Development of a Crowded Largemouth Bass Population in a Tropical Reservoir

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Abstract: This case study examines the development of an overcrowded largemouth bass population following initial stocking in a tropical reservoir and efforts to correct crowding with a protected slot length limit. Cerrillos Reservoir is a relatively new impoundment (filled 1996) in Puerto Rico and is one of only two reservoirs that have been stocked exclusively with pure Florida largemouth bass (*Micropterus salmoides floridanus*). Largemouth bass were first stocked in Cerrillos Reservoir in 1997 and the population quickly expanded. Within three years, relative weight declined from above 100 to about 80 and the population displayed characteristics of overcrowding, with much of the population composed of fish ≤ 350 mm. This condition was most likely the result of limited harvest, as angling was not allowed during the first three years of the fishery. In 2000, the reservoir was opened to angling, but access remained limited and unpredictable. A protected slot limit (356–508 mm) was implemented in 2003 to encourage harvest of smaller largemouth bass, to protect the intermediate-sized bass, and allow for occasional harvest of a trophy bass. Population sampling in 2010 indicated that overcrowding persists in Cerrillos Reservoir, with 91% of stock-size largemouth bass less than 400 mm, and 81% of those below the protected slot. The failure of the protected-slot limit in reducing largemouth bass crowding is believed to be due to limited angling pressure and unwillingness of anglers to keep smaller fish. The slot has since been removed and research has begun to address best management strategies for this reservoir.

Key words: population estimate, stockpiling, relative weight, protected slot limit

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Voluntary release of legal-size largemouth bass (*Micropterus salmoides*) has become common practice in recent years (Quinn 1996, Noble 2002, Myers et al. 2008, Willis et al. 2010). Allen et al. (2008) estimated that average fishing mortality rates for largemouth bass throughout most of the United States decreased by nearly half since 1990, likely the result of voluntary release by anglers. This raises concerns among managers that this behavior is reducing the effectiveness of harvest regulations (Bonds et al. 2008), which are one of the primary tools for largemouth bass management (Noble 2002).

Length limits can be used to alter the size structure of targeted species (Gabelhouse 1987, Perry et al. 1995). Largemouth bass are traditionally managed using either a minimum length limit or a protected slot length limit. Minimum length limits are most effective when recruitment is limited and adults must be protected until they have spawned at least once (e.g., Hunt 1974). However, this regulation may not provide any benefit if recruitment is not limited, exploitation is low, growth is slow, or anglers remove sub-legal fish (e.g., Austen and Orth 1988). Protected slot limits usually are designed to take advantage of surplus recruits and to increase growth of mid-sized fish. However, when anglers fail to harvest fish under a protected slot length limit, the regulation becomes ineffective (Noble and Jones 1999).

Failure to adequately harvest largemouth bass populations can lead to an overcrowded population when recruitment is high and stable (Willis et al. 2010). Crowding results when fish densities at a particular size range exceed prey availability for that size range. Consequently, prey consumption decreases and growth slows for that size class. Smaller fish, which can utilize an alternative prey base, grow rapidly until reaching sizes where prey availability is limited. This results in stockpiling of fish at that size class, exacerbating the crowding effect. Few fish escape the bottleneck and grow to larger sizes. While this phenomenon has been well-described for a variety of species in temperate systems (Byrd and Crance 1965, McHugh 1990, Hansen et al. 1998, Olive et al. 2005), it has been less commonly observed for tropical systems. The case study presented here provides an account of the development of a crowded largemouth bass population in a relatively new tropical reservoir. Furthermore, it examines the attempt to remedy the situation using a protected slot length limit.

Study Site

The study was conducted in Puerto Rico, a commonwealth of the United States located to the east of the Dominican Republic and west of the Virgin Islands. Puerto Rico is the smallest and easternmost island of the Greater Antilles and is approximately 180 km long (east to west) and 65 km wide (north to south). Cerrillos Reservoir is a relatively new impoundment located in the mountains northeast of Ponce, Puerto Rico, in the southwestern region of the island. Construction of the reservoir began in 1982 and was completed in 1992, but filling was not completed until 1996.

It is a 249-ha reservoir with mostly steep rocky shorelines and a maximum depth of over 80 m. Cerrillos Reservoir is mostly an oligotrophic system with very low nutrient concentrations (Neal et al. 2010) and no submerged vegetation. The primary purposes for the impoundment are flood control, hydropower, agricultural and drinking water supply, and recreation (USGS 2008), resulting in significant annual fluctuations in water level. Annual fluctuations of 10 m or more in water level are not uncommon in Cerrillos Reservoir. The watershed is mostly comprised of coffee plantations (active and abandoned).

Prey species were stocked in 1996, including threadfin shad (*Dorosoma petenense*), tilapia (*Tilapia* and *Oreochromis* spp.), and redear sunfish (*Lepomis microlophus*). Florida largemouth bass (*M. s. floridanus*) were stocked the following year. From 1997 to 2000, the reservoir was not open to the public for fishing. In 2000 the reservoir was opened three to four days a week, although long periods of closure were common. In 2003, a management station and access facility was constructed at the reservoir, and management biologists from the Puerto Rico Department of Natural and Environmental Resources (DNER) were stationed at the facility to provide reliable access Thursday to Sunday each week. Due to the steep rocky shoreline and surrounding terrain, bank angling is negligible except at the management facility, and most angling occurs in boats.

Methods

The reservoir was sampled twice per year (spring and fall) each year from 1997–2001 using a boom-mounted electrofishing unit set at 60 pulses per second to achieve a current of 7–8 amps DC. Five sampling stations were electrofished for 15 minutes of pedal-down time per site. Sites were selected based on reservoir morphology to yield samples representative of all habitat types. All samples were collected during daylight hours. At each site, all largemouth bass encountered were collected, measured in total length (TL; mm), and weighed (g). Condition was determined on all largemouth bass (≥150 mm TL) using the relative weight (W_r) index (Anderson 1980). Catch per unit of effort (CPUE; in fish/hr) were calculated for all largemouth bass (total CPUE) and stock-size bass (CPUE of fish ≥ 200 mm TL) and used as indices of population density. Proportional size distribution (PSD) was used to describe largemouth bass population size structure within the reservoir.

No sampling occurred in Cerrillos Reservoir between summer 2001 and spring 2010. In spring 2010, intensive largemouth bass population sampling was conducted to determine abundance, biomass, size structure, and condition. The entire shoreline and available off-shore habitats were sampled on 22–25 March 2010 and all largemouth bass collected were measured and weighed, and all fish ≥ 200 mm were marked by clipping the left pelvic fin prior to release.

Marked fish were given sufficient time to reintegrate into the population prior to recapture on 19 April 2010. During the recapture sampling, the entire shoreline and available off-shore habitat was sampled using boat-mounted electrofishing, and all largemouth bass were collected, measured, and examined for marks. The number of stock-size largemouth bass was estimated using Chapman's modification of the Petersen index (Chapman 1951), with a target 95% confidence interval of ± 25% of *N* (Robson and Regier 1964). Estimated population size was multiplied by the mean weight of stock-size largemouth bass to estimate total stock-sized biomass. Furthermore, mark-recapture data were divided into stock, quality, preferred, and memorable size classes as defined by Gablehouse (1984) and population size and biomass were estimated for each size class. Preferred-sized fish were further subdivided into fish in this size class that were above and below the lower slot limit of 356 mm and population and biomass estimates were made to estimate the proportion of the largemouth bass population that was below the slot limit.

Results

Cerrillos Reservoir showed substantial changes in largemouth bass population metrics from the initial stocking until spring 2001 (Figure 1). Largemouth bass were first collected only a few months after the initial stocking of about 20,000 fingerlings in early summer 1997. Catch rates of largemouth bass rapidly increased over the next couple of years, and anecdotal evidence suggested that growth of the initial stocking was rapid, with fish >400 mm TL collected the second year after stocking. Additionally, rapidly increas-

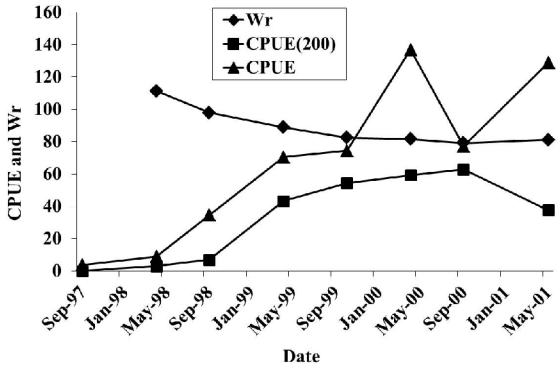

Figure 1. Overall catch-per-unit-effort (CPUE), CPUE of stock-size largemouth bass (200 mm TL or larger), and mean condition (relative weight; N ranged = 5 to 162) of largemouth bass from fall 1997 until spring 2001.

ing values of adult CPUE and presence of juvenile fish showed that successful reproduction was occurring. By April 1999 largemouth bass relative weight was 90 which suggested a balance among largemouth bass prey populations. However, electrofishing catch rates continued to increase, and relative weight continued to decline. By 2000, catch rates of stock-sized largemouth bass had stabilized around 60 fish/h and mean relative weight was stable near 80. The population was displaying characteristics of over- crowding at intermediate sizes, evident from the relationship of relative weight and total length (Figure 2).

Cerrillos Reservoir was opened to fishing in fall 2000. Following the opening of the fishery, the electrofishing catch rates of largemouth bass exceeding 200 mm TL decreased by about 40% (Figure 1). With the cessation of population growth, the declining condition stabilized and even suggested a slight increase. Although only one sample was collected after the fishery was opened, the initial trends suggested potential management through selective harvest. A protective slot length limit of 356–508 mm was implemented in 2003 to encourage harvest of smaller largemouth bass, to protect intermediate fast-growing bass, and to allow for occasional harvest of a trophy fish. This regulation allowed for a liberal harvest of 10 largemouth bass a day, but with the restriction of only one bass >508 mm.

Population sampling in spring 2010 estimated the number of stock-size largemouth bass in Cerrillos Reservoir to be 9790 ± 2053 (± 21%). The data suggested that largemouth bass stockpiling and

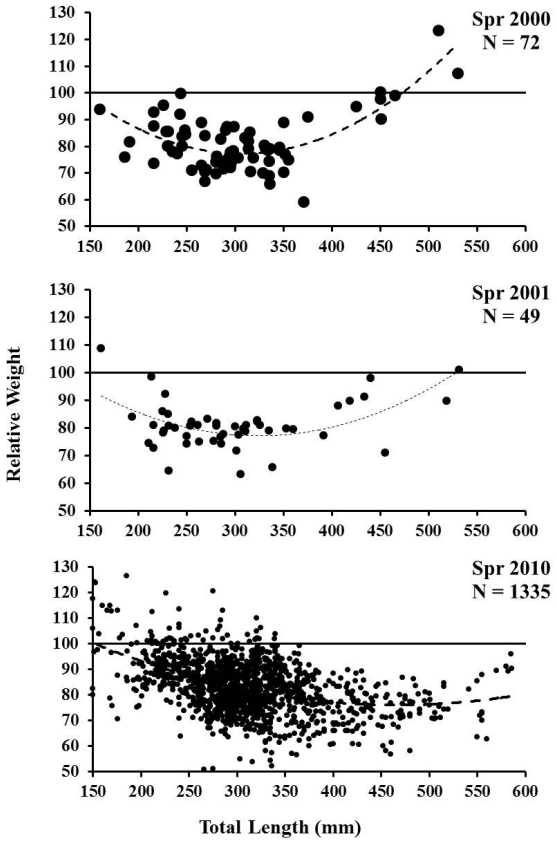

Figure 2. Relative weights for largemouth bass collected in Cerrillos Reservoir during spring 2000, spring 2001 and spring 2010. Dotted line in each graph is polynomial trend line. Solid line indicates optimum relative weight of 100.

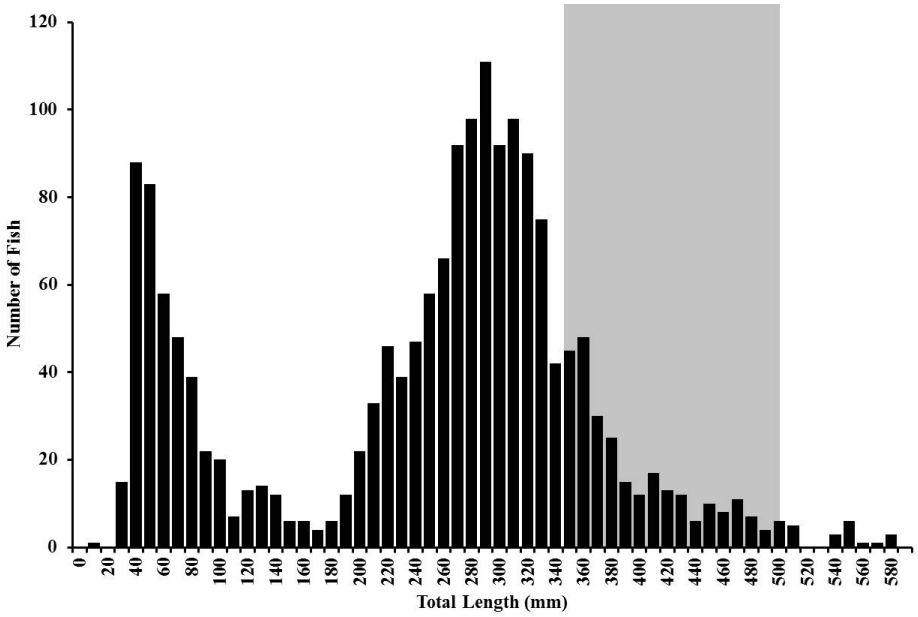

Figure 3. Largemouth bass (N = 1751) length distribution in Cerrillos Reservoir during marking procedures in March 2010. Shaded area indicates protected slot limit 356–508 mm.

crowding was not affected by the protected slot length limit, with 91% of stock-size bass still < 400 mm TL. In fact, 81% of the population was below the protected slot of 356–508 mm and available for harvest (Figure 3). The maximum catch rates of stock-size largemouth bass during the study was 64 ± 5.3 fish/hr, observed in September 2000. Proportional size distribution appeared to increase from spring 2000 to spring 2010; however, PSD-P and PSD-M both remained low over this same time frame (Table 1) indicating a lack of larger fish in the population.

Condition of largemouth bass in Cerrillos Reservoir dropped precipitously upon reaching 200 mm, and only a few fish showed increased condition after reaching 450 mm (Figure 2). Mean relative weight of largemouth bass in Cerrillos Reservoir was lower than that observed in southeastern U.S. waters in all four size classes (Table 2). Total biomass of the entire population was estimated to be 4149 kg, yielding a relative biomass of 16.7 ± 3.5 kg ha^{-1}. Largemouth bass ≤ quality size composed the majority of the biomass in Cerrillos Reservoir (Figure 4), and bass smaller than the protected slot length limit composed 57% of the biomass (Table 3).

Table 1. Proportional size distribution (PSD) of largemouth bass in Cerrillos Reservoir in spring 2000, 2001, and 2010.

Sample period	PSD-Q	PSD-P	PSD-M	PSD-T
Spring 2000	44	10	3	0
Spring 2001	47	17	4	0
Spring 2010	55	13	2	0

Table 2. Mean (±SE) relative weight for each size class (Gabelhouse 1984) of largemouth bass from Cerrillos Reservoir and lakes in the southeast United States (Bonar et al. 2009). NA indicates that no data are available.

Length (mm)	Cerrillos	Southeast US
150–199	96 ± 2.5	NA
200–299	86 ± 0.4	90 ± 1.1
300–379	82 ± 0.4	89 ± 1.1
380–509	75 ± 0.6	93 ± 1.2
510–629	79 ± 2.2	97 ± 2.1
630+	NA	NA

Table 3. Number collected (*n*), mean weight (WT, g), total biomass (TBM, kg), and percent biomass (% BM) by size class (mm, Gabelhouse 1984) of largemouth bass during marking procedures in March 2010. Quality size class is separated into two length classes to indicate fish below (300–355 mm) and within (356–379 mm) the protective slot length limit.

Size class	Stock	Quality		Preferred	Memorable	Trophy
Length (mm)	200	300–355	356–379	380	510	630
n	578	446	94	145	20	0
Mean WT	222.5	406.4	581.6	939.5	2142.1	0
TBM	128.6	181.3	54.7	136.2	42.8	0
% BM	24	33	10	25	8	0

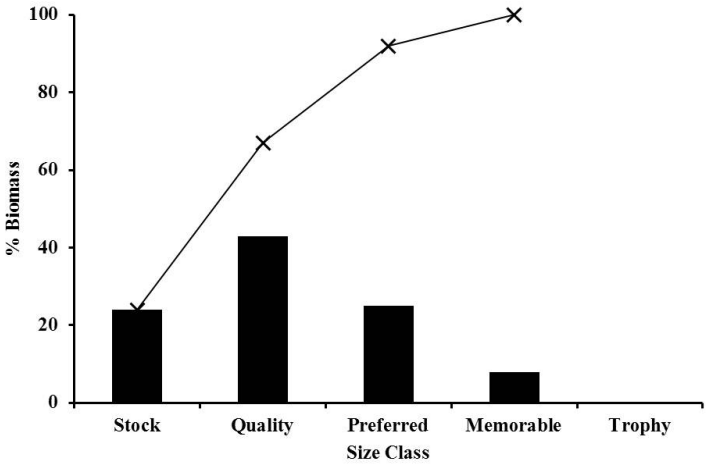

Figure 4. Percent biomass (columns) and cumulative biomass (×) by size class (Gabelhouse 1984) of largemouth bass during marking procedures in March 2010.

Discussion

Largemouth bass have been widely introduced into freshwater systems around the world, including many tropical environments, yet most management models for largemouth bass are designed for temperate areas. Although the knowledge base for largemouth bass management in Puerto Rico reservoirs is expanding (Neal et al. 2002, Waters et al. 2005, Neal and Noble 2006, Neal et al. 2008), many uncertainties still exist. Unlike in temperate regions, tropical largemouth bass grow rapidly and usually reach maturity in less than one year (Gran 1995). Spawning is prolonged up to six months with multiple spawning events (Dadzie and Aloo 1990, Gran 1995), and growth slows as a consequence. Longevity is greatly truncated, with few fish surviving beyond age 3 (Neal and Noble 2006). Thus, reservoirs typically have populations composed of many mid-sized fish and a few trophy fish that, for unknown reasons, somehow defy slow growth or early mortality.

Cerrillos Reservoir does not follow typical population dynamics of other Puerto Rico reservoirs. Instead, the largemouth bass population displays the classic pattern of a stunted bass population common to temperate ponds and lakes. Catch rates of stock-sized bass were considerably higher than lakes in the southeast United States (Bonar et al. 2009), but were lower than more productive reservoirs on Puerto Rico (e.g., mean ± SE of catch rates of largemouth bass ≥250 mm TL in Lucchetti Reservoir was 101.9 ± 13.2 from 1996–1999; Neal et al. 1999). Furthermore, overall PSD was lower than PSD values from other major reservoirs across the island (Neal et al. 1999). Thus, the population was composed of mostly small largemouth bass ≤350 mm, with a few intermediate-sized and larger bass (>500 mm). Surber (1949), Swingle (1950), and Olive et al. (2005) have all shown that lakes or impoundments

with high numbers of small largemouth bass typically have low numbers of large bass. As with catch rates, largemouth bass relative biomass in Cerrillos Reservoir was greater than the average in southeastern US systems (Bonar et al. 2009), yet less than observed in other, more productive reservoirs in Puerto Rico (e.g., mean ± SE relative biomass in Lucchetti Reservoir from 1996–1999 was 37.0 ± 3.5 kg ha^{-1}, Neal et al. 1999). Furthermore, the condition of largemouth bass in Cerrillos Reservoir declined sharply as fish enter the growth bottleneck. All of these factors point towards a high-density, slow-growing population.

Interestingly, the pattern of relative weight appears to have shifted from the period of initial crowding to the most recent sample. In the 1999–2001 data, the poorest conditions were observed for lengths around 300 mm, and relative weight increased rapidly for larger fish. Conversely, in 2010 condition was least for fish >400 mm and only increased minimally in the largest fish. This suggests that prey populations have been depleted to a point that recruitment of prey to larger sizes is no longer sufficient to afford a foraging advantage to large largemouth bass (Swingle 1950, McHugh 1990, Guy and Willis 1995, Schindler et al. 1997). Another possible cause of the low condition of larger fish could be energy partitioning. Since largemouth bass in Puerto Rico reach maturity by age 1 and spawning periods can last up to six months with individuals spawning multiple times in a single season (Dadzie and Aloo 1990, Gran 1995, Waters and Noble 2004), it is possible that more energy is being allocated towards reproduction than growth. For fish that are already in poor condition, this continued allocation of energy to gonadal growth instead of somatic growth may prohibit improvement in condition.

The current study was limited by the lack of accurate age estimates. Age and growth determination is difficult in tropical reservoirs because the fish are not subjected to major seasonal differences like fish in temperate regions. Although otoliths typically provide age information for many fishes (Welch et al. 1993, Soupir et al. 1997, Clayton and Maceina 1999), they do not provide reliable estimates of age for largemouth bass in Puerto Rico reservoirs (Neal et al. (1997). Length-frequency analyses (Guy and Brown 2007) can be used to estimate age of tropical largemouth bass because they grow rapidly for the first few years and their lifespan is usually less than four years. However, the Cerrillos Reservoir population stockpiles by age 1 into a nearly unimodal distribution, prohibiting length frequency analysis (Neal et al. 1997, Neal and Noble 2002). Although length-at-age keys have been used successfully to age largemouth bass in Puerto Rico, known age fish are not available to create length-at-age keys for Cerrillos Reservoir. Despite the fact that age and growth analyses were not included in this study, it is apparent that Cerrillos Reservoir largemouth bass are stockpiling at less than desirable sizes.

Many largemouth bass populations across the United States have responded to length limits as a form of management (Wilde 1997). Typically, imposing a slot length limit to increase harvest of small fish would restructure a largemouth bass population by freeing up resources thereby increasing growth of remaining bass (Wilde 1997, Willis et al. 2010). However, that was not the result of the protected slot length limit regulation on the largemouth bass population in Cerrillos Reservoir, and several factors may have interacted to prevent the success of this management tool. First, the reservoir has historically experienced limited angling effort due to periodic closures and limited accessibility. Restricted reservoir access following the initial introduction and subsequent population expansion allowed a largemouth bass crowded situation to become established, and limited angling effort and a truncated angling week have helped to maintain it. Second, anglers have appeared unwilling to remove small largemouth bass and do not support the protected slot length limit (D. Lopez-Clayton, Puerto Rico DNER, personal communication), despite that the majority of the largemouth bass in this reservoir were available for harvest, with only 17% protected by the regulation.

In order to succeed, fisheries management requires integrated information on the environment, the organisms, and the people (Nielsen 1999). Harvest regulations must be based on sound biological data, but also must have the potential to achieve the desired population-level effect while simultaneously generating support and compliance among the angler base. Due to its ineffectiveness and lack of support, the protected slot length limit was lifted in 2011. Also, the days of operation at the management station were extended to Wednesday-Sunday to increase public use. Shoreline access has also been expanded moderately with the addition of boardwalks and fishing docks to some areas of the shoreline. Research has been initiated to examine largemouth bass population abundance, size structure, prey resources, growth and mortality rates in Cerrillos Reservoir, with the objective of developing management strategies for this system.

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