



Inventory of Freshwater Mussels at Ozark National Scenic Riverways, 2023–2024



Current River near Big Spring Campground, August 2, 2023.
USGS / J. WESTHOFF

Inventory of Freshwater Mussels at Ozark National Scenic Riverways, 2023–2024

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Jacob T. Westhoff ¹, Ava M. Laszlo ², Billy J. Huggins ²

¹ U.S. Geological Survey
Missouri Cooperative Fish and Wildlife Research Unit
103 Anheuser-Busch Natural Resources Building
1111 Rollins St.
University of Missouri
Columbia, MO 65211

² School of Natural Resources
103 Anheuser-Busch Natural Resources Building
1111 Rollins St.
University of Missouri
Columbia, MO 65211

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Abstract

The Ozark National Scenic Riverways (OZAR) is a national park unit located in the Ozarks region of Missouri and encompasses much of the mainstem Jacks Fork and Current River. Past surveys of freshwater mussel populations indicated potential declines for many species in OZAR. We conducted occupancy-based surveys at 60 randomly selected sites during 2023–2024 to update species inventories and establish a repeatable baseline. We also examined fish and mussel records to determine if the absence of host fish should be further investigated as a potential cause of mussel decline. Visual searches detected 13 mussel species, with catch-per-unit-effort (CPUE) and species richness lower than previous surveys, suggesting continued decline. Mean species-level occupancy across the mussel community (i.e., all species detected) was low (<25%), and the probability of detecting a freshwater mussel during a 45-minute survey averaged 29%. Mussel occurrence decreased in spring-influenced reaches and riffle habitats but increased in off-channel and glide/race habitats. A host fish linkage index indicated that most mussel species have viable hosts present, though species dependent on few or lentic-associated hosts may face reproductive limitations. These results provide managers with actionable data for conservation planning and outline potential future survey methods, including targeted habitat sampling to sustain mussel diversity in OZAR.

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Permits

Freshwater mussel collection activities outlined in this report were conducted under a Scientific Collector's Permit from the Missouri Department of Conservation (2024WCP-65279) and a Scientific Research and Collecting Permit from the National Park Service OZAR Park Unit (OZAR-2023-SCI-0008).

Introduction

Freshwater mussels are among the most imperiled faunal groups in Missouri and in North America (Haag 2012; Strayer et al. 2004). Nearly 70% (~200 species) of the approximately 300 North American species within the superfamily Unionoidea (hereafter mussels) are accorded some level of conservation status, including approximately 36 species listed as presumed or possibly extinct (Pfeiffer et al. 2024; Stein et al. 2000). Approximately 65 species of freshwater mussels occur in the state of Missouri, with species richness and diversity typically higher in rivers of the Ozark Plateau than in the state's other aquatic subregions, the Mississippi Alluvial Basin and Central Plains (Haag 2012; McMurray et al. 2012; Oesch 1995). Nearly 50% of Missouri's mussel species are considered species of conservation concern (SOCC), ranking them second only to crayfish (by percentage) as the most threatened fauna in the state (MDC 2025; McMurray et al. 2012). Fourteen of the SOCC mussels in the state of Missouri are S1 or Critically Imperiled. Sixteen species are recognized as State Endangered, and 14 are listed as federally threatened, federally endangered, or proposed as endangered (MDC 2025).

The spatial distribution of freshwater mussels in the water bodies they inhabit is often described as “patchy” (Bossenbroek et al. 2018; Ries et al. 2016, 2019). Freshwater mussel distribution, diversity, and abundance are influenced by many abiotic and biotic factors spanning multiple spatial scales (Hegeman et al. 2014; McRae et al. 2004; Newton et al. 2008; Vaughn and Taylor 2000). At coarse spatial scales, historical patterns of glaciation, geology, and climate shape species assemblages and distributions (Dascher et al. 2018; Hewitt et al. 2018). The size and discharge of rivers also influence mussels as headwater streams often have fewer species and lower abundances compared to larger streams (Atkinson et al. 2012; Cao et al. 2015). Headwater streams also commonly harbor different species than larger streams, in particular small-bodied and shorter-lived species (Atkinson et al. 2012). Various hydrodynamic factors interact with substrate characteristics and environmental flows to influence freshwater mussel assemblages (*sensu* Lopez and Vaughn 2021). The location and persistence of mussel beds is hypothesized to be constrained by sediment mobility in the streambed, with stable sediments associated with mussel presence (Geist and Auerswald 2007; Strayer 1999). Consequently, mussel aggregations are thought to primarily occur in patches where scour is reduced and sediment complexity high due to the presence of velocity refugia. Other finer-scale factors such as water temperature, degree of siltation, and water quality also affect mussel assemblages (Bogan 1993; Galbraith et al. 2010; Haag 2019; Luck and Ackerman 2022; Strayer et al. 2004).

The primary method of freshwater mussel dispersal involves the use of a fish or, rarely, an amphibian (Haag 2012). This is because unionids are unique among bivalves in that they require a temporary host for their parasitic larvae termed “glochidia”. Mussels possess various strategies for attracting and infecting host fishes with their larvae (Barnhart et al. 2008). After a matter of days to months, the glochidia develop and transform into juveniles, detach from the host, and settle into bottom substrate (Haag 2012). Some species of mussels can successfully transform as juveniles on many species of fish, while other mussel species may have only a single host species (Haag 2012). Host fish distribution, habitat associations, and dispersal behavior influence freshwater mussel distribution

(Schwalb et al. 2013) and correlate with the conservation status of unionid species. Species that use hosts with shorter dispersal distances tend to be more imperiled than species that use hosts with greater dispersal distances (Schwalb et al. 2011).

Park Resource Management Issues

Natural resources staff at Ozark National Scenic Riverways (OZAR) may benefit from comprehensive and updated inventories of aquatic taxa, which they could use to formulate sound, science-based management strategies for the rivers within OZAR. They use these strategies to address issues as they relate to river use and external threats. Inventories exist for some aquatic taxa (i.e., some invertebrates and fish) but are generally lacking or in need of refinement for freshwater mussels, some species of which are rare or endangered. There are seven freshwater mussel species (Slippershell Mussel, Purple Lilliput, Black Sandshell, Flat Floater, Little Spectaclecase, Texas Lilliput, and Ouachita Kidneyshell) that have been found alive within OZAR that are classified as state SOCC. Appendix A lists the 36 species of freshwater mussels known to occur in the Jacks Fork or Current rivers in Missouri.

Mussel species and populations are in decline at OZAR based on previous surveys at select sites and recent surveys along the Jacks Fork. There have been multiple efforts to survey mussels in the Current River drainage (Figure 1), but the most significant recent efforts to assess mussel populations within OZAR occurred in 2002 (McClane Environmental Services 2004) and 2019 (McMurray and Faiman 2023). McClane Environmental Services (2004) surveyed 36 sites throughout the Jacks Fork and Current River within OZAR and concluded 14 species remained extant, but they detected shell material from another 4 species (18 total). After combining these 18 species with 4 additional species detected during surveys conducted in 1982 (MDC 2022), they further concluded that 22 total unionid species currently or historically existed within the park boundaries. Their study sites were not random and focused instead on past collection locations and areas of suspected mussel presence. McMurray and Faiman (2023) surveyed 28 sites in the Jacks Fork only, targeting previously sampled locations. They observed six live species and shell material for an additional four species, which was a decline compared to previously collected data. Most collections at a site in all past sampling efforts detected less than five species, so site-level mussel richness was determined to be low throughout the OZAR system. In total, there are occurrence records for 36 species of mussels either within OZAR or in the mainstem Current River in Missouri (listed in Appendix A). Although previous surveys provided useful information, none targeted random sites throughout both rivers, leaving large areas of the park without surveys for mussel populations. Additionally, the federally endangered or threatened Pink Mucket, Rabbitsfoot, and Western Fanshell were documented downstream of the park in the mainstem Current River (MDC 2022), but it is not known if they may also occur within park boundaries. These data gaps can complicate management decisions made by natural resources staff in those parks. There also is a need to assess mussel community structure, clarify management and mitigation needs for their protection, and evaluate long-term monitoring strategies.

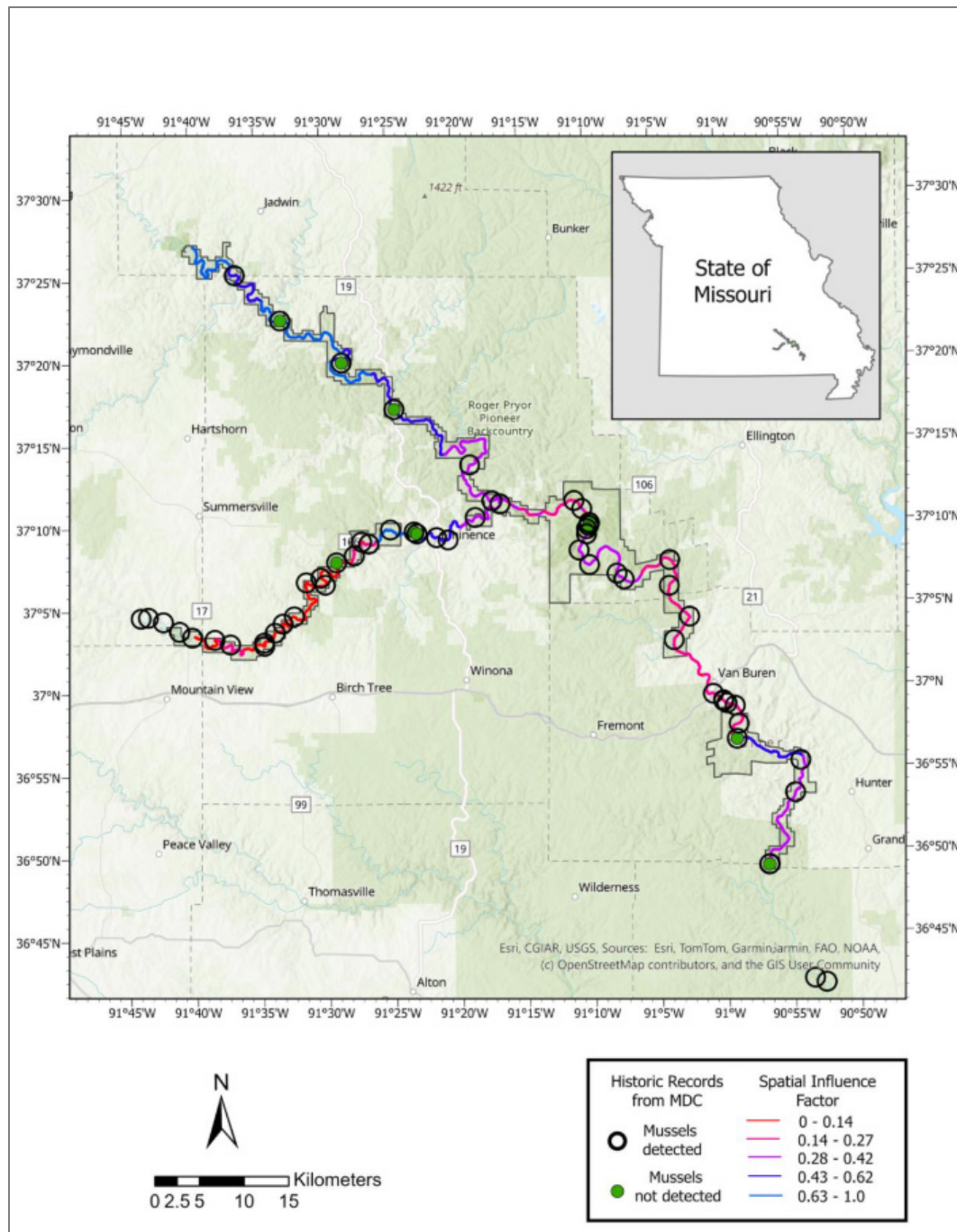


Figure 1. Map of mussel detection locations at sites surveyed in the Jacks Fork and Current River based on records from the Missouri Department of Conservation (MDC) Mollusk database prior to surveys conducted by the University of Missouri in 2023 and 2024. Sites where mussels were detected are shown with open black circles, and sites where mussels were not detected are shown with green circles. River segments are color coded to represent the spatial influence factor, a metric approximating groundwater spring influence where values near 0 indicate almost no spring inflow and values near 1 indicate a high degree of spring inflow. The gray outline delimits the boundary of the Ozark National Scenic Riverways (OZAR). An inset map shows the location of OZAR within Missouri.

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The information provided in this report directly informs ongoing park planning processes. It provides park staff with additional updated information to make science-based management decisions when evaluating proposed actions that might affect natural and cultural resources, especially as they might be deleterious for rare and endangered species. Findings can be used to support management and use planning efforts, such as design and location of river accesses. Specific triggers for implementing management actions will be based on the presence of all identified target species (all unionid species) and locations of mussel aggregations. The collected data can inform planning for aquatic animal management, including linkages to changing fish communities; coordination with ongoing endangered species management efforts; and improved interpretive presentations and connections. For example, the data provided in this report could be useful for guiding placement of new river access locations. Mussel inventories can also support future potential restoration efforts, including potentially stocking captive reared individuals, augmenting or managing host fishes that are rare or now absent from these waterways (e.g., Freshwater Drum), and documenting and managing invasive species.

Other potential project outcomes include providing data to support broader conservation efforts (i.e., informing rare species strategies over a broader geographic scope, providing field experience for conservation staff on field techniques of mussel analyses, and interpreting biological field careers for youth and the public through outreach formats). The resulting information from this report can be used by the National Park Service, Missouri Department of Conservation, and U.S. Fish and Wildlife Service, among others, to serve as a baseline inventory for future monitoring efforts and to guide management actions.

Project Goals

The primary goal of this project was to provide an updated inventory of freshwater mussels found within OZAR using a repeatable survey design. We designed and implemented a survey to estimate occupancy and detection probabilities for mussels located within OZAR, as well as to provide estimates of mussel catch per unit effort and species richness. We also examined past fish distributional records within OZAR to better understand linkages between mussels and their host fishes.

Methods

Sample Design

Study Area

The Ozark National Scenic Riverways (OZAR) is a national park unit located within the Interior Highlands Biogeographical Province (McMurray and Faiman 2023). Established in 1964, OZAR encompasses approximately 215 km of the river corridor surrounding the mainstem Current River and its tributary, the Jacks Fork, and totals approximately 327 km² in area (Figure 1). These rivers occur in primarily forested landscapes and consist of typically clear water flowing over a gravel-dominated streambed (Panfil and Jacobson 2001). Over 270 springs exist within the Current River watershed and contribute to a unique karstic geohydrologic setting where sections of both streams are dominated by groundwater inputs from springs (Mugel et al. 2009). These spring inputs create a thermally heterogeneous riverscape containing reaches of river more thermally suited for certain aquatic biota than for others (Westhoff and Paukert 2014b). Historical land-use changes in the watershed have resulted in widespread delivery of excess gravel-sized sediment that has created wave-like forms of coarse sediment and cause disturbance in these rivers (Jacobson and Bobbitt Gran 1999).

Site Selection

Our sampling frame included the mainstems of the Current River and Jacks Fork within OZAR, as well as the portions of each river that are outside of but adjacent to the park boundaries near the towns of Eminence on the Jacks Fork and Van Buren on the Current River. These small areas outside the park boundaries were included as many aquatic organisms, including mussel host fish, are mobile and likely move between OZAR and the adjacent river segments, thus influencing unionid species presence and abundance.

We used a generalized random tessellation stratified (GRTS) design procedure (Dumelle et al. 2023; Stevens and Olsen 2004) to identify a random, yet evenly dispersed and well-distributed (i.e., spatially balanced) selection of potential survey sites located throughout OZAR that represent aquatic habitat available within OZAR. Using the GRTS method ensures that sites are not “clumped” together, thus potentially decreasing the probability of potentially redundant data collected by over-sampling similar habitats in proximity.

We used the “spsurvey” R package (Dumelle et al. 2023) in Program R (version 4.4.3) to apply the GRTS algorithm and conduct the spatially balanced site selection. One hundred and twenty survey point locations within this sampling frame were identified (see Appendix B for a list of 120 GRTS points). Ninety-seven of the 120 proposed sites were approved by NPS personnel after consideration of potential disturbance of other sensitive aquatic organisms in the river. Our goal, based on sampling logistics, was to randomly select and sample 60 survey site locations, with the expectation that excess survey locations may be required if any of the selected sites were not logistically feasible. We did not sample sites in a random order due to logistical constraints.

Survey Methods

We conducted mussel surveys during the summers of 2023 and 2024. Surveys were conducted during daylight hours (~8 am–6 pm) on weekdays, and only if water level conditions (e.g., discharge and clarity) were near normal baseflow conditions as determined by site visits and accessing information from nearby stream gages.

We used a handheld GPS to navigate to a GRTS-identified survey point location on foot, by kayak, or with a 40-hp jetboat depending on site access. Once on site at a GRTS point location, the nearby adjacent areas were scouted to identify potential mussel habitats, areas that cannot be sampled, and areas that can be sampled. Scouting was confined to areas within 500 m upstream and downstream of the GRTS point (i.e., 1 km reconnaissance area) and often contained multiple habitats and channel unit types. The exact locations surveyed included areas within 500 m of the GRTS point that appeared most suitable for mussels (e.g., stable substrates, backwaters, side channels, etc.) and that were also less than 1 m in depth for snorkeling purposes. The availability of searchable area less than 1 m in depth varied throughout the streams, but we estimate from visual observation and a previous habitat assessment (Westhoff and Paukert 2014a) that about 30–50% of the water surface area was too deep to sample with snorkeling.

We conducted a 4.5-person-hour timed search in the area encompassing and directly adjacent to the survey location point (i.e., reconnaissance area) using masks and snorkels (Metcalf-Smith and Di Maio 2000; Tiemann et al. 2009). The timed search consisted of qualitative visual-tactile surveys conducted by systematically searching the surficial bed sediments visually and by feeling the stream bottom with hands to locate mussels. If required because of poor water clarity, tactile-only searches were conducted. Rocks larger than cobble size (i.e., >256 mm diameter) were not moved or flipped at any site. The field survey team of three individuals was trained on mussel identification and survey methods prior to fieldwork. At a minimum, each site had to contain enough shallow water (<1 m deep) to allow for the full 4.5-person-hour search within the reconnaissance area surrounding the point. If an insufficient area was available for snorkeling, the site was abandoned and the next closest location from the oversample list was sampled instead. Abandoned sites were noted, and a subsample of those sites were sampled using SCUBA in the 2024 field season.

Three surveyors each completed two 45-minute searches, resulting in a total effort of 4.5 person-hours (3 surveyors $\times$ 45 minutes $\times$ 2 surveys = 4.5 hours). In each 45-minute survey, a unique area was comprehensively searched so that no survey overlapped with areas searched by another person at the site. This resulted in six separate surveys of mussels at the site, and mussels encountered in each of the six surveys were recorded separately. Each live mussel captured was identified to species level, measured for length (mm), and sexed, if possible. Photographs were taken of at least one live individual to represent each live species found at a site. Shells from species not collected alive at a site were photographed and placed in the University of Missouri mussel reference collection (School of Natural Resources, Anheuser-Busch Natural Resources Building, Columbia, Missouri). No standardized bank searches for mussel shell material were conducted; however, mussel shell material encountered within the study frame was opportunistically collected, identified, and documented.

We collected data on environmental covariates in association with each 45-minute timed search effort. We calculated the area searched by measuring the length and width of the surveyed area using a laser rangefinder. We estimated bed sediment composition based on percent surficial coverage and using a modified Wentworth classification scale (Keretz et al. 2021; Wentworth 1922). The categories we used for this included clay, silt, sand, pebble, cobble, boulder, and bedrock. We defined dominant and sub-dominant substrate types using these same categories. We also defined channel unit type following the classifications of Peterson and Rabeni (2001) where patches of habitat are classified as low gradient riffle, high gradient riffle, bluff pool, lateral pool, glide, race, slough, forewater, or backwater. We estimated vegetation cover within each survey area as a percentage of total area occupied by submerged or emergent aquatic vegetation and estimated riparian coverage as the percentage of the site shaded by terrestrial vegetative cover. We created a map and recorded general observational notes for each surveyed site. We used spatial influence factor (hereafter referred to as “relative spring influence”) values as calculated by Westhoff and Paukert (2014b) to represent site-level water temperature variation (Figure 1). This metric was developed empirically and calculated specifically for OZAR and primarily represents groundwater spring influence where stream reaches with values near 0 have little groundwater inflow and reaches with values near 1 are almost entirely dominated by groundwater.

Analysis Methods

Sampling Summary and Catch-Per-Unit-Effort (CPUE)

We summarized our mussel sampling results similarly to other recent mussel surveys in the region by calculating mussel relative abundance and catch-per-unit-effort (CPUE) across our sites (McMurray and Faiman 2023). To calculate CPUE, we divided the total number of live mussels encountered at a site (regardless of species) by the total search time of 4.5 person hours. We also calculated a rough estimate of mussel density by dividing the total number of live mussels encountered at a site by the total area in square meters that was searched. We calculated these values for the entire system and separately for the sites in the Jacks Fork, upper Current River, and lower Current River. We defined the upper Current River as all sites above the confluence of the Jacks Fork, and the lower Current River as all sites below the confluence of the Jacks Fork (Figure 1).

Mussel Occupancy and Detection

After field sampling, data were proofed for quality control and processed in Program R (version 4.4.3). First, given the complexity of data gathered during time search one (TS1) and time search two (TS2), each search was treated as an independent site. For example, TS1 often involved searching the main channel, while TS2 focused on an adjacent backwater system. Because of these contrasting environmental conditions, treating each search as a separate site for our occupancy analysis enabled mussel occupancy and detectability to be linked to the unique characteristics of each search. To address potential spatial autocorrelation among clustered sites, we fit a spatially explicit model (Doser et al. 2022).

Next, raw detection records were converted into a three-dimensional detection/non-detection array indexed by species, site, and replicate. Replicates were defined by observer, with three observers independently surveying different areas within each site during a given time search. To account for

variation in detection ability, we included a random effect of observer in the detection portion of the model. Sites missing a replicate (e.g., no third observer during a SCUBA survey) were coded as missing (*NA*) in the detection array. Additionally, since the spatial latent factor multi-species occupancy model we implemented requires an ordered species array, we reordered the species following the recommendations of Doser et al. (2022). Specifically, a common mussel species, Western Rainbow, was placed first because the first species has fixed factor loadings and strongly influences interpretation of the latent factors (Doser et al. 2022). To maximize differences in occurrence patterns, a rare species, Flat Floater, was placed second. Since we only included one latent factor in the model, the rest of the species were left in their original order.

Detection covariates included observer identity, search area (m²), use of SCUBA sampling, and a visual estimation of the proportion of the site <0.5 m deep. Detection covariates were stored in site-by-replicate matrices. Continuous covariates were scaled using a z-score standardization to produce a mean of 0 and standard deviation of 1, and categorical covariates, like use of SCUBA sampling, were encoded as 0/1.

Occurrence covariates were derived from site-level habitat data. Continuous variables (e.g., substrate composition, vegetative cover, relative spring influence) were averaged across observers to produce one value for each variable per site. Missing covariate values were imputed with the across-site mean. Composite variables were created for sediment classes (clay or silt = fine; sand, pebble, cobble = loose; boulder, bedrock = large), hydrologic classes (low-gradient riffle, high-gradient riffle = riffle; bluff pool, lateral pool = pool; glide, race = glide/race), and off-channel features (slough, side channel, tributary = off-channel) by summing classes within each group. For example, high- and low-gradient riffles were summed to represent overall riffle occurrence at a given site. We combined sand, pebble, and cobble together and termed them as “loose” because these sediment grain sizes are typically consolidated and less stable than other substrate types in this system (Jacobson and Bobbitt Gran 1999). As with detection covariates, continuous occurrence covariates were scaled using a z-score standardization to produce a mean of 0 and standard deviation of 1. Categorical covariates, like river identity, were encoded with unique, numerical values (e.g., 0/1) for modeling. To account for spatial autocorrelation, representative points for each timed search were generated and projected to UTM zone 15N. Coordinates were then combined into a final data object that included detection data, occurrence covariates, and detection covariates, which were all used for subsequent modeling.

The models were implemented within a Bayesian framework, using the “spOccupancy” R package (Doser et al. 2022). Specifically, the models were implemented with a spatial latent factor multi-species occupancy model (*sfMsPGOcc* function), which accounts for imperfect detection, residual species correlations, and spatial autocorrelation through a nearest neighbor Gaussian process (NNGP) (Doser et al. 2022). This multi-species approach extends single-species models by treating species-specific parameters as random effects drawn from a community-level distribution (Dorazio and Royle 2005; Doser et al. 2022). By estimating all species simultaneously, the model borrows strength from common species to improve occupancy estimates for rarer species. The model produces an overall, community-level occupancy intercept, which represents the average occupancy propensity of species in the community (i.e., all detected species), with individual species-specific

occupancies modeled as deviations from this community mean. Each model included one spatial latent factor, 10 neighbors, and was run using three Markov Chain Monte Carlo (MCMC) chains with 5,000 burn-in iterations, a thinning interval of 2, and a batch setting of 1,000 batches $\times$ 25 iterations per batch (totaling 25,000 samples per chain). Posterior draws were assessed for convergence ($\hat{R} < 1.1$) and acceptable Bayesian p-values (~ 0.5), which describe the match between the model and our observed data.

We used model selection to determine the most suitable model by constructing a candidate set of 15 models which varied by occupancy and detection covariates (Burnham and Anderson 2002). Occupancy covariates tested included river identity (Current River vs. Jacks Fork), relative spring influence, off-channel habitat, substrate classes (fine, loose, large), hydrology (riffle, pool, glide/race), and vegetative and riparian cover. Several models also included interaction terms between relative spring influence and off-channel habitats. Detection covariates included observer identity (modeled as a random effect), search area (m^2), use of SCUBA sampling, and proportion of the site < 0.5 m deep. We compared the performance of the 15 candidate models (Table 1) using the widely applicable information criterion (WAIC), with lower values indicating better model fit. The candidate models were developed in a sequential and biologically informed manner. Specifically, we first evaluated alternative formulations of the detection process (Models 1–6). Relative spring influence and river identity were included in all models based on our expectation that these variables would strongly influence mussel occurrence. The initial comparison between Models 1 and 2 evaluated whether observer should be modeled as a fixed or random effect. Because the random effect formulation resulted in a lower WAIC, observer was subsequently modeled as a random effect. Observer was the only random effect included because different individuals contributed to surveys across seasons, introducing substantial heterogeneity in detection probability. In contrast, other covariates were measured by a consistent core field team and were therefore expected to contribute less observational variability. Detection covariate complexity was then incrementally increased, and the most parsimonious detection structure was selected based on WAIC. Model 3 had the lowest WAIC among the first six models and was therefore retained as the detection component for subsequent models. Next, we evaluated the interaction between relative spring influence and off-channel habitat (Model 7), based on the hypothesis that off-channel habitats may buffer against the effects of spring influence. Because inclusion of this interaction reduced WAIC relative to the simpler model (Model 6), the interaction term was retained in all subsequent models. Finally, we evaluated five competing formulations of the occurrence process, increasing ecological complexity in a structured manner. Model 12 produced the lowest WAIC and was selected as the final model.

Table 1. Candidate models with associated widely applicable information criterion (WAIC) values. Model 12 had the lowest WAIC value and was selected as the final model.

Model Number	Detection Covariates ^A	Occurrence Covariates ^B	WAIC Value
1	Obs	Rel_Spr_In + River	905.21201
2	(1 Obs)	Rel_Spr_In + River	898.28056
3	(1 Obs) + Area	Rel_Spr_In + River	896.29723
4	(1 Obs) + Scuba	Rel_Spr_In + River	899.11797
5	(1 Obs) + Scuba + Shallow	Rel_Spr_In + River	905.25256
6	(1 Obs) + Scuba + Shallow + Area	Rel_Spr_In + River	902.05065
7	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River	888.46934
8	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments	881.18557
9	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments	867.12139
10	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments + Large_Sediments	862.97743
11	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments + Large_Sediments + Riffle	859.10431
12	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments + Large_Sediments + Riffle + Glide_Race	858.47222
13	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments + Large_Sediments + Riffle + Glide_Race + Pool	862.6521

^A Obs represents a fixed effect of observer identity. (1 | Obs) represents a random observer effect. Area represents a fixed effect of search area (m²). Scuba represents a fixed effect indicating a SCUBA survey rather than a snorkel survey. Shallow represents a fixed effect for the proportion of site <0.5 m deep.

^B Rel_Spr_In represents a fixed effect of relative spring influence. River represents a fixed effect of river (Current River or Jacks Fork). (Rel_Spr_In * Off_Channel) represents main effects of relative spring influence, off-channel habitat, and their interaction. Loose_Sediments, Fine_Sediments, and Large_Sediments represent fixed effects of the corresponding substrate types. Riffle, Glide_Race, and Pool represent fixed effects of their respective habitat units. Vegetative_Cover represents a fixed effect of vegetative cover within the site. Riparian_Cover represents a fixed effect of riparian cover within the site.

Table 1 (continued). Candidate models with associated widely applicable information criterion (WAIC) values. Model 12 had the lowest WAIC value and was selected as the final model.

Model Number	Detection Covariates ^A	Occurrence Covariates ^B	WAIC Value
14	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Fine_Sediments + Loose_Sediments + Large_Sediments + Riffle + Glide_Race + Pool + Vegetative_Cover	863.82949
15	(1 Obs) + Area	(Rel_Spr_In * Off_Channel) + River + Loose_Sediments + Fine_Sediments + Large_Sediments + Riffle + Glide_Race + Pool + Vegetative_Cover + Riparian_Cover	865.29366

^A Obs represents a fixed effect of observer identity. (1 | Obs) represents a random observer effect. Area represents a fixed effect of search area (m²). Scuba represents a fixed effect indicating a SCUBA survey rather than a snorkel survey. Shallow represents a fixed effect for the proportion of site <0.5 m deep.

^B Rel_Spr_In represents a fixed effect of relative spring influence. River represents a fixed effect of river (Current River or Jacks Fork). (Rel_Spr_In * Off_Channel) represents main effects of relative spring influence, off-channel habitat, and their interaction. Loose_Sediments, Fine_Sediments, and Large_Sediments represent fixed effects of the corresponding substrate types. Riffle, Glide_Race, and Pool represent fixed effects of their respective habitat units. Vegetative_Cover represents a fixed effect of vegetative cover within the site. Riparian_Cover represents a fixed effect of riparian cover within the site.

Mussel and Host Fish Linkages

We obtained data on fish presence and abundance within the Current River drainage from the Missouri Department of Conservation Fish Community Database (MDC 2024). The database contained information from unstandardized fish sampling efforts and covered collection dates from 1930 to 2012. Records in the database were compiled from all known fish collection efforts for scientific or management purposes and reported spatial coordinates, species encountered, number of individuals observed, and occasionally including information on methods used (e.g., electrofishing, seining, gill nets, etc.). All fish species mentioned in this report are listed by common and scientific names and a full list is presented in Appendix C.

We obtained data on mussel presence and abundance within the Current River drainage from the Missouri Department of Conservation Freshwater Mollusk Database (MDC 2022). The database contained information from unstandardized mussel sampling efforts and covered collection dates from 1967 to 2019. Records in the database were compiled from all known mussel collection efforts for scientific or management purposes and reported spatial coordinates, species encountered, number of individuals observed, and occasionally including information on methods used (e.g., visual surveys, quadrats, transect sampling, etc.). We also used mussel data collected from our survey efforts in 2023 and 2024. All mussel species mentioned in this report are listed by common and scientific names and a full list is presented in Appendix A).

We accessed a publicly available database containing information on known relationships between mussels and their host fishes (Freshwater Mussel Host Database 2025). Records included evidence provided in scientific literature based on studies of natural infestations, natural transformations, laboratory infestations, laboratory transformations, not specified, or zero transformations documented (Hopper et al. 2025). The most robust host linkages are demonstrated by successful natural transformation of glochidia (i.e., the parasitic stage of larval mussels) of the specified mussel species on the specified host fish. Successful laboratory transformations consist of glochidia surviving after attachment to a host in a laboratory setting and becoming juveniles, but do not prove that the host relationship occurs in the wild. Infestations indicate that the glochidia can attach to a host, but encapsulation and transformation of glochidia was not observed due either to lack of host specificity or experimental conditions. Although a valuable resource, the Freshwater Mussel Host Database has limitations related to species coverage and reliability of predicted host relationships outside of captive propagation settings (Hopper et al. 2025). Mussels and their host fish found in OZAR are outlined in Appendix D.

We developed an index-based method to estimate the degree of overlap between individual mussel species and their known host fishes (Figure 2). The index components included information on the relative abundance of fish and mussels in samples, the date of last detection of fish or mussels, and the number of locations where the fish or mussels were detected. Each component of the index was scored from 0 to 3 based on criteria we determined from the available data (Table 2). For mussels, we considered a species present at a site if either a live animal or valve was recorded. We also did not differentiate between live mussels or valves when counting the number of individuals observed (the presence of shell material was counted as one individual). Once component values were assigned, we summed the values separately for the three fish-related criteria to create the fish sub-index and summed them for the three mussel-related criteria to create a mussel sub-index. Because some mussels had multiple host species, and because not every host species had a confirmed natural transformation of glochidia, we weighted the index values by multiplying the fish sub-index value by either 1 for a natural infestation, 2 for a lab transformation, or 3 for a natural transformation. Because it was possible for a single species of mussel to have multiple documented hosts present in the system, we selected the host fish of each mussel with the highest score for our weighted fish sub-index. We then weighted the mussel sub-index by the number of potential host fish species in the system where three or fewer hosts were given a weight of “1”, 4–10 hosts were given a weight of “2”, and more than 10 hosts were given a weight of “3”. The weighted mussel sub-index and weighted fish sub-index were then added together to create a raw host fish linkage index score. To standardize and aid in interpretation, we scaled the index values from 0 to 1 using min-max normalization following the equation;

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)}$$

where x' is the normalized value, x is the original value, $\min(x)$ is the minimum value in the dataset, and $\max(x)$ is the maximum value in the dataset. Values near 0 indicate that neither the mussel nor its

known host fish(es) were common in the focal geography. Values near 1 indicate that both the mussel species and at least one of its known host fish were common in the focal geography. Values near 0.5 may indicate that either the host fish was common, and the mussel was not, or that the mussel was common, but the host fish was not. In these cases, examining the individual sub-indices used to create the final index provided additional insight regarding potential broken host fish linkages.

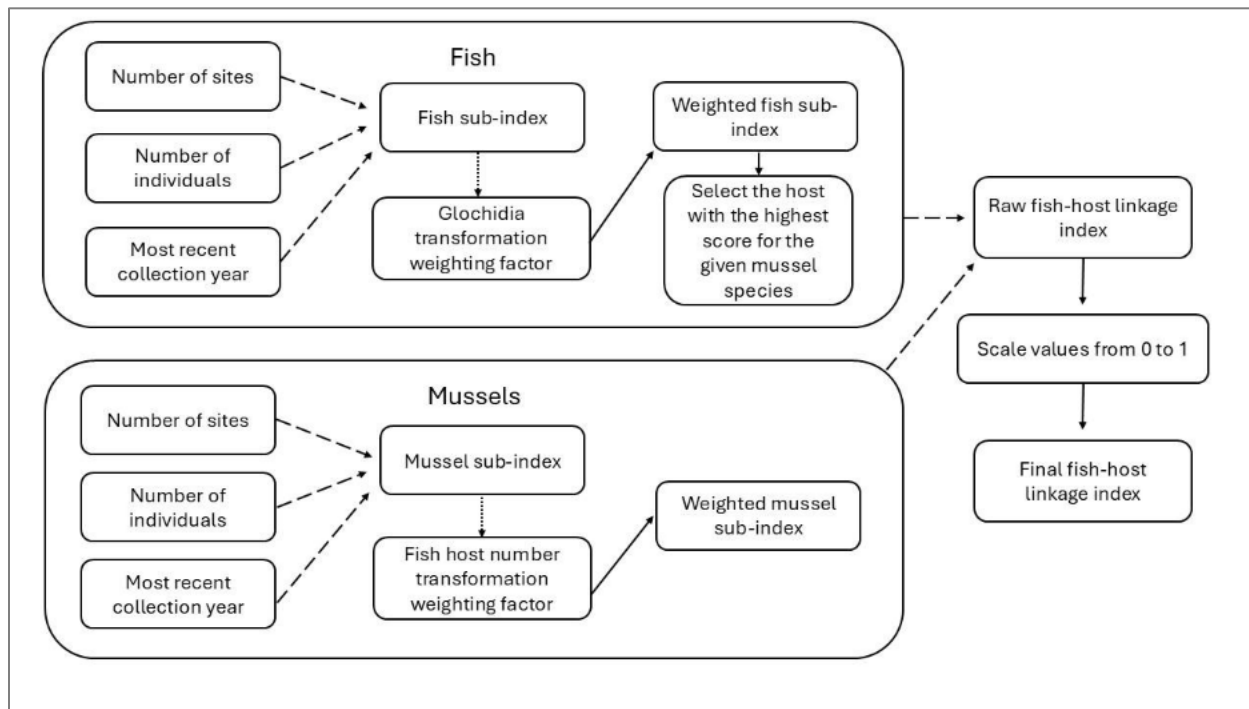


Figure 2. Conceptual diagram showing the steps and components of the host fish linkage index developed to investigate freshwater mussel populations in the Current River and Jacks Fork in the Ozark National Scenic Riverways. Dashed arrows represent values summed to create index components, dotted arrows represent the multiplication of weighting factors, and solid arrows indicate other transitions between steps in the index development process.

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Table 2. Mussel and host fish linkage index components and scoring criteria. Numbers in parentheses represent index component scores that were combined to create a composite index score for each species of mussel known to occur in the Current River drainage of Missouri.

Index component	Zero (0)	Low (1)	Medium (2)	High (3)
Number of sites (fish)	0 or 1	2–6	7–30	>30
Number of individuals (fish)	0	≤100	101–1000	>1000
Most recent collection year (fish)	Never	<1975	1975–2004	2005–present
Number of sites (mussels)	0–1	2–3	4–15	>15
Number of individuals (mussels)	0	≤10	11–100	>100
Most recent collection year (mussels)	Never	<1975	1975–2014	2015–present

We calculated values for the host fish linkage index for each species of mussel separately for each of four river reaches in the Current River drainage. River reaches for this analysis were defined as the mainstem Jacks Fork (JF), the upper Current River above Akers Ferry (Gladden Creek Confluence) to Montauk Springs which is the upstream-most boundary of OZAR (CRAA), the upper Current River below Akers Ferry (Gladden Creek confluence) to the confluence with the Jacks Fork (CRBA), and the lower Current River between the confluence of the Jacks Fork and the southern park boundary (LCR; Figure 1). We then combined data from the four river reaches and found the mean ($\pm$ standard error) of the index values for each species of mussel. Additionally, we calculated the weighted fish sub-index scores for species of mussel known to occur outside the park boundary in the lower Current River, but not within OZAR. The purpose of this was to see if a lack of host fishes may be preventing the presence of these mussel species further upstream in OZAR.

Results

Sampling Summary and CPUE

We sampled 43 sites during the first field season of the study (June 20, 2023, through September 27, 2023) and 17 sites during the second field season (June 18, 2024, through July 25, 2024) for a total of 60 sites (Figures 3 and 4; Appendix B). Of the 17 sites sampled in 2024, four sites (107B, 109B, 82B, and 66B) were sampled using SCUBA. No sites were sampled with SCUBA in 2023.

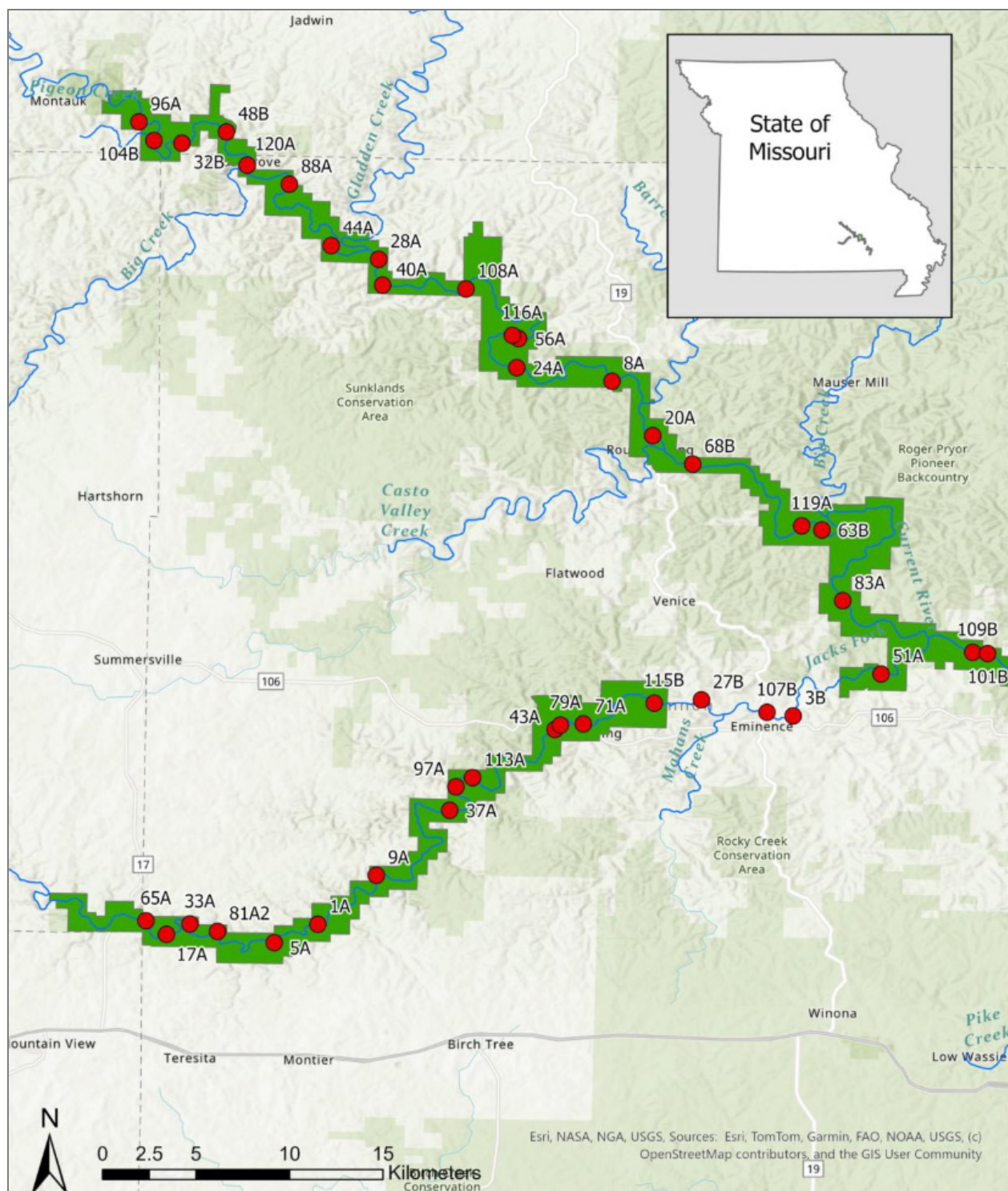


Figure 3. Map showing the upper Current River and Jacks Fork within the Ozark National Scenic Riverways (OZAR; green polygon). Red points indicate locations of sites surveyed for freshwater mussels in 2023 and 2024. Point labels correspond to coordinates and mussels observed. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. An inset map shows the location of OZAR within Missouri.

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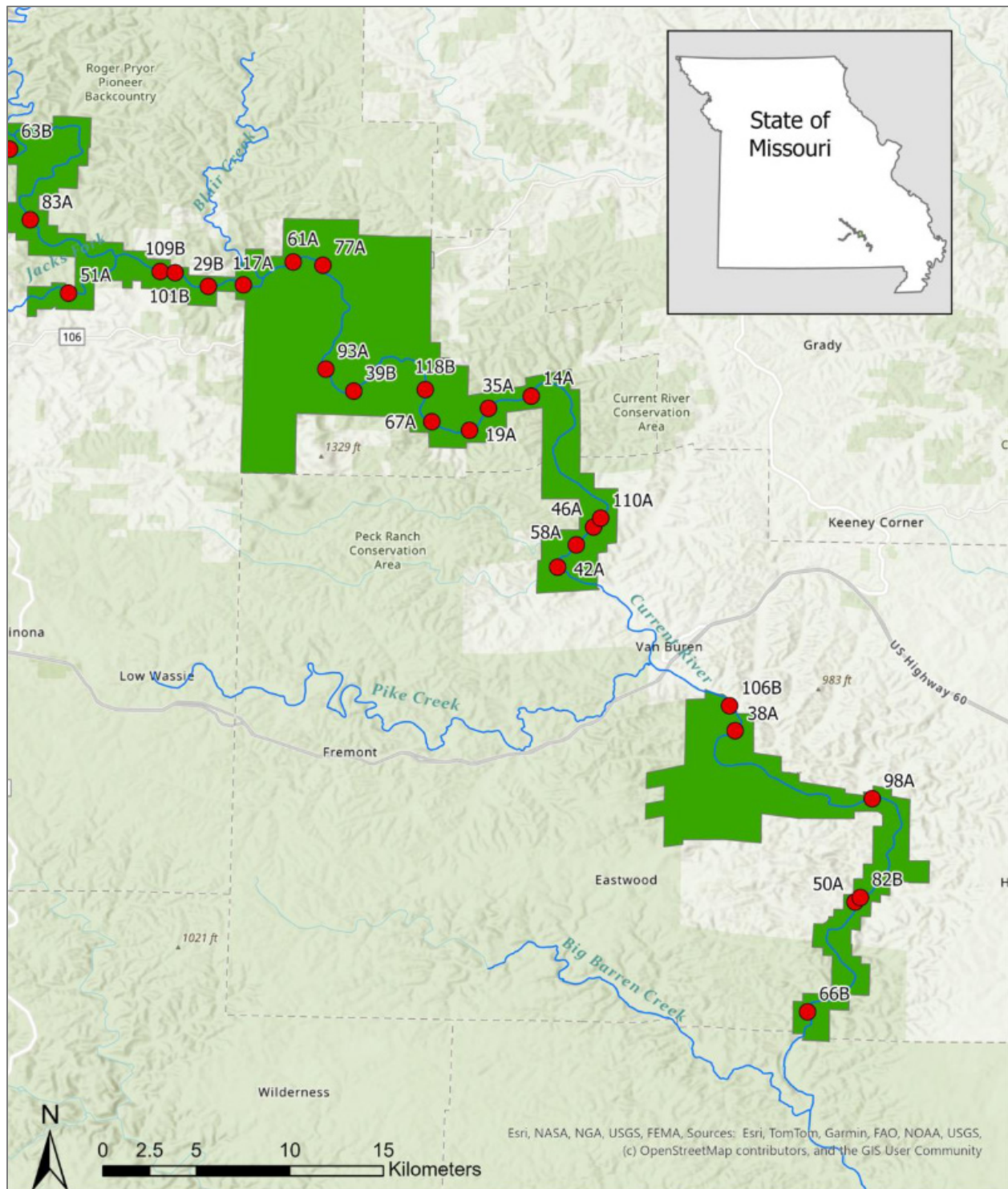


Figure 4. Map showing the lower Current River within the Ozark National Scenic Riverways (OZAR; green polygon). Red points indicate locations of sites surveyed for freshwater mussels in 2023 and 2024. Point labels link to coordinates and mussels observed. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. An inset map shows the location of OZAR within Missouri.

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We encountered live mussels at 41 of the 60 sites (68%). Four of the 19 sites without live mussel detections did have shell material. We did not detect live mussels in 12 of 19 sites (63%) in the Current River upstream of the confluence with the Jacks Fork, 5 of 18 sites (28%) in the Jacks Fork, and 2 of 23 sites (9%) in the Current River downstream of the confluence with the Jacks Fork (Appendix E). The greatest number of mussel species detected (live or shell material) at a single site in our surveys was 6, but most sites with mussels had 2 or 3 species detected (Figure 5, Appendix E). Maps of all mussel locations for individual species from past surveys and the current survey are in Appendix F.

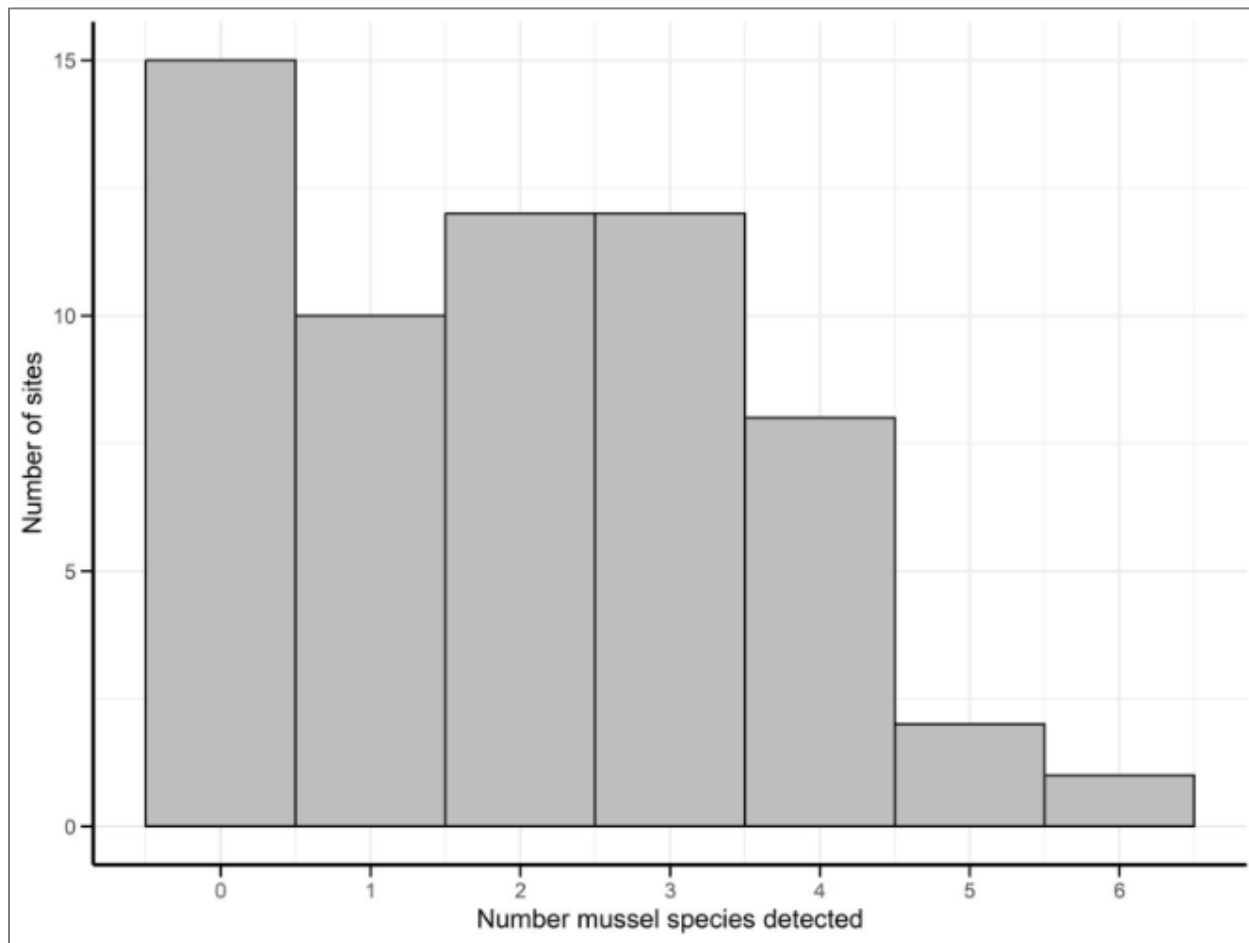


Figure 5. Histogram showing the number of freshwater mussel species detected (live and shell material) in sites surveyed in the Jacks Fork and Current River during 2023 and 2024.

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We detected 580 live mussels comprising 10 total species, with most individuals found in the Jacks Fork (Table 3 and 4). The most numerically common mussels collected alive were Western Rainbow and Arkansas Brokenray, each with over 100 individuals encountered and relative abundance values above 20% (Table 4). Of the 10 different species, Arkansas Brokenray and Western Rainbow were also the species encountered alive at the most sites, with detections of each at 25 sites (Table 4). Ozark Pigtoe, Ouachita Kidneyshell, and Paper Pondshell were all detected live at ≥ 10 sites. Flat

Floater and Fatmucket were only detected at one site each and were not observed as shell material at any sites. We did not detect any state or federally listed mussel species, but did encounter live individuals of Flat Floater, Ouachita Kidneyshell, and Purple Lilliput, which are considered species of conservation concern in Missouri (MDC 2025). We collected shell material from 28 (47%) sites representing 13 species (Table 4). The three species that were observed only as shell material were Purple Wartyback, Creeper, and Flutedshell. The species most collected as shell material were Western Rainbow and Ouachita Kidneyshell (Table 4).

Table 3. Totals of live mussels and mussel shell material found in the different sections of river within the Ozark National Scenic Riverways (OZAR) during surveys in 2023 and 2024.

River section	Total individuals found alive	Total of shell material collected
Jacks Fork	276	106
Lower Current River	187	172
Upper Current River	117	28

Table 4. Number of sites (out of 60 sampled) and the total number of individuals in the Current River and Jacks Fork within Ozark National Scenic Riverways (OZAR) where either live mussels, shell material, or both, were observed, displayed by species. Size range (minimum–maximum) in mm of mussel length for live mussels observed. Data are from surveys in 2023 and 2024.

Species	Sites found live (number individuals)	Relative abundance live individuals (%)	Sites found shell material (number individuals)	Total number of sites	Size range observed (mm)
Arkansas Brokenray	25 (136)	22.3	16 (54)	28	34–69
Creeper	0 (0)	0.0	1 (1)	1	–
Fatmucket	1 (1)	0.2	0 (0)	1	37
Flat Floater	1 (1)	0.2	0 (0)	1	117
Flutedshell	0 (0)	0.0	3 (5)	3	–
Giant Floater	3 (43)	7.4	1 (2)	3	41–162
Ouachita Kidneyshell	11 (88)	15.2	14 (75)	18	34–95
Ozark Pigtoe	10 (59)	10.2	4 (16)	11	25–70
Paper Pondshell	10 (52)	9.0	8 (27)	11	22–92
Pondmussel	4 (21)	12.8	5 (21)	7	37–97
Purple Lilliput	2 (6)	1.0	1 (1)	3	25–38
Purple Wartyback	0 (0)	0.0	1 (5)	1	–
Western Rainbow	25 (120)	20.7	21 (98)	30	11–62

Mussel CPUE varied from 0 to 18.4 mussels detected per person hour across all sites, with a mean ($\pm$ standard error) of 2.1 ($\pm$ 0.5). Mussel density varied from 0 to 0.127 mussels detected per m² across all sites, with a mean ($\pm$ standard error) of 0.008 ($\pm$ 0.002). Mean CPUE in the Jacks Fork was nearly double that in the lower Current River and approximately 2.5 times greater than in the upper Current River (Table 5). Mean mussel density was similar in the Jacks Fork and lower Current River sections, and almost double that of density in the upper Current River (Table 5).

Table 5. Summary of catch per unit effort (CPUE; live mussels encountered per hour of search) and mussel density (live mussels observed per m²) in the Current River and Jacks Fork within OZAR from surveys in 2023 and 2024. Values indicate the number of sites sampled (n), mean and standard error (se), and range (minimum–maximum).

River section	n	CPUE (mean $\pm$ SE)	CPUE range	Density (mean $\pm$ SE)	Density range
Jacks Fork	18	3.4 (1.2)	0–18.4	0.010 (0.003)	0–0.04
Lower Current River	23	1.8 (0.7)	0–15.8	0.009 (0.005)	0–0.127
Upper Current River	19	1.4 (0.6)	0–9.3	0.005 (0.002)	0–0.038

Mussel Occupancy and Detection

We used data from 10 mussel species across the study system for our spatial multi-species occupancy model. Of the 15 candidate models, Model 12 had the lowest WAIC and was therefore selected as the most parsimonious model (Table 1). Model 12 included relative spring influence, off-channel habitat, their interaction, river identity, fine, loose, and large substrates, and riffle and glide/race habitats as occupancy covariates, with observer and search area included as detection covariates. For all parameters, chains converged well ($\hat{R} \approx 1.00$ –1.02), with suitable effective sample sizes (Table 6). The Bayesian p-value (0.45) indicated adequate model fit, suggesting that simulated data were consistent with the observed data.

Table 6. Community-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Metric	Parameter	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
Occurrence Means (logit scale)	(Intercept)	-3.71	0.91	-5.30	-3.78	-1.66	1.01	7047
	Rel_Spr_In	-1.76	0.48	-2.73	-1.75	-0.86	1.01	1915
	Off_Channel	0.61	0.42	-0.19	0.60	1.46	1.00	2372
	River	-0.35	0.84	-2.06	-0.34	1.28	1.00	3361
	Fine_Sediments	0.42	0.84	-1.23	0.45	2.02	1.00	438
	Loose_Sediments	-0.38	1.05	-2.44	-0.35	1.62	1.00	402
	Large_Sediments	-0.16	1.03	-2.19	-0.14	1.82	1.00	499
	Riffle	-0.89	0.49	-1.96	-0.85	-0.01	1.01	1362
	Glide_Race	0.43	0.34	-0.24	0.43	1.12	1.00	2535
	Rel_Spr_In:Off_Channel	0.14	0.37	-0.62	0.15	0.85	1.00	2931
Occurrence Variances (logit scale)	(Intercept)	7.54	7.83	1.29	5.32	27.13	1.01	2061
	Rel_Spr_In	0.85	1.23	0.05	0.45	4.06	1.00	1913
	Off_Channel	0.79	1.16	0.05	0.44	3.63	1.01	1363
	River	5.01	7.51	0.14	2.98	21.97	1.05	1088
	Fine_Sediments	0.47	0.71	0.04	0.27	2.12	1.02	3673
	Loose_Sediments	0.34	0.47	0.04	0.21	1.47	1.00	6389
	Large_Sediments	1.92	1.97	0.17	1.36	7.08	1.00	3045
	Riffle	0.42	0.60	0.04	0.24	1.88	1.01	4298
	Glide_Race	0.26	0.32	0.03	0.16	1.05	1.01	6032
	Rel_Spr_In:Off_Channel	0.47	0.68	0.04	0.27	2.16	1.02	3329
Detection Means (logit scale)	(Intercept)	-0.88	0.31	-1.56	-0.86	-0.33	1.01	2471
	Area	-0.41	0.28	-0.98	-0.40	0.13	1.00	11790
Detection Variances (logit scale)	(Intercept)	0.32	0.55	0.03	0.17	1.54	1.04	1678
	Area	0.43	0.66	0.04	0.25	1.91	1.01	7309
Detection Random Effect Variances (logit scale)	Obs	0.34	0.24	0.06	0.28	0.97	1.02	1362

Community-Level Responses

Occurrence

At the community level, mussel occurrence was generally low (intercept = -3.71 ± 0.91) (Table 6; Figure 6), suggesting low baseline occupancy across sites. Community-level occupancy probability, or occupancy considered across all species studied, declined strongly with increasing relative spring influence ($\beta = -1.76 \pm 0.48$), suggesting mussels were much less likely to occur in sites with high spring influence. Riffle habitat was also negatively associated with occupancy ($\beta = -0.89 \pm 0.49$), whereas off-channel and glide/race habitats showed weak, positive associations ($\beta = 0.61 \pm 0.42$ and $\beta = 0.43 \pm 0.34$, respectively), suggesting mussels tended to occur more frequently in off-channel and glide/race habitats (Table 6; Figure 6). All other community-level covariates had wide credible intervals overlapping zero, indicating uncertain or species-specific effects (Table 6; Figure 6).

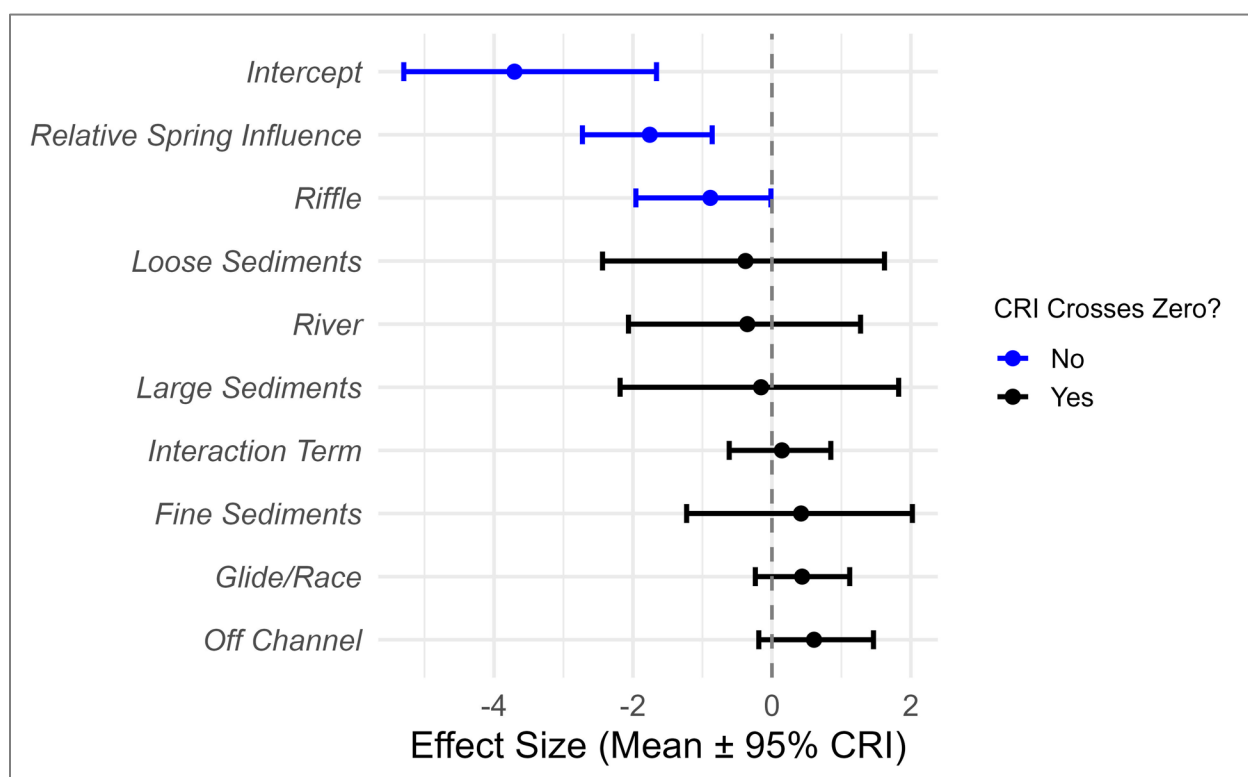


Figure 6. Effects of covariates on community-level occurrence, plotted on the logit scale. Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples. Interaction term indicates the interaction between relative spring influence and off-channel habitat.

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Detection

Community-level detection probability, or detection of a mussel when considered across all species, was moderate (intercept = -0.88 ± 0.31), corresponding to an estimated ~29% detection probability per survey (Table 6; Figure 7). Detection declined slightly with increasing search area ($\beta = -0.41 \pm 0.28$), and observer random effects indicated modest heterogeneity among surveyors ($\sigma^2 = 0.34$) (Table 6; Figure 7).

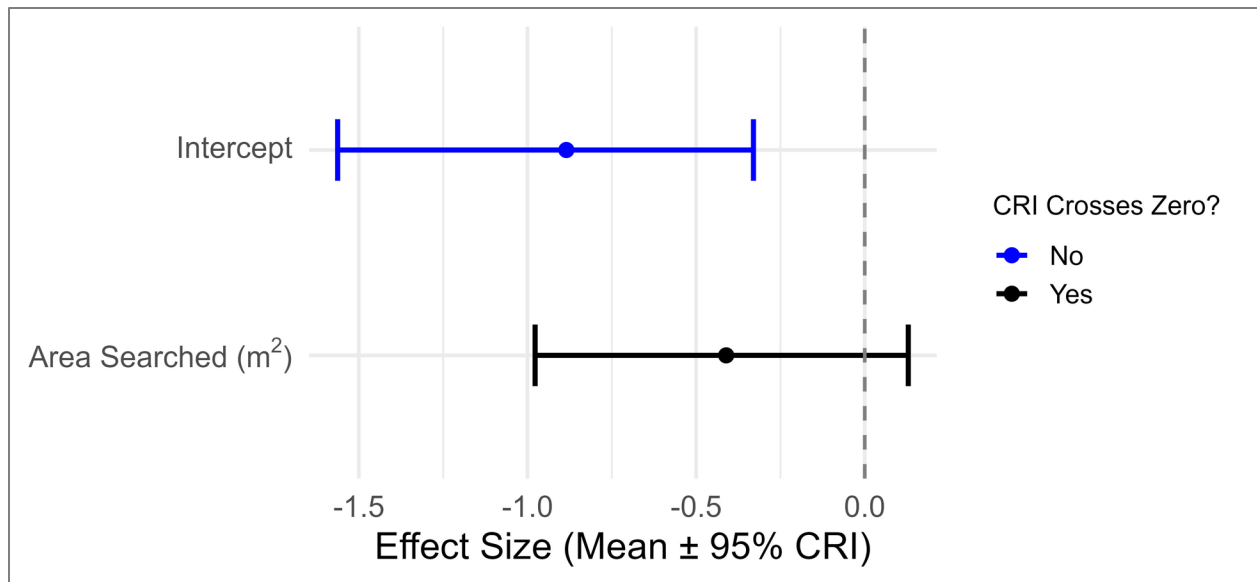


Figure 7. Effects of covariates on community-level detection, plotted on the logit scale. Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples.

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Species-Level Responses

Occurrence

Species-specific occupancy intercepts ranged from low (e.g., Flat Floater, -6.69 ± 1.69 ; Purple Lilliput, -6.06 ± 1.38) to relatively high (e.g., Western Rainbow, -1.47 ± 0.59 ; Arkansas Brokenray, -1.72 ± 0.84) (Appendix G; Figure 8). The mussels with the highest occurrence probabilities were Western Rainbow, Arkansas Brokenray, and Paper Pondshell (Figure 8).

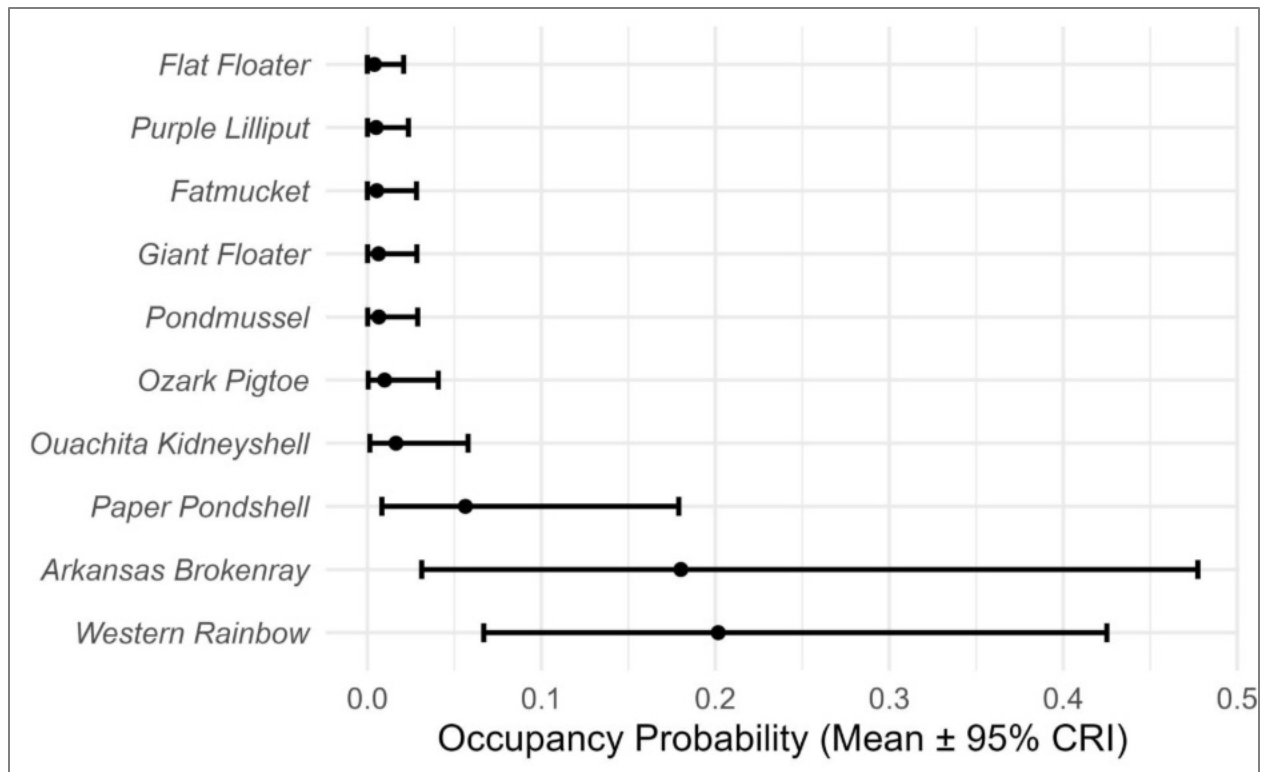


Figure 8. Species-specific occurrence intercepts, plotted on the probability scale. Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples.

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Most species exhibited negative associations with relative spring influence, consistent with the community-level pattern (Figure 9). Effects of off-channel habitats were generally positive for many species, particularly Paper Pondshell ($\beta = 1.29 \pm 0.91$) and Pondmussel ($\beta = 1.00 \pm 0.64$), though estimates were uncertain (Appendix G; Figure 9). Interestingly, the interaction effect between relative spring influence and off-channel habitats suggested that the strong negative effect of spring influence ($\beta = -1.76 \pm 0.48$) was modestly weaker in off-channel environments (interaction $\beta = 0.14 \pm 0.37$) (Appendix G; Figure 9). Several species (e.g., Western Rainbow, Paper Pondshell, Ouachita Kidneyshell, Giant Floater, Fatmucket) exhibited positive species-level interaction coefficients (Figure 9). Although credible intervals crossed zero, rendering the interaction effect uncertain, these patterns suggest that off-channel habitats may provide limited refuge from the detrimental effects of spring influence for some species.

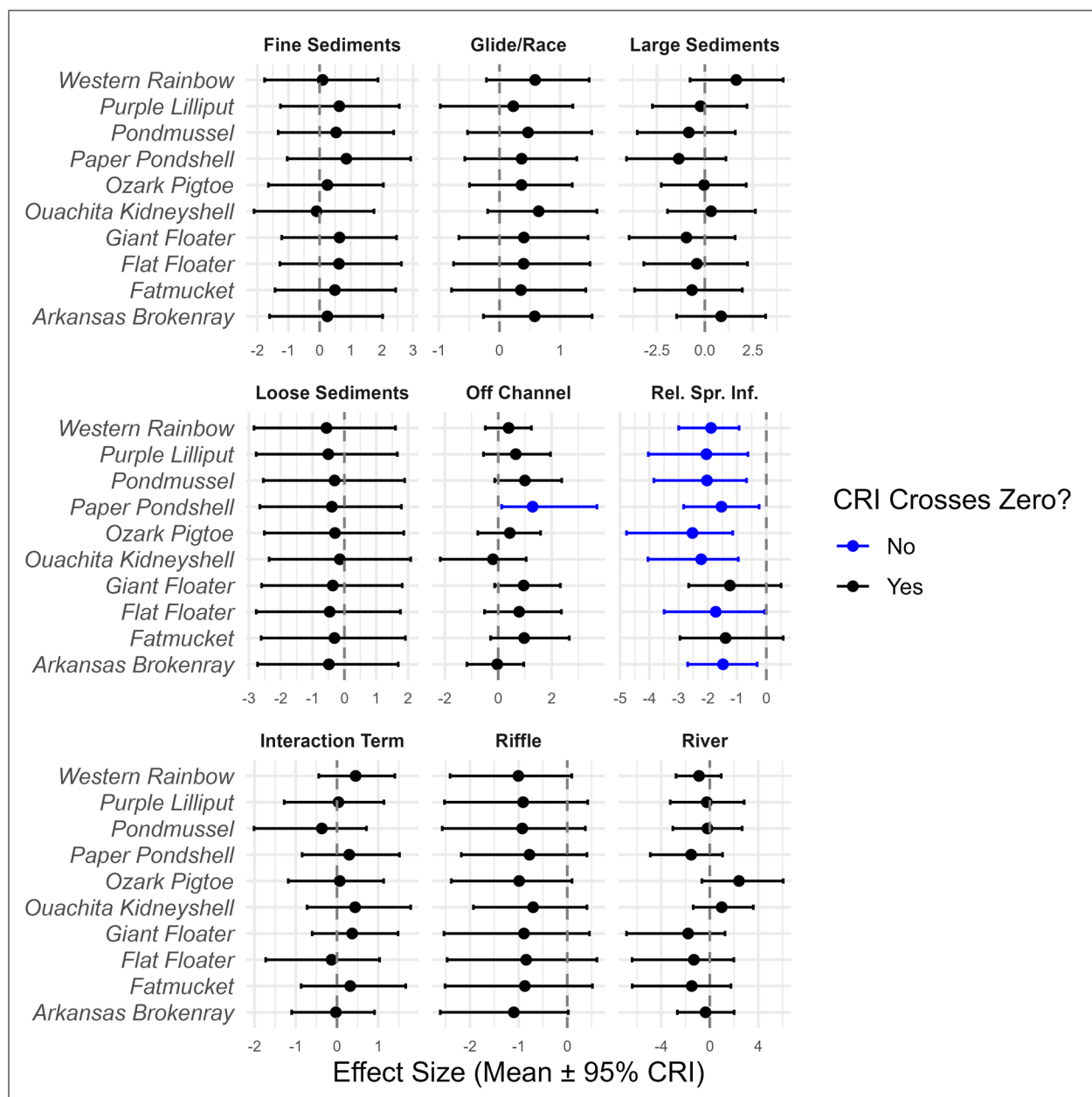


Figure 9. Effects of covariates on species-specific occurrence, plotted on the logit scale. The interaction term represents the effect of relative spring influence interacting with off-channel habitat. “River” is an indicator variable contrasting Jacks Fork (1) with the Current River (reference, 0). Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples.

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Substrate covariates like fine, loose, and large sediments showed variable or weak effects across species, although posterior distributions did suggest some species-specific effects (Figure 9). For example, although credible intervals crossed zero, Western Rainbow, Arkansas Brokenray, and Ouachita Kidneyshell were more likely to occur in habitats with large sediments, while the opposite was true for all other species (Figure 9). Again, although credible intervals crossed zero, most species

were more likely to occur in habitats with fine sediments, with the only exception being Ouachita Kidneyshell (Figure 9). Loose sediments uniformly exhibited negative associations with mussel occurrence, but with very large credible intervals indicating the covariate may not have been informative (Figure 9).

Channel unit covariates indicated some weak effects on mussel occupancy; riffles were negatively associated with occurrence for all species, whereas glides and races tended to increase occurrence probability (Figure 9). Additionally, most species occupancy did not differ between the Current River and the Jacks Fork. Although Ozark Pigtoe ($\beta = 2.41 \pm 1.72$) and Ouachita Kidneyshell ($\beta = 0.98 \pm 1.27$) were on average more likely to occur in the Jacks Fork, wide credible intervals indicated uncertainty (Appendix G; Figure 6). All other species showed weak, negative mean differences, indicating a potential association with the Current River (Figure 9). However, all credible intervals overlapped zero, suggesting no consistent or strong river-specific effects after accounting for habitat, hydrology, and detection covariates (Figure 9).

Detection

Average species-level detection per survey was variable but ranged from 26 to 34%, indicating low detection probability for our snorkel- and tactile-based mussel surveys in this system (Figure 10). Species with the highest detection probabilities were Ouachita Kidneyshell and Western Rainbow, though all species had wide credible intervals, suggesting uncertainty in detection estimates (Figure 10).

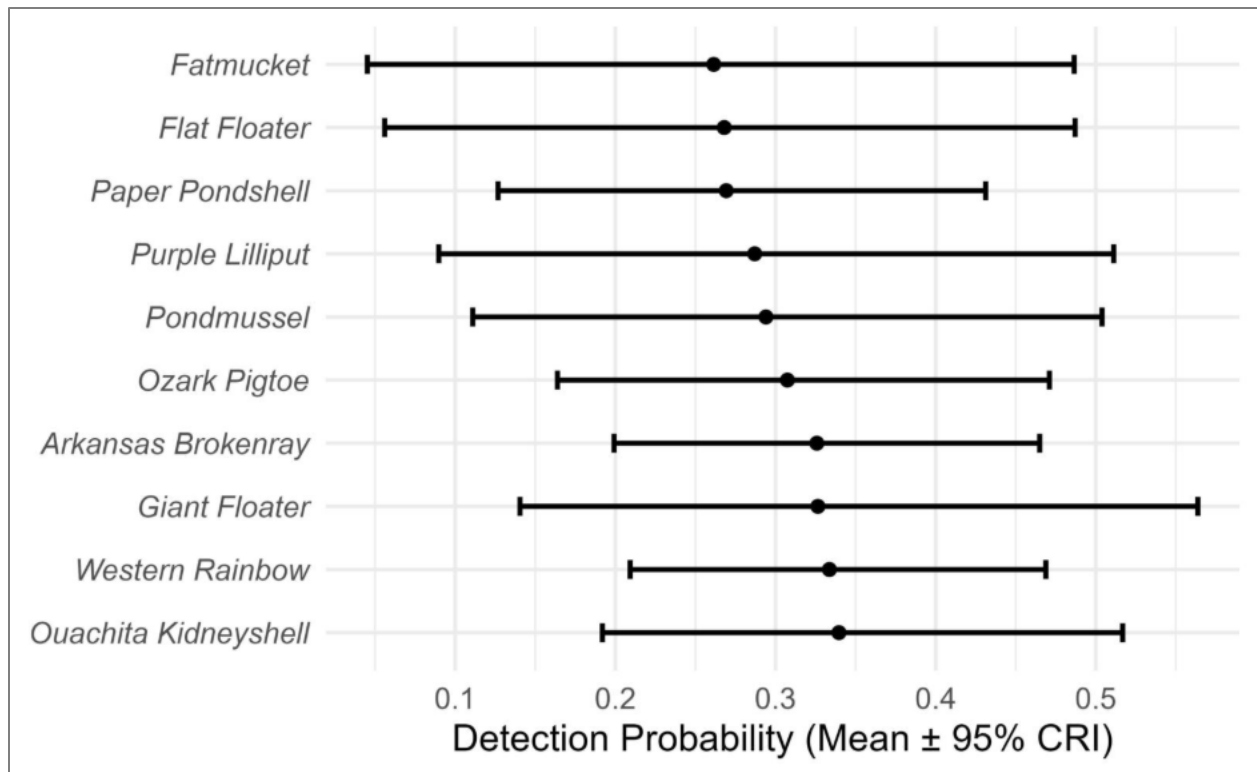


Figure 10. Species-specific detection intercepts, plotted on the probability scale. Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples.

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The effect of search area on detection was typically negative (Appendix G). Most species showed small to moderate negative coefficients, suggesting reduced detection with increasing searched area, although credible intervals overlapped zero for most taxa (Appendix G). Only Ouachita Kidneyshell and Pondmussel showed well-supported negative effects of increased search area, indicating reduced detection efficiency in larger patches for those species (Figure 11).

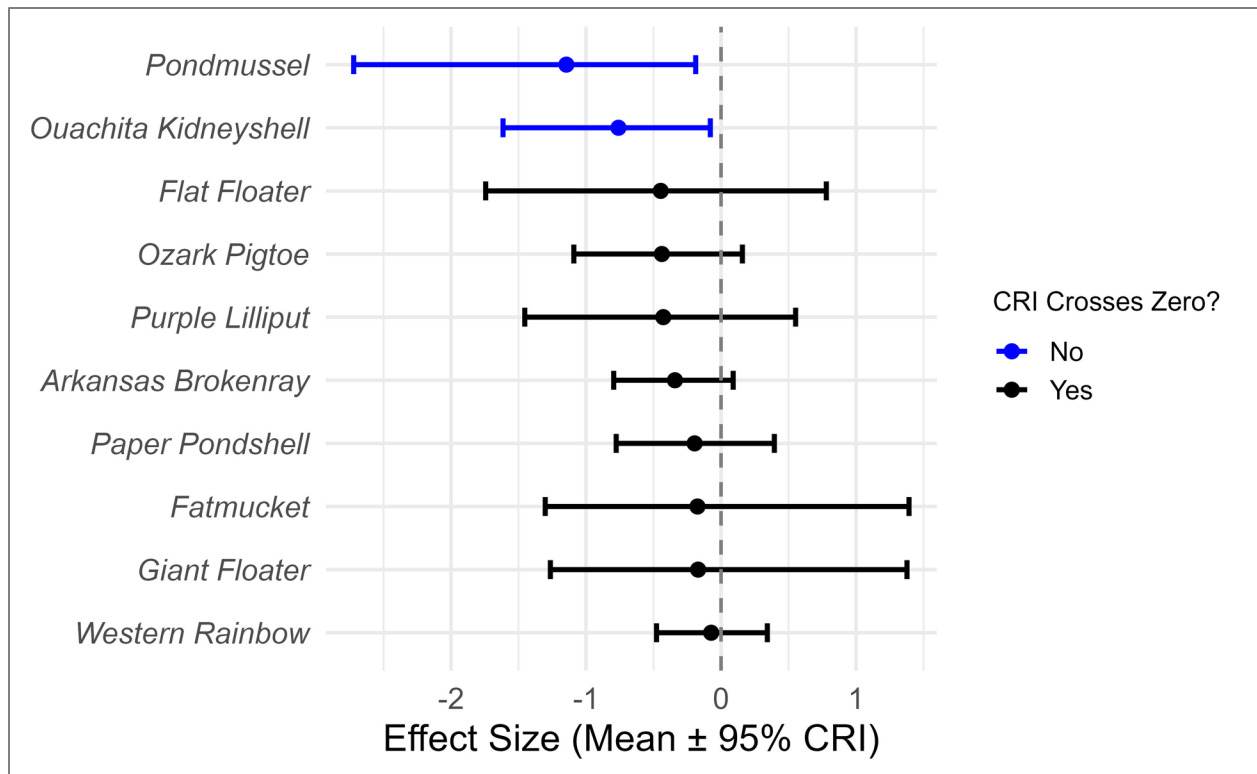


Figure 11. Effect of search area (m²) on species-specific detection, plotted on the logit scale. Points represent posterior means with 95% credible intervals (CRI) based on 30,000 posterior samples.

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Spatial Latent Factor Structure

The single spatial latent factor captured residual spatial autocorrelation in species' occupancy patterns after accounting for measured covariates. Loadings (λ) describe how closely each species' spatial distribution corresponds to that of Western Rainbow, which was fixed at $\lambda = 1.0$ as a reference.

Species with strongly positive loadings, including Arkansas Brokenray ($\lambda = 2.22 \pm 0.61$), Ouachita Kidneyshell ($\lambda = 1.50 \pm 0.55$), and Ozark Pigtoe ($\lambda = 1.28 \pm 0.55$), exhibited spatial patterns similar to Western Rainbow, suggesting co-occurrence in similar reaches, potentially those associated with main-channel or higher-flow habitats (Table 7; Figure 12).

Species with negative loadings, such as Pondmussel ($\lambda = -0.83 \pm 0.68$), Paper Pondshell ($\lambda = -0.73 \pm 0.69$), and Giant Floater ($\lambda = -0.74 \pm 0.79$), were more likely to occur in lentic areas where Western Rainbow was uncommon, (Table 7; Figure 12). Flat Floater ($\lambda = -0.38 \pm 0.78$) and Fatmucket ($\lambda = 0.20 \pm 0.85$) showed weak or ambiguous associations (Table 7; Figure 12).

Table 7. Posterior summaries of spatial factor loadings (λ) for each mussel species, including posterior mean, standard deviation (SD), and standard error (SE) estimates. Western Rainbow was used as the reference species ($\lambda = 1.0$).

Species ^A	Mean	SD	Naïve SE	Time-series SE
Western Rainbow-1	1	0	0	0
Flat Floater-1	-0.38	0.78	0.0045	0.0123
Ouachita Kidneyshell-1	1.50	0.55	0.0032	0.0099
Arkansas Brokenray-1	2.22	0.61	0.0036	0.0117
Fatmucket-1	0.20	0.85	0.0049	0.0183
Giant Floater-1	-0.74	0.79	0.0046	0.0164
Ozark Pigtoe-1	1.28	0.55	0.0032	0.0107
Paper Pondshell-1	-0.73	0.69	0.0040	0.0156
Pondmussel-1	-0.83	0.68	0.0039	0.0123
Purple Lilliput-1	0.45	0.72	0.0041	0.0131

^A -1 indicates one spatial latent factor, as described in the methods.

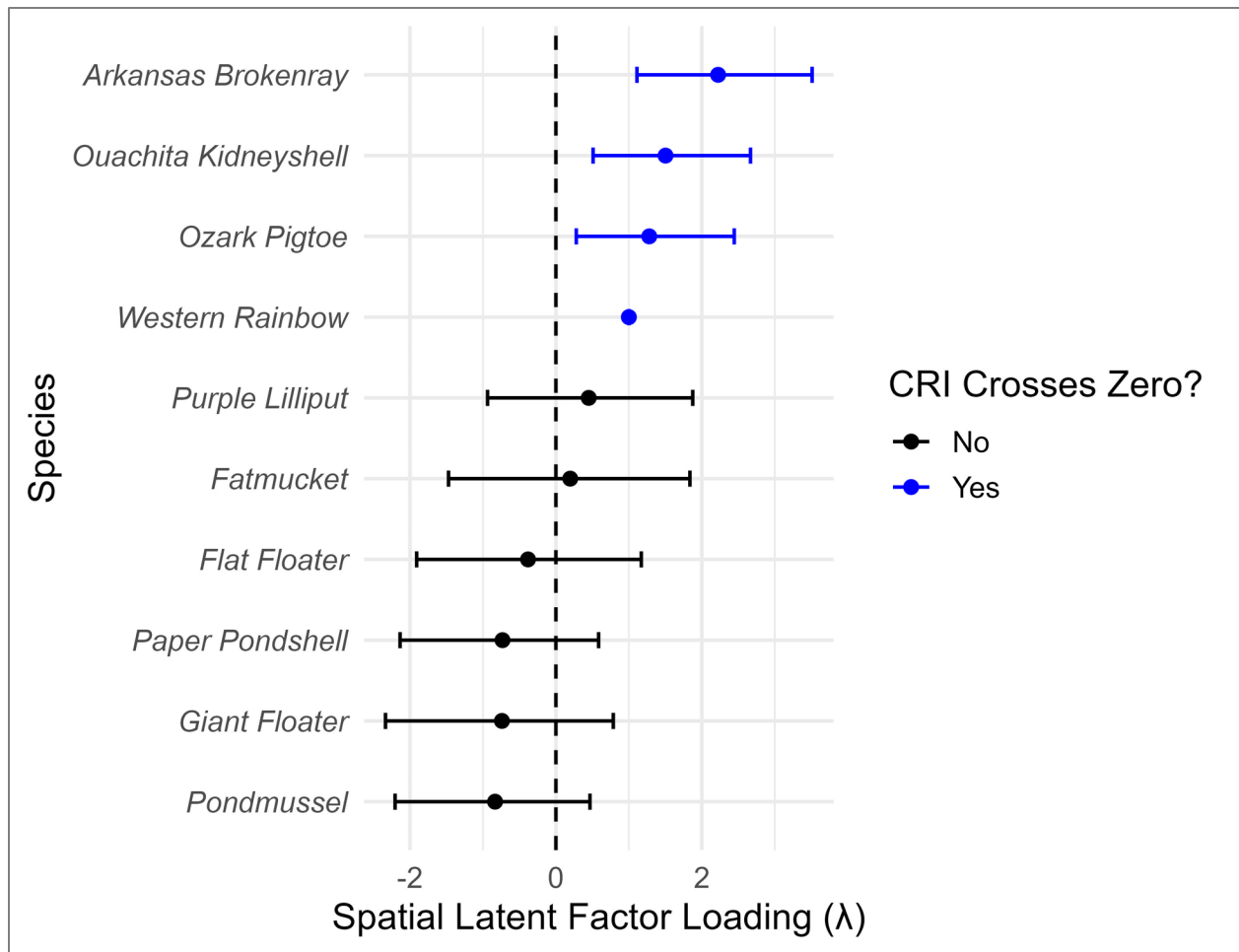


Figure 12. Spatial latent factor loadings (λ) for each mussel species. Values represent posterior means and 95% credible intervals (CRI) of spatial factor loadings (λ). Western Rainbow was used as the reference species ($\lambda = 1.0$).

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Mussel and Host Fish Linkages

The mean final host fish linkage index values calculated across all sections ranged from 0.16 to 0.89, showing a wide spread of host linkages within the system (Figure 13). Most (20 of the 25 species examined) had index values between 0.75 and 0.25. The two species with values >0.75 , Paper Pondshell and Arkansas Brokenray, appear to have strong populations of both the mussel and their host fish. The three species with index values <0.25 (Slippershell Mussel, Fragile Papershell, and Texas Lilliput) may have host linkage issues indicated by their low scores. When the weighted fish sub-index and weighted mussel sub-index components are displayed separately, the same three species <0.25 continue to show potential host fish issues as their weighted fish sub-index values are low (Figure 14). Additionally, low values for Pondmussel and Purple Wartyback in weighted fish sub-index component indicate possible low presence of known host fish, despite moderate values in the weighted mussel sub-index (Figure 14). Host fish relationship index scores displayed by river section reflect the limited mussel populations in the upper Current River (CRAA and CRBA) by the

typically low weighted mussel sub-index scores (Figure 15). A few species such as Arkansas Brokenray, Paper Pondshell, and Western Rainbow have scores ≥ 15 for both sub-indices in the upper Current River. However, low weighted fish sub-index scores for Pondmussel, Purple Wartyback, Round Pigtoe, and Fragile Papershell suggest their host fish may not be present or abundant in those sections of river (Figure 15). Weighted fish sub-index scores and weighted mussel sub-index scores were generally higher in the Jacks Fork and lower Current River, but Fragile Papershell, Slippershell Mussel, and Texas Lilliput all have low scores in both sub-indices (Figure 15).

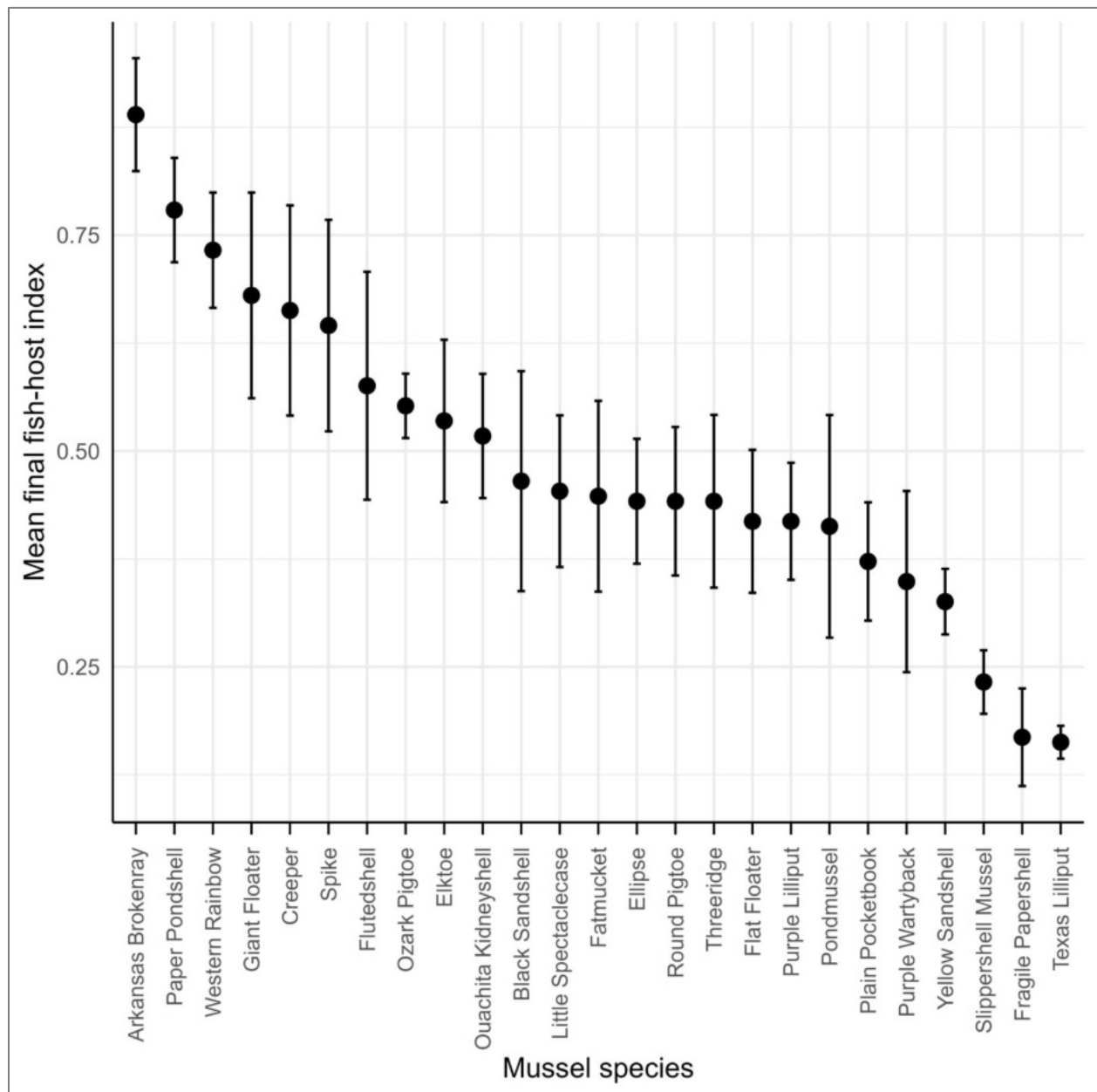


Figure 13. Mean ($\pm$ standard error) final host fish index values displayed for each species of mussel found in the Current River and Jacks Fork in the Ozark National Scenic Riverways.

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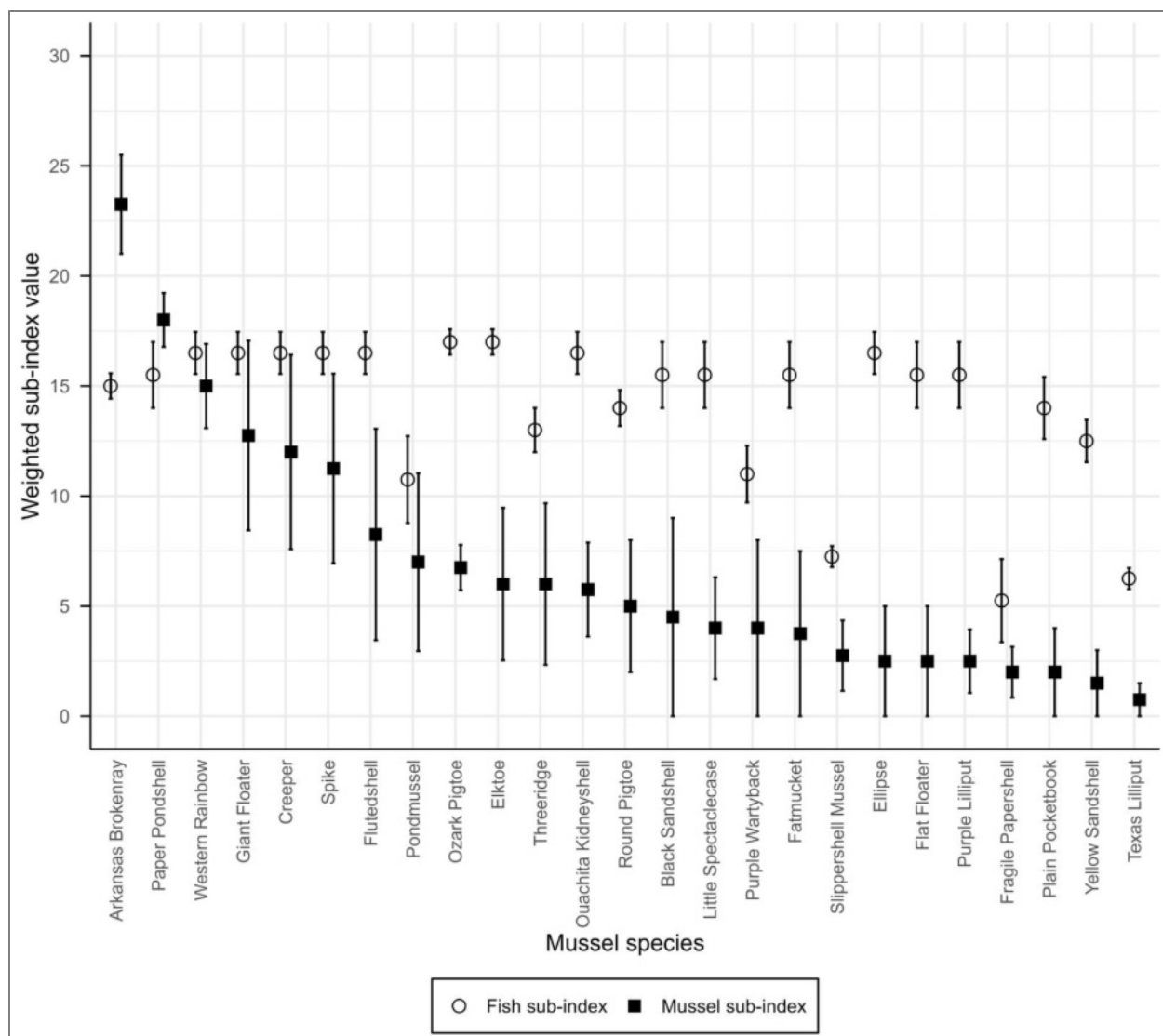


Figure 14. Mean ($\pm$ standard error) weighted sub-index values for the fish and mussel index components displayed for each species of mussel found in the Current River and Jacks Fork in the Ozark National Scenic Riverways. Open circles represent the fish sub-index and solid squares represent the mussel sub-index.

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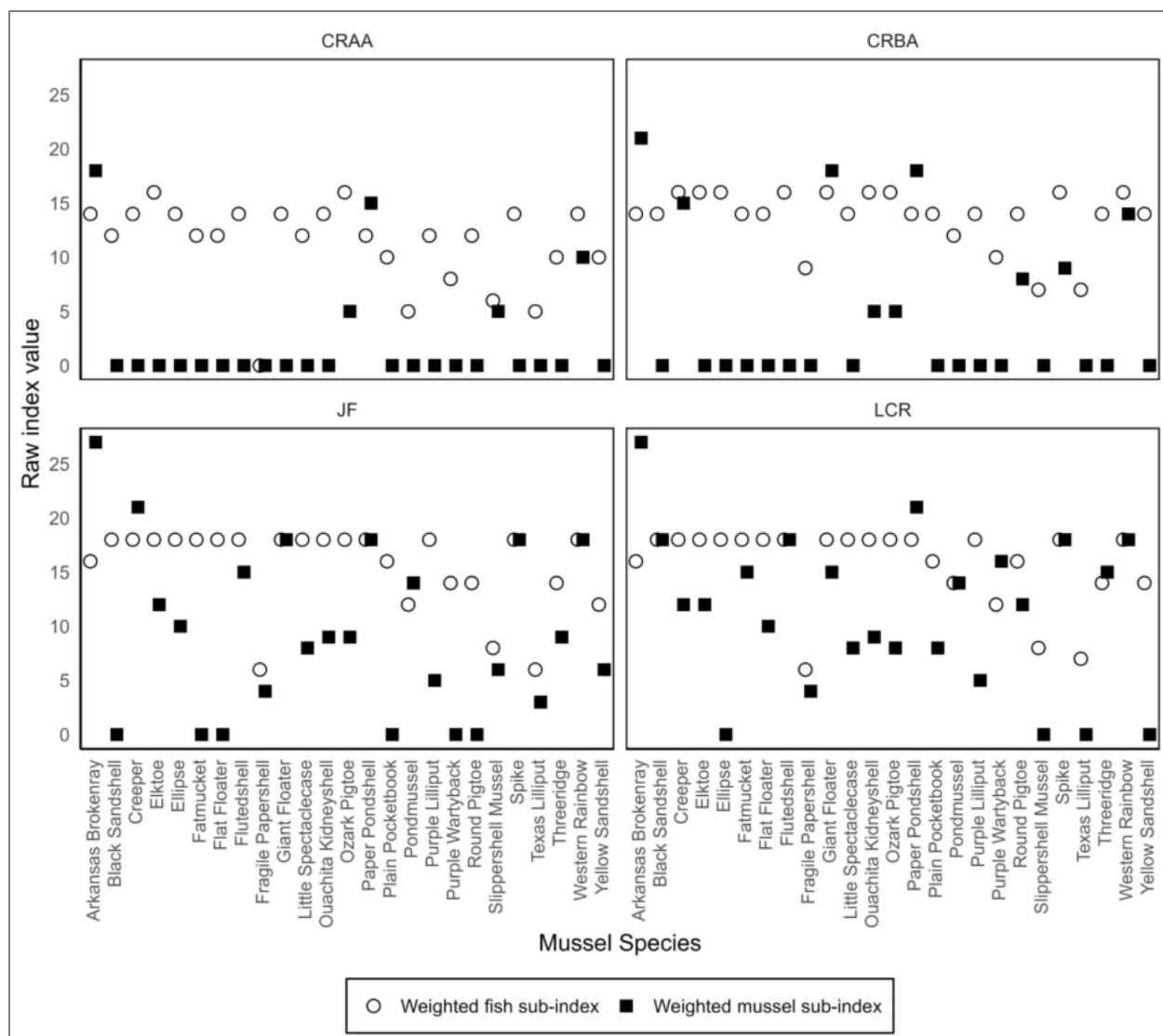


Figure 15. Raw index values for the weighted fish sub-index (open circles) and weighted mussel sub-index (solid squares) displayed for each species of mussel found in the four sections of Current River and Jacks Fork in the Ozark National Scenic Riverways. The four river sections are the mainstem Jacks Fork (JF), the lower Current River between the confluence of the Jacks Fork and the southern park boundary (LCR), the Current River below Akers Ferry to the confluence with the Jacks Fork (CRBA), and the upper Current River above Akers Ferry to Montauk (CRAA).

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Mussel species not known to occur within OZAR, but that do occur further downstream in the Current River appear to, for the most part, have known host fish documented in most sections of river in the park (Figure 16). Weighted fish sub-index scores were typically between 5 and 15 for these 12 mussel species, except for hosts for Bleufer and Pink Heelspliter appearing absent in the uppermost section of the Current River (Figure 16).

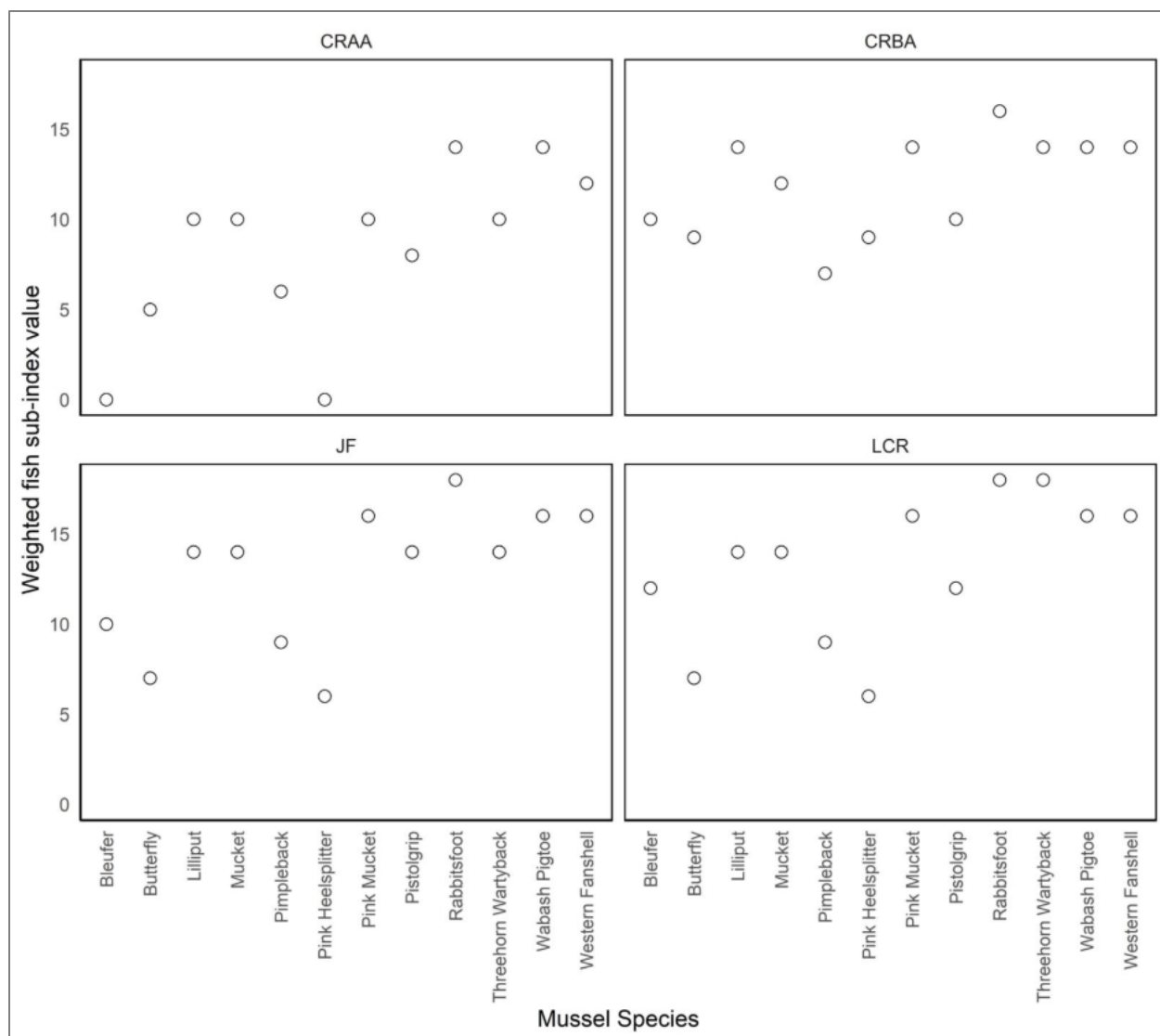


Figure 16. Raw index values for the weighted fish sub-index displayed for mussel species found only downstream of Ozark National Scenic Riverways (OZAR) in the Current River. The four river sections are the mainstem Jacks Fork (JF), the lower Current River between the confluence of the Jacks Fork and the southern park boundary (LCR), the Current River below Akers Ferry to the confluence with the Jacks Fork (CRBA), and the upper Current River above Akers Ferry to Montauk (CRAA).

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Discussion

Changes in Species and Assemblages

Historically, 22 mussel species were documented within OZAR across prior surveys. In our study, we did not detect any federally listed mussel species within OZAR. Given our low detection probabilities, it is possible they do exist within park boundaries but remain undetected. Of the seven mussel species with a state conservation status of S1–S3 (MDC 2025; Appendix A) that had been previously found alive in OZAR, we only detected Flat Floater, Ouachita Kidneyshell, and Purple Lilliput (Appendix E and F). Overall, we detected 13 of the 22 historically documented mussel species within OZAR. In the Jacks Fork, McMurray and Faiman (2023) documented 10 species during surveys in 2017–2019 and compared species presence to past samples. We documented shell material (no live specimens) of two species not encountered during the 2017–2019 Jacks Fork surveys, Flutedshell and Purple Lilliput. We did not observe four species in the Jacks Fork that McMurray and Faiman (2023) documented during their 2017–2019 surveys (Slippershell Mussel, Giant Floater, Spike, and Creeper). However, we detected Creeper (shell material) and Giant Floater (alive) in sites on the Current River during our surveys. Seven other species continued to go undetected in the Jacks Fork since at least 1982 (Elktoe, Threeridge, Yellow Sandshell, Fragile Papershell, Texas Lilliput, Fawnsfoot, and Round Pigtoe) and a ninth (Little Spectaclecase) since 2002. McMurray and Faiman (2023) concluded that CPUE, number of live individuals, species richness, and diversity were all lower in recent samples compared to past samples. Our results suggest possible continued decline with even fewer species encountered and lower CPUE values (3.4) compared to the 2017–2019 surveys (CPUE = 14.6). However, our results are not directly comparable to past efforts as our sampling was restricted to random locations and past surveys were conducted primarily at locations known to harbor mussels or in high quality mussel habitat. Like in past surveys, upstream reaches of the Jacks Fork typically contained more mussels than downstream reaches (McClane Environmental Services 2004; McMurray and Faiman 2023). Upstream reaches in the Jacks Fork tend to have larger, more stable substrate than the lower river, which may provide a favorable environment for mussel persistence.

In the Current River, the most recent comprehensive survey was completed in 2002 (McClane Environmental Services 2004). They documented 16 species (12 live and 4 shell-only) from the Current River, compared to the 13 species (10 live and 3 shell-only) in our survey. Of the 6 most abundant species encountered alive by McClane Environmental Services (2004), we did not detect Round Pigtoe at all and only detected shell material at one site for Purple Wartyback. We did detect live specimens of Fatmucket, which were not found in the 2002 surveys. However, we did not observe five species during our surveys (Black Sandshell, Little Spectaclecase, Round Pigtoe, Spike, and Threeridge) that were present in the 2002 surveys. Direct comparison of results between our surveys and the 2002 surveys should be done with caution, as the 2002 surveys targeted known mussel locations and used a wider variety of sampling methods, including methods that allowed for sampling of water deeper than 1 m (McClane Environmental Services 2004). Similar to past surveys in the Current River (McClane Environmental Services 2004), mussel richness and abundance were higher in the middle and lower reaches as compared to the upper reaches of the Current River.

Environmental Covariates and Mussel Occupancy

At the mussel community level in OZAR, our models showed a negative relationship with high spring influence reaches or with a high percentage of riffle habitat, but a positive relationship with off-channel and glide or race habitats. We do not know the mechanism that may be causing the negative relationship between spring influence and mussel occupancy, but there are various characteristics of these highly spring influenced reaches to consider. These reaches are typically cooler in the summer months and warmer in the winter months (Westhoff and Paukert 2014b), and thus the optimal growth range for many mussel species present in the system may not be realized in spring dominated reaches. Data on the thermal traits of freshwater mussels is limited, so further exploration of this mechanism may require additional study (Fogelman et al. 2023; Hopper et al. 2023). Mussels are known to ingest bacteria, algae, detritus, zooplankton, and dissolved organic matter (Vaughn et al. 2008), and it is possible that spring dominated reaches contain lower levels of these food resources compared to areas of the stream more heavily influenced by runoff from terrestrial sources. Similar to our findings, springs in Florida have low diversity and relative abundance of freshwater mussels compared to non-springs and areas with less spring influence (Walsh and Williams 2003). In other systems, spring influence is known to be positive for some species of mussels as it can mediate extreme temperatures, provide predictable flow, and buffer chemical attributes of surface water (Briggs et al. 2013; Holcomb et al. 2018).

We also found that riffle habitats had a negative, although weak, relationship with mussel occupancy. This, along with the species-level patterns of loose sediment (sand, gravel, and cobble) suggesting lower occupancy, indicated that less stable bed conditions may limit mussel persistence in some unstable reaches in OZAR. Unstable streambed conditions are hypothesized to limit mussel presence and abundance (Strayer 1999). Disturbance created by shifting substrates during high flows may bury mussels or displace them into unsuitable areas. There are documented disturbance reaches in OZAR that are defined by unstable and shifting substrate, in addition to waves of gravel moving downstream through the system that are a result of past land use practices (Jacobson and Gran 1999). The positive relationship with large sediments and glide or race habitat may indicate that those areas are more stable and thus support higher mussel occupancy. However, there is evidence that some mussel beds may persist despite bed-altering flow events that rearrange substrates and that flow refugia alone does not explain mussel presence (Randklev et al. 2019; Sansom et al. 2018).

Off-channel habitat was generally positive for mussel species occupancy, especially for species like Paper Pondshell and Pondmussel that typically occur in more lentic environments with fine sediment. Well-connected off-channel habitats in other systems are known to be favorable for freshwater mussels (Zigler et al. 2008) and may offer increased food resources or areas of flow refugia that are outside of coarse sediment routing paths. Additionally, the interaction we observed between off-channel habitat and spring influence suggested that off-channel habitats in highly spring dominated stream reaches may function differently and allow for greater mussel occupancy than otherwise observed. Our spatial latent factor results suggested two primary assemblages. The first was a main-channel group with high positive loadings (Western Rainbow, Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe) and the second was a backwater/floodplain group with negative loadings (Paper Pondshell, Pondmussel, Giant Floater). This reflects what we observed in the field anecdotally

and could have management implications. The distinct assemblages might require targeted management interventions and could be susceptible to different disturbances.

Other covariates we included did not appear to have significant effects on mussel occupancy. However, we used a limited suite of environmental covariates, and it is possible there are other important drivers for mussel occupancy in the system. We did not sample many deep habitats and although it was stated that deep pools likely do not contain mussel habitat (McClane Environmental Services 2004), we may have missed part of the mussel community that use these habitats because of this limitation and given that there were many areas up to 4 m deep in some pools.

Host Fish Linkages

Our index-based approach to examine linkages among freshwater mussels and their host fish suggested that most mussel species have adequate host fish presence in OZAR. Some of the more common host fish present in the Current River system include Smallmouth Bass, Logperch, White Crappie, Banded Sculpin, and several species of darter (Appendix D). Several of the mussel species that occur primarily in the lower Current River have mostly lentic fish species as their hosts, which may contribute to the lower prevalence of these mussel species in OZAR, especially in the upper Current River where water velocities and spring influence are greater. Other species such as Ellipse and Black Sandshell appear to have ample host fish presence but are uncommon in the system and are likely being restricted by factors other than host fish problems. Reforestation within the Current River watershed may be responsible for shifting historic fish communities to support more benthic fishes (Morrill et al. 2023), which may ultimately benefit many species of mussels in OZAR. It is also possible that mussels mostly do not occur in large aggregations in the Current River system. In that case, rare species with fewer hosts may struggle to encounter those hosts for infection because other mussel species are not nearby to attract hosts as well (Rashleigh 2008).

Freshwater Drum serve as potential hosts to at least nine of the mussel species that occur in the Current River drainage in Missouri yet are rare in OZAR. Eleven of the 12 records for Freshwater Drum in the Current River system were from before 1980, and there was only one record in the Jacks Fork. It is possible that the lack of Freshwater Drum records in the watershed is a reflection of low detection during fish sampling surveys. However, if this is not the case, it may be problematic for Fragile Papershell as Freshwater Drum are the only known host fish that occur in the Current River drainage. The only live record of Fragile Papershell was from 1982 in the Jacks Fork, and there was one observation of shell material in 2002 from the lower Current River. Freshwater Drum are not common in most Ozarks streams and prefer larger rivers with deep pool habitat (Pflieger 1997), so their low abundance in the system may be natural but limiting to some freshwater mussel species (Haag and Stoeckel 2015).

We did not detect Slippershell Mussel in our survey, but records of the species from the 1970s are in highly spring-fed sections of river most likely to harbor their known host fishes, Brown Trout and Banded Sculpin. Brown Trout have been stocked for recreational fishing in the upper Current River and are not native to the system. Banded Sculpin typically occur in spring dominated sections, but are perhaps more tolerant of warmer waters compared to other sculpin species found in Missouri

(Pflieger 1997). This may explain the two records, including one from 2017, of Slippershell Mussel in the upper Jacks Fork where spring influence is not as strong.

The other freshwater mussel species we identified as potentially having host fish linkage issues were Texas Lilliput, Pondmussel, and Purple Wartyback. These three species have different host fish (Appendix D), but most known hosts are typically associated with deeper water and slower current velocities that are not common in the upper sections of the Current River or Jacks Fork. It is also possible that these mussel species are not commonly found in mussel surveys in OZAR because they and their host fish typically use deeper water with slower current velocities that were under-sampled in mussel surveys. There has also been a shift from Ozark centrarchids (e.g., Smallmouth Bass and Longear Sunfish) to more generalist centrarchids (e.g., Spotted Bass, Bluegill) in the Current River watershed (Morrill et al. 2023), which may cause a mismatch among coevolved local mussel populations and their host fish (Hewitt et al. 2024).

Our host fish index method should be considered a coarse screening tool as it is based on available data for both fish and mussels in the system. Data within the Freshwater Mussel Host Database are biased both in species coverage and towards the inclusion of physiological hosts (Hopper et al. 2025). Host fish relationships with mussels are not well known for many species, so additional unknown host fish species may be present in the system and some of the documented host fish species present may not serve as viable hosts in the Current River. One example of this could be Slippershell Mussel where the two known host fish, Brown Trout and Banded Sculpin, are very different and thus may suggest the species could be generalist in their host requirements. Additionally, many of the host relationships in the database we used are from laboratory studies and may not indicate host use *in situ*. Our index somewhat accounted for this limitation but may still provide misleading results given the uncertainty. The collection dates of both mussels and fish data were coarsely matched by our index, but outdated records may result in mismatches occurring that would affect the index accuracy. More robust data on fish and mussel abundance, along with better spatial coverage and more recent observations could improve the performance of the index.

Limitations of Approach

Our sampling approach emphasized random selection of sampling sites whereas past surveys in OZAR focused heavily on known locations of past mussel occurrence. This likely resulted in us sampling areas less suitable for mussels and resulted in lower CPUE and species richness estimates than previous samples. One advantage to random site selection is the opportunity to sample in habitat conditions and at locations that would otherwise not be selected based on targeted surveys alone. This could allow for detection of species that do not follow typical distribution or habitat use patterns, but it also disperses sampling effort away from habitat locations that may be more likely to produce high densities of mussels or more species detections. Our detection results suggested that increasing search area may reduce the likelihood of encountering individuals, which is likely a result of the patchy distribution of species in unsuitable areas. This supports the idea that sampling regimes that target optimal mussel habitat may lead to overestimating occurrence probabilities and abundances, which could be detrimental to conservation efforts. Another advantage of our random approach to site selection is the ability to extrapolate our results throughout the system. Finally,

detection of long-term trends in populations can be biased if site selection is based on known abundances (Fournier et al. 2019), so our random approach at the site level reduced this potential bias.

The choice of how much effort to expend at a site and what methods to use when sampling freshwater mussels comes with many tradeoffs. Our decision to survey areas within a site that appeared better for mussels may have biased our estimates by reducing our ability to incorporate areas without mussels. However, we had to weigh the decision of including a degree of randomness with the reality of detecting at least some mussels given a true random approach can result in extremely low CPUE (Skorupa et al. 2024). Metcalfe-Smith and Di Maio (2000) conducted timed searches of 4.5-person-hours and found that species richness and the detection of rare species increased with an increase in person-hours. Individuals of common, uncommon, and rare species were detected in the first two time-intervals of the survey (0–1.5 person hours, and 1.5–3 person hours). However, no additional individuals of common or uncommon species were detected in the third time-interval portion of the surveys (between 3 and 4.5 person hours), whereas 29% of the rare species individuals were detected during this time (Metcalfe-Smith and Di Maio 2000). Our methods allotted 4.5 person hours per site, so our methods should have detected most species, even rare ones, if present.

The timed search method we used was intended to maximize species detection but was not the ideal method for determining mussel density, age-structure, or detecting small mussels that bury into the substrate (Strayer and Smith 2003). We did detect 10 individuals less than 30 mm in length, so we could reasonably have detected adults of any species of mussel in the system. Quadrat sampling is better suited to determine these metrics but is time intensive (Strayer and Smith 2003). Accurate and precise density estimates from quadrat samples require a level of sampling intensity that was not attainable while also achieving robust detection/non-detection data throughout the study timeframe. Our density estimates provide a reasonable estimate of mussel density, but almost certainly underrepresent true values as juvenile mussels, endobenthic mussels, and other cryptic species are known to be under-sampled by visual surveys (Strayer and Smith 2003). Timed search methods detect more mussel species than quadrat methods (Vaughn et al. 1997), which met our objective of maximizing detection of a broad range of mussel species.

Although various researchers have conducted freshwater mussel surveys using occupancy estimation (Scully-Engelmeyer et al. 2023; Shea et al. 2013; Wisniewski et al. 2014), the approach has perhaps not been as widely adopted as for other aquatic taxa (Kellner and Swihart 2014). In our context, we sought to establish a baseline survey method that is repeatable through time to track occupancy as a state variable to observe trends in mussel populations throughout OZAR. Our efforts addressed this objective, but there are limitations, and different approaches may benefit future freshwater mussel surveys in OZAR and in other systems.

Occupancy estimation requires either temporal or spatial replication, both of which must meet assumptions for the approach to be unbiased (MacKenzie et al. 2018). For temporal replication, the occupancy status of each site must be constant over all sampling periods (temporal closure), species

cannot be falsely detected, and surveys must be independent. For spatial replication, instead of surveying the same locations at a different times, researchers sample multiple locations within a larger site on the same occasion. This helps to avoid violating the temporal closure assumption but requires that if the species is present anywhere within the larger site, it must be available to be detected at the locations sampled as spatial replicates (spatial closure). This assumption is difficult to meet if areas of differing habitat are sampled as spatial replicates at the same site. For our 45-minute surveys that served as spatial replicates, it was difficult to sample homogenous habitats across the three replicates. Thus, our detection estimates may be biased high, and our occupancy estimates were likely less accurate had the spatial closure assumption been completely met. Shorter visual surveys that cover less area and are restricted to homogenous habitat patches that are likely to have equal probability of mussel occupancy throughout could address this shortcoming. However, if shorter surveys are completed, more surveys would be required to better estimate occupancy.

The use of temporal replication is not a simple solution to the spatial closure issue when sampling freshwater mussels. For freshwater mussels, the individual must often be removed from the streambed to be identified. If an individual is removed during the first survey, it is not available for detection in subsequent surveys which violates the assumption of temporal closure. Even if the individual is replaced before the next survey, it may be easier to detect because its presence is known by the sampling crew and it is almost certainly not put back in the same exact location and position as when it was found. This violates an assumption of equal detection. Researchers could conduct follow-up surveys days or weeks later which may allow sampled mussels more time to return to natural positions, but doing so requires multiple site visits, which can be prohibitively costly.

One adaptation to our sampling design that may avoid violating assumptions is to implement a higher number of shorter surveys covering more homogenous habitats within each survey. Then, instead of sampling sites as spatial replicates, one surveyor could sample the area, only count mussels observed, and identify only those mussels that can be identified without full removal from the substrate (e.g., gently pull mussel out far enough to potentially identify it underwater and put it back in the same position where it was). Next, a second surveyor could sample the same exact area and physically remove all mussels observed to ensure accurate species identification. The benefit of this approach is to avoid violating closure assumptions, but the downside is mussels observed in the first survey may not be identified if they are also not observed in the second survey. This approach would work best if the presence of any species of mussel is a useful occupancy metric but may not work as well for occupancy of specific mussel species within a larger assemblage. Another benefit of this approach is that site-level habitat covariates would be more closely tied to mussel occupancy and detection, thus allowing for more robust covariate relationships to be modeled as compared to surveys that occur over more heterogeneous areas. Finally, this approach allows for temporal replication during a single visit to the site. To further simplify sampling logistics and provide broader sampling coverage of available habitat conditions, sites could be randomly selected using GRTS approaches, but once researchers are on site, they could select multiple different habitat patches to sample in that location. This would require the occupancy models to consider spatial factors as we have.

Conclusion

Our survey of freshwater mussels in OZAR provided updated occurrence records and new locations for 13 species. However, several species of mussels were undetected by our surveys, suggesting potential population extirpations or declines, which further supports past hypotheses of mussel decline in the system (McMurray and Faiman 2023). All previous freshwater mussel sampling, including this study, had biases and may not have detected all species in all habitats. Additional sampling, especially standardized sampling over time, may help to elucidate population trends. Our methods, and the modifications we discussed, provide a starting point for future survey efforts in OZAR.

We found that occupancy of freshwater mussels within OZAR is negatively influenced by springs and shifting, medium-sized substrate. However, off-channel habitats may contain larger populations of a subset of species, and larger, more stable substrates in-channel may support mussels, albeit at low densities. We did not encounter large mussel beds with hundreds or thousands of freshwater mussels as occur in some other Ozark streams of similar size.

Although a few freshwater mussel species in OZAR may lack robust populations of host fish, most species have many potential hosts present in the system. The upper section of the Current River has the lowest abundance of mussels and host fish. The lower section of the Current River has more mussel diversity and habitat more conducive to many host fish that are more abundant in deeper, slower water.

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Appendix A.

Table 8 summarizes the common and scientific names, occurrence status within Ozark National Scenic Riverways, recent observation records, and conservation rankings for the 36 freshwater mussel species known from the Jacks Fork and Current rivers in Missouri.

Table 8. Common and scientific names of the 36 species of freshwater mussels known to occur in the Jacks Fork or Current rivers in Missouri. The 23 species indicated with a superscript “A” have been located alive within the boundaries of the Ozark National Scenic Riverways (OZAR). This includes the 22 species known to occur there prior to the 2023–2024 survey and Fatmucket, which was found alive within OZAR for the first time in 2023. Bleedingtooth Mussel (*Venustaconcha pleasii*) was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. The year of the most recent observation of a live specimen in the Current River drainage within Missouri is also noted. Conservation status of each species is indicated by either “S” for state ranks assigned by the Missouri Natural Heritage Program or “G” for global ranks assigned by the Natural Heritage/Conservation Data Center and/or NatureServe. Numbers following state or global designation indicate the degree of imperilment (1 is Critically Imperiled; 2 is Imperiled; 3 is Vulnerable; 4 is Apparently Secure; 5 is Secure). The abbreviation of “SE” indicates the species is state endangered in Missouri and “FE” indicates the species is federally endangered or “FT” indicates federally threatened as defined by the U.S. Endangered Species Act. Freshwater mussels with no listed status are either ranked as “apparently secure” or “secure” at both the state and global levels. Conservation status was obtained from the 2025 Missouri Department of Conservation Species of Conservation Concern Checklist https://mdc.mo.gov/sites/default/files/2024-03/SOCC%20Checklist%202024_ADA_0.pdf (MDC 2025).

Common name	Scientific name	Most recent observation	Conservation status
Arkansas Brokenray	<i>Lampsilis reeveiana</i>	2024	–
Black Sandshell ^A	<i>Ligumia recta</i>	2002	S2, G4G5
Creeper ^A	<i>Strophitus undulatus</i>	2017	–
Fatmucket ^A	<i>Lampsilis siliquoidea</i>	2023	–
Flat Floater ^A	<i>Utterbackiana suborbiculata</i>	2023	S2, G5
Flutedshell ^A	<i>Lasmigona costata</i>	1982	–
Fragile Papershell ^A	<i>Potamilus fragilis</i>	1982	–
Giant Floater ^A	<i>Pyganodon grandis</i>	2023	–
Little Spectaclecase ^A	<i>Leaunio lienosus</i>	2002	S3, G5
Ouachita Kidneyshell ^A	<i>Ptychobranhus occidentalis</i>	2024	S3, G3G4
Ozark Pigtoe ^A	<i>Fusconaia ozarkensis</i>	2024	–
Paper Pondshell ^A	<i>Utterbackia imbecillis</i>	2023	–
Plain Pocketbook ^A	<i>Lampsilis cardium</i>	1982	–
Pondmussel ^A	<i>Sagittunio subrostratus</i>	2023	–
Purple Lilliput ^A	<i>Toxolasma lividum</i>	2023	S1, G3
Purple Wartyback ^A	<i>Cyclonaias tuberculata</i>	2002	–

^A Species that have been located alive within the boundaries of OZAR.

Table 8 (continued). Common and scientific names of the 36 species of freshwater mussels known to occur in the Jacks Fork or Current rivers in Missouri. The 23 species indicated with a superscript “A” have been located alive within the boundaries of the Ozark National Scenic Riverways (OZAR). This includes the 22 species known to occur there prior to the 2023–2024 survey and Fatmucket, which was found alive within OZAR for the first time in 2023. Bleedingtooth Mussel (*Venustaconcha pleasii*) was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. The year of the most recent observation of a live specimen in the Current River drainage within Missouri is also noted. Conservation status of each species is indicated by either “S” for state ranks assigned by the Missouri Natural Heritage Program or “G” for global ranks assigned by the Natural Heritage/Conservation Data Center and/or NatureServe. Numbers following state or global designation indicate the degree of imperilment (1 is Critically Imperiled; 2 is Imperiled; 3 is Vulnerable; 4 is Apparently Secure; 5 is Secure). The abbreviation of “SE” indicates the species is state endangered in Missouri and “FE” indicates the species is federally endangered or “FT” indicates federally threatened as defined by the U.S. Endangered Species Act. Freshwater mussels with no listed status are either ranked as “apparently secure” or “secure” at both the state and global levels. Conservation status was obtained from the 2025 Missouri Department of Conservation Species of Conservation Concern Checklist https://mdc.mo.gov/sites/default/files/2024-03/SOCC%20Checklist%202024_ADA_0.pdf (MDC 2025).

Common name	Scientific name	Most recent observation	Conservation status
Round Pigtoe ^A	<i>Pleurobema sintoxia</i>	2002	–
Slippershell Mussel ^A	<i>Pressodonta viridis</i>	2017	S2, G4G5, SE
Spike ^A	<i>Eurynia dilatata</i>	2018	–
Texas Lilliput ^A	<i>Toxolasma texasiense</i>	1973	S3, G4
Threeridge ^A	<i>Amblema plicata</i>	2002	–
Western Rainbow ^A	<i>Cambarunio hesperus</i>	2024	–
Yellow Sandshell ^A	<i>Lampsilis teres</i>	1967	–
Bleufer	<i>Potamilus purpuratus</i>	2018	–
Butterfly	<i>Ellipsaria lineolata</i>	1982	–
Elktoe	<i>Alasmidonta marginata</i>	2002	S2, G4
Ellipse	<i>Venustaconcha ellipsiformis</i>	1975	–
Mucket	<i>Ortmanniana ligamentina</i>	1982	–
Pimpleback	<i>Pustulosa pustulosa</i>	1982	–
Pink Heelsplitter	<i>Potamilus alatus</i>	1975	–
Pink Mucket	<i>Lampsilis abrupta</i>	1982	S2, G1G2, FE
Pistolgrip	<i>Quadrula verrucosa</i>	1969	–
Rabbitsfoot	<i>Theliderma cylindrica</i>	1982	S1, G3G4, FT
Threehorn Wartyback	<i>Obliquaria reflexa</i>	1982	–
Wabash Pigtoe	<i>Fusconaia flava</i>	1975	–
Western Fanshell	<i>Cyprogenia aberti</i>	1967	S2, G1G2, FT

^A Species that have been located alive within the boundaries of OZAR.

Appendix B.

Table 9 provides the list and spatial coordinates of all 120 generalized random tessellation stratified (GRTS) points selected for potential freshwater mussel sampling in the Current River and Jacks Fork within Ozark National Scenic Riverways.

Table 9. List and spatial coordinates (decimal degrees in WGS84) of all 120 generalized random tessellation stratified (GRTS) points selected for possible freshwater mussel sampling surveys in the Current River and Jacks Fork in the Ozark National Scenic Riverways.

GRTS site number	Longitude	Latitude
1	-91.57108996	37.05270607
3	-91.12890589	37.12704393
5	-91.59162995	37.04425923
6	-90.935997	36.931837
7	-91.29122582	37.19053017
8	-91.43068123	37.31413739
9	-91.54408596	37.07429088
10	-91.02079891	36.99494884
11	-91.41314498	37.16096847
13	-91.15437502	37.13558398
14	-91.07814936	37.12315026
16	-91.64712336	37.43658532
17	-91.64454866	37.04712229
19	-91.10712511	37.10699016
20	-91.40932028	37.28620809
21	-91.51737593	37.08859249
24	-91.473291	37.319232
25	-91.53176033	37.07357365
27	-91.38359819	37.1591991
28	-91.54148331	37.37210951
29	-91.23336035	37.175925
32	-91.63626802	37.42753553
33	-91.63237065	37.05245711
35	-91.09890567	37.11668088
37	-91.50562629	37.10711739
38	-90.98490233	36.96008093
39	-91.34164077	37.15406258

Table 9 (continued). List and spatial coordinates (decimal degrees in WGS84) of all 120 generalized random tessellation stratified (GRTS) points selected for possible freshwater mussel sampling surveys in the Current River and Jacks Fork in the Ozark National Scenic Riverways.

GRTS site number	Longitude	Latitude
40	-91.54124843	37.36052436
41	-91.54788798	37.06766887
42	-91.06540799	37.04103715
43	-91.45731655	37.14583429
44	-91.56453275	37.37831363
45	-91.26035002	37.18439958
46	-91.0471429	37.06100632
47	-91.35683696	37.26197038
48	-91.61484227	37.43298019
49	-91.59883427	37.04486449
50	-90.922079	36.880667
51	-91.29882581	37.17263331
52	-91.45182101	37.32081623
53	-91.50457613	37.11521741
54	-90.9630859	36.94034964
55	-91.34041588	37.15736161
56	-91.47455389	37.33369906
57	-91.169503	37.154963
58	-91.05648483	37.05163174
59	-91.300563	37.236187
60	-91.57631424	37.39657694
61	-91.19325323	37.18760354
62	-91.06360362	37.0858572
64	-91.5865174	37.41312354
65	-91.65282982	37.05356415
66	-90.94511	36.825075
67	-91.12546008	37.11084508
68	-91.39090412	37.27346064
69	-91.55307142	37.06983491
70	-90.999791	36.983787
71	-91.44360375	37.14857799
72	-91.56194263	37.38098464
73	-91.64274636	37.0480892
75	-91.31983722	37.1704506

Table 9 (continued). List and spatial coordinates (decimal degrees in WGS84) of all 120 generalized random tessellation stratified (GRTS) points selected for possible freshwater mussel sampling surveys in the Current River and Jacks Fork in the Ozark National Scenic Riverways.

GRTS site number	Longitude	Latitude
77	-91.17890223	37.18601015
78	-91.04805775	37.03281136
79	-91.4546029	37.14848461
80	-91.57407963	37.39053869
81	-91.61774258	37.04746584
82	-90.919949	36.882266
83	-91.317683	37.207063
87	-91.313339	37.250916
88	-91.58391223	37.40902946
89	-91.51581416	37.08971365
90	-90.90208	36.913885
91	-91.29097789	37.18427566
92	-91.44509804	37.321223
93	-91.17708938	37.13704671
96	-91.65701609	37.43788646
97	-91.5039719	37.11835585
98	-90.913951	36.930145
99	-91.305392	37.196095
100	-91.54343906	37.36571491
101	-91.24922701	37.1824049
104	-91.6497773	37.42891605
105	-91.4991413	37.11245523
106	-90.97986784	36.97249328
107	-91.35599215	37.15410273
108	-91.50191605	37.3557526
109	-91.25644782	37.18293975
110	-91.04535455	37.0641527
112	-91.6270155	37.43772831
113	-91.49672462	37.12282661
114	-90.97926404	36.94606171
115	-91.40958044	37.15907798
116	-91.47803409	37.33594824
117	-91.21604763	37.17647562

Table 9 (continued). List and spatial coordinates (decimal degrees in WGS84) of all 120 generalized random tessellation stratified (GRTS) points selected for possible freshwater mussel sampling surveys in the Current River and Jacks Fork in the Ozark National Scenic Riverways.

GRTS site number	Longitude	Latitude
118	-91.1643478	37.12514773
119	-91.338575	37.243774
120	-91.60457959	37.4170807

Appendix C.

See Table 10 for common and scientific names of all fish species mentioned in this report.

Table 10. Common and scientific names of all fish species mentioned in this report.

Common name	Scientific name
Skipjack Herring	<i>Alosa chrysochloris</i>
Black Bullhead	<i>Ameiurus melas</i>
Yellow Bullhead	<i>Ameiurus natalis</i>
Bowfin	<i>Amia calva</i>
American Eel	<i>Anguilla rostrata</i>
Pirate Perch	<i>Aphredoderus sayanus</i>
Freshwater Drum	<i>Aplodinotus grunniens</i>
Central Stoneroller	<i>Campostoma anomalum</i>
White Sucker	<i>Catostomus commersonii</i>
Southern Redbelly Dace	<i>Chrosomus erythrogaster</i>
Banded Sculpin	<i>Cottus carolinae</i>
Whitetail Shiner	<i>Cyprinella galactura</i>
Blacktail Shiner	<i>Cyprinella venusta</i>
Common Carp	<i>Cyprinus carpio</i>
Gizzard Shad	<i>Dorosoma cepedianum</i>
Mud Darter	<i>Etheostoma asprigene</i>
Greenside Darter	<i>Etheostoma blennioides</i>
Rainbow Darter	<i>Etheostoma caeruleum</i>
Fantail Darter	<i>Etheostoma flabellare</i>
Johnny Darter	<i>Etheostoma nigrum</i>
Banded Darter	<i>Etheostoma zonale</i>
Northern Studfish	<i>Fundulus catenatus</i>
Blackspotted Topminnow	<i>Fundulus olivaceus</i>
Western Mosquitofish	<i>Gambusia affinis</i>
Bigeye Chub	<i>Hybopsis amblops</i>
Northern Hog Sucker	<i>Hypentelium nigricans</i>
Channel Catfish	<i>Ictalurus punctatus</i>
Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>
Brook Silverside	<i>Labidesthes sicculus</i>
Longnose Gar	<i>Lepisosteus osseus</i>
Green Sunfish	<i>Lepomis cyanellus</i>
Warmouth	<i>Lepomis gulosus</i>

Table 10 (continued). Common and scientific names of all fish species mentioned in this report.

Common name	Scientific name
Orangespotted Sunfish	<i>Lepomis humilis</i>
Bluegill	<i>Lepomis macrochirus</i>
Longear Sunfish	<i>Lepomis megalotis</i>
Redear Sunfish	<i>Lepomis microlophus</i>
Striped Shiner	<i>Luxilus chrysocephalus</i>
Bleeding Shiner	<i>Luxilus zonatus</i>
Smallmouth Bass	<i>Micropterus dolomieu</i>
Largemouth Bass	<i>Micropterus salmoides</i>
White Bass	<i>Morone chrysops</i>
Silver Redhorse	<i>Moxostoma anisurum</i>
River Redhorse	<i>Moxostoma carinatum</i>
Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>
Hornyhead Chub	<i>Nocomis biguttatus</i>
Golden Shiner	<i>Notemigonus crysoleucas</i>
Weed Shiner	<i>Notropis texanus</i>
Tadpole Madtom	<i>Noturus gyrinus</i>
Rainbow Trout	<i>Oncorhynchus mykiss</i>
Yellow Perch	<i>Perca flavescens</i>
Logperch	<i>Percina caprodes</i>
Blackside Darter	<i>Percina maculata</i>
Bluntnose Minnow	<i>Pimephales notatus</i>
White Crappie	<i>Pomoxis annularis</i>
Black Crappie	<i>Pomoxis nigromaculatus</i>
Flathead Catfish	<i>Pylodictis olivaris</i>
Brown Trout	<i>Salmo trutta</i>
Sauger	<i>Sander canadensis</i>
Walleye	<i>Sander vitreus</i>
Creek Chub	<i>Semotilus atromaculatus</i>

Appendix D.

Table 11 lists freshwater mussel species in the Current River watershed and their associated host fish.

Table 11. List of freshwater mussel species documented in the Current River watershed in Missouri along with the number and common names of host fish for each species (scientific names included in Appendix C). Host fish names were obtained from the freshwater mussel host database (Freshwater Mussel Host Database 2025). Available at: <https://mollusk.inhs.illinois.edu/resources/freshwater-mussel-host-database>. Accessed March 4, 2025.

Mussel species common name	Number of host species	Host fish common name
Arkansas Brokenray	11	Banded Darter, Banded Sculpin, Bluegill, Bluntnose Minnow, Green Sunfish, Largemouth Bass, Logperch, Northern Hog Sucker, Smallmouth Bass, White Crappie, White Sucker
Black Sandshell	11	American Eel, Black Crappie, Bluegill, Central Stoneroller, Green Sunfish, Largemouth Bass, Longear Sunfish, Orangespotted Sunfish, Sauger, Walleye, White Crappie
Bleufer	3	Freshwater Drum, Golden Shiner, Warmouth
Butterfly	3	Freshwater Drum, Green Sunfish, Sauger
Creeper	24	Banded Darter, Black Bullhead, Black Crappie, Blackside Darter, Bluegill, Bluntnose Minnow, Central Stoneroller, Channel Catfish, Creek Chub, Fantail Darter, Flathead Catfish, Golden Shiner, Green Sunfish, Johnny Darter, Largemouth Bass, Logperch, Longear Sunfish, Rainbow Darter, Rainbow Trout, Smallmouth Bass, Walleye, White Crappie, Yellow Bullhead, Yellow Perch
Elktoe	17	Banded Sculpin, Blackspotted Topminnow, Bleeding Shiner, Common Carp, Creek Chub, Golden Redhorse, Golden Shiner, Hornyhead Chub, Northern Hog Sucker, Northern Studfish, River Carpsucker, Shorthead Redhorse, Silver Redhorse, Smallmouth Buffalo, Striped Shiner, Warmouth, White Sucker
Ellipse	8	Banded Darter, Blackside Darter, Fantail Darter, Greenside Darter, Johnny Darter, Logperch, Mud Darter, Rainbow Darter
Fatmucket	17	Black Crappie, Bluegill, Bluntnose Minnow, Green Sunfish, Johnny Darter, Largemouth Bass, Longear Sunfish, Orangespotted Sunfish, Sauger, Smallmouth Bass, Striped Shiner, Tadpole Madtom, Walleye, Warmouth, White Bass, White Crappie, Yellow Perch
Flat Floater	7	Channel Catfish, Golden Shiner, Green Sunfish, Largemouth Bass, Longear Sunfish, Warmouth, White Crappie

Table 11 (continued). List of freshwater mussel species documented in the Current River watershed in Missouri along with the number and common names of host fish for each species (scientific names included in Appendix C). Host fish names were obtained from the freshwater mussel host database (Freshwater Mussel Host Database 2025). Available at: <https://mollusk.inhs.illinois.edu/resources/freshwater-mussel-host-database>. Accessed March 4, 2025.

Mussel species common name	Number of host species	Host fish common name
Flutedshell	46	American Eel, Banded Darter, Banded Sculpin, Bigmouth Buffalo, Black Bullhead, Black Crappie, Blackside Darter, Blackspotted Topminnow, Blacktail Shiner, Bluegill, Bluntnose Minnow, Bowfin, Central Stoneroller, Common Carp, Creek Chub, Fantail Darter, Flathead Catfish, Freshwater Drum, Gizzard Shad, Golden Shiner, Green Sunfish, Hornyhead Chub, Johnny Darter, Largemouth Bass, Logperch, Longear Sunfish, Longnose Gar, Northern Hog Sucker, Northern Studfish, Orangespotted Sunfish, Pirate Perch, Rainbow Darter, Redear Sunfish, River Redhorse, Sauger, Shorthead Redhorse, Silver Redhorse, Smallmouth Bass, Southern Redbelly Dace, Striped Shiner, Walleye, Western Mosquitofish, White Sucker, Whitetail Shiner, Yellow Bullhead, Yellow Perch
Fragile Papershell	1	Freshwater Drum
Giant Floater	22	Black Crappie, Bluegill, Bluntnose Minnow, Brook Silverside, Central Stoneroller, Creek Chub, Freshwater Drum, Gizzard Shad, Golden Shiner, Green Sunfish, Johnny Darter, Largemouth Bass, Longear Sunfish, Longnose Gar, Orangespotted Sunfish, Rainbow Darter, Skipjack Herring, Striped Shiner, White Bass, White Crappie, Yellow Bullhead, Yellow Perch
Lilliput	6	Bluegill, Green Sunfish, Johnny Darter, Orangespotted Sunfish, Warmouth, White Crappie
Little Spectaclecase	7	Bluegill, Channel Catfish, Green Sunfish, Largemouth Bass, Longear Sunfish, Orangespotted Sunfish, Redear Sunfish
Mucket	15	American Eel, Black Crappie, Bluegill, Central Stoneroller, Creek Chub, Green Sunfish, Largemouth Bass, Orangespotted Sunfish, Sauger, Smallmouth Bass, Tadpole Madtom, Walleye, White Bass, White Crappie, Yellow Perch
Ouachita Kidneyshell	2	Greenside Darter, Rainbow Darter
Ozark Pigtoe	2	Bleeding Shiner, Southern Redbelly Dace
Paper Pondshell	11	Black Crappie, Bluegill, Channel Catfish, Creek Chub, Golden Shiner, Green Sunfish, Largemouth Bass, Longear Sunfish, Warmouth, Western Mosquitofish, Yellow Perch
Pimpleback	8	Black Bullhead, Channel Catfish, Flathead Catfish, Gizzard Shad, Largemouth Bass, Longear Sunfish, Spotted Bass, White Crappie
Pink Heelsplitter	1	Freshwater Drum
Pink Mucket	5	Freshwater Drum, Largemouth Bass, Smallmouth Bass, Spotted Bass, Walleye
Pistolgrip	6	Channel Catfish, Flathead Catfish, Mud Darter, Weed Shiner, Western Mosquitofish, Yellow Bullhead

Table 11 (continued). List of freshwater mussel species documented in the Current River watershed in Missouri along with the number and common names of host fish for each species (scientific names included in Appendix C). Host fish names were obtained from the freshwater mussel host database (Freshwater Mussel Host Database 2025). Available at: <https://mollusk.inhs.illinois.edu/resources/freshwater-mussel-host-database>. Accessed March 4, 2025.

Mussel species common name	Number of host species	Host fish common name
Plain Pocketbook	9	Black Crappie, Bluegill, Green Sunfish, Largemouth Bass, Sauger, Smallmouth Bass, Walleye, White Crappie, Yellow Perch
Pondmussel	8	Bigmouth Buffalo, Black Crappie, Bluegill, Bowfin, Largemouth Bass, Orangespotted Sunfish, Tadpole Madtom, Warmouth
Purple Lilliput	2	Green Sunfish, Longear Sunfish
Purple Wartyback	4	Black Bullhead, Channel Catfish, Flathead Catfish, Yellow Bullhead
Rabbitsfoot	8	Bigeye Chub, Blacktail Shiner, Carmine Shiner, Emerald Shiner, Golden Redhorse, Rainbow Darter, Striped Shiner, Whitetail Shiner
Western Rainbow	10	Green Sunfish, Greenside Darter, Largemouth Bass, Longear Sunfish, Rainbow Darter, Smallmouth Bass, Spotted Bass, Striped Shiner, Western Mosquitofish, Yellow Perch
Round Pigtoe	8	Bigeye Shiner, Blacktail Shiner, Bluegill, Bluntnose Minnow, Central Stoneroller, Creek Chub, Southern Redbelly Dace, Whitetail Shiner
Slippershell Mussel	2	Banded Sculpin, Brown Trout
Spike	21	American Eel, Banded Darter, Banded Sculpin, Black Crappie, Blackside Darter, Blackspotted Topminnow, Bluegill, Flathead Catfish, Gilt Darter, Gizzard Shad, Golden Shiner, Green Sunfish, Largemouth Bass, Logperch, Longnose Gar, Rainbow Darter, Sauger, Smallmouth Bass, Walleye, White Crappie, Yellow Perch
Texas Lilliput	2	Bluegill, Warmouth
Threehorn Wartyback	8	Bluegill, Freshwater Drum, Gizzard Shad, Goldeye, Largemouth Bass, Skipjack Herring, Striped Shiner, Walleye
Threeridge	19	Black Crappie, Black Redhorse, Blacktail Shiner, Bluegill, Channel Catfish, Emerald Shiner, Freshwater Drum, Golden Redhorse, Green Sunfish, Largemouth Bass, Logperch, Longear Sunfish, Mooneye, Northern Hog Sucker, Sauger, Warmouth, White Bass, White Crappie, Yellow Perch
Wabash Pigtoe	5	Black Crappie, Creek Chub, Emerald Shiner, Hornyhead Chub, White Crappie
Western Fanshell	3	Banded Sculpin, Fantail Darter, Logperch
Yellow Sandshell	10	Black Crappie, Bluegill, Green Sunfish, Largemouth Bass, Longnose Gar, Orangespotted Sunfish, Redear Sunfish, Shortnose Gar, Warmouth, White Crappie

Appendix E.

Table 12 lists sampled sites, coordinates, mussel detections (live or shell), and species counts in the Jacks Fork and Current River within Ozark National Scenic Riverways.

Table 12. List of sites and their coordinates sampled in the Jacks Fork and Current River within the Ozark National Scenic Riverways (OZAR) along with the associated mussels encountered either live or as shell material only, and the total count of species at the site. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. Bleedingtooth Mussel *Venustaconcha pleasii* was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. Sites with no detections were indicated by “N/A”.

Stream	Site	Latitude	Longitude	Live Mussels	Shell Material	Species Count
Current River	101B	37.1824	-91.2492	N/A	Ouachita Kidneyshell, Pondmussel, Ozark Pigtoe	3
Current River	104B	37.42892	-91.6498	Arkansas Brokenray, Ozark Pigtoe, Western Rainbow	Arkansas Brokenray	3
Current River	106B	36.97441	-90.9828	Arkansas Brokenray	N/A	1
Current River	108A	37.35758	-91.4998	N/A	N/A	0
Current River	109B	37.18294	-91.2564	Arkansas Brokenray, Western Rainbow	Western Rainbow, Ouachita Kidneyshell, Arkansas Brokenray	3
Current River	110A	37.06444	-91.0447	Flat Floater, Giant Floater, Paper Pondshell, Pondmussel	Western Rainbow, Paper Pondshell	5
Current River	116A	37.33527	-91.4776	N/A	N/A	0
Current River	117A	37.17657	-91.2165	Arkansas Brokenray, Western Rainbow	Arkansas Brokenray, Western Rainbow	2
Current River	118B	37.12628	-91.1291	Arkansas Brokenray, Western Rainbow	Arkansas Brokenray, Western Rainbow	2
Current River	119A	37.24377	-91.3386	Arkansas Brokenray	N/A	1
Current River	120A	37.41706	-91.6049	Arkansas Brokenray	N/A	1
Current River	14A	37.12315	-91.0781	Pondmussel, Purple Lilliput, Western Rainbow	Pondmussel, Western Rainbow, Paper Pondshell	4
Current River	19A	37.10675	-91.1077	Arkansas Brokenray	Western Rainbow, Purple Lilliput	3

Table 12 (continued). List of sites and their coordinates sampled in the Jacks Fork and Current River within the Ozark National Scenic Riverways (OZAR) along with the associated mussels encountered either live or as shell material only, and the total count of species at the site. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. Bleedingtooth Mussel *Venustaconcha pleasii* was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. Sites with no detections were indicated by “N/A”.

Stream	Site	Latitude	Longitude	Live Mussels	Shell Material	Species Count
Current River	20A	37.28709	-91.4101	N/A	N/A	0
Current River	24A	37.31976	-91.4755	N/A	Creeper	1
Current River	28A	37.37181	-91.5418	N/A	N/A	0
Current River	29B	37.17593	-91.2333	Western Rainbow	Ouachita Kidneyshell	2
Current River	32B	37.42754	-91.6363	N/A	N/A	0
Current River	35A	37.11726	-91.0987	Paper Pondshell	Paper Pondshell	1
Current River	38A	36.96242	-90.9802	N/A	Western Rainbow	1
Current River	3B	37.15254	-91.3426	Arkansas Brokenray, Western Rainbow	Western Rainbow, Arkansas Brokenray, Ouachita Kidneyshell	3
Current River	40A	37.35945	-91.5399	N/A	N/A	0
Current River	42A	37.04104	-91.0654	Arkansas Brokenray, Ozark Pigtoe, Paper Pondshell, Pondmussel	Western Rainbow	5
Current River	44A	37.37831	-91.5645	N/A	N/A	0
Current River	46A	37.06024	-91.0482	Western Rainbow	Arkansas Brokenray, Purple Wartyback, Western Rainbow, Ouachita Kidneyshell	4
Current River	48B	37.43298	-91.6148	N/A	N/A	0
Current River	50A	36.88017	-90.9226	Fatmucket, Paper Pondshell	Paper Pondshell, Pondmussel	3
Current River	56A	37.3337	-91.4746	Giant Floater, Paper Pondshell	Giant Floater	2
Current River	58A	37.05163	-91.0565	Arkansas Brokenray, Western Rainbow	Western Rainbow	2

Table 12 (continued). List of sites and their coordinates sampled in the Jacks Fork and Current River within the Ozark National Scenic Riverways (OZAR) along with the associated mussels encountered either live or as shell material only, and the total count of species at the site. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. Bleedingtooth Mussel *Venustaconcha pleasii* was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. Sites with no detections were indicated by “N/A”.

Stream	Site	Latitude	Longitude	Live Mussels	Shell Material	Species Count
Current River	61A	37.18756	-91.1925	Ouachita Kidneyshell, Western Rainbow	Arkansas Brokenray, Flutedshell, Western Rainbow	4
Current River	63B	37.24174	-91.3288	Paper Pondshell	N/A	0
Current River	66B	36.82738	-90.9454	Arkansas Brokenray, Ouachita Kidneyshell, Western Rainbow	Western Rainbow, Arkansas Brokenray	3
Current River	67A	37.11085	-91.1259	Arkansas Brokenray, Ouachita Kidneyshell, Western Rainbow	Western Rainbow	3
Current River	68B	37.27346	-91.3909	N/A	N/A	0
Current River	77A	37.18604	-91.1782	Arkansas Brokenray, Paper Pondshell, Western Rainbow	Western Rainbow, Arkansas Brokenray, Paper Pondshell, Pondmussel	4
Current River	82B	36.88227	-90.9199	Arkansas Brokenray, Western Rainbow	Arkansas Brokenray, Western Rainbow, Ouachita Kidneyshell	3
Current River	83A	37.20776	-91.3189	Arkansas Brokenray, Western Rainbow	Arkansas Brokenray	2
Current River	88A	37.40785	-91.5847	Paper Pondshell	Paper Pondshell	1
Current River	8A	37.31325	-91.4297	N/A	N/A	0
Current River	93A	37.1361	-91.1768	Western Rainbow	Western Rainbow, Flutedshell	2
Current River	96A	37.43789	-91.657	N/A	N/A	0
Current River	98A	36.9297	-90.9143	Giant Floater, Paper Pondshell	Arkansas Brokenray, Paper Pondshell	3
Jacks Fork	107B	37.15423	-91.3553	Arkansas Brokenray, Western Rainbow	Arkansas Brokenray	2
Jacks Fork	113A	37.12283	-91.4967	Western Rainbow	N/A	1

Table 12 (continued). List of sites and their coordinates sampled in the Jacks Fork and Current River within the Ozark National Scenic Riverways (OZAR) along with the associated mussels encountered either live or as shell material only, and the total count of species at the site. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. Bleedingtooth Mussel *Venustaconcha pleasii* was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. Sites with no detections were indicated by “N/A”.

Stream	Site	Latitude	Longitude	Live Mussels	Shell Material	Species Count
Jacks Fork	115B	37.1586	-91.4095	N/A	N/A	0
Jacks Fork	17A	37.0475	-91.6438	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe	Ouachita Kidneyshell, Arkansas Brokenray	3
Jacks Fork	1A	37.05241	-91.571	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe, Western Rainbow	Ouachita Kidneyshell	4
Jacks Fork	27B	37.1602	-91.3868	N/A	N/A	0
Jacks Fork	33A	37.05253	-91.6324	Ouachita Kidneyshell	Western Rainbow, Ouachita Kidneyshell	2
Jacks Fork	37A	37.10707	-91.5076	Ouachita Kidneyshell, Ozark Pigtoe, Western Rainbow	N/A	3
Jacks Fork	39B	37.1255	-91.1634	Arkansas Brokenray, Western Rainbow	Western Rainbow, Arkansas Brokenray	2
Jacks Fork	43A	37.14598	-91.457	N/A	N/A	0
Jacks Fork	51A	37.17263	-91.3005	Arkansas Brokenray, Ozark Pigtoe	N/A	2
Jacks Fork	5A	37.0436	-91.592	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe, Western Rainbow	Western Rainbow, Ouachita Kidneyshell	4
Jacks Fork	65A	37.05403	-91.6535	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe, Purple Lilliput, Western Rainbow	Ozark Pigtoe, Ouachita Kidneyshell, Flutedshell	6
Jacks Fork	71A	37.1486	-91.4435	Paper Pondshell, Pondmussel	Paper Pondshell, Pondmussel	2
Jacks Fork	79A	37.14806	-91.4544	N/A	N/A	0

Table 12 (continued). List of sites and their coordinates sampled in the Jacks Fork and Current River within the Ozark National Scenic Riverways (OZAR) along with the associated mussels encountered either live or as shell material only, and the total count of species at the site. Site numbers with a suffix of “A” were sampled during 2023 and those with a “B” were sampled in 2024. Bleedingtooth Mussel *Venustaconcha pleasii* was tentatively identified in 2023 at a Jacks Fork site (71A), but efforts to relocate specimens for identification using genetic approaches were unsuccessful. Sites with no detections were indicated by “N/A”.

Stream	Site	Latitude	Longitude	Live Mussels	Shell Material	Species Count
Jacks Fork	81A2	37.04898	-91.6192	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe, Western Rainbow	Ozark Pigtoe, Ouachita Kidneyshell	4
Jacks Fork	97A	37.11837	-91.5046	N/A	Ouachita Kidneyshell	1
Jacks Fork	9A	37.07586	-91.5429	Arkansas Brokenray, Ouachita Kidneyshell, Ozark Pigtoe, Western Rainbow	Ouachita Kidneyshell, Western Rainbow, Arkansas Brokenray, Ozark Pigtoe	4

Appendix F.

Maps depicting the distribution of each species of freshwater mussel known to occur in the Ozark National Scenic Riverways (Figures 17–39). Historical records are from the Missouri Department of Conservation (MDC) Mollusk Database and represent records prior to 2023. University of Missouri records are from surveys completed in 2023 and 2024 as outlined in this report. Spatial influence factor is a number approximating the spring influence on stream discharge in a given segment of river where values of “0” indicate almost no influence from spring sources and values of “1” indicate reaches where spring influence is dominant.

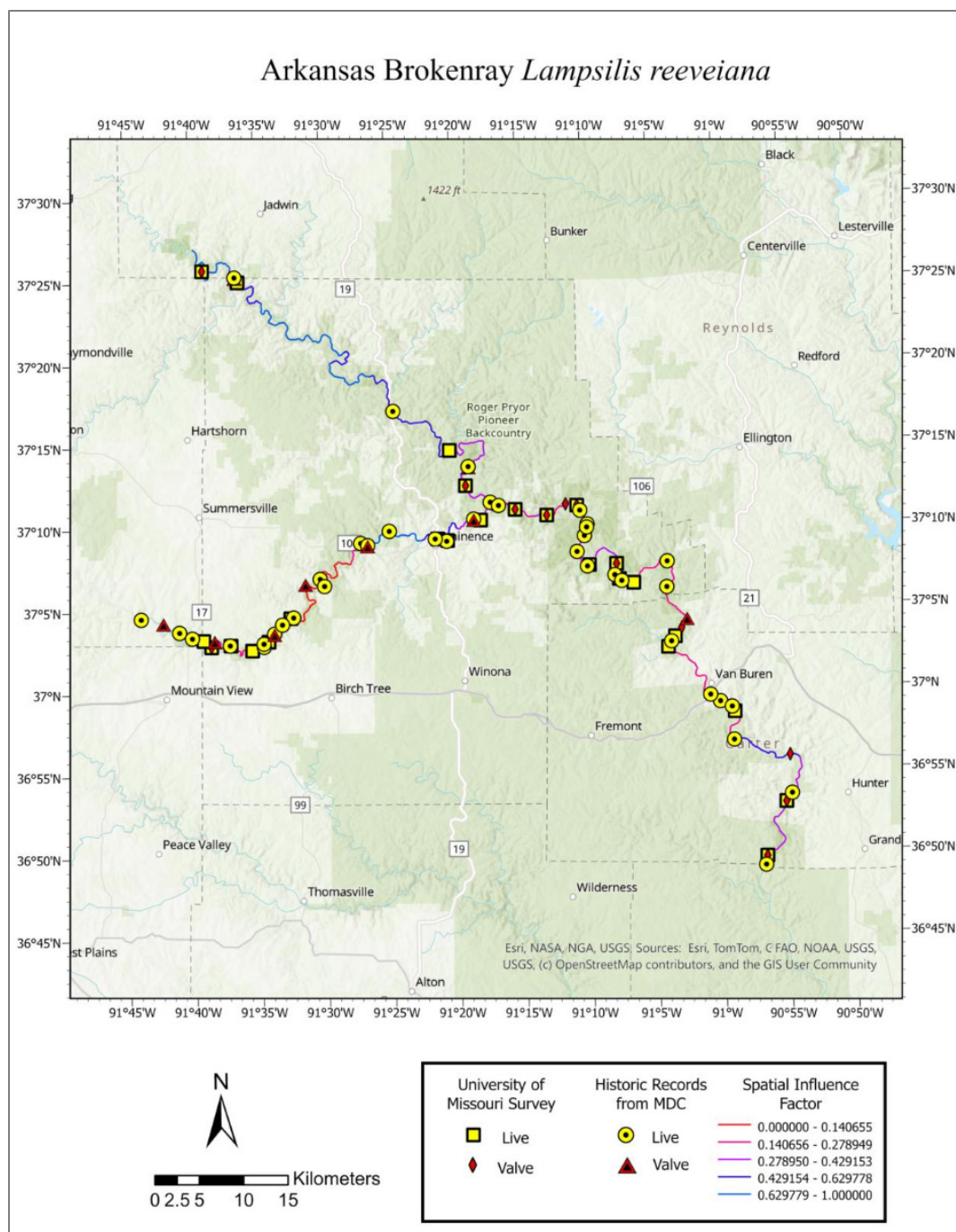


Figure 17. Map showing the distribution of Arkansas Brokenray (*Lampsilis reeveiana*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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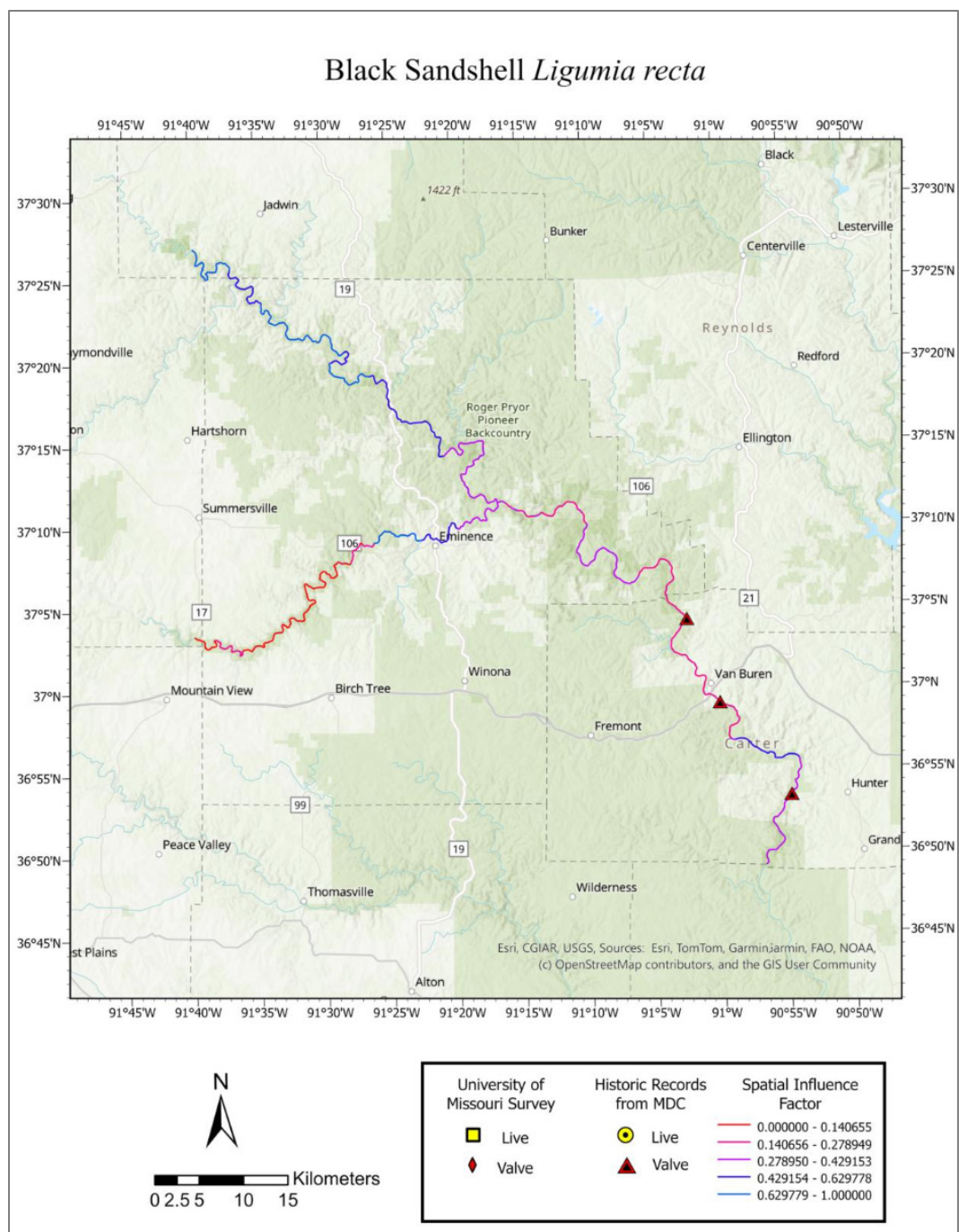


Figure 18. Map showing the distribution of Black Sandshell (*Ligumia recta*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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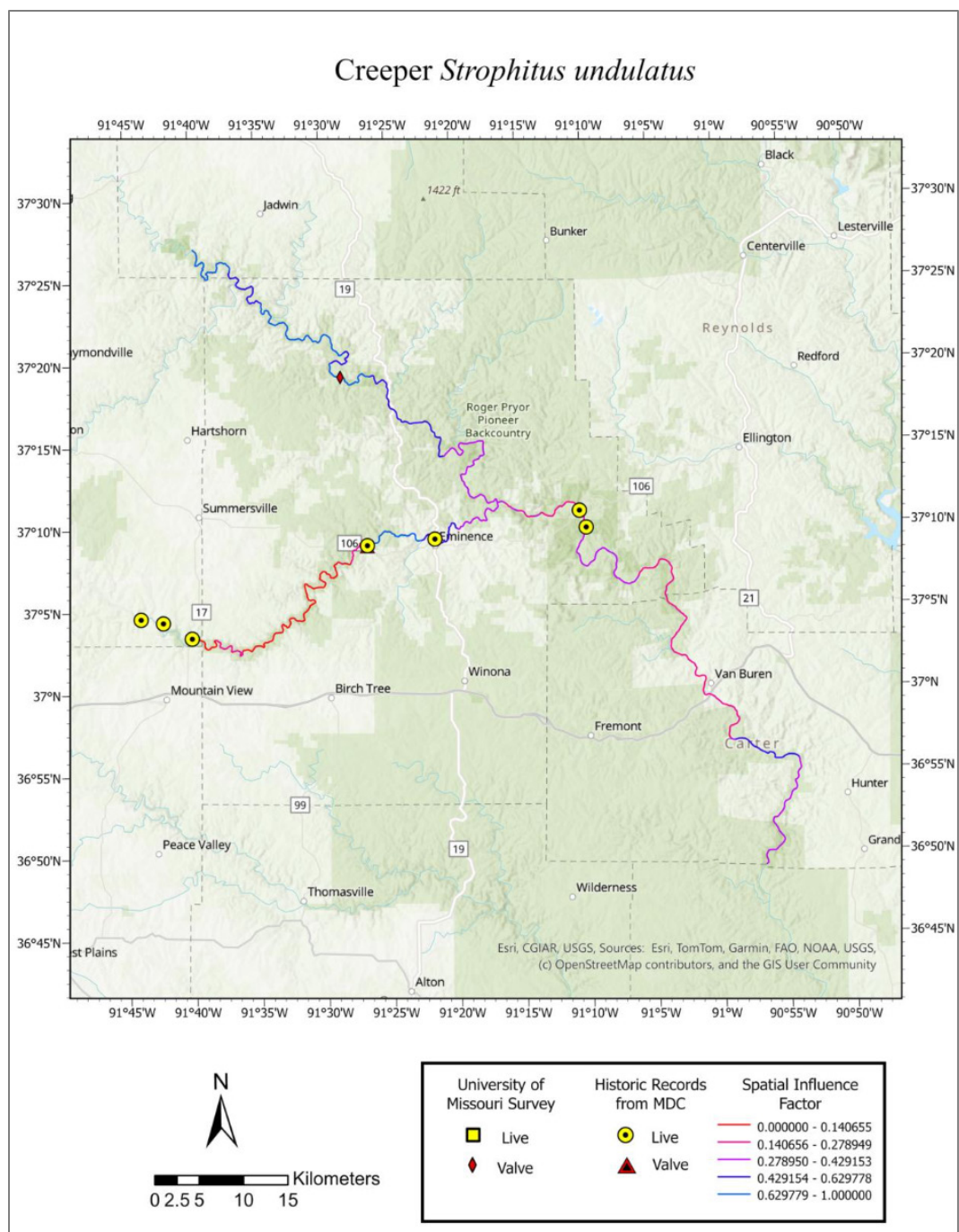


Figure 19. Map showing the distribution of Creeper (*Strophitus undulatus*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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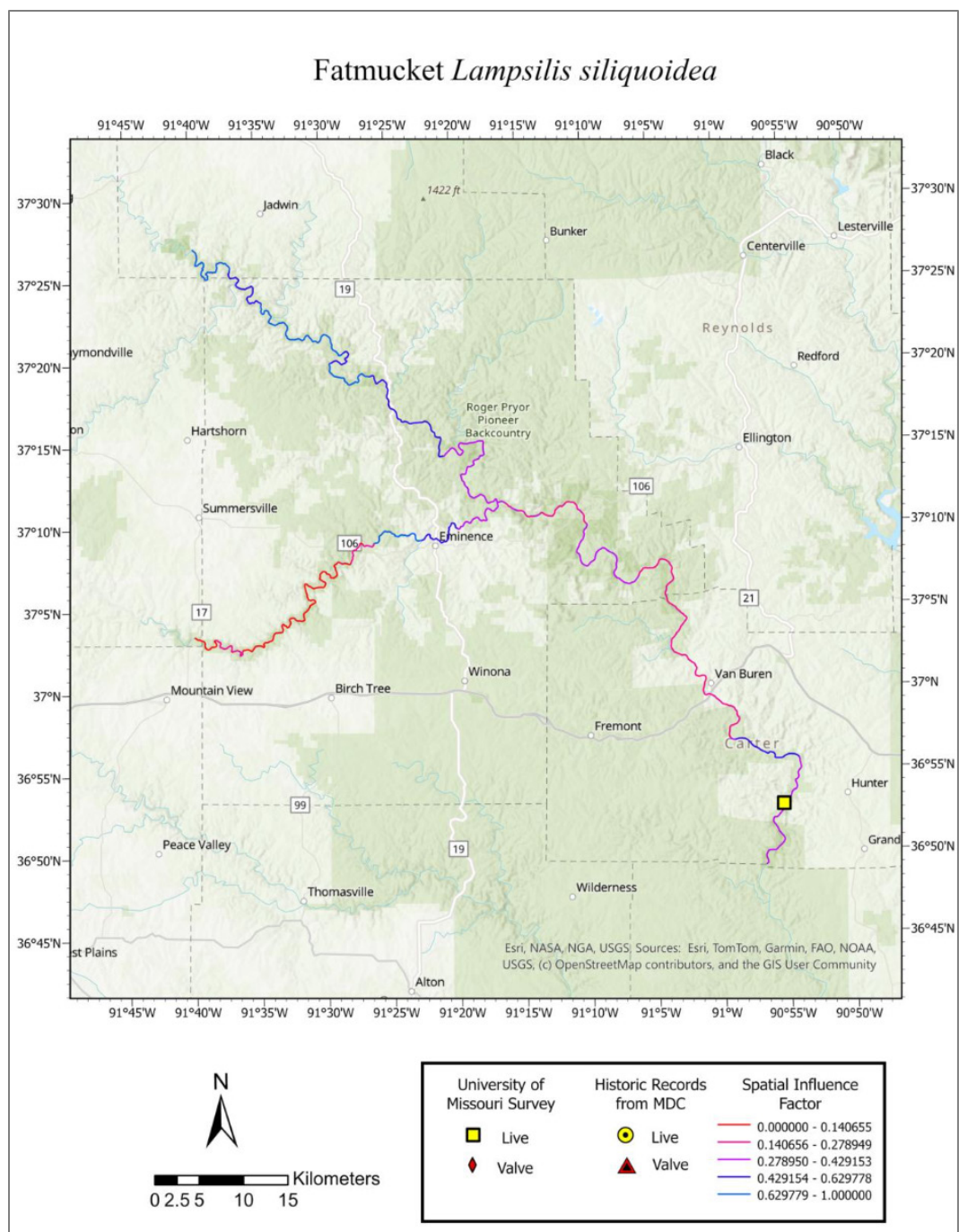


Figure 20. Map showing the distribution of Fatmucket (*Lampsilis siliquoidea*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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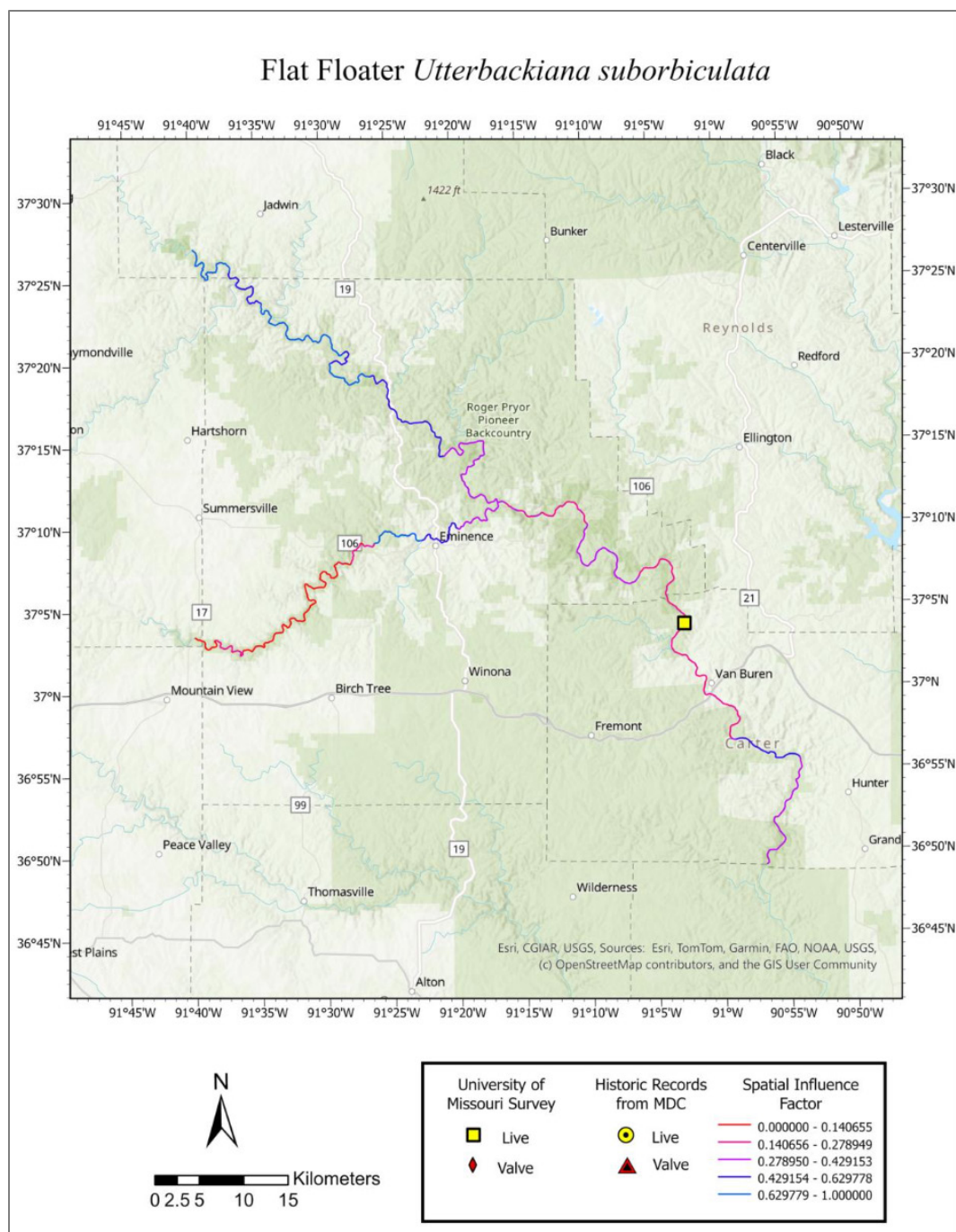


Figure 21. Map showing the distribution of Flat Floater (*Utterbackiana suborbiculata*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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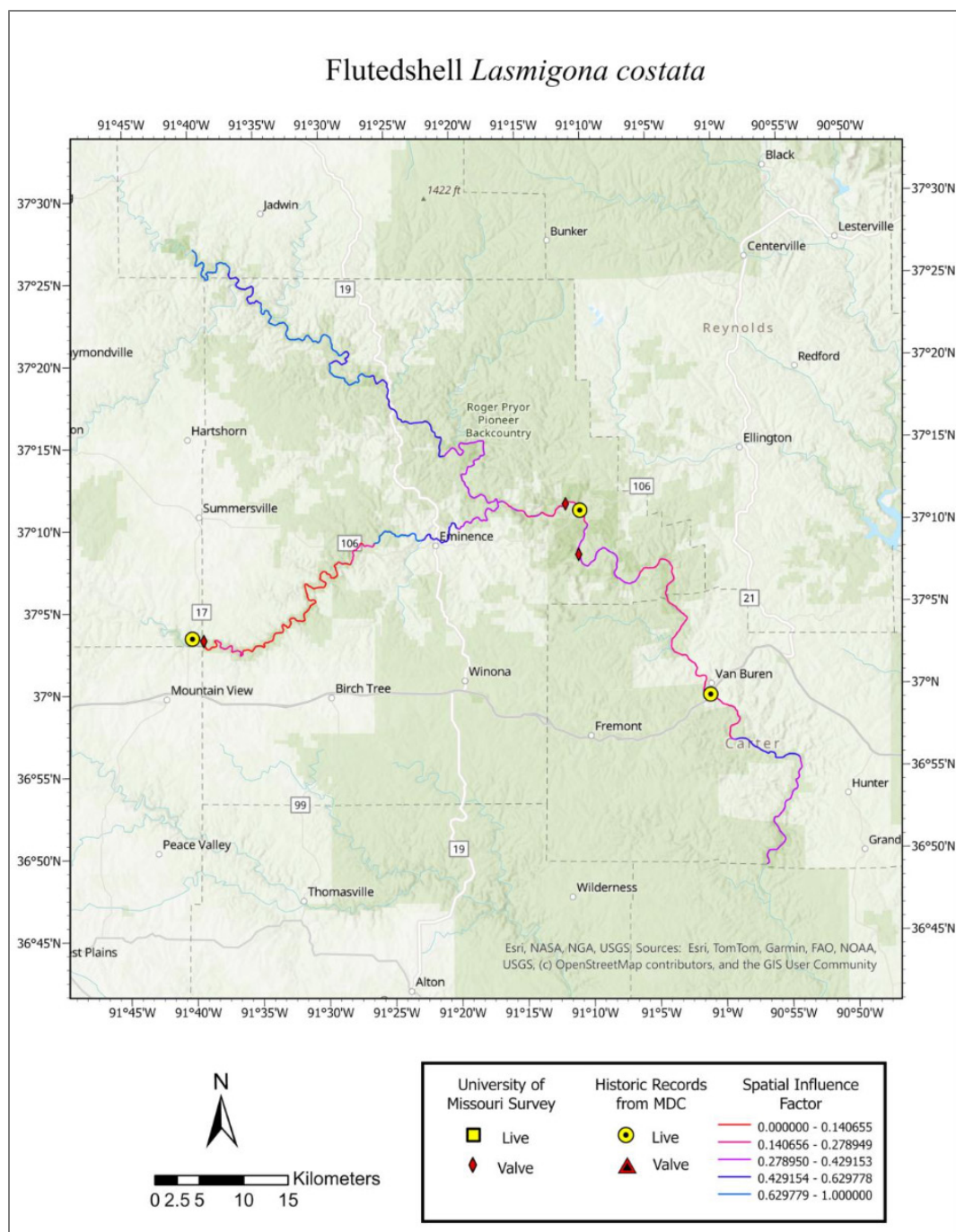


Figure 22. Map showing the distribution of Flutedshell (*Lasmigona costata*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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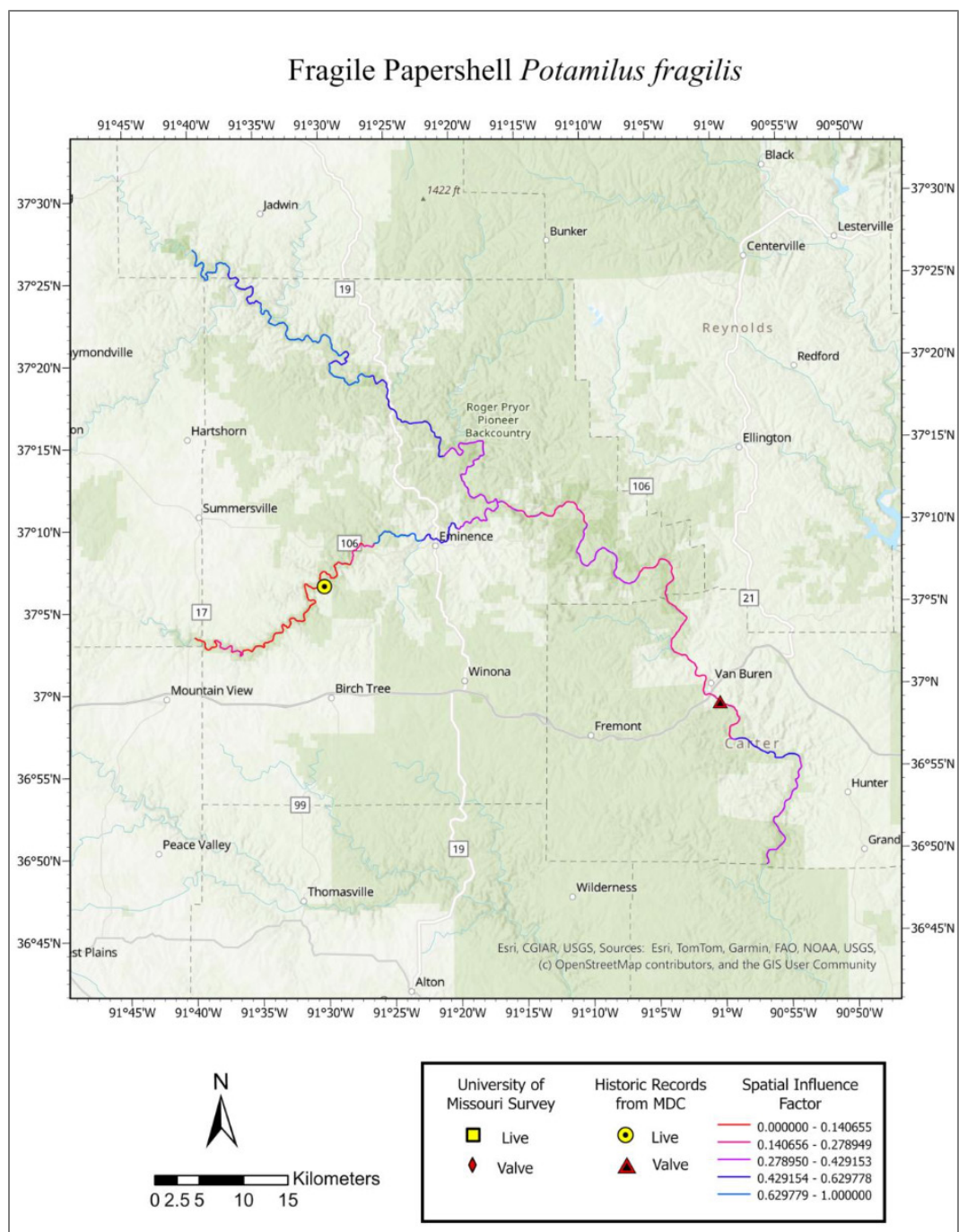


Figure 23. Map showing the distribution of Fragile Papershell (*Potamilus fragilis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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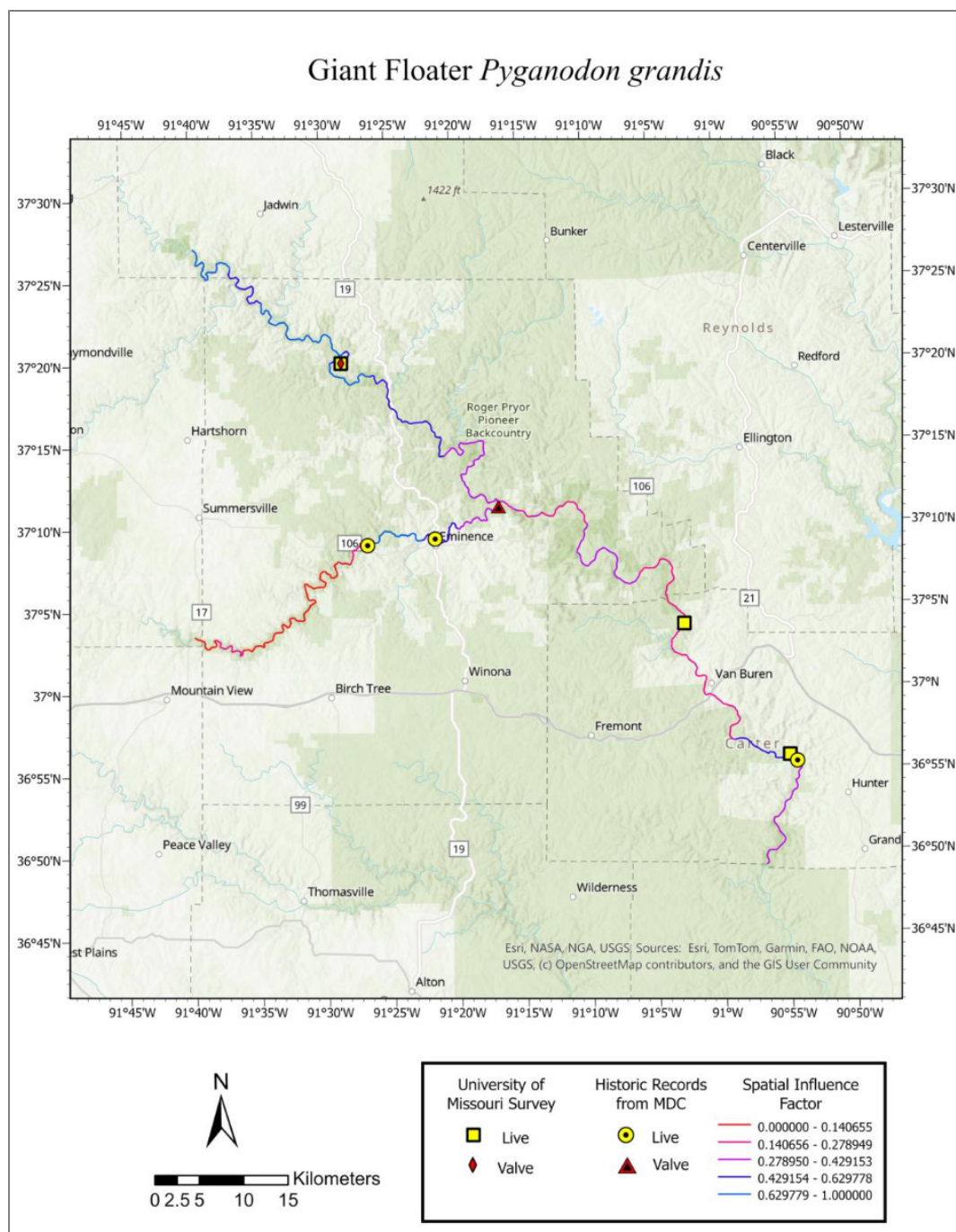


Figure 24. Map showing the distribution of Giant Floater (*Pyganodon grandis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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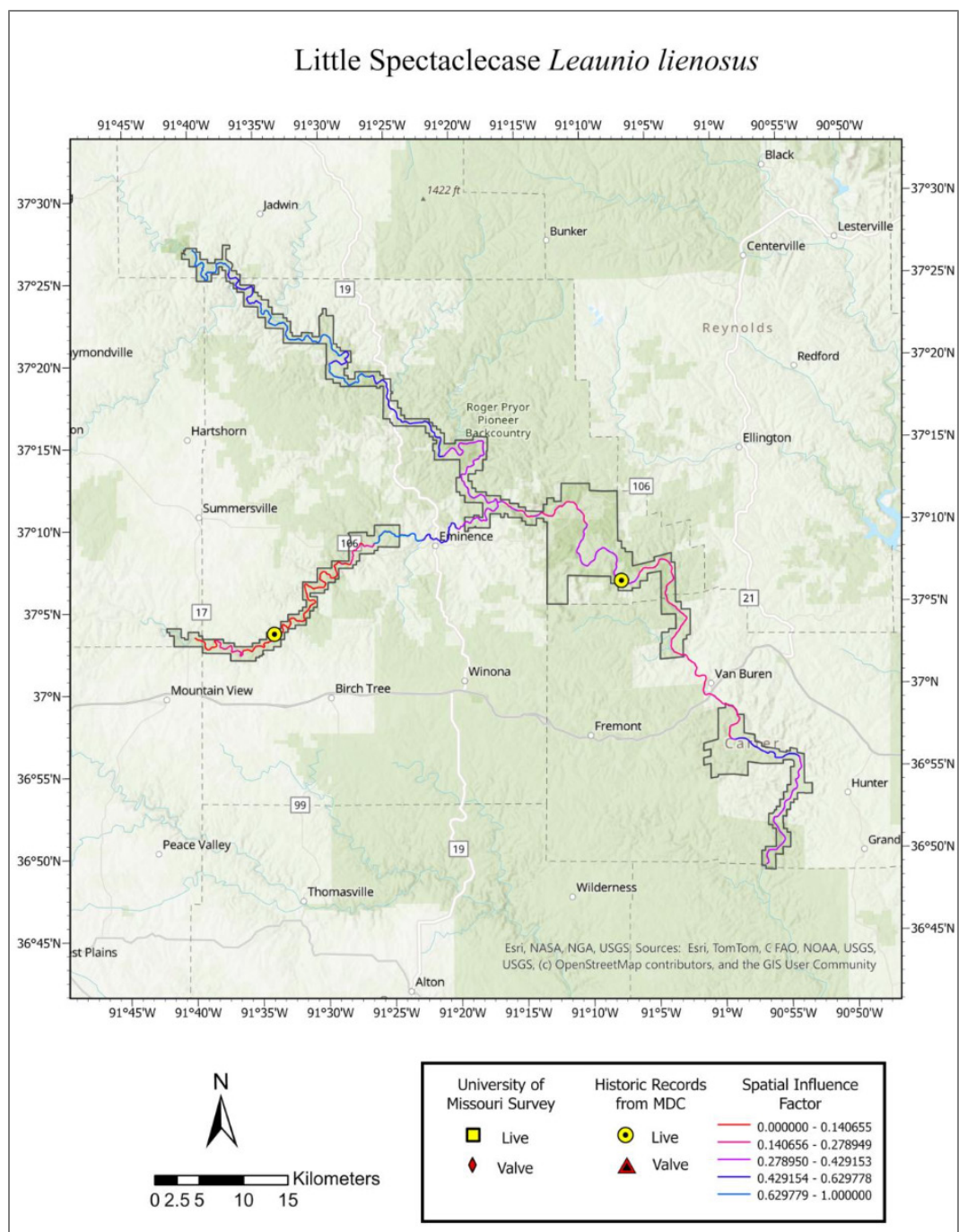


Figure 25. Map showing the distribution of Little Spectaclecase (*Leaunio lienosus*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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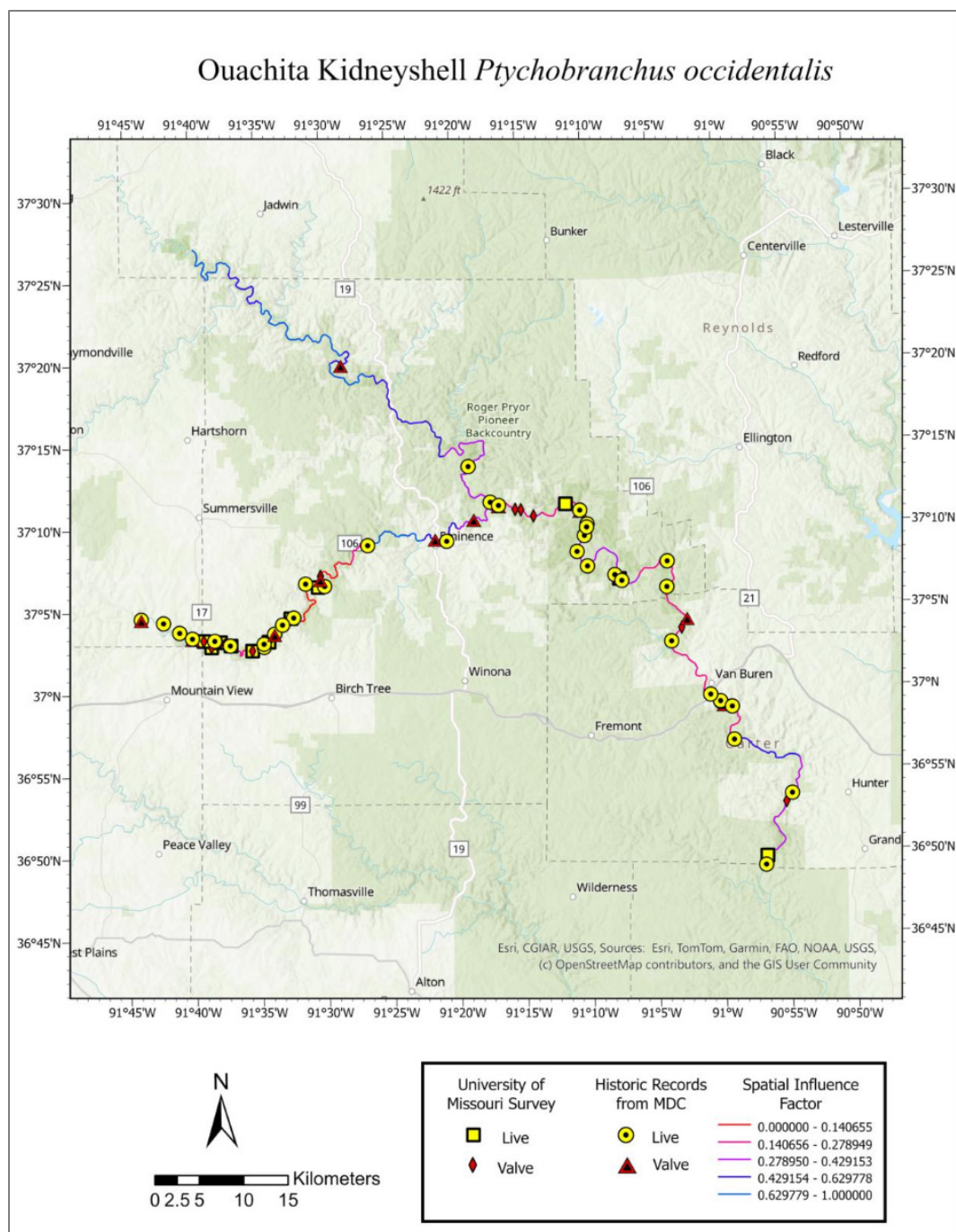


Figure 26. Map showing the distribution of Ouachita Kidneyshell (*Ptychobranhus occidentalis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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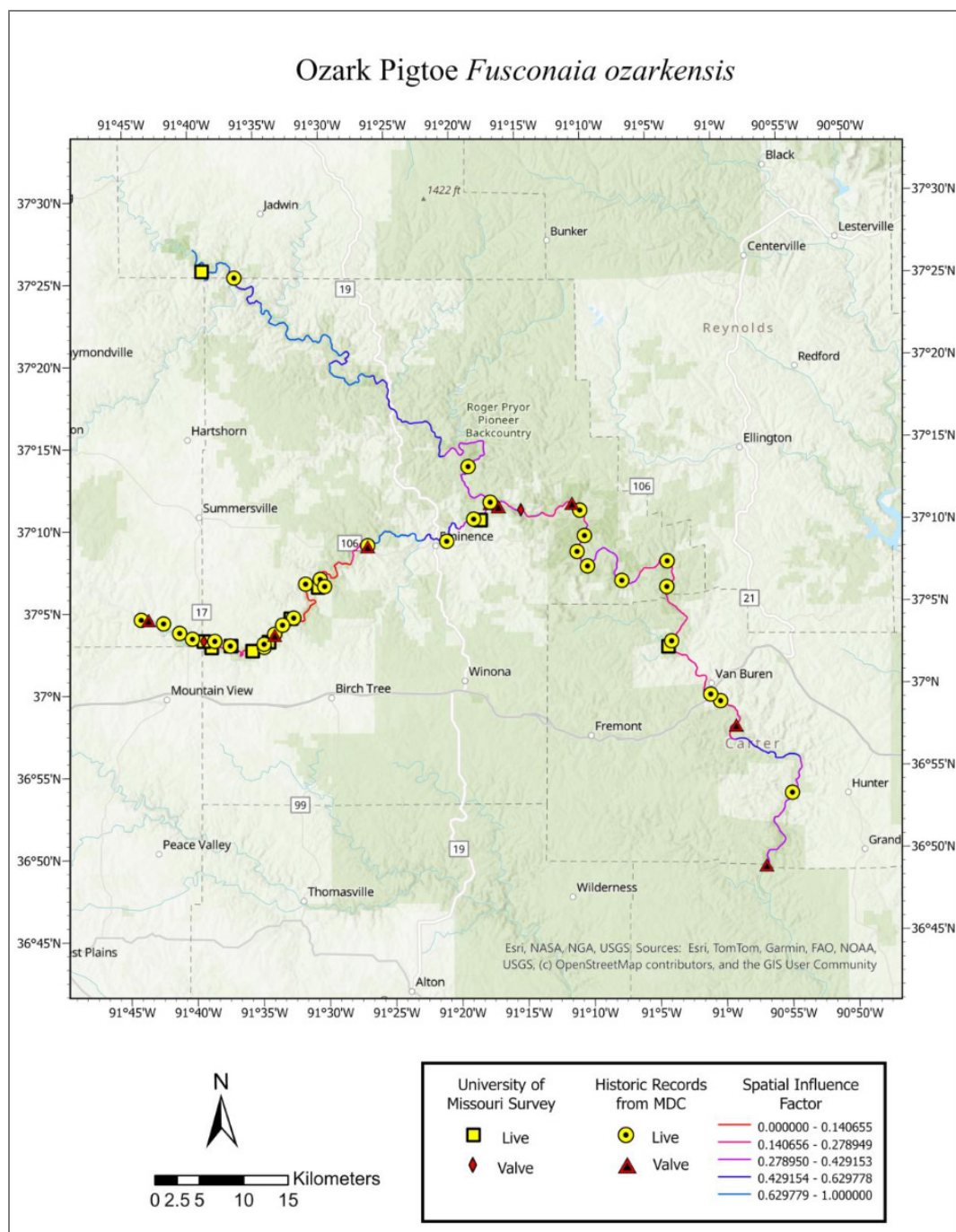


Figure 27. Map showing the distribution of Ozark Pigtoe (*Fusconaia ozarkensis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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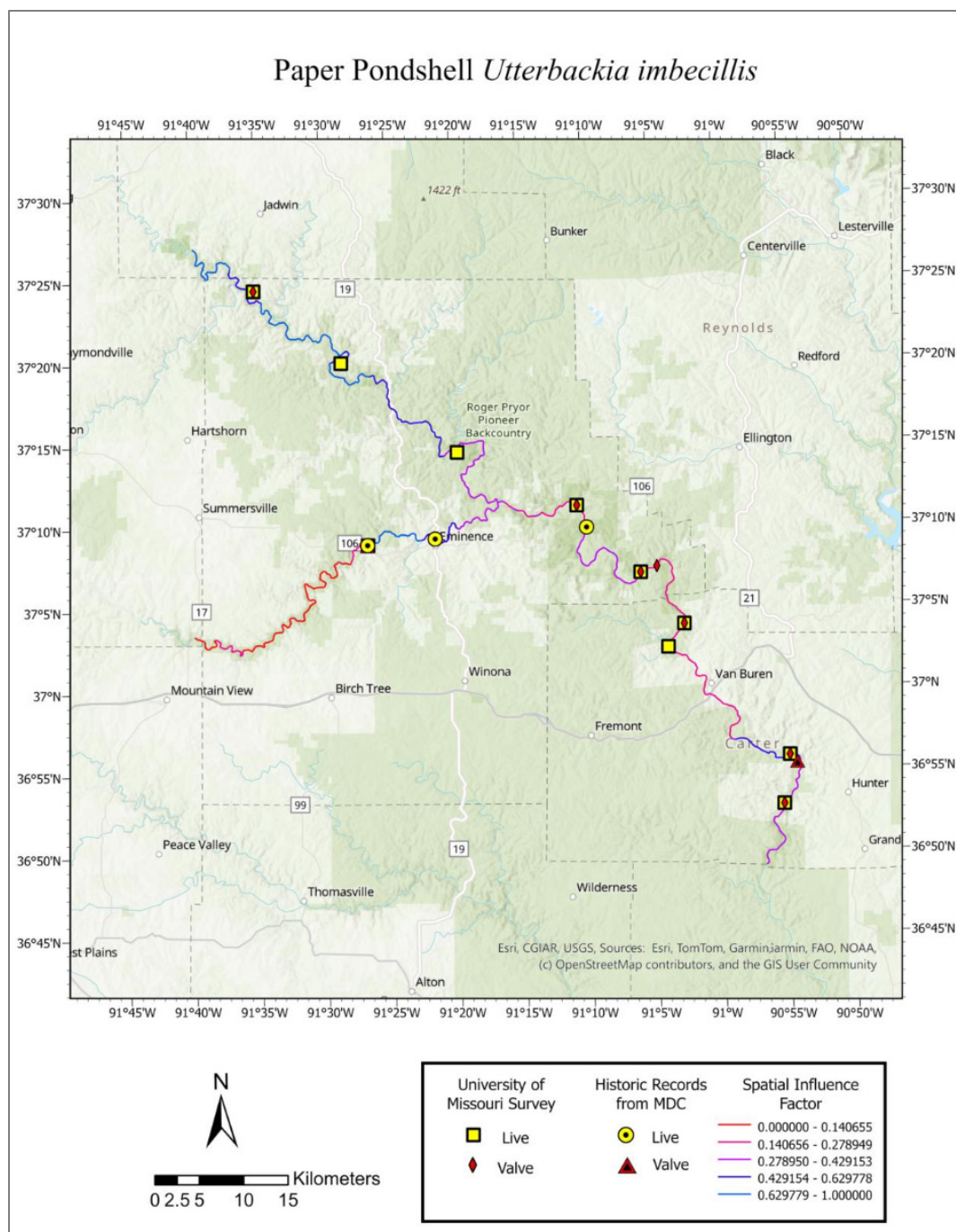


Figure 28. Map showing the distribution of Paper Pondshell (*Utterbackia imbecillis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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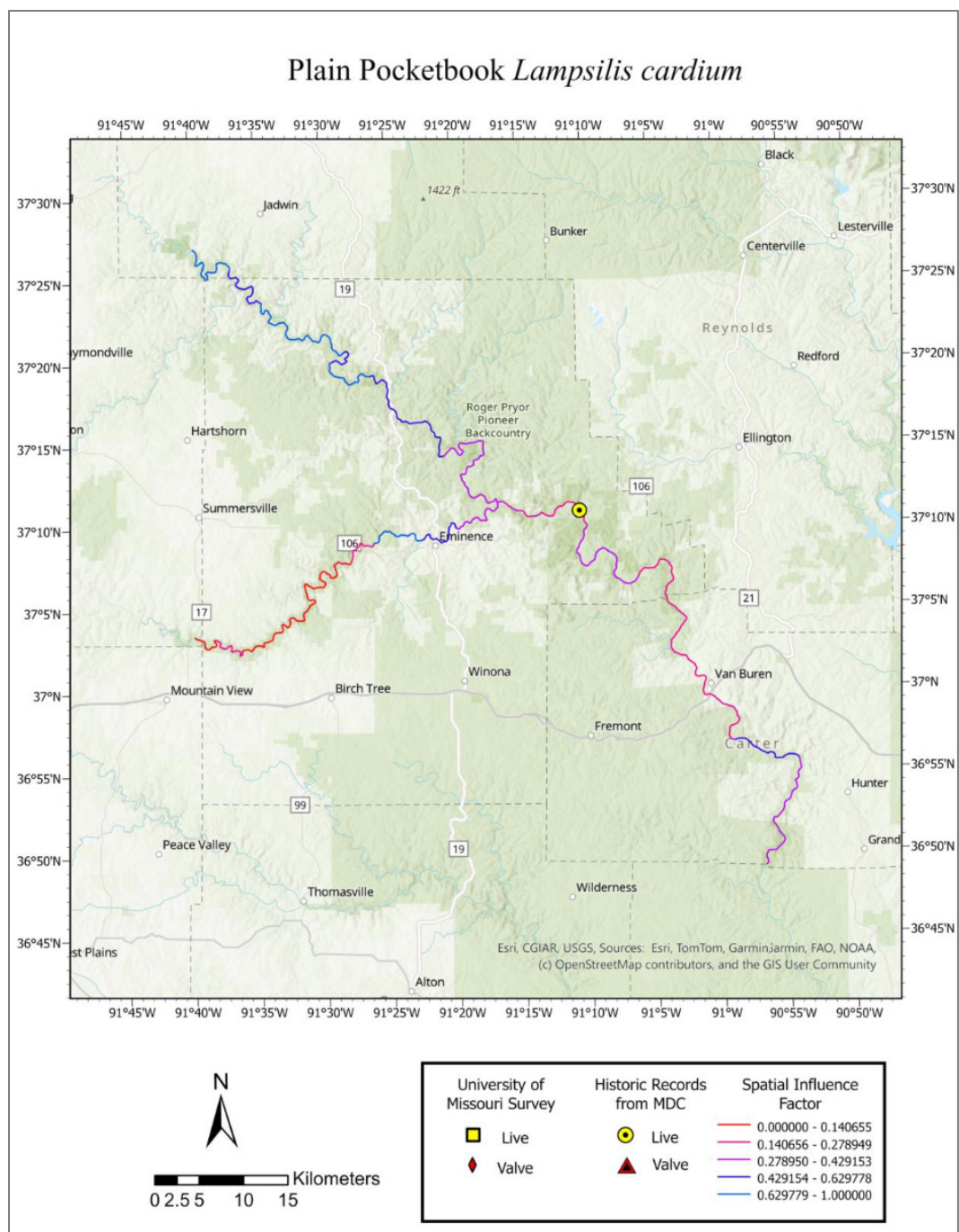


Figure 29. Map showing the distribution of Plain Pocketbook (*Lampsilis cardium*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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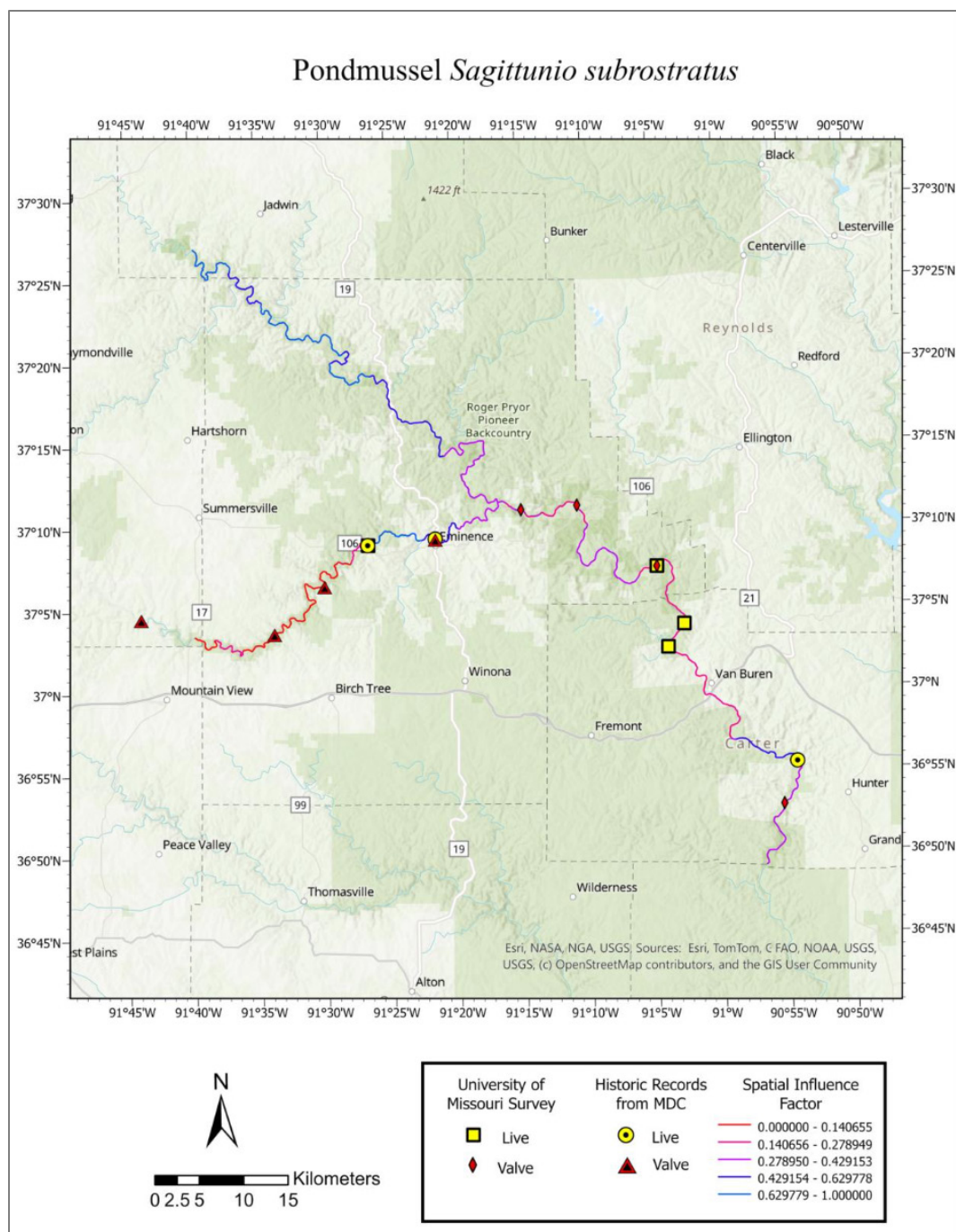


Figure 30. Map showing the distribution of Pondmussel (*Sagittunio subrostratus*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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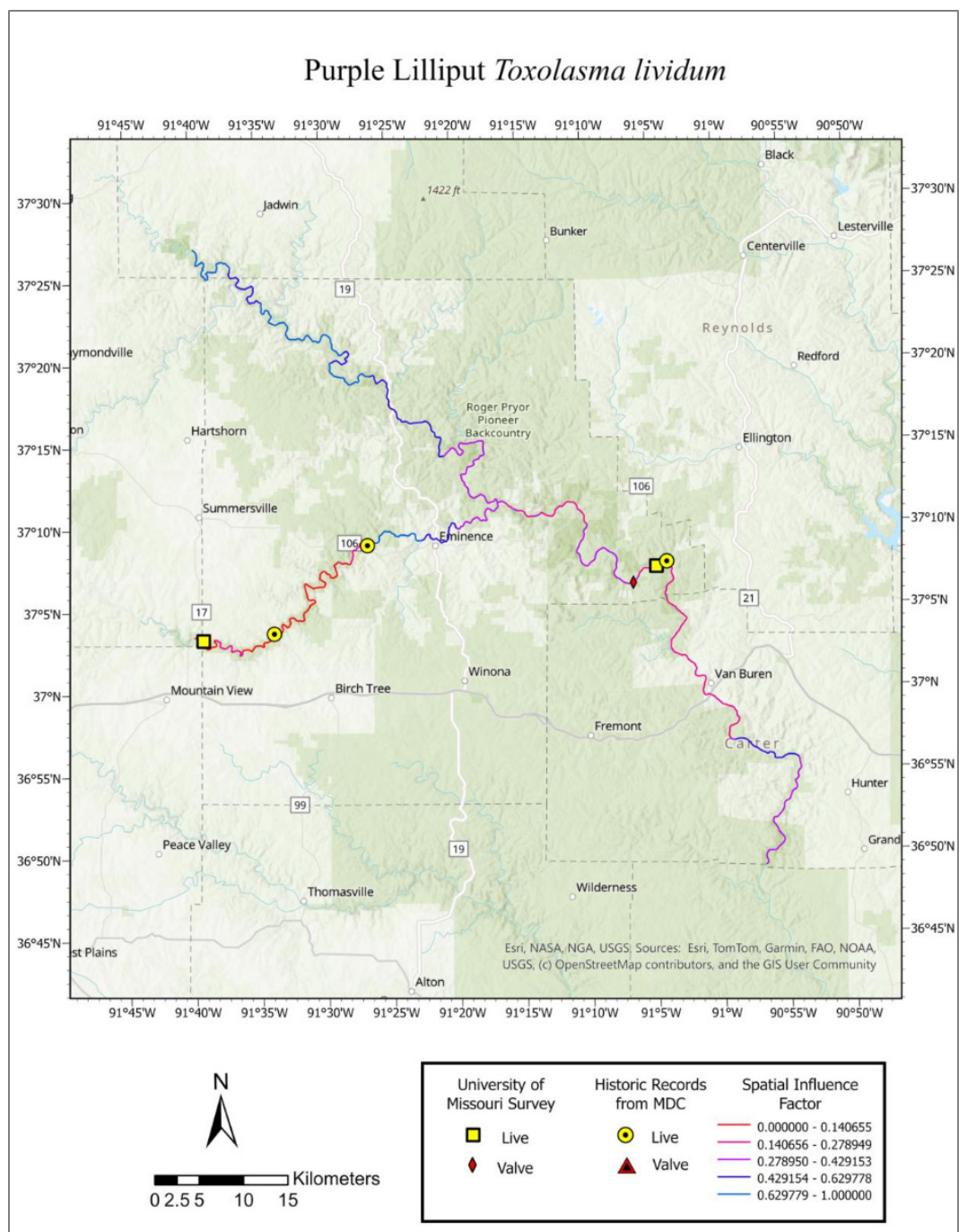


Figure 31. Map showing the distribution of Purple Lilliput (*Toxolasma lividum*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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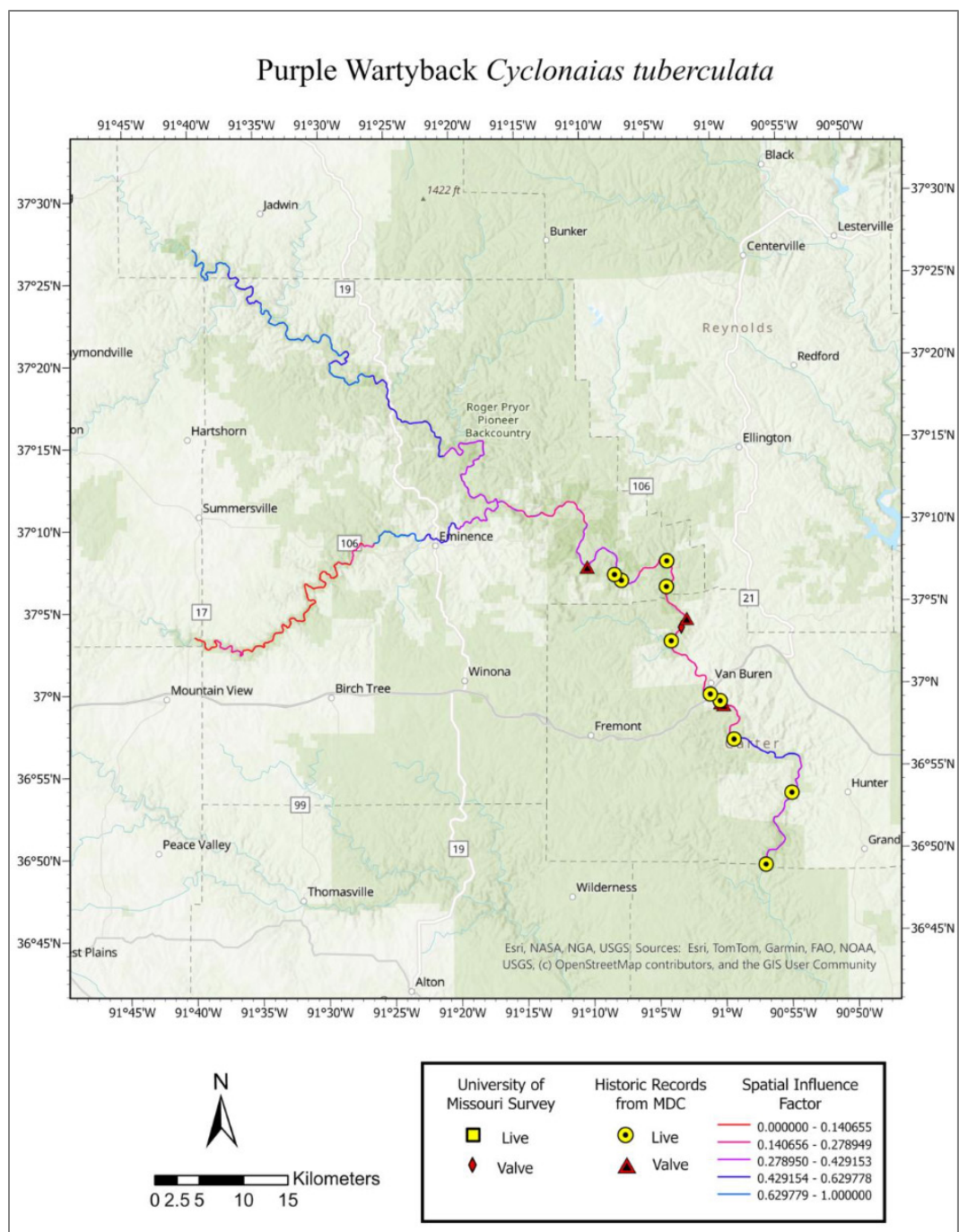


Figure 32. Map showing the distribution of Purple Wartyback (*Cyclonaias tuberculata*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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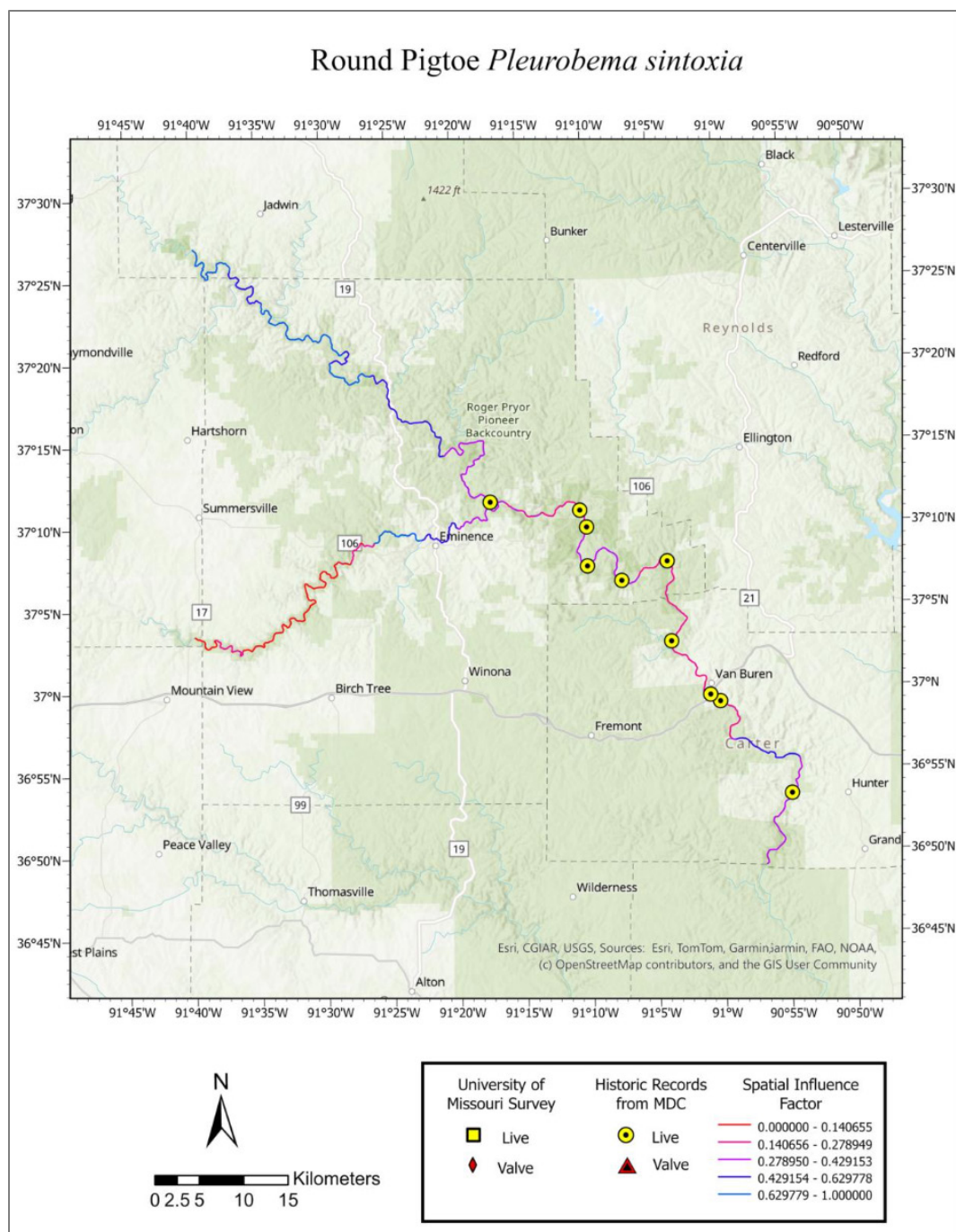


Figure 33. Map showing the distribution of Round Pigtoe (*Pleurobema sintoxia*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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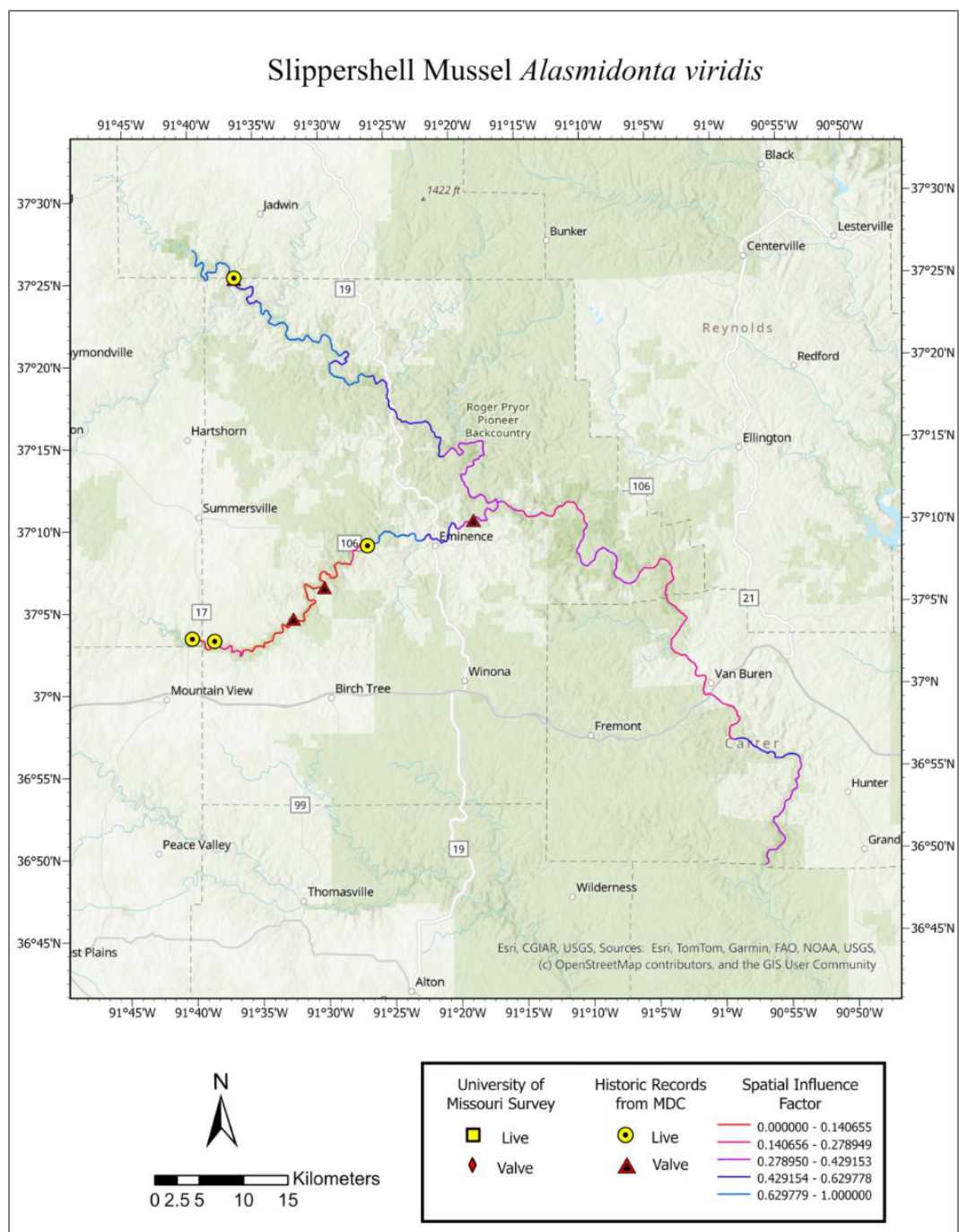


Figure 34. Map showing the distribution of Slippershell Mussel (*Alasmodonta viridis*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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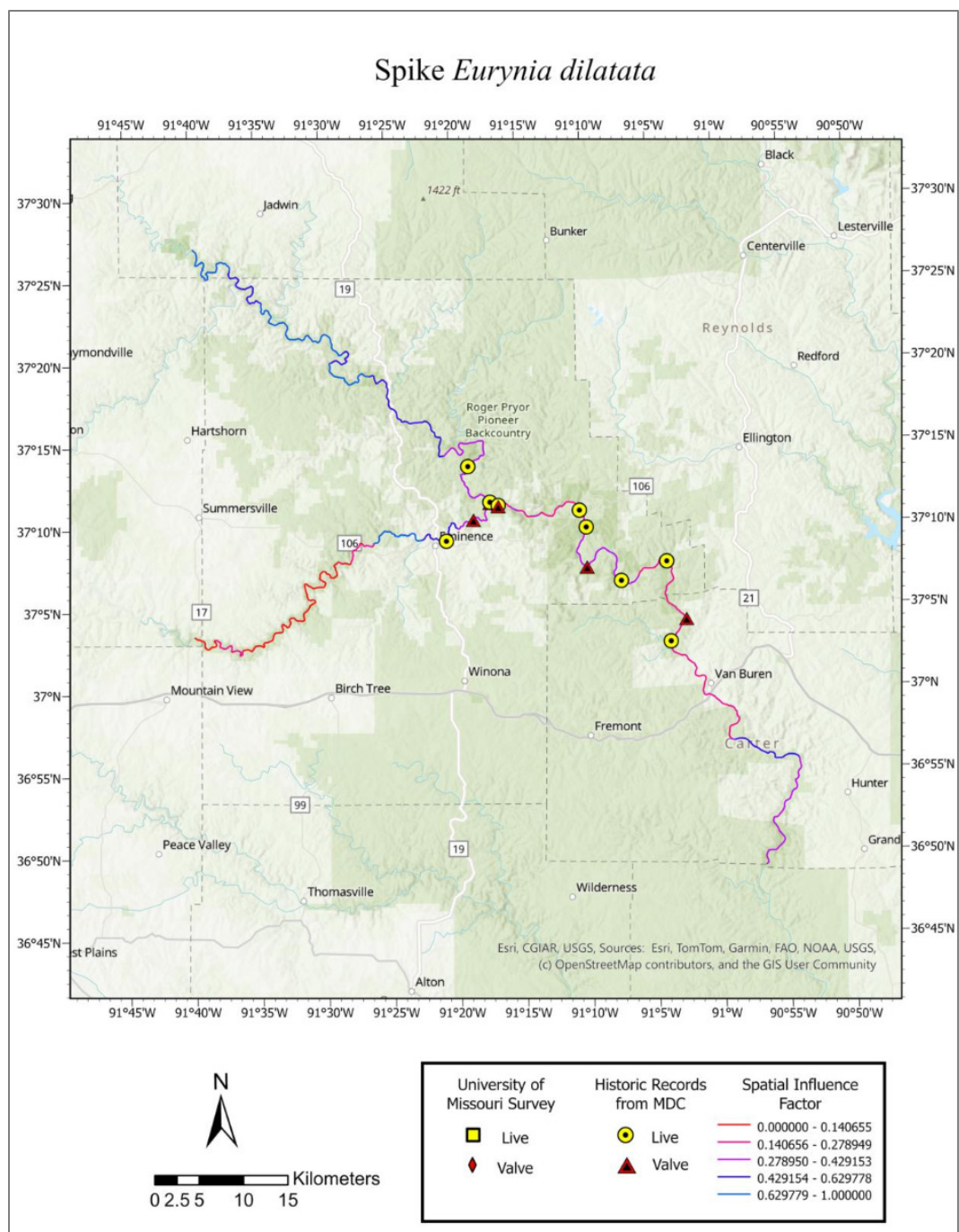


Figure 35. Map showing the distribution of Spike (*Eurynia dilatata*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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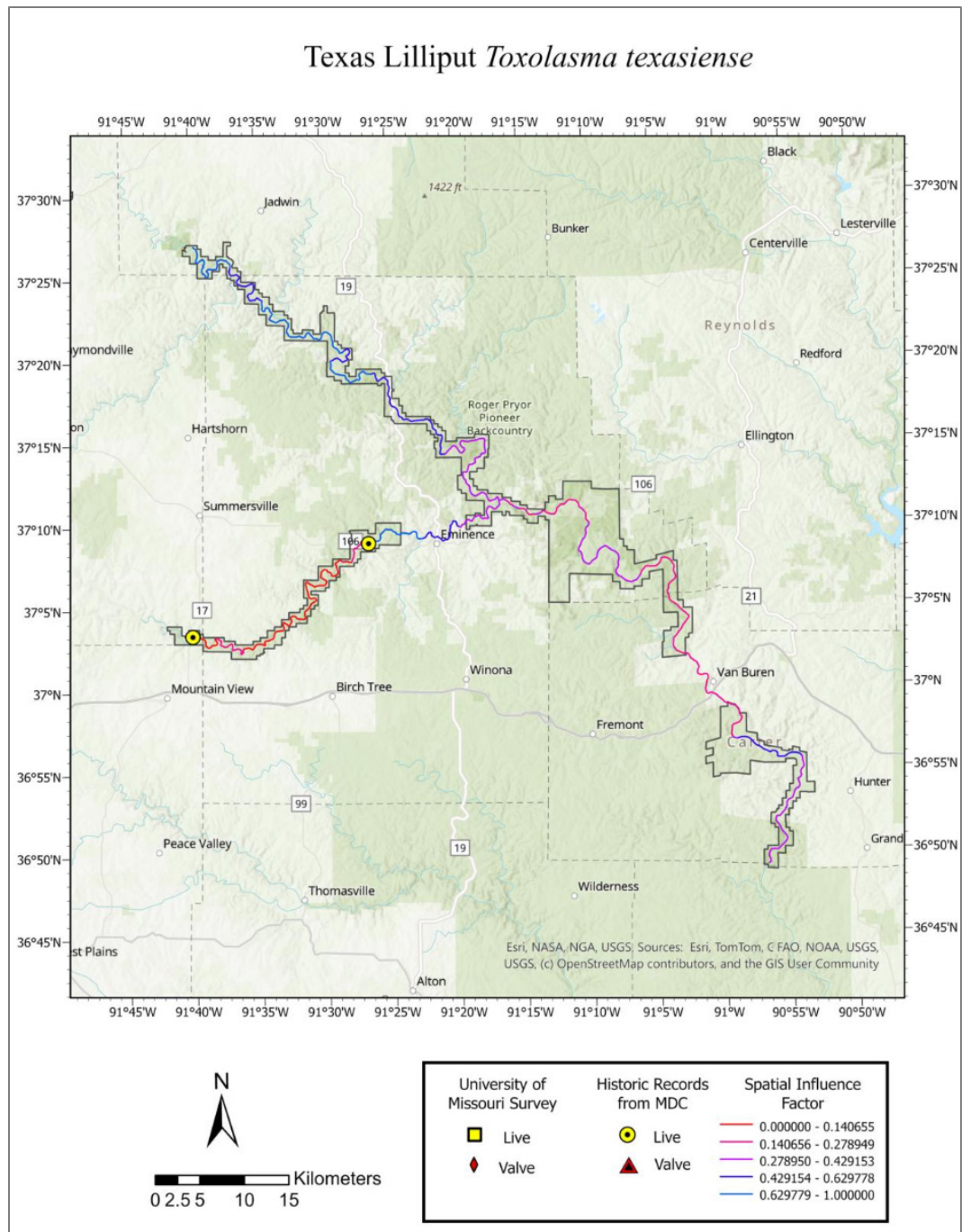


Figure 36. Map showing the distribution of Texas Lilliput (*Toxolasma texasiense*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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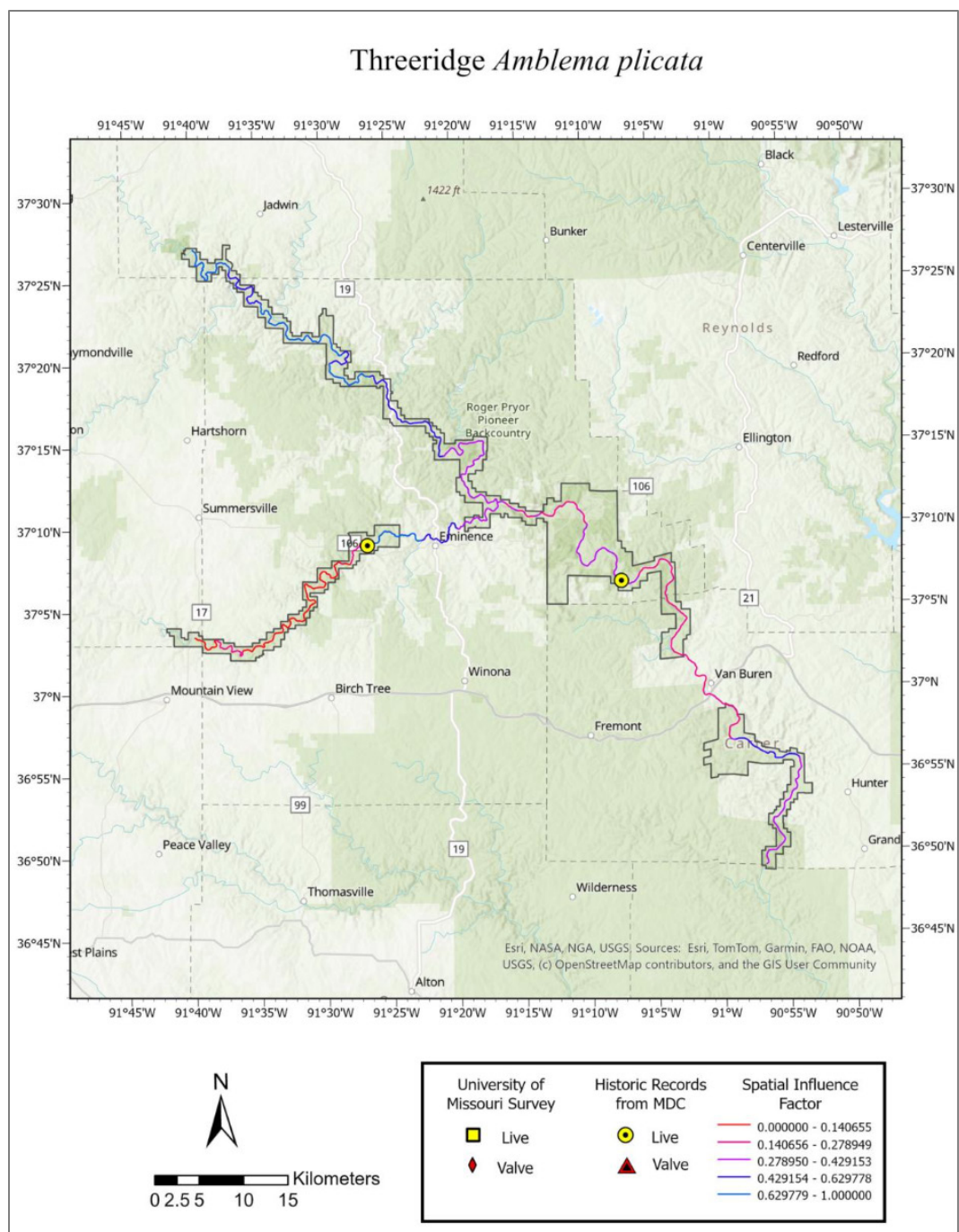


Figure 37. Map showing the distribution of Threeridge (*Amblema plicata*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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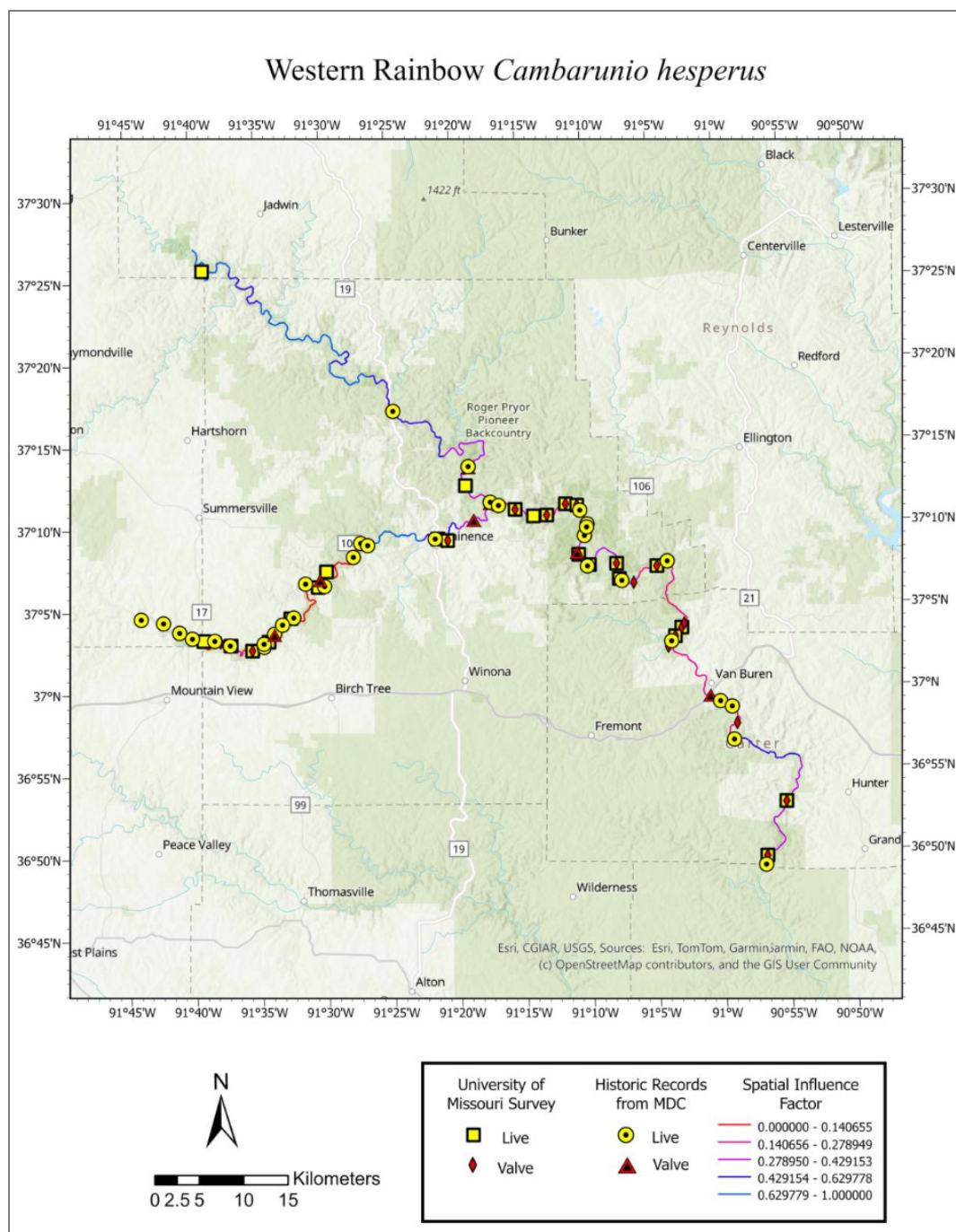


Figure 38. Map showing the distribution of Western Rainbow (*Cambarunio hesperus*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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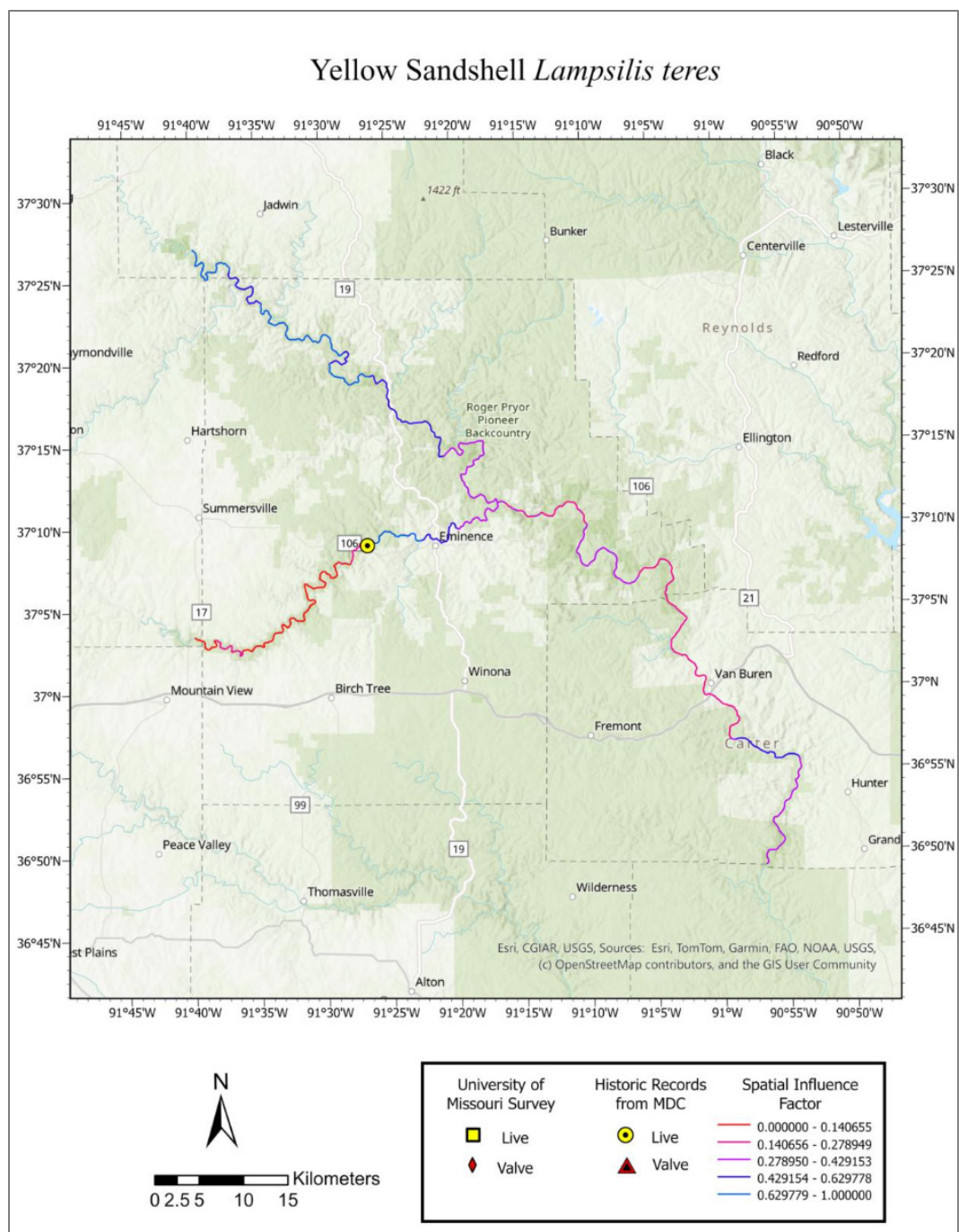


Figure 39. Map showing the distribution of Yellow Sandshell (*Lampsilis teres*) within Ozark National Scenic Riverways. Historical records from the Missouri Department of Conservation (MDC) Mollusk Database prior to 2023 are shown with yellow circles for live records and red triangles for valve records. Records from University of Missouri surveys conducted in 2023 and 2024 are shown with yellow squares for live records and red diamonds for valve records. River segments are color coded by spatial influence factor, representing the degree of groundwater spring influence along the river.

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Appendix G.

Table 13 presents species-level occupancy model results, including summary statistics and model diagnostics.

Table 13. Species-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Parameter	Occurrence (logit scale)						
	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
(Intercept)-Western Rainbow	-1.4738	0.5898	-2.6351	-1.4718	-0.302	1.0061	2209
(Intercept)-Flat Floater	-6.6888	1.694	-10.4914	-6.5157	-3.8478	1.0179	1114
(Intercept)-Ouachita Kidneyshell	-4.4784	0.9527	-6.5437	-4.4164	-2.79	1.0157	2005
(Intercept)-Arkansas Brokenray	-1.7206	0.8439	-3.4346	-1.7022	-0.0905	1.0238	985
(Intercept)-Fatmucket	-6.2263	1.5843	-9.7453	-6.0936	-3.5377	1.0026	1161
(Intercept)-Giant Floater	-5.7237	1.3327	-8.7944	-5.5755	-3.5302	1.0043	1234
(Intercept)-Ozark Pigtoe	-5.1447	1.1422	-7.6772	-5.0545	-3.1589	1.0087	1772
(Intercept)-Paper Pondshell	-3.1024	0.8264	-4.7836	-3.076	-1.5233	1.0011	3081
(Intercept)-Pondmussel	-5.6656	1.2683	-8.4935	-5.529	-3.5149	1.0001	1511
(Intercept)-Purple Lilliput	-6.0633	1.3829	-9.1059	-5.9282	-3.7242	1.0026	1639
Rel_Spr_In-Western Rainbow	-1.8927	0.5224	-2.999	-1.8693	-0.9317	1.0047	2933
Rel_Spr_In-Flat Floater	-1.7309	0.8394	-3.4952	-1.7127	-0.0595	1.0019	2917
Rel_Spr_In-Ouachita Kidneyshell	-2.2281	0.7795	-4.0481	-2.1336	-0.9591	1.0093	2156
Rel_Spr_In-Arkansas Brokenray	-1.4824	0.6037	-2.6909	-1.4761	-0.3132	1.023	1948
Rel_Spr_In-Fatmucket	-1.3949	0.8724	-2.956	-1.467	0.5764	1.0048	2316
Rel_Spr_In-Giant Floater	-1.2462	0.7956	-2.6562	-1.3177	0.5051	1.0041	2545
Rel_Spr_In-Ozark Pigtoe	-2.527	0.9293	-4.7826	-2.3696	-1.1497	1.0052	1463
Rel_Spr_In-Paper Pondshell	-1.5344	0.6516	-2.827	-1.5337	-0.2466	1.0066	3075
Rel_Spr_In-Pondmussel	-2.0304	0.7932	-3.8471	-1.9513	-0.6774	1.0036	2448
Rel_Spr_In-Purple Lilliput	-2.05	0.8534	-4.0359	-1.9601	-0.629	1.002	1993
Off_Channel-Western Rainbow	0.389	0.4346	-0.4835	0.3916	1.2426	1.0001	5248
Off_Channel-Flat Floater	0.7844	0.7167	-0.5137	0.7411	2.367	1.0037	2823
Off_Channel-Ouachita Kidneyshell	-0.1975	0.814	-2.1712	-0.0734	1.0465	1.0037	2331

Table 13 (continued). Species-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Parameter	Occurrence (logit scale)						
	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
Off_Channel-Arkansas Brokenray	-0.0374	0.5422	-1.1737	-0.0098	0.9562	1.0009	2977
Off_Channel-Fatmucket	0.9714	0.7407	-0.2869	0.8972	2.6612	1.0002	2044
Off_Channel-Giant Floater	0.9518	0.623	-0.135	0.9002	2.3275	1.0008	2777
Off_Channel-Ozark Pigtoe	0.4325	0.5892	-0.7659	0.4437	1.5846	1.0011	3684
Off_Channel-Paper Pondshell	1.2874	0.906	0.128	1.1197	3.6966	1.0017	922
Off_Channel-Pondmussel	0.999	0.6408	-0.1318	0.9529	2.3772	1.0004	2610
Off_Channel-Purple Lilliput	0.6556	0.6251	-0.5542	0.6362	1.9571	1.0035	4400
River-Western Rainbow	-0.8895	0.9454	-2.7807	-0.8834	0.9437	1.0061	3958
River-Flat Floater	-1.3111	2.1624	-6.4026	-1.0096	1.981	1.0056	1517
River-Ouachita Kidneyshell	0.9833	1.268	-1.3655	0.931	3.5882	1.0213	1353
River-Arkansas Brokenray	-0.3503	1.1728	-2.6737	-0.3546	2.0061	1.0097	2084
River-Fatmucket	-1.4874	2.0619	-6.3917	-1.1773	1.7428	1.012	2029
River-Giant Floater	-1.7844	2.1598	-6.8639	-1.402	1.2541	1.0075	1475
River-Ozark Pigtoe	2.407	1.7168	-0.6506	2.3278	6.0492	1.0331	1119
River-Paper Pondshell	-1.5349	1.5081	-4.9047	-1.3808	1.0511	1.0077	2396
River-Pondmussel	-0.1894	1.4238	-3.0444	-0.1892	2.6671	1.0001	4592
River-Purple Lilliput	-0.2476	1.508	-3.2594	-0.258	2.8339	1.0028	4274
Fine_Sediments-Western Rainbow	0.0971	0.9331	-1.7658	0.1286	1.8752	1.0004	499
Fine_Sediments-Flat Floater	0.6224	0.994	-1.2738	0.6231	2.6254	1.0026	606
Fine_Sediments-Ouachita Kidneyshell	-0.0978	0.9869	-2.1037	-0.06	1.7455	1.001	594
Fine_Sediments-Arkansas Brokenray	0.2492	0.9291	-1.6059	0.2749	2.0239	1.001	506
Fine_Sediments-Fatmucket	0.492	0.991	-1.4307	0.4948	2.4424	1.0024	582
Fine_Sediments-Giant Floater	0.6391	0.94	-1.2163	0.6474	2.4721	1.0011	549
Fine_Sediments-Ozark Pigtoe	0.2495	0.9442	-1.642	0.2777	2.0462	1.0005	523
Fine_Sediments-Paper Pondshell	0.8593	1.0036	-1.0376	0.8405	2.9234	1.0043	600
Fine_Sediments-Pondmussel	0.53	0.9508	-1.3274	0.5381	2.3775	1.0009	516
Fine_Sediments-Purple Lilliput	0.6316	0.9785	-1.2563	0.6346	2.5562	1.001	583

Table 13 (continued). Species-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Parameter	Occurrence (logit scale)						
	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
Loose_Sediments-Western Rainbow	-0.5628	1.1481	-2.8398	-0.5299	1.6055	1.0005	480
Loose_Sediments-Flat Floater	-0.4629	1.1586	-2.7713	-0.4316	1.761	1.0002	496
Loose_Sediments-Ouachita Kidneyshell	-0.1443	1.145	-2.365	-0.1271	2.083	1.0004	467
Loose_Sediments-Arkansas Brokenray	-0.4866	1.1359	-2.7284	-0.459	1.6911	1.0005	451
Loose_Sediments-Fatmucket	-0.3124	1.1622	-2.6164	-0.2878	1.917	1.0002	501
Loose_Sediments-Giant Floater	-0.3649	1.1374	-2.6015	-0.3393	1.8166	1.0002	472
Loose_Sediments-Ozark Pigtoe	-0.2965	1.1272	-2.5156	-0.2739	1.867	1.0002	466
Loose_Sediments-Paper Pondshell	-0.3953	1.1389	-2.6578	-0.3747	1.7913	1.0005	505
Loose_Sediments-Pondmussel	-0.3092	1.1394	-2.5484	-0.2853	1.8939	1.0001	452
Loose_Sediments-Purple Lilliput	-0.5054	1.1468	-2.773	-0.4763	1.6636	1.0003	488
Large_Sediments-Western Rainbow	1.6383	1.2388	-0.7696	1.6462	4.0855	1.0006	596
Large_Sediments-Flat Floater	-0.4159	1.3801	-3.183	-0.3818	2.2236	1.0024	841
Large_Sediments-Ouachita Kidneyshell	0.3268	1.1735	-1.947	0.3341	2.6354	1.0025	528
Large_Sediments-Arkansas Brokenray	0.8501	1.1857	-1.4703	0.8632	3.1722	1.0019	550
Large_Sediments-Fatmucket	-0.671	1.4368	-3.6623	-0.6132	1.9548	1.0002	863
Large_Sediments-Giant Floater	-0.9602	1.4075	-3.9471	-0.8805	1.5804	1.0017	876
Large_Sediments-Ozark Pigtoe	-0.0395	1.1404	-2.2706	-0.0214	2.1585	1.0011	540
Large_Sediments-Paper Pondshell	-1.3589	1.3249	-4.0829	-1.3154	1.0992	1.001	810
Large_Sediments-Pondmussel	-0.835	1.3075	-3.5222	-0.7883	1.5884	1.0003	727
Large_Sediments-Purple Lilliput	-0.2239	1.2613	-2.7338	-0.2003	2.1965	1.0002	663
Riffle-Western Rainbow	-1.0051	0.6337	-2.4081	-0.9468	0.093	1.0047	2326
Riffle-Flat Floater	-0.8443	0.764	-2.4691	-0.8053	0.6105	1.0034	2542

Table 13 (continued). Species-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Parameter	Occurrence (logit scale)						
	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
Riffle-Ouachita Kidneyshell	-0.7011	0.5845	-1.929	-0.681	0.4044	1.0036	2502
Riffle-Arkansas Brokenray	-1.0975	0.6646	-2.6098	-1.0305	0.022	1.0019	2155
Riffle-Fatmucket	-0.8713	0.7587	-2.5105	-0.8282	0.5176	1.0037	2283
Riffle-Giant Floater	-0.8895	0.7506	-2.5348	-0.8381	0.457	1.0048	2126
Riffle-Ozark Pigtoe	-0.9879	0.6316	-2.3825	-0.9284	0.0984	1.002	2313
Riffle-Paper Pondshell	-0.7762	0.652	-2.1779	-0.7387	0.405	1.0074	2438
Riffle-Pondmussel	-0.9241	0.7381	-2.5696	-0.8682	0.3721	1.0044	2078
Riffle-Purple Lilliput	-0.9076	0.7435	-2.5239	-0.8565	0.4215	1.0029	2382
Glide_Race-Western Rainbow	0.5876	0.429	-0.2151	0.5728	1.4805	1.0015	3763
Glide_Race-Flat Floater	0.3975	0.5607	-0.7584	0.4073	1.4939	1.0019	4346
Glide_Race-Ouachita Kidneyshell	0.6465	0.4582	-0.1953	0.6251	1.6077	1.0004	3423
Glide_Race-Arkansas Brokenray	0.5808	0.4532	-0.266	0.5655	1.5273	1.0023	3060
Glide_Race-Fatmucket	0.3528	0.5547	-0.7916	0.3651	1.4243	1.0012	4446
Glide_Race-Giant Floater	0.4014	0.5286	-0.6696	0.4044	1.4609	1.0013	4303
Glide_Race-Ozark Pigtoe	0.3626	0.4266	-0.495	0.3652	1.2009	1.0006	4323
Glide_Race-Paper Pondshell	0.3649	0.4649	-0.5735	0.3688	1.2757	1.0014	4425
Glide_Race-Pondmussel	0.4701	0.5124	-0.5278	0.4628	1.5214	1.0006	4248
Glide_Race-Purple Lilliput	0.2276	0.5477	-0.9775	0.2625	1.21	1.0017	4269
Rel_Spr_In:Off_Channel-Western Rainbow	0.4514	0.4662	-0.4425	0.4436	1.4031	1.0016	5141
Rel_Spr_In:Off_Channel-Flat Floater	-0.1308	0.7014	-1.7294	-0.0537	1.032	1.0017	3212
Rel_Spr_In:Off_Channel-Ouachita Kidneyshell	0.4396	0.6215	-0.7249	0.4041	1.7875	1.0089	5178
Rel_Spr_In:Off_Channel-Arkansas Brokenray	-0.0273	0.5055	-1.0999	-0.0034	0.9098	1.0008	4437
Rel_Spr_In:Off_Channel-Fatmucket	0.3213	0.6344	-0.8691	0.2958	1.6671	1.0041	3673
Rel_Spr_In:Off_Channel-Giant Floater	0.3687	0.5236	-0.6011	0.3468	1.4819	1.0031	4351
Rel_Spr_In:Off_Channel-Ozark Pigtoe	0.0664	0.5788	-1.1816	0.0963	1.1316	1.0002	4998
Rel_Spr_In:Off_Channel-Paper Pondshell	0.297	0.5871	-0.8454	0.2856	1.5156	1.0038	4027

Table 13 (continued). Species-level occupancy model results with mean, standard deviation (SD), 2.5%, 50%, 97.5% intervals, $\hat{R}$ values (Rhat), and effective sample sizes (ESS).

Parameter	Occurrence (logit scale)						
	Mean	SD	2.5%	50%	97.5%	Rhat	ESS
Rel_Spr_In:Off_Channel-Pondmussel	-0.3682	0.693	-2.0123	-0.272	0.7146	1.0018	3269
Rel_Spr_In:Off_Channel-Purple Lilliput	0.0361	0.5994	-1.2799	0.0694	1.1387	1.0013	4835

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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525