# DISTRIBUTION AND POPULATION DYNAMICS OF ASIAN CARP IN THE UPPER MISSISSIPPI RIVER

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**Geographic Location:** The study area of this project is the reach of the Upper Mississippi River along the southeast border of Iowa, USA and its major tributaries (Des Moines, Skunk, Iowa, Rock, and Wapsipinicon Rivers) from Pool 20 at Keokuk, IA to Pool 14 at the confluence of the Wapsipinicon River (Figure 1).

**Lead Agency:** Iowa DNR and Iowa State University

**Statement of Need:** Successful expansion and establishment of Asian carp depends on the ability for adults to travel to unestablished areas, and their ability to successfully reproduce in those new areas. Asian carp reproduction requires long stretches of sustained flowing water, and the impounded pools of the Upper Mississippi River (UMR) may limit successful reproduction. However, Asian carp eggs and larvae have been documented in parts of the UMR, and densities of adults are thought to be increasing in their invaded range. The southeast border of Iowa, USA is at the invasion front of Asian carp, and more information is needed on how these fish are expanding and reproducing along this portion of the UMR. Tributaries of the UMR throughout southeast Iowa are thought to be sources of successful reproduction events for Asian carp in the UMR, and evidence of this relationship has been documented in the Des Moines, Skunk, and Iowa Rivers (Camacho 2016). Further evaluation of both adult and egg/larval Asian carp in the UMR is needed in order to determine potential sources and drivers of range expansion and successful recruitment for these species. Detection of Asian carp range expansion and successful spawning events both spatially and temporally throughout the UMR will be important for developing more well-informed management strategies for these invasive species.

Project Objectives:

1) Evaluate Asian carp reproduction in pools 14, 15, 16, 17, 18, 19, 20 and the contribution of the Wapsipinicon, Rock, Iowa, Skunk, and Des Moines rivers to Asian carp reproduction (egg, larval and juvenile densities).
2) Evaluate adult population characteristic (abundance, distribution, size structure, condition) and dynamics (recruitment, growth, mortality) of Asian carp in pools 14, 15, 16, 17, 18, 19, and 20 of the Upper Mississippi River.

Project Highlights:

- Egg densities (all species of fish) across sampling sites peaked during May 30$^{th}$ but a second pulse of eggs was also detected late in the year on July 25th. Larval densities (all species of fish) were highest on June 16$^{th}$ and 27$^{th}$, shortly after the initial peak in egg densities. The mouths of the Rock and Des Moines rivers tended to have higher egg

densities whereas the Mississippi River sites downstream of these tributaries had higher densities of larval fish. Egg densities tended to be higher in thalweg and channel border habitats, and larval densities were generally higher within the backwater and channel border habitats.

- Adult Asian carp caught in 2017 consisted only of Silver Carp and Grass Carp, but Silver Carp were by far the most abundant Asian carp species in the UMR. Relative abundance tend to decrease with increasing latitude, but are much higher below Lock and Dam 19 than above. Average size of Silver Carp was large at 699 mm and 3.99 kg, and average age was 7 years.

Methods:

Egg and Age-0 Fish Sampling

Asian carp eggs and age-0 fish were sampled in 2017 at 18 locations (Figure 1) approximately every 10 days depending upon river conditions from beginning of May until the end of August (12 sessions, with 54 tows per session). Sampling was not conducted when water levels were too high for safe boating or too low for boat access (only the Des Moines River mouth and the Keosauqua site on the final 3 sampling dates). Ichthyoplankton (0.5 m diameter net, 500 µm mesh) tows 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 mounted in the mouth of the net to estimate volume ($m^3$) 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 (>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 fish (larvae and juveniles) were separated from debris. Asian carp larvae are difficult to distinguish among species and are being identified to genus using meristic and morphometric characteristic (Chapman 2006, Chapman and George 2011). Age-0 fishes were first categorized as larval or juveniles based on fin development. Fish recognized as having a full complement of fins are categorized as juvenile fish. All age-0 fish are currently being identified to the lowest possible taxa using morphometric and meristic characteristics described in literature (Auer 1982).

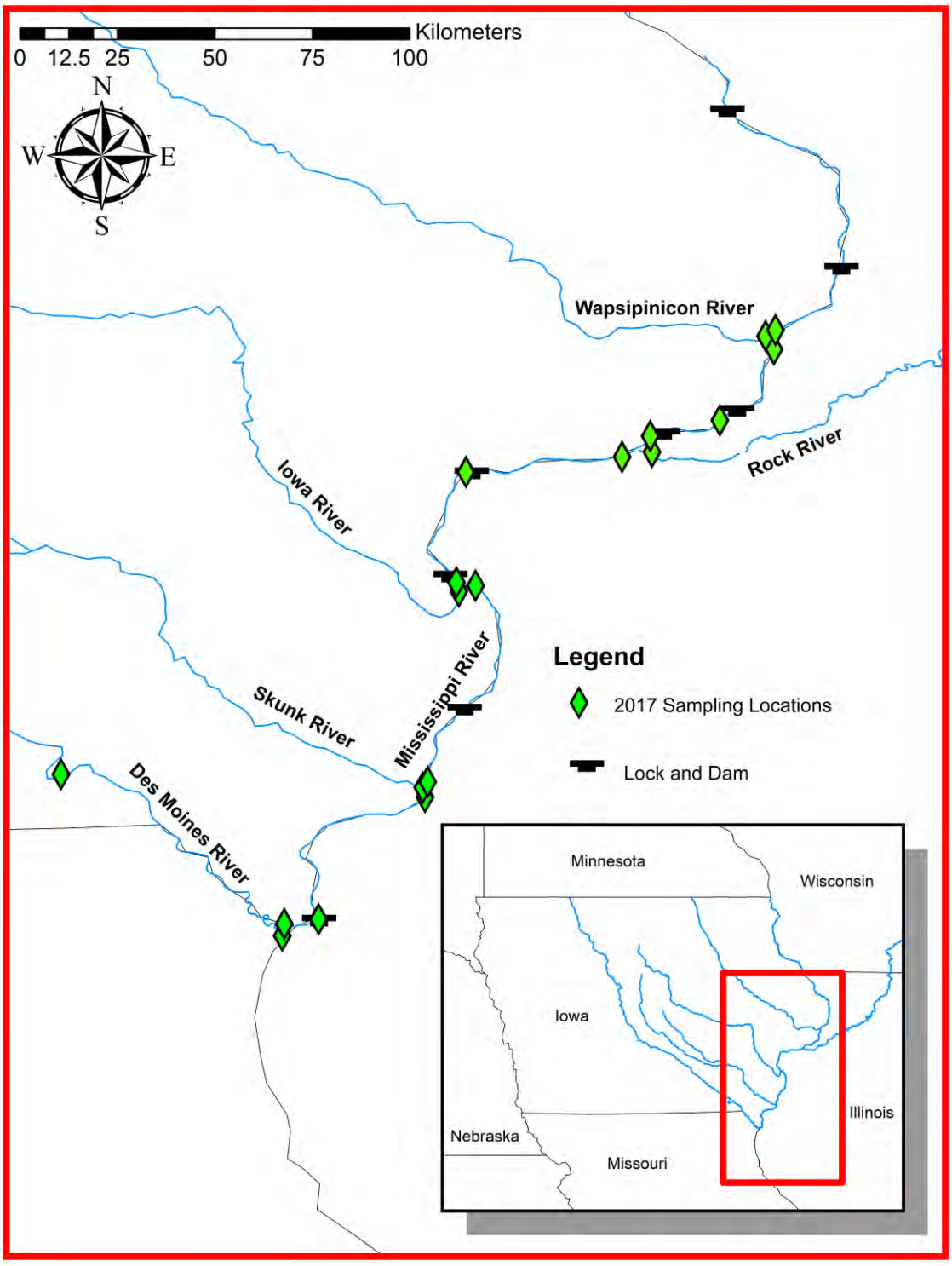


**Figure 1.** Map of study area on the southeast border of Iowa with the 18 sampling sites of larval fish and adult Bigheaded Carp indicated by green diamonds. Mississippi River lock and dams within our sampling reach in black.

Adult Asian Carp Sampling

Sampling for adult Asian carp took place in October and November of 2017 in Pools 14 – 20 of the UMR, including the mouths of five (Des Moines, Skunk, Iowa, Rock, and Wapsipinicon Rivers) major tributaries (Figure 1). Sites were chosen so that samples were obtained from upstream, downstream, and within the mouths of each of the major tributaries, as well as at least one site in every UMR Pool within our study reach. Daytime boat electrofishing (pulsed DC; amps 4-13, voltage 100-500) was used to target backwater and channel border habitats generally less than 4 meters deep where Asian carp have been shown to typically inhabit. Electrofishing transects (varying effort and transect numbers) are conducted until approximately 150 Silver Carp are captured (Pool 20) or until all available habitat at the electrofishing site is been sampled.

Adult Asian carp were identified as Silver, Bighead, or Silver x Bighead Carp hybrid using meristic and morphometric features, weighed (0.001 kg), measured (total length; 1 mm), and the first pectoral fin spine on each side and lapillus otoliths (up to 150 fish/site) were removed for age and growth analysis. Sex was determined based on visual inspection of gonads (male, female, immature, or unknown).

Lapillus otoliths were air dried at room temperature for at least four weeks following collection before being mounted in epoxy. A 1-mm thick cross section at the nucleus was cut using a Buehler Isomet low-speed saw (Isomet Corporation, Springfield, VA) with the anterior portion of the otolith oriented perpendicular to the blade. Wetted 2,000-grit sandpaper was used to polish each side of the cross section. The section was then placed in immersion oil to improve clarity and annuli viewed under a dissecting microscope with transmitted light. Lapillus otoliths were independently aged by two experienced readers with no knowledge of fish length, estimated age of other structure, or source river. If the readers disagreed, then a common age was decided in unison.

Results and Discussion:

Eggs and Age-0 Fish

In 2017, a total of 627 ichthyoplankton tows were completed. Eggs were collected during every sampling session for a total of 8,619 eggs in 2017. The largest numbers of eggs throughout 2017 were collected during the third sampling event (May 30$^{th}$ - June 1$^{st}$; 2.26 ± 1.16 SE) with a total of 3,243 eggs (Figure 2). Eggs were found in each river and every site except the backwater habitat of the Wapsipinicon mouth. A total of 429 tows were taken from the Mississippi River for a total of 5,569 eggs. An additional 201 tows were taken within the tributary mouths that captured 3,050 eggs (DSM-KQA = 421 eggs, DSM-MTH = 577 eggs, SKK-MTH = 272 eggs, IAR-MTH = 117 eggs, ROC-MTH = 1,656 eggs, WAP-MTH = 7 eggs). Mean egg density by site was highest within the Rock River (ROC-MTH) and lowest within the Mississippi River upstream of the Des Moines River (Figure 3). Across all habitats and sites, the highest egg

density (4.74 ± 4.70 SE) was found within the thalweg of the ROC-MTH (Figure 4), although catches at this site throughout the year were highly variable.

A total of 72,405 age-0 fish (combination of larvae and juveniles) were captured with ichthyoplankton tows throughout 2017. The highest densities of age-0 fish were collected on June 8th (17.54 ± 3.11 SE, 22,888 fish) and 27th (15.58 ± 8.54 SE, 16,079 fish; Figure 2). The two sessions with the highest mean density of age-0 fish were captured within thirty days of the highest eggs density in 2017. The lowest density of age-0 fish throughout all the sessions (0.17 ± 0.03 SE) was captured March 10th.

Age-0 fish were sampled from every river during 2017. The majority of age-0 fish (97%, 70,152 fish) were collected from sites within the Mississippi River downstream of tributaries, whereas only 3% (2,253 individuals) were collected from within tributaries. Mean densities of age-0 fish were higher within the Mississippi River downstream of tributaries than its tributaries (Figure 3). Larval densities were highest within the backwater or channel border throughout 2017. The highest mean density of age-0 fish within the Mississippi River backwaters (60.74 ± 36.97 SE) was collected downstream of the Des Moines River (UMR-DND), followed by (44.2 ± 36.97 SE) downstream of the Rock River (UMR-DNR). The mouth of the Wapsipinicon River (WAP-MTH), had no age-0 fish collected from the backwater habitat throughout 2017. That site also had the lowest density of age-0 fish collected in 2017 within the thalweg (0.005 ± 0.004 SE; Figure 5).

Peak egg densities during the spring of 2017 (May 30th - June 1st) followed by a peak of high larval fish densities (June 16th) was also observed within sampling during 2016. Although eggs collected during 2017 have not been genetically identified, peak mean egg densities in 2016, during May 30th, contained genetically identified Asian carp. This timing coincides with Asian carp spawning, triggered by high levels of discharge and water temperatures above 17°C. Successful Asian carp reproduction within the UMR from the Mississippi River and major tributaries has been observed in previous years (Camacho 2016).

High larval fish densities within backwater and channel border habitats is consistent with life history characteristics of juvenile fish due to their relative abundance of food, refuge from high water currents, and potential predators. Only two sites (UMR-P15 and UMR-UPR) found a higher density of larval fish within the thalweg habitat (Figure 5). Larval fish in these thalweg habitat could be due to poor quality and quantity of refuge habitats. Additionally, fluctuations of river discharge can flush larvae out of their preferred habitats in high flow events.

All ichthyoplankton samples from 2017 have been sorted into categories of yolk-sac larvae, larvae, and juveniles. Identification of age-0 fish is currently in progress. Once eggs and larvae collected in 2017 are identified, this data will add to previous research across similar sites, and provide a better understanding of Asian carp reproduction within the UMR. Further sampling of

adult and larval fish will provide additional insight into how populations are recruiting within the UMR and further define a more fine-scale location of the Asian carp invasion front in the UMR.

Adult Asian Carp Population Characteristics and Dynamics

A total of 161 Asian carp were collected from the DSM-MTH, IAR-MTH, UMR-P17, and ROC-MTH sites during a total of 7.03 hours of electrofishing across all sites in 2017. The DSM-KQA site was not sampled for adult Asian carp due to hazardous conditions resulting from low flows throughout fall 2017. The DSM-MTH sites accounted for 94% (152 fish) of all Asian carp captures, while the IAR-MTH sites accounted for 4% (6 fish), the ROC-MTH sites accounted for 1% (2 fish), and UMR-P17 accounted for 1% (1 fish). Silver Carp made up 96% (154 individuals) of total Asian carp captures across all sites, and Grass Carp made up 4% (7 individuals). No Bighead Carp or Black Carp were captured across all sites in 2017. Catch per unit effort (CPUE; fish/hr) for both Silver Carp and Grass Carp was highest at the DSM-MTH sites (Table 1). Catches of Grass Carp were low and similar across sites, and did not show any spatial trend. Catches of Silver Carp were very high below Lock and Dam 19 (LD19), and dropped to zero at all sites above LD19 except at the IAR-MTH sites. Of the 154 Silver Carp captured across all sites in 2017, 97% (150 individuals) came from the DSM-MTH sites, while the other 3% (4 individuals) came from the IAR-MTH sites. Although no Silver Carp were captured at the SKK-MTH sites, approximately 30 individuals were seen jumping out of reach of the netters. Additionally, approximately 10 other Silver Carp were observed jumping at the IAR-MTH.

Silver Carp ranged in size from 427 mm to 966 mm (mean = 699 mm), and from 0.836 kg to 10.120 kg (mean = 3.99 kg). Silver Carp size structure was lower at the IAR-MTH sites than the DSM-MTH sites, but low sample size at IAR-MTH (n=4) should be taken into consideration (Figure 6). Mean Grass Carp size structure was relatively similar across sites, but showed a slight increasing trend with latitude (DSM-MTH = 802 mm, IAR-MTH = 837 mm, UMR-P17 = 928 mm, ROC-MTH = 643 mm) except for the ROC-MTH where it was the lowest (Figure 7). Ages of Silver Carp ranged from 1 to 11 years (Figure 8), and mean age of fish at DSM-MTH (mean = 6.9 years old) was much higher than IAR-MTH (1 year old). Interestingly, Grass Carp tended to decrease in mean age at the farther North sites (Figure 9).

Although no Asian carp were caught at the SKK-MTH sites in 2017, observational data and trends from previous years show a decreasing gradient of Asian carp density as we move north from LD19. All four individual Silver Carp collected at the IAR-MTH sites in 2017 were captured at the same time and place, and were of the same age. The size structure of Silver Carp observed at the IAR-MTH sites in our samples is unusual and may not likely a true representation of the population size structure, especially given that this trend contradicts patterns observed in previous years of data.

Silver Carp are by far the most abundant Asian carp species in the UMR. Populations below LD19 are however much higher than those above. Given that LD19 is the only high-head dam in our study reach, it is likely the main deterrent of Silver Carp rapid population growth in the farther north sites. Although populations above LD19 are not as high, concern should be rising for the ecological integrity of these sites as Asian carp densities slowly grow. If the large sizes and densities of Silver Carp below LD19 are a foreshadowing of populations above, sport and commercial fisheries as well as recreational boaters will all be affected.

**Recommendation:** Tracking reproduction and recruitment is important to gage the long-term success of harvest, identify large reproductive events, identify recruitment sources and habitat, and monitor the reproductive front upstream. Assessing reproduction along the invasion front should continue to identify environmental (e.g., floods) or human (e.g., harvest) factors that may result in large year-classes, subsequently leading to population growth and expansion.

References:

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Chapman, D. C. 2006. Early development of four cyprinids native to the Yangtze River, China:U.S. Geological Survey Data Series 239.

Chapman, D. C., and A. E. George. 2011. Developmental rate and behavior of early life stages of Bighead Carp and Silver Carp: U.S. Geological Survey Scientific Investigations Report 2011–5076.

**Table 1.** Electrofishing catch per unit effort (CPUE, fish/hr, mean ± 1 SE) of Asian carp in the UMR in 2017. Individual CPUEs were calculated for each transect and averaged. No Bighead Carp were captured in 2017.

| Site Code | Transects | Total Effort (hr) | Silver Carp Catch | Silver Carp CPUE ± SE | Grass Carp Catch | Grass Carp CPUE ± SE |
|---|---|---|---|---|---|---|
| WAP-MTH | 1 | 0.570 | 0 | 0 | 0 | 0 |
| UMR-P15 | 1 | 0.661 | 0 | 0 | 0 | 0 |
| ROC-MTH | 3 | 1.809 | 0 | 0 | 2 | 0.92 ± 0.92 |
| UMR-P17 | 3 | 1.045 | 0 | 0 | 1 | 0.85 ± 0.85 |
| IAR-MTH | 4 | 0.894 | 4 | 3.14 ± 3.14 | 2 | 2.11 ± 2.11 |
| SKK-MTH | 7 | 1.299 | 0 | 0 | 0 | 0 |
| DSM-MTH | 3 | 0.752 | 150 | 228.77 ± 117.48 | 2 | 2.74 ± 2.74 |

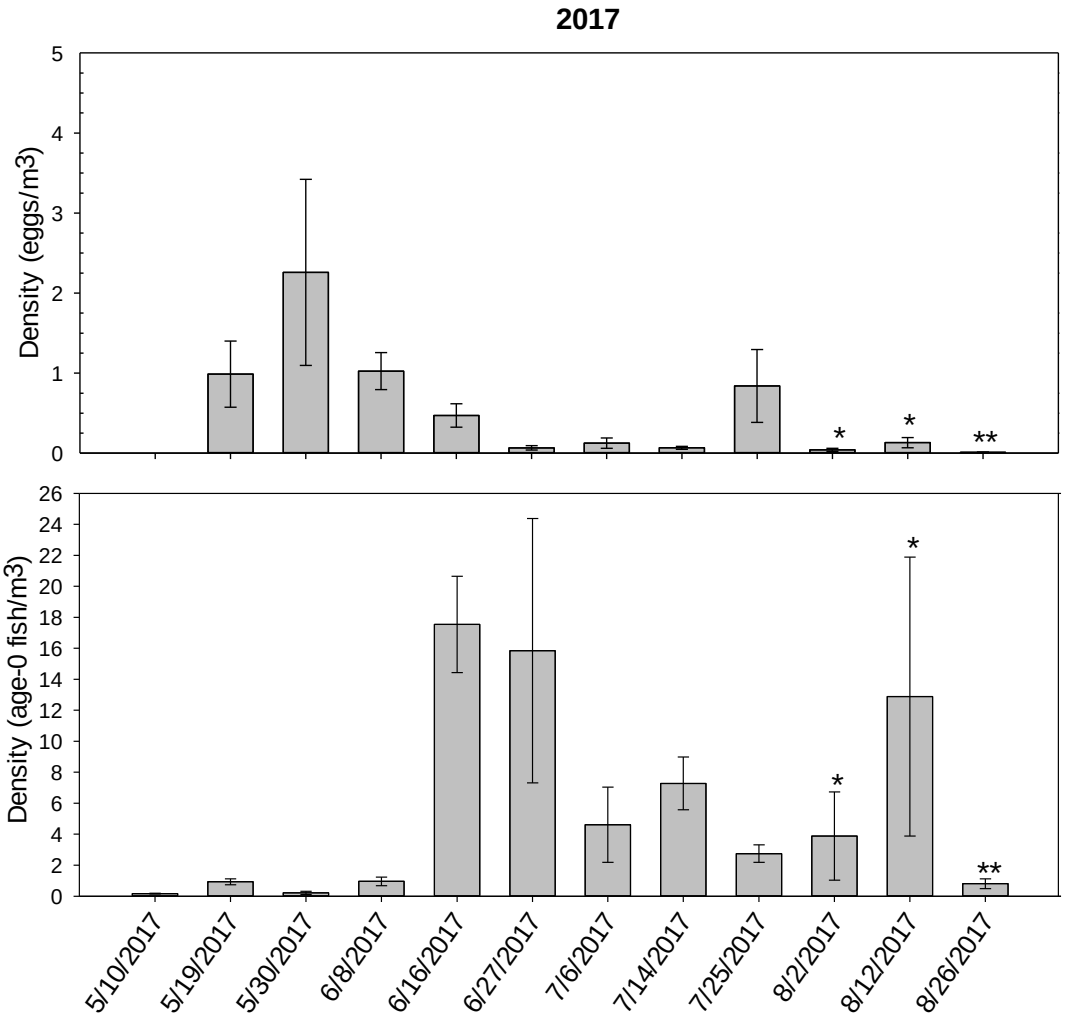


**Figure 2**. Density (mean ± 1 SE) of eggs (top) and age-0 fish (bottom) collected between April 29 and September 8, 2017.

* DSM-KQA was not sampled during this session due to low flows.

**DSM-KQA, UMR-UPD, and DSM-MTH were not sampled due to unsafe weather conditions.

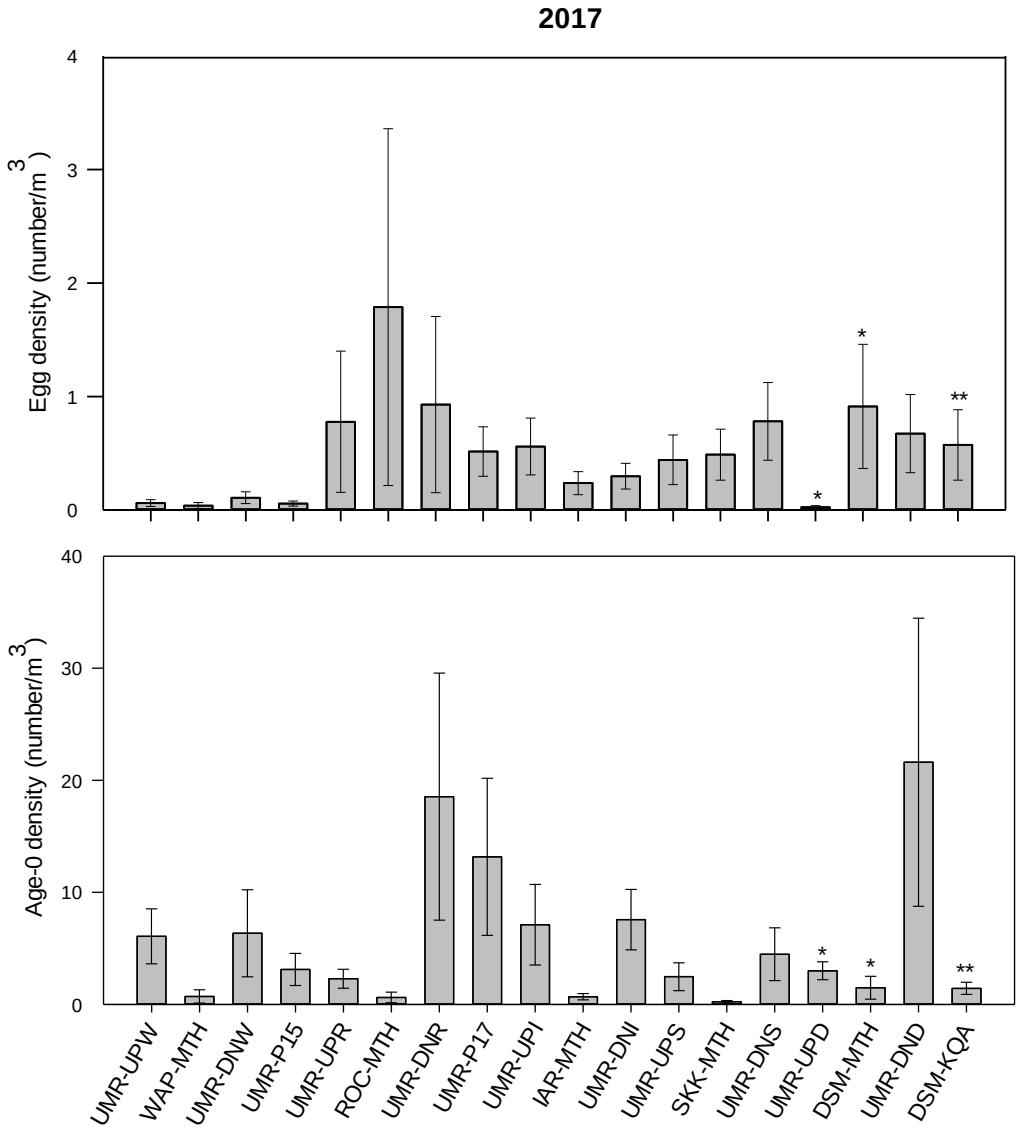


**Figure 3.** Densities (mean ± 1 SE) of eggs (top) and age-0 fish (bottom) collected from each site during 2017. Site codes are expressed in the first three letters by the river they are sampled within: UMR=Upper Mississippi River: WAP = Wapsipinicon River: ROC=Rock River: IAR = Iowa River: SKK=Skunk River: DSM=Des Moines River. The second set of letter give a more descriptive location of the site. All UMR Sites contain either UP_, or DN_ corresponding to 1 km upstream and downstream 1 km of a major tributary. For example WAP-MTH = the Wapsipinicon River at the mouth river: UMR-UPW = Upper Mississippi River, upstream 1 km of the Wapsipinicon: UMR-DNW = Upper Mississippi River, downstream 1km of the Wapsipinicon River. The only tributary with two sites is the Des Moines River, where the second site above the mouth DSM- KQA is located at the town Keosauqua.

*Site was not sampled on the last sampling session due to inclement weather.

**Site was not sampled during the last three sampling sessions due to low flows.

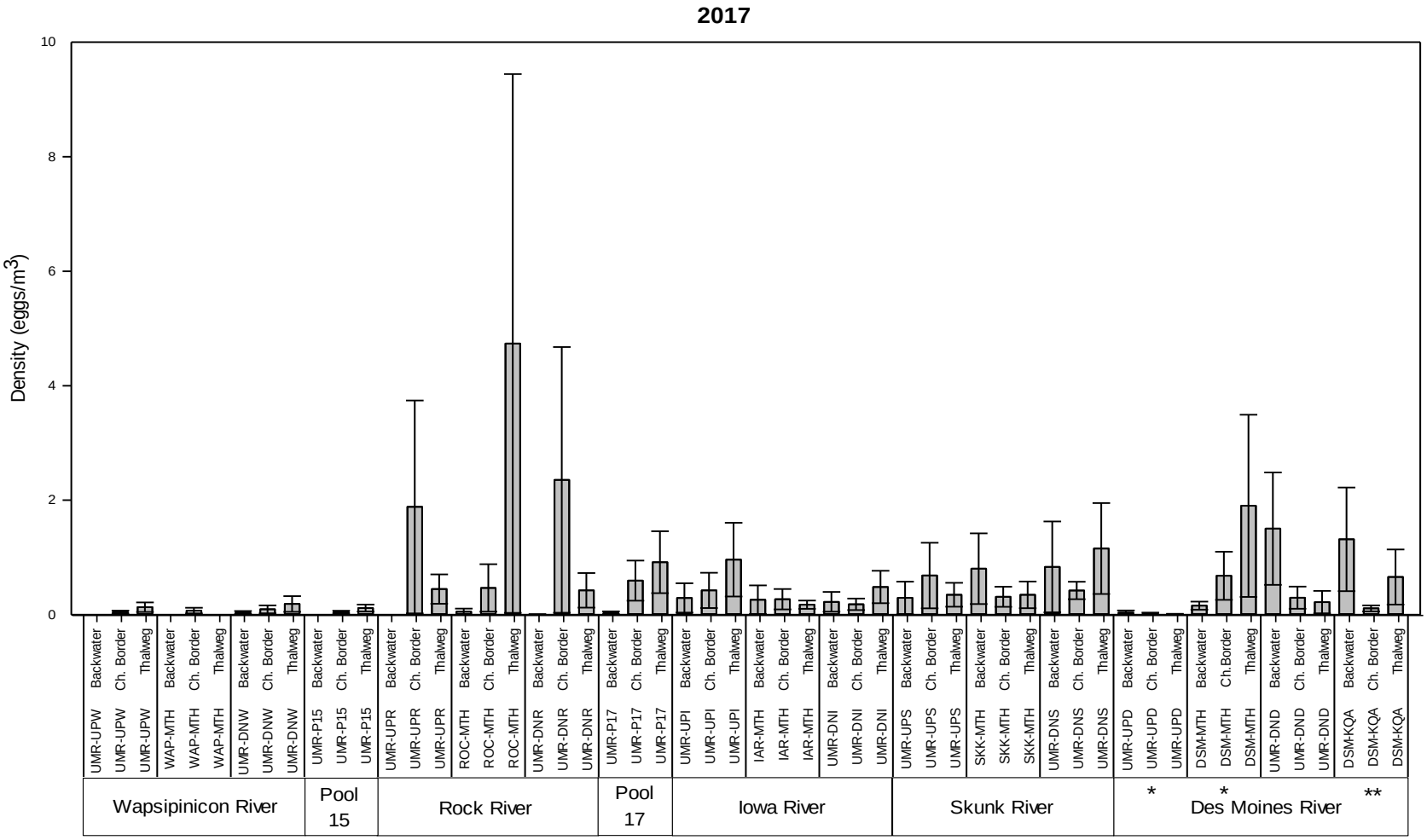


**Figure 4.** Egg densities (mean ± 1 SE) captured from backwater, channel border, and thalweg habitats in the sites sampled during 2017. Below each habitat is the site code of the site sampled. UMR (Upper Mississippi River), MTH (mouth of the tributary) P15 (Pool 15 of the Mississippi River). See Figure 3 for a more complete site label description.

*Sites were not sampled due to inclement weather during the final session during August 27th.

**Site was not sampled during the last 3 sampling sessions due to low flows.

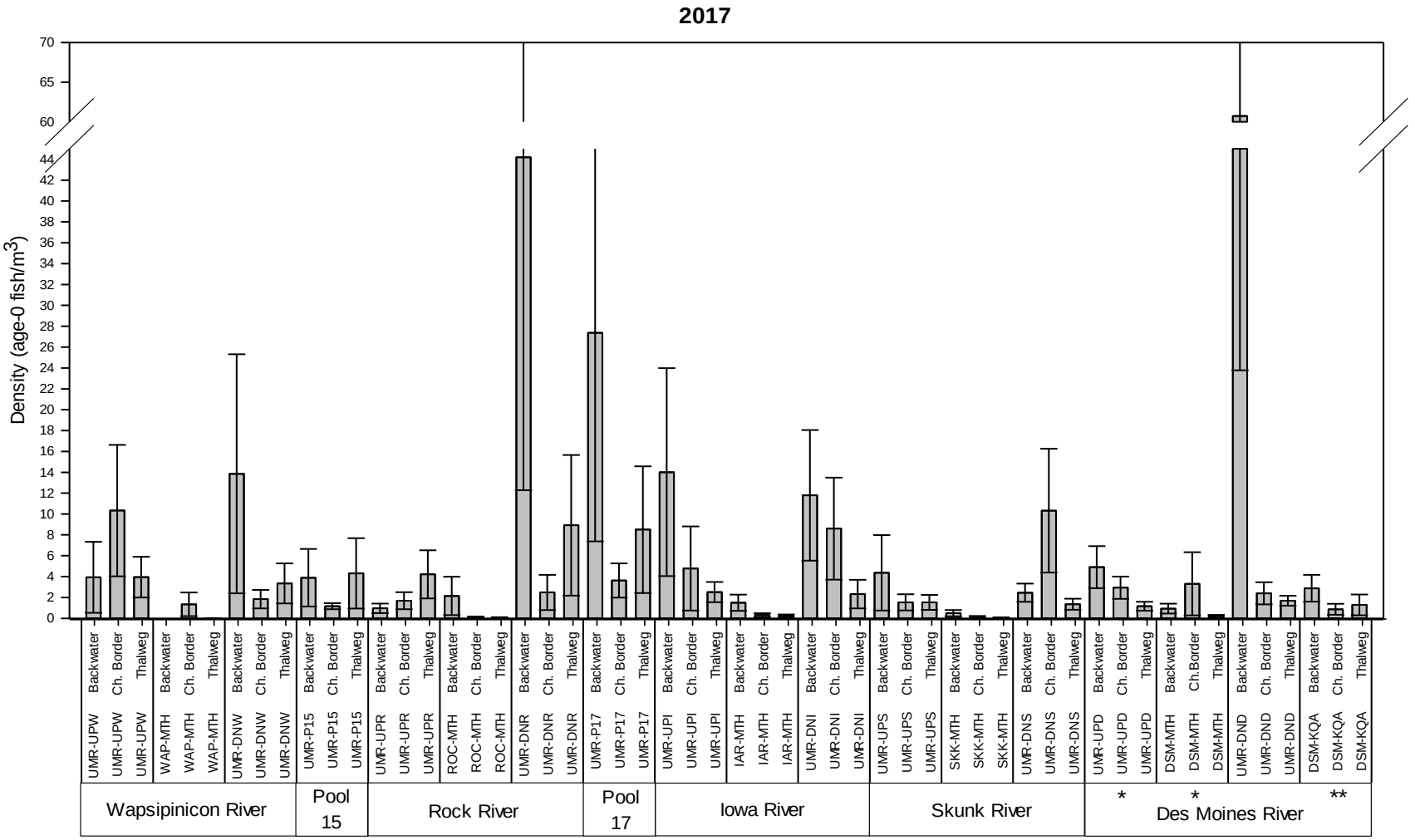


**Figure 5**. Age-0 fish densities (mean ± 1 SE) captured from backwater, channel border, and thalweg habitats in the sites sampled during 2017. Below each habitat is the site code of the site sampled. UMR (Upper Mississippi River), MTH (mouth of the tributary) P15 (Pool 15 of the Mississippi River). See Figure 3 for a more complete site label description.

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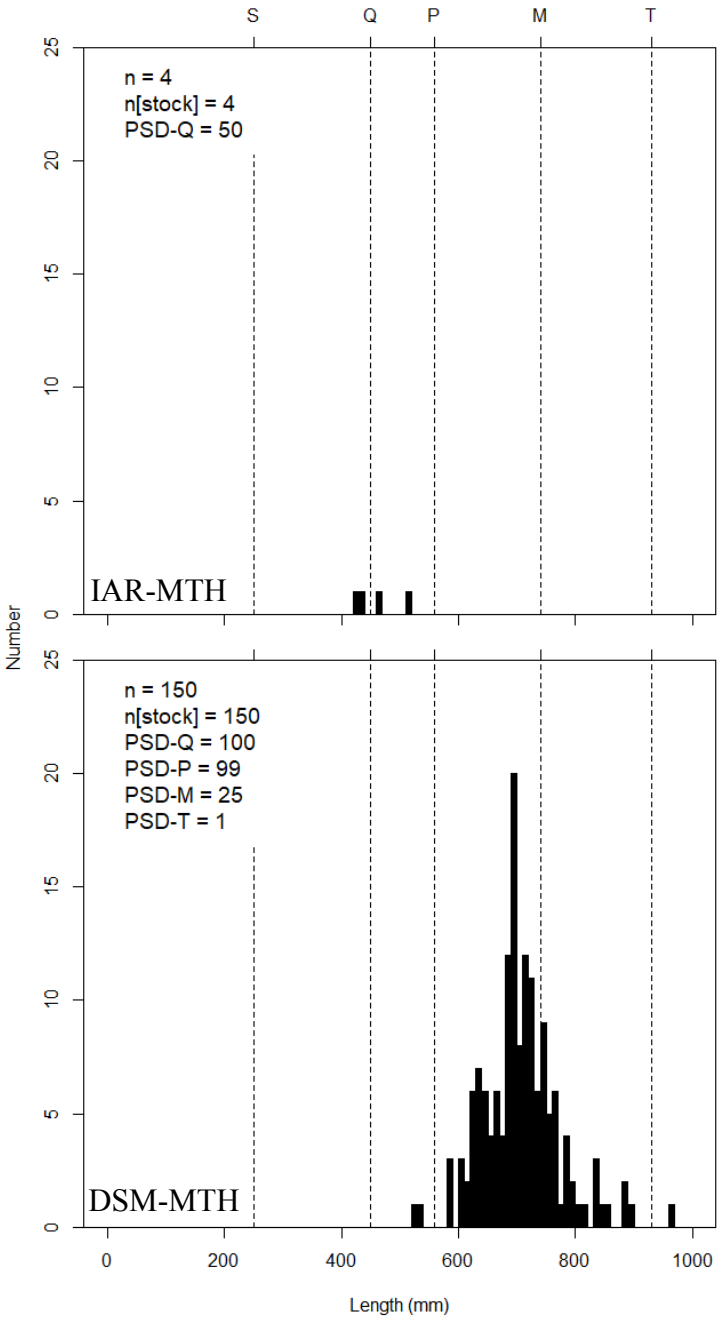


**Figure 6.** Silver Carp length-frequency histograms and proportional size distribution (PSD; S-Stock, Q-Quality, P-Preferred, M-Memorable, T-Trophy) indices of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH) and the Iowa River (IAR-MTH). No Silver Carp were captured at the mouths of the Skunk, Rock, or Wapsipinicon Rivers, or from Pools 17 or 15 of the Upper Mississippi River.

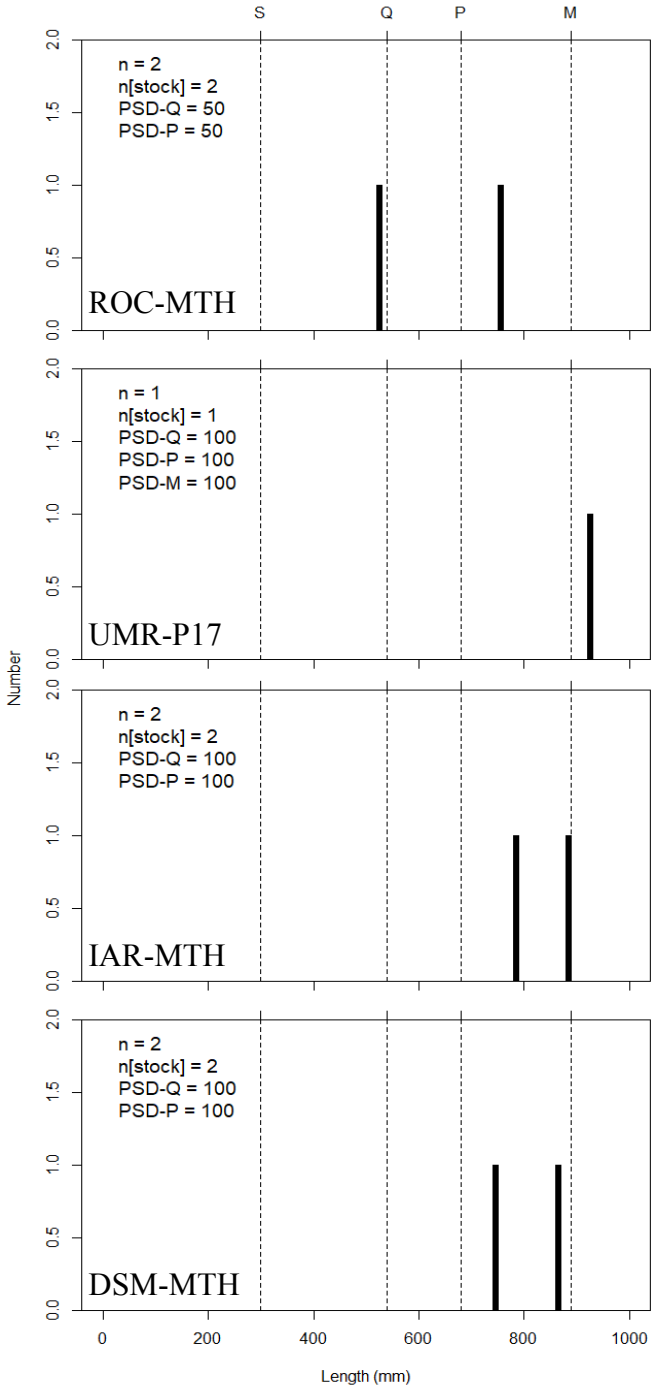


**Figure 7**. Grass Carp length-frequency histograms and proportional size distribution (PSD; S-Stock, Q-Quality, P-Preferred, M-Memorable, T-Trophy) indices of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH), Iowa River (IAR-MTH), and Rock River (ROC-MTH), as well as Pool 17 of the Upper Mississippi River (UMR-P17). No Grass Carp were captured at the mouths of the Skunk or Wapsipinicon Rivers, or from Pool 15 of the UMR.

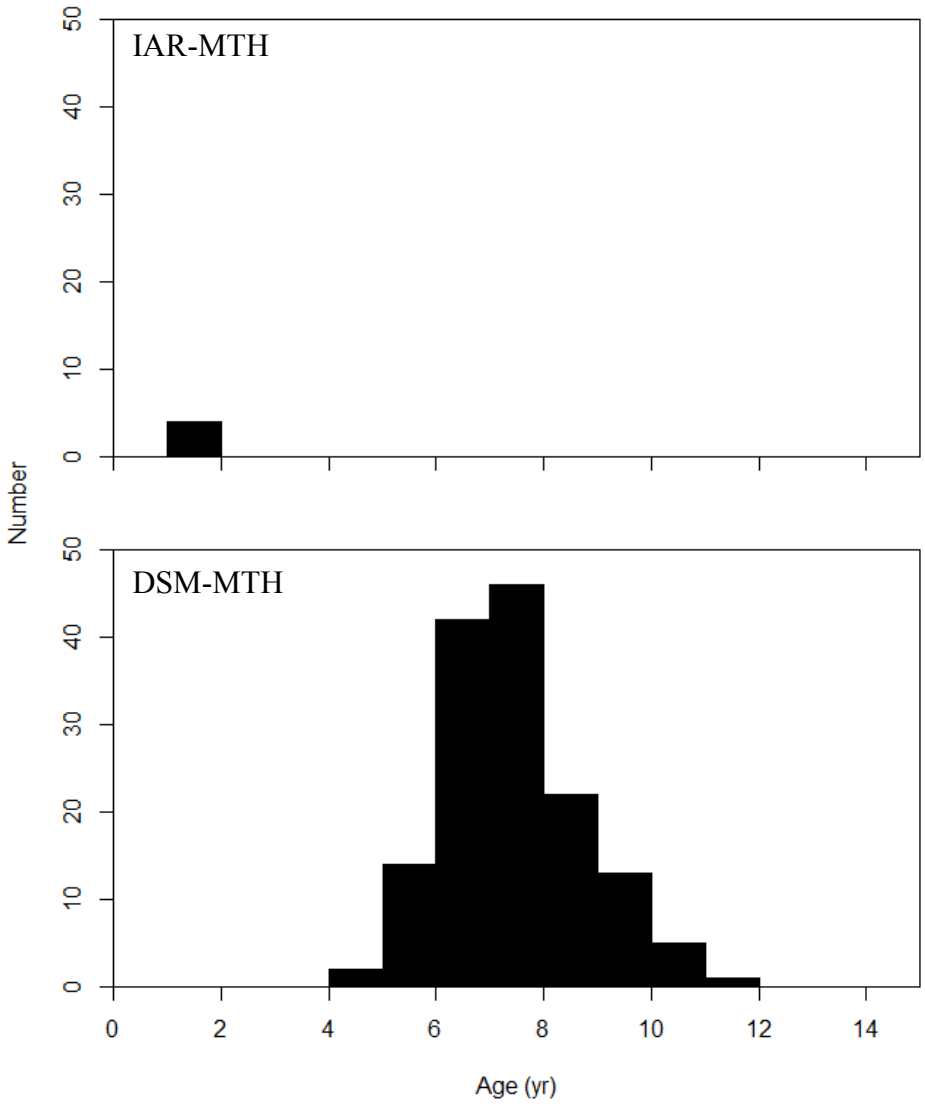


**Figure 8.** Silver Carp age-frequency histograms of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH) and the Iowa River (IAR-MTH). No Silver Carp were captured at the mouths of the Skunk, Rock, or Wapsipinicon Rivers, or from Pools 17 or 15 of the Upper Mississippi River.

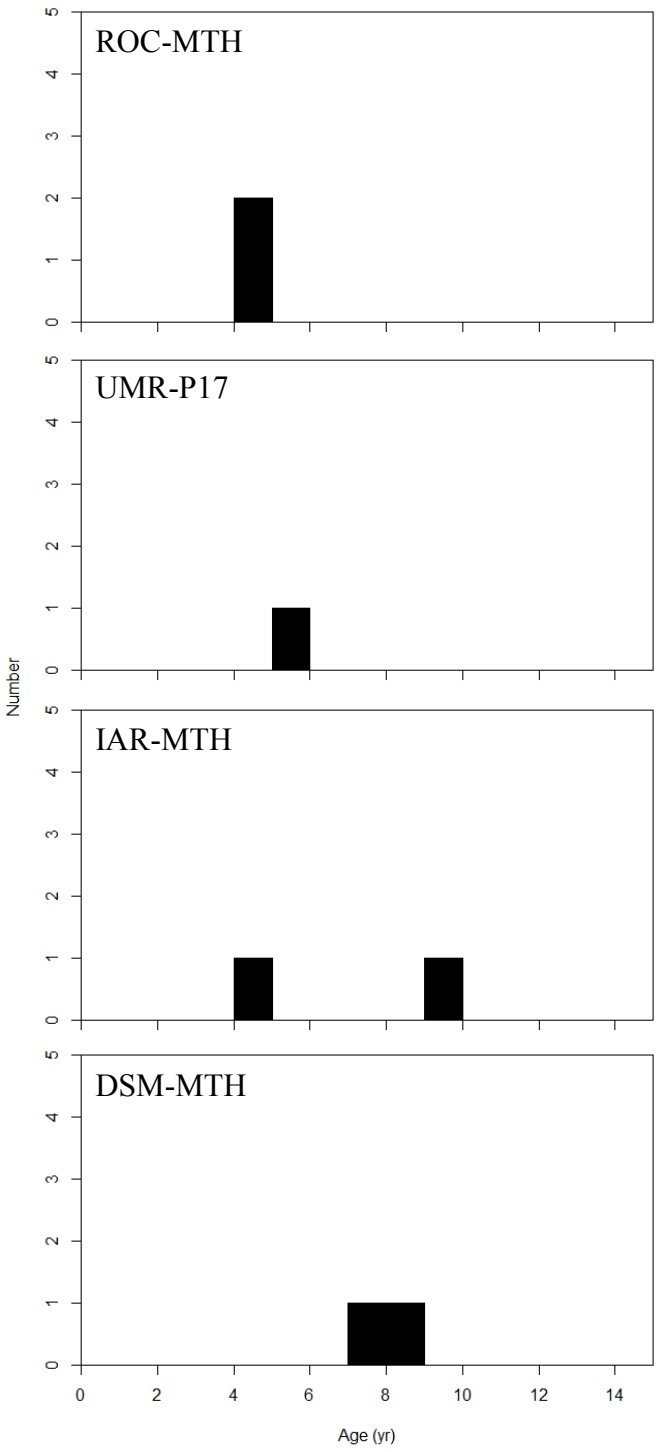


**Figure 9.** Grass Carp age-frequency histograms of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH), Iowa River (IAR-MTH), and Rock River (ROC-MTH), as well as Pool 17 of the Upper Mississippi River (UMR-P17). No Grass Carp were captured at the mouths of the Skunk or Wapsipinicon Rivers, or from Pool 15 of the UMR.