AN ASSESSMENT OF BAROTRAUMA AND STOCK CHARACTERISTICS OF TENNESSEE RIVER SAUGER POPULATIONS

Fisheries Report 09-06

A Final Report Submitted To

Tennessee Wildlife Resources Agency
By
USGS Tennessee Cooperative Fishery Research Unit and
Tennessee Technological University

Christy L. Kitterman, M.S.
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TABLE OF CONTENTS

Part I. AN ASSESSMENT OF BAROTRAUMA IN TENNESSEE RIVER SAUGERS

Part II. AN ASSESSMENT OF THE STOCK CHARACTERISTICS OF TENNESSEE RIVER SAUGER POPULATIONS

PART 1

AN ASSESSMENT OF BAROTRAUMA IN TENNESSEE RIVER SAUGERS

Abstract.- An intense winter fishery for sauger *Sander canadensis* exists in the Tennessee River. Although previous research suggested that catch-and-release mortality due to barotrauma or other factors was not a serious problem for undersized sauger (<356 mm total length), angler concerns persisted. The objectives of this study were to assess the survival of saugers inflicted with barotrauma and determine whether capture depth, ascent speed, and fish size contributed to the frequency and severity of barotrauma. In February 2008 and from January to March 2009, 81 saugers (72 alive at release, 9 euthanized) were affixed with ultrasonic transmitters; 9 of the live saugers and 2 of the euthanized fish that were tagged were lost and their movements and fate could not be described. The movements (or lack thereof) by saugers released alive and successfully tracked were compared with those of tagged euthanized fish to assess survival. The number of days that tagged fish were detected ranged from 8 to 73 d. Sauger experienced barotrauma over a wide range of capture depths (6-19 m). Barotrauma was evident in 72% of saugers collected in 2008-09; about 33% of those individuals exhibited severe barotrauma. There was a positive statistical relationship between the incidence of barotrauma and capture depth, but not between barotrauma and fish size or ascent rate. Sixty-seven percent of saugers released alive exhibited maximum daily movements that exceeded 0.5 km/d (the greatest movement of any euthanized fish) and those fish (n = 42) were classified as survivors. Mortality of released saugers was directly related to incidence of barotrauma and capture depth. Despite the high frequency of barotrauma observed in this study, most barotrauma-inflicted fish survived following release.

INTRODUCTION

The efficacy of a length limit may depend on several factors (e.g., growth rates, angler compliance); however, knowledge of discard mortality rates following catch and release is especially important. Implicit with the establishment of protective measures is that released fish will survive to contribute to the fishery at a larger size (Gigliotti and Taylor 1990); therefore, minimum length limits are counter-productive at high rates of discard mortality. Discard mortality may be immediate or delayed (Rudershausen et al. 2007), and can present itself cryptically as hooking mortality, physiological stress, and barotrauma (Coggins et al. 2007). Hooking mortality results from hooking, landing, and releasing a fish, and the severity of stress is determined by environmental conditions (e.g., temperatures, depth, dissolved oxygen), fishing gear and method (e.g., bait and hook type, landing time, handling time), and characteristics of the fish (e.g., age, length) (Muoneke and Childress 1994). Though hooking mortality of sauger *Sander canadensis* in the Tennessee River was low (<12%) in a previous study (Bettoli et al. 2000), the extent of mortality related to barotrauma remains unknown.

Barotrauma (i.e., air bladder inflation or Catastrophic Decompression Syndrome) is the physical trauma that results from a rapid reduction in pressure (Nichol and Chilton 2006). This phenomenon is common in some Orders of physoclistic fish (e.g., sauger, Order Perciformes), where air bladders are not connected to the digestive tract by open ducts (Moyle and Cech 2000); rather, gases are exchanged between the blood and air bladder through the rete mirabile (Alexander 1966), the structure and function of which may be size and species dependent (Parker et al. 2006). Boyle's Law states that under constant temperatures, gases will compress and expand as atmospheric pressure changes; gases in the air bladder are subject to expansion (i.e., decompression) when fish are hooked in deep water and brought to the surface.

Different physical, physiological, and behavioral impairments result from barotrauma, and these are often size and species-specific (Collins et al. 1999; Parker et al. 2006; Hannah and Matteson 2007; Rudershausen et al. 2007), even in the same genus (Pribyl et al. *In Press*). Common physical impairments include distended abdomens, everted esophagus and stomachs, exophthalmia, hemorrhaging and clotting, and gas bubble formation in the bloodstream and tissue (Feathers and Knable 1983; Gitschlag and Renaud 1994; Burns and Restrepo 2002; Rudershausen et al. 2007). Rummer and Bennett (2005) identified over 70 different barotrauma-related injuries in red snapper *Lutjanus campechanus*. Behavioral impairments include abnormal swimming and an inability to return to capture depth (Feathers and Knable 1983). When inflicted with barotrauma and unable to sound, fish may be vulnerable to stressful temperatures at the surface, avian predation, illegal harvest, and physical injuries from wave action or boat strikes (Lee 1992; Keniry et al. 1996; Gravel and Cooke 2008).

The frequency of barotrauma, injury severity, and fish survival following barotrauma are commonly influenced by capture depth. For instance, barotrauma-related mortality of yellow perch *Perca flavescens* increased with depth of capture (Keniry et al. 1996). Bettoli et al. (2000) found that 38% of sauger caught from a mean depth of 9 m exhibited modest to severe barotrauma. Mortality of largemouth bass *Micropterus salmoides* was greater at hyperbaric chamber pressures equivalent to depths of 18-27 m than at a depth of 9 m (Feathers and Knable 1983). Most (57%) smallmouth bass *M. dolomieu* captured at depths greater than 5 m experienced barotrauma, compared to only 2% of fish caught at shallower depths (Morrissey et al. 2005). Marine studies on black sea bass *Centropristis striata*, vermillion snapper *Rhomboplites aurorubens* (Collins et al. 1999; Rudershausen et al. 2007), red snapper (Gitschlag and Renaud 1994; Rummer and Bennett 2005), black and china rockfish *Sebastes melanops* and *S. nebulosus* (Parker et al. 2006; Hannah and Matteson 2007), and grouper *Epinephelus spp*. (Bacheler and Buckel 2004; Rudershausen et al. 2007) have also reported that mortality and injuries associated with barotrauma increased with capture depth.

Several studies argued that slowing retrieval rates to allow fish time to equalize air bladder pressure might reduce barotrauma frequency and severity. Bettoli et al. (2000) suspected that the rate at which saugers were brought to the surface affected gas bladder overinflation. Survival of yellow perch raised at faster rates of ascent was lower compared with those raised at slower rates (Keniry et al. 1996). Starr et al. (2000) reported that the effects of barotrauma in rockfish were minimal when long-line gear was retrieved at a slow rate. Black sea bass hauled up rapidly in trawls had a higher incidence of stomach eversion than fish retrieved at slower rates (Rogers et al. 1986).

Limiting the time a fish spends at the surface and immediately returning a fish to its depth of capture has improved survival in some cases. Held at the surface for 18 min, reef fish captured from 40 m all died while those captured from 20 m all lived; mortality for fish captured from 40 m was only 20% when held at the surface less than 3 min (Burns et al. 2002). Nearly all

(97%) rockfish that were recompressed in hyperbaric chambers within 30 s of "capture" survived (Parker et al. 2006). Jarvis and Lowe (2008) reported that rockfish survival improved from 78% to 83% when surface time was decreased from 10 minutes to less than 2 minutes.

Hooking mortality usually varies directly with water temperatures (Bettoli and Osborne 1998), and it is possible that a relationship between barotrauma-related mortality and temperature also exists. In hyperbaric chambers, all largemouth bass survived when only pressure was decreased, but only 22% survived when decreased pressure was combined with increased temperatures (Shasteen and Sheehan 1997). High temperatures may not be problematic for sauger that experience barotrauma in the Tennessee River because most fishing for that species occurs in winter and early spring at cold water temperatures (Bettoli et al. 2000).

The efficacy of air bladder deflation (i.e., venting or "fizzing") to improve survival has been widely investigated. Deflation of over-inflated air bladders using hypodermic needles and Sea-Grant tools improved survival of some species (Bruesewitz et al. 1993; Keniry et al. 1996; Shasteen and Sheehan 1997; Collins et al. 1999), while other studies reported no difference in survival between vented and non-vented fish (Lee 1992; Gitschlag and Renaud 1994; St. John and Syers 2005). However, in a recent meta-analysis, Wilde (2009) reported that there was little evidence that venting benefited survival, and some evidence that it was increasingly harmful to fish captured from deeper water. Other authors have cautioned that venting can lead to fatal infections (Rummer and Bennett 2005) and decreased survival when improperly performed (Siepker et al 2007). Immediate and long-term survival of vented and non-vented fish may differ and has been attributed to differences in species physiology and depth of capture (Bruesewitz et al. 1993; Burns and Restrepo 2002).

Survival can be monitored and estimated using different approaches. Tag return rates from recreational and commercial fisherman have been used to assess post-release survival (Lee 1992; Bruesewitz et al. 1993). Survival of fish inflicted with barotrauma has been monitored in pens, cages, and hyperbaric chambers (Bruesewitz et al. 1993; Gitschlag and Renaud 1994; Wilson and Burns 1996; Bettoli et al. 2000; Rummer and Bennett 2005; Hannah and Matteson 2007). Post-release behavior scores have also been used to assess survival, with fish unable to sound classified as non-survivors (Gitschlag and Renaud 1994; Wilson and Burns 1996; Collins et al. 1999; Hannah and Matteson 2007; Rudershausen et al. 2007).

Biotelemetry, the remote monitoring of free-swimming fish in their natural environments (Donaldson et al. 2008), was used to monitor hooking mortality of sauger tagged with radio transmitters in the Tennessee River (Pegg et al. 1997; Bettoli et al. 2000). However, when radio transmitters were used to track paddlefish *Polyodon spathula* in the Tennessee River, concerns regarding detectability of radio signals in deep (≥10 m) water were raised (Bettoli et al. 2007). Saugers are regularly caught by anglers in deep (≥20 m) water in the lower Tennessee River; therefore, ultrasonic telemetry may be a more appropriate approach. Ultrasonic telemetry is well suited for deep water habitats (Winter 1996) and has been used to monitor fish survival in other systems (e.g., Starr et al. 2000; Hightower et al. 2001).

Despite measures taken by TWRA biologists to improve sauger fisheries in Tennessee, angler concerns regarding their quality persist. In a 2007 survey, 44% of anglers in Tennessee claimed some level of dissatisfaction with their sauger fishing experiences and 32% thought that released sauger would die (Stephens et al. 2008). Though hooking mortality due to barotrauma or other factors is not considered a serious problem affecting survival of released sauger (Bettoli et al. 2000), angler concerns warranted further research.

Barotrauma experienced by sauger in the Tennessee River is likely a function of numerous factors, though which factors are most important remain unknown. Therefore, the objectives of this study were to: 1) determine which factors contribute to incidence of barotrauma; and 2) estimate survival of sauger that experienced barotrauma.

STUDY AREA

We collected sauger for the assessment of barotrauma from Kentucky Lake. Pickwick Dam (TRkm 332.7) serves as the upper boundary of Kentucky Lake on the lower Tennessee River. The dam was completed in 1938 and provides hydroelectric power, navigation, and flood control for the area. At full generation, six turbines release approximately 2,265 m^3/s. Sauger were collected from Shiloh Bluff (TRkm 320.3) downstream to Cerro Gordo (TRkm 289.7), a reach that encompassed deep (i.e., >20 m) water frequented by sauger anglers.

METHODS

Tag Retention Study

We tested for the possible effects of handling and tag attachment procedures on sauger survival in an experiment in December 2007. Saugers were collected below Cordell Hull Dam on the Cumberland River using experimental monofilament gill nets (1.8 x 45.5 m) with five panels (mesh sizes 19-, 25-, 38-, 51-, and 64-mm). Saugers were removed from nets as quickly as possible, placed in a live well, and transported to an aerated hauling tank on a truck. They were held in the hauling tank over night, and then transported to Eagle Bend State Fish Hatchery in Clinton, Tennessee the next morning.

Some sauger were subjected to a mock tagging procedure, whereby we recorded total length (TL, mm) and externally attached dummy transmitters made from solid acrylic rods weighing ~ 3.5 g each. A notched, metal pick was used to pass a loop of 36-kg test monofilament attached to the tag through the dorsal musculature of the fish. The tag was then passed over the back of the fish, fed through the loop, and pulled taut. The tagging procedure (i.e., handling and tagging) required less than 1.5 min. Control fish were measured but were not tagged. Fish were held in a raceway for 20 d, after which their fate (dead or alive) and physical condition (i.e., tag insertion injuries) were assessed.

Twenty-two treatment and 22 control fish were used in the experiment. Mean lengths of tagged fish (378 mm TL; SE = 39.8) and control fish (379 mm TL; SE = 31.2) were similar (t-test; P=0.91). All fish survived the 20-d observation period and no tags were shed. All fish appeared healthy and only minor amounts of inflammation were observed around the insertion and exit points of the monofilament.

We conducted a second tag retention study to test the effect of an additional attachment medium (Braided Spiderwire[1], Stealth®, 9.1 kg test) on retention of tags. Dummy transmitters were exact replicates of those transmitters used in field studies (see Methods below). Fish were tagged according to the methods described above and held in a 0.04-ha hatchery pond from 19 March to 30 April 2009. Ten treatment and 10 control fish were used in the experiment. After 42 days the pond was drained and 6 treatment and 3 control fish remained; predation by otters

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[1] The use of trade, product, industry or firm names or products is for informative purposes only and does not constitute an endorsement by the U.S. Government or the US Geological Survey.

was suspected for the losses. Inflammation of tissue around the insertion and exit points of the braided line was more evident on all 6 treatment fish compared to fish tagged the previous year with monofilament; however, all 6 fish retained their tags after 42 d.

Assessment of Barotrauma and Survival

Sauger were caught below Pickwick Dam on 12 occasions using conventional fishing gear (i.e., bucktail jig with a minnow [1/0-size hook] and trailing size-4 stinger hook) between 14-23 February 2008 and 21 January-4 March 2009. Because saugers are demersal, jigging occurred within 1 m of the bottom and it was assumed that bottom depth equaled capture depth (Bettoli et al. 2000). Ascent time (elapsed time between hook-up and landing), handling time (elapsed time between landing and release), depth, and water temperature were recorded for each fish.

The hook location (i.e., where the fish was hooked) and the hook responsible for capture (jig or stinger) were recorded. Health assessments regarding hook wounds (severity of bleeding at the point of hook penetration) and barotrauma were also recorded. The hook score was coded as 0 (none or slight bleeding) or 1 (blood dripping or flowing from the wound; Bettoli et al. 2000). Gastric distension was used as the indicator of barotrauma (Rudershausen et al. 2007) and was scored as 0 (no expansion visible), 1 (expansion visible at rear of buccal cavity), or 2 (stomach or esophagus clearly distended into buccal cavity; Bettoli et al. 2000). Each fish was then measured for total length (TL, mm) before transmitters were attached.

Ultrasonic transmitters (IBT-Series Miniature 96-5; 69-79 kHz; Sonotronics, Inc., Tuscon, AZ) were used to monitor survival of released sauger. Transmitters weighed approximately 10.4 g and had a battery life of 5 months. The weight of the smallest sonic-tagged sauger (264 mm TL) predicted from a log-weight: log-length regression model for Kentucky Lake saugers collected during 2008-2009 gill net samples (N= 243; unpublished data) was 162 g; sonic tags weighed approximately 2.1% of the weight of the average sauger tagged. Each transmitter possessed a unique identification code and pulse interval. Transmitters were labeled with contact information and the words “$25.00 Reward” in the event that fish were harvested or found dead by the public.

Upon release, swim-down behavior (i.e., whether or not a fish struggled to descend) was noted. Fish were assigned a swim-down score of 1 (normal, vigorous swimming), 2 (disoriented, erratic swimming), or 3 (floating), a slight modification of the criteria used by Rudershausen et al. (2007). Unlike other studies (e.g., Gitschlag and Renaud 1994; Wilson and Burns 1996; Collins et al. 1999; Rudershausen et al. 2007), a floating, released fish was not presumed to be a mortality.

A DH-4 directional hydrophone in combination with USR-5W and USR-96 scanning receivers (Sonotronics®) was used to track tagged fish. We attempted to locate each tagged sauger on three consecutive days post-release, then again approximately two, three, and four weeks after tagging. On each tracking day, we tracked the reach that encompassed the last known locations of all tagged saugers. On one occasion (15 March 2009), we conducted a sweep of the entire river between Pickwick Dam and the I-40 Bridge (~ 143 river km). We listened for tagged fish at 1 km intervals with the boat engine off. Upon detection, the identification code, time, and location (using a GPS receiver) were recorded.

Magnitudes of movements (or lack thereof) by tagged saugers were used to assess survival. In addition to barotrauma-inflicted sauger, “control” fish (i.e., those displaying no symptoms of barotrauma, n = 7) and dead fish (euthanized with a concussive blow to the head; n = 3 displaying barotrauma, n = 5 displaying no symptoms of barotrauma) were tagged; their movements were compared to tagged, barotrauma-inflicted saugers released alive. Daily movements of tagged saugers were calculated by dividing distance traveled between consecutive relocation points by number of days between relocations. We then selected the maximum daily movement for each tagged fish after one week at large. We considered sauger to be survivors if they were recaptured alive or if their maximum daily movement exceeded that of all euthanized fish. Distances were measured using ArcGIS 9.2 Geographic Information System (GIS) software (ESRI 2006).

We censored any fish from data analysis if it was never located following release or was only located once (Bendock and Alexandersdottir 1993). Bettoli et al. (2000) did not consider missing saugers as mortalities because some censored individuals in that study exhibited similar degrees of barotrauma and hooking wounds as survivors.

Data on capture depth and total length for fish collected in 2008-09 were pooled with similar data collected by Bettoli et al. (2000); the effects of those two factors on incidence of barotrauma were evaluated using multiple logistic regression (SAS Institute 2009). The null hypothesis that each predictor variable would have no effect on the binary response variable (no inflation = 0; modest or severe inflation = 1) was tested with the chi-squared statistic. The effects of incidence of barotrauma, severity of barotrauma (i.e., moderate or severe), and capture depth on survival of saugers in both studies were also evaluated using the chi-square statistic and multiple logistic regression. The chi-square statistic was used in a 2x2 contingency table to test whether fate and incidence of barotrauma, or fate and severity of barotrauma, were associated. Bettoli et al. (2000) did not collect ascent rate data; therefore, a separate logistic regression analysis with only 2008-09 data was performed to evaluate the effect of ascent rate (m/s) on incidence of barotrauma.

RESULTS

We experimentally caught 143 saugers in 2008-09; these data were pooled with data on 113 saugers captured in 1999 by Bettoli et al. (2000). Over both studies, saugers ranged in total length from 220 to 475 mm TL (mean = 346; SE 2.9), capture depth ranged from 5 to 19 m (mean = 10.9 m; SE 0.7), and ascent time ranged from 8 to 39 s (mean 17 s; SE 0.5); the ascent rate ranged from 1 to 5 m/s (Table 1). Water temperatures ranged from 2° to 12° C.

In 2008-2009, 55 saugers were caught by the jig hook (tipped with a minnow) and 65 saugers were caught with the stinger hook (Table 2); 10 saugers were caught by both the jig and the stinger hook. Eighty-two percent of saugers displayed little or no bleeding from the hook wound. Equal numbers of sauger were foul hooked by the jig (n = 21) and stinger hooks (n = 20); however, most (66%; 86 of 130) saugers were hooked in the jaws or mouth cavity (Table 2). Similar numbers of sauger that were subsequently classified as dead were foul hooked (n = 9) and fair hooked (n = 12).

Sauger experienced barotrauma over a wide range of capture depths (6-19 m). There was a positive relationship between incidence of barotrauma and depth of capture (logistic regression; chi-square = 10.3; df = 1; P = 0.001), but not total length (logistic regression; chi-square = 1.5; df = 1; P = 0.22). Barotrauma was evident in 72% of sauger collected in 2008-09 and 38% of sauger collected in 1999; about 33% and 11% of sauger in each collection period exhibited severe barotrauma (Figure 1). Of all the saugers collected during both studies (n = 256), 59% of saugers less than the size limit (72 of 123) and 56% of saugers above the size limit (74 of 133) had barotrauma. There was no relationship between incidence of barotrauma and ascent rate (logistic regression; chi-square = 0.20; df = 1; P = 0.66). Of the 72 fish released alive in 2008-

2009, only 7% (n = 5) struggled to descend and all were successful (i.e., none floated upon release).

Eighty-one saugers (72 alive, nine euthanized) were affixed with sonic transmitters from 14-23 February 2008 and from 21 January-4 March 2009. Seven fish (five released alive, two dead) were never relocated following release, and four fish released alive were not located after 4 d at large; therefore, tracking data are presented for 70 fish. The number of days that those 70 fish were detected ranged from 8 to 73 d. Ten tagged saugers were known to have been harvested alive (nine by commercial fisherman in gill nets and one by an angler). Movement data based on the date and location of harvest for those 10 fish were included in all analyses.

Magnitudes of movement by euthanized sauger and those released alive were highly variable (Figure 2). Maximum daily movements ranged from 0.01 to 14.9 km/d. The maximum daily movement exhibited by euthanized fish (n = 8) was 0.5 km/d. Sixty-seven percent of 63 sauger released alive exhibited maximum daily movements that exceeded 0.5 km/d, and those fish (n = 42) were classified as survivors (Figure 3). Of those 63 fish released alive, 80% (n = 4) of non-barotrauma inflicted, 64% (n = 21) of moderately inflicted, and 68% (n = 17) of severely inflicted saugers survived.

Incidence of barotrauma and depth of capture were significantly correlated; therefore, we ran two separate fate models. In the first model, saugers were more likely to die if they were afflicted with barotrauma (logistic regression; chi-square = 8.82; df = 1; P = 0.003), but the severity of barotrauma (moderate or severe) was not linked to survival (chi-square = 0.12; df = 1; P = 0.73). In the second model, the mortality of saugers tended to be higher when caught at greater depths (logistic regression; chi-square = 2.45; df = 1; P = 0.12). The relationship between total length and survival was not formally tested because most (83%) sauger in both studies survived, regardless of whether they were above (63 of 74) or below (65 of 80) the size limit. However, most (58%; 15 of 26) of the fish that died were less than the size limit.

DISCUSSION

The positive relationship between incidence of barotrauma and depth of capture in this study was expected because numerous studies have detected this relationship. Incidence of barotrauma was nearly twice as high in this study (72%) compared with that observed by Bettoli et al. (2000; 38%). The greater depths over which sauger were captured in 2008-2009 compared with 1999 may help explain differences in observed incidence of barotrauma. The use of gastric distension as an index of barotrauma was a useful criterion because it permitted rapid assessment of each individual. However, numerous other symptoms of barotrauma (e.g., distended abdomens, exophthalmia) may have been present and the criterion used in this study may have underestimated its occurrence.

Total length was not a significant predictor of barotrauma and the numbers of saugers above and below the size limit that had barotrauma were similar. However, other studies have found a relationship between fish size and barotrauma frequency. For example, more large smallmouth bass had severe barotrauma than small smallmouth bass (Gravel and Cooke 2008).

We made no attempt to determine whether the ability of a sauger to swim down following release was related to depth of capture due to the low number (5 of 72) of fish that struggled to descend. Hannah et al. (2008) reported a negative relationship between submergence success (ability to re-submerge within 5 min) and esophageal eversion for some rockfish species, but not others. They also reported a significant relationship between submergence success and depth of capture for several marine species; that is, most (80%) rockfish captured from depths less than 30 m re-submerged successfully compared with those caught at greater depths.

Several tagged fish went missing in this study and were censored from analysis. Hightower et al. (2001) listed four possible explanations for a lack of fish detection: 1) the fish was present in the area but the signal was missed; 2) transmitter failure; 3) dam passage; and 4) unreported harvest. If any of these conditions occurred, classification of the individual as dead would have inflated the mortality estimate. Upstream passage through the lock at Pickwick Dam was possible (Pegg et al. 1997); however, we located only one fish in the immediate vicinity of the dam on one occasion, after which this fish then returned downstream. It is also possible that several missing fish were harvested by commercial fisherman using gill nets; all ten tags that were returned for the $25.00 reward were by fishers familiar with this project. Therefore, it is likely that fishers (commercial or recreational) unfamiliar with the project caught fish but discarded the tags. Two euthanized fish that floated upon release were never located again. It is possible those two fish washed up on the shore where tags could not be located with the hydrophone.

Tracking euthanized saugers provided valuable insight into discerning which fish lived and which died based on movements. This method, in combination with telemetry of live-released individuals, is one way to reduce uncertainty associated with determining mortality rates (Donaldson et al. 2008). Most movements exhibited by the euthanized fish were consistent with movements of dead fish in other studies (i.e., remained immobile over consecutive fixes and moved downstream slowly over several km; Bendock and Alexandersdottir 1993; Nelson et al. 2005). However, three euthanized fish in this study moved upstream at some point, making upstream movement a faulty criterion to determine fate of individuals. This phenomenon (i.e., upstream movements by euthanized fish) deserves further scrutiny and consideration in future studies of fish movements in lotic waters; tracking the movements of a larger sample of euthanized fish would also provide additional insight into the best metric to use to designate fish released alive as subsequently "dead or alive".

The means by which those three euthanized fish moved upstream are unknown, but the most plausible explanation is that the carcasses were ingested by large piscivores common to the Tennessee River (e.g., blue catfish *Ictalurus furcatus* or flathead catfish *Pylodictis olivaris*). Observed upstream and downstream movements (less than 5 km) by euthanized fish, and by fish subsequently classified as mortalities according to their movements, were well within ranges exhibited by catfish during winter months in previous studies (Daugherty and Sutton 2005; Vokoun and Rabeni 2005). Further, catfish predation on sauger has been observed in the Tennessee River (Debbie Blackwelder, commercial fisher, personal communication).

Survival rates of barotrauma-inflicted sauger in the present study were different than survival rates of barotrauma-inflicted percids in other studies. Bettoli et al. (2000) did not detect a relationship between 12-d mortality and incidence of barotrauma, although this relationship was apparent in the present study. Sauger in the present study had a mortality rate of 30%, which is 2.5 times higher than the mortality rate of saugers observed by Bettoli et al. (2000), perhaps because mean capture depths differed in the two studies (9 m and 13 m). Keniry et al.

(1996) reported 3-d mortality rates ranging from 67% to 92% for yellow perch collected in fyke nets at 10-15 m deep. Two studies that assessed short-term (≤ 12-d) hooking mortality of walleyes attributed high survival rates (greater than 90%) to shallow capture depths (less than 10 m) and cautioned that catching walleyes at greater depths might increase mortality (e.g., Fletcher 1987; Cano et al. 2001).

Swim-down behavior and movement criteria provided much different estimates of survival in this study. According to criteria used by other studies (e.g., struggled to descend; Rudershausen et al. 2007), most fish in the present study would have been classified as survivors because few (7%) fish struggled to descend when released. This estimate is much less than the mortality estimate (30%) obtained using the maximum daily movements of individuals. Further, no fish considered "dead" according to swim down behavior were subsequently classified as dead according to their maximum daily movement.

The inverse relationship between depth of capture and survival, although statistically weak ($P = 0.12$), was expected because it is well documented that the survival of many species generally decreases as capture depth increases. Collectively, saugers in this study were captured over a wide range of depths (7-19 m), but saugers that were tagged and released in this study were not captured at depths greater than 14 m. As there was a strong relationship between capture depth and incidence of barotrauma in saugers, and between incidence of barotrauma and survival, it is reasonable to assume that a stronger relationship between survival and capture depth would have been detected if we had tagged some of the saugers captured at the greatest depths (i.e., ≥ 15 m).

While most (83%) sauger inflicted with barotrauma in the present study and in 1999 (Bettoli et al. 2000) survived, over half of the fish that died were less than the minimum size limit. The relationship between total length and survival is variable among species. Patterson et al. (2002) and Stewart (2007) reported that small snappers may be more likely to die than large snappers; however, Gitschlag and Renaud (1994) reported no differences in mortality between different sizes of snapper. Total length was not a significant predictor of mortality for West Australian dhufish *Glaucosoma hebraicum.*

Bettoli et al. (2000) suspected that ascent rate may be an important factor in determining incidence of barotrauma in sauger; however, ascent rate was not a predictor of incidence of barotrauma or survival in the present study. Implementing a sampling regime whereby fish were raised at “fast” versus “slow” rates of ascent was difficult due to preferred angler capture techniques. Saugers are generally thought to shake loose from the hook if raised at slow rates, so anglers typically reeled them in as quickly as possible. Collins et al. (1999) suspected that quick retrieval of gear by experienced anglers in a previous study had contributed to higher mortality in reef fishes. Yellow perch captured in fyke nets set at 10 m that were given time to adjust air bladder volume exhibited higher survival (91%) compared with those raised at a rate of 5 m/min (67%; Keniry et al. 1996). Stewart (2007) found no relationship between survival of snapper *Pagrus auratus* and ascent rate but attributed that finding to a narrow range of ascent rates (0.36 to 0.51 m/s) from capture depths of 8.3 to 57 m.

Although many studies have investigated whether venting air bladders would improve survival, we did not vent air bladders of barotrauma-inflicted saugers. Recent literature suggests that venting may actually decrease survival of released fish (Wilde 2009). Even if venting sauger air bladders was efficacious, survival estimates in the present study were generally high without using this method.

There is considerable inconsistency across U. S. state agencies in the way that fish angled and brought to the surface should be handled (i.e., fast versus slow ascent speeds; vented versus un-vented air bladders; Pelletier et al. 2007). The Tennessee Wildlife Resources Agency currently dissuades anglers from venting barotrauma inflicted fish and promotes quick release of individuals (TWRA Fishing Guide Book). Although Tennessee sauger anglers are often concerned about the welfare of fish angled in deep water, the results of this study should help alleviate those concerns. Despite the high frequency of barotrauma observed in this study, most barotrauma-inflicted fish survived following release.

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Table 1.—Mean total length (mm), depth of capture (m), and ascent speed (s) of saugers collected during this study (2008-2009) and by Bettoli et al. (2000) in 1999. Values in parentheses are the range.

Study	Number of Fish	Total Length	Depth	Ascent
This Study	143	349 (264-446)	13 (7-19)	17 (8-39)
Bettoli et al. (2000)	113	346 (220-475)	9 (5-18)	n/a
Total	256	348 (220-475)	11 (5-19)	17 (8-39)

Table 2.—Primary hook responsible for capture of 130 of 143 saugers using conventional fishing gear in Kentucky Lake in 2008-2009. Hook locations were not recorded for 13 of 143 saugers.

		Primary Hook	
Classification	Jig	Stinger	Both
Foul hooked in head	7	6	1
Foul hooked in gular region (throat)	8	4	2
Foul hooked in body	6	10	
Jaws or mouth cavity	34	45	7

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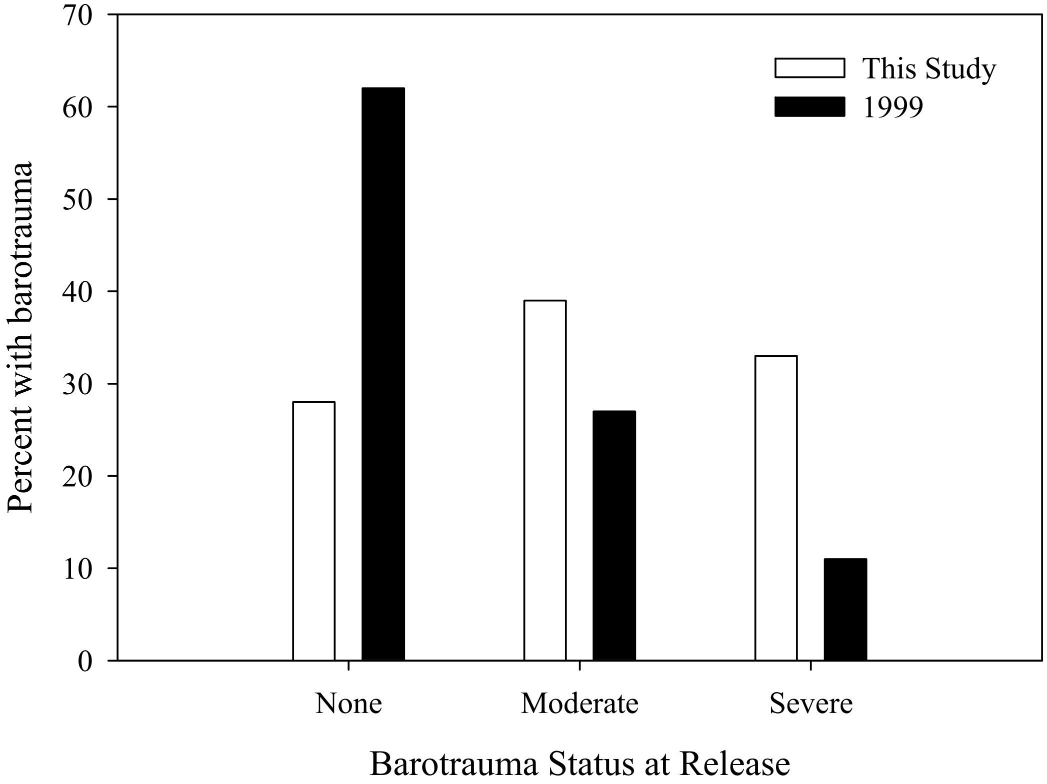

Figure 1.—Percent of saugers showing signs of barotrauma during this study (n = 143) and in 1999 (n = 113; Bettoli et al. (2000)). Fish were assigned gastric distension scores of 0 (None), 1 (Moderate; stomach visible at rear of buccal cavity), or 2 (Severe; stomach clearly distended into the buccal cavity).

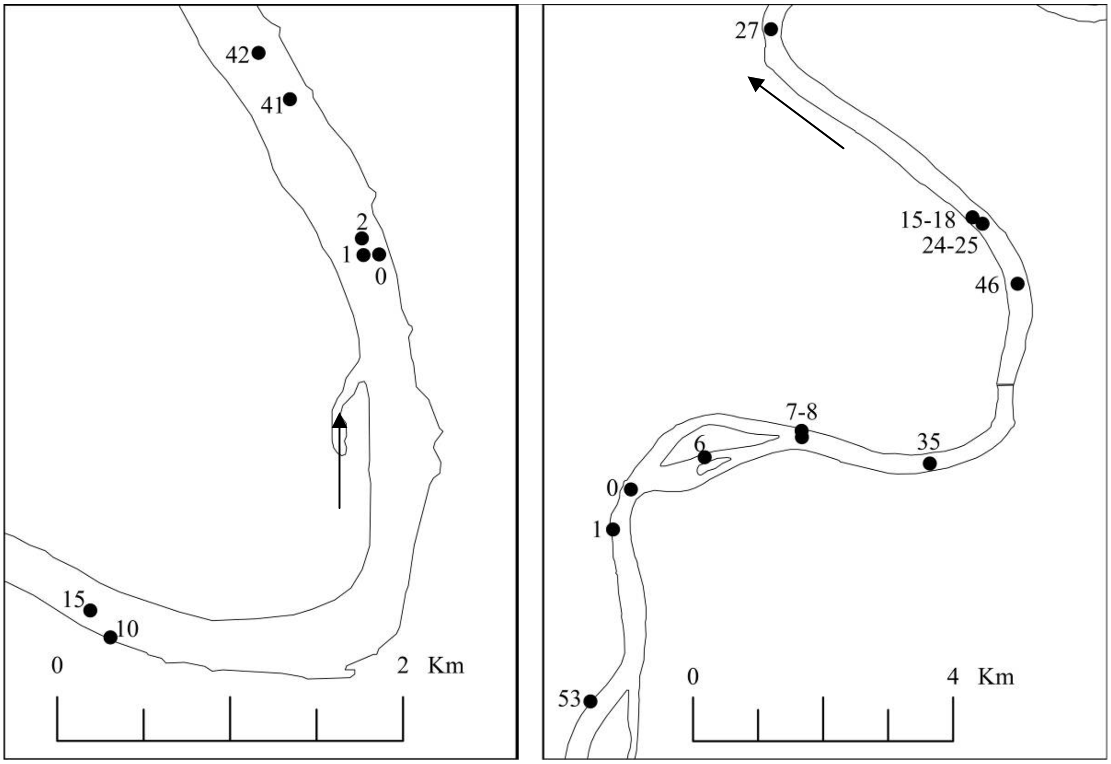

Figure 2.—Examples of movements of a tagged, euthanized sauger (left panel) and a tagged sauger released alive (right panel) in Kentucky Lake, 2008-2009. Arrows indicate direction of flow. Numbers represent days post-release.

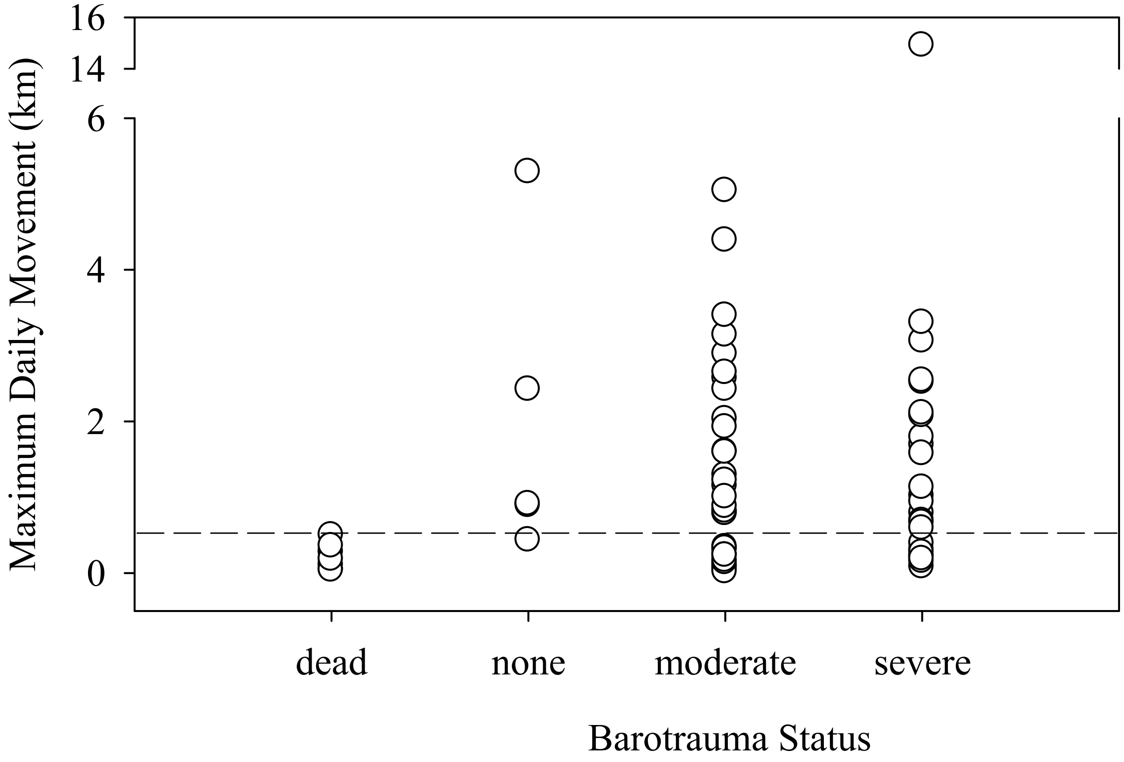

Figure 3.—Maximum daily movements of each tagged sauger in 2008-2009. The dashed line (0.5 km/d) indicates the maximum daily movement by any of the seven euthanized fish. All other fish that exhibited movements greater than 0.5 km/d (n = 42) were classified as survivors.

PART 2

AN ASSESSMENT OF THE STOCK CHARACTERISTICS OF TENNESSEE RIVER SAUGER POPULATIONS

Abstract.- In 1992, minimum length limits for sauger populations in the Tennessee River were established to reduce exploitation and improve the size distribution of sauger populations. The objectives of this study were to determine the efficacy of those limits by assessing spatial and temporal differences in stock characteristics and the likelihood of growth- and recruitment-overfishing. Saugers were collected from late winter to early spring in 2008 and 2009 in Kentucky Lake and Watts Bar Lake using monofilament experimental gill nets. Mean lengths and mean ages of sauger varied significantly among years and reservoirs and Watts Bar sauger were generally older and longer than sauger in Kentucky Lake. Although means varied significantly among years, mean ages and mean lengths did not exhibit any trends between 1990 and 2009 in either reservoir. In 2008-2009, the Kentucky Lake sauger population was not exhibiting signs of growth overfishing or recruitment overfishing under the current minimum total length limit of 356 mm. The Watts Bar Lake sauger population was not exhibiting signs of growth overfishing under the current total length limit of 381 mm, but would be susceptible to recruitment overfishing at high (>40%) exploitation rates. Eliminating the size limits in either reservoir would increase the likelihood of both growth- and recruitment overfishing, but the extent of risk would depend on the level of exploitation and natural mortality in each reservoir.

INTRODUCTION

Sauger *Sander canadensis* populations in Tennessee have historically been an important component of the sport fishery (Hackney and Holbrook 1978). Saugers are native to tributaries of the Mississippi River drainage, including the Tennessee and Cumberland Rivers. Establishment of multiple impoundments along these rivers created tailwaters where saugers congregate during winter months when they move upstream to spawn (Hackney and Holbrook 1978; Pegg et al. 1997).

Declines in sauger populations throughout Tennessee in the late 1980s prompted investigations into population structure, recruitment, and exploitation of sauger (Bettoli and Fischbach 1998). Relative year-class strengths of sauger differed among river systems and reaches; fewer, older individuals dominated the upper Tennessee River and high numbers of young individuals dominated the lower Tennessee and Cumberland Rivers (Churchill 1992; Thomas 1994). Growth overfishing was evident in the Alabama portion of the Tennessee River and the age structure of that sauger population was skewed towards younger fish (Maceina et al. 1998).

Sauger recruitment in Tennessee is highly variable (Hackney and Holbrook 1978) and is influenced by spring discharge (Thomas 1994; Buckmeier 1995). Sauger exploitation was low (~6%) in the 1980s in the upper Tennessee River (Hevel 1988; Hickman et al. 1990; St. John 1990); however, Pegg et al. (1996) estimated that exploitation of sauger in the lower Tennessee River exceeded 40% in the early 1990s. Thomas (1994) predicted that high exploitation, in combination with inconsistent recruitment, would lead to years when few large saugers were present in the lower Tennessee River.

Amidst these early investigations, the Tennessee Wildlife Resources Agency (TWRA) biologists enacted length and creel limits in 1992 to reduce exploitation and improve the size distribution of sauger populations (Fischbach 1998). The minimum length limit became 356-mm total length (TL) in the lower Tennessee River and 381-mm TL in the upper Tennessee and Cumberland Rivers, and the statewide creel limit was reduced to 10 fish per day. An intermittent stocking program was also initiated.

Responses of sauger populations to the new regulations were variable. Mean total lengths increased from 1990-1992 to 1995-1997 in the upper Tennessee River (Fischbach 1998). Mean total lengths and ages increased in Old Hickory Lake, a Cumberland River reservoir, suggesting that exploitation had been reduced in that reservoir. In the lower Tennessee River, mean ages increased but mean total lengths did not. While it was apparent that recruitment overfishing was being prevented, growth overfishing was likely still occurring in the lower Tennessee River. The relationship between the number of fry stocked and subsequent age-1 catch rates from 1990 to 1993 was significant in the upper Tennessee River (Thomas 1994), but that relationship was not evident when data from 1990-1997 were considered (Fischbach 1998). Fischbach (1998) concluded that the sauger population in Old Hickory Lake appeared to be completely dependent upon fingerling stockings.

The effects that harvest regulations have had on reducing exploitation and improving the size distribution of sauger populations over the last 16 years are unknown. Therefore, the objectives of this study were to: 1) assess spatial and temporal differences in sauger stock characteristics in the lower and upper Tennessee River; and 2) assess the likelihood of growth overfishing and recruitment overfishing for sauger populations in the Tennessee River.

STUDY AREAS

We collected sauger for age-and-growth analysis from Kentucky Lake and Watts Bar Lake. These sites were chosen to represent the lower and upper reaches of the Tennessee River that were investigated in previous sauger studies (Churchill 1992; Thomas 1994; Buckmeier 1995; Fischbach 1998). These fisheries, along with Old Hickory Lake on the Cumberland River and Chickamauga Lake on the upper Tennessee River, supported the highest amounts of fishing pressure for sauger in Tennessee from 1999-2006 (Malvestuto et al. 2001; Malvestuto and Black 2002a, 2002b, 2003, 2004, 2005, 2007; Black 2006).

Pickwick Dam (TRkm 332.7), completed in 1938, serves as the upper boundary of Kentucky Lake on the lower Tennessee River; it provides hydroelectric power, navigation, and flood control for the area. Kentucky Lake supported the highest amount of fishing pressure for sauger in Tennessee from 1999-2006 (Malvestuto et al. 2001; Malvestuto and Black 2002a, 2002b, 2003, 2004, 2005, 2007; Black 2006). Sauger populations in Kentucky Lake are supported entirely by natural recruitment (i.e., no stocking occurs in this reservoir).

Ft. Loudoun Dam (TRkm 969.3) and Melton Hill Dam (CRkm 37.2) serve as the upper boundaries of Watts Bar Lake. Ft. Loudoun Dam, completed in 1943, impounds Ft. Loudoun Reservoir on the Tennessee River. Melton Hill Dam, completed in 1963, impounds Melton Hill Reservoir on the Clinch River. Watts Bar Lake supported the third highest amount of fishing pressure for sauger in the state from 2003-2006 (Malvestuto and Black 2004, 2005, 2007; Black 2006). Sauger populations in Watts Bar Lake are stocked sporadically with fingerlings (Table 1).

METHODS

Population Characteristics

We collected sauger from late winter to early spring during 2008 and 2009 in both study reservoirs using horizontal sinking monofilament experimental gill nets (1.8 x 45.5 m) with five panels (mesh sizes 19-, 25-, 38-, 51-, and 64-mm). Sampling effort was confined to the waters immediately below dams and at Diamond Island in Kentucky Lake (TRkm 314.5) and Browder Shoals in Watts Bar Lake (TRkm 961.6) where saugers were known to congregate (Churchill 1992). Nets were set after dusk and soaked for at least 15-60 min, depending on catch rates. At each reservoir, we attempted to catch 25 individuals per collection trip or at least 100 individuals total each year. Species, net location, and mesh size were recorded in the field. Upon capture, each fish was tagged with a uniquely numbered Floy[2] tag, placed on ice, and returned to the lab.

In the lab, we recorded TL (mm), weight (g), and sex of each sauger. Gonads of sexually mature females were excised and weighed; immature individuals were assigned a gonad weight of zero. Sagittal otoliths were extracted from each individual and stored in numbered vials that corresponded to the Floy tag number. Otoliths were read twice, independently, in whole view under 40x magnification using reflected light. If more than one annulus was visible, otoliths were cracked perpendicular to the longest axis, polished using 600-grit sandpaper, and viewed using transmitted light from a fiber optic element (Heidinger and Clodfelter 1987).

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[2] The use of trade, product, industry or firm names or products is for informative purposes only and does not constitute an endorsement by the U.S. Government or the US Geological Survey.

Length-frequency and age-frequency histograms were constructed to visually assess the size and age structure of the population. Data for saugers collected in 2008-09 were pooled with similar data collected by Churchill (1992), Thomas (1994), Buckmeier (1995), and Fischbach (1998). Spatial and temporal differences in mean lengths and mean ages between reservoirs were compared using t-tests. Within-reservoir differences in mean lengths and ages over time were separately examined using a single-factor ANOVA (main factor = year) and the General Linear Model procedure (SAS Institute 2009); Tukey's studentized range test was used to detect differences at $P = 0.05$. Within-reservoir trends over time in mean age and mean length were assessed with simple linear regression models.

Population Modeling Simulations

The yield-per-recruit option in Fishery Analysis and Simulation Tools (FAST) software (Slipke and Maceina 2001) was used to determine the likelihood of growth overfishing in reservoir populations. This option uses the Jones (1957) modification of the Beverton-Holt equilibrium yield model to calculate yield (Beverton and Holt 1957; Ricker 1975; Slipke and Maceina 2001). Weighted catch-curve regressions were used to reduce the influence of fewer, older fish when estimating annual mortality (Van Den Avyle and Hayward 1999; Slipke and Maceina 2001). Saugers were assumed to have fully recruited to the gill nets by age-1. Yields (kg of fish per 100 recruits) were simulated at four different minimum length limits: the assumed minimum length of sauger that anglers would harvest given no harvest restriction (i.e., 254-mm TL; Bettoli 1998), the current length limits for Kentucky Lake (356-mm TL) and Watts Bar Lake (381-mm TL), and 406-mm TL. The simulations utilized parameters derived from the von Bertalanffy (1938) growth equations (L_{inf}, K and t_o) and the $\log_{10}$length: $\log_{10}$weight regression models. Too few old fish were collected in Kentucky Lake to accurately estimate L_{inf}; therefore, L_{inf} for the Kentucky lake population was assumed to be the same as L_{inf} for the Watts bar population (i.e., 550 mm TL). Conditional natural mortality rates (*cm*) were estimated in FAST using methods described by Quinn and Deriso (1999)[3] and Hoenig (1983)[4]. Conditional fishing

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[3] $M = -\log_e(P_s) / t_{max}$, where the proportion of the population that survived (P_s) to t_{max} (12 years; Brown 1990) was assumed to be either 0.01 or 0.05 (Shepard and Breen 1992).

[4] $\text{Log}_e(M) = 1.46 - 1.01(\log_e[t_{max}])$, and $cm = 1 - e^{-M}$

mortality rates (*cf*) from 0% to 60% were used to simulate yield over a wide range of exploitation levels.

We developed a maturation schedule for female sauger by determining the percent of mature fish in each size- and age- class, per the methods of Scholten and Bettoli (2005). Female sauger maturity was indexed with the Gonadosomatic Index (GSI), where GSI = Ovary Weight/ (Body Weight-Ovary Weight; Maceina et al. 1998). The Spawning Potential Ratio (SPR; Goodyear 1993) was simulated in FAST using age and length data, fecundity data (Churchill 1992), and the maturation schedule. The SPR is the ratio of the lifetime egg production by the average recruit in a fished and an un-fished population and is used to assess recruitment overfishing (Goodyear 1993; Scholten and Bettoli 2005). Goodyear (1993) suggested that SPR values should fall between 20% and 30% to prevent recruitment overfishing in marine species. Spawning Potential Ratios have been calculated for paddlefish in the Tennessee River (Scholten and Bettoli 2005) and channel catfish *Ictalurus punctatus* in the Mississippi River (Slipke et al. 2002); however, no critical values of SPR have been defined nor used to evaluate sauger fisheries.

RESULTS

Population Characteristics

Of the 1,066 saugers collected in Kentucky Lake, age-1 and age-2 fish represented 91% of all saugers collected from 1990-1997and 77% of all saugers collected from 2008-2009 (Figure 1). Of the 873 saugers collected in Watts Bar Lake, age-1 and age-2 fish represented 69% of all saugers collected from 1990-1997, but only 55% of those collected from 2008-2009 (Figure 2). The oldest sauger collected in Kentucky Lake during 2008-2009 was age-5; the oldest sauger in Watts Bar Lake was age-7. The size structure of sauger in Kentucky Lake in most years was skewed towards smaller fish (<400 mm TL), which were primarily age-1 to age-3 fish (Figure 3). In contrast, the size structure of sauger in Watts Bar Lake was skewed towards larger individuals in five of the seven years (Figure 4).

Mean lengths of sauger varied significantly among years and reservoirs (Table 2; one-way ANOVA; $P < 0.0001$). From 1990 to 2009, mean lengths each year ranged from 269 to 348 mm TL in Kentucky Lake and from 329 to 447 mm TL in Watts Bar Lake. Mean ages also varied significantly among years and reservoirs (Table 3; one-way ANOVA; $P < 0.0001$). From 1990 to 2009 mean ages each year ranged from 1.2 to 2.1 years in Kentucky Lake and from 1.4 to 3.0 years in Watts Bar Lake. Although means varied significantly among years, mean ages and mean lengths did not exhibit any trends over time in either reservoir (linear regression; $r^2 \leq 0.14$; $P \geq 0.29$; Table 4). In general, saugers collected in Watts Bar Lake were longer and older than saugers collected in Kentucky Lake. Mean lengths-at-age pooled across all years (1990-2009) for all saugers collected were higher in Watts Bar Lake than in Kentucky Lake (Figure 5).

Few mature female saugers in either reservoir were protected from harvest under the current length limits. In Kentucky Lake, 18% of mature females were protected, and only 11% were protected in Watts Bar Lake (Figure 6). The GSI for mature females in Kentucky Lake ranged from 10% to 31%; several saugers ($n = 4$) had spawned prior to collection and were assigned GSI values of zero. The GSI values for mature females in Watts Bar Lake ranged from 5% to 22%.

Saugers in Watts Bar Lake grew faster than saugers in Kentucky Lake (Figure 7). The predicted time it took saugers to reach the 356-mm length limit in Kentucky Lake was 2.16 years; saugers in Watts Bar Lake reached that same size in 1.79 years. The predicted time it took sauger to reach the larger 381-mm length limit in Watts Bar Lake was 2.15 years.

Population Modeling Simulations

The parameters used to estimate sauger yields were reservoir-specific (Table 5). Total annual mortality (A) was 0.65 (95% CI $\pm$ 0.08) in Kentucky Lake and 0.62 ($\pm$ 0.02) in Watts Bar Lake; conditional natural mortality (*cm*) was estimated to be 0.22 and 0.32 using the methods of Quinn and Deriso (1999) when the proportions of the populations surviving to t_{max} were 0.01 and 0.05, respectively. The estimate of *cm* using the method of Hoenig (1983) was 0.30. For the sake of clarity, yield was modeled at *cm* levels of 0.20 and 0.30.

The benefits to yield when a size limit was in place were most evident at the low natural mortality rate. At a *cm* of 20%, growth overfishing was evident (i.e., yield increased with higher size limits) in both reservoirs when exploitation rates exceeded 27%. When *cm* was 30%, growth overfishing was only evident when exploitation exceeded 43% in Kentucky Lake and 34% in Watts Bar Lake. When exploitation was 20% to 55%, eliminating the size limits at a *cm* of 20% decreased yield by approximately 9% to 48% in Kentucky Lake and by 9% to 43% in

Watts Bar Lake (Figures 8 and 9). Disparities in yield would not be as great in either reservoir if size limits were eliminated and *cm* was 30%; when exploitation was 17% to 52%, yield decreased by 6% to 27% in Kentucky Lake and by 7% to 29% in Watts Bar Lake (Figures 8 and 9).

When exploitation was 17% to 55%, simulated yields at both rates of *cm* changed little (≤ 6%) when the size limit was changed from 356 mm to 381 mm in Kentucky Lake and from 381 mm to 356 mm or 406 mm TL in Watts Bar Lake. The number of sauger harvested would change more than yield if the size limits were changed. At a *cm* of 20% and exploitation rates of 20% to 55%, the number of sauger harvested decreased 10% to 11% if the size limit was increased from 356 mm to 381 mm or 406 mm TL in Kentucky Lake, and decreased 9% if the size limit was increased from 381 mm to 406 mm TL in Watts Bar Lake (Figures 10 and 11). At a *cm* of 30% and exploitation rates of 17% to 52%, the number of sauger harvested decreased 15% to 17% if the size limit was increased to 381 mm or 406 mm TL in Kentucky Lake, and decreased 14% if the size limit was increased to 406 mm TL in Watts Bar Lake (Figures 10 and 11).

The potential for recruitment overfishing (i.e., SPR < 20%) was highest in Watts Bar Lake and was more pronounced in both reservoirs at low rates of *cm* when no size limits were in place (Figures 12 and 13). When *cm* was 20% and there was no size limit, SPR fell below 20% in Watts Bar Lake when exploitation exceeded 27%; under the current size limit (i.e., 381 mm TL), recruitment overfishing did not become evident until exploitation exceeded 46% (Figure 13). When *cm* was 30% and there was no size limit, recruitment overfishing was evident in Watts Bar Lake when exploitation exceeded 34% (Figure 13). Under the current size limit (i.e., 356 mm TL), recruitment overfishing in Kentucky Lake was not evident at either rate of *cm* over the range of exploitation modeled; however, when there was no size limit at a *cm* of 20%, recruitment overfishing was evident in Kentucky Lake when exploitation exceeded 36% (Figure 12).

DISCUSSION

Sauger populations that were subjected to high rates of exploitation had age structures skewed towards younger fish (Maceina et al. 1998). The sauger population in Kentucky Lake was heavily exploited in the 1990s (Pegg et al. 1996), and it was characterized by large numbers of younger fish before and after harvest regulations were enacted (Churchill 1992; Fischbach 1998). The age-structure of sauger in Kentucky Lake in 2008-2009 was also skewed toward younger fish, but to a lesser extent than in the 1990s. That is, there were more, older fish in the population in 2008-2009, which suggests that exploitation of smaller individuals has declined. The mean ages of sauger in Kentucky Lake during 2008 and 2009 (1.8 and 2.0 yrs) were within the range of ages that indicate a steady-state sauger population (Bettoli and Fischbach 1998). That is, saugers in Kentucky Lake continue to exhibit fairly stable recruitment from year-to-year.

The sauger population in Watts Bar Lake was dominated by few older fish throughout the 1990s and was characterized by erratic recruitment patterns (Fischbach 1998). Slight improvements to the sauger population were observed following establishment of length limits; a decrease in the mean size of saugers in the upper Tennessee River indicated recruitment was improving in that region (Bettoli and Fischbach 1998). However, the mean age of sauger in Watts Bar Lake was above that of a steady state population in 2008 (2.8 yrs); therefore, this fishery continues to exhibit erratic recruitment. Sporadic stocking does not appear to have alleviated (or exacerbated) recruitment variation in Watts Bar Lake. Fischbach (1998) suspected that variation in sauger recruitment overshadowed the benefits of stocking in the upper Tennessee River. In recent years, the Tennessee Valley has been subject to extreme drought conditions. Sauger recruitment is strongly linked to discharge in the Tennessee River (Buckmeier 1995; Fischbach 1998) and Fischbach (1998) suggested that in drought years, the recruitment of sauger populations may suffer. This may help to explain why the mean age of sauger in Watts Bar Lake in 2008 was the second highest mean age recorded from 1990 to 2009.

Differences between the age and size structures of sauger populations in Watts Bar Lake and Kentucky Lake were evident throughout the 1990s (Fischbach 1998). Watts Bar Lake saugers were generally longer and older on average than sauger in Kentucky Lake and those differences persisted through 2009. Growth rates also continue to be faster in Watts Bar Lake than in Kentucky Lake (Buckmeier 1995). The observed mean lengths-at-age in this study were always greater in Watts Bar Lake than in Kentucky Lake; however, mean lengths-at-age in both reservoirs were within ranges reported by Buckmeier (1995).

Growth overfishing was evident in the Kentucky Lake population in the late 1990s (Fischbach 1998). Bettoli and Fischbach (1998) predicted that rescinding a temporary "keep-three-fish-under-the-size-limit" regulation would reduce exploitation of small saugers and help to increase sauger yield in Kentucky Lake. In 2008-2009, the Kentucky Lake sauger population was not exhibiting signs of growth overfishing, which suggests that exploitation of smaller individuals has indeed been reduced. Simulated yields in Watts Bar Lake and Kentucky Lake were always greatest with a minimum size limit, but benefits to yield were least evident when natural mortality rates were high. Previous modeling of sauger and walleye populations in southern reservoir systems also indicated that yield would be higher with size limits (Maceina et al. 1998; Vandergoot and Bettoli 2001). Elimination of size limits in either reservoir would increase the likelihood of growth overfishing, the extent of which would be dependent upon the level of exploitation in the reservoir.

Increasing size limits in either reservoir would boost yields slightly. However, the concurrent decrease in the number of sauger harvested would probably overshadow the benefits of higher yield. The sauger population in Tennessee River is a harvest-oriented fishery and most (60%) anglers who catch sauger do so with the intention of harvesting them (Bettoli 1998). It is unknown whether sauger anglers would prefer to catch fewer large fish or more small fish. Knowledge of angler preferences should play an important part in determining which length limits are appropriate for that fishery.

Elimination of size limits in both reservoirs would subject the sauger populations to the possibility of recruitment overfishing, where individuals are exploited to a point where recruitment is substantially reduced or fails (Sissenwine and Shepard 1987). To prevent recruitment overfishing, Goodyear (1993) suggested that SPR values should be at least 20%. According to the SPR models, the current size limit is protecting saugers in Kentucky Lake from recruitment overfishing over the range of exploitation rates and natural mortality rates modeled. The current size limit in Watts Bar Lake will protect sauger from recruitment overfishing unless exploitation rates exceed 40%. However, Watts Bar Lake is unlikely to be subjected to such high exploitation, as evidenced by historical rates of exploitation that were less than 6% (Hevel 1988; Hickman et al. 1990; St. John 1990).

Minimum length limits for saugers were enacted in the Tennessee River with the objective of reducing exploitation, preventing growth and recruitment overfishing, and improving the size distribution of sauger populations (Fischbach 1998). The regulations appear to have protected these two Tennessee sauger populations from overfishing and contributed to their relative stability over the last 19 years.

ACKNOWLEDGEMENTS

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Table 1.—Number of sauger fingerlings stocked into Watts Bar Lake, 1990-2008, by the Tennessee Wildlife Resources Agency.

Year	Number Stocked
1990	110,624
1991	65, 467
1995	201,123
1996	42,220
2000	34,080
2004	117,937
2005	25,424
2006	204,365
2007	99,301
2008	174,339

Table 2.—Spatial and temporal variation in mean lengths of all saugers collected from Watts Bar Lake and Kentucky Lake, 1990-1997, 2008-2009. Within a row, means followed by an asterisk (*) were not different (Tukey's test; $P = 0.05$). Mean lengths within each reservoir (column means) varied significantly among years in each reservoir (one-way ANOVA; $P < 0.0001$).

	Watts Bar Lake			Kentucky Lake		
Year	Number	Mean	SE	Number	Mean	SE
1990	51	447	11.70	65	348	9.01
1991	100	348	7.80	122	289	4.52
1992	106	386	5.60	59	340	7.15
1993	60	408	7.32	133	269	4.62
1994	56	408	10.51	189	305	3.46
1995	103	329^*	6.55	100	330^*	5.57
1996	109	362	5.37	85	305	5.23
1997	87	390	6.93	70	282	6.22
2008	74	424	8.80	57	346	6.45
2009	127	392	6.08	186	338	4.39

Table 3.—Spatial and temporal variation in mean ages of all saugers collected from Watts Bar Lake and Kentucky Lake, 1990-1997, 2008-2009. Within a row, means followed by an asterisk (*) were not different (Tukey's test; $P = 0.05$). Mean ages within each reservoir (column means) varied significantly among years in each reservoir (one-way ANOVA; $P < 0.0001$).

	Watts Bar Lake			Kentucky Lake		
Year	Number	Mean	SE	Number	Mean	SE
1990	51	3.0	0.21	65	1.9	0.12
1991	100	1.8	0.16	122	1.2	0.06
1992	106	2.1*	0.10	59	1.8*	0.07
1993	60	2.7	0.13	133	1.2	0.04
1994	56	2.7	0.15	189	1.7	0.04
1995	103	1.4	0.07	100	2.1	0.07
1996	109	2.1	0.04	85	1.8	0.07
1997	87	2.6	0.09	70	1.5	0.08
2008	74	2.8	0.12	57	1.8	0.08
2009	127	2.3	0.10	186	2.0	0.07

Table 4.—Within-reservoir trends in mean age and mean total length (TL) from 1990 to 2009 in Watts Bar Lake and Kentucky Lake estimated using simple linear regression, where β_0 and β_1 were the regression coefficients for the intercept and slope, respectively.

Reservoir	Mean	Range	β_0	β_1	r^2	P
Watts Bar Lake	Age	1.4-3.0	-17.7	0.01	0.02	0.71
	TL	329-447	-1059.0	0.73	0.02	0.71
Kentucky Lake	Age	1.2-2.1	-32.5	0.02	0.14	0.29
	TL	269-348	-2720.5	1.52	0.12	0.32

Table 5.—Parameters used to simulate sauger yield in Watts Bar Lake and Kentucky Lake using the Beverton-Holt yield-per-recruit model in FAST (Slipke and Maceina 2001). Sample size (n) is the number of individuals used to estimate the parameters of the von Bertalanffy growth model, where L_∞ is the theoretical maximum length (held constant at 550 mm for both populations), K is the Brody growth coefficient, and t_o is the time when total length would equal zero. Slope (β_1) and Intercept (β_0) were derived from the $\log_{10}$length:$\log_{10}$weight relationship for saugers in each reservoir.

Reservoir	n	β_1	β_0	L_∞	K	t_o
Kentucky Lake	243	-6.235	3.486	550	0.297	-1.357
Watts Bar Lake	201	-5.868	3.341	550	0.384	-0.925

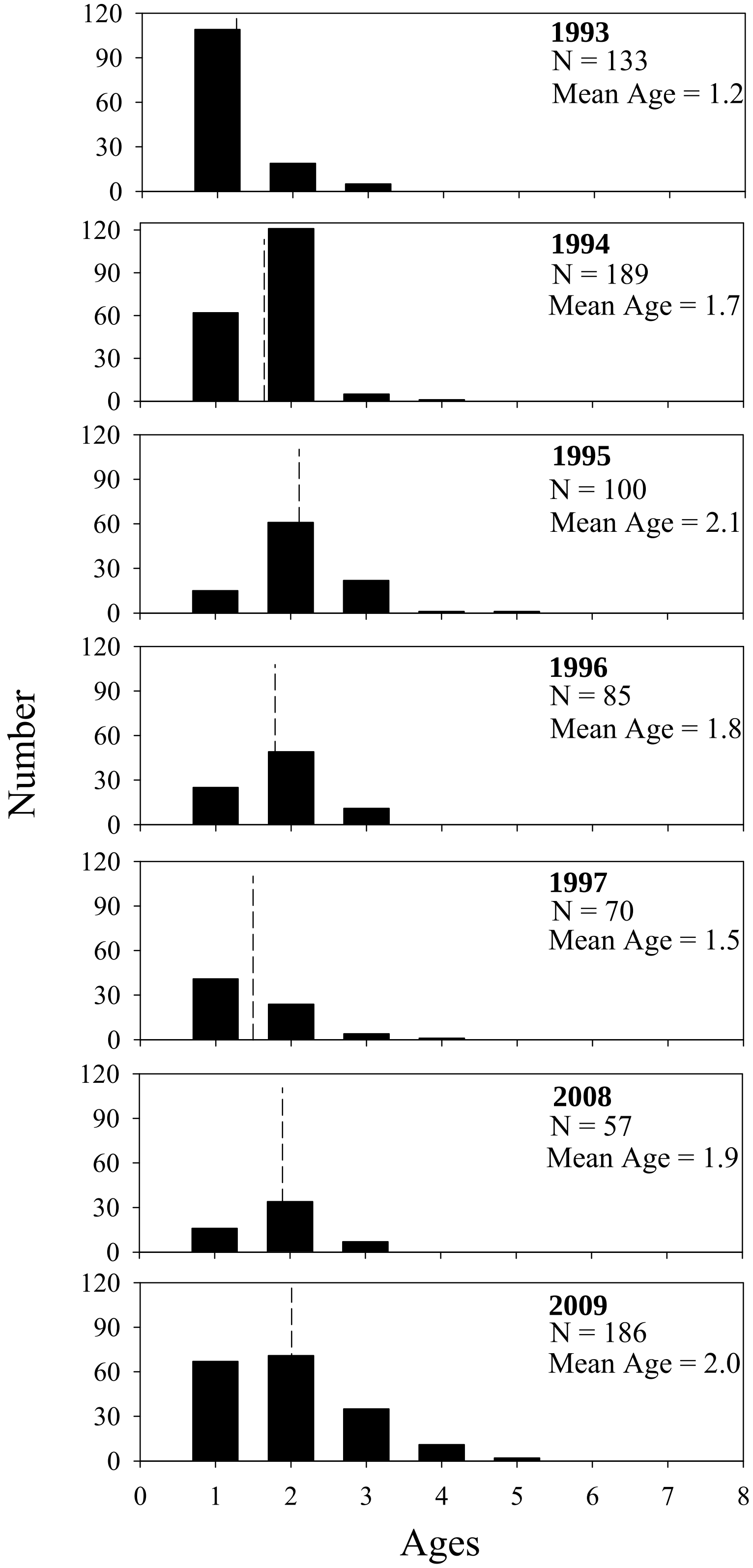

Figure 1.—Age frequency distribution for all saugers collected in Kentucky Lake from 1993-1997 and 2008-2009. Dashed lines indicate the mean age.

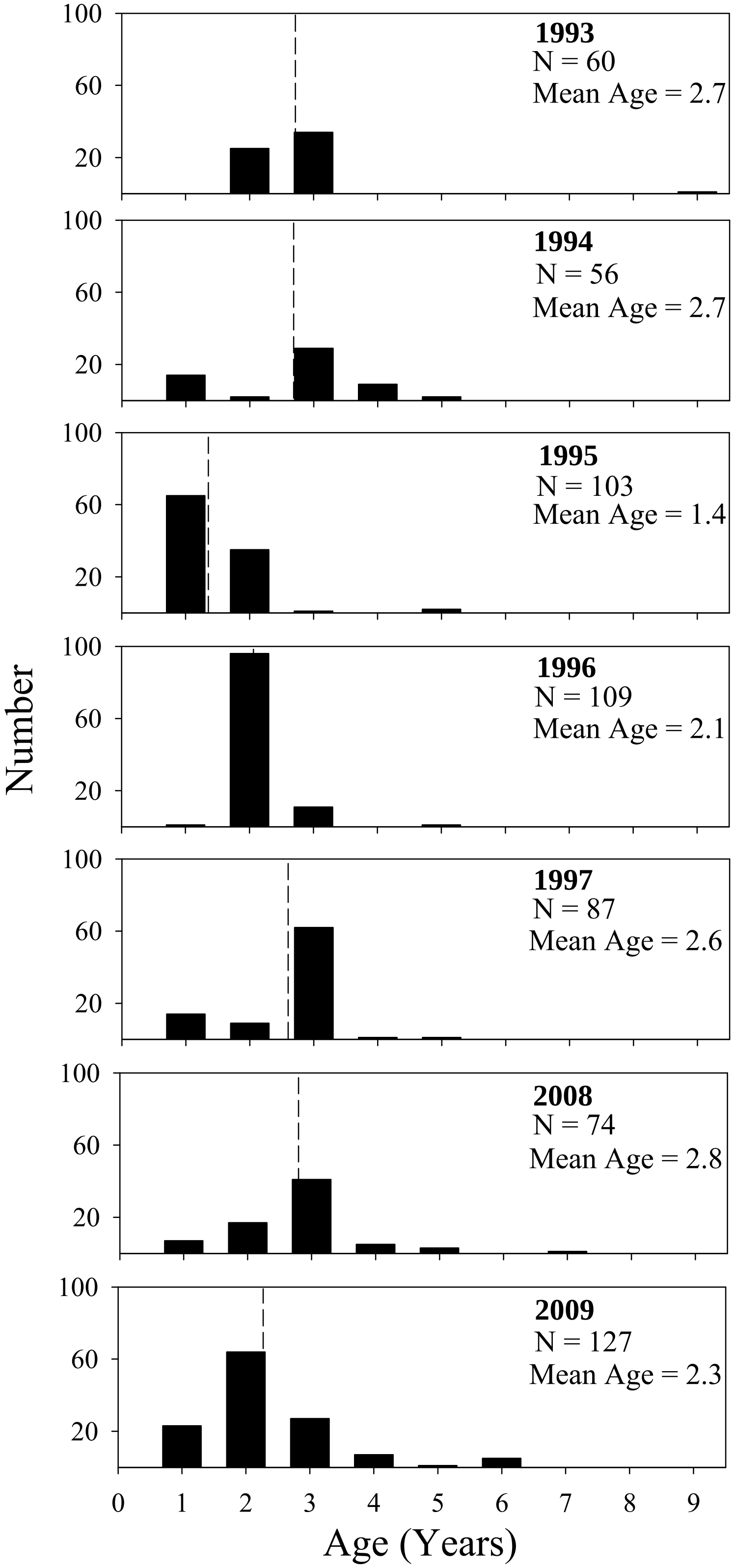

Figure 2.—Age frequency distribution for all saugers collected in Watts Bar Lake from 1993-1997 and 2008-2009. Dashed lines indicate the mean age.

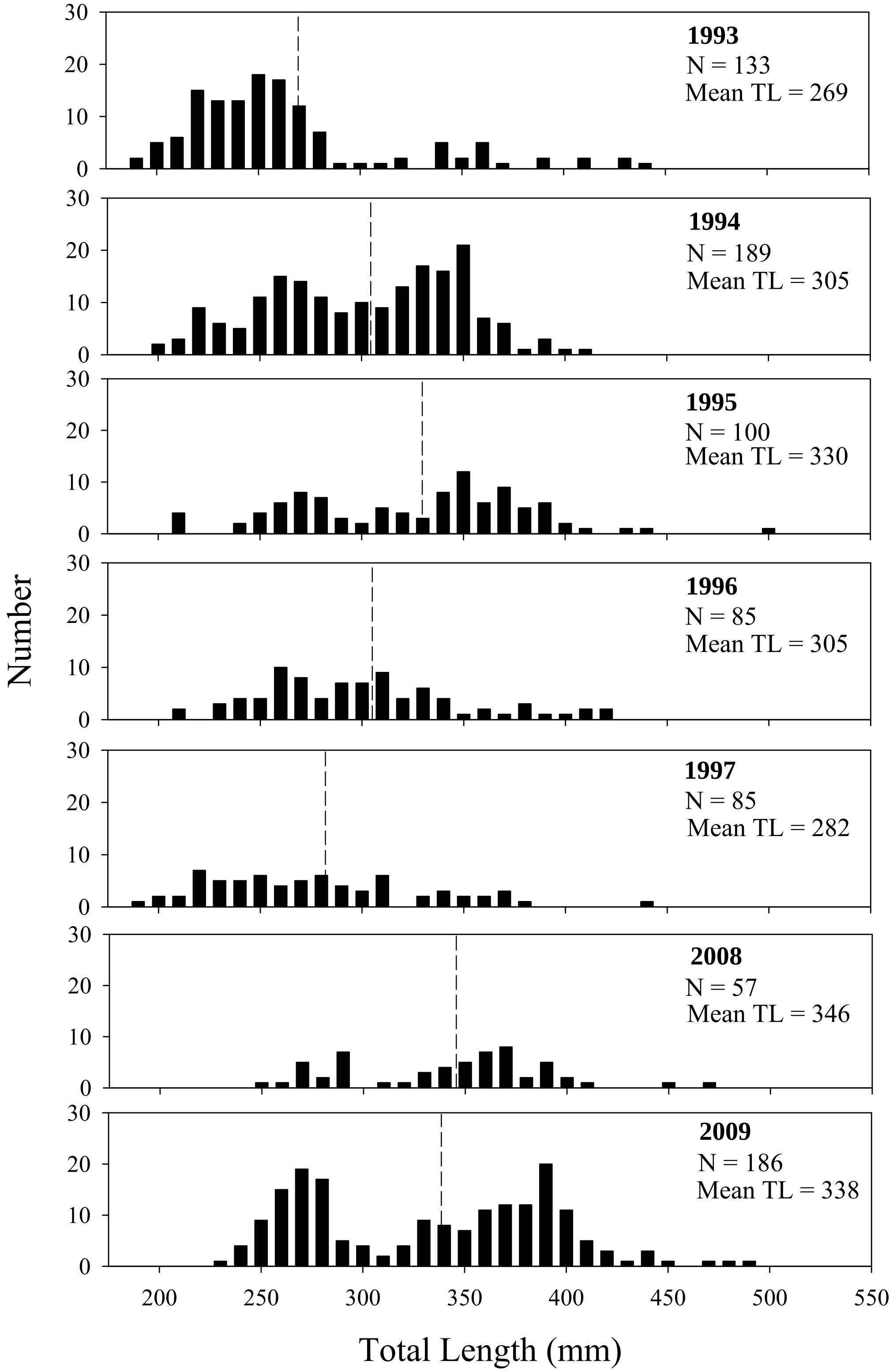

Figure 3.—Length frequency distribution for all saugers collected in Kentucky Lake from 1993-1997 and 2008-2009. Dashed lines indicate the mean length.

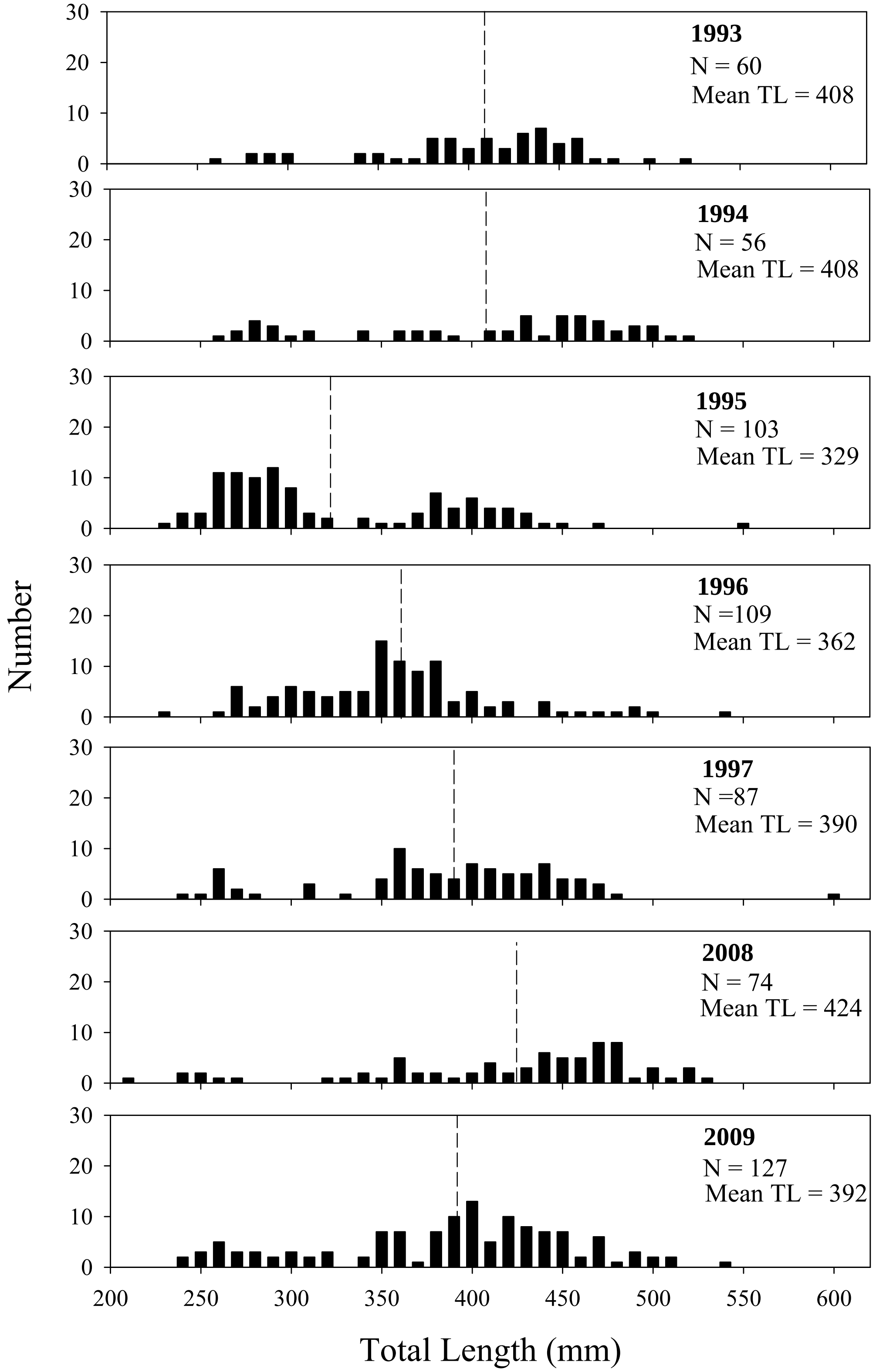

Figure 4.—Length frequency distribution for all saugers collected in Watts Bar Lake from 1993-1997 and 2008-2009. Dashed lines indicate the mean length.

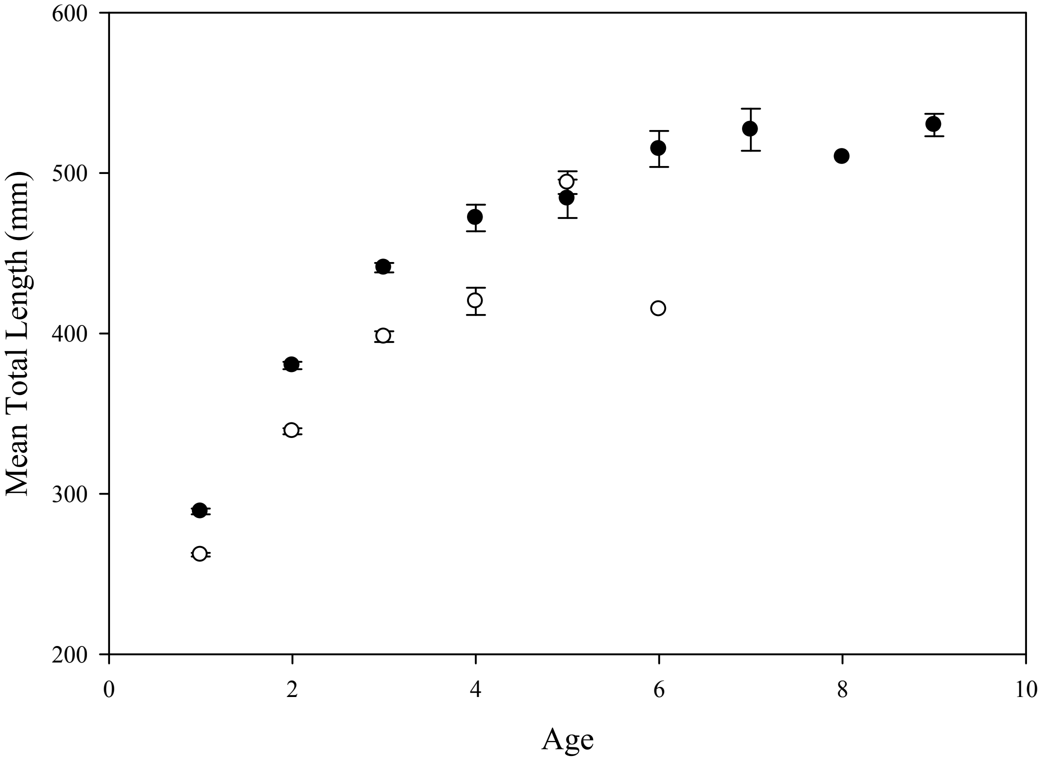

Figure 5.—Mean lengths-at-age pooled for all sauger collected from 1990-1997 and 2008-2009 in Watts Bar Lake (solid circles) and Kentucky Lake (open circles). Vertical bars represent 1 standard error.

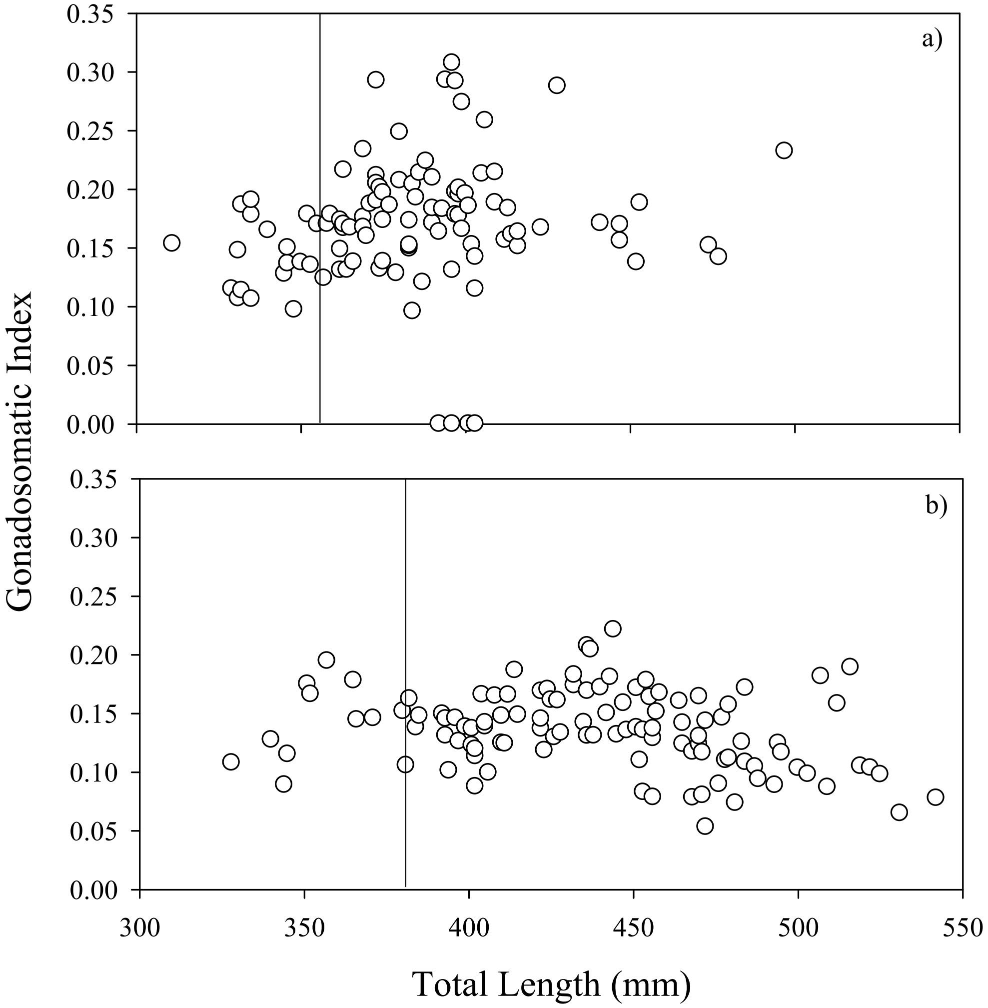

Figure 6.—Gonadosomatic Index (GSI) values for all mature female saugers collected in 2008-2009 in a) Kentucky Lake; and b) Watts Bar Lake. Four mature females in Kentucky Lake spawned prior to collection and were assigned GSI values of 0. Vertical bars represent the current minimum size limits in each reservoir (356 and 381 mm TL).

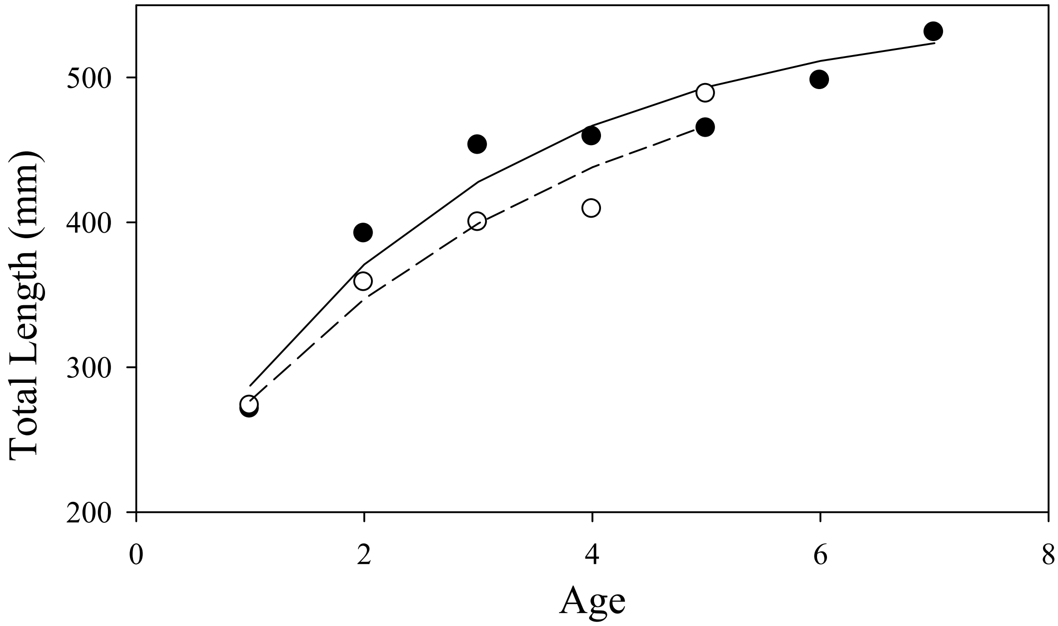

Figure 7.—Predicted length-at-age (solid lines) and observed length-at-age (closed circles) of sauger collected from Watts Bar Lake and predicted length-at-age (dashed line) and observed length-at-age (open circles) of sauger collected from Kentucky Lake in 2008 and 2009.

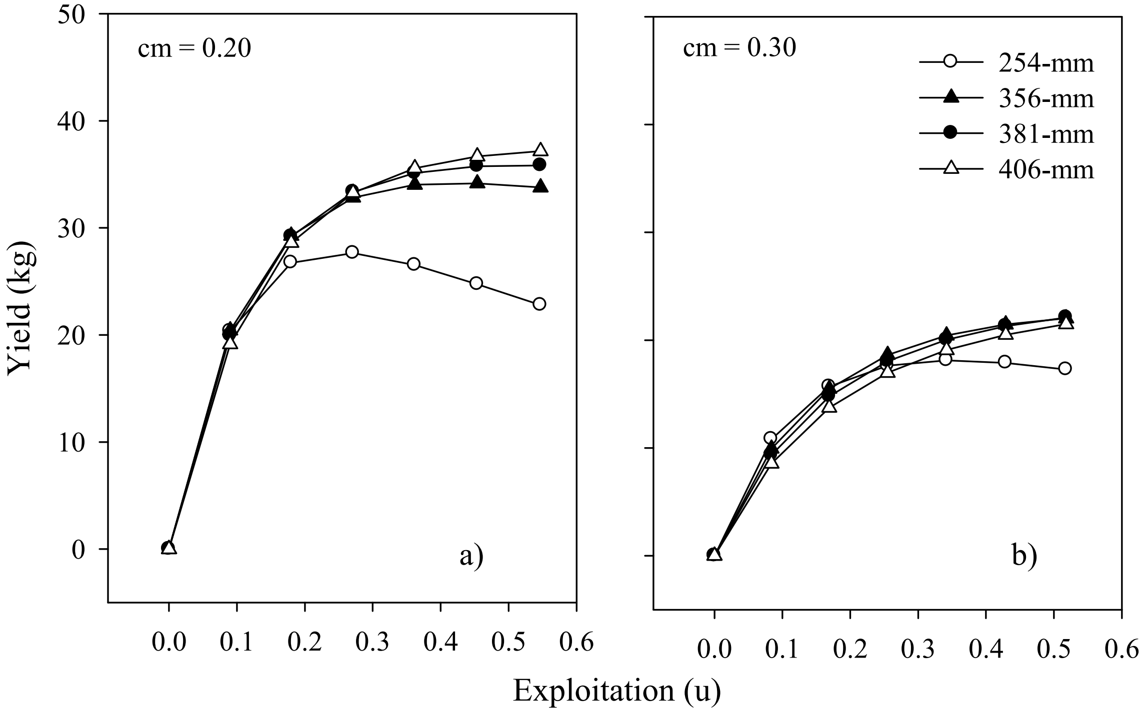

Figure 8.—Simulated yield (kg per 100 recruits) in Kentucky Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates.

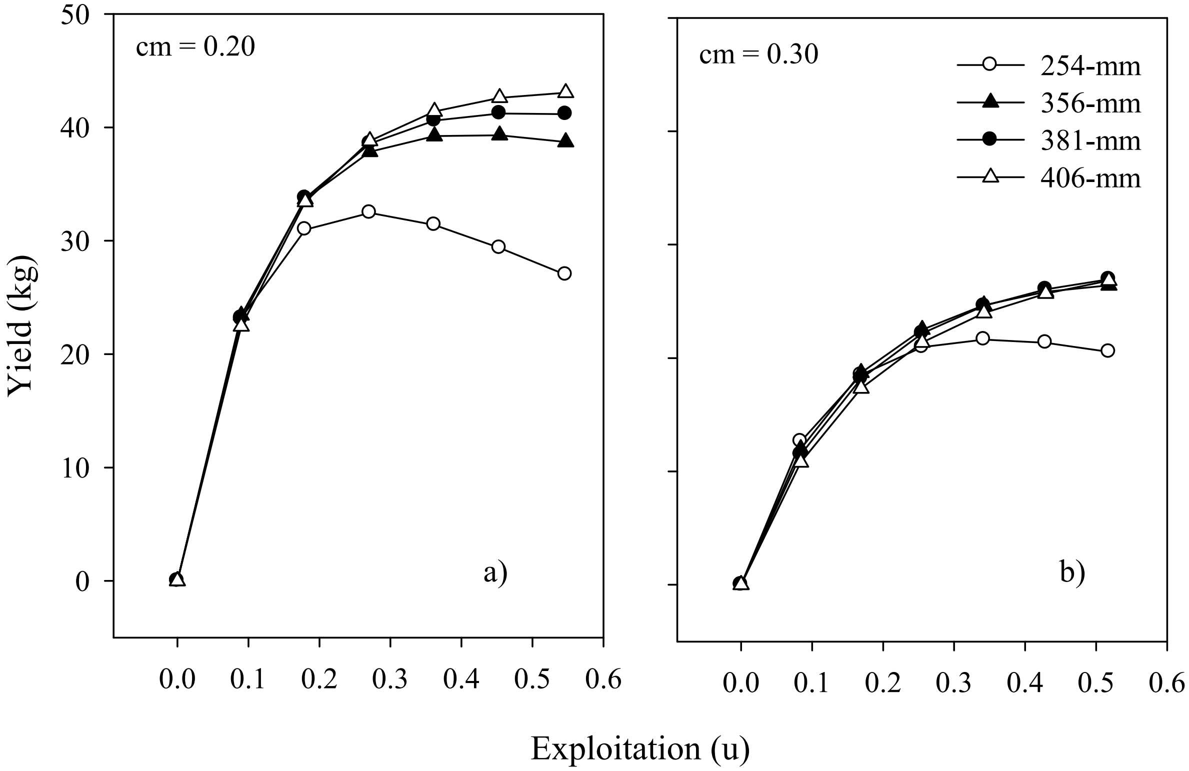

Figure 9.— Simulated yield (kg per 100 recruits) in Watts Bar Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates.

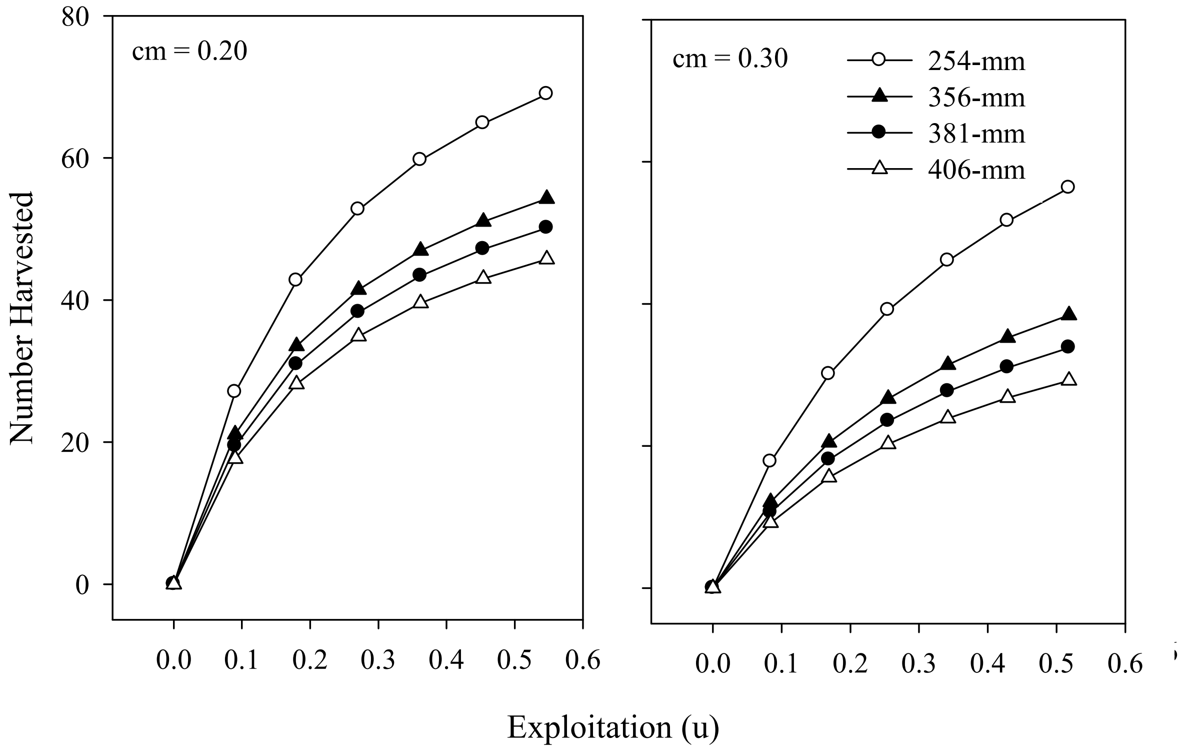

Figure 10.—Simulated number of individuals harvested in Kentucky Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates.

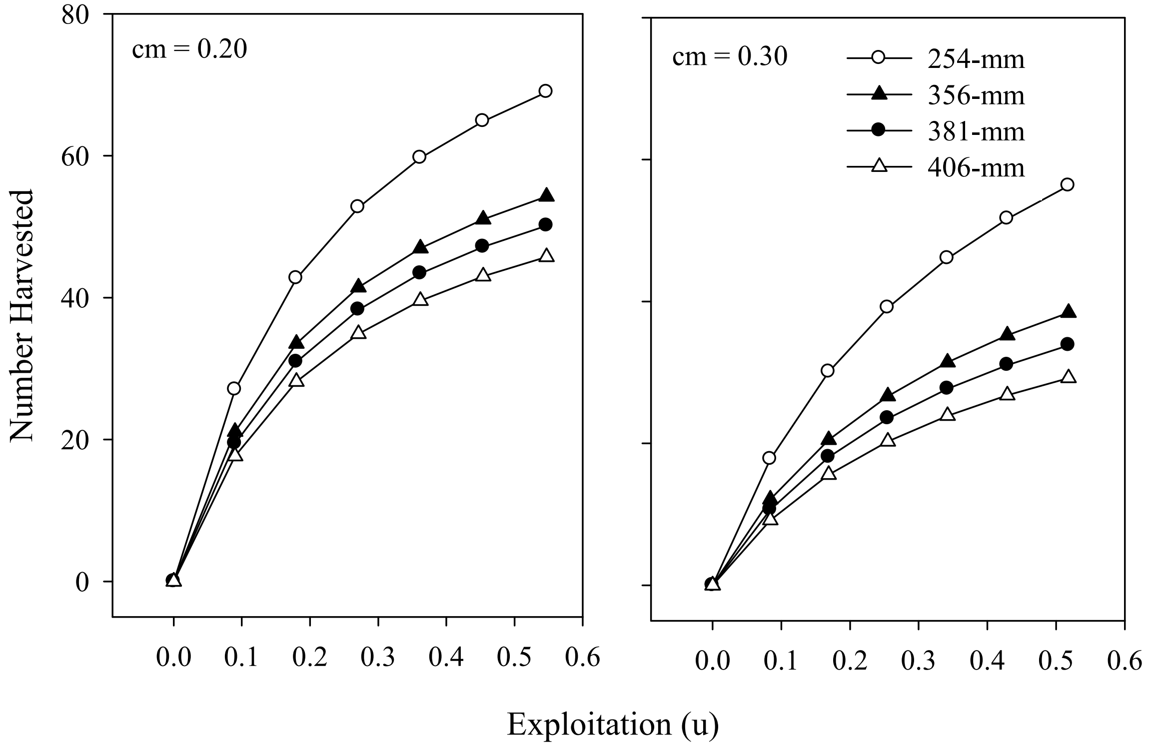

Figure 11.—Simulated number of individuals harvested in Watts Bar Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates.

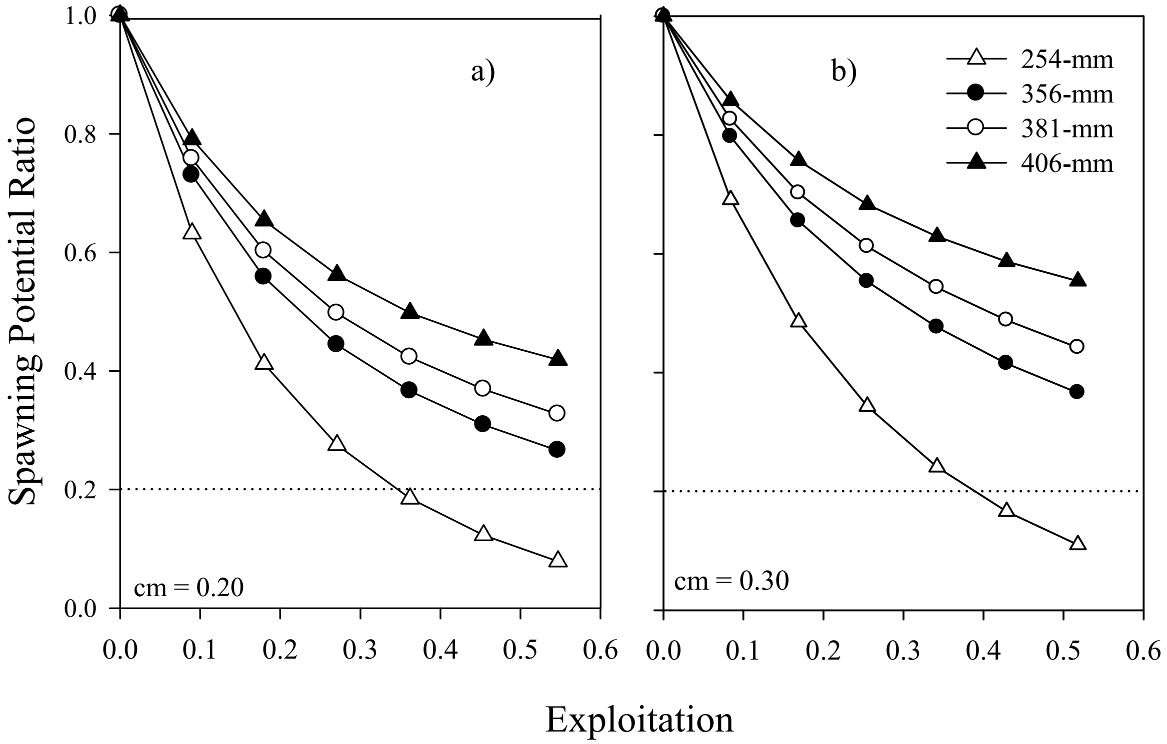

Figure 12.—Simulated spawning potential ratio (SPR) values in Kentucky Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates. SPR values less than 20% (dotted line) suggest recruitment overfishing.

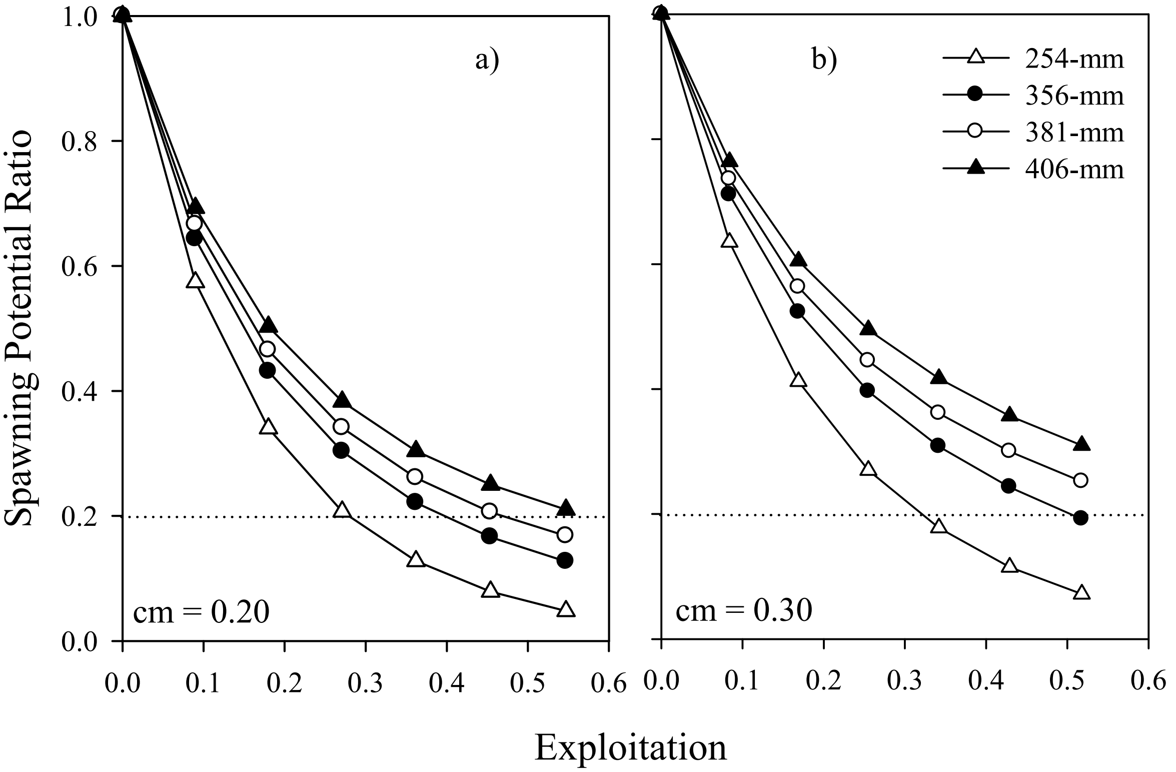

Figure 13.—Simulated spawning potential ratio values in Watts Bar Lake at four different minimum length limits and two conditional natural mortality (*cm*) rates. SPR values less than 20% (dotted line) suggest recruitment overfishing.

APPENDIX

Table A1.—Mesh size (mm), total length (TL, mm), weight (WT, g), sex, gonad weight (g), and age of sauger collected in experimental gill nets in Watts Bar Lake below Fort Loudoun Dam and Melton Hill Dam and in Kentucky Lake below Pickwick Dam from 2008 to 2009.

Table A2.—Data collected from saugers collected for the assessment of barotrauma in Kentucky Lake in 2008 and 2009.

Table A1.—Mesh size (mm), total length (TL, mm), weight (WT, g), sex, gonad weight (g), and age of sauger collected in experimental gill nets in Watts Bar Lake below Fort Loudoun Dam and Melton Hill Dam and in Kentucky Lake below Pickwick Dam from 2008 to 2009. Area tailwater abbreviations are as follows: FLTW = Fort Loudoun dam; MHTW = Melton Hill dam; and PWTW = Pickwick dam.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
25-Jan-08	KENTUCKY	PWTW	19	291	209	M	1	1
25-Jan-08	KENTUCKY	PWTW	25	299	218	M	1	1
25-Jan-08	KENTUCKY	PWTW	25	291	213	M	2	1
25-Jan-08	KENTUCKY	PWTW	25	263	161	M	2	1
25-Jan-08	KENTUCKY	PWTW	25	283	197	M	2	1
25-Jan-08	KENTUCKY	PWTW	25	335	369	M	7	2
25-Jan-08	KENTUCKY	PWTW	25	364	509	F	59	2
25-Jan-08	KENTUCKY	PWTW	25	293	200	I	.	1
25-Jan-08	KENTUCKY	PWTW	25	292	217	I	.	1
25-Jan-08	KENTUCKY	PWTW	38	375	518	I	1	2
25-Jan-08	KENTUCKY	PWTW	38	342	401	M	4	2
25-Jan-08	KENTUCKY	PWTW	38	377	494	M	6	2
25-Jan-08	KENTUCKY	PWTW	38	342	352	M	6	2
25-Jan-08	KENTUCKY	PWTW	38	393	682	M	7	2
25-Jan-08	KENTUCKY	PWTW	38	372	498	M	9	2
25-Jan-08	KENTUCKY	PWTW	38	348	406	F	36	2
25-Jan-08	KENTUCKY	PWTW	38	362	518	F	60	2
25-Jan-08	KENTUCKY	PWTW	38	374	549	F	64	2
25-Jan-08	KENTUCKY	PWTW	38	370	515	F	71	2
25-Jan-08	KENTUCKY	PWTW	38	383	562	F	73	2
25-Jan-08	KENTUCKY	PWTW	38	396	665	F	77	2
25-Jan-08	KENTUCKY	PWTW	38	383	586	F	77	2
25-Jan-08	KENTUCKY	PWTW	38	369	544	F	78	3
25-Jan-08	KENTUCKY	PWTW	38	412	783	F	106	3
25-Jan-08	KENTUCKY	PWTW	51	403	699	F	72	2
25-Jan-08	KENTUCKY	PWTW	51	452	943	F	114	3
25-Jan-08	KENTUCKY	PWTW	51	477	1143	F	142	3
22-Feb-08	KENTUCKY	PWTW	25	291	220	M	2	1
22-Feb-08	KENTUCKY	PWTW	25	359	482	F	73	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
22-Feb-08	KENTUCKY	PWTW	25	325	284	M	.	2
22-Feb-08	KENTUCKY	PWTW	25	278	209	M	.	1
22-Feb-08	KENTUCKY	PWTW	25	287	210	M	.	1
22-Feb-08	KENTUCKY	PWTW	25	279	182	M	.	1
22-Feb-08	KENTUCKY	PWTW	25	271	165	M	.	1
22-Feb-08	KENTUCKY	PWTW	25	338	390	M	.	2
22-Feb-08	KENTUCKY	PWTW	25	293	231	M	.	1
22-Feb-08	KENTUCKY	PWTW	38	360	460	M	6	2
22-Feb-08	KENTUCKY	PWTW	38	359	421	M	6	2
22-Feb-08	KENTUCKY	PWTW	38	356	435	M	7	2
22-Feb-08	KENTUCKY	PWTW	38	364	501	M	8	3
22-Feb-08	KENTUCKY	PWTW	38	311	361	F	48	2
22-Feb-08	KENTUCKY	PWTW	38	332	369	F	58	2
22-Feb-08	KENTUCKY	PWTW	38	346	460	F	60	2
22-Feb-08	KENTUCKY	PWTW	38	352	436	F	66	2
22-Feb-08	KENTUCKY	PWTW	38	365	517	F	74	2
22-Feb-08	KENTUCKY	PWTW	38	374	555	F	93	2
22-Feb-08	KENTUCKY	PWTW	38	398	670	F	101	3
22-Feb-08	KENTUCKY	PWTW	38	398	618	F	101	2
22-Feb-08	KENTUCKY	PWTW	38	401	729	F	114	2
22-Feb-08	KENTUCKY	PWTW	38	373	557	F	126	2
22-Feb-08	KENTUCKY	PWTW	38	354	414	M	.	2
22-Feb-08	KENTUCKY	PWTW	38	375	475	M	.	2
22-Feb-08	KENTUCKY	PWTW	38	395	602	M	.	3
22-Feb-08	KENTUCKY	PWTW	38	368	464	M	.	2
22-Jan-09	KENTUCKY	PWTW	25	345	459	F	52	2
22-Jan-09	KENTUCKY	PWTW	38	331	352	F	34	2
22-Jan-09	KENTUCKY	PWTW	38	355	516	F	75	2
22-Jan-09	KENTUCKY	PWTW	38	402	763	F	101	2
22-Jan-09	KENTUCKY	PWTW	38	329	384	M	.	2
22-Jan-09	KENTUCKY	PWTW	38	340	411	M	.	2
22-Jan-09	KENTUCKY	PWTW	38	414	722	M	.	3
22-Jan-09	KENTUCKY	PWTW	51	384	652	F	57	2
22-Jan-09	KENTUCKY	PWTW	51	379	650	F	74	2
22-Jan-09	KENTUCKY	PWTW	51	377	529	F	83	2
22-Jan-09	KENTUCKY	PWTW	51	403	731	F	91	3
22-Jan-09	KENTUCKY	PWTW	51	441	1000	F	146	3

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
23-Feb-09	KENTUCKY	PWTW	19	279	200	I	.	1
23-Feb-09	KENTUCKY	PWTW	19	258	172	M	.	1
23-Feb-09	KENTUCKY	PWTW	19	278	202	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	332	392	F	40	2
23-Feb-09	KENTUCKY	PWTW	25	346	391	F	47	2
23-Feb-09	KENTUCKY	PWTW	25	263	146	I	.	1
23-Feb-09	KENTUCKY	PWTW	25	240	108	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	258	151	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	263	168	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	264	160	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	264	166	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	264	163	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	266	166	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	267	165	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	270	183	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	271	192	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	274	175	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	274	190	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	277	194	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	277	187	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	278	175	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	280	199	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	281	190	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	282	213	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	282	211	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	283	233	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	287	234	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	287	211	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	288	228	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	291	222	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	303	278	M	.	1
23-Feb-09	KENTUCKY	PWTW	25	283	195	M	.	2
23-Feb-09	KENTUCKY	PWTW	25	297	254	M	.	2
23-Feb-09	KENTUCKY	PWTW	25	314	292	M	.	2
23-Feb-09	KENTUCKY	PWTW	25	315	325	M	.	2
23-Feb-09	KENTUCKY	PWTW	38	335	364	F	35	2
23-Feb-09	KENTUCKY	PWTW	38	329	349	F	36	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
23-Feb-09	KENTUCKY	PWTW	38	331	381	F	49	2
23-Feb-09	KENTUCKY	PWTW	38	357	462	F	51	2
23-Feb-09	KENTUCKY	PWTW	38	331	395	M	57	2
23-Feb-09	KENTUCKY	PWTW	38	366	512	F	62	2
23-Feb-09	KENTUCKY	PWTW	38	375	527	F	64	2
23-Feb-09	KENTUCKY	PWTW	38	362	510	F	66	3
23-Feb-09	KENTUCKY	PWTW	38	363	469	F	67	2
23-Feb-09	KENTUCKY	PWTW	38	387	641	F	69	2
23-Feb-09	KENTUCKY	PWTW	38	358	481	F	70	2
23-Feb-09	KENTUCKY	PWTW	38	369	528	F	79	2
23-Feb-09	KENTUCKY	PWTW	38	383	598	F	79	2
23-Feb-09	KENTUCKY	PWTW	38	363	585	F	85	2
23-Feb-09	KENTUCKY	PWTW	38	375	595	F	88	2
23-Feb-09	KENTUCKY	PWTW	38	392	626	F	88	3
23-Feb-09	KENTUCKY	PWTW	38	371	577	F	91	2
23-Feb-09	KENTUCKY	PWTW	38	383	637	F	94	2
23-Feb-09	KENTUCKY	PWTW	38	390	671	F	98	2
23-Feb-09	KENTUCKY	PWTW	38	416	754	F	99	3
23-Feb-09	KENTUCKY	PWTW	38	375	608	F	100	2
23-Feb-09	KENTUCKY	PWTW	38	373	606	F	103	3
23-Feb-09	KENTUCKY	PWTW	38	423	727	F	104	3
23-Feb-09	KENTUCKY	PWTW	38	390	677	F	105	3
23-Feb-09	KENTUCKY	PWTW	38	393	679	F	105	3
23-Feb-09	KENTUCKY	PWTW	38	397	714	F	108	3
23-Feb-09	KENTUCKY	PWTW	38	416	783	F	110	3
23-Feb-09	KENTUCKY	PWTW	38	397	679	F	112	3
23-Feb-09	KENTUCKY	PWTW	38	390	652	F	113	3
23-Feb-09	KENTUCKY	PWTW	38	409	719	F	114	2
23-Feb-09	KENTUCKY	PWTW	38	386	670	F	118	2
23-Feb-09	KENTUCKY	PWTW	38	388	678	F	124	3
23-Feb-09	KENTUCKY	PWTW	38	409	748	F	132	3
23-Feb-09	KENTUCKY	PWTW	38	447	930	F	135	3
23-Feb-09	KENTUCKY	PWTW	38	453	1112	F	176	4
23-Feb-09	KENTUCKY	PWTW	38	428	882	F	197	4
23-Feb-09	KENTUCKY	PWTW	38	347	392	M	.	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
23-Feb-09	KENTUCKY	PWTW	38	355	476	M	.	2
23-Feb-09	KENTUCKY	PWTW	38	360	468	M	.	2
23-Feb-09	KENTUCKY	PWTW	38	393	697	M	.	2
23-Feb-09	KENTUCKY	PWTW	38	396	659	M	.	2
23-Feb-09	KENTUCKY	PWTW	38	366	442	M	.	3
23-Feb-09	KENTUCKY	PWTW	38	379	541	M	.	3
23-Feb-09	KENTUCKY	PWTW	38	434	856	M	.	3
23-Feb-09	KENTUCKY	PWTW	38	402	519	M	.	4
23-Feb-09	KENTUCKY	PWTW	51	414	814	F	113	3
23-Feb-09	KENTUCKY	PWTW	51	413	819	F	127	3
23-Feb-09	KENTUCKY	PWTW	51	400	830	F	136	3
23-Feb-09	KENTUCKY	PWTW	51	398	819	F	137	3
23-Feb-09	KENTUCKY	PWTW	51	447	1053	F	142	3
23-Feb-09	KENTUCKY	PWTW	51	474	1123	F	148	4
23-Feb-09	KENTUCKY	PWTW	51	497	1401	F	264	5
23-Feb-09	KENTUCKY	PWTW	64	320	301	M	.	2
16-Mar-09	KENTUCKY	PWTW	19	250	128	IM	.	1
16-Mar-09	KENTUCKY	PWTW	19	272	184	IM	.	1
16-Mar-09	KENTUCKY	PWTW	19	279	191	IM	.	2
16-Mar-09	KENTUCKY	PWTW	19	238	111	M	.	1
16-Mar-09	KENTUCKY	PWTW	19	246	125	M	.	1
16-Mar-09	KENTUCKY	PWTW	19	247	129	M	.	1
16-Mar-09	KENTUCKY	PWTW	19	261	162	M	.	1
16-Mar-09	KENTUCKY	PWTW	19	262	145	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	401	559	F	0	2
16-Mar-09	KENTUCKY	PWTW	25	335	397	F	60	2
16-Mar-09	KENTUCKY	PWTW	25	247	131	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	257	145	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	258	152	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	258	143	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	259	152	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	262	165	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	265	159	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	265	148	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	267	177	IM	.	1

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
16-Mar-09	KENTUCKY	PWTW	25	270	171	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	270	166	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	271	173	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	276	178	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	278	205	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	282	206	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	284	206	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	284	183	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	286	211	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	289	212	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	292	215	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	295	225	IM	.	1
16-Mar-09	KENTUCKY	PWTW	25	292	234	IM	.	2
16-Mar-09	KENTUCKY	PWTW	25	304	263	IM	.	2
16-Mar-09	KENTUCKY	PWTW	25	308	268	IM	.	2
16-Mar-09	KENTUCKY	PWTW	25	257	140	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	259	162	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	269	162	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	275	161	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	276	184	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	278	181	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	280	200	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	285	212	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	288	211	M	.	1
16-Mar-09	KENTUCKY	PWTW	25	308	263	M	.	2
16-Mar-09	KENTUCKY	PWTW	25	323	334	M	.	2
16-Mar-09	KENTUCKY	PWTW	38	392	490	F	0	2
16-Mar-09	KENTUCKY	PWTW	38	403	609	F	0	2
16-Mar-09	KENTUCKY	PWTW	38	396	601	F	0	3
16-Mar-09	KENTUCKY	PWTW	38	353	445	F	53	2
16-Mar-09	KENTUCKY	PWTW	38	350	488	F	59	2
16-Mar-09	KENTUCKY	PWTW	38	340	445	F	63	2
16-Mar-09	KENTUCKY	PWTW	38	335	406	F	65	2
16-Mar-09	KENTUCKY	PWTW	38	362	568	F	84	2
16-Mar-09	KENTUCKY	PWTW	38	380	536	F	92	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
16-Mar-09	KENTUCKY	PWTW	38	369	491	F	93	3
16-Mar-09	KENTUCKY	PWTW	38	373	595	F	95	2
16-Mar-09	KENTUCKY	PWTW	38	399	689	F	98	2
16-Mar-09	KENTUCKY	PWTW	38	385	619	F	100	2
16-Mar-09	KENTUCKY	PWTW	38	373	590	F	103	2
16-Mar-09	KENTUCKY	PWTW	38	363	585	F	104	2
16-Mar-09	KENTUCKY	PWTW	38	380	593	F	118	2
16-Mar-09	KENTUCKY	PWTW	38	405	763	F	134	3
16-Mar-09	KENTUCKY	PWTW	38	406	682	F	140	4
16-Mar-09	KENTUCKY	PWTW	38	399	698	F	150	3
16-Mar-09	KENTUCKY	PWTW	38	339	388	IM	.	2
16-Mar-09	KENTUCKY	PWTW	38	344	361	IM	.	2
16-Mar-09	KENTUCKY	PWTW	38	348	449	M	.	2
16-Mar-09	KENTUCKY	PWTW	38	359	466	M	.	2
16-Mar-09	KENTUCKY	PWTW	38	373	530	M	.	2
16-Mar-09	KENTUCKY	PWTW	38	393	635	M	.	2
16-Mar-09	KENTUCKY	PWTW	38	338	455	M	.	3
16-Mar-09	KENTUCKY	PWTW	38	371	455	M	.	3
16-Mar-09	KENTUCKY	PWTW	38	380	452	M	.	3
16-Mar-09	KENTUCKY	PWTW	38	384	525	M	.	3
16-Mar-09	KENTUCKY	PWTW	38	392	585	M	.	3
16-Mar-09	KENTUCKY	PWTW	38	345	510	M	.	4
16-Mar-09	KENTUCKY	PWTW	38	367	477	M	.	4
16-Mar-09	KENTUCKY	PWTW	38	394	539	M	.	4
16-Mar-09	KENTUCKY	PWTW	38	408	710	M	.	4
16-Mar-09	KENTUCKY	PWTW	51	394	724	F	164	3
16-Mar-09	KENTUCKY	PWTW	51	396	787	F	185	4
16-Mar-09	KENTUCKY	PWTW	51	397	837	F	189	3
16-Mar-09	KENTUCKY	PWTW	64	384	602	F	102	2
9-Jan-08	WATTS BAR	FLTW	19	217	74	I	.	1
9-Jan-08	WATTS BAR	FLTW	25	240	115	I	.	1
9-Jan-08	WATTS BAR	FLTW	25	254	141	M	.	1
9-Jan-08	WATTS BAR	FLTW	25	243	124	M	.	1
9-Jan-08	WATTS BAR	FLTW	38	474	1121	F	.	3
9-Jan-08	WATTS BAR	FLTW	38	501	1507	F	.	3

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
9-Jan-08	WATTS BAR	FLTW	38	436	875	F	.	3
9-Jan-08	WATTS BAR	FLTW	38	432	701	F	.	4
9-Jan-08	WATTS BAR	FLTW	38	429	772	F	.	3
9-Jan-08	WATTS BAR	FLTW	38	369	471	I	.	2
9-Jan-08	WATTS BAR	FLTW	38	371	475	I	.	2
9-Jan-08	WATTS BAR	FLTW	38	335	349	M	.	2
9-Jan-08	WATTS BAR	FLTW	38	370	458	M	.	4
9-Jan-08	WATTS BAR	FLTW	38	362	442	M	.	2
9-Jan-08	WATTS BAR	FLTW	51	441	982	F	.	2
9-Jan-08	WATTS BAR	FLTW	51	462	1069	F	.	3
9-Jan-08	WATTS BAR	FLTW	51	411	780	F	.	3
9-Jan-08	WATTS BAR	FLTW	51	486	1209	F	.	4
9-Jan-08	WATTS BAR	FLTW	51	528	1859	F	.	3
9-Jan-08	WATTS BAR	FLTW	64	485	1260	M	.	3
16-Jan-08	WATTS BAR	FLTW	51	472	1130	F	57	3
16-Jan-08	WATTS BAR	FLTW	51	453	929	F	71	3
16-Jan-08	WATTS BAR	FLTW	51	456	1058	F	77	3
16-Jan-08	WATTS BAR	FLTW	51	468	1172	F	85	3
16-Jan-08	WATTS BAR	FLTW	51	476	1215	F	100	3
16-Jan-08	WATTS BAR	FLTW	51	493	1324	F	108	3
16-Jan-08	WATTS BAR	FLTW	51	519	1315	F	125	4
16-Jan-08	WATTS BAR	FLTW	51	522	1525	F	143	3
16-Jan-08	WATTS BAR	FLTW	51	525	1726	F	154	3
16-Jan-08	WATTS BAR	FLTW	64	471	1210	F	90	3
16-Jan-08	WATTS BAR	FLTW	64	509	1611	F	129	3
23-Jan-08	WATTS BAR	MHTW	51	410	785	F	87	2
23-Jan-08	WATTS BAR	MHTW	64	487	1262	M	17	3
23-Jan-08	WATTS BAR	MHTW	64	481	992	F	68	5
23-Jan-08	WATTS BAR	MHTW	64	487	1122	F	106	3
23-Jan-08	WATTS BAR	MHTW	64	472	1068	F	134	4
11-Feb-08	WATTS BAR	FLTW	25	257	143	M	0	1
11-Feb-08	WATTS BAR	FLTW	25	267	159	M	1	1
11-Feb-08	WATTS BAR	FLTW	25	325	283	M	2	2
11-Feb-08	WATTS BAR	FLTW	25	274	187	I	.	1
11-Feb-08	WATTS BAR	FLTW	38	342	369	M	4	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
11-Feb-08	WATTS BAR	FLTW	38	367	442	M	4	2
11-Feb-08	WATTS BAR	FLTW	38	352	402	M	4	2
11-Feb-08	WATTS BAR	FLTW	38	363	460	M	4	2
11-Feb-08	WATTS BAR	FLTW	38	387	617	M	8	2
11-Feb-08	WATTS BAR	FLTW	38	428	738	M	9	5
11-Feb-08	WATTS BAR	FLTW	38	397	536	M	10	2
11-Feb-08	WATTS BAR	FLTW	38	344	404	F	33	3
11-Feb-08	WATTS BAR	FLTW	38	401	697	F	84	3
11-Feb-08	WATTS BAR	FLTW	38	451	908	F	110	3
11-Feb-08	WATTS BAR	FLTW	51	452	878	F	87	3
11-Feb-08	WATTS BAR	FLTW	51	483	1148	F	128	3
11-Feb-08	WATTS BAR	FLTW	51	443	934	F	143	2
11-Feb-08	WATTS BAR	FLTW	64	484	1288	F	126	3
11-Feb-08	WATTS BAR	FLTW	64	478	1301	F	129	3
20-Feb-08	WATTS BAR	MHTW	38	442	813	M	5	3
20-Feb-08	WATTS BAR	MHTW	38	404	624	M	6	3
20-Feb-08	WATTS BAR	MHTW	38	381	517	M	6	3
20-Feb-08	WATTS BAR	MHTW	38	366	503	M	6	2
20-Feb-08	WATTS BAR	MHTW	38	443	743	M	9	5
20-Feb-08	WATTS BAR	MHTW	38	411	670	F	74	3
20-Feb-08	WATTS BAR	MHTW	38	465	1080	F	119	3
20-Feb-08	WATTS BAR	MHTW	51	442	843	F	110	3
20-Feb-08	WATTS BAR	MHTW	51	488	1328	F	114	3
20-Feb-08	WATTS BAR	MHTW	51	456	963	F	116	2
20-Feb-08	WATTS BAR	MHTW	51	503	1487	F	133	3
20-Feb-08	WATTS BAR	MHTW	51	464	1071	F	148	3
20-Feb-08	WATTS BAR	MHTW	51	477	1332	F	170	3
20-Feb-08	WATTS BAR	MHTW	64	531	1708	F	104	7
25-Mar-08	WATTS BAR	MHTW	38	431	983	F	.	2
25-Mar-08	WATTS BAR	MHTW	51	417	620	F	.	3
26-Mar-08	WATTS BAR	FLTW	64	463	906	F	.	3
26-Mar-08	WATTS BAR	FLTW	64	476	1053	F	.	3
26-Mar-08	WATTS BAR	FLTW	64	445	731	F	.	3
12-Jan-09	WATTS BAR	MHTW	51	435	956	F	119	2
12-Jan-09	WATTS BAR	MHTW	51	495	1389	F	145	3

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
9-Feb-09	WATTS BAR	FLTW	19	256	156	M	.	1
9-Feb-09	WATTS BAR	FLTW	25	328	380	F	37	2
9-Feb-09	WATTS BAR	FLTW	25	393	751	F	87	2
9-Feb-09	WATTS BAR	FLTW	25	448	905	F	108	3
9-Feb-09	WATTS BAR	FLTW	25	267	192	M	.	1
9-Feb-09	WATTS BAR	FLTW	25	267	164	M	.	1
9-Feb-09	WATTS BAR	FLTW	25	274	194	M	.	1
9-Feb-09	WATTS BAR	FLTW	38	402	658	F	53	3
9-Feb-09	WATTS BAR	FLTW	38	402	740	F	79	2
9-Feb-09	WATTS BAR	FLTW	38	402	835	F	85	2
9-Feb-09	WATTS BAR	FLTW	38	410	862	F	111	2
9-Feb-09	WATTS BAR	FLTW	38	307	311	M	.	1
9-Feb-09	WATTS BAR	FLTW	38	310	311	M	.	1
9-Feb-09	WATTS BAR	FLTW	38	326	331	M	.	2
9-Feb-09	WATTS BAR	FLTW	38	353	396	M	.	2
9-Feb-09	WATTS BAR	FLTW	38	360	481	M	.	2
9-Feb-09	WATTS BAR	FLTW	38	401	622	M	.	2
9-Feb-09	WATTS BAR	FLTW	38	412	711	M	.	3
9-Feb-09	WATTS BAR	FLTW	51	500	1398	F	131	3
9-Feb-09	WATTS BAR	FLTW	51	449	969	M	.	3
9-Feb-09	WATTS BAR	FLTW	51	493	1253	M	.	6
19-Feb-09	WATTS BAR	FLTW	19	260	152	M	.	1
19-Feb-09	WATTS BAR	FLTW	25	246	113	I	.	1
19-Feb-09	WATTS BAR	FLTW	25	273	181	M	.	1
19-Feb-09	WATTS BAR	FLTW	25	293	246	M	.	1
19-Feb-09	WATTS BAR	FLTW	25	350	373	M	.	2
19-Feb-09	WATTS BAR	FLTW	38	394	599	F	55	2
19-Feb-09	WATTS BAR	FLTW	38	406	653	F	59	3
19-Feb-09	WATTS BAR	FLTW	38	397	750	F	84	2
19-Feb-09	WATTS BAR	FLTW	38	385	699	F	90	2
19-Feb-09	WATTS BAR	FLTW	38	393	725	F	92	2
19-Feb-09	WATTS BAR	FLTW	38	426	828	F	95	3
19-Feb-09	WATTS BAR	FLTW	38	438	820	F	95	3
19-Feb-09	WATTS BAR	FLTW	38	405	813	F	99	2
19-Feb-09	WATTS BAR	FLTW	38	422	836	F	106	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
19-Feb-09	WATTS BAR	FLTW	38	428	926	F	109	2
19-Feb-09	WATTS BAR	FLTW	38	470	1056	F	149	3
19-Feb-09	WATTS BAR	FLTW	38	302	280	M	.	1
19-Feb-09	WATTS BAR	FLTW	38	365	370	M	.	2
19-Feb-09	WATTS BAR	FLTW	38	367	481	M	.	2
19-Feb-09	WATTS BAR	FLTW	38	394	666	M	.	2
19-Feb-09	WATTS BAR	FLTW	38	396	695	M	.	2
19-Feb-09	WATTS BAR	FLTW	38	406	726	M	.	2
19-Feb-09	WATTS BAR	FLTW	51	422	839	F	101	2
19-Feb-09	WATTS BAR	FLTW	51	424	714	F	104	3
19-Feb-09	WATTS BAR	FLTW	51	542	1497	F	108	6
19-Feb-09	WATTS BAR	FLTW	51	436	985	F	114	2
19-Feb-09	WATTS BAR	FLTW	51	479	1173	F	118	4
19-Feb-09	WATTS BAR	FLTW	51	456	1061	F	121	4
19-Feb-09	WATTS BAR	FLTW	51	453	1022	F	122	3
19-Feb-09	WATTS BAR	FLTW	51	471	1188	F	124	3
19-Feb-09	WATTS BAR	FLTW	51	445	1108	F	129	2
19-Feb-09	WATTS BAR	FLTW	51	425	986	F	137	2
19-Feb-09	WATTS BAR	FLTW	51	494	1255	F	139	3
19-Feb-09	WATTS BAR	FLTW	51	457	1234	F	162	3
19-Feb-09	WATTS BAR	FLTW	51	484	1181	F	173	3
19-Feb-09	WATTS BAR	FLTW	51	455	1251	F	176	4
19-Feb-09	WATTS BAR	FLTW	64	470	1371	F	158	3
19-Feb-09	WATTS BAR	FLTW	64	516	1736	F	276	6
9-Mar-09	WATTS BAR	FLTW	19	259	174	M	.	1
9-Mar-09	WATTS BAR	FLTW	19	310	291	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	340	451	F	51	2
9-Mar-09	WATTS BAR	FLTW	25	246	131	I	.	1
9-Mar-09	WATTS BAR	FLTW	25	253	136	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	263	164	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	269	186	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	272	181	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	281	223	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	283	233	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	289	234	M	.	1

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
9-Mar-09	WATTS BAR	FLTW	25	297	258	M	.	1
9-Mar-09	WATTS BAR	FLTW	25	325	311	M	.	2
9-Mar-09	WATTS BAR	FLTW	25	369	493	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	345	397	F	41	2
9-Mar-09	WATTS BAR	FLTW	38	381	607	F	58	2
9-Mar-09	WATTS BAR	FLTW	38	366	475	F	60	2
9-Mar-09	WATTS BAR	FLTW	38	371	503	F	64	3
9-Mar-09	WATTS BAR	FLTW	38	384	561	F	68	2
9-Mar-09	WATTS BAR	FLTW	38	396	613	F	78	3
9-Mar-09	WATTS BAR	FLTW	38	423	737	F	78	3
9-Mar-09	WATTS BAR	FLTW	38	357	497	F	81	3
9-Mar-09	WATTS BAR	FLTW	38	365	569	F	86	2
9-Mar-09	WATTS BAR	FLTW	38	401	787	F	86	2
9-Mar-09	WATTS BAR	FLTW	38	380	660	F	87	2
9-Mar-09	WATTS BAR	FLTW	38	382	630	F	88	2
9-Mar-09	WATTS BAR	FLTW	38	392	700	F	91	2
9-Mar-09	WATTS BAR	FLTW	38	351	618	F	92	2
9-Mar-09	WATTS BAR	FLTW	38	399	773	F	94	2
9-Mar-09	WATTS BAR	FLTW	38	408	756	F	107	2
9-Mar-09	WATTS BAR	FLTW	38	468	1020	F	107	6
9-Mar-09	WATTS BAR	FLTW	38	412	767	F	109	2
9-Mar-09	WATTS BAR	FLTW	38	404	787	F	112	2
9-Mar-09	WATTS BAR	FLTW	38	470	1046	F	115	6
9-Mar-09	WATTS BAR	FLTW	38	427	887	F	123	2
9-Mar-09	WATTS BAR	FLTW	38	422	948	F	137	2
9-Mar-09	WATTS BAR	FLTW	38	451	1039	F	152	2
9-Mar-09	WATTS BAR	FLTW	38	432	1047	F	155	2
9-Mar-09	WATTS BAR	FLTW	38	440	1138	F	167	2
9-Mar-09	WATTS BAR	FLTW	38	454	1125	F	170	3
9-Mar-09	WATTS BAR	FLTW	38	479	1275	F	173	3
9-Mar-09	WATTS BAR	FLTW	38	437	1043	F	177	2
9-Mar-09	WATTS BAR	FLTW	38	507	1452	F	223	5
9-Mar-09	WATTS BAR	FLTW	38	350	402	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	359	410	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	382	588	M	.	2

Table A1. Continued.

Date	Lake	Area	Mesh (mm)	TL	WT	Sex	Gonad Weight	Age
9-Mar-09	WATTS BAR	FLTW	38	389	752	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	398	624	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	404	734	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	404	648	M	.	2
9-Mar-09	WATTS BAR	FLTW	38	368	456	M	.	3
9-Mar-09	WATTS BAR	FLTW	38	427	706	M	.	4
9-Mar-09	WATTS BAR	FLTW	38	442	671	M	.	4
9-Mar-09	WATTS BAR	FLTW	51	352	547	F	78	2
9-Mar-09	WATTS BAR	FLTW	51	405	820	F	102	2
9-Mar-09	WATTS BAR	FLTW	51	415	827	F	107	2
9-Mar-09	WATTS BAR	FLTW	51	447	890	F	122	3
9-Mar-09	WATTS BAR	FLTW	51	436	954	F	138	3
9-Mar-09	WATTS BAR	FLTW	51	414	890	F	140	2
9-Mar-09	WATTS BAR	FLTW	51	458	1018	F	146	4
9-Mar-09	WATTS BAR	FLTW	51	432	1094	F	169	2
9-Mar-09	WATTS BAR	FLTW	51	436	1053	F	181	2
9-Mar-09	WATTS BAR	FLTW	51	444	1032	F	187	2
9-Mar-09	WATTS BAR	FLTW	51	465	1570	F	195	3
9-Mar-09	WATTS BAR	FLTW	64	512	1619	F	221	4
9-Mar-09	WATTS BAR	FLTW	64	302	260	M	.	1

Table A2.—Data collected from saugers collected for the assessment of barotrauma in Kentucky Lake in 2008 and 2009. Information recorded includes the following: Tag (transmitter identification number); total length (TL; mm); weight (WT; g; predicted from regression model); depth (m); gastric distension score (Bloat; 0= none, 1= moderate, 2=severe); swim down score (0= normal, vigorous swimming, 1 = disoriented, erratic swimming, and 2 = floating); ascent time (s); handling time (s); fate (0 = dead, 1 = alive, or unknown (U)); maximum daily movement exhibited by a tagged fish after one week at large (MDM; km); number of fixes; number of days at large; hook type; location of primary hook responsible for capture (1= head, 2 = gular region, 3 = body/fins, 4 = jaws, 5 = mouth cavity); hook score (0 = none or slight bleeding, 1 = blood dripping or flowing from wound); and water temperature (°C). Fish euthanized prior to being released are indicated with an asterisk.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM (km)	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
19-Jan-08	.	378	563	12	2	.	13	90	.	.	.	.	S	4	0	8
19-Jan-08	.	265	163	13	1	.	11	62	.	.	.	.	J	4	0	8
19-Jan-08	.	370	523	13	1	.	11	40	.	.	.	.	S	4	0	8
19-Jan-08	.	330	351	13	1	.	11	66	.	.	.	.	J	1	1	8
19-Jan-08	.	322	322	14	0	.	14	70	.	.	.	.	S	4	0	8
19-Jan-08	.	422	827	14	1	.	18	68	.	.	.	.	J	5	0	8
19-Jan-08	.	357	461	14	2	.	24	62	.	.	.	.	S	4	0	8
20-Jan-08	.	288	218	12	1	.	15	.	.	.	.	.	JS	1	0	8
20-Jan-08	.	357	461	13	2	.	18	58	.	.	.	.	J	4	0	8
20-Jan-08	.	289	221	14	0	.	11	25	.	.	.	.	J	1	0	8
20-Jan-08	.	373	538	14	2	.	12	63	.	.	.	.	J	4	0	8
20-Jan-08	.	342	397	14	0	.	30	80	.	.	.	.	S	4	0	8
20-Jan-08	.	376	553	14	2	.	25	62	.	.	.	.	S	3	0	8
20-Jan-08	.	378	563	14	2	.	11	56	.	.	.	.	S	4	0	8
20-Jan-08	.	342	397	14	2	.	12	54	.	.	.	.	J	4	0	8
20-Jan-08	.	301	255	15	2	.	15	59	.	.	.	.	JS	4	0	8
20-Jan-08	.	343	401	15	2	.	23	66	.	.	.	.	S	4	0	8

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
20-Jan-08	.	285	210	15	0	.	13	31	.	.	.	.	J	4	0	8
20-Jan-08	.	311	285	15	0	.	14	50	.	.	.	.	J	4	0	8
20-Jan-08	.	334	366	15	0	.	15	57	.	.	.	.	J	1	0	8
20-Jan-08	.	415	780	15	0	.	17	81	.	.	.	.	J	4	0	8
20-Jan-08	.	371	528	15	0	.	20	65	.	.	.	.	J	3	0	8
20-Jan-08	.	280	198	15	1	.	10	30	.	.	.	.	J	4	0	8
20-Jan-08	.	349	426	15	1	.	13	78	.	.	.	.	S	4	1	8
20-Jan-08	.	371	528	15	1	.	21	55	.	.	.	.	J	4	0	8
20-Jan-08	.	342	397	15	2	.	13	54	.	.	.	.	J	4	0	8
20-Jan-08	.	358	466	15	2	.	16	66	.	.	.	.	J	4	0	8
20-Jan-08	.	322	322	16	0	.	18	72	.	.	.	.	J	1	0	8
20-Jan-08	.	286	213	16	1	.	17	21	.	.	.	.	S	3	0	8
20-Jan-08	.	366	503	16	0	.	14	53	.	.	.	.	S	4	0	8
20-Jan-08	.	357	461	16	0	.	26	64	.	.	.	.	S	1	0	8
20-Jan-08	.	382	584	16	1	.	27	91	.	.	.	.	S	4	0	8
20-Jan-08	.	370	523	16	2	.	25	67	.	.	.	.	S	3	0	8
20-Jan-08	.	405	716	16	0	.	22	52	.	.	.	.	S	3	0	8
20-Jan-08	.	282	203	16	1	.	15	31	.	.	.	.	J	4	0	8

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
20-Jan-08	.	436	926	16	2	.	31	78	.	.	.	.	J	4	0	8
20-Jan-08	.	391	634	16	0	.	21	69	.	.	.	.	JS	4	0	8
20-Jan-08	.	380	574	16	1	.	17	66	.	.	.	.	S	4	0	8
20-Jan-08	.	298	246	17	0	.	12	51	.	.	.	.	J	4	0	8
20-Jan-08	.	362	484	17	0	.	15	75	.	.	.	.	J	4	0	8
20-Jan-08	.	311	285	17	0	.	18	43	.	.	.	.	S	1	0	8
20-Jan-08	.	331	355	17	0	.	21	62	.	.	.	.	JS	4	0	8
20-Jan-08	.	344	405	17	1	.	14	51	.	.	.	.	S	4	0	8
20-Jan-08	.	358	466	17	1	.	18	96	.	.	.	.	J	1	0	8
20-Jan-08	.	303	261	17	2	.	16	35	.	.	.	.	S	4	0	8
20-Jan-08	.	366	503	17	0	.	21	57	.	.	.	.	S	4	0	8
20-Jan-08	.	335	370	17	1	.	21	58	.	.	.	.	J	4	0	8
20-Jan-08	.	361	480	17	1	.	22	58	.	.	.	.	J	1	1	8
20-Jan-08	.	356	457	17	1	.	23	56	.	.	.	.	JS	4	1	8
20-Jan-08	.	281	200	17	2	.	9	68	.	.	.	.	J	1	1	8
20-Jan-08	.	320	315	18	0	.	14	61	.	.	.	.	JS	4	0	8
20-Jan-08	.	307	273	18	2	.	24	32	.	.	.	.	J	4	0	8
20-Jan-08	.	326	336	19	2	.	20	.	.	.	.	.	S	4	0	8
20-Jan-08	.	361	480	19	0	.	19	69	.	.	.	.	J	5	0	8

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
14-Feb-08	5	346	414	10	1	2	39	98	1	1.60	6	43	S	4	0	8
14-Feb-08	6	340	389	11	2	1	14	70	0	0.27	9	42	S	4	0	8
14-Feb-08	8	321	319	11	2	1	15	75	0	0.22	7	42	S	4	0	8
14-Feb-08	18	380	574	10	2	1	32	77	U	.	.	.	S	1	0	8
15-Feb-08	2*	361	480	.	0	.	.	.	.	0.50	6	41	.	.	.	8
15-Feb-08	3	343	401	10	2	1	22	57	1	0.66	5	41	J	3	0	8
15-Feb-08	7	276	188	10	1	1	13	66	U	.	.	.	J	4	0	8
15-Feb-08	9	309	279	10	1	1	13	75	0	0.05	5	41	S	1	1	8
15-Feb-08	10	335	370	12	1	1	24	56	1	1.00	3	15	S	5	1	8
15-Feb-08	19	363	489	10	1	1	13	82	0	0.01	4	15	J	2	0	8
15-Feb-08	26	351	435	10	1	1	17	67	0	0.23	4	15	S	4	0	8
23-Feb-08	4	334	366	12	1	1	15	59	1	5.04	6	33	S	4	0	9
23-Feb-08	16	378	563	10	2	1	15	61	1	14.90	6	34	J	4	0	9
23-Feb-08	17	384	595	12	2	1	17	49	1	1.02	6	33	J	4	0	9
23-Feb-08	20	346	414	12	2	1	14	45	1	0.59	6	34	S	4	0	9
23-Feb-08	21	360	475	12	2	1	18	68	0	0.19	6	33	J	4	0	9
23-Feb-08	22	387	611	14	1	1	15	61	U	.	.	.	J	4	0	9
23-Feb-08	23	409	741	13	2	1	11	65	1	1.13	2	34	J	3	0	9
23-Feb-08	25	380	574	11	2	1	12	47	1	2.11	3	8	S	4	0	9

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
23-Feb-08	31	345	410	13	1	1	8	59	1	0.78	6	33	J	4	0	9
21-Jan-09	82	412	760	12	0	1	15	57	U	.	.	.	J	5	0	7
21-Jan-09	83	316	302	12	0	1	20	82	0	0.43	17	73	S	2	0	7
24-Jan-09	79*	395	657	12	0	.	.	.	.	0.27	14	70	S	4	0	.
24-Jan-09	84	376	553	10	2	1	33	86	0	0.21	14	70	S	4	0	6
29-Jan-09	80*	292	229	10	0	.	22	.	.	0.04	12	64	.	.	.	6
29-Jan-09	81	381	579	8	2	1	20	69	U	.	.	.	S	3	1	6
29-Jan-09	85	399	680	8	1	1	20	66	0	0.17	5	18	S	4	0	6
29-Jan-09	86	406	723	11	1	1	23	82	U	.	.	.	JS	2	1	6
29-Jan-09	94	284	208	9	1	1	9	65	0	0.23	5	15	J	3	0	6
29-Jan-09	95	385	600	9	1	1	15	56	1	4.39	13	65	S	4	1	6
29-Jan-09	96	372	533	11	1	1	19	78	1	2.03	12	53	J	5	1	6
29-Jan-09	97	366	503	10	2	1	11	51	1	1.79	10	44	J	5	0	6
29-Jan-09	98	361	480	10	0	1	24	69	1	5.29	13	51	J	3	1	6
29-Jan-09	99*	392	639	10	0	.		.	.	0.10	11	64	J	2	1	6
29-Jan-09	100	302	258	10	1	1	15	63	0	0.10	11	64	J	5	0	6
29-Jan-09	101	373	538	10	0	1	.	89	U	.	.	.	S	3	0	6
29-Jan-09	109	271	177	9	1	1	13	73	1	0.81	12	53	S	3	0	6
30-Jan-09	110	412	760	8	0	1	27	78	1	2.42	10	52	S	4	0	6

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
30-Jan-09	111	363	489	10	1	1	18	59	1	2.89	12	63	J	2	0	6
30-Jan-09	124	401	692	11	1	1	16	82	0	0.14	11	63	S	5	0	6
3-Feb-09	125*	386	606	13	2	.	.	.	.	0.04	11	60	J	5	0	.
4-Feb-09	126	333	362	11	1	1	.	84	1	0.80	8	47	J	2	0	2
4-Feb-09	128*	362	484	12	0	.	.	.	U	.	.	.	.	.	.	2
4-Feb-09	131	339	385	12	2	1	24	89	1	1.69	7	40	S	4	1	2
4-Feb-09	140	422	827	11	1	1	21	65	1	1.92	12	59	S	5	0	2
14-Feb-09	127	264	161	11	1	1	9	77	1	1.59	6	49	S	3	0	9
14-Feb-09	130	345	410	10	1	1	13	89	1	2.57	8	48	JS	5	0	9
14-Feb-09	139	281	200	9	1	1	9	56	1	0.78	7	48	S	1	1	9
14-Feb-09	141	337	377	9	2	1	11	48	1	0.69	5	30	S	4	1	9
14-Feb-09	142	298	246	10	2	1	9	70	1	3.30	6	38	J	2	0	9
14-Feb-09	154	380	574	10	2	1	8	57	1	1.57	6	20	S	4	0	9
14-Feb-09	156	378	563	10	2	1	14	79	1	2.07	6	48	J	5	0	9
14-Feb-09	157	392	639	9	1	1	13	93	0	0.34	6	37	S	5	0	9
14-Feb-09	158	278	193	10	1	1	11	68	0	0.08	7	48	S	2	1	9
14-Feb-09	159	295	237	9	1	2	11	86	1	1.29	7	49	S	4	1	9
14-Feb-09	160	288	218	10	1	1	15	58	0	0.31	7	48	JS	2	0	9
14-Feb-09	161	365	499	12	1	1	13	51	1	1.22	6	49	S	4	0	9

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
14-Feb-09	169	269	172	9	2	1	10	56	0	0.08	5	30	J	2	1	9
14-Feb-09	170	281	200	10	2	1	12	57	0	0.15	7	48	S	3	0	9
14-Feb-09	171	286	213	10	2	1	13	40	0	0.30	7	48	S	3	0	9
14-Feb-09	173	362	484	8	2	1	15	66	1	0.94	7	48	J	5	0	9
14-Feb-09	174	361	480	9	2	1	10	.	0	0.39	5	30	J	4	0	9
14-Feb-09	176	373	538	10	2	1	16	52	1	0.79	6	37	S	4	0	9
14-Feb-09	.	304	264	9	2	.	.	.	.	.	.	.	.	.	.	9
14-Feb-09	.	293	232	11	0	.	14	.	.	.	.	.	.	.	.	9
14-Feb-09	.	391	634	11	0	.	8	.	.	.	.	.	.	.	.	9
14-Feb-09	.	396	662	10	0	.	16	.	.	.	.	.	.	.	.	9
14-Feb-09	.	446	1003	.	0	.	36	.	.	.	.	.	.	.	.	9
24-Feb-09	146	374	543	11	1	1	20	60	1	3.40	4	28	S	5	0	7
24-Feb-09	172	360	475	10	1	1	13	80	1	3.14	5	38	J	2	0	7
24-Feb-09	175	282	203	12	1	2	11	67	1	2.64	5	39	S	4	0	7
24-Feb-09	185	383	590	11	0	1	15	76	1	0.89	3	27	S	2	0	7
24-Feb-09	186	428	868	9	0	1	12	75	1	0.91	4	10	S	1	1	7
24-Feb-09	187	289	221	12	1	1	16	56	0	0.32	6	36	S	4	0	7
24-Feb-09	188	374	543	11	1	1	14	68	1	0.88	3	19	J	4	1	7
24-Feb-09	189	386	606	11	2	2	17	66	1	2.54	4	39	S	5	0	7

Table A2. Continued.

Date	Tag	TL	WT	Depth	Bloat	Swim Down	Ascent (s)	Handling (s)	Fate	MDM	Number of Fixes	Days at Large	Hook Type	Hook Location	Hook Score	Water (°C)
24-Feb-09	190	386	606	11	2	1	29	95	U	.	.	.	S	2	0	7
24-Feb-09	.	374	543	12	0	.	15	.	.	.	.	.	.	.	.	7
24-Feb-09	.	408	735	11	0	.	30	.	.	.	.	.	.	.	.	7
4-Mar-09	129	289	221	11	1	1	11	59	0	0.23	5	31	S	5	0	8
4-Mar-09	143*	265	163	11	1	.		.	.	0.18	5	31	.	.	.	8
4-Mar-09	144	351	435	11	2	1	12	65	1	2.52	6	31	S	5	0	8
4-Mar-09	145	316	302	11	1	2	12	78	1	1.15	6	31	J	2	0	8
4-Mar-09	155	403	704	11	1	.	17	53	1	2.42	4	18	S	5	0	8
4-Mar-09	184	364	494	7	2	2	11	79	1	3.06	5	30	S	5	1	8
4-Mar-09	191*	398	674	11	1	.	19	.	U	.	.	.	J	3	1	8
4-Mar-09	199	387	611	11	1	1	.	70	U	.	.	.	JS	5	0	8
4-Mar-09	.	299	249	11	0	.	15	.	.	.	.	.	.	.	.	8
6-Mar-09	186*	438	941	.	0	0	.	.	.	0.36	3	29	.	.	.	.