Identifying Overwintering Habitat of Silver and Bighead Carp in the Lower Mississippi River: Implications for Harvesting and Population Reduction

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Abstract

A total of 41 sites along a 58-mi reach of the Lower Mississippi River (LMR) were surveyed during winter 2022 for invasive carp aggregation. Sites consisting of scallops closest to the dike-vegetated bank interface with deeper, slow-moving water and consistent access back to the main channel were preferred. Carp avoided strong currents, and there was no trend in depth selection other than avoiding shallow (< 20 ft) water. In January 2023, recreation-grade sonar (e.g., side-scan and down-imaging) surveys were conducted in the same reach of the LMR to demonstrate the technology and evaluate carp population size at sites with high abundances based on previous surveys. Fish density was estimated to be 32 fish/10,000 yd3 (95% CI [31–34]) using down-imaging software, which is the first estimate of assumed bigheaded carp denisty in the LMR. Additonal fish collections are needed to confirm species composition and size abundance provided by sonar technolgy. Re-surveying sites with high carp abundance over a range of river stages would be necessary to fully characterize habitat conditions, evaluate influence of river stage on occupancy duration, and continue to evaluate species composition and mass removal techniques as a management option in the Lower Mississippi River.

Introduction

Invasive carp escaped into the Lower Mississippi River (LMR; near Vicksburg, Mississippi) in the 1970’s, or possibly before, and established reproductive populations (Kelly et al. 2011). Silver *Hypophthalmichthys molitrix* and Bighead Carp *H. nobilis*, collectively referred to as Bigheaded Carp, were initially documented in LMR research collections during the 1990’s and are now one of the most abundant large-bodied species in the LMR (Killgore and George 2020). After escaping into the LMR, their abundance and range quickly expanded into the Lower Mississippi River Valley, Missouri River, Upper Mississippi River, and Ohio-Tennessee Rivers, and they now threaten to invade the Great Lakes. Federal and State agencies are implementing control measures to reduce numbers as the invasion front continues to expand. However, continuous recruitment of Bigheaded Carp moving upstream from the LMR may render control measures ineffective in other watersheds. Perennial flow in the LMR provide virtually unlimited spawning sites, and extensive backwaters and lakes provide stable rearing areas with high productivity (Ochs et al. 2019). Bigheaded carp growth rates in the LMR exceed most other locations in the Mississippi River Basin (Killgore et al. 2024). If the goal of containing and controlling the expansion of invasive carp in the United States is ever to be realized, reduction of source populations in the LMR must be addressed.

Previous observations in the LMR during routine fisheries studies have suggested that invasive carp move downstream of dikes during the winter, sometimes in deep (>75 ft) holes, for the purpose of avoiding higher water velocities associated with mainstem river habitats. Considering that invasive carp often form tight schools, or aggregations, this behavior makes them particularly susceptible to harvesting. Colder water in the winter may also reduce their avoidance response to the deployment of fish capture gears. The LMR has approximately 800 stone dikes creating a wide range of bathymetric diversity (Killgore et al. 2014). Except for one LMR study of dike pools during summer low water conditions (Nailon and Pennington 1984), no other published information is available on fish associated with dike fields. Additional information on overwintering invasive carp in the LMR is warranted as a potential management option to locate large numbers congregated in dike fields that may be more susceptible to removal techniques.

A field study on the LMR near Vicksburg, Mississippi was conducted in 2022–2023 with the following objectives:

1. Locate large schools of Silver and Bighead Carp overwintering in the LMR associated with dike fields using recreation-grade sonar.
2. Describe the locations where carp are abundant based on water depth and dike field configuration.
3. Estimate the abundance of invasive carp using side-scan and down-imaging sonar.

This project supports multiple goals of the Lower Mississippi River Basin Invasive Carp Control Strategy Framework to manage and control invasive carp (Rodgers 2019). Identifying riverine habitats occupied by large numbers of invasive carp during winter temperatures when most fish are inactive provides an excellent opportunity for directed harvest techniques to reduce population size. Increased harvesting can potentially augment other containment and control efforts to minimize potential adverse effects of invasive carp in the Mississippi River and tributaries. This study will also provide information to the public, commercial entities, and government agencies to improve effective management and control based on accurate and scientifically valid information.

Methods

The first step was to develop bathymetric maps of the LMR reach near Vicksburg, MS (Figure 1) to facilitate boat surveys of dike fields representing a range of depths, velocities, and dike designs. Imagery of the LMR study area was obtained from the National Agriculture Imagery Program (https://naip-usdaonline.hub.arcgis.com/). Bathymetric data from river mile 360–495, including single and multi-beam survey data, along with dike locations were provided by USACE Vicksburg District or downloaded from eHydro (https://www.sam.usace.army.mil/Missions/Spatial-Data-Branch/eHydro/). Using Arc-GIS (ESRI 2021), imagery and bathymetric maps depicting depth contours primarily associated with dikes, including notched dikes, were developed for the LMR (Figure 2). The 2012 low-water aerial imagery was used to identify the notches and was helpful to locate the presence of a "deep" hole below the dike and determine if access to the deeper areas is blocked by an island or sand bar. We assumed that the presence of invasive carp in dike pools was controlled by accessibility during the fall at lower river levels and winter at low velocity.

Using the bathymetric maps, initial carp surveys were conducted during January–February 2022 in a 60-mi reach near Vicksburg (river mi 395–455). A Humminbird Solix sonar system with down-imaging and side-imaging (Johnson Outdoors, Racine, Wisconsin; 1200 kHz frequency) was used to locate schools of invasive carp in the study reach by observing concentrations of fish marks on the display (Ridgway et al. 2024). We presumed that these fish were invasive carp based on observations by Killgore and George (2020) and occasional sightings of jumping individuals in the study area. Maximum water depth was recorded at each survey location. Water temperature was measured during each sampling occasion with YSI ProDSS water quality meter (YSI Incorporated, Yellow Springs, Ohio). We classified invasive carp abundance based on the signature pattern on the Humminbird screen denoted as none, low to moderate, and high. Visual analysis of spatial clustering and density of targets were used to determine low to moderate abundance (scattered targets, less than 50% coverage on screen) and high abundance (densely spaced targets, greater than 50% coverage of screen).

In January 2023, the U.S. Geological Survey demonstrated the use of side-scan sonar and down-imaging sonar to locate and quantify fish including invasive carp (Ridgway and Fischer 2025). A dike pool in the study area was surveyed (278 yd reach) using a Humminbird Helix sonar system (Johnson Outdoors, Racine, Wisconsin; 1200 kHz frequency). The survey vessel followed a straight path along the dike structure at a rate of 3 mi/h. The transducer was mounted to the bow of the boat to avoid interference with the outboard motor. Sonar surveys including concurrent recordings of side-scan and down-imaging sonar, were saved to a single micro-SD card for data post-processing at a later time. Proprietary sonar data were converted to PNG image files (i.e., rectified and speed-corrected) using SonarTRX Pro (Leraand Engineering, Honolulu, Hawaii). Fish targets in imagery were measured (in) and enumerated using image analysis software (ImageJ; Ferreira and Rasband 2019) algorithms (e.g., Lawson et al. 2020). Side-scan and down-imaging datasets were processed multiple times across a range of sensitivity thresholds (i.e., 25–30) to incorporate variation in the sensitivity of fish detection and estimation. Total ensonified volume of down-imaging was used to compute fish density (fish/10,000 yd^3) as the sum of the product of beam coverage (yd^2; 75° isosceles; base height: mean water depth [yd]) and along track distance (yd) of rectified images. Fish less than 15.7 in were omitted to focus our analysis on fish-sizes similar to that of adult invasive carp typically greater than 15.7 inches.

Results and Discussion

Initial Survey

A total of 41 locations along the 58-mi reach near Vicksburg, MS were surveyed for invasive carp on January 26 and February 10, 2022 (Figure 1). Maps displaying relative abundance of invasive carp, dike locations, and river miles were prepared (Figure 1). River stage at Vicksburg during the survey period ranged from 19.1–31.2 ft; flood stage is 43 ft (Rivergages.com, https://rivergages.mvr.usace.army.mil/WaterControl/stationinfo2.cfm?sid=CE40EC2E&fid=ARSA4&dt=S). Water temperature during the survey period remained at 41 °F.

Bathymetric maps of the study area showing deep water habitats associated with dike fields aided in the selection of survey sites (Figure 2). We also utilized multi-beam survey data from the Vicksburg District when available to provide more detailed bathymetric coverage (Figure 2, right panel). Overall, the mean (± standard devision) depth surveyed was 50.8 ± 25.3 ft ranging from 10.0 to 121 ft.

The Humminbird was operating as we entered a dike pool, or in some cases, a deep scour hole not associated with dikes. However, we learned early that invasive carp were usually located downstream and close to a dike. The image on the Humminbird screen was diagnostic of invasive carp orientation patterns. Spatial clustering for high abundance was classified as a clumped dispersion in which individuals were tightly clustered together at high densities (Figure 3). Differences between low to medium abundance were more subjective and were combined in subsequent analysis. Surfacing Silver Carp were observed during the surveys, but no direct method was used at this time to confirm species identification and are assumed.

Mean depth of invasive carp locations, ranging from 49–56 ft, was not signficantly different among relative abudances (ANOVA, n=41, F=0.44, p=0.65; Figure 4). Maximum depth where invasive carp abundance was highest (81 ft) was less than sites without carp or abundances were low to moderate (110–121 ft). Carp avoided shallow (<20 ft) water, but had no apparent trend in occupying deeper water. This initial information indicates that over-wintering carp will occupy dike fields with a wide range of water depths (i.e., 20–80 ft) averaging around 50 ft.

Several observations on overwintering sites were recorded. Visual observations at sample locations indcated that carp avoided strong currents (approximately >0.5 m/sec) regardless of depth. Large schools were usually located downstream and next to a dike to avoid strong currents. Carp density was especially high below dikes with scallops, where flanking occurs downstream of the dike (Figure 5). Not all areas downstream of dikes with scallops had carp aggregations, suggesting other factors influence habitat selection.

Comparing aerial photography of scalloped locations at different river stages where invasive carp abundance was highest indicated that access to the channel at lower stages may also be an important habitat feature (Figure 5). Invasive carp may avoid scallops that can be accessed at higher stages but may become isolated at lower stages due to obstructions from sandbars or other stone structures. Therefore, based on our initial survey, preferred overwintering habitat appears to be scallops downstream and closest to the dike-vegetated bank interface with deeper, slow-moving water and consistent access to the main channel.

Application of Sonar

The demonstration of sonar clearly indicated that this technology has multiple uses in the LMR to estimate fish density, a population metric difficult to obtain in large rivers using traditonal methods. During the sonar demonstration, depth along the dike structure ranged from 11 to 65 ft. An estimated 327 (95% Confidence Interval [CI; 264–390]) fish targets were present in side-scan sonar imagery (n = 18 images; 278 yd x 77 yd total area), whereas 142 (95% CI [150–133]) were enumerated in down-imaging sonar. Down-imaging data estimated fish density at that time was 32 fish/10,000 yd^3 (95% CI [31–34]). We found that down-imaging sonar was well suited for detecting and enumerating fish in deepwater habitat such as dike pools because beam coverage increases with depth, and fish targets (particularly invasive carp) in the imagery are depicted in the water column (Figure 6). Furthermore, parameters necessary to compute ensonified volume and estimate fish density (i.e., fish per volume) are readily available with down-imaging sonar. Although the fish detection algorithm by Lawson et al. (2020) was originally developed for side-scan sonar, we found that only minor adjustments to the macro instructions (e.g., lowering "noise tolerance") are necessary for use in down-imaging sonar data (Figure 6); see Lawson et al. (2020) for a detailed description of the primary components of macro programming in ImageJ software and how to batch process sonar imagery. We assume bigheaded carps are the most dominant species in the study area (Killgore and George 2020). However, additional paried fish capture data (i.e., species, length, weight) could further reduce uncertainty.

Potential Next Steps

Our initial assessment concluded that invasive carp schools can be located in the LMR with recreation-grade sonar techniques. Some of these locations may be suitable for mass removal if techniques can be developed to capture large numbers of fish during cold water conditions. Additional repeated sonar surveys at various water stages may help to match capture efforts with the presence of high-density schools of invasive carp as well as when and where water conditions are amenable to capture techniques. Mapping the bathymetry of the entire LMR including the habitat features overwintering invasive carp prefer would be informative to harvest efforts and strategies in the region. Sonar data were processed using a screen-shot method; however, the data recording function may be used to record higher resolution imagery for data post-processing procedures (Lawson et al. 2020). In addition to size-based criteria, fish shape and morphology as well aggregation patterns (e.g., clustering, avoidance, and nearest neighbor distance) that may be detectible in sonar imagery and unique to invasive carp schools could be investigated to further reduce uncertainty in sonar estimates.

Disclaimers

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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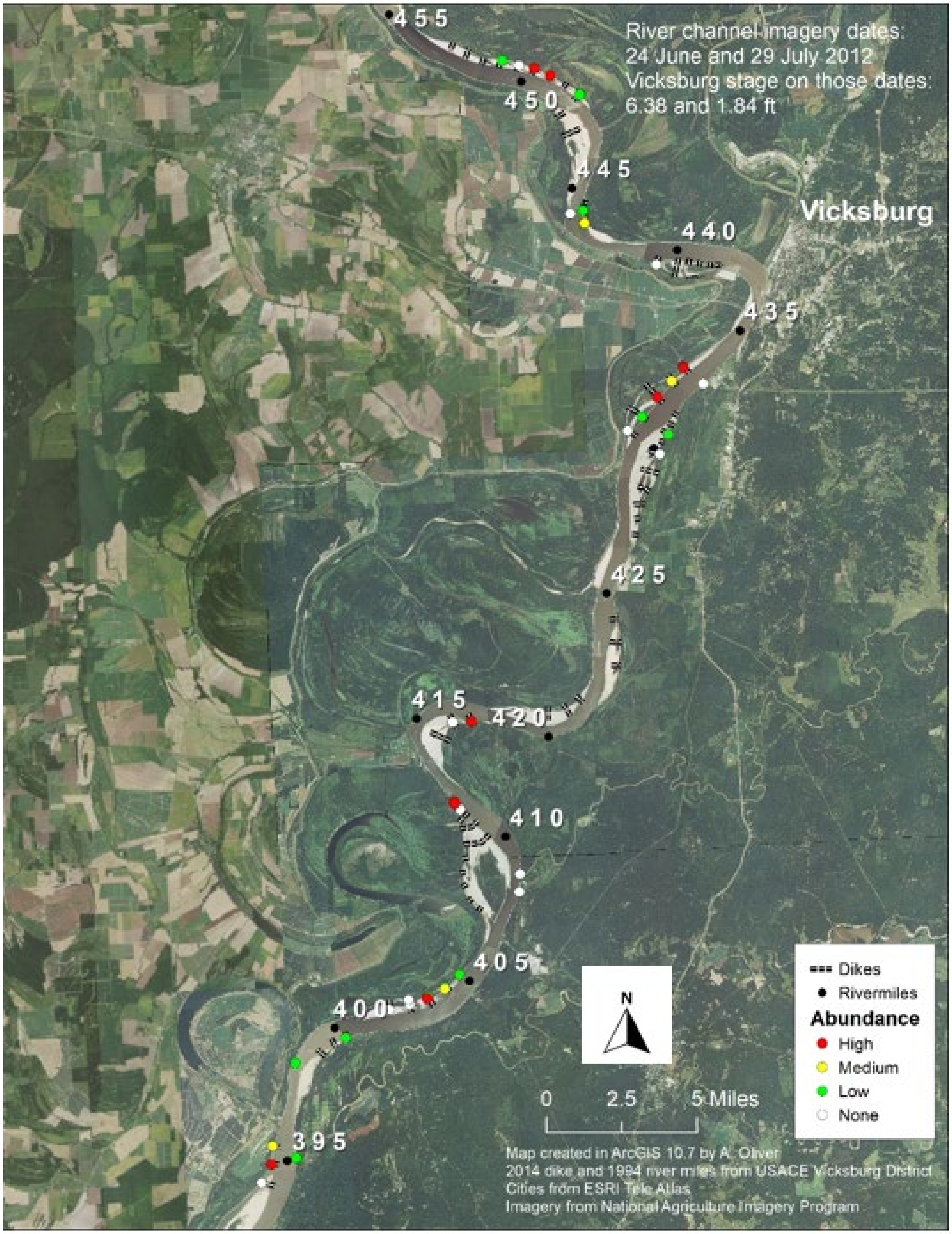

Figure 1. Google Earth map displaying the study reach near Vicksburg, Mississippi displaying the relative abundance of invasive carp (Hypophthalmichthys sp.) with dike locations by river mile. Low and medium abundances were grouped into "moderate" for final analysis.

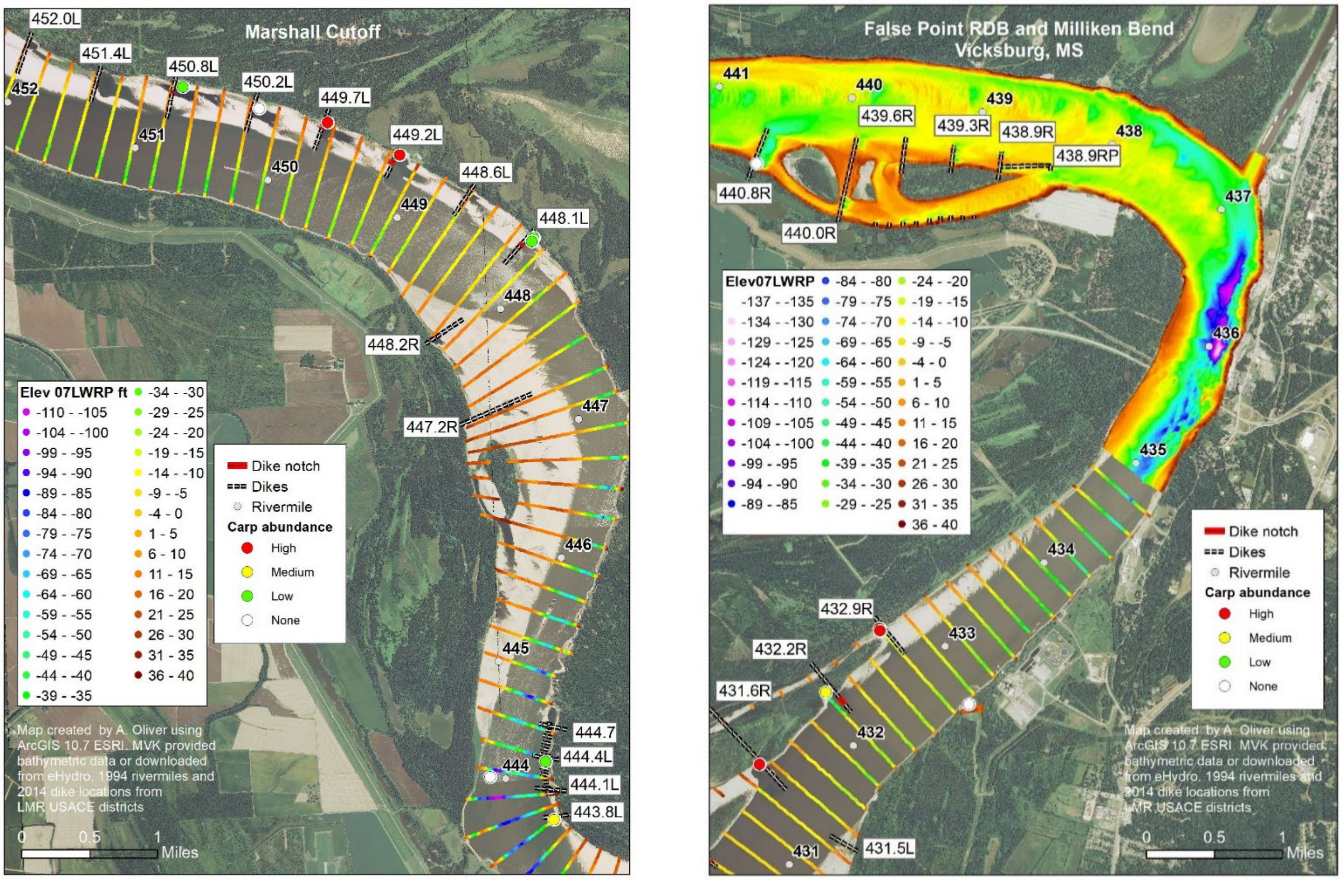

Figure 2. Example maps used to evaluate survey locations based on deep water habitat and presence of dikes (left panel), designation of invasive carp *Hypophthalmichthys* sp. abundance after survey was completed, and a comparison of mapping bathymetry using single-beam (right panel, bottom half) and multi-beam (right panel, top half) survey data. Low and medium abundances were grouped into "moderate" for final analysis.

Figure 3. Images of invasive carp displayed on the Humminbird screen. The relative abundance of fish would be rated as “high” for these three images.

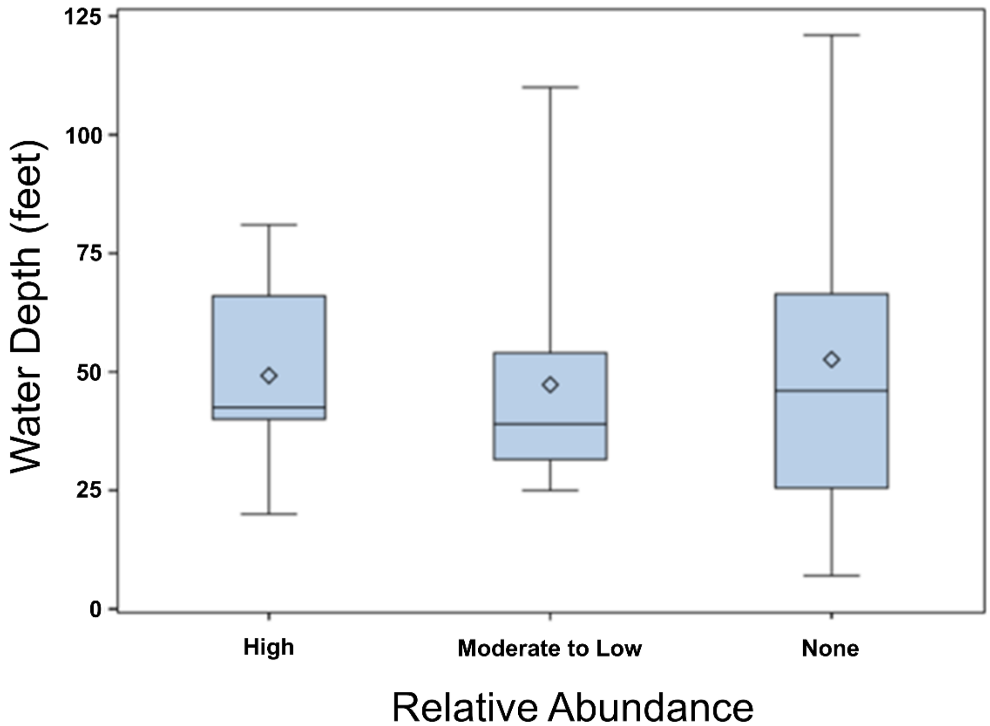

Figure 4. Box and Whisker plot of mean (symbol), mode (line) interquartile range between the 25th and 75th percentiles (shaded box) and the minimum-maximum value (whiskers). Mean depths were not statistically different among invasive carp abundance classes.

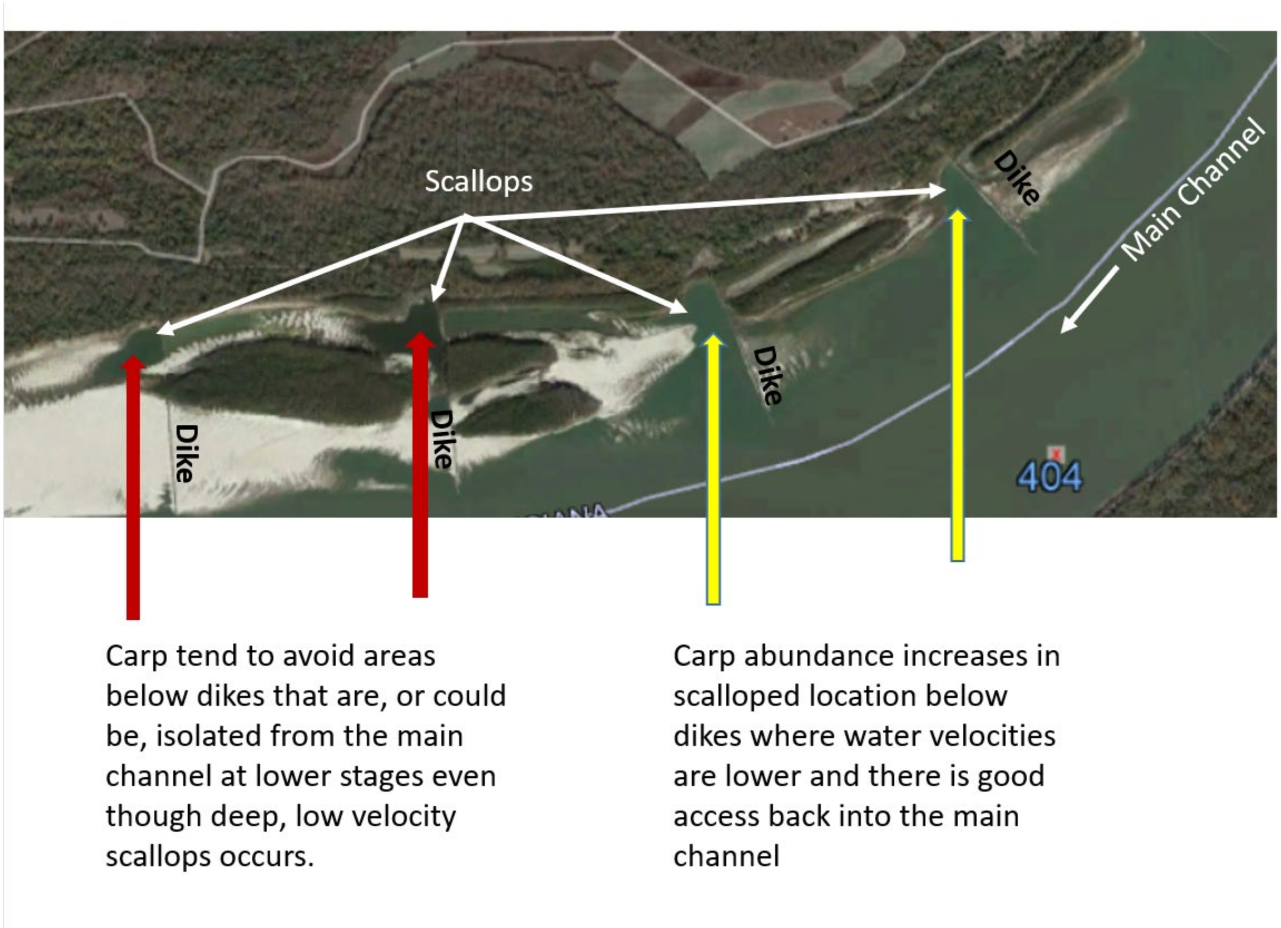

Figure 5. Google Earth image comparing differences in scallops with and without access to the main channel during lower river stages. Invasive carp may avoid areas that become isolated as river stages decline. Image Location – Coffee Point secondary channel, river mile 404.

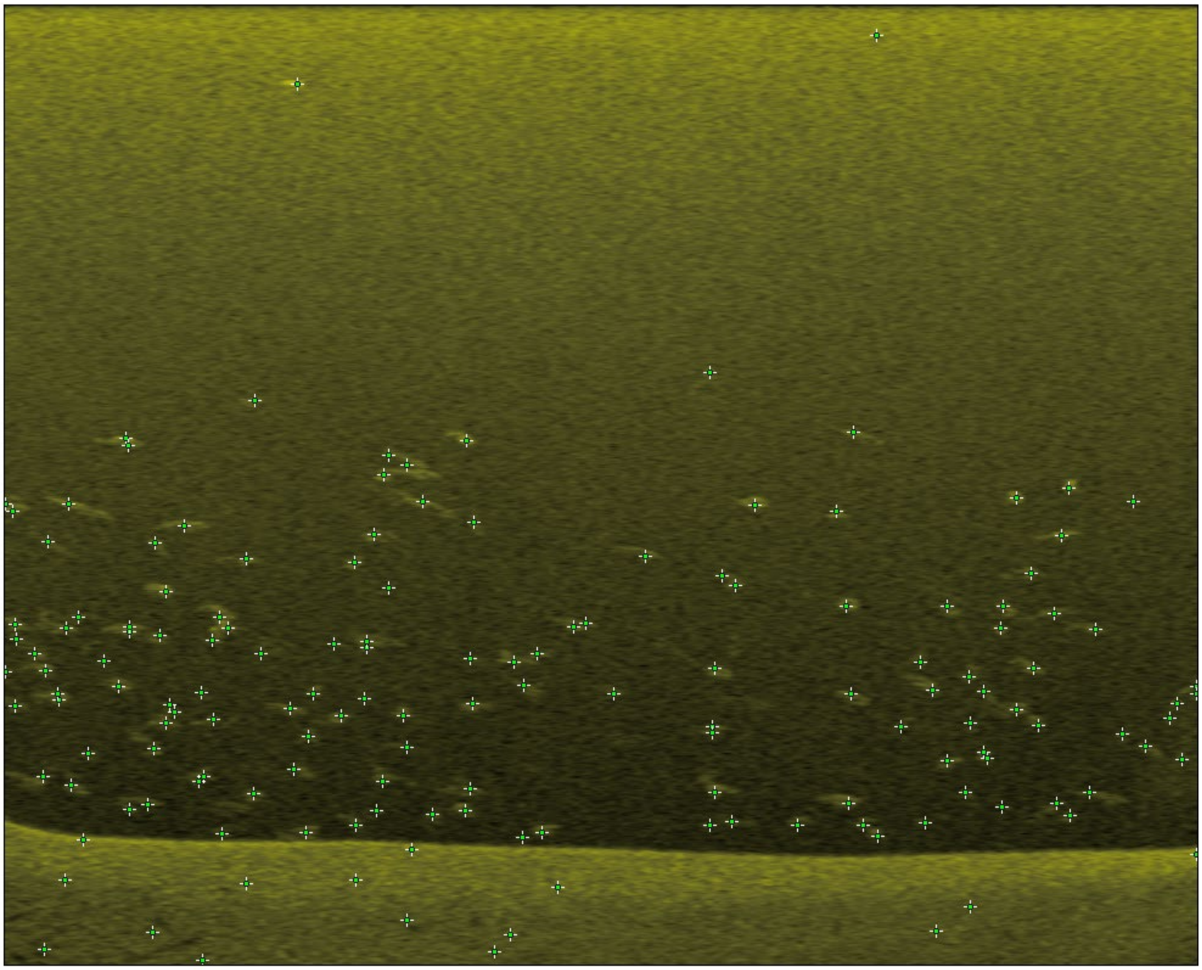

Figure 6. An example of automated fish detection in down-imaging sonar. The counting algorithm was set to a sensitivity level (i.e., “noise tolerance”) of 25, detecting 117 fish targets in this image. Note that fish targets were further filtered based on size. See Lawson et al. (2020) for a detailed description of macro programming in ImageJ software.