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Considerations for the design and interpretation of fishing release mortality estimates

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ABSTRACT

To generate mortality estimates for fish that are captured and released in recreational and commercial fisheries, it is common to temporarily hold fish in captivity. Typically, captured fish are placed in some form of pen, cage or tank with control individuals, yet little is known about how the type of holding environment influences fish condition or mortality. Here we captured freshwater fish (bluegill; *Lepomis macrochirus*) via angling and fyke net and retained them in one of four holding environments; a round flow-through tank on shore [TANK], a knotless nylon pen with natural substrate in the lake [PEN], a knotless nylon floating cage with a rigid structure [RCAGE], and a knotless nylon floating cage that lacked rigid structure [CAGE]. Mortality was low (1%) across both capture techniques and holding environments during the 14-day retention period. All mortalities were associated with capture by fyke net. A chronic stress indicator, blood glucose, was determined for a subset of fish on day 5. Although there were significant differences in blood glucose between angled RCAGE and angled PEN (Tukey, $P = 0.047$) and angled RCAGE and fyke PEN (Tukey, $P = 0.015$), the observed levels were generally quite low (range: 1.0–3.9 mmol L^{-1}) and the differences were likely associated with differences in feeding; fish in the PEN group with access to substrate (and presumably the most food) had slightly higher glucose levels. At the conclusion of the study Fulton's condition factor was similar among all groups (ANOVA, $P > 0.05$, all terms). However, fish held in the TANK treatment had the highest levels of external protozoan parasite infection by *Ichthyophthirius* (Tukey, $P < 0.05$). This study illustrates that in situ holding environments (rather than tanks) may help reduce mortality, stress, and disease during studies that estimate post-release mortality. We encourage additional research to explore how the holding environment can influence inferences made about post-release mortality and sublethal impacts of fishing.

1. Introduction

Nearly all fisheries, whether recreational or commercial, release a component of their catch (Cooke and Cowx, 2006). Although quantifying the harvest component of fisheries mortality is relatively simple (Hilborn and Walters, 1992), generating mortality estimates for released fish is more challenging (Coggins et al., 2007). As summarized in Wilde (2003), there are several approaches to doing so. One involves the use of tagging methods where fish are released and tracked with various electronic tags to assess survival (see Donaldson et al., 2008) or marked in some manner that enables determination of survival from mark-recapture analysis (Pine et al., 2003). However, the most common approach (ICES, 2014) involves holding fish in captivity (e.g., pens, cages, tanks) to assess mortality. Wild fish do not always transition well to captivity, even if for just a period of several hours or days (Casebolt et al., 1998). Captivity for wild fish can be inherently stressful (Grutter and Pankhurst, 2000; Portz et al., 2006) and is often associated with a disinterest in

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feeding (Murchie et al., 2009) and subsequent change in fish condition (Portz et al., 2006), agonistic interactions with conspecifics (Portz et al., 2006), disease outbreaks (Robertson et al., 1987; Portz et al., 2006), extensive exploratory behavior in an attempt to escape (Donaldson et al., 2011) and abrasion from the holding vessel (Portz et al., 2006; Donaldson et al., 2011). Given these potential negative consequences of holding wild fish in captivity, it would be useful to know how holding gears (e.g., pens, cages and tanks) influence how mortality estimates or even sublethal assessments are generated.

It is increasingly recognized that control fish should be used to account for handling and holding effects (Wilde, 2003). Indeed, whenever survival is not 100%, without controls it is not possible to determine if it is the treatment (e.g., a given capture gear) or some aspect of the study method (e.g., type of holding environment) that is associated with deaths (ICES, 2014). In some cases where control fish are not used, it is possible to evaluate the relative differences between treatments (e.g., handling the fish use one technique is better than another). However, it is not possible to easily incorporate such information into fisheries management models. It is rather apparent that control/background mortality differs markedly among studies (ICES, 2014), yet it is unclear how capture method or controls for the type of holding environment used influence mortality estimates. One of the common ways in which to obtain controls is to use what are perceived to be "benign" capture methods such as use of barbless hooks or passive traps (ICES, 2014). However, are these approaches truly benign? With growing scrutiny over mortality estimates (see Wydoski, 1977; Coggins et al., 2007; ICES, 2014), there remains a need to provide direction on study design to improve future research and ensure that values used in management and conservation are reliable and accurate.

The purpose of this study was to compare mortality estimates generated for two apparently benign capture methods (i.e., rapid angling and short-set fyke nets at cool temperatures) often used as controls and to evaluate how those estimates varied relative to four replicated (3 of each) types of holding environment (a round flow-through tank on shore, a knotless nylon pen with natural substrate in the lake, a knotless nylon floating cage with a rigid structure, and a knotless nylon floating cage that lacked rigid structure). We used bluegill sunfish (*Lepomis macrochirus*) as a model given that they are an abundant freshwater fish and can be captured in large numbers to provide a reasonable sample size (e.g., Cooke et al., 2003). Bluegill sunfish are commonly targeted by recreational anglers across their range (Coble, 1988; Quinn and Paukert, 2009) and small-scale commercial fisheries exist in some regions of midwestern North America (Larocque et al., 2012). The species' general morphology allows them to forage in both open-water habitats and among substrate and vegetation in the littoral zone (Ehlinger and Wilson, 1988). We evaluated both lethal (mortality rates) and sublethal endpoints (blood glucose, external parasite burden and condition factor) to assess fish condition and health. This study was designed to identify the most appropriate methods among those commonly used to identify post-release mortality. With the most appropriate methods identified, management actions would then be based on the most reliable information which would ensure that fisheries are managed to achieve both conservation targets while maximizing fishing opportunities.

2. Methods

2.1. Study location

The experiment was conducted at Queen's University Biological Station on Opinicon Lake, Ontario (44° 34′ N, 76° 19′ W). Opinicon Lake is a shallow mesotrophic lake located along the Rideau Canal waterway. The lake contains abundant populations of warmwater fish species such as largemouth bass (*Micropterus salmoides*) and bluegill sunfish. Experimental procedures were carried out between 4 May 2014 and 18 May 2014 when water temperature averaged 14 °C (range: 12–15 °C).

2.2. Holding environments

Three replicates of four different holding environment treatments were used in this experiment: floating rigid cages [RCAGE], floating cages [CAGE], pens that reached the substrate [PEN], and tanks [TANK]. Replicates for the RCAGE treatment were assembled using a 1.22 m × 1.22 m × 1.22 m frame of 2.54 cm diameter white CPVC pipe. A knotless nylon net (material obtained from Memphis Net and Twine, Heavy Delta, 12.7 mm sq.) with one unmeshed side was placed over the structure and affixed in place with cable ties. The CAGE treatment was similar except that it had only CPVC pipe around the perimeter of the unmeshed side, i.e., the remaining mesh was free to move in the water. The open side of both the RCAGE and CAGE treatments were kept afloat by pool noodles that were fixed to this part of the structures. Alternating between RCAGE and CAGE, replicates of the pens ($n = 6$) were attached at their corners using a 61 cm length of twine. The cages were taken to approximately 2.44 m of water and anchored at either end so that the entire structure remained oriented in the same direction during the experiment, i.e., parallel to shore. To construct a PEN replicate, four 2.44 m lengths of rebar were hammered into the substrate approximately 1.22 m apart in 1.07–1.22 m of water. A knotless nylon net (same material as above) with two open sides was placed around the rebar and connected to it using cable ties. The surface side of the mesh was tied to the rebar approximately 1.83–2.44 m from the surface of the water. To reduce the chance of fish escaping near the substrate, loose mesh was covered with sand, gravel, bricks, and rocks. The TANK treatments included a row of three 1000 L outdoor circular fiberglass tanks supplied with flow-through lake water at a rate of 166 L h^{-1}, where water was exchanged 4 times per day (Fig. 1).

2.3. Capture of fish

Bluegill were captured 4 May 2014 from Opinicon Lake, Ontario. Fykes nets ($n = 3$) each had 7 steel hoops that were 0.5 m apart and 0.9 m in diameter. Nets had two wings and a lead that was attached vertically to the mouth of each net. Wings were 4.6 m long by 0.9 m high, leads were 10.7 m long by 0.9 m high, and the mesh 2.54 cm square nylon (See Stoot et al., 2013 for more detail). Fyke nets were set in shallow weedy bays and checked twice during the day to capture bluegill ($n = 204$). Angling techniques used standard spinning gear with small hooks, bobbers, and a small piece of worm to capture bluegill ($n = 204$) from shallow weedy bays that were similar to those used during fyke netting. Angling occurred during the day when the fyke nets were fishing. To distinguish fish by a capture technique, individuals were marked by clipping either the upper or lower corner of the caudal fin. Treatment replicates were randomly populated with a similar size range of fish from each capture technique (17 fish per capture technique/replicate or 34 fish total/replicate; Table 1).

All holding environments were monitored three times a day at six-hour intervals from 4 May 2014 to 8 May 2014. After 8 May 2014, holding environments were monitored daily until 18 May 2014. Dead or moribund (e.g., loss of equilibrium, lethargy) bluegill were removed, checked for signs of trauma (e.g., fin abrasion scored as: none, moderate, heavy), external parasites (present/absent at this stage), and fin clip location. To identify whether holding vessel or capture method were potential sources of stress after four holding days, three fish/capture technique/replicate ($n = 72$) were