Northern Riffleshell
(*Epioblasma torulosa rangiana*)

5-Year Review:
Summary and Evaluation

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2019

U.S. Fish and Wildlife Service
Pennsylvania Field Office
110 Radnor Road, Suite 101
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5-YEAR REVIEW

Species reviewed: Northern Riffleshell (*Epioblasma torulosa rangiana*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Region 5, Martin Miller, 413-253-8615

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814-234-4090, x7447

Cooperating Field Offices:
Indiana Field Office, Lori Pruitt, 812-334-4261
Kentucky Field Office, Mike Floyd, 502-695-0468, x102
Michigan Field Office, Jessica Pruden, 517-351-8245
New York Field Office, Sandra Doran, 607-753-9699
Ohio Field Office, Angela Boyer, 614-416-8993
West Virginia Field Office, Barbara Douglas, 304-636-6586, x19

Cooperating Regional Offices:
Region 3, Laura Ragan, 612-713-5292
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1.2 Methods Used to Complete the Review

Public notice was given in the Federal Register (83 FR 39113) requesting new scientific or commercial data that have become available since the previous 5-year review was completed in 2008. Pertinent data were obtained from the previous 5-year review, from recent reports of freshwater mussel surveys, and from data submitted by U.S. Fish and Wildlife Service (Service) Field Offices and State and Provincial natural resource agencies within the range of the species. This 5-year review was completed by Robert Anderson and Melinda Turner, Assistant Field Office Supervisor and Fish and Wildlife Biologist, respectively, with the Pennsylvania Ecological Services Field Office. The purpose of this 5-year review is to review new information since the last review of the species' status in 2008 and consider whether any of this information indicates that a change in the listing status of the northern riffleshell may be warranted.

1.3 Background

1.3.1 FR Notice citation announcing initiation of this review:

83 FR 39113 (August 8, 2018): Notice of Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Reviews of 19 Northeastern Species: Roseate tern (*Sterna dougallii dougallii*), Roanoke logperch (*Percina rex*), Virginia big-eared bat (*Corynorhinus* [=*plecotus*] *townsendii virginianus*), Dwarf wedgemussel (*Alasmidonta heterodon*), Northern riffleshell (*Epioblasma torulosa rangiana*), Clubshell (*Pleurobema clava*), Purple bean (*Villosa perpurpurea*), Puritan tiger beetle (*Cicindela puritana*), Northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*), Flat-spired three-toothed [=Cheat] snail (*Triodopsis*

platysayoides), Chittenango ovate amber snail (*Novisuccinea chittenangoensis*), Bog turtle (*Glyptemys* [=*Clemmys*] *muhlenbergii*), Sandplain gerardia (*Agalinis acuta*), Peter's Mountain mallow (*Iliamna corei*), Furbish's lousewort (*Pedicularis furbishiae*), Northeastern bulrush (*Scirpus ancistrochaetus*), American hart's-tongue fern (*Asplenium scolopendrium* var. *americanum*), Knieskern's beaked-rush (*Rhynchospora knieskernii*), and Virginia sneezeweed (*Helenium virginicum*).

1.3.2 Listing history:

FR notice: 58 FR 5638-5642
Date listed: January 22, 1993
Entity listed: Subspecies
Classification: Endangered, Entire Range

1.3.3 Associated rulemakings: None

1.3.4 Review History: Last 5-year review completed in 2008.

1.3.5 Species' Recovery Priority Number at start of 5-year review: 6 (indicating that the northern riffleshell is taxonomically categorized as a subspecies, has a high degree of threat, and has low recovery potential)

1.3.6 Recovery plan:

Name of plan: Clubshell (*Pleurobema clava*) and Northern Riffleshell (*Epioblasma torulosa rangiana*) Recovery Plan
Date issued: September 21, 1994
Dates of previous revisions: None

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? The subspecies is an invertebrate; therefore, the DPS policy is not applicable to this listing.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria? Yes; however, see Section 2.2.3.

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? No.

2.2.2.2 Are all of the five 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)? No.

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:

1994 Recovery Plan Criteria

To ***reclassify*** the northern riffleshell as threatened from endangered, this criterion must be met:

1. Viable populations must be documented in 10 separate drainages for this species. A viable population consists of sufficient numbers of reproducing individuals to maintain a stable or increasing population. These populations should include as many subpopulations as possible to maintain whatever fraction of the original genetic variability that remains.

   The following drainages are identified as necessary to achieve recovery: Tippecanoe River (Indiana), Detroit River (Michigan/Ontario – contingent on zebra mussel control), Fish Creek (Ohio), Green River (Kentucky), Big Darby Creek (Ohio), Elk River (West Virginia), French Creek (Pennsylvania), Allegheny River (Pennsylvania), and two additional as yet unidentified drainages.

   This criterion is partially met. Reproducing populations occur in 2 of the 10 listed waterways: the Allegheny River and its tributary French Creek, both in Pennsylvania. Apparently reproducing populations (*i.e.*, surveys found a range of sizes, including smaller individuals that likely resulted from recent recruitment) also occur in two additional streams: East Branch Sydenham River and Ausable River, both in Ontario, Canada.

To ***remove*** the northern riffleshell from the Federal list of threatened and endangered species, the following additional criteria must be met:

2. Each of the 10 populations in Criterion 1 must be large enough to survive a single, adverse stochastic event. At this time, most populations are localized and susceptible to such impacts. Therefore, the extent of most populations must be increased, either naturally or through translocation.

3. The populations and their drainages in Criteria 1 and 2 must be permanently protected from all foreseeable and controllable threats, both natural and anthropogenic.

   The criteria have not been met and it is doubtful that they could be met. The specific condition of each of the required populations is described below in section 2.3.1.2. Zebra mussel control in the Detroit River is unlikely. The reasons for the apparent continued decline of the northern riffleshell in streams such as the Green River, Tippecanoe River, Elk River, and Big Darby Creek are not clearly understood. These streams continue to support numerous other freshwater mussel species and confirmed or potential host fish. Until the particular threats influencing northern riffleshell populations are identified, Criterion 3 cannot be achieved. Between 2010 and 2018, adult northern riffleshells have been relocated to a number of streams required to achieve species recovery, including in New York, Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and Illinois. There is no evidence of successful reproduction in these augmented or reintroduced populations, but natural reproduction and growth may not be observed for several years (see section 2.3.1.2 and table 1 for additional information).

In addition to not being met, these recovery criteria are vague, in that: (1) population viability is not defined, (2) the separation distance (between sub-populations) necessary to ameliorate catastrophic events is not identified, (3) population protection is not well defined, and (4) habitat protection is not well defined. Several recovery tasks (actions) are intended to address habitat and population protection, but the needs of this species, including its environmental tolerances, are not well understood (see section 4).

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:

We have no new information on the biology and life history of this species since the last 5-year review.

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

The northern riffleshell was listed as endangered in 1993. Historical and/or current northern riffleshell records are known from *Illinois* (Wabash River and Vermilion River); *Indiana* (Maumee River, St. Marys River, St. Joseph River, Fish Creek, Wabash River, White River, West Fork White, East Fork White, Big Blue River, Flat Rock River, Conns Creek, Brandywine Creek, Vermilion River, Wildcat Creek, Tippecanoe River, Eel River, and Mississinewa River); *Kentucky* (Ohio River, Green River, Barren River, Drakes Creek, Nolin River, Salt River, Beech Fork, and Kentucky River); *Michigan* (River Raison, Macon Creek, Huron River, Detroit River, Upper Rouge, Clinton River, Black River, and Lake St. Clair); *Ohio* (Lake Erie, Sandusky River, Maumee River, St. Joseph River, Fish Creek, Ohio River, Scioto River, Big Darby Creek, Little Darby Creek, Big Walnut Creek, Alum Creek, Olentangy River, Muskingum River, Tuscarawas River, and Mahoning River); *Pennsylvania* (Allegheny River, Mahoning River, French Creek, Conewango Creek, Muddy Creek, and LeBoeuf Creek); New York (Allegheny River); *West Virginia* (Ohio River, Kanawha River, and Elk River); and *Ontario, Canada* (Lake Erie and Lake Huron, Sydenham River, Detroit River, Ausable River, and Lake St. Clair).

At the time of listing, the northern riffleshell was thought to be extant in relatively short reaches of six streams: the Green River (Kentucky), Detroit River (Michigan), Big Darby Creek (Ohio), and French Creek, LeBoeuf Creek, and Allegheny River (Pennsylvania). The current status of each northern riffleshell population is discussed below, and extant populations are summarized in table 1. Note, the streams and locations shown in bold below are listed in the Recovery Plan as areas where stable northern riffleshell populations are necessary to achieve recovery:

Allegheny River System

- In the **Allegheny River, Pennsylvania**, northern riffleshells have been documented to occur in good abundance at several locations, but the species' distribution is discontinuous (*i.e.*, localized to areas of suitable habitat). In the most recent studies (conducted about 15 years ago), the condition of these populations ranged from those exhibiting successful reproduction to those with apparently depressed vigor and a predominance of older adults (U.S. Geological Survey (USGS) 2004). Until recently the most upstream location of live northern riffleshells in Pennsylvania was near the City of Warren, Pennsylvania (EnviroScience 2002). The Allegheny River in Warren is strongly

influenced by hypolimnetic releases from Kinzua Dam, and this population, which is downstream of the dam, appears to be dependent on warmer, more nutrient-rich water coming from Conewango Creek, which confluences with the Allegheny River immediately upstream of the habitat supporting this species. Northern riffleshells have since also been found upstream of Kinzua Dam in the Allegheny River, Cattaraugus County, New York (USFWS 2019).

Northern riffleshells appear to become a frequent member of the Allegheny River mussel community about 9 miles below Warren, with peak densities documented near the Forest and Venango County line. At that location, northern riffleshells were the dominant mussel species, with a mean density of 7.57 individuals/square meter (m^2) and an estimated population of 169,622 individuals in a 100-meter-wide cross-section of the Allegheny River (USGS 2002).

Sampling at the West Hickory bridge over the Allegheny River at West Hickory, Pennsylvania in 1999 revealed a mean density of $0.5/m^2$ (USGS 2004). Approximately 42,758 and 42,650 northern riffleshells were estimated to occur in 100-meter-wide river sections located 200 and 300 meters downstream, respectively, of the existing bridge (USGS 2000). Compared to the West Hickory site, northern riffleshells have been found to be more abundant both upstream and downstream, with a mean density of $1.8/m^2$ at five sites quantitatively sampled between Tidioute and Tionesta. Northern riffleshell populations are known from scattered locations in the middle Allegheny River (*e.g.*, near the towns of Kennerdell, Foxburg, Oil City, Parker, and East Brady and downstream to river mile 58), where population densities are generally less than $0.1/m^2$. The total population of the northern riffleshell in the Allegheny River may exceed 6,500,000 individuals (Villella 2007).

- Between 2015 and 2017, bridge construction on the Allegheny River prompted a salvage operation to remove thousands of northern riffleshell from the impacted area and relocate them to suitable habitat to reestablish or augment existing populations throughout their historical range, including streams in Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and New York. The Federal Highway Administration, in conjunction with the Pennsylvania Department of Transportation Engineering District 1-0, proposed to replace the State Route 62, Section B01 Bridge, known locally as the Hunter Station Bridge, over the Allegheny River in Tionesta Township, Forest County, Pennsylvania. As part of the Hunter Station Bridge Replacement Project, a salvage plan was developed to reduce mussel fatalities and promote northern riffleshell recovery. A total of 27,082 northern riffleshell were salvaged and translocated between 2015 and 2017 (EnviroScience 2019).

- On September 7, 2018, one northern riffleshell was discovered in the upper Allegheny River, in the Town of Olean, Cattaraugus County, New York. Although native to the Allegheny River, northern riffleshells had not previously been documented in New York. As detailed above, northern riffleshells are found below the Kinzua Dam, Pennsylvania. The Kinzua Dam/Allegheny Reservoir near the Pennsylvania and New York State line likely blocks any natural, upstream range expansion. Between 2015 and 2018, northern riffleshells were reintroduced to the upper Allegheny River by the Seneca Nation. These reintroductions occurred several miles downstream of the Cattaraugus County record and the age of the individual (5 to 6 years old) predates the downstream reintroductions. The more likely explanation derives from the 2013 stocking of gilt darters (*Percina evides*) approximately 0.5 mile upstream of the Cattaraugus County record. The gilt darter is a

known host, and stock used for relocation were collected from an area with a known population of the northern riffleshell (Foster 2014). The age of the individual northern riffleshell correlates to the gilt darter stocking event, and it is likely that this mussel encysted on a gilt darter that was collected for reintroduction, and then metamorphosed after the fish was reintroduced (USFWS 2019). Three additional northern riffleshells were located at the Olean site in July 2019.

- Between 2015 and 2018, the Seneca Nation relocated 3,058 northern riffleshells to the upper Allegheny River (above Kinzua Dam/Allegheny Reservoir), Seneca Nation Territory, New York (Titus 2019). Between 2015 and 2017, translocated mussels were from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania. In 2018, translocated mussels were from the Allegheny River, Warren County, Pennsylvania (from the location of a proposed pipeline crossing). The Seneca Nation is currently seeking funding to do a comprehensive mussel survey on the entire Seneca Nation Territory (Titus 2019).

- The northern riffleshell population is discontinuously distributed in approximately 60 miles of lower **French Creek, Pennsylvania**, from its confluence with the Allegheny River at Franklin, upstream to the vicinity of the State Route 6 Bridge at Mill Village. Within this reach, northern riffleshells range from relatively common to rare or absent at sites that have otherwise diverse mussel communities. For example, of 31 sites investigated along the length of French Creek in 2003, northern riffleshells were documented to occur at 9 of the lower 21 sites, where population estimates in 2004 ranged from 23 to over 10,000 individuals (Smith and Crabtree 2005). These 9 sites supported mussel assemblages containing from 6 to 19 species, although they were often separated by sites that appeared to be equally diverse (up to 15 species) but did not include the northern riffleshell (Smith and Crabtree 2005).

- Northern riffleshells have also been found in four Allegheny River tributaries, Conewango Creek in Warren County; Oil Creek, Venango County; Sandy Creek, Venango County; and Tionesta Creek in Forest County (downstream of Tionesta Lake; Chapman 2019), as well as in the lower reaches of two French Creek tributaries, Muddy Creek (Crawford County) and LeBoeuf Creek (Erie County). Due to the proximity of these populations to French Creek and the Allegheny River, they may represent extensions of the larger mainstem population rather than self-sustaining subpopulations.

Ohio River

- Between 2014 and 2016, northern riffleshells were translocated from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania, and released at three sites in the Ohio River: Muskingum Island and Buckley Island, Wood County, West Virginia, which are located within the Belleville Pool; and Ohio River Mile 284 in the Greenup Pool, Mason County (West Virginia Department of Natural Resources (WVDNR) 2014; Clayton 2019). A summary of each restoration site follows:

    - A total of 3,092 northern riffleshells were stocked into the Belleville Pool at Muskingum Island. Mortality has been low with only five northern riffleshells confirmed dead as of 2017 monitoring; however, relocation of stocked individuals is low (Clayton 2019).

- A total of 2,595 northern riffleshells were stocked into the Belleville Pool at Buckley Island. Thirteen dead northern riffleshell have been found again as of 2017 monitoring (Clayton 2019).

- A total of 1,894 northern riffleshells were stocked into the Greenup Pool (Ohio River Mile 284). Thirteen dead northern riffleshells have been found again as of 2017 monitoring (Clayton 2019). Locating stocked northern riffleshells again continues to be low in this area, although little mortality has been observed. With the gravel, sand, and cobble habitat, it may be that the mussels can bury deeper than the passive integrated transponder (PIT) tag reader can detect tags (WVDNR 2018a).

Wabash River System

- No living or freshly dead northern riffleshells have been found in Indiana since the last 5-year review was completed in 2008, except for those that have recently been reintroduced (Fisher 2019). In 2015, the Indiana Department of Natural Resources began reintroducing northern riffleshells to the **Tippecanoe River, Indiana**. Between 2015 and 2016, 3,083 northern riffleshells (441 PIT-tagged and 2,642 marked with glitter for future identification if the individual is found again) were collected from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania, and translocated to habitat at three locations in the Tippecanoe River, Pulaski and White Counties (Fisher 2018). As of September 2018, of the 441 PIT-tagged individuals, 31 percent (n=137) are known dead and 18 percent (n=78) are unaccounted for. Of the 2,642 glittered individuals, approximately 10 percent (n=256) are known dead (Fisher 2018).

- Staff from the Illinois Natural History Survey participated in a joint project with the Illinois Department of Natural Resources and the Service to reintroduce the northern riffleshell to Illinois. A total of 3,699 northern riffleshells have been collected from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania, and translocated to suitable habitat at eight sites in the Vermilion River basin (Middle Fork Vermilion River and Salt Fork Vermilion River) in Champaign and Vermilion Counties, Illinois. A total of 2,099 northern riffleshells were PIT-tagged to allow monitoring to determine success of the project. Monitoring data suggest very few northern riffleshells likely remain. Survival varied among translocation sites, likely a result of local scale habitat differences such as substrate or gradient. Also, high discharge events posed the greatest threat for the long-term success of this project, as survival was significantly decreased following periods of abnormally high flows. It is too early to tell if the northern riffleshell reintroduction program in Illinois has been a success because no recruitment has been documented. Repeated translocations of individuals over a period of several years across several sites could be implemented to reduce the overall risk of failure due to high discharge events or local-scale habitat differences (Stodola *et al*. 2017; Tiemann *et al*. 2019).

Saint Lawrence/Great Lakes System

- Michigan Natural Features Inventory performed mussel surveys at 21 sites in the **Detroit River, Michigan/Ontario**, in the summer of 2007, and 10 sites in Lake St. Clair,

Michigan, in the summer of 2008. The northern riffleshell has not been found alive in the Detroit River since 1990, although Michigan Natural Features Inventory personnel found several empty valves in 2005 and 2006 (Badra 2009). Northern riffleshell populations in these systems have experienced severe declines since the introduction of the nonnative zebra mussel (*Dreissena polymorpha*) in the late 1980s, and the more recent introduction of the quagga mussel (*Dreissena bugensis*). No live northern riffleshells were observed during 2007 and 2008 surveys although shells were found at six sites in Lake St. Clair and one site in the Detroit River (Badra 2009). During 2007 and 2008 surveys, live zebra and quagga mussels were observed at all of the Lake St. Clair survey locations and most of the Detroit River survey locations (Badra 2009).

- No living or freshly dead northern riffleshells have been found for at least 20 years during surveys of historical habitat in the Raisin River, Huron River, and Black River, Michigan (Kost *et al*. 2012; ASTI Environmental 2018a; ASTI Environmental 2018b).

- Northern riffleshells are present in small numbers in the Ausable River in Ontario, Canada (Lake Huron tributary). However, while showing evidence of successful recruitment, this small extant population is apparently declining (Prichard 2007, McGoldrick *et al.* 2007). *No new information since last 5-year review.*

- The northern riffleshell population in the east branch Sydenham River in Ontario, Canada, (Lake St. Clair tributary) is reported to be extant at 17 sites (Metcalfe-Smith *et al*. 2003). However, this population may have declined by 90 percent in the past 30 years and is threatened by continued siltation (Pritchard 2007). *No new information since last 5-year review.*

Maumee River System

- No living or freshly dead shells of the northern riffleshell were found during 2009, 2010, 2011, and 2012 mussel surveys on **Fish Creek, Ohio** (Ahlstedt 2009; Ahlstedt 2010; Ahlstedt 2011; EnviroScience 2012).

- Five weathered dead shells of the northern riffleshell were found during September 2012 surveys at one site on St. Joseph River (located at the mouth of Fish Creek), Williams County, Ohio (EnviroScience 2012).

Green River System

- Freshly dead shells of the northern riffleshell were reported in 1987 and 1989 from two sites in the **Green River, Kentucky**, both within the Mammoth Cave National Park (Ryan Evans, Kentucky Nature Preserves Commission, 2007 personal communication). There are no more recent survey reports from this area, and the current status of the northern riffleshell in the Green River is unknown. *No new information since last 5-year review.*

Licking River

- Between 2012 and 2016, the Kentucky Department of Fish and Wildlife Resources released 6,323 northern riffleshells at 7 locations in the Licking River, Kentucky

(McGregor 2017). According to the Recovery Plan, there were no known northern riffleshell records in the Licking River prior to these releases (USFWS 1994). In 2016, multiple live northern riffleshells from previous (*i.e.*, before 2016) releases were observed at multiple release sites (McGregor 2017).

Scioto River System

- During a survey of the lower 20 miles of **Big Darby Creek, Ohio**, a young (approximately 8-year-old) female northern riffleshell was found on June 16, 2000, in the upstream reach in Pickaway County (Angela Zimmerman, USFWS, 2007 personal communication). No other living or freshly dead shells of the northern riffleshell have been found during recent surveys of Big Darby Creek, and native populations of the species may now be extirpated (G. Thomas Watters, Ohio State University, 2007 personal communication). However, between 2008 and 2013, 7,776 northern riffleshells were translocated from the Allegheny River to Big Darby Creek to augment any remnant population of native animals. These animals are monitored on an irregular basis, and survival has been documented, but no evidence of reproduction has been found thus far (Trisha Gibson, Ohio State University, email June 20, 2019).

Kanawha River System

- Two living specimens were found in 1993 at one site in the **Elk River**, **West Virginia**. Northern riffleshell translocations into the Elk River at Queen Shoals began in 2012. As of December 2018, a total of 1,436 northern riffleshells have been placed in the Elk River via translocation and stocked juveniles. Mortality has been significant over the years, most evident by otter predation. A PIT-tag reader was scanned over the entire restoration area on July 19, 2017. Only six detections were recorded from the approximately 1,228 northern riffleshells that remain in the Elk River (WVDNR 2018a). At least 218 individuals are known to have died, and river otters have significantly impacted restoration efforts (WVDNR 2018b).

  The WVDNR in cooperation with the U.S. Environmental Protection Agency (EPA), began an environmental deoxyribonucleic acid (eDNA) research project to determine whether the nondetection of northern riffleshells in the Elk River was a result of mortality or being washed downstream. Water and sediment samples were collected October 12 and 19, 2017, for eDNA analysis. Samples were collected from the Elk River at Queen Shoals: upstream of the restoration site, at the restoration site, and at each riffle downstream of the restoration site with the last sample collected approximately 15 kilometers (km) downstream of the restoration site near Walgrove, West Virginia. Samples have not been analyzed; however, during the first day of sampling, northern riffleshells were recorded via PIT-tag reader at the restoration site. Four riffle habitats downstream of the restoration site were also surveyed using the PIT-tag reader; however, no northern riffleshells were recorded (WVDNR 2018b).

- In 2014, 100 northern riffleshell from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania, were introduced to the Kanawha River, downstream of Kanawha Falls at Glen Ferris, Fayette County, West Virginia. All specimens were PIT-tagged. In 2015, 7 live and 7 dead northern riffleshells were observed within the restoration area, and 16 additional individuals were detected by a PIT-tag reader. On

June 29, 2017, two live and three dead northern riffleshell were observed. Survey effort entailed significant sweeping of the substrate but no excavations (WVDNR 2018a).

- In 2016, a total of 1,829 northern riffleshells were translocated from the Hunter Station Bridge Replacement Project, Allegheny River, Pennsylvania, to the Kanawha River, at Deep Water, Fayette County, West Virginia. Both PIT-tags and poly-tags were used to uniquely tag 198 mussels placed into the monitoring cell. The remaining 1,631 mussels were tagged using green glitter and placed in the general area of a 100-meter transect line positioned at an obtuse angle to shore. The location for the translocation was previously identified in 2014 by the Hunter Station Bridge Replacement Project consultants working in conjunction with WVDNR Mussel Program staff. Twenty-two mussel species (including three other federally listed species) were documented at this site in 2014; therefore, it was ultimately selected as the translocation site. Unfortunately, when the mussel consultant staff returned in 2016, they placed the mussels 10 to 20 meters away from the best habitat and resident mussel populations. Northern riffleshells were placed in an area with poor habitat (*i.e.*, boulders and cobble with little interstitial sand and gravel). Between July 11 and 13, 2017, WVDNR Mussel Program staff conducted quantitative and semi-quantitative surveys of the translocation site. Only six dead individuals were observed, and no live northern riffleshells were observed during these surveys. A PIT-tag reader was scanned over the translocation area and the PIT-tag scan resulted in only 13 pings of the 198 PIT-tagged mussels placed there. Five live and seven dead northern riffleshells were observed during PIT-tag surveys. Because of the poor habitat in which they were placed, it is possible the translocated mussels were unable to adequately bury into the substrate and were washed downstream during high flow events (WVDNR 2018a).

In summary, northern riffleshells appear to be restricted to four, successfully recruiting populations in the Ohio and Saint Lawrence/Great Lakes Basins, specifically the east branch of the Sydenham River, Allegheny River, French Creek, and Ausable River populations. The Elk River population is possibly extant and has been augmented, but recruitment has not been documented as of 2018. Since the species was listed as endangered, populations in Fish Creek, Detroit River, Green River, Big Darby Creek, and Tippecanoe River have undergone severe declines and recent surveys failed to locate living specimens. Although additional surveys are ongoing, northern riffleshells may have been extirpated from these systems. However, translocations have occurred to Big Darby Creek and the Tippecanoe River as described below (table 1).

Northern riffleshells have been moved from the Allegheny River to several streams in the historical range of the species to augment existing populations or reintroduce the species to increase redundancy and species recovery. These relocations occurred from 2014 to 2018, and no evidence of successful recruitment has been documented; however, juvenile northern riffleshells take several years to reach a size that is likely to be detected.

Table 1. Currently extant northern riffleshell populations.

Basin	Population	Stream	Approximate Range	Status 2019 and notes
Saint Lawrence/Great Lakes	Lake St. Clair	East Branch Sydenham River	Lower and middle reaches, 17 sites.	Recruitment documented; declining.
	Lake Huron	Ausable River	Upper and middle reaches.	Recruitment documented; declining.
	Maumee River	Fish Creek	Last reported in early 1990s, 2-mile reach.	Status unknown; possibly extirpated. no living or freshly dead shells found during 2009, 2010, 2011, and 2012 surveys
	Detroit River	Lake St. Clair/Detroit River		Only shells were found during a 2007/2008 survey. Status unknown; possibly extirpated since the introduction of nonnative zebra and quagga mussels.
Ohio River	Green River	Green River		One to two freshly dead shells found in 1987 and 1989 at two sites. Status unknown; possibly extirpated.
	Licking River	Licking River		In 2016, multiple live individuals observed at multiple release sites. Introduction of 6,323 individuals between 2012 and 2016 at 7 locations in the Licking River, Kentucky. No evidence of reproduction.

	Scioto River	Big Darby Creek	Lower 20 miles. Reintroduction between 2008 and 2016 at 22 locations.	Last reported in early 1990s; Reintroduction of 14,821 individuals. 1,598 live and 37 dead observed during 2017 monitoring of reintroduced individuals. No evidence of reproduction.
	Wabash River	Tippecanoe River	Reintroduction between 2015 and 2016 to 3 locations in the Tippecanoe River, Pulaski and White Counties, Indiana	Reintroduction of 3,083 individuals. As of September 2018, of the 441 PIT-tagged individuals, 31 percent (n=137) are known dead and 18 percent (n=78) are unaccounted for; of the remaining 2,642 individuals, approximately 10 percent (n=256) are known dead.
		Vermilion River	Reintroduction between 2010 and 2016 at 8 sites in the Vermilion River basin (Middle Fork Vermilion River and Salt Fork Vermilion River) in Champaign and Vermilion Counties, Illinois	Reintroduction of 3,699 individuals. Monitoring data suggest very few individuals likely remain; survival significantly decreased following periods of abnormally high flows. No evidence of reproduction.

	Allegheny River	Allegheny River (PA)	Scattered over 66 miles – Warren, Forest, Venango, Clarion, and Armstrong Counties, Pennsylvania	Successful recruitment at multiple sites; stable.
		Conewango Creek	Near the confluence with the Allegheny River.	A few live individuals found in 2005; no recruitment documented; status unknown.
		Sandy Creek	Located at the 965 bridge (8.6 miles upstream from the creek's confluence with the Allegheny River).	An assessment of Sandy Creek between the known location and the Allegheny River has not been completed. Status unknown.
		Tionesta Creek	300 meters from the confluence with the Allegheny River	A single individual was observed downstream of Tionesta Lake in 2017.
		Oil Creek	Found at several sites upstream to the ice dam in Oil Creek State Park (~5.25 river miles upstream from the creek's confluence with the Allegheny River).	An assessment of Oil Creek between the upstream-most observation and the Allegheny River has not been completed. Status unknown.
		Allegheny River (NY)	1 individual discovered in Cattaraugus County, New York, in 2018. Three additional in 2019.	Possibly released during the 2013 stocking of gilt darters; mussel may have been encysted on a gilt darter and then metamorphosed after the fish was reintroduced.
			Reintroduction between 2015 and 2018 to the Seneca Nation Territory, New York	Reintroduction of 3,058 individuals to the Allegheny River. The Seneca Nation is currently seeking funding to do a comprehensive mussel survey.

	French Creek	French Creek	Scattered over 60 miles - Venango and Crawford Counties, Pennsylvania.	Successful recruitment at multiple sites; stable in 2018.
		LeBoeuf Creek	3-mile reach	Recruitment documented; stable in 2018.
		Cussewago Creek	Found near the confluence with French Creek.	Peripheral to French Creek; status unknown.
		Muddy Creek	1 site near the confluence with French Creek.	Peripheral to French Creek; status unknown.
	Kanawha River	Kanawha River	Pilot reintroduction site in 2014, just downstream of Kanawha Falls at Glen Ferris, Fayette County, West Virginia	100 individuals stocked in September 2014. Assessed in 2015 and 2017; 10 confirmed dead. No evidence of reproduction.
			Reintroduction in 2016 at Deep Water, Fayette County, West Virginia; mussels were mistakenly placed in poor habitat	Reintroduction of 1,829 individuals. Site was assessed in 2017, no live and 6 dead individuals observed; PIT-tag scan only resulted in 13 pings of the 198 PIT-tagged mussels placed there, of these, 5 live and 7 dead observed; site warrants further investigation. No evidence of reproduction.
		Elk River	One site in Kanawha County, West Virginia	Two freshly dead shells found in 2003. Status unknown; possibly extirpated.

			Augmentation in 2014 to 2017 at a site in Kanawha County, West Virginia	1,436 stocked over six events. Last assessed July 2017, 11 individuals were recorded via PIT-tags, and 1 live observed; river otters have significantly impacted restoration efforts; 198 of the 1,436 are confirmed dead over 14 monitoring efforts, most by otters.
	Ohio River	Ohio River	Reintroduction between 2014 and 2016 at Muskingum Island, Belleville Pool, Wood County, West Virginia.	Reintroduction of 3,092 individuals. Assessed in 2017; 5 confirmed dead; recovery of stocked individuals is low. No evidence of reproduction.
			Reintroduction between 2014 and 2016 at Buckley Island, Belleville Pool, Wood County, West Virginia.	Reintroduction of 2,595 individuals. Assessed in 2017; 13 confirmed dead. No evidence of reproduction.
			Reintroduction between 2014 and 2016 at Ohio River Mile 284, Greenup Pool, Mason County, West Virginia.	Reintroduction of 1,894 individuals. Assessed in 2017; 13 confirmed dead. No evidence of reproduction.
	Beaver River	Shenango River	Reintroduction between 2015 and 2016 at 3 sites in Mercer County, Pennsylvania	Reintroduction of 270 individuals. No evidence of reproduction.
TOTALS	**13 populations**	**23 streams**	**4 populations in 6 streams recruiting**	

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

We have no new information on the genetics, genetic variation, or trends in genetic variation of this species since the last 5-year review.

2.3.1.4 Taxonomic classification or changes in nomenclature:

The taxonomy of the northern riffleshell and related taxa has been variable due to uncertain species' designations, a general change in the definition of the species' concept in freshwater mussels (Williams *et al.* 2017), and ecophenotypic variation. The decline and extinction of many *Epioblasma* occurred before genetic techniques became available to provide data that could be informative to the species' taxonomy.

At the time the northern riffleshell was listed as endangered as *Epioblasma torulosa rangiana* it was one of three subspecies along with the tubercled blossom, *Epioblasma torulosa torulosa*, and green blossom, *Epioblasma torulosa gubernaculum*. The tubercled blossom and green blossom have not been reported alive since the 1960s and 1980s, respectively. Another taxon that has been confused with the northern riffleshell is the Wabash riffleshell, *Epioblasma sampsonii*, which also appears to be extinct (Stansberry 1970).

Many freshwater mussel species have shells that tend to be thicker, more rounded, and more heavily sculptured (ridges, nodules, tubercles) in larger rivers, but transition to express more compressed, larger, and smoother shells when collected from smaller streams (Ball 1922). Both the northern riffleshell and green blossom have been considered by some to be compressed, smooth, headwater forms of the tubercled blossom (*e.g.*, Johnson1978, Parmalee and Bogan 1998). The degree of shell sculpture varies by location in both sexes, but female green blossom and tubercled blossom (and Wabash riffleshell) have a distinct medial sulcus (flattened or depressed area of the shell between the medial and anterior ridge of the shell) that extends through the marsupial expansion (expansion along the anterior of the shell in reproductively active female *Epioblasma*), which is compressed. By contrast, shells of female northern riffleshells lack distinct sculpture and have no, or a very shallow, sulcus that transitions to a swollen marsupial expansion. The compressed headwater expression of tubercled blossom may have been identified as the northern riffleshell by researchers who gave deference to collection location, particularly when few adult female specimens were available to examine. The shells of the males of each of these mussel taxa can sometimes be difficult or impossible to distinguish based on shell characters alone. Specimens of the northern riffleshell from larger rivers do not develop substantial shell sculpture, tubercles, or a deep sulcus (Ortmann 1919; Ball 1922).

The northern riffleshell historically occurred sympatrically with tubercled blossom in some locations such as the Wabash River and Sciota River (Johnson 1978; Watters *et al*. 2009). Ortmann (1926) considered "torulosa" in the Green River to be "gubernaculum," but specimens identified later have been referred to as 'rangiana,' apparently based on the assumption that 'gubernaculum" is restricted to the upper Tennessee River system. These smooth, compressed headwater specimens may

represent the headwater ecophenotype of the tubercled blossom rather than the northern riffleshell.

Bogan (1997) determined that the name "biloba" is a senior synonym for "rangiana" based on a specimen from the Green River, Kentucky. The northern riffleshell is sometimes referred to as *Epioblasma torulosa biloba* (*e.g.*, Parmalee and Bogan 1998), but this change has not been widely accepted. The Service considers Williams *et al.* 2017 to be the defining taxonomy and recognizes *Epioblasma rangiana* as the correct scientific name for the northern riffleshell. As such, the northern riffleshell remains a valid listable entity. See section 4.0 for recommendation to formally change the species' scientific name.

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

The northern riffleshell was historically widespread in the lower Great Lake (Lake Huron and Lake Erie and upper Ohio River drainages but now has a restricted range, although population numbers can be high in localized areas. Of 54 streams once known to be occupied by this species, only 4 show evidence of reproduction - 2 in the Allegheny River system (Allegheny River and French Creek, Pennsylvania), 1 in the East Branch Sydenham River (Ontario, Canada), and 1 in the Ausable River (Ontario, Canada).

2.3.1.6 Habitat or ecosystem conditions:

The remaining recruiting northern riffleshell populations occur in medium to large rivers. In several streams, including the Green River, Big Darby Creek, Detroit River, and Elk River, extant northern riffleshell populations appear highly limited (a single stream reach, and a small number of individuals), except for translocated individuals, as in the case of Big Darby Creek. Because northern riffleshells appear to be relatively short-lived—surviving only 7 to 15 years (Rodgers *et al.* 2001, Crabtree and Smith 2009) —the presence of scattered live individuals suggests that successful recruitment has occurred, roughly, during the previous decade. However, unknown limiting factors (*e.g.*, altered hydrology, siltation, or inherent demographic requirements of this species) may prevent a population increase.

The northern riffleshells, as the common name suggests, is typically associated with sections of river with higher water velocities. While this habitat description applies to some locations, the subspecies also occurs within the Lake Erie/Lake St. Clair system in deep, slower water. Since 1999, populations have also been documented in deep, slow runs (down to 20 feet) in the Allegheny River, in both the free-flowing and impounded navigation channel, where limited flow and silt deposition are evident during low river discharge periods.

2.3.1.7 Other:

N/A

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 Endangered Species Act of 1973 (16 U.S.C. 1531 et seq), as amended (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 availability of alternative (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

The Recovery Plan identified four primary factors responsible for the decline of northern riffleshell populations: siltation, impoundment, instream sand and gravel mining, and pollutants (USFWS 1994).

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

Ongoing threats to the northern riffleshell include water quality degradation from point and non-point sources, particularly in tributaries that have limited capability to dilute and assimilate sewage, agricultural runoff, and other pollutants. In addition, the species is affected by hydrologic and water quality alterations resulting from the operation of impoundments such as Union City Reservoir on French Creek and Kinzua Dam on the Allegheny River. The presence of impoundments may have ameliorated the effects of downstream siltation on northern riffleshell, but these structures also control river discharges (and the many environmental parameters influenced by discharge), which may profoundly affect the ability of these populations to occupy or successfully reproduce in downstream habitats.

A variety of instream activities continue to threaten northern riffleshell populations, including sand and gravel dredging, gravel bar removal, bridge construction, and pipeline construction. Protecting these populations from the direct physical disturbance of such activities depends on accurately identifying the location of the populations, which is difficult with a cryptic species (*e.g.*, shell morphology, burying behavior) such as the northern riffleshell. These activities can directly affect the species through crushing, burying in silt/sediment, etc. In addition, the indirect effects of altering the streambed configuration following instream disturbance can result in long-lasting alteration of streamflow patterns that may cause headcutting and channel reconfiguration, thereby eliminating previously suitable habitat some distance from the disturbance.

Coal, oil, and natural gas resources are present in some of the watersheds known to support the northern riffleshell, including the Allegheny and Elk Rivers. Exploration and extraction of these resources can result in increased siltation, a changed hydrograph, and altered water quality, even at a distance from the mine or well field. Northern

riffleshell habitat in larger streams can be further affected by the cumulative effects of multiple mines and well fields.

Land-based development near streams of occurrence, including residential development and agriculture, often results in loss of riparian habitat, increased storm water runoff due to increased impervious surfaces, increased sedimentation due to loss of streamside vegetation, and subsequent degradation of streambanks. *Epioblasma*, including northern riffleshell, appear to be exceptionally sensitive to the increased siltation and associated turbidity caused by changing land use (Peacock *et al*. 2005).

Development has also increased the number of sewage treatment plants in drainages that support the northern riffleshell, and increased the amount of sewage discharged from existing plants. Freshwater mussels are more sensitive to several components of treated sewage effluent (*e.g.*, ammonia, chlorine and copper) than are the typical organisms used to establish water quality criteria protective of aquatic life (*e.g*., Newton 2003). Small streams, such as LeBoeuf Creek, are particularly vulnerable to sewage effluent, which can constitute a significant portion of the total stream flow.

In summary, the species continues to be affected by habitat loss and degradation throughout all of its range.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

The northern riffleshell is not a commercially valuable species; however, the small number of remaining populations increases its vulnerability to over-zealous scientific collecting or educational programs, and may increase their value for illegal trade by shell collectors. While the potential exists for the species to be collected, we have no evidence to suggest overutilization is a threat to the northern riffleshell.

2.3.2.3 Disease or predation:

At the time of listing, disease and predation were not considered to be significant threats to the species. Little is known about diseases in freshwater mussels (Grizzle and Brunner 2007). However, mussel die-offs have been documented in northern riffleshell streams, and some researchers believe that disease may be a factor contributing to the die-offs (Haag 2012). Since listing, mussel die-offs have occurred in two northern riffleshell streams, (Elk River (WV) and Big Darby Creek (OH)). The causes of these recent die-offs are not known. It is also not known if any northern riffleshells were affected during these events.

Mussel parasites include water mites, trematodes, oligochaetes, leeches, copepods, bacteria, and protozoa (Grizzle and Brunner 2007). Generally, parasites are not suspected of being a major limiting factor (Oesch 1984), but a summary by Butler (2007) provides contrary evidence. Reproductive output and physiological condition were negatively correlated with mite and trematode abundance, respectively (Butler 2007). Stressors that reduce fitness may make mussels more susceptible to parasites (Butler 2007). Furthermore, nonnative mussels may carry diseases and parasites that are

potentially devastating to native mussel fauna, including the northern riffleshell (Strayer 1999).

Due to the relatively small size of northern riffleshell, several animals prey on this mussel, including muskrats, raccoons, otters, molluscivous fish, and some invertebrates. Such predation could locally reduce populations of northern riffleshell. This effect may be negligible in larger populations such as those in the Allegheny River, but it could represent a significant threat to small, isolated northern riffleshell populations located elsewhere.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Coal, oil, and gas resources are present in a number of the basins where the northern riffleshell occurs, and extraction of these resources has increased dramatically since 2000 in the Utica and Marcellus shale formations, and is expected to expand further (Marcellus Shale Coalition 2019). Although oil and gas extraction generally occurs away from the river, extensive road networks are required to construct and maintain wells. These road networks frequently cross or occur near tributaries, contributing sediment to the receiving waterway. In addition, the construction and operation of wells may result in the discharge of brine, into local waterways and water withdrawals can exacerbate water quality and water quantity stresses during low flow events. Northern riffleshells are intolerant of saline conditions (see below). Point source discharges are typically regulated; however, non-point inputs such as silt and other contaminants may not be sufficiently regulated, particularly those originating some distance from a waterway. In 2006, more than 3,700 permits were issued for oil and gas wells by the Pennsylvania Department of Environmental Protection, which also issued 98 citations for permit violations at 54 wells (Hopey 2007).

Regulated point sources may adversely affect the northern riffleshell. Freshwater mussels appear to exhibit more sensitivity to some pollutants than do the organisms typically used in toxicity testing. As a result, some of the water quality criteria established by the EPA to protect aquatic life may not be protective of mussels. For example, Augspurger *et al*. (2003) found that the current EPA numeric criteria for ammonia may not protect mussels. Consequently, even those sewage treatment plants that comply with their ammonia effluent limits at all times may still be discharging water that is toxic to freshwater mussels. Few substances have been tested for their toxicity to mussels, and fewer on northern riffleshell, so “safe” concentrations for this species are not generally known.

Northern riffleshells appear to be highly vulnerable to the effects of sodium chloride (salt) exposure and an emerging threat to northern riffleshell is increasing chloride (Cl) concentrations (Patnode *et al*. 2015). Water quality criteria are often developed under the assumption that some loss of species is acceptable (*e.g.*, lethal dose at which 50 percent of the population is killed in a given period of time, or LC50); however, adverse effects can occur at less than lethal concentrations with a reduction in essential behavior patterns, including breeding, feeding, or sheltering. The EPA has chloride standards that were not developed with freshwater bivalve testing (Patnode *et al*. 2015) and these are greater than Canadian standards (which include freshwater bivalve data) with acute

exposure limits of 640 mg/L and chronic exposure limits of 120 mg/L (Environment CCME 2011). In addition, states such as Pennsylvania allow mixing zones, or zones in which numeric water quality criteria can be exceeded.

Agriculture, and suburban and urban land uses continue to expand in many watersheds within the current range of the northern riffleshell. These land use changes alter runoff patterns and flow in this species habitat, and the consequences of such changes to these remaining populations are not known. Few regulatory mechanisms exist to address land use changes that may indirectly affect stream habitat far from the source of disturbance.

Since the species was listed, there have been multiple projects (exact number unknown) that have had the potential to impact northern riffleshell populations. Some of these projects were subsequently modified to avoid all instream effects, thereby avoiding adverse effects to the northern riffleshell. Instream effects could not be avoided for some projects due to the nature of these projects, which required instream work (e.g. bridge repair or replacement projects, dam removal, pipeline stream crossings). Through consultation with the local Service Field Offices, northern riffleshells, and other mussels, are typically relocated out of harm's way for these types of projects as a last resort measure to reduce lethal take of the species when no other options area available. Survival rates for relocated mussels can vary greatly and may depend on a variety of timing and habitat factors (Hamilton *et al.* 1997; Cope *et al.* 1995). Survival rates for relocated northern riffleshells have varied by site and streams, and mortality has been documented (e.g., Stodola *et al.* 2017).

As explained under section 2.3.2.1, the northern riffleshell continues to be affected by habitat degradation, including water quality, despite the limited existing regulatory mechanisms in place throughout the species' range. Existing regulatory mechanisms have not been sufficient to significantly reduce or remove the threats to the northern riffleshell.

2.3.2.4 Other natural or manmade factors affecting its continued existence:

Effects of small population size:

As stated above, large populations appear to be necessary for the long-term conservation of this species. We do not know the northern riffleshell's effective population size. However, several populations appear to be declining, small, or both. There is a concern that these populations may become extirpated if they are below an as-yet-undetermined population density and mortality exceeds reproductive potential, (Rodgers *et al.* 2001).

Invasive species:

The zebra mussel has continued to spread in North American waterways since its accidental introduction in the 1980s. Large zebra mussel populations in Lake St. Clair, the Detroit River, and Lake Erie appear to have eliminated most native mussels from the areas colonized, including northern riffleshell, although the species may persist in refugia where habitat is less suitable for zebra mussels. In much of the remaining

northern riffleshell's range, zebra mussels have not developed large populations outside of lakes and impoundments. The effect of large zebra mussel populations developing in headwater impoundments and lakes, upstream of northern riffleshell populations, is not known, but could influence food availability or result in periodic zebra mussel population spikes downstream. Northern riffleshells occur in lower Allegheny River navigation pools 7, 8 and 9, and perhaps further downstream. These navigation impoundments may provide suitable zebra mussel habitat and this species is locally abundant in some locations in these pools, which may affect northern riffleshells in these areas.

The round goby (*Neogobius melanostomus*) first invaded North America in 1990 in the Great Lakes basin (Phillips *et al.* 2003) and in 2014, it was documented in the French Creek tributary of LeBoeuf Creek in the Allegheny River basin (Bradshaw-Wilson *et al.* 2019). Round gobies prey on mollusks and small fish that may serve as northern riffleshell host fish. The gobies have achieved high population densities that may also compete with host fish thereby limiting northern riffleshell reproduction (Fuller *et al*. 2019).

The black carp, a molluscivore, has been reported in Arkansas, Illinois, Mississippi, and Missouri (Nico and Nelson 2019). It is established in Louisiana (since the early 1990s), and was observed most recently in 2018 in Tennessee and Kentucky (Nico and Nelson 2019). The black carp is also listed as Injurious Wildlife under the Lacey Act. The species is present in the lower Ohio, Cumberland, and Tennessee River systems (Nico and Nelson 2019). There is high potential that the black carp will negatively impact native aquatic communities by direct predation, thus reducing populations of native mussels and snails, many of which are considered endangered or threatened (Nico and Nelson 2019).

Shifting precipitation and temperature:

The ultimate results of climate change remain unknown, but increased periods of drought are a possibility in some areas, as are changes in precipitation and water temperature cycles (Strayer and Dudgeon 2010). Physiological tolerances (*e.g.*, temperature, dissolved oxygen) of most mussel species are largely unknown, but changes that cross critical thresholds could disrupt life stages or host availability. The ability to physiologically adapt to changes likely varies among mussel species, but the life history of northern riffleshell make this species susceptible to extreme stochastic events.

2.4 Synthesis

The best available information indicates that the northern riffleshell is known to currently occur in 13 populations, 4 of which are stable and recruiting. Of the four recruiting populations, three are apparently large and occur in the Allegheny River, French Creek, and East Branch Sydenham River. A fourth, smaller population occurs, as of 2006, in the Ausable River. Each of these populations is susceptible to both natural stochastic events, such as floods, and anthropogenic threats, such as toxic spills. Although northern riffleshells have been documented in one additional Allegheny River tributary (besides French Creek), and two

French Creek tributaries, the species occurs in the lower reaches of these streams, and these occurrences may not be self-sustaining if the mainstem population is damaged.

In contrast to the above populations, five northern riffleshell populations have declined since the species was listed as endangered in 1994, and some of these may be extirpated. Extirpated or nearly extirpated populations include the following: the Detroit River, following zebra mussel infestation; the Green River, possibly due to point and non-point inputs, and hydrologic controls on flow and temperature from Green River Reservoir; Big Darby Creek, as a result of urban and agricultural runoff; Fish Creek, following a 1993 diesel fuel spill; and the Tippecanoe River, where no living or freshly dead northern riffleshells have been observed since the 1970s. A few individual specimens have been reported from the Elk River in West Virginia; however, no evidence of successful reproduction has been reported from this stream since 2003. Although specific events are cited as causing the apparent loss of several northern riffleshell populations, these events likely worked in concert with other events that cumulatively reduced overall population levels to the extent that a single event likely resulted in extirpation. However, translocations may bolster populations in some streams such as Big Darby Creek, which has received several thousand northern riffleshells from the Allegheny River between 2010 and 2018, and the Tippecanoe River, which has received over 3,000 northern riffleshells from the Allegheny River from 2016 to 2018.

In many cases, diverse freshwater mussel populations persist where northern riffleshells have not. Like other *Epioblasma,* this species may be more sensitive to environmental perturbations than other mussel species (Haag 2012). This may be because life history traits make recovery from a disturbance less likely than with other mussels, or because this species is more sensitive to silt and contaminants.

The large populations of the northern riffleshell in Pennsylvania provide a potential source of animals to implement recovery actions described in the Recovery Plan. For example, in 2015-2016, 27,506 individuals were removed from bridge and pipeline project sites to augment populations in 11 rivers elsewhere in the species' range. However, translocation and population augmentation will work only to the extent that historical habitat is now suitable. Because the reasons for the original decline of the northern riffleshell have often not been identified, transferred animals may also not survive.

The northern riffleshell should continue to remain listed as *endangered* because the species has continued to decline and threats have not been ameliorated, as evidenced by the unmet criterion for downlisting to threatened. Declining populations and loss of habitat in the Ohio River basin are not compensated for by the locally abundant but geographically limited populations in Pennsylvania and Ontario. Numerous threats persist for the remaining northern riffleshell populations, including invasive species, the effects of small population sizes, habitat alteration, land-use changes, changing precipitation and temperature patterns, and point and non-point source pollution. The life history and environmental sensitivity of the northern riffleshell is poorly known, increasing the threat that previously unidentified activities could cause a precipitous decline of one or more of the remaining reproducing populations.

Due to the continued threats to water and habitat quality and invasive species in areas of greatest northern riffleshell abundance and uncertain success of relocation and augmentation

efforts in other streams, we conclude that, at this time, the northern riffleshell continues to meet the definition of an endangered species under the ESA.

3.0 RESULTS

3.1 Recommended Classification: Endangered; no change is needed.

3.2 Recommended Recovery Priority Number: 5; change recommended.

Recovery Priority Number of 6 indicates that the northern riffleshell is taxonomically categorized as a subspecies, has a high degree of threat, and has low recovery potential. However, Williams *et al*. 2017 elevated the northern riffleshell from subspecies to species as *Epioblasma rangiana*, and we accept that taxonomy as the best available data.

Despite an apparently healthy population in the Allegheny River system and East Branch Sydenham River, there has been a decline, or complete loss, of more than half of the populations believed to be extant at the time of listing. In addition, habitat loss, invasive species, and effects of small population size are still occurring in the remainder of the species' range.

Consideration of the taxon as a species justifies revising the Recovery Priority Number (RPN) to RPN 5.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Recommendation: Revise recovery plan.

The northern riffleshell Recovery Plan is more than 20 years old, and a significant amount of information has since become available regarding threats to the essential recovery streams identified in the plan. As stated above, the recovery criteria are unclear and should be revised. A revised plan will assist local and State entities in planning watershed and ecosystem actions to recover habitat needed for eventual relocation efforts.

Recommendations for specific priority recovery actions.

The following recovery actions should be made a priority over the next 5 years:

Priority 1 Recovery Actions:

1) Determine sensitivity of each life stage to major contaminants likely to be found in sewage; in runoff from urban, agricultural, and energy production areas at known sites; and at potential augmentation and reintroduction sites. Develop water quality criteria recommendations for the EPA and states to protect and enhance northern riffleshell habitat.

2) Continue to monitor reintroduction and augmentation sites to determine if natural reproduction is occurring.

3) Identify and map activities or practices within each ecosystem that may affect the northern riffleshell and its host fish at known sites, and at augmentation/reintroduction sites.

4) Continue to coordinate propagation and augmentation activities between the three Service regions, and six States (including Pennsylvania, which has the source population) to maximize the chance of success and reduce any adverse effects on existing populations.

Priority 2 Recovery Actions:

1) Complete surveys of the Green River and Elk River to determine if the northern riffleshell is extant in these streams.

2) If extant populations are found in Ohio River tributaries, undertake additional genetic studies to determine their relationship to Allegheny/Great Lakes populations and those remaining elsewhere in the Ohio River basin. This will increase our understanding of the species' genetic representation across its range.

Priority 3 Recovery Actions:

1) To remain consistent with the current scientific understanding of this species, update the species name to *Epioblasma rangiana*.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Northern Riffleshell (*Epioblasma torulosa rangiana*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__✓__ No change needed

Appropriate Delisting Priority Number: N/A

Review Conducted By: Robert Anderson and Melinda Turner, Pennsylvania Field Office

REGIONAL OFFICE APPROVAL:

Approve Paul R. Phy Date 8/28/19

Assistant Regional Director - Ecological Services, DOI Unified Region 1 – North Atlantic–Appalachian, U.S. Fish and Wildlife Service