INFLUENCE OF ABIOTIC FACTORS ON WHITE BASS GROWTH IN A SUBTROPICAL TEXAS RESERVOIR

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Joe M. Martin, B.S.

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ABSTRACT

INFLUENCE OF ABIOTIC FACTORS ON THE GROWTH OF A WHITE BASS POPULATION IN A SUBTROPICAL TEXAS RESERVOIR

By

Joe M. Martin, B.S.

Texas State University-San Marcos

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SUPERVISING PROFESSOR: ALAN GROEGER

The effects of abiotic variables on the growth of white bass *Morone chrysops* were examined using twelve years of growth data from Canyon Reservoir, Texas. Air temperature had the greatest influence on growth. Air temperature influenced growth of adults and juveniles in inverse ways. Age 1 white bass displayed a positive relationship with September air temperatures while age 2 to 4 bass were negatively influenced by August air temperatures. Air temperatures in August, above 27° C, caused growth to drop in age 2 to 4 bass. With atmospheric temperatures warming, thermal tolerances could significantly inhibit growth of this species in these subtropical ecosystems.

INTRODUCTION

The dynamics of water column structure in reservoirs can have dramatic influence on available fish habitat. These include many abiotic variables such as lake elevation, inflow, and temperature that must be considered when managing a specific fish population. The climate of the Edwards Plateau in central Texas is characterized by extreme variability in precipitation and runoff (Norwine 1995; Groeger and Tietjen 1998). Thus, reservoirs in this region can be quite variable in respect to river inflow and outflow from year to year, resulting in high interannual variability in water column structure and hypolimnetic temperatures (Groeger and Tietjen 1998).

High flows into Canyon Reservoir in the spring and summer lead to high summer outflow, causing the cold bottom waters left from the previous winter to be released downstream through the hypolimnetic discharge. These cold bottom waters are replaced by the overlying water causing a warming of the hypolimnion (Groeger and Tietjen 1998). Warmer hypolimnetic water will increase microbial metabolic activity, causing an acceleration of oxygen consumption in the deeper waters. The temperature of the hypolimnion at the beginning of spring, and the rate of releases downstream, will determine how quickly deep habitat will be lost to hypoxic or anoxic conditions. This can result in stark contrasts in the reservoir between wet and dry years. In wet years, habitat can potentially be lost quickly through the formation of hypoxic conditions in the hypolimnion, which acts to concentrate predators and forage into the upper waters of the reservoir. This could provide excellent feeding opportunities for white bass, though limiting habitat to the warm summer waters of the epilimnion may result in metabolic demands that increased food consumption may not offset (Hayward and Arnold 1996). Years with dry conditions through the spring and summer result in low outflows, and the hypolimnion will remain cool through fall or winter turnover. The colder water will slow metabolic activity, resulting in less of the water column becoming anoxic (Groeger and Tietjen 1998). This will provide an increase in habitat and cooler refugia from summer water temperatures, but feeding might be reduced due to a wider distribution of forage fish.

In order to assess the influence of the various flow regimes and responding water column structure on the growth of fish, twelve years growth data from Canyon's white bass (*Morone chrysops*) population were examined. The native range of white bass only extend as far south as the Caddo Lake and the Red River drainage basins (Bonn 1956) in north Texas but have been widely introduced throughout the state (Muoneke 1994). It is a very popular sport fish in Texas and is abundant in the state's reservoirs (Wilde and Muoneke 2001).

Precipitation, surface elevation, and temperature are factors that have proven to be critical in white bass abundance. Pope et al. (1997) found strong relationships between precipitation, temperature, and year class strength of white bass, with abundant year classes being produced in warmer years with high spring inflow. Dicenzo and Duval (2002) found that year class strength in three Virginia reservoirs was positively correlated to April inflows. In Kansas reservoirs, water elevations were manipulated by using a spring and autumn rise and a summer and winter drawdown which produced higher catch rates than in pre-managed years (Willis 1986). Beck and Willis (1997) discovered that in age-0 white bass (bass spawned the spring of that year), abundance was highest when lake elevation declined the most from May to July. Yellayi and Kilambi (1976) found that a gradual increase in spring water temperature from 14-26°C produced higher recruitment into the population then if spring warming was very rapid. Temperatures outside this range could be lethal to larvae (McCormick 1978). Temperature is the most significant abiotic factor controlling the growth of fishes (McCauley and Kilgour 1990) though the lack of knowledge regarding temperature tolerances of warm water fish (Eaton and Scheller 1996) make it hard to predict how these reservoir conditions will affect the fishery. Although many studies have focused on abiotic factors contributing to age-0 white bass abundance, few have focused on how these variables affect growth (Staggs and Otis 1996, Wilde and Muoneke 2000).

The purpose of this study is to determine the impact that abiotic factors have in white bass growth throughout their life. The objectives are to determine the relationship that inflow, lake elevation, and air temperature, factors that are important to water column structure, have on the growth of white bass.

METHODS

The study was conducted in Canyon Reservoir, a deep meso-oligotrophic hardwater reservoir on the Guadalupe River in south-central Texas (Hannan et al 1979). Canyon has a surface area of 33.4 km^2 with a maximum depth of 48 m (Groeger and Tietjen 1998). White bass data from 1989 – 1996 was obtained from Texas Parks and Wildlife from their annual sampling of Canyon Reservoir. White bass were collected in the summer of 2001 through the winter of 2002 using experimental gill nets and electrofishing throughout the reservoir . Gill nets were set at sunset and retrieved at sunrise. All white bass collected were measured for total length (mm) and weights (g) were recorded. Sagittae otoliths were removed from each fish for length at age back calculation. Otoliths were sectioned using a Hillquist rock polisher using a 30 micron 3M diamond disc and placed on glass slides using thermoplastic cement for further examination. The sections were used to locate opaque bands and measurements were taken from the radius to individual bands for back calculation using the direct proportion method. Age 2 to 4 year old fish were combined to increase sample size. They were grouped on the basis of diet since age 1 fish are primarily planktonic feeders in there first year of life as opposed to adults that feed on shad. Growth increments were normalized using Z scores to adjust for differences in growth between younger and older fish (Zar 1999). All inflow data was log transformed and was obtained from a USGS gauging station (#08167500) in Spring Branch, TX. Water quality data used in this study was collected by scientists at Texas State University – San Marcos. US Army Corps of Engineers provided lake elevation and discharge data. Air temperature data was taken from the weather station at Boerne, TX. Mean monthly air temperatures were used instead of water temperatures due to the lack of a complete water temperature database and the strong relationship ($r^2 = 0.963$, $P < 0.0001$) to Canyon Reservoir surface water temperature (Groeger and Bass, manuscript submitted). SPSS 8.0 was used in statistical analysis. Initial analysis focused on bivariate relationships between growth and abiotic variables such as seasonal and monthly inflow, air temperature, mean and maximum monthly elevation, reservoir water residence time, and hypolimnetic residence time. The data were explored using graphical techniques and correlation and regression analysis.

RESULTS AND DISCUSSION

A total of 274 white bass were collected between 1989 and 2001, 135 of those coming from Texas Parks and Wildlife. Age 1 fish made up the largest portion of the sample with 151, age 2 with 59, age 3 with 39 and age 4 with 25. Ages 1-3 represented 91% of all fish sampled.

Age 1 white bass growth was positively correlated ($r^2 = 0.50$, $P < 0.005$) with September air temperatures, with growth being highest in years where air temperatures averaged above 25°C (Figure 1). Warm temperatures in September would help to extend growing season length, which has shown to be correlated with white bass growth in other studies (Staggs and Otis 1996, Wilde and Muoneke 2001). Longer growing seasons would increase growth thereby giving better chances for over winter survival (Staggs and Otis 1996).

Temperature tolerance did not seem to be a factor in juvenile growth rates. This coincides with preferred selected temperatures of yearling white bass which average 2-4°C higher than adults (Barans and Tubb 1973). Similarly, juvenile striped bass are able to withstand high summer temperatures that adults were forced to avoid (Coutant 1985).

The growth of age 2 to 4 white bass was negatively affected by the warmer mean August air temperatures. This relationship was best described by a quadratic equation

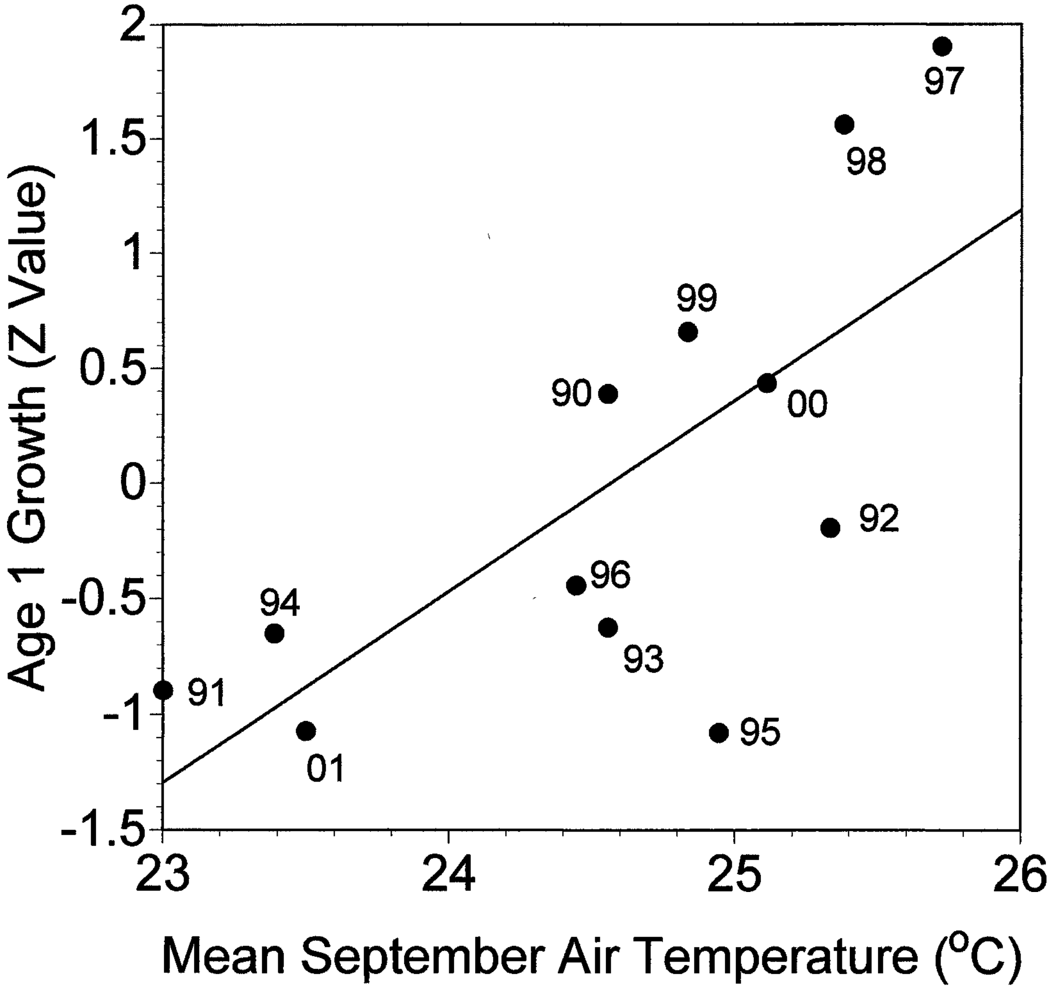

Figure 1. Relationship between mean September air temperature and Z score of age 1 white bass growth from 1990 to 2001 in Canyon reservoir. The linear equation is:

Age 1 Growth = -20.34 + (0.83 * September Air Temperature)

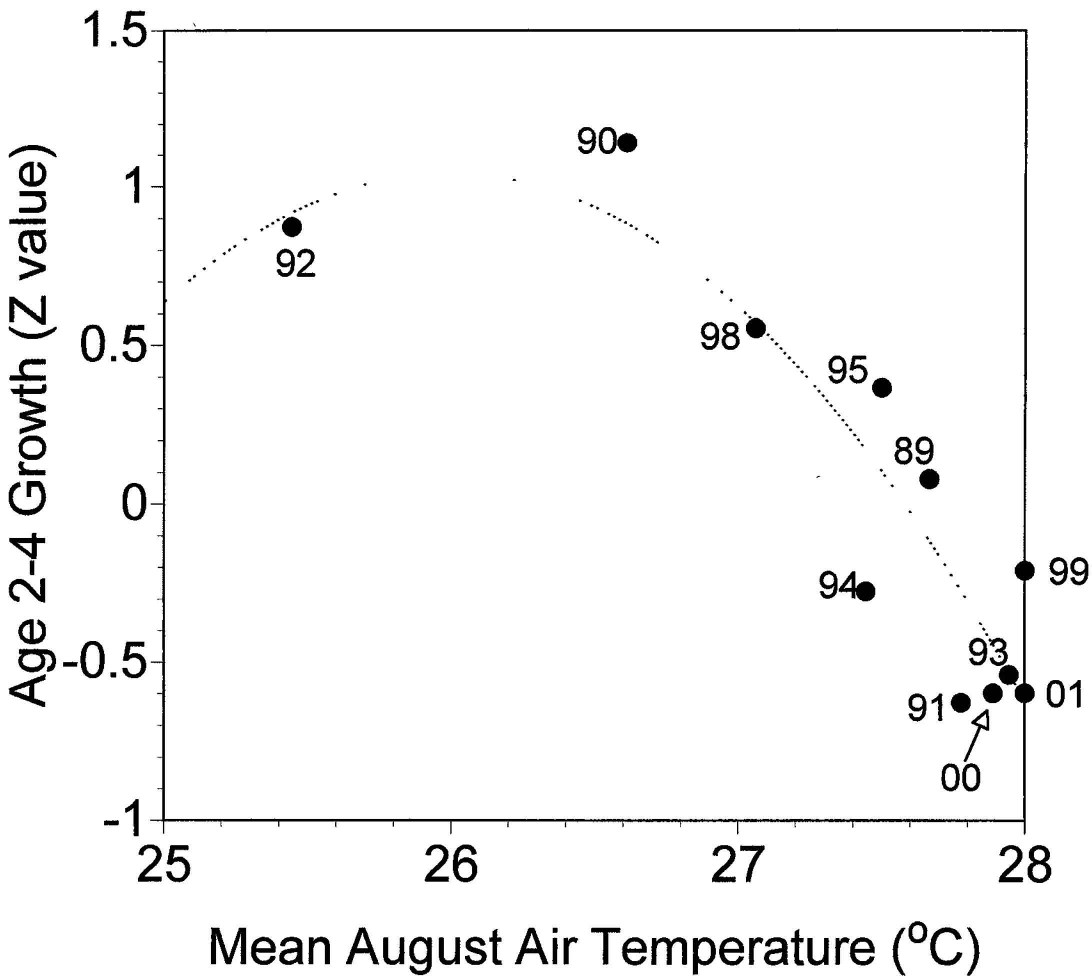

Figure 2. Relationship between mean August air temperature and Z score of age 2-4 white bass growth from 1989 to 2001 in Canyon reservoir. The quadratic equation is:

Age 2-4 growth = -278.03 + (21.47 * August Air Temperature) – 0.41* (August Air Temperature)^2

($r^2 = 0.83$, $P < 0.001$). August typically is the warmest month of the year for Canyon Reservoir in terms of air and water temperature (Groeger and Tietjen 1998). Growth decreased when air temperatures exceeded 27°C (Figure 2). This is similar to reports by McCauley and Kilgour (1990) which showed 28°C to be the air temperature where somatic growth declined in largemouth bass. Wilde and Muoneke (2001) found that growth in white bass decreased in the latitudes south of central Texas, most likely due to thermal extremes. High summer water temperatures have been shown to suppress growth in other warm water species such as striped bass and crappie (Coutant 1985, Hale 1999). Hale (1999) saw prey consumption drop sharply for crappie when water temperature reached 27°C in Kentucky Reservoir. Nordhaus et al.(1998) found that white bass in Florida rarely lived past age 4 and they suggested thermal tolerance as an explanation. These findings coincide with the data collected in this study where no fish over age 4 were collected.

August inflow was positively related ($r^2 = 0.54$, $P < 0.05$) with age 2 to 4 white bass growth, though did not add to the ability to predict growth when used in a stepwise multiple regression with mean August air temperature. This correlation could be linked with air temperature. Summer storms are usually related with high cloud cover (Bomar 1983) which could account for the relationship. Of the five years of the data set in which growth was above average, four years had summer storm events that resulted in increased inflows. These storm events facilitate cooler epilimnetic temperatures as reflected by cooler ambient air temperature. It is not likely that summer inflows had any influence on reservoir water temperature in the epilimnion although productivity could be enhanced by nutrients from the watershed.

Although spring inflows and fluctuations in reservoir elevation have shown to increase abundance in white bass, they did not have an affect on growth of white bass in this study. Increased elevation could provide beneficial foraging opportunities in the foundation of new littoral habitat but due to the pelagic nature of this species these opportunities may not be taken advantage of. Increased abundance does not translate to growth and strong year classes could hinder growth through intra-specific competition.

The white bass population in Canyon Reservoir is artificial and south of its geographical range. The sustainability of this population could be problematic due to temperature tolerances in which growth is suppressed by high temperatures in a warming climate. High summer temperatures could reduce feeding by adult bass to the point that maintenance is no longer possible or eliminate a sustainable population altogether. White bass that are restricted to epilimnetic waters due to hypoxia in the hypolimnion may see a squeezing phenomenon similar to that of striped bass in Tennessee reservoirs (Coutant 1985).

Canyon Reservoir's white bass population is characterized by fast growing, short-lived cohorts. Similar to findings in other southern reservoirs (Muoneke 1994; Nordhaus 1998; Lovell and Maceina 2002), fish over 4 years of age were rare with the majority of the population sampled being 3 years and younger. This age structure is likely due to high natural mortality, possibly caused by thermal stress. Age 1 white bass mean length (225 mm) came in just under Gablehouse's (1984) quality size of 230 mm. Age 2 fish (305 mm) did exceed the preferred size of 300 mm but the memorable size of 380 mm was rarely achieved by any fish collected in the study (Appendix 1). The lack of ability to produce a trophy fishery in Canyon Reservoir may be attributed to upper temperature tolerance of the bass or reservoir trophic status which is in the oligotrophic to mesotrophic range (Hannan et al. 1979).

Understanding environmental conditions and the effect of these conditions on the growth of an organism is paramount to better management of the species. Inflow and more importantly, temperature, play a significant role in the growth of this species. Upper temperature tolerance seems to be the abiotic factor that is most important in determining growth of the adult population of white bass in this reservoir. This becomes more significant when put into context with the geographical location of the population and warming trends in atmospheric temperatures due to global warming. Eaton and Scheller (1996) suggested that a doubling of atmospheric CO_2 would reduce white bass habitat by nearly 50% within North America. If global climate modelers are correct (e.g. Hostetler and Small 1999), white bass populations this far south of natural ranges will almost certainly lose the ability to be self-sustaining.

APPENDICES

Appendix 1. Mean back calculated length at age and standard deviation of white bass in the year of which growth occurred. Parenthetic values represent sample size.

Year	Age 1		Age 2		Age 3		Age 4	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
1989			298.19	14.79	314.02	6 16	381.33	4.62
			(3)		(3)		(2)	
1990	218.45	33.85	358.33	11.06	361.67	12.34	349.33	4.16
	(34)		(3)		(3)		(3)	
1991	207.39	29.68	292.77	17.91				
	(19)		(16)					
1992	207.21	47.20	318.33	37.93	358.87	21.38		
	(60)		(19)		(16)			
1993	200.51	28.55	279.83	40.70	309.08	31.45	367.93	5.34
	(20)		(28)		(3)		(2)	
1994	200.1	50.77	297.63	41.15	324.60	34.22	354.69	11.29
	(13)		(9)		(17)		(2)	
1995	193 43	10.45	302.05	13.64	359.60	33.11	356.15	11.15
	(6)		(8)		(3)		(7)	
1996	203.33	17.58						
	(6)							
1997	239.86	20.66						
	(6)							
1998	234.51	21.46	317.78	30.75				
	(16)		(6)					
1999	220 47	18.16	290.81	25.75	339.91	24.48		
	(21)		(19)		(6)			
2000	217	20.56	291.40	19.55	316.79	26.0	349.27	21.76
	(61)		(21)		(16)		(6)	
2001	193.53	25.25	317.59	0	320.39	4.64	325.20	4.19
	(30)		(1)		(2)		(2)	

Appendix 2. White bass back calculated length at age data. Data was obtained from Texas Parks and Wildlife annual sampling of Canyon Reservoir.

Date	Age 1	Age 2	Age 3	Age 4
2/5/91	260.00			
2/5/91	204.00			
2/5/91	225 00			
2/5/91	223 00			
2/5/91	226 00			
2/5/91	253 00			
2/5/91	199 00			
2/5/91	197 00			
2/5/91	190.00			
2/5/91	190 00			
2/5/91	192 00			
2/5/91	124 00			
2/5/91	253.00			
2/5/91	255.00			
2/5/91	257 00			
2/5/91	252.00			
2/5/91	175 00			
2/5/91	273.00			
2/5/91	204 00	348.00		
2/5/91	242 41	370 00		
2/5/91	233.90	357.00		
2/5/91	216.00	312 00	348.00	
2/5/91	247.26	282.58	365.00	
2/5/91	180.00	300 00	372.00	
2/5/91	186 43	236 14	310 71	348 00
2/5/91	202 29	252.86	321 13	354 00
2/5/91	226 69	262 48	310.21	346.00
2/5/91	168 03	313 81	370 65	378.06
2/5/91	260 53	359.78	372.19	384 59
2/5/91	127 82	208.94	270 39	319 55
1/27/93	212 00			
1/27/93	264 00			
1/27/93	268 00			
1/27/93	266.00			
1/27/93	280 00			
1/27/93	245 00			
1/27/93	252 00			
1/27/93	259.00			
1/27/93	210.00			
1/27/93	252.00			
1/27/93	230.00			
1/27/93	195 00			
1/27/93	225.00			
1/27/93	210 00			
1/27/93	245 00			
1/27/93	204.00			
1/27/93	206.92	329 00		

Appendix 2. White bass back calculated length at age data. Data was obtained from Texas Parks and Wildlife annual sampling of Canyon Reservoir.

Date	Age 1	Age 2	Age 3	Age 4
1/27/93	208.53	340.00		
1/27/93	192.39	319 97		
1/27/93	184.54	341.00		
1/27/93	224 18	322.00		
1/27/93	197.17	333 00		
1/27/93	227.49	324.00		
1/27/93	217.91	357.00		
1/27/93	220.95	298 81	343.00	
1/27/93	244.93	315.28	370 00	
1/27/93	239.41	300.35	370.00	
1/27/93	241.33	304.96	362.00	
1/27/93	194.33	288.29	331.00	
1/27/93	182.81	265.71	372.00	
1/27/93	189.47	298.36	392.00	
3/9/94	227.58			
3/9/94	245.79			
3/9/94	209.64			
3/9/94	207.67			
3/9/94	209.81			
3/9/94	210 55			
3/9/94	187.82			
3/9/94	214.42			
3/9/94	236.18			
3/9/94	187.65			
3/9/94	193.52			
3/9/94	148.38	298 88		
3/9/94	159.43	307.79		
3/9/94	140.91	297.73		
3/9/94	146 69	297.69		
3/9/94	218.02	283.66		
3/9/94	284.84	314.70		
3/9/94	161 90	310.84		
3/9/94	190 81	319.61		
3/9/94	176 00	302 00		
3/9/94	111.07	268.78		
3/9/94	187.00	305.80		
3/9/94	141 91	269.63		
3/9/94	218.57	337.57		
3/9/94	214.63	262.81		
3/9/94	138.13	265.63	337.88	
3/9/94	156.02	252.39	321.23	371.71
2/21/95	266.87			
2/21/95	192.71			
2/21/95	221.30			
2/21/95	262.55			
2/21/95	262.70			
2/21/95	168.72	330.78		

Appendix 2. White bass back calculated length at age data. Data was obtained from Texas Parks and Wildlife annual sampling of Canyon Reservoir.

Date	Age 1	Age 2	Age 3	Age 4
2/21/95	203.48	309 74		
2/21/95	207 81	345.63		
2/21/95	203.50	312.21		
2/21/95	245.07	306 87		
2/21/95	187.93	322.79		
2/21/95	195 30	273 00	354 90	
2/21/95	185.00	302.94	367.69	
2/21/95	202.78	302.97	362.61	
2/21/95	216.09	322.87	358 46	
2/21/95	121.24	269.93	347.71	
2/21/95	184.95	292.34	349.02	
2/21/95	215.33	349.60	377.47	
2/21/95	134 84	232 48	313 85	362.68
2/21/95	137 76	218.13	275 53	346.70
2/21/95	223 19	281.93	340.66	364 16
1/24/96	193 94			
1/24/96	210 22			
1/24/96	182 08			
1/24/96	197.96			
1/24/96	193 61			
1/24/96	182 74			
1/24/96	143.44	304.09		
1/24/96	169 48	289 11		
1/24/96	132 91	279 10		
1/24/96	199 40	309 65		
1/24/96	177.63	323.91		
1/24/96	182 26	300 72		
1/24/96	260 68	309.95		
1/24/96	129.43	299 84		
1/24/96	135 48	237 10	338.71	
1/24/96	177.78	288.89	397 78	
1/24/96	149.77	224 65	342.33	
1/24/96	148.12	227 88	307.64	373.72
1/24/96	153.40	241.05	300.22	352.81
1/24/96	141.57	232.58	313 48	357 98
1/24/96	150.00	210 00	280 00	346 00
1/24/96	124.36	228.00	290 18	339.93
1/24/96	138 47	197.81	286 83	360 02
1/24/96	121.67	206.83	292.00	362.57
1/22/97	237.00			
1/22/97	205 00			
1/22/97	188 00			
1/22/97	192 00			
1/22/97	197.00			
1/22/97	201.00			

Appendix 3. White bass back calculated length at age data. Data was obtained from Canyon Reservoir, January 2001 through June 2002.

Date	Age 1	Age 2	Age 3	Age 4
1/30/01	205.00			
1/30/01	222.00			
1/30/01	253.00			
1/30/01	207.00			
1/30/01	201 00			
1/30/01	195.00			
1/30/01	212.00			
1/30/01	222.00			
1/30/01	225.00			
1/30/01	211.00			
1/30/01	228 00			
1/30/01	212 00			
1/30/01	209 00			
1/30/01	212 00			
1/30/01	215 00			
1/30/01	217.00			
1/30/01	212.00			
1/30/01	198 00			
1/30/01	193.00			
1/30/01	196.00			
1/30/01	196.00			
1/30/01	216.00			
1/30/01	189 00			
1/30/01	204.00			
1/30/01	193 00			
1/30/01	246 00			
1/30/01	212 00			
1/30/01	221.00			
1/30/01	211.00			
1/30/01	203 00			
1/30/01	229.00			
1/30/01	202 00			
1/30/01	218.00			
1/30/01	294 88			
1/30/01	221 57	325 64		
1/30/01	243 59	321 09	350 62	
1/30/01	228.69	323.07	359.37	
1/30/01	261.87	308.09	338.89	350 45
6/9/01	200.16			
6/9/01	213 79			
6/9/01	215.45			
6/9/01	246 86			
6/9/01	216.30			
6/9/01	231.91			
6/9/01	211 46			
6/9/01	204 75			
6/9/01	214 59	296.85		

Appendix 3. White bass back calculated length at age data. Data was obtained from Canyon Reservoir, January 2001 through June 2002.

Date	Age 1	Age 2	Age 3	Age 4
6/9/01	260.67	302.22	336.22	
6/9/01	232.67	310.23	321.31	
6/9/01	223.32	259.44	279 15	
6/9/01	241.23	290.23	335.46	
6/9/01	234.19	353.28	377 09	381.06
6/9/01	217 95	334.52	349.73	354 79
9/20/01	220.15			
9/20/01	251 06			
9/20/01	270 40			
9/20/01	224.21			
9/20/01	235.34			
9/20/01	193.33			
9/20/01	210 38			
9/20/01	186.22			
9/20/01	187.58			
9/20/01	215.85			
9/20/01	234.00			
9/20/01	233.71			
9/20/01	184.28			
9/20/01	248.44			
9/20/01	210.11			
9/20/01	221.69			
9/20/01	233.85			
9/20/01	220.24			
9/20/01	213.33	283.22		
9/20/01	220 67	304.37		
9/20/01	221.11	285 30		
9/20/01	222.67	304.31		
9/20/01	231.00	294.00		
9/20/01	235.17	303.91		
9/20/01	211.15	287 60		
9/20/01	204 23	285.22		
9/20/01	238 02	266.97		
9/20/01	247.96	317.24		
9/20/01	188.75	242.23		
9/20/01	200.31	303 92		
9/20/01	212.62	274.48		
9/20/01	237.10	302.38		
9/20/01	235.81	310.84		
9/20/01	232.94	274.04		
9/20/01	172.96	264.52		
9/20/01	230.14	279.18	301.82	
9/20/01	190.74	228.88	260.67	
9/20/01	222 37	280.53	290.79	
9/20/01	238.33	275.00	304.33	
9/20/01	246.26	279.84	317.15	
9/20/01	239.03	316.36	333.94	

Appendix 3. White bass back calculated length at age data. Data was obtained from Canyon Reservoir, January 2001 through June 2002.

Date	Age 1	Age 2	Age 3	Age 4
9/20/01	206 58	272.84	323.51	
9/20/01	287.50	322.00	333 50	
9/20/01	226.29	272 98	316.08	337.63
9/20/01	275.21	343.07	354.38	365 69
9/20/01	233 46	299 67	317 09	324 06
2/1/02	238.00			
2/1/02	245 00			
2/1/02	160 00			
2/1/02	192.00			
2/1/02	215 00			
2/1/02	174 00			
2/1/02	220.00			
2/1/02	190.00			
2/1/02	191 00			
2/1/02	180.00			
2/1/02	145.00			
2/1/02	216 00			
2/1/02	172 00			
2/8/02	190 00			
2/8/02	222.00			
2/8/02	225 00			
2/8/02	202 00			
2/8/02	197.00			
2/8/02	207 00			
2/8/02	174.00			
2/8/02	193.00			
2/8/02	201 00			
2/8/02	184 00			
2/8/02	208 00			
2/8/02	209 00			
2/8/02	154 00			
2/8/02	145.00			
2/8/02	202 00			
2/8/02	170.00			
2/8/02	185.00			
2/8/02	235 63	317 59		
2/8/02	252.03	303 17	325 08	332 39
6/7/02	233.87	289.36	317.11	
6/7/02	234.14	303 01	323.67	
6/7/02	235.87	300 82	317.91	328.16
6/7/02	225 18	291.18	302.82	322 24

Appendix 4. Z scores for age 1-4 fish from each year collected. Z scores for age 2-4 fish were combined for statistical analysis.

Year	Age 1	Age 2	Age 3	Age 4
1989		-0.35587	-0.92817	1.522899
1990	0 390161	2.440633	1.298278	-0.31679
1991	-0.89599	-0 62666		
1992	-0.19278	0.580479	1.167604	
1993	-0.62322	-1 20967	-1.1586	0.752646
1994	-0 64927	-0.38217	-0.43353	-0.00879
1995	-1 07829	-0 17668	1 201916	0.07497
1996	-0.44168			
1997	1.90489			
1998	1.561424	0.554936		
1999	0.659642	-0 69933	0.281673	
2000	0.436462	-0.67173	-0.79877	-0.32034
2001	-1.07134	0.546069	-0.6304	-1.70459

REFERENCES

Barans, C.A. and R.A. Tubb. 1973. Temperatures selected seasonally by four fishes from western Lake Erie. Journal of the Fisheries Research Board of Canada. 30(11):1697-1703.

Beck, H. D., D. W. Willis, D.G. Unkenholz, and C.C. Stone. 1997. Relations between environmental variables and age-0 white bass abundance in four Missouri River reservoirs. Journal of Freshwater Ecology 12(4):567-575.

Bomar, G.W. 1983. Texas weather. University of Texas Press, Austin, pp. 1-265

Bonn, E. 1956. What about white bass? Texas Game and Fish. (September):8-10, 30-31.

Coutant, C.C. 1985. Striped bass, temperature, and dissolved oxygen: A speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114:31-61.

DiCenzo, V.J. and M.C. Duval. 2002. Importance of reservoir inflow in determining white bass year-class strength in three Virginia reservoirs. North American Journal of Fisheries Management 22:620-626.

Eaton, J.G. and R.M. Scheller. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. Limnology and Oceanography 41:1109-1115.

Gabelhouse, D.W. 1984. A length categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Groeger A.W., and T.E. Tietjen. 1998. Hydrological and thermal regime in a subtropical reservoir. International Review Hydrobiologia 83:83-94.

Hale, R.S. 1999. Growth of white crappie in response to temperature and dissolved oxygen conditions in a Kentucky Reservoir 19:591-598.

Hannan, H.H., I.R. Fuchs, and D.C. Whitenburg. 1979. Spatial and temporal patterns of temperature, alkalinity, dissolved oxygen, and conductivity in an oligo-mesotrophic, deep-storage reservoir in central Texas. Hydrobiologia 66:209-211.

Hayward, R.S., and E. Arnold. 1996. Temperature dependence of maximum daily consumption in white crappie: implications for fisheries management. Transactions of the American Fisheries Society125:132-138.

Hostetler, S.W. and E.E. Small. 1999. Response of North American freshwater lakes to simulated future climates. Journal of the American Water Resources Association 35:1625-1637.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAlister, and J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. Raleigh, NC: North Carolina State Museum of Natural History.

McCauley, R.W. and D.M. Kilgour. 1990. Effect of air temperature on growth of largemouth bass in North America. Transactions of the American Fisheries Society 119:276-281.

McCormick, J.H. 1978. Effects of temperature on hatching success and survival of larvae in the white bass. The Progressive Fish-Culturist 40:133-137.

Miranda, L.E., and P.P. Durocher. 1986. Effects of environmental factors on growth of largemouth bass in Texas reservoirs. Pages 115-121 in G.E. Hall and M.J. Van Den Avyle, editors. Reservoir Fisheries Management: Stratigies for the 80's. American Fisheries Society, Bethesda, Maryland.

Muoneke, M.I. 1994. Dynamics of a heavily exploited Texas white bass population. North American Journal of Fisheries Management 14:415-422.

Nordhaus, J.J., B.R. Lubinski, R.L. Cailteux, and D.A. Dobbins. 1998. Age and growth of a newly established white bass population in Florida. Florida Scientist 61:188-194.

Norwine, J. 1995. The regional climate of South Texas. Pages 138-154 in Norwine, J., Giardino, J.R., North, G.R., and J.B. Valdes, editors. The changing climate of Texas-Predictability and implications for the future. Texas A&M, College Station.

Pope, K.L., D.W. Willis, and D.O. Lucchesi. 1997. Influence of temperature and precipitation on age-0 white bass abundance in two South Dakota natural lakes. Journal of Freshwater Ecology 12:599-605.

Staggs M.D. and K.J. Otis. 1996. Factors affecting first year growth of fishes in Lake Winnebago, Wisconsin. North American Journal of Fisheries Management 16:608-618.

Wilde, G.R., and M.I. Muoneke. 2001. Climate-related and morphoedaphic correlates of growth in white bass. Journal of Fish Biology 58:453-461.

Willis, D.W. 1986. Review of water level management on Kansas reservoirs. Pages 110-114 in G.E. Hall and M.J. Van Den Avyle, editors. Reservoir Fisheries Management: Stratigies for the 80's. American Fisheries Society, Bethesda, Maryland.

Yellayi, R.R., and R.V. Kilambi. 1976. Population dynamics of white bass in Beaver Reservoir, Arkansas. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 29:172-184.

VITA

Joe Mack Martin was born on August 8, 1975 in Longview, Texas. After completing high school at Spring Hill High School, Longview, Texas he entered Texas State University- San Marcos. He received the degree of Bachelor of Science from Texas State University in 1998. After graduation, Joe worked at A. E. Wood State Fish Hatchery in San Marcos, Texas. In August 1999, he entered the Graduate College of Texas State University – San Marcos.

Permanent Address: 908 B W. Hopkins St.
San Marcos, Texas 78666

This thesis was typed by Joe Mack Martin.