1-1-1993

Reproductive Biology of the Bowfin, Amia Calva Linnaeus, from the Green Bottom Wildlife Management Area, Cabell County, West Virginia

Katie Lee McGinn Daniels
msinbs93@yahoo.com

REPRODUCTIVE BIOLOGY OF THE BOWFIN, *AMIA CALVA* LINNAEUS, FROM THE GREEN BOTTOM WILDLIFE MANAGEMENT AREA, CABELL COUNTY, WEST VIRGINIA

A Thesis

Presented to

the Faculty of the Graduate School

Marshall University

In Partial Fulfillment

of the Requirements for the Degree

Masters of Science

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by

Katie Lee McGinn Daniels

July 1993

ACKNOWLEDGMENTS

I would like to thank everyone in the lab for all of their help in the field and for their moral support during the anxious times. First, I would like to express my deepest gratitude to my advisor Dr. Donald Tarter for giving me the opportunity to do this research and for his superior guidance every step of the way. Special thanks goes to the two faculty members, Dr. Dan Evans and Dr. Ralph Taylor, for consenting to serve on my graduate committee. I would like to thank John Wirts for the endless hours of field and laboratory work that he put in with me. Many thanks to Tim Hayes, for without him we wouldn't have any bowfin larvae as proof that our bowfin population is spawning. I am forever indebted to Daniel Chaffin for providing me with his expertise in histological techniques. He sacrificed a tremendous amount of his valuable time to help me get the information I needed to confirm many of my assumptions. And, of course, thanks to Tom Jones for finding the bowfin to begin with and also for giving me a hand in the field. I want to thank my wonderful husband Brian for accompanying me to the swamp every once in a while and for all of his patience during those hectic moments when I wasn't very pleasant to be around. I wish to thank my dad for always being willing to go with me to the swamp (he even helped!) no matter what the weather was like; he never wanted me to have to go alone. Finally, and most importantly, I would like to thank both of my parents for their unyielding love, support, and encouragement throughout all of my endeavors. They made all of this possible by making me believe in myself, and it is to them that this work is dedicated.

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ABSTRACT

The bowfin, Amia calva Linnaeus, is the only extant species of the family Amiidae. The Green Bottom Wildlife Management Area (GBWMA) is the home of the only known reproducing bowfin population in the state of West Virginia. The GBWMA (38° 35' 35" N, 82° 14' 55" W) is located along the Ohio River 26 km northeast of Huntington, West Virginia. The area (ca. 364 ha) contains a valuable wetland habitat (ca. 57 ha) in the southwestern portion of the state. A study of the reproductive biology of the bowfin became important when the U.S. Army Corps of Engineers proposed a habitat modification to add replacement marshland by building levees and dykes. The information from this study will establish a baseline for reproductive activities of the bowfin prior to habitat perturbation so that their adaptation to the new environment can be accurately determined. Bowfin were collected seasonally (spring, summer, and fall) by hoop nets, pillow traps, seines, and electrofishing, with the nets and traps being most successful. Attempts were made to determine the duration of the reproductive season by: (1) calculating the seasonal gonadosomatic index (GSI), which was highest in spring fish, lowest during the summer season, and greatly increasing in the fall season, (2) observing seasonal gonadal development using histological techniques, which confirmed that most development occurs during the fall season, and (3) noting the appearance of newly hatched or Y-O-Y larvae, which were collected on May 15. Observations were also made on spawning colors (found only in spring males no younger than two years of age), fecundity ($\bar{x}$ = 22,575), egg diameters (1-2 mm) , and sexual dimorphism

(meristics and morphometrics), which showed significant differences in total length, standard length, body depth, and predorsal length. Females were slightly larger for all four characteristics. The results from this investigation will be compared with previous literature reports.

CHAPTER I

INTRODUCTION

The bowfin, *Amia calva*, is the only surviving species of the ancient family Amiidae and can be found only in eastern North America (Eddy and Underhill, 1974). Although populations are scattered throughout the Ohio River, bowfin communities in West Virginia are rare, and little information is available about them. A population was located in the Green Bottom Wildlife Management Area (GBWMA), in Cabell County, West Virginia. It is the only known reproducing population in West Virginia (Tarter, pers. comm.).

The purpose of this study is to elucidate the reproductive biology of the bowfin in the GBWMA in order to gain an understanding of the spawning habits of the sole reproducing population in the state. The information here also may be valuable in monitoring the existing population and assessing its adaptation to the newly expanded wetland that is being formed adjacent to the existing swamp to replace wetlands destroyed by the implementation of the Gallipolis Locks and Dam Replacement Project.

CHAPTER II

REVIEW OF THE LITERATURE

The bowfin is a cigar shaped fish that is dark olive above and brown to yellow in color below. The long dorsal fin, one of the distinctive properties of the bowfin, extends almost to the round caudal fin. At the base of the caudal fin is a black eyespot, or ocellus, which is often more obvious in the male.

In most areas, bowfin become sexually mature at the age of four (Carlander, 1969). During the spawning season, which runs from late March to June depending on the location (Wallus et al., 1990), mature fish exhibit spawning colors. Sexes can be distinguished at this time because the lower fins of males become bluish-green, and an orange halo forms around the ocellus (Van Meter, 1952). The females tend to be larger than the males and do not exhibit these distinct colorations (Carlander, 1969).

Bowfin spawn along lake margins, stream mouths, and bays in shallow, sluggish or stagnant water 1.2 m or deeper (Wallus et al., 1990). The preferred water is clear with an abundance of vegetation necessary for nest-building (Carlander, 1969). Temperature is the critical factor in determining the exact time of spawning, with the optimal temperatures falling between 16-19°C (Wallus et al., 1990).

The spawning act and care of the young are the responsibility of the male. The male prepares the nest by forming a depression in the muddy bottom near vegetation. He tears out the weeds until the tiny rootlets are exposed (Eddy and Underhill, 1974). Reproduction is nocturnal, and the act consists of the female lying on the bottom of the nest as the male swims around her, periodically nipping her sides and snout. Then he lies beside her in the nest, and both violently agitate their fins until milt and eggs are released (Wallus et al., 1990). The eggs range from 2.2-3.0 mm in diameter (Wallus et al., 1990) and begin to hatch when they reach about 8.0 mm in diameter (Carlander, 1969). This usually takes 8-10 days (McClane, 1965).

The male is responsible for guarding the nest until the eggs hatch and then for brooding the young until they are able to care for themselves. The young have adhesive snouts which are used to cling to the rootlets after they have hatched. At this time, they are black with a lance-shaped caudal fin. As they mature, the caudal fin becomes rounded, and their general appearance is that of a miniature adult. Then they swim in large schools along with the male (Eddy and Underhill, 1974). The young remain with the male until they are about 100 mm in length, but they are only loosely guarded after about 35 mm (Wallus et al., 1990).

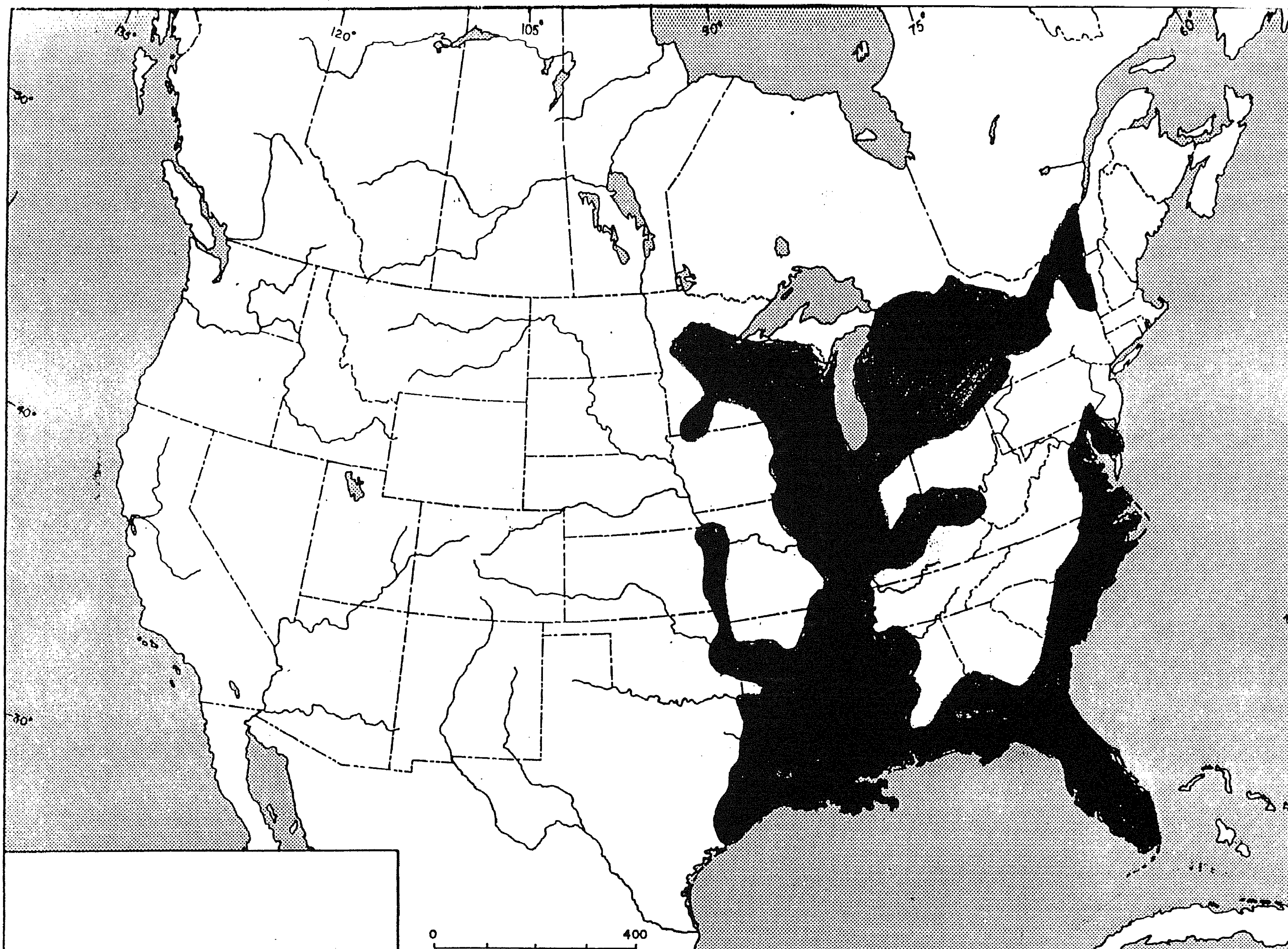
CHAPTER III

TAXONOMY AND DISTRIBUTION

The bowfin is the only extant species of the once flourishing family Amiidae. This Holostean relict, which was most abundant during the middle Mesozoic (Lagler et al., 1977), is now only found in eastern North America from the St. Lawrence River all the way down to Florida and the Gulf of Mexico (Wallus et al., 1990). The western boundary is loose and is usually considered to be the Mississippi River (McClane, 1965), although some populations have moved slightly more west into Texas, Kansas, Oklahoma, and Wisconsin (Page and Burr, 1991) (Fig. 1). In West Virginia, bowfin are uncommon in the upper two thirds of the Ohio River, although they can be found there (Wirts, 1993) (Fig. 2).

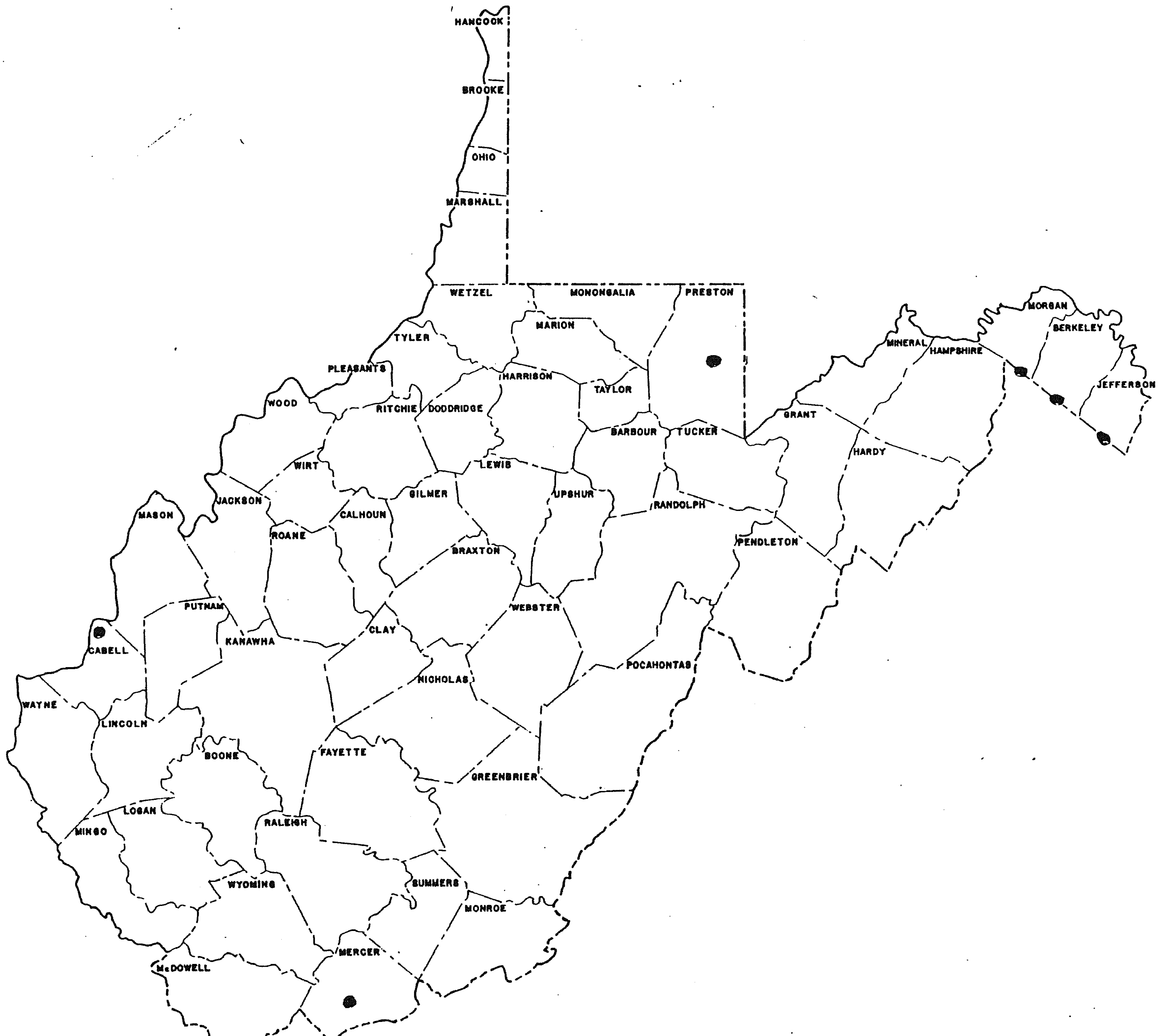
The bowfin inhabits clear sluggish rivers, sloughs, swamps, backwaters and embayments, usually with low dissolved oxygen concentrations. The habitat must contain an abundance of vegetation, as spawning occurs around it, primarily near the roots (Wallus et al., 1990).

Figure 1. Range of the bowfin throughout the United States, indicated by the shaded areas (Page and Burr, 1991).



120°
105°
90°
75°
60°
40°
30°
0
400
MILES
105°
RMB

Figure 2. Distribution of the bowfin in West Virginia, indicated by solid circles (Wirts, 1993).


HANCOCK
BROOKE
OHIO
MARSHALL
WETZEL
MONONGALIA
PRESTON
MARION
TYLER
PLEASANTS
HARRISON
TAYLOR
WOOD
RITCHIE
DODDRIDGE
BARBOUR
TUCKER
WIRT
LEWIS
UPSHUR
RANDOLPH
JACKSON
GILMER
CALHOUN
MASON
ROANE
BRAXTON
PUTNAM
WEBSTER
CLAY
CABELL
KANAWHA
POCAHONTAS
NICHOLAS
WAYNE
LINCOLN
BOONE
FAYETTE
GREENBRIER
LOGAN
MINGO
RALEIGH
WYOMING
SUMMERS
MONROE
MERCER
McDOWELL
PENDLETON
GRANT
HARDY
MINERAL
HAMPSHIRE
MORGAN
BERKELEY
JEFFERSON

CHAPTER IV

DESCRIPTION OF STUDY SITE

The study site location, the Green Bottom Wildlife Management Area (GBWMA), is a naturally occurring wetland between Route 2 and the Ohio River in Cabell County near Homestead, West Virginia. At present, the GBWMA is approximately 364 ha in area, with about 56.7 ha being wetlands (Wirts, 1993). The average water depth fluctuates seasonally from about 0.46-1.23 m and rarely drops below 0.5 m in the inner portion of the swamp (Furry, 1978). However, a mitigation project is now in progress to enlarge the wetland area in order to replace wetlands that were destroyed by the construction of the Gallipolis Locks and Dam. The new section is being formed along the western side of the existing wetland, and the water levels will be controlled with a preservation weir and a levee system (Wirts, 1993).

The largest portion of the swamp is dominated by Buttonbush, *Cephalanthus occidentalis*, with a large occurrence of Marsh Mallow, *Hibiscus mocheutos*. Duckweeds, such as *Lemna minor*, *Spirodella polyrhiza*, and *Wolffia* spp., are common floating plants throughout the area of standing water (Furry, 1978).

The area provides suitable habitat for many animal species. However, due to fluctuating water temperatures and dissolved oxygen concentrations, the fish fauna is severely limited, consisting of bowfin, grass pickerel, central mudminnow (a disjunct population), bluegill, green sunfish, black and yellow bullheads, black and white crappies, carp, and largemouth bass (probably introduced by fishermen) (McGinn et al., 1992).

CHAPTER V

MATERIALS AND METHODS

Field

Collections

Bowfin were collected from the GBWMA in the spring, summer, and fall of 1991. Due to freezing during the winter, collections could not be made at that time. Trapping methods used were hoop nets, pillow or "turtle" traps, seines, and electrofishing, with the latter two being the least successful because of the vast area of the swamp. Captured bowfin were placed on ice to prevent regurgitation and then frozen for later analysis. Attempts to find Young-of-the-year larvae were made using dip nets in shallow vegetated waters where they tend to school and feed. When some were found, they were preserved in a 10 percent formalin solution.

Water Conditions

Upon each trip to the GBWMA, water temperatures were taken using a maximum-minimum thermometer in order to determine when the fish are most active and to compare optimal spawning temperatures to the literature. Water chemistry tests were performed using a Hach chemical kit to determine dissolved oxygen (mg/L), total hardness (mg/L $CaCO_3$), total alkalinity (mg/L $CaCO_3$), and pH.

Laboratory

Weights and Gonadosomatic Ratios

Adult bowfin were thawed overnight before laboratory analysis. Then, they were weighed to the hundredth of a pound using a top loading balance. Sex was determined by observing spawning colors and the gonads after they were removed and preserved in 10 percent formalin. Gonads were weighed (0.0001 g) using an analytical balance. These weights were used to determine the seasonal GSI (percentage gonad weight of the total body weight) in order to estimate the time of development of the gonads.

Morphometrics

Morphometric measurements were made to determine if any characteristics exhibited sexual dimorphism between the males and females. Morphometrics were done using dividers and a millimeter ruler to a hundredth of a centimeter. The total length and standard length were determined using a measuring board. The morphometric measurements were made as follows (Hubbs and Lagler, 1958):

<u>Total Length</u>. The greatest dimension between the most anteriorly projecting part of the head and the farthest tip of the caudal fin when the caudal rays are squeezed together.

<u>Standard Length</u>. The distance from the most anterior part of the head backward to the end of the vertebral column or caudal base.

<u>Body Depth</u>. The greatest dimension, exclusive of fleshy or scaly structures, which pertain to the fin bases.

<u>Depth of Caudal Peduncle</u>. The least depth of the caudal

area before the caudal base.

Length of Caudal Peduncle. The oblique distance between the end of the anal base and the hidden base of the middle caudal ray.

Predorsal Length. The distance from the tip of the snout or upper lip to the structural base of the first dorsal ray.

Length of Dorsal/Anal Base. The greatest overall basal length, extending from the structural base of the first ray to the point where the membrane behind the last ray contacts the body.

Length of Anal Ray. The distance from the structural base of the longest ray to its tip.

Length of Pelvic Ray. The distance from the extreme base of the uppermost, outermost, or anteriormost ray to the farthest tip of the fin, filaments, if any, included.

Length of Pectoral Ray. The distance from the middle of the base of the fin (if the longest ray is at or near the middle of the fin) to the farthest tip of the fin.

Head Length. The distance from the most anterior point on the snout or upper lip to the most distant part of the opercular membrane.

Depth of Head. The distance from the midline at the occiput vertically downward to the ventral contour of the head or breast.

Head Width. The greatest dimension when the opercles, if dilated, are forced into a reasonably normal position.

Snout Length. The distance from the most anterior point on the snout or upper lip to the front margin of the orbit.

Postorbital Length of Head. The greatest distance between the orbit and the membranous opercular margin.

Height of Cheek. The least distance from the orbit downward to the lower edge of the anterior arm of the preopercle.

Length of Cheek. The distance from the most posterior point of the preorbital (lachrymal) horizontally backward to the caudal margin of the preopercle, including spines if present approximately along this horizontal.

Interorbital Widths. 1)Least fleshy width- the dividers are not squeezed at all or 2)Least bony width- the points are pressed tightly against the bone so as to eliminate the thickness of the flesh overlying the bony rims.

Length of Orbit. The greatest distance between the free orbital rims; often oblique.

Length of Upper Jaw. The distance from the anteriormost point of the premaxillary to the posteriormost point of the maxillary.

Width of Gape. The greatest transverse distance across the opening of the mouth.

Meristics

Meristic counts were made for scales (lateral line, above the lateral line, below the lateral line, and around the caudal peduncle) and fin rays (pectoral, pelvic, anal, and dorsal fins). Sexual dimorphism for the morphometrics and meristics was determined using ANOVA and t-tests ($p<0.05$) on the KWIKSTAT computer program. Sex ratios of the GBWMA bowfin population were calculated using the chi-square test to see if they strayed from the expected 1:1 ratio.

Sexual Maturity

Ages of all adult fish were determined by John Wirts using the gular plate method (Holland, 1964; Wirts, 1993). These were used to approximate the ages of sexual maturity for both males and females at the GBWMA as compared to bowfin in other areas.

Fecundity

The fecundity of the females was examined using the volumetric method (Lagler, 1956). A known number of eggs (35 eggs from one ovary) was placed in a water-filled graduated cylinder and the amount of displacement noted. Then, the entire ovaries were placed in a beaker of water, again noting the displacement. The fecundity could then be estimated by the ratio of the displacement from known egg numbers and the water displacement from the entire ovaries: $x_1/v_1 = x_2/v_2$, where x_1 is the known number of eggs, v_1 is the volume of water displaced by x_1, x_2 is the total number of eggs in the whole ovaries, and v_2 is the volume of water displaced by x_2. A linear regression was then done between total length and fecundity for mature females. Egg diameters were also measured.

Histology

Histological techniques were used on the gonads of both mature and immature males and females for each season that collections were made. These were performed to help confirm the developmental results that were seen in the GSI's. Sections of the ovarian and testicular tissues were made and dehydrated in a butanol series and embedded in paraffin (Brauer, 1961; Johansen, 1940). Cross-sections (10 µm) were made using a microtome equipped with a new razor blade for every couple of paraffin blocks. Sections were mounted and then stained with saffranin and fast green (Holbrook, 1975; Johansen, 1940). Gonadal sections were then compared for seasonal development of oocytes and spermatozoa.

CHAPTER VI

RESULTS AND DISCUSSION

Sex Ratio

Thirty-eight bowfin, twenty-four females and fourteen males, were collected from the GBWMA. In the spring, 11 females and 9 males were collected. In the summer, there were 5 females and 2 males, and in the fall, 6 females and 4 males. According to this, it appears that the bowfin were more active in the spring because it was the spawning season. A chi-square test was run on the total number of bowfin to determine any deviation from a 1:1 ratio (Sprinthall, 1990). The results from this test indicate that there was no deviation from the expected 1:1 ratio.

Sexual Dimorphism

Morphometrics- Twenty-eight fish, 14 males and 14 females, were chosen using the random numbers method to test for sexual dimorphism. In most cases, sexual dimorphism arises as a benefit for reproductive habits. In the GBWMA bowfin, only four characteristics were significantly different (0.05 confidence level) between the males and the females, with the females being the largest in all of them (Table 1). These were total length, standard length, predorsal length, and body depth. It is speculated that the female needs to be larger than the male to accommodate for her large ovaries during the spawning season. To account for differences in size due to age, all of the measured characteristics, aside form total and standard lengths, were divided by the total length to get

Table 1. Morphometric sexual dimorphism in the bowfin collected in the GBWMA.

MEASUREMENT	SEX	MEAN (cm)	RANGE	s	t
TOTAL LENGTH	M F	37.382 42.593	31.9-46.6 35.2-49.5	4.90 4.92	2.37*
STANDARD LENGTH	M F	31.335 35.255	26.8-39.0 28.9-41.2	4.15 3.99	2.15*
BODY DEPTH	M F	0.13222 0.14374	.113-.153 .132-.159	1.22 1.19	2.14*
LENGTH OF CAUDAL PEDUNCLE	M F	0.15609 0.15751	.141-.173 .140-.178	1.11 1.18	0.28
DEPTH OF CAUDAL PEDUNCLE	M F	0.10261 0.10562	.091-.114 .095-.137	0.0091 1.2400	0.62
PREDORSAL LENGTH	M F	0.24790 0.26852	.225-.267 .225-.297	1.4600 2.3400	2.37*
LENGTH OF DORSAL BASE	M F	0.45493 0.45283	.433-.481 .424-.473	1.3800 1.5700	-0.32
LENGTH OF ANAL BASE	M F	0.07255 0.07161	.063-.080 .063-.081	0.0088 0.0062	-0.28
LENGTH OF ANAL RAY	M F	0.09772 0.09675	.093-.103 .089-.106	0.0038 0.0058	-0.44
LENGTH OF PECTORAL RAY	M F	0.10168 0.09782	.096-.110 .091-.111	0.0039 0.0061	-1.68
LENGTH OF PELVIC RAY	M F	0.09999 0.09715	.094-.105 .091-.105	0.0039 0.0044	-1.52
HEAD LENGTH	M F	0.19394 0.19969	.183-.213 .182-.219	0.0960 0.0130	1.14
HEAD DEPTH	M F	0.11688 0.12227	.107-.132 .112-.134	0.0082 0.0074	1.55
HEAD WIDTH	M F	0.11419 0.11137	.100-.136 .104-.116	0.0110 0.0064	-0.71
SNOUT LENGTH	M F	0.06287 0.06437	.060-.069 .055-.072	0.0031 0.0049	0.81
POSTORBITAL LENGTH OF HEAD	M F	0.14321 0.14384	.131-.152 .125-.166	0.0069 0.0120	0.15
CHEEK HEIGHT	M F	0.08746 0.09220	.081-.094 .087-.102	0.0044 0.0060	2.01
CHEEK LENGTH	M F	0.10542 0.11066	.095-.119 .097-.123	0.0069 0.0084	1.52

INTERORBITAL WIDTH	M F	0.06937 0.07050	.063-.078 .067-.074	0.0049 0.0024	0.66
LENGTH OF ORBIT	M F	0.02687 0.02672	.023-.031 .022-.034	0.0033 0.0035	-0.10
LENGTH OF UPPER JAW	M F	0.09464 0.09288	.088-.108 .086-.100	0.0059 0.0039	-0.79
WIDTH OF GAPE	M F	0.06993 0.07263	.061-.082 .063-.087	0.0065 0.0068	0.91

* Significant at the 0.05 confidence level.

relative values.

Meristics- Counts were made on the same set of fish. No significant differences for these were found, and the counts obtained correspond well with the literature (Page and Burr, 1991) (Table 2).

Spawning Act

An attempt was made to observe spawning in the field and laboratory. Observation could not be made in the field due to their nocturnal habits. In the laboratory, both bowfin were males. Nevertheless, observations could be made on spawning colors. In mid-February 1993, when the temperature of the water rose to about 16°C, the fish began to exhibit spawning colors, such as the orange halo around the ocellus, bluish-green lower fins, and chainlink markings on the body.

Sexual Maturity

The age groups of the fish were determined and compared to the extracted gonads and fish possessing spawning colors in order to estimate the age of sexual maturity of the GBWMA bowfin population. Three age groups (I, II, III) were found (Table 3). All of the males that exhibited spawning colors were two years of age and ranged between 31.9 and 37.3 cm total length. No three year old males had spawning colors because none were found in the spring. The only mature females, determined by egg filled ovaries, were in age group III and ranged between 44.4 and 49.53 cm total length. These results indicate that the males are maturing when they are two years

Table 2. Sexual dimorphism with respect to meristic counts in the bowfin collected in the GBWMA.

MERISTIC COUNTS	SEX	MEAN	RANGE	s	t
SCALES					
LATERAL LINE	M F	67.6 68.9	66.5-69.0 65.0-73.0	0.7379 2.0790	1.86
ABOVE THE LATERAL LINE	M F	9.4 9.2	9.0-10.0 9.0-10.0	0.5164 0.3375	1.28 (-)
BELOW THE LATERAL LINE	M F	12.8 12.8	12.0-14.0 12.0-13.5	0.6325 0.5869	0.00
AROUND THE CAUDAL PEDUNCLE	M F	35.1 36.1	34.0-38.0 34.0-38.0	1.3703 1.2867	1.68
FINS					
PECTORAL FIN RAYS	M F	16.9 16.8	16.0-18.0 14.0-18.0	0.5676 1.0328	0.27 (-)
PELVIC FIN RAYS	M F	7.8 7.7	7.0- 8.0 7.0- 8.0	0.4216 0.4830	0.49 (-)
ANAL FIN RAYS	M F	11.4 11.6	11.0-12.0 11.0-12.0	0.5164 0.5164	0.87
DORSAL FIN RAYS	M F	49.4 50.5	45.0-52.0 49.0-52.0	2.4129 1.2472	1.28

Table 3. Summary of the age groups of the bowfin caught in the GBWMA, indicating dates collected and fish possessing spawning colors to determine sexual maturity.

DATE	I	TL	DATE	II	TL	DATE	III	TL
10-17-91	M	26.2	*4-13-91	M	37.5	4-13-91	F	44.4
			*4-13-91	M	36.7	*Spring	M	41.7
			*4-13-91	M	35.1	7-16-91	M	43.4
			*4-13-91	M	36.5	7-16-91	F	44.7
			*4-13-91	M	33.5	7-17-91	F	47.4
			4-18-91	F	38.4	7-19-91	F	44.9
			4-18-91	F	39.8	7-19-91	F	45.6
			4-18-91	F	37.7	8-1-91	M	43.5
			4-18-91	F	35.2	8-9-91	F	44.5
			4-18-91	F	38.2	10-17-91	F	46.3
			4-18-91	F	37.2	10-18-91	M	46.6
			4-18-91	F	35.9	10-24-91	F	46.0
			4-18-91	F	35.8	10-29-91	M	45.7
			*4-18-91	M	35.3	10-29-91	F	49.5
			*4-18-91	M	35.0	11-7-91	F	45.9
			*Spring	M	37.3	11-7-91	F	45.0
			Spring	F	39.3			
			Spring	F	39.2			
			10-18-91	M	31.9			
			11-7-91	F	33.9			

* Spawning colors.

old, and the females take an extra year and mature at three years. The extra year for the females is probably indicative of the larger size necessary to accommodate the egg capacity and the extra time and energy needed to produce mature ova.

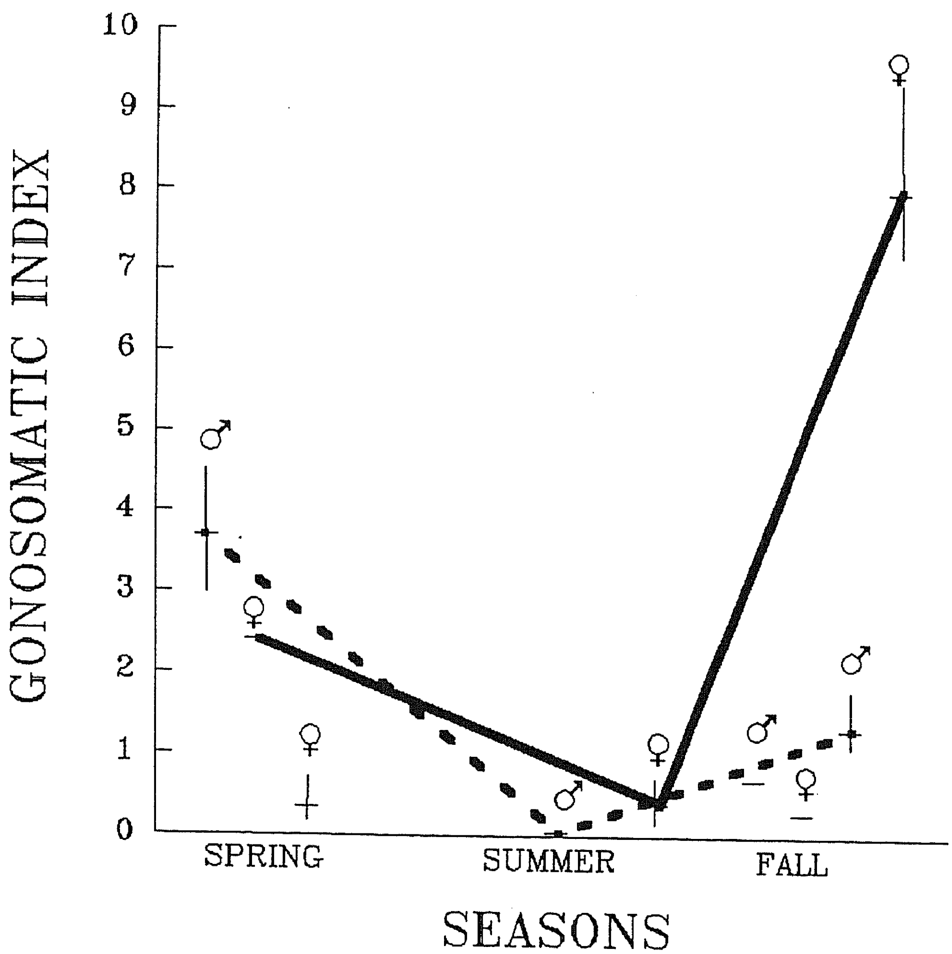
Seasonal Gonadosomatic Index (GSI)

A ratio of gonad weight to body weight was calculated to determine the correlation between percentages of gonad weights and time of spawning. For the immature fish, there was no obvious change in the GSI's. However, the mature fish displayed expected results, with the highest GSI being in the spring and the lowest being in the summer after spawning had occurred (Fig. 3). The fish, particularly the females, also showed a dramatic increase during the fall season, leading one to believe that the gonads are developing most at this time and holding over winter until the spring when spawning conditions are optimal. Only one mature female was collected during the spring season, and her GSI was much lower than the fall females', which were comparable in size. Since females tend to spawn with more than one male during a season, this female is believed to have already spawned at least once, explaining her lower GSI (Wallus et al., 1990).

Fecundity

The fecundity of a female is the number of mature ova found in the ovaries. Only six females were collected with developing eggs, five in the fall and one in the spring. The other mature females, determined by age, were collected during

Figure 3. Seasonal changes in the GSI of male and female bowfin from the GBWMA. Vertical lines = ranges, horizontal lines = means.



GONOSOMATIC INDEX
10
9
8
7
6
5
4
3
2
1
0
SPRING
SUMMER
FALL
SEASONS

the summer after the eggs had been dispensed. A linear regression was done to determine any correlation between total length and fecundity. The fall females were 49.53 cm, 46.3 cm, 45.9 cm, 46.0 cm, and 45.0 cm total length and had egg numbers of approximately 23,100, 22,225, 21,700, 25,200, and 20,650, respectively, which averaged at 22,575. The spring female was 44.4 cm in total length and only had an approximate egg count of 7,700 so was not included in the regression. The regression equation for the fall females was $y = 8072.661 + 311.57x$, with a Pearson's r (correlation coefficient) of 0.3157 and an r^2 of 0.0996. These results show almost no correlation between length and fecundity, which is probably due to the very small sample size used. In some cases, a correlation between length and fecundity in bowfin has been shown (Wallus et al., 1990), thus the spring female could have been expected to have closer to 20,000 eggs because she was in the same length range as the fall females. This assumption gives further evidence that this female had already spawned at least once. Since most females lay 2,000-5,000 eggs per nest, this fish may have already spawned twice (Wallus et al., 1990).

The egg numbers of the fall fish are comparable to other bowfin of their size with reports showing 30,170 eggs in a 48.9 cm fish and an average of 21,332 eggs in 34 mature females ranging from 47.0-84.3 cm total length (Wallus et al., 1990). The yellowish-white eggs of the GBWMA population ranged from 1-2 mm in diameter as compared to other populations which had egg diameters ranging from 2.2-3.0 mm (Wallus et al., 1990).

Histology

The gonads of mature and immature males and females from each season were histologically compared to help confirm the GSI results and to determine the time of year when most gonadal development was occurring. In the spring season, there were nine mature males and one mature female. In the summer season, there were two and five, and in the fall, there were three and five.

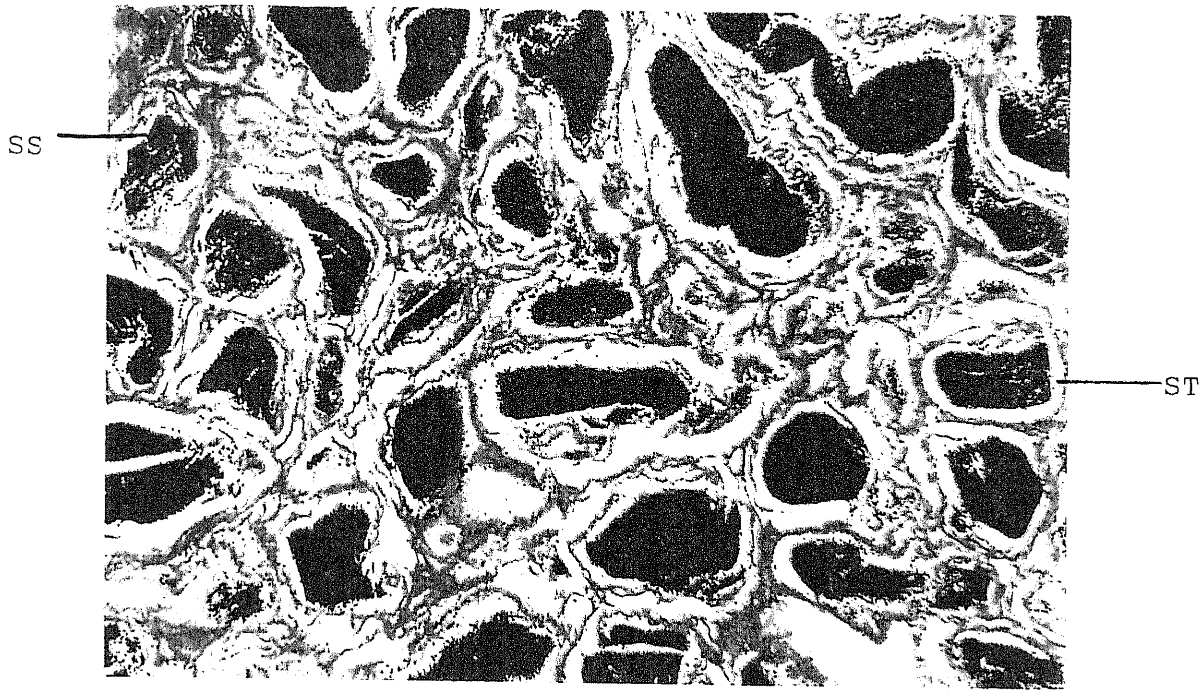
The mature fall males possessed seminiferous tubules completely full of secondary spermatocytes or possibly even full-fledged spermatozoa (Groman, 1982) (Fig. 4a). They looked capable of spawning if the conditions were right. Testes of the spring males were very similar to these except that their seminiferous tubules were partially empty, indicating that spawning may have already occurred (Fig. 4b).

The mature fall female had developing ova with the beginnings of yolk granules (Fig. 5a). Mature oocytes of the spring female differed only slightly in size, being somewhat larger, and in the further development of yolk vacuoles (Fig 5b). These were compared to an immature spring female which contained only primary follicles with no yolk formations (Groman, 1982) (Fig 5c).

These results indicate that most of the testicular and ovarian development is occurring during the fall, and the spermatozoa and ova are held over winter until the conditions, primarily temperature, are optimal for the survival of their young.

Figure 4a. Cross-section of a mature testes from a male bowfin collected in the fall season. Notice that the seminiferous tubules are full of secondary spermatocytes (red granules). Microscope was set at 200x. SS = Secondary spermatocytes, ST = Seminiferous tubule.

Figure 4b. Cross-section of a mature testes from a male bowfin collected in the spring season. Notice that the seminiferous tubules of this fish are almost empty although the size and structure of the tubules are comparable to the fall male above. Microscope was set at 200x. MS = Mature spermatozoa, ST = Seminiferous tubule.


SS
ST

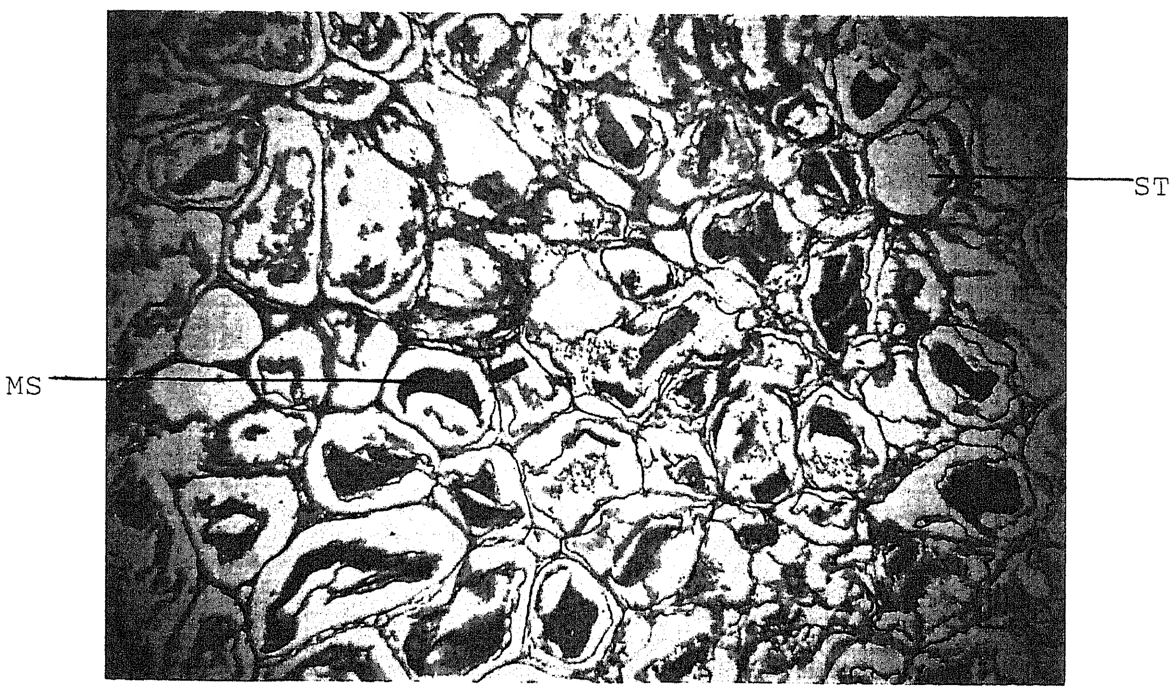

ST
MS

Figure 5a. Cross-section of a mature ovary from a female bowfin collected in the fall season. The large red structure is the secondary oocyte which contains some developing yolk granules (white areas). Microscope was set at 50x. SO = Secondary oocyte, YG = Yolk granule.

Figure 5b. Cross-section of a mature ovary from a female bowfin collected in the spring season. This oocyte is only slightly larger than the fall ovary but shows further development of the yolk vacuoles (white structures). Microscope was set at 50x. MO = Mature oocyte, YV = Yolk vacuole.


YG
SO

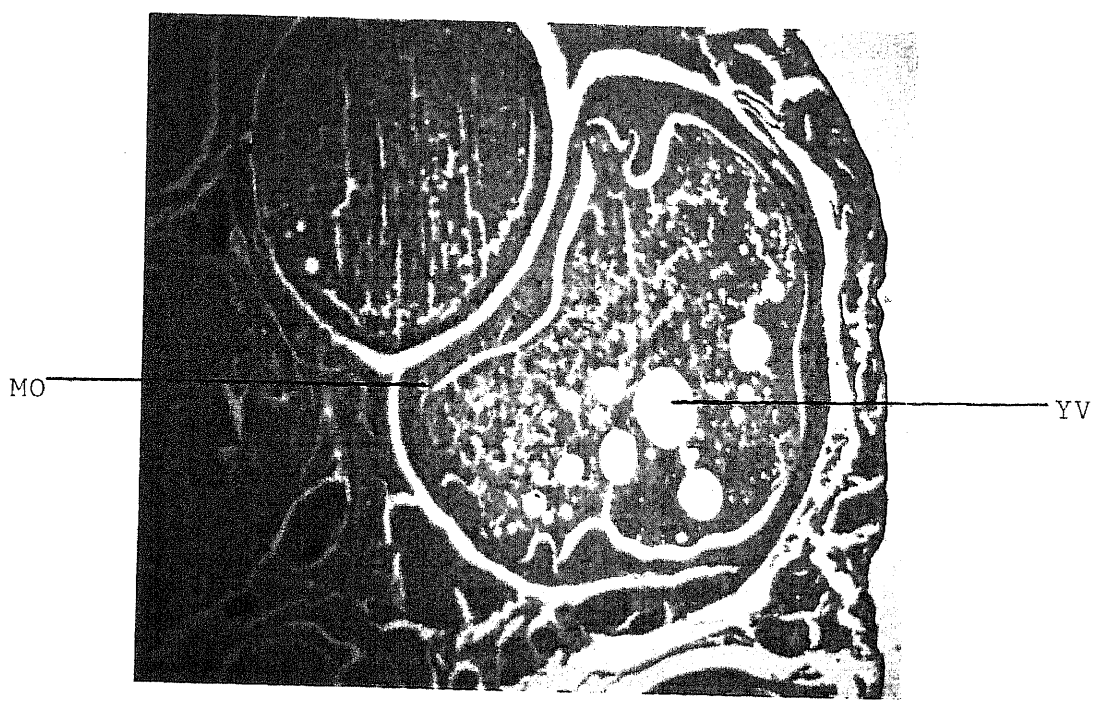
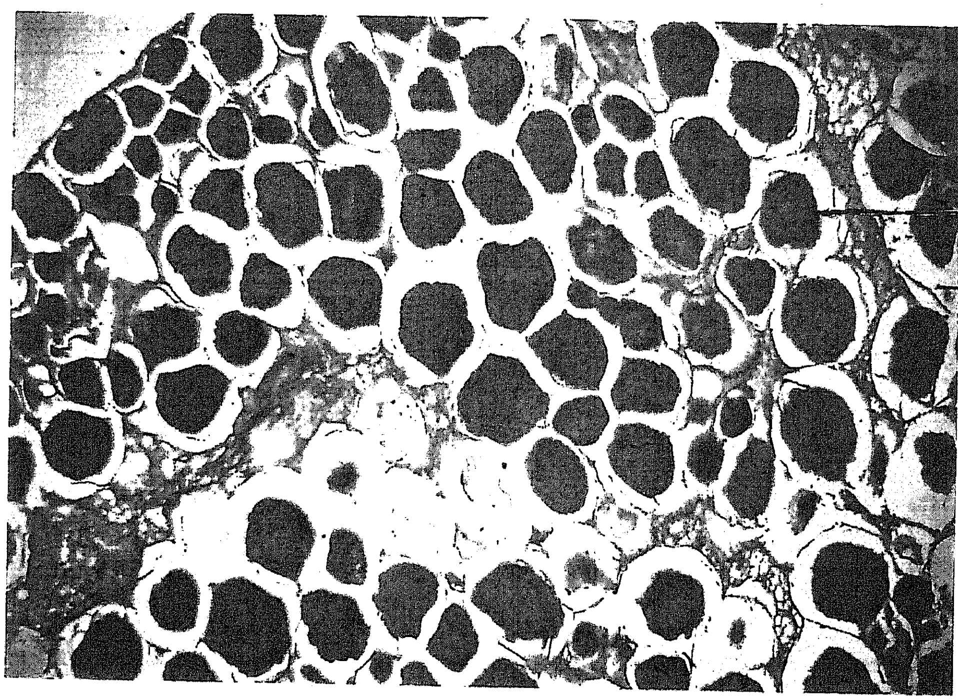

MO
YV

Figure 5c. Cross-section of an immature ovary from a female bowfin collected in the spring season. Notice the small size of these primary follicles and the absence of yolk formations. Microscope was set at 80x. PF = Primary follicle.


PF

Young-of-the-Year (Y-O-Y) Larvae

Young-of-the-year larvae were found on May 15, 1992 by Tim Hayes, who was dredging with a dip net in a heavily vegetated area near the edge of the swamp. Twenty-five larvae were measured and ranged from 23-44 mm in length, with an average of 28.68 mm. According to the literature (Wallus et al., 1990), this size indicates that they are fourth stage post-yolk sac larvae, which generally average at about 28.6 mm total length. At about 30 mm, they would have reached the juvenile stage, which some already had (Wallus et al., 1990). Based on their size, they are estimated to be about two to three weeks old and came from late April spawners (Fig. 6).

Figure 6. Young-of-the-year larvae caught on May 15, 1992. Notice the long dorsal fin and the absence of a yolk-sac along the ventral surface of the larvae.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The Green Bottom Wildlife Management Area bowfin population is spawning throughout the month of April when water temperatures reach about 17°C. Sexual dimorphism was found for total length, standard length, body depth, and predorsal length, with the females being slightly larger in all respects. Three age groups (I, II, III) were found in the population, with males maturing at age two and females at age three. Mature males exhibit spawning colors during the reproductive season.

The GSI showed that most gonadal development is occurring during the fall, and the spermatozoa and ova are being held over winter until the water conditions are optimal in the spring. These results were supported by the histological work done on the gonads, which showed highly developed spermatocytes and oocytes in the fall specimens.

Fecundity ranged from 20,650-25,200 eggs in fall females that were between 45.0 and 49.5 cm total length. The only mature spring female (44.4 cm total length) had only about 7,700 eggs and had probably already spawned since fecundity and length are usually correlated. In all of these females, the egg diameters were between 1-2 mm.

Unquestionable evidence that this bowfin population is reproducing was provided when the Y-O-Y larvae were captured. These fish had an average length of 28.68 mm and strongly resembled the adult bowfin. Larvae were in the late part of their post-yolk sac stage or the very early part of the juvenile stage.

The information from this research will hopefully provide the baseline data necessary to adequately monitor the bowfin population in the GBWMA. After the mitigation project to enlarge the swamp at Green Bottom has been completed, this study may be able to serve as baseline information to begin assessing the bowfin's adaptation to the newly expanded wetland habitat.

LITERATURE CITED

Brauer, A. 1961. Laboratory directions for histological technique. Burgess Publishing Co., Minneapolis, Minnesota.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, Vol. 1. Iowa State University Press, Ames, Iowa.

Eddy, S., and J.C. Underhill. 1974. Northern fishes with special reference to the upper Mississippi Valley. University of Minnesota Press, Minneapolis, Minnesota.

Furry, J. 1978. Vascular vegetation and flora of remnant forests in the Ohio River floodplain between the Great Kanawha and Big Sandy Rivers, West Virginia and Ohio. Unpubl. Master's thesis, Marshall University, Huntington, West Virginia.

Groman, D.B. 1982. Histology of the Striped Bass, Monograph No. 3. American Fisheries Society, Bethesda, Maryland. pp. 53-58.

Holbrook, W.P. 1975. Some aspects of reproduction in the eastern banded darter, _Etheostoma zonale zonale_ (Cope), in Twelvepole Creek, Wayne County, West Virginia. Master's Thesis, Marshall University, Huntington, West Virginia.

Holland, H.T. 1964. Ecology of the bowfin (_Amia calva_ Linnaeus) in southestern Missouri. Master's Thesis. University of Missouri, Columbia, Missouri.

Hubbs, C.L., and K.F. Lagler. 1958. Fishes of the Great Lakes region. The University of Michigan Press, Bloomfield Hills, Michigan.

Johansen, D.A. 1940. Plant microtechnique, 1st ed. The Maple Press Co., York, Pennsylvania. pp. 80-82, 130-150.

Lagler, K.F. 1956. Freshwater fishery biology, 2nd ed. Wm. C. Brown Co., Dubuque, Iowa.

Lagler, K.F., J.E. Bardach, R.R. Miller, and D.R.M. Passino. 1977. Ichthyology, 2nd ed. John Wiley and Sons, New York. p. 27.

McClane, A.J., ed. 1965. McClane's standard fishing encyclopedia and international angling guide. Holt, Rinehart, and Winston, Inc., New York. pp. 142-145.

McGinn, K., T. Hayes, T. Jones, J. Wirts, and D. Tarter. 1992. Ichthyofauna of the Green Bottom Wildlife Management Area, Cabell County, West Virginia, with preliminary observations on the spawning activities of the bowfin _Amia calva_ Linnaeus. Proc. W.Va. Acad. Sci. 64(1): 45 (Abstract).

Page. L.M., and B.M. Burr. 1991. A field guide to freshwater fishes. Houghton-Mifflin Company, Boston, Massachusetts. pp. 31-32, 357.

Sprinthall, R.C. 1990. Basic statistical analysis, 3rd ed. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. pp. 288-308.

Van Meter, H. 1952. West Virginia suffers "horrid hangovers", West Virginia Conservation. Volume XVI(5): 22-23.

Wallus, R., T.P. Simon, and B.L. Yeager. 1990. Reproductive biology and early life history of fishes in the Ohio River drainage. Volume 1: Acipenseridae through Esocidae. Tennessee Valley Authority, Chatanooga, Tennessee.

Wirts, J.C. 1993. Food habits and age and growth patterns for bowfin (_Amia calva_ Linnaeus) from Green Bottom Wildlife Management Area, Cabell County, West Virginia. Master's Thesis. Marshall University, Huntington, West Virginia.