North Anna River Low Flow Monitoring

Final Report - October 2001 to September 2003

Final Report
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1.0 Introduction

Dominion has been required to ensure discharge from Lake Anna to the lower North Anna River equals or exceeds 40 cubic feet per second (cfs) since 1970 (Virginia Power 1986). However, in response to persistent drought conditions, legislation was passed by the Virginia General Assembly in 2001 that resulted in the development of a Lake Level Contingency Plan for Lake Anna. The Contingency Plan calls for reductions in flow to the North Anna River below 40 cfs when Lake Anna surface water elevation falls to 248 feet above mean sea level (msl). Lake Anna fell to 248.0 feet msl on October 19, 2001 at 1756 hours. Flow reductions and a low flow monitoring program were implemented soon thereafter. This report summarizes results of physico-chemical and biological monitoring conducted during the period of flow reduction, the period of reduced flow and after flows returned to 40 cfs and greater.

2.0 Flow Release and Report History

Flows released to the North Anna River from Lake Anna were reduced from 40 to 20 cfs after Lake Anna surface water elevation fell below 248.0 feet msl in late October 2001. The flow reduction occurred in 5 cfs increments occurring every 3 – 4 days during the period October 22 through November 1, 2001 (Table 2.1). Flow was regulated by adjusting the height of the skimmer gate on the north side of the Lake Anna Dam. Water continued to be released from Lake Anna Dam at a rate of approximately 20 cfs from early November 2001 through early December 2002.

Table 2.1. Chronology of North Anna River flow reduction to 20 cfs, monitoring surveys conducted at 20 cfs, and flow increase to 40 cfs.

Discharge (cfs)	Date of Flow Reduction	Monitoring Survey Date
35	22 October 2001	25 October 2001
30	25 October 2001	27 October 2001
25	29 October 2001	31 October 2001
20	1 November 2001	3 November 2001
Discharge (cfs)		**Monitoring Survey Date**
20	No flow change	3 December 2001
20	No flow change	23 January 2002
20	No flow change	22 February 2002
20	No flow change	25 March 2002
20	No flow change	24 April 2002
20	No flow change	31 May 2002
20	No flow change	13 June 2002
20	No flow change	26 July 2002
20	No flow change	29 August 2002
20	No flow change	20 September 2002
20	No flow change	18 October 2002
20	No flow change	18 November 2002
20	No flow change	18 December 2002
Discharge (cfs)	**Date of Flow Increase**	**Monitoring Survey Date**
25	19 December 2002	
30	20 December 2002	
35	21 December 2002	
40	22 December 2002	
40		14 January 2003
40		4 September 2003

Following significant rainfall during November and December 2002, Lake Anna water elevation increased to exceed 248.0 ft msl. River flows were increased from approximately 20 to 40 cfs in 5 cfs increments beginning December 19, 2002 (Table 2.1). On December 22, 2002 flows returned to 40 cfs, and normal hydropower operations resumed. However, by January 14, 2003 flows were increased beyond 40 cfs due to continuing rains and rising lake level. Except for a brief period during July, flows continued to exceed 40 cfs throughout the rest of 2003 until mid-August 2003.

Results of monitoring conducted from October 2001 through February 2002 were presented in the report North Anna River Low Flow Monitoring – Update of Studies Conducted October 2001 – February 2002, submitted to the Virginia Department of Environmental Quality (DEQ) on March 15, 2002. Results of monitoring conducted from March through December 2002 were presented in update reports submitted to the DEQ on June 5, 2002 (March and April results), August 16, 2002 (May and June results), October 8, 2002 (July and August results), December 18, 2002 (September and October results), and April 9, 2003 (November and December results). The current report summarizes data contained in these updates and presents additional information collected during 2003.

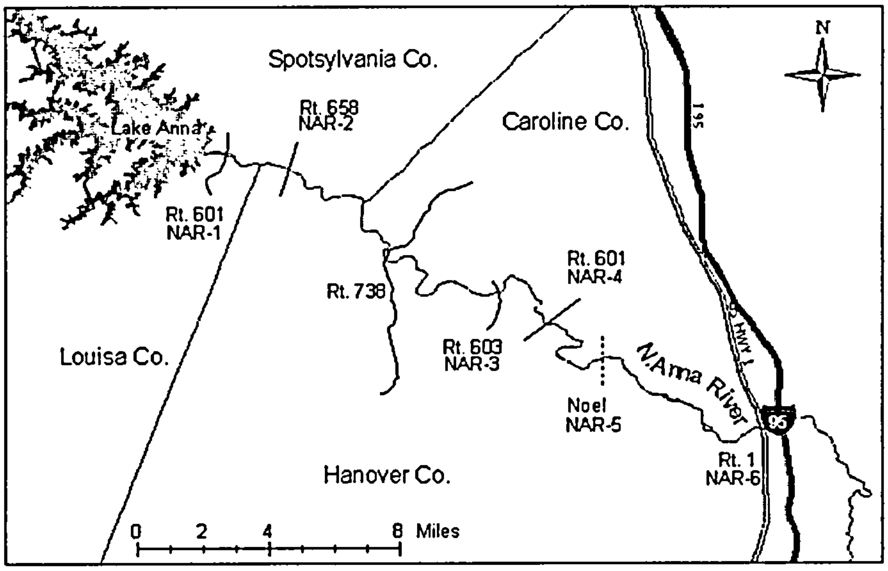
3.0 Physico-chemical

Physico-chemical Methods

Sampling and monitoring protocols followed those outlined in the final North Anna River Monitoring Plan – Low Flow Conditions, submitted to the DEQ on March 15, 2002. Two stations (NAR-1 and NAR-5) that were part of Dominion's long-term biological monitoring program for the North Anna River were selected for low flow monitoring (Figure 3.1). Stream wetted perimeter[1] (WP), depth, water temperature and dissolved oxygen (DO) were targeted for monitoring.

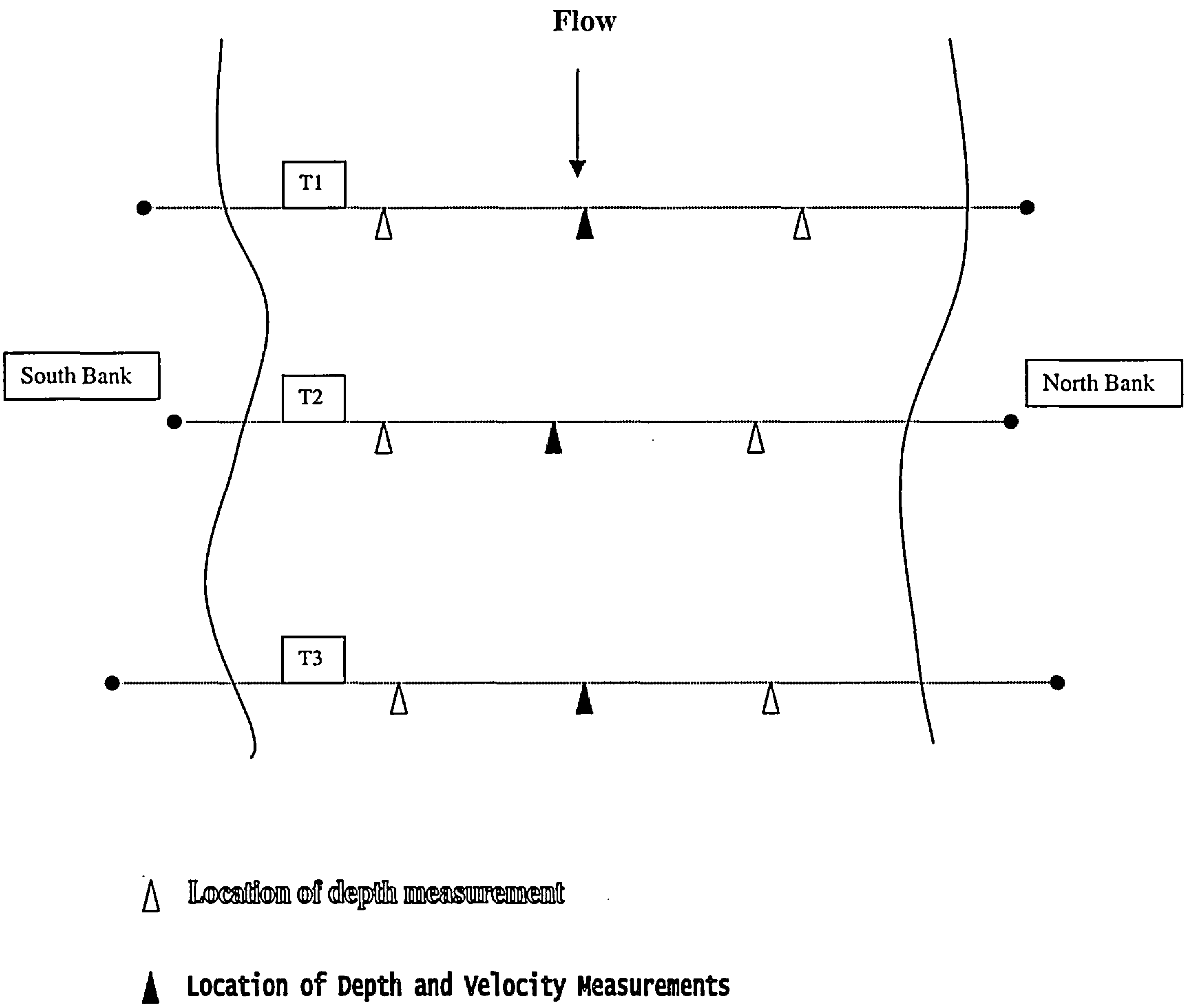
[1] The term "wetted perimeter" is used throughout this report for consistency with its use in the Lake Level Contingency Plan for Lake Anna, and monitoring update reports submitted to DEQ. More accurately, wetted stream width was measured. Waddle (2001) notes that wetted perimeter is roughly equal to wetted width plus two times mean depth.

FIGURE 3.1 Location of North Anna River temperature recording, electrofishing, and snorkel survey stations



For measurement of WP and depth, three transects perpendicular to flow were established at each station on October 25, 2001 at a river flow of approximately 35 cfs. Reinforcing bar pins were driven into the north and south river banks of each transect to establish benchmarks from which repeated measurements were obtained. Transects encompassed representative aquatic habitats at each station, were spaced 50 m apart, and were labeled T1, T2 and T3 in upstream to downstream order (Figure 3.2). For all days on which measurements were obtained (except for October 25, 2001) a measuring tape was secured to the pins in the north and south banks prior to obtaining wetted perimeter and depth measurements. On October 25, 2001 the measuring tape was held by hand at some transects instead of being secured to the pins because the tape brought on this initial survey was too short to span the distance between pins.

Figure 3.2. Conceptual layout for North Anna River wetted perimeter, depth and velocity measurements.



WP at each transect was measured to the nearest inch from the south to north bank for surveys conducted from October 2001 through March 2002, and to the nearest 0.1 ft on all subsequent surveys. Depth was measured to the nearest 1/8 inch at three locations along each transect for surveys conducted October 2001 through March 2002, and to the nearest 0.1 ft on all surveys after March 2002. The units used to measure WP and depth were changed as a result of equipment upgrades in April 2001.

The three locations where depths were measured along each transect corresponded to approximately one-fourth (0.25) river width from the north and south banks, and approximately one-half (0.5) river width when the first measurements were obtained in October 2001 (Figure 3.2). WP and depth measurements recorded in inches were converted to hundreths of feet prior to entry into an Excel spreadsheet for analysis. Average WP and average depth were respectively calculated from the three independent measures of WP and the nine independent measures of depth obtained at each station during each survey.

Visible changes in river width, wetted bank, and vegetative growth between successive flow reductions and surveys were noted when obvious changes were apparent.

Data-logging Hydrolab Minisonde 4a instruments were installed at NAR-1 and NAR-5 on October 25, 2001. The instruments were calibrated prior to installation at each station, and programmed to obtain water temperature (^{o}C) and dissolved oxygen (DO; mg/l) measurements at hourly intervals. The instruments were downloaded and serviced monthly. Servicing entailed replacing batteries and cleaning or replacing the oxygen diffuser membrane as needed. During most services water temperature and DO were measured at each station with a Yellow Springs Instruments Model 55 oxygen meter or a portable Hydrolab Minisonde that was calibrated prior to use. These data were used as checks on data recorded by the in situ water quality data loggers.

Following discussions between Virginia DEQ and Dominion, water velocity (ft/s) measurements were added to the list of observations obtained as part of the low flow monitoring effort. Beginning with the December 2001 survey, water velocity measurements were obtained at the mid-river location of each transect with a Marsh-McBirney Model 2000 Portable Flowmeter (Figure 3.2). Water velocity was initially always measured at 0.6 of water depth. In April 2002 a procedural change was made. Thereafter, water velocity was measured at 0.6 of water depth when depth was less than 2 feet at the measurement point, and at 0.2 and 0.8 of water depth when depth was 2 feet or greater. When measurements were obtained at 0.2 and 0.8 of water depth, the two readings were averaged to obtain a mean column velocity.

Physico-Chemical Results

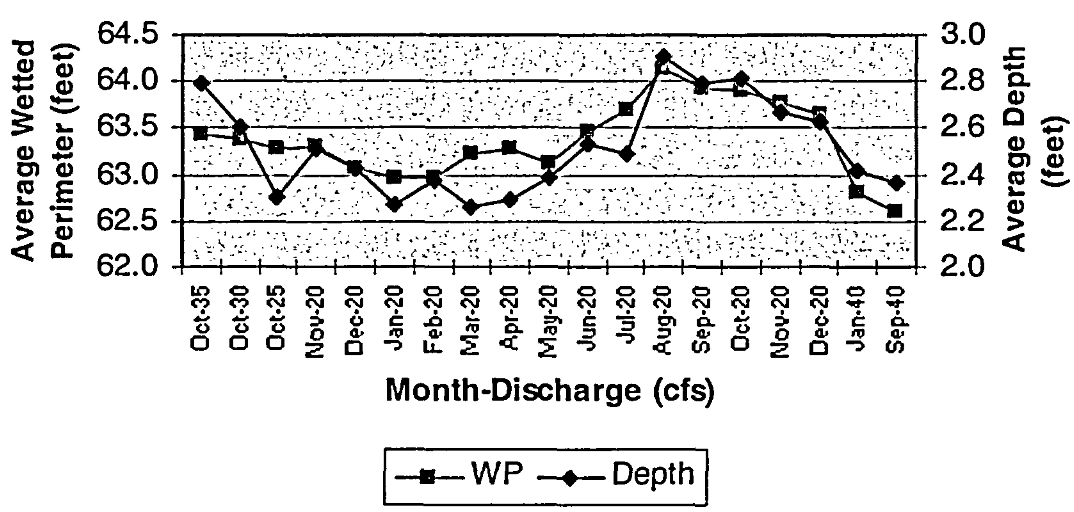
WP and depth were sampled at NAR-1 and NAR-5 at each 5 cfs decrease as flows were reduced from 35 to 20 cfs in October and November 2001 (Table 2.1). Sampling generally occurred 2 days after each flow reduction to allow time for stream flow to stabilize. Beginning in December 2001, WP and depth were sampled monthly until January 2003, after flows had returned to 40 cfs. An additional survey was conducted during September 2003 at 40 cfs to verify results of the January 2003 survey. Water temperature and dissolved oxygen (DO) were monitored from October 25, 2001 to January 14, 2003. Hydrolab instruments were downloaded and serviced during monthly WP and depth surveys.

NAR-1

NAR-1 was located approximately 2 km downstream of the Lake Anna Dam, and characterized by rocky substrate and wooded banks. Substrate at NAR-1 was predominately bedrock ledge, and the channel was roughly straight and rectangular.

Average WP and average depth at NAR-1 generally varied in the same manner over the monitoring period (Figure 3.3). As flows were reduced from 35 to 20 cfs WP decreased from 63.44 to 63.30 feet, and depth from 2.79 to 2.51 feet. The depth obtained on October 31, 2001 at approximately 25 cfs did not conform to the decreasing trend in flow as WP did, and is considered anomalous.

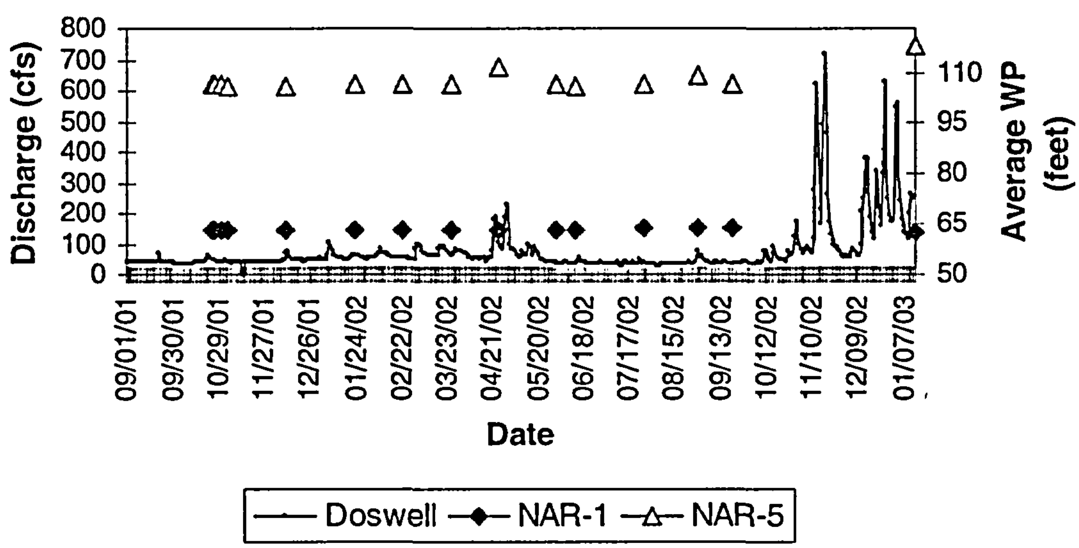
Figure 3.3. Average Wetted Perimeter and Depth at NAR-1



Average WP and average depth at NAR-1 remained within a relatively narrow band of values as flows were maintained at 20 cfs from November 2001 through May 2002. In June 2002 WP and depth were seen to increase, and continued to do so through August. Parallel increases in average WP and water depth at NAR-1 under relatively constant flow conditions may have resulted from a change in dam releases, side flows augmenting dam releases, or a change in station hydrology.

The first two possibilities seemed unlikely. A dam operator at the North Anna Dam verified that there had been no adjustments to the skimmer gate since the 20 cfs minimum release was initiated. Augmentation from side flows was unlikely because there was only limited drainage area between the Lake Anna Dam and NAR-1. There were no major tributaries between the dam and NAR-1, and rainfall events that increased North Anna River stream flow at Doswell and NAR-5 did not coincide with the increases in WP and depth observed at NAR-1 (Figures 3.3 and 3.4).

Figure 3.4. Discharge at Doswell and Wetted Perimeter (WP) at NAR-1 and NAR-5, September 2001 to January 2003.



Two potential in-stream effects that may have affected hydrology were considered: beavers had constructed a dam downstream; and expansive growth of the aquatic weed *Hydrilla verticillata* partially blocked flow, thereby displacing water to increase WP and depth. The first possibility was considered unlikely because no beaver dams were observed within several hundred meters of the station and surface water velocity generally remained relatively swift through most of the station. The second possibility seemed more likely because between May and August *Hydrilla* had grown to cover the entire wetted area of the station, along with all other nearby areas except for fast riffles. *Hydrilla* had also grown to within several cm of the surface in most areas by August, and covered the surface in many areas. These field observations were noted in periodic updates provided to DEQ.

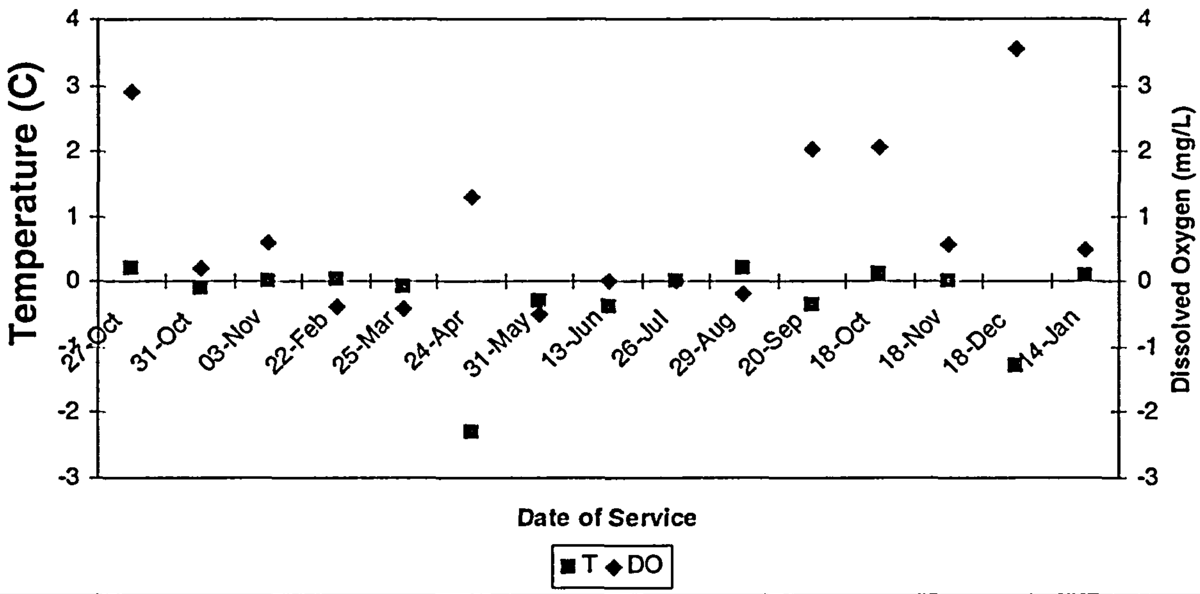
From September through December 2002 WP and depth decreased as flows were maintained at 20 cfs (Figure 3.3). These decreases coincided with decreased *Hydrilla* density as water temperatures decreased and the plants died back. This trend continued despite increased rainfall during November and December 2002. It appears that the net effect of the dense *Hydrilla* growth seen June through August was to displace water, thereby increasing depth and wetted perimeter. As the plants died back, depth and wetted perimeter decreased.

Average WP measured at approximately 40 cfs in January 2003 was less than any other average WP measured, and average depth was lower than some comparable measurements obtained at lower flows (Figure 3.3). Because WP and depth measured at 40 cfs in January 2003 should have been greater than similar measures taken at lower flows, additional WP and depth measurements were obtained at 40 cfs. This did not occur until September 4, 2003 because of exceptionally high flows during most of 2003. Readings taken on September 4, 2003 occurred after river flow had returned to 40 cfs, and been maintained at that level since August 14, 2003. Results were very similar to those obtained in January 2003.

Two possible reasons why WP and depth were lower than expected for the 40 cfs surveys were considered: there was a change in river channel morphology between December 2002 and January 2003; and releases through the skimmer gate were higher than anticipated. The first possibility seems unlikely, as major changes in channel morphology are generally brought about by high flow events. There were no such events during the December 2002 – January 2003 time frame. The second possibility is more likely. Although flow through the 40 cfs hydropower turbine at Lake Anna dam has been precisely calibrated, flow releases through the north skimmer gate have not been similarly calibrated. Estimates of flow through the skimmer gate are based on the cross-sectional area of the gate opening and lake level at the dam. Gate opening is estimated visually, and lake level is subject to fluctuation due to changes in wind speed and direction. As such, an unquantified level of error is inherent in estimating flow releases from the north skimmer gate that may have been reflected by the WP and average depth estimates obtained at releases less than 40 cfs.

Comparisons of water temperature and DO measured by the in situ Hydrolab instrument immediately prior to service with readings obtained by a portable instrument at the time of service were generally in agreement (Figure 3.5). Water temperature measured by the two instruments differed by more than 1° C in 2 of 14 comparisons. DO measured by the two instruments differed by more than 1 mg/l in 5 of 14 comparisons. Hydrolab Corporation regards their instrument laboratory accuracy to generally be $\pm$ 0. 2° C for water temperature and $\pm$ 0. 2 mg/l for DO. However, Hydrolab notes there are "many situations, such as biofouling, that will negate extrapolation of these specifications to field conditions." Another source of variability between the two instruments is the fact that the portable instrument readings were taken near, but not at, the exact location of instrument deployment. During the biologically critical summer months of June through September water temperature and DO recorded by the in situ and portable instruments were in close agreement, except for a single DO reading in late September, 2002.

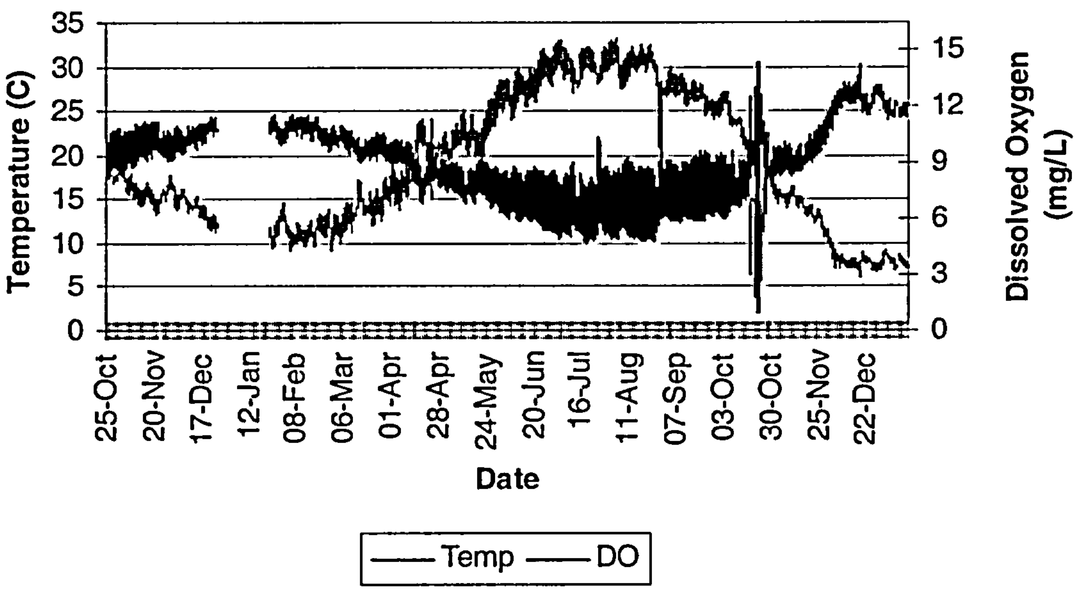
Figure 3.5. Differences between in situ and portable (in situ minus portable) temperature (T) and dissolved oxygen (DO) readings at the time of monthly instrument service at NAR-1.



The instrument at NAR-1 generally provided a continuous record of water temperature and DO for the period of study (Figure 3.6). Major data gaps exceeding 24 hours occurred during three periods due to instrument malfunctions. These periods were December 26, 2001 to January 24, 2002; October 18 to October 25, 2002; and January 7 to January 9, 2003. Other minor data gaps occurred during services, but did not exceed 24 consecutive hours.

The Virginia state criterion for water temperature in Class III streams is 32° C (www.deq.state.va.us/wqs/WQSO3.pdf). For DO, the state criteria are a daily average of 5.0 mg/l, and an instantaneous minimum of 4.0 mg/l. During the period of study there were no violations of the state DO criteria at NAR-1. However water temperatures exceeded 32° C on 20 days, all of them occurring in July or August 2002 (Figure 3.6). The maximum water temperature recorded during the period of study was 33.11° C on August 5, 2002.

Figure 3.6. Water Temperature and Dissolved Oxygen at NAR-1 10/25/01 to 1/14/03



Water velocity measurements obtained at NAR-1 as part of the study are difficult to interpret (Table 3.1). Water velocity measurements were obtained during 13 of 14 surveys conducted at flows of 20 cfs, and during both 40 cfs surveys. During 6 of the 13 surveys conducted at 20 cfs when water velocity measurements were collected (July 2002 to December 2002), *Hydrilla* interfered with obtaining measurements (Table 3.2). Water velocity measurements obtained in this study are of limited use because relatively few water velocity measurements were obtained (3 per station per survey), water velocity is highly variable within streams and *Hydrilla* interfered with obtaining water velocity measurements.

Table 3.1. Average water velocities obtained during surveys of NAR-1 by transect (T).

Date	Flow (cfs)	Average Water Velocity (ft/s)		
		T1	T2	T2
12/10/01	20	0.68	0.35	0.44
1/23/02	20	0.62	0.27	0.25
2/22/02	20	0.74	0.28	0.43
3/25/02	20	0.43	0.23	0.31
4/24/02	20	0.72	033	0.45
5/31/02	20	0.60	0.22	0.28
6/13/02	20	0.60	0.37	0.46
7/26/02	20	0.52	0.22	0.40
8/29/02	20	1.12	0.74	0.40
9/20/02	20	1.25	0.83	0.85
10/18/02	20	1.40	1.08	1.01
11/18/02	20	0.62	0.46	1.10
12/18/02	20	1.86	0.81	0.62
1/15/03	40	0.48	0.26	0.36
9/4/03	40	0.68	0.25	0.43

Table 3.2. Monitoring surveys where water velocity measurements could not be obtained due to excessive growth of *Hydrilla*.

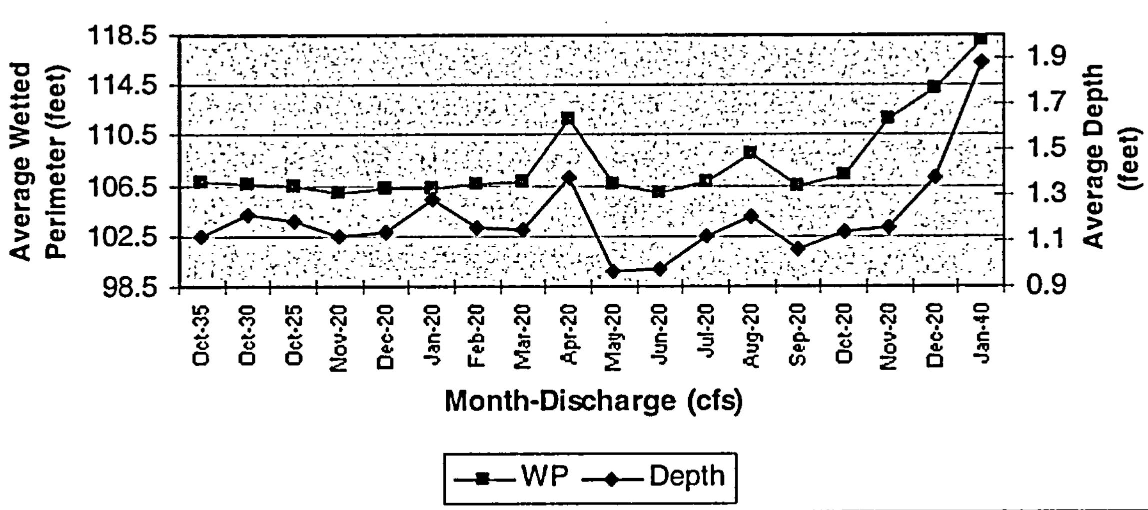
2002 Survey Date	Station	Transect
26 July	NAR-1	T2
29 August	NAR-1	T1, T2, T3
20 September	NAR-1	T1, T2, T3
18 October	NAR-1	T1, T2, T3
18 November	NAR-1	T1, T2, T3
18 December	NAR-1	T1, T2
26 July	NAR-5	T2
29 August	NAR-5	T2
20 September	NAR-5	T2
18 October	NAR-5	T2

NAR-5

NAR-5 was located about 29 km downstream of the Lake Anna Dam, and characterized by rocky substrate and wooded banks. Like NAR-1, substrate at NAR-5 was predominately bedrock ledge, but gravel and sand were more abundant. The channel at NAR-5 was wider than at NAR-1, depths were shallower, and hydraulics more complex with chutes, runs and pools present.

As at NAR-1, average WP and average depth at NAR-5 generally varied in the same manner over the monitoring period (Figure 3.7). As flows were reduced from 35 to 20 cfs, WP decreased from 106.78 to 105.84 feet. Depth did not exhibit a change from 35 to 20 cfs. Identical average depths of 1.12 feet were obtained at both flows, with very minor increases seen at 30 and 25 cfs that are likely attributable to measurement error. The similarity of depth readings at 35, 30, 25 and 20 cfs, all falling with a 0.09 foot range, was probably a function of the river being relatively shallow and wide in the lower reaches and changes in dam releases being masked by tributary side flows.

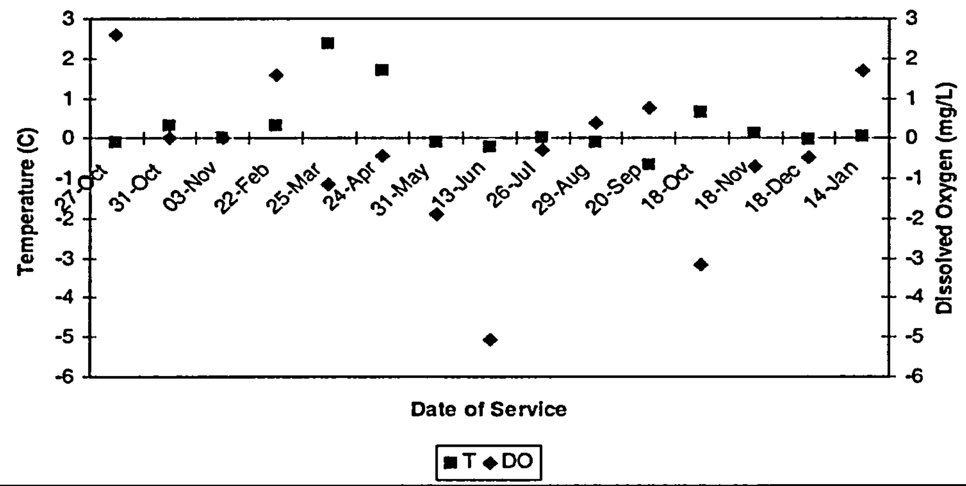
Figure 3.7. Average Wetted Perimeter and Depth at NAR-5



Average WP and average depth at NAR-5 during the period of maintaining the 20 cfs flow (November 2001 to December 2002) were more variable than at NAR-1, likely a result of tributary inflows and spates following rain events. Increases in WP and depth during this period coincided with increases in discharge recorded at the Doswell stream flow gage (Figure 3.4). Increases in WP and depth observed during November and December 2002 reflect increased rainfall and tributary inflows.

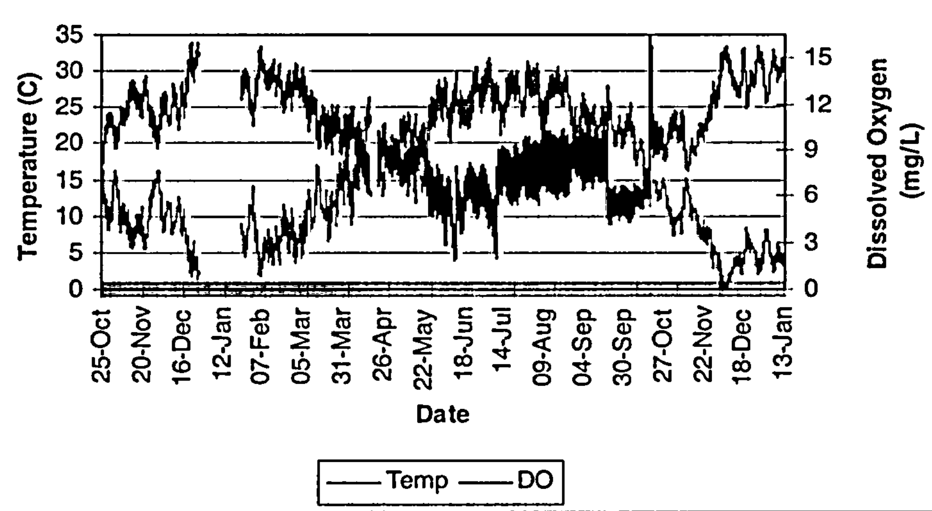
Comparisons of water temperature and DO taken by the in situ instrument and a portable instrument were generally in agreement (Figure 3.8). Water temperature measured by the two instruments differed by more than 1° C in 2 of 14 comparisons. DO measured by the two instruments differed by more than 1 mg/l in 6 of 14 comparisons. As noted in the discussion for NAR-1, several factors may have influenced the differences between readings obtained by the in situ and portable instruments. During the biologically critical summer months of July through September water temperature and DO recorded by the in situ and portable instruments were in close agreement. During June the last hourly reading obtained prior to instrument service was approximately 5 mg/l less than the portable instrument at the time of service. It is believed the presence of *Hydrilla* was at least partially responsible for the observed difference between in situ and portable instruments in June. This is because a dense stand of *Hydrilla* had grown around the instrument following the May service, and because only a minor difference was seen in a comparison of the in situ and portable instrument data for May.

Figure 3.8. Differences between in situ and portable (in situ minus portable) temperature (T) and dissolved oxygen (DO) readings at the time of monthly instrument service at NAR-5.



The Hydrolab instrument at NAR-5 generally provided a continuous record of water temperature and DO for the period of study (Figure 3.9). Major data gaps exceeding 24 hours occurred during three periods due to instrument malfunctions: December 28, 2001 to January 24, 2002; March 25 to March 26, 2002; and April 18 to 24, 2002. Other minor data gaps occurred during services, but did not exceed 24 consecutive hours.

Figure 3.9. Water Temperature and Dissolved Oxygen at NAR-5 10/25/01 to 1/14/03



During the period of study there were no violations of the state water temperature criterion at NAR-5. However, on 12 days the daily average concentration of DO was less than the state water quality criterion of 5.0 mg/l, and on 16 days the minimum instantaneous concentration of DO was less than the state water quality criterion of 4.0 mg/l. The exceedences occurred during two periods, mid-June and early July 2002. The minimum DO recorded during the period of study was 1.84 mg/l on June 12, 2002.

As discussed previously, it is believed that the presence of *Hydrilla* was, at least in part, responsible for the low DO observed at NAR-5. The dense stand of *Hydrilla* that was observed about the base of the instrument on June 13, 2002 likely affected readings obtained in early June. DO values substantially increased after the stand was removed and regular service was completed, although daily average and instantaneous values remained relatively low. By the time of the next inspection on July 10 *Hydrilla* had grown back. Again, following removal of the *Hydrilla* DO values increased substantially, indicating the presence of *Hydrilla* was affecting readings. *Hydrilla* did not appear to grow substantially between the July and August services, and DO values were consistently higher during mid to late July and August than during June and early July. An apparent decrease in DO following the September 20 service is attributed to instrument error (Figure 3.9). DO increased substantially following the October 18 service, when a comparison between the in-situ and portable instruments indicated the in-situ instrument was reading approximately 3 mg/l less than the portable instrument (Figure 3.8).

Similar to results at NAR-1, water velocity measurements obtained at NAR-5 as part of this study are difficult to interpret (Table 3.3). Water velocity measurements were only obtained during 13 of 14 surveys conducted at flows of 20 cfs, and at both surveys conducted at 40 cfs. During 6 of the 13 surveys conducted at 20 cfs when water velocity measurements were collected (July 2002 to December 2002), *Hydrilla* interfered with obtaining measurements according to protocol (Table 3.2). Further, the mid-river water velocity measurement location for Transect 1 was a backwater, where negative velocity measurements were sometimes obtained.

Table 3.3. Average water velocities obtained during surveys of NAR-5 by transect (T).

		Average Water Velocity (ft/s)		
Date	**Flow (cfs)**	**T1**	**T2**	**T2**
12/10/01	20	0.01	0.14	0.50
1/23/02	20	-0.14	0.12	0.57
2/22/02	20	0.10*	-0.11	0.55
3/25/02	20	0.10*	0.02	0.58
4/24/02	20	-0.15	0.18	0.94
5/31/02	20	0.00	0.04	0.73
6/13/02	20	-0.05	0.02	1.03
7/26/02	20	-0.05	0.00	0.38
8/29/02	20	0.02	0.09	0.62
9/20/02	20	-0.05	0.00	0.38
10/18/02	20	0.01		0.71
11/18/02	20	-0.08	0.55	0.40
12/18/02	20	-0.15	0.08	0.65
1/15/03	40	1.24	0.79	0.01

* Velocity reading taken 4.25 feet from station location due to accumulation of leaf litter.

4.0 Benthic Macroinvertebrates

Macroinvertebrate Methods

Benthic macroinvertebrate surveys were conducted in November 2001 (drought) and August 2003 (post-drought). Samples during each flow period were collected from two locations, NAR-1 and NAR-4 (Figure 3.1) previously sampled during 1984 and 1985. A standard Ellis-Rutter box sampler was used to quantitatively sample the benthos commensurate with historical sampling protocol. Three replicate grabs were collected at each location. The Ellis-Rutter was placed firmly on the stream bottom and the substrate within the sampler's 0.10 m^2 area was agitated by hand so as to dislodge any attached benthic organisms. Stream current carried the organisms into an attached 500u tail bag which was then rinsed into a plastic collecting jar.

Samples were preserved in the field using a mixture of isopropanol and rose bengal stain. Upon return to the Dominion Environmental Biology laboratory, all samples were boxed, labeled, manifested and shipped to the contract vendor (Third Rock Consultants in Lexington, Kentucky) for further processing and identification. Data were reported as the sum of the three individual grabs at each location for direct comparison to the historical studies.

Macroinvertebrate Results and Discussion

Two benthic collections were made from the North Anna River as part of the DEQ approved North Anna Low Flow Monitoring Plan. The first set of samples was collected under drought conditions in November 2001 at 20 cfs. The second set of samples was collected in August 2003 following return and stabilization at the normal 40 cfs flow under post drought conditions.

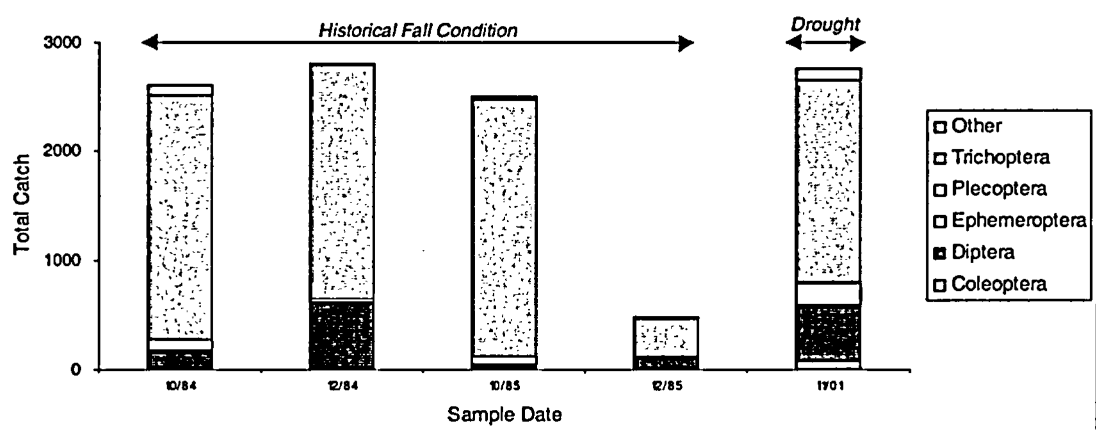
A total of 3,434 benthic macroinvertebrates was collected from the North Anna River during drought conditions in November 2001. Caddisflies, mayflies, riffle beetles and midges accounted for much of the numerical abundance and diversity of the benthic community (Table 4.1).

Table 4.1 Total catch of benthic macroinvertebrates collected during drought conditions from the North Anna River below Lake Anna, VA, 2001. Values are the sum of 3 replicate Ellis Rutter samples.

Date	Taxa	Stations	
Nov-01			
		NAR1	NAR4
	Elmidae	86	144
	Hydrophilidae	0	1
	Psephenidae	2	1
	Chironomidae	457	49
	Empididae	0	3
	Tipulidae	0	1
	Ceratopogonidae	3	0
	Simuliidae	52	0
	Ephemerellidae	0	42
	Heptageniidae	135	98
	Baetidae	45	57
	Caenidae	0	1
	Oligoneuriidae	14	27
	Corydalidae	10	4
	Corbiculidae	41	8
	Unionidae	2	0
	Coenagrionidae	9	4
	Gomphidae	4	1
	Corduliidae/Libellulidae	0	1
	Oligochaeta	42	5
	Taeniopterygidae	9	26
	Perlidae	1	14
	Nemouridae	0	35
	Perlodidae	1	12
	Hydropsychidae	1660	90
	Lepidostomatidae	3	0
	Philopotamidae	119	19
	Limnephilidae	0	4
	Polycentropodidae	2	2
	Leptoceridae	21	5
	Glossosomatidae	1	0
	Hydroptilidae	41	9
	Brachycentridae	2	6
	Hydracarina	1	2
Station Total		2763	671
Total Taxa		26	29

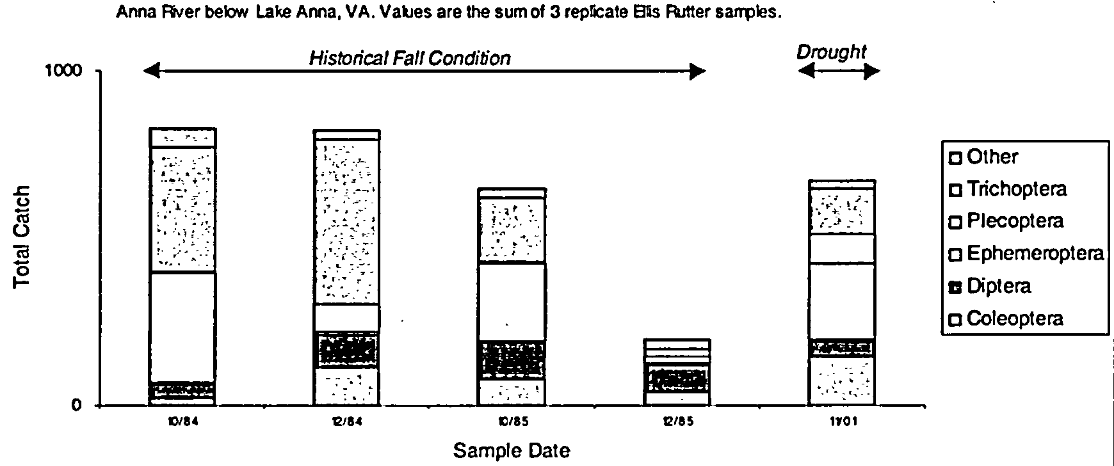
At NAR-1, total abundance of macroinvertebrates during November, 2001 compared very favorably to the historical catch (Figure 4.1). Community structure was not measurably impacted by the reduced flow at this site. The benthic community was numerically dominated by filter-feeding caddisflies (*Hydropsychidae, Philopotamidae*), midges and mayflies (*Heptageniidae, Baetidae*).

Figure 4.1 Total catch of benthic macroinvertebrates, by date, collected by Ellis Rutter from station NAR1 in the North Anna River below Lake Anna, VA. Values are the sum of 3 replicate Ellis Rutter samples.



At NAR-4, total abundance of macroinvertebrates for the November, 2001 low-flow sampling event likewise compared very favorably to the historical catch. Community structure during the low flow condition was similar to historical data and typified by large numbers of mayflies, caddisflies, riffle beetles and stoneflies (Figure 4.2).

Figure 4.2 Total catch of benthic macroinvertebrates, by date, collected by Ellis Rutter from station NAR4 in the North Anna River below Lake Anna, VA. Values are the sum of 3 replicate Ellis Rutter samples.



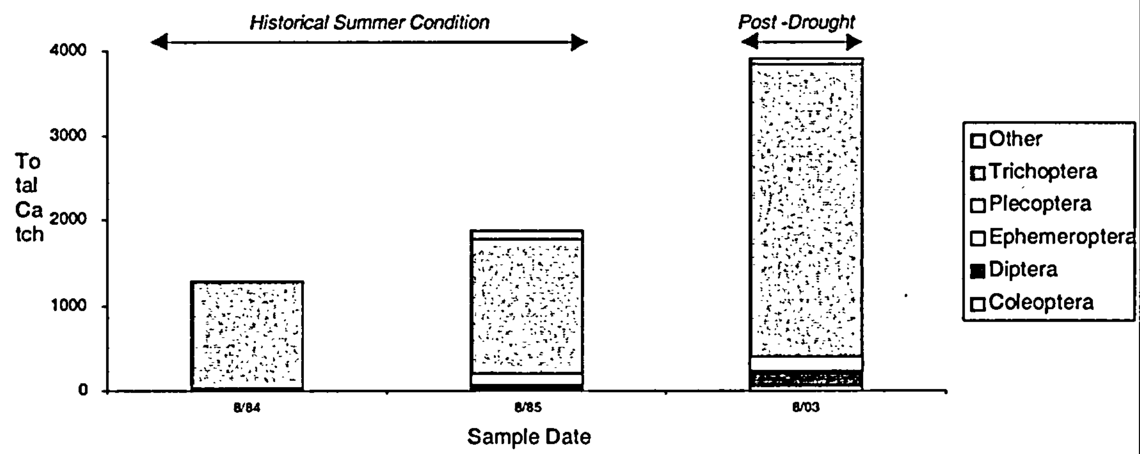
A total of 5,438 benthic macroinvertebrates was collected from the North Anna River following return to normal river flow conditions, i.e., post drought (August 2003) streamflow conditions. Caddisflies, blackflies mayflies and riffle beetles, similar to the low flow period, accounted for much of the numerical abundance and diversity of the benthic community (Table 4.2).

Table 4.2. Total catch of benthic macroinvertebrates collected during post-drought conditions from the North Anna River below Lake Anna, VA, 2003. Values are the sum of 3 replicate Ellis Rutter samples.

Date	Taxa	Stations	
Aug-03			
		NAR1	**NAR4**
	Elmidae	53	141
	Psephenidae	2	3
	Chironomidae	125	27
	Empididae	4	1
	Ceratopogonidae	0	3
	Simuliidae	54	725
	Heptageniidae	56	37
	Baetidae	100	99
	Oligoneuriidae	0	3
	Tricorythidae	14	1
	Ameletidae	0	3
	Physidae	1	0
	Corydalidae	23	9
	Sphaeriidae	0	4
	Corbiculidae	23	0
	Gomphidae	1	0
	Tubificidae	2	2
	Perlodidae	1	0
	Hydropsychidae	3393	387
	Philopotamidae	28	70
	Polycentropodidae	2	0
	Leptoceridae	26	0
	Hydroptilidae	0	7
	Brachycentridae	3	4
	Gyrinidae	0	1
Station Total		3911	1527
Total Taxa		19	19

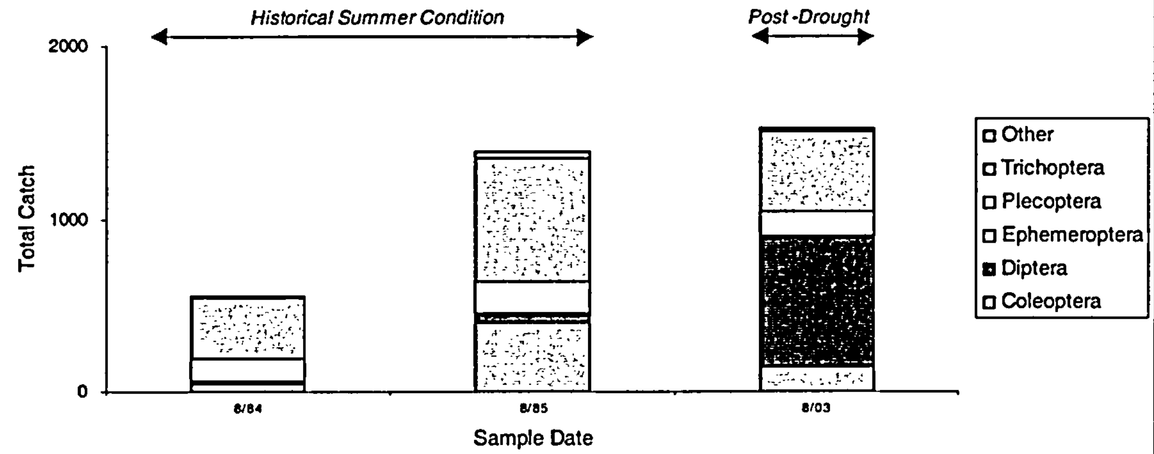
At NAR-1, total abundance of macroinvertebrates during the post drought flow collection period also compared very favorably to the historical catch (Figure 4.3) In fact, numbers collected during this period were approximately twice as high compared to past years, due in large part to increased numbers of caddisflies, (*Hydropsychidae* and *Philopotamidae*). These organisms are obligate filter feeders particularly well adapted to utilize the seston discharged from Lake Anna (Parker and Voshell 1983).

Figure 4.3 Total catch of benthic macroinvertebrates, by date, collected by Ellis Rutter from station NAR1 in the North Anna River below Lake Anna, VA. Values are the sum of 3 replicate Ellis Rutter samples.



At NAR-4, total abundance of macroinvertebrates was similar to past years with blackflies (*Simuliidae*) accounting for a large percentage of the overall catch (Figure 4.4). These organisms are obligate filter-feeders and are known to produce high, localized densities. This tendency to form "clumping" colonies may be a strategy to enhance mutually beneficial flows across their bodies, thus enhancing particulate filtering (Craig and Chance 1981). High densities of blackflies in the North Anna River have similarly been observed in the past (Virginia Power 1986).

Figure 4.4 Total catch of benthic macroinvertebrates, by date, collected by Ellis Rutter from station NAR4 in the North Anna River below Lake Anna, VA. Values are the sum of 3 replicate Ellis Rutter samples.



Based on the total catch of benthic macroinvertebrates collected and the species composition of the catch during drought and post-drought periods, there were no obvious impacts to the North Anna River benthos assemblage that can be attributed to reduced stream flow during the period of study.

5.0 Fish

Sampling and monitoring protocols followed those outlined in North Anna River Monitoring Plan – Low Flow Conditions, submitted to the Virginia DEQ on March 15, 2002. Four stations (NAR-1, NAR-2, NAR-4 and NAR-5) that are a part of Dominion's continuing long-term biological monitoring program for the North Anna River were sampled during 2002 (Figure 3.1). Abundance and species composition data for the fish assemblage were collected by electrofishing. Also, abundance and distribution data for smallmouth bass *Micropterus dolomieu* and largemouth bass *M. salmoides* were collected by direct observation during snorkel surveys. In 2003 only snorkel surveys were conducted because high flows prevented sampling with electrofishing gear.

Electrofishing Methods

Electrofishing surveys were conducted during May, August and October 2002. An approximately 70 m reach of riffle/run habitat was sampled at each station with an electric seine. Prior to sampling, each reach was blocked at the downstream end with a 6.5 mm mesh net. Sampling was conducted by working the electric seine from bank to bank in a zigzag pattern from the upstream to downstream end of the station. Nearby pool habitats were then sampled for 10 minutes of effort with a backpack electrofisher. Fish sampled by electric seine and backpack electrofisher were collected using 6.5 mm mesh dip nets.

Most fish collected were preserved in 10% formalin and transported to the laboratory for processing. Some larger fish were measured and weighed in the field and released. In the laboratory, a maximum of 15 individual specimens of each species collected from each station was measured to the nearest one (1) mm total length and weighed to the nearest 0.1 g. If more than 15 specimens of a species were collected at a station, those in excess of 15 were counted and weighed in bulk. Electric seine and backpack electrofisher collections were pooled by station and survey month for analyses.

Electrofishing Results and Discussion

A total of 1,474 fish representing 28 species was collected from the North Anna River during electrofishing surveys conducted in 2002 during drought conditions and flows of 20 cfs (Table 5.1; Figure 5.1). This total is similar to the total number of fish collected in 2001 prior to flow reductions in October and November 2001 (Figure 5.2). It also compares favorably with the median number of fish (1,609) that has been collected annually from the North Anna River since consistent sampling methods were implemented in 1981.

Table 5.1 Number and biomass (g) of fishes collected during May, August and September, 2002 electrofishing surveys of the North Anna River.

Family / Species	NAR-1 Number	NAR-1 Total Weight	NAR-2 Number	NAR-2 Total Weight	NAR-4 Number	NAR-4 Total Weight	NAR-6 Number	NAR-6 Total Weight	Total Number	Total Total Weight
Petromyzontidae										
Petromyzon marinus			1	3.0					1	3.0
Anguillidae										
Anguilla rostrata	143	1882.7	10	165.2	19	269.7	49	787.9	221	3105.5
Cyprinidae										
Cyprinella analostana	15	45.2	52	147.4	46	95.1	82	179.1	195	466.8
Lythrurus ardens	29	60.8	77	169.8	81	120.4	59	126.7	246	497.7
Nocomis leptocephalus			1	24.5	8	200.3	1	12.4	10	237.2
Nocomis micropogon			3	36.8	6	244.1	5	114.3	14	375.2
Notropis amoenus	1	1.3					1	3.3	2	4.6
Notropis procne			8	12.9	6	2.5	98	80.4	112	95.8
Notropis rubellus							1	0.6	1	0.6
Semotilus corporalis	2	52.7	15	121.2	19	110.7	14	232.5	50	517.1
Catostomidae										
Erimyzon oblongus			9	27.2	2	24.0			11	51.2
Hypentelium nigricans	1	96.9					1	2.7	2	99.6
Ictaluridae										
Amelurus natalis			5	17.7	1	4.4	1	5.7	7	27.8
Ictalurus punctatus			1	8.8					1	8.8
Noturus gyrinus							2	8.5	2	6.5
Noturus insignis	57	295.3	17	60.1	38	170.6	18	135.0	130	661.0
Centrarchidae										
Lepomis auritus	96	1632.8	104	534.4	113	743.4	47	602.3	360	3512.9
Lepomis macrochirus	8	127.7	4	119.5	1	2.8	1	10.6	14	260.6
Micropterus dolomieu	1	13.7							1	13.7
Micropterus salmoides	2	13.8	7	87.7					9	101.5
Pomoxis nigromaculatus							1	6.4	1	6.4
Percidae										
Etheostoma olmstedi	11	15.0	8	7.1	5	7.0	4	7.5	28	36.6
Etheostoma vitreum							13	11.3	13	11.3
Percina peltata	5	19.0	3	8.7			5	8.8	13	36.5
Aphredoderidae										
Aphredoderidae sayanus			1	2.3					1	2.3
Esocidae										
Esox niger					4	94.0	2	22.7	6	116.7
Poeciliidae										
Gambusia holbrooki					1	0.4	2	0.5	3	0.9
Total	371	4276.9	326	1554.3	350	2069.4	427	2359.2	1474	10259.8
Number of species	13		18		15		22		28	

Figure 5.1 Number of fish collected from individual North Anna River stations during electrofishing surveys conducted 1981-2002.

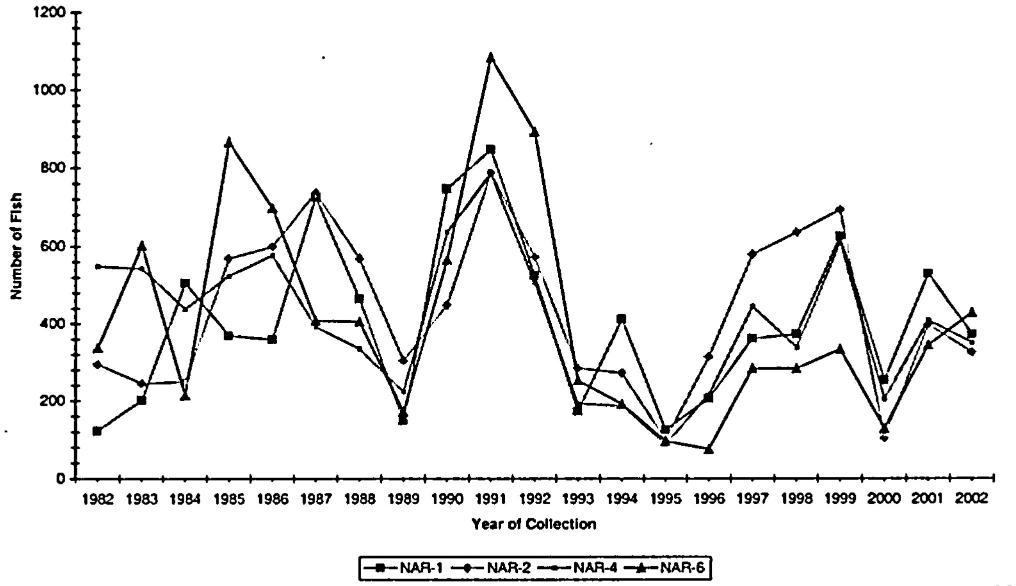
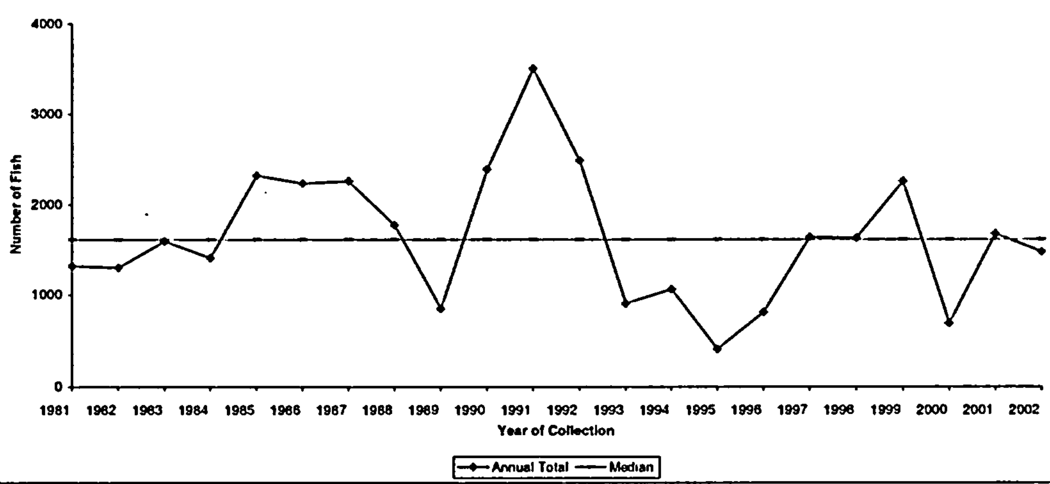


Figure 5.2 Number of fish collected from all North Anna River stations during electrofishing surveys conducted 1981-2002.



Different sampling stations typically account for varying percentages of the overall catch of fishes from the North Anna River in different years. In part, this is due to a large portion of the catch being comprised of schooling fishes, such as satinfin shiners *Cyprinella analostana* and swallowtail shiners *Notropis procne*. The presence of large schools of shiners within a sampling reach in one year but not another can dramatically alter that station's rank in relative abundance. In 2002 the greatest number of fish were collected from NAR-6, followed by (in decreasing order) NAR-1, NAR-4 and NAR-2 (Table 5.1). The greatest biomass of fish was collected from NAR-1, followed by (in decreasing order) NAR-6, NAR-4 and NAR-2. The greater biomass at NAR-1 is, in part, attributable to the relatively high number of redbreast sunfish *Lepomis auritus* and American eels *Anguilla rostrata* collected at that station.

Over the past 22 years of fish collections, 50 species of fish have been collected from the North Anna River, with annual totals ranging from 18 to 32 species. In 2002 a total of 28 species representing 10 families was collected (Table 5.1). In comparison, a total of 27 species representing 8 families was collected during 2001 prior to flow reductions in October and November. The 2002 collection included one species that had not been recorded from the North Anna River previously – the eastern mosquitofish *Gambusia holbrooki*. An inhabitant of shallow lentic waters, the eastern mosquitofish is common throughout the Virginia Piedmont, the York River drainage and has been documented from Lake Anna (Jenkins and Burkhead 1993; Dominion 2001).

Table 5.2 Ranked abundance of species comprising greater than 80 percent of the pooled annual North Anna River electrofishing catch from all stations, 1981-2002. A species rank of 1 indicates it was the most abundant fish collected.

Species	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Notropis procne	2	1	1	1	1	1	1	1	1	4	2	3	1	2	7	3	2	2	4	--	7	6
Cyprinella analostana	1	2	2	3	2	2	5	2	3	2	1	1	3	6	6	1	1	4	2	--	4	4
Lepomis auritus	3	3	3	2	3	4	2	3	2	1	4	2	2	1	1	2	3	1	1	1	1	1
Notropis rubellus	--	5	8	8	10	3	3	4	4	3	3	5	4	3	5	--	8	6	--	--	--	--
Noturus insignis	8	--	--	--	6	5	4	6	7	6	5	6	5	4	3	--	4	7	6	4	5	5
Percina peltata	--	--	7	4	5	6	--	5	--	5	6	--	8	5	8	6	10	--	--	6	--	--
Anguilla rostrata	4	4	4	6	9	--	6	--	6	7	--	7	6	7	4	4	6	5	7	3	3	3
Lythrurus ardens	--	--	--	--	7	7	7	--	--	--	7	4	7	--	2	--	5	3	3	2	2	2
Nocomis micropogon	6	--	5	--	--	8	--	--	--	--	8	8	--	--	9	--	--	--	--	--	--	--
Nocomis leptocephalus	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Semotilus corporalis	--	--	9	--	4	9	--	--	--	--	--	--	--	--	--	--	9	--	5	5	6	
Notropis amoenus	7	6	--	7	--	--	--	--	5	--	--	--	--	--	--	5	7	8	--	--	--	--
Hypentelium nigricans	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Notemigonus crysoleucas	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis macrochirus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	--	--	--	--	--	--
Total number of species collected	26	27	29	31	31	29	32	30	18	25	25	29	25	25	22	20	24	28	28	23	27	28
Number of species accounting for >80%	8	6	9	7	10	9	7	6	7	7	8	8	8	7	9	7	10	8	7	6	7	6
Percent of electrofishing catch	83	82	81	83	83	83	80	82	80	80	84	83	83	85	82	82	84	80	82	83	84	86

*-- indicates species was not among those comprising greater than 80% of the electrofishing catch

Similar to most warmwater streams (Matthews 1982), a few species tended to numerically dominate the North Anna River's stream fish assemblage. Six (6) to 10 species have accounted for greater than 80 percent of the North Anna River electrofishing catch from all stations in any year since sampling began in a consistent manner in 1981 (Table 5.2). In 2002, six (6) species accounted for greater than 80 percent of all fish collected. In decreasing order, these were redbreast sunfish, rosefin shiner *Lythrurus ardens*, American eel, satinfin shiner, margined madtom *Noturus insignis* and swallowtail shiner. These species have consistently been among the most abundant species collected from the North Anna River since 1981.

Based on the relative abundances of fish collected and the species composition of the electrofishing catch for 2002, there were no obvious impacts to the North Anna River fish assemblage that can be attributed to reduced stream flow during the period of study.

Snorkel Methods

Consistent underwater observation techniques have been used for monitoring smallmouth bass (SMB) and largemouth bass (LMB) in the North Anna River since 1987.

Counts of SMB and LMB were made while swimming 100 m transects along the north and south banks of stations NAR-1, NAR-2, NAR-4 and NAR-5. Transects followed an approximately one meter depth contour. During each survey, three successive counts were made at each station at each bankside transect. All bass sighted were categorized by species as to young-of-year (YOY; fish $\leq$120 mm), stock size (120 mm<SMB<280 mm, or 120 mm <LMB<305 mm), or quality size

(SMB≥280 mm, or LMB≥305 mm). Each observer made an independent estimate of the distance that YOY SMB could be distinguished from YOY LMB at each station. Lateral visibility at each station was estimated by averaging the independent estimates of both observers. Four (4) stations were surveyed twice per month during 2002 in July, August and September. Extreme high water conditions made it difficult to obtain underwater observations during 2003. Both snorkel surveys scheduled for July 2003 were cancelled due to high water. At NAR-2, two (2) additional surveys were not conducted because visibility was unacceptable (< 1.0 m).

Counts of SMB and LMB were converted to density estimates (number/hectare of bankside channel) to account for differences in average visibility among survey days and sampling stations. Density estimates for all SMB and LMB larger than YOY size were then pooled by species, station and sample year to facilitate identification of species-specific and station-specific changes over time. YOY densities were not calculated as it was doubtful that YOY were as susceptible to the observation technique as larger fish were, due primarily to their small size and cryptic nature.

Snorkel Results and Discussion

Historically, LMB have dominated fish counts at the upper river stations (NAR-1 and NAR-2), and SMB have been more abundant at the lower river stations (NAR-4 and NAR-5). In recent years, less geographic separation has been observed, with more SMB observed in the upper river, and more LMB observed in the lower river (Dominion 2001). Variability between counts of LMB and SMB at the north and south banks of any station have appeared to be related to habitat complexity. Fewer fish have consistently been observed along banks characterized by monotypic habitat than along banks with a variety of habitat types (e.g., wood and bedrock ledges).

Very different results were obtained from fish counts conducted in 2002 and 2003, which respectively represented a low water year following several years of drought, and an extreme high water year. In 2002, LMB continued to dominate fish counts at the upper river stations, but also dominated fish counts at the lower river stations for the first time on record (Table 5.3). This was due, in large part, to an apparently strong year class of young-of-year LMB being produced in both the upper and lower river. In contrast SMB appeared to have produced very few young-of year in the lower river, its traditional habitat. For unknown reasons, many more SMB YOY (37) were counted at the upper river stations than SMB YOY (8) at the lower river stations during 2002.

Table 5.3 Number of smallmouth bass and largemouth bass observed during North Anna River snorkel surveys conducted in 2002. Sample size (n) equals the number of times each count was performed in 2002.

				Smallmouth bass [1]			Largemouth bass [2]		
Station	Bank	Count	n	SMBYOY	SMB<11	SMB>11	LMBYOY	LMB<12	LMB>12
NAR-1	North	1	6	3	1	0	8	14	7
		2	6	4	0	0	6	13	2
		3	6	6	0	0	8	15	2
	South	1	6	3	0	0	4	4	5
		2	6	0	2	0	3	3	9
		3	6	0	0	0	7	4	11
NAR-2	North	1	6	3	0	1	17	10	6
		2	6	1	3	0	17	9	5
		3	6	7	2	0	16	13	6
	South	1	6	1	7	0	7	13	8
		2	6	7	3	0	11	10	4
		3	6	2	2	0	12	3	6
NAR-4	North	1	6	2	0	3	0	6	0
		2	6	2	2	0	0	5	4
		3	6	1	4	2	0	5	1
	South	1	6	0	5	3	0	4	1
		2	6	0	4	5	1	6	2
		3	6	0	7	2	1	2	4
NAR-5	North	1	6	1	16	7	2	14	5
		2	6	0	16	5	1	9	1
		3	6	0	10	4	3	4	4
	South	1	6	0	7	3	12	4	1
		2	6	1	2	0	14	1	0
		3	6	1	6	2	16	3	0

[1] SMYOY were less than or equal to 120 mm, SMB<11 were 121-279 mm, SMB>11 were larger than or equal to 280 mm TL.

[2] LMBYOY were less than or equal to 120 mm, LMB<11 were 121-304 mm, LMB>11 were larger than or equal to 305 mm TL.

In 2003, numbers of LMB and SMB observed were much lower than in 2002 (Table 5.4). This was at least partly due to fewer surveys being conducted during 2003 due to high water and limited visibility. LMB again dominated fish counts at both upper and lower river stations, and only two (2) SMB were observed at the upper river stations. LMB YOY were more abundant than SMB YOY, but still relatively scarce.

Table 5.4 Number of smallmouth bass and largemouth bass observed during North Anna River snorkel surveys conducted in 2003. Sample size (n) equals the number of times each count was performed in 2003.

				Smallmouth bass [1]			Largemouth bass [2]		
Station	Bank	Count	n	SMBYOY	SMB<11	SMB>11	LMBYOY	LMB<12	LMB>12
NAR-1	North	1	4	0	0	0	10	3	0
		2	4	0	0	0	11	3	3
		3	4	0	0	0	7	0	0
	South	1	4	0	0	1	2	1	1
		2	4	0	0	0	1	2	1
		3	4	0	0	0	0	0	2
NAR-2	North	1	2	0	0	0	0	1	1
		2	2	0	0	0	0	2	1
		3	2	0	0	0	0	0	2
	South	1	2	0	0	0	1	4	0
		2	2	0	1	0	0	1	0
		3	2	0	0	0	0	3	3
NAR-4	North	1	4	0	1	1	1	1	0
		2	4	0	0	0	5	2	1
		3	4	0	0	0	2	1	0
	South	1	4	3	0	1	4	0	0
		2	4	0	0	0	2	0	0
		3	4	0	1	0	2	0	0
NAR-5	North	1	4	0	1	4	0	1	0
		2	4	0	1	3	0	0	2
		3	4	0	2	6	0	0	1
	South	1	4	0	0	0	4	1	0
		2	4	0	0	0	1	1	0
		3	4	0	0	0	2	1	0

[1] SMYOY were less than or equal to 120 mm, SMB<11 were 121-279 mm, SMB>11 were larger than or equal to 280 mm TL.

[2] LMBYOY were less than or equal to 120 mm, LMB<11 were 121-304 mm, LMB>11 were larger than or equal to 305 mm TL.

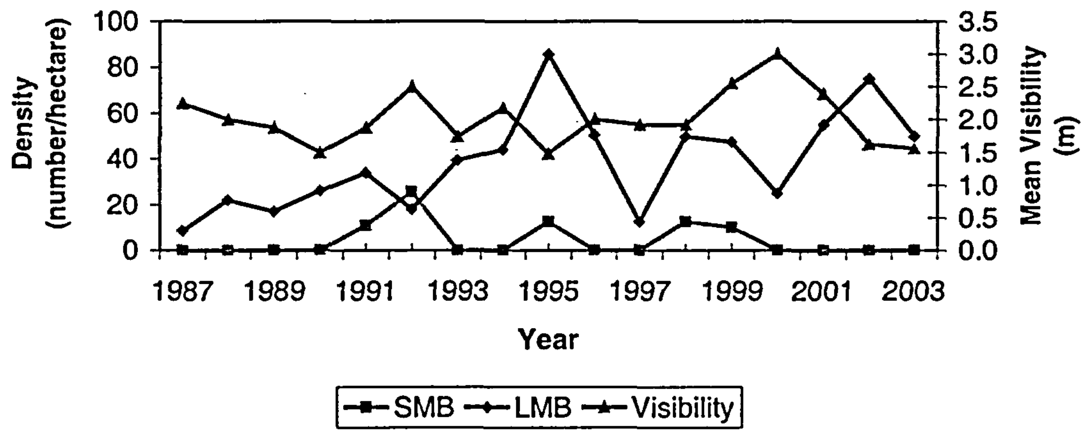
It is possible that reduced flows in the North Anna River during 2002 contributed to a strong year-class of LMB. LMB are better adapted to lentic (stillwater) versus lotic (moving water) conditions. Reduced flows during 2002 may have resulted in more spawning habitat with little or no current, and the increased stability of river flow may have improved spawning success and YOY survival. Increased LMB YOY survival may have had a detrimental effect on YOY SMB survival, which is generally good under low, stable flow conditions (Fajen 1975; Smith 2002). However, this hypothetical scenario does not explain the relatively high numbers of YOY SMB observed at the upper river stations, and therefore is unlikely.

The low numbers of SMB YOY observed in 2003 (3 YOY) may be attributed to the extreme high water conditions that persisted throughout the year. High flows during and following spawning are known to have detrimental effects on SMB reproduction (Graham and Orth 1986; Lucas 1993; Smith 2002). The greater relative abundance of LMB YOY may be due to one or more factors not investigated, such as differences in the timing of LMB spawning, or spillover of YOY from Lake Anna.

Count data provide insight into the relative abundance of LMB and SMB, but are somewhat difficult to interpret because they do not account for visibility differences among surveys. They further do not account for repetitive counts of the same fish on different counts during a survey, or for LMB and SMB (or different sizes of fish of the same species) reacting to observers in different ways on different counts. Use of median density estimates derived from fish counts and visibility estimates tends to reduce error associated with the above variables, and is used to compare changes in relative abundance over time and among stations. The median is the number in the middle of an ordered group, with half the values higher than the median and half lower. The advantage of using the median as an indicator of fish density is the effect of uncharacteristically high or low values is reduced, making the median a more appropriate index of long-term relative abundance. However, it is noteworthy that in situations where fish are observed in fewer than half the counts the median value will be zero, despite the fish's documented presence.

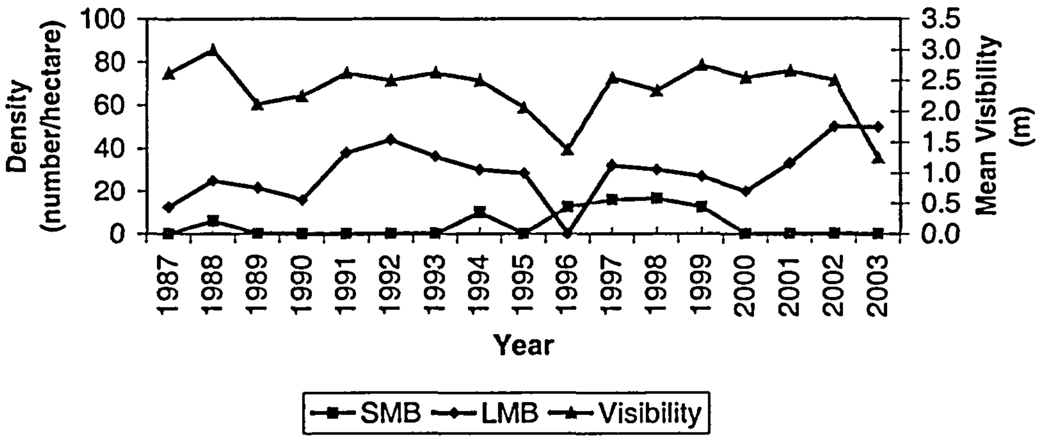
During 2002 the median density of LMB observed at NAR-1 increased to the second highest on record since 1987 (Figure 5.3), and then decreased but remained at a relatively high level during 2003. The median density of SMB observed at NAR-1 was equal to zero during both 2002 and 2003, as it has been since 2000.

Figure 5.3 NAR-1 smallmouth and largemouth bass median densities, and mean visibilities, 1987-2003.



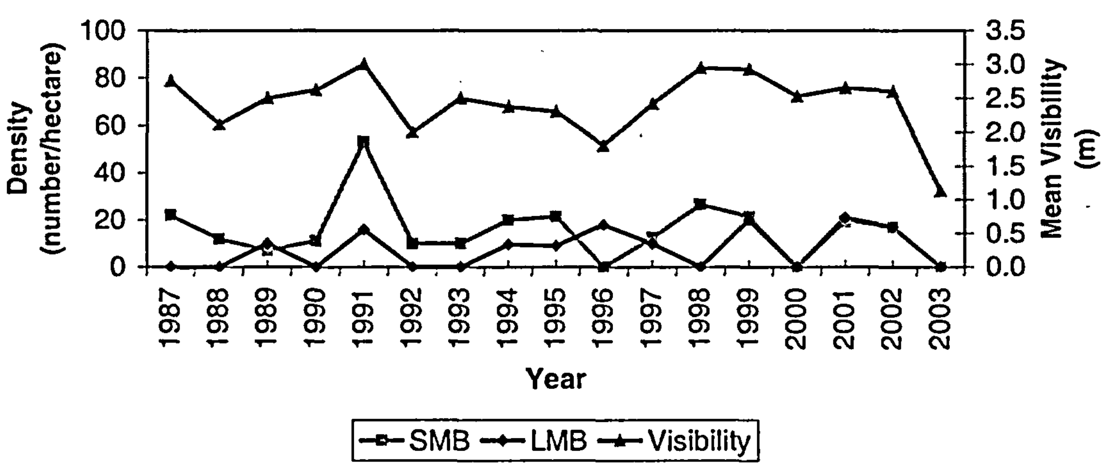
A similar pattern was observed at NAR-2 (Figure 5.4), with record high median LMB densities and median SMB densities equal to zero during 2002 and 2003. Density estimates for NAR-2 were likely affected by very low mean visibility during 2003 (Figure 5.4), which was attributable to inflow from Northeast Creek 1-2 km upstream. Reduced sample size in 2003 also may have affected NAR-2 median density estimates.

Figure 5.4 NAR-2 smallmouth and largemouth bass median densities, and mean visibilities, 1987-2003.



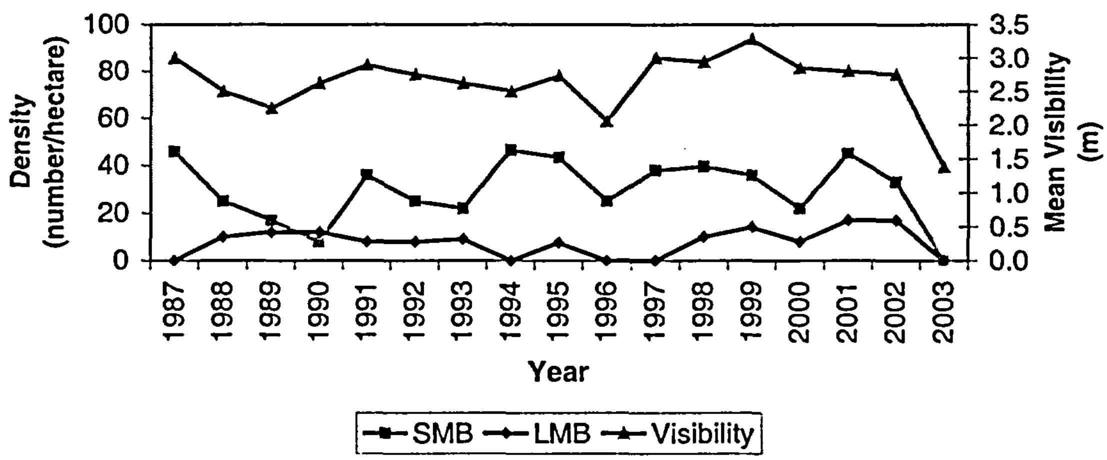
Median density estimates for LMB and SMB at NAR-4 have been of similar magnitude and generally exhibited the same variable pattern of change from year to year since 1999, and continued to do so during 2002 and 2003 (Figure 5.5). Median density estimates for both species were above average during 2002, and then decreased to zero during 2003. Similar to NAR-2, density estimates for NAR-4 were likely affected by very low mean visibility during 2003 due to turbidity contributed by Northeast Creek and other smaller tributary steams.

Figure 5.5 NAR-4 smallmouth and largemouth bass median densities, and mean visibilities, 1987-2003.



NAR-5 was the only station where SMB clearly dominated LMB during 2002 (Figure 5.6). However, during 2003 both LMB and SMB median densities decreased to zero. Again, low visibility likely affected fish density estimates.

Figure 5.6 NAR-5 smallmouth and largemouth bass median densities, and mean visibilities, 1987-2003.



Year to year changes in density estimates of LMB or SMB may be affected as much by biotic factors (e.g., effects of a previous year's spawn) as by flow conditions in any year. In general, through the severe drought period of 2001-2002 LMB densities increased at the upper river stations, but remained stable at relatively high levels at the lower river stations. Median SMB densities were zero at the upper river stations as they have been since 2000, but remained relatively high at the lower river stations. There was no obvious effect of the reduced flows during 2002.

During 2003, median LMB densities remained at high levels at the upper river stations, while median SMB densities were zero. At the lower river stations median LMB and SMB densities were both zero. However, due to the nature of the sampling technique (direct observation), it is unlikely fish counts accurately represented the abundance of LMB and SMB at these stations during 2003. Underwater observations within the North Anna River are most useful when visibility is sufficient to enable observers to scan two or more meters of water in any direction. The reduced visibility conditions encountered during 2003 severely reduced the area within which observers were able to scan fish (generally only about 1-1.5 m), and were uncharacteristic of the North Anna River's typically clear waters. It is likely density estimates will increase in the next year if counts are performed under more typical conditions.

6.0 Summary

Flow to the lower North Anna River was reduced to approximately 20 cfs in 5 cfs increments from October 19 through November 1, 2001.

A DEQ-approved low flow monitoring program was implemented October 25, 2001 that included measurements of physical, chemical and biological attributes.

Wetted perimeter (WP) and depth were measured at two stations (NAR-1 and NAR-5) separated by about 27 km. Measurements were made while flow was reduced from 40 cfs, at monthly intervals while flow was maintained at 20 cfs, and when flow returned to approximately 40 cfs in January 2003. Water velocity at these stations was also measured from December 2001 through January 2003.

Water temperature and dissolved oxygen (DO) were measured at hourly intervals by hydrolab instruments at the same two stations from October 2001 through January 2003.

At NAR-1, average WP and depth varied in like manner. Excessive *Hydrilla* growth during summer and fall of 2002 appeared to increase average WP and depth. Average WP and depth measured at 40 cfs was less than expected, and may be related to difficulty in measuring flow releases not directed through the North Anna hydropower turbines.

Water temperatures and DO at NAR-1 exhibited seasonal profiles. Water temperatures at NAR-1 exceeded 32° C on 20 days during July and August 2002. Daily average DO was never less than 5.0 mg/l, or an instantaneous value of 4.0 mg/l.

Water velocity measurements at NAR-1 were affected by *Hydrilla* growth, and were difficult to interpret.

At NAR-5, average WP and depth also varied in like manner. Average WP and depth exhibited less change as flow varied, likely due to greater stream width at NAR-5 and inflows from tributary streams. Average WP and depth at NAR-5 were more affected by rainfall events than at NAR-1.

Water temperatures and DO at NAR-5 exhibited seasonal profiles. Water temperatures never exceeded 32° C. However, daily average DO was less than 5.0 mg/l on 12 days, and instantaneous values less than 4.0 mg/l were observed on 16 days during mid-June and early July 2002. *Hydrilla* growth around the monitoring instrument may have affected readings.

Water velocity measurements at NAR-5 were affected by *Hydrilla* growth and backwater habitats, and were difficult to interpret.

Benthic macroinvertebrate surveys were conducted in November 2001 (low flow) and August 2003 (recovered flow), respectively. Abundance and species composition data for the benthic assemblage were collected using an Ellis-Rutter portable invertebrate box sampler, consistent with historical methods and procedures.

Caddislflies, mayflies, riffle beetles and midges accounted for much of the numerical abundance and diversity of the benthic community during both the low and recovered flow sampling periods.

Benthic macroinvertebrate abundance observed during the recent studies compared very favorably to historical collections taken during the same time of year.

The benthic macroinvertebrate community evident in the North Anna River during the low flow monitoring studies compared very favorably to that observed in the mid-1980's. All of the major groups and trophic levels continue to be well represented and there were no obvious impacts that can be attributed to reduced stream flow.

Fish were sampled by electrofishing during 2002 at four stations that have been sampled in a consistent manner since 1981 to assess long-term changes in the North Anna River fish assemblage. (Electrofishing was not conducted during 2003 due to extremely high water.)

The total number of fish collected by electrofishing during 2002 was similar to the number collected in 2001 prior to flow reductions, and was similar to the median number of fish collected annually since 1981.

In 2002 a total of 28 species was collected representing 10 families. In comparison, a total of 27 species representing 8 families was collected during 2001. The median number of species collected annually since 1981 has also been 27.

The 2002 collection included one species that had not been recorded from the North Anna River previously – the eastern mosquitofish *Gambusia holbrooki.*

In 2002 six species accounted for more than 80% of the electrofishing catch. These species have consistently been among the most abundant species collected from the North Anna River since 1981.

Based on the relative abundances of fish collected and the species composition of the electrofishing catch for 2002, there were no obvious impacts to the North Anna River fish assemblage that can be attributed to reduced stream flow during the period of study.

Counts of SMB and LMB were made by snorkeling at four stations twice per month during July, August and September 2002 using protocol in place since 1984. During 2003, no fish counts were conducted during July due to extremely high water, and two additional surveys were cancelled at NAR-1 due to low visibility.

Fish counts were converted to density estimates based on visibility estimates, and were used to compare changes in relative abundance of stock and quality sized fish over time and among stations.

LMB dominated fish counts at the upper and lower river stations during 2002. The relatively high count for LMB was primarily due to a strong year-class of LMB YOY being produced throughout the river. More SMB YOY were observed at the upper river stations during 2002 than at the lower river stations, in contrast to the typical pattern of SMB abundance.

During 2003 fewer LMB and SMB were observed than in most previous years, a condition likely attributable to the high flows and corresponding reduced visibility encountered during 2003.

In general, median LMB density estimates for the upper river increased during the severe drought period of 2001-2002, and remained stable at relatively high levels at the lower river stations. Although some SMB were observed in the upper river, median SMB densities were zero, as they have been since 2000. Median SMB densities remained relatively high at the lower river stations.

During 2003, LMB densities remained at high levels at the upper river stations, while median SMB densities were zero. At the lower river stations median LMB and SMB densities were both zero. Reduced visibility during 2003 likely reduced sampling effectiveness and affected density estimates.

The snorkel surveys indicated that there were no obvious effects of the reduced flows on LMB or SMB during 2002 or 2003.

7.0 References

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