Final Report

Assessment of vital rates (exploitation, size structure, age and growth, and total annual mortality) to evaluate the current harvest regulations for flathead catfish (*Pylodictis olivaris*) in the Missouri and Mississippi rivers

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Abstract

Flathead catfish (*Pylodictis olivaris*) are native to the Missouri and Mississippi rivers, and support extremely important fisheries on these big rivers. The Missouri River supports a recreational fishery, and the Mississippi River supports both recreational and commercial fisheries. Missouri's big river, flathead catfish populations have not been intensively managed in the past, and information needed to inform management and regulatory decisions is limiting. Flathead catfish were sampled in the Mississippi and Missouri rivers using low-frequency electrofishing, and these data, along with tag return information, were used to estimate exploitation and other population demographics (e.g., size structure, age and growth, and total annual mortality). Management and regulatory recommendations focus on increasing yield available to fishers and ensuring sustainability of big river, flathead catfish populations.

A total of 8,395 flathead catfish ranging in size from 2-50 inches (51-1,270 mm) total length (TL) was collected from eight study sites. Pectoral spines were aged from 2,114 flathead catfish; ages ranged from 1-24 years on the Missouri and Mississippi rivers. In the Missouri River, flathead catfish reached 14 inches by age 4 (1 pound), 18 inches by age 5 (2 pounds), 24 inches by age 7 (5 pounds), 30 inches by age 10 (10 pounds), and 36 inches by age 17 (20 pounds). Mississippi River flathead catfish were estimated to take the same number of years to reach 14 and 18 inches as Missouri River fish but took an additional year to reach 24 inches, two additional years to reach 30 inches, and four additional years to reach 36 inches. To estimate exploitation, we tagged 836 flathead catfish in the Mississippi River and 850 in the Missouri River, with approximately 70 percent of tags having a standard reward value ($25) and the remainder having a high reward value ($150). As of 1 January 2020, 281 flathead catfish tags were reported by fishers. Reporting rates differed between sites and rivers; reporting rates on the Mississippi River ranged from 43-88 percent and from 46-78 percent on the Missouri River. Total annual exploitation was 10 percent (7 percent for recreational harvest and 3 percent for commercial harvest) on the Mississippi River and 12 percent (all recreational harvest) on the Missouri River. On the Mississippi River local exploitation ranged from approximately 9 percent at sites 2 and 4 to 12 percent at site 1. Local exploitation on the Missouri River ranged from 9 percent at sites 5 and 7 to 16 percent at site 6.

Growth or recruitment overfishing was not evident in our simulations. If fishing effort remains steady, our models predict that a minimum length limit (MLL) would offer a slight improvement in yield and trophy fishing potential. Furthermore, recreational anglers are thought to be more supportive of a MLL to improve chances of catching a trophy-sized flathead catfish as opposed to other regulations including gear restrictions or reduced daily bag limits. Commercial fishers may also support a MLL given the predicted increase in yield. Therefore, fisheries managers aiming to increase yield on the Mississippi and Missouri rivers should consider a MLL (e.g., 18 or 21 inches TL). In our simulations a protected slot limit of 26-34 inches, like the blue catfish regulation at Lake of the Ozarks and Harry S. Truman Lake, improved the trophy fishing potential more than predicted with a MLL, but decreased yield by 16-36 percent. If public opinion favors trophy fishing potential and fishers are willing to accept a minimal decline in yield, then restricting the number of fish over 30 inches per day should be considered, as well.

This option would be most appropriate on the Missouri River where maintaining or improving yield is not currently a management objective.

Recommendations:

- In coordination with Outreach & Education Division, staff develop a communication plan during FY2021. Inform stakeholders about the outcomes of this research and determine constituent attitudes and opinions concerning catfish harvest regulations and management objectives.
  - Survey recreational and commercial catfish fishers during FY2021, to determine attitudes and preferences associated with catfish management, angling, and harvest.
  - During FY2021 inform and coordinate with neighboring state agencies (IL, KS, KY, NE, and TN) responsible for managing border water fisheries.
  - Conduct public meetings during FY2021.
- Based on the results of this study (blue catfish final report (MDC 2019) and this report), public input (catfish harvest survey and public meetings), and discussions with neighboring state agencies:
  - If public sentiment is similar to existing human dimensions data (i.e., fishers are in large part harvest oriented):
    - Coordinate communication, planning, and development of regulation change proposals (if necessary at all) for blue catfish and flathead catfish concurrently during FY2021.
    - If minimum length limits are proposed for blue catfish and it is desirable to have similar regulations for both blue catfish and flathead catfish:
      - Propose a minimum length limit on recreationally harvested flathead catfish from the Missouri and Mississippi rivers during FY2021
      - Propose a minimum length limit on commercially harvested flathead catfish from the Mississippi River and possibly the St. Francis River during FY2021
      - Recreational and commercial minimum length limits should be set at the same level on the Mississippi River and possibly the St Francis River.
  - If public sentiment is different than existing human dimensions data (e.g., anglers are willing to sacrifice yield to improve trophy fishing potential):
    - Develop appropriate regulation change proposals (if necessary at all) for blue catfish and flathead catfish concurrently during FY2021.
    - If necessary, propose regulation changes on recreationally harvested flathead catfish from the Missouri and Mississippi rivers during FY2021.
    - If necessary, propose regulation changes on commercially harvested flathead catfish from the Mississippi River and possibly the St. Francis River.
    - Recreational and commercial length limits should be set at the same level on the Mississippi River and possibly the St. Francis River.
- Update Missouri's catfish management plan and objectives by FY2023. Consideration should be given to drafting more quantitative management objectives (e.g., catch per unit effort, size

structure, or growth rates), and objectives that outline recommendations for reevaluation of these fisheries.

Introduction

Flathead catfish support important recreational and commercial fisheries in Missouri. Catfish ranked third in popularity among recreational freshwater anglers in the U.S., drawing 8.1 million anglers in 2016 (USDI 2018). On big rivers such as the Missouri River, as much as 70 percent of total angler effort may be directed toward catfish (Weithman and Fleener 1988). Commercial catfish harvest was prohibited in the Missouri River beginning in 1992 due to increasing harvest and declines in the proportion of legal catfish in the population, and to allow more opportunity for recreational anglers (Stanovick 1999). In the Mississippi River, flathead catfish accounted for only 2 percent (18,959 lbs) of fish harvested by commercial fishers during 2018 but represented 6 percent ($10,604.52) of the total wholesale value (MDC 2020a).

Attitudes and preferences of recreational anglers and commercial fishers have recently changed. Although most recreational catfish anglers do not fish in tournaments or consider themselves trophy anglers, trophy catfish angling and catfish tournaments are increasing in popularity (Arterburn et al. 2002). Commercial fishing for catfish in the past has primarily focused on harvest for flesh. However, focus has recently increased in some rivers such as the Ohio River to also harvesting larger-sized fish to sell to fee-based fishing lakes for stocking.

The Missouri Department of Conservation (MDC) has been contacted by constituents who believe that overharvest has caused declines in the number of large catfish in the Mississippi and Missouri rivers. Both commercial and recreational catfish fishers are more harvest oriented and size-selective than anglers fishing for other species (Wilde and Ditton 1999), making catfish populations susceptible to growth overfishing (i.e., fish are harvested before reaching their growth potential) and recruitment overfishing (i.e., high proportion of large fish harvested over a long-time period thereby reducing the fishery's fecundity). Flathead catfish populations could potentially be growth or recruitment overfished given this species can live more than 20 years, are relatively slow growing, take several years to sexually mature, and larger, older individuals are more fecund (Colehour 2009). In response to these concerns, other states (e.g., Alabama and Tennessee) have restricted take of large catfish (e.g., only one catfish over 34 inches may be harvested per day) (SDAFS 2011). However, regulations that restrict the harvest of large catfish seem to be based on public sentiment rather than scientific evidence of their effectiveness.

Even though catfish support important fisheries that seem to be growing in popularity among recreational and commercial fishers, big river catfish populations have not been intensively researched or managed. In the *Big River Management and Coordination White Paper* (MDC 2010), the Division Review Team listed flathead catfish population monitoring as a priority. *Managing Missouri's Catfish; A Statewide Catfish Management Plan* (MDC 2003) listed four objectives pertaining to flathead catfish populations in the Missouri and Mississippi rivers:

- Increase abundance of flathead catfish greater than 30” long in a designated reach of the Missouri River.
- Increase yield of catfish on the Mississippi River to recreational and commercial fishers.
- Continue to refine existing standardized sampling techniques that provide a more representative sample of flathead catfish and blue catfish populations in big rivers.
- Develop creel survey methods that will accurately measure angler effort and harvest of catfish populations in large rivers.

Information needed to manage Missouri’s big river, flathead catfish fisheries was limited to exploitation estimates in Pools 20, 21, and 22 of the upper Mississippi River and the upper Missouri River near St. Joseph. Because data was limited, a pilot project was conducted to assess the feasibility of accomplishing a statewide study (MDC 2015). During spring and fall 2013 and spring 2014, flathead catfish were sampled using low-frequency electrofishing (EF) on the Mississippi and Missouri rivers. Specifically, the pilot study was designed to determine if low-frequency electrofishing is effective and efficient at sampling flathead catfish in big rivers and to determine the amount of electrofishing effort necessary to collect sufficient numbers of fish for population and exploitation analysis. Additionally, the pilot study identified the most appropriate and standardized electrofishing methods to employ. Pilot study results were used to design the subsequent statewide investigation to collect data needed to assess big river, catfish fisheries and evaluate current and potential harvest regulations. Fisheries data was collected to assess population demographics (e.g., longevity, age and growth, size structure, and total annual mortality) among Mississippi and Missouri river flathead catfish populations and estimate exploitation by recreational and commercial fishers. Management and regulatory recommendations resulting from this study focus on increasing yield available to fishers and ensuring sustainability of big river, flathead catfish populations.

Methods

Site Description

Study sites were selected on the Missouri River and Mississippi River. There were 459 locations (i.e., river miles) on the Missouri River and 229 locations on the Mississippi River considered for sampling sites. Unsuitable river reaches (e.g., highly industrialized, limited accessibility, or variable water conductivity) were not considered (Table 1). Using the R package ‘spsurvey’, four locations were selected using Generalized Random Tessellation Stratified survey design (Stevens and Olsen 2004; R Core Team 2014) on each river (Table 2, Figure 1). Each location selected served as the downstream boundary of each study site. Study sites were 20 river miles (32 km) in length; slightly larger than the median annual movement range of flathead catfish in the lower Missouri River and upper Mississippi River (Garrett and Rabeni 2011, Travnichek 2004).

Recreational fishing regulations on the Missouri River allow anglers to harvest five flathead catfish daily, with no length limits or closed season (MDC 2020). On the Mississippi River, recreational anglers can harvest 10 flathead catfish daily, with no length limits or closed season. Commercial catfish harvest in Missouri is restricted to the Mississippi River and the portion of the St. Francis River that forms the

Missouri-Arkansas border where an unlimited number of catfish over 15-inches TL may be commercially harvested year-round.

Sampling Protocols

Sampling protocols were finalized and distributed to field crews prior to the commencement of the study. Sampling protocols are presented in Appendix 1.

Size Structure

Descriptive statistics of length-structure distributions included mean total length, length-frequency histograms, and proportional size distributions (PSD) by river. PSD indices were calculated using flathead catfish length categories described by Anderson and Neumann (1996) as follows: stock (350 mm or 14 in), quality (510 mm or 20 in), preferred (710 mm or 28 in), memorable (860 mm or 34 in), and trophy (1020 mm or 40 in). Mean lengths and proportional size distributions by river and year were compared using one-way Analysis of Variance (α=0.05). The length frequency distributions of fish collected in 2015 and 2016 were compared with Kolmogorov-Smirnov (KS) two-sample tests.

Fish Tagging and Estimating Exploitation

All flathead catfish were measured to total length (TL) and a subset were weighed, fitted with Carlin dangler tags below the dorsal fin, and released at the capture location (Guy et al. 1996; Sullivan and Vining 2011; Bodine et al. 2018). Tags were distributed among 12 size groups (2-inch intervals except 35-39.9 and ≥40 in TL) starting at 15 inches, the minimum length limit (MLL) for commercial harvest and the size catfish become vulnerable to angler size-selective exploitation (Travnichek 2011). We attempted to tag 132 fish in each site with equal numbers of tagged fish in each size group (Pollock et al. 2001). Fish were tagged during standard sampling and during additional targeted sampling. To encourage tag reporting by fishers, tags were marked with a reward value of either US$25 or $150. We attempted to tag, in random order and in each size group, 75 percent of fish with standard tags ($25) and 25 percent with high-reward tags, except the two larger size groups were split 50/50 to more precisely estimate exploitation of memorable and trophy class fish. Each tag contained the reward value, a contact phone number, and a unique tag number. Two tag colors were used to distinguish the reward value and minimize misidentification by fishers. However, specific reward values and site locations were not mentioned to prevent artificially increased fishing effort (i.e., fishing for tags). Fishers catching tagged fish provided information regarding fish length, date and location caught, capture method (e.g., fishing gear), permit type, and whether the fish was harvested or released. Rewards and information regarding date and location the fish was tagged were mailed to the fishers after the tag was returned to MDC.

Annual exploitation rate (μ) was estimated following Bodine et al. (2018) at the local-site scale and at the river scale for three categories (total, fishing gear, and size specific) as

$$\mu_i = \frac{\sum_r \left(\frac{H_{r,i}}{RR_{r,.}}\right)}{\left(\sum_r M_{r,i} \times (1 - TL_{.,.}) - \left[\sum_r \left\{\frac{CR_{r,i}}{RR_{r,.}}\right\}\right]\right)}$$

where r = reward value of a tag, either \$25 or \$150; i = category (i.e., fishing gear or size-group); $M_{r,i}$= number of marked fish with a tag value r released in category i; $H_{r,i}$= number of harvested fish with a tag value r in category i, limited to the first year post-tagging; $CR_{r,i}$= number of caught and released fish with a tag value r released in category i, limited to the first year post-tagging; $RR_{r,.}$= reporting rate for tag value r, assuming the same for all categories i; and $TL_{.,.}$= tag loss rate of 1.1 percent (Sullivan and Vining 2011), assuming the same for all values r and categories i.

Reporting rate of standard tags (RR_{25}) was estimated as

$$RR_{25} = \frac{\left(\frac{R_{25}}{M_{25}}\right)}{\left(\left[\frac{R_{150}}{M_{150}}\right] \Big/ RR_{150}\right)}$$

where R_{25}= number of standard tags reported; M_{25}= number of marked fish with standard tags; R_{150}= number of high-reward tags reported; M_{150}= number of marked fish with high-reward tags; and RR_{150}= reporting rate of high-reward tags, assumed to be 100 percent. All tags reported before 1 January 2020 were included in our reporting rate estimate.

Age, Growth, and Mortality

For a subset of flathead catfish collected, weight was regressed against length after all data were log-transformed. Weight-length regressions were used in model calculations of mean weight of fish harvested and total yield.

Pectoral spines, including the articulating process, were removed from fish with the target of collecting 10 spines from fish in each 2-inch size group starting at 7 inches from each site. Otoliths were not collected from sampled fish because of the lethality, even though spines have been shown to underestimate ages of catfish compared to otolith age estimates (Nash and Irwin 1999; Columbo et al. 2010; Olive et al. 2011; Homer et al. 2015). However, otoliths were collected from a sample of commercially harvested fish within the study sites on the Mississippi River and were compared to spine age estimates. Pectoral spines and lapilli otoliths were processed using methods described by Buckmeier et al. (2002). Ages were estimated for each fish by three independent readers with agreement defined as either unanimous or two readers agreed with the third reader within one year. Disagreements were reconciled during a subsequent concert read. A scatter plot of pairwise comparisons of age estimates from otoliths and spine sections was generated to assess bias in age assignment (Campana et al. 1995). Difference in age estimates between structures was computed and plotted against total length to demonstrate direction of error in age estimates (Nash and Irwin 2000).

Growth was estimated by calculating mean TL at age and fitting the von Bertalanffy curve (von Bertalanffy 1938). Changes in TL, standardized to 365 days, of fish tagged and recaptured during sampling in subsequent years were compared to annual change of mean TL at estimated age.

For mortality estimation, all aged fish were used to construct an age-length key for each river. The key was used to assign ages to all unaged, newly fin clipped fish collected during standard sampling. All fish that were recaptured during standard sampling (identified by fin clip) or collected during targeted sampling were excluded from mortality estimation. The weighted catch curve method was used to estimate instantaneous total mortality rate (Z; Robson and Chapman 1961; Ricker 1975). Ages that were on the ascending limb of the catch curve were assumed to not be fully recruited to our standard EF sampling and were omitted from the analysis. Instantaneous total mortality was converted to total annual mortality ($A = 1-e^{-Z}$) and total annual survival ($S = 1-A$).

Total annual survival was also estimated using a tag recovery model (Brownie et al. 1985) corrected for bias of catch and release fishing where the fish is released, but the tag is removed (Smith et al. 2000). Our tag recovery models used additional data from fishers who, in theory, were spread out across the population range and had the chance to encounter and report tags. Therefore, the assumption of population closure did not apply, and true survival could be estimated. For comparison with the survival estimates derived from catch curve regression, tag recovery models were restricted to the same ages that were fully recruited to standard EF sampling when applicable. The total annual survival estimates were converted to total annual mortality ($A = 1-S$).

Annualized natural mortality (v) was estimated by subtracting our estimates of exploitation (μ) from our two estimates of A. Also, we used Fishery Analysis and Modeling Simulator (FAMS) version 1.64.4 (Slipke and Maceina 2014) to examine potential ranges of instantaneous natural mortality (M) and conditional natural mortality (cm) based on our von Bertalanffy parameters, maximum age, and average water temperature.

Simulation Modeling to Predict the Effects of Length Limits

Population modeling was performed using FAMS version 1.64.4 (Slipke and Maceina 2014). Conditional mortality rates were needed for modeling and were calculated as

$$cf = 1 - e^{(\mu \times Z)/(1-S)}$$

$$cm = 1 - e^{(v \times Z)/(1-S)}$$

where cf= conditional fishing mortality and cm= conditional natural mortality.

We used a yield-per-recruit model to examine how total yield (pounds of fish harvested), spawning potential ratio (SPR), and number of size-specific fish in the population were affected by various exploitation rates and length limits. We identified exploitation rates that would likely induce growth and recruitment overfishing. Growth overfishing was identified by the descending limb of the yield curve and recruitment overfishing was identified as the point at which the SPR was less than 20 percent (Goodyear and Christensen 1984). For SPR, Colehour (2009) found that flathead catfish collected from the

Mississippi River were sexually mature beginning at age 5, or 426 mm. We used a log-transformed length-fecundity relationship adapted from Colehour (2009).

$$\log(Fecundity) = 2.81(\log[TL]) - 3.76$$

Trophy fish was defined based on the size of flathead catfish the highest percentage (15.3 percent) of Missouri anglers surveyed considered to be a trophy (20 lb [9,071 g]; Reitz 2003). The second most popular opinion with 12.5 percent of responses was 50 pounds (22,680 g). Other specific sizes of fish we were interested in examining included 10 pounds (4,534 g), 5 pounds (2,267 g), and 2 pounds (907 g) based on work by Reitz and Travnichek (2006). Those reports were based on weight, so we converted weights to lengths for population modeling using our weight-length regressions.

We also simulated what effects length limits (i.e., MLL and slot limits) and "big fish" daily bag limits may have on total yield and number of size-specific fish in the population. The two "big fish" daily bag limits simulated were where fishermen were allowed to harvest one flathead catfish 30 inches or larger per day (similar to the current regulation for the state of Nebraska for the Missouri River main-stem) and where fishermen were allowed to harvest one flathead catfish 35 inches or larger per day (similar to the current regulation in several states for the Ohio River main-stem). We were unaware of any studies that reported data for flathead catfish that could have been used to predict how limiting harvest to one fish over 30 or 35 inches per angler per day would reduce exploitation. Therefore, we used our trotline sampling data from this study to estimate reduced harvest for these simulations (Appendix 2). Based on those results, we decreased our number of flathead catfish over 30 inches harvested by 34 percent and calculated new exploitation rates for the one fish over 30 inches per day simulation. Similarly, we decreased our number of flathead catfish over 35 inches harvested by 8.7 percent and calculated new exploitation rates for the one fish over 35 inches per day simulation. All model predictions were compared to a 15-inch MLL which represented current conditions where flathead catfish were not vulnerable to harvest until 15 inches.

Results

Missouri River

Sampling Effort and Fish Collection

Standardized, stratified-random electrofishing (EF) runs were made in the Missouri River during fall 2015 (N=308) and 2016 (N=296) for a total effort of 50.6 EF hours. An additional 84.4 hours of EF, 6 hoop net nights, and 1,456 trotline hooks were deployed during fall targeted sampling. A total of 3,604 flathead catfish was collected during fall 2015 and 2016 sampling, ranging from 2-50 inches (53-1,282 mm) TL. Special efforts were made during early spring 2017 to finish reward tagging the fall 2016 tagging cohort. These efforts included 27.3 hours of EF, 10 hoop net nights, and 424 trotline hook nights resulting in the collection of 247 flathead catfish.

Size Structure

Mean length of flathead catfish collected was significantly higher in 2016 than in 2015 ($p<0.001$). Length-frequency distributions were also significantly different between 2015 and 2016 ($p=0.0003$). The difference between 2015 and 2016 length-frequency distributions was due largely to high catches of fish under 10 inches in 2015 (Figure 2). Length-frequency distributions of fish over 10 inches were not significantly different between years ($p=0.054$). There was no significant year effect on flathead catfish PSD-Q ($p=0.63$), which averaged 65 percent across all Missouri River sites (range 53-76%). PSD-P, PSD-M, and PSD-T were also not significantly different between years and averaged 17, 10, and 3 percent, respectively (Figure 3).

Age and Growth

Length was a significant predictor of weight resulting in a significant weight-length regression for the Missouri River ($p<0.0001$, $R^2=0.98$). Lengths of flathead catfish that averaged 2, 5, 10, 20, and 50 pounds were 18, 24, 30, 36, and 50 inches (430, 610, 762, 914, and 1270 mm), respectively (Table 3).

We processed and estimated ages for 1,074 flathead catfish pectoral spines collected during standard and targeted sampling. Based on spine age estimates, mean TL increased on average by 1.8 inches (44.7 mm) per year in the Missouri River (Table 4; Figure 4). Comparatively, when we examined growth of recaptured, tagged fish (n=19) during subsequent years of sampling in the Missouri River, fish TL increased by an average of 1.2 inches (29.6 mm) per year (Figure 5).

Aged fish from the Missouri River ranged from 1 to 24 years, and the von Bertalanffy growth curve was a good fit to the length-at-age data ($p<0.0001$, $R^2=0.95$; Table 5). Growth curves predicted fish to reach 14 inches by age 4, 18 inches by age 5, 24 inches by age 7, 30 inches by age 10, and 36 inches by age 13 (Table 3).

Fish Tagging and Exploitation

During our fall 2015/spring 2016 and fall 2016/spring 2017 efforts, we tagged 433 and 417 flathead catfish in the Missouri River, respectively. Approximately 70 percent of tags during each year were the standard reward value. As of 1 January 2020, 158 flathead catfish tags from the Missouri River were reported by fishers (Appendix 2). Our empirical estimates of reporting rates were 65 percent on the Missouri River (all recreational permit holders) with reporting rates by site ranging from 43-99 percent (Table 6).

For all size classes combined, annual exploitation was 11.9 percent on the Missouri River (Table 7). Site-specific total annual exploitation estimates were based on local reporting rates and was lowest at sites 5 and 7 (9 percent), slightly higher at site 8 (12 percent), and highest at site 6 (16 percent).

Size-specific exploitation was estimated at the local-site scale using local reporting rates. Averaged across sites, exploitation was not significantly different among size groups ($p=0.51$) and in all Missouri

River sites, annual exploitation was zero for the smallest size group (15-16.9 inches; Table 8 and Figure 6).

Flathead catfish were harvested from five different gears on the Missouri River. Gear-specific exploitation was highest with trotlines and bankpoles (3.5 and 3.3 percent, respectively). Rod and reel fishing was the third highest method of harvest, even though catch and release was more popular with this gear (Table 9).

Mortality

Full recruitment to our sampling appeared to occur at age 2 (Figure 7). The weighted catch curve regression indicated that total annual mortality of flathead catfish age 2 and older was 31.0 percent on the Missouri River (Z=-0.37, R^2=0.97; Figure 8). In comparison, our estimates of total annual mortality from the tag recovery model was 29.7 percent.

Annualized natural mortality was estimated as the remainder of total mortality unexplained by fishing mortality. Therefore, our estimates of annual natural mortality (*v*) on the Missouri River ranged from 17.8 to 19.1 percent (M=-0.211 to -0.228; cm=0.190 to 0.204). These estimates were near the upper range of the empirical estimators of natural mortality calculated using FAMS where estimates of M ranged from 0.15-0.22 and cm ranged from 0.14-0.19.

Population Modeling

Our models indicated that with no size selective harvest and a 15-inch MLL (representing an implicit length limit by anglers under current regulations; Travnichek 2011), growth and recruitment overfishing would both occur when exploitation rates exceeded 21.6 percent. With an 18-inch MLL, growth and recruitment overfishing would occur at exploitation rates above 26.2 percent and 28.0 percent, respectively. Under a 21 or 24-inch MLL, growth or recruitment overfishing were not predicted to occur at any level of exploitation less than 35 percent (Figure 9).

At current levels of exploitation (11.9 percent for all fish sizes combined), our models indicated maximum yield gain of 4 percent was achieved when the MLL was increased to 18 or 21 inches. A 24-inch MLL was predicted to increase yield by 1 percent (Figure 9). Slot limits, where fish within the slot were protected, or vice versa, and reduced daily bag limits all predicted reduced yield.

An 18-inch MLL was predicted to increase numbers of all sizes of fish by 13 percent compared to a 15-inch MLL (Figure 10). The number of fish harvested was predicted to decrease by 18 percent and the average weight of harvested fish would increase by 26 percent (increase of 1.5 lb [682 g]; Figure 10). Under a 21-inch MLL our models predicted the number of 18-inch fish would increase by 13 percent compared to a 15-inch MLL; however, these fish would not be legal to harvest under this scenario. The number of 24, 30, and 36-inch fish were all expected to increase by 30 percent, the average weight of harvested fish would increase by 58 percent (3.3 lb [1,514 g]), and number of fish harvested would decrease by 34 percent (Figure 10). With a 24-inch MLL our models predicted the number of 18-inch and 24-inch fish would increase by 13 percent and 51 percent, respectively, compared to a 15-inch MLL;

however, these fish would not be legal to harvest under this scenario. The number of 30 and 36-inch fish were all expected to increase by 51 percent, the average weight of harvested fish would increase by 97 percent (5.5 lb [2,510 g]), and number of fish harvested would decrease by 49 percent (Figure 10).

A slot limit of 26-34 inches (660-864 mm), where fish within the slot were released, was predicted to decrease yield on the Missouri River by 21 percent compared to a 15-inch MLL. The numbers of fish within the slot and above the slot were predicted to increase by 30 percent and 80 percent, respectively (Figure 12). The number of fish harvested and mean weight of fish harvested were predicted to decrease by 16 and 6 percent, respectively (Figure 11).

Exploitation of fish over 30 inches was reduced to 7.0 percent in our models simulating a "big fish" daily bag limit of no more than one flathead catfish over 30 inches per angler per day. This simulation predicted an 8 percent reduction in yield, 3 percent reduction in the number of fish harvested, and fish harvested weighed 6 percent less (Figure 11). The number of 36-inch fish in the population was predicted to increase by 17 percent with a simulated daily limit of one over 30 inches (Figure 12). In our simulation of a daily bag limit of no more than one flathead catfish over 35 inches per angler per day, exploitation of fish over 35 inches was reduced to 11.0 percent. This simulation predicted slight decreases in yield (0.9 percent), number of fish harvested (0.2 percent), and mean weight of fish harvested (0.6 percent; Figure 11) and a slight increase in the number of 36-inch fish in the population compared to a 15-inch MLL (1 percent; Figure 12).

Mississippi River

Sampling Effort and Fish Collection

Standardized, stratified-random electrofishing (EF) runs were made in the Mississippi River during fall 2015 (N=296) and 2016 (N=302) for a total effort of 70.5 EF hours. An additional 43.3 hours of EF, 6 gill net and 2 hoop net nights, and 560 trotline hooks were deployed during fall targeted sampling. A total of 3,979 flathead catfish was collected during fall 2015 and 2016 sampling, ranging from 2-49 inches (53-1,244 mm) TL. Special efforts were made during early spring 2017 to finish reward tagging the fall 2016 tagging cohort. These efforts included 43.9 hours of EF and 3 gill net and 1 hoop net nights resulting in the collection of 565 flathead catfish.

Size Structure

Mean length of flathead catfish collected was significantly higher in 2016 than in 2015 ($p<0.001$). Length-frequency distributions were also significantly different between 2015 and 2016 ($p<0.0001$). The difference between 2015 and 2016 length-frequency distributions was due largely to high catches of fish under 13 inches in 2015 (Figure 2). Length-frequency distributions of fish over 13 inches were not significantly different between years ($p=0.188$). Proportional size distributions of flathead catfish were not significantly different between years ($p=0.75$), but PSD-Q and PSD-P were significantly lower in site 4 ($p=0.003$). PSD-Q and PSD-P averaged 20 percent and 2 percent in site 4 and averaged 65 percent and 14 percent in sites 1-3. PSD-M and PSD-T were not significantly different among sites and averaged 4 and 1 percent, respectively (Figure 3).

Age and Growth

Length was a significant predictor of weight resulting in a significant weight-length regression for the Mississippi River ($p<0.0001$, $R^2=0.99$). Size of fish that were legal to commercially harvest (≥15 inches) averaged 1.3 pounds (590 g). Lengths of flathead catfish that averaged weights of 2, 5, 10, and 20 pounds were 18, 24, 30, and 36 inches, respectively (Table 3).

We processed and estimated ages for 1,040 flathead catfish pectoral spines collected during standard and targeted sampling. In addition, lapilli otoliths and pectoral spines were collected from 191 and 199 commercially harvested fish with both aging structures collected from 190 fish. Only 38 percent of ages from spine sections were in exact agreement with ages from otoliths; but, 75 percent were within one year of agreement. Age estimates from spine sections and otoliths were never in exact agreement beyond an otolith age estimate of 14 (Figure 13). The difference in age estimates between spine sections and otoliths was not correlated to fish length less than 45 inches. However, for fish greater than 45 inches spine sections always underestimated age compared to age estimates from otoliths (Figure 14). Based on spine age estimates, mean TL increased on average by 1.8 inches (46.9 mm) per year in the Mississippi River (Table 4; Figure 4). Comparatively, when we examined growth of recaptured, tagged fish (n=39) during subsequent years of sampling in the Mississippi River, fish TL increased by an average of 1.0 inch (25.7 mm) per year (Figure 5).

Aged fish from the Mississippi River ranged from 1 to 24 years, and the von Bertalanffy growth curve was a good fit to the length-at-age data ($p<0.0001$, $R^2=0.96$; Table 5). Growth curves predicted fish to reach 14 inches by age 4, 18 inches by age 5, 24 inches by age 8, 30 inches by age 12, and 36 inches by age 17 (Table 3).

Fish Tagging and Exploitation

During our fall 2015/spring 2016 and fall 2016/spring 2017 efforts, we tagged 458 and 378 flathead catfish in the Mississippi River, respectively. Approximately 70 percent of tags during each year were the standard reward value. As of 1 January 2020, 123 flathead catfish tags from the Mississippi River were reported by fishers (Appendix 2). The reporting rate of standard tags on the Mississippi River was 62 percent and recreational anglers were more likely to report standard tags than commercial fishers. Reporting rates varied by site and ranged from 46-78 percent (Table 6).

For all size classes combined, annual exploitation was 10.1 percent on the Mississippi River (Table 7). Most exploitation on the Mississippi River was from recreational fishers (7 percent) and not commercial fishers (3 percent). Site-specific total annual exploitation estimates were based on local reporting rates and was lowest at sites 2 and 4 (9 percent), slightly higher at site 3 (10 percent), and highest at site 1 (12 percent).

Size-specific exploitation was estimated at the local-site scale using local reporting rates. Averaged across sites, exploitation was not significantly different among size groups (p=0.33). However, annual exploitation for the smallest size group (15-16.9 inches) was relatively low and was zero in 3 of the 4 Mississippi River sites (Table 8 and Figure 6).

Flathead catfish were harvested from seven different gears on the Mississippi River. Gear-specific exploitation was highest with trotlines followed by rod and reel (4.0 and 2.2 percent, respectively). Hoop net was the third highest method of harvest with exploitation at 1.1 percent (Table 9).

Mortality

Full recruitment to our sampling appeared to occur at age 3 (Figure 7). The weighted catch curve regression indicated that total annual mortality of flathead catfish age 3 and older was 31.3 percent on the Mississippi River (Z=-0.376, R^2=0.94; Figure 8). In comparison, our estimates of total annual mortality from the tag recovery model was 32.8 percent.

Annualized natural mortality was estimated as the remainder of total mortality unexplained by fishing mortality. Therefore, our estimates of annual natural mortality (v) on the Mississippi River ranged from 21.2 to 22.6 percent (M=-0.255 to -0.275; cm=0.225 to 0.241). These estimates were near the upper range of the empirical estimators of natural mortality calculated using FAMS where estimates of M ranged from 0.13-0.22 and cm ranged from 0.12-0.18.

Population Modeling

Our models indicated that with no size selective harvest and a 15-inch MLL (representing an implicit length limit by anglers under current regulations; Travnichek 2011), growth and recruitment overfishing would occur when exploitation rates exceeded 22.5 percent and 24.3 percent, respectively. With an 18-inch MLL, growth and recruitment overfishing would occur at exploitation rates above 31.6 percent and 34.4 percent, respectively. Under a 21 or 24-inch length limit growth or recruitment overfishing were not predicted to occur at any level of exploitation less than 45 percent (Figure 15).

At current levels of exploitation (10.1 percent for all fish sizes combined), our models indicated when the MLL was increased to 18 inches the gain in yield was only 1 percent. A 21-inch and 24-inch MLL were predicted to decrease yield by 1 percent and 9 percent, respectively (Figure 15). Slot limits, where fish within the slot were protected, or vice versa, and reduced daily bag limits all predicted reduced yield.

An 18-inch MLL was predicted to increase numbers of all sizes of fish by 14 percent compared to a 15-inch MLL (Figure 18). The number of fish harvested was predicted to decrease by 23 percent and the average weight of harvested fish would increase by 31 percent (increase of 1.5 lb [702 g]; Figure 16). Under a 21-inch MLL our models predicted the number of 18-inch fish would increase by 14 percent compared to a 15-inch MLL; however, these fish would not be legal to harvest under this scenario. The number of 24, 30, and 36-inch fish were all expected to increase by 33 percent, the average weight of harvested fish would increase by 70 percent (3.5 lb [1,580 g]), and number of fish harvested would decrease by 42 percent (Figures 16 and 18). With a 24-inch MLL our models predicted the number of 18-inch and 24-inch fish would increase by 14 percent and 57 percent, respectively, compared to a 15-inch MLL; however, these fish would not be legal to harvest under this scenario. The number of 30 and 36-inch fish were all expected to increase by 57 percent, the average weight of harvested fish would increase by 118 percent (5.6 lb [2,655 g]), and number of fish harvested would decrease by 58 percent (Figures 16 and 18).

A slot limit of 26-34 inches (660-864 mm), where fish within the slot were released, was predicted to decrease yield on the Mississippi River by 26 percent compared to a 15-inch MLL. The number of fish harvested and mean weight of fish harvested were both predicted to decrease by 14 percent (Figure 17). The numbers of fish within the slot and above the slot were predicted to increase by 46 percent and 99 percent, respectively (Figure 18).

Exploitation of fish over 30 inches was reduced to 6.8 percent in our models simulating a "big fish" daily bag limit of no more than one flathead catfish over 30 inches per angler per day. This simulation predicted a 4 percent reduction to yield, 1 percent reduction in the number of fish harvested, and fish harvested weighed 3 percent less (Figure 17). The number of 36-inch fish in the population was predicted to increase by 16 percent with a simulated daily limit of one over 30 inches (Figure 18). In our simulation of a daily bag limit of no more than one flathead catfish over 35 inches per angler, exploitation of fish over 35 inches was reduced to 9.4 percent. This simulation predicted slight decreases in yield (0.3 percent), number of fish harvested (0.1 percent), and mean weight of fish harvested (0.3 percent; Figure 17) and no increase in the number of 36-inch fish in the population compared to a 15-inch MLL (Figure 18).

Discussion

Flathead catfish support extremely important recreational and commercial fisheries on Missouri's big rivers. Harvesting catfish is important to Missourians, however trophy and tournament angling for catfish is increasing in popularity. An increase in demand for large, live catfish for use in pay lakes has been identified as a potential concern and some constituents believe that overharvest has caused declines in the number of large catfish in the Mississippi and Missouri rivers. This study was conducted to assess big river catfish fisheries and evaluate harvest regulations to identify those that will ensure sustainability and increase yield of flathead catfish available to fishers. MDC's current catfish management objectives are qualitative, but serve as a basis for this report's recommendations. The results of this study could be used to establish a new management plan with more quantitative objectives (e.g., catch per unit effort, size structure, or growth rates).

Our range of population dynamic rate estimates were generally similar between the Missouri River and Mississippi River and comparable to previous studies. Growth of flathead catfish was similar between the Missouri and Mississippi river up to age 9 but fish from the Mississippi River took 1 additional year to reach 24 inches, two additional years to reach 30 inches, and four additional years to reach 36 inches. These growth rates were like those reported in the Kansas River, Kansas (Makinster and Paukert 2008; only report mean length at age-1 and age-3), Lake Wilson, Alabama (Marshall et al. 2009), and Lake Palestine, Texas (Bodine et al. 2016). However, our estimated theoretical maximum age of 21 years was much less than in Lake Palestine (age-28) and may be due to higher exploitation in our sites (Bodine et al. 2016). Except Lake Palestine, our range of estimated exploitation rates of flathead catfish was similar to those in the literature (8-20 percent; Makinster and Paukert 2008; Marshall et al. 2009; Travnichek 2011).

Oftentimes, only a few individual anglers will account for a large portion of the total fish harvest. For example, when commercial fishing was legal on the Missouri River, Stanovick (1999) reported that commercial fishers accounted for 38 percent of catfish harvest but represented only 11 percent of recreational and commercial harvesters combined. Likewise, 15 commercial fishers (14 percent of the angler population) accounted for 39 percent of blue catfish harvest on the Mississippi River (MDC 2019). However, in this study, commercial fishers represented 23 percent of the total number of individuals reporting tags and 28 percent of harvest on the Mississippi River. This may suggest that flathead catfish resources on the Mississippi River may be more evenly allocated between commercial fishers and recreational anglers than compared to other populations.

Growth or recruitment overfishing of flathead catfish was not evident in any of our study sites. However, exploitation rates were variable among sites and our study sites represented less than 15 percent of the total length of the Missouri and Mississippi rivers in Missouri. There could be reaches on the Missouri or Mississippi rivers with higher exploitation than we observed in this study, so it is possible that local growth overfishing is occurring. The effects of local overfishing could persist as flathead catfish were less mobile than blue catfish moving an average of 27.6 river miles between captures (median distance = 3.2 river miles; Appendix 3).

States such as Kentucky, where pay lakes are becoming very popular and sources of trophy catfish for stocking pay lakes include public waters such as the Ohio River, have implemented regulations that limit harvest of trophy catfish (KDFWR 2019). Stricter regulations on the Ohio River could reallocate commercial harvest of trophy catfish to the Mississippi River. Therefore, we strongly advise that commercial harvest of trophy catfish in the Mississippi River be monitored in the future.

Lowering exploitation of flathead catfish would improve trophy fishing opportunity but reducing daily bag limits may not be an effective or socially supported strategy to do so. We did not conduct creel surveys during this study, but during trotline sampling we rarely caught a daily limit of 5 flathead catfish on the Missouri River and never caught a daily limit of 10 flathead catfish on the Mississippi River. Therefore, we hypothesize that Missouri's recreational, daily bag limits on flathead catfish from the Mississippi and Missouri rivers only slightly limit harvest and an extreme reduction in the current daily bag limit would be needed to reduce exploitation and improve trophy fishing opportunities. On the Mississippi River where there is no daily bag limit for commercial fishers, a reduced limit could reduce exploitation, but may decrease yield and have economic impacts. Also, Missouri catfish anglers were heavily opposed to reduced daily bag limits (Reitz and Travnichek 2006).

Regulations limiting the harvest of larger flathead catfish to one fish per day may improve the trophy fishing potential if unregulated harvest of larger flathead catfish is high. During trotline sampling we found that multiple flathead catfish greater than 30 inches (762 mm) would rarely be caught during a single recreational angling trip. However, these rare instances accounted for 34 percent of the potential harvest of flathead catfish of that size. Our models that reduced harvest of larger fish were based on our own trotline sampling, but we hypothesize that commercial fishers would be more likely to harvest multiple flathead catfish greater than 30 inches per day. Therefore, limiting harvest of larger flathead catfish where commercial fishing is allowed may have greater impact on the trophy fishing potential, but would also be likely to decrease yield more than the 4 percent as predicted in our simulations.

In 2014, to meet management objectives for blue catfish on Harry S. Truman Lake and Lake of the Ozarks, Missouri, new regulations were imposed by MDC that increased the daily bag limit from 5 to 10, created a protected slot limit of 26-34 inches, and limited harvest of fish above the slot to two fish daily (MDC 2020b). We simulated this slot limit for our flathead catfish populations as well in case stakeholders were interested in these predictions for comparison. In our simulations on the Missouri and Mississippi rivers, a protected slot limit of 26-34 inches improved the trophy fishing potential more than predicted with an increased MLL, but decreased yield by 21 and 26 percent, respectively.

The greatest improvement in both yield and trophy fishing potential in our simulations where fishing effort remained steady was predicted with an increased MLL. However, even in the best-case scenario, improvements in yield were minimal (i.e., 1 percent increase on the Mississippi River with an 18-inch MLL; 4 percent increase on the Missouri River with an 18 or 21-inch MLL). Reitz and Travnichek (2006) found that Missouri anglers were like Texas anglers (Wilde and Riechers 1994), where flathead catfish anglers were more supportive of a MLL to improve chances of catching a trophy-sized catfish as opposed to other regulations such as gear restrictions or reduced daily bag limits. Based on our simulations, fisheries managers aiming to increase yield on the Mississippi River could use a MLL (i.e., 18inches TL) to meet specific management objectives. However, it should be noted that the increase in yield may be imperceptible to fishers. Additionally, if a MLL was implemented for blue catfish, it could be desirable to have the same MLL for flathead catfish, for purposes of homogenizing regulations. If public opinion favors trophy fishing potential and fishers are willing to accept a minimal decline in yield, then restricting the number of fish over 30 or 35 inches per day should be considered, as well. This option would be most appropriate on the Missouri River where maintaining or improving yield is not currently a management objective.

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Tables

Table 1. River reaches not considered during site selection.

River	Unsuitable Areas to be Avoided	River Miles Excluded from the Random Site Selection Process
Mississippi River	Ohio River Confluence – LMR RM 932-952 & UMR RM 0-35	LMR RM 913-952 & UMR RM 0-35
Mississippi River	St. Louis Riverfront – UMR RM 169-180	UMR RM 150-180
Mississippi River	Mel Price Lock & Dam – UMR RM 201	UMR RM 182-201
Mississippi River	Lock & Dam 25 – UMR RM 242	UMR RM 223-246
Mississippi River	Lock & Dam 24 – UMR RM 274 (Upstream Boundary)	UMR RM 255-274
Missouri River	Osage River Confluence – MOR RM 115-130	MOR RM 96-130
Missouri River	Kansas City Riverfront – MOR RM 360-380	MOR RM 341-380
Missouri River	MO-IA Border – MOR RM 553 (Upstream Boundary)	MOR RM 534-553

Table 2. Study sites and corresponding river miles.

River	Sites	From (Downstream Boundary)	To (Upstream Boundary)
Mississippi River	Site 1 – Donaldson Point to Hickman Bend	LMR RM 902	LMR RM 922
Mississippi River	Site 2 – Picayune Chute to Grand Tower	UMR RM 61	UMR RM 81
Mississippi River	Site 3 – Chester to Ste. Genevieve	UMR RM 105	UMR RM 125
Mississippi River	Site 4 – Norton Wood Access to Lock & Dam 24	UMR RM 253.4	UMR RM 273.4
Missouri River	Site 5 – St. Charles to Weldon Springs	MO RM 25	MO RM 45
Missouri River	Site 6 – Lamine River to Lisbon Bottoms	MO RM 200	MO RM 220
Missouri River	Site 7 – Cranberry Bend to Lexington	MO RM 290	MO RM 310
Missouri River	Site 8 – Bob Brown to Thurnau	MO RM 487	MO RM 507

Table 3. Average age (years) for flathead catfish to reach various lengths and weights in the Mississippi River and Missouri River.

Total length (in)	Total length (mm)	Weight (lbs)	Age to reach size Mississippi River	Age to reach size Missouri River
14	381	1	4	4
18	457	2	5	5
24	610	5	8	7
30	762	10	12	10
36	965	20	17	13

Table 4. Sample sizes and mean total lengths by age estimates from spines of flathead catfish in the Mississippi River and Missouri River. Two standard errors are shown in parenthesis.

Age (years)	Sample Size - Mississippi River	Sample Size - Missouri River	Mean Total Length (in) - Mississippi River	Mean Total Length (in) - Missouri River	Mean Total Length (mm) - Mississippi River	Mean Total Length (mm) - Missouri River
1*	28	31	7.9 (1.1)	8.5 (1.2)	210 (14.5)	227 (15.9)
2	61	78	9.1 (0.8)	9.4 (0.8)	242 (13.0)	251 (13.4)
3	122	99	11.2 (0.7)	11.8 (1.0)	296 (11.1)	310 (18.0)
4	122	128	14.9 (0.9)	14.5 (1.0)	390 (17.5)	379 (18.3)
5	134	143	18.9 (1.0)	19.2 (0.9)	492 (19.1)	498 (17.1)
6	120	157	20.9 (1.1)	20.8 (1.0)	541 (20.6)	538 (19.9)
7	67	108	22.6 (1.6)	22.3 (1.3)	584 (30.6)	575 (25.9)
8	94	80	25.9 (1.5)	25.8 (1.7)	667 (30.5)	665 (35.0)
9	84	48	26.5 (1.7)	28.8 (2.2)	682 (35.2)	744 (41.3)
10	68	57	29.5 (1.9)	32.2 (2.1)	760 (39.0)	828 (40.5)
11	38	31	30.3 (2.5)	36.3 (2.7)	780 (48.9)	931 (49.8)
12	10	24	30.6 (6.6)	37.6 (3.2)	787 (144.5)	964 (61.8)
13	8	13	31.6 (7.0)	37.1 (5.1)	814 (148.4)	954 (92.6)
14	7	9	31.7 (5.0)	35.1 (5.2)	815 (80.5)	901 (98.2)
15	4	5	31.5 (6.9)	43.6 (7.8)	810 (93.2)	1119 (116.9)
16	4	4	36.3 (8.2)	38.0 (8.2)	929 (154.6)	976 (125.2)
17	5	1	38.2 (6.1)	42.0	976 (133.2)	1089
18		2		42.0 (12.0)		1070 (256.8)
19	3		33.7 (8.6)		866 (99.0)	
20	1		41.0		1064	
21		2		38.0 (5.9)		968 (66.6)
22	1		35.0		906	
23						
24	1	1	44.0	42.0	1123	1087

* Mean length of age-1 is likely an overestimate because age structures were not collected from flathead catfish <7 inches.

Table 5. Population parameters estimated for the flathead catfish population in the Mississippi River and the Missouri River. Weight-length regression is with log_{10}-transformed length (mm) and weight (g) data.

Parameter	Value - Mississippi River	Value - Missouri River
Weight-length regression slope (b)	3.2395	3.0832
Weight-length regression intercept (a)	-5.5927	-5.1811
von Bertalanffy growth curve - L_∞	1160.1	1224.1
von Bertalanffy growth curve - K	0.0890	0.106
von Bertalanffy growth curve - t_0	-0.867	-0.116
Weighted catch curve - Z	-0.376	-0.3705
Weighted catch curve - Max age	22.8	21.3

Table 6. Number of standard-reward ($25) and high-reward ($150) tags marked and reported prior to January 2020 and estimated standard tag reporting rate by river, permit type, and site.

River / Site	Marked $25	Marked $150	Reported $25	Reported $150	Reporting Rate
Mississippi River	586	250	73	50	0.62
Recreational			55	36	0.65
Commercial			18	14	0.55
1	173	75	16	15	0.46
2	145	62	20	11	0.78
3	130	53	14	10	0.57
4	138	60	23	14	0.71
Missouri River	589	261	94	64	0.65
5	132	63	24	13	0.88
6	174	76	30	24	0.55
7	112	48	23	10	0.99
8	171	74	17	17	0.43

Table 7. Number of standard-reward ($25) and high-reward ($150) tags harvested and caught and released within 365 days post-tagging and estimates of total annual exploitation by river, permit type, and site.

River / Site	Harvested $25	Harvested $150	Caught and Released $25	Caught and Released $150	Exploitation Rate
Mississippi	35	26	6	5	0.10
Recreational	27	17	5	5	0.07
Commercial	8	9	1	0	0.03
1	10	8	1	1	0.12
2	10	6	0	1	0.09
3	7	6	3	1	0.10
4	8	6	2	2	0.09
Missouri	46	25	16	9	0.12
5	12	3	3	3	0.09
6	16	10	5	2	0.16
7	10	3	3	1	0.09
8	8	9	5	3	0.12

Table 8. Size-specific exploitation rates of flathead catfish on the Mississippi River and Missouri River.

Size (inches)	**Exploitation Rate** - Missouri	**Exploitation Rate** - Mississippi
Overall	0.119	0.101
15-16.9	0	0.019
17-18.9	0.067	0.055
19-20.9	0.146	0.104
21-22.9	0.088	0.110
23-24.9	0.110	0.141
25-26.9	0.216	0.088
27-28.9	0.141	0.223
29-30.9	0.274	0.080
31-32.9	0.139	0.106
33-34.9	0.132	0.176
35-39.9	0.099	0.080
40+	0.079	0.080

Table 9. Gear-specific exploitation rates of flathead catfish on the Mississippi River and Missouri River.

Method	Mississippi River Harvested	Mississippi River Released	Mississippi River Exploitation Rate	Missouri River Harvested	Missouri River Released	Missouri River Exploitation Rate
Bank Pole	5		0.008	22	5	0.033
Gill Net	2		0.003			
Hoop Net	7	1	0.011			
Jug Line				2	1	0.004
Limb Line	3	1	0.005	8		0.014
Rod/Reel	13	4	0.022	17	10	0.028
Trammel Net	2		0.002			
Trot Line	24	4	0.040	22	7	0.035
Unknown	5	1	0.008		2	

Table 10. Pounds of flathead catfish commercially harvested and number of commercial flathead catfish harvesters from the Mississippi River and from each study site annually from 2015-2018 (unpublished data).

Location	2015 Harvest (lbs.)	2015 Harvesters (No.)	2016 Harvest (lbs.)	2016 Harvesters (No.)	2017 Harvest (lbs.)	2017 Harvesters (No.)	2018 Harvest (lbs.)	2018 Harvesters (No.)
Mississippi River	27,205	65	19,934	56	21,703	53	18,959	44
- **Site 1**	990	3	34	2	0	0	0	0
- **Site 2**	98	2	78	1	247	2	27	1
- **Site 3**	691	2	140	2	116	1	0	0
- **Site 4**	1,674	5	808	5	3,797	9	3,827	12

Figures

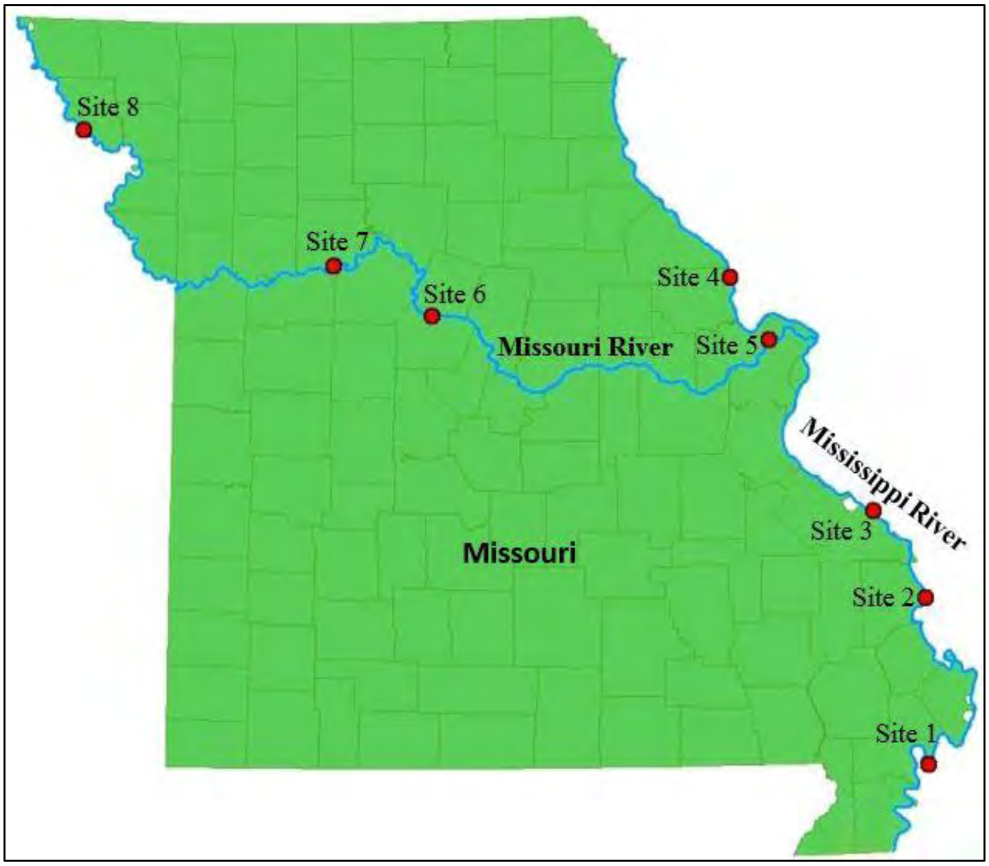


Figure 1. Map of study sites.

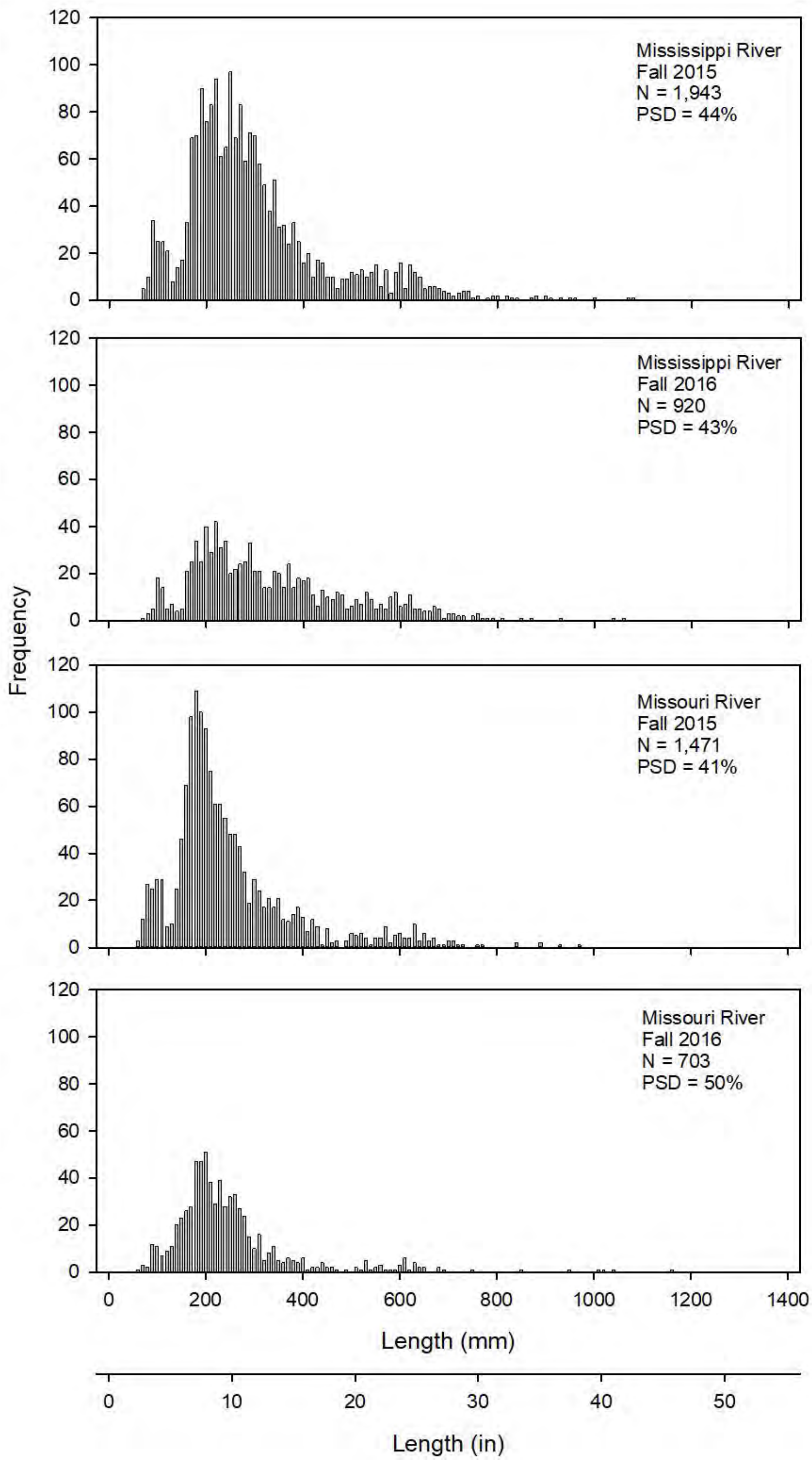


Figure 2. Length-frequency distributions of flathead catfish collected during standard, random electrofishing sampling.

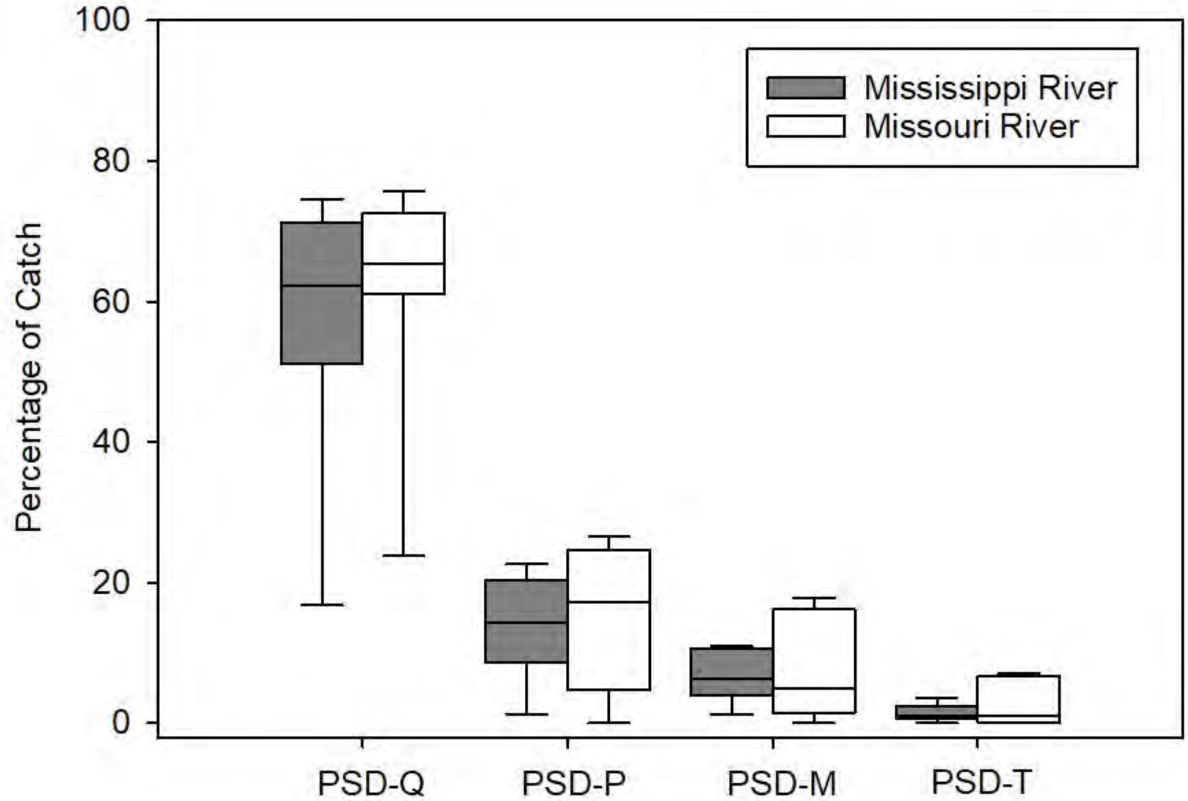


Figure 3. Proportional-size distributions of flathead catfish collected in the Mississippi River and the Missouri River. PSD indices were calculated using flathead catfish length categories described by Anderson and Neumann (1996) as follows: stock (14 in or 350 mm), quality (20 in or 510 mm), preferred (28 in or 710 mm), memorable (34 in or 860 mm), and trophy (40 in or 1020 mm).

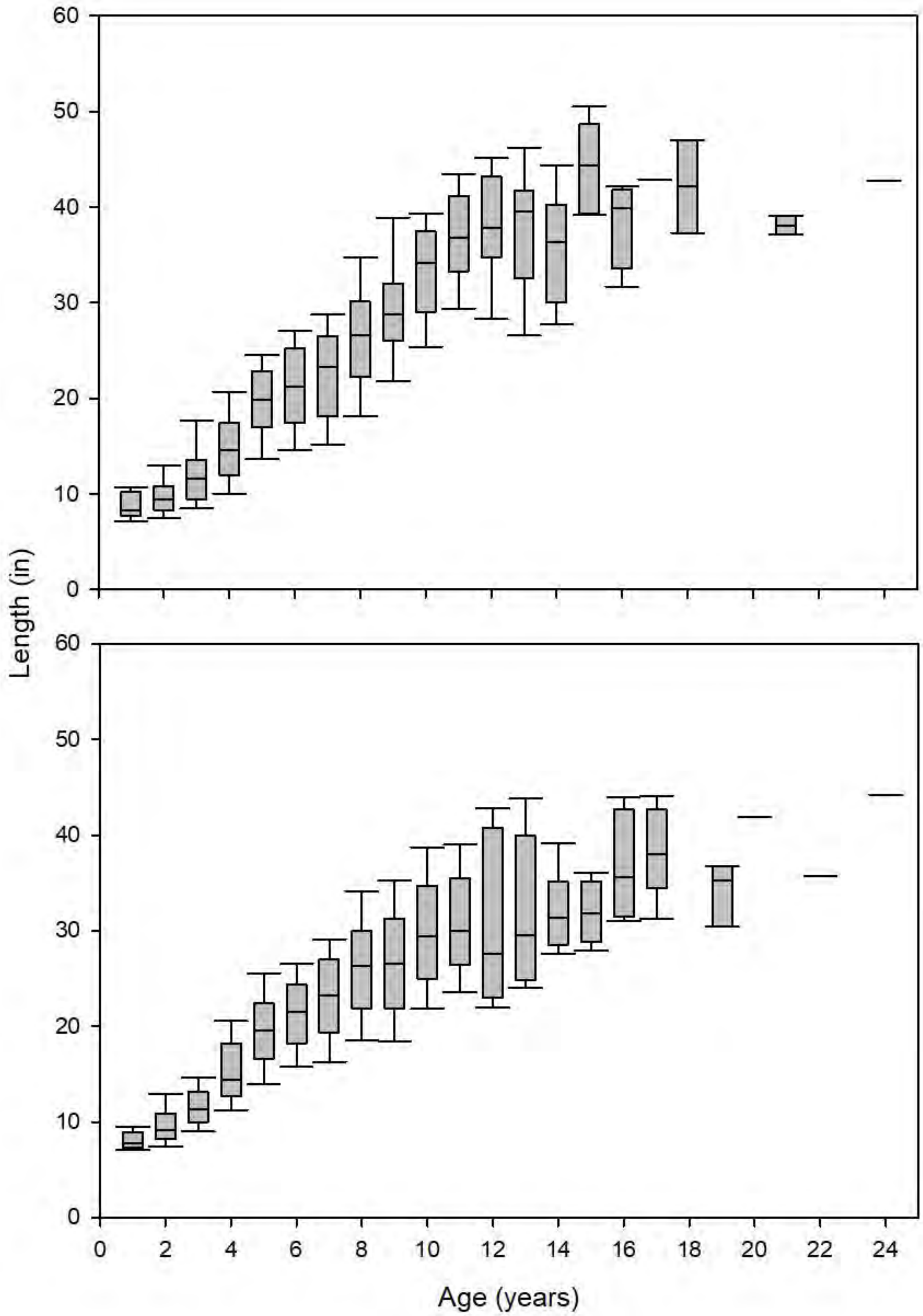


Figure 4. Boxplot of total length by estimated age of flathead catfish collected in the Missouri River (top panel) and the Mississippi River (bottom panel). Boxes represent upper and lower quartiles with the median depicted by the line within the box. Vertical error bars represent the 10^{th} and 90^{th} percentiles.

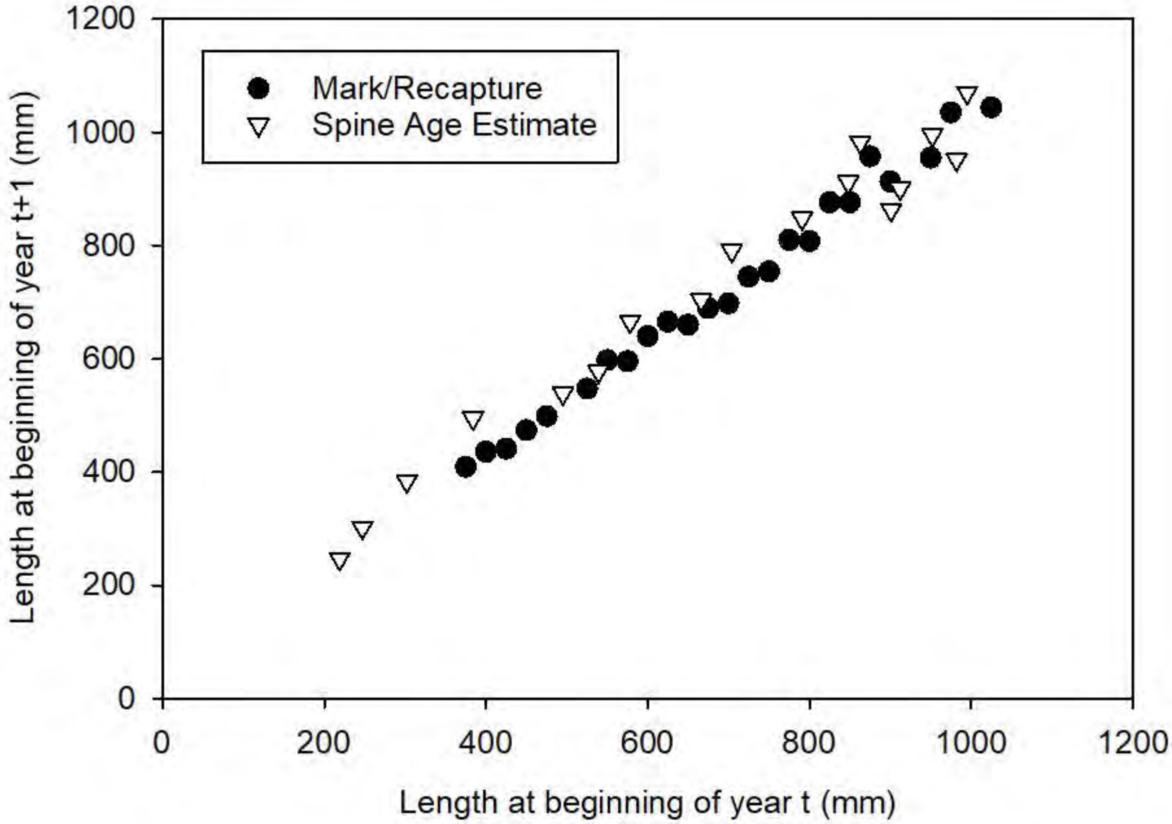


Figure 5. Annual growth increments of flathead catfish calculated from tagged fish that were recaptured during subsequent years and from pectoral spine age estimates.

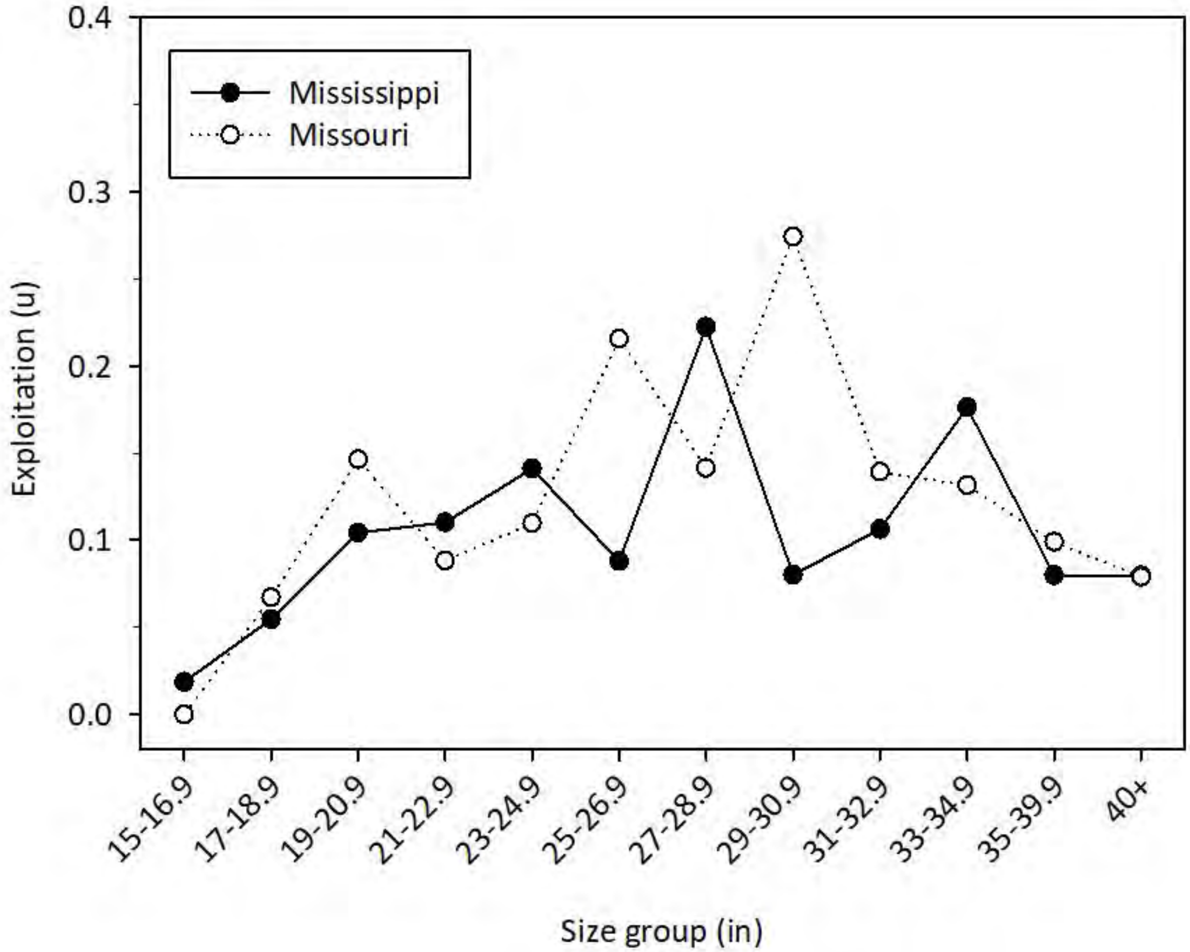


Figure 6. Exploitation of flathead catfish by size group on the Mississippi River and Missouri River.

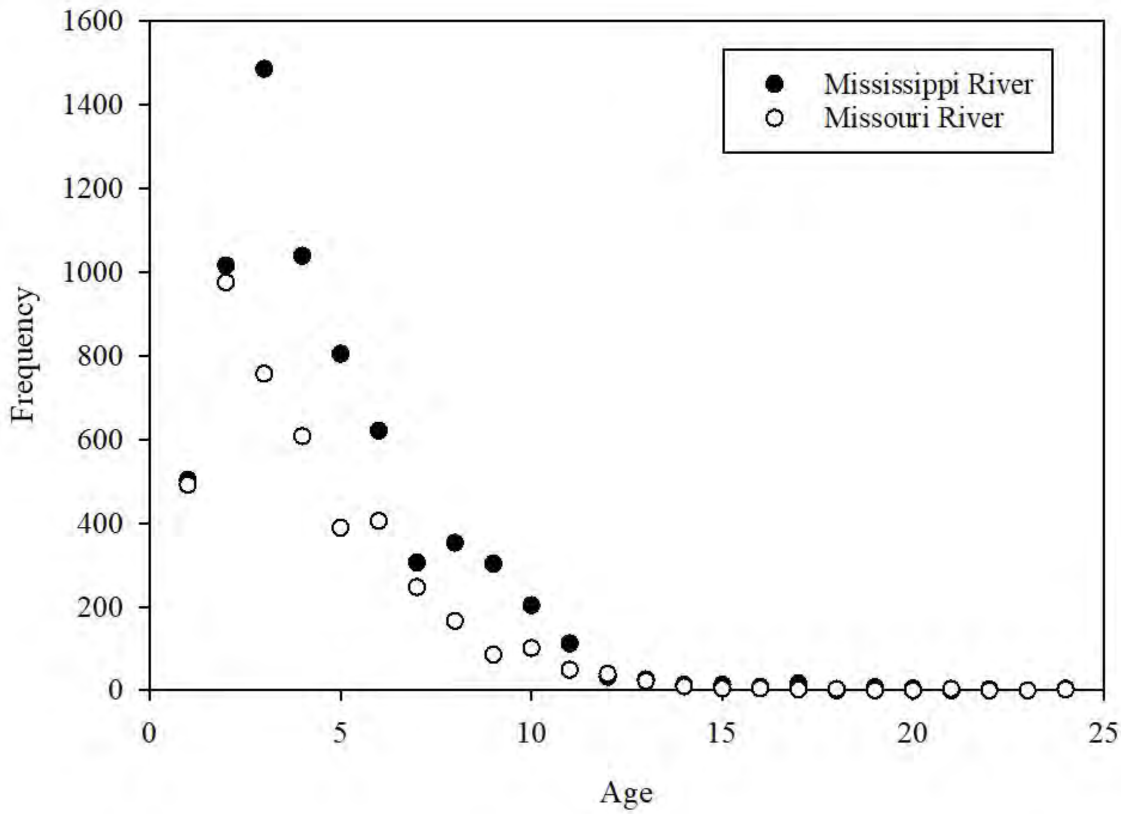


Figure 7. Age frequency plot of flathead catfish collected during sampling in the Mississippi River and the Missouri River.

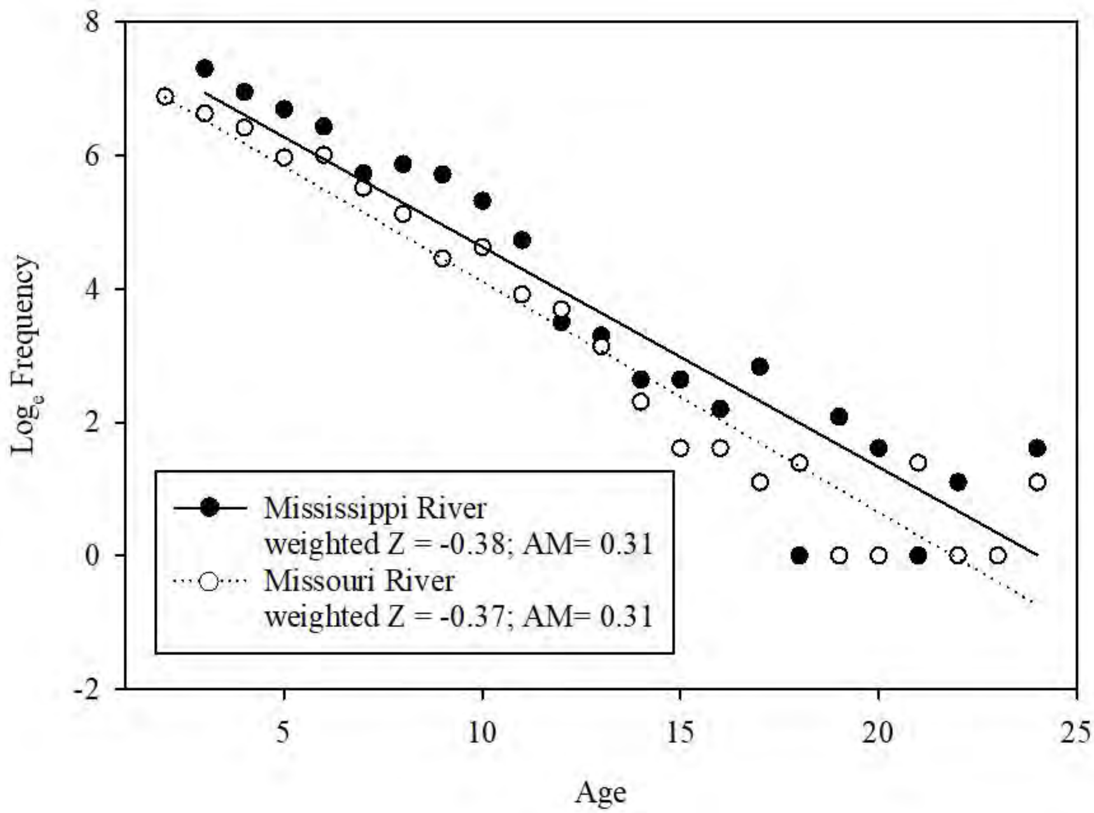


Figure 8. Weighted catch-curve for total annual mortality estimation of flathead catfish in the Mississippi River and the Missouri River.

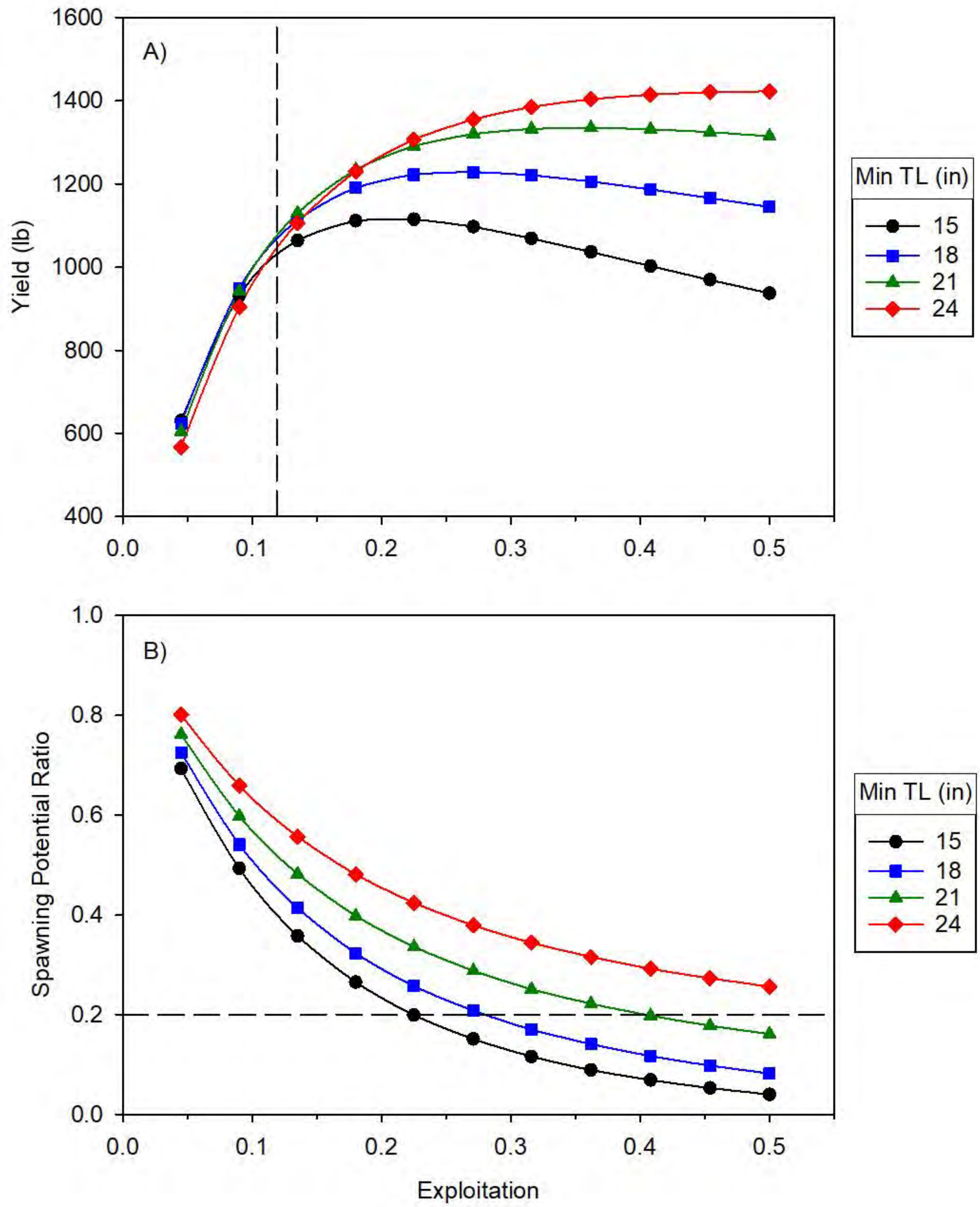


Figure 9. Missouri River. Yield-per-recruit model under varying minimum length limits with cm=0.20 and exploitation equal among all sizes. At current levels of exploitation (vertical dashed line) predicted yield was greatest with an 18 to 21-inch minimum length limit (panel A). Exploitation rates that would induce growth overfishing were identified by the descending limb of the yield curve. Recruitment overfishing was identified as the point where the spawning potential ratio dropped below 0.20 (horizontal dashed line; panel B).

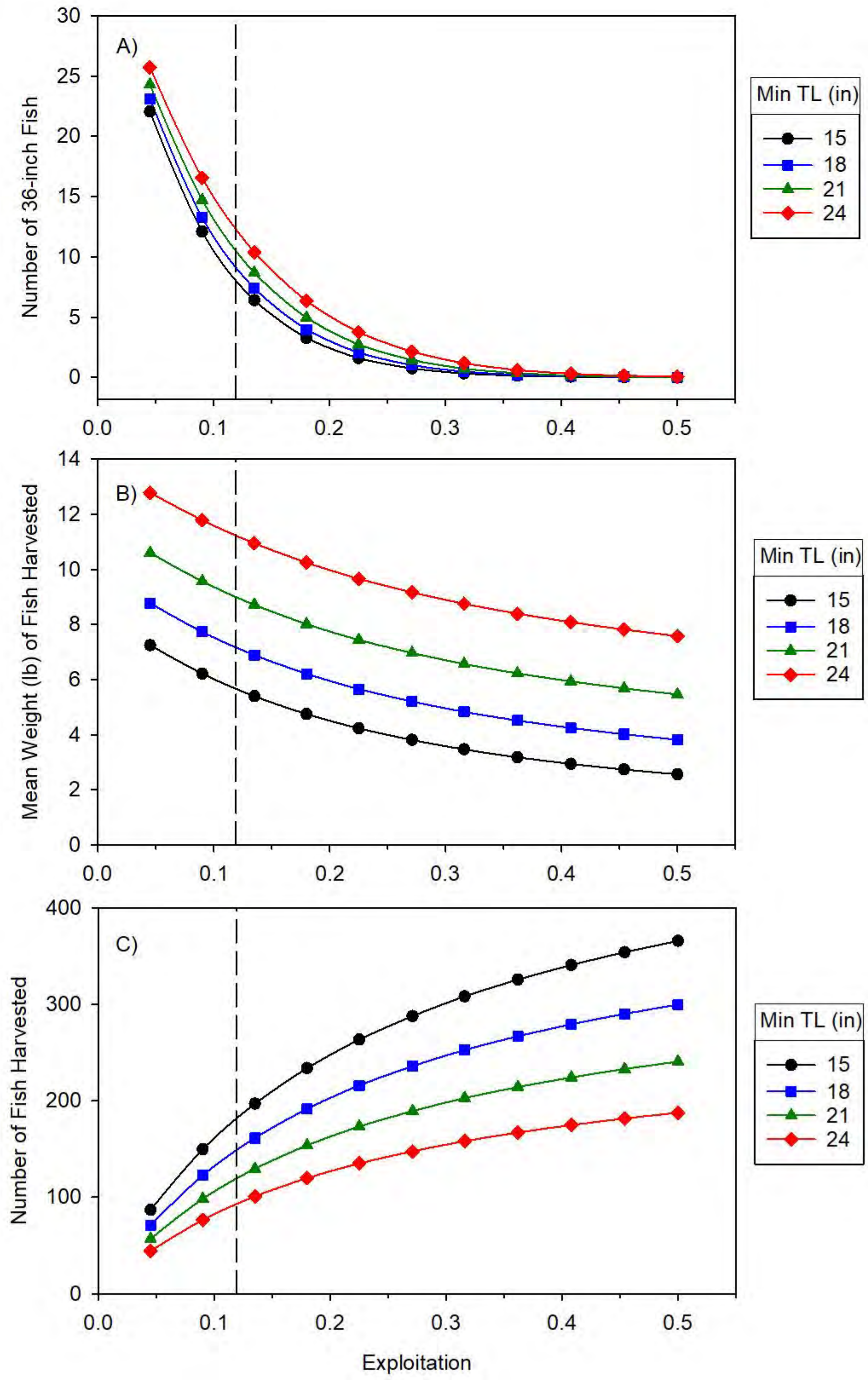


Figure 10. Missouri River. Yield-per-recruit model with cm=0.20 and exploitation equal among all sizes. Predicted number of trophy-size (38 inches) flathead catfish (panel A), mean weight of fish harvested (panel B), and number of fish harvested (panel C) under varying minimum length limits. Estimates of overall of exploitation (11.9 percent) is depicted by the vertical dashed line in all panels.

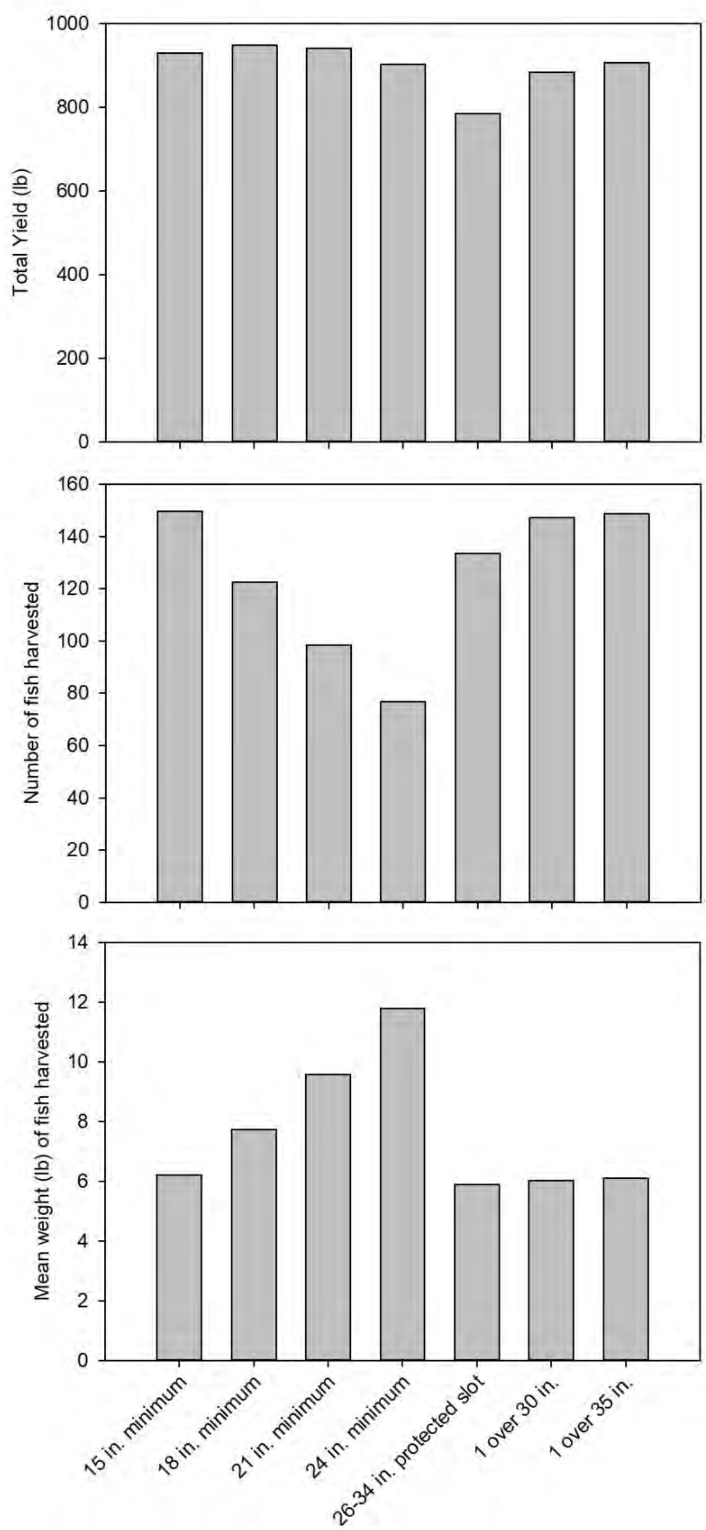


Figure 11. Missouri River. Comparison of the predicted yield (top panel), number of flathead catfish harvested (middle panel), and mean weight of flathead catfish harvested (bottom panel) under various harvest regulations (cf=0.13; cm=0.20).

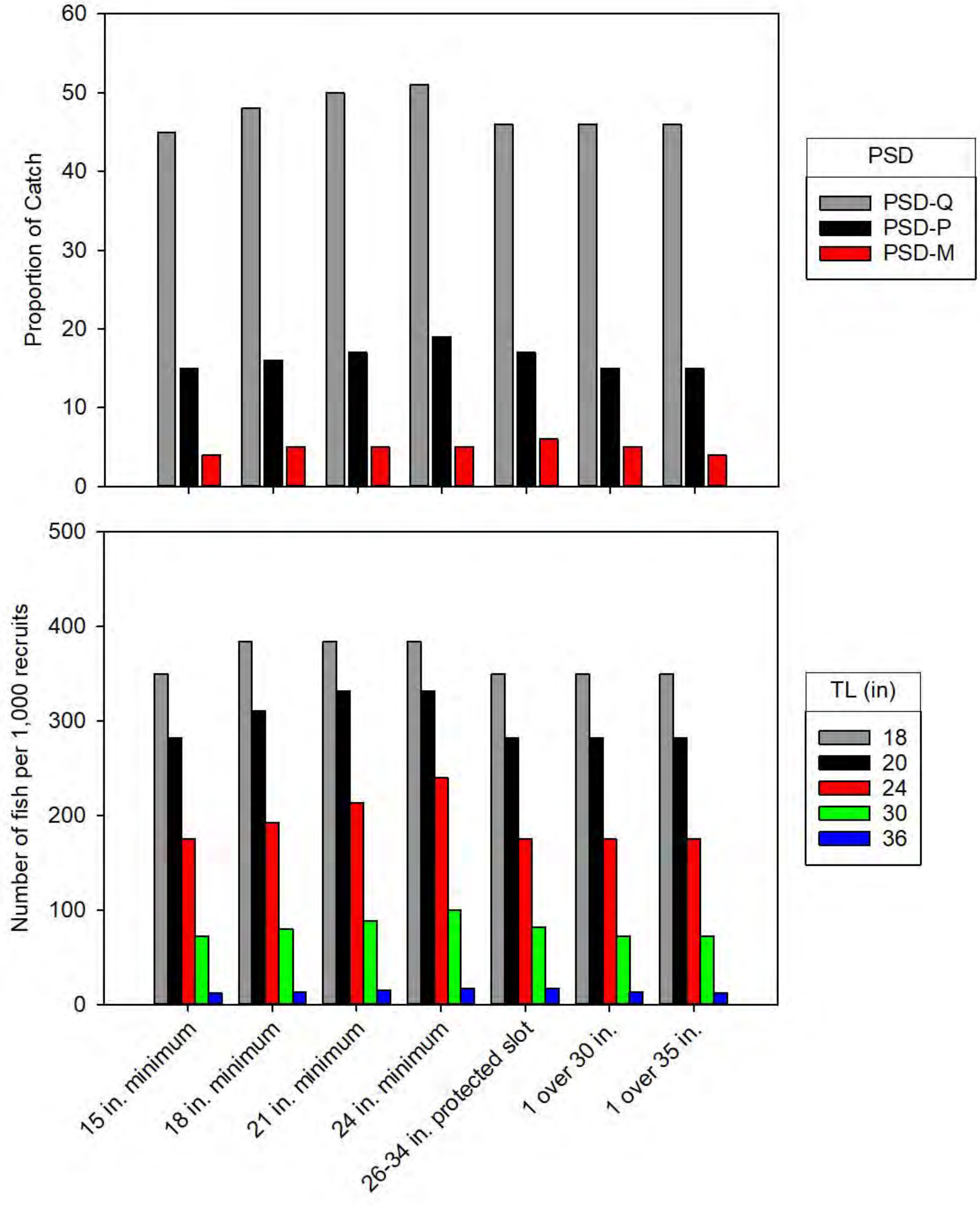


Figure 12. Missouri River. Comparison of the proportional size distributions (top panel) and number of flathead catfish at specific sizes (bottom panel) under various harvest regulations.

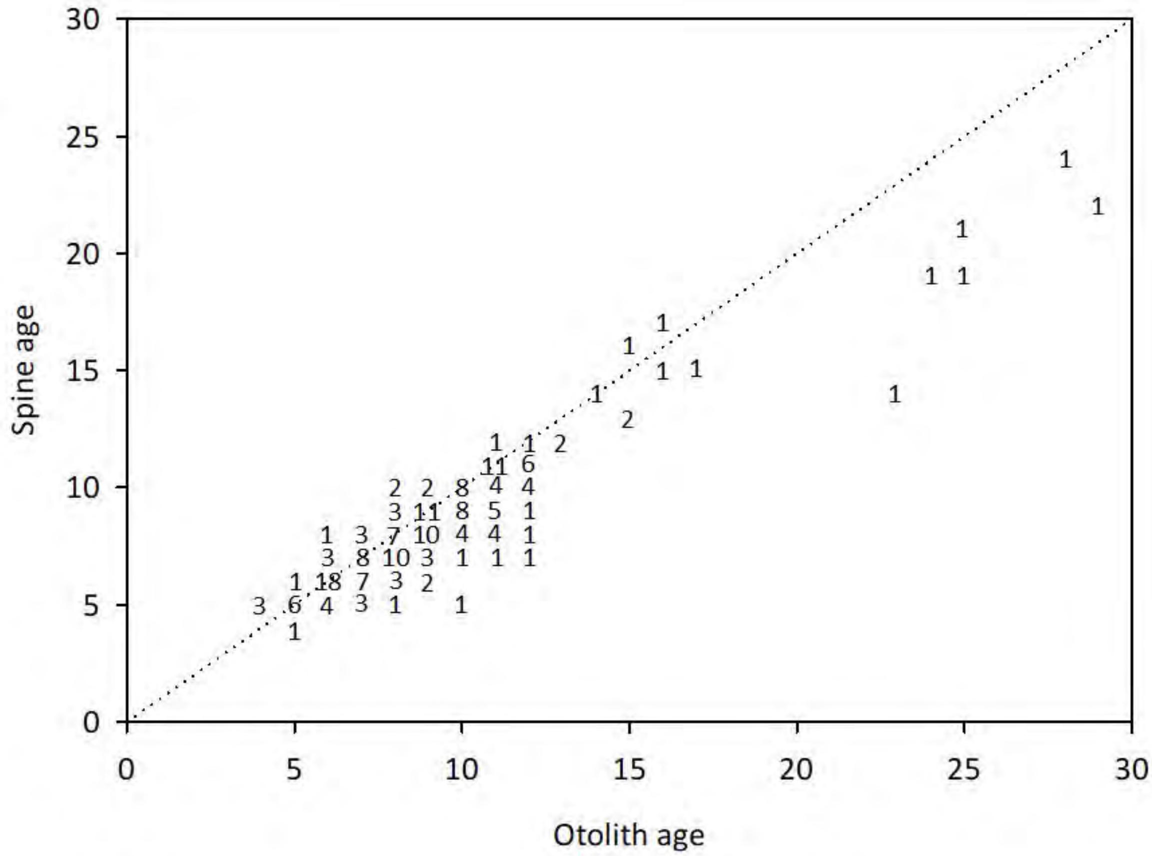


Figure 13. Age bias plot for age estimates of flathead catfish (concert read) from otoliths and spine sections. Numbers indicate sample sizes. The dashed line represents agreement between age estimates.

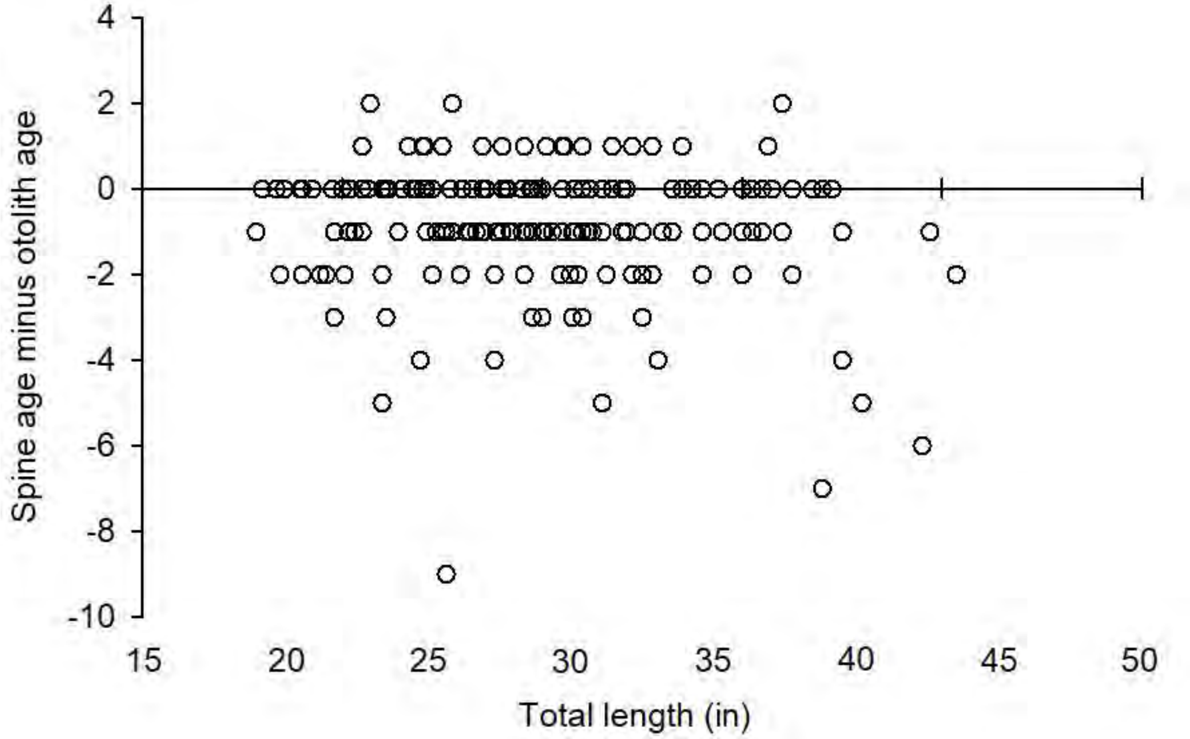


Figure 14. Differences between ages estimated from spine and otolith sections in relation to total length of flathead catfish.

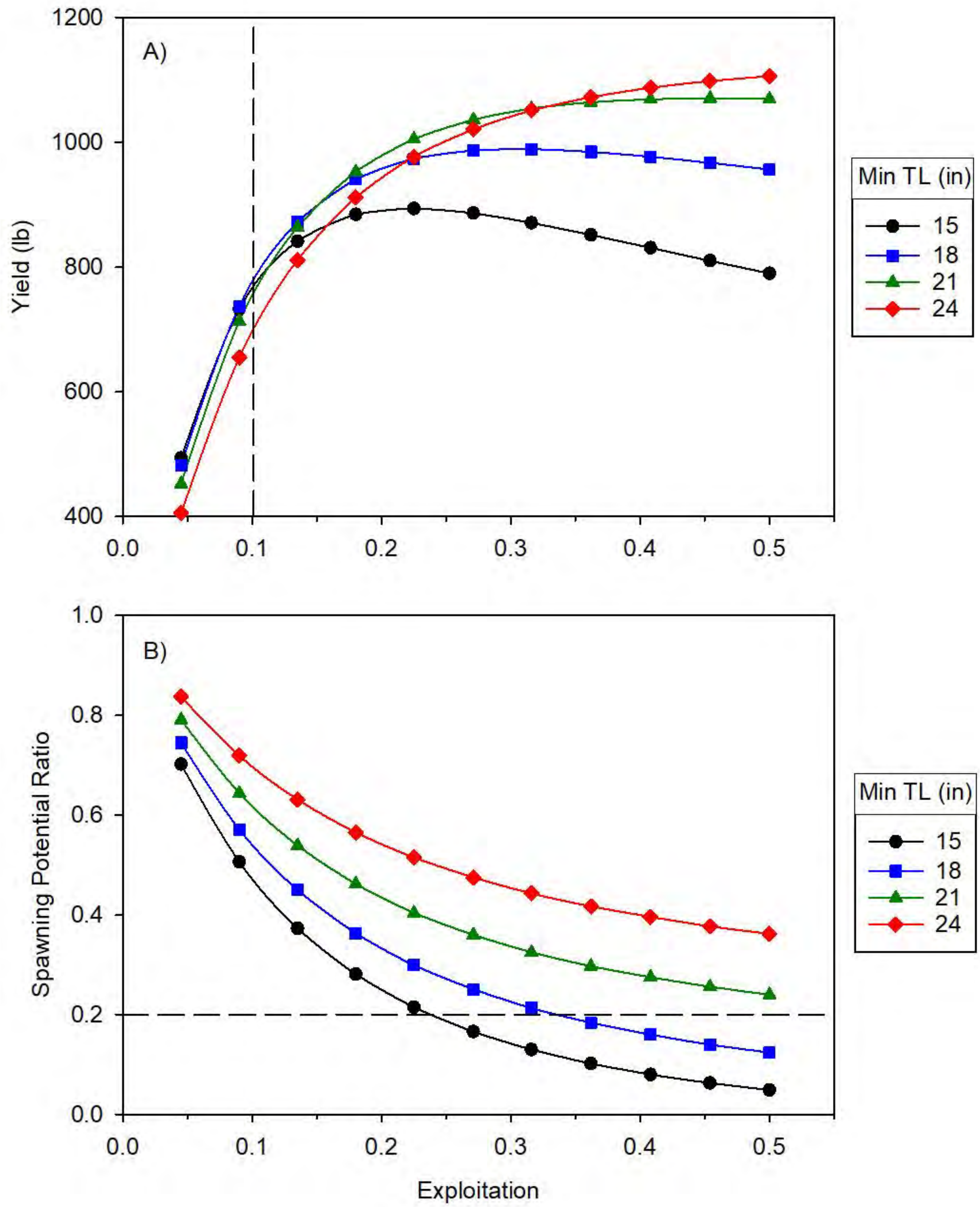


Figure 15. Mississippi River. Yield-per-recruit model under varying minimum length limits with cm=0.20 and exploitation equal among all sizes. At current levels of exploitation (vertical dashed line) predicted yield was greatest with a 15 to 18-inch minimum length limit (panel A). Exploitation rates that would induce growth overfishing were identified by the descending limb of the yield curve. Recruitment overfishing was identified as the point where the spawning potential ratio dropped below 0.20 (horizontal dashed line; panel B).

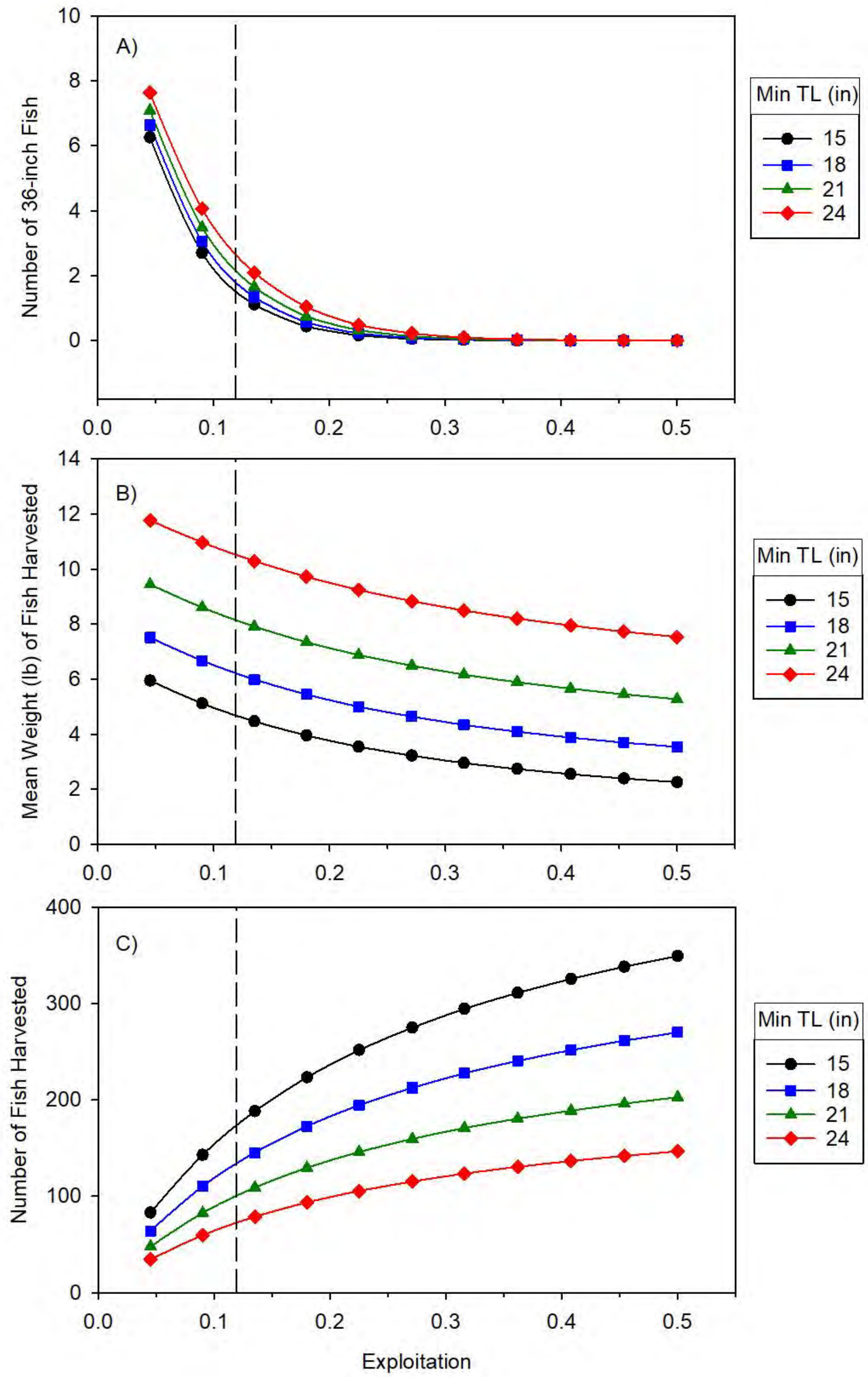


Figure 16. <u>Mississippi River.</u> Yield-per-recruit model with cm=0.20 and exploitation equal among all sizes. Predicted number of trophy-size (38 inches) flathead catfish (panel A), mean weight of fish harvested (panel B), and number of fish harvested (panel C) under varying minimum length limits. Estimates of overall exploitation (10.1 percent) is depicted by the vertical dashed line in all panels.

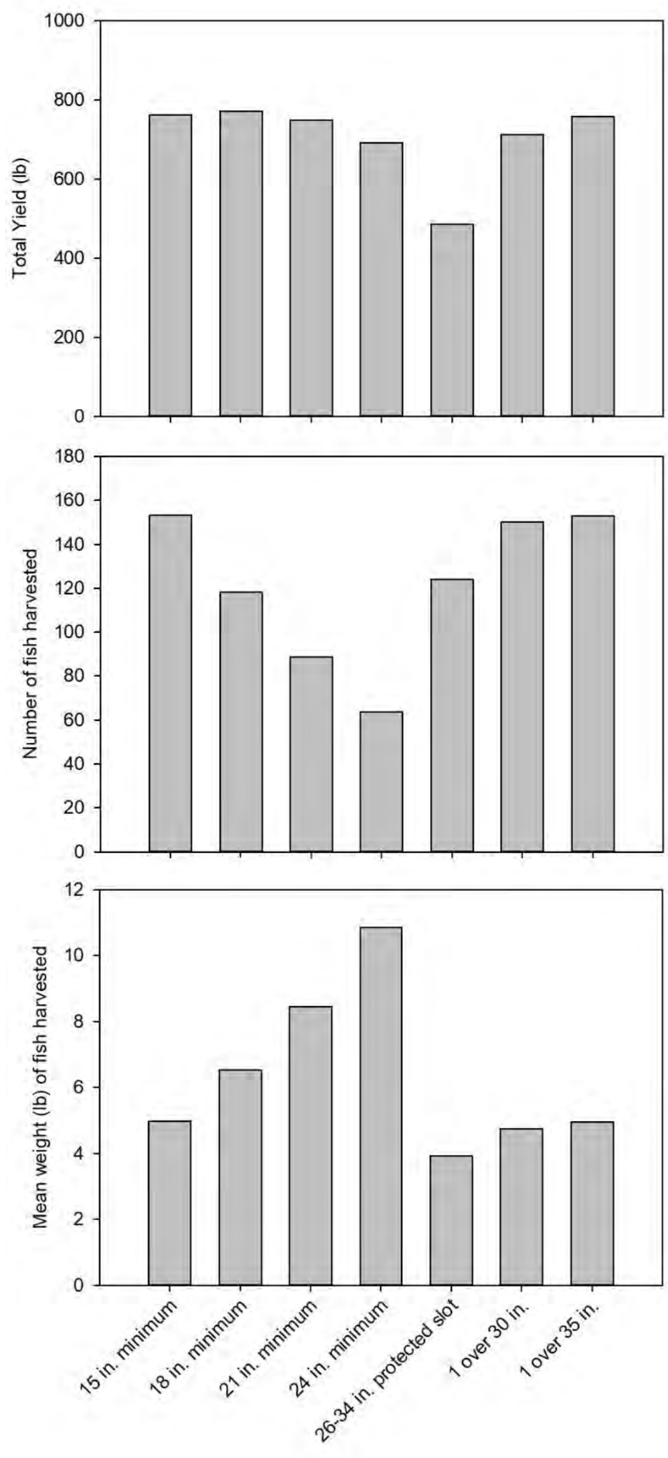


Figure 17. Mississippi River. Comparison of the predicted yield (top panel), number of flathead catfish harvested (middle panel), and mean weight of flathead catfish harvested (bottom panel) under various harvest regulations (cf=0.11; cm=0.20).

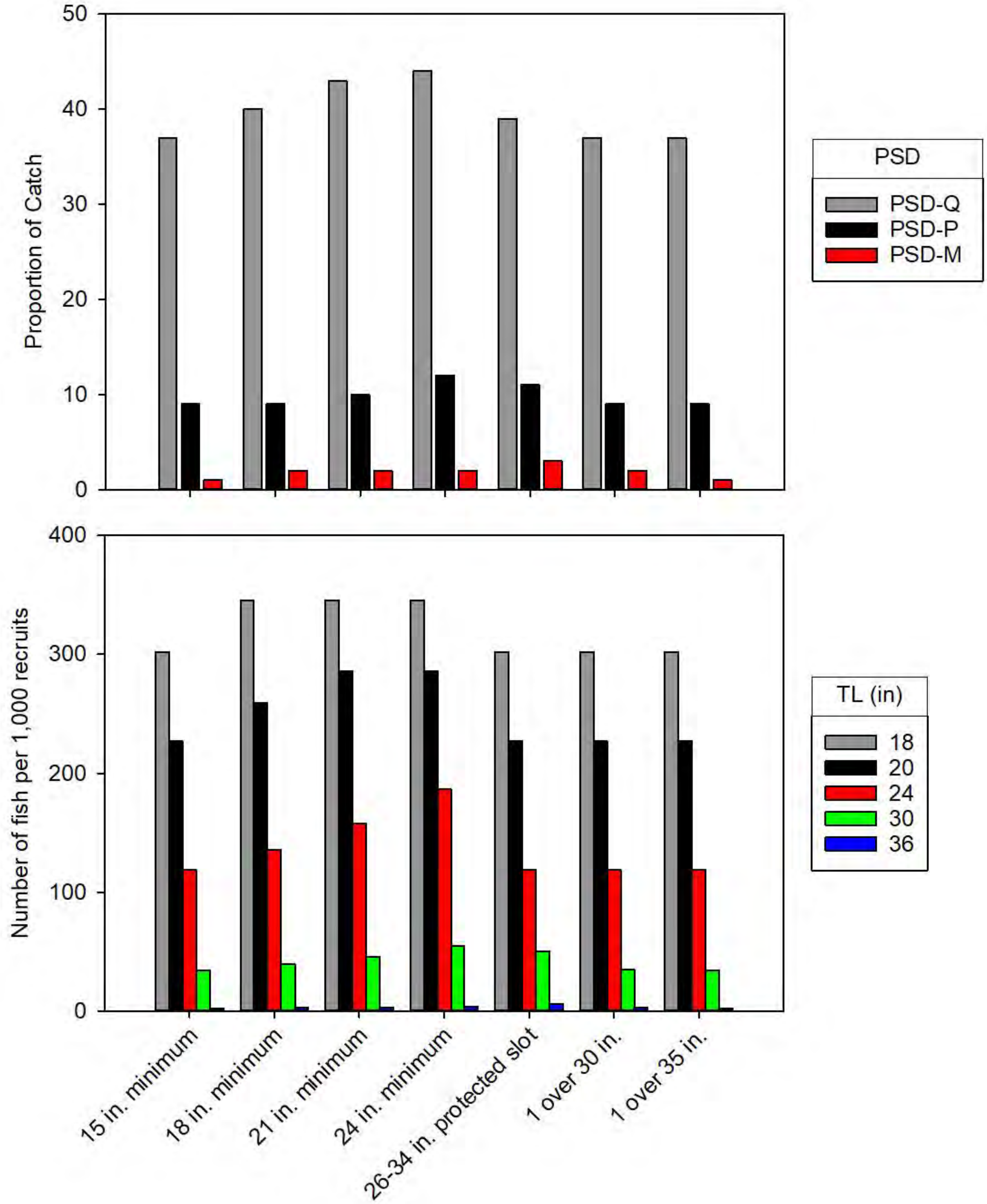


Figure 18. Mississippi River. Comparison of the proportional size distributions (top panel) and number of flathead catfish at specific sizes (bottom panel) under various harvest regulations.

Appendices

Appendix 1. Sampling Protocols

Electrofishing requires potentially hazardous equipment; at least two crew members must acquire cardiopulmonary resuscitation and first aid certification prior to the commencement of sampling.

A data sheet is completed for each sampling run and habitats are sampled consistently.

Standard Random Sampling

Blue catfish and flathead catfish are collected during the spring and fall, respectively, at water temperatures ranging from ≈13 to 24°C (55 to 75°F). Catfish are collected from the Mississippi and Missouri rivers with low-frequency pulsed-DC (15 Hz; 30 percent duty cycle) boat electrofishing at 8 randomly selected sites during daylight hours. Each site is 32.2 river kilometers (20 river miles), of which, one-quarter (25 percent) will be randomly selected for standard sampling. Overall, 25 percent of all potential sampling run locations are randomly selected for standard sampling each calendar year. Standard sampling runs are temporally distributed so that the total effort equals approximately 90 minutes per week (power on time). Not more than one random sampling event (≈90 minutes shock time/25 percent of runs) will occur within a single week. Random run locations for standard sampling are proportionally distributed among habitat types within each site. Alternative random run locations are available for cases when priority random run locations are inaccessible or present a potentially hazardous situation.

Prior to electrofishing runs, ambient water conductivity is measured, or specific water conductivity and water temperature are measured and ambient water conductivity is calculated as $\mathbf{Ca} = \mathbf{Cs\ x\ 1.02^\wedge(T-25)}$, where Ca is the ambient water conductivity, Cs is the specific water conductivity, and T is the water temperature **in °C**. Ambient water conductivity must be re-measured whenever water temperature changes >3°C or at/near tributary mouths. For each run, the peak voltage goal is determined based on ambient water conductivity in order to standardize fish response (Table 1). The voltage meter readings on some electrofishing control boxes (e.g., VVP-15B) do not match actual peak output; therefore, boat specific meter readings are adjusted to produce actual peak outputs within 2 standard errors of the voltage goal (Table 2). Boats with electrofishing control boxes with accurate peak meter readings (e.g. Infinity, ETS) should be used if available.

The total length (TL) of all blue catfish and flathead catfish collected during standard random sampling is measured (mm) and all fish receiving a reward tag are weighed (g). Ten pectoral spines per length group, per species, per site, per year are obtained for age determination of blue catfish and flathead catfish ≥177 mm (≥7 in) TL (see *Ageing Structure Protocol*). Pectoral spines are collected from blue catfish in the spring only and from flathead catfish in the fall only. Otoliths and pectoral spines are collected from mortalities encountered afield or from harvesters willing to donate structures. Eleven reward tags per length group, per species, per site, per year are affixed to blue catfish and flathead catfish ≥381 mm (≥15 in) TL (see *Reward Tagging Protocol*). Blue catfish receive reward tags in the spring only; flathead catfish receive reward tags in the fall only. All fish ≥177 mm (≥7 in) TL captured during standard random sampling which do not receive a reward tag receive a fin clip to identify recaptures.

One electrofishing boat will shock and collected stunned fish while one chase boat assists with the capture of stunned fish. The electrofishing boat has, at a minimum, a three-member crew, one pilot and two netters. The chase boat has, at a minimum, a two-member crew, one pilot and one netter. Additional crew members may be utilized but the number of active netters per boat must remain constant. Dip nets must be a minimum of 30-cm (12-in) deep with no larger than 1.3-cm (1/2-in) mesh size on non-conductive handles. Netters collect each catfish as it surfaces, regardless of size or species and place them in holding tanks until the run is terminated. Utilize aerators or regular water exchanges between river and tank to ensure healthy holding conditions for fish. Non-target species are released.

The primary responsibility of the electrofishing boat's crew is to shock each habitat type in a standardized manner while netting catfish that can be captured without drastically deviating from its current position or path to the extent possible. Deviations may be necessary to avoid obstructions or when the chase boat is overwhelmed with the collection of large numbers of surfacing catfish. During a run, the pilot operates the boat at a speed and along a path such that 3 to 10 minutes of effort allows coverage of the approximate sampling area. A timer is used to measure the time spent electrofishing with the power on at each run location. The accessible sampling area of any individual run may vary depending on water level. Portions of the run which may exhibit higher habitat complexity or quality (i.e., large woody debris, brush piles, scours, etc.) are shocked thoroughly until they no longer yield fish. The pilot is free to modify the forward and backward movement of the boat to permit the most effective collection of fish only to the extent that such movement does not interfere with the objective of obtaining 100 percent area coverage with a single 3 to 10 minute run. The primary responsibility of the chase boat's crew is to net as many catfish as possible without interfering with the electrofishing boat.

Sampling is conducted so long as the river stage nearest to a site is below Action Stage. Sampling may be delayed should a site be deemed unsafe to navigate or if a crew's ability to access the river is compromised. Visit the U.S. Geologic Service's National Water Information System at http://waterdata.usgs.gov/nwis/rt or the National Weather Service's Advanced Hydrologic Prediction Services at http://water.weather.gov/ahps/ to check current and projected river stages. To ensure that sampling is completed statewide, each season, it may be necessary to assist crews that are presented with a shorter sampling window due to inhospitable weather and/or river stages.

Non-Random Sampling

Non-random sampling may be necessary to collect adequate numbers of some length groups of blue catfish and flathead catfish for aging and tagging. Non-random sampling methods may include the use of hoop nets, trotlines, gill nets, trammel nets, or targeted electrofishing runs (standard sampling protocols for electrofishing do not need to be followed for non-random sampling. Non-random sampling must occur within the boundaries of a site at water temperatures ranging from 10 to ≈27^{o}C (50 to 80^{o}F). All blue catfish and flathead catfish collected during non-random sampling are measured for total length (TL) (mm). **Catfish collected during non-random sampling do not receive a fin clip.**

Table 1. Peak output voltage goal (VGoal) by ambient water conductivity (Ca). Voltage goals are based on an assumed effective fish conductivity (115 µS/cm) and peak output power levels used during initial pilot sampling. This represents preliminary output goals until further research is done.

Ca	VGoal	+/- 2SE	Ca	VGoal	+/- 2SE
10	2624	74	130	396	11
20	1417	40	140	382	11
30	1014	29	150	371	10
40	813	23	170	352	10
50	693	20	200	331	9
60	612	17	250	306	9
70	555	16	300	290	8
80	512	14	400	270	8
90	478	13	600	250	7
100	451	13	800	240	7
110	429	12	1000	234	7
120	411	12	115	420	12

Table 2. Boat specific (identified by Biologist's last name) voltage meter readings compared to actual peak voltage output for each Biologist's respective control box.

Box Meter Reading Volt Setting	Knuth	Ostendorf	Peper	Dames	Gemming	Allman	Mason
100	109	100	142	105	112	94	139
125	138	125	176	133	138	125	167
150	166	150	210	161	164	156	195
175	195	175	244	188	190	187	223
200	223	200	277	216	216	219	251
225	252	225	311	244	242	250	279
250	281	250	345	272	268	281	307
275	309	275	379	299	294	312	335
300	338	300	413	327	320	343	363
325	366	325	446	355	346	374	390
350	395	350	480	383	371	406	418
375	423	375	514	410	397	437	446
400	452	400	548	438	423	468	474
425	481	425	581	466	449	499	502
450	509	450	615	493	475	530	530
475	538	475	649	521	501	562	558
500	566	500	683	549	527	593	586

Habitat Types and Associated Sampling Techniques

Sampling methods vary by habitat type. Figures 1 through 4 depict where sampling is required (blue arrows) and where sampling is optional (orange arrows), water depths permitting and if safe to do so.

Main Channel Natural Bank: Main channel banklines which are primarily comprised of naturally deposited materials such as clay, silt, sand, gravel, boulders, rock outcroppings, or any combination of these materials. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the bankline and sample slowly and continuously. Maneuver to alternate the boat's position relative to the bankline and pause or slow the boat as needed (Figure 1).

Main Channel Other Structure: Main channel rock structures including chevrons, W-dikes, and multiple roundpoint structures (MRS) but excluding wing dikes and trail dikes. Sampling Method: Begin sampling by positioning the electrofishing boat near the scour hole just downstream of the main channel tip of the structure and remain stationary/near the scour for a minimum of three minutes. Maneuver the electrofishing boat close to the structure and sample along its entire length slowly and continuously. Sample the down then upstream sides of emergent structures. Sample from the downstream side and cross just over submerged structures if possible. Maneuver to alternate the boat's position relative to the structure and pause or slow the boat as needed.

Main Channel Revetted Bank: Homogenous main channel banklines which are covered by an erosion resistant material (e.g., stone rip rap or articulated concrete mattress (ACM)) and are devoid of dikes. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the bankline and sample slowly and continuously. Maneuver to alternate the boat's position relative to the bankline and pause or slow the boat as needed (Figure 1).

Main Channel Sandbar: Main channel sand deposits in proximity to but often disjunct from main channel banklines or structures. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the sandbar and sample slowly and continuously. Maneuver to alternate the boat's position relative to the sandbar and pause or slow the boat as needed. Sample the channel then bankline sides of emergent sandbars, or over submerged sandbars (Figure 1).

Main Channel Trail Dike (L-Dike): Rock trail dikes including all portions of the structure from the bankline to the tip nearest the main channel and a portion of the bankline up and downstream of the foot of the dike (from the foot of the dike upstream 50 meters and downstream to just past the downstream portion of the bank scour). Sampling Method: Begin by positioning the electrofishing boat near the scour hole just downstream of the main channel tip of the structure and remain stationary/near the scour for a minimum of three minutes. Approach the main channel tip of the structure and continue slowly and continuously along the main channel side of the portion of the structure that is approximately parallel to flow, to its most upstream point. Sampling may be continued along the bankline side of the structure, down/upstream of the portion of the structure that is approximately perpendicular to flow to the foot of the dike and along the banklines down/upstream of the structure. If emergent, sample main channel then bankline sides and down then upstream sides of the structure and associated banklines. Sample from the main channel/downstream side and cross just over submerged structures if possible. Maneuver to alternate the boat's position relative to the structure and associated banklines, and pause or slow the boat as needed (Figure 2).

Main Channel Wing Dike: Rock wing dikes including all portions of the structure from the bankline to the tip nearest the main channel and a portion of the bankline up and downstream of the foot of the dike (from the foot of the dike upstream 50 meters and downstream to just past the downstream portion of the bank scour). Sampling Method: Begin sampling by positioning the electrofishing boat near the scour hole just downstream of the main channel tip of the structure and remain stationary/near the scour for a minimum of three minutes. Maneuver the electrofishing boat close to the main channel tip of the structure and continue slowly and continuously along the downstream edge toward the bankline. Sampling may be continued to the foot of the dike and along the banklines down/upstream of the structure. Sample the down then upstream sides of emergent structures and associated banklines. Sample from the downstream side and cross just over submerged structures if possible. Maneuver to alternate the boat's position relative to the structure and banklines, and pause or slow the boat as needed (Figure 3).

Side Channel Natural Bank: Side channel banklines which are primarily comprised of naturally deposited materials such as clay, silt, sand, gravel, boulders, rock outcroppings, or any combination of these materials. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the bankline and sample slowly and continuously. Maneuver to alternate the boat's position relative to the bankline and pause or slow the boat as needed (Figure 1).

Side Channel Revetted Bank: Homogenous side channel banklines which are covered by an erosion resistant material (e.g., stone rip rap or articulated concrete mattress (ACM)) and are devoid of dikes. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the bankline and sample downstream slowly and continuously. Maneuver to alternate the boat's position relative to the bankline and pause or slow the boat as needed (Figure 1).

Side Channel Structure: Side channel rock structures including dikes and closing structures. Sampling Method: Maneuver the electrofishing boat close to the structure and sample along its entire length slowly and continuously. Sample the down then upstream sides of emergent structures. Sample from the downstream side and cross just over submerged structures if possible. Maneuver to alternate the boat's position relative to the structure and pause or slow the boat as needed.

Tailwater Open: Open water within the tailwater of a mainstem dam (from the point of discharge from the dam to 0.5 river miles downstream). Sampling Method: Begin sampling at the main channel side of the earthen dam. Maneuver the electrofishing boat close and parallel to the earthen dam sampling slowly and continuously toward the bankline then back toward the main channel through the deeper scour. Continue sampling downstream of the main dam keeping the boat pointed upstream and moving closely along the dam. Finish the run by sampling the current seam downstream of the main dam-earthen dam connection. Maneuver to alternate the boat's position relative to the dam and banklines and pause or slow the boat as needed.

Tailwater Structure: Rock structures within the tailwater of a mainstem dam (from the point of discharge from the dam to 0.5 river miles downstream) including wing dikes, trail dikes, chevrons, and multiple roundpoint structures (MRS). Sampling Method: Follow methods for Main Channel Wing Dike, Main Channel Trail Dike, or Main Channel Other Structure where appropriate (Figures 2 or 3)

Tributary Mouth: The mouth of tributary streams 4th order or larger, including the main channel or side channel banklines within 50 meters up and downstream of the confluence and the tributary banklines within 200 meters upstream of its mouth. Sampling Method: Begin at the up or downstream boundary of the run. Maneuver the electrofishing boat close and parallel to the bankline and sample slowly and continuously to where the tributary bankline meets that of the main channel. Sample each tributary bankline and finish the run by sampling the remainder of the main channel bankline. Maneuver to alternate the boat's position relative to the banklines and pause or slow the boat as needed (Figure 4).

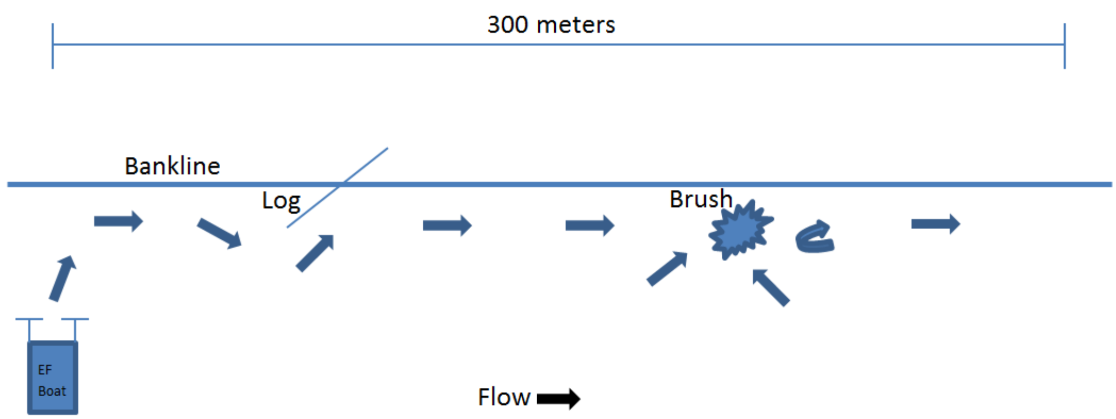


Figure 1: Diagram of electrofishing boat maneuvers for Main Channel Natural Bank, Main Channel Revetted Bank, Side Channel Natural Bank. Main Channel Revetted Bank and Main Channel Sandbar habitats.

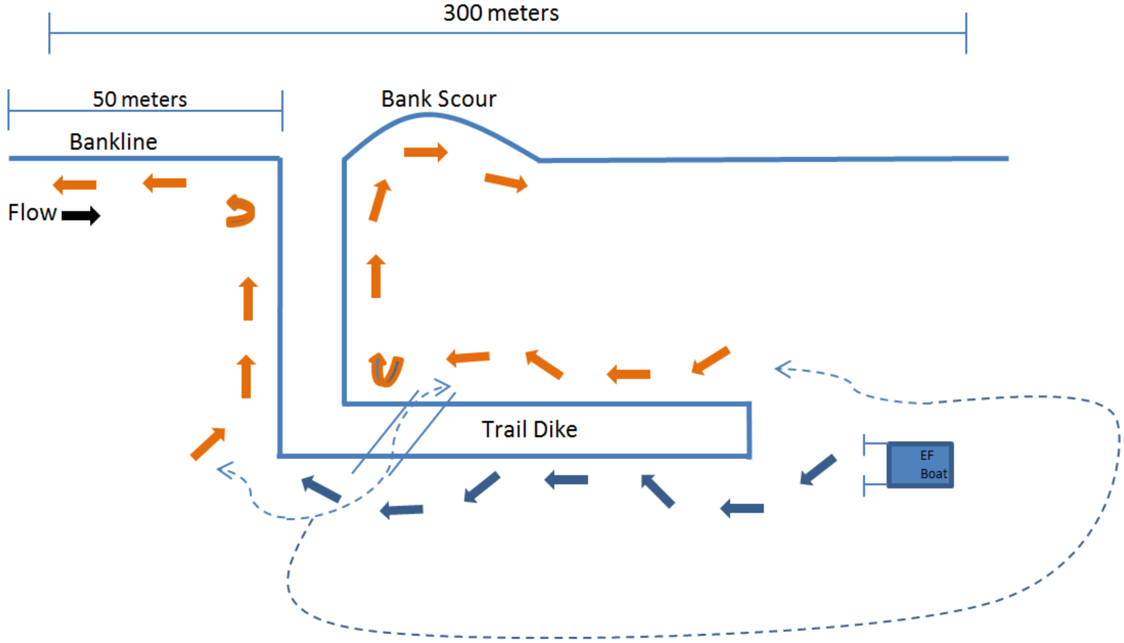


Figure 2: Diagram of electrofishing boat maneuvers for Main Channel Trail Dike (L-Dike) and Tailwater Structure habitats. Blue arrows signify required sampling locations; orange arrows indicate potential sampling locations.

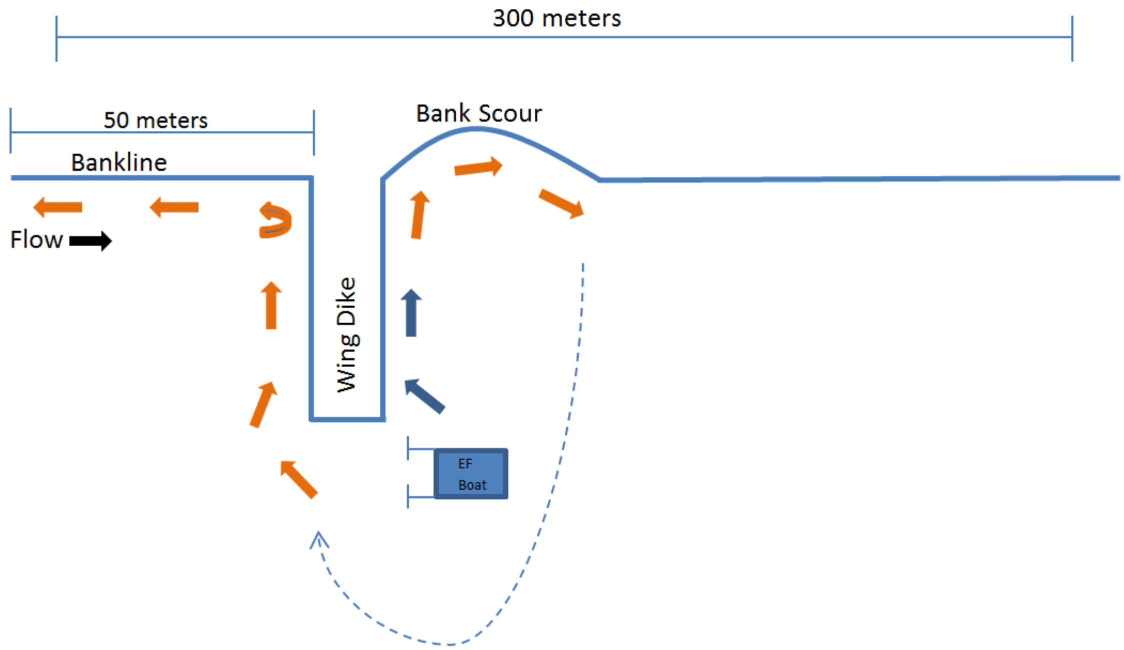


Figure 3: Diagram of electrofishing boat maneuvers for Main Channel Wing Dike, Side Channel Structure and Tailwater Structure habitats. Blue arrows signify required sampling locations; orange arrows indicate potential sampling locations.

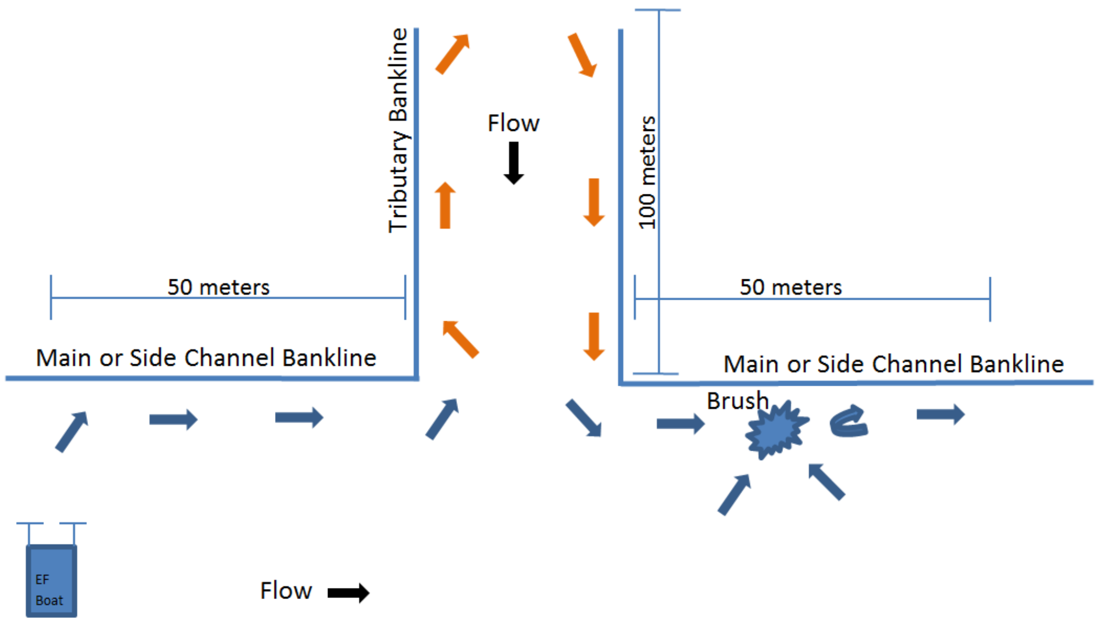


Figure 4: Diagram of electrofishing boat maneuvers for Tributary Confluence habitat. Blue arrows signify required sampling locations; orange arrows indicate potential sampling locations.

Data Sheet Instructions

A data sheet is completed for each run; all fields are required during standard random sampling.

File Name: *Big Rivers Catfish Assessment Data Sheet.pdf*

Location: *SharePoint/Fisheries/Big Rivers/Documents/Big Rivers Catfish Assessment*

SAMPLING DATE: Date that sampling was conducted

SECCHI DISK DEPTH: Water depth of secchi disk measurement. Unit = cm (if not, specify units)

WATER CONDUCTIVITY: Measurement of water conductivity using conductivity meter (RECORD conductivity for each run; re-measure if temperature changes (>3^{o}c) or at/near tributary mouths). Unit = µS/cm. Specify whether measurement is **Specific** - or - **Ambient Conductivity** (circle one) as measured by your conductivity meter (check the instruction manual if needed). Specific Conductivity (σ_s) is adjusted to a specific water temperature **(T_s = 25°C)**. Ambient Conductivity (σ_a) is measured at the ambient (actual) water temperature (T_a). Specific Conductivity can be converted to Ambient Conductivity using the following equation: $\sigma_{a} = \frac{\sigma_s}{1.02^{(T_s - T_a)}}$ (requires temperature in °C) (Equation on p.315 in 3rd Edition of Fisheries Techniques). Electrofishing success depends on ambient conductivity, not specific conductivity. Conductivity changes by 2 percent for every 1°C change in water temperature.

WATER TEMP: Surface water temperature at time of sampling (measure temperature before each run). Unit = °C or °F (circle one)

CONTROL BOX TYPE: Smith-Root VVP-15B, Infinity Box, or ETS Box (circle one)

EF FREQUENCY: Frequency setting on the control box. Use 15 Hz (or pps) as standard setting. Do NOT change setting during a sampling run.

DUTY CYCLE: Duty cycle setting on control box. Use 30-40 percent range as standard setting, other duty cycles can be tried. Do NOT change setting during a sampling run.

EFFORT IN MINUTES: Pedal time (shock time) of sampling run. Unit = minutes (or list seconds off box meter and convert to minutes).

TIME OF DAY: Time when sampling run started.

RIVER STAGE: Stage at nearest river gage. Unit = feet.

GAGE STATION #: The USGS gage station # used to determine river stage. Specify if a NOAA river gage is used rather than USGS

 # OF NETTERS: The number of dip netters used during a run (EF and Chase boat combined). Standard sampling should be a total of 3 netters, 2 on the electrofishing boat and 1 on the chase boat.

EF VOLTS: Voltage setting based on control box output meter – METER READING. Unit = Volts. Do NOT change setting during a sampling run except if necessary to pursue surfacing fish. If adjustments must be made, then return to original settings as soon as possible.

EF AMPS: Amperage based on control box output meter – METER READING. Unit = Amps.

EF POWER (WATTS = V · A): Manual calculation of Volts x Amps = Power – METER READING. Unit = Watts

PROJECT BIOLOGIST: Full name of lead biologist.

RIVER DISCHARGE: Discharge based on nearest river gage station. Unit = cfs.

SITE #: Site number (Table 1 & Figure 1)

RUN #: Consecutive integer identifying the run number. Run number begins at 1 each day of sampling.

 # OF NETTERS: Record the number of netters during non-random electrofishing runs (2 netters per shock boat and 1 netter per chase boat are required for standard random sampling)

START/STOP UTM NORTHINGS (7 DIGITS): Start and Stop UTM Northings for each sampling run.

START/STOP UTM EASTINGS (6 DIGITS): Start and Stop UTM Eastings for each individual sampling run.

HABITAT TYPE: Circle ONE**:** MCNB (Main Channel Natural Bank)**,** MCOS (Main Channel Other Structure)**,** MCRB (Main Channel Revetted Bank)**,** MCS (Main Channel Sandbar)**,** MCTD (Main Channel Trail Dike (L-Dike))**,** MCWD (Main Channel Wing Dike)**,** SCNB (Side Channel Natural Bank)**,** SCRB (Side Channel Revetted Bank)**,** SCS (Side Channel Structure)**,** TO (Tailwater Open)**,** TS (Tailwater Structure)**,** TM (Tributary Mouth).

RANDON/NON-RANDOM: Circle ONE**:** R – Random, N – Non-Random. Identify whether the subsample is for a randomly selected run or is for a non-random (i.e. targeted) run.

GEAR TYPE: Circle ONE: EF (Electrofishing), HN (Hoop Net), GN (Gill Net), TN (Trammel Net), TL (Trotline), OTHER. Provide details in the NOTES field concerning the method of collection if "Other" is selected.

SPECIES: BCF = blue catfish, FHC = flathead catfish, NFS = No Fish.

LENGTH: Measure and record the total length of all catfish >=177 mm. Units = millimeters.

WEIGHT: Measure and record the WEIGHT of each catfish that receives a reward tag. Units = grams, (if not, specify units).

TAG NUMBER: Includes 2 letter tag prefix (FS, FH, BS or BH) plus the 4-digit number following it.

TAG M/R: M – Mark (initial tagging), N – No Mark, R – Recapture (recaptured tag), S – Shed Tag.

FIN CLIP: M – Mark, N – No Mark, R – Recapture (previously fin clipped).

AGING STRUCTURE: P – Pectoral Spine, O – Otolith, N – None, PO – Pectoral Spine and Otolith.

COMMENTS: Any additional comments specific to a fish record (e.g. deformed spine, CHEP tag number).

OTHER NOTES: List any other unique information specific to a sampling run.

PAGE______ OF______: List the number of data sheets used to record data for each sampling run

Ageing Structure Protocol

Each year of sampling, pectoral spines (Figure 5) are collected from blue catfish (spring only, N=1,280) and flathead catfish (fall only, N=1,280) ≥177 mm (7 inches) for aging (Table 3). Collected spines will be equally divided among species and sites; 160 spines from each species will be collected from each site, each year. Collected spines will be distributed among ten 50 mm length groups for fish from 177-890 mm (7-34.9 in). Fish larger than 889 mm (34.9 in) are divided into two length groups, 890-1015 mm (35-39.5 in) and ≥1016 mm (≥40 in). Ten pectoral spines are collected from each length group.

Disarticulate the pectoral spine by gently twisting it downward and around when the fish is relaxed and the spine is not locked in joint at the articulating process. Remove the spine with a sharp scalpel and place the structure in an envelope. Fill out the information on the envelope and freeze it as soon as possible.

Otoliths and pectoral spines are collected from mortalities that are encountered afield or from harvesters willing to donate ageing structures. Tools needed to remove otoliths include a hacksaw (fillet knife or scalpel for small fish), wire cutters and forceps. Otoliths are in pockets along the sides of the cranium below the posterior portion of the brain (Figures 7 & 8). To remove the otoliths dorsally, extend the pectoral spines (Figure 9), cut 3-5 mm anterior to a line that connects them (Figure 10) and push the skull downward to force open the cut (Figure 11). Glide the forceps along each side of the braincase until you feel the pocket in which each otolith is located; grasp and remove each otolith (Figure 7). If you are unable to locate the otoliths use a wire cutter to remove the top of the skull. To remove the otoliths ventrally, cut the isthmus (Figure 12), remove gills and scrape the skin from the otic capsule. Cut the otic capsule with wire cutters (Figure 13) and break it open; grasp and remove otoliths (Figure 14).

Figure 5: Catfish pectoral spine.

Table 3: Pectoral spine collections by length group.

Length Group	Pectoral Spines
177-227 mm (≈7-8.9 in)	10
228-278 mm (≈9-10.9 in)	10
279-329 mm (≈11-12.9 in)	10
330-380 mm (≈13-14.9 in)	10
381-431 mm (≈15-16.9 in)	10
432-482 mm (≈17-18.9 in)	10
483-533 mm (≈19-20.9 in)	10
534-584 mm (≈21-22.9 in)	10
585-635 mm (≈23-24.9 in)	10
636-686 mm (≈25-26.9 in)	10
687-737 mm (≈27-28.9 in)	10
738-788 mm (≈29-30.9 in)	10
789-839 mm (≈31-32.9 in)	10
840-890 mm (≈33-34.9 in)	10
891-1015 mm (≈35-39.9 in)	10
≥1016 mm (≈≥40 in)	10

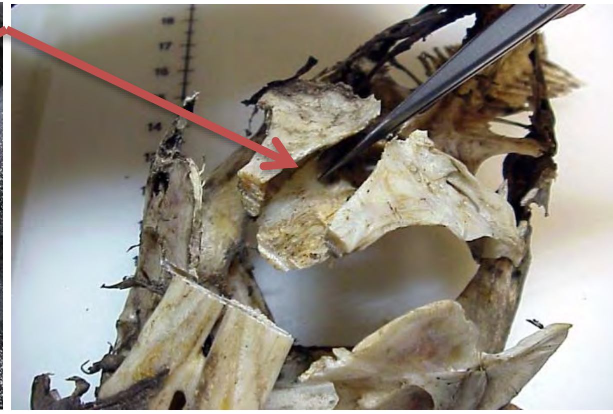
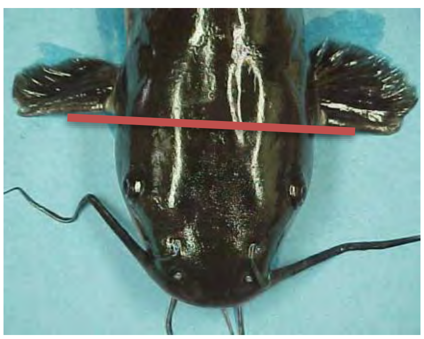


Figure 6. Location of otoliths. Figure 7. Location of otoliths.

Dorsal otolith removal:



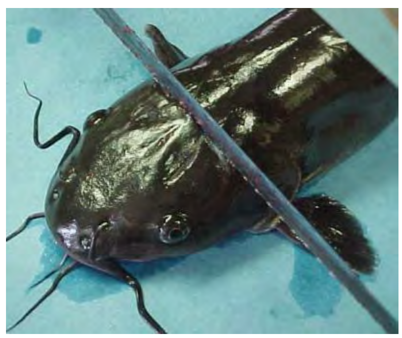


Figure 8. Extend pectoral spines. Figure 9. Cut the skull. Figure 10. Push skull down.

Ventral otolith removal:

Figure 11. Cut the isthmus. Figure 12. Cut the otic capsule. Figure 13. Remove the otolith.

Reward Tagging Protocol

Each year of sampling, blue catfish (N=1,088) and flathead catfish (N=1,088) ≥381 mm (15 inches) will be tagged using uniquely numbered Carlin dangler tags with reward values of either $25 (standard reward value) or $150 (high reward value) to estimate tag reporting and exploitation rates (Table 6). Tags will be equally divided among species and sites; 136 fish of each species will be tagged from each site, each year. Carlin dangler tags will be distributed among ten 50 mm length groups for fish from 381-889 mm (15-34.9 in), each group randomly receiving 8 low reward tags and 3 high reward tags. Fish larger than 889 mm (34.9 in) are divided into two length groups, 890-1015 mm (35-39.5 in) and ≥1016 mm (≥40 in), each group randomly receiving 6 low reward tags and 5 high reward tags.

Following each run, blue catfish (spring only) and flathead catfish (fall only) are marked with individually numbered Carlin dangler tags attached to the middle of a stainless steel wire. To tag catfish, secure the fish (Figure 15) insert the double hypodermic needles through the fish under the dorsal fin between dorsal pterygiophores being sure to maintain ≈0.5 inch spacing between the needles (Figure 16). The two wire ends must encompass at least one dorsal pterygiophore to ensure that the tag is properly secured. Insert the wires into the protruding needles (Figure 17) then pull the needles out leaving behind the double wires (Figure 18). Insert spacer sticks between the two wires, one on each side of the fish (Figure 19), to prevent tearing the flesh if the wires are over tightened. Twist wires together with hemostat pliers (Figure 20), cut off excess wire (Figure 21), ensure that the tag is secure and push both ends of it toward the dorsal end of the fish (Figure 22). Fish are released within the site and near the run they were collected from.

Table 6: Reward tag allocations by length group.

Length Group	Low Reward ($25)	High Reward ($150)	Total
381-431 mm (≈15-16.9 in)	8	3	11
432-482 mm (≈17-18.9 in)	8	3	11
483-533 mm (≈19-20.9 in)	8	3	11
534-584 mm (≈21-22.9 in)	8	3	11
585-635 mm (≈23-24.9 in)	8	3	11
636-685 mm (≈25-26.9 in)	8	3	11
686-736 mm (≈27-28.9 in)	8	3	11
737-787 mm (≈29-30.9 in)	8	3	11
788-838 mm (≈31-32.9 in)	8	3	11
839-889 mm (≈33-34.9 in)	8	3	11
890-1015 mm (≈35-39.9 in)	6	5	11
1016+ mm (≈40+ in)	6	5	11

Figure 14. Secure the fish.

Figure 15. Insert the double hypodermic needles through the fish under the dorsal fin between dorsal pterygiophores with ≈ 0.5” spacing between needles. The two wire ends of the tag must encompass at least one dorsal pterygiophore to ensure that the tag is properly secured.

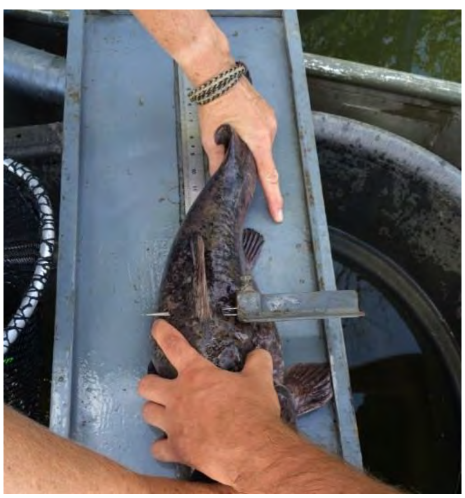


Figure 16. Insert the wires of the tag into the tips of the protruding needles.

Figure 17. Pull the needles out of the fish leaving behind the wires and tag.

Figure 18. Insert spacer sticks between the two wires, one on each side of the fish, to prevent tearing the flesh if the wires are over tightened.

Figure 19. Twist wires together with hemostat pliers.

Figure 20. Cut off excess wire.

Figure 21. Ensure that the tag is secure and push both ends of it toward the posterior end of the fish.

Appendix 2. Summary of trotline sampling data: River, site number, sampling date, total number of hooks deployed, number of angler equivalents (Mississippi River 50 hooks=1 angler day; Missouri River 33 hooks=1 angler day), total number of flathead catfish collected, number of flathead catfish over 30 inches and 35 inches collected, and potential reduced harvest with the limitation of keeping one fish over 30 or 35 inches per angler day.

River	Site	Sampling date	Num. of hooks	Minimum number of angler equivalents	Number of flathead catfish collected	Count over 30 inches	Count over 35 inches	Potential reduced harvest - One over 30 inches daily	Potential reduced harvest - One over 35 inches daily
Mississippi	1	3/28/2016	220	5	1	0	0	0	0
		3/29/2016	200	4	0	0	0	0	0
	3	4/15/2015	165	4	0	0	0	0	0
		4/28/2015	210	5	0	0	0	0	0
		4/29/2015	210	5	0	0	0	0	0
		9/14/2015	100	2	8	1	0	0	0
	4	5/28/2015	90	2	0	0	0	0	0
		6/1/2015	84	2	0	0	0	0	0
		10/27/2015	100	2	1	0	0	0	0
		10/28/2015	100	2	1	0	0	0	0
		11/3/2015	120	3	0	0	0	0	0
		11/4/2015	140	3	1	0	0	0	0
Missouri	5	3/17/2015	10	1	0	0	0	0	0
		4/24/2015	110	4	3	0	0	0	0
		7/6/2015	80	3	3	0	0	0	0

River	Site	Sampling date	Num. of hooks	Minimum number of angler equivalents	Number of flathead catfish collected	Count over 30 inches	Count over 35 inches	Potential reduced harvest - One over 30 inches daily	Potential reduced harvest - One over 35 inches daily
		7/8/2015	100	3	6	2	0	0	0
		7/13/2015	120	4	3	2	1	0	0
		7/14/2015	128	4	2	0	0	0	0
		8/31/2015	100	3	5	0	0	0	0
		9/1/2015	70	3	2	0	0	0	0
		9/30/2015	100	3	8	1	1	0	0
		10/1/2015	100	3	1	1	1	0	0
		11/3/2015	100	3	1	0	0	0	0
		11/4/2015	100	3	1	0	0	0	0
		11/5/2015	90	3	1	1	1	0	0
		5/4/2016	120	4	3	0	0	0	0
		5/5/2016	120	4	0	0	0	0	0
		5/24/2016	100	3	1	0	0	0	0
		5/25/2016	90	3	1	0	0	0	0
		5/26/2016	80	3	0	0	0	0	0
		10/6/2016	130	4	1	0	0	0	0
		6/1/2017	75	3	5	0	0	0	0
		6/14/2017	100	3	11	3	1	0	0
		6/15/2017	100	3	4	1	0	0	0
		6/19/2017	100	3	10	1	0	0	0

River	Site	Sampling date	Num. of hooks	Minimum number of angler equivalents	Number of flathead catfish collected	Count over 30 inches	Count over 35 inches	Potential reduced harvest - One over 30 inches daily	Potential reduced harvest - One over 35 inches daily
	6	8/27/2015	80	3	12	5	3	2	0
		9/15/2015	198	6	22	9	3	3	0
		9/16/2015	100	3	17	4	2	1	0
		9/29/2015	72	3	13	6	2	3	0
		9/30/2015	48	2	9	4	0	2	0
		10/6/2015	48	2	8	4	3	2	1
		10/14/2015	24	1	11	4	2	3	1
		10/21/2015	96	3	7	6	3	3	0
		6/15/2017	49	2	1	1	0	0	0
	8	5/17/2016	11	1	0	0	0	0	0
Total					184	56	23	19	2

Appendix 3. Tagging and capture data.

Tag Number	Length (in)	Tagging Site	Tagging Date	Capture Date	Days at Large	Distance Traveled (River Miles)
FH 8283	23.1	8	8/14/2015	8/12/2017	729	2.5
FH 8284	17.8	8	8/14/2015	7/19/2016	340	6.4
FH 8286	18.5	8	8/14/2015	6/4/2016	295	10.7
FH 8288	16.1	8	8/14/2015	6/2/2017	658	8.7
FS 3659	23.3	8	8/14/2015	10/28/2015	75	33.1
FS 3660	34.2	8	8/14/2015	7/17/2017	703	7.4
FS 3661	31.1	8	8/14/2015	8/22/2015	8	0.2
FS 3670	18.1	8	8/19/2015	8/7/2016	354	1.8
FH 8291	35.6	8	8/19/2015	6/10/2016	296	0.9
FH 8201	23.5	6	8/19/2015	5/28/2016	283	3.0
FH 8203	21.4	6	8/19/2015	11/10/2015	83	0.6
FH 8204	17.9	6	8/19/2015	7/9/2017	690	4.4
FH 8205	20.1	6	8/19/2015	6/11/2016	297	1.5
FS 3464	16.8	6	8/19/2015	6/9/2018	1025	0.0
FH 8206	20.5	6	8/19/2015	9/26/2015	38	0.4
FH 8207	25.5	6	8/19/2015	10/31/2016	439	0.5
FS 3467	22.2	6	8/19/2015	10/15/2015	57	0.7
FS 3469	18.3	6	8/19/2015	9/19/2015	31	1.7
FS 3476	30.0	6	8/20/2015	9/5/2015	16	4.0
FS 3477	22.8	6	8/20/2015	9/26/2015	37	3.8
FH 8209	38.1	6	8/20/2015	8/5/2017	716	15.5
FS 3479	25.2	6	8/20/2015	6/30/2018	1045	1.6
FS 3482	25.5	6	8/21/2015	7/10/2016	324	1.2
FS 3483	20.2	6	8/21/2015	7/17/2016	331	3.5
FS 3490	16.8	6	8/24/2015	7/24/2017	700	11.9
FS 3680	18.9	8	8/25/2015	6/22/2017	667	0.0
FH 8297	19.5	8	8/25/2015	6/5/2016	285	0.2
FS 3377	23.4	5	8/25/2015	5/26/2018	1005	3.5
FS 3381	25.0	5	8/25/2015	9/26/2015	32	0.1
FH 8167	25.5	5	8/25/2015	6/10/2018	1020	1.5
FS 3380	28.7	5	8/25/2015	5/20/2016	269	0.1
FS 3553	28.3	7	8/26/2015	6/10/2017	654	2.2
FH 8241	19.8	7	8/26/2015	5/22/2016	270	2.8
FH 8243	22.2	7	8/26/2015	5/22/2016	270	2.8
FS 3694	18.3	8	8/27/2015	8/27/2015	0	1.1
FH 8217	30.9	6	8/27/2015	9/5/2015	9	0.2
FH 8218	26.7	6	8/27/2015	10/29/2015	63	0.9
FS 3372	24.6	5	8/27/2015	9/12/2015	16	3.4
FH 8001	38.8	1	8/27/2015	6/22/2016	300	267.0

FH 8007	38.3	1	8/27/2015	5/13/2018	990	384.8
FS 3007	16.9	1	8/27/2015	7/17/2016	325	1.4
FS 3016	24.8	1	8/27/2015	10/16/2015	50	3.4
FS 3014	20.8	1	8/27/2015	10/23/2015	57	3.4
FS 3498	24.8	6	8/31/2015	7/2/2016	306	16.7
FH 8219	22.8	6	8/31/2015	6/23/2016	297	1.7
FS 3503	26.5	6	8/31/2015	9/13/2015	13	0.3
FS 3504	20.0	6	8/31/2015	9/5/2015	5	1.5
FS 3507	22.2	6	8/31/2015	5/1/2016	244	3.4
FH 8121	17.0	4	8/31/2015	8/17/2019	1447	23.9
FH 8168	20.2	5	8/31/2015	5/24/2016	267	192.6
FS 3388	27.5	5	8/31/2015	9/4/2017	735	9.0
FH 8169	25.3	5	8/31/2015	5/29/2017	637	2.7
FH 8015	22.6	1	8/31/2015	10/28/2018	1154	1.5
FH 8016	26.6	1	8/31/2015	10/6/2015	36	0.4
FH 8012	24.5	1	8/31/2015	6/6/2016	280	231.1
FH 8017	30.2	1	8/31/2015	9/9/2015	9	2.3
FS 3696	26.0	8	9/3/2015	7/31/2016	332	2.8
FS 3698	27.8	8	9/3/2015	8/28/2016	360	0.2
FS 3187	24.8	3	9/14/2015	8/10/2016	331	4.9
FH 8082	23.8	3	9/14/2015	8/20/2017	706	82.0
FS 3511	31.2	6	9/15/2015	6/12/2016	271	1.1
FH 8224	30.5	6	9/15/2015	9/3/2016	354	4.1
FS 3512	26.6	6	9/15/2015	10/2/2016	383	5.0
FS 3514	25.7	6	9/15/2015	7/17/2016	306	7.8
FS 3515	25.4	6	9/15/2015	5/27/2016	255	98.7
FS 3517	22.6	6	9/15/2015	9/4/2017	720	13.2
FH 8225	41.6	6	9/15/2015	9/21/2016	372	5.7
FS 3518	30.2	6	9/15/2015	7/8/2016	297	0.7
FH 8226	34.4	6	9/15/2015	10/28/2018	1139	1.5
FH 8245	25.5	7	9/15/2015	6/11/2017	635	0.2
FS 3557	16.4	7	9/15/2015	8/7/2017	692	3.6
FS 3558	22.3	7	9/15/2015	10/15/2016	396	0.9
FH 8026	39.8	1	9/15/2015	11/5/2016	417	432.1
FS 3049	25.6	1	9/15/2015	10/23/2015	38	7.2
FH 8027	28.8	1	9/15/2015	3/22/2017	554	2.7
FH 8228	19.4	6	9/16/2015	6/9/2017	632	66.0
FS 3528	29.6	6	9/16/2015	5/28/2016	255	5.4
FS 3705	22.5	8	9/21/2015	9/25/2015	4	2.4
FH 8304	21.5	8	9/22/2015	7/28/2018	1040	7.2
FS 3194	22.0	3	9/22/2015	2/11/2018	873	23.3
FS 3212	21.9	3	9/22/2015	5/26/2016	247	1.5
FH 8091	17.0	3	9/22/2015	7/2/2016	284	3.7

FS 3204	30.5	3	9/22/2015	5/28/2018	979	182.3
FH 8085	20.4	3	9/22/2015	6/11/2017	628	0.1
FS 3198	21.5	3	9/22/2015	7/17/2016	299	5.8
FH 8049	35.5	2	9/23/2015	6/15/2017	631	313.9
FH 8048	23.3	2	9/23/2015	6/19/2016	270	10.8
FS 3064	17.7	1	9/24/2015	6/6/2016	256	1.3
FH 8033	41.8	1	9/24/2015	10/19/2015	25	42.4
FS 3065	34.3	1	9/24/2015	6/4/2018	984	129.6
FS 3294	18.5	4	9/25/2015	5/26/2018	974	1.1
FS 3291	19.2	4	9/25/2015	8/23/2017	698	4.5
FH 8173	21.6	5	9/25/2015	10/2/2016	373	0.0
FS 3567	19.6	7	9/25/2015	10/17/2015	22	1.0
FS 3565	27.7	7	9/25/2015	7/3/2017	647	239.7
FS 3568	22.2	7	9/25/2015	6/18/2016	267	1.6
FS 3110	23.3	2	9/25/2015	5/22/2016	240	0.6
FH 8306	30.8	8	9/28/2015	6/14/2016	260	5.4
FH 8130	23.6	4	9/29/2015	6/4/2016	249	5.6
FS 3536	30.6	6	9/29/2015	10/27/2018	1124	8.6
FH 8028	32.2	1	9/29/2015	6/21/2016	266	18.7
FH 8133	21.2	4	9/30/2015	6/23/2017	632	0.4
FH 8132	19.1	4	9/30/2015	6/15/2016	259	2.4
FH 8235	34.5	6	9/30/2015	6/1/2016	245	45.4
FS 3397	25.8	5	9/30/2015	5/29/2016	242	8.1
FS 3396	27.0	5	9/30/2015	8/19/2016	324	155.9
FS 3115	16.8	2	10/5/2015	6/11/2018	980	1.2
FS 3113	23.2	2	10/5/2015	6/2/2018	971	182.5
FS 3117	23.4	2	10/5/2015	6/12/2018	981	44.9
FS 3543	31.9	6	10/6/2015	11/7/2015	32	0.9
FH 8239	46.4	6	10/6/2015	7/31/2016	299	0.4
FS 3573	24.8	7	10/7/2015	6/18/2016	255	3.3
FH 8052	30.0	2	10/7/2015	6/30/2016	267	0.7
FH 8100	19.5	3	10/13/2015	6/18/2016	249	0.8
FS 3128	22.4	2	10/13/2015	8/1/2017	658	0.0
FH 8058	26.1	2	10/13/2015	8/1/2017	658	0.7
FS 3130	20.1	2	10/13/2015	8/4/2016	296	1.5
FH 8313	30.0	8	10/14/2015	9/7/2016	329	0.2
FH 8314	36.2	8	10/14/2015	10/17/2015	3	0.8
FH 8315	31.5	8	10/14/2015	7/29/2017	654	3.8
FS 3403	21.3	5	10/14/2015	7/14/2016	274	1.0
FH 8255	23.7	7	10/14/2015	8/10/2017	666	18.6
FS 3582	25.5	7	10/14/2015	9/11/2017	698	1.0
FH 8061	23.0	2	10/14/2015	8/21/2016	312	1.7
FH 8062	19.6	2	10/14/2015	7/10/2016	270	2.2

FS 3135	21.3	2	10/14/2015	6/10/2016	240	10.9
FS 3132	22.4	2	10/14/2015	8/4/2019	1390	1.2
FH 8102	38.2	3	10/16/2015	10/15/2018	1095	94.9
FS 3413	37.5	5	10/19/2015	5/27/2017	586	129.4
FS 3726	29.7	8	10/22/2015	6/18/2016	240	0.6
FS 3728	27.3	8	10/22/2015	7/1/2017	618	1.7
FS 3583	19.0	7	10/22/2015	5/6/2017	562	2.5
FS 3584	20.8	7	10/22/2015	7/17/2016	269	3.5
FS 3595	27.5	7	10/26/2015	5/28/2016	215	0.9
FS 3591	36.8	7	10/26/2015	5/22/2016	209	0.7
FH 8260	26.4	7	10/28/2015	4/24/2016	179	5.0
FH 8036	35.4	1	10/30/2015	5/23/2016	206	9.1
FS 3145	35.2	2	11/9/2015	4/8/2016	151	367.0
FS 3159	33.7	2	4/18/2016	6/29/2018	802	258.8
FS 3644	32.2	7	4/19/2016	8/6/2017	474	22.8
FH 8072	28.0	2	4/19/2016	7/15/2017	452	9.1
FS 3164	25.6	2	4/21/2016	7/1/2018	801	237.7
FS 3318	23.7	4	4/22/2016	5/22/2016	30	0.5
FS 3317	29.3	4	4/22/2016	6/29/2018	798	0.2
FS 3316	24.1	4	4/22/2016	4/1/2017	344	18.9
FH 8104	40.0	3	4/25/2016	6/18/2016	54	185.9
FS 3160	29.4	2	4/26/2016	6/11/2017	411	368.0
FH 8106	28.8	3	4/26/2016	5/28/2016	32	10.6
FS 3161	27.8	2	4/26/2016	5/22/2016	26	148.0
FH 8107	30.0	5	4/28/2016	4/28/2017	365	48.0
FS 3321	24.3	4	4/29/2016	6/29/2018	791	0.4
FH 8139	29.9	4	4/29/2016	9/13/2017	502	253.7
FS 3322	23.8	4	4/29/2016	6/11/2016	43	0.9
FS 3086	34.5	1	5/3/2016	3/19/2017	320	0.1
FS 3157	27.1	2	5/5/2016	9/9/2016	127	0.4
FH 8142	23.0	4	5/10/2016	8/23/2017	470	2.7
FH 8143	26.8	4	5/10/2016	10/23/2016	166	5.1
FS 3327	27.2	4	5/10/2016	6/25/2016	46	3.2
FH 8150	35.7	4	5/18/2016	6/20/2016	33	0.2
FH 8147	27.5	4	5/18/2016	8/18/2018	822	1.2
FS 3735	33.4	8	5/18/2016	8/4/2018	808	5.5
FH 8031	33.6	1	5/19/2016	6/6/2016	18	0.6
FH 8152	31.7	4	5/23/2016	6/10/2017	383	0.0
FS 3351	31.2	4	5/23/2016	7/4/2016	42	1.7
FS 3352	36.5	4	5/23/2016	6/14/2019	1117	17.2
FS 3354	30.5	4	5/24/2016	5/31/2017	372	1.6
FS 3355	35.2	4	5/24/2016	6/3/2016	10	1.6
FH 8188	28.5	5	5/24/2016	7/1/2017	403	37.1

FH 8069	27.2	2	6/7/2016	8/8/2016	62	9.1
FS 3640	38.7	7	6/14/2016	6/4/2018	720	44.1
FS 3551	45.9	6	6/17/2016	8/18/2017	427	0.3
FH 8525	19.3	6	9/7/2016	9/3/2018	726	1.3
FS 4201	27.3	6	9/7/2016	10/17/2016	40	0.3
FH 8601	25.6	8	9/8/2016	9/2/2017	359	0.8
FH 8603	19.5	8	9/8/2016	8/26/2017	352	1.2
FH 8602	21.1	8	9/8/2016	9/1/2018	723	1.2
FH 8527	20.8	6	9/13/2016	5/17/2019	976	27.5
FS 3743	25.3	1	9/13/2016	7/3/2018	658	2.0
FS 3742	28.2	1	9/13/2016	11/18/2017	431	0.2
FS 3752	23.9	1	9/13/2016	7/3/2018	658	4.1
FS 4404	20.6	8	9/20/2016	6/12/2017	265	1.1
FS 4414	22.0	8	9/21/2016	8/12/2017	325	3.0
FS 4420	26.5	8	9/21/2016	6/29/2017	281	5.4
FH 8620	19.2	8	9/21/2016	6/18/2017	270	6.3
FS 3775	28.5	1	9/21/2016	6/1/2017	253	346.1
FH 8336	29.8	1	9/21/2016	3/21/2017	181	1.6
FS 3773	21.8	1	9/21/2016	7/7/2018	654	2.3
FS 3772	28.5	1	9/21/2016	8/1/2017	314	12.5
FH 8571	35.1	7	9/22/2016	8/12/2018	689	0.1
FH 8570	26.4	7	9/22/2016	6/10/2018	626	27.1
FS 3780	22.8	1	9/28/2016	8/7/2017	313	0.5
FH 8528	24.0	6	9/29/2016	10/28/2018	759	7.5
FS 4205	29.3	6	9/29/2016	10/21/2016	22	0.8
FS 4207	20.1	6	9/29/2016	6/4/2017	248	13.2
FH 8624	24.7	8	9/29/2016	7/8/2017	282	0.5
FH 8404	20.8	3	9/29/2016	7/29/2017	303	1.8
FS 3927	27.2	3	9/29/2016	7/29/2017	303	3.2
FS 3930	19.9	3	9/29/2016	9/25/2017	361	2.0
FS 3928	23.6	3	9/29/2016	6/25/2018	634	0.6
FH 8365	24.0	2	10/3/2016	6/30/2018	635	2.1
FS 3832	19.0	2	10/3/2016	8/1/2017	302	0.4
FH 8573	22.8	7	10/4/2016	10/5/2017	366	1.0
FS 4307	17.7	7	10/5/2016	7/1/2017	269	1.6
FS 4309	36.4	7	10/5/2016	7/30/2017	298	0.7
FS 4313	19.8	7	10/5/2016	8/18/2018	682	1.2
FS 4433	21.5	8	10/5/2016	7/29/2017	297	4.0
FS 4441	25.1	8	10/6/2016	6/17/2017	254	30.0
FH 8342	20.2	1	10/6/2016	9/29/2018	723	18.3
FS 4220	21.8	6	10/7/2016	5/25/2018	595	0.6
FH 8483	24.0	5	10/11/2016	6/18/2017	250	0.3
FH 8484	16.2	5	10/11/2016	6/23/2018	620	8.1

FS 4317	26.5	7	10/11/2016	7/16/2017	278	32.9
FS 4322	28.1	7	10/12/2016	6/3/2017	234	1.0
FS 4324	21.7	7	10/12/2016	6/7/2017	238	1.5
FH 8578	25.5	7	10/12/2016	5/27/2018	592	23.7
FS 3801	34.0	1	10/12/2016	7/5/2017	266	12.5
FH 8533	21.2	6	10/13/2016	5/12/2018	576	9.8
FH 8349	15.8	1	10/13/2016	7/16/2019	1006	0.7
FS 3940	26.2	3	10/13/2016	6/29/2017	259	29.9
FH 8443	20.6	4	10/17/2016	5/27/2017	222	0.0
FH 8537	20.2	6	10/17/2016	9/11/2019	1059	12.2
FS 3840	18.3	2	10/17/2016	8/20/2017	307	1.7
FS 3847	26.1	2	10/17/2016	5/22/2018	582	1.9
FS 4030	15.4	4	10/18/2016	6/29/2018	619	1.0
FS 4024	19.5	4	10/18/2016	9/9/2017	326	0.2
FS 4027	17.4	4	10/18/2016	6/8/2018	598	9.7
FH 8541	41.8	6	10/18/2016	6/2/2017	227	318.8
FS 4114	23.1	5	10/20/2016	9/4/2017	319	0.0
FS 4337	23.3	7	10/20/2016	8/20/2017	304	3.4
FS 3856	18.9	2	10/21/2016	6/23/2018	610	0.1
FS 4342	26.8	7	10/24/2016	8/11/2018	656	3.3
FH 8453	25.4	4	10/25/2016	6/3/2017	221	25.0
FS 4046	30.8	4	10/25/2016	4/15/2017	172	6.2
FS 4047	23.3	4	10/25/2016	5/26/2018	578	0.2
FH 8413	27.1	3	10/25/2016	5/29/2017	216	94.5
FS 3956	25.0	3	10/25/2016	7/15/2017	263	57.3
FS 3959	20.5	3	10/25/2016	8/4/2018	648	3.5
FS 3958	26.8	3	10/25/2016	7/15/2017	263	57.2
FH 8416	22.8	3	10/25/2016	7/29/2017	277	0.7
FS 4258	27.7	6	10/26/2016	10/3/2017	342	11.0
FS 4051	26.4	4	10/27/2016	8/8/2018	650	7.8
FH 8456	30.1	4	10/27/2016	6/4/2017	220	2.3
FS 4055	28.6	4	10/27/2016	7/21/2017	267	12.7
FH 8455	22.7	4	10/27/2016	5/27/2017	212	41.7
FS 4050	22.2	4	10/27/2016	7/14/2019	990	56.7
FS 3961	34.7	3	10/27/2016	3/24/2017	148	1.0
FH 8548	30.5	6	10/28/2016	10/28/2018	730	0.3
FS 3863	22.4	2	10/28/2016	8/18/2017	294	29.3
FH 8486	18.6	5	11/3/2016	5/25/2018	568	1.0
FH 8587	36.4	7	11/7/2016	6/17/2017	222	7.1
FS 4347	39.7	7	11/8/2016	8/3/2017	268	1.3
FH 8384	26.0	2	11/8/2016	6/5/2017	209	2.2
FH 8387	43.1	2	2/21/2017	6/18/2017	117	84.3
FS 4133	21.2	5	4/20/2017	7/22/2018	458	0.6

FS 4138	21.3	5	4/20/2017	10/23/2019	916	26.1
FS 4129	24.3	5	4/20/2017	6/17/2018	423	0.8
FS 4140	26.8	5	4/24/2017	6/15/2018	417	0.5
FH 8496	15.3	5	4/24/2017	6/14/2017	51	0.1
FS 4141	34.5	5	4/24/2017	6/12/2017	49	0.5
FS 3892	33.2	2	4/24/2017	7/3/2017	70	3.8
FS 4143	25.9	5	4/26/2017	6/6/2017	41	34.0
FH 8501	42.9	5	4/27/2017	5/31/2017	34	72.2
FS 4151	25.6	5	4/27/2017	6/23/2018	422	5.2
FS 4153	41.2	5	5/12/2017	7/13/2017	62	0.9
FS 4155	33.3	5	5/12/2017	8/1/2017	81	6.3
FS 4159	27.5	5	5/16/2017	6/8/2017	23	64.8
FS 4161	31.8	5	5/17/2017	6/7/2017	21	79.9
FS 4160	28.0	5	5/17/2017	6/15/2017	29	3.7
FS 3815	31.2	1	5/31/2017	5/22/2018	356	9.7
FS 4168	30.2	5	6/1/2017	6/2/2018	366	11.2
FH 8508	28.0	5	6/1/2017	6/9/2018	373	11.2
FH 8509	29.2	5	6/2/2017	7/16/2017	44	9.7
FH 8635	34.1	8	6/6/2017	8/27/2017	82	11.0
FS 3975	27.1	3	6/12/2017	1/25/2018	227	8.1
FS 4060	25.3	4	6/13/2017	6/29/2018	381	0.5
FS 4059	23.1	4	6/13/2017	9/9/2017	88	0.8
FS 4171	30.6	5	6/14/2017	5/26/2018	346	10.1
FS 4062	27.5	4	6/14/2017	6/16/2018	367	11.4
FS 4272	30.5	6	6/15/2017	10/27/2018	499	1.9
FS 4278	29.0	6	6/22/2017	5/12/2018	324	8.1
FH 8556	34.6	6	6/29/2017	7/15/2017	16	6.7