

INVASIVE CARP SAMPLING REPORT
JANUARY – DECEMBER 2018
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
SECTION OF FISHERIES



UPPER MISSISSIPPI RIVER, POOLS 1-8
LOWER ST. CROIX RIVER, BELOW ST. CROIX FALLS
MINNESOTA RIVER, BELOW GRANITE FALLS

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Introduction

Bighead Carp *Hypophthalmichthys nobilis*, Silver Carp *H. molitrix*, Grass Carp *Ctenopharyngodon idella*, and Black Carp *Mylopharyngodon piceus* (hereafter collectively referred to as Invasive Carps) are invasive species currently found in the United States. These species were introduced into the United States during the early 1970's as aids in fish aquaculture operations (Henderson 1976). Subsequently, large flood events allowed these species to escape into the Mississippi River drainage, where they began reproducing and spreading (Freeze and Henderson 1982). Invasive Carps have migrated up the Mississippi River, and adjoining tributaries, quickly establishing populations in newly invaded areas. In Minnesota, Bighead and Grass carp have been collected in the Mississippi, Minnesota, and St. Croix rivers while Silver Carp have only been captured in the Mississippi and St. Croix rivers (Figure 1). Black Carp have never been collected in Minnesota or Wisconsin waters. Currently, there is no evidence of Invasive Carp reproduction in Minnesota waters.

Invasive Carps have the potential to devastate local ecosystems by competing with native planktivores and overcrowding other native species. With high fecundity and the ability to populate new areas quickly, Invasive Carps can reach high abundances, sometimes comprising most of the fish biomass in certain systems (MICRA 2002). Invasive Carps have a voracious appetite, and coupled with their large size (>70 pounds), have the ability to consume large amounts of food by filtering zooplankton, phytoplankton, and organic particles out of the water column (Jennings 1988; Smith 1989; Voros 1997). If Invasive Carp populations establish in Minnesota, native planktivores such as Paddlefish *Polyodon spathula*, Bigmouth Buffalo *Ictiobus cyprinellus*, Gizzard Shad *Dorosoma cepedianum*, and the larval stages of many other native fishes may be in direct competition with Invasive Carps for food resources. Evidence from the Illinois River suggests that competition with Invasive Carps resulted in reduced

condition factors for Bigmouth Buffalo and Gizzard Shad (Irons et al. 2007). Worldwide, introductions of Invasive Carps have led to declines in fish species diversity and abundances of commercially desirable species (Spatura and Gophen 1985; Petr 2002).

With the continuing progression of Invasive Carps up the Mississippi River, Minnesota waters are threatened by a potential invasion. A better understanding of the current status of individual Invasive Carp and populations in Minnesota will allow for more effective efforts to prevent their spread and/or eradicating them. Although standard fish sampling assessments have been ongoing in Minnesota's major rivers and have the potential to catch Invasive Carps, the gears and methods used in the standard assessments are not the most efficient methods for capturing Invasive Carps. The purpose of this sampling effort is to use more carp-specific gears and techniques to monitor all life stages of Invasive Carps and associated native fishes in Minnesota waters.

Objectives

- Detect and monitor all life stages of Invasive Carps to:
 - o Inform management efforts in Minnesota; and
 - o Provide information for Upper Mississippi River managers on carp population changes in the presence front.
- Monitor native fish species that may be affected by the establishment of Invasive Carps.
- Implement novel monitoring and removal techniques of Invasive Carps to increase removal efficiency.

Sampling Sites

In the Mississippi River, standard Invasive Carp sampling occurred in approximately 89 km of water from St. Anthony Falls Lock and Dam in Minneapolis, MN to Pool 8 near La

Crosse, WI. In the St. Croix River, standard effort was focused on an 83 km stretch from the dam near Taylors Falls, MN to the confluence with the Mississippi River near Prescott, WI. In response to Invasive Carp captured or reported to have been captured, additional sampling occurred on the Minnesota River near Granite Falls and on Sunrise Lake in Blaine, MN.

Sampling Methods

Sampling information for Invasive Carps included in this report took place between January 1, 2018 and December 31, 2018. Gears, methods, and targeted locations were derived from personal communications with biologists who have been sampling Invasive Carps (V. Santucci, Illinois Department of Natural Resources, personal communication; J. Lamer, Western Illinois University, personal communication) and conducting research on the most efficient gears to sample Invasive Carps (M. Diana, Illinois Natural History Survey, personal communication), literature review of sampling techniques and habitat preferences (Lohmeyer and Garvey 2009; Williamson and Garvey 2005; Dettmers et al. 2001; DeGrandchamp et al. 2007; Kolar et al. 2007; DeGrandchamp et al. 2008; Wanner and Klumb 2009; ACRCC 2012), and experience from prior field seasons.

Commercial Fishing

Commercial fishermen were contracted to target Invasive Carp with gill nets and seines for both sampling and response efforts. Minnesota Department of Natural Resources (MN DNR) personnel accompanied contracted commercial fishermen to direct sampling locations and monitor efforts. The number of fish caught by species was estimated during gill netting operations and total weight harvested was requested from the commercial fishermen for both gill netting and seining operations.

Invasive Carp Acoustic Tagging and Tracking

In Minnesota, Statute 84D.05, Subdivision 1 stated “A person may not possess, import, purchase, sell, propagate, transport, or introduce a prohibited invasive species.” In 2017, the legislature passed and the governor signed an amendment to this statute: *Subd. 1a. **Permit for invasive carp.** The commissioner may issue a permit to departmental divisions for tagging bighead, black, grass, or silver carp for research or control. Under the permit, the carp may be released into the water body from which the carp was captured. This subdivision expires December 31, 2021.* As part of the permitting process, DNR fisheries developed a protocol to characterize and minimize potential risk while maximizing the amount of information gained. For further information regarding the tagging and tracking procedures, please see the permit issued by the Department of Natural Resource’s Division of Ecological and Water Resources.

Based on the tagging results, MN DNR staff have gained a better understanding of movement patterns and habitat preferences, while posing a very low risk to native fish populations or risk of increasing Invasive Carp populations. Other states have already begun work of this nature in riverine environments and have shown significant results and ability to remove additional fish with this tagging method. This information will be continue to be used to inform sampling and removal efforts.

The DNR was permitted to tag one or two Invasive Carp at a time with acoustic tags. The DNR utilized both passive telemetry (a stationary receiver array already in place) and active tracking (using a portable receiver) to determine preferred habitats, longitudinal movement patterns, depth preferences, and specific locations for capture efforts.

The state of Minnesota has a total of 88 receivers from above the Coon Rapids Dam to Lock and Dam 5 in the Mississippi River, from the Mississippi River confluence at Prescott, WI

to Taylor's Falls in the St. Croix River, and from the Mississippi River confluence to the County Road 6 bridge north of Delhi, MN, in the Minnesota River (river mile 209). Sixty-nine receivers are maintained by the East Metro office, nine are maintained in the Minnesota River by the Hutchinson office (from river mile 18.7 to river mile 209), and ten are maintained by the Lake City office in the Chippewa River and Pools 4 and 5 of the Mississippi River. In addition, the U.S. Fish and Wildlife Service maintains seven receivers in Minnesota waters and 47 additional receivers that extend downstream to Pool 19 near Keokuk, IA. Additional receivers are maintained by other states and universities that include, but are not limited to, 11 receivers maintained by the Missouri Department of Conservation from Pool 19 to the confluence with the Ohio River. In addition, in 2019 the MN DNR will be installing a real-time receiver on the St. Croix River which will send emails and/or text messages to field staff to direct when tagged Invasive Carp are in the area for effective rapid response actions.

By tagging one or two Invasive Carp, we expect to capture additional Invasive Carp if they are present. Recapture actions will continue to be taken, including the use of commercial fishermen, when tagged fish are in jeopardy of being un-trackable due to tag life nearing completion, leaving the passive array footprint, or to support removal of other conspecifics. The DNR will take all reasonable measures to ensure all tagged fish are tracked and their locations known through active tracking and an extensive passive tracking network. Comprehensive removal efforts will be employed to remove tagged and un-tagged fish from Minnesota waters.

The impacts of releasing wild-caught Invasive Carp back into the wild have been considered and are believed to be minimal when compared to the potential information gained from this project. As outlined in this report, MN DNR maintains an extensive monitoring and removal program to ensure populations are adequately sampled and document if reproduction is

occurring in Minnesota waters to provide accurate information for Upper Mississippi River managers on carp population changes in the presence front. Finally, Minnesota is remaining conservative with only one or two fish permitted to be tagged and released at a time, with all other Invasive Carp euthanized.

Pool 2 Stable Isotope Analysis

With the financial support of the Minnesota Environment and Natural Resources Trust Fund (ENRTF) from the Legislative-Citizens Commission on Minnesota Resources (LCCMR), samples were collected from Pool 2 of the Mississippi River for Carbon (C^{13}) and Nitrogen (N^{15}) stable isotope analysis during the 2017 field season. The purpose of this project is to use stable isotope analysis to examine the aquatic food web within Pool 2 and provide baseline trophic data before Invasive Carp establishment. The results of this study are currently being compiled for peer reviewed publication.

Larval Trawling

Larval trawling was conducted in the Mississippi River Pools 2 and 3 and the St. Croix River to target early life stages of Invasive Carps. Eight standardized sites were sampled in Pool 2 (Figure 2) and the St. Croix (Figure 3). A bow mounted ichthyoplankton net (0.75 m x 3 m) consisting of 500 um mesh was pushed near the surface into the current so that the velocity of the water entering the net is between 1.0 to 1.5 m/s. At sampling locations where no water current exists (e.g. backwaters), sampling occurred towards a random direction that allowed for a complete sample to be taken in a relatively linear path. A mechanical flow meter was placed in the mouth of the net to determine the volume of water sampled. Since 2017, water quality measurements have been collected for all samples including surface temperature, dissolved

oxygen, conductivity, and pH. A total of eight locations were sampled in each standardized system with two, 5-minute pushes conducted at each location. In Pool 2 and the St. Croix River, sampling sites were located in the following macro habitats: 4 main channel, 2 side channel, and 2 backwater locations in each system. For all samples, contents were placed in containers labeled with sample location, name of the water body, and date, and preserved. For preservation, samples were placed into 10% buffered formalin for 24-48 hours and then the formalin was removed and replaced by 90% alcohol. All samples were sifted to remove all excess material, with only eggs and fish kept for later identification. Fish and eggs were examined to determine if any Invasive Carp species were collected and to identify specimens to the lowest possible taxonomic level. Samples were also sent to an external researcher for verification and to create a reference collection of the species caught for future reference. Sampling site locations, sampling dates, gear description, effort, habitat type (main channel border, backwater, wing dike, etc.), water depth, and crew details were recorded for each site.

Buffalo Tagging

This study will provide information on population dynamics and movements of Smallmouth Buffalo and Bigmouth Buffalo in Pool 2 of the Mississippi River. From the literature and previous experience, Bigmouth Buffalo are often found with Silver and Bighead Carp. As a result this species is being studied to serve as a surrogate for tagging additional Bighead or Silver Carp. During the 2018 field season, this project was not a large priority as other higher priorities were encountered that had to be addressed.

Beginning in the spring of 2015, Buffalo sampled in the Mississippi River Pool 2 have been collected primarily from large mesh gill net and seine commercial fishing operations, as well as standard large mesh gill nets, trammel nets, and electrofishing have been tagged. Buffalo

are tagged externally with a yellow Floy t-bar tag, along with a secondary mark by removing one pelvic fin ray. This allows recaptured Buffalo to be identified for as long as the tags are retained (>4 years) and to assess tag retention. Pelvic fin rays are being used for ageing purposes to determine variation in movement patterns by age as well as validate ageing techniques by re-ageing recaptured fish using the original fin when the fish was tagged and the fin clip when the fish is re-captured in subsequent years. To date, no known studies have validated Buffalo ageing techniques.

As one of the United States' most prolific and valuable freshwater commercial fisheries, it is also imperative that fisheries managers develop management plans and quotas to ensure populations are sustainably harvested and do not become overfished. Further, Buffalo are native to the United States, occupying a distinct ecological niche that may ultimately be filled by Invasive Carp species should Buffalo populations become overfished. Bighead and Silver Carp have adverse effects on all life stages of native fish species because they feed on plankton, the primary food source of several adult fish (Irons et al. 2007), all larval fish (Schrank et al. 2003), as well as all mussel species (Kolar et al. 2007) creating cascading trophic effects throughout the food web. The full impacts of Invasive Carp, should they become established in Minnesota, cannot be well documented without this biological data from commercial fish species.

Electrofishing

Electrofishing occurred in a variety of habitats including backwaters, side channels, main channel borders, and over wing dikes. Sampling locations consisted of eight standardized sampling locations in Pool 2 (Figure 2) and the St. Croix River (Figure 3), and all other sampling events occurred at non-standardized locations in the aforementioned habitats at the discretion of the sampler. Standardized sampling locations were selected based on habitats Invasive Carps are

likely to occupy and are 1/3 mile (500 meters) in length. At these set sampling locations, all observed fish were collected, identified, measured and weights and ageing structures were taken from fish included in the age and growth analysis. If positive identification was not possible, voucher specimens were kept, labeled, and preserved in 90% ethanol for later identification. At non-standardized sampling sites, fish were identified in the water and only Invasive Carps and fish needed to collect ageing structures were collected. This reduced unnecessary processing time and allowed for greater sampling effort. Sampling site locations, sampling dates, gear description, effort, habitat type (main channel border, backwater, wing dike, etc.), water depth, and crew details were recorded for each electrofishing run.

Trap Netting

Trap netting was conducted on Pool 2 of the Mississippi River in 2018 using standard and mini-fyke nets June 25-29, 2018. Trap netting was not conducted in the St. Croix River this field season. The mini-fyke nets consist of a double frame (27 in. x 39 in.), 4 hoops (2 ft.), a single throat, and a 25 ft. lead, with a square mesh size of 0.125 in. throughout. All fish were identified and enumerated in the field.

Seining

A small 35-foot seine was used to sample shallow water habitats for young fish from June through August on Pool 2 of the Mississippi River with 19 seine hauls completed over 5 days. The seine measure 35 ft. long and 6 ft. deep with 3 ft. square bag (3 ft. x 3 ft. x 3 ft.) located at the center of the net, consisting of "Ace"-type nylon netting 1/8 in. mesh, with a mudline.

Fish Tagging Efforts

Currently several species of fish in the Mississippi River Pool 2 and the St. Croix River are tagged according to study guidelines as part of ongoing tagging studies when encountered. These species included Flathead Catfish *Pylodictis olivaris*, Channel Catfish *Ictalurus punctatus*, Smallmouth Buffalo *Ictiobus bubalus*, and Bigmouth Buffalo in Pool 2. In the St. Croix River, Lake Sturgeon *Acipenser fulvescens*, Muskellunge *Esox masquinongy*, White Bass *Morone chrysops*, Flathead Catfish, and Channel Catfish are being tagged. In both Pool 2 and the St. Croix River, Paddlefish are also tagged.

Age and Growth Analysis

In 2018, age and growth analyses were limited to Smallmouth Buffalo and Bigmouth Buffalo. Bigmouth Buffalo are native planktivores that may be in direct competition with Bighead and Silver Carp. Smallmouth Buffalo, as well as Bigmouth Buffalo, are commercially important and a better understanding of these species will be useful to determine effects from commercial fishing and/or the presence of Invasive Carp. For the previously mentioned species, lengths, weights, and ageing structures were collected as follows: for fish less than 300 mm, up to 5 individuals in each 10 mm length group and for fish 300 mm and greater up to ten individuals in each 25 mm length group. For Smallmouth and Bigmouth Buffalo, pelvic fin rays were extracted and compared. During the 2015, 2016, 2017, and 2018 field seasons, nearly 4,500 Smallmouth and Bigmouth Buffalo (2,140 Smallmouth Buffalo and 2,220 Bigmouth Buffalo) have been tagged with Floy tags and their pelvic fins were removed for ageing and to validate ageing analyses using re-captured fish in the future as part of another study. Since 2015, there have been a total of 265 recaptures of tagged fish (97 recaptures of Smallmouth Buffalo and 168 recaptures of Bigmouth Buffalo). Fin rays were dried and cut using a low-speed isomet saw. Two independent readers counted each opaque band as an annulus under a dissecting

microscope, using both reflected and transmitted light sources. If counts differed between readers, the readers re-examined the structure independently a second time. If readings differed the second time, the readers conferred until a consensus was reached. The results of this study are presented in an annual MN DNR tagging report.

Gill and Trammel Netting

Gill netting and trammel netting occurred during multiple sampling events on each system. Large mesh gill nets of depths from 8 to 24 feet and lengths of 150 to 300 feet with square mesh sizes of 4 to 6 inches were used to target adult Invasive Carps. Trammel nets with outside wall square mesh sizes of 14 inches and inner square mesh sizes of 4 inches were also used to target adult Invasive Carps. Experimental gill nets 250 feet in length and 6 feet deep consisting of 50 foot complements of net with square mesh sizes 0.75, 1, 1.25, 1.5, 2 inches were used to target juvenile Invasive Carps. Nets were set either short-term or overnight, with short-term sets favored when water temperatures were greater than 60° F. All fish caught were identified and measured.

Results and Discussion

Sampling Results

In total, 102 days were spent sampling between January and December 2018 on the Mississippi River Pool 1, 2, 3, 5A, 6, and 8, and the Minnesota and St. Croix rivers with gears appropriate for sampling Invasive Carps (Table 1; Figure 4). A greater amount of effort was focused on Pool 2 and the St. Croix River, because Invasive Carps were found above Lock and Dam 2 on the Mississippi River in 2014 and due to the finding of multiple Bighead Carp at the Allen S. King Plant discharge on the St. Croix in 2015. In 2018 there was also an increase in

field sampling off the Minnesota River due to a Bighead Carp captured near Redwood Falls in June 2017 and previous captures.

In 2018, a total of 3 Bighead Carp were caught in Minnesota waters and Wisconsin boundary waters (Table 2). On May 11, 2018 while tracking the tagged Bighead Carp, MN DNR crews located the tagged fish within Andersen Bay on the St. Croix River. MN DNR personnel set gill nets across the mouth of the bay and within the bay. The nets yielded one mature male and one mature female Bighead Carp. These two Bighead Carp would probably not have been caught without the ability to track the tagged individual. The tagged Bighead Carp was able to escape capture through a flooded forest. On September 27, 2018 MN DNR staff from the Hutchinson office set gill nets directed for tagging Paddlefish on the Minnesota River downstream of Granite Falls, MN and captured one mature male Bighead Carp.

On June 13, 2018 DNR staff set large mesh gill nets in Sunrise Lake in Blaine, MN after receiving a report with photographic evidence of a Grass Carp that was alleged to have been caught in the lake. No Invasive Carp were captured during sampling. To ensure this large lake was sufficiently sampled, DNR staff electrofished the lake on June 14, 2018 and again did not capture any Invasive Carp but successfully captured Common Carp. It was later ascertained that the picture provided was found online and was not of the actual fish captured in Sunrise Lake.

A large, collaborative effort took place on April 9th. MN DNR fisheries crews from East Metro, along with Wisconsin DNR, and U.S. Fish and Wildlife Service blocked off a bay in Pool 8 of the Mississippi River where Bighead Carp had been captured in years past. Large mesh gill nets were used to block off the bay and within the bay along with extensive electrofishing and no Invasive Carp were captured. In addition, on May 15th U.S. Fish and Wildlife staff assisted with

MN DNR netting around the tagged Bighead Carp. Through the day, 3,300 feet of large mesh gill nets along with electrofishing were used but did not capture any Invasive Carp.

Contracted commercial fishermen were hired to use large mesh gillnets and seines to sample in the Mississippi River in Pools 2, 3 near Red Wing, Pool 5A near Winona, Pool 6 near Winona, and Pool 8 near La Crosse, and in the St. Croix River from Lake St. Croix to the confluence with the Mississippi River near Prescott, WI. Contracted commercial fishermen set approximately 65,200 feet of gill nets during eight days of effort and conducted eight seine hauls between January and December 2018. Gill nets were set short term (2-3 hours) and fish were chased towards the net with boats, typically in large backwater areas. In 2018, three regular commercial fishing operations were also monitored for the presence of Invasive Carp.

Larval trawling was conducted for a total of 134 total trawls during 10 days by the Invasive Carp fisheries personnel. All samples were sifted by Invasive Carp fisheries personnel and all samples with fish larvae or eggs are preserved and have been sent to Colorado State University for expert analysis to determine the species caught and their respective number.

Both random and standardized electrofishing sampling was conducted on Pool 2 of the Mississippi and the St. Croix rivers. A total of 2,055 minutes of “on time” over 31 days were spent electrofishing between January and December 2018. In 2018, twenty standardized electrofishing sites were sampled once for a total of 354 minutes. Random electrofishing was used to monitor for Invasive Carp and for collection of individuals for age and growth.

Trap netting was conducted using fyke nets over June 25-29 for a total of thirty-nine net nights on Pool 2 of the Mississippi River. All fish were counted and measured in mini fyke nets, except Emerald Shiners *Notropis atherinoides* and Common Carp *Cyprinus carpio* due large numbers captured.

Gill nets and trammel nets set by MN DNR personnel were often used to sample behind wing dikes and in smaller side channel and backwater areas where it wasn't feasible for commercial fishermen to target with their larger operations. In 2018, a total of 50,900 feet of gill and trammel nets were set in Pool 2 and the St. Croix River during 29 days, with most net sets being short-term sets (2-5 hours).

Numerous unique or rare native fishes worth mentioning were encountered during these sampling events. Of note for 2018, one Crystal Darter was collected on the St. Croix River near Taylor's Falls in August. After 5 years of extensive monitoring, the first confirmed collection of Black Buffalo *Ictiobus niger* in Pool 2 occurred in June and our first young of the year Blue Sucker was found in a Pool 2 off channel. Lastly, three other new species were added to our on-going species list from Pool 2: Weed Shiner *Notropis texanus*, Bigmouth Shiner *Notropis dorsalis*, and Shoal Chub *Macrhybopsis hyostoma*. Also, from past experiences and in conjunction with tracking the tagged Bighead Carp, a large number of Paddlefish were caught and jaw and acoustic tagged as part of other MN DNR studies. A complete species list of species caught and observed on Pool 2 and the St. Croix River from January 2013 through December 2018 has been compiled (Table 3).

Determining if Invasive Carp seen in Minnesota are pioneering individuals or are indicative of a population is a key question for managers. While it is likely there are additional Invasive Carp present in the Minnesota waters of the monitored rivers, the level of effort invested and resulting capture data support the hypothesis that the carp currently present are individual, wandering adults and not part of a larger population present in Minnesota waters.

Invasive Carp Acoustic Tagging and Tracking

On July 28, 2017 during routine monitoring at the Allen S. King Plant on the St. Croix River, a Bighead Carp was caught by MN DNR staff in a large mesh gill net. The fish was then tagged using a VEMCO V16TP-6H (VEMCO Ltd., Nova Scotia, 69 kHz) continuously transmitting acoustic tag containing sensors to measure pressure (depth) and temperature transmitting every 60 seconds on average (minimum transmission delay of 30 seconds, maximum delay of 90 seconds) and released. This fish was actively tracked using a VEMCO VR100 every day for a week after release, followed by actively locating the fish once a week every week until September 5, 2017. After September 5, 2017 the fish was located routinely until the last day in the field on November 20, 2017. In 2018, the fish was routinely tracked except when found in areas where sampling was too difficult, at which time tracking resumed within two weeks to ensure the fish did not make large scale movements or leave the St. Croix River. In addition, this fish was routinely identified and data recorded by the passive VR2W receiver array in place, with the last VR2W downloaded on September 14, 2018 and the last detection using active tracking and the VR100 occurring on November 20, 2018. Details of when and where this fish were located can be found in Figure 5. In 2017, we received 30,388 data points from the VR2W array up until November 20 (115 days) and 319 data points from active tracking with the VR100 up until November 27 (122 days). In 2018, we received 131,650 data points from the VR2W array up until September 14 (256 days) and additional data points were collected from active tracking with the VR100.

This fish was observed on the St. Croix River to range over an extent of 23.3 river miles from Stillwater, MN to the confluence with Pool 3 of the Mississippi River and entered Pool 3 and traveled 2.5 miles from the confluence to Lock and Dam #2 (Figure 5). Over the course of this second field season, several areas of recurring use were observed including a high

prevalence within Lake St. Croix. In general, the tagged Bighead Carp was observed to remain within Lake St. Croix from October 2017 through April 2018 and returned again and remained within Lake St. Croix in October 2018. Based on the first two field seasons, this fish spends over 50% of its time within Lake St. Croix. In 2018, the tagged fish did not show as much site fidelity to specific locations and appears to have moved over a broader range through the field season as compared to observations from 2017.

From the temperature and depth data, it appears this fish comes to the water's surface more often and inhabits a wider range of depths, 0 to 68.6 feet, than commonly believed (Figure 6) and tolerates temperatures ranging from 88 to 33 degrees Fahrenheit (Figure 7) (see MN DNR 2018 for data collected from the first field season). Over the 2018 field season, the Bighead Carp consistently encountered similar or warmer water temperatures than the data loggers on our acoustic array at the Allen S. King Plant discharge and the USGS gauge located in Stillwater, MN. Unlike in 2017, depth data did not show deep diving activity and as a result did not show the fish occupying colder temperatures than either gauge for any prolonged period of time. In 2017, the temperature the Bighead Carp was experiencing was colder than the Stillwater USGS gauge data on September 15 through 18 and again on September 24 through 26, 2017 with depth data showing these temperatures were associated with deep dives including the deepest dive observed over the entire study to 68.6 feet.

In 2018, recapture efforts began in May as soon as ice was off the river. Over nineteen days of concerted effort to recapture the tagged fish or capture fish schooling near the tagged individual, 29,550 feet of gillnet, 4.6 hours of electrofishing, and 7,700 feet of large mesh commercial gill nets and four commercial seines were deployed. The tagged fish was not recaptured; however, on May 11, 2018 while tracking and attempting to recapture the tagged

Bighead two additional Bighead Carp were caught. Unfortunately due to flooding conditions, the tagged Bighead was able to escape through flooded timber. From June 19 through June 23, 2018 the tagged fish was observed to move into Pool 3 and approach the downstream side of Lock and Dam #2. While the fish had been residing within the St. Croix River, the timing of the fish's movement to Lock and Dam #2 corresponded to periods of high flow and discharge through the dam. Flows reached open river conditions on June 26 and remained open river until July 6 and again on July 13 through July 14 (Figure 8). In total, the dam experienced open river conditions above 6100 cubic feet per second (cfs) three times in 2018. From research conducted in other states, movements below a lock and dam are often associated with discharges when flows are at their greatest. At this time, we do not believe this behavior is indicative of an attempted spawning run but may have just occurred at a similar time as when high flows were occurring in Pool 3. Continued monitoring in the St. Croix and Pool 3 will be conducted in 2019 to ensure no reproduction occurred in 2018.

Again in 2018, the tagged Bighead spent a large majority of its time within Lake St. Croix between Hudson, WI and Afton, MN suspended 20-30 feet below the surface which proved difficult to sample when the depth ranged from 50-60 feet deep in the area. Standard gill nets reach less than 25 feet from the surface or bottom and even commercial seines only reach 30-40 feet of water. From these experiences, MN DNR has purchased additional 24 feet deep large mesh gill nets to better sample the Lake St. Croix and deeper St. Croix River habitats. In addition, the DNR has also purchased of a 2,000 feet long and 40 feet deep commercial sized purse seine to better sample these deep water habitats to be ready for the 2019 field season. Further, for 2019 a real-time acoustic receiver will be in place to send immediate notification to staff when the tagged Bighead Carp is present in an area that can be sufficiently sampled as a

rapid response measure. The real-time receiver will be fitted with a modem that will send text messages and emails to staff when the fish is detected and will allow staff to mobilize to more effectively respond when recapture success is greatest. Lastly, a crew of two temporary staff will be present in 2019 to track the tagged Bighead and set nets if possible to attempt to recapture the tagged Bighead or catch additional fish for tagging, if permitted.

From this tagged Invasive Carp, we have learned of additional areas where this fish has resided for prolonged periods of time including a potential overwintering site in Lake St. Croix. Based on information from other areas tracking carp and historic sightings in Minnesota, the hypothesis was that this fish would inhabit the King Plant discharge periodically with forays to Lake St. Croix and overwinter near a natural point where flow is constricted on the river with the most likely location being at Point Douglas, near Prescott, WI. From the tracking data collected, the fish was never observed within the King Plant discharge despite continued monitoring within the discharge. Over two field seasons, the fish has been observed to inhabit a much wider spatial range but has exhibited some site fidelity, inhabiting several key locations for prolonged periods of time. These locations will be sampled extensively during the 2019 field season to determine if other Invasive Carp also use these areas and if this tagged Bighead Carp can reveal the locations of other Invasive Carp using the “Judas fish” technique.

The tagged Bighead Carp has been critical to the capture of two additional Bighead Carp in 2018, without the tagged individual DNR personnel would not have fished that area at that time. From previous captures and the understanding of Invasive Carp movements and biology, the DNR had focused efforts on a relatively few areas (including the Allen S. King Plant and Point Douglas on the St. Croix River), with sporadic sampling in areas considered less suitable to Invasive Carp. While the data collected only represents the movements of one individual, it

appears that some of the areas that were considered less suitable may be frequented as often as areas where sampling was focused in previous years. Finally, timing of sampling is critical for effective management and removal. This tagged fish has shown relatively large movements and has inhabited confined areas suitable for complete sampling for short periods of time. As a result, the ability to track a tagged individual to better understand additional habitat preferences and the duration of residence will be invaluable into the future.

Based on the findings of 2018, tracking methods and field sampling will be adjusted accordingly for 2019. MN DNR staff will continue to track tagged fish and analyze the data to increase sampling and removal efficiencies.

Pool 2 Stable Isotope Analysis

During the 2017 field season fish, invertebrates, and environmental samples were collected as part of a stable isotope analysis of the complex Pool 2 ecosystem. For more information on the samples collected and project design, please see the 2017 MN DNR Invasive Carp report (MN DNR 2018).

Mass spectrometry was contracted with the University of Minnesota for Carbon (C^{13}) and Nitrogen (N^{15}) stable isotope analysis. Due to problems with the mass spectrometer, the University of Minnesota could not complete analysis and samples were subsequently sent to Cornell University. Results are currently being compiled for peer review publication.

Recommendations

Continued monitoring and removal of Invasive Carp from Minnesota waters is recommended for the foreseeable future. Although this project is funded in part by the Minnesota Environment and Natural Resources Trust Fund through June 2020, it is recommended this project continue beyond that date to ensure Invasive Carp do not establish populations or if they

do, adequately document the effects of Invasive Carp to native fish populations. Further, it is recommended that Invasive Carp acoustic tagging continue and once the technique is proven it is recommended that the project expand the number and duration of tagged fish at liberty in Minnesota waters. At this time (per the permit) only two Invasive Carp will be at liberty at any given time.

Further age and growth analysis as well as population dynamics validation (including fecundity and recruitment) is recommended for commercially valuable Bigmouth and Smallmouth Buffalo, which may be in direct competition for food resources with Invasive Carps. In some states, current Invasive Carp population control efforts include increasing commercial fishing effort to decrease Invasive Carp abundance, although increased commercial effort in Minnesota would potentially negatively affect native species. Resource agencies would benefit from a greater understanding of the population dynamics of our commercially important native fishes. In addition to age and growth analyses, over 4,000 Bigmouth Buffalo and Smallmouth Buffalo have been tagged in Pool 2 during 2015, 2016, 2017, and 2018 as part of a study investigating movement, exploitation, age and growth, and other key population dynamics of these commercially important species. It is recommended that this tagging project continue to better understand movement patterns and approximate the numbers of individuals present in the Pool 2 of the Mississippi River via mark-recapture techniques.

Paddlefish are another native planktivore that may compete for food resources with Invasive Carps and therefore may be negatively affected. Currently, Paddlefish are a threatened species in Minnesota and populations across their range have suffered due to commercial navigation projects that impede movement and alter habitats, pollution, and overexploitation (Jennings and Zigler 2000). If Invasive Carps become established in Minnesota rivers, local

Paddlefish populations would be further stressed. Being a state threatened species, non-lethal means of studying Paddlefish populations are also recommended including continued tagging of encountered Paddlefish using jaw and acoustic tags. Efforts to tag and release Paddlefish are invaluable to gain more information about their populations and life history, as well as provide a population estimate for management purposes. Further effort should also be used to encourage boaters to report any deceased Paddlefish for age and growth analysis and other MN DNR offices should collect all deceased Paddlefish for analysis.

Acknowledgements

The monitoring and removal of Invasive Carp in Minnesota is a collaborative program funded by the Minnesota Department of Natural Resources, U.S. Fish and Wildlife, and the Minnesota Environment and Natural Resources Trust Fund.

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Tables

Table 1. Invasive Carp sampling summary for the Mississippi River Pools 1, 2, 3, 5A, 6, and 8 and the St. Croix and Minnesota Rivers for January through December 2018. Number of Invasive Carp Captured represents the number of individuals caught by MN DNR, contracted commercial fishermen, or monitored commercial fishing.

Invasive Carp Sampling Summary January – December 2018			Days
Random Sampling Effort			
Gill/Trammel Netting	50,900	feet	29
Electrofishing	1,700	minutes	21
Trap Netting	39	net/nights	5
Standardized Sampling Effort			
Electrofishing	354	minutes	10
Larval trawling	134	trawls	10
Targeted Commercial Fishing Effort			
Gill Netting	65,200	feet	13
Seining	8	hauls	8
Monitored Commercial Fishing Effort			
Seining	4	hauls	4
Number of Invasive Carp Captured			
Total Number of Days Sampled	3	fish	100

Table 2. Invasive Carp caught from January through December 2018 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	River Mile	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Age
5/11/2018	Bighead Carp	St. Croix River	Andersen Bay	19	1105	21000	Female	Mature	Gill Net	11
5/11/2018	Bighead Carp	St. Croix River	Andersen Bay	19	1186	18000	Male	Mature	Gill Net	10
9/27/2018	Bighead Carp	Minnesota River	Near Granite Falls, MN	235	1173	16900	Male	Mature	Gill Net	10 or 11

Table 3. Species list for the Mississippi River Pool 2 and the St. Croix River from January 2013 through December 2018, including 82 native and invasive species.

Common Name	Genus Species	Pool 2	St. Croix River
American Eel	<i>Anguilla rostrata</i>	x	
Bighead Carp	<i>Hypophthalmichthys nobilis</i>	x	x
Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>	x	x
Bigmouth Shiner	<i>Notropis dorsalis</i>	x	
Black Buffalo	<i>Ictiobus niger</i>	x	
Black Bullhead	<i>Ameiurus melas</i>		x
Black Crappie	<i>Pomoxis nigromaculatus</i>	x	x
Blackside Darter	<i>Percina maculata</i>	x	x
Blue Sucker	<i>Cypleptus elongatus</i>	x	x
Bluegill	<i>Lepomis macrochirus</i>	x	x
Bluntnose Minnow	<i>Pimephales notatus</i>	x	x
Bowfin	<i>Amia calva</i>	x	x
Brassy Minnow	<i>Hybognathus hankinsoni</i>		x
Brook Silverside	<i>Labidesthes sicculus</i>	x	
Brook Stickleback	<i>Culaea inconstans</i>	x	
Brown Trout	<i>Salmo trutta</i>		x
Bullhead Minnow	<i>Pimephales vigilax</i>	x	
Burbot	<i>Lota lota</i>		x
Central Mudminnow	<i>Umbra limi</i>	x	
Channel Catfish	<i>Ictalurus punctatus</i>	x	x
Common Carp	<i>Cyprinus carpio</i>	x	x
Channel Shiner	<i>Notropis wickliffi</i>	x	
Crystal Darter	<i>Crystallaria asprella</i>		x
Emerald Shiner	<i>Notropis atherinoides</i>	x	x
Fathead Minnow	<i>Pimephales promelas</i>	x	
Flathead Catfish	<i>Pylodictis olivaris</i>	x	x
Freshwater Drum	<i>Aplodinotus grunniens</i>	x	x
Gilt Darter	<i>Percina evides</i>		x
Gizzard Shad	<i>Dorosoma cepedianum</i>	x	x
Goldeye	<i>Hiodon alosoides</i>	x	
Golden Redhorse	<i>Moxostoma erythrurum</i>	x	x
Golden Shiner	<i>Notemigonus crysoleucas</i>	x	
Grass Carp	<i>Ctenopharyngodon idella</i>	x	
Greater Redhorse	<i>Moxostoma valenciennesi</i>	x	x
Green Sunfish	<i>Lepomis cyanellus</i>	x	x
Hornyhead Chub	<i>Nocomis biguttatus</i>	x	x
Hybrid Sunfish	<i>Lepomis microlophus</i> x <i>L. cyanellus</i>	x	x
Iowa Darter	<i>Etheostoma exile</i>		x
Johnny Darter	<i>Etheostoma nigrum</i>	x	x
Lake Sturgeon	<i>Acipenser fulvescens</i>	x	x
Largemouth Bass	<i>Micropterus salmoides</i>	x	x
Logperch	<i>Percina caprodes</i>	x	x
Longnose Gar	<i>Lepisosteus osseus</i>	x	x
Mimic Shiner	<i>Notropis volucellus</i>	x	x
Mooneye	<i>Hiodon tergisus</i>	x	x
Muskellunge	<i>Esox masquinongy</i>	x	x
Northern Hogsucker	<i>Hypentelium nigricans</i>		x
Northern Pike	<i>Esox lucius</i>	x	x
Orangespotted Sunfish	<i>Lepomis humilis</i>	x	x
Paddlefish	<i>Polvodon spathula</i>	x	x
Pumpkinseed	<i>Lepomis gibbosus</i>	x	x
Quillback	<i>Carpoides cyprinus</i>	x	x
Rainbow Darter	<i>Etheostoma caeruleum</i>		x
River Carpsucker	<i>Carpoides carpio</i>	x	x
River Darter	<i>Percina shumardi</i>	x	x
River Redhorse	<i>Moxostoma carinatum</i>	x	x
Rock Bass	<i>Ambloplites rupestris</i>	x	x
Sand Shiner	<i>Notropis stramineus</i>	x	x
Sauger	<i>Sander canadensis</i>	x	x
Shoal Chub	<i>Macrhybopsis hyostoma</i>	x	
Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>	x	x
Shortnose Gar	<i>Lepisosteus platostomus</i>	x	x
Silver Carp	<i>Hypophthalmichthys molitrix</i>	x	x

Table 3 (continued). Species list for the Mississippi River Pool 2 and the St. Croix River from January 2013 through December 2018, including 82 native and invasive species.

Common Name	Genus Species	Pool 2	St. Croix River
Silver Chub	<i>Macrhybopsis storeriana</i>	x	
Silver Lamprey	<i>Ichthyomyzon unicuspis</i>	x	x
Silver Redhorse	<i>Moxostoma anisurum</i>	x	x
Skinjack Herring	<i>Alosa chrysochloris</i>	x	
Slenderhead Darter	<i>Percina phoxocephala</i>	x	x
Smallmouth Bass	<i>Micropterus dolomieu</i>	x	x
Smallmouth Buffalo	<i>Ictiobus bubalus</i>	x	x
Spotfin Shiner	<i>Cyprinella spiloptera</i>	x	x
Spottail Shiner	<i>Notropis hudsonius</i>	x	x
Spotted Sucker	<i>Minytrema melanops</i>	x	x
Tadpole Madtom	<i>Noturus gyrinus</i>	x	
Trout Perch	<i>Percoopsis omiscomaycus</i>		x
Walleye	<i>Sander vitreus</i>	x	x
White Bass	<i>Morone chrysops</i>	x	x
Weed Shiner	<i>Notropis texanus</i>	x	
White Crappie	<i>Pomoxis annularis</i>	x	x
White Sucker	<i>Catostomus commersonii</i>	x	x
Yellow Bullhead	<i>Ameiurus natalis</i>	x	
Yellow Perch	<i>Perca flavescens</i>	x	x

Figures

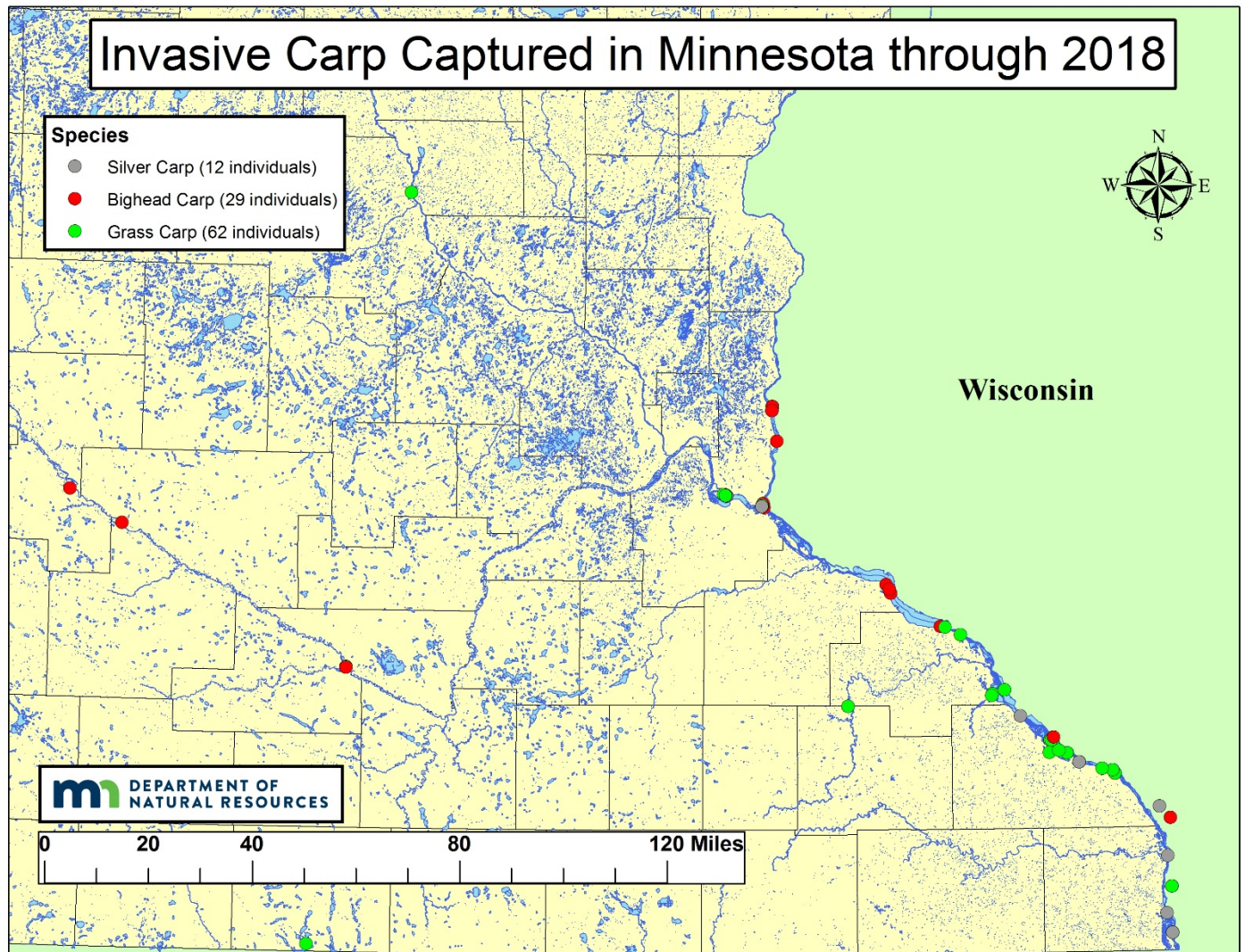


Figure 1. Locations of all known Invasive Carp captured in Minnesota waters through 2018.

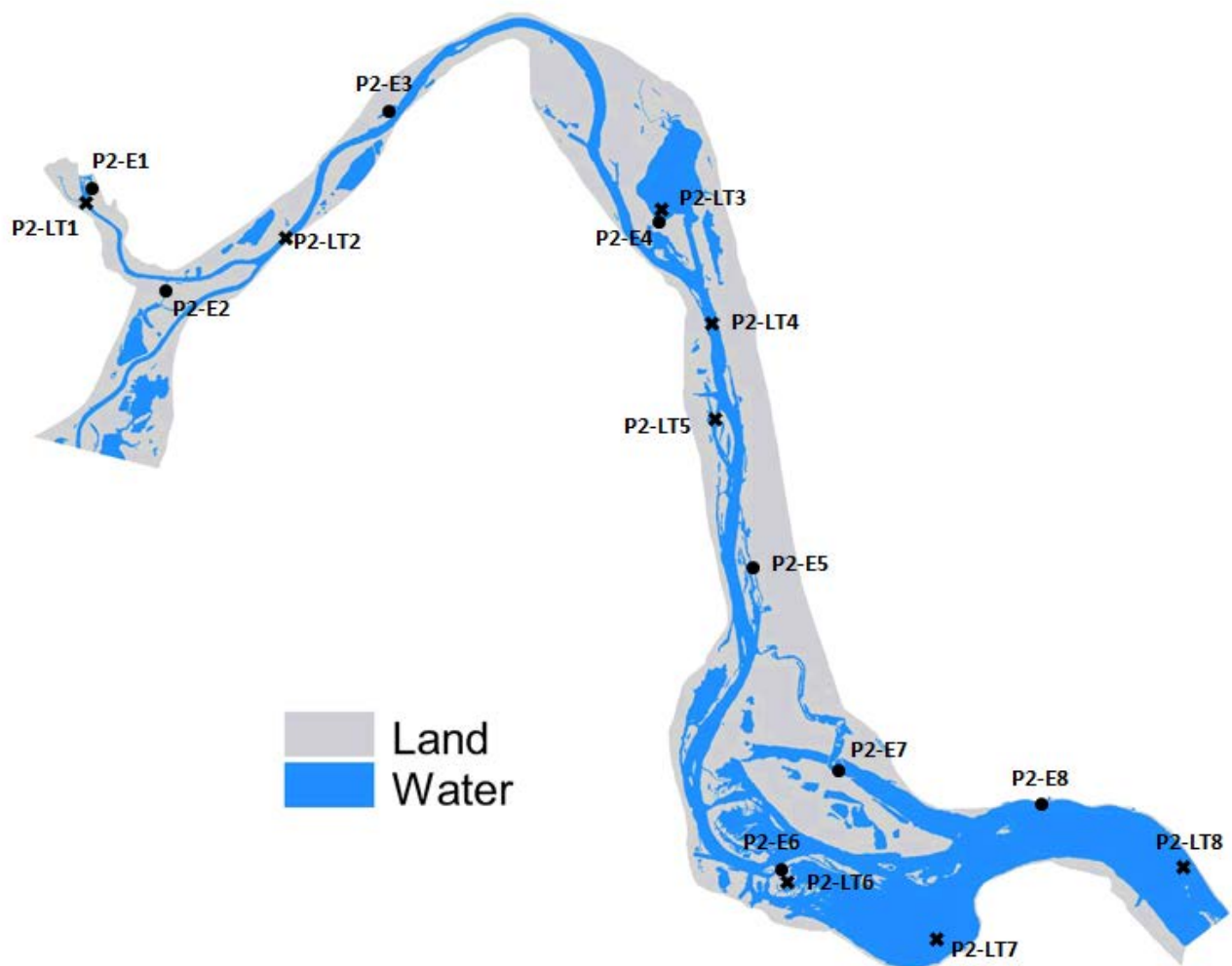


Figure 2. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 8) locations on Pool 2 (P2) of the Mississippi River.

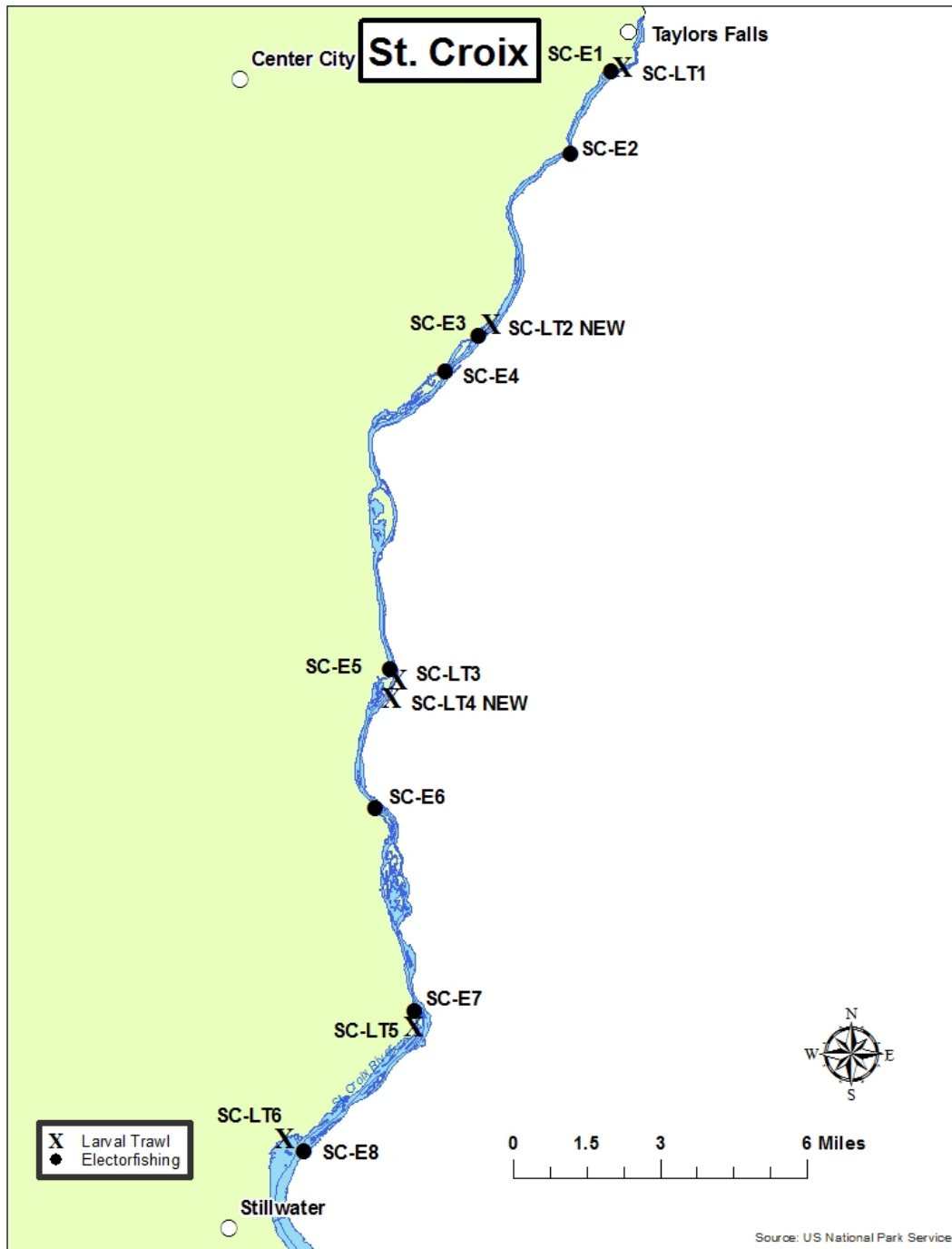


Figure 3. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 6) locations on the St. Croix River (SC). Sites SC-LT2 and SC-LT4 were moved in 2016 due to the site becoming too shallow to trawl.

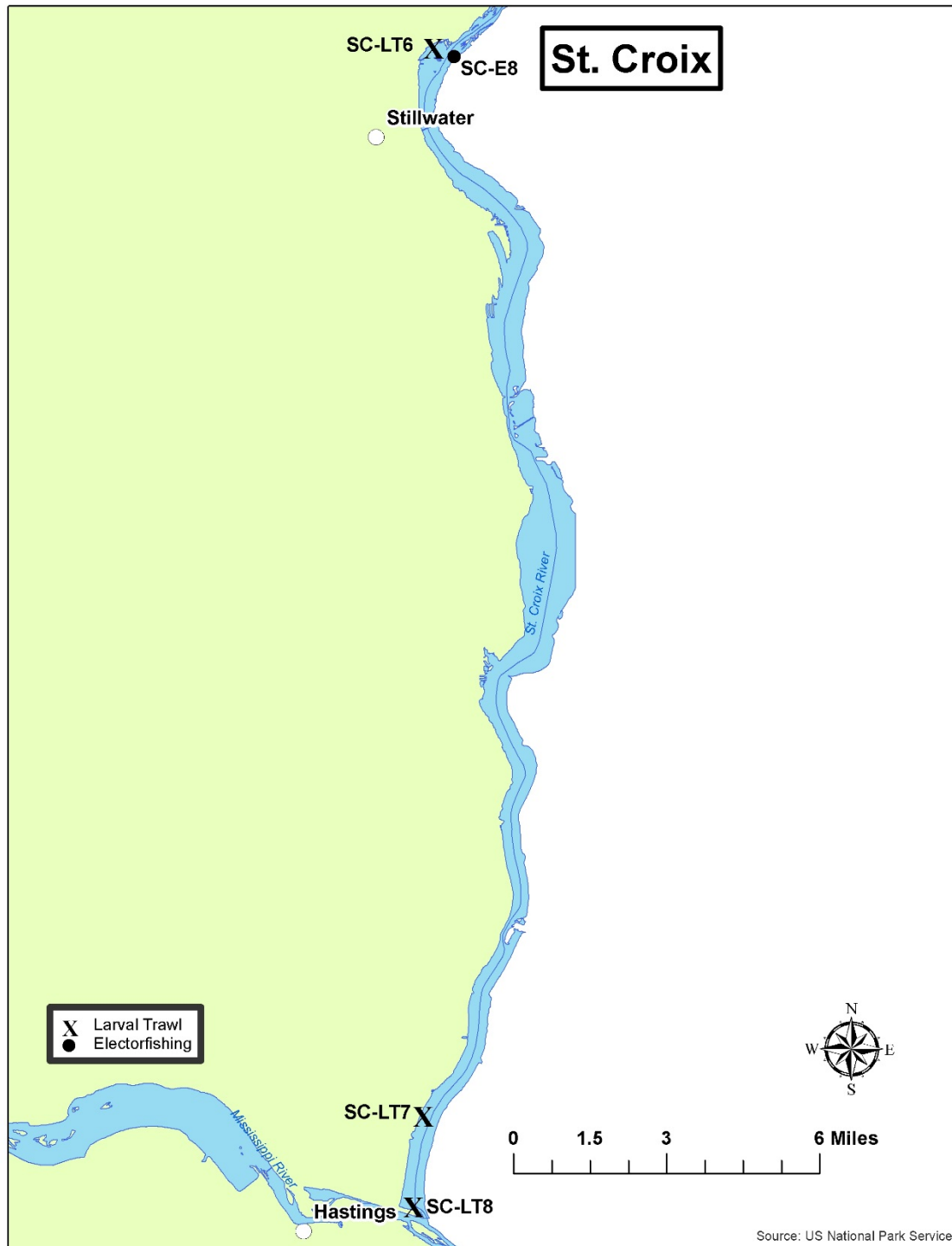


Figure 3 (Continued). Standardized electrofishing (dark circle, E8) and larval fish trawling (dark cross, LT 6 - LT 8) locations on the St. Croix River (SC).

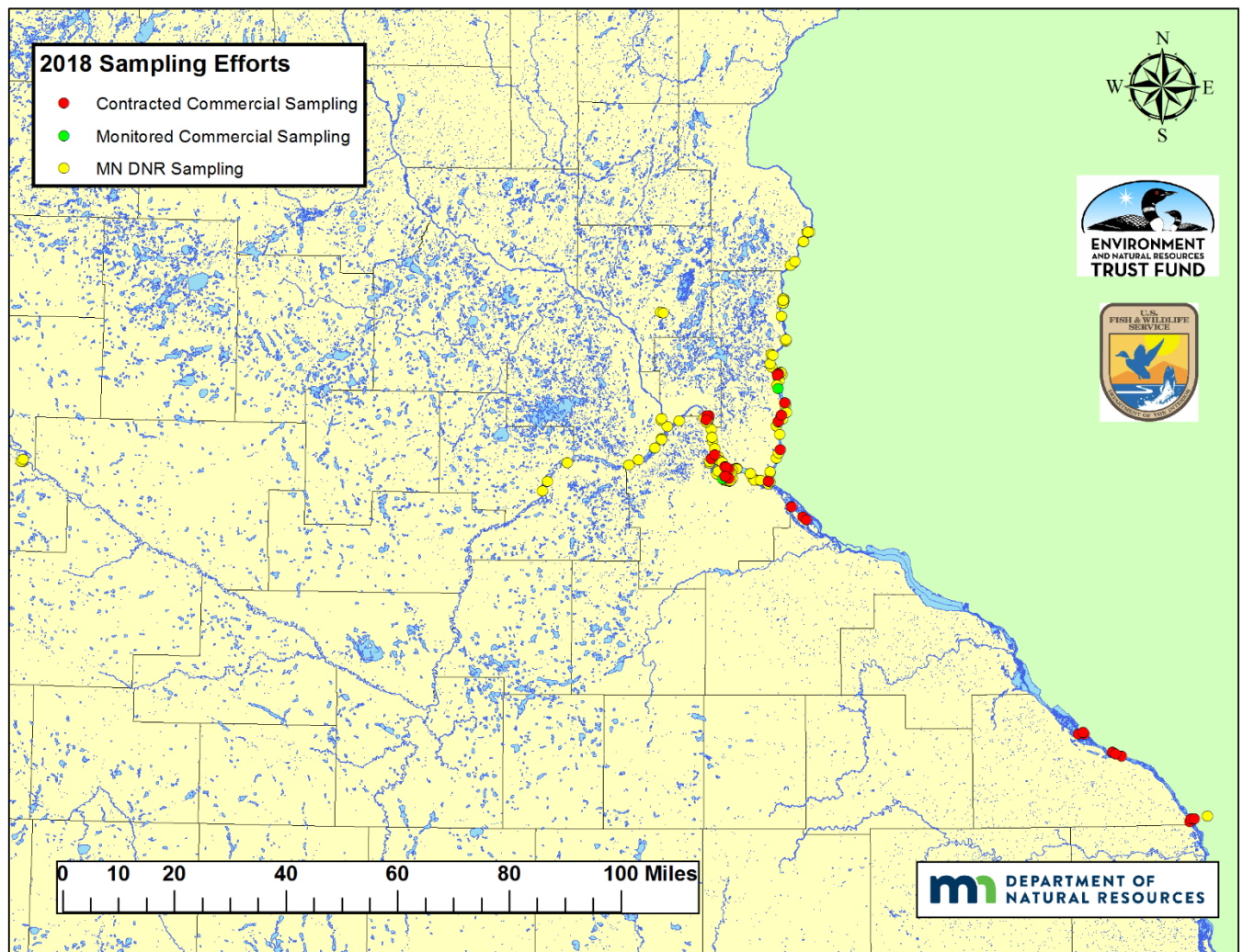


Figure 4. All sampling locations for contracted commercial sampling and MN DNR sampling on the Mississippi, St. Croix, and Minnesota Rivers during 2018.

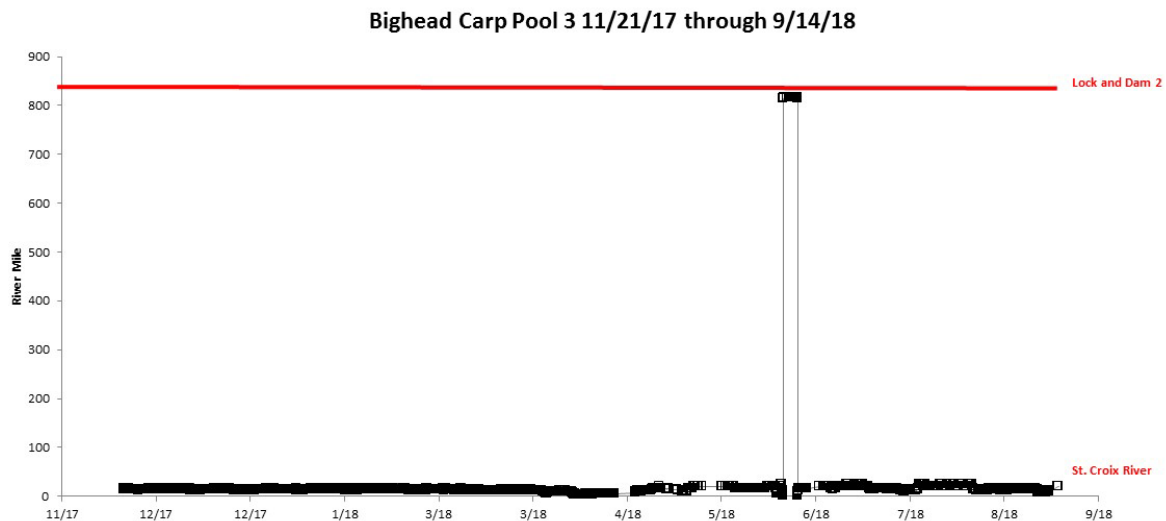
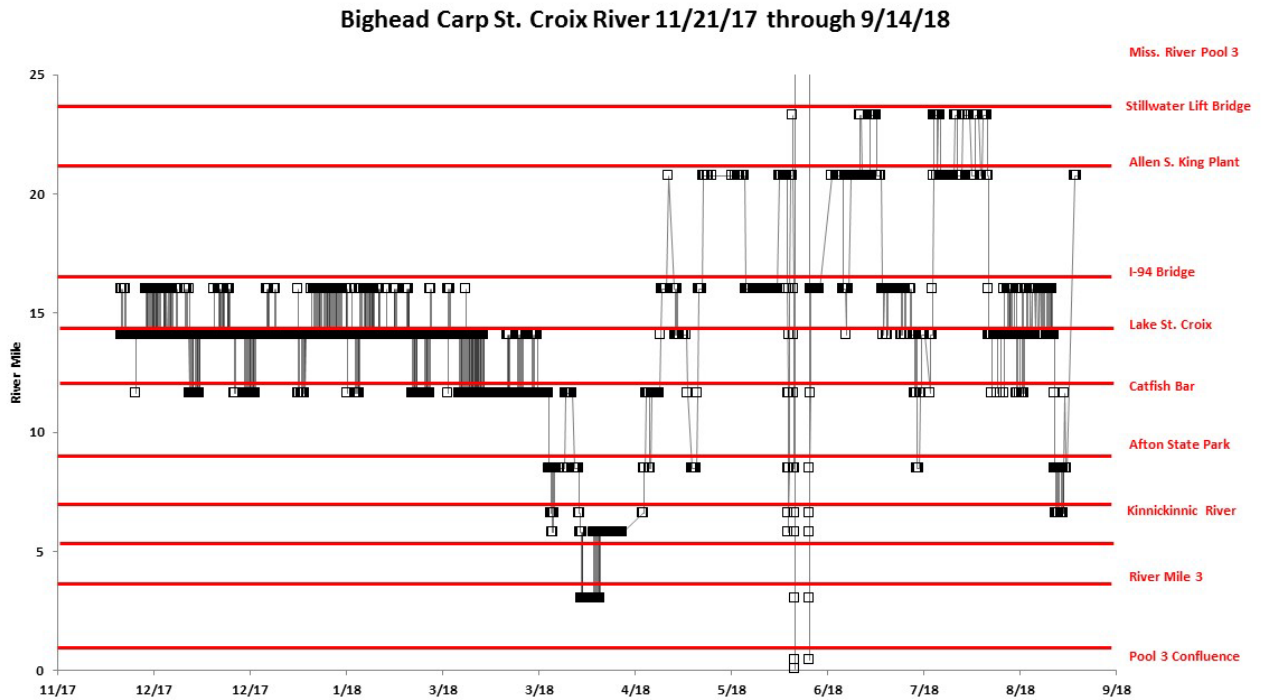


Figure 5. Movement patterns by River Mile over time of a tagged Bighead Carp from November 21, 2017 through the last receiver download for 2018 on September 14, 2018. The tagged Bighead Carp left the St. Croix River and entered Pool 3 of the Mississippi River June 19 through June 23, 2018, approaching the downstream side of Lock and Dam #2 before returning to the St. Croix River.

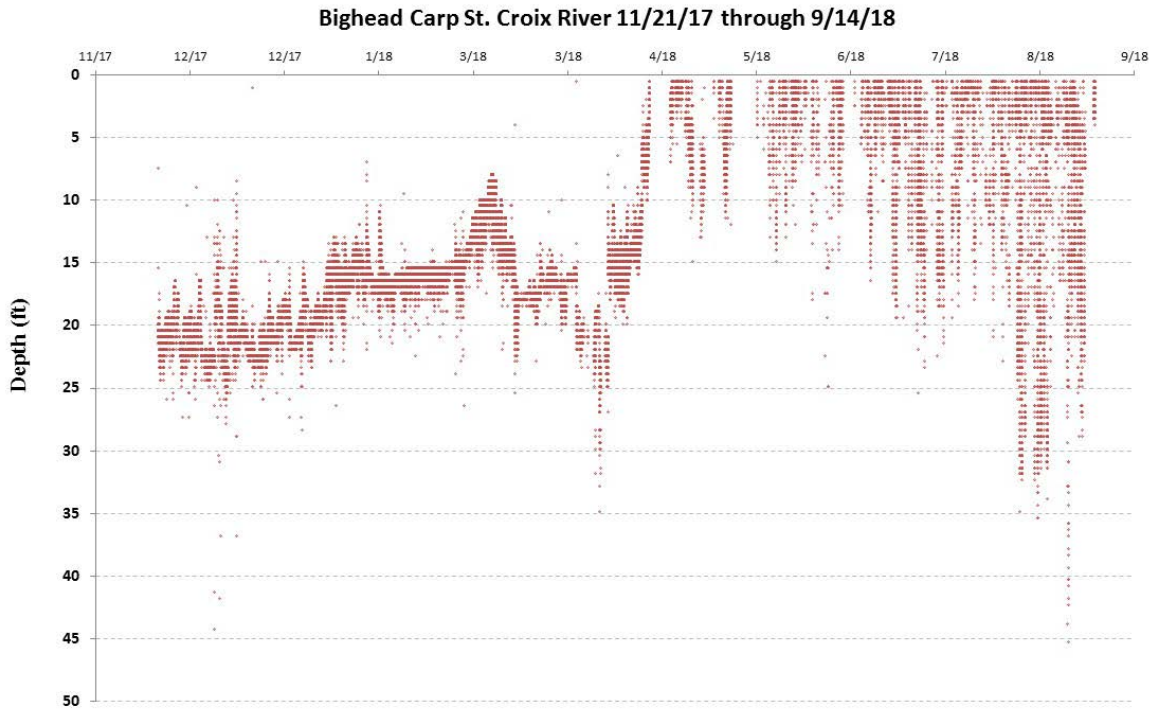


Figure 6. Depth patterns of tagged Bighead Carp from November 21, 2017 through the last receiver download for 2018 on September 14, 2018. Depths ranged from the surface (0 feet) to a maximum depth of 45 feet. Average depth occupied was 13.5 feet below the surface.

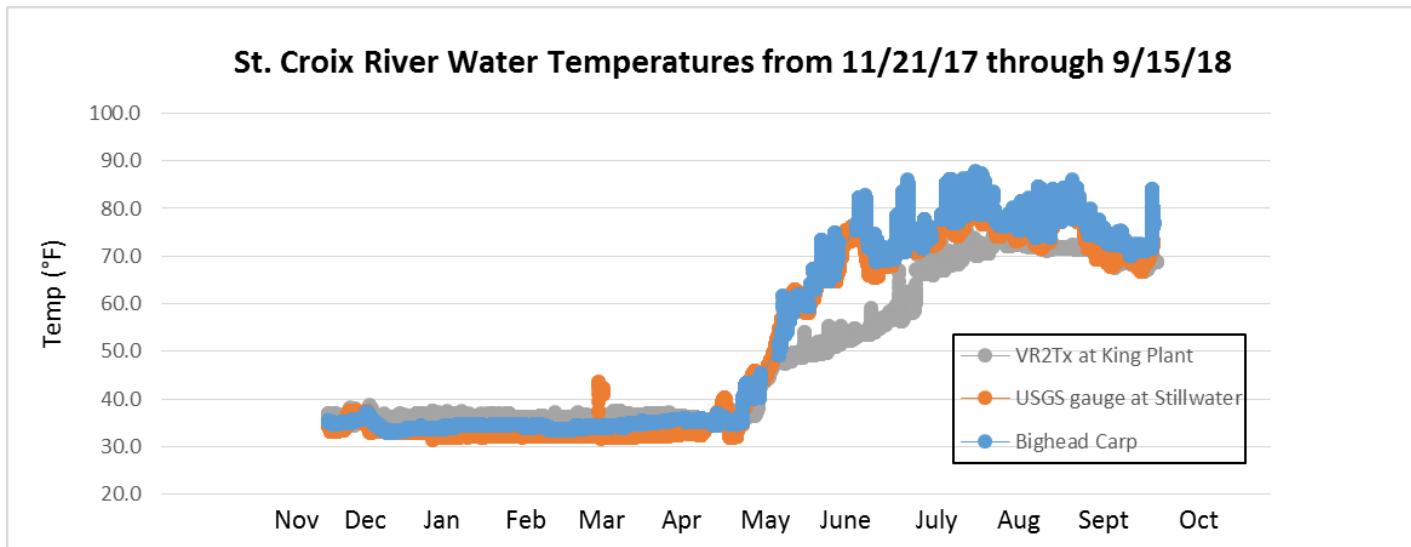


Figure 7. Temperature patterns of tagged Bighead Carp from November 21, 2017 through the last receiver download for 2018 on September 14, 2018. USGS gauge (05341550) data available from November 21, 2017 through September 14, 2018.

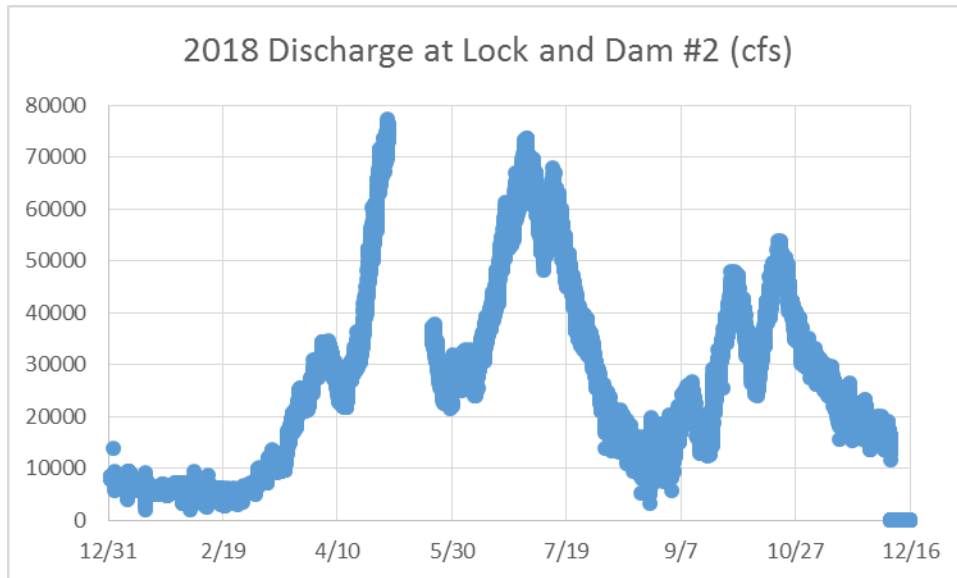


Figure 8. Discharge patterns of USGS gauge (05331580) at Hastings, MN in Pool 3 of the Mississippi River from December 31, 2017 through December 16, 2018. The tagged Bighead Carp was detected in the vicinity of the Lock and Dam June 19 through June 23, 2018 when flows were approaching open river conditions or 61000 cubic feet per second (cfs). In total, the gauge shows three open river high flow events occurring in 2018.

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Date: