North and South Anna Rivers Investigation

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Background

A study was conducted during July, 2006 to assess fishery resources of the North Anna River below Lake Anna, Virginia. The impetus of this study was partially the projected expansion of Dominion Power's North Anna Nuclear Station with its potential to further reduce flows to this reach. Two flow-through reactors have been operational since the reservoir was constructed in the early 1970s, and Dominion plans to expand their facility. Current discharge from Lake Anna is reduced from the natural hydrograph due to consumptive water usage by the existing reactors and evaporation. Projected plant expansion would likely exacerbate low flow conditions and drought frequencies below Lake Anna.

Dominion currently operates using 40 cubic feet per second (CFS) minimum release unless the reservoir pool reaches 248 feet at which time flow is reduced to 20 CFS. The overall drought frequency of the tailwater has increased as a result of the current operating schedule, and many seasonal flow peaks are mitigated due to the reservoir's presence. In addition, median flows from March through October were reduced compared to pre-impoundment conditions. However, even in cases of severe drought, a 20 CFS flow is mandated thus potentially providing more flow than natural without augmentation. Downstream impacts from the impoundment (in the form of water quality improvements) and resulting changes in the tailwater may benefit smallmouth bass *Micropterus dolomieui* and other species. King et al. (1991) hypothesized that faster growth rates were achieved by smallmouth bass in the North Anna River (as compared to the South Anna River) because of decreased turbidity, a longer growing season, and elimination of severe low-flow events.

Virginia Department of Game and Inland Fisheries (VDGIF) biologists have historically conducted single qualitative surveys of the North Anna River, but gauging the quality of the fishery was difficult from these sporadic surveys. Additionally, no age and growth data were available since King et al. (1991), and no comparative stream reaches were typically sampled. Thus, this study was undertaken to better understand the current status of the North Anna River fish community with emphasis on the sport fishery.

Study Site/Methods

The South Anna River was chosen as a companion river with which to compare the North Anna River due to its similar watershed size and location (King et al. 1991). However, the North Anna River has a larger watershed at the point where both rivers have comparable USGS gage stations in the vicinity of the fall line. The gage station typically used by Dominion Power for flow analysis on the North Anna River (Hart Corner near Doswell) has a drainage area of 462 mi^2, while the gage station on the South Anna River at Ashland has a drainage area of 395 mi^2. These gage stations were used to evaluate and compare mean monthly flows for the period of record.

The South Anna River has no major impoundments upstream of Route 1 (the fall line), and flows are thus unregulated. Access is limited to both rivers, and all riparian property ownership is private; so access was considered along existing VDOT rights-of-ways. There were six such crossings on the North Anna River between the dam and Route 1 and over ten on the South Anna River within an adjacent reach. Three access sites were chosen on the North Anna River based on logistical ability to access the river with sample gear; and then three sites, as similar as possible, were selected on the South Anna River. Selection criteria included location in the reach (distance upstream from Route 1), habitat similarity, and logistical feasibility.

No boat ramps existed; and typical conditions, such as shallow bedrock ledges, limited the utility of even small electrofishing boats. However, these rivers were too wide to be effectively sampled by backpack electrofishing gear and largely too wide for single tote barge so, two tote barges were used. Each barge had a 2.5 GPP Smith Root electrofishing unit, three anodes, and deployment was in a side-by-side alignment to minimize fish avoidance. Two sites on each river were qualitatively sampled, and one site on each river was quantitatively (depletion) sampled (Table 1). Efforts were made to sample reaches that contained natural barriers to movement at each end (e.g., gradient barriers), as block nets were not used. Thus, sample site section lengths were variable. Depletion goals were based on significant negative linear regressions of adult redbreast sunfish *Lepomis auritus* catch. Redbreast sunfish were chosen as an indicator fish to gage depletion success because they are an important game and forage fish, and they were believed to be abundant. Furthermore, redbreast sunfish should have been present in multiple size classes and were likely to be found in a variety of habitats.

Most data analyses were conducted on the redbreast sunfish and smallmouth bass populations since these were believed to be the most popular sportfish in the rivers. However, all fish from each run were identified, measured for total length (mm) and weighed to the nearest gram and held in net pens until conclusion of all runs. Total counts of all species were calibrated based on the length of all sample reaches combined and standardized by number/km. Margalef's diversity index (Ney 1993), also known a species richness metric (Greenstreet and Rogers 2006), was calculated for the fish community in each river. Metric values are influenced considerably by variation in sample size. Thus, sample sites within rivers were combined (Greenstreet and Rogers 2006) to calculate Margalef's diversity index.

Otoliths were taken from a subsample of redbreast sunfish and all smallmouth bass for length-at-age, recruitment and mortality estimates. Ages were estimated based on annuli count from cracked sagittal otoliths (Slipke et al. 1998). Stomach contents of black bass were evaluated for frequency of occurrence of food items, but evaluations were included only for smallmouth bass due to low sample size (of fish and/or gut contents) of largemouth and spotted bass.

Population estimates were generated with MicroFish software (Kulp and Moore 2000). Estimates with associated capture probabilities and 95% confidence limits were calculated for selected populations of all individuals (e.g., juveniles and adults combined). Population and biomass estimates were obtained by expanding for sample area. FAST software was used to derive catch curve-based mortality rates and growth coefficients (Slipke and Maceina 2001). Differences in mean length-at-age were tested using analysis of variance (ANOVA) and Bonferroni's pairwise procedure, and species differences in mean total length between rivers were tested using paired T-tests (alpha=0.05).

Results

Smallmouth bass were marginally more abundant in the South Anna River based on total number caught at all sites (Table 2) and population estimates from depletions (Table 3), but biomass estimates were nearly identical (3.8 vs. 3.7 kg/ha). However, smallmouth bass only accounted for 44% of black bass caught in the South Anna River, as spotted bass *Micropterus punctulatus* and largemouth bass *Micropterus salmoides* comprised 50% and 6% of the sample. Spotted bass were more abundant than smallmouth bass in the South Anna River but absent in the North Anna River, which had a smaller but significant portion of largemouth bass. Biomass estimate of black bass (all species combined) was higher in the South Anna River (6.3 kg/ha) than in the North Anna River (5.5 kg/ha).

Smallmouth bass appeared to grow more slowly in the South Anna River (Table 4). Mean total length of age-2 smallmouth bass was significantly greater in the North Anna River (249 mm vs. 204 mm), and it is likely differences would have been seen in other age groups if sample sizes had been larger. Only three year classes (maximum age-5) were present in North Anna River samples (n=31), while five year classes (maximum age-6) were present in South Anna River samples (n=41).

Smallmouth bass total annual mortality rates were relatively high on both rivers (49% on the South Anna River and 59% on the North Anna River), but sample sizes were low. Variable recruitment, if present, was not apparent based on catch curves, but cohorts were missing. Growth coefficients could not be calculated for smallmouth bass from the North Anna River due to low number of year classes sampled, but the flattened growth curve for smallmouth bass from the South Anna River produced a low L_{inf} of 344 mm.

Stomach contents of smallmouth bass indicated that fish in both rivers foraged on similar food items (Table 5). Crayfish and darters were the dominant items, and insects (both aquatic and terrestrial) were less frequently consumed. However, fish (all species combined) were consumed more commonly on the North Anna River (64%) than in the South Anna River (36%).

Redbreast sunfish were more abundant in the North Anna River based on total number caught at all sites (Table 2) and population estimates from depletions (Table 3), but biomass was greater (10.1 vs. 7.1 kg/ha) on the South Anna River due to the presence of larger individuals in the population (Figure 1). Redbreast sunfish mean total length was significantly greater on the South Anna River (101 vs. 85 mm), and only nine quality-size (150 mm or greater) redbreast sunfish were sampled on the North Anna River (compared to 58 on the South Anna River).

The between-river trend of redbreast sunfish growth and longevity patterns were similar to those of smallmouth bass. Redbreast sunfish attained significantly greater length at age-3 on the North Anna River (Table 6), but only five year classes (maximum age-7) were present in the samples. Alternatively, eight year classes were present in South Anna River samples with maximum age-9.

Redbreast sunfish total annual mortality was much higher on the North Anna River (50%) than on the South Anna River (27%). Maximum age was projected to be 11.4 years on the latter while only 7.0 years on the former. Several year classes were apparently missing from the redbreast population on the North Anna River; however, year class distribution on the South Anna River suggested variable recruitment. The 2001 and 2002 year classes seemed dominant on the South Anna River, but some consistency between rivers was noted. For example, the 1999 year classes had high catch curve residuals for both rivers indicating universally strong recruitment.

A species list was compiled for the communities of both rivers (Table 6). More species were collected in the South Anna River than in the North Anna River (41 vs. 28). Margalef's richness index was 5.06 in the South Anna River and 3.35 in the North Anna River.

Streamflows in the North Anna River were usually modestly higher during most months outside of summer. However, streamflows in the South Anna River were typically greater during summer and early fall months (Figure 2).

Discussion

Biomass and abundance of smallmouth bass were similar between rivers. King et al. (1991) did not focus on abundance but did note that smallmouth bass distribution was clumped in the North Anna River with most fish occurring in the vicinity of the fall line. King et al. (1991) collected more than twice as many smallmouth bass from the North Anna River as the South Anna River using boat electrofishing and hook-and-line, but effort was not disclosed. Paragamian (1991) noted higher standing stocks of smallmouth bass in reaches downstream of dams (compared to areas above the dams). Abundance of smallmouth bass in the North and South Anna Rivers (46-50/ha) was modestly lower than estimates from other, larger Virginia rivers. For example, smallmouth bass abundance in the Rappahannock and James Rivers was 75/ha and 69/ha (Odenkirk and

Smith 2005). The cohabitation of other black bass species (32% largemouth in the North Anna River and 50% spotted bass in the South Anna River) may have resulted in lower overall abundances of smallmouth bass.

Growth patterns of smallmouth bass in the North and South Anna Rivers were similar to observations by King et al. (1991). In both studies, smallmouth bass in the North Anna River grew faster. King et al. (1991) hypothesized that elevated growth rates were due to a longer growing season (estimated to be 3-4 weeks) imparted by thermally enriched waters from Lake Anna, reduced turbidity, and a lower incidence of extreme (< 20 CFS) low flows. The latter two variables were also attributable to the presence of Lake Anna and the mandated minimum flow requirement. Mean total length of age-2 smallmouth bass in the North Anna River was above average (mean of Virginia rivers was 215 mm; Scott Smith, Virginia Department of Game and Inland Fisheries, personal communication), while age-2 fish from the South Anna River averaged below this mark. Growth rates of redbreast sunfish were also greater in the North Anna River further suggesting an inherent advantage favoring fish growth in the North Anna River.

Reservoirs may benefit tailwaters by fulfilling desirable functions such as turbidity reduction, but they can also negatively impact downstream fisheries by altering flow regimes and changing thermal patterns (Ruane et al. 1986). Correlations have been identified linking temperature to year class strength in smallmouth (Casselman et al. 2002) and largemouth (Parkos and Wahl 2002) bass populations. Additionally, nutrient reduction, especially in storage impoundments like Lake Anna, can result in decreased downstream productivity. Reduced biomass of black bass and redbreast sunfish in the North Anna River may have been related to a reduction in primary productivity.

However, it was unclear why redbreast sunfish population size structure varied between rivers. It was possible that the North Anna River population was limited by inconsistent recruitment and/or low productivity, either of which may have been related to temperature or flow.

High estimates of smallmouth bass mortality rate, based on single-year catch curves, may have been biased by variable recruitment. In lotic populations of smallmouth bass, variable recruitment appears to be the rule rather than the exception, but better recruitment occurs when mean June flow is average (Smith et al. 2005). Mean June flow in the North Anna River for the period of record averaged 257 CFS, and two of the three years with missing year classes were composed of a flood year (2003, mean June flow was 1140 CFS) and a drought year (2002, mean June flow was 38 CFS). The South Anna River smallmouth bass sample had representatives of the 2003 year class but not the 2002 year class. Four of the most recent eight years (1999-2006) in the North Anna River had June flows characterized by either flooding or very dry conditions (flows 46% of normal or less).

Biologists with Dominion Power have collected a total of 52 species of fish representing 15 families by electrofishing in the North Anna River conducting annual surveys since 1981. However, they only collected 27 species in 2006 – the most recent year for which data were available (Dominion 2008). Dominion's species count in 2006 was very similar to the species count recorded in the present study (28) which also occurred in 2006. Greater species abundance in the South Anna River (41) resulted in an elevated Margalef's richness index of 5.06 suggesting this river suffered less from environmental perturbations than the North Anna River where this index was only 3.35.

In a study of 24 tributary watersheds in the Little Tennessee and French Broad Rivers in North Carolina, Harding et al. (1995) found that Margalef's richness indices ranged from 4.04 to 6.70. Margalef's index for the South Anna River fell within this range, while the index for the North Anna River was below it.

The paucity of year classes in both the smallmouth bass and redbreast sunfish populations in the North Anna River along with the apparent reduction in species richness, relative to the South Anna River, bear further scrutiny to determine if gear bias or environmental factors were in play.

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Table 1. Descriptive characteristics of sample sites on the North (NAR) and South (SAR) Anna Rivers (Upstream km = approximate distance upstream of Route 1). Areas provided for depletion sites only.

River	Sample site	Upstream km	Length (m)	Mean width	Area (ha)
NAR	Route 1	0	165	22	
NAR	Hewlett	18	154	52	0.80
NAR	Mt. Olive	38	138	16	
SAR	Route 1	0	182	26	
SAR	Route 54	14	230	25	0.58
SAR	Route 33	24	303	26	

Table 2. Total numbers of selected fish caught at all sites on the North (NAR) and South (SAR) Anna Rivers (percentage of population within river listed in parentheses for black bass). SMB=smallmouth bass, LMB=largemouth bass, SPB=spotted bass, and RDB=redbreast sunfish.

River	SMB	LMB	SPB	RDB
NAR	39(68%)	18(32%)	0	506
SAR	46(44%)	6 (6%)	53(50%)	467

Table 3. Population estimates for selected fish collected from quantitative sampling sites on the North (NAR) and South (SAR) Anna rivers. N=population estimate, and P=capture probability from Micro Fish. SMB=smallmouth bass, SPB=spotted bass, LMB=largemouth bass, RDB=redbreast sunfish, AME=American eel.

Species	River	N	95% CI	P	No./ha.	Kg./ha.
SMB	NAR	37	32-42	0.59	46	3.8
SMB	SAR	29	19-39	0.46	50	3.7
SPB	SAR	35	31-39	0.64	60	2.6
LMB	NAR	11	6-16	0.5	14	1.7
RDB	NAR	499	463-535	0.48	624	7.1
RDB	SAR	255	243-267	0.62	440	10.1
AME	NAR	358	315-401	0.42	448	10.3
AME	SAR	109	98-120	0.56	188	8.7

Table 4. Length-at-age (mm) and sample size (n) for smallmouth bass collected from the North (NAR) and South (SAR) Anna Rivers, all sites. Asterisk denotes significant difference within age between rivers.

River	Age-0	Age-1	Age-2*	Age-3	Age-4	Age-5	Age-6
Year Class		2005	2004	2003	2002	2001	2000
NAR		147 (18)	249 (12)			394 (1)	
SAR		139 (28)	204 (8)	256 (3)		307 (1)	315 (1)

Table 5. Frequency of occurrence of food items from smallmouth bass stomachs containing food (n=28) collected from the North (NAR) and South (SAR) Anna Rivers.

Food Item	SAR	NAR
Crayfish	50%	29%
Darter	36%	29%
Redbreast sunfish		14%
Margined Madtom		14%
Unid. Fish		7%
Aquatic insect	7%	7%
Terrestrial insect	7%	7%

Table 6. Length-at-age (mm) and sample size (n) for redbreast sunfish collected from the North (NAR) and South (SAR) Anna rivers, all sites. Asterisk denotes significant difference within age between rivers.

River	Age-2	Age-3*	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9
Year Class	2004	2003	2002	2001	2000	1999	1998	1997
NAR	108(28)	127(21)	146 (6)	155 (2)		164 (2)		
SAR	105 (5)	117(18)	140(56)	160(23)	160 (2)	148 (4)	175 (2)	162(1)

Table 6. Relative abundance (number/km.) of fish species collected from the North and South Anna Rivers during sampling in 2006 (three sites per river).

Species	North Anna	South Anna
smallmouth bass	85	64
spotted bass		74
largemouth bass	39	8
redbreast sunfish	1107	653
American eel	678	512
bluegill sunfish	7	36
pumpkinseed sunfish	2	6
redear sunfish	2	6
green sunfish	2	1
black crappie		3
warmouth		3
white catfish		1
channel catfish		1
brown bullhead		3
margined madtom	166	81
chain pickerel	2	1
bowfin	2	1
striped bass		3
American brook lamprey	37	183
least brook lamprey	13	36
yellow perch		1
shield darter	61	83
Johnny darter	136	27
stripeback darter		53
glassy darter	31	10
white sucker		1
northern hogsucker	103	38
creek chubsucker	9	
gizzard shad		25
fallfish	105	102
bluehead chub	188	150
river chub	9	21
satinfin shiner	91	34
swallowtail shiner	15	35
comely shiner	90	175
rosefin shiner	57	77
rosyface shiner	133	185
ironcolor shiner	7	
golden shiner		3
common shiner		1
spottail shiner		1
common carp	4	
mosquitofish		1
hogchoker		4
Total species	28	41
Total individuals	3181	2703

Figure 1. Length frequency histograms of all redbreast sunfish caught electrofishing at all sites on the North and South Anna Rivers.

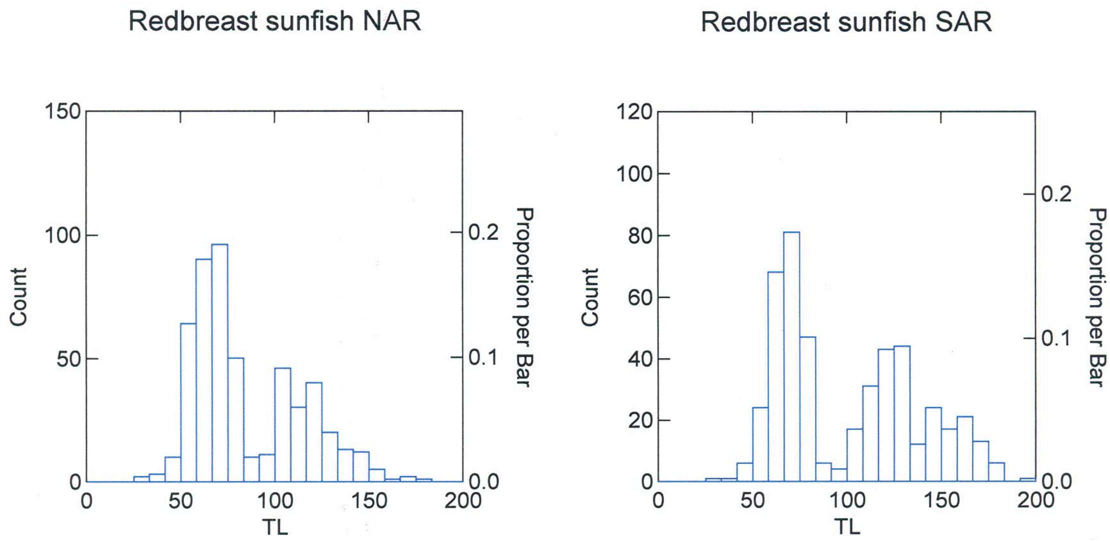

Figure 2. Mean monthly stream flows (period of record) for the North and South Anna Rivers (Hart Corner and Ashland Gages).