Recovery Plan for the endangered Speckled Pocketbook (*Lampsilis streckeri*)
https://ecos.fws.gov/docs/recovery_plan/920102.pdf

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DRAFT AMENDMENT 1

We have identified the best available information that indicates the need to amend recovery criteria for the Speckled Pocketbook (*Lampsilis streckeri*) since the recovery plan was completed. In this proposed modification, we synthesize the adequacy of the existing recovery criteria, show amended recovery criteria, and the rationale supporting the proposed recovery plan modification. The proposed modification is shown as an addendum that supplements the recovery plan, superseding in part page 5 of the recovery plan, by adding delisting criteria. The recovery objective and the step-down outline are described in Part II A and B (pages 5 – 7) of the Speckled Pocketbook Recovery Plan (RP) and revised in part herein (USFWS 1992). Recovery plans are a non-regulatory document that provide guidance on how best to help recover species.

For
U.S. Fish and Wildlife Service
Southeast Region
Arkansas Field Office
Conway, Arkansas

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METHODOLOGY USED TO COMPLETE THE RECOVERY PLAN AMENDMENT

The proposed amendments to the recovery criteria were developed using the most recent and best available information for the species. Primary sources of information included this species' most recent 5-year review (USFWS 2015) and the current recovery plan (USFWS 1992). The lead biologist gathered the information and notified conservation partners of the Service's process to complete this amendment. Ultimately, biologists and managers in the Arkansas Ecological Services Field Office (AESFO) developed the amended recovery criteria for the Speckled Pocketbook.

ADEQUACY OF RECOVERY CRITERIA

Section 4(f)(1)(B)(ii) of the Endangered Species Act (Act) requires that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination…that the species be removed from the list." Legal challenges to recovery plans (see Fund for Animals v. Babbitt, 903 F. Supp. 96 (D.D.C. 1995)) and a Government Accountability Audit (GAO 2006) also have affirmed the need to frame recovery criteria in terms of threats assessed under the five listing factors.

Recovery Criteria

The RP (USFWS 1992) provides criteria for reclassifying Speckled Pocketbook from endangered to threatened. **https://ecos.fws.gov/docs/recovery_plan/920102.pdf**

Synthesis

The Speckled Pocketbook was listed as endangered on February 28, 1989 (54 *Federal Register* 8339). No critical habitat has been designated for the species. The most recent status review for the Speckled Pocketbook was in 2015 (USFWS 2015), which recommended no change to the species endangered status. The 5-year review summarizes new information, since the recovery plan, pertaining to the species' life history and genetics.

Speckled Pocketbook is extant in the Middle Fork Little Red River from the upper reaches of Greers Ferry Reservoir upstream to the confluence of Little Red Creek (101 km, 63 mi), the South Fork Little Red River extending from Arkansas Highway 95 upstream to near the western boundary of Gulf Mountain Wildlife Management Area and the Ozark National Forest (24 km, 15 mi), Archey Fork Little Red River from approximately ¾ km upstream of U.S. Highway 65 to the confluence of Castleberry Creek (26 km, 16 mi), lower Turkey Creek (3 km, 1.9 mi), and Beech Fork (18 km, 11 mi). The known range of Speckled Pocketbook in Big Creek is thought to include the reach from Tylar Road to the western (also most downstream) boundary of Big Creek Natural Area (27 km, 17 mi). No comprehensive survey data exists for Big Creek. Therefore, we consider this portion of its range to be "presumed extant" (Davidson pers. comm. 2018).

Based on a 2004/2005 threats assessment conducted by AESFO (Davidson and Wine, 2004; Davidson, 2005) and several other recent studies by The Nature Conservancy (Inlander 2012; M. Allen pers. comm. 2018), the sources of degradation to suitable habitat of the Speckled Pocketbook are well-known. They include inundation due to reservoir management, rock mining, unrestricted cattle access into streams, water diversion, lack of adequate riparian buffers, construction and maintenance of unpaved roads, eroding stream banks, and non-point source pollution.

The construction of Greers Ferry Reservoir resulted in the permanent loss of habitat and isolation of populations (Middle and Devils forks, Big Creek) due to inundation and cold tailwater releases downstream of the dam. Information on gene flow between populations and effective population size is lacking at this time. Fragmentation and isolation of small populations, particularly in Big Creek and Devils Fork, may play a magnified role in population extirpation associated with stochastic events.

Threats associated with sediment in the Speckled Pocketbook's range are derived from a variety of land use practices (e.g. gravel and rock mining, agricultural and forestry practices, dirt and gravel road maintenance and construction, etc.). Two primary sources of sediment in rural forested watersheds are eroding stream banks and unpaved roads (Edwards and Evans 2004). Increases in construction activities related to the development of the Fayetteville shale gas play from 2006 – 2012 exacerbated sediment issues in the southern portions of the South, Archey, and Middle forks and Big Creek (Entrekin et al. 2018a and b; Entrekin et al. 2011; Davidson pers. comm. 2018). Natural gas infrastructure development has subsided substantially since circa 2012. It appears

unlikely, at this time, that substantial development of mineral resources (*i.e*., natural gas) will occur in the upper South Fork, mid to upper Middle Fork, Archey Fork, and upper Devils Fork watersheds due to insufficient quantities of profitable natural gas reserves.

In 2012, TNC completed an unpaved road inventory for the forks of the Little Red River with the goal of mapping position and accessibility of roads, to document sediment-related characteristics and drainage conditions of roads and ditches, and to document other road features such as stream crossings and barriers to aquatic passage. The Arkansas Unpaved Roads Program focuses on best management practices (BMPs) that reduce the effect of sediment and road runoff to streams, rivers, and drinking water supplies while reducing long-term unpaved county road maintenance costs. During the past several years, numerous unpaved road projects have targeted high sediment delivery road segments in the South and Middle forks (Davidson pers. comm. 2018). Sedimentation from unpaved roads continues to threaten Speckled Pocketbook and its habitat, but efforts such as the Arkansas Unpaved Roads Program and other similar efforts on private unpaved roads demonstrates progress towards alleviating this threat.

The non-riparian water use (NRWU) program administered by the Arkansas Natural Resources Commission is designed to monitor surface water use outside of the riparian zone through the evaluation of surface water diversions, and subsequent determination actions (to include permits where appropriate) associated with each use. Surface water users are required to obtain certification from the state verifying the use of surface water will comply with the Arkansas State Water Plan and applicable state water law. There are 17 NRWU permits currently issued in the upper Little Red River and Big Creek watersheds. Four of these permits are set to expire in late 2018, six have been renewed, and three are active (S. Jackson pers. comm., 2018). Increases in construction activities related to the development of the Fayetteville shale gas play historically exacerbated water diversion issues in the lower portions of the South, Archey, and Middle forks and Big Creek (Entrekin et al. 2018a and b; Entrekin et al. 2011, Davidson pers. comm. 2018). However, this activity subsided substantially circa 2012 and water diversion is not considered a threat at this time.

Gravel and rock mining are activities that may negatively affect water quality in Speckled Pocketbook habitat. Instream and alluvial gravel mining has been implicated in the destruction of mussel populations (Hartfield 1993; Brim Box and Mossa 1999). Hillside rock mining occurs in the Middle Fork watershed and has contributed to acute sedimentation concerns while the activity is ongoing and shortly thereafter (Davidson pers. comm. 2018).

A major threat at the time of listing was channelization of the lower Archey and South forks. With completion of the Archey Fork restoration project in 2014, this threat has been alleviated and suitable habitat for recolonization is present.

There are three point-source discharges (all municipal) within the range (South and Middle forks) of the Speckled Pocketbook. There is no data to suggest that these point source discharges pose a threat to Speckled Pocketbook. However, there is no specific information known about the sensitivity of Speckled Pocketbook to chemical pollutants commonly found in municipal effluents.

Exact critical thermal limits for Speckled Pocketbook survival and normal physiological functions are unknown, but closely related species are classified as thermally sensitive (e.g., *Lampsilis cardium* and *Lampsilis teres*; Spooner and Vaughn 2008). High temperatures can reduce dissolved

oxygen concentrations in the water, which slows growth, reduces glycogen stores, impairs respiration, may inhibit reproduction, and reduce righting speed (various reflexes that tend to bring the body into normal position in space and resist forces acting to displace it out of normal position) (Fuller, 1974; Bartsch et al. 2000; Watters and O'Dee 2000; Gray et al. 2002; Watters et al. 2001; Allen et al. 2007; Schwalb and Pusch 2007; Steingraeber et al. 2007). Data for the Kiamichi River in southeast Oklahoma suggests that over a 17-year period, as water and air temperatures increased, mussel beds once dominated by thermally sensitive species are now dominated by thermally tolerant species (Galbraith et al., 2010; Spooner and Vaughn, 2008). As temperature increases due to climate change throughout the range of Speckled Pocketbook, it may experience population declines as warmer rivers are more suitable for thermally tolerant species.

During the past decade, numerous conservation partners have dedicated resources to a variety of Speckled Pocketbook conservation efforts. A range-wide programmatic Safe Harbor Agreement was signed in 2007 by the AESFO, AGFC, Natural Resources Conservation Service, and The Nature Conservancy (TNC). To date, 14,714 acres are enrolled in the Agreement, protecting approximately 96 km (60 mi) of intermittent and perennial streams. TNC acquired tracts on South, Archey and Middle forks perpetually protecting approximately 2,900 acres. In fiscal year 2016, NRCS awarded TNC $816,000 under the Regional Conservation Partnership Program to address water quality degradation and inadequate habitat for fish and wildlife in the upper Little Red River watershed through reduction of erosion, sedimentation, and excess nutrient runoff. TNC also has implemented multiple stream restoration and road improvement projects in the watershed to further reduce sedimentation.

AMENDED RECOVERY CRITERIA

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be reclassified to threatened, or that the protections afforded by the Act are no longer necessary and the Speckled Pocketbook may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants. Reclassification is moving a species from endangered to threatened or vice versus. The term “endangered species” means any species (species, sub-species, or DPS) which is in danger of extinction throughout all or a significant portion of tis range. The term “threatened species” means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to the Lists, including delisting or reclassification of a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species (or not) because of threats to the species. Section 4(b) of the Act requires that the determination be made “solely on the basis of the best scientific and commercial data available.” Thus, while recovery plans provide important guidance to the Service, States, and other partners on methods of minimizing threats to listed species and measurable objectives against which to measure progress towards recovery, they are guidance and not regulatory documents.

Recovery criteria should help indicate when we would anticipate that an analysis of the species’ status under section 4(a)(1) would result in a determination that the species is no longer an endangered species or threatened species. A decision to revise the status of or remove a species

from the Federal Lists of Endangered and Threatened Wildlife and Plants, however, is ultimately based on an analysis of the best scientific and commercial data then available, regardless of whether that information differs from the recovery plan, which triggers rulemaking. When changing the status of a species, we first propose the action in the *Federal Register* to seek public comment and peer review, followed by a final decision announced in the *Federal Register*.

The Speckled Pocketbook RP (USFWS 1992) only developed reclassification criteria as discussed above. We provide amended recovery criteria for the Speckled Pocketbook, which will supersede (replace) the existing downlisting criteria (refer to page 5 of the RP (USFWS 1992). The recovery criteria below describe recovery of the Speckled Pocketbook, or conditions that, when met, enable the species to be considered for removal from the List of Endangered and Threatened Wildlife (50 CFR 17).

Delisting Recovery Criteria

The Speckled Pocketbook will be considered for delisting when:

1. Three (3) existing populations in the South Fork (1), Middle Fork (1), and Archey Fork (1) exhibit a stable or increasing trend, natural recruitment, and multiple age classes (Factors A, D, and E).

2. Individuals in populations (as defined in Criterion 1) are spatially distributed sufficient to protect against stochastic and catastrophic disturbance events.

3. Threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future (Factors A, D, and E).

Justification

The delisting recovery criteria reflect the best available and current information for the Speckled Pocketbook. The recovery criteria address Factors A, D, and E. Factors B and C are not considered threats to Speckled Pocketbook. Ensuring that populations are distributed throughout the range (*e.g.* multiple rivers), in addition to within each river (e.g. multiple sites distributed from headwaters to confluence) addresses resiliency (proportion of habitat occupied) and redundancy (spatial distribution within each river and across basin) (as defined in Criteria 1 and 2). For the Speckled Pocketbook it is believed that 3 populations exhibiting these traits are necessary to provide sufficient redundancy to ensure the species will no longer require protection under the Act.

The main threat to Speckled Pocketbook continues to be habitat loss and degradation resulting from a variety of land uses primarily associated with intolerable levels of erosion and sedimentation for the species. Consequently, many historically occupied sites are extirpated or have suffered a decline in Speckled Pocketbook abundance. Criterion 3 responds to safeguarding existing suitable habitat while improving degraded areas that historically supported Speckled Pocketbook.

Rationale for Recovery Criteria

Using the ecological principles of representation, resiliency, and redundancy and through expert elicitation using a qualitative process, resiliency was determined to be low in all Speckled Pocketbook populations; redundancy high, and representation low to moderate. Captive propagation efforts are underway to stabilize or reverse decline and to increase resiliency. Redundancy is lower than prior to reservoir construction, with one historical population (main stem Little Red River) permanently extirpated. Due to the restricted range, geographic isolation of most extant populations, and small population size, the species is likely suffering genetic isolation and reduced adaptive capacity throughout much of its range, resulting in lower representation.

Criterion 1: Five Speckled Pocketbook populations persist within the Little Red River basin. Reservoir construction isolated all populations except the Archey and South forks. Speckled Pocketbook individuals are widely scattered in isolated concentrations with low abundance within each population (river). Recovery Criterion 1 maximizes resiliency by ensuring presence of multiple age classes, including juveniles, and sufficient number of individuals to sustain population resiliency. This criterion maximizes representation by ensuring sufficient habitat diversity (presence in a variety of suitable habitat types) and presence and abundance of fish hosts.

Criterion 2: Historical and recent (past 10 years) surveys delineate the potential spatial distribution of Speckled Pocketbook in each of the four Little Red River forks. Sustaining this spatial distribution of the species distributed throughout each targeted recovery river protects against catastrophic or stochastic events that may eliminate or substantially reduce isolated or fragmented populations. In the South Fork watershed, sites upstream of Arkansas Highway 95 are more prone to seasonal drying associated with extreme drought conditions. However, sites downstream of Arkansas Highway 95 that historically may have provided refugia for the species have been substantially reduced due to a variety of land use activities. Therefore, spatial distribution and sufficient quantity of sites upstream and downstream of Arkansas Highway 95 reduces effects associated with catastrophic and stochastic events and maximizes resiliency. This also applies to the Middle Fork population upstream and downstream of U.S. Highway 65. Several sites also persist downstream of Arkansas Highway 9 in the Middle Fork, but are prone to periodic inundation and subsequently increased sedimentation associated U.S. Army Corps of Engineers water (flood) management at Greers Ferry Lake.

Criterion 3: The life-history traits and habitat requirements of Speckled Pocketbook, and other freshwater mussels in general, make them extremely susceptible to environmental change. Unlike other aquatic organisms (*e.g.*, aquatic insects and fish), mussels have limited refugia from stream disturbances (*e.g.*, droughts, sedimentation, chemical contaminants). Mechanisms leading to Speckled Pocketbook imperilment range from local (*e.g.*, riparian clearing, chemical contaminants, etc.), to regional influences (*e.g.*, altered flow regimes, population isolation, etc.), to potentially global climate change. The synergistic (interaction of two or more components) effects of threats are often complex in aquatic environments, making it difficult to predict changes in mussel and fish host(s) distribution, abundance, and habitat availability that may result from these effects. While these stressors may act in isolation, it is more probable that many stressors are acting simultaneously (or in combination) (Galbraith et al. 2010) on Speckled Pocketbook populations. The Service will continue to evaluate these threats on the species and its habitat. In order to achieve this criterion, it is essential that tools such as TNC's bank erosion hazard index and unpaved roads

inventory datasets be routinely updated to track recovery progress (*i.e*. monitor major stressors) and prioritize conservation efforts in areas with the highest sediment delivery.

Speckled Pocketbook populations have demonstrated some resilience to potential threats in isolated areas, in part due to the implementation of recovery actions and monitoring. Actions towards monitoring and threats abatement will continue in order to ensure the populations meet the new criteria.

ADDITIONAL AND AMENDED RECOVERY ACTIONS

Revise Part II B.1 (page 5) as follows: Protect known populations and their habitats from further adverse effects. The continued survival of this species requires that every effort is expended to protect these populations.

Revise Part II B.1.1 (page 5) as follows: Conduct population surveys. Monitor populations at 7-year intervals to establish trends. Big Creek should be comprehensively surveyed to establish current distribution and abundance of Speckled Pocketbook and then monitored at the same interval as other populations.

Revise Part II B.2.0 (page 6) as follows: Conduct research on the species. While protecting Speckled Pocketbook and its habitat, it is important to address data gaps regarding the species biological requirements to ensure survival and recovery. This task should address important life history and water and sediment quality and quantity requirements.

Add the following recovery activity to Part II B.2.0 (page 6): 2.4 Determine genetic variation within and among populations. Knowing the genetic structure and diversity of Speckled Pocketbook will inform future conservation recovery tasks. Populations are isolated from one another by Greers Ferry Reservoir. This recovery task will analyze the genetic structure and diversity of extant populations. It will provide information on population heterozygosity, observed number of alleles, and effective population size.

Add the following recovery activity to Part II B.2.0 (page 6): 2.5 Determine sediment deposition rates v. survivorship of Speckled Pocketbook. Excessive sedimentation and its associated effects are not good for mussels or free-flowing streams. Many mussel declines have been attributed to sedimentation from a variety of land use activities. Understanding why nearly all mussel species have exhibited population declines when some species are silt tolerant (and in some cases silt dependent) is important to understanding the stressors limiting population growth. This recovery task will provide information on particle size, rate of deposition, timing of deposition events, and how bed load dynamics influence Speckled Pocketbook survival.

Revise Part II B.3.2 (page 7) as follows: Develop a plan for reestablishing mussel populations. "… by transplanting from extant populations, …". Remove and replace the last sentence in Part II B.3.2 as follows: Evaluate existing habitat and assess suitability of sites considered for reintroduction and augmentation. Ensure genetic stock representative of genetic diversity.

Revise Part II B.3.3 (page 7) as follows: Implement plan to restore historical habitat. Based upon information gained through TNC's bank erosion hazard index and unpaved roads inventory, as well

as current distribution and abundance of Speckled Pocketbook, the lower South Fork (defined as areas downstream of Lo Gap Road) and upper Middle Fork (defined as areas upstream of Elba) should be the highest priority for habitat restoration.

Revise Part II B.4.1 (page 7) as follows: Determine effective population size. See Action 2.0. This action will determine the effective population size required for viable populations through population genetics.

COSTS, TIMING, PRIORITY OF ADDITIONAL RECOVERY ACTIONS

The revised cost for implementing Recovery Action 1.1 is approximately $20,000 every 7th year. Revised actions under 2.0 are estimated to cost approximately $250,000. We are unable to estimate projected costs for revised Recovery Action 3.2 and 3.3 as associated costs are project specific and highly variable depending on type of action. Costs associated with Recovery Action 4.1 are incorporated into estimated costs for Recovery Action 2.0.

LITERATURE CITED

Allen, D. C., B. E. Sietman, D. E. Kelner, M. C. Hove, J. E. Kurth, J. M. Davis, J. L. Weiss, and D. J. Hornbach. 2007. Early life-history and conservation status of *Venustaconcha ellipsiformis* (Bivalvia, Unionidae) in Minnesota. *American Midland Naturalist* 157:74-91.

Bartsch, M. R., D. L. Waller, G. W. Cope, and S. Gutreuter. 2000. Emersion and thermal tolerances of three species of unionid mussels: survival and behavioral effects. *Journal of Shellfish Research* 19:233-240.

Brim-Box, J.B., and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. *Journal of North American Benthological Society* 18:99-117.

Clarke, A.E. 1987. Status survey of *Lampsilis streckeri* Frierson (1927) and *Arcidens wheeleri* (Ortman and Walker 1912). A report to the U.S. Fish and Wildlife Service. 24 pp. plus field notes.

Edwards, Pamela J.; Evans, Gregory L. 2004. Giving greater consideration to cross-drainage discharge from forest roads. In: Proceedings, Riparian Ecosystems and Buffers: Multi-scale Structure, Function, and Management, American Water Resources Association Summer Specialty Conference. 2004 June 28-30; Olympic Valley, CA. American Water Resources Association. 6 p.

Entrekin, S., Trainor, A., Saiers, J., Patterson, L., Maloney, K., Fargione, J., Kiesecker, J., Baruch-Mordo, S., Konschnik, K., Wiseman, H. and Nicot, J.P., 2018a. Water stress from high-volume hydraulic fracturing potentially threatens aquatic biodiversity and ecosystem services in Arkansas, United States. *Environmental science & technology*, 52(4), pp.2349-2358.

Entrekin, S.A., Austin, B.J., Evans-White, M.A. and Haggard, B.E., 2018b. Establishing the linkage among watershed threats, in-stream alterations and biological responses remains a challenge: Fayetteville Shale as a case study. *Current Opinion in Environmental Science & Health*.

Entrekin, S., M.A. Evans-White, B. Johnson, and E. Hagenbuch. 2011. Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment* 9(9): 503-511.

Fuller, S. L. H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp. 215-273 *in*: C.W. Hart, Jr., and S.L.H. Fuller, eds. Pollution ecology of freshwater invertebrates. Academic Press, New York.

GAO. 2006. Endangered species: time and costs required to recover species are largely unknown. Letter to congressional requesters. Washington, D.C. 27 pp.

Galbraith, H. S., D. E. Spooner, and C. C. Vaughn. 2010. Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. *Biological Conservation* 143:1175-1183.

Gray, E. V. S., W. A. Lellis, J. C. Cole, and C. S. Johnson. 2002. Host identification for *Strophitus undulatus* (Bivalvia:Unionidae), the Creeper, in the Upper Susquehanna River Basin, Pennsylvania. *Am. Midl. Nat.* 147:153-161.

Hartfield, P.D. 1993. Headcuts and their effect on freshwater mussels. Pp. 13–141, *In* K.S. Cummings, A.C. Buchanan, and L.M. Koch (Eds.). Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC Symposium, 12–14 October, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. 293 pp

Harris, J.L. 1985. Search for Lampsilis streckeri Frierson in the forks of the Little Red River at Clinton, Arkansas. Unpublished report. 6 pp.

Harris, J.L. 1991. Survey for *Lampsilis streckeri* in the Middle Fork Little Red River at the proposed NOARK pipeline crossing, Van Buren County, Arkansas. Prepared for ENSR Consulting and Engineering, Houston, TX. 10pp.

Harris, J.L. 1992a. Temporary relocation of the Speckled Pocketbook (Lampsilis streckeri) at the NOARK pipeline crossing, Middle Fork Little Red River, Van Buren County, Arkansas. Unpublished report. 10 pp. + appendix

Harris, J.L. 1992b. Status of *Lampsilis streckeri* in segments of the Middle, South, and Archey forks of the Little Red River, Stone and Van Buren counties, Arkansas. Prepared for the U.S. Fish and Wildlife Service, Endangered Species Office, Jackson, MS. 23pp. + field notes.

Harris, J.L. 1993. Habitat characterization and species associates of the speckled pocketbook (*Lampsilis streckeri*) in the Middle Fork Little Red River, Arkansas. Prepared for the U. S. Fish and Wildlife Service, Endangered Species Office, Jackson, MS. 28pp. plus appendices.

Inlander, E. 2012. Inventory, assessment, and prioritization for unpaved roads and stream crossings in the upper Little Red River watershed, Ozarks ecoregion, Arkansas. Unpublished report submitted to U.S. Fish and Wildlife Service, Conway, Arkansas. 33 pp.

Schwalb, A. N., and M. T. Pusch. 2007. Horizontal and vertical movements of unionid mussels in a lowland river. *Journal of the North American Benthological Society* 26:261-272.

Spooner, D.E. and C.C. Vaughn. 2008. A trait-based approach to species' roles in stream ecosystems: climate change, community structure, and material cycling. *Oecologia* 158:307-317.

Steingraeber, M. T., M. R. Bartsch, J. E. Kalas, and T. J. Newton. 2007. Thermal Criteria for Early Life Stage Development of the Winged Mapleleaf Mussel (*Quadrula fragosa*). *American Midland Naturalist* 157:297–311.

Watters, G. T., and S. H. O'Dee. 2000. Glochidial release as a function of water temperature: Beyond bradyticty and tachyticty. Pp. 135-140 *in:* R.A. Tankersley et al*.,* eds. Proceedings of the Conservation, Captive Care, and Propagation of Freshwater Mussels Symposium, 1998. Ohio Biological Survey Special Publications, Columbus, Ohio.

Watters, G. T., S. H. O'Dee, and S. Chordas. 2001. Patterns of vertical migration in freshwater mussels (Bivalvia: Unionoida). *Journal of Freshwater Ecology* 16:541-549.

USFWS. 2015. Speckled Pocketbook (*Lampsilis streckeri*) 5-Year Review: Summary and Evaluation. USFWS Southeast Region, Arkansas Ecological Services Field Office, Conway, Arkansas. 20 pp.

USFWS. 1992. Speckled Pocketbook mussel (*Lampsilis streckeri*) recovery plan. USFWS, Jackson, Mississippi. 14 pp.

Winterringer, R. 2003. Population dynamics and reproductive patterns of the federally endangered freshwater mussel, *Lampsilis streckeri* (Frierson 1927). M.S. thesis. Arkansas State University, State University, Arkansas. 74pp.