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Size structure suppression and obsolete length regulations in recreational fisheries dominated by catch-and-release

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ABSTRACT

Catch-and-release (CR) rates now approach 100% for some fisheries, which may hamper the ability of harvest-oriented fisheries management tools to positively influence population characteristics. In fisheries where CR practices predominate, mortality associated with CR may comprise the majority of all fishing-related mortality and thus impact population characteristics of management concern such as size and age structure. We evaluated the efficacy of length limits and the effects of CR mortality on population size structure in two impoundments. To do so we estimated total Largemouth Bass *Micropterus salmoides* catch over two years via angler creel survey and bass tournament monitoring in two Connecticut impoundments. Each year, catch exceeded the population size by 2–3 times. Harvest was rare, representing 0–1.8% of catch events. Using an equilibrium population model, we identified the harvest rate thresholds below which minimum length limits failed to alter size and age structure. Additionally, we evaluated CR mortality rate thresholds above which size structure was suppressed in simulated populations. Our model revealed that harvest rates in our study fisheries were likely too low for the simulated length limits to alter size structure. However, CR mortality was substantial enough that modulation of population size and age structure was possible. Our model assumed relatively low probabilities of death following CR events, yet even these low CR mortality rates ultimately suppressed size structure by compounding over multiple catch events and seasons. Some traditional management tools, such as length limits, may be ineffective in the catch-and-release era, suggesting the need for creative new approaches to manage CR mortality.

1. Introduction

The concept of catch-and-release (CR) is not new; in the 1930s Lee Wulff suggested in his *Handbook of Freshwater Fishing* that "game fish are too valuable to be captured only once", and the first scientific study of CR mortality concluded that hooking mortality of immature trout was low (Westerman, 1932). Quinn (1989) reported that CR could "recycle" fish and improve fishing quality in some situations. Since that time, trends in voluntary CR angling have increased and spread globally (e.g., Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007; Thomé-Souza et al., 2014; Gupta et al., 2015; Lennox et al., 2015; Taylor et al., 2015). CR rates for some fisheries approach 100% (Quinn, 1996; Cooke and Cowx, 2004; Bartholomew and Bohnsack, 2005), and while the proportion of fish released through CR practices varies substantially by species and geography, many recreational fisheries are now dominated by CR practices. Catch-and-release may be implemented voluntarily as a conservation practice by anglers seeking to reduce their impact on fish populations (Quinn, 1996; Cooke and Suski, 2005; Arlinghaus et al., 2007), or be mandated by regulations (Quinn, 1996; Arlinghaus et al., 2007). For fisheries where CR predominates, due either to regulations or voluntary angler practices, unintentional mortality associated with the hooking and handling of fish that are released may represent the majority of population-wide fishing mortality. Most commonly implemented recreational fisheries management tools were designed to reduce or redirect harvest (e.g., length and slot limits; Radomski et al., 2001; Wilde et al., 2003; Lewin et al., 2006). Such tools may be increasingly, if not already, obsolete for fisheries where most fishing mortality occurs unintentionally (e.g., Pollock and Pine, 2007; Miranda et al., 2017), forcing fisheries scientists to respond to new ecological and social challenges associated with managing recreational fisheries.

Catch-and-release mortality varies substantially among species and is related to a wide range of factors including angler gear, fishing depth, water temperature, fish condition, and reproductive status as well as

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complex interactions among these factors (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Gingerich et al., 2007; Hühn and Arlinghaus, 2011). We herein define "CR mortality" as unintentional mortality of fish caught and released by anglers either voluntarily or in accordance with regulations, and "CR mortality rate" as the probability of mortality resulting from a single capture event. A fundamental challenge for fisheries managers is that, unlike harvest mortality which can be directly observed (e.g., from creel surveys), CR mortality goes largely unobserved (Coggins et al., 2007). However, an increasing body of literature provides recommendations for the study and quantification of CR mortality (Cooke and Schramm, 2007; Pollock and Pine, 2007; Kerns et al., 2012; Ferter et al., 2013).

Recognition of the potential management importance of CR mortality is increasing (e.g., Coggins et al., 2007; Pollock and Pine, 2007; Kerns et al., 2012, 2016). Many studies provide valuable estimates of the CR mortality rates for fish species across a variety of conditions (e.g., Munoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Hühn and Arlinghaus, 2011). Much attention has been given to best practices, methods, and gear to reduce CR mortality rates at the time of capture (e.g., Cooke and Suski, 2005; Bartholomew and Bohnsack, 2005; Hühn and Arlinghaus, 2011; Bergmann et al., 2014; Lennox et al., 2015). Researchers have attempted to estimate the potential magnitude of CR mortality relative to harvest mortality (e.g., Kerns et al., 2016). However, despite increased attention to CR mortality, the implications of the rise in CR fishing for traditional approaches to fisheries management are still not well understood. Kerns et al. (2012) reported that many fisheries professionals consider high CR mortality rates as potentially problematic, but low CR mortality rates are not considered to be of management concern. Few studies have attempted to estimate the cumulative population level effects of CR mortality (but see Pollock and Pine, 2007; Kerns et al., 2015, 2016). However, even low CR mortality rates may result in high population CR mortality and contribute substantially to overall population fishing mortality under the right circumstances, e.g., very high catch rates, or long lived and low productivity species (Bartholomew and Bohnsack, 2005; Muller and Taylor, 2006; Coggins et al., 2007; Hühn and Arlinghaus 2011).

We characterized the Largemouth Bass *Micropterus salmoides* recreational fisheries in two separate impoundments over two open water fishing seasons to better understand the effects of CR mortality on populations of a popular sport fish species. Our study had three primary objectives. The first objective was to estimate the total number of angler catch events in relation to population size in each lake each season. Such data are rarely available, but are important to understand the potential magnitude of CR mortality. The second objective was to use these data in an equilibrium population simulation to estimate the harvest rate at which length limit regulations would no longer affect population size and age structure under a variety of scenarios. Finally, through additional population simulations, we determined the minimum CR mortality rate at which population size and age structure would be altered compared to an unexploited population.

2. Materials and methods

We estimated the total number of catch events and population size of catchable sized (250 mm; Dotson et al., 2013) Largemouth Bass for two Connecticut impoundments, Mansfield Hollow Reservoir (hereafter Mansfield, 186 ha; N 41°46′6.53", W 72°10′31.73") and Gardner Lake (hereafter Gardner, 214 ha; N 41°30′39.66", W 73°13′38.77") for two open water fishing seasons each (Mansfield sampled in 2012 and 2013; Gardner sampled in 2013 and 2014). Both impoundments are mesotrophic systems and popular Largemouth Bass fisheries (Edwards et al., 2004a, 2004b), having averaged over 30 small club tournaments per year since 2000 (Connecticut Department of Energy and Environmental Protection, unpublished data). Both Mansfield and Gardner are managed using a protected slot (305–406 mm), but tournaments are given exemptions allowing for the capture and delayed release of fish over 305 mm. All the tournaments that we monitored used 305 mm as their minimum length. Population estimates of catchable sized Largemouth Bass (250 mm, Dotson et al., 2013) were made for both impoundments during the first year of monitoring using the Schnabel method (Schnabel, 1938) and a multi-lap mark-recapture nighttime electrofishing survey. This survey entailed electrofishing each impoundment's littoral areas for Largemouth Bass. All captured fish were examined for previous marks and if unmarked were given fin clips on their right ventral and anal fins. Three complete laps of each impoundment were conducted. All three laps were conducted within two working weeks to meet assumptions of a closed population. The combination of multiple fin clips, consistent crew members, and short duration between electrofishing efforts minimized the possibility of failing to recognize a marked individual.

Tournament monitoring was combined with creel surveys to estimate the total number of fish captured by anglers in both impoundments for two open water fishing seasons each. The monitoring of Largemouth Bass tournaments provided a direct observation of a substantial number of catch events occurring in each impoundment. The State of Connecticut requires that organized fishing tournaments obtain free permits, and publicly publishes tournament schedules online, which facilitated our efforts to monitor each tournament. At each tournament, we made contact with the tournament director and asked him or her to allow us to examine each fish after normal weigh-in, when tournament activities had been completed. After anglers had completed their weigh-in procedure, fish were brought in bags containing lake water and were placed in covered plastic laundry baskets immersed in the impoundment to await processing. For processing, the entire laundry basket containing fish was moved to a large cooler full of lake water. All fish were measured to the nearest mm total length, examined for clips from previous tournaments (see below), mortality status determined (alive or dead), and were given fin clips that designated the fish as a tournament-captured individual. Fish were then released back into the impoundment. Each angler was also asked how many tournament legal size fish ($>$ 305 mm) had been captured but released prior to weigh in. Anglers often reported releasing a range of fish (e.g. 10–12 fish captured but released prior to weigh in); to ensure that total catch estimates were as conservative as possible, we used the low end of the range for catch estimates. All procedures performed in this study were approved by the University of Connecticut Office of Research Compliance Institutional Animal Care and Use committee under protocol A12-012.

Initial CR mortality for tournament-captured fish was estimated as the proportion of fish that were dead when we examined them compared to the total number of fish captured in tournaments. While this study did not directly estimate delayed mortality, delayed mortality rates were obtained from a recent study of bass tournament anglers conducted on these same systems (Edwards et al., 2004a, 2004b). In their study Edwards et al. (2004a, 2004b) estimated delayed mortality by holding fish captured in tournaments in net pens for 72 h, making observations at 24, and 48 h, respectively. Their study encompassed spring, summer and fall tournaments on the same impoundments studied here.

The Connecticut Department of Energy and Environmental Protection (CT DEEP) Inland Fisheries Division conducted stratified random roving creel surveys at Mansfield and Gardner for both years in which we monitored tournaments. Surveys were stratified by season (spring: 3rd Saturday in April–June 15th, summer: June 16th – September 15th, fall: September 16th – October 31st) and by weekdays, weekend/holidays. During each calendar week, we conducted creel samples on two weekdays and both weekend days. Each sample consisted of an hourly count and incomplete trip angler interviews. The hourly counts were conducted at randomly selected times. Hourly creel counts were used to estimate daily angler effort using the equation: