Sub-lethal Effects of Repeated Catch and Release Angling on Bluegill (*Lepomis macrochirus*)

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Abstract

Catch and release fishing is often used as a way to reduce the impact of angling on fish populations in recreational fisheries. There is some evidence, however, that suggests that catch and release angling practices have negative impacts on the fish populations. This experiment was aimed at understanding the effect of catch and release angling practices on bluegill fish populations. This was done using mesocosms broken into two treatment levels, some fish populations were subjected to angling and left others unfished. After the study, the masses of the bluegill populations were compared to their pre-experiment masses to assess their growth rates. The result of the experiment showed that angling pressure altered foraging behavior in fish, causing them to lose weight. This suggests that catch and release fishing has negative effects on the health of fish populations.

Introduction

Recreational fisheries are becoming increasingly recognized for their economic and socio-cultural importance. Globally, recreational fisheries contribute billions of dollars to the world economy, providing thousands of full-time jobs for guides, conservation wardens, and bait and tackle manufacturers (Arlinghaus et al., 2017). A 2015 estimate placed the number of recreational anglers at over 750 million (Arlinghaus et al. 2015a). The high participation rates of fishing points to its important role in society and culture, providing a rewarding hobby for many people.

Much of the value of recreational fishing stems from the joy that it brings to anglers. Many anglers enjoy fishing because it allows them to spend time in nature (Arlinghaus et al., 2017). Anglers tend to rate the overall quality of their experience based on their catch rates and the size of the fish that they caught, putting pressure on fisheries managers to maintain healthy fish populations and high catch rates for anglers (Kuparinen et al., 2010). To accomplish this, many wardens opt to stock lakes and ponds with commercially raised fish, but this can present a host of problems such as invasive species, diseases, and genetic mutations to the native fish populations (Johnson et al., 2009; Cowx et al., 2010; Laikre et al.,2010; van Poorten et al., 2011; Lorenzen et al., 2012). Ideally, fisheries managers would be able to institute practices to promote sustainable native fish populations without stocking, but with many current management policies this is often not possible. In catch and release fisheries, this phenomenon is largely attributed to learned hook avoidance, suggesting that high angling pressures impact fish behavior (Sneddon 2003).

Because of the large number of active anglers, recreational fishery management is required to prevent the extirpation of fish populations from lakes and streams. Past failures to regulate recreational fisheries have resulted in significant changes in genetic variation of fish populations and the removal of fish species from certain fisheries (Lewin et al., 2006; Biro and Post, 2008; Philipp et al.,2009; Saura et al., 2010; Matsumura et al., 2011; Sutter et al., 2012; Alos et al., 2014). To alleviate the negative impacts of overfishing on local fish populations, many fisheries enforce bag and size limits, which allows many fish to be returned to the water after being caught. These measures have proven to be effective in both improving the health of the native fish populations and increasing the size of some fish species (Rypel 2015). Other fisheries adopt strict catch and release policies aimed at protecting certain fish species while still allowing anglers to recreate (Sneddon 2003). As it has historically been viewed as a harmless practice, few public access lakes and ponds have regulations on catch and release fishing.

Despite this perception, a considerable amount of research suggests that catch and release angling may not be as harmless as many game wardens once thought. The studies discussed above indicate that angling in catch and release fisheries has sublethal effects on fish that can have a serious negative impact on the health of fish populations and aquatic ecosystems. Catch and release fishing has been found to take fish away from their eggs, leaving them unprotected and therefore more vulnerable to predation[CD1][DP2] (Cooke & Schramm 2007). There is also evidence that barbed hooks and other baits inflict physical harm on fish, causing the possibility for debilitating injuries or even death (Cooke & Schramm 2007).

A study on largemouth bass suggested that angling impacts dietary behavior. After being caught, the bass tended to lose weight for about six days, likely due to learned food aversion. After this fasting period, the fish would generally experience a recovery period in which they regained the lost weight. Though this study suggested that fish alter their foraging behavior in response to angling pressure, the researchers concluded that it was not damaging to fish health because of the increased foraging in the recovery period (Cline et al 2012). This study, performed in a lake, had limited ability to closely monitor individual fish, and had no control population with which they could compare the growth rates of the angled fish.

The results of Cline et al. (2012) suggest that the angled fish would be forced to adopt more aggressive foraging behavior in order to compensate for weight loss accrued in the post-angling starvation period. These heightened foraging rates associated with the recovery period could make the fish more susceptible to angling. This would prevent fish from recovering from the initial angling event. A continuation of this cycle could cause severe weight loss and eventual starvation in repeatedly angled fish. This study will examine the effect of intensive fishing pressure on the growth rates of bluegills (*Lepomis macrochirus*) to identify possible differences in growth rates between unfished and angled bluegill populations.

Materials and Methods

Model Organism –L. macrochirus was used in this experiment because they are a small fish more suitable for the available tanks than many other game fish species. As a predominantly carnivorous species, it can reasonably be assumed that *L. macrochirus* exhibits many characteristics commonly seen in other freshwater game fish species (Wilson & Godin, 2009). *L. macrochirus* tend to be aggressive fish and are widely considered to be an easy fish to catch, meaning that they would likely be susceptible to repeated angling over the course of the experiment (Kieffer & Colgan, 1992).

Study Area - All of the fish used in this experiment were caught using artificial baits over a two-week period on Bay Lake at the University of Notre Dame Environmental Research Center (UNDERC) located in the Upper Peninsula (46° 13' 29.688" N, 89° 29' 57.876" W). The fish were then brought to a lab on the UNDERC property where the experiment took place.

Experimental Procedure: Tank Setup - To test the effects of angling on *L. macrochirus* growth, ten 380-gallon tanks were filled to function as lake mesocosms. To maintain high water quality, the tanks were cleaned and the water was replaced on a weekly basis. Small rocks and artificial weeds were placed in the tank to provide some habitat variety for the fish. Two aerators were placed on opposite ends of each tank to oxygenate the water. Four fish were randomly selected to be placed in each tank, giving a total of forty fish. Five tanks were randomly selected to be exposed to angling, leaving the other five as the control tanks. The fish were allowed a one-week acclimation period.

Experimental Procedure: Feeding - The fish were fed on a diet composed of protein-based pellet food supplemented with beef liver. Prior to the experiment, the fish were fed on a daily basis. Once trials started, this feeding schedule was altered to a four-day cycle that incorporated starvation periods to ensure fish were susceptible to angling. On the first day, the fish were starved. On the second and third days, trials were conducted and the fish were fed immediately after trials on the third day. On the fourth day the fish were fed normally. The fish were subjected to five cycles over the course of 20 days before final measurements were taken.

Experimental Procedure: Trials - The caudal fins of the fish were clipped for identification purposes. Prior to the start of the experiment, each fish was weighed and measured. During the trials, each experimental tank was fished for fifteen minutes. Each tank was exposed to one trial of live bait angling and one trial of artificial bait angling during each four-day cycle. During live bait trials, tanks were fished using earthworms on #8 hooks. Artificial bait trials were conducted using 1/8-ounce jigs. Fish were massed and measured upon being caught during the trials. Dead fish were measured and then immediately removed from the tanks to be disposed. At the conclusion of the experiment, all of the fish were netted and measured before being released.

Data Analysis - The differences in mass changes between the control tanks and the angled tanks were analyzed using an ANCOVA and an independent t-test. Mortality rates were compared using a Pearson's Chi-Square test and a health index assessment was completed with a two-sample t-test. RStudio Version 1.1.414 [CD3]was used to run all of the statistical tests and to make the accompanying graphs (R Core Team, 2017).[CD4]

<u>Results</u>

Over the course of the experiment, all twenty of the fish in the angled treatment were caught at least once, 9 of which were caught twice. A comparison of mass change in fish before and after the experiment showed fish in the angling treatment had significantly lower mass accumulation than the tanks with unfished *L. macrochirus* (mean ± SE; Angled, -15.65 ± 3.44; Unfished, .16 ± 1.73, t_8= -4.066, p = 0.0036; Figure 1). The greatest observed change in mass occurred in an angled fish that lost 34 grams, representing 26% of its original body mass. The most growth was measured in a fish left unexposed to angling; it gained 31 grams over the course of the study.

In the unfished tanks, one of the original twenty fish died over the course of the experiment. In the experimental tanks, three out of the original twenty fish died. A chi-square test comparing these mortality rates showed that the difference was not statistically significant ($n = 40$, $df = 1$, $p = .29$). [CD5]

Discussion

The results of this experiment support the hypothesis that exposure to high angling pressure has an adverse effect on growth rates of *L. macrochirus*[CD6]. This is most apparent when looking at the changes in mass over the course of the study for the angled population of fish compared to the unfished population.[CD7] Despite having the same number of feeding opportunities, there was a large difference in the growth rates of the fish. The angled fish were 15.65 grams lighter on average compared to their starting masses whereas the control group was 0.16 grams larger on average compared to their starting masses. Research conducted in conjunction with this study found that angled bluegill became less bold and wary of novel objects introduced into their environment. Furthermore, the number of bites recorded during angling trials declined over the course of the study, further suggesting that fish modified their behavior in response to being angled. This supports the hypothesis that the weight loss observed in the angled bluegills was likely due to a learned avoidance of food caused by the association of foraging with the stresses of angling.[CD8]

Though this study did not show a significant difference in mortality rates between the two treatments, the bluegills subject to angling lost an average of 14.1% of their original body mass. This rate of weight loss would be unsustainable over an extended period of time. It would be interesting to do a similar study over a longer duration of time to see if the observed weight loss would ultimately lead to raised mortality rates or if the fish would adjust to angling and recover lost weight.

The results of this study are limited in that the trials occurred in an artificial habitat where the bluegills were given a foreign food source and confined to a abnormally small habitats. It is possible that the results would have been less extreme in a natural environment, as the fish would have been alleviated of the stress caused by a change in their surroundings. Given the time and resources, it would be worthwhile to conduct a similar experiment using lakes instead of cattle tanks

Ultimately, the findings of this study support the growing body of research that indicates that catch and release fishing practices are not harmless to fish populations. Angling catalyzed changes in bluegill foraging behavior could help explain the decreasing catch rates per unit effort in catch and release fisheries over time (in addition to learned hook avoidance) (Kuparin et al 2010). This study also provides a possible explanation to a recent study that found that high angling pressure has led to the stunted growth of bluegill in Wisconsin's recreational fisheries, and how regulations aimed at decreasing this pressure can help stimulate growth (Rypel 2015).

The biggest shortcoming of this study is that it did not reveal any obvious solutions to maintain healthy fish populations while allowing anglers to continue fishing at the same rate. However, this study does open the door to future studies that could do better to address this issue. One possibility would be to test how seasonal changes in metabolic rates of fish could impact the degree to which angling harms them[CD9]. It is likely that the fish would be most negatively impacted in the summer, when metabolic rates are highest (Kolehmainen 2011). A study confirming this could prompt game wardens to restrict angling on recreational fisheries during times where fish have high metabolic rates.

Another possibility is that different types of bait could have different effects on food aversion in fish. In this study, a combination of artificial and live bait was used in all experimental tanks to try to replicate conventional angling pressure that bluegills are typically subjected to in recreational fisheries. A similar study testing the effects of different bait combinations on fish growth rates could offer potential conservation practices to fishery managers, allowing them to ban certain baits or angling methods.

Recreational fishing is an important pastime, offering both economic and cultural benefits to millions of people annually (Arlinghaus et al., 2017). In order to keep fishing sustainable, it is important to preserve healthy fish populations in recreational fisheries for generations of anglers to come. The current method of overfishing and restocking leads to an increased spread of pathogens and the destruction of natural genetic variation in fish populations (Arlinghaus et al., 2017). To improve conservation efforts, it is important that we advance our understanding of fish responses to angling. Continuing to research fish behavior and the effects of angling could help conservationists and game wardens take positive steps towards securing the futures of our fisheries.

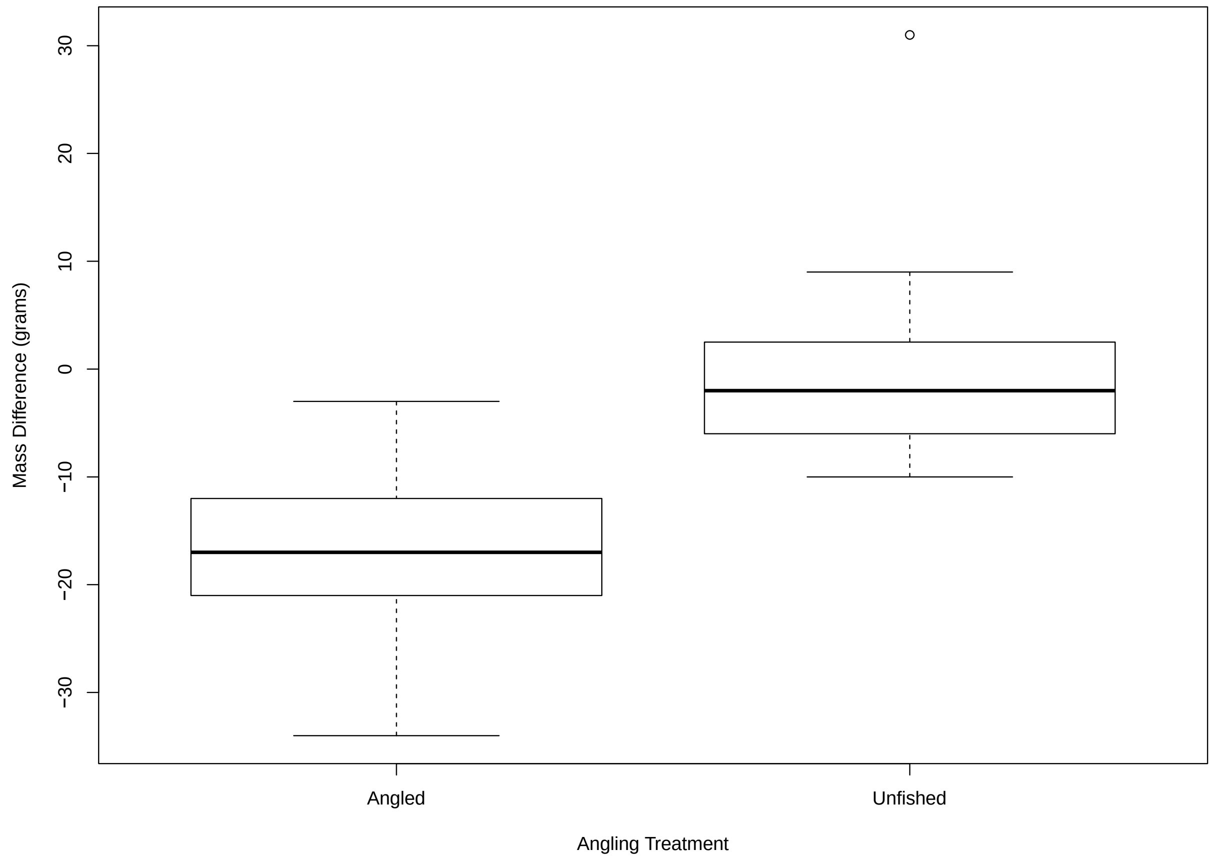

Figure 1: Change in mass of angled and unfished *L. macrochirus* populations (mass, grams). The results of a two-sample t-test reveal a significant difference between the changes in mass for the two populations over the twenty-day trial period, yielding values: $t_8 = -4.0667$ and $p = 0.0036$.

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