Final Report for Big Cypress Bayou Paddlefish Reintroduction Assessment

February 2014 to May 2015

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Report in fulfillment of MIPR agreement with the U.S. Army Corps of Engineers and reimbursable agreement with Caddo Lake Institute.

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Executive Summary

The Big Cypress Bayou American Paddlefish Restoration Project seeks to evaluate habitat restoration efforts for 40 river miles of Big Cypress Bayou (BCB) and 27,471 surface acres of Caddo Lake, and their impacts on reintroduction efforts for the Texas state-threatened species, American paddlefish (*Polyodon spathula*). Recently adopted provisions for the management of water releases from Lake O' the Pines and the installment of a gravel shoal spawning area as part of a river restoration project from the City of Jefferson have addressed two of the main reasons believed to be responsible for decline and loss of American paddlefish from BCB and Caddo Lake. The American paddlefish is endemic to the BCB and Caddo Lake, in the Red River drainage. In 1959, Ferrell's Bridge Dam was completed creating Lake O' the Pines, and the paddlefish abundance began to decline, and by the 1980s no paddlefish had been collected. It is hypothesized that this population crashed due to the altered hydrological regime that reduced spring flood pulses and restricted channel connectivity to backwater areas.

On 18-21 February 2014, 47 American paddlefish (*Polyodon spathula*) were implanted with radio tags. All 47 of the fish survived the procedure and were stocked into the BCB on 3 March 2014.

By 21 April 2014, 44% (21) of the paddlefish had been contacted at the Lake O' the Pines spillway (LOPSW). Another 27% (13) paddlefish were contacted within the BCB, and one paddlefish was contacted in Caddo Lake. A total of 35 fish were contacted in April 2014 after the release in March. The BCB, from CLSP to the LOPSW is about 34 miles, and from Jefferson to LOPSW is about 11 miles. The trend for paddlefish to move upstream to the LOPSW continued throughout the study. In addition, some fishes showed a high fidelity for the LOPSW site. By April 2014 at least 16 paddlefish were below the LOPSW (34%) and did not leave for the duration of the study. A total of 30 of the 47 (64%) tagged paddlefish were contacted at the LOPSW during the study (Figure 5). The largest number of fish contacted below the LOPSW was in February of 2015 with 26 fishes present (51%). The number of paddlefish present within a half mile of the LOPSW showed a significant positive correlation (r

= 0.62, t = 2.37, p = 0.04) with the amount of water being released from Lake of the Pines (Figure 6).

In September of 2015 an opportunistic stocking event was conducted in BCB consisting of 2,000 juvenile paddlefish around a foot in size. These fish were donated from TNFH. During April 2015 some of these fish were seen near other tagged fish while tracking. All fish introduced to the area in September have been fitted with coded wire tags for identification.

Our findings suggest that the paddlefish stocked at or upstream of CLSP will show a high fidelity to the BCB, and relatively few will leave the system. It is our recommendation that adult paddlefish be radio tagged and released into the BCB system and tracked to further understand habitat use by adults in this system.

Introduction

The BCB American Paddlefish Restoration Project proposed to evaluate habitat restoration efforts for 40 river miles of BCB and 27,471 surface acres of Caddo Lake, and their impacts on reintroduction efforts for the Texas state-threatened species, American paddlefish. Recently adopted provisions for the management of water releases from Lake O' the Pines and the installment of a gravel shoal spawning area as part of a river restoration project from the City of Jefferson have addressed two of the main reasons believed to be responsible for decline and loss of American Paddlefish from BCB and Caddo Lake.

The American paddlefish is endemic to the BCB and Caddo Lake, in the Red River drainage. In 1959, Ferrell's Bridge Dam was completed creating Lake O' the Pines, and the paddlefish fishery began to decline, and by the 1980's no paddlefish have been collected. It is believed that this population crashed due to the loss of spawning shoals and increased sedimentation caused by the altered hydrological regime that reduced spring flood pulses and restricted channel connectivity to backwater areas.

Between 1992 and 1998, as part of a larger paddlefish restoration project by Texas Parks and Wildlife Department (Betsill 1999), over 73,438 fingerling paddlefish (http://tpwd.texas.gov/fishboat/fish/action/stock_byspecies.php?timeframe=all&oddspecies=0009&Submit=Go) were stocked into Caddo Lake and Big Cypress Bayou, averaging less than 250

mm in total length (TL). No returns have been documented in Caddo Lake or within the Big Cypress Bayou. The results of the larger paddlefish project were also not encouraging. Recapture rates in other systems were extremely low, and no survival rates or population estimates were able to be calculated. However, none of the recapture efforts or telemetry conducted was in the BCB or Caddo Lake.

As early as 2004, a number of stakeholders started to develop a plan for BCB and for Caddo Lake to establish a more naturalized flow regime, to enhance upland and swamp forest dynamics, bayou channel maintenance, and habitat for native aquatic and terrestrial fauna.. These stakeholders include the Caddo Lake Institute (CLI), The Nature Conservancy (TNC), U.S. Army Corps of Engineers (USACE), Northeast Texas Municipal Water District NETMWD, U.S. Geological Survey (USGS), TPWD, Texas Commission on Environmental Quality (TCEQ), Louisiana Department of Wildlife and Fisheries (LDWF) Cypress Valley Navigation District (CVND), the City of Jefferson, United States Fish and Wildlife Service (USFWS) and others. The plan was expanded in 2006 with added focus on water pollutants, nutrient loading, and invasive aquatic plant management. Paddlefish restoration represents one of many goals of the protection plan.

In June of 2010, The Region D Planning Group for water management in Northeast Texas voted to adopt provisions recommended by Caddo organizations seeking to assure adequate flows to Caddo Lake. The Group recognized the need to maintain adequate water in the lakes, rivers and streams to support many other activities and the ecology of the river basin.

In 2008, USACE completed a $600,000 project that installed 1,500 linear-feet of gravel shoal in the BCB, just upstream of the Town of Jefferson, and is intended to serve a suite of 35 fish species, including the paddlefish. This project is part of a larger project in the city of Jefferson that will include restoration of 30 acres of riparian habitat for native aquatic and terrestrial fauna, educational features for the public, and paddling trails.

In 2011, USACE and NETMWD agreed to implement the key recommendations of the stakeholders for the flow regime in BCB. They intend to release water from Lake O' the Pines for the next five years to provide base flows and certain pulses while the stakeholders monitor the results. The pulses include flows needed for paddlefish spawning.

This study evaluated if the newly implemented hydrological regime and newly constructed spawning bar will improve habitat enough to maintain paddlefish fidelity in the

BCB. Thus, the primary purpose of this project is to determine the fidelity and migration of paddlefish in BCB. Paddlefish are a flow-dependent indicator species that is listed as threatened by the State of Texas. Paddlefish have historically occurred in Lake O' the Pines and Caddo Lake. It has been hypothesized that certain life history patterns in paddlefish have been disturbed by the addition of dams in the late 1950's which may have hindered migration (Hubbs 2002) and altered historical flows and pulses (Winemiller et al. 2005).

Methods

On 18-21 February 2014, Pete Diaz (TXFWCO) traveled to Tishomingo National Fish Hatchery (TNFH) to implant 47 hatchery reared paddlefish with radio tags for the project. Kerry Graves, the project leader at TNFH, provided almost everything for the surgeries including supplies, surgical experience, support crews, and the paddlefish (Figure 1). The surgeries went well, with all 47 paddlefish surviving to the stocking date two weeks later and beyond. Three tags were intentionally not implanted to use as test tags for the testing equipment and tag longevity.

Figure 1 Paddlefish undergo surgery at Tishomingo National Fish Hatchery.

On 3 March 2014, TXFWCO biologists traveled to the BCB area to set up radio telemetry towers at three locations. Towers were erected on private property above Jefferson, on private property just below CLSP, and on U.S. Army Corps of Engineers (USACE) land above the Caddo Lake spillway on the Louisiana side (Figure 2). The first telemetry station (Tower 1) was erected adjacent to the gravel shoal spawning area installed by the USACE. A tower was erected with two directional antennas to detect movement past the tower, and a solar panel that recharged an axillary battery that powered the Advanced Telemetry Systems R4500S datalogger. Another tower (Tower 2) was erected on private land downstream of CLSP. The tower had two directional antennas and AC power to power the datalogger. The third telemetry station (Tower 3) was erected on an existing tower owned by USACE at the spillway of Caddo Lake in Louisiana. The telemetry station had two directional antennas to detect directional movement and determine if the tagged paddlefish passed over the spillway. The tower also consisted of a solar panel, a battery and a datalogger.

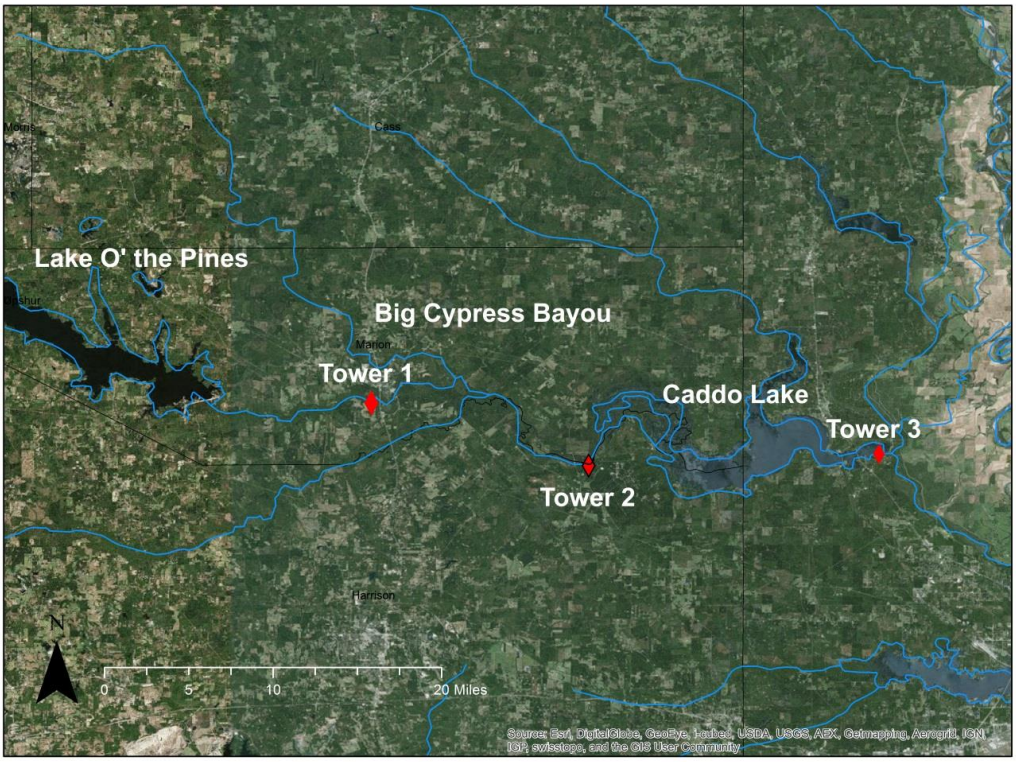

Figure 2 Map of the study area showing locations of the towers.

The fish were transported to the BCB and Caddo Lake on 5 March 2014 by staff from the Texas Freshwater Fisheries Center (Athens, TX), using two new circular tank trailers (Figure 3) made specifically for hauling paddlefish. The trip took about 4.5 hours and the fish arrived in terrific shape for the release. A total of 36 radio tagged paddlefish were released at CLSP, and eleven additional radio tagged paddlefish were released 18 miles upstream at the boat ramp in Jefferson Texas.

Figure 3 Transport tanks from Texas Parks and Wildlife Department.

Figure 4 Pete Diaz (USFWS) holds a radio tagged paddlefish for the media and crowds to see.

Active searches for the tagged paddlefish were conducted by boat. The searches were conducted once a month from March of 2014 to April of 2015, which was the active battery life of the implanted transmitter. Locations of the paddlefish were determined through triangulation of signal strength on the radio receiver. Data collected for each contacted radio-tagged fish included date, time of day, location, and water quality data where the fish has been contacted. Water quality was measured using a HydroTech Hydrolab and included dissolved oxygen, pH, conductivity, and temperature taken one foot below the water surface and one foot above the bottom.

On four different occasions, an electrofishing boat was used to recapture paddlefish below the LOPSW. Recaptured paddlefish were weighed, measured, and released.

Hobo Pendant Temperature Data Loggers UA-001-64 were deployed in multiple locations for the duration of the study.

Plankton tows were collected in November of 2014 from three main areas within the study area, and provide data on prey density within these sites. Plankton tows were taken from the area below the LOPSW, by tower 2, and within Caddo Lake along the boat road (sections where plankton tows were taken within Caddo Lake: A-113; A-106.; and G-7). Zooplankton samples were collected in triplicate by vertical tows through the water column with a 64-µm mesh 12-cm diameter Wisconsin net. Each tow was taken by anchoring the boat and dropping the sampler to the bottom, logging the depth, and then slowly retrieving the sampler.

Data Analysis

Tower Data and Monthly Data

The telemetry towers were hampered by excessive interference that created false data that was collected by the dataloggers. Tagged paddlefish that were known to be in a specific location were often falsely recorded elsewhere by the towers. To determine the validity of the contacts from towers two different filters were applied to the data. The first filter was to remove any hits with accuracy below 75%. The accuracy was calculated by taking the number of matched pulses and dividing that by the number of pulses detected. The second filter was to remove any contacts from the towers with four or less matches. All tower data was verified when possible, with ground truthing from boat tracking. Relationships between night and day movement were examined. All data from towers will be used to examine this relationship, except for data from March 5, 2104 (stocking day).

Abiotic Data

Three types of abiotic data were collected that were expected to be relevant to the life history patterns of paddlefish within BCB. These data included temperature loggers, gated flow from LOPSW, and gauge height from a USGS gauge below the LOPSW. Temperature loggers deployed at all sites were lost over the course of the study. Although the loggers were replaced, the problem persisted. Due to the lack of data temporally, historical data was collected from TCEQ stations, ranging from 2001-2009 from four sites along the BCB (Figure 5). These sites included the area below LOPSW (TCEQ site numbers 15135; 13630), Jefferson at HWY 59 (TCEQ site number 15511), the Marshal Intake (TCEQ site number 16254), and at the State HWY 43 bridge (TCEQ site numbers 10295; 15022). These data allowed for an average temperature profile to be created. Gated flow from Lake O' Pines was downloaded from USACE website (http://www.swf-wc.usace.army.mil/cgi-bin/rcshtml.pl?page=Hydrologic) and ranged from January 2001 to April of 2015. Data on gauge height was collected from USGS gauge 07346000 BCB near Jefferson, TX and encompassed from October 2007 to April of 2015. The actual location of the near Jefferson, TX gauge is below the LOPSW. These data will be examined and compared to literature from areas where paddlefish are known to persist.

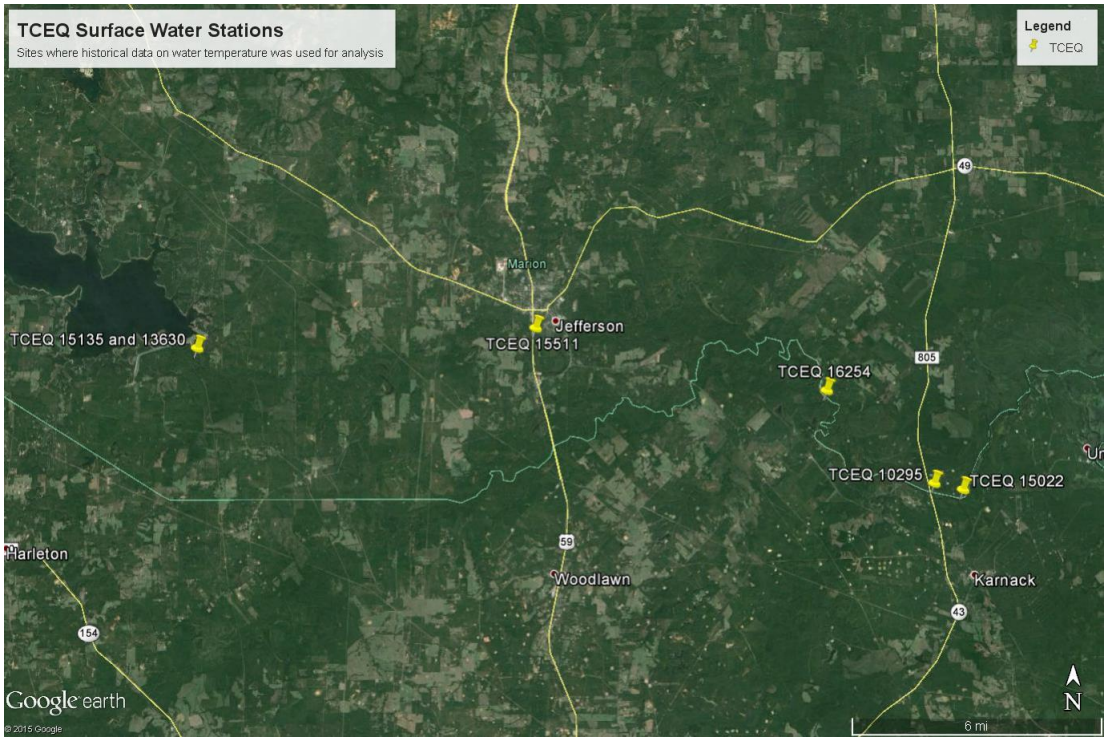

Figure 5. Locations where historical data was used to create temperature profile for the Big Cypress Bayou.

Zooplankton Samples

Samples were preserved with 95% ethanol in the field. In the lab, zooplankton were enumerated with a Nikon SMZ 1500 dissecting scope. Copepod adults and copepodids were identified to Order (calanoid or cyclopoid) and cladocera and any rotifers were typically identified to genus. Each sample was enumerated until at least 10% of sample volume or a minimum of 150 individuals were counted. A one-way ANOVA was run in SPSS v.20 to examine differences in densities across the study area.

Results

Tower Data

A total of 9,070 contacts were logged from the telemetry towers during the study period. Pre-filtered data had Tower 3 with the most contacts (5,283), Tower 2 had 2,509 contacts and Tower 1 had a total of 1,278 contacts (Table 1). After the second filter was applied, the number of tower contacts decreased at all towers: Tower 1 with 967 contacts, Tower 2 with 1540 contacts, and Tower 3 with 17 contacts. A total of 27% of all data was used after filtering. Accuracy rates for each tower and the amount of data used are available in Table 1. Post filtering accuracy of the data increased to at least 96% for all towers.

Table 1. Data collected from towers and final accuracy of tower data for analysis

Tower	Unfiltered	1st Filter	2nd Filter	Final Accuracy	Percent of Data Used
1	1278	1070	967	97%	75
2	2509	1700	1540	97%	61
3	5283	1284	17	96%	0.32

Active Search Data

The majority of paddlefish moved upstream after they were released. Eight of the 11 fish released at Jefferson were detected at Tower 1 (2.5 miles upstream of the Jefferson release site) from the 5-10 March 2014. Of the 36 paddlefish stocked at CLSP, 20 were detected at Tower 1 in March 2014; with an additional five detected in April 2014. The trend of upstream movement by a majority of the paddlefish within the BCB was consistent throughout the study (Figure 7). In addition, there was a significant positive correlation between the number of paddlefish below the dam and log transformed data on the flows being released from the LOPSW ($r = 0.62$; $t =$

2.37; p = 0.04). The number of paddlefish detected below the LOPSW peaked in March of 2015, with a total of 25 fish (53%) present within around half a mile below the LOPSW (Table 2). On 24 February 2015, the first of the three test tags reached the end of its battery life and quit sending radio signals. It is safe to assume that other tags were beginning to quit transmitting about this time as well.

Figure 6 Sixty four percent of the tagged paddlefish were contacted at the spillway at one time or another during the study period.

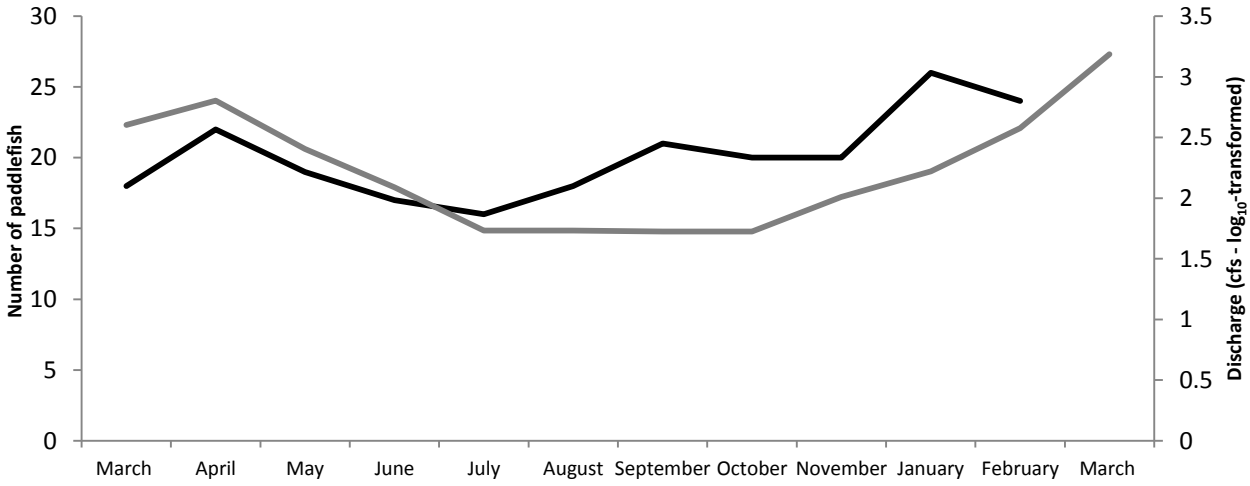

Figure 7 Paddlefish present within half a mile from the Lake O' the Pines spillway from April 2014 to March 2015 (left y-axis; black line). The grey line shows the flows released from Lake O' the Pines (right y-axis) log transformed. No sampling was done in December of 2014.

A second group of paddlefish showed high fidelity to the area between Black Cypress Bayou and Little Cypress Bayou (Figure 8). Seven paddlefish were detected in this area for at least three months out of the study. Six out of the seven paddlefish were detected between Black Cypress Bayou and Little Cypress Bayou for over five months.

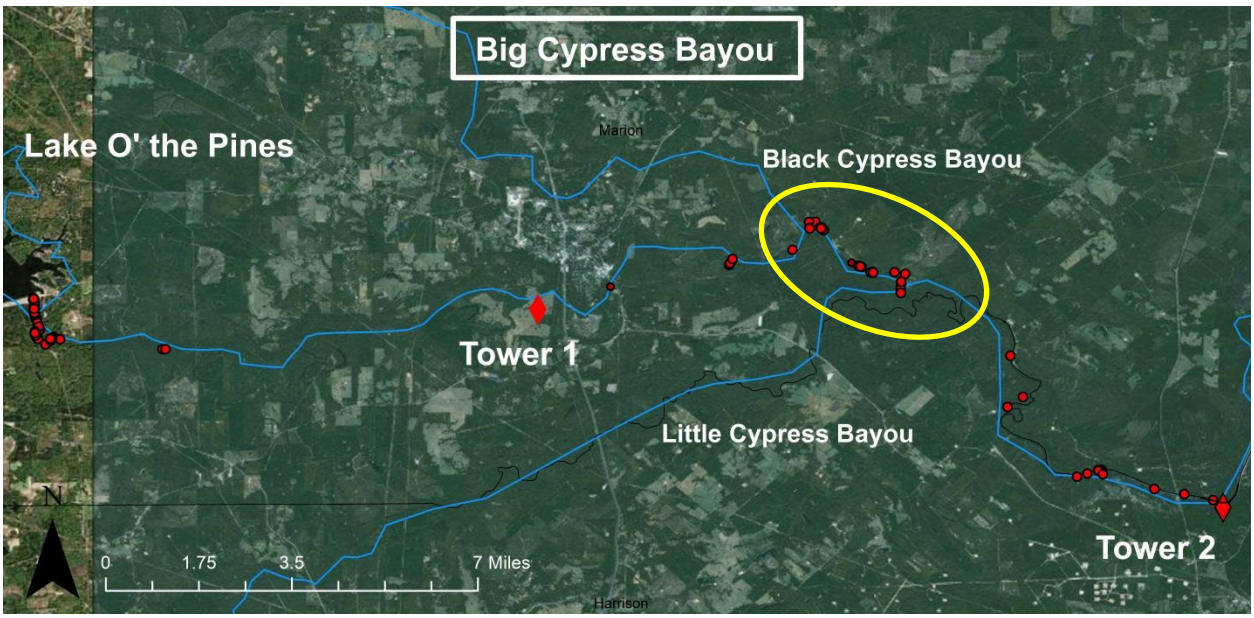

Figure 8. Map showing clusters for paddlefish found at Lake O' Pines and between Black Cypress Bayou and Little Cypress Bayou from boat tracking within the BCB from March 2014 to April 2015.

Paddlefish associated with the BCB and areas below LOPSW more than the Caddo Lake area. Out of the filtered contacts (2,967) only 0.67% were within the Caddo Lake area below Tower 2. The remainder of the contacts from the two towers and tracking were within the BCB. In addition, the contacts within the BCB are from areas below Jefferson and above Tower 2. All verified contacts of paddlefish by telemetry towers or boat tracking are presented in Table A2.

Three main types of movement were seen from the paddlefish over the course of the study. The majority (27) of the paddlefish released went upstream to the LOPSW and stayed there or nearby downstream for the duration of the study (ex: 424; 414; 385). There were paddlefish (10) that remained within the BCB between Tower 2 and Jefferson, around Black Cypress Bayou and Little Cypress Bayou (ex: 394; 463; 204). Two of these ten paddlefish returned from LOPSW to remain in this area (ex: 444; 053). Finally, there were paddlefish (10) that moved downstream into Caddo Lake, followed no distinctive pattern, or were never detected again (ex: 184; 285;294). Refer to Table A2 for verified detailed activity.

The hours of dusk and dawn were identified as a more active time for paddlefish movement based on data collected from the towers. In addition to a higher number of contacts from the tower, a larger number of fish were detected during these crepuscular times (Figure 9).

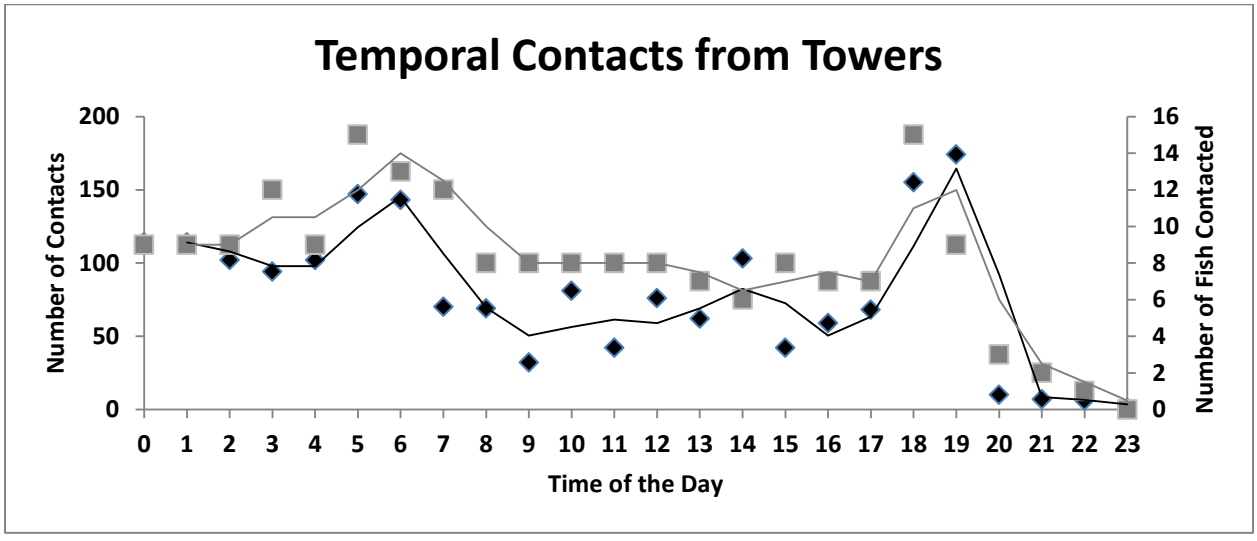

Figure 9. Contacts from tower data excluding the stocking day. Black dots and the black line are the number of contacts for each hour of the day. Grey dots and the grey line are the number of individual paddlefish contacted for each hour of the day.

During August, September and November, paddlefish were captured below LOPSW using an electrofishing boat (Table 3). In August three paddlefish were captured. In September a single paddlefish was captured. And finally in November five paddlefish were captured with one recapture from August. All fish had grown in length and weight. Change in growth from the November fish showed averages of 8.38 inches in length and 4.87 pounds in weight of growth from original calculations of weight on March 5th using equations established by George et al. (1995). Fish number 235 had the most growth over the course of the study with 11.55 inches in length and 6.24 pounds in weight.

Figure 10 Paddlefish captured in August 2014 during electroshocking below Lake O' the Pines spillway.

Water quality data collected from sites where paddlefish were present represent no ecological threshold regarding abiotic parameters. Although some sites with deeper water showed anoxic values associated with bottom of the channel and with temperatures over 24 ºC. Sites below LOPSW displayed a more even vertical profile of abiotic parameters due to the mixing of the water, compared to other sites within BCB (Appendix 1).

Table 2. Data collected on paddlefish locations within the study area from March 2014 to April of 2015. Grey highlighted months were not used in any analysis.

	March	April	May	June	July	August	September	October	November	January	February	March	April	Last Known
LOP Spillway	0	18	22	19	17	16	18	21	20	20	26	25	13	25
BCB	47	13	14	7	7	1	4	14	3	13	12	16	12	16
Caddo	0	1	0	0	2	0	0	1	1	5	1	3	7	3
Miles Searched		10	30	50	50	50	46	36	42	45	50	26		
Totals	47	32	36	26	26	17	22	36	24	38	39	44	32	45
Expired Total	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Percentage LOP		38	47	40	36	34	38	45	43	43	55	53	28	53
Percentage BCB		28	30	15	15	2	9	30	6	28	26	34	26	34
Percentage Caddo		2	0	0	4	0	0	2	2	11	2	6	15	6

Table 3. Data gathered from paddlefish recaptures. Length was measured as total length, and weight was calculated using the equation from George et al. 1995.

Tag Number	March 2014		August 2014		September 2014		November 2014		Total Change
	Length (in)	Weight (lbs)	Length (in)	Weight (lbs)	Length (in)	Weight (lbs)	Length (in)	Weight (lbs)	Weight (lbs)
4014	31.50	3.63					40.55	9.12	5.49
4164	32.75	4.19	34.00	4.80					
4235	28.60	2.55					40.15	8.80	6.25
4263	33.00	4.30					38.58	7.61	3.31
4364	30.50	3.23					39.96	8.64	5.41
4374	34.50	5.06			36.00	5.91			
4385	32.00	3.85	36.00	5.91					
4424	33.50	4.55	34.00	4.80			39.76	8.49	3.94

Abiotic Data

Yearly temperature fluctuations within the BCB were noted using historical data. Basic relationships with a longitudinal distribution from the LOPSW were observed. The LOPSW site had the most stable temperature over the course of a year as shown by the lowest score from the coefficient of variation analysis (Table 4). The effects of water moving downstream had a lag effect on temperature curves for the entire data set. For example, the moving average lines drawn on Figure 11, show that the two most downstream sites exhibit the highest temperature in the summer time (June, July, and August), presumably due to longer retention time. The deviations in temperature between sites start to be evident in March as the downstream sites begin to exhibit higher temperatures on average. During the winter most areas had the same water temperature. (November, December, January, February).

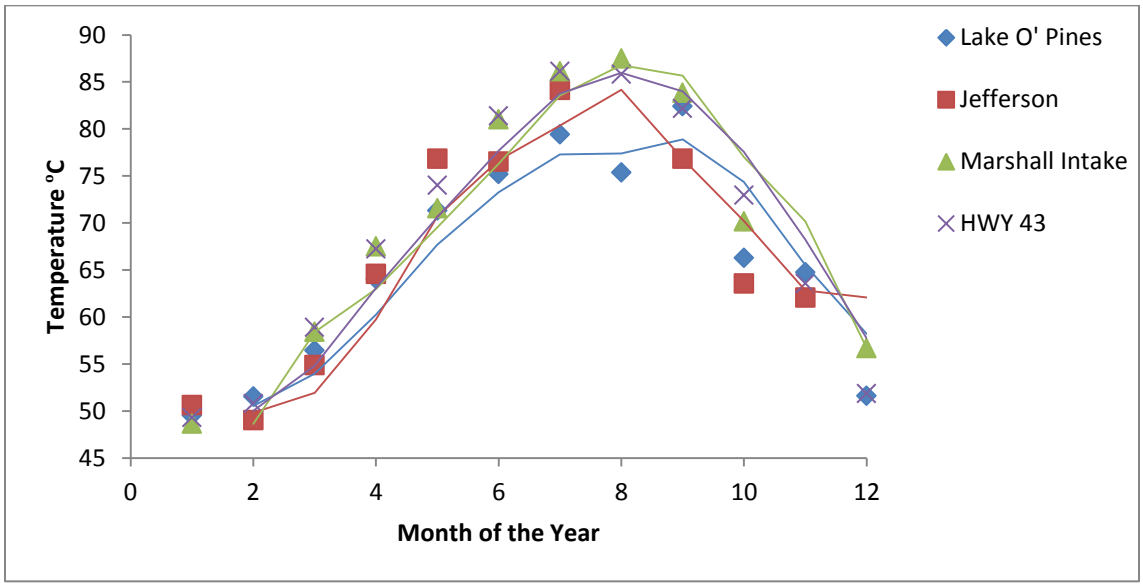

Figure 11. Average temperatures recorded by the Texas Commission on Environmental Quality surface water station in BCB from 2001-2009. Sites are in longitudinal order from Lake O' Pines to Highway 43 near Karnack.

Data used to create average flows out of LOPSW were taken from over 5,244 data points from 2001 to May 11, 2015. Historically, the data examined from 2001 to May 11, 2015 shows that March has the largest releases from the LOPSW, while September has the lowest average flows (Table 4). The longer post-dam data set (1980-2003) by Winemiller et al. (2005) has the highest discharge coming from the LOPSW in February (green triangle), with low flows still in September (Figure 12). By subdividing the data set between years before the Environmental

Flows Agreement (2001-2010) and after (2011-2014), the peak discharge period shifts slightly (March to April) between the post rules and the pre rules, along with a decrease in the magnitude of the released flows in the post environmental flows period (Table 4). Flow released from LOPSW showed significant negative correlation with temperature at all of the TCEQ monitoring sites ($p < 0.04$; Table 4). Flow data and gauge height show a strong positive correlation ($r = 0.92$; $t = 7.71$; $p > 0.0001$; Table 4). The highest gauge height was in March followed by April. The lowest average gauge height was in June, followed by September. A change in gauge height over six feet was recorded 14 times over the time period for this data. Rises that occurred within the hypothesized seasonal cues for paddlefish account for seven events from October 2007 to April of 2015.

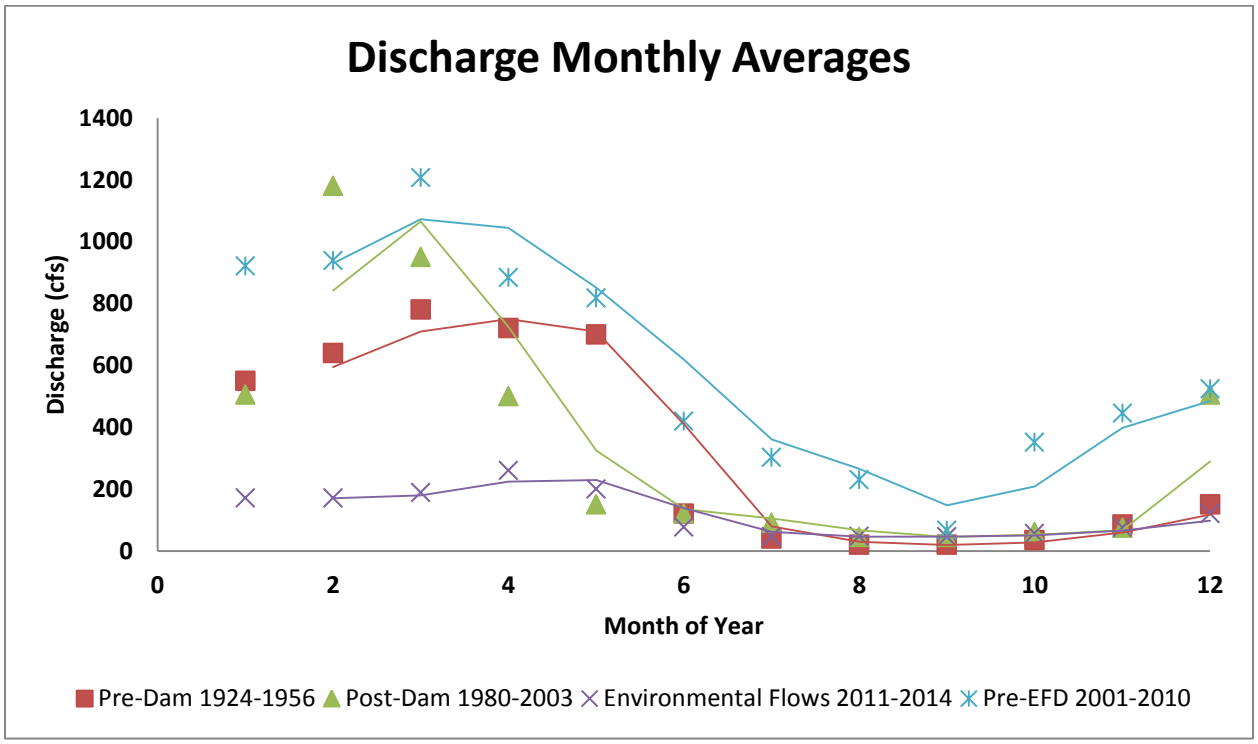

Figure 12. Average of water released from the Lake O' Pines reservoir from 1980-2003 (green). Average of water released from the Lake O' Pines reservoir from 2011-2014, under the environmental flows prescription (purple). Average of water released from the Lake O' Pines reservoir from 2001-2010, pre-environmental flows (Pre-EFD; light blue). Average flow in cubic feet per second is displayed on the y-axis and the months of the year are on the x-axis.

Zooplankton Data

The density and composition of zooplankton communities varied across sites, especially with regard to the sites that were in upstream locations and those that were located within Caddo Lake. In general, the two upstream sites (LOPSW and Tower 2) were less species rich than the

sites within Caddo (Caddo A-113, Caddo G-7, and Caddo A-106; correspond to site on boat trail within Caddo Lake), containing from ~3 zooplankton taxa versus ~5 zooplankton taxa, respectively. Across all sites, the zooplankton communities were dominated by small-bodied zooplankton taxa (≤500 µm length), with the cyclopoid copepods and copepod nauplii being the most abundant groups at all sites. However, the densities of cyclopoid copepods, copepod nauplii, Ceriodaphnia sp., and total zooplankton significantly varied across sites (Appendix 5). Across sites, the densities of cyclopoid copepods, nauplii, *Ceriodaphnia* sp., and total zooplankton were significantly lower at LOPSW and Tower 2 than at the Caddo A-113, G-7, and A-106 sites (Appendix 4). Thus, the more downstream and lake-associated sites exhibited substantially higher zooplankton densities and Cladocerans (i.e., *Ceriodaphnia* sp., *Bosmina* sp., and *Daphnia lumholtzi*) were only present in the downstream Caddo Lake sites. The dominant zooplankters numerically across all sites were cyclopoid copepods and copepod nauplii. The more common non-dominant zooplankters included calanoid copepods, *Ceriodaphnia* sp., *Bosmina* sp., and *Daphnia lumholtzi*.

Table 4. Average abiotic parameters calculated from historical data for the BCB. Temperature data comes from Texas Commission on Environmental Quality fixed stations from 2001-2009. Flow data comes from the U.S. Army of Corps of Engineers from 2001- April 31, 2015. The pre rules data is from 2001 to 2010, and the post rules data is from 2011-2014. The gauge data is from the U.S. Geological Survey station below Lake O' Pines from 2007-April 2015. The average for each month is presented at the bottom of the table along with a coefficient of variation. Italicized numbers have been taken from one year of data.

	Average Temperature from 2001-2009				USGS Gauge		USACE Release Data	
Date	Lake O' Pines	Jefferson @ 59	Marshall Intake	SH 43 Bridge	Gauge Height	Flow	**Pre Rules**	**Post Rules**
Jan	49.53	50.63	48.64	49.29	8.26	670.29	921.32	170.72
Feb	51.54	49.01	NA	50.78	8.87	700.50	938.88	171.28
Mar	56.43	54.86	58.41	58.89	11.08	750.68	1206.17	188.40
Apr	64.04	64.58	67.51	67.22	10.50	714.86	884.36	259.87
May	71.32	*76.82*	71.57	73.99	8.61	709.68	817.71	199.99
Jun	*75.20*	76.52	81.02	81.40	6.39	321.99	419.85	77.33
Jul	79.40	84.16	86.10	86.14	4.88	229.07	302.25	46.11
Aug	75.37	NA	87.49	85.80	5.81	177.41	229.63	46.85
Sep	*82.40*	*76.82*	*83.84*	82.16	4.93	60.59	66.44	45.98
Oct	66.29	63.56	70.16	72.94	6.76	266.47	350.72	55.86
Nov	64.73	62.06	NA	63.55	7.06	339.88	445.49	75.83
Dec	*51.62*	NA	*56.66*	51.85	7.49	408.84	524.04	120.84
Average	65.66	65.90	71.14	68.67				
Correlation with Flow	-0.69	-0.60	-0.72	-0.68	0.92			
Coefficient of Variation	0.17	0.19	0.19	0.20				

Discussion

The BCB and Caddo Lake area appears to be made up of three spatial zones. The first (zone 1) being the most natural reach from LOPSW to the city of Jefferson. This zone is characterized as a mostly narrow channel with high canopy cover and swifter moving water. The second zone (zone 2), is the area below Jefferson and to around HWY 43 bridge. This zone is has wider and deeper channels along with less canopy cover due to the width of the channel. The third zone (zone 3) is the Caddo Lake area, which is everything else downstream of the HWY 43 bridge. Data collected in this study suggests a high fidelity to the BCB (first two zones) for juvenile paddlefish, and in particular to areas where allochthonous inputs are present: LOPSW, Little Cypress Bayou, and Black Cypress Bayou.

This observation followed by clusters of data from boat tracking is not completely unexpected (Figure 8). Paddlefish have been shown to congregate below man-made structures such as dams (Zigler et al. 2004; Mettee et al. 2006). In addition, a study by Barry et al. (2007) showed that after four days, 77% of all tagged juvenile paddlefish were contacted below a dam, in the tailwaters. However, the areas below Jefferson and above Tower 2, particularly between Black Cypress Bayou and Little Cypress Bayou, had a number of paddlefish showing fidelity to this stretch of river, without any man-made structures. One major similarity between both sites where paddlefish congregated for months, was that both sites are a major source of allochthonous input coming into the system. These areas where tributaries and the mainstem meet have been shown to be "hot spots" for diversity and productivity (Rice et al. 2008) by providing habitat complexity (Kiffney et al. 2006). This theory in riverine systems may provide some insight into the fidelity shown by some of the paddlefish to the area between Black Cypress Bayou and Little Cypress Bayou.

The lack of presence within Caddo Lake by the juvenile paddlefish with telemetry tags was unexpected. At most in January of 2015 there were potentially five paddlefish within this lower zone (below highway 43 bridge). It was assumed that the paddlefish would occupy the habitat with the highest density of zooplankton, which was Caddo Lake. There could be many reasons for the lack of usage by the juvenile paddlefish within Caddo Lake. One hypothesis is that the hatchery raised paddlefish were all originally released upstream of Caddo lake, and due to their

natural predisposition to move upstream when released may have not detected the higher density of zooplankton in the lake compared to upstream reaches.

Caddo Lake and its tributaries have been listed repetitively as a 303d stream by TCEQ. A listing as a 303d stream or segment has violated a law from the federal Clean Waters Act regulating the amount of effluent entering Texas water bodies. This listing has been issued for bacteria, low dissolved oxygen, mercury in edible tissue, and pH. In regards to paddlefish, hypoxia has been shown to affect locomotion at temperatures between 18 and 26 ºC with levels of dissolved oxygen below 4.7 mg/L (Aboagye and Allen 2014). Other issues may involve boat traffic or historical oil and gas activity prior to regulation.

Data from the towers was plagued with "noise". Noise is defined for this document as ambient electronic interference (Blundell et al. 2014), which was often logged by the data loggers. The amount of data collected was significantly higher than the amount of data that was usable (27%) (Table 1). By filtering the data, probable detections were able to be differentiated from the noise. Tower 3 had the most significant noise present throughout the study period and may be due to the close proximity of large radio towers present within the area. In addition, the noise detected caused the loggers to scan through both antennas constantly, thus increasing the probability of missing a real radio signal in the area.

Individual Fish Examples of typical movement

Example 1 (fidelity to zone 1)

Paddlefish 385, was stocked at the CLSP. This fish moved upstream from the initial stocking, and by March 15, 2014 fish 385 had been contacted by tower 1 and was moving upstream. Fish 385 remained at the LOPSW for the duration of the study. The only movement registered by fish 385 was downstream movement in August of 2014 when the fish was recorded a mile downstream from the LOPSW. This type of behavior is not unique to the BCB and LOPSW. Barry and others (2007) showed the same type of behavior with juvenile paddlefish in the Ohio River. Juvenile paddlefish stocked at any location within the associated pool swam upstream and congregated within 600 m below the spillway (Barry et al. 2007). The mechanism for such behavior is unknown, but could be a feeding preference or a habitat availability issue (Barry et

al. 2007). With the Barry et al. (2007) study the juvenile paddlefish remained below the dam for about 9 weeks. The fish in the above mentioned study were caught on site and were about a year old. The fish used in this study were two years old and longer and heavier in general. In addition, the majority of the paddlefish remained below the dam for the duration of the study. Although short trips up and downstream may have occurred, the lack of a tower below the LOPSW only allowed for contacting these fish during boat surveys. In all, 18 paddlefish were always present below the LOPSW from April or May of 2014 to March of 2015, with other fish coming and going at the site throughout the study.

Example 2 (fidelity to zone2)
Fish 463 and others like it (9 fish in total) stayed within the BCB for the duration of the study. Fish 463 stayed between Black Cypress Bayou and Little Cypress Bayou from March 2014 to April 2015 (8 detections).

Example 2 continued (fidelity to zone2)
Paddlefish 444 showed a large range in movement throughout the course of the study. This fish was stocked at Jefferson and was first contacted by Tower 1 on 5 April 2014. This is exactly one month after the stocking event. By 24 April 2014, fish 444 was detected within a mile of the LOPSW. Fish 444 stayed at the LOPSW until November and then proceeded to swim downstream to the area between Black Cypress Bayou and Little Cypress Bayou, where it remained from January 2015 to 11March 2015. On 18 March 2015, this fish was again detected by Tower 1. This upstream movement occurred within four days of a major increase in releases from LOPSW (from 25 cfs on the 15th to 1070 on the 18th, followed by flows in the 2500+ range) with a change in gauge height of 7.45 feet within the last four days. The fish however was detected periodically at Tower 1 from 18 May to 25 April 2015. The last detection of this fish was between Black Cypress Bayou and Little Cypress Bayou on 29 April 2015. Fish 463 was the only fish to show fidelity to the area between Black Cypress Bayou and Little Cypress Bayou after swimming upstream to LOPSW.

Example 3 (Movement into zone 3)

Four tagged fish (045, 243, 285, and 294) were contacted throughout the study in Caddo Lake itself. While these fish moved into Caddo Lake, they showed no patterns of movement within the lake, and were only detected sporadically, presumably due to the vastness of the lake and our inability to cover the entire lake every tracking event. Of the four fish known to have moved downstream into the lake, the filtered data from Tower 3 suggests that only one (243) potentially went over the spillway of Caddo Lake.

Three fish (184, 305, and 484) were never contacted again after the initial contact at Tower 2 on the stocking date.

Migration

Firehammer and Scarnecchia (2006) found that movement was significantly influenced by river discharge and suspended sediment. O'Keefe and others (2007) found that most eggs were deposited between 16.9 and 19.4 °C with a change in gauge height of around nine feet. This change in gauge height also corresponds with a study by Purkett (1961) in the Osage River. Although there are fluctuations in temperature ranges for stimulation of migration between studies (Purkett 1961; Wallus 1986; Lein and DeVries 1998), it should be noted that the change in gauge height and discharge are always present as an indicator of potential migration. Based on the literature and historical data collected, that would've provided for around seven events within the established range of gauge height and temperature from October 2007 to April of 2015 within the hypothesized migration period (February to May; Southall and Hubert 1984, O'Keefe et al. 2007). The abiotic parameters within the BCB (zones 1 and 2) do not seem to be a factor in limiting the juvenile paddlefish distribution.

The size of the basin available for adult paddlefish to migrate may be considered minimal (36 miles within the BCB) compared to other larger rivers where paddlefish fisheries exist such as in the upper Mississippi River where the range is 182 miles for migration and habitat selection (Zigler et al. 2004) and over 250 miles in the Missourri River (Firehammer and Scarnecchia 2006). The home ranges of adult paddlefish have been shown to range from small (3 to 59 miles; Brantly 1997) to rather large (200 miles; Mettee et al. 2006). The implications for the

smaller migration routes within the BCB are still unknown. However, the lack of adult paddlefish recorded within the BCB over the last 20 years may have to do with the restriction of the home range or the area available for migrations along with other unmeasured factors.

As the population within the area of the BCB and the Caddo Lake area grows, water use patterns that mimic drought conditions could persist due to the increase in population and the selling of water out of the basin. Drought plans and exercises to mediate the loss of water within the BCB may prove to be valuable for future conditions related to population growth. The flows identified in the building blocks (1,500 cfs) seem to be sufficient to cause the change in gauge height and other factors (discharge, temperature) necessary for the stimulation of paddlefish migration. Thought should be considered to moving the timing of the release back to late February or early March to coincide with historical temperature changes within the system.

Recommendations

Water released from the LOPSW provides the majority of the water present within the BCB above the city of Jefferson and is highly correlated with temperature and the gauge height as the water moves longitudinally downstream to Jefferson and past. In 2011, USACE and NETMWD agreed to implement key recommendations made by the stakeholders to provide ecological base flows and certain pulses for the flow regime over the next five years in BCB. This stretch (zone 1) should be considered an important theoretical thoroughfare for the paddlefish during migration, considering the number of fish moving below the LOPSW throughout the year. Although the amount of water appears to be sufficient within a normal weather year; during drought years, releases should still be managed in the same way, but on a smaller scale that might still benefit the aquatic community dependent upon releases from the Lake O' the Pines. We recommend that ecological base flows continue into the future, beyond the original five year span, which will end in 2016. The lessons learned from this current period of drought can be applied in the future when water demands become higher due to increase in population to the area in the future.

Our findings suggest that the paddlefish stocked at or upstream of CLSP will show a high fidelity to the BCB, and relatively few will leave the system. We recommend future stockings of

paddlefish occur at or upstream of CLSP.

The results of the study indicate that the juvenile paddlefish movements are being limited by the Ferrell's Bridge Dam. For future studies on paddlefish, we recommend that more radio tagged juvenile fish be released on the lake side of the dam and their continued movement be tracked. This area upstream may prove to be vital to their lifecycle.

We now know what juvenile paddlefish will do when released in the BCB, but what will adults do in the same situation. It is our recommendation that adult paddlefish be radio tagged and released into the BCB system and tracked to further understand habitat use by adults in this system. The tagged fish from this study are still congregating below the LOPSW and could be recaptured and retagged with longer life tags now that they are bigger fish. Knowing that paddlefish tend to be found below dams at man-made structures, an attempt to capture adult paddlefish below the Caddo Lake spillway should be made. Captured fish should be tagged and released upstream of the dam. They could then be tracked longer term to determine their life history needs.

We recommend continued stocking of 350 mm paddlefish into the BCB system over the next five years. There are currently so few paddlefish in the system that they are nearly impossible to study unless they are radio tagged. The continued stocking of paddlefish should increase the population size enough to make studying them possible.

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Appendix 1: Abiotic parameters recorded at paddlefish locations within the BCB.

DS = Downstream; US = Upstream; T2 = Tower 2

Date	Site	Top/Bottom	Temperature (C°)	Dissolved Oxygen (mg/L)	Conductivity (µs)	pH	Latitude	Longitude
4/22/2014	Just DS 43 Bridge	T	19.29	5.87	181.8	6.56	32.69695	-94.1873
4/22/2014	Just DS 43 Bridge	B	19.3	5.94	181.6	6.48	32.69695	-94.1873
4/24/2014	3 Miles DS LOPSW	T	17.64	8.86	179.2	7.00	32.73932	-94.4537
4/24/2014	3 Miles DS LOPSW	B	17.65	8.85	179.2	6.81	32.73932	-94.4537
4/24/2014	0.5 Miles DS LOPSW	T	17.66	9.34	179.7	7.12	32.74074	-94.499
4/24/2014	0.5 Miles DS LOPSW	B	17.56	9.55	180	7.14	32.74074	-94.499
4/25/2014	Above Hwy 134	T	19.18	8.19	176	7.01	32.75261	-94.3429
4/25/2014	Above Hwy 134	B	19.19	8.2	175.6	6.9	32.75261	-94.3429
6/18/2014	0.5 Miles US T2		27.9	6.65		6.75	32.6969	-94.1861
6/18/2014	4 Miles US T2		27.2	3.84		6.48	32.72054	-94.2342
6/18/2014	Between Black and Little		27.35	6.08		6.69	32.75887	-94.2748
6/19/2014	3.5 Miles DS T2		26.84	3.27	120.8	6.43	32.7318	-94.1457
7/23/2014	Between Black and Little	T	26.89	9.25	173	7.52	32.75704	-94.271
7/23/2014	Between Black and Little	B	24.12	0.22	154.3	6.61	32.75704	-94.271
7/23/2014	1.5 Miles above Black	T	25.99	5.5	182	6.63	32.75952	-94.3098
7/23/2014	1.5 Miles above Black	B	25.06	4.55	181.8	6.55	32.75952	-94.3098
7/23/2014	Between Black and	T	28.56	10.82	174	8.16	32.75704	-94.271

	Little							
7/23/2014	Between Black and Little	B	24.3	0.4	155.8	6.25	32.75704	-94.271
7/24/2014	Below LOPSW	T	27.07	7.44	185.8	7.1	32.74956	-94.4994
7/24/2014	Below LOPSW	B	27.03	7.46	185.7	7.11	32.74956	-94.4994
8/20/2014	Below LOPSW	T	27.39	5.75	189.7	6.91	32.73895	-94.49821
8/20/2014	Below LOPSW	B	27.37	5.77	189.6	6.91	32.73895	-94.49821
8/20/2014	Below LOPSW	T	27.44	7.08	190.7	6.97	32.74971	-94.49936
8/20/2014	Below LOPSW	B	27.13	7.1	190.8	6.91	32.74971	-94.49936
8/21/2014	DS T2	T	30.4	7.8	142.6	7.23	32.71075	-94.16647
8/21/2014	DS T2	B	27.89	0.83	149.4	6.55	32.71075	-94.16647
9/25/2014	Just US of Little		26	6.04	159.2	6.98	32.70342	-94.2086
11/18/2014	1.5 Miles DS of LOPSW	T	11.15	10.19	175	6.91	32.73852	-94.4949
11/18/2014	1.5 Miles DS of LOPSW	B	11.08	10.12	175	6.27	32.73852	-94.4949
11/18/2014	Below LOPSW	T	11.76	10.57	175.6	7.55	32.74948	-94.4993
11/18/2014	Below LOPSW	B	11.73	10.48	174.7	7.46	32.74948	-94.4993
11/19/2014	At T2	T	11.35	6.35	154.1	6.46	32.69549	-94.1733
11/19/2014	At T2	B	10.88	6.1	152.8	6.22	32.69549	-94.1733
1/26/2014	Below LOPSW	T	9.14	11.06	170	6.91	32.7497	-94.4995
1/26/2014	Below LOPSW	B	9.13	11.09	170.1	6.84	32.7497	-94.4995
1/27/2014	3 Miles below LOPSW		9.33	10.85	169.4	6.67	32.73932	-94.4712
1/28/2014	Between Black and Little	T	8.77	9.19	105.4	6.09	32.76899	-94.2848
1/28/2014	Between Black and Little	B	8.72	9.27	104.9	6.17	32.76899	-94.2848

Appendix 2: Verified data on paddlefish movement within the BCB and the Caddo Lake area.

Fish Data

Tag 014:

- Fish stocked at CLSP
- Contacted 3/12/14 and 3/13/14 at tower 1 (20 miles)
- Contacted at LOPSW 15 times over 13 months (April 2014-April 2015)
- Captured in November 2014 at LOPSW. It had gained 12.1 kg and 228 mm, and increased its body weight by 250%.
- Last contact: LOPSW 4/27/15

Tag 023:

- Fish stocked at CLSP
- Contacted 3/11/14 at tower 1 (20 miles)
- Contacted at LOPSW 6 times over next 12 months (June 14-April 2015)
- Last contact: LOPSW 4/28/15

Tag 045:

- Fish stocked at CLSP
- Contacted 3/7/14 and 3/8/14 at tower 2
- Possible contact with tower 3; 5/30 through 7/20/14
- Last contact: 7/22/14 in main body of Caddo Lake, nearing Mooringsport

Tag 053:

- Fish stocked at CLSP
- Contacted 5/5/14 at tower 2
- Contacted 6/18/14 four miles upstream below Black Cypress Bayou and Little Cypress Bayou
- Contacted 7/21-23/14 at tower 2
- Contacted 10/15/14 above tower 2
- Contacted 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 2/3-5/14 at tower 2
- Contacted 2/10/15 below LOPSW
- Contacted from 2/19 to 3/9/2015 at tower 2
- Contacted 3/11/15 just below Black Cypress Bayou and Little Cypress Bayou
- Last contact: 4/28/15 at tower 2

Tag 064:

- Fish stocked at CLSP
- Contacted 2/6/14 upstream of tower 2
- Contacted 3/7/14 and 3/12/14 at tower 2
- Contacted 3/13/14 4 miles upstream of tower 2
- Contacted 3/15/14 at tower 1 (20 miles)
- Contacted at LOPSW 16 times over 13 months (April 2014-March 2015)
- Last contact: 3/11/15 at LOPSW

Tag 074:

- Fish stocked at CLSP
- Contacted 3/6/14 below tower 2
- Contacted 3/7/14 to 3/9/14 at tower 2
- Contacted 3/12/14 at tower 1 (20 miles)
- Contacted 4/5/14 at tower 1
- Contacted at LOPSW 16 times over 13 months (April 2014-March 2015)
- Contacted 3/11/15 at tower 1
- Contacted 4/13/15 at tower 1
- Contacted 4/19/15 at tower 1
- Contacted 4/20/15 at tower 2
- Contacted 4/22/15 at tower 1
- Last confirmed contact: 4/29/15 at tower 2

Tag 084:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/18/14 at tower 2
- Contacted 7/23/14 above Black Cypress Bayou and Little Cypress Bayou
- Contacted 10/15/14 above Black Cypress Bayou and Little Cypress Bayou
- Contacted above Black Cypress Bayou and Little Cypress Bayou (January-April 2015)
- Fish stayed within a 50 meter radius; potentially expired
- Last confirmed contact: 4/29/15 just above Black Cypress Bayou and Little Cypress Bayou

Tag 104:

- Fish Stocked at CLSP
- Contacted 3/6/14 downstream of tower 2

- Contacted 3/13/14 by Gum Slough upstream of State Highway 43 bridge
- Contacted 9/25/14 by Gum Slough upstream of State Highway 43 bridge
- Contacted 10/15/14 by Gum Slough upstream of State Highway 43 bridge
- Contacted 1/28/15 by Gum Slough upstream of State Highway 43 bridge
- Last confirmed contact: 2/12/15 inside of Gum Slough

Tag 113:

- Fish Stocked at CLSP
- Contacted 3/6/14 downstream of tower 2
- Contacted 4/22/14 just downstream of Jefferson
- Contacted at LOPSW 4 times over 3 months (February-April 2015)
- Last confirmed contact: at LOPSW on 4/27/15

Tag 124:

- Fish Stocked at CLSP
- Last contact: 4/22/14; 1.5 miles downstream of Jefferson

Tag 144:

- Fish Stocked at CLSP
- Contacted 3/6/14 downstream of tower 2
- Contacted 4/22/15 downstream of Jefferson
- Contacted 8/22/15 at Tower 1
- Contacted at LOPSW 16 times over 11 months (May 2014 to April 2015)
- Last contact: 4/27/15 at LOPSW

Tag 164:

- Fish Stocked at CLSP
- Contacted 3/16/14 at Tower 1 (20 miles)
- Contacted at LOP spillway 13 times over 12 months (April 2014-April 2015)
- Captured in August 2014 at LOPSW. It had grown 31mm and gained 1.3 kg
- Last contact: 4/27/15 at LOPSW

Tag 173:

- Fish Stocked at CLSP
- Contacted 3/6/14 downstream of tower 2
- Contacted 4/15/14 at tower 1
- Contacted 4/19/14 at tower 1

- Contacted 2 times at the LOPSW (7/24/14 and 3/11/15)
- Last contact: 3/11/15 at LOPSW

Tag 184:

- Fish Stocked at CLSP
- Stayed near CLSP for 5 days
- Last contact: Release date at CLSP

Tag 194:

- Fish Stocked at CLSP
- Contacted 3/10/14 at tower 1 (20 miles)
- Contacted at LOPSW 15 times over next 12 months (April 2014-March 2015)
- Tag likely went dead in April
- Last contact: 3/11/15 at LOPSW

Tag 204:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/10/14 at tower 1 (2.2 miles)
- Contacted 3/13/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/21/14 at tower 1
- Contacted 4/15/14 at tower 1
- Contacted 4/27/14 at tower 1
- Contacted 7/23/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted December 2014 to January 2015 at tower 2
- Contacted 1/27/15 above tower 2
- Contacted 2/11/15 above tower 2
- Last contact: 3/4/15 at tower 2

Tag 215:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/7/14 at tower 1
- Contacted 4/23/14 at LOPSW
- Contacted 3/7/14 at tower 1
- Contacted at LOPSW 12 times over next 13 months (April 2014-April 2015)
- Last contact: 4/27/15 at LOPSW

Tag 224:

- Fish Stocked at CLSP
- Contacted 3/6/14 downstream of tower 1
- Contacted 3/9/14 at tower 2
- Contacted 3/12/14 at tower 1 (20 miles)
- Contacted at LOPSW 14 times over next 12 months (April 2014-March 2015)
- Last contact: 3/11/15 at LOPSW

Tag 235:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/8/2014 at tower 1 (2.2 miles)
- Contacted at LOP spillway 13 times over next 11 months (May 2014-March 2015)
- Fish was captured alive and well at the LOPSW in November 2014, and had gained 294 mm and 13.8 kg, effectively increasing its body mass by 345% and gaining about 10 inches in length
- Last contact: 3/11/15 at LOPSW

Tag 243:

- Fish Stocked at CLSP
- Contacted March to May 2014 at tower 2
- Last confirmed contact: 6/3/14, at tower 3
- Fish may have gone over the L.A. Spillway

Tag 255:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/6/14 at tower 1 (2.2 miles)
- Contacted 3/13/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 4/15/2014 at tower 1
- Contacted 7/23/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 9/24/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 2/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/11/15 between Just above Black Cypress Bayou
- Last contact: 4/29/15 between Black Cypress Bayou and Little Cypress Bayou

Tag 263:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/7/4 at tower 1 (2.2 miles)
- Contacted at LOPSW 19 times over next 13 months (April 2014-April 2015)
- This fish was captured alive and well at the LOPSW in November 2014, and had gained 142 mm and 1.5 kg
- Last contact: 4/28/15 at LOPSW

Tag 273:

- Fish Stocked at Jefferson boat ramp
- Contacted 6/18/14, and again on each tracking trip at the exact same position, upstream of Highway 59 bridge past Jefferson
- Fish has expired

Tag 285:

- Fish Stocked at CLSP
- Contacted 3/6/14; 2.1 km downstream of CLSP
- Last contact: 3/13/14 near Goose Island in Caddo Lake

Tag 294:

- Fish Stocked at CLSP
- First and Last contact: 3/22/14 by Big Green Break in Caddo Lake

Tag 305:

- Fish Stocked at CLSP
- Last contact: Stocking day at tower 2

Tag 313:

- Fish Stocked at CLSP
- Contacted 3/9/14 at tower 1 (20 miles)
- Contacted 3/12/14 at tower 1
- Contacted 3/30/14 at tower 1
- Contacted 4/15/14 at tower 1
- Contacted at LOPSW 16 times over next 12 months (April 2014-March 2015)
- Last contact: 3/11/14 at LOPSW

Tag 325:

- Fish Stocked at CLSP
- Contacted on 3/13/14 by Marshall water intake
- Contacted on 3/17 and 3/18/14 at tower 1

- Contacted on 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted on 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted on 2/11/15 just below Little Cypress Bayou
- Contacted on 3/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Last contact: 4/29/15 between Black Cypress Bayou and Little Cypress Bayou

Tag 333:

- Fish Stocked at CLSP
- Contacted on 3/18/14 at tower 2
- Contacted 3/20/14 tower 1 (20 miles)
- Contacted at LOP spillway 8 times over next 13 months (April 2014-April 2015)
- Last contact: 4/28/15 at LOPSW

Tag 344:

- Fish Stocked at Jefferson boat ramp
- Contacted on 3/7/14 at tower 1 (2.2 miles)
- Contacted on 6/18/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted on 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 12/18/14 at tower 1
- Contacted on 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted on 3/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Last contact: 4/28/15 between Black Cypress Bayou and Little Cypress Bayou

Tag 353:

- Fish Stocked at CLSP
- Contacted 3/6/14 below tower 2
- Contacted 3/8/14 to 3/10/14 at tower 2
- Contacted 3/12/14 at tower 1
- Contacted 4/3/14 at tower 1
- Contacted 4/7/14 at tower 1
- Contacted 4/10/14 at tower 1
- Contacted at LOPSW 9 times over next 13 months (April 2014-February 2015)
- Last contact: 2/10/15 at LOPSW

Tag 364:

- Fish Stocked at CLSP
- Contacted 3/7/14 at tower 2
- Contacted 3/9/14 at tower 2
- Contacted 3/10/14 at tower 2
- Contacted 3/13/14 at tower 1 (20 miles)
- Contacted 3/14/14 at tower 1
- Contacted at LOP spillway 7 times over next 10 months (April 2014-February 2015)
- Fish was captured alive and well at the LOPSW in November 2014, and had gained 240 mm and 2.5 kg, effectively increasing its body mass by 267% and gaining about 9 inches in length. Tag likely went dead in February
- Last contact: 2/10/2015 at LOPSW

Tag 374:

- Fish Stocked at CLSP
- Contacted 3/6/14 at tower 2
- Contacted 3/7/14 at tower 2
- Contacted 3/9/14 at tower 2
- Contacted 3/7/14 at tower 2
- Contacted 3/10/14 at tower 1 (20 miles)
- Contacted at LOP spillway 16 times over next 13 months (April 2014-April 2015)
- Fish was captured alive and well at the LOPSW in September 2014, and had gained 38 mm and 0.4 kg
- Last contact: 4/27/2015 at LOPSW

Tag 385:

- Fish Stocked at CLSP
- Contacted 3/9/14 at tower 2
- Contacted 3/13/14 between tower 2 and Little Cypress Bayou
- Contacted 3/15/14 at tower 1
- Contacted at LOP spillway 16 times over next 13 months (April 2014-March 2015)
- Fish was captured alive and well at the LOPSW in August 2014, and had gained 100 mm and 0.9 kg
- Last contact: 3/11/2015 at LOPSW

Tag 394:

- Fish Stocked at CLSP
- Contacted from at tower 2 throughout the entire study

- Contacted 6/19/14 3.5 miles downstream from tower 2
- Fish initially went down stream, but shows a high fidelity to the stocking location (CLSP). The fish spends time both up and downstream of tower 2, but not out of contact much more than 3 weeks at a time. 851 contacts for this fish, mostly from tower 2.
- Last contact: 4/18/15 at tower 2

Tag 404:

- Fish Stocked at CLSP
- Contacted on 3/13/14 by Marshall water intake
- Contacted 3/15/14 at tower 2
- Contacted 3/17/14 at tower 1
- Contacted 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 2/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Last contact: 4/29/15 between Black Cypress Bayou and Little Cypress Bayou

Tag 414:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/7/14 at tower 1 (2.2 miles)
- Contacted 3/15/14 at tower 1
- Contacted 4/14/14 at tower 1
- Contacted at LOPSW 19 times over next 13 months (April 2014-April 2015)
- Last contact: 4/28/15 at LOPSW

Tag 424:

- Fish Stocked at CLSP
- Contacted 3/10/14 at tower 2
- Contacted 3/13/14 just upstream of Marshall water intake
- Contacted 3/24/14 at tower 1
- Contacted at LOP spillway 18 times over next 13 months (April 2014-April 2015)
- Fish was captured alive and well at the LOPSW in both August and November 2014, and had gained 159 mm and 1.8 kg by the November capture
- Last contact: 4/27/2015 at LOPSW

Tag 435:

- Fish Stocked at CLSP
- Contacted 3/6/14 below tower 2
- Contacted 3/9/14 at tower 1 (20 miles)
- Contacted at LOP spillway 4 times over next 7 months (April 2014-November 2014). No confirmed contacts since November 2014
- Last contact: 11/18/2014 at LOPSW

Tag 444:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/6/14 below tower 2
- Contacted 4/5/14 at tower 1
- Contacted at LOP spillway 10 times over next 7 months (April 2014-November 2014)
- Contacted 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 2/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/18/15 at tower 1
- Contacted 4/21/15 at tower 1
- Last contact: 4/29/15 between Black Cypress and Little Cypress Bayous.

Tag 463:

- Fish Stocked at CLSP
- Contacted 3/6/14 4 miles downstream from tower 2; at mouth of Caddo Lake
- Contacted 3/10/14 tower 2
- Contacted 3/13/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 7/23/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 9/24/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 10/15/14 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 1/28/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 2/11/15 between Black Cypress Bayou and Little Cypress Bayou
- Contacted 3/9/15 LOPSW
- Last contact: 4/29/15 between Black Cypress Bayou and Little Cypress Bayou

Tag 475:

- Fish Stocked at CLSP
- Contacted 3/8/14 tower 2
- Contacted 3/12/14 tower 1
- Contacted at LOPSW 16 times over next 13 months (April 2014-April 2015)
- Last contact: 04/27/2015 at LOPSW

Tag 484:

- Fish Stocked at CLSP
- Fish was contacted the day after stocking (3/6/14) 5.6 km downstream from tower 2, near Mound Pond. This was the last confirmable contact

Tag 493:

- Fish Stocked at CLSP
- Contacted 3/10/14 at tower 1 (20 miles)
- Contacted at LOP spillway 16 times over next 12 months (April 2014-March 2015)
- Last contact: 04/27/2015 at LOPSW

Tag 505:

- Fish Stocked at CLSP
- Contacted 3/16/14 at tower 1 (20 miles)
- Contacted 10/14/14 a mile below LOPSW
- Contacted 1/27/15 a mile below LOPSW
- Contacted 2/10/15 a mile below LOPSW
- Last contact: 3/9/15 a mile below LOPSW

Tag 514:

- Fish Stocked at Jefferson boat ramp
- Contacted 3/6/14 at tower 1 (2.2 miles)
- Contacted in BCB 3.2 miles below LOPSW 4 times over next 10 months (April 2014-February 2015)
- Last contact: 4/28/15 in BCB 3.2 miles below LOPSW

Tag 525:

- Fish Stocked at CLSP
- Contacted 3/10/14 at tower 2
- Contacted 3/14/14 at tower 1
- Contacted at LOPSW 15 times over next 12 months (April 2014-March 2015)

- Last contact: 3/11/2015 at LOPSW

Appendix 3: Additional Figures (Photographs)

Figure 13. Installation of Tower 1 in Zone 1 (most upstream tower)

Figure 14. Tower 2 Near the top of zone 3 (near Caddo Lake State Park)

Figure 15. Tower 3 at the Caddo Lake Spillway.

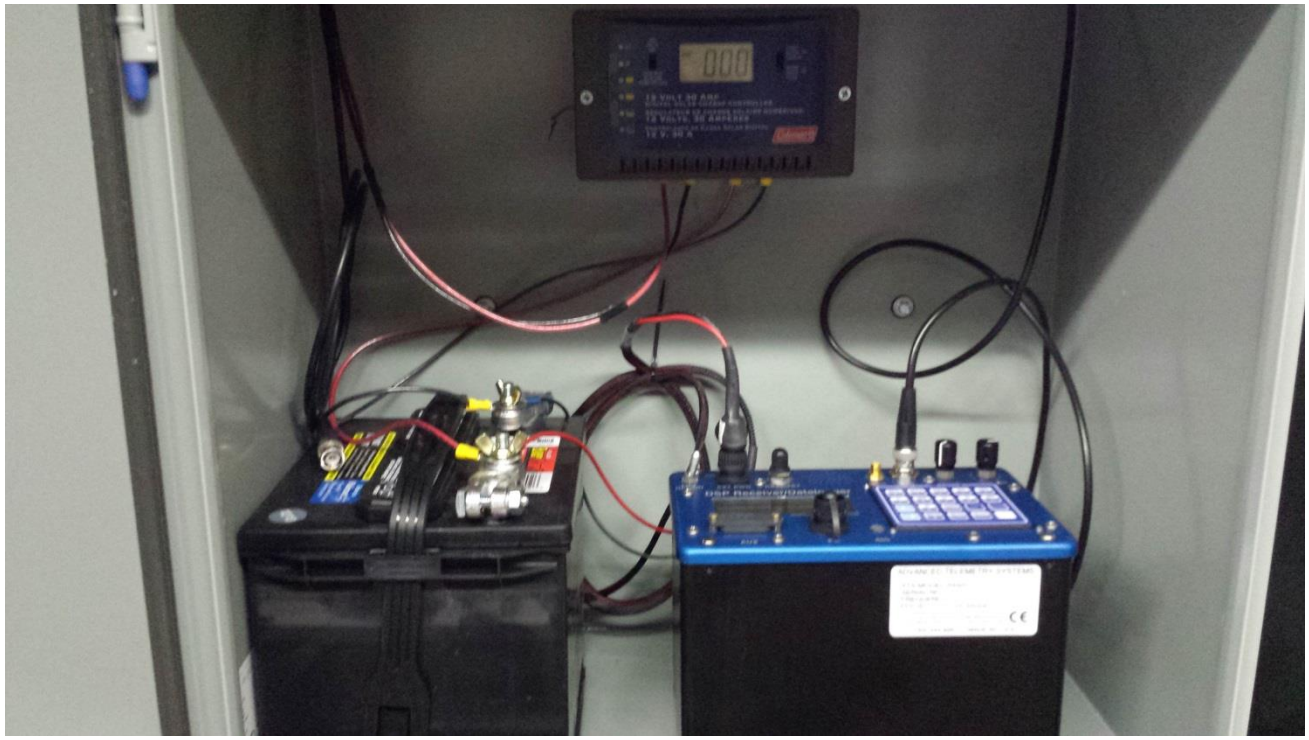

Figure 16. Typical configuration of data logger inside of protective boxes. The loggers were connected to an external battery that was recharged by a solar panel.

Figure 17. Partners TPWD and USFWS tracking radio tagged paddlefish in Big Cypress Bayou.

Figure 18. Paddlefish were easily detectable at the spillway of Lake o' the Pines. Up to 25 fish were detected just below the spillway in April 2015.

Figure 19. Electrofishing below the spillway of Lake O' the Pines. Eight tagged paddlefish were recaptured over the course of the study, one of them twice. All recaptured paddlefish were health and had gained weight and length since stocking.

Figure 20. Recaptured paddlefish

Figure 21. 2000 additional juvenile paddlfish were opportunistically stocked at Caddo Lake State Park in September 2014. The fish were excess from Tishomingo National Fish Hatchery and were approximately 12 inches long.

Figure 22. Typical radio receiver configuration for boat tracking. Two receivers running concurrently to reduce the chance of passing tagged fish as the radios scan through the 47 tag numbers.

Figure 23. Severe rains and flooding occurred in March 2015. The Caddo Lake spillway barrier was almost nonexistent at this time.

Appendix 4: Zooplankton Tow Data

	Spillway			Tower 2		
TAXON	Mean #/L	St Dev	St Error	Mean #/L	St Dev	St Error
Cyclopoid copepods	2.00	0.86	0.50	0.55	0.55	0.32
Calanoid copepods	0.00	0.00	0.00	0.24	0.20	0.12
Copepod nauplii	25.21	12.17	7.03	1.77	0.92	0.53
Ceriodaphnia sp.	0.00	0.00	0.00	0.00	0.00	0.00
Bosmina sp.	0.00	0.00	0.00	0.00	0.00	0.00
Daphnia lumholtzi	0.00	0.00	0.00	0.00	0.00	0.00
Chydorus sp.	0.00	0.00	0.00	0.00	0.00	0.00
Ostacoda	0.00	0.00	0.00	0.16	0.27	0.16
Chaoborus sp.	0.00	0.00	0.00	0.04	0.07	0.04
Asplanchna sp.	0.00	0.00	0.00	0.00	0.00	0.00
Total zooplankton	27.20	12.36	7.13	2.76	1.10	0.63

	Caddo A-113			Caddo G7			Caddo A106		
TAXON	Mean #/L	St Dev	St Error	Mean #/L	St Dev	St Error	Mean #/L	St Dev	St Error
Cyclopoid copepods	6.03	2.19	1.27	7.97	2.32	1.34	5.83	0.91	0.52
Calanoid copepods	0.37	0.32	0.18	0.20	0.18	0.10	0.46	0.52	0.30
Copepod nauplii	44.56	11.96	6.90	42.74	17.77	10.26	30.85	8.62	4.98
Ceriodaphnia sp.	0.73	0.32	0.18	0.41	0.18	0.10	0.11	0.20	0.11
Bosmina sp.	0.18	0.32	0.18	0.10	0.18	0.10	0.11	0.20	0.11
Daphnia lumholtzi	0.00	0.00	0.00	0.10	0.18	0.10	0.11	0.20	0.11
Chydorus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.20	0.11
Ostacoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaoborus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asplanchna sp.	0.18	0.32	0.18	0.00	0.00	0.00	0.34	0.34	0.20
Total zooplankton	52.05	13.30	7.68	51.53	19.61	11.32	37.93	9.60	5.54

Appendix 5: ANOVA from Zooplankton Tows

	Sum of Squares	df	Mean Square	F	Sig.
Cyclopoids	1.59	4	0.398	45.69	>0.0001
Calanoides	0.04	4	0.01	0.97	0.467
Nauplii	3.42	4	0.854	28.77	>0.0001
Ceriodaphnia	0.14	4	0.034	12.39	0.001
Bosmina	0.01	4	0.003	0.52	0.725
Daphnia	0.01	4	0.002	0.75	0.58
Chydorus	0.01	4	0.001	1.00	0.452
Ostracoda	0.01	4	0.002	1.00	0.452
Chaoborus	0.00	4	0	1.00	0.452
Asplanchna	0.04	4	0.009	1.77	0.212
Total Zoops	3.16	4	0.789	32.38	>0.0001