

## Locomotory Impairment of Nesting Male Largemouth Bass Following Catch-and-Release Angling

STEVEN J. COOKE<sup>1\*</sup>

Waterloo Biotelemetry Institute, Department of Biology,  
University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

DAVID P. PHILIPP

Center for Aquatic Ecology, Illinois Natural History Survey,  
Champaign, Illinois 61820, USA

JASON F. SCHREER<sup>2</sup> AND R. SCOTT MCKINLEY

Waterloo Biotelemetry Institute, Department of Biology,  
University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

**Abstract.**—Catch-and-release angling of black bass *Micropterus* spp. during the parental care period may lead to brood predation and premature nest abandonment. Furthermore, physiological disturbance incurred while landing angled males may impair their ability to provide parental care long after release. To assess the extent of this physiological disturbance, we examined the relative energetic expenditures of nesting ( $N = 4$ ) and nonnesting ( $N = 2$ ) male largemouth bass *Micropterus salmoides* exposed to staged angling events in experimental ponds. Information on fish locomotion, through activity of the axial musculature, was remotely collected using electromyogram transmitters. During angling, nonnesting fish fought with a higher intensity, probably expending significantly more energy than did nesting fish. In addition, although the locomotory activity of nonnesting fish appeared to recover as early as 2 h after angling release, the locomotory activity of nesting fish was still impaired 24 h postangling. Overall mean activity for 24 h postrelease was 98% of basal for nonnesting fish, but only 63% for nesting fish. The reduced energetic capability of a nesting male largemouth bass following angling, together with brood predation incurred as a result of the temporary removal of that fish from the nest during angling, increases the likelihood of that male abandoning his brood prematurely. This study provides further insight into the physiological disturbances and behavioral consequences incurred as a result of catch-and-release angling and highlights the need for addressing population level effects of catch-and-release angling on parental care and reproductive success of black bass.

Largemouth bass *Micropterus salmoides* spawn in shallow nests in the spring, and the males remain alone to provide all parental care for the brood. During the parental care period, males are particularly vulnerable to angling because they vigorously defend the nest from intruders (Ridgway 1988; Philipp et al. 1997). When guarding males are removed from the nest (or free-swimming brood) by anglers, even for short periods of time, predators such as other small centrarchids or per-

cids can quickly consume the offspring (Neves 1975), with the level of predation proportional to the length of time the fish is absent from the nest (Kieffer et al. 1995; Philipp et al. 1997). If that male is harvested before his offspring are independent of parental care, they are quickly eliminated by predation.

In some northern states and many Canadian provinces seasonal closures are used to restrict angling and harvest of black bass *Micropterus* spp. during the reproductive period (Quinn 1993). Although it is illegal in some jurisdictions to even attempt to angle for bass during this closed period, compliance with such regulations has been observed to be minimal in many areas (Schneider et al. 1991; Kubacki 1992; Philipp et al. 1997). Furthermore, local climatic variability often results in the season opening before the completion of spawning and nest guarding activities by all individuals (Kubacki 1992). When this occurs, anglers may legally catch and harvest nesting fish.

\* Corresponding author: scooke@uiuc.edu

<sup>1</sup> Present address: Program in Natural Resource Ecology and Conservation Biology, Department of Natural Resources and Environmental Sciences, University of Illinois and Center for Aquatic Ecology, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, Illinois 61820, USA.

<sup>2</sup> Present address: Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Received November 15, 1999; accepted April 15, 2000

Anglers often assume that as long as the fish are released, they will return to the nest and raise a successful brood. Recent studies, however, indicate that the behavioral and physiological effects of exhaustive exercise, such as catch-and-release angling during the spawning period, may reduce reproductive success (Kieffer et al. 1995; Philipp et al. 1997).

Studies of catch-and-release angling have quantified seasonal hooking and handling mortality (see Muoneke and Childress 1994), as well as the physiological disturbance of exhaustive exercise caused by catch and release (Kieffer et al. 1995). Other studies have assessed the immediate behavioral responses of fish following release, the degree of nest predation while the guarding male is absent, and the increased rate of abandonment resulting in decreased reproductive success (Philipp et al. 1997). For fish that do not abandon their nests following an angling release, it is not known to what extent the angling experience might impair the ability of that fish to continue to guard its brood. Because guarding males probably only forage opportunistically while defending their nest (Hinch and Collins 1991), physiological disturbance is particularly harsh on their overall vigor because parental care, of itself, can be energetically costly (Hinch and Collins 1991; Mackereth 1995; Gillooly and Baylis 1999).

Examining fish activity patterns to assess catch-and-release angling impacts can be difficult. Conventional locational telemetry has been used to monitor the postangling survival and behavior of chinook salmon *Oncorhynchus tshawytscha* (Bendock and Alexandersdottir 1993), lake trout *Salvelinus namaycush* (Lee and Bergersen 1996), and striped bass *Morone saxatilis* (Bettoli and Osborne 1998). Movements of smallmouth bass *Micropterus dolomieu* and largemouth bass have been studied after release from competitive angling events (e.g., Blake 1981; Healey 1990; Stang et al. 1996) or after simulated displacements (Ridgway and Shuter 1996). None of these studies, however, were able to monitor activity at the temporal or spatial scale that is possible using locomotory activity telemetry. Demers et al. (1996) reported that largemouth and smallmouth bass expended a significant portion of their daily activity budget undertaking localized movements (measured using locomotory activity telemetry) that would be undetectable using conventional telemetry.

Videography has also been used to monitor activity of nesting fish, although for a study such as

ours, videography alone would create major limitations. For example, Hinch and Collins (1991) used videography to monitor the nesting behavior of male smallmouth bass. Videography permitted the quantification of tail beats and provided insight into the behavior of these fish, but data could only be collected when fish were within the camera field of view. In our study, nesting fish were expected to be out of the camera's field of view during and following angling. In addition, the nonnesting fish were unrestricted in their distribution within the ponds and, as such, were expected to be difficult to monitor with a video camera.

Our purpose was to quantify changes in the level of parental care of nesting male largemouth bass following catch-and-release angling. To accomplish this, we compared the relative activity levels of nesting and nonnesting male largemouth bass in experimental ponds exposed to angling. Fish activity was monitored remotely using signals from electromyogram transmitters and coordinated with specific individual behaviors documented with underwater videography.

### Methods

*Study site and animals.*—All experiments were conducted in 0.1-ha clay-lined, earthen ponds at the Illinois Natural History Survey Aquatic Research Field Laboratory in Champaign, Illinois, during 1998. In the spring, ponds were filled with water from the municipal water supply, and invertebrates and plants were allowed to colonize. Largemouth bass used in the study were obtained from local impoundments with electrofishing and were held in large holding tanks before implanting transmitters.

*Telemetry equipment.*—Transmitters (EMGi, Lotek Engineering Inc., Newmarket, Ontario) consisted of an epoxy-coated transmitter with a pair of electrodes and a single antenna (Kaselloo et al. 1992; Beddow and McKinley 1998). Nine-karat gold electrodes measuring 7 mm were affixed to the end of the electrode wires. The electrodes detect the electromyographic (EMG) activity within the axial red muscle and adjacent white musculature. The EMG activity then charges a capacitor, and when the capacitance has been reached, a pulse is emitted from the transmitter. The signal recorded by the receiver is an EMGi pulse interval (ms), which is inversely related to muscular activity. As the muscle activity increases, the capacitor is charged more rapidly, thus decreasing the interval between pulses.

The tags used in this study weighed 18.0 g in

air and measured 51 mm in length and 13 mm in diameter. Transmitters constituted up to 4% of the body weight of the fish in air. Although this is heavier than the generally accepted "2% rule," there is a growing body of literature suggesting that the value is more plastic and must be considered on a species-specific basis (Brown et al. 1999). In general, transmitters have been implanted in spawning phase largemouth bass without impairing behavior (e.g., Crumpton 1985; Richardson et al. 1997). Transmitters broadcast at distinct frequencies within an operating band of 148–150 MHz. Signals were detected and recorded automatically using three SRX-400 radio receivers with W/20 software (Lotek Engineering Inc.). Two of the receivers were placed in environmental chambers that were each connected to H-antennas adjacent to the study ponds. The receivers were set to scan continuously. A third receiver was used to collect data when receivers were offline for downloading or to focus monitoring on specific individuals during manipulations. The receiver system operated throughout the duration of the study, except when offline for downloading data to a computer when the data storage banks approached capacity.

*Surgical procedure.*—Fish were anesthetized using a 60-ppm induction bath of clove oil and ethanol (Anderson et al. 1997). Fish lost equilibrium after several minutes and were then measured (total length, mm) and weighed (g) before being placed ventral side up in a V-shaped acrylic trough lined with neoprene. A maintenance dose of anesthetic (30 ppm) in oxygenated water continuously irrigated the gills.

Surgical procedures were similar to that of Demers et al. (1996). A 3-cm incision was cut into the ventral surface, just posterior to the pectoral girdle. Because Demers et al. (1996) noted that the external electrode anchors on a smallmouth bass were damaged during an angling event, we modified the electrode insertion procedure so that the electrodes were anchored internally; i.e., we used a pair of 16.5-gauge rods to position the electrodes 10 mm apart in the red axial musculature below the lateral line (Bunt 1999). Electrode placement was standardized at the anterior portion of the dorsal fin (Beddow and McKinley 1999). Once in place, a plunger was used to secure the electrodes in the muscle, allowing the rods to be removed. The transmitter was then inserted through the incision and pushed anteriorly into the body cavity. A 16.5-gauge hypodermic needle was then pushed through the body cavity wall, shielding the viscera

with a scalpel handle, and the antenna wire was passed through to the outside. The incision was closed using four simple interrupted braided silk sutures (2/0 Ethicon). A small amount of cyanoacrylate glue (Vet-Bond, 3M Inc.) was then applied to the sutures to increase their resistance to the abrasion that might occur during spawning and to make the knot more secure. The entire procedure lasted less than 5 min, and fish recovered quickly when returned to fresh oxygenated water. Fish were held in the holding tank, where they were allowed to recover for several hours before release. After recovery, fish were released into one of four ponds.

*Angling.*—Observers from shore visually monitored ponds throughout the reproductive period several times daily. In addition, at least two EMG receivers continuously scanned in sequence for signals from tagged individuals. Males on nests were angled 4–7 d following spawning, when offspring were in the wriggler stage (Ridgway 1988). Daily maximum surface water temperatures during angling ranged from 18°C to 23°C.

When a nesting male was chosen for angling, an underwater camera was placed adjacent to the nest several hours before angling to obtain preangling baseline videographic data (Collins et al. 1991; Cooke 1999). Before angling individual fish from nests, at least one receiver was programmed with the frequency of the targeted fish and set to record and store every pulse interval.

All fish were angled from shore. If fish were not captured within several minutes, they were left alone and angling was attempted later. When hooked, fish were played for 150 s because this interval was deemed appropriate to exhaust black bass (Kieffer et al. 1995; Philipp et al. 1997). Some studies have used behavioral exhaustion as a criterion for fatigue (e.g., Kieffer et al. 1995), which would also be consistent with our chosen time interval. After being played for 150 s, fish were lipped and held out of the water for 30 s to remove the hook and then immediately returned to the water at their nest site. Immediate postrelease behavior was observed from a distance. When the nest site was obscured by cover or surface glare, and to avoid influencing the behavior of the fish, additional detailed observations were provided by the underwater videography.

Nonnesting males were individually angled by sight so that the receiver could focus on that individual during angling. Nonnesting males were treated in the same manner as nesting males; i.e., they were released after capture at the landing site.

Because nonnesting fish were less spatially localized (i.e., not on a single nest), we had to rely more heavily on visual observations than videography to assess their behavior.

*Data analysis.*—Data (EMGi pulse intervals) were summarized as means and standard errors for 0.5-h intervals for each individual fish (SAS Institute, 1999). During the angling and recovery period fish activity was assessed in 5-s intervals during angling, 1-min intervals following release for the first 10 min, 10-min intervals for the next 50 min, and 1-h intervals for the next 23 h. Males guarding nests of larvae of a similar developmental stage were equally active throughout the diel period; this permitted average activity values of individual fish for the 24-h period before angling to be used as basal levels for each individual nesting fish. Nonnesting fish experienced remarkably consistent fluctuations in diel activity, enabling basal values to be calculated on an hourly basis and then compared with hourly activity values collected after the fish were angled. Such adjustments were required to eliminate the obscuring of results in diel activity patterns. All values were transformed so that they could be reported as percent of basal (preangling levels).

To determine whether fish locomotory activity decreased as fish became exhausted during the 150-s angling period, we compared the mean activity levels during the first 30 s of angling to the mean activity levels during the last 30 s of angling. We also tested whether the mean activity level during angling differed between nesting and nonnesting fish. Before analyses, *F*-tests revealed that the variances were unequal, so data were log-transformed. A *t*-test for independent means was then used to test for differences. Next, we calculated the proportion of time that activity levels during angling were below basal levels and compared these values using a *t*-test for independent means. Paired *t*-tests were then used to compare the postangling activity levels of nesting and nonnesting fish. These tests were conducted separately on three time intervals (first 10 min postrelease in 60-s increments, first 1 h postrelease in 10-min increments, and first 24 h post release in 1-h increments). All tests were considered significant at  $\alpha = 0.05$ .

## Results

### Angling Period

We attempted to angle seven fish and were able to hook and land all but one (Table 1). Two of the fish angled were males that were not guarding

TABLE 1.—Male largemouth bass angled from experimental ponds in central Illinois in May 1998. All fish were implanted with electromyographic activity transmitters and allowed to spawn naturally before being angled. Fish that did not spawn (nonnesting males) were also angled.

Total length (mm)	Weight (g)	Fish code	Date angled	Status
324	480	128	May 08	Nesting
314	459	706	May 08	Nesting
352	509	206	May 09	Nesting
335	566	106	May 10	Nesting
378	903	284	May 09	Nonnesting
372	728	761	May 10	Nonnesting

nests and four were males that had been on the nest for 4–7 d after spawning. During angling, fish exhibited a combination of burst swimming behavior and steady swimming. The overall locomotory output for all fish in both nesting and nonnesting groups decreased significantly during the time they were played (Figure 1). For nesting and nonnesting fish, activity levels during the first 30 s of angling were significantly higher than the last 30 s ( $t = 6.91$ ,  $df = 12$ ,  $P < 0.001$ ;  $t = 8.01$ ,  $df = 12$ ,  $P < 0.001$ ), respectively. Mean activity levels during the first 30 s of angling were  $177.7 \pm 11.2\%$  of basal levels for the nesting fish and  $535.5 \pm 13.6\%$  of basal levels for the nonnesting fish. During the final 30 s of angling, mean activity levels for both nesting and nonnesting fish had fallen to  $132.6 \pm 8.4\%$  and  $340.3 \pm 23.49\%$  of basal levels, respectively. By the end of the angling event, all fish were having difficulty maintaining an upright position in the water column, were quite close to the surface, and made very few burst swimming attempts. Nonnesting fish had significantly greater mean angling intensities ( $348.0 \pm 171.0\%$  of basal) than did the nesting fish ( $124.5 \pm 26.5\%$  of basal;  $t = 2.77$ ,  $df = 4$ ,  $P = 0.042$ ). Nesting fish also spent a significantly higher proportion of the angling period at locomotory levels that were below basal ( $37.8 \pm 9.8\%$ ) than did nonnesting fish ( $7.2 \pm 1.0\%$ ;  $t = -2.08$ ,  $df = 4$ ,  $P = 0.047$ ).

After fish were angled for 150 s, they were landed quickly, and EMGi signals rapidly decreased. Sporadic movements in response to hook removal and other stimuli sometimes resulted in contractions of the axial musculature during the 30 s of air exposure. All fish survived the angling, with none being hooked deeply. None of the hook wounds caused any visible damage that would have been expected to result in immediate mor-

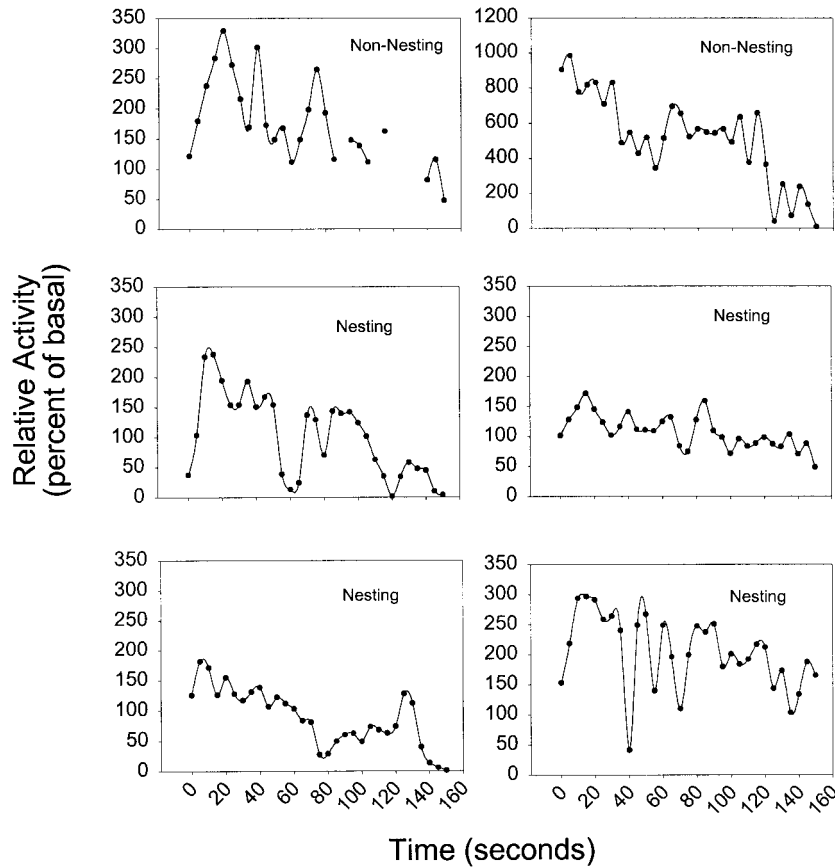


FIGURE 1.—Exhaustion patterns, expressed as activity levels above basal activity, of two nonnesting (two upper panels) and four nesting (four lower panels) male largemouth bass during 150 s of angling. Basal activity (100% of basal) represents the activity level of fish before angling.

tality, and all fish survived throughout the remainder of the study period.

#### Recovery Period

Nesting fish were released within 1 m of the nest, and generally swam quickly away in a series of bursts. Following release, all nesting fish first swam past the nest into deeper water and returned to their nests within a short time (<3 min). The initial postrelease behavior resulted in activity levels being slightly higher (73% of basal) than during the remainder of the recovery period but still much lower than basal levels (Figure 2).

After returning to their nests, males resumed nest-guarding activities. None of the angled fish abandoned their nest following angling. Activity levels, however, decreased following their initial slight hyperactivity, then began to rise slowly after 7 min (Figure 2), and continued to increase slightly for the next hour (Figure 3). The lowest average

activity level noted for the nesting fish (38% of basal) occurred 6 min following release (Figure 2). Over the next 24 h relative activity remained below 100% basal levels (Figure 4): average 24-h postangling value was  $63.0 \pm 1.4\%$  of basal. Even after 24 h, activity levels had not returned to 100% basal values (Figure 4).

Nonnesting fish behaved quite differently; the mean activity level of nonnesting bass during the first 24 h postrelease was  $98.0 \pm 4.1\%$  of basal. The lowest activity levels recorded for nonnesting fish (77% of basal) occurred 10 min after release (Figure 2). As with nesting males, nonnesters exhibited hyperactivity for the first 3 min following release before entering a resting phase. Activity remained low for the next few minutes, but fish again exhibited hyperactivity beginning at 20 min postangling and stabilizing by the second hour after release (Figures 3, 4). Activity following this period was similar to basal, averaging 97.9% of

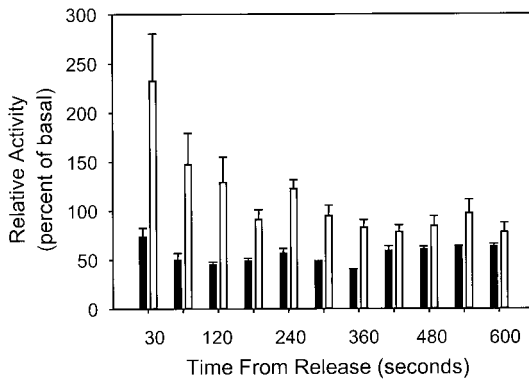


FIGURE 2.—Comparative recovery patterns of nesting (solid bars) and nonnesting (open bars) largemouth bass during the first 10 min of recovery following their angled catch, holding for 30 s, and release. Data are means + 1 SE for activity levels of basal activity. Basal activity (100% of basal) represents the activity level of fish before angling.

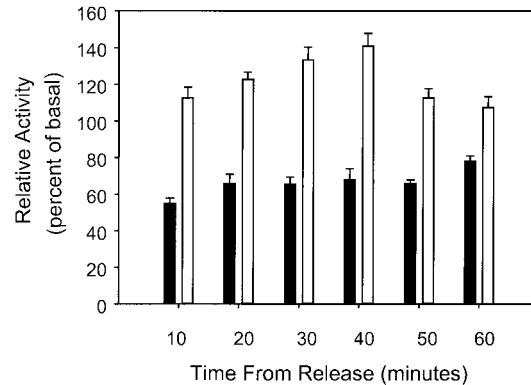


FIGURE 3.—Comparative recovery patterns of nesting (solid bars) and nonnesting (open bars) largemouth bass during the first 1 h of recovery following their angled catch, holding for 30 s, and release. Data are means + 1 SE for activity levels of basal activity. Basal activity (100% of basal) represents the activity level of fish before angling.

basal until monitoring was terminated at 24 h post-angling.

During the initial 10 min after release (Figure 2), mean activity levels of nonnesting fish ( $114.0 \pm 12.6\%$ ) were significantly greater than nesting individuals ( $57.0 \pm 3.5\%$ ;  $t = -4.51$ ,  $df = 10$ ,  $P = 0.001$ ). The same pattern held for 10-min intervals during the first hour after release (Figure 3;  $t = -8.68$ ,  $df = 5$ ,  $P < 0.001$ ), and for 1-h intervals during the first 24 h following angling (Figure 4;  $t = -6.28$ ,  $df = 23$ ,  $P < 0.001$ ). Mean activity levels were  $122.0 \pm 5.4\%$  for nonnesting males and  $66.3 \pm 3.0\%$  for nesting fish during the first hour of recovery. Mean activity levels were  $98.0 \pm 4.1\%$  for nonnesting males and  $63.0 \pm 1.7\%$  for nesting males during the 24 h postangling.

### Discussion

There were several limitations in our study that precluded the collection of data from more fish. First, the transmitters used for this study are expensive (US\$600). Second, we implanted 16 male fish for this project, but some did not spawn. To control for known variation in angling effects with water temperature, we needed to angle fish within several days of each other. Furthermore, for comparative purposes, we needed to angle fish that were guarding offspring of a similar developmental stage because parental effort varies with stage of larval development (Ridgway 1988). Considering all of these limitations, we were only able to compare two control fish and four nest-guarding

fish. The low sample sizes are problematic in that physiological and behavioral responses can vary widely among individuals. However, for this study, an individual also serves as its own control (i.e., data collected before versus during and after disturbance). For this discussion, we present information on both largemouth bass and smallmouth bass because they have similar life histories and behavioral characteristics. However, it must be noted that interspecific differences also exist, so caution must be used when directly comparing results from the two species.

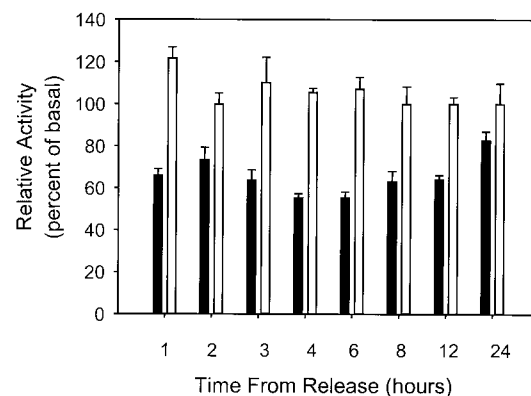


FIGURE 4.—Comparative recovery patterns of nesting (solid bars) and nonnesting (open bars) largemouth bass during 24 h of recovery following their angled catch, holding for 30 s, and release. Data are means + 1 SE for activity levels of basal activity. Basal activity (100% of basal) represents the activity level of fish before angling.

During angling, nonnesting fish exhibited relatively higher activity levels than did nesting fish and therefore probably expended significantly more energy. The lower levels of activity exhibited by nesting fish are probably attributable to decreased levels of available energy reserves, as affected by the energy expended for spawning (Cooke 1999) and parental care (Gillooly and Baylis 1999). Furthermore, because basal activity levels during the parental care period are several fold higher for nesting males, their available scope for activity is decreased. Also, because nonnesting fish were larger than nesting fish, it is possible that they might have been able to swim at faster speeds during angling, thus contributing more bioelectric potential energy to the filling of the capacitor, resulting in higher activity levels. Reliable accounts of fish behavior and physiology during angling are scarce in the literature. However, Gustaveson et al. (1991), studied hematological responses in largemouth bass every minute during a 5-min angling period. They reported that at intermediate temperatures (16–20°C) largemouth bass displayed a pronounced physiological response to length of time they were hooked and played; a mild hypoglycemia occurred, plasma osmolarity increased significantly, and blood lactate concentrations rose.

Angling is probably one of the most severe forms of exercise for fish during normal environmental conditions (Wood 1991). The severity of physiological disturbance in black bass due to angling is influenced by many factors, including water temperature, angling duration while hooked, and length of air exposure (Gustaveson et al. 1991). Because nesting black bass also have the added stress of decreased food consumption during the parental care period (Kramer and Smith 1962; Hinch and Collins 1991), this time is regarded as an energetically costly period in the life of the fish. During the parental care period, male bass are continually active (Hinch and Collins 1991), probably expending more energy than free-swimming, nonnest-guarding fish that have a period of reduced nocturnal activity (Emery 1973). Preliminary data from related EMG/telemetry studies indicate that nesting male bass are approximately twice as active as nonnesting male bass (Cooke 1999), which highlights the increased energetic demands faced by nest-guarding males relative to nonnesting fish.

The high activity levels of bass during the first 2 min after release may further increase the physiological disturbance incurred during angling.

Non-nesting fish experienced a heightened level of activity immediately following release that was probably a response to the perceived threat from the angler and a desire to locate suitable cover. Nesting fish, however, also expended energy locating the nest and, perhaps, determining whether it was safe to return. The bursting action often used by fish upon release comprises a series of rapid swimming movements attempting to escape, which may further increase production of lactic acid (Gustaveson et al. 1991). This additional stress has not been considered in previous studies measuring postangling physiological disturbance. The results of our study suggest that catch-and-release angling causes a significant locomotory impairment in nesting largemouth bass following exhaustive angling. This impairment was still evident 24 h after release from angling. Locomotory impairment among nonnesting fish, however, seemed to last only about 1 h.

Kieffer et al. (1995) reported that following exhaustive exercise of nesting male smallmouth bass, phosphocreatine (PCr) and adenosine triphosphate (ATP) were depleted in the white muscle. During anaerobic burst-type muscular activity, PCr has been shown to be one of the first energy sources used, and ATP is usually the next energy source (Dobson and Hochachka 1987). These depletions could be quite important for the short-term bursting activities used by nesting bass to defend against potential brood predators (Kieffer et al. 1995). Furthermore, the buildup of muscle lactate in exhaustively exercised fish is indicative of depleted muscle glycogen, which is another important energy reserve (Kieffer et al. 1995). Additional stress may be manifested in osmoregulatory disturbance (Gustaveson et al. 1991) and intracellular acidosis, which in severe cases may cause death (Wood et al. 1983). Although no death was observed by Kieffer et al. (1995) or in our study, the physiological disturbances noted for smallmouth bass could be substantial enough to disrupt nest-guarding by males (Kieffer et al. 1995). Hinch and Collins (1991) reported that one of the nesting fish they monitored with videography prematurely abandoned its nest, perhaps due to the energetic demands of an extended parental care period without opportunistic feeding.

Several studies have attempted to link the physiological disturbance of angling to the nest-guarding activities of male bass. Kieffer et al. (1995) observed that nesting male smallmouth bass played to exhaustion took four times longer to return to the nest than did those played less extensively, and this ex-

tended absence resulted in heightened nest predation. However, they were unable to monitor or quantify the subsequent impairment of nest-guarding activities after the male returned to the nest. Philipp et al. (1997) also observed an almost four-fold increase in time required for exhaustively played black bass to return to the nest compared with briefly played fish. Qualitative observations suggested that, even after returning to the nest, exhaustively played individuals were disoriented and did not aggressively defend their broods from predators. Our results strengthen the qualitative observations presented by Philipp et al. (1997) and support the notion that fish have a reduced willingness or ability to defend the nest after catch-and-release angling. The Philipp et al. (1997) study confirmed that catch-and-release angling of nesting black bass can increase brood predation, as previously found through experimental removals of fish from nests (Neves 1975). Once a fish has been angled and landed, it is apparent that the level of physiological disturbance experienced by that fish affects its future parental care activities. However, when a fish has returned to the nest and has begun to protect the brood, it is unclear how that physiological disturbance might impair future locomotory needs. Another finding by Philipp et al. (1997) was that nest abandonment increased with successive or iterative capture and release of individuals, a sign of cumulative physiological damage. Individual-based modeling simulations by Ridgway and Shuter (1997) indicated that even brief exhaustion and handling of nesting male bass may result in significant declines in age-0 fish by fall. Research on catch-and-release angling effects on the parental care period have generally focused on the potential increase in brood predation during the male's absence from the nest. The impaired ability of a male to defend the nest after being angled and released have rarely been considered.

### Management Implications

The results of our study, when combined with previous research, indicate that simple measures may be taken to minimize the physiological disturbance of catch-and-release angling on nesting male bass and associated impacts on recruitment. As noted by Kieffer et al. (1995), short-duration, nonexhaustive angling minimizes disturbance relative to exhaustive angling. When landed, air exposure of fish can further exacerbate physiological disturbance, especially when fish are exhausted or injured (Ferguson and Tufts 1992). Air exposure duration is influenced by terminal tackle (e.g., barbless versus barbed, organic versus artificial

baits), the experience of the angler in handling fish, and the number of photographs taken. Based on these results, we suggest that during the nest-guarding phase, if anglers target bass or if a nesting bass is hooked accidentally, the angler should attempt to land the fish as rapidly as possible to minimize exhaustion, remove the hook rapidly, and return the fish to the water quickly. Although we did not vary angling duration, it is likely that had the fish not been angled to exhaustion, activity levels may not have been impaired to the extent we observed. If managers, out-reach personnel, conservation organizations, and the media can effectively disseminate this information to anglers, the negative effects of catch-and-release angling on nesting male bass could be reduced.

In the United States, it is often thought that warmer temperatures and nutrient-rich waters compensate for predation of age-0 bass through improved growth rates, which prompts many agencies to allow year-round harvest of bass. In a few northern jurisdictions, managers have taken a more conservative approach. Our research (in mid-latitudes of Illinois) indicates that catch-and-release angling may impair nest-guarding activities. Furthermore, catch-and-release angling of nesting male bass may affect recruitment, genetic variability, disease resistance, and overwinter survival of the adult. As such, studies that consider the ecological consequences of physiological disturbance should emphasize recruitment and population level effects of catch-and-release angling during the parental care period. We predict that the disturbance experienced by nesting fish in southern jurisdictions would probably be higher because of increased water temperatures, possibly negating the thermal benefits to the offspring. Managers throughout North America need to consider the potential effects of catch-and-release angling and perhaps do more to promote practices that protect nesting fish from angling activity. We also urge further study to elucidate the latitudinal influence on physiological disturbance of nesting bass and to determine what factors (brood devaluation, physiological effects of angling, or both) lead to premature nest abandonment.

### Acknowledgments

This study benefited enormously from the expert field assistance of Anders Koed, Roy Wilhelm, Amy McAninch, Josh Snyder, Matt Deters, and Julie Claussen. Todd Kassler was instrumental in pond setup and made several appearances as guest angler. Additional support and assistance was pro-



vided by Gary Anderson, Toni Beddow, and Val Butler. Lotek Engineering, and, in particular, Rob Krause provided technical advice related to receiver operation. Videography equipment was generously provided by Nick Collins and Richard Brown. This project was supported by an NSERC grant to RSM and an NSERC postgraduate scholarship to Steven Cooke. The Illinois Natural History Survey, University of Illinois, and the University of Waterloo provided additional in-kind support. The contents of this paper constitute a portion of the requirements for an Master of Science degree for SJC from the University of Waterloo. This paper has benefited from reviews by Patricia Schulte, Mark Ridgway, Scott Hinch, and several anonymous reviewers.

### References

- Anderson, W. G., R. S. McKinley, and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effects on swimming performance. *North American Journal of Fisheries Management* 17:301–307.
- Beddow, T. A., and R. S. McKinley. 1998. Effects of thermal environment on electromyographical signals obtained from Atlantic salmon (*Salmo salar* L.) during forced swimming. *Hydrobiologia* 371/372: 225–232.
- Beddow, T. A., and R. S. McKinley. 1999. Importance of electrode positioning in biotelemetry electromyographic studies of Atlantic salmon (*Salmo salar*). *Journal of Fish Biology* 54:819–831.
- Bendock, T., and M. Alexandersdottir. 1993. Hooking mortality of Chinook salmon released in the Kenai River, Alaska. *North American Journal of Fisheries Management* 13:540–549.
- Bettoli, P. W., and R. S. Osborne. 1998. Hooking mortality of striped bass following catch and release angling. *North American Journal of Fisheries Management* 18:609–615.
- Blake, L. M. 1981. Movement of tournament-caught and released bass. *New York Fish and Game* 28:115–117.
- Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge the “2% rule” for biotelemetry. *North American Journal of Fisheries Management* 19:867–871.
- Bunt, C. M. 1999. A tool to facilitate implantation of electrodes for electromyographic telemetry experiments. *Journal of Fish Biology* 55:1123–1128.
- Collins, N. C., S. G. Hinch, and K. A. Baia. 1991. Non-intrusive time-lapse video monitoring of shallow aquatic environments. *Canadian Technical Report of Fisheries and Aquatic Sciences* 1821.
- Cooke, S. J. 1999. Remote measures of the locomotory activity of fish with application to stress, physiological energetics, behaviour, and management. Master's thesis. University of Waterloo, Waterloo, Ontario.
- Crumpton, J. E. 1985. Effects of dummy radio transmitters on the behavior of largemouth bass. *Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies* 36(1982):351–357.
- Demers, E., R. S. McKinley, A. H. Weatherley, and D. J. McQueen. 1996. Activity patterns of largemouth and smallmouth bass determined with electromyogram biotelemetry. *Transactions of the American Fisheries Society* 125:434–439.
- Dobson, G. P., and P. W. Hochachka. 1987. Role of glycolysis in adenylate depletion and repletion during work and recovery in teleost white muscle. *Journal of Experimental Biology* 129:125–140.
- Emery, A. R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. *Journal of the Fisheries Research Board of Canada* 30:761–774.
- Ferguson, R. A., and B. L. Tufts. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout (*Oncorhynchus mykiss*): implications for “catch and release” fisheries. *Canadian Journal of Fisheries and Aquatic Sciences* 49:1157–1162.
- Gillooly, J. F., and J. R. Baylis. 1999. Reproductive success and the energetic cost of parental care in male smallmouth bass. *Journal of Fish Biology* 54: 573–584.
- Gustavson, A. W., R. S. Wydowski, and G. A. Wedemeyer. 1991. Physiological response of largemouth bass to angling stress. *Transactions of the American Fisheries Society* 120:629–636.
- Healey, T. P. 1990. Movement and survival of tournament-caught black bass at Shasta Lake. *California Fish and Game* 76:36–42.
- Hinch, S. G., and N. C. Collins. 1991. Importance of diurnal and nocturnal nest defense in the energy budget of male smallmouth bass: insights from direct video observations. *Transactions of the American Fisheries Society* 120:657–663.
- Kasello, P. A., A. H. Weatherley, J. Lotimer, and M. D. Farina. 1992. A biotelemetry system recording fish activity. *Journal of Fish Biology* 40:165–179.
- Kieffer, J. D., M. R. Kubacki, F. J. S. Phelan, D. P. Philipp, and B. L. Tufts. 1995. Effects of catch-and-release angling on nesting male smallmouth bass. *Transactions of the American Fisheries Society* 124:70–76.
- Kramer, R. H., and L. L. Smith. 1962. Formation of year classes in largemouth bass. *Transactions of the American Fisheries Society* 91:29–41.
- Kubacki, M. R. 1992. The effectiveness of a closed season for protecting nesting largemouth and smallmouth bass in southern Ontario. Master's thesis. University of Illinois, Urbana.
- Lee, W. C., and E. P. Bergersen. 1996. Influence of thermal and oxygen stratification on lake trout hooking mortality. *North American Journal of Fisheries Management* 16:175–181.
- Mackereth, R. W. 1995. Size-based variation in the allocation of energy to parental care by male smallmouth bass (*Micropterus dolomieu*). Doctoral dissertation. University of Guelph, Ontario.

- Muoneke, M. I., and W. M. Childress. 1994. Hooking mortality: a review for recreational fisheries. Reviews in Fisheries Science 2:123–156.
- Neves, R. J. 1975. Factors affecting fry production of smallmouth bass (*Micropterus dolomieu*) in South Branch Lake, Maine. Transactions of the American Fisheries Society 104:83–87.
- Philipp, D. P., C. A. Toline, M. F. Kubacki, D. B. F. Philipp, and F. J. S. Phelan. 1997. The impact of catch-and-release angling on the reproductive success of smallmouth bass and largemouth bass. North American Journal of Fisheries Management 17: 557–567.
- Quinn, S. 1993. Bass seasons, conservation measure or needless regulation? In-Fisherman 18(6):30–38.
- Richardson, C. A., A. A. Heft, and L. Fewlass. 1997. Catchability and spawning behavior of largemouth bass tagged with dummy transmitters. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 49(1995):250–255.
- Ridgway, M. S. 1988. Developmental stage of offspring and brood defense in smallmouth bass (*Micropterus dolomieu*). Canadian Journal of Zoology 66:1722–1728.
- Ridgway, M. S., and B. J. Shuter. 1996. Effects of displacement on the seasonal movements and home range characteristics of smallmouth bass in Lake Opeongo. North American Journal of Fisheries Management 16:371–377.
- Ridgway, M. S., and B. J. Shuter. 1997. Predicting the effects of angling for nesting male smallmouth bass on production of age-0 fish with an individual-based model. North American Journal of Fisheries Management 17:568–580.
- SAS Institute. 1999. SAS/STAT User's guide, version 8.0. SAS Institute, Cary, North Carolina.
- Schneider, J. C., J. R. Waybrant, and R. P. O'Neal. 1991. Results of early season, catch-and-release bass fishing at six lakes. Michigan Department of Natural Resources, Fisheries Technical Report 91-6, Ann Arbor.
- Stang, D. L., D. M. Green, R. M. Klindt, T. L. Chiotti, and W. W. Miller. 1996. Black bass movements after release from fishing tournaments in four New York waters. Pages 163–171 in L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.
- Wood, C. M. 1991. Acid-base and ion balance, metabolism, and their interactions, after exhaustive exercise in fish. Journal of Experimental Biology 160: 285–308.
- Wood, C. M., J. D. Turner, and M. S. Graham. 1983. Why do fish die after severe exercise? Journal of Fish Biology 22:189–201.