Fish Population Analysis for Nantucket Lake Using Active Sampling Methods Points Towards Reduced Numbers of Large Bass in a Possible Feeding Dilemma

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Abstract.—In September of 2009, Dr. Gelwick and a group of students preformed a fishery assessment on Nantuckett Lake located in Brazos County. Sampling was conducted using three active sampling techniques (seining, electroschocking, and angling). The purpose of the study was to analyze population dynamics, age-growth relationships, and predator prey associations in the 13 hectare impoundment, in order to provide recommendations to the Nantuckett community on future management options that will result in achieving their goal for the fishery. A total of 154 specimens were collected (32 largemouth bass, 89 bluegill, 3 redear sunfish, 21 gizzard shad, 5 mosquito fish, and 1 golden shiner), with 65% of the largemouth specimens collected belonging to the stock or quality length classes. The presence of fingerling bluegill and young of the year largemouth bass in the sample indicate a successful spawn had occurred in the spring. Length at age analysis revealed that largemouth bass in Nantuckett Lake took an additional one year to reach quality and two additional years to reach the preferred length classes when compared to state of Texas averages, indicating that young bass appear to be lacking the period of rapid growth that is typical of these life stages. In addition, bass relative weights ranged from 77-86 well below the ideal value of 100. The low relative weight values, slow bass growth, and seemingly adequate prey abundance levels point to an underlying feeding complication in the lake. The likely explanation for the low relative weights and slow growth comes from evidence of high turbidity levels which reduce the overall ability of largemouth bass to effectively seek and catch prey. Results from a Nantuckett stakeholder survey indicated that the largemouth bass is the most important game species in the lake and recommendations were thus centered around this species. Suggestions included the implementation of the big bass management option and to address the turbidity issue we recommend the application of calcium sulfate (gypsum) to clear the water.

On September 28th and September 30th, 2009, students in the Principles of Fisheries Management course directed by Patrick Ireland (Graduate Teaching Assistant, Texas A&M University), and Dr. Fran Gelwick (Associate Professor, Texas A&M University) reassessed fish population characteristics of Nantuckett Lake, which had been assessed in October 2004. Nantuckett Lake is located off of Highway 6 between College Station and Navasota within the Navasota River drainage in Brazos County. The focus of this survey is to address concerns raised by the stakeholders of Nantucket Lake. Of interest is the apparent declining numbers and quality of fish in the lake. Nantuckett Lake was previously surveyed in October 2004 using two types of active sampling (seining and electrofishing). The objective of the survey was to describe population characteristics of three important fish species (*Micropterus salmoides, Lepomis machrochirus*, and *Lepomis microlophus*) present in the ecosystem. The analysis of data collected during sampling is intended to aid property owners in developing and executing proper management decisions for the lake based on stakeholders goals for the ecosystem.

Central to the management process is the evaluation of actions taken to achieve management goals, which allows learning from past management and results in the development of an information base for future decision making. There are three principal components of fisheries management: habitat, biota, and people (Murphy and Willis 1996). The habitat component includes such factors as water quality characteristics, limnology (the study of inland waters), water quantity, pond reservoir construction, and vegetation composition. The biotic element covers factors such as native and exotic species, age-growth relationships, stocking, and population dynamics. Finally, the human component involves matters such as management plans, reservoir usage, regulations, and sociocultural factors (Krueger and Decker 1999). To learn more about lake usage, a brief questionnaire was made available to stakeholders. Data provided by stakeholders along with assessment of lake resources, allowed us to focus our recommendations on stakeholder interests. Data from the survey showed that approximately 81% of residents use the lake for some type of recreational activity, with 63.6% of the stakeholder responses indicating they use the lake for fishing (Figure 1). Furthermore, the survey designates fishing as the most important activity at the lake (43% of respondents). Students sampled September 28th and 30th to collect data in order to analyze population dynamics, age-growth relationships, and predator prey associations for the largemouth bass, bluegill, and the redear sunfish.

The lake was impounded in 1964, has a surface area of approximately 13 hectares, with an average depth of 3.1m, ranging from 1m near the boat dock to 5m at the Caliche Dam. To have a feel for the lay out of the lake an aerial map has been included for reference (Figure 1).

The spillway drains into Alum Creek. A small spring provides some natural flow, although primary water input is from rainfall runoff, which may at times connect the lake to Peach Creek. Nantucket Lake and its tributaries are apart of the Brazos and Navasota River drainages. In addition, a few small ponds are in the upstream drainage, one of which was previously known to contain blue tilapia (*Tilapia aurea*). The lake habitat includes flooded timber, old stream channels, and many coves. The 2004 survey indicated that water quality, vegetation cover, and the dissolved oxygen concentration were all below ideal, so these conditions will be measured as they often act as limiting factors for largemouth bass, bluegill, redear sunfish, and gizzard shad. The soil type is predominantly clay and approximately 95% of the 220 homes have septic systems, which can be a potential source of excess nutrients if the system is not properly maintained. Lake regulations allow only homeowners and their guests to fish and harvest their catch.

Twelve years ago (1997), after deciding that coverage by vegetation was greater than desired, residents obtained a permit from Texas Parks and Wildlife to stock the lake with 212 grass carp (*Ctenopharyngodon idella*) and (as required by the permit) a fence was constructed to prevent escape of fish downstream when water ran over the spillway. However, limited signs of grass carp were seen during sampling, leading our groups to believe that few grass carp currently remain in the lake. Grass carp feed exclusively on aquatic vegetation, and the noted disappearance of vegetation in Nantuckett Lake is an indicator that the vast majority of the aquatic vegetation has been removed. This could potentially affect the dissolved oxygen concentration in the lake, as vegetation helps produce oxygen via photosynthesis. Subsequent to the decline in vegetation cover, residents perceived that the lake had become murky and stakeholders experienced a decline in the quality of largemouth bass angling. After analysis, the 2004 study indicated, based on the examination of otoliths, Nantuckett Lake largemouth bass appeared to be experiencing below average growth compared to average growth rates across the state of Texas, taking approximately 1 year longer to reach stock size and two years longer to reach preferred size. A contributing factor to this could be the presence of both black and white crappie in 2004. A large crappie population heightens competition with largemouth bass for food and can lead to stunted populations over time if food becomes scarce. It appears that no further major management actions have been implemented since the 2004 study, such as stocking of baitfish, planting of vegetation, removal of all crappie and flathead catfish, or the evaluation of predator prey PSD (proportional stock density) ratios, so we expect results to be similar to that found during the 2004 survey. The overall goal for the fishery is to provide a generally high quality angling experience, especially for largemouth bass, including increased catch rate and increased average size of fish captured by anglers. The majority of residents (2009 Survey) would be willing to support activities (such as removal of noxious weeds, stocking of fish, and the installment of feeders and underwater fish structure) that would support improvement of the health and fitness of the fishery.

Methods

Several inches of rain had fallen just days prior to our visit to Nantuckett Lake; however, on our sample day the weather conditions were sunny and calm with a high temperature of approximately 28 C. Dissolved oxygen, water temperature, pH, and conductivity (using a YSI-85 multimeter) were taken in the water near the fishing pier. Conditions were only measured once each day, as surface water characteristics were assumed to be similar throughout the small impoundment.

Three sampling methods were used during the lab time which began at approximately 1300 hours and lasted until 1500 hours. The first method employed was seining (an active sampling method). Seining was conducted along shallow littoral zones at ten haphazardly selected points along the lake shore. Target species included members of the genera *Lepomis*, *Dorosoma*, *Notemigonus*, and other small schooling species. In general, beach seines tend to have higher catch efficiencies for fishes residing in the middle of the water column than for demersal fishes (Lyons 1986). Seining was conducted using a 6.5 by 1.3 m bag seine with a bar length of 3mm. To ensure standardization while seining each pass was conducted by the same two volunteers in a set pattern. One student anchored at the starting point on shore while the other waded with the opposite end of the seine extended in a semicircle fashion surrounding the sampling area (Hayes et al. 1999). Seined fish were collected, sorted by species, counted, and then released.

The next method of active sampling employed was electrofishing. Sampling began at 1300 hours. Electrofishing was used to effectively sample fish species across a more diverse array of habitat types including shoreline, vegetation and structure, the fishing pier, islands, creeks, as well as some deep water habitat types. For efficiency, effectiveness, and safety the electric shocker box was set to pulse (DC) or direct current in which the charged particles all flow the same way. In low DC fish move toward the anode (like an electron), in high DC narcosis or muscle relaxation and loss of equilibrium occur (Reynolds 1999). Continuous DC is less likely to injure fish than AC (alternating current) or pulsed DC (Reynolds 1999). The shocker box was set to run between 250-280 volts or 12-15 amps. This method of sampling targeted different species of fish from a wider range of depths and habitat types, in particular members of the family Centrarchidae. The electroshocking gear was provided by the Wildlife and Fisheries Department at Texas A&M University. Gear was mounted in a 15' aluminum jon boat powered by a 40 hp outboard motor. Additional gear included a gas powered generator, shocker box, and a boom carried the electrodes. Electrodes were effective to a depth of approximately 2 meters. The boat and shocker box were operated by Dr. Gelwick. Two students were positioned on the bow of the watercraft and netted stunned fish using a 3 m long-handled 35 cm wide dip net. A third student helped place fish into the holding container. All passengers wore a personal flotation device. In addition, netters wore lineman's rubber gloves (10,000 KW) for safety. At the end of each collecting run fish were classified to species, weighed, measured, and given an identification number to correlate data. In the laboratory, Patrick Ireland removed the sagittal otolith from each specimen for age length analysis and examined gut contents. The otoliths were sectioned through the nucleus, polished with fine grit sandpaper, and then examined using a dissecting microscope. Under a microscope annuli (annual growth rings) can be identified and counted, this data would yield specimen age. Theoretical maximum age was also calculated and was found to be approximately 11 years for the population. Three separate electrofishing runs were made, each by three new students. A new area of the lake was sampled during each trip to ensure adequate sampling from all habitat types on the lake. Total shock time was approximately 52 minutes, with each run lasting approximately 15 minutes. The total shock time can be used to calculate catch per unit effort or CPUE as number of fish per hour.

The final method of sampling was student angling. Although, angling with a rod and reel is typically thought of as a sport fishing method, it can be used to acquire samples for research (Hayes et al. 1999). The size structure of the largemouth bass samples procured through angling using a systematic procedure are well correlated with the size structure in electrofishing samples. Size selectivity was considered in that each angler was allowed to use only artificial lures and fished with a particular size lure for thirty minute intervals. Each lure size was measured and recorded, because lure size is highly selective on catch size.

Water Quality Characteristics:

Dissolved oxygen analysis measures the amount of gaseous oxygen dissolved in an aqueous solution. The concentration of dissolved oxygen in any body of water varies over time due to plant photosynthesis (net increase in DO), microbial and animal respiration (net decrease in DO), wind and temperature (higher diffusion mixing possible under turbulent conditions; cooler water holds more dissolved oxygen if atmospheric pressure is constant). Oxygen enters the water from the air as the two are mixed together naturally by wind and waves or artificially by aerators, paddlewheels, and sprayers (Lock 2004). Oxygen is produced by plants (macrophytes and phytoplankton) during photosynthesis, but is also consumed by all biota. DO concentration is typically measured as the number of milligrams of oxygen dissolved in one liter of water recorded as milligrams per liter (mg/L). Optimal levels depend on the species of fish. Desirable DO concentration in fresh water is usually > 5.0 mg/L, although the growth of largemouth bass slows when oxygen levels are < 8 mg/L, and poor feed conversion efficiency occurs at values < 4 mg/L (Stuber et al. 1982). Largemouth bass actively avoid water having DO < 3 mg/L, but can tolerate values near 1 mg/L at 25^{o} C for short periods (hours).

Transparency readings we estimated by use of a secchi disk index value. The disk is round and divided by radii into quarters; opposite quarters are painted black or white. The disk is mounted to a stick or suspended from a rope, with depth measurements marked. The disk is lowered in the water until it is no longer visible, which is recorded as the Secchi depth. Water clarity is reduced by both suspended clay or other inorganic particles as well as blooms of microscopic algae. The transparency range is useful in evaluating phytoplankton blooms, but is also affected by turbidity due to clay, mud, and silt (Texas Chapter of the American Fisheries Society 2005). Suspended clays are undesirable and may be reduced by addition of aluminum sulfate or calcium sulfate (gypsum). A reading ranging between 46 and 61 cm is optimal if most of this is due to planktonic algae as it indicates adequate primary production of food resources at the base of the food web. Transparency also influences the foraging success for some fishes. Largemouth bass, which feed by sight, require water clarity > 15" to adequately feed, but do best in clarity of > 60 cm (Davis and Lock 1997).

The three primary macronutrients limiting the development of phytoplankton biomass in an aquatic system are nitrogen, phosphorous, and potassium. High total phosphorous concentrations or low Secchi disk depths are indicative of eutrophic conditions. However, turbidity resulting from suspended inorganic particles such as clay will bias results obtained with the Secchi disk method (McMahon et al. 1996).

The pH value is a measure of the concentration of hydrogen ions in water, and is related to alkalinity. Proper alkalinity is critical for healthy fish populations. Fertilization is ineffective if proper alkalinity is not present to buffer such changes. An alkalinity measurement of 20 ppm is desired, and if the value drops below this level liming is recommended. If pH values drop below 5 or rise above 10, then fish can become stressed and die (Lock 2004).

Temperature affects the metabolic rate of fish and proper range is critical for reproduction. Optimal temperature for growth of adult largemouth bass (Stuber et al. 1982) ranges from 24 to 30^{o}C (75 to 86^{o}F), and very little growth occurs < 15^{o}C (< 59^{o}F) or > 36^{o}C (> 97^{o}F).

Results

Water Sample*:* Data collected from the water sample showed very high levels of phosphorous and low D.O. levels, additional water characteristics are included as well (Table 1).

Table 1. Water Quality Analysis of Nantucket Lake

Parameters	Sample 1	Sample 2
DO % Saturation	62.6	70.4
Do mg/L	5.11	6
Specific Conduct.	250	236.6
Water Temp C	26.9	25.9
Secchi Depth (cm)	41	43
Orthophsphte (mg/L)	49.3	51.4
Nitrate mg/L	1.6	1.4

The fish community assessment of Nantuckett Lake was based on data from all three active sampling methods. Total catch was recorded for the most abundant species and represents totals from all sampling types (angling, seining, and electro-shocking Table 2).

Table 2. Total catch of species by gear type for Nantucket Lake

Species	Total seining	Total shocking	Angling
Largemouth bass, *Micropterus salmoides*	2	26	4
Bluegill, *Lepomis macrochirus*	79	10	0
Redear sunfish, *Lepomis microlophus*	0	3	0
Gizzard shad, *Dorosoma cepedianum*	11	10	0
Golden Shiner, *Notemigonus crysoleucas*	1	0	0
Mosquito fish, *Gambusia affinis*	5	0	0

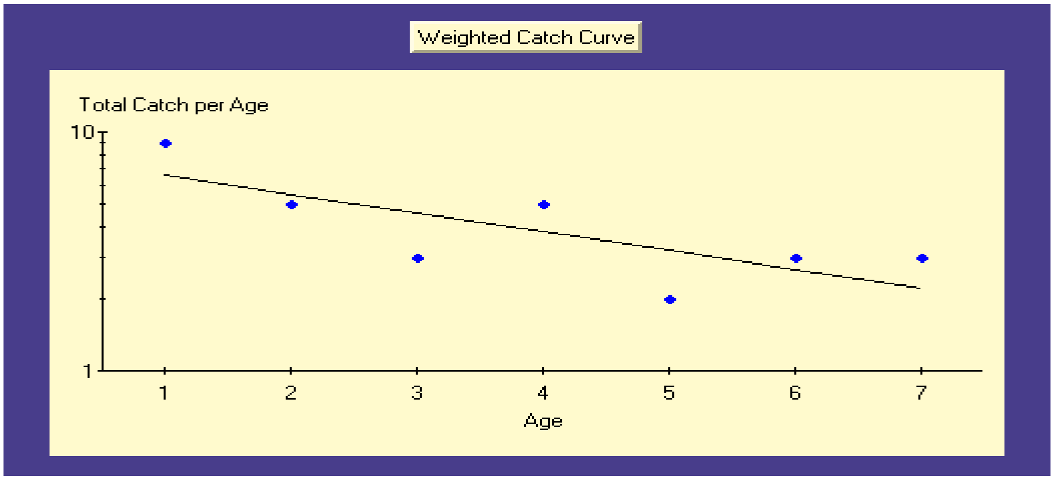
Bluegill fingerlings (< 80 mm total length) dominated each seine sweep, indicating a successful spawn had occurred during the recent spring and summer months. Largemouth bass was the primary species collected via electro-fishing, comprising approximately 54% of specimens collected and occurred in all four angling samples. Overall 154 total fish were collected, which was less than the numbers seen in the 2004 sample. The CPUE or catch per unit effort (total number of specimens/ total shocking time) for largemouth bass was approximately 30.06 bass per hour of shocking. The number of fish collected in each size class for game and forage species are listed from smallest to largest (Table 3; substock, stock, quality, preferred, memorable, and trophy; Gablehouse 1984). Minimum stock and quality lengths are defined as some length within 20-26% and 36-41%, respectively, of angling world record length (Anderson and Weithman 1978). These length categories correspond roughly to the minimum sizes at which anglers will first catch the species (stock and when anglers consider the specimen desirable quality length) (Ney 1999). The additional length groups are as follows: preferred: minimum 45-55%, memorable: minimum 59-64%, and trophy: 74-80% of world record lengths.

Table 3. Size distribution of fishes caught via electroshocking in Nantuckett Lake and Minimum Lengths per Size Class for each Species

Size class (mm)	Species Largemouth bass	Number collected	Species Bluegill	Number collected	Species Redear sunfish	Number collected
> Stock	>203	5	>80	0	>100	0
Stock	203	9	80	9	100	1
Preferred	305	8	150	1	180	0
Quality	381	8	200	0	230	2
Memorable	508	0	250	0	280	0
Trophy	635	0	300	0	330	0

Noteworthy, is the fact that no memorable or trophy sized largemouth bass were collected during sampling, compared to 9 in 2004. The majority (65%) of collected largemouth bass were either the stock or quality length classes. In addition, no bluegill greater than preferred size were collected. The total catch per age class for largemouth bass in Nantuckett Lake (Figure 2) was dominated by fish under 4 years of age and showed low numbers of older fish present despite a theoretical maximum age of approximately 11 years projected by the length-age relationship for individuals within the population.

Figure 2. Weighted Total Catch Curve per Age for Nantuckett Lake



Proportional Stock Density (PSD) and relative stock density (RSD) are numerical descriptors of length-frequency data with values ranging between 0-100. Given representative samples of a population, PSD and RSD values can provide insight or predictive ability about population dynamics (Kohler 1999).

PSD = [(number $\geq$ quality size) / (number $\geq$ stock size)] x 100

RSD-P = [(number $\geq$ preferred size) / (number $\geq$ stock size)] x 100

RSD-M = [(number $\geq$ memorable size) / (number $\geq$ stock size)] x 100

RSD-T = [(number > trophy size) / (number > stock size)] x 100

The PSD's and RSD's for three potential management options along with calculated PSD values for Nantuckett Lake are compared (Table 4). The PSD and RSD-P respectively for largemouth bass were within the ideal range for the balanced or big bass management options. However, when prey PSD is plotted vs. predator PSD indicates a stunted prey population that could potentially interfere with predator reproduction and success of young of the year largemouth bass. The redear sunfish and bluegill, in concert, comprise the essential forage base for largemouth bass, as they produce a wide range of prey sizes for predator consumption. The bluegill had a PSD value of 11 which was near the minimum PSD for the species if the trophy bass option is desired. In addition, larger size class redear sunfish and bluegill can provide further angling opportunities.

Table 4. Optimum PSD and RSD index values for three management plans and Nantuckett Lake.

Plan	Largemouth bass			Bluegill	
	PSD	RSD-P	RSD-M	PSD	RSD-P
Balance	40-70	10-40	0-10	20-60	05-20
Panfish	20-40	0-10		50-80	10-30
Big Bass	50-80	30-60	13-25	10-50	0-10
Nantuckett	67	38	0	11	0

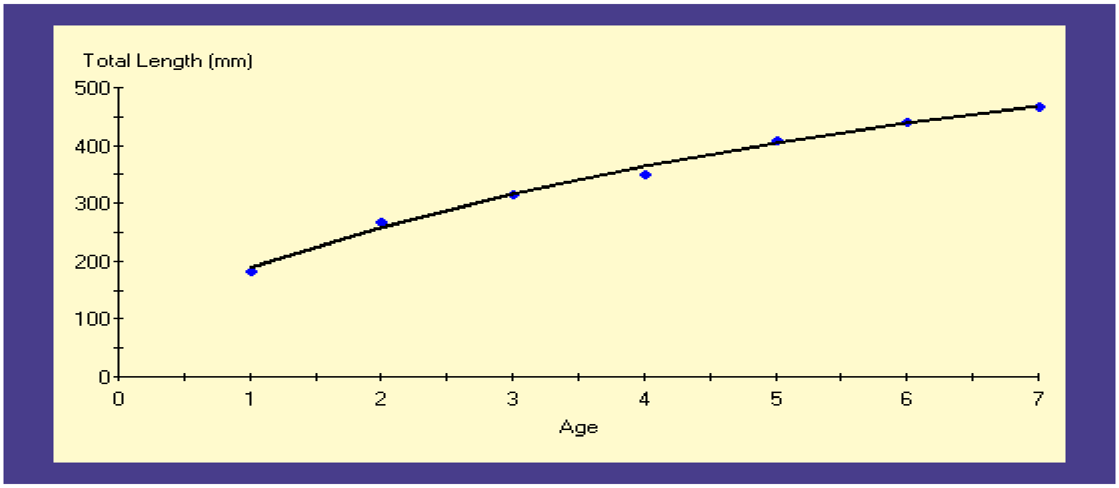
Length to weight and length to age relationships another important indicator of the overall state of the fishery, and can often help to suggest future management plans. Growth in fishes is indeterminate, thus they can continue to increase in size throughout life (Van Den Avyle and Hayward 1999). The mean growth in length (mm) for age classes of largemouth bass in Texas is compared to the mean length for year classes in Nantuckett Lake (Table 5). Data suggests that bass in Nantuckett took an additional one year to reach the quality size class and two years extra to reach preferred size, as compared to averages across the state.

Table 5. Comparison of Average length vs. Age between Texas and Nantucket Lake

Age	Texas Averages	Nantuckett lake
	Largemouth bass	Largemouth bass
1	200, S	183, < S
2	296, Q	269, S
3	371, P	316, Q
4	420, P	351, Q
5	445, P	410, P
6		441, P
7		468, P

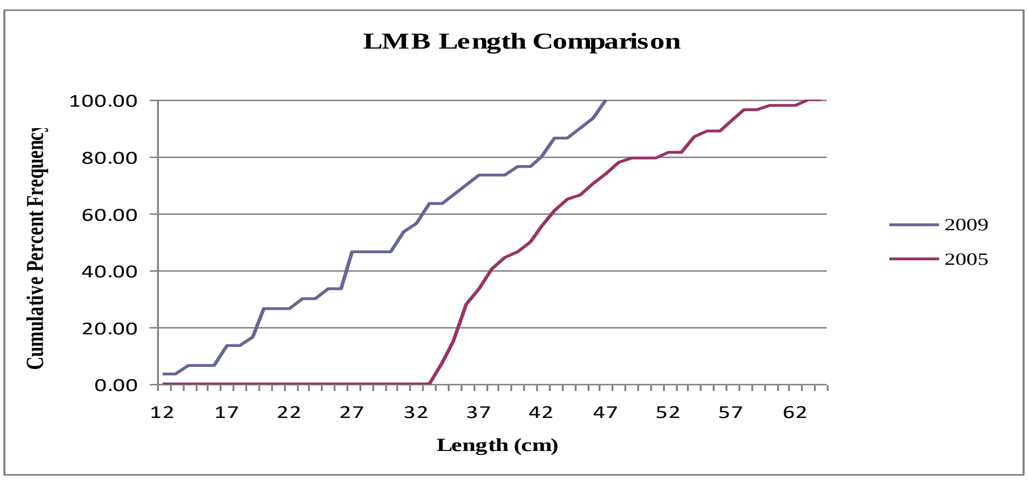
Although, growth is indeterminate, trends of length and weight of a cohort throughout life usually show an early period of rapid growth rate and a subsequent period of a more gradual increase. One useful model in particular mimics this pattern of declining growth with age, and was originally described by von Bertalanffy. A von Bertalanffy model shows the relationship between total length and age (Figue 3). The curves slope is rather gradual and linear showing a slow and steady rate of growth, lacking the period of rapid growth as is expected.

Figure 3. Von Bertalanffy Model Comparing Total Length to Age



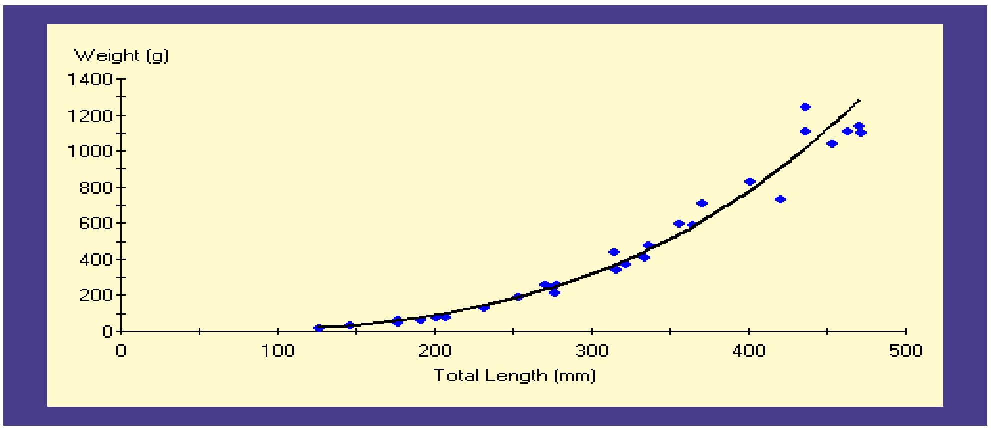
The comparison of cumulative length distributions for largemouth bass between the 2004 survey and present (Figure 4) indicates the data from 2009 show approximately a 10 cm decline in average length of individual largemouth bass as compared to data from 2004.

Figure 4. Largemouth bass Length Comparison for Nantuckett Lake



Another condition factor that is often evaluated is the weight-length relationship of individuals in a population. The ratio of the weight of a fish to its length varies with the species, the fish's size, and the ecological conditions under which it feeds and expends energy to live (Ney 1999). The relationship between total length and weight for largemouth bass in Nantuckett Lake is show below (Figure 5).

Figure 5. Weight Length Relationship for Largemouth bass in Nantuckett Lake



One final index when analyzing members of a population is the calculation of relative weight (Wr), which enables direct comparison of different sizes and species of fishes and provides an instant benchmark for evaluating the well-being or plumpness of individual fish in a population (Ney 1999). The ideal value for Wr is 100. When values rise above this mark this may be a sign of a surplus of prey and the addition of more predators could be handled. When the relative weight index falls below 100 problems may exist in feeding conditions (Anderson and Neumann 1996). Because relative weight is a function of many factors such as available forage, environmental conditions (e.g., temperature, DO), and fish length or gape-size limitation, a comparison of relative weights for fish in different length classes is very informative. These values are based on the ratio of a fish's weight (W) to that of an expected standard-weight (W_s) for a fish of that length and species that is considered to be in good condition (75th percentile of weight), as follows:

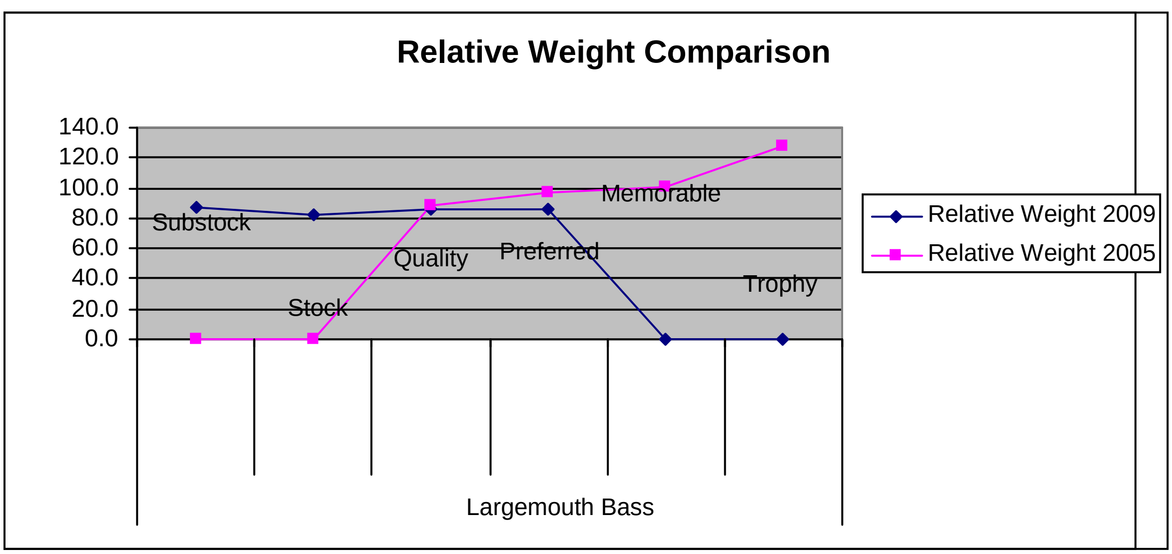
$W_r = (W / Ws) \times 100$

In lab relative weights were calculated for each size class. The mean relative weights of largemouth bass for 2009 show relative weights that ranged from 77-86 for all size classes (Table 6) significantly under the desired value of 100, meaning that the bass were below the proper weight for their length. Whereas, values from 2004 were much higher across all sizes classes and had a low of only 88. Fish sampled in 2004 on average showed greater plumpness for every size category (Figure 6).

Table 6. Relative Weights of Largemouth bass for 2005 and 2009

Size Category	Relative Weight 2009	Number of Fish	Relative Weight 2005	Number of Fish
Substock	87.4	5	--	0
Stock	82.7	9	--	0
Quality	85.8	8	88.2	18
Preferred	77.6	8	96.6	28
Memorable	--	0	100.3	8
Trophy	--	0	127.3	1

Figure 6. Chart Comparing Relative Weights between 2005 and 2009 for Nantuckett Lake



Discussion

Total catch (via seining, electroshocking, and angling) on the 32 hectare impoundment south of College Station, Texas, was less for all species when compared to 4 years ago (reasonably assuming similar effort in terms of time and gear used in each sample period). The largemouth bass showed a decline from 57 specimens in 2004 to only 32 specimens in the 2009 survey; this, potentially, could have been caused by the warm temperatures that were present on the days of sampling in 2009, during which fish tend to occupy deeper, cooler waters where electroshocking is less effective. However, as sampling in 2004 was performed under similar circumstances, we do not assume this to be the case. Seine hauls revealed abundant fingerling bluegill and electroshocking resulted in nine young of the year largemouth bass signifying a successful spawn had occurred despite the lower water levels that were seen during the summer months from a severe drought. In addition, the 2009 sample yielded no memorable or trophy sized largemouth bass and revealed limited numbers of the preferred length class, whereas, the previous study included specimens in all three of the aforementioned length classes and was dominated by largemouth bass in the preferred class. These results could be indicative of a possible growth retardation event in Nantuckett Lake as larger individuals seem to be rare, coupled with the fact that specimens in the preferred length class ranged in age from 5-7 years, which is considerably older than Texas state averages. In addition to the low numbers of largemouth bass, no crappie and limited numbers of redear sunfish were collected in 2009 whereas both species were plentiful during the 2004 survey.

Other important statistical indices that afford information on the relative health and condition of a species are PSD, RSD, and Wr. The comparatively high predator PSD of 67 contrasted to the extremely low prey PSD of 11 indicates a low relative density of predators or ineffective predation (bass are not successfully finding/feeding on prey as expected and therefore prey are small due to crowding) which could be associated with habitat problems. The abundance of small bluegill may be directly competing with young of the year largemouth bass for limited resources and thus restraining predator growth (Anderson and Neumann 1996). Additional information on relative density, abundance, growth, recruitment, and mortality are suggested in order to confirm the notion.

The fact that largemouth bass in Nantuckett Lake took an additional year to reach quality size and two extra years to reach the preferred length, coupled with lower than ideal relative weights across all size classes hints at a potential feeding complication. Low Wr values below 100 for an individual or size class indicate that problems may exist in food availability or feeding conditions (Anderson and Neumann 1996), providing additional evidence that a feeding complication is the likely scenario as multiple data references point to this circumstance. One potential explanation for poor feeding conditions, when adequate prey is available, can be attributed to high turbidity levels which reduce the bass's sight and thus ability to effectively seek and catch prey. Numerous studies (citations needed here0 have shown a significant relationship exists between relative weights and estimated annual length increments. Low Wr, that is, low energy reserves should be expected to be related to relatively higher rates of mortality from increased vulnerability to pathogens and other environmental stresses e.g. low D.O.

concentrations when compared to fish with ideal Wr values near 100. More supporting evidence of possible retardation of growth in largemouth bass (Figure 3), where the gradual slope of the graph indicates young largemouth bass lack a period of explosive growth which is typical, which could potentially be linked to the competition with the abundant stock sized bluegill relative to stock size largemouth bass.

Finally, if the low D.O. values of 5.11 mg/L and 6.00 mg/L are characteristic of the lake and not related to the recent weather conditions as expected, this could be a fisheries independent condition that results in many problems for the ecology of the lake.

In Nantuckett Lake, forage species primarily included bluegill, redear sunfish, and gizzard shad. Bluegills are a valuable food source as the species undergoes multiple reproductive bouts throughout the spawning season resulting in a wide range of prey sizes for predator consumption. Overproduction and stunting of bluegill can be due to over harvest of predators, but is usually due to excessive weed cover (> 20% of pond surface area as a general guideline) in which small bluegill can hide from largemouth bass. Redear sunfish are an excellent supplemental forage species and larger individuals increase the angling opportunities for another species of panfish. Because redear sunfish eat snails, they produce an added benefit by reducing the risk of white grub (parasitic worm) infection in the meat of fishes by breaking the parasite life cycle.

Recommendations

Based on our findings, several suggestions have been formulated to improve the fishery and the overall aesthetic value and enjoyment of the lake by the community. First, results from the survey signify the largemouth bass is the most important game species in the lake; thus, if the goal is to produce trophy largemouth bass without regard to bluegill size, catch rate will be low, but the largemouth bass caught should be large. Angler harvest can be used as an important management tool for adjusting the population structure of sport species. In a pond of average fertility, 75 largemouth bass ranging from 20-30 cm long and about 12 largemouth bass ranging between 30-38 cm long should be harvested per hectare each year. Unless a trophy bass is caught, all bass over 38 cm should continue to be released (Flickinger et al. 1999). Bluegill can be harvested at every opportunity as they are prolific and repeat spawners. As largemouth bass consume bluegill, they reduce competition leading to greater numbers of quality-sized bluegill and a balanced fishery with additional bluegill angling opportunities. In this scenario, it is also an option to stock threadfin shad at a rate of 50 per hectare, as they serve as food for large largemouth bass (Flickinger et al. 1999).

Although, no catfish were collected, blue and channel catfish do not compete with largemouth bass and can provide additional angling opportunities. The All-Purpose Option allows for the harvest of bass, bluegill, and channel catfish of a variety of sizes. Bluegill and channel catfish can be harvested as desired, but channel catfish should be replaced with 20 cm or longer channel catfish. With this option, if anglers do not obey the slot limit, over harvest of largemouth bass can result in overpopulation of bluegills. On the other hand, if anglers release largemouth bass in the slot limit, but do not harvest largemouth bass under the slot, overpopulation and stunting of largemouth bass can occur (Flickinger et al. 1999). Follow guidelines of Texas Chapter of the American Fisheries Society (2005) with regard to number and size to stock if channel catfish are desired.

Furthermore, anglers should be encouraged to help maintain a record of their catches (date, species, length, weight of specimen) as this provides an estimate of the size composition and relative abundance of game species. The type of lure or bait used and the size of lure used can influence the resulting size structure of the sample and could lead to improper recommendations, so it is important that this is recorded (Flickinger et al. 1999).

If conditions of low D.O. and high turbidity are chronic, further assessment as to the reasons for these problems will be needed. Turbidity limits sunlight penetration into pond water which restricts primary productivity. In addition, sight-feeding fish such as largemouth bass are less successful at feeding in ponds with severe turbidity. Since the majority of the soils in Brazos County are clay based, we predict that much of the suspended particles are colloidal clay, which does not settle out. Flocculating compounds such as aluminum sulfate (alum) and calcium sulfate (gypsum) work through a process that allows clay particles to combine into larger clumps, or flocs, that become large enough to sink out of suspension. Gypsum is recommended as it does not cause a loss in alkalinity. Flocculents should be applied only after the cause of the turbidity is determined. Follow guidelines of Texas Chapter of the American Fisheries Society (2005) for these and other habitat-related actions. Hypolimnetic aeration is a method to increase the oxygen content of the hypolimnion without disrupting thermal stratification (Wirth 1981) which is an option in combating low D.O. levels.

Finally, the pond can also provide additional enjoyment to community members if areas to attract and view birds and wildlife are established. Nesting boxes placed in the pond can provide artificial cavities for wood ducks (Lock 2004). Native shrubs, trees, and other vegetation in specific maiden cane can be allowed to grow along parts of the shoreline, which will attract birds, other wildlife, filter runoff, and provide aesthetic appeal. When managing for a fishery, it is important to consider all components of the management process (i.e. sociocultural, political, ecological, and economic factors) as well as the diversity in stakeholder preferences.

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