Project Title: Detection of and response to invasive carp in the presence front and at the invasion front in the Upper Mississippi River

Geographic Location: Upper Mississippi River Basin

Lead Agency: Minnesota Department of Natural Resources (MNDNR)

Participating Agencies: U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), Wisconsin Department of Natural Resources (WIDNR), Iowa State University through the Iowa Department of Natural Resources (IADNR), National Park Service (NPS)

Statement of Need:

Bighead Carp *Hypophthalmichthys nobilis*, Black Carp *Mylopharyngodon piceus*, Grass Carp *Ctenopharyngodon idella*, and Silver Carp *H. molitrix* (collectively called invasive carp) are non-indigenous fishes that were introduced to the USA in the 1960s and 1970s from Asia for human consumption and biological control. Since that time, invasive carp have expanded their range (e.g., escaping secure facilities) and are now occurring more frequently throughout the Upper Mississippi River Basin. Current scientific evidence supports a strong likelihood of negative impacts to native species (Kramer et al 2019, Nico et al 2019, Phelps et al 2017, and Solomon et al 2016). Preventing population expansion is the most cost effective way to limit negative impacts. Understanding current population dynamics and employing response actions are a key component in a deterrent and control strategy.

Partners continue adaptive development and implementation of a comprehensive and complementary early detection and response program for Bighead, Silver, Grass, and Black carps in the Upper Mississippi River Basin. This early detection program helps define the current presence, invasion, and established fronts and evaluate how these fronts change through time, important knowledge for management decisions. Additionally, this effort helps evaluate the effects of management actions: a commercial harvest program and the Upper Mississippi River Deterrent Strategy (USFWS 2017). Sampling uses a diverse array of traditional and novel gears to sample all potential life stages in targeted areas. Responding to invasive carp captures has also been part of the program but has taken on an increased significance in 2020 with the capture of 51 invasive carp in Pool 8 in March 2020 (see Figure 1 for locations of all known captures in Minnesota waters).

Prior to 2018, the monitoring project included the entire Upper Mississippi River (UMR). Using data collected from the monitoring project in 2015-2017, there is a better understanding of invasive carp populations throughout the river and the UMR Asian carp partnership has identified zones of river where population differences exist for each species (USFWS 2017). There is an established zone, a management zone, a presence but unestablished zone, and the

section where carp have not been found. Given the different objectives and sampling strategies in each zone, the UMR partnership decided to split the monitoring project into two projects. Though split, monitoring participants will still coordinate and communicate efforts throughout the basin. Overlap does occur between the sections of river to ensure there are no gaps.

Understanding the population status in the presence zone is important for a variety of reasons. At this time, there are no deterrents in place on the Mississippi River. While lock and dams likely slow the upstream movement, invasive carp are still able to make it upstream as evidenced by the capture of 51 invasive carp in Pool 8 in March 2020. It is important to know where carp are established or reaching spawning thresholds to decide when and where to implement management strategies such as deterrents or removal efforts. Also, response removal efforts may help delay populations from reaching numbers that result in successful spawning events. Lastly, having a strong data set helps managers measure the success of management efforts.

Project Objectives:

1. *Invasion Front Population Characteristics and Distribution*

A coordinated, basin wide Asian carp population evaluation program was established in 2015 with the formalization of the UMR Asian carp workgroup. Adjustments to both MNDNR and UMR workgroup goals, methodologies, and sampling targets have occurred annually utilizing knowledge gained from this data.

2. *Tracking Invasive Carp*

Detecting and accurately estimating the density of invasive carp in the presence zone is difficult. Captures of invasive carp in the presence front have been relatively stable the past five years. Biologists are fairly confident this is an accurate picture of the current population status based on negative larval samples and improving sampling strategies. Using tracking data to improve sampling methodology increases certainty in results. Secondarily, partner agencies in the established and management zone have shown that using telemetry tagged fish has increased invasive fish captures.

3. *Larval Fish Sampling*

This objective focuses on understanding the reproductive boundary of invasive carps. This is critical information for managers in the UMR who are determining the placement of deterrents and guiding targeted commercial efforts to prevent the range expansion of invasive carps.

4. *Employ Reasonable Response Efforts to New Captures of Invasive Carp*

This objective focuses on responding to a large capture of invasive carp in the presence zone. Understanding the population size in Pool 8 and removing invasive carp is important to prevent spawning in this section of the river.

Project Highlights:

Minnesota Department of Natural Resources

In 2021, Minnesota DNR sampled for invasive carp using a suite of approaches including larval trawls, electrofishing, seining, gill netting, and commercial fishing. We also continue our tagging and tracking program to inform management. In total, 71 invasive carp were captured in Minnesota waters in 2021. This year saw the first 2 Modified-Unified Method (MUM) events deployed in Pool 8 of the Mississippi River, which removed a total of 33 Silver Carp. Those events will continue in future years as long as need and funding remain. The recent increase in captures of invasive carp in the Upper Mississippi River Basin underscore the need to continue and increase these efforts.

Iowa Department of Natural Resources (Iowa State University):

Iowa State University sampled ichthyoplankton in pools 14-16 of the Upper Mississippi River approximately every 7 days between 4 May and 6 July 2021. Egg densities (all fish taxa) across sampling sites peaked during June 15th whereas densities of age-0 fishes (yolk-sac larvae, mesolarvae, and juveniles) were highest during June 21st. Age-0 invasive carp were not collected in pools 14-16 during 2021. *Cyprinidae*, *Percidae*, *Centrarchidae, Catostomidae*, and *Clupeidae* represented the most abundant families and peak densities occurred during May 5th (*Percidae*), May 13th (*Catostomidae*), and June 21st (*Cyprinidae*, *Centrarchidae*, and *Clupeidae*). Chlorophyll *a* concentrations (µg/L) were highest in backwater habitats and within the Rock and Wapsipinicon rivers and lowest at most of the Mississippi River sites.

Methods:

Minnesota Department of Natural Resources

Sampling for invasive carp took place between January 1, 2021 and December 31, 2021. Gear types, methods, and targeted locations were derived from personal communications with biologists who have been sampling invasive carp (V. Santucci, Illinois Department of Natural Resources, personal communication; J. Lamer, Western Illinois University, personal communication, Duane Chapman, USGS, personal communication) and conducting research on the most efficient gear to sample invasive carp (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.

Invasive Carp Acoustic Tagging and Tracking

In Minnesota, Statute 84D.05, Subdivision 1 states, "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. As part of the permitting process, MNDNR 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 Minnesota Department of Natural Resource's Division of Ecological and Water Resources.

The MNDNR was permitted to tag invasive carp on a fish by fish basis with acoustic transmitters. The MNDNR 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.

There are 80 stationary receivers placed throughout the state of Minnesota. They are located on the Mississippi River above the Coon Rapids Dam to Lock and Dam #5, on the St Croix River from the Mississippi River confluence at Prescott, WI to Taylor's Falls, and on the Minnesota River from the Mississippi River confluence to the County Road 6 bridge north of Delhi, MN (river mile 209). Sixty-one receivers are maintained by the East Metro fisheries office, nine are maintained in the Minnesota River by the Hutchinson fisheries 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 outside of Minnesota 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.

By tracking tagged 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 anglers, when tagged fish are in jeopardy of being un-trackable due to tag life nearing completion, leaving the passive array network, or to support removal of other conspecifics. The MNDNR 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.

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, MNDNR 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 present front. MNDNR is strategic in both the species and locations where tagged invasive carp are released, so as to maximize the information we gain through their tracking. Most captured invasive carp are removed and euthanized.

Based on the tagging results, MNDNR 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 help to improve sampling and removal efforts.

Fish Acoustic Tagging Efforts

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

Larval Trawling

Larval trawling was conducted during the 2021 field season. Sampling was conducted in Pool 8 of the Mississippi River. Trawls were conducted on a weekly basis from May-August. Each day of sampling, 12 trawls were pulled for 5 minutes per trawl 15-20 minutes apart. The samples were then put into plastic containers and transported back to the lab at the East Metro Fisheries office. Fisheries Biologists then drained the water and put in 10% buffered formalin for 24-48 hours in order to preserve the contents of the trawl. After 24-48 hours the formalin was drained and preserved in alcohol until the contents could be sorted through for larval fish and eggs in the winter months. Once sorted, the larval eggs and fish will be professionally identified by an outside vendor. Sampling locations can be found in Figures 2, 3 & 4.

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), the St. Croix River (Figure 3) and Minnesota River (Figure 5), and all other sampling events occurred at non-standardized locations in the aforementioned habitats at the discretion of the sampler. Standardized electrofishing sampling locations were selected based on habitats invasive carp are likely to occupy. Sites averaged 1137 seconds of on-time. At these set sampling locations, all observed fish were collected, identified,

measured and weighed. 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 carp 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.

Seining

A small 35-foot seine was used to sample shallow water habitats for young fish from July through August on the St. Croix River with 3 seine hauls completed over one day. The seine measures 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 a knotless "Ace"-type nylon netting 1/8 in. mesh, with a mudline. No invasive carp were captured during 2021 using the shallow seine.

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 bar mesh sizes of 4 to 6 inches were used to target adult invasive carp. Nets were set either short-term or overnight, with short-term sets favored when water temperatures were greater than 60º F. All fish caught were identified.

Commercial Fishing

Commercial anglers were contracted to target invasive carp with gill nets and seines for sampling and response efforts. Minnesota Department of Natural Resources (MNDNR) personnel accompanied contracted commercial anglers 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 anglers for both gill netting and seining operations. See Figure 6 for sampling locations.

Iowa Department of Natural Resources (Iowa State University)

Chlorophyll *a*, fish eggs, and age-0 fishes were sampled in 2021 at seven locations (Figure 7) approximately every seven days depending upon river conditions from early May until early July (10 sessions, seven sites, three habitats equating to 21 tows per session, or 210 ichthyoplankton tows during 2021). Sampling sites are abbreviated to distinguish tributary sites from sites within the Mississippi River upstream and downstream from the tributary site (Table 1). Sestonic chlorophyll *a* was sampled in conjunction with each tow for eggs/age-0 fish by filtering 50 – 100 mL of water through a GF/F Whatman© glass fiber filter (47-µm porosity) that was placed on ice in the field and frozen in the laboratory. Chlorophyll *a* was extracted with 90% acetone and quantified using an Aquafluor Handheld Fluorometer (Turner Designs) to obtain chlorophyll *a* concentrations (µg/L). Ichthyoplankton tows (0.5 m diameter net, 500 µm mesh) were conducted

at the surface at a constant boat speed relative to the shoreline up to four minutes depending on debris load. A General Oceanics flowmeter (Model 2030R) was attached in the mouth of the net to estimate volume (m3) of water filtered during each tow. Three tows were conducted at each site parallel to river flow: the first tow was in the main thalweg for drifting eggs and larvae (<24 hours post fertilization), the second tow occurred near channel borders where water velocity is moving downstream slower than the thalweg, and the third was in an adjacent backwater area for mobile larvae and juveniles (>24 hours post fertilization). After each tow, ichthyoplankton net contents were rinsed toward the cod end, placed in sample jars, and preserved in 95% ethanol.

In the laboratory, eggs and age-0 fishes (yolk-sac larvae, mesolarvae, and juveniles) were separated from debris. Samples containing ≥1,000 age-0 fish (n=1) were subsampled so that at least 25% (minimum 250 fish) were identified using a Fulsom Plankton Splitter. All age-0 fishes have been identified to the lowest possible taxonomic level using morphometric and meristic characteristics described in literature (Auer 1982). Invasive carp larvae are difficult to distinguish among species and are being identified to genus using meristic and morphometric characteristics (Chapman 2006, Chapman and George 2011). Age-0 fishes were first categorized as yolk-sac larvae, larvae, or juveniles based on fin development and complete absorption of the yolk-sac. Fish recognized as having a full complement of fins are categorized as juvenile fish. Data and figures presented here includes all age-0 fishes without distinguishing ontogenetic categories.

Results and Discussion:

Minnesota Department of Natural Resources

In total, 79 days were spent sampling between January and December 2021 on the Mississippi River Pools 2, 3, 4, 5, 6, 7 and 8, and the Minnesota and St. Croix rivers with gear appropriate for sampling invasive carp (Table 2; Figure 6). A greater amount of effort was focused on Pool 8 in 2021. In early April 2021 we conducted a weeklong multi-agency netting effort in Pool 8 called the Modified Unified Method or MUM. During the Spring MUM 33 Silver Carp were caught. Follow-up sampling was conducted by a contracted commercial angler in Pool 8. Six additional invasive carp were caught during the spring in Pool 8. Capture data and response actions were shared with multiple agencies including the Wisconsin Department of Natural Resources, USGS, and Western Illinois University.

Intensive fall sampling occurred in Pool 8 of the Mississippi River including an additional MUM. Fall sampling resulted in the capture of a total of 13 Silver Carp. These fish were caught by contracted commercial anglers in back waters and side channels. Capture data and response actions were shared with multiple agencies including the Wisconsin Department of Natural Resources, USGS, and Western Illinois University. A total of 71 invasive carp were caught in Minnesota waters and Minnesota-Wisconsin boundary waters in 2021 (Table 3).

Contracted commercial anglers were hired to use large mesh gill nets and seines to sample in the Mississippi River in Pools 2, 3, 4, 5, 6, 7, and 8, and in the St. Croix River from Andersen Bay in Bayport to the confluence with the Mississippi River near Prescott, WI. Contracted commercial anglers set approximately 19,100 feet of gill nets during 29 days of effort and conducted 72 seine hauls between January and December 2021. Gill nets were set short term (2-3 hours) and fish were chased towards the net with boats, typically in large backwater areas. In 2021, nine regular commercial fishing operations were also monitored for the presence of invasive carp.

A total of 136 larval samples were collected in 2021. Those samples will be screened for invasive carp eggs and larvae by an external lab in spring 2022. See Table 4 for historic data.

Both random and standardized electrofishing sampling was conducted on Pool 2 of the Mississippi, the Minnesota and the St. Croix rivers. A total of 1,048 minutes of "on time" over 19 days was spent electrofishing between January and December 2021. In 2021, sixteen standardized electrofishing sites were sampled once, for a total of 303 minutes. Random electrofishing was used to monitor for invasive carp.

Gill nets set by MNDNR personnel were often used to sample behind wing dikes and in smaller side channel and backwater areas where it wasn't feasible for commercial anglers to target with their larger operations. In 2021, a total of 3,450 feet of gill net were set in Pool 2 over two days, with most net sets being short-term sets (2-5 hours). In 2021, no invasive carp were captured during routine gill netting operations, seining or electrofishing.

Although no new species were added to the list in 2021, numerous unique or rare native fishes were encountered during these sampling events. A complete species list of species caught and observed on Pools 2, 3, and 4, the Minnesota River and the St. Croix River, from January 2013 through December 2021, has been compiled (Table 5).

Determining if invasive carp captured in Minnesota are pioneering individuals or are indicative of established populations is a key question for MNDNR managers. While it is likely there are additional invasive carp present in Minnesota's monitored rivers based on the previously mentioned captures of larger congregations of fish, the degree to which invasive carp populations have change is unclear. The increase in captures could be attributed to a successful year class migrating upstream during extended periods of high water in 2019, but it remains to be seen what the implications will be for the future abundance of invasive carp in Minnesota waters.

Invasive Carp Acoustic Tagging and Tracking

During the 2021 field season MNDNR personal were unable to tag any additional invasive carp. Previously tagged invasive carp were continued to be tracked such as the Bighead Carp in the St. Croix River and the tagged Silver Carp in Pool 8. The tagged Bighead Carp in the St. Croix

River showed similar movements to years past. Capture attempts were set in motion during May of 2021 but the low water led to less use by the tagged Bighead Carp. Of the 5 tagged Silver Carp in Minnesota waters, only one was found during passive and active tracking in 2021 and that fish was in Pool 8 but never in a vulnerable location for capture. Movement data is still being collected and processed for that fish.

There is one tagged Bighead Carp in Minnesota waters, located in the Lower St. Croix River. That individual was vital in the capture of two Bighead Carp in 2018, four additional invasive carp in 2019, one Silver Carp in 2020, and none in 2021. Without tracking information from the tagged carp, MNDNR personnel would not have fished certain location over the last three years. From previous captures and the understanding of invasive carp movements and biology, MNDNR had focused efforts on relatively few areas (e.g. the Allen S. King Plant, Andersen Bay, 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, areas that were considered less suitable may be frequented as often as areas of primary focus in previous years. Because this tagged fish has shown relatively large movements and has inhabited confined areas suitable for complete sampling for short periods of time, timing of sampling is critical for effective management and removal. The ability to track a tagged individual will allow biologists to better understand additional habitat preferences and the duration of residence preferences. Data analysis of the 2021 movements of the Bighead Carp is currently under review and will be released in the 2021 Invasive Carp Sampling Report.

Tracking methods and field sampling will be adjusted accordingly for 2022. MNDNR staff will continue to track tagged fish while analyzing the data to increase sampling and removal efficiencies.

Iowa Department of Natural Resources (Iowa State University)

Chlorophyll a

Chlorophyll *a* concentrations within the two tributaries to the Mississippi River were consistently higher than within the Mississippi River throughout 2021, with some of the highest concentrations being the backwater of the Wapsipinicon River mouth (86.81 µg/L ± 11.28 SE), the channel border of the Wapsipinicon River mouth (77.00 µg/L ± 6.02 SE), and the thalweg of the Wapsipinicon River mouth (80.24 µg/L ± 8.45 SE; Figure 8). Backwater sites tend to have higher chlorophyll *a* concentrations than both channel border and thalweg sites (Figure 8). Within tributary mouths, chlorophyll *a* concentrations tend to decrease with latitude from the Wapsipinicon River to the Des Moines River. Interestingly, the opposite trend presents itself within the Mississippi River proper, albeit in a less obvious manner (Figure 8). While chlorophyll *a* concentrations within tributaries may be more dependent on the local watershed, chlorophyll *a* within the main-stem UMR will likely be the cumulative result of tributary

contributions as well as its own productivity. Sites directly downstream of tributaries (UMR-DNW channel border and UMR-DNR channel border) tend to have increased chlorophyll a concentrations, likely a result of tributary contributions.

Eggs and Age-0 Fishes

A total of 210 ichthyoplankton tows were completed in 2021. Eggs were collected during every sampling session for a total of 2,342 eggs in 2021. The largest number of eggs were collected during June 15th (258.9 per 100m^3 ± 178.4 SE; Figure 9). A total of 150 tows were conducted in the Mississippi River that collected a total of 2,181 eggs. An additional 60 tows were taken within the tributary mouths that captured 161 eggs (Rock = 124 eggs and Wapsipinicon = 37 eggs). Egg density appeared highest in the Mississippi River at Pool 14 (UMR-UPW and UMR-DNW; Figure 10). Across all tributary sites and habitats, the highest egg density (29.4 per 100m^3 ± 26.9 SE) was within the channel border of the Rock River whereas the highest overall egg density was within the thalweg habitat of the Mississippi River (Figure 11).

A total of 21,826 age-0 fishes were captured in 2021. The highest density of age-0 fishes was collected June 21st (2,911.0 per 100m^3 ± 1,204.1 SE; Figure 9). Peaks in age-0 fish density occurred during the two sessions immediately following the main peak in egg density (Figure 9). The sampling session with the lowest density of age-0 fishes (14.00 per 100m^3 ± 4.1 SE) occurred on May 19th.

Age-0 fishes were collected from every river in 2021. The majority of age-0 fishes were captured either upstream (9,198 fish) or downstream (10,142 fish) of tributaries compared to within tributary mouths (306 fishes; Figure 10). Densities of age-0 fishes varied among the upstream, downstream, and within tributaries. Densities of age-0 fishes were higher upstream than downstream on the Wapsipinicon, but higher downstream than upstream on the Rock River (Figure 10). Across sites, densities of age-0 fishes tended to be highest within backwater or channel border habitats compared to the thalweg (Figure 11).

Ichthyoplankton from 2021 have been identified to family except for non-native carp which were identified to genus. *Cyprinidae* were the most abundant age-0 fishes collected followed by *Percidae*, *Centrarchidae*, *Catostomidae*, and *Clupeidae* (Figure 12). Other taxa present but at lower densities include *Sciaenidae*, *Cyprinus carpio*, *Lepisosteidae*, *Atherinopsidae*, and *Moronidae* (Figure 12). Age-0 *Cyprinidae* density peaked during June 21st (2,830.9 per 100m^3 ± 1,163.6 SE;). Age-0 *Centrarchidae* (29.6 per 100m^3 ± 15.1 SE) and *Clupeidae* (42.7 per 100m^3 ± 37.3 SE) densities also peaked on June 21st during the same period as *Cyprinidae*.

No age-0 invasive carp were collected across any of the sites, habitats, and sessions this year. It is unlikely that invasive carp underwent a significant undetected spawning events during this time period due to uncharacteristically low water levels in our study area. There is no

documented age-0 invasive carp catches in these pools. However, continued monitoring of pools 14-16 and their tributaries is recommended due to their proximity to known reproductive strongholds and the current expansion of the invasive carp range.

Recommendation:

We recommend that monitoring and response efforts continue in the presence and invasion fronts of the Upper Mississippi River Basin. Invasive carp captures have been increasing in recent years, which is a cause of concern for both further invasion upstream and for the potential for reproduction to occur. Monitoring for all life stages of invasive carp helps managers decide how best to deploy containment and control responses. It is important that this information be available going forward, especially at this critical moment.

To that end, we recommend: continued larval sampling in likely areas of reproduction, continued agency-led monitoring efforts for adults and juveniles, increased contracted commercial fishing, increased tagging and tracking of invasive carp to inform management actions, and continued efforts to locate and remove invasive carp that utilize the best available knowledge and technology.

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Appendix: Tables and Figures

Table 1. Sampling site codes for 2021 sampling seasons. See Figure 7 for sampling locations.

Site Codes	Site Names
UMR-UPW	Upper Mississippi River, Upstream of the Wapsipinicon River
UMR-DNW	Upper Mississippi River, Downstream of the Wapsipinicon River
WAP-MTH	Mouth of the Wapsipinicon River
UMR-P15	Upper Mississippi River, Pool 15
UMR-UPR	Upper Mississippi River, Upstream of the Rock River
UMR-DNR	Upper Mississippi River, Downstream of the Rock River
ROC-MTH	Mouth of the Rock River

Table 2. Invasive Carp sampling summary for the Mississippi River Pools 2, 3, 5, 6, 7 and 8 and the St. Croix and Minnesota Rivers for January through December 2021. Number of Invasive Carp Captured represents the number of individuals caught by MNDNR, contracted commercial anglers, or monitored commercial fishing.

Invasive Carp Sampling Summary January – December 2021			Days
Random Sampling Effort			
Gill/Trammel Netting	3,450	feet	2
Electrofishing	744	minutes	11
Small Seine	3	Hauls	1
Standardized Sampling Effort			
Electrofishing	303	minutes	12
Larval Trawl	136	Hauls	
Targeted Commercial Fishing Effort			
Gill Netting	19,100	feet	9
Seining	72	hauls	43
Monitored Commercial Fishing Effort			
Seining	9	hauls	9
Tracking*			
2-person crew	70.5	hours	
Number of Invasive Carp Captured	71	fish	
Total Number of Days Sampled			79

***Does not include tracking by real-time receivers (MNDNR, USFWS) in the St. Croix River and Pool 8**

Table 3. Invasive Carp caught from January through December 2021 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	State	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Captured By
3/5/2021	Silver Carp	Mississippi River	Pool 8	WI	721	3914	Male	Mature	Monitored Comm. Seine	Commercial Angler
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	624	2400	Male	Mature	Winterkill	MN DNR Windom
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	600	1800	Male	Mature	Winterkill	MN DNR Windom
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	666	2690	Female	Mature	Winterkill	MN DNR Windom
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	611	2405	Male	Mature	Winterkill	MN DNR Windom
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	572	1502	Male	Mature	Winterkill	MN DNR Windom
3/14/2021	Silver Carp	Lake Bella Outlet	Nobles County	MN	605	--	--	Mature	Winterkill	MN DNR Windom
3/16/2021	Silver Carp	Mississippi River	Pool 8	WI	723	5050	Male	Mature	Commercial Seine	Commercial Angler
3/18/2021	Silver Carp	Mississippi River	Pool 8	WI	729	4150	Male	Mature	Commercial Seine	Commercial Angler
3/18/2021	Silver Carp	Mississippi River	Pool 8	WI	768	5990	Female	Mature	Commercial Seine	Commercial Angler
3/18/2021	Silver Carp	Mississippi River	Pool 8	WI	756	4921	Male	Mature	Commercial Seine	Commercial Angler
3/18/2021	Silver Carp	Mississippi River	Pool 8	WI	759	4572	Male	Mature	Commercial Seine	Commercial Angler
3/21/2021	Silver Carp	Mississippi River	Pool 8	WI	763	5350	Male	Mature	Commercial Seine	Commercial Angler
3/21/2021	Hyb Silver-Bighead	Mississippi River	Pool 8	WI	777	6020	Female	Mature	Commercial Seine	Commercial Angler
3/21/2021	Silver Carp	Mississippi River	Pool 8	WI	783	4963	Male	Mature	Commercial Seine	Commercial Angler
3/21/2021	Hyb Silver-Bighead	Mississippi River	Pool 8	WI	720	4009	Male	Mature	Commercial Seine	Commercial Angler
3/21/2021	Silver Carp	Mississippi River	Pool 8	WI	755	4827	Male	Mature	Commercial Seine	Commercial Angler
3/21/2021	Silver Carp	Mississippi River	Pool 8	WI	730	3883	Male	Mature	Commercial Seine	Commercial Angler

Table 3 (continued). Invasive Carp caught from January through December 2021 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	State	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Captured By
3/21/2021	Silver Carp	Mississippi River	Pool 8	WI	750	4665	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	813	6570	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	755	4349	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	800	6905	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	771	5414	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	717	3963	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	771	6806	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	766	4600	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	761	4796	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	760	5084	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	735	4472	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	760	4884	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	769	6413	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	758	5337	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	766	5085	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	777	5002	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	742	5321	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	779	4981	Male	Immature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	757	5263	Male	Mature	Commercial Seine	Commercial Angler

Table 3 (continued). Invasive Carp caught from January through December 2021 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	State	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Captured By
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	770	4620	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	741	4403	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	823	8337	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	726	3971	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	724	4111	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	765	4684	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	742	4705	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	735	5122	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	794	7297	Female	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	724	4124	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	735	4770	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	775	4615	Male	Mature	Commercial Seine	Commercial Angler
4/7/2021	Silver Carp	Mississippi River	Pool 8	WI	815	6579	Female	Mature	Commercial Seine	Commercial Angler
4/9/2021	Silver Carp	Mississippi River	Pool 8	WI	775	4615	Male	Mature	Commercial Seine	Commercial Angler
4/9/2021	Silver Carp	Mississippi River	Pool 8	WI	815	6579	Female	Mature	Commercial Seine	Commercial Angler
4/15/2021	Silver Carp	St. Croix River	Pt. Douglas	MN	761	6000	Female	Mature	Commercial Seine	Commercial Angler
4/15/2021	Silver Carp	Mississippi River	Pool 8	WI	773	4857	Male	Mature	Commercial Seine	Commercial Angler
4/15/2021	Silver Carp	Mississippi River	Pool 8	WI	721	4275	Male	Mature	Commercial Seine	Commercial Angler

Table 3 (continued). Invasive Carp caught from January through December 2021 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	State	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Captured By
4/15/2021	Silver Carp	Mississippi River	Pool 8	WI	822	7582	Female	Mature	Seine	MNDNR
5/11/2021	Grass Carp	Mississippi River	Pool 8	WI	868	7400	Female	Mature	Seine	MNDNR
5/11/2021	Silver Carp	Mississippi River	Pool 8	WI	840	8445	Female	Mature	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/15/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Seine	MNDNR
9/23/2021	Silver Carp	Mississippi River	Pool 8	WI	890	10420	Female	Mature	Seine	MNDNR
12/2/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Commercial Seine	Commercial Angler
12/2/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Commercial Seine	Commercial Angler
12/2/2021	Silver Carp	Mississippi River	Pool 8	WI	--	--	--	--	Commercial Seine	Commercial Angler

"--" indicates missing or unavailable data at time of report.

Table 4. Larval trawl sampling for the St. Croix and Mississippi Rivers from 2013 to 2021.

Year	Number of Sites		Total number of Samples		Number of Samples with Larval Fish		Number of Larval Invasive carp	
	St. Croix River	*Mississippi River*	*St. Croix River*	*Mississippi River*	*St. Croix River*	*Mississippi River*	*St. Croix River*	*Mississippi River*
2013	8	8	16	28	6	16	0	0
2014	9	13	28	44	17	28	0	0
2015	8	18	52	253	23	139	0	0
2016	9	16	46	102	25	83	0	0
2017	7	17	20	73	20	73	0	0
2018	8	8	66	68	37	44	0	0
2019	2	4	52	100	37	64	0	0
2020	0	0	0	0	0	0	0	0
2021	0	1	0	136	0	~11	0	--

--Pending results

Table 5. Species list for the Minnesota, St. Croix and Mississippi (Pool 2, Pool 3 and Pool 4) Rivers from January 2013 through December 2021, including 89 native and invasive species.

Common Name	Genus Species	Pool 2	Pool 3	Pool 4	St. Croix River	Minnesota River
American Eel	*Anguilla rostrata*	x				
Bighead Carp	*Hypophthalmichthys nobilis*	x	x		x	x
Bigmouth Buffalo	*Ictiobus cyprinellus*	x	x	x	x	x
Bigmouth Shiner	*Notropis dorsalis*	x				
Black Buffalo	*Ictiobus niger*	x				
Black Bullhead	*Ameiurus melas*				x	
Black Crappie	*Pomoxis nigromaculatus*	x	x		x	x
Black Redhorse	*Maoxostoma duquesnei*				x	
Blackchin Shiner	*Notropis heterodon*				x	
Blacknose Shiner	*Notropis heterolepis*	x				
Blackside Darter	*Percina maculata*	x			x	
Blue Sucker	*Cycleptus elongatus*	x			x	x
Bluegill	*Lepomis macrochirus*	x			x	x
Bluntnose Minnow	*Pimephales notatus*	x			x	
Bowfin	*Amia calva*	x		x	x	x
Brassy Minnow	*Hybognathus hankinsoni*				x	
Brook Silverside	*Labidesthes sicculus*	x			x	
Brook Stickleback	*Culaea inconstans*	x				
Brown Trout	*Salmo trutta*				x	
Bullhead Minnow	*Pimephales vigilax*	x				
Burbot	*Lota lota*				x	
Central Mudminnow	*Umbra limi*	x				
Central Stoneroller	*Campostoma anomalum*				x	
Channel Catfish	*Ictalurus punctatus*	x		x	x	x
Channel Shiner	*Notropis wickliffi*	x				
Common Carp	*Cyprinus carpio*	x	x	x	x	x
Common Shiner	*Luxilus cornutus*	x			x	
Creek Chub	*Semotilus atromaculatus*	x				
Crystal Darter	*Crystallaria asprella*				x	
Emerald Shiner	*Notropis atherinoides*	x	x		x	x
Fathead Minnow	*Pimephales promelas*	x			x	x
Flathead Catfish	*Pylodictis olivaris*	x	x	x	x	x
Freshwater Drum	*Aplodinotus grunniens*	x	x	x	x	x
Gilt Darter	*Percina evides*				x	
Gizzard Shad	*Dorosoma cepedianum*	x	x		x	x
Golden Redhorse	*Moxostoma erythrurum*	x			x	x
Golden Shiner	*Notemigonus crysoleucas*	x			x	
Goldeye	*Hiodon alosoides*	x	x			x
Grass Carp	*Ctenopharyngodon idella*	x				
Greater Redhorse	*Moxostoma valenciennesi*	x			x	
Green Sunfish	*Lepomis cyanellus*	x			x	x
Highfin Carpsucker	*Carpiodes velifer*	x			x	x
Hornyhead Chub	*Nocomis biguttatus*	x			x	
Hybrid Sunfish	*Lepomis microlophus* x *L.*	x			x	
Iowa Darter	*Etheostoma exile*				x	
Johnny Darter	*Etheostoma nigrum*	x			x	
Lake Sturgeon	*Acipenser fulvescens*	x	x	x	x	
Largemouth Bass	*Micropterus salmoides*	x			x	x
Logperch	*Percina caprodes*	x			x	
Longnose Gar	*Lepisosteus osseus*	x	x		x	x
Mimic Shiner	*Notropis volucellus*	x			x	
Mooneye	*Hiodon tergisus*	x			x	x
Muskellunge	*Esox masquinongy*	x			x	
Northern Hogsucker	*Hypentelium nigricans*				x	
Northern Pike	*Esox lucius*	x	x	x	x	x
Orangespotted Sunfish	*Lepomis humilis*	x			x	
Paddlefish	*Polyodon spathula*	x	x	x	x	x

Table 5 (continued). Species list for the Minnesota, St. Croix and Mississippi (Pool 2, Pool 3 and Pool 4) Rivers from January 2013 through December 2021, including 89 native and invasive species.

Common Name	Genus Species	Pool 2	Pool 3	Pool 4	St. Croix River	Minnesota River
Pumpkinseed	*Lepomis gibbosus*	x			x	
Quillback	*Carpiodes cyprinus*	x	x		x	x
Rainbow Darter	Etheostoma caeruleum				x	
River Carpsucker	*Carpiodes carpio*	x	x	x	x	x
River Darter	*Percina shumardi*	x			x	
River Redhorse	*Moxostoma carinatum*	x			x	
Rock Bass	*Ambloplites rupestris*	x	x		x	
Sand Shiner	*Notropis stramineus*	x			x	x
Sauger	*Sander canadensis*	x	x		x	x
Shoal Chub	*Macrhybopsis hyostoma*	x				
Shorthead Redhorse	*Moxostoma macrolepidotum*	x	x	x	x	x
Shortnose GarSmallmouth	*Lepisosteus platostomus*	x	x		x	x
Silver Carp	*Hypophthalmichthys*	x		x	x	
Silver Chub	*Macrhybopsis storeriana*	x			x	
Silver Lamprey	*Ichthyomyzon unicuspis*	x			x	
Silver Redhorse	*Moxostoma anisurum*	x	x		x	x
Skipjack Herring	*Alosa chrysochloris*	x				
Slenderhead Darter	*Percina phoxocephala*	x			x	
Smallmouth Bass	*Micropterus dolomieu*	x		x	x	x
Smallmouth Buffalo	*Ictiobus bubalus*	x	x	x	x	x
Spotfin Shiner	*Cyprinella spiloptera*	x			x	x
Spottail Shiner	*Notropis hudsonius*	x			x	x
Spotted Sucker	*Minytrema melanops*	x			x	
Tadpole Madtom	*Noturus gyrinus*	x				
Trout Perch	*Percopsis omiscomaycus*	x			x	
Walleye	*Sander vitreus*	x	x	x	x	x
Weed Shiner	*Notropis texanus*	x				
White Bass	*Morone chrysops*	x	x		x	x
White Crappie	*Pomoxis annularis*	x			x	x
White Sucker	*Catostomus commersonii*	x			x	x
Yellow Bullhead	*Ameiurus natalis*	x				
Yellow Perch	*Perca flavescens*	x			x	

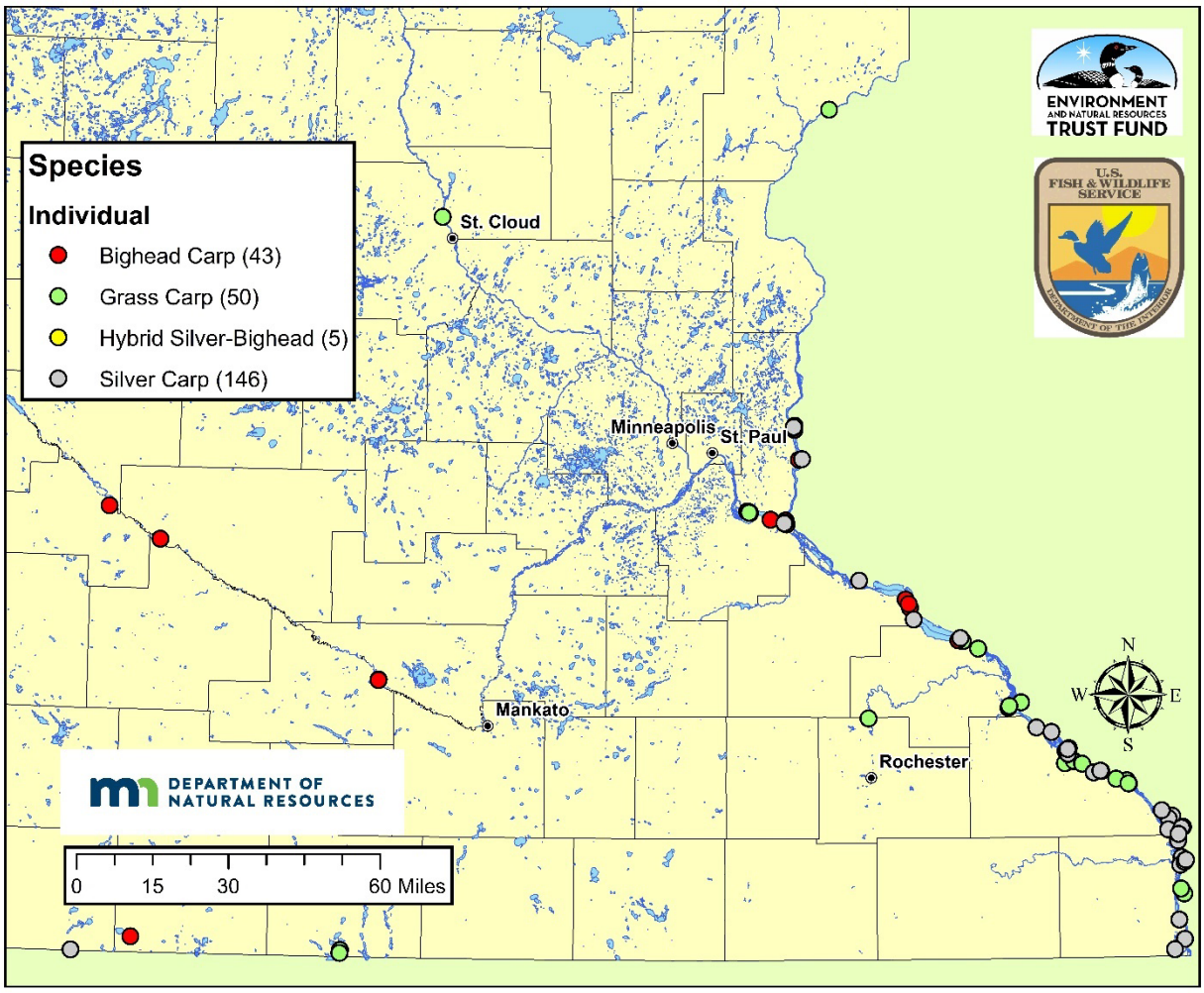

Figure 1. Locations of all known invasive carp captured in Minnesota waters through 2021.

Figure 2. Standardized electrofishing (dark circle, EF1 – EF8) and larval fish trawling (dark cross, P2-LT6 and P2-LT2019) locations on Pool 2 (P2) and larval fish trawling (dark cross, P3-LT4 and P3-LT2019) locations on Pool 3 (P3) of the Mississippi River.

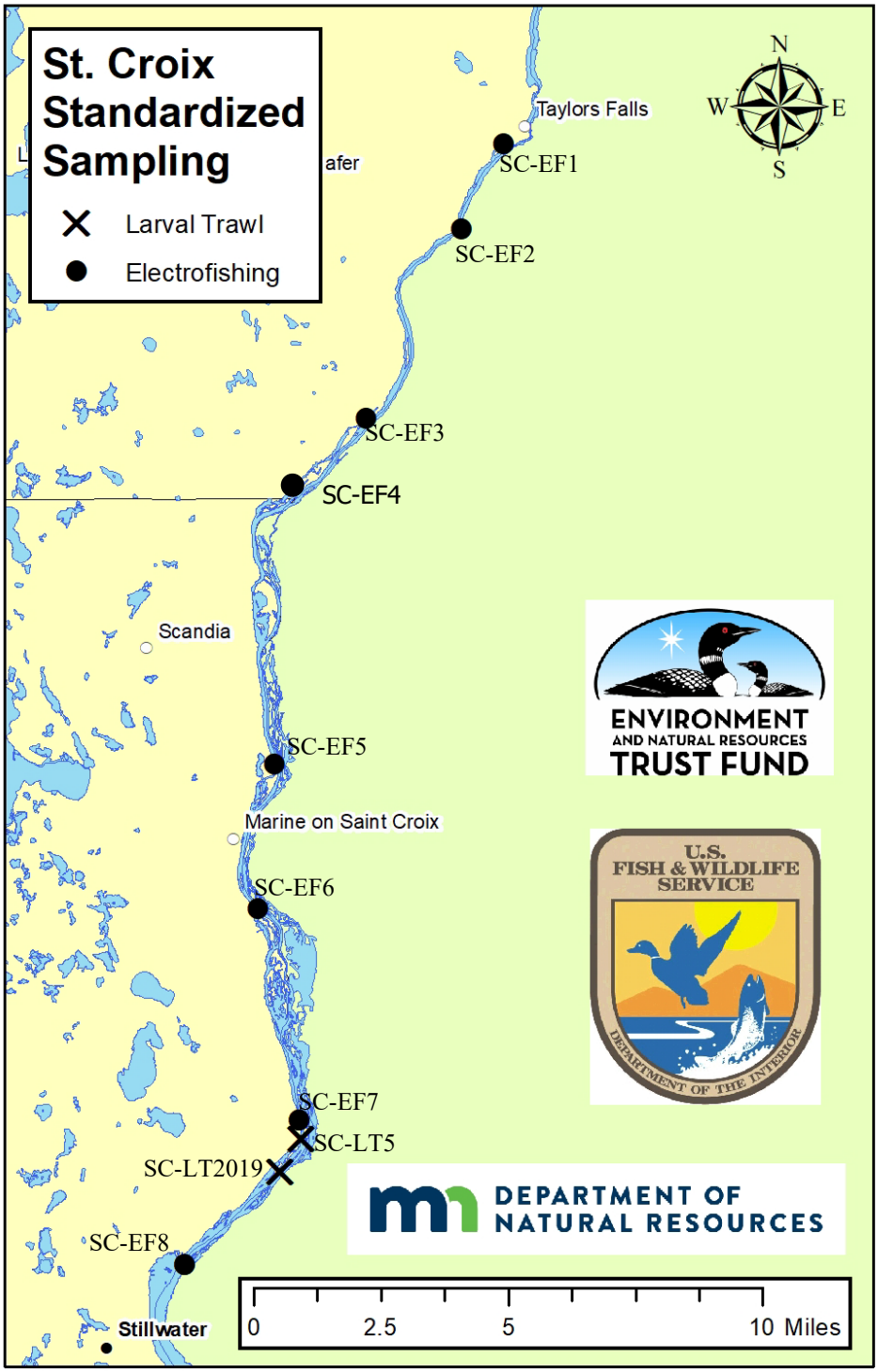

Figure 3. Standardized electrofishing (dark circle, EF1 – EF8) and larval fish trawling (dark cross, SC-LT5 and SC-LT2019) locations on the St. Croix River (SC).

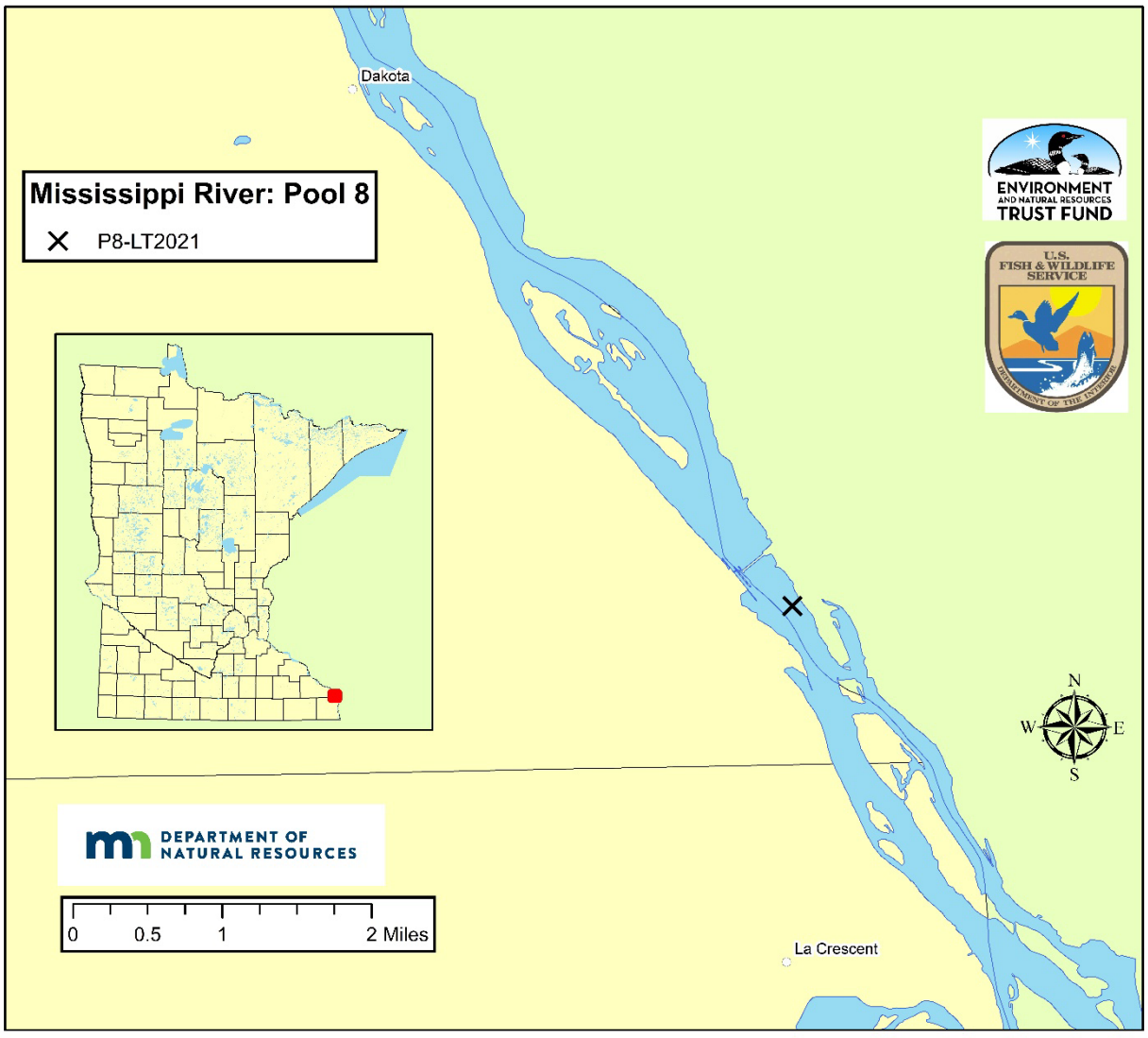

Figure 4. Standardized larval fish trawling (dark cross, P8-LT2021) locations on the Mississippi River.

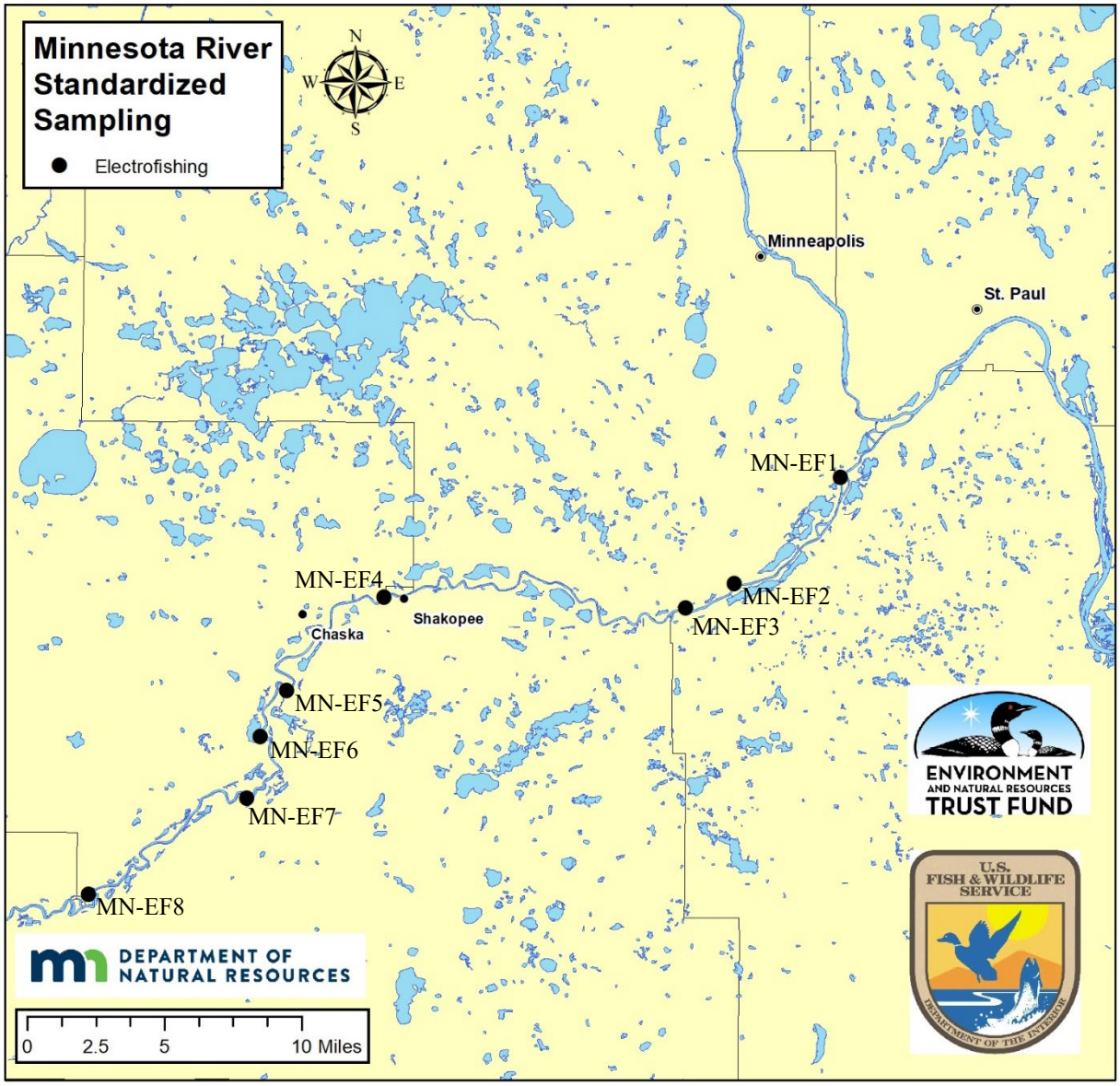

Figure 5. Standardized electrofishing (dark circle, EF1 – EF8) locations on the Minnesota River.

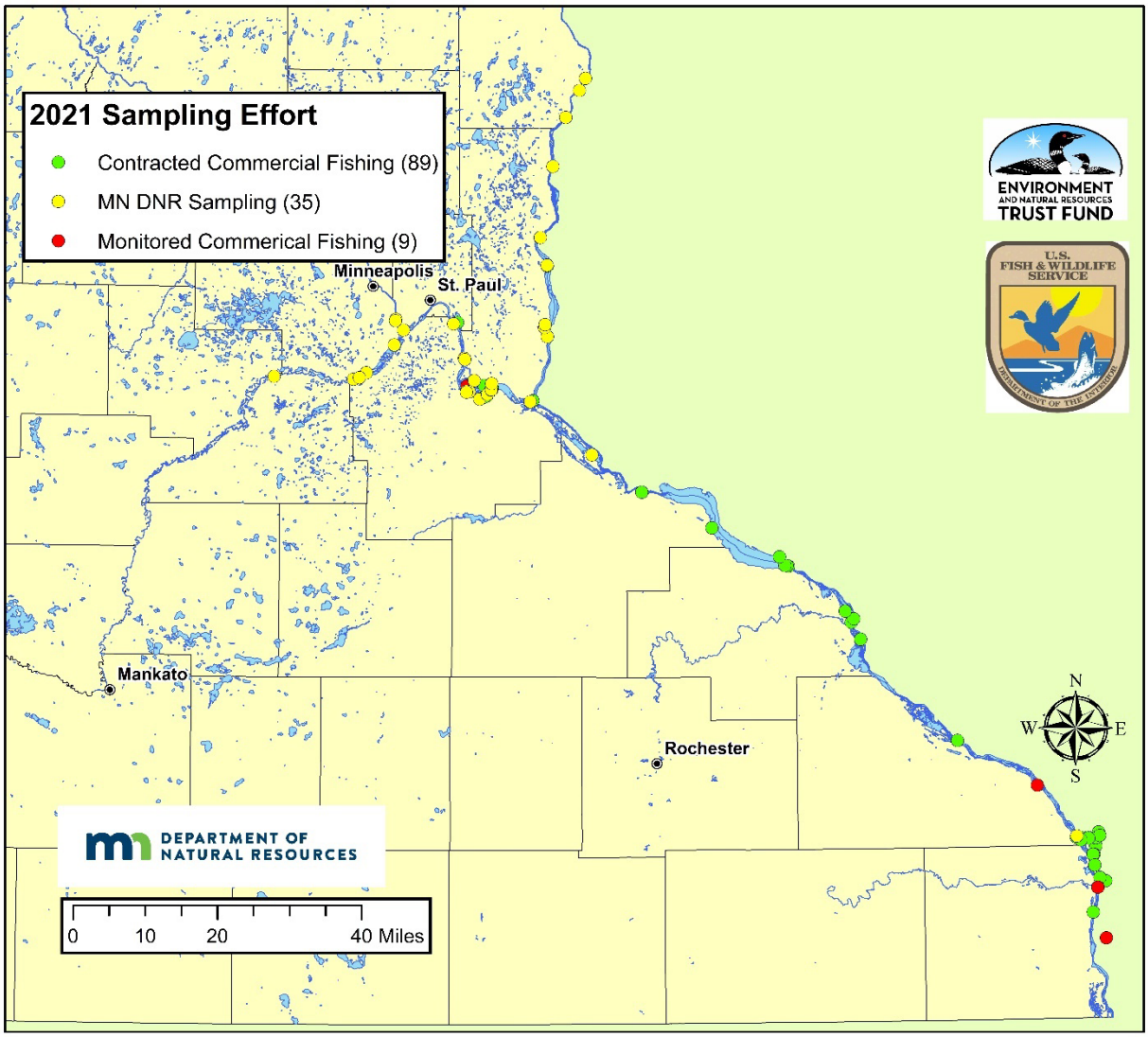

Figure 6. All sampling locations for contracted commercial sampling and MDNR sampling on the Mississippi, St. Croix, and Minnesota Rivers during 2021.

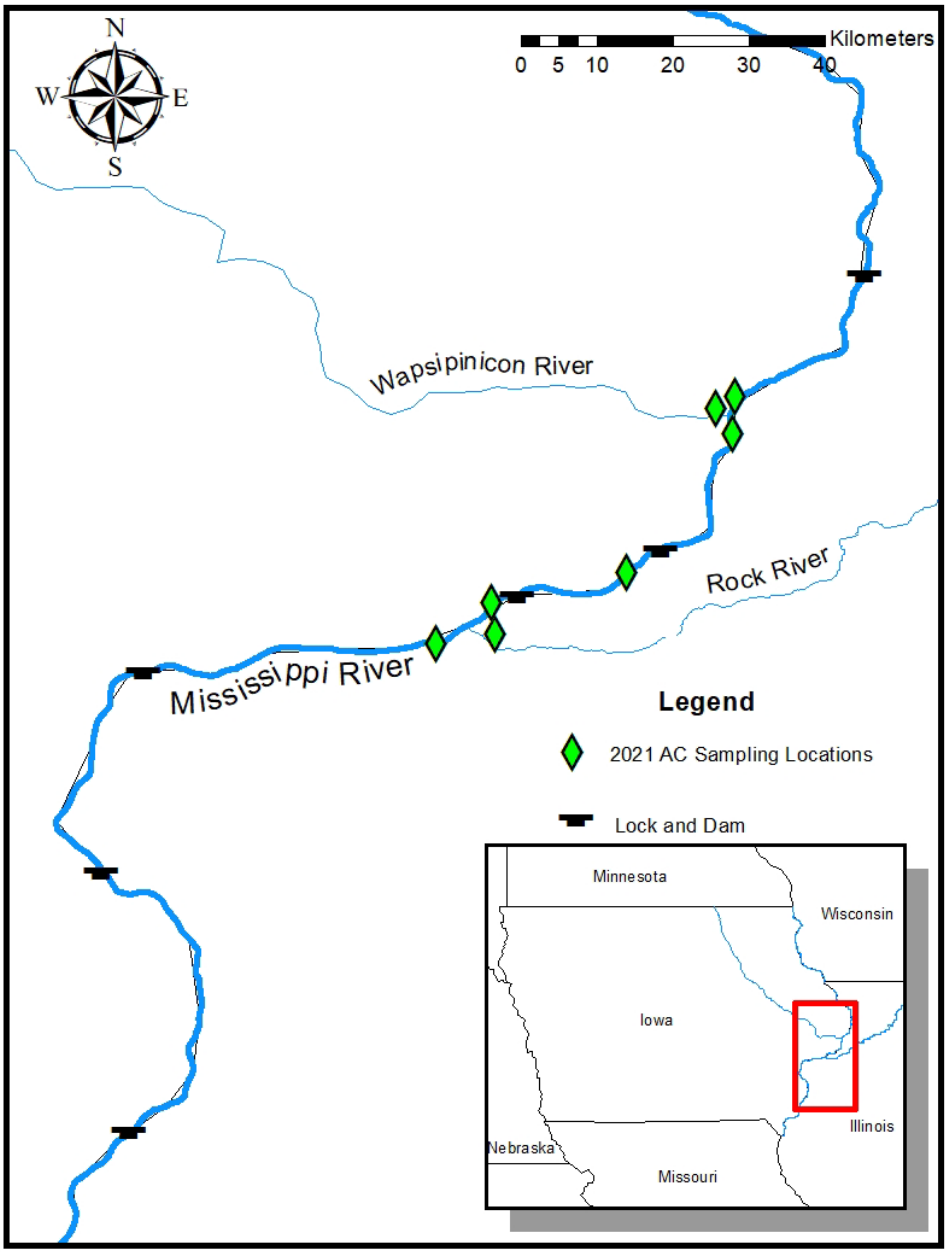

Figure 7. Map of study area depicting pools 14-16 on the Upper Mississippi River on the southeast border of Iowa. The seven sampling sites where chlorophyll *a*, fish eggs, and age-0 fishes were sampled are indicated by green diamonds. Mississippi River lock and dams within the sampling reach in black XXX.

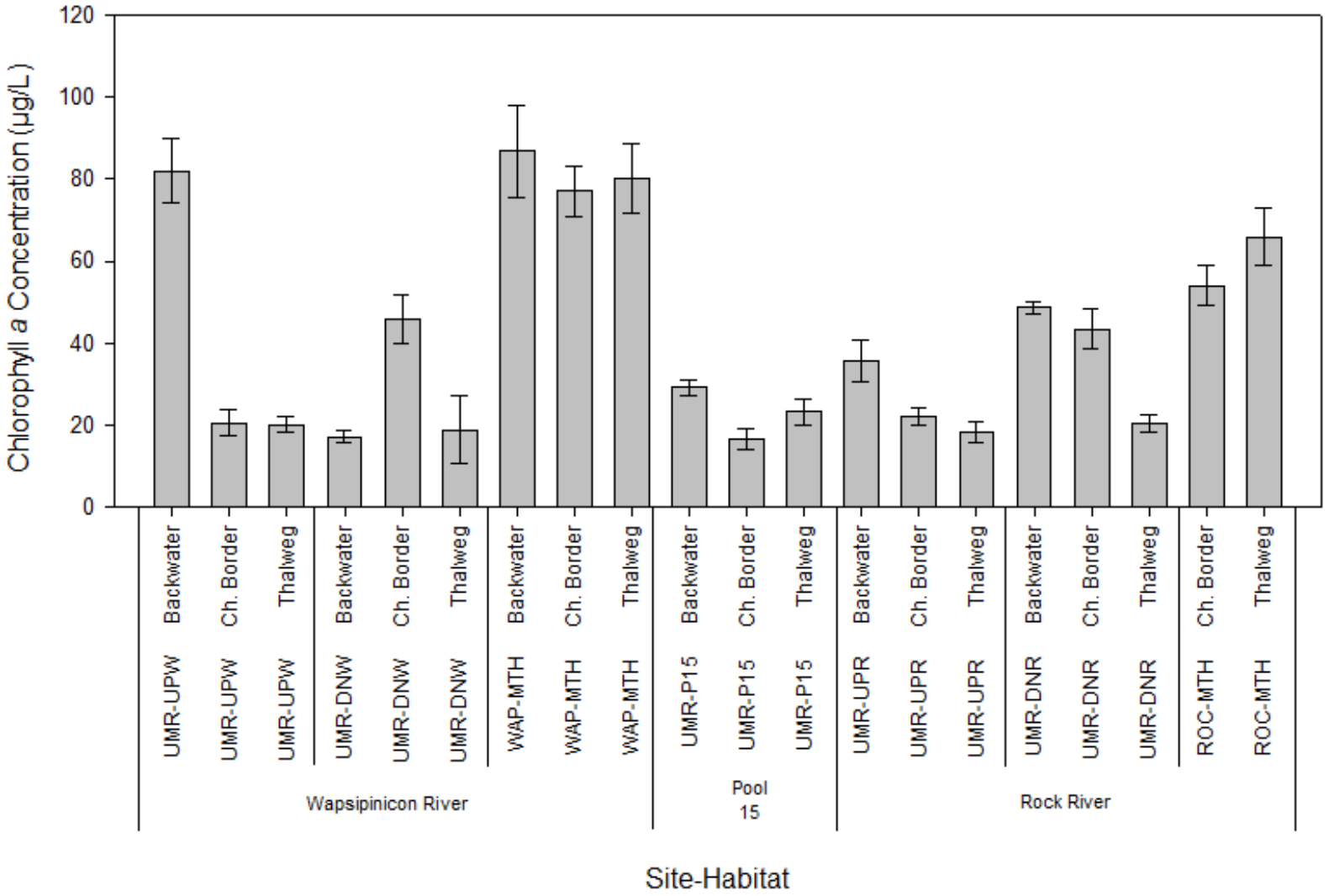

Figure 8. Chlorophyll *a* (mean ± SE) of each site collected between May 4th and July 6th, 2021

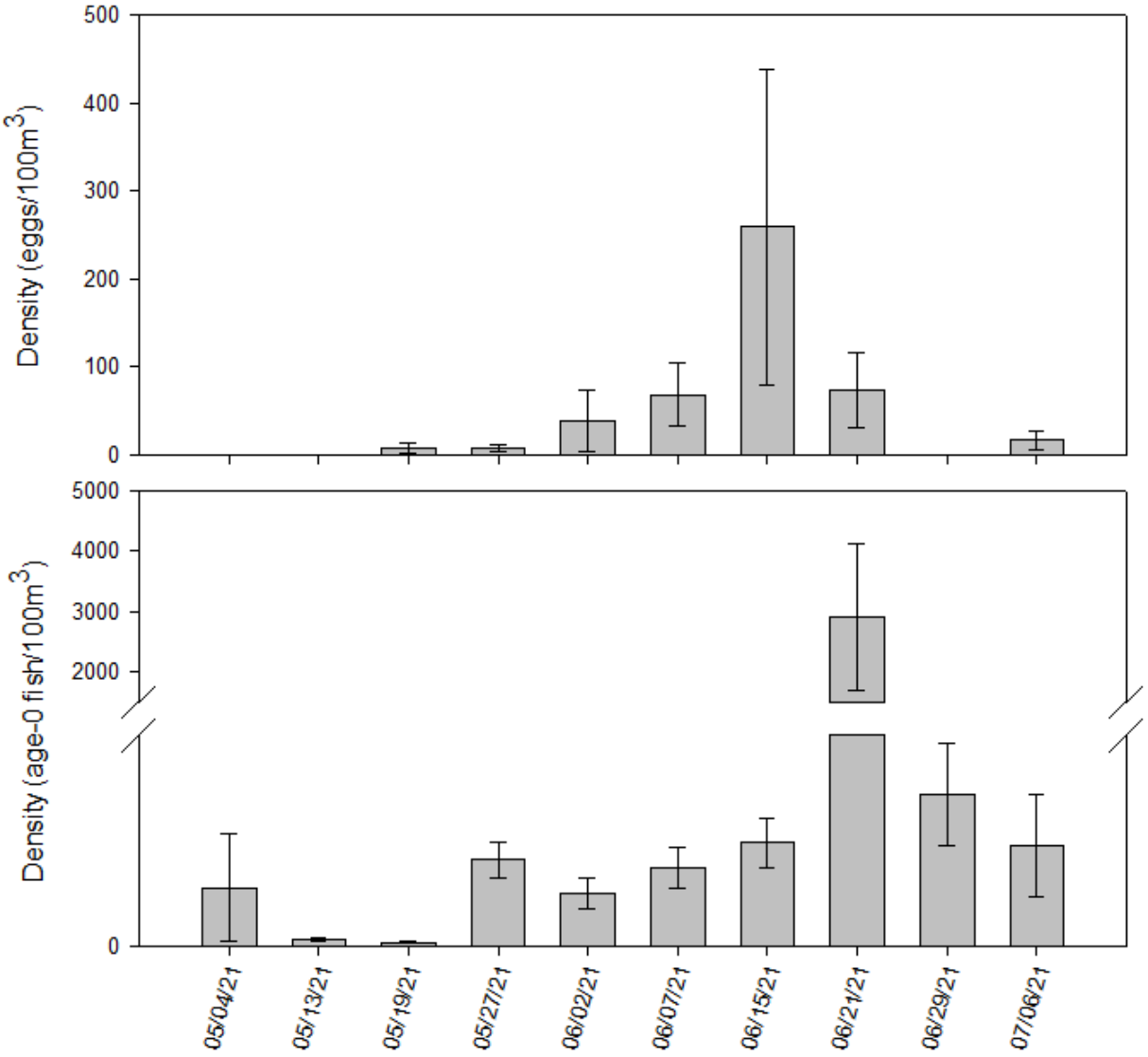

Figure 9. Mean density (mean ± 1 SE) of fish eggs (top) and age-0 fishes (bottom) collected May 4th and July 6th, 2021.

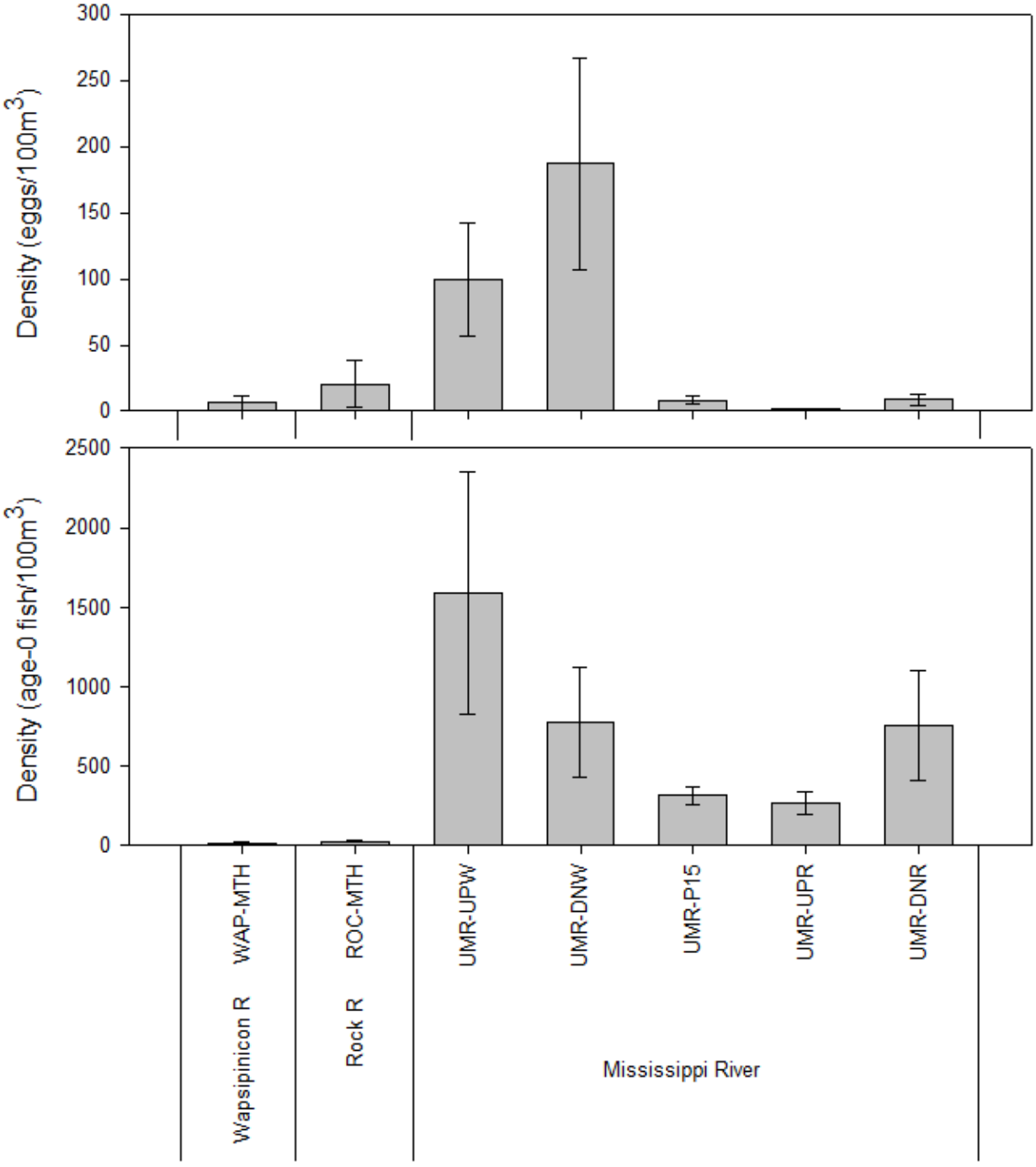

Figure 10. Mean density (mean ± 1 SE) of fish eggs (top) and age-0 fishes (bottom) collected across all dates from each site during 2021. Site codes are defined in Table 1.

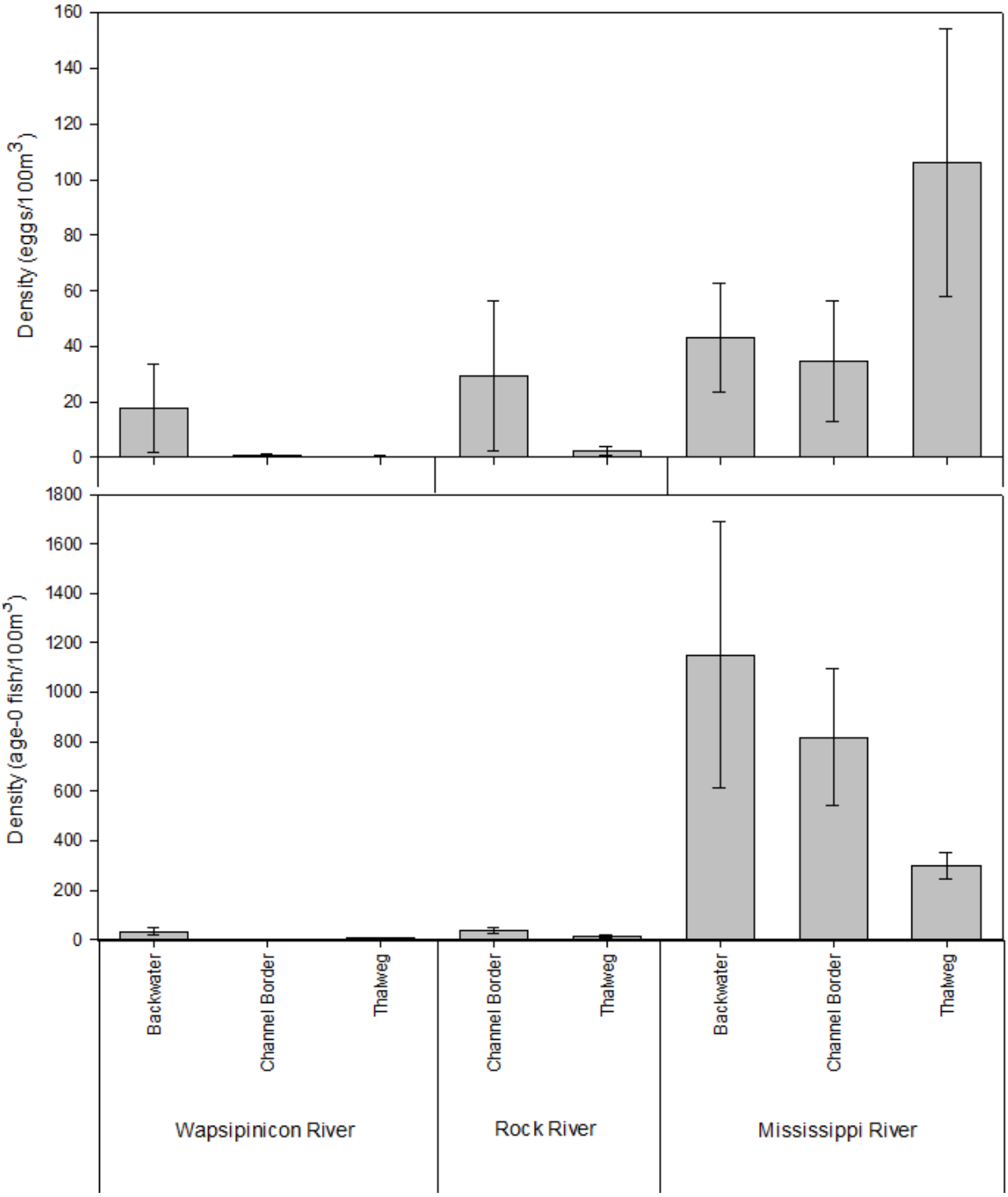

Figure 11. Density (mean ± 1 SE) of fish eggs (top) and age-0 fish (bottom) by habitat from the Wapsipinicon (WAP-MTH), Rock (ROC-MTH), and all sites sampled within the Mississippi river from UMR-UPW down to UMR-DNR during 2021. A list of sites can be found on Table 1.

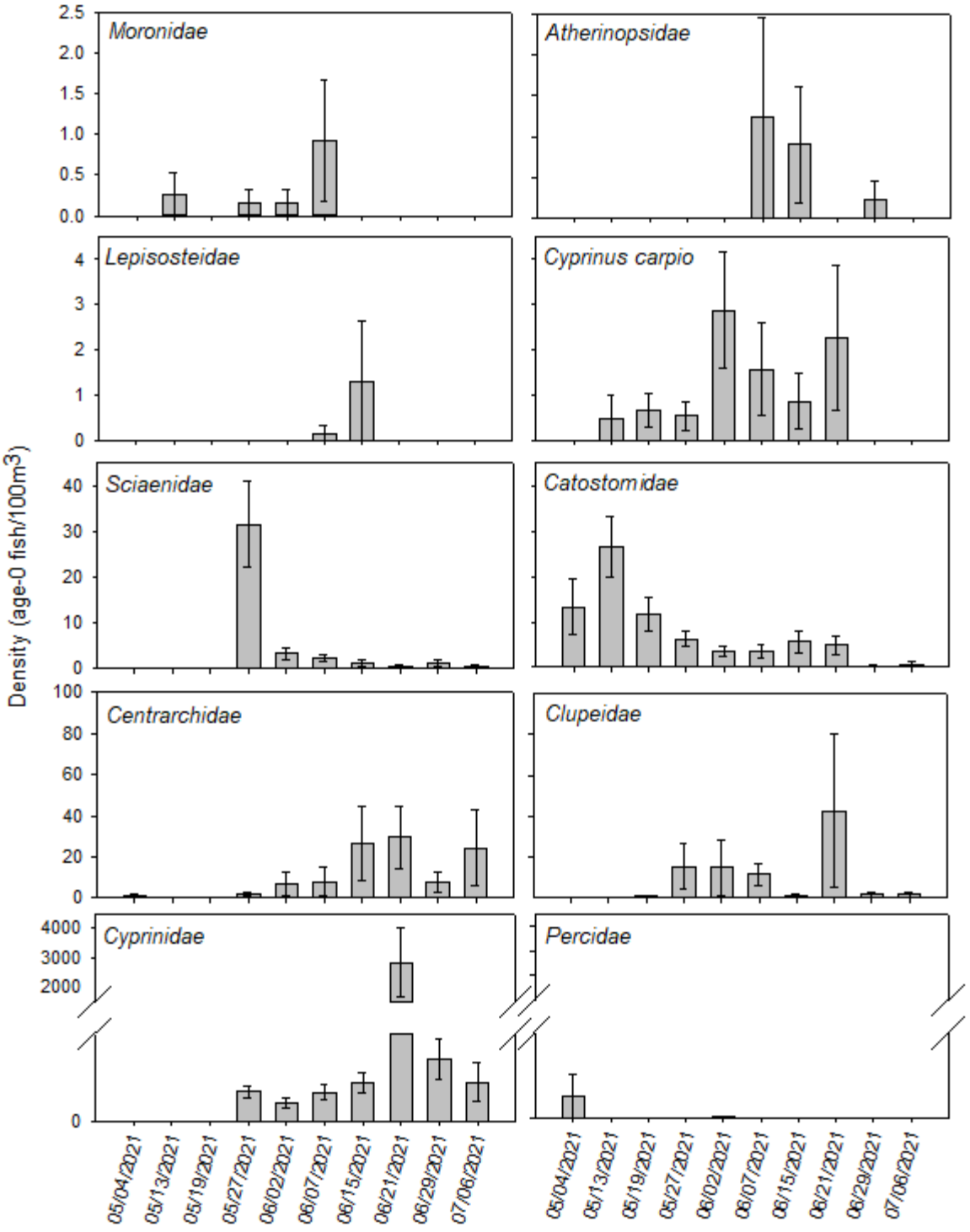

Figure 12. Density (mean ± 1 SE) of age-0 fishes by family from each sampling session in 2021. Note differences in y-axis scale among panels.