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Seasonal Habitat Use, Movement, and Exploitation of Sauger in the Arkansas River

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SEASONAL HABITAT USE, MOVEMENT, AND EXPLOITATION OF SAUGER IN THE ARKANSAS RIVER

By

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SEASONAL HABITAT USE, MOVEMENT, AND EXPLOITATION
OF SAUGER IN THE ARKANSAS RIVER

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Abstract

Sauger (*Sander canadensis*) are a native game fish present in the Arkansas River and have an affinity for high nutrient levels, high turbidity, and deep moving water. Little is known about Sauger habitat use and movement among navigation pools in the Arkansas River. However, they aggregate below lock and dams during winter and early spring leaving them susceptible to overharvest. I caught 330 Sauger using experimental gillnets downstream from dams in two navigation pools. Fish were externally tagged with Floy T-bar anchor tags (FD94). Of the 330 fish tagged, only five were harvested resulting in a low estimation of exploitation at 3.9% adjusted for the rate of angler reporting. Another 50 adult Sauger were implanted with acoustic telemetry tags to assess habitat use and movement using both active and passive receivers. Tracking was limited to four months due to high flow and unsafe boating conditions resulting in missing important Sauger movement events. Interpool movement was detected for 22% of Sauger in both up and down stream directions traveling up to 140 km, suggesting dams may not be restrictive to the species. Sauger in the Arkansas River should be managed as a single population and the species may benefit from interjurisdictional management near state borders. Habitat was delineated based on anthropogenic influences and identified as main channel, channel edge, wing dike, dam, flats, and backwater. Second order compositional analysis of habitat use suggests channel edge is being used the most in Pool 9 and wing dike is being used the most in Pool 10. Third order compositional analysis of habitat use suggests main channel is being used the most in Pool 9 and wing dike is being used the most in Pool 10. Sauger are utilizing habitats that have heavy anthropogenic influences that typically result in fast moving water in the channel and optimal forage opportunity near wing dikes. Future studies should focus on analyzing habitats year-round on a finer scale to determine factors influencing Sauger preference for channel and wing dike habitats.

Table of contents

Page

List of Tables

List of Figures

Introduction

Sauger *Sander canadensis* is a game fish found in moderate to large freshwater rivers and lakes in North America extending across much of Canada and the southeastern United States (Scott and Crossman 1973; Robison and Buchanan 1992; Pegg et al. 1997; Maceina et al. 2005). Sauger prefer turbid rivers and shallow lakes (Pegg 1997), but rivers are thought to be their place of evolutionary origin (Balon et al. 1977). Sauger have a well-developed tapetum lucidum which allows them to see better in more turbid waters, giving them an advantage over other predatory fishes. Adult Sauger feed on fish while the young feed on invertebrates and small fish (Robison and Buchanan 1992).

Sauger is a member of the family Percidae, which includes darters, freshwater perches, and zander (Sloss et al. 2004). They have a slender streamlined body that includes three to four dusky saddles extended down their sides. Adult Sauger are typically 457 mm in total length, weighing about 1 kg (Robison and Buchanan 1992). They are most similar to Walleye *Sander vitreus*, but Sauger are smaller and have a shorter life expectancy (Carlander 1997). In the southern portion of their distribution, adult Sauger live to no more than seven years (Robison and Buchanan 1992), while in the most northern extent of their range they can reach a maximum lifespan of 13 years (Carlander 1997).

Sauger tend to select habitats with strong currents near the ends of rock dikes and banks composed of riprap (Robison and Buchanan 1992). They also have an affinity for river bottoms (Kerr et al. 1997), preferring clean hard substrates that offer abundant cover structure including boulders, rooted submerged vegetation, trees, and logs (Holt et al. 1977; Schlagenhaft and Murphy 1985; Johnson et al. 1988; Paragamian 1989; Bozek et al. 2011a). During the spawning season that starts in early spring when water temperatures reach 5.6ºC, Sauger will broadcast spawn over gravel or rocks at depths of 0.6 to 5.5 m and velocities from 0.33 to 0.98 m/s (Bozek et al. 2011a). The incubation period lasts approximately 21 days and absolute fecundity is 10,000-209,000 eggs/female (Robison and Buchanan 1992, Carlander 1997, Jaeger et al. 2005). Fifty percent maturity is reached between two and eight years depending on longitude, increasing when further north (Carlander 1997). Male and female juvenile Sauger usually grow at the same rate until they reach maturity, when females sustain higher growth rates. Some studies have shown that in the southern part of their distribution where growth rates tend to be faster, females grow larger than males in their first year (Carlander 1997, Bozek et al. 2011b). Sauger have been shown to forage on copepods and cladocerans during early life stages and will switch to piscivory at lengths greater than 100 mm. Juveniles also fed on benthic invertebrates and zooplankton (Nelson 1968). If prey fish are readily available to young Sauger, they often shift to piscivory in their first growing season (Chipps and Graeb 2011).

Sauger are native to several Arkansas rivers including the White River, Strawberry River, St. Francis River, Mississippi River, Saline River, and Arkansas River (Robison and Buchanan 1992). Sauger are most commonly found in the Arkansas River because of their affinity for high nutrient levels, high turbidity, and deep moving water (Robison and Buchanan 1992). Although Sauger are not typically a highly targeted game fish when compared to other game species (U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau 2016), they are a popular angling opportunity in late winter to early spring when they congregate below dams (Robison and Buchanan 1992).

Sauger populations have experienced decreases in abundance across their range. Several factors have attributed to Sauger population declines including: hybridization with Walleye (Billington et al. 1997), creation of artificial aggregations below dams that leave Sauger susceptible to overharvest (Maceina et al. 1996; Pegg et al. 1997), and construction of large dams that hinder spawning migrations (Amadio et al. 2005; Jaeger et al. 2005). Dam construction can also negatively impact fish species on rivers by altering fish habitat and fragmenting and isolating populations (Auer 1996; Baker and Borgeson 1999; Bevelhimer 2002). Sauger population dynamics have not been well studied since the creation of the McClellan-Kerr Arkansas Navigation System (MKARNS) on the Arkansas River, but general consensus among Sauger anglers claim the fishery is not as good as it used to be 20 years ago (F. Leone, personal communication).

Sauger angling is popular throughout their range, mainly during winter months below dams (Maceina et al. 1996; Pegg et al. 1997; Amadio et al. 2005). Artificial aggregations below dams on the Arkansas River leave the species susceptible to overharvest. Sauger in the Arkansas River are at risk of “growth overfishing” and Leone (2006) reported that “growth overfishing” was likely to occur if exploitation reaches 25%. Pegg et al. (1996) estimated an unsustainable exploitation rate greater than 50% for the tailwaters of Pickwick Dam on the Tennessee River, warranting special management regulations. The exploitation rate of Sauger in the Arkansas River is currently unknown, but is needed for management purposes. Maceina et al. (1996) found through model simulations that a minimum length limit (MLL) of 356 mm for Sauger in the Tennessee River would increase yields at both high and low exploitation rates. Current Arkansas Game and Fish (AGFC) fishing regulations for Sauger include a daily bag limit of six fish per day which offers some protection (Leone 2006), but does not contain a MLL. AGFC modeled yield-per-recruit and spawning potential ratio using FAMS. Simulations were run at varying minimum length limits and three theoretical levels of exploitation. Recruitment overfishing was detected in several models when exploitation was high and a 254 mm MLL was used, but not when the 356 mm MLL was included in the model. If exploitation of Sauger is high, the population might benefit from a MLL. Crawford et al. (2006) conducted an exploitation study on Redear Sunfish *Lepomis macrolophus* and found that a MLL on sunfish would be unnecessary because anglers are already size selective when they harvest. An exploitation study on Sauger could have similar results, implicating that a MLL would not be effective as a management tool. Exploitation estimates are necessary to determine if Sauger anglers behave in a similar manner. A 254 mm MLL was considered “no MLL” because very little harvest of Sauger occurs at this size (Leone 2017). Although anglers may be creating their own MLL, it may not be enough to prevent recruitment overfishing of Sauger on the Arkansas River.

Sauger are considered to be the most migratory species in the family Percidae and will travel hundreds of kilometers in river systems to spawn (Collette et al. 1973;Scott and Crossman 1973; Jaeger et al. 2005; Bellgraph et al. 2008; Kuhn et al. 2008, Bozek et al. 2011a). Sauger have demonstrated the ability to traverse low-head diversion dams during migrations, however; distribution can be limited in impounded rivers (Jaeger et al. 2005). Almost all river systems throughout the range of distribution of Sauger have been altered by dams (Kuhn et al. 2008). Movement of Sauger between pools in the Arkansas River are currently unknown. To better manage the Sauger fishery, movements and dispersal from aggregations near dams must be understood. For example, Pegg et al. (1997) found that Sauger exhibited movement through locks and traveled as far as 200 km, warranting a need for interjurisdictional management. In a similar study, Kuhn et al. (2008) used telemetry to determine that Sauger passage was key to successful management. By keeping spawning migration routes free of barriers, Sauger were able to successfully complete life history events.

Sauger habitat use in the Arkansas River is currently unknown and may be an important information need for management and species sustainability. Sauger have shown to be associated with main channel habitat (Hesse 1994; Vallazza et al. 1994;Maceina et al. 1996; Pegg et al. 1997; Gangl et al. 2000; Jaeger et al. 2005). Amadio et al. (2005) found that preservation of natural fluvial processes were necessary to maintain physical habitat features important to Sauger life history events. Arkansas River habitat composition has been altered with the construction of the McClellan-Kerr Arkansas Navigation System (MKARNS), which makes the river navigable for 716 km (O'Dell 2007). McClellan-Kerr Arkansas Navigation System is maintained by the U.S. Army Corps of Engineers, which dredges the main channel depth to a minimum 2.7 m and the width to a minimum of 76 m (O'Dell 2007). These anthropogenic influences may have altered Sauger habitat preference in the Arkansas River. By knowing what habitats Sauger are selecting during the spawn and summer time, fisheries managers may focus efforts on protecting or creating this invaluable habitat.

To better manage Sauger in the Arkansas River, natural mortality rates must be known. The Arkansas River Sauger report from 2006 completed by AGFC includes models developed in software FAST 2.0 (Fishery Analyses and Simulation Tools – Auburn University) to predict yield per recruit and spawning potential ratio from varying rates of natural and fishing mortality. Models would benefit from knowing these actual mortality rates. Telemetry studies have proven effective as a method of estimating natural mortality because the fate of tagged fish is known (Pollock et al. 2004). Methods developed by Hightower et al. (2001) can be implemented to effectively estimate Sauger natural mortality in the Arkansas River. Hightower used transmitter tagged fish to determine the fate of each fish in a closed system. Each fish was determined to be dead or alive when relocated with missing fish considered harvested.

My study was conducted on Pools 9 and 10 of the Arkansas River that includes Lake Dardanelle and Winthrop Rockefeller Lake, respectively. The main goal of my study was to expand the knowledge of Sauger biology to enhance management efforts of the species in the Arkansas River. Specifically habitat use, intrapool and interpool movement, and estimates of exploitation are needed to effectively manage the Arkansas River Sauger population. The primary objectives for my study were to: (1) identify Sauger habitat preference through active tracking, quantifying habitat, and conducting a second and third order compositional analysis; (2) determine intrapool and interpool movement through lock systems and home ranges through active and passive tracking; and (3) estimate natural and fishing mortality of Sauger by conducting an exploitation study and known-fates of transmitter tagged fish.

Methods

Study Area

The Arkansas River is the sixth longest river in the United States and ranks sixteenth for discharge, releasing on average about 12,500 m/s at the confluence with the Mississippi River (Kammerer 1990). It is the second longest tributary of the Mississippi River. The stream source of the Arkansas River is the East Fork Arkansas River in Colorado. The River flows about 2,400 km primarily east and southeast, passing through four states including Colorado, Kansas, Oklahoma, and Arkansas. My study was conducted on two consecutive pools on the Arkansas River, Lake Dardanelle (Pool 10, 13,887 ha, 82.6 km long) and Winthrop Rockefeller Lake (Pool 9, 1,988 ha, 45 km long) (Figure 1). Lake Dardanelle and Winthrop Rockefeller Lake are popular fishing lakes where Sauger are native and were chosen for my study in consultation with AGFC because of interest in improved management efforts for the species. Lake Dardanelle is a major reservoir on the Arkansas River that was created by the construction of the Dardanelle Lock and Dam in 1971. Lake Dardanelle extends from the Ozark Jetta-Taylor Lock and Dam in Ozark to the Dardanelle Dam in Russellville. The Dardanelle Dam is also where Winthrop Rockefeller Lake starts and extends down river to the Arthur V. Ormond Dam in Morrilton. Both are part of MKARNS, which includes 18 locks and dams, wing dikes, and riprap stabilized banks. The MKARNS is maintained by the United States Army Corps of Engineers, providing commercial navigation, hydroelectric power, flood control, and bank stabilization (Limbird 1993). In an effort to better understand Sauger movement, the study area was extended up and down river to Morrilton (Pool 8) and Ozark (Pool 12).

Fish collection

Sauger were collected from December 2017 to February 2018 using monofilament experimental gill nets in the tailwaters directly below dams when fish were concentrated during the spawning run. The dam inhibits passage and creates an artificial aggregation making collection efficient at this time of the year. Gillnets were 45 m long, 2.5 m tall and consisted of three 15 m sections, each with a different mesh sizes (32 mm, 38 mm, and 51 mm). Nets were set at various locations below each dam using river anchors and float markers. Four nets were set parallel and directly below the floodgates as Sauger seemed to be attracted to water that sprayed through the spillway gates. Two nets were placed perpendicular to shore in tailwaters no more than 1 km below the dams. All nets were set from hours 1600-2300 as this timeframe coincides with high Sauger activity and low angling pressure, which maximized catch (Cobb 1960). Nets were checked continuously every hour to minimize fish stress and net injury. Sauger were removed from gillnets and placed in an aerated 570 L tank filled with lake water. Each fish was measured for total length to the nearest millimeter and weight to the nearest gram. All Sauger received a single standard green tag, a single high reward red tag, or were double tagged with one color using Floy FD94 anchor tags and a Mark-II tagging gun. Fish were tagged perpendicular between dorsal fin spines. High reward tags were used to estimate angler return rate and double tagged fish were used to estimate tag loss. Sauger were then placed in a recovery tank and released back to the river about 500 m from capture location. All Floy tags were marked "Fish ID # AGFC Reward" on one side, and an AGFC phone number on the other side. To educate the public about the study, posters (Figure 2) were placed at popular boat ramps and bait shops throughout the study site.

Surgical techniques

Twenty-five Sauger from each pool were selected for transmitter implants. Sauger were visually examined with only healthy individuals selected to ensure the best probability of survival. Fish exhibiting deformations, open wounds, or lethargy from gillnets were measured and immediately released. Surgery candidates were > 335 mm total length and > 475 g. This criteria was based on Winter's (1983) 2% guideline, which suggests a tag must weigh no more than 2% of a fish's body weight. Surgeries were performed immediately after all nets were checked. Sauger were surgically implanted with Sonotronics acoustic telemetry transmitter model CT-82-2-I (53 mm long, 15.6 mm in diameter, weighs 9.5 g in water). This transmitter model has a range of 1 km, and a 14 month battery life. Surgery methods were modified from Hart and Summerfelt (1975). Transmitters were sterilized for 24 h in a diluted chlorhexidine solution. Fish were anesthetized using a CO_2 bath containing 30 L of lake water, 80 g of sodium bicarbonate, and 30 mL of glacial acetic acid (Peake 1998). Fish remained in the anesthesia until stage-4 anesthesia was reached, typically about 4-7 minutes. A small ventral incision of about 3 cm was made on the midline and the transmitter was pushed into coelomic cavity. The incision was closed with monofilament absorbable suture in a simple interrupted pattern and an iodine ointment was applied to incision as an antiseptic preventative. A maintenance dose of anesthesia was applied to gills, if necessary, using a baster during surgery. Fish were placed in a recovery tank of lake water for 15 to 20 minutes and released back to the river about 500 m from capture locations.

Acoustic telemetry

Acoustic telemetry was used to track Sauger movements in Lake Dardanelle and Winthrop Rockefeller Lake from March 2018 through September 2018. The original objective was to track for an entire year, but due to high-flows resulting in low detectability and hazardous boating conditions, the tracking was limited to six months. Additional tracking sessions were conducted in Pools 8 and 12 in June 2018 to search for lost fish that may have moved through lock and dam systems. Sauger were actively tracked bi-weekly using two Sonotronics USR-14 receivers in conjunction with a DH-4 directional hydrophone and a TH-2 towed omni-directional hydrophone. Tracking sessions started at the top of each study area down river from dams, working downstream 2 to 6 km/h scanning through 14 frequencies (70kHz-83kHz) with a USR-14 narrow band receiver and the TH-2 omni-directional hydrophone. All 14 frequencies were scanned simultaneously using a USR-14 wideband receiver with a separate TH-2 omni-directional hydrophone. This helped increase detection probability while boating and parse out multiple tag frequencies. The boat traveled mid-river where the total width of the river was narrow enough to scan the complete area. On wider stretches of the river, a zig zag movement pattern was used to ensure complete reception coverage. Backwater habitats were tracked every other tracking session due to time constraints. When a tag had been identified on the receiver that tags exact frequency was selected and the directional hydrophone was used to discern the exact location of the fish. Once the position was found, location was recorded in the Universal Transverse Mercator 15N coordinate system with a handheld global positioning system (GPS) (Garmin eTrek 20x). Turbidity (ntu) was recorded with a Hach 2100Q portable turbidity meter. Depth (m) was recorded with a Marcum Lx-I handheld sonar and date and time were also noted. Water temperature (°C) and dissolved oxygen (mg/l) were recorded with a YSI Professional Series Pro2030 Dual Dissolved Oxygen/Conductivity meter once per tracking day. A tracking session was considered completed when the entire study site had been traversed.

Sauger were passively tracked from January 2018 to October 2018 with the use of Sonotronics Submersible Underwater Receiver (SUR) units. SUR's were set up 500m above and below both Ozark Dam and Dardanelle Dam to monitor interpool movement. A fifth receiver was set up 500 m below Arthur V. Ormond Dam in Morrilton. Receivers were anchored with a cement cinder block and kept off the river bottom with a float. Anchors were attached to the river bank with a 15 m long 10 mm diameter steel cable. SUR's were checked every 3 months to collect data and change batteries.

Telemetry analysis

Sauger minimum displacement per day (MDPD) and home range estimates were calculated in the ArcGIS v10.3 Fish Tracker 10.1 program. Home range size was compared between pools using a Kruskal-Wallis one-way analysis of variance. MDPD based on environmental variables were evaluated with an ordinary least squares regression. Interpool movements were analyzed as the proportion of transmitter tagged fish that were confirmed to have moved through a lock system compared to all transmitter tagged fish. Compositional analysis was conducted in program R (R 3.4.2, The R foundation for Statistical computing) using package "adehabitatHS" to determine habitat usage based on availability. The statistical significance threshold (α) was set at 0.05. Habitats were delineated into six categories based on anthropogenic influences, ArcMap aerial imagery, and ground-truthing. Area of each habitat was calculated by digitizing in ArcMap (Table 1).

Exploitation analysis

A passive one-year tag reward study was conducted to estimate annual exploitation. Pollock's (2001) formula was used to assess exploitation of the Sauger fishery.

(1)
$$u = N_r / [N_o(1-t)(1-m)(\lambda)]$$

N_r is the number of tags returned from harvested fish and N_o is the number of total tagged fish. Assumptions of this model include: (1) No tags are lost; (2) The mortality of tagged fish does not differ from the mortality of untagged fish; (3) All tags are recognized and reported upon recovery; (4) Tagged fish randomly mix with untagged fish; (5) Tagged fish are caught at the same rate as untagged fish; and (6) All fish are released instantaneously at the start of each interval.

This formula accounts for all assumptions of the model. Tag loss (t) was accounted for by double-tagging 20% of fish and finding the retention rate based on number of double-tagged fish returned that only had a single tag compared to number of double-tagged fish returned that still had both tags. Tagging mortality (m) was assumed to be negligible based on Crawford et al's (2006) study of sunfish, which had zero tagging mortality. Tag reporting rate (λ) was accounted for by using the following formula;

(2)
$$\lambda = \frac{R/N}{R'/N'},$$

where (R) is the number of standard tags returned, (N) is the number of standard tags released, (R') is the number of high-reward tags returned, and (N’) is the number of high-reward tags released. Thirteen percent of tagged Sauger received a “high-reward” tag that had a guaranteed US$100 reward. This amount was chosen based on Nichols (1991) study on band reporting rates for Mallards *Anas platyrhynchos*, which found that a reward value of $100 was needed to assume a 100% reporting rate of tagged individuals in 1988. Accounting for inflation using the consumer price index, a reward of over $200 would be necessary to assume a 100% reporting rate. An error arises when 100% reporting of high-reward tags is falsely assumed and needs to be incorporated into equation (1) (Conroy and Williams 1981). Percent error is $100 \cdot [(1/ \lambda_r) - 1)]$, where λ_r is the actual reporting rate taken from Nichols (1991), which is 80.7% for a $50 reward in 1988 and translates to $109 in 2019. All other tagged Sauger received a standard reward green tag that ranged from $10 to $50 and amount was chosen randomly.

Results

Telemetry fish collection and Surgery

The goal of collecting and surgically implanting transmitters in 25 adult Sauger downstream from Dardanelle Dam and Ozark Jetta Taylor Dam was achieved in 10 nights (Dardanelle = 6 nights, 30 nets; Ozark = 4 nights, 21 nets) from December 18, 2017 to January 15, 2018. All healthy Sauger were surgically implanted with coded ultrasonic transmitters. Sauger ranged in total length from 369 to 510 mm (*n* =50, median = 422) with 50% of tagged fish between 408 and 450 mm. Tagged Sauger ranged in total weight from 460 to 1545 g. (*n* =50, median = 743) with fifty percent between 662 and 833 g. All implanted Sauger recovered and were released without mortality during surgical procedures. Mortality may have occurred between tagging and the first tracking session for Sauger that were never relocated but it is more likely that they left the system.

Acoustic telemetry

Of the 50 Sauger implanted with transmitters, 26 (52%) were excluded from the telemetry analyses due to natural mortality (*n* = 1, 2%), fishing mortality (*n*=1, 2%), never relocating the fish after release (*n* = 11, 22%), or not being able to relocate the fish more than twice during the summer months (*n* = 13, 26%). Natural mortality was determined by locating a tag in the exact same location on three or more consecutive tracking sessions. An accurate measure of natural mortality was unable to be calculated due to the system not being closed and technical difficulties of SUR units. Of the eight fish that were only located twice, four (8%) were found in Pool 12 of the Arkansas River where they remained throughout the study. Detection probability was 39% throughout the study and it is likely that there were up to six other Sauger in the Ozark pool that were not detected. For the remaining 24 Sauger, individual number of relocations ranged from 4 to 11, for a total of 136 relocations in 16 complete pool tracks (Pool 10 = 8 tracks; Pool 9 = 8 tracks). All Sauger Locations were recorded from May 25, 2018 to September 27, 2018. The goal of tracking Sauger for a full year was limited to four months because of high-flows, which limited our detection and created unsafe boating conditions. High-flows also sometimes prevented tracking each pool twice per month during the four-month tracking period (Figure 3). Median number of relocations was 8 (*n* = 14 fish) for Pool 9 and 6 (*n* = 10 fish) for Pool 10.

Sauger movement

Sauger interpool movement was recorded in 11 (22%) individuals based on both active and passive tracking. Almost all interpool movements were recorded by active tracking except for one fish that moved from Pool 9 to Pool 8. Of the eleven fish that moved between pools on the Arkansas River, nine moved upstream, while two moved down stream. None of the fish returned to their original tagging pool during the study period. Fish that were never relocated after tagging were not recorded for moving from pool to pool, so interpool movement was likely higher than 22%.

Median total movement of Sauger was 115 m/day for Pool 10 and 88 m/day for Pool 9. This difference was not statistically significant ($X^2 = 0.051$, df = 1, $P = 0.822$). Ninety percent home range ranged from 0.04 to 9.84 km^2 with 50% between 0.09 and 1.26 km^2. Median 90% core home range of Sauger was 0.2 km^2 for Pool 10, and 0.7 km^2 for Pool 9. This difference was not statistically different ($X^2 = 0.454$, df = 1, $P = 0.501$). Since movement was not significantly different between the two pools, all further movement analyses were pooled. Linear regression was conducted to determine if MDPD was influence by water quality variables measured. The relationship between MDPD and flow was statistically significant but had little explanatory value due to a small R^2 value (Figure 4). No relationship of MDPD with surface water temperature or depth was observed (Figures 5 and 6). Additionally, turbidity and conductivity were excluded from this analysis because of equipment failure and no relationship was tested due to reduced sample sizes.

Habitat use

Sauger habitat use was analyzed using both second and third order compositional analysis outlined by Atchison (1960), Johnson (1983), and Aebischer (1986). Second order compositional analysis was conducted on the proportions of each habitat type that overlapped a Sauger's 90% home range compared to the total availability of each habitat type in Pool 9 and Pool 10 combined (Table 1). Ninety percent home range was determined for 24 individuals from May 25, 2018 to September 27, 2018. Tracking sessions outside of these dates were inconsistent, therefore excluded from the compositional analysis. Sauger did not establish a home range at random ($\lambda = 0.027$, df = 5, $P < 0.001$). Channel edge was ranked highest having the greatest percentage occurring in Sauger 90% home ranges based on total availability of the study area, followed by main channel, wing dike, dam, backwater, and flat respectively. Flat habitat was used significantly less than all other habitat types and backwater habitat was significantly less used than all other habitat types excluding flat habitat. Among the top three habitats, channel edge and main channel were used significantly more than wing dike. Dam was used significantly less than the top three ranked habitats but (Table 2).

When pools were analyzed separately using second order compositional analysis, 14 Sauger did not establish a home range at random in Pool 9 ($\lambda = 0.005$, df = 4, $P < 0.001$) or Pool 10 ($\lambda = 0.008$, df = 5, $P < 0.001$). Channel edge habitat was ranked the highest for Sauger in Pool 9, followed by main channel, wing dike, dam, and backwater respectively. Flat habitat was excluded from this analysis because it was not observed in Pool 9 (Table 3). Channel edge was significantly preferred over all other habitat types except main channel and backwater was significantly preferred against compared to all other habitat types. Main channel habitat was ranked highest for 10 Sauger in Pool 10, followed by wing dike, channel edge, dam, backwater, and flat respectively (Table 4). The top three ranked habitats were not significantly preferred over one another.

Third order compositional analysis was conducted from 136 fish locations of 24 Sauger compared to the proportions of each of the six delineated habitat types in each individual's 90% home range. Locations of fish were recorded from May 25, 2018 to September 27, 2018. Sauger were rarely observed in dam, backwater, and flat habitats therefore those habitat types were excluded in the third order analyses. Habitat use of Sauger for both study sites pooled was random ($\lambda = 0.912$, df = 2, $P = 0.478$). While selection of habitat was random, rankings may still be important. Wing dike was ranked as the most used habitat based on proportion occurring in home ranges (Table 5). Habitat use of 10 Sauger for Pool 10 alone was also random ($\lambda = 0.671$, df = 2, $P = 0.272$). Wing dike habitat was ranked the highest (Table 6). Habitat use of 14 Sauger in Pool 9 was not random ($\lambda = 0.480$, df = 2, $P = 0.024$). Main channel was ranked as the most used habitat based on proportion occurring in home ranges, followed by wing dike and channel edge respectively. Main channel was significantly preferred compared to channel edge habitat. (Table 7). Fish were found at water depths that ranged from 0.6 to 13.3 m. Median water depth of location where fish were found was 5.9 m with fifty percent between 4.2 and 6.4 m. Surface water temperatures ranged from 25.4 to 32.6ºC. Median surface water temperature was 29.5ºC with fifty percent between 28.1 and 31.1ºC.

Exploitation

Two-hundred-eighty-seven Sauger were caught using experimental gill nets at Dardanelle Dam and 43 were caught at Ozark Jetta Taylor Dam on 13 net nights

(Dardanelle = 6 nights, 30 nets; Ozark = 7 nights, 36 nets) from December 18, 2017 to February 18, 2018. All healthy Sauger received an external Floy T-bar anchor tag (FD94). Sauger tagged in Pool 9 ranged in total length from 293 mm to 494 mm (*n* = 43, median = 409 mm) with 50% of tagged fish between 369 mm and 441 mm (Figure 7). Sauger tagged in Pool 10 ranged in total length from 223 mm to 512 mm (*n* =287, median = 416 mm) with 50% of tagged fish between 392 mm and 445 mm (Figure 8). Two hundred twenty one (66.96%) Sauger received a green standard reward tag, 44 (13.33%) received a red high reward tag, 55 (16.66%) were double tagged with green tags, and 10 (3.03%) were double tagged with red high reward tags. Of the 330 Sauger externally tagged, only five (1.51%) were turned in for a reward by anglers. Of the five tags turned in, two (0.90%) were single green standard reward fish, one (0.45%) was a red high reward fish, and two (0.90%) were double-tagged reward fish. Four Sauger were caught in December 2018 and one was caught in January 2019. No double-tagged fish were turned in missing one of their tags. Tag loss was not adjusted in the analyses because it was negligible during the duration of the study. Tagging mortality was also excluded from the analyses because it was deemed negligible based on tank study by Crawford and Allen (2006) that found zero tagging mortality. Tag reporting rate was estimated to be 39.13% with error of 23.9%. Exploitation of Sauger on Pools 9 and 10 of the Arkansas River was estimated to be 3.9%.

Discussion

Movement

Twenty-four Sauger were tracked from May 2018 to September 2018 in the Arkansas River. Tracking sessions from February 2018 to early May 2018 were excluded from the analyses because of inconsistent tracking. Seventy-eight percent of

Sauger remained in the pool they were tagged in for the duration of the study. Sauger that moved between pools likely navigated through the locks shortly after being tagged and during their spawning migration. In my study, one Sauger was observed traveling more than 140 km through two lock systems. It was tagged in mid-January below Dardanelle Dam and recaptured in early February 82 km up river below Ozark dam. The same individual then proceeded to traverse another 58 km in 4 days to the James W. Trimble Lock and Dam where it was caught and harvested. It is likely that several tagged Sauger traveled further than what was observed because further pools were not tracked. Pegg et al. (1997) observed similar movement of Sauger in the Tennessee River, Tennessee where some fish moved over 200 km in 10 days. Jaeger et al. (2005) also observed Sauger moving up to 350 km upstream in the Lower Yellowstone River, MT. The number of Sauger that moved through lock systems during my study suggest dams may not be overly restrictive. The 11 fish that were never found likely moved out of the system before the first tracking session was conducted. Movement did not appear to be affected by environmental factors during my study likely due to a lack of variation in environmental factors (Tables 8 and 9). For example, temperature ranged from 10 to 32.1 °C throughout the study. However, 50% of water temperatures were between 26.4 and 31.0 °C. A wider range of temperatures was not possible to obtain due to our limited study duration. An extended study including all seasons or shorter intervals between tracking sessions would likely determine which environmental factors affect Sauger movement. Kirby et al. (2017) by means of a diel tracking study, found that Walleye in Onondaga Lake, New York were found in significantly shallower water during the day than the night. Shorter intervals between tracking sessions would likely result in a more accurate representation of Sauger movement and what influences it. Sauger have displayed substantial movements during the fall to distinct areas during spawning migrations (Nelson 1968; Pegg et al. 1997; Welker et al. 2002, cited by Kuhn et al. 2008). Unfortunately, we were not able to track movement during this time period due to high flow, but we would likely see similar results.

Sauger tended to reside in sections of the river that were more riverine than the reservoir, which is contrary to most other Sauger movement studies taking place in large modified rivers. Pegg et al. (1997) found most Sauger moved to the main basin of Kentucky Lake, Tennessee after the spawn. Stodola (1992, cited by Pegg et al. 1997) also found Sauger frequenting the main basin of the Douglas reservoir in Tennessee. The findings of my study only had Sauger traversing through the main basin of Lake Dardanelle, as no individuals were found there on two consecutive tracking sessions. Sauger likely avoided the main basin because of the lack of structure and deep moving water (Robison and Buchanan 1992). Sauger in my study mainly resided over the summer within 13 km below the dam they were tagged and showed high site fidelity (Figures 9 and 10). Due to high flow, which created unsafe boating conditions and low detectability, Sauger were unable to be tracked during a majority of spring, fall, and winter. Geike's (2016) study on Paddlefish in the Arkansas River, AR found detectability was inversely correlated with flow. He observed 1200 m^3/s flow as the threshold to maintain a high probability of detecting tagged fish. Kuhn et al. (2008) observed Sauger remaining relatively sedentary during fall, winter and early spring in the Little Wind River drainage in Wyoming, suggesting that Sauger in the Arkansas River may behave similarly. Jaeger et al. (2005) also observed similar behavior in the Lower Yellowstone River in Montana.

Habitat use

Tagged Sauger were released below the dams they were captured at in the Arkansas River and tracked biweekly to evaluate habitat use using both second and third order compositional analysis. Home ranges and available habitat were quantified in ArcGIS v10.3. Sauger did not use habitat types proportional to availability throughout the duration of the study. Second order compositional analysis yielded dam habitat as the highest rank for Sauger in pools 9 and 10 combined, followed by main channel and channel edge respectively. This ranking may be artificial as a result of dam habitat making up such a small portion of the available habitat and due to the fact that all tagged Sauger were caught in dam habitat, but were rarely found there after being tagged. Channel edge habitat was ranked the highest in Pool 9, followed by dam and main channel respectively. Wing dike habitat was ranked the highest in Pool 10, followed by dam and channel edge respectively. Pool 9 on the Arkansas River is more riverine than Pool 10, which contains a large reservoir and a transition zone. This could explain the difference in habitat ranking between the pools.

Third order compositional analysis yielded main channel habitat as the highest rank for Sauger in pools 9 and 10 combined. Main channel habitat was ranked the highest in Pool 9, followed by wing dike and channel edge respectively. Wing dike habitat was ranked the highest in Pool 10, followed by main channel and channel edge respectively. It is clear that Sauger are utilizing habitats that have heavy anthropogenic influences that typically result in fast moving water (Robison and Buchanan 1992) in the channel and optimal forage opportunity near wing dikes (Schloesser et al. 2011). They preferred main channel, channel edge, and wing dike habitats while avoiding flat and backwater habitats during the summer. This is contrary to what Gangl et al. (2000) observed, where Sauger were primarily found in backwater and side channel habitats in Pool 2 of the Upper Mississippi River, Minnesota during summer months. This difference could be because the Minnesota Department of Natural Resources did not quantify habitat availability or home ranges of Sauger for their analysis of habitat use. It should be noted that a certain degree of bias exist when using home ranges to evaluate habitat use because fish may be simply traversing certain habitat types included in the quantified home range while never actually utilizing it. Other Sauger habitat use studies delineated habitat types differently than my study such as Kuhn et al. (2008), who delineated the Little Wind River drainage in Wyoming into three habitat types; pool, run, and riffle. Sauger in the Little Wind River selected large deep pools while avoiding runs and riffles, which is similar to my study despite the difference in habitat delineation. Sauger appear to have an affinity for deeper water throughout their range.

Exploitation

Exploitation of Sauger in the Arkansas River was calculated for 330 individuals using Pollock et al.'s (2001) formula. Of the 330 Sauger externally tagged, only five were turned in for a reward by anglers including one high-reward tag, two standard reward tags, and two double tagged standard-reward tags. No double-tagged Sauger were turned in missing a tag so tag loss was determined to be negligible and not adjusted for. Tagging mortality was also determined to be negligible based on Crawford and Allen's (2006) tank study on Redear Sunfish. Of the five tags turned in by anglers, four were originally tagged at Ozark Jetta-Taylor Dam and one was originally tagged at Dardanelle Dam. The exploitation formula was adjusted for angler reporting rate, which was estimated to be 39.13%. Exploitation of Sauger was estimated to be 3.9% and does not warrant any changes in current management of the species. Exploitation may have been low from February 2018 to February 2019 because of high flows making angling efforts difficult. Pegg et al. (1996) observed exploitation of Sauger in the Tennessee River exceeding rates of 35% or more in a two-year exploitation study and concluded that exploitation was coupled with upstream migration, which left Sauger vulnerable to harvest. However, angler demographics may differ between Arkansas and Tennessee. My study only looked at exploitation for a single year that had an atypical amount of flow, which may not be representative of all years. A year with more angler friendly weather conditions may have resulted in higher exploitation. Sauger are primarily targeted when they are aggregated below dams in winter months, and if water velocity through the dam is too great it can be hard to fish effectively and fish may retreat to refuge areas downstream (Sedell et al. 1990). Personal communication with anglers suggest the Sauger fishery in the Arkansas River used to be quite satisfactory, but has seen a decline. Exploitation of Sauger also may be low because the general public is not aware of them as a good-tasting game fish.

Conclusion

During my study, Sauger movement in the Arkansas River was not restricted due to barriers as at least 22% of transmitter tagged individuals passed through locks during their spawning run. They can travel great distances in short periods of time, which could warrant the need for interjurisdictional management with Oklahoma. Sauger in my study traveled 54 km in four days and average MDPD was 177 m during the summer. Oklahoma has a 356 mm MLL while Arkansas does not have a MLL for Sauger and the populations are likely not independent. A majority of Sauger that moved between pools were in an upstream direction. Sauger movement between the two states is likely in one direction and a comparison between population structures may be beneficial for determining if interjurisdictional management is necessary. Pegg et al. indicated that Sauger in the Lower Tennessee River need to be interjurisdictionaly managed because tagged individuals movements encompassed Kentucky, Tennessee, Mississippi, and Alabama. Conflicting management regulations near state borders will likely not result in successful completion of management objectives. If angler demographics are significantly different between Arkansas and Oklahoma, interjurisdictional management may not be effective. Management of Sauger near state borders could benefit from a creel survey that focuses on determining angler attitudes toward Sauger. Sauger in the Arkansas River could also benefit from a DNA study determining if individuals from connecting rivers are unique or similar. This could have management implications that would recommend managing each river separately or could further support the claim that interjurisdictional management is necessary. If interjurisdictional management is necessary, Arkansas and Oklahoma fisheries managers must collaborate to manage Sauger effectively. Sauger in the Arkansas River were not well studied until this project and it is clear that anglers are not utilizing this resource. Public outreach to educate anglers about this unused resource could prove beneficial to the fishery. Future studies should focus on analyzing habitats on a finer scale to determine what factors influence Sauger to prefer channel and wing dike habitats. This could aid in management efforts to maintain suitable habitat for Sauger in the Arkansas River. Sauger should also be tracked for a span of one full year to encompass all seasons and determine what factors influence movement. Fall drop in water temperatures would likely be a driving factor for large-scale movements for the species. Sauger are currently sampled by Arkansas Game and Fish Commission using gillnets below dams when they are aggregated, but location density maps of Sauger show several high density areas that may be viable for sampling at different times of the year with gillnets or electrofishing (Figures 9 and 10). I would not recommend adding a MLL for Sauger on the Arkansas River because exploitation is low. Based on modeling in FAMS by AGFC, “growth overfishing” and “recruitment overfishing” are not likely to occur; however, exploitation of Sauger should continue to be monitored with the tags that are currently out there to determine if weather plays an important role in exploitation rates. The exploitation rate of 3.9% could have been artificially low because there were limited opportunities to harvest Sauger when they were aggregated below the dams in 2018. Sauger are not a well-known eating fish in Arkansas (F. Leone, personal communication), which likely contributes to the low exploitation rate. I recommend some form of public outreach to educate the angling public on this resource that is not being utilized. A fishing clinic demonstrating how to catch, clean, and cook Sauger has the potential to create a new group of anglers and provide diverse fishing opportunity.

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Table 1- Description and availability of each macrohabitat in Pool 9, Pool 10, and Pools 9 and 10 combined of the Arkansas River, Arkansas.

		Percent Availability		
Habitat Type	Description	Pool 9	Pool 10	Combined
Main Channel	Main navigation channel, typically has fastest currents, maintains a minimum depth of 2.7 m and a minimum width of 76 m.	33.45	15.54	14.66
Channel Edge	The area directly adjacent to the main river channel, typically has low slope and depths greater than 3 m. Includes rip rap banks.	33.39	19.86	19.90
Dam	The area 500 m above and below dam structures that can have turbulent water from spillway when flow exceeds 1250 m^3/s.	3.90	0.65	1.02
Wing Dike	The immediate area surrounding and between rock levees, can have highly variable depths.	19.10	2.17	14.75
Backwater	Areas of the river not reached by the main river current.	10.16	30.09	24.87
Flat	Large expanses of habitat lacking structure and is generally 1 to 5 m deep.	0	31.69	24.80

Table 2− Proportion of each habitat type occurring in 24 Sauger 90% home ranges compared to total available habitat in Pools 9 and 10 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by second order compositional analysis including rank. Shaded blocks denote significant differences between habitat types.

	Habitat type						
Habitat type	Channel edge	Main channel	Wing dike	Dam	Backwater	Flat	Rank
Channel edge	0	+	+++	+++	+++	+++	1
Main channel	-	0	+++	+++	+++	+++	2
Wing dike	---	---	0	+++	+++	+++	3
Dam	---	---	---	0	+++	+++	4
Backwater	---	---	---	---	0	+++	5
Flat	---	---	---	---	---	0	6

Table 3- Proportion of each habitat type occurring in 14 Sauger 90% home ranges compared to total available habitat in Pool 9 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by second order compositional analysis including rank. Shaded blocks denote significant differences between habitat types.

	Habitat type					
Habitat type	Channel edge	Main channel	Wing dike	Dam	Backwater	Rank
Channel edge	0	+	+++	+++	+++	1
Main channel	-	0	+	+++	+++	2
Wing dike	---	-	0	+++	+++	3
Dam	---	---	---	0	+	4
Backwater	---	---	---	-	0	5

Table 4- Proportion of each habitat type occurring in 10 Sauger 90% home ranges compared to total available habitat in Pool 10 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by second order compositional analysis including rank. Shaded blocks denote significant differences between habitat types.

	Habitat type						
Habitat type	Main channel	Wing dike	Channel edge	Dam	Backwater	Flat	Rank
Main channel	0	+	+	+++	+++	+++	1
Wing dike	-	0	+	+++	+++	+++	2
Channel edge	-	-	0	+++	+++	+++	3
Dam	---	---	---	0	+	+++	4
Backwater	---	---	---	-	0	+	5
Flat	---	---	---	---	-	0	6

Table 5- Macrohabitat preference of Sauger in Pools 9 and 10 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by third order compositional analysis including rank. Shaded blocks denote significant differences between habitat types.

	Habitat type			
Habitat type	Wing dike	Main channel	Channel edge	Rank
Wing dike	0	+	+	1
Main channel	-	0	+	2
Channel edge	-	-	0	3

Table 6- Macrohabitat preference of Sauger in Pool 10 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by third order compositional analysis including rank. Shaded blocks denote significant differences between habitat types. Dam, flat, and backwater habitats were excluded from this analysis.

	Habitat type			
Habitat type	Wing dike	Channel edge	Main channel	Rank
Wing dike	0	+	+	1
Channel edge	-	0	+	2
Main channel	-	-	0	3

Table 7- Macrohabitat preference of Sauger in Pool 9 of the Arkansas River, Arkansas from May 2018 to September 2018 determined by third order compositional analysis including rank. Shaded blocks denote significant differences between habitat types. Dam, flat, and backwater habitats were excluded from this analysis.

	Habitat type			
Habitat type	Main channel	Wing dike	Channel edge	Rank
Main channel	0	+	+++	1
Wing dike	-	0	+	2
Channel edge	---	-	0	3

Table 8- Sauger location environmental variables in Pool 9 of the Arkansas River, Arkansas.

	Temperature	Depth	Turbidity	Dissolved Oxygen
Mean	29.97	17.25	22.52	6.76
SD	1.94	5.46	15.75	1.04
Median	30.9	18.30	20.55	6.85
Minimum	25.4	2	5.57	5.18
Maximum	32.6	27.5	65	8.58

Table 9- Sauger location environmental variables in Pool 10 of the Arkansas River, Arkansas.

	Temperature	Depth	Turbidity	Dissolved Oxygen
Mean	28.67	16.66	22.42	6.88
SD	1.78	9.26	13.76	1.21
Median	28.90	15.80	17.60	7.61
Minimum	25.70	4.10	7.72	4.89
Maximum	31.40	41.10	58.70	7.96

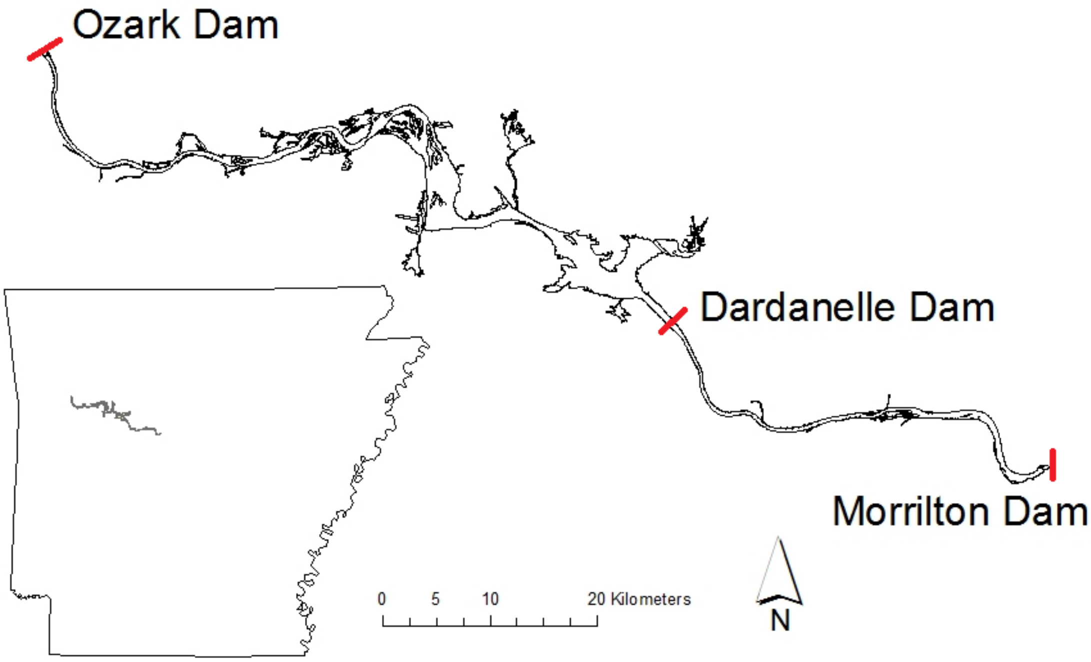

Figure 1- Map of study site including Pools 9 and 10 of the Arkansas River, Arkansas.

REWARD

Arkansas River Sauger Exploitation Study
Please help us collect this information:

1. Tag 2. Length 3. Number Sauger Caught 4. Date 5. Location

$10 to $50: amount chosen randomly

Red "High Reward" tags are $100 guaranteed

Please Contact AGFC at 1-877-967-7577 with your information.

Figure 2- Reward poster posted at high-use boater access points and bait shops.

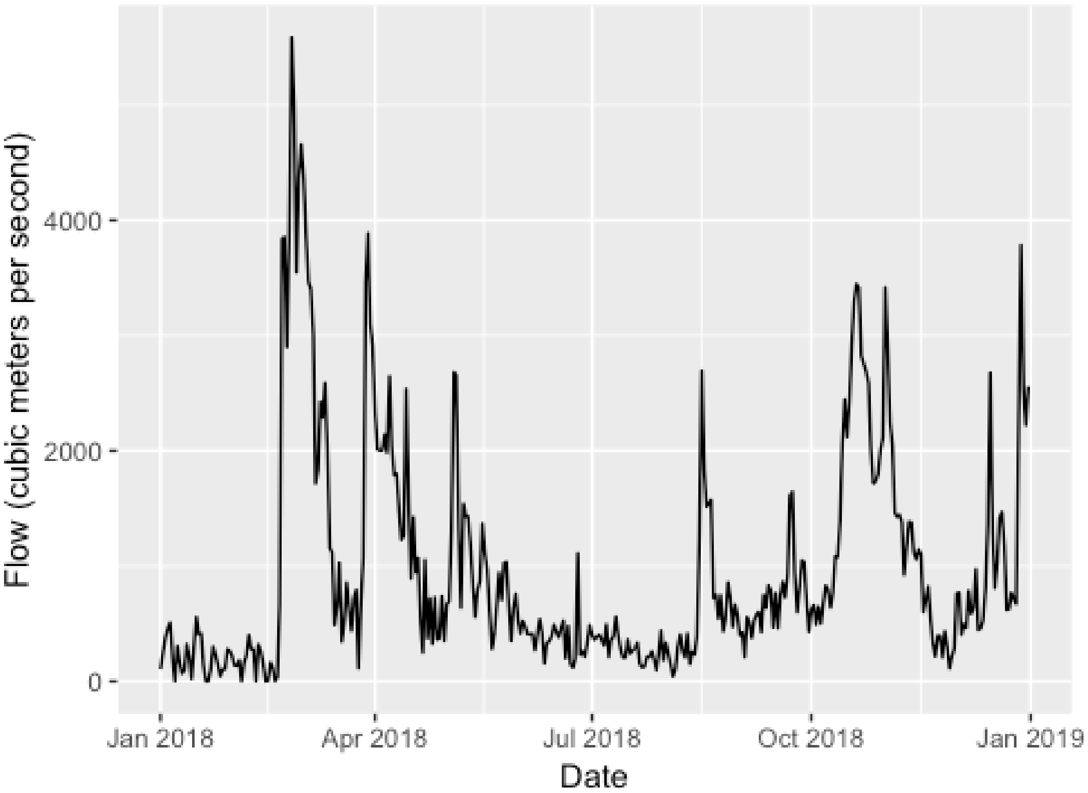

Figure 3– Flow in the Arkansas River, Arkansas in 2018.

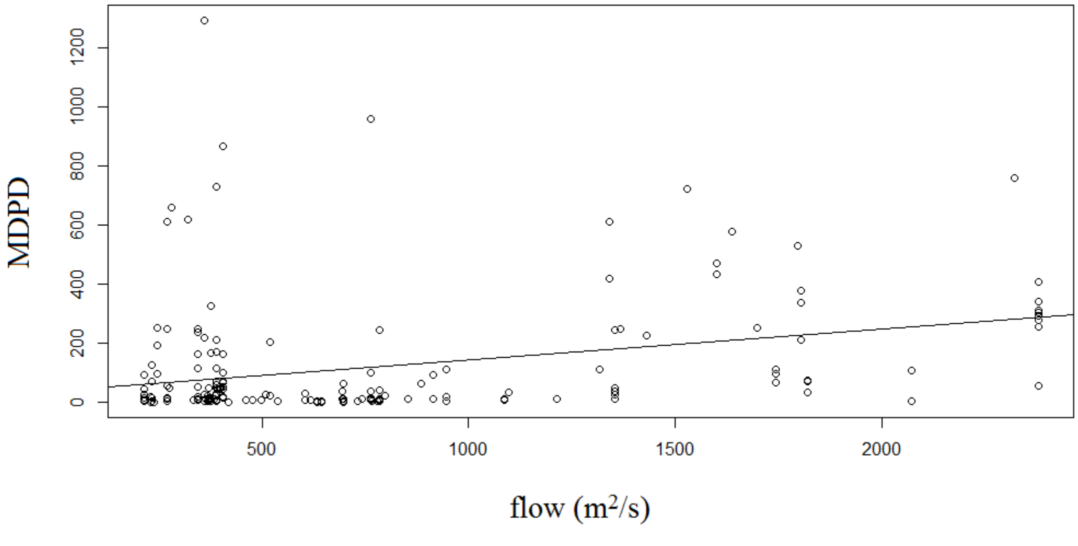

Figure 4- Linear relationship of MDPD and flow with an $R^2 = 0.096$ ($F_{1, 184} = 19.62$, $R^2 = 0.096$, $P < 0.001$).

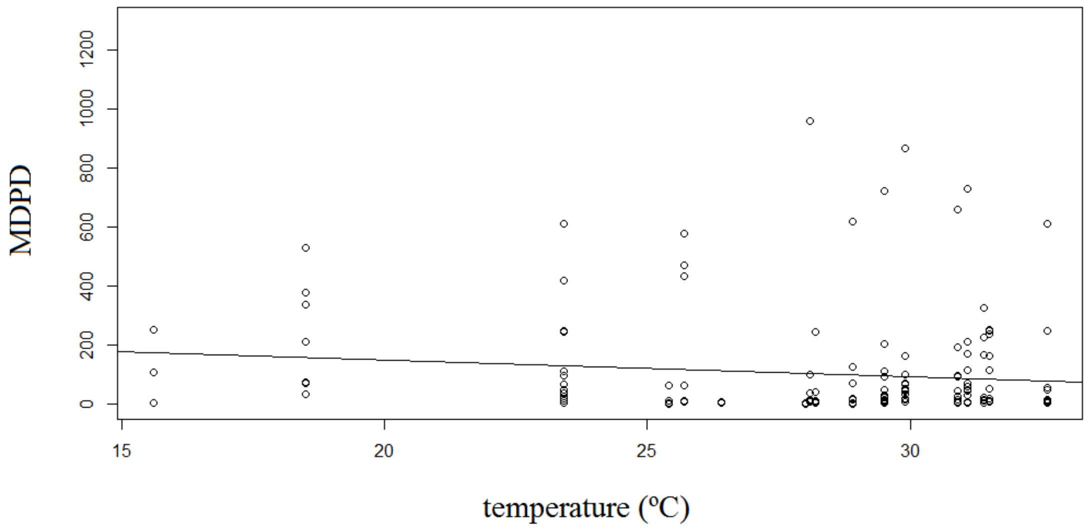

Figure 5- Linear relationship of MDPD and temperature with an $R^2 = 0.014$ ($F_{1, 163} = 2.25$, $R^2 = 0.014$, $P = 0.135$).

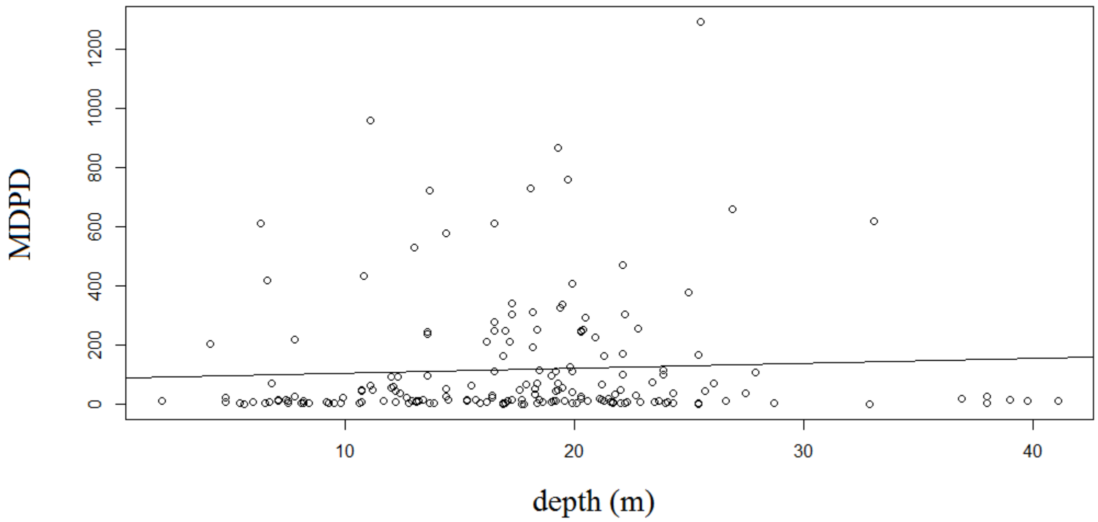

Figure 6- Linear relationship of MDPD and depth with an $R^2 = 0.003$ ($F_{1, 184} = 0.62$, $R^2 = 0.003$, $P = 0.430$).

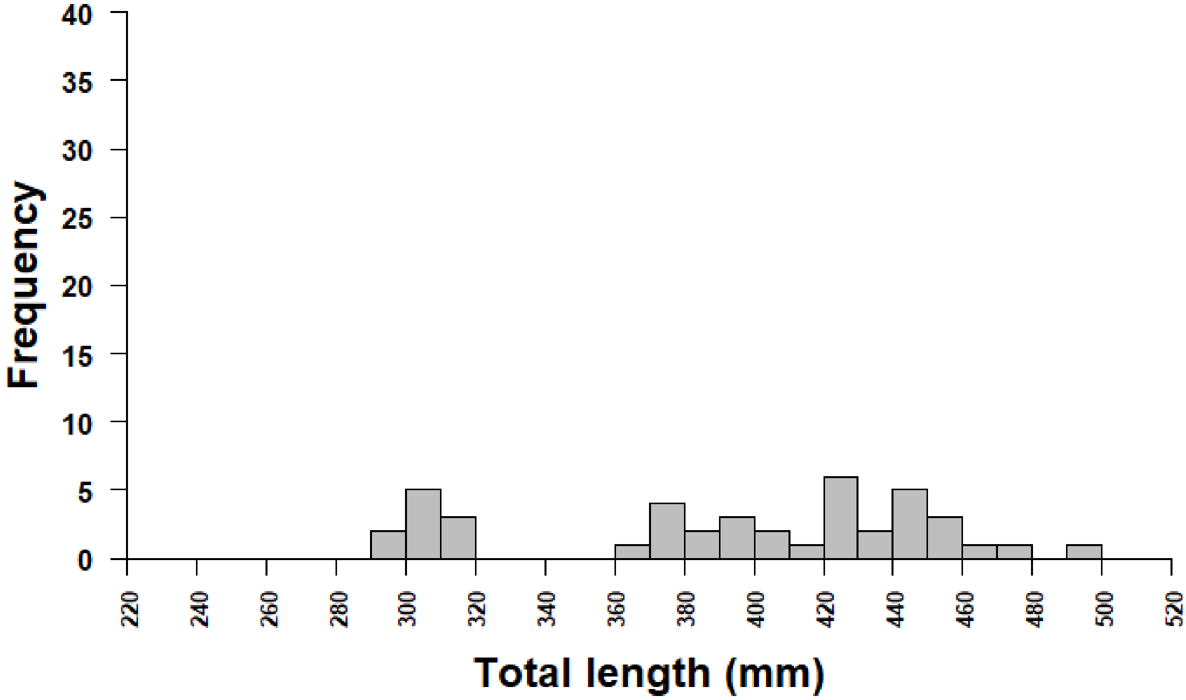

Figure 7- Length frequency of Sauger in Pool 9 of the Arkansas River, AR.

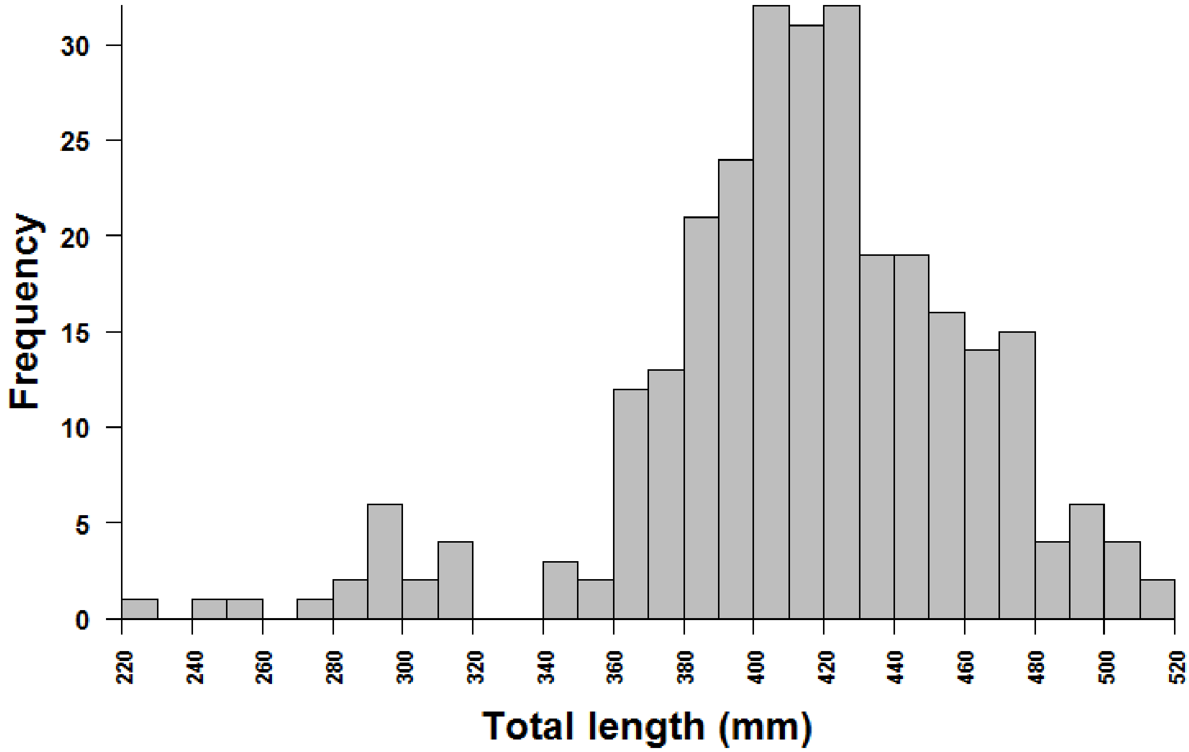

Figure 8- Length frequency of Sauger in Pool 10 of the Arkansas River, AR.

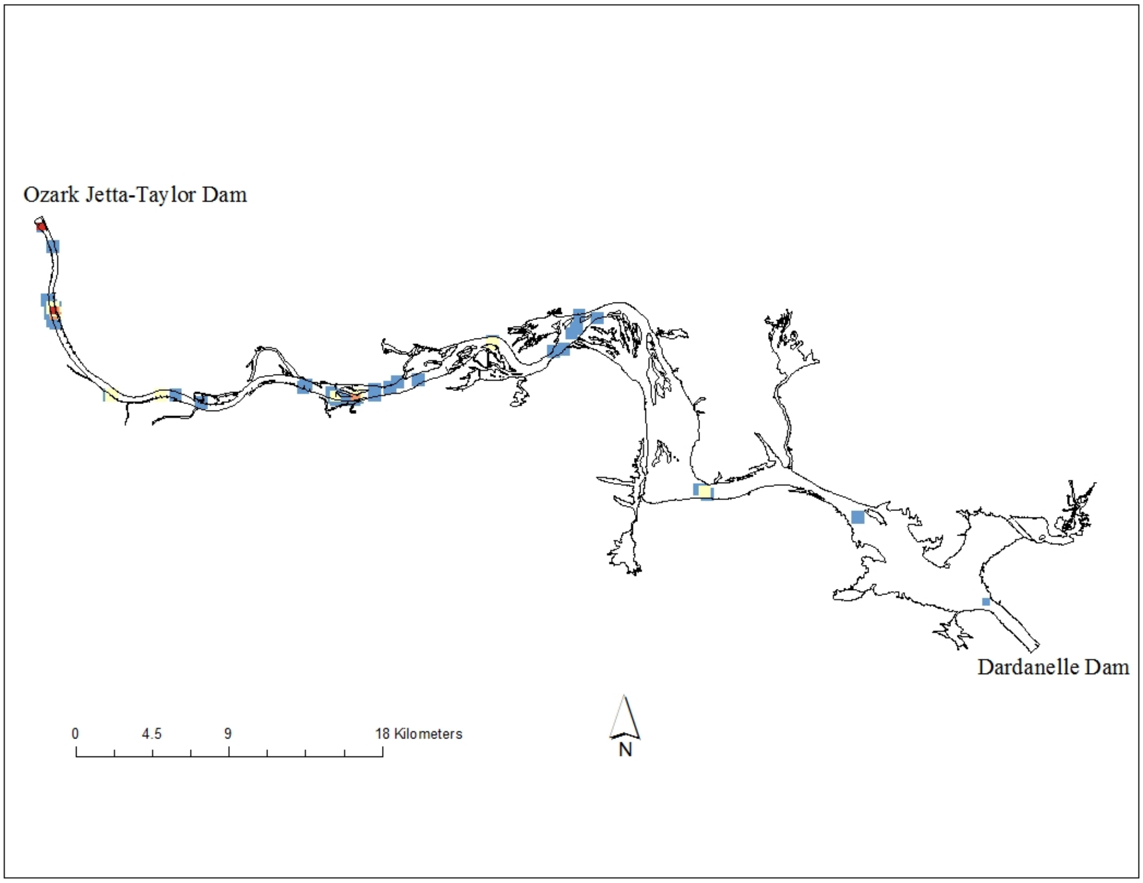

Figure 9− Heat map of Sauger density in Pool 10 of the Arkansas River, AR.

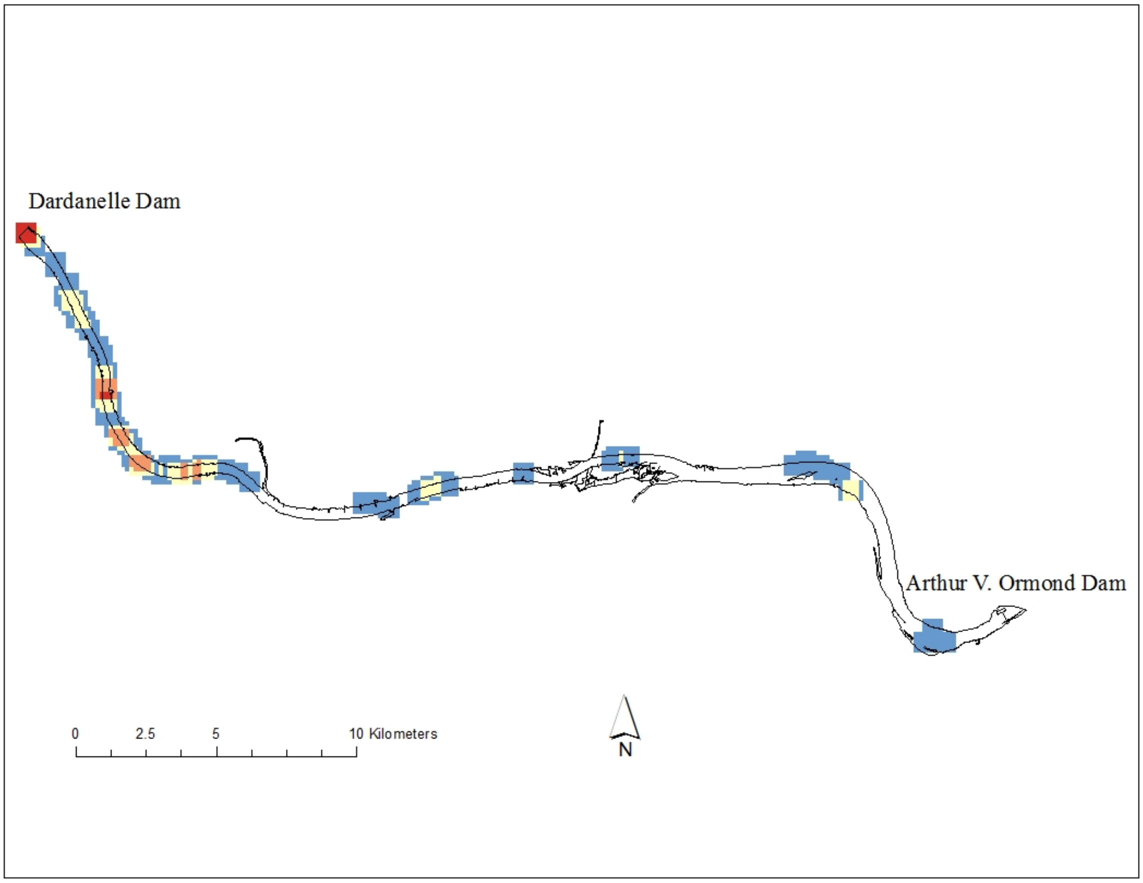

Figure 10− Heat map of Sauger density in Pool 9 of the Arkansas River, AR.

Appendix

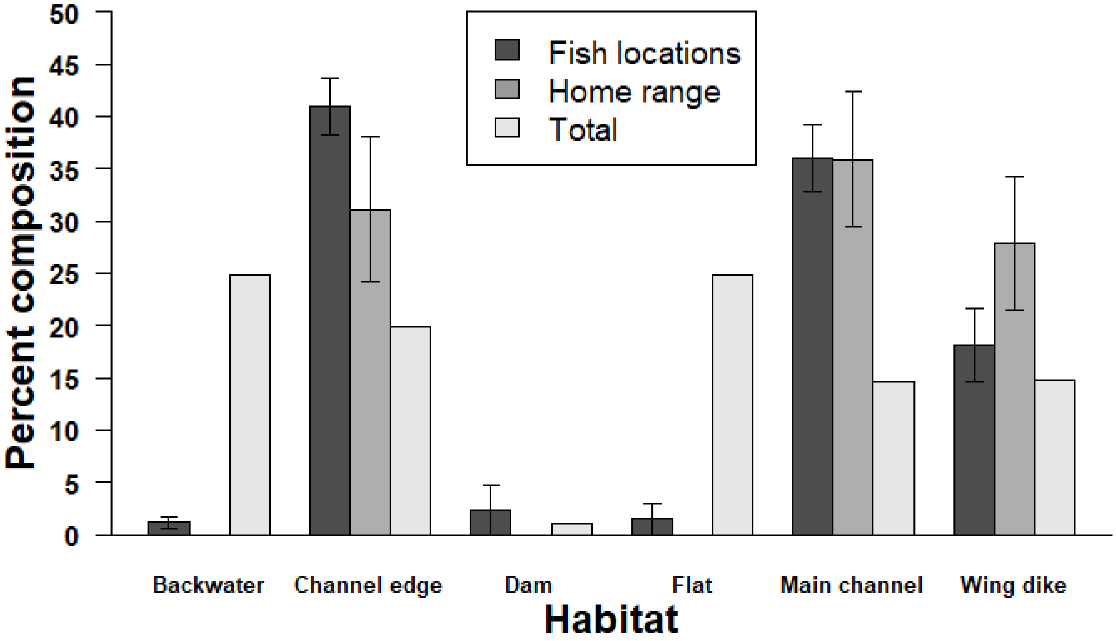

Figure 11− Percent composition of habitats used by Sauger and the total available habitat in Pools 9 and 10 of the Arkansas River, Arkansas.

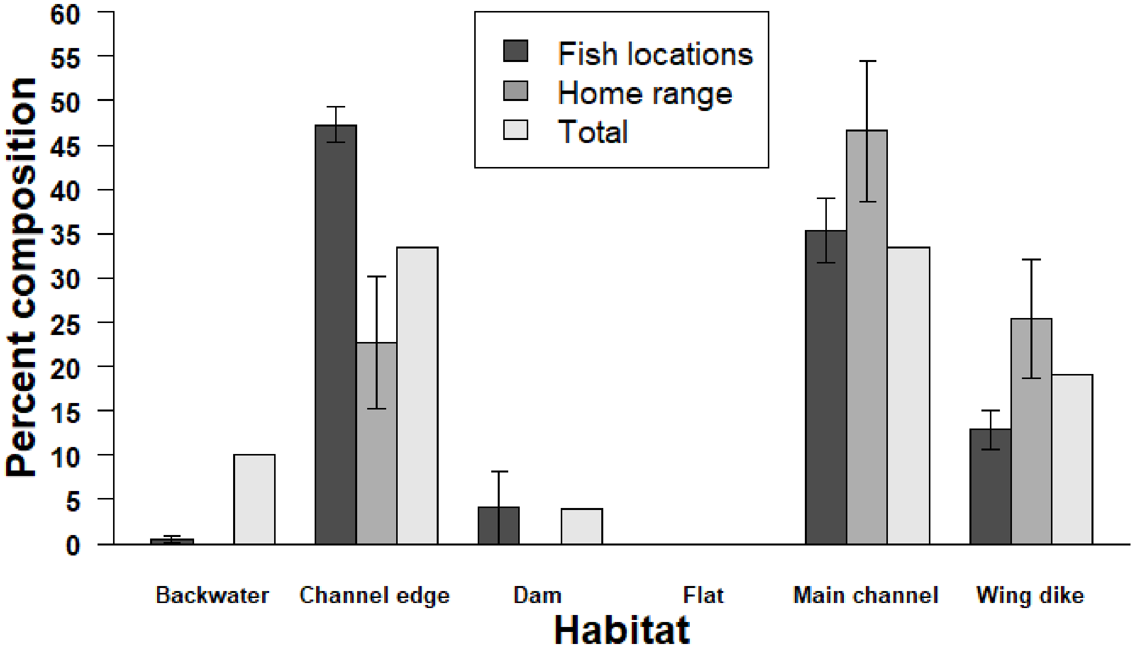

Figure 12− Percent composition of habitats used by Sauger and the total available habitat in Pool 9 of the Arkansas River, Arkansas.

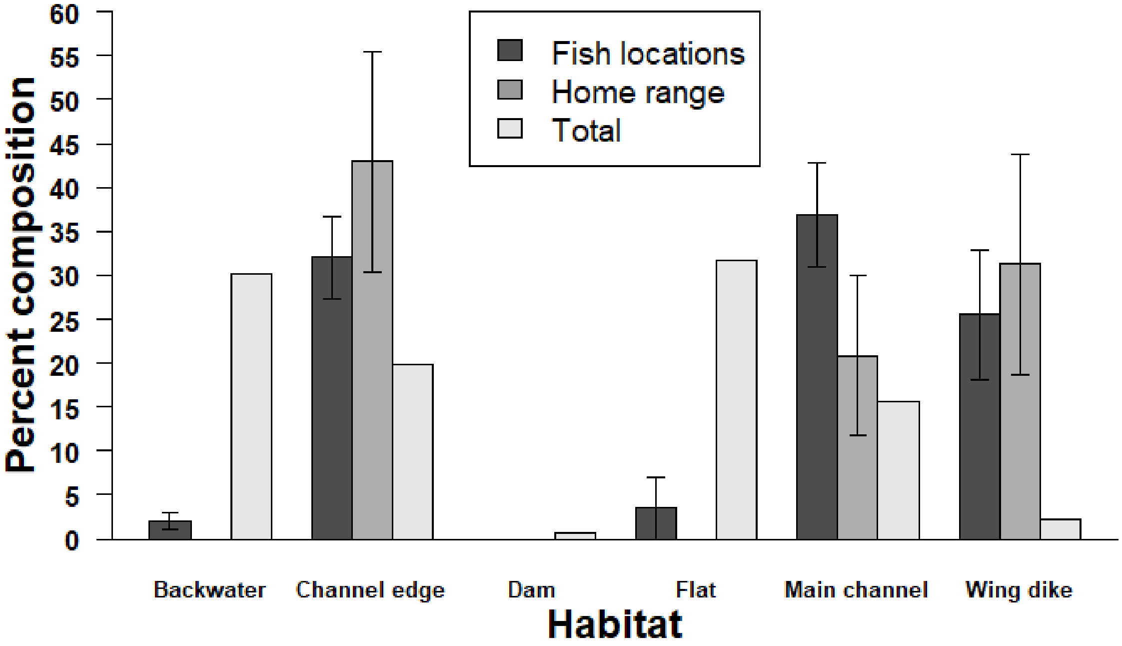

Figure 13− Percent composition of habitats used by Sauger and the total available habitat in Pool 10 of the Arkansas River, Arkansas.

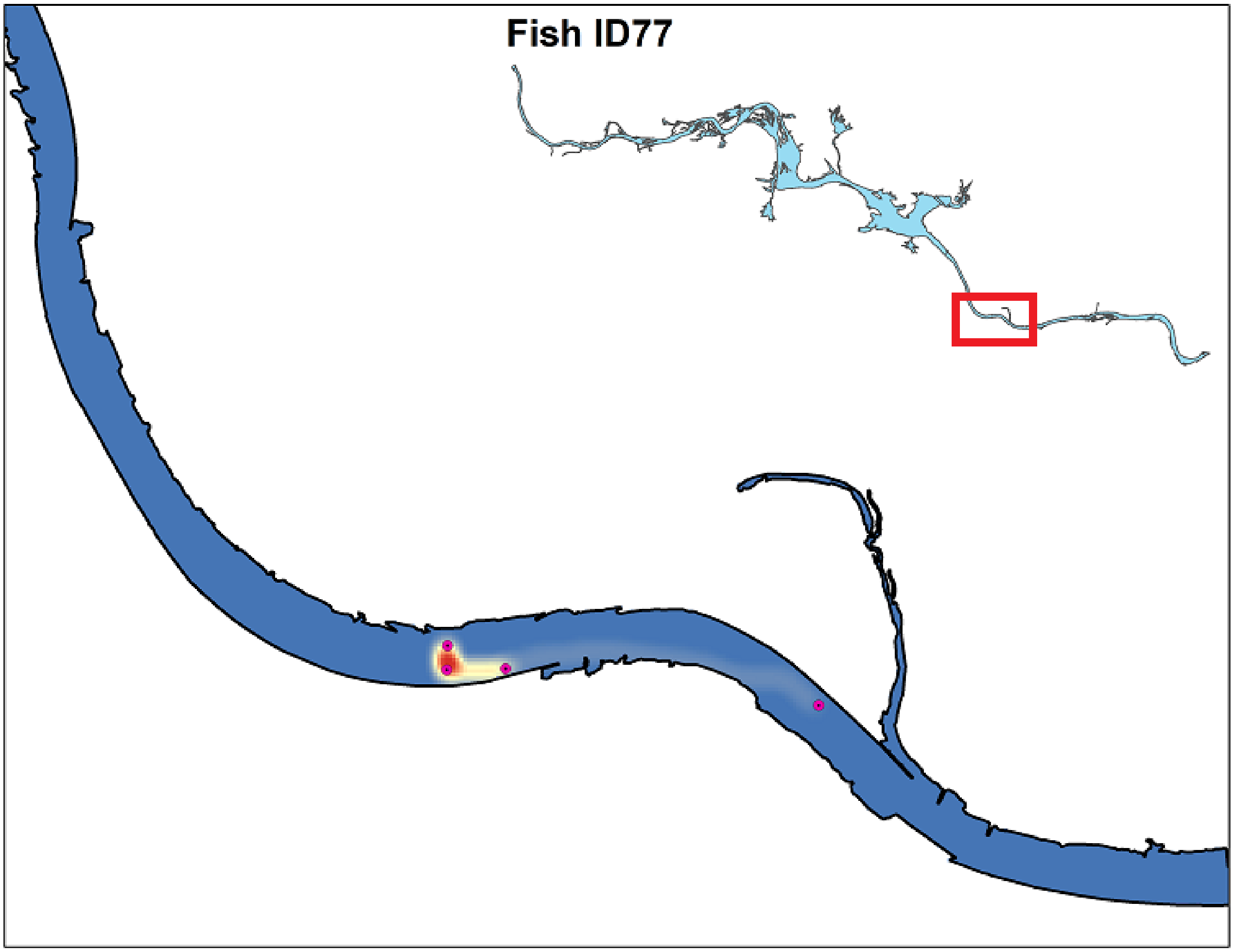

Figure 14− Kernel density of Fish ID77 in the Arkansas River, AR.

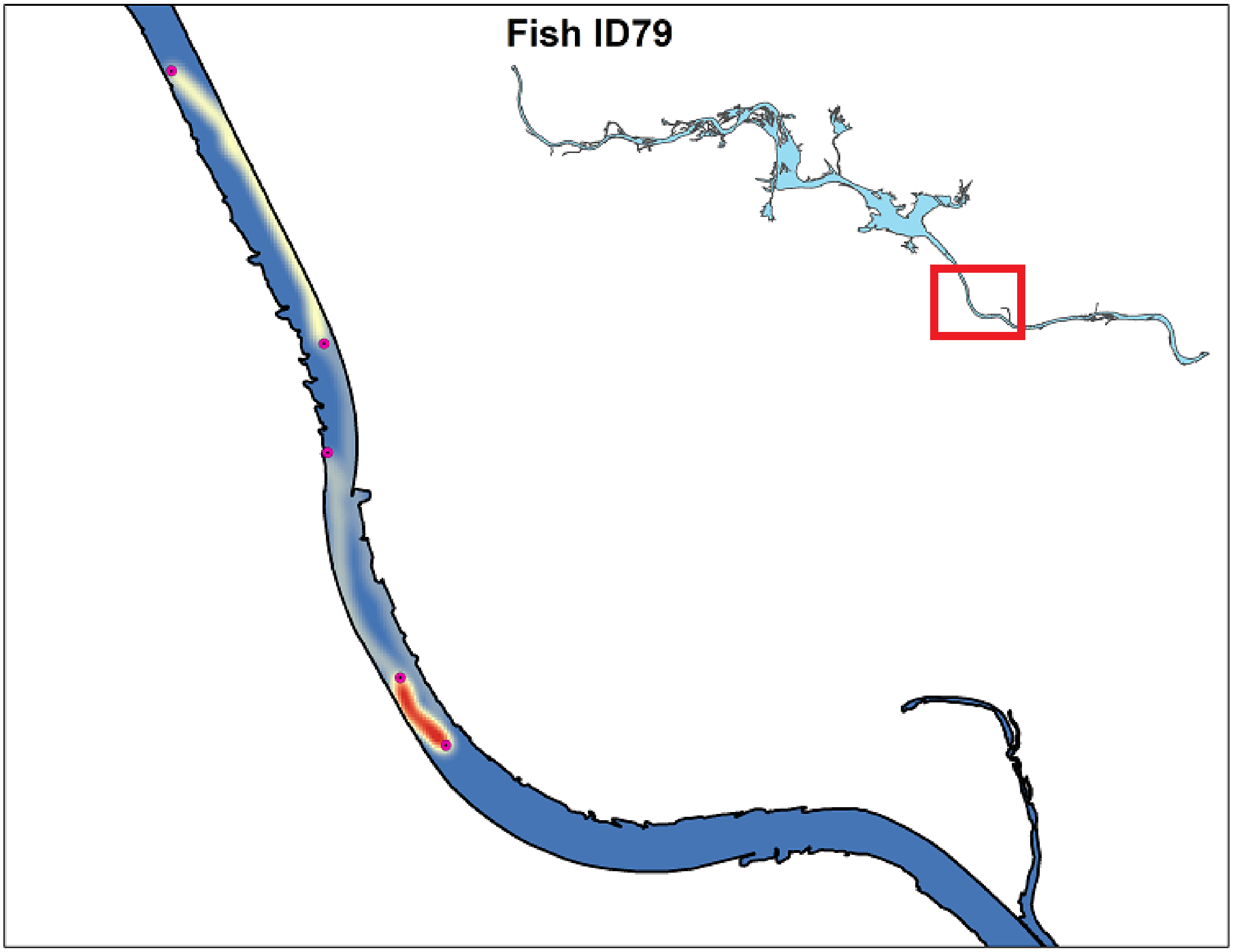

Figure 15− Kernel density of Fish ID79 in the Arkansas River, AR.

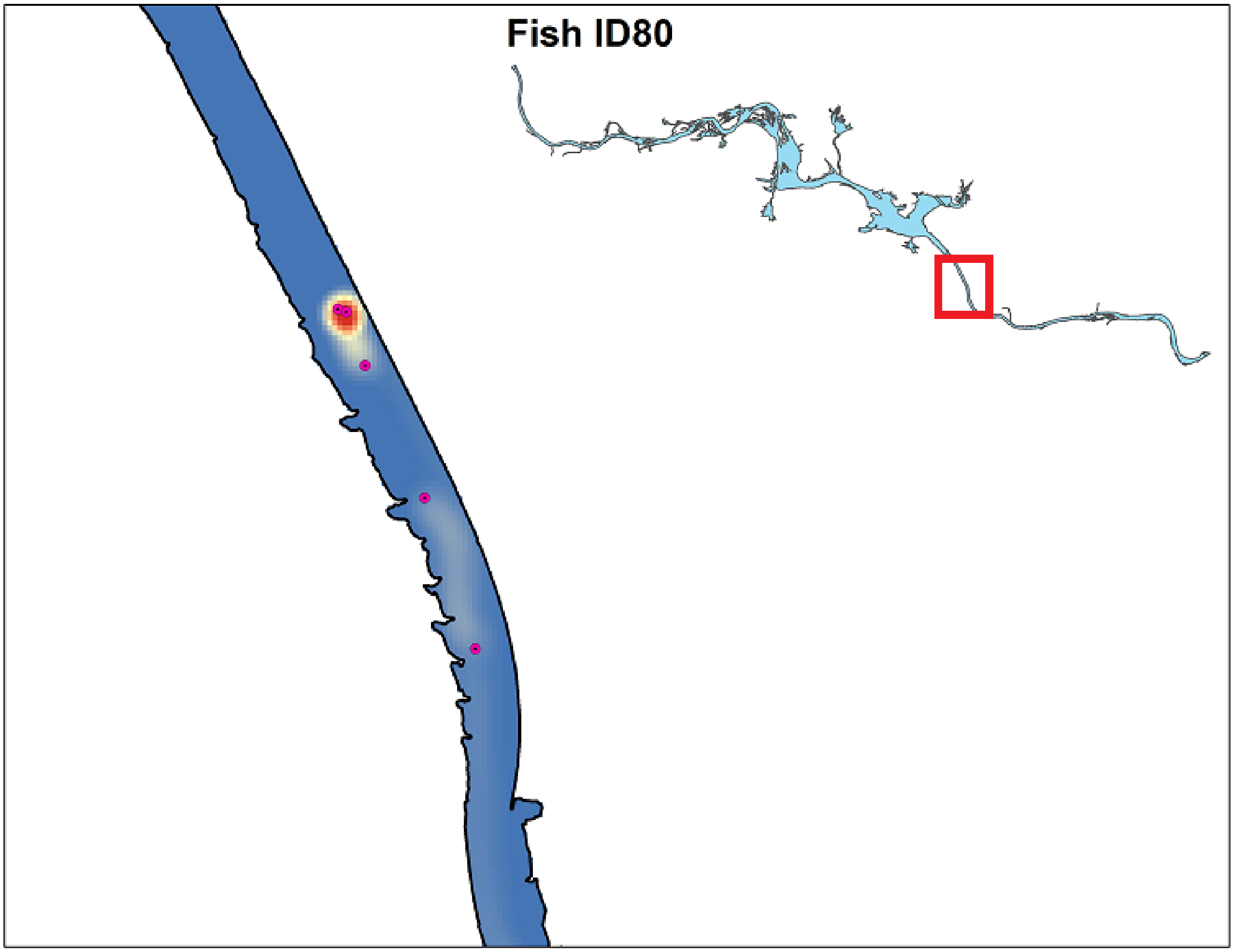

Figure 16− Kernel density of Fish ID80 in the Arkansas River, AR.

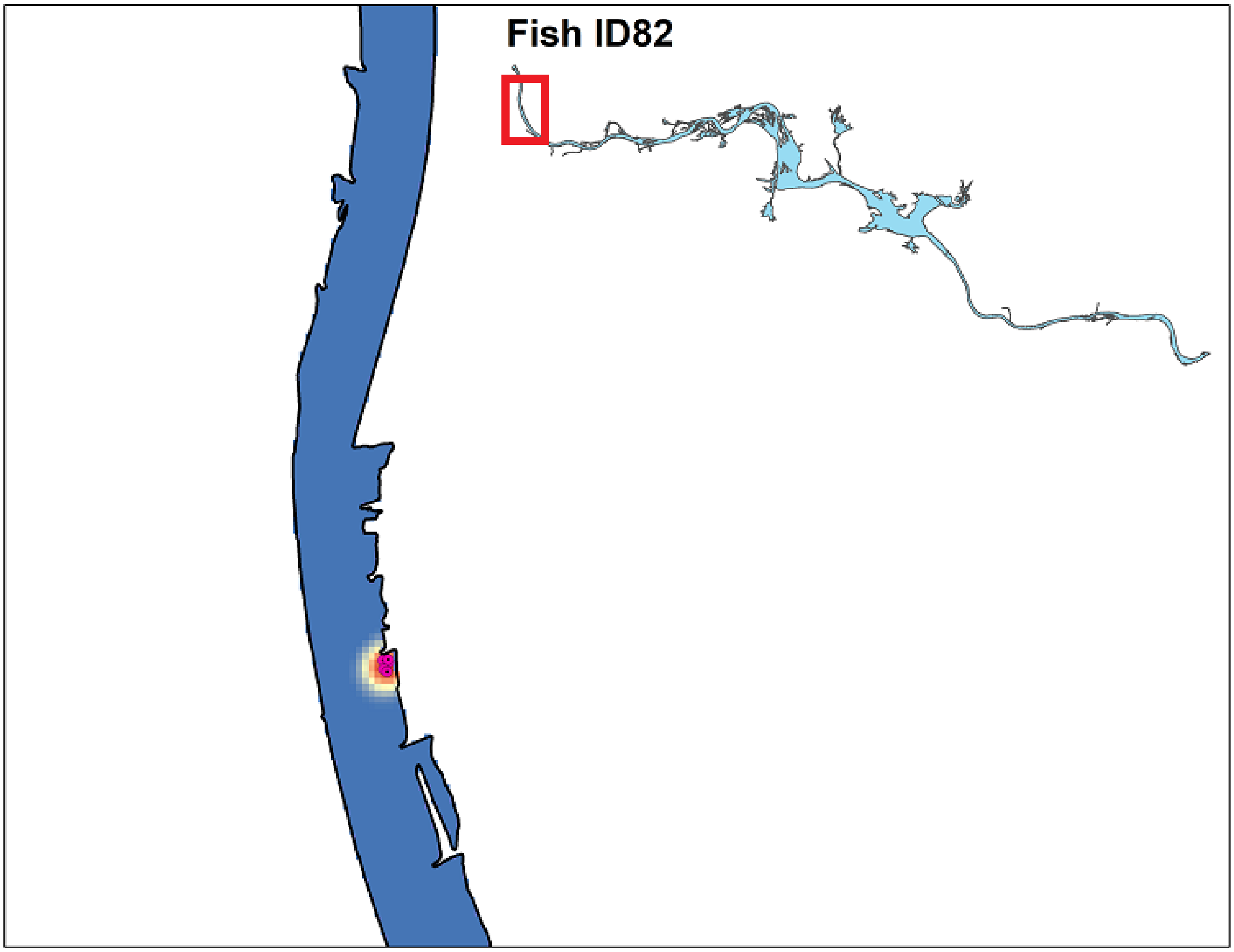

Figure 17− Kernel density of Fish ID82 in the Arkansas River, AR.

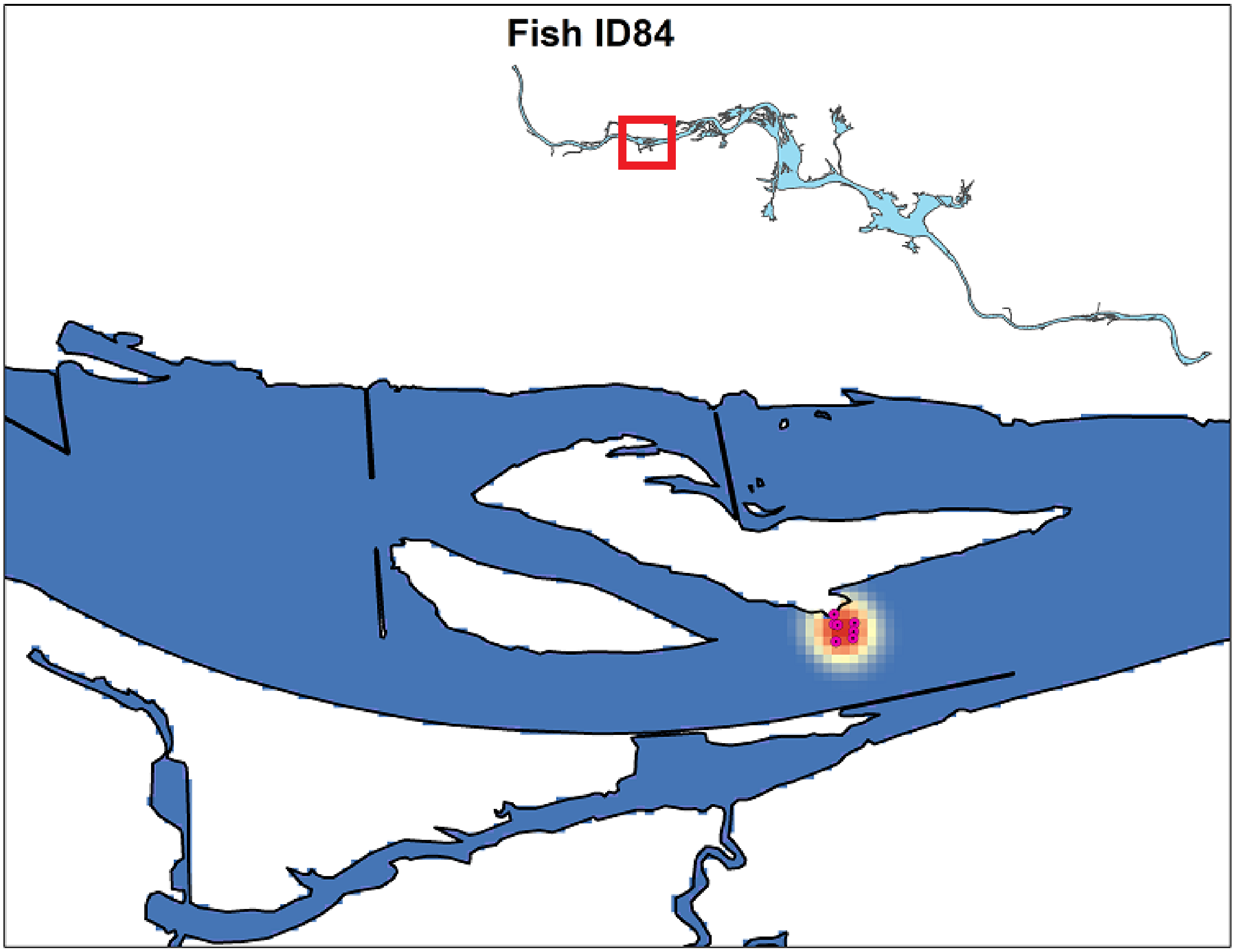

Figure 18− Kernel density of Fish ID84 in the Arkansas River, AR.

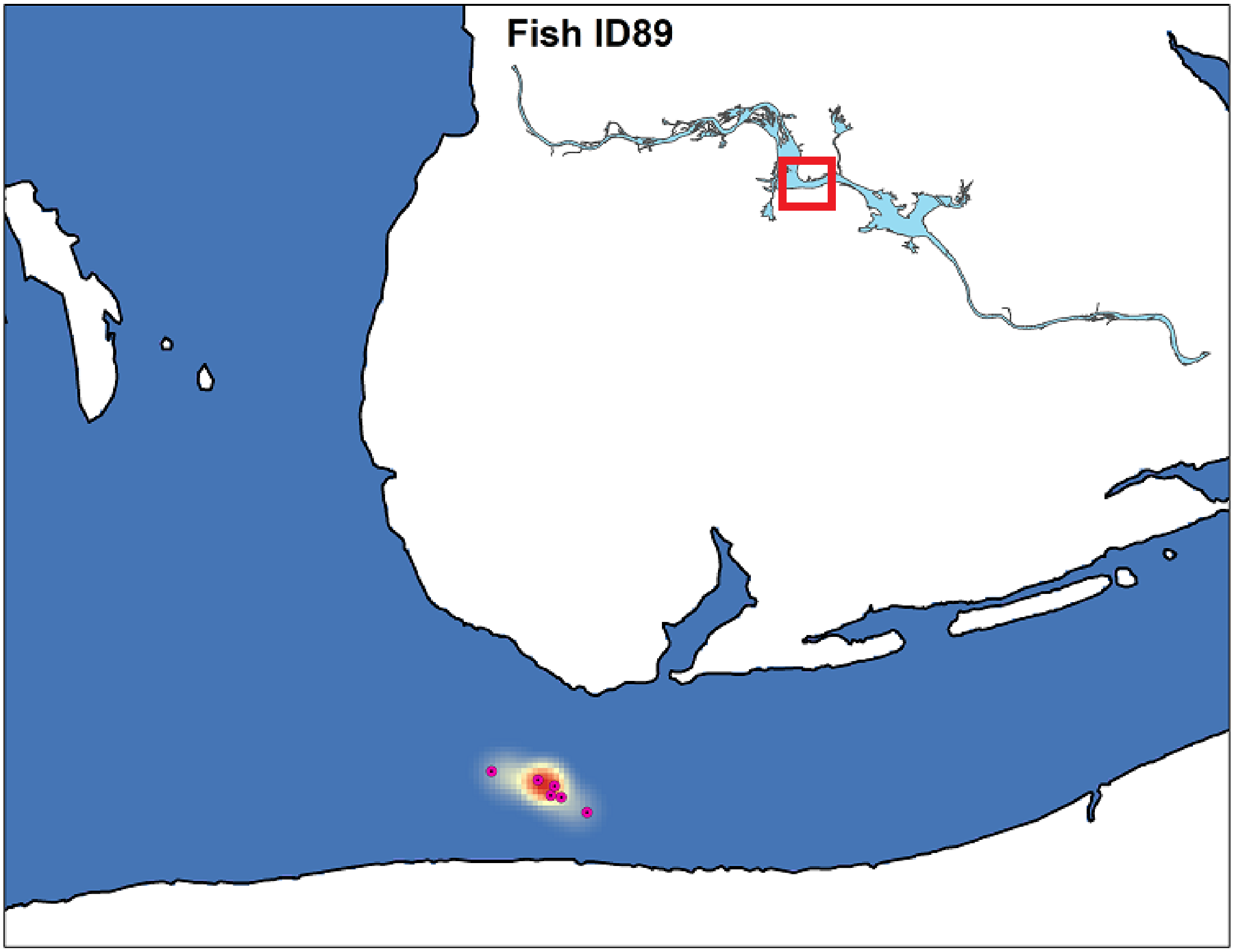

Figure 19− Kernel density of Fish ID89 in the Arkansas River, AR.

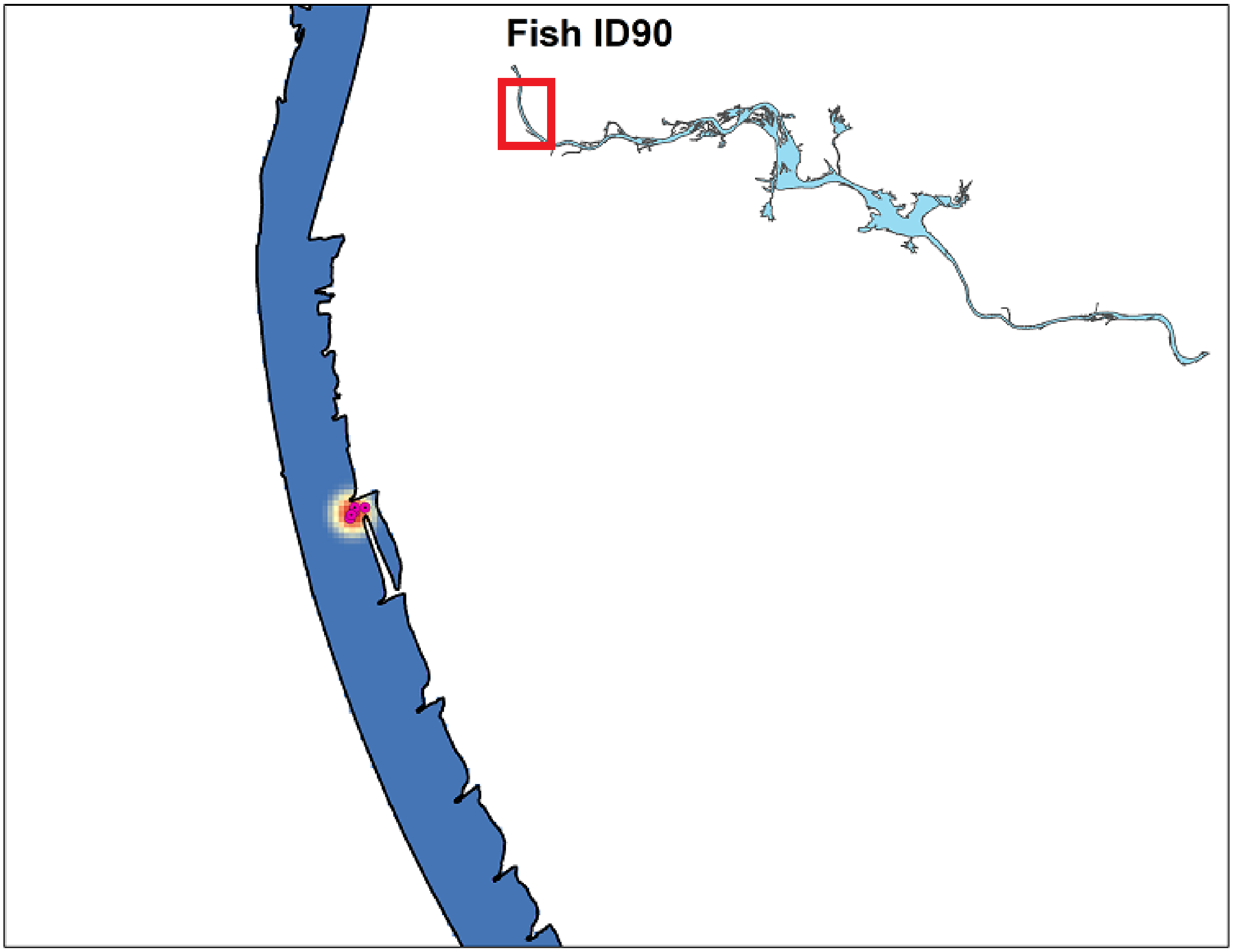

Figure 20− Kernel density of Fish ID90 in the Arkansas River, AR.

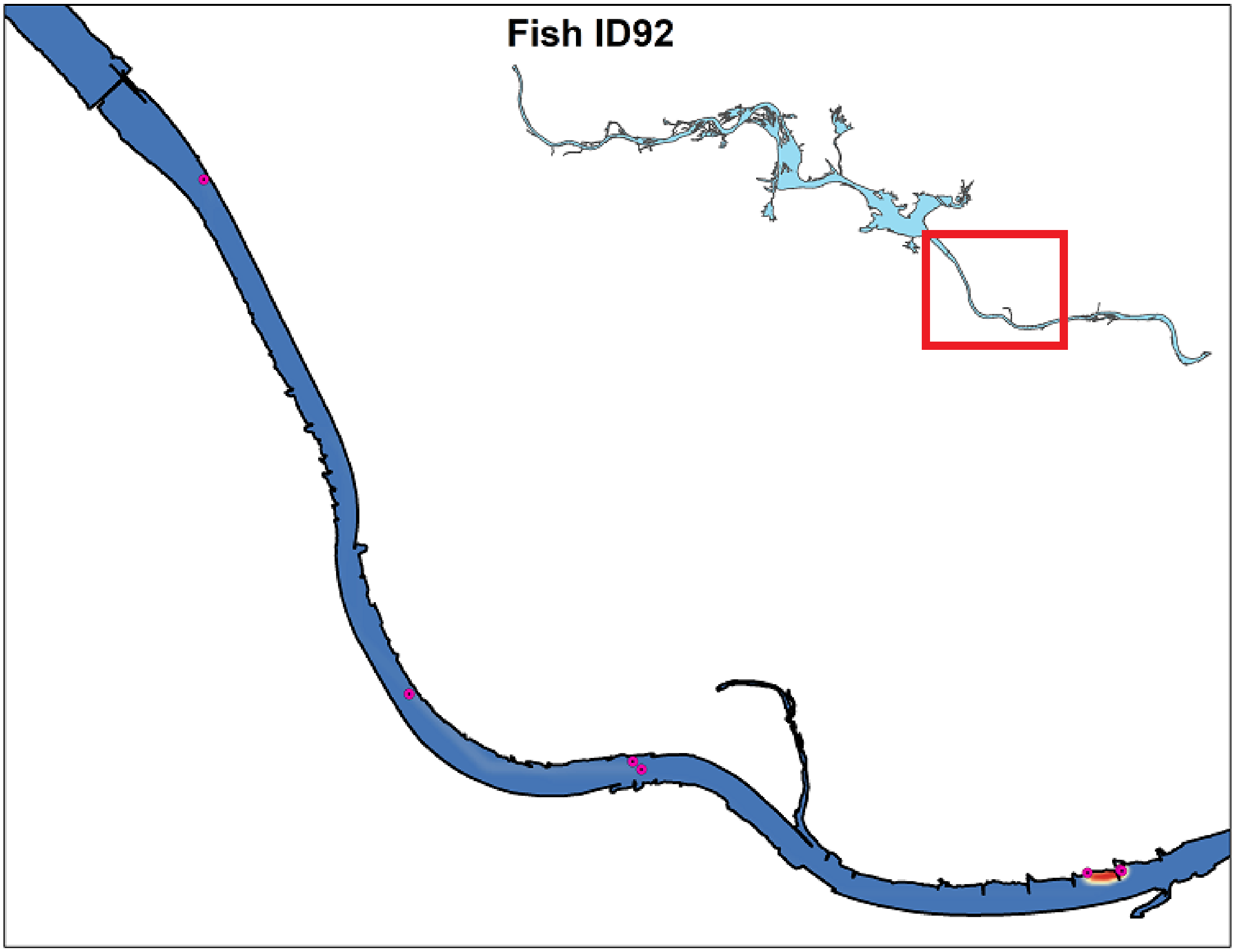

Figure 21− Kernel density of Fish ID92 in the Arkansas River, AR.

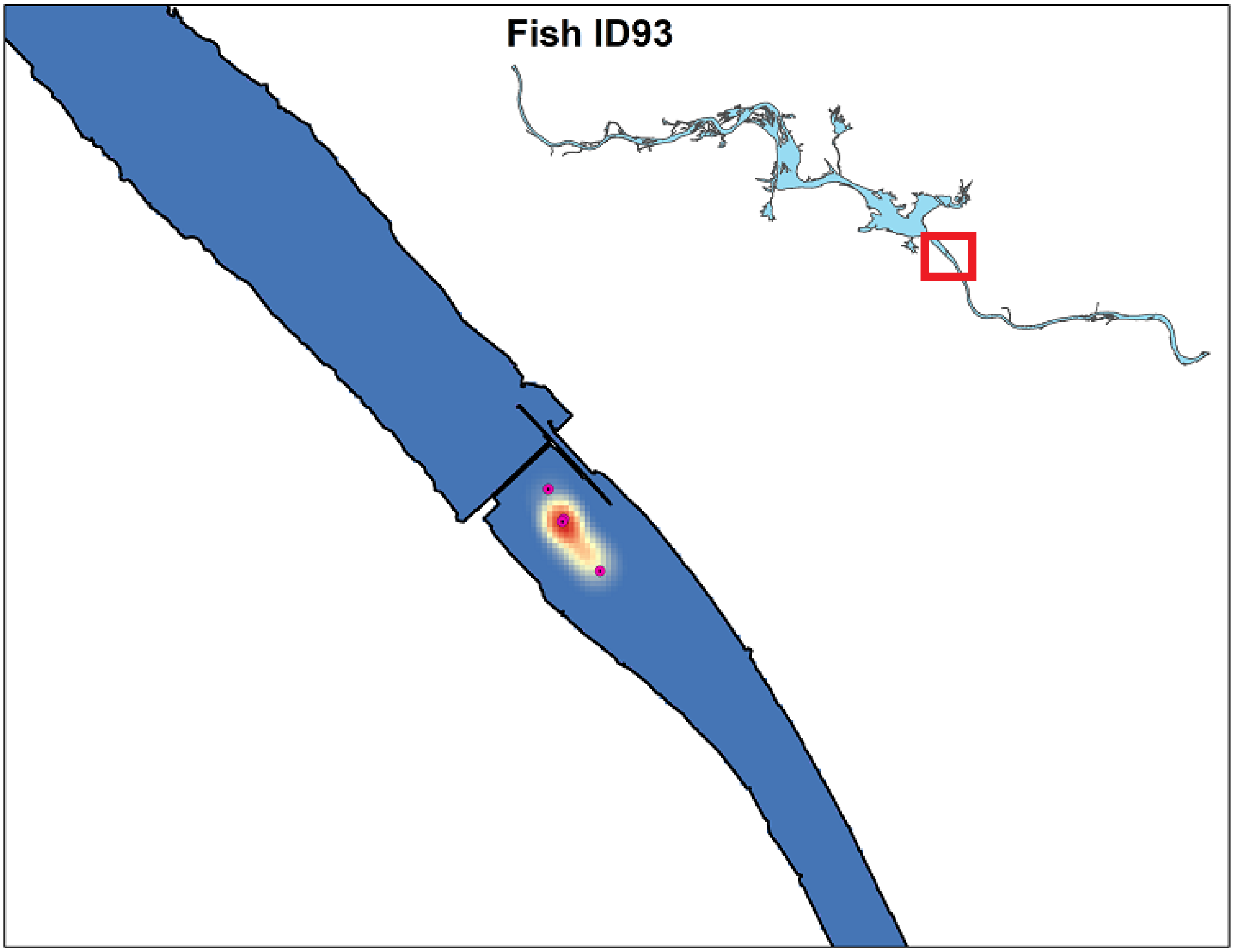

Figure 22− Kernel density of Fish ID93 in the Arkansas River, AR.

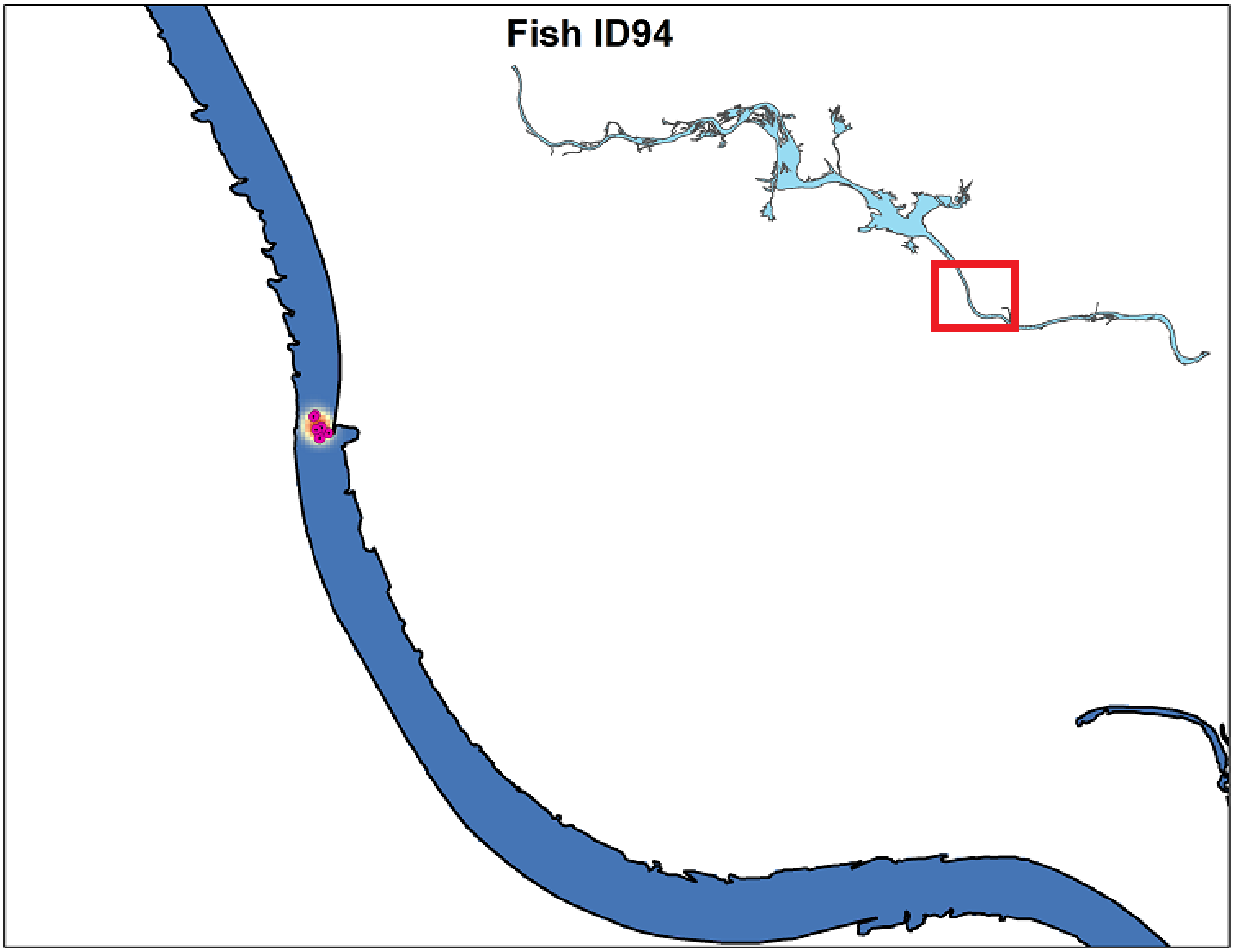

Figure 23− Kernel density of Fish ID94 in the Arkansas River, AR.

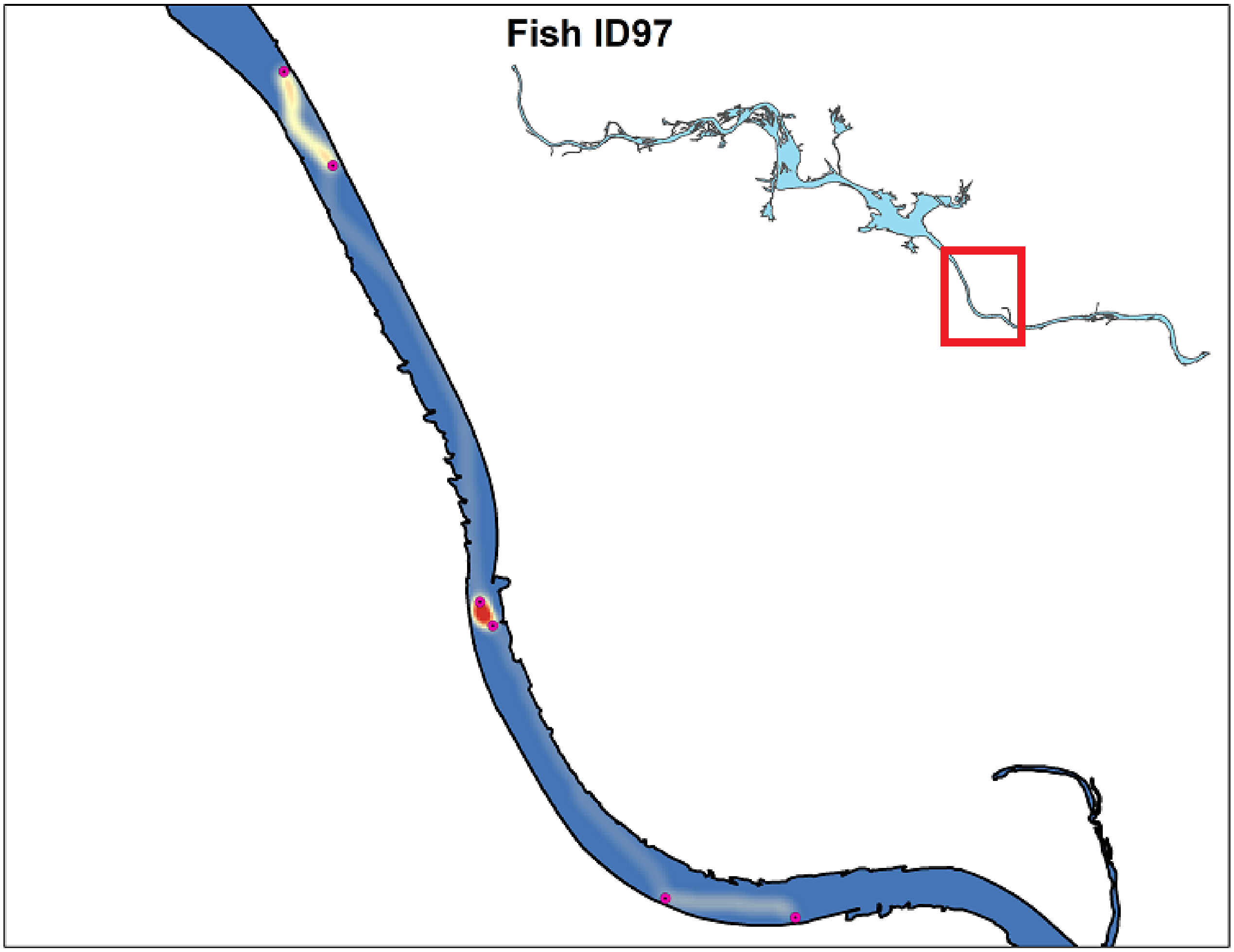

Figure 24− Kernel density of Fish ID97 in the Arkansas River, AR.

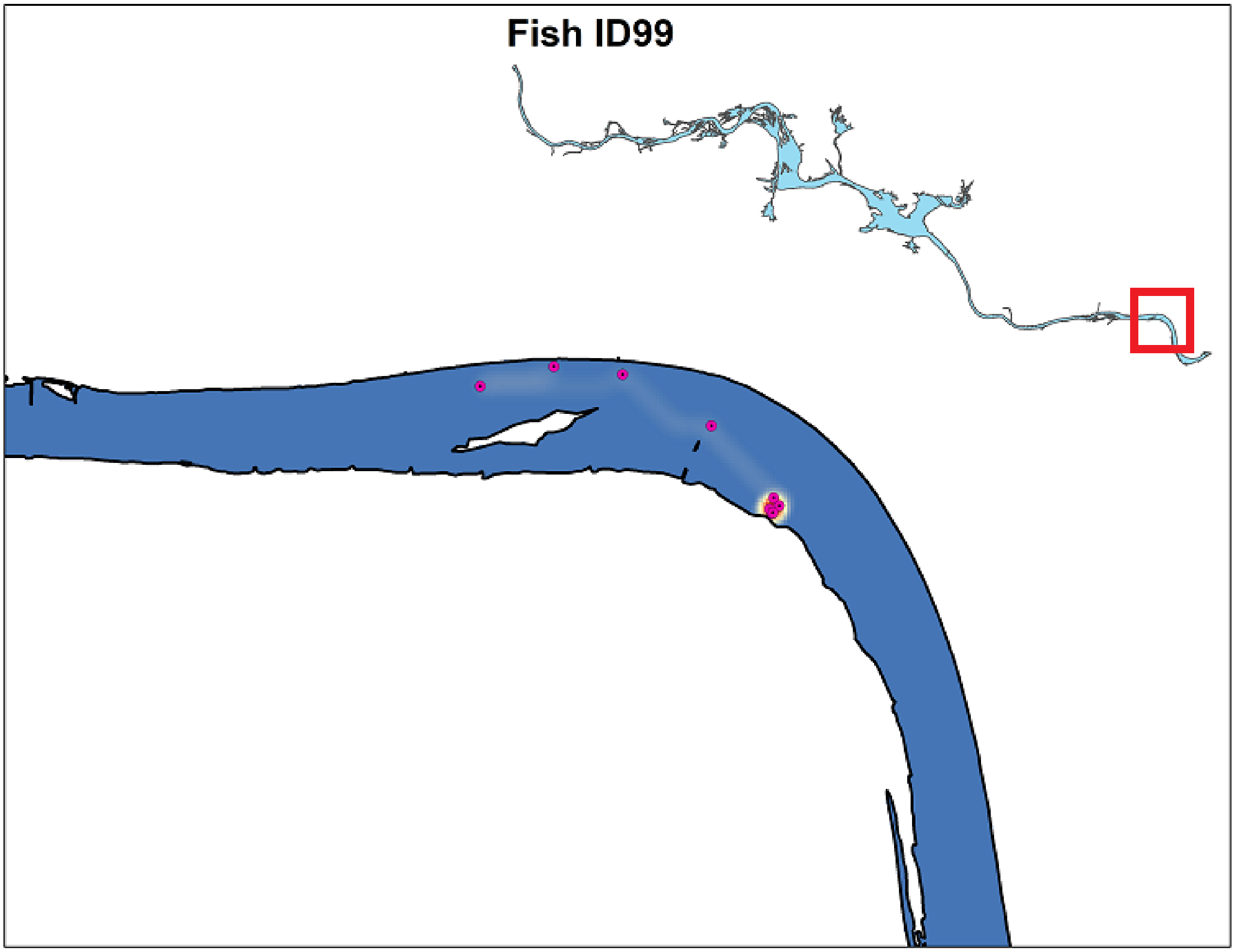

Figure 25− Kernel density of Fish ID99 in the Arkansas River, AR.

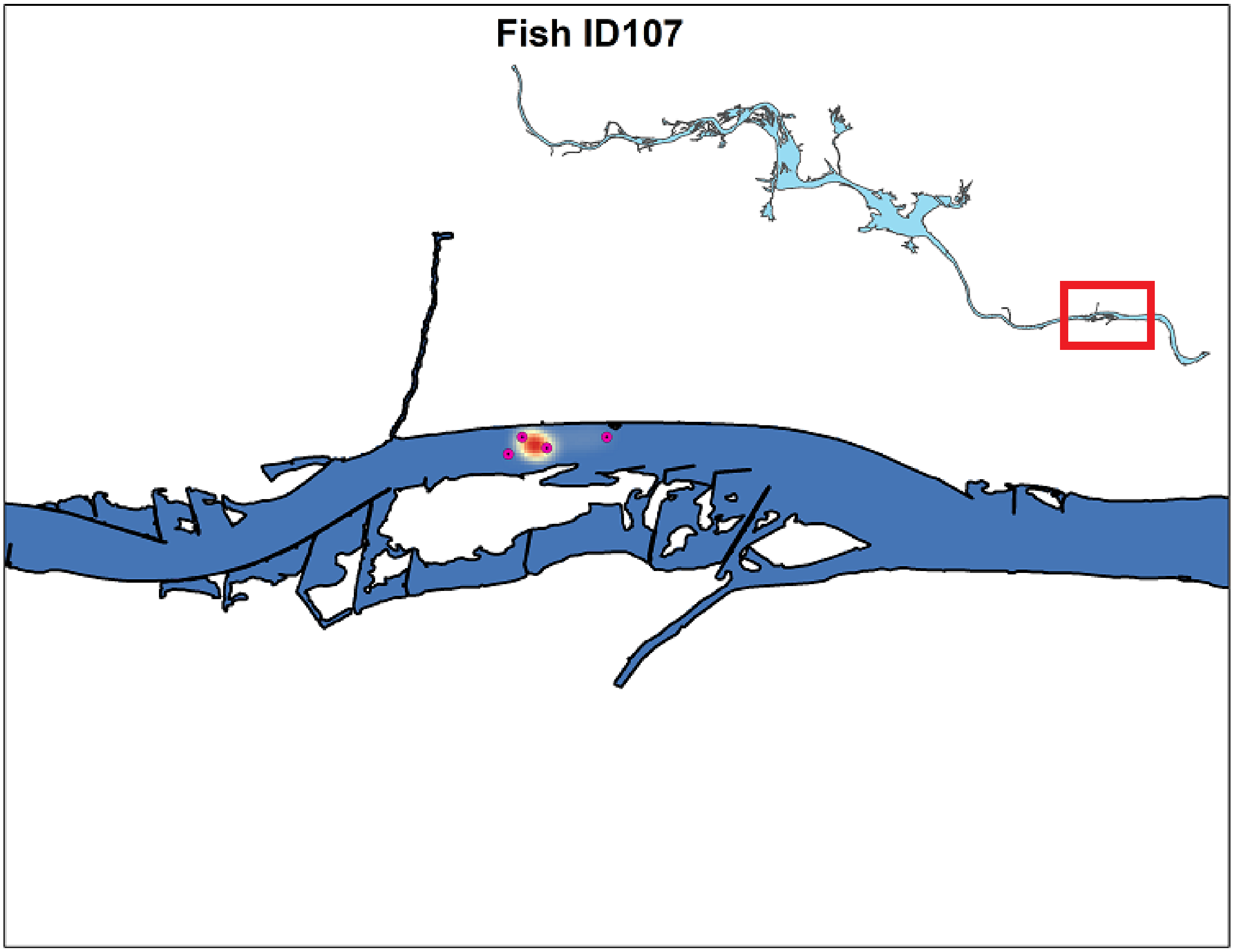

Figure 26− Kernel density of Fish ID107 in the Arkansas River, AR.

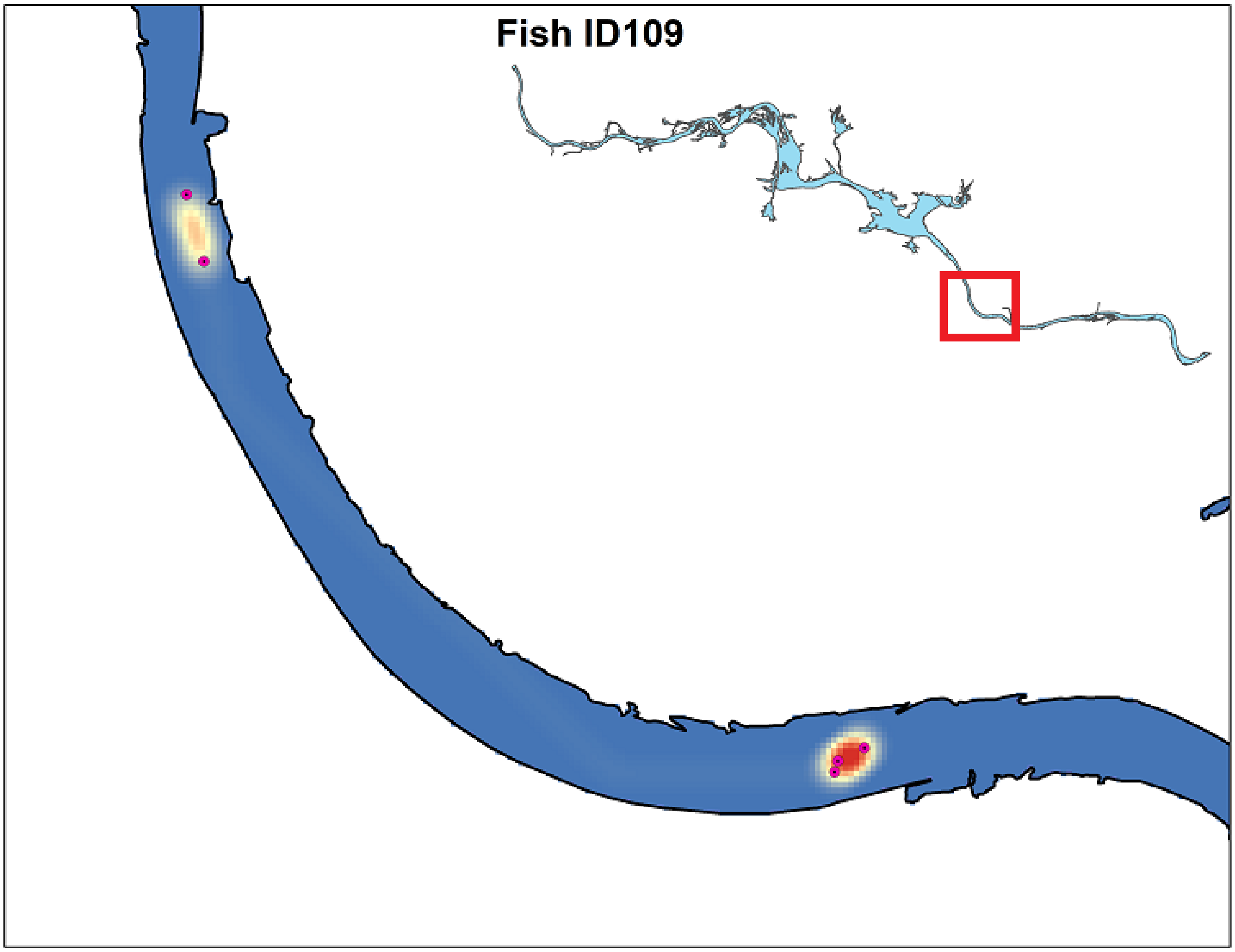

Figure 27− Kernel density of Fish ID109 in the Arkansas River, AR.

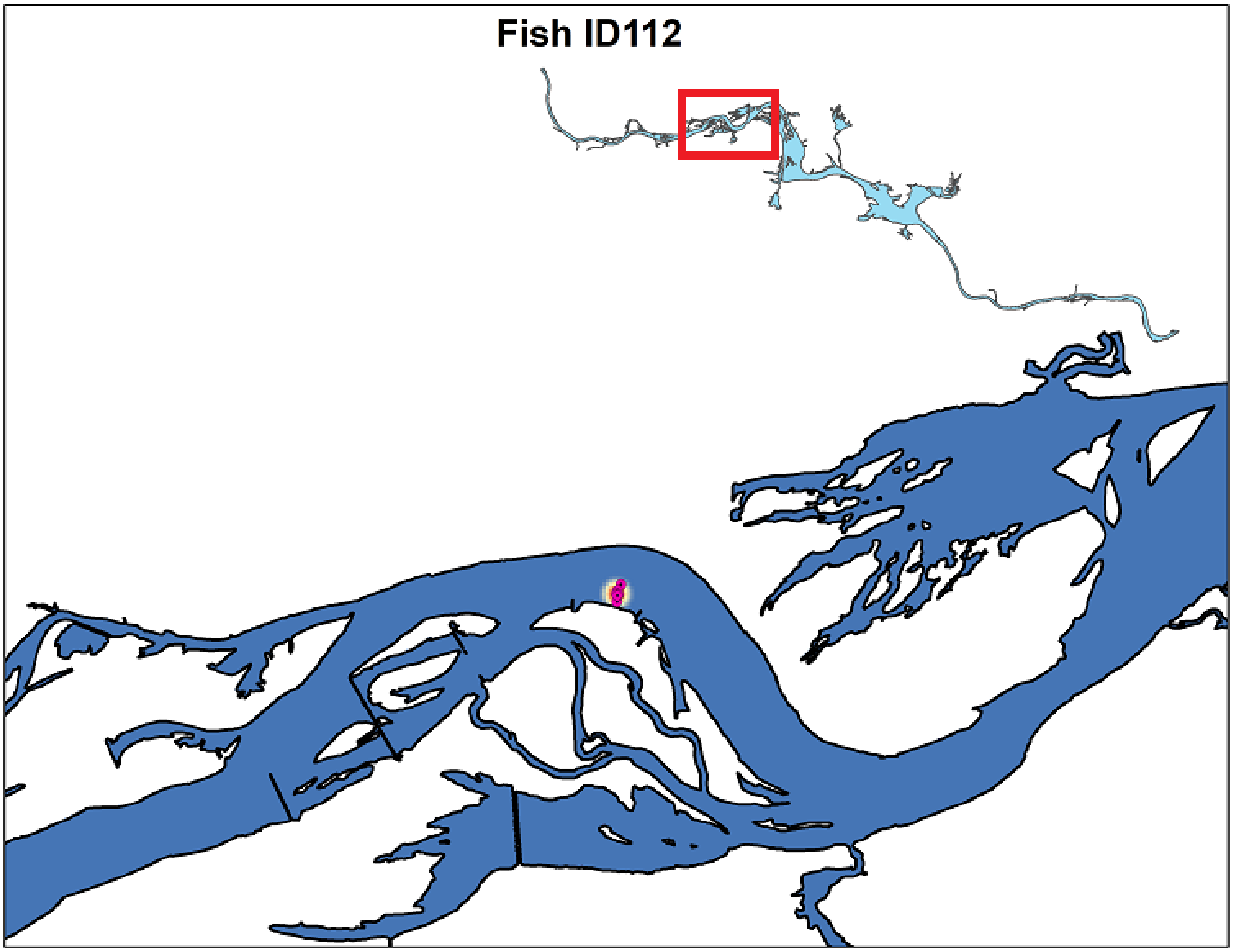

Figure 28− Kernel density of Fish ID112 in the Arkansas River, AR.

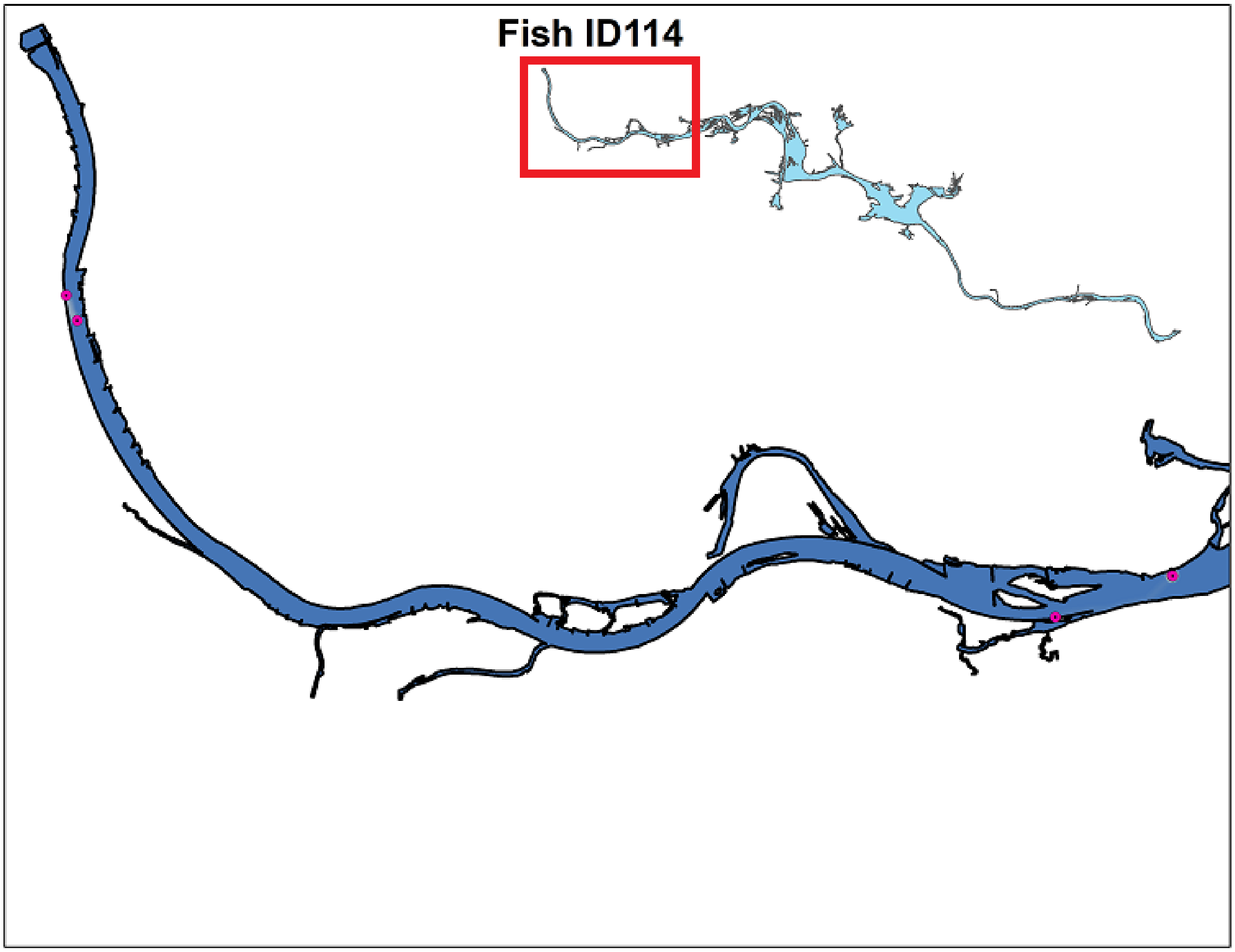

Figure 29− Kernel density of Fish ID114 in the Arkansas River, AR.

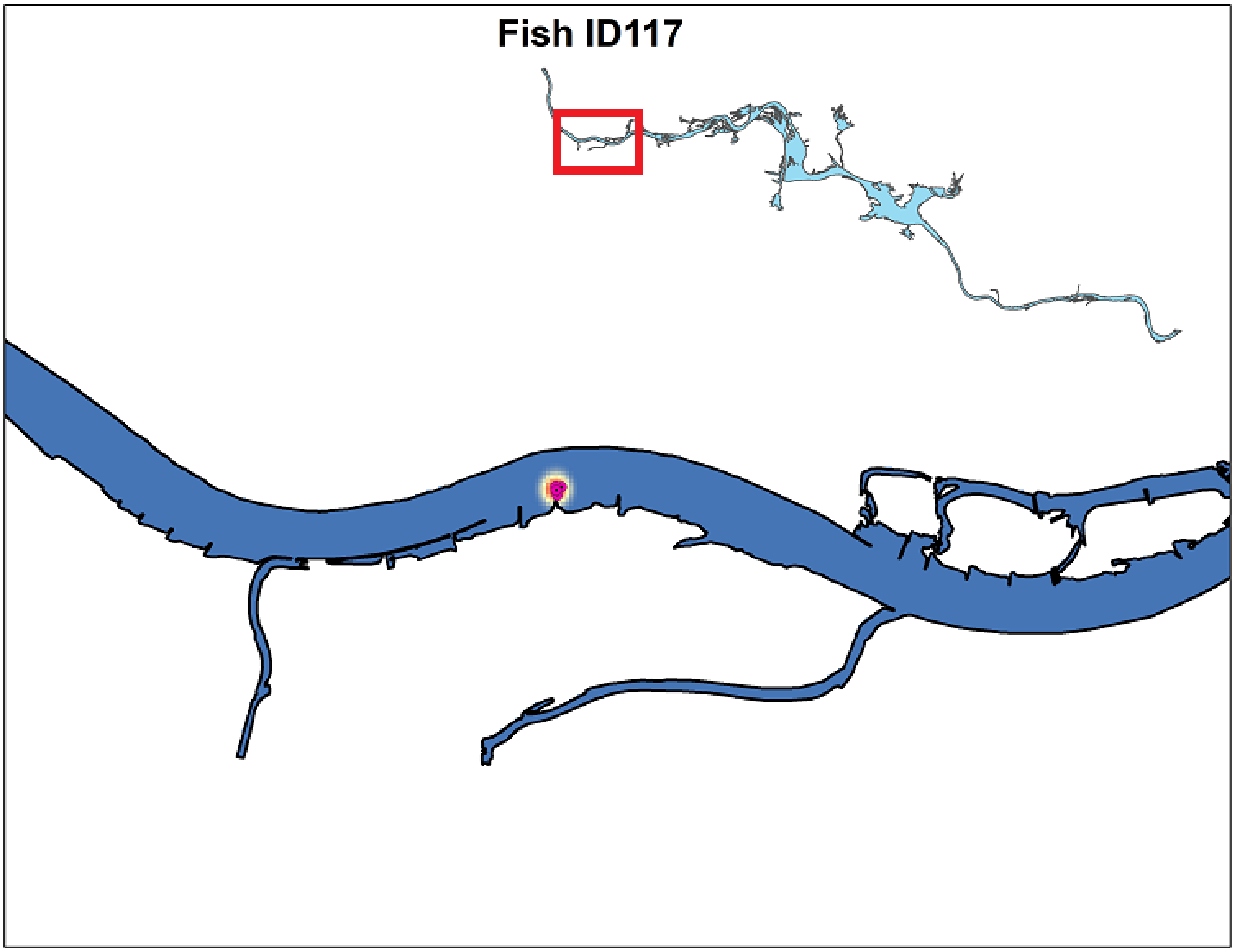

Figure 30− Kernel density of Fish ID117 in the Arkansas River, AR.

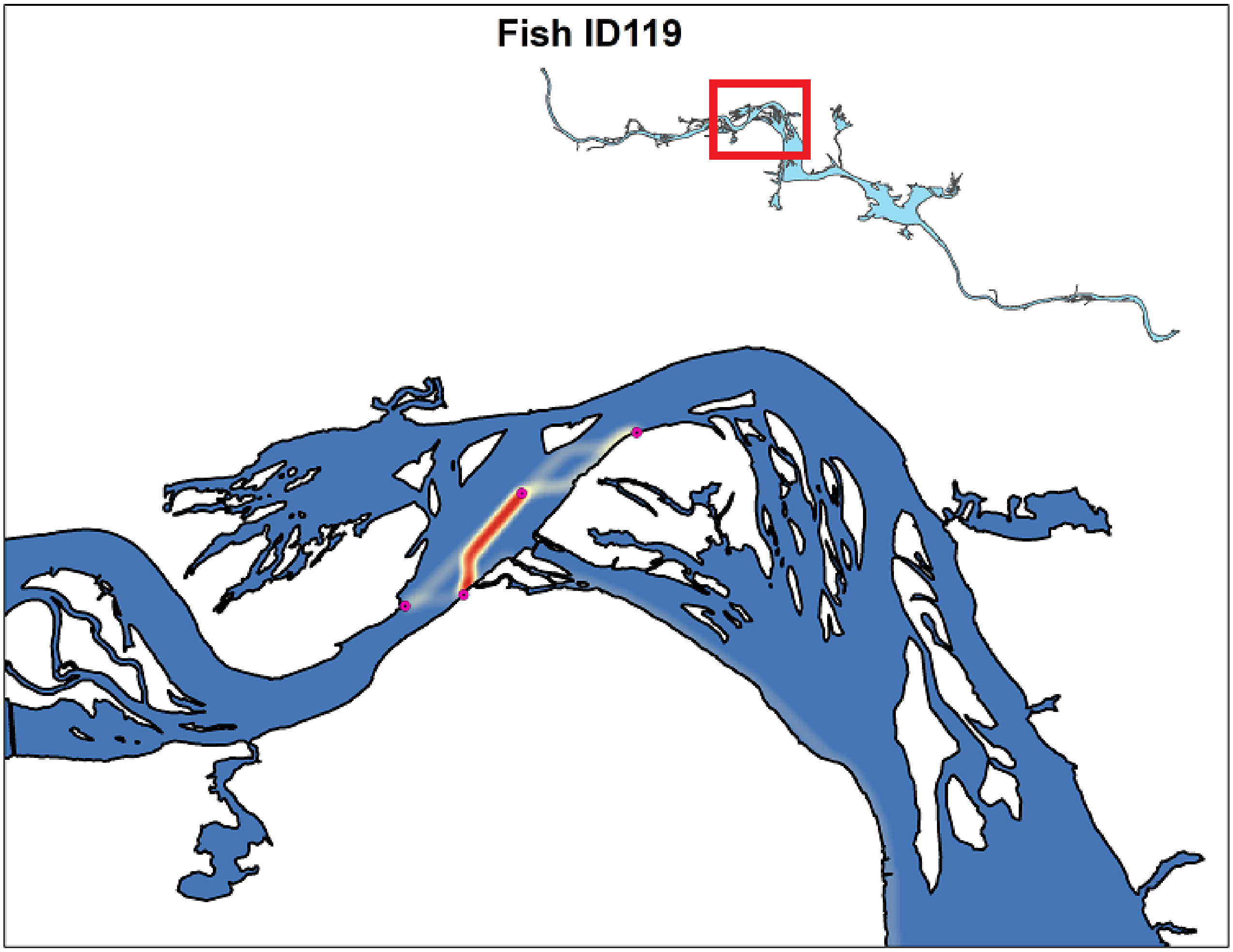

Figure 31− Kernel density of Fish ID119 in the Arkansas River, AR.

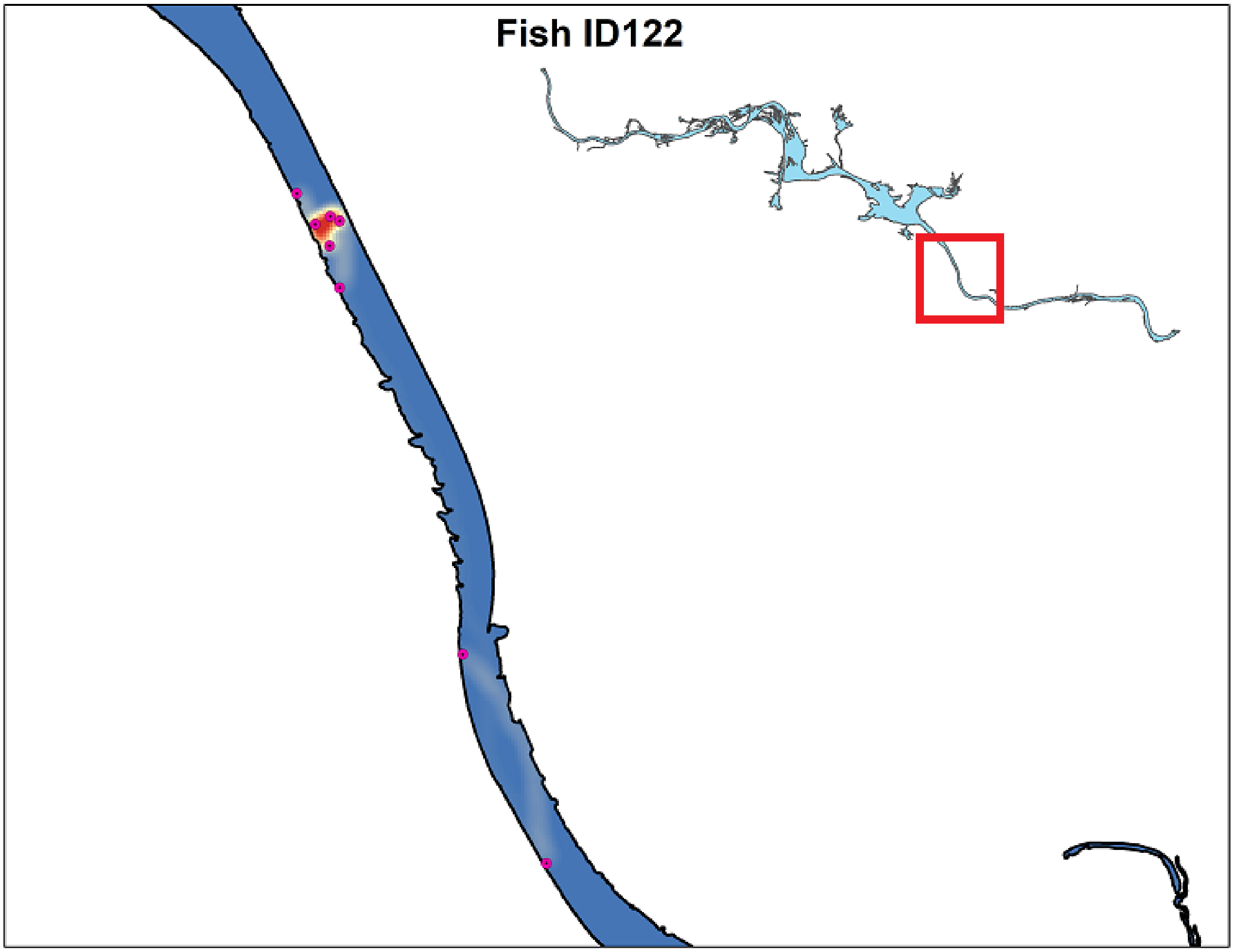

Figure 32− Kernel density of Fish ID122 in the Arkansas River, AR.

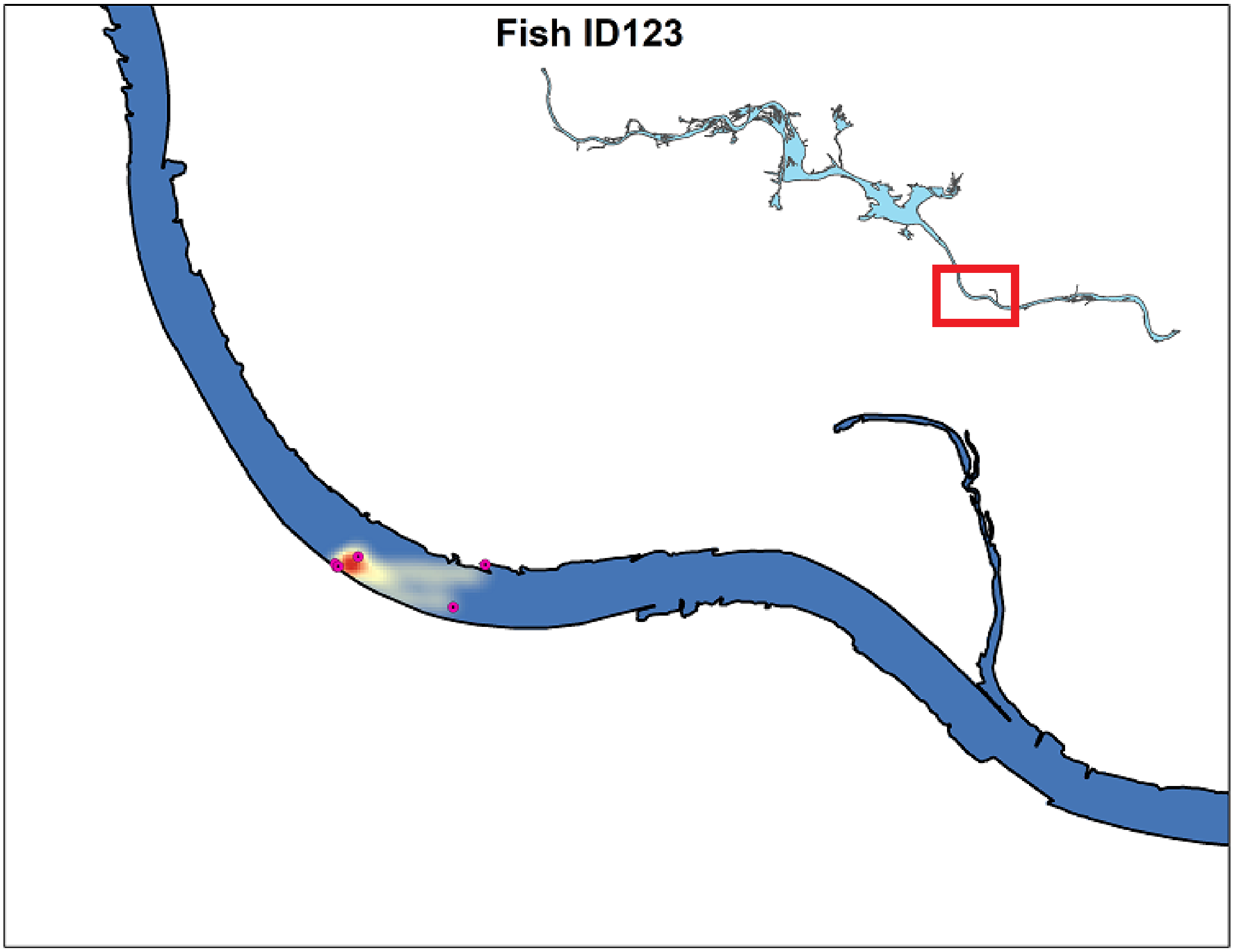

Figure 33− Kernel density of Fish ID123 in the Arkansas River, AR.

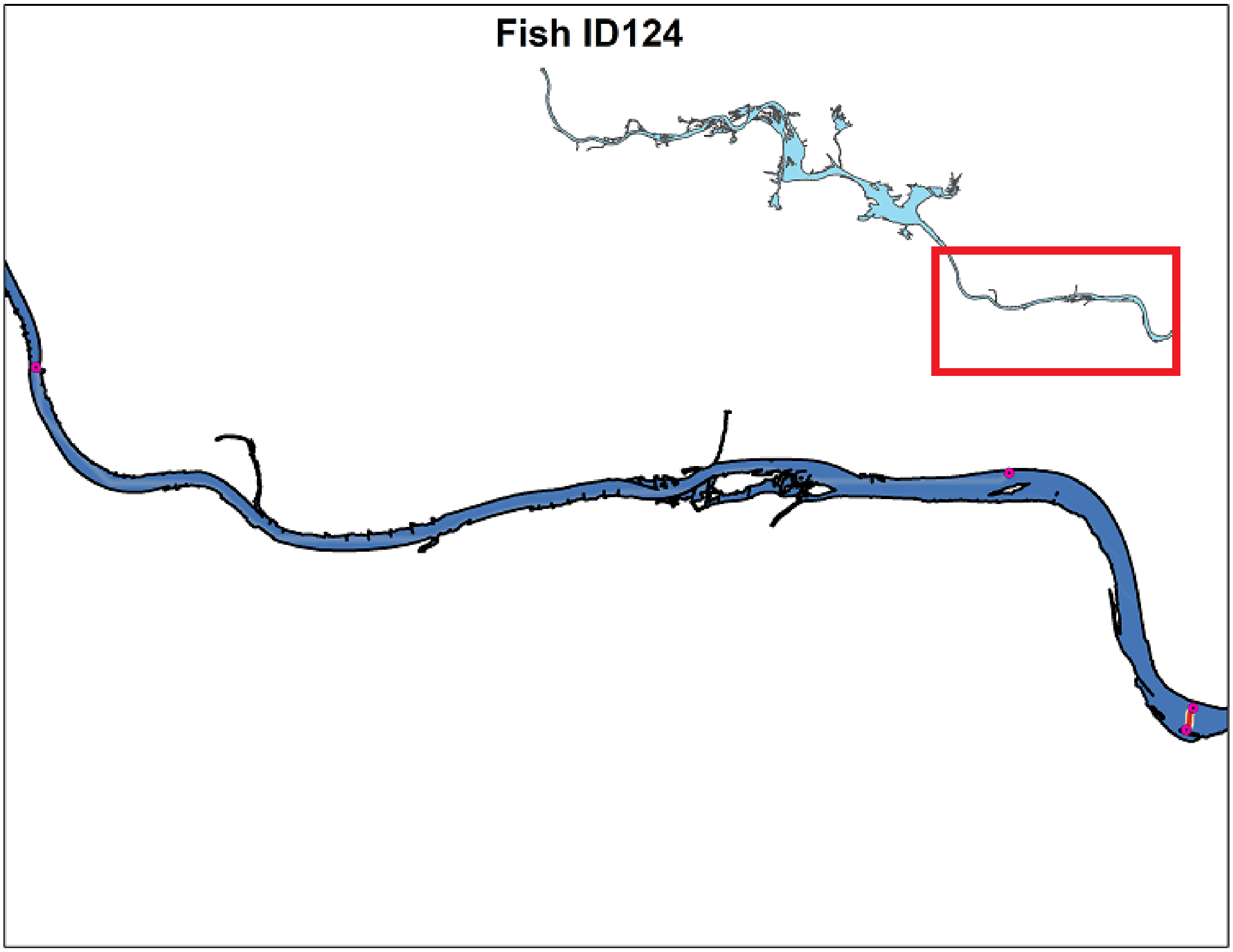

Figure 34− Kernel density of Fish ID124 in the Arkansas River, AR.

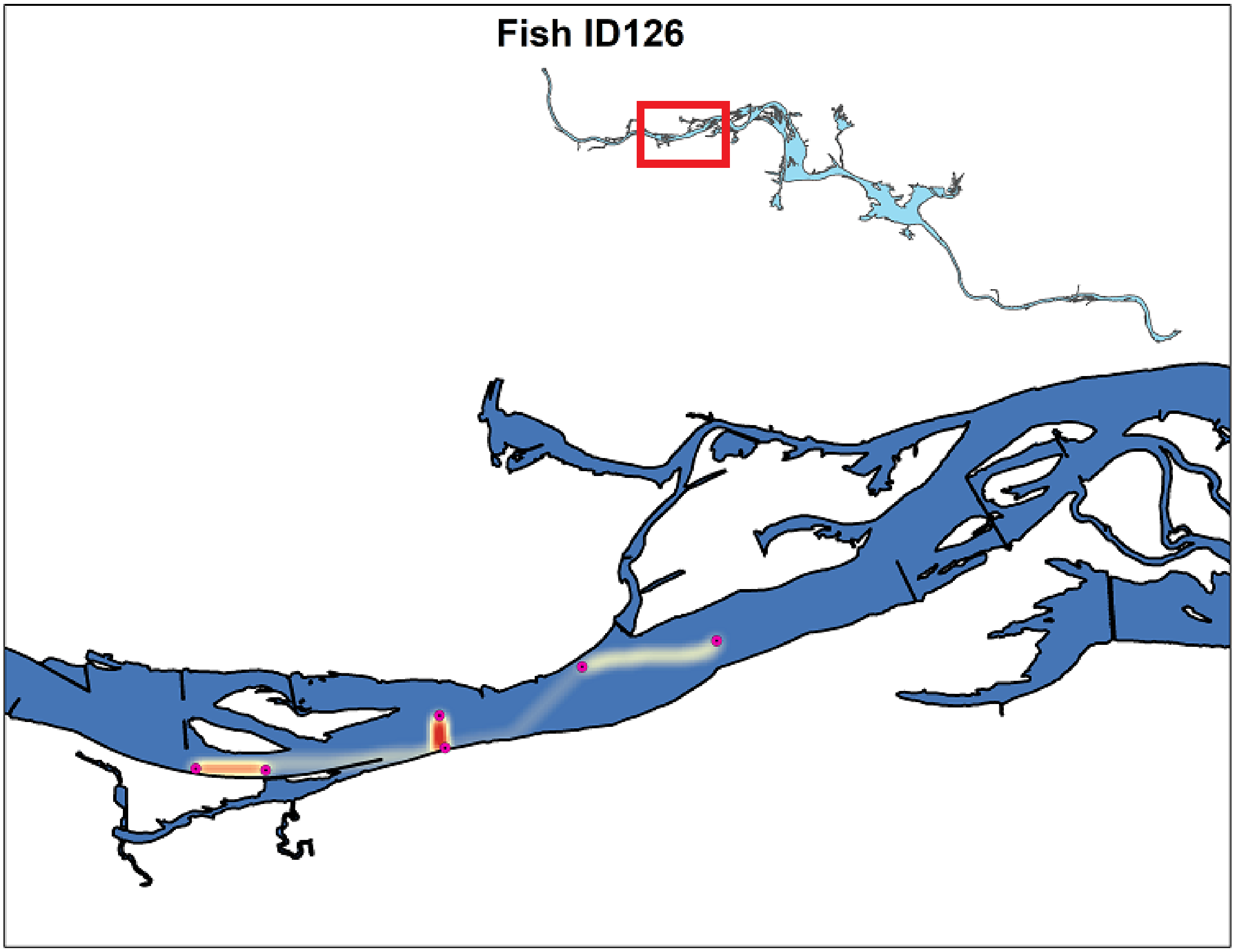

Figure 35− Kernel density of Fish ID126 in the Arkansas River, AR.

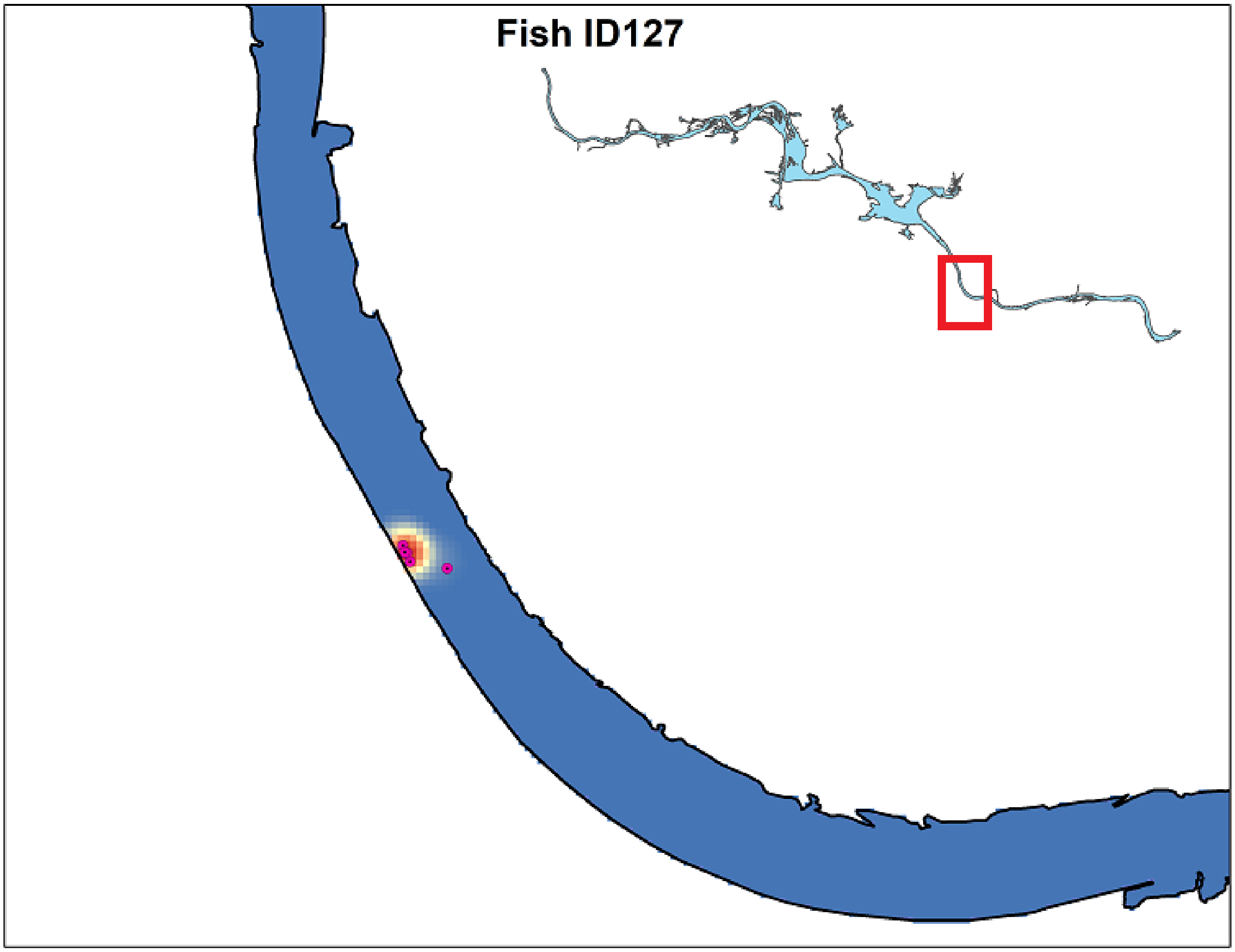

Figure 36− Kernel density of Fish ID127 in the Arkansas River, AR.

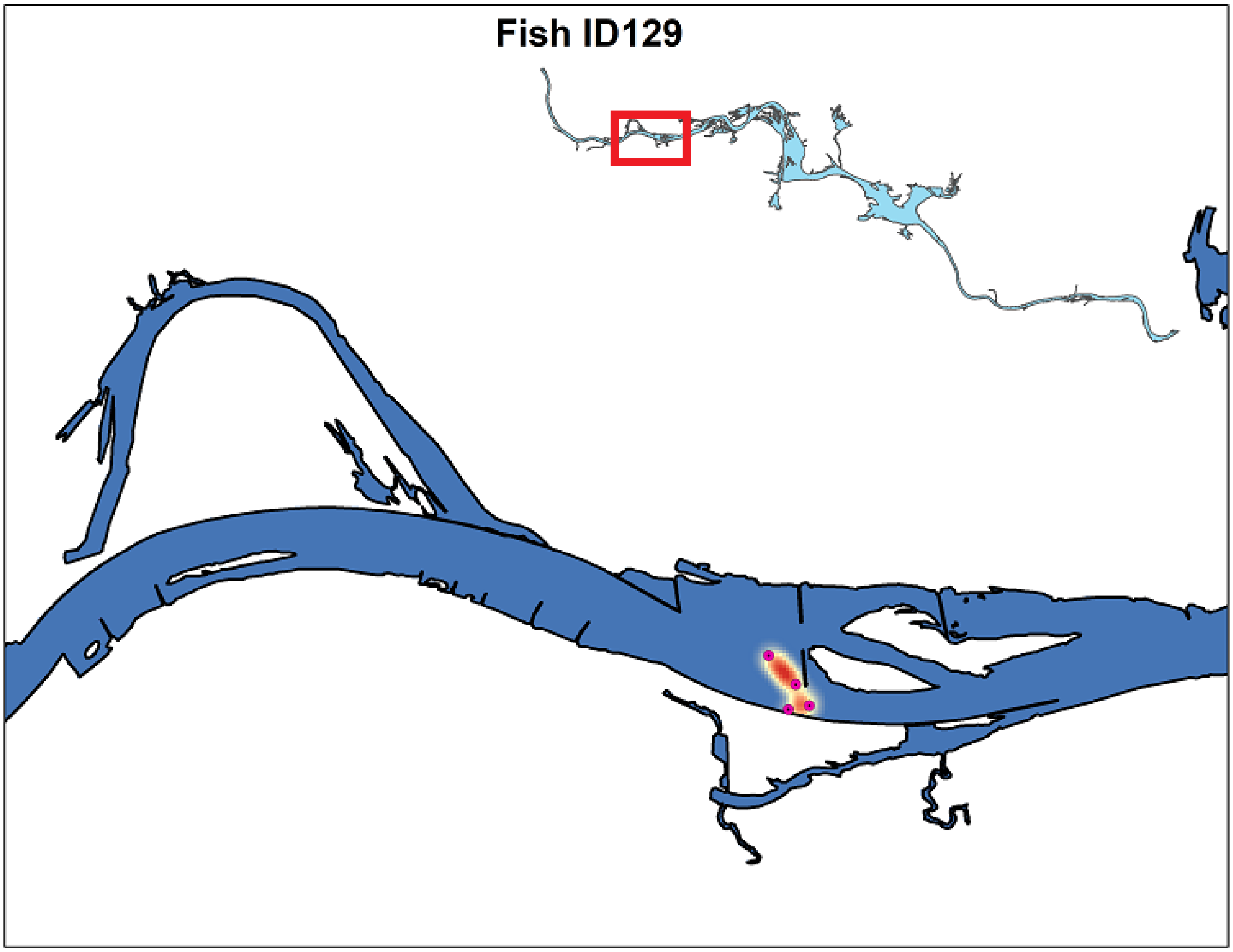

Figure 37− Kernel density of Fish ID129 in the Arkansas River, AR.