Fisheries Report 07-10

Physiology and survival of tournament-caught largemouth bass

A Final Report Submitted To

Tennessee Wildlife Resources Agency
Nashville, Tennessee

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ABSTRACT

J. Percy Priest Reservoir, located east of Nashville, Tennessee, hosts over 400 fishing tournaments per year and most tournament pressure is focused on largemouth bass, *Micropterus salmoides*. During standard weigh-in procedures, bass are transferred to the weighing station in water-filled plastic bags and then weighed in a dry bag. An alternative “water weigh-in” system developed in Canada, whereby fish are held in water prior to the weighing event and then weighed in a basin of water, has been used in locales throughout North America to reduce hypoxia and physiological stress in tournament-caught fish on the presumption that this would lower delayed mortality. To assess stress and delayed mortality of largemouth bass in J. Percy Priest Reservoir, radio tags (n = 81) were attached externally to largemouth bass and blood samples (n = 208) were collected from fish at 16 tournaments held between March 2006 and February 2007. Plasma lactate and cortisol concentrations were not reduced in tournament-caught largemouth bass subjected to the water weigh-in procedure compared to fish that experienced a standard weigh-in procedure. Osmolarity was lower in fish that experienced a water weigh-in, similar to results from previous studies, but only at high temperatures. Pooled delayed mortality rates of tagged fish were high (63%) during July and August when water temperatures approached 30°C. Delayed mortality was 32% (pooled over all tournaments) and varied directly ($P \leq 0.02$) with surface water temperature and fish length in a logistic regression model. However, no other variables (including the type of weigh-in) were related ($P > 0.20$) to delayed mortality. On their final location, most (70%) fish that died were within the embayment in which they were released. Although air exposure was minimized compared to a traditional weigh-in, the water weigh-in did not mitigate changes in blood lactate or cortisol concentrations and had only minimal effects on plasma osmolarity; moreover, it did not reduce delayed mortality in tournament-caught-and-released largemouth bass.

INTRODUCTION

The number of live-release fishing tournaments has increased considerably since the 1970s, especially those targeting black bass *Micropterus* spp. (Schramm et al. 1991). Delayed mortality of largemouth bass *Micropterus salmoides* in live-release tournaments was estimated to range from 10% to 23% (Wilde 1998). Delayed mortality occurs after release due to stress associated with weigh-in procedures and can be responsible for a considerable portion of the total mortality. For instance, Kwak and Henry (1995) observed a delayed mortality rate 2.5 times greater than initial mortality (before the weigh-in) at live-release bass fishing tournaments in Minnesota. Previous studies showed delayed mortality is most likely to occur within the first six days after tournament release, with the majority of mortality occurring within 24 hours (Plumb et al. 1974; Schramm et al. 1987). Previous studies have linked mortality with tournament size (Schramm et al. 1987; Hartley and Moring 1995), fish size (Meals and Miranda 1994), tournament organizational procedures (Weathers and Newman 1997), and live-well conditions (Carmichael et al. 1984a; Kwak and Henry 1995).

Initial mortality and delayed mortality rates are strongly influenced by water temperature (Schramm et al. 1987; Bennett et al. 1989; Wilde 1998; Taylor 1990; Neal and Lopez-Clayton 2001; Edwards et al. 2004). The probability of delayed mortality increased at water temperatures above 25° C in live-release fishing tournaments on a Connecticut reservoir (Edwards et al. 2004).

Researchers usually measure delayed mortality by confining tournament-caught fish in net pens and directly observing their fate (e.g., Gilliland 1997; Wilde et al. 2002; Schramm et al. 2006). However, the net pen environment can create conditions that support bacterial infections; thus perhaps affecting survival (Schramm et al. 2006). Also, individual fish in a cage or series of cages are often treated incorrectly as replicates. Considering each fish and not each cage as the experimental unit is termed pseudo-replication and can lead to biased mortality estimates (Pollock and Pine 2007).

Suski et al. (2003) analyzed the physiological disturbances of largemouth bass in live-release tournaments and documented depleted muscle energy stores, elevated plasma osmolarity, and elevated concentrations of plasma lactate and cortisol. Suski et al. (2004) noted that the weigh-in process in live-release fishing tournaments caused a physiological disturbance due to air exposure and confinement in transfer bags. Moderately hypoxic water in transfer bags decreased the ability of bass to recover from various stressors (Suski et al. 2006). In the three aforementioned studies, the authors implied that the stress of tournament weigh-ins (as revealed by changes in blood chemistry) could compromise the survival of released fish. Walleyes *Sander vitreus* exhibited similar stress responses to hypoxic conditions in live-release tournaments (Killen et al. 2003). Edwards et al. (2004) cited the weigh-in and handling procedure as a key variable influencing delayed mortality.

In conjunction with Queens University (Ontario, Canada) and the Natural Sciences and Engineering Research Council of Canada, the fishing tackle manufacturer Shimano, Canada, Ltd., developed the “Water Weigh-In System” in an effort to reduce stress-induced physiological effects in tournament-caught fish. This system consists of a series of troughs with aerated water. Each tournament angler receives a plastic tub with drain holes into which the angler transfers the catch and the tubs are submersed in the aerated troughs as anglers form a queue. The tubs with the fish are removed from the troughs and drained quickly, and then re-immersed and weighed in a water-filled basin positioned on a scale that has been tared to discount the weight of the tub, water, and basin. This alternative weighing method was designed to minimize stress responses to hypoxia and handling in tournament-caught fish. Use of this system minimizes handling time and air exposure and some tournament organizers in North America have used the water weigh-in system to reduce stress in largemouth bass.

To date, a field study has not been performed to assess the efficacy of a water weigh-in system. Suski et al. (2004) compared immediate physiological responses in largemouth bass subjected to simulated standard and water weigh-in procedures. In their simulations, physiological stress was reduced in the water treatment; however, the mean size of the fish used in that experiment (327 mm total length [TL]) was less than the 381 mm TL size limit imposed on many reservoirs in the southeastern U.S.. Moreover, the average water temperature in their simulation was 23°C; whereas, water temperatures in southeastern U.S. reservoirs often approach or exceed 30°C during summer tournaments.

Attaching external transmitters to largemouth bass to estimate delayed mortality would eliminate biases associated with net pen confinement and pseudo-replication. Bettoli and Osbourne (1998) and Bettoli et al. (2000) used external radio tags to estimate hooking mortality of free-ranging striped bass *Morone saxatilis* and sauger *Sander canadense* caught in recreational fisheries. Telemetry could also be used to determine dispersal rates of tournament-caught bass and whether released fish are concentrating near the release site. In a telemetry study of largemouth bass in Chesapeake Bay, Richardson-Heft et al. (2000) noted that the majority of tournament-caught largemouth bass returned to their capture areas, with those captured in the spring returning the fastest. Over a 1-yr period in Lake Thunderbird, Oklahoma, 49% of tournament-caught largemouth bass remained within 0.8 km of the release site (Gilliland 1999). On Lake Mead, Arizona-Nevada, most (63%) tagged fish were located within 0.5 km of the tournament release site after 43 d (Wilde and Paulson 2003). In a dispersal study on Lake Martin, Alabama, Ricks (2006) noted that the majority of largemouth bass released from tournament weigh-in sites remained within 3 km of the release site for up to 3 months. Tournament-released largemouth bass also remained near the release site for several months before dispersing throughout Lake Martin, leading to an increase in the biomass of largemouth bass within 2 km of the release site (Hunter 2006).

The goal of this study was to evaluate the efficacy of a water weigh-in system in reducing stress and delayed mortality compared to standard weigh-in techniques in tournament-caught largemouth bass. The specific objectives were to (1) compare three commonly used indicators of the primary and secondary stress responses (plasma lactate, cortisol, and osmolarity) in fish subjected to each type of weigh-in procedure; (2) model delayed mortality as a function of plasma chemistry, weigh-in procedure, fish size, tournament duration, dissolved oxygen, and water temperature; and (3) describe dispersal of largemouth bass after release from the tournament weigh-in site.

STUDY AREA

J. Percy Priest reservoir was created in 1968 by the impoundment of the Stones River, a tributary of the Cumberland River in middle Tennessee. The reservoir has a surface area of approximately 7,630 ha at full pool and has 343 km of shoreline. The U.S. Army Corp of Engineers manages the reservoir for recreation, flood control, hydropower, and navigation on the Cumberland River. The reservoir has an average depth of 9 m. Smallmouth bass, largemouth bass, and spotted bass occur in the reservoir. Largemouth bass and smallmouth bass are managed with a 381-mm total length (TL) size limit. There is no minimum size limit on spotted bass, but many fishing clubs impose a 305-mm (TL) size-limit. The creel limit of black bass is five per day in aggregate. J. Percy Priest Reservoir experiences intense fishing activity due to its proximity to Nashville, Tennessee. At least 471 fishing tournaments, sponsored by more than 40 clubs, occurred on J. Percy Priest Reservoir in 2004 (Kaintz 2005).

Largemouth bass were tagged at two locations in J. Percy Priest reservoir (Figure 1). Tournament weigh-ins occurred at Elm Hill Marina at the lower end of the reservoir from May 2006 to July 2006. The Elm Hill Marina embayment has a surface area of 35 ha. Fate Sanders Marina hosted tournament weigh-ins from April 2006 to February 2007; its embayment has an area of 41 ha.

METHODS

Water Weigh-In System Components

Three portable aluminum troughs on frames were transported to bass tournaments at J. Percy Priest Reservoir. The troughs were made from 0.476 mm Aluminum 6061-T6 sheets and measured 2.74 m long x 0.61 m wide x 0.38 m deep. The frames for the troughs consisted of 2.54 cm x 5.08 cm x 0.64 cm Aluminum 6063 T52 tubing. Five sets of 25.4 cm tubing pieces were welded to the sides of the frame in order to hold the troughs in place. Five sets of 61.6 cm tubing pieces were welded on the frame, with 30.5 cm tubing cross-supports, which act as legs for the trough and frame. The trough and frame assemblies were not welded together in order to expedite breakdown and transport to tournament weigh-in sites. Each trough held five plastic totes (57.2 cm long x 39.4 cm wide x 32.4 cm deep; Storage Systems, Cerritos, California) and each tote had eighteen drain holes. Each trough was equipped with two air-stones (30.3 cm x 3.7 cm x 3.7 cm) supplying bottled oxygen to maintain saturated dissolved oxygen concentrations.

Tournament Protocols and Sample Collection

Seventeen fishing tournaments (nine water weigh-in tournaments and eight standard weigh-in tournaments) were attended between March 2006 and February 2007. Bass clubs followed standard tournament procedures (i.e., using a central weigh-in station and a designated weigh-in time for all anglers). Winter tournament weigh-ins occurred during daylight hours and summer tournament weigh-ins were usually conducted in the evening or at dawn. During standard weigh-ins, anglers removed their catches from their livewells and placed them into standard 68.6 cm x 61.0 cm plastic transfer bags. Anglers held their catch in the transfer bags containing lake water until reaching the scale, where fish were judged alive or dead, measured, and weighed collectively by the tournament organizer. At tournaments with water weigh-ins, anglers transferred their catch from transfer bags into plastic totes positioned in the holding troughs. To weigh fish collectively or individually, totes were removed, drained, and immediately re-immersed in a water-filled basin positioned on a scale that was previously tared with an empty basket. The largest fish in both weigh-in procedures were usually weighed again, individually, to compete for the "big fish " prize in the tournaments.

Largemouth bass were randomly sampled for the purposes of drawing blood. Approximately 1 ml of blood was drawn from the caudal vein of non-anesthetized fish using a 21-G needle and a 6 mL vacuum tube containing sodium fluoride (15 mg) and potassium oxalate (12 mg) to inhibit coagulation and glycolysis. The blood samples were placed in a water-ice slurry, centrifuged at the conclusion of the weigh-in, and stored at -12 °C. Plasma cortisol concentrations were determined using a commercial radioimmunoassay kit (Coat-a-Count, Diagnostic Products Corporation, Los Angeles, California), as in Suski et al. (2003). Plasma osmolarity was measured using freezing-point osmometry (Advanced Micro-Osmometer Model 3300, Advanced Instruments, Inc., Norwood, Massachusetts). Plasma lactate concentrations were measured using the method and reagent provided by Biomedical Research Service Center (Buffalo, New York).

The plasma lactate assay sample size (n = 127) was smaller compared to sample sizes for plasma cortisol and osmolarity (n = 208). Plasma lactate values obtained from March 2006 to May 2006 were censored from the analysis because the blood collection tubes used in those months lacked a glycolytic inhibitor; therefore, lactate production may have continued after the samples were obtained from the fish.

Radio Telemetry

In order to determine the fate of free-ranging bass released from the weigh-in sites, radio tags were attached externally to a subsample of fish from each of the two weigh-in groups. The radio tag attachment procedure was performed in a holding tank filled with lake water before blood was drawn. In order to control for procedural variation, the same person attached tags at each tournament and only two individuals drew all of the blood samples. The radio tags had a message attached offering a $50 reward for returning the tag. The radio tags (model F1820; Advanced Telemetry Systems (ATS), Inc., Isanti, Minnesota) had an approximate lifespan of 7 months and were equipped with mortality switches that activated when the tag did not move for either 6 or 12 hours.

Each tag assembly was attached to the fish with #2 braided silk suture (Ethicon, Inc., Somerville, New Jersey). A 3/8-circle reverse cutting needle, gripped with a needle holder, was passed through the dorsal musculature posterior to the dorsal fin. The suture was secured to the fish using two half hitch knots. The braided silk acted as a long- term, slowly absorbing suture.

Radio-tagged fish were tracked using a boat-mounted loop antenna and ATS Model R2000 receiver. Each fish was identified by a unique radio frequency between 30.000 and 31.999 MHz. Tagged fish were tracked once within 36 h of their release, on three separate days during the first week, and at least twice again after the first week, or until their fate was determined. The coordinates of each fish location were entered into a global positioning system receiver (Garmin GPSMAP 172C, Garmin International, Inc.). The geographic coordinates were then transferred to ArcGIS 9 to develop a map of post-release dispersal. Minimum distance traversed was calculated using Garmin MapSource software.

Radio transmitter range decreases exponentially with increasing water conductivity (Winter 1996). J. Percy Priest reservoir has relatively high conductivity (i.e., ~ 275 μS/cm); therefore, low detection range was problematic. The ranges of two randomly chosen radio transmitters were tested by suspending the transmitters at different depths. The average ranges of the tags positioned at the surface and at depths of 3 m, 6 m, and 7.5 m were 162 m, 48 m, 4 m, and 0 m, respectively.

Testing for Handling Effects

A single experiment was performed to test for possible effects of tag attachment and blood sampling on survival. Largemouth bass were collected in March 2007 from J. Percy Priest reservoir using a boat outfitted with DC electrofishing gear. Fish were transferred to a hatchery truck and transported in untreated lake water to a Tennessee Wildlife Resources Agency hatchery pond. Twenty largemouth bass had blood drawn and mock radio tags attached following the same procedures described above for tournament-processed fish. The remaining 20 control fish were not subjected to those procedures. All fish were released into a 0.04-ha pond and held for 11 d, after which the pond was drained and the fate (alive or dead) of each fish determined.

Fate Determination

The fate of each radio-tagged fish was assigned at the conclusion of each 14-d tracking period. Fate determination protocols were based on the methods developed by Bendock and Alexandersdottir (1993) and Kerns (2006). The fates (i.e., dead or alive) were defined as follows:

(1) Survived – Fish was located at least twice and moved 200 m or more between its last two or three locations, fish was recaptured alive, or the fish traveled less than 150 m between its last two or three locations but the mortality switch was never activated.
(2) Died – Fish was located at least twice and moved less than 150 m between its last two or three locations and the mortality switch was activated at least once, or the fish was found dead.
(3) Censored – Fish was located only once or not at all.

No tags were observed transmitting continuously (i.e., during several consecutive locations) with the mortality switch on, presumably because scavengers of a tagged carcass caused the transmitter to move from time to time (and reset the switch). Therefore, the doubled-pulse signal transmission initiated by a mortality switch in the "on" position was used as a secondary indicator of mortality and distance moved between consecutive locations was the primary indicator.

Hightower et al. (2001) noted that there were four explanations for not locating a fish in a tracking event: (1) the fish was present in the study area but the signal was missed; (2) transmitter failure; (3) the fish passed through dam turbines; and (4) unreported harvest. Missed signals in the present study were possible due to poor transmitter range if the tagged fish was 6 m or deeper.

Data Analysis

The mean concentrations of plasma lactate (µmol/L), cortisol (ng/mL), and osmolarity (mOsm/L) were compared separately between the two weigh-in systems using a *t*-test. The relationships between delayed mortality (a binomial variable) and the blood chemistry variables as well as several environmental variables were examined using stepwise multiple logistic regression. Variation in delayed mortality was modeled as a function of plasma cortisol, lactate, and osmotic concentrations (continuous variables), tournament weigh-in procedure (a binomial variable), fish total length (TL, mm), tournament duration (h), surface water temperature (°C), and surface dissolved oxygen (mg/L) (all continuous variables) at the weigh-in site. Variables were entered into the model if the probability of a Type I error was less than 10%. The fit of the data to the logistic model was assessed using the Hosmer and Lemeshow Goodness-of-Fit test. Pearson's correlation analysis was used to assess multicollinearity. Variation in blood chemistry parameters (cortisol, lactate, and osmolarity) was separately evaluated using analysis-of-covariance (ANCOVA), where water temperature (°C), fish length (mm), and tournament length (h) were covariables and weigh-in procedure was the independent variable. The assumption of equal slopes was tested using an *f*-test before performing an *f*-test of adjusted means. Variation in blood chemistry parameters was evaluated using two-way analysis-of-variance (ANOVA) when ANCOVA was not a suitable model. All statistical analyses were performed using statements written for the Statistical Analysis System program (SAS Institute 2005).

RESULTS

Handling Effects

Forty largemouth bass (TL range: 336 to 533 mm; mean = 421; SE = 7.8) were electrofished in March 2007 when the reservoir surface water temperature was 16°C. One of the 20 treatment (handled, tagged, and bled) fish and 2 of 20 control (handled only) fish released into the hatchery pond died during the 11-d observation period. Thus, the fate of each fish was not influenced ($\chi^2 = 0.36$, df = 1, $P = 0.5483$) by tag attachment and blood sampling. Although the treatment of these fish did not mimic exactly conditions that fish experienced when subjected to the tournament weigh-ins (e.g., fish were electrofished versus angled and transported in hatchery trucks versus held in boat livewells), this experiment does support our contention that experimental procedures did not contribute to any observed mortality.

Plasma Assays

Blood was sampled from 208 largemouth bass (TL range: 340 to 570 mm; mean = 443 mm; SE = 3.1) subjected to one of the two weigh-in procedures. Plasma cortisol concentrations did not differ between largemouth bass subjected to either weigh-in system ($t = 0.91$; $df = 206$; $P = 0.3630$) (Figure 2). Cortisol concentrations for both weigh-in procedures increased with water temperature and total length of fish (linear regression; $F \geq 4.15$; $P \leq 0.0440$). However, adjusted mean cortisol concentrations did not differ between weigh-in procedures when temperature ($F = 0.97$; $df = 1, 205$; $P = 0.3257$) or total length ($F = 0.47$; $df = 1, 204$; $P = 0.4949$) was a covariable.

The type of weigh-in procedure did not affect plasma lactate concentrations ($t = -1.67$; $df = 125$; $P = 0.0968$) (Figure 2). Plasma lactate concentrations varied directly with water temperature for both weigh-in procedures (linear regression; $F \geq 17.32$; $P \leq 0.0001$) but adjusted mean lactate concentrations did not differ ($F = 0.18$; $df = 1, 124$; $P = 0.6722$) between weigh-in procedures when temperature was a covariable. Lactate concentrations did not vary with total length for fish from the water weigh-in or for all fish combined (linear regression; $F \leq 1.75$; $P \geq 0.1887$). However, lactate concentration increased with total length for fish from the standard weigh-in ($F = 10.43$; $df = 1, 66$; $P = 0.0019$); these findings might suggest an advantageous effect of the water weigh-in procedure (i.e., it may negate length-related increases in lactate).

Osmolarity was significantly higher in fish subjected to the standard weigh-in procedure compared to the water weigh-in procedure ($t = 5.26$; $df = 206$; $P \leq 0.0001$) (Figure 2). Osmolarity values did not follow a linear pattern with water temperature and an analysis of covariance was not applicable; instead, a two-way analysis of variance (with weigh-in type and temperature range as classification variables) was performed. Osmolarity values differed among low (≤ 11°C), medium (11°C – 21°C), and high temperature (≥ 21°C) groups ($F = 253.07$; $df = 2, 202$; $P \leq 0.0001$) and between the two weigh-in types ($F = 8.68$; $df = 1, 202$; $P \leq 0.0001$); the interaction term was significant ($P = 0.0001$). Osmolarity was higher (LSMEANS test; $P < 0.0001$) in fish from the standard weigh-ins compared to fish from the water weigh-in at high temperatures, but the means were similar ($P \geq 0.1746$) between weigh-ins at low and intermediate temperatures. Within each type of weigh-in procedure, osmolarity was similar ($P \geq 0.6845$) at low and high temperatures, but lower ($P < 0.001$) at intermediate temperatures.

Osmolarity concentrations did not vary with total length for fish from either weigh-in procedure, or for all fish combined (linear regression; F ≤ 1.17; *P* ≥ 0.2815).

Delayed Mortality

Eighty-one largemouth bass (mean TL = 448; SE = 5.2) were randomly selected for radio transmitter attachment from April 2006 to February 2007. Largemouth bass were tagged and released into water with surface temperatures ranging from 7.4 to 29.9°C (mean = 21°C; SE = 2.2). Tournaments ranged in duration from 4 to 8 h (mean = 6.0 h; SE = 0.43). Thirty-six largemouth bass were tagged after a water weigh-in and 45 fish were tagged after a standard weigh-in. Eight fish from the standard weigh-in and one fish from the water weigh-in were subsequently censored from the analysis of fate because they were located only once or not at all.

Thirteen (37%) of the tagged largemouth bass died after the water weigh-in procedure and 10 (27%) of the tagged largemouth bass died after the standard weigh-in procedure. The type of weigh-in procedure did not affect the fate of the tagged fish ($\chi^2 = 0.85$, df = 1, $P = 0.3575$). Pooling fish from the two weigh-in methods, delayed mortality was higher at water temperatures above 27°C (63%) compared to water temperatures less than 22°C (13%) ($\chi^2 = 19.1$, df = 1, $P < 0.0001$). Nearly all (91%) delayed mortality occurred within six days of being released at a tournament (Figure 3). Overall, delayed mortality was 32% across all seasons and weigh-in types.

The only two variables selected for entry into the logistic regression model as significant predictors of delayed mortality were water temperature (WTEMP) and total length ($P = 0.0069$ and $P = 0.0235$, respectively). Mortality increased directly with water temperature and total length and these two variables were not correlated (r = -0.0726; $P = 0.5195$). The two-variable model passed the Hosmer and Lemeshow Goodness-of-Fit test ($\chi^2 = 7.0$, df = 8, $P = 0.5342$) and was

$$\text{Probability of Delayed Mortality} = \frac{e^{-11.7669+0.1492(WTEMP)+0.0173(TL)}}{1+e^{-11.7669+0.1492(WTEMP)+0.0173(TL)}}\ .$$

The probability of delayed mortality increased from 2-18% at 10°C for fish 381 – 508 mm TL to 19-68% at 25°C for the same sized fish (Figure 4). The binomial variable "type of tournament weigh-in" was selected for entry into the forward-selection model only when the probability for entry was raised to $P = 0.21$. That is, in a three-variable model containing the variables

WTEMP, TL, and Weigh-in Type, the probability of a Type I error associated with Weigh-In Type was *P* = 0.2075; thus, the type of weigh-in that fish experienced did not significantly influence their subsequent survival.

Eight radio tags were recovered from 81 largemouth bass tagged and released after tournament weigh-ins. Fishermen were given $400 (8 tags @ $50/tag) in exchange for returning recovered radio tags. Six tags were returned from fish caught by anglers, one tag was recovered from a dead fish, and one tag was found on the shoreline (unattached to a fish carcass).

Movement and Dispersal

Fish tended to remain near the release site for several days before dispersing. Three days after release, most (60%) fish were located within the embayment where they were released. The average distance traversed by all fish that survived within the first three days of release was 0.68 km (SE = 0.07), compared to 0.57 km (SE = 0.09) by fish that died (t = -1.02; df = 60; *P* = 0.3101) (Table 1). The minimum distance traversed by tagged largemouth bass that survived averaged 1.48 km (SE = 0.16) after six days; fish that subsequently died traversed only 1.16 km (SE = 0.22) in the same period (t = -1.19; df = 38; *P* = 0.2411) (Table 1). Seven days post release, 62% of the surviving largemouth bass were with 0.5 km of their release site. All largemouth bass that survived traversed an average minimum distance of 2.48 km (SE = 0.38) during the first 13-d after release. Minimum distances traversed within 13 d were similar for largemouth bass that survived the water weigh-in and standard weigh-in procedures (t = -0.61; df = 12; *P* = 0.5531). Fish that were tagged after the water weigh-in procedure and survived traversed a minimum distance of 2.71 km (SE = 0.60) and fish that were subjected to the standard weigh-in procedure and survived traversed a minimum distance of 2.24 km (SE = 0.48). The greatest minimum distance traversed in 13-d was 5.33 km by a fish subjected to a water weigh-in and released from Fate Sanders Marina. On their final location, most (70%) largemouth bass that succumbed to delayed mortality were in the embayment in which they were released. Of the 23 fish that died, 8 (35%) were within 100 m of their respective release site.

Largemouth bass released from the Fate Sanders Marina generally remained in the embayment for several days before following the shoreline uplake or downlake. Most fish traveling downlake traversed the shallow eastern shore, opposite the Stones River channel. Only 9 (13%) largemouth bass crossed the Stones River Channel, located approximately 0.5 km from the release site. Fish released from Elm Hill Marina also tended to remain in the embayment for several days. Many largemouth bass located outside the embayment traveled along the western shore, moving downlake towards the dam.

DISCUSSION

Physiological Effects

Stress responses of largemouth bass had not been compared between fish subjected to either a water weigh-in or a standard (in air) tournament weigh-in prior to the present study. Suski et al. (2003) compared plasma osmolarity, lactate, and cortisol in largemouth bass subjected to standard tournament weigh-ins, in control fish held in a laboratory, and in control fish rapidly collected in the wild by angling. Fish subjected to the standard tournament weigh-in had elevated blood plasma constituents compared to either control group. In a follow up study, Suski et al. (2004) observed lower plasma lactate concentrations in largemouth bass from a simulated (i.e., in the laboratory) water weigh-in compared to fish from a simulated air weigh-in. Suski et al. (2003, 2004) recommended that air exposure during tournament weigh-ins be minimized to reduce physiological stress, and thus presumably post-release mortality. In the present study, plasma osmolarity was also higher in fish from standard weigh-ins compared to fish from water weigh-ins when temperatures were high (≥ 21°C); however, plasma lactate and cortisol concentrations were not reduced by the water weigh-in procedure compared to those that experienced a standard weigh-in. Lack of concordance between the results of Suski et al. (2003, 2004) and the present study *vis-à-vis* mitigation of elevated cortisol and plasma lactate concentrations may have resulted from the confounding effects of different temperature regimes. Suski et al. (2003, 2004) examined the stress responses in largemouth bass over a narrow temperature range (22 -24°C); whereas, the tournaments at J. Percy Priest Reservoir occurred at water temperatures ranging from 7°C to 30°C. Moreover, the fish tested by Suski et al. (2004) averaged 327 mm TL, much smaller than the average size (448 mm TL) in the present study. Plasma lactate concentrations can vary with fish length (as observed for fish subjected to standard weigh-ins in the present study). Whereas the studies described by Suski et al. (2003, 2004) were well designed to reduce confounding factors in order to more clearly reveal experimental effects and fish responses, the present field study reflects the more extreme and highly variable nature of largemouth bass fishing tournaments in southern U.S. water bodies.

It has been common for researchers to assess delayed mortality by direct observation of fish in net pens or raceways for up to 4 d after capture (Kwak and Henry 1995; Weathers and Newman 1997; Neal and Lopez-Clayton 2001; Edwards et al. 2004). In the present study, delayed mortality in some fish was observed up to 10 d after release. Similar to the findings of Schramm et al. (1987), the majority of delayed mortality in the present study occurred within 6 d of tournament release. Researchers who plan to use the net pen confinement method to assess delayed mortality should extend their observation to at least 6 d.

Subjecting fish to a water weigh-in did not reduce delayed mortality compared to standard weigh-in procedures. However, this finding does not obviate the potential efficacy of a water weigh-in protocol because live-well conditions, duration of containment in transfer bags, and other factors were not controlled in this study. Likewise, some fish were exposed to air after blood drawing and radio attachment in order for anglers to take pictures of their catch. Nevertheless, such uncontrolled variability is likely to be the norm in most fishing tournaments and the findings reported herein offer a realistic evaluation of the efficacy of a water weigh-in to reduce delayed mortality.

The failure of a water weigh-in procedure to reduce delayed mortality may have been related to the fact that handling (and stressing) largemouth bass at high water temperatures will result in high mortality, regardless of the nature of the stressor or attempts to alleviate stress and improve survival. For instance, Schramm et al. (2006) electrofished largemouth bass to use as a reference (control) in a study examining mortality of largemouth bass held under different livewell conditions. Water temperatures ranged from 27.8 to 32.8 °C and fish remained in a temperature-controlled aerated tank on the boat for no longer than 1 h before being hauled to net-pens or raceways. Despite such precautions, delayed mortality averaged 61% over 5 d. In another study, harvesting and hauling hatchery-reared largemouth bass at high water temperatures resulted in substantial (88%) mortality (Carmichael et al. 1984b).

The rate of delayed tournament mortality observed in J. Percy Priest Reservoir (32%; pooled over all tournaments and weigh-in procedures) was comparable to the 36% rate of delayed mortality observed by Neal and Lopez-Clayton (2001) in Lucchetti Reservoir, Puerto Rico, at water temperatures between 23°C and 28°C. On Lake Eufaula, Alabama, Weathers and Newman (1997) recorded an average delayed mortality rate of 22% at water temperatures ranging from 27.2°C to 32.8°C. High water temperatures likely account for the similarity in delayed mortality rates among Lucchetti Reservoir, Lake Eufaula, and J. Percy Priest Reservoir.

Conversely, Kwak and Henry (1995) and Edwards et al. (2004) recorded much lower delayed mortality rates of 1% to 3% for largemouth bass in average water temperatures of 20°C and 22°C. Similar to the findings of Schramm et al. (1987) and Edwards et al. (2004), the present study showed a positive relationship between water temperature and the probability of delayed mortality.

Meals and Miranda (1994) observed a direct relationship between size and mortality in largemouth bass in Mississippi tournaments, a finding similar to that in the present study. The direct relationship between size and mortality could be explained by higher oxygen requirements of larger fish (Herman and Meyer 1990), making larger fish more likely to suffer hypoxia and stress. The relationship between delayed mortality and fish size is of particular interest because prize money in many fishing tournaments is usually awarded to anglers presenting the highest collective catch weight and the largest single fish. Hence, tournament anglers often target larger fish, which in turn increases the probability of delayed mortality.

Movement and Dispersal

Several researchers have attempted to describe the movements and dispersal of largemouth bass from tournament release sites. Richardson-Heft et al. (2000) reported that 64% of radio-tagged largemouth bass were located within 0.5 km from their release site after one week, a behavior they termed “stockpiling.” Wilde and Paulson (2003) reported that 63% of tagged fish remained within 0.5 km of the release site after 43 d. Of the largemouth bass in the present study located 7 d after release, 62% displayed stockpiling behavior. Stockpiling of largemouth bass near tournament release sites could lead to greater exploitation by non-tournament anglers (Gilliland 1999), assuming stockpiled fish are available to the fishery. Stockpiling could also lead to an increase in the biomass of largemouth bass in a relatively small area, which might negatively affect growth, body condition, and mortality (Hunter 2006).

MANAGEMENT IMPLICATIONS

Delayed mortality rates of released largemouth bass were high at elevated water temperatures, regardless of the weigh-in procedure; thus, holding summer tournaments is not compatible with releasing all fish alive and healthy. Tournament organizers and anglers alike have long embraced (and researchers have long studied) livewell practices such as aeration, exchanging water, and the addition of chemicals to reduce fish stress and improve survival (e.g., Plumb et al. 1988; Gilliland et al. 2002). However, the findings reported herein and the results of previous studies indicate that high mortality of tournament-caught-and-released largemouth bass is difficult to avoid at high water temperatures, regardless of how the fish are treated.

Tournament bass fishing is very popular on J. Percy Priest Reservoir and the current structure of the largemouth bass population reflects all the forces of mortality acting on that population, including tournament-associated mortality. If anglers and managers were satisfied with the current abundance and structure of the largemouth bass population, it would be difficult to argue for restrictions on fishing tournaments. Likewise, limiting the number of tournaments (or when they could be held) would not be justified unless subsequent study revealed that delayed mortality after tournaments represented a large percentage of fishing mortality. For example, tournament mortality only accounted for 6-28% of all fishing mortality for largemouth bass at Sam Rayburn Reservoir, Texas (Driscoll et al. 2007) and no restrictions on tournaments were justified. If tournament-associated mortality is only a minor component of total mortality for largemouth bass in J. Percy Priest Reservoir, the only concern facing tournament organizers is the possible negative publicity associated with sponsoring tournaments and unintentionally killing fish during hot, summer months.

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Table 1. Mean minimum distances traversed by largemouth bass that survived and died during the 14-d tracking period.

Days after release	N	Mean Distance (km)	SE
		Survived	
1	30	0.20	0.03
3	40	0.68	0.07
6	21	1.48	0.16
10	25	1.87	0.23
13	14	2.48	0.38
		Died	
1	8	0.13	0.05
3	22	0.57	0.09
6	19	1.16	0.22
10	14	1.46	0.29
13	12	1.56	0.35

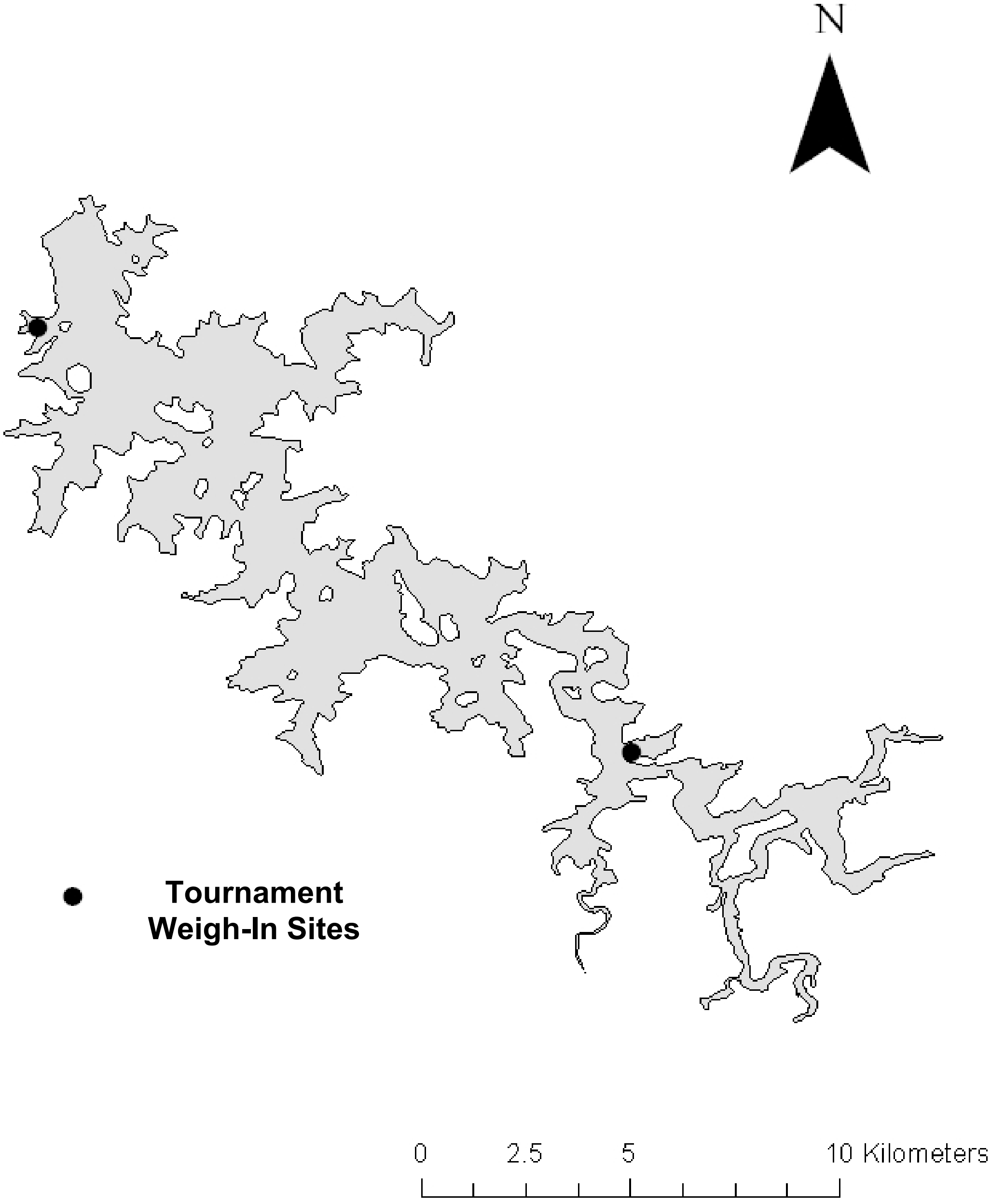

Figure 1. Map of tournament weigh-in sites in J. Percy Priest Reservoir: Elm Hill Marina (near the dam) and Fate Sanders Marina (uplake).

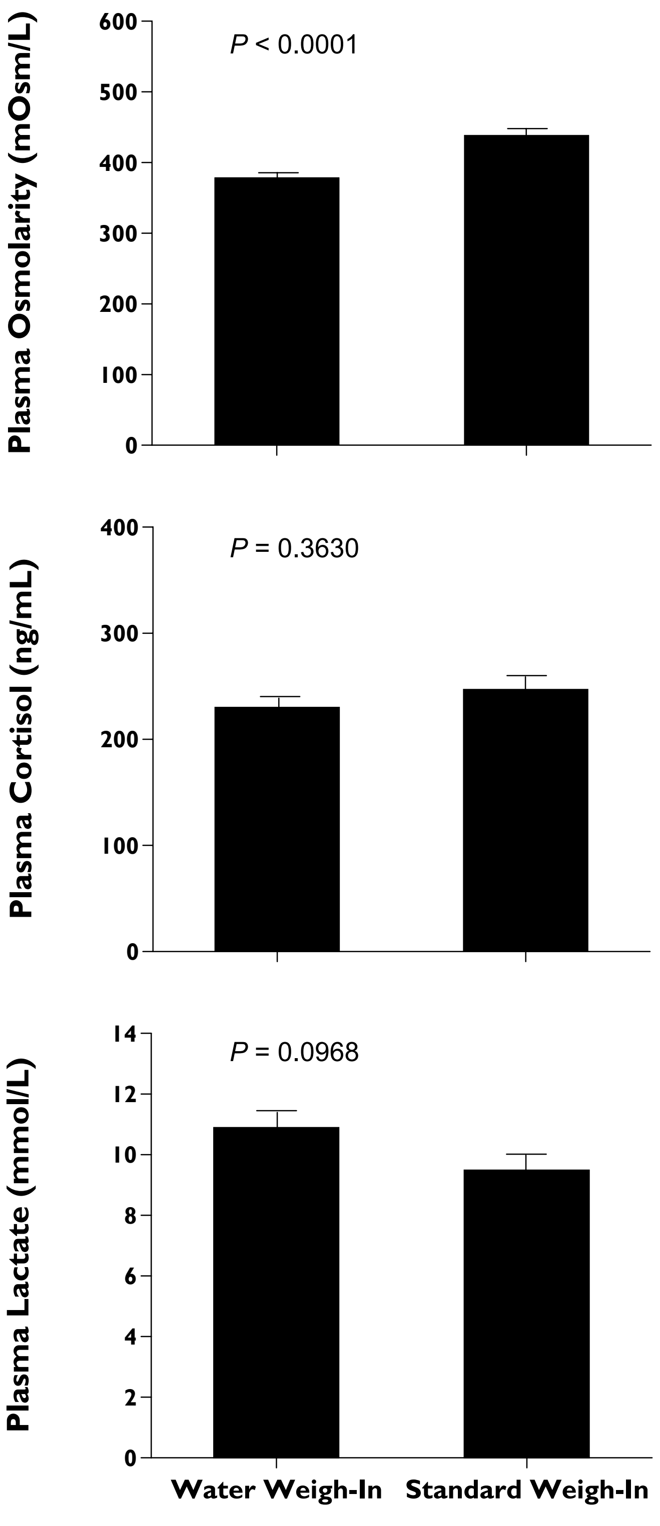

Figure 2. Mean (+SE) (**A**) plasma osmolarity, (**B**) cortisol, and (**C**) lactate concentrations for tournament-caught largemouth bass on J. Percy Priest Reservoir, Tennessee.

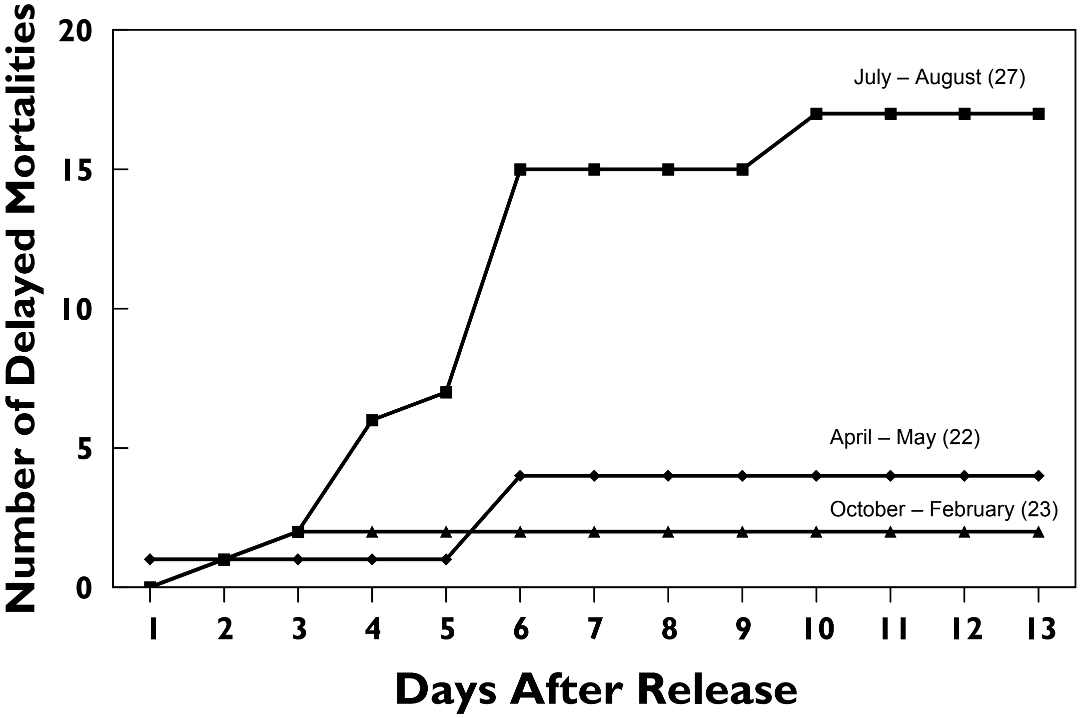

Figure 3. Cumulative delayed mortalities in three seasons for largemouth bass released from water weigh-in and standard weigh-in tournaments on J. Percy Priest Reservoir, Tennessee. Sample size in parentheses. Average water temperatures were 29 °C in July – August, 20 °C in April – May, and 15 °C in October - February.

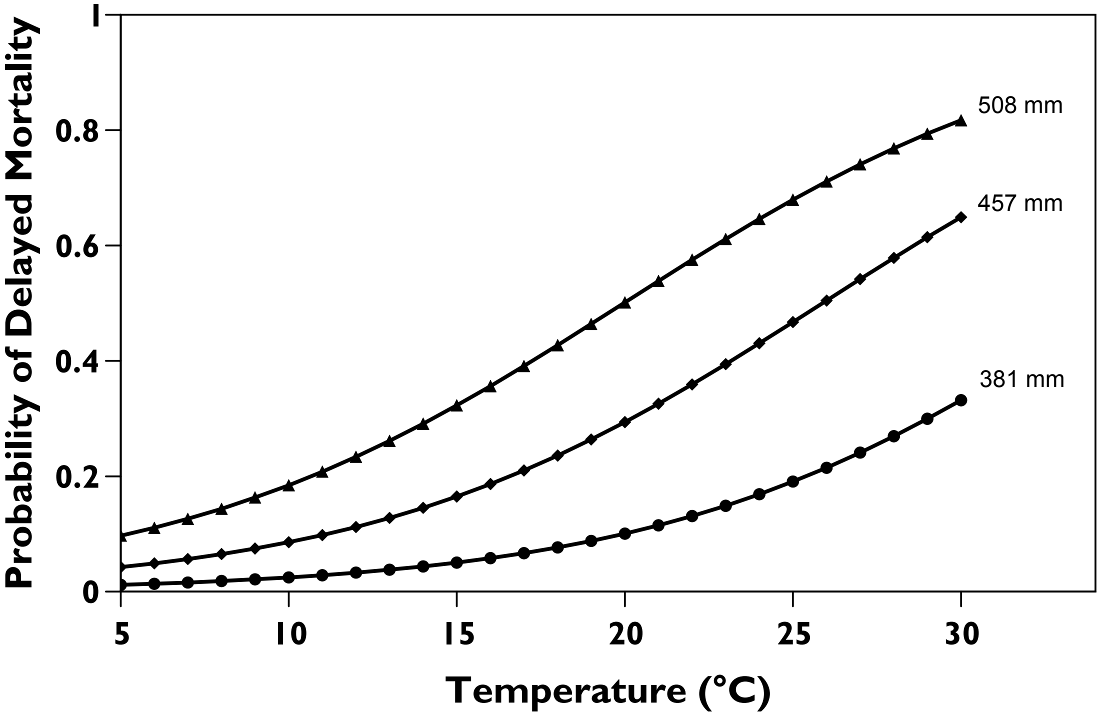

Figure 4. Probability of delayed mortality as a function of total length and water temperature for tournament caught largemouth bass on J. Percy Priest Reservoir, Tennessee. The three lengths depicted represent the minimum, mean, and maximum total lengths of fish utilized in this study.

APPENDIX

Table A1. Summary of radio telemetry data for tournament-caught largemouth bass on J. Percy Priest Reservoir, Tennessee from May 2006 to February 2007. Minimum distance traversed is the distance between the release point and the final location. Weigh-In codes are: W = water weigh-In; and S = standard weigh-In. Fate codes are: A = alive; D = dead; and C = censored.

Fish ID	Tag Number	Date Tagged	Weigh-In Type	Number of Fixes	Minimum Distance Traversed (km)	Fate
2 - 3	30.240	4/15/06	W	3	2.05	A
2 - 10	31.312	4/15/06	W	4	4.01	A
2 - 7	31.553	4/15/06	W	1	.	C
2 - 4	31.612	4/15/06	W	2	0.31	A
2 - 2	31.958	4/15/06	W	2	0.95	A
3 - 11	30.250	4/17/06	S	4	0.29	A
3 - 2	31.262	4/17/06	S	0	.	C
3 - 12	31.282	4/17/06	S	3	1.00	A
3 - 7	31.553(B)	4/17/06	S	3	0.07	D
3 - 8	31.792	4/17/06	S	4	0.57	A
3 - 9	31.939	4/17/06	S	2	0.71	A
4 - 21	30.170	5/13/06	W	3	0.41	A
4 - 6	30.180	5/13/06	W	6	0.54	D
4 - 1	30.732	5/13/06	W	4	0.67	D
4 - 9	31.034	5/13/06	W	6	2.50	A
4 - 18	31.122	5/13/06	W	7	5.19	A
4 - 14	31.142	5/13/06	W	8	1.56	D
4 - 2	31.652	5/13/06	W	4	1.21	A
4 - 20	31.979	5/13/06	W	2	0.70	A
5 - 2	30.259	5/15/06	S	6	2.76	A
5 - 3	30.692	5/15/06	S	1	.	C
5 - 9	31.102	5/15/06	S	3	1.10	A
5 - 8	31.202	5/15/06	S	6	2.45	A
5 - 6	31.593	5/15/06	S	5	1.17	A
5 - 1	31.771	5/15/06	S	5	1.00	A
8 - 6	31.034(B)	7/9/06	W	8	0.87	D
8 - 2	31.122(B)	7/9/06	W	8	0.51	D
8 - 4	31.222	7/9/06	W	8	0.55	D
8 - 3	31.302	7/9/06	W	7	1.00	D
8 - 1	31.422	7/9/06	W	4	2.43	A
8 - 7	31.572	7/9/06	W	7	3.83	A
8 - 5	31.919	7/9/06	W	2	0.94	A
9 - 8	30.189	7/10/06	S	5	0.24	D
9 - 4	30.199	7/10/06	S	1	.	C
9 - 1	30.209	7/10/06	S	1	.	C
9 - 3	30.219	7/10/06	S	4	1.10	A
9 - 5	30.312	7/10/06	S	1	.	C

Table A1. Continued.

Fish ID	Tag Number	Date Tagged	Weigh-In Type	Number of Fixes	Minimum Distance Traversed (km)	Fate
9 - 9	30.332	7/10/06	S	3	1.24	A
9 - 7	30.801	7/10/06	S	0	.	C
12 - 1	30.452	8/27/06	W	8	2.09	D
12 - 6	30.812	8/27/06	W	8	0.99	A
12 - 5	30.872	8/27/06	W	8	0.74	D
12 - 4	31.082	8/27/06	W	8	1.33	D
12 - 2	31.502	8/27/06	W	8	1.52	D
12 - 3	31.742	8/27/06	W	7	2.72	D
13 - 6	30.412	8/27/06	S	5	2.01	A
13 - 13	30.492	8/27/06	S	8	2.09	D
13 - 11	30.512	8/27/06	S	7	3.19	A
13 - 1	30.571	8/27/06	S	8	4.60	D
13 - 4	30.772	8/27/06	S	8	0.67	D
13 - 12	30.832	8/27/06	S	7	2.03	A
13 - 3	30.891	8/27/06	S	4	0.55	D
13 - 14	30.912	8/27/06	S	0	.	C
13 - 9	30.932	8/27/06	S	8	0.59	D
13 - 2	31.242	8/27/06	S	8	0.86	D
13 - 8	31.672	8/27/06	S	8	0.26	A
13 - 10	31.701	8/27/06	S	8	1.27	D
14 - 2	30.432	10/7/06	W	8	4.34	A
14 - 1	30.642	10/7/06	W	7	2.67	A
14 - 6	30.662	10/7/06	W	8	2.32	A
14 - 4	30.852	10/7/06	W	4	1.30	A
14 - 3	31.352	10/7/06	W	7	1.21	A
14 - 9	31.392	10/7/06	W	8	2.13	A
14 - 5	31.632	10/7/06	W	8	5.33	A
15 - 1	30.392	10/7/06	S	1	.	C
15 - 5	30.712	10/7/06	S	8	3.33	A
15 - 3	30.752	10/7/06	S	7	1.93	A
15 - 4	31.063	10/7/06	S	8	3.79	A
15 - 2	31.162	10/7/06	S	6	0.97	A
16 - 3	30.372	2/24/07	W	6	1.48	A
16 - 2	30.552	2/24/07	W	3	0.21	A
16 - 1	30.952	2/24/07	W	7	0.18	D
17 - 4	30.472	2/25/07	S	6	0.36	A
17 - 8	30.532	2/25/07	S	7	1.04	A
17 - 5	30.602	2/25/07	S	7	0.61	D
17 - 10	30.971	2/25/07	S	7	2.28	A
17 - 7	31.192	2/25/07	S	5	0.69	A
17 - 2	31.332	2/25/07	S	7	0.62	A

Table A1. Continued.

Fish ID	Tag Number	Date Tagged	Weigh-In Type	Number of Fixes	Minimum Distance Traversed (km)	Fate
17 - 9	31.372	2/25/07	S	4	1.17	A
17 - 6	31.442	2/25/07	S	3	0.87	A
17 - 3	31.522	2/25/07	S	6	1.33	A

Table A2. Summary of data collected at tournament weigh-ins and plasma parameters for largemouth bass sampled from tournament weigh-ins on J. Percy Priest Reservoir, Tennessee.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (µM)	Plasma Osmolarity (mOsm/L)
1 - 7	.	3/18/07	W	8	462	14.7	.	152	.	321
1 - 8	.	3/18/07	W	8	407	14.7	.	54	.	314
1 - 11	.	3/18/07	W	8	496	14.7	.	90	.	331
1 - 14	.	3/18/07	W	8	384	14.7	.	75	.	304
1 - 15	.	3/18/07	W	8	460	14.7	.	102	.	317
1 - 16	.	3/18/07	W	8	340	14.7	.	55	.	284
1 - 18	.	3/18/07	W	8	390	14.7	.	59	.	313
1 - 19	.	3/18/07	W	8	425	14.7	.	50	.	308
1 - 20	.	3/18/07	W	8	417	14.7	.	91	.	300
1 - 21	.	3/18/07	W	8	395	14.7	.	126	.	330
1 - 22	.	3/18/07	W	8	432	14.7	.	89	.	309
1 - 23	.	3/18/07	W	8	385	14.7	.	82	.	307
1 - 24	.	3/18/07	W	8	390	14.7	.	239	.	293
1 - 25	.	3/18/07	W	8	405	14.7	.	122	.	309
1 - 26	.	3/18/07	W	8	390	14.7	.	166	.	313
2 - 1	.	4/15/07	W	6	432	19.3	.	149	.	322
2 - 2	31.958	4/15/07	W	6	408	19.3	.	97	.	325
2 - 3	30.240	4/15/07	W	6	427	19.3	.	105	.	327
2 - 4	31.612	4/15/07	W	6	502	19.3	.	270	.	323
2 - 5	.	4/15/07	W	6	431	19.3	.	152	.	329
2 - 6	.	4/15/07	W	6	396	19.3	.	169	.	315
2 - 7	31.553	4/15/07	W	6	395	19.3	.	272	.	323
2 - 8	.	4/15/07	W	6	433	19.3	.	133	.	329
2 - 9	.	4/15/07	W	6	387	19.3	.	191	.	316

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
2 - 10	31.312	4/15/07	W	6	409	19.3	.	181	.	326
2 - 11	.	4/15/07	W	6	435	19.3	.	186	.	329
2 - 12	.	4/15/07	W	6	463	19.3	.	55	.	303
2 - 13	.	4/15/07	W	6	460	19.3	.	137	.	311
2 - 14	.	4/15/07	W	6	389	19.3	.	97	.	315
2 - 15	.	4/15/07	W	6	457	19.3	.	110	.	333
3 - 1		4/17/07	S	4	388	20.5	9.57	140	.	321
3 - 2	31.262	4/17/07	S	4	454	20.5	9.57	222	.	339
3 - 3	.	4/17/07	S	4	475	20.5	9.57	301	.	322
3 - 4	.	4/17/07	S	4	519	20.5	9.57	55	.	330
3 - 5	.	4/17/07	S	4	414	20.5	9.57	111	.	317
3 - 6	.	4/17/07	S	4	425	20.5	9.57	217	.	304
3 - 7	31.553(B)	4/17/07	S	4	455	20.5	9.57	102	.	319
3 - 8	31.792	4/17/07	S	4	425	20.5	9.57	134	.	309
3 - 9	31.939	4/17/07	S	4	460	20.5	9.57	239	.	320
3 - 10	.	4/17/07	S	4	410	20.5	9.57	119	.	314
3 - 11	30.250	4/17/07	S	4	435	20.5	9.57	129	.	310
3 - 12	31.282	4/17/07	S	4	390	20.5	9.57	113	.	337
4 - 1	30.732	5/13/07	W	8	520	20.4	10.19	312	.	328
4 - 2	31.652	5/13/07	W	8	393	20.4	10.19	253	.	308
4 - 3	.	5/13/07	W	8	399	20.4	10.19	143	.	312
4 - 4	.	5/13/07	W	8	422	20.4	10.19	361	.	318
4 - 5	.	5/13/07	W	8	424	20.4	10.19	.	.	.
4 - 6	30.180	5/13/07	W	8	525	20.4	10.19	355	.	320
4 - 7	.	5/13/07	W	8	434	20.4	10.19	371	.	327

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
4 - 8	.	5/13/07	W	8	463	20.4	10.19	.	.	.
4 - 9	31.034	5/13/07	W	8	465	20.4	10.19	234	.	305
4 - 10	.	5/13/07	W	8	470	20.4	10.19	243	.	321
4 - 11	.	5/13/07	W	8	545	20.4	10.19	.	.	.
4 - 12	.	5/13/07	W	8	.	20.4	10.19	341	.	290
4 - 13	.	5/13/07	W	8	403	20.4	10.19	213	.	308
4 - 14	31.142	5/13/07	W	8	435	20.4	10.19	263	.	336
4 - 15	.	5/13/07	W	8	512	20.4	10.19	608	.	322
4 - 16	.	5/13/07	W	8	500	20.4	10.19	509	.	315
4 - 17	.	5/13/07	W	8	446	20.4	10.19	330	.	326
4 - 18	31.122	5/13/07	W	8	442	20.4	10.19	250	.	317
4 - 19	.	5/13/07	W	8	540	20.4	10.19	152	.	303
4 - 20	31.979	5/13/07	W	8	515	20.4	10.19	482	.	319
4 - 21	30.170	5/13/07	W	8	472	20.4	10.19	195	.	329
4 - 22	.	5/13/07	W	8	485	20.4	10.19	.	.	.
4 - 23	.	5/13/07	W	8	448	20.4	10.19	417	.	288
4 - 24	.	5/13/07	W	8	430	20.4	10.19	51	.	339
4 - 25	.	5/13/07	W	8	414	20.4	10.19	472	.	332
4 - 26	.	5/13/07	W	8	498	20.4	10.19	560	.	324
4 - 27	.	5/13/07	W	8	418	20.4	10.19	212	.	317
5 - 1	31.771	5/15/07	S	4	520	18.4	7.65	48	.	304
5 - 2	30.259	5/15/07	S	4	440	18.4	7.65	.	.	.
5 - 3	30.692	5/15/07	S	4	470	18.4	7.65	245	.	306
5 - 4	.	5/15/07	S	4	490	18.4	7.65	208	.	343
5 - 5	.	5/15/07	S	4	560	18.4	7.65	456	.	315

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
5 - 6	31.593	5/15/07	S	4	470	18.4	7.65	192	.	322
5 - 7	.	5/15/07	S	4	460	18.4	7.65	169	.	308
5 - 8	31.202	5/15/07	S	4	390	18.4	7.65	116	.	309
5 - 9	31.102	5/15/07	S	4	370	18.4	7.65	300	.	321
5 - 10	.	5/15/07	S	4	460	18.4	7.65	278	.	319
5 - 11	.	5/15/07	S	4	420	18.4	7.65	122	.	309
5 - 12	.	5/15/07	S	4	430	18.4	7.65	300	.	299
5 - 13	.	5/15/07	S	4	400	18.4	7.65	122	.	298
5 - 14	.	5/15/07	S	4	480	18.4	7.65	390	.	311
5 - 15	.	5/15/07	S	4	440	18.4	7.65	95	.	294
5 - 16	.	5/15/07	S	4	382	18.4	7.65	169	.	320
5 - 17	.	5/15/07	S	4	385	18.4	7.65	44	.	306
6 - 1	.	6/3/07	S	9	514	27.5	10.31	244	13041	516
6 - 2	.	6/3/07	S	9	438	27.5	10.31	215	6764	579
6 - 3	.	6/3/07	S	9	539	27.5	10.31	815	21728	438
6 - 4	.	6/3/07	S	9	437	27.5	10.31	311	6262	537
6 - 5	.	6/3/07	S	9	408	27.5	10.31	307	12840	485
6 - 6	.	6/3/07	S	9	426	27.5	10.31	357	16104	411
6 - 7	.	6/3/07	S	9	492	27.5	10.31	456	14447	452
6 - 8	.	6/3/07	S	9	400	27.5	10.31	366	6965	557
6 - 9	.	6/3/07	S	9	485	27.5	10.31	.	.	.
6 - 10	.	6/3/07	S	9	467	27.5	10.31	307	17761	434
6 - 11	.	6/3/07	S	9	444	27.5	10.31	581	5459	522
6 - 12	.	6/3/07	S	9	436	27.5	10.31	401	14598	506
6 - 13	.	6/3/07	S	9	412	27.5	10.31	530	12790	433

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
6 - 14	.	6/3/07	S	9	404	27.5	10.31	463	13041	563
6 - 15	.	6/3/07	S	9	500	27.5	10.31	248	15351	484
6 - 16	.	6/3/07	S	9	463	27.5	10.31	604	14397	489
6 - 17	.	6/3/07	S	9	425	27.5	10.31	.	.	.
6 - 18	.	6/3/07	S	9	439	27.5	10.31	526	11987	414
6 - 19	.	6/3/07	S	9	424	27.5	10.31	516	4354	587
8 - 1	31.422	7/9/07	W	6	392	28.7	5.80	276	21076	404
8 - 2	31.122(B)	7/9/07	W	6	469	28.7	5.80	542	14949	452
8 - 3	31.302	7/9/07	W	6	383	28.7	5.80	268	14548	382
8 - 4	31.222	7/9/07	W	6	435	28.7	5.80	251	16958	386
8 - 5	31.919	7/9/07	W	6	394	28.7	5.80	192	16154	398
8 - 6	31.034(B)	7/9/07	W	6	480	28.7	5.80	145	24942	410
8 - 7	31.572	7/9/07	W	6	415	28.7	5.80	489	11284	416
9 - 1	30.209	7/10/07	S	4	445	27.5	6.55	.	.	.
9 - 2	.	7/10/07	S	4	413	27.5	6.55	186	7417	505
9 - 3	30.219	7/10/07	S	4	514	27.5	6.55	232	16707	427
9 - 4	30.199	7/10/07	S	4	480	27.5	6.55	400	9275	478
9 - 5	30.312	7/10/07	S	4	434	27.5	6.55	233	9375	491
9 - 6	.	7/10/07	S	4	431	27.5	6.55	238	9024	441
9 - 7	30.801	7/10/07	S	4	463	27.5	6.55	103	11685	474
9 - 8	30.189	7/10/07	S	4	511	27.5	6.55	281	16104	442
9 - 9	30.332	7/10/07	S	4	405	27.5	6.55	337	8271	448
10 - 1	.	8/5/07	W	9	468	30.5	5.75	.	.	.
10 - 2	.	8/5/07	W	9	483	30.5	5.75	101	11886	374
10 - 3	.	8/5/07	W	9	440	30.5	5.75	189	8321	475

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
10 - 4	.	8/5/07	W	9	434	30.5	5.75	338	13895	352
10 - 5	.	8/5/07	W	9	503	30.5	5.75	.	.	.
10 - 6	.	8/5/07	W	9	457	30.5	5.75	200	9074	439
10 - 7	.	8/5/07	W	9	395	30.5	5.75	203	13644	448
10 - 8	.	8/5/07	W	9	532	30.5	5.75	389	11535	430
10 - 9	.	8/5/07	W	9	471	30.5	5.75	.	.	.
10 - 10	.	8/5/07	W	9	435	30.5	5.75	236	14246	411
10 - 11	.	8/5/07	W	9	485	30.5	5.75	237	10781	414
10 - 12	.	8/5/07	W	9	375	30.5	5.75	213	17912	445
10 - 13	.	8/5/07	W	9	373	30.5	5.75	360	20925	441
10 - 14	.	8/5/07	W	9	428	30.5	5.75	168	18515	388
10 - 15	.	8/5/07	W	9	378	30.5	5.75	226	13091	388
10 - 16	.	8/5/07	W	9	406	30.5	5.75	341	14347	418
10 - 17	.	8/5/07	W	9	484	30.5	5.75	308	14598	373
10 - 18	.	8/5/07	W	9	445	30.5	5.75	345	8321	376
10 - 19	.	8/5/07	W	9	450	30.5	5.75	175	8472	381
10 - 20	.	8/5/07	W	9	513	30.5	5.75	202	7015	435
10 - 21	.	8/5/07	W	9	390	30.5	5.75	279	7768	459
10 - 22	.	8/5/07	W	9	570	30.5	5.75	361	8020	341
10 - 23	.	8/5/07	W	9	380	30.5	5.75	277	12187	423
10 - 24	.	8/5/07	W	9	478	30.5	5.75	169	13342	416
10 - 25	.	8/5/07	W	9	392	30.5	5.75	207	10380	362
10 - 26	.	8/5/07	W	9	392	30.5	5.75	.	.	.
10 - 27	.	8/5/07	W	9	420	30.5	5.75	187	5860	485
10 - 28	.	8/5/07	W	9	405	30.5	5.75	417	9827	413

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
10 - 29	.	8/5/07	W	9	530	30.5	5.75	137	9727	355
10 - 30	.	8/5/07	W	9	397	30.5	5.75	228	10430	400
10 - 31	.	8/5/07	W	9	482	30.5	5.75	207	17259	418
10 - 32	.	8/5/07	W	9	462	30.5	5.75	187	10781	402
10 - 33	.	8/5/07	W	9	477	30.5	5.75	283	14397	343
10 - 34	.	8/5/07	W	9	532	30.5	5.75	200	15903	416
10 - 35	.	8/5/07	W	9	428	30.5	5.75	241	11083	408
10 - 36	.	8/5/07	W	9	398	30.5	5.75	238	7116	387
10 - 37	.	8/5/07	W	9	442	30.5	5.75	298	9225	474
10 - 38	.	8/5/07	W	9	395	30.5	5.75	255	7819	411
11 - 1	.	8/5/07	S	5.5	461	30.5	6.90	336	13393	407
11 - 2	.	8/5/07	S	5.5	445	30.5	6.90	75	8472	505
11 - 3	.	8/5/07	S	5.5	460	30.5	6.90	186	8020	543
11 - 4	.	8/5/07	S	5.5	445	30.5	6.90	474	13644	433
11 - 5	.	8/5/07	S	5.5	425	30.5	6.90	221	8120	545
11 - 6	.	8/5/07	S	5.5	491	30.5	6.90	440	13242	450
11 - 7	.	8/5/07	S	5.5	408	30.5	6.90	340	18515	418
11 - 8	.	8/5/07	S	5.5	411	30.5	6.90	154	11685	493
11 - 9	.	8/5/07	S	5.5	430	30.5	6.90	313	9878	488
12 - 1	30.452	8/27/07	W	6	496	29.9	8.08	239	7065	467
12 - 2	31.502	8/27/07	W	6	403	29.9	8.08	320	7065	502
12 - 3	31.742	8/27/07	W	6	435	29.9	8.08	297	4555	598
12 - 4	31.082	8/27/07	W	6	454	29.9	8.08	255	9375	501
12 - 5	30.872	8/27/07	W	6	419	29.9	8.08	279	5408	511
12 - 6	30.812	8/27/07	W	6	355	29.9	8.08	469	12238	492

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
13 - 1	30.571	8/27/07	S	.	504	29.9	8.08	359	5760	462
13 - 2	31.242	8/27/07	S	.	513	29.9	8.08	139	9175	478
13 - 3	30.891	8/27/07	S	.	392	29.9	8.08	236	5961	665
13 - 4	30.772	8/27/07	S	.	490	29.9	8.08	429	17309	467
13 - 5	.	8/27/07	S	.	391	29.9	8.08	230	6111	591
13 - 6	30.412	8/27/07	S	.	465	29.9	8.08	183	8421	500
13 - 7	.	8/27/07	S	.	390	29.9	8.08	235	9827	571
13 - 8	31.672	8/27/07	S	.	419	29.9	8.08	143	7116	574
13 - 9	30.932	8/27/07	S	.	546	29.9	8.08	424	10832	450
13 - 10	31.701	8/27/07	S	.	488	29.9	8.08	283	11032	476
13 - 11	30.512	8/27/07	S	.	435	29.9	8.08	236	13543	471
13 - 12	30.832	8/27/07	S	.	390	29.9	8.08	.	.	.
13 - 13	30.492	8/27/07	S	.	536	29.9	8.08	246	11183	498
13 - 14	30.912	8/27/07	S	.	426	29.9	8.08	228	8572	528
13 - 15	.	8/27/07	S	.	412	29.9	8.08	381	10681	506
13 - 16	.	8/27/07	S	.	515	29.9	8.08	191	13393	415
14 - 1	30.642	10/7/07	W	6	384	21.7	6.17	238	8572	444
14 - 2	30.432	10/7/07	W	6	454	21.7	6.17	216	6764	583
14 - 3	31.352	10/7/07	W	6	533	21.7	6.17	251	8421	443
14 - 4	30.852	10/7/07	W	6	405	21.7	6.17	249	7618	441
14 - 5	31.632	10/7/07	W	6	405	21.7	6.17	127	6162	488
14 - 6	30.662	10/7/07	W	6	439	21.7	6.17	185	11685	547
14 - 7	.	10/7/07	W	6	429	21.7	6.17	235	6162	515
14 - 8	.	10/7/07	W	6	455	21.7	6.17	136	8572	564
14 - 9	31.392	10/7/07	W	6	401	21.7	6.17	173	7618	494

Table A2. Continued.

Fish ID	Radio Frequency	Tournament Date	Weigh-In Type	Tournament Duration (h)	TL (mm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Plasma Cortisol (ng/mL)	Plasma Lactate (μM)	Plasma Osmolarity (mOsm/L)
15 - 1	30.392	10/7/07	S	5.5	450	21.7	6.17	200	7166	468
15 - 2	31.162	10/7/07	S	5.5	414	21.7	6.17	94	7718	487
15 - 3	30.752	10/7/07	S	5.5	403	21.7	6.17	72	3149	526
15 - 4	31.063	10/7/07	S	5.5	400	21.7	6.17	248	4053	539
15 - 5	30.712	10/7/07	S	5.5	495	21.7	6.17	130	11133	496
15 - 6	.	10/7/07	S	5.5	410	21.7	6.17	158	5810	497
15 - 7	.	10/7/07	S	5.5	438	21.7	6.17	167	11384	458
15 - 8	.	10/7/07	S	5.5	498	21.7	6.17	332	12840	443
15 - 9	.	10/7/07	S	5.5	400	21.7	6.17	163	4906	511
15 - 10	.	10/7/07	S	5.5	386	21.7	6.17	180	6664	516
16 - 1	30.952	2/24/07	W	6	516	7.4	4.75	108	2832	433
16 - 2	30.552	2/24/07	W	6	480	7.4	4.75	104	2580	477
16 - 3	30.372	2/24/07	W	6	392	7.4	4.75	166	2276	426
17 - 2	31.332	2/25/07	S	8	536	8.4	6.64	.	.	.
17 - 3	31.522	2/25/07	S	8	396	8.4	6.64	118	1312	523
17 - 4	30.472	2/25/07	S	8	490	8.4	6.64	118	2312	428
17 - 5	30.602	2/25/07	S	8	411	8.4	6.64	91	2847	550
17 - 6	31.442	2/25/07	S	8	469	8.4	6.64	80	1178	623
17 - 7	31.192	2/25/07	S	8	473	8.4	6.64	152	2821	468
17 - 8	30.532	2/25/07	S	8	423	8.4	6.64	110	2284	452
17 - 9	31.372	2/25/07	S	8	495	8.4	6.64	68	2649	437
17 - 10	30.971	2/25/07	S	8	476	8.4	6.64	137	2289	434
17 - 11	.	2/25/07	S	8	407	8.4	6.64	199	3391	456