modified to stop carp (and allow native fish to pass). Four years of previous LCCMR-funded laboratory research show that: 1) spillway gates, and especially those at Lock and Dam #8, can be adjusted in ways that block carp without affecting safety, scour or navigation; 2) two types of sound system can block approximately 85% - 99% of carp, one of which, the SILAS system (see below) could easily be deployed at Lock and Dam #8 where it would be much more effective than the home-built system we installed in that location in 2012. This location is also ideal (and better than Lock and Dam #5 where we initially had thought of working) because the bigheaded carp have not passed it yet (at least in biologically relevant numbers) so it is the southernmost location in Minnesota we can work, our data suggest gate operations would be very effective here, and the USACE has already granted us a license to work at this location. (In the meantime, Lock and Dam #5 is an excellent fallback.) Herein, we describe a plan to add a custom-designed "SILAS" system ("Synchronized light and sound system" designed by Fish Guidance Systems Ltd. [FGS]) to the lock gate doors at Lock and Dam #8, while continuing to coordinate changes to spillway gate operations we have suggested as part of LCCMR—funded work to reduce carp passage, and then monitoring the passage of carp and native fish to gauge efficacy and make improvements. In addition, we will evaluate the population of predatory fishes located above and below Lock and Dam #8 because studies by others suggest that predators can help control carp abundance at low densities. The SILAS system is the third generation sound system produced by FGS and produces a series of highly effective patented sweeping or chirping sounds which are controlled by computer and are combined with light system. It could, if needed, at project end be updated to a more effective but more complex and expensive Bioaccoustic Fish Fence (or "BAFF" incorporates an air curtain that must be mounted on the bottom of the river and would require custom engineering and special permits while costing well over $1,000,000 to install), or left in place or moved to a different location in the river. We chose to lease (vs purchase) the SILAS system for this study because it saves the state approximately $50,000, offers the state flexibility to modify/upgrade/improve, and comes with a pre-paid service package that should also save additional costs. Further, we have as part of our proposed lease, an option to purchase this system at a significant discount at the end of the study.

II. OVERALL PROJECT STATUS UPDATES:

First Update January 31, 2019

Overall, work is going well. The SILAS deterrent and its engineering support systems are now fully designed and superior to those originally planned (it has internet connectivity, new custom control system, and new light system suggested by our lab studies). Although an initial 3-week technical test of the system has been delayed by the aforementioned design modifications and administrative requirements associated with leasing and importing the SILAS sound deterrent system from an English company (FGS) all permits are now in place so the system can definitely be installed first thing this spring when the ice melts. Additionally, an initial survey of river fisheries data (Activity 2) suggest an analysis of river predators is possible. We request a 6 month no-cost extension through June 2021 (within the scope of the appropriation) to take advantage of this shift in schedule to both complete final data analysis and if reasonable turn management of the deterrent system over to management agencies (see below).

Amendment request

We request an amendment to add a 6-month period to the end of the proposed 2.5 year project period (the project will still be completed by July 2021) because of a delay in initial engineering test of the deterrent system and to rebalance the budget to both permit full data analysis and accommodate small unanticipated changes in deterrent design, shipping and installation costs:

- *Increase in "Professional, Technical and Service Contracts" from $414,000 to $424,000 because the cost of our 2 –year lease for the SILAS acoustic deterrent increased by $10,000 because of unanticipated changes in foreign currency and financing agreements (prices are now fixed).*
- *Decrease in the overall cost of "Equipment, Tools and Supplies" from $163,636 to $159,636 for several reasons related to finalizing experimental design and small changes in equipment needs. First, the estimated costs of engineering supplies decreased from $6,000 to $3,636 (the deterrent comes with more custom modifications than we had initially expected a year ago). Second, the cost of fish tracking supplies decreased from $140,000 to $110,000 because it appears we need fewer tags than anticipated. Third, the cost of fish tag receiver batteries for fish tags decreased from $14,000 to $0 as we have changed to a solar-powered system without batteries that is technologically superior and can download data to the internet directly – a big improvement for the science (see below). Fourth, the cost of fish tag receiver systems has increased by $8,614 (i.e. misc supplies increase from $3636 to $12,250) as we need to add wireless equipment and solar panels (antennas, routers, etc.) as well as solar panels to our fish tag receivers (new ones are being purchased; see item below) to increase system reliability (our old archival receivers needed batteries and failed frequently). Fifth, we as part of using a solar-powered, wireless system we now need a new different type of fish tag receiver that allows for internet connectivity and can receive solar power for $33,750 (vs. $0 before). These receivers will also be more reliable and faster, permitting better data collection.*
- *Decrease in "Travel" from $38,421 to $33,421; Because we did not have a fall 2018 technical test (see below), the Sorensen lab travel budget decreases from $35,000 to $30,000.*
- *"Other overall" decreases from $15,000 to $14,000 because overseas shipping of the deterrent is less than expected ($2500 vs. $5000) and shipping the equipment from St. Paul to Lock and Dam 8 is also less ($500 vs $1500). However, we now request funds for cell phone (modem) and internet services for the fish tag receivers so we can easily and safely collect and directly download data via the internet (as described above) when, where and as needed. This is important for a remote site*

Second Update June 30, 2019

Work is going well. The carp deterrent is now installed and fully operational at Lock and Dam #8. A fish tag receiver array has also been installed to detect tagged fish in the area and is now monitoring whether and how tagged fish pass the structure and respond to the deterrent. A dozen fish have also been tagged and released in the areas. We are in contact with the biologist who collects and analyzes fish data from Pool 8 so that we can proceed with predator analysis next fall.

Amendment request.

We request an amendment because installation of the deterrent proved to be both more complicated and somewhat different from that initially envisaged based on construction plans (which proved to out –of-date). Some changes were also unexpectedly needed in the fish tag monitoring system to fully automate it (software had to be updated). The major unexpected change however, was that we discovered that adding the speakers to the navigation lock at Lock and Dam 8 (LD8) was more complicated and time-consuming than expected. This process involved inserting speakers into small openings underwater in the gate grid-work which our hired dive team discovered once on site had been modified (and made smaller) since their construction in the 1930s and deviated from construction diagrams. This could not have been anticipated and involved more diver time, modifying speaker mounts, and longer cable runs (electrician time) that had to be inserted in channelized concrete (which we were made responsible for), which the US Army Corps of Engineers (USACE) only informed us about on the day of the project. Further, the river was in record flood which also complicated installation. Notably, most of the costs associated with these changes are associated with the cost of the just-completed deterrent installation, very few of which are presently reflected in the "spent" category of the attached budget sheet (June 17) because they have not yet been paid by the University (the deterrent was complete June 1 and the there typically is a 3-4 week lag in paying bills). Values presently found in the "Amount Spent" category are those reported (and actually paid; "expenses") by the University accounting system on June 17. To re-budget accurately we collected unpaid invoices directly from both our vendors (hardware stores, etc.) and service providers (divers, electricians, etc.). Suggested changes are described below:

- *Decrease in overall "Personnel" from $366,943 to $327,968 ($38,975). Salaries were reduced by $38,975 to help pay for increased costs of Professional and technical Services (divers and electricians, see below). The main source of this decrease came from a voluntary reduction in Sorensen summer salary from $45,299 to $27,200 (-$18,099), an ability to eliminate undergraduate help because of MS student's help (-$7,000) and small voluntary reductions in P&A engineering staff salaries (about $13,876).*
- *Increase in overall "Professional, Technical and Service Contracts" from $424,000 to $478,100 ($54,100). Service contracts need to be increased by a total of $54,100 with $38,975 coming from Personnel (above), $10,454, from Equipment (see below), $1,421 from Travel, and $3,250 from "Other." In particular, the estimate for diver time needed for installation (and eventual removal) increased substantially from $30,000 to $74,000 (3 8h-days initial installation plus $5000 mobilization fee, 1 long-day with mobilization fee to remove in fall, 1 long-day plus mobilization fee to re-install in spring 2020, final removal in fall 2020 with mobilization fee; +$44,000). The cost of electrical contractor also increased from $7,000 to $24,000 (+$17,000) because they needed to buy and use longer and heavier gauge cabling than expected and it had to be installed in the concrete, which also had to be channelized (unexpected). The internet contractor was reduced to $100 from $7,000 (-$6,900) because we were able to install internet on-site ourselves with the help of the electrician (to save money).*
- *Decrease in the overall cost of "Equipment, Tools and Supplies" from $159,636 to $149,182 (-$10,454). This savings was realized in several sub-categories. The cost of Miscellaneous engineer supplies to attach the speakers (clamps, wires, cables) increased from $3,636 to $10,000 ($6,364) because attaching the projectors proved much more complicated than anticipated due because of the navigational gate design was different than expected based on the old design drawing we had been provided with (see above).*

Acoustic fish tags can be reduced by $10,000 to $100,000 (-$10,000) because we now need 50 fewer tags due to the flooding and late start. Field supplies were reduced from $12,250 to $9,182 (-$3,068) because we needed fewer supplies due to the late start and flooding. Acoustic receiver costs reduced from $33,750 to $30,000 (-$3,750) because we found we needed one fewer receiver to cover the Lock and Dam 8.

- *Decrease in "Travel" from $33,421 to $32,000 (-$1,421). Engineer travel increased by $579 to $4,000 from $3421 (more help –and travel- needed on site than expected), while Sorensen travel decreased from $30,000 to $28,000 (-$2,000) because of the flooding and late start.*
- *Decrease in "Other overall" from $14,000 to $10,750 (-$3,250). We discovered that shipping back to the U.K will be $4,200, not $2,500 as originally budgeted (+$1,700). Shipping to Lock and Dam 8 was $800, not $500 because of truck rental (+$300). On-site Internet and electrical service will be less than originally estimated, $750, versus $2500 (-$1,750). Cell phone service on site is no longer needed because the wireless we installed ($0 vs. $2,500; -$2,500). Repairs are reduced from $5,000 to $4,000 (-$1,000).*

Amendment Approved by LCCMR 7/29/2019

Third Update January 31, 2020

Results are in from the first year of the study. We tagged and released a total 225 adult common carp as well 20 American drum and a few other miscellaneous native fishes (this number was slightly lower than initially proposed because of river flooding and the unexpectedly high costs of deterrent installation which required us to internally cover some of the costs of the SAFL engineers from the biology portion of our budget). Fortunately, fish survival was excellent and the tracking system worked well; we were able to determine the swimming paths taken by over 90% of our tagged fish. However, river flow was unusually high (in flood stage over 80 days versus a typical 10-15 days), meaning that the spillway gates were out of the water and many fish were able to pass this spillway gate structures without passing through the lock a great deal of the time. Nevertheless, this enhanced passage rate of fish through the spillway gates matched that predicted by our computational model, confirming that it can be used to estimate carp passage throughout the river including other locks and dams which have more promise that Lock & Dam 8 for blocking invasive fish (because their spillways gates are of the water less). The sound/light (SILAS) deterrent was operated at about 75% amplitude (as planned) and decibel levels approaching 145db were obtained while all lights worked so the test was a success and we gained very useful data. It showed that when operated in this manner, the sound/light deterrent has little apparent effect on carp passage (10 common carp passed when it was off, 8 when it was on). Next year we will boost sound levels to 100% and replace one defective sound projector. Fish Guidance Systems Ltd reduced the contract cost to make up for this problem, and the USFWS has expressed interest in granting us some additional funds to pay for more native fish tags. In June 2020 once we know the full ramifications of the unexpectedly high costs of deterrent re-installation after the winter, we will likely request a final re-budget for the remainder of the project. Finally, to address objective 2, data searches found a large number of predators for young carp in Pool 8. A plan is now in place to analyze these data using other pools as controls.

Fourth Update June 30, 2020

Work is going well. Since our last progress report we have been analyzing data from the 2019 field season, tagging fish, and preparing to re-install the SILAS fish deterrent. New analyses have provided evidence that the SILAS sound/light system deterred carp, albeit weakly, but that sound levels could be increased. We also found evidence that the population of largemouth bass, a juvenile carp predator, is relatively large in Pool 8 above the SILAS compared to locations with carp. If managed properly largemouth bass may have the potential to impede the invasion of Bigheaded (invasive) carp. Unfortunately, the start of our field season has been delayed and complicated by the coronavirus pandemic, but we have now identified a way to proceed with an abbreviated, but still meaningful, study in 2020. This will require an amendment and re-budget which we describe below.

Amendment request

We request an amendment because challenges of the coronavirus pandemic have greatly increased our labor and travel costs, while also reducing our need for fish tags (delayed field season). Labor and travel costs are largely covered by a negotiated decrease in the cost of leasing the SILAS fish deterrent. Requested changes are as follows:

- *Increase in "Personnel (Wages and benefits) – overall" from $327,968 to $337,968 (an increase of $10,000). This increase will pay for the additional time needed by technicians with the university's applied engineering group to re-install the SILAS deterrent because of distancing requirements associated with the pandemic and the fact that Fish Guidance Ltd. (FGS- the leasor) cannot be present because of travel restrictions.*
- *Decrease in "Professional/Technical/ Service Contracts" from $478,100 to $466,600 (an overall decrease of $11,500). We negotiated a decrease in the cost of the lease with Fish Guidance Systems Ltd. of $27,500 with their leased SILAS system. However, this decrease was partially offset by the increased cost of the commercial divers needed to install the SILAS deterrent system in LD8 this spring (and remove it next fall; their costs increased by about $16,000 because of their need for social distancing.*
- *Decrease in "Equipment/Tools/Supplies" from $149,182 to $146,182 (an overall decrease of $3,000). The cost of supplies needed by the university's applied engineering group increased because of the increased burden on them to do the reinstall ourselves (see below) ($11,500 to $14,500, a $3000 increase). However, the number of fish tags needed decreased ($100,000 to $95,450; a $4,550 decrease) because of the late start this year owing to the pandemic. The cost of receiver batteries increased ($0 to $2000; a $2000 increase) because of problems with the solar arrays (that were meant to replace batteries). Our need for field supplies increased slightly ($7,682 to $7,927; a $235 increase). Finally, our need for receivers decreased as no new ones are needed this year ($30,000 to $26,305; a $3,695 decrease).*
- *Increase in "Travel in Minnesota" from $32,000 to $36,500 ($4,500). This increase is attributable to the applied engineering group which needs more vehicles and hotel rooms for reinstalling (and eventually removing) the SILAS system because of social distancing requirement (more cars, more rooms).*
- *No overall change in "Other-Overall" (it remains $10,750) although we seek to adjust the cost of some its components. In particular, we anticipate requiring more funding to ship the SILAS system back to England at the end of 2020 ($4200 to $4500; a $300 increase). However, we no longer need to pay for shipping the deterrent from LD8 to the University (prior to air freight) as we are renting a truck ourselves (a decrease of $800). Finally, we need to pay for research boat storage at Lock and Dam 8 ($500, a new cost).*

Amendment approved by LCCMR: July 6, 2020.

Fifth Update January 31, 2021

Data collection for this project has now been completed except for small tag validation project. Although we were able to install the sound/light SILAS carp deterrent in early July of 2020, it unfortunately failed within 2 weeks and we were unable to get engineers on site to repair it owing to COVID travel restrictions so we could not study it for a second summer. Nevertheless, we believe the work we completed in 2019 was adequate to tentatively conclude that the SILAS is not sufficiently effective to warrant further consideration for Minnesota. On a more positive note, we were given nearly a one-third discount on the lease price for the SILAS and we were able to study the passage rates of common carp through Lock and Dam #8 in some detail last summer. The latter work went very well because river flows were relatively low and different than in 2019 providing us with a complete dataset. Preliminary data analysis of these passage data shows that our computational model (FPM) is correct and that carp can only pass locks and dams when their spillway gates are either mostly, or completely

lifted out of the water, meaning that Lock and Dam #5 is an excellent (better) location to stop these carps because its gates are rarely completely lifted. Our data and the FPM also showed exactly why and how invasive carp were able to pass through Lock and Dam 8 in 2019 and now infest Pool #8 which is now a management problem for the state. We are now working on a publication. In addition to the field study, we also completed a new analysis of carp predator-prey literature. This analysis suggests that largemouth bass in the upper Mississippi River might be managed to help control juvenile bigheaded carp although further research is required. This conclusion reinforces our early 2019 work. In addition, using savings from the SILAS lease, we now propose two new activities in the remaining 3 months. We propose a new activity (3) to conduct an engineering analysis of the potential of all locks and dams located in southern Minnesota to stop carp using information collected from Lock and Dam 8 and new activity 4 to conduct a virtual workshop/forum that evaluates and disseminate information gleaned by this study on Lock and Dam 8. This will require an amendment and re-budget (using unspent funds for the SILAS lease) and includes a contract with Barr Engineering Company which we describe below.

Amendment request

We request an amendment because the challenges of the coronavirus pandemic increased our personnel, travel, supplies and shipping costs but reduced the cost of leasing the SILAS carp deterrent. In addition to addressing changes in personnel, supply and shipping costs while reducing lease costs (see below), we also now wish to use the funds saved from the reduction in the lease for two new related activities: i) a new Activity 3 to acquire new information (i.e. assess) on the structure and function of locks and dams located north of Lock and Dam 8 (LD8) to determine how they could accommodate an carp deterrent knowing what we now know about LD8 especially now that carp have moved past it; ii) a new Activity 4 to disseminate what we and others have learned in 2020 at LD8 as part of an Invasive Carp forum or "summit." Activity 3 ($35,000) will be conducted with the assistance of Barr Engineering Company, the only engineering company in MN with the required team of engineers needed to do this assessment work (structural engineers, hydrologists, fisheries scientists, etc.). Barr will be contracted for the key work (see below). Activity 4, the invasive carp forum, will be hosted online by the university in conjunction with the MN DNR and other agencies (because the MN DNR is unable to do so this year because of COVID19). Holding it will require professional assistance; we have selected Barr Engineering to help facilitate because they have the required staff, knowledge and will also be presenting at the forum. The forum is especially important this year because invasive carp are now officially in MN waters (Pool8) and there have been many recent scientific and management advances that could address this. The forum will be open to all agencies, NGOs and the general public and will be virtual with a roundtable to find solutions and a published summary. For both activities (3 and 4) , Barr Engineering Co. will bill for time and materials at competitive rates (Zweig 2020 report) as part of a single contract following state and university guidelines for small contracts with short time lines (3 months). Requested budget changes are as follows:

- *Increase in "Personnel (Wages and benefits) – overall" from $337,968 to $400,000 (an increase of $62,032). This increase will pay for the additional time needed by technicians with the university's applied engineering group to prepare the SILAS deterrent for shipping because of distancing requirements associated with the pandemic and a small increase in time needed by the Sorensen team to: 1) conduct a small week-long experiment this spring to determine/confirm exactly how well our acoustic tag were / are functioning in the river (we need this data to publish 2019-2020 data and inform other studies), 2) finish field data analysis and publish; 3) help run our virtual workshop/forum (undergraduate help needed).*
- *Decrease in "Professional/Technical/ Service Contracts" from $466,600 to $389,100 (an overall decrease of $77,500). Final costs of the divers were about $20,000 lower because than expected they were able to remove the SILAS more quickly than expected because did the work in late season when little boat traffic was present on the river. The lease with FGS for the SILAS was reduced from $352,500 to $250,000 (a $102,000 reduction) because the SILAS could not be deployed for most the summer owing to inherent circuitry design issues/failure. A 3-month contract for $45,000 with Barr Engineering Company is now added to cover the cost of both a new Activity 3 ($35,000) and a new Activity 4 ($10,000). For Activity 3,*

Barr will be contracted by the University to conduct an engineering assessment of locks and dams north of Lock and Dam 8 (LD8) using our new information on LD8. For Activity 4, Barr will be contracted by the University to facilitate a virtual forum/summit to disseminate our findings to the MN DNR and other agencies and the public which would also participate. Barr is the only MN engineering company with both lock and dam experience as well direct expertise in carp barriers and then the ability to disseminate this information and that of others including the University quickly via their communications staff. Barr will charge for time and materials at established competitive rates following national standards according to University of Minnesota (and state) guidelines for professional services contracts.

- *Increase in "Equipment/Tools/Supplies" from $146,182 to $151,900 (an overall increase of $5,718). The cost of miscellaneous engineering supplies increased by $1,000 to $15,500 (we had to buy new "international" palates and coverings for shipping the leased SILAS carp deterrent back to the UK). We also request at additional $3,600 (increase from $95,400 to $99,000) for 10 carp acoustic tags to conduct a small experiment this spring to determine /confirm the detection range and accuracy of the tags in the river that we employed last year and thereby their performance relative other tag types to help interpret and publish already collected data and to plan. Finally a small increase in field supplies ($1,168; an increase $7,927 to $9,095) is requested to pay for boat gas, nets for the final mini-study/validation of tag performance mentioned above.*
- *Decrease in "Travel in Minnesota" from $36,500 to $35,000 (decrease of $1,500). This decrease is attributable to the university's needing fewer because of the COVID-induced reduction in the field season ($2,500 reduction to $24,000). However, the applied engineering group needed more vehicles and hotel rooms for removing the SILAS because of COVID (+$1,000 to $11,000).*
- *Increase in "Other-Overall" from $10,750 to $22,000 (increase of $11,250) largely because the cost of air freight to the UK to return the SILAS has increased greatly owing the COVID19 effects on shipping (we provide an estimate at this time: $8,500) and we have had to make numerous unexpected repairs to our equipment (both our boat engine and tag receiver were broken) ($7,000 increase to $11,000). Also, the projected costs of electrical and internet service increased slightly to $1,000.*

Amendment approved by the LCCMR: 3/22/2021

Amendment request as of 07/22/2021

We request an amendment to shift funds from Personnel to Supplies and Repairs. This shift in funds is required because the challenges of the coronavirus pandemic coupled with unanticipated spring weather complicated our final spring field work (confirming tag function): increasing the need for tags, supplies, and repairs (see below). Personnel costs were lower than expected, however.

- *Decrease in "Personnel (Wages and benefits) – overall" from $400,000 to $385,000 (a decrease of $15,000). We did not need as much part-time help this spring as expected because our primary researcher was able to accomplish more than expected (he stayed until the end of the project) and the USFWS offered us assistance with carp capture*
- *Increase in field supplies: We needed more fish tags and of a different type ($5000) as well as field supplies for our field boat ($5000) than originally expected (overall increase of $10,000 from $151,900 to $161,900).*
- *Increase in repairs: We unexpectedly needed to repair/upgrade our fish tag receiver for fish tags. Also, after winter storage, our field truck needed some unexpected repairs. (overall increase of $5,000 from $11,000 to $16,000).*

Amendment Approved by LCCMR 7/28/2021.

Final update June 30, 2021

The purpose of our project was to determine how to stop invasive carp. Because all carp must pass through locks-and-dams we focused on these structures, focusing on Lock and Dam 8 (LD8) near the Iowa border. We specifically examined whether and how carp could be stopped at LD8 by adjusting its spillway gates, installing a sound-light deterrent in its lock, and managing native fish predators in its vicinity. While we found that this combination has little promise at LD8, nearly all carp could be stopped upstream at LD5 using a variant of it, sparing Lake Pepin and most of the state. Insight came from several aspects of our research. First, by releasing acoustically-tagged common carp at biweekly intervals and tracking their movements upstream through LD8, we discovered that carp passage through spillway gates only occurs at high discharges as predicted by a fish passage model -- proving that LD8 is a poor location to stop carp because its gates open infrequently, but that LD5 is an excellent location because its gates do. Second, we found that carp passage through locks is predictably low, meaning that the lock at LD5 is an excellent location to install a deterrent because of this LD's low spillway passage rates. Third, while we found that a sound-light deterrent was ineffective at blocking carp, a sound-light-bubbling system (BAFF) is. An engineering analysis supported using a BAFF at LD5. Fourth, when we examined whether native predatory fishes might control invasive carp, we discovered no support: no common predator feeds on fish (carp) eggs and floodplain predators do not favor their young. Finally, we created a numeric model which showed that a BAFF at LD5, coupled with spillway optimization, and carp removal at that site would stop 99.6% of all carp in Minnesota – a solution has been identified.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Install a SILAS sound deterrent system at Lock & Dam #8 and conduct a proof-of-concept test.
Description: To invade Minnesota waters, bigheaded carp must pass through Lock and Dam #8 which is located just upstream of our southern border. Laboratory tests have already identified a relatively simple yet highly effective (approximately 85-95%) and inexpensive sound-light system, known as "SILAS" manufactured by Fish Guidance Systems Ltd (FGS) which can be placed in a lock. We will work with FGS to custom –design a SILAS system for this location and install it on the lock gates at Lock and Dam #8 while continuing to work with the USACE to modify spillway gate operations to deter carp passage via that route. The SILAS system will be controlled by a computer to produce various a few types of sounds and lights in multiple ways, depending on sound transmission properties in the lock and the ways that barges pass through it. Its operating protocols will offer the option of manual control and remote monitoring. Because this is the first time a SILAS system has been installed on lock gates, we allow for an initial several month period to optimize system operations, after which the system will be removed for the winter when the lock also shuts for the winter. Following winter-time the SILAS system will be modified (if appropriate) then be re-installed and its efficacy stopping carp and other native fish (walleye, bass, sturgeon, etc.) studied until lock winter shut-down when it will removed and reinstalled for a second season and study. We will work with the USACE to evaluate different operating protocols (volumes, times turned on/off, etc.) for this system. Success will evaluating by monitoring the movements and passage rates of over 500 acoustically-tagged common carp and native fishes using a custom built acoustic receiver array that will be placed across Lock and Dam #8 and allow us to determine exactly what species of fish pass and at what location (lock, tainter gate, roller gate) and why (so changes can be made). Each season of study the sound system will be turned on, and off, for approximate week-long periods of time. We aim for a 90^{+}% block. The USFWS will work as our partner and assist by catching and tagging fish, and monitoring. The USACE has already issued a license for this work and is presently working with us to evaluate and improve spillway gate operations. At the end of this project we will, depending on the system's performance at Lock and Dam #8, recommend options for next steps including: purchasing this system (the lease offers a deep discount) or improving it; and leaving it in place, moving it, and/or installing other similar systems elsewhere to create redundancy and greater protection.

ENRTF BUDGET: $889,750

Outcome	Completion Date
1. Install SILAS Deterrent and perfect it with initial engineering pilot work	January 31, 2019
2. Test effects of SILAS on the passage rates of carp and native fish throughout 2019	January 31, 2020
3. Test effects of SILAS on the passage rates of carp and native river fish 2020, summarize findings, and make recommendations.	January 31, 2021
4. Publish report and findings, train the MN DNR	June 30 2021

First Update January 31, 2019

All licenses, leases, agreement and designs for the SILAS sound and light deterrent are now place, and the deterrent is 90% complete. Briefly, we now a property lease agreement with the US Army Corps of Engineers (USACE) to use Lock and Dam # 8 for this study and have reached agreement (after several on site meetings) with the USACE staff on exactly how it will be installed and operated. We have also obtained agreements with the WI and MN DNRs on testing. Arrangements have now been formalized with the US Fish and Wildlife Service (USFWS) to partner with us and help with tagging and monitoring. Importantly, Fish Guidance Systems Ltd, (FGS) the manufacturer of the SILAS system, has reached and signed a nondisclosure agreement with us and the University of Minnesota that specifies how we can use and report on their technology. We also now have a signed 2 year lease with FGS for the SILAS with whom we have been working to perfect a customized design includes state of the art sound and lights (co-deigned by us) as well as internet monitoring and control systems including software that can also monitor tagged fish – at our request). The deterrent system is now 90% compete and arrangement have been made for shipping. It is superior to the system originally anticipated. Finally, we are also now partnered with the St Anthony Falls (SAFL) Applied Engineering group who have completed designed a control building along with custom software and internet systems. Internet and electrical system designs are complete. The control building is now being installed at Lock and Dam 8. While this took longer than expected (we had hoped to have it installed and a 3-week engineering test completed before winter ice-up), we anticipate onsite installation of the deterrent and all control equipment in April 2019 as soon as the ice is off at which time FGS engineers will also visit us to help with start-up as part of their contract.

Second Update June 30, 2019

Mr. Jeff Whitty was hired to lead this project with a MS student, Andy Riesgraf as his assistant. All required permits have been obtained. Work has started. The deterrent has also been installed. It was an enormous effort, taking approximately 3 12-h days because of the complications with the gate design, which was not what was expected based on the drawings provided. Nevertheless, it is now fully operational and producing both sound and light at full volume on a continuous basis. The signal is also being actively monitored and reported via the internet. The USACE personnel are pleased with the arrangements. We will run the system as is for at least two weeks to ensure that all parties including barge operators are pleased. We communicate daily. If need be the system volume can be reduced or lights can be turned off. Eight ATS acoustic receivers were also installed on Lock and Dam #8 between May 29th and 31st. An additional five receivers, which couldn't be installed due to flooding related issues, will be installed above and below the lock and dam by June 25th (i.e. the planned date of the first tagging trial). Acoustic receivers have been tested and are functioning. We can download data using WiFi and the internet. Preliminary sampling (electrofishing) and tagging of common carp and native fishes occurred in Pool 8 (above Lock and Dam #8) on June 10th with the help of the USFWS to determine what species would be optimal for this study (e.g. abundant, able to handle the stresses of transport and tagging, and show intent to challenge the lock and dam). Only the most abundant large fishes were retained

for tagging. In total, 12 tags were deployed internally in common carp (n = 5), freshwater drum (*Aplodinotus grunniens*; n = 3), smallmouth bass (*Micropterus dolomieu*; n = 2), largemouth bass (*Micropterus salmoides*; n = 1), and channel catfish (*Ictalurus punctatus*; n = 1). Initial observations of receiver data has shown some tagged fishes to have already moved upstream. Starting June 25th, we plan to tag and release 25 common carp every two weeks for 8 weeks (i.e. a total of 200 common carp will be tagged in 2019). In addition, 10 native fish of four different species will be tagged and released twice (once when the deterrent is on and once when it is off) during 2019 (i.e. a total of 80 native fishes will be tagged in 2019). The MN DNR, WI DNR, USACE and USFWS are all now being updated weekly on the project.

Third Update January 31, 2020

An array of nine acoustic receivers was installed across Lock and Dam 8 (LD8) (Fig 1-1). Range tests demonstrated that the receivers detected three of six transmissions per one-minute period at a distance of 150 m. The range of receivers installed on dam gates (i.e. receivers 3 and 4) was limited to 25 m due to water-entrained noise. The SILAS deterrent system was in operation for the entirety of the study, although it experienced numerous short-term unexpected power outages, which eventually disabled one of the 12 projectors (FGS is reducing contract costs to compensate and has offered the system gratis in 2021 to the DNR [they expressed no interest]). Tests showed the system produced sound levels of about 145 dB at the source (as designed). The light system worked but intensity was limited by high water turbidity. The deterrent system was operated for nine 2-week periods, alternating between a on and off status. Experiments continued through October, after which it was removed for winter storage. Removal proved challenging because of the lock gate design and more diver and engineer time was needed than originally budgeted.

Record-level flooding occurred in spring 2019, with the dam being in open water condition (dam spillway gates were completely removed from the water) for 85 full days during the spring alone (as opposed to 10 to 37 d during the whole year in 2016 to 2018, noting gates are occasionally removed during fall flooding)) (Table 1-1). This is also double that of Lock and Dam 5, which clearly appears to be better place to block carp if this work is to continue (Table 1-1). Tagging of fish was delayed until June 25th, after spillway gates were lowered. During the study period (i.e. June 25th to October 31st), spillway gates were removed from the water between October 8 and October 31. Water temperature ranged between 4.4 and 27.2 °C (mean = 20.4 °C ± 0.54 SE), and discharge ranged between 993.9 and 3415.0 cms (mean = 2177.8 ± 62.6 SE).

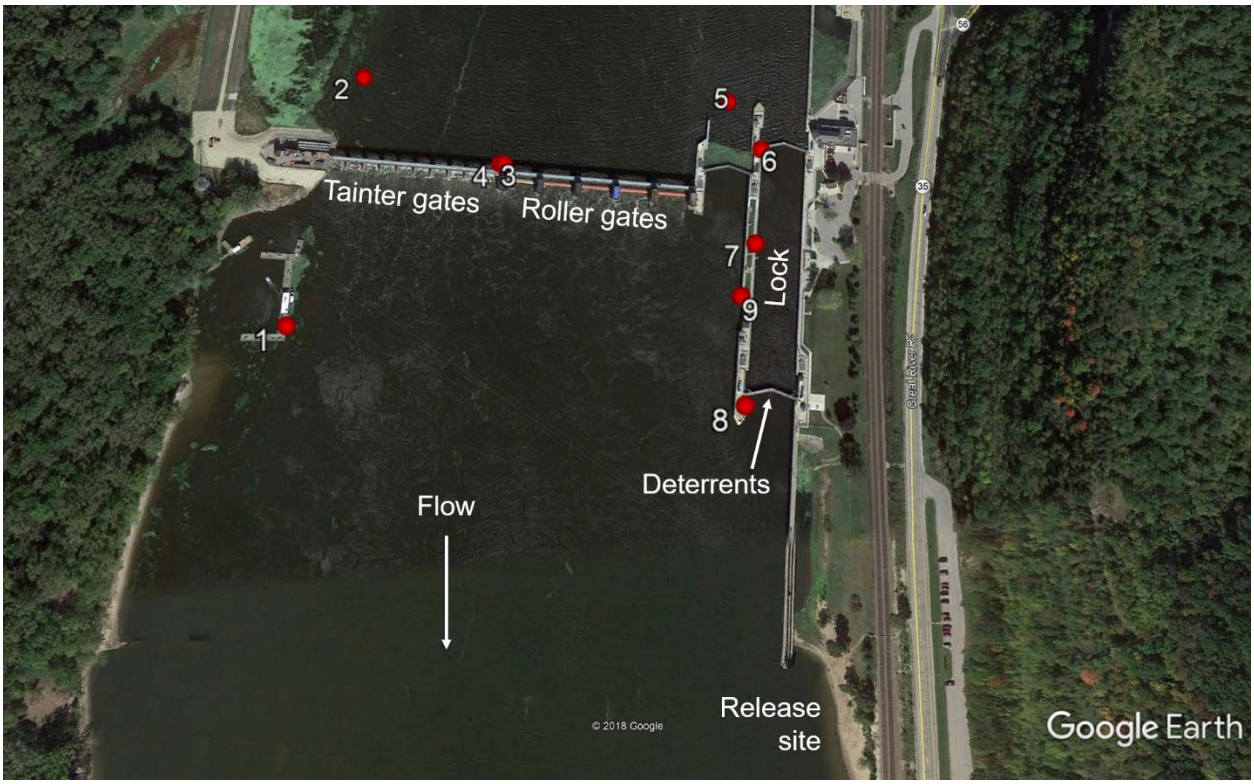

Figure 1-1. Map of Lock and Dam 8, Genoa, WI. Red dots denote locations of acoustic receivers 1 to 9.

Table 1-1. Number of complete days (full 24 h) that LD4, 5, and 8 spillway gates were out of the water.

Year	LD4	LD5	LD8
2016	1	0	10
2017	8	0	12
2018	28	2	37
2019*	79	48	85

*Up to Sept 25, 2019

In the 2019 study period, a total of 225 common carp (404 to 950 mm TL [mean = 657 ± 79.4 SD]; nine groups of 25 were tagged and released below LD8 (80% of which were detected in the study area within 2 weeks). Detected carp were at liberty for 1 to 119 days (mean = 22 d ± 1.8 SD), and were moderately resident in the approach area below the dam (mean RI = 0.52 ± 0.32 SD). Over a third of the detected carp were observed to move upstream through the spillway gates or into the lock, between 1 and 71 d post release (65% of these carp moved upstream within 12 d post release). Of all passages, 50.1% occurred through the tainter gates, 8.2% occurred through the roller gates (as predicted), and 41.1% occurred through the lock gates; 9% of the carp that moved upstream did so two to four times. This generally was a result of carp moving into, but not through the lock (28% of carp that moved into the lock chamber did not fully move through the chamber and returned downstream). When only considering initial passage of carp, 52% occurred through tainter gates, 8.0% occurred through roller gates, and 39.7% occurred through the locks. However, passages through spillway gates did not occur when spillway gate openings were less than <2.6 m (tainter gates) and <4.2 m (roller gates; Fig. 1-2) – as predicted by the computational model. In 2019, 20 freshwater drum (381 to 605 mm TL [mean = 521 ± 61.3 SD]) were also tagged and released below LD8 (only 25% were detected during the study period). Detected drum

were at liberty for 13 to 71 d (mean = 39 d ± 35.0 SD) but only two were observed to move upstream, and they did so through the lock. More native fish will tested in 2020 if we get the opportunity.

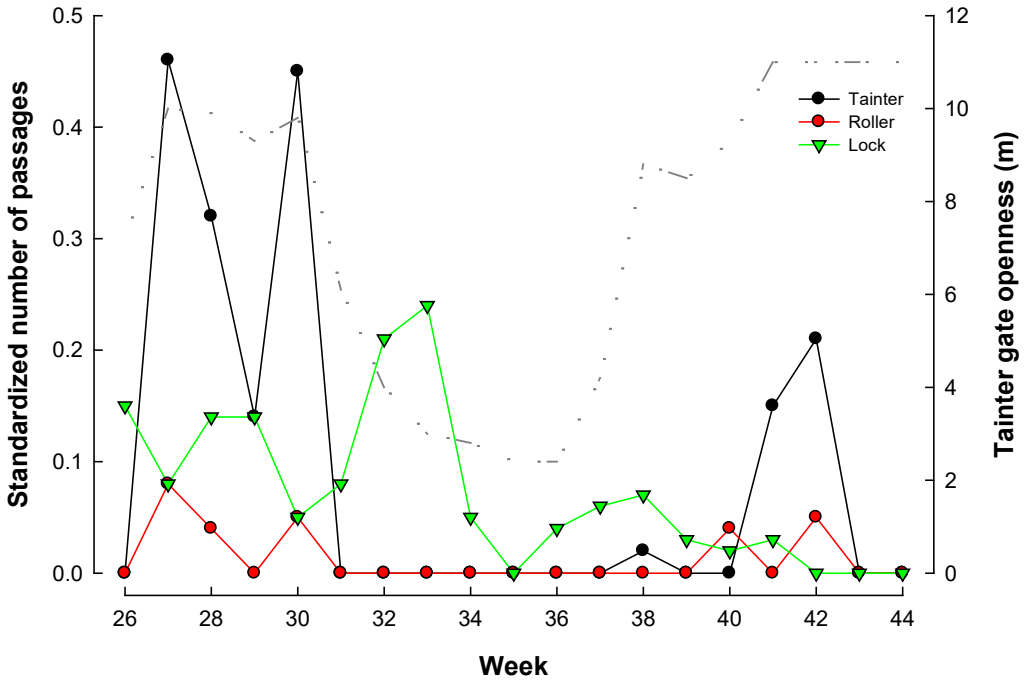

Figure 1-2. Weekly standardized passages (number of passages/ number of fish detected in approach area) through tainter, roller, and lock gates in comparison to tainter gate opening.

The deterrent did not appear to affect fish passage as operated at 75% of maximum amplitude. No significant difference was observed in the overall number of carp to move into the lock chamber between deterrent on and deterrent off trials ($p = 0.36$) (Table 1-2). At least one abiotic variable was significantly different ($p > 0.05$) between all paired trials so paired tests are not reported here and did complicate comparisons. In 2020 the deterrent will be operated at a higher amplitude and the broken projector will be repaired.

Table 1-2. Number of common carp to be detected and to enter lock chamber during deterrent on- and off - trials.

Trial	Deterrent status	# carp in lock
1	off	4
2	on	4
3	off	2
4	on	3
5	off	0
6	on	0
7	off	4
8	on	1

In sum, this study demonstrated that upstream common carp movement was impeded by increased water velocity through dam spillway gates, but was not significantly influenced by the sound/light deterrents in a lock gate when played at 75% volume in 2019. Although this study faced a few setbacks including unforeseen mechanical failures as well as budget and environmental constraints, the obtained results improve our understanding of the upstream migration of common carp through a dam and will be of great use in designing and running fieldwork to maximize results in 2020. In 2020, we plan to run the deterrent at peak sound level (it was only run at less than peak because we thought barge operators might complain about the noise, but they did not) and additional native fish will tested, weather and budget permitting. As mentioned in the project synopsis we may request a rebudgeting to permit this. Notably, the river is still running exceptionally high this winter because of atypical weather patterns (rainy and warm). Changing climate would greatly complicate efforts to stop and control aquatic invasive species such as carp.

Fourth Update June 30, 2020

We have completed our analysis of common carp passage through the lock when the SILAS deterrent was active and on (versus off) in 2019. We have also finished analyzing the sound and light data from 2019. While previous analysis (reported January 2020, data shown above in Table 1-2), demonstrated that activating the sound/light system did not significantly reduce common carp passage through it, a more detailed analysis did show a reduction in the number of times that tagged common carp visited (approached) the system at the gate when it was on (average number of visits= 173 when off, vs 116 when on; $p<0.05$) (Table 1-2 below). Interestingly, the number of individual carp responsible for this behavior did not change (average – 12.75 individuals when off vs. 14.75 individual when on; $P>0.05$) suggesting that changes in individual carp behavioral responses to the sound/light were responsible. We also found that water turbidity in the lock was so high that at a distance of 6 m from the strobe lights located on the SILAS (the closest we could get with our light meter), these lights were not measurable above background levels (60 lux). We will obtain a more sensitive light meter with a longer lead in 2020 to get better data. A sound map of the sound field created by the SILAS is shown below; peak decibels in the vicinity of the deterrent was approximately 145db, and slightly lower on the west gate where a projector malfunctioned (Figure. 1-3). We will increase the sound level this year. No additional analyses were performed on fish passage through the spillway gates although we confirmed that river flows were unusually high last year so we will endeavor to collect more passage data for common carp during times of lower water this year to enhance model simulations.

Table 1-2. Common carp counts (out of 25 for earch trial) and visits below the lock gate and within the lock at Lock and Dam 8, Genoa, WI during respective deterrent on and off trials. Lock gate receiver was not active for entiretry of Trial 8 in 2019

Year	Trial	Deterrent	# carp at gate	# visits at gate	# carp in lock
2019	1	off	19	374	4
2019	2	on	12	67	5
2019	3	off	5	43	2
2019	4	on	11	98	3
2019	5	off	17	201	0
2019	6	on	17	196	0
2019	7	off	10	77	4
2019	8	on	$\geq$19	$\geq$103	1

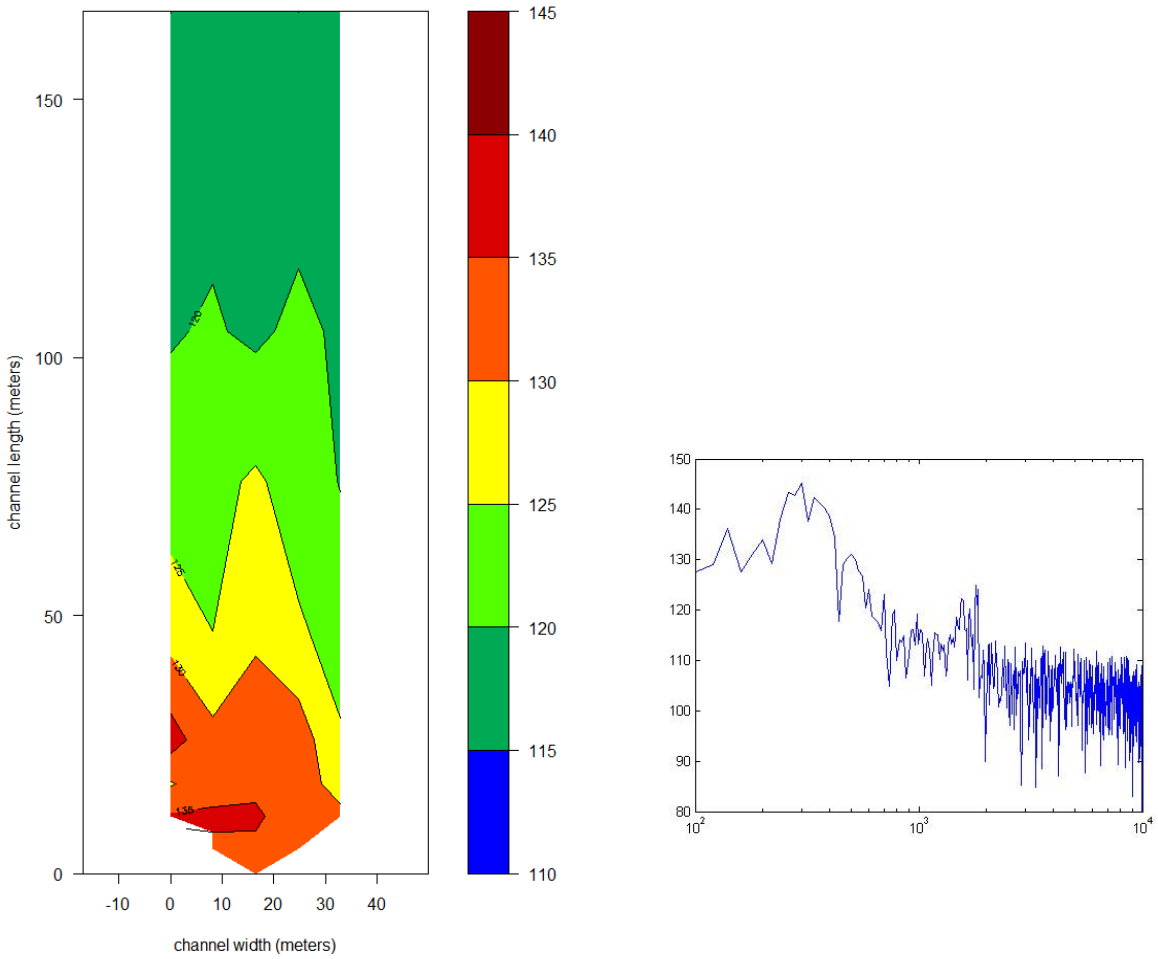

Figure 1-3. Left Panel: Contour map of peak sound pressure (20 to 2000 Hz) at respective distances from the lock gate, and Right Panel: power spectrum of a 0.05 second sound sample measured at sound source (mid-water column) in 2019.

The 2020 field season has been greatly complicated by the coronavirus pandemic and university travel bans which were partially lifted in May. Our partner, the USFWS, has not yet lifted their travel bans but the USACE has recently allowed us on site at Lock and Dam 8 (LD8) for some preliminary work (below). Meanwhile Fish Guidance Ltd engineers (FGS, the English company from whom we lease the deterrent) have been unable to travel to the USA to assist with re-commissioning as planned but have helped in other key ways. Because my team has fortunately been healthy to date, we have been able to start and now have a realistic plan to finish. Briefly, Nate Banet (full-time) and Natalie Windells (part-time undergraduate) were hired to help project manager, Jeff Whitty, this field season. Working with Jeff, this team has already re- installed an acoustic fish tracking array around LD8 in May. We had made detailed plans to re-install the SILAS system the first week of March (the sound projectors and their computer driven controls were removed for the winter by divers last December); unfortunately, our plan had to be canceled just two days before implementation because the FGS commissioning engineers had to fly back to England, and the commercial divers had to return to their office in Wisconsin because of the coronavirus. Re-installation is a complex multi-day affair that involves teams of divers, electricians, computer connections with FGS in England, technicians, and USACE coordination with barge traffic. Re-installation and re-commissioning are now scheduled for July 14, after almost a 4 month delay, the soonest we could manage with university travel regulations, divers scheduling, and developing alternative plans. Although the FGS commissioning engineers still cannot be onsite because of international travel bans, they have manufactured and shipped us many spare parts (ex. an extra sound projector, communication hub, and computer controller) by international air freight at their expense. Further, FGS has also prepared detailed instructions with solutions for all problems we can presently anticipate as we now plan to re-install this system in their absence. Meanwhile, we have also hired a part-time engineering university student to work in his

garage with FGS (via the internet) to refurbish the system (which was removed for winter storage) and review all parts while the computer system is being tested by software engineers at SAFL. We have also set up a wireless system to communicate with FGS on site at LD8 so they can still guide us during the actual re-install. The divers have also accommodated us by adding an extra boat while the USACE has adjusted their schedule. Weekly coordination meetings with all parties via ZOOM continue and all parties believe we now have a very workable plan.

We anticipate successful re-installation and re-commissioning of the SILAS system July 14-16. We are also planning a field experiment using carp to test it immediately afterwards (if we can run our first deterrent trial by July 20 we will still be able to complete a meaningful experiment in 2020). Nevertheless, there remains some risk that recommissioning may not be possible because of unforeseeable circumstances, such as broken underwater cables, unexpected FGS equipment failures, floods, etc. In this case, we could not attempt another re-installation because there simply would neither be time, nor funds, to fabricate/obtain new parts (which also probably could not be shipped), reschedule divers and engineers, and pay other additional costs. In this unlikely scenario, we would remove the deterrent and adjust the field season to include native fish and then release, track, and monitor both carp and native fish passage around LD8 and its spillway gates. (This would still advance our understanding of fish passage and further test our fish passage model, which if found accurate and robust, could be used to adjust all LD operations in Minnesota to stop carp (Zielinski et al. 2018)). Alternatively, in the other likely case of successful re-commissioning, we will follow a variant of our original plan that focuses on carp: we will conduct 6 trials using 33 adult common carp (instead of the 8 trials of 25 we had originally planned). This approach is statistically valid because of the higher number of carp per trial, although it will be more of a logistical challenge to get more carp needed for each trial, especially if the USFWS still cannot help. We will play the SILAS system at its highest amplitude for half (3/6) of these trials, and off for the others. We also still hope to test some native fishes as part of this favored scenario (and indeed have already tagged and released 20 shovelnose sturgeon and 10 channel catfish in pilot tests of passage through spillway gates). Further, we have applied for supplemental funding from the USFWS to help us conduct some native fish tagging in early September. While the USFWS has told us it intends to fund us, it is presently unclear whether they and the MNDNR (which would act as the intermediary for these funds) can process the funds quickly enough to allow this to happen. If this effort does not succeed, a test with carp alone (our primary species) will still occur. We are optimistic for a successful study of the fully-activated SILAS as a carp deterrent in 2020 as long as university personnel remain healthy. If the LCCMR has concerns about our proposed approach and these scenarios, they should let us know immediately and we will try to readjust plans.

Fifth Update January 31, 2021

While we were able to install the SILAS sound/light deterrent on the lock gates at Lock and Dam 8 (LD8) in early July, this system experienced internal electrical faults within the first 2 weeks of operations and had to be shut down, so it unfortunately could not be tested in meaningful manner this year. It was removed in November when new measurements of sound and light levels were also taken. While the manufacturer and lessor (Fish Guidance Systems Ltd, UK; FGS) worked hard to fix the system remotely, they were barred from traveling by COVID-19 travel restrictions, so we were unable to repair it this year or test it when played at full amplitude as planned. FGS reduced the cost of the lease by approximately $80,000 to compensate. Notably, we were able to complete a good test of the SILAS deterrent in 2019 and feel confident in concluding that this technology (i.e. sound and light projected from a lock gate) is unfortunately not adequate to address Minnesota's needs (see June 2020 report). The 2019 data have now been fully analyzed (although we want/need to collect data from another 10 tags this spring to confirm their detection ranges) and include new sound and illumination maps (available on request). These new analyses showed that the river is too turbid to render a light deterrent useful and only a ~15-25% overall deterrence rate can be achieved with sound. A draft manuscript has been completed for the peer-reviewed journal, *River Research and Application*s which we will complete and submit

before the project ends. Because conclusions about the SILAS have not changed since our last report (June 2020) we do not present them again here.

Although we were unable test the SILAS sound/light deterrent this year, we were (as we proposed in the June 2020 report), able to test the ability of the spillway gates to stop common carp moving upstream. During the 2020 study period, an array of 13 acoustic ATS receivers was installed both above and below LD8 (4 more than in 2019, with 2 new receivers added downstream of the original array). Range tests demonstrated that these receivers detected tags at a distance of 50 to 150 m depending on conditions. As in 2019, groups of 25 adult common carp were captured upstream of LD8, tagged with acoustic ATS tags and released below LD8. A small number of native fishes (20 sturgeon and 10 channel catfish) were tagged in 2020 (we had hoped to do more but the DNR/USFWS could not award us the promised funds owing to the COVID pandemic). Even so, we did find that no sturgeon passed LD8 (as predicted by our Fish Passage Model [Zielinski et al. 2018] because of their by their small size) and 5 catfish moved through the lock but not through its spillway gates (also as predicted). Owing to the much larger number of common carp we were able to study, our emphasis is thus on that species in this report and the manuscript we are presently preparing.

In 2020, a total of 175 adult common carp (mean total length = 631 mm ± 61.9 SD) were released between July 21st and September 28th (work started 2 months late because of COVID-related travel restrictions). Of these tagged carp, 97% were detected in the study area through Oct. 13th, of which 93% were observed to move upstream into the 'approach area' (the area immediately below the lock and dam). Detected carp were at liberty for 1 to 85 days (mean = 27.9 d ± 25.1 SD), and were once moderately "resident" (i.e. spent substantial time) in the approach area (mean RI = 0.6 ± 0.32 SD). In 2020, river flow was much less (about half) than that in 2019, and dam gates were never in "open river" position (removed from water) (Figure 1-4). As predicted based on the Fish Passage Model at these flows and gate settings, no (0) carp were observed to move upstream through the spillway gates (either roller or tainter gates). However, 28% of the tagged carp were observed to move upstream into the lock (Fig. 1-4), with 57% (28) of these passing. Notably water temperatures were nearly identical in 2020 to 2019, so only river discharge (flow) differed. This permitted the two data sets to be combined in a very meaningful manner and these are now the only data in existence on how carp approach and pass LDs whose spillway gates are operated in relatively typical manners and opened 10-20% of the year (the only other study was of LD2 [Finger et al. 2020] but its spillway gates are only opened- ~3% of the year). Together, our LD8 data from 2019 and 2020 show that carp can only pass through the spillway gates when their tainter gates are nearly completely open or in open river (i.e. no carp passed through the gates in 2020 when discharge was below 2400 cms [LD8's gates start to open around 2400 cms [cubic meters per second] and open fully at 2700 cms]). Preliminary runs of the Zielinski et al. (2018) Fish Passage Model appear to confirm these result although final analysis waits. Further, as predicted by the Fish Passage Model, few carp pass through the roller (vs tainter) gates. Finally and equally importantly, peak passage rates through the locks are less than through the spillways gates (when spillway gate passage is possible) and appear unrelated to river flow. This set of preliminary conclusions suggest that those Mississippi River LDs that rarely experience open river condition, such as LD5, should be truly excellent places to stop carp because few, if any carp, will pass their spillways- and deterrents can be added to locks (perhaps a bioaccoustic fish fence or BAFF). Together the 2019-2020 carp passage dataset is uniquely valuable and will be fully analyzed and written up for publication in the remaining months of this project. It should be very useful in guiding future efforts to control carp further upstream, especially if disseminated (Activity 3, see below) to the appropriate agencies.

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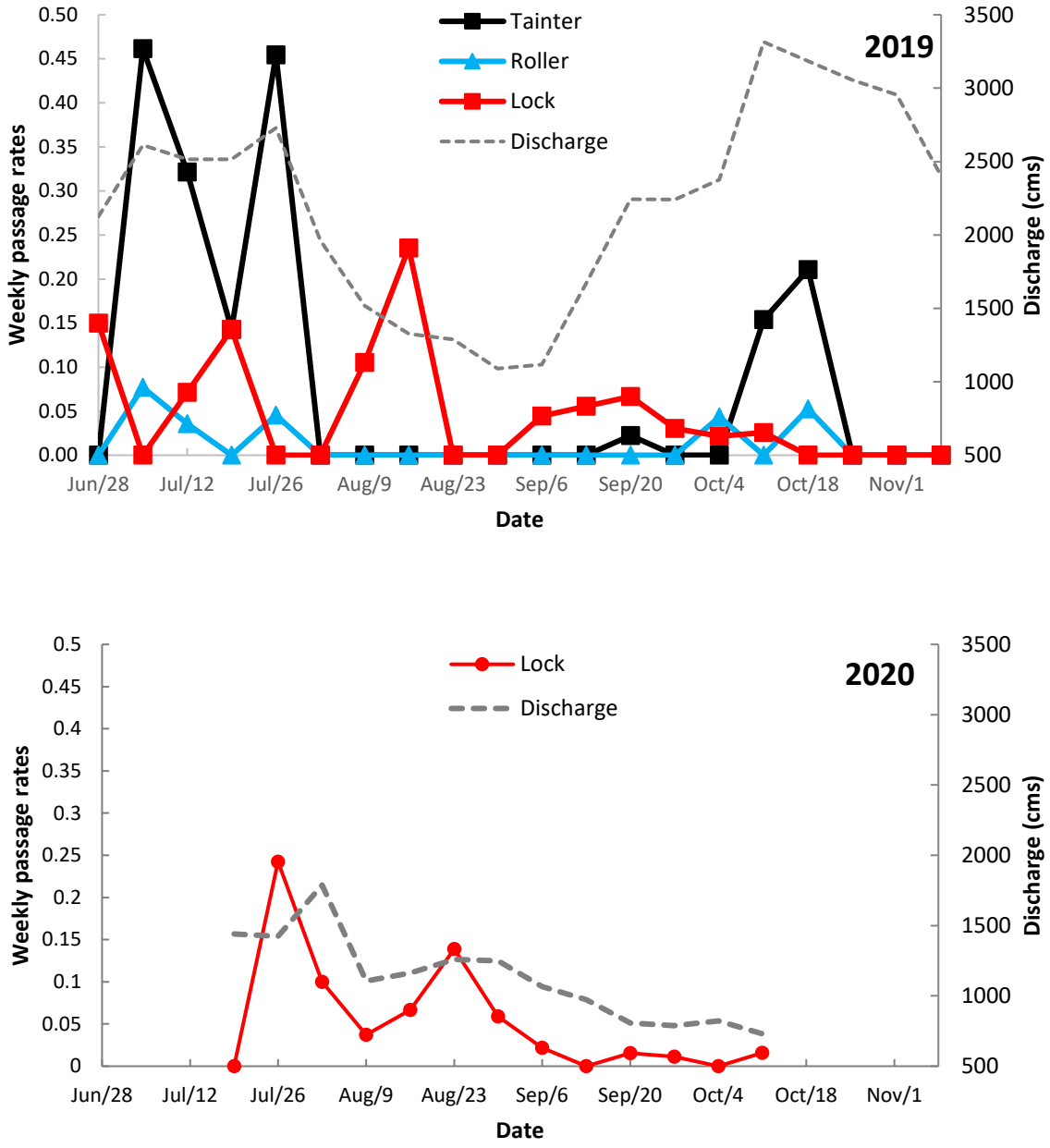

Figure 1-4. Common carp weekly passage rates (number of passages in a week/ number of carp detected in approach area during the respective week) through tainter, roller, and/or lock gates in comparison to discharge at Lock and Dam 8, Genoa, WI in 2019 (top; data reanalyzed from previous report) and 2020 (bottom; new data). Lock passages only include individuals that passed upstream through the lock, unlike in the 2019 report figure (Figure 1-2), which included all lock entries. Dates of weekly passage rates and mean discharge are represented ts the 4th day of each analyzed week. Carp were released every other week. Spillway gates start to come out of the water at 2400 cms (cubic meters per sec) or 85000 cfs (USACE) and leave the water entirely at 2700 cms (96000 cfs).

Final report summary

Our study of carp passage through Lock and Dam #8 (LD8) while it was equipped with an experimental carp sound- light deterrent system (SILAS) demonstrated how invasive carp can be stopped in Minnesota. Nearly 200 acoustical tagged carp were tracked for 2 years under a variety of conditions at LD8. In particular, we developed

a basic understanding of carp movement which allowed us to deduce that while carp cannot be stopped at LD8, they can be stopped at LD5 (but no other location in Minnesota) using a combination of three techniques: 1) adjusting its spillway gates, 2) adding a BAFF deterrent to its lock, and 3) removing crucial number of carp. Four discoveries enabled by this ENTRF project led us to this solution which was also made possible because LD8 and LD5 are extremely similar structures so findings from LD8 can be transferred to LD8. First, our carp tracking studies at LD8 show that about 20% of all carp can be expected to pass through a LD's lock system, irrespective of their spillway gates and river discharge – this means that deterrent actions will be greater at locations such as LD5 where spillway gate settings are such that they block passage. Second, while our tracking study showed that a sound-light deterrent is not adequate (it only deterred about 20% of all carp), related work conducted by Sorensen team as part of ENRTF2016 and ongoing related work with the USFWS strongly points to the possibility that a bioacoustic fish fence (BAFF) which has sound, light and bubbles can stop 80-98% of carp, making it a viable option for LD5. Third, our tracking study also showed that carp can only pass the dam portion of locks and dams when flows are approaching flood or in open-river stage. This finding strongly supports the numeric passage models developed by ENRTF2013 and ENRT2016 (Zielinski et al. 2018; Zielinski & Sorensen 2021), meaning that LD5, will pass only few percent of the carp passed by LD8 because its spillway gates are fully open and in "open river' only 2-3% of the year (LD8 is open-river lose to 10% of the year). Lastly, we learned from this study that only tainter gates (and not the roller gates) are passable by carp, again allowing us to identify LDs that are less passable than others- and LD5 is one. In conclusion, we now understand carp behavior around locks and dams well enough to identify LD5 is a perfect place to stop invasive carp.

ACTIVITY 2: Describe the population of predatory fish in Pool 8 and determine if it could be managed to enhance carp control.

Description: Recent studies in experimental ponds suggest that young bigheaded carp and their eggs are subject to predation by several species of predatory fish including bass and alligator gar (Lamer and Anderson, Western Illinois University; Duane Chapman, USGS, personal communication). While we do not expect predatory fish alone to be able to control an established population of carp in the open river, it is conceivable that predators could control a small population of young carp that might happen to pass through Lock and Dam #8 (although we aim for 90+% overall efficiency, "acts of God" [ex. floods, barge breakdowns in the lock, etc.] means that we should address the possibility that a very small number of fish could still pass). This study will evaluate this possibility of using predators for redundancy in Pool #8 by examining fisheries datasets already collected and managed by the U.S. Geological Survey (USGS) as part of its 30-year old Long Term Resource Monitoring-Environmental Management Program (LTRM). This dataset, which is publically available, includes fish survey data from Pool #8 and several pools downstream. We will evaluate these datasets and then analyze them, likely in collaboration with Brain Ickes, a statistician from the USGS who runs this program and has expressed interest in working with us.

ENRTF BUDGET: $98,250

Outcome	Completion Date
1. Evaluate LTRM dataset	January 31, 2019
2. Analyze data from Pool 8	January 31, 2020
3. Analyze data from a pool which has carp and if possible, one other that does not, summarize make recommendations.	January 31, 2021
4. Publish report and possible manuscript	June 31, 2021

First Update January 31, 2019

We have located the LTRM databases online and discerned they are adequate to address initial questions about the role of predator fish in controlling bigheaded carp abundances. We have also spoken with the LTRM data manager (Brian Ickes) about a possible collaboration.

Second Update June 30, 2019

We have discussed this project with the biologist in charge of LTRM fishing monitoring project, Andrew Bartels, with the WI DNR. He will work with us this summer and particularly next fall to understand and analyze data. He reports a good predator community, which includes many largemouth bass and flathead catfish.

Third Update January 31, 2020

A literature search was conducted using Google Scholar to identify known predators of bigheaded carp in the Mississippi River. The list of carp predators was cross-referenced with the USGS Longterm Resource Monitoring Program Database (LTRMP; https://umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html) to determine which species regularly (i.e. present in >95% of sampled years) inhabit Pool 8. The LTRMP database is a multi-species annual monitoring program that uses multiple capture methods in stratified random sampling to document large scale temporal (seasons to years) and spatial (km) changes in fish populations in select pools throughout the Mississippi River, including Pool 8 (Ickes *et al*. 2014; Ratcliff *et al*. 2014). The literature search produced two published articles and a thesis that documented predation of bigheaded carp by 12 native fishes, but focused on larval predators (not eggs). Ten of the 12 predators were found to regularly inhabit Pool 8 (Table 2-1). The LTRMP database (only using day electrofishing captures) was also used in a Kruskal-Wallis with a Tukey's post hoc test to assess the differences in mean relative abundance of regularly occurring carp predators between the various strata. Of these ten regularly occurring predators, all were observed at least once in backwater habitats, where juvenile bigheaded carp inhabit. There was a significant difference ($p < 0.05$) between the different strata CPUE of all fishes except longnose gar and channel catfish. CPUE of yellow perch, black crappie, and largemouth bass was greater in backwater shoreline than other sampled strata. CPUE of smallmouth bass was lowest in backwater shoreline than other sampled strata.

Table 2-1. Pool 8 day electrofishing capture information (1993 to 2018) of known bigheaded carp predators. Data sourced from LTRMP.

Species	# years captured	CPUE (# fish/15 min)			
		Backwater	Impounded	Main Channel	Side channel
Largemouth bass (*Micropterus salmoides*)	26	20.2	8.2	6.5	16.3
Yellow perch (*Perca flavescens*)	26	5.6	1.5	0.8	2.4
Black crappie (*Pomoxis nigromaculatus*)	26	1.9	0.4	0.3	1.3
Freshwater drum (*Aplodinotus grunniens*)	26	0.7	0.9	0.3	0.5
Smallmouth bass (*Micropterus dolomieu*)	26	0.6	2.9	5.0	2.9
White bass (*Morone chrysops*)	26	0.3	0.2	0.7	0.4
Channel catfish (*Ictalurus punctatus*)	26	0.2	0.1	0.2	0.2
Longnose gar (*Lepisosteus osseus*)	26	0.1	0.1	0.2	0.2
Flathead catfish (*Pylodictis olivaris*)	25	0.1	0.0	0.1	0.2
Shortnose gar (*Lepisosteus platostomus*)	25	0.1	0.1	0.0	0.0
White crappie (*Poxomis annularis*)	21	0.02	0	0	0
Yellow bass (*Morone mississippiensis*)	7	0	0	0	0

Together, these initial findings demonstrated young-of-year (YOY) bigheaded carp predators are common in Pool 8 of the Mississippi River, with at least three species (i.e. largemouth bass, yellow perch, and black crappie) occurring in relatively high abundance in backwater habitats where juvenile bigheaded carp occur. However, further effort is needed to determine which predator/s would have the greatest influence, and what current populations of that predator/s would be able to consume. In 2020, we will expand our research to explore variations in populations of our 10 predators in pools with and without bigheaded carp to attempt to identify what effects they have on carp populations, using methods similar to that of Chick *et al*. 2018. We also plan to further research the prey consumption abilities of known predators to better understand how effective these predators would be with bigheaded carp YOY and eggs.

Fourth Update June 30, 2020

We continued our analysis of the relationship between known predators on juvenile invasive carp and juvenile invasive carp to determine whether these predators could be managed to help control carp in Pool 8. Our earlier work (January 2020 report) showed that three species of fish known to prey on invasive carp (e.g. largemouth bass, yellow perch, and black crappie) are relatively abundant in Pool 8. We are now examining whether existing historical data from other locations support the possibility that these species (or their absence) could explain patterns in the abundance of juvenile invasive carp in the Mississippi River, and thus possibly their absence in Pool 8 (at least to date). We have discovered that high-quality fisheries monitoring data exist for 5 Mississippi River pools (i.e. Pools 4, 8, 13, 26, La Grange) and an open river site, extending back to 1995 and 6 years before invasive carp were common in the Mississippi River Basin. Initial analysis of these LTRM data has further shown that while juvenile silver carp have been caught in both Pool 26 and the La Grange Pool since 2005 (Figure 2-1), both pools have few largemouth bass and seeming no yellow perch, unlike Pool 8, which is the opposite (Figure 2-2). Notably, the relative abundance of largemouth bass is about 100 times lower ($P<0.05$) in both Pool 26 and La Grange Pools (including in years that witnessed recruitment) than in Pools 8 and 13, which seemingly lack silver carp. Black crappie are similarly abundant in these pools with juvenile silver carp as those with this carp. While these correlations are intriguing, they still do not prove cause and effect. Accordingly, next winter after our field season is over, we will seek a statistician to help us determine if numeric relationships might be quantified and tested between the relative abundance of invasive silver carp and their predators across time using repeated measured mixed models in the Pools with carp. We plan to attempt to examine individual predators as well as the group as whole and possibly expand the study to include common carp as a surrogate species.

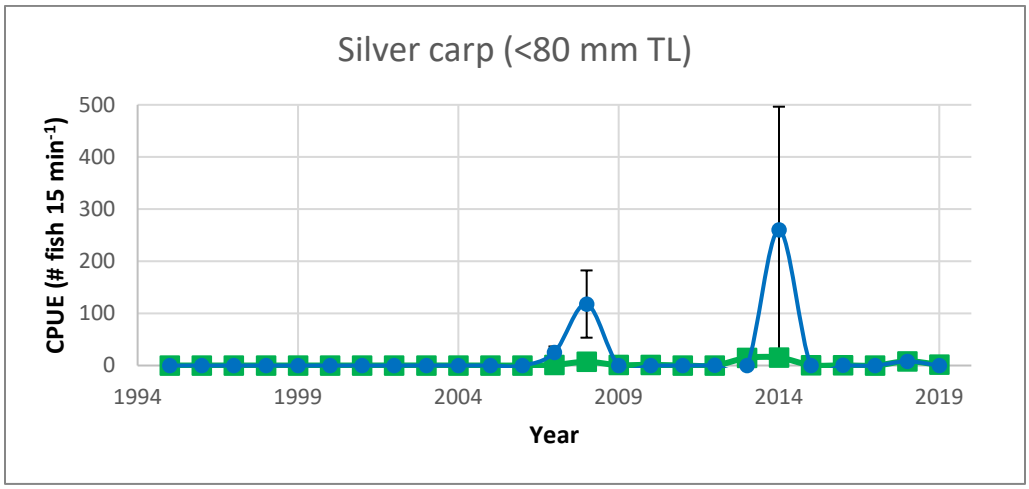

Figure 2-1. Pool wide day electrofishing mean catch-per-unit effort or CPUE (±SE) of juvenile silver carp in Pool 26 (green line) and the La Grange Pool (blue Line) in the Mississippi River. CPUE is a measure of relative abundance. No juvenile silver

or bighead were captured in either Pools 8 or 13. The relative abundance of juvenile bigheaded carp was very low in both Pool 26 and the La Grange Pool. Data from USGS LTRMP.

A

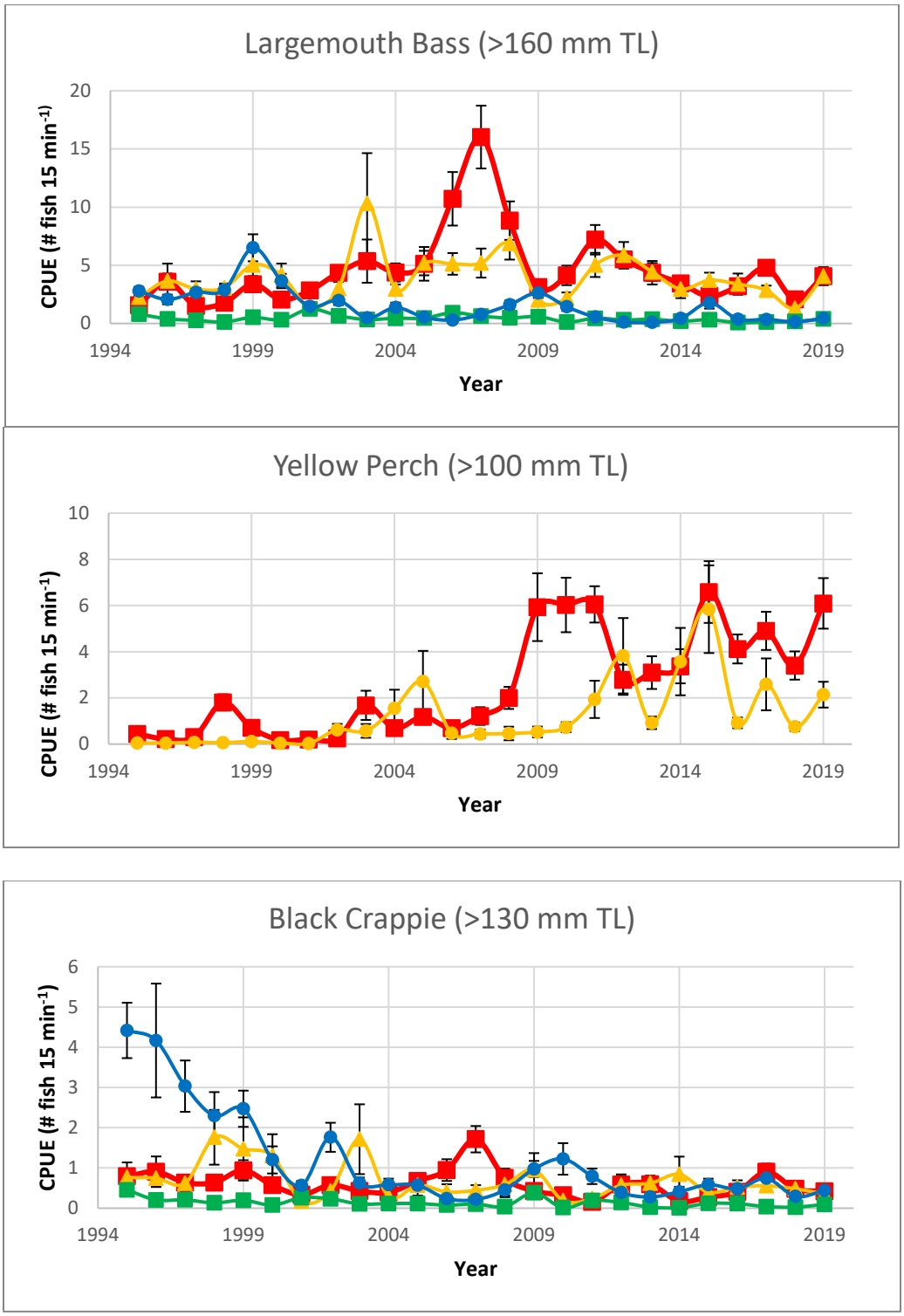

Figure 3-2. Pool wide day electrofishing mean catch –per-unit effort or CPUE (±SE) of (A) largemouth bass, (B) yellow perch, and (C) black crappie (known bigheaded carp predators) in Pool 8 (red Line) , Pool 13 (yellow Line), Pool 26 (green line), and La Grange Pool (blue line) in the Mississippi River drainage system. Data from USGS LTRMP.

Fifth Update January 31, 2021

We examined the possibility of using statistical tests to evaluate the significance of the apparent negative correlation between the abundance of largemouth bass and the abundance of bigheaded carp in Mississippi River Pools (June 2019 report, Figure 3-2) but came to the conclusion that tests were not reasonable. Briefly, not only are there too few data (only 5 pools), but they are confounded by time as well as environmental effects, and CPUE is not a fully quantifiable method. Instead, we decided to examine published data on predator –prey relationships for different life stages of bigheaded carp to examine the possibility that native fish predators in Pool 8 might limit bigheaded carp success. This analysis, which is described below, also suggested promise for predator control of bigheaded carp (especially of young) but showed that there is also a strong need for more study. Nevertheless, we believe we have created a path for this work to occur by others in the future and will make this point in our proposed workshop (new Activity 3). A synopsis of a draft report (and possible manuscript) of this information is presented below.

DRAFT REPORT: Evaluating the possibility that native fishes might control bigheaded carp in Pool 8 using published data on predator-prey relationships.

Pool 8 presently lacks reproducing populations of bigheaded carps and therefore might benefit from an integrated management plan that manages native predators of bigheaded carp, if they could be identified. However, very little is presently known about predator and prey relationships in the Mississippi River, including for carp (see above). Accordingly, we examined the potential that various native predators might control bigheaded carp eggs, young and adults in Pool 8 using all available lab and pond data. In addition to focusing on published data for known predators on each of the carp's major life history stages (eggs/larvae, young-of-year (YOY), adults), we also examined data for ecologically-similar river fishes that might be important predators on these species although they have not yet been studied. We examined data on predator feeding abilities and preferences, their ability to locate and then catch prey (mouth size or gape), prey and predator habitat preferences (abundance in relevant locations and times), and predator consumption rates. We review and summarize the literature as it relates to three life history stages of bigheaded carp (prey, and the predators) and then summarize our findings in this report (a more detailed version is available upon request).

i.Possible predation on carp eggs and recently-hatched (drifting) larvae.

-Prey (i.e. carp eggs/larvae): Bigheaded carps are highly fecund; female silver carp produce 26,650 to 3.68 million eggs /year depending on region and female size (Garvey *et al.* 2006; Schrank and Guy 2002; Williamson and Garvey 2005). Bighead and silver carp broadcast spawn in main channel environments during discharge peaks in spring and summer months (DeGrandchamp *et al.* 2007; Deters *et al.* 2013; Garvey *et al.* 2006), potentially releasing large number of eggs into highly turbulent waters. Newly spawned eggs measure ~1.5 mm in diameter, which George *et al.* (2017) observed to quickly swell to a mean (± SD) diameter of 4.7 ± 0.4 mm (silver carp) and 5.8 ± 0.5 mm (bigheaded carp) after hardening. The eggs are negatively buoyant and presumably perish if not suspended in the water column by the current and turbulence (Kolar *et al.* 2007) by flows between 15 and 70 cm s^{-1} (Murphy and Jackson 2013; reviewed by Lohmeyer and Garvey 2009). Drifting eggs take 24 to 48 h to hatch (George and Chapman 2013), meaning they require between 25 to 100 km (depending on temperature, flow, and river depth) of uninterrupted, turbulent, high flow main channel habitat to accommodate for this (Garcia *et al.* 2013; Kolar *et al.* 2007; Murphy and Jackson 2013). Size of larvae is dependent on hatch duration and water temperature (Chapman and George 2011). Chapman and George (2011) measured mean (± SD) total length (TL) of bighead and silver carp larvae that were raised at ~20 °C to be 5.5 mm ± 0.12 TL and 5.55 mm ± 0.28 TL, respectively, during the hatching stage, and 8.55 mm ± 0.13 TL and 8.2 mm ± 0.37 TL at swim bladder inflation, respectively (Chapman and George 2011). Within a few days (4-6 days, but

varies with temperature) of hatching, larvae inflate their swim bladders and appear to swim to the sides of rivers and into flood plains (Deters *et al.* 2013; George and Chapman 2013).

-*Predators:* The possibility that predatory fish exist that might consume large, relevant numbers of drifting silver carp eggs and larvae has not been formally studied. However, predation on bigheaded carp eggs likely occurs because the gape sizes of known egg predators including bluegill sunfish and yellow perch [see Cooke *et al.* 2005; Miittlebach and Persson 1998]) is large enough that they could consume relatively large eggs. Notably, these fishes are not typically found in the middle of the river and are also visual feeders and the river is turbid (Henley *et al.* 2000; Huenemann and Fleming 2012). Further, while open-river plankton feeding fish such as paddlefish and gizzard shad may consume some bigheaded carp and larvae, they are distributed throughout the water column and then only during high flow events, so predation by them on these stages (George *et al.* 2017), seems unlikely to be high. Paddlefish numbers are also seemingly not abundant in Pool 8 at present, although their exact numbers are not known.

-*Tentative conclusion.* Although the possibility that predators exist that exert high levels of control on bigheaded carp eggs and larvae has not been formally studied in the Upper Mississippi River, it seems unlikely because bigheaded carp eggs and larvae are only found in the flowing turbulent waters in the middle of the river where these possible predators are not typically found.

ii. Young–of-year (age-0 or juvenile) carp

- *Prey (i.e Juvenile carp):* Juvenile, or young-of-year (YOY) bigheaded carp are known to inhabit shallow (<1.5 m), low velocity shorelines and backwaters in the Mississippi River including its floodplains (Haupt and Phelps 2016; Kolar 2007). Growth of both carp species is rapid in the first year with individuals reaching ~200+ mm TL by year one (Hayer *et al.* 2014; Ridgway and Bettoli 2017; Williamson and Garvey 2005). Nevertheless, these young fish appear to be palatable and susceptible to predation.

-*Possible predators on carp:* Several studies have examined the possibility that native predators consume YOY carp in biologically-relevant manners and the results are promising but inconclusive. Briefly, 12 Mississippi River native fish species have been shown in field and controlled lab studies to consume YOY bigheaded carp (Table 2-1; Anderson 2016; Sanft *et al.* 2018; Wolf and Phelps 2017), 10 of which occur within Pool 8 and its backwaters, suggesting they could be important to YOY control. Gape sizes of these predators are adequate to consume YOY carp. However, the level of control that these predators would actually exert depends their abundance and feeding preferences and their abilities to locate YOY carp – and these data that are simply not available at present. Thus, while some data exist on prey preferences of bass (Anderson 2016; Sanft et al. 2018; Wolf and Phelps 2017), it is limited, and no data were found for the actual abundance of possible predators including largemouth bass in Pool 8, although it seems high based on electrofishing data (see June 20202 report).

-*Tentative conclusion.* The possibility that predators exist that exert high, biologically-relevant levels of control on juvenile (YOY) carp seems high but conclusive data are presently lacking.

iii. Adult carp

-*Prey (adult carp).* Bigheaded carp are fast growing and mature at age 2-3 (Kolar *et al.* 2007; Schrank and Guy 2002; Williamson and Garvey 2005). Sizes of age-3 bigheaded carp vary by region within the Mississippi River drainage system, with mean TL of this age-class ranging between ~500 to 800 mm TL in silver carp (Cox 2020; Hayer *et al.* 2014; Ridgway and Bettoli 2017; Stuck *et al.* 2015; Williamson and Garvey 2005) and 556 to 723 mm TL for bighead carp (Cox 2020; Schrank and Guy 2002). These fish are too large for most predators and also good swimmer (Hoover et al. 2017).

-*Possible Predators:* No published data was found on predation on adult bigheaded carp. Reviews of North American freshwater piscivorous predators demonstrated that consumed median and maximum prey lengths to be generally 10 to 20% and 32 to 46% of predator lengths, respectively, (Gaeta *et al.* 2018), with prey lengths of adult predators such as the largemouth bass, smallmouth bass, crappie, and walleye being <250 mm TL (Gaeta *et al.* 2018; Mittelbach and Persson 1998), meaning these species cannot consume adult carp. However, there

are few possible exceptions. The northern pike (*Esox lucius*) is one of the largest potential predators of the these carp in Pool 8, and is capable of consuming a 475 mm TL fish at 1000 mm TL, depending on prey depth (Gaeta *et al.* 2018; Mittelbach and Persson 1998; Nilsson *et al.* 1995). However, while capable of eating large fishes, the northern pike prefers smaller prey items (Nilsson and Brönmark 2000; Nilsson *et al.* 1995). Alligator gar (*Atractosteus spatula*) have also been suggested as a potential predator to aid in carp control in the southern United States, but alligator gar do not occur within Pool 8 of the Mississippi River. Anecdotal evidence has suggested that large blue catfish may consume adult silver carp but they also do not inhabit Pool 8, although flathead catfish do. Data on the abundance of large piscivorous fish in Pool 8 in recent years could not be found (we only have CPUE data), and while it seems likely that native predators could exert some control on adult bigheaded carp, the potential seems low.

-*Tentative conclusion.* The possibility that predators exist that could exert high, meaningful levels of control on adult bigheaded carp seems low but conclusive data are lacking.

iv. Summary

In summary, the information compiled by our literature review suggests that while bigheaded carp eggs, YOYs, and adults are likely all eaten by native predators currently living in Pool 8, it is likely that only YOYs are susceptible to this type of management because carp eggs/larvae are only present briefly and then in midwater, and the adults are likely to be too large and fast to be easily captured. However, there is promise for juveniles especially by largemouth bass in Pool 8. To accurately assess this possibility, future studies are needed or predator abundance in the pool and their prey preferences relative to species found in that pool. We will summarize our results and our specific recommendations in a final report in June.

Final Report Summary

Our study reviewed all available literature (half-a -dozen papers) and data on predators that might control bigheaded carps and came to the important conclusion that native predators are very unlikely to be able control bigheaded carp in Minnesota waters although more research would be desirable. In our study, we examined the literature for possible predators for bigheaded carp eggs and larvae, juvenile carp and adult carp. Invasive carp eggs and larvae are found mid-river and we found no references to there being large numbers of filter-feeders in this habitat that could control small eggs or larvae. The possibility that predators could control juvenile bigheaded carp found in flood plains also seemed slim from our work. Briefly, while several laboratory and pond studies (ex. Sanft et al. 2018; Anderson 2016) have found that several flood plain fishes including largemouth bass (which are relatively abundant in Pool 8), yellow perch, crappie and bullhead carp will at times consume young bigheaded carp, studies also clearly show that these predators do not prefer them, a requisite if they are to control them. This conclusion was also supported by a field study (Wolf and Phelps 2017). Finally, while adult bigheaded carp are known to be consumed by a few predators such as alligator gar, there is no evidence from our study that even these large fish can consume enough to reduce the population in biologically relevant manner. In summary, while native fish predators might conceivably help control bigheaded carp should carp breed in Minnesota waters, it seems unlikely the role of predators would be a significant one although further work on the feeding preferences and rates, and abundance of these fishes in local waters would be helpful.

ACTIVITY 3: Employing what was learned about carp passage at Lock and Dam 8 at other locks and dams

Because adult invasive carp have now passed Lock and Dam 8 (LD8) into Minnesota waters in significant numbers (March 2020), it is extremely important to take the lessons that the U of MN learned at LD 8 (carp will

pass through the spillway gates of certain structures at certain flows) and see if they could eventually be used upstream at other LDs. This requires information on the hydraulics and site characteristics of upstream LDs. Activity 3 would accomplish this by contracting with Barr Engineering Company, which is the only local engineering company with a working understanding of locks and dams and carp deterrents. Barr would perform an initial engineering assessment of site characteristics at LD4, LD5, LD6 and LD7 -LD8 as well as their hydraulics (all LDs between Lake Pepin and LD 8) and how in their present condition they might permit carp to pass or not, and if there is chance to alter this (work that was last performed in 2005 by Fishpro, before Sorensen's work). Barr would complete this assessment working with the U of MN in 3 months, summarize it as a 8-12 page report, and then present these findings at the virtual summit which Barr will also facilitate (see Activity 4 below).

ENRTF BUDGET: $35,000

Outcome	Completion Date
1. Evaluate the feasibility of installing effective carp barriers at Lock and Dams 4,5,6,7, 8.	June 15, 2021

Final Report Summary

Barr Engineering Company was contracted to perform an initial engineering assessment of the suitability of locks and dams 4 through 8 (south of Lake Pepin) to block invasive carp. Engineers examined sites, flows, and lock operations at these 6 locks and dams. Lock and Dams 5A, 6, 7, and 8 were found to have fixed crest spillways which over flow at high water events, making them poor candidates for carp control. Further, detailed analysis of river discharge (historic and modern-day) showed Lock and Dam 4 and Lock and Dam 5 to be best suited among the 6 sites to stop carp with LD5 being the best suited, because it reaches open-river conditions (when the gates and open and carp can pass) only 1.1-2.5 % of the time. The pool immediately upstream of LD5 (Pool 5) is also short and amenable to carp removal while LD5's lock was deemed capable of supporting a BAFF. Lock and Dam 5 was recommended as the most promising site for implementing an effective invasive carp control strategy in Minnesota. A final report was filed with the university and is being shared with the MN DNR.

ACTIVITY 4: Disseminating was learned about carp passage at Lock and Dam 8 and the status of carp in 2020,

A great deal has transpired with invasive carp management in the past year in spite of the pandemic: invasive carp have moved past Lock and Dam 8, Sorensen now understands exactly why this happened and how it could be presented at more northerly sites, one deterrent has been shown not to work (SILAS) and another has been shown to work (the BAFF in Kentucky). The MN DNR and USFWS have also learned much. In past years annual information on invasive carp has been disseminated at a "carp summit" hosted by the MN DNR which the U of MN has always attended but because of COVID19 the MN DNR cannot do hold the summit this year. Nevertheless, the MN DNR, USFWS, and the "Stop Carp Coalition" would still like to have carp summit to discuss recent developments and options. They are anxious to work with Dr. Sorensen (he is now the only fulltime invasive carp researcher in the state) to make this happen, but he presently lacks the resources. Activity 4 would make these resources available by allowing the U of MN to work with (i.e. contract) Barr Engineering Company, which is not the only local engineering company with a working understanding of locks and dams and carp deterrents but also has the required communications staff. Barr will facilitate a virtual forum, entitled "*Invasive bigheaded carp in Minnesota: where are we now and what might we do*?" Barr and the U of MN will invite government agencies including the MN DNR, WI DNRs, USACE, USFWS, LCCMR, and USGS, as well educational institutions and the general public (including advocacy groups- Stop Carp Coalition) to attend and participate. Barr will facilitate this forum by establishing a website, working with Sorensen to send out invitations, schedule speakers, organize a round table and lastly prepare a summary report. MN DNR and USFWS are in touch and willing to present their recent data but organization must start immediately. This

putative half-day forum will review a number of topics including: the status of invasive carp in Upper Mississippi River, the status and promise of invasive carp deterrent systems (U of MN this study), effects of spillway gate adjustments (this study), fishing-down carp (MN DNR), the hydraulics and potential of LDs to stop carp (Barr), as well other topics suggested by others as well as agencies with whom we are in communication with now. Possible effects of carp control on native fish could also be addressed. Options for how agencies and institutions could work effectively together and possible next steps would also be explored at a roundtable and results summarized and reported by Barr.

ENRTF BUDGET: $10,000

Outcome	Completion Date
1. Organize, promote, hold a public/ virtual carp forum "*Invasive bigheaded carp in Minnesota: where are we now and what might we do", and then summarize/ distribute.*	June 30, 2021

Final Report Summary

A 5 hour-long virtual carp forum "Invasive bigheaded carp in Minnesota: where are we now and what might we do?" was held June 17, 2021. It was facilitated by Barr Engineering Company and went very well. There were nearly 150 registrants (many time that of previous summits) including the MN DNR, WI DNR, USACE, USFWS, LCCMR, and USGS, as well as several educational institutions and the general public (including advocacy groups-Stop Carp Coalition). Several news outlets (MN Public radio, StarTribune, Outdoor news) covered the event. Over 100 individuals were online for the entire forum which had 4 speakers that welcomed us (Assistant commissioner MN DNR, District Chief USAFWS) and 10 speakers. An update on carp in Minnesota, control strategies used elsewhere, progress on barriers, a solution for Minnesota were presented. These talks can be found at: https://invasive-carp-forum-mn.barrevents.com/. Follow-up conversations are underway with the USFWS, congressional aids, and the MN DNR about next steps as result of this forum.

IV. DISSEMINATION:

Description: Findings will disseminated via peer-reviewed publications, presentations to both scientific and lay audiences, and the website of FWCB and the Minnesota Aquatic Species Research Center.

First Update January 31, 2019

We have had several meetings about the deterrent with the USFWS, USACE and MN DNR.

Second Update June 30, 2019

The MN DNR and WI DNR have been informed about the project. They are too busy to meet so we are keeping in touch with weekly emails. We have met with USACE and USFWS.

Third Update January 31, 2020

Results to data were presented as talks at the Stop Carp Coalition meeting with the MNDNR and three talks and a poster at the Midwest Fish and Wildlife Conference in Springfield, IL.

Fourth Update June 30, 2020

We published one paper and gave three presentations this past winter

Dennis III, C. E., and P. W. Sorensen. 2020. High-intensity light blocks Bighead Carp in a laboratory flume. *Management of Biological Invasions* 11 (2020). (in press)

Whitty, J., Riesfgraf, A., Zielinski, D., and Sorensen, P. (2020). Integrating a sound/light deterrent and dam gate operations at Lock and Dam 8, Mississippi River to reduce upstream migration of common carp (*Cyprinus carpio*). Midwest Fish and Wildlife Conference: January 26-29. Springfield, Illinois. (Poster)

Whitty, J., Riesfgraf, A., Zielinski, D., and Sorensen, P. (2020). Integrating a sound/light deterrent and dam gate operations at Lock and Dam 8, Mississippi River to reduce upstream migration of common carp (*Cyprinus carpio*). American Fisheries Society – Minnesota: Feb 11, 2020. Willmar, Minnesota. (Poster)

Whitty, J., Riesfgraf, A., Zielinski, D., and Sorensen, P. (2020). Integrating a sound/light deterrent and dam gate operations at Lock and Dam 8, Mississippi River to reduce upstream migration of carp. Upper Midwest Stream Restoration Conference: Feb 24, 2020. Stillwater, Minnesota. (Presentation)

Fifth Update January 31, 2021

We attended several virtual meetings (Mississippi River Basin Aquatic Nuisance Species Task Force, Stop Carp Coalition). Three manuscripts are in draft form (2 on sound deterrents at LD8, 1 on carp passage at LD8). More are being written and we hope and plan for summit.

Final Report Summary

The results of this project have been disseminated widely in half-a dozen peer-reviewed scientific publications (listed below), several stories by the press (Star Tribune, Outdoor News, MPR), several public presentations at both scientific and nonscientific forums, and via our recent Carp Forum https://invasive-carp-forum-mn.barrevents.com/. Publications include:

Dennis CE., Sorensen PW. (2020). High-intensity light blocks Bighead Carp in a laboratory flume. *Management of Biological Invasions* 11: 441-460.

Finger JS., Riesgraf AT. Zielinski DP, Sorensen PW (2020). Monitoring upstream fish passage through a Mississippi River lock and dam reveals species differences in lock chamber usage and supports a fish passage model which describes velocity-dependent passage through spillway gates. *River Research and Applications*, *36*(1), 36 – 46. https:/doi.org/10.1002/rra.3530

Zielinski DP, Sorensen PW (2021) Numeric simulation demonstrates that the upstream movement of invasive bigheaded carp can be blocked at sets of Mississippi River locks-and-dams using a combination of optimized spillway gate operations, lock deterrents, and carp removal. Fishes 6, 10. https://doi.org/10.3390/fishes6020010

Whitty JM, Riesgraf AT, Zielinkski DP, Sorensen PW. (in review). Upstream passage rates of common carp through the roller gates, tainter gates, and lock of a typical Upper Mississippi River lock and dam. *River Research and Applications.*

Riesgraf AT, Finger JS, Zielinski DP, Dennis CE, Whitty JM, Sorensen PW. (in review). Evaluation of a broadband sound projected from the gates of a navigation lock in the Mississippi River shows it to be a weak deterrent for common carp. *Management of Biological Invasions*

V. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview: See attached budget spreadsheet

Explanation of Capital Expenditures Greater Than $5,000: n.a.

Explanation of Use of Classified Staff: n.a.

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 10,000	Divide by 2,080 = TOTAL FTE: 4.5

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 400	Divide by 2,080 = TOTAL FTE: 0.20

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period:			
	$	$	
Other State $ To Be Applied To Project During Project Period:			
	$	$	
Past and Current ENRTF Appropriation:			
ENRTF M.L. 2009 Chp.143, Sec. 2, Subd. 6d.	$300,000	$300,000	Fish bubble barriers, successfully completed
ENRTF M.L. 2012, Chp. 264, Art.4, Sec. 3	2,000,000	$1,930,000	MAISRC incl Carp repellents and eDNA, all completed except for one modeling study
ENRTF M.L. 2013, Chp. 52, Sec. 2, Subd. 06a	8,700,000	8,350,000	MAISRC incl carp attractants and sound. Successfully completed except for ongoing work with sound
ENRTF M.L. 2014, Chp. 226, Sec. 2, Subd. 04a	854,000	854,000	Carp deterrents, successfully completed
Other Funding History:			
Minnesota DNR	$880,000	$720,000	Successfully confirming numeric models of fish passage, Last year of this project

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
U.S. Fish and Wildlife Service	Biologist	LaCross Lab	Assist with fish tagging at Lock and Dam #8

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

VIII. REPORTING REQUIREMENTS:

- **The project is for3 years, will begin on July 1, 2018, and end on January 31, 2021.**
- **Periodic project status update reports will be submitted January 31 of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2021.**

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet
D. Acquisition, Easements, and Restoration Requirements
E. Research Addendum

FINAL Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet

Project Title: An effective and practical invasive carp deterrent
Legal Citation: M.L. 2018, Chp. 214, Art.4, Sec. 2., Subd. 06E
Project Manager: Peter Sorensen
Organization: University of Minnesota
College/Department/Division: CFANS, Fisheries, Wildlife & Conservation Biology
M.L. 2018 ENRTF Appropriation:
Project Length and Completion Date: 3.0 years, June 30 2021
Date of Report: August 8 2021

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent
BUDGET ITEM		
Personnel (Wages and Benefits) - Overall	**$385,000**	**$383,497**
Professor/PI, Sorensen , 4 weeks/yr x 2.5; $3100/wk (74% salary, 26% benefits), 0.20FTEs (Total estimated amount $41,920) ($ 45298) (June2019- 27 200)		
Postdoc or Biological technician, TBD, fulltime x 2.5 ; $48,000 (79% salary, 21%benefits), 2.5 FTEs (Total estimated amount $152,400) (June 2019 163,200)		
Technician, TBD, partime $10,000 (.2FTE)(June 2019- $61,100)		
Graduate student, TB; 50% time x 2.25yr; $48,000 (49% salary, 51%benefits), 1.13 FTE(Total estimated amount $108,000)($96427) (june 2019- 44 000)		
Undergraduate fish student#1, 400h@$15 (100% salary), 0.14FTE (Total estimated amount $6,000)($ 7000)		
Engineer/PI, Marr, 48hrs@$52.7; (74% salary, 26% benefits), 0.04FT (Total estimated amount $3,379)		
Technician, Christopher, 600h@$32.8; (74% salary, 26%benefit)0.22 FTE (Total estimated amount $26,289)		
Undergraduate Eng student#2, Gabrielsen, 316h @$21, (79% salary, 21% benefits), 0.1 FTE (Total estimated amount $8,433)		
Assoc Engineer, Milliren, 156h@$25.4 (79% salary, 21% benefits), 0.1 FTE (Total estimated amount $5,040)		
Coord Enginner, Ericksen, 144h@$29.9 (79% salary, 21% benefits), 0.1 FTE (Total estimated amount $5,482)		
Professional/Technical/Service Contracts	**$389,100**	**$377,562**
*Dive team ($5000/day *6) to install, remove FGS deterrent / year (SAFL)*	$70,000	$66,190
Internet contractor - to be selected competitively (SAFL)	$100	$100
Electrical contractor- to be selected competitively (SAFL)	$24,000	$22,575
Lease (with buy option), Fish Guidance System (small increase; Jan 2019 PWS)	$250,000	$248,697
Barr Engineering Company (Act 3 assessment + Act 4 forum)	$45,000	$40,000
Equipment/Tools/Supplies	**$161,900**	**$154,813**
Misc engineering supplies for deterrent assembly and mounting	$15,500	$15,500
700 accoustic fish tags@$200 (Total estimated amount $140,000)(go to 600 tags Jan 2019)	$104,000	$100,000
ATS batteries for receivers for fish tags 50+ @$248 (PWS, not needed as of jan 2019)	$2,000	$2,000
Misc biology field supplies (gas, nets, boots, electrodes, etc) (PWS add supplies to add wireless capability to fish tag receivers, Feb2019)	$14,095	$11,008
9 SR3017 ATS receivers (@$3750) (update PWS Jan 2019)	$26,305	$26,305
Travel expenses in Minnesota	**$35,000**	**$31,430**
Engineer travel, hotel and meals to L&D #8 (Total estimated amount $3421)	$11,000	$9,211
*Sorensen lab travel to LD8 (400miles*50 trips/ full year =40,000 miles; lease +gas=10K/y) , 25 hotel overnight with meals/y ($4000/v)*	$24,000	$22,219
Other - overall	**$27,000**	**$21,342**
Fish management workshops, travel outstate Total estimated amount $1,000)(Sorensen)	$1,000	$1,000
Shipping FGS equipment (Total estimated amount $5,000)(Sorensen, general services?)	$8,500	$7,314
Shipping FGS gear to LD8 from SAFL (Total estimated amount $1,500)(SAFL general services?)	$0	$0
Internet and electrical service (Total estimated amount $2,500) for equipment installed at the lock and da (a service privded by SAFL)(SAFL general services?)	$1,000	$457
Cell phone data service for receivers (PWS, general services)	$0	$0
Field equipment repairs (Total estimated amount $5,000, 1K SAF, 4k PWS)	$16,000	$12,571
Short term lease for boat storage	$500	$0
COLUMN TOTAL	**$998,000**	**$968,644**