New River Crayfish Range Wide Status Assessment

William T. Russ, *North Carolina Wildlife Resources Commission, Division of Inland Fisheries, 645 Fish Hatchery Road, Marion, NC 28752*

Zach J. Loughman, *West Liberty University, Department of Natural Sciences and Mathematics, Campus Service Center Box 139, West Liberty University, West Liberty, WV 26074*

Roger F. Thoma, *Midwest Biodiversity Institute, Inc., 4673 Northwest Parkway, Hilliard, OH 43026*

Brian T. Watson, *Virginia Department of Game and Inland Fisheries, 1132 Thomas Jefferson Road, Forest, VA 24551*

Todd D. Ewing, *North Carolina Wildlife Resources Commission, Division of Inland Fisheries, 1721 Mail Service Center, Raleigh, NC 27699*

Abstract: The New River crayfish, (*Cambarus chasmodactylus*), was described in 1966 from the East Fork of the Greenbrier River, West Virginia, and historically occurred throughout the New River Basin from the Greenbrier River sub-basin in West Virginia, upstream through Virginia, and into the headwaters of the South Fork New River in North Carolina. The New River crayfish was part of a federal listing species petition in 2010 and it is currently being evaluated for listing as either threatened or endangered by the U.S. Fish and Wildlife Service under the Endangered Species Act. In order to understand the current distribution and status of this species, a range-wide assessment was undertaken by various organizations and agencies in West Virginia, Virginia, and North Carolina. Biological information was summarized, including species description, habitat use, life history, and current distribution. All historical and recent collections were compared and spatially displayed using GIS software. The New River crayfish was collected in three 8-digit hydrologic unit codes (HUCs) and 14 counties in three states, with the majority of occurrences in the Upper New and Greenbrier River sub-basins. Occurences were reported in 92 12-digit HUCs and in approximately 100 different streams throughout the range. Current records, from 2000–2014, show New River crayfish in 54 12-digit HUCS and 13 counties in three states. Given the wide distribution of this species in the New River Basin, localized high abundances where it occurs, lack of any major threats, and the existing protections in the New River Basin, the New River crayfish is considered stable, and therefore does not warrant federal listing at this time.

Key words: Cambarus chasmodactylus, Endangered Species Act, endemic species

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In North America there are at least 390 endemic crayfish, 75% of the world's total (Lodge et al 2000). Despite this biodiversity, crayfish have traditionally been under-studied resulting in the lack of basic distributional data, habitat requirements, and life history information. Multiple impacts resulting from hydrological alteration and habitat degradation threaten localized populations, yet the greatest ecological threat to crayfish is believed to be the introduction of nonindigenous species (Lodge et al. 2000, Taylor et al. 2007). In recent years taxonomists and aquatic biologist have begun to focus more research on crayfish providing managers information necessary for effective conservation actions. Great advances have been made in understanding the distribution and taxonomy of the crayfish fauna in West Virginia, Virginia, and North Carolina (Simmons and Fraley 2010, Loughman and Welsh 2013, Russ and Fraley 2014, Thoma 2014). A more complete understanding of the New River crayfish (*Cambarus chasmodactylus*) taxonomy, distribution, and abundance, is necessary for resource managers to determine conservation status and to develop effective monitoring and management strategies (Simmons and Fraley 2010).

The crayfish family Cambaridae is considered the most ecologically diverse and largest in the world with 444 recognized species (Fetzner 2007); 99% of these occur in North America and of those 90% occur in the eastern United States (Taylor and Schuster 2004). The New River crayfish is a dorsally-flattened, large crayfish (James 1966) with a maximum observed carapace length of 62 mm (Loughman 2013). Further morphometric information can be found in James (1966). Geographical isolation of the New River crayfish in the Greenbrier and upper New River sub-basins as well as the particularly large size attained by individuals are reliable distinguishing characters of this species. Typical crayfish identification methods depend on Form I males but this is not necessarily needed with this species. All New River crayfish adults can be distinguished from those of other species in the family, and from the sub-genus *Hiaticambarus,* by their lack of setae between the fingers, and the moveable finger is twice as long as the inner margin of the palm in unregenerated chelae (James 1966). Similar species in the *Hiaticambarus* sub-genus, found outside the New River Basin, include the longnose crayfish (*Cambarus longirostris*) and

the Atlantic Slope crayfish (*Cambarus longulus*); these two species are found, respectively, in the upper Tennessee River Basin and the James River south to the Yadkin River.

The New River crayfish was first collected in 1890 and was identified as *Cambarus longulus longulus* from the New River in Wytheville, Virginia (Faxon 1890). It was later described from the East Fork Greenbrier River, Pocahontas County, West Virginia, by James (1966) as *Cambarus longulus chasmodactylus* and, along with longnose crayfish, was designated species status separate from the Atlantic Slope crayfish. In 1969, it was fully recognized as a species (Hobbs 1969).

The New River crayfish is generally found in third and fourth-order streams (Fortino and Creed 2007) and is normally encountered under large, flat, slab rocks, in moderate to high velocities (James 1966, Loughman 2013). Like other members in this subgenus, this crayfish is limited ecologically to rocky, riffle areas in unsilted streams (Cooper and Cooper 1977, Loughman et al. 2013). Simmons and Fraley (2010) reported it from streams ranging in width from 1–14 m. Adults tend to be found mid-stream while juveniles are found closer to stream edges (James 1966, Loughman et al. 2013). In North Carolina, Fortino and Creed (2007) found that adults and young-of-the-year (YOY) were dominant in third-order streams but only adults were observed in the fourth-order South Fork of the New River. Fortino and Creed (2007) speculated that rock bass (*Ambloplites rupestris*) predation may prevent YOY from thriving in larger streams.

Loughman (2013) established that the New River crayfish can live at least six years and sexual maturity is probably reached at three years of age. Reproduction may occur from as long as March through November, although some studies have reported shorter seasons (Loughman 2013, Simmons and Fraley 2010, Thoma 2014). Instars have been carried from September–October, possibly into December and through the winter, but following instar development stages, YOY entered the population in July (Loughman 2013).

The New River crayfish's historical distribution was considered to be limited to the New River basin from the Greenbrier sub-basin in West Virginia upstream to the headwaters of the South Fork of the New River in North Carolina (James 1966, Hobbs 1969). In James' (1966) description the New River crayfish, it was noted from the Bluestone and East rivers, in the Middle New River basin; however, due to surveys by Jezerinac et al. (1995) and Loughman and Welsh (2013) these records are considered erroneous; in West Virginia the species is now believed to be always limited to the Greenbrier River sub-basin.

The New River crayfish was part of a federal listing species petition in 2010 and is currently being evaluated for listing as either threatened or endangered by the U.S. Fish and Wildlife Service under the Endangered Species Act. The U.S. Fish and Wildlife Service protocol and format for status assessment was implemented to evaluate the status of the New River crayfish across its entire range. Five factors must be addressed to federally list a species: A.) the present or threatened destruction, modification, or curtailment of the species' habitat or range, B.) overutilization for commercial, recreational, scientific, or educational purposes, C.) disease or predation, D.) inadequacy of existing regulatory mechanisms, E.) other natural or manmade factors effecting existence. In order for a species to be listed as endangered it must be at the brink of extinction now, and for a species to be listed as threatened it must be at the brink of extinction in the near future.

All relevant and existing information that pertained to the five factors for federal listing are addressed in this study. The North Carolina Wildlife Resources Commission (NCWRC) worked cooperatively with the North Carolina Museum of Natural Science (NCMNS), Ohio State University Museum of Biological Diversity (OSUMBD), Virginia Department of Game and Inland Fisheries (VDGIF), and West Liberty University (WLU) in order to summarize all historical and current information associated with the New River crayfish. The objective of this study was to provide the U.S. Fish and Wildlife Service with all current information associated with the New River crayfish and present conclusions on whether the species should be federally listed.

Methods

An extensive literature review was conducted on the New River crayfish focusing on literature specific to the species' description, taxonomy, habitat use, life history, and historical distribution. Published and unpublished literature, reports, and data, along with personal communication were obtained. Historical locality data were queried from the NCWRC Aquatics Database, the NCMNS, OSUMBD, VDGIF, and WLU. These data were incorporated into a GIS database, and ArcGIS software was used to spatially and temporally analyze historical and current collections. Historical collections were considered pre-2000 and current collections were considered 2000–2014.

The majority of historical records were either incidental catch or opportunistic collections. In these old records, during fish and mussel surveys, crayfish were collected opportunistically by hand while electrofishing and seining or with snorkeling or using bathyscope equipment. These collections were generally reported via scientific collection permits to state databases or reported by state agency personnel. Opportunistic collection is defined as surveys when one or more New River crayfish was collected. Beginning in 2005 and more recently in 2012–2014 state agencies, universities, and biologists focused more on crayfish-specific collections. These crayfish-specific collections added beneficial, current data but were primarily limited to presence/absence information. Primary col-

lection techniques for these surveys were rock flipping and kicking into a seine (2.4, 3.0, and 3.7 m with 5.7-cm mesh). For more information on crayfish collection techniques see: Loughman and Welsh (2013), Russ and Fraley (2014), or Simmons and Fraley (2010). Typically, a minimum of 10 seine hauls were recorded, but as many as 30 were reported. The primary goal of crayfish-specific surveys was to show presence/absence of the targeted crayfish species, thus no consistency or uniformity was observed in effort. For the purpose of this study absence information was not included since effort was not standardized throughout time or across states. All collection data was summarized into an ArcGIS project and historical and current distribution were evaluated.

Results

The New River crayfish is still extant throughout the Greenbrier River sub-basin in West Virginia and the New River basin in Virginia and North Carolina. Collection localities were reported from three 8-digit hydrologic unit codes (HUCs) from 1941–2014 (Figure 1); a total of 288 localities were reported. The most records in West Virginia were from the Greenbrier River sub-basin in Pocahontas County, the Little River sub-basin in Virginia (Floyd County), and the upper South Fork New River sub-basin in North Carolina (Watauga County). In West Virginia, the most downstream record was in a tributary to the Greenbrier River, Mill Creek, at County Rd 54/4, and the most upstream record was from the West Fork Greenbrier River at Forest Service Rd 17. The Middle New River 8-digit HUC overlaps West Virginia and Virginia; the most downstream record was from the New River adjacent to Wolf Creek at Virginia Hwy 61, and the most upstream record was from Walker Creek at Virginia Rt. 658. No records exist in the Middle New River 8-digit HUC in West Virginia. The Upper New River 8-digit HUC overlaps Virginia and North Carolina; the most downstream record was in Radford, Virginia, at US Hwy 11, and the most upstream record was from the Middle Fork New River at the Blue Ridge Parkway (Figure 1).

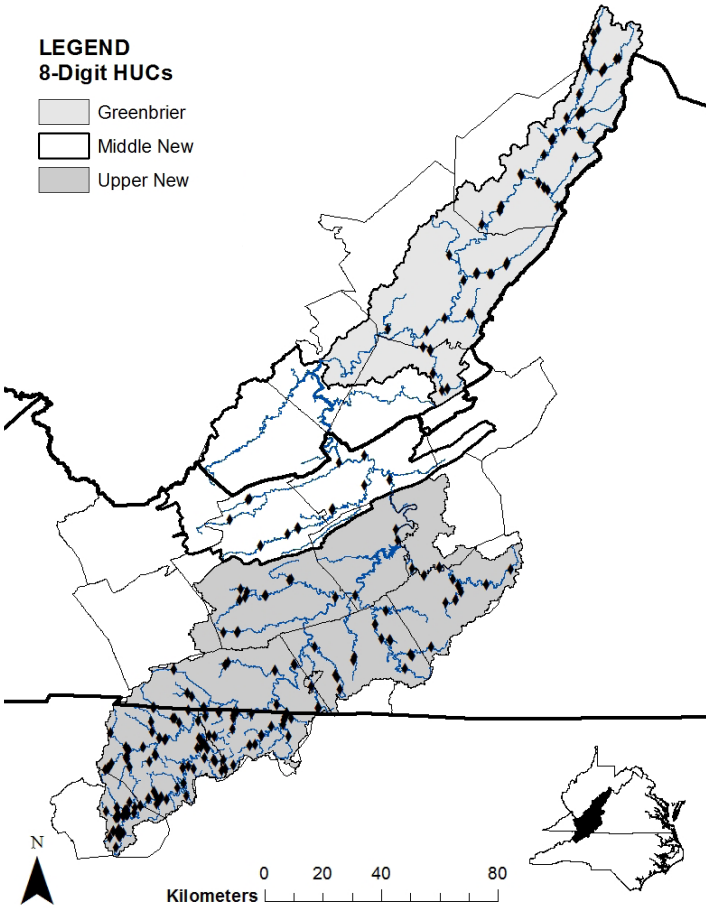

Figure 1. Total collection localities for the New River crayfish in the Greenbrier River, Middle New River, and Upper New River 8-digit HUCs in West Virginia, Virginia, and North Carolina (1941–2014). Data provided by W. T. Russ, North Carolina Wildlife Resources Commission, North Carolina Museum of Natural Science , Z. J. Loughman, West Liberty University, R. F. Thoma, Ohio State University Museum of Biological Diversity , B. T. Watson, and Virginia Department of Game and Inland Fisheries.

In West Virginia, the crayfish was reported from three counties (Monroe, Greenbrier, and Pocahontas) within the Greenbrier River sub-basin (Jezerinac et al. 1995, Loughman and Welsh 2013). New River crayfish were collected in West Virginia at 29 streams and were historically reported from 19 12-digit HUCs; current records were reported from 15 12-digit HUCs. A total of 51 records were reported, 24 historical from 1969–1989 and 27 current from 2008–2012 (Figure 2). Most observations, historical and current, were from Pocahontas County; currently no records exist in Mercer or Summer counties. Of the 27 current records all but five were from Pocahontas County (Figure 2). In Anthony Creek, West Virginia, high densities were observed co-occurring with an introduced population of virile crayfish. Large populations exist in Anthony Creek, Dunlap Creek, and the middle section of the Greenbrier River in the vicinity of Marlinton, West Virginia. New River crayfish are considered common to abundant throughout much of the Greenbrier River basin, except for the lower Greenbrier River mainstem. Due to high water quality throughout much of the Greenbrier River basin the New River crayfish populations in West Virginia are considered stable.

In Virginia, New River crayfish were collected from eight counties, 26 streams, and historically reported from 36 12-digit HUCs; current records were reported from 15 12-digit HUCs. A total of 97 records were reported, 69 historical from 1950–1999 and 28 current from 2000–2012 (Figure 3). The majority of recent records were collected upstream of Claytor Lake in Wythe, Carroll, and Grayson counties. Several historical records exist from Bland County but only one was reported since 1998. In addition, only a single current record exists from Wythe County (2011) and only

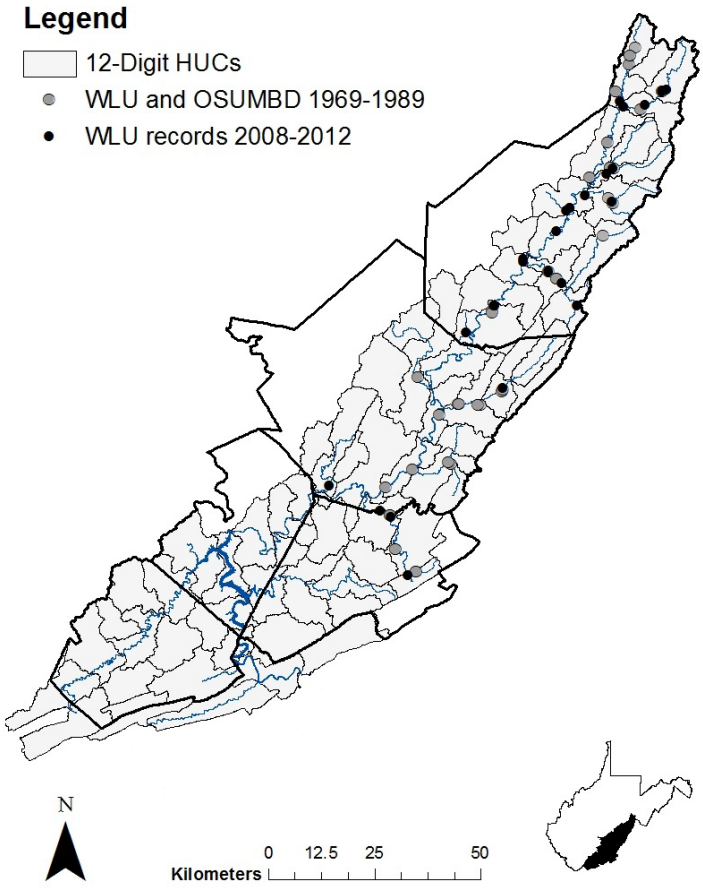

Figure 2. Collection localities for the New River crayfish in the Greenbrier River Drainage, West Virginia 12-Digit HUCs (1969–2012). Data provided by Z. J. Loughman, West Liberty University and R. F. Thoma, Ohio State University Museum of Biological Diversity.

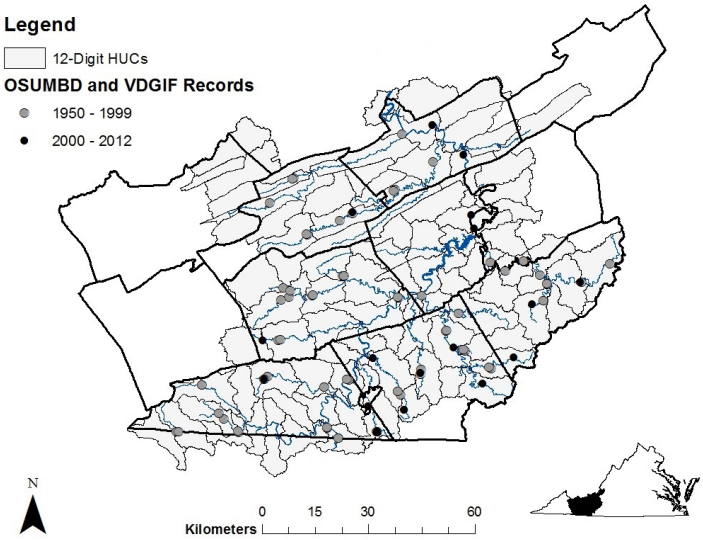

Figure 3. Collection localities for the New River crayfish in Virginia 12-Digit HUCs (1950–2012). Data provided by R. F. Thoma, Ohio State University Museum of Biological Diversity and B. T. Watson, Virginia Department of Game and Inland Fisheries.

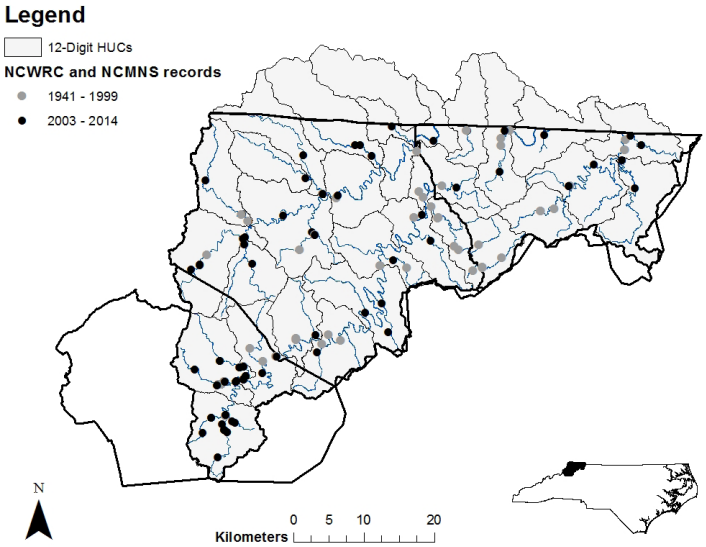

Figure 4. Collection localities for the New River crayfish in North Carolina 12-Digit HUCs (1941–2014). Data provided by the W. T. Russ, North Carolina Wildlife Resources Commission and North Carolina Museum of Natural Science.

two current records were reported from Giles County. In 1998, 42 New River crayfish were collected at a single site in Helton Creek and more recently in 2007, many individuals were observed in Crooked Creek ($n = 39$). In Virginia there are several streams and long reaches where New River crayfish surveys have not been conducted; with more current surveys a more complete assessment of the distribution in Virginia would be understood.

In North Carolina, the crayfish was collected in 41 streams, in three counties (Watauga, Ashe, and Alleghany) and was historically reported from 20, 12-digit HUCs; current records were reported from 24 12-digit HUCs. The only 12-digit HUC with no reported records, historical or current, was Wilson Creek. Yet only a small portion of this HUC is in North Carolina and there were four collection localities from this HUC in Virginia. A total of 140 records were reported, 70 historical from 1941–1999 and 70 current from 2003–2014 (Figure 4). The majority of recent records were collected Watauga County in the Upper South Fork New River and tributaries such as Middle and East Fork New rivers, and Meat Camp and Howard creeks. In North Carolina, New River crayfish are common to abundant in the majority of second-and third-order streams, but it appears to be uncommon lower downstream in the North and South forks of the New River and the mainstem New River.

Discussion

Population estimates for the New River crayfish are not available; however, recent surveys in all three states, typically presence/

absence data, revealed widespread, well established populations. The current range of this crayfish is well understood and recent surveys revealed populations throughout the historically known range, often at levels considered common to abundant. The species is likely in most second and third-order streams in the Greenbrier River sub-basin in West Virginia and in the New River basin in North Carolina. Future efforts should focus on more surveys in the Middle New River basin; this will likely reveal more populations.

Summary of Information Pertaining to the Five Factors

Factor A.—In West Virginia, the Greenbrier River drainage encompasses ~4263 km^2 and 2000 Census data showed only 38,402 people (~9 people km^{-2}) living within the watershed (West Virginia Department of Environmental Protection [WVDEP] 2008). Approximately 78% of the Greenbrier River watershed is forested and less than 1% is classified as urban/residential (WVDEP 2008). Water quality protection in this drainage is provided by the Monongahela National Forest (1088 km^2; ~25% of the watershed) and numerous other public lands (Greenbrier State Forest, Seneca State Forest, Beartown State Park, Watoga State Park, Handley Wildlife Management Area, Cass Scenic Railroad State Park, Spice Run Wilderness Area, and Big Draft Wilderness Area). Additionally, the Greenbrier River Watershed Association and other nonprofit organizations help leverage protection for the water quality in this basin.

In Virginia, the New River drainage covers approximately 7946 km^2, 59% of the basin is forested, 35% is cropland or pasture, and 3% is urban (Virginia Department of Environmental Quality [VDEQ] 2012). The New River drainage is the least populated basin in Virginia with 208,395 people (~26 people km^{-2}) as of the 2000 Census (VDEQ 2012). Water quality protection in this drainage is provided by Grayson Highlands State Park, Mount Rogers National Recreation Area, and Jefferson National Forest totaling approximately 1273 km^2. In addition, The National Committee for the New River affords protection for the river and the New River Land Trust (NRLT) has protected over 174 km^2 in Virginia portion of the watershed (NRLT 2013).

In North Carolina, the New River basin covers approximately 1981 km^2, and 66% of the basin is forested, 27% is agriculture, and 6% is developed (NCDENR 2011). 2000 Census data indicate that about 61,000 people (~31 people km^{-2}) lived in the basin in North Carolina (NCDENR 2011). Water quality protection in approximately 98 km^2 of this drainage is provided by Cherokee National Forest, Elk Knob State Park, NCWRC Game Lands, Mt. Jefferson State Natural Area, Blue Ridge Rural Land Trust, National Committee for the New River, and New River State Park (NCDENR 2011).

Crayfish are vulnerable to similar threats as other aquatic organisms, as regards habitat loss and nonnative species introductions (Taylor and Schuster 2004). These threats are often exacerbated by the limited range of many crayfish species and the influx of silt and sediment resulting from various anthropogenic sources (Taylor et al. 2007). Some habitat loss has occurred in the range of the New River crayfish, such as in the impounded reach of Claytor Lake, Virginia; however, in the future, more introductions of nonnative crayfish could perhaps be the greatest threat to the continued existence of the species (Lodge et al 2000, Taylor and Schuster 2004). Though threats do exist for the New River crayfish, much of its range occurs within forested areas and large sections of land throughout the three states are protected.

One threat that will undoubtedly persist for the New River crayfish will be increased siltation. Siltation degrades natural habitats that negatively affect the ability of crayfish to feed, reproduce, and find shelter. Loughman (2013) and Loughman et al. (2013) determined that New River crayfish preferred large slab boulders as daily refugia as well as ovopositioning sites. Future impacts in the Greenbrier River system that lead to elevated siltation may limit New River crayfish access to slab boulders, leading to localized population declines (Loughman et al 2013, Loughman and Welsh 2013). Further, at high siltation levels, homogenous substrates are created that may benefit nonnative species such as virile crayfish. In West Virginia, the virile crayfish has been introduced alongside the New River crayfish; however, the current, relatively pristine conditions in the Greenbrier River system may limit the ability of this nonnative crayfish to colonize new habitats (Loughman and Welsh 2013). The virile crayfish has extirpated two *Orconectes* species from West Virginia (Loughman and Welsh 2013); it is unknown if the virile crayfish will have the same affect on the New River crayfish. Monitoring the effects of this nonnative crayfish will be a priority in the future.

In Virginia, impoundments have historically had the highest impact to the New River crayfish population. Numerous reservoirs exist in Virginia, five impound the mainstem New River: Field Dam at Mouth of Wilson, Fries, Buck, Byllesby, and Claytor lakes. The largest reservoir is Claytor Lake; completed in 1939 this 4,500-acre reservoir converted many streams into lentic habitats, eliminating preferred habitat for the New River crayfish (Cooper and Cooper 1977). Much of the initial negative effects of these reservoirs occurred decades ago; now these reservoirs potentially provide benefits by acting as sediment sinks yet may also represent important source populations for nonnative crayfish (Loughman and Welsh 2013). In Virginia it is currently unknown if nonnative crayfish have been introduced alongside New River crayfish populations. The prevention of this threat should be a high priority and monitored by the VDGIF.

In North Carolina, the construction of a large reservoir was

once considered a major threat to the New River crayfish (Cooper and Cooper 1977). This threat no longer exists and currently the primary threat in North Carolina is siltation. Perhaps siltation has increased in the New River Basin in North Carolina; yet the problem does not appear to have adversely effected populations. The South Fork of the New River is rapidly being developed, primarily in and around the city of Boone; however, the largest numbers of New River crayfish still exist in Howard Creek (upper South Fork New River tributary) and much of this watershed is developed.

Fortino and Creed (2007) found mean YOY densities in Howard Creek at 5.1 m^{-2}. In 1998, the crayfish was noted as common to abundant throughout the basin, and in 2005 it was collected from 9 of 13 previously unsurveyed sites (Simmons and Fraley 2010). Despite recent population development in the headwaters in the South Fork of the New River the population appears to be stable. The entire North Fork of the New River is considered a High Quality Water and Outstanding Resource Water; this designation is the highest level the state of North Carolina provides for water quality (NCDENR 2011). These designations confer stringent erosion and sediment controls, buffer widths, dictate the use of best management practices, and restrict new waste water discharges. Currently in North Carolina no nonnative crayfish introductions have become established in the New River basin. The prevention of this threat should be a high priority and monitored by the NCWRC.

Factor B.—There is no evidence that the New River crayfish is over-utilized for any purpose. Individual specimens are occasionally collected by fishermen in minnow traps and used as bait and are also collected by researchers for phylogenetic and population ecology studies; however, neither activity poses a significant threat.

Factor C.—In the future, introductions of nonnative crayfish species may spread disease in localized populations (Lodge et al 2000); however, this is currently not a threat. The crayfish is undoubtedly eaten by predators (Fortino and Creed 2007, Loughman and Welsh 2013) but this occurs naturally and often localized. Predation does not pose a significant threat to the population.

Factor D.—In West Virginia, regulations allow a person with a valid fishing license to have possession of no more than 100 crayfish (WVDNR 2015) whereas those catching/selling bait can have 250, with a sale limit of 50 per purchaser (West Virginia Legislative Rule 1983). In Virginia, with a valid fishing license, up to 50 crayfish may be possessed and no crayfish may be bought or sold (VDGIF 2015). In North Carolina, with a valid fishing license, crayfish are classified as nongame fish and up to 200 may be possessed, but like Virginia, no crayfish may be sold (NCWRC 2015). In all three states regulations exist that prevent nonnative crayfish introductions; however, it is doubtful that law enforcement officers possess the identification skills to determine a native crayfish versus an introduced species. Recent efforts in all three states focus on public outreach and education of the effects of nonnative crayfish. In addition, efforts to change current state crayfish regulations will decrease the chance of exotic crayfish introductions.

The New River crayfish is designated by NatureServe as apparently secure (G4) throughout its range primarily due to its widespread distribution (10,000–20,000 km^{-2}) and decent viability in each state (NatureServe 2015). The International Union for the Conservation of Nature (IUCN) lists the species as Least Concern (LC) because the species is widespread and has an extent of occurrences of 15,900 km^2 (Cordeiro et al. 2010). West Virginia populations are considered stable and in certain populations common to abundant (Loughman and Welsh 2013). In Virginia the New River crayfish was recommended to be removed from the list of species of greatest concern due to its abundance and widespread distribution throughout the New River Basin. It is currently listed as a tier IV species in that state (range is I–IV with I in most critical need). Thoma (2014) suggested the New River crayfish should still receive some level of conservation status in Virginia, with the VDGIF possibly creating a tier within their State Wildlife Action Plan that includes species that are stable but occupy a restricted range. Without creating a new tier, the species will remain tier IV. North Carolina Natural Heritage placed the New River crayfish on its Watch List in 2012 (NCNHP 2012). Species on the Watch List are those species that are not necessarily declining but have increasing amounts of threats to their associated habitats. However, it was removed from the Watch List in 2014 (NCNHP 2014). None of these listing designations provide any legal protection for this species but the overall consensus is similar; the New River crayfish does not warrant state listing in any of the three states.

Factor E.—Given the uncertainty in most models, it is impossible to predict with much confidence what the effects of climate change will have on the New River crayfish in the future. NCDENR (2010) predicts that climate change will have relatively little negative effects on montane cool water communities such as those inhabited by this species. In addition, NCDENR (2010) ranks climate change as much less of a threat to water quality as most of the other factors discussed above. Still, Simmons and Fraley (2010) believed climate change may affect endemic species found at higher elevations, such as this species. More research and long-term monitoring is needed at certain populations to examine the potential effects of climate change.

Finding/Conclusion

Given the wide distribution of this species in the New River Basin, the locally high abundances where it occurs, the lack of

any major threats, and the protections already in place for many streams in the basin, we conclude that the New River crayfish does not warrant federal listing as endangered or threatened at this time. The current distribution is well understood in West Virginia and North Carolina and more recent life history and habitat use information have been documented for this species. It is clear that monitoring and surveys are needed for this species especially in West Virginia where it is limited to the Greenbrier River sub-basin and in Virginia where the least is known about the current range. Future work in all three states should focus on monitoring the introduction of nonnative crayfish and devoting resources into the prevention of the spread of all aquatic nuisance species.

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