

James Spiny mussel
(Parvaspina collina)

**5-Year Review:
Summary and Evaluation**



James spiny mussel
(Credit: Jennifer Stanhope, U.S. Fish and Wildlife Service)

**U.S. Fish and Wildlife Service
Virginia Field Office
Gloucester, Virginia**

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5-YEAR REVIEW
James spinymussel (*Parvaspina collina*)

TABLE OF CONTENTS

| | | |
|---------|--|----|
| 1.0 | GENERAL INFORMATION..... | 3 |
| 1.1 | Reviewers..... | 3 |
| 1.2 | Methodology Used to Complete This Review:..... | 3 |
| 1.3 | Background:..... | 3 |
| 2.0 | REVIEW ANALYSIS..... | 4 |
| 2.1 | Application of the 1996 Distinct Population Segment (DPS) policy..... | 4 |
| 2.2 | Recovery Criteria..... | 4 |
| 2.3 | Updated Information and Current Species Status..... | 8 |
| 2.3.1 | Biology and Habitat..... | 8 |
| 2.3.1.1 | New information on the species' biology and life history:..... | 8 |
| 2.3.1.2 | Abundance, population trends, demographic features, or demographic trends: 16 | |
| 2.3.1.3 | Genetics, genetic variation, or trends in genetic variation:..... | 46 |
| 2.3.1.4 | Taxonomic classification or changes in nomenclature:..... | 48 |
| 2.3.1.5 | Spatial distribution, trends in spatial distribution, or historic range:..... | 48 |
| 2.3.1.6 | Habitat or ecosystem conditions:..... | 54 |
| 2.3.2 | Five-Factor Analysis:..... | 57 |
| 2.3.2.1 | Factor A. Present or threatened destruction, modification, or curtailment of its habitat or range:..... | 57 |
| 2.3.2.2 | Factor B. Overutilization for commercial, recreational, scientific, or educational purposes:..... | 62 |
| 2.3.2.3 | Factor C. Disease or predation:..... | 63 |
| 2.3.2.4 | Factor D. Inadequacy of existing regulatory mechanisms:..... | 63 |
| 2.3.2.5 | Factor E. Other natural or manmade factors affecting its continued existence: 66 | |
| 2.4 | Synthesis..... | 68 |
| 3.0 | RESULTS..... | 75 |
| 4.0 | RECOMMENDATIONS FOR FUTURE ACTIONS..... | 75 |
| 5.0 | REFERENCES..... | 77 |
| | APPENDIX A: COORDINATION LIST OF PARTNERS AND EXPERTS..... | 89 |
| | APPENDIX B: OCCURRENCE WATERBODIES OF JAMES SPINYMUSSEL..... | 90 |

5-YEAR REVIEW

James spinymussel (*Parvaspina collina*)

1.0 GENERAL INFORMATION

1.1 Reviewers

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Technical Reviewers/Experts:

See Appendix A (Coordination List of Partners and Experts) for list of technical reviewers and experts.

1.2 Methodology Used to Complete This Review:

This 5-year review, conducted primarily by the lead recovery biologist for James spinymussel (JSM) (*Parvaspina collina*; formerly *Pleurobema collina* [see section 2.3.1.4]), summarizes and evaluates new information relevant to the listing status of the species under the Endangered Species Act (ESA). New data and information regarding the species' population status and habitat used in this report were based on: peer-reviewed literature; survey reports; and information and occurrence data from state natural resource agencies, mussel hatcheries, and researchers. In 2008, the U.S. Fish and Wildlife Service (Service) drafted a 5-year review document but did not finalize it. In early 2021, Service offices (e.g., Field Offices, Service hatcheries), state natural resource agencies, Federal agencies, and researchers were contacted for up-to-date information on species' occurrences, threats, and recovery activities (see appendix A for list of partners and experts who provided responses). Since the 2008 5-year review was not finalized, this review provides the first comprehensive status review of the species since the 1990 recovery plan was written (Service 1990). All pertinent literature and documents on file at the Virginia Field Office were used for this review.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review: 85 FR 64527-64529 (October 13, 2020)

1.3.2 Listing history:

FR notice: 53 FR 27689-27693

Date listed: July 22, 1988

Entity listed: species

Classification: endangered

1.3.3 Associated rulemakings: None

1.3.4 Review history:

Previous 5-Year Review

Initiated: 73 FR 3991-3993 (January 23, 2008)

Date Finalized: review drafted but not finalized and signed

Results: not applicable

Initiated: 56 FR 56882-56900 (November 6, 1991)

Date Finalized: No record or documentation of review being drafted or finalized.

Results: not applicable

1.3.5 Species' Recovery Priority Number at start of review: 8. This designation corresponds to a species experiencing a moderate degree of threat and a high recovery potential.

1.3.6. Recovery Plan:

Name of plan: James spinymussel (*Pleurobema collina*) Recovery Plan

Date issued: September 24, 1990

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate? No. The JSM is an invertebrate, and the DPS policy does not apply.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria? Yes, the species has an approved plan containing objective, measurable criteria. However, criterion 1C, is too general and merits clarification to support objective evaluation and achievability. Criterion 2E is too specific and also merits clarification to support objective evaluation and achievability.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat? Yes, the biology and habitat of the species are relatively unchanged. There is an expansion of the range of the species to the Roanoke River basin in North Carolina that is not reflected in criterion 2D, which merits clarification to include waterbodies in the Roanoke River basin.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)? Yes.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The criteria for delisting are:

Objective 1. Reclassify *P. collina* from endangered to threatened status when the likelihood of extinction in the foreseeable future has been eliminated by meeting the following criteria:

- A. Populations of *P. collina* throughout the Craig Creek Drainage (including Johns Creek) and 80 percent of all other known populations are stable or expanding (as shown by monitoring over 10-year period) and show evidence of recruitment (specimens age five or younger).

This criterion has not been met as stated. From the recovery plan (Service 1990), known populations of JSM in the Craig Creek Drainage were described as: Craig Creek (three subpopulations or areas), Johns Creek (two subpopulations or areas), Dicks Creek, and Patterson Creek. For these waterbodies as of 2021, only the Dicks Creek population and one subpopulation in Johns Creek are stable or expanding based on monitoring over a 10-year period and show evidence of recruitment; thus only 50 percent of the waterbodies (2 of 4) and 29 percent of subpopulations or areas (2 of 7) in the Craig Creek Drainage meet this criterion, based on known populations at the time of the recovery plan (see tables 1, 4, and 6 in section 2.3.1.2). The Patterson Creek population and two subpopulations in Craig Creek are possibly extirpated or their population status is unknown (see table 1 in section 2.3.1.2). One new JSM waterbody, Little Oregon Creek, has been discovered in the Craig Creek Drainage since 1990, but it does not meet this criterion because the population trend is decreasing mainly due to raccoon (*Procyon lotor*) predation.

For populations noted as historical or present in the recovery plan outside of the Craig Creek Drainage, two waterbodies meet this criterion, South Fork Potts Creek and Mill Creek¹ (VA), representing 17 percent (2 of 14) of known populations in 1990 (see tables 1, 4, and 6 in section 2.3.1.2). Since the 1990 recovery plan, many new waterbodies have been discovered with JSM; however, none of them meet this

¹ There are two Mill Creeks with JSM, one in Virginia and one in North Carolina. Hereafter, references to Mill Creek are assumed to be in Virginia, except when noted as in North Carolina.

criterion. Rocky Creek in Virginia is a new population that is stable (with large variations in number of JSM) and has evidence of recruitment, but the status is not based on monitoring over a 10-year period.

Therefore, only four waterbodies across the range meet this criterion. When including all JSM historically occupied waterbodies as of 2021 (e.g., including those in the expanded range in the Roanoke River basin), only 10.8 percent (4 of 37) meet this criterion. If based on all currently present (i.e., extant) waterbodies, only 16.7 percent (4 of 24) meet this criterion (see tables 4 and 6 in section 2.3.1.2).

B. Populations in at least four rivers (or creeks) are distributed widely enough within their respective habitats such that it is unlikely a single adverse event in the river would result in the total loss of that population.

The probable locations of these four populations are:

- Craig Creek and its larger tributaries from Webbs Mill downstream to its confluence with the James River, and Johns Creek from its headwaters to its confluence with Craig Creek
- Potts Creek
- Pedlar River
- Mechums River

This criterion has been met as stated. The overarching trend across the species' range is that JSM usually numbers less than 10 individuals at any site or reach, and often just one individual is found. For most waterbodies that have moderate to high approximate abundance (e.g., greater than 100 live individuals observed cumulatively in past 20 years or estimated from repeated surveys, mark-recapture study, or other quantitative/semiquantitative approach), JSM is predominately found in single, small reaches, ranging from 0.1 to 1.4 kilometers (km) in length (appendix B), making them susceptible to an adverse event that could eliminate high density reaches of JSM within a waterbody. Depending on the type, scale, and location of the adverse event (e.g., spill, flash flood, dam breach, hurricane) and waterbody characteristics (e.g., width, stream flow), small reaches of habitat with few JSM may remain and the population may not be a total loss; however, they may not be considered viable, as defined under criterion 2D (see below). If we assume that an adverse event will not affect JSM more than 8 km downstream of an event² and consider the total river length of where all live JSM were found in the last 20 years (2002-2021; appendix B), there are 10 waterbodies with live JSM distributed widely enough within their habitats such that it is unlikely a single adverse event would result in total loss of

² To help define adverse events in terms of length of waterbody affected, we conducted a brief review of published literature and readily available reports/information about spills and other events that impacted mussels. Due to limited, reliable data about the length of waterbodies where mussels were affected, we also included fish kill data due to spills related to the federally listed endangered Roanoke logperch (*Percina rex*) provided in Roberts et al. (2016). We conservatively assumed these spills that killed Roanoke logperch would have also killed mussels. The average length of stream affected is 8 km, with a range of 0.1 to 19 km (n=9) (Jones et al. 2001; The Catena Group 2007; Roberts et al. 2016; B. Watson, VDWR, email to R. Mair, Service, October 25, 2018).

population (Cowpasture River, Johns Creek, Craig Creek, Mill Creek, Pedlar River, Buck Mountain Creek, Swift Run, Dan River, South Fork Mayo River, and Mayo River).

- C. All known populations of the species are protected from present and foreseeable anthropogenic and natural threats that may interfere with their survival.
Based on documentation that anthropogenic and natural threats have occurred and may continue to occur in nearly all JSM occurrence watersheds and interfere with their survival (see section 2.3.2, e.g., dams, severe flooding, land modification causing water quality degradation, predation), criterion 1C as stated has not been met. However, this criterion is not objective or measurable and quite possibly not achievable.

Objective 2. Remove *P. collina* from the Federal list of endangered and threatened species when the following criteria has been met, in addition to A - C above:

- D. Through reestablishment and/or discoveries of new populations, viable populations¹ of the species exist in two additional rivers or three river segments within the James River drainage. Each river or river segment will contain at least three population centers² which are dispersed to the extent that a single adverse event would be unlikely to eliminate *P. collina* from its natural or reestablished location. For a reestablished population, surveys must show that three year-classes, including one year-class of age 10 or older, have been naturally produced within each of the population centers.

Footnotes:

1. viable population – a reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural habitats.

2. population center – a single shoal or grouping of shoals which contain *P. collina* in such close proximity that they can be considered as belonging to a single breeding unit.

This criterion has not been met as stated. Since the 1990 recovery plan, many new occurrences of live JSM and shells have been found, increasing the number of waterbodies (rivers, streams, tributaries) currently and likely occupied by JSM from 11 to 26 total (136-percent increase), and expanding the current range to the Roanoke River basin in North Carolina (see section 2.3.1.2, tables 1 and 4). The new discoveries are due to a greater number of surveys being conducted rather than new populations being established. With the expansion in range, this criterion should be clarified to include the Roanoke River basin. Genetic analyses are in progress, and we do not have sufficient information to help assess and define what is a viable population (e.g., large enough population to maintain sufficient genetic variation). Recognizing the lack of sufficient genetic analyses and data to conduct a population viability analysis, we made an assessment based on the assumptions that a viable population is a waterbody with (1) moderate to high approximate abundance, (2) evidence of recruitment, and (3) stable or increasing population trend. Based on these assumptions, Rocky Creek is a new waterbody with a viable population (see tables 1 and 6, appendix B); however, with all JSM occurrences within a 3-km stream reach, Rocky Creek does not have three population centers dispersed to the extent that a

single adverse event would be unlikely to eliminate JSM from this waterbody. In addition, Mill Creek is a rediscovered waterbody with a viable population (considered historical in 1990 and rediscovered in 1996), but it has only one known population center that is considered viable with most JSM occurrences within a 1.3-km reach (see tables 1 and 6, appendix B). These two waterbodies do not meet the second elements of this criterion.

If we expand the criteria to include multiple waterbodies instead of focusing on single rivers or river segments, there is one area with three streams with moderate to high JSM approximate abundance, Little Oregon Creek, Dicks Creek, and Johns Creek, located within a 1-km radius circle (i.e., less than 2 km apart), that may meet the definition of three “population centers” and Little Oregon Creek is a newly discovered stream. Due to their close proximity to each other, they are more susceptible to a wide-scale adverse event, such as hurricane or drought; however, a single adverse event, such as a spill or dam breach, may only affect up to two of these waterbodies. Little Oregon Creek drains to Dicks Creek and the high JSM abundance stream reach in Johns Creek is upstream of the confluence with Dicks Creek (e.g., Dicks Creek drains into Johns Creek downstream of the reach with high JSM abundance). However, Little Oregon Creek has a decreasing population trend, and therefore these three streams as a group would not meet the first element of this criterion.

- E. Habitat protection strategies have been successful, as evidenced by recruitment and an increase in population density and/or an increase in the population size and length of river reach inhabited at 75 percent of the sites with viable populations.

This criterion has not been met as stated. As discussed above, we assumed that a viable population is a waterbody with (1) moderate to high approximate abundance, (2) evidence of recruitment, and (3) stable or increasing population trend. Based on these assumptions, five waterbodies are potentially viable: South Fork Potts Creek, Dicks Creek, Johns Creek, Mill Creek, and Rocky Creek (see table 6). Only Mill Creek has had an increase in population size, but this was due to augmentation with propagated juveniles, not habitat protection strategies. This criterion is too specific and merits clarification to support objective evaluation and achievability. This criterion should be clarified to include other recovery tools, such as propagation, augmentation, stream restoration, predator trapping, and modification or removal of dams, because protecting habitat may not be sufficient to address the main threats to these waterbodies.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species’ biology and life history:

Basic biology and life history requirements are found in the JSM recovery plan (Service 1990). Since 1990, research has been conducted on multiple topics to provide new information on JSM’s biology and life history. See section 2.3.1.3

for research related to genetics and section 2.3.1.6 for research about habitat characterization. Below is a summary of research and observations related to morphological features, reproduction, fish hosts, lengths vs. age relationships, population structure, detection rates, and propagation.

Life History Strategy, Morphology, Host Fish, and Glochidia

Moore et al. (2021) confirmed that JSM's previously described life history strategy by Haag (2012) is "equilibrium," which are mussel species that "tend to have longer life spans, mature more slowly and have a moderate to large body size and (with some notable exceptions) lower fecundity."

Petty (2005) provided the following new information: (1) contrary to earlier observations that adults rarely have spines (Service 1990, Hove and Neves 1994), Petty reported that JSM adults in the Dan and Mayo Rivers (164 individuals) generally have spines, up to 8 spines in one individual; (2) no consistent differences were observed among JSM anatomy, fecundity, shell material morphology, and fish hosts (or fish host specificity) between the James and Roanoke River drainages; and (3) glochidia of Roanoke River populations were statistically significantly ($p < 0.05$) longer than James River populations.

A North Carolina Wildlife Resources Commission (NCWRC) biologist reported that the vast majority of JSM found in the Dan River subbasin since 2015 do not have spines (M. Perkins, NCWRC, email to J. Stanhope, Service, May 20, 2022). Ostby, who has conducted many JSM surveys and studies, also reported that spines are rare (< 5 percent of JSM he has monitored) and are usually nubs (B. Ostby, DC, email to J. Stanhope, Service, May 30, 2022).

Hove (1990) identified the following seven host fish species based on laboratory experiments: bluehead chub (*Nocomis leptocephalus*), rosieside dace (*Clinostomus funduloides*), satinfin shiner (*Cyprinella analostana*), rosefin shiner (*Lythurus ardens*), central stoneroller (*Camptostoma anomalum*), blacknose dace (*Rhinichthys atratulus*), and mountain redbelly dace (*Phoxinus oreas*). NCWRC biologists identified two additional host fish species for JSM: white shiner (*Luxilus albeolus*) and crescent shiner (*Luxilus cerasinus*) (M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021). These host fish species are common in both the James River and Roanoke River basins and overlap with JSM range (M. Perkins, NCWRC, email to J. Stanhope, Service, and T. Russ, NCWRC, November 4, 2022; M. Pinder, VDWR, email to J. Stanhope, Service, and B. Watson, VDWR, November 4, 2022).

The recovery plan identified the following species to co-occur with JSM: creeper (*Strophitus undulatus*), notched rainbow (*Venustaconcha* [formerly *Villosa*] *constricta*), triangle floater (*Alasmidonta undulata*), yellow lance (*Elliptio lanceolata*), Atlantic pigtoe (*Fusconaia masoni*), green floater (*Lasmigona subviridis*), and eastern elliptio (*Elliptio complanata*). Additional mussel species identified to co-occur with JSM include: eastern floater (*Pyganodon cataracta*),

Northern lance (*Elliptio fisheriana*), and yellow lampmussel (*Lampsilis cariosa*) (Virginia Department of Wildlife Resources [VDWR] 2020a, 2020b; M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021). Atlantic spike (*Elliptio producta*) and Carolina lance (*Elliptio angustata*) were also documented to co-occur with JSM surveys; however, with potential taxonomic changes related to the *Elliptio* complex, it is believed that these species may actually be northern lance and yellow lance (B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). Therefore, if Atlantic spike or Carolina lance are indicated to occur at a survey site, they may be northern lance or yellow lance.

Shell Length, Age, and Population Structure

Although shell lengths of JSM were not reported in the 1990 recovery plan, Petty (2005) indicated maximum length of approximately 70 to 74 millimeters (mm), which agrees with maximum length of 75 mm in Hove (1990). Larger JSM have been observed in Rocky Creek and Johns Creek in Virginia, with shell lengths up to 84 mm and 92 mm, respectively (Ostby 2015; B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). Ostby (2019a) evaluated the relationship of shell length vs. external growth rings of live and predated shells of JSM from Rocky Creek. The modeled relationship was somewhat similar to Hove (1990) but suggested “more rapid growth rate in Rocky Creek than observed by Hove (1990) in Dicks and Johns Creek (Craig County, VA) [figure 1]. It must be noted that the Hove (1990) dataset was based on internal annuli [i.e., thin-sectioning], whereas our charted relationships were based on external growth rings assumed to be annual.”

The shell length-age relationship is not accurate for larger and older JSM because incremental growth rates decrease with age (Hove 1990). Brian Watson, VDWR state malacologist, indicated he is still observing tagged JSM from 2006 in Mill Creek during ongoing mark-recapture studies (B. Watson, VDWR, emails to J. Stanhope, Service, January 24, 2022 and June 24, 2022). The JSM that were tagged in 2006, with an approximate length of 50 mm and age of 8 to 9 years old, are likely 25 years old now, according to B. Watson. Based on these and other observations of JSM in the field, he estimated the typical lifespan for JSM is 15 to 20 years with a maximum age of at least 30 years. Thin-sectioning of JSM shells from Mill Creek and other sites will help to verify the average and maximum lifespan of JSM.

There are a few new studies with information about population structure. Petty (2005) observed size range of 16.9 to 66.8 mm for 98 JSM in South Fork Mayo River and estimated the age range to be 0 to 18 years, with mean age of about five years (mean length 38.1 mm) (age based on Hove 1990). For JSM in Rocky Creek, Ostby (2015) observed mean length was 47.7 mm (n=31, range: 14-84 mm) in 2011-2012 and 46.9 mm (n=50, range: 30-62 mm) in 2015; mean age would be about seven to eight years (age based on Hove 1990). For JSM collected in 2017, mean and range for lengths were not provided, but Ostby (2019a) indicated that the “[p]opulation structure for Rocky Creek *P. collina* has shifted

slightly to larger and older individuals since 2011-2012...[and s]ampling in 2017 demonstrated continued recruitment in recent years.”

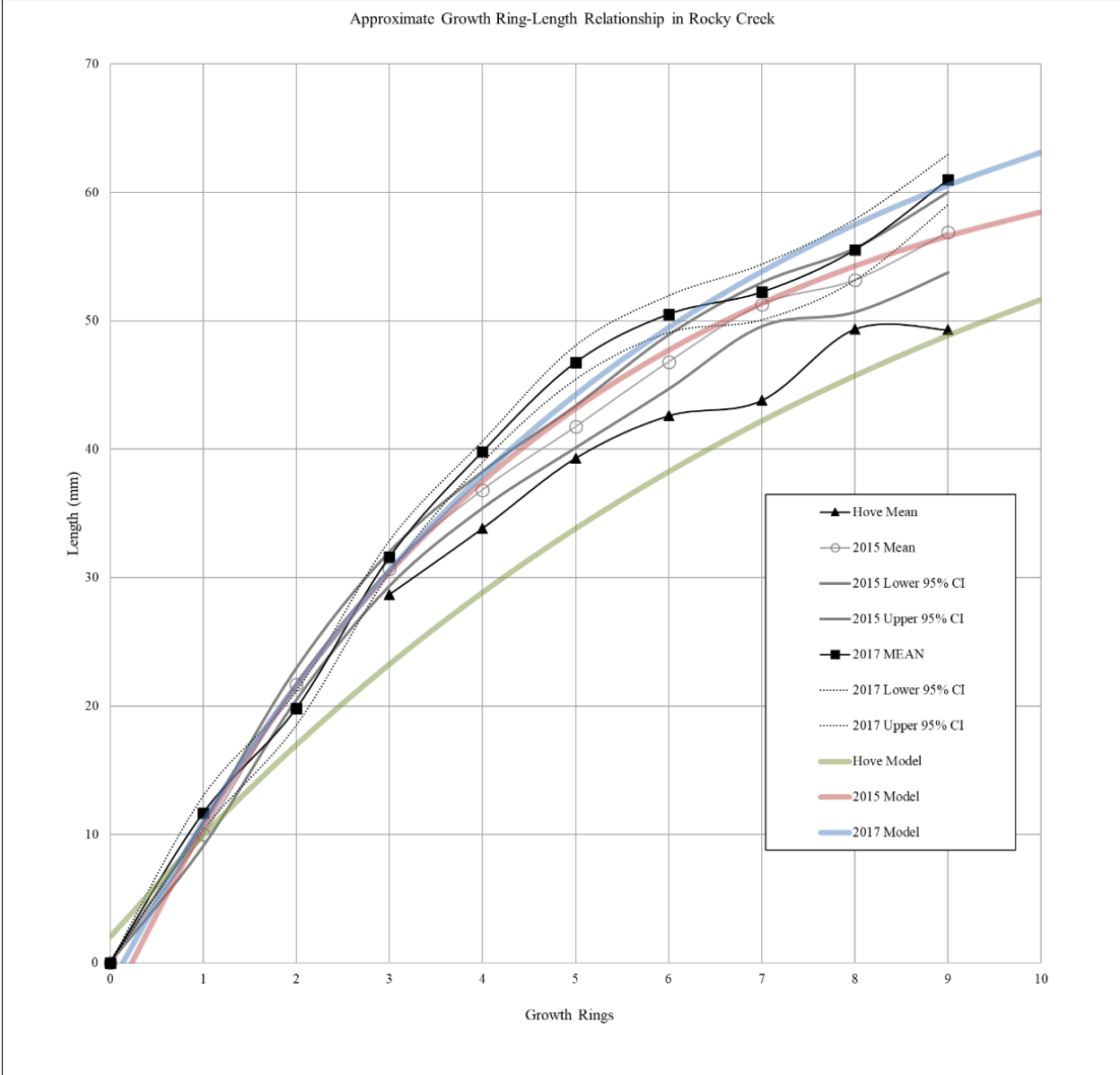


Figure 1. Shell length (mm) versus external growth ring (mean and 95-percent confidence intervals) for Rocky Creek JSM in 2015 and 2017 (figure from Ostby 2019a) Mean values and modeled von Bertalanffy growth values from Hove (1990) are included for reference; however, the modeled line (green) in this figure does not appear to match the modeled line in Hove (1990) and should be viewed with caution. In addition, Hove (1990) values are based on internal growth rings from Dicks and Johns Creek JSM in Craig County, VA.

Surveying and Detection Factors and Rates

As with many native freshwater mussels, JSM is difficult to detect during visual surveys because of its small size, color (tan to brown) being similar to stream substrates, and behavior of burying in the substrate. Numerous studies have examined factors that may affect detection (e.g., when mussels are at the surface, which increases the probability of detection during visual surveys) and measured detection probabilities. Key results are provided below:

- Ostby and Angermeier (2012) assumed that only 20 percent of JSM are at the surface and detectable during visual surveys based on previous work in the James River basin, when calculating probability of detecting JSM during semiquantitative surveys.
- Esposito (2015) found that a PIT tag reader could detect on average 76 percent of PIT-tagged mussels, including JSM, but only 7.5 percent of the mussels were visible at the surface during repeated surveys from July to October 2014 in Swift Run in Virginia. For JSM (n=21), the best-fitting logistic regression model predicted that the probability for visual detection (e.g., at the surface) was 0.14 in the summer and 0.02 in the fall. The author hypothesized that JSM are at the surface more during the summer months because it is breeding season.
- During quantitative sampling (using excavation sampling method) in Rocky Creek in Virginia in Spring 2012, 40 percent of all freshwater mussels found were observed at the surface, while in October 2015, only 3.2 percent of all freshwater mussels and no JSM were observed at the surface (Ostby and Angermeier 2012, Ostby 2015). Ostby (2015) also noted that mussels were found only when disturbing the surface layer of substrate in Rocky Creek during informal survey effort in 2014.
- Based on mark-recapture studies at multiple sites, detection rates of JSM for visual surveys were affected the most by season, with the lowest detection rates in October (survey months of April-October), as low as 0 percent in Johns Creek and 5 percent in Little Oregon Creek (Three Oaks Engineering [TOE] and Daguna Consulting [DC] 2016). Detection rates for JSM varied by site and date, as described below:
 - Little Oregon Creek: From August 3, 2010, to September 29, 2010, during six surveys, modeled mean detection rates ranged from approximately 7.5 to 30 percent and the lowest detection rate occurred when there was higher flow and surveyors used primarily viewscopes instead of direct visual detection.
 - For six sites (Dicks Creek, Mills Creek, Johns Creek, Little Oregon Creek, Craig Creek-Anderson Ford, Craig Creek-Carters Ford): From August 2010 to April 2013 during eight surveys, modeled mean detection rates range from approximately 2.5 to 34 percent, with the lowest detection rate occurring in October 2011 and October 2012 and the highest rate in April 2013. Estimated mean detection rates were approximately 11 to 17 percent in the other sampling months (August 2010, August 2011, April 2012, July 2012, August 2012).

- Mill Creek: During three surveys in October 2012, July 2013, and September 2013, estimated mean detection rate for all dates was approximately 8 percent, and detection rate by event did not appear to be related to flow, weather, or temperature. In this same analysis, estimated mean detection rates for eastern elliptio and creeper (approximately 30 percent) were significantly greater than for JSM.
- In an updated analysis of detection rates for Mill Creek, based on the mark-recapture study from October 2012 to September 2016 during 14 surveys, the revised estimated mean detection rate for all dates was 28 percent and ranged from <0.1 to 60 percent, with the lowest rate observed in October 2012 and highest rate in April 2016 (B. Ostby, DC, email to J. Stanhope, Service, July 13, 2017).
- In a field study with JSM and notched rainbow in Swift Run in Virginia, Boisen (2016) observed a pattern of more mussels at the surface after higher stream flows than during lower flows; the author hypothesized that mussels may burrow during flooding events to avoid displacement but then resurface to feed after being suppressed. Patterns of surfacing were not related to water temperature.
- Ostby (2019a) indicated that JSM were easier to detect in Rocky Creek than in Swift Run, possibly due to higher density or greater mean particle size of streambed substrate in Rocky Creek. “Sand-dominated habitats typical for occupied habitats of Swift Run also presented detection problems. Mussels may have buried deeply into these habitats. During quantitative sampling of site replicate S7, Ostby and Angermeier (2012) found that sampling units had no definable depth that demarcated suitable from unsuitable habitat. They stopped excavation [at] an arbitrary depth. A mussel could have burrowed deeper” (Ostby 2019b). However, in some cases, mussels may be easier to observe because of sand trails (Esposito 2015).
- In updated analyses of all datasets and sites in the 2010-2019 mark-recapture studies, Ostby (2022a) made the following conclusions regarding modeled detection rates:
 - positively related to JSM length (size), in which younger JSM are more difficult to find. For example, the modeled relationship estimates that a 60 mm (adult) is approximately 2.5 times more likely to be detected than a 10 mm juvenile (detection rates of approximately 20 percent and 7.5 percent, respectively);
 - weak or no significant relationships with stream flow, temperature, and weather;
 - lowest during surveys in late September and October; and
 - varied from 1 to 38 percent for individual survey dates for Dicks Creek, Johns Creek, and Little Oregon Creek, with mean monthly rates generally higher in April through August and average monthly detection rates across all months (April through October) of approximately 17, 14, and 14 percent for Dicks Creek, Johns Creek, and Little Oregon Creek, respectively (figure 2) (B. Ostby, DC, email to J. Stanhope, Service, April 22, 2022).

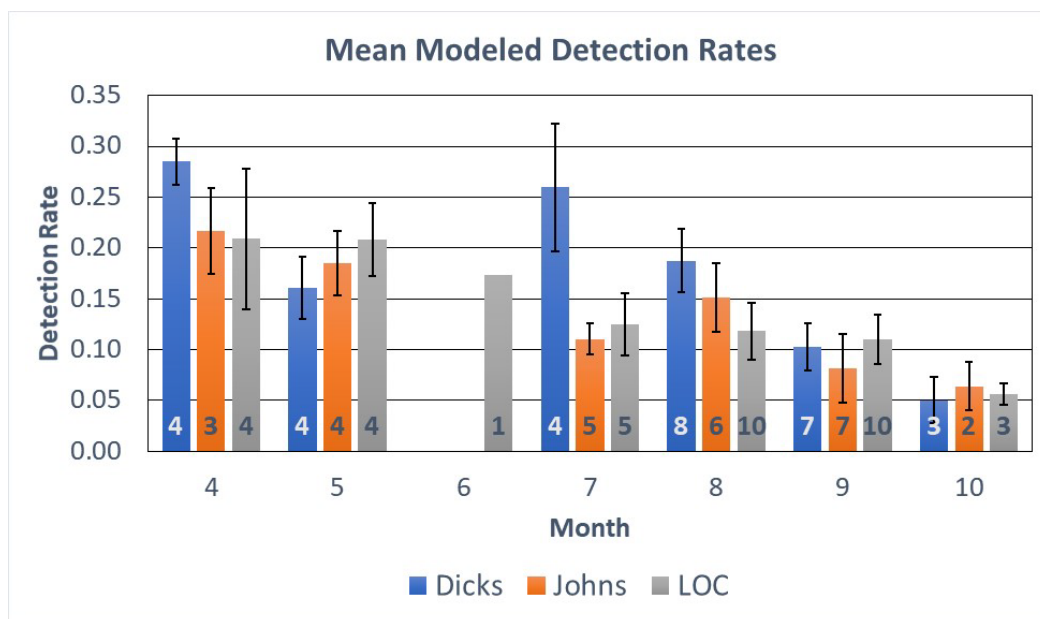


Figure 2. Mean modeled detection rate by site and month with standard error bars from 2010-2019 in Dicks Creek, Johns Creek, and Little Oregon Creek (LOC) (based on model results provided by B. Ostby, DC, email to J. Stanhope, April 22, 2022). Number in bar indicates number of surveys during that month.

Studies suggest that at some sites, JSM may not remain at a specific site or mussel bed and there is movement in and out of sites due to high streamflows, which will affect detection rates when revisiting a site. Ostby (2015) hypothesized a “source-sink metapopulation dynamic” for Swift Run because of the changes in occupancy of stream reaches throughout the survey area; JSM may be “detected in ‘sink’ habitats, where reproduction is insufficient to balance local mortality...[but are] being locally maintained by continued immigration from more productive ‘sources’ nearby (Pulliam, 1988).” Based on modeled results and observations from mark-recapture studies, there is movement of JSM into (immigration) and out of (emigration) sites at Mill Creek, Rock Island Creek, Craig Creek, and Swift Run (Verdram 2020, Ostby 2022a). At Swift Run, Verdram (2020) found that immigration and emigration were both significantly greater after flood events ($\geq 3,500$ cubic feet per second). At Rock Island Creek, Watson found tagged, propagated JSM in the lower site that were released at an upstream site, which likely moved downstream due to flood events (B, Watson, VDWR, email to J. Stanhope, Service, June 6, 2022).

The low detection rates for JSM during qualitative, visual surveys suggest caution when interpreting results of presence-absence surveys for the species, in particular in October.

Environmental DNA (eDNA) methods have been developed specifically for JSM based on primers targeting the genetic region surrounding the mitochondrial gene ND-1 (NADH dehydrogenase-1). At three sites with an estimated abundance of 10 to 20 JSM based on prior qualitative mussel surveys, the eDNA analysis was

able to detect JSM DNA, with 17 to 33 percent of eDNA filters yielding positive detections (Dyer and Roderique 2017, Dyer et al. 2021). The methodology was unable to detect JSM DNA at two sites with estimated abundances of four to five JSM based on prior qualitative mussel surveys, suggesting the limited ability of the methodology to detect JSM eDNA when there are very low numbers of JSM. In addition, Polymerase Chain Reaction (PCR) inhibition from organic and/or inorganic compounds in the water samples was observed at four sites (Johns Creek, Dicks Creek, and Mill Creek, Little Oregon Creek), which reduced DNA amplification and detection (Dyer and Roderique 2017). For Little Oregon Creek, the study site with the highest density and abundance of JSM, PCR inhibition resulted in no detection of JSM DNA (i.e., false negative likely cause by samples that contained inhibitory compounds). Dyer et al. (2021) developed methods to reduce PCR inhibition to some degree but recommended that any negative eDNA result be tested for inhibition to identify potential false negatives. The eDNA methods are still being developed and evaluated and have not been used to determine presence or absence of JSM in subsection 2.3.1.2 “Abundance and populations” below.

Propagation technology for augmentation and reintroduction

Efforts to develop propagation techniques for JSM by the Service and VDWR have been successful, beginning in 2008 at the Service’s White Sulphur Springs National Fish Hatchery, then in 2015 at the Virginia Fisheries and Aquatic Wildlife Center (VFAWC). VFAWC is a cooperative mussel propagation facility managed by VDWR and the Service, located at the Service’s Harrison Lake National Fish Hatchery. Gravid females have been collected from multiple sites and propagated juveniles (two to three years old) released to augment JSM populations, as described below (B. Watson, VDWR, emails to J. Stanhope, December 10, 2021 and June 6, 2022):

- Mill Creek (Bath County, VA) source population: propagated JSM released to Mill Creek and Cowpasture River (Bath County, VA)
- Johns Creek (Craig County, VA) source population: propagated JSM released to Craig Creek (at Carters Ford, Botetourt County, VA) and Pedlar River (Amherst County, VA). Future releases are planned to the same two locations, Craig Creek (at Oriskany, Botetourt County, VA), and the James River (at Scottsville, Albemarle County, VA) in 2022.
- Rock Island Creek (Buckingham County, VA) source population: propagated JSM released to Rock Island Creek and Tye River (Nelson County, VA).
- Rocky Creek (Albemarle County, VA) source population: propagated JSM will be released to Rocky Creek in 2022.

NCWRC’s Conservation Aquaculture Center at Marion, NC also propagated JSM using broodstock from the Dan River in North Carolina in 2018 and 2019 (M. Perkins, NCWRC, emails to J. Stanhope, Service, November 13, 2020, March 2, 2021, and March 15, 2022; NCWRC 2019, 2020a, 2021). Four JSM adults, held in captivity for propagation since 2018, died in April to May 2019, and the remaining JSM were returned to the collection site soon after health screening.

Propagation efforts in 2019 were unsuccessful due to protozoan (*Vortecilla* sp.) and fungal outbreaks. Approximately 30 juvenile JSM from the 2018 propagation effort survived and were released to Mill Creek (NC) in 2021 to augment the population.

Genetic analysis of JSM has been ongoing and considered before release to sites (See section 2.3.1.3 for additional information); in addition, distance from the source population, isolation of the release sites (e.g., dams), and approximate abundance at the release site were considered.

Monitoring surveys at Mill Creek, Cowpasture River, and Rock Island Creek indicate that many of the released propagated juvenile JSM are found in years after release. At Mill Creek, the estimated annual survival rates of wild JSM (0.87-0.98) were similar to survival rates of propagated JSM (0.88-0.96) from 2014 to 2020 (Ostby 2022b).

Summary of new information on the species' biology and life history

Since 1990, new information on JSM's biology and life history clarified and provided additional details about its life history strategy, morphological features, reproduction including host fish species, and population structure at different sites, but overall, most information about the species is unchanged. The JSM may be more long-lived than originally expected, with the typical lifespan for JSM estimated at 15 to 20 years with a maximum age of at least 30 years. Thin-sectioning of JSM shells from Mill Creek and other sites will help to verify the average and maximum lifespan. Multiple studies confirmed the difficulty in detecting JSM, with estimated or modeled detection rates varying by site and month, as low as 0 percent and as high as 60 percent but frequently less than 20 percent; however, common patterns among the studies indicate that October has the lowest rates of detection and that smaller, juvenile JSM are more difficult to detect. These low detection rates for JSM during qualitative, visual surveys suggest caution when interpreting results of presence-absence surveys for the species, in particular when detection rates are low. Propagation technologies for JSM have been developed and proven successful based on initial monitoring surveys in several sites in Virginia.

2.3.1.2 Abundance, population trends, demographic features, or demographic trends:

Abundance and populations

The following subsection provides a summary of new records for the JSM and negative surveys in rivers where the species occurred at the time the 1990 recovery plan was issued. The species has also been discovered in new rivers and drainages since the 1990 recovery plan, which is described below. *Unless noted as a shell, observations of JSM discussed below are of live individuals.* Table 1 provides a summary of the waterbodies where JSM has been documented and its population status in 1990, 2008, and 2021 and approximate abundance based on

the last 20 years (2002-2021). This timeframe was chosen because the typical lifespan for JSM is estimated to be 15 to 20 years, as discussed in section 2.3.1.1 above. Appendix B provides a table of detailed information for each JSM occurrence waterbody.

The following terms were used to describe population/sub-population status in 2021:

- **Present:** Live JSM observed 2007 and later (less than 15 years ago);
- **Likely present:** JSM last observed 2002-2006 (approximately 15 to 20 years ago) and may still be present based on typical lifespan, but few surveys have been conducted to verify presence;
- **Unknown:** Most known JSM sites within the waterbody have not been surveyed in more than 20 years and limited survey effort overall in this river.
- **Possibly extirpated:** Last live JSM observed 30 to 50 years ago or only shell observed, but limited survey effort recently and/or throughout waterbody.
- **Historical/presumed extirpated:** Last live JSM observed more than 50 years ago; categorized as historical occurrence in the 1990 recovery plan (Service 1990).

Many of the mussel surveys were qualitative and conducted at a limited number of sites and/or on a limited number of dates; surveyors typically recorded the number of live individuals or dead shells observed at a location or reach and sometimes total time surveyed and number of surveyors (i.e., catch per unit effort [CPUE]). CPUE may be an indirect measure of abundance, but with varying detection rates for JSM as discussed above (see section 2.3.1.1), the varying types of survey data are not conducive for providing accurate abundance estimates. For some sites, quantitative or semiquantitative approaches to surveys were conducted (e.g., mark-recapture studies, quadrat sampling to estimate density, repeated surveys along multiple reaches), which allowed improved estimates of mussel abundance (e.g., range of estimated abundance based on the lower and upper 95 percent confidence intervals of modeled results or density estimates; range of number of JSM observed during repeated surveys). Thus, for waterbodies when survey data were predominantly qualitative, we used the cumulative record of the total number of live individuals observed within a waterbody to provide an approximate estimate of abundance; however, when estimates of abundance were available, we used those numbers for assigning the waterbody to the approximate abundance categories. The following are the criteria for the approximate abundance categories:

- **High:** High numbers (over 300) of live individuals observed cumulatively in past 20 years *or* estimated from repeated surveys, mark-recapture study, or other quantitative/semiquantitative approach;
- **Moderate:** Moderate numbers (101 to 300) of live individuals observed cumulatively in past 20 years *or* estimated from repeated surveys, mark-recapture study, or other quantitative/semiquantitative approach;

- **Low:** Low numbers (11 to 100) of live individuals observed cumulatively in past 20 years *or* estimated from repeated surveys, mark-recapture study, or other quantitative/semiquantitative approach;
- **Very Low:** Low numbers (1 to 10) of live individuals observed cumulatively in past 20 years *or* estimated from repeated surveys, mark-recapture study, or other quantitative/semiquantitative approach; and
- **None:** No live JSM observed in last 20 years.

Table 1. Summary of occurrence waterbodies of JSM and their population status, approximate abundance, and year live JSM was last observed and surveyed. Not reported=JSM was not discovered yet. See appendix B for additional information. Shaded rows indicate historical (i.e., presumed extirpated) or possibly extirpated status.

| Basin/Sub-basin (HUC8) | Waterbody | Area/Subpopulation ¹ | County | State | Population Status in | | | Approximate Abundance ³ | Live JSM Last Observed | Last Surveyed |
|--------------------------|-----------------------------|---------------------------------|---------------------|-------|---------------------------------|---------------------------------------|---------------------|------------------------------------|--------------------------------|--------------------------------|
| | | | | | 1990 Recovery Plan ¹ | 2008 Draft 5-Year Review ² | 2021 ³ | | | |
| James River basin | | | | | | | | | | |
| Upper James | South Fork Potts Creek | | Monroe | WV | Present | Present | Present | Low to high | 2021 | 2021 |
| Upper James | Potts Creek | | Craig, Alleghany | VA | Present | Possibly extirpated | Possibly extirpated | None | 1990 | 2006 |
| Upper James | Cowpasture River | | Bath, Alleghany | VA | Not reported | Present | Present | Low | 2006 (wild); 2021 (propagated) | 2017 (wild); 2021 (propagated) |
| Upper James | Bullpasture River | | Highland | VA | Not reported | Present | Likely present | Very low | 2006 | 2019 |
| Upper James | Little Oregon Creek | | Craig | VA | Not reported | Present | Present | High | 2021 | 2021 |
| Upper James | Dicks Creek | | Craig | VA | Present | Present | Present | Moderate to high | 2021 | 2021 |
| Upper James | Johns Creek | Near Maggie | Craig | VA | Present | Present | Present | High | 2021 | 2021 |
| Upper James | | Along Sevenmile Mountain | Craig | VA | Present | Present | Present | Low | 2007 | 2021 |
| Upper James | Craig Creek | Near New Castle | Craig | VA | Present | Unknown | Possibly extirpated | None | 1987 | 2012 |
| Upper James | | Near Silent Dell | Botetourt | VA | Present | Present | Present | Low | 2019 | 2019 |
| Upper James | | Near Eagle Rock | Botetourt | VA | Present | Unknown | Unknown | None | 1988 | 1999 |
| Upper James | Patterson Creek | | Botetourt | VA | Present | Possibly extirpated | Possibly extirpated | None | 1988 | 2004 |
| Upper James | Catawba Creek | | Botetourt | VA | Present | Possibly extirpated | Possibly extirpated | None | 1988 | 2007 |
| Maury | Calfpasture River | | Rockbridge | VA | Historical | Historical | Historical | None | 1845 | 2017 |
| Maury | Maury River | | Rockbridge | VA | Historical | Historical | Historical | None | 1845 | 2017 |
| Maury | Mill Creek | | Bath | VA | Historical | Present | Present | Moderate to high | 2021 | 2021 |
| Middle James- Buffalo | Pedlar River | | Amherst | VA | Present | Present | Present | Low | 2021 | 2021 |
| Middle James- Buffalo | Hardware River | | Fluvanna, Albemarle | VA | Not reported | Present | Present | Very low | 2019 | 2021 |
| Middle James- Buffalo | Rock Island Creek | | Buckingham | VA | Not reported | Not reported | Present | Low | 2021 | 2021 |
| Middle James- Buffalo | Tye River | | Nelson | VA | Not reported | Not reported | Present | Low | 2019 | 2019 |
| Middle James- Buffalo | Totier Creek (relic shells) | | Albemarle | VA | Not reported | Not reported | Possibly extirpated | None | Unknown | 2017 |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Subpopulation ¹ | County | State | Population Status in | | | Approximate Abundance ³ | Live JSM Last Observed | Last Surveyed |
|------------------------|--|-------------------------------------|-----------------------|-------|---------------------------------|---------------------------------------|---------------------|------------------------------------|------------------------|---------------|
| | | | | | 1990 Recovery Plan ¹ | 2008 Draft 5-Year Review ² | 2021 ³ | | | |
| Rivanna | Mechums River | | Albemarle | VA | Present | Present | Present | Very low | 2021 | 2021 |
| Rivanna | Moormans River | | Albemarle | VA | Present | Possibly extirpated | Possibly extirpated | None | 1990 | 2005 |
| Rivanna | Wards Creek (mis-identified as Rocky Run [Moormans River]) | | Albemarle | VA | Present | Present | Present | Low | 2011 | 2017 |
| Rivanna | Rocky Creek | | Albemarle | VA | Not reported | Present | Present | Moderate to high | 2021 | 2021 |
| Rivanna | Buck Mountain Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2021 | 2021 |
| Rivanna | Piney Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2012 | 2021 |
| Rivanna | Ivy Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2011 | 2012 |
| Rivanna | NF Rivanna River | | Albemarle | VA | Not reported | Present | Present | Very low | 2015 | 2015 |
| Rivanna | Swift Run | | Albemarle, Greene | VA | Not reported | Present | Present | Low | 2019 | 2019 |
| Rivanna | Unnamed tributary to Swift Run | | | | Not reported | Not reported | Present | Very low | 2017 | 2019 |
| Rivanna | Welsh Run | | Greene | VA | Not reported | Present | Likely present | Very low | 2005 | 2019 |
| Rivanna | Rivanna River | Near Columbia, Palmyra, and Crofton | Fluvanna | VA | Historical | Historical | Historical | None | 1968 | 2011 |
| Rivanna | Mechunk Creek (relict shell) | | Fluvanna | VA | Not reported | Not reported | Possibly extirpated | None | Unknown | 2007 |
| Upper James | James River | at Buchanan | Botetourt | VA | Historical | Historical | Historical | None | pre-1967 | 2021 |
| Upper James | | near Natural Bridge | Rockbridge | VA | Historical | Historical | Historical | None | pre-1967 | 2005 |
| Middle James- Buffalo | | at New Canton | Buckingham, Fluvanna | VA | Historical | Historical | Historical | None | 1966 | 2018 |
| Middle James- Willis | | at Columbia | Fluvanna, Cumberland | VA | Historical | Historical | Historical | None | 1966 | 2012 |
| Middle James- Willis | | at Pemberton and Cartersville | Goochland, Cumberland | VA | Historical | Historical | Historical | None | 1966 | 2012 |
| Middle James- Willis | | at Rock Castle | Goochland, Powhatan | VA | Historical | Historical | Historical | None | 1966 | 2013 |
| Middle James- Willis | | opposite Maidens | Goochland, Powhatan | VA | Historical | Historical | Historical | None | 1966 | 2012 |
| Middle James- Willis | | at Maidens | Goochland, Powhatan | VA | Historical | Historical | Historical | None | 1966 | 2012 |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Subpopulation ¹ | County | State | Population Status in | | | Approximate Abundance ³ | Live JSM Last Observed | Last Surveyed |
|----------------------------|-----------------------|---------------------------------|--------------------------------------|--------|---------------------------------|---------------------------------------|---------------------|------------------------------------|------------------------|---------------|
| | | | | | 1990 Recovery Plan ¹ | 2008 Draft 5-Year Review ² | 2021 ³ | | | |
| Roanoke River basin | | | | | | | | | | |
| Upper Dan | Dan River | | Stokes, Rockingham | NC | Not reported | Present | Present | Moderate | 2019 | 2019 |
| Upper Dan | Big Creek (shell) | | Stokes | NC | Not reported | Present | Possibly extirpated | None | Unknown | 2019 |
| Upper Dan | Mill Creek | | Stokes | NC | Not reported | Not reported | Present | Very low | 2018 | 2019 |
| Upper Dan | South Fork Mayo River | | Patrick, Henry (VA); Rockingham (NC) | VA, NC | Not reported | Present | Present | Moderate | 2012 | 2016 |
| Upper Dan | Mayo River | | Rockingham | NC | Not reported | Present | Present | Low | 2016 | 2019 |

¹ From 1990 recovery plan (Service 1990), Table 1, Historic and Present occurrences of the James spiny mussel in 1990.

² From 2008 draft 5-year review for James spiny mussel (Service 2008), appendix 1, Present occurrence rivers of the James spiny mussel in 2008

³ See definitions for status and approximate abundance above.

James River major drainage basin

Upper James subbasin (VA; HUC8 02080201)

South Fork Potts Creek (Monroe County, WV) – Six surveys have been conducted over the past 30 years (approximately once every five to six years) by various agencies, including the Service and West Virginia Division of Natural Resources (WVDNR). There are six survey reaches of various lengths (265 to 1,800 meters [m]) along an approximately 7-km stretch of South Fork Potts Creek (Everhart and Clayton 2016). Table 2 provides a summary of survey efforts and results since 1983.

Table 2. Summary of surveys conducted in South Fork Potts Creek (based on Table 1 in Eliason and Everhart 2021)

| Survey Year | Total Number of Live JSM Collected | Number of Reaches Surveyed | Number of Reaches with JSM | Percent of JSM Located in One Reach | Report Authors (as cited in Eliason and Everhart 2021) |
|-------------|------------------------------------|----------------------------|----------------------------|-------------------------------------|--|
| 1983-1984 | present (number not provided) | 2 | 2 | n/a | Zeto and Schmidt 1984 |
| 1987-1989 | 168 | not provided | not provided | n/a | Hove and Neves 1994 |
| 1995 | 82 | 5 | 3 | 89.0 | Ensign and Neves 1995 |
| 2000 | 62 | 4 | 3 | 85.5 | Ensign and Neves 2000 |
| 2006 | 339 | 5 | 2 | 97.3 | Kane et al. 2006 |
| 2011 | 31 | 6 | 2 | 54.8 | Smith and Kane 2013 |
| 2016 | 80 | 5 | 3 | 88.8 | Everhart and Clayton 2016 |
| 2021 | 85 | 6 | 2 | 98.8 | Eliason and Everhart 2021 |

One reach was not surveyed in 1996, 2006, and 2016 because of access issues, but when access was granted, 14 JSM were observed in 2011 and none in 2021. Another stream reach was not surveyed in 2000 because it was determined to be unsuitable mussel habitat and no JSM have been found when this stream reach was surveyed in other years (Eliason and Everhart 2021). Most of the JSM occurrences have been documented in a single reach (1.4 km), representing 54.8 to 98.8 percent of observations. Within this reach, some recruitment likely occurred in the five years prior to 2021 based on six JSM measuring approximately 35 to 40 mm in length (based on length vs. age relationship in

Hove 1990); the average length was 52.45 mm for 84 JSM (Eliason and Everhart 2021). In summary, the survey results suggest a stable, but highly variable population located primarily in one reach and in up to three reaches total, and that recruitment is likely occurring.

Potts Creek (Craig and Alleghany Counties, VA) – No JSM have been found in Potts Creek during surveys since the 1990 recovery plan (McGregor and Baisden 2002, Petty and Neves 2006, VDWR 2020a). The last known survey for JSM in Potts Creek in Craig and Alleghany Counties, VA, was conducted by Petty and Neves (2006) in 2006, which was a qualitative and intensive effort over 25 km (25 sites of approximately 1,000 m length) and no JSM were found; other native freshwater mussels were observed, including notched rainbow and creeper. A site in Potts Creek in Monroe County, WV (not previously known for JSM), was surveyed in 2021, downstream of the confluence of the North and South Fork Potts Creek, but no JSM were found (Eliason and Everhart 2021). In summary, JSM is possibly extirpated in this creek and has not been observed since 1990, but this is not confirmed because there has been limited survey effort in the Potts Creek since 2006 (VDWR 2020a).

Cowpasture River (Bath and Alleghany Counties, VA) – The Cowpasture River is a new occurrence river for JSM³ since the 1990 recovery plan. One JSM was found each in 2002 and 2003 within 0.5 km of each other in Bath County, VA by a Service biologist (VDWR 2020a, b). In 2004, two JSM were found approximate 1.3 km upstream from the previous occurrences. In 2006, the JSM's documented range in the river was extended 42 km downstream into Alleghany County with one JSM found; however, this occurrence is the last time the species was observed in this river (VDWR 2020a, b). Survey effort in Cowpasture River is limited, where surveys at seven other sites of the Cowpasture River (Bath and Alleghany Counties, VA) by VDWR and permittees in 1993, 2000, 2001, 2008, 2009, 2010, and 2017 found no JSM but other native freshwater mussels (e.g., notched rainbow, creeper, eastern elliptio, triangle floater, Carolina lance, Atlantic spike) (Petty et al. 2008, Environmental Solutions & Innovations, Inc. [ESI] 2017, VDWR 2020a). There is no information available indicating if the known JSM sites have been resurveyed. Fish kills were reported in the Cowpasture River from 2007-2010, but the cause of the mortality/disease events were not determined (<https://dwr.virginia.gov/fishing/fish-kill/>; accessed March 28, 2022).

In 2018, 278 propagated JSM (from Mill Creek [Bath County, VA] broodstock) were released in the Cowpasture River on U.S. Forest Service (USFS) land (Bath County, VA), between the documented occurrences in Bath and Alleghany Counties. Monitoring found 61 JSM in 2019 before the pit tag reader stopped working and 111 JSM in 2021. An additional 35 propagated JSM were released in 2021 (B. Watson, VDWR, email to J. Stanhope, Service, June 24, 2022). In summary, for the wild Cowpasture River population, there is insufficient data to evaluate stability, recruitment, and approximate abundance. Propagation efforts

³ Hereafter, a “new occurrence river for JSM” refers to being discovered since the recovery plan was issued in 1990.

have created a low- to moderate-sized population in one area that is surrounded by protected USFS land, and future monitoring will evaluate its success in being established.

Bullpasture River (Highland County, VA) – The Bullpasture River is a new occurrence river for JSM. In 2006, five adult JSM were discovered in two sites of the Bullpasture River, approximately 0.9 km apart (VDWR 2020a, b). A relict shell was also found approximately 1.4 km downstream and 9.5 km upstream of the JSM occurrences. Survey effort appears to be very limited in this river since 2006, with only one of the two sites with JSM resurveyed in 2019; VDWR did not find JSM but did observe a few notched rainbows (B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). Surveys at two sites of the upper Bullpasture River (>8.5 km upstream of known JSM site) did not find any freshwater mussels in 2000 and 2001 (McGregor and Baisden 2002). A survey at one site in 2008 by VDWR did not find JSM but did observe creeper (VDWR 2020a). In summary, JSM is likely present in Bullpasture River, but there is insufficient data to evaluate status, stability, recruitment, and approximate abundance of the population due to lack of survey effort.

Little Oregon Creek (Craig County, VA) – The Little Oregon Creek, a tributary to Dicks Creek, is a new occurrence river for JSM. Gatenby and Neves (1994) discovered seven JSM in the Little Oregon Creek prior to its confluence with Dicks Creek. Multiple surveys since 1994 have documented most of the species in a 0.2-km reach of Little Oregon Creek (VDWR 2020a, b). Within this area, a 100-m reach is part of an ongoing mark-recapture study since 2010; this mark-recapture site in Little Oregon Creek and the mark-recapture sites in Dicks Creek, Johns Creek, Rock Island Creek, and Mill Creek, were selected because they are “population centers [for JSM] having disproportionately greater density than found elsewhere in the James River basin” (B. Ostby, DC, email to J. Stanhope, Service, December 3, 2021). Based on the mark-recapture study, modeled abundance estimates were highly dynamic and as high as 2,003 JSM in 2016 but declined to 646 JSM in 2018 and 771 JSM in 2019 (table 3) (Ostby 2022a). This significant decline was likely due to high rates of raccoon predation observed in 2015 and 2016, impacting JSM originally tagged in 2010 and 2011, based on a large number of fresh dead shells with claw and teeth marks found during surveys. Low to moderate rates of raccoon predation were also observed in 2013, 2017, and 2018 (Ostby 2022a). The modeled survival rates were also explained by raccoon predation. Anecdotal observations and analysis of 2019 data suggest that the JSM population may be recovering and stable. More than 10 years of mark-recapture surveys have been completed at Little Oregon Creek as of 2021, and data analysis is in progress and will provide more information on recovery and stability of the site.

Table 3. James spiny mussel mark-recapture study analyses in Virginia from Ostby (2022a, 2022b) and TOE and DC (2019). Abundance (N) point estimates and 95 percent confidence intervals (CI) for wild and propagated JSM in reaches surveyed, based on Robust Design Huggins Models.

| Waterbody | Year | Wild N | CI Lower | CI Upper | Propagated N | CI Lower | CI Upper |
|--|------|--------|----------|----------|--------------|----------|----------|
| Little Oregon Creek ¹ | 2010 | 1769 | 1696 | 1855 | n/a | n/a | n/a |
| | 2011 | 1785 | 1611 | 1992 | n/a | n/a | n/a |
| | 2012 | 1616 | 1477 | 1779 | n/a | n/a | n/a |
| | 2013 | 2003 | 1866 | 2163 | n/a | n/a | n/a |
| | 2014 | 1691 | 1483 | 1944 | n/a | n/a | n/a |
| | 2015 | 1613 | 1468 | 1785 | n/a | n/a | n/a |
| | 2016 | 1537 | 1161 | 2058 | n/a | n/a | n/a |
| | 2017 | 833 | 692 | 1022 | n/a | n/a | n/a |
| | 2018 | 646 | 469 | 911 | n/a | n/a | n/a |
| | 2019 | 771 | 701 | 860 | n/a | n/a | n/a |
| Dicks Creek ¹ | 2011 | 197 | 122 | 350 | n/a | n/a | n/a |
| | 2012 | 302 | 274 | 343 | n/a | n/a | n/a |
| | 2013 | 440 | 394 | 500 | n/a | n/a | n/a |
| | 2014 | 446 | 355 | 573 | n/a | n/a | n/a |
| | 2015 | 544 | 496 | 605 | n/a | n/a | n/a |
| | 2016 | 445 | 368 | 550 | n/a | n/a | n/a |
| | 2017 | 416 | 333 | 533 | n/a | n/a | n/a |
| | 2018 | 432 | 309 | 618 | n/a | n/a | n/a |
| | 2019 | 373 | 329 | 434 | n/a | n/a | n/a |
| Johns Creek ¹ | 2012 | 398 | 287 | 593 | n/a | n/a | n/a |
| | 2013 | 911 | 793 | 1064 | n/a | n/a | n/a |
| | 2014 | 1009 | 849 | 1218 | n/a | n/a | n/a |
| | 2015 | 1043 | 878 | 1255 | n/a | n/a | n/a |
| | 2016 | 685 | 592 | 806 | n/a | n/a | n/a |
| | 2017 | 694 | 548 | 895 | n/a | n/a | n/a |
| | 2018 | 791 | 570 | 1119 | n/a | n/a | n/a |
| Craig Creek - Anderson Ford ² | 2012 | 2 | 2 | 5 | n/a | n/a | n/a |
| | 2013 | 2 | 2 | 5 | n/a | n/a | n/a |
| | 2014 | 2 | 1 | 10 | n/a | n/a | n/a |
| | 2015 | 0 | 0 | 1 | n/a | n/a | n/a |
| | 2016 | 4 | 2 | 11 | n/a | n/a | n/a |
| | 2017 | 0 | 0 | 1 | n/a | n/a | n/a |
| | 2018 | 0 | 0 | 1 | n/a | n/a | n/a |
| | 2019 | 0 | 0 | 1 | n/a | n/a | n/a |
| Craig Creek - Carters Ford ² | 2012 | 3 | 3 | 6 | n/a | n/a | n/a |
| | 2013 | 3 | 3 | 6 | n/a | n/a | n/a |
| | 2014 | 6 | 3 | 18 | n/a | n/a | n/a |
| | 2015 | 1 | 1 | 3 | n/a | n/a | n/a |
| | 2016 | 5 | 3 | 14 | n/a | n/a | n/a |
| | 2017 | 4 | 4 | 7 | n/a | n/a | n/a |
| | 2018 | 3 | 2 | 10 | n/a | n/a | n/a |
| Mill Creek ^{1,3} | 2012 | 65 | 65 | 65 | n/a | n/a | n/a |
| | 2013 | 161 | 100 | 439 | n/a | n/a | n/a |
| | 2014 | 208 | 196 | 238 | 138 | 115 | 223 |
| | 2015 | 105 | 101 | 118 | 99 | 69 | 205 |
| | 2016 | 155 | 148 | 174 | 132 | 101 | 248 |
| | 2017 | 152 | 143 | 193 | 183 | 138 | 303 |
| | 2018 | 214 | 197 | 274 | 309 | 250 | 430 |
| | 2019 | 168 | 167 | 204 | 209 | 199 | 484 |
| | 2020 | 122 | 116 | 167 | 117 | 112 | 159 |
| | 2021 | 171 | 171 | 171 | 197 | 197 | 197 |
| Rock Island Creek Reach 1 ² | 2013 | 54 | 38 | 90 | n/a | n/a | n/a |
| | 2014 | 47 | 44 | 55 | n/a | n/a | n/a |
| | 2015 | 53 | 44 | 71 | n/a | n/a | n/a |
| | 2016 | 46 | 35 | 68 | n/a | n/a | n/a |
| | 2017 | 40 | 32 | 56 | n/a | n/a | n/a |
| | 2018 | 58 | 43 | 88 | n/a | n/a | n/a |
| Rock Island Creek Reach 2 ^{2,4} | 2013 | 83 | 59 | 131 | n/a | n/a | n/a |
| | 2014 | 109 | 103 | 121 | n/a | n/a | n/a |
| | 2015 | 105 | 89 | 131 | n/a | n/a | n/a |
| | 2016 | 132 | 107 | 174 | n/a | n/a | n/a |

| Waterbody | Year | Wild N | CI Lower | CI Upper | Propagated N | CI Lower | CI Upper |
|-----------|------|--------|----------|----------|--------------|----------|----------|
| | 2017 | 81 | 67 | 104 | n/a | n/a | n/a |
| | 2018 | 88 | 67 | 129 | n/a | n/a | n/a |

¹ Ostby 2022a and 2002b

² TOE and DC 2019

³ 2012 estimate for Mill Creek is likely an overly conservative underestimate and violated model assumptions because no recaptures were made over 2 sampling events the first year of sampling (B. Ostby, DC, email to J. Stanhope, Service, January 5, 2022).

⁴ This reach is no longer suitable due to high flows from Hurricane Florence and/or Michael in 2018 significantly degrading the instream habitat

In 2016, a large number of juvenile JSM (approximately 20 mm long) were observed during a mark-recapture survey, indicating reproduction had likely occurred within the previous two years (based on length vs. age relationship; Hove 1990).

Prior to the high predation years, Little Oregon Creek had the highest documented density and abundance of JSM of all populations. It is thought that a small impoundment and predominantly forested watershed upstream of the population provide habitat stability (e.g., thermal and stream flow), good water quality, and high primary production for feeding (TOE and DC 2016). In addition, the invasive Asian clam (*Corbicula fluminea*) was detected in Little Oregon Creek in the mid-2010s and increased to high density in the late 2010s, potentially competing for resources with JSM; however, effects from the Asian clam have not been assessed (B. Watson, VDWR, email to J. Stanhope Service, January 24, 2022; see section 2.3.2.5 for additional information about the Asian clam). In summary, the JSM population appears to have declined due to the high raccoon predation but is potentially recovering; analyses of monitoring data collected since 2019 will be informative in assessing its ability to recover from the predation and coexist with the Asian clam.

Dicks Creek (Craig County, VA) – The JSM occurrence in Dicks Creek (a tributary to Johns Creek) noted in the 1990 recovery plan was reconfirmed by Gatenby and Neves (1994) with a find of three JSM. Multiple surveys since 1994 have documented most of the species in a 1-km reach of Dicks Creek (VDWR 2020a, b). This area is part of an ongoing mark-recapture study since 2010 and modeled abundance estimates were highly dynamic and as high as 544 JSM in 2015 and as low as 197 in 2011; however, the confidence intervals indicate that these estimates over 9 years are generally not significantly different (table 3) (Ostby 2022a). Juvenile JSM (less than 30 mm) were detected in 2019. There is an impoundment upstream of the JSM occurrences that may be beneficial to this population, similar to the impoundment in Little Oregon Creek. The JSM population appears stable with large variation and has evidence of recruitment. Ten years of mark-recapture surveys have been completed at Dicks Creek as of 2021, and data analysis is in progress.

Johns Creek (Craig County, VA) – In Johns Creek, a tributary to Craig Creek, JSM were noted as present in the 1990 recovery plan in two areas or subpopulations: (1) near Maggie, VA and (2) along Sevenmile Mountain (i.e., downstream of Maggie, VA to the confluence with Craig Creek).

Near Maggie, VA: Multiple surveys since 1999 have documented JSM at 10 sites in Johns Creek from Maggie to approximately 8.3 km upstream of its confluence with Dicks Creek, with observations of 3 to 83 JSM at a site (VDWR 2020b, Orcutt 2021). One site, a 100-m reach, is part of an ongoing mark-recapture study since 2012, and modeled abundance estimates were as high as 1,043 JSM in 2015 and as low as 398 JSM in 2012; the most recent estimated abundance was 758 JSM in 2019 (Ostby 2022a). High raccoon predation rates on JSM have been observed in this reach in different years, affecting this subpopulation; most recently in 2020, 250 JSM shells with signs of predation were found during three survey events (B. Watson, VDWR, email to J. Stanhope, Service, September 16, 2020). There is an impoundment upstream of the JSM occurrences that may be beneficial to this subpopulation, similar to the impoundment in Little Oregon Creek. This site is used as a source of broodstock for propagation and as an augmentation site for the resulting propagated, juvenile JSM. In Giles County, VA, there was a documented occurrence upstream of the impoundment in 1984 (22 live JSM and one shell); however, when revisited in 2019, no JSM were observed ((Virginia Department of Conservation and Recreation-Division of Natural Heritage [VDCR-DNH] 2021). This subpopulation in Johns Creek (near and upstream of Maggie) appears stable with large variation in JSM numbers and has evidence of recruitment. Ten years of mark-recapture surveys have been completed as of 2021, and data analysis is in progress.

Along Sevenmile Mountain: For the subpopulation in Johns Creek downstream of Maggie along Sevenmile Mountain to the confluence Craig Creek, surveys found two JSM at one site in 2001 and 12 JSM at another site in 2007; the two sites are approximately 4.8 km apart (VDWR 2020b). One shell was also found each in 2004 and 2021 at sites 0.9 km and 1.7 km downstream of the 2007 site, respectively (VDWR 2020b, Orcutt 2021). Survey effort in Johns Creek downstream of Maggie is limited (within the 11-km reach downstream of Maggie), where surveys at nine additional sites by VWDR, VDCR-DNH and permittees in 1999, 2000, 2004, 2007, 2010, and 2019 found no JSM, but found other native freshwater mussels (e.g., notched rainbow, creeper, eastern elliptio, triangle floater, Atlantic spike, yellow lance, Atlantic pigtoe) (VDWR 2020a). From 2019 to 2021, the number of sites surveyed along this portion of Johns Creek increased when VDCR-DNH surveyed 10 reaches (some overlap with previously surveyed sites; 450-m long reaches) and found no JSM (except the one shell as noted above) but found other native freshwater mussels (Orcutt 2021).

For the remainder of Johns Creek (approximately 32.2 km to the confluence with Craig Creek) and since 1990, we are aware of seven sites surveyed. For one of these sites, six JSM were previously documented in 1989, and the site was resurveyed in 1991, 1999, 2001, and 2019, finding other native freshwater mussels, but not JSM (VDWR 2020a, b; VDCR-DNH 2021; Orcutt 2021); this specific site may be extirpated. For a second site, no JSM or other native freshwater mussel were found during surveys in 2010 and 2014. From 2019 to 2021, VDCR-DNH surveyed six reaches along this portion of Johns Creek

(including the 1989 site, as described above) and found no JSM but found other native freshwater mussels (e.g., eastern elliptio, notched rainbow) (Orcutt 2021). Orcutt (2021) noted that large portions of Johns Creek remain unsurveyed.

In summary, this subpopulation of Johns Creek appears to have low abundance, but there is insufficient data to evaluate stability and recruitment.

Craig Creek (Craig and Botetourt Counties, VA) – In Craig Creek, a tributary to the James River, JSM were noted as present in the 1990 recovery plan in three areas or subpopulations: (1) near New Castle (Craig County, VA), (2) near Silent Dell (Botetourt County, VA), and (3) near Eagle Rock (Botetourt County, VA).

Near New Castle (Craig County, VA): For this subpopulation prior to the 1990 recovery plan, JSM was documented at one site approximately 23.3 km upstream of New Castle (one JSM in 1987) and at two sites approximately 3.9 km and 10.4 km downstream of New Castle (respectively, 11 and 2 JSM in 1984 and 1987). Since 1990, surveys at six sites as far as 28.8 km upstream of New Castle found no JSM (1991 and 1999) and did not appear to revisit the previous site with JSM; surveys at four of the six sites did find other native freshwater mussels (e.g., creeper, notched rainbow, and eastern elliptio). Downstream of New Castle in Craig County, a survey at one site in 1999 found one shell of JSM (approximately 5.2 km downstream from the 1987 JSM occurrence) and a resurvey of a JSM site in 1999 found no JSM but found other native freshwater mussels (e.g., eastern elliptio and notched rainbow). Surveys at two additional sites further downstream on Craig Creek (one site in 1999 and the other site in 1992 and 2012) found no JSM, but other native freshwater mussels were found (e.g., notched rainbow and Atlantic pigtoe). In summary, JSM is possibly extirpated in this subpopulation of Craig Creek, and a live JSM has not been observed since 1987, but it is not confirmed because there has been limited survey effort since 2012 with most surveys conducted in 1999 (VDWR 2020a).

Near Silent Dell (Botetourt County, VA): Near Silent Dell was listed in the recovery plan as a JSM occurrence location in Craig Creek from 1984. There were also two JSM sites from 1987 approximately 15 km and 16 km upstream (near Oriskany) in the same county (VDWR 2020b). Since then, surveys have found JSM in four reaches within an approximately 17.6-km section of Craig Creek in Botetourt County and confirmed the presence of JSM at or near the three sites identified before 1990. JSM occurrences for these four reaches are described below.

In a 1.4-km reach of Craig Creek west and southwest of Oriskany, JSM have been observed at five sites from 2003 to 2019, where one to three JSM were found (VDWR 2020a, b). A 0.5-km reach within this area, which includes a ford crossing maintained by VDOT (Reid's Ford), was monitored annually from 2006 to 2017 as part of biological opinion (BO) requirements, and only one JSM was documented in 2012, but other native freshwater mussels were observed (e.g.,

Atlantic pigtoe, northern lance [*Elliptio fisheriana*], notched rainbow, eastern elliptio) (Wolf 2019). One JSM site near Oriskany was impacted by a debris jam that built up behind a sycamore tree, which had fallen into the creek in 2019 or 2020, likely due to high storm flow or flooding events eroding the streambank (B. Watson, VDWR, email to J. Stanhope, Service, April 6, 2022). The USFS in coordination with VDWR removed the tree and debris jam in April 2022. VDWR revisited the site and found that habitat was slightly altered but somewhat similar to conditions prior to the debris jam (B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022).

In a 0.5-km reach southeast of Oriskany, JSM have been observed from 2006 to 2016, where one to three JSM were found (VDWR 2020a, b). One site (<0.1-km reach) was part of the mark-recapture study from 2012 to 2018 (Craig Creek - Anderson Ford) and was a mussel bed upstream of a ford crossing of the creek. The modeled abundance estimates were variable, from zero to four JSM, but zero JSM recently in 2018 (table 3) (TOE and DC 2019). This 0.5-km reach was monitored annually from 2006 to 2017 as part of BO requirements discussed above. After the mark-recapture study was initiated, only the downstream portion (0.4 km) was monitored, and no JSM were found from 2012 to 2017, but other native freshwater mussels were observed (e.g., northern lance, notched rainbow) (Wolf 2019).

In a 0.5-km reach, approximately 9 km downstream of the reach described above, JSM have been observed from 2000 to 2018, where one to three JSM were found (VDWR 2020a, b). One site in this reach (<0.1-km reach), a mussel bed downstream of a ford crossing of the creek, was part of the mark-recapture study from 2012 to 2018 (Craig Creek - Carter Ford). The modeled abundance estimates were variable, from one to six JSM (table 3) (TOE and DC 2019). This 0.5-km reach was monitored annually from 2006 to 2017 as part of BO requirements discussed above. After the mark-recapture study was initiated, a portion (0.4 km) was monitored, and no JSM were found from 2012 to 2017, but other native freshwater mussels were observed (e.g., Atlantic pigtoe, northern lance, notched rainbow, creeper) (Wolf 2019). In October 2021, 274 propagated, juvenile JSM were released at the mark-recapture site (B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). Without information about the success of the release, the number of propagated JSM was not included in the assessment of approximate abundance.

In a 0.7-km reach, near Silent Dell, JSM have been observed from 1999 to 2012, where one to three JSM were found (VDWR 2020a, b). A 0.5-km reach within this area was monitored annually from 2006 to 2017 as part of BO requirements discussed above (Hannah's Ford), and no JSM were documented 2013 to 2017, but other native freshwater mussels were observed (e.g., northern lance, notched rainbow, creeper, triangle floater, eastern elliptio) (Wolf 2019).

In summary, the subpopulation appears to have patchy distribution and low abundance and may be decreasing based on the lack of JSM observed during recent annual surveys. There is insufficient data to evaluate stability and recruitment.

Near Eagle Rock (Botetourt County, VA): No live JSM have been found in this subpopulation of Craig Creek since the 1990 recovery plan was completed (last observed in 1988); however, there appears to be limited survey effort in this area (VDWR 2020a, b; VDCR-DNH 2021). One survey in 1999 at a known JSM site did not observe any JSM but found eastern elliptio (VDWR 2020a). A site approximately 8.4 km upstream (i.e., not previously known for JSM) was surveyed in 1995, and two shells of JSM were found (VDCR-DNH 2021). With most known sites with JSM not being surveyed in more than 20 years and limited survey effort, the status of this JSM subpopulation in Craig Creek is unknown.

Patterson Creek (Botetourt County, VA) – No JSM have been found in Patterson Creek, a tributary to Craig Creek, since the 1990 recovery plan was completed. Surveys at four sites in Patterson Creek by VDWR and permittees in 1992, 2000, and 2004 found no JSM and no other native freshwater mussels (O’Connell and Neves 1992, McGregor and Baisden 2002, Johnson and Neves 2004a, VDWR 2020a). The 2004 survey appears to be near the previously documented JSM site, and surveyors observed suitable mussel habitat, but found only relict shells of notched rainbow. Due to live individuals not being observed since 1988 (VDWR 2020b, VDCR-DNH 2021), JSM appears extirpated in this creek, but it is not confirmed because survey effort has been limited throughout Patterson Creek.

Catawba Creek (Botetourt County, VA) – No live JSM have been found in Catawba Creek, a tributary to Craig Creek, since the 1990 recovery plan was completed. Surveys at three sites in 1999 and 2007, including a previously documented JSM site, found shells of JSM (VDWR 2020b, VDCR-DNH 2021). Surveys at four sites in 1991, 2004, and 2007 found no JSM, but other native freshwater mussels were found (e.g., notched rainbow, eastern elliptio, many relict shells of notched rainbow and eastern elliptio), and surveys at two sites in 1999 found no native freshwater mussels (Johnson and Neves 2004a, VDWR 2020a). In 2006, surveys for mussels following a diesel spill in Catawba Creek, yielded no JSM. Surveys at three other sites in Catawba Creek by VDWR and permittees in 1991, 2000, and 2004 found no JSM and no other native freshwater mussel (VDWR 2020a). Due to live individuals not being observed since 1988 (VDWR 2020b, VDCR-DNH 2021), JSM appears extirpated in this creek, but it is not confirmed because survey effort has been limited throughout Catawba Creek.

Maury sub-basin (VA; HUC8 02080202)

Calfpasture River (Rockbridge County, VA) – JSM was listed as a historical occurrence in the Calfpasture River in Rockbridge County in the 1990 recovery

plan. Surveys at two sites of the Calfpasture River (Rockbridge and Augusta Counties, VA) by VWDR and permittees in 1996, 2001, and 2005 found no JSM, but found other native freshwater mussels (e.g., notched rainbow, creeper, eastern elliptio, triangle floater) (McGregor and Baisden 2002, VDWR 2020a). Surveys at three sites of the upper Calfpasture River (Augusta County, VA) did not find any freshwater mussels in 2016 and 2017 (ESI 2016, 2017). In summary, JSM appears extirpated in this river and has not been observed since 1845 (VDCR-DNH 2021), but it is not confirmed because survey effort has been limited throughout the Calfpasture River.

Maury River (Rockbridge County, VA) – JSM was listed as a historical occurrence in the Maury River in the 1990 recovery plan. Surveys of four sites in the Maury River in 2001 by McGregor and Baisden (2002) found no JSM but found other native freshwater mussels (e.g., notched rainbow, eastern elliptio, northern lance) (VDWR 2020a). VDWR surveyed downstream and upstream of the Jordan Point Dam in 2017 prior to its removal and found no JSM but did find other native freshwater mussels (e.g., northern lance) (B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). JSM appears extirpated in this river and has not been observed since 1845, but it is not confirmed because survey effort has been limited throughout the Maury River.

Mill Creek (Bath County, VA) – JSM was listed as historical in the 1990 recovery plan but multiple surveys since 1996 have documented the species in three sites/reaches of Mill Creek with most observations occurring within a 1.3-km reach (VDWR 2020a, VDCR-DNH 2021). Within this area, a 155-m reach is part of an ongoing mark-recapture study since 2012, and modeled abundance estimates in 2021 were 171 JSM, with some fluctuations over the years (65-214 JSM) (table 3) (Ostby 2022b). This area is also a source for propagation broodstock since 2011 and an augmentation site for the 532 propagated juvenile JSM in 2013, with modeled abundance estimates of 99 to 309 JSM (see section 2.3.1.1 for information about propagation efforts). Based on the abundance estimates, estimated high survival rates (0.87 to 0.95), and observations of wild juvenile JSM (VDWR 2020b), the wild JSM population appears stable with some variation and evidence of recruitment. With augmentation, the JSM population is increasing overall. Ten years of mark-recapture surveys have been completed as of 2021.

Middle James-Buffalo sub-basin (VA; HUC8 02080203)

Pedlar River (Amherst County, VA) – Multiple surveys since the 1990 recovery plan was completed have confirmed the occurrence of JSM in the Pedlar River, a tributary to the James River, at more than 13 sites from 1992 to 2021 (i.e., 1992, 1999, 2000, 2004, 2005, 2009, 2011, 2016, 2017, 2018, 2019, 2020, 2021) within an approximately 11.6-km section of the Pedlar River (from about 4.6 km upstream of the confluence with the James River to about 8.8 km downstream of the Pedlar River Dam); one to seven JSM were observed at these sites (VDWR

2020a, J. Alderman, Alderman Environmental Services, Inc., email to S. Dressler et al., VDWR, April 7, 2020; VDCR-DNH 2021; B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). During more recent surveys conducted in 2017 to 2020, no more than two JSM have been observed at a site. Some of these surveys took place due to VDOT bridge replacement work and proposed pipeline crossings (e.g., maintenance, replacement) on the Pedlar River. There is no information to indicate if a JSM site from 1989, upstream of Pedlar River Dam, has been resurveyed. Subadult JSM (less than 30 mm in length) have been observed, one in 2004 and one in 2019, suggesting some reproduction is occurring in the Pedlar River. In summary, JSM is distributed throughout the Pedlar River with low abundance and some recruitment, but there is insufficient data to evaluate stability.

Hardware River (Fluvanna and Albemarle Counties, VA) – The Hardware River, a tributary to the James River, is a new occurrence river for JSM. In 1999 a JSM shell was found at one site, and in 2004, eight JSM total were discovered within a 1-km reach at three sites in Fluvanna and Albemarle Counties (Johnson and Neves 2004b, VDWR 2020b). Four JSM from the two sites downstream of a bridge were prematurely relocated to the 3rd JSM site upstream of the bridge during a survey conducted for VDOT. In 2019, one JSM was found within this 1-km reach, confirming presence of JSM (VDWR 2020b). Surveys in the Hardware River are limited with one survey in 2011 immediately upstream of the 1-km reach and another survey in 2021, conducted 0.1 km upstream and 0.9 km downstream of a mill dam (survey ended approximately 1.3 km upstream of the 1-km reach); both surveys in Albemarle County did not observe any JSM, but did find other native freshwater mussels (e.g., eastern elliptio, notched rainbow) (VDWR 2020b, Ostby and Carey 2021). In the latter survey, Ostby and Carey (2021) observed that the reach downstream of the mill dam appeared to be degraded with no crayfish and less fish and aquatic invertebrates in comparison to other streams in this county. Surveys downstream of the JSM 1-km reach, from approximately 7.4 km downstream of this reach to the confluence with the James River, found no freshwater mussels at one site in 1997 and other native freshwater mussels at three sites in 1999 and 2011 (e.g., eastern elliptio). In summary, the Hardware River appears to have very low abundance, but there is insufficient data to evaluate stability and recruitment of the population.

Rock Island Creek (Buckingham County, VA) – Rock Island Creek, a tributary to the James River, is a new occurrence river for JSM. Surveys in 2011 found 75 JSM in two reaches of the creek within an approximately 2.1-km section of the creek (Chazal et al. 2012, VDWR 2020b). An additional reach with JSM was found within this section, and two of these reaches were part of the mark-recapture study from 2013 to 2018; after 2018, only reach #1 is included in the ongoing mark-recapture study. Modeled abundance estimates in 2018 were 58 and 88 JSM in reach #1 (approximately 175-m long) and #2 (approximately 100-m long, upstream of reach #1), respectively, with some fluctuations over the years (table 3) (TOE and DC 2019). These reaches were also a source for propagation

broodstock since 2015 and are augmentation sites for the resulting propagated juvenile JSM since 2017 (see section 2.3.1.1 for information about propagation efforts). However, in 2018 as a result of high flows from Hurricane Florence and/or Michael, multiple trees fell along a bank in reach #2, which severely degraded the instream habitat (B. Watson, VDWR, email to R. Mair, Service, October 25, 2018). Very few tagged JSMs could be found during the October 2018 survey, and the VDWR biologist thought that the JSM were either washed downstream, buried under sand, or remained in small areas of suitable habitat. Coarse sand appeared to have been carried downstream to the lower reach. The surveys in 2019 of reach #1 observed 41 JSM (7 recaptured, which included propagated JSM, 34 new individuals) in May and 100 JSM in September (62 were pit-tagged in previous surveys and found subsurface using the pit tag reader; therefore, this count is not comparable to previous surveys). A few tagged JSM from reach #2 were found in reach #1, indicating some JSM were washed downstream and found suitable habitat. Due to the loss of reach #2 as a healthy JSM site, Rock Island Creek was removed from the mark-recapture study and will not be used as a source for propagation broodstock. Propagated JSM have been released to reach #1, but mark-recapture data for these individuals have not been analyzed and there are no estimates of survival rates or their abundance; therefore, propagated JSM was not included in the assessment of approximate abundance. In summary, based on the abundance estimates, the JSM population appears stable at reach #1 with some variation and evidence of recruitment, but the population has declined overall with the loss of suitable habitat in reach #2. Nine years of mark-recapture surveys have been completed at reach #1 as of 2021, and data analysis is in progress.

Tye River (Nelson County, VA) – The Tye River, a tributary to the James River, is a new occurrence river for JSM. A fresh shell of JSM was found in a 2010 survey and a second fresh shell was found in the same general area in 2011 (Chazal et al. 2012). VDCR-DNH conducted 26 surveys in a 10-km reach of the Tye River in 2016 to 2017 and found JSM at six sites (1 to 2 JSM per site) within an approximately 2.2-km reach (Orcutt 2017). It was noted that all the observed native mussels occurred within a 3.1-km reach (which contains the 2.2 km-reach with JSM). Some of these sites were revisited in 2018 and 2019 to swab the JSM for DNA samples, and one to four JSM per site were found, with some JSM recaptured after being tagged on earlier surveys (VDWR 2020b). The JSM individuals found at these sites were older, and none were less than 30 mm in length. In 2019, 650 propagated juvenile JSM (broodstock from Rock Island Creek) were released to three sites in the Tye River, two sites within the 2.2-km reach with known JSM occurrences and a new site with suitable habitat, potentially extending the total range 31.7 km. Post release monitoring is planned for 2022; due to the lack of information about the success of the release, the number of propagated JSM was not included in the assessment of approximate abundance. Upstream of the confluence with the James River, surveys in the Tye River at five sites in 2001, 2006, 2007, 2010, and 2011 found no JSM but found other native freshwater mussels (e.g., green floater, eastern elliptio) (VDWR

2020a). In summary, the Tye River JSM population is mainly located within a 2.2-km reach and appears to have low abundance, but there is insufficient data to evaluate stability and recruitment.

Totier Creek (Albemarle County, VA) – Totier Creek, a tributary to the James River, is a new occurrence river for JSM. Two relict shells of JSM were found in 2011 and 2012 in an approximately 0.4-km reach, as well as two to three live notched rainbows (Chazal et al. 2012, Chazal 2013). High sedimentation was observed at the JSM reach, with all substrate surfaces covered with sediment. There appears to be limited survey effort in this creek, with surveys in two sites in 2011-2012, 4.8 km upstream and 3.5 km downstream of the JSM reach, which found no native freshwater mussels (Chazal et al. 2012, Chazal 2013). A survey in 2017 at a site 1.5 km upstream of the JSM reach found only notched rainbow (VDWR 2020a). There is an impoundment downstream of the site, reducing connectivity to the James River. JSM is possibly extirpated in this creek, but it is not confirmed because survey effort has been limited.

Rivanna sub-basin (VA; HUC8 02080204)

Mechums River (Albemarle County, VA) – Surveys in Mechums River, a tributary to the South Fork Rivanna River, since 1990 have found JSM at three sites in 1992 and 1999 within an approximately 0.9-km reach and at one site about 5.3 km downstream (near the confluence with Lickinghole Creek) in 1998; one to three JSM were observed at these sites (VDWR 2020b, VDCR-DNH 2021). A relict JSM shell was found in 1991 at the confluence of Mechums River and Lickinghole Creek, and it is unclear which waterbody was the source of the shell. A site where JSM was previously found in 1990, approximately 9 km downstream from the confluence with Lickinghole Creek, was surveyed in 2004 and no JSM was found (VDCR-DNH 2021). In 2020 and 2021, four JSM (two each year) were found by a St. Anne's-Belfield School teacher (VDWR permittee) and students upstream of a known JSM site and were photo verified by VDWR malacologist B. Watson (B. Watson, VDWR, email to J. Stanhope, Service, January 21, 2022). There appears to be limited survey effort in Mechums River in the past 20 years, with three additional sites surveyed in 2004, 2007, and 2008 (none at JSM sites) and no JSM found; other native freshwater mussels were observed at one site (e.g., creeper) (VDWR 2020a). In summary, Mechums River appears to have very low abundance, but insufficient data to evaluate recruitment and stability, with most known sites with JSM not surveyed in more than 22 years and limited survey effort overall.

Moormans River (Albemarle County, VA) – No live JSM have been found in the Moormans River, a tributary to the South Fork Rivanna River, since the 1990 recovery plan was completed. JSM was observed at only one site in 1990 downstream of a bridge (7 JSM), and surveys in 1992, 1995, 1998, and 2003 did not find any JSM (VDWR 2020a, VDCR-DNH 2021). It appears this bridge may have been replaced, based on notes in the element occurrence record (VDCR-

DNH 2021). Surveys at three sites in 1998 and 2005, upstream of the confluence with the South Fork Rivanna River, and at one site in 1998 more than 5.6 km upstream of the JSM site, detected no JSM, but other freshwater mussels were found (species not indicated) (VDWR 2020a). In summary, JSM appears extirpated in this river, but it is not confirmed because survey effort has been limited throughout the Moormans River.

Wards Creek (Albemarle County, VA) – Wards Creek, a tributary to Moormans River, was mis-identified as “Rocky Run (Moormans River)” in the 1990 recovery plan and Hove (1990). Based on the site description provided in Hove (1990), the two JSM were found in Wards Creek in 1989. Multiple surveys since 1990 have confirmed the occurrence of JSM at this site in 1992, 1998, 2003, and 2004, with 2 to 11 JSM found (VDWR 2020a, b). JSM was found at a new site in 1992 in Wards Creek before the confluence with South Fork Rivanna River. In 2011, Ostby and Angermeier (2012) conducted semiquantitative surveys at 31 reaches within 6.6 km of Wards Creek and found one JSM each at two new sites. One shell was found at another site approximately 0.7 km upstream of the 1989 occurrence site. Juvenile JSM were observed in the 2003 survey at the 1998 occurrence site and at another site in 2011. Ostby reported that he surveyed a small section of Wards Creek in 2017 with James Madison University and Virginia Commonwealth University students (upstream and downstream of the mouth of Rocky Creek) and found no JSM (B. Ostby, DC, email to J. Stanhope, Service, May 30, 2022). In summary, Wards Creek appears to have low abundance, patchy distribution, and some recruitment, but insufficient data to evaluate stability.

Rocky Creek (Albemarle County, VA) – Rocky Creek, a tributary to Wards Creek, is a new occurrence river for JSM. Two JSM and four shells of JSM were found in 1998 at one site (VDWR 2020b). In 2011, Ostby and Angermeier (2012) conducted semiquantitative surveys at reaches within 3 km of Rocky Creek and found 17 JSM total at 15 sites within an approximately 1.3-km reach. The goals of these surveys were to detect presence of JSM and understand probabilities of detection. They also conducted quantitative sampling in a 0.35 km-reach in 2012 using a systematic random sampling approach because there was no clear spatial pattern for occupied quadrats (e.g., 0.25 m² quadrats in suitable habitat with freshwater mussels) and estimated a density of 0.52 JSM/m². Ostby and Angermeier (2012) noted that JSM were usually found in aggregations in Rocky Creek compared to other streams where the species are usually found as single specimens.

In 2015 and 2017, Ostby (2015, 2019a) resurveyed the same reaches in Rocky Creek applying the same methods of Ostby and Angermeier (2012) and found that JSM was observed in many of the same 2011 and 2012 sites. They also expanded surveys upstream to near a manmade impoundment, a farm pond, and downstream to the confluence with Wards Creek and found new sites downstream, increasing the range of the species to 3.0 km total of Rocky Creek

(VDWR 2020a). No mussels were detected upstream of the impoundment, which reduces connectivity. The impoundment may provide beneficial effects to JSM as those described for Little Oregon Creek, Johns Creek, and Dicks Creek, but may also limit minimum flows because the farm pond may have less regulatory oversight. Rocky Creek was also resurveyed in 2019 at the same reaches and the number of live JSM observed in 2015, 2017, and 2019 were 6, 39, and 80, respectively (B. Ostby, DC, email to J. Stanhope, Service, January 5, 2022). Predation was also observed based on 5 to 25 JSM shells with claw and teeth marks each year in 2015-2019. The density of JSM observed during quantitative sampling of one reach in 2015 was similar to density in 2012, with mean density of approximately 0.6 and 0.5 JSM individuals/m², respectively (Ostby 2015). Based on extrapolating the density estimate to the 1,100 m² sample area, Ostby (2015) estimated the population size to be 236 to 1,153 JSM (95 percent confidence intervals) in this area. Ostby (2019a) indicated that individuals of the species were highly detectable in Rocky Creek, suggesting either that they exist at a high density or are easier to detect in a stream with greater mean particle size. Ostby and Angermeier (2012) observed that “its stream bottom was bedrock covered by at most 10 cm [centimeters] of cobble, gravel, and sand,” while for streams nearby (e.g., Wards Creek, Swift Run, Buck Mountain Creek, and Piney Creek), sand was the dominant substrate, and JSM were more difficult to find because they are more likely to be subsurface. The repeated sampling in 2015 and 2017 indicated that the JSM population had grown older and larger since 2011-2012, but there is recruitment with a small number of individuals detected that are less than 30 mm in length (Ostby 2019a). This site is used as a source of broodstock for propagation and will be an augmentation site for the resulting propagated juvenile JSM.

Since 2016, a site in Rocky Creek, which overlaps with the high density reach where quantitative sampling was conducted as indicated above, is part of an ongoing mark-recapture study being conducted by a St. Anne’s-Belfield School teacher and students, but no data have been provided. However, immediately downstream of the site is a failing double culvert, and it was reported that debris falling through the holes was creating a dam effect and possibly impacting JSM by causing low flows in the riffle habitat they inhabit; the debris was cleared (B. Watson, VDWR, email to J. Chiles, M. Hartman, and S. Alexander, VDOT, January 2, 2022). VDOT is planning to replace the culverts in 2022-2023, which will likely adversely affect JSM during construction. A second mark-recapture site was added in 2020, downstream of the impoundment (B. Watson, VDWR, email to J. Stanhope, Service, February 18, 2022).

In summary, the Rocky Creek population appears stable with large variation and evidence of recruitment, based on nine years of available monitoring data (2011-2019).

Buck Mountain Creek (Albemarle County, VA) – Buck Mountain Creek, a tributary to South Fork Rivanna River, is a new occurrence river for JSM. Ten

JSM and four shells of JSM (“4 paired valves”) were found in 1996 at eight sites over approximately 2.9 km of Buck Mountain Creek (P. Stevenson, consultant, letter to P. Nickerson, Service, January 24, 1997). In 1999, JSM was observed (number of individuals not indicated) approximately 3 km upstream from the previous occurrences (VDWR 2020b). In 2004, the JSM’s documented range in the creek was extended 1.8 km downstream with one JSM found. In 2011, Ostby and Angermeier (2012) conducted semiquantitative surveys at 39 reaches within 14.4 km of Buck Mountain Creek and found five JSM and one shell total at four new sites, which were located within the known range of the species. They also conducted quantitative sampling in a 0.09-km reach in 2012 using a stratified sampling approach because there was a clear spatial pattern for occupied quadrats (i.e., 0.25 m² quadrats in suitable habitat with freshwater mussels) and estimated a density of 0.26 JSM/m². In 2021, a survey found three JSM at a previously documented site (Alexander 2021). In summary, Buck Mountain Creek appears to have very low abundance and patchy distribution, but insufficient data to evaluate stability and recruitment.

Piney Creek (Albemarle County, VA) – Piney Creek, a tributary to Buck Mountain Creek, is a new occurrence river for JSM. Two shells of JSM (“2 paired valves”) were found in 1996 at one site (P. Stevenson, consultant, letter to P. Nickerson, Service, January 24, 1997). Ostby and Angermeier (2012) conducted semiquantitative surveys at seven reaches within 1.4 km of Piney Creek and found one JSM in 2012 at another site approximately 0.4 km downstream of the JSM shells. Ostby reported that he surveyed several kms of the upstream reaches of Piney Creek in 2019 and found no JSM (B. Ostby, DC, email to J. Stanhope, Service, May 30, 2022). In 2021, a survey downstream of the 2012 site did not find JSM (Alexander 2021). In summary, Piney Creek appears to have very low abundance, but there is insufficient data to evaluate stability and recruitment.

Ivy Creek (Albemarle County, VA) – Ivy Creek, a tributary to the South Fork Rivanna River, is a new occurrence river for JSM. In 1997, three JSM and six shells of JSM (one fresh dead, five relict) were found at four sites in an approximately 1.4-km reach in Ivy Creek, and two more relict shells were found within this reach in 1999 (VDWR 2020b, VDCR-DNH 2021). The range in Ivy Creek was extended by approximately 8.2 km upstream when three JSM were found in a 1998 survey (VDWR 2020b). In 2011, Ostby and Neves (2011) conducted a survey in a 3.0-km reach of Ivy Creek and found two JSM approximately 0.3 km upstream of the 1.4-km reach from 1997. There appears to be limited survey efforts since 2011, with a survey in 2012 of a 1-km reach in Ivy Creek upstream of the confluence with Little Ivy Creek (i.e., not the same area where JSM were previously detected) that found no freshwater mussels (Ostby et al. 2012). Ivy Creek joins the South Fork Rivanna River in a transition zone (e.g., slow flow and greater depth, silt, and organic matter on stream bottom) with the South Fork Rivanna Reservoir, restricting connectivity to other JSM rivers. Ostby and Neves (2011) observed that the lower portion of Ivy Creek (1.4-km-long starting at the transition zone and upstream) is very unstable and degraded, likely

due to intense land use activities in the watershed and/or nearby. In summary, Ivy Creek appears to have very low abundance, but there is insufficient data to evaluate stability and recruitment.

North Fork Rivanna River (Albemarle County, VA) – The North Fork Rivanna River, a tributary to the Rivanna River, is a new occurrence river for JSM. In 1998, six sites were surveyed in the North Fork Rivanna River, and one JSM was found at one site more than 2 km upstream of the confluence with Swift Run (McGregor 1999). Surveys in 2005 and 2013 that found one JSM each at two sites total extended the range in the North Fork Rivanna River approximately 13.0 km downstream (VDWR 2020b), and another survey in 2015 detected two JSM between the 2005 and 2013 occurrences (The Catena Group 2015, VDWR 2020a). For the new 2015 site, a survey was conducted in the same reach in 2010 and did not find any JSM, highlighting the difficulty in detecting JSM (Creek Laboratory, LLC 2010). It also supports resurveying reaches if there is suitable mussel habitat and JSM is known to occur in the waterbody. The JSM found in 2013 was less than 35 mm in length and possibly four to five years old, which suggests some recruitment in the previous five years. There has been limited survey effort in the North Fork Rivanna River, with surveys in 2006, 2008, and 2018 at four sites that found no JSM but other native freshwater mussels (e.g., notched rainbow), and a survey in 2008 found no native freshwater mussels (VDWR 2020a). The negative JSM survey in 2018 was conducted at a site where JSM was previously documented in 2005 and Alexander (2018) observed “severe flooding caused erosion and excessive sediment deposition within the river channel.” In summary, the North Fork Rivanna River appears to have very low abundance and some recruitment, but there is insufficient data to evaluate stability.

Swift Run (Greene and Albemarle Counties, VA) – Swift Run, a tributary to the North Fork Rivanna River, is a new occurrence river for JSM. First discovered in 1998, multiple surveys in 2003, 2004, 2007, 2008, and 2009 found JSM at multiple sites in approximately 7.4 km of Swift Run, with 1 to 15 JSM, including juveniles, observed at individual sites (VDWR 2020a, b). The surveys conducted in 2007 and 2008 were required monitoring after frac-out (i.e., discharge of sediment/bentonite-laden water) occurred during horizontal directional drilling for a pipeline crossing, where the closest known JSM occurrence was more than 15 km downstream (Dickinson 2007). Twelve sites were surveyed from downstream of the crossing to the confluence with Welsh Run, and three sites detected JSM, approximately 11.5 km downstream of the pipeline crossing (VDWR 2020b). Based on four monitoring periods, Dickinson (2008) did not detect observable changes in stream condition related to the frac out and concluded that there were minimal to no impacts on native mussels monitored at the JSM sites.

In 2011 and 2012, Ostby and Angermeier (2012) conducted semiquantitative surveys at 21 reaches within 8.7 km of Swift Run and found 24 JSM, 4 shells, and 1 fresh dead shell total at 14 new sites, expanding the downstream range of the

species to a total of 9.1 km in Swift Run (B. Ostby, DC, email to J. Stanhope, Service, January 5, 2022). They also conducted quantitative sampling in a 0.05-km reach in 2012 using a stratified sampling approach because there was a clear spatial pattern for occupied quadrats (i.e., 0.25 m² quadrats in suitable habitat with freshwater mussels) and estimated a density of 0.21 JSM/m².

In 2015 and 2017, Ostby (2015, 2019a) resurveyed the same 21 reaches in Swift Run applying the same methods of Ostby and Angermeier (2012) and JSM (live and shells) were not observed in many of the same 2011/2012 sites. For only two reaches, JSM (live and shells) was detected in all three survey years (i.e., 2012/2012, 2015, 2017), and for six reaches, JSM was detected in two of the three survey years. The number of live JSM observed in 2015 and 2017 were 6 and 12, respectively (B. Ostby, DC, email to J. Stanhope, Service, January 5, 2022). These studies, along with those conducted by James Madison University researchers (e.g., Esposito 2015, Boisen 2016, Draper 2016, Verdream 2020) indicate that JSM have “highly variable spatio-temporal occupancy and detection patterns in Swift Run [and] [n]o single habitat in Swift Run appeared to support a robust and definable population center” (Ostby 2019b). Many of the JSM sites in Swift Run, including mussel beds, appear to be transient and occur in unstable stream reaches, in contrast to typical JSM sites that are stable and typically not transient, as observed in Rocky Creek and Little Oregon Creek (Ostby 2019b, Verdream 2020). In 2019, Ostby (2019b) repeated the study by surveying the same 21 reaches in Swift Run and additional areas in Swift Run and its tributaries in 2019 (total 27.5 km). Only five JSM were observed in the 21 reaches, the lowest number detected in all four surveys. For only six reaches, JSM (live and shells) was detected in three of the four years. JSM mussel beds/aggregates were previously observed in 2011, but now JSM is only found as individuals. Ostby (2019b) was unable to find a stable, source population center in Swift Run.

Juvenile JSM have been observed in Swift Run in 2003 and 2014, with lengths of 24.85 and 32.51 mm in the latter date (Esposito 2015, VDWR 2020b), indicating recruitment had likely occurred in the four years before 2014 (based on length vs. age relationship in Hove 1990).

In summary, the JSM population in Swift Run appears to have low abundance, some recruitment, and highly variable and patchy distribution. It is not clear if the lower number of JSM observed in 2019 was due to lower detection rates or if the population in Swift Run is declining. High flows in 2018 and 2019 may have displaced and moved JSM to downstream locations.

Unnamed Tributary to Swift Run (Greene County, VA) – The unnamed tributary to Swift Run is a new occurrence stream for JSM. This unnamed, perennial tributary flows from the north-northwest direction and joins Swift Run approximately 1.3 km upstream of the confluence of Quarter Creek and Swift Run. Surveys in 2017 and 2019 found one JSM and one JSM shell, respectively, in close proximity to each other (Ostby 2019a and 2019b). The 2019 survey,

which searched the lower 3.1 km of the tributary, also found many other native freshwater mussels, including notched rainbow and creeper. In summary, the JSM population in the unnamed tributary to Swift Run appears to have very low abundance, but there is insufficient data to evaluate stability and recruitment.

Welsh Run (Greene County, VA) – Welsh Run, a tributary to Swift Run, is a new occurrence stream for JSM. In 2005, VDWR biologists found two JSM and one JSM shell at two sites in Welsh Run (VDWR 2020b). Surveys in 2017 and 2019 (on the latter date the lower 2.8 km of Welsh Run was surveyed) did not observe JSM but found other native freshwater mussels (Ostby 2019a and 2019b). In summary, the JSM population in the Welsh Run is likely present, but there is insufficient data to evaluate status, recruitment, stability, and approximate abundance due to limited survey effort.

Rivanna River (Fluvanna County, VA) – No live JSM have been found in the Rivanna River, a tributary to James River downstream of Charlottesville, VA, since the 1990 recovery plan was completed. The recovery plan noted three areas or subpopulations in the Rivanna River in Fluvanna County (near Columbia, near Palmyra, and at Crofton); survey efforts in the Rivanna River as a whole are described below.

Surveys at multiple sites (>40 sites, including previously documented JSM sites) throughout the Rivanna River in both Albemarle and Fluvanna Counties in 1991, 1992, 1996, 1997, 1998, 2000, 2001, 2006, 2007, 2009, and 2011 found no JSM, but other native freshwater mussels were found (e.g., notched rainbow, eastern elliptio, creeper, green floater, Carolina lance, triangle floater, northern lance, Atlantic pigtoe) (McGregor 1999, VDWR 2020a). Due to live individuals not being observed since 1968 (VDWR 2020b, VDCR-DNH 2021), JSM is presumed extirpated in this river; however, it is not confirmed due to difficulty in surveying a large river (67.8 km), surveys sites did not occur in all reaches of the Rivanna River, low detection rates for JSM, and there continues to be suitable mussel habitat.

Mechunk Creek (Fluvanna County, VA) – Mechunk Creek, a tributary to the Rivanna River, is a new occurrence river for JSM. One relict shell of JSM was found in 2004 (VDWR 2020b). In 2007, surveys were conducted at two sites by VDWR biologists and found no JSM, but did observe other native freshwater mussels (e.g., Atlantic spike, eastern elliptio, notched rainbow) (VDWR 2020a). JSM appears extirpated in this creek, but it is not confirmed because survey effort has been limited.

James River mainstem

In the James River mainstem, the population was noted as historical and the species has not been found since the 1990 recovery plan was completed. The recovery plan noted eight areas or subpopulations in the James River, and surveys

conducted by sub-basin from west to east (upstream to downstream) on the river since 1990 (numbers indicate the subpopulation identified in the recovery plan) are summarized below.

Upper James (HUC8 02080201): James River near (1) Buchanan (Botetourt County, VA) and (2) Natural Bridge (Rockbridge County, VA) – Surveys in 2001 at Buchanan and near Natural Bridge by VWDR found no JSM or other native freshwater mussels (McGregor and Baisden 2002). Ostby and Angermeier (2009) conducted reconnaissance surveys by canoe and land to identify suitable mussel habitat in six reaches of the James River in Botetourt County (40.6 km of 80 km in this county) and conducted semiquantitative mussel surveys at 15 sites in 2009 (47,200 m² total of stream bottom). No live native freshwater mussels were detected at these sites, with only one shell of eastern elliptio found. Other surveys conducted in the James River, in 1997 near the confluence with Craig Creek and in 2005 near the confluence with the Maury River, found other native and nonnative freshwater mussels (e.g., eastern elliptio and other *Elliptio* species) (VDWR 2020a). A small area (approximately two 100 m-long reaches near piers) in the James River at Buchanan was surveyed in 2021 for a VDOT bridge project, and no JSM were found (Carey 2021). In summary, JSM appears extirpated in this area of the James River and has not been observed since before 1967 (date unknown) (VDWR 2020b, VDCR-DNH 2021), but it is not confirmed because large rivers are difficult to survey, surveys sites did not occur in all reaches of the river, and JSM has low detection rates.

Middle James-Buffalo (HUC8 02080203): James River near (3) New Canton (Buckingham and Fluvanna Counties, VA) – Surveys at and downstream of the historical JSM site (approximately 2.1-km reach) in 1994, 2001, 2006, 2007, 2008, 2011, 2012, 2013, and 2018 by VWDR and permittees found no JSM but did find other native freshwater mussels (e.g., creeper, eastern elliptio, green floater, Carolina lance, triangle floater, Atlantic spike). In 2011 and 2012, Chazal et al. (2012) conducted qualitative and semiquantitative surveys at 43 sites in 10 reaches in the James River (greater than 136,000 m² total of stream bottom) from Warren (about 1 km upstream of confluence with Rock Island Creek) to Powhatan Correctional Facility (about 3 km downstream of Maidens), including all historical areas/subpopulations in the Middle James-Buffalo and Middle James-Willis subbasins. No JSM were found during these surveys, but Chazal et al. (2012) noted that they “sampled a relatively small amount of the suitable habitat at each location, which does not include large areas of the river that were not surveyed.” The New Canton historical area is adjacent to the Bremo Power Station, and its mixing zone for the station’s thermal discharge may cause adverse impacts to mussels. In summary, JSM appears extirpated in this area of the James River and has not been observed since before 1966 (VDWR 2020b), but it is not confirmed because large rivers are difficult to survey, surveys sites did not occur in all reaches of the river, and JSM has low detection rates.

Middle James-Willis (HUC8 02080205): James River near (4) Columbia (Fluvanna and Cumberland Counties, VA), (5) Pemberton and Cartersville (Goochland and Cumberland Counties, VA), (6) Rock Castle (Goochland and Powhatan Counties, VA), and (7, 8) Maidens and opposite Maidens (Goochland and Powhatan Counties, VA) – Surveys at the historical JSM sites and other areas of the James River in 1997, 1998, 2001, 2005, 2007, 2009, 2010, 2011, 2012, and 2013 by VWDR and permittees found no JSM but did find other native freshwater mussels (e.g., creeper, eastern elliptio, green floater, Carolina lance, eastern floater, Atlantic spike) (VDWR 2020a). As described above for Chazal et al. (2012), no JSM were detected during surveys of 43 sites in 10 reaches of the James River. In summary, JSM appears extirpated in this area of the James River and has not been observed since before 1966 (VDWR 2020b), but it is not confirmed because large rivers are difficult to survey, surveys sites did not occur in all reaches of the James River, and JSM has low detection rates.

Roanoke River major drainage basin

Upper Dan sub-basin (VA, NC; HUC8 03010103)

Dan River (Stokes and Rockingham Counties, NC) – The Dan River is a new occurrence river for JSM, and the first time the species was documented outside of the James River drainage basin. First discovered in 2000, multiple surveys in 2000-2010 found JSM at multiple sites in approximately 57 km of the Dan River in Stokes County, with 1 to 76 JSM observed at individual sites/dates and cumulatively 370 JSM over this time period (NCWRC 2020b). In 2003, more than 170 JSM were relocated due to a North Carolina Department of Transportation (NCDOT) bridge replacement project; however, after a major flood event in fall 2004, only 15 JSM were initially detected and then none were detected during followup monitoring after the first year (M. Perkins, NCWRC, email to J. Stanhope, Service, November 13, 2020 and March 2, 2021).

Surveys efforts increased in 2015, and NCWRC biologists observed approximately 80 JSM throughout the upper Dan River from 2015-2019; four new sites in Rockingham County extended the range of the species 85.4 km downriver in the Dan River to near the Virginia-North Carolina border (NCWRC 2020b; M. Perkins, NCWRC, email to J. Stanhope, Service, November 13, 2020). One live JSM was observed at each of three sites and one JSM shell at one site, suggesting very low density and patchy distribution of JSM in the lower portion of the Dan River in North Carolina. NCWRC biologists also observed three JSM less than five years old during the surveys in Stokes County, NC, which suggests some recruitment in the last five years. Based on catch per unit effort and occupancy area from 2016-2020 in the Dan River within an approximately 35-km reach in Stokes County, “NCWRC biologists have estimated a total number of extant individuals in NC at approximately $n=200$ and a decline of approximately 70% from the period of 2001-2017 (NCWRC unpublished data)” (M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021 and January 7, 2022). On

the Dan River, primary threats to the JSM and its habitat are hydrologic disturbances from hydroelectric dam operations (e.g., peak releases to generate energy) and natural flood events (e.g., in 2004, 2018, 2019) (M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021) (see section 2.3.2.1 and 2.3.2.5 for additional information about these threats).

Petty (2005) surveyed the Dan River in Patrick County, VA, at 11 sites in 2003-2004 (2 of these sites were also surveyed in 2002) and found no JSM but did observe other native freshwater mussels at six sites (e.g., eastern elliptio and notched rainbow). Petty and Neves (2007) surveyed one additional site in the Dan River and observed no JSM but did observe other native freshwater mussels. In 2014, four of the six sites with native freshwater mussels were resurveyed by Chazal (2014), and no JSM were observed, but other species of native freshwater mussels were observed.

In summary, the JSM population in the Dan River appears to have moderate, but declining abundance and some recruitment.

Big Creek (Stokes County, NC) – Big Creek, a tributary to the Dan River, is a new occurrence river for JSM. One JSM shell (“2 valves in good condition”) was found in 2012, and live notched rainbows within a 1- to 2-km reach (NCWRC 2020b; M. Perkins, NCWRC, email to J. Stanhope, Service, January 7, 2022). High sedimentation and “flashy” flows are observed upstream of this reach. Additional surveys over a 1-km reach were conducted in 2016 and 2019, and no JSM were found. JSM is possibly extirpated in this creek with no live individuals found but is not confirmed due to limited survey effort throughout Big Creek.

Mill Creek (Stokes County, NC) – Mill Creek, a tributary to Town Fork Creek (tributary to the Dan River), is a new occurrence river for JSM (NCWRC 2020b). One JSM was found in 2017, and the site was resurveyed in 2018 and 2019 (survey effort and distance varied each year), with the same individual found in 2018 only, but hundreds of eastern elliptio have been observed (M. Perkins, NCWRC, email to J. Stanhope, Service, January 7, 2022). There is a large earthen dam upstream of the JSM occurrence, possibly providing instream stability, similar to small dams in Little Oregon Creek and near other JSM populations. Upstream of the dam in Mill Creek has not been surveyed. In 2021, 30 propagated juvenile JSM (broodstock from the Dan River) were released to Mill Creek (M. Perkins, NCWRC, email to J. Stanhope, Service, March 15, 2022); these JSM are not included in the assessment of approximate abundance because we do not know if they have survived and successfully established. Town Fork Creek was last surveyed in 2015, and no JSM detected, but there are few native freshwater mussel records, and the creek is considered to have a low-quality watershed. In summary, the JSM population in Mill Creek appears to have very low abundance and there is insufficient data to evaluate stability and recruitment.

South Fork Mayo River (Patrick and Henry Counties, VA; Rockingham County, NC) – The South Fork Mayo River, a tributary to the Mayo River, is a new occurrence river for JSM. Petty (2005) discovered JSM in 2002 at 12 sites in both Virginia and North Carolina (approximately 18.9 km total), with 1 to 57 JSM observed at individual sites and 96 JSM total (note: VDWR [2020b] indicates 107 JSM total were observed in the South Fork Mayo River in 2002). Based on the lengths of 98 JSM (range: 16.9-66.8 mm), JSM were estimated to be 0 to 18 years old, with mean age of about five years (mean length 38.1 mm) (age based on Hoves 1990); reproduction was likely occurring with four juveniles (less than 15 mm, not measured) observed (Petty 2005). Additional surveys were conducted further upriver of the JSM sites in 2003-2004 (12 sites), 2006 (3 sites), and 2013 (2 sites) in Patrick County, VA, and no JSM were found but other native freshwater mussels were found (e.g., eastern elliptio and notched rainbow) (Petty 2005, Petty and Neves 2007, Chazal 2014). Petty (2005) observed “a large, extensive falls area (height approximately 1.2 m)” that may serve as a barrier to upstream dispersal of host fish and may be the upstream end of the JSM range in the South Fork Mayo River. Since 2006, additional surveys reconfirmed JSM at two sites in 2012 (three JSM) in Henry County, VA (VDCR-DNH 2021) and one site in 2008 (four JSM) in Rockingham County, NC (NCWRC 2020b). In 2016, only one JSM shell each were detected at two sites in 2016 near the 2008 occurrence (NCWRC 2020b). It is unknown if other JSM sites in Virginia have been resurveyed since 2002. In summary, the JSM population in the South Fork Mayo River appears to have moderate abundance and some recruitment, but there is insufficient data to evaluate stability with limited survey effort throughout occupied areas of the river since the species was discovered in 2002.

Mayo River (Rockingham County, NC) – The South Fork Mayo River, a tributary to the Dan River, is a new occurrence river for JSM. First discovered in 2001, multiple surveys in 2001-2002 found JSM at multiple sites in approximately 21.3 km of the Dan River in Stokes County, NC, with 1 to 11 JSM observed at individual sites and 35 JSM total (NCWRC 2020b). During surveys conducted in 2008-2009, eight JSM were observed at four sites within a 1.3-km reach of the upper Mayo River. NCWRC biologists conducted intensive surveys in 2016 at seven sites in approximately 1.5 km of the Mayo River and found only two older JSM from the same area as the 2008-2009 occurrences, suggesting possible declining abundance in the Mayo River (M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021 and January 7, 2022). Other native freshwater mussels were observed (e.g., eastern elliptio, notched rainbow, and green floater). Three sites were surveyed in 2019-2021, one near a JSM site and two downstream of the known JSM range in the Mayo River, and no JSM were found. NCWRC noted threats of declining habitat and water quality due to sedimentation from agricultural watersheds, in particular from the North Fork Mayo River, and two dams in the lower Mayo River creating barriers to host fish dispersal. In summary, the JSM population in the Mayo River appears to have low abundance and may be declining based on the lack of JSM observed during annual surveys. There is insufficient data to evaluate recruitment.

Lower Dan subbasin (NC; HUC8 03010104)

County Line Creek (Caswell County, NC) – An individual mussel was collected in 1998 in County Line Creek, a tributary to the Dan River, and vouchered with the North Carolina Science Museum (NCWRC 2020b). It was initially identified as Atlantic pigtoe by B. Watson because the foot was pink and not orange, when he worked for NCWRC and collected the specimen, but then other biologists later thought it to be JSM (B. Watson, VDWR, email to J. Stanhope, June 6, 2022). , NCWRC biologists now think “it more closely resembles *F. masoni* [Atlantic pigtoe]” and repeated attempts to conduct DNA analysis have failed (M. Perkins, NCWRC, email to J. Stanhope, Service, January 7, 2022). They also noted the “stream is highly degraded although other rare mussel species including *A. undulata* [triangle floater] and *S. undulatus* [creeper] are still present in small numbers.” Surveys in the waterbody, including in 2018, have not detected JSM or additional unidentified specimens. Due to the unconfirmed individual collected in 1998 and no confirmed JSM found, County Line Creek is not considered a new population.

Summary of abundance, population trends, demographic features, or demographic trend

Since the 1990 recovery plan, many new occurrences of live JSM and shells have been found, increasing the number of waterbodies (rivers, streams, tributaries) currently and likely occupied by JSM (i.e., present and likely present) from 11 to 26 total (136-percent increase) and expanding the current range to the Roanoke River basin in North Carolina (table 4). The new discoveries are due to a greater number of surveys being conducted rather than new populations being established. Mill Creek was considered historical in 1990 and rediscovered in 1996. Based on number of waterbodies (not river miles), approximately 70 percent of all historically occupied waterbodies (26 of 37) are currently or likely occupied by JSM. Although there are newly discovered occupied waterbodies, approximately 30 percent of all historically occupied waterbodies (11 of 37) are presumed or possibly extirpated, which is an increase from 5 to 11 waterbodies from 1990 to 2021 (120-percent increase). JSM is presumed extirpated from four large rivers with historical occurrences in the James River basin (James River, Maury River, Rivanna River, and Calfpasture River) and is possibly extirpated from four other waterbodies, in which the species has not been found since 1990 (Patterson Creek, Catawba Creek, Potts Creek, and Moormans River). For the four waterbodies that are possibly extirpated, survey effort for mussels has been limited and surveys were last conducted 2007 or earlier. In addition, there are three waterbodies in which only shells have been found since the 1990 recovery plan (Totier Creek, Mechunk Creek, and Big Creek), in most cases relict shells, and the species may be extirpated. Additional surveys should be conducted to verify the status of the JSM in these waterbodies.

Table 4. Number of JSM waterbodies by status in 1990, 2008, and 2021 in the James and Roanoke River basins.

| Basin | 1990 | | | 2008 | | | | 2021 | | | | |
|---------------|------------|-----------|-----------|------------|---------------------|-----------|-----------|------------|---------------------|----------------|-----------|-----------|
| | Historical | Present | Total | Historical | Possibly Extirpated | Present | Total | Historical | Possibly Extirpated | Likely Present | Present | Total |
| James River | 5 | 11 | 16 | 4 | 4 | 19 | 27 | 4 | 6 | 2 | 20 | 32 |
| Roanoke River | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 1 | 0 | 4 | 5 |
| Total | 5 | 11 | 16 | 4 | 4 | 22 | 30 | 4 | 7 | 2 | 24 | 37 |

The overarching trend across the range is that JSM usually numbers less than 10 individuals at any site or reach, and often just one individual is found. Of historically occupied waterbodies (37 total), 27.0 percent have very low approximate abundance (1 to 10 individuals), 21.6 percent have low approximate abundance (11 to 100 individuals), and 21.6 percent have moderate and higher approximate abundance (>100 individuals), based on the last 20 years (2002-2021) (table 5). The waterbodies with very low or low approximate abundances usually have low density and patchy distribution over the river or stream. Low density populations may lead to a loss of recruitment because the distance between the mussels is too great for reproduction and may contribute to loss of genetic variability. Rock Island Creek has a low abundance estimate in 2018 because of high flows from hurricanes severely degrading an occupied reach and washing away JSM. The eight waterbodies with the moderate and higher abundance estimates are: South Forks Potts Creek in West Virginia (note: the range [31 to 339 individuals from 2000 to 2021] includes low approximate abundance); Little Oregon Creek, Dicks Creek, Johns Creek, Mill Creek, and Rocky Creek in Virginia; Dan River in North Carolina; and South Fork Mayo River in Virginia and North Carolina.

Table 5. Number of JSM waterbodies by approximate abundance category in 2021 in the James and Roanoke River basins.

| Basin | None | Very low | Low ¹ | Moderate ² | Moderate to High | High | Total |
|---------------|-----------|-----------|------------------|-----------------------|------------------|----------|-----------|
| James River | 10 | 9 | 7 | 1 | 3 | 2 | 32 |
| Roanoke River | 1 | 1 | 1 | 2 | 0 | 0 | 5 |
| Total | 11 | 10 | 8 | 3 | 3 | 2 | 37 |

¹ Includes Cowpasture River with low to moderate approximate abundance because site was recently augmented with propagated JSM

² Includes South Forks Potts Creek with low to high approximate abundance.

Based on multiple years of monitoring over at least a 10-year time period, the species is reproducing and considered stable (with large variations in number of individuals) or increasing in four waterbodies in the James River basin (South Fork Potts Creek, Dicks Creek, Johns Creek, and Mill Creek) (table 6). Rocky Creek also has a JSM population that is reproducing and considered stable, but monitoring has not been conducted for the 10-year period. The Mill Creek population has doubled due to augmentation with propagated juvenile JSM. The abundance in Cowpasture River has significantly increased from 5 to at least 111 individuals due to augmentation with propagated juvenile JSM, but evidence of recruitment has not been observed, and monitoring has not been conducted for the 10-year period. JSM is decreasing or possibly decreasing in four waterbodies: two in the James River basin (Little Oregon Creek, Rock Island Creek) and two in the

Roanoke River basin (Dan River, Mayo River). For most of the waterbodies described above, JSM is predominately found in single, small reaches, ranging from 0.1 to 1.4 km in length (appendix B), making them susceptible to an adverse event that could eliminate the high density reaches of JSM within a waterbody. The high density reaches in Little Oregon Creek, Dicks Creek, and Johns Creek are located within a 1-km radius circle (i.e., less than 2 km apart) and are connected (i.e., Little Oregon Creek drains to Dicks Creek), making them more susceptible to a wide-scale adverse event, such as hurricane or drought. However, a single adverse event, such as an oil spill or dam breach, may only affect up to two of these waterbodies because only Little Oregon Creek drains to Dicks Creek and the high JSM abundance stream reach in Johns Creek is upstream of the confluence with Dicks Creek (i.e., Dicks Creek drains into Johns Creek downstream of the reach with high JSM abundance). More than half of the waterbodies with JSM present (13 of 24) have an unknown population trend due to the lack of sufficient monitoring data.

Table 6. Summary of approximate abundance, recruitment, population trend, and if based on 10 years of monitoring for JSM waterbodies that are present in 2021 (see table 1 and appendix B). Bolded waterbodies have evidence of recruitment and stable or increasing population trend based on 10 years of monitoring. Gray-shaded rows have decreasing population trend. Unknown = insufficient monitoring data to qualitatively assess the population trend.

| Basin/ Sub-basin (HUC8) | Waterbody | Area/ Subpopulation ¹ | Approximate Abundance | Evidence of Recruitment | 2021 Trend (unknown, increasing, stable, decreasing) | Based on 10 Years of Monitoring ² | |
|--------------------------|--------------------------------|----------------------------------|-------------------------|-------------------------|---|--|------------------------|
| James River basin | | | | | | | |
| Upper James | South Fork Potts Creek | | Low to high | Yes | Stable, large variation | Yes | |
| | Cowpasture River | | Low to moderate | No | Increasing due to augmentation with propagated juveniles; wild population unknown | No | |
| | Little Oregon Creek | | High | Yes | Decreasing, large variation and possible recovery | Yes | |
| | Dicks Creek | | Moderate to high | Yes | Stable, large variation | Yes³ | |
| | Johns Creek | Near Maggie | | High | Yes | Stable, large variation | Yes³ |
| | | Along Sevenmile Mountain | | Low | No | Unknown | No |
| | Craig Creek | Craig Creek near Silent Dell | Low | No | Decreasing | Yes ³ | |
| Maury | Mill Creek | | Moderate to high | Yes | Increasing due to augmentation with propagated juveniles; wild population is stable, large variation | Yes | |
| Middle James- Buffalo | Pedlar River | | Low | Yes | Unknown | No | |
| | Hardware River | | Very low | No | Unknown | No | |
| | Rock Island Creek | | Low | Yes | Decreasing | No ⁴ | |
| | Tye River | | Low | No | Unknown | No | |
| Rivanna | Mechums River | | Very low | No | Unknown | No | |
| | Wards Creek | | Low | Yes | Unknown | No | |
| | Rocky Creek | | Moderate to high | Yes | Stable, large variation | No ⁴ | |
| | Buck Mountain Creek | | Very low | No | Unknown | No | |
| | Piney Creek | | Very low | No | Unknown | No | |
| | Ivy Creek | | Very low | No | Unknown | No | |
| | NF Rivanna River | | Very low | Yes | Unknown | No | |
| | Swift Run | | Low | Yes | Not clear because of large variation and low detection rates | Yes | |
| | Unnamed tributary to Swift Run | | Very low | No | Unknown | No | |

| Basin/ Sub-basin (HUC8) | Waterbody | Area/ Subpopulation ¹ | Approximate Abundance | Evidence of Recruitment | 2021 Trend (unknown, increasing, stable, decreasing) | Based on 10 Years of Monitoring ² |
|----------------------------|-----------------------|----------------------------------|-----------------------|-------------------------|--|--|
| Roanoke River basin | | | | | | |
| Upper Dan | Dan River | | Moderate | Yes | Possibly decreasing | Yes |
| | Mill Creek (NC) | | Very low | No | Unknown | No |
| | South Fork Mayo River | | Moderate | Yes | Unknown | No |
| | Mayo River | | Low | No | Possibly decreasing | Yes ⁵ |

¹ From 1990 recovery plan, Table 1, Historic and Present occurrences of the James spiny mussel in 1990.

² Monitoring data collected over a 10-year time period, but frequency of surveys varies - annually at some waterbodies and every four to seven years at other waterbodies.

³ There is at least 10 years of available monitoring data, but only 7 to 9 years of data analyzed from mark-recapture studies for abundance estimates.

⁴ Nine years of available data (2011-2019).

⁵ At low frequency (e.g., 7 to 8 years apart over 15 years).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation:

Population structure

Petty (2005) conducted a genetic analysis of four JSM populations (Dan River, South Fork Mayo River, Wards Creek, and South Fork Potts Creek), based on phenotypic variation and sequencing of mitochondrial (357 bp of cytochrome-b [CYT-B], 916 bp of ND-1) and nuclear (502 bp of internal transcribed spacer-1 [ITS-1]) DNA; the following is a summary of key findings: (1) Based on morphological, anatomical reproductive similarities, similar fish host specificity, and many shared mitochondrial and nuclear DNA genetic sequences, the JSM is the same species throughout its range in the Dan River subbasin of the Roanoke River basin and James River basin; (2) at this time the Dan River subbasin of the Roanoke River basin and James River basin populations should be managed as separate management units because they are subject to reduced gene flow with no potential for exchange, and evidence of genetic distinctiveness of several haplotype frequencies; (3) genetic haplotype frequency data indicate no reason to restrict reciprocal exchanges of JSM from the Dan and South Fork Mayo Rivers in the Roanoke drainage; (4) Ward's Creek JSM appears to be isolating and evidences a loss of genetic diversity (smallest number of haplotypes); and (5) analysis of allele frequency at microsatellite loci is recommended before reciprocal exchanges among the South Fork Mayo, Dan, and South Fork Potts populations is recommended.

Virginia Commonwealth University researchers, Dr. Rodney Dyer and Bonnie Roderique, conducted a spatial analysis of genetic structure of JSM based on 5 microsatellite loci/primers of nuclear DNA from 12 and 2 waterbodies, respectively, in the James River and Roanoke River basins (Dyer 2019). Their findings indicate: (1) within population estimates of inbreeding are generally high, suggesting populations are likely isolated and have had small breeding populations for sustained periods of time; (2) genetic differences among populations in the James River basin are likely due to dams, habitat fragmentations, and smaller population size; (3) Dicks Creek, Johns Creek, and Little Oregon Creek are the most genetically similar, based on structure analysis; and (4) the James River and Roanoke River sites were not fully genetically distinct. Due to small sample size at four sites (\leq eight individuals; Tye River,

Pedlar River, Craig Creek, and Wards Creek), drawing conclusions on their genetic structure will be difficult and limited. Further analysis of the data is required to make additional conclusions on genetic diversity and structure of the populations.

As part of ongoing population genetics work, Dr. Jamie Roberts (Georgia Southern University), Scott Meyer, and other collaborators have successfully developed ~4,900 single-nucleotide-polymorphism (SNP) markers to assess fine-scale trends in genetic diversity (M. Perkins, NCWRC, email to J. Stanhope, Service, November 13, 2020; Meyer 2021). SNP markers are nuclear-based and provide more contemporary information regarding population structure, while mitochondrial-based markers provide historical structure. A total of 34 JSM in the Roanoke River basin (Dan River, NC [Dan River n=28, Mill Creek n=1]; South Fork Mayo River, VA n=5) and 5 JSM in the James River basin (South Fork Potts Creek, WV) were genotyped in this study. “Their findings suggest that at the population-scale, the Dan and [South Fork] Mayo populations exhibit relatively high differentiation, possibly as a result of small effective population size (estimates are not finalized) and genetic drift i.e., limited recent gene flow. Heterozygosity is higher in the Dan River population when compared to the [South Fork] Mayo and is not an effect of sample size.” (M. Perkins, NCWRC, email to J. Stanhope, Service, November 13, 2020, and March 2, 2021). The genetic differentiation between the Dan and South Fork Mayo populations may be due to long-term evolutionary isolation or two large dams between the two waterbodies on the Mayo River, NC: the Mayo Dam and the Avalon Dam, built in 1898 and 1900, respectively (Meyer 2021). Additional research on potential outbreeding depression is recommended before mixing these populations. Not surprisingly, the Dan and South Fork Mayo populations were also highly differentiated from the South Fork Potts population. Additional JSM from the James River basin have been collected for continued population genetics work.

Species delineation

In examining the three only known Atlantic Slope freshwater mussel species with spines, Perkins et al. (2017) conducted a genetic analysis, sequencing of mitochondrial (Cytochrome oxidase-1 [CO-1] and ND-1) and nuclear [ITS-1] DNA, of four JSM populations (same rivers as Petty [2005]), two Tar River spiny mussel (TRS) populations (*Elliptio steinstansana*), and one Altamaha spiny mussel population (*Elliptio spinosa*), and the following is a summary of key findings: (1) all three spiny mussel species do not form a monophyletic group; (2) JSM and TRS are sister species and form a monophyletic clade; and (3) this clade with JSM and TRS is genetically distinct from both *Elliptio* and *Pleurobema*, thus merits a new unique genus, named *Parvaspina*, which includes both JSM (*Parvaspina collina*) and TRS (*Parvaspina steinstansana*).

In examining the mitochondrial DNA CO-1 sequences from 110 recognized species in the Pleurobemini tribe to understand phylogenetic relationships, Inoue et al. (2018) found that yellow lance “formed a distinct cluster sister to [JSM]”

and thus are closely related; however, these results do not change species delineations for JSM. Lohmeyer's (2020) analysis using both mitochondrial (CO-1 and ND-1) and nuclear (ITS-1 and 28S) DNA sequences supported this conclusion.

Summary of genetics, genetic variation, or trends in genetic variation

Results of genetic studies conducted thus far suggest that the JSM is the same species throughout its range in the Dan River subbasin of the Roanoke River basin and James River basin, but the species should be managed as separate units. Although initial genetic analyses suggested that JSM from the Dan River and South Fork Mayo River in the Roanoke River basin may be exchanged, new genetic analyses suggest that they are relatively highly differentiated. Additional research on potential outbreeding depression is recommended before mixing these populations. Initial analysis indicates there are also some genetic differences among populations in the James River basin, and inbreeding is generally high across all populations in both basins; further analysis of the data is required to make additional conclusions on genetic diversity and structure of the populations. JSM is a distinct species from other freshwater mussels with spines and other freshwater mussels in the Pleurobemini tribe and forms a new monophyletic clade with the TRS in a new genus named *Parvaspina*.

2.3.1.4 Taxonomic classification or changes in nomenclature:

Perkins et al. (2017), as described above in section 2.3.1.3, concluded that JSM and TRS formed their own clade based on genetic analysis and described a new genus, *Parvaspina*, in the tribe Pleurobemini. Williams et al. (2017) provided a revised list of freshwater mussels in the United States and Canada and updated the taxonomy and nomenclature of many mussels, including the change of genus name for JSM from *Pluerobema* to *Parvaspina*. Therefore, the commonly accepted scientific name for JSM is *Parvaspina collina*. On February 17, 2022, the Service formalized the taxonomic change in the Federal Register (87 FR 8960-8967).

2.3.1.5 Spatial distribution, trends in spatial distribution, or historic range:

The species has a wider spatial distribution than previously known, extending to the Upper Dan subbasin the Roanoke River basin (NC, VA) and adding additional waterbodies and HUC12 subwatersheds in the Upper James, Middle James-Buffalo, and Rivanna subbasins (VA) (figure 3). Therefore, JSM's historical and current range is in the James River basin in Virginia and West Virginia and the Roanoke River basin in Virginia and North Carolina. Notable range extensions due to increased survey effort include an about 140-km reach in the Dan River (NC), 21-km reach in the Mayo River (NC), 19-km reach in the South Fork Mayo River (VA, NC), 50-km reach in the Cowpasture River (VA), 9.1-km reach in Swift Run (VA), and 5.2-km reach in North Fork Rivanna River (VA) (see appendix B for estimated river length of all live JSM in last 20 years [2002-

2021]). Although there is an increased spatial distribution of the species, JSM generally occurs in relatively low density and abundance (< 10 individuals) at many sites across the range. JSM lost redundancy in the James River basin in the eastern and some central portions of the range prior to 1990 (14 HUC12s with “Historical” status) and continued to lose redundancy since 1990, mostly in the western portion of the range with 11 HUC12s with “Possibly Extirpated” status total across the range (figure 3). However, the species increased redundancy overall, predominantly in the northern and southern parts of the range, with 32 currently or likely occupied HUC12 total, of which 23 discovered since 1990 due to increased survey effort.

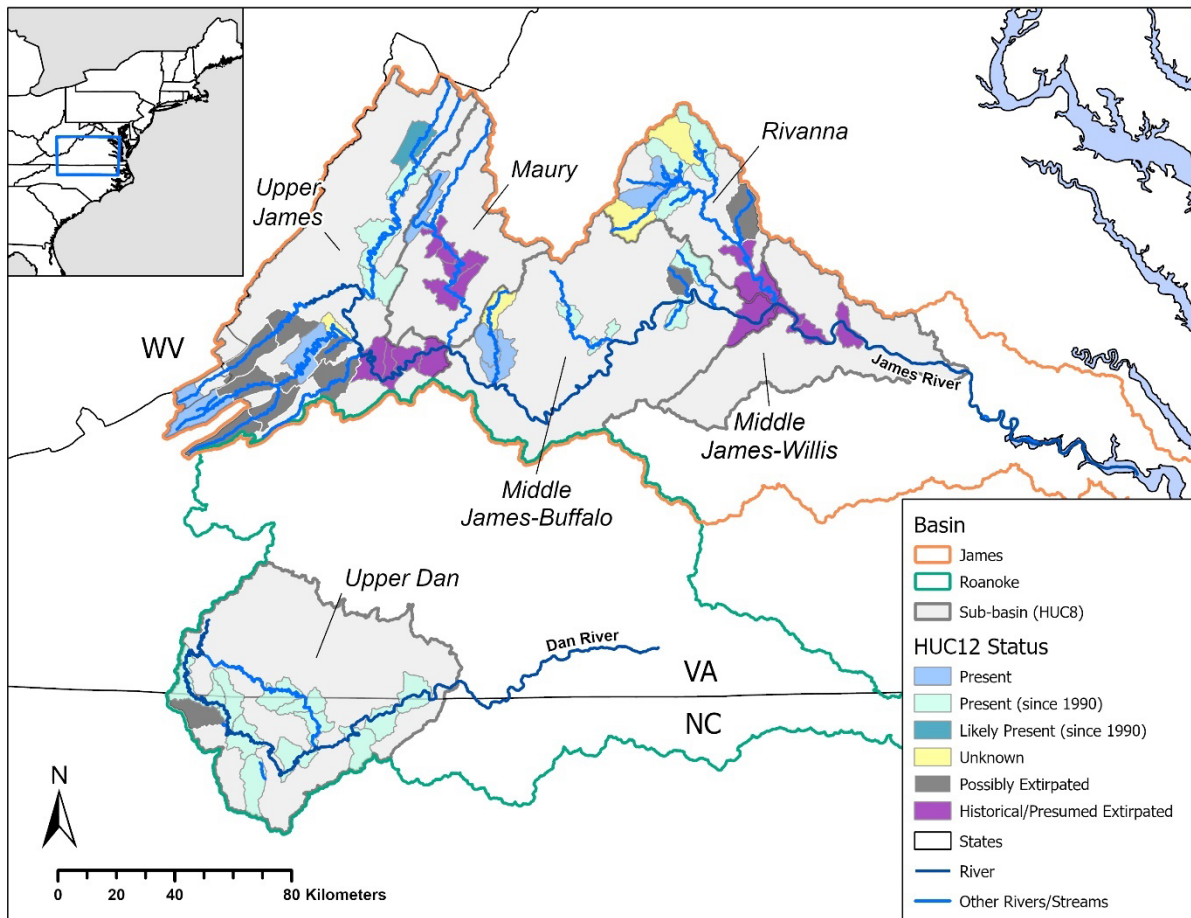


Figure 3. Historical and current range of JSM as shown by basin, subbasin, and HUC12 subwatersheds with documented occurrences. Subbasins are labeled. HUC12s with JSM occurrences since 2007 have “Present” status, and if they were discovered since the 1990 recovery plan, have “Present (since 1990)” status. “Likely Present” = last JSM occurrence was 2002-2006 (approximately 15 to 20 years ago). “Unknown” = most known JSM sites within the HUC12 have not been surveyed in more than 20 years and limited survey effort overall in this river. “Possibly extirpated” = last live JSM observed 30 to 50 years ago or only shell observed, but limited survey effort recently and/or throughout waterbody. “Historical/presumed extirpated” = last live JSM observed more than 50 years ago; categorized as historical occurrence in the 1990 recovery plan (Service 1990).

The range limits for JSM are generally well defined, but additional surveys in the James and Roanoke River basins may find new waterbodies or rediscover JSM in presumed or possibly extirpated waterbodies. Petty (2005) and Petty and Neves (2007) surveyed both qualitatively and quantitatively in the Roanoke River basin and did not detect live JSM or shells in the Dan, Smith, and Banister Rivers in Virginia and upstream of an extensive falls area in the South Fork Mayo River. They concluded that “sufficient effort (~ 6 person-hours per site) was expended to state with ~95 percent confidence that the James spiny mussel does not occur in the 48 km of stream reaches sampled in this drainage (Petty 2005).” With new information since these surveys indicating low and variable detection rates of JSM, especially in the fall season (e.g., when Petty and Neves [2007] conducted their surveys in 2006), the probability of detection or confidence percentage is likely lower, and additional surveys are recommended to better define the range limits for JSM in the Roanoke River basin. For some of the larger rivers in the James River basin, such as the Maury, Rivanna, and James Rivers, surveys are minimal and may be difficult to conduct due to its size, depth, and/or topography, and JSM may be rediscovered where there is suitable mussel habitat. For example, Chazal et al. (2012) noted that “[w]hile Ostby and Angermeier (2009) did not find any mussels in the James River in Botetourt County, we know good numbers of mussels exist at the boat ramp in Lynchburg which is at least 40 river miles upstream of Warren. The reach from Warren to Botetourt County should be surveyed since minimal past surveys have been conducted.”

To better understand the distribution of JSM occurrences by its status, table 7 provides a summary of HUC12s and waterbodies/subpopulations by basin and subbasin (HUC8) and their status and approximate abundance in 2021. Because some waterbodies cross multiple subbasins, such as the James River, subpopulations as defined in the 1990 recovery plan were counted in place of waterbody. Within the James River basin, JSM is extant in 80 percent of its subbasins (four of five) and occupies only 42 percent of the historically occupied HUC12s; the Middle James-Willis subbasin remains unoccupied with all HUC12s “Historical/Presumed Extirpated” (table 7 and figure 3). For the Maury subbasin, JSM occupies only 20 percent of the historically occupied HUC12s. Within the Roanoke River basin, with one subbasin, JSM is extant and occupies 92 percent of the historically occupied HUC12s. Across the range, JSM occupies 52 percent (32 of 61) of the historically occupied HUC12s, and its status is unknown in 7 percent of the historically occupied HUC12s due to limited of survey effort.

Table 7. Summary of HUC12s and waterbodies/subpopulations by basin and subbasin (HUC8) and their status and approximate abundance in 2021. See section 2.2.1.2 for definitions of status and approximate abundance category. Gray shaded row is historical/presumed extirpated subbasin.

| Basin/Sub-basin (HUC8) | Number of HUC12s with JSM Occurrences in 2021 by Status | | | | Number of Waterbodies/Subpopulations ¹ by Approximate Abundance in 2021 | | | | | | | |
|----------------------------|---|----------|-------------------------|-----------|--|-------------------|----------|------------------|-----------------------|------------------|----------|-----------|
| | Historical/Presumed or Possibly Extirpated | Unknown | Likely Present/ Present | Total | Unknown | None ² | Very low | Low ³ | Moderate ⁴ | Moderate to high | High | Total |
| James River basin | | | | | | | | | | | | |
| Upper James | 12 | 1 | 7 | 20 | 1 | 7 | 0 | 3 | 1 | 1 | 2 | 15 |
| Maury | 4 | 0 | 1 | 5 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 3 |
| Middle James- Buffalo | 2 | 1 | 6 | 9 | 0 | 2 | 1 | 3 | 0 | 0 | 0 | 6 |
| Middle James-Willis | 3 | 0 | 0 | 3 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| Rivanna | 3 | 2 | 6 | 11 | 0 | 3 | 7 | 2 | 0 | 1 | 0 | 13 |
| Total | 24 | 4 | 20 | 48 | 1 | 19 | 8 | 8 | 1 | 3 | 2 | 42 |
| Roanoke River basin | | | | | | | | | | | | |
| Upper Dan | 1 | 0 | 12 | 13 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 5 |
| Total - All | 25 | 4 | 32 | 61 | 1 | 20 | 9 | 9 | 3 | 3 | 2 | 47 |

¹ Waterbodies and subpopulations/areas from 1990 recovery plan, Table 1, Historic and Present occurrences of the James spiny mussel in 1990.

² Waterbodies/subpopulations that are historical/presumed extirpated or possibly extirpated.

³ Includes Cowpasture River with low to moderate approximate abundance.

⁴ Includes South Forks Potts Creek with low to high approximate abundance.

Figure 4 provides approximate abundance by waterbody/subpopulation within HUC12s occupied by JSM. When examining the distribution of waterbodies/subpopulations by approximate abundance in 2021 in the James River basin (table 7), the Upper James subbasin has the most waterbodies/subpopulations with moderate or greater approximate abundance, which are concentrated in the southwestern portion of the subbasin (four total; 26.7 percent of historically occupied waterbodies/subpopulations in the subbasin) (figure 4). The Maury and Rivanna subbasins have only one waterbody/subpopulation each with moderate approximate abundance (33.3 percent and 7.7 percent of historically occupied waterbodies/subpopulations, respectively in their subbasin). The Middle James- Buffalo subbasin has only waterbodies with low (50.0 percent), very low (16.7 percent), and none (33.3 percent) approximate abundance. The Roanoke River basin’s only subbasin, the Upper Dan, has two waterbodies with moderate approximate abundance (40.0 percent of historically occupied waterbodies in the subbasin; note: there are no subpopulations designated in the Roanoke River basin). The waterbodies/subpopulations with moderate or greater approximate abundance are widely distributed throughout JSM’s range (Figure 4).

In terms of distribution of JSM across physiographic province, historical and present HUC12 subwatersheds occur in the Valley and Ridge, Blue Ridge, and Piedmont (figure 5). Upper portions of the HUC12s in the Rivanna subbasin and the HUC12 containing the Tye River in the Middle James- Buffalo subbasin cross into the Blue Ridge; however, JSM occurrences in those HUC12s occur only in the Piedmont; therefore, these HUC12s are considered to occur in the Piedmont.

Within the Valley and Ridge, JSM currently occupies 33.3 percent of the historically occupied HUC12s (8 of 24; includes HUC12s with “Likely Present” status and does not include “Unknown” status). Within the Blue Ridge, JSM occupies 50 percent of the historically occupied HUC12s (2 of 4). Within the Piedmont, JSM occupies 66.7 percent of the historically occupied HUC12s (22 of 33).

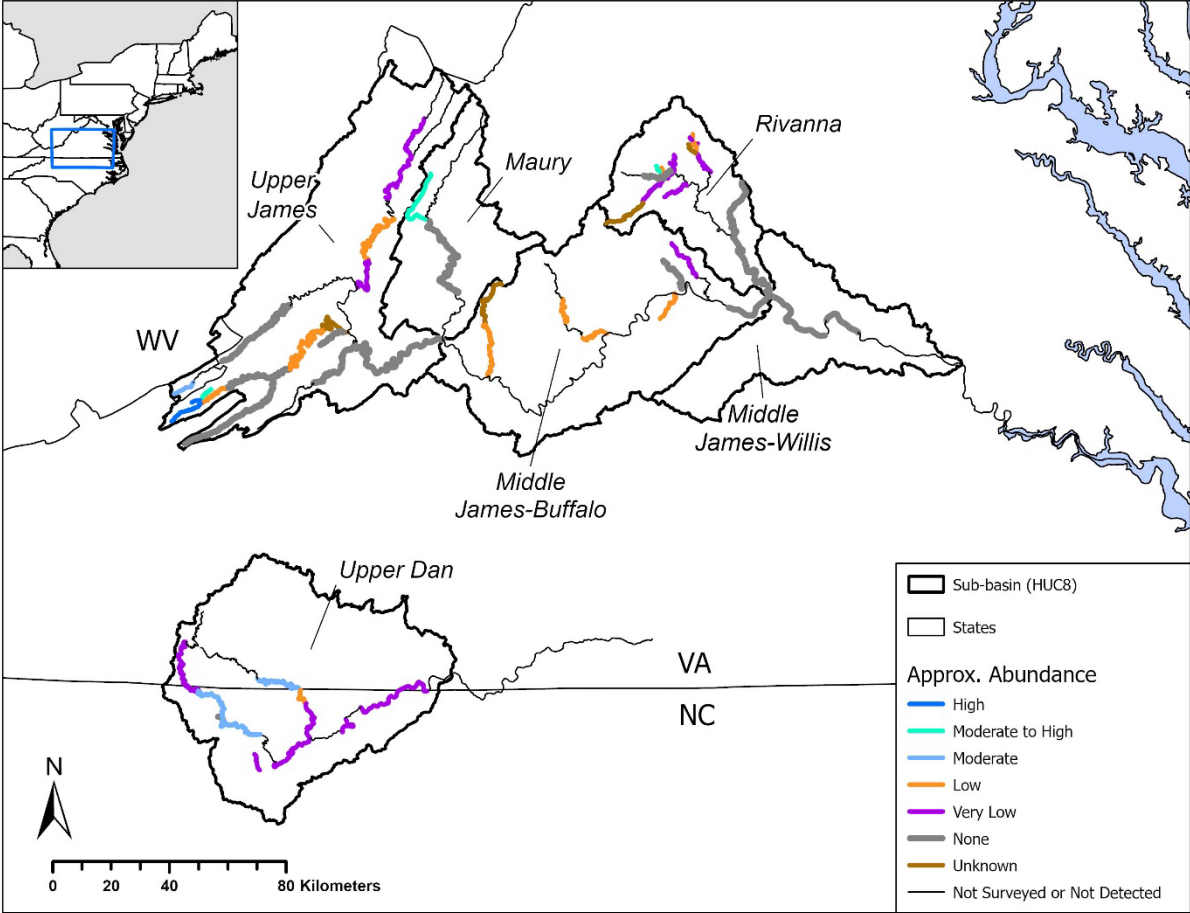


Figure 4. Approximate abundance for JSM waterbodies/subpopulations within HUC12 subwatersheds identified in figures 3 and 5. Note that the stream reaches shown should not be used to determine total stream length occupied by JSM (e.g., may be shorter), but provides a maximum approximation. Subbasins are labeled. See section 2.3.1.2 for definitions of approximate abundance category. One stream reach of Cowpasture River is categorized as low because it was recently augmented with propagated juvenile JSM and South Fork Potts Creek is categorized as moderate because it has low to high approximate abundance.

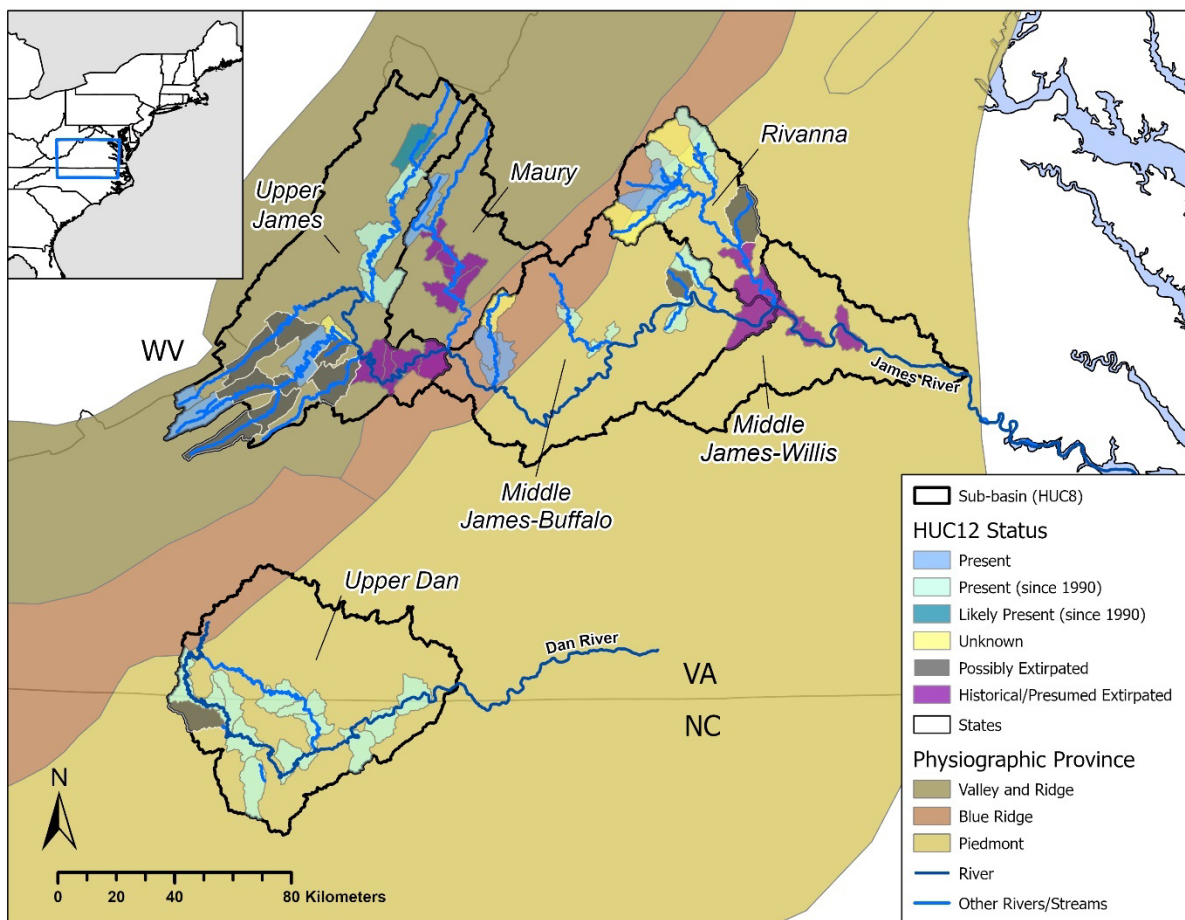


Figure 5. Historical and current range of JSM by physiographic province. Subbasins are labeled. See figure 3 caption for description of HUC12 status.

Summary of spatial distribution, trends in spatial distribution, or historic range

The species has a wider spatial distribution than previously known, extending to the Upper Dan subbasin the Roanoke River basin (NC, VA) and adding additional waterbodies and HUC12 subwatersheds in the Upper James, Middle James-Buffalo, and Rivanna subbasins (VA). Therefore, JSM’s historical and current range is in the James River basin in Virginia and West Virginia and the Roanoke River basin in Virginia and North Carolina. Although there is an increased spatial distribution of the species, JSM generally occurs in relatively low density and abundance (< 10 individuals) at many sites across the range and has lost redundancy in some portions of the range, both prior to and since 1990, with 14 HUC12s with “Historical” status and 11 HUC12s with “Possibly Extirpated” status across the range. However, the species has increased redundancy overall, predominantly in the northern and southern parts of the range, with 32 currently or likely occupied HUC12s total, of which 23 were discovered since 1990 due to increased survey effort.

Across the range, JSM occupies 52 percent (32 of 61) of the historically occupied HUC12s. Within the James River basin, JSM is extant in 80 percent of its subbasins (4 of 5) and occupies only 42 percent of the historically occupied HUC12s; the Middle James-Willis subbasin remains unoccupied with all HUC12s “Historical/Presumed Extirpated.” For the Maury subbasin, JSM occupies only 20 percent of the historically occupied HUC12s. Within the Roanoke River basin, with one subbasin, JSM is extant and occupies 92 percent of the historically occupied HUC12s. When examining the distribution of waterbodies/subpopulations by approximate abundance in 2021, the Upper James subbasin has the most waterbodies/subpopulations with moderate or greater approximate abundance, which are all concentrated in the southwestern portion of the subbasin (four total; 26.7 percent of historically occupied waterbodies/subpopulations in the subbasin). The Maury and Rivanna subbasins have only one waterbody/subpopulation each with moderate approximate abundance (33.3 percent and 7.7 percent of historically occupied waterbodies/subpopulations, respectively in their subbasin). The Middle James-Buffalo subbasin has only waterbodies with low (50.0 percent), very low (16.7 percent), and none (33.3 percent) approximate abundance. The Roanoke River basin’s only subbasin, the Upper Dan, has two waterbodies with moderate approximate abundance (40.0 percent of historically occupied waterbodies in the subbasin). The waterbodies/subpopulations with moderate or greater approximate abundance are widely distributed throughout JSM’s range. In terms of distribution across physiographic provinces, JSM currently occupies 33.3 percent, 75.0 percent, and 66.7 percent of the historically occupied HUC12s in the Valley and Ridge, Blue Ridge, and Piedmont, respectively.

2.3.1.6 Habitat or ecosystem conditions:

The habitat requirements for JSM described in the 1990 recovery plan and Hove (1990) appear relatively unchanged since then. It was indicated that JSM occupies streams varying from 1.5-m to 23-m wide and 0.15-m to 2-m deep. Historically, JSM occurred in the James River, which was much wider (up to 155 m) and deeper. With the discovery of the JSM in the Roanoke River basin (e.g., Dan, Mayo, and South Fork Mayo Rivers), JSM currently occupies rivers with greater widths (e.g., up to 80 m, based on aerial image of site) than observed before 1990. The species is found in a range of substrates, including sand, gravel, and cobble with or without boulders, pebbles, or silt (Service 1990, Hove 1990). The water velocity at sites supporting this species is slow to moderate, in pools to riffles/runs. Petty (2005) also observed JSM in a range of habitat types in the South Fork Mayo River, including “shallow riffle, run, slack or low-velocity areas and pool (50 to 70 percent < 61 cm depth) with abundant sand/gravel bars present in the riffle, run, and slack stream segments.”

Ostby and Angermeier (2012) visually assessed the biological and physical habitat qualities of reaches occupied and unoccupied by JSM and other native mussels in the upper Rivanna subbasin and found no significant differences in the

quality metrics, including those based on scores from the U.S. Environmental Protection Agency's "Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers" (EPA RAPID). The overall pattern was that the habitat increased in quality (i.e., greater EPA RAPID scores) moving upstream from the mouth of each creek. "[They] often found JSM in habitats considered poor quality and rarely found mussels in habitats considered high quality in that basin. Further testing that observation using the same dataset, Lane (2012) found little support that visually assessed habitat metrics were associated with [JSM] detection or occupancy" (Ostby 2015). The EPA RAPID method appears to not be appropriate for assessing suitable JSM and other native freshwater mussel habitat, particularly in the Rivanna subbasin. Verdream (2020) analyzed freshwater mussel occupancy in Swift Run and Little Oregon Creek and found that maximum water depth was the only significant predictor of occupancy, not water velocity or substrate size, predicting 60 percent of patches in Swift Run and 85 percent of patches in Little Oregon Creek. The highest likelihood of occupancy occurred at 15 cm water depth and decreased with greater water depth and no occupancy occurred at less than 15 cm water depth. In Swift Run, occupied and unoccupied patches had a median water depth of approximately 35 cm and 55 cm, respectively.

Dams are known to reduce connectivity for freshwater mussels and their host fish and reduce suitable habitat. However, some dams or impoundments (e.g., low-head dams, earthen dams, farm ponds) on lower order streams (e.g., in the headwater area) appear to be providing beneficial effects to JSM and its habitat such as in Little Oregon Creek, Dicks Creek, Johns Creek, and Rocky Creek, which are streams with documented higher JSM density and abundance. The dams are potentially providing hydraulic stability, greater food availability, and increased water temperature from the impounded water. JSM downstream of the low-head dam on John Creek are atypically large, up to 92 mm in length, likely related to the increased primary productivity in the impoundment and increased water temperature (TOE 2016; B. Watson, VDWR, email to J. Stanhope, Service, June 6, 2022). The Rocky Creek impoundment is a farm pond, different from the low-head dams on Little Oregon Creek, Dicks Creek, and Johns Creek, and there are concerns about the pond limiting minimum stream flows, especially during droughts (B. Watson, VDWR, email to J. Stanhope, February 18, 2022). Studies on effects of small dams on other mussel species in Alabama, North Carolina, and St. Croix streams have documented beneficial effects immediately downstream of these dams, including higher mussel density and growth rate due to greater geomorphic stability, increased water temperature, and greater food availability (Gangloff et al. 2011, Singer and Gangloff 2011, McCormick 2012, Hornback et al. 2014).

Ostby (2021) compiled a list of streams in the James River basin with small dams and impoundments similar in size to those in Rocky Creek and Little Oregon Creek (e.g., "Rocky Creek was at most 5 m wide flowing out from a 19,000 m² impoundment, and Little Oregon Creek was 5 to 6 m wide flowing out from a

40,000 m² impoundment”). After prioritizing the streams, 20 were surveyed in 2019-2020 (most in the Rivanna subbasin), but no JSM were found.

A species distribution model (SDM) for JSM for the James River basin in Virginia was developed by VDCR-DNH using Random Forest modeling that predicts potential suitable habitat for the species in stream reaches based on occurrence data (VDCR-DNH 2015). The model variables most important to predicting suitable habitat were annual precipitation, baseflow, annual streamflow, drainage area, and percent of forest and shrub landcover in the watershed. This model showed new potential areas for JSM suitable habitat within the James River basin and the Service’s Virginia Field Office previously used the model results to inform ESA Section 7 project reviews. Another SDM for JSM for the James River basin in Virginia was developed by Roderique (2018) using Maximum Entropy modeling, and model variables most important to predicting suitable habitat were associated with landcover and anthropogenic effects. “[JSM] preferred locations with a low percentage of the catchment area classified as agriculture and occurred more often in areas with low to moderate gradients and low levels of forest loss within the watershed. They appear to avoid areas with high levels of colluvial sediment and open water (i.e., less tree cover over waterways)” (Roderique 2018). Host fish distribution was not an important variable. This model also showed new potential areas for JSM suitable habitat and VDWR utilizes the results to help inform recovery actions and some regulatory review. A rangewide SDM was developed by the Service, based on multiple modeling techniques and reviewed by state agencies and Service field offices in Virginia, West Virginia, and North Carolina. Flow rate was found to be the dominant predictor variable for all the models with some landcover variables (e.g., less developed landcover, greater watershed integrity) having importance (Service 2022). The Service is currently using the model results to inform ESA Section 7 project reviews rangewide.

Summary of habitat or ecosystem conditions

The habitat requirements for JSM described in the 1990 recovery plan and Hove (1990) appear relatively unchanged since then. It was indicated that JSM occupies streams varying from 1.5 m to 23 m wide and 0.15 m to 2 m deep, and with the discovery of JSM in the Roanoke River Basin, JSM currently occupies rivers with greater width (e.g., up to 80 m). The species continues to be found in a range of substrates, including sand, gravel, and cobble with or without boulders, pebbles, or silt (Service 1990, Hove 1990). The water velocity at sites supporting this species is slow to moderate, in pools to riffles/runs. An evaluation of biological and physical habitat qualities of reaches occupied and unoccupied by JSM, including EPA RAPID, found no significant differences. The EPA RAPID method appears to not be appropriate for assessing suitable JSM and other native freshwater mussel habitat, particularly in the Rivanna subbasin. Some dams or impoundments (e.g., low-head dams, earthen dams, farm ponds) on lower order streams (e.g., in the headwater area) appear to be providing beneficial effects to JSM and its habitat in Little Oregon Creek, Dicks Creek, Johns Creek, and Rocky

Creek, which are streams with documented higher JSM density and abundance. The dams are potentially providing hydraulic stability, greater food availability, and increased water temperature from the impounded water. Multiple species distributions models for JSM have been developed, with predictor variables related to streamflow and landcover (e.g., less agriculture and developed landcover).

2.3.2 Five-Factor Analysis:

The purpose of a 5-Year Review is to recommend whether a listed taxon continues to warrant protection under the ESA and, if so, whether it should be reclassified (from threatened to endangered or from endangered to threatened). This task requires that the analysis of the threats to the species be performed while assuming that the species is not receiving the regulatory protections, funding, recognition, and other benefits of ESA listing. Summaries of ongoing applications of ESA protections may shed light on some future activities that constitute threats to the species. However, the analysis under Factor D (Inadequacy of Existing Regulatory Mechanisms) focuses on the adequacy of existing alternative (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

2.3.2.1 Factor A. Present or threatened destruction, modification, or curtailment of its habitat or range:

The final listing rule described habitat modification as a major threat to JSM and the cause of its decline (53 FR 27689-27693). Adverse habitat changes were caused by dam construction, industrial pollution, chemical spills, channelization, agricultural runoff (including pesticides and fertilizers), and sewage discharges at multiple locations within the species' historical range in the James River basin. The final listing rule also indicated erosion and siltation from logging operations in the upper Craig Creek watershed and other locations as a threat to habitat. Recent information shows that some of the threats described in the final listing remain ongoing and occur throughout the species' range, in particular dams, industrial pollution, agricultural runoff, sewage discharges, and erosion/siltation (e.g., sedimentation/turbidity), and that they are expected to continue in the future. There are also additional anthropogenic disturbances that are adversely affecting habitat. The ongoing and new threats are described below.

Dams: Many existing dams, except some dams or impoundments (e.g., low-head dams, earthen dams, farm ponds) on lower order streams as described in section 2.3.1.6, continue to be a threat to JSM by (1) restricting movement of host fish and dispersal of JSM, which isolate JSM populations from each other and reduce genetic diversity (Watters 1996); (2) reducing habitat quality and quantity upstream and downstream of the dam; and (3) changing hydrologic flow regime downstream of the dam (Watters 1999). In reviewing existing resources for dams, including the U.S. Army Corps of Engineers' (USACE) National Inventory of Dams (NID) (USACE 2022) and the Southeast Aquatic Resources Partnership (SARP) inventory of aquatic barriers (SARP 2022), there are 40 dams on

waterbodies historically and currently occupied by JSM, with the largest numbers of dams on the Dan River and James River (figure 6). In these inventories, dates were provided for construction of 24 of the dams, which ranged from 1839 to 1975. At least five dams have been removed since 1990, including two on the Dan River and one each on the Maury River, Tye River, and Rivanna River. As noted in section 2.3.1.6, some dams on lower order streams (e.g., in the headwater area) appear to be providing beneficial effects to JSM and its habitat; however, most dams are likely negatively affecting JSM as described above. Fourteen dams are hydroelectric dams regulated by the Federal Energy Regulatory Commission (FERC) (figure 6) (see section 2.3.2.4 regarding existing regulatory mechanisms). Multiple dams located in the middle or near the mouth of waterbodies are likely restricting connectivity and isolating JSM populations, including those in the Tye River, Cowpasture River, Ivy Creek, North Fork Rivanna River, South Fork Mayo River, Mayo River, and Dan River; they may have also contributed to presumed or possible extirpation of JSM in the Maury River, Totier Creek, and James River. Genetic analyses of JSM also indicate genetic isolation and high inbreeding rates in many populations, likely due in part to dams (see section 2.3.1.3).

At the time of listing, JSM was not known in Roanoke River basin, including the Dan River in North Carolina, and the species was not considered during relicensing of the Pinnacles Dam in Virginia in 1991, a facility that generates electricity via peaking, especially during summer months (i.e., generally releasing water at higher rates to generate electricity during high or peak demand). The Service and NCWRC have observed increased turbidity in the Dan River in North Carolina where JSM occur after peak releases have occurred. They are currently assessing the factors contributing to poor observed reproduction in the Dan River and evaluating possible effects of peaking flows on the JSM recruitment and increased and prolonged turbidity. The critical period for successful reproduction and recruitment of JSM is from mid-June through August. The NCWRC and Service have been conducting preliminary studies on effects of peaking operations on JSM and communicating with FERC and owners of Pinnacles Dam about modifying flow regimes prior to the next relicensing in 2031. Hydrological disturbance from dam operations and floods is a primary threat to the JSM and its habitat for the Dan River, along with decline of habitat quality due to sediment input from land use practices (M. Perkins, NCWRC, email to J. Stanhope, Service, March 2, 2021).

While construction of new dams is unlikely a current threat, most dams continue to be a threat by reducing connectivity and habitat quality and quantity.

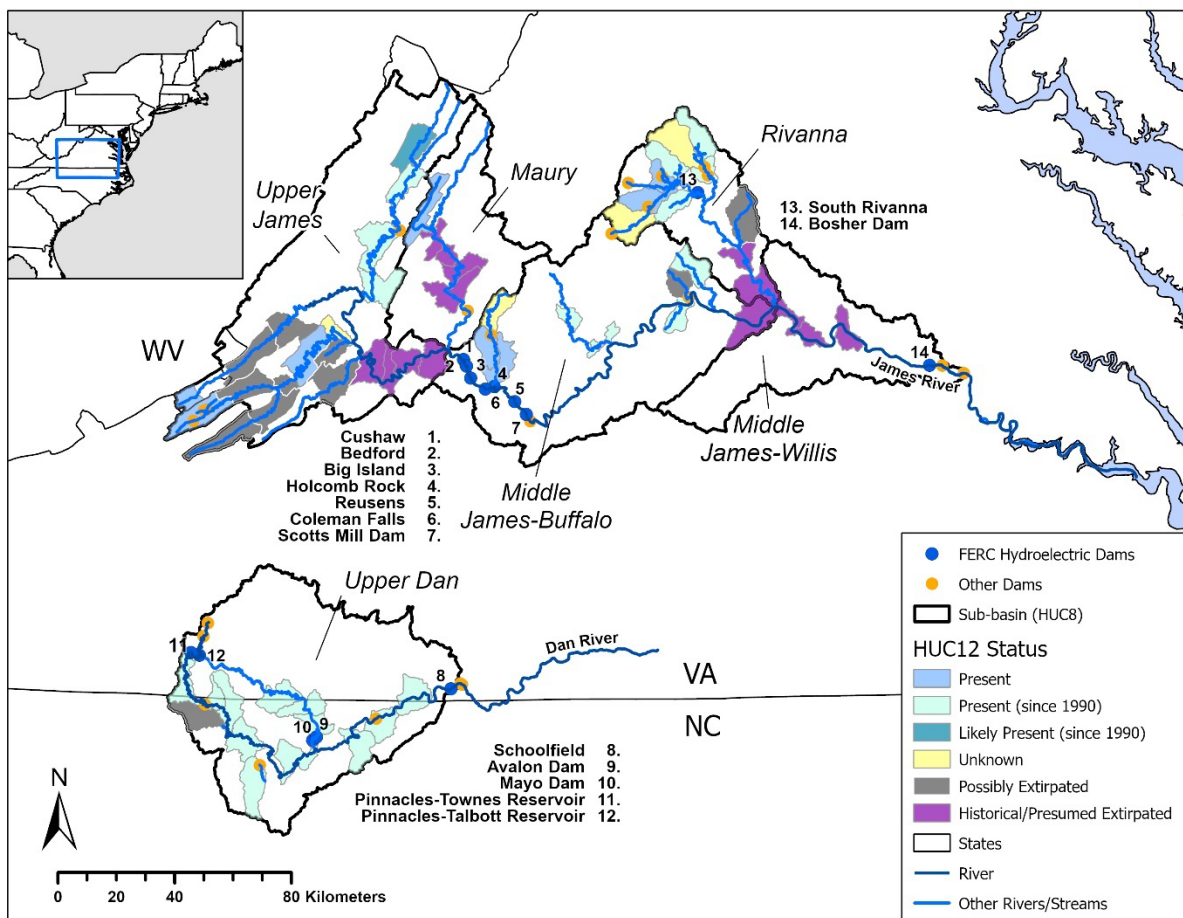


Figure 6. Location of FERC-regulated hydroelectric dams and other dams throughout the historical and current range of JSM. FERC-regulated dams and subbasins are labeled. See figure 4 caption for description of HUC12 status.

Land Use Modification: We use the term “land use modification” to refer to the alteration of the natural landscape, including (but not necessarily limited to) land conversion for development and its associated infrastructure (roads, bridges, utilities), forestry activities, and agriculture. Activities associated with land use modification continue to be a threat to JSM and its habitat, in particular the effects on water quality and direct disturbances to JSM and its instream habitat.

Specific water quality threats include sediment, nutrients, and contaminants (e.g., copper, pesticides, herbicides). Sedimentation/turbidity were noted as threats in the final listing and 1990 recovery plan. Since then, research continues to confirm adverse effects of suspended sediments on freshwater mussels (not specifically tested on JSM), including reduced feeding efficiency and reproductive success (Gascho Landis et al. 2013, Gascho Landis and Stoeckel 2016, Tuttle-Raycraft et al. 2017). Sedimentation/turbidity have also been well documented in adversely affecting fish, and host fish are essential for reproductive success of freshwater mussels (Service 2020). Pesticides were also noted as threats in the final listing. Research since then confirms adverse effects of pesticides (including, fungicides

herbicides, and surfactants) on freshwater mussels (not specifically tested on JSM) including reduced growth and death (Bringoff et al. 2007a, b, c; Jardak et al. 2016).

Nutrients were not specifically mentioned as a threat related to water quality in the final listing or recovery plan except indirectly as “fertilizers,” but they are likely a threat to JSM. New research since 1990 has found that inorganic nitrogen pollution (e.g., ammonia) is harmful to freshwater mussels, in particular during early life stages, through multiple pathways (e.g., direct toxicity, lethal effects) (Augspurger et al. 2003; Wang et al. 2007a, b). Ammonia (NH₃) toxicity in fish and invertebrates may cause asphyxiation, reduction in blood oxygen, disruption of osmoregulatory activities in the liver and kidneys, repression of the immune system, and increased disease susceptibility (Hernandez et al. 2016). Sensitivity to ammonia and other contaminants has not been tested on JSM but has been tested on the TRS and other species (i.e., notched rainbow, yellow lance) that may serve as surrogates for JSM (Augspurger et al. 2014). These three species were found to be sensitive to ammonia and copper during acute toxicity tests (e.g., endpoint of death), thus JSM would likely be sensitive to these contaminants. Copper is a contaminant detected in municipal wastewater effluent.

While water quality has generally improved in the James River basin, with reductions in nitrogen and phosphorus loading primarily due to wastewater treatment plant upgrades and agricultural and forestry best management practices, water quality threats persist (James River Association 2021). These water quality threats include nutrients, sediment, and contaminants (pesticides, herbicides, Kepone, mercury, PCBs) and are caused by agricultural runoff, stormwater runoff from impervious surfaces in developed areas, failing septic tanks, streambank erosion, land disturbances (e.g., construction, development, loss of riparian buffer), and industrial discharges (Virginia Environmental Endowment 2018). Sediment (i.e., sedimentation and turbidity) is listed as the “greatest ongoing pollution problem in the James [River basin] (James River Association 2021). The long-term trend (1985-2020) for suspended sediment load delivered annually from the nontidal portion of the James River to the Chesapeake Bay is rated as “degrading,” which indicates that sediment loads are statistically higher at the end date (Mason et al. 2021).

In the Upper Dan subbasin, turbidity was documented as a water quality issue in the Dan River (three stations) and Mayo River (one station) (North Carolina Department of Environmental Quality [NCDEQ] 2010). At one station in the Dan River (at NC 704 near Francisco), the long-term trend (1980-2010) for ammonia and specific conductance (i.e., may indicate polluted water) was upward. The increasing long-term trend of specific conductance was also observed at the station in Mayo River and another station in the Dan River (at State Route 2150 near Wentworth). The potential causes of the water quality issues in the Upper Dan are “construction sites, mining operations, agricultural operations, logging

operations, and excessive stormwater flow off impervious surfaces” (NCDEQ 2012).

Threats related to water quality have been observed at multiple JSM waterbodies (see appendix B) and are likely greater in watersheds with higher percentages of agriculture and developed land cover (figure 7).

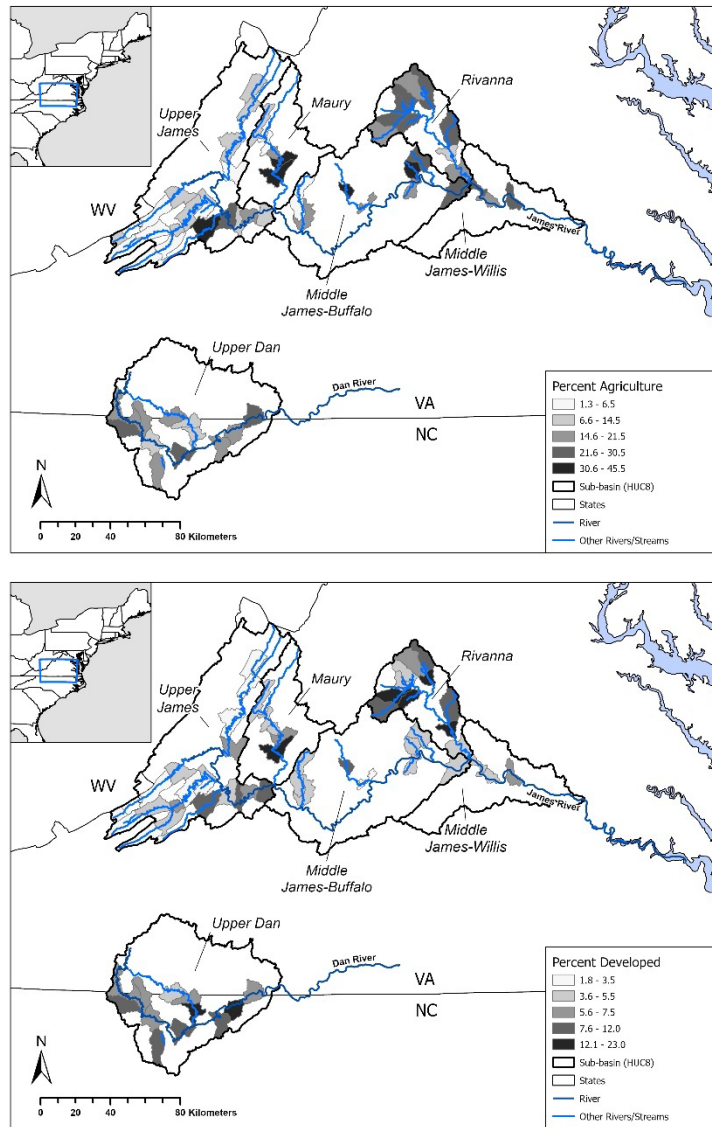


Figure 7. Percent of agriculture (top) and developed (bottom) land cover in the HUC12 subwatersheds based on the 2019 National Land Cover Database (NCLD) (USGS 2021). Percentages of land cover type by HUC12 provided by Doug Newcomb, Service, Raleigh Field Office.

Activities contributing to direct disturbances to JSM and instream habitat include: (1) instream work related to construction and maintenance of roads (culverts, bridges), sewer systems, and electric and gas lines; and (2) livestock accessing JSM waterbodies. Instream work related to bridge and culvert replacements and

pipeline repairs has been documented and is currently planned at multiple JSM waterbodies (e.g., Dan River, Pedlar River, Rocky Creek, and Piney Creek), contributing to crushing/death of JSM not relocated during construction, stress to JSM when relocated out of the construction area, temporary and permanent loss of habitat (e.g., cofferdams, riprap), and increased sedimentation/turbidity (see appendix B). The threat to JSM of livestock accessing streams include crushing mussels and causing streambank erosion. This threat has been observed at South Fork Potts Creek, Craig Creek, Pedlar River, Little Oregon Creek, and possibly Buck Mountain Creek. For South Fork Potts Creek, this threat and sedimentation associated with agriculture are considered the largest threats (K. Eliason, WVDNR, *in* email from A. Silvis, WVDNR, to J. Stanhope, Service, March 8, 2021). WVDNR, the West Virginia Conservation Agency, and the Service have been working with private landowners on South Fork Potts Creek and in 2015 established fencing along the entire length of a property to exclude cattle from the highest JSM abundance stream reach, except for flash grazing (letter from A. Silvis, WVDNR, to J. Stanhope, Service, March 8, 2021). The West Virginia Land Trust also acquired a tract of land on South Fork Potts Creek that has documented JSM, and they plan to conduct habitat restoration in cooperation with the Service, pending funding.

For at least four JSM waterbodies (Rock Island Creek, Craig Creek, North Fork Rivanna River, and Dan River), severe flooding or stormflow events were noted as a threat due to extreme scour and erosion of the streambanks and JSM habitat, fallen trees in the stream blocking flow and accumulating debris, washing JSM out of suitable habitat, and introducing silt and different sized sediment to downstream suitable habitat. Although these flooding events are natural, land use changes, in particular increased development and impervious surface in watersheds, alter flow regimes and contribute to greater frequency and intensity of severe flood events (<https://www.usgs.gov/special-topic/water-science-school/science/impervious-surfaces-and-flooding>; accessed May 5, 2021). Development in the southeastern U.S. is predicted to increase, thus a greater percentage of impervious surface in watersheds and more severe flood events are likely. Terando et al. (2014) projected urban sprawl changes for the next 50 years for the southeastern U.S., and the extent of urbanization in the region is projected to increase 101 to 192 percent. Climate change is also predicted to contribute to greater flooding events (see section 2.3.2.5).

In summary, water quality issues, in particular sedimentation/turbidity and nutrients, are widespread threats to JSM, while instream construction activities and livestock access to streams are localized threats in numerous JSM waterbodies. Severe flooding/stormflow events are also localized but serious threats to JSM and may be increasing with greater development and climate change effects.

2.3.2.2 Factor B. Overutilization for commercial, recreational, scientific, or educational purposes:

At the time of listing there was no specific information available to suggest that

this factor presented a threat to JSM (53 FR 27689-27693). This continues to be accurate. There is no new relevant information regarding overutilization.

2.3.2.3 Factor C. Disease or predation:

At the time of listing there was no specific information available to suggest that this factor presented a threat to JSM (53 FR 27689-27693). There is no new relevant information regarding disease specific to this species. However, there is new information to indicate that predation from raccoons and muskrats (*Ondatra zibethicus*) is a threat to JSM. Predation on JSM has been observed in multiple populations, including Little Oregon Creek, Dicks Creek, Johns Creek, Rocky Creek, and Swift Run. In Little Oregon Creek, at least two years of predation by raccoons has been documented in significantly reducing the JSM population in (see section 2.3.1.2 “Little Oregon Creek” and table 3). At the mark-recapture sites in Johns Creek, surveyors found 250 JSM shells (127 tagged and 123 untagged) with evidence of predation marks (i.e., claws and teeth marks by raccoons) during three survey dates between July 30, 2020, and September 16, 2020 (B. Watson, VDWR, email to J. Stanhope, Service, September 16, 2020). Further surveys and data analysis are needed to determine the effects of the high predation rate on the Johns Creek subpopulation. B. Watson indicated he observed very high density of JSM in May 2020 and hypothesized that this made the mussels easier to find by predators; this pattern of very high density followed by high predation rates occurred in Little Oregon Creek. VDWR has contracted with the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services to proactively trap for raccoons at Little Oregon Creek, Dicks Creek, and Johns Creek.

In summary, predation by raccoons and muskrats is currently a localized but serious threat to JSM.

2.3.2.4 Factor D. Inadequacy of existing regulatory mechanisms:

The final listing rule indicated that Virginia State Law required a scientific collection permit for freshwater mussels, and that JSM was state listed as endangered in Virginia; however, the rule described limited protections provided by this state law and designation because “State laws are difficult to enforce and do not protect the species’ habitat from the potential impacts of federal projects” (53 FR 27689-27693). There is new relevant information regarding existing regulatory mechanisms.

VDWR continues to require permits for collection and surveys of all freshwater mussels (live or shells), including state and federally listed species. Virginia State Law prohibits the taking, transporting, processing, selling, or offering to sale endangered or threatened species without a permit (section 29.1-564; <https://law.lis.virginia.gov/vacodefull/title29.1/chapter5/article6/>, accessed March 31, 2022). Since discovery of JSM, North Carolina has listed the species as endangered. The North Carolina Endangered Species Act (NC ESA) generally prohibits killing, harming, possessing, or trading protected species without a

permit (North Carolina General Statutes section 113-337; <https://law.justia.com/citations.html>, accessed March 31, 2022), and regulates collection and commercial trade of species listed under the statute. The Virginia and North Carolina State Laws do not protect the species' habitat, and the NC ESA does not "limit the rights of a landholder in the management of his lands for agriculture, forestry, development or any other lawful purpose without his consent" (North Carolina General Statutes section 113-332). West Virginia does not have a state endangered species law; however, it is illegal to possess mussels or any parts of them (K. Eliason, WVDNR, *in* email from A. Silvis, WVDNR, to J. Stanhope, Service, March 8, 2021). In addition, the WVDNR implemented a standardized mussel protocol in 2012, which lists South Fork Potts Creek as a Group 2 mussel stream and therefore requires mussel surveys and (if necessary) salvage of all mussels before instream work. If this species is delisted, removing state protections might occur after independent state review, but would not automatically change with Federal status.

Under the authority of the Clean Water Act, EPA revised the water quality criteria for ammonia in 2013 (EPA 2013). Acute and chronic criteria were developed to protect organisms from both immediate effects, such as mortality, and longer-term effects on reproduction, growth, and survival, respectively. EPA provides several supporting documents to aid states considering adoption of the updated criteria, but North Carolina and West Virginia have not undertaken this effort. The Virginia Department of Environmental Quality issued updated ammonia surface water quality criteria in 2020 designed to provide protection to freshwater mussels and early life stages of fish; permitted dischargers, including wastewater treatment plants, are provided an extended period of time for compliance with the criteria (<http://register.dls.virginia.gov/details.aspx?id=8059>, accessed March 31, 2022). Although reducing ammonia from point sources will likely help to improve water quality in Virginia, reducing the contributions from non-point sources are more difficult to manage and control.

Also, recent studies indicate that pharmaceuticals and personal care products are commonly being discharged into surface waters and may be having acute and chronic impacts on aquatic species. For example, Fluoxetine, an often prescribed antidepressant drug, is increasingly being detected in surface waters at high enough levels that it can cause female mussels to discharge/abort undeveloped glochidia and has the potential to disrupt numerous other aspects of native mussel reproduction (Bringolf et al. 2010). However, very few, if any, treatment plants monitor for these contaminants, and there are no Federal or state standards regulating the discharge of pharmaceuticals or numerous other pollutants commonly found in wastewater discharges. At present, it is unknown if these contaminants are a threat to JSM.

FERC regulates a relatively small number of large dams in the U.S. (approximately 1,600 non-Federal dams that affect navigable waters) (<https://www.ferc.gov/administration-and-compliance>, accessed March 23, 2022).

At these dams, FERC regulates hydropower activities, including building, maintenance, and operation of hydroelectric dams, which includes 13 of the 39 dams in JSM range. Pursuant to the ESA, FERC is required to consult with the Service on new or amended hydropower activities that may affect federally listed species, including JSM. If a hydroelectric dam was licensed before listing of the species or the presence of the species was unknown, FERC will consider the effects of the hydropower operations during the relicensing process. For example, the Service and NCWRC are currently coordinating with FERC and the owners of Pinnacles Dam on the Dan River, before license expiration in 2031 (the notice of intent for license renewal is scheduled to begin in 2026, and the license application is due in 2029), to revise flow requirements necessary for recruitment and survival of JSM juveniles and adults. Without ESA protection for JSM, FERC would likely approve activities without requiring measures to avoid or minimize impacts to the species, and there would likely be a further reduction in JSM habitat quality and quantity and a resultant decrease in abundance and recruitment downstream of hydroelectric dams. There are 26 dams in the JSM range that are not regulated by FERC, and besides the ESA no mechanisms exist that provide regulatory protections for the JSM from threats associated with these dams.

Neither state laws nor the local governments with jurisdictions within the watersheds of streams supporting populations of the JSM currently have regulations/ordinances that are adequate to protect the species from many of the adverse effects of residential and commercial development, agriculture, and private forestry activities. For example, they generally do not restrict development in JSM watersheds or removal of trees in the vegetated buffers, therefore not addressing impacts to the streams' hydrograph, stormwater runoff of sediments and other non-point source pollutants, or degradation and loss of riparian buffers. The one exception is for watersheds in the James River basin, in which the Chesapeake Preservation Act and Regulations generally protect existing vegetated buffers no less than 100 feet wide adjacent to waterbodies with perennial flow, providing some protection of the riparian buffer, but does not protect area outside of the riparian buffer in the watershed that also affect water quality.

As described above, existing regulatory mechanisms continue to be inadequate to protect JSM from primary threats, including degraded water quality (e.g., contaminants, nutrients, and sediment from runoff and other non-point source discharges) and most dams. However, removing ESA protections would exacerbate the threats by removing requirements to implement measures that avoid and minimize impacts to the species and their habitat for projects with a Federal nexus, including FERC-regulated dams and construction projects requiring Corps permits, and by removing resources/funding to support propagation and other recovery efforts.

2.3.2.5 Factor E. Other natural or manmade factors affecting its continued existence:

The final listing rule described competition from high densities of nonnative Asian clam as a threat by potentially reducing availability of phytoplankton (JSM food source) and interfering with reproduction by filtering JSM sperm from the water column (53 FR 27689-27693). This was based on the temporal correlation between the disappearance of JSM in the James River and appearance and proliferation of Asian clam. There is new relevant information regarding the Asian clam and its spread to additional JSM waterbodies and other natural or manmade factors potentially affecting JSM.

Asian Clam: Since listing of JSM, nonnative Asian clam has continued to spread throughout JSM range in the James River and Roanoke River basins. As described in section 2.3.1.2 for Little Oregon Creek, the species was detected there in the mid-2010s and increased to high density in the late 2010s; however, effects from the Asian clam have not been assessed, and the JSM population appears to be thriving except for predation effects (B. Watson, VDWR, email to J. Stanhope Service, January 24, 2022). B. Watson also indicated there are high densities of Asian clam in Johns Creek where JSM is not observed (i.e., not in the mark-recapture sites in Johns Creek), but there are also a high number of notched rainbows, which are native. In addition, JSM abundance in Dicks Creek appears stable even though Asian clam has been documented in this waterbody.

Yeager et al. (2000) found that high densities of Asian clam affected survival and growth of rainbow mussel (*Villosa iris*) glochidia and juveniles in laboratory experiments. Another mechanism for how Asian clams may negatively affect freshwater mussels is water quality degradation (ammonia release and low dissolved oxygen) during mass Asian clam die-offs, which typically occur during summer droughts (Cherry et al. 2005). Haag (2019) reviewed potential causes of enigmatic declines of freshwater mussels and indicated that research is providing greater evidence of food competition by Asian clam with native freshwater mussels, but it does not explain why some streams with Asian clam, in particular in the Coastal Plain, continue to support native mussels. Haag et al. (2021) also found that juvenile mussel growth rate for four species in the Rockcastle River system in Kentucky was positively related to water temperature and negatively related to Asian clam abundance, providing likely evidence of food competition in relatively unproductive streams.

In summary, with high densities of Asian clam coexisting with some JSM populations, it is unclear if Asian clams are a current threat to JSM populations, and additional research is needed.

Climate Change: The Intergovernmental Panel on Climate Change (IPCC) predicts that many freshwater species face a greater threat of extinction, along with irreparable changes to the structure and function of freshwater ecosystems under projected climate change (IPCC 2014). Since the 1950s, the North

American climate trends demonstrate an increase in overall temperature and an increase in the number of heavy precipitation events (IPCC 2014, Wuebbles et al. 2017). Temperatures are expected to continue rising, and heat waves and extreme precipitation events are predicted to become more frequent, last longer, and become more intense by the mid-21st century (IPCC 2014, Wuebbles et al. 2017). Climate projections downscaled to the Southeast region, which overlaps with the JSM range and are based on 11 global climate models, indicate that the following climate variables will increase during the 2011-2050 period when compared to 1981-2005: average annual temperature (median of about 1.2°C), number of extreme hot days (median of about 20 days), percent change of annual precipitation (median of about 1 percent), and percent change of number of precipitation extremes (mean of about 11 percent; precipitation extreme is when “daily precipitation magnitude exceeds the climatological value of the 95th percentile of the baseline precipitation”) (Ashfaq et al. 2016). Models developed for Virginia project average temperature increases from about 3°C to 6°C by 2100 (Kane et al. 2013).

With a warming climate, some studies predict an increase in the frequency of more intense hurricanes (e.g., category 4 and 5) by the end of the 21st century, in particular in the western Atlantic Ocean north of 20°N latitude (i.e., Cuba and north), which would likely cause periodic, extreme inland flooding events (Bender et al. 2010, Knutson et al. 2010), potentially resulting in loss of JSM habitat and populations, such as when the following negative effects occur: trees fall and block and change the flow of streams; streams experience extreme scour; upstream sediments flow into JSM-occupied reaches and bury JSM; and JSM move out of suitable habitat. Hurricanes may also cause dam or impoundment failures, which could adversely affect important JSM populations such as Little Oregon Creek, Dicks Creek, Johns Creek, and Rocky Creek. Extreme drought may negatively affect JSM by reducing river flow and leaving JSM stranded when stream width decreases. However, minor temperature increases may be beneficial to JSM by promoting growth and increasing phytoplankton production (a food source), although we are unaware of specific information about JSM temperature tolerances. High temperature increases are likely harmful to JSM. When propagating JSM, mortality of juvenile JSM in culture was observed during two power outages in the summer and water temperatures increased significantly; the water temperatures were not measured but likely in the high 20°C's (R. Mair, Service, email to J. Stanhope, Service, November 9, 2022). Based on modeled, downscaled projections of multiple climate variables, Kane et al. (2013) predicted that the modeled current species distribution in Virginia (i.e., percentage of mapped area in Virginia where the species is likely to be located) will increase from 4.6 percent to 18.7 percent and 24.2 percent by 2050 and 2100, respectively. They predicted that climate conditions will become more favorable for JSM, although they did not account for changes in water quality and quantity due to climatic effects (e.g., runoff, reduced baseflow). The effects on host fish will depend on whether they are cool- or warm-water species, with cool-water species having variable responses and warm-water species potentially benefiting and

expanding distribution (Conte et al. 2013). If host fish have different thermal tolerances than JSM, increased stream temperatures may potentially decouple mussel-host relationships and cause mussel population decline (Pandolfo et al. 2012).

In summary, effects of climate change related to increased flooding have been observed and are likely to increase, but other effects, such as temperature increase, are less clear and may or may not have negative impacts on JSM.

2.4 Synthesis

Since the 1990 recovery plan, the JSM has a wider spatial distribution than previously known. Additional surveys have revealed that the spatial distribution extends to the Upper Dan subbasin in the Roanoke River basin (NC, VA) and HUC12 subwatersheds in the Upper James, Middle James-Buffalo, and Rivanna subbasins (VA). The JSM historical and current range is in the James River basin in Virginia and West Virginia and the Roanoke River basin in Virginia and North Carolina. Based on number of waterbodies (not river miles), approximately 70 percent of all historically occupied waterbodies (26 of 37) are currently or likely occupied by JSM. Conversely, approximately 30 percent of all historically occupied waterbodies (11 of 37) are presumed or possibly extirpated, increasing from 5 to 11 waterbodies from 1990 to 2021 (120 percent increase).

Although there is an increase in spatial distribution and number of currently occupied waterbodies, JSM generally occurs in relatively low density and abundance (<10 individuals) at many sites across its range, and often just one individual is found at a site or reach. Of the currently or likely occupied waterbodies (26 total), 27.0 percent have very low approximate abundance (1 to 10 individuals), 21.6 percent have low approximate abundance (11 to 100 individuals), and 21.6 percent have moderate and higher approximate abundance (>100 individuals), based on the last 20 years (2002-2021). This time frame was chosen based on the assumption that the lifespan for JSM is 15 to 20 years. The waterbodies with very low or low approximate abundances usually have low density and patchy distribution over the river or stream. Low density populations may lead to a loss of recruitment due to the distance between individual mussels being too great for successful reproduction and may contribute to loss of genetic variability. There are 8 waterbodies with the moderate and higher abundance estimates: South Forks Potts Creek in West Virginia (note: the range [31 to 339 individuals from 1987 to 2021] includes low approximate abundance); Little Oregon Creek, Dicks Creek, Johns Creek, Mill Creek, and Rocky Creek in Virginia; Dan River in North Carolina; and South Fork Mayo River in Virginia and North Carolina.

Based on multiple years of monitoring over at least a 10-year time period, the species is reproducing and considered stable (with large variation) or increasing in four waterbodies in the James River basin (South Fork Potts Creek, Dicks Creek, Johns Creek, and Mill Creek). The JSM population in Rocky Creek is reproducing and considered stable, but monitoring has occurred for less than 10 years. JSM is decreasing or possibly decreasing in four waterbodies: two in the James River basin (Little Oregon Creek, Rock Island Creek) and two in the Roanoke River basin (Dan River, Mayo River). For most of the waterbodies listed above, JSM is

predominately found in single, small reaches, ranging from 0.1 to 1.4 km in length, making them susceptible to an adverse event that could eliminate the high density reaches of JSM within a waterbody. More than half of the waterbodies with JSM present have an unknown population trend due to the lack of monitoring data over time.

Across the range, JSM occupies 52 percent (32 of 61) of the historically occupied HUC12s, of which 23 were discovered since 1990 due to increased survey effort. Within the James River basin, JSM is extant in 80 percent of subbasins (4 of 5) and occupies 42 percent (20 of 48) of the historically occupied HUC12s; the Middle James-Willis subbasin remains unoccupied (0 of 3) and the Maury subbasin has only 20 percent (1 of 5) of its HUC12s occupied. Within the Roanoke River basin, with one subbasin, JSM is extant and occupies 92 percent (12 of 13) of the historically occupied HUC12s. When examining the distribution of waterbodies/subpopulations by approximate abundance in 2021, the Upper James subbasin has the most waterbodies/subpopulations with moderate or greater approximate abundance, which are concentrated in the southwestern portion of the subbasin (4 total; 26.7 percent of historically occupied waterbodies/subpopulations in the subbasin). For the Maury and Rivanna subbasins, they have only one waterbody/subpopulation each with moderate approximate abundance (33.3 percent and 7.7 percent of historically occupied waterbodies/subpopulations, respectively in their subbasin). The Middle James-Buffalo subbasin has only waterbodies with low (50.0 percent), very low (16.7 percent), and none (33.3 percent) approximate abundance. In the Roanoke River basin, its only subbasin, the Upper Dan, has two waterbodies with moderate approximate abundance (40.0 percent of historically occupied waterbodies in the subbasin). The waterbodies/subpopulations with moderate or greater approximate abundance are widely distributed throughout JSM's range. In terms of distribution across physiographic provinces, JSM currently occupies 33.3 percent, 75.0 percent, and 66.7 percent of the historically occupied HUC12s in the Valley and Ridge, Blue Ridge, and Piedmont, respectively.

Propagation efforts have been successful in augmenting populations with juvenile JSM. The Mill Creek population has doubled and the abundance in the Cowpasture River has significantly increased from 5 to at least 111 individuals. Other JSM waterbodies have been augmented with propagated juvenile JSM, but monitoring data are being analyzed or monitoring has not been conducted yet to assess success; these waterbodies include Craig Creek, Pedlar Creek, Rock Island Creek, and Tye River in Virginia and Mill Creek in North Carolina.

The habitat requirements for JSM described in the 1990 recovery plan and Hove (1990) appear relatively unchanged since then. It was indicated that JSM occupies streams varying from 1.5-m to 23-m wide and 0.15-m to 2-m deep, and with the discovery of JSM in the Roanoke River Basin, JSM currently occupies rivers with greater width (i.e., up to 80 m). The species continues to be found in a range of substrates, including sand, gravel, and cobble with or without boulders, pebbles, or silt (Service 1990, Hove 1990). The water velocity at sites supporting this species is slow to moderate, in pools to riffles/runs. Some dams or impoundments (e.g., low-head dams, earthen dams, farm ponds) on lower order streams (i.e., in the headwater area) appear to be providing beneficial effects to JSM and its habitat in Little Oregon Creek, Dicks Creek, Johns Creek, and Rocky Creek, which are streams with documented higher JSM density and abundance. The dams are potentially providing hydraulic stability, greater food availability, and increased water temperature from the impounded water. Multiple species distributions models

for JSM have been developed, with predictor variables related to streamflow and landcover (e.g., less agriculture and developed landcover).

Results of genetic studies suggest that JSM is the same species throughout its range in the Dan River subbasin of the Roanoke River basin and James River basin, but the species should be managed as separate units. Although initial genetic analyses suggested that JSM from the Dan River and South Fork Mayo River in the Roanoke River basin may be exchanged, new genetic analyses suggest that they are relatively highly differentiated, likely due to two large dams between them on the Mayo River. Initial analysis indicates there are also some genetic differences among populations in the James River basin, and inbreeding is generally high across all populations in both basins; further analysis of the data is required to make additional conclusions on genetic diversity and structure of the populations. JSM is a distinct species from other freshwater mussels with spines and other freshwater mussels in the Pleurobemini tribe and forms a new monophyletic clade with the TRS in a new genus named *Parvaspina*.

The final listing rule described habitat modification as a major threat to JSM and the cause of its decline (53 FR 27689-27693). Adverse habitat changes were caused by dam construction, industrial pollution, chemical spills, channelization, agricultural runoff (including pesticides and fertilizers), and sewage discharges at multiple locations within the species' historical range in the James River basin. The final listing rule also indicated erosion and siltation from logging operations in the upper Craig Creek watershed and other locations as a threat to habitat. Recent information indicates that dams and activities related to land use modification remain threats throughout the species range and are expected to continue in the future. While construction of new dams is unlikely a current threat, most dams continue to be a threat by reducing connectivity and isolating JSM populations, reducing habitat quality and quantity, and changing hydrologic flow regime downstream of the dam. Water quality issues due to land use modification, in particular sedimentation/turbidity, nutrients, and contaminants, are widespread threats to JSM, while instream construction activities and livestock access to streams are localized threats in numerous JSM waterbodies. Severe flooding/stormflow events are also localized but serious threats to JSM for at least four JSM waterbodies (Rock Island Creek, Craig Creek, North Fork Rivanna River, and Dan River). Land use changes, in particular increased development and impervious surface in watersheds, alter flow regimes and contribute to greater frequency and intensity of severe flood events. The threats of land disturbance activities are likely to increase in the future with the extent of urban sprawl projected to increase 101 to 192 percent in the next 50 years for the southeastern United States.

The final listing rule described competition from high densities of nonnative Asian clam as a threat by potentially reducing food availability and interfering with reproduction. With high densities of Asian clam coexisting with some JSM populations, it is unclear if Asian clams are a current threat to JSM populations, and additional research is needed. Inadequacy of existing regulatory mechanisms was also described in the final listing rule. Existing regulatory mechanisms continue to be inadequate to protect JSM from primary threats, including degraded water quality (e.g., contaminants, nutrients, and sediment from runoff and other non-point discharges) and most dams. However, removing ESA protections would exacerbate the threats by removing requirements to implement measures that avoid and minimize impacts to the species and their habitat for projects with a Federal nexus, including FERC-regulated dams and

construction projects requiring Corps permits, and providing resources/funding to support propagation and other recovery efforts.

New threats to JSM include predation and climate change effects. Predation by raccoons and muskrats is currently a localized but serious threat to JSM. Effects of climate change related to increased flooding have been observed and are likely to increase, but other effects, such as temperature increase, are less clear and may or may not have negative impacts on JSM.

The Service established a framework in which we consider what a species needs to maintain viability over time by characterizing the biological status of the species in terms of its Resiliency, Redundancy, and Representation (“the 3 Rs”; Smith et al. 2018). **Resiliency** means having sufficiently healthy populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, population size, if that information exists. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of human activities. **Redundancy** means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

Representation means having the breadth of genetic makeup of the species to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species’ range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. Table 8 summarizes the information provided in this report in terms of the 3 Rs.

Table 8. Resiliency, redundancy, and representation (3Rs) for James spiny mussel and its current condition

| 3Rs | Requisites | Description | Current Condition |
|---|----------------------------------|---|--|
| Resiliency (ability to withstand stochastic events) | Healthy populations and habitat. | Populations (waterbodies) with: <ul style="list-style-type: none"> • Excellent water quality, • Suitable instream substrate: clean sand, gravel, and cobble, • Sufficient water quantity with slow-to-moderate current to maintain healthy habitat and water quality, • Healthy riparian and adjacent upland habitat, and • Connectivity — waterways without significant barriers between populations. | Each population (waterbody) with moderate to high approximate abundance is thought to be healthy and have adequate habitat, thus has moderate or high resiliency, respectively. <ul style="list-style-type: none"> • 26 of 37 waterbodies (70.3%) are likely or currently occupied by JSM. • Approximate abundance status: <ul style="list-style-type: none"> – 2 waterbodies (5.4%) high – 3 waterbodies (8.1%) moderate to high – 3 waterbodies (8.1%) moderate – 8 waterbodies (21.6%) low – 10 waterbodies (27.0%) very low – 11 waterbodies (29.7%) none (possibly extirpated or historical) |

| 3Rs | Requisites | Description | Current Condition |
|---|---|--|---|
| Redundancy (ability to withstand catastrophic events) | Sufficient distribution of healthy populations. | Sufficient distribution of healthy populations to prevent catastrophic losses of species' adaptive capacity due to natural events (e.g., severe flood, drought). Multiple healthy populations and occupied HUC12s within the species' range are important for the species' redundancy. | <ul style="list-style-type: none"> • Healthy populations (waterbodies with moderate to high approximate abundance) found throughout range but limited in spatial extent and not evenly distributed: none in the central and eastern portions of the range. • In the James River basin – loss of occupied HUC12s mostly in the: <ul style="list-style-type: none"> ○ eastern and some central portions of range (historically; prior to 1990) ○ western portion of the range (since 1990) • Overall, increase in total number of occupied HUC12s, predominantly in the northern and southern portions of range due to new discoveries. |
| Redundancy (ability to withstand catastrophic events) | Sufficient number of healthy populations. | Sufficient number of healthy populations and occupied HUC12s to prevent catastrophic losses of adaptive capacity. | <ul style="list-style-type: none"> • 8 of 37 waterbodies (21.6%) have moderate to high approximate abundance across the range. <ul style="list-style-type: none"> – James basin: 6 of 32 (18.8%) have moderate to high approximate abundance. 7 of 32 (21.9%) have low approximate abundance. – Roanoke basin: 2 of 5 (40.0%) have moderate to high approximate abundance. 1 of 5 (20.0%) have low approximate abundance. • 32 of 61 HUC12s (52.5%) currently or likely occupied. |
| Representation (ability to adapt) | Sufficient capacity to adapt to new, continually changing environments. | <p>Genetic diversity within and among populations contribute to and maintain adaptive capacity.</p> <p>Occupied subbasins and HUC12s distributed across the range, including the ecological diversity of river basins and physiographic provinces that contribute to and maintain adaptive capacity.</p> <p>Adequate dispersal ability for the species to migrate to suitable habitat and climate over time.</p> | <p>Connected and occupied HUC12s found in both river basins and in all physiographic provinces, but lower proportion of them in the James River basin and Valley and Ridge province.</p> <p>River basin:</p> <ul style="list-style-type: none"> • James – 20 of 48 HUC12s (42.0%) occupied. 4 of 5 (80%) subbasins occupied. Middle-James Buffalo subbasin presumed extirpated and Maury subbasin only has 1 of 5 HUC12s occupied. • Roanoke – 12 of 13 HUC12s (92.3%) occupied. 1 of 1 subbasin occupied. <p>Physiographic province:</p> <ul style="list-style-type: none"> • Valley and Ridge – 8 of 24 HUC12s (33.3%) occupied. • Blue Ridge – 2 of 4 HUC12s (50.0%) occupied. • Piedmont – 22 of 33 HUC12s (66.7%) occupied. |

When assessing the 3 Rs, 70.3 percent of historically occupied waterbodies (26 of 37) are currently or likely occupied by JSM; however, the health (resiliency) of those waterbodies varies across the range, with 21.6 percent of historically occupied JSM waterbodies (8 of 37) considered healthy (i.e., moderately to highly resilient, based on approximate abundance) (table 8). They are found throughout the range but are limited in number and spatial extent and not evenly distributed (redundancy). No healthy populations are found in the eastern and central portions of the range. There is a loss of occupied HUC12s in the eastern and some central portions of the range prior to 1990 and western portion of the range since 1990. However, there is an overall increase in the total number of occupied HUC12s, predominantly in the northern and southern portions of the range. With genetic analyses in progress, we assume that the species' representation requirements are best met by retaining its distribution within the river basins and physiographic provinces. The species occurs in connected HUC12s in both river basins and all physiographic provinces, but it occupies only 42.0 percent of the historically occupied HUC12s in the James River basin (20 of 48), with the Middle-James Buffalo subbasin presumed extirpated and Maury subbasin having only one HUC12 occupied (1 of 5). The Valley and Ridge province also lost the most representation with 33.3 percent of historically occupied HUC12s occupied (8 of 24).

The primary factors influencing the current status include existing dams, activities related to land use modification (e.g., alteration of the natural landscape, including, but not necessarily limited

to, land conversion for development and its associated infrastructure [roads, bridges, utilities], forestry activities, and agricultural activities, including livestock access to streams), severe flooding/stormflow events, predation, and climate change effects. The threats with the most potential to increase and affect species viability in the future are development and impervious surfaces in watersheds (Terando et al. 2014) (i.e., affecting water quality and stormflow events) and flooding and droughts due to climate change (Bender et al. 2010, Knutson et al. 2010, Ashfaq et al. 2016). Applying the definitions of viability and probabilities of persisting for element occurrences from Nature Serve (2020), we assume that waterbodies with moderate to high approximate abundance have good to excellent viability and are likely to very likely to persist, respectively, if current conditions prevail. We assume waterbodies with low approximate abundance have fair viability and an uncertain probability of persisting and waterbodies with very low approximate abundance have poor viability and a poor probability of persisting and a high risk of extirpation, if current conditions prevail. In projecting a likely future scenario with predicted increased development and climatic changes and no conservation measures implemented, we predict good to excellent viability waterbodies will have sufficient resiliency to persist for the foreseeable future. We predict waterbodies with fair viability and greater developed landcover (e.g., ≥ 5 percent in a subwatershed in 2019) and waterbodies with poor viability are likely to be extirpated if further stressed by predicted changes in land cover and climatic patterns that may result in decreased water quality and increased floods/drought. We also predict HUC12s will likely become extirpated when the entire waterbody is predicted to become extirpated. There is significant uncertainty in the likelihood of the future scenario driven by many uncertainties associated with predicting climate effects (discussed in section 2.3.2.5) and land cover changes (Terando et al. 2014); however, we consider it a conservative approach by assuming waterbodies that currently have fair resiliency in more developed watersheds or poor resiliency in any watershed will not be able to tolerate the additional stress imposed by reduced water quality and climatic changes to their habitats and be extirpated. This is also a conservative approach because we are assuming no conservation measures will be implemented; however, we believe it is possible that efforts such as propagation, augmentation, and reintroduction will continue if there is funding because VDWR and the Service have been successfully conducting these efforts the past 10 years.

In our future scenario, we project 12 additional waterbodies in the James River basin and two additional waterbodies in the Roanoke River basin will likely be extirpated, leaving 12 of 37 waterbodies (32.4 percent of historically occupied waterbodies) remaining across three states. As a result, 22 waterbodies (68.8 percent) and 3 waterbodies (60.0 percent) total in the James and Roanoke River basins, respectively, will likely be extirpated when including waterbodies that are currently possibly extirpated or historical. We project a loss of 17 occupied HUC12 subwatersheds, leaving 29.5 percent (18 of 61) of the historically occupied HUC12s remaining, and redundancy will be reduced (figure 8). The species will continue to occur in both river basins, but representation will be lost in the Blue Ridge with no occupied HUC12s (0 of 4) and only 18.8 percent of the historically occupied HUC12s in the James River basin (9 of 48) will be extant. The Middle James-Buffalo and Rivanna subbasins will lose the most HUC12s, which are in the central and northeastern portions of the range, with 11.1 percent (1 of 9) and 9.1 percent (1 of 11) of historical occupied HUC12s remaining, respectively.

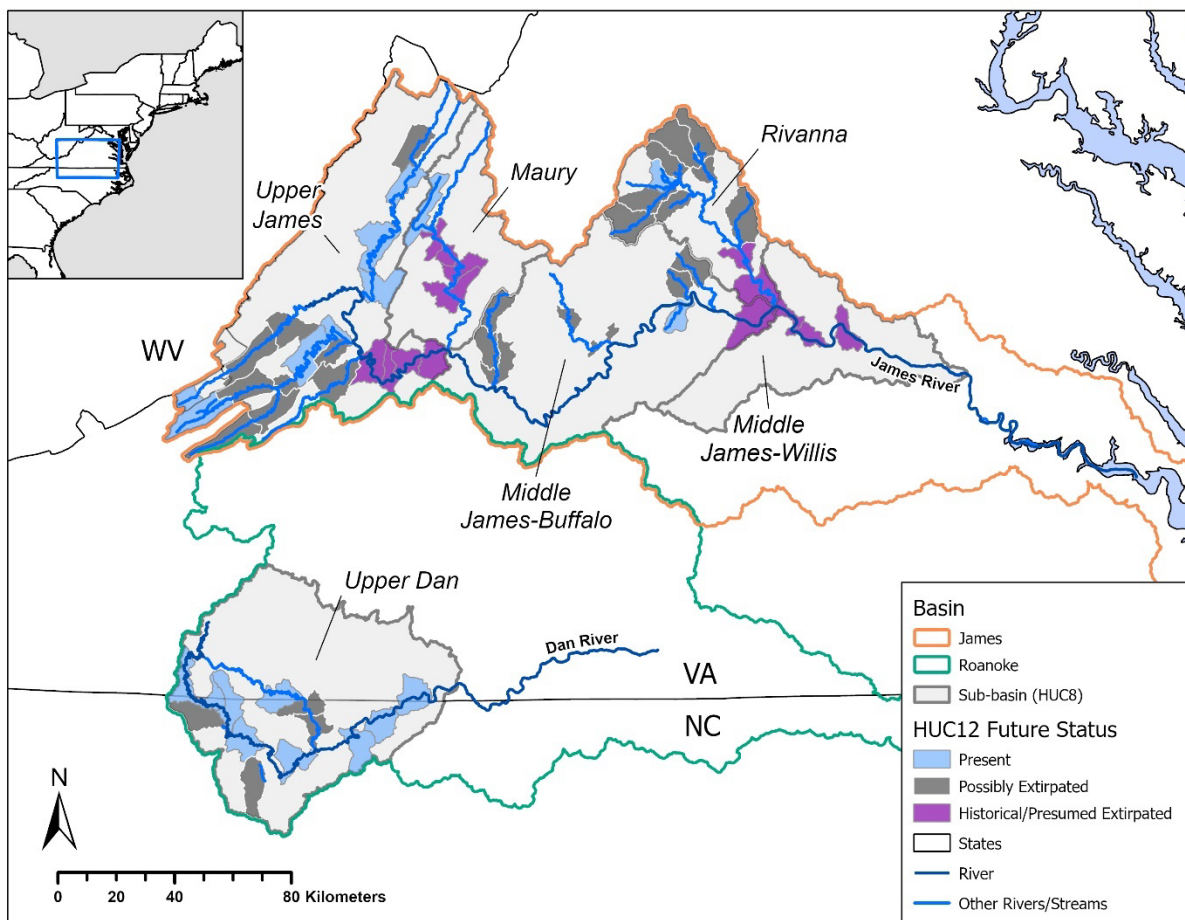


Figure 8. Future status of JSM by HUC12 subwatersheds. Subbasins are labeled.

In summary, as a whole, the rangewide status of the species has improved, with an increased number of waterbodies and HUC12 subwatersheds occupied by JSM and the range expanded to the Roanoke River basin. However, the JSM continues to face ongoing and likely increasing threats to its continued existence throughout its range. JSM population trends across the range are variable, ranging from stable/increasing in six waterbodies in the James River basin to decreasing or possibly decreasing in five waterbodies in both the James River and Roanoke basins. For more than half of the waterbodies with JSM present (13 of 24), the population trend is unknown due to the lack of sufficient monitoring data. Although only one of the three reclassification criteria has been met, the 3 Rs assessment provides additional information to characterize the biological status of the species. In addition, the third criterion (1C) is not objective, measurable, and quite possibly not achievable.

When evaluating the status of the species and current and future threats, we conclude that the JSM does not meet the definition of an endangered species but does meet the definition of a threatened species under the ESA⁴.

⁴ The ESA defines an endangered species as a species that is “in danger of extinction throughout all or a significant portion of its range,” and a threatened species as a species that is “likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.”

3.0 RESULTS

3.1 Recommended Classification:

Downlist to Threatened

Uplist to Endangered

Delist (*Indicate reasons for delisting per 50 CFR 424.11*):

Extinction

No longer meets the definition of threatened or endangered

No longer meets the definition of a species

No change is needed

3.2 New Recovery Priority Number: **No change**

Brief Rationale: The species continues to experience a moderate degree of threat and has a high recovery potential if recommendations for future actions are implemented.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Clarify recovery criteria 1C and 2E to support objective evaluation and achievability and 2D to reflect current information. Criterion 1C is too general and merits clarification because as written, it is quite possibly not achievable to protect all known populations of the species from present and foreseeable anthropogenic and natural threats that may interfere with their survival. Criterion 2E is too specific and is based on demonstrating success based on habitat protection strategies; this criterion should be clarified to include other recovery tools, such as propagation, augmentation, stream restoration, predator trapping, and modification or removal of dams. Criterion 2D should be clarified to include the Roanoke River basin.

Recommendations for specific recovery actions and priority number (1-3, based on priority number definitions in the JSM recovery plan [Service 1990]):

Recommendations for specific research and data needs

1. Continue long-term, systematic monitoring of JSM populations to improve measurement and understanding of demographic vital rates (e.g., population density and size, recruitment rate, survival rate, fecundity, maturity schedule, age structure, sex ratio), population trends, and changes in populations in response to threats and management actions [Priority 1].
2. Conduct a population viability analysis to define what is a viable population and to inform management decisions [Priority 1].
3. Continue genetic analyses of JSM populations to assess genetic diversity and to support development of propagation plans and a genetic management plan [Priority 2].
4. Continue to assess and survey occurrence streams for JSM, in particular sites that have not been surveyed in more than 15 years, and identify opportunities for JSM recovery [Priority 2].
5. Continue to conduct research and monitoring to determine the effects of water quality and other stressors/threats, including effects of hydropower peaking operations and Asian clam, on JSM population dynamics [Priority 2].

Recommendations for conservation actions:

1. Protect and maintain the dams on lower order streams, including Little Oregon Creek, Dicks Creek, and Johns Creek, that appear to be providing beneficial effects to JSM and its habitat [Priority 1].
2. With the state natural resource agencies, identify opportunities for population augmentation to extant waterbodies and reintroduction to historical waterbodies and finalize a captive propagation plan and site-specific augmentation/reintroduction plans for the JSM [Priority 2].
3. With State and Federal agencies and partners, work to reduce the impacts of dams restricting connectivity and affecting the hydrologic flow regime downstream of the dam, including FERC-licensed hydroelectric dams. Actions may include removing all or part of the dam, revising flow requirements during the FERC relicensing process, and reopening FERC licenses with exemptions (e.g., non-expiring) on waterbodies where JSM was discovered after the exemption was issued [Priority 2].
4. With the partners, actively promote water quality improvement, stream riparian buffer preservation and establishment, and stream preservation and restoration (if appropriate) projects in the James (i.e., Rivanna subbasin, Little Oregon Creek, Mill Creek, Johns Creek, Craig Creek, Rock Island Creek) and Roanoke River (i.e., Dan River, Mayo River, and South Fork Mayo River) basins. Focus on stream and riparian restoration projects that improve agricultural practices in areas that are somewhat degraded and can be improved, including but limited to: Little Oregon Creek, Mill Creek, South Fork Potts Creek, Pedlar River, Tye River, Johns Creek, Dan River, and South Fork Mayo River [Priority 2].
5. Maintain and increase the present populations through watershed-level conservation approaches that address sediment, nutrient, and contaminant loading and stormwater flows. Work with partners to preserve and improve ecological processes that provide the water quality and quantity and habitat required for the JSM and participate in watersheds planning with Virginia, North Carolina, and West Virginia [Priority 3].

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the James spinymussel (*Parvaspina collina*)

Current classification: Endangered

Recommendation resulting from the 5-Year Review:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Jennifer Stanhope, Virginia Field Office

LEAD REGIONAL OFFICE APPROVAL

Assistant Regional Director, Fish and Wildlife Service

Approve _____ Date _____

APPENDIX A: COORDINATION LIST OF PARTNERS AND EXPERTS

The following partners and experts were contacted for information to support the 5-year review and provided responses, in addition to those listed in Section 1.1 (Reviewers):

State agencies

- North Carolina Natural Heritage Program (Judith Ratcliffe*)
- North Carolina Wildlife Resources Commission (Michael Perkins*)
- Virginia Department of Conservation and Recreation, Division of National Heritage (Rene' Hypes)
- Virginia Department of Wildlife Resources (Brian Watson*)
- West Virginia Division of Natural Resources (Alexander Silvis, Kevin Eliason*)

Other

- Daguna Consulting (Brett Ostby*)
- James Madison University (Christine May)

*All State and other partners listed above were provided the opportunity to review a draft 5-year review document. Those with an * provided comments or a response that they had no comments.

APPENDIX B: OCCURRENCE WATERBODIES OF JAMES SPINYMUSSEL

Table B-1. Part 1 of detailed population information on James spiny mussel waterbodies and subpopulations/areas. Pop=population; Approx.=approximate ND=not detected; PoExt=Possibly Extirpated; PreExt=Presumed Extirpated.

| Basin/Sub-basin (HUC8) | Waterbody | Area/Sub-population ¹ | County | State | Pop status in 1990 recovery plan ¹ | Pop status in 2008 draft 5-Year Review ² | Pop status in 2021 ³ | Approx. abundance size (if present) ³ | Live JSM last observed | Last Surveyed | Estimated river length (km) where all live JSM were found in last 20 years (2002-2021) | Number of live JSM found in last observation year | Cumulative number of live JSM observed in last 20 years (2002-2021). Range provided if based on estimates from (A) repeated surveys, (B) mark-recapture study (C) density. |
|--------------------------|------------------------|----------------------------------|------------------|-------|---|---|---------------------------------|--|--------------------------------|--------------------------------|--|---|--|
| James River Basin | | | | | | | | | | | | | |
| Upper James | South Fork Potts Creek | | Monroe | WV | Present | Present | Present | Low to high | 2021 | 2021 | most within 1.4-km reach, all in 5.8 km | 85 | range: 31-339 (A) (# of reaches surveyed varied) |
| Upper James | Potts Creek | | Craig, Alleghany | VA | Present | ND/ PoExt | ND/ PoExt | None | 1990 | 2006 | None | 2 | None |
| Upper James | Cowpasture River | | Bath, Alleghany | VA | Not reported | Present | Present | Low to moderate | 2006 (wild); 2021 (propagated) | 2017 (wild); 2021 (propagated) | most within 0.1 km reach, all in 50 km (wild); 0.1 km (1 site; propagated) | 1 (wild); 111 (propagated) | 5 (wild); range (propagated): 61-111 (A) |
| Upper James | Bullpasture River | | Highland | VA | Not reported | Present | Likely present | Very low | 2006 | 2019 | 1.4 km | 5 | 5 |
| Upper James | Little Oregon Creek | | Craig | VA | Not reported | Present | Present | High | 2021 | 2021 | 0.2 km | estimated 771 in 2019 in 0.1-km reach ⁴ | range: 646-2003 (B) |
| Upper James | Dicks Creek | | Craig | VA | Present | Present | Present | Moderate to high | 2021 | 2021 | 1.0 km | estimated 373 in 2019 in 0.05-km reach ⁴ | range: 197-544 (B) |
| Upper James | Johns Creek | Near Maggie | Craig | VA | Present | Present | Present | High | 2021 | 2021 | most within 0.1-km reach, all in 8.3 km | estimated 758 in 2019 in 0.1-km reach ⁴ | range: 398-1043 (B) |
| Upper James | | Along Sevenmile Mountain | Craig | VA | Present | Present | Present | Low | 2007 | 2021 | 0.5 km | 12 | 12 |
| Upper James | Craig Creek | near New Castle | Craig | VA | Present | ND/ unknown | ND/ PoExt | None | 1987 | 2012 | None | 3 | None |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Sub-population ¹ | County | State | Pop status in 1990 recovery plan ¹ | Pop status in 2008 draft 5-Year Review ² | Pop status in 2021 ³ | Approx. abundance size (if present) ³ | Live JSM last observed | Last Surveyed | Estimated river length (km) where all live JSM were found in last 20 years (2002-2021) | Number of live JSM found in last observation year | Cumulative number of live JSM observed in last 20 years (2002-2021). Range provided if based on estimates from (A) repeated surveys, (B) mark-recapture study (C) density. |
|------------------------|-------------------|----------------------------------|---------------------|-------|---|---|---------------------------------|--|------------------------|---------------|--|---|--|
| Upper James | | Craig Creek near Silent Dell | Botetourt | VA | Present | Present | Present | Low | 2019 | 2019 | 17.6 km | 2 | 17 in 2 reaches; range: 1-9 (estimated based on mark-recapture study at 2 additional sites) |
| Upper James | | Craig Creek near Eagle Rock | Botetourt | VA | Present | ND/unknown | ND/unknown | None | 1988 | 1999 | None | 19 | None |
| Upper James | Patterson Creek | | Botetourt | VA | Present | ND/ PoExt | ND/ PoExt | None | 1988 | 2004 | None | 1 | None |
| Upper James | Catawba Creek | | Botetourt | VA | Present | ND/ PoExt | ND/ PoExt | None | 1988 | 2007 | None | 3 | None |
| Maury | Calfpasture River | | Rockbridge | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1845 | 2017 | None | Unknown | None |
| Maury | Maury River | | Rockbridge | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1845 | 2017 | None | Unknown | None |
| Maury | Mill Creek | | Bath | VA | Historical | Present | Present | Moderate to high | 2021 | 2021 | most within 1.3-km reach, all in 9.7 km | estimated 171 (wild) and 197 (propagated) in 2021 within 0.16-km reach ⁴ | range (wild): 65-214; (propagated): 99-309 (B) |
| Middle James- Buffalo | Pedlar River | | Amherst | VA | Present | Present | Present | Low | 2021 | 2021 | 11.3 km | 1 | 49 |
| Middle James- Buffalo | Hardware River | | Fluvanna, Albemarle | VA | Not reported | Present | Present | Very low | 2019 | 2021 | 1.0 km | 1 | 9 |
| Middle James- Buffalo | Rock Island Creek | | Buckingham | VA | Not reported | Not reported | Present | Low | 2021 | 2021 | most within 2 non-adjacent reaches (#1: 0.2 km, #2: 0.1 km); all occurrences in 2.1 km | estimated 58 native JSM in 2018 in 0.2-km reach (reach #1) ^{4,5} | range: 40-58 (B) (at reach #1) ⁵ |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Sub-population ₁ | County | State | Pop status in 1990 recovery plan ¹ | Pop status in 2008 draft 5-Year Review ² | Pop status in 2021 ³ | Approx. abundance size (if present) ³ | Live JSM last observed | Last Surveyed | Estimated river length (km) where all live JSM were found in last 20 years (2002-2021) | Number of live JSM found in last observation year | Cumulative number of live JSM observed in last 20 years (2002-2021). Range provided if based on estimates from (A) repeated surveys, (B) mark-recapture study (C) density. |
|------------------------|--|----------------------------------|-----------|-------|---|---|---------------------------------|--|------------------------|---------------|--|---|--|
| Middle James- Buffalo | Tye River | | Nelson | VA | Not reported | Not reported | Present | Low | 2019 | 2019 | 2.2-km reach | 4 in 2019; 12 in 2018 | 26 ⁶ |
| Middle James- Buffalo | Totier Creek (relic shells) | | Albemarle | VA | Not reported | Not reported | ND/ PoExt | None | unknown | 2017 | None | None | None |
| Rivanna | Mechums River | | Albemarle | VA | Present | Present | Present | Very low | 2021 | 2021 | 0.1 km (1 site) | 2 | 4 |
| Rivanna | Moormans River | | Albemarle | VA | Present | ND/ PoExt | ND/ PoExt | None | 1990 | 2005 | None | 7 | None |
| Rivanna | Wards Creek (mis-identified as Rocky Run [Moormans River]) | | Albemarle | VA | Present | Present | Present | Low | 2011 | 2017 | 0.8 km | 2 | 15 |
| Rivanna | Rocky Creek | | Albemarle | VA | Not reported | Present | Present | Moderate to high | 2021 | 2021 | 3.0 km | 36 in 2021; 80 in 2019 | range: 236-1153 (C) (95% confidence interval in 0.35-km reach) |
| Rivanna | Buck Mountain Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2021 | 2021 | 7.8 km | 3 | 9 |
| Rivanna | Piney Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2012 | 2021 | 0.1 km (1 site) | 1 | 1 |
| Rivanna | Ivy Creek | | Albemarle | VA | Not reported | Present | Present | Very low | 2011 | 2012 | 0.1 km (1 site) | 2 | 2 |
| Rivanna | NF Rivanna River | | Albemarle | VA | Not reported | Present | Present | Very low | 2015 | 2015 | 5.2 km | 2 | 4 |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Sub-population ¹ | County | State | Pop status in 1990 recovery plan ¹ | Pop status in 2008 draft 5-Year Review ² | Pop status in 2021 ³ | Approx. abundance size (if present) ³ | Live JSM last observed | Last Surveyed | Estimated river length (km) where all live JSM were found in last 20 years (2002-2021) | Number of live JSM found in last observation year | Cumulative number of live JSM observed in last 20 years (2002-2021). Range provided if based on estimates from (A) repeated surveys, (B) mark-recapture study (C) density. |
|----------------------------------|--------------------------------|---|-----------------------|-------|---|---|---------------------------------|--|------------------------|---------------|--|---|--|
| Rivanna | Swift Run | | Albemarle, Greene | VA | Not reported | Present | Present | Low | 2019 | 2019 | 9.1 km | 5 | cumulative: 75 (2003-2012); range: 5-24 (A) (2011-2019) |
| Rivanna | Unnamed tributary to Swift Run | | | | Not reported | Not reported | Present | Very low | 2017 | 2019 | 0.1 km (1 site) | 1 | 1 |
| Rivanna | Welsh Run | | Greene | VA | Not reported | Present | Likely present | Very low | 2005 | 2019 | 0.7 km | 2 | 2 |
| Rivanna | Rivanna River | near Columbia, Palmyra, and Crofton | Fluvanna | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1968 | 2011 | None | Unknown | None |
| Rivanna | Mechunk Creek (relict shell) | | Fluvanna | VA | Not reported | Not reported | ND/ PoExt | None | unknown | 2007 | None | Unknown | None |
| Upper James (mainstem) | James River | James River at Buchanan | Botetourt | VA | Historical | ND/ PreExt | ND/ PreExt | None | pre-1967 | 2021 | None | Unknown | None |
| Upper James (mainstem) | | James River Bridge near Natural Bridge | Rockbridge | VA | Historical | ND/ PreExt | ND/ PreExt | None | pre-1967 | 2005 | None | Unknown | None |
| Middle James- Buffalo (mainstem) | | James River at New Canton | Buckingham, Fluvanna | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2018 | None | Unknown | None |
| Middle James-Willis (mainstem) | | James River at Columbia | Fluvanna, Cumberland | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2012 | None | Unknown | None |
| Middle James-Willis (mainstem) | | James River at Pemberton and Cartersville | Goochland, Cumberland | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2012 | None | Unknown | None |
| Middle James-Willis (mainstem) | | James River at Rock Castle | Goochland, Powhatan | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2013 | None | Unknown | None |

| Basin/Sub-basin (HUC8) | Waterbody | Area/Sub-population ¹ | County | State | Pop status in 1990 recovery plan ¹ | Pop status in 2008 draft 5-Year Review ² | Pop status in 2021 ³ | Approx. abundance size (if present) ³ | Live JSM last observed | Last Surveyed | Estimated river length (km) where all live JSM were found in last 20 years (2002-2021) | Number of live JSM found in last observation year | Cumulative number of live JSM observed in last 20 years (2002-2021). Range provided if based on estimates from (A) repeated surveys, (B) mark-recapture study (C) density. |
|--------------------------------|-----------------------|----------------------------------|--------------------------------------|--------|---|---|---------------------------------|--|------------------------|---------------|--|---|--|
| Middle James-Willis (mainstem) | | James River opposite Maidens | Goochland, Powhatan | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2012 | None | Unknown | None |
| Middle James-Willis (mainstem) | | James River at Maidens | Goochland, Powhatan | VA | Historical | ND/ PreExt | ND/ PreExt | None | 1966 | 2012 | None | Unknown | None |
| Roanoke River Basin | | | | | | | | | | | | | |
| Upper Dan | Dan River | | Stokes, Rockingham | NC | Not reported | Present | Present | Moderate | 2019 | 2019 | most within 35-km reach; all in 142.4 km | 13 | 200 in about 35-km reach ⁷ |
| Upper Dan | Big Creek (shell) | | Stokes | NC | Not reported | Not reported | ND/ PoExt | None | unknown | 2019 | None | None | None |
| Upper Dan | Mill Creek | | Stokes | NC | Not reported | Not reported | Present | Very low | 2018 | 2019 | 0.1 km (1 site) | 1 | 1 ⁸ |
| Upper Dan | South Fork Mayo River | | Patrick, Henry (VA); Rockingham (NC) | VA, NC | Not reported | Present | Present | Moderate | 2012 | 2016 | 18.9 km | 3 | 103-114 ⁹ |
| Upper Dan | Mayo River | | Rockingham | NC | Not reported | Present | Present | Low | 2016 | 2019 | 21.3 km | 2 | 23 |

¹ From U.S. Fish and Wildlife Service 1990 recovery plan, Table 1, Historic and Present occurrences of the James spiny mussel in 1990.

² From U.S. Fish and Wildlife Service 2008 Draft 5-year review for James spiny mussel, appendix 1, Present occurrence rivers of the James spiny mussel in 2008

³ See definitions for status in Section 2.3.1.2.

⁴ Estimated abundance based on modeling of mark-recapture study within a specific survey distance. Abundance is possibly larger because Johns Creek is augmented with propagated juveniles but we do not have post-release monitoring data.

⁵ Estimated abundance for reach #2 not reported because site was heavily degraded after high flow events and fallen trees in stream. In addition, propagated JSM have been released in the creek, but abundance was not estimated.

⁶ In 2019, 650 propagated juvenile JSM were released to 3 sites in the Tye River, potentially extending the total range to 31.7 km. These JSM are not included in the assessment of approximate abundance because we do not know if they have survived and been successfully established.

⁷ Estimate based on catch per unit effort and area of occupancy from 2016-2020. Cumulative not provided because some counts are mark-recapture data.

⁸ In 2021, 30 propagated juvenile JSM were released to Mill Creek; these JSM are not included in the assessment of approximate abundance because we do not know if they have survived and been successfully established.

⁹ Range provided because the number of JSM observed in 2002 varied from 96 to 107, depending on data source (Petty and Neves 2005, VDWR 2020b).

Table B-2. Part 2 of detailed population information on James spiny mussel waterbodies and subpopulations/areas. The first 5 columns are repeated from Table B-1. Pop=population; ND=not detected; PoExt=Possibly Extirpated; PreExt=Presumed Extirpated

| Basin/Subbasin (HUC8) | Waterbody | Area/Subpopulation ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|--------------------------|------------------------|---------------------------------|-------|---------------------------------|--|--|---|--|--|
| James River Basin | | | | | | | | | |
| Upper James | South Fork Potts Creek | | WV | Present | Yes, in past 5 years based on mussels in 35-45mm size class (Eliason and Everhart 2021) | Stable, large variation | Yes | lack of intact riparian zone, bank hardening, livestock entering stream/crushing mussels, agricultural watersheds, sedimentation | Everhart and Clayton 2016, Eliason and Everhart 2021 |
| Upper James | Potts Creek | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort since 2006 | No | bank erosion, cattle grazing in adjacent land, agricultural watersheds | VDWR 2020b |
| Upper James | Cowpasture River | | VA | Present | No | Increasing due to augmentation with propagated juveniles | No | dam, past fish kills, ford crossing | VDWR 2020b |
| Upper James | Bullpasture River | | VA | Likely present | Unknown | Unknown | No | | VDWR 2020b |
| Upper James | Little Oregon Creek | | VA | Present | Yes; in 2016, a large number of juvenile JSM (approximately 20 mm long) were observed during a mark-recapture survey | Decreasing, large variation and possible recovery | yes | predation, dam removal, invasive Asian clam, livestock entering stream/ damaging habitat and crushing mussels | Ostby 2022a |
| Upper James | Dicks Creek | | VA | Present | Yes; juvenile JSM (less than 30 mm) were detected in 2019 | Stable, large variation | Yes, but only 9 years of data analyzed from mark-recapture study. | predation, dam removal | Ostby 2022a |
| Upper James | Johns Creek | Near Maggie | VA | Present | Yes; site used as source of broodstock for propagation | Stable, large variation | Yes, but only 8 years of data analyzed from mark-recapture study. | predation, dam removal, eroding banks, agricultural watersheds, invasive Asian clam | VDWR 2020b, Ostby 2022a |
| Upper James | | Along Sevenmile Mountain | VA | Present | No | Unknown | No | livestock entering stream/ damaging habitat, causing siltation, and crushing mussels; invasive Asian clam | VDWR 2020b, Orcutt 2021 |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|-----------------------|-------------------|----------------------------------|-------|---------------------------------|--|--|---|--|--|
| Upper James | Craig Creek | near New Castle | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort since 2012 and most surveys occurring in 1999 | No | livestock entering stream/ damaging habitat and crushing mussels. | VDWR 2020b, VDWR 2020 |
| Upper James | | Craig Creek near Silent Dell | VA | Present | No | Decreasing | Yes, but only 7 years of data analyzed from mark-recapture study. | road/ford crossings, flooding/storms causing fallen trees and debris jams | VDWR 2020b |
| Upper James | | Craig Creek near Eagle Rock | VA | ND/ unknown | n/a | Unknown; most known sites with JSM have Not been surveyed in more than 20 years | No | | VDWR 2020b, VDCR-DNH 2021 |
| Upper James | Patterson Creek | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout creek | No | | VDWR 2020b, VDCR-DNH 2021 |
| Upper James | Catawba Creek | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout creek | No | agricultural watersheds | VDWR 2020b, VDCR-DNH 2021 |
| Maury | Calfpasture River | | VA | ND/ PreExt | n/a | Presumed extirpated; limited survey effort throughout river | No | | Service 1990; VDCR-DNH 2021 |
| Maury | Maury River | | VA | ND/ PreExt | n/a | Presumed extirpated; limited survey effort throughout river | No | dams | VDCR-DNH 2021; Watson pers. comm. 2022 |
| Maury | Mill Creek | | VA | Present | Yes; site used as source of broodstock for propagation | Increasing due to augmentation with propagated juveniles | Yes | | Ostby 2022a |
| Middle James- Buffalo | Pedlar River | | VA | Present | Yes; 2 sub-adults found in 2004 and 2019 | Unknown | No | bridge replacement, pipeline crossing maintenance/replacement, agricultural watersheds, past livestock access (Ostby 2009 survey report) | VDWR 2020b, VDCR-DNH 2021, Alderman 2020 pers. comm. |
| Middle James- Buffalo | Hardware River | | VA | Present | No | Unknown | No | | VDWR 2020b |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|-----------------------|--|----------------------------------|-------|---------------------------------|--|--|--|--|---|
| Middle James-Buffalo | Rock Island Creek | | VA | Present | Yes; site used as source of broodstock for propagation | Decreasing | No, only 9 years of available data (2011-2019) | sedimentation, bank erosion, high stormflow/flooding event caused falling trees into stream changing habitat, mowing to rivers edge | TOE and DC 2019, VDWR 2020b, Ostby 2022a |
| Middle James-Buffalo | Tye River | | VA | Present | No | Unknown | No | wastewater discharge, heavy siltation and sedimentation, possible herbicides from adjacent agricultural land. | VDWR 2020b |
| Middle James-Buffalo | Totier Creek (relic shells) | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout creek | No | heavy siltation and sedimentation, agricultural land adjacent to stream, dam | Chazal et al. 2012, Chazal 2013, VDWR 2020 |
| Rivanna | Mechums River | | VA | Present | No | Unknown | No | | VDWR 2020a, b; VDCR-DNH 2021 |
| Rivanna | Moormans River | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout river | No | agricultural watersheds | VDWR 2020a, b; VDCR-DNH 2022 |
| Rivanna | Wards Creek (mis-identified as Rocky Run [Moormans River]) | | VA | Present | Yes, juvenile JSM were observed in 2003 and 2011. | Unknown | No | residential development, eroding banks, pasture/agricultural runoff | Ostby and Angermeier 2012, VDWR 2020a. Ostby pers. comm. 2022 |
| Rivanna | Rocky Creek | | VA | Present | Yes; juvenile JSM (<30 mm) were detected in 2015 and 2017; site used as source of broodstock for propagation | Stable, large variation | No (only 9 years of available data 2011-2019) | failing culverts, lumber harvest, predation, farm pond restricting flow | Ostby 2015 and 2019, VDWR 2020b, Alexander 2021 |
| Rivanna | Buck Mountain Creek | | VA | Present | No | Unknown | No | possible livestock access to stream, pasture/agricultural runoff, clearing of riparian buffer, pipeline crossing, bridge replacement | Ostby and Angermeier 2012, Alexander 2021 |
| Rivanna | Piney Creek | | VA | Present | No | Unknown | No | | Ostby and Angermeier 2012, Alexander 2021 |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|------------------------|--------------------------------|-------------------------------------|-------|---------------------------------|---|--|---|---|---|
| Rivanna | Ivy Creek | | VA | Present | No | Unknown | No | reservoir/dam downstream restricting flow/connectivity; residential development | Ostby and Neves 2011, VDWR 2020b, VDCR-DNH 2021 |
| Rivanna | NF Rivanna River | | VA | Present | Yes, 1 small JSM (<35 mm) detected in 2013. | Unknown | No | flooding, urban expansion of Charlottesville | The Catena Group 2015, VDWR 2020 |
| Rivanna | Swift Run | | VA | Present | Yes, 2 juvenile JSM less than 4 years old detected in 2014. | Not clear because of large variation and low detection rates | Yes | muskrat and raccoon predation, eroding banks, pasture/agricultural runoff | Ostby 2019a and 2019b, VDWR 2020b, Ostby pers. comm. 2021 |
| Rivanna | Unnamed tributary to Swift Run | | | Present | No | Unknown | No | | Ostby 2019a and 2019b, VDWR 2020b |
| Rivanna | Welsh Run | | VA | Likely present | Unknown | Unknown | No | | Ostby 2019a and 2019b, VDWR 2020b |
| Rivanna | Rivanna River | near Columbia, Palmyra, and Crofton | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | VDWR 2020a, b |
| Rivanna | Mechunk Creek (relict shell) | | VA | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout creek | No | | VDWR 2020a, b |
| Upper James (mainstem) | James River | James River at Buchanan | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Ostby and Angermeier 2009 VDWR 2020a, b; Carey 2021 |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|---------------------------------|-----------|---|-------|---------------------------------|---|--|---|--|-----------------------------------|
| Upper James (mainstem) | | James River Bridge near Natural Bridge | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | VDWR 2020a, b |
| Middle James-Buffalo (mainstem) | | James River at New Canton | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | power plant discharges, coal ash ponds | Chazal et al. 2012, VDWR 2020a, b |
| Middle James-Willis (mainstem) | | James River at Columbia | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Chazal et al. 2012, VDWR 2020a, b |
| Middle James-Willis (mainstem) | | James River at Pemberton and Cartersville | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Chazal et al. 2012, VDWR 2020a, b |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ₁ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|--------------------------------|-----------|----------------------------------|-------|---------------------------------|--|--|---|---|--|
| Middle James-Willis (mainstem) | | James River at Rock Castle | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Chazal et al. 2012, VDWR 2020a, b |
| Middle James-Willis (mainstem) | | James River opposite Maidens | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Chazal et al. 2012, VDWR 2020a, b |
| Middle James-Willis (mainstem) | | James River at Maidens | VA | ND/ PreExt | n/a | Presumed extirpated; difficult to survey a large river, surveys sites did not occur in all reaches of the river, low detection rates for JSM, and there continues to be suitable mussel habitat. | No | | Chazal et al. 2012, VDWR 2020a, b |
| Roanoke River Basin | | | | | | | | | |
| Upper Dan | Dan River | | NC | Present | Yes, 3 JSM less than 5 years old observed. | Possibly decreasing | Yes | natural flood events, hydroelectric dam operations, bridge replacement, sediment and nutrients from construction sites, mining operations, agricultural operations, logging operations, and excessive stormwater flow off impervious surfaces | NCWRC 2020; Perkins pers. comm. 2020, 2021, 2022 |

| Basin/Subbasin (HUC8) | Waterbody | Area/Sub-population ¹ | State | Pop status in 2021 ² | Evidence of recruitment (if yes, explain) | 2021 Trend (unknown, increasing, stable, decreasing, or presumed extirpated) | Based on 10 years of monitoring (yes or no) | Primary threats to JSM | references |
|-----------------------|-----------------------|----------------------------------|--------|---------------------------------|---|--|---|--|--|
| Upper Dan | Big Creek (shell) | | NC | ND/ PoExt | n/a | Possibly extirpated; limited survey effort throughout creek | No | | NCWRC 2020b, Perkins pers. comm. 2022 |
| Upper Dan | Mill Creek | | NC | Present | No | Unknown | No | | NCWRC 2020; Perkins pers. comm. 2021, 2022 |
| Upper Dan | South Fork Mayo River | | VA, NC | Present | Yes, 4 juveniles (<15 mm) observed in 2002. | Unknown | No | agricultural watersheds | Petty 2005, VDWR 2020b, NCWRC 2020b, VDWR-DNH 2021 |
| Upper Dan | Mayo River | | NC | Present | No | Possibly decreasing | Yes, but at low frequency (e.g., 7-8 years apart over 15 years) | agricultural watersheds, sedimentation, dams, treatment plant discharges | NCWRC 2020b, Perkins pers. comm. 2021 |

¹ From U.S. Fish and Wildlife Service 1990 recovery plan, Table 1, Historic and Present occurrences of the James spiny mussel in 1990.

² See definitions for status in Section 2.3.1.2.