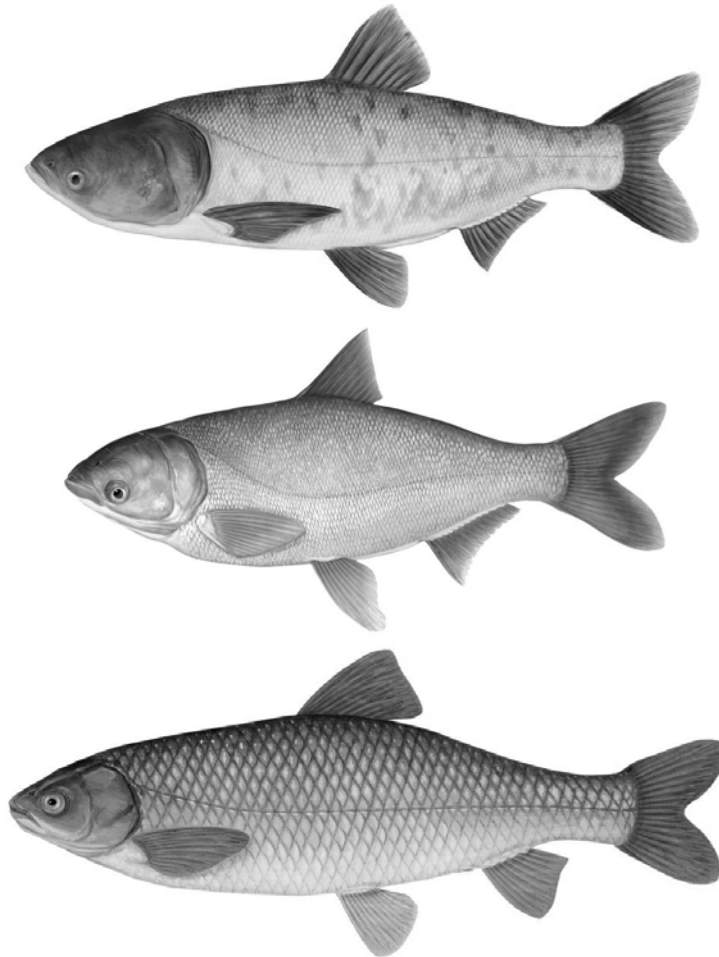


INVASIVE CARP SAMPLING REPORT
JANUARY – DECEMBER 2013
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
SECTION OF FISHERIES



UPPER MISSISSIPPI RIVER, POOL 2
LOWER ST. CROIX RIVER, BELOW ST. CROIX FALLS

April 4th, 2014



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INTRODUCTION

Bighead *Hypophthalmichthys nobilis* and Silver *H. molitrix* carp (hereafter referred to as Invasive Carp) 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 carp to escape into the Mississippi River drainage, where they began reproducing and spreading (Freeze and Henderson 1982). Invasive Carp have migrated up the Mississippi River, and adjoining tributaries, quickly establishing populations in newly invaded areas. In Minnesota, individual Bighead Carp have been collected as far north as Lake St. Croix, near Prescott, WI, and Silver Carp have been found as far north as Pool 6 of the Mississippi River, near Winona, MN. Currently, there is no evidence of Invasive Carp reproduction in Minnesota waters.

Invasive Carp have the potential to devastate local ecosystems by competing with native planktivores and overcrowding other native species. With high fecundity and an ability to populate new areas quickly, Invasive Carp can reach high abundances, sometimes making up most of the fish biomass in certain systems (MICRA 2002). Invasive Carp have a voracious appetite, and coupled with their large size (>70 lbs.), 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 fishes may be in direct competition with Invasive Carp for food resources. Evidence from the Illinois River, Illinois, suggests that competition with Invasive Carp resulted in reduced condition factors for Bigmouth Buffalo and Gizzard Shad (Irons et al. 2007). Worldwide, introductions of Invasive Carp 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 Carp up the Mississippi River, Minnesota waters are threatened by a potential invasion. A better understanding of the current status of Invasive Carp individuals or populations in Minnesota will allow for more efficient efforts of preventing their spread and/or eradicating them if populations do exist. Standard fish sampling assessments have been ongoing in Minnesota's major rivers and have the potential to catch Invasive Carp. However, the gears and methods used in these assessments are not the most efficient methods for capturing Invasive Carp. To date, Invasive Carp in Minnesota have only been caught by commercial fishermen. The purpose of this sampling effort is to use gears more specific to Invasive Carp to monitor all life stages of Invasive Carp and associated native fishes in the Mississippi River Pool 2 and the Lower St. Croix River.

OBJECTIVES

- Detect and monitor all life stages of Invasive Carp.
- Monitor native fish species that may be affected by the establishment of Invasive Carp.

SAMPLING SITES

Navigational Pool 2 of the Mississippi River spans approximately 52 km from Lock and Dam 1 in St. Paul, MN to Lock and Dam 2 near Hastings, MN. In the St. Croix River, 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.

Sampling Methods

Gears, methods, and habitats where sampling was focused were derived from a collection of 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) and conducting research on the most efficient gears to sample Invasive Carp (M. Diana, Illinois Natural History Survey, personal communication), along with a variety of literature that included 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). Sampling information for Invasive Carp included in this report took place between January 1, 2013 and December 31, 2013.

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* and Channel Catfish *Ictalurus punctatus* in Pool 2 and Lake Sturgeon *Acipenser fulvescens*, Muskellunge *Esox masquinongy*, White Bass *Morone chrysops*, Flathead Catfish, and Channel Catfish in the St. Croix. In both Pool 2 and the St. Croix River, Paddlefish are also tagged.

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 14 ft. and lengths of 150 to 300 ft. with square mesh sizes of 4 to 6 in. were used to target adult Invasive Carp. Trammel nets with outside wall square mesh sizes of 14 in. and inner square mesh sizes of 4 in. were also used to target adult Invasive Carp. Experimental gill nets 250 ft. in length and 6 ft. deep consisting of 50 ft. complements of net with square mesh sizes 0.75, 1, 1.25, 1.5, 2 in. were used to target juvenile

Invasive Carp. 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. Catch-per-unit-effort (CPUE) per 1000 feet of net was calculated for each net and averaged across nets.

Commercial Fishing

Commercial fishermen were contracted to target Invasive Carp with both gill nets and seines. 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.

Hoop Netting

Hoop netting was conducted during 3 separate sampling events. Two different sized hoop nets were used. Large 4 ft. diameter “buffalo” nets consisted of 9 tapered steel hoops and three throats, with a tapered mesh size of 3 in. sq. mesh at the mouth, 2 in. sq. mesh in the middle, and 1.5 in. sq. mesh at the cod end. Small 3 ft. diameter hoop nets consisted of 7 tapered steel hoops and two throats, with either 1 in. or 2 in. sq. mesh throughout. All fish sampled were identified and measured. CPUE per net night was calculated for each net, and averaged across nets.

Trap Netting

Trap netting was conducted during four sampling events on Pool 2. Trap netting was not conducted in the St. Croix 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. The standard trap nets consist of a double frame (36 in. x 72 in.), 5 hoops (30 in.), two throats, and a 40 ft. lead, with a square mesh size of 0.75 in. throughout. All fish were identified and enumerated in the field.

Electrofishing

Electrofishing occurred in a variety of habitats including backwaters, side channels, main channel borders, and over wing dikes. Sampling locations consisted of 8 standardized sampling locations in both Pool 2 (Figure 1) and the St. Croix River (Figure 2 and 3), and all other sampling events occurred at random locations in the aforementioned habitats at the discretion of the sampler. In 2013, 26 standardized electrofishing sites were sampled for a total of 393 minutes. Standardized sampling locations were selected based on habitats Invasive Carp are likely to occupy and are 500 m in length. At these set sampling locations, all observed fish were collected, identified, measured and weights and aging 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 random sampling sites, fish were identified in the water and only fish needed to collect aging structures and 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.

Larval trawling

Larval trawling was conducted in Pool 2 and the St. Croix River to target the early life stages of Invasive Carp. All eight sites were sampled twice in Pool 2 (Figure 1) and once in the St. Croix (Figure 2 and 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. A total of eight locations were sampled in each system with two, 5-minute pushes conducted at each location. Sampling locations were located in the following macro habitats: 4 main channel, 2 side channel, and 2 backwater locations in each system. Sample contents were placed in containers labeled with sample location, name of the water body, and date, and preserved in 90% ethanol. All samples were sifted to remove all excess material, with only eggs and fish kept. 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.

eDNA

MN DNR personnel assisted Loren Miller (MN DNR) 4 days acquiring water samples for environmental DNA (eDNA) analysis. A total of 50 water samples were collected each day, as well as 2 control samples that were not opened but were dipped into the water to determine if

sample contamination was occurring. All samples were filtered the day of collection at the University of Minnesota and filter papers were archived at the University for future analysis.

Age and Growth Analysis

Gizzard Shad, Freshwater Drum *Aplodinotus grunniens*, and both Smallmouth *Ictiobus bubalus* and Bigmouth buffalo were collected during sampling events and processed for age and growth analysis. Gizzard Shad and Bigmouth Buffalo are native planktivores that may be in direct competition with Bighead and Silver carp. Paddlefish, another native planktivore, are currently a state listed threatened species in Minnesota; therefore low abundances and the lack of a non-lethal aging method for paddlefish make sacrificing fish to acquire ages unjustifiable. However, one individual was found dead in the St. Croix River and was subsequently collected and aged using the dentary bone. Smallmouth Buffalo and Freshwater Drum 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 aging structures (except for Paddlefish) were collected as follows: for fish less than 300 mm, up to 5 individuals in each cm length group and for fish 300 mm and greater up to ten individuals in each 25 mm length group. For Freshwater Drum and Gizzard Shad, sagittal otoliths were used for ageing. For both Smallmouth and Bigmouth buffalo, scales, lapillus otoliths, and pectoral fin rays were extracted and compared. Otoliths were embedded in epoxy and cut using an isomet saw, fin rays were dried and cut using the isomet saw, and scales were examined under a dissecting microscope. For preliminary analyses, one reader counted each opaque band as an annulus under a dissecting microscope, using both reflected and transmitted light sources. At a later time a second reader will independently count annuli and if

counts differ from those of the first reader, the readers will re-examine the structure and if readings differed a second time, the readers will confer until a consensus can be reached.

RESULTS AND DISCUSSION

Sampling Results

In total, 64 days were spent sampling between January and December 2013 on the Mississippi River Pool 2 and St. Croix River with gears appropriate for sampling Invasive Carp (Table 1). A greater amount of effort was focused on Pool 2 (Figure 4), because Invasive Carp had not been found above Lock and Dam 2 on the Mississippi River. Determining whether there were individuals or populations of Invasive Carp in Pool 2 was of high importance. With the results from this sampling effort, it is possible that more Invasive Carp are present in these systems. However, this increased sampling effort decreases the likelihood that populations of Invasive Carp do exist in these systems and reinforces assumptions that Invasive Carp previously caught in the area were only wandering individual adults.

Effort was expended by MN DNR personnel to monitor contracted commercial fishermen targeting adult Invasive Carp and to sample for various life stages of Invasive Carp with MN DNR gear using gill and trammel netting, hoop netting, and trap netting (Table 1). One Grass Carp *Ctenopharyngodon idella* was collected in Pool 2 in Grey Cloud Slough by contracted commercial fishermen and no Invasive Carp were collected in the St. Croix River during sampling efforts. Although only one Invasive Carp was collected by MN DNR contracted commercial fishermen, bycatch from the additional sampling yielded information on several native fishes and gears that may be best suited for sampling Invasive Carp.

Contracted commercial fishermen set 52,750 feet of gill and trammel nets during 11 days of effort and conducted three seine hauls between January and December 2013. Gill nets were

set short term (2-3 hours) and fish were chased towards the net with boats, typically in large backwater areas. Buffalo (both Bigmouth and Smallmouth) dominated the commercial catches, making up 58.42% of the catch (by weight), followed by Common Carp *Cyprinus carpio* (32.25%), “Carp Suckers” *Carpiodes* spp. (7.45%), and Freshwater Drum (1.88%) (Figure 7). The commercial fishermen harvested a total of 79,902 lbs. of fish during the 11 days of effort (Figure 8).

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. A total of 60,100 feet of gill and trammel nets were set in Pool 2 and the St. Croix River during 9 days, with most net sets being short-term sets (2-5 hrs.)(Table 1). Smallmouth Buffalo (52.5%, by number) were the most abundant fish caught in gill and trammel nets, followed by Common Carp (22.9%), Bigmouth Buffalo (6.5%), Channel Catfish (4.6%), River Carp Sucker *Carpiodes carpio* (3.7%), and Freshwater Drum (3.7%) (Figure 5). Of the gill and trammel nets set by MN DNR personnel, the trammel nets produced the highest CPUE of “Invasive Carp like” fish (Figure 6), with “Invasive Carp like” fish including those that were similar to adult Invasive Carp in size, morphology and/or behavior and consisted of Common Carp, Buffalo spp., and Carpsucker spp. (*Carpiodes* spp.). Hoop nets of varying sizes were typically set in side channel and main channel habitats with at least some flow. Hoop netting effort totaled 86 net nights during 2013. Freshwater Drum (52.1%, by number) dominated the hoop net catch, followed by Common Carp (10.9%), Black Crappie *Pomoxis nigromaculatus* (10.4%), Flathead Catfish (8.3%), and Smallmouth Buffalo (6.5%) (Figure 9). The large “buffalo” style hoop nets may be the best style of hoop nets to use

for targeting Invasive Carp, as they had the highest CPUE for all fish and for “Invasive Carp like” fish (Figure 10).

Trap netting was conducted using fyke nets for a total of 73 net nights. Large fyke nets caught mostly Black Crappie (50.1% by number), followed by Silver Redhorse *Moxostoma anisurum* (8.8%), White Bass *Morone chrysops* (8.0%), Common Carp (7.3%), Bluegill *Lepomis macrochirus* (6.0%), Shorthead Redhorse *Moxostoma macrolepidotum* (5.4%), Freshwater Drum (3.7%), and 8 other species (10.7% combined)(Figure 11). Small fyke nets caught a total of 29 species with the catch distributed among species. The most common species caught by small fyke nets were Bluegill (34.4%) and Spotfin Shiner *Cyprinella spiloptera* (24.3%), followed by Emerald Shiner *Notropis atherinoides* (11.4%), Bluntnose Minnow *Pimephales notatus* (8.1%), Black Crappie (7.5%), with the remaining 25 species accounting for 14.3% of the catch (Figure 12).

Both random and standardized electrofishing sampling was conducted with 871 minutes during 3 days spent on random sampling and 393 minutes during 16 days conducting standardized sampling. Random electrofishing was used to monitor for Invasive Carp and for collection of individuals for age and growth analyses. Standardized electrofishing sampled a total of 44 species. The most common species caught during standardized electrofishing sampling were Silver Redhorse (16.1%) and Shorthead Redhorse (9.3%), followed by Common Carp (7.1%), Freshwater Drum (7.1%), Gizzard Shad (6.1%), Walleye *Sander vitreus* (5.7%), Golden Redhorse *Moxostoma erythrurum* (5.1%), White Bass (5.0%), Bluegill (5.0%), Emerald Shiner (5.0%), Smallmouth Bass *Micropterus dolomieu* (4.5%), Quillback *Carpiodes cyprinus* (4.1%), and Smallmouth buffalo (2.6%), with the other 31 species representing 17.3% of the catch (Figure 13).

Larval trawling was conducted for 48 total trawls during 8 days. Although sampled, fish and eggs have been not been analyzed by a larval fish expert, we are confident no Invasive Carp were caught. Samples are preserved and awaiting expert analysis to determine the species caught and their respective number.

Numerous other unique or rare native fishes worth mentioning were encountered during these sampling events. Numerous Blue Suckers *Cycleptus elongatus* and several Goldeyes *Hiodon alosoides*, Mooneyes *H. tergisus*, a Shortnose Gar *Lepisosteus platostomus*, and an American Eel *Anguilla rostrata* were observed in Pool 2. Several Paddlefish, Northern Hogsuckers *Hypentelium nigricans*, Spotted Sucker *Minytrema melanops*, Longnose Gar *Lepisosteus osseus*, River Redhorse *Moxostoma carinatum*, and Greater Redhorse *M. valenciennesi* were observed in the St. Croix River.

Age and Growth Analysis

Age and growth analysis was completed for two of the species of interest and the one deceased paddlefish by one reader. In 2014, a second reader will age the species collected in 2013 and a consensus will be reached if readings differ among readers. Buffalo age and growth was not completed during this reporting period due to difficulties reading the structures taken. In the 2014 field sampling season, additional effort will be made to validate other structures including dorsal fin rays.

Preliminary analyses illustrate differences between Pool 2 and the St. Croix River for Gizzard Shad. A total of 20 Gizzard Shad were aged from Pool 2 and 43 from the St. Croix. Individuals from the St. Croix River were found to be smaller and younger than those found in Pool 2. Also, the two systems showed differing growth rates with the same age fish observed to be smaller in Pool 2 than those from the St. Croix River. The number of annuli observed ranged

from 0 to 7 in Pool 2 and 0 to 2 in the St. Croix River (Figure 14). Although twenty-two Freshwater Drum were aged from Pool 2, many individuals were not sexed (which is likely important in this species). In Freshwater Drum, number of annuli ranged from 3 to 18 in Pool 2 (Figure 15). For both Smallmouth and Bigmouth buffalo, pectoral fin rays were found to produce the best results for analysis. Sixty-three Smallmouth Buffalo and thirty-nine Bigmouth Buffalo were collected from Pool 2, however the results are viewed as preliminary and will be further tested in the near future. A deceased Paddlefish was found in the St. Croix River off Afton beach on July 17, 2013. The dentary bone was cleaned, preserved, and aged using methods similar to those used by Reed et al. (1992) and Hoxmeier and DeVries (1997). Two readers observed 15 annuli. The individual showed mild decay and measured 58 inches (1473 mm) total length, approximately 37.5 inches (952 mm) eye-to-fork length. This individual was not weighed due to the state of decay.

RECOMMENDATIONS

Acquiring additional gears to more effectively sample for various life stages Invasive Carp is recommended. A smaller electroshocking boat fitted with a jet outboard engine will be used during the 2014 field season to electrofish for Invasive Carp in shallow water areas, including possible overwintering areas. Also, gill nets with mesh sizes of 3.5" to 4" will be used as they may be better suited for targeting adult Invasive Carp, along with nets of varying depths (e.g. up to 24' deep) would allow sampling of the entire water column in additional locations.

Additionally, further age and growth analysis is recommended for native planktivores, such as Bigmouth Buffalo and Gizzard Shad, which may be in direct competition for food resources with Invasive Carp, as well as other native species such as Smallmouth Buffalo and Freshwater Drum that are commercially important. 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 affect native species. We would benefit from a greater understanding of the population dynamics of our commercially important native fishes. Further, the sex of age and growth specimens will be necessary to better understand the patterns found in these preliminary analyses.

Paddlefish are another native planktivore that may directly compete for food resources with Invasive Carp and therefore may be negatively affected. Currently, Paddlefish are a state threatened species in Minnesota, and populations across their range have suffered due to commercial navigation projects that impede movement and alter habitats, pollution, and over exploitation (Jennings and Zigler 2000). If Invasive Carp 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. Further effort should also be used to promote boaters to report any deceased paddlefish for age and growth analysis and other MN DNR offices should collect all deceased Paddlefish for analysis.

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Table 1. Invasive Carp sampling summary for the Mississippi River Pool 2 and the St. Croix River for June through December 2013.

Invasive Carp Sampling Summary			
January – December 2013			
Gear	Measure	Unit	Days
<i>Random Sampling Effort</i>			
Gill/Trammel Netting	7,350	feet	9
Electrofishing	871	minutes	3
Hoop Netting	86	net/nights	5
Trap Netting	73	net/nights	9
<i>Standardized Sampling Effort</i>			
Electrofishing	393	minutes	16
Larval trawling	48	trawls	8
Targeted Commercial Fishing Effort			
Gill Netting	52,750	feet	11
Seining	3	hauls	3
Number of Invasive Carp Captured	1	fish	
Total Number of Days Sampled			64

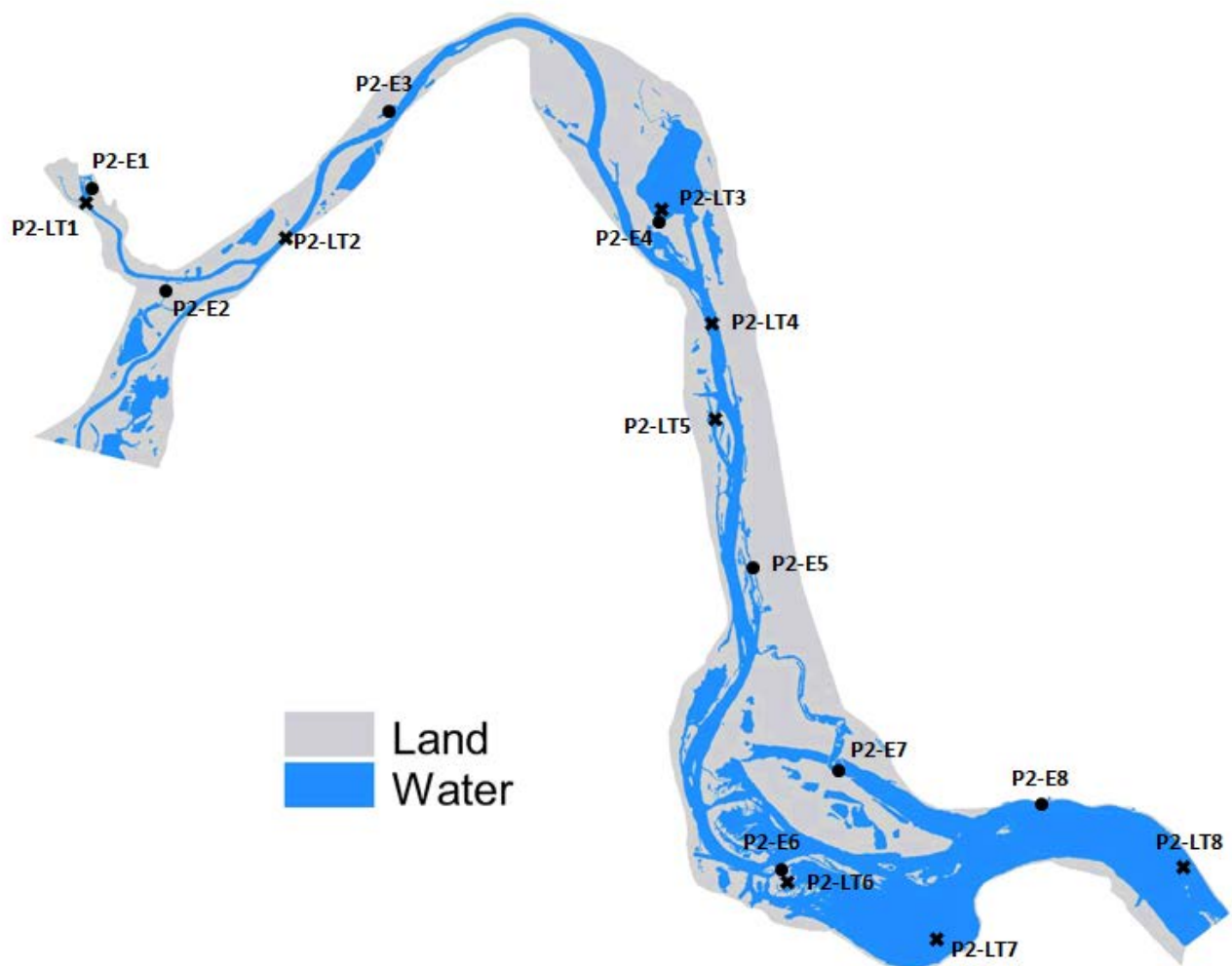


Figure 1. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 8) locations on Pool 2 (P2) of the Mississippi River.

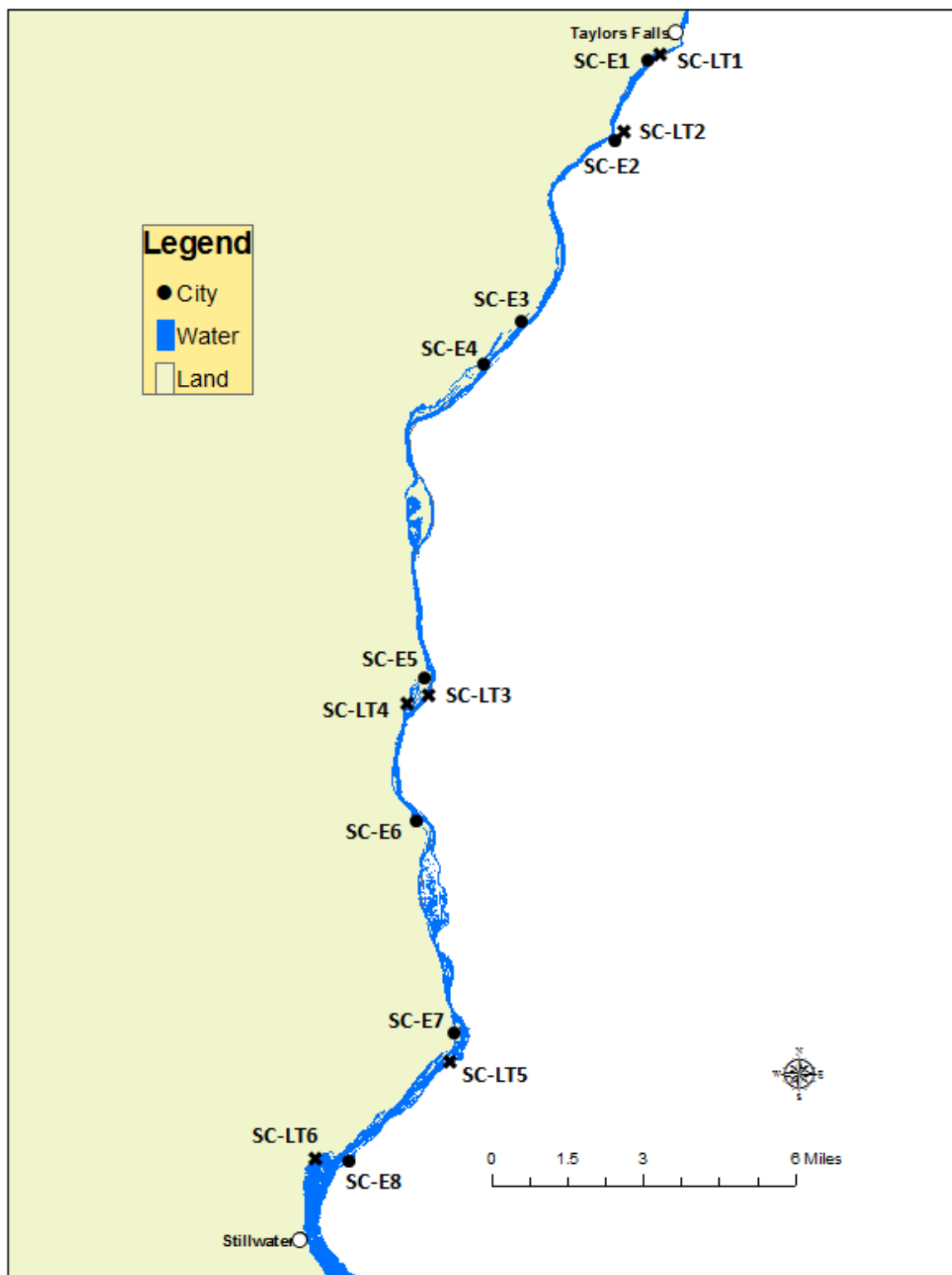


Figure 2. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 6) locations on the St. Croix River (SC).



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

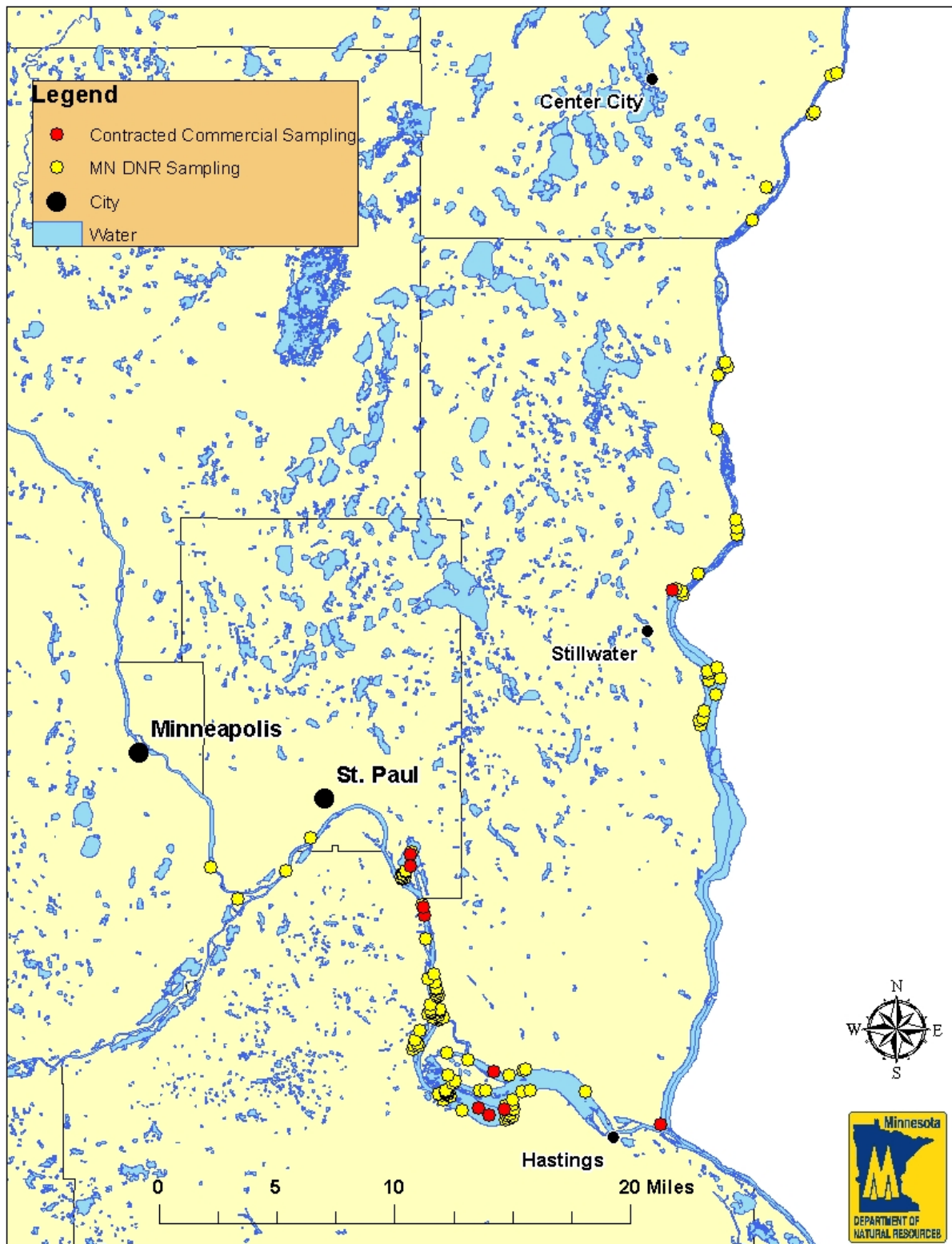


Figure 4. All sampling locations for contracted commercial sampling and MN DNR sampling on the Mississippi River Pool 2 and the St. Croix River during 2013.

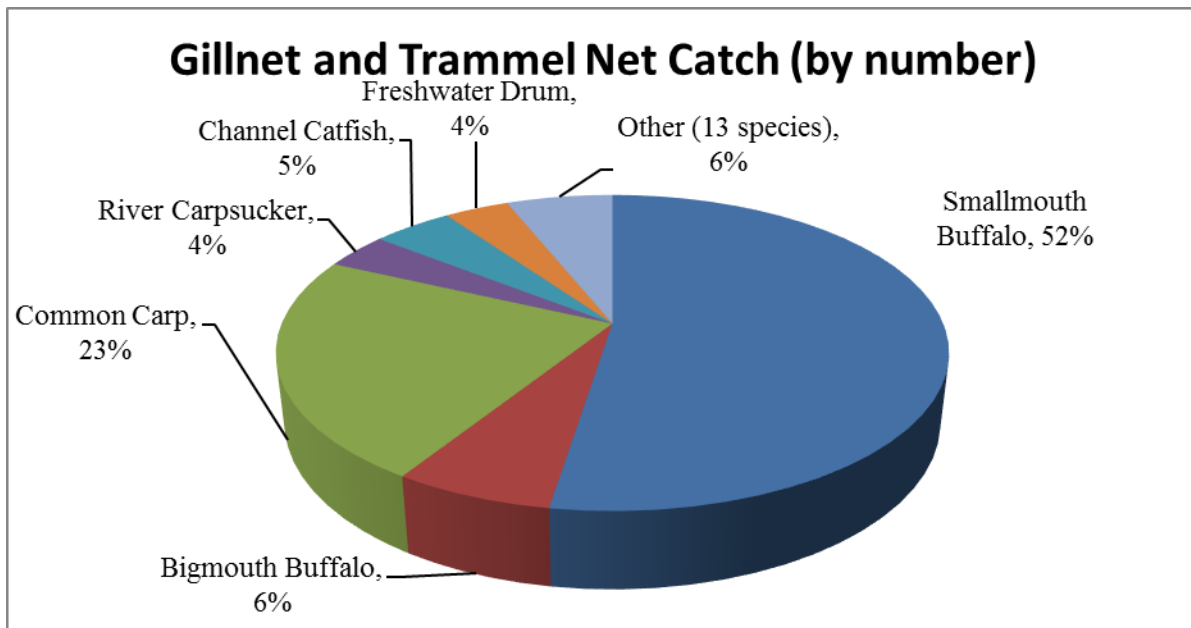


Figure 5. The percent catch by number of all fish caught in MN DNR gill and trammel nets on the Mississippi River Pool 2 and St. Croix River during 2013.

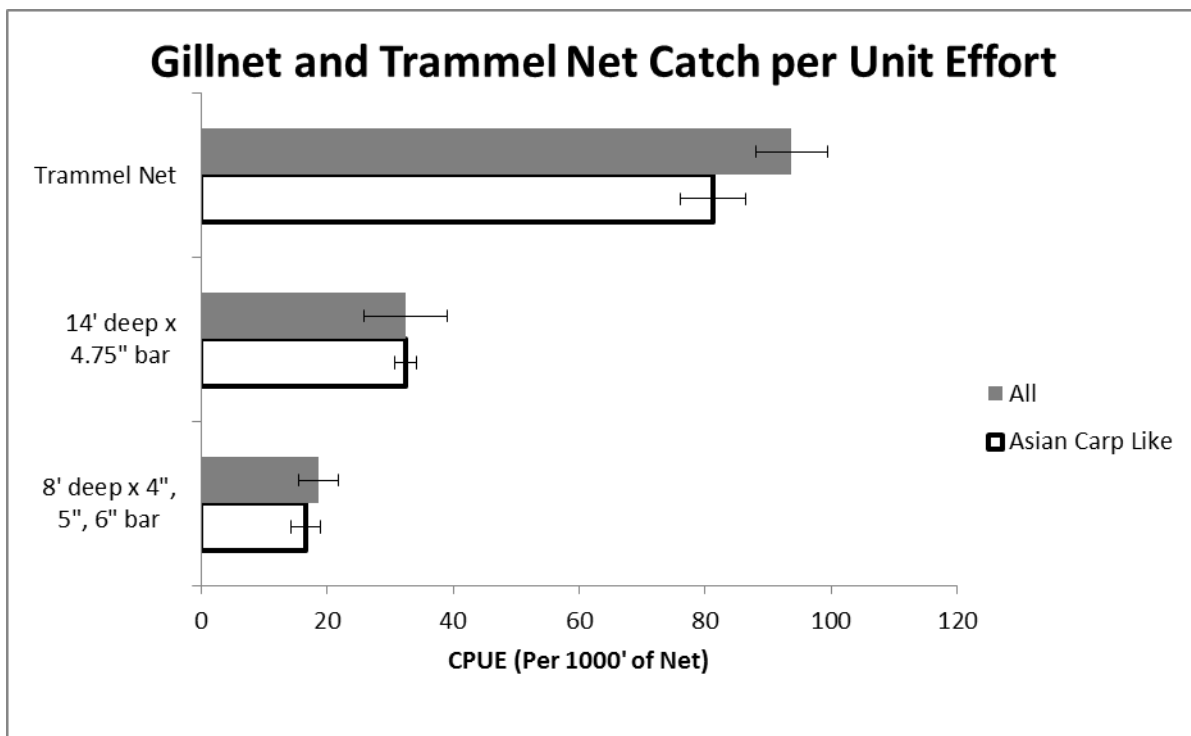


Figure 6. Catch-per-unit-effort (per 1000' of net) for all fish and for fish similar to adult Invasive Carp in size, morphology, and/or behavior ("Invasive Carp like") for two types of gill nets as well as trammel nets from the Mississippi River Pool 2 and St. Croix River

during 2013. Error bars equal one standard error. “Invasive Carp like” fish were considered Common Carp, Buffalo spp., and Carpsucker spp. (*Carpiodes spp.*).

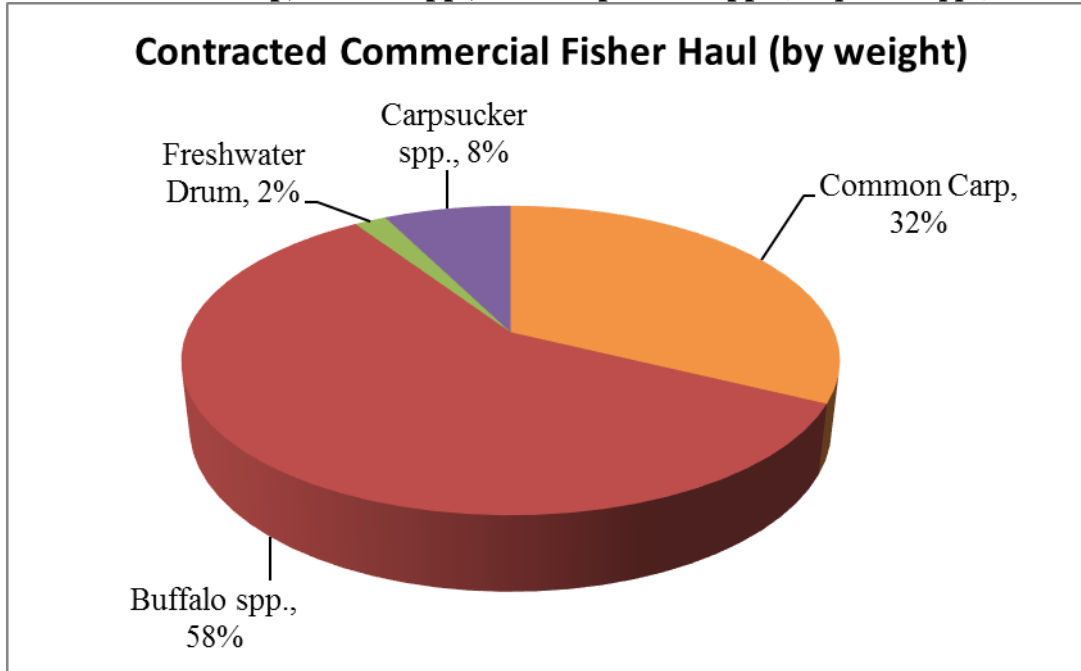


Figure 7. The percent catch by weight in pounds of all fish caught using seines and trammel and gill nets during contracted commercial fishing efforts on the Mississippi River Pool 2 and the St. Croix River during 2013.

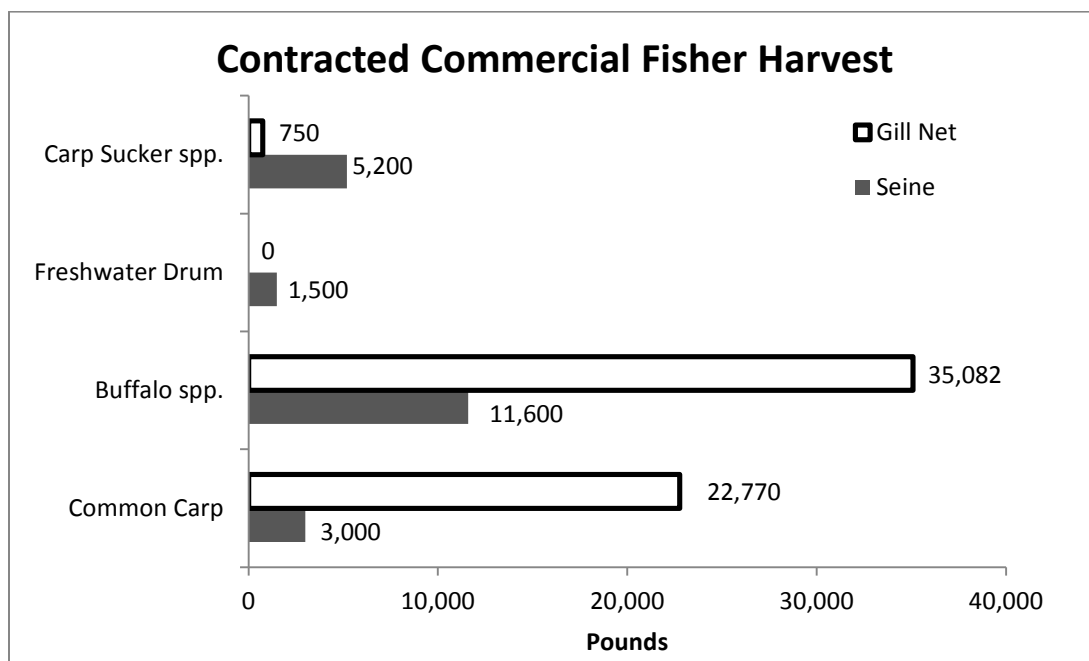


Figure 8. The reported harvest from contracted commercial fishermen on the Mississippi River Pool 2 and the St. Croix River during 2013.

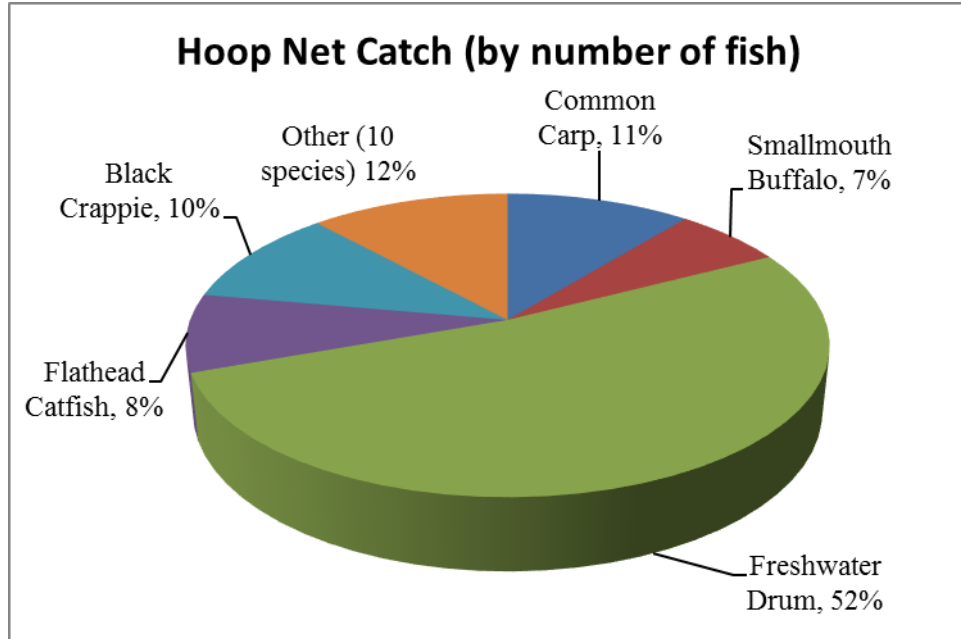


Figure 9. The percent catch by number of all fish caught in hoop nets on the Mississippi River Pool 2 and St. Croix River during 2013.

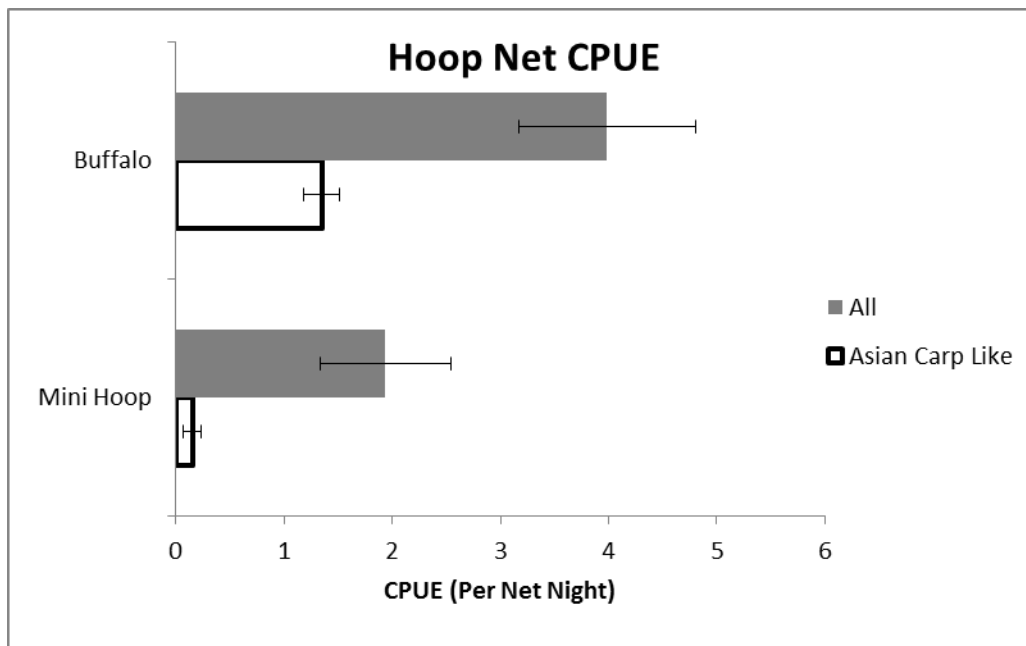


Figure 10. Catch-per-unit-effort (per net night) for all fish and for fish similar to adult Invasive Carp in size, morphology, and/or behavior (“Invasive Carp like”) for two types of hoop nets from the Mississippi River Pool 2 and the St. Croix River during 2013. Error

bars equal one standard error. “Invasive Carp like” fish were considered Common Carp, Buffalo spp., and Carpsucker spp. (*Carpiodes spp.*).

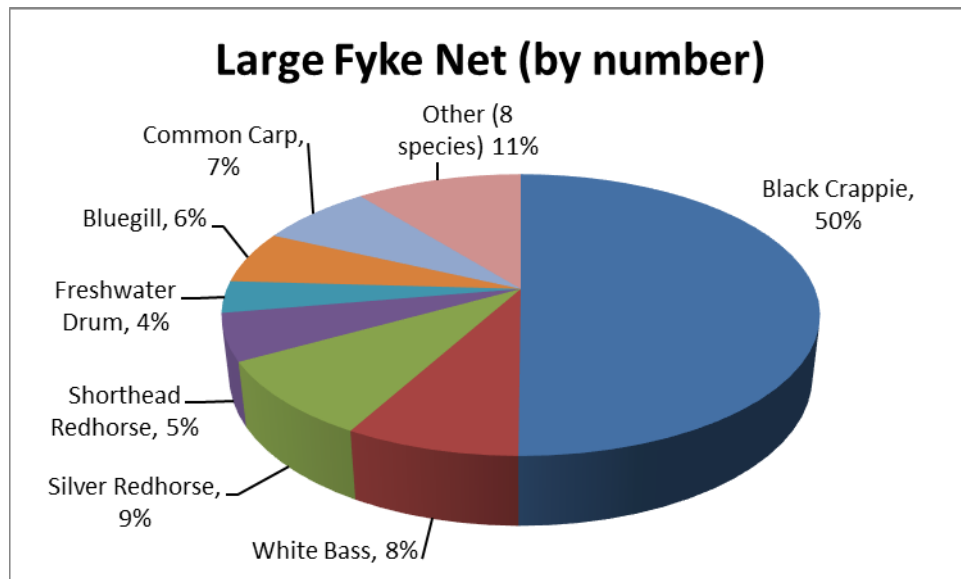


Figure 11. The percent catch by number of fish caught in large fyke nets on the Mississippi River Pool 2 during 2013.

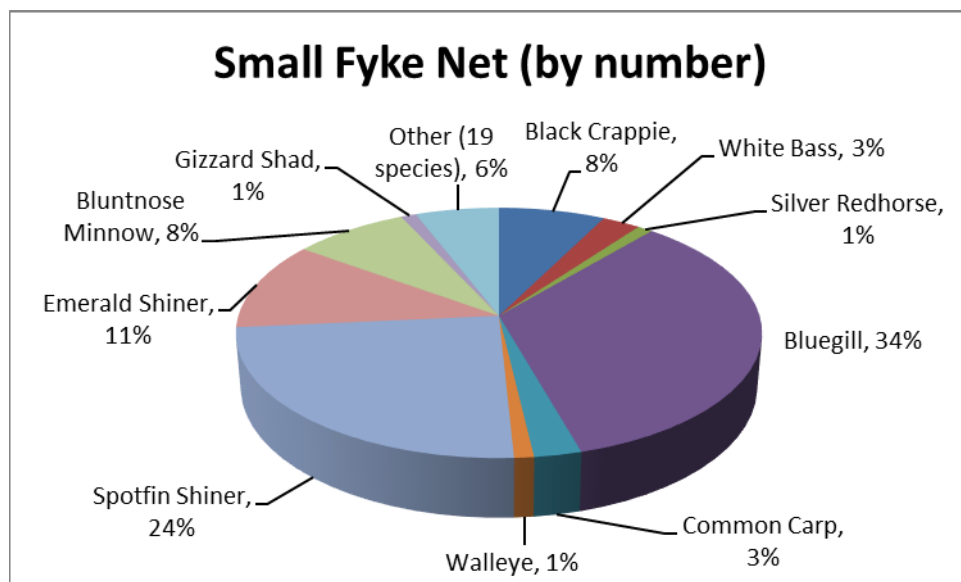


Figure 12. The percent catch by number of fish caught in small fyke nets on the Mississippi River Pool 2 during 2013.

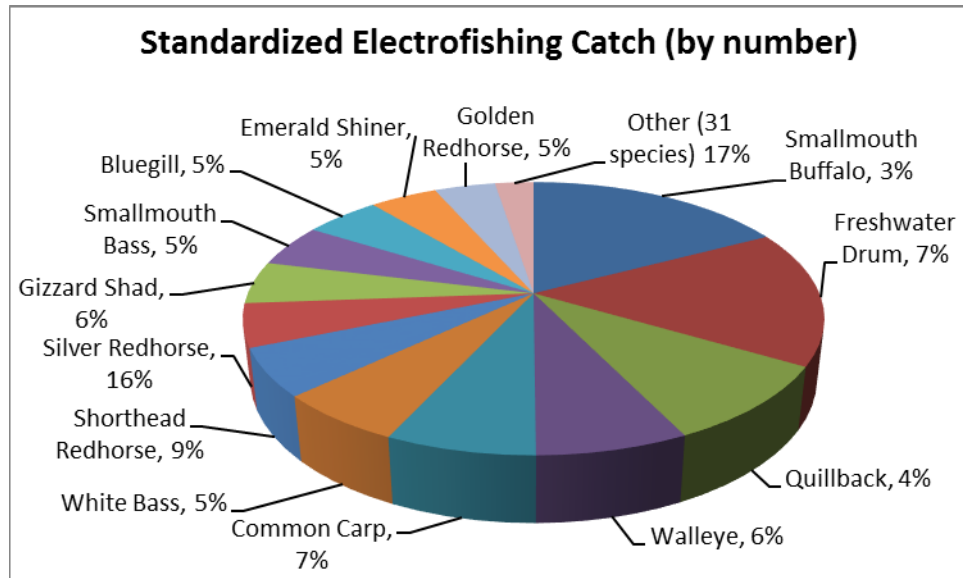


Figure 13. The percent catch by number of fish caught during standardized electrofishing on the Mississippi River Pool 2 and St. Croix River during 2013.

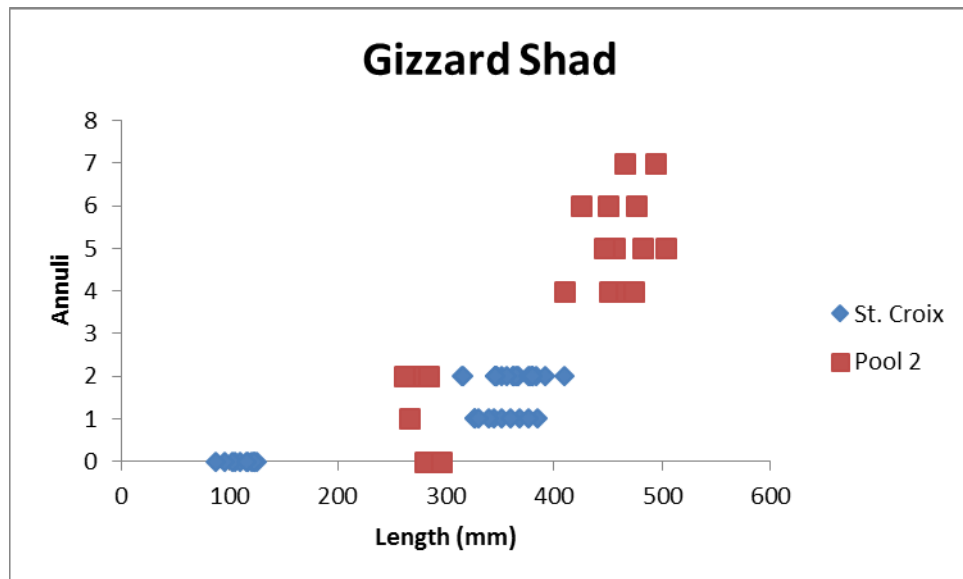


Figure 14. Preliminary age and growth analyses of Gizzard Shad using lapillus otoliths in Pool 2 of the Mississippi River and the St. Croix River. A total of 20 Gizzard Shad were aged from Pool 2 and 43 from the St. Croix.

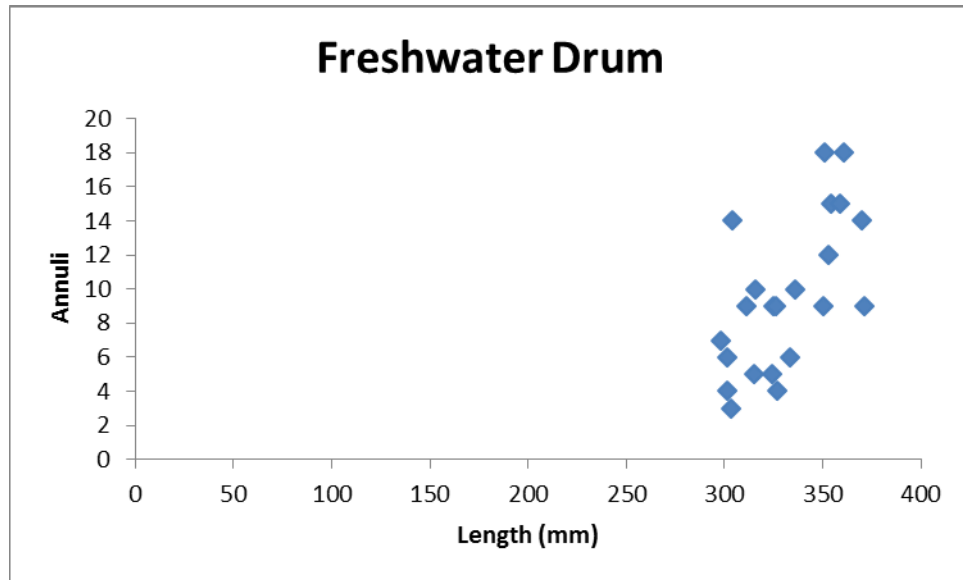


Figure 15. Preliminary age and growth of Freshwater Drum using lapillus otoliths in Pool 2 of the Mississippi River. A total of 22 Freshwater Drum were aged from Pool 2.