SANTEETLAH RESERVOIR LARGEMOUTH BASS SURVEY, 2013–2015

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Abstract.—Largemouth Bass *Micropterus salmoides* were sampled between late April and early May 2013–2015 using boat-mounted electrofishing gear from 12, 300-m sites on Santeetlah Reservoir. All fish were weighed, measured and aged. A total of 1,082 Largemouth Bass were collected in 12.1 h of effort for a mean catch rate of 90 fish/h (SE = 4.9) over the three-year survey. Largemouth Bass ranged 58–531 mm TL. Proportional size distribution (PSD; ≥300mm TL) values were 34, 69, and 68 during the survey period. However, few (2%) Largemouth Bass reached the PSD-preferred (≥380 mm TL) length category, resulting in values well below those of balanced populations (10–40). Throughout the three-year survey, body condition was poor and decreased with fish length. Mean relative weights of 84–90 suggest that reservoir productivity, forage availability, density-dependent interactions, or a combination of factors, are contributing to less than desirable body condition. Growth also was poor and Largemouth Bass did not reach 356 mm TL until age 7.9 according to a von Bertalanffy growth model.

Santeetlah Reservoir a 1,165-ha impoundment on the Cheoah River in Graham County, N.C., is a hydroelectric development operated by Brookfield Smoky Mountain Hydropower LLC. (Federal Energy Regulatory Commission Project Number 2169-109). Santeetlah Dam was completed in 1928 and the full-pool elevation is 592 m above mean sea level. Santeetlah Reservoir is an oligotrophic reservoir characterized by clear water, step shorelines, rock and clay substrates, abundant shoreline woody cover, and a relatively stable year-round pool elevation. Water level fluctuations were limited to ±1 m in the 2005 Federal Energy Regulatory

Commission settlement agreement. The fishery resources, including cold-, cool- and warmwater species, are managed by the North Carolina Wildlife Resources Commission (Commission) through creel and size limit regulations. A variety of resource management and habitat enhancement related activities are jointly conducted between the Commission and the U.S. Forest Service, the predominant shoreline property owner, to benefit aquatic fauna in the reservoir.

Fishery surveys have been conducted infrequently on Santeetlah Reservoir. One of the earliest surveys performed by Commission staff occurred 1957–1959 which used cove rotenone sampling, gill nets and trammel nets to assess the fish community (Tebo 1961). This effort was followed by a similar comprehensive reservoir fish community assessment in 1963 and 1965 (Messer 1966). Davies (1981) employed cove rotenone sampling, gill netting and shoreline electrofishing techniques to assess the fish community. A shoreline electrofishing survey of limited scope was performed in 1987 to address angler concerns of a declining black bass fishery (Wynne and Paulk 1988). Finally, a three-year shoreline electrofishing survey, 1997–1999, and concurrent angler survey (1998–1999), was completed by Commission staff (Yow et al. 2002; Loftis and Yow 2004).

The reservoir supports a diverse sportfish community; however, boat angling effort data reported in the 1998–1999 creel survey found that the black bass fishery (Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *M. dolomieu*) garnered the highest directed angling effort (41%) and Walleye *Sander vitreus* were second highest (24%). The remaining boat angling effort on Santeetlah Reservoir was undirected effort reflecting minimal targeted interest in catfish, crappie, sunfish, trout or White Bass *Morone chrysops* (Yow et al. 2002).

There were no black bass surveys on Santeetlah Reservoir between the 1997–1999 shoreline electrofishing survey and the current three-year back bass population assessment effort, 2013–2015. The goal of this shoreline electrofishing survey was to perform a stock assessment on the Santeetlah Reservoir black bass population.

Methods

Field Collections.—Boat-mounted electrofishing gear was used to collect black bass from 12 sites on Santeetlah Reservoir between the last week of April and early-May, 2013–2015. Electrofishing gear included a 5.5 m jonboat, 7,500 W generator, and a Smith-Root 7.5 GPP that produced 2–4 A of pulsed DC current. One dipnetter collected stunned fish. All sites were approximately 300 m long and distributed throughout the lake (Figure 1). All black bass collected were measured for total length (TL; mm), weighed (g) and sexed. Sagittal otoliths were removed for age and growth determination.

Relative Abundance.—Relative abundance, an index of CPUE of electrofishing time, is expressed as number of collected fish/h. Annual relative abundance was described as the mean number of fish/h collected for all sites combined. Standard error (SE) values were calculated to measure variability of the annual CPUE estimates.

Size Structure.—Length-frequency histograms describe fish TL grouped by 25-mm size classes. Proportional size distributions (PSDs) were calculated according to Anderson and Neumann (1996) and Guy et al. (2007). Total length classes were used to assess size distributions and are defined as stock size (≥200 mm TL), quality size (≥300 mm TL), preferred size (≥380 mm TL), memorable size (≥510 mm TL), and trophy size (≥630 mm TL) (Gabelhouse 1984).

Condition Indices.—Wege and Anderson (1978) introduced the concept of body condition for Largemouth Bass and developed a standard length-weight equation. Relative weight (W_r) values were calculated for Largemouth Bass greater than 150 mm TL in this survey using the following equation:

$$W_r = W / W_s \times 100,$$

where W_r is the relative weight, W is the wet weight, and W_s is the length-specific standard weight of an individual. To calculate W_r values we used the standard weight equation for Largemouth Bass developed by Henson (1991):

$$\log_{10}W_s = -5.316 + 3.191 \cdot \log_{10}(TL),$$

Age and Growth.—All otoliths were immersed in water and read with a 10X dissecting microscope illuminated with a fiber-optic light. Otoliths determined to have more than one annuli were halved at the midpoint, perpendicular to the long axis. The rough edge was wet-sanded with 400–600 grit sandpaper before counting annuli. Two readers independently aged each otolith, and annuli count discrepancies were resolved by re-reading the otolith in concert. A final annuli count was then recorded for each fish. Fish were assigned an age equal to the number of annuli plus one because they were in the process of laying down a new annulus during our spring surveys (Taubert and Tranquilli 1982).

Mean TL at age was calculated for all Largemouth Bass and a von Bertalanffy growth curve was constructed using Fisheries Analysis and Modeling Simulator software (Slipke and Maceina 2014) to estimate growth rates (Van Den Avyle and Hayward 1999). The von Bertalanffy growth equation is defined as:

$$L_t = L_\infty \left(1 - e^{-K(t - t_o)}\right),$$

where L_t is the predicted TL at time t, L_∞ is the mean maximum TL of the population, K is the growth parameter, t is time in years, and t_o is the time at which L_t is zero.

Results and Discussion

Relative Abundance.—A total of 1,082 Largemouth Bass were collected in 12.1 h of electrofishing effort over the three survey years (Mean = 90 fish/h; SE = 4.9) (Table 1). Catch-per-unit-effort for the 12 sites surveyed in 2013 ranged from 52 to 160 fish/h with a mean of 89 fish/h (N = 437; SE = 9.6). In 2014, CPUE by site ranged from 67 to 196 fish/h, resulting in a mean of 107 fish/h (N = 399; SE = 10.3). A CPUE of 48 to 103 fish/h by site and a mean of 74 fish/h was calculated for the 2015 sample, lowest among the three-year survey (N = 246; SE = 5.9). Smallmouth Bass (N = 29) and Spotted Bass *M. punctulatus* (N = 10) were collected in each of the three years; however, catch rates for both species were too low to quantify stock assessment indices. Spotted Bass were not previously collected in Santeetlah Reservoir during the creel survey (Yow et al. 2002) or the previous black bass monitoring survey (Loftis and Yow 2004). The rare occurrence of Spotted Bass in this survey suggests that the species was likely introduced recently.

Future genetics surveys are needed to determine the species of the fish that we identified as Spotted Bass. Recent black bass genetic surveys have revealed that most North Carolina populations previously identified as Spotted Bass are Alabama Bass *M. henshalli* (unpublished data). For example, 2019 genetic testing of black bass in nearby Lake Fontana confirmed the presence of Alabama Bass (District 9, unpublished data). Management issues can arise over unauthorized introduction of fish species due to concerns of negative interactions with the existing fisheries, such as changes in a species relative abundance or hybridization concerns.

Largemouth Bass CPUE from other western North Carolina reservoirs are variable and often range from 25–74 fish/h (Davies 1981; Loftis and Goudreau 2000; Loftis and Yow 2004; Wood 2014). Relative abundance estimates for Largemouth Bass in Santeetlah Reservoir exceeded this range in 2013 and 2014. Similar electrofishing gear was used across samples; therefore, sampling efficiency is not considered a likely contributor to the observed abundance differences. However, the relative abundance differences may be due annual variations in the timing of black bass spawning behavior. Although the surveys were scheduled to coincide with the Largemouth Bass spawning period, environmental conditions (e.g., moon phase, water temperature, photo-period, water level, rainfall, and weather conditions) may influence the timing of spawning behavior. These environmental factors influence the number of fish present in shallow water (≤3 m), therefore vulnerable to electrofishing gear (McInerny and Cross 2000). It is suspected that many of the variables worked in concert, including pre-determined sampling dates, to overlap when most Largemouth Bass were in shallower water and susceptible to the gear. Moreover, many fish were observed in pairs and displayed spawning behavior during the 2014 survey, when the mean abundance estimate (107 fish/h) for Santeetlah Reservoir was 45% higher when compared to historic values from other mountain region reservoirs. However, regardless the combination of environmental variables, the comparatively high CPUEs during this survey may simply reflect a high number of Largemouth Bass present.

Size Structure.—Total lengths of Largemouth Bass collected during this survey ranged from 58–550 mm (Table 1). The modal distribution of fish sizes, when grouped in 25 mm TL classes, were 275–299 mm (2013; 36%), 300–324 mm (2014; 38%), and 325–349 mm (2015; 24%) (Figure 2). The mean TL of all Largemouth Bass collected each of the three survey years ranged from 286–292 mm (Table 1). In 2013 (N = 437), 96% of fish captured were <356 mm TL, 94% were <356 mm TL in 2014 (N = 399), and in 2015 (N = 245), 86% were <356 mm TL (Figure 2). The minimum size requirement for harvest at the onset of the survey was ≥356 mm TL. The majority of Largemouth Bass collected in this survey were below the TL requirement for harvestable size.

The PSD (34%) was below the desired range (40–70%) for a balanced Largemouth Bass population in 2013 because many fish were below the quality length category (≥300 mm). In 2014 and 2015, PSD values were at the upper range (69% and 68%, respectively) for a balanced population (Willis et al. 1993; Table 1). However, few Largemouth Bass collected reached the PSD-preferred (≥380 mm TL) length-class category, resulting in values well below the balanced population range of 10–40 (Table 1). Less than 1% were in the memorable (≥510 mm TL) length-class in 2014 and 2015 and no memorable-length fish were collected in 2013. No fish in the trophy (≥630 mm TL) length-class were captured during this survey. Length structure indices during this survey where markedly different from the PSD and PSD-preferred values calculated for Largemouth Bass collected during the 1997–1999 survey. The values from the previous survey were 55–84% for PSD and 4–12% for the PSD-preferred length categories. Conversely, the PSD-memorable values (1–2%) were similar among all years. Only one fish has been collected in the PSD-trophy length-class (≥630 mm TL; 1998).

At the time of this survey, anglers could harvest five black bass per day but only two could be <356 mm TL. This regulation went into effect on August 1, 2012 during the 2012–2013 regulation cycle, the summer before the start of this survey. Following the regulation change, local anglers expressed concern about the high number of small bass that were routinely being caught. Prior to the 2012–2013 regulation cycle, the previous size limit for black bass in Santeetlah Reservoir, along with other mountain region reservoirs, was 305 mm TL and two fish <305 mm TL could be kept.

This information prompted the Commission to enact a black bass regulation exception specifically for Santeetlah Reservoir and implement a three-year survey to evaluate the existing population structure to have baseline data at the on-set of the high harvest intentioned black bass regulation exception. For the Santeetlah Reservoir exception, the creel limit was removed for all black bass <356 mm TL, allowing for unlimited harvest, but harvest of black bass ≥356 mm was limited to five black bass in combination. This regulation change became effective August 1, 2013, the summer following the first year of this survey.

The size structure of the Largemouth Bass population during each of the three years surveyed revealed that most fish collected were not harvestable size and the liberal harvest potential of the black bass regulation exception could have the intended effect on the population structure, assuming high angler harvest. A shoreline electrofishing survey to evaluate this harvest-oriented regulation exception should be performed in the spring of 2021 to evaluate the effectiveness this regulation exception has had in reshaping the Largemouth Bass size structure.

Condition Indices.—Mean W_r values for Largemouth Bass increased each year of the survey from 84 (SD = 7.4) in 2013, to 87 (SD = 7.3) in 2014, and reaching the highest mean value in 2015 (90; SD = 15.4); however, body condition generally decreased with increased fish length (Table 1; Figure 3). These mean W_r values were below the recommended range (95–105) for balanced fish populations (Anderson 1980) but within the range of mean values (81–90) observed during the 1997–1999 surveys (Loftis and Yow 2004). Although W_r values were within the range observed during the previous survey, decreasing body condition with increasing fish length was not as apparent in the 1997–1999 survey. Mean W_r values of stock-, quality-, preferred-, and memorable-length categories for Largemouth Bass declined with each larger length category in 2013 and 2014. However, in 2015, for quality-, preferred-, and memorable-length categories the mean W_r values improved, were more consistent between categories, and approached the minimum condition value suggested for a balanced population (Table 2).

Low W_r values could indicate less-than-favorable reservoir conditions such as a limited forage base, low productivity, poor physical habitat or water quality (Cone 1989; Anderson and Newman 1996; Blackwell et al. 2000). The reduced body condition observed during the first two survey years (2013–2014) might be related to the higher densities of black bass, evident in the CPUE values, and influenced by prey availability since the amount of available forage would be expected to decrease as total bass numbers increase. With the lower CPUE in 2015, yet improved W_r over the previous two survey years, this could be a plausible interpretation of the poor, yet improving, condition indices over the three-year survey.

Age and Growth.—Combing age data from all years (2013–2015), Largemouth Bass ranged from 1–12 years in age (N = 1,076) with age-4 fish (N = 299) the most frequently (28%) collected (Table 3). Age determination from otolith annuli counts revealed a strong 2009 year-class. In 2013, age-4 fish represented 41% of fish collected. Age-5 fish in the 2014 survey comprised 31% of fish sampled. The 2009 year-class (age 6) in 2015 was again the highest in occurrence (21%) of all fish captured age 3 and older. Other than the age-2 cohort collected in 2015, the 2009 year-class dominated the age structure each of the three survey years. Interestingly, the strength of the age-2 cohort (33%), apparent in 2015 survey, was not obvious in the 2014 collection (Figure 4). This may suggest that the age-1 fish had not fully recruited to the gear when sampled in 2014. The mean length of the age-1 cohort in 2014 was 117 mm TL (SE = 6.5).

Another indication that the Santeetlah Reservoir Largemouth Bass population is slow growing is that 96% of the Largemouth Bass collected were ≤7 years old and below the current minimum length requirement (356 mm TL; Table 3). Additional evidence that growth rates were slow is the estimated 7.9-years required for Largemouth Bass to reach harvestable size. The von Bertalanffy growth curve,

$$\text{Mean TL} = 425.3 * (1 - e\ (^{-0.25\ (\text{age}-0.636)}),$$

explained 94% of the variation in mean total length at age (Figure 5).

In the previous Santeetlah Reservoir survey (1997–1999), when otoliths were first used to determine mean total length at age of capture, it was estimated that Largemouth Bass reached harvestable size (305 mm TL) during age 3 (Loftis and Yow 2004). A minimum size limit of 305 mm TL was in place at the time of the 1997–1999 survey. Tebo (1961) also reported that Largemouth Bass attained harvestable size during age 3. Davies (1981) and Wynn and Paulk (1988) reported harvestable size was reached at age 4, and Clemmons (1990) reported harvestable size was not attained until age 6. It should be noted that all of the Santeetlah Reservoir age and growth results preceding the 1997-1999 survey were based on back-calculated length at age estimates from scale-aged fish, and therefore, length-at-age estimates should not be considered comparable to that of contemporary otolith-aged fish. Moreover, the vast discrepancy observed in length at age results from the current study compared to the 1997-1999 survey results suggests that the annual growth rates of Largemouth Bass have decreased dramatically over the 10–15 years since last evaluated.

Additionally, the size limit for black bass on Santeetlah Reservoir increased from 305 mm TL to 356 mm TL in 2012 to provide uniformity with a comprehensive black bass size and creel regulation on public waters in North Carolina. It is apparent from this survey that a minimum size limit of 356 mm TL would allow for the legal harvest of less than 5% of fish collected in the current study and further hinder a desirable population structure. Therefore, the more liberal creel regulation exception, including no daily harvest limit for black bass under 356 mm TL, enacted in the 2013–2014 regulation cycle, should promote harvest and improve the size and growth potential of Largemouth Bass in Santeetlah Reservoir.

Management Recommendations

1. Continue to manage the Santeetlah Reservoir black bass population with the current unlimited harvest exception for fish <356 mm and a five bass in aggregate harvest limit for fish ≥356 mm.
2. Perform a consecutive three-year survey of the black bass population to evaluate the efficacy of harvest-oriented regulation; perform a stock assessment to evaluate the relative abundance, age and length structure, condition, and growth of the Largemouth Bass population.
3. Collect black bass tissue samples from Santeetlah Reservoir to genetically identify the introduced black bass species; assess the level of introgression of Florida Largemouth Bass genes, if any, in the Largemouth Bass population; and determine the level of hybridization, if any, in the Smallmouth Bass population.

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TABLE 1.—Total catch (N), mean catch-per-unit-effort (CPUE; fish/h) with associated standard error (SE), total length range (TL; mm), mean TL with associated SE, proportional size distribution (PSD; ≥300 mm TL), PSD-preferred (PSD-P; ≥380 mm TL), PSD-memorable (PSD-M; ≥510 mm TL) and mean relative weight (W_r) results for Largemouth Bass collected during spring electrofishing surveys on Santeetlah Reservoir, NC, 2013–2015.

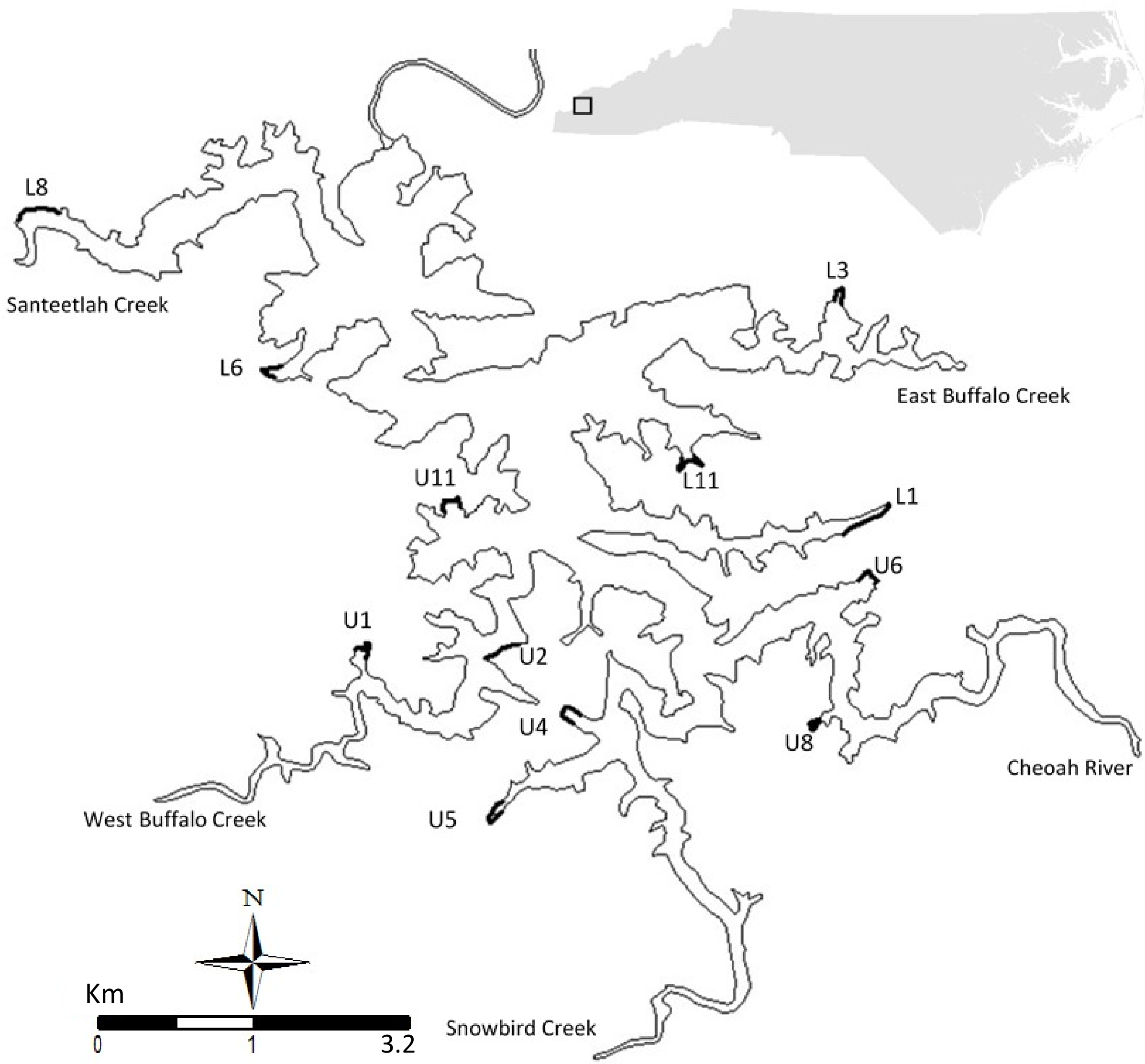
Year	N	CPUE (SE)	TL Range (mm)	Mean TL (SE)	PSD	PSD-P	PSD-M	Mean *Wr*
2013	437	89 (9.6)	82–493	286 (2.0)	34	2	0	84 (0.4)
2014	399	107 (10.3)	58–531	292 (3.3)	69	2	0	87 (0.4)
2015	246	74 (5.9)	85–550	292 (4.5)	68	2	0	90 (1.0)

TABLE 2.—Mean relative weight (W_r), with associated standard error (SE), by proportional size distribution category: stock (200–299 mm), quality (300–379 mm), preferred (380–509 mm), and memorable (510–629 mm) length categories for Largemouth Bass collected during spring electrofishing surveys on Santeetlah Reservoir, NC, 2013–2015.

Year	Mean *Wr* PSD-stock	Mean *Wr* PSD-quality	Mean *Wr* PSD-preferred	Mean *Wr* PSD-memorable
2013	95 (2.7)	85 (0.4)	81 (0.6)	78 (3.2)
N	6	289	123	8
2014	98 (2.2)	87 (0.6)	87 (0.5)	85 (4.8)
N	11	119	234	6
2015	93 (1.3)	95 (2.9)	87 (0.6	91 (7.5)
N	18	72	142	3

TABLE 3.—Age class size (N), occurrence percent (%), TL range (mm), and mean TL at age with associated standard error (SE) for Largemouth Bass collected during spring electrofishing surveys on Santeetlah Reservoir, NC, 2013–2015 combined.

Age	N	Occurrence (%)	TL range (mm)	Mean TL	SE
1	41	3.8	58–266	125.7	6.4
2	149	13.8	62–311	216.9	3.2
3	187	17.4	134–324	276.5	1.5
4	299	27.8	203–373	300.1	1.1
5	199	18.5	231–452	322.1	1.6
6	126	11.7	240–380	331.2	2.0
7	28	2.6	232–415	337.9	5.9
8	17	1.6	330–398	357.5	4.7
9	14	1.3	350–493	387.4	11.6
10	11	1.0	325–531	385.8	17.7
11	3	0.3	360–550	453.0	54.9
12	2	0.2	376–415	395.5	19.5



Site	Start Latitude	Start Longitude	Stop Latitude	Stop Longitude
L-01	35.35046	-83.83344	35.35273	-83.82970
L-03	35.36770	-83.83480	35.36800	-83.83540
L-06	35.36097	-83.88536	35.35993	-83.88601
L-08	35.37150	-83.90610	35.37072	-83.91008
L-11	35.35540	-83.84820	35.35640	-83.84774
U-01	35.33940	-83.87620	35.34010	-83.87710
U-02	35.33996	-83.86563	35.34110	-83.86250
U-04	35.33601	-83.85650	35.33549	-83.85730
U-05	35.32927	-83.86345	35.32867	-83.86380
U-06	35.34691	-83.83053	35.34710	-83.83220
U-08	35.33668	-83.83528	35.33649	-83.83508
U-11	35.35147	-83.86867	35.35120	-83.87029

FIGURE 1.—Map and GPS coordinates of Santeetlah Reservoir electrofishing sites surveyed in 2013–2015, Graham County, North Carolina. Shoreline sites on the map are represented with bold black lines. Each site was approximately 300 m long.

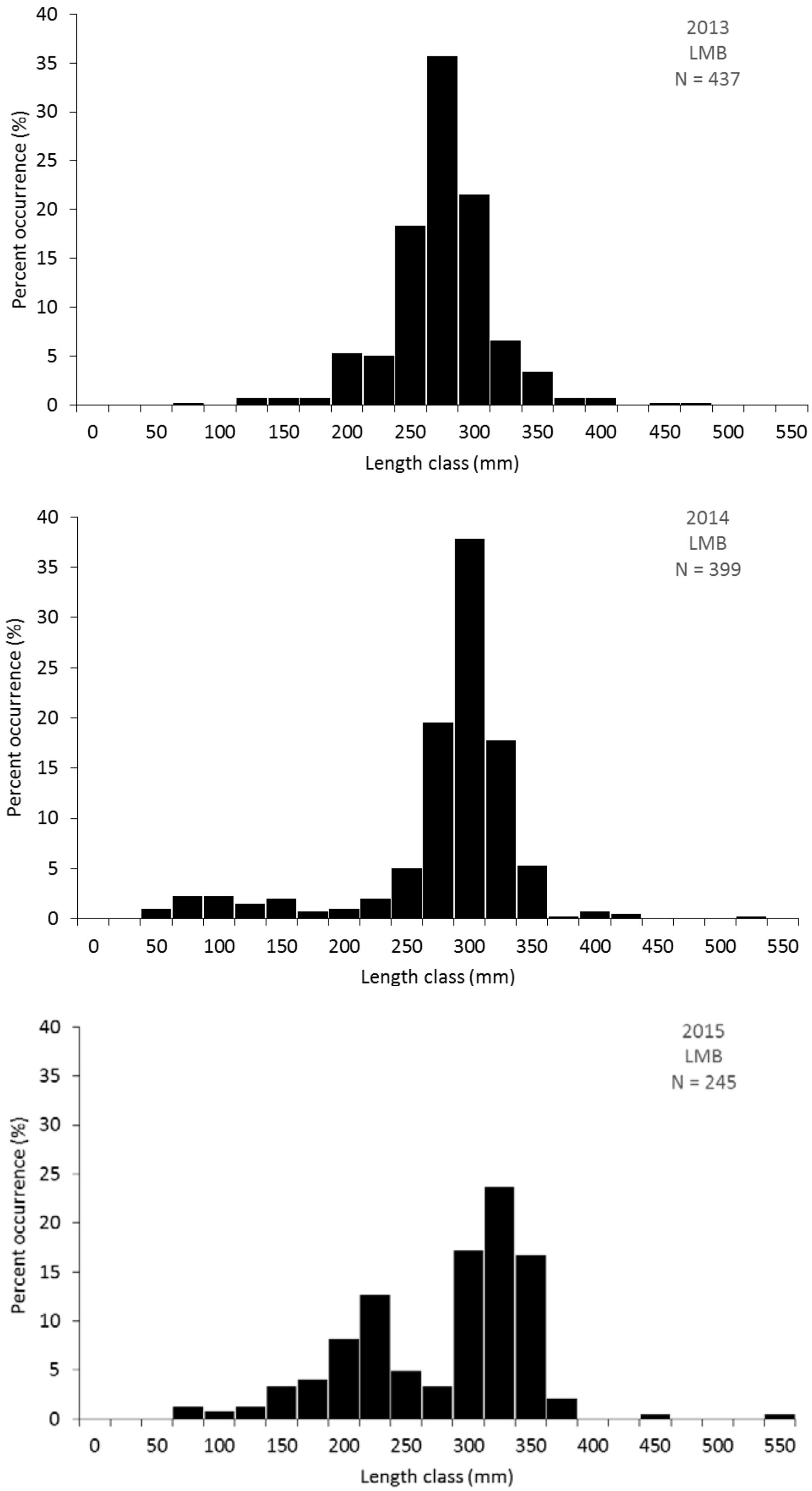


FIGURE 2.—Length frequency distribution of Largemouth Bass (LMB) collected by electrofishing, Santeetlah Reservoir, Graham County, North Carolina, spring 2013–2015.

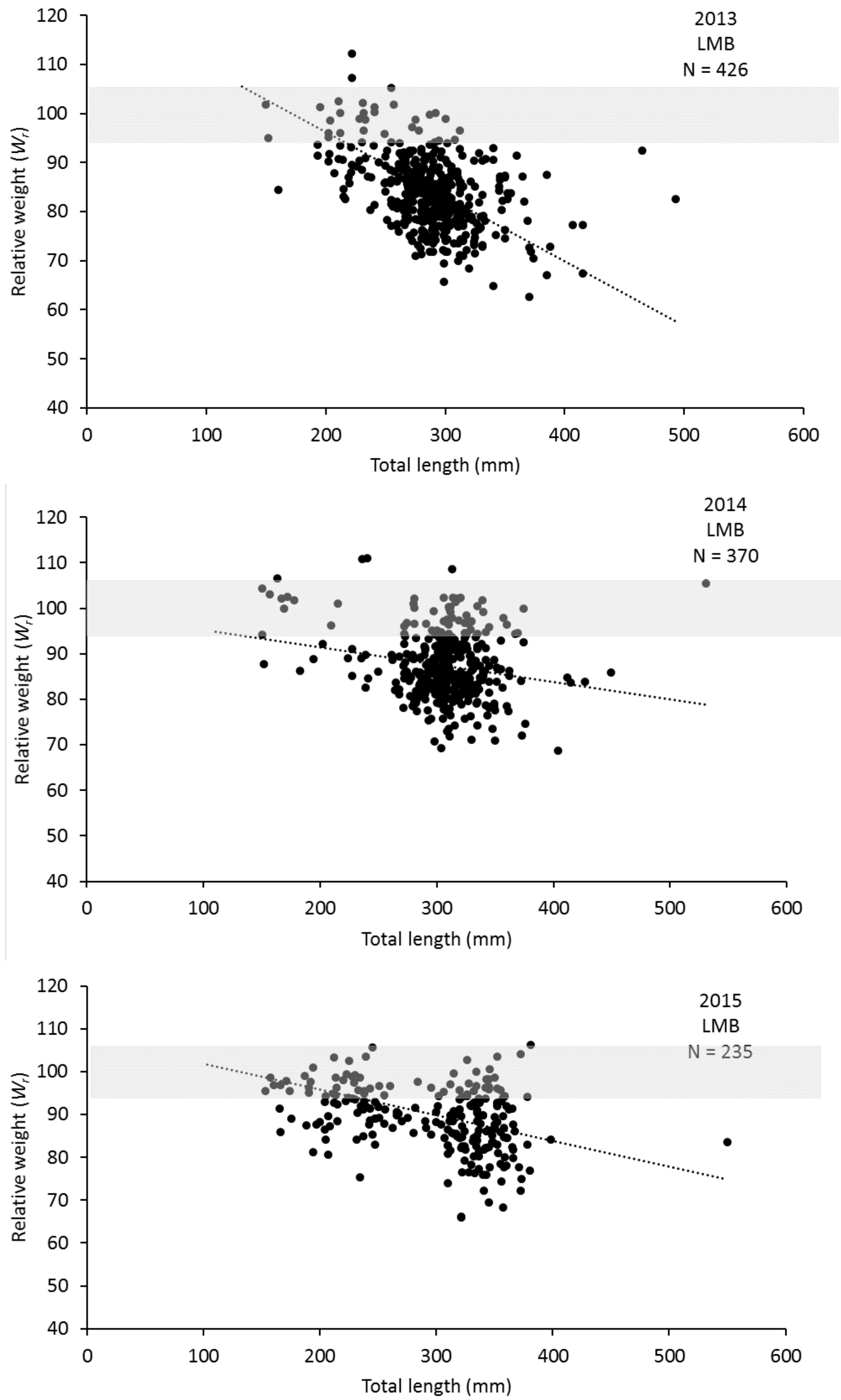


FIGURE 3.—Relative weights of Largemouth Bass (LMB) collected by electrofishing, Santeetlah Reservoir, Graham County, North Carolina, spring 2013-2015. Dotted line represents relative weight to length relationship. The shaded area represents the desired range of relative weights (95–105).

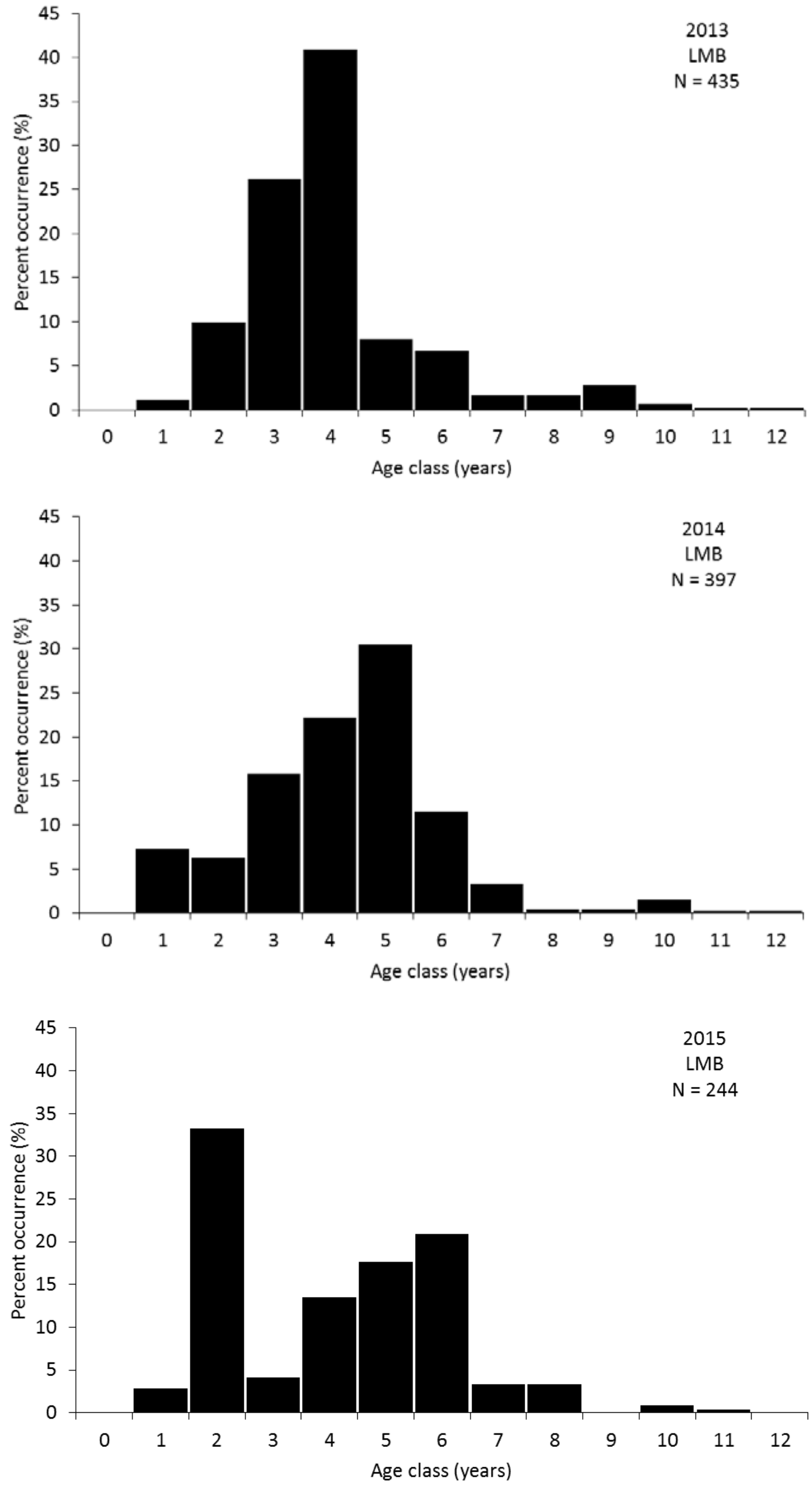


FIGURE 4.—Age frequency distribution of Largemouth Bass (LMB) collected by electrofishing, Santeetlah Reservoir, Graham County, North Carolina, spring 2013-2015.

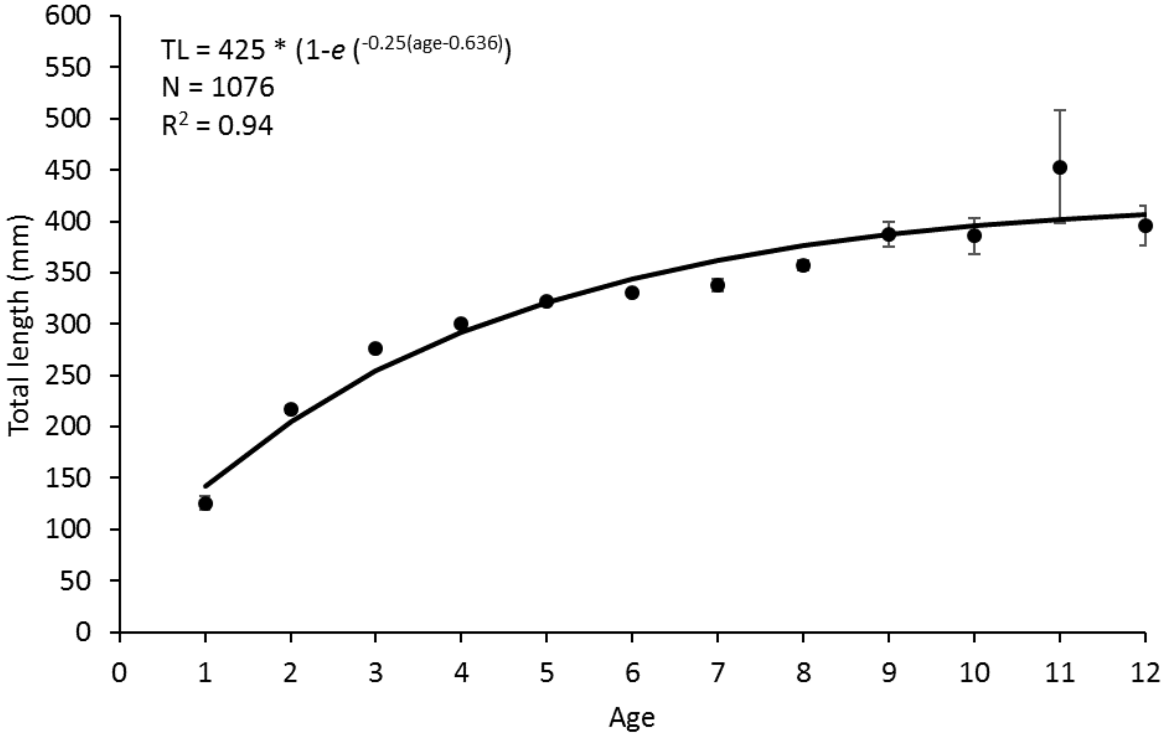


FIGURE 5.—Observed mean total length (TL; mm) at age (dots) and the predicted von Bertalanffy growth curve (solid line) for Largemouth Bass collected by electrofishing, Santeetlah Reservoir, Graham County, North Carolina, 2013–2015 combined. Vertical bars represent total length at age mean standard error.