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Evaluating effects of catch-and-release angling on peacock bass (*Cichla ocellaris*) in a Puerto Rican reservoir: A rapid assessment approach

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ABSTRACT

Catch-and-release recreational angling is growing in developing countries in tropical regions and can generate valuable economic activity. However, management agencies may not have the capacity for studies to determine how angling and handling practices influence the fate of released fish, an important consideration for effective management of the resource. We developed a 3-day rapid assessment protocol and used it to evaluate the consequences of recreational fishing using artificial lures to target peacock bass (*Cichla ocellaris*) in the La Plata reservoir, Puerto Rico. Peacock bass were angled using conventional rod and reel and exposed to either short (minimum angling times and air exposures <45 s) or extended (extended angling times and air exposures >1 min) handling practices in water temperatures averaging $30 \pm 1\,^{\circ}$C. Angling-related injuries, post-capture physiological stress (as measured by blood sampling) and reflex impairment were quantified prior to holding angled fish in floating net pens overnight to quantify mortality. Blood glucose and lactate levels were elevated post-capture, although the changes to reflex impairment were negligible. Injuries were minimal with most fish hooked in the jaw. Peacock bass exhibited high post-capture survival (95%, $n = 97$, size range 140–495 mm total length) with mortality only associated with the extended handling treatment. Using a rapid assessment protocol we were able to generate useful information on the consequences of catch-and-release on a poorly studied sportfish and identify where efforts should be directed for future studies on this and similar species.

1. Introduction

Catch and release (C&R) angling is growing in popularity in recreational fisheries around the world to comply with harvest regulations (*i.e.*, mandatory) or due to conservation ethics of anglers (*i.e.*, voluntary; Arlinghaus et al., 2007; Cowx, 2002). C&R is often used as a management strategy to promote sustainability of angled fish populations, yet the success of the practice depends heavily on the angler's awareness of best practices pertaining to catching these species, and on the species-specific responses to the practice itself (Cooke and Schramm, 2007). Fish can exhibit a highly diverse continuum of responses to C&R, ranging from almost complete survivorship and negligible sub-lethal effects to extremely high levels of mortality (up to 90%) and extensive sub-lethal effects such as depressed feeding, reproduction and immune response (see reviews by Arlinghaus et al., 2007; Bartholomew and Bohnsack, 2005; Muoneke and Childress, 1994).

The number of species being targeted worldwide in C&R fisheries renders research into species-specific responses a challenge, both financially and logistically (Cooke and Suski, 2005). However, such research is essential in order to validate the utility of C&R (Cooke and Schramm, 2007), particularly in fisheries targeting sensitive, endangered or keystone species (*e.g.*, taimen (*Hucho taimen*), Cooke et al., 2015; Jensen et al., 2009; Shiffman et al., 2014). In many instances little is known about how sportfish respond to C&R, particularly in tropical waters, as most research effort is devoted to several popular species in temperate regions (Cooke and Suski, 2005). Rapid assessments, defined in this context as a brief field study designed to establish a basic but comprehensive understanding of the sensitivity of particular species/population to C&R,

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may act as a tool to provide relevant data in an efficient and cost-effective manner. During such an assessment, measurement of C&R impacts enables quantification of post-release mortality, injury and impairment, and these data can serve to assist in the development of management strategies and prioritizing future research. Although there are basic traits among fish that can be used to inform how they respond to C&R, species-specific differences can preclude extrapolating beyond well-studied species (Cooke and Suski, 2005). This rapid assessment approach has the potential to address this issue by identifying where problems may exist (*i.e.*, similar to a triage approach; Bottrill et al., 2008) that require additional focused research effort or management action.

Activities such as capture via angling can induce physiological stress responses arising from rapid bursts of anaerobically-fueled locomotion (Kieffer, 2000). Although there are a suite of physiological alterations associated with anaerobiosis, the elevation of glucose and lactate levels in the blood and decreased blood pH represent simple and effective means of quantifying such disturbance (Barton et al., 2002; Kieffer, 2000), and these can rapidly be measured in the field using portable point-of-care devices thus negating the need to store or transport tissue samples (Stoot et al., 2014). Measurements of these stress responses can serve as powerful indicators of fish responses to C&R events, and facilitate an understanding of the mechanisms behind behavioral impairment or mortality (Cooke et al., 2013; Skomal, 2007). If a stressor is of sufficient magnitude or duration, physiological stress may result in 'whole body' responses (Barton, 2002) that may be identified by measuring reflex impairment. Reflex impairment tests are useful tools for assessing fish condition in relation to fisheries stressors because they can be measured quickly and non-invasively (Davis, 2010). Developed primarily under the name 'reflex action mortality predictors' (RAMP; Davis, 2010), a series of indicators have emerged as effective proxies for underlying physiological stress, post-release behavioral impairment, and delayed mortality in a range of fishes in relation to fisheries stressors (Brownscombe et al., 2013, 2015; Cooke et al., 2014; Danylchuk et al., 2014; Raby et al., 2012).

Peacock bass (*Cichla ocellaris*) are a popular sportfish native to tropical regions of South America that were first introduced to Puerto Rico from Colombia in 1967 (Welcomme, 1988) and are currently believed to be maintaining small self-sustaining populations in half of the reservoirs (Department of Natural and Environmental Resources [DNER], 2009). Inland recreational fishing is popular in Puerto Rico, and contributes tens of millions USD per year in expenditures to the economy (Clark et al., 1994), yet despite the economic benefits and popularity of the peacock bass recreational fishery, no studies have been conducted to evaluate the responses of the species to the practice of C&R in Puerto Rico. Indeed, the first and only other study on peacock bass mortality arising from C&R practices (Thomé-Souza et al., 2014) took place on the Negro River, Brazil and determined that C&R practices did not substantially increase mortality in three *Cichla* species (*i.e., Cichla temensis*, *C. ocellaris* and *Cichla monoculus*). Given the many emerging fisheries for peacock bass in tropical waters, research on how peacock bass respond to C&R angling practices is prudent.

The primary objectives of this study were to quantify injury and mortality rates resulting from C&R of peacock bass and to evaluate related physiological stress responses in the species. To do so, we developed and applied a rapid assessment approach to determine the suitability of C&R practices for peacock bass based on a short field study. Results of this study can be used to inform existing and future management practices designed to support the peacock bass recreational fishery in Puerto Rico, to assist the angling community develop best practices for C&R, and to refine a rapid assessment approach that may be applied to other fish species.

2. Methods

2.1. Study site: La Plata reservoir, Puerto Rico

This study was undertaken in the La Plata reservoir (18.3386° N, 66.2357° W), in May 2013. The reservoir (405 ha) was developed in 1974 by the Puerto Rico Aqueduct and Sewer Authority and serves as a source of potable water for nearby municipalities (USGS, 2008). La Plata is one of five reservoirs that hosts infrastructure for recreational use in Puerto Rico (Neal et al., 2009). Its depth at the dam wall fluctuates between fall and winter (52 m in winter of 2012) and shallower depths occur in late spring and summer (49 m in spring of 2013; USGS, 2008). Water temperatures during the study averaged 30 °C ± 1 °C.

2.2. Angling protocols

Angling was conducted over the entirety of the La Plata reservoir during three days using seven anglers divided up among four boats. Anglers were free to use their discretion regarding the lure size and type, but as the majority of fish caught were landed using single hook, 1/4 oz barbed jigs ($n = 73$ of 97; the remaining fish were caught on an assortment of crankbaits, poppers, and bucktails) the impacts of lure and hook type on injury and mortality were not analysed. Live bait was not used during this study, as it is not generally employed by C&R and tournament anglers in the area (Till Brauer, local guide, pers. comm.). All anglers used mid-weight spinning rods and employed casting methods to present the lures. Depth of capture was not measured for this study, but all peacock bass were landed in the littoral zone, consistent with their feeding ecology (Fugi et al., 2008).

2.3. Rapid assessment

In total, 97 fish were angled during the rapid assessment. Angling time (the amount of time [s] from hooking to landing) was recorded for each fish. On landing, all peacock bass were measured (total length in mm; TL) and amount of air exposure (the duration of time, in cumulative seconds, that a fish is removed from water) during handling was recorded.

RAMP (Davis, 2010) was assessed in all landed fish after air exposure and prior to blood-sampling if applicable, to generate a post-angling RAMP score. Four reflex indicators were used: 'tail grab', the presence of burst swimming action when a fish is grabbed by the tail; 'body flex', the presence of flexion in the torso when a fish is held along the dorsoventral axis; 'head complex', the presence of steady operculum beats during handling; and, 'equilibrium', the ability of the fish to right itself within three seconds after being placed upside down in water. These indicators were chosen due to their simplicity of use and their previous validation in physiological and behavioral impairment studies in other species (*e.g.*, *Onchorhynchus kisutch*, Raby et al., 2012 *Albula vulpes*, Brownscombe et al., 2013). For individual indicators, binary RAMP scores of 0 (reflex present) and 1 (reflex absent) were used. Indicator scores were then converted to a proportional impairment score ranging from 0 to 1, where a cumulative score of 0 indicated no overall impairment and a score of 1 indicated total impairment.

Using the same methodology described above, a second RAMP score was measured for all fish after holding. This RAMP score was termed post-holding RAMP score.

2.4. Blood-sampled subset

To quantify the physiological response of peacock bass to C&R angling via measurements of secondary stress responses, non-lethal blood samples were obtained from a subset ($n = 31$) of the

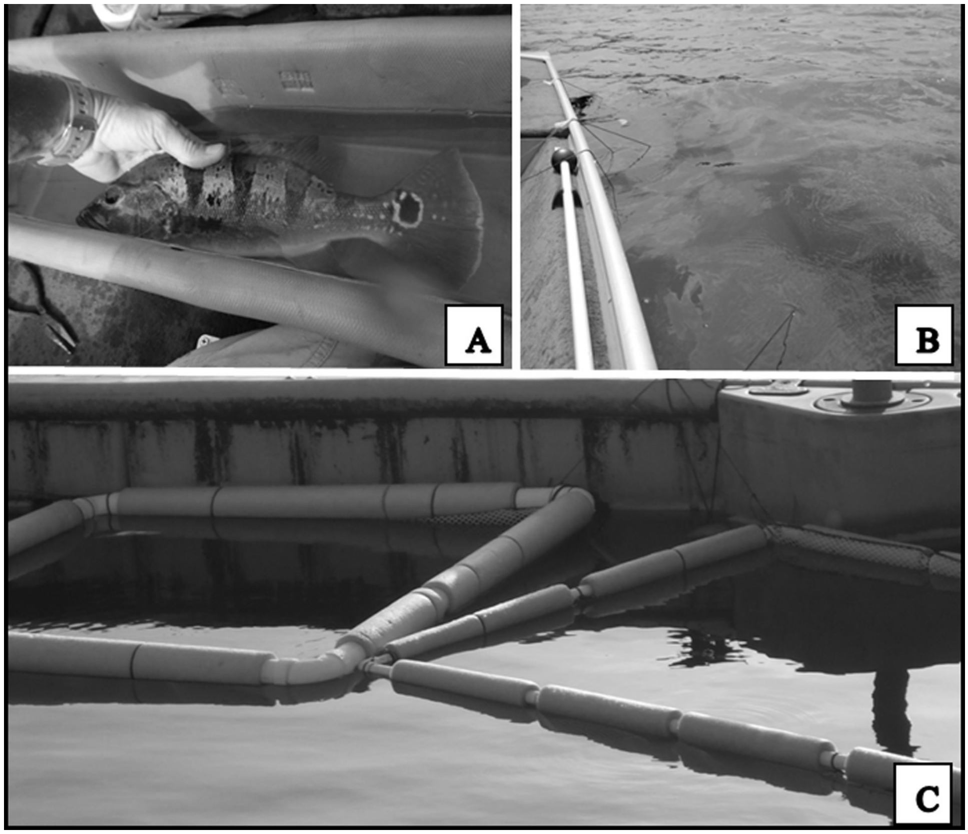

Fig. 1. (A) A peacock bass undergoing measurements in a padded holding trough filled with freshwater; (B) bags containing peacock bass affixed to the side of the boat during timed treatments; and, (C) net pens affixed to a stationary dock for overnight holding of peacock bass from the handling treatment group.

total number of fish landed ($n = 97$). These fish were subject to the same measurements on landing as described above; however, measurements of injury (see Section 2.5) were excluded to reduce cumulative handling time. Fish in this subset were separated into subgroups, to be blood sampled at post-landing intervals: 0 min (baseline), 30 min (no air exposure), 30 min (60 s air exposure) and 120 min (no air exposure); as recommended in Cooke et al. (2013). Fish in the 0 min (baseline subgroup; $n = 10$) were angled, measured, sampled, and RAMP-tested immediately (*i.e.,* <60 s) to record baseline measurements for blood values (as per Meka and McCormick, 2005). Fish in the 30 min subgroup ($n = 14$) were retained in fish holding bags (Dynamic Aqua Ltd., Vancouver, BC; 75 cm in length; as used in Brownscombe et al., 2013; Donaldson et al., 2013) for 30 min after measurements and prior to blood sampling. Bags were attached either to available structure or to a stationary boat (Fig. 1b). Fish in the 30 min subgroup were further subdivided into "no air exposure" ($n = 7$) and "60 s air exposure" ($n = 7$) treatments. Lastly, seven fish were held in bags for 120 min prior to sampling to ascertain whether blood levels had changed over this extended time period. Fish in the 120 min subgroup ($n = 7$) were not subjected to an air exposure treatment owing to an insufficient number of landed fish to make this treatment feasible.

With the exception of the baseline subgroup which was measured and immediately released, RAMP measurements were taken from each fish after landing and air exposure, if applicable (post-angling RAMP score). RAMP was measured a second time after removal of the fish from the bag and prior to blood sampling (post-holding RAMP score).

Blood samples were obtained using a padded trough (see Fig. 1a), and <2 ml of blood was drawn from the caudal vasculature with a 1½″ 22G needle and vacutainer (#367871, 75 USP lithium heparin, Becton, Dickinson and Company (BD), New Jersey, USA). Blood was analyzed immediately after phlebotomy for blood-plasma lactate (mmol L^{-1}, Lactate Pro LT-1710, Arkray Inc., Kyoto, Japan), glucose (mmol L^{-1}, Accu-Chek Compact Plus, Roche Diagnostics, Basel, Switzerland) and pH (HI-99161, Hanna Instruments, Woonsocket, Rhode Island, USA); these devices have been previously validated for use on fish (Stoot et al., 2014). Fish that were blood sampled were released immediately after sampling was completed. To account for differences in handling style, all anglers caught fish for each treatment group.

2.5. *Handling treatment groups*

To determine injury and mortality associated with capture of peacock bass, the remaining angled fish ($n = 66$) were not blood sampled, but measured for RAMP (post-angling score), examined for injury, and held in net pens to monitor post-release mortality. In these treatments groups, hooking location was recorded and the time taken to remove the hook was measured in seconds for each fish. A score of 0 was assigned if the hook required <20 s to remove (easy) and a score of 1 was assigned if the hook took >20 s to remove (difficult). Fish were also categorized according to injury level, from 0 to 3, where 0 indicated no discernible injury; 1 indicated minor injury such as a bloodless tear <5 mm in length; and 2 indicated a moderate injury, such as the presence of bleeding, bruising or tissue tear >5 mm in length. A score of 3 to indicate severe injury such as ocular damage was discarded from analysis after no angled fish exhibited injuries at this level.

Handling treatment fish were also subdivided into two treatment groups termed "short" ($n = 27$) and "extended" ($n = 39$) based on the amount of air exposure accrued during handling such that fish included in the short treatments had shorter average air exposures (*i.e.,* ≤45 s) and fish included in the extended treatment had longer average air exposure (*i.e.,* ≥60 s). No fish were subject to air exposures of 45–60 s in duration. As angling times also varied between treatments, with fish in the short treatment recorded as having angling times averaging 8 ± 1 s, and fish landed for the extended treatment recording average angling times of 19 ± 1 s, the angling time variable was included as part of the treatment in analysis.

Following handling, fish were transferred to one of two mesh cages (measuring 1.2 m × 1.2 m × 1.2 m and 1.2 m × 1.8 m × 1.2 m; knotless nylon suspended at the surface by floats; Fig. 1c) for holding overnight to monitor mortality. Surviving fish were assessed for RAMP scores again prior to release (post-holding RAMP score). In order to account for the additional capture stress placed on fish during removal from the pens, only those fish removed within three min ($n = 25$) were included in these post-holding RAMP measurements.

All experimental manipulations performed during this study were conducted in accordance with Canadian Council of Animal Care regulations under permit number B13-02 and with the support of the DNER, Puerto Rico.

2.6. Statistical analyses

To compare secondary stress response among blood-sampled fish (0 min (baseline), 30 min (no air exposure), 30 min (60 s air exposure) and 120 min), differences in fish size (length), angling time, blood glucose, lactate and pH were evaluated using either parametric one-way analysis of variance (ANOVA) tests or non-parametric Kruskal–Wallis equivalents. Where significant differences were found, treatments were then compared using Tukey's honestly significant difference (HSD) post-hoc tests.

RAMP scores were treated as objective measurements during analysis, a common assumption in studies using RAMP scoring (see Brownscombe et al., 2013; Nguyen et al., 2014; Raby et al., 2012 for examples). RAMP scores recorded immediately after landing (post-angling RAMP score) for blood-sampled fish were measured prior to holding, enabling comparisons across all time treatments for this score. The post-holding RAMP measurements of blood-sampled fish, those taken after holding, sampling and just prior to release (post-holding RAMP score), were not comparable across all treatments for blood-sampled fish due to the timing of scoring (*i.e.,* after timed treatments and just prior to sampling), subsequently, comparisons of post-holding RAMP score were limited to the 30 min (no air exposure; $n = 7$) and 30 min (60 s air exposure; $n = 7$) treatments. To evaluate impairment in the blood-sampled subset and handling treatment groups, post-angling and post-holding RAMP scores were converted to ordinal variables (0.0, 0.25, 0.5, 0.75, 1) and compared using Kruskal–Wallis tests. Significant differences among subgroups were evaluated using Tukey's HSD.

To determine whether angling treatments resulted in significant differences in mortality, injury, and difficult hook removal rates between short and extended treatments we employed Exact McNemar Tests. *T*-tests were used to identify any significant differences in mean length, and confirm differences in mean angling time and air exposure time between short and extended treatments.

To assess the dataset's compliance with assumptions of homogeneity of variance and normality of distribution, Levene and Shapiro-Wilk tests were performed on each variable prior to analysis. Variables found to meet assumptions underwent one-way ANOVAs or *t*-tests where applicable, while the remainder were subject to the non-parametric analyses described above. Unless otherwise noted, all data are presented as mean ± standard error. All analyses were conducted using R (version 3.1.0, © 2014, The R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Physiological response

Fish in the blood-sampled subset ($n = 31$) averaged 252 ± 65 mm TL and there were no significant differences in mean length and angling time among groups ($F = 0.134$, df = 3, $P = 0.939$) (Table 1). Peacock bass blood glucose and lactate concentrations in all timed subgroups (30 min, 120 min) were significantly higher post-capture than those in the baseline subgroup, while pH values were lower (Tukey's HSD; $P < 0.001$; Table 1). Lactate levels were also significantly higher in 30 min (60 s air exposure) *vs.*120 min subgroups ($P_{30air\text{-}120noair} = 0.005$) (Table 1). The pH among subgroups varied less (Table 1), though pH was significantly different between baseline and 30 min (60 s air exposure) subgroups ($P_{base\text{-}30air} = 0.015$), and 30 min (60 s air exposure) and 120 min subgroups ($P_{30air\text{-}120no\ air} = 0.010$).

3.2. Reflex impairment

Ten (32%) of the 31 peacock bass angled in the blood-sampled subset exhibited reflex impairment. Of the indicators measured, tail grab and body flex reflexes were the most commonly impaired (see Fig. 2a). Of the 14 blood-sampled fish included in analysis of the post-holding RAMP score (those from the 30 min, no air exposure [$n = 7$] and 30 min, 60 s air exposure [$n = 7$] groups), seven (50%) exhibited reflex impairment. Here also, tail grab was the reflex response most likely to be absent and contributed the most to mean RAMP score (see Fig. 2b). No significant differences among groups were noted for either score measurement (post-angling RAMP score $\chi 2 = 4.40$, df = 2, $P = 0.11$; post-holding RAMP score $\chi^2 = 7.70$, df = 3, $P = 0.50$).

In the handling group treatments, five of 66 fish (8%) recorded non-zero post-angling RAMP scores. Tail grab and body flex were the reflexes most commonly impaired (see Fig. 2c). Twelve of 30 fish (40%) in the handling treatment groups showed non-zero post-holding RAMP scores. Body flex and tail grab were reversed in prevalence for post-holding RAMP score, with body flex more likely to be impaired than tail grab (see Fig. 2d). Differences between short and extended treatments for both post-angling and post-holding RAMP score were not statistically significant (post-angling RAMP score $\chi^2 = 1.44$, df = 2, $P = 0.49$; post-holding RAMP score $\chi^2 = 2.29$, df = 4, $P = 0.68$).

Four mortalities occurred in the handling treatment groups: two died overnight (a post-holding RAMP score of '1') and two died shortly before release. Of the latter, one fish recorded a post-holding RAMP score of 1, indicating total impairment of reflexes measured, while the second fish exhibited only tail grab and body flex responses, for a post-holding RAMP score of 0.5.

3.3. Injury and mortality

Fish in the handling treatment group ($n = 66$) averaged 260 ± 6 mm TL; those in the short treatment averaged 241 ± 9 mm TL, while those in the extended treatment averaged 273 ± 7 mm TL. These differences were found to be statistically significant ($t = -2.92$, df = 54, $P = 0.005$), although as the source of the difference was the presence of two outliers in the short treatment (measuring 140 and 180 mm), we interpreted these differences as not being biologically significant.

Four peacock bass (one in the short treatment and three in the extended treatment) exhibited delayed mortality in the net pens within 12–18 h of angling, for a total (immediate + delayed) mortality rate of 6% ($n = 66$) (Table 2). In addition, one fish from the blood-sampled subset died as a result of post-release predation, yielding a mortality rate of 5% ($n = 97$) overall.

Table 1
Results of blood plasma analysis of peacock bass after recreational angling, including mean values for length, angling time, glucose, lactate and pH level per baseline and time treatment group with associated one-way ANOVA and Kruskal–Wallis outputs. Statistically significant result are indicated with an *, where $\alpha \leq 0.05$ for ANOVA tests and Kruskal–Wallis tests. Unless otherwise noted, all data are presented as mean ± standard error.

Variable	Baseline $n=10$	30 min (no air exposure) $n=7$	30 min (60 s air exposure) $n=7$	120 min $n=7$	Comparison
Total body length (mm)	262 ± 32	253 ± 20	249 ± 14	241 ± 12	$F=0.134$, df = 3, $P=0.939$
Angling time (s)	19 ± 4	11 ± 4	19 ± 8	12 ± 1	$F=0.772$, df = 3, $P=0.520$
Blood glucose (mmol L^{-1})	2.9 ± 0.1	12.2 ± 0.8	11.7 ± 1.1	11.4 ± 1.0	$\chi^2=18.6$, df = 3, $P<0.000$*
Blood lactate (mmol L^{-1})	1.8 ± 0.1	9.4 ± 0.5	10.4 ± 0.5	7.8 ± 0.7	$\chi^2=21.8$, df = 3, $P<0.000$*
pH	7.3 ± 0.1	7.2 ± 0.1	6.9 ± 0.1	7.4 ± 0.1	$\chi^2=10.9$, df = 3, $P=0.012$*

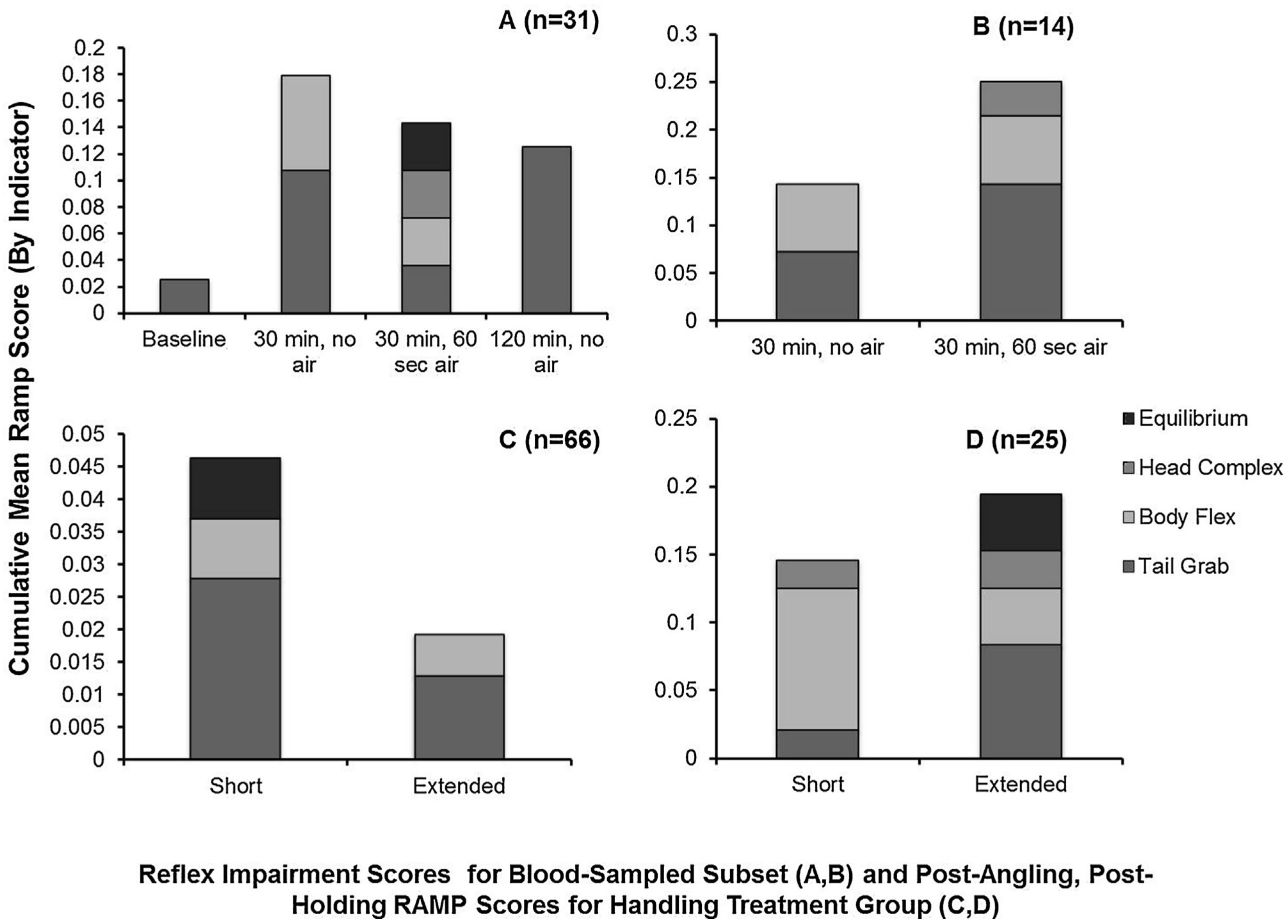

Fig. 2. Mean indicator scores as a proportion of post-angling and post-holding RAMP scores by treatment and timed group. (A) Mean indicator scores as a proportion of mean post-angling RAMP score for blood-sampled subset; (B) mean indicator scores as a proportion of mean post-holding RAMP score for the comparable blood-sampled subsets: 30 min, no air exposure and 30 min, 60 s air exposure; (C) mean indicator scores as a proportion of mean post-angling RAMP score for handling treatment groups; (D) mean indicator scores as a proportion of mean post-holding RAMP score for handling treatment groups.

Table 2
Mean values for total body length, angling time and exposure time and rates of injury, difficult hook removal and mortality per treatment group. Those variables not subject to intentional experimental manipulation are rendered in bold. Unless otherwise noted, all data are presented as mean ± standard error.

Variable	Short treatment ($n=27$)	Extended treatment ($n=39$)	Comparison
Total bodylength (mm)	241 ± 9	273 ± 7	$t=-2.92$, df = 54, $P=0.005$*
Angling time (s)	7.5 ± 0.3	19.3 ± 1.6	$t=-6.68$, df = 55, $P<0.000$*
Exposure time (s)	32.5 ± 0.5	111.4 ± 8.7	$t=-8.90$, df = 40, $P<0.000$*
Injury rate (%)	7%	13%	$\chi^2=0.136$, df = 1, $P=0.712$
Rate of difficult hook removals (%)	0%	8%	$\chi^2=0.379$, df = 1, $P=0.538$
Mortality rate (%)	4%	8%	$\chi^2=0.742$, df = 1, $P=0.389$

Seven of the 66 fish evaluated in the handling treatment group demonstrated signs of angling-related injury: five were categorized as having minor injury and two were described as having moderate injury, resulting in an overall injury rate of 11% (minor injury rate: 8%; moderate injury rate: 3%; major injury rate: 0%; Table 2). Of the seven fish exhibiting injury, three were also categorized as having difficult hook removals and were hooked in areas other than the mouth: throat, top of stomach and gill arch. The remainder of the injured fish, and 93% of all fish angled, were hooked in the upper or lower jaw. None of the injured fish, or those recorded as having difficult hook removals, expired during the course of the assessment.

4. Discussion

Measurements of physiological stress response in angled peacock bass revealed that levels of glucose, lactate and pH in the blood remained elevated from baseline levels 2 h after the angling event regardless of the absence of air exposure, indicating that physiological recovery from C&R angling in peacock bass occurs over a prolonged period (*i.e.*, >2 h). These rapid assessment results are consistent with those from different research techniques used for other species (*e.g.*, bonefish, *A. vulpes*, late season Atlantic salmon, *Salmo salar*) which found that blood lactate required 2–4 h (*A. vulpes*) and 4 h (*S. salar*) to return to baseline levels after exercise and air exposure (Booth et al., 1995; Suski et al., 2007). The indication that lactate levels were beginning to decline towards baseline after 2 h while glucose levels remained elevated, though not significantly different among time groups in this study, was also consistent with physiological responses of other species to angling. For example, Arlinghaus et al. (2009) found that muscle lactate in northern pike (*Esox lucius*) subjected to exercise and air exposure returned to baseline levels in <1 h, while blood glucose levels remained elevated after 6 h.

Angling and air exposure times have also been found to influence the degree of response and rate of recovery in a variety of species (*e.g.*, *Onchorhynchus mykiss*, Cooke and Suski 2005, Ferguson and Tufts 1992; *A.vulpes*, Suski et al., 2007). In a study of largemouth bass (*Micropterus salmoides*), White et al. (2008) noted a significant difference in blood lactate levels in fish subjected to extended angling times (1.35 ± 0.14 mmol L^{-1} at 20 s *vs.* 3.69 ± 0.48 mmol L^{-1} at 180 s) and increased blood glucose levels that correlated with increased air exposure times (up to 10 min). While differences in this study were not statistically significant, mean blood lactate was lower in fish subjected to lower angling times in the 30 min groups and higher in fish subjected to air exposure (9.4 ± 0.5 mmol L^{-1} at 11 ± 4 s with no air exposure *vs.* 10.4 ± 0.5 mmol L^{-1} at 19 ± 8 s with 60 s air exposure). This suggests that, to take a risk averse approach, C&R anglers may assume a heightened stress response based on extended angling times or air exposures.

The number of peacock bass exhibiting reflex impairment (as recorded by RAMP scores) varied among handling treatments and blood-sampled subset, with lower rates of impairment occurring in the post-angling RAMP score for the handling treatment group and blood-sampled subset, and higher rates of impairment occurring in post-holding RAMP scores. The instances of impairment prior to release may have been a result of cage stress in both the handling treatment groups (held in pens overnight) and the blood-sampled subset (held in bags). However, mean post-angling and post-holding RAMP scores for both groups were low, suggesting that even when rates of impairment were higher the severity of impairment remained low. Our results also revealed higher mean RAMP scores in treatment groups subjected to air exposure, but these differences were determined not to be statistically significant overall. Similar studies have reported significantly increased impairment resulting from air exposure (*e.g.*, in *A. vulpes*, Brownscombe et al., 2013).

Variability among RAMP scores were observed in this study, indicating that some measures may be more suitable for determining stressor intensity than others in peacock bass. For example, tail grab and body flex may be more suitable for indicating minor impairment, and may combine with the latter two indicators (equilibrium and head complex) as indicators of moderate or major impairment in peacock bass. In related studies with more instances of mortality (*e.g.*, in Raby et al. (2012), $n_{\text{mort}} = 13$ (26%) for migrating *O. kisutch*; where RAMP scores were significantly higher for unsuccessful migrants), the patterns of indicator prevalence were similar. Raby et al. (2012) also found that tail grab and body flex were the indicators most likely to be recorded as impaired, followed by loss of equilibrium and regular operculum beats. A study by Brownscombe et al. (2013) measuring impairment of *A. vulpes* as a result of air exposure also found the same order of indicator prevalence. This implies that peacock bass anglers can use RAMP measurements to estimate the severity of impairment, and use the results to make decisions on whether to release or retain fish.

During the rapid assessment, five of 97 (5%) fish died: one as a result of post-release bird predation (see Raby et al. (2014) for discussion of post-release predation) following a 30 min holding period in the blood-sampled subset; and, four died during the course of overnight holding in the handling treatment group. All but one of these mortalities occurred in peacock bass that had been air exposed. In a recent study of mortality in *Cichla* spp. targeted for recreational angling in Brazil, Thomé-Souza et al. (2014) calculated mortality rates of 3.5%, 2.5%, and 5.2% for speckled peacock bass, butterfly peacock bass and popoca peacock bass respectively. A study conducted on cichlids of the Zambezi River, nembwe (*Serranochromis robustus)* and threespot tilapia (*Oreochromis andersonii*), found no mortalities resulting from C&R angling in water temperatures of 27–30 °C (Thorstad et al., 2007). While these estimates seem lower compared to the outcomes of this study, it is important to note that mortality studies designed to include air exposure treatments (such as in this rapid assessment) typically have small sample sizes and have been suggested to be subject to inflated estimates (Cooke et al., 2013). Thus, the estimate of 6% mortality for peacock bass targeted by C&R in the summer in Puerto Rico could be considered risk averse if that value were to be used in management models.

Another consideration in analyzing mortality rate estimates is cumulative or interactive effects. Gingerich et al. (2007) found a significant interactive effect between the impacts of air exposure and water temperature on mortality in bluegill (*Lepomis macrochirus*), such that delayed mortality in water temperatures of 27.4 °C increased to 80% for fish exposed to more than four minutes of air. Extended air exposure or air exposure of similar duration in temperatures greater than those in this study (30 ± 1 °C) could result in mortality rates higher than our projected estimates. Finally, intrinsic factors such as fish size and life stage may influence mortality. Of the fish that expired during the course of the study conducted in the Negro River on three peacock bass species, all were <420 mm in length (Thomé-Souza et al., 2014). All peacock bass captured in this study were small, ranging from 140 to 495 mm in TL (all four mortalities occurred in fish <273 mm TL) and most were immature, including all four expired fish. As such, these factors may represent another source of inflation for mortality estimates in this species.

The consequences of C&R mortality on fish populations depend on numerous factors including the abundance and stability of the target populations and the rates of mortality arising from other sources. Holley et al. (2008) found that modelled exploitation rates of *C. temensis* in a fishery subject to recreational and commercial harvest on the Negro River were projected to be similar to instantaneous natural mortality rates (estimated in the model to range from 0.19–0.44), and would result in significantly decreased abundance of large-bodied fish. For a species such as the slow-growing white sturgeon (*Acipenser transmontanus*), it was determined that a fishing mortality rate of even 0.08 would be sufficient to further compromise stock sizes in the Fraser River, B.C., Canada (Walters et al., 2006). While peacock bass are an introduced species in Puerto Rico and are not considered threatened, there is little information currently available on the stock status in Puerto Rican reservoirs and populations are believed to be declining (DNER, 2009). Thus, mortality estimates resulting from this study can serve to guide management decisions regarding the sustainability of current fishing effort and regulations.

Acknowledging the limitations of a rapid assessment is a crucial component of evaluating its potential to act as a tool for eliciting targeted data in a swift, cost-effective manner. A rapid assessment can serve to generate key data that can inform management and act as a tool for guiding future research priorities, but it should not represent the sum total of necessary information, nor should its results be interpreted outside of fishery-specific context. Also, the nature of a rapid assessment (*i.e.,* that it takes place over a limited amount of time) infers challenges in the form of experimental design. Angling studies conducted in the field are often subject to analytical issues arising from small sample sizes (Cooke et al., 2013) and the short time frame during which a rapid assessment occurs increases this risk. Further, the short time frame for a rapid assessment means that results will not be indicative of the full range of environmental conditions (*e.g.,* water temperature). A method for circumventing this concern is to perform the assessment during seasons that exhibit peak values for parameters at issue. For example, where high water temperatures are likely to affect recovery, it is advisable to perform rapid assessments when water temperatures are highest so as to provide a conservative estimate for mortality and/or post-capture effects. In addition, a rapid assessment is not suitable for providing thorough analysis of biological and ecological constraints on the target species outside of the angling event that may yet contribute to the response, such as impacts derived from climate change.

Despite these limitations, the number of data-poor recreational fisheries and number of angled fish species listed as threatened suggests that it is increasingly important to pro-actively manage these recreationally targeted species. By providing managers with estimates of mortality, injury and impairment rates under specific sets of conditions, rapid assessments can be a way to facilitate such pro-active management. Unexpected or extreme results, such as sensitivity to air exposure or high levels of mortality resulting from minor injury may serve to identify and triage priorities for additional study, therefore rapid assessments may also be suitable as a tool for conducting preliminary research on under-studied or previously un-studied target species, allowing fisheries personnel to funnel resources and attention into appropriate avenues. The results of this rapid assessment indicate that while peacock bass are robust to C&R, development of evidence-based, species-specific best practices may serve to further reduce mortality and sub-lethal effects resulting from the angling event.

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