Linwood Lake
Carp Management
Feasibility Assessment

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Contents

Preface

This in an interim report that presents carp management and a feasibility analysis of future management through July 2019. As of this date all major components of management and analysis are completed such that findings can be reported with confidence. However, new data is continuously being collected and this report will be updated accordingly from time to time.

Purpose

The purpose of this report is to provide science-based recommendations for if and how carp management should be pursued in Linwood Lake of Anoka County, Minnesota. This assessment determined the abundance and biomass of common carp (*Cyprinus carpio*) population in Linwood Lake, how often the lake recruits new carp to the population, and monitored movement patterns in order to determine if further study and management is worthwhile.

Executive Summary

Linwood Lake is located in Anoka County Minnesota and is impaired for excessive nutrients that cause algal blooms. Total maximum daily load (TMDL) and watershed restoration and protection strategies (WRAPS) have been previously prepared that identified carp as an important target for lake management. This study evaluated the carp population and concluded that currently, carp biomass is relatively low but it is near a tipping point. If the biomass increases further, it would most likely impact the healthy aquatic plant community that exists in the lake. If that occurs, shallow areas of Linwood lake would switch to a de-vegetated state. Thus, carp management should be considered as a preventive measure. Particularly troubling is the fact that we discovered a significant presence of young carp in the lake. Determining the source of carp recruitment and conducting a preventive biomass reduction is a priority to prevent deterioration of Linwood Lake.

Carp biomass in Linwood Lake is 98 lbs/acre. By comparison, research at the University of Minnesota has found that lake health quickly deteriorates when carp populations exceed 89 lbs/acre (Bajer 2018). This is a relatively modest exceedance of that threshold.

Carp have recruited in Linwood Lake in each of the last nine years, but less frequently in the prior years. Nearly all of the last nine years have had greater carp recruitment than the year before. If this trend continues, and this cohort of young carp spawns successfully in large numbers, the carp population could grow substantially.

Carp removals are recommended as a way to prevent further population growth that otherwise seems likely. These removals should aim for the science-based goal of 89 lbs/acre. These goals are modest enough as to be achievable in 1-3 years by box netting.

If recruitment sources are determined and prevented/managed, project life should exceed 10 years. “Maintenance” carp removals might be needed occasionally (once every 10 years), to keep the biomass down below the threshold but only if evidence of recruitment occurs. Boat electrofishing surveys (low effort) might be also considered as a routine practice (every other year) to closely monitor the status (biomass, abundance, size structure) of the carp population.

We also recommend that sources of carp recruitment (nurseries) are identified to slow down the population growth.

We estimated the cost effectiveness of carp removal to be $179 per pound of phosphorus. Generally, water quality practices below $500 per pound of phosphorus are considered highly cost effective. Our cost effectiveness estimate contains a large number of conservative assumptions in order to recognize that the science of these calculations is still developing.

This measure of cost effectiveness does not take into account the benefits of preventive management., which is often by far the most cost effective. Allowing carp population to increase unchecked might lead to Linwood Lake switching to a de-vegetated state with poorer clarity. Switching a lake back to a clearer water stable state is generally difficult. Preventative management now avoids those higher costs of restoration later.

TMDL studies seem to suggest that carp management is not only part of a management strategy, it is essential if goals are to be reached. Reaching water quality standards is a high priority locally because Linwood Lake is only marginally impaired and removing it from the impaired waters list is a realistic goal. Addressing "nearly/barely" impaired waters like this is also a state priority. Further elevating the priority of Linwood Lake is that work there will benefit downstream impaired waters including Martin Lake, the Sunrise River and St. Croix River.

Watershed and Morphology

Linwood Lake is located in northeastern Anoka County of Minnesota, generally in the Twin Cities metropolitan area (Figure 1***Figure 1*** – ***Location map.***). Its watershed is mostly rural residential, wetland and forests. This lake is a priority locally and regionally due to its suitability for recreation, wildlife and because it is connected to other priority waterbodies including Martin Lake, the Sunrise River and St. Croix River.

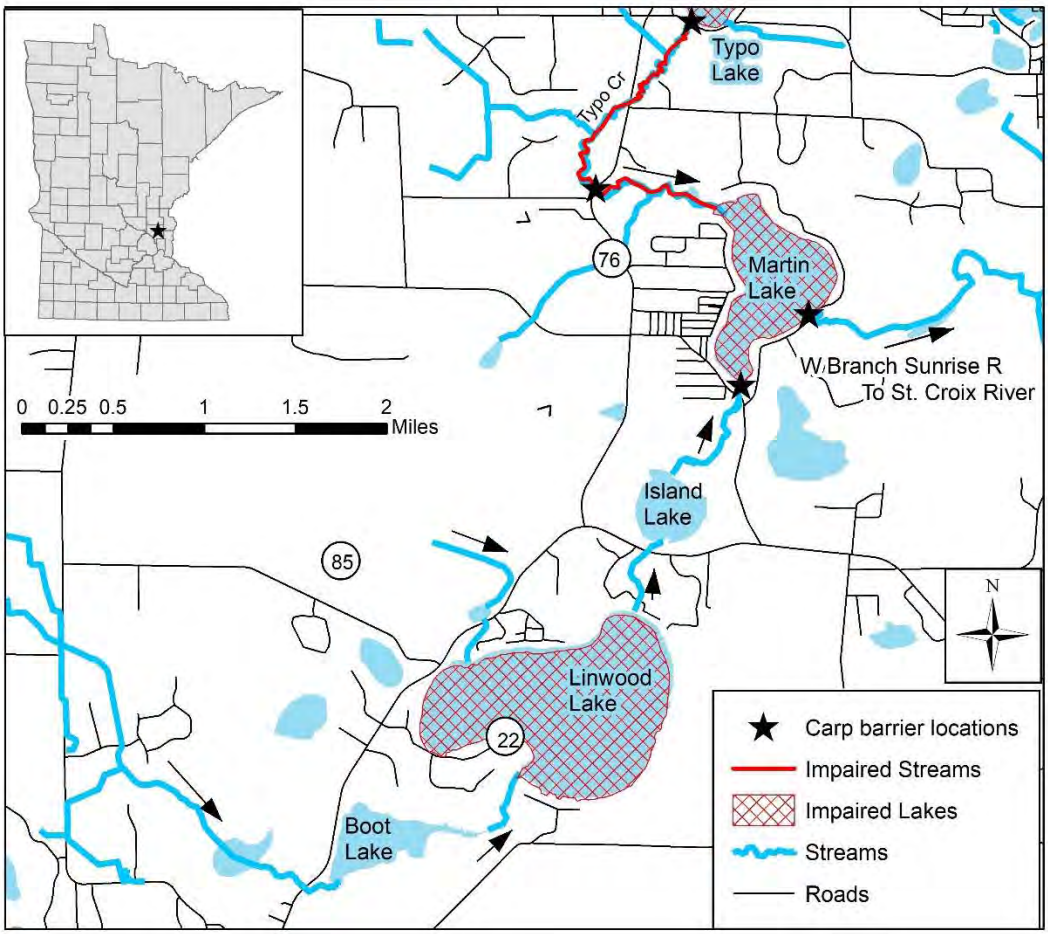
Linwood Lake is on the state list of impaired waters for excess phosphorus that fuels algae blooms. A TMDL study has been conducted to identify the sources of impairment and phosphorus reductions needed (Chisago SWCD et al. 2013). Additional discussion of the severity and nature of the impairments is below in the water quality section of this report.

Linwood Lake is hydrologically connected to several other waterbodies, some of which are impaired (see Figure 1). The inlet stream to Linwood Lake comes from Boot Lake. Boot Lake is entirely within a State Scientific and Natural Area, with no homes or public access allowed. There, phosphorus levels are similar, or slightly lower than, Linwood Lake but there is a greater abundance of macrophytes and lesser algae.

Downstream of Linwood Lake are Island Lake, Martin Lake, the Sunrise River and the St. Croix River. Island Lake is a smaller waterbody with no homes largely surrounded by county parkland. Martin Lake is impaired for excess nutrients, and is a popular recreational lake that has a developed shoreline. The Sunrise River was listed as impaired until 2018 for high pH due to eutrophication in upstream lakes. It was recently removed from the impaired list due to improvements and a recognition that the problem will be addressed by focusing on Typo and Martin Lakes. Generally, management plans for all of these interconnected waters have

recognized the importance of working first on Martin and Typo Lakes, as they are the farthest upstream and work there will benefit the downstream waters.

Figure 1 – **Location map.**



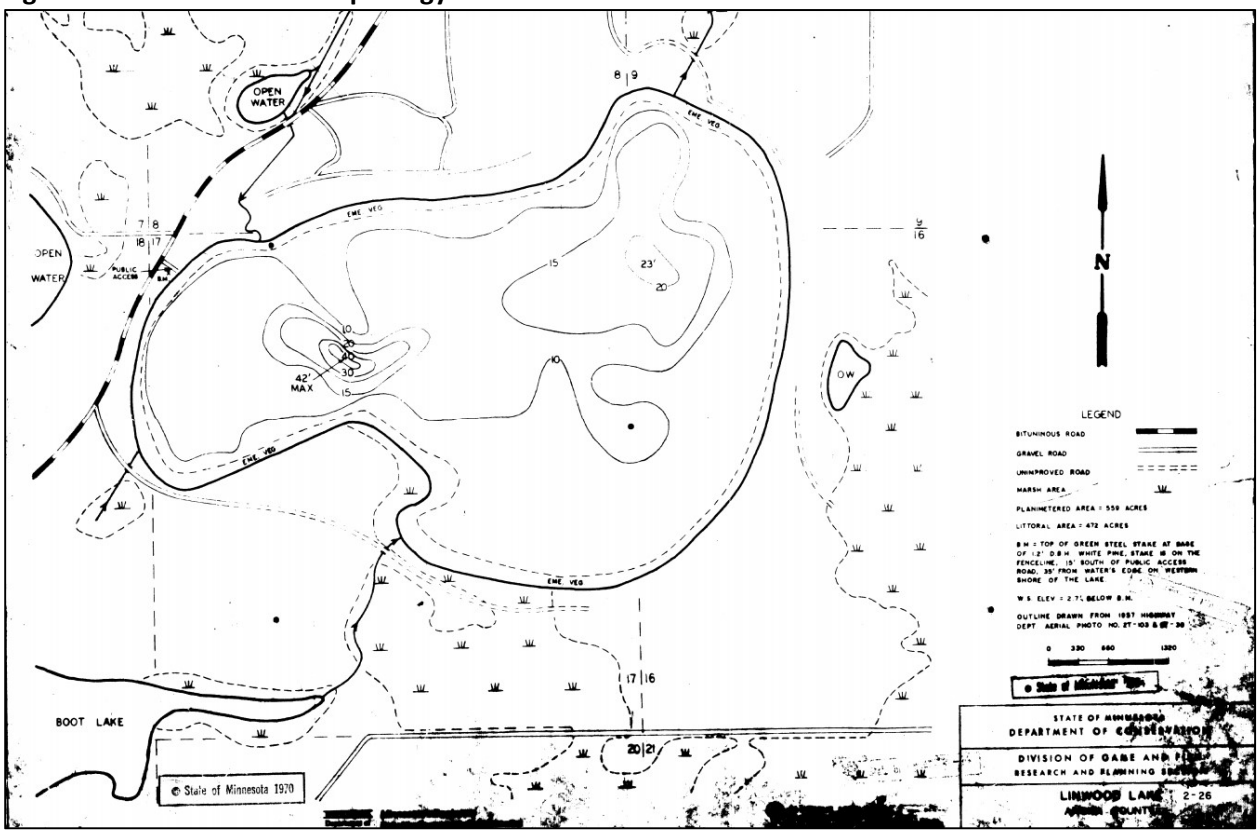
Linwood Lake is 569 acres. It has a maximum depth of 42 feet and mean depth of 9.2 feet (

Figure **2**). 85% of the lake is littoral.

Linwood Lake's watershed is 7,366 acres. Forests and wetlands make up 59% of the watershed. Developed lands are 4%. The remainder is grassland (11%), cropland (15%) and open water (10%).

Of the 4.51 miles of shoreline, 1.3 miles (28%) is county park or state wildlife management area. The remainder is residentially developed, with the exception of a retreat center with approximately 0.3 miles of shoreline.

Figure 2 – Linwood Lake morphology. Source: MN DNR.



Assessment of Aquatic Invasive Species

Linwood Lake is designated as "infested waters" by the State in 2014 due to the presence of Eurasian watermilfoil. Curly leaf pond weed is also present. The Linwood Lake Association began herbicide treatments to control these species around 2017.

Efforts are underway to protect these lakes against infestation by other AIS. Anoka County's AIS Prevention Program includes watercraft inspectors, outreach and education, and early detection sampling plates for zebra mussels.

Vegetation

Aquatic vegetation is relatively abundant in Linwood Lake. Detailed point intercept surveys are not available. However, it seems within reason to say that >50% of the lake has robust vegetative growth. In recent years there are concerns that this growth has become disproportionately species that are generalists or able to thrive in lower clarity water, such as coontail.

Annual meandering boat plant surveys began in 2015 to comply with MN DNR permits for AIS control. A permit was obtained but later withdrawn for curly leaf pondweed treatment and Eurasian water milfoil treatment in 2015. Treatments were done for Eurasian water milfoil in

2016 (8.25 acres) and 2017 (42.2 acres). Treatments were done for curly leaf pondweed in 2017 (20 acres), 2018 (30.3 acres) and 2019 (57.0 acres). These surveys were most recently conducted in 2019 to delineate AIS for treatment. Additionally, in 2017, 2018 and 2019 citizen monitoring surveys of aquatic vegetation have been completed and filed with the Anoka County AIS Prevention Program.

Lake Water Quality

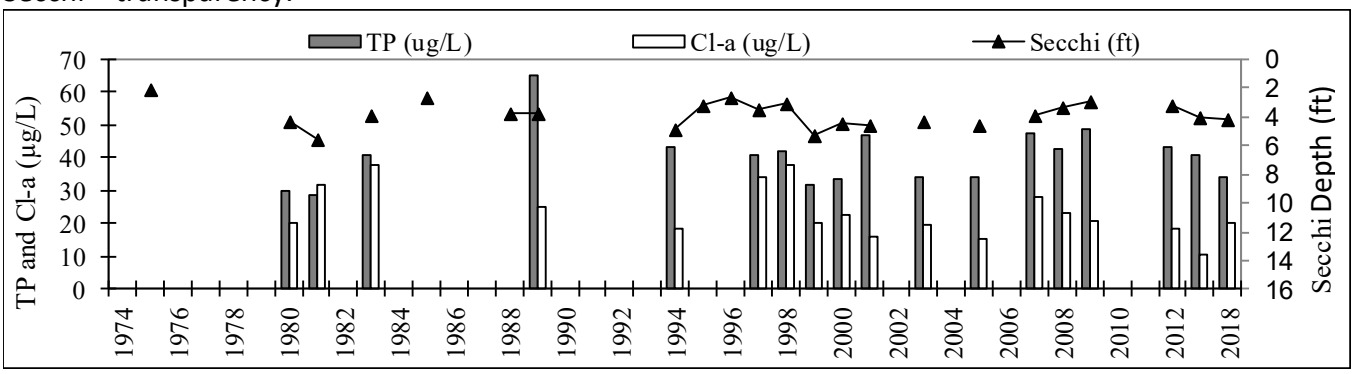
Linwood Lake is impaired for excessive nutrients that result in algal blooms that affect aquatic recreation and habitat. Frequent water quality monitoring and a total maximum daily load (TMDL) study have occurred to track and understand the nature of these impairments. In simple terms, Linwood Lake has an "C" water quality letter grade.

Table 1 - Linwood Lake water quality summary. Measurements were taken at a depth of one meter.

Water Quality Parameter	Linwood Lake 2018 Average	Applicable state water quality standard
pH	8.65	
Turbidity (NTU)	11.2	
Dissolved oxygen (mg/L)	8.50	
Chlorophyll-a (µg/L)	20.0	<14
Total phosphorus (µg/L)	34.5	<40
Secchi transparency (ft)	3.6	>4.6

Eighteen years of water quality data have been collected by the Metropolitan Council (1980, '81, '83, '89, '94, '97, and 2008) and the ACD (1998-2001, 2003, '05, '07, '09, '12, '15, and '18). Water quality has not significantly changed from 1980 to 2018 (repeated measures MANOVA with response variables TP, Cl-a, and Secchi transparency; $F_{2, 15}$=2.74, p=0.10).

Figure 3 – Linwood Lake historic water quality. TP = total phosphorus. Cl-a = Chlorophyll-a. Secchi = transparency.



Phosphorus Loading Sources and Reductions Needed

A total maximum daily load (TMDL) study of Linwood Lake was finalized in 2013. That study focused upon determining phosphorus sources and reductions needed. It included monitoring, modeling, professional judgement and recommended management approaches.

The TMDL found that a 23% (341.3 lbs/yr) pollutant reduction is needed. The existing loading and TMDL goals are shown in Table 2. The TMDL noted that there was a large part of the phosphorus load that was unaccounted for in the model, and "likely a mix of internal load and load from failing septic systems." It further noted "internal load…is underrepresented…and likely much greater."

Table 2 – Linwood Lake pollutant loading and TMDL goals.

Type	Source	Existing (lb/yr)	TMDL Goal (lb/yr)	Reduction (lb/yr)	Reduction (%)
Wasteload	City of East Bethel	21.3	21.3	0	0%
	Construction stormwater	3.7	3.7	0	0%
	Industrial stormater	3.7	3.7	0	0%
Load allocations	Watershed	1050.3	762.0	288.3	27%
	Internal/unknown	307.0	277.9	29.1	9%
	SSTS	110.3	86.4	23.9	22%
	Atmospheric	152.3	152.3	0	0%
Margin of Safety			145.3		
Total		1,648.6	1,452.6	341.3	

Management approaches specific to Linwood Lake are presented in both the TMDL and the Sunrise River Watershed Restoration and Protection Strategies (WRAPS). The TMDL study recommended management should focus on internal loading, shoreline practices, and agricultural and developed lands. The WRAPS has more detailed list of recommended management strategies. Those strategies, and progress made on each, is shown in the next section.

History of Water Quality Projects

The Sunrise River Watershed Restoration and Protection Strategies (WRAPS) provided a management prioritization for improving Linwood Lake, which is presented below. Numbered items are the management priorities with more detailed description from the WRAPS in parentheses. Following each management priority is a description of recent work completed and upcoming work in the Sunrise River Watershed Management Organization's plan.

WRAPS Priorities and Projects Accomplished or Upcoming:

1. **Internal load management** (evaluate boat motor restrictions, carp management, aquatic plant management)
    - **2018-2019 - A feasibility study carp management** (this study).
    - **2017-ongoing – Herbicide treatments** to control curly leaf pondweed.
2. **Septic system upgrades** (convert all failing and imminent threat to public health systems to compliant)
    - **2017-2018 – Linwood Lake SSTS targeted outreach** was conducted by Linwood Township and the Anoka Conservation District. Property records with possible failing septic systems were identified through building records, pumping permits and direct communications with residents. Those residents were offered technical and financial assistance.
    - **2017-ongoing – SSTS fix up grant** program was established to incentivize septic system fixes.
    - **2021 or later – Point of sale inspection ordinance is planned by the township and watershed organization** to better identify failing SSTS and get them fixed.
3. **Conservation tillage** (10% of cropland converted to conservation tillage)
    - **2021-2022 – Conservation planner** housed at Chisago SWCD has a goal of creating 10 conservation plans with landowners. The Sunrise River WMO has a goal of implementing at least five of those plans.
4. **Manure management** (collection, storage and treatment of manure at two sites)
    - **2021-2022 – Conservation planner** housed at Chisago SWCD has a goal of creating 10 conservation plans with landowners. The Sunrise River WMO has a goal of implementing at least five of those plans.
5. **Lakeshore lawn care** (25% of all parcels with turf grass maintained and limit runoff)
    - **2012-Ongoing** – Three lakeshore restorations using bioengineering techniques have been completed to correct shore erosion. The most recent data indicate 20% of lakeshore is mowed to the water's edge, which is better than the WRAPS goal.
    - **2012-Ongoing – Outreach and education** including direct communications with residents about management of their own property.
    - **2022 and beyond – A new incentive program** will be created for lakeshore restorations, to be run as a collaborative between the lake association and Sunrise River Watershed Management Organization.
6. **Determine Boot Lake's impact on Linwood Lake** (watershed of Boot Lake studied, monitored and reported)
    - **2018-2020 – Three years of water quality monitoring** in Boot Lake. Results so far indicate Boot Lake has neutral influence on Linwood Lake.
7. **Determine connection of fertilizer to shallow ground water** (complete study)
    - **No progress.**
8. **Buffer strips** (22 acres of buffer strips)
    - **2018-2019 – State buffer law took effect and enforced.**
9. **Sedimentation ponds** (130 acres treated)

- **2023-2024 – Subwatershed assessment study** to identify and rank stormwater BMP opportunities.

10. **Bioretention and infiltration** (BMPs on 36% of all parcels)
    - **2022 and beyond – A new incentive program** will be created for lakeshore restorations, to be run as a collaborative between the lake association and Sunrise River Watershed Management Organization.

Carp Population Assessment

To conduct an assessment of the carp population, four days of boat electrofishing surveys were conducted in Linwood Lake following protocols developed by Bajer and Sorensen (2012). These surveys were conducted on September 22, September 24, September 26, and October 5, 2018. For each survey, the number of captured carp was counted and the mean catch per unit of effort (CPUE; carp/hour) was calculated. The CPUE values were used to generate estimates of carp density and biomass using an equation developed by Bajer and Sorensen (2012). In addition, because electrofishing allows for capturing carp in good physical condition, 20 of the captured carp were also implanted with radio transmitters and released to facilitate radio tracking (see below).

Over the four survey days, 76 carp were captured in 480 minutes of boat electrofishing. The overall mean CPUE was 9.5 carp per hour (Table 3

Table 3). This catch rate suggested that Linwood Lake was inhabited by approximately 9,851 carp. Their lengths ranged from 300 mm to 877 mm (Figure 4). Using the mean length (24.7 in) and weight (3.2 kg or 7 lbs), the surveys suggested that the biomass of carp in Linwood Lake was 110 kg/ha, or 98 lb/ac (Table 4). The management goal for carp in lake ecosystems is 100 kg/ha or 89 lb/ac (Bajer et al. 2009), thus common carp biomass appears to be marginally above this threshold.

Figure 4 - Length distribution for carp captured during electrofishing surveys.

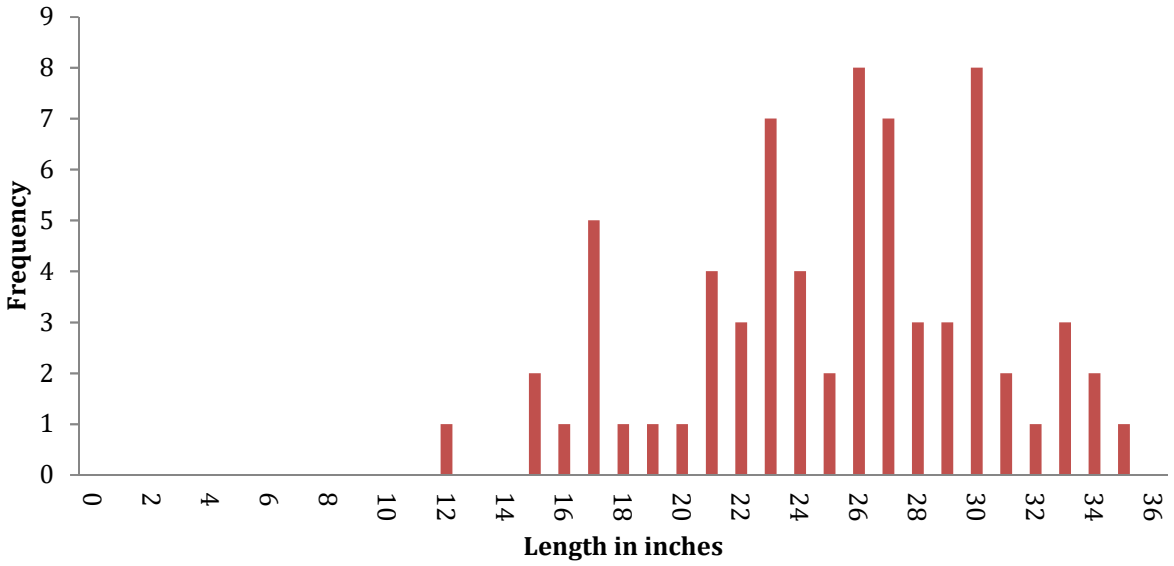


Table 3 - Electrofishing survey data. * transect not included in the overall CPUE since its location was not chosen randomly (we targeted an area with high catch rate to collect carp for ageing analysis).

Date	Electrofishing time (minutes)	Carp caught per transect	CPUE (carp/hour)
9/22/2018	20	1	3
9/22/2018	20	0	0
9/22/2018	20	0	0
9/22/2018	20	2	6
9/22/2018	20	2	6
9/22/2018	20	1	3
9/24/2018	20	0	0
9/24/2018	20	1	3
9/24/2018	20	4	12
9/24/2018	20	5	15
9/24/2018	20	10	30
9/24/2018	20	3	9
9/26/2018	20	5	15
9/26/2018	20	0	0
9/26/2018	20	0	0
9/26/2018	20	1	3
9/26/2018	20	2	6
9/26/2018	20	9	27
10/5/2018	20	0	0
10/5/2018	20	2	6
10/5/2018	20	1	3
10/5/2018	20	3	9
10/5/2018	20	4	12
10/5/2018	20	20	*60
Mean CPUE			9.5

Table 4 - Summary of carp population and biomass statistics for Linwood Lake.

Lake area	Ave. Length	Ave. CPUE	Ave. Mass	Density	Abundance	Biomass
232 ha	24.7 inches	7.3 carp/hour	3.2 kg (7 lbs)	32.8 carp/ha	7609	110 kg/ha

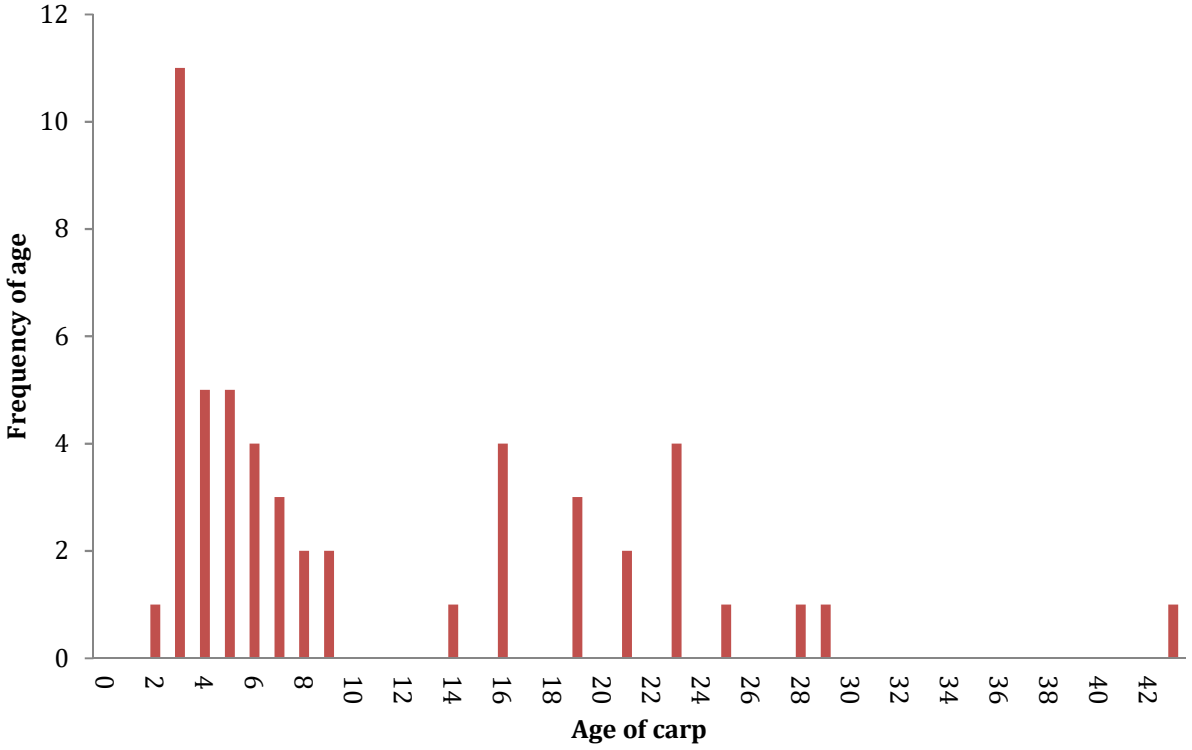
Carp Ages and Recruitment History

Determining recruitment dynamics is often the most critical element of assessing carp management strategies. This activity had two components: 1) aging analysis to determine **when/how often** young carp recruit into the population and 2) surveys of peripheral ponds as well as Linwood Lake itself to determine from **where** carp recruit (nurseries – see next section).

A sample of 50 carp from electrofishing surveys were euthanized and kept for aging analyses using otoliths (inner ear bones). The otoliths were removed, embedded in epoxy, sectioned into 300-micron slices using an isomet saw and examined for age under a microscope.

Aging analyses show that the population of carp in Linwood Lake appears to be relatively young. They range from two to 43 years old (Figure 5). A large portion (65%) of the sample was spawned within the last decade with the biggest spike only three years ago. One third of the sample was spawned about every two years between 14 and 29 years ago.

Figure 5 - The age structure of a sample of carp (n=51) analyzed from Linwood Lake.



Nursery area identification

Linwood Lake and Boot Lake were surveyed as potential nurseries young carp. Survey sites were sampled with 3/8”-mesh trap nets, a device known to effectively capture juvenile carp (Bajer et al. 2012). All nets were set overnight and retrieved the next day. The surveys were

conducted in the fall when young of the year carp would be large enough to sample. Five nets were set both in Boot and Linwood Lakes.

No carp, and no young of the year carp, were captured in either lake (Table 5). Bluegill, green sunfish and pumpkinseed sunfish were the only species captured.

Table 5 - Number of each species captured per trap net in each lake.

Species	Linwood Lake	Boot Lake
Common carp	0	0
Bluegill sunfish	22	0
Green sunfish	0.7	0
Pumpkinseed	1.3	2.7

After trap netting in Boot Lake and Linwood Lake, a third possible nursery area was identified – a small pond north of the lake in a DNR Aquatic Management Area (Figure 6). That pond is connected to Linwood Lake by a small stream. Because contracted trap netting had already been completed, this site was monitored for carp activity by "listening" for radio tagged carp whenever radio tracking was completed, especially in late winter and spring 2019. No tagged carp were heard in this basin.
Skunk or Rice Lake appear to be possible nursery areas for Linwood Lake carp, but were not surveyed (Figure 6). Skunk Lake is isolated, with no inlet or outlet and was therefore not surveyed. Rice Lake is hydrologically connected to Linwood Lake and should be included in future surveys.

Figure 6 – Location of pond (circled) within DNR Aquatic Management Area identified as a possible nursery area but not trap netted.

Carp Movements and Tracking

Twenty carp in Linwood Lake were surgically radio tagged in September 2018 for the purpose of understanding carp seasonal movements that could aid in carp harvests to benefit lake health. In spring 2019 and the winter and spring of 2020 Carp Solutions LLC conducted a total of seven telemetry surveys to record carp locations and two additional surveys were conducted by another firm for carp seining purposes. Out of the 20 carp originally tagged in Linwood Lake, the following were their locations as of the end of May 2020:

- 11 were found consistently in Linwood in all surveys.
- Two remained in Linwood Lake but had mortality signals.
- Five left Linwood Lake in the downstream direction. Of these,
    - Two were found in Martin Lake.
    - One was found in Island Lake
    - Two were found in Island Lake in April in early May 2020, and not located in late May 2020.
- Two were found in Linwood Lake in 2019 and not located in 2020.

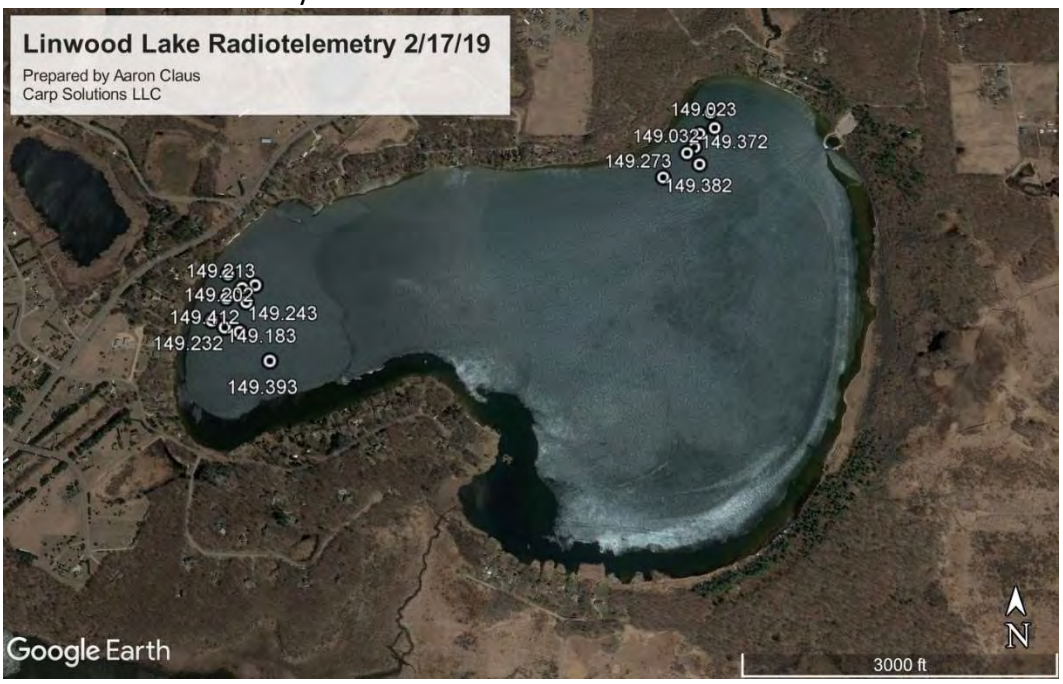
Surveys in 2019 included Linwood Lake, Boot Lake and a DNR Aquatic Management Area north of Linwood Lake on Viking Boulevard. In 2020 Island and Martin Lake were added.

Telemetry survey findings include:

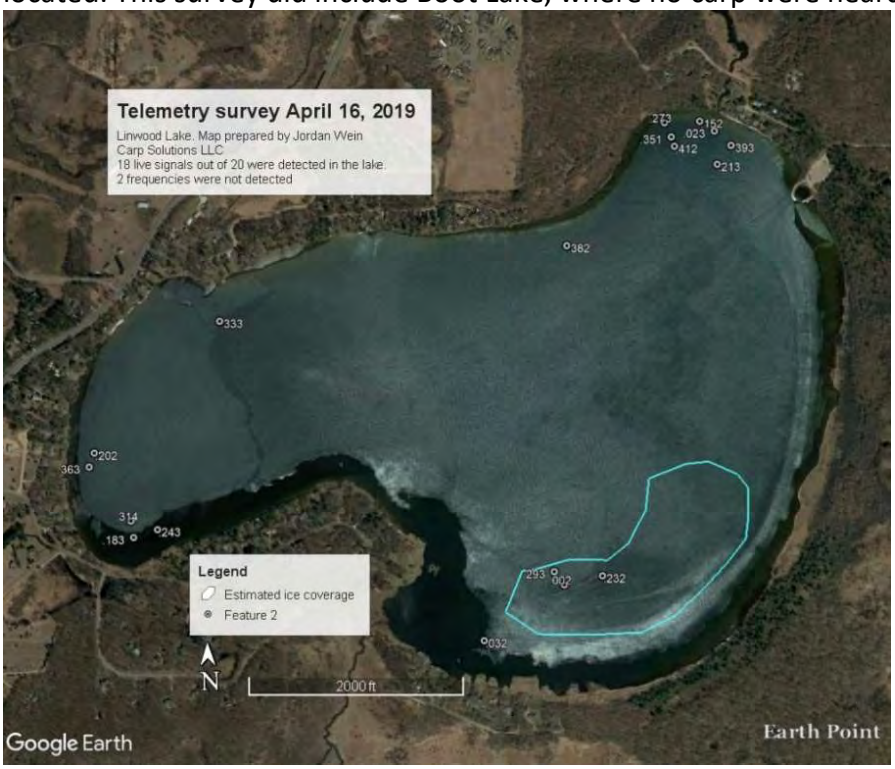
- Carp did not move between Linwood and Boot Lake or the DNR Aquatic Management Area on Viking Boulevard, which were suspected spawning and nursery areas.
- Carp spawning migrations through streams were not observed.
- At least five carp did move from Linwood Lake to Island Lake. Of these, at least two continued to Martin Lake. They were able to bypass the barrier at Martin Lake, presumably during sustained high water in 2019. It is suspected that the barrier was lifted slightly by high flows. The Anoka Conservation District is modifying the barrier so this does not happen in the future.
- Because of carp movement between the lakes, they should be managed together as a chain of lakes including Linwood, Island, Martin and Typo.
- Linwood Lake carp do aggregate within the lake in winter and spring. This creates opportunities to remove them by seining.

Results of each telemetry survey are detailed below, and summarized in a table at the end of this report.

February 17, 2019: 17 of the 20 tagged carp were located in Linwood Lake. 3 tagged carp were not located. This survey did not include Boot Lake.



April 16, 2019: 18 of the 20 tagged carp were located in Linwood Lake. 2 tagged carp were not located. This survey did include Boot Lake, where no carp were heard.



May 21, 2019: 18 of the 20 tagged carp were located in Linwood Lake. All signals were live. The remaining two carp (265 and 372) were not heard. In addition to checking Linwood Lake from a boat, Boot Lake, Island Lake, and the DNR Aquatic Management area next to Viking Blvd NE were checked from the road. No signals were heard at these locations.

February 21, 2020: A radio telemetry survey was conducted on Linwood Lake on February 21, 2020. Of the 20 radio tagged fish, 13 were located in the lake, one being a mortality signal . 11 of these carp were aggregated in the northeast corner of the lake. Boot Lake, Island Lake, and the DNR Aquatic Management Area (AMA) located next to Viking Blvd NE were also checked. In Island Lake, 3 live carp were heard. There were no signals heard at the pond or Boot Lake. A total of 4 tagged carp were not found (412, 351, 152, & 372).

February 21, 2019 carp tag numbers found: 333, 032, 202, 232, 265, 243, 293, 273, 382, 023, 393, 363, and a mortality signal for 002.

February 21, 2019 carp aggregated in the NE corner in Linwood Lake, inset map.

Carp located in Island Lake February 21, 2020.

April 6, 2020: Only Linwood Lake was surveyed by WSB and Associates to locate any carp aggregations for seining.

April 9, 2020: An incomplete survey of Linwood Lake was conducted by WSB and Associates to locate any carp aggregations for seining.

April 14, 2020: A radio telemetry survey was conducted on Linwood Lake on April 14, 2020. During the survey Linwood and Island Lake were checked from boat, as well as Boot Lake and DNR Aquatic Management Area along Viking Blvd NE from roadside. 12 tagged carp were located in Linwood Lake, and 3 were located in Island Lake. 5 tagged carp were not heard at any location (293, 412, 351, 152, & 372).

April 14, 2020 carp map. Tag numbers found: 265, 023, 363, 393, 382, 032, 333, 243, 232, 202, 273, and a mortality signal for 002.

April 14, 2020 carp located in Island Lake. Tag numbers found: 213, 182 & 314.

May 6, 2020: A radio telemetry survey was conducted on Linwood Lake on May 5, 2020. During the survey Linwood and Island Lake were checked from a boat in the lake. In addition, Boot Lake, Martin Lake, and the DNR Aquatic Management Area along Viking Blvd NE were scanned from roadside. 13 of the 20 tagged carp were located in Linwood Lake, 3 were located in Island Lake, and 2 were heard in Martin Lake. The tagged carp that were in Island Lake have been heard there since February 21, 2020. The 2 carp that were found in Martin Lake were heard from the boat launch (152 & 351). There were no other carp heard at the other roadside locations. 2 of the 20 carp were not found (372 & 412). These 2 carp and the additional 2 that were found in Martin were last located in Linwood Lake in May 2019. They were not found in

Linwood in the winter or spring surveys of 2020.

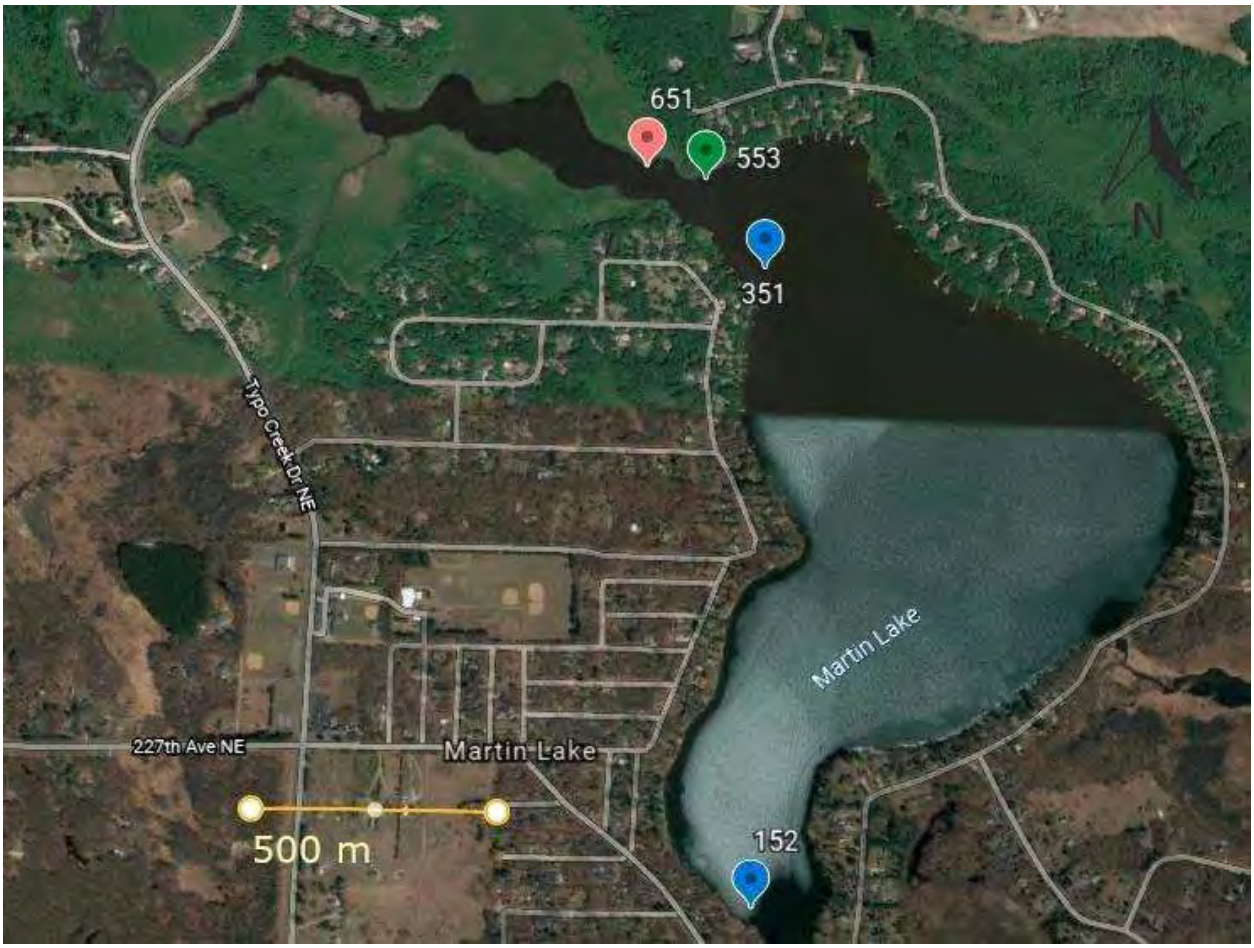
May 6, 2020 tag numbers found in Linwood Lake: 265, 023, 363, 393, 382, 032, 333, 243, 232, 202, 273, 293, and a mortality signal for 002.

May 6, 2020 carp located in Island Lake. Fish tag numbers found: 213, 182 & 314.

May 28 and June 1, 2020: During a radiotelemetry survey of Linwood Lake on 5/28/20, Linwood and Island Lakes were checked by boat. Boot Lake, Martin Lake, and the DNR Aquatic Management Area along Viking Blvd NE were scanned from the road. Out of the 20 tagged carp, 13 were located, 12 in Linwood Lake (002, 023, 032, 202, 232, 243, 273, 293, 333, 363, 382, and 393) and 1 in Island Lake (213). Frequencies 002 and 333 were heard as mortality signals. No signals were heard from the road at Boot Lake, the DNR Aquatic Management Area, or Martin Lake. It was possible that at least some of the missing tags were in Martin Lake but could not be heard from the road. In order to locate these missing tags, we launched a boat onto Martin Lake on 6/1/20 to track it more thoroughly. Only 2 of the remaining 7 missing tags were found in Martin Lake (152 and 351). Tags that had been found live in Martin in May 2019 were scanned for in the vicinity of the Linwood tags in order to find spawning aggregations. Only 2 carp tagged in Martin Lake were found near the other ones, 553 and 651 (mortality signal). Carp were observed spawning at the mouth of Typo Creek near the location of 351, 553, and 651. After these two surveys, frequencies 183, 265, 314, 372, and 412 were not located in any of the scanned waterbodies.

Carp located in Linwood and Island Lake on May 28, 2020. Twelve frequencies, 002 (mortality), 023, 032, 202, 232, 243, 273, 293, 333 (mortality), 363, 382, and 393, were found in Linwood Lake. 213 was found in Island Lake near the beach.

Inset map of carp in the western bay of Linwood Lake on May 28, 2020.



Carp located in Martin Lake on June 1, 2020. Frequencies 152 and 351 were originally tagged in Linwood Lake. Frequencies 553 and 651 (mortality signal) were tagged in Martin Lake and were located because of their proximity to 351 from Linwood Lake.

Table 6: History of status and location of carp radio tagged in Linwood Lake on September 24, 2018.

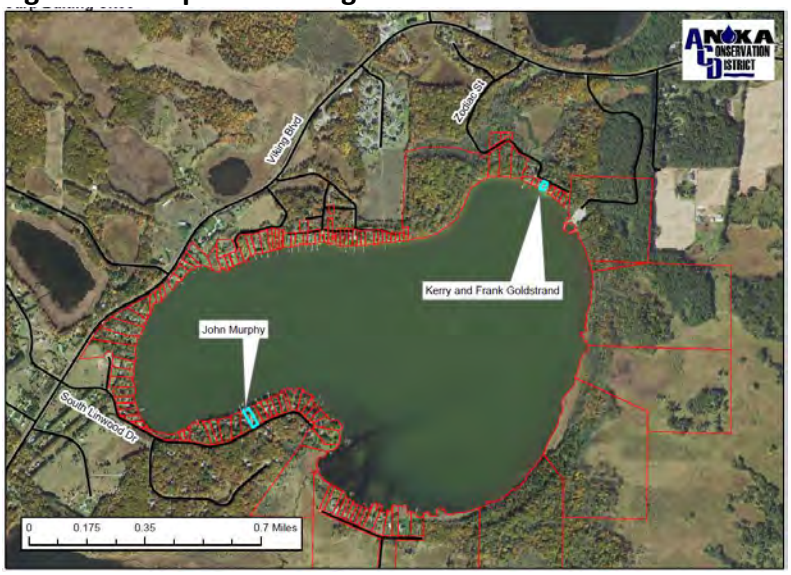
Radio Frequency	Length on Sept. 24, 2019 (mm)	2/17/2019		4/16/19		5/21/19		2/21/20		4/6/2020		4/9/2020		4/14/20		5/6/20		5/28/20 and 6/1/20	
149.002	590	Not Found		Live	LINWOOD	Live	LINWOOD	Mortality	LINWOOD	Mortality	LINWOOD	Mortality	LINWOOD	Mortality	LINWOOD	Mortality	LINWOOD	Mortality	LINWOOD
149.023	724	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.032	743	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.152	686	Not Found		Live	LINWOOD	Live	LINWOOD	Not Found		Not Found		Not Found		Not Found		Live	MARTIN	Live	MARTIN
149.183	703	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	ISLAND	Not Found		Not Found		Live	ISLAND	Live	ISLAND	Not Found	
149.202	542	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.213	761	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	ISLAND	Not Found		Not Found		Live	ISLAND	Live	ISLAND	Live	ISLAND
149.232	642	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.243	674	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.265	855	Not Found		Not Found		Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found	
149.273	562	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.293	755	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Not Found		Live	LINWOOD	Live	LINWOOD
149.314	713	Not Found		Live	LINWOOD	Live	LINWOOD	Live	ISLAND	Not Found		Not Found		Live	ISLAND	Live	ISLAND	Not Found	
149.333	676	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Mortality	LINWOOD
149.351	727	Not Found		Live	LINWOOD	Live	LINWOOD	Not Found		Not Found		Not Found		Not Found		Live	MARTIN	Live	MARTIN
149.363	842	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.372	578	Live	LINWOOD	Not Found		Not Found		Not Found		Not Found		Not Found		Not Found		Not Found		Not Found	
149.382	785	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.393	877	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD
149.412	738	Live	LINWOOD	Live	LINWOOD	Live	LINWOOD	Not Found		Not Found		Not Found		Not Found		Not Found		Not Found	

Carp Responsiveness to Box Netting

Box netting has been used for carp removals in other nearby lakes, but its effectiveness in Linwood Lake is untested. This technique uses cracked corn bait to train carp to come to a net that is periodically sprung. In July 2019 the Anoka Conservation District coordinated "test baiting" without a net to see if this technique might work well in Linwood Lake.

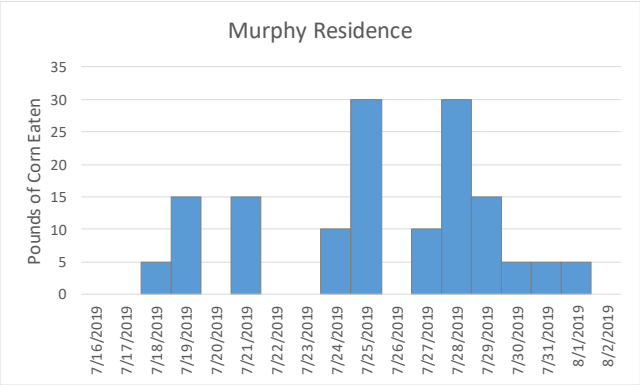
Carp were baited at two locations by volunteers (Figure 7). The locations were places where radio tracking had shown carp sometimes congregate. A mesh laundry bag with cracked corn bait was placed in the lake in 2-3 feet of water. Corn consumption was tracked daily.

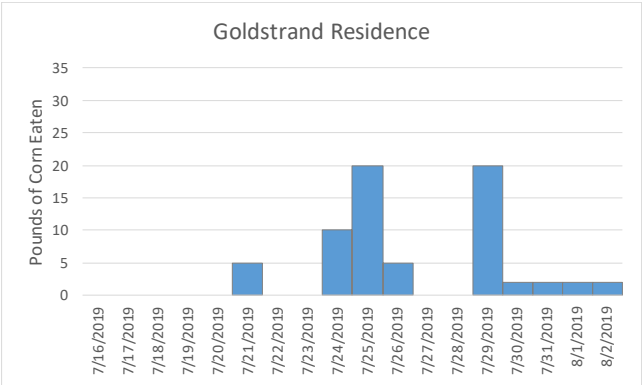
Figure 7 – Carp test baiting locations.



Carp in Linwood Lake ate the corn only intermittently and at lower levels that would be desired for box netting. They did eat up to 30 lbs per night and created "craters" where they rooted around the bait bags. However, there were many nights with 5 or fewer pounds of corn eaten.

Figure 8 - Corn consumption during test baiting.





Timing may have been one reason the carp did not respond in large number to the test baiting. July 2019, when test baiting occurred, has been an effective month for carp removals at other nearby lakes in the past. But even at those other lakes with four-times the carp density, July 2019 had lackluster carp feeding. Late August or September has historically been the best time for carp baiting/netting at other lakes.

In the end, the results suggest box netting at Linwood Lake could be a cost effective way to remove carp, and may even be advised to prevent a future population increase. But the test baiting was relatively inconclusive as to whether large carp reductions could be quickly achieved. It's unclear whether carp came to baits only lightly because of time of the year, whether, or other factors that are unique to the lake and its carp.

Waterbody Interconnectedness and Barriers

Linwood Lake is part of a West Branch of the Sunrise River Chain of Lakes (Figure 1). Carp management is ongoing elsewhere in this chain. Because Linwood Lake is hydrologically connected, it should be considered within any management planning for the rest of the chain. However, because Linwood Lake's carp population is of different density and age structure from elsewhere in the chain, and because it is separated from downstream waters by a low head weir, strategies will be different.

Immediately upstream of Linwood Lake is Boot Lake. The stream channel between these lakes is 0.7 miles of wetland. The channel was passable in a canoe 10 or more years ago, but has since become so dense with cattails that it cannot be navigated. Boot Lake is 92 acres. Nearly the entire basin is shallow, with aquatic vegetation growing to the surface, however there is one small area of 23 foot depth. Boot Lake is entirely within the 660 acre Boot Lake Scientific and Natural Area where there are no structures and no public entry allowed.

Boot Lake water quality was monitored for the first time in 2018 by the Anoka Conservation District using a special permit from the MN DNR. They found phosphorus concentrations similar to Linwood Lake (35.5 µg/L), but less chlorophyll-a and greater transparency. This difference is likely due to the abundant macrophytes in Boot Lake.

The inlet stream to Boot Lake, which comes from Rice Lake, has been monitored in 2001 and 2003. The average phosphorus concentration was 117 µg/L, which is typical for the area streams.

Linwood Lake outlets toward Island Lake via a low head weir (Figure 9). Carp could traverse this structure, particularly in high water. Residents have not described seeing carp congregating near it. In 2019 at least five carp tagged in Linwood Lake went to Island Lake. Two of those continued to Martin Lake.

Figure 9 – Linwood Lake outlet. Shown during low water conditions with no lake discharge.

Downstream of Linwood Lake is Island Lake. Island is small and circumscribed by public lands. It is not impaired, but also not regularly monitored. Carp are known to be present. The area's permitted commercial fisherman believes there are numerous carp in Island Lake, and some radio tagged carp from Linwood Lake did move to Island Lake. However, fisheries surveys have not sampled high numbers of carp in Island Lake.

Further downstream is Martin Lake. There is a mechanical carp barrier between Island and Martin Lakes (see Figure 1). The purpose of this barrier was to prevent carp from beginning to move to Island Lake to spawn when other inlets/outlets to Martin Lake were also blocked by barriers. Martin Lake has abundant carp at nearly four times the threshold for lake health of 100 kg/ha (Bajer 2018). In addition to barriers, carp removals are actively occurring at Martin Lake and upstream Typo Lake. The barriers prevent seasonal migrations between over wintering and spawning habitats, and prevent carp recolonization after harvests.

The chain of lakes discharges out Martin Lake into the West Branch of the Sunrise River. That river discharges to the St. Croix River. These waters are of regional importance.

Carp Management to Date

Carp management has been infrequent at Linwood Lake. While residents recall instances of commercial carp removals these occurred more than 20 years ago. Carp management was identified as a management approach in the 2013 TMDL study for the lake.

In April 2020 a commercial seining of carp was attempted in Linwood Lake. Carp were aggregated. During the seine at least three radio tagged carp were in the net. However, upon completion no tagged carp were in the net and only 30 total were captured. The failure appears linked to slightly lifting the net to get it over underwater topography. Additional attempts in the future may occur.

TMDL Water Quality Improvement Strategies

A number of projects that could improve lake water quality have been scrutinized through TMDL or feasibility studies. Each provides an estimate of the phosphorus reductions the project would achieve, costs, and overall cost-effectiveness. Additionally, we have used the best available information to create similar estimates for carp management.

The TMDL report states that the needed pollutant reductions can be achieved through:

- Internal load reductions of 9%.
- SSTS reductions of 22% from upgrading all failing septic systems (i.e. 0% failure rate).
- Watershed runoff reductions of 27%.

The proposed reductions for watershed runoff and septic systems will be challenging to reach. The watershed is largely undeveloped with nearly no stormwater conveyance systems, therefore watershed runoff is relatively small already. Reducing it by another 27% will require large efforts. Septic systems are perhaps easier to address, but reaching a 0% failure rate is always ambitious. Knowing this, managers might consider that more than 9% internal load reductions are necessary. At the least, it appears fair to say that there is no reasonable expectation that water quality goals can be reached unless internal load reductions including carp management are completed.

Cost-Benefit Analysis of Water Quality Improvement Options

A subwatershed study is planned in the coming years to identify and rank stormwater retrofits and shoreline BMPs by cost effectiveness. Given that study is not yet complete, we have examined cost effectiveness of similar stormwater BMPS that have been analyzed in neighboring watersheds of Coon and Martin Lakes. There, cost effectiveness has ranged generally from $300 to over $2,000+ per pound of phosphorus, however most projects were below $1,400 per pound of phosphorus reduction. Projects less than $500 have been viewed as highly cost effective, and those less than $1,000 are often pursued depending upon options available.

Calculating the pollutant reductions achieved by carp management is new and includes considerations of the phosphorus content of the carp themselves, direct effects of carp through sediment disturbance, indirect effects of carp removing vegetation or displacing native fish, and more. In case of Linwood Lake, carp management would be used to prevent lake deterioration (loss of macrophytes, increased sediment disturbance) rather than to restore it from a deteriorated state. Thus, typical calculations of $ per lbs of P removed may not be very applicable. Nevertheless, it is worthwhile to examine relative cost effectiveness estimates.

We calculated phosphorus reduction by carp management as follows:

Typically, carp biomass reduction to 89 lb/ac at the least is the goal. That is the threshold at which lake health deteriorates (Bajer 2018). However, in the case of Linwood Lake a more appropriate goal may be a 25%+ reduction to prevent population increase and increase the likelihood of long-lasting benefits.

The present carp population is 9,851 with a biomass of 98 lbs/ac. A 25% reduction would mean removing 2,238 carp. Removing these carp yields both direct and indirect phosphorus reductions.

Direct phosphorus reductions are from removal of the carp themselves. 0.05% of carp is phosphorus. Knowing that the average weight of carp in Linwood Lake is 7 lbs, the phosphorus content of 2,238 carp removed is 1.1 lbs.

Indirect phosphorus removals and positive feedbacks are larger than direct benefits. By removing carp we remove phosphorus introduced into the water column by their feeding, spawning and defecating. Moreover, carp removal allows greater macrophyte establishment which has positive feedbacks within the lake such as reducing wind disturbance, providing refugia for zooplankton that eat algae, providing spawning & hiding habitat game fish, & providing waterfowl habitat. All of these multiply the phosphorus reduction.

There are no existing estimates or models of the phosphorus loading caused indirectly by carp. Therefore, we referred to the TMDL study for an estimate of internal loading. That study estimated 307.0 pounds of internal loading in Linwood Lake but also noted it is likely much larger than that model estimate. The TMDL recommends a 9% internal loading reduction (29.1 lbs). However, as discussed earlier in this report achieving watershed phosphorus reduction goals will likely be difficult and expensive, so managers may wish to achieve greater internal load reductions in order to have a higher chance of reaching lake water quality goals.

We conservatively figured that half of internal loading is due to carp. So, a 25% reduction of carp biomass might be expected to achieve a 12.5% internal loading reduction. This would equate to 38 pounds of phosphorus.

To calculate cost effectiveness, we divided direct and indirect phosphorus into the estimated cost of carp removals. The estimated cost of carp removals is $70,000. Over a 10-year estimated duration of benefit the phosphorus removals achieved would be 1.1 lbs direct removal plus 38 lbs indirect removal multiplied by 10 years. This equals 391 pounds of phosphorus. **The cost effectiveness is therefore $179 per pound of phosphorus removed**. For other BMPs, anything below $500 per pound is considered highly cost effective.

This calculation contains a number of conservative estimates. We do this in order to recognize that the science of calculating phosphorus reductions from carp management is still developing, the inherent error in TMDL models, and the desire to not over-state the likely cost effectiveness of carp management. In addition to the conservative assumptions discussed above, others include:

- We neglect phosphorus loading *prevention* by keeping the carp population in check.

- We neglect the higher costs of correcting a high carp population compared to preventing it.
- We neglect secondary benefits to fish and wildlife.

In summary, key assumptions and calculations are:

9,851 carp present

98 lb/ac carp biomass

Goal of 25% carp reduction (removing 2,238 carp)

Half of TMDL-estimated internal loading is from carp

TMDL estimated internal loading = 307.0 lbs/yr, likely more

Direct carp phosphorus content = 2,238 carp x 7 lbs per carp x 0.05% P content = 1.1 lbs

Indirect phosphorus removals = 25% carp biomass reduction will yield a 12.5% reduction of TMDL-estimated internal loading = 12.5% x 307.0 lbs/yr = 38 lbs/yr reduced

10-year phosphorus reduction = (1.1 lbs/yr direct removed + 38 lbs/yr indirect removed) x 10 yrs = 391 lbs phosphorus

10-year cost = $70,000

Cost effectiveness $70,000/391 lbs = $179/lb-P

Social Considerations

The Anoka Conservation District (ACD) provided information regarding the social considerations as it might pertain to carp management. Overall, social factors seem to favor carp management as one tool to improve water quality, ecology and fisheries in Linwood Lake. The preliminary findings of this report have been presented to, and favorably received by, stakeholder groups including the lake association, township, Sunrise River Watershed Management Organization (SRWMO) and ACD.

The lake is a priority because it is impaired, but near State water quality standards. It is also a headwaters lake that drains to other impaired downstream waterbodies that would benefit from work at Linwood Lake. Linwood Lake itself is a priority in the SRWMO watershed management plan.

While water quality (nutrients, excess algae and poor clarity) are priorities, vegetative management may be even more important to some lake residents. Because much of the lake is littoral, robust vegetative growth is expected. In recent years there have been concerns about increased vegetative growth including aquatic invasive species (AIS). Because of this, the use of alum as a means to achieve water quality goals is not favored as strongly as carp management. This is because alum may make the water “too clear” and create a perceived over-abundance of vegetation including AIS. Instead, some favor carp management because it will not likely create overly clear water and addresses ecological health, the game fishery, and water clarity.

Local groups are raising funds for carp and other lake management. The lake association has been fundraising and the Sunrise River Watershed Management Organization is including it in their watershed management plan. While outside grants would likely be needed for carp management, local matching dollars for a grant are available. Carp management at other nearby lakes has been funded with State grants.

Carp Management Recommendations

Electrofishing surveys suggest that Linwood Lake is only slightly above the threshold for management of common carp (110 kg/ha compared to a 100 kg/ha threshold). Aging analysis showed that young carp recruited relatively frequently into the population in the last 10 years. If the sustained level of recruitment continues into the future, the population might substantially exceed the ecological threshold of 100 kg/ha, have a negative impact on water quality and the aquatic plant community, and be difficult to reverse.

We recommend:

- **Determine sources of recruitment:** Because adult carp home to their natal areas during the spawning season, tracking radio-tagged carp during spring might identify carp nurseries within the system. The radio tags installed in 2018 have a battery life of at least three years. Small mesh trapnet surveys in potential nursery locations (Rice Lake) are also recommended. This effort is expected to cost ~$10,000 (2 seasons).
- **Monitoring of carp abundance and biomass.** We recommend boat electrofishing surveys once every 2 years to monitor carp biomass, abundance and length structure. These surveys would cost on average $3,000 per year assuming they are conducted every other year).
- **Preventative carp removals:** Remove carp now to keep the young population in check and prevent large population growth within Linwood Lake, as well as to reduce carp moving to other lakes. This effort is expected to cost $30,000. A modest investment now may prevent a larger population and larger management costs later. We anticipate the effects of carp removal to last at least 10 years. At most lakes, removals to at least 100 kg/ha (89 lb/ac) is recommended to be at the threshold for health. At Linwood Lake, achieving biomass below this threshold is desirable due to the young population structure.
- **Manage Linwood Lake carp as part of the chain of lakes with Island, Martin and Typo Lakes.** Carp do move between the lakes. Present barriers only allow carp movement from Linwood to Island and Martin Lakes. Therefore, if carp populations are not managed in Linwood Lake, it could become an important source of carp to Island and Martin Lakes. Island Lake's carp biomass should be further studied and managed accordingly.
- **Consider a carp barrier at Linwood Lake outlet.** The outlet is in disrepair. When repaired or replaced, a design that prevents carp movement is recommended.

Winter seine and box netting appear the most likely carp removal method. The results from telemetry surveys showed that the carp stay in Linwood Lake and tend to congregate in a few

places. These aggregations could make Linwood a candidate for winter seining. We can make efforts to contact commercial fishermen to conduct the seines, however we have had limited success contracting their work in recent years. Box netting in the summer will be our fallback.

In comparison to the rest of the chain of lakes on the West Branch of the Sunrise River, Linwood Lake is a moderate priority. Martin and Typo Lakes have been a higher priority due to ongoing management successes that make continued success a high likelihood, presence of carp barriers and substantial prioritization work that has been done. At Linwood Lake carp management is necessary to reach water quality goals in Linwood Lake, preventing carp population growth in Linwood Lake, and prevent carp recolonization of Martin and Typo Lakes.

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