INVASIVE GOLDFISH POPULATION AND INTER-WATERBODY MOVEMENT ASSESSMENT IN LAKE CORNELIA SYSTEM

Report for the Nine Mile Creek Watershed District

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INTRODUCTION

Invasive goldfish were recently added to the Minnesota Aquatic Invasive Species Research Center (MAISRC) priority list for investigation. They are being released into lakes around the Twin Cities metro area. Education is needed to prevent initial infestations. Little is known about the risk of spread of this invasive species to other connected water bodies if an infestation has been confirmed. The results of this study and education initiative have and will continue to work to prevent introductions as well as guide planning and management of watersheds to take rapid action to stop the spread of goldfish in this system and others in Hennepin County.

In addition to goldfish, common carp are well-known to be a significant driver of poor water quality parameters. While foraging, they root around in lake sediments where nutrients like phosphorous can be locked up in an inactive form. When disturbance occurs from an overabundance of carp, large amounts of phosphorous are reintroduced to the water column where it becomes available for algae. This in turn promotes green algae blooms as well as turbid water conditions. Both North and South Cornelia are on the Minnesota Pollution Control Agency's Impaired Waters list due to excess nutrient loads. The main parameters that are measured to decide if a water body belongs on this list are total phosphorous (TP), chlorophyll-a (algae abundance), and clarity (measured by secchi depth). Goldfish and common carp can contribute significantly to the internal loading of TP and management of their populations below a threshold of 100kg/ha (Bajer et al, 2009) is generally considered to be an inexpensive method of managing internal loading (Bartodziej et al, 2017).

In 2018, surveys completed by Riley Purgatory Bluff Creek Watershed District for Nine Mile Creek Watershed District (NMCWD) identified carp in Cornelia Lake and surrounding potential nursery lakes. Goldfish and carp were found in numbers that warranted more rigorous assessment and understanding of inter-lake spatial usage in order to guide future long-term management. To properly assess for goldfish and carp biomass levels and the presence of Young of Year (YOY), WSB recommended that electrofishing surveys be properly completed as deemed by protocols in Bajer and Sorensen (2012). **Although carp were not the focus of this study, the methodology and interpretation of results were dependent on comparing similar gear types and mathematical relationships as have been used for carp. Therefore, the carp results were included in this report.**

It was also important to understand and therefore study the movement capabilities and patterns between and within lakes in the Cornelia system. WSB utilized passive integrated transponder (PIT) tags to track movement via antennas at strategic locations in the Cornelia system. To understand the history of recruitment in this system, an age structure needed to be developed for goldfish and carp to connect past environmental conditions in which the lake system was at risk. That structure will also help determine how often biomass reduction efforts are needed over the long-term time scale moving forward. Finally, WSB needed to test a system for biomass reduction that has been found to be effective at species specific capture of carp. It was tested in Nancy Lake where the population of goldfish was found to be very high.

This test allowed the watershed district to plan for the future of removals, if needed and found to be affective, and costs associated with that effort. In general, the data collected in this work will serve as the scientific baseline to determine if/what population reduction is needed to meet biomass goals, understand important pathways to movement, and strategize if/what management of goldfish and/or carp should be planned for the future in order to improve water quality and promote the health of the lake ecosystems.

The following is a detailed description of the methods, results, and discussion of each objective:

ELECTROFISHING SURVEYS TO ESTIMATE POPULATION AND IMPLANT PIT TAGS

METHODS:

Electrofishing consists of a boat with an onboard gasoline generator that supplies power to a dual boom cathode array that hangs off the front of the boat, as shown in ***Figure 1*** below. A control box run by the navigator adjusts the type of electrical output depending on lake depth, temperature, and conductivity. Generally, the output runs around 18-22 amps and 2,000-3,000 watts. This amount of electricity causes a phenomenon known as electrotaxis, movement toward an electric field, and as the fish enters the strongest area of electricity, it is immobilized and able to be netted without long term harm to the fish. The fish generally returns to normal behavior between a few seconds to a few minutes after removal from the electric field. The zone which immobilizes fish is generally about four feet around each boom array and about four feet deep.

Electrofishing efficiency can be affected by characteristics of the lake and water quality. The most effective areas are within 20-30 feet from shore and less than four feet deep. However, navigation becomes difficult when depths are less than two feet. Catch efficiency can also be reduced with low water clarity and an overabundance of aquatic vegetation. Water clarity somewhat impaired catch rates in all lakes, but vegetation only had an effect on catch rate on Swimming Pool Pond where there were abundant amounts of vegetation to navigate around.

Electrofishing surveys were completed on all four lakes: North Cornelia Lake, South Cornelia Lake, Swimming Pool Pond and Lake Nancy.

The goals of the surveys were multifaceted, and included capturing goldfish and carp for the following reasons:

1. Mark and recapture population estimates
2. Analyze catch per unit effort (CPUE) to develop a rapid population estimation relationship using electrofishing
3. Implant passive integrated transponder (PIT) tags
4. Remove otoliths to age a sample of the population and develop a length to age relationship
5. Qualitatively survey other species in each lake to assess fisheries assemblage.

Figure 1: An electrofishing crew on Lake Nancy

These surveys are best done between the months of July and September while carp are more evenly distributed around the lake. Each lake was surveyed on three different occasions between July 7 and August 5, 2020. Each survey included three transects of a minimum of 20-minutes in randomized sections of shoreline in each water body. We conducted these surveys on three different days at least one week apart. This is to account for differences in environmental conditions that may bias the catch rate. We would use the catch per unit effort (CPUE) model described in Bajer and Sorensen (2012) to quickly determine the carp density and average size of the carp and goldfish and scale that to the lake for an overall carp biomass (kg/ha). A major component of this study was to determine if the carp CPUE relationship was also applicable to the closely related goldfish.

While we had fish in hand, we measured and weighed a sample, as shown in ***Figure 2*** below, implanted a PIT tag into a sample, and gave a pelvic fin clip before releasing back to the lake.

We were able to capture and release enough goldfish in each lake to implant PIT tags, collect the ageing sample and release captured fish with marks in the form of pelvic fin clips. We put a unique fin clip mark for each lake so we could identify if a recaptured fish had come from a different lake as shown in ***Figure 3***.

In subsequent capture events, we checked each fish for the previously given marks in order to calculate a mark/recapture population estimate. This is generally more reliable but requires more effort and cost.

RESULTS:

Figure 2: A sample scoop during electrofishing surveys. Weighing a large goldfish in South Cornelia

Figure 3: Examples of recaptured goldfish with visible fin clip marks.

CARP SPECIFIC RESULTS:

Carp were not abundant in any of the water bodies we electrofished. We caught a total of nineteen (19) among the four locations. The highest catch rate was in Swimming Pool Pond. This matches the trends that were seen in Riley Purgatory Bluff Creed Watershed District's (RPBCWD) survey in 2018. However, contrary to their survey, we did not observe any YOY carp. Zero carp were captured in Lake Nancy. The size distribution is summarized in ***Table 1*** below.

Table 1: Size Distribution of Carp in Cornelia System

Length categories (inches)	North Cornelia Lake	South Cornelia Lake	Lake Nancy	Swimming Pool Pond
0-2				
2-4				
4-6				
6-8				
8-10				2
10-12				5
12-14		2		4
14-16				
16-18	1			1
18-20	1			1
20-22	1			

Since all carp captured were euthanized for ageing purposes, we were not able to conduct a proper mark and recapture estimate of the population. However, using the established estimate relationship using catch per unit effort (CPUE) of electrofishing for carp, we were able to generate population and biomass estimates based on Bajer and Sorensen's (2012) methodology. The calculations are summarized in ***Table 2*** below.

Table 2: Summary of Population and Biomass Estimates for Carp in the Cornelia System Using Electrofishing CPUE.

Lake	Date	Average CPUE	Population estimate	Average mass (kg)	Biomass (kg/ha)
Lake Nancy	7/8/2020	0	6	0.5*	<2*
	7/15/2020	0	6	0.5*	<2*
	8/5/2020	0	6	0.5*	<2*
				Average	**<2***
Swimming Pool Pond	7/9/2020	3	58	0.62	10.6
	7/22/2020	8	139	0.6	24.4
	7/31/2020	2	42	0.43	6
				Average	**13.6**
North Cornelia Lake	7/10/2020	1	60	1.5	10.3
	7/22/2020	0	23	1.6*	2.2
	8/3/2020	1.1	37	1.8	13.7
				Average	**8.7**
South Cornelia Lake	7/7/2020	2	167	0.77	9.5
	7/15/2020	0	41	0.73*	2.2
	8/3/2020	0	41	0.73*	2.2
				Average	**4.6**

* indicates an estimated value based on similar lakes' data. All biomass estimates fall under the 100 kg/ha threshold.

<u>GOLDFISH SPECIFIC RESULTS:</u>

For comparison purposes of each lake and their size distribution, ***Table 3*** below is presented for goldfish in each lake. Although the sample sizes range from 315 in Nancy to 212 in Swimming Pool Pond, the general trends are evident. Relatively small individuals were found in Lake Nancy and Swimming Pool Pond, and larger goldfish were found in North and South Cornelia Lakes.

Table 3: Size Distribution of Goldfish in Cornelia System

Length category (inches)	North Cornelia Lake	South Cornelia Lake	Lake Nancy	Swimming Pool Pond
0-2				1
2-4	4	1	48	128
4-6	126	11	118	78
6-8	38	79	131	5
8-10	10	46	18	
10-12	57	78		
12-14	4	27		
14-16				
16-18	1			
18-20				

To illustrate the growth curve of goldfish in the system, a sample of captured goldfish were weighed and compared. Few wide-ranging size differences in the same watershed exist in the literature for this geographic area. The results are illustrated below in ***Figure 4.***

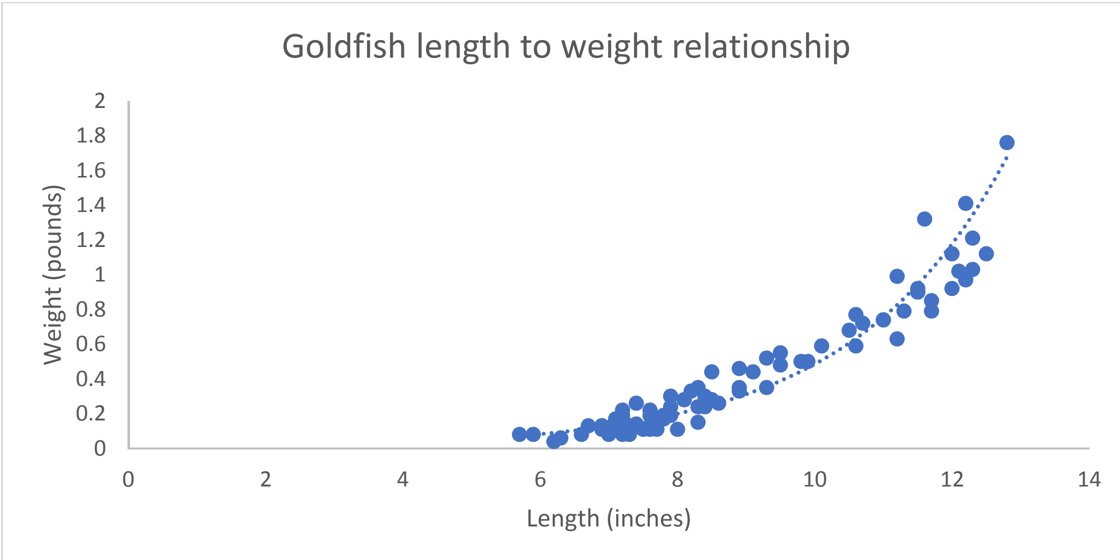


Figure 4: A trendline showing a sample of goldfish captured and their weight to length relationship. This includes goldfish from all lakes.

Mark and recapture estimates were possible in these lakes since the effort was sufficient to catch and recapture some goldfish. The calculation in the most basic for follows this equation:

$$\hat{N} = \frac{Kn}{k},$$

Here, N is the total population, n is the total captured in events following the marking event, K is the number of marks given in previous events, and k is the number of recaptured fish that had a fin clip mark or a PIT tag. This formula has been adjusted to more accurately fit different types of populations and different types of marking periods.

In this case, we chose to use the Chapman estimator for mark and recapture population estimates. This small modification is more appropriate for multiple marking and recapture events, which means it's appropriate for our work. The modified formula is as follows:

$$\hat{N}_C = \frac{(K+1)(n+1)}{k+1} - 1$$

Table 4 below summarizes the marking and recapture efforts. The population estimates are found in the far-right column. Each lake had two opportunities to recapture marked fish. The two days of recaptures were averaged to give the overall population based on the average of both events.

Table 4: Mark and Recapture Estimate Summary for Goldfish in Cornelia System

Lake	Date	Total captured (n)	Total marks in lake (K)	Recaptured marks (k)	Population estimate (N)	Confidence interval
Lake Nancy	7/8/2020	195	0	--	--	
	7/15/2020	264	195	6	7419	±3000
	8/5/2020	424	350	12	8568	±2253
				Average	**7993**	**±2626**
Swimming Pool Pond	7/9/2020	143	0	--	--	
	7/22/2020	217	143	0	31391	±22145
	7/31/2020	89	359	2	10799	±6165
				Average	**21095**	**±14155**
North Cornelia Lake	7/10/2020	181	0	--	--	
	7/22/2020	251	180	1	22805	±13114
	8/3/2020	521	430	6	32139	±13057
				Average	**27472**	**±13085**
South Cornelia Lake	7/7/2020	181	0	--	--	
	7/15/2020	151	35	0	5471	±3855
	8/3/2020	173	186	5	5394	±2170
				Average	**5433**	**±3013**

The mark and recapture results were presented first because they are generally found to be more accurate than a CPUE relationship. Although recaptures were obtained in all lakes, there were relatively few of them. The estimates become more accurate with increasing number of recaptures. Hence, we have confidence in the estimates for each lake, but much of the variability can be explained by the low number of recaptures.

Table 5 below summarizes the CPUE of goldfish averaged by day and eventually by each lake overall. The population estimate was calculated with the exact relationship used for carp for a benchmark reference point for comparison between the species.

Table 5: Summary of goldfish population estimates using the Bajer and Sorensen (2012) relationship for carp estimates using electrofishing CPUE.

Lake	Date	Average CPUE	Population estimate
Nancy	7/8/2020	374	3885
	7/15/2020	264	2744
	8/5/2020	312	3242
		Average	**3290**
Swimming Pool Pond	7/9/2020	143	2302
	7/22/2020	217	3488
	7/31/2020	169	2719
		Average	**4374**
North Cornelia	7/10/2020	181	6594
	7/22/2020	251	9135
	8/3/2020	291	10600
		Average	**8776**
South Cornelia	7/7/2020	105	6674
	7/15/2020	151	9580
	8/3/2020	173	10960
		Average	**9071**

While focusing on goldfish and carp capture, netters also noted all other species seen and collected a sample the was representative to each lake. Although this was not the primary objective, an updated species assemblage and comparative abundance is presented below in ***Figure 5.***

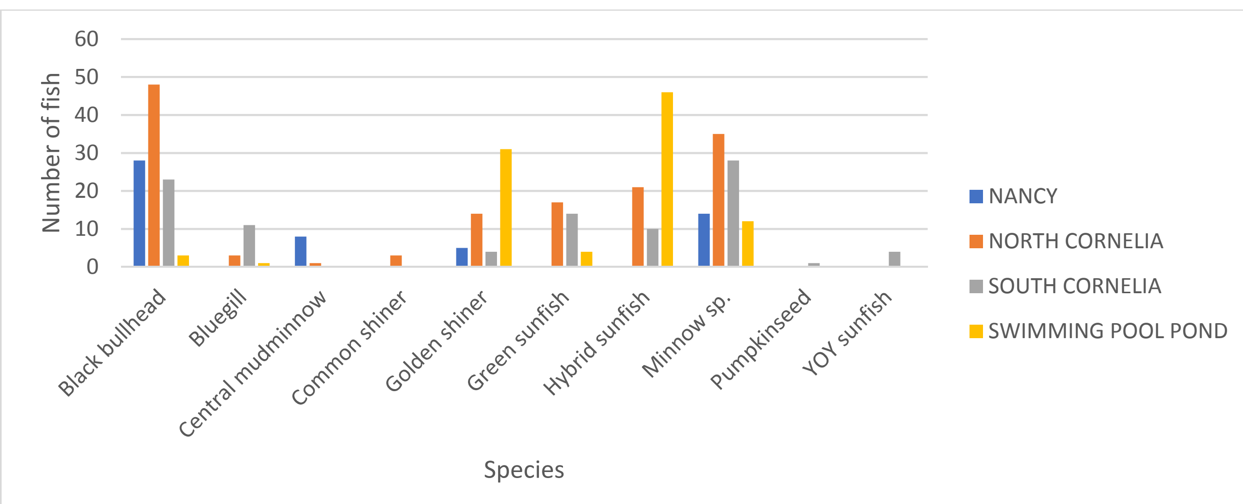


Figure 5: General fish assemblage in Cornelia system. Goldfish and carp are not included in this figure.

DISCUSSION:

During these surveys and also comparing to surveys completed by the more general survey in 2018 by Riley Purgatory Bluff Creek Watershed District, carp were not overly abundant. The highest catch rates were in Swimming Pool Pond which still did not indicate a carp biomass over the threshold that warrants significant management. Although it was not surveyed with this project, Swimming Pool Pond shares a nearby open-water connection to Point of France Pond which was indicated to have an abundance of YOY carp. Judging by the size of carp and the spacing of the bars in the grate that covers the pipe where water flows from Swimming Pool Pond to North Cornelia Lake, it does not appear that these lakes are functioning as significant nurseries for carp as shown in ***Figure 6***.

Figure 6: A grate covers the culvert where water runs to North Cornelia Lake. It is unlikely that adult or subadult carp could pass, but possibly small goldfish.

Future removal efforts for goldfish on the lakes will likely be effective for carp as well as goldfish and will be a worthwhile use of time and effort.

Goldfish were abundant in all lakes. In general, the populations' size structure in Lake Nancy and Swimming Pool Pond were smaller than North and South Cornelia Lakes. This is not surprising since the Cornelia basins, being somewhat deeper, have a lower chance to suffer winter kills. That allows longer-lived adults to persist in the main basins, as reflected in the age structure below.

One main question was if the literature-based relationship for quick population estimates for carp were accurate for goldfish as well. Comparing Table 2 to Table 5, it appears that the carp estimate model underestimates the population in Lake Nancy, North Cornelia, and Swimming Pool Pond. Conversely, it overestimates the population for South Cornelia. It is currently unclear of the explanation. It is noteworthy to mention that the variability in recapture rate and CPUE can change the population estimates significantly due to the relatively small sample size of recaptured marked fish and the number of days the electrofishing CPUE were determined. More data will need to be collected to develop a model that accurately and rapidly estimates goldfish populations. The more robust estimator available currently is mark and recapture estimates which can be improved with further marking efforts before large-scale removal events. With the dual benefit of tracking movement as well as a permanent mark on the fish (fin clips grow back within 6 months and are indistinguishable), we recommend more PIT tags be implanted into goldfish in the lakes.

INSTALLING PIT ANTENNAS TO MONITOR CARP MOVEMENT BETWEEN LAKES

METHODS:

Passive integrated transponder (PIT) antennas consist of a power source, an antenna tuner, the antenna itself, and a reader of the signals being detected by the antenna. Each unique RFID number detected is recorded and time stamped. Three of the four stations were powered by a deep cycle marine battery which was continuously charged by a single 100-watt solar panel. One antenna station on Lake Nancy was powered by 110-volt power from a residential household. The power was converted to 12-volt power that is needed to run the antennas.

Antennas were constructed, installed and tested to monitor the movements of tagged goldfish and carp in the Cornelia Lake system. Antennas were installed in four locations, as shown in ***Figure 7,*** to determine which water bodies are important in the recruitment of carp in the system. The results will determine what time of year, what proportion of the population is moving and how often they use the pathway between bodies.

The antenna stations were uninstalled at the end of November before the lakes began to cover in ice to prevent damage to the antenna components. We intend to reinstall them as ice is melting from the lakes.

These antennas were in place before PIT tags were implanted during the electrofishing surveys described above***. These antennas will be needed to collect movement in the spring of 2021, when spawning migrations are anticipated to occur. Furthermore, long term PIT monitoring data is very valuable to capture trends of movement over longer periods of time. We recommend considering further monitoring of these locations for the future***.

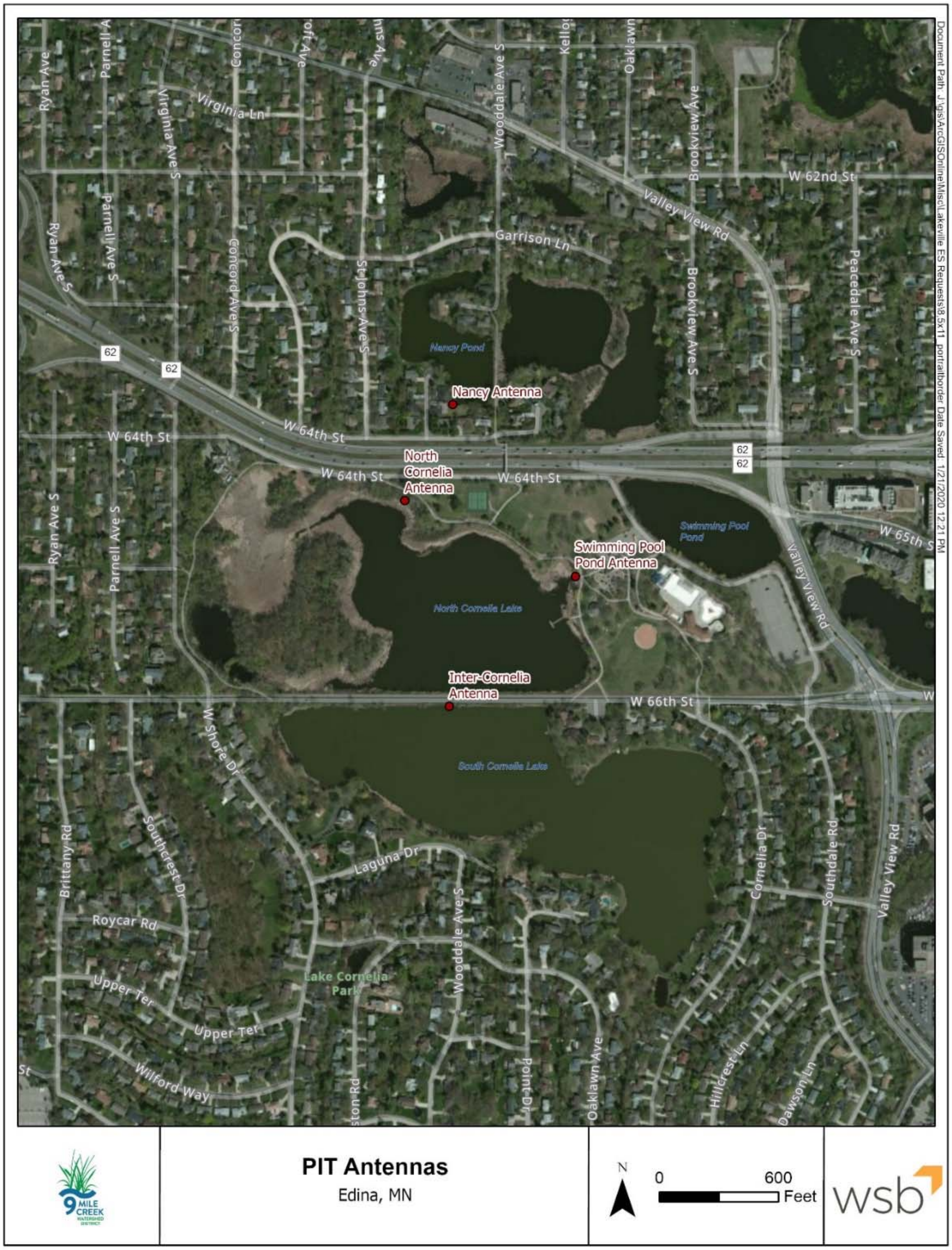


Figure 7: Illustration of locations of PIT antennas strategically placed in potential fish pathways.

Results of the movement of tagged fish through one or more pathways will be us in consideration of barriers to impede movement and/or a trap to target the migrations for biomass removal.

Figure 8: A solar powered PIT antenna station located between North and South Cornelia.

RESULTS:

The Nancy, Inter-Cornelia, and North Cornelia/Nancy antennas were all powered and detecting tag numbers accurately from day of their installation. No system shut down due to a power failure. A firmware glitch from the manufacture caused issue with two antenna systems which caused the time/date stamp to be inaccurate. Therefore, we do not know definitively when some tag crosses occurred. The glitch has since been resolved. In addition, the North Cornelia/Swimming Pool Pond antenna was vandalized minutes after WSB finished installation and left the antenna. Unfortunately, the system was not functional until the unit could be refurbished and reinstalled in August. It is possible that tagged fish could have crossed during that time. Table 6 summarizes the results of PIT tagging efforts in the four water bodies.

Table 6: Summary of PIT tagged goldfish in the Cornelia system.

South Cornelia Lake		North Cornelia Lake		Lake Nancy		Swimming Pool Pond	
Number tagged	Average length	Number tagged	Average length	Number tagged	Average length	Number tagged	Average length
85	11.4	129	8.8	168	6.9	42	5.4

Most fish detected at antennas were from the same water body in which they were originally tagged. The exception is the Inter-Cornelia antenna where fish from both basins were detected (Table 7).

Table 7: Summary of PIT tag detections and their origins

	Inter Cornelia	North Cornelia/Nancy	Nancy	North Cornelia/Swimming Pool Pond
Tag detections	4 unique tags	6 unique tags	6 unique tags	6 unique tags
Implant origin	2 from North Cornelia and 2 from South Cornelia	5 from North Cornelia and 1 from South Cornelia	All tags from Nancy	All tags from North Cornelia

DISCUSSION:

The number of tags detected by the antennas was relatively low (between 0% and 5.4% of a body's total implanted tags). Anecdotally, this is similar to YOY carp that were tagged in known nursery lakes upstream of Long Lake in the Rice Creek Chain of Lakes. However, this could be due to a number of things. The antennas were actually only running for a portion of the open water season. It is well known that carp most actively move from one water body to another during spawning migrations that occur in spring months. In addition, the number of tags in the system could be increased to detect the portion of the population that leaves the lake more accurately.

Of course, it is also plausible to imagine that goldfish actually do not move between lakes often enough to constitute the "carp-like" nursery system that is hypothesized. However, at this point the amount of data collected is not sufficient enough to draw confident conclusions. **Again, we highly recommend that the PIT antenna stations be monitored for as long as possible to understand trends that are not well-understood at this point for this invasive species.**

TESTING RAPID MANAGEMENT ACTION TO ADDRESS LOCALIZED INFESTATIONS

METHODS:

We tested a technique found to be successful in small water bodies with common carp to determine efficacy with goldfish. A box net trap refers to a mesh net that lays on the lake bottom with attached walls around the outside. These walls are attached to vertical metal pipes that extend above the water surface. The walls are attached to ropes that are run to shore and when the ropes are pulled in, the walls quickly rise above the surface trapping the fish within the trap area inside. The fish are corralled to a corner and removed with a dip net.

A modified baited-box-net trap, one with a mesh size appropriate for goldfish instead of adult carp, was deployed in Lake Nancy and baited with cracked corn, sweet corn and freeze-dried blood worms. The bait was broadcast by a resident daily. This method has been found to be over 98% selective for carp. All fish captured will be counted and measured. All goldfish were to be removed from the lake.

Surveys of the lake and its bottom showed only one location that was able to install the trap. The trap requires moderately firm substrate in the area that the net would lay. Approximately 15 feet from shore along the entire shoreline was moderately firm and worked well. However, farther than that from shore was completely unconsolidated and wading past that point was nearly impossible. Minor modifications were done to the trap to install it as shown in ***Figure 9***. The effectiveness baiting was difficult for the resident to determine since regular wading out to a bait bag was not feasible. She noticed; however, periodic instances of fish around the shoreline, but clarity of the water made it difficult to determine.

Figure 9: In the process of installation of the box net in the Northwest corner of Lake Nancy.

RESULTS:

The trap was deployed once after broadcast baiting for 3 weeks. Lifting the net out of the mud was difficult and the launching a large boat to assist the lifting was problematic with no true boat launch. The net captured 102 goldfish with an average length of 7.6 inches. This is slightly above the average for the whole lake. It was noted that three larger goldfish captured, two from the box net and one from electrofishing near the trap, were excreting corn upon examination.

DISCUSSION:

The box net was quite difficult to install and maneuver in Lake Nancy due to its bottom consistency. It did not seem to be significantly more effective than electrofishing at capturing goldfish in this situation. Due to the extra time required to install, bait, uninstall and decontaminate, we do not recommend further effort be focused on this strategy in the future. Since we did observe evidence of corn consumption from larger goldfish, it seems like corn is relatively effective at attracting larger goldfish and this technique could be effective in a different lake with larger goldfish and areas with firmer bottoms.

UNDERSTANDING RECRUITMENT STATUS IN THE LAKE COMPLEX

METHODS:

WSB collected and euthanized samples of goldfish and carp populations during electrofishing surveys as shown in ***Figure 10***. By removing the inner ear bones called otoliths and cross sectioning them under a microscope, we were able to document the growth rings, annuli, shown in ***Figure 11***. The ages were grouped to determine past year classes of recruitment. This is otherwise known as an age structure for the population. This is important to understand in order to project management impacts over the span of many years to determine sustainability.

Figure 10: An illustration of some goldfish aged from South Cornelia.

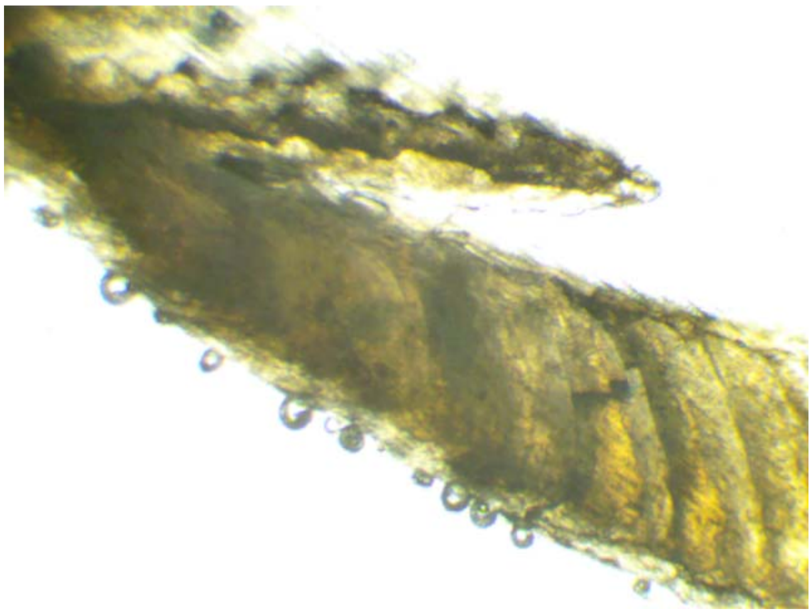


Figure 11: An example of an otolith cross section as seen through the microscope while determining age.

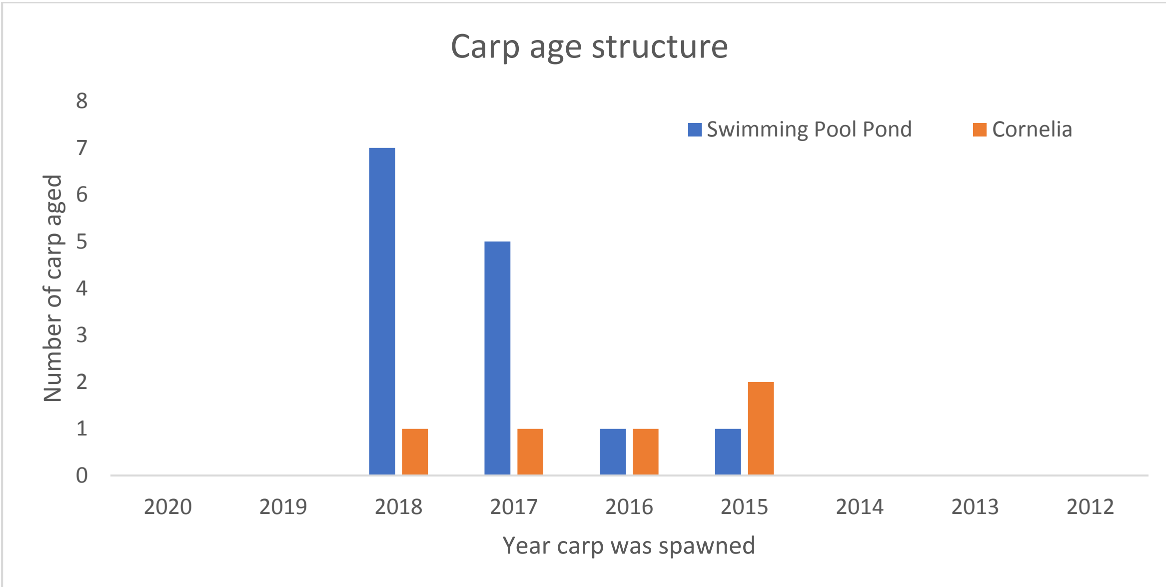
RESULTS:

All carp captured were euthanized and examined for age. Only a total of 19 were captured among the four water bodies. All individuals were likely adults or subadults due to size range. Zero young of year carp, smaller than six inches, were observed. Most carp were captured from Swimming Pool Pond, totaling fourteen, with three coming from North Cornelia Lake and two from South Cornelia Lake. Zero were captured in Lake Nancy. It appears that there were large recruitment years in 2017 and 2018.

All goldfish samples were taken from South Cornelia and Nancy Lakes. It was assumed that North and South Cornelia Lakes are considered essentially one lake since there is an open water connection between them and PIT tagged goldfish were found to cross the antenna between the basins. Goldfish from Lake Nancy were examined due to the previous survey that indicated a high number of small goldfish compared to Swimming Pool Pond. In addition, it was assumed more likely that goldfish would easily travel from Lake Nancy to Cornelia Lake since a trash grate with narrow bars between Swimming Pool Pond and Cornelia was likely preventing large goldfish from moving between the lakes. Therefore, it was of special interest to understand the age structure of the presumed nursery for Cornelia.

Goldfish seem to have recruited each year between 2013 and 2018 with the exception of 2016 which shows a low level of recruitment. The degree to recruitment was relatively steady during those years but was strongest increases in age class between 2012 to 2013 and 2016 to 2017 as shown in ***Figure 12***.

It is noteworthy to mention that there were also surviving YOY goldfish captured in all locations. Since goldfish with lengths of 4.5, 4.5, and 4.6 were aged 1, 2 and 2 respectively, it was assumed that any goldfish less than three inches was age 0, young of year.



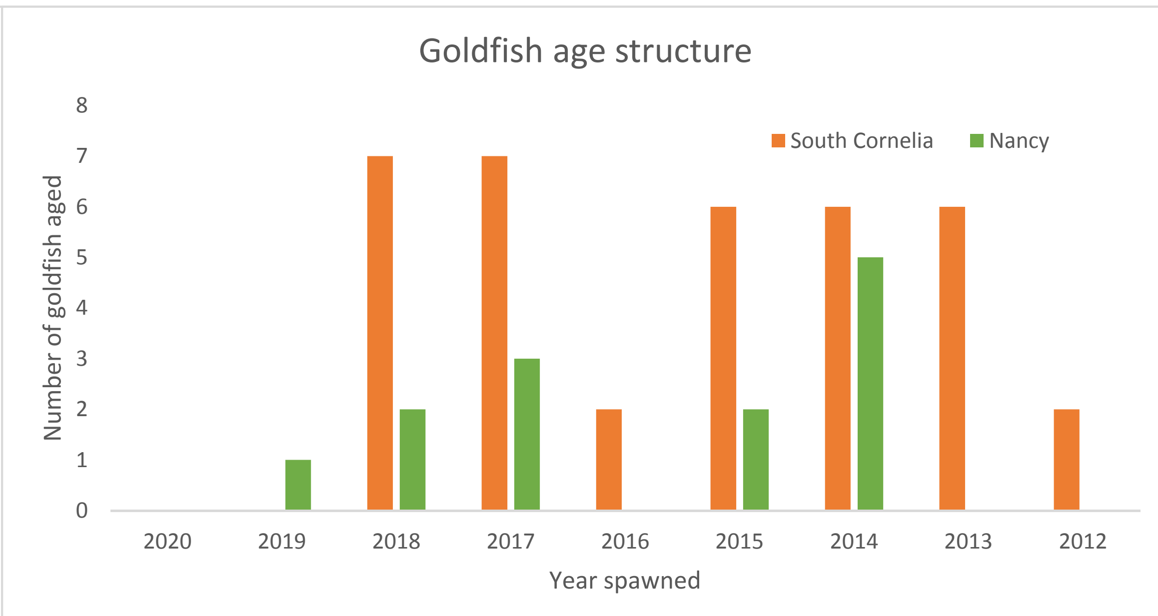


Figure 12: Carp age structure (top) and goldfish age structure (bottom) expressed in year the sampled fish was spawned.

DISCUSSION:

Analysis of otolith samples from both goldfish and carp shoes somewhat similar trends. It appears recruitment occurred in 2017 and 2018 and to a lesser degree in 2015 and 2016. The survey by Riley Purgatory Bluff Creek Watershed District noted a partial winterkill in the winter of 2017/2018. According to the MN DNR winter fish kill tracker, low dissolved oxygen (DO) is blamed for a fish kill in Cornelia during the winter of 2013/2014. Currently, DO measurements are not routinely collected during winter months on the lakes that were part of this study. Consistently raising DO above 2 mg/l is recommended to prevent winterkill of hypoxia vulnerable species like bluegill. Bluegill have been found to be significant predators of carp eggs and larvae when in abundance (Poole and Bajer, 2019, Silbernagel and Sorensen, 2013). When present, those populations can be the most effective measure to limit carp recruitment. It is plausible to believe, although not as well understood, that these species can naturally control goldfish recruitment as well.

Table 8: MN DNR Fish Stocking Report for Cornelia Lake from 2010 through 2020.

Year	Species	Size	Number	Pounds
2016	Bluegill Sunfish	adults	300	64.1
2015	Bluegill Sunfish	adults	150	32.6
2014	Black Crappie	adults	3	1
	Bluegill Sunfish	adults	56	14
	Hybrid Sunfish	adults	4	1
	Pumpkinseed Sunfish	adults	4	1
2012	Bluegill Sunfish	adults	297	63.6
2011	Bluegill Sunfish	adults	248	53.9
2010	Bluegill Sunfish	adults	312	52

EDUCATION

Goldfish were likely introduced to this system as unwanted pets. This is not an uncommon problem and there is and will continue to be a need for education of the public about the impacts of releasing pets into the wild. While WSB and NMCWD, in partnership with the City of Edina were hoping to hold a MN Sea Grant Habitattitude event to arrange a pet surrender in the summer/fall of 2020, so unwanted aquatic pets could be responsibly relinquished without causing damage to the natural environment, this was not possible due to the COVID-19 Pandemic. That said, in hope to raise awareness around the city and specifically to residents and visitors of the Cornelia Lake system, NMCWD and the City of Edina highlighted the risk of introducing pets that cause damage to our waters through park signage and in their quarterly newsletters and on their websites and other forms of social media.

In addition, while on the lakes, WSB and the NMCWD staff took every opportunity to explain the objective of the study and why goldfish and carp have become a problem to interested park and lake users. There was a common element of surprise that pets like goldfish could sustain and multiply in these lakes.

If management efforts are to be sustainable, the element of education needs to be an ongoing effort. The message of our work and its potential impacts were produced into two news stories that have and will reach large audiences within and outside the City of Edina as ***Figure 13*** *shows*. A story was broadcast to the City of Edina's community television series and the same story will be broadcast by the popular outdoor news series Minnesota Bound in Spring of 2021 on the Lake Cornelia goldfish study and the influence goldfish and carp can have on lake water quality and how introducing such pets into the wild can be problematic.

Figure 13: Two film crews join the electrofishing surveys to document the work on the project.

SUMMARY

In less than one year of work studying goldfish populations, their behavior, and options for management, we have gathered very useful results. They are a nice follow up to the RPBCWD fisheries assessment in 2018. We have summarized the main takeaways from the results of field work and laboratory analysis with recommended follow up work associated with each.

1. We have only been monitoring inter-lake movements for 5 months (when most of PIT tags were in place). The most useful programs track this data for several years to decipher the trends to be expected in the long-term. PIT antennas tracking. **Recommendation: Continue monitoring for at least one more year to detect during springtime when spawning migrations are most likely. Currently, there is not enough data to make recommendations on fish barriers between lakes.**
2. Ageing analysis shows relatively large recruitment events happen in the year or two after documented winter kill events. This is common in shallow lakes that typically require a number of years for the native fish populations to recover. In recent history, that would include winter of 2013/2014 and winter of 2017/2018. **Recommendation: Consider winter aeration. This has already been recommended in the past. Power is supplied to the park already and could be a partnership with the City of Edina.**
3. Although a small sample size, data shows a correlation with low recruitment when bluegill sunfish were most heavily stocked by MN DNR leading up to winter kill events. In order to avoid years where the lake is void of key native egg and larval predators like bluegill sunfish, stocking could prevent large recruitment events and help bolster more recreational use of the lake by anglers. **Recommendation: Coordinate with DNR to continue/expand FiN program to support bluegill stocking. Allocate additional funding to increase stocking amounts each year to limit recruitment.**
4. Although population estimates are somewhat variable, the estimates generally indicate large populations of goldfish. It is clear that the dominant species in the lake is goldfish followed by bullhead. To help return the balance of the fisheries back to native fish, and to remove the presence of bioturbators in order to improve water quality, methods should be developed to efficiently remove goldfish and other rough fish if possible. **Recommendation: Test multiple types of removal efforts to reduce the population. This can include baited box netting where appropriate, bait and seining efforts and stream trapping. Due to difficulty to gain approval for whole-lake drawdowns or fish poisoning, mechanical removal is the best option available currently.**
5. PIT tag monitoring is very important and PIT tags are long lasting marks as compared to fin clips. They are unique identifiers that are traceable to an exact marking effort. This leads to multi-year understanding of population dynamics and growth rates. **Recommendation: Continue to add PIT tags to live goldfish for tracking purposes and to continue to refine population estimates in the future.**
6. It is becoming better understood how carp are attracted to corn in the wild and how their groups interact with the bait. However, little is known about goldfish and their attraction to corn. It is important to understand the selectiveness of removal efforts to minimize the impact of non-target fish. **Optional recommendation: Implant stocked and captured non-target fish with PIT tags and employ an additional PIT antenna on a bait location to monitor activity of tagged fish of all species at the bait.**
7. Past experiments have been completed in nursery lakes to examine the effect of excluding rough fish like carp. Typical results show a boost in macrophyte abundance, improved water quality, and the ability to test the impact of rooting fish on alum treatments. **Recommendation: Conduct simple exclosure experiments in study lakes to compare the impact of removal of goldfish which has not been as well studied.**

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