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Salt River Reservoirs Golden Alga Project

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Arizona Game and Fish Department Mission
To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

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INTRODUCTION

Golden algae (*Prymnesium parvum*) is a naturally occurring microscopic flagellated alga that typically occurs in brackish water. This phytoflagellate has been implicated in fish kills around the world since the 1920's (Reichenbach-Klinke 1973; Johansson and Graneli 1999). Under certain unknown environmental stresses this algae produces an ichthyotoxin that is toxic to gill-breathing species such as fish, mollusks, arthropods, and to the gill-breathing stage of amphibians (Paster 1973). The ichthyotoxin targets the permeability mechanism of the gill (Yarive and Hestrin 1961). In fish, the first damage is to the exposed skin and gill cells. The outer layer cells are damaged, then the next cell layer is affected, and so on. Soon the gills are so badly damaged they are unable to function, blood vessels in the gills leak into the water (hemorrhage), and fish behave as if there is not enough oxygen in the water. At the same time, toxins and other waterborne chemicals are entering into the circulatory system of the fish, damaging internal organs. Bleeding also occurs in fins and other exposed areas. Affected fish persist at the top of the water surface or rest on the bottom in edges and shallow areas. Kills due to *P. parvum* blooms are normally accompanied by water with a golden-yellow coloration that foams in riffles (Rhodes and Hubbs 1992).

Control of golden alga is possible with the use of copper-based algaecides in small impoundments (Barkoh et al. 2010; Rodgers et al. 2010). However, it would be extremely difficult and expensive to treat large reservoirs, such as those located in central Arizona. Recent studies that utilize pH manipulation and hydrologic flushing manipulation, in addition to ammonia addition manipulation, have been shown to reduce or, in some cases, prevent algae blooms in Lake Granbury, Texas (Harris et al. 2010). In 2007, a large inflow event at Lake Granbury, as a result of a very wet year, eliminated a highly toxic *P. parvum* bloom. Hydraulic flushing as a bloom-terminating mechanism has been observed for other algae blooms (Jacoby et al. 2000; Moustake-Gouni et al. 2006), but flushing events were rare and may become rarer as human populations expand and the need for water storage increases.

Golden algae has been identified in 15 different states across the United States, and it is not known if it is naturally present or introduced artificially. In Texas, the first confirmed fish kill due to *P. parvum* occurred in October and November 1985 in the Pecos River, with approximately 110,000 fish dying between Iraan, Pecos Co., to the mouth of Independence Creek (James and De La Cruz 1989; Rhodes and Hubbs 1992). From 1985 to 2001, golden algae fish kills across the state of Texas have contributed to the loss of over 7.6 million fish (some threaten and endangered), valued at over 4.4 million dollars (Harris 2010). An economic impact study of golden alga impacts on recreational fishing at Possum Kingdom Lake in Texas estimated that a golden algal bloom and subsequent fish kills in 2001 had a total economic impact of $2.8 million dollars (Oh and Ditton 2005).

Golden alga was discovered in Arizona in 2005 and has been found in three large reservoirs (Saguaro, Canyon, and Apache Lakes) and in the Salt River above Roosevelt Lake located on the Tonto National Forest. Additionally, golden alga has been found in more than 30 small municipal or private waters and several urban fishing lakes in central Arizona. Golden alga was likely present as early as 2001 following a substantial die-off of Asian clam (*Corbicula fluminea*) in Saguaro Lake. The first fish kill occurred in July 2003 at Apache Lake and was composed mostly of threadfin shad (*Dorosoma petenense*). A more extensive fish kill occurred the following year between March 30 and June 10, 2004, extensively killing multiple species of fish including threadfin shad, largemouth bass (*Micropterus salmoides*), flathead catfish (*Pylodictus olivaris*), channel catfish (*Ictalurus punctatus*), and bluegill (*Lepomis macrachirus*), at Saguaro, Canyon, and Apache Lakes. The cause of these kills was not identified at that time. Between April 6 and July 10, 2005, a large fish kill was observed at Saguaro and Canyon Lakes, affecting many large-bodies sport fish species. Water samples taken during the kill identified the presence of golden algae. Additional golden alga related fish kills occurred the next year at Saguaro and Apache Lakes, but to a lesser degree.

To enhance the remaining wild population of largemouth and smallmouth bass (*Micropterus dolomieu*) at Saguaro, Canyon, and Apache Lakes following the 2005 fish kills, and to develop a response to future golden alga related fish kills, the Arizona Game and Fish Department implemented a temporary supplemental stocking program. One purpose for this supplemental program was to determine the most effective stocking strategy for largemouth and smallmouth bass. Supplemental stocking of largemouth bass is a common management practice (Mesing et al. 2008). Benefits of supplemental stocking include increased harvest rates (Boxrucker 1986; Buynak and Mitchell 1999), and supplementing weak year-classes of wild fish (Boxrucker 1986). For supplemental stocking to be successful, stocked fish must contribute to the remaining natural population following a fish kill. Previous studies have shown varying degrees of success and often the contribution of stocked fish to year-class strength is low (Boxrucker 1986; Buynak and Mitchell 1999; Buckmeier and Betsill 2002; Hoxmeier and Wahl 2002; Hoffman and Bettoli 2005; Diana and Wahl 2008). Many factors can influence the survival of stocked fish and may be the cause of variable stocking success for largemouth bass. The size at which fish are stocked has been shown to be related to survival for a number of different species including largemouth bass. Growth and survival of four sizes of largemouth bass in four small Illinois reservoirs showed no difference in survival among medium (100 mm), large (150 mm) and advanced (200 mm) fingerlings, but survival of small (55 mm) fingerlings was very low (Diana and Wahl 2009). In addition to the supplemental stocking program, the Arizona Game and Fish Commission imposed a two year temporary 13-16 inch largemouth and smallmouth bass slot limit with harvest of one fish in the slot beginning in 2009. The purpose of this slot was to protect the remaining spawning population of bass in all three reservoirs.

Following the 2004 and 2005 fish kills, the Arizona Game and Fish Department conducted fish surveys to assess the impacts of the fish kills at Saguaro, Canyon, and Apache Lakes. The golden alga related kills resulted in an estimated loss of nearly 70% of largemouth bass at Saguaro Lake, 50% loss of largemouth bass at Canyon Lake, and 40% of largemouth bass at Apache Lake. Further, all smallmouth bass were eliminated from Apache Lake. In response to the kills, the Department developed a study with the following objectives:

Objectives

- Determine the population response of all fish species following golden alga related fish kills
- Determine the most effective stocking strategy for largemouth and smallmouth bass in Saguaro, Canyon, and Apache Lake

- Monitor Fish Kill and associated water quality.

METHODS

Study Area

The Salt River is located within the Tonto National Forest, Arizona. The Salt River contains four storage reservoirs northeast of Phoenix, Arizona that form a continuous chain of lakes nearly 96 km long (Figure 1). Roosevelt Lake, the upper most reservoir and also the largest in the chain (8,698 ha), receives water from two main sources; Tonto Creek and the Salt River. Water levels at Roosevelt Lake fluctuate based on inflow from its two main tributaries (Figure 2), while levels at the lower three reservoirs remain fairly constant.

The lowest reservoir on the Salt River chain, Saguaro Lake, is located approximately 66 km east of Phoenix, Arizona, and was formed by the completion of Stewart Mountain Dam in 1930 (Figure 3). Saguaro Lake has a total surface area of 510 ha, littoral zone surface area of 253 ha, 35.7 km of shoreline, and a maximum depth of 36 m. A 2001 statewide survey of anglers identified Saguaro Lake as the 6th highest use lake in Arizona (Pringle 2004).

Canyon Lake is located approximately 82 km east of Phoenix, Arizona, and was formed by the completion of Mormon Flat Dam in 1925 (Figure 4). Canyon Lake is the smallest of the three reservoirs with a total surface area of 384 ha, littoral zone surface area of 213 ha, 45.5 km of shoreline, and a maximum depth of 43 m. A 2001 statewide survey of anglers identified Canyon Lake as the 9th highest use lake in Arizona (Pringle 2004).

Apache Lake is located approximately 105 km east of Phoenix, Arizona, and was formed by the completion of Horse Mesa Dam in 1927 (Figure 5). The reservoir has a total surface area of 1,075 ha, littoral zone surface area of 412 ha, 66.7 km of shoreline, and a maximum depth of 80 m. A 2001 statewide survey of anglers identified Apache Lake as the 10th highest use lake in Arizona (Pringle 2004).

There are 20 fish species present among the three reservoirs (Table 1). The prominent self-sustaining sport fish include largemouth bass, smallmouth bass, bluegill, yellow bass (*Morone mississippiensis*), channel catfish, and flathead catfish. Additionally, a put and take fishery exists for rainbow trout (*Oncorhynchus mykiss*) and a put-grow-and take fishery for walleye (*Sander vitreus*), which are stocked annually in one or all of the three reservoirs.

Fish stocking

The study was conducted for a period of three years from June 2007 to May 2010. A target of roughly 200,000 fingerlings (25-50 mm) and 20,000 subadult (150-200 mm) largemouth bass were stocked among the three reservoirs in spring and fall, respectively. The proportion of fish stocked was based on the shorelines length of each reservoir. While not the primary target of this study, smallmouth bass were also stocked at various sizes and seasons throughout this three-year study period. Most stocking efforts for smallmouth bass were focused on Apache Lake where historical populations have been abundant. All stocked largemouth bass were marked with either a coded wire tag (subadult) or oxytetracycline (OTC; fingerlings) chemical mark. Volunteers with boats were used to distribute stocked fish in suitable habitat throughout each reservoir.

Fish Marking (OTC)

Marking procedures

Fingerlings were marked using an OTC bath technique. For the first year of the study, Arizona Game and Fish Department (AGFD) personnel used marking procedures similar to Brooks et al.

(1994). Five gallon buckets were used to dissolve OTC (500 mg/L) in distilled water. The OTC mixture was added to holding tanks along with a buffer solution of sodium phosphate ($NaPO_4$) to reach a neutral pH of approximately 7. Largemouth bass from Inks Dam Fish Hatchery (Burnet, Texas) were added to the OTC bath/buffer mixture for six hours. Largemouth bass were then transported to a designated lake and stocked.

In subsequent years a contractor was hired to deliver OTC marked largemouth bass. The contractor also used methods similar to Brooks et al. (1994) by dissolving Terramycin-343 (500 mg/L of haul H_2O) in 0.5 L H_2O. A buffer solution of 5 L of sodium phosphate for 100 gal tanks and 4 L for 80 gal tanks was added to the water. Readings of pH were taken prior to and after adding $NaPO_4$ buffer and OTC and no significant declines occurred. Fish were left in a six hour bath before being released into ponds or transferred to a desired location.

To test our ability to effectively identify OTC marks, we conducted a blind-test study at Bubbling Ponds Fish Hatchery (Page Springs, Arizona), where thirty largemouth bass were split into two groups, A and B. Group A was treated with an OTC bath following AGFD marking procedures mentioned above and group B, the control group, were given a fin clip. Both groups were placed in a tank to mature over the next eight months. Fish mortalities during the study were stored and their otoliths were examined for the presence or absence of an OTC mark.

At the end of eight months, all surviving fish were sacrificed and otoliths were removed. Two independent readers examined each otolith to determine the presence or absence of OTC marks. Discrepancies between the two readers were solved with a concert read. Results from our blind test were later compared to the known-marked fish.

Otolith processing

To look for OTC-marked largemouth bass post-stocking, a subset of young-of-year bass were collected from each sample site until a minimum of 30 fish were collected, if possible . Additionally, largemouth bass incidentally taken from gill netting surveys were placed in whirl paks and frozen to identify OTC marks and estimate length at age at a later date. Sagittae otiliths were removed, rinsed with water, and placed in vials. To clean, a 3:1 ration of a glycerin alcohol solution was placed in the vials to soak otoliths for one to three days. Otoliths were then rinsed in water, dried, and returned to vials. Vials were stored in a dark closet to protect otoliths with possible OTC marks from mark degrading (Muth and Bestgen 1991).

Otoliths were sectioned by either one of two methods. The first method mounted the otolith vertically on a glass slide using thermoplastic cement. Otoliths were sanded to the nucleus using 500 to 1500 grit sandpaper, then flipped and sanded again in order to obtain a thin section of the nucleus to age. The second method used a low speed Buehler iso-met saw to obtain a thin section of the nucleus. White candle wax was used to attach an otolith to a square piece of folder. The otolith was placed on the folder concave-side up and a line was drawn above and below the nucleus to designate where to section. The otolith was then completely covered with wax and allowed to dry. The folder was mounted on the iso-met saw with the right side of the thick red line aligned with the blade and a cut was made through the otolith. Using the saw's micrometer, the blade was moved to the left between 200 and 500 micrometers and another cut was made obtaining a thin section of the nucleus. Following the cut, the section was mounted to a glass slide using thermoplastic cement and polished with 1500 grit sand paper.

Identifying OTC

We used an Olympus B-Max Phase microscope (model BX40F) with an attached modular filter cube for fluorescence microscopy. The cube contained a narrow band blue-violet excitation, exciter filter BP 400 – 420, dichromatic beam splitter DM 455, and a barrier filter BA 475. A mercury lamp was used as a light source to detect otolith OTC marks. Two readers independently examined all otoliths and determined whether a mark was present or absent. Discrepancies between readers were solved with a concert read.

Fish Marking (Coded Wire Tags)

Smallmouth and largemouth (Florida and Northern Strain) bass were delivered from external contractors to Bubbling Pond Fish Hatchery (Page Springs, AZ) on 10 different occasions between 2007 and 2010 (Table 2). Mark IV tagging machines (Northwest Marine
Technology Inc, Shaw Island, Washington) were used to insert coded wire tag in either the nape, caudal peduncle, or just below the dorsal fin of the fish, depending on the year. Two to four tagging machines were set in a stationary position on a table. Fish were transferred from a holding raceway into a live well near the tagging station. After tagging, individual fish were scanned and passed through a PVC rinsing tube and collected in a net pen within the raceway where the fish were scanned again for the presence of CWT using a hand-held detector (Northwest Marine Technology). If a tag was found, the fish was released into another raceway to await stocking.
If no tag was found, the fish was returned back to the live well. A random subset of fish were measured to determine a mean length of stocked fish.

To assess tag retention, random samples of 30 largemouth bass tagged using the method described above were held in a tank at Bubbling Ponds Fish Research Facility. Fish were periodically checked for the presence/absence of a CWT using a hand-held detector and measured for total length. Holding times (days) for fish at the research facility varied depending by year and fish were always stocked prior to receiving the next batch of fish.

Fish Sampling

Site Selection

Sampling data was limited for each of the three reservoirs at the time of this study to run a power analysis to detect appropriate sample size. Therefore data from Lake Pleasant (Bryan 2004) was used. A combination of fixed and stratified random sites were chosen according to the AGFD standardized sampling protocol (Bryan 2004).

Saguaro, Canyon, and Apache Lakes were each divided into three different basins; lower, middle, and upper. These basins were defined by a lacustrine zone, transition zone, and riverine zone. A map was generated with a site every 500 meters around the perimeter of the lake. The number of sites in each basin was counted and a percentage was generated to identify how many sites in each basin should be surveyed for an accurate estimation of the fish population. For example, the lower basin of Saguaro Lake consisted of 52 total sites covering about 71% of the lake, which led to 15 sites being sampled.

Sites were randomly chosen in each basin and if any site was unsuitable, an alternate site was sampled. Fixed sites were selected based on historical survey sites and expert opinion. Based on electrofishing and gill netting results at Lake Pleasant (Bryan 2004), a similar reservoir to the ones in this study, we determined that with existing personnel we could detect a 30% change in CPUE with 70% confidence by sampling a minimum of 24 sites at each lake. Sampling at Saguaro and Canyon

Lakes each consisted of 24 electrofishing sites (3 fixed sites and 21 random sites) and 24 gill netting sites (4 fixed and 20 random), while Apache Lake consisted of 30 electrofishing sites (4 fixed sites and 26 random sites) and 30 gill netting sites (6 fixed and 24 random; Figures 3-5).

Gill net surveys

We conducted gill net surveys concurrently with electrofishing surveys on Saguaro, Canyon, and Apache Lakes twice per year (spring and fall seasons) beginning in fall 2007 and ending in spring 2010. Experimental monofilament gill nets were used with dimensions of 45.7 m x 1.8 m with six panels of varying mesh size (1.3-7.6 cm in 1.3 cm increments). Gill nets were set in the early evening, fished overnight, and retrieved the following day.

A minimum of 24 nets (fixed and random) in Saguaro and Canyon Lakes, and 30 nets in Apache Lake, were fished with a goal of setting a minimum of 8 nets in each of 3 nights during each sampling survey. Nets were placed in fixed sites during every sample survey at each lake. The random sites were selected without replacement from strata containing the remaining sample sites found in each lake. Hand-held GPS units were used to locate each gill net site.

Electrofishing surveys

We conducted electrofishing surveys coincident with gill net surveys at Saguaro, Canyon, and Apache Lakes. For each electrofishing survey, we used two different hard-hulled aluminum boats outfitted for electrofishing, applying pulsed DC (range of volts and amps; Sharber et al. 1994) to two adjustable spice arrays. Boat one was equipped with a Smith-Root 5.0 GPP electrofishing unit and a 5 kw generator and boat two was equipped with an S-R VVP-15B electrofishing unit with a 8 kw generator. Crews consisted of a minimum of four people per boat; two netters, a processor for the fish, and a boat operator. One netter operated a trolling motor that guided the boat in a counter-clockwise direction along the shore, while the other supplied the electrical power through a foot pedal. Each electrofishing site was sampled for roughly 900 seconds (Bryan 2004). Electrofishing sampling commenced shortly after dusk and persisted 5-7 hours per night for three consecutive nights.

A minimum of 24 electrofishing sites (fixed and random) in Saguaro and Canyon Lakes, and 30 sites in Apache Lake, were sampled over three days per lake. Fixed electrofishing sites were sampled during each sample survey. Random sites were selected without replacement from strata containing the remaining sample sites found in each lake. Hand-held GPS units were used to locate each electrofishing site.

Fish handling

We measured total length (mm) for all fish captured and weight (g) for most fish when conditions permitted accurate weight measurements. With the exception of largemouth and smallmouth bass, fish species too numerous to process were sub-sampled where the first 25 fish of each species were measured and weighed. All largemouth and smallmouth bass captured were scanned for the presence of a coded wire tag (CWT). If a tag was identified, the exact location of the tag was recorded along with length and weight data. Largemouth bass otoliths were removed and prepared as described above. Largemouth and smallmouth bass otoliths were removed from fish incidentally killed during gill net surveys and a subset of largemouth bass were collected from each electrofishing site until a minimum of 30 fish were collected, if possible. Otoliths were later examined in the laboratory for age analysis and/or the presence of an OTC chemical mark. All captured fish, excluding those taken for laboratory analysis, were released near their original site of capture.

Creel

A combination of roving and access creel surveys were conducted from June 2007 to May 2010 at each lake to estimate angler catch, harvest, effort, and return to creel of stocked bass. All three lakes were surveyed equally in a stratified random manner. Similar to Bryan 2004, each year was divided into three seasons; summer (June-September), fall (October-January), and spring (February-May). Additionally, surveys were stratified by weekend/weekday, time of day, and boat ramp. Due to the draw down and closure at Canyon Lake, no surveys were conducted during the fall 2007 season.

During the first year, days were split equally into three time periods. For the second and third years, the three time periods were stratified for each season based on use from the previous years (i.e., more effort during high angler use times). Sampling strata for each lake and year can be found in Appendix A.

Time periods began 15 minutes before sunrise and ended 15 minutes after sunset based on mean monthly sunrise and sunset times. Start times were adjusted during summer 2008 to begin at 6:00 am as very few interviews were conducted the previous year before that time.

Access surveys were conducted at two boat ramps at each Lake: Saguaro at ramp 1 and ramp 2, Canyon at Palo Verde and Laguna, and Apache at Main Launch and Burnt Coral. Roving surveys were designed to sample shore anglers. Based on expert opinion (J. Warnecke, personal communication) of shores use, the first year roving surveys made up about 10% of our surveys. The percentage of roving surveys was adjusted annually based on information collected from the previous year (Appendix A).

Access Surveys

Each of the three lakes have relatively limited shoreline access; therefore the majority of surveys conducted were exit surveys where anglers were interviewed at boat ramps after they finished their fishing trip (Appendix B). Surveys were stratified by weekend/weekday, time of day, and boat ramp. During the first year, stratification was based on expert opinion and adjusted seasonally for the second and third years based on the results from year one. The creel clerk interviewed individual angler(s) as they completed their trip. If the number of anglers coming off the lake were too numerous to interview, the creel clerk either counted every angler and interviewed every other angler, or used their discretion to systematically interview anglers when all anglers could not be contacted.

Roving Surveys

Since shoreline anglers could not be effectively interviewed through access surveys, roving surveys were designed to interview those from shore. Shore angler counts were completed either by boat or foot prior to and after interviews were conducted (Appendices B, C). The two counts were then averaged to estimate fishing effort. Progressive counts were conducted separately from interviews to avoid biases (Wade et al. 1991).

Because shore fishing is limited to a few select areas at the three reservoirs, angling areas were randomly selected and the creel clerk proceeded in a counter-clockwise direction interviewing all anglers if possible, or a pre-determined proportion of anglers encountered. The clerk systematically omitted parties in an objective manner if anglers were too numerous for all to be interviewed.

Data Analysis

Population Indices

We computed catch-per-unit-effort (CPUE) for each species as the number of fish captured per 900 seconds of electrofishing time during the electrofishing surveys, and the number of each species captured per hour during the gill net surveys. Size structure of the popular sportfish species captured was indexed by calculating proportional stock density (PSD; Anderson and Nueman 1996; Bister et al. 2000) as the ratio of "quality" sized fish to the sum of "quality" and "stock" sized fish, or

$$\text{PSD} = \frac{\text{No. of fish} \geq \text{quality length}}{\text{No. of fish} \geq \text{stock length}} \times 100$$

Incremental relative stock densities (RSD-) was also indexed as the ration of several designated length categories for the popular sportfish species capture,
or

$$\text{RSD} = \frac{\text{No. of fish within size category}}{\text{No. of fish} \geq \text{stock length}} \times 100$$

We calculated relative weight (W_r; Wege and Anderson 1978) to evaluate condition of the popular sportfish species captured, where

$$W_r = \frac{\text{Weight of fish}}{W_s} \times 100$$

where W is the weight of an individual fish and Ws is the length specific standard weight for individual species (Anderson and Nusemann 1996; Bister et al. 2000). Analysis of variance (ANOVA) was used to compare species-specific CPUE and Wr among sampling events. All statistical tests were considered statistically significant at the $\alpha = 0.05$ level.

Aging and Growth

Largemouth bass otoliths were removed for age determination from 114 fish (4.1% of total captured), 115 fish (3.5%) and 126 fish (3.2%) from Apache, Canyon, and Saguaro Lakes, respectively. Otoliths were sectioned and mounted using the process mentioned above and images of each otolith were captured and analyzed using CapturePro image analysis software. The number of visible annuli, the distance (mm) from the focuse to each annuli, and the readical distance (mm) from the forces to the outer edge of the otolith was used to back-calculate length at age. Two independent readers examined each otolith and discrepancies between readers were solved with a concert read.

Back-calculation of length at age of all captured largemouth bass was examined using the Fraser-Lee method (Slipke and Maceina 2000), and incorporated into a von-Beralanffy growth model using Wang (1998) methodology. Body growth coefficient (K), the theoretical time where total length equals 0 (t_0), and the theoretical maximum length (L_∞), were estimated based upon back calculations at age information from the otoliths collected and applied to all other largemouth bass captured but not sacrificed during our sampling efforts.

Access Creel

Annual fishing effort at an access point was calculated based on start and stop times for each group exiting the lake. Whole lake estimates of annual effort for each year were extrapolated from effort at the single access point by adjusting the data for site selection and period probabilities (Polluck et al. 1994). Annual effort estimates ($\hat{E}$) for each year were calculated for both weekend and weekday as follows:

$$\hat{E} = \sum_{i=1}^{n} (e_i / \pi_i)$$

Where e is the total time spent fishing (end time – start time) and π_i is the total probability that fishing period i is included in the sample.

Catch and similarly harvest was estimated by:

$$\hat{C} = \sum_{i=1}^{n} c_i \pi_i$$

Where n is the number of surveys, c is the total catch during the survey period and π_i is the total probability that fishing period i is included in the sample.

Catch rates for completed trips were estimated by the ratio of means method:

$$\hat{R}_1 = \frac{\sum_{i=1}^{n} c_i / n}{\sum_{i=1}^{n} L_i / n}$$

where c_i denotes catch of angler i, and L_i is the length of time angler i fished for any given day.

Roving Creel

Roving effort was calculated based on instantaneous counts and the length of the fishing period:

$$\hat{E} = \sum_{i=1}^{n} ((I_i x T) / \pi_i)$$

where I is the instantaneous count of anglers at time i, T is the length of the fishing period and π is the total probability that fishing period i is included in the sample. To calculate catch and harvest for roving surveys effort at any given time period is multiplied by catch rates:

$$\hat{C} = \hat{E} \; x \; \widehat{R_2}$$

where R_2 is the catch rate (Mean of ratio method) calculated from incomplete trips:

$$\hat{R}_2 = \frac{\sum_{i=1}^{n} (c_i / L_i)}{n}$$

Water Quality

Discharge data for most of the dams within the Salt River chain of reservoirs was not available at the time of reporting. However, this data was available through the USGS for Stewart Mountain Dam impounding Saguaro Lake dating from 1934 to current (http://waterdata.usgs.gov/az/nwis/dv/?site_no=09502000&agency_cd=USGS&referred_module=sw). Daily discharges were averaged per month from 1994 to current to represent the water storage capacities of each reservoir downstream of Roosevelt Lake. We assumed periods of higher discharge from Stewart Mountain Dam represented excess water inputs into Apache, Canyon, and Saguaro Lakes and, thus, excess water was exported through the system to maintain operation of each dam.

Water samples have been collected annually at Roosevelt, Apache, Canyon, and Saguaro Lakes since 2004, with periodic sampling occurring in Roosevelt, Canyon, and Saguaro Lakes since 2000. Samples within each lake were collected from a minimum of three sites per trip; the primary inflow area of each reservoir (i.e., immediately downstream of dams for each reservoir in the chain downstream of Roosevelt Lake), the approximate center of each reservoir, and the primary outflow of each reservoir (i.e., immediately upstream of dams for each reservoir in the chain downstream of Roosevelt Lake; Bryan 2004). All samples, except those collected for identification and enumeration of algae, were analyzed in the AGFD Water Quality Laboratory, which is a State of Arizona licensed environmental laboratory certified through the Arizona Department of Health Services. Algal samples were collected at each reservoir site from a maximum of 2 m below the surface and preserved with lugols solution for identification to genus and enumeration. Unpreserved samples were also collected for determination of the presence of golden algae. Limnological field parameters were also measured at all the reservoir sites for each date and sample collection. Depth profiles for temperature, dissolved oxygen, pH, conductivity, and oxidation-reduction potential were measured using a Hydrolab Surveyor 4 display with a Datasonde 4a sond.

RESULTS

Stocking

Throughout the study, a total of 469,152 largemouth bass (Florida and Northern strain) fingerlings were stocked with an OTC mark. Stockings took place in May/June of 2008 and 2009. The mean size of OTC marked largemouth bass among stocking events ranged from 29 to 42 mm. Approximately 25% of the bass were stocked into Saguaro and Canyon Lakes and 50% were stocked into Apache Lake (Table 2).

In May 2008, 47, 437 Northern strain largemouth bass were stocked into Saguaro Lake and 50,784 were stocked into Canyon Lake. The average length at stocking was 29 mm. Saguaro and Canyon received 23,300 (38 mm average length) Florida strain largemouth bass each and Apache Lake received 110,300 Northern strain largemouth bass (34 mm average length) in June 2008. In May 2009, Northern strain largemouth bass were stocked into Saguaro, Canyon, and Apache Lakes; 54,000, 55,000, and 105,000 respectively. The average lengths at stocking were 35, 38, and 42 mm. Results from our two OTC blind-test experiments suggested our accuracy in detecting OTC marks on largemouth bass otoliths was generally low for 2 trial conducted during each experiment. During experiment 1, accuracy of OTC detection among the two readers was 62 and 42% for trial 1 and 2, respectively. During experiment 2, accuracy of OTC detection among the two readers improved to 81% for both trials 1 and 2.

A total of 54,132 subadult largemouth (Florida and Northern strain) and 5,891 smallmouth bass were tagged with CWT throughout the study and released into Apache, Canyon, and Saguaro Lakes. The mean size of largemouth bass among stocking events ranged from 92 to 200mm. Approximately 25% of the bass were stocked into Saguaro and Canyon Lakes and 50% were stocked in Apache Lake (Table 2). Studies of CWT retention were conducted following each major stocking event and averaged 91%, which corroborates the findings of Wallin and Van Den Avyle (1994) and Brennan et al. (2005).

Stocking Survival

Otoliths were removed from 495 largemouth bass; 225 (8.1% of total largemouth bass captured) from Apache, 137 fish (4.1 %) from Canyon, and 133 fish (3.4%) from Saguaro, for OTC detection. A total of 17 OTC-marked largemouth bass from the spring 2008 stocking were recaptured during subsequent sampling events in all three reservoirs. A total of 3 OTC-marked largemouth bass from the spring 2009 stocking were recaptured during subsequent sampling events in all three reservoirs. The contribution of recaptured OTC-marked fish to the numbers of similarly aged fish captured during each sampling even never exceeded 2.75% for all three reservoirs combined (Table 3).

Recapture rates of marked CWT largemouth bass were generally low, ranging between 0.5 to 18% across all three lakes. Saguaro Lake CWT recapture rates were always below 5%, with the highest observed during the fall 2009 sampling event (3.8%). Canyon Lake CWT recapture rates ranged between 0.4 and 6.7%, with the highest recapture rates observed during the spring 200 sampling event. Apache Lake experienced the highest recapture of CWT largemouth bass (18% during spring 2008), and ranged between 1.1 and 18% (Figure 6). Over all three reservoirs, a total of 98, 188, and 70 CWT fish from the fall 2007, fall 2008, and fall 2009 stockings, respectively, were recaptured during subsequent sampling events. The contribution of recaptured CWT fish to the numbers of similarly aged fish captured during each sampling even ranged between 0.5% and 27.6% for all three reservoirs combined (Table 4).

Saguaro Lake Fish Sampling

Effort

A total effort of approximately 36 hours of electrofishing Saguaro Lake captured 21,744 fish comprising 16 different species. A total effort of about 2,408 hours of gill netting captured 6,901 fish comprising 14 different species. Electrofishing effort averaged 6.0 hours while gill netting averaged 404.7 hours across all six sampling events in Saguaro Lake.

Species composition

A total of 21,744 fish comprising 16 species were captured during spring and fall electrofishing surveys on Saguaro Lake from 2007 to 2010. Catches were dominated by bluegill (46-85% of the catch), largemouth bass (7-18%), and threadfin shad (2-39%; Table 5). A total of 6, 092 fish comprising 15 species were captured during spring and fall gill net surveys from 2007 to 2010. Yellow bass dominated the catch (19-62% of the catch), followed by largemouth bass (13-41%), and channel catfish (7-24%; Table 6).

Catch-per-unit-effort

Saguaro Lake CPUE for all species was typically higher during springs versus fall electrofishing surveys (Table 7). Bluegill was the most frequently captured species, ranging between 66.16 and 160.33 fish per 900 seconds. Largemouth bass CPUE was also highest during spring surveys and ranged between 6.63 and 41.04 fish per 900 seconds across all electrofishing sampling events. Smallmouth bass were not observed during the fall 2007 and spring 2008 electrofishing surveys and were sparsely captured during remaining surveys with CPUE ranging between 0.05 and 0.17 fish per 900 seconds (Table 7).

Catch-per-unit-effort of all species was generally consistent between seasons during gill net surveys in Saguaro Lake (Table 8). Yellow bass was the most frequently captured species, ranging between 0.64 and 1.65 fish per hour. The highest largemouth bass CPUE was observed during the first sampling event (1.59 fish per hour) and ranged between 0.28 and 0.60 fish per hour thereafter. Channel catfish CPUE remained consistent across all sampling events, ranging between 0.19 and 0.49 fish per hour (Table 8).

Relative weight

Common carp relative weight was the highest compared to all other species captured during electrofishing surveys, ranging between 112 and 136 (Table 9). The highest relative weights for largemouth bass were observed during the first two sampling events (fall 2007, Wr = 110 and spring 2008, Wr = 109), and ranged between 86 and 100 thereafter. Yellow bass relative weight was typically higher during the spring and ranged between 77 and 98 (Table 9).

Channel catfish relative weight was generally the highest observed among sport fish compared to all other species captured during gill net surveys, ranging between 102 and 124 (Table 10). Similar to the electrofishing data, largemouth bass relative weight was highest during the first two gill net surveys. Yellow bass relative weight was also relatively high ranging between 91 and 106 (Table 10).

Size structure

Analysis of fish length data for several of the sportfish species from Saguaro Lake suggested the size structure improved across years and seasons over the course of the study. Bluegill and largemouth bass PSD improved from 18 and 20% in fall 2007 to 29 and 61% in fall 2009, respectively (Table 11). Similarly, bluegill and largemouth bass PSD during spring surveys increased from 18 and 4% in spring 2008 to 33 and 72% in spring 2010, respectively. Incremental relative stock densities remained relatively low for largemouth bass, with RSD-P ranging from 7 to 11% and 2 to 13% during fall and spring surveys, respectively. Yellow bass relative stock densities suggested robust populations of larger fish with RSD-P ranging between 7 and 41% and 23 and 52% during fall and spring surveys, respectively (Table 12).

Length frequency analysis

Length frequency analysis from Saguaro Lake suggested the majority of common carp captured during electrofishing and gill net surveys were larger fish (> 600 mm; Figure 8 and 9). Smaller carp (200-400 mm) were observed during gill net surveys in fall 2007 but were infrequently captured thereafter. Too few channel catfish were captured during electrofishing surveys to evaluate length distribution. However, analyses from gill net surveys suggested a relatively uniform distribution of channel catfish across all length groups (Figure 10). Electrofishing length frequency analysis of bluegill suggested the persistence of a single dominant cohort from fall 2007 through spring 2009 (Figure 11). Larger and older fish dominated the gill net catch of bluegill except for the fall 2007 survey (Figure 12). Too few smallmouth bass were captured during electrofishing and gill nets surveys in Saguaro Lake to evaluate length distributions. Similar to bluegill, largemouth bass length frequency distributions from electrofishing suggested a single cohort dominated the catch from fall 2007 to spring 2009 (Figure 13). Data collected from gill net surveys additionally suggested a single cohort dominated the catch, with modes centered around 200 mm in fall 2007 increasing to 300-400 mm in spring 2010 (Figure 14). Yellow bass length frequency distributions were dominated by larger fish (>150 mm) during spring 2008 through spring 2009 electrofishing surveys, and by smaller fish (<150 mm) during all other surveys (Figure 15). Yellow bass length frequency distributions during gill net surveys were dominated by larger fish (> 150 mm; Figure 16).

Age and growth

Otoliths were examined from 133 largemouth bass in Saguaro Lake and ages of all largemouth bass captured ranged from 0 to 6 years (Figure 17). Age 0 to 2 fish dominated the catch during fall 2007 and spring 2008 surveys comprising roughly 95 and 72% of the catch, respectively. Age 2 to 4 fish dominated the catch during fall 2008 and spring 2009 surveys comprising roughly 73 and 79% of the catch, respectively. Age 3 to 4 largemouth bass dominated the catch during fall 2009 and spring 2010 surveys comprising roughly 62 and 74% of the catch, respectively (Figure 17).

We modeled largemouth bass predicted length at age based upon OTC and CWT recaptured fish following the Wang (1998) methodology. We then compared the model predictions to the length at age information derived from our otolith analysis. Results from our modeling efforts showed agreement through age 3 but differed considerably thereafter (Figure 18). The parameters estimated by the model (K = 0.001, L_∞ = 70,285) were not reasonably attainable, which was likely a result of a small sample size of larger fish used for aging. The mean length of largemouth bass sacrificed for otolith analysis was 268 mm TL (range 143 – 482 mm TL). Largemouth bass mean length at age in Saguaro Lake was the lowest for ages 1 to 5 amongst all lake studied (Figure 43).

Canyon Lake Fish Sampling

Effort

A total effort of roughly 26 hours of electrofishing Canyon Lake yielded 17, 969 fish comprising 18 different species. A total effort of about 2,356 hours of gill netting yielded 2, 420 fish comprising 16 different species. Electrofishing effort averaged 6.1 hours while gill netting averaged 388.2 hours across all 6 sampling events in Canyon Lake.

Species composition

A total of 17,969 fish comprising 18 species were captured during spring and fall electrofishing surveys on Canyon Lake from 2007 to 2010. Catches were dominated by bluegill (37-70% of the catch), largemouth bass (14-20%), and threadfin shad (7-41%; Table 13). A total of 2,424 fish comprising 16 species were captured during gill net surveys from 2007 to 2010. Yellow bass dominated the catch (13-48% of the catch), followed by channel catfish (17-27%), threadfin shad (2-40%), and largemouth bass (5-31%; Table 14).

Catch-per-unit-effort

Canyon Lake CPUE for popular sportfish species was generally consistent during spring and fall electrofishing surveys (Table 15). Bluegill was the most frequently captured species, ranging between 53.99 and 65.58 fish per 900 seconds. Largemouth bass CPUE remained relatively stable throughout the study period ranging between 16.10 and 24.46 fish per 900 seconds across all electrofishing sampling events. Smallmouth bass were not observed during the fall 2007 electrofishing survey and were sparsely captured during remaining surveys with CPUE ranging between 0.13 and 0.45 fish per 900 seconds (Table 15).

Catch-per-unit-effort of all species was generally consistent between seasons during gill net surveys in Canyon Lake (Table 16). Yellow bass was the most frequent captured species, ranging between 0.12 and 0.53 fish per hour. The highest largemouth bass CPUE was observed during the fifth sampling event (0.25 fish per hour) and ranged between 0.06 and 0.18 fish per hour overall. Channel catfish CPUE remained consistent across all sampling events ranging between 0.18 and 0.34 fish per hour (Table 16).

Relative weight

Common carp relative weight was the highest compared to all other species captured during electrofishing surveys, ranging between 104 and 117 (Table 17). The highest relative weights for largemouth bass were observed during the first two sampling events (fall 2007, Wr = 101 and spring 2008, Wr = 102), and ranged between 92 and 101 thereafter. Yellow bass relative weight differed significantly throughout the study and ranged between 83 and 111 (Table 17).

Channel catfish relative weight was generally the highest compared to all other species captured during gill net surveys, ranging between 101 and 120 (Table 18). Similar to the electrofishing data, largemouth bass relative weight was highest during the first two gill net surveys and ranged between 95 and 100 thereafter. Yellow bass relative weight was also relatively high, ranging between 93 and 113 (Table 18).

Size structure

Analysis of fish length data for several of the sportfish species from Canyon Lake suggested the size structure improved across years and seasons over the course of the study, excluding largemouth bass and yellow bass. Green sunfish and bluegill PSD improved from 45 and 22% in fall 2007 to 60 and 49% in fall 2009, respectively (Table 19). Similarly, bluegill PSD during spring surveys increased from 20% in spring 2008 to 64% in spring 2010. However, largemouth bass and yellow bass declined from 93 and 93% in fall 2007 to 49 and 47% in fall 2009, respectively. A similar trend was observed with both species during spring surveys where PSDs declined from 86 and 94% in spring 2008 to 62 and 72% in spring 2010, respectively. Incremental relative stock densities also declined for largemouth bass over the course of this study, with RSD-P declining from 61 to 12% and 67 to 18% during fall and spring surveys, respectively. Yellow bass relative stock densities suggested robust populations of larger fish with RSD-P ranging between 26 and 54% and 46 and 56% during fall and spring surveys, respectively (Table 20).

Length frequency analysis

Length frequency analysis from Canyon Lake suggested the majority of common carp captured during electrofishing and gill net surveys were larger fish (Figure 19 and 20). Too few channel catfish were captured during electrofishing surveys to evaluate length distribution. However, analyses from gill net surveys suggested a relatively uniform distribution of channel catfish across all length groups (Figure 21). Electrofishing length frequency analysis of bluegill suggested the persistence of a single dominant cohort throughout the study period (Figure 22). Too few bluegill were captured during gill net surveys to evaluate length distribution. Also, too few smallmouth bass were captured during electrofishing and gill net surveys in Canyon Lake to evaluate length distributions. Similar to bluegill, largemouth bass length frequency distributions from electrofishing suggested a single cohort dominated the catch from fall 2007 to spring 2009. Evidence of a spring 2009 largemouth bass cohort was observed during the fall 2009 electrofishing survey (Figure 23). Data collected from gill net surveys additionally suggested a single cohort dominated the catch, with modes centered around 100 mm in fall 2007 increasing to 300-400 mm in spring 2010 (Figure 24). Yellow bass length frequency distributions were dominated by larger fish (> 150 mm) during fall 2007 and spring 2008 electrofishing surveys, and by smaller fish (< 150 mm) during fall 2008, fall 2009, and spring 2010 surveys (Figure 25). Yellow bass length frequency distributions during gill net surveys were dominated by larger fish (>150 mm) from fall 2007 to spring 2009 surveys (Figure 26). Walleye were not observed during the fall 2007 gill net surveys at Canyon Lake but were more frequently captured during subsequent surveys. Catch of walleye was dominated by larger fish (> 200 mm; Figure 27).

Age and growth

Otoliths were examined from 137 largemouth bass in Canyon Lake and ages of all largemouth bass captured ranged from 0 to 11 years (Figure 28). Age 0 to 1 fish dominated the catch during fall 2007 and spring 2008 surveys comprising roughly 80 and 69% of the catch, respectively. Age 1 to 3 fish dominated the catch during fall 2009 and spring 2009 surveys comprising roughly 82 and 78% of the catch, respectively. Age 0 to 4 largemouth bass dominated the catch during fall 2009 and spring 2010 surveys comprising roughly 85 and 93% of the catch, respectively (Figure 28).

Comparisons of the modeled recapture data and the observed otolith data indicated poor agreement across all ages (Figure 29). Our back-calculated otolith information underestimated length at age compared to the model predictions. The model estimated reasonable growth parameters (K = 0.25, L_∞ = 605 mm), suggesting sufficient numbers of largemouth bass were recaptured. The mean length of largemouth bass sacrificed for otolith analysis was 275 mm TL (range 99 – 544 mm TL).

Apache Lake Fish Sampling

Effort

A total effort of roughly 46 hours of electrofishing Apache Lake captured 15,621 fish comprising 16 different species. A total effort of about 3,605 hours of gill netting captured 10,753 fish comprising 16 different species. Electrofishing effort averaged 7.6 hours while gill netting averaged 512.2 hours across all 6 sampling events in Apache Lake.

Species composition

A total of 15,621 fish comprising of 16 species were captured during spring and fall electrofishing surveys on Apache Lake from 2007 to 2010. Catches were mostly dominated by threadfin shad (22-64% of the catch), bluegill (9-43%), and largemouth bass (9-18%; Table 21). A total of 10,743 fish comprising 16 species were captured during gill net surveys from 2007 to 2010. Threadfin shad dominated the catch (40%-85% of the catch), followed by yellow bass (6-25%), and channel catfish (2-13%; Table 22).

Catch-per-unit-effort

Apache Lake CPUE for popular sportfish species was typically higher during spring versus fall electrofishing surveys, but CPUEs in Apache Lake were the lowest observed among all three lakes sampled (Table 23). Bluegill was the most frequently captured species, ranging between 7.42 and 26.55 fish per 900 seconds. Largemouth bass electrofishing CPUE increased incrementally throughout the study period from 1.59 fish per 900 seconds during fall 2007 to 26.24 fish per 900 seconds during spring 2010. Smallmouth bass were not observed during the fall 2007 electrofishing survey and were sparsely captured during remaining surveys with CPUE ranging between 0.06 and 3.44 fish per 900 seconds (Table 23).

Catch-per-unit-effort of all species was generally consistent between seasons during gill net surveys in Apache Lake (Table 24). Yellow bass was the most frequently captured species, ranging between 0.15 and 0.57 fish per hour. The highest largemouth bass CPUE was observed during the fifth sampling event (0.38 fish per hour) and ranged between 0.01 and 0.19 fish per hours overall. Channel catfish CPUE remained consistent across all sampling event, ranging between 0.08 and 0.15 fish per hour (Table 24).

Relative Weight

Common carp relative weight in Apache Lake was the highest compared to all other species captured during electrofishing surveys, ranging between 107 and 112 (Table 25). The highest relative weight for largemouth bass was observed during the second sampling event (spring 2008, Wr = 102), and ranged between 94 and 98 during other surveys. Yellow bass relative weight remained relatively stable throughout the study and ranged between 92 and 100 (Table 25).

Channel catfish relative weight was generally the highest compared to all other species captured during gill net surveys, ranging between 103 and 123 (Table 26). Largemouth bass relative weight was highest during the spring 2009 gill net survey and ranged between 97 and 105 during other surveys. Yellow bass relative weight was also relatively high ranging between 93 and 109 (Table 26).

Size Structure

Analysis of fish length data for several of the sportfish species from Apache

Lake suggested the size structure remained relatively stable across years and seasons over the course of the study, excluding largemouth bass and yellow bass. Common carp and channel catfish PSD ranged from 94 to 100% and 90 to 94% during fall surveys, respectively (Table 27). However, largemouth bass and yellow bass declined from 68 and 100% in fall 2007 to 29 and 86% in fall 2009, respectively. A similar trend was observed with both species during spring surveys where PSDs declined from 51 and 93% in spring 2008 to 28 and 83% in spring 2010, respectively. Incremental relative stock densities also decline for largemouth bass, with RSD-P declining from 60 to 4% and 35 to 8% during fall and spring surveys, respectively. Yellow bass relative stock densities suggested robust populations of larger fish with RSD-P ranging between 33 and 100% and 45 and 91% during fall and spring surveys, respectively (Table 28).

Length frequency analysis

Length frequency analysis from Apache Lake suggested the majority of common carp captured during electrofishing and gill net surveys were larger fish (Figures 30 and 31). Too few channel catfish were captured during electrofishing surveys to evaluate length distribution. However, analyses from gill net surveys suggested a relatively uniform distribution of channel catfish across all length groups (Figure 32). Electrofishing length frequency analyses of bluegill suggested the persistence of dominant spring cohorts, as evidenced by the contribution of 100 mm fish captured during fall surveys (Figure 33). Too few bluegill were captured during gill net surveys to evaluate length distribution. Smallmouth bass were not captured during fall 2007 electrofishing surveys in Apache Lake. However, two modes were observed between 100-200 mm and 250-350 mm during fall 2009 and spring 2010 (Figure 34). Adult smallmouth bass appeared to dominate the catch during gill net surveys with one cohort observed from spring 2008 to spring 2010 (Figure 35). Multiple modes of largemouth bass were observed during fall 2007 and spring 2008 electrofishing surveys and a single dominant cohort was observed from fall 2008 to spring 2010 (Figure 36). Data collected from gill net surveys additionally suggested a single cohort dominated the catch, with a mode centered around 200 mm in spring 2008 increasing to 200-300 mm in spring 2010 (Figure 37). Yellow bass length frequency distributions were likely dominated by a single cohort throughout all electrofishing surveys (Figure 38). Similarly, yellow bass length distributions during gill net surveys were dominated by larger fish (> 250 mm) from fall 2007 to spring 2009 surveys (Figure 39). Walleye were more frequently captured during gill net surveys at Apache Lake compared to Saguaro and Canyon Lakes and larger fish dominated the catch from fall 2007 through spring 2009, after which smaller cohorts were observed (Figure 40).

Age and growth

Otoliths were examined from 225 largemouth bass in Apache Lake and ages of all largemouth bass captured ranged from 0 to 8 years (Figure 41). Capture of all age classes was relatively consistent and low during the fall 2007 sampling event. Age 0 to 3 fish dominated the catch during the spring 2008 survey, comprising roughly 86% of the catch. Age 1 to 2 fish dominated the catch during fall 2008, spring 2009, and fall 2009 surveys, comprising roughly 80, 78, and 74% of the catch, respectively. Age 1 to 3 largemouth bass dominated the catch during the spring 2010 survey, comprising roughly 90% of the catch (Figure 41).

Saguaro Lake Creel Survey

Effort

Creel surveys at Saguaro Lake began in June 2007 and continued through May 2010. A total of 262 access and 77 roving surveys were conducted and 3,931 anglers were interviewed (Table 29). Each year the ratio of exit to roving surveys decreased as data revealed more anglers were fishing from shore than originally thought. Annual effort ranged from 100,142 hours during the first year to 151,327 hours during the second year (Table 30). Over the period of this study, shore anglers contributed to 47.4% and boat anglers contributed to 52.6% of the total effort.

Catch and Harvest

Total annual catch for all species ranged from 62,094 during the first year to 135,353 during the second year of this study. Overall catch was highest for bluegill/sunfish (160,869), largemouth bass (92,896), and yellow bass (33,381; Table 31). Shore anglers were responsible for 68.5% of the total bluegill/sunfish catch while boating anglers were responsible for 93.1% of the total largemouth bass catch. Yellow bass catch was nearly equal for shore and boat anglers. Annual harvest for all species ranged from 14,167 the first year to 47,861 the third year. Overall harvest was highest for bluegill sunfish (82,078), yellow bass (9,821), and largemouth bass (7,061; Table 32). The percentage of fish harvested for all species (where annual catch was greater than 10,000) was higher for shore anglers. The percent harvested was highest for bluegill/sunfish (51.0%), catfish (50.3%), rainbow trout (34.8%), and yellow bass (29.4%). Harvest for all other species was less than 10% of the catch (Table 33). Catch rates for largemouth bass increased from 0.01 fish/hr (SE = 0.01) in 2007 to 0.69 fish/hr (SE = 0.17) in 2008 (Figure 44). Catfish catch rates appeared to decline over the duration of the project while bluegill/sunfish catch rates increased (Figure 44). Largemouth bass were harvested as small as 127 mm TL and as large as 460 mm TL. The mean size of largemouth bass harvested was 302 mm TL (Table 34).

Canyon Lake Creel Survey

Effort

Creel surveys at Canyon Lake began in June 2007 and continued through May 2010. No surveys were conducted from October 2007 through February 2008 as access to the lake was closed due to dam maintenance. A total of 2,072 anglers were interviewed from 235 access and 69 roving surveys (Table 29). Each year the ratio of access to roving surveys decreased as data revealed that more anglers were fishing from shore than originally thought. Estimated annual angler effort ranged from 36,549 hours during the first year to 85,362 hours during the second year (Table 30). Over the period of this study, shore anglers contributed 56.3% and boat anglers contributed 43.7% of the total effort.

Catch and Harvest

Total annual catch for all species ranged from 7,232 during the first year to 45,348 during the second year of this study. Overall catch was highest for bluegill/sunfish (66,053), largemouth bass (17,618), and catfish (6,537; Table 35). Bluegill/sunfish and catfish comprised 77.2% and 61.9% of the shore angler catch, respectively. Largemouth bass and yellow bass comprised 68% and 69% of the boat angler catch, respectively. Annual harvest for all species ranged from 2,379 the first year to 15,527 the third year. Overall harvest was highest for bluegill/sunfish (20,927), largemouth bass (2,143), and catfish (1,963; Table 36). The percent harvested was highest for rainbow trout (39.6%), bluegill/sunfish (31.7%), catfish (30.0%), and crappie (21.3%). Harvest for all other species was less than 15% of the catch (Table 33). Catch rates for largemouth bass peaked at 0.33 fish/hr (SE = 0.010) during spring 2009. Catfish catch rates appeared to decline over the duration of the project while bluegill/sunfish catch rates increased (Figure 45). The mean size of largemouth bass harvested was 312 mm TL and ranged from 160 mm TL to 501 mm TL (Table 34).

Apache Lake Creel Survey

Effort

Creel surveys at Apache Lake began in June 2007 and continued through May 2010. A total of 279 access and 75 roving surveys were conducted and 835 anglers were interviewed (Table 29). Each year the ratio of access to roving surveys decreased as data revealed that more anglers were fishing from shore than originally thought. Annual effort increased from 21,726 hours during the first year to 37,776 hours during the third year (Table 30). Over the period of this study, shore anglers contributed 64.0% and boat anglers contributed 36.0% of the total effort.

Catch and Harvest

Total annual estimated catch for all species ranged from 1,794 during the first year to 25,705 during the third year of this study. Overall catch was highest for yellow bass (9,683), largemouth bass (9,447), and bluegill/sunfish (6,744; Table 37). Yellow bass comprised 99% of the shore angler catch, while largemouth bass comprised 83.2% of the boat angler catch. Annual harvest for all species ranged from 364 the first year to 2,758 the third year. Overall harvest was highest for bluegill/sunfish (1,509) and yellow bass (742; Table 38). The percent harvested was highest for smallmouth bass (34.5%), catfish (33.1%), rainbow trout (23.9%), and bluegill/sunfish (22.4%). Harvest for all other species was less than 10% of the catch (Table 33). Catch rates for largemouth bass increased from 2007 (0.02 fish/hr, SE = 0.02) to the summer 2009 (0.42 fish/hr, SE = 0.21). No apparent trends appear for all other species (Figure 46). The mean size of largemouth bass harvested was 330 mm TL and ranged from 200 mm TL to 530 mm TL (Table 34).

Other Creel Information

Angler Satisfaction

Anglers were asked to rate their fishing experience as very poor, poor, fair, good or excellent. Greater than 50% of anglers were satisfied with their experience at all three lakes. Overall, anglers were most satisfied fishing at Saguaro Lake (71.2%) followed by Canyon Lake (67.4%) and Apache Lake (65.6%). Apache Lake showed the greatest increase in angler satisfaction over the course of this study from 51% in year one to 69% in year three. When data for all three lakes was pooled, a significant positive correlation between largemouth bass catch rates and angler satisfaction was observed ($r_p = 0.9$, $P < 0.05$; Figure 47).

Angler Experience

At all lakes, most anglers (73%) fished less than one time per month. Also, shore anglers represented a larger portion of anglers with the least amount of experience than boat anglers (Table 39). Anglers at Saguaro Lake tended to have the greatest amount of experience while anglers at Apache Lake had the least amount of angling experience.

Target Species

Anglers were additionally asked the species of fish they were attempting to catch. The majority of anglers (>43%) at each lake indicated no preference for a particular species. Anglers seeking largemouth bass, or any bass (largemouth or smallmouth), ranked second or third at each lake. Other than largemouth bass, the most sought after species were catfish, bluegill, and rainbow trout, but all were targeted by less than 9% of the anglers surveyed (Table 40). Rainbow trout and walleye are the only fish that are regularly stocked in these reservoirs. Rainbow trout are targeted by a small proportion of anglers (2.0 – 3.4%) across all three reservoirs (Table 40). Walleye are most commonly stocked in Apache Lake with occasional stockings in Saguaro and Canyon Lakes. Anglers targeted walleye 1.5% of the time at Apache Lake and < 1% of the time a Saguaro and Canyon Lakes.

Post hoc analysis

A post hoc power analysis for creel survey sample size was conducted for the three reservoirs. Results revealed that Saguaro Lake can have an effective sample size anywhere from 15 to 380 surveys per year, Canyon Lake could be surveyed 15 to 374 per year, and Apache Lake would have to be sampled anywhere from 48 to 1205 per year to detect a 50% to 10% change respectively in each reservoir. Post hoc analysis of sample strata showed that many more anglers were fishing from shore (60-80%) that originally thought at each reservoir. Angling use varied seasonally with summer typically having the lowest use (Table 41).

Water Quality

We analyzed discharge from Stewart Mountain over three distinct time periods since 1994; 1994 to 1998, 1999 to 2005, and 2006 to 2010. These distinct periods were chosen following *post hoc* analyses as it was evident each period differed in discharge, likely due to drought conditions that occurred throughout the Southwest during the late 1990s. Mean daily discharge per month between 1994 and 1998 ranged between 1 and 1,800 ft^3/second annually, with significant peaks observed between February and April and June and September (Figure 48). Between 1999 and 2005, mean daily discharge per month ranged between roughly 0 an 1,000 ft^3/second annually, with the only significant peak observed during the summer monsoonal season. Trends in mean daily discharge per month between 2006 and 2010 were similar to those observed between 1994 and 1998, however, discharge during the summer monsoonal season was reduced between 2006 and 2010 (Figure 48).

Mean annual conductivity in Apache, Canyon, and Saguaro Lakes showed similar trends from 2001 to 2011. Conductivity within each lake remained at or above 1,500 uS/cm until 2006, and has decreased within each lake each following year (Figure 49). Conductivity in Roosevelt Lake, however, showed drastic changes annually between 2000 and 2005, reaching a peak of about 2,600 uS/cm in 2002 and decreasing to about 600 uS/cm in 2005. Trends in Roosevelt Lake conductivity has remained similar to those observed in Apache, Canyon, and Saguaro Lakes since 2007 (Figure 49).

Analysis of water samples collected from each reservoir revealed densities of golden alga were reduced following the 2004 and 2005 fish kills. The highest densities of golden alga were observed in Saguaro Lake during December 2007 water quality monitoring. Golden alga was not observed in Saguaro Lake following that sampling effort. Small densities of golden alga were only found in Canyon Lake during one occasion (June 2008). The highest densities of golden alga in Apache Lake were found during June 2008 water quality monitoring (Figure 50).

DISCUSSION

Fish Stocking

A total of five stocking events took place during the course of the study; three fall events consisting of subadult (6-8”) largemouth and smallmouth bass marked with coded wire tags and two spring events consisting of fingerling (1-2") largemouth bass marked with OTC. Approximately 12 times the amount of fingerlings were stocked in the spring compared to subadult largemouth bass stocked in the fall for each reservoir. However, the cost of stocking subadults was about 6.5 times higher than stocking fingerlings. As such, if stocking fingerlings is the most cost effective method, we would have expected the proportion of OTC recaptures to be greater than 1.8 times that of the subadult stocked largemouth bass, assuming survival of fall and spring stocked largemouth bass is similar (however, see Buynak et al. 1999).

The contribution of stocked largemouth bass to the wild population within each reservoir studied was variable but remained relatively low. Recapture rates of stocked fish ranged between about 1 to 15% across all reservoirs sampled, which was comparable to previous studies in Arkansas and Illinois (Colvin et al. 2008; Diana and Wahl 2008). It is likely that the sampling effort we employed during this study was insufficient to evaluate survival of stocked fish immediately after stocking events (Buckmeier et al. 2003; Diana and Wahl 2009). All sampling events took place several months after stocking therefore short term mortality could not be evaluated. However, if stocked fingerling or subadult largemouth bass provided major contributions to the wild population, we would have expected higher recapture rates of these fish as adults during latter surveys of this study.

The stocking of subadult smallmouth bass appeared to benefit each of the three lakes. Initial sampling events rarely captured smallmouth bass, indicating this species was heavily impacted by the fish kills. The contribution of stocked smallmouth bass captured during sampling surveys was 78%, 47%, and 35% across all surveys in Saguaro, Canyon, and Apache Lakes respectively. However, these proportions are likely overestimates due to the rare captures of smallmouth bass, particularly in Saguaro and Canyon Lakes. Apache Lake is the only reservoir sampled where it appears smallmouth bass are rebounding following the 2004 and 2005 fish kills.

Marking

The use of OTC to mark fish is an effective tool for tracking an entire cohort of fish (Bilton 1986; Bumgardner 1991; Brooks et al. 1994). However, marking and then identifying fish with OTC marks is a time consuming process. The identification process requires sacrificing fish, processing otoliths, and purchasing and using specialized equipment to view the mark. Due to the popularity of largemouth bass in Arizona and angler concerns over Department personnel sacrificing fish, only a subsample of fish were sacrificed for laboratory analyses, thus decreasing our chances of retrieving a marked bass (Nate and Bremigan 2005). It is likely that, in order to obtain a representative sample of OTC marked fish, the number of fish sacrificed had to be an order of magnitude higher than those taken during this study. Further, previous research has shown relatively high uncertainty may exist between readers in identifying OTC marked otiliths (Conover and Sheehan 1999; Mauk 2008; Mesign et al. 2008; Logsdon et al. 2009). Reader error from known marked fish suggests that reading marks can be difficult (Logsdon et al. 2009). To reduce uncertainty surrounding our mark and recapture efforts for OTC marked fish, we would recommend increasing recapture efforts and the number of samples sacrificed for laboratory analyses in the future.

Marking efforts for coded wire tags were relatively intensive and required 10 to 15 people over multiple days. Initial tagging efforts resulted in a loss of over a quarter of the tags due to injector inexperience. Tagging methods were reevaluated and tagged fish were submerged into a net pen in the raceway, allowed to swim and scanned a second time. Tags improperly inserted or stuck to the side of the fish were thus rinsed. Following this minor adjustment, tag retention increased to 100%. Fish were marked without the use of anesthesia and very little short-term mortality (<1.5%) was observed throughout all tagging efforts.

Recapture success

As mentioned above, roughly 12 times the number of fingerlings (OTC) were stocked into each reservoir versus subadult (CWT) largemouth bass. Over the course of the study, however, the majority of recaptures observed were from the subadult stocking events. For example, recaptures of similar aged subadult fish from the fall 2007 stocking event ranged between 0.3 and 12.3 % during subsequent sampling events. Alternatively, recaptures of similar aged fingerlings from the spring 2008 stocking event ranged between 0.2 to 2.8% during subsequent stocking events. It is likely differences in return of fingerling and subadult fish is related to differential growth or mortality rates among cohorts, reader error, or other density dependent factors (Mesing et al. 2008; Diana and Wahl 2009). However, in order to evaluate factors leading to the observed differences, the sampling effort needed to be at least twice the effort employed during this study. Similarly, the number of fish sacrificed to detect OTC marks likely need to be an order of magnitude higher. Angler concerns over scientific take of such magnitude precluded that from our study, especially since angler groups donated funds and volunteer time toward stocking fish.

Fish Sampling

Site selection/gear types

Two different gear types were used to obtain sufficient representation of the fish assemblage in each reservoir. Initially, data from previous surveys was used to estimate sample size to detect varying levels of change with 80% confidence. Due to high variance and small sample sizes from previous surveys, our power analysis revealed sample sizes for each lake that exceeded manpower and budgetary capabilities. Thus, the numbers of sites selected for each gear type were adjusted to accommodate available manpower and budgetary allowances.

We sampled 24 sites at Saguaro and Canyon Lakes and 30 sites at Apache Lake for both gear types. Post hoc power analysis suggests under those sample sizes for electrofishing, managers (with 80% confidence) can detect a 45%, 40%, and 30% change in largemouth bass CPUE at Saguaro, Canyon, and Apache Lakes, respectively. The percent delectability may appear high, but the effort is sufficient to detect large scale fish kills caused by golden alga or other major changes in the largemouth bass populations such that management actions may need to be taken.

For gill netting, the number of sets deployed during this project can only detect an 80% change in Canyon and Apache Lake and a 50% change in Saguaro Lake, which may not be sufficient to detect large scale changes in the largemouth bass population. However, gill nets are important for detecting changes in other popular sport fish species such as yellow bass and catfish. The numbers of sites surveyed in the fall were sufficient to detect (with 80% confidence) a 35% change in channel catfish population at Saguaro Lake and 50% change at Canyon and Apache Lakes in channel catfish populations. For yellow bass, the gill netting sample design allowed for detection of 60%, 80%, and 50% change at Saguaro, Canyon, and Apache Lakes, respectively.

Species composition

Species composition analyses of electrofishing and gill net data suggests similar fish assemblages reside in all three reservoirs sampled during this study. All species captured pre fish kill were captured during our surveys. The most fish were captured in Saguaro Lake followed by Apache and Canyon Lakes. The numbers of fish captured using both gears remained relatively consistent in Saguaro and Canyon Lakes, but increased substantially during each sampling event in Apache Lake. This suggests Apache Lake was most impacted by the golden algae fish kills and still may be in a recovery phase. Relatively consistent proportions of largemouth bass were observed during electrofishing surveys in Saguaro and Canyon Lakes, while the proportion of largemouth bass captured in Apache Lake nearly doubled from the beginning to the end of the study period. Similarly, proportions of bluegill, a common prey item for largemouth bass, collected during electrofishing surveys remained relatively consistent in Saguaro and Canyon lakes, while bluegill proportions declined by roughly half in Apache Lake, likely due to the large population increase of largemouth bass.

During gill net surveys, proportions of largemouth bass remained consistent in Canyon and Apache Lakes, while proportions of largemouth bass declined by roughly 60% in Saguaro Lake from the beginning to the end of the study period. Threadfin shad, another common prey item of largemouth bass, was captured relatively consistently in Saguaro and Canyon Lake gill net surveys, while threadfin shad catch increased by roughly 90% in Apache Lake over the study period. However, caution should be used when assessing threadfin shad populations because of the great variability in catch and would suggests using other great types such as a trawl to estimate shad trends. Proportions of yellow bass, a potential competitor of largemouth bass, increased dramatically in Saguaro Lake, remained consistent in Canyon Lake, and decreased by roughly 40% in Apache Lake during gill net surveys throughout the study period.

Smallmouth bass were rarely captured throughout the course of the study, particularly in Saguaro and Canyon Lakes. The contribution of recaptured smallmouth bass from stocking efforts in all three lakes was about 37%. This suggests smallmouth bass may have been heavily impacted by the golden alga fish kills and may be in a recovery period. However, our inferences about the impact of golden alga are limited due to paucity of long-term species composition information in these reservoirs. The most robust population of smallmouth bass likely resides in Apache Lake suggesting improved angling conditions for this species in the near future.

Taken in context together, data collected during electrofishing and gill net surveys indicated largemouth bass populations may have recovered from the 2004-2005 fish kills related to golden algae; prior to initiation of this project (Maceina and Grizzle 2006; Diana and Dahl 2008). Additionally, both gear types appeared to capture robust forage species (i.e., sunfish species, threadfin shad) and generalist and predator species that typically display low capture probabilities with electrofishing and gill nets (i.e., catfish species, common carp). Limited quality information was available to compare fish assemblages of each reservoir pre-and post-fish kill. Small sample sizes and fixed site data made it difficult to accurately assess baseline data (pre-fish kill). Such data would have likely revealed the extent to which reservoir has recovered.

Relative Abundance

Relative abundance of total species captured during electrofishing and gill net surveys remained relatively stable across all sampling events in Saguaro and Canyon Lakes, and increased incrementally across all sampling events in Apache Lake. However, relative abundance of total species captured in Apache Lake was substantially lower during initial electrofishing surveys than those observed in other reservoirs, further indicating this lake was heavily impacted by fish kills. The highest largemouth bass relative abundance was typically observed in Canyon Lake electrofishing surveys, which was comparable to previous studies (Buynak and Mitchell 1993; Miranda et al. 1996; Tate et al. 2003); however, largemouth bass relative abundance during electrofishing surveys in Apache Lake increased incrementally over the period of study, further suggesting this reservoir may be in a period of recovery Electrofishing CPUE for largemouth bass in Apache Lake was the lowest observed among the three reservoirs from fall 2007 and fall 2008 (Figure 7). Also, largemouth bass CPUEs in Apache Lake gill net surveys were similar to those observed in Canyon Lake across all surveys. However, CPUE for largemouth bass in Apache Lake during electrofishing and gill net surveys were similar to those observed in Saguaro and Apache Lakes by the end of the study (Figure 7).

Threadfin shad and bluegill relative abundance during electrofishing surveys were the highest among all other species in each reservoir suggesting a sufficient prey base exists for sport fish species. Also, yellow bass relative abundance remained relatively high throughout the study period across all three reservoirs. A similar trend was observed for walleye in Apache Lake, where fish were rarely captured during initial surveys and commonly captured during the last two surveys. These data imply the fish fauna in each reservoir has recovered from the fish kills events observed in 2004 and 2005.

Relative weight

Relative weight of the several sport fish species captured ranged from fair to good and remained relatively stable across all sampling events and reservoirs. The highest relative weight for largemouth bass was observed during initial project sampling events but remained in good condition throughout the period of study, which were comparable to other studies (Stone and Modde 1982; Guy and Willis 1990; Kleinsasser et al. 1990; Neal and Noble 2002, 2008). Similar trends were observed for bluegill and yellow bass in each reservoir. The ability for forage fish to recover faster thus being available in high quantities compared to their predators could explain the high largemouth bass relative weights. The generally high relative weights observed indicate several species are exceeding maintenance energy requirements and thus able to produce gametes. As such, we expect successful spawns of several sport fish species. Future sampling will elucidate if successful recruitment of species of special concern to anglers is occurring. If so, we expect improved angling conditions in the near future within each reservoir.

Size structure

Size structure of popular sport fish species captured was generally highest in Canyon Lake during electrofishing and gill net surveys. Throughout the study period within Canyon and Apache Lakes, however size structure generally declined suggesting density dependent constraints may be limiting the trophy potential of several species (Guy and Willis 1991). In contrast, size structure of sport fish species in Saguaro Lake increased over the study period but few species were captured of preferred or memorable size. Previous studies have shown that similar largemouth bass size structures to the ones we found in each reservoir indicate that growth potential beyond quality size exists (Bonvechio et al. 2008; Carlson and Isermann 2010), with the greatest potential of trophy-sized fish likely residing in Canyon Lake. Similarly, the yellow bass size structure in all three reservoirs indicated growth potential beyond preferred size exists, with the greatest potential of trophy-sized fish likely residing in Apache Lake. Future sampling will likely determine if density dependent constraints in each reservoir will limit species size structure as fish assemblages continue to recover and potentially expand.

Age and growth

Comparisons of the modeled recapture data and the observed otilith data indicated poor agreement after age 1 (Figure 42). Our back-calculated otolith information underestimated length at age compared to the model predictions for all other ages. The model estimated unattainable growth parameters ($K = 0.05$, $L_{\infty} = 2{,}645$ mm), which was likely a result of a small sample size of larger fish used for aging. The mean length of largemouth bass sacrificed for otolith analysis was 262 mm TL (range 115 – 551 mm TL). Largemouth bass mean length at age in Apache Lake was similar to those observed for Canyon Lake through age 7 (Figure 43).

We observed a wide range in largemouth bass size at each age amongst each reservoir sampled. Age-2 largemouth bass ranged between 109 and 233 mm, 105 and 280 mm, and 97 and 306 mm in Saguaro, Canyon, and Apache Lakes, respectively. Further, age-5 largemouth bass ranged between 258 and 405 mm, 268 and 442 mm, and 262 and 465 mm in Saguaro, Canyon, and Apache Lakes, respectively. These large variations may be related to differential growth or mortality rates among cohorts (Stone and Modde 1982; Beamesderfer and North 1995; Buynak and Mitchell 1999; Buckmeier and Betsill 2002), ageing error (Inman et al. 1977; Taubert and Tranquilli 1982; Schramm et al. 1992; Maceina et al. 2007), or other density dependent factors (McNew and Summerfelt 1978; Allen et al. 2002; Ridgeway 2002; Wilson et al. 2002; Slaughter et al. 2008). Larger sample sizes than those collected during the study may have elucidated potential factors; however, angler concerns of take limited our collection abilities. Nevertheless previous research has shown wide variation in largemouth bass growth is typical (Allen et al. 2002; Neal and Noble 2002).

Growth of largemouth bass to quality size was generally attained by age 4 in Canyon and Apache Lakes which was comparable with previous research (Inman et al. 1977; Beamesderfer and North 1995; Whitworth 1989; Allen et al. 2002; Krause et al 2002), with slower growth occurring in Saguaro Lake. Preferred sizes were typically reached by age 6, which was slower growth than those observed in southeastern U.S. reservoirs (Bettoli and Miranda 2001; Bulak and Crane 2002). Small sample sizes limited our inference in Saguaro Lake. The highest proportions of preferred and memorable size fish were captured in Canyon Lake, and no trophy sized largemouth bass were collected during the study.

Angler Surveys

Effort and sample design

The intensive angler survey component of this study produced over 6,800 interviews over nearly 1,000 surveys days. Angling effort was highest at Saguaro Lake and lowest at Apache Lake. Effort was lowest during the first year of the study at all three lakes, but significantly increased by year two at Saguaro and Canyon Lakes, and by year three at Apache Lake. Low angling effort at Canyon Lake during the first year was a result of a 4-month lake closure due to dam maintenance. However, a strong positive correlation between largemouth bass catch rates and effort suggests as catch rates for largemouth bass increases, so does effort.

Survey efforts were spread equally across all three reservoirs, but 56% of angler contracts came from Saguaro Lake, likely due to the angler use based on the proximity to the Phoenix metro area. Canyon and Apache Lakes represented about 33 and 11% of total angler contacts for this project, respectively. Apache Lake is the furthest of the three reservoirs from Phoenix with access by way of either Roosevelt or Canyon Lakes on dirt roads. The difficulty of accessing Apache Lake, coupled with closer angling opportunities and poor fishing, likely explains the low rate of angler contracts.

During initial designs of this study, shore angling was thought to represent about 10% of total angler use at each reservoir. Angler surveys at Lake Pleasant showed an overwhelming majority of anglers fished from boats (Bryan 2004). However, our data revealed, with the exception of Saguaro Lake, more anglers fish from shore than from boats. Despite limited shoreline access at each reservoir, high concentrations of anglers at designated angling piers contributed to much of the effort. Saguaro and Canyon Lakes are very popular with non-angling boat users and could be a deterrent for boat anglers desiring a peaceful fishing experience. Unlike those anglers interviewed at Saguaro and Canyon Lakes, many of the angler's primary activity at Apache Lake was camping, which may explain why Apache Lake had the highest proportion of shore anglers to boat anglers during this study.

Angler preference

The majority of anglers contacted at each reservoir did not target a specific species. However, largemouth bass was overwhelmingly the most targeted species at Saguaro and Canyon Lakes and, to a lesser degree, the most popular fish sought at Apache Lake. Many anglers responded they were targeting bass with no preference to smallmouth or largemouth bass. Thus, we created a category called any bass which was the third ranked preference when asked what species was targeted. All other species were targeted by less than 10% of anglers at each reservoir. Catfish ranked as the 4th preferred species at Canyon and Apache Lakes, and the 5th preferred at Saguaro Lake.

Thousands of catchable rainbow trout are regularly stocked during fall and winter months at all three reservoirs. Most trout likely do not survive over summer due to warm lake temperatures and low dissolved oxygen levels. However, a small percentage of anglers (2.0% at Saguaro, 3.4% at Canyon, and 2.3% at Apache Lakes) target rainbow trout. Several bass anglers were interested in rainbow trout stockings as it was believed trout provide an additional food source for largemouth bass. Over the three years of study, an average of nearly 2,583 hours, 2,238 hours, and 642 hours were expended angling for rainbow trout at Saguaro, Canyon, and Apache Lakes, respectively. Although preference for rainbow trout was low, more anglers targeted rainbow trout than bluegill sunfish at Canyon and Apache Lakes.

Anglers at Apache Lake preferred fishing for yellow bass more than rainbow trout and bluegill sunfish. Several yellow bass captured at Apache Lake during our surveys were of trophy size. The opportunity to catch a state record at Apache Lake likely led to increased numbers of anglers targeting yellow bass at Saguaro and Canyon Lakes.

Catch and Harvest

Annual estimated catch was highest for bluegill/sunfish at each reservoir each year, with the exception of the third year at Apache Lake. Yellow bass dominated the angler catch in Apache Lake during the third year of study, and was followed by largemouth bass. Boat anglers caught significantly more largemouth bass than shore anglers at each reservoir. Shore anglers caught more bluegill/sunfish than boat anglers, but the difference was only significant at Saguaro Lake. Additionally, shore anglers caught significantly more yellow bass at Apache Lake than boat anglers.

Historically, Arizona anglers harvested a greater proportion of fish than today. In 1985, estimated harvest for largemouth bass was 63% at Saguaro Lake, 92% at Canyon Lake, and 76% at Apache Lake (Warnecke 1988). Currently however, anglers seeking largemouth bass harvest limited numbers of fish. Among all three reservoirs studied, only 8% of largemouth bass caught were harvested. Canyon Lake had the highest percentage of harvest (12.2%) over the course of the study, likely due to more fish that were considered harvestable. A 13-16 inch slot limit with harvest of one fish within the slot was implemented half way through this project. Despite the change in regulations, no difference in harvest was observed indicating that the slot limit had little effect on harvest. The mean size of largemouth bass harvested at each reservoir was just over 12 inches.

Angler Satisfaction

Overall, Arizona anglers were satisfied with their experiences at all three reservoirs studied. Anglers had the most satisfying experience at Saguaro Lake, likely owing to the proximity of the reservoir to the city of Phoenix. Apache Lake anglers, which were perhaps the anglers most impacted by the fish kills, showed increased satisfaction by the end of the study period. This is likely correlated to the observed increase in the largemouth bass population of the reservoir. We expect angler satisfaction to remain at this level or perhaps increase as the largemouth bass population continues to rebound from the fish kills in the near future.

Water Quality

Drought conditions across the Southwestern states, particularly between 1999 and 2005, likely influenced the fish kills we observed in 2004 and 2005. Discharges below Saguaro Lake during the winter months between 1999 and 2005 were an order of magnitude lower than those observed between 1994-1998 and 2006-2010 during winter months. This suggests all four reservoirs within the chain received reduce amount of spring runoff between 1999 and 2005 that limited the flushing capabilities of each reservoir. Our ability to relate the toxic blooms with discharge are limited since data was only available from Stewart Mountain Dam. However, since it is the lowest dam within the Salt River chain of reservoirs, we assumed this location represented the best data available to indicate water surplus/shortage within the system. Nevertheless, additional discharge data from the other three dams in the system would greatly benefit future analyses.

Although data is limited, there appears to be a direct relationship between reservoir conductivity and the fish kills in Apache, Canyon, and Saguaro Lakes. Similar trends in conductivity between the three reservoirs was observed since 2003, where conductivity peaked in 2003 and remained above about 1,500 uS/cm through 2005. This period bounds the time period of the fish kills observed in each reservoir. The trend in conductivity was not observed in Roosevelt Lake between 2000 and 2005, which may explain why fish kills were not observed in this reservoir. Roosevelt Lake conductivity showed an alternating pattern between these years and has remained similar to those observed in Apache, Canyon, and Saguaro Lakes since 2007 (i.e. below 1,500 uS/cm). These results are comparable with previous research in Texas, where periods with low conductivity resulted in reduced densities of golden algae (Harris et al. 2010).

Analyses of water samples revealed the highest densities of golden algae were observed during 2007 in Saguaro Lake. However, golden algae have not been found in any of the three reservoirs since 2008. It is likely that the relatively 'wet' winter season experienced in Arizona from about 2006 through 2010, and the resultant low conductivity and higher dam discharge in each reservoir, have worked to keep densities of golden algae low since 2005. Similar research has shown densities of golden algae were reduced following periods of high inflow (Harris et al. 2010). However, our ability to make further inference about this relationship is limited due to the lack of hydrologic data from each of the reservoirs within the system.

MANAGEMENT RECOMMENDATIONS

As mentioned above, roughly 12 times the number of fingerlings (OTC) were stocked into each reservoir versus subadult (CWT) largemouth bass. In order for the stocking of fingerlings to be the most cost-effective method, we expected the return of stocked fish to be at least 1.8 times higher than the return of subadult fish. Further, knowledge of a returned subadult fish was inexpensive and immediate. This was not the case for recapture fingerlings, where sacrificing the fish and specialized equipment was required to process each sample taken. A significant amount of laboratory time was needed for otolith processing. Also, significant discrepancies were apparent between readers indentifying marks which further reduced our confidence using this technique. Our assumption of similar survival between fingerling and subadult stocked fish is likely understated given previous research. However, given the high numbers of fingerlings stocked during the study, we expected higher returns of these fish in reservoirs that were essentially reset following large fish kills. The sampling effort employed during this study represents a standard for managers to use to evaluate fisheries' response to future fish kills. To evaluate which stocking strategy is most beneficial, we suggest implementing a more intensive sampling strategy immediately following stocking events, and for months afterwards, where tracking fate of stocked fish is the primary focus of the study. Such a design would also require significantly more sacrifice of fish, which may conflict with angler desires. Regardless, our results implying higher return of subadult fish suggest stocking larger largemouth bass most benefits Arizona reservoirs that had experience dramatic fish kills.

Results from our creel surveys indicated that a small proportion of anglers target the fall and winter rainbow trout stocking efforts in Saguaro, Canyon, and Apache Lakes. Not only do rainbow trout serve as an additional prey item for largemouth bass and other predators, but also as a unique angling experience for the Phoenix metro area. We recommend the continuation of trout stocking until further analysis of the cost/benefit can be fully evaluated. Additionally, we suggest adding a question to future creel surveys that will evaluate the public's opinion on trout stocking at these reservoirs. Perhaps asking the question "Would you still fish here if there was not an opportunity to catch a rainbow trout?"

While it appears the largemouth and smallmouth bass populations are recovering from the 2004-2005 fish kills, other sport fish species may still provide excellent angling opportunities, especially in Apache Lake. Our sampling data revealed relative abundance of walleye increased in Saguaro and Apache Lakes throughout the study period, particularly during our gill net surveys. Size structure analyses showed good proportions of fish within quality and preferred sizes. Additionally, the yellow bass population appears to consist of robust, healthy fish. Relative abundance of yellow bass in Apache Lakes also increased over the study period suggesting high success rates for anglers seeking this species. Apache Lake was the only lake studied where yellow bass attained trophy size. Both species represent unique angling opportunities for statewide anglers. As such, future management efforts should incorporate similar sampling methods (i.e., electrofishing and gill nets) to monitor these unique opportunities.

Our post-hoc power analysis identified electrofishing as the most efficient capture technique to reliably detect changes in largemouth bass populations within each reservoir studied. While the number of sites sampled were likely insufficient to detect inter-annual changes in populations, they were adequate to confidently detect large-scale changes typically associated with golden alga related fish kills. In contrast, our ability to detect similar changes using gill nets was limited. Analyses revealed that an order of magnitude more gill nets than those employed would have been required for similar levels of detection and confidence. This type of effort was beyond the budgetary, personnel, and time limits originally set for this study. For future assessment of fisheries' response to fish kills, we recommend electrofishing surveys as the primary capture method, in both configuration and numbers of sites sampled, to detect changes in largemouth bass populations. Sampling should occur at least twice per year (i.e., spring and fall) to ensure spawning and recruitment to adulthood is occurring.

While power analyses of gill net data lacked the precision needed to confidently measure changes in largemouth bass populations, it is likely the efforts used during this study adequately represented populations of other sport fish species. Given that our creel surveys showed roughly 8% of anglers surveyed targeted species other than largemouth bass in the three reservoirs, managers may benefit from knowledge of additional species. Fall gill net surveys, in particular, sufficiently detected at least an 80% change in yellow bass and channel catfish populations across all three reservoirs. Descriptive information of yellow bass revealed this species is able to reach memorable and trophy sizes in Apache Lake. Such data suggests unique angling opportunities outside of typical largemouth and smallmouth bass fisheries exist in each reservoir that should be promoted and maintained for Arizona's angling public. Thus, future monitoring of these reservoirs should consist of seasonal electrofishing and gill net surveys to monitor and maintain these valued resources.

Often times determining the appropriate sample size for a particular survey can be difficult due to lack of data. We were able to collect a sufficient amount of data to run a post hoc power analysis to determine sample sizes need to detect a 20%, 30%, 40%, and 50% change in annual angler catch rates where alpha = 0.7. Analysis of Saguaro and Canyon Lakes revealed that feasible amount of effort (less < 100 survey days/yr) can be applied at each of the two lakes to detect a desire level of change within the 20-50% range. Due to the lack of angling effort and success at Apache Lake post hoc analysis revealed that an unreasonable amount of creel effort (225 surveys/yr to detect 50% change) is needed to detect changes in catch rates and would not recommend conducting creel surveys at Apache Lake if managers are interested in detecting changes in catch rates. If creel surveys are desired at Apache Lake an all roving survey may be the best approach to intercept all anglers on the Lake at any given point in time.

Our primary objective of this study was to evaluate stocking strategies for largemouth bass. However, immediate stocking following a kill may not be the best option. Several factors need to be considered in the event of a major fish kill, including water levels in Roosevelt Lake, dam operations, and conductivity levels of all four reservoirs. We recommend that managers follow the steps outlined in Appendix D.

This study provided a solid baseline for comparison to future surveys. We suggest that managers continue routine monitoring to continue to improve on baseline conditions which can be used to inform us about the extent of future fish kills and lead to better management actions.

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Table 1. Species captured during electrofishing and gill net surveys in Saguaro, Canyon, and Apache Lakes. The + symbol represents a species presence.

Species	Saguaro	Canyon	Apache
Yellow Bullhead (*Ameiurus natalis*)	+	+	+
Goldfish (*Carassius auratus*)	+	+	
Common Carp (*Cyprinidae carpio*)	+	+	+
Threadfin Shad (*Dorosoma petenense*)	+	+	+
Mosquito Fish (*Gambusia affinis*)	+	+	+
Channel Catfish (*Ictalurus punctatus*)	+	+	+
Buffalo Fish (*Ictiobus species*)	+	+	+
Green Sunfish (*Lepomis cyanellus*)	+	+	+
Pumpkinseed (*Lepomis gibbosus*)		+	+
Bluegill (*Lepomis macrochirus*)	+	+	+
Redear Sunfish (*Lepomis microlophus*)	+	+	
Smallmouth Bass (*Micropterus dolomieu*)	+	+	+
Largemouth Bass (*Micropterus salmoides*)	+	+	+
Yellow Bass (*Morone mississippiensis*)	+	+	+
Rainbow Trout (*Oncorhynchus mykiss*)	+	+	+
Yellow Perch (*Perca flavescens*)	+	+	
Black Crappie (*Pomoxis nigromaculatus*)		+	+
Flathead Catfish (*Pylodictis olivaris*)	+	+	+
Walleye (*Sander vitreus*)	+	+	+
Talapia (*Tilapia spp.*)	+	+	

Table 2. Delivery date, species stocked, tag type used to mark fish, mean size (mm), stocking location, and numbers of largemouth bass and smallmouth bass marked and stocked into Saguaro, Canyon, and Apache Lakes during the Golden Algae project, 2007-2010.

Delivery date	Species tagged	Tag type	Mean length (mm)	Stocking location (number stocked)
October 2007	smallmouth bass (4,375)	No tag	178	Canyon Lake – 545 Apache Lake – 3,830
November 2007	N. strain largemouth bass (12,634)	CWT	178	Saguaro Lake – 3,208 Canyon Lake – 3,080 Apache Lake – 6,346
May 2008	N. strain largemouth bass (98,221)	OTC	29	Saguaro Lake – 47,437 Canyon Lake – 50,784
June 2008	N. strain largemouth bass (110,331)	OTC	34	Apache Lake – 110,331
	Fl. strain largemouth bass (46,600)		38	Saguaro Lake – 23,300 Canyon Lake – 23,300
	smallmouth bass (2,255)		127	Saguaro Lake – 955 Canyon Lake – 1,300
October 2008	Fl. strain largemouth bass (4,674) smallmouth bass (1,765)	CWT	92 92	Saguaro Lake – 1,883 largemouth bass, 665 smallmouth bass Canyon Lake – 1,888 largemouth bass, 700 smallmouth bass Apache Lake – 903 largemouth bass, 400 smallmouth bass

Table 2. Continued.

Delivery date	Species tagged	Tag type	Mean length (mm)	Stocking location (number stocked)
November 2008	N. strain largemouth bass (17,858)	CWT	180	Saguaro Lake – 4,880 Canyon Lake – 4,995 Apache Lake – 7,983
	Fl. strain largemouth bass (1,387)		100	Saguaro Lake – 694 Canyon Lake – 683
December 2008	smallmouth bass (4,126)	CWT	158	Apache Lake – 4,126
May 2009	N. strain largemouth bass (214,000)	OTC	35-42	Saguaro Lake – 54,000 Canyon Lake – 55,000 Apache Lake – 105,000
October 2009	Fl. strain largemouth bass (5,316)	CWT	123	Saguaro Lake – 500 Canyon Lake – 2,162 Apache Lake – 2,654
	smallmouth bass (12,995)	No tag	131	Canyon Lake – 2,998 Apache Lake – 9,997
November 2009	N. strain largemouth bass (12,263)	CWT	189	Canyon Lake – 4,000 Apache Lake – 8,263

Table 3. Percentage of largemouth bass recaptured during sampling events that possessed an OTC mark from previous stocking events in Saguaro, Canyon, and Apache Lakes combined. Percentages were based upon numbers of recaptured fish / numbers of fish captured per age class during each sampling event.

Stocking event (number stocked)	Sampling Event							
	Fall 2008		Spring 2009		Fall 2009		Spring 2010	
	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2
Spring 2008 (255,152)	1.08%		0.20%			2.75%		0.17%
Spring 2009 (214,000)	N/A		N/A		0.43%		0.27%	

Table 4. Percentage of largemouth bass recaptured during sampling events that possessed a CWT mark from previous stocking events in Saguaro, Canyon, and Apache Lakes combined. Percentages were based upon numbers of recaptured fish / numbers of fish captured per age class during each sampling event.

Stocking Event (number stocked)	Sampling event														
	Spring 2008			Fall 2008			Spring 2009			Fall 2009			Spring 2010		
	Age			Age			Age			Age			Age		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Fall 2007 (12,634)	12.3%				2.0%			3.4%				0.33%			0.94%
Fall 2008 (23,909)		N/A		0.50%			27.6%				15.3%			5.3%	
Fall 2009 (17,579)		N/A			N/A			N/A		0.85%			17.9%		

Table 5. Species composition of fish captured during electrofishing surveys in Saguaro Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	**Fall 2007**	**Spr. 2008**	**Fall 2008**	**Spr. 2009**	**Fall 2009**	**Spr. 2010**
Yellow bullhead	10 *(<1%)*		14 *(<1%)*		3 *(<1%)*	
Common carp	9 *(<1%)*	21 *(<1%)*	17 *(1%)*	7 *(<1%)*	11 *(<1%)*	16 *(<1%)*
Threadfin shad	1356 *(39%)*	516 *(9%)*	295 *(10%)*	293 *(11%)*	64 *(2%)*	1451 *(33%)*
Mosquitofish			1 *(<1%)*			
Channel catfish	1 *(<1%)*	8 *(<1%)*	8 *(<1%)*	6 *(<1%)*	29 *(1%)*	15 *(<1%)*
Buffalo spp			1 *(<1%)*	1 *(<1%)*		
Green sunfish	52 *(1%)*	83 *(1%)*	98 *(3%)*	24 *(1%)*	47 *(2%)*	30 *(<1%)*
Hybrid sunfish				5 *(<1%)*	12 *(<1%)*	8 *(<1%)*
Bluegill	1623 *(46%)*	3937 *(69%)*	2125 *(74%)*	1723 *(63%)*	2195 *(85%)*	2058 *(47%)*
Redear sunfish		39 *(1%)*	7 *(<1%)*			
Smallmouth bass			4 *(<1%)*	2 *(<1%)*	2 *(<1%)*	1 *(<1%)*
Largemouth bass	307 *(9%)*	1003 *(18%)*	218 *(8%)*	432 *(16%)*	174 *(7%)*	472 *(11%)*
Yellow bass	21 *(1%)*	113 *(2%)*	63 *(2%)*	225 *(8%)*	16 *(<1%)*	291 *(7%)*
Rainbow trout		2 *(<1%)*				4 *(<1%)*
Flathead catfish	2 *(<1%)*	1 *(<1%)*	4 *(<1%)*		3 *(<1%)*	1 *(<1%)*
Tilapia spp	122 *(3%)*	8 *(<1%)*	7 *(<1%)*	1 *(<1%)*	12 *(<1%)*	14 *(<1%)*
TOTAL	**3503**	**5731**	**2862**	**2719**	**2568**	**4361**

Table 6. Species composition of fish captured during gill net surveys in Saguaro Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	**Fall 2007**	**Spr. 2008**	**Fall 2008**	**Spr. 2009**	**Fall 2009**	**Spr. 2010**
Yellow bullhead	4 *(<1%)*	1 *(<1%)*	5 *(1%)*			1 *(<1%)*
Goldfish		1 *(<1%)*	1 *(<1%)*			
Common carp	36 *(2%)*	14 *(1%)*	16 *(2%)*	12 *(1%)*	7 *(1%)*	10 *(1%)*
Threadfin shad	304 *(18%)*	195 *(20%)*	36 *(5%)*	82 *(10%)*	134 *(15%)*	133 *(13%)*
Channel catfish	150 *(9%)*	184 *(19%)*	158 *(24%)*	107 *(13%)*	154 *(18%)*	75 *(7%)*
Green sunfish		1 *(<1%)*			2 *(<1%)*	2 *(<1%)*
Bluegill	113 *(7%)*	23 *(2%)*	9 *(1%)*	21 *(2%)*	32 *(4%)*	20 *(2%)*
Largemouth bass	695 *(41%)*	217 *(22%)*	116 *(18%)*	141 *(17%)*	217 *(25%)*	133 *(13%)*
Yellow bass	318 *(19%)*	345 *(35%)*	292 *(44%)*	476 *(56%)*	267 *(31%)*	568 *(62%)*
Rainbow trout		1 *(<1%)*				
Yellow perch		1 *(<1%)*				
Flathead catfish	17 *(1%)*	5 *(1%)*	13 *(2%)*	3 *(<1%)*	12 *(1%)*	8 *(1%)*
Walleye	3 *(<1%)*	3 *(<1%)*	4 *(1%)*	1 *(<1%)*	3 *(<1%)*	5 *(<1%)*
Tilapia spp	60 *(4%)*		10 *(2%)*		37 *(4%)*	1 *(<1%)*
TOTAL	**1700**	**991**	**660**	**843**	**865**	**1033**

Table 7. Mean catch-per-unit-effort and standard error of the mean of fish captured during electrofishing surveys in Saguaro Lake. Superscripts indicate significant differences of means at the α = 0.05 level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

	Fall 2007 (24)		**Spr. 2008 (24)**		**Fall 2008 (24)**		**Spr. 2009 (24)**		**Fall 2009 (24)**		**Spr. 2010 (22)**	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead	0.41	0.17			0.58	0.42			0.12	0.07		
Common carp	0.37	0.15	0.86*	0.22	0.71	0.25	0.29*	0.11	0.45	0.13	0.72	0.20
Threadfin shad	55.20*	18.34	21.45^	14.09	12.07*[#]	4.48	12.18*[+]	3.63	2.67*[a]	0.69	63.51^[#+a]	23.80
Mosquitofish					0.04	0.04						
Channel catfish	0.04*	0.04	0.33^	0.14	0.33[#]	0.11	0.25[+]	0.09	1.20*^[#+]	0.37	0.67*	0.21
Buffalo spp.					0.04	0.04	0.04	0.04				
Green sunfish	2.11*	0.43	3.43^	0.91	4.05*[#]	1.02	1.00^[#]	0.25	1.94[#]	0.35	1.34^[#]	0.26
Hybrid sunfish							0.21	0.08	0.50	0.16	0.35	0.14
Bluegill	66.16*	15.43	160.33*^	14.23	86.66^	11.33	71.69^	12.15	90.51^	10.41	92.05^	10.99
Redear sunfish			1.61*	0.78	0.29*	0.16						
Smallmouth bass					0.17	0.13	0.08	0.06	0.08	0.06	0.05	0.05
Largemouth bass	12.49*	2.29	41.04*^	6.63	8.93^[#]	1.69	17.98^[+]	2.68	7.18^[+a]	0.94	21.21^[#a]	3.90
Yellow bass	0.87*	0.34	4.66^	1.17	2.62[#]	1.08	9.36*[+]	3.08	0.65[+a]	0.30	13.08*^[#a]	6.59
Rainbow trout			0.07	0.05							0.18	0.08
Flathead catfish	0.08	0.06	0.04	0.04	0.17	0.13			0.12	0.09	0.05	0.05
Tilapia spp.	4.98*	1.03	0.33*	0.19	0.28*	0.09	0.04*	0.04	0.50*	0.18	0.64*	0.42
TOTAL	**142.71***	**28.18**	**234.14*^**	**28.40**	**116.94^[#]**	**13.41**	**113.13^[+]**	**14.75**	**105.93^[a]**	**11.14**	**193.84[#+a]**	**25.70**

Table 8. Mean catch-per-unit-effort and standard error of the mean of fish captured during gill net surveys in Saguaro Lake. Superscripts indicate significant differences of means at the $\alpha = 0.05$ level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

Species	**Fall 2007** (24)		**Spr. 2008** (24)		**Fall 2008** (24)		**Spr. 2009** (24)		**Fall 2009** (24)		**Spr. 2010** (24)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead	0.01	0.01	<0.01	<0.01	0.01	0.01					<0.01	<0.01
Goldfish			<0.01	<0.01	<0.01	<0.01						
Common carp	0.08*	0.02	0.04*	0.01	0.04*	0.01	0.03*	0.01	0.02*	0.01	0.02*	0.01
Threadfin shad	0.69	0.36	0.53	0.26	0.09	0.03	0.22	0.11	0.30	0.23	0.33	0.14
Channel catfish	0.34*	0.05	0.49*^	0.07	0.39#	0.05	0.27^	0.04	0.37+	0.04	0.19*^#+	0.04
Green sunfish			<0.01	<0.01					<0.01	<0.01	0.01	<0.01
Bluegill	0.26*	0.06	0.06*	0.02	0.02*	0.01	0.06*	0.02	0.08*	0.01	0.05*	0.01
Largemouth bass	1.59*	0.24	0.60*	0.19	0.28*	0.06	0.37*	0.08	0.52*	0.07	0.36*	0.06
Yellow bass	0.74*	0.14	0.97	0.27	0.72^	0.12	1.22	0.35	0.64#	0.19	1.65*^#	0.33
Rainbow trout			<0.01	<0.01								
Flathead catfish	0.04*	0.02	0.01*	0.01	0.03	0.01	0.01*	<0.01	0.03	0.01	0.02	0.01
Walleye	0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01
Tilapia spp.	0.14*	0.03			0.02*	0.01			0.09*	0.02	<0.01*	<0.01
Total	**3.89***	**0.41**	**2.72***	**0.59**	**1.62***	**0.17**	**2.18***	**0.40**	**2.05***	**0.33**	**2.66***	**0.38**

Table 9. Mean relative weight and standard error of the mean of fish captured during electrofishing surveys in Saguaro Lake. Superscripts indicate significant differences in means at the α = 0.05 level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

Species	Fall 2007		Spr. 2008		Fall 2008		Spr. 2009		Fall 2009		Spr. 2010	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	*123*	*4.80*	136*	3.53	113*	2.76	*124*	*7.46*	112*	3.57	119*	3.97
Channel catfish	*109*		*126*	*6.24*	*114*	*12.45*	*124*	*2.88*	108	2.36	115	3.25
Green sunfish	99	3.46	107*	3.80	92*	2.48	100	2.27	93*	1.76	96*	2.48
Bluegill	103*	1.32	106^	1.32	92*^$^{\#}$	0.74	99^$^{\#+}$	0.70	89*^$^{\#+}$	1.06	88*^$^{\#+}$	0.88
Smallmouth bass							*103*		*86*	*3.47*	*87*	
Largemouth bass	110*	1.77	109^	1.51	86*^$^{\#}$	0.87	89*^$^{+}$	0.48	94*^$^{\#a}$	1.11	100*^$^{\#+a}$	0.71
Yellow bass	91	3.96	97*	2.00	86*^	1.19	98^$^{\#}$	1.02	77*$^{\#}$	9.65	88*$^{\#}$	3.00
Flathead catfish	*128*	*14.00*	*147*		*99*	*2.71*			*94*	*1.40*	*110*	

Table 10. Mean relative weight and standard error of the mean of fish captured during gill net surveys in Saguaro Lake. Superscripts indicate significant differences in means at the $\alpha = 0.05$ level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

	Fall 2007		**Spr. 2008**		**Fall 2008**		**Spr. 2009**		**Fall 2009**		**Spr. 2010**	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	121	1.99	124	4.45	116	2.77	118	2.87	*109*	*3.79*	114	3.79
Channel catfish	117*	2.09	124*^	2.31	105*^[#]	1.17	118^[#+]	1.40	102*^[+a]	1.36	116^[#a]	2.09
Green sunfish			*103*						*92*	*8.40*	*89*	*13.96*
Bluegill	101*	3.94	105^	2.54	*98*	*9.63*	112*[#]	4.42	94[#]	4.02	83*^[#]	4.38
Largemouth bass	114*	0.81	102*^	0.91	89*^[#]	0.98	100*[#]	1.56	100*[#]	0.76	99*[#]	0.90
Yellow bass	102*	1.42	106*^	1.03	91*^[#]	0.70	103[#+]	1.08	92*^[+a]	1.14	98*^[#+a]	0.94
Flathead catfish	105	2.79	*130*	*10.01*	107	4.59	*101*	*5.88*	103	3.99	*124*	*9.54*
Walleye	*96*	*2.02*	*108*	*2.52*	*98*	*5.43*	*154*		*101*	*6.13*	*102*	*3.02*

Table 11. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during fall surveys in Saguaro Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

Species	PSD			RSD-P			RSD-M			RSD-T		
	F07	**F08**	**F09**	**F07**	**F08**	**F09**	**F07**	**F08**	**F09**	**F07**	**F08**	**F09**
Common carp	71	100	100	68	94	82	15*	56	71	2*	3*	0*
Channel catfish	69	74	78	15	11	12	2*	1*	1*	0*	0*	0*
Green sunfish	8*	31	59	0*	1*	6*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	18	13	29	0*	0*	0*	0*	0*	0*	0*	0*	0*
Smallmouth bass	0*	0*	50*	0*	0*	0*	0*	0*	0*	0*	0*	0*
Largemouth bass	20	21	61	11	3*	7	1*	0*	0*	0*	0*	0*
Yellow bass	80	75	78	41	17	7	13	2*	1*	0*	1*	0*
Flathead catfish	71	73	69*	6*	13*	8*	0*	0*	0*	0*	0*	0*
Walleye	100*	75*	33*	67*	50*	33*	0*	0*	0*	0*	0*	0*

Table 12. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during spring surveys in Saguaro Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

	PSD			RSD-P			RSD-M			RSD-T		
Species	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**
Common carp	97	100	100	94	95	100	69	74	92	6*	0*	8*
Channel catfish	66	71	65	6*	14	9*	0*	1*	0*	0*	0*	0*
Green sunfish	14	30*	74	4*	0*	10*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	18	25	33	2	0*	0*	0*	0*	0*	0*	0*	0*
Smallmouth bass	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
Largemouth bass	4	24	72	2	3	13	0*	0*	1*	0*	0*	0*
Yellow bass	67	91	72	52	23	27	13	1*	3*	1*	0*	0*
Flathead catfish	100*	100*	57*	0*	33*	0*	0*	0*	0*	0*	0*	0*
Walleye	67*	100*	0*	67	0*	0*	0*	0*	0*	0*	0*	0*

Table 13. Species composition of fish captured during electrofishing surveys in Canyon Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	Fall 2007	Spr. 2008	Fall 2008	Spr. 2009	Fall 2009	Spr. 2010
Yellow bullhead	32 *(1%)*				9 *(<1%)*	7 *(<1%)*
Goldfish						1 *(<1%)*
Common carp	67 *(2%)*	38 *(1%)*	15 *(1%)*	39 *(1%)*	22 *(1%)*	8 *(<1%)*
Threadfin shad	469 *(17%)*	1065 *(33%)*	159 *(7%)*	609 *(22%)*	422 *(13%)*	1461 *(41%)*
Mosquitofish	3 *(<1%)*					
Channel catfish	31 *(1%)*	2 *(<1%)*	3 *(<1%)*	15 *(1%)*	8 *(<1%)*	6 *(<1%)*
Buffalo spp.	1 *(<1%)*	1 *(<1%)*	1 *(<1%)*	1 *(<1%)*		1 *(<1%)*
Green sunfish	58 *(2%)*	21 *(1%)*	31 *(1%)*	38 *(1%)*	63 *(2%)*	42 *(1%)*
Hybrid sunfish			3 *(<1%)*	19 *(1%)*	3 *(<1%)*	7 *(<1%)*
Bluegill	1462 *(51%)*	1461 *(45%)*	1544 *(70%)*	1575 *(57%)*	1572 *(47%)*	1303 *(37%)*
Redear sunfish	1 *(<1%)*					
Smallmouth bass		4 *(<1%)*	3 *(<1%)*	3 *(<1%)*	11 *(<1%)*	8 *(<1%)*
Largemouth bass	560 *(20%)*	559 *(17%)*	393 *(18%)*	414 *(15%)*	469 *(14%)*	594 *(17%)*
Yellow bass	138 *(5%)*	75 *(2%)*	59 *(3%)*	47 *(2%)*	762 *(23%)*	90 *(3%)*
Rainbow trout		1 *(<1%)*		3 *(<1%)*		1 *(<1%)*
Flathead catfish	13 *(<1%)*		1 *(<1%)*	1 *(<1%)*	7 *(<1%)*	3 *(<1%)*
Walleye	1 *(<1%)*		7 *(<1%)*	1 *(<1%)*	9 *(<1%)*	25 *(1%)*
Tilapia spp.	7 *(<1%)*		1 *(<1%)*			
TOTAL	**2843**	**3227**	**2220**	**2765**	**3357**	**3557**

Table 14. Species composition of fish captured during gill net surveys in Canyon Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	Fall 2007	Spr. 2008	Fall 2008	Spr. 2009	Fall 2009	Spr. 2010
Yellow bullhead	4 *(1%)*	1 *(<1%)*	2 *(1%)*	3 *(1%)*	1 *(<1%)*	2 *(<1%)*
Goldfish	1 *(<1%)*					
Common carp	18 *(4%)*	23 *(5%)*	8 *(2%)*	11 *(3%)*	4 *(1%)*	10 *(2%)*
Threadfin shad	53 *(12%)*	116 *(25%)*	145 *(40%)*	53 *(13%)*	7 *(2%)*	65 *(15%)*
Channel catfish	88 *(20%)*	123 *(27%)*	69 *(19%)*	74 *(17%)*	80 *(24%)*	75 *(18%)*
Green sunfish	6 *(1%)*	1 *(<1%)*		4 *(1%)*	3 *(1%)*	4 *(1%)*
Pumpkinseed						1 *(<1%)*
Bluegill	11 *(3%)*	4 *(1%)*	2 *(1%)*	12 *(3%)*	16 *(5%)*	12 *(3%)*
Smallmouth bass		1 *(<1%)*				
Largemouth bass	52 *(12%)*	24 *(5%)*	73 *(20%)*	46 *(11%)*	102 *(31%)*	47 *(11%)*
Yellow bass	169 *(39%)*	157 *(34%)*	47 *(13%)*	204 *(48%)*	81 *(25%)*	178 *(42%)*
Yellow perch	1 *(<1%)*	2 *(<1%)*				
Black crappie	2 *(<1%)*					
Flathead catfish	25 *(6%)*	5 *(1%)*	9 *(2%)*	4 *(1%)*	9 *(3%)*	4 *(1%)*
Walleye		4 *(1%)*	5 *(1%)*	11 *(3%)*	25 *(8%)*	22 *(5%)*
Tilapia spp	2 *(<1%)*		1 *(<1%)*			
TOTAL	**432**	**461**	**361**	**422**	**328**	**420**

Table 15. Mean catch-per-unit-effort and standard error of the mean of fish captured during electrofishing surveys in Canyon Lake. Superscripts indicate significant differences of means at the α = 0.05 level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

	Fall 2007 (24)		**Spr. 2008** (24)		**Fall 2008** (24)		**Spr. 2009** (24)		**Fall 2009** (24)		**Spr. 2010** (24)	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead	1.33*	0.37							0.37*	0.13	0.29*	0.11
Goldfish											0.04	0.04
Common carp	2.76*	0.63	1.53	0.63	0.61*	0.23	1.62	0.95	0.91*	0.31	0.33*	0.14
Threadfin shad	19.38	3.81	43.58	17.47	6.52	1.90	25.37	13.18	17.01	6.65	59.96	43.47
Mosquitofish	0.12	0.07										
Channel catfish	1.28*	0.33	0.09*^	0.06	0.12*#	0.09	0.62*^#	0.16	0.33*	0.14	0.25*	0.11
Buffalo spp.	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04			0.04	0.04
Green sunfish	2.41*	0.78	0.87*^	0.35	1.28	0.44	1.58	0.53	2.59^	0.55	1.74	0.47
Hybrid sunfish					0.12*	0.09	0.79*^	0.28	0.12^	0.09	0.29^	0.14
Bluegill	60.59	14.02	60.25	10.34	63.35	8.25	65.58	10.11	64.55	10.39	53.99	7.96
Redear sunfish	0.04	0.04										
Smallmouth bass			0.16	0.08	0.13*	0.07	0.13^	0.09	0.45*^	0.17	0.33	0.18
Largemouth bass	23.18	4.29	23.08	3.34	16.10	2.80	17.24	2.47	19.34	2.84	24.46	3.99
Yellow bass	5.66	1.88	3.13*	0.75	2.43^	1.16	1.96#	0.71	31.70*^#+	23.78	3.74+	1.20
Rainbow trout			0.05	0.05			0.12	0.09			0.04	0.04
Flathead catfish	0.54*	0.20			0.04*	0.04	0.04*	0.04	0.29	0.14	0.13*	0.07
Walleye	0.04*	0.04			0.29	0.15	0.04^	0.04	0.37	0.15	1.00*^	0.63
Tilapia spp.	0.29	0.13			0.04	0.04						
Total	**117.67**	**19.58**	**132.77**	**19.24**	**91.08**	**9.64**	**115.15**	**16.84**	**138.02**	**24.51**	**146.63**	**42.68**

Table 16. Mean catch-per-unit-effort and standard error of the mean of fish captured during gill net surveys in Canyon Lake. Superscripts indicate significant differences of means at the $\alpha = 0.05$ level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

Species	**Fall 2007** (24)		**Spr. 2008** (24)		**Fall 2008** (24)		**Spr. 2009** (24)		**Fall 2009** (24)		**Spr. 2010** (24)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead	0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Goldfish	<0.01	<0.01										
Common carp	0.05	0.02	0.06*	0.03	0.02*	0.01	0.03	0.01	0.01*	<0.01	0.02	0.01
Threadfin shad	0.13	0.06	0.32	0.18	0.36*	0.17	0.15	0.10	0.02*	0.01	0.16	0.10
Channel catfish	0.22	0.05	0.34*	0.06	0.18*	0.03	0.19*	0.06	0.20*	0.03	0.19*	0.05
Green sunfish	0.01	0.01	<0.01	<0.01			0.01	0.01	0.01	0.01	0.01	<0.01
Hybrid sunfish												
Bluegill	0.03	0.01	0.01*	0.01	0.01^	<0.01	0.03	0.01	0.04*^	0.01	0.03	0.01
Smallmouth bass			<0.01	<0.01								
Largemouth bass	0.13	0.05	0.06*	0.02	0.18	0.05	0.12	0.04	0.25*	0.07	0.12	0.06
Yellow bass	0.42	0.14	0.41	0.15	0.12*	0.03	0.53*	0.19	0.20	0.06	0.44	0.13
Black crappie	0.01	<0.01										
Flathead catfish	0.06*	0.02	0.01*	0.01	0.02*	0.01	0.01*	0.01	0.02*	0.01	0.01*	<0.01
Walleye			0.01*	0.01	0.01^	0.01	0.03	0.02	0.06*^	0.02	0.05*^	0.02
Tilapia spp.	0.01	<0.01			<0.01	<0.01						
Total	**1.07**	**0.26**	**1.24**	**0.28**	**0.90**	**0.21**	**1.10**	**0.34**	**0.81**	**0.11**	**1.04**	**0.24**

Table 17. Mean relative weight and standard error of the mean of fish captured during electrofishing surveys in Canyon Lake, AZ. Superscripts indicate significant differences in means at the α = 0.05 level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

Species	Fall 2007		Spr. 2008		Fall 2008		Spr. 2009		Fall 2009		Spr. 2010	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	112*	1.43	117^	2.56	105^[#]	2.64	115[#+]	2.23	104*^[+]	2.27	*109*	*3.78*
Channel catfish	106	2.75	*97*	*9.14*	*103*	*8.07*	113	5.17	*104*	*4.93*	*110*	*3.51*
Green sunfish	105	2.56	103	6.33	98*	5.53	104^	4.09	95^[#]	1.94	115*^[#]	3.24
Bluegill	109*	1.08	110^	1.52	92*^[#]	1.00	101*^[#+]	0.96	97*^[#+a]	1.42	101*^[#a]	0.92
Smallmouth bass			*93*	*5.59*	*90*	*5.96*	*93*		87	3.61	*89*	*5.43*
Largemouth bass	101*	1.74	102^	1.62	92*^[#]	0.55	97*^[#+]	0.69	95*^[#a]	0.87	101[#+a]	0.92
Yellow bass	98*	0.99	101^	1.31	83*^[#]	2.20	102[#+]	1.71	89*^[+a]	4.68	111*^[#+a]	2.75
Flathead catfish	93	1.33			*102*		*127*		*97*	*2.27*	*103*	*10.99*
Walleye	*77*				*139*	*41.84*	*100*		*93*	*3.23*	103	1.09

Table 18. Mean relative weight and standard error of the mean of fish captured during gill net surveys in Canyon Lake, AZ. Superscripts indicate significant differences in means at the $\alpha = 0.05$ level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

	Fall 2007		**Spr. 2008**		**Fall 2008**		**Spr. 2009**		**Fall 2009**		**Spr. 2010**	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	107	1.76	105	3.31	*107*	*2.42*	109	3.51	*104*	*6.90*	108	4.04
Channel catfish	101*	2.32	120*^	9.84	102^	1.76	107	1.17	102^	1.39	107	2.55
Green sunfish	*108*	*8.21*	*139*				*110*	*5.63*	*92*	*11.03*	*91*	*10.32*
Bluegill	131*	9.13	*100*	*14.22*	*91*	*20.52*	81*^	6.30	95*	3.65	100*^	2.81
Smallmouth bass	*90*											
Largemouth bass	108*	2.67	123*^	12.62	96*^	1.48	98*^	1.97	95*^#	0.83	100*^#	1.64
Yellow bass	98*	0.60	113*^	5.48	93^#	2.51	98^	1.10	93^+	1.49	105^#+	1.17
Flathead catfish	97	2.14	*151*	*29.96*	*111*	*4.25*	*111*	*4.25*	*102*	*1.80*	*127*	*5.16*
Walleye			*105*	*3.35*	*86*	*3.76*	96	1.53	95	3.85	101	1.88

Table 19. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during fall surveys in Canyon Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

Species	PSD			RSD-P			RSD-M			RSD-T		
	F07	F08	F09	F07	F08	F09	F07	F08	F09	F07	F08	F09
Common carp	100	100	100	100	100	96	70	82	80	0*	0*	0*
Channel catfish	54	63	71	7*	6*	11*	1*	0*	0*	0*	0*	0*
Green sunfish	45	15	60	3*	0*	3*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	22	13	49	1*	0*	0*	0*	0*	0*	0*	0*	0*
Smallmouth bass	0*	100*	0	0*	0*	0*	0*	0*	0*	0*	0*	0*
Largemouth bass	93	24	49	61	22	12	6*	2*	3*	0*	0*	0*
Yellow bass	93	57	47	54	26	40	13	9*	8*	0*	0*	1*
Flathead catfish	55	80*	63*	3*	0*	0*	3*	0*	0*	0*	0*	0*
Walleye	100*	43*	50*	0*	0*	0*	0*	0*	0*	0*	0*	0*

Table 20. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during spring surveys in Canyon Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

Species	PSD			RSD-P			RSD-M			RSD-T		
	S08	S09	S10	S08	S09	S10	S08	S09	S10	S08	S09	S10
Common carp	100	100	100	100	100	100	86	70	94	2*	0*	0*
Channel catfish	55	51	51	7*	8*	3*	0*	0*	0*	0*	0*	0*
Green sunfish	21*	22*	68	0*	0*	2*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	20	23	64	1*	0*	2	0*	0*	0*	0*	0*	0*
Smallmouth bass	0*	0*	50*	0*	0*	0*	0*	0*	0*	0*	0*	0*
Largemouth bass	86	38	62	67	29	18	6*	3*	2	0*	0*	0*
Yellow bass	94	93	72	56	46	54	12	11	6	0*	0*	0*
Flathead catfish	50*	60*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
Walleye	67*	0*	5*	33*	0*	0*	0*	0*	0*	0*	0*	0*

Table 21. Species composition of fish captured during electrofishing surveys in Apache Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	**Fall 2007**	**Spr. 2008**	**Fall 2008**	**Spr. 2009**	**Fall 2009**	**Spr. 2010**
Yellow bullhead	1 *(<1%)*		6 *(<1%)*	1 *(<1%)*	35 *(1%)*	2 *(<1%)*
Common carp	41 *(8%)*	42 *(2%)*	17 *(1%)*	45 *(2%)*	19 *(1%)*	15 *(<1%)*
Threadfin shad	176 *(34%)*	442 *(22%)*	1318 *(58%)*	727 *(29%)*	1745 *(51%)*	3129 *(64%)*
Mosquitofish	1 *(<1%)*	2 *(<1%)*	1 *(<1%)*			
Channel catfish	8 *(2%)*	10 *(1%)*	6 *(<1%)*	6 *(<1%)*	7 *(<1%)*	1 *(<1%)*
Buffalo spp.	5 *(1%)*	14 *(1%)*	2 *(<1%)*	11 *(<1%)*	2 *(<1%)*	21 *(<1%)*
Green sunfish	15 *(3%)*	367 *(19%)*	92 *(4%)*	191 *(8%)*	187 *(5%)*	125 *(3%)*
Hybrid sunfish			1 *(<1%)*	56 *(2%)*	49 *(1%)*	21 *(<1%)*
Bluegill	224 *(43%)*	714 *(36%)*	358 *(16%)*	807 *(32%)*	745 *(22%)*	455 *(9%)*
Smallmouth bass		104 *(5%)*	2 *(<1%)*	44 *(2%)*	27 *(1%)*	23 *(<1%)*
Largemouth bass	48 *(9%)*	229 *(12%)*	353 *(16%)*	446 *(18%)*	523 *(15%)*	799 *(16%)*
Yellow bass	4 *(1%)*	43 *(2%)*	116 *(5%)*	206 *(8%)*	25 *(1%)*	87 *(2%)*
Rainbow trout		6 *(<1%)*		5 *(<1%)*		
Black crappie					1 *(<1%)*	1 *(<1%)*
Flathead catfish	1 *(<1%)*	1 *(<1%)*	3 *(<1%)*	1 *(<1%)*	6 *(<1%)*	2 *(<1%)*
Walleye	1 *(<1%)*	2 *(<1%)*			65 *(2%)*	182 *(4%)*
TOTAL	**525**	**1976**	**2275**	**2546**	**3436**	**4863**

Table 22. Species composition of fish captured during gill net surveys in Apache Lake from 2007-2010. Numbers in parentheses represent the contribution of each species per sampling event. Golden Algae project, 2007-2010.

Species	**Fall 2007**	**Spr. 2008**	**Fall 2008**	**Spr. 2009**	**Fall 2009**	**Spr. 2010**
Yellow bullhead		1 *(<1%)*			1 *(<1%)*	
Common carp	43 *(8%)*	61 *(2%)*	31 *(2%)*	42 *(2%)*	36 *(3%)*	47 *(2%)*
Threadfin shad	215 *(40%)*	2255 *(83%)*	1173 *(85%)*	1477 *(75%)*	601 *(50%)*	2235 *(76%)*
Channel catfish	73 *(13%)*	71 *(3%)*	51 *(4%)*	44 *(2%)*	39 *(3%)*	71 *(2%)*
Buffalo spp	10 *(2%)*	15 *(1%)*	2 *(<1%)*	4 *(<1%)*	8 *(1%)*	6 *(<1%)*
Green sunfish	1 *(<1%)*	8 *(<1%)*	2 *(<1%)*	35 *(2%)*	10 *(1%)*	15 *(1%)*
Pumpkinseed						1 *(<1%)*
Hybrid sunfish				2 *(<1%)*		
Bluegill	1 *(<1%)*	3 *(<1%)*		9 *(<1%)*	2 *(<1%)*	5 *(<1%)*
Smallmouth bass		27 *(1%)*	3 *(<1%)*	13 *(1%)*	18 *(2%)*	12 *(<1%)*
Largemouth bass	7 *(1%)*	27 *(1%)*	14 *(1%)*	45 *(2%)*	198 *(17%)*	98 *(3%)*
Yellow bass	136 *(25%)*	199 *(7%)*	78 *(6%)*	265 *(13%)*	160 *(13%)*	303 *(10%)*
Rainbow trout		15 *(1%)*	1 *(<1%)*			
Black crappie					1 *(<1%)*	
Flathead catfish	20 *(4%)*	15 *(1%)*	7 *(1%)*	9 *(<1%)*	10 *(1%)*	7 *(<1%)*
Walleye	38 *(7%)*	28 *(1%)*	11 *(1%)*	22 *(1%)*	114 *(10%)*	147 *(5%)*
TOTAL	**544**	**2725**	**1373**	**1967**	**1198**	**2947**

Table 23. Mean catch-per-unit-effort and standard error of the mean of fish captured during electrofishing surveys in Apache Lake. Superscripts indicate significant differences of means at the $\alpha = 0.05$ level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

Species	Fall 2007 (30)		Spr. 2008 (30)		Fall 2008 (30)		Spr. 2009 (30)		Fall 2009 (30)		Spr. 2010 (30)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead	0.03*	0.03			0.20^	0.14	0.03$^{\#}$	0.03	1.14*^$^{\#+}$	0.33	0.06^{+}	0.04
Common carp	1.36*	0.29	1.39^	0.38	0.56*^$^{\#}$	0.15	1.49$^{\#+}$	0.30	0.63*^$^{+}$	0.17	0.50*^$^{+}$	0.18
Threadfin shad	5.86*	2.15	14.53^	5.21	43.17	9.11	24.21	7.30	57.74	30.22	103.59*^	61.62
Mosquitofish	0.03	0.03	0.07	0.05	0.03	0.03						
Channel catfish	0.27	0.11	0.32*	0.11	0.19	0.10	0.20	0.10	0.23	0.08	0.03*	0.03
Buffalo spp.	0.17*	0.08	0.46	0.18	0.07^	0.05	0.35	0.20	0.07$^{\#}$	0.05	0.70*^$^{\#}$	0.28
Green sunfish	0.50*	0.16	12.15*^	3.22	2.87^	0.79	6.28*^	1.16	6.10*^	1.27	4.12^	0.94
Hybrid sunfish					0.03*	0.03	1.85*^	0.32	1.57*	0.74	0.69^	0.22
Bluegill	7.42*	1.56	23.30*^	5.43	11.58^$^{\#}$	2.70	26.55*$^{\#+}$	2.92	24.52*$^{\#a}$	3.34	14.92^{+a}	2.78
Smallmouth bass			3.44*	1.06	0.06*	0.06	1.45*	0.50	0.88*	0.28	0.76*	0.25
Largemouth bass	1.59*	0.34	7.50*^	1.66	11.57*$^{\#}$	1.56	14.70*^$^{+}$	1.68	17.22*^$^{\#a}$	2.04	26.24*^$^{\#+a}$	2.59
Yellow bass	0.13*	0.08	1.42^	0.58	3.82*$^{\#}$	1.07	6.80*^$^{\#+}$	1.76	0.81$^{\#+}$	0.29	2.88*$^{+}$	0.98
Rainbow trout			0.19	0.07			0.16	0.07				
Black crappie									0.03	0.03	0.03	0.03
Flathead catfish	0.03	0.03	0.03	0.03	0.10	0.06	0.03	0.03	0.20	0.11	0.07	0.07
Walleye	0.03*	0.03	0.04^	0.04					2.14*^$^{\#}$	0.62	5.93*^$^{\#}$	1.09
Total	**17.43***	**2.84**	**64.84^**	**9.60**	**74.25$^{\#}$**	**10.10**	**84.11**	**8.81**	**113.28***	**29.45**	**160.53*^$^{\#}$**	**61.55**

Table 24. Mean catch-per-unit-effort and standard error of the mean of fish captured during gill net surveys in Apache Lake. Superscripts indicate significant differences of means at the $\alpha = 0.05$ level. Golden Algae project, 2007-2010. The number in parenthesis indicates sample size.

Species	**Fall 2007** (30)		**Spr. 2008** (30)		**Fall 2008** (30)		**Spr. 2009** (30)		**Fall 2009** (30)		**Spr. 2010** (30)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow bullhead			<0.01	<0.01					<0.01	<0.01		
Common carp	0.08	0.01	0.13	0.04	0.06	0.01	0.08	0.02	0.07	0.02	0.09	0.03
Threadfin shad	0.40	0.10	4.60	1.75	2.30	0.46	2.86	1.74	1.13	0.67	4.30	3.63
Channel catfish	0.14	0.02	0.15*	0.03	0.10	0.02	0.09	0.02	0.08*	0.01	0.14	0.03
Buffalo spp.	0.02	0.01	0.03	0.01	<0.01	<0.01	0.01	<0.01	0.02	0.01	0.01	0.01
Green sunfish	<0.01*	<0.01	0.02^	0.01	<0.01$^{\#}$	<0.01	0.07*^$^{\#+}$	0.03	0.02^{+}	0.01	0.03^{+}	0.01
Hybrid sunfish							<0.01	<0.01				
Bluegill	<0.01*	<0.01	0.01	<0.01			0.02*	0.01	<0.01	<0.01	0.01	<0.01
Smallmouth bass			0.05*	0.02	0.01*	0.01	0.03	0.01	0.03	0.02	0.02	0.01
Largemouth bass	0.01*	0.01	0.06^	0.02	0.03$^{\#}$	0.01	0.09^{+}	0.02	0.38*^$^{\#+a}$	0.08	0.19*^$^{\#a}$	0.07
Yellow bass	0.25*	0.05	0.41^	0.08	0.15^$^{\#}$	0.04	0.53*$^{\#+}$	0.09	0.30^{+a}	0.06	0.57*$^{\#a}$	0.10
Rainbow trout			0.03	0.01	<0.01	<0.01						
Black crappie									<0.01	<0.01		
Flathead catfish	0.04*	0.01	0.03	0.01	0.01*	0.01	0.02	0.01	0.02	0.01	0.01*	0.01
Walleye	0.07*	0.02	0.06^	0.02	0.02$^{\#}$	0.01	0.04^{+}	0.01	0.22*^$^{\#+}$	0.05	0.29*^$^{\#+}$	0.06
Total	**1.01**	**0.11**	**5.58**	**1.79**	**2.69**	**0.49**	**3.85**	**1.76**	**2.27**	**0.73**	**5.65**	**3.76**

Table 25. Mean relative weight and standard error of the mean of fish captured during electrofishing surveys in Apache Lake, AZ. Superscripts indicate significant differences in means at the $\alpha = 0.05$ level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

Species	Fall 2007		Spr. 2008		Fall 2008		Spr. 2009		Fall 2009		Spr. 2010	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	107	1.90	112	2.56	109	3.02	111	2.17	107	2.12	112	2.94
Channel catfish	*110*	*4.74*	116	5.30	*114*	*12.20*	*114*	*5.23*	*105*	*7.40*		
Green sunfish	100	3.50	107*	3.89	87*^	3.13	113^$^{\#}$	2.30	94*$^{\#+}$	1.97	114^$^{+}$	2.09
Bluegill	83*	2.66	104*^	1.14	81^$^{\#}$	1.43	103*$^{\#+}$	1.13	84^$^{+a}$	1.19	98*^$^{\#+a}$	1.28
Smallmouth bass			111*	1.54	*100*	*10.57*	109^	2.05	91*^	3.36	91*^	3.27
Largemouth bass	94*	1.57	102*^	0.88	98^$^{\#}$	0.90	97^$^{+}$	0.68	95^$^{\#+}$	0.76	94^$^{\#+}$	0.49
Yellow bass			93	4.26	92*	2.37	98	1.62	93	14.50	100*	1.32
Flathead catfish			*106*		*95*	*2.68*	*108*		*93*	*5.02*	*118*	*10.24*
Walleye	*82*		*106*	*8.95*					84*	1.03	96*	0.53

Table 26. Mean relative weight and standard error of the mean of fish captured during gill net surveys in Apache Lake, AZ. Superscripts indicate significant differences in means at the $\alpha = 0.05$ level. Numbers in italics indicate fewer than 10 individuals of a given species were captured and thus were not used in the relative weight analysis. Golden Algae project, 2007-2010.

Species	Fall 2007		Spr. 2008		Fall 2008		Spr. 2009		Fall 2009		Spr. 2010	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Common carp	99*	1.72	109*^	1.67	106*[#]	1.42	103*^	1.62	100^[#]	1.46	103*^	1.35
Channel catfish	103*	1.44	117*^	1.62	107^[#]	1.87	123*^[#+]	4.56	104^[+a]	1.94	115*[#+a]	1.65
Green sunfish			*117*	*10.69*	*78*		108	4.56	102	10.19	111	3.41
Bluegill	*80*		*104*	*1.37*			*121*	*28.91*	*131*	*4.52*	*104*	*6.10*
Smallmouth bass			110*	3.85	*98*	*3.80*	94*	8.13	95*	2.06	93*	5.39
Largemouth bass	*101*	*2.92*	105	2.79	97	3.72	109*	10.92	101	1.14	98*	1.31
Yellow bass	105*	0.64	104^	0.77	93*^[#]	1.95	103[#+]	1.03	100*^[#a]	1.08	109*^[#+a]	1.11
Flathead catfish	98*	2.48	111*^	3.28	*95*	*3.71*	*108*	*4.04*	100^	3.55	*123*	*5.01*
Walleye	88*	1.19	109*^	2.27	91^[#]	2.01	106*[#+]	1.94	92^[+a]	0.92	101*[a]	2.23

Table 27. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during fall surveys in Apache Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

	PSD			RSD-P			RSD-M			RSD-T		
Species	**F07**	**F08**	**F09**	**F07**	**F08**	**F09**	**F07**	**F08**	**F09**	**F07**	**F08**	**F09**
Common carp	94	100	100	87	85	96	14	23	21	0*	0*	0*
Channel catfish	94	93	90	30	31	21*	6*	2*	0*	0*	0*	0*
Green sunfish	40*	5*	28	0*	0*	1*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	4*	12	14	1*	0*	0*	0*	0*	0*	0*	0*	0*
Smallmouth bass	0*	67*	88	0*	0*	4*	0*	0*	0*	0*	0*	0*
Largemouth bass	68	50	29	60	15*	4	0*	2*	0*	0*	0*	0*
Yellow bass	100	36	86	100	33	40	79	25	16	3*	1*	2*
Flathead catfish	81	100*	82*	14*	44*	18*	5*	11*	0*	5*	0*	0*
Walleye	100	100	7*	8*	45*	6*	3*	0*	0*	0*	0*	0*

Table 28. Proportional stock density (PSD), relative stock density of preferred-sized fish (RSD-P), relative stock density of memorable-sized fish (RSD-M), and relative stock density of trophy-sized fish (RSD-T) captured during spring surveys in Apache Lake. Numbers with * indicate fewer than 10 individuals of a given species were captured and thus were not included in size structure analyses. Golden Algae project, 2007-2010.

	PSD			RSD-P			RSD-M			RSD-T		
Species	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**	**S08**	**S09**	**S10**
Common carp	98	99	100	90	98	98	12	20	16*	0*	0*	0*
Channel catfish	91	76	88	20	20	31	4*	0*	2*	0*	0*	0*
Green sunfish	18	26	53	1*	1*	4*	0*	0*	0*	0*	0*	0*
Bluegill sunfish	10	14	17	0*	0*	1*	0*	0*	0*	0*	0*	0*
Smallmouth bass	1*	13*	75	0*	6*	15*	0*	0*	0*	0*	0*	0*
Largemouth bass	51	27	28	35	13	8	1*	0*	1*	0*	0*	0*
Yellow bass	93	50	83	91	45	51	69	31	20	8	2*	1*
Flathead catfish	75	100*	75*	6*	44*	0*	0*	11*	0*	0*	0*	0*
Walleye	100	100	2*	17*	57	1*	0*	5*	0*	0*	0*	0*

Table 29. Total number of surveys and anglers interviewed for access and roving surveys at Saguaro, Canyon, and Apache Lakes for each year of the study. Each year of the study began in June and ended in following May, starting June 2007 and ending in May 2010.

Saguaro Lake		**Access**	**Roving**	**Total**
Year 1	Surveys	108	10	118
	Interviews	908	113	1,021
Year 2	Surveys	91	18	109
	Interviews	1,125	285	1,410
Year 3	Surveys	63	49	112
	Interviews	850	650	1,500
Canyon Lake				
Year 1	Surveys	72	8	80
	Interviews	339	56	395
Year 2	Surveys	95	18	113
	Interviews	479	219	698
Year 3	Surveys	68	43	111
	Interviews	447	532	979
Apache Lake				
Year 1	Surveys	107	9	116
	Interviews	121	42	163
Year 2	Surveys	96	18	114
	Interviews	112	73	185
Year 3	Surveys	76	48	124
	Interviews	167	320	487

Table 30. Annual angling effort of boat and shore anglers at Saguaro, Canyon, and Apache Lakes during each year of the study. Each year of the study began in June and ended in the following May, starting June 2007 and ending in May 2010.

	Saguaro Lake		Canyon Lake		Apache Lake	
Boat Anglers	**Hours**	**SE**	**Hours**	**SE**	**Hours**	**SE**
Year 1	46,647	6,705	24,864	3,791	10,708	2,588
Year 2	76,904	10,468	27,258	3,915	7,752	2,612
Year 3	80,312	11,427	34,166	4,450	11,644	3,288
Shore Anglers						
Year 1	53,496	18,018	11,685	6,088	11,017	4,664
Year 2	74,423	14,769	58,104	13,316	16,474	4,509
Year 3	55,636	6,110	41,368	5,633	26,133	5,136
Total Anglers						
Year 1	100,142	19,226	36,549	7,172	21,726	5,334
Year 2	151,327	18,102	85,362	13,880	24,226	5,211
Year 3	135,948	12,958	75,534	7,178	37,776	6,098

Table 31. Estimated annual catch of boat and shore anglers for popular sport fish species at Saguaro Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending in May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Channel catfish		Sunfish spp.		Rainbow trout		Black crappie	
Boat Anglers	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**
Year 1	18,750	3,973	159	77	4,076	1,428	2,945	1,005	9,590	3,020	544	194	20	15
Year 2	40,592	7,037	774	287	6,516	1,631	1,931	486	19,850	6,405	548	341	99	69
Year 3	27,171	4,573	242	96	7,925	3,548	1,030	257	21,175	5,230	1,071	896	137	98
Shore Anglers														
Year 1	438	243	0	0	5,540	5,368	1,643	1,014	11,915	6,720	6,474	4,656	0	0
Year 2	3,826	1,005	332	332	6,336	3,161	3,497	2,940	49,124	15,149	1,348	964	579	495
Year 3	2,119	1,086	153	98	2,987	1,848	735	290	49,215	14,554	718	292	0	0
Total Anglers														
Year 1	19,188	3,981	159	77	9,616	5,555	4,588	1,427	21,505	7,367	7,018	4,660	20	15
Year 2	44,418	7,109	1,105	439	12,853	3,557	5,428	2,980	68,975	16,447	1,896	1,023	678	499
Year 3	29,290	4,700	396	137	10,912	4,001	1,765	387	70,390	15,465	1,789	942	137	98

Table 32. Estimated annual harvest of boat and shore anglers for popular sport fish species at Saguaro Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Channel catfish		Sunfish spp.		Rainbow trout		Black crappie	
Boat Anglers	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**
Year 1	194	182	0	0	364	166	944	409	2,352	1,018	190	83	0	0
Year 2	4,165	2,791	110	104	339	157	595	229	4,664	1,864	70	53	0	0
Year 3	1,125	330	13	13	3,275	1,916	369	142	5,860	2,674	134	79	63	49
Shore Anglers														
Year 1	0	0	0	0	457	373	1,501	1,034	6,379	4,616	1,786	1,681	0	0
Year 2	1,099	731	0	0	2,855	1,599	2,009	1,470	29,919	11,993	952	952	0	0
Year 3	477	352	20	20	2,530	1,813	504	275	32,903	12,640	587	246	0	0
Total Anglers														
Year 1	194	182	0	0	821	409	2,445	1,112	8,732	4,727	1,975	1,683	0	0
Year 2	5,264	2,885	110	104	3,195	1,607	2,604	1,487	34,584	12,137	1,022	954	0	0
Year 3	1,602	483	33	24	5,805	2,638	873	310	38,763	12,920	722	259	63	49

Table 33. Percent harvest of popular sport fish species at Saguaro, Canyon, and Apache Lakes from June 2007 to May 2010.

Species	**Saguaro Lake**	**Canyon Lake**	**Apache Lake**	**All Lakes**
Bluegill/Sunfish	51.0%	31.7%	22.4%	44.7%
Catfish	50.3%	30.0%	33.1%	42.4%
Rainbow Trout	34.8%	39.6%	23.9%	34.7%
Yellow Bass	29.4%	14.1%	7.7%	23.9%
Smallmouth Bass	8.6%	4.1%	34.5%	17.8%
Crappie	7.6%	21.3%	0.0%	12.2%
Largemouth Bass	7.6%	12.2%	4.3%	8.0%

Table 34. Mean, minimum, and maximum lengths (TL; mm), weights (WT; g), and number (N) of popular sport fish species harvested at Saguaro, Canyon, and Apache Lakes during creel surveys from June 2007 to May 2010.

Species		Saguaro Lake				Canyon Lake				Apache Lake			
		Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N
Channel Catfish	TL	431	220	730	50	379	140	545	33	562	460	745	18
	WT	1,125	180	5,510	42	731	53	2,181	26	2,727	1,280	5,400	7
Bluegill	TL	177	116	222	176	187	130	227	66	166	153	194	9
	WT	118	60	190	27	153	60	341	40	101	60	150	8
Smallmouth Bass	TL	228	225	230	2	272	222	365	3	309	255	406	17
	WT	.	.	.	0	354	158	550	2	386	240	560	13
Largemouth Bass	TL	302	127	460	109	312	160	501	72	330	200	530	31
	WT	414	100	1,710	61	724	70	2,041	47	533	220	860	13
Yellow Bass	TL	233	160	317	43	281	259	298	3	275	219	305	3
	WT	235	90	570	21	250	250	250	2	535	440	630	2
Rainbow Trout	TL	268	204	375	20	283	232	360	8	202	152	251	2
	WT	467	400	580	3	431	140	1,216	8	120	50	190	2

Table 35. Estimated annual catch of boat and shore anglers for popular sport fish species at Canyon Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending in May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Channel catfish		Sunfish spp.		Rainbow trout		Black crappie	
Boat Anglers	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**
Year 1	1,525	415	79	56	530	155	1,508	380	997	373	372	196	8	8
Year 2	5,550	1,234	170	74	617	196	473	143	2,751	1,024	205	91	0	0
Year 3	4,904	1,001	289	149	804	352	512	173	11,329	4,078	241	116	330	230
Shore Anglers														
Year 1	107	77	0	0	76	76	471	184	1,560	985	0	0	0	0
Year 2	4,814	2,235	461	280	489	314	3,117	1,158	26,596	11,043	0	0	105	105
Year 3	720	271	200	103	312	161	456	161	22,820	7,486	324	135	51	51
Total Anglers														
Year 1	1,631	422	79	56	606	173	1,979	422	2,557	1,053	372	196	8	8
Year 2	10,364	2,553	632	289	1,106	370	3,590	1,167	29,346	11,090	205	91	105	105
Year 3	5,623	1,038	489	181	1,116	386	968	236	34,150	8,524	565	178	381	236

Table 36. Estimated annual harvest of boat and shore anglers for popular sport fish species at Canyon Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Channel catfish		Sunfish spp.		Rainbow trout		Black crappie	
Boat Anglers	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**
Year 1	48	27	0	0	50	31	360	145	181	98	164	92	0	0

Year 2	697	269	37	23	91	52	162	73	275	209	75	61	0	0
Year 3	330	149	10	10	121	91	207	115	4,200	1,953	111	78	0	0
Shore Anglers														
Year 1	76	76	0	0	0	0	156	129	1,346	835	0	0	0	0
Year 2	697	666	0	0	137	137	830	509	5,025	3,138	0	0	105	105
Year 3	295	156	2	2	0	0	248	114	9,900	3,930	103	67	0	0
Total Anglers														
Year 1	124	80	0	0	50	31	515	194	1,526	841	164	92	0	0
Year 2	1,394	718	37	23	228	146	993	514	5,301	3,145	75	61	105	105
Year 3	625	216	12	10	121	91	455	162	14,100	4,389	214	103	0	0

Table 37. Estimated annual catch of boat and shore anglers for popular sport fish species at Apache Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending in May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Catfish spp		Sunfish spp.		Rainbow trout		Walleye		Black Crappie	
Boat Anglers	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**	**Catch**	**SE**
Year 1	155	98	9	9	28	21	239	83	584	390	44	36	0	0	0	0
Year 2	433	165	42	27	0	0	261	137	629	257	72	45	0	0	0	0
Year 3	7,277	3,620	889	408	68	36	301	195	2,218	1,731	10	10	20	20	0	0
Shore Anglers																
Year 1	0	0	0	0	113	113	169	118	56	56	396	396	0	0	0	0
Year 2	0	0	0	0	80	61	335	335	398	398	0	0	0	0	0	0
Year 3	1,582	605	955	405	9,394	6,985	42	24	2,859	1,208	33	33	0	0	56	56
Total Anglers																
Year 1	155	98	9	9	141	115	408	144	640	394	441	398	0	0	0	0
Year 2	433	165	42	27	80	61	595	362	1,027	474	72	45	0	0	0	0
Year 3	8,859	3,670	1,844	575	9,462	6,985	343	197	5,077	2,111	44	35	20	20	56	56

Table 38. Estimated annual harvest of boat and shore anglers for popular sport fish species at Apache Lake during each year of the study period. Each year of the study began in June and ended in the following May, starting June 2007 and ending May 2010. Abbreviations for each species are given in Table 1.

	Largemouth bass		Smallmouth bass		Yellow bass		Catfish spp		Sunfish spp.		Rainbow trout		Walleye		Black Crappie	
Boat Anglers	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**	**Harvest**	**SE**
Year 1	19	13	0	0	0	0	110	55	0	0	9	9	0	0	0	0
Year 2	0	0	0	0	0	0	243	137	83	76	10	10	0	0	0	0
Year 3	258	151	133	82	6	6	9	9	28	22	0	0	20	20	0	0
Shore Anglers																
Year 1	0	0	0	0	57	57	56	56	0	0	113	113	0	0	0	0
Year 2	0	0	0	0	57	57	0	0	398	398	0	0	0	0	0	0
Year 3	135	59	521	326	621	359	28	20	998	786	0	0	0	0	0	0
Total Anglers																
Year 1	19	13	0	0	57	57	166	78	0	0	123	114	0	0	0	0
Year 2	0	0	0	0	57	57	243	137	482	406	10	10	0	0	0	0
Year 3	393	162	654	336	628	359	37	22	1,027	786	0	0	20	20	0	0

Table 39. Experience levels of boat and shoreline anglers at Saguaro, Canyon, and Apache Lakes during the period of study. Each year of the study began in June and ended in the following May, starting June 2007 and ending May 2010.

	Saguaro Lake		Canyon Lake		Apache Lake	
Times fished per month	**Boat**	**Shore**	**Boat**	**Shore**	**Boat**	**Shore**
Less than 1 time per month	73	79	77	86	96	97
1 to 2 times per month	14	10	14	9	3	2
2 to 5 times per month	11	7	7	4	1	1
More than 5 times per month	3	3	2	1	0	0

Table 40. Percentage of species targeted by anglers at Saguaro, Canyon and Apache Lakes. 'Any Bass' refers to largemouth and smallmouth bass and the Other category includes carp, crappie and walleye.

Species targeted	Saguaro Lake	Canyon Lake	Apache Lake
Any species	43.9%	52.2%	58.7%
Largemouth Bass	29.8%	23.6%	8.8%
Any Bass	12.5%	10.7%	13.0%
Catfish	4.3%	5.6%	8.5%
Bluegill/sunfish	5.0%	3.1%	1.5%
Trout	2.0%	3.4%	2.3%
Yellow Bass	1.7%	0.2%	2.9%
Smallmouth Bass	0.2%	0.2%	1.8%
Other	0.4%	1.1%	2.5%

Table 41. Suggested stratification for future creel surveys base on survey type (roving = shore anglers and exit = boat anglers), season, time of day by season, and boat ramp.

Saguaro				Canyon				Apache			
Survey Type				**Survey Type**				**Survey Type**			
Roving	60%			Roving	70%			Roving	81%		
Exit	40%			Exit	30%			Exit	19%		
Season				**Season**				**Season**			
Spring	41%			Spring	39%			Spring	41%		
Summer	18%			Summer	26%			Summer	34%		
Fall	42%			Fall	35%			Fall	26%		
Time of Day	AM	Midday	PM	**Time of Day**	AM	Midday	PM	**Time of Day**	AM	Midday	PM
Spring	10%	49%	41%	Spring	6%	42%	52%	Spring	0%	58%	42%
Summer	35%	44%	21%	Summer	27%	41%	32%	Summer	7%	50%	43%
Fall	4%	36%	61%	Fall	8%	32%	60%	Fall	9%	49%	43%
Boat Ramp				**Boat Ramp**				**Boat Ramp**			
Ramp 1	30%			Palo Verde	74%			Main Launch	44%		
Ramp 2	70%			Laguna	26%			Burnt Coral	56%		

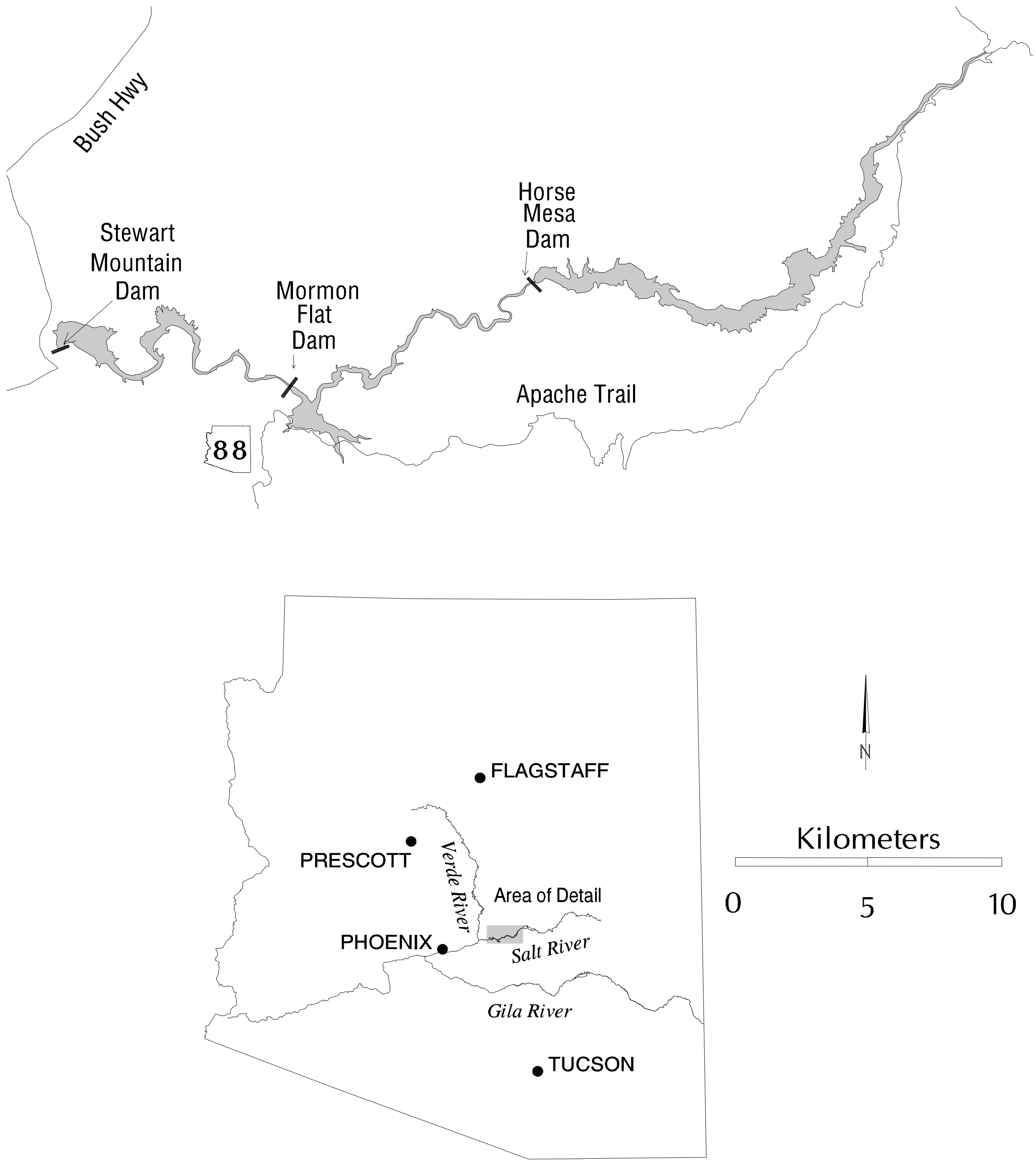

Figure 1. Map showing the Salt River chain of reservoirs, AZ., beginning upstream with Apache Lake (impounded by Horse Mesa Dam), Canyon Lake (impounded by Mormon Flat Dam), and Saguaro Lake (impounded by Stewart Mountain Dam).

Figure 2. Annual average lake elevations 1970-2007 at Roosevelt Lake (the upstream-most reservoir in the Salt River chain of lakes, AZ.). The solid bar at approximately 2150 m represents the maximum elevation of the reservoir at full capacity.

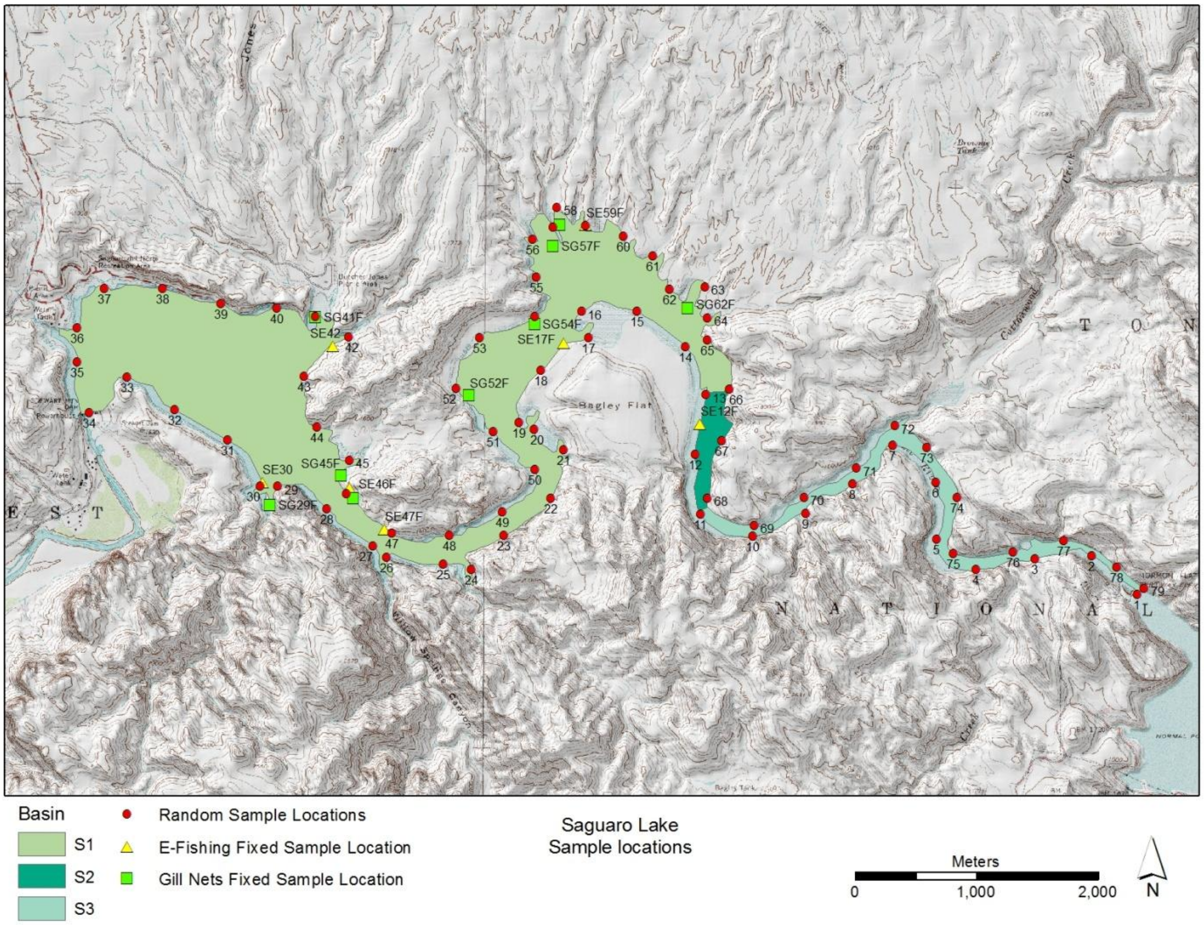

Figure 3. Aerial map of Saguaro Lake showing the upper (light blue), middle (teal), and lower (light green) sub-basins of the lake. Also shown are all possible 500-m random sample locations (red dots), fixed electrofishing locations (yellow triangles), and fixed gill net locations (green squares). Golden Algae project, 2007-2010.

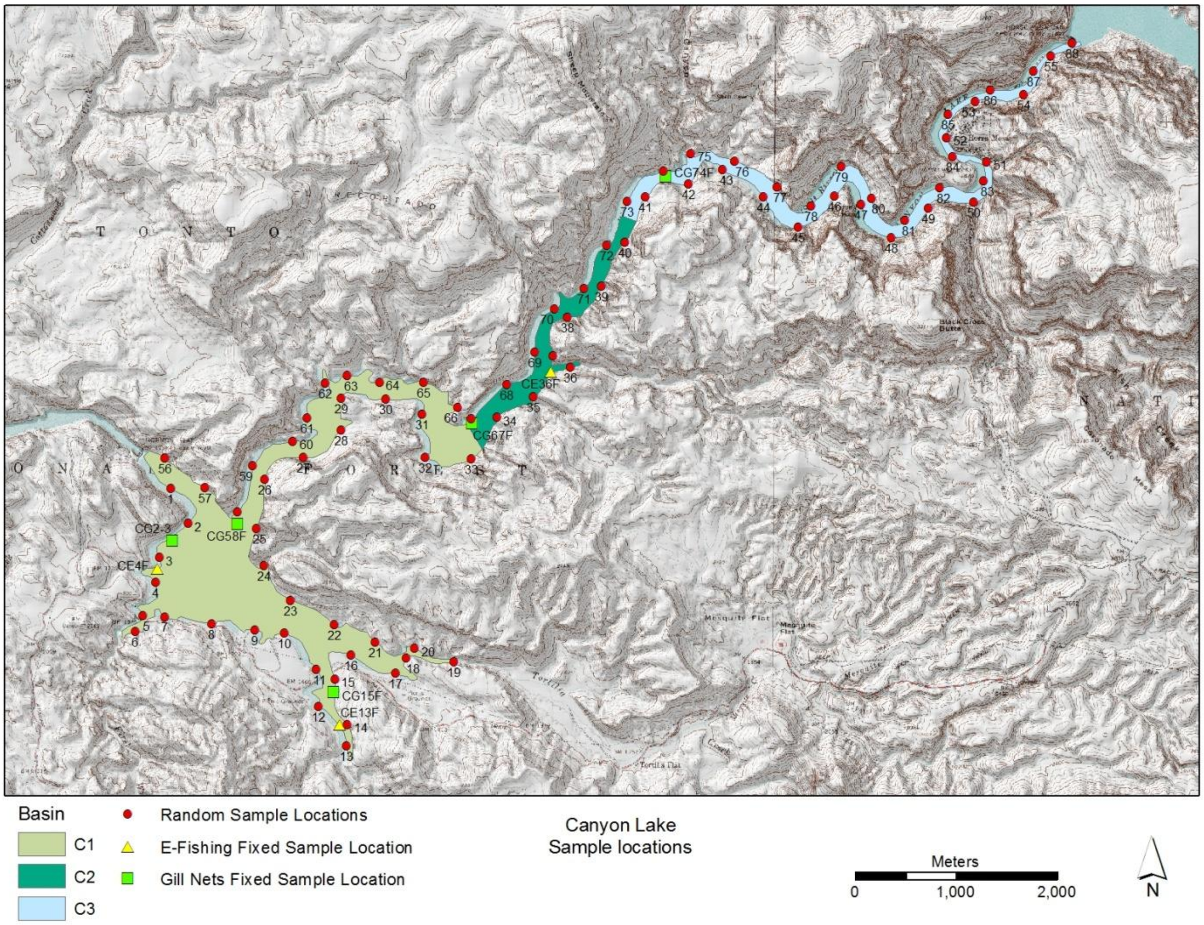

Figure 4. Aerial map of Canyon Lake showing the upper (light blue), middle (teal), and lower (light green) sub-basins of the lake. Also shown are all possible 500-m random sample locations (red dots), fixed electrofishing locations (yellow triangles), and fixed gill net locations (green squares). Golden Algae project, 2007-2010.

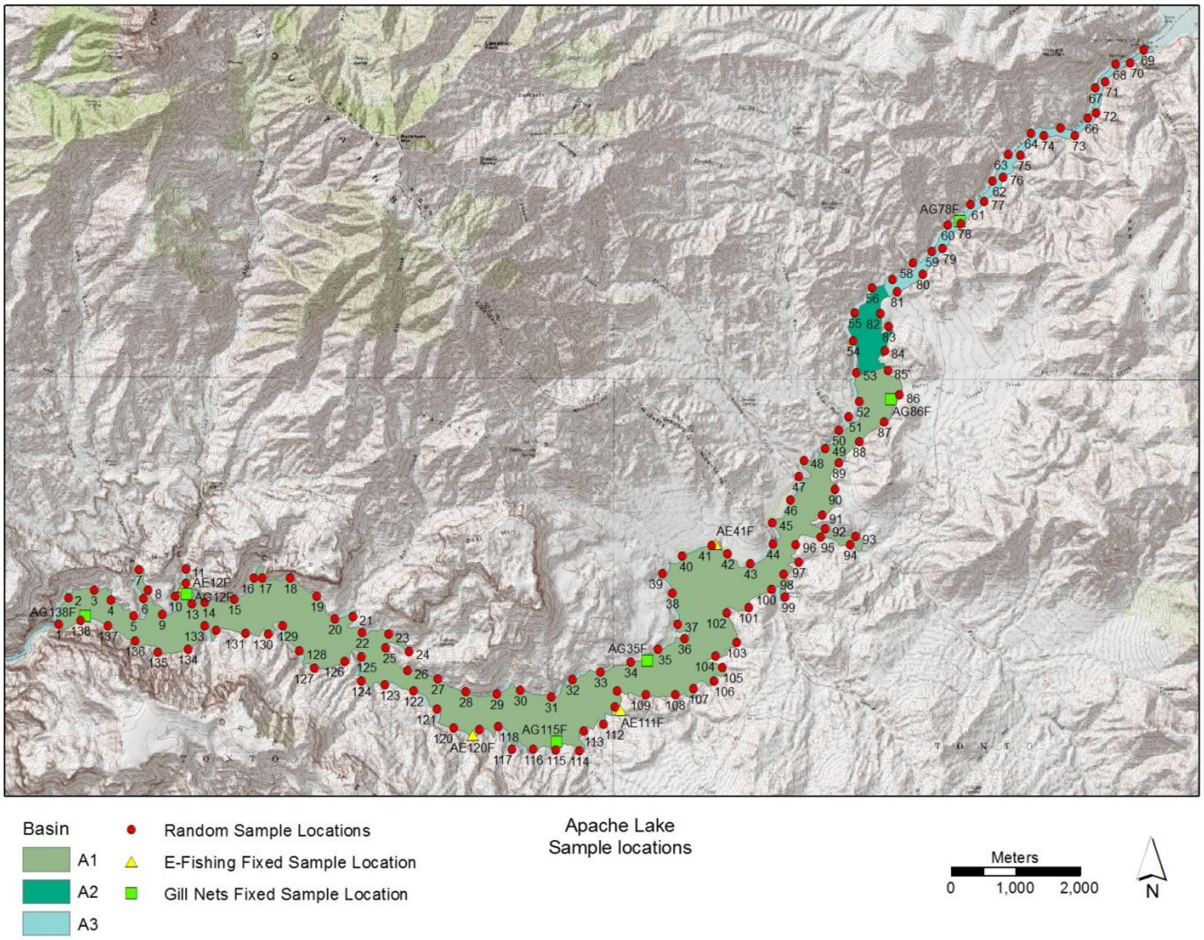

Figure 5. Aerial map of Apache Lake showing the upper (light blue), middle (teal), and lower (light green) sub-basins of the lake. Also shown are all possible 500-m random sample locations (red dots), fixed electrofishing locations (yellow triangles), and fixed gill net locations (green squares). Golden Algae project, 2007-2010.

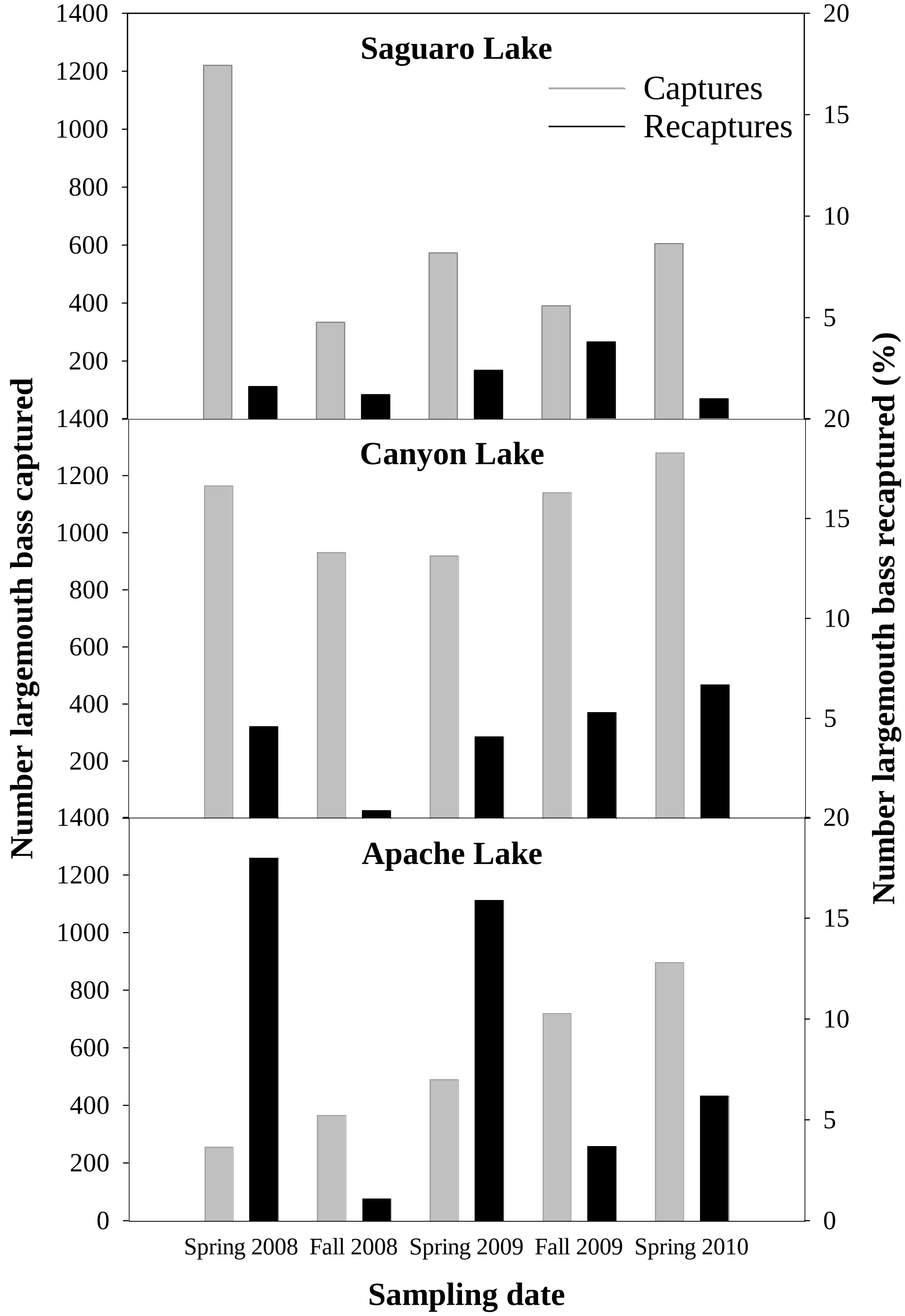

Figure 6. Number of largemouth bass captured (grey bars) and percentage of those fish recaptured (black bars) during electrofishing and gill net surveys in Saguaro (top panel), Canyon (middle panel), and Apache Lakes (lower panel) from 2008-2010. Recaptures consisted of fish that were marked initially with a coded-wire tag or Oxytetracycline mark and later recaptured. Golden Algae project, 2007-2010.

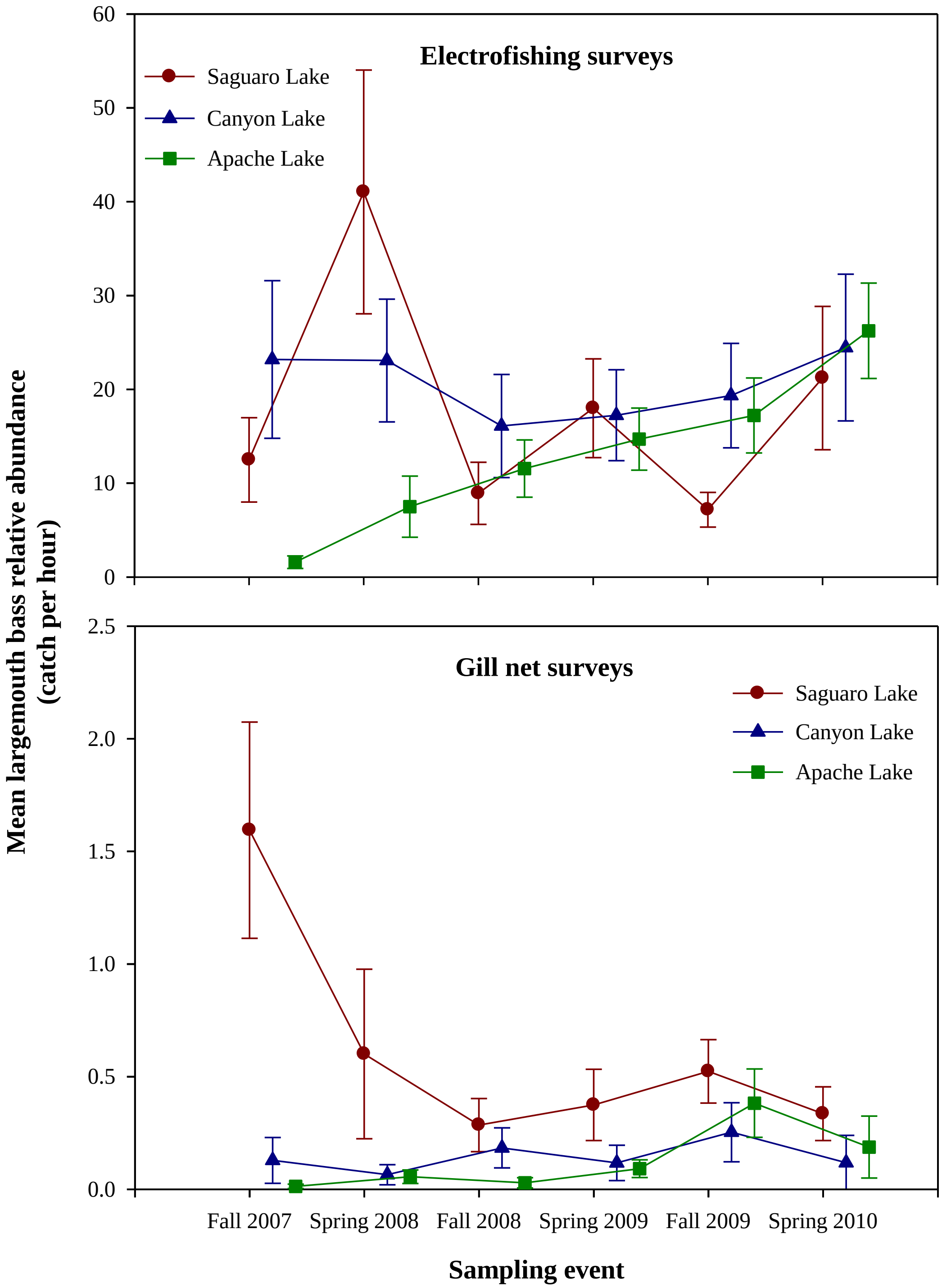
Electrofishing surveys
Saguaro Lake
Canyon Lake
Apache Lake
Gill net surveys
Saguaro Lake
Canyon Lake
Apache Lake
Mean largemouth bass relative abundance
(catch per hour)
60
50
40
30
20
10
0
2.5
2.0
1.5
1.0
0.5
0.0
Fall 2007
Spring 2008
Fall 2008
Spring 2009
Fall 2009
Spring 2010
Sampling event

Figure 7. Largemouth bass mean relative abundance (catch per hour) during electrofishing surveys (top panel) and gill net surveys (bottom panel) in Saguaro (red bars), Canyon (blue bars), and Apache Lakes (green bars). Bars represent ± 2 standard errors of the mean. Golden Algae project, 2007-2010.

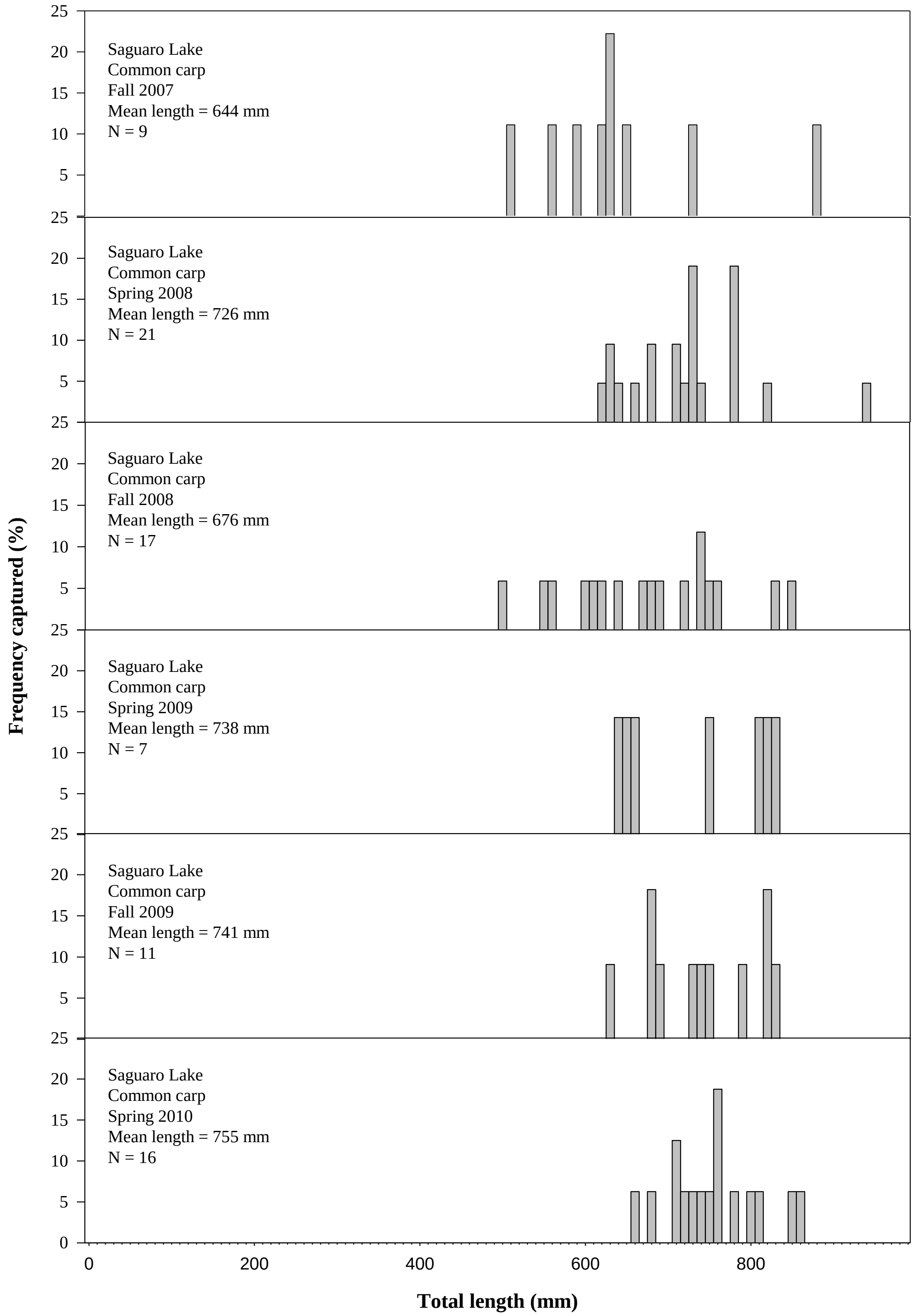

Figure 8. Length frequency distribution of common carp captured during electrofishing surveys in Saguaro Lake. Golden Algae project, 2007-2010.

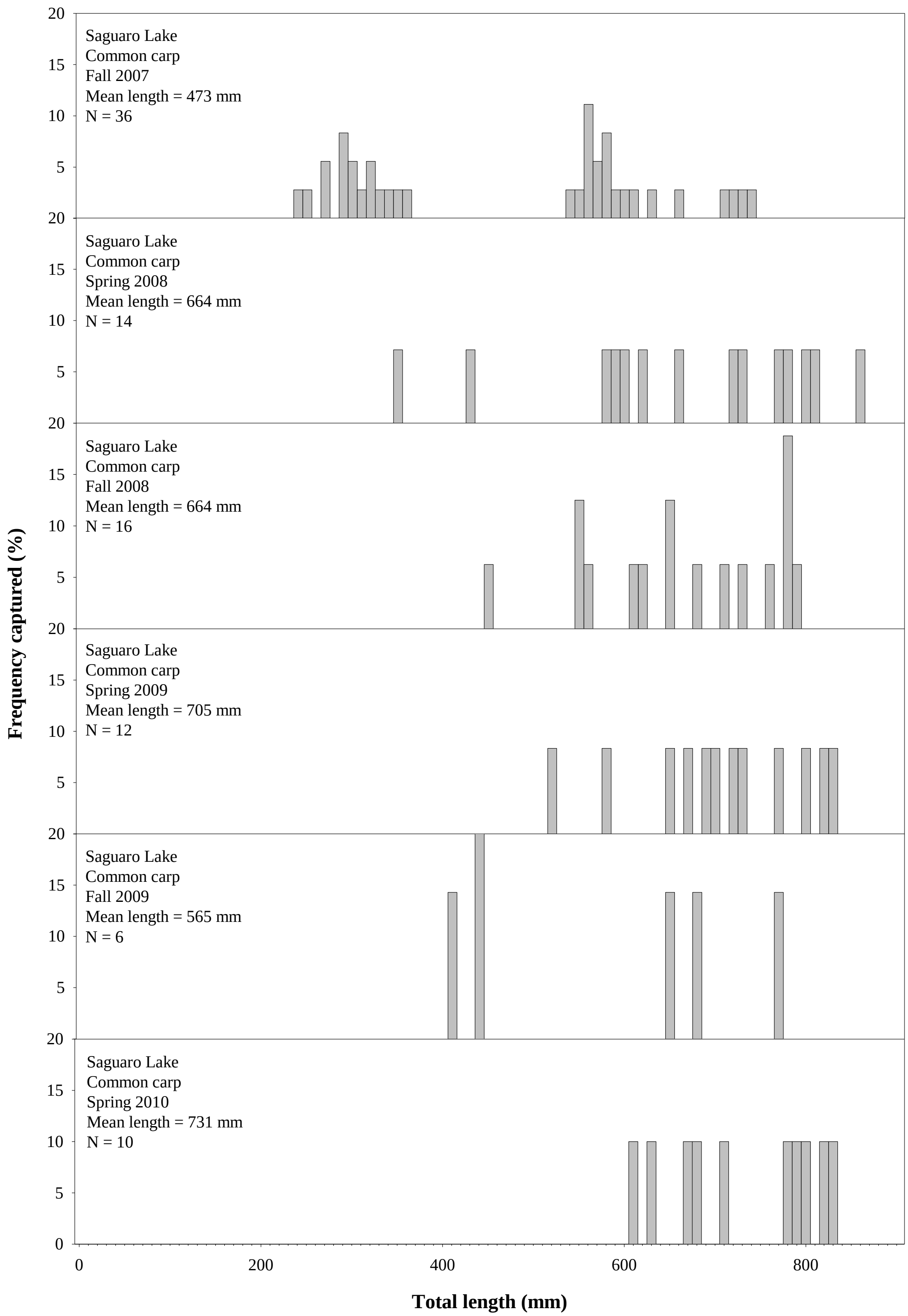

Figure 9. Length frequency distribution of common carp captured during gill net surveys in Saguaro Lake. Golden Algae project, 2007-2010.

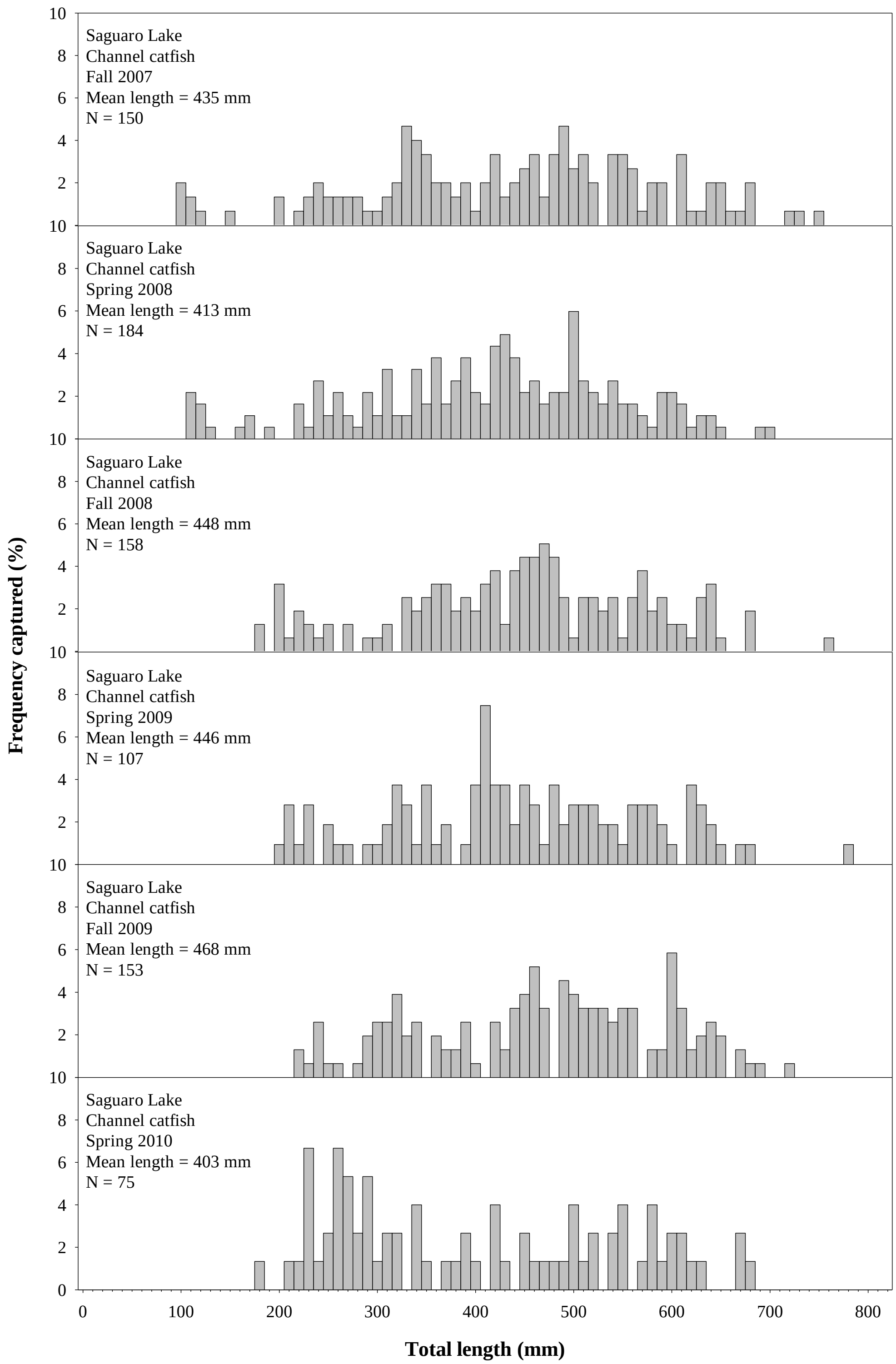

Figure 10. Length frequency distribution of channel catfish captured during gill net surveys in Saguaro Lake. Golden Algae project, 2007-2010.

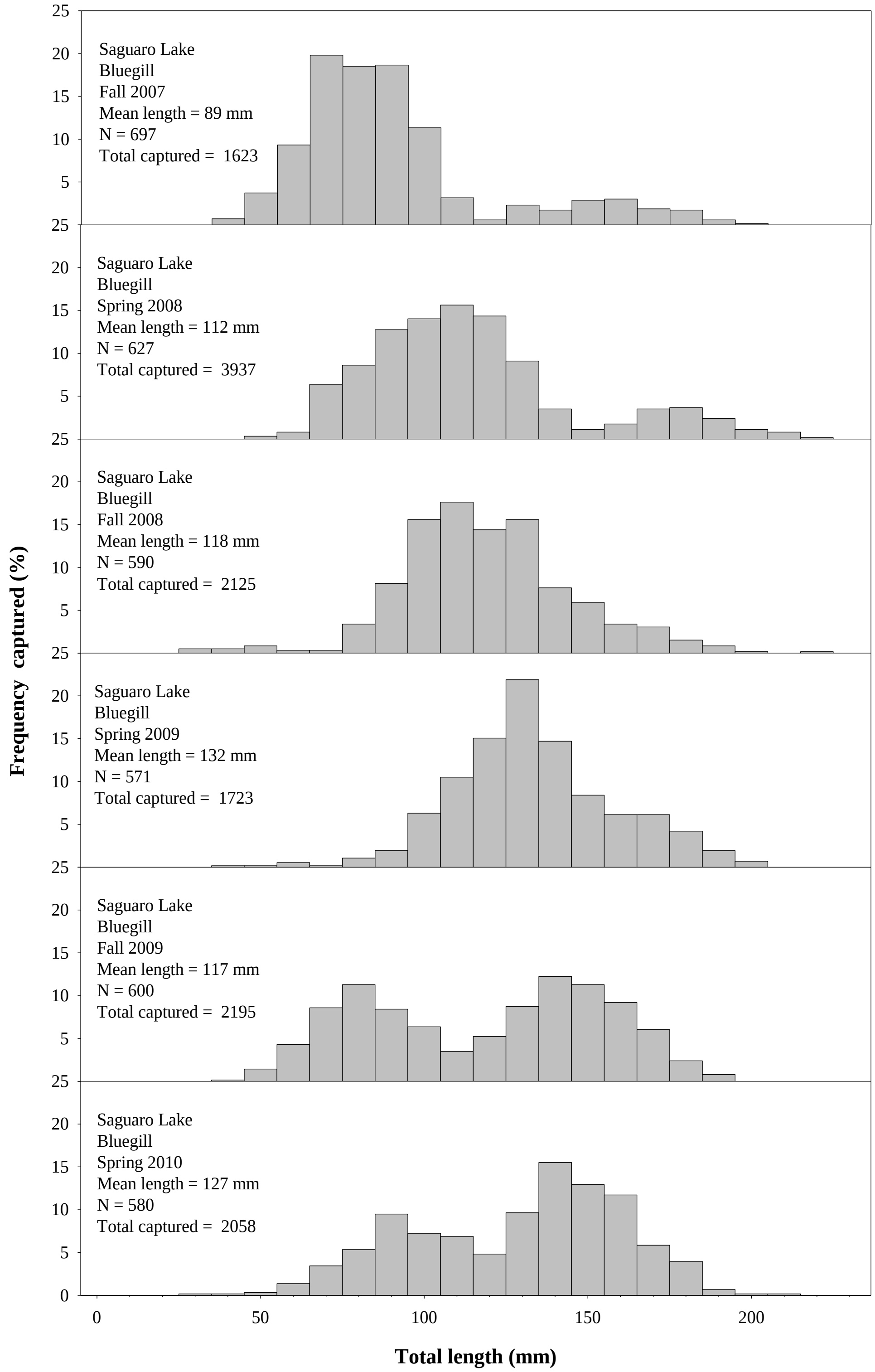

Figure 11. Length frequency distribution of bluegill captured during electrofishing surveys in Saguaro Lake. Golden Algae project, 2007-2010.

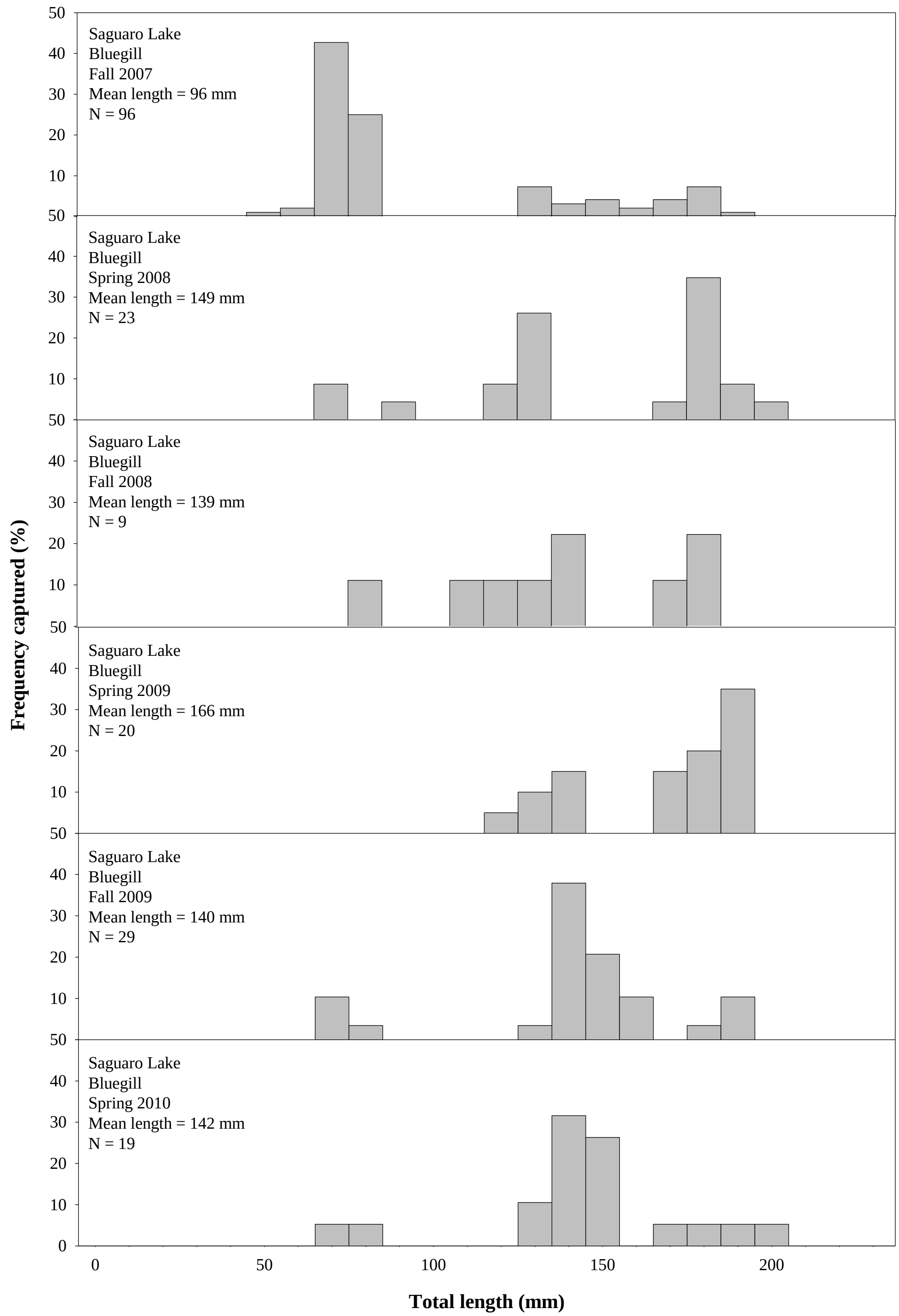

Figure 12. Length frequency distribution of bluegill captured during gill net surveys at Saguaro Lake. Golden Algae project, 2007-2010.

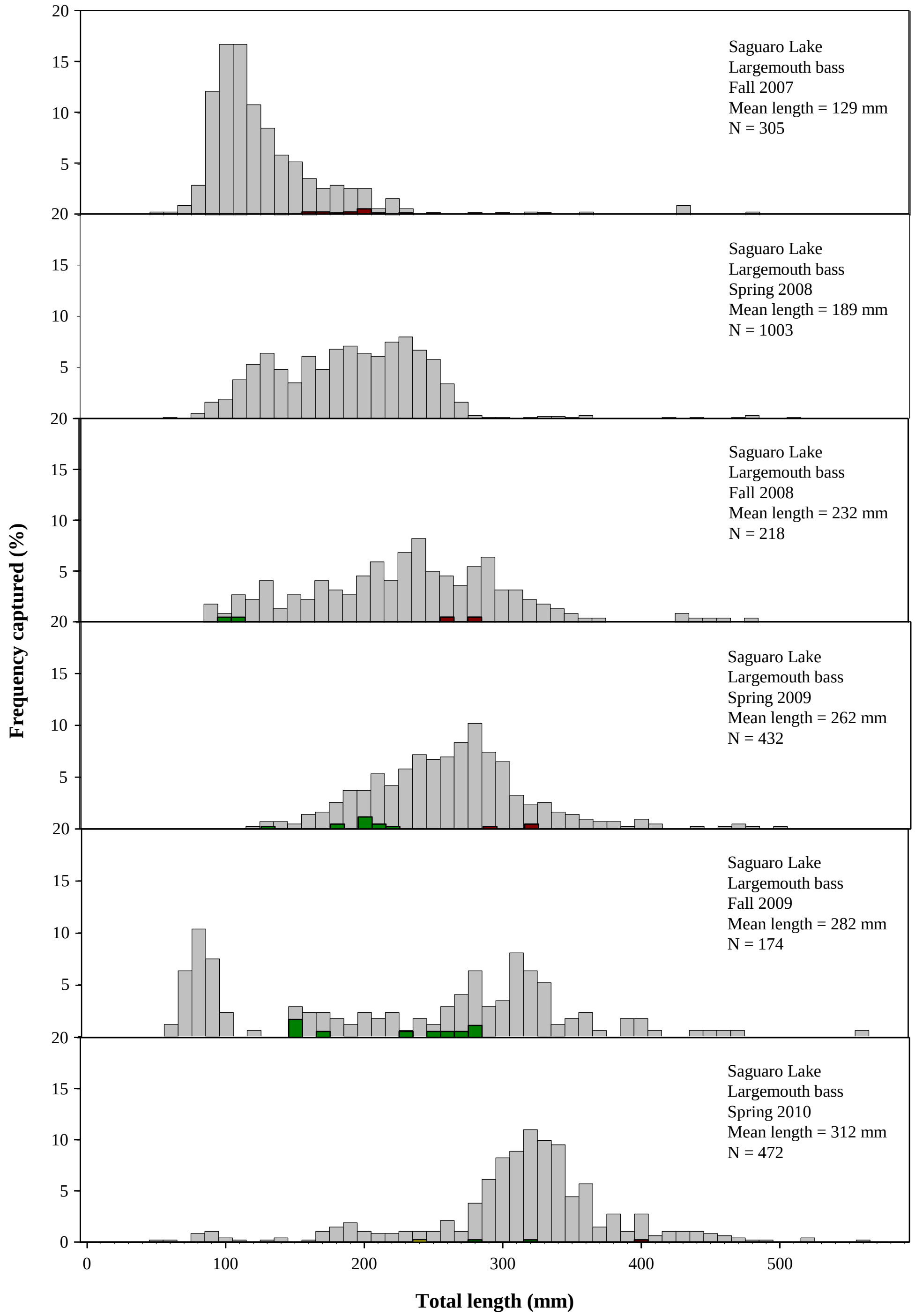

Figure 13. Length frequency distribution of largemouth bass captured during electrofishing surveys in Saguaro Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars) and Fall 2008 (green bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) stocking of OTC-marked fish. Golden Algae project, 2007-2010.

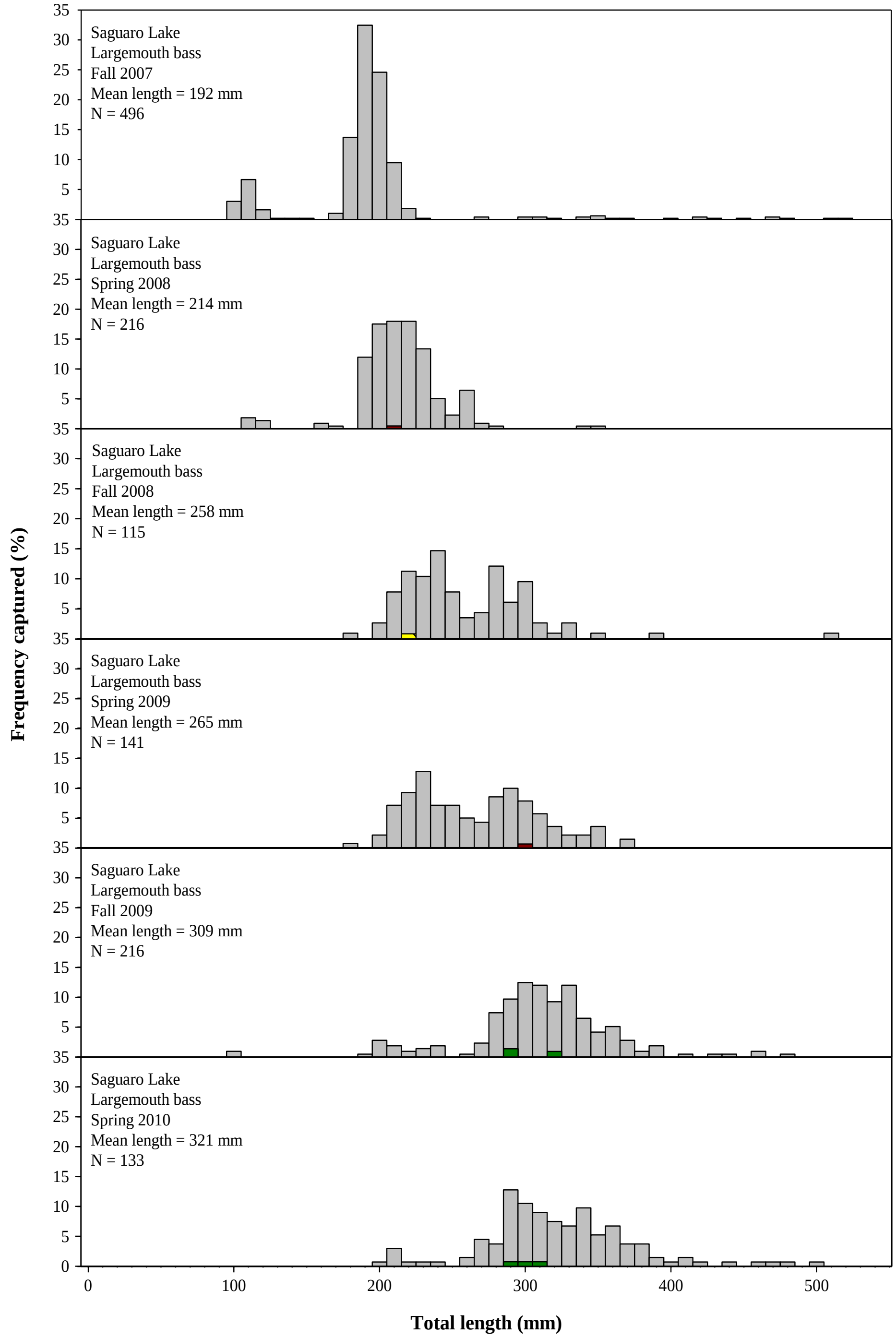

Figure 14. Length frequency distribution of largemouth bass captured during gill net surveys at Saguaro Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars) and Fall 2008 (green bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) stocking of OTC-marked fish. Golden Algae project, 2007-2010.

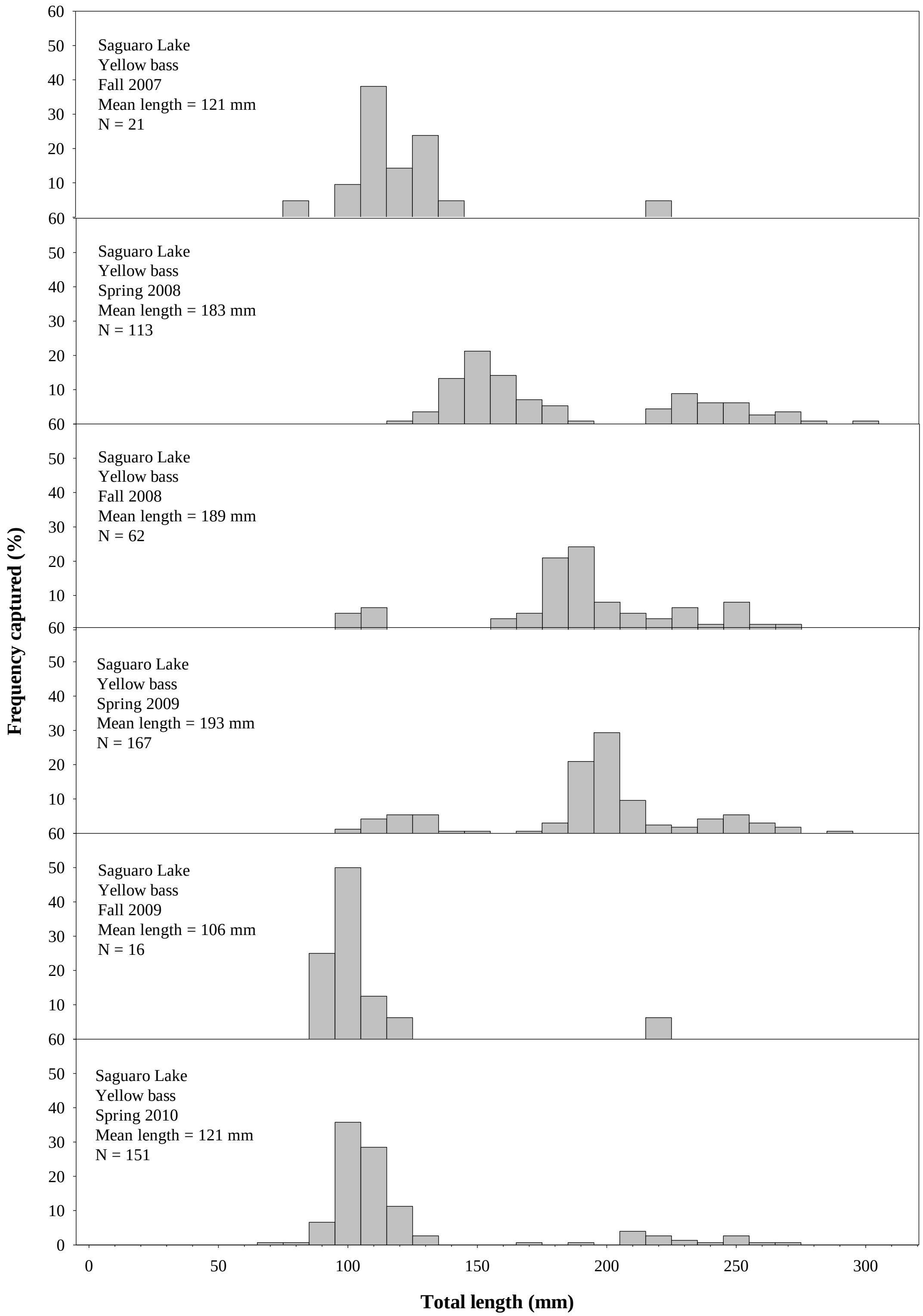

Figure 15. Length frequency distribution of yellow bass captured during electrofishing surveys in Saguaro Lake. Golden Algae project, 2007-2010.

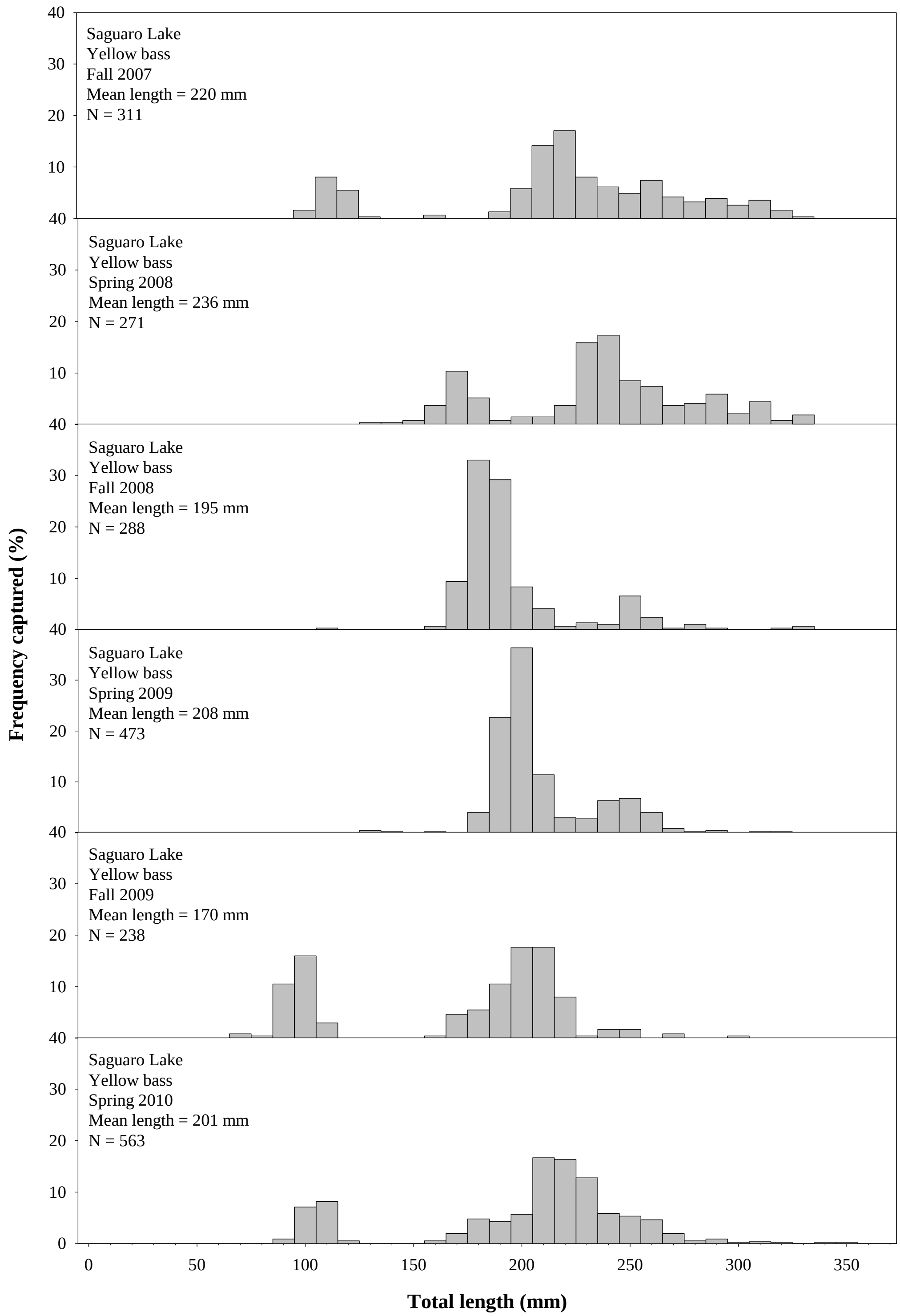

Figure 16. Length frequency distribution of yellow bass captured during gill net surveys at Saguaro Lake. Golden Algae project, 2007-2010.

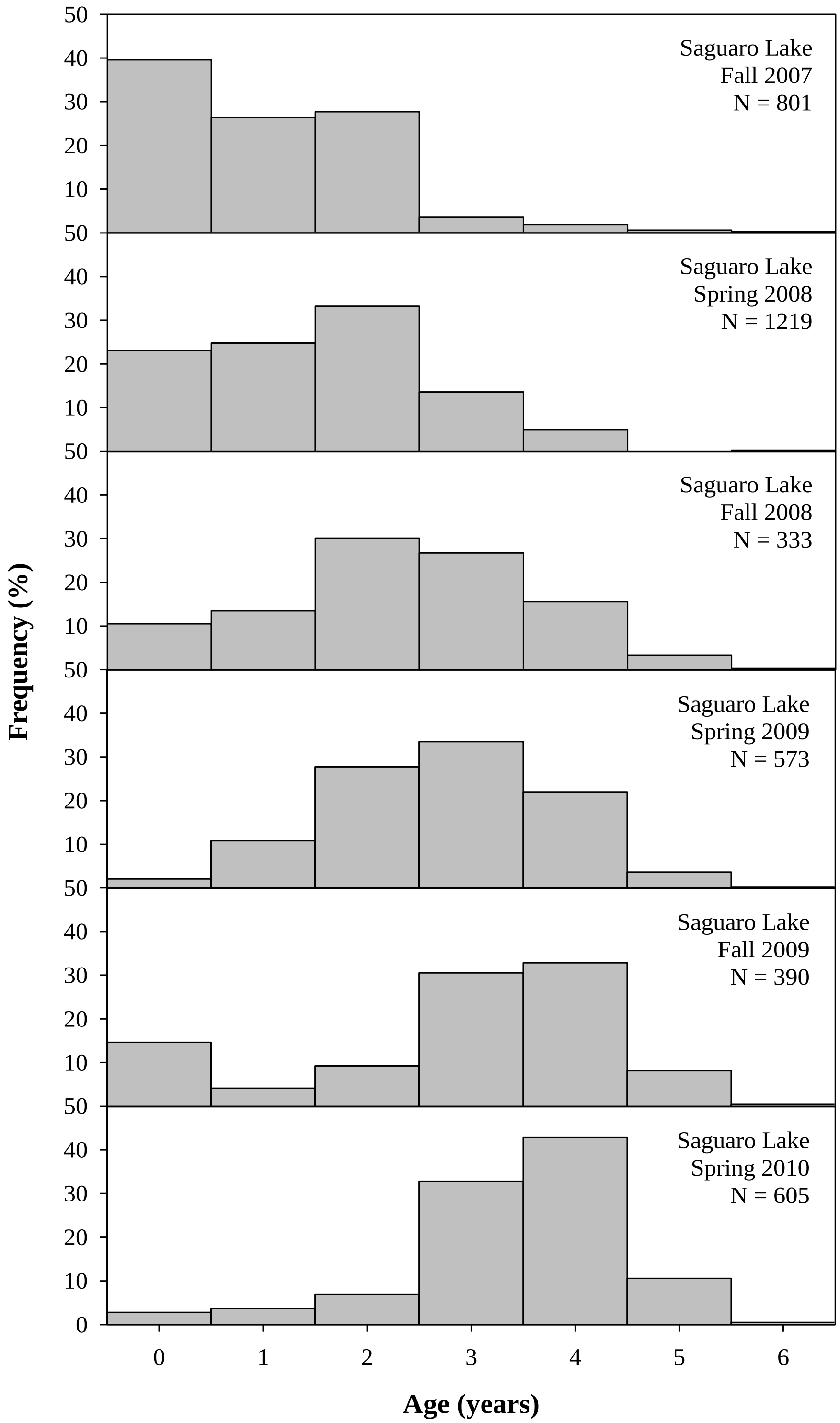

Figure 17. Age-frequency distribution of all largemouth bass captured during electrofishing and gill net surveys in Saguaro Lake. Golden Algae project, 2007-2010.

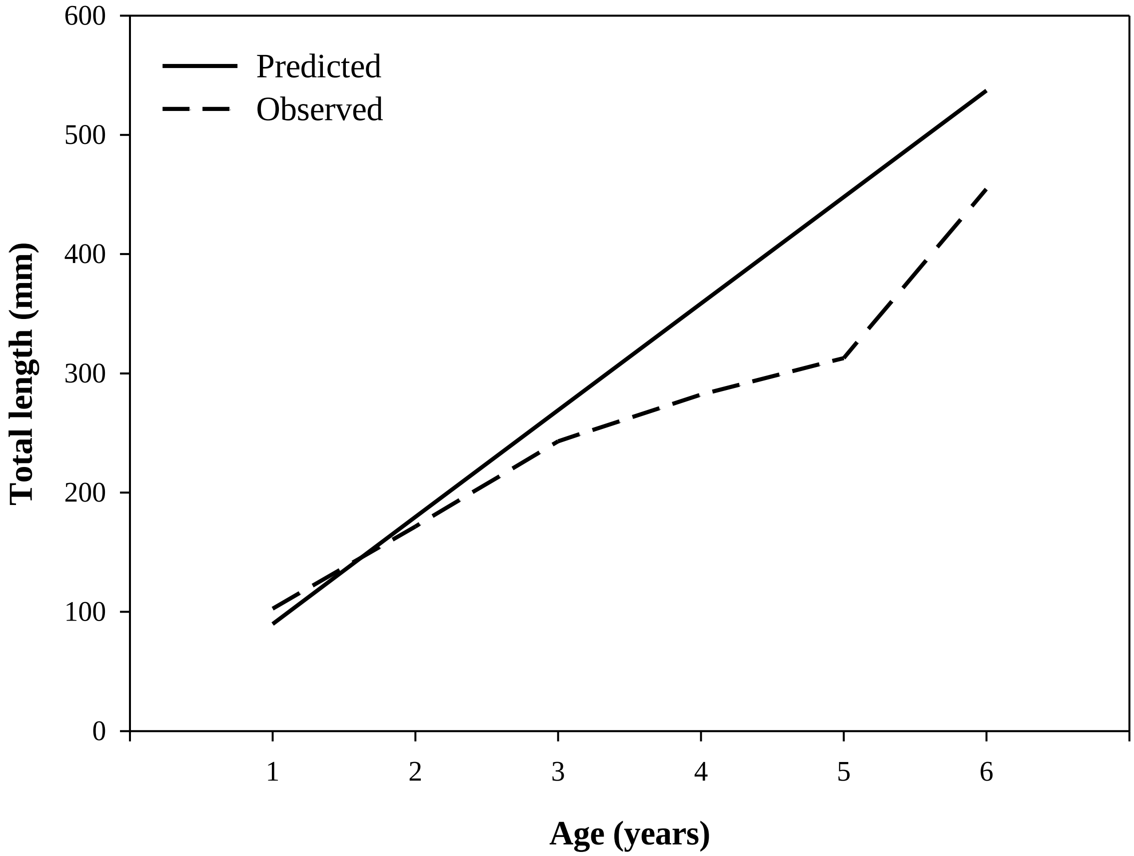

Figure 18. Predicted and observed largemouth bass mean length at age from fish captured during electrofishing and gill net surveys in Saguaro Lake. Observed estimates (dashed line) were derived from back-calculations of otoliths. Predicted estimates were derived from recapture information of marked fish and then incorporated into a von-Bertalanffy growth model following Wang (1998) methodology.

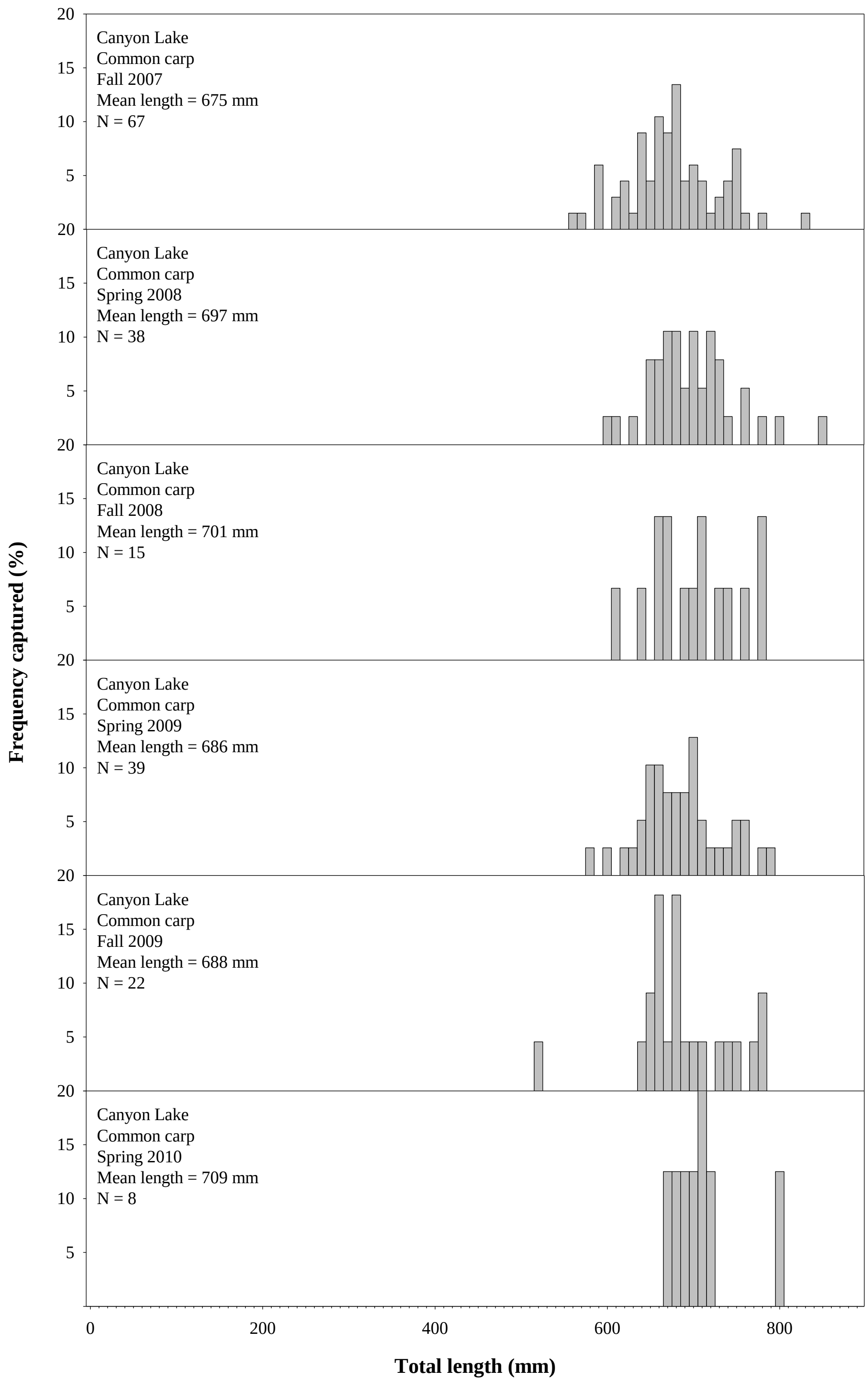

Figure 19. Length frequency distribution of common carp captured during electrofishing surveys at Canyon Lake. Golden Algae project, 2007-2010.

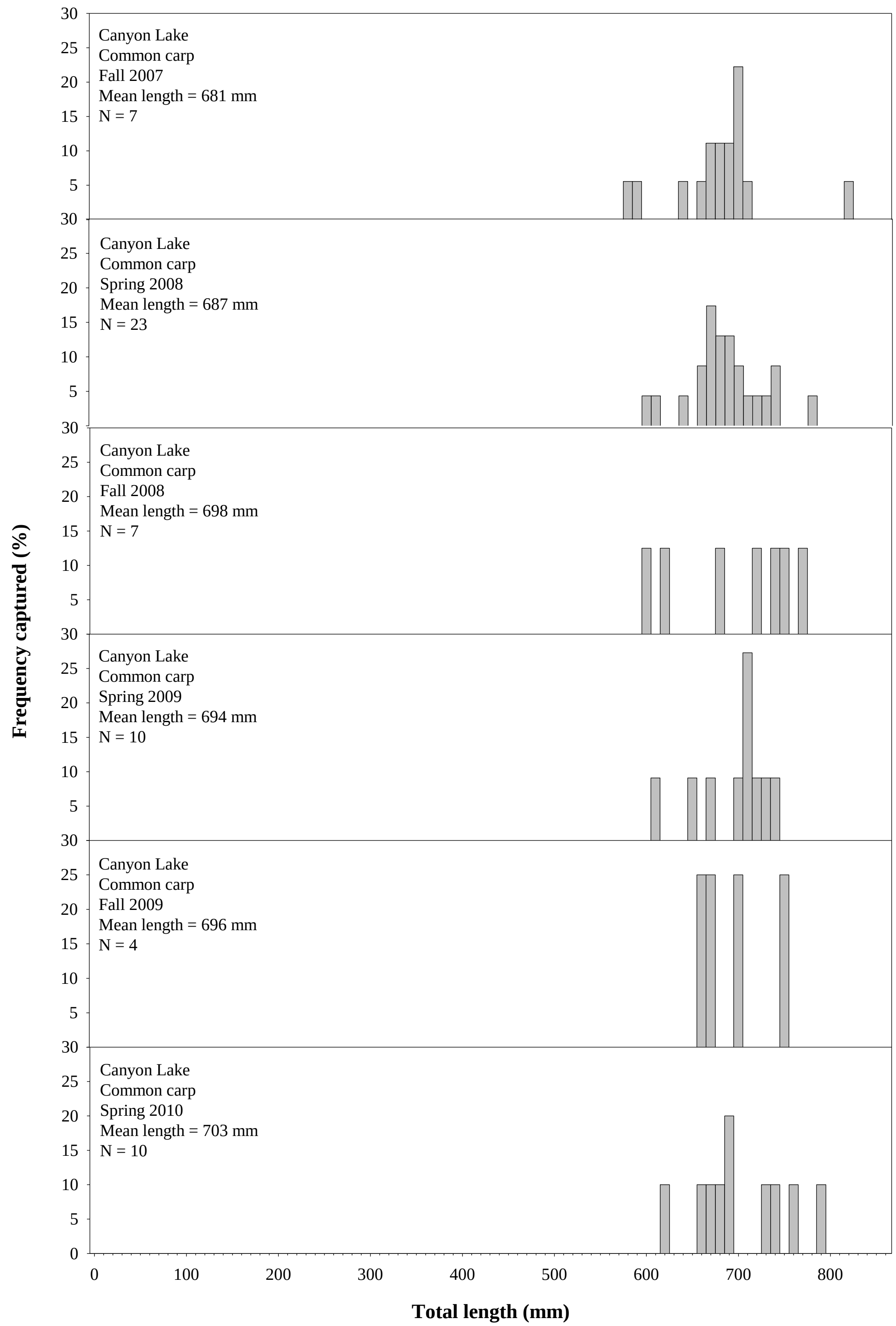

Figure 20. Length frequency distribution of common carp captured during gill net surveys at Canyon Lake. Golden Algae project, 2007-2010.

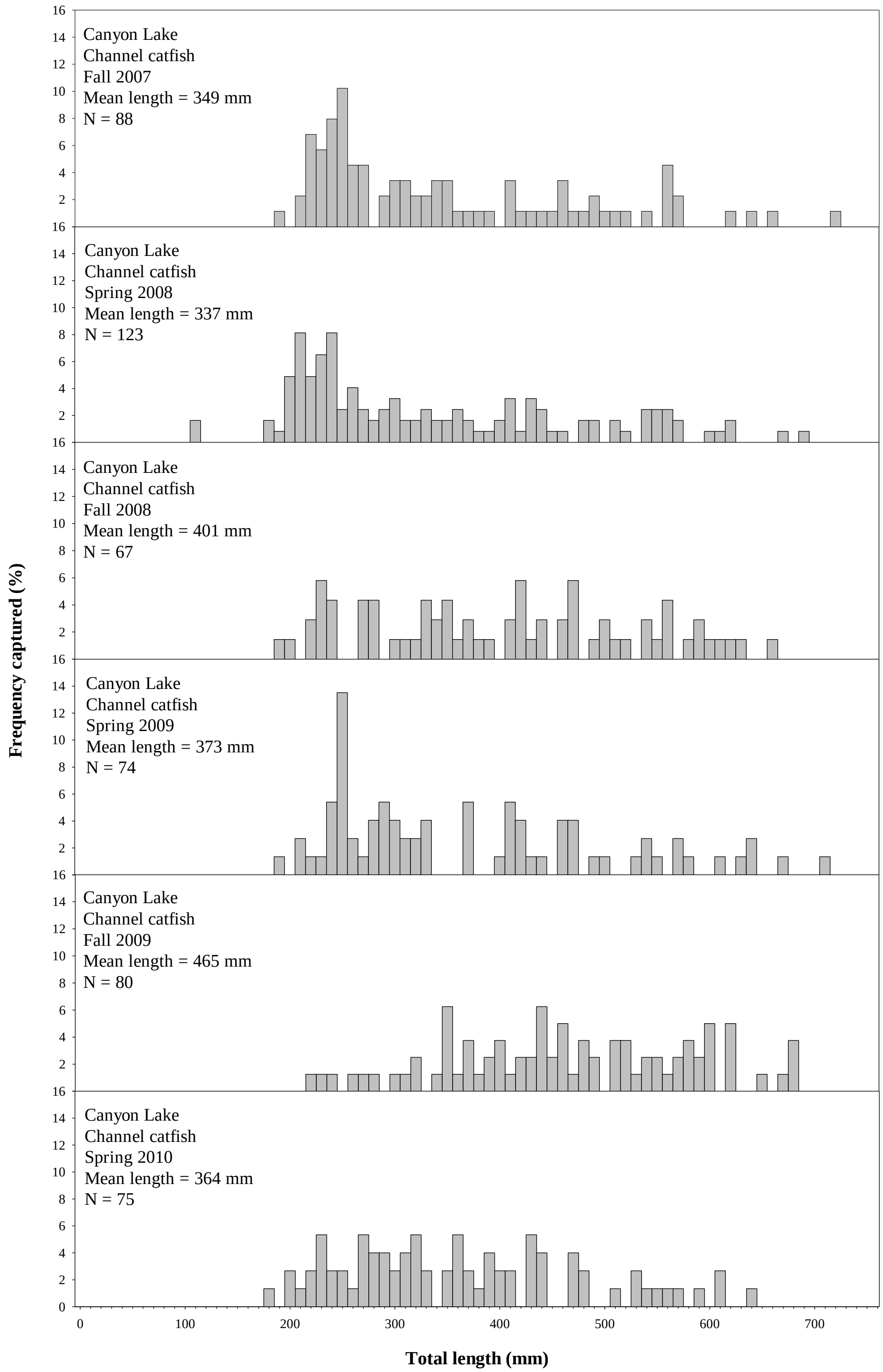

Figure 21. Length frequency distribution of channel catfish captured during gill net surveys at Canyon Lake. Golden Algae project, 2007-2010.

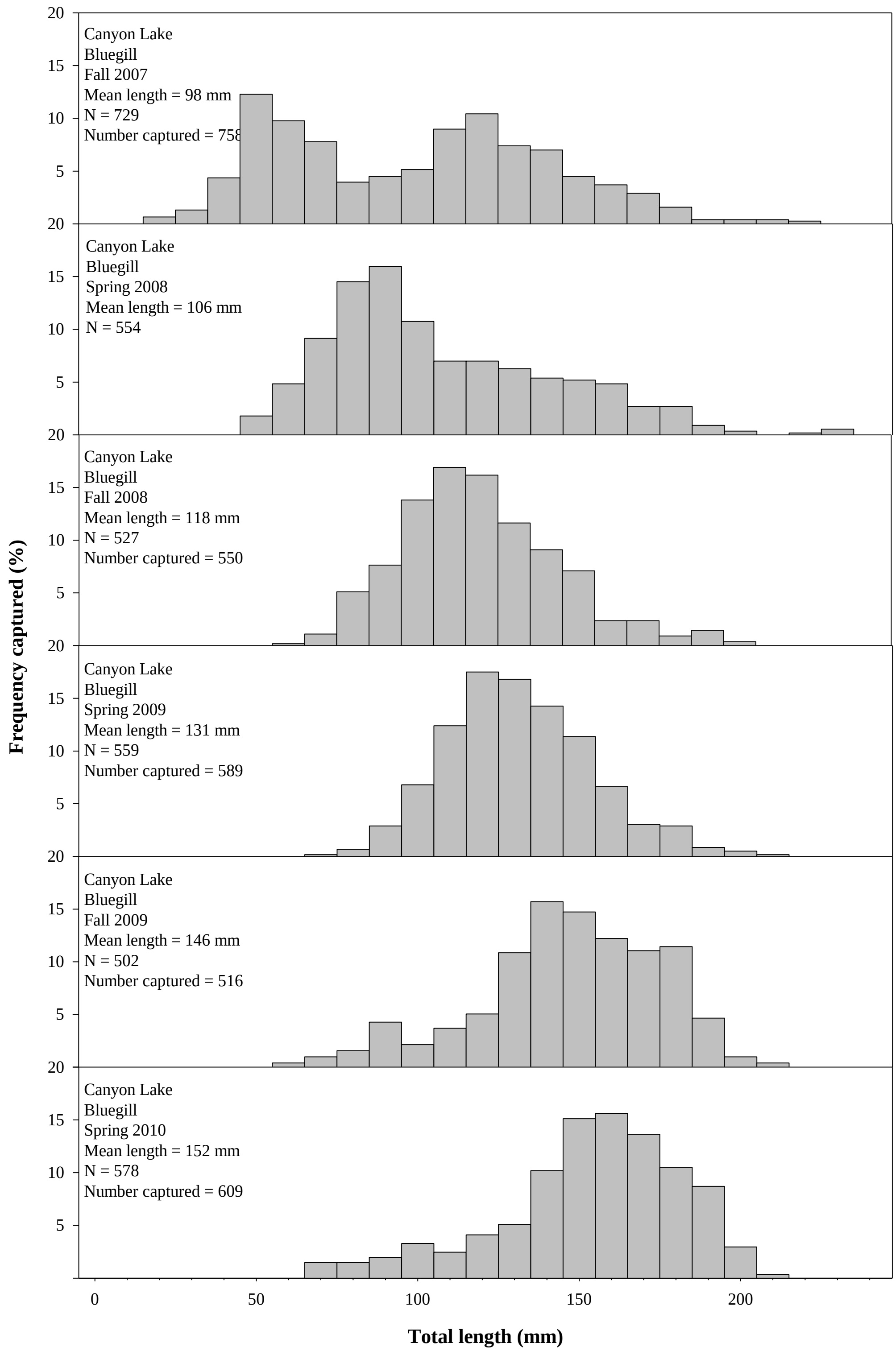

Figure 22. Length frequency distribution of bluegill captured during electrofishing surveys at Canyon Lake. Golden Algae project, 2007-2010.

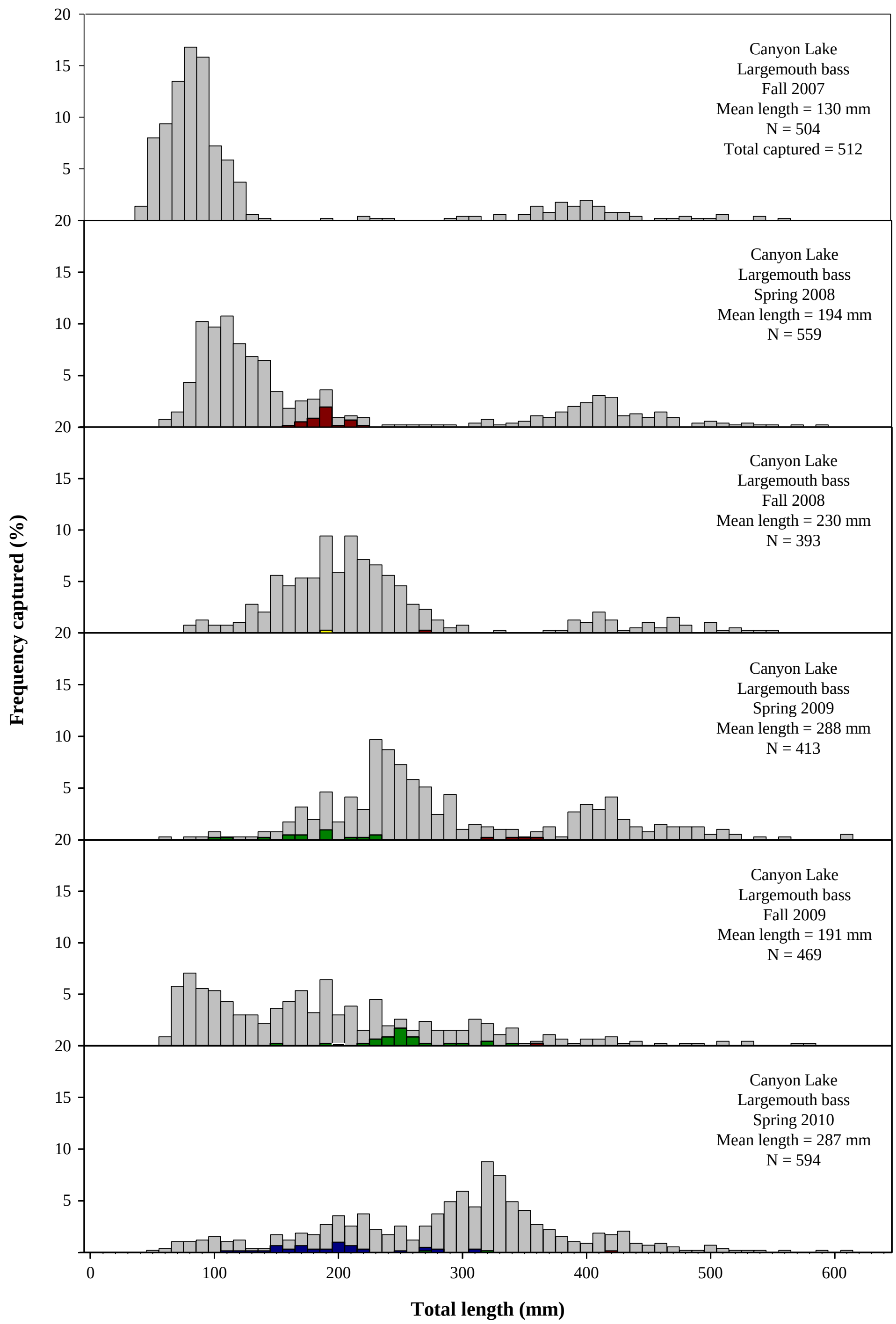

Figure 23. Length frequency distribution of largemouth bass captured during electrofishing surveys at Canyon Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars), Fall 2008 (green bars), and Fall 2009 (blue bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) and Spring 2009 (black bars) stockings of OTC-marked fish. Golden Algae project, 2007-2010.

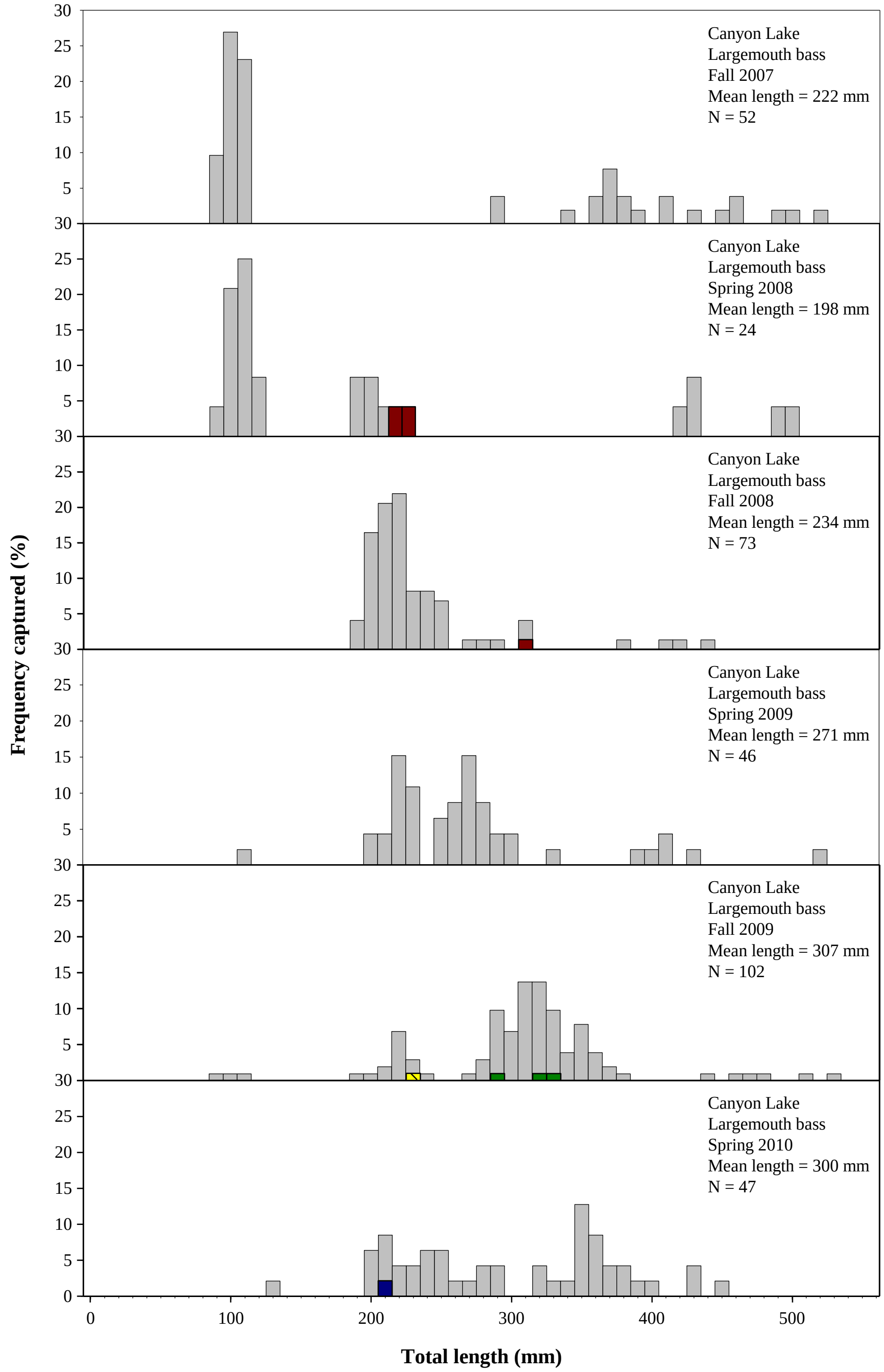

Figure 24. Length frequency distribution of largemouth bass captured during gill net surveys in Canyon Lake. Golden Algae project, 2007-2010. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars), Fall 2008 (green bars), and Fall 2009 (blue bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) stocking of OTC-marked fish. Golden Algae project, 2007-2010.

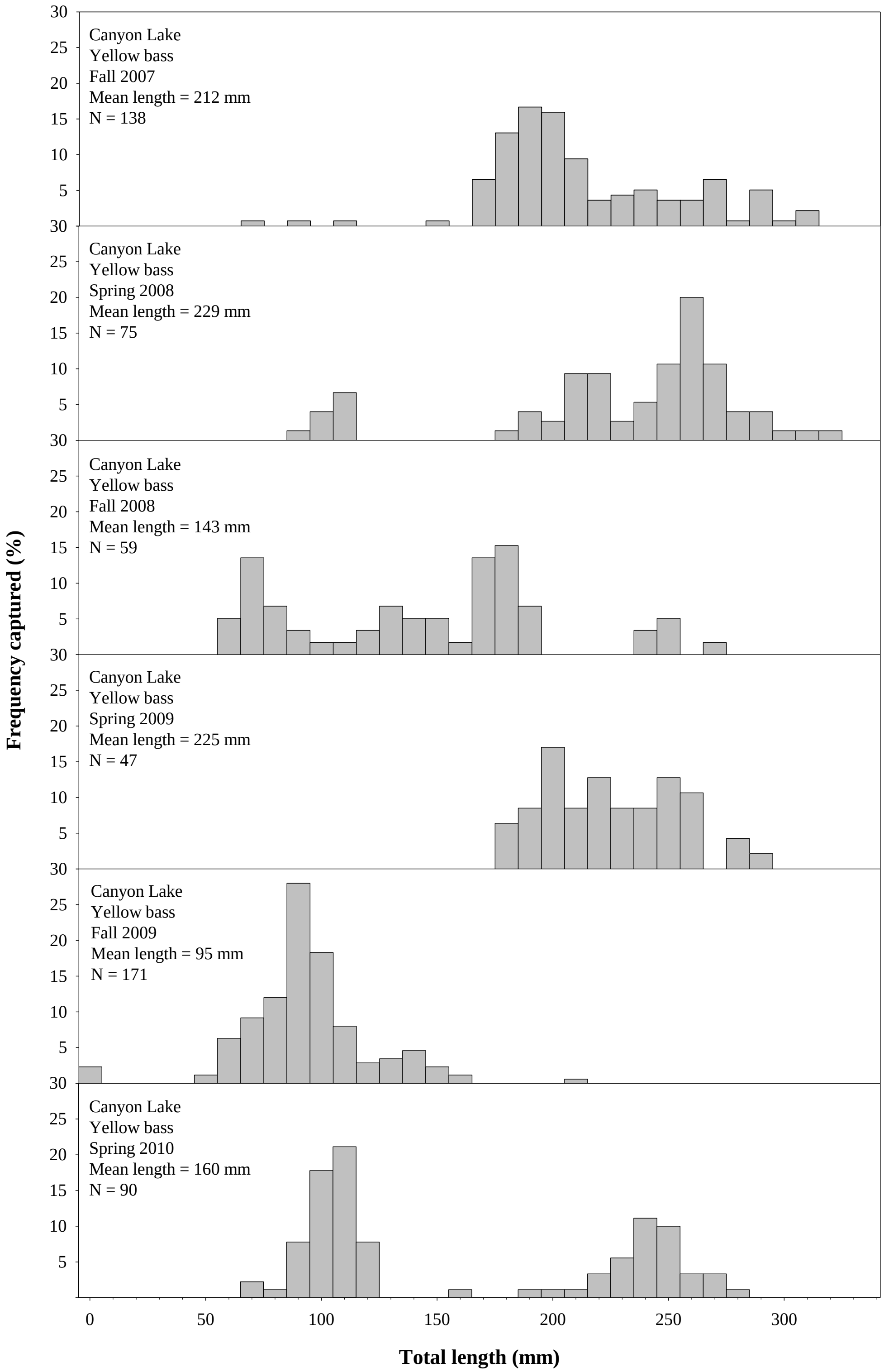

Figure 25. Length frequency distribution of yellow bass captured during electrofishing surveys at Canyon Lake. Golden Algae project, 2007-2010.

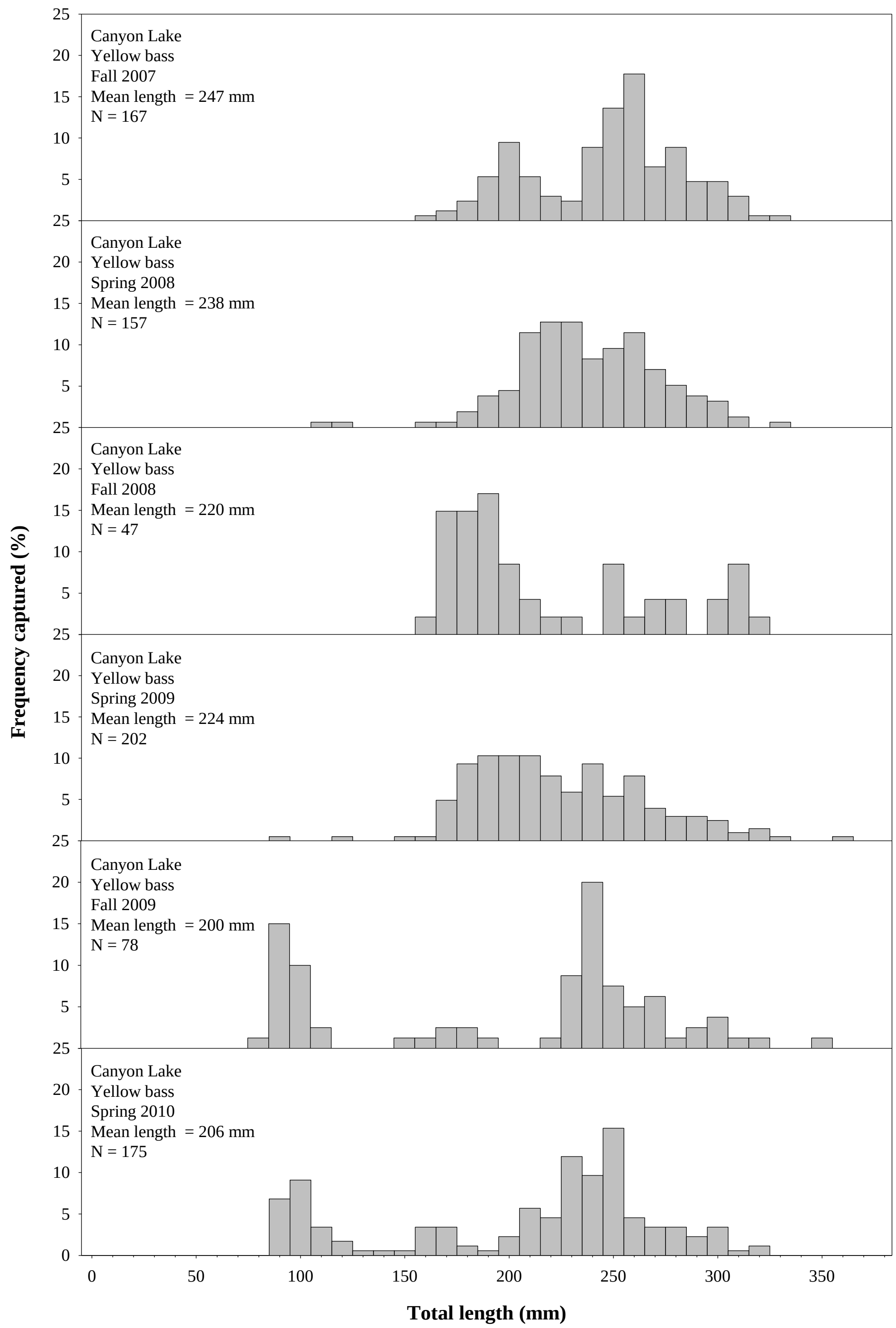

Figure 26. Length frequency distribution of yellow bass captured during gill net surveys at Canyon Lake. Golden Algae project, 2007-2010.

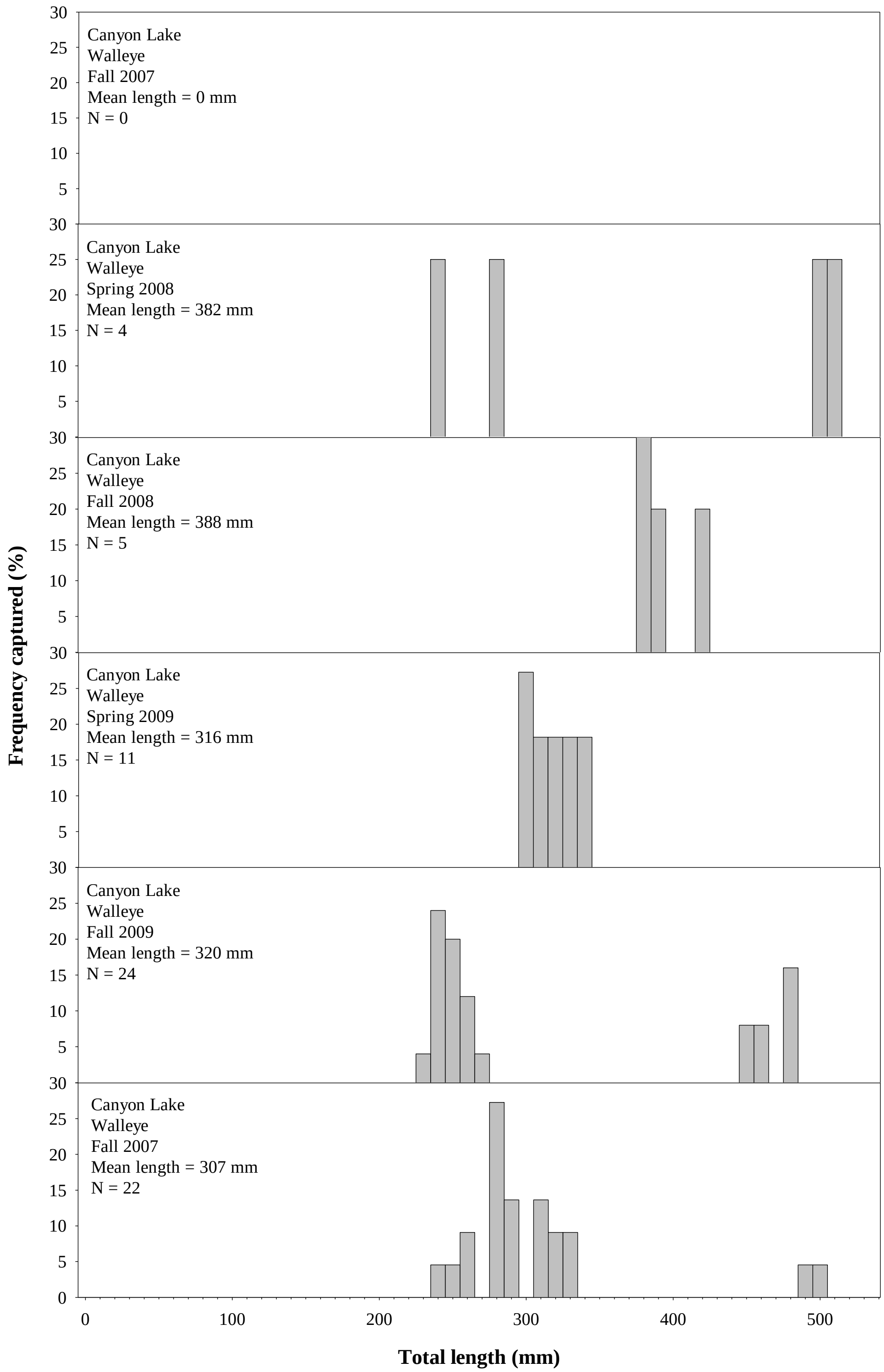

Figure 27. Length frequency distribution of walleye captured during gill net surveys at Canyon Lake. Golden Algae project, 2007-2010.

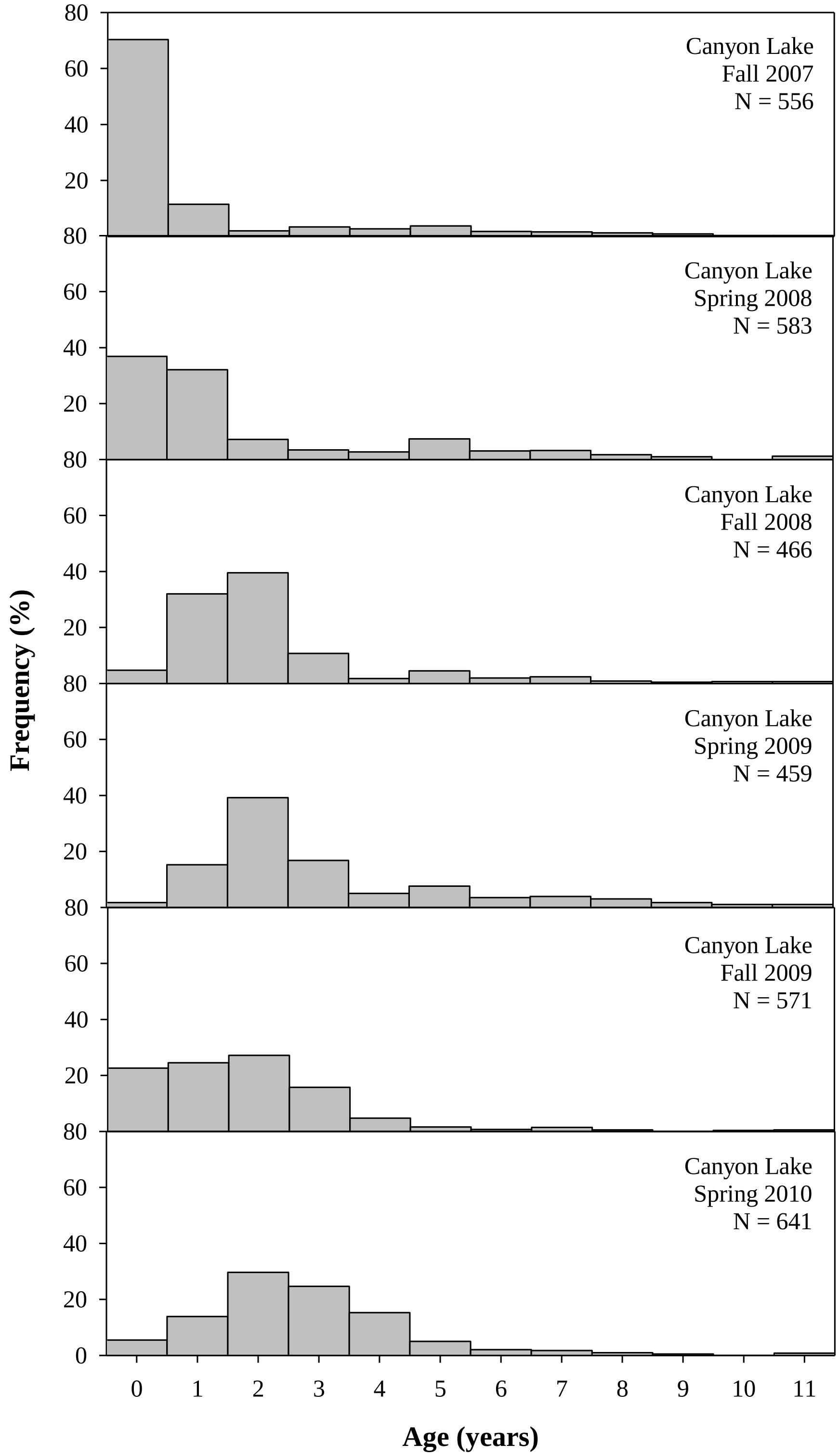

Figure 28. Age-frequency distribution of largemouth bass captured during electrofishing and gill net surveys in Canyon Lake. Golden Algae project, 2007-2010.

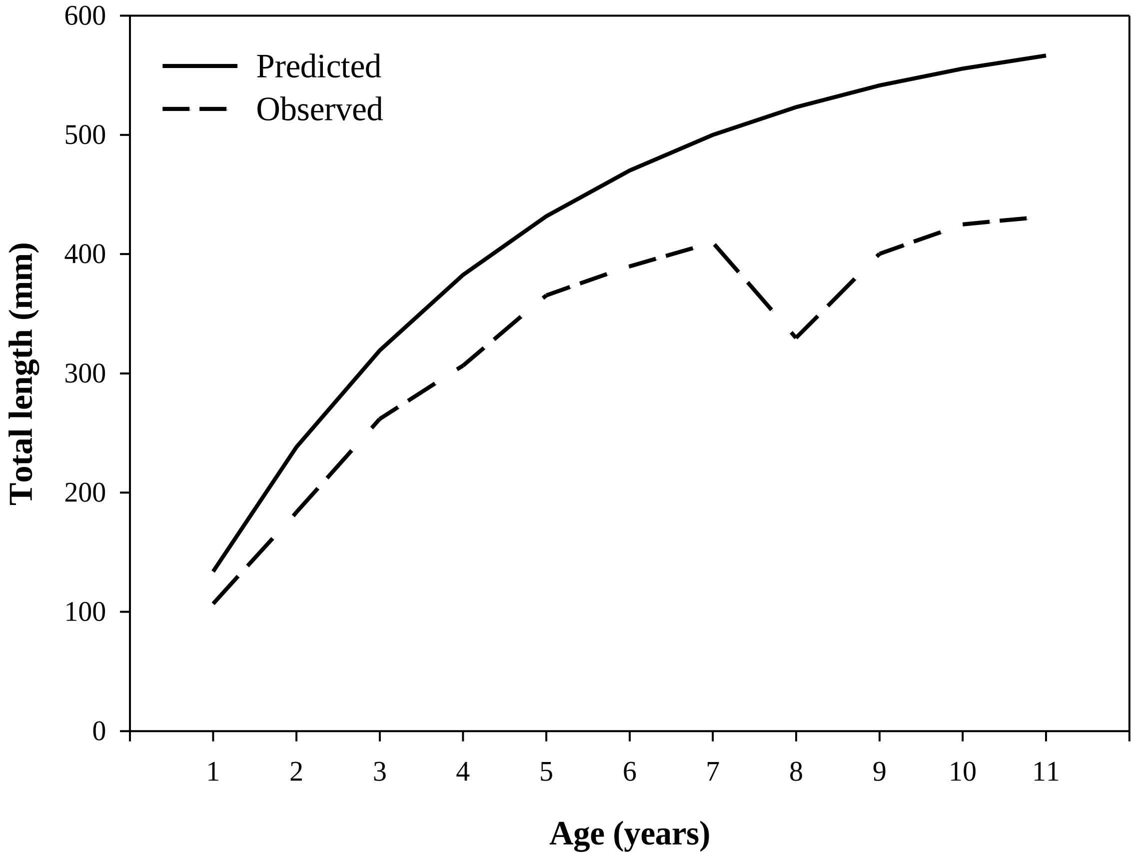

Figure 29. Predicted and observed largemouth bass mean length at age from fish captured during electrofishing and gill net surveys in Canyon Lake. Observed estimates (dashed line) were derived from back-calculations of otoliths. Predicted estimates were derived from recapture information of marked fish and then incorporated into a von-Bertalanffy growth model following Wang (1998) methodology.

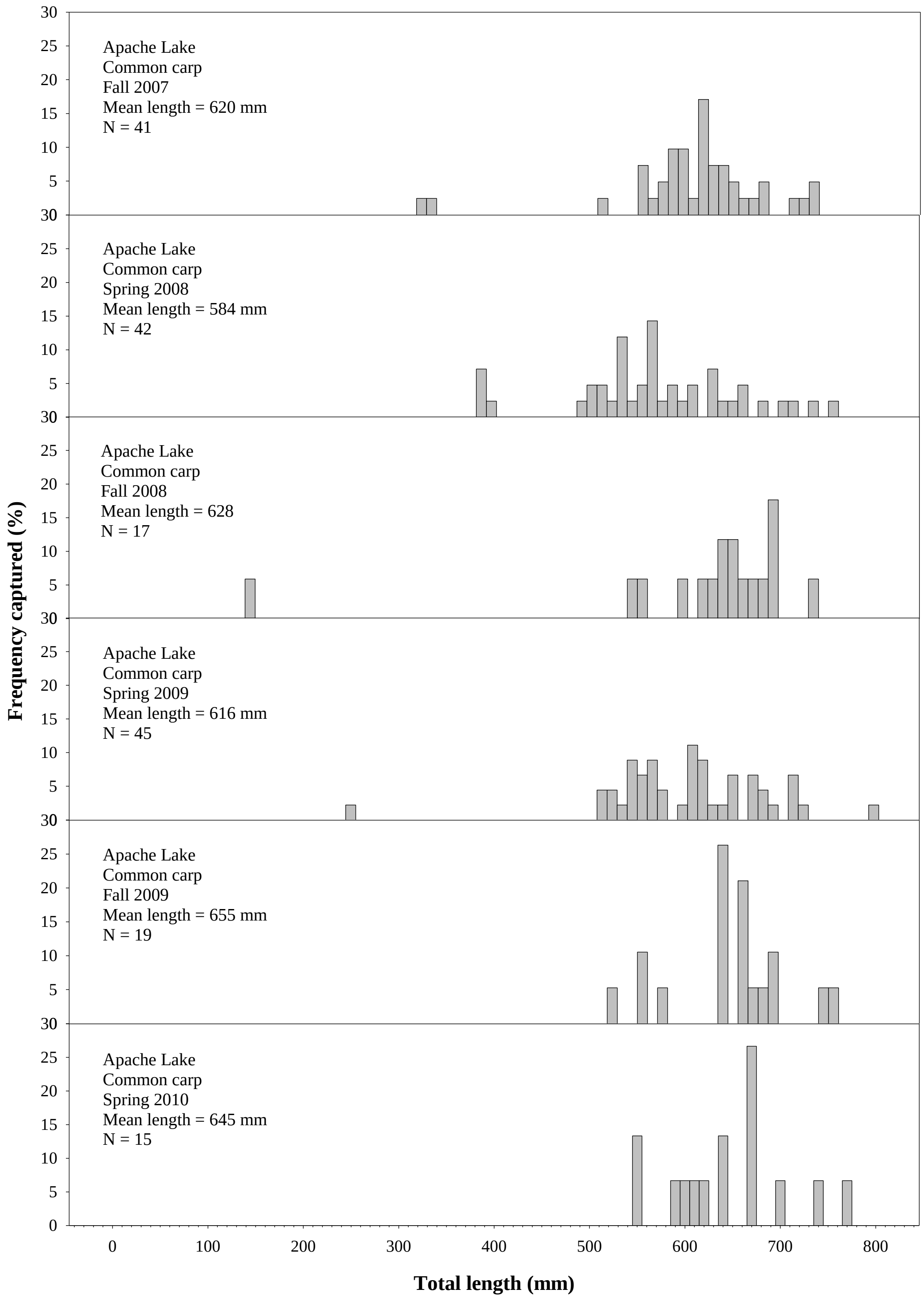

Figure 30. Length frequency distribution of common carp captured during electrofishing surveys at Apache Lake. Golden Algae project, 2007-2010.

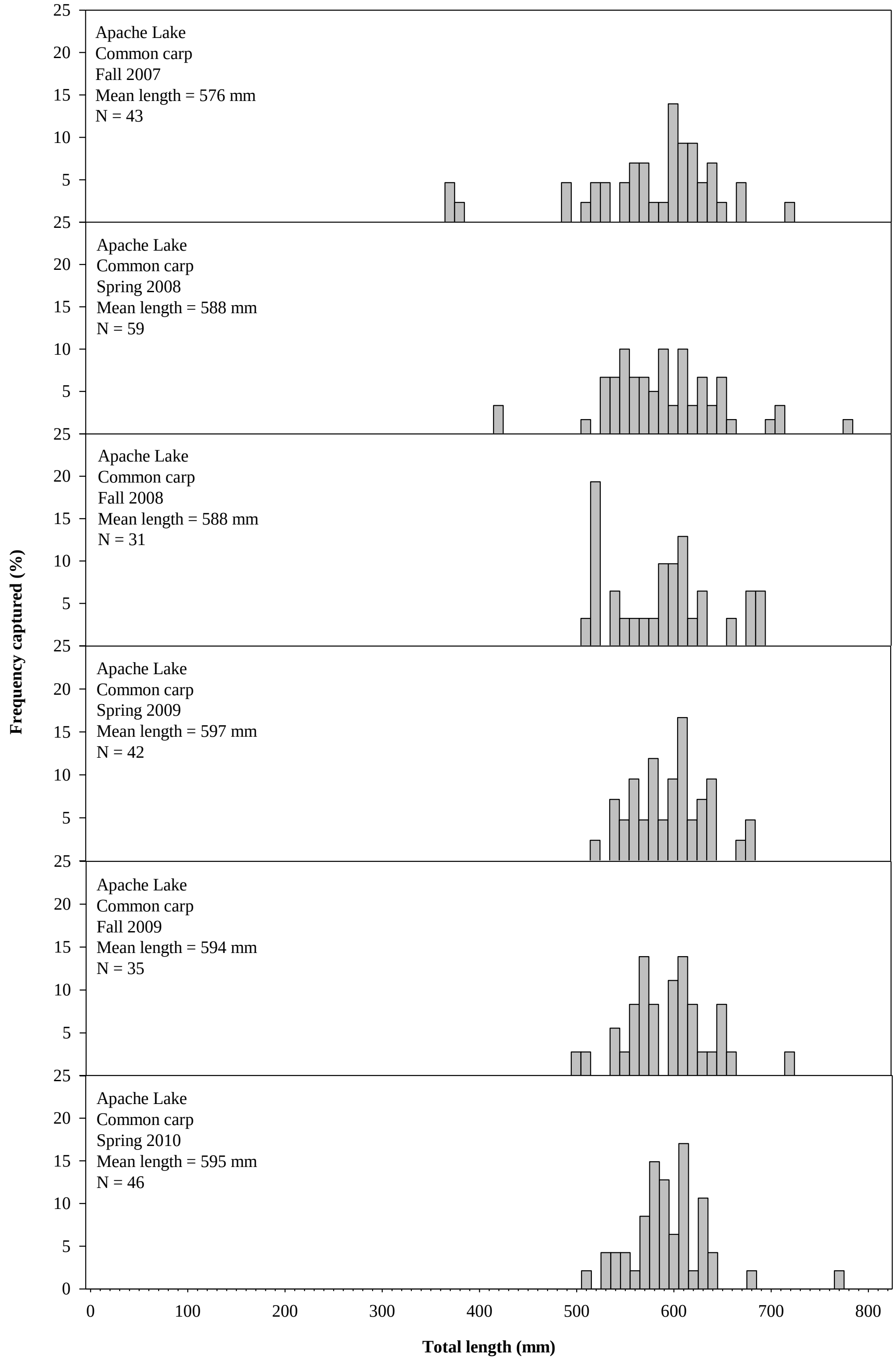
Apache Lake
Common carp
Fall 2007
Mean length = 576 mm
N = 43
Apache Lake
Common carp
Spring 2008
Mean length = 588 mm
N = 59
Apache Lake
Common carp
Fall 2008
Mean length = 588 mm
N = 31
Apache Lake
Common carp
Spring 2009
Mean length = 597 mm
N = 42
Apache Lake
Common carp
Fall 2009
Mean length = 594 mm
N = 35
Apache Lake
Common carp
Spring 2010
Mean length = 595 mm
N = 46
Frequency captured (%)
Total length (mm)
0
5
10
15
20
25
0
100
200
300
400
500
600
700
800

Figure 31. Length frequency distribution of common carp captured during gill net surveys at Apache Lake. Golden Algae project, 2007-2010.

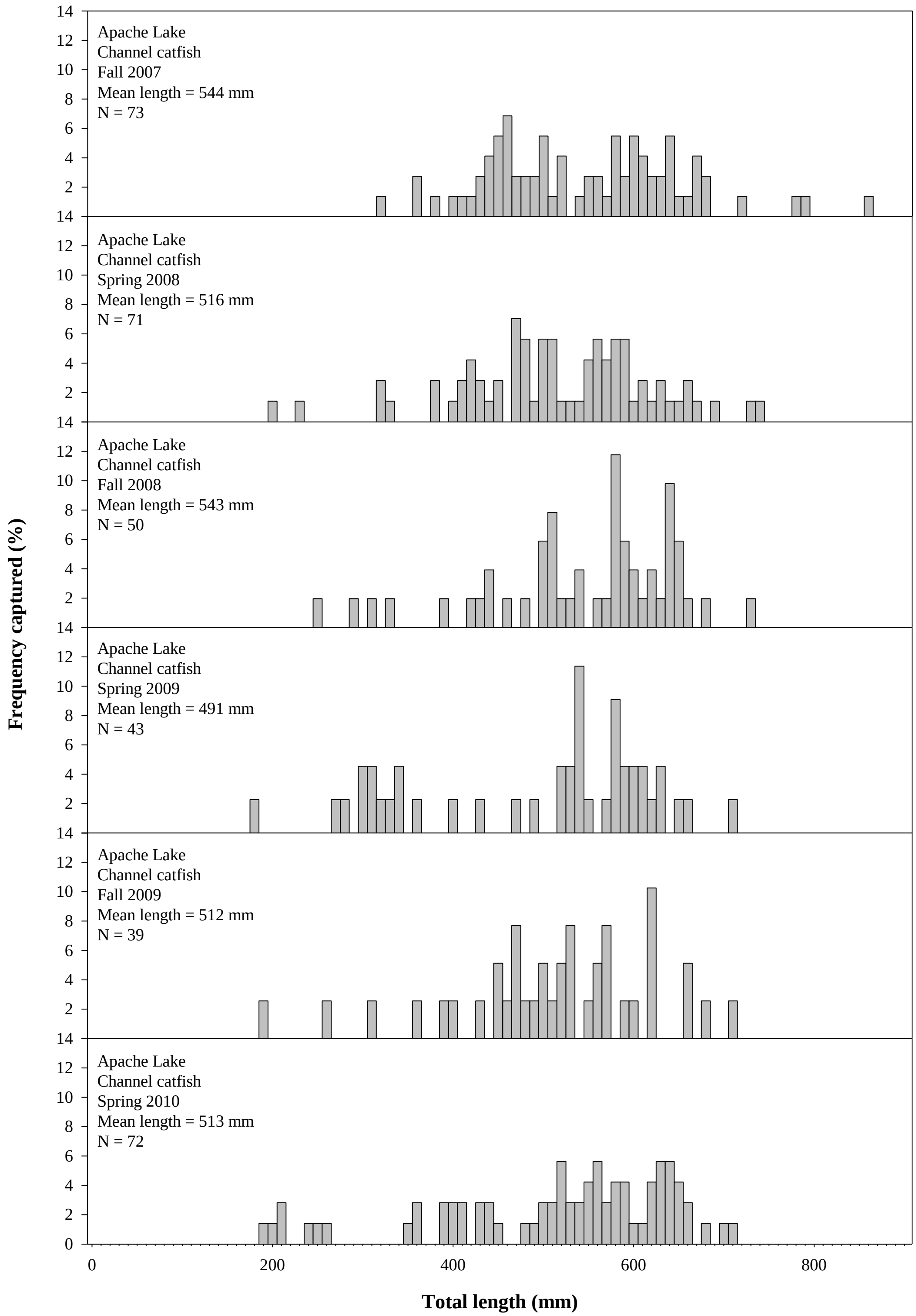

Figure 32. Length frequency distribution of channel catfish captured during gill net surveys at Apache Lake. Golden Algae project, 2007-2010.

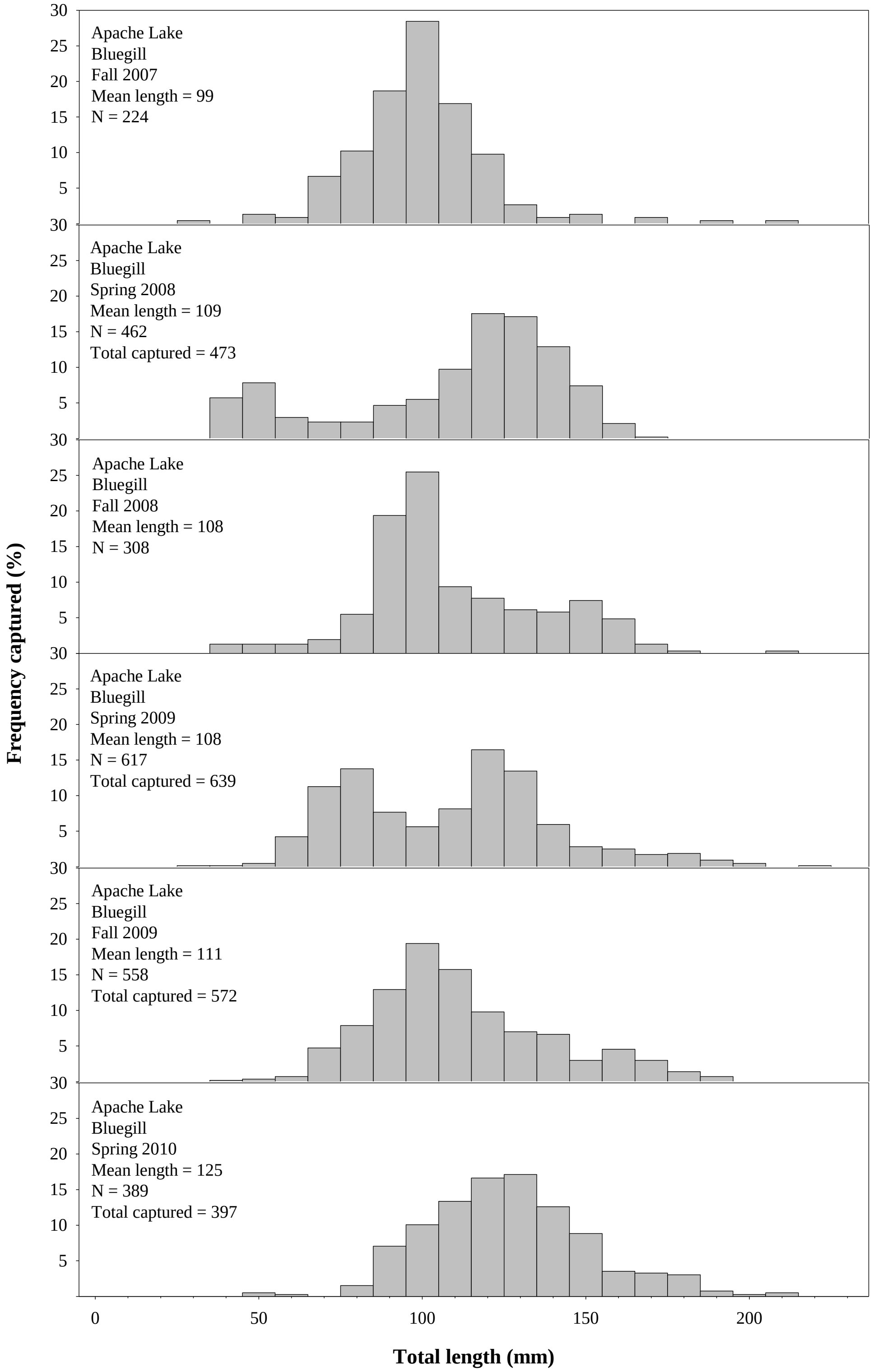

Figure 33. Length frequency distribution of bluegill captured during electrofishing surveys at Apache Lake. Golden Algae project, 2007-2010.

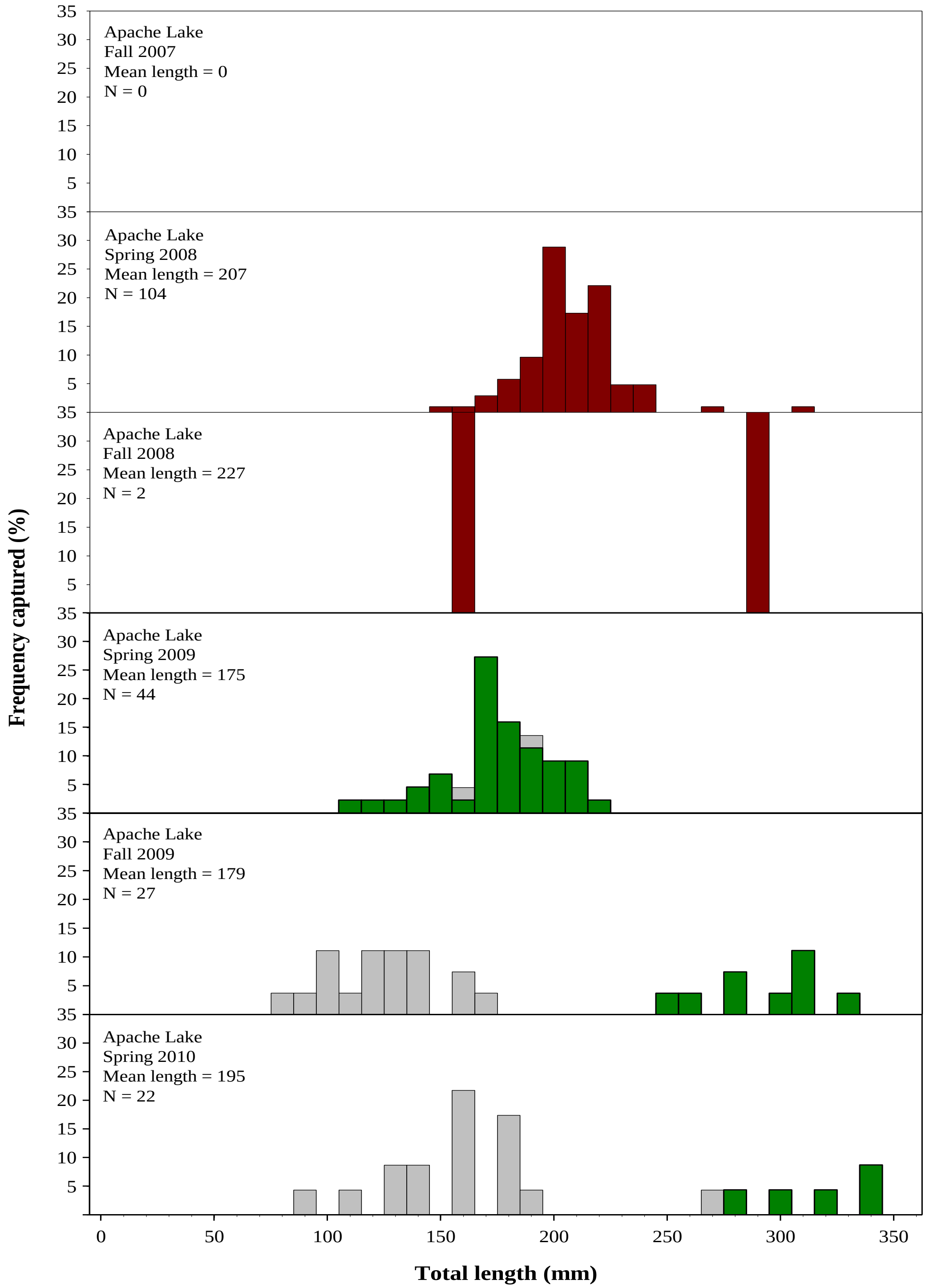

Figure 34. Length frequency distribution of smallmouth bass captured during electrofishing surveys at Apache Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 stocking of OTC-marked fish (red bars), and the Fall 2008 stocking of coded wire tagged fish (green bars). Golden Algae project, 2007-2010.

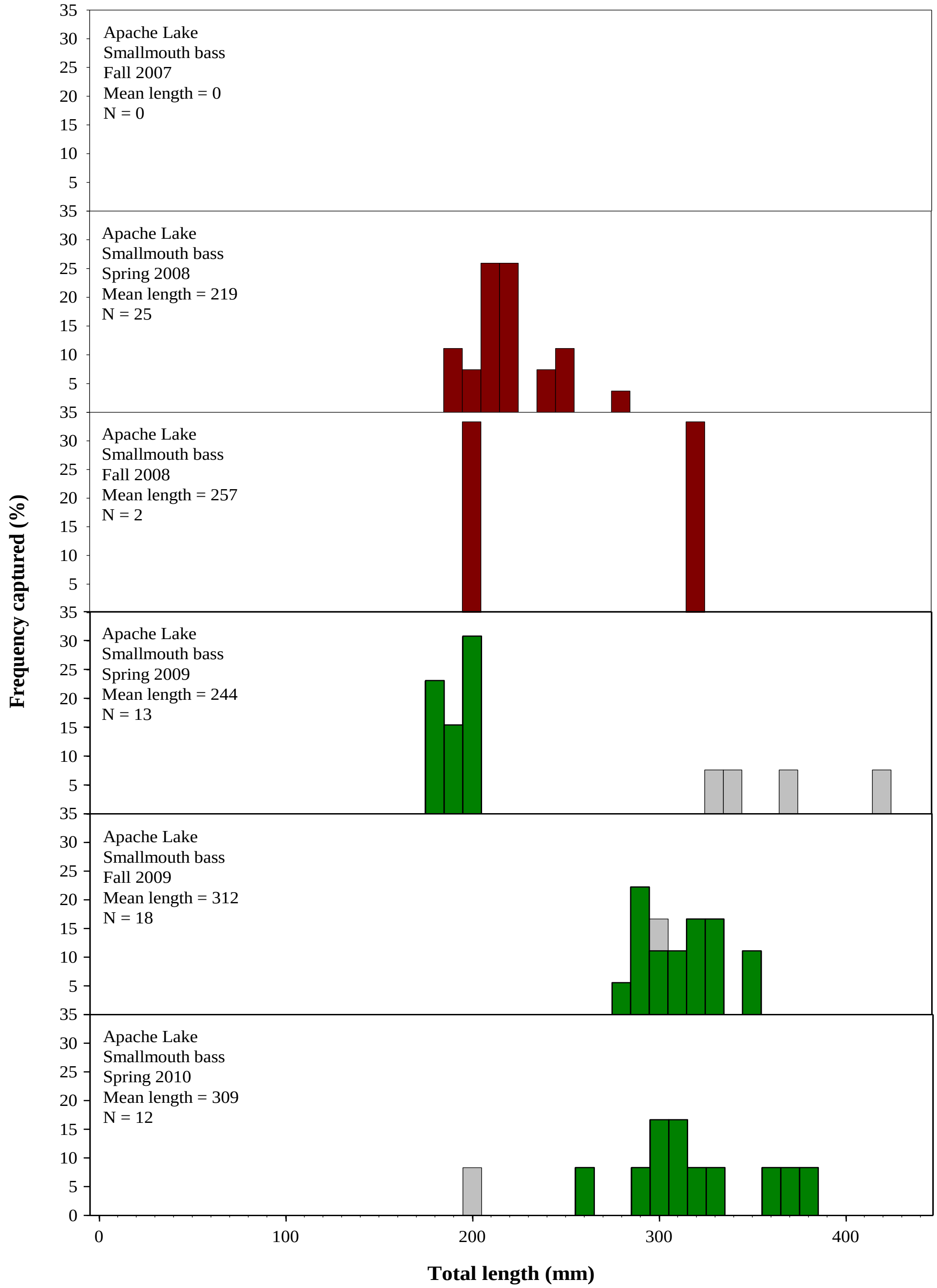

Figure 35. Length frequency distribution of smallmouth bass captured during gill net surveys at Apache Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 stocking of OTC-marked fish (red bars), and the Fall 2008 stocking of coded wire tagged fish (green bars). Golden Algae project, 2007-2010.

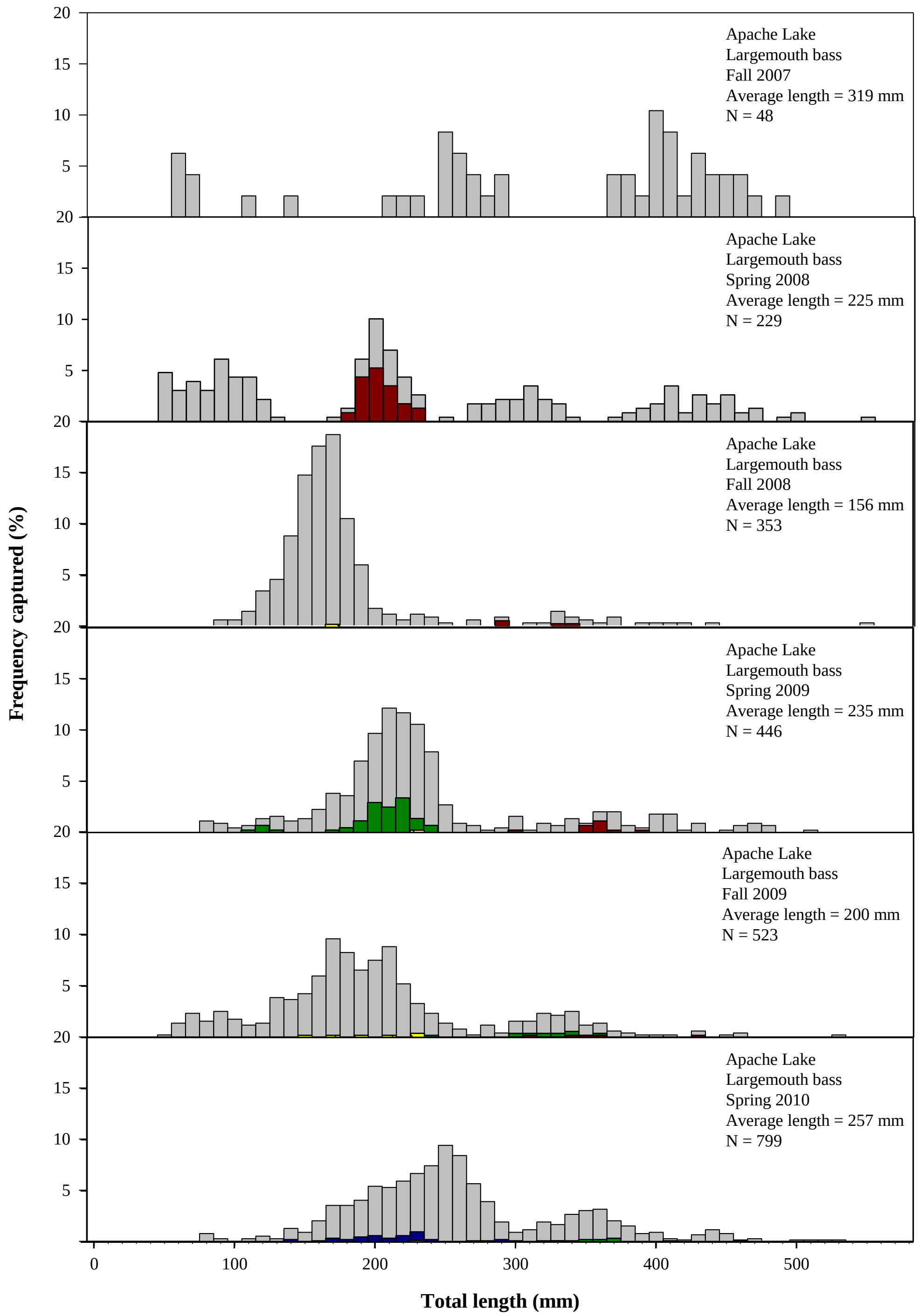

Figure 36. Length frequency distribution of largemouth bass captured during electrofishing surveys at Apache Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars), Fall 2008 (green bars), and Fall 2009 (blue bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) stocking of OTC-marked fish. Golden Algae project, 2007-2010.

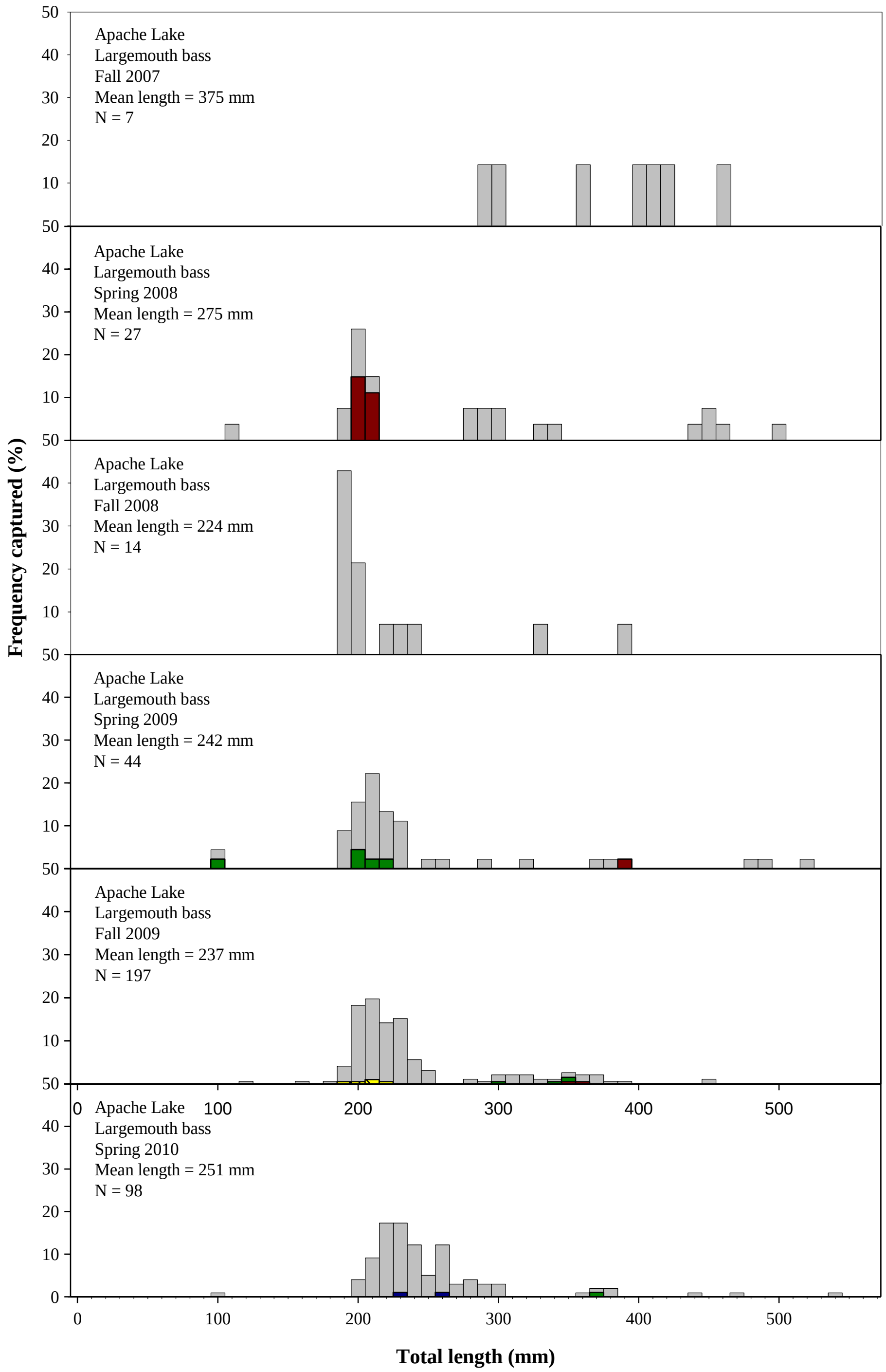

Figure 37. Length frequency distribution of largemouth bass captured during gill net surveys at Apache Lake. Solid shaded bars represent recaptures of fish from the Fall 2007 (red bars), Fall 2008 (green bars), and Fall 2009 (blue bars) stockings of coded-wire tagged fish. Hashed bars represent recaptures of fish from the Spring 2008 (yellow bars) stocking of OTC-marked fish. Golden Algae project, 2007-2010.

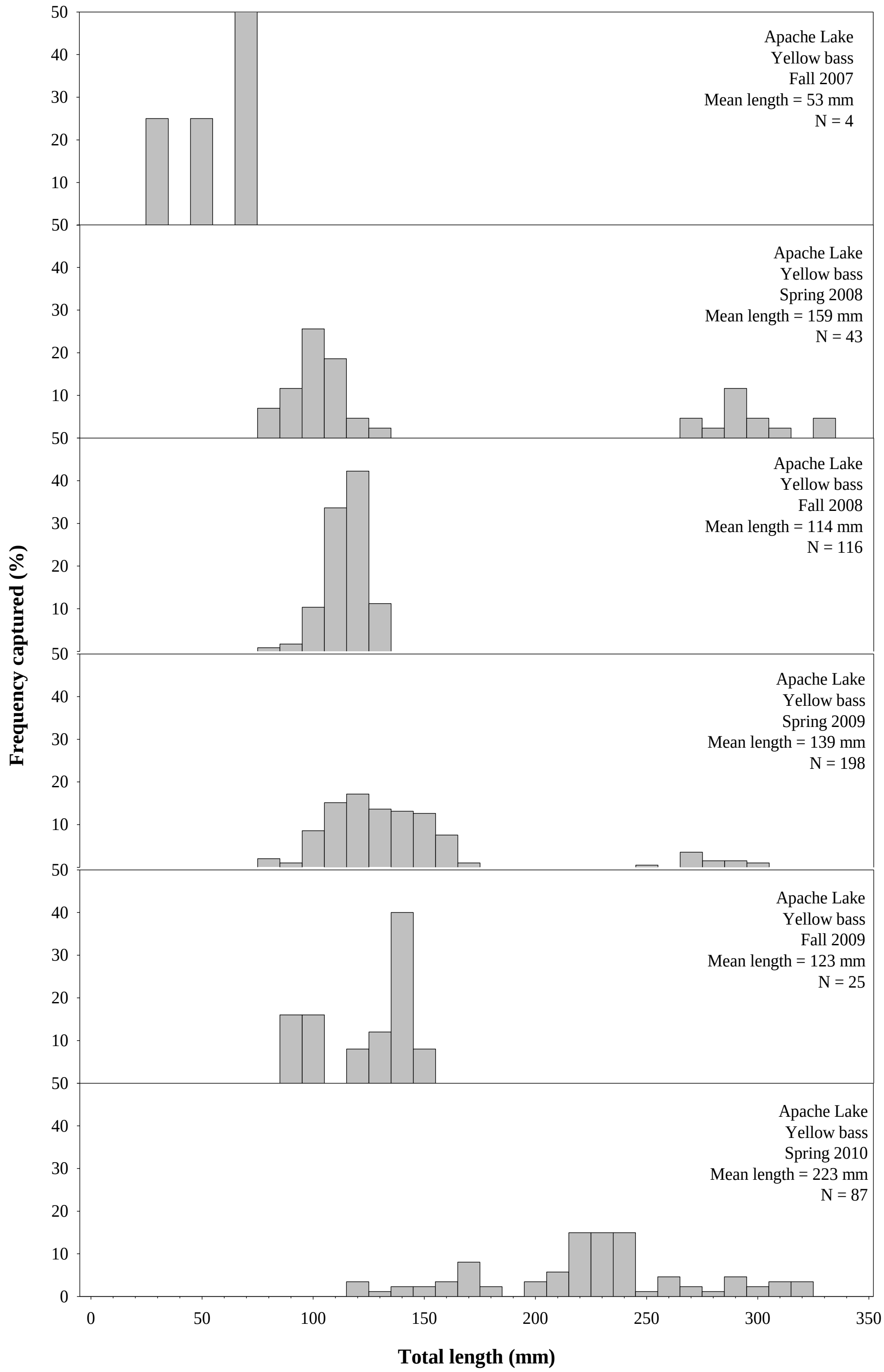

Figure 38. Length frequency distribution of yellow bass captured during electrofishing surveys at Apache Lake. Golden Algae project, 2007-2010.

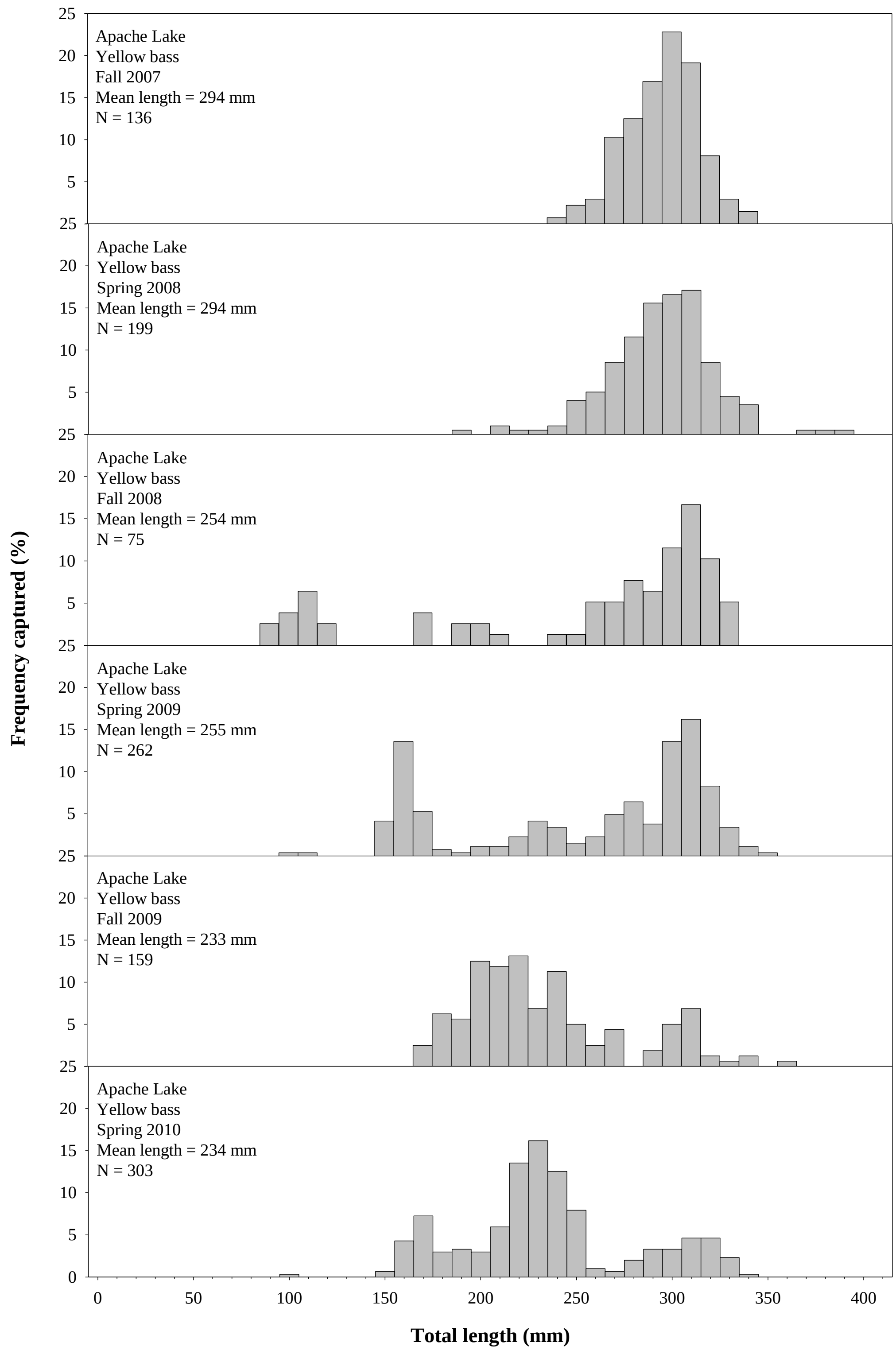

Figure 39. Length frequency distribution of yellow bass captured during gill net surveys at Apache Lake. Golden Algae project, 2007-2010.

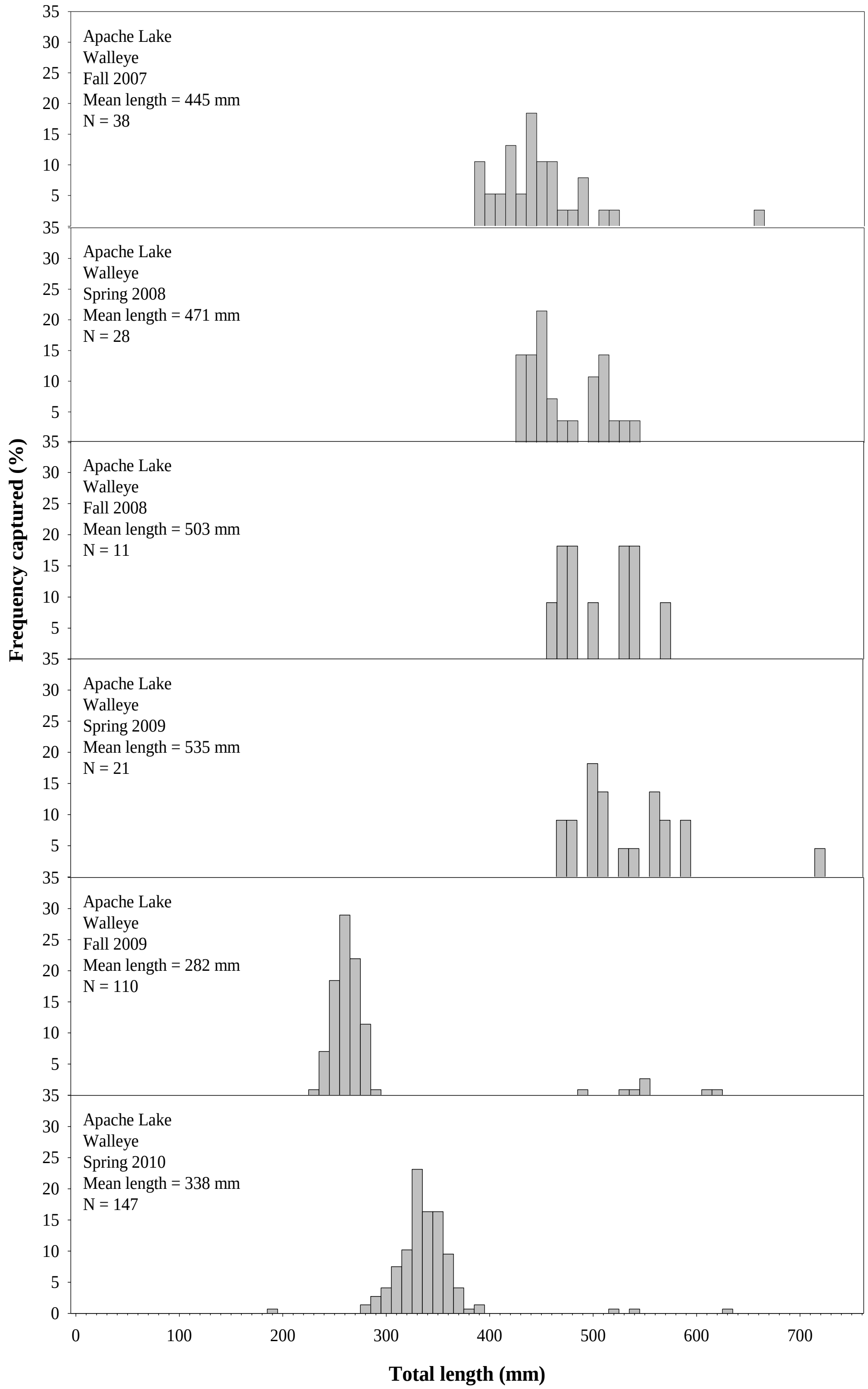

Figure 40. Length frequency distribution of walleye captured during gill net surveys at Apache Lake. Golden Algae project, 2007-2010.

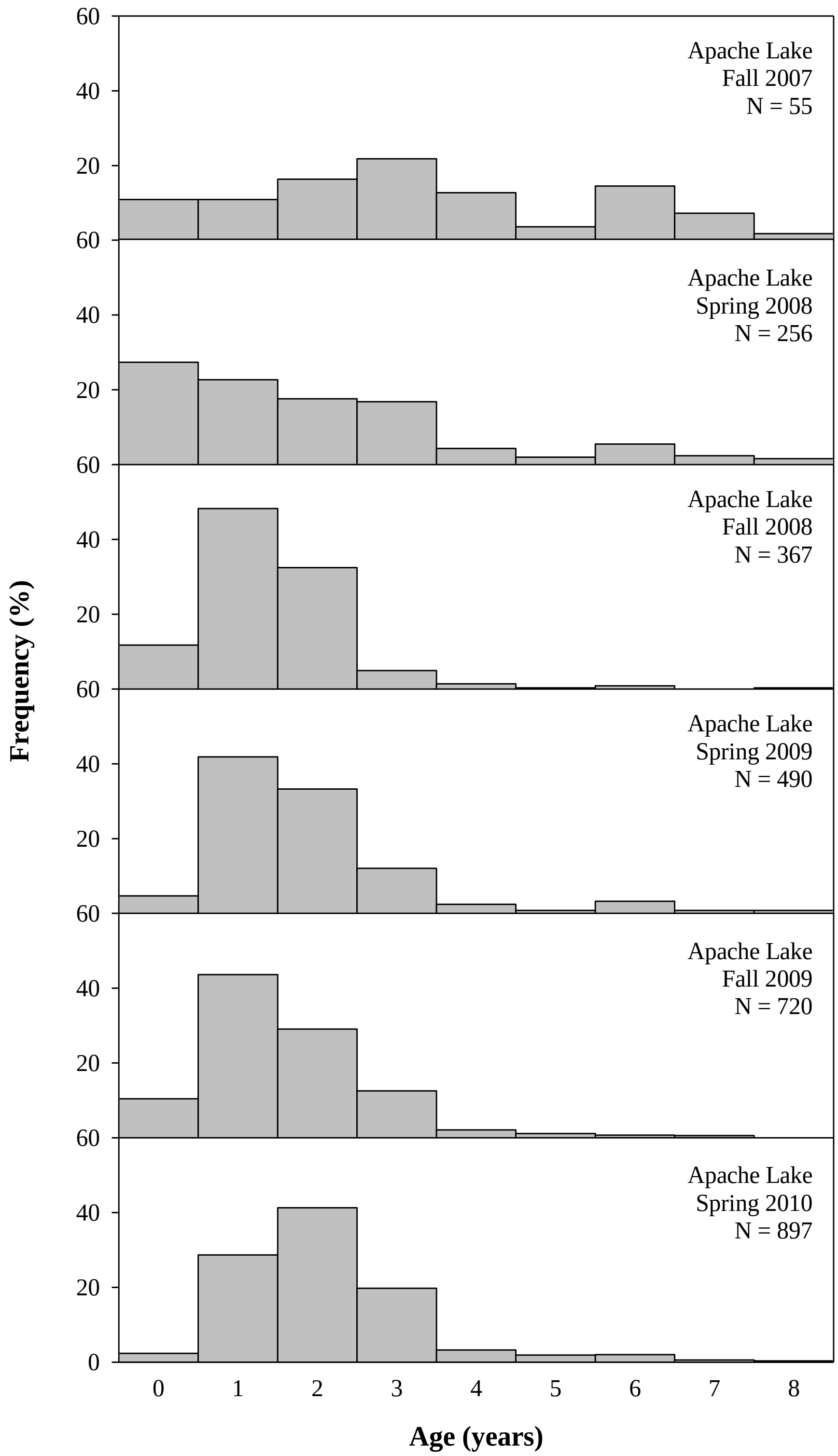

Figure 41. Age-frequency distribution of largemouth bass captured during electrofishing and gill net surveys in Apache Lake. Golden Algae project, 2007-2010.

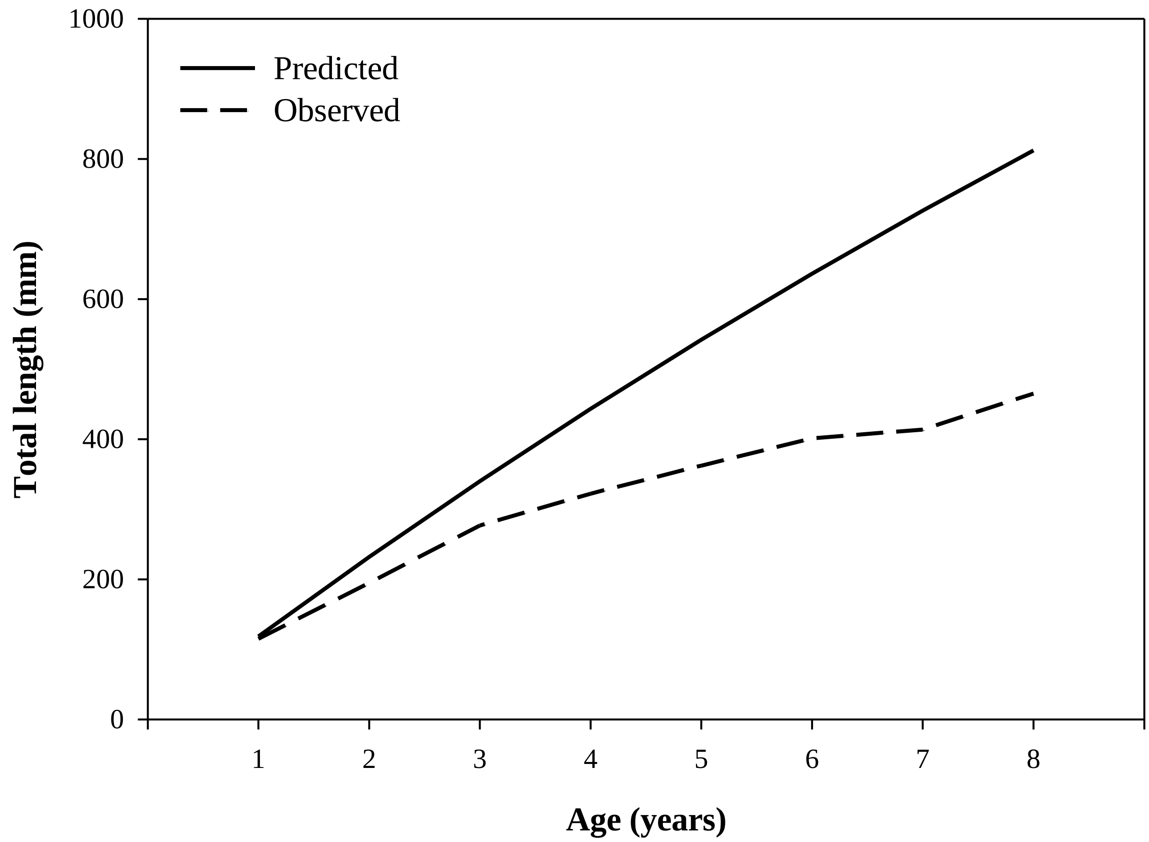

Figure 42. Predicted and observed largemouth bass mean length at age from fish captured during electrofishing and gill net surveys in Apache Lake. Observed estimates (dashed line) were derived from back-calculations of otoliths. Predicted estimates were derived from recapture information of marked fish and then incorporated into a von-Bertalanffy growth model following Wang (1998) methodology.

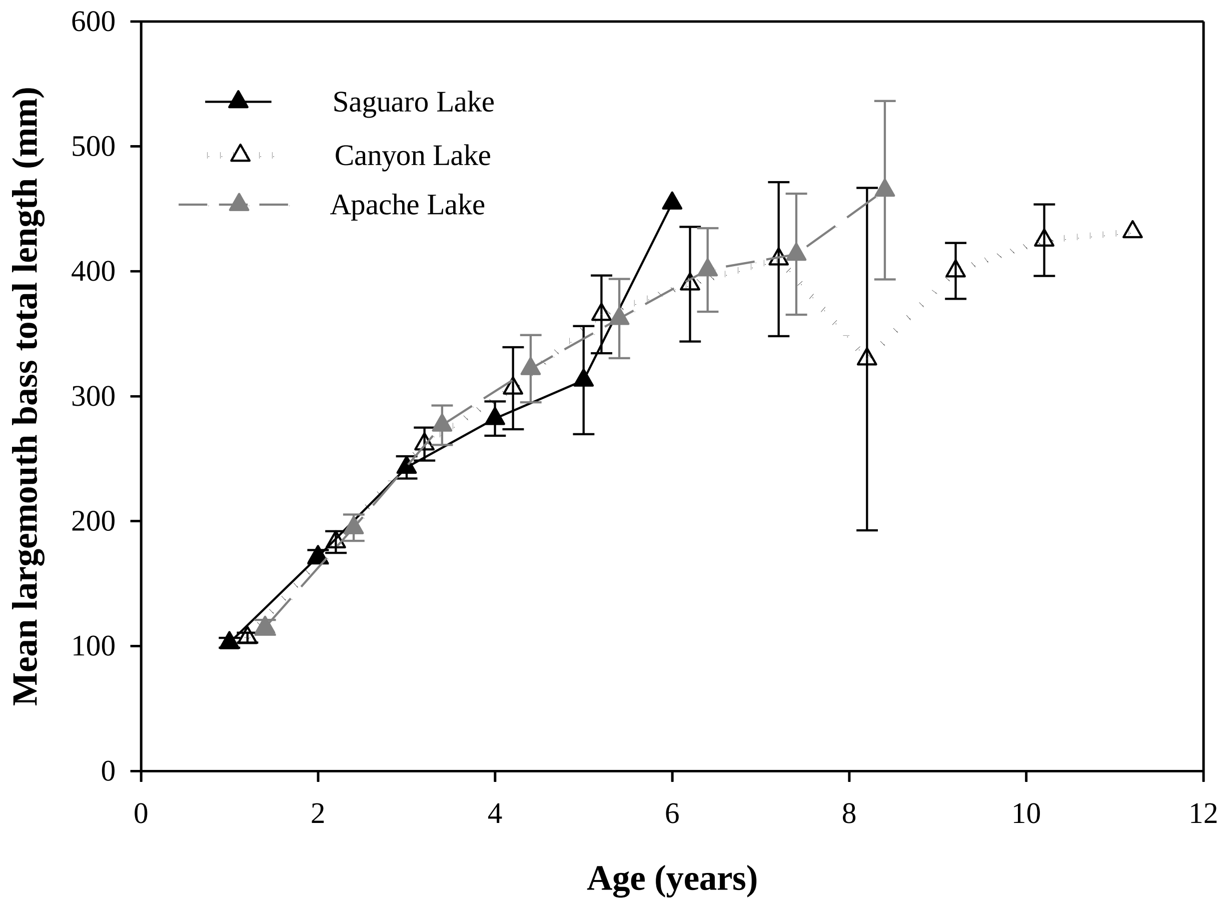

Figure 43. Largemouth bass mean length at age of fish captured during electrofishing and gill net surveys in Saguaro (solid line), Canyon (dotted line), and Apache Lakes (dashed line). Means were derived from back-calculations of otoliths. Bars represent ± 2 standard errors of the mean. Golden Algae project, 2007-2010.

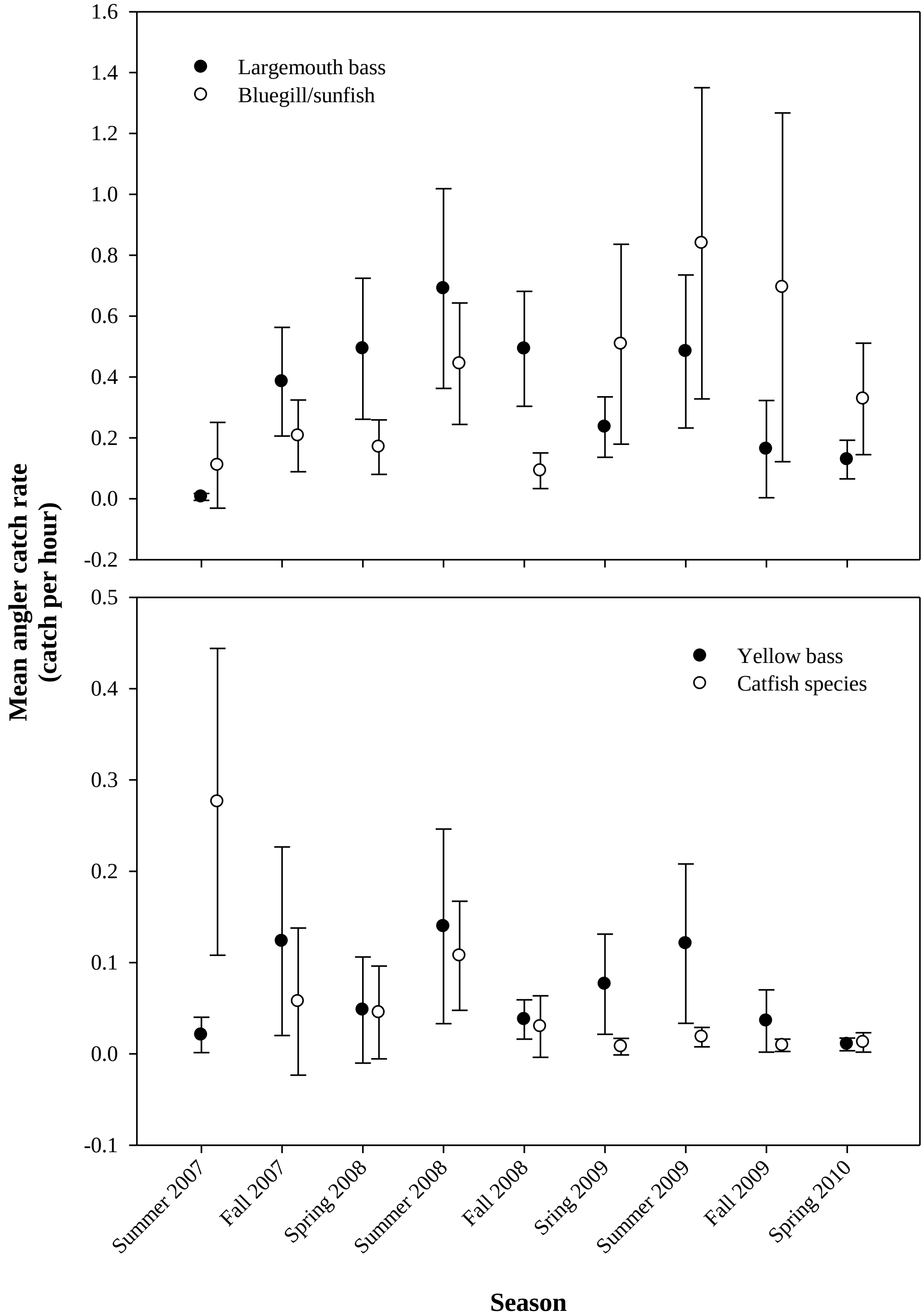

Figure 44. Mean angler catch rates (catch per hour) for largemouth bass and bluegill/sunfish (top panel) and yellow bass and catfish species (bottom panel) in Saguaro Lake. Bars represent ± 2 standard errors of the mean. Golden Algae project, 2007-2010.

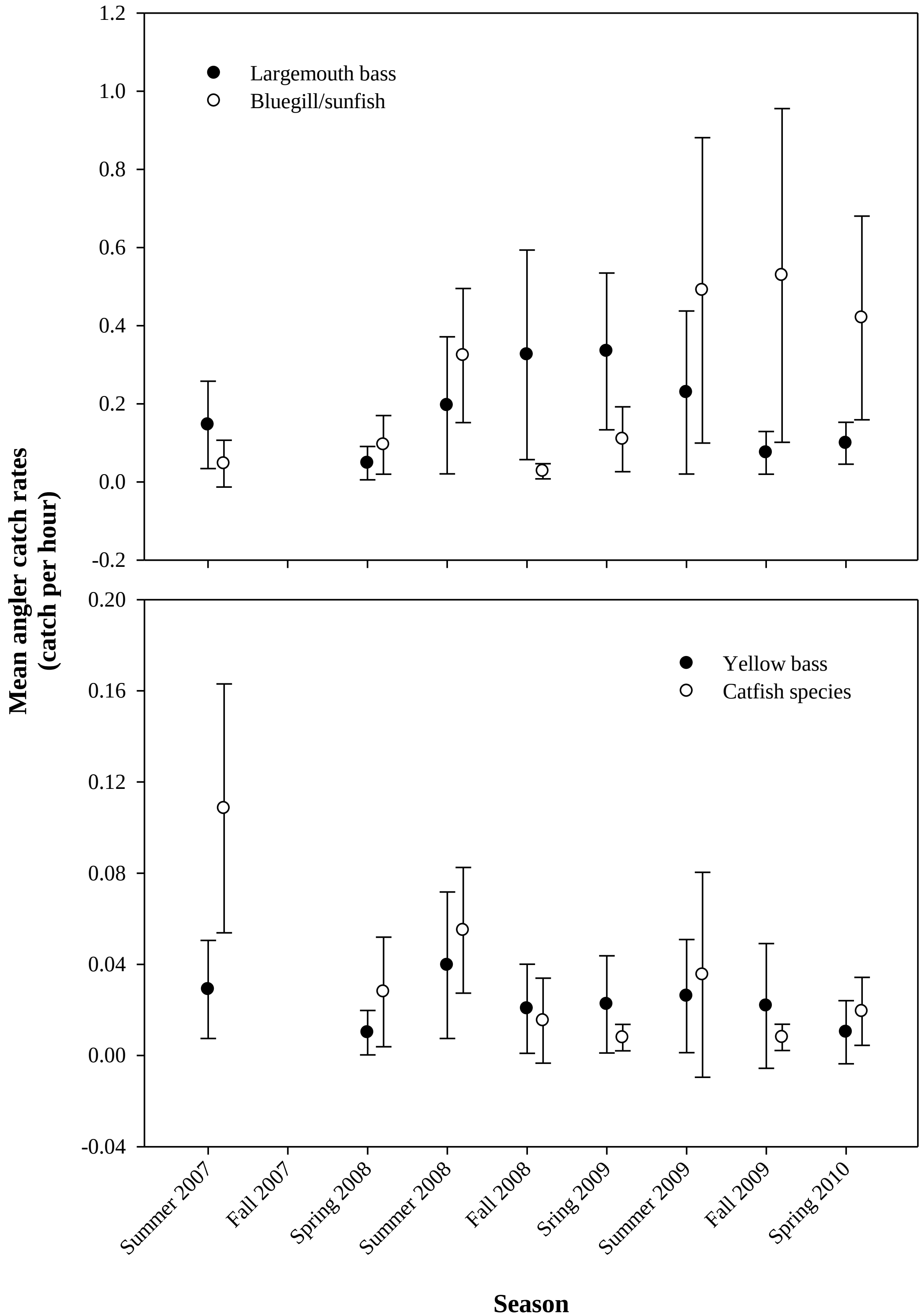

Figure 45. Mean angler catch rates (catch per hour) for largemouth bass and bluegill/sunfish (top panel) and yellow bass and catfish species (bottom panel) in Canyon Lake. Bars represent ± 2 standard errors of the mean. Golden Algae project, 2007-2010.

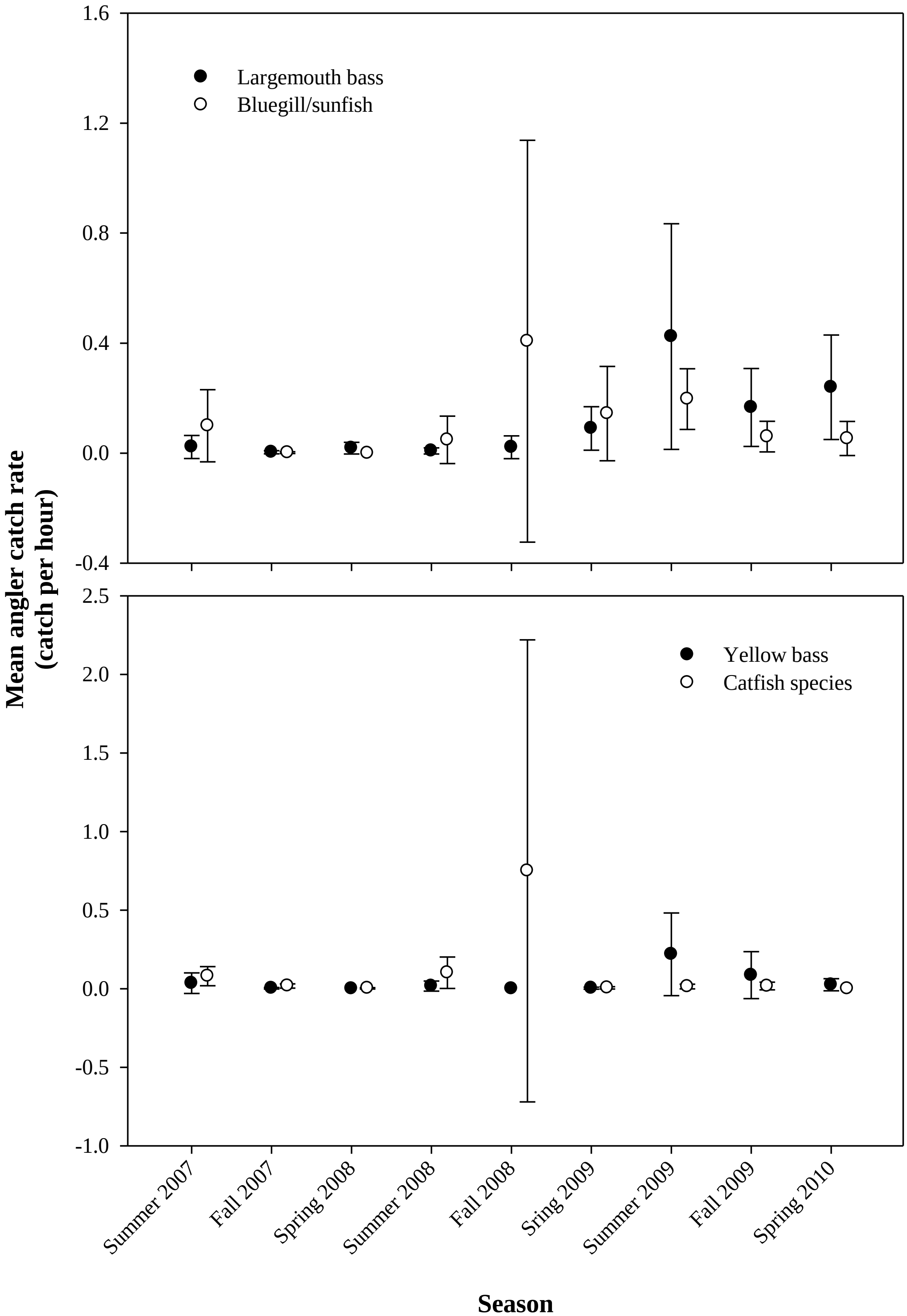

Figure 46. Mean angler catch rates (catch per hour) for largemouth bass and bluegill/sunfish (top panel) and yellow bass and catfish species (bottom panel) in Apache Lake. Bars represent ± 2 standard errors of the mean. Golden Algae project, 2007-2010.

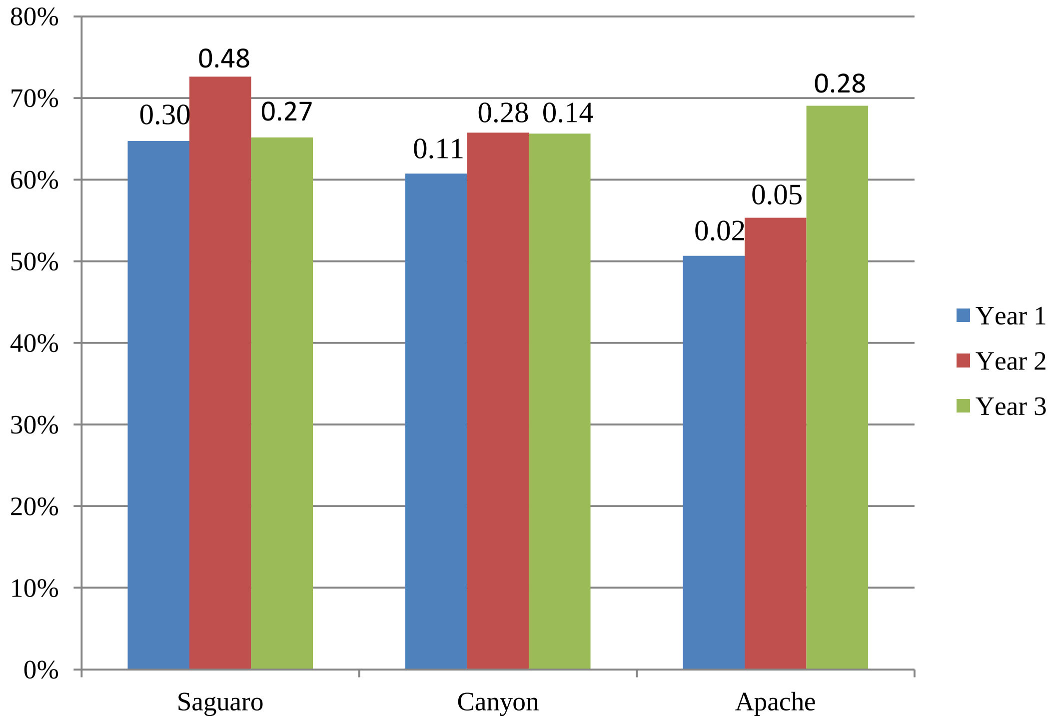

Figure 47. Percent of anglers who rated their fishing experience as Fair, Good, or Excellent at Saguaro, Canyon, and Apache Lakes for each year of this study compared to catch rates for largemouth bass (fish/hr).

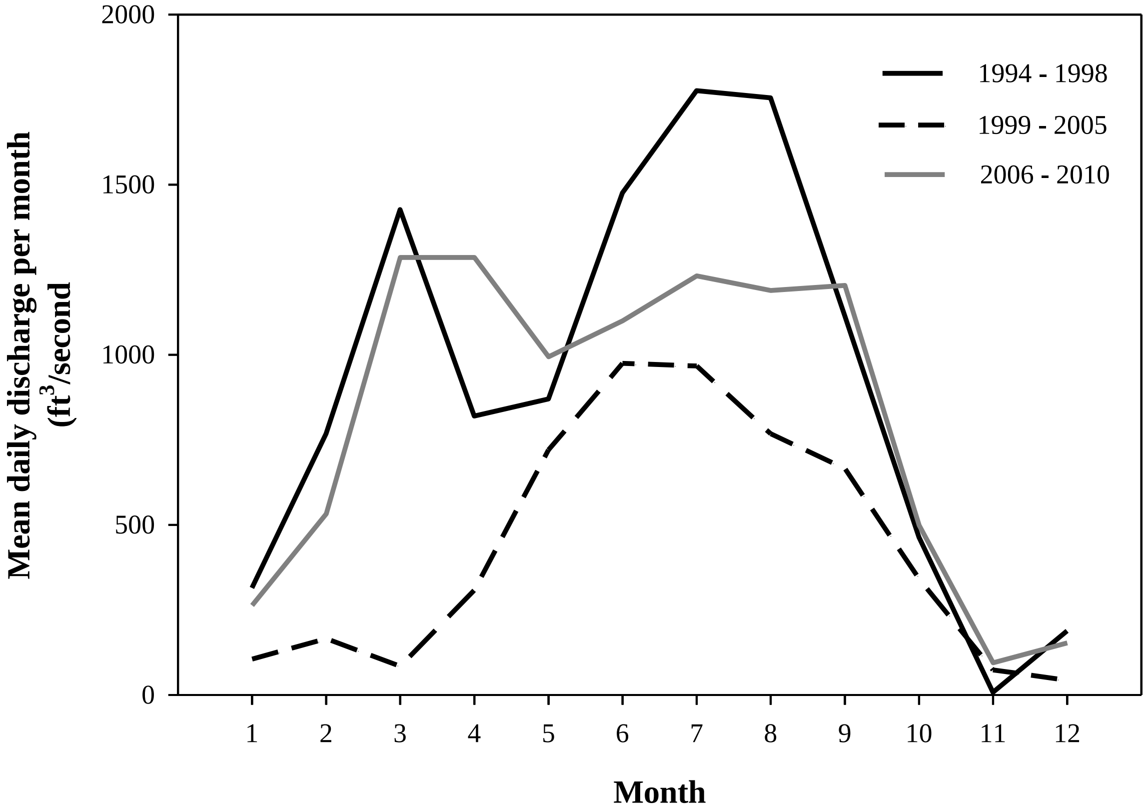

Figure 48. Mean daily discharge per month (ft3/second) from Stewart Mountain Dam, impounding Saguaro Lake, on the Salt River chain of reservoir during 1994-1998 (solid black line), 1999-2005 (dashed black line), and 2006-2010 (solid gray line).

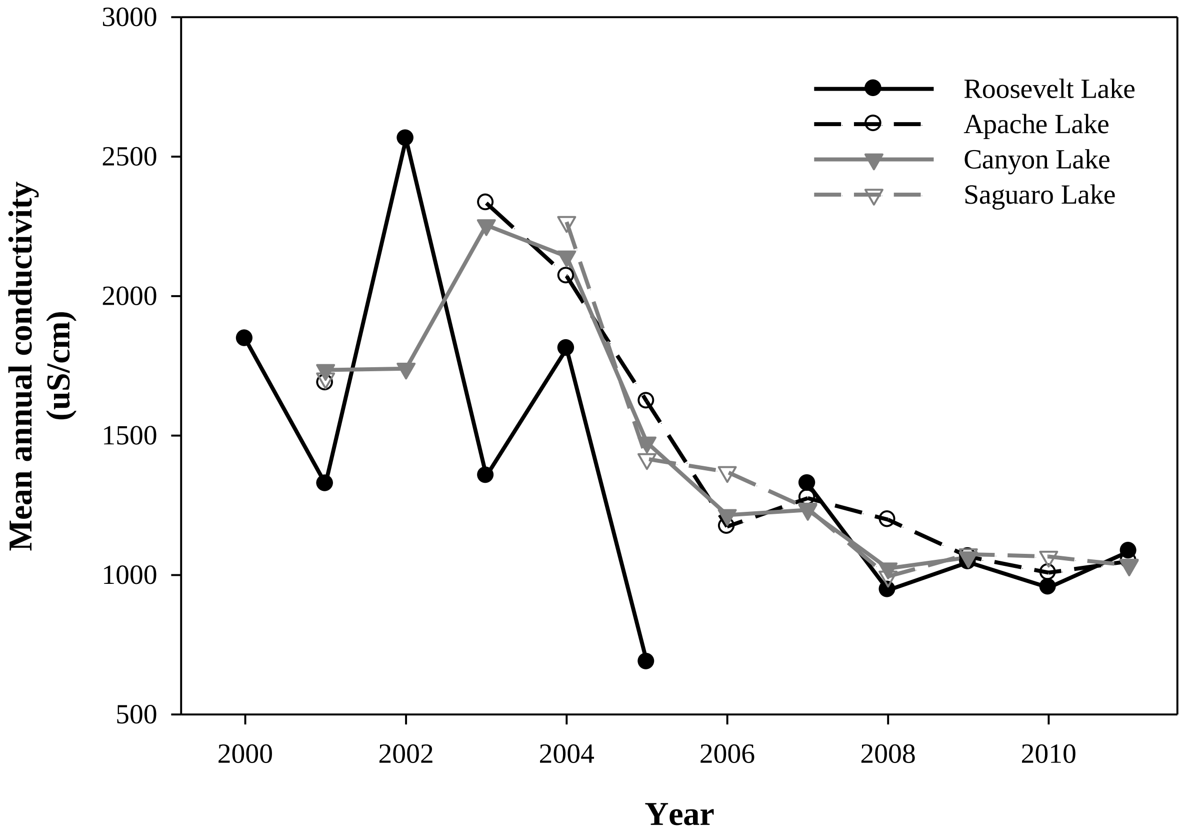

Figure 49. Mean annual conductivity (uS/cm) in Roosevelt Lake (solid circles), Apache Lake (open circles), Canyon Lake (solid triangles), and Saguaro Lake (open triangles), 2000-2011.

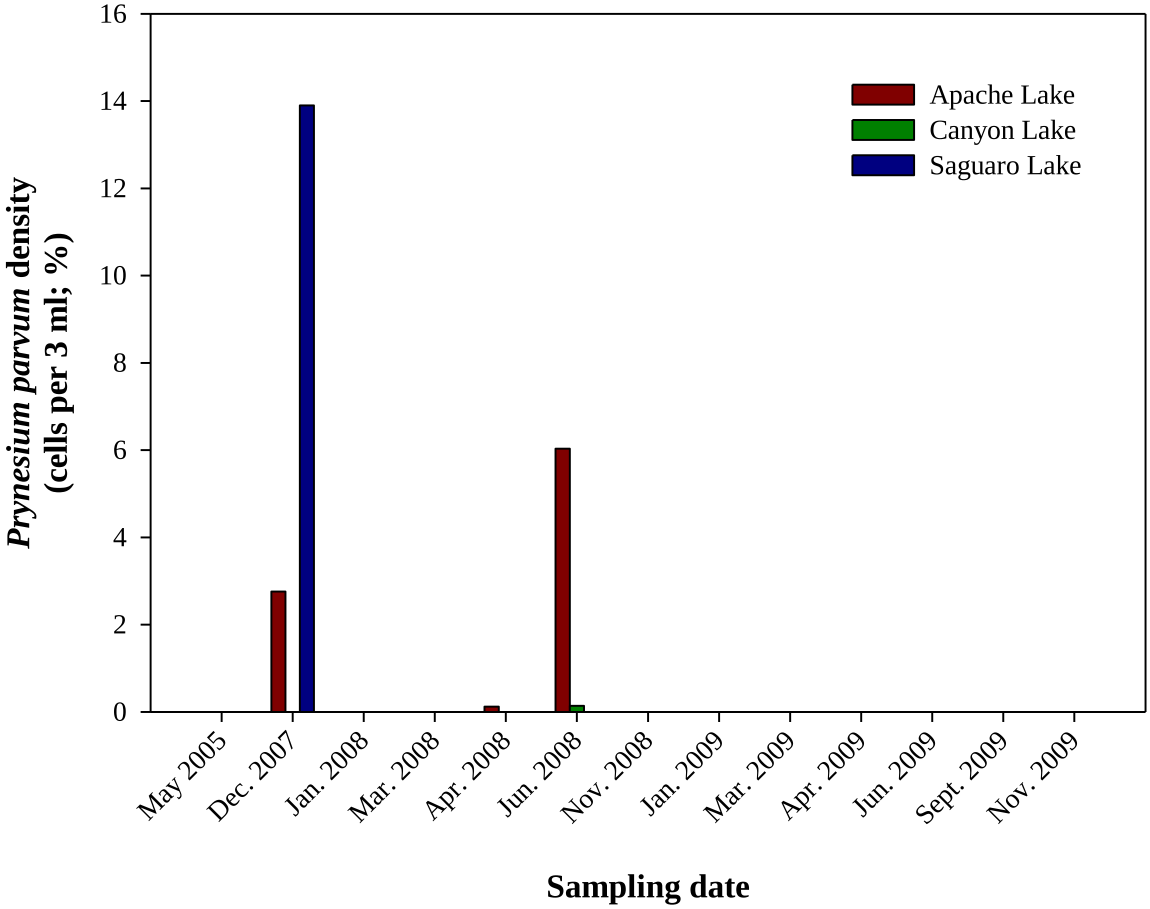

Figure 50. Density of golden algae (Prymnesium parvum; cells per 3 ml) present in samples collected from Apache Lake (solid red bars), Canyon Lake (solid green bars), and Saguaro Lake (solid blue bars), 2005-2009. Samples were only analyzed for Canyon Lake beginning in March 2008. Samples only collected from Apache Lake were analyzed in May 2005.

APPENDIX A. Sampling strata for creel surveys at Saguaro, Canyon, and Apache Lakes from 2007-2010.

Saguaro Exit Strata

Year 1

Summer			Fall			Spring		
Weekdays		Weekends	Weekdays		Weekends	Weekdays		Weekends
0.4		0.6	0.4		0.6	0.4		0.6
Ramp 1		Ramp 2	Ramp 1		Ramp 2	Ramp 1		Ramp 2
0.2		0.8	0.2		0.8	0.2		0.8
T1	T2	T3	T1	T2	T3	T1	T2	T3
0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Year 2

Summer			Fall			Spring		
Weekdays		Weekends	Weekdays		Weekends	Weekdays		Weekends
0.35		0.65	0.4		0.6	0.4		0.6
Ramp 1		Ramp 2	Ramp 1		Ramp 2	Ramp 1		Ramp 2
0.2		0.8	0.25		0.75	0.25		0.75
T1	T2	T3	T1	T2	T3	T1	T2	T3
0.3	0.45	0.25	0.1	0.25	0.65	0.1	0.25	0.65

Year 3

Summer			Fall			Spring		
Weekdays		Weekends	Weekdays		Weekends	Weekdays		Weekends
0.45		0.55	0.4		0.6	0.4		0.6
Ramp 1		Ramp 2	Ramp 1		Ramp 2	Ramp 1		Ramp 2
0.3		0.7	0.3		0.7	0.45		0.55
T1	T2	T3	T1	T2	T3	T1	T2	T3
0.35	0.4	0.25	0.15	0.35	0.5	0.25	0.35	0.4

Canyon Exit Strata

Year 1

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.4		0.6	0.4		0.6	0.4		0.6
Palo Verde		**Laguna**	**Palo Verde**		**Laguna**	**Palo Verde**		**Laguna**
0.7		0.3	0.7		0.3	0.7		0.3
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Year 2

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.35		0.65	0.45		0.55	0.45		0.55
Palo Verde		**Laguna**	**Palo Verde**		**Laguna**	**Palo Verde**		**Laguna**
0.55		0.45	0.75		0.25	0.75		0.25
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.2	0.5	0.3	0.1	0.45	0.45	0.1	0.45	0.45

Year 3

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.4		0.6	0.35		0.65	0.45		0.55
Palo Verde		**Laguna**	**Palo Verde**		**Laguna**	**Palo Verde**		**Laguna**
0.6		0.4	0.7		0.3	0.6		0.4
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.25	0.4	0.35	0.15	0.4	0.45	0.1	0.5	0.4

Apache Exit Strata

Year 1

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.4		0.6	0.4		0.6	0.4		0.6
Main		**Burnt Coral**	**Main**		**Burnt Coral**	**Main**		**Burnt Coral**
0.35		0.65	0.65		0.35	0.65		0.35
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Year 2

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.35		0.65	0.4		0.6	0.4		0.6
Main		**Burnt Coral**	**Main**		**Burnt Coral**	**Main**		**Burnt Coral**
0.5		0.5	0.35		0.65	0.35		0.65
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.1	0.4	0.5	0.1	0.3	0.6	0.1	0.3	0.6

Year 3

	Summer			**Fall**			**Spring**	
Weekdays		**Weekends**	**Weekdays**		**Weekends**	**Weekdays**		**Weekends**
0.35		0.65	0.35		0.6	0.4		0.6
Main		**Burnt Coral**	**Main**		**Burnt Coral**	**Main**		**Burnt Coral**
0.55		0.45	0.6		0.4	0.6		0.4
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
0.1	0.7	0.2	0.15	0.4	0.45	0.1	0.45	0.45

APPENDIX B. Angler interview questionnaire asked during each exit creel survey.

SALT RIVER RESERVOIR EXIT CREEL　　CREEL CLERK____________

MM/DD/YY	SHORE/BOAT	MTWTFSSH	SPECIES	TL(MM)	WT(G)	MARKED
___/___/___	1　0	1 2 3 4 5 6 7 8	_ _ _ _ _	_______	_______	Y/N
PERIOD	LAKE	BOAT LAUNCH	_ _ _ _ _	_______	_______	Y/N
T1 T2 T3	S C A	R1 R2 PV L ML BC	_ _ _ _ _	_______	_______	Y/N
# OF ANGLERS	TIME START	TIME END	_ _ _ _ _	_______	_______	Y/N
____	___:___	___:___	_ _ _ _ _	_______	_______	Y/N

COMMENTS____

Angler 1: Youth/Adult　Zip Code______

How many times have you fished in the last 6 months?_____

How would you rate your fishing experience?

Very Poor　Poor　Fair　Good　Excellent

How many times have you fished at this Lake in the last 6 months? ________

Have you heard of golden algae? Y/N

How many fish did you catch?____

What kind of fish were you trying to catch?_____

SPECIES	# CAUGHT	# HARVESTED
_ _ _ _ _	______	______
_ _ _ _ _	______	______
_ _ _ _ _	______	______
_ _ _ _ _	______	______

What Lake do you fish most often? Other __________

Saguaro　Canyon　Apache　Roosevelt　Pleasant　Bartlett

When you catch a bass (largemouth or smallmouth), what do you do most often?

a. keep all bass of edible size
b. keep some of the bass of edible size
c. release all bass

Have you been interviewed before? Y/N

Bass regulation changes for this lake have been discussed in the past. What is your level of support or opposition to the following management options for bass at this lake?

(Strongly Support - 4, Support - 3, Oppose - 2, Strongly Oppose - 1, No Opinion - 0)

a. A protected slot________ b. Increase the bag limit_______ c. Decrease the bag limit______
d. Catch and release_______ e. Minimum length limit_________

COMMENTS____

Angler 2: Youth/Adult　Zip Code______

How many times have you fished in the last 6 months?_____

How would you rate your fishing experience?

Very Poor　Poor　Fair　Good　Excellent

How many times have you fished at this Lake in the last 6 months? ________

Have you heard of golden algae? Y/N

How many fish did you catch?____

What kind of fish were you trying to catch?_____

SPECIES	# CAUGHT	# HARVESTED
_ _ _ _ _	______	______
_ _ _ _ _	______	______
_ _ _ _ _	______	______
_ _ _ _ _	______	______

What Lake do you fish most often? Other __________

Saguaro　Canyon　Apache　Roosevelt　Pleasant　Bartlett

When you catch a bass (largemouth or smallmouth), what do you do most often?

a. keep all bass of edible size
b. keep some of the bass of edible size
c. release all bass

Have you been interviewed before? Y/N

Bass regulation changes for this lake have been discussed in the past. What is your level of support or opposition to the following management options for bass at this lake?

(Strongly Support - 4, Support - 3, Oppose - 2, Strongly Oppose - 1, No Opinion - 0)

a. A protected slot________ b. Increase the bag limit_______ c. Decrease the bag limit______
d. Catch and release_______ e. Minimum length limit_________

COMMENTS____

Date/Initials entered__________　　Date/Initials checked__________

APPENDIX C. Datasheet for roving counts of boat and shoreline anglers during creel surveys.

SALT RIVER RESERVOIR
ROVING COUNT

MM/DD/YY	WEEKDAY (1) OR WEEKEND (2)	PERIOD	LAKE
___/___/___	1 2	T1 T2 T3	S C A

COUNT START TIME (1)	COUNT END TIME (1)	# OF SHORE ANGLERS
__ __ : __ __	__ __ : __ __	____
COUNT START TIME (2)	COUNT END TIME (2)	# OF SHORE ANGLERS
__ __ : __ __	__ __ : __ __	____

CREEL CLERK[1]

Boat	Beginning hours	Ending hours

[1] Updated 9-3-08

APPENDIX D. Recommendation for fish kill response plan.

Golden Alga Fish Kill Response Plan

Golden alga was discovered in Arizona in 2005 and has been found in all of the reservoirs (Saguaro, Canyon, Apache, and Roosevelt Lakes) and in the Salt River above Roosevelt Lake located on the Tonto National Forest. Golden alga was likely present as early as 2001 following a substantial die-off of Asian clam (*Corbicula fluminea*) in Saguaro Lake. The first fish kill occurred in July 2003 at Apache Lake and was composed mostly of threadfin shad (*Dorosoma petenense*). A more extensive fish kill occurred the following year between March 30 and June 10, 2004, extensively killing multiple species of fish including threadfin shad, largemouth bass (*Micropterus salmoides*), flathead catfish (*Pylodictus olivaris*), channel catfish (*Ictalurus punctatus*), and bluegill (*Lepomis macrachirus*), at Saguaro, Canyon, and Apache Lakes. Between April 6 and July 10, 2005, a large fish kill was observed at Saguaro and Canyon Lakes, affecting many large-bodies sport fish species. Water samples taken during the kill identified the presence of golden algae. Additional golden alga related fish kills occurred the next year at Saguaro and Apache Lakes, but to a lesser degree.

To enhance the remaining wild population of largemouth and smallmouth bass (*Micropterus dolomieu*) at Saguaro, Canyon, and Apache Lakes following the 2005 fish kills, the Arizona Game and Fish Department implemented a temporary supplemental stocking program and a research study that evaluated the effectiveness of the stocking program. Results of this study are summarized below in the form of a response plan to future fish kill events (Figure 1).

For more information on this study please refer to the technical report:

Stewart, W.T., A.S. Makinster, A. K. Vasey, and L.D. Avenetii. 2012. Salt River Resevoir Golden Alga Project. Arizona Game and Fish Department, Research Branch, Technical Guidance Bulletin No. xx. Phoenix. 144 pp.

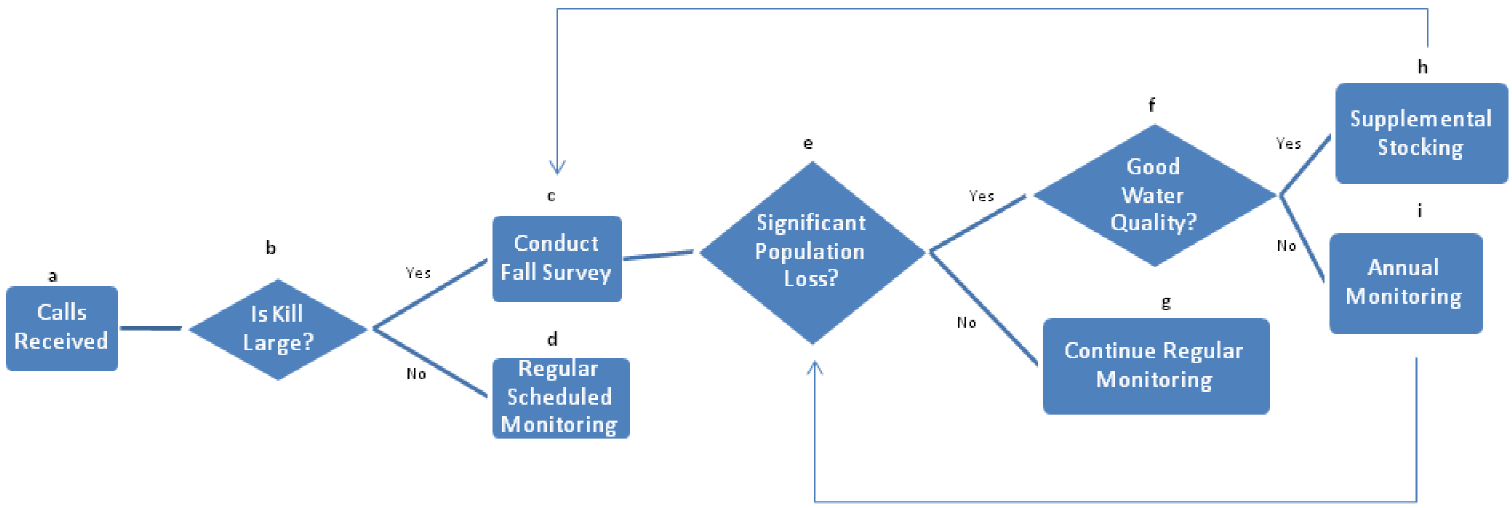

Figure 1. Process flow chart for responding and evaluating fish kills at the Salt River Reservoirs

a. Calls Received

Fish kill investigations begin at the initial call indicating a fish kill and proceeds through the various stages to help in the preparation of a fish kill report. These stages are outlined in a fish kill protocol which was developed as part of the Golden Alga project. Defining the magnitude and location of a fish kill is essential for biologists and managers to make informed decisions about the severity of the kill, regulation changes, need for stocking, and potential long-term effects to the ecosystem.

b. Is Kill Large?

As described in the fish kill protocol a decision will be made to determine if the kill is large enough to warrant an investigation. A warranted field investigation must occur when reports are received indicating a fish kill consisting of multiple sportfish species numbering in the hundreds and/or threatened or endangered species or a pollutant is indentified. The kill responses will be a priority and the appropriate number of personnel will respond depending on the magnitude of the kill and the size of the waterbody. The Department's Water Quality Program and Regional Fish Program have the responsibility to co-investigate fish kills and will direct and coordinate the Department's response. As primary investigators the Regional Fish Program Manager is responsible for coordinating the sampling including, determining the extent of the kill and quantifying the kill. The water quality program is responsible for coordinating water quality and tissue/specimen collection. Investigators should rely upon all available resources (e.g., Regional personnel, wildlife managers, research biologists, volunteers) to assist in fish kill examination. A large kill will be lake wide and constitute thousands of dead multiple aged sportfish species.

c. Conduct Fall Survey

Electrofishing and gill netting surveys are planned on a regular basis often happening once every two to three years on the Salt River reservoirs. If a fish kill investigation reveals a large fish kill, an electofishing and gill netting survey should be conducted the next fall after the fish kill. Results from our study identified electrofishing as the most efficient capture technique to reliably detect changes in largemouth bass populations within each reservoir studied. While the number of sites sampled were likely insufficient to detect inter-annual changes in populations, they were adequate to confidently detect large-scale changes typically associated with golden alga or other large scale fish kills. Results from our study suggest that 24 sites at Saguaro and Canyon Lakes, and 30 sites at Apache Lake are sufficient to detect at least a 45% change with 80% confidence at any of these lakes. This change should be adequate to detect a substantial loss in the largemouth bass and blue gill populations that may warrant future action. A similar large-scale change can be detected for catfish and yellow bass by conducting gill net surveys with the same sample size that is recommend for electrofishing.

d. Regular Scheduled Monitoring

If the kill is not extensive then conduct surveys as regularly scheduled. Results from our study indicate that 24 sites at Saguaro and Canyon Lakes, and 30 sites at Apache Lake are sufficient to detect at least a 45% change with 80% confidence at any of these lakes. This change should be adequate to detect a substantial loss in the largemouth bass population that may warrant future action. However, if inter-annual changes in the largemouth bass population are needed a much larger sample size will be required.

e. Significant Population Loss?

A significant loss to the population should be focused on the major sportfish species lost at each reservoir. In most instances, largemouth bass and catfish are specific species that are most targeted by anglers (Table 1). However, at all reservoirs the majority of anglers prefer to catch anything which includes sportfish species such as smallmouth bass, yellow bass, and bluegill. These less frequently targeted species however, do make up the majority of the total catch from each reservoir and need equal consideration when determining the extent of the fish kill.

Table 1.Percentage of species targeted by angler at Saguaro, Canyon and Apache Lakes. ‘Any Bass’ refers to largemouth and smallmouth bass and the ‘Other’ category includes carp, crappie and walleye.

Species targeted	Saguaro Lake	Canyon Lake	Apache Lake
Any species	43.9%	52.2%	58.7%
Largemouth Bass	29.8%	23.6%	8.8%
Any Bass	12.5%	10.7%	13.0%
Catfish	4.3%	5.6%	8.5%
Bluegill or sunfish	5.0%	3.1%	1.5%
Trout	2.0%	3.4%	2.3%
Yellow Bass	1.7%	0.2%	2.9%
Smallmouth Bass	0.2%	0.2%	1.8%
Other	0.4%	1.1%	2.5%

Parameters on what constitutes a kill depend on the structure of the population that exists following the kill. If sportfish species that were abundant or maintained at sustainable levels prior to the kill are completely missing post kill then this would be considered a significant loss. Year class losses will vary from species to species. For largemouth bass we recommend the following indicators as trigger points for stocking and monitoring.

1. If fall CPUE for largemouth bass greater than 200 mm (8 inches) = 0 fish/hr, then consider stocking.

2. If fall total CPUE for largemouth bass is less that 10 fish/hr then consider stocking.

3. If fall CPUE for largemouth bass greater than 200 mm (8 inches) is greater than 0 fish/hr, but less than 10 fish/hr then monitor annually.

4. If fall CPUE for largemouth bass greater than 200 mm (8 inches) is greater than 10 fish/hr, then resume monitoring as scheduled.

f. Good Water Quality?

To avoid stocking fish that soon die due to another fish kill it is important that water quality conditions are suitable for fish to survive for a longer term allowing for a return on our investment and a benefit to the angler. Beginning in 2001 when the first corbicula die off was observed, conductivity within each lake remained at or above 1,500 uS/cm until 2006, and decreased within each lake each following year through 2011 (Figure 2). The upper most reservoir on the chain of lakes, Roosevelt Lake, drives the conditions in the lower reservoirs and should be used as the gauge to determine water quality conditions. A large volume of surface runoff (low salinity) will dilute the constant high salinity spring flows from the Salt River above Roosevelt and the inevitable increase in salinity from evaporation. A large reservoir volume and lower conductivity would provide a few years of suitable downstream environmental conditions with little or no surface run off from the Salt River or Tonto Creek. To be confident that adequate conditions exist to support survival of stocked fish, conductivity at Roosevelt should be less than 1,000 uS/cm and reservoir capacity should be greater 80% . Under these conditions we estimate that water quality will be good enough where we do not expect a fish kill for at least two years. Water quality will be monitored regularly at these reservoirs.

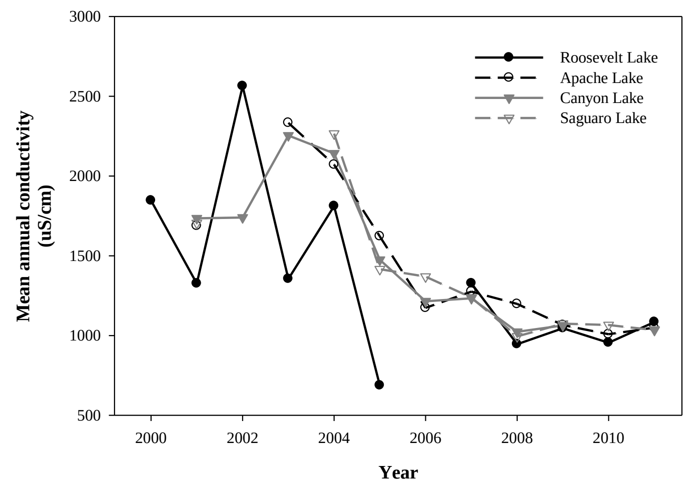

Figure 2. Mean annual conductivity (uS/cm) in Roosevelt Lake (solid circles), Apache Lake (open circles), Canyon Lake (solid triangles), and Saguaro Lake (open triangles), 2000-2011.

g. Conduct Regular Monitoring

If the kill is not extensive then conduct surveys as regularly scheduled. Results from our study indicate that 24 sites at Saguaro and Canyon Lakes, and 30 sites at Apache Lake are sufficient to detect at least a 45% change with 80% confidence at any of these lakes. This change should be adequate to detect a substantial loss in the largemouth bass population that may warrant future action. However, if inter-annual changes in the largemouth bass population are needed a much larger sample size will be required.

h. Supplemental Stocking:

The primary objective of the golden alga project was to evaluate stocking strategies for largemouth bass. We set out to evaluate whether stocking fingerling largemouth bass (1-2") in high numbers provided a higher return to anglers than stocking lower number of catchable largemouth bass (6-8"). Roughly 12 times the number of fingerlings was stocked into each reservoir versus catchable largemouth bass. All stocked fish during this study were marked. In order for the stocking of fingerlings to be the most cost-effective method, we expected the return of stocked fingerlings to be at least 1.8 times higher than the return of catchable fish. Further, knowledge of a returned catchable fish was inexpensive and immediate as those fish were marked with a tag that could be detected in the field. This was not the case for recapture fingerlings which were chemically marked where sacrificing the fish and specialized equipment was required to process each sample taken. Concerns of sacrificing too many fish limited our ability to confidently evaluate the return of stocked fingerlings. However, given the high numbers of fingerlings stocked during the study, we expected higher returns of these fish in reservoirs that were essentially reset following large fish kills. Our results combined with similar studies done on other systems conclude a higher return of catchable fish and we suggest stocking catchable largemouth bass following a major fish kill. We recommend that all stocked fish are marked and a follow up survey should be conducted the October or November following the supplemental stocking to assess the population status, contribution of stocked fish to the wild population and to determine if additional stocking is needed. Stocking numbers should not exceed those defined in the warm water stocking protocol.

i. Annual Monitoring

If conditions at Roosevelt Lake are poor following a fish kill then water quality and fish monitoring should be continued annually. We suggested monitoring fish in the fall because that is the time of year when young-of-year largemouth bass are vulnerable to our electrofishing gear and will provide a good indication of recruitment. Our creel data showed that over 50% of anglers rated their fishing experience as fair, good, or excellent despite low catch rates in certain years for largemouth bass. However, it was evident at Apache Lake that there was a significant difference in angler satisfaction when largemouth bass catch rates were low. When comparing angler catch rates to electrofishing catch rates we see a similar trend. Immediately following the 2005 fish kill, electrofishing catch rates for largemouth bass at all reservoirs were less than 20 fish/hr. Using angler satisfaction as a gauge for acceptable catch rates we recommend that annual monitoring be continued until electrofishing catch rates exceed 20 fish/hr.

The recommendations in this report are to inform managers on how to proceed in the event of future fish kills at Saguaro, Canyon, and Apache Lakes. It is not the intent for the triggers outlined in this document to be fixed, but rather adapted as we learn more about how fish populations in each reservoir respond to future fish kills. It is critical that we continue to study future stocking efforts to better refine the necessary stocking levels to meet the needs of our warm water anglers.