Middle Colorado River Basin Bioassessment




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Cover photos from top left, and proceeding clockwise: Guadalupe Bass from Gorman Creek at Colorado Bend State Park, Pimpleback from the Colorado River, Longear Sunfish from Spicewood Creek at Colorado Bend State Park, and the Colorado River at Colorado Bend State Park

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EXECUTIVE SUMMARY

One aquatic bioassessment study area encompassing three sites at Colorado Bend State Park and 33 supplemental collection sites were sampled across five Central Texas counties in the middle Colorado River Basin during the spring and summer of 2017. Data were collected on fish, mussels, benthic macroinvertebrates, crayfish, and riparian plant species.

Overall a total of 11,313 individuals and 44 species of fish were documented from the middle Colorado River Basin. Fish species richness by site ranged from three to 21. Three fishes classified as species of greatest conservation need were documented (*Dionda* sp., Texas Shiner, and Guadalupe Bass). Two species were added to the sub-basin species checklist, Blue Catfish and Blue Tilapia; however, both species are previously known from other parts of the basin. Species non-native to the Colorado River Basin made up a low percentage of total catch and included Common Carp, Mexican Tetra, Redbreast Sunfish, White Bass, Rio Grande Cichlid, and Blue Tilapia.

Ten species of freshwater mussels were collected during this study with species richness by site ranging from zero to six. One species, Texas Pimpleback, is listed as state-threatened and was collected from three sites. Four species of crayfish were collected across the study area.

Biological sampling within Colorado Bend State Park included data collection on fish, mussels, aquatic benthic macroinvertebrates, the riparian area, and overall stream health. Twenty-six species of fish, one species of freshwater mussel, one species of crayfish, 37 benthic macroinvertebrate taxa, and 24 riparian species were documented. Fish collected included several species that offer angling opportunity such as Largemouth Bass, Guadalupe Bass, White Crappie, Blue Catfish, White Bass, and several sunfish species. Overall, the health of the Colorado River at Colorado River Bend State Park was rated as good, meaning the river is ecologically functioning well; however, the riparian area condition could be improved.

Colorado Bend State Park provides public bank fishing and boat ramp access to the Colorado River upstream of Buchanan Reservoir. Other access to the Colorado River within the study area is largely limited to unimproved access sites under highway crossings. Tributaries that offer recreational opportunities within the study area through road crossings and local parks include Pecan Bayou, Brady Creek, and the San Saba River. There is one paddling trail on Pecan Bayou within the study area.

This study updated fish occurrence records for 36 sites across the middle Colorado River Basin. This information will be used in conservation planning by Texas Parks and Wildlife Department for their Native Fish Conservation Areas initiative (Birdsong et al. 2019). The study area falls within the Central Edwards Plateau Native Fish Conservation Area. Sport fish species data and recreational access information will also inform the agency's recreational access initiatives such as the Texas Paddling Trails and the River Access and Conservation Areas programs, both of which work with local landowners and partners to increase public access for fishing and paddling.

INTRODUCTION

Study Area

Colorado River: The Colorado River flows 1,337 km through Texas before emptying into the Gulf of Mexico (Huser 2000). While the Colorado River Basin extends into New Mexico, the mainstem, which originates just south of the Panhandle, is contained entirely within the state of Texas. The watershed cuts diagonally northwest to southeast across the state and drains an area of 103,340 km^2. It spans eight of the 12 ecoregions in Texas: High Plains, Southwestern Tablelands, Texas Blackland Prairies, Central Great Plains, Cross Timbers, Edwards Plateau, East Central Texas Plains, and Western Gulf Plains (Griffith et al. 2004). Major tributaries to the Colorado River include the Concho River, Pecan Bayou, Llano River, San Saba River, and Pedernales River. The Colorado River is one of the most impounded rivers in Texas and includes EV Spence Reservoir, OH Ivie Reservoir, and the chain of six reservoirs near Austin known as the Highland Lakes (Buchanan Reservoir, Inks Reservoir, LBJ Reservoir, Marble Falls Reservoir, Travis Reservoir, and Ladybird Reservoir).

Two reaches, spanning 160 km of the Colorado River have been recognized by the Nationwide Rivers Inventory for having remarkable cultural, geologic, historic, recreational, scenic, and fish and wildlife habitat value (NPS 2010). One of those reaches, from Bend, TX to the headwaters of Buchanan Reservoir, covers part of the river studied during this bioassessment and is recognized for its scenic and ecological value. Additionally, this reach has been named as an ecologically significant stream segment nominee for high water quality, exceptional aquatic life, high aesthetic value, the presence of listed species, and for the presence of a riparian conservation area at Colorado Bend State Park (TPWD 2018a). Gorman Creek, a tributary to the Colorado River that runs through Colorado Bend State Park, was also named as a nominee as part of a riparian conservation area (TPWD 2018a).

> Colorado Bend State Park: Colorado Bend State Park (CBSP) is located along the Colorado River in San Saba and Lampasas counties. The park is comprised of 2,156 ha (TPWD 2018b). In addition to the river, the park contains two spring-fed tributaries: Gorman Creek and Spicewood Creek. The park offers many recreational activities including camping, hiking, biking, fishing, swimming, kayaking, boating, caving, wildlife viewing, and drawn public hunts.

Survey and Management History

Biological Surveys: University of Texas' Fishes of Texas database includes historic records for 55 species of freshwater fishes from the middle Colorado River sub-basin (Hendrickson and Cohen 2015); however, there are many data gaps (i.e., area with no fish records or outdated records). No comprehensive biological fish or aquatic assemblage studies were found for the study area.

Basin-wide, 23 species of freshwater mussels are known to occur in the Colorado River Basin (TPWD 2008). Recent surveys include IRNR (2017) and Bonner et al. (2018), with the first only surveying targeted taxa and the second collecting 12 species from the middle Colorado River Basin.

Imperiled Species: Historical fish collections from the middle Colorado River Basin document five freshwater species currently identified by TPWD (2012) as species of greatest conservation need (SGCN): Guadalupe Roundnose Minnow *D. nigrotaeniata*, Texas Shiner *Notropis amabilis*, Red River Pupfish *Cyprinodon rubrofluviatilis*, Clear Creek Gambusia *Gambusia heterochir*, and Guadalupe Bass *Micropterus treculii* (Hendrickson and Cohen 2015). The Clear Creek Gambusia is listed as federally endangered and is restricted to Clear Creek. Two species reported from the middle Colorado River Basin are proposed for inclusion as SGCN: Plains Minnow *Hybognathus placitus* and Shoal Chub *Macrhybopsis hyostoma* (Cohen et al. 2018).

The Guadalupe Roundnose Minnow has recently been split into three species, two of which occur within the study area: *Dionda* sp. 3 in the upper Colorado River Basin and *Dionda flavipinnis* in the middle Colorado River Basin (Schönhuth et al. 2012). The exact boundary between these two species is currently undetermined, but it is thought to be in the vicinity of Colorado Bend State Park. Because Guadalupe Roundhose Minnow was listed as SGCN prior to this split, all newly split species are covered under this status until the next revision of the list.

Four SGCN mussels have historically occurred in the Colorado River Basin: Texas Fatmucket *Lampsillis bracteata*, Texas Pimpleback *Cyclonaias petrina* (formerly *Quadrula petrina*), False Spike *Fusconaia mitchelli*, and Texas Fawnsfoot *Truncilla macrodon* (TPWD 2008). Texas Fatmucket, Texas Pimpleback, and Texas Fawnsfoot are currently candidates for federal listing under the Endangered Species Act. False Spike is under review for federal listing.

Sport Fish Harvest Regulations: Sport fishes in the study area are managed under statewide fishing regulations (TPWD 2019a).

Fish Stockings: The Texas Parks and Wildlife Department stocked Largemouth Bass *Micropterus salmoides* (50 fingerlings), Guadalupe Bass (401 adults), Bluegill *Lepomis macrochirus* (878 individuals), and Channel Catfish *Ictalurus punctatus* (805 fingerlings) in the Colorado River adjacent to Colorado Bend State Park between 1988 and 1993 (TPWD 2019b). The only other documented riverine stockings within the study area occurred at Brady Creek in Richards Park in Brady, TX. Near annual stockings occurred here from 1992 to present of Largemouth Bass, Channel Catfish, or Rainbow Trout *Oncorhynchus mykiss* (TPWD 2019b). Several small impoundments and neighborhood fishing lakes within the study area (Brady Creek Reservoir, Old Coleman Reservoir, Mill Creek Park Lake, Coleman City Reservoir, Novice City Reservoir, Sealy Reservoir, Hords Creek Reservoir, San Tana Reservoir, and Talpa City Reservoir) have been stocked over the years with Blue Catfish *I. furcatus*, Channel Catfish, Largemouth Bass, Smallmouth Bass *M. dolomieu*, Bluegill, Rainbow Trout, Black Crappie *Pomoxis nigromaculatus*, Palmetto and Sunshine Bass *Morone saxatilis x M. chrysops*, and Threadfin Shad *Dorosoma cepedianum* (TPWD 2019b).

Water Quality: Three stream segments within the study area are listed by the Texas Commission on Environmental Quality (TCEQ) for water quality impairments (TCEQ 2016). Two segments were listed for recreational contact bacteria concerns: San Saba River (TCEQ segment 1416) and Upper Pecan Bayou (1432). One segment was listed for depressed dissolved oxygen readings: Brady Creek (1416A). In each of these cases TCEQ recommended a review of standards or additional data collection (TCEQ 2016).

STUDY SITES

The middle Colorado River Basin bioassessment consisted of sampling at 36 sites across five counties in Central Texas (Figures 1 and 2; Tables 1 and 2). Three sites were within Colorado Bend State Park and 33 additional sites were distributed throughout the basin.

TABLE 1. Middle Colorado River Basin study site locations and the fish sampling gear used at each during May¬¬– July 2017 in Brown, Coleman, McCulloch, Mills, and San Saba counties, TX. Mussels were also sampled for using snorkeling gear and time searches at a subsample of sites.

Site	Location	Coordinates	Sampling Date	Seine	Gill net	Trammel	Backpack	Frame net	Dip net	Mussels
A-C	Colorado Bend State Park	(See Fig. 2; Table 2)								
	Mainstem Colorado River Sites									
1	Colorado River at FM 503	31.4934, -99.5741	6/13/2017	x	x			x		
2	Colorado River at US 377	31.4680, -99.1610	7/26/2017	x	x					x
3	Colorado River at CR 443	31.2888, -98.5979	7/21/2017	x	x					
4	Colorado River below San Saba River	31.2533, -98.5955	7/28/2017	x	x					x
5	Colorado River near Timberlake	31.2616, -98.5946	7/28/2017							x
6	Colorado River at Barefoot RV Camp	31.1107, -98.4571	7/27/2017	x	x					
	Tributary Sites									
7	Hords Creek at E Live Oak St	31.8313, -99.4139	6/14/2017	x			x			
8	Jim Ned Creek at CR 135	31.8728, -99.2643	6/14/2017	x	x					
9	Pecan Bayou below Lake Brownwood	31.8381, -99.001	6/14/2017	x						
10	Home Creek at CR 270	31.6886, -99.3901	6/14/2017	x						
11	Mukewater Creek at FM 1173	31.5884, -99.2263	6/13/2017	x						
12	Clear Creek at US 377	31.5329, -99.0981	7/20/2017	x	x					
13	Clear Creek at FM 586	31.5295, -99.0787	6/13/2017	x						
14	Rough Creek at FM 574	31.4676, -98.8567	7/21/2017	x						
15	Pecan Bayou at CR 257	31.6423, -98.8773	6/14/2017	x	x					
16	Blanket Creek at CR 549	31.5882, -98.7652	7/21/2017	x						
17	Blanket Creek at CR 550	31.5314, -98.7446	7/21/2017	x						
18	Pecan Bayou at FM 573	31.5173, -98.7415	7/26/2017	x	x					x
19	Salt Creek at FM 765	31.3927, -99.5878	6/13/2017	x						
20	Saddle Creek at CR 330	31.4139, -99.4733	6/13/2017	x						
21	Unnamed tributary at FM 503	31.2542, -99.5998	6/13/2017					x		
22	Brady Creek at CR 128	31.1675, -99.4934	6/13/2017	x						
23	Brady Creek at Richards Park	31.1311, -99.3492	5/24/2017	x				x		
24	San Saba River at CR 214	31.0162, -99.1970	5/24/2017	x						
25	Richland Springs Creek at CR 224	31.2523, -98.8256	7/20/2017	x						
26	Wallace Creek at RR 1030	31.2523, -98.8256	7/20/2017	x						
27	San Saba River at SH 16	31.2130, -98.7196	7/20/2017	x						
28	Mills Creek Spring Run at US 190	31.1955, -98.7130	7/21/2017	x						
29	San Saba River near Colorado River	31.2525, -98.5962	7/28/2017							x
30	Horse Creek at CR 146	31.3063, -98.6364	7/21/2017	x						
31	Elliot Creek at CR 143	31.2965, -98.5239	7/21/2017	x						
32	Cherokee Creek at SH 16	30.9975, -98.7088	7/20/2017	x				x		
33	Cherokee Creek at CR 432	31.0728, -98.5460	7/20/2017	x			x			

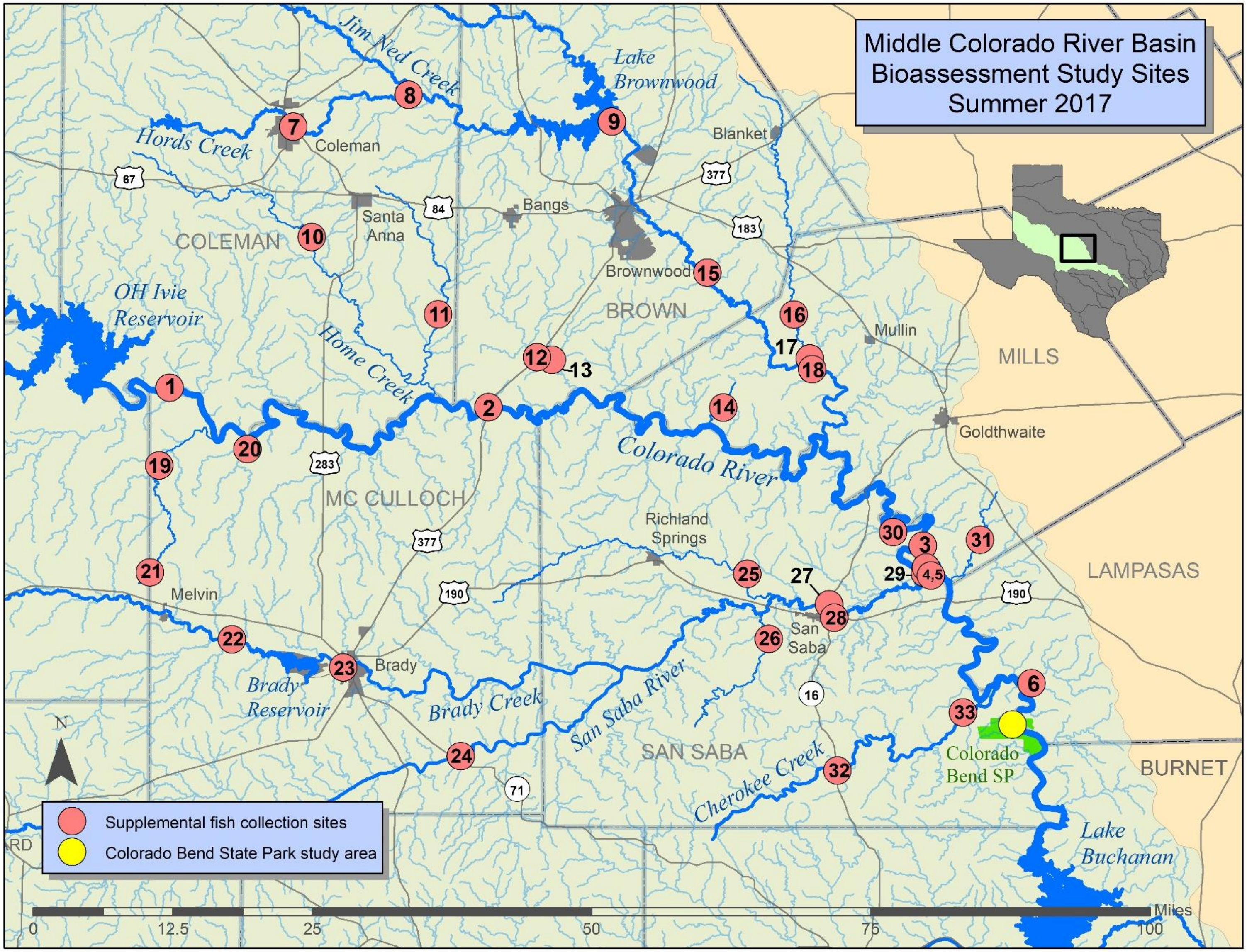

FIGURE 1.—Locations of middle Colorado River Basin data collection sites in Brown, Coleman, McCulloch, Mills, and San Saba counties, TX in spring and summer 2017. See Table 1 for specific site locations.

Colorado Bend State Park

Colorado Bend State Park was selected as the primary bioassessment study area, meaning it was a site of more intensive data collection than supplemental sites. Collections at the park included benthic macroinvertebrate, mussel, and fish assemblage data at three sites (Sites A–C; Figure 2).

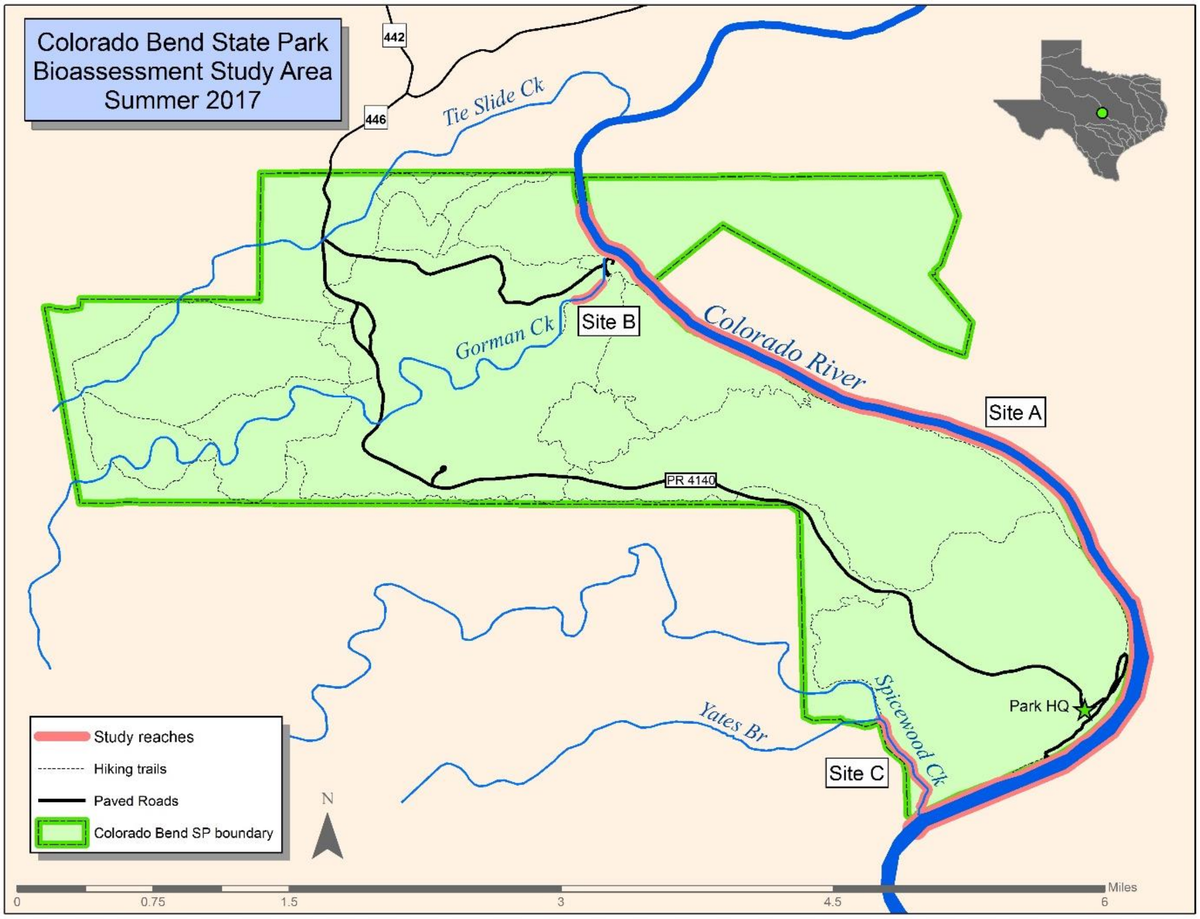

FIGURE 2.—Locations of study sites within the bioassessment study area at Colorado Bend State Park, San Saba County, TX. See Table 2 for specific site locations.

TABLE 2. Bioassessment area study site locations and the fish sampling gear used at each site from Colorado Bend State Park in San Saba County on May 23, 2017 and July 27, 2017. Mussels and aquatic invertebrates were also sampled.

Site	Location	Coordinates	Sampling Date	Seine	Boat Electrofish	Backpack Electrofish	Gill net	Frame net	Mussels	Macro-Invertebrate
A	Colorado River	31.0570, -98.4796	7/27/2017	x	x				x	x
B	Gorman Creek	31.0571, -98.4819	5/23/2017	x		x	x	x		
C	Spicewood Creek	31.0144, -98.4573	5/23/2017	x		x				

Site A (Figure 3) was a 7 km reach on the Colorado River that bordered most of the eastern park boundary. It occured on a gradient from more riverine habitats on the upstream end of the park, to more impounded pool-like habitats, likely influenced by Buchanan Reservoir, on the downstream end. Depths and velocities were variable throughout the study reach. Substrates were almost entirely composed of gravel, cobble, bedrock, and boulder with little to no aquatic vegetation present.

Sites B and C (Figure 3) occurred on spring-fed tributaries to the Colorado River within CBSP. Site B, a 0.25 km reach of Gorman Creek, contained considerably more silt and aquatic vegetation than sites A or C. The riparian area for Gorman Creek had also been invaded by non-native elephant ear *Colocasia esculenta*. Site C, a 0.5 km reach of Spicewood Creek, contained bedrock and gravel substrates and occurred as a series of shallow runs and riffles followed by step pools. Spicewood Creek had minimal aquatic vegetation and elephant ear was absent.

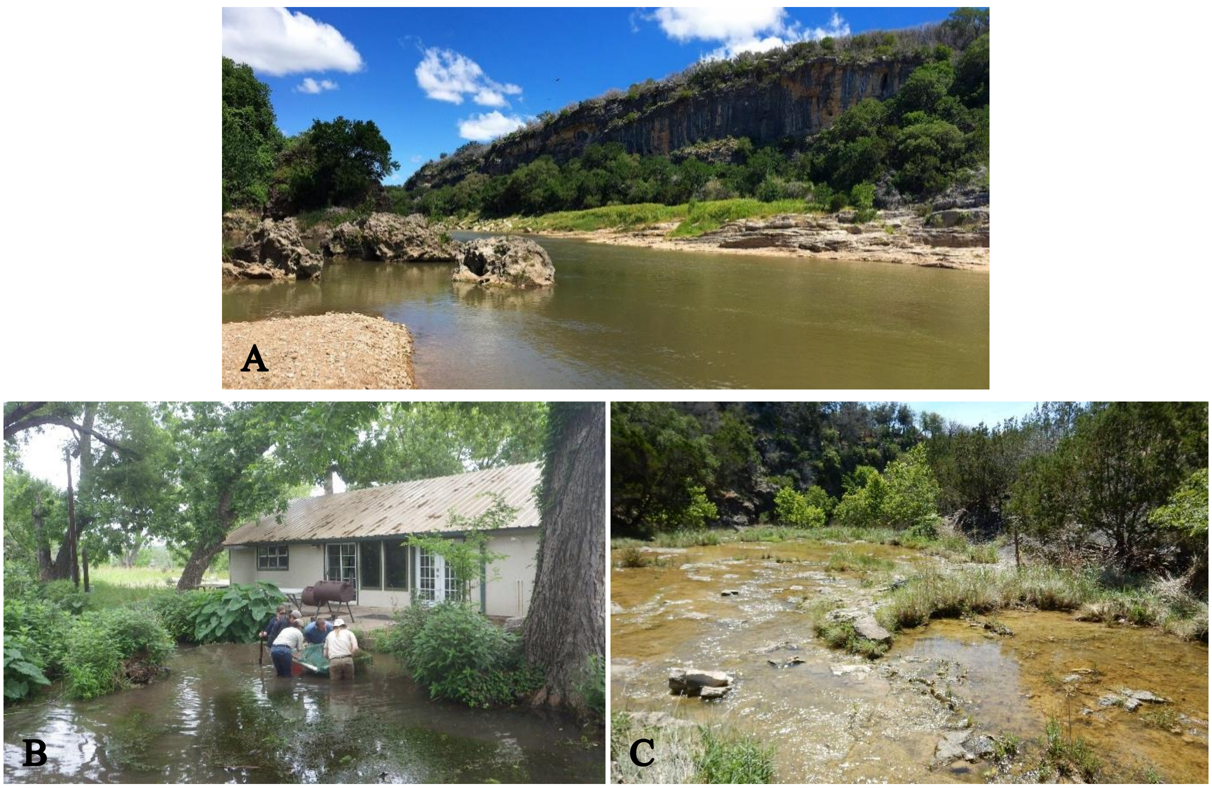

FIGURE 3.—Photos showing representative habitats of sites sampled within Colorado Bend State Park in San Saba County, TX in May and July 2017. Photos are labeled with the corresponding site letters found in Table 2 and Figure 2.

Mainstem Colorado River Sites

Six mainstem supplemental collection sites were sampled throughout the middle Colorado River Basin (Sites 1–6; Figure 1; Table 1). These sites were sampled to update fish occurrence data in the statewide Fishes of Texas Project database (Hendrickson and Cohen 2015). A subset was selected for mussel sampling (Sites 2, 4, and 5). Limited quantitative habitat data was collected from supplemental sites; however, photos of each site are included to provide a reference of conditions at the time of sampling (Figure 4).

FIGURE 4.—Supplemental sites 1–6 on the Colorado River sampled in summer 2017 in McCulloch and San Saba counties, TX.

Colorado River Basin Tributary Sites

Twenty-six supplemental tributary sites were sampled throughout the basin (Sites 7–33; Figure 1; Table 1). These sites were sampled to fill temporal or spatial fish data gaps and two were selected for mussel surveys (Sites 18 and 29). Limited quantitative habitat data was collected; however, photos of each site are included to provide a reference of conditions at the time of sampling (Figure 5).

FIGURE 5.—Supplemental tributary sites 7–33 (*29 not pictured) on the Colorado River sampled in spring and summer 2017 in Brown, Coleman, McCulloch, Mills, and San Saba counties, TX.

FIGURE 5.— Continued.

FIGURE 5.— Continued.

WATER QUALITY and QUANTITY

Methods: A YSI™ multi-parameter water quality sonde was deployed at Site A on the Colorado River at CBSP, but it failed to record data.

Results and Discussion: The sample area within CBSP lies within two TCEQ classified water quality stream segments, 1408 and 1409, Buchanan Reservoir and Colorado River above Buchanan Reservoir, respectively. The upper reach of segment 1408 has concerns for exceedances for chlorophyll-*a* (TCEQ 2014), which are likely a result of reduced inflow and pooling at the upper end of the reservoir (LCRA and UCRA 2017). There were no other water quality concerns noted.

Stream discharge at the time of sampling was considerably lower than what is typical of historical conditions during July. According to data from USGS gage 08147000 (Colorado River near San Saba, TX), discharge during the sampling period fluctuated between 20 and 30 cfs. Monthly median discharge (for July) calculated from data reported from the USGS gage near San Saba for the period of record (1931–2017) is 231 cfs.

FISH ASSEMBLAGE

Colorado Bend State Park (Sites A-C)

Methods: Fish were collected from the study reach on the Colorado River (Site A) in CBSP on July 26–27, 2017 utilizing seines, boat electrofishing, and minnow traps to assess fish community composition. Supplemental sampling occurred in two additional study reaches, Gorman Creek and Spicewood Creek (Sites B and C) in CBSP on May 23, 2017 using seines, backpack electrofishing, and minnow traps. Gill nets and frame nets were also employed in Gorman Creek (Site B).

Sampling techniques were selected based on perceived effectiveness for capturing fish at each sampling site given the depth, velocity, substrate, and cover present. Expanding upon TCEQ sampling protocols (TCEQ 2014), a minimum sampling effort of 10 seine hauls and 900 seconds of electrofishing was utilized at each site; however, additional sampling was conducted until all habitat types had been effectively sampled and new species were no longer collected.

Once captured, larger fish were identified to species, measured, photographed, and released. Smaller specimens were fixed in a 10% solution of formalin for identification and enumeration in the laboratory. All fish were examined for external deformities, disease, lesions, tumors, and skeletal abnormalities. Vouchered specimens will be permanently housed at the University of Texas' Biodiversity Collections in Austin, Texas. Data will be available online through the Fishes of Texas Project (www.fishesoftexas.org; Hendrickson and Cohen 2015).

The fish assemblage from Site A was evaluated using a draft large river Index of Biotic Integrity (IBI) specifically developed for the reach of the Colorado River running through the Edwards Plateau (G. Linam, TPWD, personal communication). An aquatic life use was assigned based upon the summation of the scores from the 14 draft metrics. Possible ratings included exceptional, high, intermediate, and limited.

TABLE 3. Number of fish collected by species combined across all sampling gear types by site from Colorado Bend State Park from May–July, 2017, San Saba County, Texas.

Family	Scientific name	Common name	Site A Colorado River	Site B Gorman Ck	Site C Spicewood
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	28		
	Dorosoma petenense	Threadfin Shad	39		
Cyprinidae	*Campostoma anomalum*	Central Stoneroller		5	35
	Cyprinella lutrensis	Red Shiner	96		
	Cyprinella venusta	Blacktail Shiner	16		
	Cyprinus carpio	Common Carp	7		
	Dionda sp.	Roundnose Minnow sp.			7
	Pimephales vigilax	Bullhead Minnow	124		
Characidae	*Astyanax mexicanus*	Mexican Tetra			31
Ictaluridae	*Ameiurus natalis*	Yellow Bullhead		22	
	Ictalurus furcatus	Blue Catfish	1		
Atherinopsidae	*Menidia beryllina*	Inland Silverside	22		
Poeciliidae	*Gambusia affinis*	Western Mosquitofish	6	13	43
Moronidae	*Morone chrysops*	White Bass	4		
	Morone chrysops x saxatilis	Morone hybrid	1		
Centrarchidae	*Lepomis auritus*	Redbreast Sunfish	3		
	Lepomis cyanellus	Green Sunfish			1
	Lepomis gulosus	Warmouth	1		
	Lepomis macrochirus	Bluegill	11		
	Lepomis megalotis	Longear Sunfish	31	48	21
	Lepomis microlophus	Redear Sunfish	1		
	Lepomis sp.	unknown sunfish (juv.)	8	2	
	Micropterus salmoides	Largemouth Bass	17		
	Micropterus treculii	Guadalupe Bass	4	10	
	Pomoxis annularis	White Crappie	6		
Percidae	*Percina carbonaria*	Texas Logperch	1		
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum	3		
	Number of species collected		**21**	**5**	**6**
	Number of individuals collected		**430**	**100**	**138**

FIGURE 6.—The most abundant species collected across all sites in Colorado Bend State Park shown from left to right were Bullhead Minnow, Longear Sunfish, Red Shiner, and Western Mosquitofish.

Results and Discussion: A total of 668 individuals consisting of ten families and 26 species were collected across all sites in CBSP (Table 3). Site A on the Colorado River yielded the most species, with 21 collected, while species richness on the two tributary sites ranged from five at Site B (Gorman Creek) to six at Site C (Spicewood Creek). The most abundant species collected across all sites in the park were Bullhead Minnow *Pimephales vigilax*, Longear Sunfish *Lepomis megalotis*, Red Shiner *Cyprinella lutrensis*, and Western Mosquitofish *Gambusia affinis* (Table 3; Figure 6).

Clear differences in species composition were noted between the Colorado River and the two tributary sites, with 18 species unique to the mainstem and five to the tributaries (Table 3; Figure 7). Specifically, five families were only found in the Colorado River: Clupeidae (shad), Atherinopsidae (silverside), Moronidae (temperate bass), Percidae (darters), and Sciaenidae (drum). Aside from Texas Logperch *Percina carbonaria*, all species collected from these families are typically residents of open-water habitats in moderate to large river systems.

Conversely, one family was only collected from a tributary site: Characidae (tetra). Mexican Tetra *Astyanax mexicanus* is the only species represented by this family in the United States and is often associated with small, headwater spring-fed streams that contain habitats with moderate current velocities and high amounts of instream cover such as aquatic vegetation and small woody debris (Thomas et al. 2007). Other species only collected from tributary sites included Central Stoneroller *Campostoma anomalum*, *Dionda* sp., Yellow Bullhead *Ameiurus natalis*, and Green Sunfish *Lepomis cyanellus* (Figure 7). As previously discussed, the Roundnose species collected could be one of two species (Dionda sp. 3 or *Dionda flavipinnis)*, but genetic analysis is needed for confirmation.

FIGURE 7.—Unique species that were only collected in the study reach on the Colorado River (Site A) shown starting at the top left and proceeding to the right are Gizzard Shad, Inland Silverside, White Bass, Freshwater Drum, and Largemouth Bass; five species only collected at one or both of the tributary sites (Sites B and C) are shown in the bottom row from left to right are Central Stoneroller, *Dionda* sp., Mexican Tetra, Yellow Bullhead, and Green Sunfish.

Five native cyprinid (minnow) species were collected across all sites within CBSP, with three species only occurring at Site A on the Colorado River and two species only in tributaries (Table 3). Of the two that were only collected in tributaries, Central Stoneroller and *Dionda* sp., both prefer spring-fed waters of small to medium sized streams similar to habitats found in Gorman and Spicewood creeks. Central Stoneroller are associated with gravel, cobble, and bedrock substrates in riffles, runs and pools (Burr 1980; Thomas et al. 2007), while *Dionda* species are usually found in clear, vegetated runs and pools with little temperature variation common to smaller headwater streams (Hubbs et al. 2008).

Nine centrarchid (sunfish and bass) species were collected across all sites (Table 3). Longear Sunfish was the most common and widely distributed sunfish species throughout CBSP. Aside from Longear Sunfish, Green Sunfish was the only other species of sunfish collected at a tributary site; the remaining four species of sunfish were all collected at Site A on the mainstem. Another species unique to the mainstem was White Crappie *Pomoxis annularis*. While several Guadalupe Bass were collected at Site A on the Colorado River, most were collected at Site B on Gorman Creek. Largemouth Bass were only collected on the mainstem study reach (Figure 7).

The fish assemblage from Site A rated as having an intermediate aquatic life use. Of the 14 metrics comprising the draft large river IBI, six received the highest score (species richness, number of sunfish species, number of intolerant species, percentage of individuals as invertivores, percentage of individuals as piscivores, and percentage of individuals with disease or anomalies), seven received an intermediate score (number of native cyprinid species, number of benthic invertivore species, percentage of individuals as tolerant species, number of broadcast spawning species, number of large river species, percentage of individuals as omnivores, and percentage of individuals as non-native species), and one received the lowest score (catch per-unit-effort).

Mainstem Colorado River Sites (Sites 1–4, 6)

Methods: Fish were collected along the mainstem Colorado River between Buchanan Reservoir and OH Ivie Reservoir at an additional five sites outside of CBSP in June and July, 2017 (Table 4, Figure 8). Sampling gear included seines and gill nets with a minimum of 15 seine hauls (including kick seining) and 1-2 hours of gill net set-time. At Site 1 a frame net was also used. All available habitats were sampled and effort continued until no new species were collected.

A subset of all representative species was preserved in buffered 10% formalin and brought back to the University of Texas, Biodiversity Collection for identification, further processing, and deposition. Tissue samples were taken at three of the five sites (Sites 3, 4, and 6) from select vouchers ad libitum and were deposited at the university's Genetic Resource Collection, along with the preserved whole specimens. Photo vouchers of species collected at each site are currently available on the iNaturalist Fishes of Texas Project (http://www.inaturalist.org/projects/fishes-of-texas) and all data will eventually be made public through the Fishes of Texas website (www.fishesoftexas.org), which feeds to major biodiversity data repositories such as, the Global Biodiversity Information Facility (www.gbif.org) and iDigBio Integrated Digitized Biocollections (www.idigbio.org).

Results and Discussion: A total of 2,573 individuals from 13 families representing 28 species were collected from the five mainstem Colorado River sites outside of the park during this study (Table 4). Species richness ranged from 16 to 21 across sites, with Site 6 (Colorado River at Barefoot RV Camp) having the highest number of species.

Several species were found at all five sites, including: Longnose Gar *Lepisosteus osseus*, Gizzard Shad, Blacktail Shiner *Cyprinella venusta*, Bullhead Minnow, Western Mosquitofish, Orangespotted Sunfish *Lepomis humilis*, Longear Sunfish, and Largemouth Bass (Table 4, Figure 8). The most abundant species was Bullhead Minnow.

The least widespread and abundant species, having only one individual collected from a single mainstem site included: Central Stoneroller, Common Carp *Cyprinus carpio*, Fathead Minnow *Pimephales promelas*, Green Sunfish, and Naked Goby *Gobiosoma bosc*.

All species collected were considered native to the basin, except Common Carp, White Bass, and possibly White Crappie. A recent exercise in which nativities for all Texas freshwater fish species were analyzed, based on vouchered occurrences and a panel of experts determined White Crappie to be 'possibly native' to the Colorado River (Cohen et al. 2018).

TABLE 4.—Number of fish collected by species for sites 1-6 on the mainstem Colorado River in McCulloch, Mills, and San Saba counties, TX: 1. Colorado River at FM 503 (6/13/2017), 2. Colorado River at US 377 (7/26/2017), 3. Colorado River at CR 443 (7/21/2017), 4. Colorado River below San Saba River confluence (7/28/2017), 6. Colorado River at Barefoot RV Camp (7/27/2017).

Family	Scientific Name	Common Name	1	2	3	4	6
Lepisosteidae	*Lepisosteus osseus*	Longnose Gar	2	5	3	2	1
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	16	8	36	8	16
	Dorosoma petenense	Threadfin Shad			2		5
Cyprinidae	*Campostoma anomalum*	Central Stoneroller					1
	Cyprinella lutrensis	Red Shiner		17	560	132	208
	Cyprinella venusta	Blacktail Shiner	1	3	4	1	26
	Cyprinus carpio	Common Carp	1				
	Notropis buchanani	Ghost Shiner			96	5	
	Pimephales promelas	Fathead Minnow				1	
	Pimephales vigilax	Bullhead Minnow	17	11	448	49	101
Catostomidae	*Carpiodes carpio*	River Carpsucker		1	68	2	1
	Moxostoma congestum	Gray Redhorse		1	1		5
Ictaluridae	*Ictalurus furcatus*	Blue Catfish			5		
	Ictalurus punctatus	Channel Catfish			11	1	6
Atherinopsidae	*Menidia beryllina*	Inland Silverside	11	32			33
Fundulidae	*Fundulus notatus*	Blackstripe Topminnow		5			4
Poeciliidae	*Gambusia affinis*	Western Mosquitofish	4	34	55	25	10
Moronidae	*Morone chrysops*	White Bass			1	1	
Centrarchidae	*Lepomis sp.*	Juvenile sunfish	25	15	161		5
	Lepomis cyanellus	Green Sunfish					1
	Lepomis gulosus	Warmouth	20				
	Lepomis humilis	Orangespotted Sunfish	18	8	45	13	5
	Lepomis macrochirus	Bluegill	15	10	2		3
	Lepomis megalotis	Longear Sunfish	5	1	30	9	21
	Micropterus salmoides	Largemouth Bass	1	4	1	2	2
	Pomoxis annularis	White Crappie	3	9	6	2	
Percidae	*Percina carbonaria*	Texas Logperch	18			2	1
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum			4		2
Gobiidae	*Gobiosoma bosc*	Naked Goby	1				
	Number of individuals		**1588**	**164**	**1,539**	**255**	**457**
	Number of species		**15**	**15**	**19**	**16**	**20**

FIGURE 8.—Common species collected during the mainstem Colorado River sampling shown from left to right: Orangespotted Sunfish, Bullhead Minnow, Largemouth Bass (juvenile), Longnose Gar (juvenile), and Gizzard Shad.

All species collected were previously documented in the study area except for Blue Catfish. Five small juveniles were collected at Site 3 located approximately 80 km upstream from Buchanan Reservoir (Figure 1). Only two other occurrences of Blue Catfish are documented for the Colorado River Basin in the Fishes of Texas database; however, both fall outside of the study area and are located near the Texas Gulf Coast (Hendrickson and Cohen 2015). Texas Parks and Wildlife Department stocking reports show 1990 as the most recent year Blue Catfish were stocked in Buchanan Reservoir (Hendrickson and Cohen 2015, TPWD 2019b); however, they have been stocked at other locations within the study area more recently (i.e. Lake Brownwood in 2016; TPWD 2019b). Blue Catfish were also collected at one of the tributary sites from this study (next section), Site 9 - Pecan Bayou below Lake Brownwood.

Another noteworthy find is the Naked Goby collected at Site 1 (Figure 9), which has only recently been detected this far upstream in the Colorado River. Previous records of this species include a 2010 study on river-reservoir transitional habitats of the Colorado River (Buckmeier et al. 2014) and a 2008 collection from the Concho River by TPWD biologists (TNHC 57882). Naked Goby is native to lower reaches of the Colorado River, but has been introduced to the study area, likely incidentally through sport fish stockings.

FIGURE 9.—Naked Goby collection from Site 1 on the Colorado River.

Colorado River Basin Tributary Sites (Sites 7–28 and 30–33)

Methods: Fish were also collected at twenty-six tributary sites within the middle Colorado River sub-basin for this study in June and July 2017 (Tables 5 and 6). All sampling gears and preservation methods described in the mainstem sites section above were utilized at these sites, with the addition of one additional gear type, backpack electrofisher, which was added at two sites (Sites 7 and 33). The purpose of sampling at tributary sites within these statewide bioassessments targets several objectives for the overall study. These collections seek out habitats typically not found within the mainstream corridor (small tributaries, ditches, ponds, disconnected pools, etc.). The aim is to fill in historical data gaps in the Fishes of Texas database (Hendrickson and Cohen 2015) and give a more complete snapshot of the fish community for the entire system.

Results: A total of 41 species were collected throughout the tributary sites, comprising 14 families and 8,072 individual specimens (Tables 5 and 6). Site 24 on the San Saba River yielded the most species (16) and Sites 16 and 21 (Blanket Creek and an unnamed tributary), both characterized as mucky stretches with no flow, yielded the least (3).

The most common species in occurrence were Western Mosquitofish (24 sites), Bluegill (20 sites), Largemouth Bass (20 sites), Longear Sunfish (19 sites), and Green Sunfish (17 sites). Western Mosquitofish and four cyprinid species (Red Shiner, Blacktail Shiner, Mimic Shiner *Notropis volucellus*, and Bullhead Minnow) were the most numerous throughout the sites. The goal of sampling at these sites was to capture the overall species richness for the study area, and effort was not recorded. Fishes that were rare during tributary sampling (one specimen collected from one site) included Smallmouth Buffalo *Ictiobus bubalus*, Yellow Bullhead, and White Bass *Morone chrysops*.

TABLE 5.—Number of fish collected by species and sites for Colorado River Basin tributary sites (7–19) in Brown, Coleman, Angelina, McCulloch, and Mills counties, TX: 7. Hords Creek at E Live Oak St (6/14/2017), 8. Jim Ned Creek at CR 135 (6/14/2017), 9. Pecan Bayou below Lake Brownwood (6/14/2017), 10. Home Creek at CR 270 (6/14/2017), 11. Mukewater Creek at FM 1176 (6/13/2017), 12. Clear Creek at US 377 (7/20/2017), 13. Clear Creek off FM 586 (6/13/2017), 14. Rough Creek at FM 574 (7/21/2017), 15. Pecan Bayou at CR 257 (6/14/2017), 16. Blanket Creek at CR 549 (7/21/2017), 17. Blanket Creek at CR 550 (7/21/2017), 18. Pecan Bayou at FM 573 (7/26/2017), 19. Salt Creek at FM 765 (6/13/2017).

Family	Scientific Name	Common Name	7	8	9	10	11	12	13	14	15	16	17	18	19
Lepisosteidae	*Lepisosteus osseus*	Longnose Gar		2	1	13					1		1		
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad		3		9		6	3		1			197	12
Cyprinidae	*Campostoma anomalum*	Central Stoneroller													
	Cyprinella lutrensis	Red Shiner		177	2					1	664	1	2	1000	
	Cyprinella venusta	Blacktail Shiner		35											
	Cyprinus carpio	Common Carp							1						
	Notemigonus crysoleucas	Golden Shiner				10									5
	Notropis amabilis	Texas Shiner													
	Notropis buchanani	Ghost Shiner									78				
	Notropis stramineus	Sand Shiner													
	Notropis volucellus	Mimic Shiner													
	Pimephales promelas	Fathead Minnow								21					161
	Pimephales vigilax	Bullhead Minnow		28	31	291	12		1	2	43		1	70	
Catostomidae	*Carpiodes carpio*	River Carpsucker				14									
	Ictiobus bubalus	Smallmouth Buffalo			1										
	Moxostoma congestum	Gray Redhorse									1		1		
Characidae	*Astyanax mexicanus*	Mexican Tetra													
Ictaluridae	*Ameiurus melas*	Black Bullhead						4		54					2
	Ameiurus natalis	Yellow Bullhead													
	Ictalurus furcatus	Blue Catfish			2										
	Ictalurus punctatus	Channel Catfish		1				1			4			3	
	Pylodictis olivaris	Flathead Catfish		2											
Atherinopsidae	*Menidia beryllina*	Inland Silverside			47										
Fundulidae	*Fundulus notatus*	Blackstripe Topminnow	12		8									2	
Poeciliidae	*Gambusia affinis*	Western Mosquitofish	32	16	111	32	37	4	5		23	16	19	17	473
Moronidae	*Morone chrysops*	White Bass									1				

TABLE 5 — CONTINUED

Family	Scientific Name	Common Name	7	8	9	10	11	12	13	14	15	16	17	18	19
Centrarchidae		Sunfishes												29	
	Lepomis sp.	Juvenile sunfish				18				30					13
	Lepomis auritus	Redbreast Sunfish													
	Lepomis cyanellus	Green Sunfish	14	2		3	8	2		15					19
	Lepomis gulosus	Warmouth	2		1			5							
	Lepomis humilis	Orangespotted Sunfish				13		3	3		16			6	16
	Lepomis macrochirus	Bluegill	12	1		24	21	10	4	1	5		13		18
	Lepomis macrochirus x megalotis	Bluegill x Longear Sunfish hybrid			6										
	Lepomis megalotis	Longear Sunfish	18	17		11	2	14	8		20		15	9	10
	Lepomis microlophus	Redear Sunfish			5			1							
	Micropterus salmoides	Largemouth Bass	3	7	6	34	1	9	8		9	5	7	2	4
	Micropterus treculii	Guadalupe Bass													
	Pomoxis annularis	White Crappie				5	5	24	20					1	
Percidae	*Etheostoma pulchellum*	Plains Orangethroat Darter													
	Percina carbonaria	Texas Logperch		2	2						2				
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum			1						1			1	
Cichlidae	*Herichthys cyanoguttatus*	Rio Grande Cichlid													
	Oreochromis aureus	Blue Tilapia													
	Number of individuals		**93**	**293**	**224**	**477**	**86**	**83**	**53**	**124**	**869**	**22**	**59**	**1337**	**733**
	Number of species		**7**	**13**	**14**	**12**	**7**	**12**	**9**	6	**15**	**3**	**8**	**11**	**10**

TABLE 6. Number of fish collected by species and site for Colorado River Basin tributary sites (20–28 and 30–33) in McCulloch, Mills, and San Saba counties, TX: 20. Saddle Creek at CR 330 (6/13/2017), 21. unnamed tributary at FM 503 (6/13/2017), 22. Brady Creek at CR 128 (6/13/2017), 23. Brady Creek at Richards Park (5/24/2017), 24. San Saba River at CR 214 (5/24/2017), 25. Richland Springs Creek at CR 224 (7/20/2017), 26. Wallace Creek at RR 1030 (7/20/2017), 27. San Saba River at SH 16 (7/20/2017), 28. Mill Creek Spring Run at US 190 (7/21/2017), 30. Horse Creek at CR 146 (7/21/2017), 31. Elliot Creek at CR 143 (7/21/2017), 32. Cherokee Creek at SH 16 (7/20/2017), 33. Cherokee Creek at CR 432 (7/20/2017).

Family	**Scientific Name**	**Common Name**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**30**	**31**	**32**	**33**
Lepisosteidae	*Lepisosteus osseus*	Longnose Gar													
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	2		45					4					
Cyprinidae	*Campostoma anomalum*	Central Stoneroller					6		2		1		8		82
	Cyprinella lutrensis	Red Shiner			358			23		140			1		
	Cyprinella venusta	Blacktail Shiner					228		24	64	10			137	525
	Cyprinus carpio	Common Carp						31				31		1	
	Notemigonus crysoleucas	Golden Shiner	2		5										
	Notropis amabilis	Texas Shiner									99				
	Notropis buchanani	Ghost Shiner													
	Notropis stramineus	Sand Shiner													19
	Notropis volucellus	Mimic Shiner					66		200	102					6
	Pimephales promelas	Fathead Minnow			33										
	Pimephales vigilax	Bullhead Minnow					3		30	51		1			2
Catostomidae	*Carpiodes carpio*	River Carpsucker					1*								
	Ictiobus bubalus	Smallmouth Buffalo													
	Moxostoma congestum	Gray Redhorse					6		1	2					
Characidae	*Astyanax mexicanus*	Mexican Tetra									6				
Ictaluridae	*Ameiurus melas*	Black Bullhead	18	3								3	2		
	Ameiurus natalis	Yellow Bullhead									1				
	Ictalurus furcatus	Blue Catfish													
	Ictalurus punctatus	Channel Catfish	4						1	1				1	12
	Pylodictis olivaris	Flathead Catfish								3		1			9
Atherinopsidae	*Menidia beryllina*	Inland Silverside			11	9									
Fundulidae	*Fundulus notatus*	Blackstripe Topminnow				3				2					
Poeciliidae	*Gambusia affinis*	Western Mosquitofish	18		132	33	31	348	9	12	59	8	9	13	18
Moronidae	*Morone chrysops*	White Bass													

TABLE 6 — CONTINUED

Family	Scientific Name	Common Name	20	21	22	23	24	25	26	27	28	30	31	32	33
Centrarchidae		Sunfishes													
	Lepomis sp.	Juvenile sunfish													
	Lepomis auritus	Redbreast Sunfish					12							7	4
	Lepomis cyanellus	Green Sunfish	5	4	1	10	1	6	15			4	11		13
	Lepomis gulosus	Warmouth	9				1								
	Lepomis humilis	Orangespotted Sunfish	11									11			
	Lepomis macrochirus	Bluegill	7	1	6	45	10		1		6		6	9	3
	Lepomis macrochirus x megalotis														
	Lepomis megalotis	Longear Sunfish	10		1		18			17	16	1	16	18	9
	Lepomis microlophus	Redear Sunfish													
	Micropterus salmoides	Largemouth Bass				39	7		1	2	2		2	13	2
	Micropterus treculii	Guadalupe Bass					9		1	5	30				2
	Pomoxis annularis	White Crappie	6												
Percidae	*Etheostoma pulchellum*	Plains Orangethroat Darter					3			1				2	3
	Percina carbonaria	Texas Logperch				4	14			2					
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum													
Cichlidae	*Herichthys cyanoguttatus*	Rio Grande Cichlid									8				
	Oreochromis aureus	Blue Tilapia									4				
	Number of individuals		**92**	**8**	**592**	**143**	**416**	**408**	**285**	**408**	**242**	**60**	**55**	**201**	**709**
	Number of species		**11**	**3**	**9**	**7**	**16**	**4**	**11**	**15**	**12**	**8**	**8**	**9**	**15**

As with the mainstem study sites, the two families with the most species representation were Centrarchidae (10 species) and Cyprinidae (11 species). Non-native species collected from tributary sites included Redbreast Sunfish, Mexican Tetra, Rio Grande Cichlid *Herichthys cyanoguttatus*, Blue Tilapia *Oreochromis aureus* (Hubbs et al. 2008), and potentially White Crappie (Cohen et al. 2018). Blue Tilapia is a new addition to the study area checklist, but have been found elsewhere within the Colorado River Basin in the past (Hendrickson and Cohen 2015).

River Carpsucker *Carpiodes carpio* were collected from several mainstem and two tributary sites; however, one individual collected from Site 24 on the San Saba River, appeared morphologically distinct (Figure 10). This individual had more lateral line scales and lacked the lower lip nipple that is a distinct identification character for River Carpsucker. Based on these characteristics, this individual could be identified as a Quillback *Carpiodes cyprinu*s; however, that species is not known to occur in Texas and this individual lacked the very long first dorsal ray that is characteristic of Quillbacks (Pflieger 1997). Other unusual *Carpiodes* have been collected from the Llano River, another major tributary to the Colorado River, in recent years and some have suggested perhaps they are an undescribed species of sucker similar to, but distinct from the River Carpsucker. To date, there are no publications describing such. This individual was preserved and genetic material retained. For the purposes of this study this individual was identified as River Carpsucker, but differences were noted.

FIGURE 10.—Unique River Carpsucker collected from Site 24 on the San Saba River. This individual displayed different morphological characteristics than others collected, including more lateral line scales and the lack of a nipple-like projection on the lower lip.

Summary of Fish Collection Data

A total of 11,313 individuals consisting of 44 species were collected during this assessment. Across all sites, notable differences were documented between mainstem and tributary sites. Two species were only collected from mainstem sites (Threadfin Shad and Naked Goby), while 13 species were only collected from tributaries (*Dionda* sp., Golden Shiner *Notemigonus crysoleucus*, Texas Shiner, Ghost Shiner *Notropis buchanani*, Sand Shiner *Notropis stramineus*, Mimic Shiner, Smallmouth Buffalo, Mexican Tetra, Black Bullhead *Ameiurus* melas, and Yellow Bullhead, Flathead Catfish *Pylodictus olivaris*, Plains Orangethroat Darter *Etheostoma pulchellum*, Rio Grande Cichlid, and Blue Tilapia). Several of the species collected solely from tributaries are spring-associates (Texas Shiner, *Dionda* sp., Mexican Tetra, and Blue Tilapia) suggesting spring influences are greater in the headwaters of these smaller streams as compared to the mainstem, and thus drive some of the assemblage differences.

Historically, Hendrickson and Cohen (2015) report 55 species from the hydrologic units contained within the study area. Overall, two species were added to the regional checklist: Blue Catfish and Blue Tilapia; however, neither are new additions to the overall basin checklist. Additionally, this study has provided TPWD and the Biodiversity Collections with updated fish records and vouchers for 35 sites, all of which will be made available to the public through the Fishes of Texas Project website (www.fishesoftexas.org/).

MUSSEL ASSEMBLAGE

Methods: Mussels were surveyed at a subset of sites in the Colorado River mainstem and tributaries (Table 1) using timed snorkel or tactile searches in all available mesohabitat types (Strayer and Smith 2003). Minimum effort at each site was one person-hour. All live mussels encountered during timed searches were enumerated and returned to the habitat in which they were found. Mussel shells that were encountered during surveys were also noted.

Results and Discussion: Sampling effort for this survey totaled 19.0 person-hours of total search time over six sampling sites with 88 total live mussels collected representing 10 species (Table 7; Figure 11). The Colorado River site downstream of the Tarleton State University's Timberlake Field Station (Site 5) had the highest diversity (six species), and highest catch per-unit-effort (22.00 mussels per hour) of the six sites. Pecan Bayou (Site 18) was the only site where no live mussels were collected. Howells (1997) sampled this site previously and also collected no live mussels. At the bioassessment site (Site A) on the Colorado River at CBSP only one live Pistolgrip *Tritogonia verrucosa* was found during 5 person-hours of searches. Howells (1997) also sampled this site and reported no live mussels, but did similarly find a recently dead Pistolgrip in subsequent surveys. Habitat may be a limiting factor for mussels at this site given the majority of Site A is comprised predominantly of bedrock and boulder substrates and deep pools with steep clay/silt banks.

Texas Pimpleback, False Spike, Texas Fatmucket, and Texas Fawnsfoot are state-listed species known to occur in the Colorado River Basin. Smooth Pimpleback *Cyclonaias houstonensis* also occurs in the Colorado River Basin and is currently listed as state-threatened, but recent genetic analysis has found this not to be a valid species, instead it has been synonymized with Pimpleback *Cyclonaias pustulosa* (Johnson et al. 2018). Of these four state-listed species, only Texas Pimpleback was collected live. It was found at three of the six sampling sites (Sites 2, 4, and 5). Texas Pimpleback was also found to be relatively abundant in recent surveys within the San Saba and Llano Rivers (IRNR 2017), as well as other mainstem Colorado River sites upstream of Colorado Bend State Park (Bonner et al. 2018). A long-dead shell of Texas Fawnsfoot was also found at Site 4.

FIGURE 11.—Some of the mussel species collected during the middle Colorado River Bain bioassessment in summer 2017 include Pimpleback, Threeridge, and Pistolgrip.

TABLE 7.—Mussel species historically known from the Colorado River Basin in 2008 (TPWD 2008), with the number of live mussels collected (shell material noted with an X) at six sites in the Colorado River Basin during July 2017.

Common Name	**Species**	**Site A**	**Site 2**	**Site 4**	**Site 5**	**Site 18**	**Site 29**	**Total**
Threeridge	Amblema plicata			X	7	X		7
Rock Pocketbook	Arcidens confragosus							
Texas Pimpleback[1]	Cyclonaias petrina		1	2	25			28
Pimpleback	Cyclonaias pustulosa		X		12			12
Tampico Pearlymussel	Cyrtonaias tampicoensis		X		1			1
False Spike[1]	Fusconaia mitchelli							
Texas Fatmucket[1]	Lampsilis bracteata							
Yellow Sandshell	Lampsilis teres		1					1
Fragile Papershell	Leptodea fragilis	X	X	2	3		4	9
Pond Mussel	Ligumia subrostrata							
Washboard	Megalonaias nervosa							
Bleufer	Potamilus purpuratus		X	2				2
Giant Floater	Pyganodon grandis	X	1				1	2
Southern Mapleleaf	Quadrula apiculata	X	3			X		3
Creeper	Strophitus undulatus							
Lilliput	Toxolasma parvus							
Texas Lilliput	Toxolasma texasense							
Pistolgrip	Tritogonia verrucosa	1		2	18		2	23
Texas Fawnsfoot[1]	Truncilla macrodon			X				
Tapered Pondhorn	Uniomerus declivis							
Pondhorn	Uniomerus tetralasmus							
Paper Pondshell	Utterbackia imbecillis		X					
	Total Species	1	4	4	6	0	3	10
	Total Abundance	1	6	8	66	0	7	88
	Search Time (hrs)	5	3	2	3	3	3	19
	CPUE (#/hr)	0.2	2	4	22	0	2.33	4.63

[1] – State-threatened X - shell only

For the remaining three state-listed species not encountered live during our sampling efforts, False Spike and Texas Fawnsfoot are generally considered rare in the Colorado River Basin, especially within the mainstem of the Colorado River (IRNR 2017, Bonner et al. 2018). Texas Fatmucket is generally known to occur in headwaters and tributary habitats where they are relatively abundant in some locations (IRNR 2017). Only a few live individuals of False Spike have been reported from the San Saba and Llano rivers (Randklev et al. 2013a, Randklev et al. 2013b, IRNR 2017) with no recent records within the mainstem of the Colorado River to date. Similarly, only a few live individuals of Texas Fawnsfoot have been reported from the San Saba River in recent surveys (Sowards et al. 2013).

Compared to other river systems in Texas, species richness and abundance appear to be low in the middle Colorado River Basin except for a few sites on the mainstem and some tributary sites. A potential contributing factor for the low abundance of mussel species in this basin could be lingering impacts from the severe drought in 2011. At the USGS gage on the Colorado River in San Saba, the average of the mean annual discharge for the entire period of record for this gage (1931–2017), including the drought of record in the 1950's, was 898 cfs. During the drought of 2011, flows approached zero during the peak of the drought in the summer of that year and the mean annual discharge for the entire year was only 69.8 cfs, the lowest mean annual flow observed for the period of record for this stream gage. Additionally, hydrologic alterations from reservoir construction, land-use changes, and increasing water demand in the basin have potentially contributed to the low abundance of freshwater mussels in this river basin.

BENTHIC MACROINVERTEBRATE ASSEMBLAGE

Methods: Aquatic macroinvertebrates were collected using a D-frame kicknet from two locations within Site A on the Colorado River at CBSP (Figure 2) following TCEQ sampling procedures (TCEQ 2014). Sampling locations were located approximately 140 m apart, with one in the upstream, more lotic section of river and the other in the downstream, more lentic section. Substrate composition at the collection areas was primarily bedrock, with some medium gravel and sand. Macroinvertebrates were picked in the field, preserved with 70% ethanol, and identified in the laboratory to the lowest possible taxonomic group (generally to genus).

Indices used to evaluate the assemblage data included Shannon's diversity index (SDI; Shannon and Weaver 1949), ratio of tolerant to intolerant taxas (Barbour et al. 1999), Hilsenhoff biotic index (HBI; Hilsenhoff 1987; 1988), and the relative proportions of Ephemeroptera, Plecoptera, and Trichoptera taxa (EPT index; Lenat 1988). The SDI provides information about the rarity or commonness of taxa in a community and gives a way to compare communities across sites.

Results and Discussion: The benthic macroinvertebrates collected from Site A were represented by nine orders, 23 families, and 37 genera, with a total of 340 individuals (Table 8). Upstream lotic habitat contained two more taxa than the downstream lentic habitat (25 vs 23 genera) and a slightly greater SDI (2.4 versus 2.2). The data from the two locations were averaged for the subsequent analyses to generally assess the macroinvertebrate community.

The dominant order collected was Ephemeroptera (mayfly) and the dominant family, Baetidae. The three most abundant mayfly genera were *Vacupernius*, *Neochoroterpes*, and *Thraulodes*. All indices indicate this stretch of the Colorado River to be in relatively good ecological condition. The ratio of tolerant to intolerant taxa scored moderately high (metrics value = 4.13) indicating an overall assemblage with relative sensitivity to pollution. Sensitive taxa were represented primarily by the high diversity of mayflies. The HBI, which is an indicator of organic pollution, scored 3.6, indicating excellent condition and low organic pollution. The EPT index also scored moderately high (68%). A high EPT is typically indicative of a lack or low concentration of pollutants.

TABLE 8.— Macroinvertebrates with the number collected and trophic guilds from two locations on the Colorado River within the Colorado Bend State Park in July 2017. Trophic guilds are abbreviated: collector gatherer (CG), filtering collector (FC), predator (P), scraper (SCR), and shredder (SHR). Life stages are abbreviated as: adult (A) and larval (L).

Order	Family	Genus	Lifecycle Stage	Trophic Guild	Downstream location	Upstream location
Coleoptera	Elmidae	*Neoelmis*	A	SCR/CG		1
		Neoelmis	L	SCR/CG		3
		Stenelmis	A	SCR/CG	21	13
		Stenelmis	L	SCR/CG	1	7
	Gyrinidae	*Gyretes*	L	P	2	6
Diptera	Ceratopogonidae		L	P/CG		1
	Chironomidae		L	P/CG/FC	2	3
Ephemeroptera	Baetidae	*Acentrella*	L	SCR/CG		1
		Baetis	L	SCR/CG		1
		Camelobaetidius	L	SCR/CG		9
		Fallceon	L	SCR/CG	2	6
		Procloeon	L	CG	1	
		Pseudocloeon	L	SCR/CG	1	
		Paracloeodes	L	SCR/CG	1	
	Caenidae	*Brachycercus*	L	CG	1	
		Caenis	L	SCR/CG	4	
	Heptageniidae	*Stenonema*	L	SCR/CG		1
	Leptohyphidae	*Vacupernius*	L	CG	54	2
	Leptophlebiidae	*Neochoroterpes*	L	CG/SCR	35	13
		Thraulodes	L	CG/SCR	9	39
		Traverella	L	FC		42
	Oligoneuriidae	*Isonychia*	L	FC	1	10
	Tricorythidae	*Tricorythodes*	L	CG		1
Hemiptera	Corixidae	*Trichocorixa*	L	P/CG	2	
	Gelastocoridae	*Gelastocoris*	L	P	1	
	Gerridae	*Trepobates*	L	P	7	1
		Metrobates	L	P	9	
	Veliidae	*Microvelia*	L	P	1	
		Rhagovelia	L	P	5	
Hirudinea	Leech		A	P	2	1
Lepidoptera	Pyralidae	*Petrophila*	L	SCR		1
Megaloptera	Corydalidae	*Corydalus*	L	P		2
Odonata	Coenagrionidae	*Argia*	L	P	1	2
	Gomphidae		L	P		1
		Dromogomphus	L	P	1	
Trichoptera	Hydropsychidae	*Hydropsyche*	L	FC		3
	Leptoceridae	*Nectopsyche*	L	SHR/CG/P	2	
		Oecetis	L	P/SHR		1
	Philopotamidae	*Chimarra*	L	FC		3
		Number of individuals collected			**166**	**174**
		Number of taxa collected			**23**	**25**

Of the total 37 taxa collected, the predator feeding guild was represented by 11 taxa, followed by the scraper-collector-gatherer feeding guild with 10 taxa. The predator guild was represented by many top-water taxa (Hemipterans). A higher percentage of top-water taxa is often associated with stream sections that are disconnected temporally as a result of low discharge levels. Discharge levels at the time of sampling were considerably lower than the historical median.

Although no prior macroinvertebrate data exists from CBSP, TCEQ has been monitoring three sites upstream of the park since 1993. While differences exist, there is a broad overlap of taxa between our study and those collected upstream. Differences can likely be explained by number of samples and habitat. The greater taxa diversity at the TCEQ sites can be attributed to the larger sample size (18 samples at three distinct sites verses one sample; TCEQ 2018) and the TCEQ collections being spread out over several years reflecting a variety of environmental conditions. Habitat differences could also be a factor as bedrock was the primary substrate at our site and current velocity was reduced due to the lake effect caused by proximity to Buchanan Reservoir.

Despite limited complex habitat availability and low discharge levels, the reach was in fairly good ecological condition as indicated by the benthic macroinvertebrate community. The high intolerant to tolerant taxa ratio score suggests a functioning system. Although Hemipterans were collected in large numbers, possibly indicating temporal disconnection, the richness and abundance of Ephemeropterans indicates resilience of the system.

CRAYFISH

Methods: Baited crayfish traps were deployed for approximately 12 hours at sites within CBSP (Sites A, B, C). Additionally, all crayfish encountered while seining from all collection sites were photographed and released. Photo vouchers and locality information were placed on the website iNaturalist (http://www.inaturalist.org/) for species identification and verification.

Results and Discussion: Four species of crayfish were collected from 14 sites (Table 9; Figure 12). Red Swamp Crayfish *Procambarus clarkii* was the most common species, occurring at 7 sites. Red Swamp Crayfish and Southern Plains Crayfish *Procambarus simulans* have a NatureServe conservation status of G5, meaning the species are secure due to a large geographic range and have common occurrence throughout that range (NatureServe 2017). Red Swamp Crayfish, while thought to be native to Texas and surrounding states, has expanded its range to many other states across the United States (Nagy et al. 2020). This species has been classified as a high ecological risk by the United State Fish and Wildlife Service (USFWS 2015) due to its ability to invade new habitats and outcompete native species within those systems. Additionally, this species alters habitats and has been known to reduce populations of native macroinvertebrates, mussels, and fish (USFWS 2015).

Pecan Bayou Crayfish *Faxonius castaneus* and Western Freckled Crayfish *Faxonius occidentalis* have not been evaluated on NatureServe. These species have only recently been described (Johnson 2010; Crandall and De Grave 2017) and little information is available. Both species are thought to be Texas endemics and deserve further evaluation for conservation status.

TABLE 9.—Species of crayfish encountered during fish sampling and targeted sampling in the summer of 2017 as part of the middle Colorado River Basin bioassessment and the waterbodies and sites each species were found at. See Table 1 for site information.

Scientific Name	Common Name	Waterbody	Site
Faxonius castaneus	Pecan Bayou Crayfish	Jim Ned Creek	8
		Pecan Bayou	15
Faxonius occidentalis	Western Freckled Crayfish	Mills Creek spring run	28
Procambarus clarkii	Red Swamp Crayfish	Brady Creek	22,23
		Colorado River	A, 3
		Gorman Creek	B
		Spicewood Creek	C
		Wallace Creek	26
Procambarus simulans	Southern Plains Crayfish	Horse Creek	30
		Mills Creek spring run	28
		Richland Creek	25
		Rough Creek	14
		Saddle Creek	20
Number of species encountered			**4**

FIGURE 12.—Photos documenting each species collected during the middle Colorado River Basin bioassessment in spring and summer 2017, from top left, and moving clockwise: Pecan Bayou Crayfish, Western Freckled Crayfish, Red Swamp Crayfish, and Southern Plains Crayfish.

IMPERILED SPECIES

Three species of fishes classified as SGCN were collected during this study: undetermined Roundnose species *Dionda* sp., Texas Shiner (G4- apparently secure; NatureServe 2017), and Guadalupe Bass (G3- vulnerable; Figure 13). These three species are presumed to only occur in Texas (NatureServe 2017). Texas Shiner once occurred in New Mexico but is thought to be extirpated from that portion of its range.

FIGURE 13.—Fish species of greatest conservation need collected from the middle Colorado River Basin bioassesment in 2017 from left to right are *Dionda* sp., Texas Shiner, and Guadalupe Bass.

Texas Shiner and *Dionda* sp. are thought to be spring-associates, meaning they rely on stenothermal habitats in spring-dominated systems (Gilbert 1998; Brown 1953). The largest threat facing these species is reduced spring discharges due to groundwater pumping or drought. Reliance on a threatened habitat coupled with their narrow distributions, led these species to be listed as species of concern in Texas, warranting further research.

Guadalupe Bass, the state fish of Texas, is a state endemic and valued riverine sportfish; however, it currently faces several threats including habitat loss and hybridization with non-native Smallmouth Bass. Smallmouth Bass were stocked in Brady Creek and O. H. Ivie reservoirs in the 1980s; however, subsequent surveys of Guadalupe Bass genetics in the nearby San Saba River found very low introgression rates (Bean 2017). The population in O. H. Ivie persists however, and could act a source of introduction to the downstream Colorado River. Due to these low rates of hybridization and the presence of both Smallmouth Bass and Guadalupe Bass in the basin, the San Saba River and Middle Colorado River were prioritized for Guadalupe Bass population restoration in TPWD's 2017–2026 Guadalupe Bass Conservation Plan (Bean 2017).

Fish classified as SGCN were collected at six sites across the study area. Of these, all fall within the existing bounds of the Central Edwards Plateau Native Fish Conservation Area Native Fish Conservation Areas (Birdsong et al. 2019), except for Site 24 (San Saba River) where Guadalupe Bass were collected.

One mussel SGCN, Texas Pimpleback, was collected at three of the six sites sampled for mussels. Texas Pimpleback is a Texas endemic and concurrently listed as state-threatened. It is ranked as G1- critically imperiled by NatureServe (2017). One of the most immediate threats to populations of this species is stream dewatering which has occurred intermittently in reaches of the Middle Colorado and San Saba rivers in recent years.

RIPARIAN ASSEMBLAGE

Methods: A qualitative visual assessment of the riparian area was conducted to obtain a basic understanding of its overall functioning condition. Dominant species present, age class distribution, and vigor of the plants within the riparian corridor were noted. Non-native species were also documented.

Results and Discussion: While conducting the qualitative assessment some common tree species observed within the riparian area included:

- cedar elm *Ulmus crassifolia*
- American elm *Ulmus americana*
- green ash *Fraxinus pennsylvanica*
- American sycamore *Platanus occidentalis*
- pecan *Carya illinoinensis*
- soapberry *Sapindus saponaria* var. *drummondii*
- hackberry *Celtis leavigata*
- black willow *Salix nigra*

Common herbaceous and shrub species observed included:

- greenbrier *Smilax* sp.
- inland sea oats *Chasmanthium latifolium*
- blue mistflower *Conoclinium coelistinum*
- Virginia wild rye *Elymus virginicus*
- Canada wild rye *Elymus canadensis*
- grape *Vitus sp.*
- emory sedge *Carex emoryi*
- frostweed *Verbesina virginica*
- horsetail *Equisetum hyemale*
- Mexican hat *Ratibida columnifera*
- sunflower *Helianthus sp.*

Non-native species noted during the qualitative assessment included:

- chaste tree *Vitex agnus-castus*
- King Ranch bluestem *Bothriochloa ischaemum*
- fire ants *Solenopsis* sp.
- johnson grass *Sorghum halepense*
- chinaberry *Melia azedarach*
- Bermuda grass *Capriola dactylon*

Additionally, the non-native plant elephant ear was noted along Gorman Creek, which prompted a consultation with our TPWD Invasive Species Team. This consultation resulted in the attached "Gorman Creek Adaptive Invasive Species Management Plan" (Appendix A). Treatments of elephant ear thus far have been quite successful, with reductions of 90-95% along Gorman Creek's riparian corridor.

Overall, the riparian areas within the CBSP boundary appeared to be in good condition, but high herbivory rates on riparian plants were observed, and very few seedlings were noted. As previously noted, this reach of the Colorado River and Gorman Creek have been recognized as riparian conservation areas (TPWD 2018a). This designation is based on the presence of a contiguous riparian corridor occurring on publicly owned lands including state and federal refuges, wildlife management areas, preserves, parks, mitigation areas, etc. This designation is indicative of the potential ecological value these riparian areas can achieve, but not necessarily of the riparian condition at ground level. In the case of this assessment, the riparian areas at CBSP could provide additional function and ecological value by corridor widening through the reduction of mowing and weed eating along the riparian buffer. The park has done a good job of directing river access for park visitors to targeted areas, while not manicuring the areas in between. Maintaining these "target" access sites while allowing the rest of the area to grow up into a diverse array of thick vegetation will allow for a healthy, high functioning riparian area.

When riparian areas are functioning properly, a chain reaction occurs. Riparian vegetation dissipates energy and slows the velocity of floodwater, thus protecting banks from excess erosion. This slowing of floodwaters allows for sediment to drop out of the water column, where it is trapped by riparian vegetation and can provide further stabilization. This leads to the floodplain or "riparian sponge" being enlarged, which in turn increases groundwater recharge and sustains base flow over time.

STREAM HEALTH

Methods: To obtain a snapshot of the overall stream condition, a modified Stream Visual Assessment Protocol (SVAP2; TPWD 2015) was conducted in the CBSP bioassessment area. The SVAP2 is based on the SVAP protocol created by the Natural Resources Conservation Service (NRCS 2009), but includes modifications to make it more relevant to Texas streams. This protocol allows for a basic level of ecological assessment to qualitatively evaluate the condition of aquatic ecosystems associated with wadeable streams. The modified SVAP2 utilizes scores from thirteen major scoring elements including: channel condition, hydrological alteration, bank stability, riparian area quantity, riparian area quality, water appearance, nutrient enrichment, barriers to aquatic species movement, stream habitat complexity, pools, aquatic invertebrate community, riffle embeddedness, and salinity. After scoring each element, scores are summed and divided by the number of elements to provide an overall SVAP2 score. Scores are graded as follows: 1.0–2.9 = Severely Degraded, 3.0–4.9 = Poor, 5.0–6.9 = Fair, 7.0–8.9 = Good, and 9.0–10.0. = Excellent.

Results and Discussion: Overall stream health was scored as "Good" (SVAP2 Score= 7.3, Table 10). Individual scored values can be used as general statements about the state of the stream environment. This site is ecologically functioning well, as almost all the individual category scores fell in the good category.

TABLE 10.—Element scores from the modified Stream Visual Assessment Protocol (SVAP2) conducted on the Colorado River at Colorado Bend State Park in September 2017. Element scores are rated from 1 (severely degraded) to 10 (excellent). The average of the element scores is listed as the stream health score.

Element	Score
Channel Condition	7.0
Hydrologic Alteration	8.0
Bank Condition	6.5
Riparian Area Quantity	6.0
Riparian Area Quality	6.8
Water Appearance	8.0
Nutrient Enrichment	8.5
Barriers to Aquatic Species Movement	8.0
Stream Habitat Complexity	7.0
Pools	7.0
Aquatic Invertebrate Community	8.0
Riffle Embeddedness	Not scored
Salinity	Not scored
Stream Health Score	**7.3**

The elements that scored lowest were Bank Condition (6.5), Riparian Area Quantity (6.0), and Riparian Area Quality (6.8). By creating targeted public access sites to the river and allowing the areas in between to grow up with diverse vegetation types; allowing the riparian area to expand where possible by reducing mowing/weed eating; and controlling herbivory these values can increase, which will improve overall stream and riparian health and condition over time.

RECREATIONAL ACCESS

Although this region of Texas primarily consists of privately-owned ranch and agricultural lands, public access points are available on the middle Colorado River, and its main tributaries: San Saba River, Pecan Bayou, and Brady Creek. Locations highlighted in Figure 14 and Table 11 offer public access for launching a canoe or kayak, while a limited number provide opportunity for launching small, motorized boats as well. Many access points within the middle Colorado River Basin occur at bridge crossings where use of a four-wheel drive vehicle is recommended to navigate steep grades to parking areas. Many of these sites require carrying vessels to the water. Several access points exist at local parks where opportunity for bank fishing, day use, or overnight camping is available (Table 11). Through local and state partnership, the Pecan Bayou Paddling Trail has been developed at Fabis Primitive Park near the City of Brownwood, Texas (TPWD 2020a; Figure 15). This 4.8–6.5 km loop trail is on a serene stretch of Pecan Bayou that can be paddled in either an upstream or downstream direction.

FIGURE 15. —Access point for the Pecan Bayou Paddling Trail at Fabis Park near Brownwood, TX.

Colorado Bend State Park in San Saba County provides a variety of recreational opportunities both on and off the Colorado River. In addition to a boat ramp for launching paddle craft or small motorized boats, CBSP provides over 56 km of hiking trails; one of which leads to a very scenic natural feature in the park, Gorman Falls. Gorman Falls is considered a “living” waterfall because it grows bigger over time. Changes in temperature and pressure dissolve minerals in the water forming deposits on tiny underwater plants and surfaces. Over time the deposits build up and form a rock called travertine, which has made Gorman Falls 198 m wide and 18 m thick over millions of years. These soft layers of travertine can be easily crushed, so the area right around the waterfall is restricted to foot traffic in order to preserve the fragile environment. Fishing, camping, caving, and wildlife viewing are just some of the other activities one can enjoy within the park.

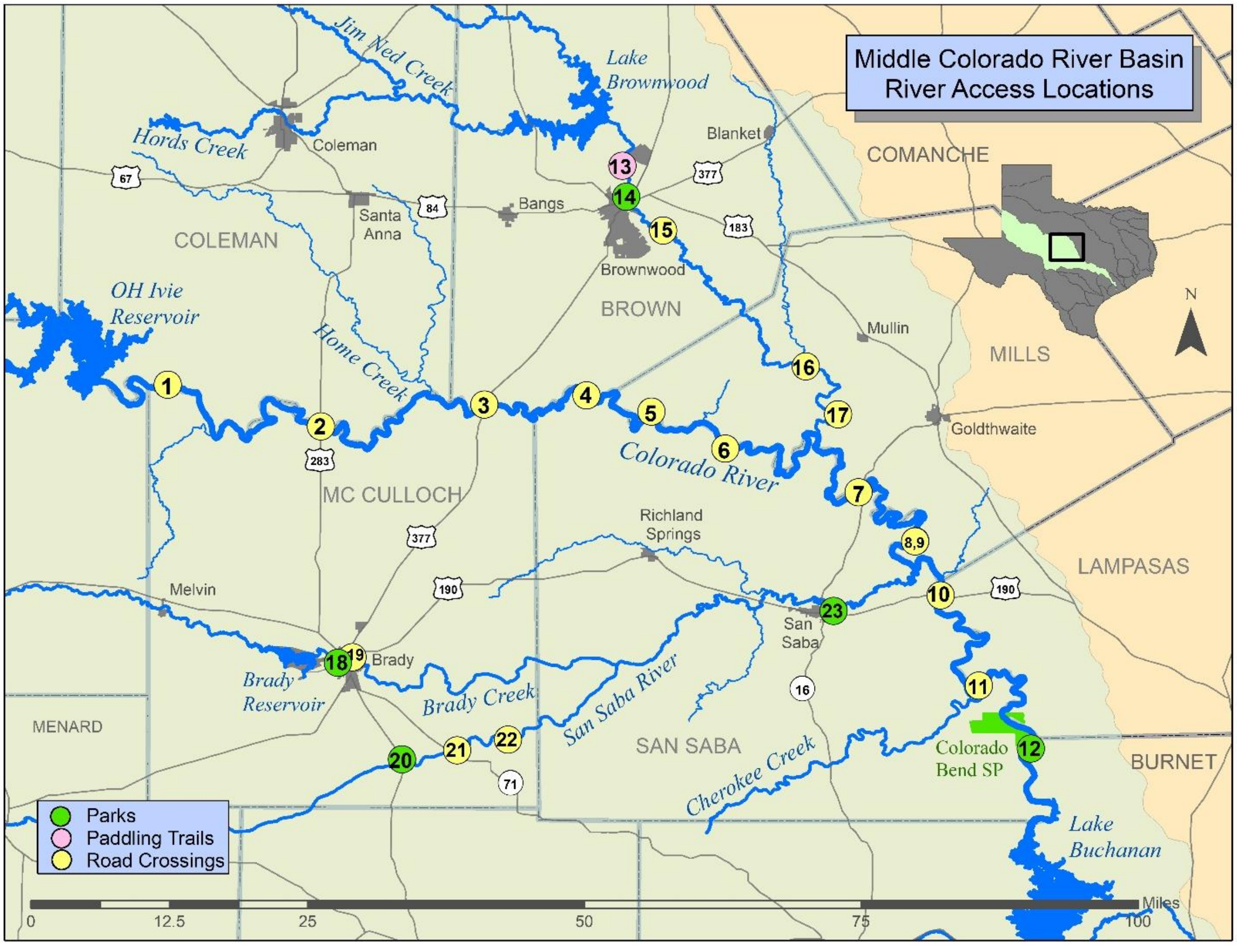

FIGURE 14. —River access locations for public recreational use throughout the study area. More information can be found in Table 11.

TABLE 11.—List of Middle Colorado River Basin public river access locations.

Site #	Site Name	Location	Access Fee	Use	Controlling Authority	Comments
			Colorado River			
1	FM 503 (Stacy Bridge)	31.4938, -99.5751	free		Coleman County	unimproved dirt ramp; steep bank
2	US Highway 283	31.4394, -99.3747	free		Coleman County	steep banks; must carry vessels
3	US Highway 377 (Winchell Bridge)	31.4680, -99.1611	free		McCulloch County	no ramp; 4WD to access area
4	Key's Crossing	31.4800, -99.0274	free		Brown County	no ramp; slick road if wet
5	FM 45	31.4586, -98.9426	free		San Saba County	steep bank; must carry vessels
6	County Road 433 (Regency Suspension Bridge)	31.4104, -98.8461	free		San Saba County	no ramp; steep bank
7	State Highway 16	31.3532, -98.6717	free		San Saba County	no ramp; steep bank

Site #	Site Name	Location	Access Fee	Use	Controlling Authority	Comments
8	Double Ford Crossing	31.2893, -98.5978	free		San Saba County	no ramp; primitive access
9	County Road 124 (Shaw Bend)	31.2889, -98.5980	free		San Saba County	no ramp; primitive access
10	US Highway 190	31.2184, -98.5645	free		San Saba County	steep bank; must carry vessels
11	FM 580	31.1004, -98.5147	free		San Saba County	no ramp; primitive access
12	Colorado Bend State Park	31.0183, -98.4467	adult $5 children free		TPWD	ramp; easy launch
			Pecan Bayou			
13	Fabis Primitive Park	31.7799, -98.9806	free; camp $10		Brown County	ramp
14	Riverside Park	31.7396, -98.9756	free; permit required		City of Brownwood	ramp
15	FM 2126	31.6954, -98.9274				doesn't appear to be usable access
16	FM 573	31.5178, -98.7408	free		Mills County	primitive access; must carry vessels
17	FM 574	31.4553, -98.6986	free		Mills County	primitive access; must carry vessels
			Brady Creek			
18	Richards Park	31.1303, -99.3526	free		McCulloch County	unimproved ramp
19	Elm Street Crossing	31.1378, -99.3335	free		City of Brady	unimproved ramp
			San Saba River			
20	Camp San Saba	31.0042, -99.2688	free		McColloch County	primitive access area; must carry vessels
21	County Road 214	31.0159, -99.1966	free		McColloch County	primitive access area; must carry vessels
22	County Road 212 (Lost Creek Crossing)	31.0300, -99.1303	free		McColloch County	primitive; limited parking along roadside
23	Riesen Park	31.1981, -98.7046	free		McCulloch County	steep bank; must carry vessels

Camping Bank fishing access Kayak/Canoe launch Small motorized boat

SPORT FISHING OPPORTUNITIES

During this study six game fish species were collected from sites on the mainstem Colorado River: Largemouth Bass, Guadalupe Bass, White Bass, White Crappie, Channel Catfish, and Blue Catfish (Figure 16). All species except Channel Catfish were collected within the boundaries of CBSP. The park provides the public good bank access to the river and is just upstream from Buchanan Reservoir which is well-known for its angling opportunities (De Jesus and Farooqi 2016). Sampling of Site A using an electrofishing boat yielded the most game fish of legal harvestable size, including five Largemouth Bass over 14 inches in length (Figure 17). Twelve sub-legal Largemouth Bass were collected from electrofishing and seining. In addition, Site A also yielded White Crappie and White Bass which are targeted by anglers in Buchanan Reservoir.

FIGURE 16. —Some of the sportfish species collected from the middle Colorado River and Colorado Bend State Park are from left to right: Guadalupe Bass, White Bass, and White Crappie.

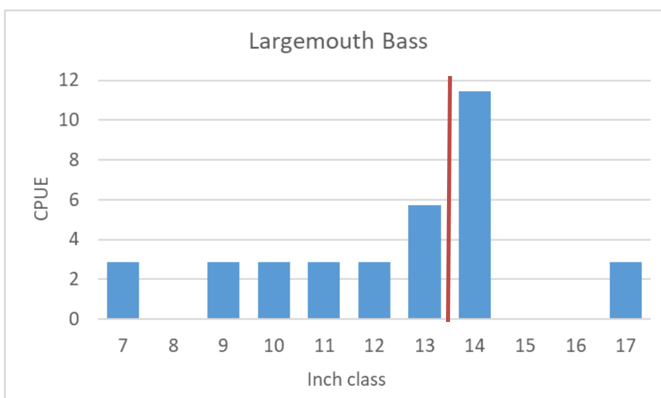

FIGURE 17. —Number of Largemouth Bass collected by inch class caught per hour (CPUE) during boat electrofishing at Site A on the Colorado River at Colorado River Bend State Park on July 27, 2017 with the red line denoting the minimum length limit. Additional juevenile Largemouth Bass were collected seining, but were not measured for total length and are not included here.

White Bass are recognized as the most popular sport fish in Buchanan Reservoir with 39.9% of anglers targeting this species (De Jesus and Farooqi 2012). In 2014 and 2015 fisheries management surveys, the population structure of White Bass in the Colorado River was mostly comprised of harvestable-size (≥10 inches) individuals with good body condition (most relative weight (*Wr)* values above 90; De Jesus and Farooqi 2016).

The popularity of this species is partially due to the heavy directed angling effort at CBSP during the spring when the White Bass spawning run takes place (late February – May). During this run the White

Bass move in large numbers upstream from Buchanan Reservoir into the Colorado River and congregate on spawning shoals. Many of these shoals occur in the reach of the river at CBSP, making it a popular destination for wade and bank anglers (Betsill and Pitman 2002). A 2011 economic impact study conducted by TPWD using the Minnesota IMPLAN program (Minnestota IMPLAN Group 2010) showed that in the Spring of 2011, total expenditures resulting from White Bass fishing at Buchanan Reservoir was estimated at $2.5 million (S. Magnelia, TPWD, unpublished data). Most of this impact was from anglers fishing in the river above the reservoir at CBSP.

River connectivity between Buchanan Reservoir and CBSP has been impacted by severe drought in recent years. In most systems, this loss of river-reservoir connectivity can be detrimental to the springtime White Bass spawning run; however, White Bass in Buchanan Reservoir appear to be resilient during these times and have been documented to spawning habitat use from river shoals to wind-blown sandy shorelines in the Buchanan Reservoir (De Jesus and Farooqi 2016). These fish are able to sustain themselves, at least in the short-term, despite the loss of river connectivity; however, the lack of a spring spawning run during these low-water periods greatly decreases the economic impact of anglers who would normally fish the area around CBSP for White Bass. Likewise, high stream flows during the spring, though likely beneficial to the spawning run, can also severely limit angler access.

Additional species collected during this study that provide recreational fishing opportunities in around CBSP included seven species of sunfish, Channel and Blue Catfish, Flathead Catfish, Guadalupe Bass, Hybrid Striped Bass, and Striped Bass. Of the sunfish, Bluegill, Redear, Longear, and Redbreast Sunfish were collected and are known to be popular angling targets. Though only a single Blue Catfish was collected in Site A during this study, Channel, Blue, and Flathead catfish are abundant in Buchanan Reservoir and should provide angling opportunities in the riverine habitat of CBSP (De Jesus and Farooqi 2016). Gear to target catfish (low frequency electrofishing, hoop nets, gill nets) were not employed during this study in Site A may have played a role in the low number of catfish collected due to gear bias.

Guadalupe Bass are present in low densities in Buchanan Reservoir, based on historic boat electrofishing catch rates (De Jesus and Farooqi 2016); however, since this is a riverine species, it may be targeted by anglers accessing the river in the state park. Hybrid Striped Bass and Striped Bass are annually stocked in Buchanan Reservoir and generate directed angler effort. These two species likely travel into and inhabit the riverine reach within CBSP and provide additional angling opportunity.

SUMMARY AND RECOMMENDATIONS

Middle Colorado River Basin

This study updated fish assemblage data for 35 sites including six mainstem and 29 tributary sites. Forty-four species of fish were collected across all sites, including three listed as SGCN (*Dionda* sp., Texas Shiner, and Guadalupe Bass). Two new species were added to the regional checklist: Blue Catfish and Blue Tilapia; however, both species are previously known from other areas of the basin. Overall, the relative abundance of non-native fish species (Common Carp, Mexican Tetra, Redbreast Sunfish, Rio Grande Cichlid, White Bass, and Blue Tilapia) was low.

Ten species of live freshwater mussels were collected from the six sites searched. One state-threatened species, Texas Pimpleback, was collected from half of the sites sampled. Four species of crayfish were collected across all study sites.

The study area has a high number of public access sites; however, many of them are unimproved roads under highway crossings and require a four-wheel-drive vehicle or for users to carry their vessel to the river. Improved public access sites include CBSP on the Colorado River and Riverside and Fabis Primitive Parks on Pecan Bayou, which have boat ramps. Fabis Primitive Park is also home to the Pecan Bayou Paddling Trail. Species targeted by anglers in the study area included Largemouth and Guadalupe Bass, White Bass and other Morone *sp*., Channel, Blue, and Flathead catfish, and a variety of sunfish species.

Colorado Bend State Park

Sampling at CBSP documented 26 fish species, one freshwater mussel species, one crayfish species, 37 benthic macroinvertebrate taxa, and 24 riparian species. The fish assemblage data collected from the Colorado River at CBSP was rated as having an intermediate aquatic life use (falling just short of a high rating).

Fish species collected included several species that offer angling opportunities such as Largemouth Bass, Guadalupe Bass, White Crappie, Blue Catfish, White Bass, and several sunfish species. The most numerous sport fish collected was Largemouth Bass, which included several individuals exceeding the minimum length limit. Further, CBSP offers anglers abundant bank fishing access and a boat ramp.

Overall stream health of the Colorado River at CBSP was rated as good, meaning the river is well-functioning. A few areas for improvement included enhancing the riparian area condition, which had high herbivory and a low recruitment of seedlings.

Recommendations

Fish Assemblage

Overall, the fish assemblage of the middle Colorado River Basin appears in good health. There was a low percentage of non-native species, species were present from a diversity of families and trophic positions, and several SGCNs were documented, which are generally sensitive to environmental alteration.

Mussel Assemblage

Further sampling of freshwater mussels is recommended throughout the basin in the immediate future. Data gaps still exist in the distribution of mussels throughout the study area and this information is critical for informing listing decisions for species currently under federal review. Species currently under review for federal listing under the Endangered Species Act include Texas Pimpleback, Texas Fawnsfoot, False Spike, and Texas Fatmucket.

Riparian Assemblage

It is recommended that CBSP continue to direct river access to targeted areas and not manicure the riparian area between these sites. Maintaining these "target" access sites while allowing the rest of the riparian area to grow up into a diverse array of thick vegetation allowing for a healthier, higher functioning riparian area. An improved riparian area will provide benefits such as dissipating floodwater energy and reducing erosion. Educational signage providing information on these "grow zones" or "no mow zones" can alleviate concerns of park visitors and educate them on the importance of healthy riparian areas.

Invasive Species

It is recommended that park staff and other partners implement long term monitoring of elephant ear in Gorman Creek and adhere to recommendations in the invasive species management plan (Appendix A).

Recreational Access

Relative to other regions of the state, the number of public access sites in the study area appear to provide ample recreational opportunity. However, the long distances between existing access points and the ease of access at many of the locations creates challenges for those wishing to paddle or boat the areas rivers and streams. Many access locations require the user to negotiate unimproved dirt access roads and carry their vessel down steep banks to launch. Controlling authorities in this region should consider applying for funding from the TPWD Boating Access Grant Program (BAG; TPWD 2020b). Funds awarded through the BAG are eligible for various kinds of improvements including access roads, parking areas, restrooms, land acquisition, etc. for the purpose of improving or creating access sites for boating. Such improvements at existing public access points would reduce the difficulty of launching vessels and likely lead to increased recreational utilization.

Furthermore, long stream distances between existing access points (e.g., greater than 35 river km between sites 1 and 2 in Figure 13) makes paddling a canoe or kayak downstream within a reasonable time period (4–8 hours) very difficult. The establishment of additional access areas that decrease distances between public access points should be considered. The River Access and Conservation Areas Program (RACA; TPWD 2020c) uses federal grant funding to lease private streamside properties for public river access. The establishment of one to three RACA sites along the middle Colorado River would provide better paddling connectivity within long stream reaches and further enhance stream-based recreational opportunities such as kayak fishing.

Sport Fishing Opportunities

Given the angling opportunities and high recreational use in the vicinity of CBSP, TPWD district management biologists should continue conducting creel surveys to further obtain angling pressure, harvest, and economic impact data.

Conclusions

This study has documented a diversity species occurring in the middle Colorado River Basin; however, it is only a snapshot in time. More data, similar to this, which is interdisciplinary and widespread throughout the watershed is needed to fully assess the health and stability of the system. The largest threat facing this region is water availability during times of drought. Decreased longitudinal connectivity during the spawning season could potentially impact White Bass populations and will surely impact the White Bass fishery upstream of Buchanan Reservoir, a major contributor to the local economy. Stream dewatering, even in localized areas, could be especially detrimental to mussel populations, given their immobile nature, including species that are already listed as state threatened. As previously noted, stream flows on the middle Colorado River approached zero during the drought of 2011, the worst one-year drought on record in Texas which caused substantial stream flow declines across the state (Winters 2013). As unprecedented human population growth continues to put increasing pressure on Texas aquifers and surface waters (TWDB 2017), the predicted increase in occurrence and severity of future droughts (United States Global Climate Change Research Program 2018) will only compound negative effects on habitat availability and suitability for our native aquatic species. It is vital to continue monitoring aquatic species in this basin, and to use that data to develop science-based recommendations to mitigate for those changes.

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APPENDIX A

GORMAN CREEK ADAPTIVE INVASIVE SPECIES MANAGEMENT PLAN

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1 - PROJECT OVERVIEW

1.1 - NEED

Elephant ear (Araceae: *Colocasia esculenta* L. Schott), also known as wild taro, is an emergent, aquatic plant native to Southeast Asia that has been introduced and become invasive in Texas (Nesom 2009; Owens et al. 2001) and in the other Gulf Coast states (Benson et al. 2001; USDA-NRCS 2013). However, it is also an economically valuable species popularized in the ornamental plant trade (Wirth 2004) and, consequently, is not prohibited in Texas as a harmful or potentially harmful plant [31 TAC 57A]. This species was reportedly first introduced in Texas in the 1920s via the ornamental plant trade and has come to dominate shorelines of many spring-fed streams and rivers (Bowles and Bowles 2017; Poole and Bowles 1999).

Elephant ear is a waxy-leaved, plant with a shallow, weak root system. The plant structure consists of large corms—tuber-like roots—that store energy and large, waxy leaves that emerge from these corms. Reproduction and dispersal occurs through rhizomes and fragmentation. Although flowers and seeds are produced, propagation via seeds rarely occurs (Benson et al. 2001). This plant is known to form monoculture stands in riparian habitats and along mid-channel bars, crowding out native plants (Bowles and Bowles 2017; Poole and Bowles 1999). Elephant ear does not alter channel morphology as it is relatively easily uprooted during periods of high flow, but it can invade and alter near-bank habitats. This habitat alteration has been implicated in the decline and probable extinction of the San Marcos Gambusia (*Gambusia georgei*; USFWS 1995)

Elephant ear has broad physiological tolerances that enable it to invade and persist in aquatic, riparian, and adjacent upland habitats. Unlike some other “thirsty” riparian invasive plants such as Arundo (*Arundo donax*) elephant ear has been shown to use less water and have lower evapotranspiration use than sedge (*Cyperus latifolius*), reed (*Phragmites mauritianus*), and, often, sugarcane (Everson and Mengistu 2011). However, elephant ear growing in flooded areas may use more water than plants growing in drier upland conditions and achieve greater corm weight (Uyeda et al. 2011). Some mortality and lower leaf production are to be expected under drought (Mabhaudi 2012, Mabhaudi et al. 2013), although some cultivars are able to withstand periods of low water availability by flowering and senescing early (Mabhaudi 2012; Mabhaudhi et al. 2013).

1.2 - HISTORY

In 2017, a bioblitz survey was conducted at Colorado Bend State Park by Texas Parks & Wildlife Department (TPWD) River Studies Program staff. During the survey, a severe infestation of elephant ear was identified as posing a significant threat to riparian and aquatic habitats. Large monocultures of elephant ear dominated the riparian areas along Gorman Creek above the falls as well as the upper face of the falls, with plants having reportedly begun to spread to the areas below the falls. Elephant ear patches growing on woody debris impeded the flow of water in the creek. Clearing and mowing of riparian areas and lack of recruitment of woody plants likely contributed to the establishment of elephant ear. A report of the bioblitz survey results is not yet available at the time of this revision.

River Studies staff facilitated consultation with the TPWD invasive species management subject matter expert. Active management of elephant ear and chinaberry (*Melia azederach)* began in October of 2017. The initial survey found no elephant ear upstream of large patches near the conference center, and anecdotal reports suggest that they may have been planted at this location. Elephant ear in this location can be categorized as a Tier III species (Chilton 2018)—meaning that control could be achieved given adequate resources, plants are stable or declining—in this case during the treatment timeframe, and there is little chance of the infestation being spread to a nearby water body—in this case because it is already present downstream. Chinaberry trees did not dominate the riparian areas but appeared to be spreading to new areas; spread of chinaberry was likely exacerbated by lack of woody plants and mowing of the riparian area.

1.3 - Funding

Funding for this project was provided by the 85th Texas Legislature under Rider 32: Statewide Aquatic Vegetation and Invasive Species Management. Costs for this project consist of staff time, travel costs, herbicides and adjuvants and equipment maintenance. Current herbicide costs can be found on Texas SmartBuy. Camping at Colorado Bend State Park is free of charge and has been used to reduce overall project cost and costs to the state.

1.4 – Equipment & Staffing

Equipment used for this project includes the John Deere Gator utility vehicle (UTV), Stinger skid-mounted herbicide sprayer, and trailer. Hand-pump herbicide sprayers are also now used for smaller plants and the UTV may not be needed in 2019. Two staff are required for UTV-based herbicide applications to ensure safety and prevent spills or sprayer pump damage. A third staff member may be helpful for data collection and manual application of herbicide during UTV-based treatment events. Only one staff member is needed for site visits for pre- and post-treatment surveys provided that surveys and photos are taken from a location that minimizes job hazards.

1.5 - Collaborators

Collaboration plays an important role in this project. No other agencies or non-governmental organizations collaborate on this effort.

1.5.1 - Texas Parks & Wildlife Department Staff.—Communication with the Colorado Bend State Park superintendent and park biologist is needed as their permission is required for all treatment and restoration efforts. Communication with the district Wildlife Division biologist is recommended. The senior scientist for aquatic invasive species management should be consulted when the management strategy (e.g., treatment rates and frequency) is adapted.

1.5.2 - Volunteers.—Volunteer assistance can be used to minimize staff time by assisting during treatment events and conducting pre- and post-treatment surveys. Contact the state park superintendent for a list of current volunteers. The TPWD Samaritan volunteer management system could also be used to recruit and manage volunteers.

2 - PROJECT OBJECTIVES & IMPLEMENTATION

2.1 - Adaptive Integrated Pest Management Strategy

Integrated pest management (IPM) is an ecosystem-based strategy for long-term management of, and prevention of impacts from, invasive nuisance species. The IPM strategy employs a combination of techniques—essentially, the right methods for the right species, location, and situation. Management of elephant ear and chinaberry implemented in this project to date includes chemical and physical control methods. No effective biological control agents are available for the target species. Cultural control methods are described below in the restoration sections below (§§2.3, 4.3).

2.1.1 - Job Hazards and Safety Equipment.—There are several key hazards of note for this project; please see the Job Hazard Analysis developed for this project and appended to this plan. Staff should also review the TPWD Safety Program Manual available on the WildNet.

2.1.2 - Herbicide Application.—Complete control of chinaberry can be rapidly achieved if the correct herbicide and application method is used, although birds and upstream chinaberry trees could result in reintroduction. In Fall 2017, chinaberry trees along Gorman Creek were mapped and many were treated by State Parks staff and volunteers using cut-stump application of herbicide. There are no official records of the herbicides, and concentrations thereof, that were used, but post-treatment surveys found that the treatment was not very effective. By September 2018, re-sprouting of many chinaberry tree stumps was observed.

Chemical treatment of elephant ear using an aquatic herbicide with the active ingredient the ammonium salt of imazamox (i.e., Clearcast) and methylated seed oil (MSO) as an adjuvant has proven effective for achieving control of elephant ear. In October 2017, elephant ear was surveyed along ~180 meters of Gorman Creek and spot-treated with a 1% v/v (i.e., 1.3 oz/gal) solution of imazamox with MSO adjuvant and a UTV-based application. An infestation area of ~0.08 acres with ~75% coverage was mapped; equipment damage precluded precise mapping of individual patches. Most plants exceeded 6’ in height and large monocultures were present.

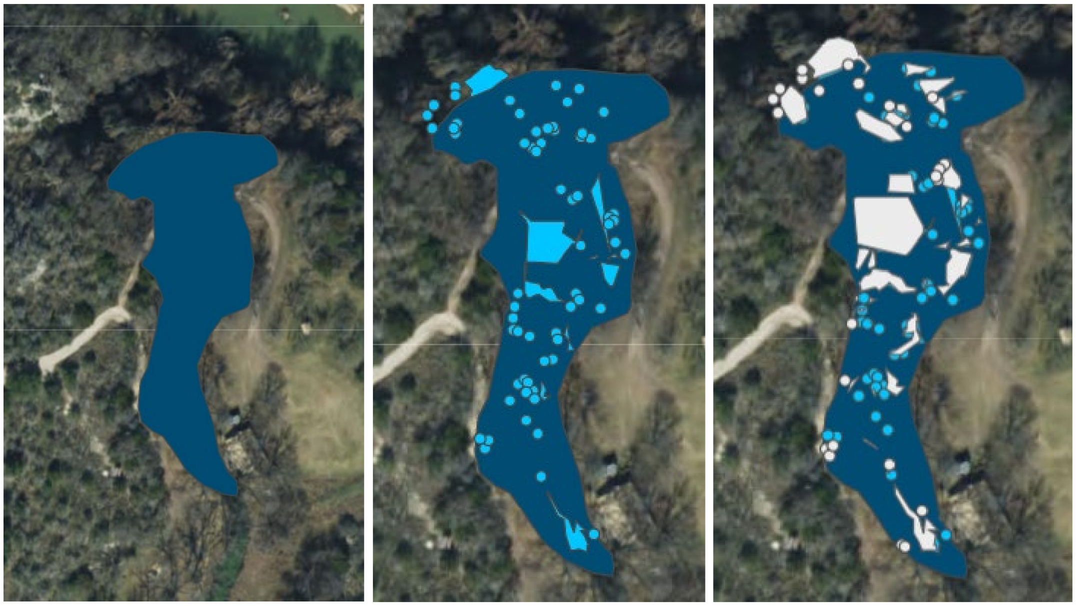
In May 2018, the same area was surveyed and re-treated with the same herbicide mixture and UTV-based application; elephant ear density had declined to ~25% of the original infestation footprint and most plants were < 6’ in height. This decline in coverage and plant height facilitated treatment of elephant ear closer to the face of the falls.

By September 2018, elephant ear coverage had declined to ~5-10% of the original infestation footprint and most plants were < 3’ in height. Herbicide was applied using a 1.85% v/v (i.e., 2.4 oz/gal; herbicide inadvertently mixed at lower rate) imazamox solution using a combination of UTV-based application and manual application with hand-pump sprayers. The herbicide rate was increased to enhance effectiveness as, by September 2018, risk of overspray and non-target damage had been lessened by the significant reduction in plant density and height.

Herbicide application and pre-/post-treatment survey data sheets are available in the AIS team documents.

2.1.3 - Mechanical Removal.—Mechanical removal is only cost-effective when dealing with relatively small plants; removal of large patches can destabilize creek banks, resulting in erosion. This method was first employed in September 2018, when the reduction in the infestation above the falls and availability of a volunteer allowed time for a search of the areas below the falls. Approximately five larger plants (i.e., ~3’ in height) and 10-15 smaller plants were physically removed by hand.

Map of elephant ear treatment areas along Gorman Creek at Colorado Bend State Park*; map shows, from left to right, the cumulative treatment effort. October 2017 generalized treatment area is shown in dark blue; May 2018 treatment points and patches are shown in bright blue; September 2018 treatment points and patches are shown in pale gray.*



2.1.4 – *Pesticide Related Requirements*.— The nuisance aquatic vegetation index webpage provides a guidance document (Chilton 2018) and pertinent references and forms that should be reviewed thoroughly—including all laws and regulations—prior to herbicide applications. This resource can be found on the TPWD website at:
https://tpwd.texas.gov/landwater/water/environconcerns/nuisance_plants/

An aquatic nuisance vegetation treatment proposal (hereafter, treatment proposal) must be prepared and submitted to the district fisheries management biologist and to aquaticinvasives@tpwd.texas.gov for review. However, tacit approval of the treatment proposal by these individuals is not required. The fillable, treatment proposal form available in the AIS team documents should be used. For this project, the AGOL web mapping application 'print' function should be used to prepare the map that must be attached to the treatment proposal. Requirements for treatment proposals do not preclude submission of a single treatment proposal that lists a date range (e.g., June and September) for proposed treatment. The treatment proposal now remains valid through the end of the calendar year and must be resubmitted annually.

An e-mailed notice of intent to apply herbicides must be sent at least two weeks in advance of treatment to the persons on the contact list, as required per the TPWD Pesticide Discharge Management Plan. The treatment proposal should be attached to the notice along with the label and SDS for the chemical(s) and adjuvant(s) proposed for application.

The same two-week notice email must also be sent to the correct river controlling authority contact for review; if, as occurs in some cases, the controlling authority does not reply by the day before the proposed application, a licensed pesticide applicator with an aquatic certification and individuals working under their supervision in accordance with Texas Department of Agriculture regulations may perform the treatment.

The same two-week notice should also be sent to the district fisheries management biologist, and aquaticinvasives@tpwd.texas.gov; tacit approval is not required. The Aquatic Habitat Enhancement Team receives these emails and will properly archive the treatment proposal and periodically update the list of current treatment proposals on the nuisance aquatic vegetation index webpage.

The operators of any potable water intakes (PWIs; see master ArcGIS files) within two miles downstream of an herbicide application must also be notified at least two weeks in advance of any treatment within two miles upstream of the intake. In some cases, a voicemail must substitute for the notification if a live person cannot be reached and an email address is not available.

Pre- and post-treatment surveys are required. The forms required for these surveys in the 'master' version on GoFish in the PDMP section have been modified for riparian projects such that the pre- and post-treatment forms are separate and fillable. These documents are available in the AIS team documents. Survey and treatment records should be entered into the GoFish PDMP database within two weeks of the treatment event. Staff must complete training prior to entering or verifying data in the database.

2.1.5 – *Data Collection*.—ArcGIS Online (AGOL) is used for collection and curation of map data for this project; GIS data are available from this map. The AGOL map can be opened in ArcMap and the layers exported to geodatabase files as a backup. When the AGOL map is opened in ArcMap, layers should not be removed as this will damage the online map. The Gorman Creek layer and the Chinaberry mapped points layer appear to have been recently deleted from the web map as well as from the AGOL content, but should be re-added for project tracking and for preparation of treatment proposal maps.

The Collector for ArcGIS application is used to view and collect data during site visits and herbicide applications. This app is available for both iOS and Android platforms. Cell phones or Samsung tablets with Garmin GLO GPS receivers and waterproof cases are used for data collection. Offline base maps are recommended.

A web mapping application was created to be used for project review and creation of maps for treatment proposals (http://bit.ly/CoBendEE); the data for this map come from the project web map and update automatically when the web browser is refreshed.

2.2 – Monitoring

Monitoring to date has consisted solely of pre- and post-treatment surveys and taking georeferenced photos during most treatment events. These photos are available in the AIS team documents; note that some photos for this project were taken by a volunteer using a professional camera and are not georeferenced.

2.3 - Restoration

To date, no restoration measures have begun and focus has been on achieving control of the infestation. Although several discussions were held with State Parks superintendents and staff, recommendations regarding expansion of the riparian buffer area were not implemented. Development of a closer partnership with State Parks staff is needed to enable implementation of restoration techniques.

2.4 – Demonstration

Development of individual, multipurpose demonstration signs, each focusing on a topical area (e.g., elephant ear management, healthy riparian buffers, focused access) was originally planned for development in Winter 2018-2019. Staff were tasked with development of draft sign content during that time. Following the Habitat Conservation Branch reorganization in November 2018, the status of this effort is unknown.

The 'Fighting Aquatic Invaders' webpages on the main TPWD site include an elephant ear management page with a section on the Gorman Creek project. Periodic updates to this content may be needed but inclusion of information that will quickly become updated and inclusion of any specific information regarding herbicides used is strongly cautioned against.

3 - FUTURE CHALLENGES

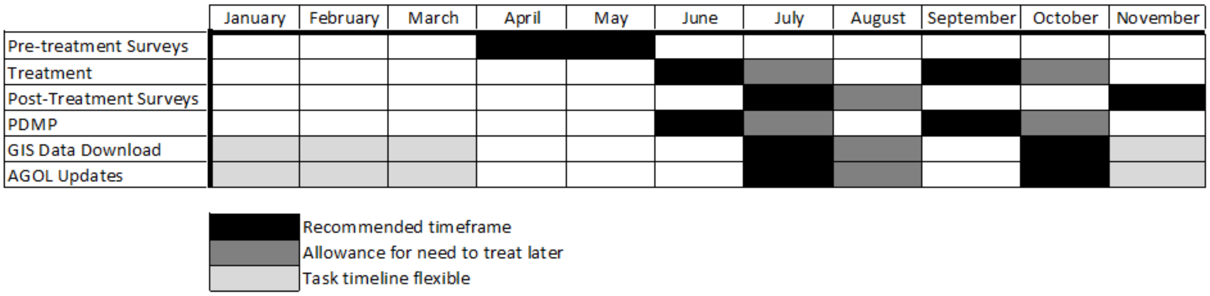
One great challenge for this project lies in the need to continue to follow through on post-treatment monitoring for an adequate amount of time and at appropriate intervals to ensure that elephant ear regrowth does not go undetected and this invasive plant be allowed to reestablish dominance. Another challenge will be developing an active collaboration with State Parks staff such that both divisions are actively invested in restoration and demonstration efforts. One significant impasse for restoration is the presence of a low-water crossing located just above the top of the falls—the impacts of this crossing on creek habitat and the riparian habitats should be evaluated and alternatives explored.

4 - RECOMMENDATIONS

4.1 – Adaptive Management

Chinaberry distribution and treatment effectiveness should be evaluated during the next elephant ear treatment event. The most effective treatment for chinaberry is cut-stump herbicide application of triclopyr; aquatic formulation is recommended and is required if treatment site is below the mean high water mark. Preferably, larger trees would be felled by State Parks staff trained in safe chainsaw operation. However, where a large, dead tree would not pose a hazard to park visitors, treatment could be implemented using the Hypo Hatchet herbicide injection system. Smaller trees and root sprouts should be cut with hand saws and/or loppers to a height of approximately ten inches. Within ten minutes of the wood being cut, herbicide should be applied to the cut surface and stump bark. A 50/50 volume/volume mix of triclopyr and methylated seed oil applied with the small stump sprayers has proven highly effective for treatment of woody invasive trees such as chinaberry; however, applications must follow label rates for the specific chemical being applied. Treatment of chinaberry trees as described above constitutes a 'spot treatment' and should be proposed and reported as such. Any cut trees or branches should have any viable seeds removed and bagged for disposal to prevent germination around the treated area or brush collection location.

Generalized calendar of key Gorman Creek elephant ear management timelines



Elephant ear treatments should continue until the site can be placed into maintenance status. Two treatment events per year (e.g., early to mid-Summer, mid-Fall) are recommended until returns on staff effort diminish at which time this could be reduced to one treatment per year. Pre-treatment surveys will be needed to inform decisions regarding treatment interval and consultation with the senior scientist for aquatic invasive species management is recommended. In spring 2019, UTV-based treatment should only be used if warranted by the number of remaining patches of large (i.e., height > 3’); herbicide treatment rate should not exceed 2% v/v due to increased potential for non-target plant mortality. Smaller plants should be treated manually with hand-pump sprayers; a higher treatment rate of 5% imazamox is recommended to enhance effectiveness and aid in achieving control.

When no elephant ear has been found for two subsequent treatment events and/or thorough (i.e., conducted by project lead/staff) survey efforts, monitoring and herbicide application should be conducted one year later and, if no elephant ear plants are found, the project should be placed into maintenance status with surveys at 3-5 year intervals until such time as staff experts are confident that reoccurrence is unlikely. Monitoring, as described in §4.2, plays a key role in strategy adaptation. Data collection using AGOL and collection of images at photo points should continue to document project progress and facilitate evaluation of treatment and preparation of treatment proposals.

At least ten non-native fishes have been found in this river subbasin (i.e., HUC 12090201; www.fishesoftexas.org)—species for which the most likely introduction pathways have been bait bucket introduction/transfer and fish stocking. Data from the 2017 TPWD Bioblitz should be reviewed to determine whether non-native fishes were found in Gorman Creek above the falls. If so, careful evaluation of potential impacts of these species and whether management actions are warranted and/or feasible should be conducted in consultation with the appropriate River Studies subject matter experts.

4.2 - Monitoring

Several pre-treatment surveys should be conducted to determine whether only two treatments should be conducted; these evaluations can significantly reduce staff time required for this project. Due to the high accessibility of the site and presence of TPWD staff onsite, site visits could be conducted or TPWD staff or volunteers could be recruited to conduct surveys.

The AGOL web map for this project should continue to be used for collection of data on herbicide applications. The web map will require editing each year; staff should consult with the senior scientist for aquatic plant management for guidance and training on how this specific AGOL web map must be updated. This web map is currently ready for use for 2019 treatment events and needs no updates until after 2019 treatments are completed.

In the interim between full web map updates, new individual layers can be added to the content as zipped shapefiles, moved to the Colorado Bend Elephant Ear content folder—if not uploaded directly to that folder, and then added to the AGOL Colorado Bend Elephant Ear web map. Added shapefiles will retain only the GIS data; time spent setting shapefile properties in ArcMap would be wasted. All properties (e.g., layer functionality, symbology, map/app pop-up, etc.) should be set in the AGOL web map itself. Any layers deleted from the web map should also be deleted from the AGOL content in order to maintain curation of these files and avoid errors.

Photo points should be established based on the locations of selected, geotagged photos from past treatment events and used to show change over time since elephant ear management was initiated. New photos should be taken during each treatment event. A photo point layer can be added to the AGOL map but training is recommended. Photos should be framed similarly for each monitoring event and staff should not be included in these photos.

A biomonitoring survey of Gorman Creek above the falls should be completed in 2020, or at latest in 2022, at the same time of year and using the same methodology as was employed in the 2017 TPWD Bioblitz. Key measurements should include the stream visual assessment protocol with species richness, indices of fish and aquatic invertebrate species richness and community biotic integrity, and flow measurements. If aquatic habitat was mapped in the 2017 Bioblitz, remapping in this survey is highly recommended. When finalized, the 2017 Colorado Bend State Park Bioblitz report should be used to inform future biomonitoring efforts.

4.3 - Restoration

Collaboration with State Parks staff is needed to implement active revegetation of some highly disturbed riparian areas and create focused access points that reduce riparian impacts as well as risks posed to park visitors by venomous snakes. Planting of bare-root seedlings in previously identified areas with little sub-canopy and/or canopy is recommended; only site-collected or watershed/regional seed sources should be used. Planting of large, containerized, native riparian grasses with strong root systems or other woody plants with high stability ratings. Planting of these grasses and or woody plants should also take into consideration aesthetics—for example, gammagrass, switchgrass, or buttonbush could be used. The AGOL web map could be augmented to further facilitate restoration mapping and evaluation of restoration success.

4.4 - Demonstration

Development of individual, multipurpose demonstration signs, each focusing on a topical area (e.g., elephant ear management, healthy riparian buffers, focused access) has not yet been completed. Installation of such signs would prove beneficial for communicating the efforts undertaken at Colorado Bend State Park to the public and would support restoration success. State Park staff have shown interest in establishing the area near the Gorman Springs trailhead and conference center as a demonstration site for future park visitors.

State Park staff have also expressed interest in—but lack of funding for—printing and installation of venomous snake caution signs using a design already developed within that division. Installation of these signs would not only enhance visitor safety but would also encourage use of only focused access points. Focus should also be placed on spotlighting management, restoration, and demonstration efforts on the Colorado Bend State Park website.

If any fish Species of Greatest Conservation Need other than Texas Shiner (see §1.2) were found in Gorman Creek, the potential for live bait introductions to have deleterious effects should be evaluated in consultation with River Studies subject matter experts. A logical step to accomplish prior to such consultations would be determination of whether fishing occurs in Gorman Creek—through consultation with State Parks staff, installation of game cameras, or both. If prevention of bait-bucket introductions is deemed to pose a conservation concern, outreach signage regarding the potential impacts of live bait should be developed.

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Job Hazard Analysis

Safety Information

Colorado Bend State Park

Invasive Riparian Plant Management

Task	Hazards	Controls
1. Herbicide transport	Concentrated herbicide spills	Place herbicides into a secure bin for transport.
2. Utility vehicle and sprayer transport	Load shifting resulting in vehicular accident Damage to equipment Harm to other motorists and their vehicles	Tie-down straps have been secured to the trailer; ensure straps are in good repair and secured and tensioned correctly for transport; take spare straps; stop frequently to re-evaluate strap tension; evaluate and find solutions for strap loosening. Ensure that straps securing sprayer unit and hose reel are in good repair and secured and tensioned correctly prior to transport. Ensure that spray gun has been removed from the hose and placed into the toolbox for storage; ensure that hose reel is locked and hose end secured.

	3. Working in vegetated areas along Gorman Creek	Venomous cottonmouth snakes (Crotalidae: *Agkistrodon piscivorus*) Stinging and biting insects	Wear thick leather boots with loose pants made of thick fabric (e.g., denim); snake guards are recommended. Relocate cottonmouths to a secure container for the duration of the treatment using snake tongs—only trained staff should attempt. Ensure that the project lead is aware of any insect allergies and the severity thereof; check for ticks after the event; maintain a well-supplied first-aid kit. Use radios to communicate regarding snake hazards.
	4. Utility vehicle operation	Rollover; other harm to staff and volunteers	Operate UTV only if trained and/or experienced and follow manufacturer guidelines when operating on inclines; turn off UTV when unattended; set parking brake.
	5. Sprayer motor and reel operation	Hearing loss; herbicide spills or staff exposure; severe burns; gas fire.	Wear appropriate hearing protection at all times when within 50 feet of the running motor. Check all hose clamps prior to operation to prevent spills and staff exposure to herbicide. Take care to avoid the exhaust area of the sprayer motor when adjusting the motor and winding the hose reel. Turn off the motor before refilling fuel and touch metal on UTV to discharge static before fueling.

	6. Herbicide mixing and application	Herbicide exposure Fatal falls	Wear the appropriate personal protective equipment during mixing and application. Pour concentrated herbicide into a measuring container located on a level, impermeable surface. Keep a spill kit at or near the mixing location. Ensure that an eye wash kit, water hose, or other water source is readily available at the mixing location. Ensure that herbicide application equipment is well maintained and all connections checked and tightened prior to use; check valves and lubricate o-rings annually or as recommended by the manufacturer; ensure that the spray nozzle is securely attached prior to starting motor Do not let sprayer pump pressure fall into the 'red zone' or exceed 200 psi pressure. Apply herbicides on the falls side of the safety fence only when another staff member is in close proximity—leave motor unattended if needed; remain as far as possible from the face of the falls when applying herbicide; use higher sprayer pressure and place a spotter at a safe distance below the falls with a radio to help target herbicide application. Only a trained and experienced rock climber using the appropriate rappelling equipment should attempt to descend the face of the falls to apply herbicide.

	Required Training: Staff should be experienced in operation of the utility vehicle and herbicide application or should be trained by experienced staff. Staff should be experienced or trained in sprayer operation prior to use. Staff should not handle venomous snakes unless properly trained in their handling and should be trained in rapid snakebite emergency response. Basic first aid training is recommended.	**Required Personal Protective Equipment (PPE)** Hearing protection rated for the decibel level of the Honda sprayer motor. Personal protective equipment for herbicide mixing and application, as required by the herbicide label; take care to ensure that glove thickness and material are correct.
Other Information:	See manuals for John Deere Gator utility vehicle, Honda motor, Stinger and hand-held/backpack sprayers. See herbicide labels and Safety Data Sheets for all herbicides to be applied.	
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