Tournament-associated Mortality in Black Bass

By Gene R. Wilde

ABSTRACT

I compiled estimates of tournament-associated mortality in black basses (*Micropterus* spp.) for 130 tournaments held between 1972 and 1996. Initial mortality decreased significantly ($P < 0.0001$) between the 1970s (19.5%), and the 1980s (6.6%) and 1990s (6.5%). I found no difference in initial mortality ($P = 0.9885$) between the 1980s and 1990s. Delayed mortality was 10.4% in the 1970s based on limited data. Estimates of delayed and total mortality for the 1980s (20.9% and 26.2%, respectively) and 1990s (23.3% and 28.3%, respectively) were not significantly different ($P \geq 0.7222$). Thus, no evidence exists of a decline in initial, delayed, or total mortality since at least the mid-1980s. This suggests that recommendations made by previous researchers for reducing tournament-associated mortality were disregarded or ineffective. Meta-analysis of correlations shows a strong positive relationship between water temperature, and initial ($\bar{r} = 0.51 \pm 0.00$) and delayed mortality ($\bar{r} = 0.36 \pm 0.000$). There was a strong negative relationship between tournament size and initial mortality ($\bar{r} = -0.54 \pm 0.000$), and a moderately strong positive relationship with delayed mortality ($\bar{r} = 0.30 \pm 0.000$). I also found a moderately strong but nonsignificant positive relationship between fish size and initial mortality ($\bar{r} = 0.31 \pm 0.197$), and a moderately weak negative relationship with delayed mortality ($\bar{r} = -0.13 \pm 0.056$). Nonlinear regression of initial, delayed, and total mortality on water temperature for tournaments conducted during 1980–1996 explained 20%–30% of the variation in mortality. Initial mortality appears to be compensatory in its effect on total mortality. Estimates of initial mortality alone provide no information on the magnitude of total tournament-associated mortality; therefore, both initial and delayed mortality must be measured. These results also suggest that a substantial portion of tournament-associated mortality is the result of injuries sustained during hooking, playing, and landing of fish.

Prior to the mid-1970s, black basses (*Micropterus* spp.) captured in tournaments suffered a high rate of mortality (Holbrook 1975). Widespread adoption of live-release practices and improved procedures for handling captured fish apparently reduced tournament-associated mortality, and several studies have suggested that tournament angling has little effect on black bass populations (Chapman and Fish 1985; Lee et al. 1993; Kwak and Henry 1995). Nevertheless, fishery managers continue to express concerns about the potential biological impacts of tournament angling (Schramm et al. 1991). Anglers also continue to question tournament effects on fisheries. Wilde et al. (1998) reported that 40% of black bass anglers in Texas who do not participate in tournaments believes that most tournament-caught black bass do not survive weigh-in and release. Additionally, 51% of black bass anglers in Texas believes that tournaments harm their fishing enjoyment.

Gene R. Wilde is an assistant professor in the Department of Range, Wildlife, and Fisheries Management at Texas Tech University, Lubbock, TX 79409; 806/742-1983; gwilde@ttu.edu.

Schramm et al. (1991) suggested that such concerns are based more on perception than on documented impacts. However, Wilde et al. (1998) argued that considerable potential for conflict exists between tournament and nontournament anglers, and this potential cannot be resolved or dismissed simply because it may be based on anglers' perceptions.

Problems associated with tournament angling are exacerbated by the growth in popularity of fishing tournaments (Shupp 1979; Duttweiler 1985; Schramm et al. 1991). Based on a survey of fishery management agencies conducted in 1989, the American Fisheries Society (AFS) Competitive Fishing Committee estimated that 29,500 competitive fishing events were held annually on inland waters of North America and that 78% of these events targeted black basses (Schramm et al. 1991).

Schramm et al. (1991) identified a need for more information on the potential biological effects of tournament angling. In addition, there is a need for critical evaluation and synthesis of information currently available on these issues. For example, although fishery biologists generally agree that tournament-associated mortality of black bass has decreased since the 1970s, few agree on the magnitude of this decrease. Holbrook's (1975) estimates of initial mortality, ranging from 0 to 61%, have been widely used as a benchmark against which subsequent estimates are compared. Since Holbrook's report, summaries of the literature have indicated that initial mortality decreased to 10%–15% in "recent years" (Archer and Loycano 1975), typically ranged from 20%–60% for tournaments held during 1975–1982 (Schramm et al. 1985), ranged from 0%–43% in "recent studies" (Kwak and Henry 1995), or decreased to 20% in some tournaments held during the 1980s (Gilliland 1997a). Similar inconsistencies occur in summaries of delayed (Archer and Loycano 1975; Hartley and Moring 1995; Kwak and Henry 1995) and total mortality (Schramm et al. 1987; Kwak and Henry 1995). An accurate assessment of the magnitude of initial, delayed, and total mortality as well as any decreases that have occurred through time, is necessary to evaluate potential impacts of tournament angling (e.g., Hayes et al. 1995) and the effectiveness of procedures intended to reduce mortality.

Tournament-associated mortality in black basses has been correlated with water temperature (Schramm et al. 1987; Bennett et al. 1989; Watson and Johnson 1997), fish size (Meals and Miranda 1994; Weathers and Newman 1997), number of participants or teams (Schramm et al. 1985, 1987; Hartley and Moring 1995), live-well conditions (Plumb et al. 1988; Kwak and Henry 1995; Gilliland 1997a), and tournament procedures (Kwak and Henry 1995; Weathers and Newman 1997). However, the magnitude and statistical significance of these correlations frequently varies among studies. For example, strong ($r \geq 0.5$), statistically significant correlations ($P \leq 0.05$) between water temperature and mortality were reported by Schramm et al. (1987), Bennett et al. (1989), and Watson and Johnson (1997), but relatively weak, nonsignificant correlations were reported by Schramm et al. (1985), Steeger et al. (1994), and Weathers and Newman (1997). This variation among studies complicates any understanding of the contribution of water temperature, fish size, number of participants, etc., to tournament-associated mortality.

In this paper, I compile and evaluate estimates of tournament-associated mortality for black basses obtained from the published literature and unpublished project completion, and Sport Fish Restoration Act Program reports. My objectives are to (1) determine average rates of initial (prerelease), delayed (postrelease), and total (initial + delayed) mortality associated with black bass fishing tournaments; (2) determine whether any change in the magnitude of these sources of mortality has occurred since the 1970s; (3) use meta-analysis to combine results from independent studies to assess the overall effects of water temperature, tournament size (number of teams, anglers), and size of fish captured on tournament-associated mortality; and (4) model the relationship between water temperature and initial, delayed, and total mortality.

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An estimated 29,500 competitive fishing events are held annually on inland waters of North America, and more than three-quarters of the events target black basses.

Methods

Black bass tournaments target largemouth bass (*M. salmoides*), smallmouth bass (*M. dolomieu*), and spotted bass (*M. punctulatus*) singly or, more commonly, in aggregate. Most studies combined results for all black bass species captured. Bennett et al. (1989) and Jackson and Willis (1991) presented results for tournaments in which anglers caught smallmouth bass only. In tournaments studied by Klindt and Shiavone (1991) and Hartley and Moring (1995), anglers caught both largemouth bass and smallmouth bass, and results for these two species were presented separately. Although there is reason to expect different black bass species to respond differently to tournament angling (e.g., Muoneke and Childress 1994;

Hartley and Moring 1995), I combined results for all species in my analyses because insufficient information is available to perform separate analyses for species other than largemouth bass; most studies do not present separate mortality estimates for all black bass species captured; and few, if any, tournaments discriminate among species.

I calculated mean initial and delayed mortality for three periods (1970–1979, 1980–1989, and 1990–1996) and used mortality estimates for individual tournaments whenever available. Schramm et al. (1985, 1987) and Steeger et al. (1994) presented means, sample sizes, and estimates of variability (sample standard deviations or standard errors) for initial and delayed mortality, so I weighted their mean estimates by the number of tournaments examined. Bennett et al. (1989) presented individual results for initial mortality but only the range (0.8%–9%) for delayed mortality. Estimates of delayed mortality (see references in Table 1) generally were slightly right-skewed. I assumed that delayed mortality in Bennett et al.'s study was similarly skewed and calculated mean delayed mortality as $0.6 \times (9 - 0.8) = 4.92$. I weighted this mean by the number of tournaments studied. I estimated the standard deviation (SD = 2.362) for delayed mortality in Bennett et al.'s study from the sample range using the method described by Dixon and Massey (1969). I calculated sums of squares for each period and used analysis of variance (ANOVA) to determine whether mortality varied among periods. This allowed me to include results from Schramm et al. (1985, 1987), Bennett et al. (1989), and Steeger et al. (1994) in statistical analyses. Although mortality estimates were slightly right-skewed, ANOVA is known to be robust with respect to moderate departures from normality (Sokal and Rohlf 1981).

Estimates of initial and delayed mortality have been combined in various ways to estimate total tournament-associated mortality (e.g., Schramm et al. 1985; Kwak and Henry 1995; Weathers and Newman 1997). I calculated total mortality (TM) as

$$TM = 100 \times (1 - ((1 - IMP) \times (1 - DMP))),$$

where IMP is the proportion of fish that die prior to weigh-in and release (initial mortality), and DMP is the proportion of fish that die after release (delayed mortality). Both IMP and DMP range from 0 to 1.0. This method assumes that initial and delayed mortality are independent and multiplicative, and yields a slightly lower estimate of total mortality than other methods.

An implicit assumption in previous studies of tournament-associated mortality is that initial and delayed mortality are additive rather than compensatory in their effect on total mortality. I examined the relationships among

Table 1 summarizes results from 130 black bass fishing tournaments.

State	Number of tournaments	Month(s)	Year	Water temp. (°C)	Range in initial mortality (%)	Range in delayed mortality (%)	Observation period for delayed mortality (days)	Source
FL	1	March	1972		15.6	15.0	6	May (1973)
GA	1	March	1972		56.5			Holbrook et al. (1973)
FL	1	April	1973		24.6	2.2	19	Plumb et al. (1975)
MS	1	April	1973		10.6	5.7	19	Welborn and Barkley (1975)
SC	1	May	1973	24.0	16.1	3.3	14	Archer and Loycano (1974)
Several southeast states	17[1]	February–October	1972–1974		2.0–61.0	22.0[2]		Holbrook (1975)
FL	1	February	1974		6.1	11.1	6–8	Moody (1976)
TX	2	March	1974	20.0–21.0	22.8–23.6	11.0–12.5	28	Seidensticker (1975a)
ID	15	April–August	1981	7.0–25.0	0.0–15.8	0.8–9.0	1–1.5	Bennett et al. (1989)
FL	18		1983–1984		0.0–31.0	0.0–13.0	<1	Schramm et al. (1985)
FL	11		1984–1985		0.0–18.8	2.1–31.5		Schramm et al. (1987)
ME	9	June–October	1989	18.0–26.0	0.0–14.6	0.0–9.4	2	Hartley and Moring (1995)
NY	2	September–October	1989			1.0–3.4	42	Klindt and Schiavone (1991)
MS	6		1989–1991	24.0–33.0	4.0–18.0			Meals and Miranda (1994)
AL–GA	8		1991		2.4–14.9	11.0–52.0	4	Steeger et al. (1994)
SD	1	June	1991	23.0	4.9	0.0	2	Jackson and Willis (1991)
AL	14	May–September	1991–1992	27.2–33.9	2.4–18.4	1.3–50.0	4	Weathers and Newman (1997)
MN	2	May–September	1991–1992	15.0–23.0	0.9–2.0	2.7–4.0	3	Kwak and Henry (1995)
FL	9	January–December	1994–1995	18.5–31.0	0.0–14.0	0.0–14.0	5	Watson and Johnson (1997)
OK	10	April–September	1995–1996	15.0–30.0	0.0–3.8	0.9–43.5	6	Gilliland (1997a)

[1] Holbrook (1975) actually reported results for 25 tournaments; however, results for eight of these tournaments were reported in other (original) sources cited herein.

[2] Based on one tournament.

initial, delayed, and total mortality using correlation analysis. A positive relationship with total mortality is evidence that initial and delayed mortality have an additive effect, whereas the absence of a significant relationship is evidence of a compensatory effect.

Three studies (Schramm et al. 1985, 1987; Bennett et al. 1989) used correlation analysis to assess the relationship between tournament mortality and various tournament characteristics. Schramm et al. (1985, 1987) used Spearman's rank correlation r_s to assess these relationships, whereas Bennett et al. (1989) used Pearson's product-moment correlation r. Several additional studies presented information that allowed me to calculate correlations (r) between mortality and other variables (Table 2).

I performed a meta-analysis on correlations to determine the strength of the relationships between initial and delayed mortality, and other variables identified from the literature that appeared to influence tournament-associated mortality. I calculated mean weighted-correlations following the methods of Hunter and Schmidt (1990), which involves three steps. First, the magnitude of a correlation is affected by the range of variation observed in the explanatory variable. For example, one would expect to observe a stronger relationship between mortality and water temperature when temperatures range between 0° and 30°C than when the range is from 0° to 10°C. Therefore, I adjusted sample correlations (r, r_s) for differences in the standard deviation of the independent variable by assigning each correlation a weight u that ranges from 0 to 1. These weights were calculated as

$$u = \frac{S_i}{S_{max}}$$

where s_i is the standard deviation of the independent (nonmortality) variable for correlation i, and s_{max} is the maximum standard deviation observed among studies for that variable. Second, the adjusted correlation r_a was calculated as

$$r_a = \frac{u \cdot r}{\sqrt{(u^2 - 1) \cdot r^2 + 1}}.$$

Table 2 shows the correlations between initial and delayed mortality and measures of water temperature, tournament size, and fish size used in a meta-analysis of correlations.

Variables	Correlation coefficient	N	P	Source
Water temperature				
Initial mortality * Water temperature	0.50	18	0.0173	Schramm et al. (1985)
Initial mortality * Water temperature	0.53	11	0.0468	Schramm et al. (1987)
Initial mortality * Water temperature	0.49	15	0.0322	Bennett et al. (1989)
Initial mortality * Water temperature	0.44	9	0.1204	Hartley and Moring (1995)
Initial mortality * Water temperature	0.22	6	0.3405	Meals and Miranda (1994)
Initial mortality * Water temperature	0.16	14	0.2972	Weathers and Newman (1997)
Initial mortality * Water temperature	0.71	9	0.0168	Watson and Johnson (1997)
Initial mortality * Water temperature	0.02	10	0.4781	Gilliland (1997a)
Delayed mortality * Water temperature	0.00	18	0.5000	Schramm et al. (1985)
Delayed mortality * Water temperature	0.64	11	0.0170	Schramm et al. (1987)
Delayed mortality * Water temperature	0.50	9	0.0852	Hartley and Moring (1995)
Delayed mortality * Water temperature	0.03	14	0.5432	Weathers and Newman (1997)
Delayed mortality * Water temperature	0.01	8	0.4869	Steeger et al. (1994)
Delayed mortality * Water temperature	0.74	9	0.0115	Watson and Johnson (1997)
Delayed mortality * Water temperature	0.48	10	0.0802	Gilliland (1997a)
Tournament size				
Initial mortality * Number of teams	-0.28	18	0.1302	Schramm et al. (1985)
Initial mortality * Number of teams	-0.16	11	0.3192	Schramm et al. (1987)
Initial mortality * Number of anglers	0.00	14	0.5000	Weathers and Newman (1997)
Initial mortality * Number of boats	-0.28	7	0.2715	Meals and Miranda (1994)
Delayed mortality * Number of teams	0.15	18	0.2762	Schramm et al. (1985)
Delayed mortality * Number of teams	-0.07	11	0.5810	Schramm et al. (1987)
Delayed mortality * Number of anglers	0.18	14	0.2713	Weathers and Newman (1997)
Fish size				
Initial mortality * Mean weight per team	0.25	18	0.1585	Schramm et al. (1985)
Initial mortality * Mean weight of captured fish	-0.13	11	0.6484	Schramm et al. (1987)
Initial mortality * Mean weight fish captured per boat	0.38	14	0.0889	Weathers and Newman (1997)
Delayed mortality * Mean weight per team	-0.10	18	0.3465	Schramm et al. (1985)
Delayed mortality * Mean weight of captured fish	0.33	11	0.8392	Schramm et al. (1987)
Delayed mortality * Mean weight fish captured per boat	-0.25	14	0.1983	Weathers and Newman (1997)

Finally, the mean weighted-correlation $\bar{r}$, adjusted for variation in the independent variable, was calculated as

$$\bar{r} = \frac{\sum_{i=1}^{k} r_{ai} \cdot n_i}{\sum_{i=1}^{k} n_i},$$

where r_{ai} is the ith adjusted correlation, and n_i is the number of observations on which the adjusted correlation is based. I assessed the significance of $\bar{r}$ by determining whether the 95% confidence interval included 0. I then performed a meta-analysis of correlations, including calculations of mean weighted-correlations and their standard errors with BASIC programs provided by Hunter and Schmidt (1990).

A review of the literature and inspection of meta-analysis results suggest that water temperature is the most important variable influencing tournament-associated mortality of black basses. I used nonlinear regression to model the relationships among initial, delayed, and total mortality of black bass and water temperature.

Results

Initial mortality estimates for 130 black bass tournaments ranged from 0 to 61% (Table 1). Initial mortality averaged 19.5% in tournaments held during the 1970s, but was significantly lower ($P < 0.0001$) in tournaments held during the 1980s (6.6%) and 1990s (6.5%). I found no difference ($P = 0.9885$) in initial mortality estimates from the 1980s and 1990s. Estimates of delayed mortality ranged from 0 to 52%. Delayed mortality showed no consistent temporal pattern, averaging 10.4% in the 1970s, 7.7% in the 1980s, and 18.1% in the 1990s.

I found little consistency in methods used for determining delayed mortality. In particular, the length of time fish were held for evaluation of delayed mortality ranged from < 1 to 42 days. Length of the observation period was reported for only a few of the estimates of delayed mortality made during the 1970s. However, reporting of the observation period was more consistent during the 1980s and 1990s (Figure 1). A significant linear relationship existed between individually reported values for delayed mortality (RDM) and length of the observation period (OP): RDM = -1.466 + 3.674 x OP ($r^2 = 0.12$; $n = 45$; $P = 0.0213$). I used this relationship to adjust estimates of delayed mortality to a standard 6-day period because this was the longest period for which results from several individual tournaments were available, and previous studies (Plumb et al. 1975; Schramm et al. 1987) had shown that most delayed mortality occurs within six days (an exception is the study by Archer and Loycano 1975). After adjustment, mean estimates of delayed mortality for the 1980s (20.9%) and 1990s (23.3%) were not significantly different ($P = 0.7222$). Combining estimates of initial mortality and adjusted estimates of delayed mortality yielded an estimated total mortality of 26.2% for the 1980s and 28.3% for the 1990s. There was no significant difference

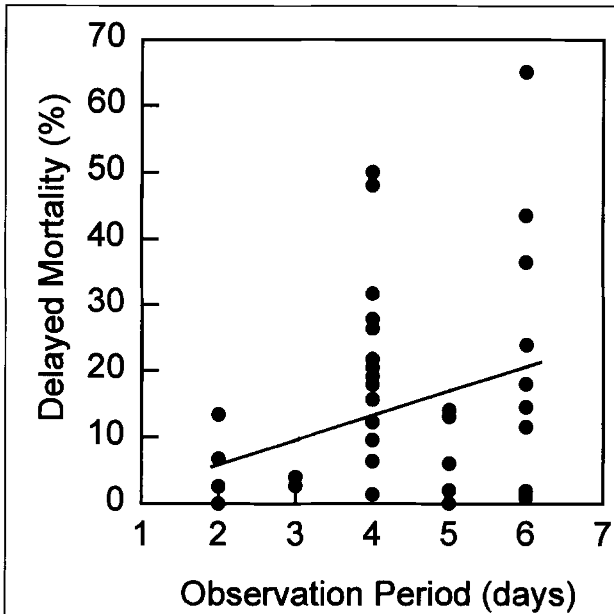

Figure 1 shows the linear relationship between delayed mortality and the duration of the observation period over which tournament-associated mortality was assessed in black bass.

($P = 0.8450$) in estimates of total mortality between the 1980s and 1990s.

Both initial ($r = 0.44$; $n = 45$; $P = 0.0010$) and delayed mortality ($r = 0.97$; $n = 45$; $P < 0.0001$) were directly related to total mortality (Figure 2). However, because initial, delayed, and total mortality all were correlated with temperature, positive correlations between these forms of mortality might be observed because each increases, on average, with water temperature. I used partial correlation to control for the effects of water temperature. The partial correlation between initial and total mortality was nonsignificant ($r = 0.24$; $n = 45$; $P = 0.1147$), whereas the partial correlation between delayed and total mortality was highly significant ($r = 0.96$; $n = 45$; $P < 0.0001$).

Correlations (r, r_s) between water temperature and initial (range = 0.02 to 0.71) and delayed mortality (0.00 to 0.74) could be determined for eight and seven studies, respectively (Table 2). Overall, mean weighted-correlations showed there is a strong positive relationship between water temperature and both initial ($\bar{r} = 0.51 \pm 0.000$) and delayed mortality ($\bar{r} = 0.36 \pm 0.000$). Correlations between tournament size (number of boats, anglers, or teams), fish size and initial and delayed mortality could be determined from ≤ 4 studies. Analysis of mean weighted-correlations showed a strong negative relationship between tournament size and initial mortality ($\bar{r} = -0.54 \pm 0.000$) and a moderately strong positive relationship between tournament size and delayed mortality ($\bar{r} = 0.30 \pm 0.000$). Thus, larger tournaments were associated with a lower initial mortality but an increased delayed mortality. Mean weighted-correlations showed a moderately strong but nonsignificant positive relationship between fish size and initial mortality ($\bar{r} = 0.31 \pm 0.197$), and a moderately weak negative relationship with delayed mortality ($\bar{r}$ = -0.13 ± 0.056). Meals and Miranda (1994) reported that initial mortality in larger largemouth bass was significantly greater ($P < 0.05$) than in smaller fish. I used Fisher's method of combining probabilities from independent tests (Sokal and Rohlf 1981) to combine this probability ($P = 0.05$) with those associated with individual sample correlations in Table 2. Overall, evidence existed of a positive relationship between fish size and initial mortality ($X^2 = 15.38$; df = 8; $P = 0.0521$). These results indicated that larger black bass experience greater initial mortality and lower delayed mortality than do smaller black bass.

Relationships between water temperature and initial, delayed (adjusted for observation period), and total mortality in tournaments conducted during 1980–1996 were positive and curvilinear (Figure 3). Water temperature explained only 20%–30% of the variation in tournament-associated mortality; however, I expected a high residual variance because mortality is known to be affected by numerous variables (tournament size and fish size, among others). Based on average values presented here, initial mortality (6.5%–6.6%) comprised approximately one-fourth of total mortality (26.2%–28.3%). Because these forms of mortality increase at different rates relative to water temperature, initial mortality comprises a smaller proportion of total mortality at lower temperatures than at higher temperatures. I found that assuming a constant ratio (1:4) between the two forms of mortality (e.g., Lee et al. 1993) will result in an underestimate of total mortality at water temperatures < 25°C and an overestimate at higher temperatures.

Discussion

Since the 1970s, initial mortality of black bass captured in fishing tournaments decreased by two-thirds, from 19.5% to 6.5%. Most of this decrease was accomplished by the mid-1980s, and there is no evidence that initial mortality has decreased since then. Because of the paucity of data, delayed mortality cannot be estimated reliably for the 1970s. However, some decrease in delayed mortality likely occurred between the 1970s and 1980s based on the large observed decrease in initial mortality. I found no evidence of a decrease in either delayed (20.9% versus 23.3%) or total mortality (26.2% versus 28.3%) between the 1980s and 1990s, respectively.

A decrease in tournament-associated mortality since the 1970s also is indicated by self-reported estimates of initial mortality provided by fishing clubs and tournament sponsors. Based on tournaments conducted in Florida between 1975 and 1982, Chapman and Fish (1985) reported a 20%–60% initial mortality rate. This decreased to 2.4% in tournaments conducted during 1992–1995 (Watson and Johnson 1997). In California, Lee et al. (1993) reported that mortality averaged 1.9% in tournaments conducted during 1985–1989. Self-reported estimates of mortality generally are lower than those reported by fishery biologists. Means for self-reported estimates of mortality in Florida during 1992–1995 (2.4%) were less than half those observed by fishery biologists (5.4%) during this same period (Watson and Johnson 1997). Self-reported estimates of tournament mortality originally were solicited as part of Gilliland's (1997b) program; however, spot checks of initial mortality made by fishery biologists were consistently lower than those reported by some organizations (G. Gilliland, Oklahoma Department of Wildlife Conservation, pers. comm.). Differences between self-reported estimates of mortality and those observed by fishery biologists probably are the result of variation in the criteria used to determine whether fish are dead at weigh-in, and the unwillingness of some organizations to accurately report mortality.

There are several limitations to the estimates of initial, delayed, and total mortality I present here. First, my estimates are primarily based on tournaments sponsored by regional organizations. Relatively few estimates of mortality are available for small club tournaments. Such events account for the greatest number of tournaments

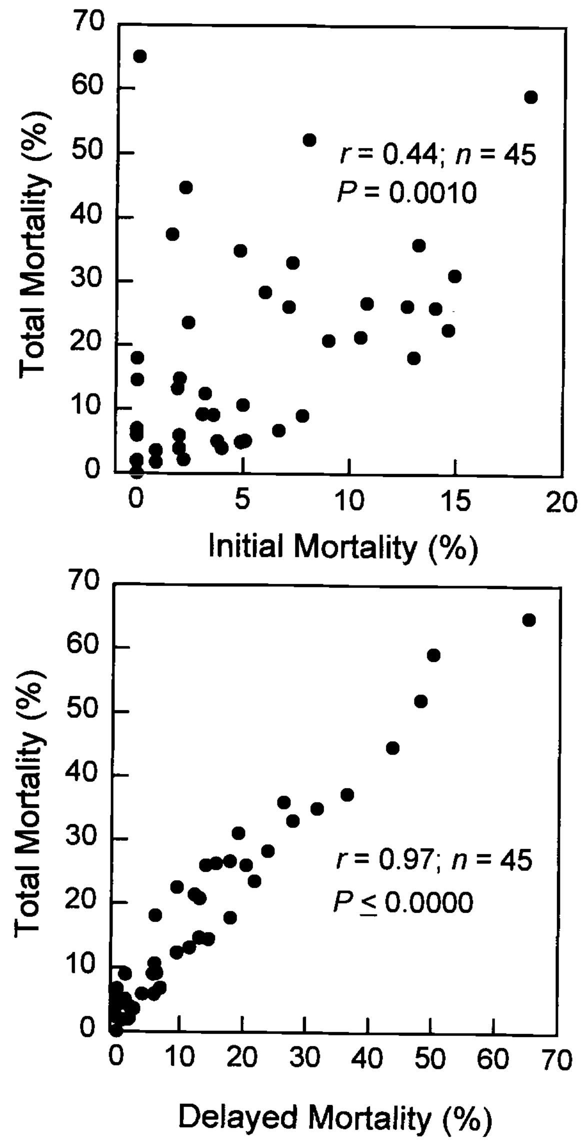

Figure 2 shows the relationship between and initial and delayed mortality and total mortality in tournament-caught black bass.

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...relatively few estimates of mortality are available for events sponsored by large regional and national organizations

Large, well-organized events may have lower fish mortalities than do small club tournaments.

and are likely to be relatively unorganized and, therefore, may be associated with a greater mortality than reported here. Similarly, relatively few estimates of mortality are available for events sponsored by larger regional and national organizations (e.g., Bass Anglers Sportsman's Society). These events generally are well organized, and mortalities may be lower, on average, than those reported here. Second, my estimates do not account for fish captured, held in live wells, and later released ("culled") by anglers when larger fish are captured. These fish may be confined in live wells for an extended time prior to their release and may represent a potential source of tournament-associated mortality that is likely to go unobserved (Fielder and Johnson 1994). Most importantly, although tournaments are conducted throughout the year, most available estimates of mortality are for tournaments held in the summer. If proportionally more tournaments are held in spring or fall (when water temperatures are low) than in summer (when water temperatures and tournament-associated mortality are high) (Lee et al. 1993; Chapman and Fish 1985), my results may overestimate total mortality. Particularly in southeastern states, an overall estimate of total tournament-associated mortality, weighted by the number of tournaments conducted each month, could be considerably less than the 26.2%–28.3% estimated from results summarized in Table 1.

Although there is considerable scatter about the regression used to adjust estimates of delayed mortality for length of observation period (Figure 2), this adjustment is appropriate for two reasons. First, the length of the observation period in studies conducted in the 1980s generally ranged from 1–2 days, whereas observation periods were longer in the 1990s, 3–6 days (excluding one tournament in which fish were observed for 2 days). Because delayed mortality of black bass occurs for at least 6 days after release, differences in observation period length should result in higher unadjusted estimates of delayed mortality for the 1990s (18.1%) than the 1980s (7.7%), as I observed. Second, although the coefficient of determination for this regression is low ($r^2 = 0.12$), this suggests other factors (i.e., water temperature, live-well conditions) influence delayed mortality, but not that variation clearly attributable to length of observation period should be ignored or left uncorrected.

The observed decrease in tournament-associated mortality since the 1970s is generally attributed to the adoption of live-release practices by tournament-sponsoring organizations, improvements in handling of captured fish, and changes in angler attitudes (Holbrook 1975; Schramm et al. 1985; Barnhart 1989). Since then, several studies have recommended ways to further reduce tournament-associated mortality. These recommendations have been disregarded or were ineffective in reducing mortality. For example, based on the apparent relationship between mortality and water temperature, Seidensticker (1975a), Bennett et al. (1989), and Schramm et al. (1987) recommended restricting tournament activity when water temperatures were high. Nevertheless, even in the southern United States where surface water temperatures regularly exceed 30°C, many organizations continue to sponsor black bass tournaments during summer months. Recommendations—including those to reduce the length of the tournament day (Seidensticker 1975a;

Bennett et al. 1989), maintain acceptable conditions (e.g., temperature and dissolved oxygen concentrations) in live wells (May 1973; Welborn and Barkley 1974; Gilliland 1997a), use live-well conditioners (Carmichael et al. 1984a; Plumb et al. 1988), minimize playing and handling (Welborn and Barkley 1974; Gustaveson et al. 1991), and award "points" to anglers who keep their fish alive and in good condition (Seidensticker 1975a)—have been unevenly adopted. As a result the average total mortality associated with black bass tournaments has remained approximately 26%–28% since the 1980s. The widespread perception that tournament-associated mortality is "low" and does not harm black bass populations possibly has led to complacency among both fishery managers and the tournament-angling community that has limited efforts to further reduce tournament-associated mortality.

The relationship between water temperature and tournament-associated mortality in black bass has been recognized since the 1970s (Welborn and Barkley 1974; Holbrook 1975; Seidensticker 1975a). However, the strength of this relationship previously has been underestimated: water temperature explains 20%–30% of the variation in initial, delayed, and total mortality. My results show that tournament-associated mortality increases exponentially with temperature. Consequently, high rates of mortality may be observed in tournaments held at warmer temperatures. Total mortalities of 10%, 24%, and 40% can be expected at water temperatures of 15°, 25°, and 35°C, respectively, based on the regression equation developed in this study (Figure 3). Hoffman et al. (1996) observed a similar exponential relationship between water temperature and tournament-associated mortality in walleye (*Stizostedion vitreum*).

Tournament-associated mortality in black basses is believed to result from the cumulative effect of a series of sublethal stressors (Schramm et al. 1987) that apparently are additive (Carmichael et al. 1984b). This would suggest that initial and delayed mortality are positively related to total mortality. However, the observed relationship between initial and total mortality was more consistent with the hypothesis that initial mortality is compensatory in effect. One would expect a compensatory effect if a substantial portion of tournament-associated mortality results from injuries sustained during hooking, playing, and landing of fish. Captured fish may sustain mortal wounds, in which case live-well conditions, handling at weigh-in, etc., will determine whether death is immediate or delayed. Fish with less-severe wounds likely will survive unless live-well or other conditions are intolerable. Thus, additive components of mortality are likely to contribute to delayed and, hence, total mortality. A relationship between hooking-related mortality and tournament-associated mortality is supported by two observations. First, estimates of hooking mortality for black basses generally are comparable to, or slightly less than, those for tournament mortality: 11.2%–38.0% for largemouth bass (Rutledge and Pritchard 1977; Pelzman 1978), 4.2%–47.3% for smallmouth bass (Weidlein 1987; Clapp and Clark 1989), 8.5% for spotted bass (Muoneke 1992), and 2.4% for Guadalupe bass (*Micropterus treculi*) (Muoneke 1991). Second, hooking mortality is strongly related to water temperature and fish size (Taylor and White 1992; Muoneke and Childress 1994), as is tournament mortality.

Too little information is available to provide definitive statements about the effects of tournament size and fish size on tournament-associated mortality; however, correlations among these variables are consistent with the hypothesis that initial mortality is compensatory in effect. Tournament size is negatively correlated with initial mortality but positively correlated with delayed mortality. This suggests that larger tournaments may be better organized and conducted with rules and procedures that successfully reduce initial mortality. However, if initial and total mortality are uncorrelated as my results suggest, then reducing initial mortality may not result in any

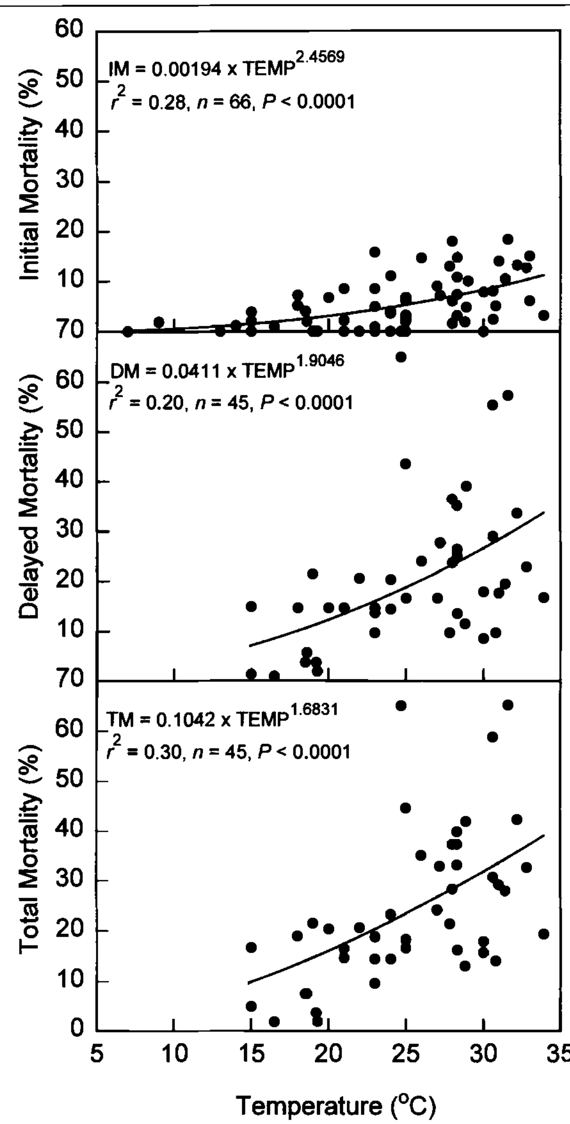

Figure 3 shows the results of nonlinear regression of initial (IM), delayed (DM), and total (TM) mortality on water temperature (TEMP) for tournament-caught black bass.

decrease in delayed mortality. Fish size was positively correlated with initial mortality but negatively correlated with delayed mortality. Larger fish possibly experience greater stress when confined in live wells (Meals and Miranda 1994) and, consequently, may be more likely to die prior to weigh-in and release than smaller fish. Again, if initial mortality is compensatory in effect, this might result in a greater initial mortality but a lower delayed mortality, in larger fish. A lower initial mortality, coupled with greater delayed mortality, might be expected for smaller fish.

The compensatory-mortality hypothesis for initial mortality has at least three implications for fishery management. First, tournament-associated mortality cannot be monitored simply by observing initial mortality. Both initial and delayed mortality must be measured, or total mortality should be estimated based on water temperature using the equations developed here. Second, many tournament-sponsoring organizations report a low rate of initial mortality for their events. Studies of initial and delayed mortality are necessary to determine whether these organizations do, in fact, have a low overall rate of mortality or are successful only in postponing mortality until after weigh-in and release. Third, reduced tournament-associated mortality may be achieved by improving live-well conditions and handling; however, the greatest gains likely will come from practices that reduce hooking-related mortality. These practices include (1) restricting gears that tend to be swallowed deeply or modifying gear to reduce injuries sustained during hooking, playing, and landing; (2) restricting on the numbers and types of tournaments held during warmer periods; (3) adopting practices to reduce stress on larger fish such as encouraging early weigh-in and release of these fish; and (4) adopting alternatives to traditional weigh-in tournaments—including those in which fish are captured, measured or photographed, and immediately released (e.g., Willis and Hartmann 1986)—that appear to reduce mortality (Wilde et al., in press).

A comparison of tournament catch rates with creel survey results for several southeastern lakes led Holbrook (1975) to conclude that tournaments accounted for a small proportion of the black bass harvest. Subsequent studies (Chapman and Fish 1985; Dolman 1991; Lee et al. 1993) also concluded that black bass populations were not affected by tournaments. These conclusions were reached subjectively. For example, Dolman (1991) concluded that tournament angling had a negligible effect because it accounted for $\leq 2\%$ of black bass harvest statewide. However, on 6 Texas reservoirs studied by Dolman (1991), black bass fishing-club tournaments accounted for 7%–50% of weekend daily fishing effort and 6%–80% by number and 7%–69% by weight of the black bass harvested from these reservoirs. Dolman (1991) noted that tournament anglers captured larger fish than did recreational anglers but did not consider the possible effects of tournament harvest on black bass population size structure. Hayes et al. (1995) modeled the effects of tournament angling on largemouth bass and walleye populations, and concluded that population size structure may be degraded before any evident decrease in population size occurs. Potential impacts of fishing tournaments may be magnified because tournaments are concentrated on some lakes (Seidensticker 1975b; Watson and Johnson 1997). Hulon et al. (1994) reported that tournament anglers captured 35% of largemouth bass caught on Lake Kissimmee, Florida. Even if all tournament-caught fish were released, associated mortality represents a substantial loss of fish from lakes where tournament anglers contribute such a large proportion of the angling effort.

The magnitude of tournament-associated mortality may vary as a result of genetic and physiological differences among populations. Kwak and Henry (1995) observed that tournament-associated mortality was lower in northern than in southern states. Data summarized in Table 1 generally support this observation. Initial and delayed mortality were both lower in tournaments held in northern states (3.8% and 19.5%, respectively) than in southern states (7.5% and 23.2%, respectively). These differences were significant for initial mortality ($P = 0.0258$) but not for delayed mortality ($P = 0.4285$). Kwak and Henry (1995) suggested the difference in mortality between northern and southern states was due to lower water temperatures in northern lakes. However, physiological differences between northern and southern strains of largemouth bass also may contribute to this difference. Williamson and Carmichael (1986) reported that Florida largemouth bass were more sensitive to confinement and experienced greater stress than northern largemouth bass. Hybrids between the two races were intermediate in their sensitivity to confinement. Differences among strains in their sensitivity to confinement suggest that hybrid and Florida largemouth bass may experience greater stress while confined to live wells. Similarly, Hartley and Moring (1995) suggested that differences in tournament-associated mortality between smallmouth bass and largemouth bass are physiologically based. Confinement-related stress potentially could affect estimates of delayed mortality; however, black bass captured by electrofishing and confined to pens and cages for use as controls in studies of delayed mortality generally experience little mortality (Schramm et al. 1987; Gilliland 1997a; Watson and Johnson 1997).

Directions for Future Studies

Tournament-associated mortality results from the complex interaction of several stressors. Consequently, no single study can provide a definitive estimate of the magnitude of mortality or the relationship between mortality and different explanatory variables. Although my estimates of tournament-associated mortality are based on a rather sizable data set, relatively little information is available with which to assess relationships between mortality and tournament size, fish size, etc. This is largely the result of nonreporting of available information viewed as unimportant. Future reviews will be aided if authors explicitly describe all aspects of the tournaments that they study (e.g., sponsoring organization, length of fishing day, length of contest, weather conditions, etc.), in addition to presenting information such as mortality rates, water temperature, number of anglers, and number of fish caught. It is particularly important that the tournament sponsor be identified so that potential organizational effects can be better understood. Also, weather conditions, particularly rough waters, are important contributors to tournament-associated mortality in walleye (Goeman 1991; Fielder and Johnson 1994) but are infrequently reported in descriptions of black bass fishing tournaments. Finally, unless the number of tournaments studied is unwieldy, results of individual tournaments rather than summaries should be presented. However, when summary statistics are presented, these should include means, estimates of variability (standard deviations or standard errors), and sample sizes for all relevant variables.

Studies of tournament-associated mortality in black bass to date have considered only tournaments in which prizes are awarded based on total weight of fish captured. Anglers in some states have adopted alternatives to the traditional total-weight tournament. For example, Willis and Hartmann (1986) indicated that most Kansas bass clubs practiced catch, measure, and release fishing. This practice eliminates stresses associated with confinement in live-wells and handling during weigh-in, and apparently reduces tournament-associated mortality. A number of alternative tournament formats exist (Wilde et al., in press) that may be useful in reducing mortality, particularly during periods such as immediately after spawning, when fish are already stressed (Hartley and Moring 1995). However, no estimates of mortality for tournaments conducted according to various alternative formats are available. Such information would be valuable in assessing the potential fishery benefits of these formats.

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