ENVIRONMENTAL STUDY OF LAKE ANNA,
THE WASTE HEAT TREATMENT FACILITY
AND LOWER NORTH ANNA RIVER

2022 ANNUAL REPORT

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Executive Summary

This report presents the findings of various ecological studies conducted by Dominion Energy biologists in 2022 on Lake Anna (lake), the Waste Heat Treatment Facility (WHTF) and the North Anna River downstream of the dam. The studies were conducted in accordance with the 2014 study plan that was approved by the Department of Environmental Quality (DEQ) and the Virginia Department of Wildlife Resources (DWR). The 2022 studies were performed to address the requirements of the VPDES permit for North Anna Power Station and continue to support the 316(a) demonstration for the station that the operation of the power station has not resulted in significant harm to the biological community. The 2022 study results did not identify any negative impacts from the operation of North Anna Power Station. The temperature data recorded in Lake Anna is within the historical minimum and maximum temperatures and the lake stratifies and mixes seasonally as expected. The fisheries are diverse, represented by multiple species and in numbers that are in balance. Electrofishing catch rates in the North Anna River are highly variable which is common to streams. Diversity and evenness indices have remained high in the North Anna River which is indicative of a healthy and robust fish assemblage.

Units 1 and 2 were intermittently shut down in 2022 for maintenance and refueling, and the units periodically generated above calculated capability ratings. These ratings are calculated based on historical summer and winter operating conditions at times of peak demand as well as other operating variables that affect unit output. Therefore, during favorable conditions the units can generate more electricity than the calculated rating using the same amount of power from the nuclear reactors. Units 1 and 2 were shut down for approximately 39 and 72 days in 2022, respectively. The maximum hourly water temperature recorded in 2022 was 39.5°C in August at station NADISC1, located in the WHTF. Conversely, the minimum was 2.4°C in January at station NAL719ST, located in the lake. The maximum and minimum temperatures recorded in the Lake and WHTF are within the previous historical ranges. In addition to hourly temperature monitoring, standard physicochemical measurements (water temperature, dissolved oxygen, pH, and conductivity) were recorded at the time of biological sampling and were within the values known to support a healthy fish assemblage.

Quarterly lake and WHTF gill net samples were collected in 2022 with Gizzard Shad, Channel Catfish, Striped Bass, White Catfish, Largemouth Bass, and White Perch as the

numerically dominant species caught. These fish commonly rank high in the gill net catches in the lake and WHTF. Their consistent presence in the gill net samples indicates a stable species composition in the lake and WHTF.

In 2022, Centrarchids (sunfishes, including Largemouth Bass) continue to be the numerically dominant fish taxa collected by quarterly electrofishing surveys in the lake and WHTF. A total of twenty-four species of fish representing eight families were collected by electrofishing in the lake and WHTF in 2022. In the lake, sunfish catch per unit effort (CPUE) was lower than the 2002-2021 average. Largemouth Bass CPUE was marginally higher than the 2002-2021 average. Overall, annual gill netting and boat electrofishing results demonstrate a balanced, indigenous fish community in the lake and WHTF; and physicochemical parameters were within the ranges to support a healthy fishery.

The lower North Anna River showed a maximum recorded temperature at station NAR-1 in 2022 of 33.1˚C in August. North Anna River electrofishing surveys typically occur three times a year, in May (survey 1), July (survey 2) and September (survey 3) and utilize electric seine and backpack electrofishing. Twenty-eight species of fish representing nine families were collected by electrofishing in the North Anna River in 2022. Shannon's diversity index and Pielou's evenness index scores were calculated for the years 2002-2022 for the North Anna River. Diversity scores have stayed consistent among years ranging from 1.96 – 2.64 with an average score of 2.32. Evenness scores have also been consistent over the years ranging from 0.62-0.83 with an average score of 0.72.

Biological systems are highly complex and are influenced by many environmental factors. It is difficult to determine exact causes of changes seen in sampling results especially since there are so many natural shifts in reproduction, growth, survival, and distributions of aquatic organisms. Overall, 2022 results (species richness, diversity, water quality and relative abundance of fishes) indicate that the lake, WHTF and river downstream of the lake continue to support a diverse, healthy, and balanced finfish community.

Young of year (YOY) Smallmouth Bass sampling was conducted in 2022 to continue investigating Smallmouth Bass spawning, recruitment and to examine the influence of the North Anna River flow and water temperature on spawning. YOY sampling was performed by using fine-mesh, acrylic dip nets while snorkeling. This has proven safer and more effective at capturing the target species than previous efforts. YOY collection surveys in 2022 were

conducted throughout June, July, and August. Fifty YOY were collected and aged from these collections. On the North Anna River, data indicates that spawning begins when water temperatures exceed 15°C. Temperature is likely the variable that triggers spawning in the North Anna River; however, periods of high flow may reduce spawning success by washing out the spawning beds. Dominion Energy is required to maintain a discharge into the North Anna River equal to or greater than 40 cubic feet per second, which has proven supportive of Smallmouth Bass spawning success. Ninety percent of the YOY that were collected in 2022 spawned when river flows were less than or equal to 400 cfs. According to previous data collected, spawning seems most successful after the last high flow event for the season or during years where extreme flows were absent such as 2017.

In addition to the YOY analysis, data for adult and juvenile Smallmouth Bass collected on 10/06/2022 during the fall population sample at NAR-5 were analyzed. In 2022, 68 bass were collected at a rate of 32.6 fish per hour of electrofishing. A linear regression model was applied to the sample data to demonstrate the relationship between Age-1 catch rates and fall collected Age-0 bass. The regression line appears to show a relatively predictable relationship between Age-1 bass abundance and this cohort's young-of-year abundance from the previous year; however, continued data collection will be needed to strengthen the statistical comparison. Boat electrofishing surveys will be continued to provide annual catch rates to gauge year class strength. Since each data point is derived from two years of collections, many more years of sampling will be needed to strengthen and verify this observation. In the coming years as the data set grows, CPUE for age-1 Smallmouth Bass will continue to be compared to the CPUE for Age-0 bass from the previous year.

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1.0 Introduction

In 1972, the North Anna River was impounded to create Lake Anna, a 3885-hectare (9600 acres) reservoir (lake) that provides condenser cooling water for the North Anna Power Station (NAPS). Adjacent to Lake Anna is a 1376-hectare (3400 acre) Waste Heat Treatment Facility (WHTF) that receives the cooling water and transfers excess heat from the water to the atmosphere before discharging into the lake.

Aquatic monitoring studies have been conducted on Lake Anna, the WHTF and the North Anna River below the dam since their creation. In January 1984, the Company initiated an extensive Section 316(a) demonstration study (P.L. 95-500) to determine if proposed effluent limitations on thermal discharges from the power station were more stringent than necessary to assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in Lake Anna and the lower North Anna River. The final report (Virginia Power 316(a) Report 1986) successfully demonstrated that the operation of the power station had not resulted in significant harm to the biological community. The Virginia Water Control Board (VWCB) accepted the study as a successful demonstration in September 1986.

Subsequent to the 316(a) study, the Company committed to continue selected environmental studies on Lake Anna, the WHTF and the lower North Anna River as part of a post-316(a) agreement. A new VPDES permit for NAPS (permit VA0052451) was issued in May 2014. In accordance with, “Section E, Post 316(a) monitoring”, a Department of Environmental Quality (DEQ) approved monitoring plan was created and implemented in 2014 which is based on historical studies. A report summarizing data from each year is prepared and submitted to the Virginia Department of Environmental Quality (DEQ) and the Virginia Department of Wildlife Resources (DWR). This report presents the findings for calendar year 2022.

2.0 Station Operation

North Anna Power Station operated at an average factor of 90.1% for Unit 1 and 82.0% for Unit 2 of net megawatt generation capacity in 2022. Capability ratings are calculated based on historical summer and winter operating conditions at times of peak demand as well as other operating variables that affect unit output. Therefore, during favorable conditions the units can

generate more electricity than the calculated rating using the same amount of power from the nuclear reactors. Unit 1 was shut down for approximately 39 days in 2022 for maintenance and a routine fueling outage, while Unit 2 was shut down for approximately 72 days in 2022 for maintenance and a routine fueling outage (Figures 1 and 2).

Figure 1. 2022 North Anna Unit 1 Daily Power Level

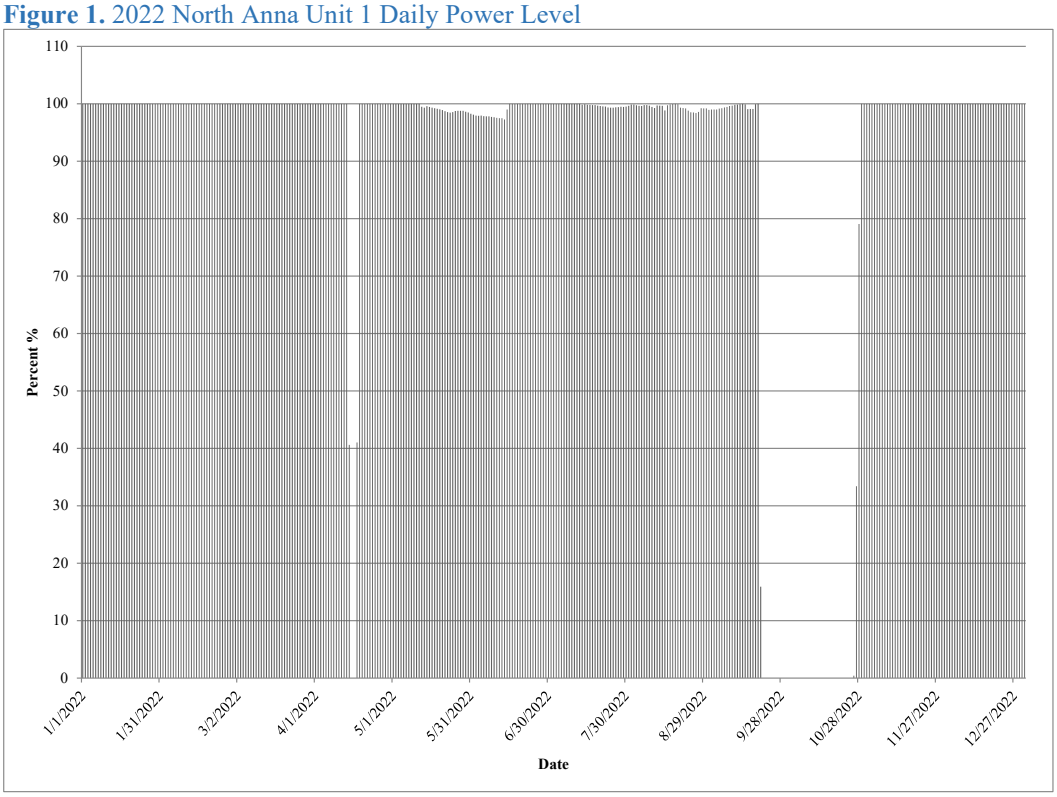
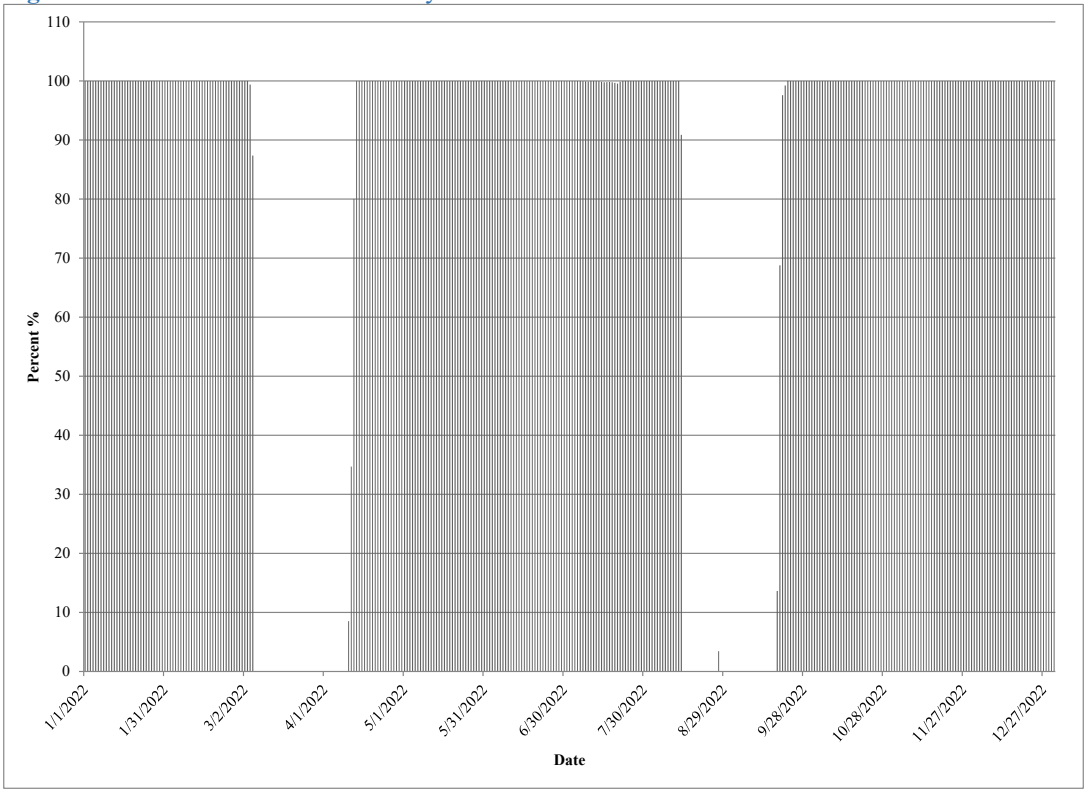


Figure 2. 2022 North Anna Unit 2 Daily Power Level



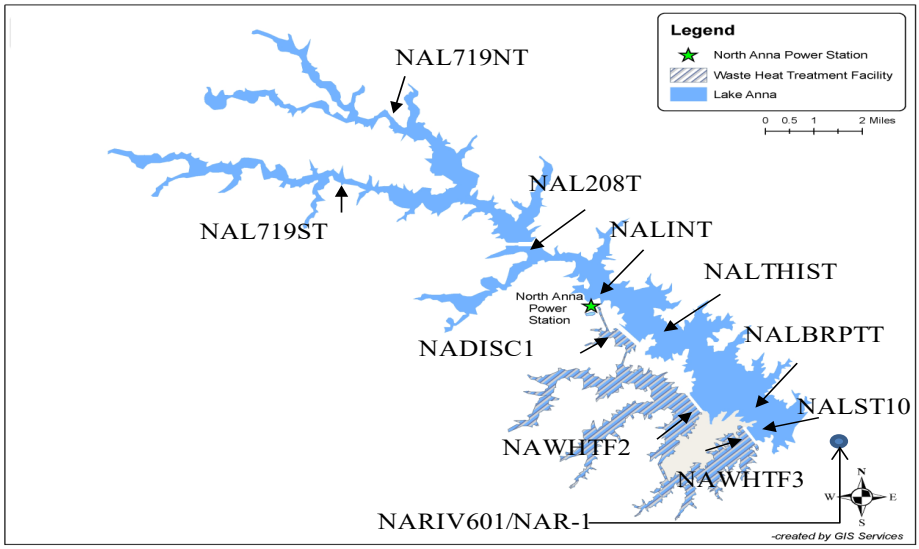
3.0 Lake Anna and WHTF

3.1 Temperature

Methods

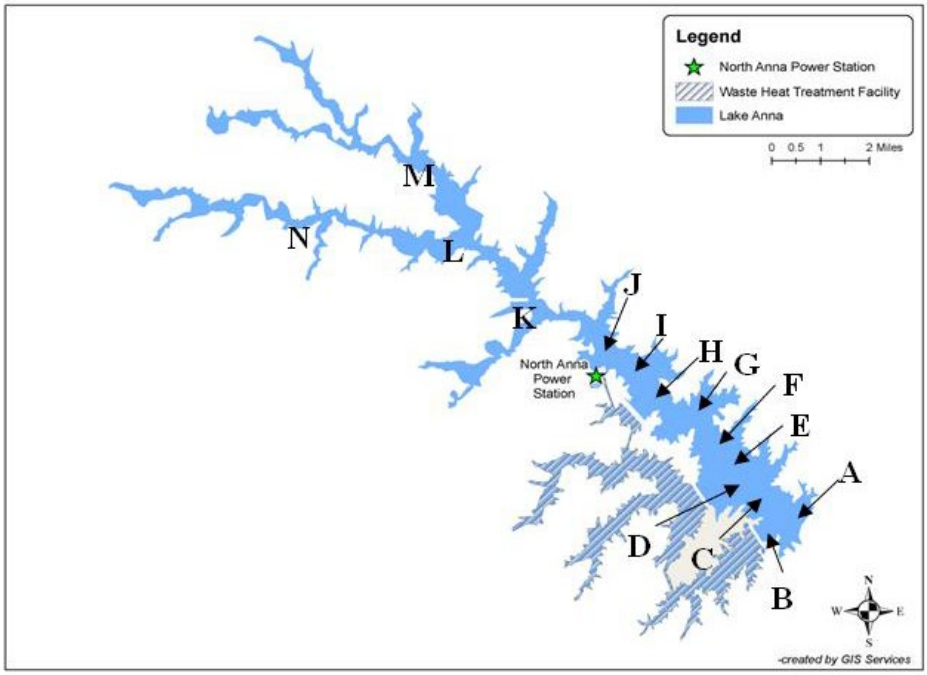
Lake, WHTF, and North Anna River water temperature data were collected using continuous monitors (fixed temperature recorders) and instantaneous temperature field surveys. Continuous temperature recorders measured and recorded the water temperature at one-hour intervals. Temperature recorders were placed at a depth of one meter at six stations in the lake, three stations in the WHTF and one station in the river (Figure 3). The instrument at NALST10 was located at a depth of three meters to account for the turbulence associated with water discharges from the WHTF to the lake.

Figure 3. Approximate location of temperature recorders in Lake Anna, WHTF, and the North Anna River



Instantaneous temperature was measured using a Hydrolab MS5 data sonde (± 0.1°C). Instantaneous temperature was measured at one-meter intervals, from the surface to the bottom, at each of 14 stations in Lake Anna (Figure 4).

Figure 4. Approximate location of thermal plume sampling stations on Lake Anna



Results and Discussion

The maximum hourly temperature recorded in the WHTF in 2022 by continuous monitors was 39.5°C in August at station NADISC1 which is located at the end of the discharge canal (Table 1). The maximum temperature in the WHTF in 2022 was in the range of previously recorded temperatures for the WHTF. The minimum hourly temperature recorded in the WHTF in 2022 was 11.1°C in December at Station NAWHTF3 which is located near the dike in the third lagoon. The minimum temperature in the WHTF for 2022 is in the range of previously reported temperatures for the WHTF. Lagoon 2 and 3 continuous monitoring data loggers (Figure 3; annotated as NAWHTF2 and NAWHTF3, respectively) were lost in late Spring due to mechanical failure of the anchor lines where logging instruments were affixed, resulting in data gaps between mid-January to mid-June in those two locations (noted in Table 1).

The maximum hourly temperature recorded in the lake in 2022 by continuous temperature monitors was 33.5°C in August at station NAL719ST. The minimum hourly temperature recorded in the lake in 2022 was 2.4°C in January at NAL719ST. Temperatures recorded in the lake are within the range of previously reported maximum and minimum lake temperatures.

The instantaneous temperature surveys were conducted in March, June, August, and November to provide temperature data to assess seasonal thermal stratification patterns in the lake (Table 2, 3). Results of the June survey show a maximum temperature decrease of 9.3°C from surface to bottom indicating that the lake is stratifying. The June survey also shows a thermocline (a layer within a body of water where the temperature changes rapidly with depth) beginning to form at the 9 to 12-meter depths at Station A up lake to Station K. Beyond that point, in the upper lake, a thermocline was less pronounced as indicated by more gradual changes in temperatures from surface to bottom. The August survey shows stratification occurring at greater depths, while March and November show very minimal temperature change with depth indicating turnover has occurred.

Table 1. Summary of fixed temperature recorder data during 2022. All results are calculated from hourly temperatures (°C). *Indicates missing data

January	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	11.3	11.6	13.4	13.5	14.0	14.4	14.8	26.7	21.9	18.4	15.0
Mean Temp	5.5	5.8	7.2	8.2	8.5	10.2	11.3	21.4	17.8	15.1	10.1
Min Temp	2.4	2.6	4.0	5.2	5.8	7.3	8.7	18.5	14.5	12.8	7.8
Hours	744	744	744	744	744	744	744	744	299	299	744
February											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	10.1	10.0	10.1	10.3	11.3	12.6	12.6	23.3	*	*	13.1
Mean Temp	6.5	6.2	6.6	7.6	8.3	9.8	10.9	20.7	*	*	10.1
Min Temp	3.6	3.7	3.5	5.1	5.8	7.4	8.9	18.6	*	*	7.8
Hours	672	672	672	672	672	672	672	672	*	*	672
March											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	14.7	15.1	14.9	14.1	14.1	14.6	14.9	25.5	*	*	15.7
Mean Temp	12.0	11.9	11.9	12.0	12.3	12.8	13.3	23.1	*	*	12.9
Min Temp	8.5	8.3	9.1	9.6	10.2	11.1	11.9	18.1	*	*	10.7
Hours	744	744	744	744	744	744	744	744	*	*	744
April											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	21.2	21.3	20.9	20.6	20.4	20.5	20.3	27.8	*	*	21.4
Mean Temp	16.4	16.4	15.9	15.9	16.0	16.5	16.9	23.3	*	*	16.6
Min Temp	12.5	12.2	12.1	12.2	12.2	13.1	13.9	18.2	*	*	12.9
Hours	720	720	720	720	720	720	720	720	*	*	720
May											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	27.9	27.4	28.4	28.0	26.7	26.8	25.6	33.2	*	*	28.4
Mean Temp	22.1	22.0	21.9	21.8	21.9	22.2	22.1	29.1	*	*	22.1
Min Temp	18.4	18.2	18.2	18.2	18.5	19.4	19.8	26.0	*	*	18.1
Hours	744	744	744	744	744	744	744	744	*	*	744
June											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	30.0	29.8	33.6	30.2	30.1	30.1	29.4	36.7	34.9	33.3	30.9
Mean Temp	27.7	27.6	27.7	27.5	27.7	27.7	27.7	35.0	32.6	31.2	27.6
Min Temp	26.3	26.0	26.2	25.9	26.2	26.1	25.4	33.0	31.4	30.4	25.2
Hours	719	718	720	719	719	719	719	720	324	325	719
July											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	31.8	32.2	32.2	32.1	32.4	32.3	31.7	39.1	36.7	35.1	32.6
Mean Temp	29.9	30.0	30.0	29.8	30.1	30.3	30.4	37.7	34.6	33.2	30.1
Min Temp	28.2	28.2	28.4	28.2	28.5	28.3	28.9	36.1	32.8	31.6	27.4
Hours	744	744	744	744	744	744	744	744	744	744	744
August											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	33.5	32.5	32.4	32.3	32.5	32.4	32.3	39.5	36.9	35.9	33.1
Mean Temp	29.8	29.8	30.1	30.1	30.3	30.5	30.8	36.1	33.5	32.6	30.1
Min Temp	27.9	27.9	28.4	28.6	28.7	29.2	29.6	33.4	28.8	30.5	27.9
Hours	744	744	744	744	744	744	744	744	744	744	744
September											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	30.3	30.6	30.6	31.0	30.5	30.9	30.5	35.3	33.2	32.3	30.8
Mean Temp	27.0	27.1	27.5	27.6	27.7	28.1	28.4	33.5	30.2	29.2	27.3
Min Temp	21.7	21.9	22.7	23.0	23.2	23.3	23.3	30.5	25.4	23.6	22.2
Hours	720	720	720	720	720	720	720	720	720	720	720
October											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	21.6	21.8	22.6	22.9	23.1	23.3	23.3	30.5	25.6	23.5	22.5
Mean Temp	18.4	18.4	19.2	19.4	19.7	20.2	20.5	26.4	22.9	21.2	19.5
Min Temp	16.1	15.2	16.8	17.3	17.7	18.5	19.3	22.5	20.7	19.6	16.6
Hours	744	745	744	744	744	744	744	744	744	744	744
November											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	19.0	18.8	20.2	21.2	20.4	20.8	20.9	29.4	26.5	24.0	21.0
Mean Temp	14.7	14.6	16.1	16.4	16.9	18.0	18.7	25.9	22.2	20.2	17.2
Min Temp	10.8	10.8	12.6	13.6	14.0	15.0	16.2	23.2	19.3	17.3	14.1
Hours	720	720	720	720	720	720	720	720	720	720	720
December											
	NAL719ST	NAL719NT	NAL208T	NALINT	NALTHIST	NALBRPTT	NALST10	NADISC1	NAWHTF2	NAWHTF3	NARIV601
Max Temp	10.8	10.8	13.0	13.6	14.0	15.5	16.3	23.2	20.0	17.6	15.0
Mean Temp	7.5	7.7	10.2	11.0	11.6	13.0	13.9	21.7	17.3	15.0	12.5
Min Temp	2.6	3.1	6.3	7.3	8.0	9.4	10.5	18.6	13.7	11.1	8.9
Hours	744	744	744	744	744	744	744	744	744	744	744

Table 2. Lake Anna water temperatures for the instantaneous temperature surveys (March and June) measured (°C) at one-meter intervals. *A technical fault with data recording software resulted in the loss of data at stations A and B in June.

3/16/2022	Depth (m)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
MARCH	0	12.9	12.7	12.7	12.7	12.8	12.9	12.7	12.4	11.9	12.5	12.0	12.2	12.3	12.3
	1	12.8	12.2	12.1	12.1	12.3	12.7	12.6	12.2	11.9	12.3	12.0	12.3	12.3	12.2
	2	12.6	12.1	12.0	12.0	12.2	12.6	12.3	11.4	11.6	11.7	11.6	11.5	12.0	11.6
	3	12.6	12.0	11.6	11.5	12.0	12.4	12.1	11.1	11.6	11.6	11.3	11.2	10.5	10.1
	4	12.5	11.6	11.4	11.2	11.3	12.2	12.1	10.8	11.1	11.4	11.2	10.9	10.2	10.0
	5	11.9	11.4	11.3	11.1	11.2	12.0	12.0	10.8	10.9	11.2	11.1	10.5	9.9	9.9
	6	11.5	11.3	11.1	11.1	11.1	11.7	11.8	10.7	10.8	11.0	10.7	10.3	9.9	9.8
	7	11.2	11.1	11.0	11.1	11.0	11.3	11.3	10.7	10.8	10.8	10.1	10.3	9.8	
	8	11.1	11.1	11.0	11.0	11.0	11.0	10.9	10.7	10.8	10.7	10.0			
	9	11.1	11.1	11.0	11.0	11.0	10.9	10.8	10.7	10.7	10.5	10.0			
	10	11.0	11.0	10.9	10.9	11.0	10.9	10.8	10.7	10.7	10.5	10.1			
	11	11.0	11.0	10.9	10.9	11.0	10.8	10.7	10.6	10.6	10.4	10.1			
	12	11.0	11.0	10.9	10.9	11.0	10.8	10.7	10.6	10.6	10.2	10.0			
	13	11.0	11.0	10.9	10.9	10.9	10.8	10.7	10.6	10.5	10.2	10.0			
	14	11.0	11.0	10.9	10.9	10.9	10.7	10.6	10.6		10.2	10.0			
	15	11.0	11.0	10.9	10.8	10.8	10.6	10.6	10.6						
	16	11.0	11.0	10.9	10.8	10.8	10.6	10.6							
	17	11.0		10.9	10.8	10.8	10.6	10.5							
	18	11.0		10.9	10.8	10.8	10.6	10.5							
	19	11.0		10.9	10.8		10.6	10.5							
	20	10.9					10.6								
	21														

Warm — Cool

6/9/2022	Depth (m)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
JUNE	0	*	*	27.0	26.9	26.9	27.1	27.8	26.8	26.9	27.0	27.1	27.0	27.6	27.8
	1	*	*	27.0	26.9	26.9	27.0	26.9	26.6	26.9	27.0	27.1	26.8	27.4	27.6
	2	*	*	27.0	26.9	26.9	26.8	26.8	26.5	26.8	27.0	27.0	26.7	26.5	27.2
	3	*	*	26.9	26.9	26.9	26.7	26.6	26.5	26.6	27.0	26.9	26.7	26.1	26.6
	4	*	*	26.9	26.9	26.7	26.6	26.5	26.3	26.6	27.0	26.6	26.7	26.0	26.0
	5	*	*	26.8	26.7	26.4	26.5	26.4	26.2	26.4	26.7	26.6	26.6	25.8	25.9
	6	*	*	26.7	26.7	26.3	26.4	26.4	26.2	26.2	26.5	26.5	26.5	25.4	25.8
	7	*	*	26.7	26.6	26.2	26.3	26.4	26.3	26.2	26.3	26.4	26.3	24.7	25.5
	8	*	*	26.7	26.6	26.1	26.3	26.4	26.0	26.0	26.2	26.4	26.2	24.3	
	9	*	*	26.8	26.5	26.0	25.3	26.3	24.8	23.7	26.0	26.1	25.6		
	10	*	*	26.6	26.1	24.5	23.4	25.8	24.7	22.8	24.9	26.0			
	11	*	*	26.5	26.0	22.5	23.3	23.7	23.4	22.6	23.2	25.3			
	12	*	*	22.2	22.9	22.0	22.8	22.4	22.8	22.1	22.8	23.4			
	13	*	*	22.2	22.1	21.5	22.0	21.9	22.2	21.9	22.6	23.0			
	14	*	*	22.4	21.8	21.5	21.6	21.2	20.9		22.0	21.7			
	15	*	*	22.4	22.0	21.4	20.3	20.0	20.8			22.9			
	16	*	*	21.8	22.1	21.3	20.2	19.3	20.5			21.7			
	17	*	*	20.2	21.3	20.5	18.7	18.9				21.3			
	18	*	*	19.1	19.7	18.6						21.0			
	19	*	*	17.7	18.7	17.8						21.0			
	20	*	*												
	21	*	*												

Warm — Cool

Table 3. Lake Anna water temperatures from the instantaneous temperature surveys (August and November) measured in (°C) at one-meter intervals.

8/16/2022	Depth (m)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
AUGUST	0	30.2	30.1	30.3	30.4	30.3	29.4	29.4	29.3	29.2	29.2	28.9	28.7	28.6	28.7
	1	30.2	30.4	30.3	30.4	30.3	29.4	29.4	29.2	29.2	29.2	28.9	28.7	28.4	28.6
	2	30.2	30.3	30.3	30.2	30.2	29.4	29.3	29.1	29.2	29.1	28.9	28.7	28.2	28.5
	3	30.1	30.3	30.2	30.1	29.8	29.3	29.3	28.9	29.1	29.0	28.7	28.7	28.1	28.4
	4	30.0	30.3	30.0	29.7	29.8	29.3	29.2	28.9	29.1	28.9	28.7	28.4	28.0	28.0
	5	29.9	30.3	29.8	29.7	29.7	29.3	29.3	28.9	29.1	28.8	28.5	28.4	28.0	27.9
	6	29.8	30.3	29.7	29.7	29.5	29.3	29.3	28.9	29.1	28.8	28.5	28.4	27.9	27.8
	7	29.7	30.0	29.6	29.6	29.5	29.3	29.2	28.9	29.1	28.8	28.5	28.3	27.9	
	8	29.5	29.7	29.6	29.6	29.5	29.3	29.2	28.9	29.1	28.8	28.5	28.3		
	9	29.5	29.5	29.6	29.6	29.5	29.3	29.2	28.9	29.0	28.7	28.4			
	10	29.5	29.2	29.6	29.6	29.5	29.2	29.1	28.8	28.9	28.7	28.4			
	11	29.4	29.0	29.5	29.5	29.4	29.1	29.0	28.8	28.8	28.7	28.3			
	12	29.0	28.9	29.5	29.4	29.4	29.1	28.9	28.8	28.8	28.7	28.3			
	13	28.8	28.7	29.4	29.4	29.4	29.1	28.9	28.8	28.8	28.6				
	14	28.5	28.4	29.3	29.4	28.4	29.1	28.8	28.8	28.6	28.2				
	15	27.1	27.8	27.8	29.4	27.7	28.9	28.7		28.0	24.9				
	16	26.3	27.7	26.2	29.0	27.0	26.9	27.1							
	17	24.2		25.1	28.7	28.2	27.1	26.6							
	18	23.3		24.7	24.3	26.2	24.2	24.2							
	19	21.4		22.7	22.7		21.2	21.6							
	20	22.3		21.9			20.6								
	21	19.8													
	22	19.0													

Warm — Cool

11/29/2022	Depth (m)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
NOVEMBER	0	16.4	16.5	16.1	16.0	16.0	15.5	14.8	14.6	14.3	14.0	13.6	12.4	11.2	11.2
	1	16.3	16.5	16.1	16.0	16.0	15.5	14.8	14.6	14.2	14.0	13.6	12.3	11.2	11.2
	2	16.0	16.4	16.1	16.0	16.0	15.5	14.8	14.5	14.2	14.0	13.6	12.0	11.1	11.2
	3	16.0	16.4	16.1	15.9	15.9	15.4	14.7	14.3	14.2	14.0	13.5	11.7	11.1	10.7
	4	16.0	16.4	16.1	15.4	15.4	15.3	14.7	14.1	14.2	13.9	13.4	11.7	11.0	10.5
	5	16.0	16.4	15.8	15.1	15.0	15.3	14.7	14.1	14.1	13.7	13.0	11.7	10.8	10.3
	6	15.7	16.2	15.4	14.9	15.0	15.2	14.7	14.0	13.9	13.7	12.6	11.7	10.4	10.2
	7	15.5	16.0	15.1	14.9	15.0	15.0	14.6	13.9	13.9	13.6	12.5	11.7	9.6	10.2
	8	15.2	15.9	14.9	14.9	15.0	14.7	14.5	13.8	13.7	13.5	12.1	11.7		
	9	15.0	15.7	14.9	14.9	15.0	14.7	14.2	13.2	13.6	13.1	12.0			
	10	14.9	15.4	14.9	14.8	14.9	14.7	14.1	13.1	13.4	13.0	11.7			
	11	14.8	15.3	14.9	14.8	14.9	14.5	13.9	13.1	13.1	12.7	11.7			
	12	14.8	15.2	14.9	14.8	14.9	14.5	13.8	13.0	12.9	12.7	11.6			
	13	14.0	15.1	14.9	14.8	14.9	14.1	13.6	13.0	12.7	12.3	11.6			
	14	14.6	15.1	14.8	14.7	14.7	13.1	13.3	12.6	12.4	12.2	11.6			
	15	14.6	15.1	14.8	14.7	14.7	13.1	12.9		12.4	12.2	11.5			
	16	14.6	15.1	14.8	14.7	14.6	13.1	12.8		12.4		11.5			
	17	14.6	15.1	14.8	14.6	14.6	13.1	12.8		12.4					
	18	14.6		14.8	14.6	14.4	13.1	12.8		12.4					
	19	14.6		14.8	14.4		13.1	12.8							
	20	14.6			14.4		13.1	12.8							
	21	14.6													

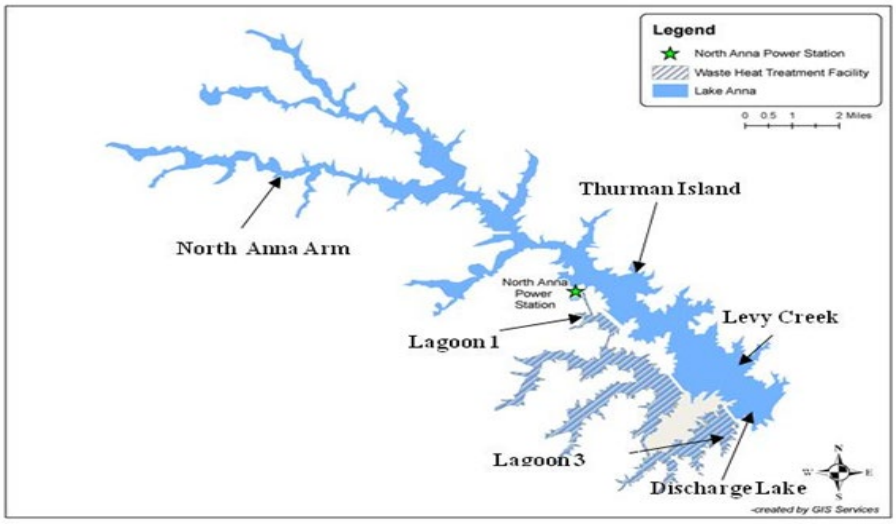
Warm — Cool

3.2 Fish Population Studies-Gill Netting

Methods

Monitoring of fish abundance and species composition for Lake Anna and the WHTF continued in 2022 using the same sampling methods as previous years, gill netting and boat electrofishing. Gill netting was used to capture fishes which normally inhabit the deeper strata of the lake or exhibit a movement to and from the shoreline within a 24-hour period. Like previous years, gill net surveys for 2022 were conducted seasonally (February, May, August, and November) at each of six stations (Figure 5). Gill nets were set near littoral (near the shoreline) drop-off areas and left overnight. Standard physicochemical measurements including surface water temperature (°C), dissolved oxygen (mg/l), pH and conductivity (uS/cm) were recorded at the time of each sample collection. Fish collected by gill netting were brought to the laboratory for processing. Length (mm) and weight (g) were recorded for gamefish while non-game fish were only enumerated. Catch per unit effort (CPUE) was calculated as the number of fish per net night. CPUE for 2022 was compared to historical average CPUE using a one sample t-test with a 95% confidence interval (CI).

Figure 5. Location of gill netting stations on Lake Anna and WHTF



Results and Discussion

Standard physicochemical measurements recorded during gill net surveys are shown in Table 4. The data demonstrate expected seasonal changes in temperature and dissolved oxygen, while conductivity and pH were relatively stable. The data are consistent with historical trends

and indicate that these water quality parameters in Lake Anna and the WHTF are within the ranges known to support a healthy fish assemblage.

Table 4. Surface water temperature (°C), conductivity (uS/cm), pH (su) and dissolved oxygen (mg/L) recorded at time of gill net sampling during 2022. *the low August pH reading at "Dike 3 Discharge Lake" may be attributable to field instrumentation not fully equilibrating following storage in an acidic (pH 4.0) buffer solution

February					August				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**	**Station**	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE3 DISCHARGE LAKE	11.0	64	6.2	10.6	DIKE3 DISCHARGE LAKE	32.2	79	5.1	4.8
LAGOON 1 WHTF	20.4	65	6.6	11.4	LAGOON 1 WHTF	38.6	78	6.4	5.9
LAGOON 3 WHTF	13.6	64	6.5	10.3	LAGOON 3 WHTF	34.7	79	6.3	6.7
LEVY CREEK	10.8	64	6.1	10.9	LEVY CREEK	32.8	78	5.8	7.3
NORTH ANNA ARM GN	6.7	92	7.1	14.5	NORTH ANNA ARM GN	32.5	82	7.4	10.0
THURMAN ISLAND GN	7.5	63	6.6	11.9	THURMAN ISLAND GN	32.5	77	6.4	7.6
May					**November**				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**	**Station**	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE3 DISCHARGE LAKE	24.4	75	6.5	7.8	DIKE3 DISCHARGE LAKE	20.3	75	6.6	7.7
LAGOON 1 WHTF	26.4	75	6.6	8.4	LAGOON 1 WHTF	26.4	77	6.3	8.2
LAGOON 3 WHTF	22.3	73	6.8	8.1	LAGOON 3 WHTF	22.3	75	6.3	7.9
LEVY CREEK	23.9	75	6.5	8.3	LEVY CREEK	19.2	74	6.7	8.6
NORTH ANNA ARM GN	22.1	86	7.3	9.9	NORTH ANNA ARM GN	16.9	78	6.9	10.2
THURMAN ISLAND GN	23.3	75	6.5	8.9	THURMAN ISLAND GN	17.9	73	6.7	8.2

Twenty-one species of fish representing seven families were collected in Lake Anna and the WHTF by quarterly gill netting in 2022 (Table 5). Table 6 summarizes the gill net catch data by species and season for all lake stations in 2022. The numerically dominant species collected in the lake were Gizzard Shad *Dorosoma cepedianum*, Channel Catfish *Ictalurus punctatus,* White Perch *Morone americana,* White Catfish *Ameiurus catus* and Striped Bass *Morone saxatilis*. These five species represented 77% of the total gill net catch.

Table 5. Fishes collected in Lake Anna and the WHTF by gill netting during 2022

FAMILY	SPECIES	LAKE	WHTF
Catostomidae	*Carpiodes cyprinus*	x	x
	Moxostoma macrolepidotum	x	
Centrarchidae	*Lepomis macrochirus*	x	x
	Lepomis microlophus	x	x
	Micropterus salmoides	x	x
	Pomoxis nigromaculatus	x	x
Clupeidae	*Alosa aestivalis*	x	
	Dorosoma cepedianum	x	x
	Dorosoma petenense	x	x
Cyprinidae	*Cyprinus carpio*	x	x
	Lythrurus ardens	x	
	Notropis hudsonius	x	
Ictaluridae	*Ameiurus catus*	x	x
	Ameiurus natalis		x
	Ictalurus furcatus		x
	Ictalurus punctatus	x	x
Moronidae	*Morone americana*	x	x
	Morone chrysops X saxatilis	x	x
	Morone saxatilis	x	x
Percidae	*Sander vitreum x canadense*	x	x
	Sander vitreus	x	

Table 6. Gill net summary for pooled lake stations during 2022; Number and Weight (g)

	February		**May**		**August**		**November**		**TOTALS**		**% OF TOTAL**	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Alosa aestivalis					1				1		0%	
Ameiurus catus	18	2,892	15	3,318	6	537	18	2,510	57	9,257	7%	5%
Carpiodes cyprinus							1		1		0%	
Cyprinus carpio			3		1		2		6		1%	
Dorosoma cepedianum	21		101		69		34		225		29%	
Dorosoma petenense							16		16		2%	
Ictalurus punctatus	15	10,552	41	19,427	21	11,411	28	16,423	105	57,813	14%	29%
Lepomis macrochirus	1	42	1	49	2	13	3	17	7	121	1%	0%
Lepomis microlophus			6	1,763	1	161			7	1,924	1%	1%
Lythrurus ardens							1		1		0%	
Micropterus salmoides	8	4,633	9	7,198	7	4,054	5	3,016	29	18,901	4%	10%
Morone americana	32	974	39	2,897	7	487	43	2,750	121	7,108	16%	4%
Morone chrysops X saxatilis	9	7,015	10	10,568			4	3,208	23	20,791	3%	11%
Morone saxatilis	24	17,636	40	24,628	1	2,120	16	13,302	81	57,686	11%	29%
Moxostoma macrolepidotum					1		5		6		1%	
Notropis hudsonius	5								5		1%	
Pomoxis nigromaculatus	18	2,364	9	851	4	264	9	1,111	40	4,590	5%	2%
Sander vitreum x canadense	14	5,378	1	542			6	5,029	21	10,949	3%	6%
Sander vitreus							11	8,547	11	8,547	1%	4%
Totals	**165**	**51,486**	**275**	**71,241**	**121**	**19,047**	**202**	**55,913**	**763**	**197,687**	**100%**	**100%**

The numerically dominant species collected by gill netting in the WHTF in 2022 were Channel Catfish, followed by Gizzard Shad, White Catfish, Largemouth Bass *Micropterus salmoides,* and White Perch (Table 7). Together these species represented 86% of the number of fish collected. CPUE (#/net night) for the top 5 gill net species for the lake and WHTF were compared to their 2002-2021 historical averages and are presented in Table 8.

Table 7. Gill net summary for pooled WHTF stations during 2022; Number and Weight (g)

	February		May		August		November		TOTALS		% OF TOTAL	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Ameiurus catus	10	2,311	12	2,480	1	231	9	1,773	32	6,795	7%	6%
Ameiurus natalis			1	242					1	242	0%	0%
Carpiodes cyprinus	1						4		5		1%	
Cyprinus carpio	1		7		1		8		17		4%	
Dorosoma cepedianum	65		56		20		17		158		34%	
Dorosoma petenense	1		5				1		7		1%	
Ictalurus furcatus			1	5,798					1	5,798	0%	5%
Ictalurus punctatus	52	22,166	58	22,570	19	6,176	39	15,704	168	66,616	36%	61%
Lepomis macrochirus					3	102	1	51	4	153	1%	0%
Lepomis microlophus			5	663	5	400	2	356	12	1,419	3%	1%
Micropterus salmoides	9	6,957	3	821	8	3,259	3	859	23	11,896	5%	11%
Morone americana			5	697	2	320	13	1,574	20	2,591	4%	2%
Morone chrysops X saxatilis	3	2,794							3	2,794	1%	3%
Morone saxatilis	2	4,280	13	5,736					15	10,016	3%	9%
Pomoxis nigromaculatus	1	321							1	321	0%	0%
Sander vitreum x canadense	2	929							2	929	0%	1%
Totals	**147**	**39,758**	**166**	**39,007**	**59**	**10,488**	**97**	**20,317**	**469**	**109,570**	**100%**	**100%**

Table 8. CPUE for the top 5 species in 2022, 2002-2021 averages and p-values (1 sample T-test; 95%CI) for gill-net samples in the Lake and WHTF

Lake			
Species	2022 CPUE	02-'21 Average CPUE	CPUE (p-value)
Gizzard Shad	14.06	10.23	<0.001
White Perch	7.56	5.86	0.010
Channel Catfish	6.56	7.02	0.385
Striped Bass	5.06	4.34	0.016
White Catfish	3.56	3.48	0.823

WHTF			
Species	2022 CPUE	02-'21 Average CPUE	CPUE (p-value)
Channel Catfish	21.00	15.94	<0.001
Gizzard Shad	19.75	12.04	<0.001
White Catfish	4.00	1.66	<0.001
Largemouth Bass	2.88	3.76	0.033
White Perch	2.50	3.23	0.034

In the lake, Gizzard Shad, White Perch, and Striped Bass had CPUEs that were significantly higher than the 2002-2021 average. Striped Bass abundance in Lake Anna is managed by the Virginia Department of Wildlife Resources (DWR) annual stocking program. In 2014, DWR began stocking Hybrid Striped Bass in Lake Anna to supplement the Striped Bass stockings (Odenkirk 2016). The cumulative catch rate of Striped Bass and Hybrid Striped Bass in the lake in 2022 was 6.5 fish per net night.

In the WHTF, Channel Catfish, Gizzard Shad, and White Catfish had CPUEs that were significantly higher than the historical average. White Perch and Largemouth Bass had significantly lower catch rates than the historical averages. CPUE for the 2022 numerically dominant gill net species in the Lake and WHTF are displayed graphically from 2001-2022 in Figure 6 and Figure 7.

Over the last 20 years, Channel Catfish catch rates have been slowly increasing in the lake (Figure 6). Striped Bass and White Catfish catches have been consistent over time while Gizzard Shad and White Perch catch rates at the lake stations show relatively high annual variability and seem to follow a cyclic pattern. In the WHTF, Channel Catfish and Gizzard Shad have shown a highly variable, increasing catch rate over time while White Perch, Largemouth Bass and White Catfish catch rates have been stable (Figure 7).

Gizzard Shad, Channel Catfish, White Perch, Largemouth Bass, Striped Bass and White Catfish have commonly ranked high in the gill net catches in the lake and WHTF. Their consistent presence in gill net samples indicates a stable species composition in both the lake and WHTF.

Figure 6. Annual lake CPUE for the 2022 numerically dominant gill net species 2002-2022

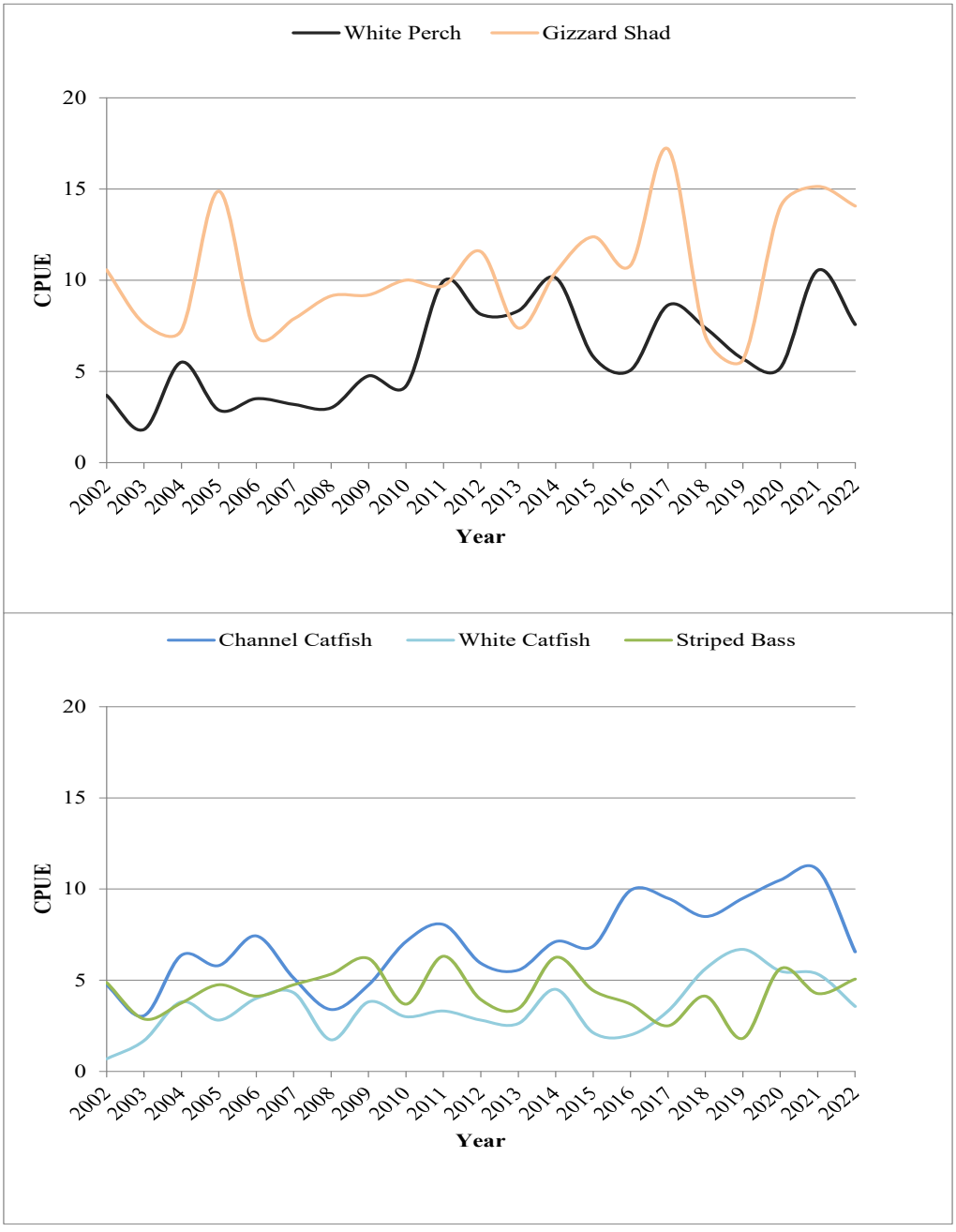
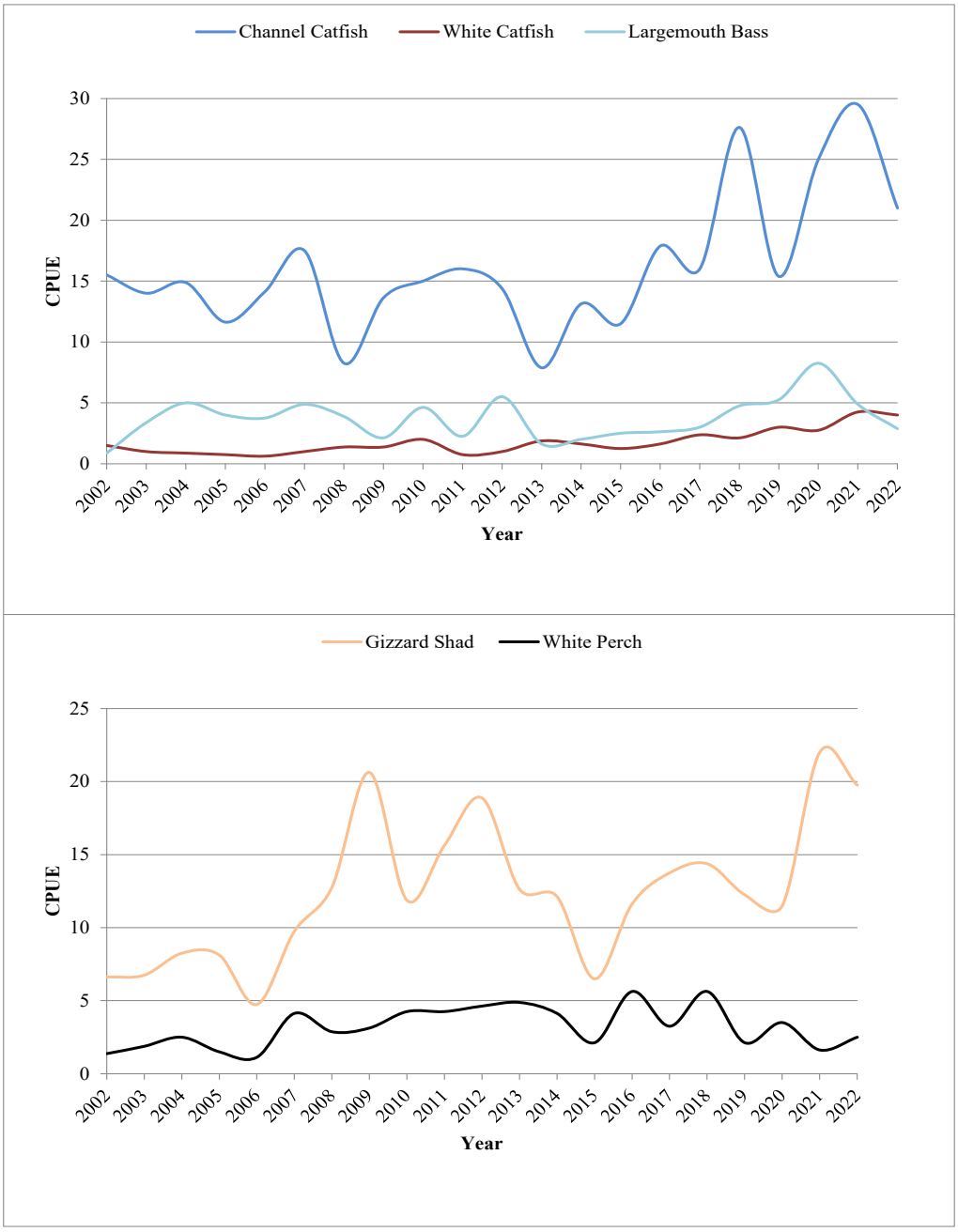


Figure 7. Annual WHTF CPUE for the 2022 numerically dominant gill net species 2002-2022



3.3 Fish Population Studies - Electrofishing

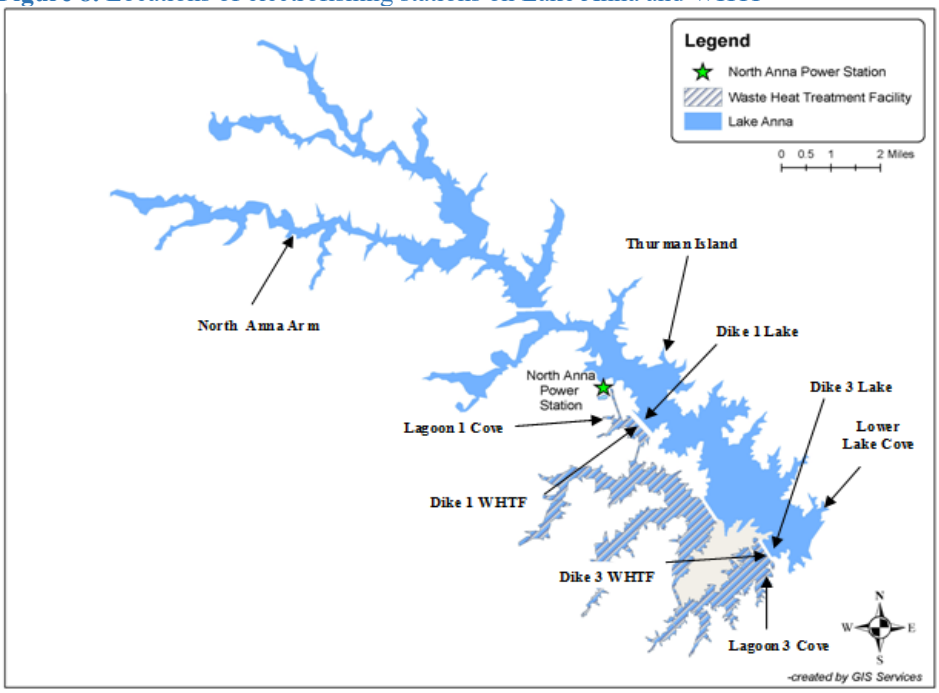
Methods

Boat electrofishing was used in 2022 to evaluate finfish community structure associated

with shoreline habitat. Sampling was conducted in February, May, August, and November at each station (Figure 8). Transects are 100 meters in length and are sampled by electrofishing for approximately 10 minutes. Sampling stations normally include a brush pile except for the dike stations which are comprised of uniform riprap. Standard physicochemical measurements of surface water temperature (°C), dissolved oxygen (mg/l), pH and conductivity (µmhos) were recorded at the time of each sample collection.

All fish collected were either brought to the laboratory for processing or released in the field (i.e., larger game fish are typically measured, weighed, and released in the field while non-game fish are typically only enumerated and released in the field). In the laboratory, fish were sorted by species and up to 25 individuals per species from each station were measured for total length (mm) and weighed (g). Remaining game fish (per species) were enumerated and bulk weighed. CPUE was calculated as the number of fish collected per hour of electrofishing. CPUE for 2022 was compared to historical averages using a one sample t-test with a 95% CI.

Figure 8. Locations of electrofishing stations on Lake Anna and WHTF



Results and Discussion

Physicochemical measurements recorded at each station during electrofishing surveys are presented in Table 9. Seasonal changes in water temperatures and dissolved oxygen were

noticeable and expected while conductivity and pH remained relatively stable throughout the year. Data are consistent with historical trends and indicate that these water quality parameters in Lake Anna and the WHTF are within values known to support a healthy fish assemblage.

Table 9. Surface water temperature (°C), conductivity (uS/cm), pH (su) and dissolved oxygen (mg/l) recorded at time of electrofishing sampling during 2022.

February				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE 1 LAKE	7.4	67	6.5	11.6
DIKE 3 LAKE	10.4	67	6.4	10.7
LAGOON 1 WHTF COVE	19.3	65	6.5	11.4
LAGOON 1 WHTF DIKE	19.8	65	6.5	11.3
LAGOON 3 WHTF COVE	12.4	64	6.5	10.3
LAGOON 3 WHTF DIKE	12.8	64	6.6	10.3
LOWER LAKE COVE	10.0	67	6.5	11.0
NORTH ANNA ARM EF	6.1	101	6.7	14.8
THURMAN ISLAND EF	7.1	63	6.5	11.7
May				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE 1 LAKE	19.4	73	6.6	8.6
DIKE 3 LAKE	20.6	74	6.6	7.6
LAGOON 1 WHTF COVE	26.0	75	6.7	8.4
LAGOON 1 WHTF DIKE	26.5	74	6.6	8.3
LAGOON 3 WHTF COVE	22.5	73	6.7	8.0
LAGOON 3 WHTF DIKE	22.7	73	6.7	8.0
LOWER LAKE COVE	20.2	73	6.7	8.1
NORTH ANNA ARM EF	19.4	86	7.2	10.1
THURMAN ISLAND EF	19.0	73	6.6	8.6
August				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE 1 LAKE	32.6	78	5.9	7.4
DIKE 3 LAKE	32.4	79	5.2	4.9
LAGOON 1 WHTF COVE	37.7	79	6.5	6.1
LAGOON 1 WHTF DIKE	38.0	78	5.8	6.0
LAGOON 3 WHTF COVE	34.1	78	5.8	7.2
LAGOON 3 WHTF DIKE	33.9	78	5.5	6.8
LOWER LAKE COVE	33.1	78	5.7	7.3
NORTH ANNA ARM EF	31.7	83	7.5	10.5
THURMAN ISLAND EF	32.9	76	6.8	8.3
November				
Station	**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**
DIKE 1 LAKE	18.6	74	6.7	8.8
DIKE 3 LAKE	20.0	75	6.6	8.2
LAGOON 1 WHTF COVE	26.5	77	6.6	8.5
LAGOON 1 WHTF DIKE	26.3	76	6.6	8.4
LAGOON 3 WHTF COVE	21.8	75	6.6	8.1
LAGOON 3 WHTF DIKE	21.8	75	6.6	8.2
LOWER LAKE COVE	19.6	74	6.6	8.5
NORTH ANNA ARM EF	16.9	78	6.9	10.2
THURMAN ISLAND EF	17.9	73	6.7	8.2

Twenty-four species of fish representing eight families were collected by electrofishing in the lake and WHTF in 2022 (Table 10). Table 11 presents the electrofishing catch data by species and season at lake stations in 2022. The numerically dominant species collected in the lake were Bluegill *Lepomis macrochirus*, Largemouth Bass, Redear Sunfish *Lepomis microlophus,* Redbreast Sunfish *Lepomis auritus*, and Green Sunfish *Lepomis cyanellus*. These 5 species represent 93% of the total lake electrofishing catch. Table 12 presents the electrofishing catch data by species and season at WHTF stations in 2022. The numerically dominant species collected in the WHTF were Bluegill, Redear Sunfish, Largemouth Bass, Green Sunfish, and Redbreast Sunfish. These 5 species represented 99% of the total electrofishing catch. The 2022 CPUE for the numerically dominant electrofishing species for the lake and WHTF were compared to their 2002-2021 historical averages in Table 13.

Table 10. Fishes collected in Lake Anna and the WHTF by electrofishing during 2022

FAMILY	SPECIES	LAKE	WHTF
Centrarchidae	*Chaenobryttus gulosus*	×	×
	Lepomis auritus	×	×
	Lepomis cyanellus	×	×
	Lepomis gibbosus	×	×
	Lepomis macrochirus	×	×
	Lepomis microlophus	×	×
	Micropterus salmoides	×	×
	Pomoxis nigromaculatus	×	×
Clupeidae	*Alosa aestivalis*	×	
	Dorosoma cepedianum	×	
Cyprinidae	*Cyprinella analostana*	×	
	Cyprinella spiloptera	×	
	Cyprinus carpio	×	
	Lythrurus ardens	×	
	Notemigonus crysoleucas	×	
	Notropis procne	×	
Esocidae	*Esox niger*	×	
Fundulidae	*Fundulus diaphanus*	×	
Ictaluridae	*Ameiurus catus*	×	
	Ameiurus natalis	×	×
	Ictalurus punctatus	×	×
Moronidae	*Morone americana*	×	
Percidae	*Etheostoma olmstedi*	×	
	Perca flavescens	×	

Table 11. Electrofishing summary for pooled lake stations during 2022; Number and Weight (g)

	February		May		August		November		TOTALS		% OF TOTAL	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Alosa aestivalis	2								2		0%	
Ameiurus catus					1	57			1	57	0%	0%
Ameiurus natalis			2	621			2	108	4	729	0%	1%
Chaenobryttus gulosus	9	205	4	222	2	10	14	376	29	813	1%	1%
Cyprinella analostana			4						4		0%	
Cyprinella spiloptera					2				2		0%	
Cyprinus carpio					1				1		0%	
Dorosoma cepedianum			1		15		2		18		1%	
Esox niger							1	82	1	82	0%	0%
Etheostoma olmstedi							1		1		0%	
Fundulus diaphanus	1								1		0%	
Ictalurus punctatus			5	2,519	2	976			7	3,495	0%	6%
Lepomis auritus	25	1,705	5	86	4	167	38	1,340	72	3,298	4%	5%
Lepomis cyanellus	28	448	2	21	2	141	22	727	54	1,337	3%	2%
Lepomis gibbosus	8	190	1	20	3	88	11	481	23	779	1%	1%
Lepomis macrochirus	577	14,610	127	2,365	65	1,162	776	10,247	1,545	28,384	76%	47%
Lepomis microlophus	54	951	12	133	6	299	18	301	90	1,684	4%	3%
Lythrurus ardens							1		1		0%	
Micropterus salmoides	53	7,066	27	4,956	12	1,172	22	4,669	114	17,863	6%	29%
Morone americana			1	41	2	105	5	153	8	299	0%	0%
Notemigonus crysoleucas			1						1		0%	
Notropis procne							1		1		0%	
Perca flavescens			3	44	3	53	26	205	32	302	2%	0%
Pomoxis nigromaculatus	1	138	4	924	2	321	5	362	12	1,745	1%	3%
Totals	**758**	**25,313**	**199**	**11,952**	**122**	**4,551**	**945**	**19,051**	**2,024**	**60,867**	**100%**	**100%**

Table 12. Electrofishing summary for pooled WHTF stations during 2022; Number and Weight (g)

	February		May		August		November		TOTALS		% OF TOTAL	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Ameiurus natalis					1	20			1	20	0%	0%
Chaenobryttus gulosus	1	62					1	28	2	90	0%	0%
Ictalurus punctatus			8	3,253					8	3,253	0%	7%
Lepomis auritus	9	481			3	41			12	522	1%	1%
Lepomis cyanellus	17	268	20	538	26	129	27	304	90	1,239	4%	3%
Lepomis gibbosus	3	56	4	101					7	157	0%	0%
Lepomis macrochirus	478	6,746	387	4,489	71	829	717	6,326	1,653	18,390	80%	39%
Lepomis microlophus	132	2,080	36	450	10	93	17	493	195	3,116	9%	7%
Micropterus salmoides	50	12,097	28	5,256	7	32	13	2,002	98	19,387	5%	41%
Pomoxis nigromaculatus	1	527	5	834					6	1,361	0%	3%
Totals	**691**	**22,317**	**488**	**14,921**	**118**	**1,144**	**775**	**9,153**	**2,072**	**47,535**	**100%**	**100%**

Table 13. CPUE (#/hr) for the top 5 species in 2022, 2002-2021 averages and p-values (1 sample T-test; 95% CI) for electrofishing samples in the Lake and WHTF

		Lake	
	2022	02-'21 Average	
Species	CPUE	CPUE	CPUE (p-value)
Bluegill	509.43	760.19	<0.001
Largemouth Bass	37.59	32.35	0.075
Redear Sunfish	29.68	36.50	0.035
Redbreast Sunfish	23.74	38.43	0.001
Green Sunfish	17.81	49.99	<0.001
		WHTF	
	2022	02-'21 Average	
Species	CPUE	CPUE	CPUE (p-value)
Bluegill	681.18	495.63	0.001
Redear Sunfish	80.36	30.72	<0.001
Largemouth Bass	40.38	28.70	<0.001
Green Sunfish	37.09	57.13	0.067
Redbreast Sunfish	4.95	12.79	0.042

In the lake, Largemouth Bass had a 2022 CPUE that was marginally higher than the 2002-2021 average. Bluegill, Redear Sunfish, Redbreast Sunfish, and Green Sunfish CPUE was lower than the 2002-2021 average. In the WHTF, Bluegill, Redear Sunfish and Largemouth Bass had a CPUE that was significantly higher than the 2002-2021 average. Green Sunfish and Redbreast Sunfish CPUE was lower than the historical average. CPUE for the 2022 numerically dominant electrofishing species in the lake and WHTF are displayed graphically from 2002-2022 in Figure 9 and Figure 10. Largemouth Bass CPUE in the WHTF in 2022 (40.38) is down from a 20 year high of 56.3 fish per hour in 2015 but is still higher than the historical average. Bluegill CPUE in the WHTF in 2022 (681.18) is below the previous maximum in 2020 (840.0), but higher than the historical average of 495.63. Green Sunfish catches in the WHTF have been on a decline since they reached a high of 182 fish per hour in 2006 but now seem to be stabilizing at a similar rate to Redear and Redbreast sunfish. Sunfish remain the dominant species group in the WHTF electrofishing catches, comprised mostly of Bluegill. Overall, electrofishing catch rates in the WHTF in 2022 have remained consistent with historical trends.

Figure 9. Annual Lake CPUE (#/hr) for the 2022 numerically dominant electrofishing species 2002-2022

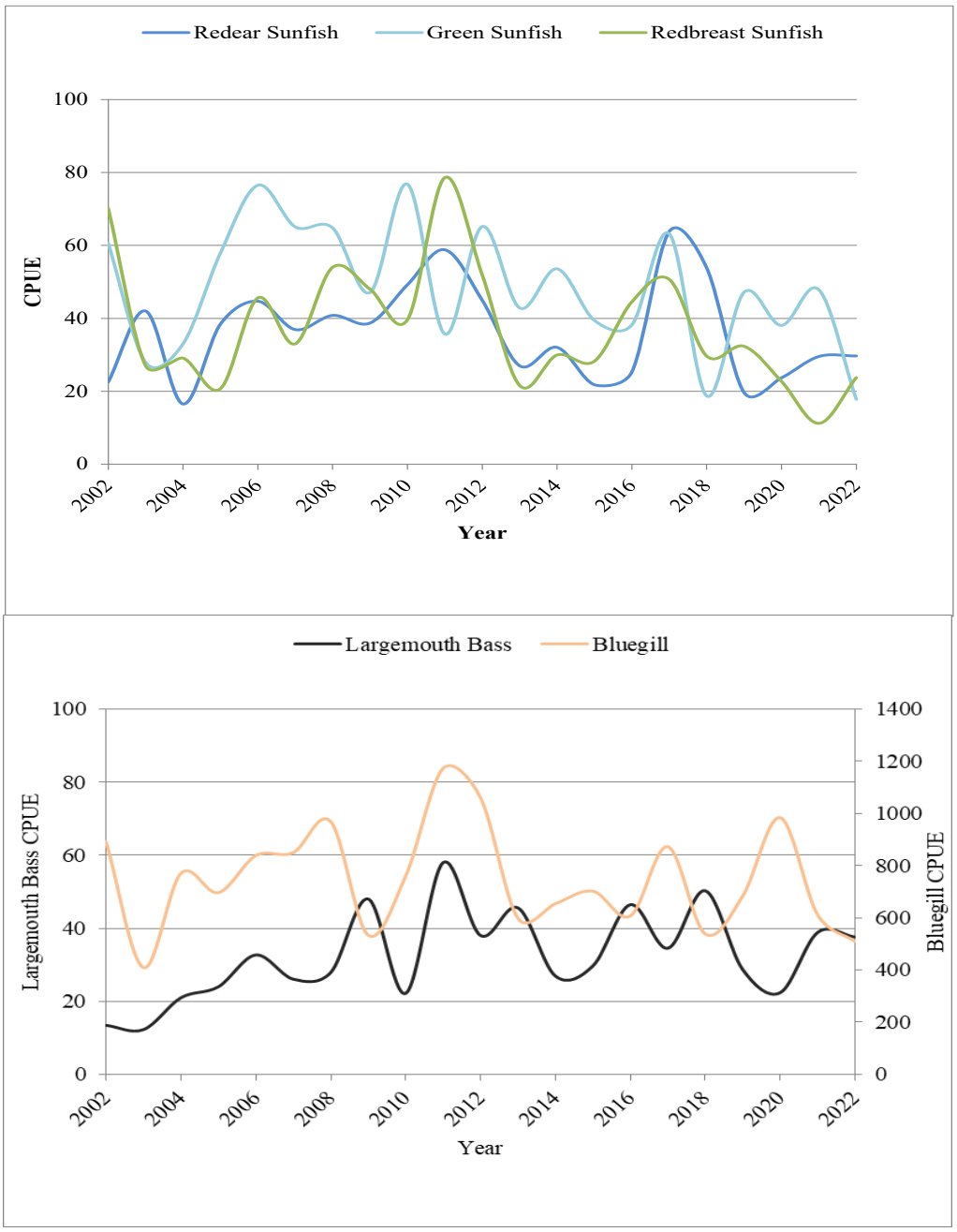
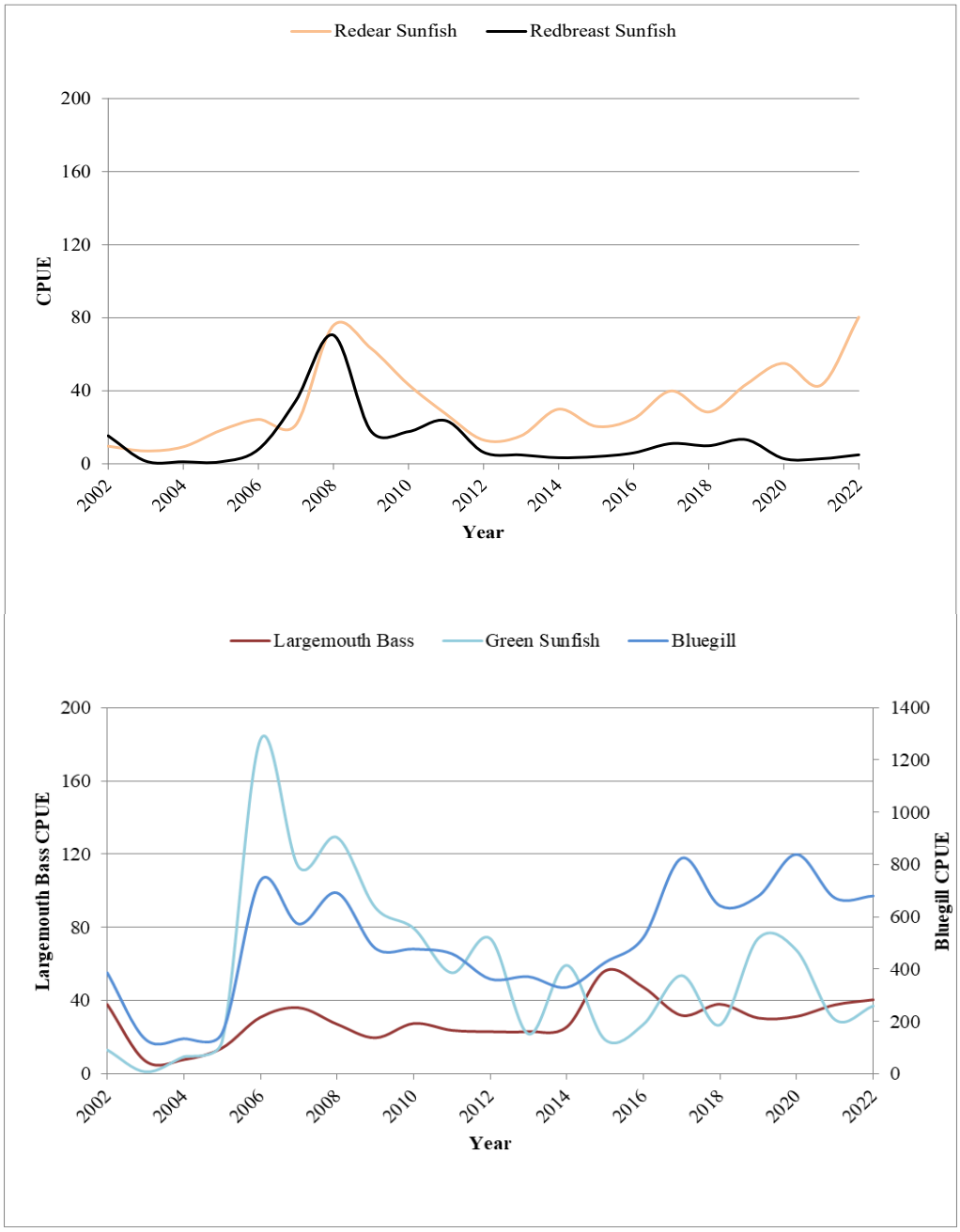


Figure 10. Annual WHTF CPUE (#/hr) for the 2022 numerically dominant electrofishing species 2002-2022



Biological systems are highly complex and are influenced by many environmental factors. It is difficult to determine exact causes of changes seen in sampling results especially since there are so many natural shifts among numerous factors affecting reproduction, growth, survival, and distributions of aquatic organisms. Regardless of this natural variability, overall electrofishing results in 2022 continue to show a healthy, balanced, indigenous fish community in the lake and WHTF.

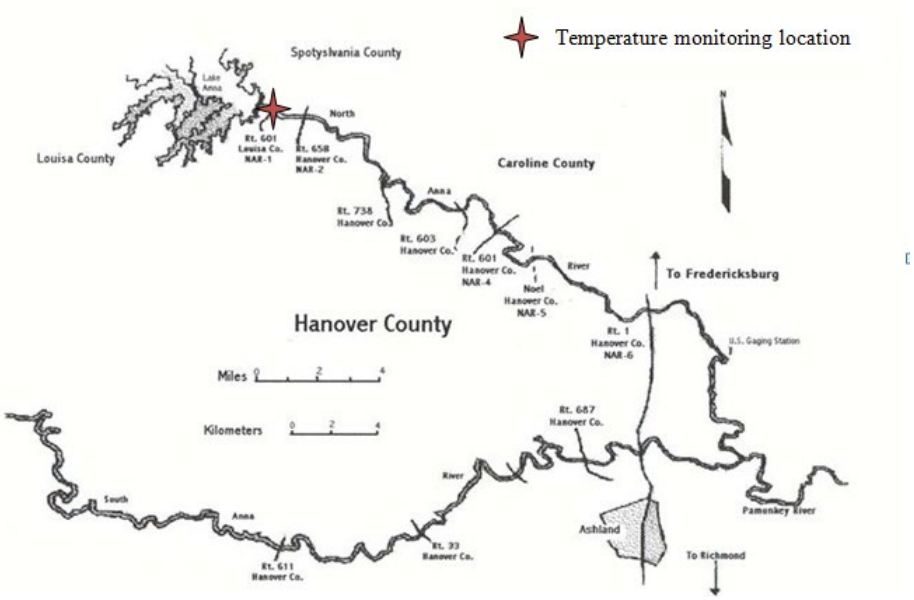
4.0 North Anna River

4.1 Temperature

Methods

Water temperatures (°C) were recorded hourly at station NAR-1 in the lower North Anna River during 2022 (Figure 11) using Onset Hobo Tidbit data loggers. Station NAR-1 is located approximately one kilometer downstream of Lake Anna dam.

Figure 11. Location of North Anna River temperature monitoring station



Results and Discussion

Temperature data from the North Anna River is summarized in Table 14. The maximum recorded temperature in 2022 was 33.1˚C in August. The maximum mean monthly temperature was 30.1˚C in July and August. Winter water temperatures at NAR-1 recorded in 2022 had a minimum monthly mean of 10.1˚C recorded in January and February and a minimum hourly temperature of 7.8˚C recorded in February.

Table 14. Mean, maximum and minimum hourly water temperatures (°C) recorded in the North Anna River, at station NAR-1 by month during 2022. Sample size (N) equals the number of hourly records each month.

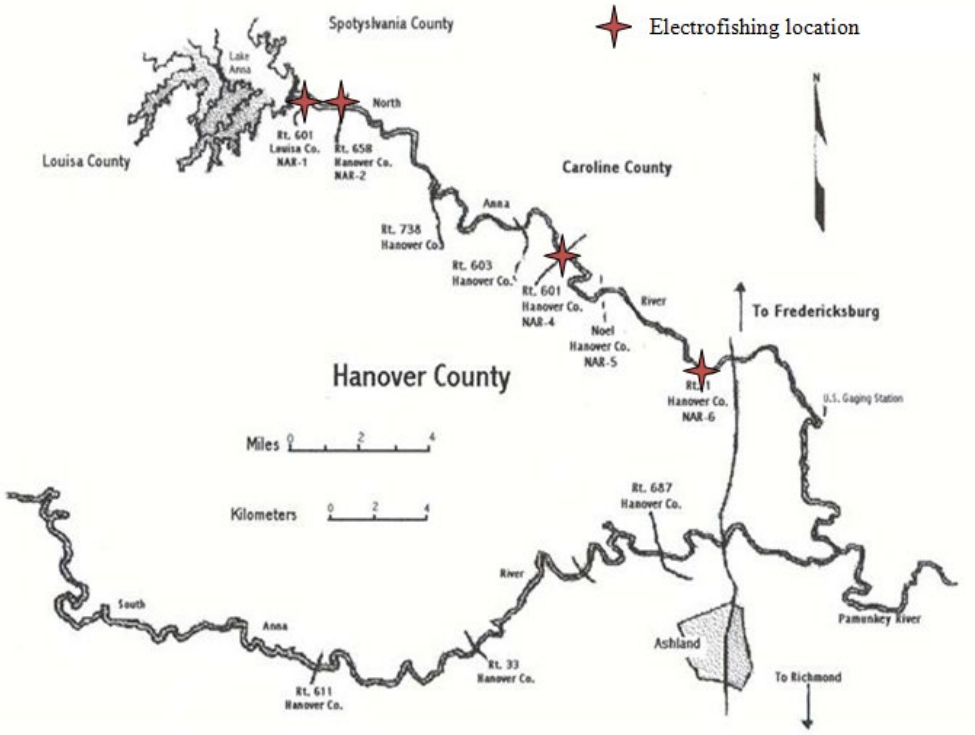
Month	Mean	MAX	MIN	N=
January	10.1	15.0	7.8	744
February	10.1	13.1	7.8	672
March	12.9	15.7	10.7	744
April	16.6	21.4	12.9	720
May	22.1	28.4	18.1	744
June	27.6	30.9	25.2	719
July	30.1	32.6	27.4	744
August	30.1	33.1	27.9	744
September	27.3	30.8	22.2	720
October	19.5	22.5	16.6	744
November	17.2	21.0	14.1	720
December	12.5	15.0	8.9	744

4.2 Fish Population Studies-Electrofishing

Methods

Abundance and species composition data for the North Anna River fish assemblage in 2022 were collected during electrofishing surveys. Consistent sampling techniques have been used in all North Anna River electrofishing surveys since 2012. The locations of the four electrofishing stations are shown in Figure 12: NAR-1 (Route 601 Louisa Bridge); NAR-2 (Route 658 Bridge); NAR-4 (Route 601 Hanover Bridge); and NAR-6 (U.S Route 1 Bridge). An approximately 70-meter reach of riffle/run type habitat is sampled at each station with an electric seine. Prior to sampling, each reach is blocked at the downstream end with a 6.5-mm mesh net. Sampling is conducted by working the electric seine from bank to bank in a zigzag pattern from the upstream to the downstream end of the section. Nearby pool type habitats are then sampled for 10 minutes with a backpack electrofishing unit. Fish sampled by electric seine and backpack electrofishing are collected using 6.5-mm mesh dip nets.

Figure 12. Location of North Anna River electrofishing stations



Game fish collected are weighed (g) and measured to total length (mm) in the field and released while non-game fish are enumerated in the field and released. If more than fifteen specimens of a gamefish species are collected, excess are counted and weighed in bulk. Electric seine and backpack electrofishing collections were then pooled by station and survey month for analyses. Sample frequency for electrofishing is typically once per month each year in May, July, and September. Consequently, this provides for a total of 24 river electrofishing collections for a typical sample year (May, July and September; 12 electric seine and 12 backpack).

Results and Discussion

Twenty-eight species of fish representing nine families were collected by electrofishing in the North Anna River in 2022 (Table 15). Historically (2002-2021), species richness (number of species present in the sample) in the North Anna River has remained high with a mean of 26 species. Species richness was highest at Station NAR-2 in 2022, with 21 species collected. Species richness at NAR-1, -4 and -6 was 19 at each site.

Table 15. Fishes collected from the North Anna River during 2022 electrofishing surveys

Family		NAR-1	NAR-2	NAR-4	NAR-6
Achiridae	*Trinectes maculatus*				X
Anguillidae	*Anguilla rostrata*	X	X	X	X
Aphredoderidae	*Aphredoderus sayanus*		X		
Catostomidae	*Hypentelium nigricans*	X	X	X	X
	Moxostoma macrolepidotum			X	
Centrarchidae	*Lepomis gibbosus*	X			X
	Micropterus punctulatus				X
	Micropterus salmoides	X	X	X	
	Lepomis macrochirus	X	X	X	X
	Lepomis microlophus	X	X		
	Micropterus dolomieu	X	X	X	X
	Lepomis auritus	X	X	X	X
	Lepomis cyanellus	X			X
Cyprinidae	*Cyprinella analostana*	X	X	X	X
	Notropis hudsonius	X		X	X
	Notropis procne	X	X	X	X
	Nocomis	X	X	X	X
	Semotilus corporalis	X	X	X	
	Lythrurus ardens	X	X	X	X
	Semotilus atromaculatus		X	X	
Ictaluridae	*Noturus insignis*	X	X	X	X
	Ameiurus natalis	X			
Percidae	*Etheostoma olmstedi*	X	X	X	X
	Percina peltata	X	X	X	X
	Etheostoma vitreum		X	X	X
	Percina notogramma		X	X	
	Etheostoma flabellare		X		
Petromyzontidae	*Lethenteron appendix*		X		X

In addition to species richness, Shannon's diversity (H') and Pielou's evenness (J') indices are calculated to account for differences in the abundance of species. H', typically ranging from 1.5-3.5, takes into consideration the proportion of each species to the total and is calculated by the following formula where S is the total number of species in the sample and p_i is the proportion of S for each species (Magurran 1988, Magurran 2004).

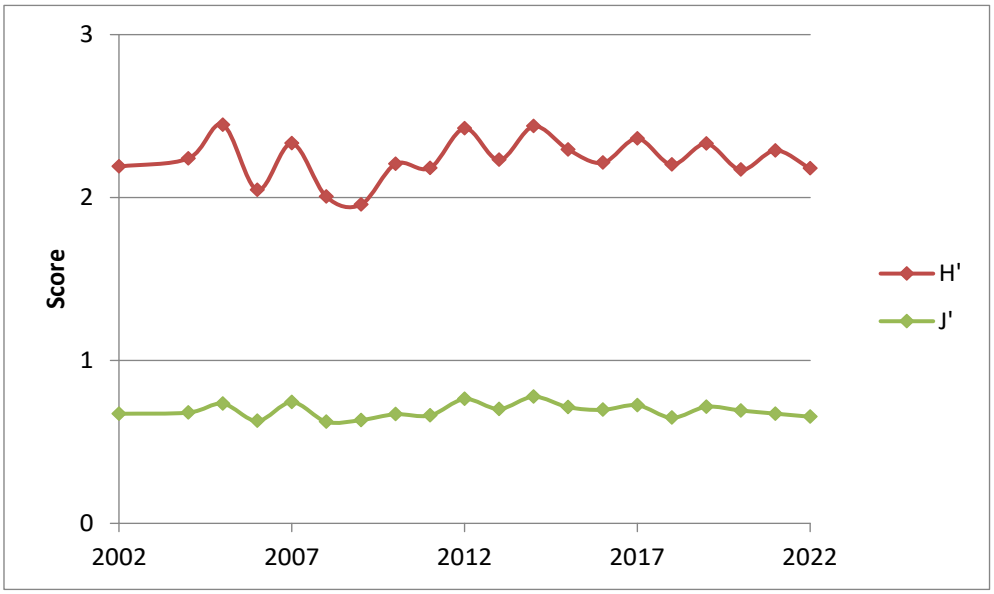
$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

J' measures how even the proportions of each species are among the sample and ranges from 0 (no evenness) to 1 (complete evenness) and is calculated by the formula below. H' is calculated from Shannon's diversity index and H_{MAX} is the maximum diversity that could occur if each species was equally abundant (Magurran, 1988).

$$J' = H' / H_{MAX} = H' / \ln S$$

Shannon's diversity index and Pielou's evenness scores for the North Anna River 2001-2022 are displayed graphically in Figure 13. Diversity in the North Anna River samples have stayed consistent among years ranging from 1.96 – 2.64 with an average score of 2.32. Evenness scores have also been consistent over the years with scores ranging from 0.62 - 0.83 with an average of 0.72. Variation from year to year is influenced by several factors. Although efforts are made to standardize sampling efforts as much as possible, changes in manpower, weather conditions and streamflow have the potential to impact catch rates.

Figure 13. Shannon's diversity index (H') and Pielou's evenness index (J') for the North Anna River collections 2002-2022



Beginning in 2014, fishes were identified, and data were collected in the field instead of preserving the fish and bringing them back to the lab. This change in methodology was made to increase the number of fish returned to the stream. Field identification and release of fishes

reduced the level of taxonomic identification feasible for some species. Therefore, some species have been identified to genus when they were previously identified to species (i.e., Nocomis spp.) which reduces the species richness in samples. *Nocomis* species data (prior to 2014) were grouped to genus to maintain consistency throughout the time-series indices in Figure 13, above. In 2022, a total of 3,607 fish were collected by electrofishing in the North Anna River (Table 16). The total number of fish collected was highest at station NAR-2 and lowest at station NAR-6.

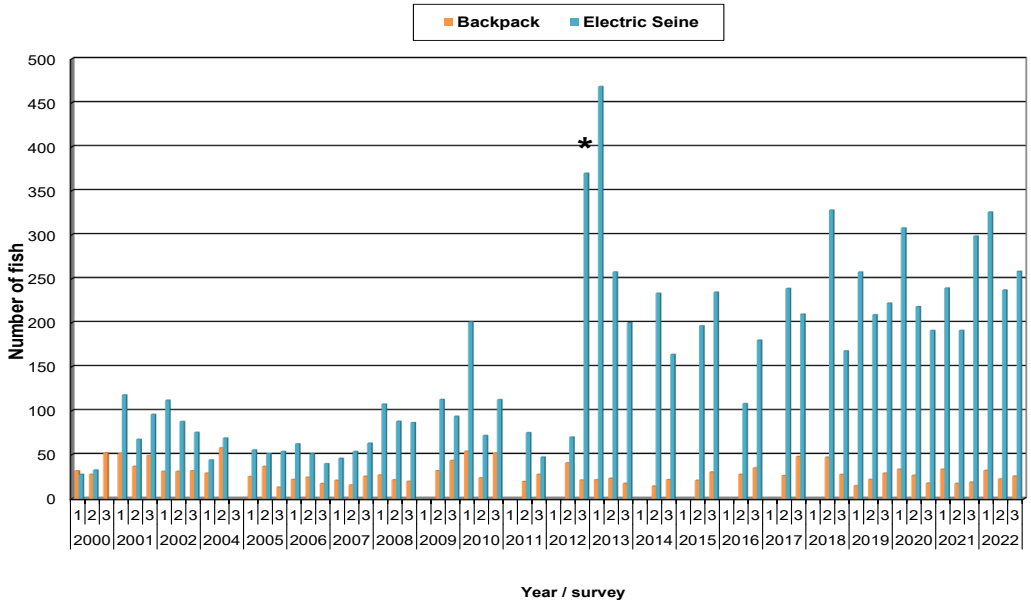
Table 16. Number and weight-game fish only (g) of fishes collected during May, July and September 2022 electrofishing surveys of the North Anna River

		2022									
		NAR-1		NAR-2		NAR-4		NAR-6		Total	
Family	Species	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Ictaluridae	*Ameiurus natalis*	1	110							1	110
	Noturus insignis	125		17		94		1		237	
Anguillidae	*Anguilla rostrata*	482		67		85		17		651	
Aphredoderidae	*Aphredoderus sayanus*			1	3					1	3
Cyprinidae	*Cyprinella analostana*	19		159		94		13		285	
	Lythrurus ardens	219		483		133		44		879	
	Nocomis	2		6		21		4		33	
	Notropis hudsonius	28				1		3		32	
	Notropis procne	17		516		36		5		574	
	Semotilus atromaculatus			1		10				11	
	Semotilus corporalis	10		2		9				21	
Percidae	*Etheostoma flabellare*			1						1	
	Etheostoma olmstedi	2		21		18		4		45	
	Etheostoma vitreum			11		1		36		48	
	Percina notogramma			2		1				3	
	Percina peltata	2		27		9		2		40	
Catostomidae	*Hypentelium nigricans*	79		27		6		6		118	
	Moxostoma macrolepidotum					1				1	
Centrarchidae	*Lepomis auritus*	159	3,684	86	953	189	3,464	88	930	522	9,031
	Lepomis cyanellus	4	82					2	45	6	127
	Lepomis gibbosus	1	45					1	14	2	59
	Lepomis macrochirus	13	136	7	205	1	1	6	49	27	391
	Lepomis microlophus	1	33	1	3					2	36
	Micropterus dolomieu	2	84	1	9	3	514	6	44	12	651
	Micropterus punctulatus							1	11	1	11
	Micropterus salmoides	5	186	5	60	3	14			13	260
Petromyzontidae	*Lethenteron appendix*			3				5		8	
Achiridae	*Trinectes maculatus*							33		33	
Total		**1,171**	**4,360**	**1,444**	**1,233**	**715**	**3,993**	**277**	**1,093**	**3,607**	**10,679**

Since surveys and/or samples can be missed due to high flows, river flows must be considered when comparing total fish numbers among surveys and years. Therefore, a method to

calculate the average number of fish caught per sampling station was developed and shows gear type, survey, and year to represent a catch per unit effort (CPUE) to better compare fish numbers over time (Figure 14).

Figure 14. Average numbers of fish caught per station by survey, gear type and year 2000-2022 *Denotes switch to DC seine



The minimum, maximum and mean CPUE per survey for the electric seine (2012-2021) and backpack (1997-2021) are compared to the respective CPUE in 2022 (Table 17). The mean CPUE per survey in 2022 for backpack samples was compared to the historical mean using a one-sample t-test with a 95% confidence interval. In 2012 the electric seine was upgraded to a newer version that uses DC current which has shown to be more effective and less lethal to the fish. Since the change in gear type has influenced the catch rate, it should not be compared to historical catches in a statistical manner. Currently, we have 11 years of data for the DC seine which does not provide the statistical strength to accurately measure significant differences; therefore, the t-test was not run for the electric seine samples. All samples were consistent with historical trends, but CPUE for Survey 2 and 3 backpack samples was significantly lower than the historical mean with a p-value of 0.006 and 0.035, respectively.

Electrofishing CPUE in the North Anna River is highly variable as can be seen from the large range of minimum and maximum CPUEs in Table 17. Species richness, diversity and

evenness have remained high in the North Anna River samples indicating the river is able to support a healthy and diverse fish assemblage.

Table 17. Fish CPUE Summary on the North Anna River 1997-2022

Electric Seine					
Survey	Min 2012-2021	Max 2012-2021	Mean 2012-2021	CPUE 2022	T test p-value
1	257.7	468.5	318.4	325.8	-
2	108.0	328.0	220.1	237.0	-
3	164.0	370.0	223.9	258.5	-
Backpack					
Survey	Min 1997-2021	Max 1997-2021	Mean 1997-2021	CPUE 2022	T test p-value
1	14.7	79.8	33.9	32.3	0.697
2	14.3	57.8	29.6	22.5	0.006
3	13.3	60.5	32.6	25.8	0.035

4.3 Smallmouth Bass

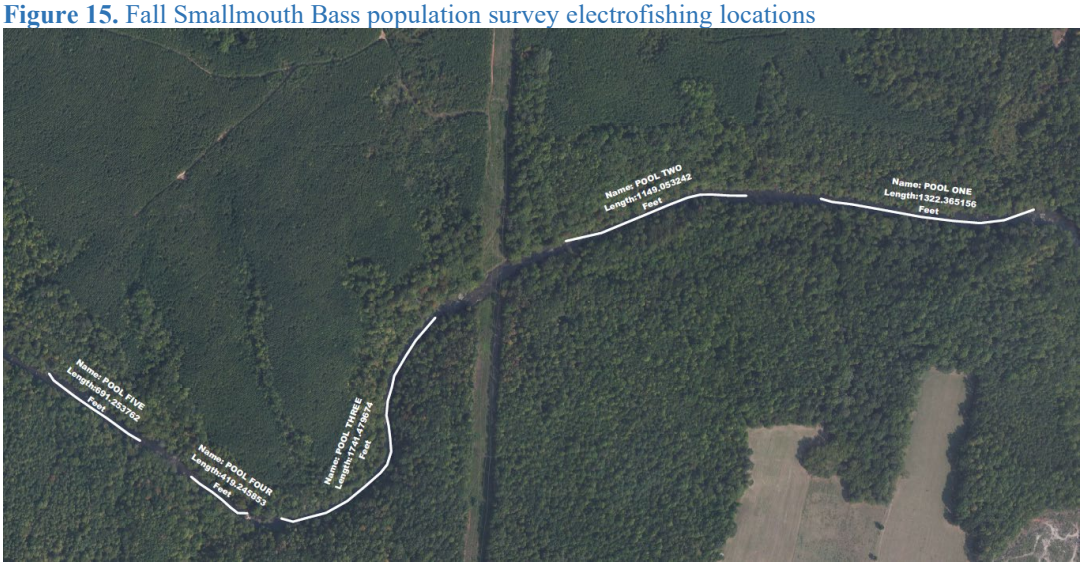
The DEQ- approved monitoring plan for Lake Anna, WHTF and the lower North Anna River includes a Smallmouth Bass *Micropterus dolomieu* study to assess the potential effects of water temperature and river discharge on spawning success of Smallmouth Bass in the North Anna River below the dam. To obtain a better understanding of Smallmouth Bass spawning success in the river in relation to physical variables (temperature and discharge), an attempt to collect a minimum of 50 young-of-year (YOY) was made in 2022. Otoliths from collected fish are examined by the Virginia Commonwealth University (VCU) Center for Environmental Studies to determine daily ages. A Fall Smallmouth Bass survey was also conducted to investigate and quantify the relative abundance of all size classes of Smallmouth Bass in hopes to develop an index of YOY recruitment.

Methods

Summer Smallmouth Bass YOY collections and a fall Smallmouth Bass population sample were conducted in 2022 by a snorkel survey and electrofishing, respectively. YOY were collected early- to mid-summer in the vicinity of NAR-3, -4 and -6 using a 15”x18” clear-frame, fine-mesh dip net while snorkeling. Smallmouth Bass of all sizes were sampled for the population survey on October 6, 2022 at a sequence of five pools in the vicinity of NAR-5,

where the power lines cross the North Anna River in Noel, VA. These pools were consecutively sampled using a Zodiac electrofishing boat with a single boom umbrella array (Figure 15). Electrofishing was conducted in an upstream to downstream direction using pulsed DC from the Zodiac outfitted with a Smith-Root Type VI-A control box, a 5000W Honda generator and an umbrella array. Sampling effort was measured by the amount of time that the electrofishing unit was energized and delivering current to the water. Bass were collected, measured for total length, and released, except for YOY bass. YOY bass collected from YOY sampling were supplemented with the fall population samples if the target sample size of (n=50) was not reached. Retained samples are frozen and sent to VCU for identification and aging.

Figure 15. Fall Smallmouth Bass population survey electrofishing locations



Back-calculation of spawning dates involved subtraction of the number of days required from spawning to swim-up (early stage of swimming up for food after absorption of egg or yolk sac is complete), days required from hatching to swim-up, and daily age from the Julian date of collection. River water temperature data from the NARIV601/NAR-1 continuous temperature logger was used for calculation of days required from hatching to swim-up. River water temperatures collected at NAR-1 were also used along with river discharge data, collected from the United States Geological Survey (USGS) gauging station 01670400 near Partlow, VA, to assess the potential effects of water temperature and river discharge on spawning success and spawning duration in the North Anna River. The accumulation of heating degree days (degree

days) greater than 10°C was examined in relation to the beginning of the Smallmouth Bass spawning season, 2008-2022. The accumulation of degree days greater than 10°C was calculated from mean daily water temperatures and defined as the sum of the number of degree days greater than 10°C for all days before and including any day from 4/1 to 6/30 of any given year (Graham and Orth 1986). An example of how degree days were calculated is presented in Table 18.

Table 18. Example of Heating Degree Day Calculation

Date	Daily Average Water Temperature	Degree Days	Accumulated Degree Days
February 1, 2008	8.30	0.00	0.00
February 2, 2008	8.93	0.00	0.00
February 3, 2008	9.49	0.00	0.00
February 4, 2008	10.08	0.08	0.08
February 5, 2008	10.85	0.85	0.93
February 6, 2008	11.69	1.69	2.62

Results and Discussion

Smallmouth Bass spawning habitat on the North Anna River (NAR) tends to be in areas with low water velocities (≤0.2 m/s) and water depths in the range of 0.44 to 1.76 m (Groshens and Orth 1993). These conditions are usually found in pools and backwater areas which allow the male Smallmouth Bass to construct a depression or nest in the substrate where a female will deposit her eggs to be fertilized by the male. After fertilization, eggs hatch in approximately two days and swim-up usually occurs in one to two weeks. Mortality of YOY from predation is highest after swim-up when they first start actively feeding and have limited escape abilities (Tringali 2015). Disturbances to the nest, including high flows and predation during this time, will affect YOY Smallmouth Bass survival.

Snorkel surveys in 2022 were conducted throughout June, July, and August resulting in fifty YOY being collected. Figures 17 and 18 display Smallmouth Bass spawn dates, accumulated degree days, and river flow for years 2008-2022. No YOY were collected in 2009, 2016, and 2018 due to multiple high flow events. 2013 YOY sampling resulted in a total of six Smallmouth Bass being collected. This low number is likely attributable to the high flow events

seen during the typical spawn window in early May and again throughout the beginning of June (Figure 16). Smallmouth Bass spawning is known to begin when water temperatures exceed 15°C and degree-days greater than 10°C exceed 350 (Tringali 2015). On the North Anna River, data show spawning also beginning in each year generally when water temperatures exceed 15°C but nine out of fifteen years showed spawning occurring with degree-days less than 350 (Figure 17 and 18). This variation suggests a more complicated relationship between environmental variables and localized spawning success. Since Smallmouth Bass are known to inhabit both lakes and streams and have northern and southern populations, the 350 degree-days is considered general to the species and may not represent specific populations. According to the data, spawning seems most successful after the last high flow event for the season or during years where extreme flows were absent.

Figure 16. Estimated spawn date of YOY Smallmouth Bass, accumulated degree days (°C) and river flow (cfs) on the North Anna River (2008-2022)

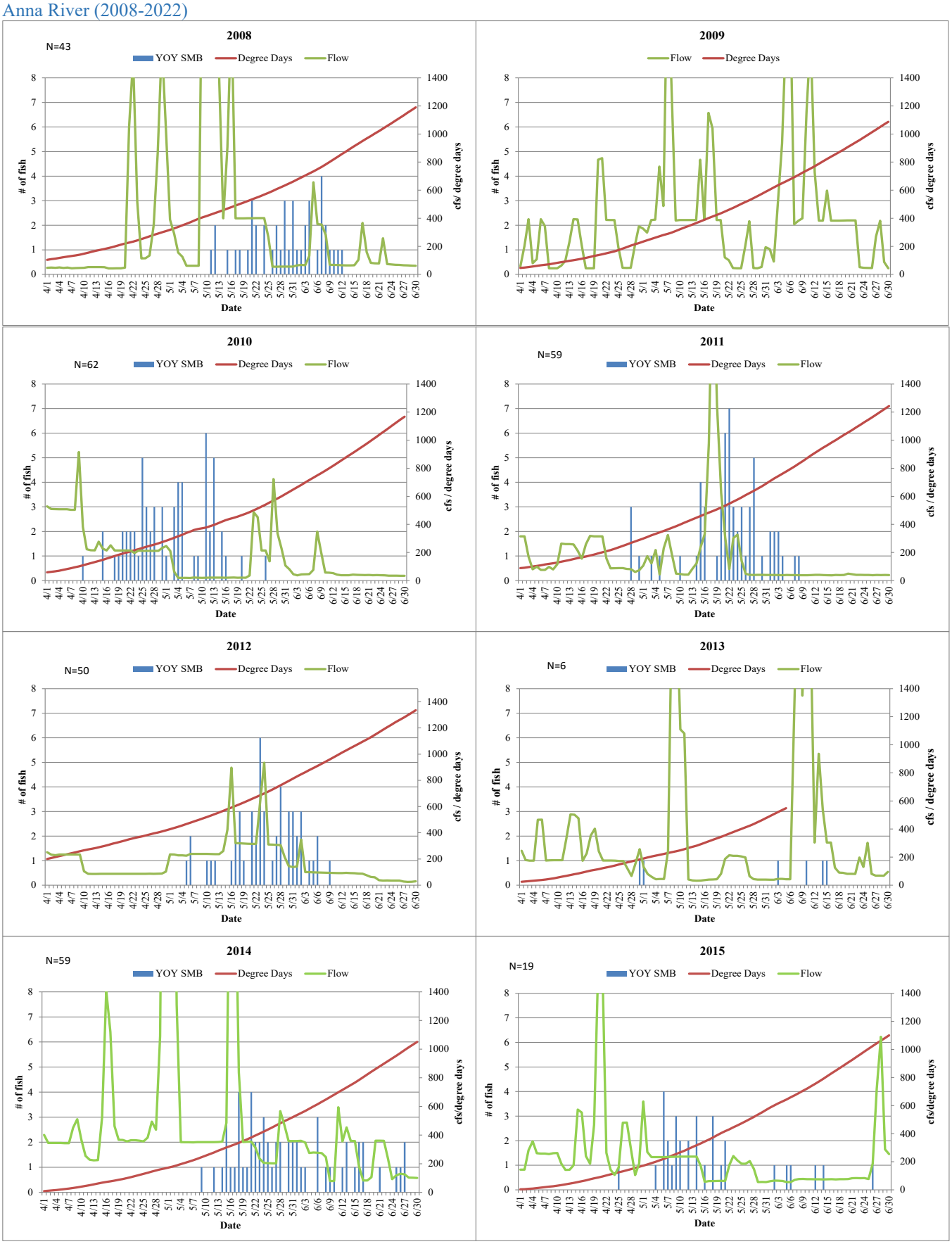
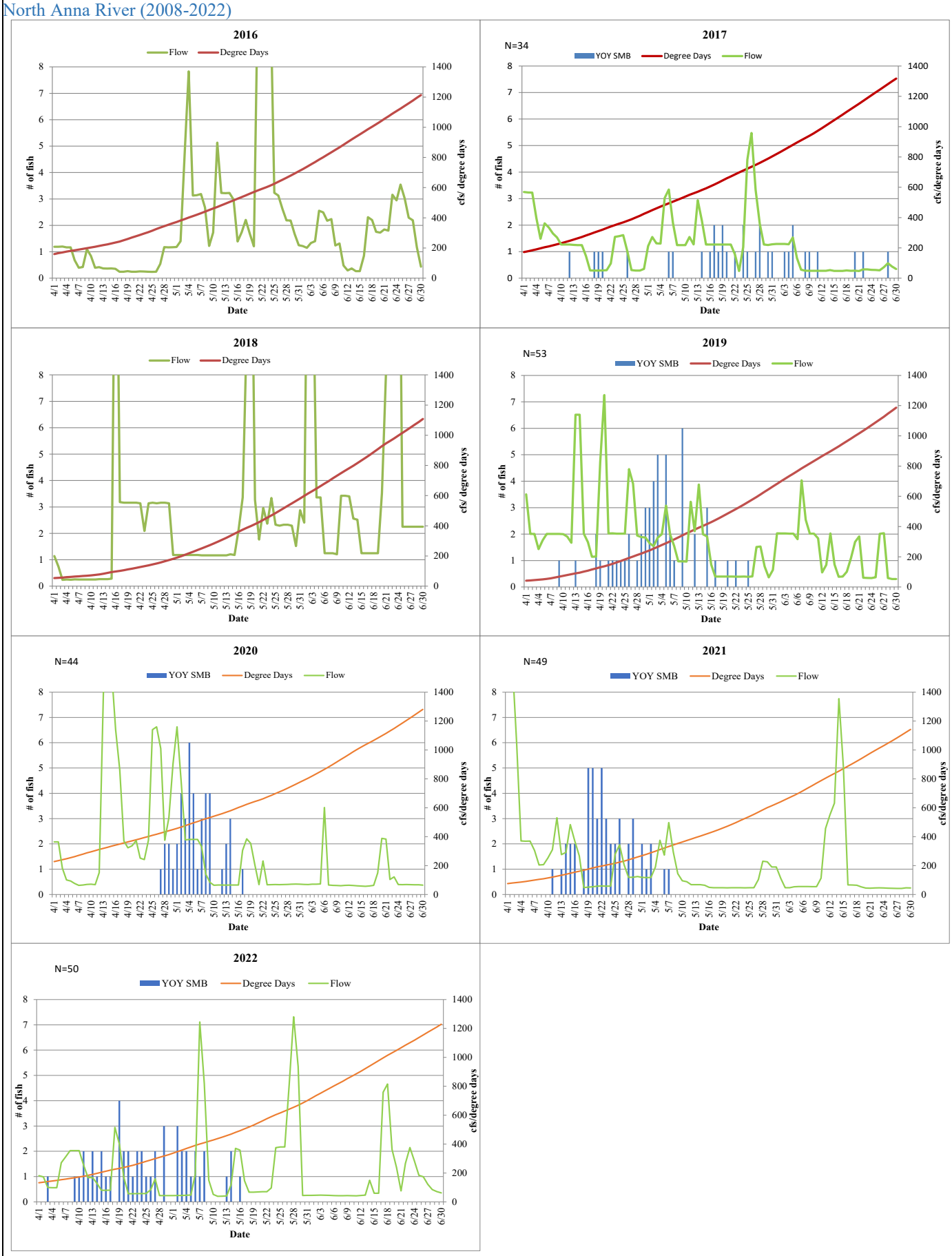


Figure 17. (cont'd) Estimated spawn date of YOY Smallmouth Bass, accumulated degree days (°C) and river flow (cfs) on the North Anna River (2008-2022)



River flows during the spawning season are variable and are highly dependent on spring rains and storms. Smallmouth Bass males often build nests near rocky or woody cover which tends to protect the nest and limit disturbances from waves and flow, and reduces access by predators (Tringali 2015). Specific Smallmouth Bass nest locations may explain why some YOY are able to survive periodic peaks in flow during the spawning season and others not. A complex relationship exists between flow and temperature in relation to spawning success and recruitment of SMB. Data indicate these interactions between flow and temperature are the best predictors of SMB spawn timing, relative spawning success, and recruitment into older age classes.

Spawning and recruitment to age-1 success has been shown to be highly variable but inversely related to rainfall throughout spawning and rearing periods. Decreased flow during these periods improves spawning and recruitment success, leading to an improved year-class strength (Middaugh and Magoulick 2018, Buynak and Mitchell 2022). Conversely, rising temperatures during warmer months paired with lack of flow has been shown to have negative impacts on growth and success of SMB (Middaugh 2017). Further, it was determined that groundwater inflow during these drought conditions provides thermal refuge and promotes summertime growth. These patterns highlight the complexity of abiotic variable interactions and the resultant impact on fish assemblage. Throughout the flow continuum, spawning success and recruitment is inversely related to flow. However, systems without regulated flow regimes may reach a point where lack of flow could result in temperatures rising to a point at which individual growth and success could be hindered. Continuous discharge from the North Anna spillway along with additive flow from tributaries along the lower North Anna River combine to maintain water temperatures supportive of a healthy SMB fishery.

Dominion Energy 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 cubic feet per second (cfs) when Lake Anna surface water elevation falls to or below 248.0 feet above mean sea level (msl). Lake Anna fell to 248.0 feet msl on 19 October 2017. Flow reductions and a low flow monitoring program were implemented soon thereafter.

Two locations along NAR were assessed in late 2017 and early 2018 for wetted width and stream depth measurements before and during low flow conditions (Table 19). These conditions are characterized by discharge being gradually reduced and stabilized below the required 40 cfs to maintain safe lake levels within Lake Anna reservoir (as required by the DEQ-approved Lake Level Contingency Plan). Depths at NAR-1 and NAR-5 (locations noted in Figure 12) averaged 0.67m and 0.24m, respectively, prior to flow reductions in October 2017. Following flow reduction to 20 cfs, depths at NAR-1 and NAR-5 averaged 0.49m and 0.21m, respectively. Average depth at NAR-1 remained within the suggested optimal spawning range of 0.44 to 1.76m (Groshens and Orth 1993). Additionally, the North Anna Spillway operated in "low flow conditions" from September 2007 to February 2008 and again from October 2017 to February 2018. These dates do not fall within the spawning window for SMB in NAR; therefore, are presumed to have had no impact on spawning success. Wetted width at NAR-1 and NAR-5 averaged 72.7 ft and 116.4 ft, respectively, prior to discharge stabilization below 40 cfs. Flow reduction to 20 cfs resulted in respective wetted widths of 64.7 ft and 111.4 ft at NAR-1 and NAR-5. This equates to an 11.0% and 4.3% reduction in wetted width at the two monitoring locations (Table 19).

Table 19. Wetted-width and depth measurements, in feet, taken prior to establishment of flow below 40 cfs (Pre-reduction) and during low-flow conditions (post-reduction). The relative differences in measurements are shown in the (Δ) column. Data represent measurements from the 2017-2018 low flow conditions

	Pre-reduction		Post-reduction		Δ	
	NAR-1	NAR-5	NAR-1	NAR-5	NAR-1	NAR-5
Width	72.7	116.4	64.7	111.4	8.0	5.0
Depth	2.2	0.8	1.6	0.7	0.6	0.1

The most recent data collected during low flow conditions on North Anna stream flow characteristics (taken at 32 cfs, measured by the USGS Partlow Gage) show calculated water velocities of approximately 0.2-0.3 ft/s at stations NAR-1 and NAR-5, respectively (Dominion Energy 2019) (Table 20). These values are within the optimal velocity ranges for all life stages of Smallmouth Bass on the North Anna River (Groshens and Orth 1993 and Dominion Energy 2007) (Figure 16 and Figure 20); thus, data suggest that this monitored stretch of river

will not fall below optimal velocity for Smallmouth Bass through continued operation of the North Anna spillway.

SMB growth rate and abundance were compared to flow characteristics with an added emphasis towards the lower spectrum of expected flow rates. A comparative threshold was set at 50 cfs for statistical analysis due to an inherent lack of data below 40 cfs. This threshold represents the lower bounds of expected flow in the North Anna River while also providing sufficient data to support statistical testing. The relationship between abundance and flow is not well-defined due to a lack of available abundance data relative to flow. Continued population surveys are expected to strengthen these comparisons, from which a clearer relationship between reduced flows and abundance may be detected. Growth rate (determined by dividing total length of captured YOY fish by age of fish) was compared to the number of days averaging below 50 cfs from April to August during the year of capture, resulting in no clear correlation between growth rate and flow at the tested threshold (Figures 18 and 19). This supports results obtained in a previous study on Smallmouth Bass in the North Anna River (Groshens and Orth 1993). The lower end of expected flow rates is not expected to have a negative, population level impact on the species. Rather, minimum regulated flow regime on the North Anna River is demonstrated to be protective and sustainable for a healthy population of Smallmouth Bass.

Figure 18. North Anna River Smallmouth Bass young-of-year growth rates (mm/day) classified by number of days where flow averaged below 50 CFS. Blue line represents the relationship between growth rate and number of low flow days with associated 95% confidence intervals

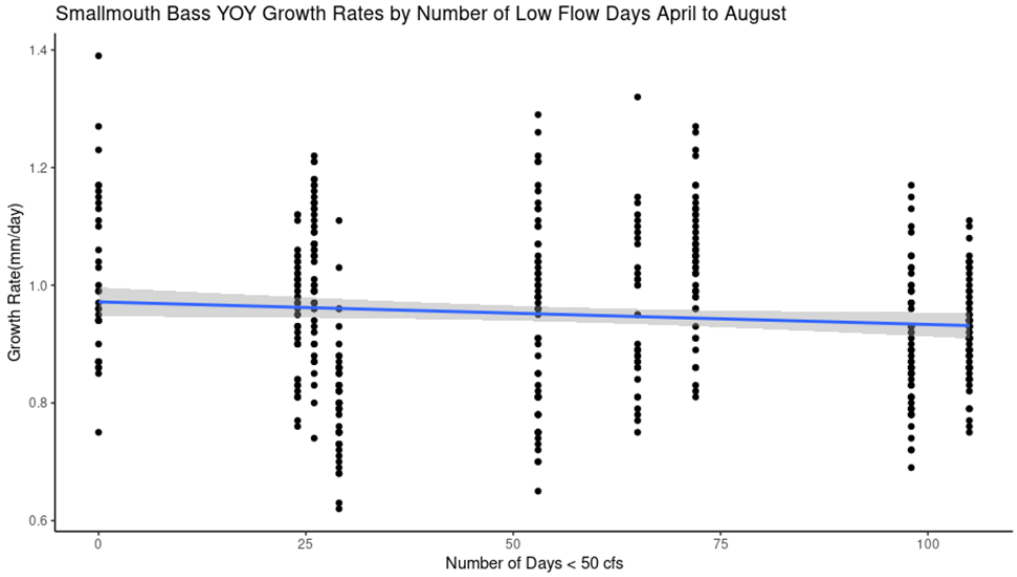


Figure 19. North Anna River Smallmouth Bass young-of-year length (mm) at age (days). Colors represent a gradient of number of days where flow was below 50 CFS from April to August in the year of capture from none/few days (blue) to many days (red)

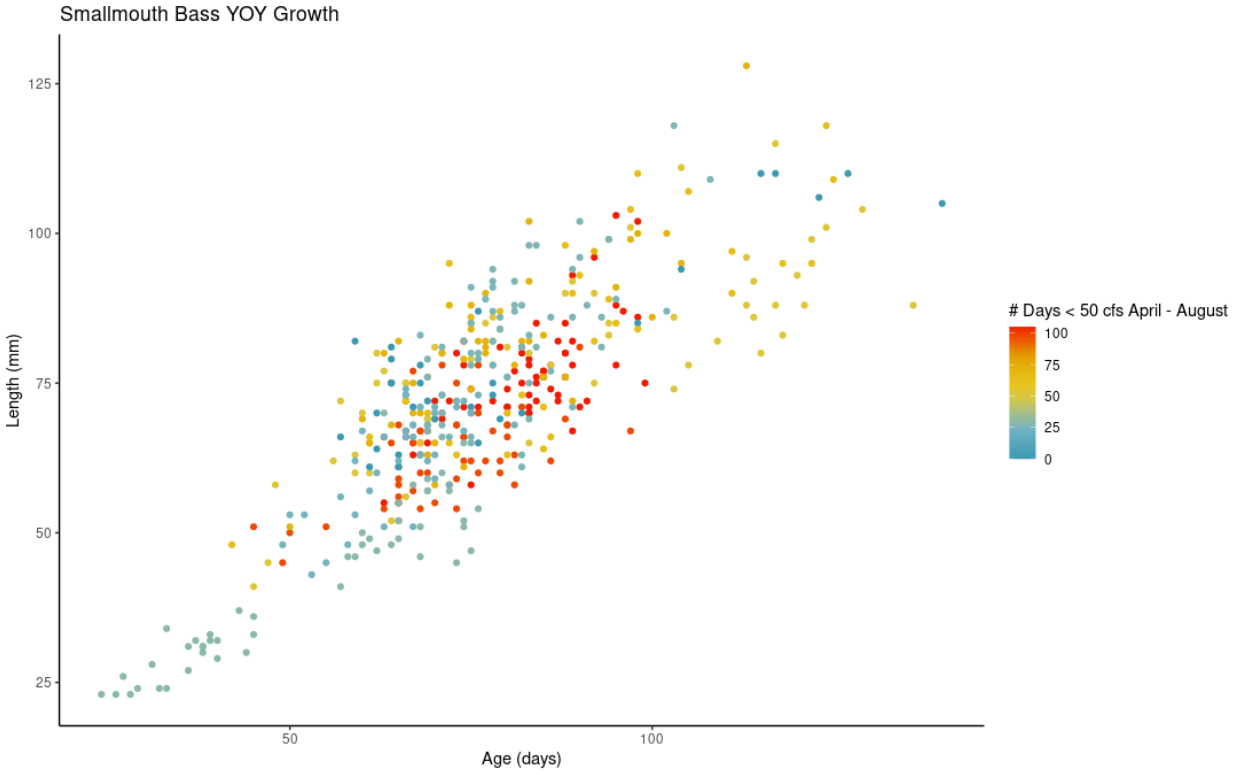
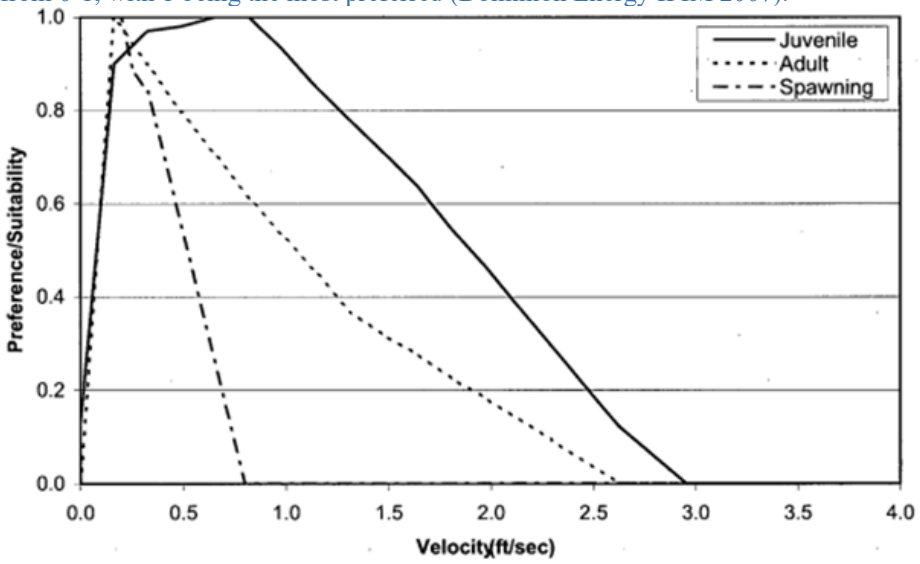


Table 20. Calculated velocity measurements taken at 32 cfs and during established low-flow conditions (21 cfs) based on estimated cross-sectional area at locations of sampling and flow data obtained from USGS Partlow Gage. The relative differences in measurements are shown in the (Δ) column. Data represent measurements from the 2017-2018 low flow conditions.

Discharge	**32 CFS**		**21 CFS**		**Δ**	
Station	**NAR-1**	**NAR-5**	**NAR-1**	**NAR-5**	**NAR-1**	**NAR-5**
Velocity (ft/s)	0.20	0.33	0.20	0.26	0.00	0.07

Figure 20. Smallmouth Bass velocity preference/suitability within North Anna River with preference and suitability values ranging from 0-1, with 1 being the most preferred (Dominion Energy IFIM 2007).



In addition to the YOY analysis, data for adult and juvenile Smallmouth Bass caught during the fall population sample at NAR-5 were analyzed. In 2022, 68 bass were collected at a rate of 32.6 fish per hour of electrofishing. Figure 21 displays the fish collected in 2022 by 50 mm length classes. Smallmouth Bass lengths follow a normal distribution when plotted. CPUE (#/hr.) for each length class is presented in Table 21.

Figure 21. Length frequency distribution (50mm intervals) of Smallmouth Bass collected at NAR-5 during the 2022 fall population survey.

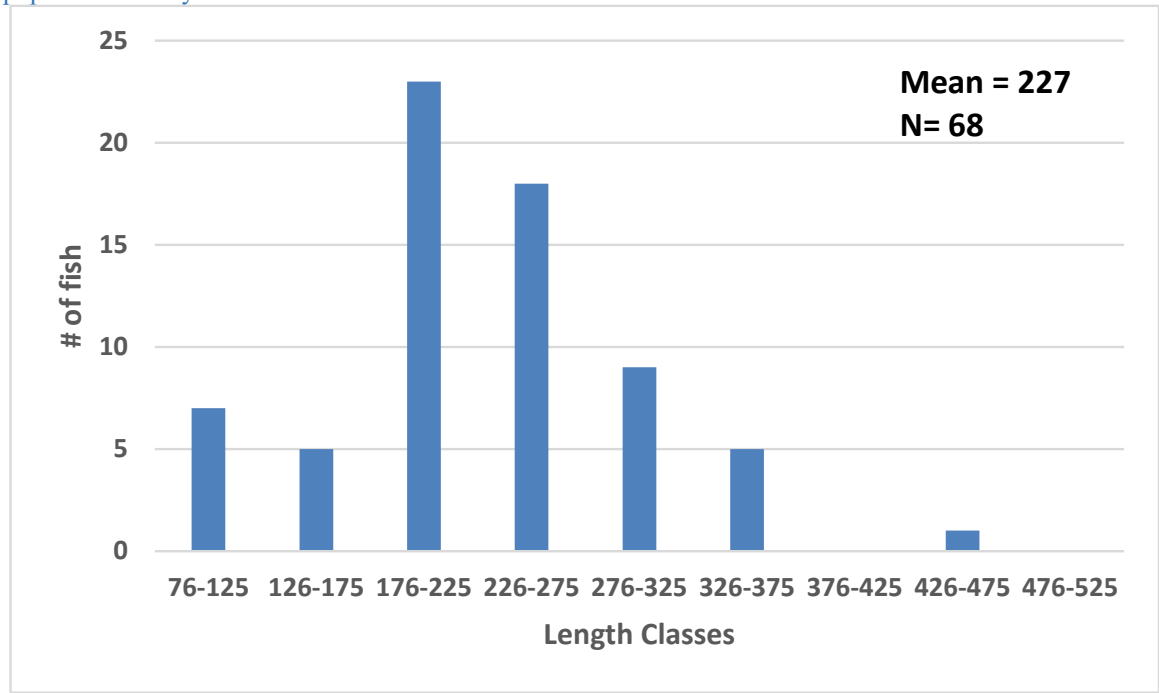


Table 21. CPUE (#/hr) of Smallmouth Bass per size class at NAR-5 during the 2022 fall population survey.

Length Class (mm)	#	CPUE (#/hr)
76-125	7	3.4
126-175	5	2.4
176-225	23	11.0
226-275	18	8.6
276-325	9	4.3
326-375	5	2.4
376-425	0	0.0
426-475	1	0.5
476-525	0	0.0

Boat electrofishing surveys have been conducted since 2012 to provide annual catch rates to gauge year class strength and to compare the CPUE for age-1 Smallmouth Bass to the CPUE for age-0 bass from the previous year. A linear regression model was applied to the sample data to demonstrate the relationship between age-1 catch rates and fall collected age-0 bass (Figure 22). The regression line gives an r-squared value of 0.22 for the relationship between Age-1 bass and the previous year class strength, indicating a weak correlation between these variables. However, continued data collection will be utilized to strengthen the statistical comparison and provide a more robust analysis. The cause of variation in catch rate displayed in Table 22 is

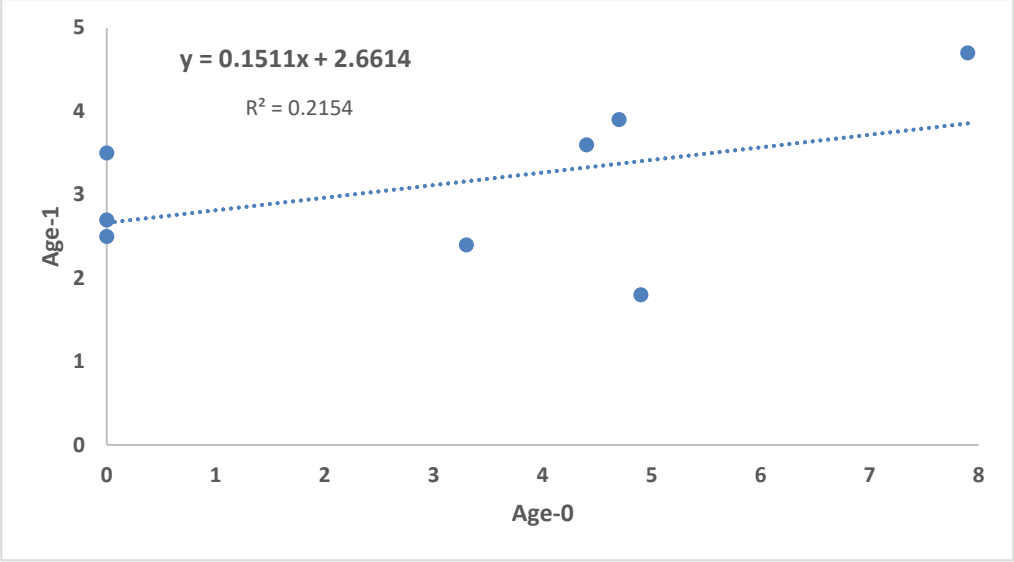
unclear, but further study will help define the relationships between environmental variables and annual catch rates.

Table 22. CPUE for Smallmouth Bass by year class; collected during the 2022 fall population survey

Year Class	Age-0	Age-1
2012	4.4	3.6
2013	2.1	0
2014	7.9	4.7
2015	4.7	3.9
2016	0	2.5
2017	4.1	0.6
2018	0	3.5
2019	4.9	1.8
2020	0	2.7
2021	3.3	2.4

Since each data point is derived from two years of collections, more years of sampling will be needed to strengthen and verify this observation. In the coming years as the data set grows, CPUE for age-1 Smallmouth Bass will continue to be compared to the CPUE for age-0 bass from the previous year. This relationship will hopefully allow us to predict YOY recruitment based off the current years age-0 year class strength.

Figure 22. Linear Regression of fall collected age-0 Smallmouth Bass catch rate vs age-1 Bass catch rate on the North Anna River (2012-2021) (*2013 and 2017 cohort removed)



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