Common Carp Population Size and Characteristics in Lake Carl Etling, Oklahoma

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Abstract: Common Carp (*Cyprinus carpio*) is a highly invasive species and tolerates a diversity of habitats with a broad range of water-quality characteristics. Following extended drought conditions from 2005 - 2012, a noticeable increase in Common Carp densities was observed at Lake Carl Etling. Higher Common Carp numbers suggested other management techniques would be needed to control the population, which required knowledge of Common Carp population abundance. Therefore, our objective was to estimate the population size using a Schnabel estimator, body condition, and size structure of the carp population. We sampled the entire perimeter of the shoreline once monthly using boat electrofishing from May through November 2017. During the first sampling event in May, all Common Carp captured were measured (total length [TL], mm), weighed (g), given a hole punch mark through the left operculum, and released. In subsequent samples (June-November), each captured fish was examined for a hole punch mark on the left operculum, and if present was recorded as a recapture and released. However, if no mark was observed, the fish was measured, weighed, marked, and released. The mark recapture population estimate was constrained to Common Carp >200 mm because small fish (< 200 mm) were not fully recruited to the electrofishing gear. During the six month mark-recapture period, 2,848 Common Carp ranging 111 to 620 mm TL were collected. We marked and released 2,752 (≥ 200 mm TL) of the 2,848 fish captured. We recaptured 207 marked fish, resulting in a population estimate of 13,783 Common Carp (95% CI = 11,262-16,648). Common Carp density was estimated at 214 fish/ha^{-1} (95% CI = 181-267 fish/ha^{-1}) and biomass was 148 kg/ha^{-1} (95% CI = 125-184 kg/ha^{-1}). Most (93%) Common Carp in Lake Carl Etling were < quality size, but a small proportion exceeded preferred size. Condition of Common Carp in this population was below average (mean Wr = 90). Our results suggest the density of Common Carp in Lake Carl Etling is high and may be regulating size structure and condition of these fish. Further, based on our results fisheries managers can remove enough Common Carp from this system to improve water quality conditions and sport fish populations.

Introduction

Common Carp (*Cyprinus carpio*) is an invasive fish in North America that has negative consequences on invaded waters. Common Carp are native to Asia and Europe but have become widely distributed across the globe as a result of intentional stockings for aquaculture and recreational angling (Penne and Pierce 2008, Weber and Brown 2011, Weber et al. 2011, Carl et al. 2016). Their wide tolerance to temperature, salinity, and dissolved oxygen concentrations allows them to survive a range of habitats, which makes them highly invasive (Bajer and Sorensen 2010). Once established, Common Carp populations can become extremely dense if not controlled through predation or by management biologists (Drenner et al 1997). As population densities of Common Carp exceed 100 – 250 kg/ha^{-1} in aquatic systems, negative effects on water clarity, aquatic macrophytes, macroinvertebrates, and native fish fauna occur as a result of their benthic feeding behavior, and nutrient release from this disturbance can cause excessive algal blooms (Koehn 2004, Weber et al. 2011, Carl et al. 2016).

Management biologists have attempted to control Common Carp populations but often success is difficult to evaluate due to lack of baseline abundance estimates. For example, commercial fisheries are commonly used to control Common Carp biomass but lack a formal stock assessment prior to removal (Colvin et al. 2012). Additionally, control techniques used by management biologists include water level manipulation, piscicide application, and removal efforts by agency personnel or commercial fishing (Weier and Starr 1950, Neess et al. 1957, Verrill and Berry 1995, Fritz 1987, Stuart et al. 2006), however these efforts have varying successes. To accurately assess the effects of a Common Carp removal effort and to implement effective management strategies, biologists require abundance estimates of Common Carp for removal efforts to have meaningful management targets. However, a management strategy to remove a specific percentage of the Common Carp population relies on an accurate population estimate.

Management of high-density Common Carp scenarios requires knowledge of baseline population characteristics, which is limited in Oklahoma. Although historical records suggest Common Carp are absent from Oklahoma's panhandle (Miller and Robison 2004), Lake Carl Etling (located in the furthest northwest corner of the Oklahoma panhandle) supports a robust population of Common Carp. The density of Common Carp in Lake Carl Etling is high enough to contribute to increased turbidity levels that follow annual spawning events in May (i.e., spawning activity increases suspended solids) that typically last through fall. The increased turbidity levels negatively impacted the foraging ability of stocked Tiger Muskellunge (*Esox masquinongy* × *E. Lucius*) and resulted in reduced survival and failure of the stocking program (Snow et al. 2017; Snow et al. 2018). This failed attempt to biologically control Common Carp numbers resulted in the need to evaluate the population size of Common Carp in Lake Carl Etling and consider other management techniques. Because the abundance of Common Carp is unknown and this information is important for management of this species, our study objective was to estimate the population size of Common Carp in Lake Carl Etling using mark-recapture. Further, because high fish abundances can result in deteriorated body condition and size structure, we described relative weight and proportional size distribution for Common Carp in Lake Carl Etling.

Methods

Study Area

Lake Carl Etling is a 64.3 ha impoundment located in northwest Oklahoma and is surrounded by the diverse Mesa de Maya/Black Mesa ecoregion (Snow et al. 2017). The reservoir was formed by impounding South Carrizo Creek, a tributary of the Cimarron River, in 1958. Lake Carl Etling is shallow (mean depth of 1 meter and maximum depth of 5.5 meters) and hypereutrophic. The shoreline, particularly in the upper one-third of the lake, is sparsely vegetated with submerged and emergent macrophytes. The Mesa de Maya ecoregion typically receives 42.4 cm annually (Woods et al. 2005; Kenton, Oklahoma, Mesonet station #52 for annual rainfall). Minimal precipitation in the watershed makes Lake Carl Etling prone to drought. During periods of drought, herbaceous and woody vegetation colonizes the shoreline and results in abundant woody habitat around the perimeter when the lake returns to normal pool conditions. The mean monthly secchi depth at Lake Carl Etling was 23.4 cm from October 2015 through May 2017 (Figure 1; Snow et al. 2017). Further, increased turbidity levels coinciding

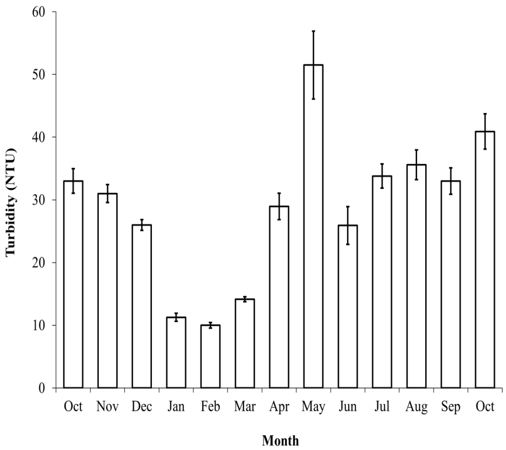

Figure 1. Turbidity measurements taken monthly during October 2015 - October 2016 from Lake Carl Etling, Oklahoma. Mean turbidity (NTU) measurements were taken using a turbidity tube (Myre and Shaw 2006). Error bars represent standard error of the mean.

with large numbers of Common Carp spawning was observed in 2015 and 2016, suggesting that Common Carp numbers were high enough to have detrimental effects on water quality. Lake Carl Etling experiences a wide range of water temperatures (1.7-33.4 ºC) during a typical year.

Sampling

Common Carp were sampled, using boat electrofishing (pulsed DC, high voltage, 7.5 GPP, Smith Root, Vancouver, Washington). The entire perimeter of the shoreline was sampled monthly from May through November 2017. All Common Carp captured were measured for TL (mm), weighed (g), administered a left operculum hole-punch mark, and released. On each following trip, any fish observed to have an operculum hole-punch mark were considered a recapture. If no mark was observed the fish was measured, weighed, and marked as directed above. All fish were processed, held in a live well, and released into an area of the lake that had already been sampled to avoid recapturing these fish and biasing the population estimate. We used mark-recapture to estimate population size and biomass of Common Carp in Lake Carl Etling. After capture Common Carp were marked by hole punching the left operculum of each fish using a 6.4 mm circular paper hole punch tool (Figure 2; Snow et al. 2020). This marking technique was shown to have 100% retention through 184 days (Snow et al. 2020).

Analysis

Common Carp population abundance was estimated using a Schnabel estimator (Seber 1982) with 95% confidence intervals based on a Poisson distribution (Krebs 1999). Mark-recapture sampling events occurred monthly (May to October 2017; n = 6 efforts). Based on the length distribution of Common Carp in Lake Carl Etling, it appears fish ≤ 200 mm were not fully recruited to the sampling gear, therefore fish of this size were not included in the population estimate. Although the primary assumption of a Schnabel estimator is a closed population (i.e., one with no immigration, emigration, recruitment, or mortality), it is robust to some departure from this assumption (Ricker 1975). We met the closure assumption over our study period (6 months) as there were no major rain events resulting in enough inflow or outflow from Lake Carl Etling to allow Common Carp immigration or emigration. It is possible that mortality and recruitment events could have occurred within the study period, however, we conducted the mark-recapture efforts over a short duration (6 months) to minimize the effects of these factors on estimated population

Figure 2. Photo illustrating a Common Carp with two distinct opercular hole punch scars, which was the marking technique used to estimate the population size of the Common Carp In Lake Carl Etling, Oklahoma.

size. Once population size was estimated for Common Carp, we estimated fish density (fish/ha^{-1}) and biomass (kg/ha^{-1}). Biomass by weight was calculated by applying the mean weight from the 2,848 Common Carp captured to the population estimate.

We used a variety of metrics to describe the size structure and condition of the carp population. A length-frequency histogram and proportional size distribution (PSD) of quality (410 mm, PSDq) and preferred (530 mm, PSDp; Anderson and Gutreuter 1983) sized fish were used to visualize and quantify Common Carp size structure. A weight to TL simple regression was used to describe the weight:length relationship of the population. Common Carp condition was evaluated by calculating relative weight (W_r) using the standard weight equation (W_s = -4.639 + 2.920 × log10 TL) presented by Anderson and Gutreuter (1983).

Results

We collected 2,848 Common Carp (ranging 111 to 620 mm TL; Figure 3) during our 6-month mark-recapture evaluation. Of the 2,848 Common Carp collected, 2,752 (individuals ≥ 200 mm TL) were marked and released to estimate population size. We recaptured 7% (207 of 2,752) of our marked fish in subsequent sampling efforts and marked 20% of the population, which produced a population estimate of 13,783 Common Carp (95% CI = 11,609 -17,161; Table 1). Common Carp density was estimated at 214 fish/ha^{-1} (95% CI = 181-267 fish/ha^{-1}) with an estimated biomass of 148 kg/ha^{-1} (95% CI = 125-184 kg/ha^{-1}).

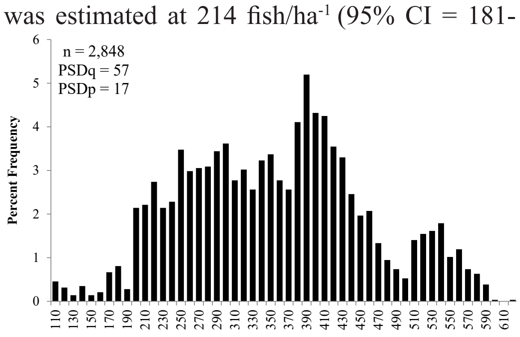

Figure 3. Length frequency distribution and proportional size distribution (PSD) of Common Carp collected from Lake Carl Etling, Oklahoma.

Most Common Carp in Lake Carl Etling were of stock and quality size (PSDq = 57), but a small proportion exceeded preferred size (PSDp = 17). The mean weight of Common Carp in Lake Carl Etling population was 692 g (range = 11- 2,965 g; Figure 4). The length-weight relationship of Common Carp was highly correlated (r^2 = 98; Figure 4). Common Carp from Lake Carl Etling were classified as below average body condition (mean W_r = 90), and condition was similar across length categories (stock = 91, quality = 89, and preferred = 90).

Discussion

This study provides a population estimate for Common Carp in a small Oklahoma impoundment based on mark-recapture methods. Our mark-recapture effort was confined to six months and larger Common Carp (≥ 200 mm TL) because of gear recruitment and the hole punch marks become less discernible for smaller fish after 7 months (Snow et al. 2020). Therefore, our density estimate of 214 fish/ha^{-1} is likely conservative given the exclusion of carp < 200 mm. This may explain why our estimate was lower than the median density estimates (15 to 569 fish/ha^{-1}) reported in the literature for small impoundments (4.7 to 159.2 ha; Bajer et al. 2009, Bajer and Sorensen 2010, Bajer et al. 2011, Bajer et al. 2012). Further, these population estimates are from impoundments in the northern United States, overall effects of climate and habitat could be driving differences.

Our biomass estimate (148 kg/ha^{-}1) for Common Carp in Lake Carl Etling was likely quite conservative but helps us identify a management target for removal. Our estimate is considerably lower than values reported in the literature, which can exceed 300 kg/ha^{-1} (Keohn 2004, Weber and Brown 2011, Bajar and Sorensen 2015). Negative impacts to aquatic systems have been observed when Common Carp reach a critical biomass of 198 kg/ha^{-1} (Vilizzi et al. 2015).Bajer et al. (2016) determined a Common Carp biomass of ~200

Table 1. Monthly mark-recapture information for Common Carp (≥200 mm total length) captured in Lake Carl Etling, Oklahoma from May through October 2017. Population estimates were calculated using the Schnabel method. The 95% confidence intervals (CIs) were produced using a Poisson distribution.

Month	Captured Monthly	Cumulative Marked	Cumulative Recaptured	Population Estimate	Lower 95% CIs	Upper 95% CIs
May	883	832	-	-	-	-
June	469	1,278	51	7,136	5,709	10,028
July	525	1,749	93	10,096	4,403	15,677
August	301	1,976	131	10,037	7,350	16,206
September	263	2,204	158	10,978	8,816	14,793
October	407	2,752	207	13,783	11,609	17,161

kg/ha^{-1} caused a 90% reduction in vegetation in Midwestern, US lakes. When Common Carp biomass exceeds 100 kg/ha^{-1}, negative impacts to aquatic systems can occur (Bajer et al. 2009). Therefore it seems maintaining a biomass < 100 kg/ha^{-1} is an appropriate management goal. Based on our estimates, we would need to remove 4,400 Common Carp from Lake Carl Etling to reduce the biomass below 100 kg/ha^{-1}. We captured 2,848 Common Carp using 7 sampling trips, so with a few days of additional effort, the remaining 1,552 Common Carp could have been captured to achieve a management goal of maintaining < 100 kg/ha^{-1} in Lake Carl Etling. A dedicated removal effort could be even more efficient if we identified and targeted areas where Common Carp congregate in the reservoir.

Common Carp aggregate during periods associated with overwintering and spawning, and these aggregations often occur at the same locations over consecutive years (Penne and Pierce 2008). Bajar et al. (2011) found Common Carp aggregations during winter in Midwestern lakes and showed that targeting these aggregations for removal could reduce 68% of a Common Carp population. We observed a Common Carp aggregation in the South Carrizo Creek confluence of Lake Carl Etling during winter over two consecutive years (2016-2018; Figure 5). Knowledge of this large, seasonal aggregation of Common Carp in Lake Carl Etling makes the goal to maintain abundance < 100 kg/ha^{-1} feasible, because these fish can easily be exploited for removal purposes.

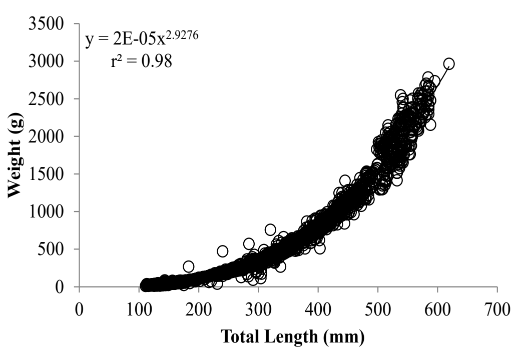

Figure 4. Length-weight relationship of Common Carp collected from Lake Carl Etling, Oklahoma.

Although our data are from one small impoundment in Oklahoma, this study provides important baseline data on abundance, body condition, and size structure of Common Carp. We do not have data from other Common Carp populations in Oklahoma for comparison, so it is unknown if the Lake Carl Etling Common Carp population is representative. Based on our results, the Lake Carl Etling population appears to be relatively high density and may be regulating its size structure (high abundance fish >200 mm TL) and body condition (below average W_r) of these fish. Common Carp are dense may improve stocking success or resident sportfish populations. Common Carp population assessments should be expanded to other Oklahoma small impoundments, as this information is lacking statewide and is critically important for managing sportfish populations. Our results suggest that it may be feasible for fisheries managers to remove enough Common

Figure 5. This photograph illustrates a Common Carp aggregation observed while electrofishing in the South Carrizo Creek confluence of Lake Carl Etling during the winters of 2016-2018.

Carp from this system to improve water quality conditions, based on results from previous evaluations.

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