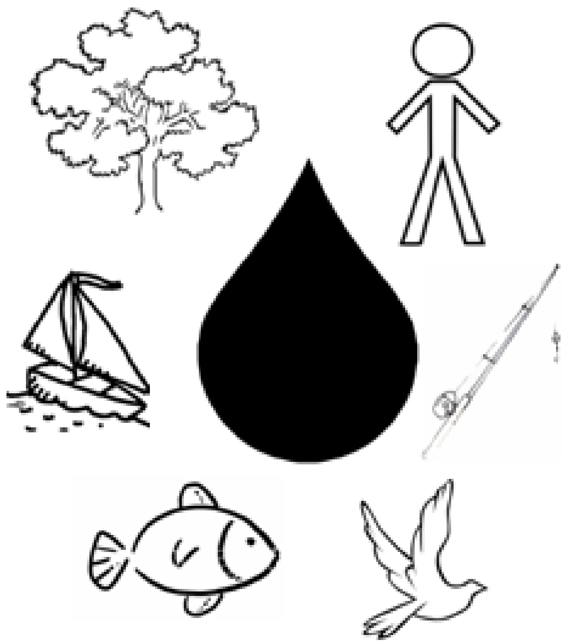
Non-Consumptive Uses in West Virginia



Prepared for
West Virginia Department of Environmental Protection

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Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviations

DEP	West Virginia Department of Environmental Protection
DNR	West Virginia Department of Natural Resources
ELOHA	Ecological Limits Of Hydrologic Alteration
HUC8	8-Digit Hydrologic Unit Code
HUC12	12-Digit Hydrologic Unit Code
ICPRB	Interstate Commission on the Potomac River Basin
MPRWA	Middle Potomac River Watershed Assessment
NHD	National Hydrography Dataset
U.S.	United States
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Units of Measurement

sqmi	Square miles

1 Introduction

The West Virginia Water Resources Protection and Management Act requires the projection of "existing and future non-consumptive use needs of the water resources required to serve areas with important or unique natural, scenic, environmental or recreational values of national, regional, local or statewide significance." Non-consumptive uses comprise the numerous uses of water that do not result in a loss of water (i.e. the water is not consumed during use). For example, whitewater rafters depend on sufficient quantities of water; however, their use of the water does not reduce the quantity for other users.

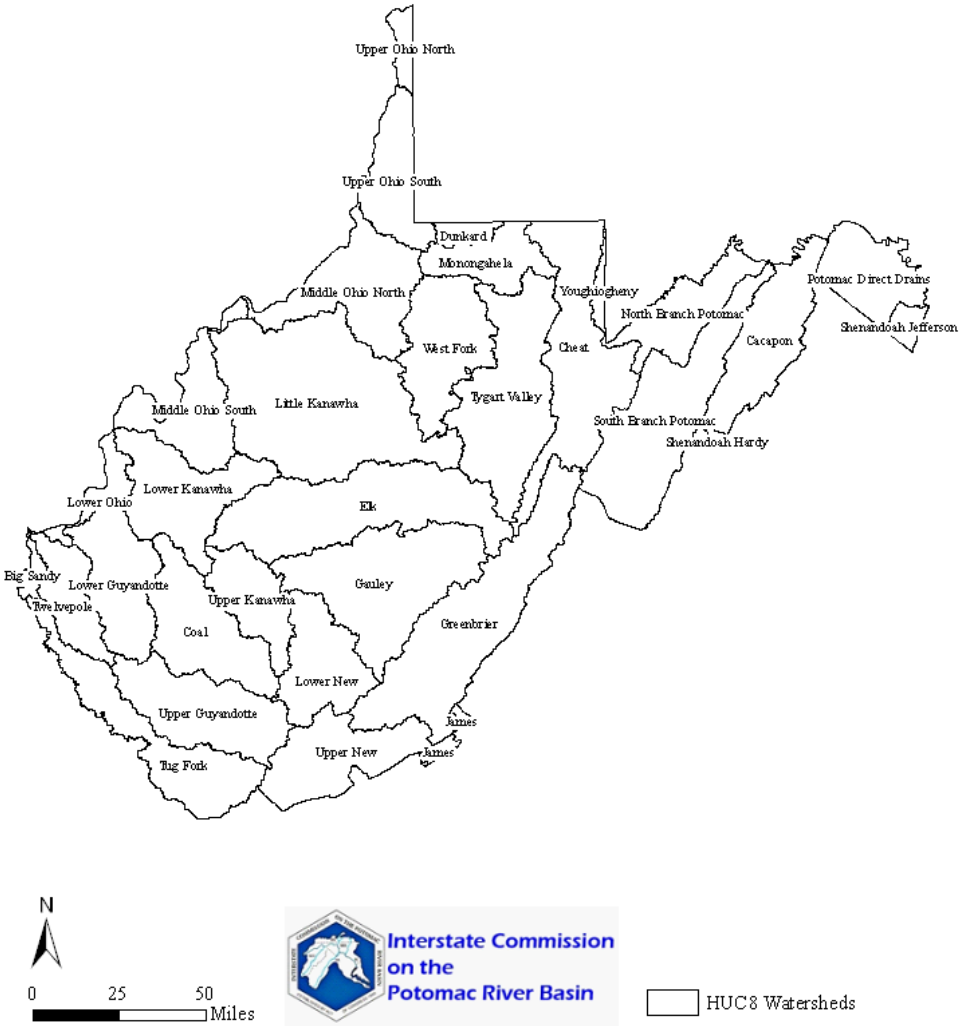
There are numerous non-consumptive uses of West Virginia waters, several of which will be reviewed here. These uses include wildlife and associated habitats (rare, threatened, and endangered species; critical habitat; mussels; and trout), public lands, wild and scenic rivers, and designated uses. Each of the non-consumptive uses is discussed below, including existing and projected water uses.

Designated Use – "Those uses specified in water quality standards for each waterbody or segment." Source: EPA

One method for quantifying the amount of water needed to sustain human and ecosystem uses is the Ecological Limits Of Hydrologic Alteration (ELOHA) approach. Lessons learned from a recent application of the ELOHA methodology in the Middle Potomac watershed are described to assist in potential environmental flow studies in West Virginia.

Where possible, the analyses non-consumptive uses were identified at the 8-Digit Hydrologic Unit Code (HUC8) watershed level (**Figure 1**). The hydrologic unit system was originally developed by the U.S. Geological Survey (USGS) as a standardized way of numbering and delineating watershed systems throughout the country. There are 32 HUC8 watersheds that fall completely or partially in West Virginia.

Figure 1. HUC8 watersheds of West Virginia. Data source: Department of Environmental Protection (DEP).



2 Wildlife and Associated Habitats

West Virginia is rich in biological diversity. Significant work has been done to understand the species' ranges, habitats, and relationships to water resources. Studies such as the West Virginia Gap Analysis have attempted to document the range of many species across the state utilizing available land cover data (USGS 2002). Organizations such as the West Virginia Department of Natural Resources (DNR) and the United States Fish and Wildlife Service (USFWS) track species across the state. The non-consumptive uses of water by rare, threatened, and endangered species; critical habitat; mussels; and trout are considered here.

2.1 Rare, Threatened, and Endangered Species

As defined in the Endangered Species Act, endangered species are "any species which is in danger of extinction throughout all or a significant portion of its range other than species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under the provisions of the Act would present an overwhelming and overriding risk to man." Threatened species are "any species which is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range." Rare species in West Virginia have few individuals across their entire range, are decreasing regionally, and/or require unique habitats[1,2].

There are 15 federally endangered species in West Virginia (not including those considered to be extirpated or accidental) including 11 animal and 4 plant species (**Appendix A**). The diamond darter is a proposed endangered species not included in these numbers. There are 5 federally threatened species in West Virginia (**Appendix A**). Two species, the peregrine falcon and the bald eagle, were removed from the federal list in 1999 and 2007, respectively (DNR 2012). These and many other rare species are given state ranks by the Natural Heritage Program and global ranks by NatureServe and are subsequently tracked by DNR for management purposes[3].

Availability of water resources is essential to protecting the rare, threatened, and endangered species. The nature of the relationship to the water resources for a particular species depends on a number of factors. For example, if the water resources in an area become insufficient, is the organism able to move to another water source? Does the organism depend on the waterways for an occasional drink or does it live in the water for its entire life cycle? **Appendix A** documents the importance of water resources for each of the federally listed species in West Virginia.

The count of these rare, threatened, and endangered individuals by HUC8 is provided in **Table 1**. The Elk watershed, followed by the Middle Ohio South watershed, has the largest count of rare, threatened, and endangered individuals. The Shenandoah Hardy watershed has the fewest individuals with only two element occurrences[4]. **Figure 2** and **Figure 3** show the areas with the largest number of individuals by HUC12 for terrestrial and aquatic species, respectively.

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[1] http://www.wvdnr.gov/wildlife/endangered.shtm, accessed 2/25/2013.
[2] There is no state endangered species legislation in West Virginia so the state threatened and endangered species are those listed by the federal government (http://www.wvca.us/envirothon/w8.html, accessed 1/7/2013).
[3] Lists of West Virginia rare, threatened, and endangered plant and animal species can be obtained from http://www.wvdnr.gov/Wildlife/RareSpecList.shtm, accessed 12/31/2012.
[4] Element occurrences are the count of rare, threatened, and endangered individuals.

Table 1. Total count of rare, threatened, and endangered individuals by HUC8 watershed. Data source: DNR.

HUC8	Watershed Name	Element Occurrences*
05050007	Elk	3938
05030202	Middle Ohio South	2977
05020004	Cheat	2846
05030201	Middle Ohio North	2388
05030203	Little Kanawha	2182
05050003	Greenbrier	2133
05050006	Upper Kanawha	1711
02070001	South Branch Potomac	1535
05090101	Lower Ohio	1048
05050005	Gauley	1033
02070004	Potomac Direct Drains	798
02070003	Cacapon	761
05050002	Upper New	632
05050008	Lower Kanawha	625
05050004	Lower New	624
05020001	Tygart Valley	567
02070002	North Branch Potomac	514
05020002	West Fork	484
05020005	Dunkard	426
05030106	Upper Ohio South	388
05090102	Twelvepole	314
05070201	Tug Fork	276
05050009	Coal	230
02070007	Shenandoah Jefferson	220
05070102	Lower Guyandotte	215
05020006	Youghiogheny	136
05020003	Monongahela	135
05070101	Upper Guyandotte	130
05030101	Upper Ohio North	113
02080201	James	111
05070204	Big Sandy	34
02070006	Shenandoah Hardy	2

*The element occurrences field is a count of rare, threatened, and endangered individuals.

Figure 2. Count of rare, threatened, and endangered terrestrial individuals by HUC12. Data source: DNR.

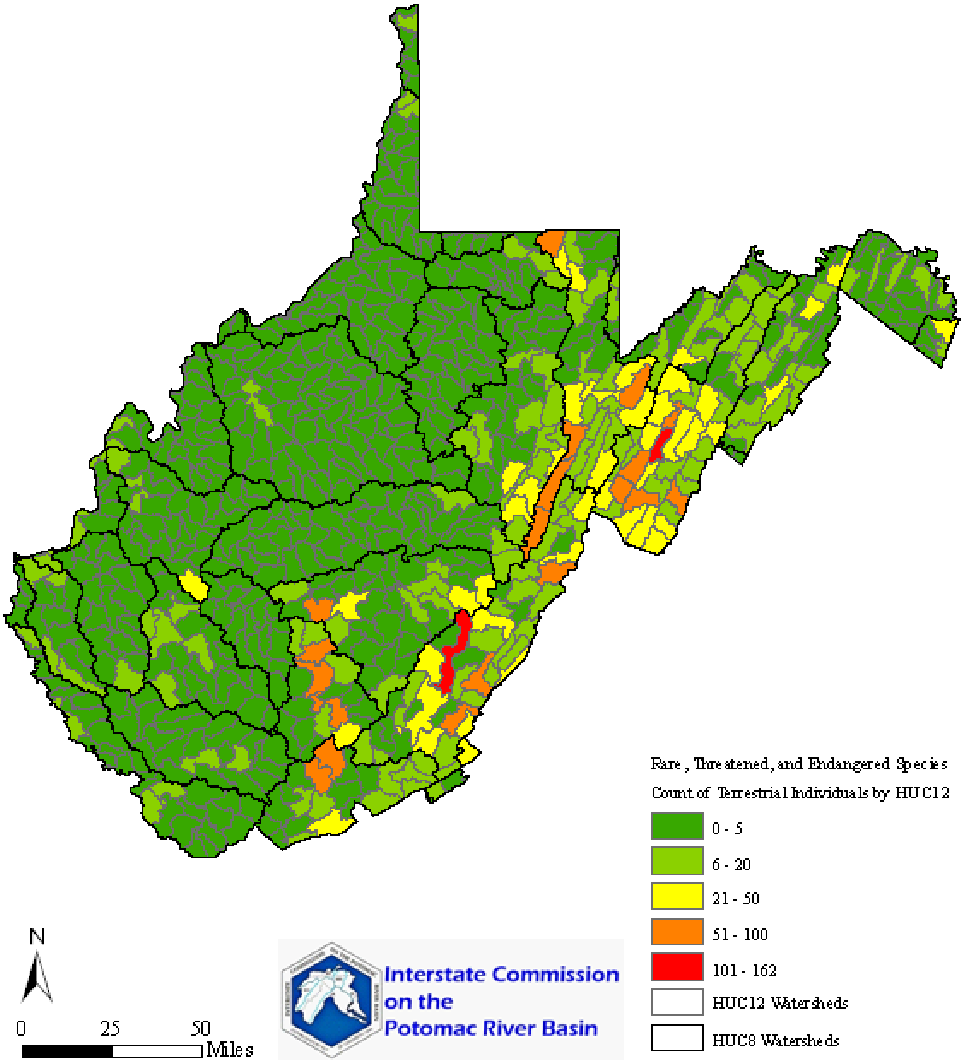
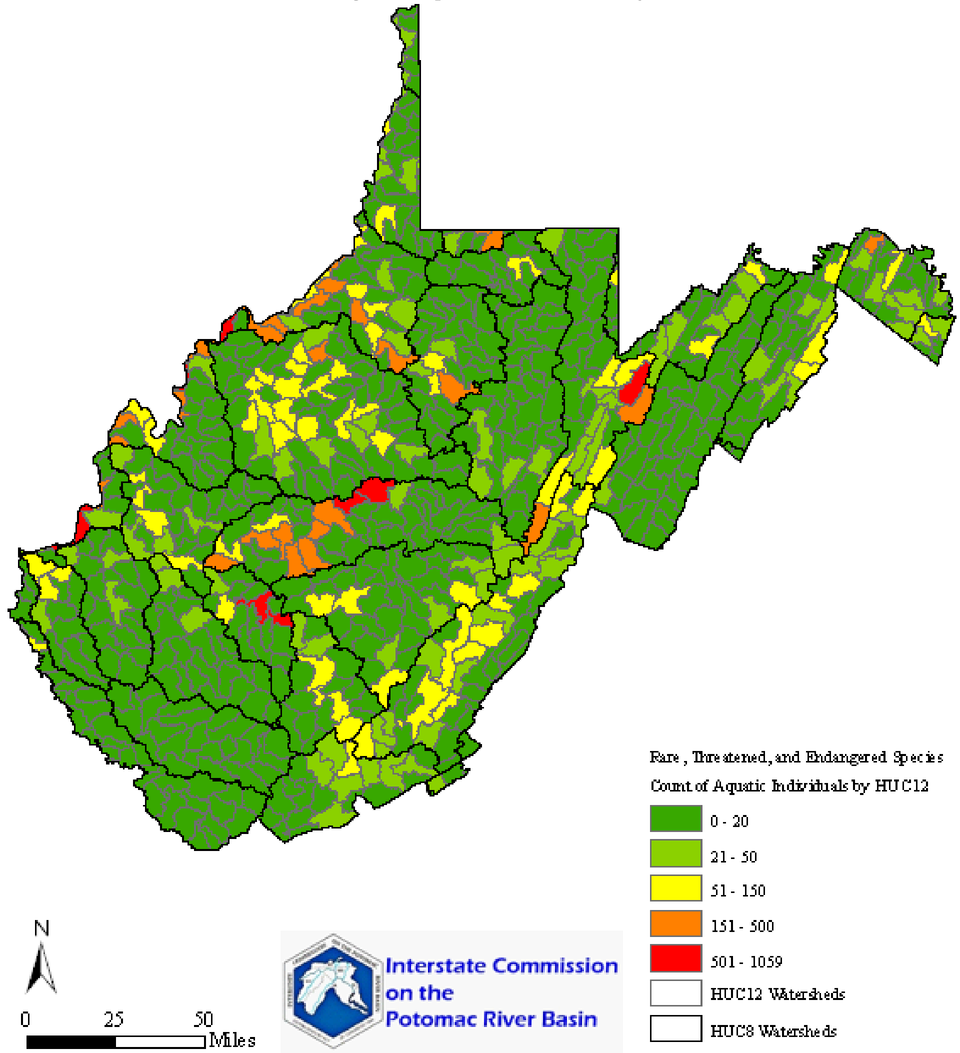


Figure 3. Count of rare, threatened, and endangered aquatic individuals by HUC12. Data source: DNR.

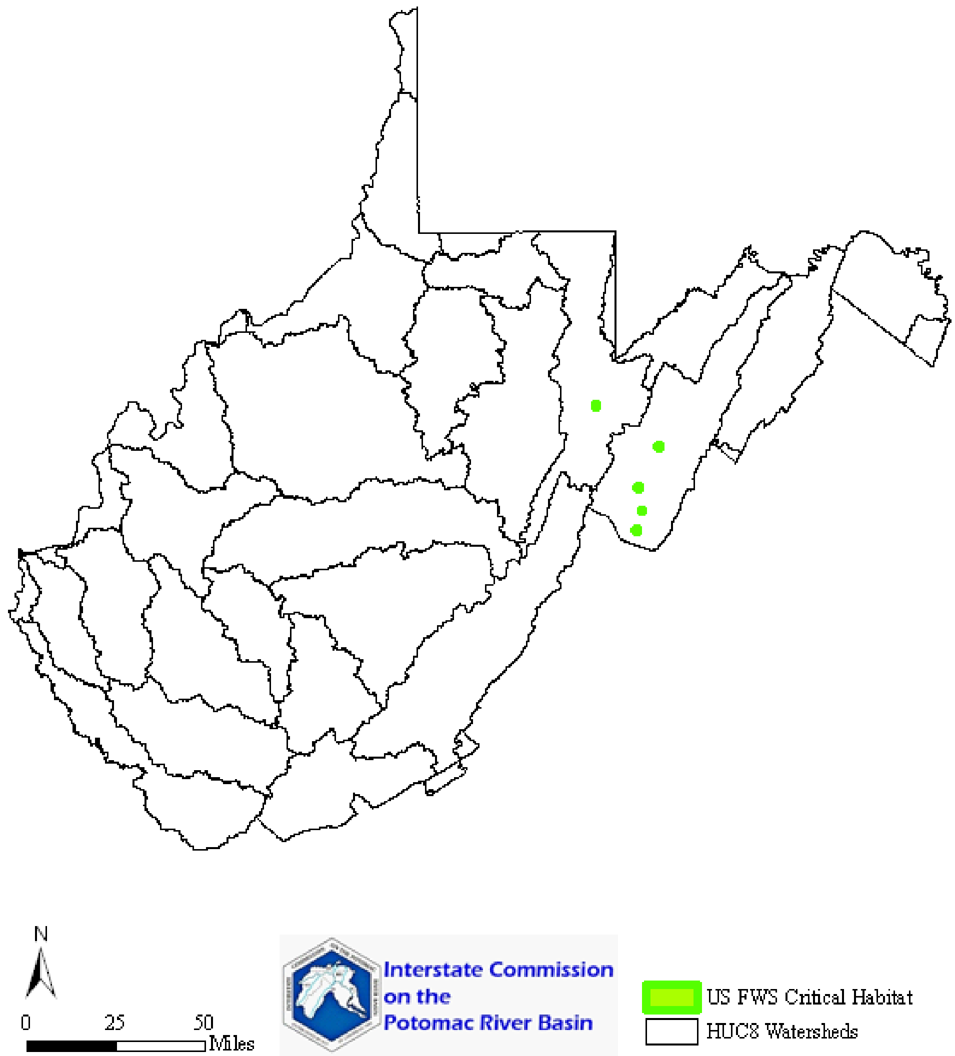


2.2 Critical Habitat

Critical habitat is defined as a geographic area that is essential for the protection of a threatened or endangered species under the Endangered Species Act (USFWS 2009). Federal activities in these areas must be approved by the USFWS to ensure the conservation of the species. Critical habitat has not been officially designated for many of the threatened or endangered species in the state (personal comm., USFWS, 12/21/2012); however, five areas of critical habitat were designated by the USFWS in West Virginia (**Figure 4**). The habitats are for the Virginia big-eared bat and the Indiana bat and are located in the Cheat and South Branch Potomac HUC8s.

One additional critical habitat is being proposed for the diamond darter in the lower Elk River near Charleston. The diamond darter is extremely rare. The species was thought to be extinct until it was rediscovered in West Virginia in 1980. Since then, fewer than 50 have been identified (The Charleston Gazette 2012). Threats to the diamond darter include habitat destruction by coal mining, oil and gas development, sedimentation, untreated sewage, and impoundments. Further, the diamond darter is vulnerable due to overutilization for human uses (such as scientific, commercial, and/or recreation purposes), disease or predation, and due to the inadequacy of current regulatory mechanisms (Federal Register 2012).

Figure 4. Critical habitat designations in West Virginia. Sizes are exaggerated to enhance visibility. Data source: USFWS.



2.3 Mussels

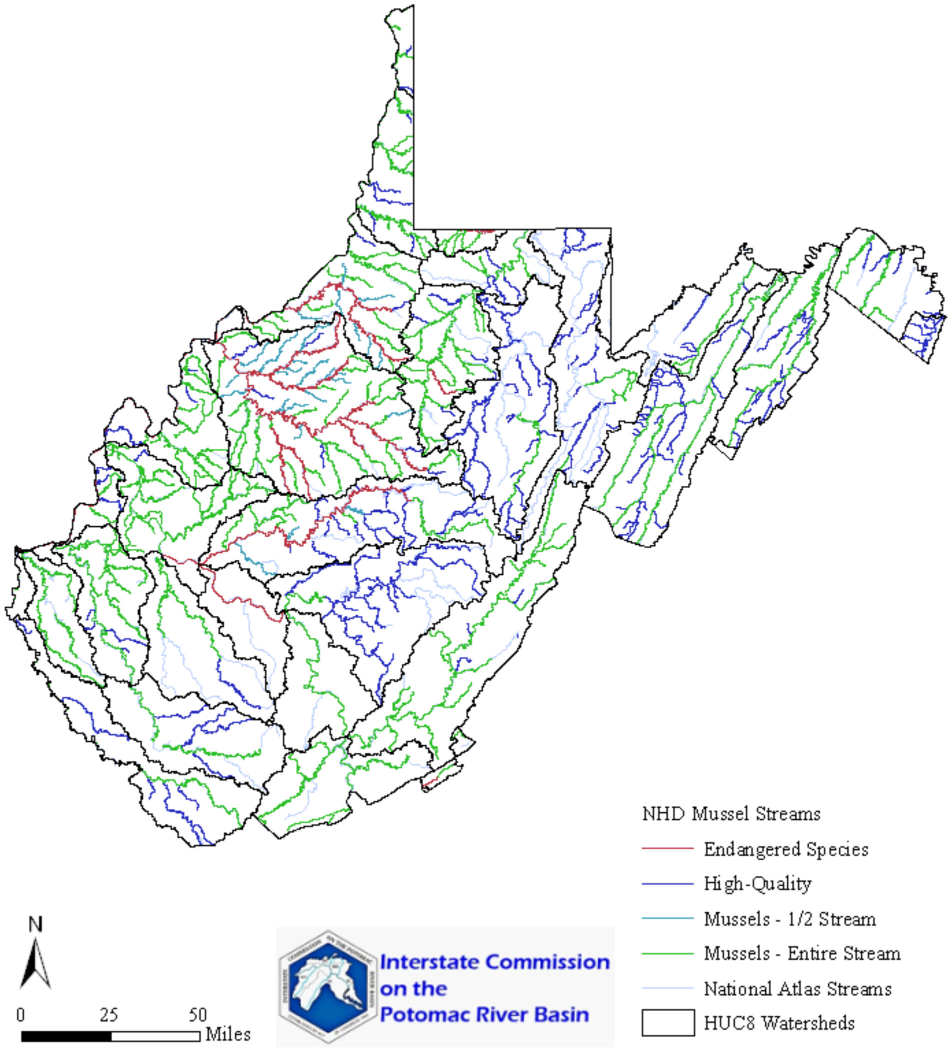
Mussel populations are found in many West Virginia streams (**Figure 5**). In general, mussels are very sensitive to changes in water quality because they are sedentary filter feeders. Due to their sensitivity, mussels are a commonly used indicator species (Cummins et al. 2010), meaning that deterioration in the mussel populations can indicate trouble for other species.

Threats to mussels in West Virginia include increased siltation (e.g. impoundments, channelization, forestry, mining, agriculture, etc.). Because mussels are dependent on fish to be hosts and disperse larvae, mussel populations are secondarily affected by any impacts to the host species[5]. Siltation can smother the mussels, affect food supplies, and negatively impact the host fish. Toxins can also harm

[5] http://www.wvdnr.gov/wildlife/RETSpecies.asp, accessed 3/28/2013.

mussels because they can be exposed over long periods of time. Other threats include erosion, acid runoff, trampling, changes in water temperatures, and competition from invasive species such as zebra mussels.

Figure 5. Locations of mussel populations in West Virginia. "Endangered Species" streams are those with or likely to have endangered species. "Mussels – 1/2 stream" are streams that join an endangered species stream. These streams may need to address potential endangered species impacts in the lower half mile. "Mussels – Entire Stream" may need to address potential endangered species impacts in the entire stream.   "High-Quality" streams are those that have the potential for mussels but no survey data exists. Data source: DNR.



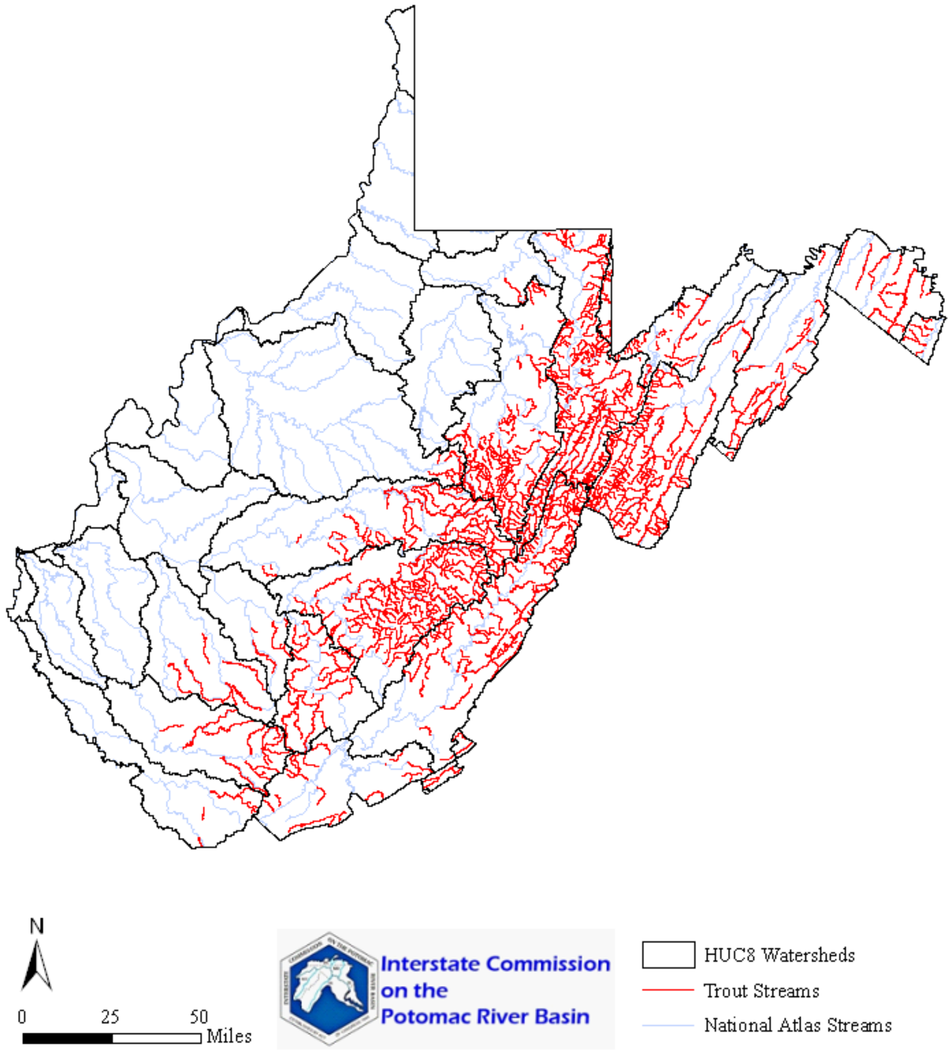
2.4 Trout

According to the DNR, there are approximately 500 miles of native trout streams in the state. Brook trout is the only native trout species[6]. DNR stocks for rainbows, browns, brook, and West Virginia golden rainbows[7]. Trout are dependent on sufficient quality and quantity of waters and associated habitats for survival. Habitat suitability requirements for the rainbow, brown, and brook trout are

[6] http://www.wvdnr.gov/Wildlife/BTrout.shtm, accessed 3/28/2013.
[7] http://www.wvdnr.gov/fishing/PDFFiles/FISHtourweb04.pdf, accessed 3/28/2013.

provided in **Appendix B**. In total, the state has over 120 stocked trout streams. Stocking begins in January and continues through May. Trout streams in West Virginia are mapped in **Figure 6**.

Figure 6. Trout streams in West Virginia. Data source: DEP.



3 Public Lands

Public lands are important for a number of ecological, environmental, and social reasons (Loomis 2002). These areas are important for maintaining wildlife because the sole habitats of many species occur on public lands. For example, the majority of the federally threatened flat-spired three-toothed snail's range occurs within Cooper's Rock State Forest (USFWS 1983). Further, the pervious spaces on public lands provide opportunity for infiltration, groundwater recharge, and water quality protection. Recreation often occurs on public lands. In West Virginia, approximately "71,000 hunters, 156,000 birdwatchers, hikers and nature photographers, and more than 300,000 anglers" recreate on public lands and waters each year, amounting to an economic impact of approximately $350 million per year (Brown 2003).

There are approximately 2,500 square miles (sqmi) of public lands in West Virginia including national forests, national historic parks, national recreation areas, national rivers, national scenic rivers, national wildlife refuges, state forests, state parks, state recreation areas, and wildlife management areas

(**Figure 7**). The Cheat watershed has the largest amount of public lands, with 491.1 sqmi, followed by the Greenbriar, Gauley, and the South Branch Potomac watersheds (**Table 2**).

Public lands in West Virginia are primarily owned by the federal government followed by the state government (**Table 3**). As management of these lands is in the public sphere, activities that are harmful to water quality and quantity can be appropriately minimized and beneficial activities can be promoted.

Figure 7. Location of public lands in West Virginia by type. Data source: DEP.

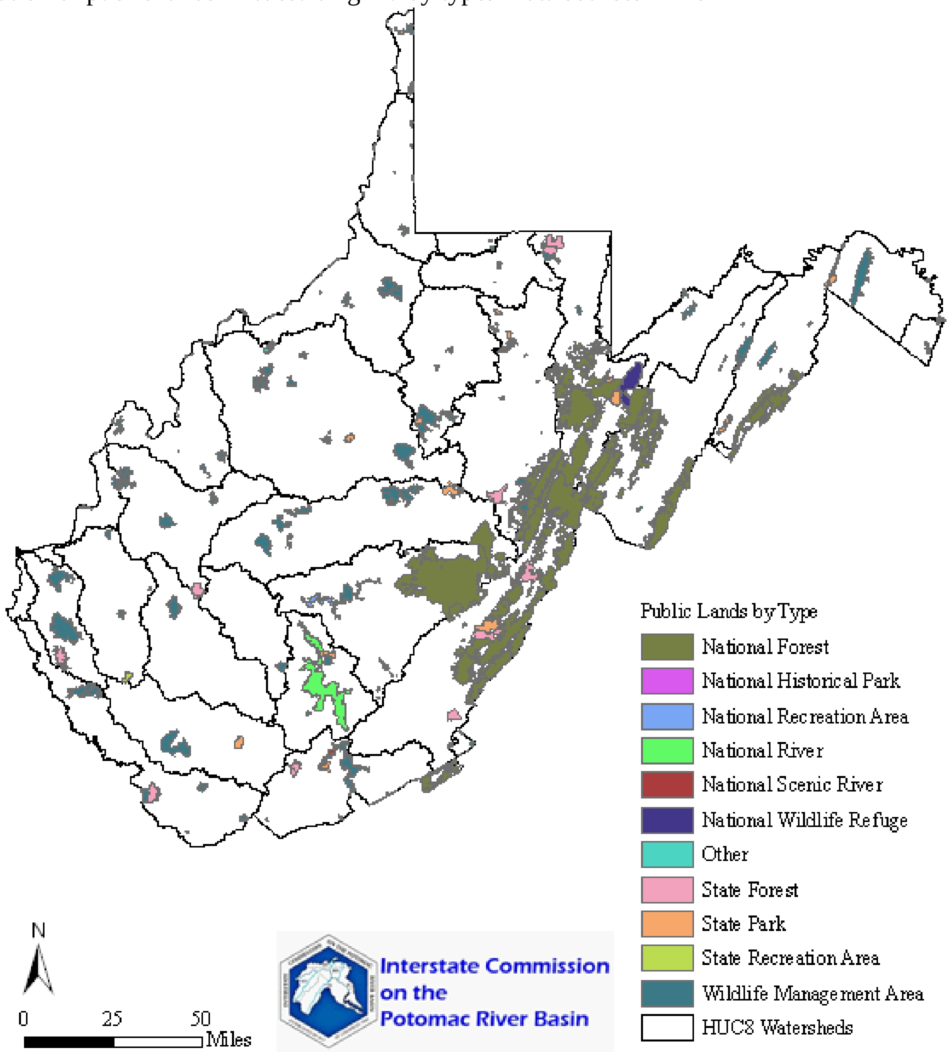


Table 2. Area of public lands by type for each HUC8 (sqmi).

	Federal						State		Federal and/or State	Federal, State, or Local	
Watershed	Wildlife Refuge	Scenic River	Recreation Area	River	Historical Park	Forest	Rec Area	Park	Wildlife Management Area	Other	**Sum**
Cheat	39.2	0	0	0	0	432.7	0	12.7	6.5	0	**491.1**
Greenbrier	0	0	0	0	0	461.9	0	18	1.1	0	**481**
Gauley	0	0	17.4	0	0	281.2	0	0.4	21	0	**320**
South Branch Potomac	0	0	0	0	0	238.8	0	0	16.3	0	**255.1**
Elk	0	0	0	0	0	52.6	0	11	64.9	0	**128.5**
Lower New	0	0	0	113.1	0	0	0	7.2	5	0	**125.3**
Cacapon	0	0	0	0	0	82.6	0	9.4	17.3	0	**109.3**
Tygart Valley	0	0	0	0	0	44.6	0	10.2	12	2.5	**69.3**
Twelvepole	0	0	0	0	0	0	0	0	59.2	0	**59.2**
Little Kanawha	0	0	0	0	0	0	0	7.2	44.6	3.3	**55.1**
Upper New	0	6.8	0	0	0	3.9	0	8.3	29.4	0	**48.4**
Potomac Direct Drains	0	0	0	0	0.3	0	0	6.8	36	0.8	**43.9**
West Fork	0	0	0	0	0	0	0	3.7	35.2	0	**38.9**
Upper Guyandotte	0	0	0	0	0	0	0	5.9	31.1	0	**37**
Tug Fork	0	0	0	0	0	0	0	0	33.2	0	**33.2**
Middle Ohio North	2.6	0	0	0	0	0	0	0	25.5	1.3	**29.4**
James	0	0	0	0	0	27.1	0	0	1.7	0	**28.8**
Lower Kanawha	0	0	0	0	0	0	0	0	24.1	0	**24.1**
Middle Ohio South	3.1	0	0	0	0	0	0	0.8	11.9	0	**15.8**
Coal	0	0	0	0	0	0	0	0	13.7	0	**13.7**
Lower Guyandotte	0	0	0	0	0	0	4.8	0	4.8	0.2	**9.8**
Upper Ohio North	0.7	0	0	0	0	0	0	2.1	6.6	0	**9.4**
Lower Ohio	0.2	0	0	0	0	0	0	0	9.1	0	**9.3**
North Branch Potomac	0.1	0	0	0	0	0.1	0	0	8.7	0	**8.9**
Upper Ohio South	1.6	0	0	0	0	0	0	0	5.1	0	**6.7**
Upper Kanawha	0	0	0	0	0	0	0	0	4.9	0	**4.9**
Shenandoah Jefferson	0	0	0	0	1.4	0	0	0	2.3	0	**3.7**
Shenandoah Hardy	0	0	0	0	0	3.5	0	0	0	0	**3.5**
Monongahela	0	0	0	0	0	0	0	0	1.8	0	**1.8**
Dunkard	0	0	0	0	0	0	0	0	1.2	0.0	**1.2**
Youghiogheny	0	0	0	0	0	0	0	0.2	0	0	**0.2**
Total	**47.5**	**6.8**	**17.4**	**113.1**	**1.7**	**1629**	**4.8**	**103.9**	**534.2**	**8.1**	**2466.5**

Table 3. Public lands by owner type for the state of West Virginia.

Type	Percent of Public Lands
Federal	77.4
State	20.1
Private	1.3
State & Private	0.8
State & Federal	0.2
County	0.2

4 Wild and Scenic Rivers

The Wild and Scenic Rivers Act was signed by President Lyndon Johnson in 1968, creating the National Wild and Scenic Rivers System. The purpose of the act is to preserve rivers with "outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations." The distinguishing characteristics of wild and scenic rivers are listed below[8].

Wild rivers are:
1) free of impoundments,
2) generally inaccessible except by trail,
3) essentially primitive in terms of watersheds or shorelines, and
4) free of water pollution.

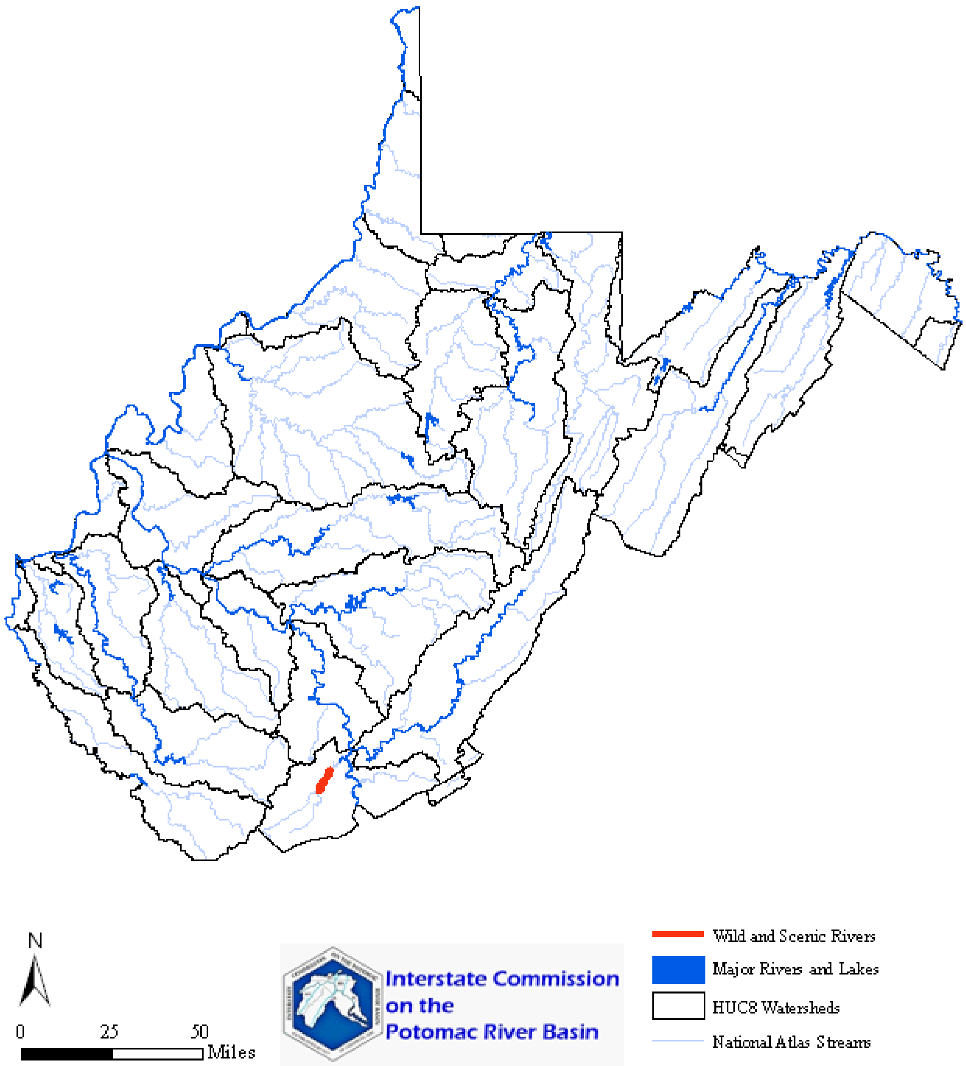
Scenic rivers are:
1) free of impoundments,
2) largely primitive in terms of shorelines or watersheds,
3) shorelines largely undeveloped, but
4) accessible in places by roads.

According to the National Wild and Scenic Rivers System, there are 12,598 river miles of designated waters in the country. The 12.7 miles of designated West Virginia waters are, therefore, only 0.1 percent of the nation's Wild and Scenic Rivers.

The Bluestone River is the only National Wild and Scenic River in West Virginia, originally designated in 1988. The Bluestone River is located in the Upper New HUC8 watershed (**Figure 8**). The designated segment is 12.7 miles in length. Starting its journey on the East River Mountain in Virginia, the Bluestone River flows 77 miles before joining the New River at Bluestone Lake. The designated portion of the river is in the Bluestone Gorge between Pipestem and Bluestone State Parks. The gorge offers a myriad of outdoor activities including warmwater fishing, whitewater boating, hiking, and hunting[9]. The river is home to diverse aquatic and terrestrial species including fish (e.g. smallmouth bass, bluegill, catfish), birds (e.g. kingfishers and great blue herons), and mammals (e.g. beaver, fox, bobcat, deer). The region is forested and includes maple, oaks, hickories, birch, and sycamores[10].

[8] http://www.rivers.gov/rivers/, accessed 2/20/2013.
[9] http://www.rivers.gov/rivers/rivers/bluestone.php, accessed 2/20/2013.
[10] http://www.nps.gov/blue/index.htm, accessed 2/19/2013.

Figure 8. Location of the designated segment of the Bluestone River in the Upper New HUC8. Data source: National wild and scenic rivers system.



Two other West Virginia river segments worth noting are the New River Gorge National River and the Gauley River National Recreation Area. According to the National Park Service, the New River Gorge was declared a National River in 1978 and includes over 50 miles of the New River from Bluestone Dam to Hawk's Nest Lake. The Gauley River National Recreation Area is comprised of 25 miles of the Gauley River and 6 miles of the Meadow River.

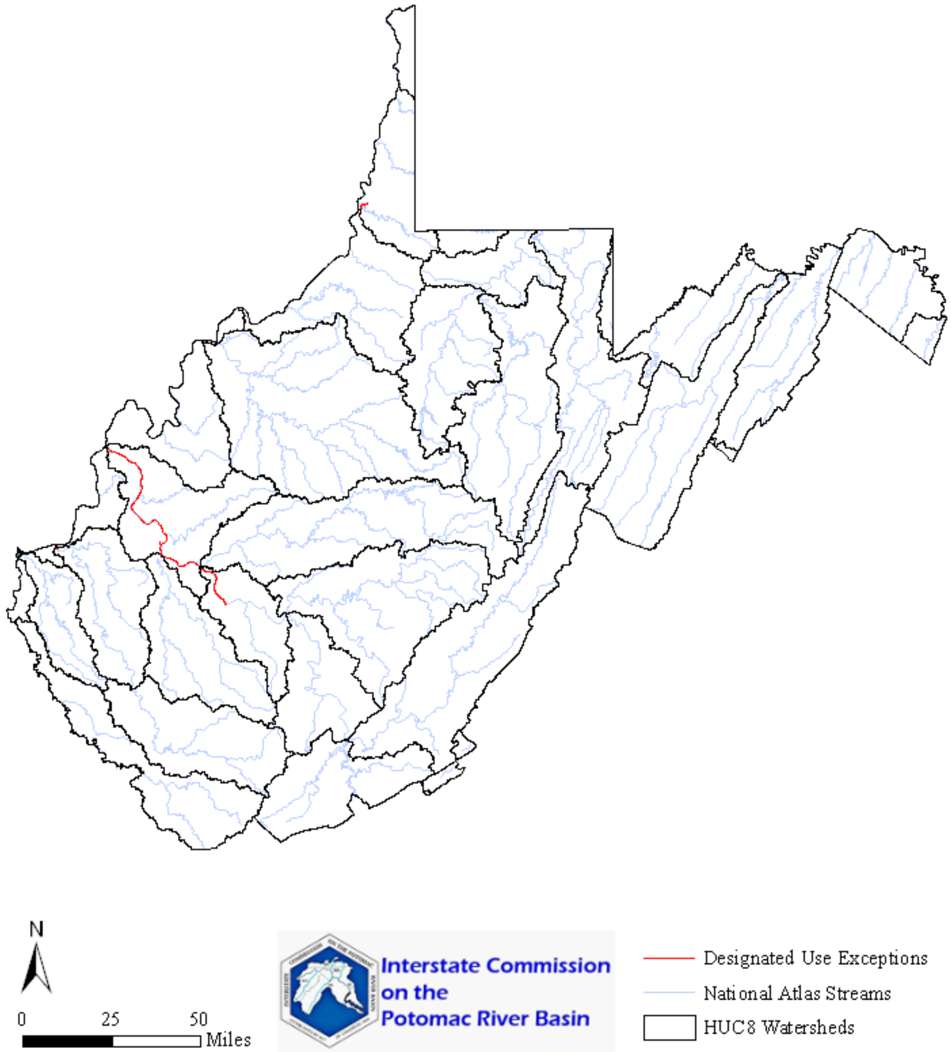
5 Designated Uses

Water quality regulations in West Virginia are primarily governed by the U.S. Clean Water Act, based on the 1972 amendments to the Federal Water Pollution Control Act. Under authority granted by the federal government, the state of West Virginia assigns designated uses for each waterway (contact recreation, aquatic life-trout water, aquatic life-warm water, drinking water, industrial, agriculture, and irrigation). Some of these designated uses are non-consumptive. Subsequently, numeric water quality criteria are established for each designated use and waterways are evaluated to determine whether they meet the established criteria. Water quality standards for West Virginia waterways are documented in the Requirements Governing Water Quality Standards Rule – Title 47CRS2.

Antidegradation rules are also in place to prevent further deterioration of water quality. West Virginia maintains a three-tier system that designates waterbodies depending on the level of protection necessary to protect/maintain conditions. The higher the tier the more protections are in place. Tier 1 maintains and protects existing uses and includes all impaired waters. Tier 2 maintains and protects all high quality waters, or those not listed on the 303d list[11]. Tier 3 maintains and protects outstanding national resource waters[12].

The majority of streams in West Virginia are designated for all uses (contact recreation, aquatic life-trout water, aquatic life-warm water, drinking water, industrial, agriculture, and irrigation). There are 119 stream reaches that have exceptions to these uses, including sections of the Kanawha River (upper and lower), Detz Hollow, Little Scary Creek, and Conner Run (**Figure 9**).

Figure 9. Designated use exceptions. Data source: DEP.



[11] The 303d list is a compilation of waterways that do not meet the water quality standards established for the designated use.
[12] http://www.dep.wv.gov/WWE/Programs/wqs/Pages/default.aspx, accessed 1/8/13.

6 Current and Future Water Uses

6.1 Rare, Threatened, and Endangered Species

West Virginia rare, threatened, and endangered species are dependent on water resources for their life cycle requirements such as habitat and food sources (**Appendix A**). Protection of rare, threatened, and endangered aquatic species, therefore, may depend on protecting flows and natural variability. **Appendix C** provides general habitat requirements for the fish species listed as "critically imperiled" in the state. Habitat suitability indices are also available from the USFWS for a handful of the **Appendix C** species and may be used as examples of the effort required to determine suitable habitats for a particular species.

Efforts are underway and will continue to protect and encourage the survival of these species. The USFWS conducts a recovery program for listed species[13]. Some of the funding for this program has been provided to assist West Virginia species. For example, in August 2012, a $700,000 USFWS grant was awarded to acquire known habitat for the threatened flat-spired three-toothed land snail and the endangered Indian bat in Preston County[14]. To the extent that these efforts are successful, the dependence on the resources will grow along with the number of individuals of these species.

6.2 Public Lands

The non-withdrawal uses of water on public lands include water necessary to sustain the wildlife and ecosystems, tourism, and support the recreational and the for-profit use of the lands (e.g. timber harvesting). The amount of water necessary for these uses is site-specific and varies by use and often by season. Quantifying these uses will require detailed ecosystem and human use studies for each public land area. For example, the West Virginia Statewide Forest Resource Assessment provides a plan for the conservation and maintenance of the forests and forest resources (West Virginia Division of Forestry 2010).

Acquisition of additional lands is the goal of the Wildlife Resource Section's efforts "spurred by the decline in public access to private land and by the continued destruction of critical habitats." Other programs across the state aim to enhance open spaces such as the West Virginia Land Trust, West Virginia Division of Forestry Forest Legacy Program, and the Voluntary Farmland Protection Act.

6.3 Wild and Scenic Rivers

Daily flows are available on the Bluestone River near Pipestem, West Virginia, since July 1950 (USGS gage 03179000). The drainage area above the gage is 395 square miles. Select flow characteristics of the Bluestone River are provided in **Table 4** (water years 1951 to 2012). Since this segment is a designated Wild and Scenic River, maintenance of these and other flow characteristics may be desirable.

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[13] http://www.fws.gov/northeast/EcologicalServices/recovery.html, accessed 12/31/2012.
[14] http://www.fws.gov/westvirginiafieldoffice/news1.html, accessed 2/19/2013

Table 4. Flow metrics for the Bluestone River near Pipestem, West Virginia (water years 1951 to 2012). Analyses run in IHA software (The Nature Conservancy 2007) with the exception of Richards-Baker (RBI) Flashiness which was calculated using an ICPRB macro in Excel.

Metric	Value	Units
RBI Flashiness	0.37	NA - ratio
Median daily flow	213	cfs
3-day minimum	25	cfs
3-day maximum	4707	cfs
Low pulse count	8	#/year
Low pulse duration	7	days/year
High pulse count	12	#/year
High pulse duration	5	days/year
Rise rate	44.5	cfs/day
Fall rate	-29.5	cfs/day
Number of reversals	97.5	#/year
Extreme low frequency	3	#/year

6.4 Designated Uses

Maintaining numeric water quality standards associated with West Virginia designated uses requires the availability of sufficient quantities of water. The amount of water necessary will depend on the amount and type of the pollutants of concern and the hydrologic characteristics of individual waterways.

7 Environmental Flows

Determining the amount of flow needed to sustain humans and ecosystems is a complex process that requires consideration of multiple flow components including magnitude, duration, timing, and rate of change of flows. Further, flow characteristics sufficient to sustain uses in one watershed may be insufficient in another. The Interstate Commission on the Potomac River Basin (ICPRB), in collaboration with The Nature Conservancy and the U.S. Army Corps of Engineers, conducted an environmental flows study, the Middle Potomac River Watershed Assessment (MPRWA) (U.S. Army Corps of Engineers et al. 2012). The MPRWA endeavored to "quantify Potomac watershed environmentally sustainable flows – flows that sustain healthy river ecosystems and the goods and services that humans derive from them." Lessons learned from that effort may illuminate the work necessary to complete such a project in West Virginia.

The MPRWA modified the ELOHA approach developed by Poff et al. (2010) to understand the relationships of hydrologic alteration and ecological degradation in the Potomac basin. Initially, available data were collected that describe the human uses of land and water across the study area (e.g. withdrawals, discharges, impoundments, and land uses). A hydrologic model was used to simulate current, baseline, and future scenario streamflows for 747 watersheds in the study area, ranging from headwater streams to major rivers. Ecological health was represented in the study with macroinvertebrate data. Flow metrics based on the hydrologic model results were paired with biometrics at each watershed outlet to generate flow alteration–ecological response curves. The results may be used in water resources and land management decision-making by illustrating how much alteration in ecological health is associated with a particular amount of hydrologic alteration. For example, the results may assist in determining the potential ecological impacts of a newly permitted water withdrawal. Similar impacts could be determined for new or altered impoundment operations or changes in land use. Determining whether the amount of ecological alteration is acceptable is a social or political decision.

The findings of the MPRWA illustrate that there is a strong relationship between impervious surface, flow alteration, and significant ecological impacts in the Potomac basin. The hydrologic effects can be seen with as little as 0.5 to 2.0 percent increases in impervious surface in a watershed. Land use planners may find these results useful for stormwater management and urban land use planning. Water withdrawals and discharges, on the other hand, impact flows when they represent a substantial percentage of mean annual flow. Agriculture was not found to directly impact streamflow, however, the effects may be confounded with the impacts of impervious surface. The relationships between land and water uses, hydrologic alteration, and ecological health can be used to inform managers about when and to what extent withdrawals, discharges, impoundments, and land uses alter streamflow.

There are several benefits to this type of environmental flows project. The results can be used for informed decision-making and, therefore, may reduce water management conflicts. When acted upon, knowledge of how flow alteration relates to biological health can be used to prevent ecological degradation by protecting key components of the natural flow regime. The flow alteration–ecological response relationships may be used to evaluate alternative scenarios for human land and water uses.

Lessons learned from the MPRWA include the following. Considerable effort is required to simulate and evaluate current, baseline, and potential future flow regimes using hydrologic models. Alternatives to full models are available such as the USGS' Sustainable Yield Estimator (Archfield et al. 2010); however, hydrologic models offer considerable additional information with the simulation of future scenarios. Future scenarios are a valuable addition to environmental flow studies because they allow evaluation of changes in hydrologic condition under different "what if" future watershed conditions. However, future scenarios have inherent uncertainty because the nature of future conditions is unclear. Modeled future scenarios, therefore, can be thought of as defining the range of possible future conditions and not attempting to quantify actual future conditions. Another lesson learned is that model verification and flow metric testing are essential steps in building confidence in the modeled flow time series. Without verification, it will be unclear whether the modeled flows are an acceptable representation of reality. Lastly, including managers, regulators, scientists, and interested citizens in the process is essential to conveying the large quantities of technical information and requesting feedback on methodologies and presentation of results.

A considerable challenge to implementing an ELOHA approach is the availability of necessary research, analyses, data, monitoring, and modeling. The MPRWA conclusions identified the following additional information needs for ELOHA projects such as may be pursued in West Virginia:

- consider a range of flow metrics and biometrics as necessary to represent the full range of conditions;
- include other taxa, such as fish, in addition to macroinvertebrates to develop flow alteration–ecological response relationships;
- when possible, conduct the analyses using family versus genus level biological data;
- develop flow alteration–ecological response relationships with additional stream classification factors, in addition to bioregion;
- compare predicted hydrologic alteration to the model's margin of error;

- consider the reliability of data at extreme ends of the flow alteration–ecological response curves, given the scarcity of data at the extremes; and
- develop specific flow-ecology hypotheses.

The MPRWA report also recommends enhancing understanding of:

- flow alteration in areas that are hydrologically unique (e.g. karst watersheds);
- the confounding influences of non-flow factors impacting ecosystems and biological communities;
- available best management practices that may eliminate or reduce the negative impacts of both low and high flow conditions; and
- responses by aquatic and riparian communities to natural droughts.

Ongoing and additional data needs for the Potomac study included:

- continuous stream gage monitoring at existing sites (primarily located on large and medium rivers) and additional monitoring in small streams, karst watersheds, and in reference watersheds;
- basin-wide data sets of other biometrics besides macroinvertebrates (e.g. fish);
- groundwater withdrawal data that is sufficiently detailed to include in the hydrologic model and a hydrologic model that is capable of simulating groundwater withdrawals;
- high resolution meteorological data for modeling small watersheds; and
- selection of a modeling tool that is capable of evaluating site-specific land use changes and best management practices.

Overall, the MPRWA provides managers and decision-makers with valuable information on the ecological impacts of hydrologic alteration. The ELOHA process requires extensive research, analyses, data, monitoring, and modeling. Filling identified information gaps would facilitate successful completion of future ELOHA projects.

The cost of the MPRWA was $1.3 million. Approximately 75 percent of the cost was covered by the U.S. Army Corps of Engineers. The Nature Conservancy was the local cost share partner. ICPRB conducted the technical work and also contributed financially to the project.

8 Discussion

Non-consumptive uses of West Virginia waters include wildlife and associated habitats, public lands, wild and scenic rivers, and designated uses. Flows should be managed in a way that protects non-consumptive uses. Failure to sustain these uses may have environmental, economic, and social impacts locally and statewide.

The ELOHA methods to quantifying environmental flows, as implemented in the Middle Potomac watershed, is a useful tool for planning and management purposes. Implementing an environmental flows process in West Virginia may provide insight into the magnitude, timing, duration, and rate of change of flows necessary to sustain the non-consumptive uses described here.

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Appendix A

Importance of water resources for federally threatened and endangered species in West Virginia

Common Name	Scientific Name	Type	Status	Importance of Water	Threats and Prospects	Source
Clubshell	Pleurobema clava	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	DNR Wildlife Resources†
Fanshell	Cyprogenia stegaria	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	DNR Wildlife Resources†
Harperella	Ptilimnium nodosum	Plant	Federally endangered	Habitat in WV consists of wet soils near clear, swiftly flowing streams	Grazing, habitat alteration (e.g. siltation)	DNR Wildlife Resources†
Indiana Myotis	Myotis sodalis	Bat	Federally endangered	Feeds in wooded areas along rivers and upland forests	Because these bats are concentrated into just a few caves during the winter, they are very vulnerable to disturbance. It is estimated that one cave in Pendleton County harbors over 90 percent of the Indiana myotis in West Virginia. Also contamination of food supplies.	DNR Wildlife Resources†
James Spiny Mussel	Pleurobema collina	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	DNR Wildlife Resources†
Northeastern Bulrush	Scirpus ancistrochaetus	Plant	Federally endangered	Grows at the edge of ponds and other small expanses of standing water	Water quality deterioration, trampling by deer, off road vehicle damage, competition from other vegetation, permanent flooding (e.g. beaver dams)	DNR Wildlife Resources†
Northern Flying Squirrel	Glaucomys sabrinus fuscus	Squirrel	Federally endangered	General consumption and maintenance of foods	Habitat loss to timbering and development	DNR Wildlife Resources†
Northern Riffleshell	Epioblasma torulosa rangiana	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	DNR Wildlife Resources†
Pink Mucket Pearly Mussel	Lampsilis abrupta	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	DNR Wildlife Resources†

Common Name	Scientific Name	Type	Status	Importance of Water	Threats and Prospects	Source
Running Buffalo Clover	Trifolium stoloniferum	Plant	Federally endangered	General life cycle requirements	Loss of habitat, invasive non-native species	USFWS fact sheet**
Shale Barren Rockcress	Arabis serotina	Plant	Federally endangered	General life cycle requirements	Road construction, hiking, foraging	DNR Wildlife Resources†
Sheepnose*	Plethobasus cyphyus	Mussel	Federally endangered	Aquatic species	Primarily creation of dams, but also sedimentation/water quality deterioration, mining, channels, and dredging, oil and gas development	Federal register 3/13/2012
Snuffbox	Epioblasma triquetra	Mussel	Federally endangered	Aquatic species	Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels	Federal register 2/14/2012
Spectaclecase	Cumberlandia monodonta	Mussel	Federally endangered	Aquatic species	Primarily creation of dams, but also sedimentation/water quality deterioration, mining, channels, and dredging, oil and gas development	Federal register 3/13/2012
Virginia Big-Eared Bat	Corynorhinus townsendii virginianus	Bat	Federally endangered	General life cycle requirements	Human disturbance in the cave roosts	DNR Wildlife Resources†
Cheat Mountain Salamander	Plethodon nettingi	Salamander	Federally threatened	Primary habitat requires moisture	Habitat alteration	DNR Wildlife Resources†
Flat-Spired Three-Toothed Land Snail	Triodopsis platysayoides	Snail	Federally threatened	Soil moisture content and humidity requirements, general life cycle requirements	Due to restricted range, local catastrophes could impact a large segment of the population, recreational activities, development, habitat alteration	DNR Wildlife Resources†
Madison Cave Isopod*	Antrolana lira	Isopod	Federally threatened	Aquatic species	Groundwater contamination.	DNR Wildlife Resources†
Small Whorled Pogonia	Isotria medeoloides	Plant	Federally threatened	General life cycle requirements	Cutting of forest habitats and conversion of the landscape to other land uses, digging of plants	DNR Wildlife Resources†
Virginia Spirea	Spiraea virginiana	Plant	Federally threatened	Habitat is usually rocky, flood scoured banks of high-energy streams or rivers	Reduction in required flood-scouring, riverside clearing, overuse by hikers, fishermen, and boaters, reservoir construction,	DNR Wildlife Resources†

*Listed species occurring in this state that is not listed in this state according to USFWS listing and occurrences for West Virginia.

†Available online at http://www.wvdnr.gov/wildlife/endangered.shtm, accessed 1/10/13.

**Available online at http://www.fws.gov/midwest/endangered/plants/runningb.html, accessed 1/10/13.

Appendix B

Habitat suitability requirements of brook, brown, and rainbow trout
(Quoted and paraphrased from USFWS habitat suitability index models – see footers for citations)

	Brook Trout[15]	**Brown Trout**[16]	**Rainbow Trout**[17]
Food	Opportunitistic sight feeders -- bottom-dwelling and drifting macroinvertebrates and terrestrial insects.	Generally feed on terrestrial and aquatic insects, but as they exceed 25cm, fish and crustaceans become more important in the diet.	Opportunistic feeders that consume a variety of foods including aquatic insects, zooplankton, terrestrial insects, fish, vegetation (for the attached invertebrates).
Habitat	Typical habitat conditions include cold temperate climate, cool spring-fed groundwater, and moderate precipitation. Optimal riverine habitat is characterized by clear, cold spring-fed water; a silt-free rocky substrate in riffle-run areas; an approximate 1:1 pool-riffle ratio with areas of slow, deep water; well vegetated stream banks; abundant instream cover; and relatively stable water flow, temperature regimes, and stream banks.	Habitat characterized by clear, cool to cold water; a relatively silt-free rocky substrate in riffle-run areas; a 50% to 70% pool to 30% to 50% riffle-run habitat combination with areas of slow, deep water; well vegetated, stable streambanks; abundant instream cover; and relatively stable annual water flow and temperature regimes. Prefer the lower reaches of low to moderate gradient areas (<1%) in suitable, high gradient river systems.	Clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well-vegetated stream banks; abundant instream cover; and relatively stable water flow, temperature regimes, and stream banks. A major factor limiting the densities may be the amount of adequate overwintering habitat, rather than the amount of summer rearing habitat.
Vegetation	Well vegetated stream banks are an important habitat characteristic for temperature control, source of organic material, erosion control.	Canopy cover is important to keep water temperatures down during the summer and provides habitat for prey and provides the materials for primary production. Well-vegetated riparian areas help control erosion.	Vegetation for feeding stations, escape cover, and winter cover are required.

[15] Quoted and paraphrased from Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. USFWS FWS/OBS-82/10.24. 42p.
[16] Quoted and paraphrased from Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. USFWS Biol. Rep. 82(10.124). 65p. [First printed as: FWS/OBS-82/10.71 , September 1984].
[17] Quoted and paraphrased Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow trout. USFWS FWS/OBS-82/10.60. 64p.

	Brook Trout[15]	Brown Trout[16]	Rainbow Trout[17]
Water Flows and Velocities	The most critical flows are the lowest flows of late summer to early winter. A baseflow greater than or equal to 55% of the average annual daily flow is considered excellent, 25-50% is considered fair, and a baseflow of <25% is considered poor for maintaining trout habitat.	Critical period of the flow regime is the time between egg deposition in late summer and fall, and fry emergence in the following spring. Although flows must be adequate to meet the needs of the developing embryos and yolk sac fry in the gravel, abnormally low or high flows can be destructive. A baseflow greater than or equal to 50% of the average annual daily flow is considered excellent, 25-50% is considered fair, and a baseflow of <25% is considered poor for maintaining trout habitat. A velocity tolerance range over nesting sites is 15-90cm/s, with an optimal range of 40-70cm/s.	A baseflow greater than or equal to 50% of the average annual daily flow is considered excellent, 25-50% is considered fair, and a baseflow of <25% is considered poor for maintaining trout habitat. Focal point velocities between 10 and 14, with a maximum of 22cm/s.
Turbidity	Sensitive to turbidity because it inhibits their ability to locate food; optimum turbidity values are approximately 0-30 JTUs, with a range of 1-130.	Clear water is a habitat requirement.	Clear water is a habitat requirement.
Dissolved Oxygen (DO)	High oxygen concentrations with optimum conditions at dissolved oxygen concentrations near saturation and temperatures above 15C (>7 mg/L at temperatures <15C, >9 mg/L at temperatures >15C). They avoid waters with dissolved oxygen levels less than 5 mg/L.	Optimal levels appear to be greater than or equal to 9mg/L at temperatures <=10C and >=12mg/L at temperatures >10C. In the summer, trout avoid waters with dissolved oxygen levels less than 5 mg/L. Less than 3 mg/L is lethal.	High oxygen concentrations with optimum conditions at dissolved oxygen concentrations near saturation and temperatures above 15C (>7 mg/L at temperatures <15C, >9 mg/L at temperatures >15C). They avoid waters with dissolved oxygen levels less than 5 mg/L.
Salinity	Some coastal populations of brook trout may move into salt water from coastal streams of eastern Canada and northeastern United States.	No information provided.	Can migrate from fresh to salt water.
pH	Tolerant of pH between 3.5-9.8; however, continued exposure to pH below 6.5 results in decreased hatching and growth.	5-9.5, with an optimal range of 6.8-7.8.	5.5-9, with an optimal range of 6.5-8.

	Brook Trout[15]	Brown Trout[16]	Rainbow Trout[17]
Adult Specific	Prefer moderate flows: typically <15cm/s.	Temperature is the single most important environmental variable in determining the geographic distribution of suitable brown trout streams. The upper limit, near lethal, water temperature is 27.2C. Optimal temperatures are 12-19C, with a temperature tolerance range of 0-27C. Water depth >=15cm and a focal point velocity of <15cm/s are recommended for optimal resting and feeding habitat. Adult brown trout seek cover more than any other trout species. Move upstream in the fall to spawn, or in the case of lakes and reservoirs, into tributary streams. Migrations appear to be triggered by decreasing day length, increased late fall flows, or drops in water temperatures. Occupy different habitats in summer than in winter. In winter, they show a strong hiding or cover response behavior, triggered by low temperatures (4-8C).	Depth distribution is usually a function of dissolved oxygen, temperature, and food.
Embryo Specific	Temperatures range from 4.5-11.5C for egg incubation. Dissolved oxygen concentrations should not fall below 50% saturation	Optimal incubation temperatures are approximately 2-13C, with a tolerance range of 0-15C. Optimal velocity and oxygen are assumed to be the same as for nesting site selection by spawning adults.	Combined effects of temperature, dissolved oxygen, water velocity, and gravel permeability are important for successful incubation.
Fry Specific	Temperature is an important limiting factor of growth and distribution of young brook trout. Overwinter in shallow areas of low velocity.	Optimal temperature range from 7-12C. After onset of feeding, growth is best at 12.8C.	When residing in streams, they prefer shallower water and slower velocities than other life stages of stream trout.
Juvenile	Temperatures of 11-14C are optimum. Velocities range from 8-9cm/, with a maximum of 24cm/s. Dissolved oxygen requirements similar to adults.	Temperature optima for juveniles are 7-19C, with a range of 0-27C. Occur at shallower depths and lower velocities than adults. Both fry and juveniles prefer velocities <15cm/s.	Temperature and oxygen requirements assumed similar to adults.

Appendix C

Habitat requirements and threats for "critically imperiled" species in West Virginia
(Quoted and paraphrased from NatureServe Explorer[18])

Common Name	Scientific Name	Habitat	Threats
Diamond darter	Crystallaria cincotta	Habitat includes clean sand, gravel, and cobble runs of small to medium rivers. This darter has been collected from riffles and pools with <1.5 meter depth and moderate flow. Based on habitats used by its sister species (C. asprella), it may also use areas of deeper pool and run habitats.	Siltation from incompatible land use practices.
Black bullhead	Ameiurus melas	This catfish occurs in ponds, small lakes, river backwaters, swamps, impoundments, and stream pools, in areas with warm and turbid water, muddy bottoms, slow currents, and few other fish species.	No major threats known.
Slimy sculpin	Cottus cognatus	Typical habitats are deep oligotrophic lakes and swift rocky-bottomed streams. Sometimes this sculpin occurs in brackish water. It may move into lake shallows at night, into deeper water during day (often 30-100+ m deep).	No information given.
Bluestone sculpin	Cottus sp. 1	Virginia: cool to cold, strongly flowing limestone spring runs (upper Bluestone River, its main and small tributaries, and high-volume springs) with substrates dominated by gravel and rubble; stream widths are 1-10 m; lengthy slow sections of the main channel and some springs are heavily silted; watercress, moss, and emergent plants are common in some areas; juveniles and adults are found most often in runs and riffles of boulder and rubble; juveniles are common on gravel and sometimes among plants, uncommon or rare in silted slack water.	Small range in the upper Bluestone River system of Virginia and West Virginia; nearly extirpated in West Virginia by mining impacts; a section of the Bluestone River has been degraded by organic pollution; potentially threatened by general commercial and residential development in Virginia.
Blue sucker	Cycleptus elongatus	Habitat includes the largest rivers and lower parts of major tributaries. Usually this sucker occurs in channels and flowing pools with moderate current (1.0-2.6 meters/sec). It also occurs in some impoundments. Adults probably winter in deep pools. Young occupy shallower and less swift water than do adults.	Wide distribution in large rivers in central North America; generally common but greatly reduced in abundance around margins of range as a result of dam construction and reductions in water quality.
Satinfin shiner	Cyprinella analostana	Habitat includes rocky and sandy runs (less often pools) of creeks and small to medium rivers, usually near riffles. Occasionally this species is found in headwaters and tidal portions of some large rivers. Eggs are attached to branches, stumps, logs, cracks in rocks; in crevices under loose submerged bark, between exposed tree roots, or under flat rocks.	No information given.

[18] Quoted and paraphrased from NatureServe Explorer: http://www.natureserve.org/explorer, accessed 2/19/2013.

Common Name	Scientific Name	Habitat	Threats
Northern lance	Elliptio fisheriana	The northern lance seems to be found primarily in soft sediments in shallow water less than two feet from stream and river banks that are highly stable with an intact riparian zone.	Difficult to determine as taxonomy has not been resolved.
Gravel chub	Erimystax x-punctatus	Habitat includes clear to moderately turbid waters of large creeks and small to large rivers; in areas of moderate flow (usually riffles) over fine gravel or occasionally rocky substrate. Possible spawning occurred in meter-deep swift water adjacent to a gravel bar.	Siltation and impoundment are the greatest threats.
Longfin darter	Etheostoma longimanum	Habitat includes rocky riffles of creeks and small rivers, with cool to warm, typically clear water; runs and riffles of gravel to boulder. Eggs are laid probably on the undersides of rocks or other cover.	Fairly abundant within a limited range.
Spotted darter	Etheostoma maculatum	Habitat includes large rubble and boulder areas, adjacent to or in swift deep riffles, in small to medium, clear rivers. Adults apparently spend the winter in areas somewhat deeper and with slower current. In the Elk River, West Virginia, spotted darters were observed primarily in glide habitats near large rocks and in moderate current velocities. Eggs are laid on undersides of stones in quiet water areas near heads of riffles in water 15-60 cm deep.	Riverine habitat is widely degraded by pollution and siltation.
Candy darter	Etheostoma osburni	Habitat includes fast rubble riffles of small to medium rivers; swift water over stones and boulders in cool montane streams; rocky, typically clear, cold and warm, small to large creeks; adults generally occur in unsilted runs, riffles, and swift pockets of current in and around large rubble and boulders; cool to warm waters of small streams to medium sized rivers in the Ridge and Valley Province of Virginia and West Virginia, and the Appalachian Plateau of West Virginia. In three streams in West Virginia, this darter occurred in fast current velocities over rock substrate in water depths of 20-30 cm. Spawning may occur in patches of sand in swift water.	Hybridization with an introduced darter species, stream siltation, effects of stocked trout, and possibly habitat disturbance by anglers.
Eastern silvery minnow	Hybognathus regius	Habitat includes quiet weedy inshore waters of lakes, and pools and backwaters of low gradient creeks and small to large rivers. Adults move to well-vegetated lagoon or slow lower reaches of tributary streams to spawn. Eggs are scattered among vegetation in shallow water.	No major threats known. In Virginia, extirpations or declines in the upper Shenandoah and James river drainages can be attributed to pollution.
Northern brook lamprey	Ichthyomyzon fossor	Habitat includes clean, clear gravel riffles and runs of small rivers; this species usually does not occur in large rivers or small brooks. Usually it occurs over gravel or sand-silt bottoms in moderately warm water, generally unsuitable for brook trout. Larvae burrow into sand-silt bottoms in eddies. Spawning occurs in coarse gravelly or stony bottoms of creeks or small rivers in areas of strong current.	The species is vulnerable to local extirpation through indiscriminant use of fish toxicants.

Common Name	Scientific Name	Habitat	Threats
Mountain brook lamprey	Ichthyomyzon greeleyi	Habitat includes clean, clear, gentle- or high-gradient creeks (1-23 meters wide, 30-60 centimeters deep) with substrates generally of sand, pebbles, and small stones. Adults occur in riffles or runs, under overhanging banks, or occasionally they attach to stones in the current; larvae burrow into beds of mixed sand, mud, and organic debris in pools and backwaters. In Pennsylvania, spawning occurred just above swift riffles and throughout slow to moderate riffles. In West Virginia, spawning occurred in the middle and lower portions of riffles. In Virginia, a spawning group was observed in a gentle, shallow run of mostly small, loose gravel in a stream 2-4 meters wide.	Extirpated from some areas as a result of habitat degradation due to pollution, siltation, and dams; secretive, likely more abundant than available information indicates; now probably relatively stable, but better information is needed.
Warmouth	Lepomis gulosus	Ponds, lakes, swamps, and streams of low gradient with mud or debris over bottom; a pool species in streams where it often is near beds of vegetation or other cover; weedy turbid areas of rivers and backwaters. Tolerant of low oxygen levels of polluted waters. Common in lowlands, uncommon in uplands. Eggs are laid in a bowl-like nest made by male often in sand or rubble bottom with thin covering of silt or detritus near a rock, stump, clump of vegetation, or similar object, at depths of 15 cm to 1.5 m. Nests usually are separated from one another.	Localized threats may exist, but on a range-wide scale no major threats are known.
Orangespotted sunfish	Lepomis humilis	Sloughs, lakes, ponds, rivers, and creeks; in quiet pools in streams; often in turbid water; usually near brush. Eggs laid on gravel in nest (often in colonies) made by male on bottom in shallow water.	Localized threats may exist, but on a range-wide scale no major threats are known.
Rosefin shiner	Lythrurus ardens	Pools, backwaters near flowing water, and runs of warm large creeks and rivers of moderate gradient and clear to often turbid water; generally in mid- and higher depths over soft and hard bottoms. Absent from high elevation trout streams. In deeper quiet pools in midwinter. Spawns in faster currents of riffles and pools, usually over nests of chubs, sometimes fallfish.	Localized threats may exist, but on a range-wide scale no major threats are known.
Shorthead redhorse	Moxostoma macrolepidotum	Rocky pools, runs, and riffles of small to large rivers, natural lakes, and impoundments. Spawns usually over gravel in runs and riffles; may move out of larger bodies of water into smaller rivers and streams to spawn.	Localized threats may exist, but on a range-wide scale no major threats are known.
Bigeye shiner	Notropis boops	Flowing pools of moderately clear creeks and small to medium rivers with large permanent pools over bottom of clear sand, gravel, or rock. Often at stream margin in beds of emergent vegetation.	Decline due to siltation, increased turbidity, and impoundment.
Swallowtail shiner	Notropis procne	Warm, moderate to low gradient, clear to often turbid, creeks and small to large rivers; usually occupies pools and slow runs with sand, gravel, or rock bottom.	Localized threats may exist, but on a range-wide scale no major threats are known.
Northern madtom	Noturus stigmosus	Typical habitat includes large creeks and small rivers with clear to turbid water and moderate current; this madtom avoids extremely silty situations; it occurs in areas with little cover other than tree limbs and debris. This species occurs in streams with shifting sand and mud bottom and in streams with swift rocky riffles. Illinois records were from strong current over a bottom of sand and gravel with some detritus, in medium and large rivers. Eggs are laid under flat stones (or sometimes in cans with large openings) in current.	Declining due to stream channelization and stream quality deterioration.

Common Name	Scientific Name	Habitat	Threats
Stripeback darter	Percina notogramma	Riffles and pools of creeks and small to medium rivers. Stony riffles are preferred springtime habitat, especially in weedbeds. Moves into pools adjacent to riffles in summer. Spawns apparently in riffles.	Localized threats may exist, but on a range-wide scale no major threats are known.
Shield darter	Percina peltata	Moderate gradient riffles and runs of creeks and small to medium rivers. Most common over fine gravel on downstream side of rubble riffles. Sometimes aggregates in summer and fall in beds of aquatic plants. In same habitat all year. Eggs are buried in gravel.	Localized threats may exist, but on a range-wide scale no major threats are known.
Slenderhead darter	Percina phoxocephala	Runs and riffles of creeks and small to medium rivers with moderate to strong flow and gravel, rubble, or bedrock substrate. Frequents gravel shoal areas. Can do well in gravel and rubble ruins below dams. Apparently moves downstream to deeper water in colder months, returns upstream in spring. Very few lake or reservoir records. Spawns in swift gravel riffles 15-60 cm deep.	Moderately intolerant of silt.
River darter	Percina shumardi	Large rivers and lower part of tributaries; deep chutes and riffles where current is swift and bottom is coarse gravel or rock. Smaller individuals generally occur in slower water than do larger ones. Adults generally at depth of 1 m or more. May typically spawn at depths of 1/2 m or a little more in areas of strong current, scattered rubble, and associated clean gravel.	Destruction of habitat seems to be the biggest threat. Impoundments, channelization, and dredging have led to extirpation and declines in some rivers due to loss of shallow water and riffle habitat. Pollution may be a threat, but this species is more tolerant of turbidity than are some darters.
Suckermounth minnow	Phenacobius mirabilis	Plains species tolerant of moderate turbidity; runs and riffles of creeks and small to medium (sometimes large) rivers with substrates ranging from sand and gravel to large boulders. Spawns presumably over gravelly riffles.	Localized threats may exist, but on a range-wide scale no major threats are known.
Paddlefish	Polyodon spathula	Habitat includes slow-flowing water of large and medium-sized rivers, river-margin lakes, channels, oxbows, backwaters, impoundments with access to spawning areas. This fish prefers depths greater than 1.5 m; it seeks deeper water in late fall and winter. Individuals may congregate near human-made structures that create eddies and reduce current velocity. In summer, in the unimpounded, unchannelized Missouri River in South Dakota-Nebraska, paddlefish are most often found in areas downstream from submerged sandbars. Spawning occurs in fast shallow water over gravel bars, including significant tailwater sections below upstream impoundments. Larvae may drift from reservoir to reservoir.	Threats include habitat alteration, pollution, and harvesting for caviar.
Shovelnose sturgeon	Shovelnose sturgeon	Deep channels and embayments of large turbid rivers; often over sand mixed with gravel or mud in areas with strong current.	There is concern about overexploitation of this species as a result of the collapse of the European and Asian caviar industry.

Common Name	Scientific Name	Habitat	Threats
Central mudminnow	Umbra limi	Usually in moderately to densely vegetated streams, sloughs, or swamps; sometimes in bog lakes. Avoids areas with current and water more than 0.5 m deep (but occurs in deep pools in winter). Often in ooze and detritus on bottom. Tolerant of low oxygen and high temperature. Spawns in overflow areas along creeks.	Localized threats may exist, but on a range-wide scale no major threats are known.