

PERFORMANCE REPORT

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INLAND FISHERIES DIVISION MONITORING AND MANAGEMENT PROGRAM

2015 Survey Report

Waco Reservoir

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SURVEY AND MANAGEMENT SUMMARY

Fish populations in Waco Reservoir were surveyed in 2015 using electrofishing and in 2016 using trap nets and gill nets. This report summarizes the results of the surveys and contains a management plan for the reservoir based on those findings.

- **Reservoir Description:** Waco Reservoir is an 8,465-acre impoundment supplied by the North, Middle, and South Bosque Rivers within the Brazos River Basin, McLennan County. Water levels were above conservation pool (462 feet above mean sea level [MSL]) during 2015 electrofishing and 2016 trap net surveys and at conservation pool during 2016 gill net surveys. Fish habitat at the time of sampling was dominated by natural, rock, and gravel shorelines. Bank and boat access (12 ramps) to the reservoir is abundant.
- **Management history:** Important sport fish include Largemouth Bass, White Bass, palmetto bass, White Crappie, and catfishes. The management plan from the 2012 survey report included annual monitoring of noxious vegetation; enhancing aquatic habitat using native vegetation; investigating alternative funding sources for habitat enhancement; enhanced monitoring of the palmetto bass population; stocking Florida Largemouth Bass fingerlings in 2013 and 2015; and addressing invasive aquatic species threats to Waco Reservoir.
- **Fish Community**
 - **Prey species:** All major forage species were collected at rates above their historical average. Most Gizzard Shad were a suitable prey size and available to predators.
 - **Catfishes:** Blue and Channel Catfish were present in ample numbers, and individuals of both species were in good to excellent condition. Flathead Catfish were not collected.
 - **Temperate Bass:** White Bass were sampled at historically high rates over the previous three surveys. Palmetto bass catch rates continued to increase to a historic high in 2016.
 - **Largemouth Bass:** Largemouth Bass catch rate improved since previous surveys and was higher than the average. Body condition was excellent, and the proportion of Florida alleles was greater than prior surveys.
 - **White crappie:** White Crappie were collected at a rate similar to the historical average. Black Crappie were collected at an historic high catch rate.
- **Management Strategies:** Continue managing Waco Reservoir's fisheries, except Blue Catfish, with statewide regulations. Conduct electrofishing and trap netting in 2019 and gill netting in 2018 and 2020. Discontinue annual monitoring for hydrilla. Continue native aquatic plant enhancement efforts. Evaluate hybrid Striped Bass fry versus fingerling recruitment increasing sampling effort to collect age structures. Support partners' efforts to prevent the spread of zebra mussels to or from Waco Reservoir. Work closely with the Friends of Lake Waco chapter to identify angler needs and facilitate action.

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INTRODUCTION

This document is a summary of fisheries data collected from Waco Reservoir in 2012-2016. The purpose of the document is to provide fisheries information and make management recommendations to protect and improve the sport fishery. While information on other species of fishes was collected, this report deals primarily with major sport fishes and important prey species. Historical data are presented with the 2015-2016 data for comparison.

Reservoir Description

Waco Reservoir is an 8,465-acre impoundment supplied by the North, Middle, and South Bosque Rivers within the Brazos River Basin, McLennan County. It is operated by the U.S. Army Corps of Engineers and primary water uses included flood control, municipal water supply and recreation. Mean and maximum depths are 28 and 92 feet, respectively. Waco has a drainage area of 1,670 square miles, a storage capacity of 104,100 acre-feet, and a shoreline length of 60 miles (Table 1). Water level was 2.5 feet below conservation pool (462 feet above MSL) during 2015 electrofishing and at or above full pool during 2016 trap net and gill net surveys (Figure 1). Fish habitat at the time of sampling was dominated by natural, rock, and gravel shorelines. Exotic hydrilla was first documented in the reservoir in 2003. The high water levels during 2007 reduced hydrilla to just a few plants, but it had expanded to 9.4 acres as documented in the 2011 survey. Recent surveys have found minimal or no hydrilla present. Bank and boat access (12 ramps) on the reservoir is good, but there are currently no facilities for disabled constituents (Table 2). More information about Waco Reservoir and its facilities can be obtained by visiting the Texas Parks and Wildlife Department's (TPWD) web site at www.tpwd.state.tx.us and navigating within the *Fishing* link.

Management History

Previous management strategies and actions: Management strategies and actions from the previous survey report (Tibbs and Baird 2012) included:

1. Monitor the reservoir for noxious vegetation annually through 2015.
Action: Noxious vegetation surveys were conducted annually to monitor for hydrilla and other potentially noxious species. The infestation never posed a threat to reservoir access, and no control efforts were made. Existing hydrilla was reclassified as a Tier III infestation in 2013, and only required monitoring every four years.
2. Enhance native vegetation in the reservoir and investigate alternative funding sources for aquatic habitat enhancement.
Action: Native plants were grown in the Waco Wetland nursery and planted in Reservoir in 2012, 2013 and 2014 with the help of summer interns and volunteers from the Student Conservation Association. Water-willow plants were also collected from existing stands in the reservoir and transplanted in other locations. Buttonbush were purchased from a private source using funds from the Baylor Chapter of the Society of Environmental Toxicology and Chemistry and planted in the reservoir. A Friends of Waco Reservoir Chapter was formed in 2014 and they assisted with funding to create habitat in the form of "crappie condos". This, combined with previous efforts, resulted in a total of 85 different locations throughout the reservoir, some with multiple crappie condos.
3. Monitor the developing Palmetto bass fishery with gill nets in 2014 and 2016. Complete a Category II age and growth sample for palmetto bass.
Action: The palmetto bass fishery was sampled in 2014 by setting 10 gill nets. Sampling was repeated in 2016 as part of an objective-based sampling approach to obtain 50 stock-length fish. A total of 47 stock-length fish were collected during 2016 sampling. Collection of age data will be deferred to 2020 to collect data on fry versus fingerling recruitment, which requires a Category III age and growth sample.
4. Conduct supplemental electrofishing and trap netting surveys in 2013.

- Action:** Supplemental electrofishing and trap netting were completed in 2013.
5. Work with local media outlets and local TPWD game wardens to educate public about Blue Catfish harvest regulations and improve compliance.

Action: Concerns with compliance were raised repeatedly with local game wardens. Two tickets were reportedly issued for illegal Blue Catfish.
 6. Request Florida Largemouth Bass stockings in 2013 and 2015 and assess prevalence of alleles in 2015.

Action: Florida Largemouth Bass were stocked in 2013 and 2014 and genetics were collected in 2015.
 7. Continue evaluating the Blue Catfish slot limit regulation. Present information to interested angler groups and at professional meetings.

Action: The Blue Catfish evaluation has continued on schedule. Presentations have been made to several local angler groups, and both oral and poster presentations were conducted at the Texas Chapter of the American Fisheries Society.
 8. Address invasive aquatic species in the reservoir.

Action: A vegetation survey was conducted on Waco Reservoir during summer 2015. In addition, zebra mussel prevention and control efforts were undertaken. Invasive species signage was posted at all Waco access points during summer 2013. District biologists have made a speaking point about invasive species, while meeting with local constituent groups such as the Central Texas Flyrodders, Legacy Outfitters, and Brazos River Sportsman's Club over the past several years. Interns from the City of Waco were hired to interview boaters at the reservoir in 2014 and 2015. Interbasin water transfers are a permanent fixture in this report now, and will be updated appropriately.

Harvest regulation history: Sportfishes in Waco Reservoir are currently managed with statewide regulations with the exception of Blue Catfish. The Blue Catfish regulation changed on September 1, 2009. Blue Catfish are currently managed with a 30- to 45-inch slot limit, where Blue Catfish less than 30 inches or greater than 45 inches can be retained; only one Blue Catfish greater than 45 inches may be retained each day, and the daily bag limit is 25 Blue and Channel Catfish in any combination (Table 3).

Stocking history: Waco Reservoir was stocked with Florida Largemouth Bass, palmetto bass, and sunshine bass during 2012-2016. The complete stocking history is in Table 4.

Vegetation/habitat history: Efforts from the aquatic habitat enhancement initiative begun in 1998 had produced nearly 75 acres of native species by 2003; however, hydrilla was also observed late that season. The new conservation pool in October 2003 reduced native and noxious vegetation alike to remnant populations of water-willow, several native floating-leaved species, and wild celery. While native species struggled to regain a foothold, hydrilla expanded to 73 acres by 2006, with the main areas of infestation being Twin Bridges Park, Speegleville Park, Airport Park, and Reynolds Creek. The Speegleville and Twin Bridges Park areas were treated with the aquatic herbicide *Nautique* during summer 2006, however high densities of hydrilla remained throughout the year. Prolonged high water levels in 2007 knocked-back most of the hydrilla once again, yet a few sprigs were observed in 2008, and 1.72 acres were visible around the Speegleville Marina by mid-summer 2009. The 2010 noxious vegetation survey showed an increase in hydrilla coverage to 4.53 acres, and another exotic species, giant reed was first observed during this survey. The 2011 vegetation survey showed some improvement in native vegetation coverage, with 13.3 acres each of arrowhead, cattail, and rice cutgrass, and 0.1 acres each of bulrush and water-willow. Bulrush and water-willow were planted prior to that date as part of cooperative effort between TPWD and the City of Waco. Non-native hydrilla and giant reed also expanded to 9.4 and 0.1 acres, respectively in 2011. However, in 2012 hydrilla was not observed. Hydrilla has since not been observed in Waco Reservoir, including the most recent comprehensive vegetation survey in 2015. Giant reed was found at a single location in the Airport Park Campground.

Water Transfer: Waco Reservoir, a U.S. Army Corps of Engineers reservoir, is primarily used for flood

control, municipal water supply, and recreation. There is one raw water intake station on the reservoir which transfers water offsite to the City of Waco Water Utilities Services Department treatment plant adjacent to the dam. From the dissolved air flotation (DAF) plant, partially treated water is pumped to two filtration plants, and then to nearly 200,000 customers in Central Texas. There are no inter-basin transfers.

Reservoir capacity: Waco Reservoir was impounded in 1965. Original plans calculated the reservoir's capacity at conservation pool (455 feet above mean sea level) to be 152,500 acre-feet with a surface area of 7,270 acres. Two volumetric surveys have been conducted since impoundment: one in 1970 by the US Army Corps of Engineers, and one in 1995 by the Texas Water Development Board. The 1970 survey found a volume of 149,189 acre-feet and a surface area of 7,237 acres at top of conservation pool (TOL), whereas the 1995 survey found a volume of 144,830 acre-feet at normal elevation pool, indicating a loss of approximately 2.9% in surface acreage (i.e., 174.8 acre-feet per year during the 25-year period between surveys). A permanent pool rise occurred in October 2003, which raised the conservation pool level to 462 feet above MSL. Yet, additional surveys by the Texas Water Development Board have not been conducted.

METHODS

Surveys were conducted to achieve survey and sampling objectives in accordance with the objective-based sampling (OBS) plan for Waco Reservoir (TPWD unpublished). Primary components of the OBS plan are listed in Table 5. All survey sites were randomly selected and all surveys were conducted according to the Fishery Assessment Procedures (TPWD, Inland Fisheries Division, unpublished manual revised 2015).

Electrofishing – Largemouth Bass, sunfishes, Gizzard Shad, and Threadfin Shad were collected by electrofishing (0.8 hour at 10, 5-min stations). Catch per unit effort (CPUE) for electrofishing was recorded as the number of fish caught per hour (fish/h) of actual electrofishing.

Trap netting – White Crappie were collected using trap nets (15 net nights at 15 stations). CPUE for trap netting was recorded as the number of fish caught per net night (fish/nn).

Gill netting – Channel Catfish, Blue Catfish, Palmetto bass and White Bass were collected by gill netting (10 net nights at 10 stations). CPUE for gill netting was recorded as the number of fish caught per net night (fish/nn).

Genetics – Genetic analysis of Largemouth Bass was conducted according to the Fishery Assessment Procedures (TPWD, Inland Fisheries Division, unpublished manual revised 2015). Micro-satellite DNA analysis was used to determine genetic composition of individual fish.

Statistics – Sampling statistics (CPUE for various length categories), structural indices [Proportional Size Distribution (PSD), terminology modified by Guy et al. 2007], and condition indices [relative weight (W_r)] were calculated for target fishes according to Anderson and Neumann (1996). Index of vulnerability (IOV) was calculated for Gizzard Shad (DiCenzo et al. 1996). Standard error (SE) was calculated for structural indices and IOV. Relative standard error (RSE = 100 X SE of the estimate/estimate) was calculated for all CPUE statistics.

Creel survey – No creel was conducted during the period covered by this report.

Habitat – A structural habitat survey was conducted in 2011 (Tibbs and Baird 2012). Habitat was assessed using 2010 U.S. Department of Agriculture National Agricultural Imagery Program, 1-meter resolution satellite imagery (TPWD, Inland Fisheries Division, unpublished manual revised 2015). Vegetation surveys were conducted using an adaptation of the point method during 2015 (TPWD, Inland

Fisheries Division, unpublished manual revised 2015). Points were randomly generated on the shoreline and averaged a minimum of one point per shoreline mile. Aquatic vegetation has always been found close to the shore in Waco Reservoir, so stratifying the random points to exclude deep-water areas increased precision and resulted in better data.

Water level – Source for water level data was the United States Geological Survey (USGS 2016).

RESULTS AND DISCUSSION

Habitat: Littoral zone habitat consisted primarily of natural and rocky shoreline with standing timber and inundated stumps in 2012, the last time a habitat survey was completed (Tibbs and Baird, 2012). An aquatic vegetation survey was conducted in summer, 2015 (Table 6). Buttonbush and water-willow were the two vegetation species that were present.

Prey species: Threadfin and Gizzard Shad were collected by electrofisher at 289.2/h and 219.6/h respectively in 2015. The Index of vulnerability (IOV) for Gizzard Shad was good, and 84% of Gizzard Shad were available to existing predators as forage. Other important forage species collected were Bluegill (373.2/h), Longear Sunfish (201.6/h), Redear Sunfish (26.4/h), Green Sunfish (10.8/h), and Warmouth (7.2/h). Sunfish seldom reach preferred size classes in Waco, and few anglers actively seek them. (Figures 2 and 3; Appendices A and B).

Catfishes: Blue Catfish were collected with gill nets at 2.0/nn in 2016; 20 individuals were collected, and the rate was below the historical average. The OBS target of 50 stock-size fish was not met. Proportional size distribution values have remained similar over the past two surveys indicating acceptable recruitment, growth, and mortality. Body condition, expressed as relative weight (W_r), was good to excellent across all size classes (Figure 4; Appendices A and B).

Channel Catfish were collected with gill nets at 5.4/nn in 2016; 54 individuals were collected. The OBS target of 50 stock-size fish was not met. The CPUE-12 was 3.8/nn, indicating good numbers of legal-sized fish available to anglers. Body condition was good, generally increasing with length. (Figure 5; Appendices A and B).

Flathead Catfish are a low-density population in Waco Reservoir, and are generally caught incidentally to other targeted species. This species was not targeted, or collected during the 2015-2016 OBS surveys, but are still included in Appendices A and B.

Temperate bass: White Bass were collected with gill nets at 4.2/nn in 2016 ($N = 42$) which was well above the historical average for the species. The OBS target of 50 stock-size fish was not met. The PSD for White Bass has remained similar over the past three surveys, indicating stable recruitment, growth, and mortality. Body condition was excellent across all size classes (Figure 6; Appendices A and B).

Palmetto bass stockings began in 2009 through a cooperative effort between TPWD and the City of Waco. Palmetto bass were collected with gill nets at 4.7/nn in 2016 ($N = 47$). The OBS target of 50 stock-size fish was not met. This continued a steep upward trend in catch rates, and represents excellent recruitment to the fishery given the low stocking rate of 5 fish/acre. The CPUE-18 was 4.1, indicating that most collected Palmetto Bass were of legal size. Body condition was excellent across most size classes (Figure 7; Appendices A and B).

Largemouth Bass: Largemouth Bass were collected by electrofishing at 230.4/h in 2015; this catch rate equates to 192 collected individuals, and was higher than the historical average. The OBS target of 10 per inch group was met. The CPUE-14 was 18.0/h, indicating most collected fish were below the legal length limit. Body condition was excellent with relative weights (W_r) averaging above 90 for all size classes. Florida Largemouth Bass influence increased in the most recent survey, with the percentage of

Florida alleles reaching 59% (Figure 8; Table 7; Appendices A and B). This is likely due to stockings in 2013 and 2014, and subsequent sampling of those fish during the 2015 electrofishing sample.

Spotted Bass were categorized as a low-density population in Waco Reservoir in the 2015-2016 OBS plan. However, they were collected at rates much higher than the historical average and are included in Appendices A and B.

White crappie: White Crappie were collected from trap nets at 5.6/nn in 2016; this catch rate is similar to the long-term average for White Crappie in the reservoir. The OBS target of 50 stock-size fish was met. The CPUE-10 was 2.5/nn, which is much higher than the previous two samples. Body condition (W_r) remained above 90 across all size classes. (Figure 9; Appendices A and B). Some caution should be used when looking at these results, as the sample was taken in January because of high water in November and December.

Black Crappie are a low-density population in Waco Reservoir, and are generally caught incidentally to other targeted species. This species was not targeted, yet was collected in small numbers during the most recent survey, and are included in Appendices A and B.

Fisheries management plan for Waco Reservoir, Texas

Prepared – July 2016.

ISSUE 1: Varying water levels over the period of this report eliminated most if not all of the hydrilla in Waco Reservoir. Since the infestation never posed a threat to access, and control efforts are unlikely, it was reclassified as a tier III infestation in 2013.

MANAGEMENT STRATEGIES

1. Discontinue yearly monitoring for noxious exotic vegetation in the reservoir, and re-survey vegetation and habitat in summer 2019.

ISSUE 2: Although the 2011 and 2015 vegetation surveys documented the presence of native aquatic vegetation, aquatic habitat enhancement is needed to create important fish habitat to mitigate loss of woody habitat over time.

MANAGEMENT STRATEGIES

1. Utilize appropriate species of native vegetation being grown at the City of Waco Wetlands facility for plantings on Waco Reservoir.
2. Request appropriate species of native vegetation from the Texas Freshwater Fisheries Center (TFFC) aquatic plant nursery, and plant vegetation as needed.
3. Use transplants from existing colonies within the reservoir to start new colonies.
4. Investigate alternative funding sources to promote aquatic habitat enhancement on the reservoir.

ISSUE 3: Recruitment of palmetto bass from fingerling stockings has been very good, despite the low stocking rate. Creel survey data show both targeted and incidental catch by anglers and widespread support for continued stockings. A recent fry versus fingerling stocking evaluation on Belton Reservoir documented improved recruitment and cost savings associated with fry stockings. This approach is likely to be successful on Waco Reservoir as well.

MANAGEMENT STRATEGIES

1. Gill net in spring 2018 and 2020 to monitor the development of the palmetto bass fishery.
2. Alternate stocking hybrid Striped Bass fry (50/acre, either palmetto bass or sunshine bass) and palmetto bass fingerlings (5/acre) to determine which approach is better.
3. Collect a Category III age and growth sample of hybrid Striped Bass in 2020 to document survival rates of fry relative to fingerlings. If possible, compare differences between sunshine and palmetto bass fry, if both are used.
4. Work with local media, the Friends of Lake Waco chapter, and game wardens to ensure education and compliance by anglers.

ISSUE 4: Despite prevention efforts by the TPWD and the City of Waco, zebra mussels were found in a single location on Waco Reservoir on September 26, 2014 (see details in Appendix D). Educational signage previously posted was replaced with new signage, warning boaters that the reservoir was infested with zebra mussels. During summer in 2014 and 2015, public awareness efforts continued with the help of eight interns hired by the City of Waco to educate boaters and other watercraft users about zebra mussels, the new water draining rules, and how to inspect and maintain watercraft. City interns educated 1,173 watercraft owners on Waco during weekends and holidays, 2014, and 1,057 in 2015. The City plans to continue hiring interns.

MANAGEMENT STRATEGIES

1. Cooperate with the controlling authority to maintain warning signage at access points.
2. Maintain contact with marina owners about invasive species, and provide them with posters, literature, etc. so that they can continue to educate their customers.
3. Provide training to City of Waco interns on zebra mussels annually as needed prior to summer efforts. Update data entry forms as needed, train interns on data entry protocols, and warehouse completed survey data in Excel format.
4. Make a speaking point about invasive species when presenting to constituent and user groups.
5. Keep track of (i.e., map) existing and future inter-basin water transfers to facilitate potential invasive species responses.

ISSUE 5: A Friends of Lake Waco chapter was formed in 2014. The purpose of this group of citizens is to inform TPWD of desired management efforts on Waco Reservoir and assist with those efforts. The chapter provided monetary support for the construction of 75 crappie condos, 55 of which were placed in Waco Reservoir and 20 in Lake Tradinghouse Creek. The chapter has expressed a desire to assist financially with other efforts.

MANAGEMENT STRATEGIES

1. Identify needs on Waco Reservoir that would best be accomplished by a citizen group. Examples include building crappie condos or funding small habitat or angler-oriented projects.
2. Periodically update chapter on management efforts at Waco Reservoir and potential projects in which they may be interested in participating.

Objective Based Sampling Plan and Schedule 2016-2020

Sport fish, forage fish, and other important fishes:

Sport fishes in Waco Reservoir include Largemouth Bass, hybrid striped bass, White Bass, Channel Catfish, Blue Catfish, and White Crappie. Important forage fish species include Gizzard Shad, Threadfin Shad, Bluegill, Redear and Longear Sunfish.

Fishes with low-density populations:

Spotted Bass, Flathead Catfish, and Black Crappie occur in very low abundance in Waco Reservoir and are generally caught incidentally to other targeted species. We will continue collecting and reporting data for these species, and upgrade their status if appropriate.

Survey objectives, fisheries metrics, and sampling objectives

Fall Electrofishing: This survey will be used to evaluate Largemouth Bass, and the primary forage species (Bluegill, Redear Sunfish, Longear Sunfish, Gizzard Shad and Threadfin Shad). Black bass were the most sought species group by anglers in Waco Reservoir during the 2011–2012 creel survey (14.8 hours/acre). The popularity of bass fishing at this reservoir, including tournaments, justifies sampling time and effort. Trend data on CPUE size structure (all listed species), and body condition (Largemouth Bass) have been collected since 1999 with fall nighttime electrofishing with the next sample scheduled for Fall, 2019. The goal of the 2019 electrofishing survey would be general monitoring of trend data to characterize the Largemouth Bass population and make comparisons with historical and future data. Electrofishing catch rates of Largemouth Bass in 2015 were sufficient to achieve a CPUE RSE ≤ 0.25 in 10 stations. A minimum of 12 randomly selected 5-minute electrofishing stations will be sampled at night in fall 2019. This will allow us to compare CPUE data among years with a calculated RSE ≤ 0.25 . If the Largemouth Bass goal isn't attained, and catch rates indicate that an RSE ≤ 0.25 is reasonable, sampling will continue at random stations. Genetic samples from 30 randomly selected Largemouth Bass will also be collected to continue evaluating the 2013 and 2014 stockings. Since the forage species survey objectives are only exploratory, additional sampling will not be necessary beyond that which is done for Largemouth Bass.

Winter Trap Netting: This survey will be used to evaluate White Crappie, which are the dominant crappie species in Waco Reservoir. The 2011-2012 creel survey showed directed angling effort for crappie to be 3.6 hours/acre. Collecting a minimum of 50 stock-length fish in 2019 winter trap netting will allow us to calculate proportions (e.g. PSD) with an 80% confidence interval. A minimum of 10 randomly selected trap net stations will be sampled in winter, 2019. If catch rates indicate that collecting 50 stock-length fish is reasonable, sampling will continue at random stations until that target is reached.

Spring Gill Netting: This survey will be used to evaluate temperate bass (hybrid Striped Bass and White Bass), Blue Catfish and Channel Catfish. Temperate bass were the fourth most sought species group by anglers in Waco Reservoir during the 2011-2012 survey (1.0 hour/acre combined for palmetto and White Bass). Catfish were the second most sought species group in the creel survey, with 5.9 hours/acre angling effort for the catfish group. Trend data on CPUE, size structure, and body condition for these species have been collected biennially since 2004 with spring gill netting. Collecting a minimum of 50 hybrid striped bass $\geq 12"$ in 2018 spring gill netting will allow us to calculate proportions (e.g. PSD) with an 80% confidence interval. A minimum of 10 randomly selected gill net stations will be sampled in spring, 2018. If catch rates indicate that collecting 50 hybrid striped bass $\geq 12"$ is reasonable, sampling will continue at random stations until that target is reached. We will collect a Category III age sample (200 fish $\geq 12"$) for hybrid striped bass in spring 2020 to compare fry and fingerling stockings as well as to document growth, recruitment and mortality. This will likely require 40 gill net stations, which will allow us to obtain 50 stock length fish from the other species collected using gill nets.

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Figure 1. Daily mean water levels for Waco Reservoir from January 1, 2012 through June 1, 2016. Conservation pool level is 462 feet above mean sea level (USGS 2016).

Table 1. Characteristics of Waco Reservoir, Texas.

Characteristic	Description
Year Constructed	1965
Controlling authority	U.S. Army Corps of Engineers
County	McLennan
Reservoir type	Tributary
Shoreline Development Index (SDI)	5.0
Conductivity	325 umhos/cm

Table 2. Boat ramp characteristics for Waco Reservoir, Texas, July, 2015. Reservoir elevation at time of survey was 462.3 feet above mean sea level (0.3 feet above conservation pool).

Boat ramp	Latitude/Longitude (dd)	Parking capacity (N)	Condition
Airport Beach	31.59636/-97.23046	80	Very good
Airport Park	31.60110/-97.24166	22	Good
Airport Park Marina	31.59531/-97.23046	20	Good
Flat Rock	31.60629/-97.26981	25	Adequate
Koehne park	31.54085/-97.21802	15	Good
Midway Park	31.52609/-97.22869	28	Good
Reynold's Creek	31.59025/-97.24950	22	Very good
Ridgewood Marina	31.53386/-97.22563	10	Adequate
Speegleville Park	31.55563/-97.23569	46	Very good
Twin Bridges	31.53792/-97.23920	72	Very good
Old Reynolds Creek	31.59030/-97.24955	38	Adequate
Old Speegleville	31.56131/-97.24506	22	Good

Table 3. Harvest regulations for Waco Reservoir.

Species	Bag Limit	Minimum-Maximum Length (inches)
Catfish, Blue ¹	25 (fish in combination) if <30 inches; 1 fish >45 inches	30- to 45-inch slot
Catfish, Channel	25 (in any combination)	12 - No Limit
Catfish, Flathead	5	18 - No Limit
Bass, White	25	10 - No Limit
Bass: Largemouth	5	14 - No Limit
Bass: Spotted	5 (in any combination)	No Limit - No Limit
Crappie: White and Black Crappie, their hybrids and subspecies	25 (in any combination)	10 - No Limit

¹Blue Catfish are currently managed with a 30- to 45-inch slot limit, where Blue Catfish less than 30 inches or greater than 45 inches can be retained; only one Blue Catfish greater than 45 inches may be retained each day; the daily bag limit is 25 for Blue Catfish, Channel Catfish, their hybrids and subspecies.

Table 4. Stocking history of Waco, Texas. Life stages are fry (FRY), fingerlings (FGL), advanced fingerlings (AFGL), adults (ADL) and unknown (UNK). Life stages for each species are defined as having a mean length that falls within the given length range. For each year and life stage the species mean total length (Mean TL; in) is given. For years where there were multiple stocking events for a particular species and life stage the mean TL is an average for all stocking events combined.

Species	Year	Number	Life Stage	Mean TL (in)
Blue Catfish	1988	15	ADL	15.8
	1989	72,800	FGL	2.7
	2000	91,499	FGL	2.1
	2004	6,610	AFGL	6.0
	2004	125,011	FGL	2.1
	Total	295,935		
Channel Catfish	1972	90,000	AFGL	7.9
	1990	60,768	FGL	3.9
	Total	150,768		
Florida Largemouth Bass	1981	19,875	FRY	1.0
	1982	19,980	FRY	1.0
	1983	4,500	AFGL	5.0
	1983	20,350	FRY	1.0
	1994	300,466	FGL	1.3
	1996	35,076	FGL	1.3
	2004	143,249	FGL	1.6
	2013	415,086	FGL	1.5
	2014	424,755	FGL	1.8
	Total	1,383,337		
Largemouth Bass	1971	400,000	FRY	0.7
	Total	400,000		
Palmetto bass (Striped X White Bass hybrid)	1975	72,233	UNK	UNK
	1977	73,121	UNK	UNK
	1979	65,700	UNK	UNK
	2009	42,776	FGL	1.4
	2010	37,555	FGL	1.8
	2011	42,727	FGL	1.6
	2013	43,566	FGL	1.7
	2014	41,069	FGL	1.7
	2016	41,293	FGL	1.6
Total	460,040			
ShareLunker Largemouth Bass	2008	2,884	FGL	1.5
	Total	2,884		
Striped Bass	1983	72,300	UNK	UNK
	1995	116,260	FGL	1.3
	1996	80,768	FGL	1.3

Species	Year	Number	Life Stage	Mean TL (in)
	Total	269,328		
Sunshine bass (White Bass x Striped Bass hybrid)	2015	425,000	FRY	0.2
	Total	425,000		
Threadfin Shad	1984	500	AFGL	3.0
	Total	500		
Walleye	1974	138,000	FRY	0.2
	1975	70,000	FRY	0.2
	1976	78,500	FRY	0.2
	1978	1,357,000	FRY	0.2
	Total	1,643,500		

Table 5. Objective-based sampling plan components for Waco Reservoir, Texas 2015 – 2016.

Gear/target species	Survey objective	Metrics	Sampling objective
<i>Electrofishing</i>			
Largemouth Bass	General monitoring and trend data	CPUE – stock Size structure	RSE- Stock \leq 25 10 fish/inch group
	Genetics	% FLMB	N = 30, any age
Bluegill ^a	Exploratory	Presence/Absence	Practical effort
Gizzard Shad ^a	Exploratory	Presence/Absence	Practical effort
<i>Gill netting</i>			
Channel Catfish	General monitoring and trend data	Size structure	N \geq 50 stock
Blue Catfish	General monitoring and trend data	Size structure	N \geq 50 stock
Hybrid striped bass	General monitoring and trend data	Size structure	N \geq 50 stock
White Bass	General monitoring and trend data	Size structure	N \geq 50 stock
<i>Trap netting</i>			
White Crappie	General monitoring and trend data	Size structure	N \geq 50 stock

^a No additional effort will be expended to achieve an RSE \leq 25 for CPUE of prey species if not reached from designated Largemouth Bass sampling effort. Instead, Largemouth Bass body condition can provide information on forage abundance, vulnerability, or both relative to predator density.

Table 6. Survey of structural habitat types, Waco Reservoir, Texas, 2012. Linear shoreline distance (miles) and percent of linear shoreline distance was recorded for each habitat type greater than one percent. Percent of total shoreline distance is blank for boat docks/piers because they were dually coded with adjacent habitat; counts are given instead. Survey was conducted using 2010 NAIP, 1-meter resolution satellite imagery. Sixty-seven boat docks were documented in the survey.

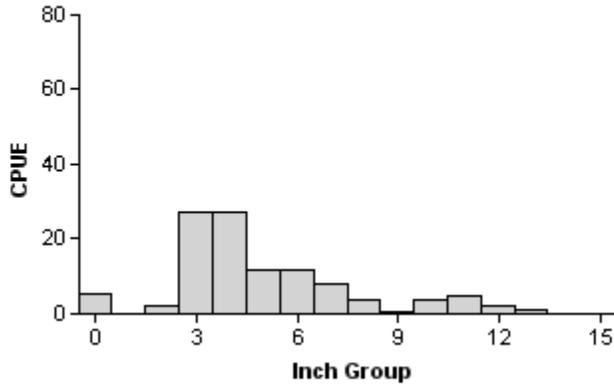
Habitat type	Shoreline Distance (miles)	% of total
Bulkhead	1.1	1.7
Rock shoreline (rocks>4")	4.8	7.5
Gravel shoreline	2.1	3.2
Natural shoreline	55.9	87.6

Table 7. Survey of aquatic vegetation, Waco Reservoir, Texas, 2015. An adaptation of the point method was used to determine percent of shoreline distance, in which values represent the percentage of the randomly-selected points where species occurred.

Vegetation	2015
American water-willow (<i>Justicia americana</i>)	7% (4 of 61)
Common buttonbush (<i>Cephalanthus occidentalis</i>)	46% (28 of 61)

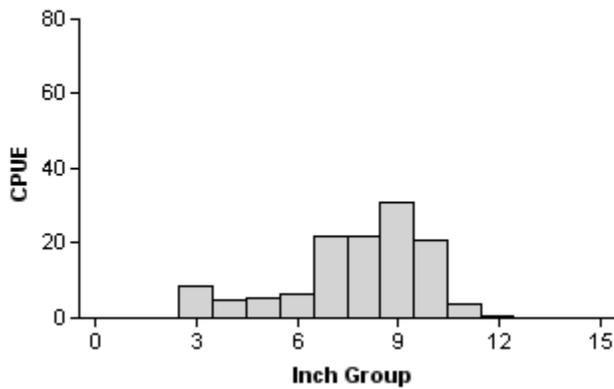
Gizzard Shad

2011



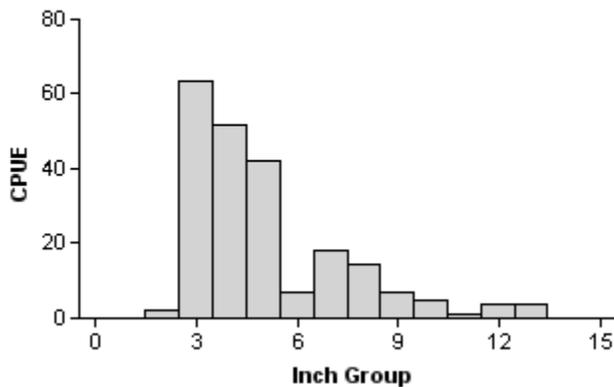
Effort = 1.5
 Total CPUE = 110.7 (25; 166)
 Stock CPUE = 24.7 (24; 37)
 IOV = 85 (5)

2013



Effort = 1.5
 Total CPUE = 125.3 (22; 188)
 Stock CPUE = 100.0 (26; 150)
 IOV = 38 (5)

2015

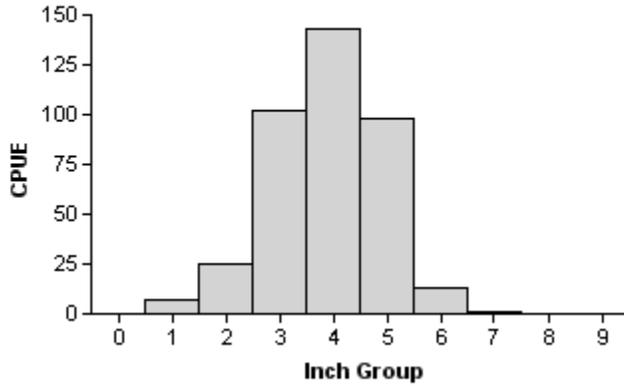


Effort = 0.8
 Total CPUE = 219.6 (29; 183)
 Stock CPUE = 52.8 (29; 44)
 IOV = 84 (3)

Figure 2. Number of Gizzard Shad caught per hour (CPUE) and population indices (RSE and N for CPUE and SE for IOV are in parentheses) for fall electrofishing surveys, Waco Reservoir, Texas, 2011, 2013, and 2015.

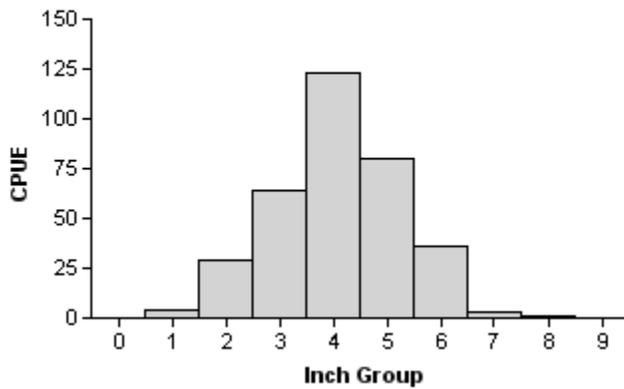
Bluegill

2011



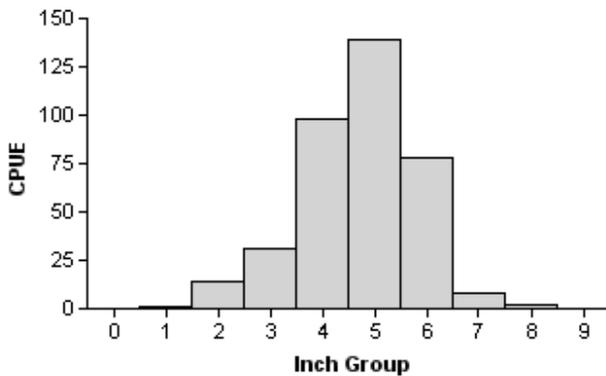
Effort = 1.5
 Total CPUE = 388.7 (27; 583)
 Stock CPUE = 356.7 (29; 535)
 PSD = 4 (1)

2013



Effort = 1.5
 Total CPUE = 339.3 (23; 509)
 Stock CPUE = 306.7 (22; 460)
 PSD = 13 (3)

2015



Effort = 0.8
 Total CPUE = 373.2 (17; 311)
 Stock CPUE = 357.6 (17; 298)
 PSD = 25 (6)

Figure 3. Number of Bluegill caught per hour (CPUE) and population indices (RSE and N for CPUE and SE for size structure are in parentheses) for fall electrofishing surveys, Waco Reservoir, Texas, 2011, 2013, and 2015.

Blue Catfish

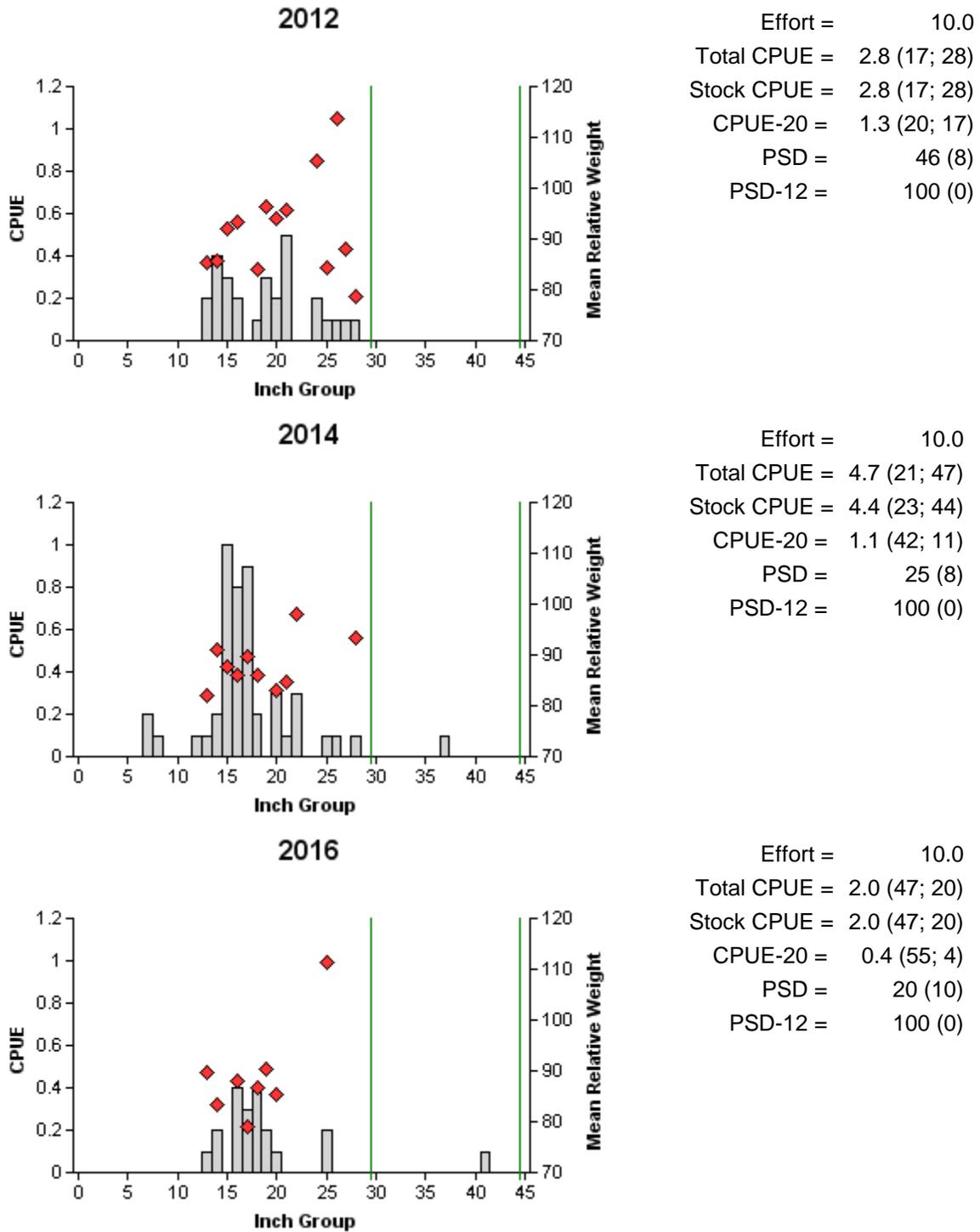


Figure 4. Number of Blue Catfish caught per net night (CPUE), population indices (RSE and N for CPUE and SE for size structure in parentheses), and mean relative weight (diamonds) for spring gill net surveys, Waco Reservoir, Texas, 2012, 2014, and 2016. Vertical lines represent the 30 to 45-inch slot limit.

Channel Catfish

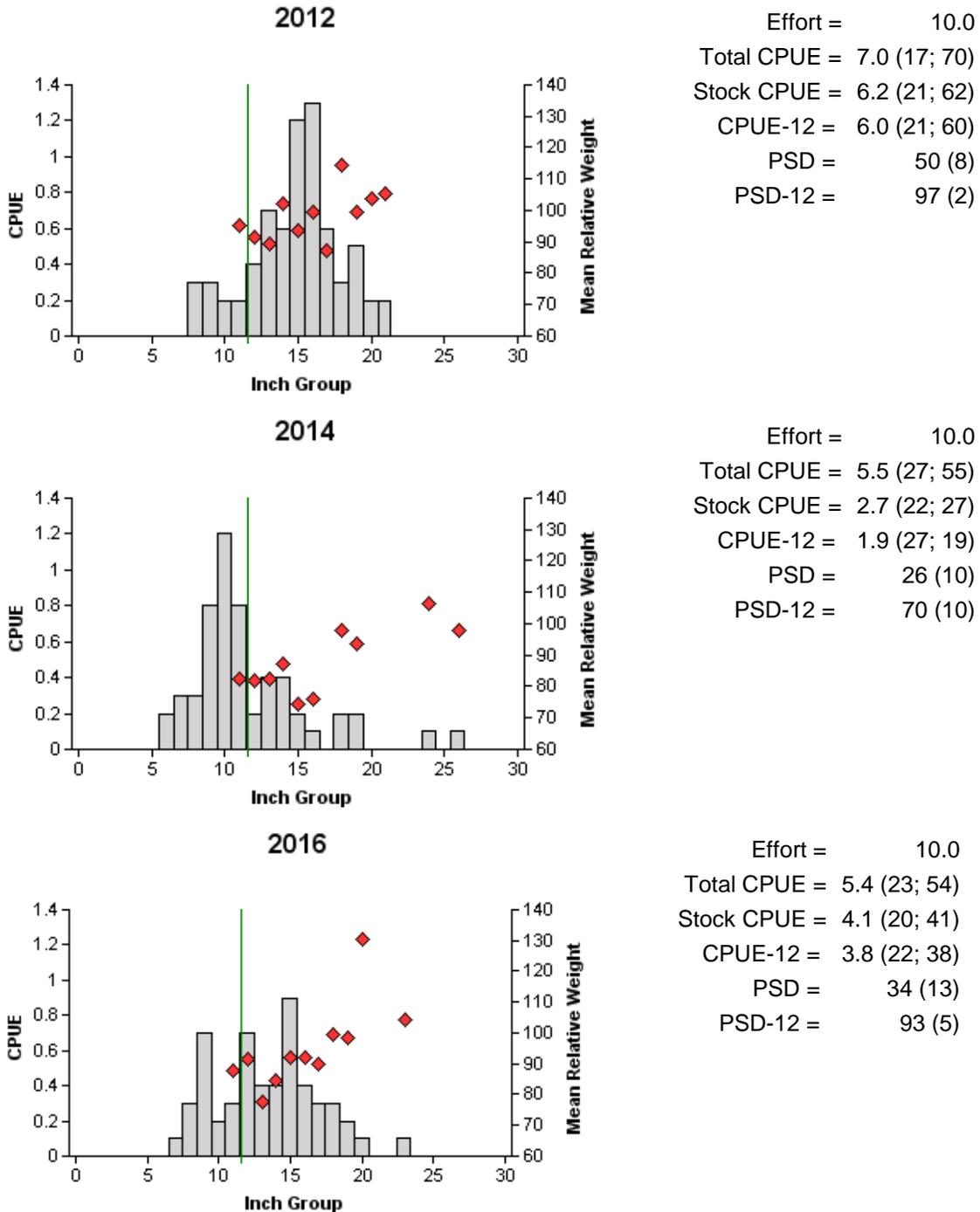


Figure 5. Number of Channel Catfish caught per net night (CPUE), population indices (RSE and N for CPUE and SE for size structure are in parentheses), and mean relative weight (diamonds) for spring gill net surveys, Waco Reservoir, Texas, 2012, 2014, and 2016. Vertical line represents the 12-inch minimum length limit.

White Bass

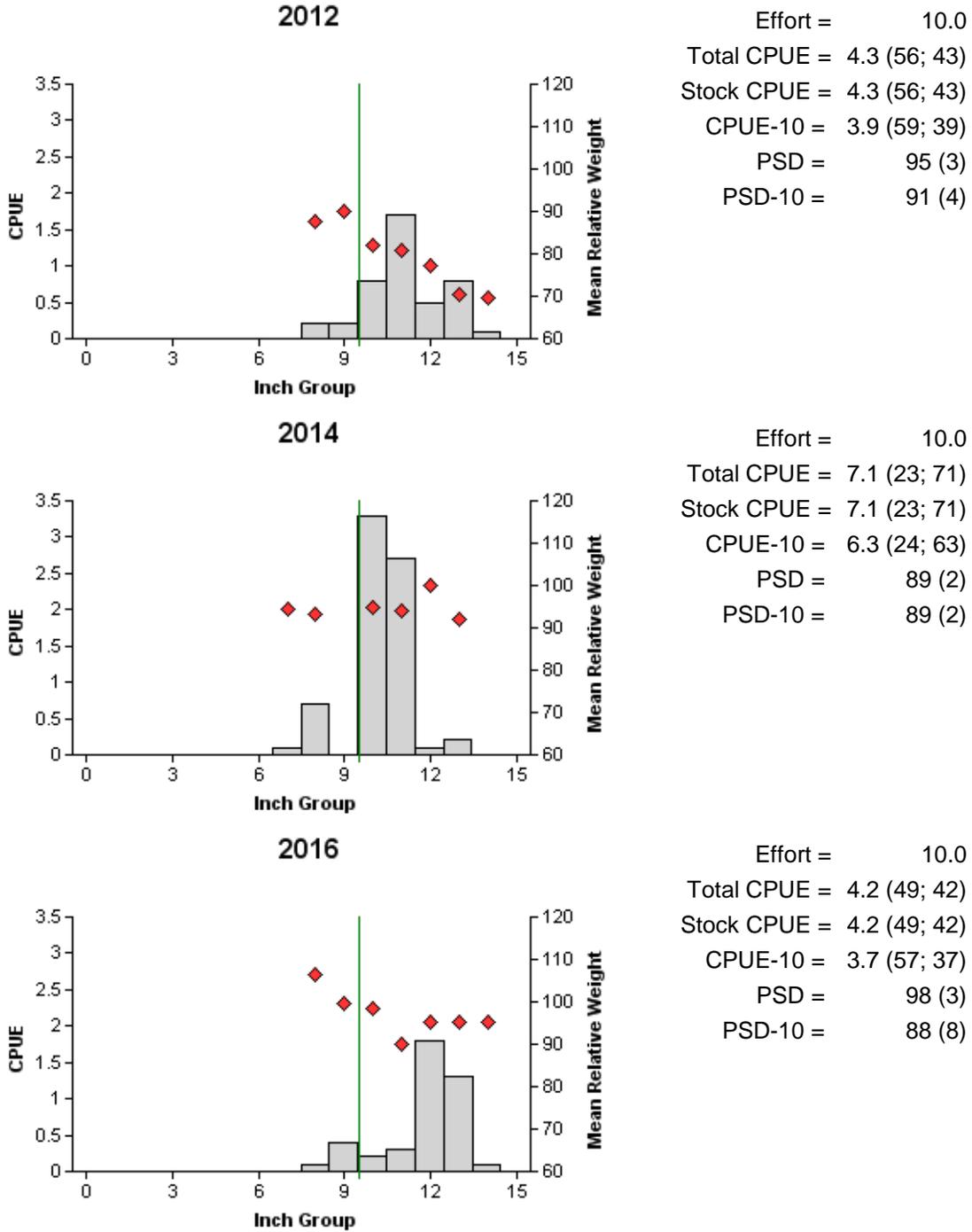


Figure 6. Number of White Bass caught per net night (CPUE), population indices (RSE and N for CPUE and SE for size structure are in parentheses), and mean relative weight (diamonds) for spring gill net surveys, Waco Reservoir, Texas, 2012, 2014, and 2016. Vertical line represents the 10-inch minimum length limit.

Palmetto bass

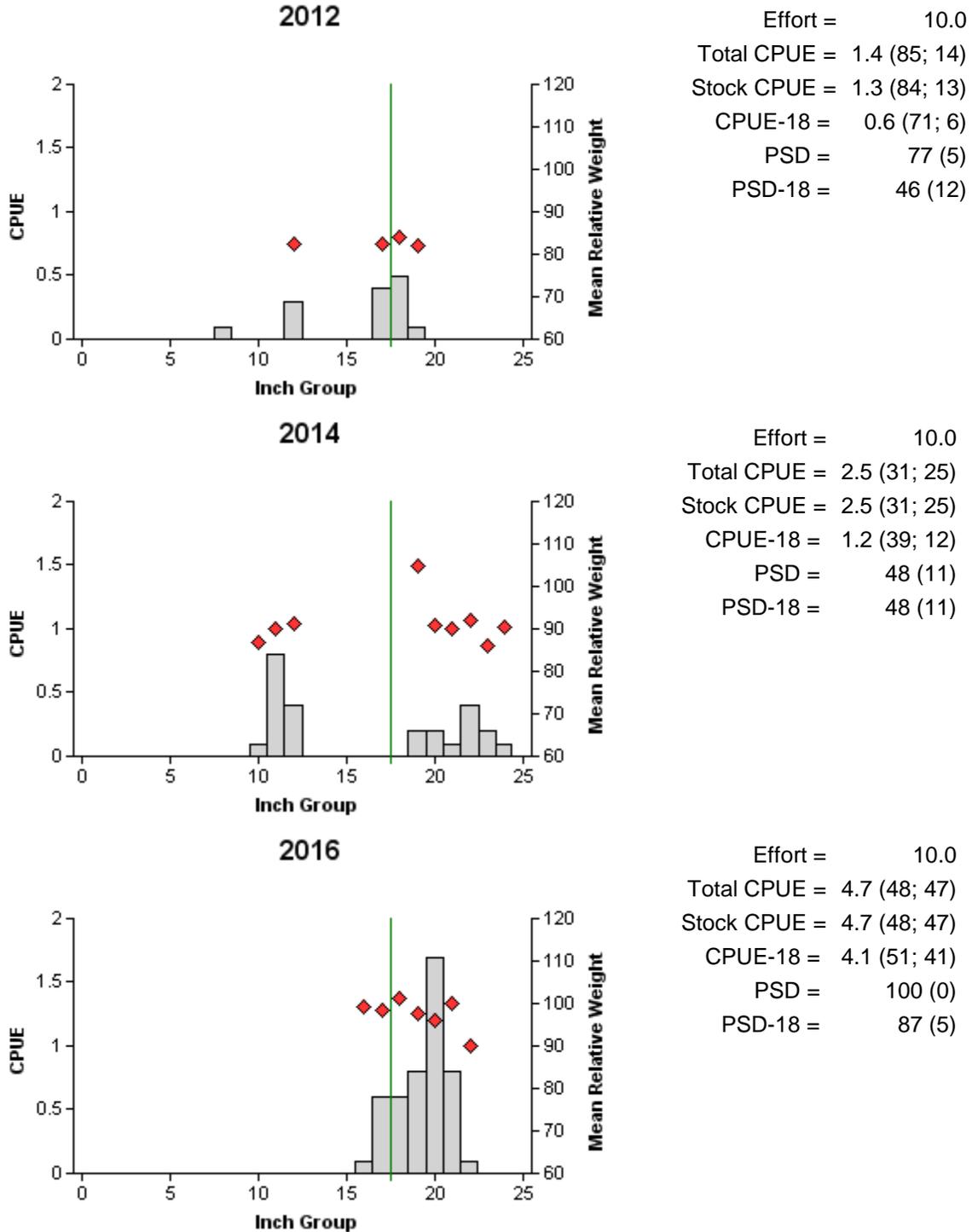


Figure 7. Number of palmetto bass caught per net night (CPUE), population indices (RSE and N for CPUE and SE for size structure are in parentheses), and mean relative weight (diamonds) for spring gill net surveys, Waco Reservoir, Texas, 2012, 2014 and 2016. Vertical line represents the 18-inch minimum length limit.

Largemouth Bass

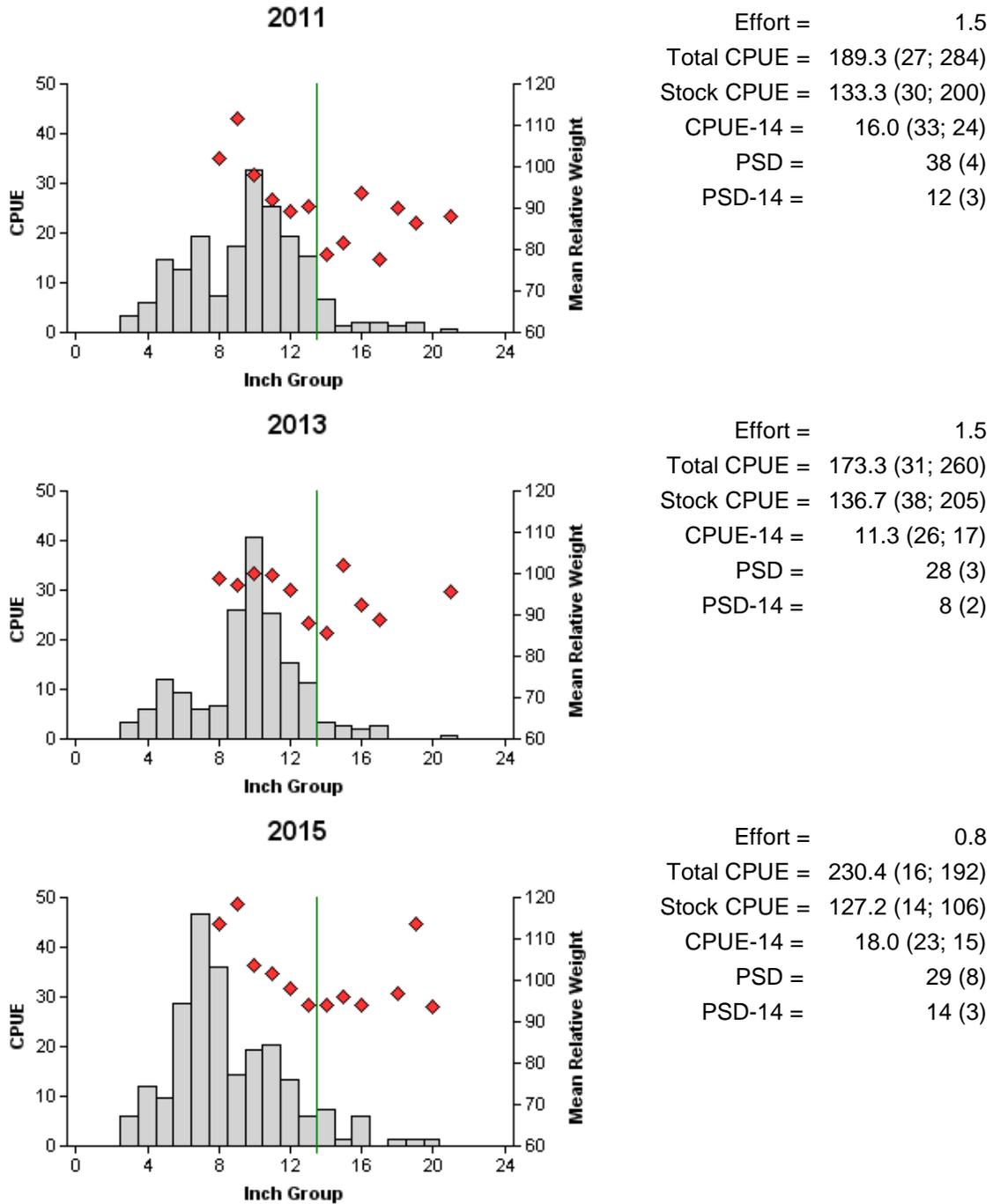


Figure 8. Number of Largemouth Bass caught per hour (CPUE), population indices (RSE and N for CPUE and SE for size structure are in parentheses), and mean relative weight (diamonds) for fall electrofishing surveys, Waco Reservoir, Texas, 2011, 2013, and 2015. Vertical line represents the 14-inch minimum length limit.

Table 8. Results of genetic analysis of Largemouth Bass collected by fall electrofishing, Waco Reservoir, Texas, 2005, 2011, and 2015. FLMB = Florida Largemouth Bass, NLMB = Northern Largemouth Bass, Intergrade = hybrid between a FLMB and a NLMB. Genetic composition was determined by micro-satellite DNA analysis.

Year	Sample size	Number of Fish			% FLMB alleles	% FLMB
		FLMB	Intergrade	NLMB		
2005	30	0	30	0	43	0
2011	30	0	28	2	48	0
2015	30	1	29	0	59	3

White Crappie

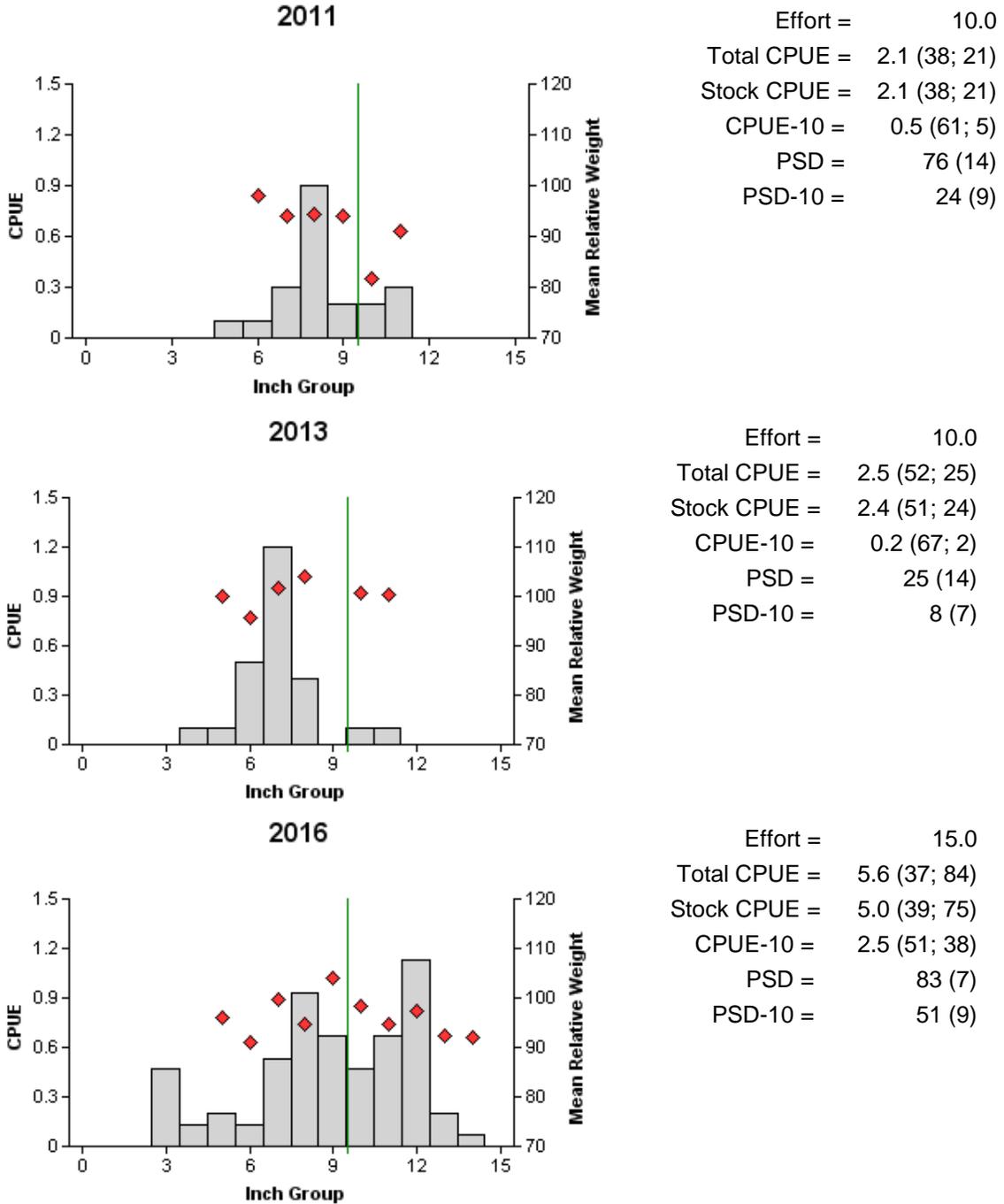


Figure 9. Number of White Crappie caught per net night (CPUE), population indices (RSE and N for CPUE and SE for size structure are in parentheses), and mean relative weight (diamonds) for fall trap net surveys, Waco Reservoir, Texas, 2011, 2013 and 2016. The most recent survey was completed in January due to high water levels during November and December, 2015. Vertical line represents the 10-inch minimum length limit.

Table 9. Proposed sampling schedule for Waco Reservoir, Texas. Gill net surveys are conducted in the spring, vegetation and access surveys are conducted in the summer, and electrofisher and trap net surveys are conducted in the fall. Standard survey denoted by S and additional survey denoted by A.

Survey year	Electrofish Fall(Spring)	Trap net	Gill net	Habitat			Creel survey	Report
				Structural	Vegetation	Access		
2016-2017								
2017-2018			A					
2018-2019								
2019-2020	S	S	S		S	S		S

APPENDIX A

Number (N), relative standard error (RSE), and catch rate (CPUE) of all target species collected from all gear types from Waco Reservoir, Texas, 2015-2016.

Species	Gill Netting		Trap Netting		Electrofishing	
	N/RSE	CPUE	N/RSE	CPUE	N/RSE	CPUE
Gizzard Shad					183/29	219.6
Threadfin Shad					241/55	289.2
Blue Catfish	20/47	2.0				
Channel Catfish	54/23	5.4				
White Bass	42/49	4.2				
Palmetto bass	47/48	4.7				
Green Sunfish					9/58	10.8
Warmouth					6/51	7.2
Bluegill					311/17	373.2
Longear Sunfish					168/37	201.6
Redear Sunfish					22/51	26.4
Spotted Bass					49/61	58.8
Largemouth Bass					192/16	230.4
White Crappie			84/37	5.6		
Black Crappie			10/73	0.7		

APPENDIX B

Historical catch rates (CPUE) of targeted species by gear type for standard surveys on Waco Reservoir, Texas, 1996 to present. All stations were randomly selected. Electrofishing stations were shocked with a 5.0 Smith-Root GPP (Gas Powered Pulsator) until 2011, when a 7.5 Smith-Root GPP began being used. Species averages (Avg) are in bold. N/A indicates that the species did not exist in the reservoir at that time.

Gear	Species	Sampling Period										
		96	99	00	01	03/04	05/06	07/08	11/12	13/14	15/16	Avg.
Electrofisher	Largemouth Bass	74.0	176.7	71.3	194.0	194.0	154.7	420.7	189.3	173.3	230.4	187.9
	Spotted Bass	0.7	11.3	26.7	4.7	2.7	2.7	8.7	17.3	1.3	58.8	13.5
	Gizzard Shad	409.3	34.7	71.3	317.3	91.3	110.0	614.0	110.7	125.3	219.6	210.35
	Threadfin Shad	8.0	0.7	1.3	32.0	3.3	168.7	174.0	108.0	137.3	289.2	92.2
	Bluegill Sunfish	120.0	92.7	156.7	342.7	314.7	238.7	314.0	388.7	339.3	373.2	268.1
	Redear Sunfish	2.7	5.3	12.0	19.3	22.7	25.3	22.7	32.7	46.0	26.4	21.5
	Longear Sunfish	24.7	12.0	68.7	73.3	130.7	40.0	99.3	114.0	78.7	201.6	84.3
	Green Sunfish	0.0	0.7	1.3	0.0	6.0	0.0	2.0	6.0	0.0	10.8	2.7
	Warmouth	2.0	2.7	2.0	1.3	7.3	3.3	2.7	2.0	2.0	7.2	3.2
Gill nets	Blue Catfish	0.0	0.1			3.2	3.7	5.3	2.8	4.7	2.0	2.7
	Channel Catfish	5.7	7.2			5.7	2.1	7.5	7.0	5.5	5.4	5.8
	White Bass	1.3	1.8			0.4	2.8	0.9	4.3	7.1	4.2	2.8
	Palmetto bass	N/A	N/A			N/A	N/A	N/A	1.4	2.5	4.7	3.6
	Flathead Catfish	0.1	0.6			0.1	0.2	0.1	0.1	0.0	0.0	0.2
Trap nets	White Crappie	2.0	9.0			5.2	3.0	14.8	2.1	2.5	5.6	5.5
	Black Crappie	0.0	0.0			0.0	0.0	0.4	0.0	0.1	0.7	0.2

APPENDIX C



Location of sampling sites, Waco Reservoir, Texas, 2015-2016. Trap net, gill net, and electrofishing stations are indicated by squares, triangles, and circles, respectively. Water level was 2.5 feet below conservation pool (462 feet above mean sea level) during 2015 electrofishing surveys and at or slightly above conservation pool during 2016 trap net and gill net surveys.

APPENDIX D**Response to Zebra Mussel Infestation in Waco Reservoir**

A zebra mussel infestation was discovered by City of Waco staff at the Ridgewood Country Club boat ramp on September 26, 2014. Subsequently, a work barge was discovered in Ridgewood Marina that was covered with zebra mussels. This barge was removed on October 1 and the owners were ticketed and fined by TPWD game wardens. The extent of the small population of adult mussels next to the ramp was quantified, and plans were made to cover the zebra mussels with 30 mil PVC pond liners weighted with sand bags. From October 21 to October 23, 9 150'x35' tarps were placed and covered with sandbags to prevent movement. The tarps were monitored over the winter to limit damage due to waves and loss of sandbags, both of which occurred. The tarps were removed March 17-19 2016 at which time two live adult zebra mussels were located by divers. A comprehensive survey was not completed at that time. Sampling in spring and fall, 2015 did not detect either zebra mussel veligers or DNA. A comprehensive visual and tactile survey of marina structures as well as the boat dock and shoreline in the vicinity of the project was completed by the TPWD Waco Management Office and TPWD Regional Office on August 25 and 26, 2016. No adult zebra mussels were observed or collected.

A comprehensive report on the infestation and control efforts can be found here:

Planning for an Invasive Species Response. Conry, T. et al. *in press*. Lake and Reservoir Management. 2016.