

# Water Quality in the North Fork Shenandoah River, Virginia, During the Drought of 1999: Implications for Minimum Instream Flow

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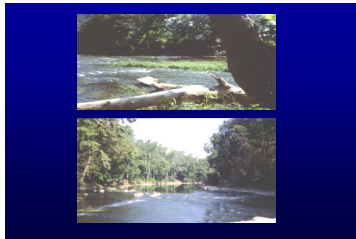


Figure 1. The North Fork Shenandoah River

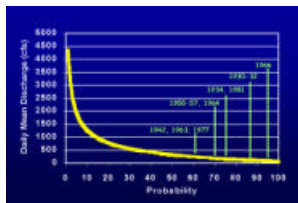
## Abstract

The North Fork Shenandoah River represents 20% of the mainstem discharge but has received 60% of the population growth (1980 to 1990) in the Shenandoah River basin. Management needs for the North Fork include 1) developing reliable tools for assessing instream flow needs, 2) relating population dynamics of smallmouth bass and other fishes to habitat variability and 3) including land-use and water withdrawal effects on instream water quality and quantity. To identify research needs, the U.S. Geological Survey conducted an investigation of water quality during a severe low-flow in July, 1999. Of 52 sites studied, 11% failed to meet Virginia water quality standards for maximum temperature, 35% were near the upper thermal limits for smallmouth bass and 25% exceeded the state standards for pH. Dissolved oxygen fluctuated greatly at most sites with 37% of the sites falling below the minimum standard of 4 mg/L. Study results imply that during severe low flows, physical habitat must be considered in combination with water quality to determine usable habitat for fishes. There exists a need to quantify the duration of exposure to stressful water quality conditions and examine the contribution of water withdrawal and land-use practices to naturally limiting conditions during low flows. How low the river can go depends on knowledge of associations between biologic metrics and habitat/water quality changes for given discharges, as well as allowable withdrawals and land use.

## Introduction

The North Fork Shenandoah (Figure 1) represents an important resource for domestic water supply, waste assimilation, agricultural use and economically important, recreational activity (smallmouth bass fishery). Although it represents only 20% of the water of the Shenandoah River (Figure 2), the North Fork has received 60% of the population growth (1980 to 1990) of the Shenandoah basin, creating an imbalance between use and demand. Water issues for the basin include water supply (consumption/irrigation/inter-basin transfer), water quality (fecal coliform, nutrient loading, fish kills during low flows) and recurring droughts with low channel flows which threaten many current river uses. Harsh or severe droughts have occurred repeatedly during the last century, some of which have lasted for periods as long as ten years (Figure 3). Therefore, management needs for the North Fork include 1) developing a reliable set of tools for assessing instream flow needs, 2) relating population dynamics of smallmouth bass and other fishes to habitat variability, and 3) including land-use and water withdrawal effects on instream water quality and quantity.

Figure 3. A flow exceedance curve for the North Fork Shenandoah based on daily mean discharge from 1925 to 1998 at the Strasburg, VA gauge. The most severe droughts are marked on the curve. The median flow (50% probability) is 319 cfs. During the summer of 1999 median flow was 56 cfs, exceeding 1966.



During low channel flows, aquatic organisms can be challenged by a lack of suitable physical habitat, deteriorating water quality, or both. To meet management needs of the North Fork, an understanding of water quality during low flows is needed to properly frame research questions. However, only limited data on water quality during a severe drought is available. Therefore, an intensive sampling of water quality during drought was required.

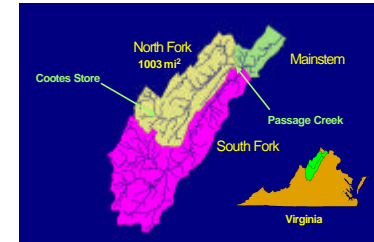


Figure 2. The Shenandoah River basin

## Conclusions

Water quality in the North Fork Shenandoah River deteriorates to stressful and lethal conditions for aquatic life during severe drought. The results of this study imply that during severe low-flows, available fish habitat must be considered in combination with water quality to determine total usable habitat. To determine when and where smallmouth bass (Figure 8) and other aquatic life are at risk will require quantifying seasonal variation in flow as it relates to water demand and the duration of stressful water quality conditions. Virginia water quality criteria are not legally binding during droughts because it is expected that natural conditions of low-flow will exceed threshold levels. Therefore, more research is needed to examine the effects of water withdrawal and land use practices to water quality during low flows. Additionally, it will be critical to quantify habitat limited by drought versus limitations induced by water consumption and land use.

Identifying temporal, seasonal and low-flow conditions at which resources are limiting will help local decision makers implement stream protection through best management practices and consumption conservation measures. How low the river can go will depend on a the relationship between biotic metrics and habitat/water quality changes for given discharges, as well as allowable withdrawals and effluent discharges.

## Literature Cited

Eaton, J. G., J. H. McCormick, B. E. Goodno, D. G. O'Brien, H.G. Stefany, M. Hondzo, and R. M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. *Fisheries* 20(4): 10-18.  
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## Acknowledgments

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Figure 8. Smallmouth bass, *Micropterus dolomieu*, as illustrated in 'Fishes of Iowa' under the Iowa Department of Natural Resources' web site ([www.state.ia.us/government/dnr/index.html](http://www.state.ia.us/government/dnr/index.html)), Fisheries Bureau.

## Objectives

The objectives of this study were to determine longitudinal trends in temperature ranges, dissolved oxygen levels and pH levels in the North Fork Shenandoah during severe drought.

## Methods

Data on temperature, pH, and dissolved oxygen were collected at 52 sites, July 12-30, 1999, using Y.S.I. 6-series, multi-parameter probes. Pre-dawn and mid-day point sampling was conducted at 34 sites, while continuous monitoring was conducted at 18 sites, every half hour for one to eight days. Sites were located from Cootes Store at the headwaters downstream to Passage Creek, just above the confluence with the South Fork. Recorded measurements are compared with state water quality criteria.

## Results

### Temperature

- Green line marks VA water quality standard of 31°C (State Water Control Board 1997) (Figure 4)
- Red line marks upper thermal limit for smallmouth bass (Eaton and six others 1995)
- 11% of sites failed to meet Virginia water quality standard for temperature
- 35% of sites were at or above the upper thermal limit for smallmouth bass

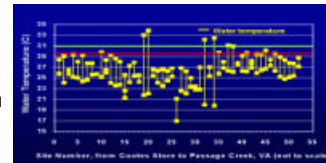


Figure 4. High/Low Water Temperature in North Fork Shenandoah, July 12-30, 1999

### pH

- Green line marks VA maximum allowable pH at 9.5 (State Water Control Board 1997) (Figure 5)
- pH levels at most sites were approximately 8
- Five sites (10%) were at the state standard, reaching lethal levels for fishes (Wetzel 1983)

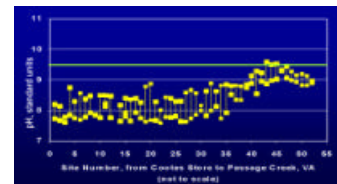


Figure 5. High/Low pH in North Fork Shenandoah, July 12-30, 1999.

### Dissolved Oxygen Ranges

- Large fluctuations of dissolved oxygen were recorded (Figure 6)
- Green line marks the Virginia minimum standard of 4 mg/L (State Water Control Board 1997)
- 37% of sites fell below the Virginia minimum criteria

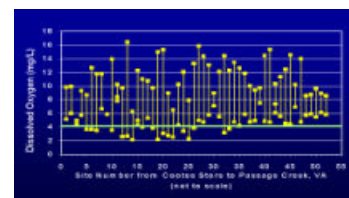


Figure 6. High/Low Dissolved Oxygen Levels in North Fork Shenandoah, July 12-30, 1999.

### Dissolved Oxygen Trends over 24 Hours

- Green line marks Virginia minimum criteria of 4 mg/L (State Water Control Board 1997) (Figure 7).
- Peak levels occurred during mid-afternoon
- Lowest levels occurred before dawn
- Differences ranged as much as 14 mg/L during one day
- At some sites, the state criteria was not met for 7 hrs during one day

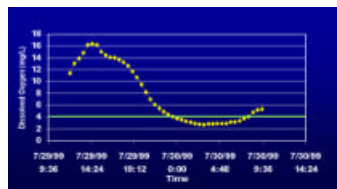


Figure 7. Dissolved Oxygen over 24 Hours downstream of Timberville, VA, in the North Fork Shenandoah, July 1999.