**Behavioral adaptations to artificial and natural baits after catch-and-release fishing in Bluegill (*Lepomis macrochirus*)**

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ABSTRACT

As catch-and-release fishing becomes increasingly more important and popular within the fishing and conservation industries, it is important to understand the behavioral responses that fish may exhibit when caught and released back into their habitat. This includes adaptations such as hook-shyness to both artificial and natural baits. Most anglers would like lures that will increase their catch rates and therefore examining hook-shyness in both techniques is crucial because while it is important to understand how quickly fish can react to these new regulations, it is also necessary to consider if hook avoidance is developed quicker with artificial lures. In the present study, Bluegill fish, *Lepomis macrochirus,* were angled in a controlled lab setting. Although there was no significant difference between the two techniques, trial number did have a significant effect on bite numbers, suggesting that fish do exhibit hook-shyness over time. In addition to examining behaviors to lures, the latency to approach a novel object was also observed. Fish were presented with a Lego and attention paid was recorded. It was found that non-angled fish paid significantly more attention to the novel object than angled fish. Also, as trial number increased, the fish paid significantly less attention. These findings pave way for a clear and better understanding of fish behavior after being exposed to catch-and-release fishing.

INTRODUCTION

Whether it be fishing for sustenance dating back roughly 40,000 years or our current era, where fishing can be developed as a hobby or sport, being successful and increasing the catch rate has always been the main goal of angling. Due to increasing efforts to conserve fish and preserve aquatic wildlife, catch-and-release regulations have become more common. As the popularity of fishing continues to grow, the angling media will increase its efforts to try and create lures that boost fishermen catches. Because more fishermen are having to abide by these restrictions, they would benefit most by using lures that fish have not learned to avoid through consistent fishing. Anglers use lures that can be roughly organized into two categories, natural baits which include live organisms such as worms or minnows, and artificial lures such as crankbaits, spoons, etc. are known to come in bright and flashy colors as well as be much more extravagant in comparison to simple natural baits. Currently, not much is known about whether or not these baits actually increase catch rates (Arlinghaus et al. 2017) or decrease the chances of hook avoidance. In addition to this, it is thought that fish may adopt a habit of hook avoidance to artificial baits more quickly than they would to natural baits. Regardless of lure type, it has become increasingly important to monitor reactions and adaptions to prolonged exposure of catch-and-release fishing. There are of course, studies looking at other factors that could potentially affect angling; for example, there is substantial evidence indicating that boldness in fish is associated with anti-predator defenses (Toms et al. 2010). It is known that an increase in angling pressure can decrease catch rates, meaning that it is important to know how catch-and-release fishing can affect this and also how specific lures can affect this rate of decrease in catches as well (Phillip et al. 2009). This lack in knowledge regarding the real consequences of these regulations calls for more research comparing the responses of fish to both types of lures.

Catch-and-release fishing regulations in popular recreational fisheries are successful in conserving the population and biodiversity of the fishery but can also potentially decrease catch rates due to a change in fish behavior to avoid predation (Askey et al. 2006). Studies looking at both temperate and tropical locations suggest that fish behavior can be changed as a direct response to fishing (Januchowski-Hartly et al. 2013). Therefore, examining fish response plays a significant role in determining limits and moderating the impact of fishing on wild populations, as it affects the vulnerability to these animals to fishing gear (Alos et al. 2015). If lakes and coastal regions are not well monitored, the over exploitation of fishes in these populations can affect biodiversity and also entire ecosystems (Cooke & Schramm 2007). Many studies have examined behavioral responses to different stimuli in order to observe fish boldness, such as latency to approach objects other than lures or angling gear. Some have looked at how the latency to approach another fish may change between active and slow fish, finding that those fish that are more active entered the subject area and approached the new fish quicker and with a short latency when compared to the slow and less active fish (Budaev et al. 1999). A similar observation of latency can create a better understanding for what is causing the behavioral changes in regard to bait type. As seen in previous projects, latency to approach can change significantly depending on the conditions. In a study done by Frost and colleagues (2006), individual Rainbow Trout (*Oncorhynchus mykiss*) changed their approach behaviors to novel objects depending on their success rates during fights, with losers increasing latency and winners decreasing latency. With all of the considerations when monitoring behavioral responses including bait type, bait size, etc., it is integral to determine if their reactions are exclusive to fishing gear. Use of latency can determine if observed responses are limited to the gear used or if they are universal to all objects presented to the fish. Anxiety and fear may both play a large part in increasing or decreasing the likelihood to approach an unfamiliar object. For example, angling fish can cause a development of pain-specific fear and avoidance behavior (Sneddon et al. 2003). In the present study, both responses to angling gear as well as novel objects were observed. It was predicted that over time, Bluegill will have less of a behavioral response to natural baits in comparison to artificial lures. In regard to the latency of approach, it was hypothesized that previously angled Bluegill will have a longer latency to approach a novel object while those that have not experienced angling will have a shorter latency.

METHODS

*Experimental procedure*

For this study, a total of 40 Bluegill were caught in Bay Lake on the property of the University of Notre Dame Environmental Research Center (N 46.240600, W -89.499381). To accurately examine and monitor the behaviors of these fish, they were placed and kept inside of mesocosms. With a total of 10 mesocosms, 5 were treated as controls and 5 treated with angling. For the analysis of behaviors between artificial and natural lures, Cubby Mini-Mites were used to examine reactions to artificial lures and the natural baits included worms caught on the property and placed on a plain metal hook. In order to measure avoidance over time, the amount of strikes was recorded rather than whether or not the fish was caught. This is due to possible human error in angling that would potentially affect the final interpretation of the data. Before beginning trials, each fish in the tanks was tagged in order to be able to identify them in the future. The fish were on a consistent feeding schedule which included two days of being fed and two days of being starved before starting the trials. Every trial day consisted of fishing in each of the 5 tanks counting every strike and catch done within 15 minutes. The treatment given to each tank was random, meaning that some days all were treated with natural bait or artificial bait, while some days it included 2 treated one way while 3 were treated with the other. A total of 9 trials were done on all 5 tanks.

To be able to measure latency of approach, an object novel to the fish needed to be used. In the present study, a pink Lego piece was placed on a string with an attached metal sinker to keep the Lego from floating. A ruler was sent at the bottom of the tank and 5 minutes were allotted to let the fish get acclimated to its presence. Once the time had passed, the Lego was placed into the water. The overall amount of time spent paying attention and contemplating approaching to Lego was recorded as well as the time it took for a fish to get within 5 cm of the Lego and the time spent within the 5 cm.

*Statistical analysis*

Data were analyzed in RStudio by using an analysis of covariance (ANCOVA) for both the bait comparison and latency to approach analyses.

RESULTS

An ANCOVA test was run to compare number of bites on a lure by Bluegill to tank treatment and trial number. Results of that test indicate that trial number had a significant effect (p=0.003) while treatment did not (p=0.945). For the ANCOVA comparing the amount of attention given to the Lego, the both tank treatment (p=0.003) and trial number (p=0.138) did have a significant effect. The ANCOVA testing time to enter the 5 cm to treatment (p=0.958) and trial number (p=0.695) showed that neither had a significant effect. When running an ANCOVA on the time spent inside of the 5 cm similar results were found with both treatment (p=0.819) and trail number (p=0.568) being insignificant.

DISCUSSION

It was previously predicted that over time, Bluegill would have a less significant behavioral response to the natural bait than to the artificial lures. Overall, the type of lure did not have an effect on whether or not the fish became hook shy (Figure 1). Although, the fish did show significant behavior of hook-shyness as it was found that trial number did affect the number of strikes. During the initial analyzation of data, it was found that every individual fish that was treated with angling was caught at least once. When each fish was caught, their length and mass were both measured in order to collect data for another study. Because of this, whenever the fish was caught, it spent an extended period of time outside of its tank rather than simply removing the hook and placing them back in. This could have played a large role in the quick development of hook-shyness as they were exposed to a more elongated and traumatic time when caught which may have cause them to change their behavior in short amount of time. A substantial portion of the fish we angled had small scars or bumps on their mouths that appeared during the first few trials and never disappeared. These physical injuries and scars can also be a probable cause for our Bluegill to have developed an anti-predator defense. The two types of bait used did not differ in the frequency of strikes. This could be due to the fact these fish were kept on a diet of beef liver and food pellets. It is possible that they learned to avoid eating anything that was not part of their usual diet. This potential cause is supported by the novel object trials that were performed as well.

For the latency to approach trials, it was hypothesized that the angled fish would have a longer latency to approach the novel object, while those that were not would have shorter latency. While treatment did not affect the time that it took for the Bluegill to approach the object at 5 cm, it did affect the amount of time they paid attention to the Lego. The non-angled fish spent significantly more time paying attention and contemplating approach to the object, while the angled fish did not pay as much attention or simply did not care to look at all (Figure 2). This is likely caused by fish adopting a habit of not eating, and in this case not approaching, any object that isn’t a part of their everyday diet. While the non-angled fish did pay more attention to the Lego, it was also found that there was an overall significant decrease in time spent paying attention as the trials went on (Figure 3). This finding then suggests that the behavioral adaptations observed during the first part of the study are not limited to fishing gear and can be developed for any object over time. Although there were a number of useful findings in this study, it is important to know that there were a few drawbacks to our experimental design. One of the most noticeable problems was the clear hierarchy in each tank. Even though each tank had a total of 4 fish, it seemed that each had one fish that dominated the rest; therefore, sometimes only one fish was effectively being tested for the trial because the rest would not want to strike. If this were to be done again, it would be wise to separate the fish during the trials to prevent this from happening. Problems such as this could have had an effect in the data and caused a problem in its final interpretation.

Findings such as the ones seen here are an integral start to becoming aware of how catch-and-release regulations may be changing animal behaviors. The habits adopted here for predator defense are a few of the repercussions that can be seen from consistent catches and releases. Because this experiment was done in a limited amount of time with a limited amount of space and test subjects, it is possible that more behavioral responses could be found with a larger scale study. Therefore, this study suggests further research in the field to better understand the effects of catch-and release-fishing.

FIGURES

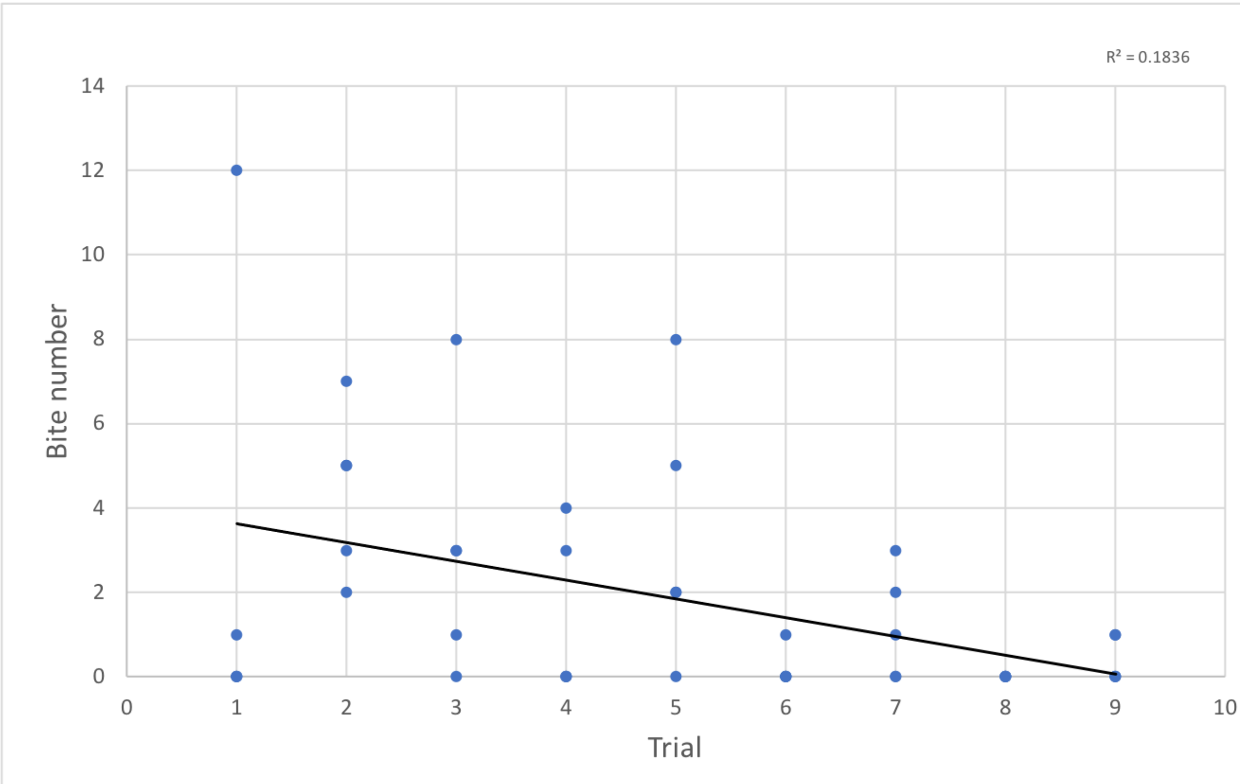


**Figure 1. Bite Number VS Trial Number.**
An ACOVA test comparing bite number and trial number found that there is significant difference in bite numbers as the trial number increases (Df= 1, F value= 0.0047, p= 0.003295).

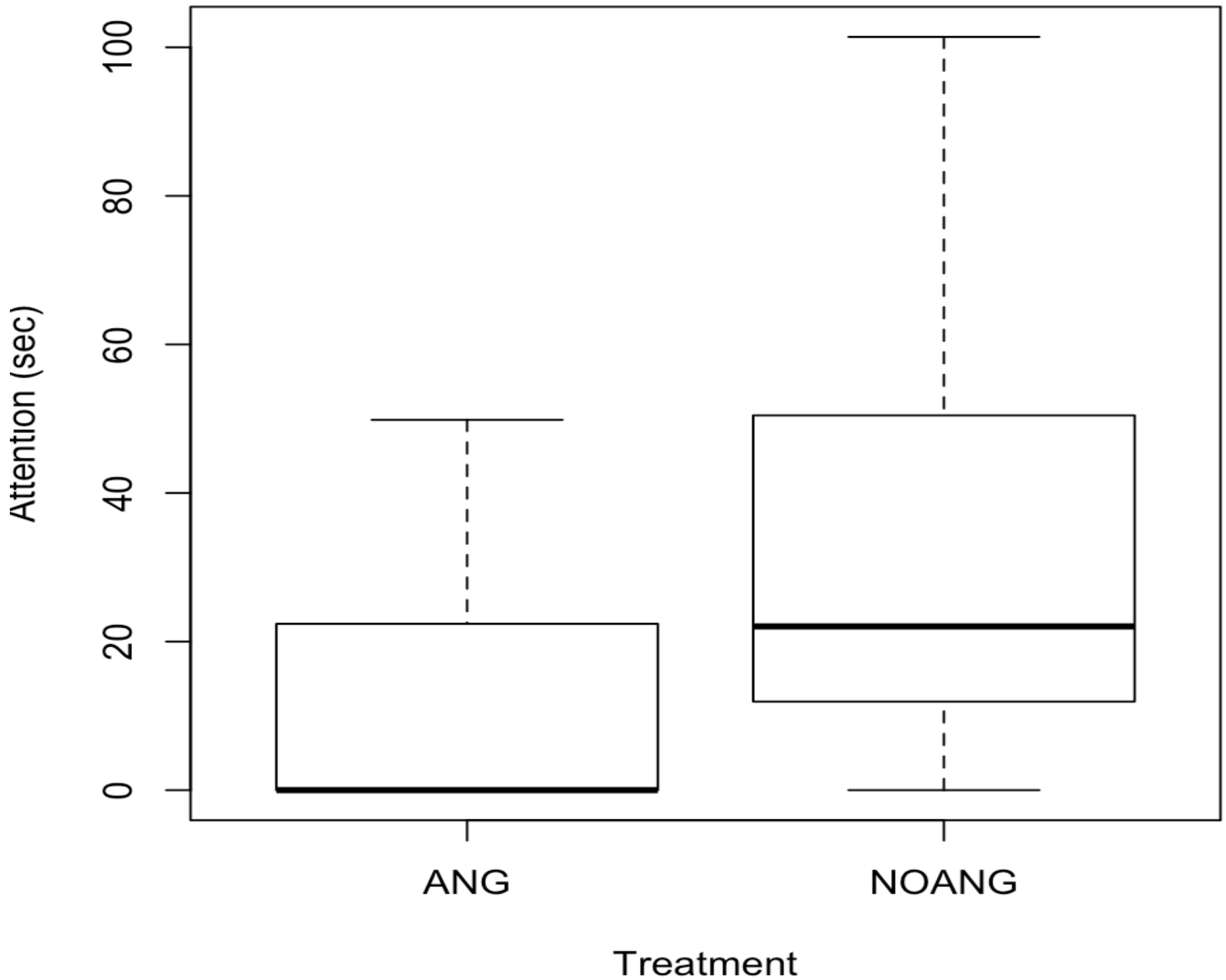


**Figure 2. Attention VS Tank Treatment of Angled and Non-angled.**
An ANCOVA test comparing time spent paying attention to a novel object of both angled and non-angled tanks found a significant difference between the two
(Df= 1, F value= 9.7652, p=0.003045).

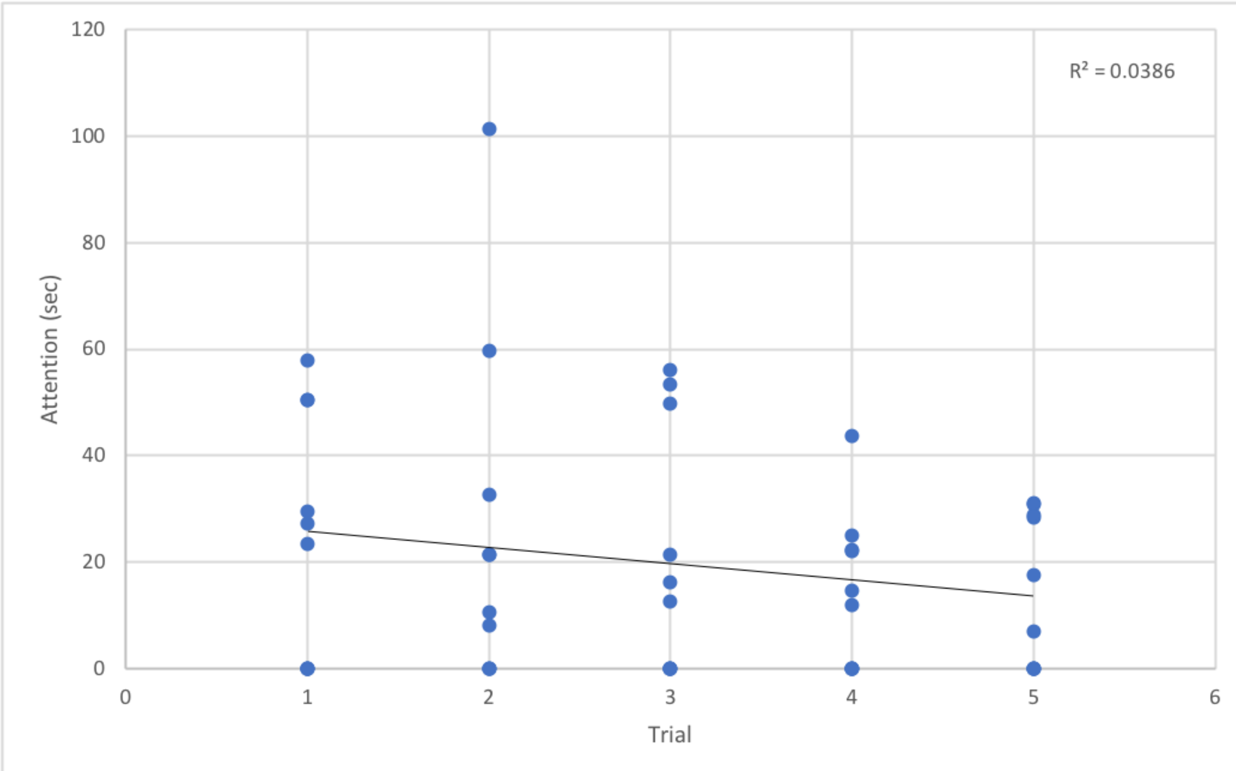


**Figure 3. Attention VS Trial Number.**
An ANOCVA test comparing time spent paying attention to a novel object and trial number found a significant difference in seconds spent as trial number increases
(Df= 1, F value= 2.2807, p=0.137690).

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