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Short communication

Does lure colour influence catch per unit effort, fish capture size and hooking injury in angled largemouth bass?

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ABSTRACT

The contemporary tackle box for recreational angling is packed with lures that cover the full spectrum of colours with the assumption that colour influences fishing success. Yet, there is little research that identifies how lure colour might influence capture rates or size-selectivity. Moreover, while much is known about the factors that influence hooking injury or hooking depth (which is a good predictor of mortality in released fish), to our knowledge no studies have examined if such factors are influenced by lure colour in fishes. Here we tested the effects of lure colour on catch-per-unit-effort (CPUE), size-selectivity and hooking injury of largemouth bass, *Micropterus salmoides*, using artificial 12.7 cm unscented soft-plastic worms. Lures comprising six colours in three colour categories (i.e., dark – bream 'blue', leech 'black'; natural – cigar 'red', wasp; bright – pearl 'white', sherbert 'orange'), which were individually fished for 20-min intervals multiple times per day. Data analysis revealed that CPUE was similar across individual colours and categories. However, bright colours appeared to selectively capture larger fish than either dark or natural lure colours. Lure colour did not influence length-corrected hooking depth or anatomical hooking location. Our study reveals that while different lure colours might capture the imagination and wallet of the angler, they do not influence CPUE or hooking injury in bass but appear to have a small influence on the size of captured fish.

1. Introduction

Recreational fisheries science has made great strides in understanding how various factors influence the catchability of fish (Anderson and LeRoy Heman, 1969; Ward et al., 2013), the size-selectivity of angling (Arlinghaus et al., 2008), and the factors that influence hooking injury and mortality in angled fish (Bartholomew and Bohnsack, 2005; Cooke and Schramm, 2007). Interestingly, to our knowledge there has been little effort to understand how lure colour influences these factors, which is the focus of this study. The contemporary tackle box for recreational angling is packed with lures that cover the full spectrum of colours with the assumption that colour influences fishing success but this, to a large extent, remains a formally untested hypothesis. Largemouth bass are a popular and intensively managed recreational species targeted by anglers in freshwater lakes and ponds and are frequently targeted by anglers using a diversity of lure colours (Quinn and Paukert, 2009). As such, they serve as an ideal model to explore issues related to lure colour and catchability, size selectivity, and hooking mortality.

Largemouth bass are sight feeders with their vision playing a major role in food consumption (Howick and O'Brien, 1983) and presumably how they interact with fishing lures. Indeed, catch rates of largemouth bass were negatively correlated with turbidity of the water reflecting the impact of vision on feeding behaviour (Kuwamura and Kishimoto, 2002). Experiments involving different coloured pipettes suggest that largemouth bass view colour in a manner similar to a human wearing yellow-tinted glasses. Bass are able to distinguish red, green, yellow, and blue individually but have difficulty distinguishing blue from green (Brown, 1937). An experiment using different coloured lures to examine hooking rates in mackerel, *Pneumatophorus tapeinocephalus*, commercial long line fishing indicated the hooking rates varied by colour, but not significantly (Hsieh et al., 2001). Little research on this topic exists for a recreational fishery. Different fishing gear can also be size-selective (e.g., Jørgensen et al., 2009), although this is often examined in the context of commercial fishing gear and relates to mesh size in nets (e.g., Heino and Godø, 2002). Size-selectivity can also occur in

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recreational fisheries but has typically been examined in the context of lure size (Wilde et al., 2003; Arlinghaus et al., 2008), with little work on lure colour. In one of the few studies of lure colour size-selectivity, Wilde et al. (2003) examined catch rates of largemouth bass using actively fished lures (i.e., stick-bait crankbaits) in four colours and had findings that were equivocal.

In the context of catch-and-release angling, whether done voluntarily or to comply with regulations, some component of the catch does not survive the capture, handling, and release process (Wydoski, 1977; Cooke and Schramm, 2007). Catch-and-release mortality can be acute, generally associated with injury or stress, or come in the form of delayed mortality, which often includes a disease component (Arlinghaus et al., 2007). Of all the potential factors that influence hooking mortality, location of hooking injury is the best determinant of mortality (Bartholomew and Bohnsack, 2005; Muoneke and Childress, 1994), including for largemouth bass (Wilde and Pope, 2008). Shallow hooking locations such as the jaw region tend to have comparatively lower levels of mortality than deeper locations such as the gill or gullet. Generally, the deeper the hook is ingested, the greater the amount of bleeding and the higher the chance of mortality for the released fish (Arlinghaus et al., 2007). Many factors influence deep hooking such as hook type (Cooke and Suski, 2004), type of bait/lure (Bartholomew and Bohnsack, 2005) and size of bait (Wilde et al., 2003; Arlinghaus et al., 2008), but little is known about how lure colour influences deep hooking.

The quality of black bass fisheries are influenced by many factors including the level of fishing pressure and the effectiveness of catch and release programmes, which can either support or undermine the quality of the fisheries as indicated by larger fish size or better catch rates (Cooke and Schramm, 2007). To develop a successful catch and release management strategy it is important to determine how different types of angling gear influence injury and bleeding of fish given that it is a variable anglers can directly control (Cooke and Suski, 2005). We are unaware of any studies that have examined how lure colour, when lure type is standardized and lures are fished rather passively such that fish have time to inspect the lure, influences aspects of catchability, size-selectivity and hooking injury. The purpose of this study was to determine if colour of artificial lures influences such factors in largemouth bass.

2. Methods

2.1. Study site

The study was carried out at Queens University Biological Station on Lake Opinicon in Leeds and Grenville United Counties, Ontario. Lake Opinicon is a shallow mesotrophic lake with significant littoral habitat characterized by abundant macrophytes (Keast and Fox, 1992). The fish community is centrarchid-dominated with reasonable populations of largemouth bass that are targeted by resident and visiting anglers. The experiment was conducted from July 28 until August 13, 2014 when water temperature was stable at 26 °C (Fig. 1).

2.2. Sampling procedure

Largemouth bass were caught using artificial 12.7 cm unscented soft-plastic worms in six colours representing three colour categories (i.e., dark – leech 'black', bream 'blue'; natural – cigar 'red', wasp; bright – sherbert 'orange', pearl 'white'); a medium-action spinning rod and reel with braided line (6 kg breaking strength), and size 1 octopus hooks. The soft-plastic lures were fished quite passively where they were cast out and left to slowly sink at which time the angler would pick up the slack line and then slowly bring the lure back to the boat. Nearly all fish took the lure

Fig. 1. The six artificial lure worm colours (black, blue, red, wasp, orange, and white) with the accompanying octopus hook used to angle largemouth bass in Lake Opinicon. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

on the fall rather than the retrieve. The anglers ($N = 8$) were considered to be intermediate in experience. Each lure colour was fished for 20-min intervals. Fishing all six colours for a 20-min interval by an individual angler was referred to as a cycle and an entire cycle was completed before a previously fished lure colour was fished again. After a cycle was completed each participating angler started the new cycle with a different lure colour than they had used in the previous cycle. We did not record "angler" or use it as a factor in the analysis because it was randomized and each angler completed entire cycles. Each largemouth bass caught was processed as follows. First, the lure colour and size of the fish (total length in mm) were recorded. Next, hooking depth was measured from the tip of the nose to the location of hook insertion (as per Cooke et al., 2001; mm) and anatomical hooking location was recorded. Hooking locations were standardized by classifying them as shallow or deep; shallow hooking was considered to include upper jaw, lower jaw, and corner, and deep hooking was considered to include; roof, gullet, and tongue. Next we qualitatively assessed bleeding at the hook wound site as being present or absent, if bleeding was present it was classified as (A) 'some bleeding' or (B)'lots of bleeding'. At time of release we assessed whether the fish was able to maintain equilibrium as an indicator of fish condition (Davis, 2010) and as a predictor of post-release mortality (Raby et al., 2012). We also noted any immediate hooking mortality and if the fishing line needed to be cut to release the fish given that the hook placement was too deep to safely remove with pliers.

Largemouth bass were caught from all around Lake Opinicon with a particular focus on littoral areas, with occasional fishing taking place in the deeper pelagic waters near the middle of the lake. Fishing took place each day (rain or shine) and only ceased in the presence of lightning/thunder, with fishing being resumed when the lightning/thunder ceased. Fishing occurred from approximately dawn to dusk each day.

2.3. Data analysis

For all analyses we examined both individual colours (i.e., six) as well as three groups where we categorized lure colour as dark, natural or bright given similarities among several lure colours. Catch per unit effort was determined by finding the sum of the time in minutes spent fishing with each lure colour for each day and dividing the amount of fish caught for each day by the total time in minutes. The resulting value of fish caught per minute was multiplied by 60 to receive the number of fish caught per hour for that day. One-way ANOVA was used to compare CPUE with associated individual and grouped lure colours. One-way ANOVA was performed to examine if there was a relationship between total lengths of fish in mm to the individual and grouped lure colour used for capture. Hooking depth was used as a quantitative proxy for hooking injury, with deeper hooking representing greater chances for mortality and injury. The recorded hooking depth was length-corrected by dividing hooking depth in mm by the total length in mm (as per Cooke et al., 2001). An ANOVA was performed to determine if hooking depth was related to lure colour. Hooking location was used as a qualitative proxy for potential hooking injury and mortality post release. A Pearson's Chi Square test was used to compare hooking location and the individual lure colour and grouped lure colour used for capture. The data collected were analyzed using R statistical environment (R Core Team, 2014) with the rcmdr statistics package interface (Fox, 2005). Significance was assessed at alpha = 0.05 (Fig. 2).

3. Results

Over the study period, 119 largemouth bass were captured ranging in size from 211 mm to 492 mm (n = 25 on blue, 23 on black, 22 on white, 17 on wasp, 16 on orange, and 16 on red). Largemouth bass CPUE was not significantly affected by individual lure colour (F = 1.934, df = 5, p = 0.096). Similarly, when lure colour was grouped by category there was no relationship detected to the CPUE (F = 2.416, df = 2, p = 0.095). There was no difference in the total length of fish captured among the individual lure colours that were tested (F = 1.41, df = 5, p = 0.226). When lure colour was grouped into the dark, natural, and bright categories there was a significant relationship detected between the colour categories and the total length in mm of captured fish (F = 3.341, df = 2, p = 0.039). The bright lure colour category caught fish that were significantly longer (mean total length of 349 mm) than fish captured on the dark (318 mm) and natural (318 mm) colour categories (Fig. 3).

Lure colour did not have a significant effect on length-corrected hooking depth of captured largemouth bass with respect to individual colours (F = 0.857, df = 5, p = 0.51) or when lure colour was grouped by category (F = 1.626, df = 2, p = 0.20). Similarly, there was no relationship between individual lure colour and hooking location (χ^2 = 7.40, df = 5, p = 0.19) or when the lures were grouped by colour (χ^2 = 2.82, df = 2, p = 0.24). Across all the lure colours the most common hooking location was in shallow locations (i.e., the jaw). We observed no initial mortality and orientation reflexes were positive for all fish examined. Of the 119 angled largemouth bass it was necessary to cut the line for 9 of the bass but there was no discernable colour-related trend (i.e., 3 on white, 3 on blue, 2 on wasp, and 1 on black). Minor bleeding occurred with 14 bass and was generally associated with hooking in anatomical locations such as the roof of the mouth. Although insufficient data for statistical analysis, bleeding was more common on the bright colours (i.e., 5 on white, 3 on orange) than on the other colours (i.e., 2 on red, 2 on blue, 1 on black, and 1 on wasp) (Fig. 4).

4. Discussion

Largemouth bass are voracious predators that rely on their vision to discern potential prey and capture it (Howick and O'Brien, 1983; Kuwamura and Kishimoto, 2002). Research has shown that largemouth bass are able to distinguish colours in the visible spectrum with vision similar to that of a human wearing yellow tinted

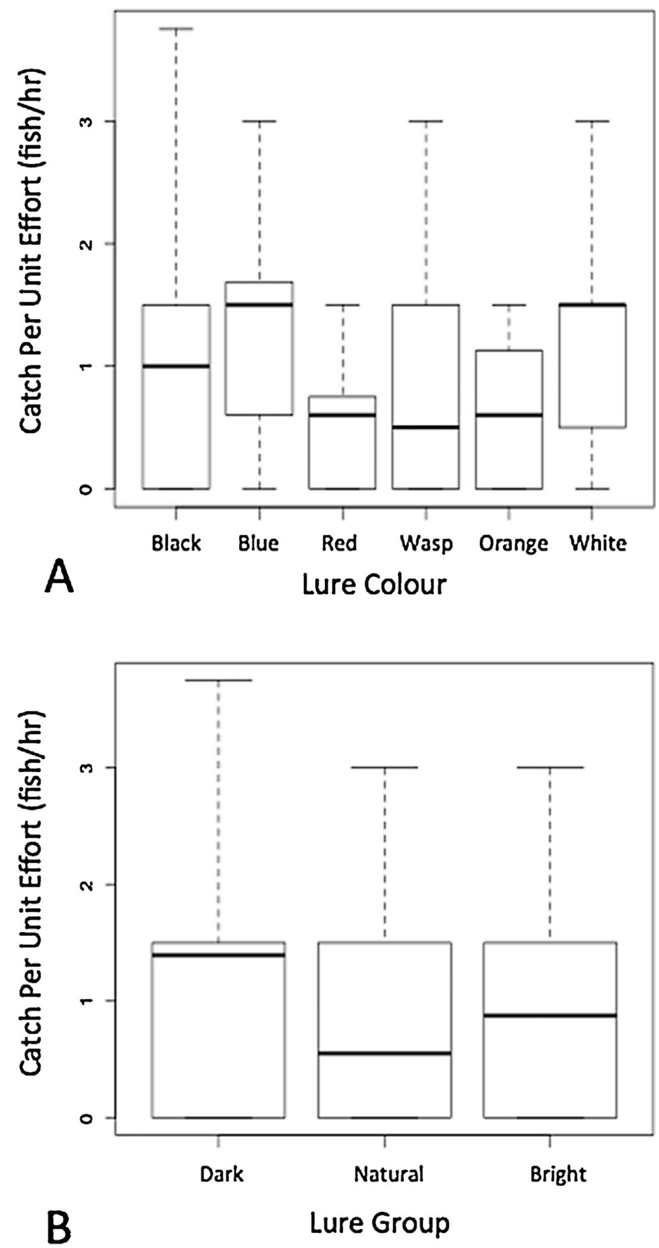

Fig. 2. CPUE for angled largemouth bass from Lake Opinicon. Calculated on an hourly basis per fishing day for the individual lure colour (A) and grouped (B) lure colour.

glasses (Brown, 1937). An experiment performed by Wilde et al. (2003) examined catch rates of largemouth bass by fishing in 30 min intervals with four 89 mm crankbait lures varying in colour pattern; 'blue shiner' blue upper portion with a white underside, 'brown trout' brownish-yellow gradient with black spots, 'fathead minnow' green upper portion with a light yellow-white lower portion separated by a parallel yellow and a black stripe, and 'firetiger' green with black stripes. Wilde et al. (2003) found that catch rates for the firetiger lure were significantly lower than those of the other 3 lure colours, but there was no apparent difference in the catch rates among the lure colour-pattern combinations. Given that crankbaits are actively fished, more so than the soft-plastic worms we used, we would expect that colour might be more meaningful as worms were likely examined more closely by fish given the slower retrieval and near-passive fishing approach. However, our findings were consistent with the results of Wilde et al. (2003) suggesting that lure colour plays little if any role in CPUE, at least

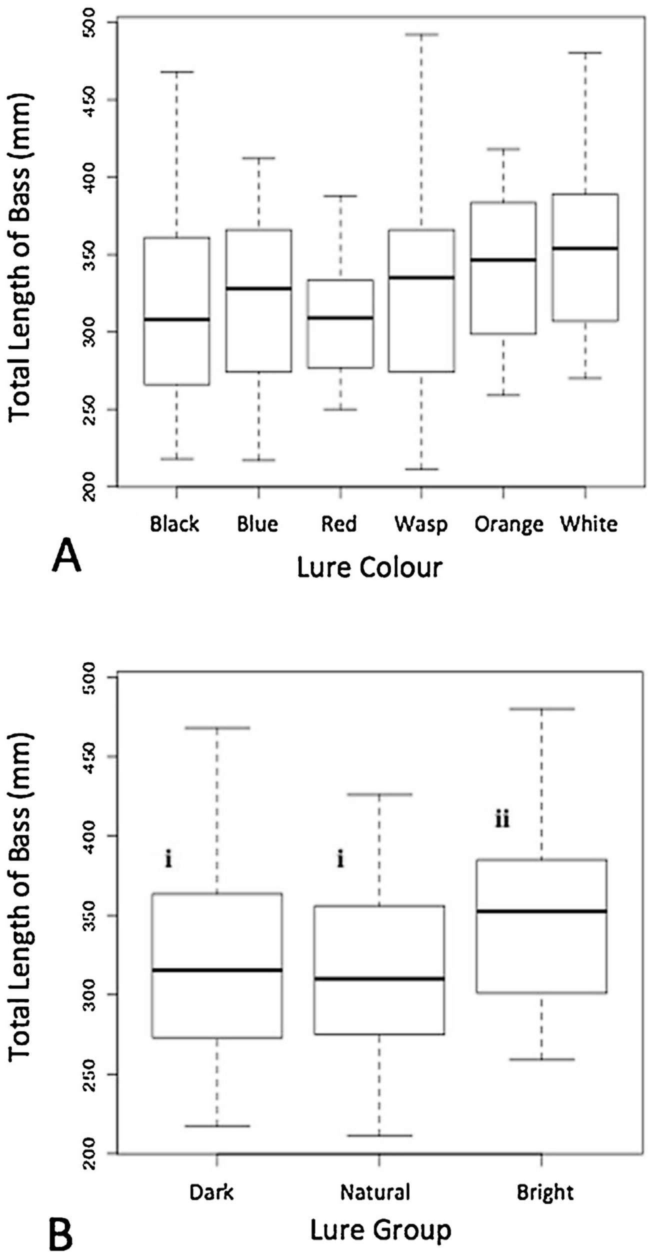

Fig. 3. Total length (in mm) of angled largemouth bass from Lake Opinicon and the respective lure colours used for capture, individually (A) and grouped (B) lure colour; bright lures (i) angled significantly longer largemouth bass than did dark (ii) or natural (ii) lure colours.

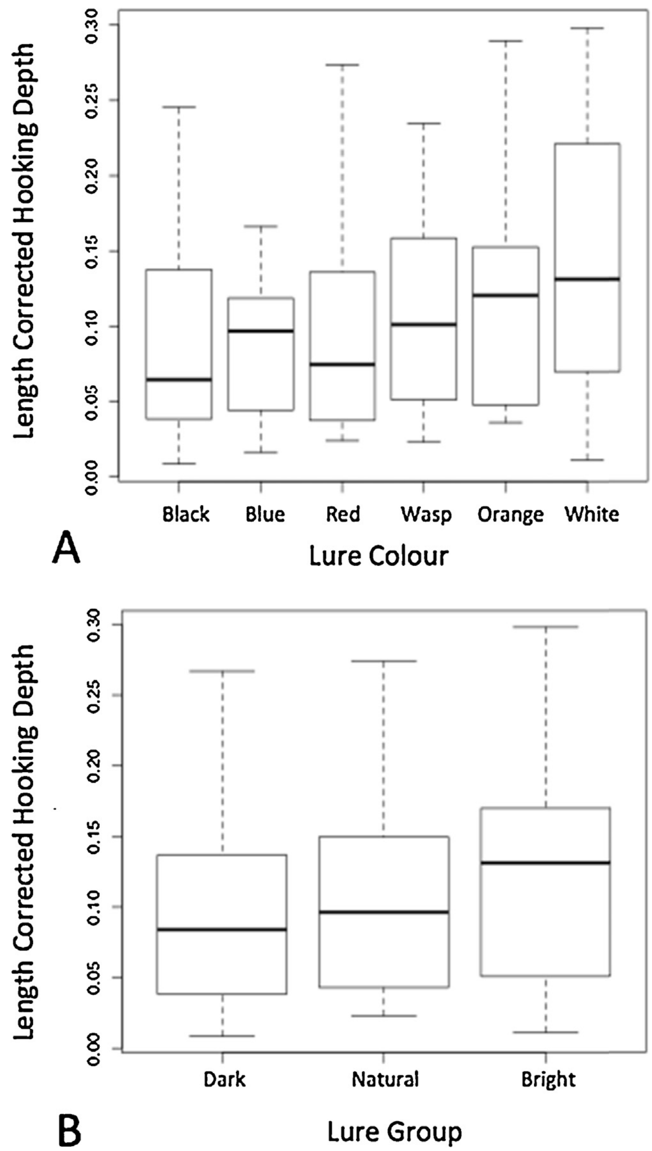

Fig. 4. Length-corrected hooking depth, calculated by dividing hooking depth by total length of the fish, with individual lure colour (A) and grouped (B) lure colour.

for largemouth bass irrespective if lures are fished actively (as per Wilde et al., 2003) or passively (this study).

Research suggests that lure colour is not a significant factor determining catch rates in mackerel long line fisheries when lure type is standardized (Hsieh et al., 2001). A study performed by Hsieh et al. (2001) examined different lure colours, in the form of PVC cloths applied to hooks, in mackerel long line fishing to determine if there was a difference in the catch rates among the lure colours. The lure colours used were transparent, purple, blue, white, pink, yellow-orange, reddish-orange, yellow-green, and black. There were statistically significant differences in the catch rates for; the transparent lure when compared to the catch rates of all other tested lures except the purple lure, the purple lure when compared to the catch rates of all the other colours except the blue lure, and the blue lure compared to the catch rates found for the red and black lures. The transparent lure was treated as a control given that no colour was present and had expectedly the lowest catch rates. There were no statistically significant differences detected in the catch rates amongst the remaining lures. The results of Hsieh et al. (2001) are consistent with the results obtained in this experiment, which reflect that lure colour does not significantly impact catch per unit effort when comparing lure colours used in common between the two studies. Unlike the Hsieh et al. (2001) study, our research found no difference between the catch per unit effort of the blue lure compared to the other lure colours. This could be due to the fact that the blue lure used in this study consisted of a bilateral blue and black pattern, given that black was significantly different from blue with regard to catch per unit effort (Hsieh et al., 2001) its presence might mitigate the effect of the blue in the lure (Fig. 5).

Christensen and Moore (2007) examined prey selectivity of largemouth bass functional feeding groups through ontogeny measured as total length of fish in mm. The authors separated the bass into 4 size groups with smallest at <100 mm, small 100–199 mm, medium 200–299, and large >300 mm and demonstrated that functional feeding groups were structured by total length of the bass.

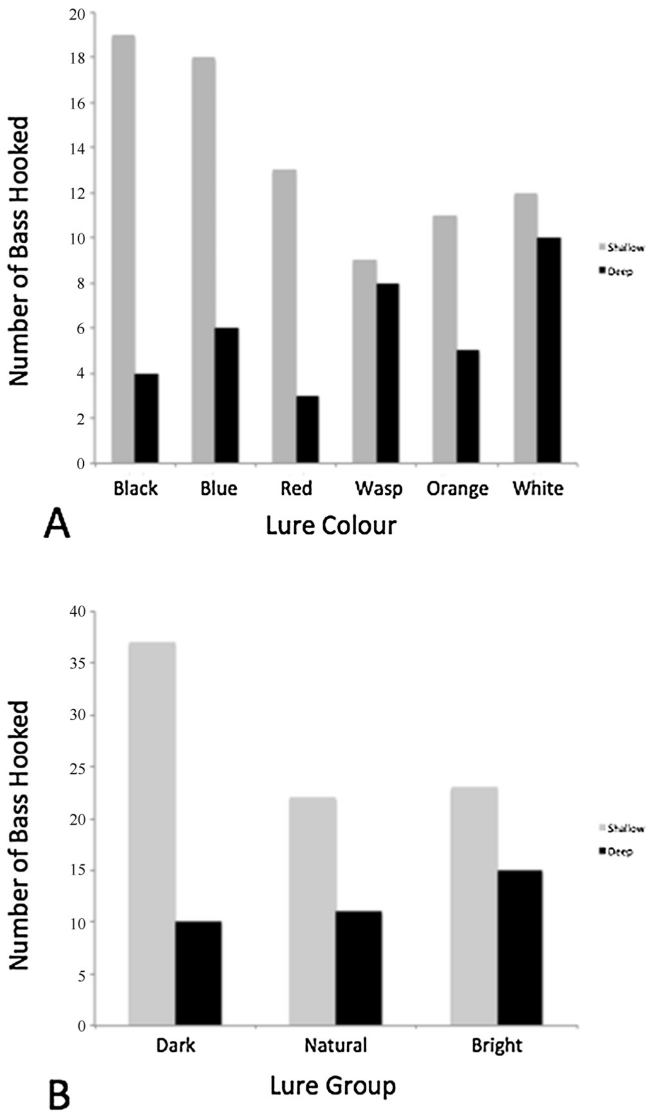

Fig. 5. Number of bass that were considered to be shallow and deep hooking events for individual (A) and grouped (B) lure colour.

Smaller bass (200–299 mm) consumed mostly macroinvertebrates, crawfish, *Decopoda*, and golden shiner, *Notemigonus crysoleucus*, whereas larger bass (>300 mm) focused primarily on golden shiner and transitioned exclusively to piscivory. Golden shiners have orange undersides and shiny upper bodies, which could appear white. In our study bright lure colours, orange and white, had a significant relationship with the total length of fish in mm. It is possible that like bass in the Christensen and Moore (2007) experiment, largemouth bass in Lake Opinicon have functional feeding groups structured by total length. The dark; black and blue, and wild; wasp and red, lure colour groups did not have a significant difference from one another in terms of total length of the fish caught; this could be because the functional feeding group of smaller bass (200–299 mm), as suggested by Christensen and Moore (2007), mostly consists of macroinvertebrates and crawfish that often have brown, red, and blue colouring.

Survival of captured and released fish is influenced by several factors such as hooking location, hooking depth, air exposure, and handling time (reviewed in Cooke and Suski, 2005; Arlinghaus et al., 2007). In the present study lure colour did not influence anatomical hooking location or length-corrected hooking depth. Relatedly, incidences of deep hooking such that the line needed to be cut were generally low with no apparent trends among colours. In centrarchids, deep hooks have been documented to be expelled after short periods (several days) with mortality much lower than if deeply placed hooks are removed (Fobert et al., 2009). Anatomical hooking location is generally regarded as the strongest predictor of post-release survival in a variety of species (Bartholomew and Bohnsack, 2005) including largemouth bass (Wilde and Pope, 2008). Hence, our study provides rather compelling evidence that lure colour used when fishing passively for bass has little bearing on hooking mortality. There was some anecdotal evidence of greater bleeding in bass captured on brighter coloured lures but the level of bleeding was minor and the sample sizes were sufficiently low that statistical analysis was not appropriate. The bleeding tended to be associated with hooks in the roof of the mouth, which is not considered to be an area prone to lethal injury. As such, lure colour does not appear to be an important factor with regard to hooking injury or presumably mortality. Indeed, no immediate mortality was observed for any fish captured in this study nor was the orientation reflex impaired for any fish again emphasizing that the fish were in uniformly good condition at time of release.

We present one of the first studies to evaluate the role of lure colour on CPUE, size-selectivity and hooking injury of an important recreational sportsfish. Our study reveals that while different lure colours might capture the imagination and wallet of the angler, they do not influence CPUE or hooking injury in bass but appear to have a small influence on the size of captured fish. As such, it is unlikely that there is any management value in regulating lure colour. Nonetheless, we expect that anglers will continue to experiment with different colours of lures in their quest for the most and biggest fish. Of course, we only presented findings from a single species and lake so there is ample scope for asking similar questions in other systems.

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