SPORTFISH POPULATION DYNAMICS IN LAKE MATTAMUSKEET, 2013, AND DISCUSSION OF AN ACTIVE LAKE LEVEL MANAGEMENT PLAN TO ENHANCE THESE FISHERIES

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Abstract.—Largemouth Bass *Micropterus salmoides* and Bluegill *Lepomis machrochirus*, were sampled in shoreline electrofishing transects in main lake sites on Lake Mattamuskeet, Jarvis Canal, Main Canal, and Rose Bay Canal in October 2013. Black Crappie *Pomoxis nigromaculatus* were sampled in Main Canal and Rose Bay Canal using trap, hoop, and fyke nets in November 2013. Largemouth Bass length frequency and PSD analysis indicated a healthy and balanced population in the canals, but low water levels prevented adequate sampling within the main lake sites. A total of 174 Largemouth Bass were collected from the canals, whereas only 16 were collected from the main lake samples. Multiple size groups were collected from the canals, and mean relative weight (Wr = 97.5) suggested Largemouth Bass were in excellent condition. Abundance of Largemouth Bass greater than 200 mm was higher in Jarvis, Main and Rose Bay canals (mean CPUE 45.5 fish/h) than in the main lake (12.1 fish/h). Overall, the Bluegill sample was comprised mostly of stock length fish (80–149 mm) and had very few fish greater than preferred length. Abundance of stock-length and greater Bluegill in the canals (88.7 fish/h) was greater than in the main lake (56.8 fish/h). Standard trap nets with 25.4-mm mesh were most efficient at capturing Black Crappie in Main Canal and Rose Bay Canal. Length frequency distributions of Black Crappie in Main Canal and Rose Bay Canal had a wide range of sizes indicating multiple age classes. The majority of Black Crappie were fast-growing age-1 fish with fish up to age 6 collected; however, mortality of fish >age 3 was apparently high. No age-0 Black Crappie were collected indicating a potential failed year class. Future efforts should focus on assessing the extent of possible year class failures for Largemouth Bass and Black Crappie and the relationship with water quality and lake levels in the main lake and associated canals. The NC Wildlife Resources Commission recommends that the USFWS Mattamuskeet National Wildlife Refuge implement an active lake level management plan that focuses efforts throughout the year to hold water levels of either 2.1 ft (east side) or 2.3 ft (west side) within ±0.2 ft as measured at the permanent USGS gauging stations to promote quality and quantity of fisheries habitats in the main lake.

Background

Lake Mattamuskeet is a 16,194-ha natural lake located in Hyde County, North Carolina. The lake is encompassed by a National Wildlife Refuge managed by the U.S. Fish and Wildlife Service (USFWS) primarily for waterfowl and migratory bird habitat; however, the lake's fisheries resources have been recognized for their ecological, recreational, economic, and cultural importance. Lake Mattamuskeet is connected to the Pamlico Sound by four large drainage canals (Main, Lake Landing, Waupoppin and Rose Bay), and each canal is equipped with water control structures designed to let excess water flow out of the lake, keeping average water depths generally less than 1 meter. These water control structures have the benefit of providing passage of Alewife *Alosa pseudoharengus* and Blueback Herring *A. aestivalis* into the lake during the spring; however, the top hinge and side-opening designs of the flap gates are often lodged open by debris resulting in episodic saltwater intrusion into the lake. Lake Mattamuskeet is divided by a causeway formed by N.C. Highway 94. Five concrete culverts enable the movement of water between the east and west sections of the lake, but exchange is dependent on water level, wind speed and direction. Water inputs to the lake come from direct precipitation as well as small canals that drain forested and agricultural areas. Additionally, landowners within the Mattamuskeet Drainage District are allowed to pump water from agricultural lands into canals feeding the lake, and landowners are also able to pump water from adjoining canals onto farmland for waterfowl impoundment management purposes. United States Geological Survey (USGS) gaging stations were recently installed on the east side and west side of the lake; these stations allow for daily monitoring of lake levels and a suite of water quality parameters.

Lake Mattamuskeet and its associated canals boast a variety of fishing opportunities; anglers can catch Largemouth Bass *Micropterus salmoides*, Black Crappie *Pomoxis nigromaculatus,* Bluegill *Lepomis machrochirus*, and various estuarine species including Southern Flounder *Paralichthys lethostigma*, Striped Mullet *Mugil cephalus*, and Blue Crab *Callinectes sapidus*. Current fishing regulations established by the North Carolina Wildlife Resources Commission (NCWRC) include a 5 fish daily creel limit and a minimum size of 14 inches (356 mm) for Largemouth Bass, a 20 fish daily creel limit and minimum size limit of 8 inches (203 mm) for Black Crappie and a 30 fish daily creel limit for sunfish. Federal regulations prohibit boating, sport fishing, bow fishing, and crabbing from 1 November to 28 February, except in designated areas (USFWS 2010). Additionally, federal regulations dictate a daily creel limit of 12 Blue Crabs with a minimum carapace width of 5 inches within the refuge boundaries.

The survey objective was to collect fisheries data needed to manage Largemouth Bass, Black Crappie, and sunfish in Lake Mattamuskeet and associated canals. This report also provides specific recommendations to the USFWS Mattamuskeet National Wildlife Refuge regarding the development of an active lake level management plan. Chronic depression of water levels in the main lake, particularly in the summer months, limits fish accessibility to shoreline habitats. Extremely low lake levels accompanied by periods of saltwater intrusion are suspected to result in poor or failed year class production, especially when salinity levels are documented to be higher than the tolerance levels for many freshwater fishes. The establishment of an active lake level management plan would provide expanded access to main lake habitats for the benefit of the fisheries community in Lake Mattamuskeet.

Methods

Boat electrofishing.—Largemouth Bass, Bluegill and Black Crappie were collected with boat-mounted electrofishing gear from 28 to 31 October 2013. Boat-mounted electrofishing gear consisted of a Smith Root 7.5 GPP electrofisher with boom electrodes that delivered 170–340 volts of pulsed direct current at 13–50 amperes. Six shoreline electrofishing transects in the main lake, two transects in Jarvis Canal, five transects in Main Canal, and five transects in Rose Bay Canal were sampled (Figure 1). The majority of transects were approximately 900 seconds in length, but three main lake transects were stopped early because of shallow water and inefficient sampling conditions. All fish species were collected for the first 300 seconds and then only Largemouth Bass, sunfish, and Black Crappie were collected during the remaining portion of the transect. Total length was measured to the nearest millimeter for all game fish (TL, mm), and weight was recorded to the nearest gram for Largemouth Bass and Black Crappie. A subsample of Black Crappie in each 10 mm length group from Jarvis, Main, and Rose Bay canals was sacrificed for otolith removal and ageing. Sagittal otoliths from sacrificed Black Crappie were extracted and stored in numbered vials. At each site, water quality parameters were recorded; water temperature (Celsius), % saturation, dissolved oxygen (mg/L), specific conductivity (µS/cm), and salinity (ppt) (Table 1).

Trap, hoop and fyke netting.—Black Crappie in Main Canal and Rose Bay Canal were sampled using standard trap, double hoop, and fyke nets from 5 to 7 November 2013. Nets were deployed at 8 sites in Main Canal and 11 sites in Rose Bay Canal and were checked at 1 or 2 day intervals (Figure 1). Multiple net types were evaluated to standardize future sampling efforts; net types included: 12.7 and 25.4-mm mesh trap nets; 25.4 and 50.8-mm mesh fyke nets; and 12.7-mm mesh double hoop nets. Soak time, set type, and depth for each net sample were recorded. Total length (mm) and weight (g) of all Black Crappie collected was recorded. A subsample of Black Crappie from Main and Rose Bay canals was sacrificed for otolith removal and ageing, which resulted in at least 5 Black Crappie per 10 mm length group in each canal when combined with Black Crappie collected via electrofishing.

Data analysis.—Largemouth Bass and Bluegill relative abundance was indexed with catch per unit effort (CPUE), expressed as the number of fish collected per electrofishing hour. Relative abundance of Largemouth Bass and Bluegill was evaluated separately for lake and canal sample sites. Black Crappie relative abundance was indexed with CPUE, expressed as the number of fish caught per net-night in Main and Rose Bay canals. Black Crappie CPUE was assessed for each net type in Main and Rose Bay canals, to account for any differences in gear efficiency and abundance.

Size structure of Largemouth Bass, Bluegill, and Black Crappie was evaluated with length-frequency distributions and calculations of proportional size distribution metrics for quality (PSD), preferred (PSD-P), and memorable (PSD-M) length groups (Guy et al. 2007). Stock, quality, preferred, and memorable minimum lengths were 200, 300, 380 and 510 mm for Largemouth Bass and 80, 150, 200 and 250 mm for Bluegill (Anderson and Neumann 1996). For Black Crappie, stock, quality, preferred, and memorable minimum lengths were 130, 200, 250 and 300 mm (Gabelhouse 1984). Length frequency and PSD metrics of Largemouth Bass were calculated using combined data from all canal sites. Length Frequency and PSD metrics of Bluegill were calculated separately for the main lake and canal sample sites. Length frequency and PSD of Black Crappie were assessed for Main Canal and Rose Bay Canal and were reported by net type.

Largemouth Bass and Black Crappie body condition was assessed with a relative weight index (Wr) described by Wege and Anderson (1978). Relative weight was calculated as, Wr = (W/Ws)*100, where W is the measured weight (g) of each fish, and Ws is a length-specific standard weight. The Ws equation for Largemouth Bass was, $\log_{10}(Ws) = -5.316 + 3.191*\log_{10}(TL)$ and the Ws equation for Black Crappie was $\log_{10}(Ws) = -5.168 + 3.345*\log_{10}(TL)$ as described by Murphy et al. (1991). Mean relative weight of Largemouth Bass was calculated for PSD length groups for canal sites, and mean relative weight of Black Crappie was calculated for PSD length groups from fish collected in all net types for Rose Bay and Main canals. Length and weight data were $\log_{10}$-transformed for linear regression analysis.

Age structure of Black Crappie in the canals was assessed with age distributions and mean length at age analyses. Otolith age was assessed for 200 Black Crappie by two independent readers using a dissecting microscope. Annuli (opaque bands) were counted; if otoliths were not readable in whole view, or age discrepancies occurred between readers, the otoliths were sectioned to obtain age. Agreement between readers was 94% after the initial read, and discrepancies of the remaining ages were resolved in concert. Ages for all un-aged fish (n=258) in the sample were assigned using an age-length key generated from the 200 aged Black Crappie collected from Main and Rose Bay canals with boat electrofishing and net surveys. The age-length key was created using S-Fat add-in for Microsoft Excel. Age and growth parameters of Black Crappie populations were evaluated by calculating mean length at age, using S-Fat add-in for Microsoft and von Bertalanffy growth models were computed using FAST 3.0 software.

Results

A total of 25 fish species was collected from electrofishing and net surveys in the main lake and the canals in 2013 (Table 2). Only 16 Largemouth Bass were collected during electrofishing surveys in the main lake (CPUE 12.1 fish/h). Of the 14 fixed sampling sites in the main lake, only 6 were accessible in 2013, and in those sites, low water conditions prevented sampling in shoreline areas with vegetation and large woody debris (i.e., habitats suitable for Largemouth Bass). The majority of Largemouth Bass (n=10) collected in the main lake were captured near the mouth of Rose Bay Canal and inflated estimates of relative abundance in the main lake. Largemouth Bass collected from the main lake ranged in length from 206 to 456 mm. PSD and condition factors (Wr) were not calculated from the main lake Largemouth Bass samples due to the low sample size. USGS gaging stations measured daily mean gage heights of 1.1 ft (east side, USGS Station 0208458893) and 1.3 ft (west side, USGS station 0208458892) during October electrofishing sampling; at these levels, access to main lake sites was restricted and data were likely not representative of the entire population.

Electrofishing surveys in the canals collected 174 Largemouth Bass: Jarvis Canal (n=31), Main Canal (n=76), and Rose Bay Canal (n=67). Mean CPUE of Largemouth Bass >200 mm was 31.9 fish/h in Jarvis Canal, 53.2 fish/h in Main Canal, and 43.5 fish/hour in Rose Bay Canal (Figure 2). Mean CPUE of Largemouth Bass >200 mm combined for the three canals was 45.5 fish/h (n=141). Length frequency distributions of Largemouth Bass collected in Jarvis, Main, and Rose Bay canals signified the presence of multiple age classes (Figure 3). Largemouth Bass PSD in canals (63%) was within the acceptable range for balanced, healthy populations (40–70, Anderson 1980; Figure 4). Largemouth Bass PSD analysis indicated a large proportion of fish were quality length with memorable and preferred length fish present in smaller proportions; Largemouth Bass greater than 500 mm represented 3.5% of the canal samples (Figure 4).

Body condition of Largemouth Bass collected in Jarvis, Main, and Rose Bay canals was excellent and suggested the presence of an adequate forage base. Relative weights were greater than 90, on average, for stock, quality, preferred, and memorable length fish (Figure 5). Mean relative weight increased with length from stock length to memorable length in the canals and may be related to decreased competition at larger lengths. Mean relative weight for preferred length Largemouth Bass was 97.9 (SE = 2.0) for fish collected in Jarvis, Main, and Rose Bay canals, which is slightly below Wr values in Main and Rose Bay canals in 1996 (Wr=103, SE=7; Thomas 1997). Log_{10} transformed weight and length regression equations calculated for canal samples indicated excellent Largemouth Bass condition. The slope for the standard weight equation for Largemouth Bass is 3.191 (Wege and Anderson 1978). Slopes were 3.14 for Largemouth Bass collected in Jarvis, Main, and Rose Bay canals, indicating that fish are becoming more rotund as length increases (Figure 6).

In 2013, a total of 346 Bluegill >80 mm were collected during electrofishing sampling in the main lake (n=75; CPUE 56.8 fish/h), Jarvis Canal (n=82; CPUE 154.3 fish/h), Main Canal (n=58; CPUE 46.0 fish/h), and Rose Bay Canal (n=131; CPUE 103.5 fish/h). Mean CPUE of Bluegill >80 mm combined for the three canals was 88.6 fish/h (Figure 7). Bluegill from the main lake and the canals ranged in length from 30 to 242 mm with the majority of both samples composed of 90–120 mm fish (Figure 8). Bluegill PSD indicated the population was comprised mostly of stock length fish (Figure 9) and suggests a stunted population where competition has reduced growth. Bluegill PSD in Jarvis, Main and Rose Bay canals (23%) was at the bottom of the acceptable range of a balanced population (PSD values between 20 and 40; Anderson 1980), but Bluegill PSD (16%) was lower than the acceptable range in the main lake samples. The abundance of small fish provides an excellent forage base for Largemouth Bass, whereas the few large, preferred-sized Bluegill support limited angling opportunities.

In October 2013, Black Crappie were collected by electrofishing from Jarvis Canal (n=10), Main Canal (n=33), and Rose Bay Canal (n=10). In November 2013, a total of 175 Black Crappie were collected during 18 net-nights in Main Canal using: 12.7-mm mesh trap nets (n=30; CPUE 5.6 fish/net-night), 25.4-mm mesh trap nets (n=104; CPUE 22.5 fish/net-night), 50.8-mm mesh fyke nets (n=39; CPUE 19.5 fish/net-night), and 12.7-mm mesh double hoop nets (n=2; CPUE 0.8 fish/net-night; Figure 10). In Rose Bay Canal, 258 Black Crappie were collected in 22 net-nights using: 12.7-mm mesh trap nets (n=26; CPUE 5 fish/net-night), 25.4-mm mesh trap nets (n=193; CPUE 26.1 fish/net-night), 25.4-mm mesh fyke nets (n=23; CPUE 5.4 fish/net-night), and 12.7-mm mesh double hoop nets (n=16; CPUE 3.2 fish/net-night; Figure 10). Relative abundance for Black Crappie collected with 25.4-mm mesh trap nets in 2013 was higher than net surveys from November 1996, when CPUE in Main Canal was 0.37 fish/net-night and 1.69 fish/net-night in Rose Bay Canal (Thomas 1997). Mean CPUE of Black Crappie combined for all net types was 12.2 fish/net-night in Main Canal and 10.4 in Rose Bay Canal.

To evaluate the potential to standardize future net sampling, CPUE was compared between net types to assess catch rates of each gear. CPUE was highest for standard 25.4-mm mesh trap nets in Main Canal and Rose Bay Canal, and with 50.8-mm fyke nets in Main Canal (Figure 10). CPUE for all other net types was less than 5 fish per net night (Figure 10). This analysis suggests standard trap nets with 25.4-mm mesh should be used as standard gear in future net surveys in the canals at Lake Mattamuskeet.

Length frequency distributions of Black Crappie in Main Canal and Rose Bay Canal indicate multiple age classes were present (Figure 11). The presence of large fish >300 mm in Main and Rose Bay canals indicates good survival for large fish and reduced competition with size. Very few Black Crappie less than stock length (130 mm) were collected in the canals and no fish <100 mm were collected. It is likely this trend is a result of low recruitment because trap net surveys from past studies were successful in capturing young-of-year fish <100 mm (Thomas 1997). Analysis of Black Crappie PSD indicated a population comprised of large individuals (Figure 12). The calculated PSD values for Main Canal (95%) and Rose Bay Canal (72%) were higher than values recommended for balanced populations (30–60) in Piedmont reservoirs (Oakley and Dorsey 2013). Additionally, PSD-P and PSD-M values in Main and Rose Bay canals reveal Black Crappie >250 mm comprised a relatively high percent of the population (Table 3). Patterns in size structure of Black Crappie collected with net surveys revealed that Main Canal had a higher proportion of preferred and memorable length fish than Rose Bay Canal. In Main and Rose Bay canals, Black Crappie greater than quality length were available for capture in high proportions. Six age groups (age 1–6) were represented in net surveys (Figure 13). Age-1 individuals dominated Black Crappie catch in Main and Rose Bay canals; of 433 Black Crappie collected in net surveys, 61% were age 1, 8% were age 2, 29% were age 3, and 2% were ≥ age 4. The low abundance of age-2 Black Crappie indicates poor recruitment of the 2011 year class.

Mean length at age of Black Crappie was estimated for each canal. This analysis revealed age-1 fish had extremely high growth rates and reached quality length in their second growing season (Figure 14). Age-1 fish in Main and Rose Bay canals had mean lengths of 235 mm and 207 mm, respectively, and analysis also indicated fish reached preferred lengths in their third growing season. The 2012 year class (age-1) exhibited extremely fast growth that may be a result of reduced competition with the less abundant 2011 year-class. Future survey efforts should determine if Black Crappie growth rates and year class formation are influenced by variable environmental conditions.

Body condition of Black Crappie collected in Main and Rose Bay canals was good, suggesting growth is not limited by prey availability. Stock, quality, preferred, and memorable length fish had mean relative weights >90 (Figure 15). Mean Wr of Black Crappie in Main and Rose Bay canals declined slightly between stock and memorable lengths; however, Wr remained above 90 for all length groups. Log_{10} transformed weight and length regression equations calculated for each canal indicate good growth of Black Crappie. The slope for standard weight equation for Black Crappie is 3.345 (Murphy et al.1991). Slopes calculated for Black Crappie was 3.210 for Main Canal and Rose Bay Canal, indicating that weight increased proportional to length (Figure 16).

Discussion

Largemouth Bass abundance measured in the three canals (45.5 fish/h (n=141), was higher than mean CPUE for Largemouth Bass collected in Main and Rose Bay canals in spring of 1996 (CPUE=24.6 fish/h; Thomas 1997), fall 2011 (CPUE=15.8 fish/h) and spring 2012 (CPUE=19.9 fish/h; NCWRC unpublished data). Differences in sample season (i.e., spring and fall) limit the validity of comparisons between surveys, but it appears that Largemouth Bass in the canals were abundant in 2013. The presence of larger (> 500 mm) Largemouth Bass in the canal samples suggested an expanded age structure. Despite the relatively high number of quality and preferred-length Largemouth Bass in the canal samples, few fish less than 200 mm were collected. The relative absence of young-of-year Largemouth Bass may be a function of reduced reproductive success or poor recruitment. Adult Largemouth Bass can tolerate moderate levels of salinity (9–12 ppt), but salinities greater than 3.2 ppt are lethal to eggs and fry (Tebo and McCoy 1964). Salinity measurements were not collected in canals during the Largemouth Bass spawning period in spring 2013; however, salinity measurements at or above the Largemouth Bass spawning threshold and near adult Largemouth Bass tolerance levels were recorded during August 2013 in Main Canal (range 5.0–9.4 ppt) and Rose Bay Canal (range 1.3–3.2 ppt) by refuge personnel (P. Campbell, USFWS, personal communication). Additionally, salinity readings collected during this survey ranged between 1.0–4.9 ppt (Table 1). If similar elevated salinity conditions existed in the canals during the spring spawning season, Largemouth Bass reproduction and recruitment may have been negatively affected. Supplemental stockings of Largemouth Bass should be considered as a management option to offset poor recruitment in some years. Although the WRC stocked Largemouth Bass into the main lake from 2003 to 2007, the contribution of these stockings to the Largemouth Bass population was not formally evaluated. Thus, research is needed to determine the effectiveness of supplemental stocking as a viable management strategy, especially in years when lake levels continue to decline after fish are stocked in early summer.

Recruitment in Black Crappie populations is also known to fluctuate due to density-dependent competition and variable environmental conditions (Allen and Miranda 2001). High salinities in Main and Rose Bay canals (4.2–14.9 ppt) documented during spring 2011 (McCargo et al. 2012) could have caused poor Black Crappie reproduction and recruitment in 2011; additional monitoring of salinity levels is needed to better define the role of salinity in influencing year class formation. The absence of age-0 Black Crappie from the 2013 survey could also be attributed to another failed year class. Salinity data are not available for spring 2013, but recruitment failure could have occurred if salinities exceeded thresholds for successful Black Crappie spawning during spring 2013. Alternatively, the relatively low abundance of sexually mature Black Crappie (>age 2) in the population could have contributed to poor production in 2013. The apparent lack of fish >age 3 could be a result of specific year class failures or high fishing mortality. Angler creel surveys would help determine if mortality of these fish is natural or due to high levels of harvest. Good numbers of quality and preferred-sized Black Crappie should be available for anglers fishing the canals in 2014. However, the majority of these fish will be from the 2012 year class. Because of fast growth rates, an increase in the Black Crappie minimum size limit to 10 inches may be necessary to protect fast-growing year classes to maturity at age 2. Increased survival could also result in more memorable-sized Black Crappie available to anglers.

Water levels in the main lake in 2013 were too low to allow for efficient sampling in the fall; subsequently, the fisheries community in the main lake was difficult to characterize. Although an annual comprehensive lake level data set has not been available until 2013, extremely low lake level conditions have been documented in the lake periodically since 2001, especially in drought years (2001, 2002, 2008 and 2009). Lake Mattamuskeet water levels fluctuated seasonally in 2013 with daily means ranging between 0.91–2.36 ft on the east side (USGS 0208458893) and 1.04–2.40 ft on the west side (USGS 0208458892; Figures 17 and 18). The general trend in 2013 was for lake levels to be highest earlier in the year (January–April) before declining continually through the summer and fall to their lowest recorded levels during the first week of October. Although these fluctuations were relatively small in magnitude (approximately 1.4 ft), holding water levels in the lake near the upper end of the range observed in 2013 would provide significant benefits to the lake's fisheries community. Analysis of the USGS lake level data suggests that the east side of the lake is approximately 0.2 ft lower than the west side of the lake. Active management of the water control structures by Mattamuskeet National Wildlife Refuge that would hold lake levels strategically throughout the year at a guide curve of 2.1 ft on the east side or 2.3 ft on the west side as measured at the USGS gauging stations would increase abundance of young-of-year and ultimately adult fishes by increasing quantity and quality of spawning, rearing and holding habitats. These specific levels were selected due to their frequency in the observed data set at the upper end of the range. The critical spawning period for most of the lake's fish species occurs between February and June, and is dependent primarily upon species-specific water temperatures. To promote sustained natural reproduction of the various fish species in the lake, priority should be given to holding lake levels at the guide curve recommended above during the February–June spawning window. Scheduled openings at the water control structures to promote passage of Alewife, American Eel *Anguilla rostrata* , and Blue Crab into the main lake during critical migration periods should also be considered within the scope of an active lake level management plan. As diadromous fish and Blue Crabs enter the lake, their survival, spawning potential, and movement patterns are also ultimately tied to lake level fluctuations.

Seasonal movements of Largemouth Bass between the main lake and the canals are unknown; however, given changes in water levels and salinity dynamics in Lake Mattamuskeet, periodic concentrations of Largemouth Bass and other fish species in the canals are suspected. Canals may serve as refuge habitat during low lake level conditions when water temperatures in the main lake exceed a threshold for survival, or when optimal fisheries habitats in the lake become scarce. Growth, condition and abundance of Largemouth Bass as measured in the 2013 canal electrofishing surveys suggest that quality fish are available to redistribute into main lake habitats when lake levels approach 2.1 ft (east side) or 2.3 ft (west side) for prolonged periods of time. Review of the 2013 USGS gage height data reveals that the lake was near or exceeded these levels from early January through approximately mid-May. As lake levels declined to approximately 1.0 ft through the first week in October (Figures 17 and 18), it is hypothesized that reduction in main lake habitats resulted in movement of Largemouth Bass into the canals throughout the summer and fall. A better understanding of movements of Largemouth Bass and other species between the main lake and the canal system over a range of lake levels is needed.

Fluctuations in lake levels during or after Largemouth Bass spawning have been associated with decreased production and survival of fry and fingerlings in other systems. Waters and Noble (2004) documented low recruitment of Largemouth Bass in reservoirs when water levels dropped following spawning; maintenance of high, stable water levels during the spawning season was recommended to improve age-0 abundance. Similarly, research from Lake George, Minnesota, reported Largemouth Bass spawned in 10–40 inches of water in this shallow lake (Kramer and Lloyd 1962). Primary sources of mortality during the spawning period were water temperature and wind in the Lake George study. The effect of these two variables upon Largemouth Bass egg survival and nest success was influenced by the depth of water over the nests and bottom type. Wind velocities exceeding 17 miles per hour resulted in wave action that uprooted or damaged vegetation, scoured the nests, or covered the eggs with sand. Deeper water over a nest was found to lessen the effect of wave action, as the shallower nests in the study area were the ones destroyed by wind action (Kramer and Lloyd 1962). Similar environmental conditions are common in Lake Mattamuskeet as prevailing winds often exceed 20 miles per hour resulting in marked increases in wave action over areas of shallow water. Lake level declines were also responsible for habitat loss of structural refuge in the littoral zone and subsequent decline of forage species in a Wisconsin lake (Gaeta et al. 2014). Submerged complex woody habitat along the shoreline fringe became inaccessible to the lake's forage species, resulting in a decline in Largemouth Bass growth rates. In addition, White Perch (ranging in length 30–120 mm) are abundant throughout Lake Mattamuskeet and are known nest predators of Walleye *Sander vitreus* (Schaeffer and Margraf 1987). A similar relationship with Largemouth Bass nests has not been documented, but research to examine the level of Largemouth Bass nest predation by White Perch in Lake Mattamuskeet is warranted if recruitment issues are verified in future studies. Continued sampling is necessary to document improvements in recruitment, changes in abundance, and age structure expansion of the sportfish populations in Lake Mattamuskeet and the associated canal system that might accompany an active lake level management plan.

Management Recommendations

The North Carolina Wildlife Resources Commission will continue to monitor fisheries populations in Lake Mattamuskeet. To better understand and enhance the lake's recreational fisheries, we intend to execute the following recommendations:

1. Stock 20,000 Largemouth Bass fingerlings into the main lake for the next three years (2014–2016) to evaluate the effectiveness of supplemental stocking as a management tool to offset poor recruitment. This evaluation will utilize genetic markers to conclusively determine the hatchery contribution to the population.

2. Evaluate seasonal movement of Largemouth Bass between the main lake and the canal system. This project will involve the use of Passive Integrated Transponder (PIT) tags to track movement of tagged Largemouth Bass between main lake sample sites and sites within Rose Bay Canal and Main Canal in 2014.

3. Conduct an angler creel survey at fishing access areas around Lake Mattamuskeet from 1 March to 31 October 2014. Information regarding angler access, effort, catch, and harvest trends is needed to determine angler use patterns and effectiveness of current regulations.

4. Maintain the current size and harvest regulations for Largemouth Bass and Bluegill in Lake Mattamuskeet. Evaluate modifying the current 8-inch minimum length of Black Crappie to a 10-inch minimum length and maintain the daily limit of 20 fish.

5. Continue to annually monitor Largemouth Bass, Bluegill, and Black Crappie population characteristics. Conduct electrofishing surveys in Lake Mattamuskeet during periods (spring and fall) when lake levels and water temperatures are conducive for efficient data collection. Utilize standard trap nets with 25.4-mm mesh to assess the Black Crappie population in the canals.

The North Carolina Wildlife Resources Commission does not operate or maintain the four water control structures connected to Lake Mattamuskeet. However, to enhance fisheries habitats in Lake Mattamuskeet, we offer the following recommendations to the USFWS Mattamuskeet National Wildlife Refuge:

1. Actively manage the four water control structures to hold lake levels strategically throughout the year at 2.1 ft (east side) or 2.3 ft (west side) as measured on the USGS gauging stations on the lake. Priority should be given to maintaining these levels during the critical spawning and rearing periods (February through June) for most of the lake's fish species.

2. Develop a schedule for openings at the water control structures to promote passage of Alewife, American Eel and Blue Crab into the main lake during critical migration periods. Consideration should be given to holding lake levels higher (2.1 ft or 2.3 ft as measured on the east side or west side USGS gauging stations) during winter months (December and January) in anticipation of spring releases intended to provide attractant flow for diadromous fish.

3. Monitor salinity levels at the four water control structures and in the lake, including the highway 94 culverts. Continue to work to reduce saltwater intrusion, particularly when lake levels fall below 1.5 ft on the USGS gaging stations.

4. Establish a weekly or bi-weekly lake level monitoring program that would initiate response measures intended to hold lake levels within ±0.2 ft of the levels recommended above. Deviations from this strategy would be expected to occur in the event of extreme environmental conditions (e.g., heavy rainfall, drought, or cyclones).

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Literature Cited

Allen, M. S., and L. E. Miranda. 2001. Quasi-cycles in crappie populations are forced by interactions among population characteristics and environment. Canadian Journal of Fisheries and Aquatic Sciences 58:594–601.

Anderson, R. O. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive indices for fish populations and communities. Pages 27–33 *in* S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980's. American Fisheries Society, New York Chapter.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–481 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. 2nd Edition. American Fisheries Society, Bethesda, Maryland.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273–285.

Gaeta, J. W., G. G. Sass, and S. R. Carpenter. 2014. Drought-driven lake level decline: effects on coarse woody habitat and fishes. Canadian Journal of Fisheries and Aquatic Sciences 71:315-325.

Guy, C. S., R. M. Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution (PSD): a further refinement of population size structure index terminology. Fisheries 32:348.

Kramer, R. H., and L. L. Smith Jr. 1962. Formation of year classes in Largemouth Bass. Transactions of the American Fisheries Society 91:29-41.

McCargo, J. W., B. R. Ricks, K. J. Dockendorf, C. D. Thomas. 2012. Review of fisheries management activities at Lake Mattamuskeet, 2003–2011, and recommendation of enhancement strategies. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Murphy, B. R., D. W. Willis, and T. A. Springer. 1991. The relative weight index in fisheries management: status and needs. Fisheries 16(2):30–38.

Oakley, N. C. and L. Dorsey. 2013. Data collection and analysis guidelines for the Piedmont Region. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh.

Schaeffer, J. S., and F. J. Margraf. 1987. Predation on fish eggs by White Perch, *Morone americana,* in western Lake Erie. Environmental Biology of Fishes 18:77–80.

Tebo, L. B, Jr., and McCoy, E. G. 1964. Effect of sea-water concentration on the reproduction and survival of Largemouth Bass and Bluegills. Progressive Fish-Culturist 26(3):99–106.

Thomas, C. D. 1997. Assessment of the fish community in Rose Bay and Main Canals, Lake Mattamuskeet. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

USFWS (U.S. Fish and Wildlife Service). 2010. Mattamuskeet National Wildlife Refuge sport fishing regulations. Mattamuskeet National Wildlife Refuge, Swanquarter, North Carolina.

Wege, G. J., and R. O. Anderson. 1978. Relative weight (Wr): a new index of condition for Largemouth Bass. Pages 79–91 *in* G. Novinger and J. Dillard, editors. New approaches to the management of small impoundments. American Fishery Society, North Central Division, Special Publication 5, Bethesda, Maryland.

TABLE 1.— Mean, standard error, minimum, and maximum water quality measurements for Lake Mattamuskeet collected from the main lake, Jarvis Canal, Main Canal, and Rose Bay Canal during electrofishing surveys in October 2013 and net surveys in November 2013.

Location	Parameters	Mean	Standard Error	Minimum	Maximum
Lake Sites	Temp (°C)	15.8	0.6	14.3	17.8
	% Saturation	114.9	6.1	91.9	132.3
	DO (mg/L)	11.37	0.53	9.22	12.72
	Spec Cond (µS/cm)	2361	77	2046	2609
	Salinity (ppt)	1.5	0.1	1.3	1.6
Jarvis, Main, and Rose Bay canals	Temp (°C)	16.1	0.2	14.1	19.1
	% Saturation	86.3	3.5	37	125
	DO (mg/L)	8.28	0.32	3.51	11.40
	Spec Cond (µS/cm)	3848	265	1579	7275
	Salinity (ppt)	2.5	0.2	1	4.9

TABLE 2.—Number and size range of fish species collected from Lake Mattamuskeet in the main lake, Jarvis Canal, Main Canal, and Rose Bay Canal during electrofishing surveys in October 2013 and net survey in November 2013.

Species	Common name	Number	Length Range (mm)
Alosa pseudoharengus	Alewife	2	76–87
Alosa pseudoharengus[1]	Alewife[1]	18[1]	81–94[1]
Amia calva	Bowfin	43	195–632
Anguilla rostrata	American Eel	6	173–500
Cyprinus carpio	Common Carp	3	344–543
Dorosoma cepedianum	Gizzard Shad	13	64–394
Dorosoma petenense	Threadfin Shad	7	62–80
Elops saurus	Ladyfish	4	315–333
Enneacanthus gloriosus	Bluespotted Sunfish	3	54–62
Esox niger	Chain Pickerel	1	234
Gambusia affinis	Mosquitofish	6	20–28
Ictalurus punctatus	Channel Catfish	2	550–740
Leiostomus xanthurus	Spot Croaker	2	138–172
Lepisosteus osseus	Longnose Gar	1	712
Lepomis gibbosus	Pumpkinseed	144	52–162
Lepomis gulosus	Warmouth	13	84–203
Lepomis machrochirus	Bluegill	362	30–243
Lepomis microlophus	Redear Sunfish	40	91–212
Lepomis spp.	Hybrid Sunfish	1	167
Menidia menidia	Atlantic Silverside	13	26–87
Micropterus salmoides	Largemouth Bass	190	111–556
Morone americana	White Perch	269	71–278
Mugil cephalus	Striped Mullet	52	159–474
Notemigonus crysoleucas	Golden Shiner	4	31–172
Paralichthys lethostigma[1]	Southern Flounder[1]	52[1]	360–590[1]
Perca flavescens	Yellow Perch	22	48–221
Pomoxis nigromaculatus	Black Crappie	53	118–324
Pomoxis nigromaculatus[1]	Black Crappie[1]	434[1]	136–341[1]

[1]Species collected in net surveys

TABLE 3.— Proportional size distribution for quality (PSD), preferred (PSD-P), and memorable (PSD-M) Black Crappie collected in the canals associated with Lake Mattamuskeet using electrofishing in October 2013 and trap, hoop, and fyke nets in November 2013.

Method	Location	n	PSD	PSD-P	PSD-M
Net Surveys	Main Canal	175	95.4	61.7	25.7
	Rose Bay Canal	258	72.1	23.6	6.6
Electrofishing	Main Canal	33	59.3	33.3	18.5
	Rose Bay Canal	10	60.0	20.0	10.0
	Jarvis Canal	10	62.5	50.0	12.5

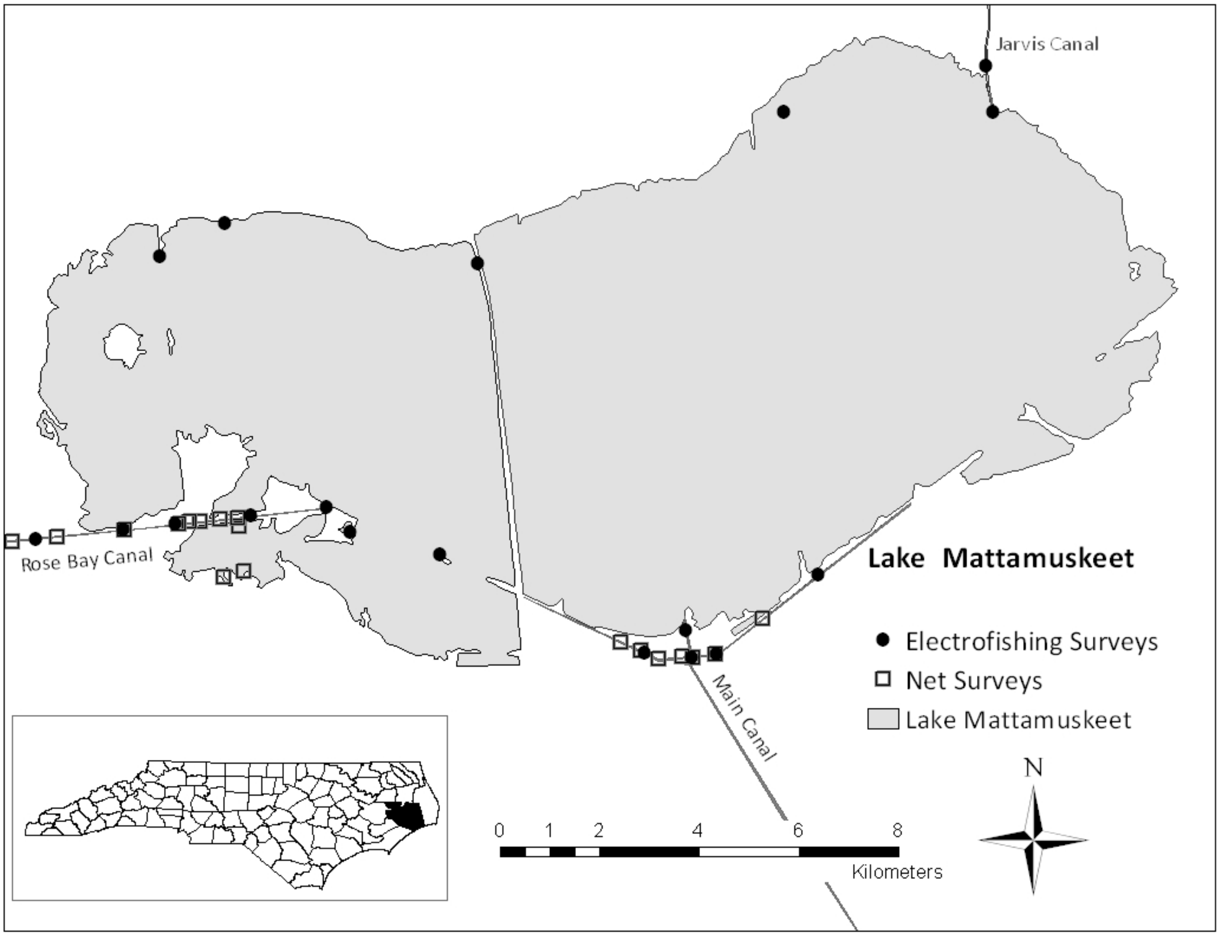


FIGURE 1.—Electrofishing and net survey site locations in Lake Mattamuskeet and associated canals (Jarvis Canal, Main Canal and Rose Bay Canal), October and November 2013.

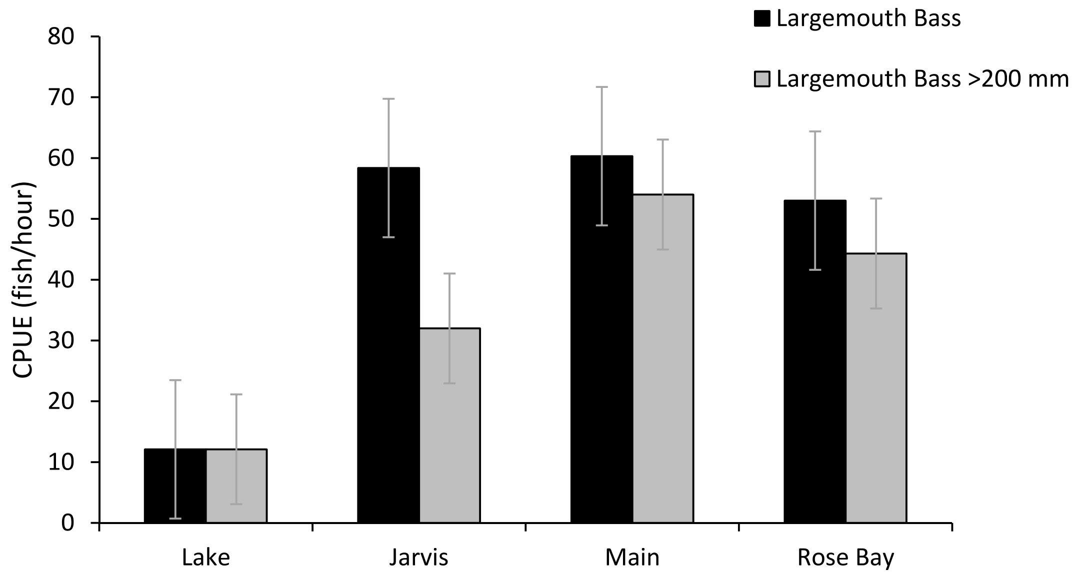


FIGURE 2.—Catch per unit effort of Lake Mattamuskeet Largemouth Bass collected in electrofishing transects in the main lake (Lake), Jarvis Canal, Main Canal, and Rose Bay Canal, October 2013. Error bars represent one standard error.

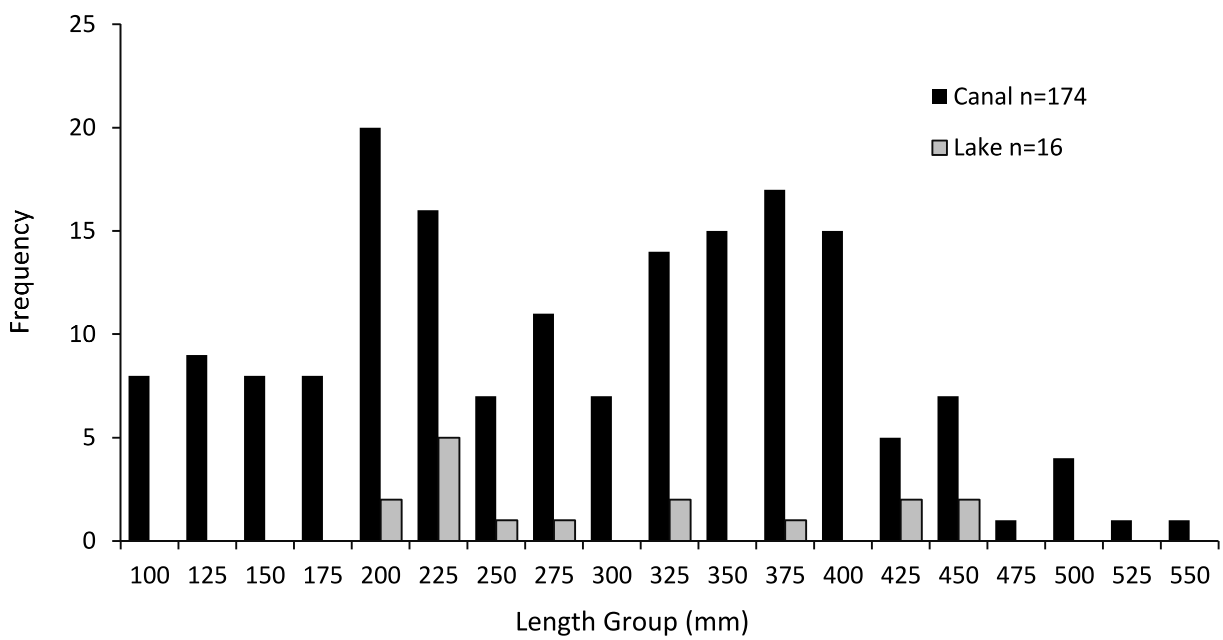


FIGURE 3.—Length frequency distribution of Lake Mattamuskeet Largemouth Bass recorded in 25-mm length groups collected by electrofishing in the main lake (Lake) and canals (Canal), October 2013.

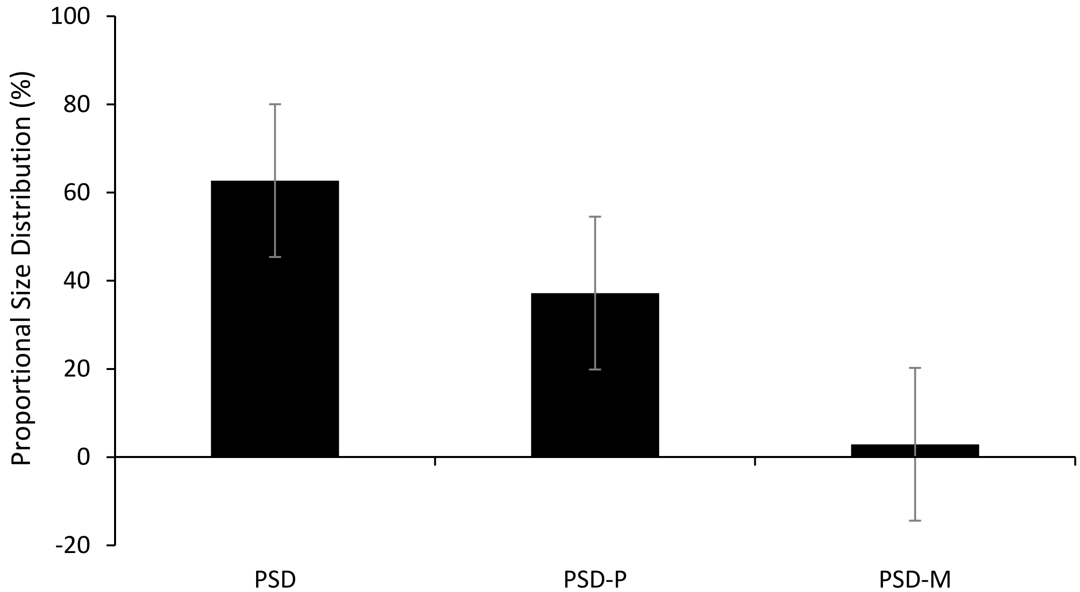


FIGURE 4.—Proportional size distribution for quality, preferred, and memorable Largemouth Bass collected by electrofishing in Lake Mattamuskeet's Jarvis Canal, Main Canal, and Rose Bay Canal, October 2013. Error bars represent one standard error.

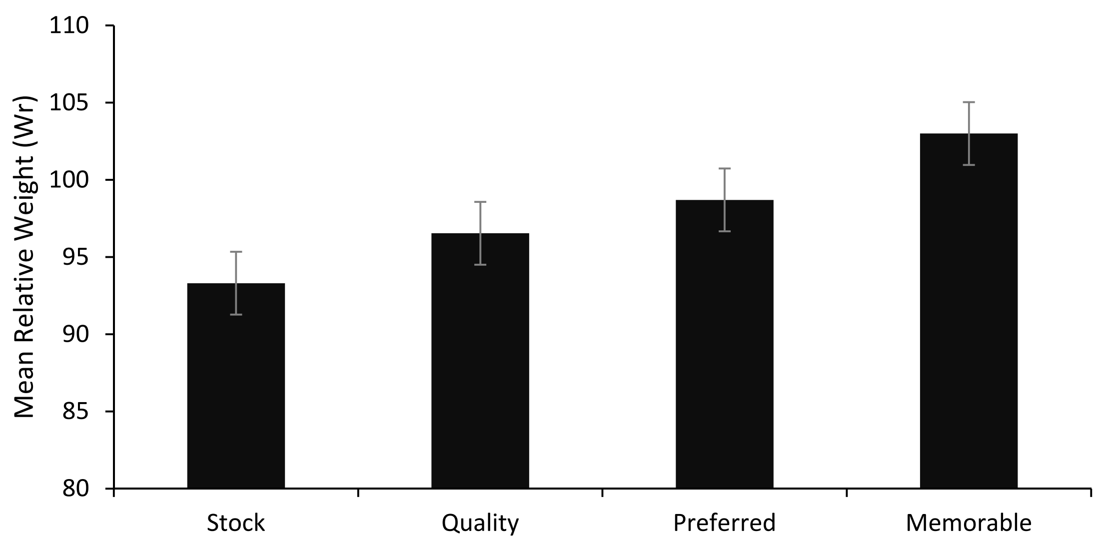


FIGURE 5.—Mean relative weights of Lake Mattamuskeet Largemouth Bass by proportional stock distribution category for fish collected by electrofishing in Jarvis Canal, Main Canal and Rose Bay Canal, October 2013. Error bars represent one standard error.

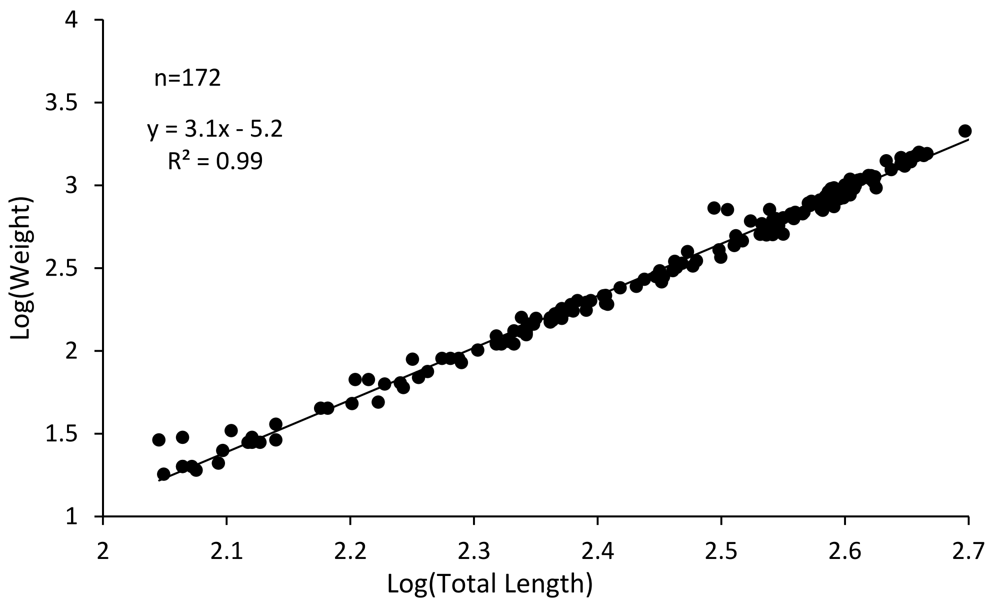


FIGURE 6.—Linear regression of the $\log_{10}$ transformed weight versus $\log_{10}$ transformed total length of Lake Mattamuskeet Largemouth Bass collected by electrofishing in Jarvis Canal, Main Canal, and Rose Bay Canal, October 2013.

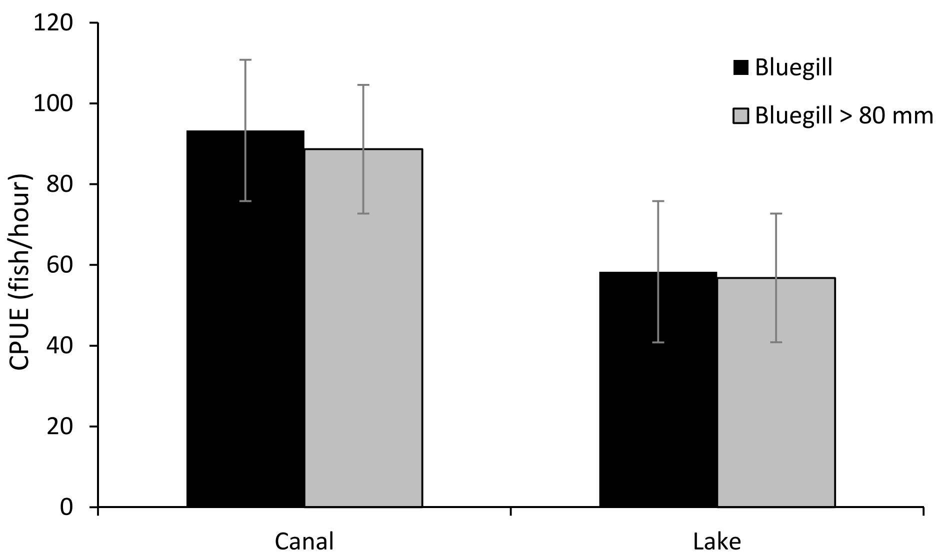


FIGURE 7.—Catch per unit effort measured in fish per hour for Lake Mattamuskeet Bluegill collected by electrofishing in the main lake (Lake) and canal samples (Canal), October 2013. Error bars represent one standard error.

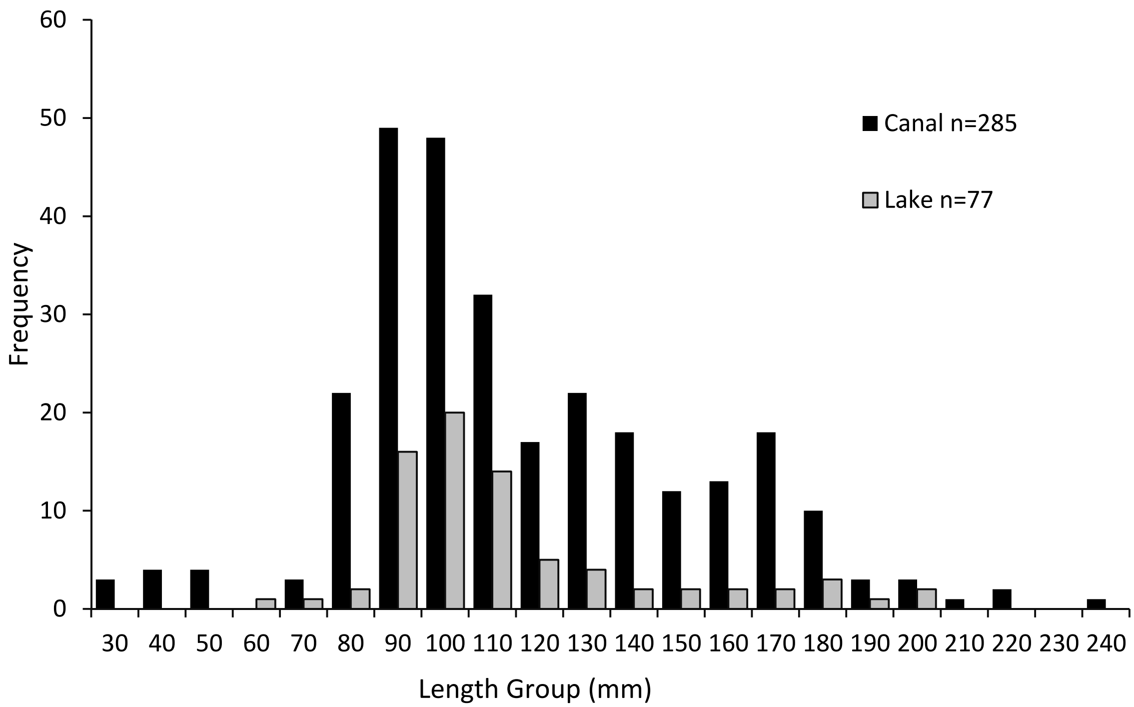


FIGURE 8.—Length Frequency distribution of Lake Mattamuskeet Bluegill recorded in 10 mm length groups, collected by electrofishing in the main lake (Lake) and canals (Canal), October 2013.

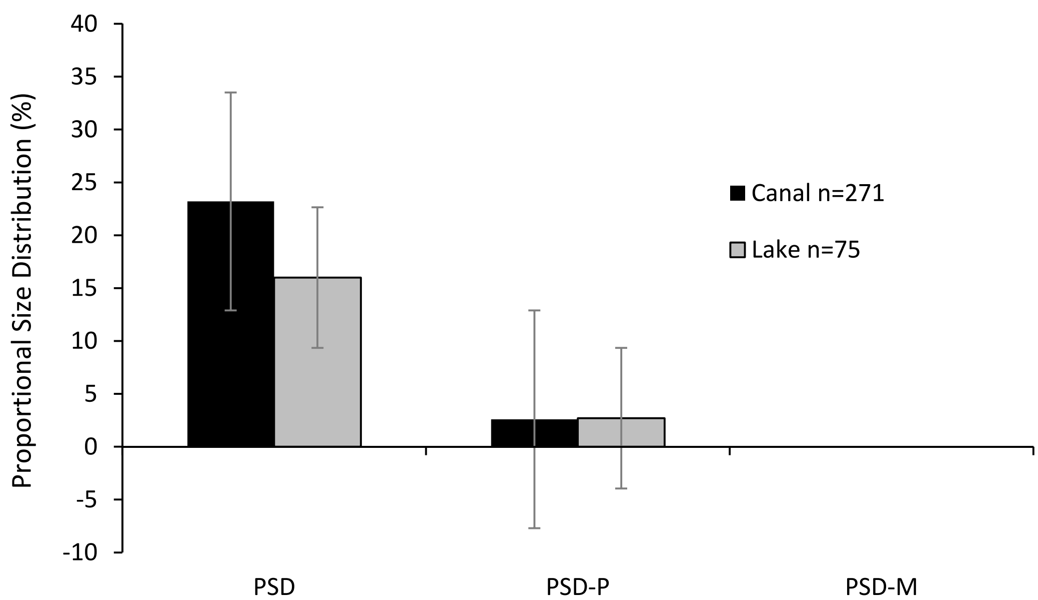


FIGURE 9.—Proportional size distribution for Lake Mattamuskeet quality, preferred, and memorable Bluegill collected by electrofishing in the main lake (Lake) and canals (Canal), October 2013. Error bars represent one standard error.

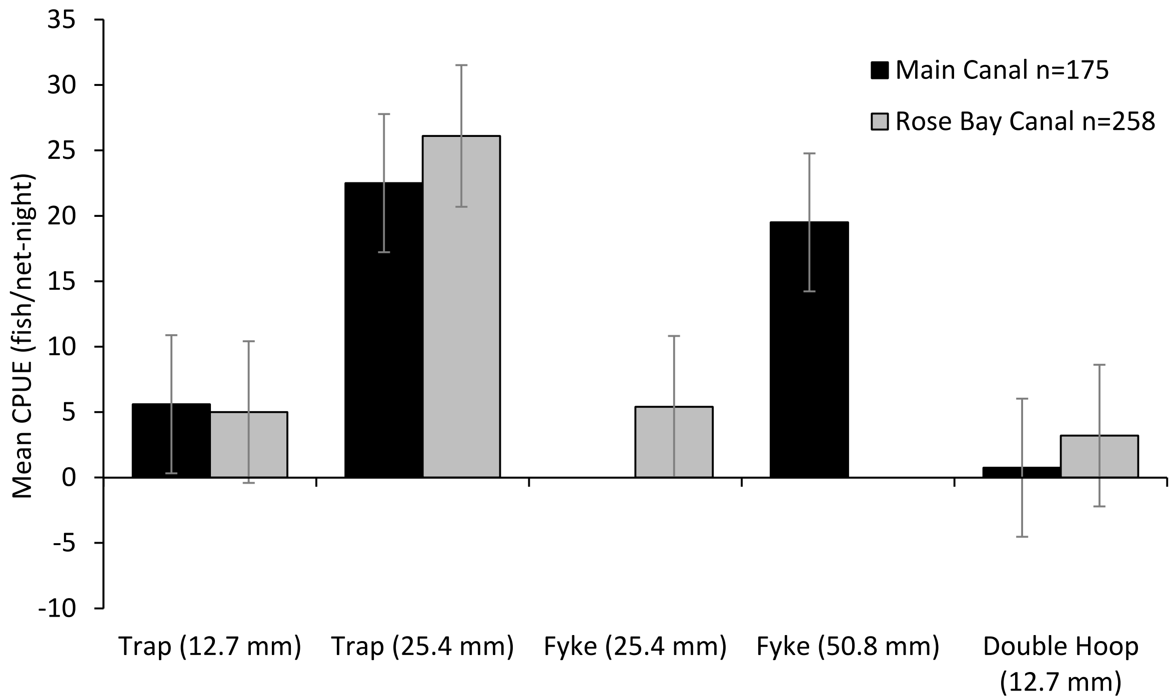


FIGURE 10.—Catch per unit effort (fish caught per net night) for Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013. Error bars represent one standard error.

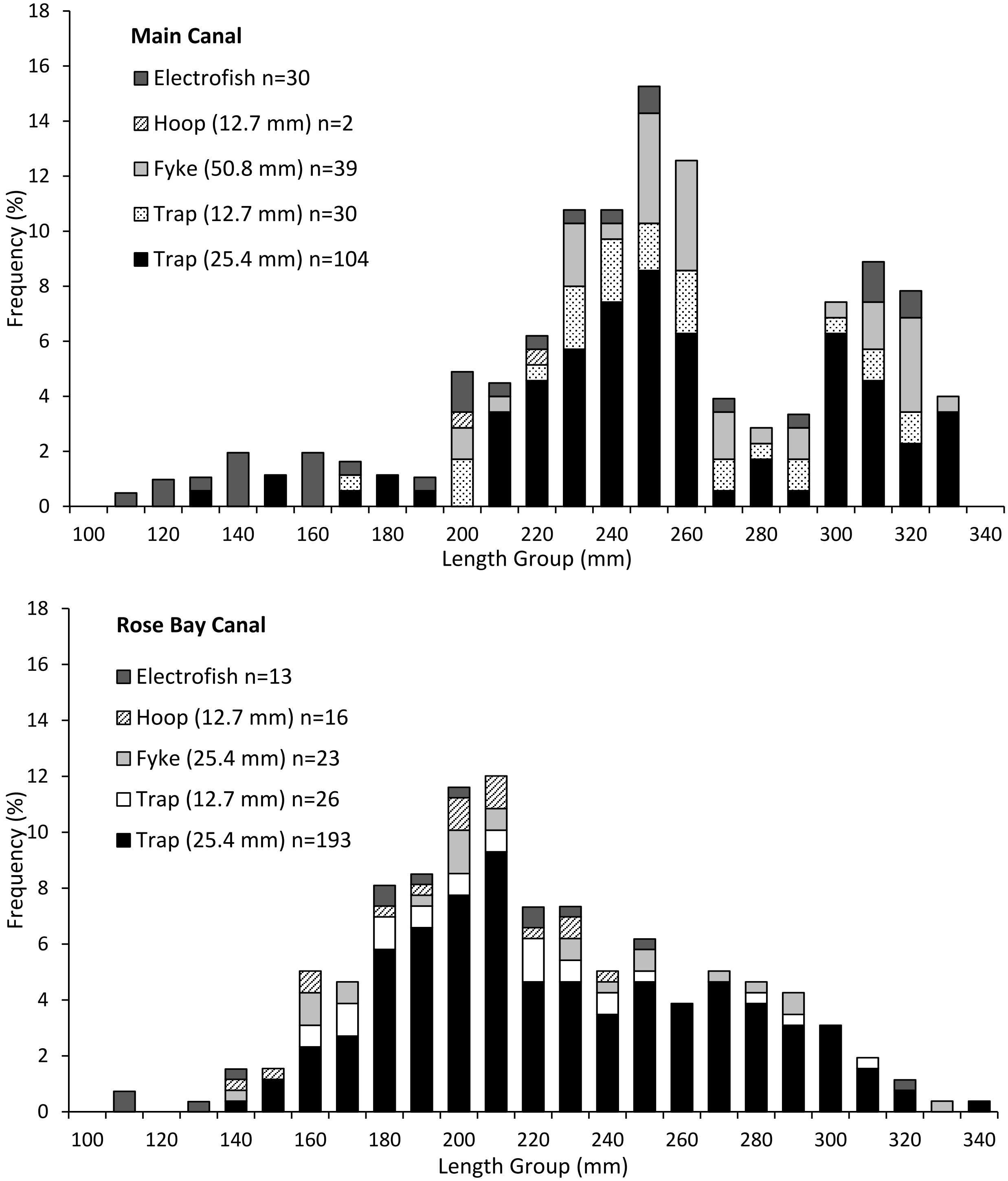


FIGURE 11.— Length frequency histograms for Black Crappie collected in Lake Mattamuskeet's Main Canal and Rose Bay Canal by electrofishing in October 2013 and trap, hoop, and fyke nets in November 2013.

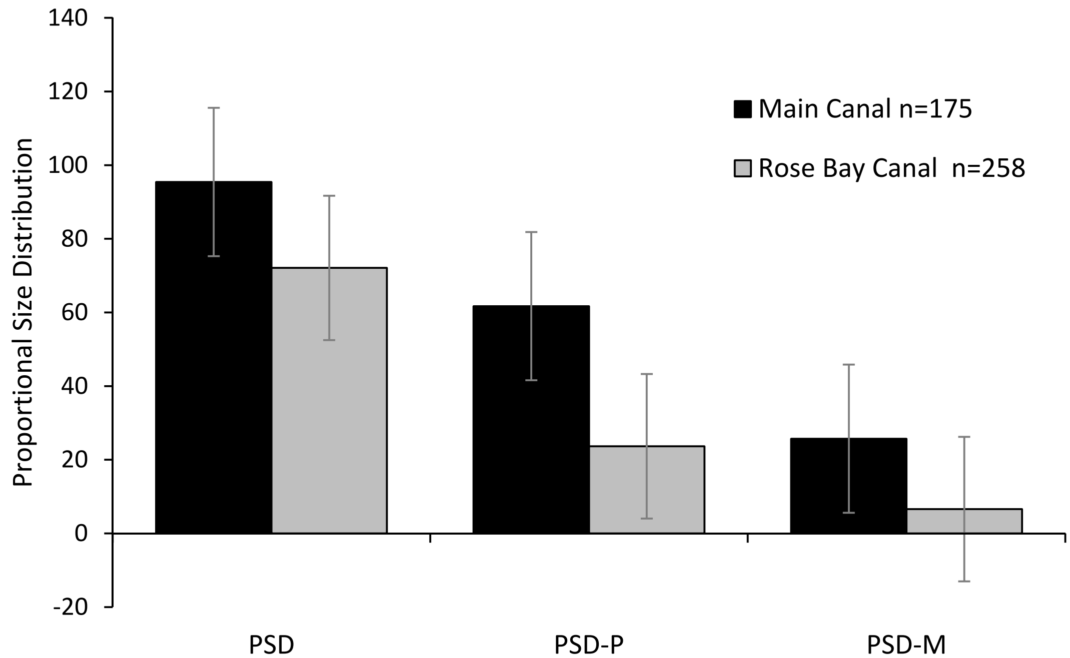


FIGURE 12.—Proportional size distribution for quality, preferred, and memorable Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013. Error bars represent one standard error.

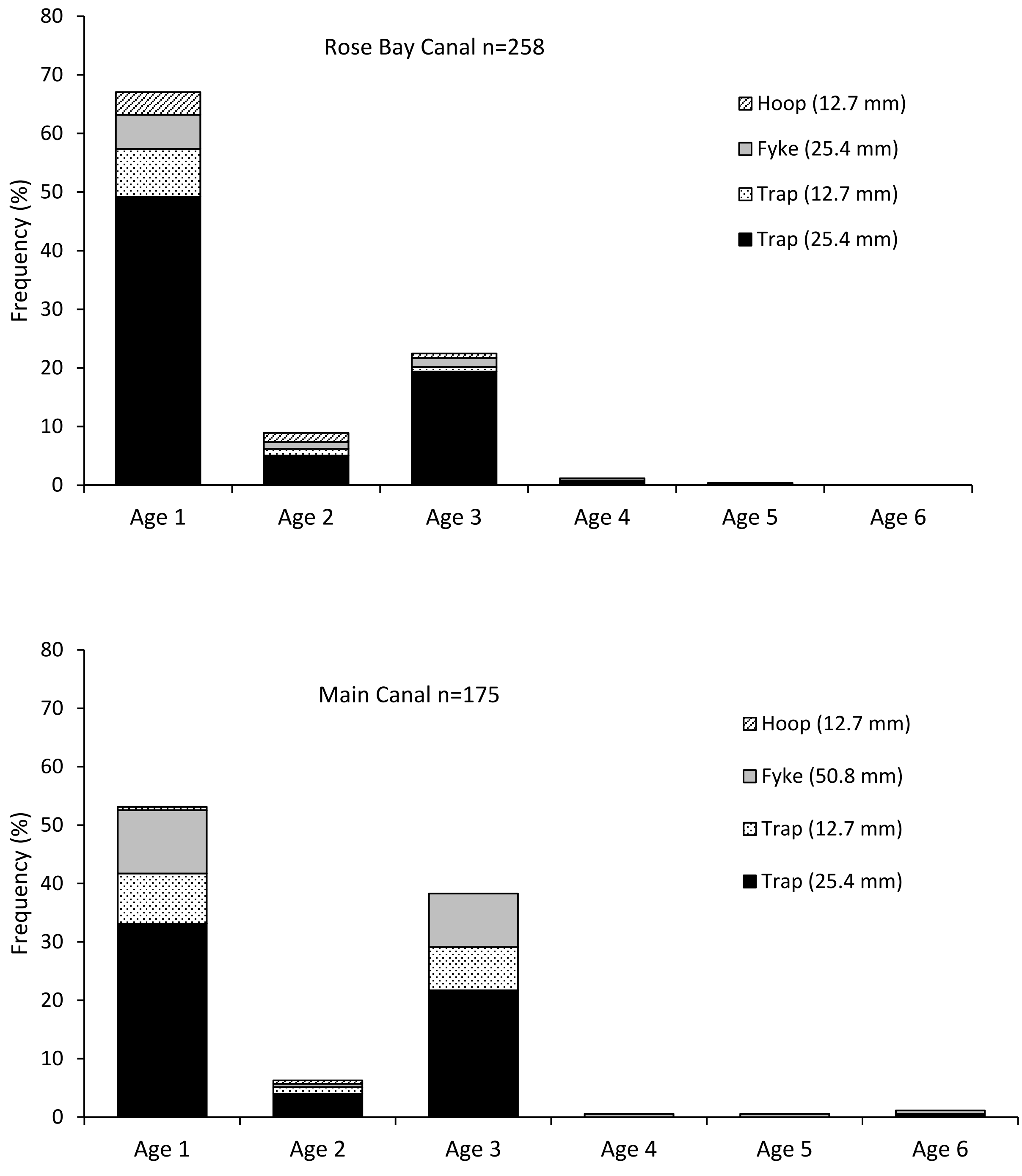
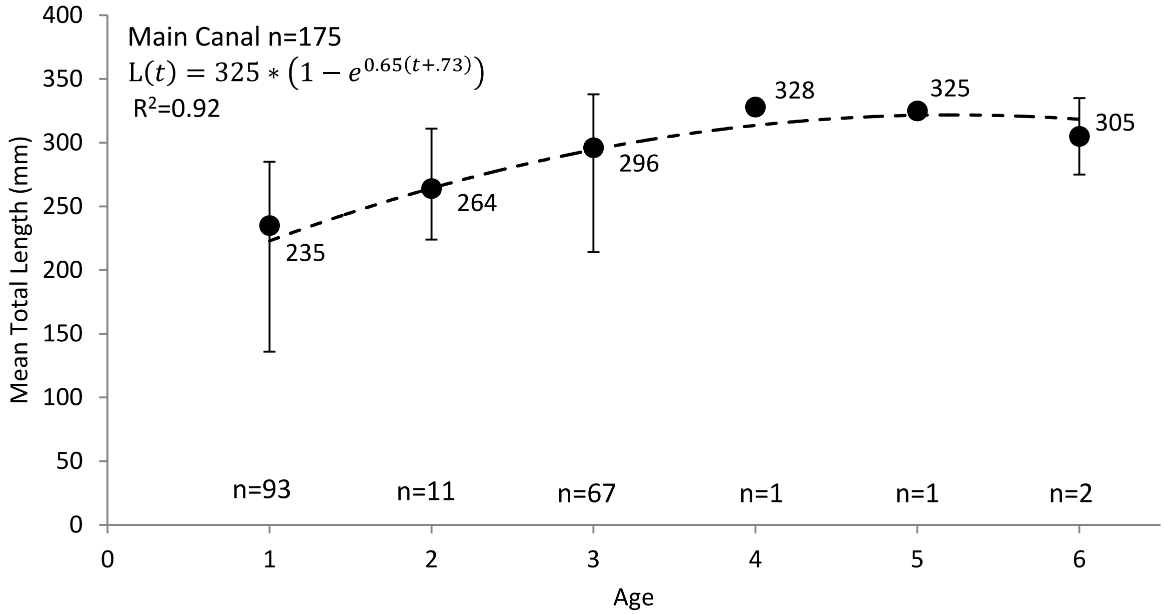


FIGURE 13.—Age frequency for 433 Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013.



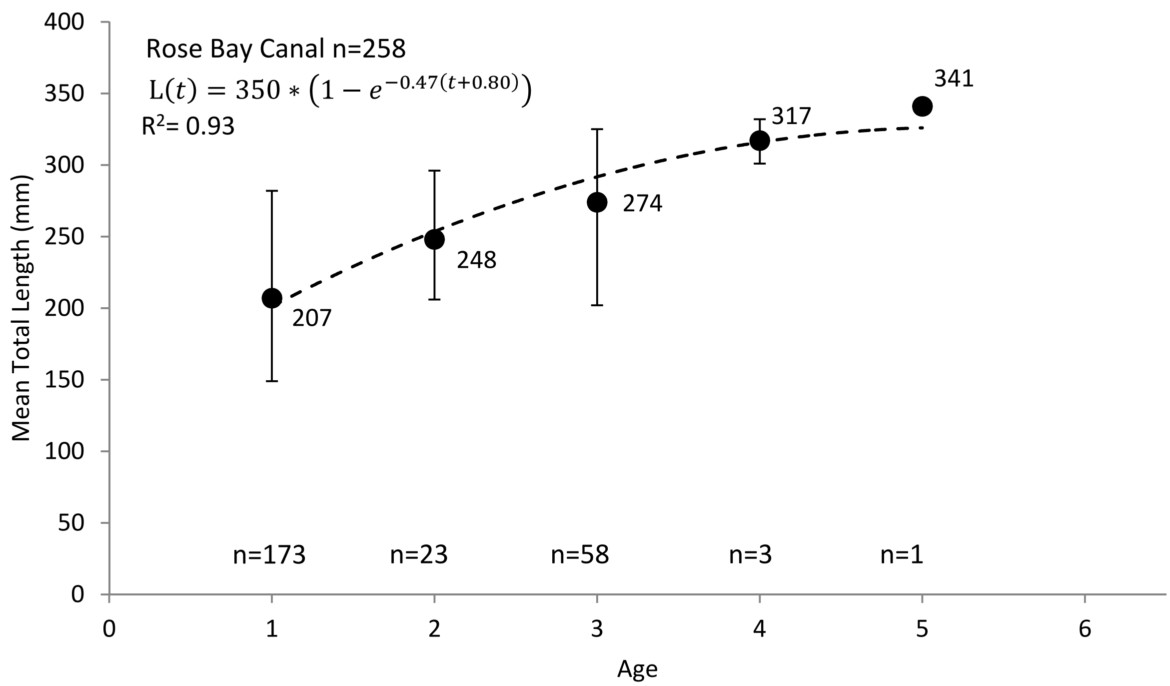


FIGURE 14.—Mean total length at age of Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013. Circles represent mean total length; bars represent maximum and minimum length observed at each age. Dashed lines indicate von Bertalanffy growth models described by equations on each chart.

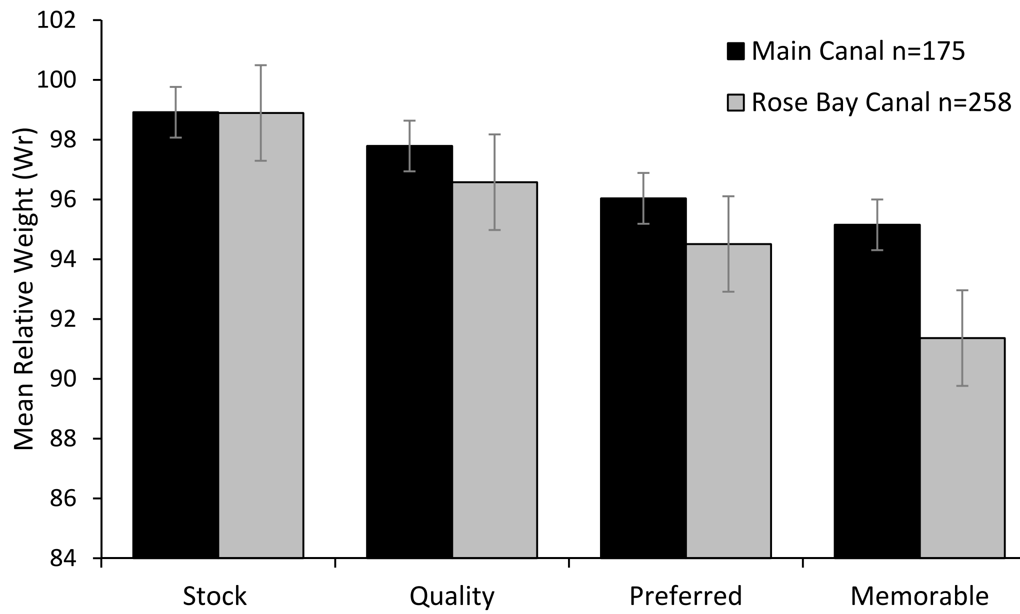


FIGURE 15.—Mean relative weights of stock, quality, preferred, and memorable length Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013. Error bars represent one standard error.

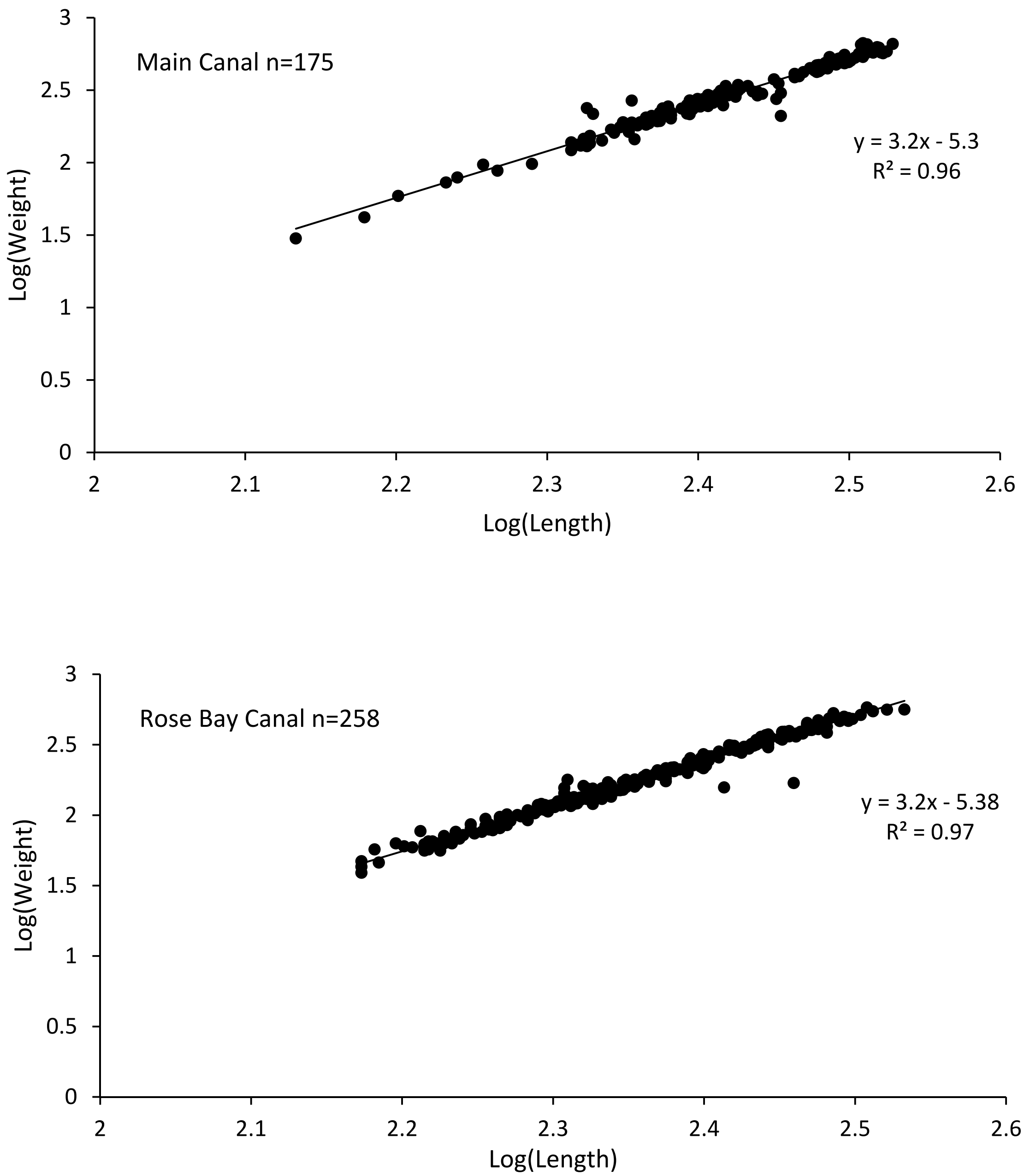


FIGURE 16.—Linear regression of the $\log_{10}$ transformed weight versus $\log_{10}$ transformed length of Black Crappie collected by trap, hoop, and fyke nets in Lake Mattamuskeet's Main Canal and Rose Bay Canal, November 2013.

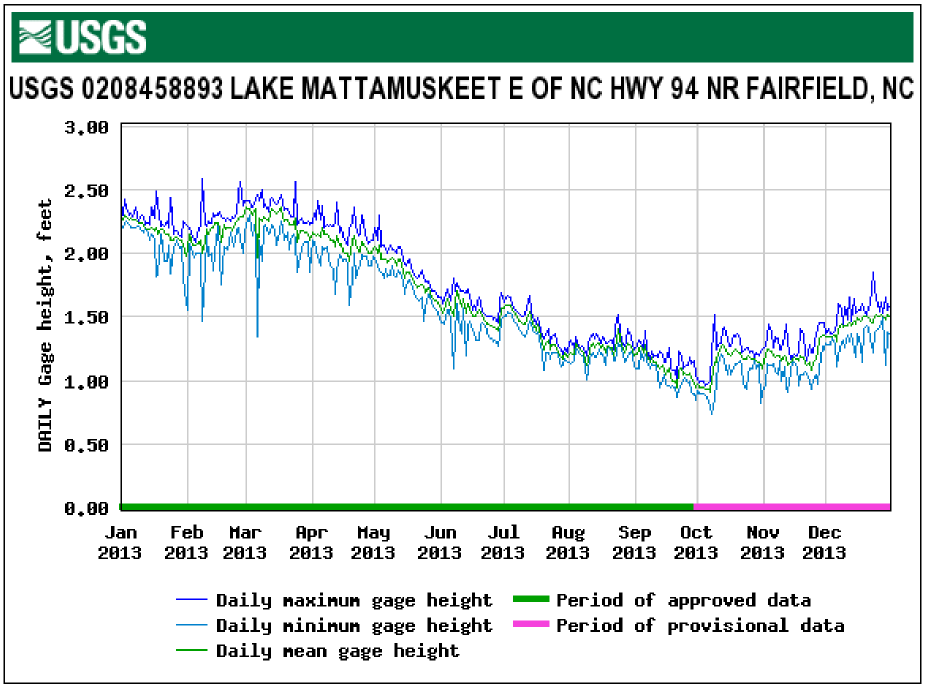


FIGURE 17.—2013 daily mean lake level fluctuations in Lake Mattamuskeet from the period 1 January to 31 December as measured from USGS station 0208458893 located on the east side of the lake.

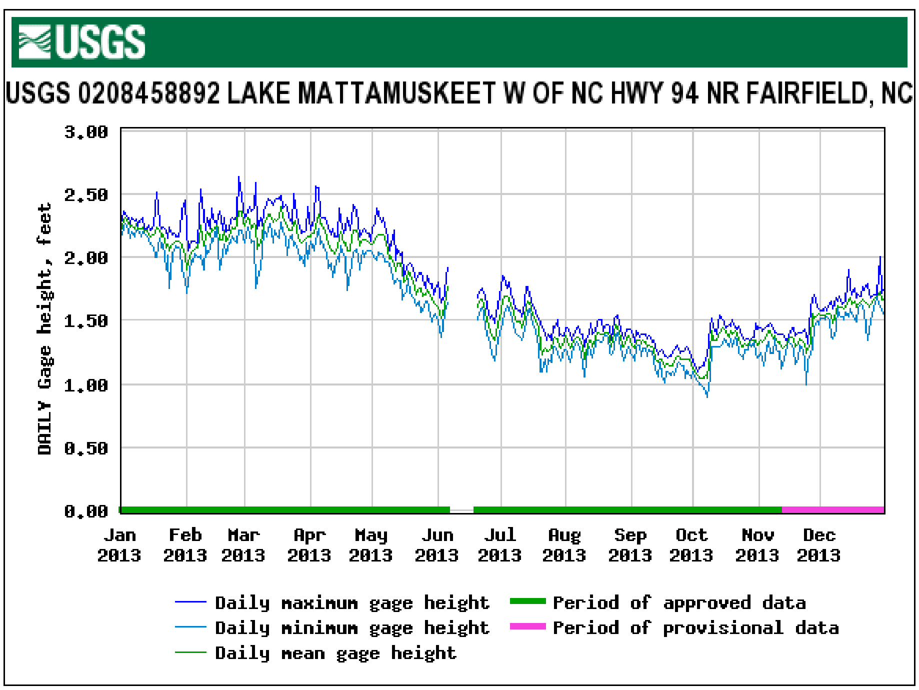


FIGURE 18.—2013 daily mean lake level fluctuations in Lake Mattamuskeet from the period 1 January to 31 December, as measured from USGS station 0208458892 located on the west side of the lake.