Largemouth Bass Population Trends in Two Texas Reservoirs with LMBV-attributed Die-offs

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Abstract: Largemouth bass (*Micropterus salmoides*) die-offs attributed to largemouth bass virus (LMBV) occurred during 1998 at Sam Rayburn Reservoir and 1999 at Lake Fork, Texas. We assessed largemouth bass electrofishing catch per unit effort (CPUE), mean length at age 3, relative weight (*Wr*), and angling success before (pre-LMBV) and after (post-LMBV) fish kill periods to address concerns that LMBV had negatively impacted the largemouth bass populations and fisheries at these two popular Texas reservoirs. There was no decline in angling catch rates, mean length at age 3, or *Wr* in the post-LMBV period for either reservoir. Only electrofishing CPUE at Lake Fork was significantly lower post-LMBV. However, it was difficult to establish a definitive causal link between this difference and LMBV. Results suggest that prolonged adverse effects from the LMBV-disease events at these two reservoirs were not likely.

Key words: largemouth bass, population trends, LMBV, fish kill, Texas

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Largemouth bass virus (LMBV) has been a cause of concern for fishery managers and the angling public since the first LMBV-attributed fish kill at Santee-Cooper Reservoir, South Carolina, in 1995 (Plumb et al. 1996). Within its range, LMBV has been associated with at least 24 largemouth bass (*Micropterus salmoides*) die-offs (Grizzle and Brunner 2003). Many of these die-offs occurred in systems noted for providing high-quality largemouth bass angling such as Sardis Reservoir, Mississippi (Hanson et al. 2001), and Lake Eufaula, Alabama (Weathers et al. 2000). Much has been learned about LMBV since it was first discovered in Florida in 1991 (Grizzle et al. 2002). For example, fish found positive for LMBV do not always succumb to disease (Plumb et al. 1999), and fish are more susceptible to LMBV at higher water temperatures (Grant et al. 2003). However, questions remain regarding the possibility of sublethal effects of LMBV on largemouth bass populations.

Diseases can have sublethal effects on fish populations. George et al. (1977) found that muskellunge (*Esox masquinongy*) infected with a myxosporidan parasite (*Myxobolus dentium*) had significantly lower mean coefficient of condition (K-factor) than uninfected fish. Harrison and Hadley (1982) stated that northern pike (*E. lucius*) with black-spot infections grew slower than fish without the disease. There is little published information available describing largemouth bass population and fishery trends in reservoirs where LMBV-attributed die-offs have occurred. However, several state agencies including Alabama (Maceina and Grizzle 2006), Arkansas (C. Dennis, Arkansas Game and Fish Commission, personal communication), and Oklahoma (G. Gilliland, Oklahoma Department of Wildlife Conservation, personal communication) indicated that angling catch rates declined and/or the average time to catch larger fish increased in the presence of LMBV. Maceina and Grizzle (2006) reported that largemouth bass infected with LMBV had lower relative weight (*Wr*) and slower growth after age-3 than fish that were not infected in five Alabama reservoirs.

In Texas, largemouth bass die-offs attributed to LMBV occurred at Sam Rayburn Reservoir in 1998 when an estimated 1,800 fish died in three specific areas of the 45,092-ha impoundment (TPWD 2000) and at Lake Fork (11,034 ha) in 1999 when

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an estimated 4,800 fish died reservoir-wide (Jones 1999). Even though the estimated number of dead fish during each die-off investigation was likely a small percentage of total fish in each population, Texas Parks and Wildlife Department (TPWD) biologists received reports from largemouth bass anglers following the kill events that fishing success, especially for larger fish had declined. Anglers and others speculated that the fish kills had greater negative effects on the populations than initially indicated. Thus, the objective of this study was to determine if largemouth bass relative abundance, growth, condition, and angling success changed in Lake Fork and Sam Rayburn reservoirs after the occurrence of LMBV-associated die-offs.

Methods

We assessed differences in population and fishery metrics between pre-LMBV and post-LMBV periods at Lake Fork and Sam Rayburn reservoirs. The die-off events that occurred at each reservoir were used to separate years into pre- and post-LMBV periods. We considered the pre-LMBV period to be from 1991–1998 at Lake Fork and from 1991–1997 at Sam Rayburn Reservoir. The post-LMBV period was defined as 1999–2005 at Lake Fork and 1998–2005 at Sam Rayburn Reservoir. Data from each die-off year were included in the post-LMBV period.

Stratified, uniform, and nonuniform probability creel surveys (Malvestuto 1996) were used to estimate largemouth bass angling catch rates from 1991–2004. Data were not available for 2005. Sample days were randomly selected for each day-type strata (weekday and weekend). Temporal and spatial sampling units were chosen randomly for each sample day. Annual access point creel surveys were conducted at Lake Fork throughout the study period. However, in December 1999, the Sam Rayburn Reservoir creel was changed from an access point survey to a roving design.

Largemouth bass populations were sampled annually during fall by night electrofishing beginning in 1991 (2 hours at 24 5-min stations). In 2002, electrofishing effort was increased to 4 hours (48 5-min stations) at Sam Rayburn Reservoir. All largemouth bass were tallied by 25.4-mm group and at least two randomly-selected fish per 25.4-mm group were measured (TL, mm) and weighed (g) from each station. In years that age and growth analysis was conducted, otoliths were collected from five randomly-selected fish per 25.4-mm group each year.

Largemouth bass relative abundance was determined by electrofishing catch per unit effort (CPUE, mean number of fish caught per 5-min electrofishing station). Because TPWD Inland Fisheries sampling protocol changed from fixed-site sampling to random sampling in 1996, and the length of electrofishing time at each station changed from 15 minutes to 5 minutes, we did not include CPUE data prior to 1996 in our analyses. Catch rates were calculated for two categories, CPUE of stock-size largemouth bass (≥ 203 mm, $CPUE_{203}$) and CPUE of fish ≥ 356 mm ($CPUE_{356}$). Mean length at capture of age-3 largemouth bass collected during fall electrofishing was used to monitor changes in fish growth. Age and growth analyses were not conducted during 1994, 1997, 2003, 2004, or 2005 at Sam Rayburn Reservoir or during 2005 at Lake Fork. Body condition was monitored using *Wr* (Wege and Anderson 1978) which was determined from the standard weight equation recommended by Henson (1991). Mean *Wr* was summarized by two length categories, 203–355 mm ($Wr_{203-355}$) and ≥ 356 mm (Wr_{356}). Electrofishing CPUE and *Wr* data were divided into two size categories because die-off investigations (Jones 1999, TPWD 2000) reported that the majority of largemouth bass observed during the two events were mostly ≥356 mm. Also, the minimum length limit for largemouth bass at Sam Rayburn Reservoir was 356 mm. This approach allowed us to assess relative abundance and condition of larger fish in addition to smaller fish in each population. Sub-stock fish (<203 mm) were not included in our analyses because fish of this size are not fully recruited to electrofishing gear used in this study (Reynolds and Simpson 1978, Jackson and Noble 1995).

Data Analysis

Because both roving and access angler creel surveys designs were used during this study, it was necessary to calculate angling success using the mean party estimator (Crone and Malvestuto 1991) to maintain consistency and allow for comparison between periods. Annual estimates of fishing success were determined with mean party angling catch rates for anglers seeking largemouth bass. In addition, because each die-off event occurred during the summer, and other die-offs and laboratory research have implicated warmer water temperatures with LMBV-related events (Goldberg 2002, Grant et al. 2003), separate summer (July-September) catch rate estimates were computed for comparison between periods. For each metric, the pre-and post-LMBV period means were an average of the annual means within the period. Comparisons of angling success, mean length at age 3, and *Wr* between periods were made using *t*-tests ($\alpha = 0.05$). Because electrofishing CPUE data were not normally distributed, we made statistical comparisons with analysis of variance (ANOVA, SAS 2000) following a logarithmic transformation [$\log_{10}(n+1)$] so the data more closely approximated a normal distribution.

Results

Annual estimates of largemouth bass angling catch rates were variable and ranged from 0.29 fish/h to 0.49 fish/h at Lake Fork

Table 1. Annual and summer (July-September) mean party (±SE) largemouth bass angling catch rates (number of fish/hour) including pre-LMBV and post-LMBV period means, for anglers targeting largemouth bass during angler creel surveys conducted at Lake Fork and Sam Rayburn Reservoir, Texas, from 1991 to 2004. The pre-LMBV period was 1991–1998 at Lake Fork and 1991–1997 at Sam Rayburn Reservoir. The post-LMBV period was 1999–2004 at Lake Fork and 1998–2004 at Sam Rayburn Reservoir. Period means within the same column with different superscripts were significantly different (*t*-test; $P \leq 0.05$).

	Lake Fork				Sam Rayburn Reservoir			
Year	Annual		Summer		Annual		Summer	
1991	0.40	(0.03)	0.58	(0.06)	0.71	(0.04)	0.91	(0.07)
1992	0.43	(0.03)	0.45	(0.04)	0.61	(0.03)	0.75	(0.06)
1993	0.30	(0.02)	0.42	(0.04)	0.52	(0.03)	0.69	(0.07)
1994	0.43	(0.03)	0.62	(0.07)	0.64	(0.03)	0.73	(0.08)
1995	0.43	(0.03)	0.43	(0.05)	0.79	(0.04)	1.16	(0.09)
1996	0.42	(0.03)	0.51	(0.10)	0.70	(0.03)	0.71	(0.05)
1997	0.32	(0.02)	0.40	(0.06)	0.83	(0.06)	1.47	(0.17)
1998	0.38	(0.03)	0.59	(0.09)	0.79	(0.04)	0.97	(0.09)
1999	0.36	(0.02)	0.36	(0.05)	0.63	(0.04)	0.50	(0.08)
2000	0.29	(0.02)	0.39	(0.03)	0.61	(0.05)	0.53	(0.11)
2001	0.36	(0.03)	0.46	(0.06)	0.87	(0.06)	0.93	(0.15)
2002	0.41	(0.03)	0.52	(0.07)	0.87	(0.05)	0.85	(0.11)
2003	0.46	(0.04)	0.53	(0.08)	0.82	(0.03)	1.04	(0.07)
2004	0.49	(0.04)	0.76	(0.10)	0.63	(0.02)	0.81	(0.06)
Pre-LMBV	0.39[A]	(0.02)	0.50[A]	(0.03)	0.69[A]	(0.04)	0.92[A]	(0.11)
Post-LMBV	0.39[A]	(0.03)	0.50[A]	(0.06)	0.75[A]	(0.05)	0.80[A]	(0.08)

and from 0.52 fish/h to 0.87 fish/h at Sam Rayburn Reservoir (Table 1). There were no differences between mean annual pre-LMBV and post-LMBV largemouth bass angling catch rates at Lake Fork (0.39 fish/h vs. 0.39 fish/h, $P = 0.88$) or Sam Rayburn Reservoir (0.69 fish/h vs. 0.75 fish/h, $P = 0.34$). Also, estimates of summer angling catch rates at Lake Fork were not different between periods (0.50 fish/h vs. 0.50 fish/h, $P = 0.95$) and ranged from 0.36 fish/h to 0.77 fish/h over the study period (Table 1). Summer angling catch rates at Sam Rayburn Reservoir ranged from 0.50 fish/h to 1.47 fish/h (Table 1) and were not different between periods (0.92 fish/h vs. 0.80 fish/h, $P = 0.43$).

No difference in mean length at age 3 was detected between periods at Lake Fork (417 mm vs. 422 mm, $P = 0.58$), and ranged from 396 to 470 mm throughout the study period (Table 2). Mean length of age-3 largemouth bass was similar between periods at Sam Rayburn Reservoir (371 mm vs. 391 mm, $P = 0.27$) and annual estimates ranged from 347 to 437 mm throughout the study period (Table 2).

Mean *Wr* was similar among periods for both size categories examined at Lake Fork ($Wr_{203-355}$, 104 vs. 101, $P = 0.07$, range 96–107; Wr_{356}, 103 vs. 102, $P = 0.55$, range 97–111; Table 3). At Sam Rayburn Reservoir, mean *Wr* was actually higher during the post-LMBV period for both length groups ($Wr_{203-355}$, 95 vs. = 99, $P = 0.01$, range 91–102; Wr_{356}, 91 vs. 96, $P = 0.01$, range 86–101; Table 3).

Electrofishing catch rates (log-transformed) of largemouth bass did not differ between periods at Sam Rayburn Reservoir for either length group examined ($CPUE_{203}$, 9.2 fish/5 min vs. 10.8 fish/5 min, $P = 0.9$; $CPUE_{356}$, 2.5 fish/5 min vs. 2.4 fish/5 min, $P = 0.9$; Table 4). Annual mean $CPUE_{203}$ at Sam Rayburn was variable throughout the study (range = 3.8 to 17.9 fish/5 min, Table 4). At Lake Fork, mean CPUE was significantly lower in the post-LMBV period for both length groups ($CPUE_{203}$, 12.1 fish/5min vs. 5.8 fish/5 min, $P = 0.002$; $CPUE_{356}$, 3.8 fish/5 min vs. 1.6 fish/5 min, $P = 0.01$; Table 4).

Discussion

Because of the popularity of largemouth bass as a sport fish, LMBV has been a great cause of concern for anglers and fisheries biologists throughout the southeastern United States. Anglers at

Table 2. Mean (±SE) length (mm) of age-3 largemouth bass collected from Lake Fork and Sam Rayburn Reservoir, Texas, from 1991 to 2004 including pre-LMBV and post-LMBV period means. The pre-LMBV period was 1991–1998 at Lake Fork and 1991–1997 at Sam Rayburn Reservoir. The post-LMBV period was 1999–2004 at Lake Fork and 1998–2004 at Sam Rayburn Reservoir. Missing data indicates years in which age and growth analysis was not conducted. Period means within the same column with different uppercase superscripts were significantly different (*t*-test; $P \leq 0.05$).

Year	Lake Fork		Sam Rayburn Reservoir	
1991	421	(9.6)	358	(8.1)
1992	417	(11.5)	358	(11.2)
1993	408	(7.5)	385	(9.6)
1994	397	(9.6)		
1995	430	(9.6)	392	(15.9)
1996	414	(8.3)	360	(14.6)
1997	409	(10.8)		
1998	438	(11.3)	405	(15.2)
1999	407	(10.3)	347	(11.9)
2000	409	(6.7)	376	(9.4)
2001	413	(24.3)	388	([a])
2002	412	(25.0)	437	(16.9)
2003	470	(17.0)		
2004	424	(12.7)		
Pre-LMBV	417[A]	(4.6)	371[A]	(7.3)
Post-LMBV	422[A]	(9.8)	391[A]	(15.1)

a. Sample size insufficient to calculate standard error.

Table 3. Mean (±SE) relative weight (*Wr*) for two size groups of largemouth bass collected from Lake Fork and Sam Rayburn Reservoir, Texas, from 1991 to 2005 including pre-LMBV and post-LMBV period means. The pre-LMBV period was 1991–1998 at Lake Fork and 1991–1997 at Sam Rayburn Reservoir. The post-LMBV period was 1999–2005 at Lake Fork and 1998–2005 at Sam Rayburn Reservoir. Period means within the same column with different uppercase superscripts were significantly different (*t*-test; $P \leq 0.05$).

	Lake Fork				Sam Rayburn Reservoir			
Year	203–355 mm		≥356 mm		203–355 mm		≥356 mm	
1991	102	(0.8)	102	(1.5)	91	(0.6)	89	(1.1)
1992	106	(1.8)	107	(1.1)	91	(0.5)	86	(0.9)
1993	104	(0.8)	106	(1.5)	96	(0.8)	90	(1.3)
1994	104	(1.0)	102	(1.3)	96	(1.2)	92	(1.3)
1995	105	(0.7)	102	(1.2)	96	(0.7)	89	(1.5)
1996	101	(0.8)	97	(1.0)	94	(0.9)	92	(1.2)
1997	104	(0.7)	111	(2.2)	99	(0.9)	96	(1.5)
1998	104	(0.7)	99	(1.1)	98	(0.7)	90	(1.7)
1999	101	(1.6)	99	(1.9)	97	(0.9)	94	(1.7)
2000	103	(1.4)	100	(1.9)	102	(1.6)	98	(1.9)
2001	107	(1.1)	104	(2.1)	100	(0.7)	101	(1.8)
2002	101	(0.9)	105	(2.1)	93	(0.5)	93	(0.7)
2003	96	(0.8)	100	(2.2)	98	(0.7)	97	(0.8)
2004	99	(0.8)	107	(2.6)	102	(0.6)	97	(0.9)
2005	99	(0.9)	100	(1.2)	99	(0.6)	96	(1.0)
Pre-LMBV	104^A	(0.6)	103^A	(1.6)	95^A	(1.1)	91^A	(1.1)
Post-LMBV	101^A	(1.3)	102^A	(1.2)	99^B	(1.0)	96^B	(1.2)

Sam Rayburn Reservoir and Lake Fork perceived that their fishing success declined following the largemouth bass die-off events that occurred during 1998 and 1999. Anglers especially complained about the decline in catches of larger fish at each reservoir. Unfortunately, adequate angling data pertaining to larger fish were not available during this study for analysis. However, the average time to catch largemouth bass ≥2.27 kg increased for tournament anglers since LMBV was first documented in Arkansas (C. Dennis, Arkansas Game and Fish Commission, personal communication). Oklahoma also documented that angling effort required to catch largemouth bass ≥1.81 kg increased in the presence of LMBV (G. Gilliland, Oklahoma Department of Wildlife Conservation, personal communication). Maceina and Grizzle (2006) presented Alabama largemouth bass tournament data that showed an increase in angling effort to catch fish ≥2.27 kg.

Maceina and Grizzle (2006) reported that slower largemouth bass growth and lower relative weights were associated with LMBV infection in Alabama reservoirs. However, the data in our study indicated no difference in mean length at age 3 or *Wr* between pre-and post-LMBV periods in these two Texas reservoirs. This may be due to the decline in prevalence of LMBV from 56.7% at Lake Fork in 1999 (the year of the die-off) to only 3.3% the following year (TPWD unpublished data). This lower prevalence in the population may have reduced the potential for long-term negative effects. In addition, findings of the Texas statewide LMBV survey in 2001 suggested that largemouth bass length, weight, and condition were unaffected by the presence of LMBV (TPWD unpublished data).

We did not detect a difference in largemouth bass relative abundance at Sam Rayburn Reservoir between periods. Electrofishing CPUE at Lake Fork was the only negative change we detected following the die-off in 1999. However, because changes in largemouth bass relative abundance may have been related to many factors, it was difficult to establish a definitive link between this difference and LMBV. Low water levels as well as declines in submersed aquatic vegetation at both Sam Rayburn Reservoir and Lake Fork occurred in close proximity to die-off events, and the difference in largemouth bass relative abundance at Lake Fork could have been confounded by these changes. Previous research has demonstrated that abundance of largemouth bass can be influenced by changes in vegetation abundance (Durocher et al. 1984, Hoyer and Canfield 1996, Tate et al. 2003). Largemouth bass year class strength can also be influenced by seasonal air temperature (Jackson and Noble 2000, Paukert and Willis 2004) or water lev-

Table 4. Mean (±SE) electrofishing catch per unit effort (fish/5 min) for two size groups of largemouth bass collected from Lake Fork and Sam Rayburn Reservoir, Texas, from 1996 to 2005 including pre-LMBV and post-LMBV period means. The pre-LMBV period was 1996–1998 at Lake Fork and 1996–1997 at Sam Rayburn Reservoir. The post-LMBV period was 1999–2005 at Lake Fork and 1998–2005 at Sam Rayburn Reservoir. Period means within the same column with different uppercase superscripts were significantly different (ANOVA; $P \leq 0.05$). Statistical tests were conducted using $\log_{10}(n+1)$-transformed data.

	Lake Fork				Sam Rayburn Reservoir			
Year	≥203 mm		≥356 mm		≥203 mm		≥356 mm	
1996	10.1	(1.2)	5.1	(0.6)	7.6	(1.3)	2.2	(0.5)
1997	9.0	(1.6)	2.4	(0.5)	10.8	(1.3)	2.8	(0.6)
1998	17.1	(2.1)	3.9	(0.8)	17.9	(5.4)	1.9	(0.3)
1999	7.5	(1.0)	2.9	(0.6)	11.2	(1.5)	3.0	(0.4)
2000	4.5	(0.7)	1.8	(0.4)	3.8	(0.7)	1.5	(0.3)
2001	7.4	(1.6)	2.0	(0.4)	10.1	(1.6)	1.3	(0.2)
2002	4.5	(0.8)	1.0	(0.2)	10.1	(1.0)	2.7	(0.4)
2003	5.4	(0.8)	1.1	(0.3)	9.3	(1.3)	2.6	(0.3)
2004	5.3	(0.9)	1.1	(0.3)	10.1	(1.1)	2.7	(0.4)
2005	5.7	(0.9)	1.5	(0.4)	13.6	(2.0)	3.2	(0.5)
Pre-LMBV	12.1^A	(1.4)	3.8^A	(0.5)	9.2^A	(2.7)	2.5^A	(0.5)
Post-LMBV	5.8^B	(0.9)	1.6^B	(0.3)	10.8^A	(1.4)	2.4^A	(0.2)

els (Maceina and Bettoli 1998). Also, it would have been desirable to have more comparable pre-LMBV electrofishing CPUE data to include in this study to have a better picture of annual variation in largemouth bass abundance prior to the die-offs. However, because TPWD changed sampling protocol from fixed to random stations in 1996, data prior to 1996 were not included in electrofishing CPUE analyses.

Our results suggest that prolonged effects from the LMBV-disease events at these two reservoirs were not likely. Also, we believe that although future LMBV events in Texas could have an immediate negative impact on a reservoir, largemouth bass populations and angling success should be expected to rebound within a few years to pre-event levels.

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