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Evaluation of the interactive effects of air exposure duration and water temperature on the condition and survival of angled and released fish

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Abstract

At present, there is a reasonable understanding of the independent effects of catch-and-release (C&R) angling stressors, such as air exposure and water temperature, on endpoints such as physiological disturbance, behavioural impairment and mortality. However, little is known about the multiplicative or interactive nature of these different C&R stressors. This study used bluegill (*Lepomis macrochirus*) as a model to evaluate the combined effects of water temperature and air exposure on fish behaviour, equilibrium status and short-term mortality following C&R. Experiments were replicated over 3 days with different ambient water temperatures (18.3, 22.8 and 27.4 °C). On each day, fish were captured by standard angling techniques, exposed to a range of air exposure durations (0, 30, 60, 120, 240, 480 and 960 s), and subsequently monitored for behavioural changes (within the first 300 s) and short-term (48 h) delayed mortality. Additional fish were captured by seine net for use as controls. There was an interactive effect of temperature and air exposure, whereby fish exposed to the highest temperature and longer air exposure durations lost equilibrium more often and had depressed ventilation rates relative to fish exposed to minimal air exposure and the lowest temperature. Immediate mortality at the lowest temperatures was negligible. However, significant delayed mortality (up to 80%) was noted at the highest water temperature (27.4 °C) in fish exposed to the three longest air exposure groups. In addition, at 27.4 °C, mortality among fish exposed to 480 and 960 s occurred at a faster rate than in any other treatment group. These results indicate that at low to moderate water temperatures, extended air exposure for bluegill may result in little mortality. However, at high water temperatures, short-term mortality (within 48 h) can be substantial, especially for fish that experience extended air exposure durations. Anglers and managers must recognize that C&R stressors can interact to have more dire consequences than when applied independently.

Keywords: Air exposure; Water temperature; Catch-and-release; Equilibrium; Mortality

1. Introduction

Research evaluating the effects of catch-and-release (C&R) angling on fish and fisheries has increased dramatically in recent years (summarized in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Arlinghaus et al., 2007), reflecting a growing interest in reducing mortality as well as sublethal consequences (e.g., stress, injury, behavioural alterations, fitness impairments (Cooke and Suski, 2005)). Several recent syntheses have identified air exposure and water temperature as two of the most prominent factors affecting fish survival and stress associated with C&R angling events (Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Arlinghaus et al., 2007). Research on bycatch in the commercial fishing sector has evaluated the interactive effect of air exposure and water temperature (e.g., Ross and Hokenson, 1997; Davis et al., 2001). However, to date, no studies have systematically evaluated the interactive effects of air exposure duration and water temperature in a C&R angling context. Considering the

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independent negative consequences of long air exposure durations and high water temperature on angling, there is a need to understand how these two factors interact to provide realism to C&R research (Cooke and Schramm, 2007).

High water temperature has been shown to impact C&R fisheries, as angling at high water temperatures is associated with increased physiological disturbances and probability of immediate or delayed mortality (reviewed in Cooke and Suski, 2005). Typically, higher water temperatures are associated with a number of physiological changes at the cellular level and organismal level including altered enzymatic function and elevated metabolic rate (Fry, 1971; Prosser, 1991; Somero and Hofmann, 1996). When combined with the stress and exercise associated with C&R angling, high water temperature often leads to a suite of behavioural and physiological changes. Behavioural changes may include a lack of movement or equilibrium loss (see S.E. Danylchuk et al., 2007) and physiological changes can include increases in cardiac output (heart rate and stroke volume; Anderson et al., 1998; Schreer et al., 2001) and alterations in blood and muscle biochemistry (Wilkie et al., 1996, 1997). There are also clear relationships between high water temperature and probability of post-release mortality (e.g., Wilkie et al., 1997; Anderson et al., 1998; Wilde, 1998; Thorstad et al., 2003). Reduced concentrations of dissolved oxygen which tend to occur at high water temperatures can impair post-release recovery (Killen et al., 2006; Suski et al., 2006). Currently, some jurisdictions regulate C&R fisheries at high temperatures as a strategy to reduce stress and mortality (summarized in Arlinghaus et al., 2007).

Air exposure has long been assumed to be harmful to fish. Typically, air exposure occurs when anglers remove the fish from the water to remove fishing hooks/lures, admire, photograph and weigh/measure the fish (Cooke and Suski, 2005). During this time, the gill lamellae collapse leading to adhesion of the gill filaments and physiological changes including acidosis, hemoglobin increase and shifts in blood gasses (Boutilier, 1990; Ferguson and Tufts, 1992; Suski et al., 2004). In addition, the duration of air exposure influences the recovery time for cardiovascular variables (Cooke et al., 2001, 2002a) and blood and muscle parameters (Suski et al., 2004; Killen et al., 2006), which can lead to impairments in swimming performance (Schreer et al., 2005). In a laboratory setting, extended air exposure after exercise similar to that induced during C&R angling caused higher mortality than when air exposure was avoided (Ferguson and Tufts, 1992). In a pond study, mortality was lowest for fish that were not exposed to air relative to air exposure periods of 60, 120 or 240 s (Arlinghaus and Hallermann, 2007). In field settings, extended air exposure has been implicated in loss of equilibrium and post-release predation (Cooke and Philipp, 2004; S.E. Danylchuk et al., 2007). Though studied in laboratory settings, field studies evaluating the consequences of air exposure on fish have rarely occurred.

Here, bluegill (*Lepomis macrochirus*) were used as a model to determine the magnitude and nature of possible interactions between water temperature and air exposure duration on a suite of sublethal indicators and subsequent short-term mortality. Bluegill were chosen as a model species for several reasons, including the fact that they are actively pursued by many recreational anglers (Barthel et al., 2003; Cooke et al., 2003), and inhabit waters that experience dramatic seasonal changes, providing an opportunity to assess responses across a broad thermal range similar to multiple economically important warmwater game fish species (e.g., black bass *Micropterus* spp., crappie *Pomoxis* spp., muskellunge, *Esox masquinongy*, etc.). They are also extremely abundant, leading to ease of capture and manipulation for experimental purposes (both via angling and seining to capture control fish). For the purposes of this study, behavioural observations were made including the ability to maintain equilibrium, ventilation rate, time required to recover from equilibrium loss, and immediate (1 h) and short-term (48 h) mortality to determine the interactive effect of temperature and air exposure on bluegill. Using this approach, the current study evaluated the hypothesis that the interaction between water temperature and air exposure would be more detrimental to fish than if either stressor was applied independently. Specifically, it was predicted that individuals angled at the warmest water temperatures and exposed to the longest durations of air exposure would display the most extensive sublethal effects and experience the highest levels of mortality.

2. Methods

2.1. Sampling

Sampling occurred on Lake Opinicon at the Queen's University Biological Station, located in southeastern Ontario. The lake is mesotrophic, with a game fish community comprised mainly of largemouth bass (*M. salmoides*), smallmouth bass (*M. dolomieu*), northern pike (*E. lucius*), black crappie (*P. nigromaculatus*), pumpkinseed (*L. gibbosus*) and bluegill. Sampling took place from a series of large docks or aboard a 4 m barge. All angling was focused in the littoral zone at a depth of approximately 0.5–1.5 m. The experiment was replicated on 3 days (May 11, June 1 and July 18, 2006), which provided three different water temperature treatments (18.3, 22.8 and 27.4 °C, respectively). Temperatures on the day of angling (noted in previous sentence) were observed using a digital thermometer in a secondary monitoring tank (SMT) with fresh lake water flowing through at 13:00 h on the day of capture. Water temperatures during the 48 h monitoring period were assessed using a fixed temperature monitoring station (depth 1 m) and reported as hourly means (±S.E.; first holding period, 17.3 ± 0.1 °C, second holding period, 22.2 ± 0.1 °C, third holding period, 27.7 ± 0.1 °C). Anglers used standardized gear consisting of medium action spinning rods and reels with 3.63 kg test monofilament line. All rods were rigged with small balsa spring floats (76 mm stem) placed between 50 and 100 cm above the hook (size 6 Mustad hooks, model 92141, non-offset small "J" style bait hook). A single 3/0 weight was positioned 15 cm above the hook. Hooks were baited with commercially available crappie bait (Crappie Nibbles, Berkley Inc.) measuring 5 mm × 5 mm and weighing about 0.2 g each. This configuration has previously been used to capture bluegill in Lake Opinicon yielding