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Age and growth of black crappie pomoxis nigromaculatus in Lake Anna, a Virginia Power cooling impoundment

Robert Mason Daniels

AGE AND GROWTH OF BLACK CRAPPIE POMOXIS NIGROMACULATUS IN LAKE ANNA, A VIRGINIA POWER COOLING IMPOUNDMENT

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ROBERT MASON DANIELS
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BY

ROBERT MASON DANIELS

APPROVED:

COMMITTEE CHAIRMAN

COMMITTEE MEMBERS

EXAMINING FACULTY:

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Acknowledgments

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A special note of gratitude is due my wife, Susan, for her patience and support during the course of this study.

Abstract

A study of the age and growth of black crappie, *Pomoxis nigromaculatus*, was conducted in Lake Anna, Virginia, a cooling impoundment for Virginia Power's North Anna Power Station. Growth of the population in the reservoir was compared to that of the population in North Anna's Waste Heat Treatment Facility. Analysis of covariance (ANCOVA) using age as the covariate indicated the growth rate of the two populations did not differ significantly at the .05 level. The populations were combined and tests were conducted to determine differences in growth rates between the sexes. ANCOVA indicated the growth rates of males and females differed significantly; however, frequency distributions indicated there was no substantial difference in growth of the sexes. Growth of the black crappie population in Lake Anna was then compared to similar populations in Virginia and surrounding states. The Lake Anna population grew at a slower rate than was reported for other populations. Habitat availability, lake characteristics, and food availability were discussed as factors which may have limited the growth rate of the Lake Anna population.

Introduction

Black crappie, *Pomoxis nigromaculatus*, is an important pan fish that has been introduced into ponds and lakes throughout the United States. Studies by Schoffman (1940), Johnson (1945), Stroud (1948), and Neil (1961) as summarized by Schneberger (1977) have shown that growth rates are highly variable among populations of black crappie and are determined by factors such as habitat, temperature, food availability, geographic location and population composition.

Virginia Power created Lake Anna by impounding the North Anna River in the Piedmont Province of Virginia in 1972. The 3885 hectare reservoir provides condenser cooling water for the North Anna Nuclear Power Station. A Waste Heat Treatment Facility (WHTF) of 1376 hectares adjacent to Lake Anna receives the cooling water and transfers excess heat to the atmosphere before discharge into the lower end of the reservoir.

Virginia Power conducted a 316(a) demonstration of Lake Anna as allowed under the Clean Water Act (P.L. 92-500) from 1984-1986 in an effort to determine if the State's temperature standard was more stringent than necessary to assure the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife. The demonstration included age and growth studies of the Lake's major game species.

The present study, which examined the age and growth of an indigenous population of black crappie in Lake Anna was included in the 316(a) demonstration. Parameters of the lake population were compared to those of a population in the WHTF, other thermally influenced reservoirs, and ambient temperature reservoirs in the Eastern United States.

Study Area

Many characteristics of Lake Anna (physical/chemical and limnological parameters) have been monitored by Virginia Power and consultants since its formation. Such studies provided a thorough description of the reservoir (Reed and Associates 1979, VEPCO 1983). The following physical/chemical data were taken in part from Virginia Power's 316 (a) demonstration (1986).

Lake Anna is an oligo-mesotrophic, dimictic reservoir located in the York River basin (lat 38°01'00", long. 77°42'39") (Fig. 1). Its elevation is 76 m above mean sea level and the overall mean depth is 7.6 m (mean depths range from 4 m in the upper lake to 11 m in the lower lake). The lower and mid parts of the reservoir form the main body. The upper section is represented by two shallow arms that receive drainage from the North Anna River and Pamunkey Creek. Many smaller creeks and streams enter the 27 km long lake resulting in a dendritic shoreline of 438 km with many coves and branches. Four large marinas, a state park, and numerous permanent and vacation homes have been constructed along the lake's extensive shoreline.

Since the station began operation in 1978, surface water temperature has reached maximum mean monthly values during July, ranging from 27.3 to 30.8 C. During the same month, surface temperatures varied less than 2 C from the upper to lower lake. The power station had the effect of expanding the epilimnion from approximately 5 m prior to station operation to 10 m during station operation. This reflects the mixing caused by a current established by the circulating water pumps of the power station.

The headwaters of the York River basin generally have excellent water quality. Annual mean pH in the upper and lower lake, respectively, was consistently near 7.1 and 6.9. Turbidity values ranged from 6 to 10 NTUs in the upper lake and 2 to 5 NTUs in the lower lake. Alkalinity ranged from 14 to 16 mg/L in the upper lake to 8 to 12 mg/L in the lower lake.

The WHTF was formed by diking off a portion of Lake Anna and consists of three bodies of water designated WHTF 1, 2 and 3, which are interconnected by canals. WHTF 2, the largest of the three, is fed by two primary tributaries, Elk Creek and Millpond Creek. When the station was operating at normal levels, water temperature across the condenser was elevated 7.6 C in the summer to 15.5 C in the winter. The estimated residence time of water in the WHTF is 14 days. Surface water temperatures in the WHTF generally were 2 to 7 C warmer than lake temperatures during the summer. Water quality in the WHTF was similar to that of the lake.

The lake and WHTF were clearcut prior to impoundment resulting in large bodies of water with little submerged structure. Natural structure consisted of beaver lodges and limited aquatic macrophytes. Man-made structure utilized by fishes included three rip-rap dikes, bridge pilings, boat docks, and seven artificial fish structures (in the lake) that were constructed by Virginia Power.

Materials and Methods

Black crappie were collected in Lake Anna and the WHTF from 1982 to 1984 during routine and supplementary surveys by Virginia Power's North Anna Laboratory personnel. Collections were made bi-monthly with a boat-mounted Smith-Root Type IV electrofisher (output 1000 V 3-4 amps) and experimental gill nets consisting of six 15 m panels (25.4, 50.8, 76.2 101.6, 127 and 152.4 mm stretch mesh). Routine electrofishing collections were made at 15 stations (seven in the lake and eight in the WHTF); gill nets were set at 11 stations (six in the lake and five in the WHTF). Supplementary electrofishing collections were made at three stations in the WHTF. Rotenone samples were taken once a year in August at four coves in the lake and one in the WHTF. Six of the crappie included in the study were caught by angling. Fish samples were either preserved in the field with 10% formalin or directly returned to the laboratory. Laboratory workup of fish from all sampling methods consisted of measuring total length (mm) and weight (0.1 g). Date, location, method of capture and sex were recorded for each specimen.

Scales were removed from the left side of the fish directly below the center of the spinous dorsal fin and at least one scale row above the lateral line. Five scales from each fish were pressed onto 1 mm thick acetate slides with a Wildco roller press. Scale impressions were read at 43x with a Ken-a-Vision micro-projector. Age was determined by counting the number of annuli on the best of the five impressions. Scale measurements for back-calculating lengths were taken from the scale focus to each annulus and to the margin on a line perpendicular to the anterior edge of the scale. The Frasier method of back calculating lengths was employed using the following formula:

$$L^n = a + \frac{S^n}{S} (L - a)$$

Where:

L^n = fish length at age n

S^n = distance to annulus n

S = scale radius at time of capture

L = length of fish at time of capture

a = the Y intercept which best describes a straight line regression between scale length and body length

High variability in the regression analysis of scale length to body length precluded the use of the calculated intercept (a-value). Therefore, a standard intercept (a=35 mm) was adopted from Carlander (1982) as the constant in the equation. Carlander proposed that the error in intercepts calculated from inadequate or poorly distributed samples (usually too few small specimens as was the case in this study) was greater than the natural variation in intercept values between populations.

It is generally agreed annuli of otoliths are clearer and more accurate than those of scales. As a result, otoliths have been used to verify age determinations by scales (Heidinger and Clodfelter 1987, Maceina and Betsill 1987). Therefore, sagittal otoliths were removed from 100 specimens to verify age derived from scales in the present study. Otoliths were removed only from fresh specimens according to the method of Schneidervin and Hubert (1986) and stored in envelopes. Whole otoliths submerged in water and illuminated with high intensity transmitted light were read under a dissecting microscope.

Growth of black crappie in Lake Anna and the WHTF was compared using frequency distributions and was tested with analysis of covarience (log-normal transformation). The significance level for statistical tests was accepted at 0.05. Growth trends of black crappie over time were compared for fish ages 1-6 using two methods of analysis. The first compared back-calculated lengths of fish the same age from each year class (i.e. the year fish was spawned). The second compared annual incremental growth of each age from year to year (i.e. the amount of growth between successive ages compared annually).

Growth of black crappie in Lake Anna was compared with that of black crappie from other reservoirs (Carlander 1977, Smith and Kaufman 1982, Barswick and Lorenzen 1984). Both ambient and thermally influenced reservoirs were used in the comparison.

Sex ratios of black crappie were determined for the lake and WHTF. Growth of each sex was compared between these two locations and tested with analysis of covariance. Growth of male versus female was then compared combining the two locations and tested with analysis of covariance. Finally, growth in the total lake population was compared to the WHTF population.

Results

A total of 842 black crappie (413 from the lake and 429 from the WHTF) were used in the present study. Electrofishing, the primary collection technique, yielded 67% of the specimens from the lake and 95% of those from the WHTF. Rotenone samples produced 28% and 5% of the lake and WHTF specimens, respectively. Gill netting and angling yielded 5% of the specimens from the lake and less than 1% of those from the WHTF.

Age determination with scales was difficult because of large areas of resorption and numerous false annuli. Therefore, scale readings were verified by a second reader. Otoliths also exhibited multiple checks (false annuli) in the annual growth bands beyond age two, however, it was possible to determine true from false annuli. In general, there was good agreement between ages derived from otoliths and scales. Age distribution of samples was similar between the Lake and WHTF with the four year old age group most frequently represented in both systems (Fig. 2).

Back-calculation produced length data for year classes 1974-1983 from the lake (Table 1). The 1974 and the 1975 year classes were represented by one specimen each, ages ten and seven respectively. Data from the WHTF represented eight year classes from 1976-1983 (Table 2). Because of inadequate sample sizes of older fish from both locations, statistical analyses was limited to age six and under. Year classes prior to 1976 in the lake and prior to 1977 in the WHTF, represented by one specimen each, were not included in determination of growth trends.

The growth curve constructed for the lake population depicted a slow growth rate as indicated by the shallow slope of the curve. Growth rate of crappie in the WHTF did not differ significantly from that of the lake population (Fig. 3).

There was no significant difference (p .05) in the lengths of fish of the same sex from the lake and WHTF. Therefore, locations were combined and tested to determine if differences in length existed between sexes. Analysis of covariance indicated sexes were growing at different rates (p .01), however, when frequency distributions were compared, there was no substantial difference (Fig. 4). The ratio of male to female was consistent between the lake (1:1.4) and the WHTF (1:1.5) and because of the similarities of the two populations, sexes were combined for further comparisons between locations.

Comparisons of lengths attained at each age in the lake, when compared by year class, indicated age groups one through four experienced an increase from the 1976 year class to the 1983 year class (Table 1; Fig. 5). Lengths of five and six year olds increased from the 1976 to 1977 year class, but declined in subsequent year classes. Incremental growth analysis (yearly growth) showed an increasing trend only in the growth of age groups one and two (Fig. 6). The growth of fish at age three regardless of year class remained relatively stable. Incremental growth of crappie ages four and five declined slightly in 1982 and 1983, as did age six in 1983.

An increasing overall trend in lengths attained was noted for one and two year old fish in the WHTF, but the increase in age two fish was limited to the 1979 to 1982 year classes (Fig. 7). Lengths attained by three year old fish were variable with no overall trend. A decreasing trend in lengths attained was observed for fish ages four, five and six. Incremental growth analysis revealed only an increase in age group one with the growth of age groups two, three and four relatively constant. During 1983, growth of fish ages five and six declined (Fig. 8).

The growth of crappie over one year old in Lake Anna was found to be below the Virginia state average for reservoirs (Smith and Kauffman 1982) (Table 3). It also was below the average growth of crappie from contiguous states (Carlander 1977).

Discussion

In a stable fish population, it is expected there would be a greater number of young fish (ages 1 and 2) than in older age groups. In the present study, however, collections did not reflect this distribution as the number of fish ages one through three were substantially less than those of age four. Either recent year classes contributed few crappie to the population, or collection methods used were selective toward older fish. If the collections are representative of the populations, the strong age four group should appear as a large number of small crappie in the 1980 collections. This was not the case as rotenone sampling of coves and shore electrofishing have consistently produced low percentages of crappie under age four as early as 1979 in Lake Anna (Virginia Power 1986). It is probable that the collection methodology is age selective. Young crappie have been described as pelagic, occupying the open waters of reservoirs and therefore would be less susceptible to shoreline and cove sampling (O'Brien et al. 1984).

Changes in growth rates were slight and apparently age specific. Frequency distributions were used for general comparisons of the growth rates of crappie from the two areas and between sexes. Length at age analysis of growth trends revealed information on changes in lengths fish attained, but did not accurately indicate at what age those changes occurred. Any change in the growth at one age affects lengths of all subsequent ages for a given year class. The incremental growth analysis provided two types of information. First, it accurately indicated changes in the growth of each age group over time without being biased by previous growth rates. Secondly, by arranging the plot by year of growth rather than year class, it also could be determined whether changes in growth of fish for a given year were limited to a particular age group, or if several ages were similarly affected.

All analyses indicated the growth of crappie from the lake and the WHTF was similar with a slow rate of growth in both populations. Although there were increasing and/or decreasing trends for each age group over time, changes were generally small with the exception of age one fish which showed a decided increase in incremental growth. The dramatic decreases in growth of five and six year old crappie in 1983 is attributed to the high variability of small sample size.

Crappie tend to stunt easily compared to other centrarchids. Scale resorbsion and false annuli probably are characteristic of a stressed population. Factors that could contribute to slow growth of a population are unfavorable water temperature, the quality and availability of food, and overpopulation (Mitzner 1984).

It is unlikely elevated water temperature directly affected the growth of black crappie in the reservoir as crappie in the WHTF, where water temperatures were consistently higher (at least 2 C) than those in the lake, experienced similar growth. Water temperatures in Lake Anna were within the range proposed by Edwards et al. (1982) for optimal growth of crappie. In Keeowee Reservoir, South Carolina, growth of crappie was unaffected by increased water temperatures due to the operation of a nuclear power station (Barwick and Lorenzen 1984); however, it is difficult to follow this analysis since their data seemed to indicate increased growth with the initiation of power generation.

Growth of crappie can be greatly influenced by food availability, especially small forage fish (Edwards et al. 1982).

Typically, as crappie increase in size they undergo a dietary shift from plankton, to insects, to small fish. The shift to fish, if it occurs, is at about 150 mm (Keast 1968, Barwick and Lorenzen 1984, Ellison 1984).

Food studies of crappie in other reservoirs have shown mayfly nymphs are a primary food item (Siefert 1969). Substrate sampling in Lake Anna, yielded low levels of mayfly nymphs (Virginia Power 1986). If mayfly nymphs are the preferred forage of black crappie in Lake Anna, low food availability may have contributed to the slow growth rate of the population.

Adult crappie prefer structure such as shoreline vegetation and submerged brush, both of which were minimal in Lake Anna. The areas of the lake best suited for crappie are beaver lodges, small areas of shoreline vegetation, fish structures and bridge pilings; all of which comprise a small area of the lake relative to its expansive shoreline. Although the overall density of black crappie was low in Lake Anna compared to other reservoirs (Virginia Power 1986), the small areas of suitable habitat in Lake Anna may have been quickly populated to the point of overcrowding resulting in a slow growth rate.

There are other characteristics of Lake Anna that make it a sub-optimal system for the growth of crappie. For example clear cutting prior to impoundment which eliminated structure, contributed to a silty muddy bottom that is unsuitable for black crappie. Depths of the mid and lower portions of the reservoir are greater than those of optimal adult crappie habitat as crappie are essentially shallow water fish (Edwards et al. 1982). Additionally, the upper portion of the reservoir is characterized by high turbidity (a result of intensive farming) which according to Edwards et al (1982) is an unfavorable condition for black crappie.

In conclusion, because of the lack of habitat and possible limited availability of forage, black crappie in Lake Anna have experienced slow growth. Positive actions, such as fish structures constructed in the lake and stocking of threadfin shad, which began in 1983, may improve the growth of crappie through expanded habitat and food availability. Low availability of forage may be a factor in the prevention of growth sufficient to stimulate a dietary conversion from benthic insects to fish. Evaluation of the impact of shad stocking and construction of fish structures must await further study. It is unlikely that Lake Anna will provide a quality fishery for black crappie in the near future since the conditions that now limit growth probably will remain or become worse with increased real estate development of the area that will result in increased siltation and further reduction of shoreline habitat.

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Table 1. Mean calculated length (millimeters) at annulus of black crappie from Lake Anna, VA (number of fish in parentheses).

Year Class	Age 1	2	3	4	5	6	7	8	9	10
1974	71 (1)	95 (1)	134 (1)	160 (1)	177 (1)	192 (1)	221 (1)	233 (1)	252 (1)	267 (1)
1975	58 (1)	75 (1)	99 (1)	126 (1)	141 (1)	160 (1)	184 (1)			
1976	65 (6)	87 (6)	116 (6)	139 (6)	163 (6)	177 (6)	181 (2)			
1977	70 (8)	104 (8)	131 (8)	153 (8)	180 (8)	194 (8)	179 (1)			
1978	71 (45)	107 (45)	139 (45)	161 (45)	173 (39)	178 (17)				
1979	73 (109)	114 (109)	143 (109)	160 (106)	171 (92)					
1980	77 (158)	118 (158)	147 (157)	165 (157)						
1981	82 (56)	124 (56)	152 (56)							
1982	88 (13)	130 (13)								
1983	92 (16)									
Mean	76 (413)	116 (397)	145 (383)	162 (324)	172 (147)	182 (33)	189 (5)	233 (1)	252 (1)	267 (1)

Table 2. Mean calculated length (millimeters) at annulus of black crappie from the North Anna WHTF, VA (number of fish in parentheses).

Year Class	Age 1	2	3	4	5	6	7
1976	61 (1)	86 (1)	123 (1)	144 (1)	165 (1)	187 (1)	
1977	70 (8)	112 (8)	148 (8)	173 (8)	195 (8)	219 (6)	183 (1)
1978	73 (22)	112 (22)	144 (22)	167 (22)	189 (19)	183 (10)	
1979	72 (81)	111 (81)	142 (81)	161 (71)	175 (55)		
1980	76 (242)	113 (242)	142 (240)	162 (236)			
1981	77 (43)	118 (42)	154 (42)				
1982	86 (3)	134 (3)					
1983	77 (22)						
Mean	75 (422)	113 (399)	143 (338)	162 (83)	180 (17)	183 (1)	

Table 3. Comparisons of black crappie growth (millimeters) from Lake Anna, VA; Keowee Reservoir, SC; the Virginia state average for reservoirs; and the average for the waters of DE, MD, NC and SC.

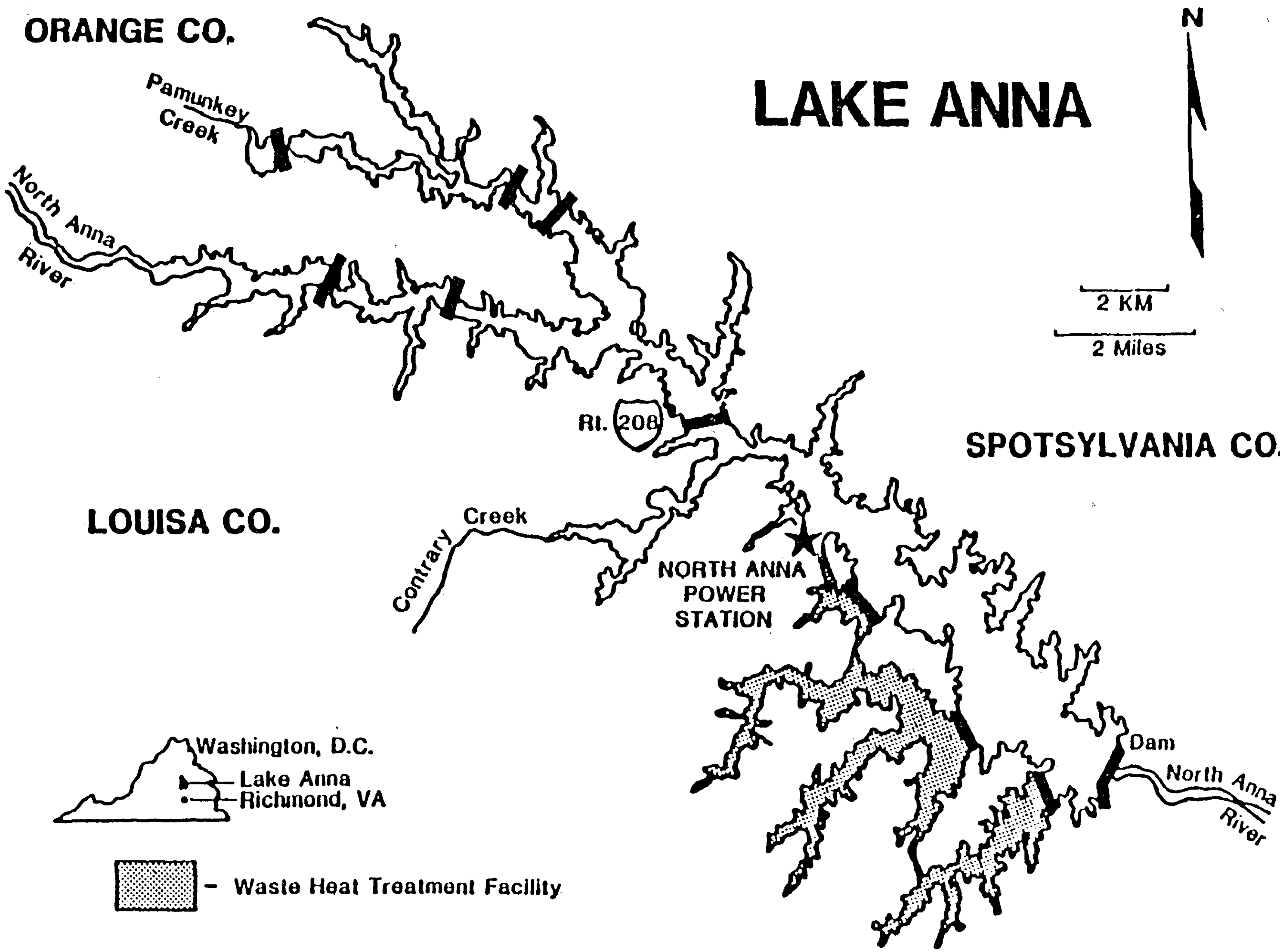
	Age									
	1	2	3	4	5	6	7	8	9	10
Lake Anna, VA	76	116	145	162	172	182	189	233	252	267
Mean for VA Reservoirs [1]	86	155	218	249	292	310	345			
Keowee Reservoir [2]	74	145	206	246						
Mean for DE, MD, NC and SC waters [3]	75	148	197	242	291	323	350	360		

[1] Smith and Kauffman 1982

[2] Barwick and Lorenzen 1984

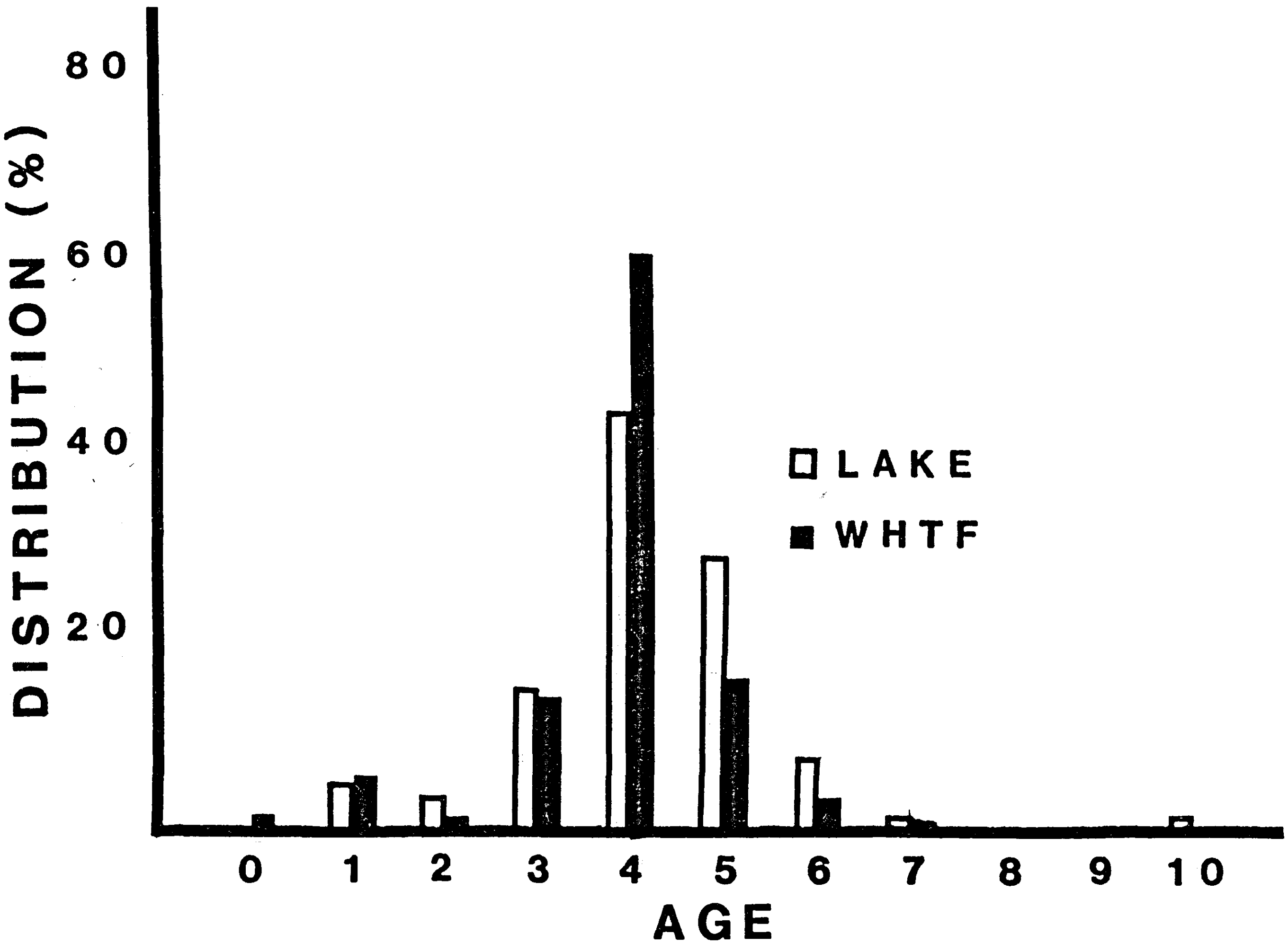
[3] Carlander 1977

Fig. 1. Lake Anna, VA.



ORANGE CO.
LAKE ANNA
N
2 KM
2 Miles
Pamunkey Creek
North Anna River
Rt. 208
SPOTSYLVANIA CO.
LOUISA CO.
Contrary Creek
NORTH ANNA POWER STATION
Dam
North Anna River
Washington, D.C.
Lake Anna
Richmond, VA
- Waste Heat Treatment Facility

Fig. 2. Age distribution of black crappie collected from Lake Anna and the North Anna WHTF, VA.



DISTRIBUTION (%)
80
60
40
20
LAKE
WHTF
0
1
2
3
4
5
6
7
8
9
10
AGE

Fig. 3. Frequency distributions of black crappie ages 1-6 from Lake Anna and the North Anna WHTF, VA (range, two standard errors of the mean and mean are indicated).

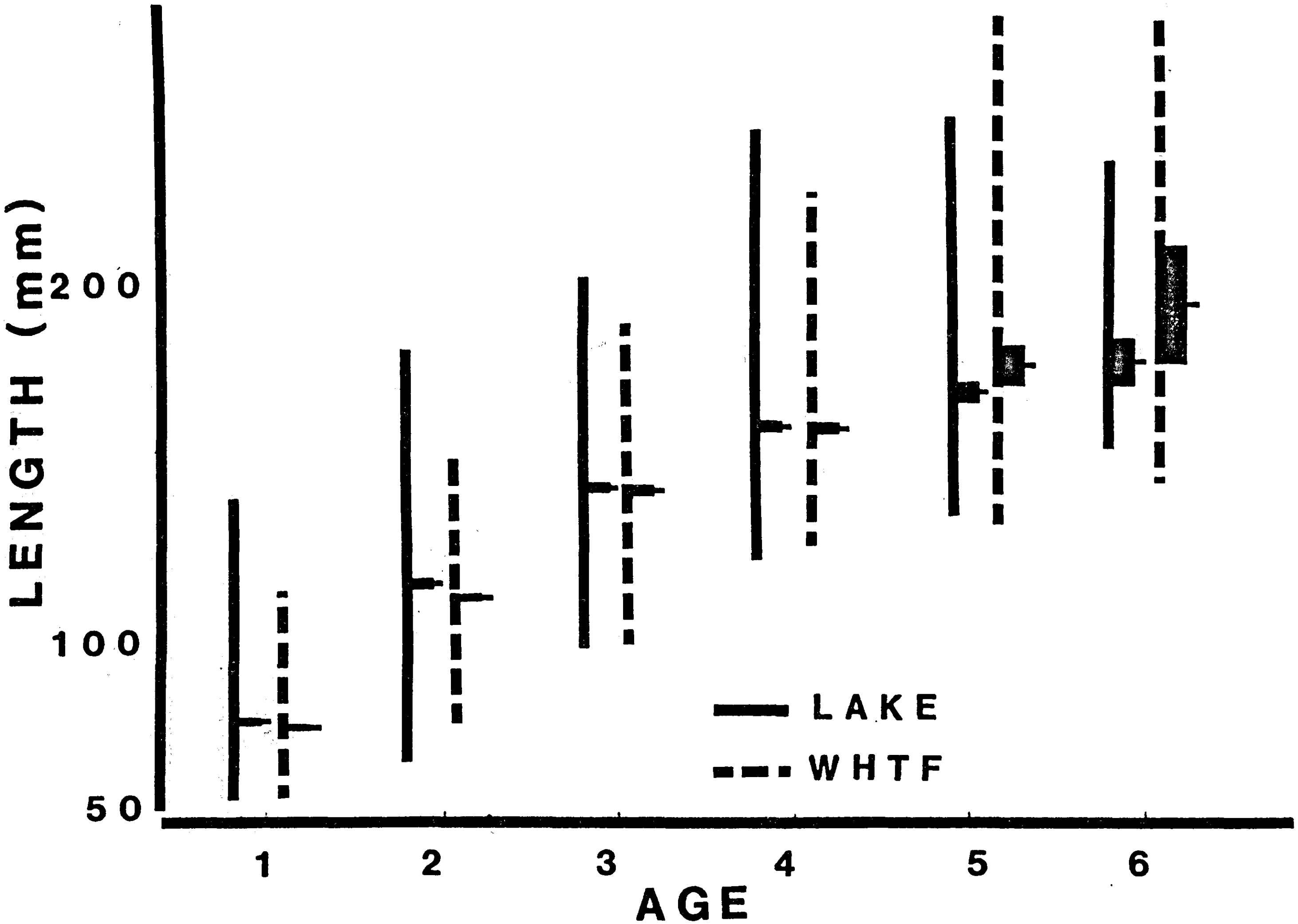
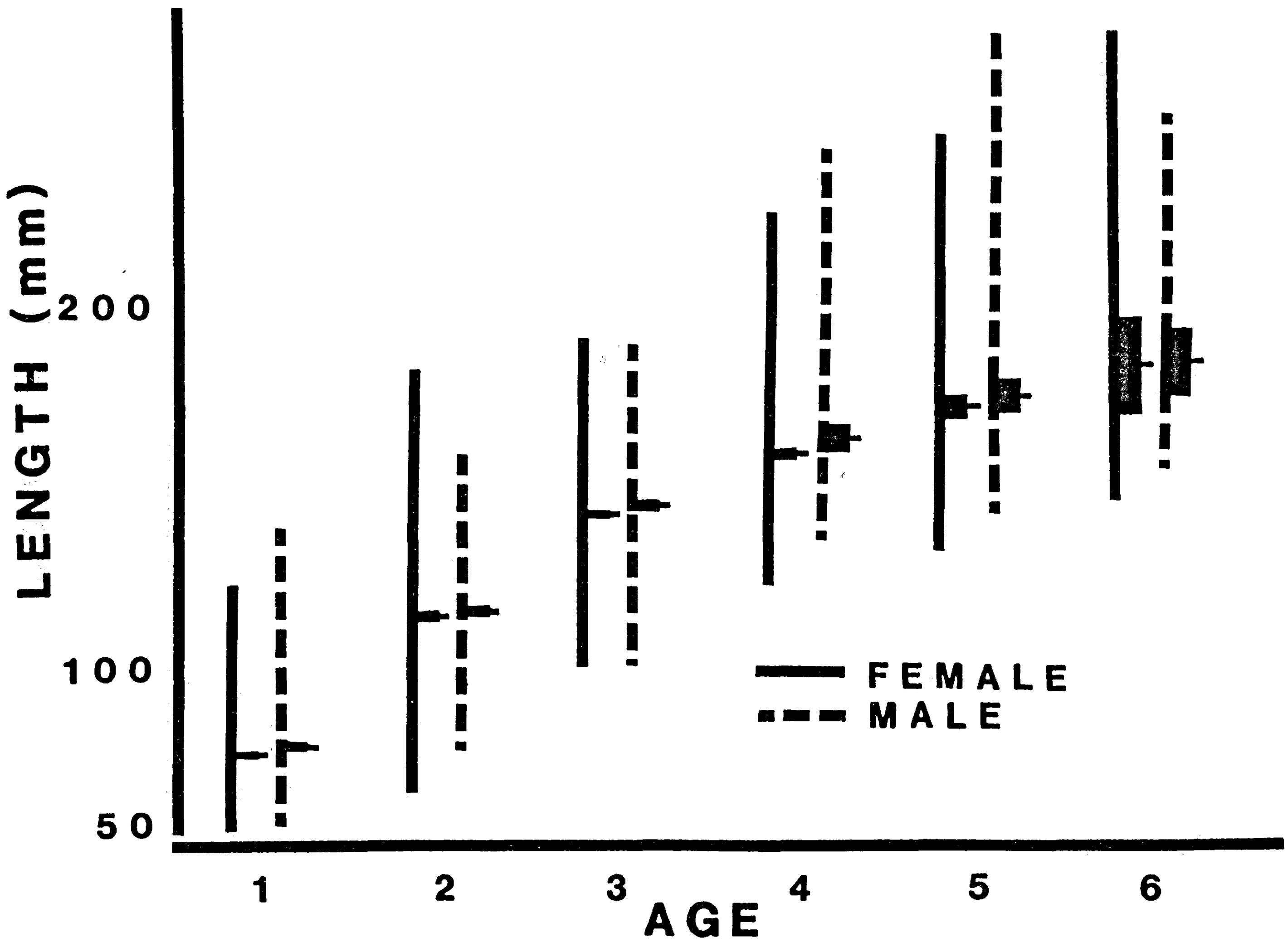
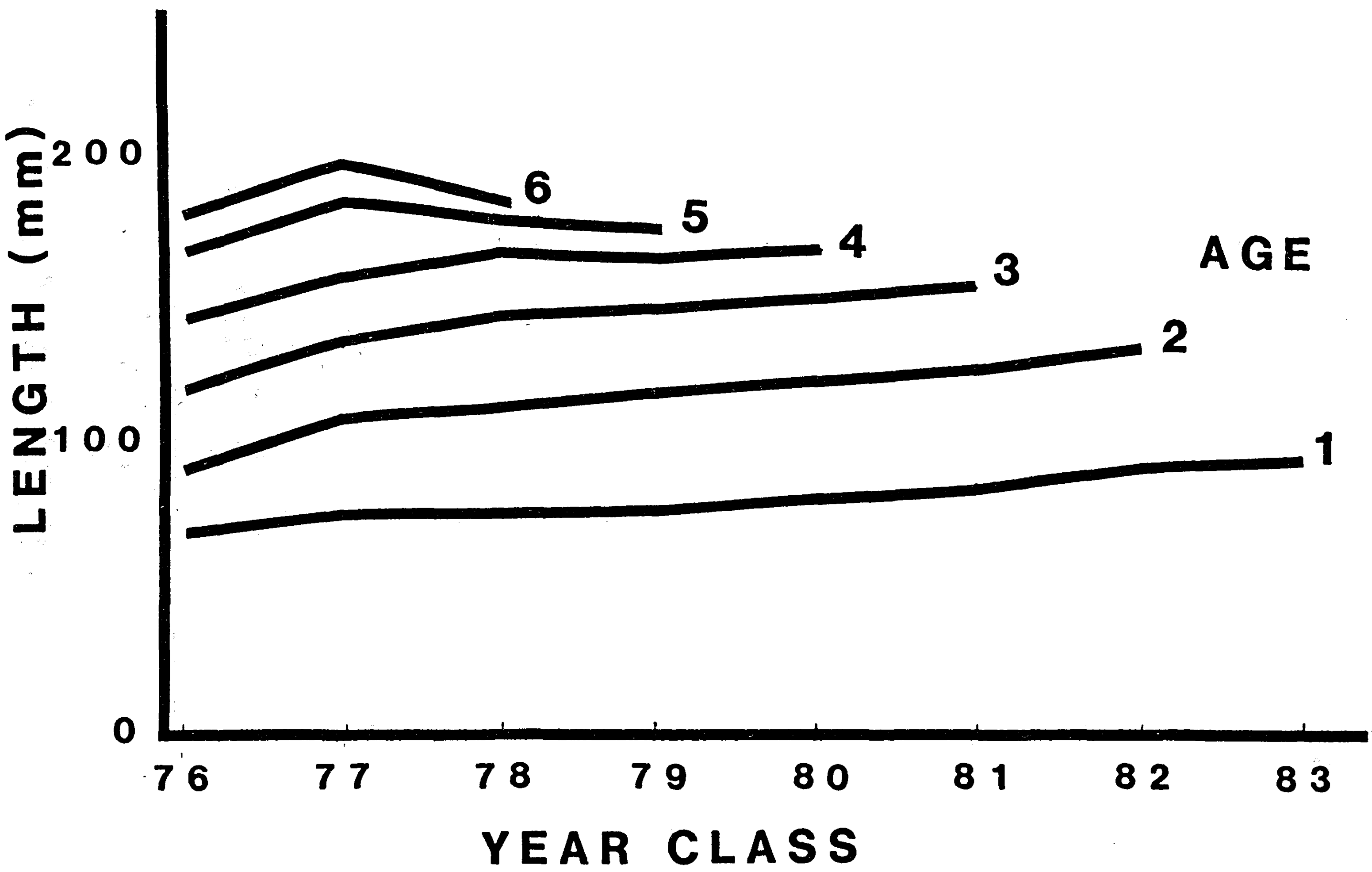

LENGTH (mm)
200
100
50
LAKE
WHTF
1
2
3
4
5
6
AGE

Fig. 4. Frequency distributions of male and female black crappie ages 1-6 using combined data from Lake Anna and the North Anna WHTF, VA (range, two standard errors of the mean and mean are indicated).



LENGTH (mm)
200
100
50
1
2
3
4
5
6
AGE
FEMALE
MALE

Fig. 5. Mean lengths for black crappie ages 1-6 from Lake Anna, VA.



LENGTH (mm)
200
100
0
6
5
4
3
2
1
AGE
76
77
78
79
80
81
82
83
YEAR CLASS

Fig. 6. Incremental growth values for black crappie ages 1-6 from Lake Anna, VA.

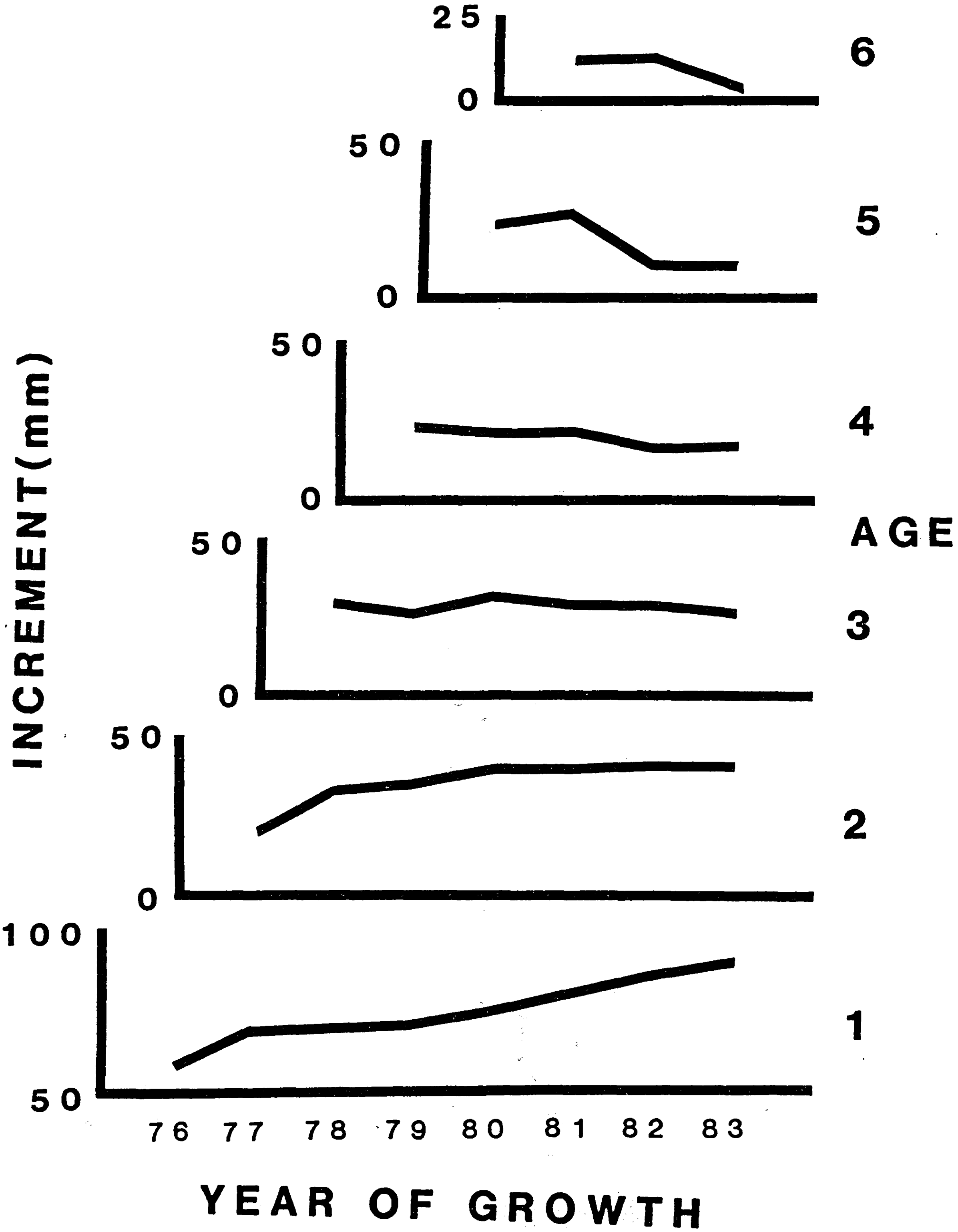
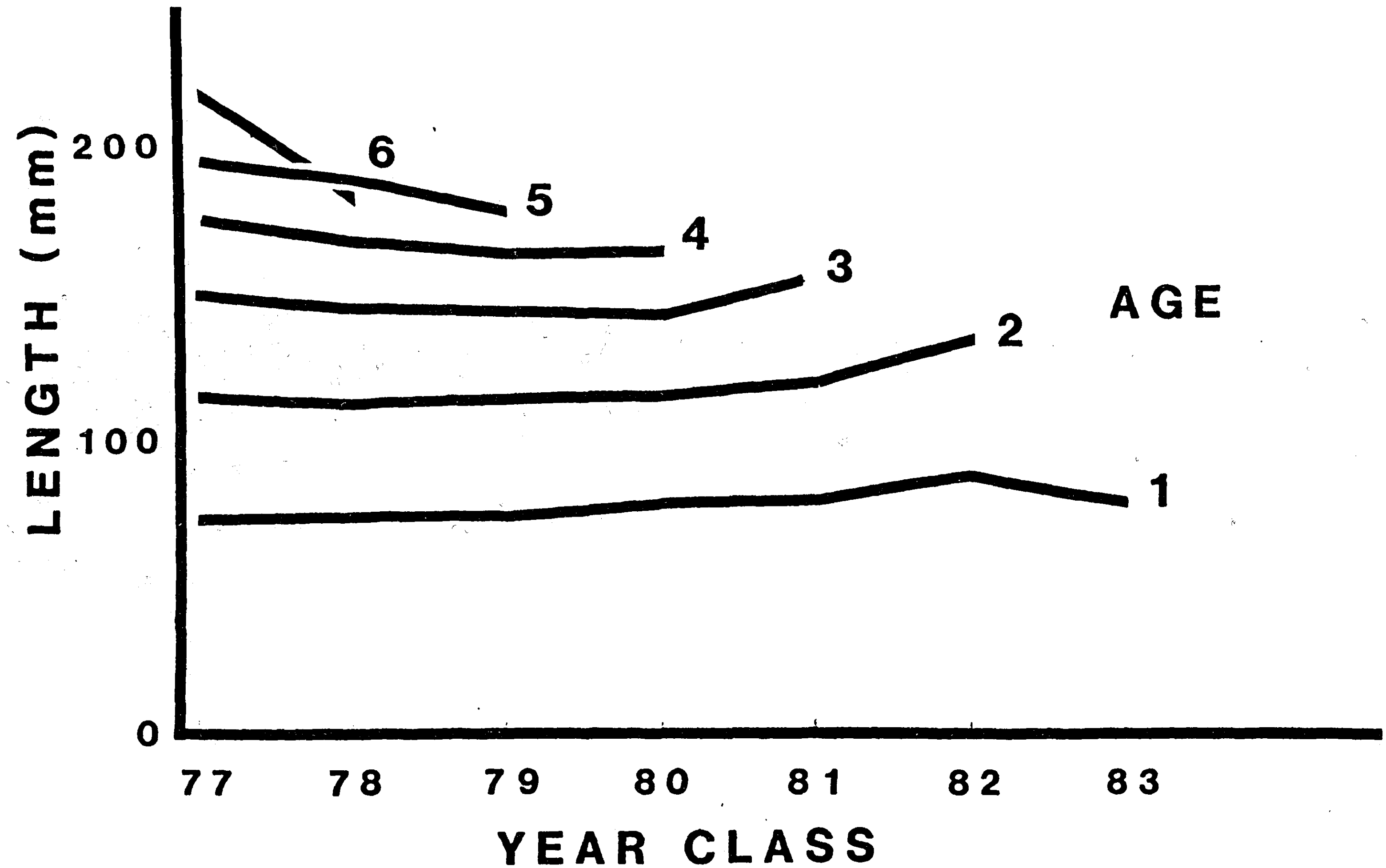
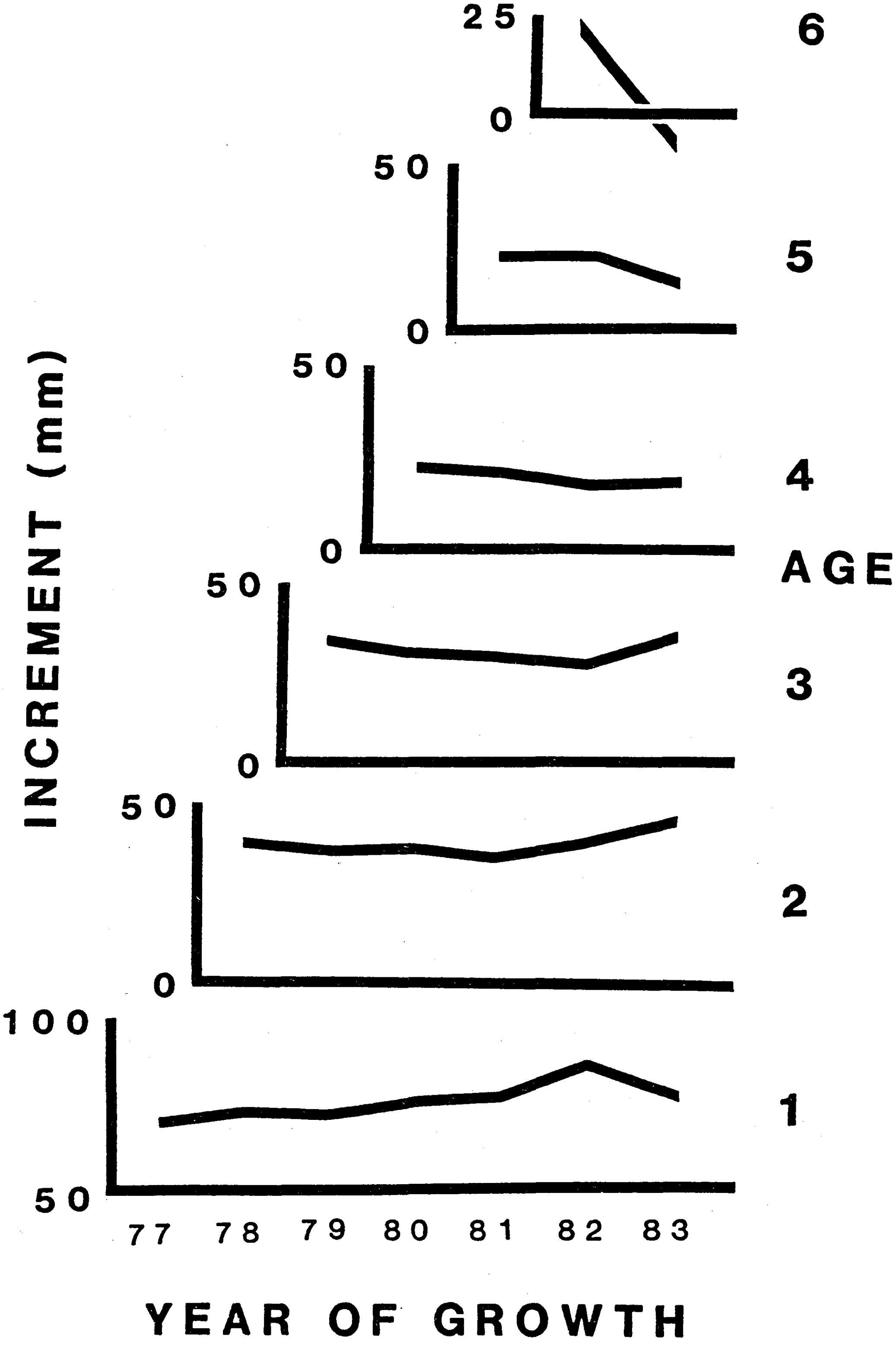

25
0
6
50
0
5
50
0
4
AGE
50
0
3
50
0
2
100
50
1
INCREMENT(mm)
76
77
78
79
80
81
82
83
YEAR OF GROWTH

Fig. 7. Mean lengths for black crappie ages 1-6 from the North Anna WHTF, VA.



LENGTH (mm)
200
100
0
6
5
4
3
2
1
AGE
77
78
79
80
81
82
83
YEAR CLASS

Fig. 8. Incremental growth values for black crappie ages 1-6 from the North Anna WHTF, VA.


INCREMENT (mm)
25
0
6
50
0
5
50
0
4
AGE
50
0
3
50
0
2
100
50
1
77 78 79 80 81 82 83
YEAR OF GROWTH

VITA

Robert Mason Daniels was born October 4, 1961 in Arlington, Virginia. He graduated from Yorktown High School in 1979 and received his BS Degree in Biology from the University of Richmond in 1983. He attended the University of Richmond Graduate School and received his MS Degree in Biology in August 1987. During his second year of graduate study he accepted the position of environmental technician with Virginia Power. He was married to Susan Burt in March, 1986.