APPLICATION OF THE LOWER COLORADO RIVER AUTHORITY FOR EMERGENCY AUTHORIZATION	§ § § §	**BEFORE THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY**

AFFIDAVIT OF BRYAN COOK

THE STATE OF TEXAS	§	
	§	
COUNTY OF TRAVIS	§	

Before me, the undersigned authority, personally appeared Bryan Cook, a person known by me to be competent and qualified in all respects to make this affidavit, who being by me first duly sworn, deposed as follows:

1. I am over 21 years of age, of sound mind, and have never been convicted of a felony or crime of moral turpitude. I am fully competent and qualified in all respects to make this affidavit.

2. The facts stated in this affidavit are within my personal knowledge and are true and correct.

3. I, Bryan Cook, am an individual residing in Austin, Texas.

4. I have a Bachelor of Science in Resource and Environmental Studies and a Masters of Science in Aquatic Biology, both from Southwest Texas State University. I have a Masters of Public Affairs from the University of Texas at Austin, LBJ School of Public Affairs. A true and correct copy of my resume, detailing my prior work history and education, is attached hereto under Tab 1.

5. I have worked for the Lower Colorado River Authority (LCRA) for 17 years. For the last 17 years, I have worked with the LCRA's water quality and water supply planning business. My current title is Water Quality Supervisor.

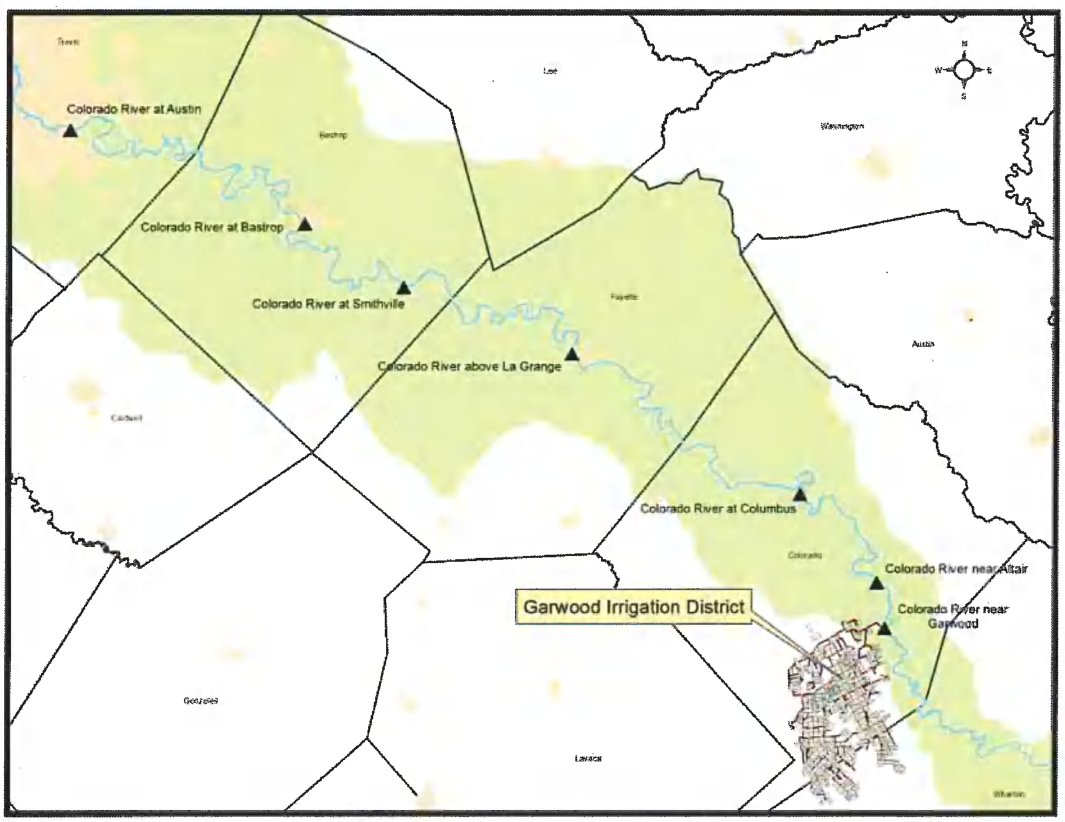
6. I served as Vice Chair of the Colorado-Lavaca Basin and Bay Expert Science Team, which established environmental flow recommendations for streams in the Colorado and Lavaca River and Matagorda and Lavaca Bay

7. As part of my duties at the LCRA, I regularly monitor and assess water quality data for the lower Colorado River basin. I have been directly involved in overseeing various studies of the aquatic habitat and water quality of the lower Colorado River and Matagorda Bay. My opinion is based on this review and my experience in the field. It is my opinion that:

    a. The lower 290 miles of the Colorado River below Austin flows through the East Central Texas Plains, Blackland Prairies, and Western Gulf Coast Plains ecoregions. The river basin transitions from the rocky Hill County to deep clay soils, cutting through geologically distinct zones that create distinct physical habitat characteristics. Instream flow in the lower Colorado River is a master variable that directly and indirectly influences habitat, biology, and water quality.

b. The Blue Sucker (*Cycleptus elongatus*) is a state-listed threatened species in Texas and is a species of concern throughout its range due to its unique biological characteristics. Blue Suckers are long-lived (up to 20 years), depend on specific habitat related to high flow, and have low recruitment of young into the population. This combination of factors makes them particularly sensitive to alterations to the flow regime. The Blue Sucker is uniquely adapted to life in swift currents. (It is elongated and tubular in shape and has large pectoral fins which facilitate movement in swift currents.) Adults utilize high velocity flow areas over hard substrate such as bedrock outcrop, boulders, and cobble riffles. These habitat types are present between Bastrop and Eagle Lake (downstream of the Colorado River at Columbus gage). *See* Figure 1.

Figure 1. Colorado River below Austin



c. Blue Suckers are known to undertake long spawning migrations, often covering hundreds of miles. Radio-tagged fish in the lower Colorado River which had traveled from La Grange, Smithville, and Bastrop were located in a spawning aggregation with about 50 other Blue Sucker just below Longhorn Dam in 2005. After spawning, the fish returned to their 'home' area. Two male Blue Suckers tagged at Altair migrated to Onion Creek and Utley, but did not return to the 'home' area. In other years, fish were observed to not make long spawning runs, opting to spawn near the 'home' areas, when flow and water temperature conditions were suitable. (*See* Tab 2, Blue Sucker Life History Studies Summary Report, BIO-WEST, Inc., Oct. 2007 pp 3-3 through 3-8, 4-1, hereinafter "2007 Blue Sucker Summary Report.")

d. LCRA has conducted instream flows studies evaluating the habitat of the Blue Sucker and the impact of streamflows on water quality. The most recent study was performed as part of the LCRA-SAWS Water Project. The study followed the principles of the Texas Instream Flow Program, recommended several levels of instream flow and was also the basis for the Senate Bill 3 Environmental Flow Standards for the lower Colorado River. This study used the latest data and science to assess the relationship between various factors and Blue Sucker habitat. (*See* Tab 3, *excerpts from* Lower Colorado River, Texas Instream Flow Guidelines, BIO-WEST, Inc., March 2008, hereinafter "2008 Instream Flow Guidelines Report.") Those factors included habitat suitability criteria (depth, velocity, substrate) and data recorded during observations of spawning fish such as depth, velocity, substrate, and temperature. The computer models and data analysis in the study were used to develop instream inflow criteria for the Colorado River. Prior to this study, LCRA conducted a study in conjunction with the Texas Parks and Wildlife Department (TPWD) in 1992. (*See* Tab 4, *excerpts from* Instream Flows for the Colorado River, Mosier and Ray, June 1992, hereinafter "1992 Instream Flow Study.") This study established critical and target instream flow criteria for several locations in the lower Colorado River. The study also recommended a release of 500 cubic (cfs) for a continuous six week period in March, April and May to provide spawning habitat for Blue Sucker (until addition study was conducted to refine the criteria). The 2010 WMP[1] uses the critical instream flow criteria (including the 500 cfs release) from the 1992 study.

e. The recent studies affirmed that instream flows were important to the maintenance of adequate spawning habitat for the Blue Sucker. The "subsistence" criteria in the 2008 Instream Flow Guidelines Report are analogous to LCRA's "critical" flow requirements in the current WMP. The new criteria are reflected in the Texas Commission on Environmental Quality's environmental flow standards for new permits in the lower Colorado River basin. 30 Tex. Admin Code ch. 298, subch. D. Table 1, below, summarizes both sets of criteria.

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[1] Although called the 2010 WMP, the proposed amendments were filed with TCEQ in 2003, *before* the study underlying 2008 Instream Flow Guidelines Report was completed.

Table 1. Instream Flow Criteria

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Subsistence Flows (New Study)												
Bastrop	208	274	274	184	275	202	137	123	123	127	180	186
Columbus	340	375	375	299	425	534	342	190	279	190	202	301
Wharton	315	303	204	270	304	371	212	107	188	147	173	202
Critical Flows (current WMP)												
Bastrop to Eagle Lake	120	120	500 for 6 weeks; 120 for remainder			120	120	120	120	120	120	120

f. As shown in the table, the subsistence criteria during the March-May timeframe are lower than the 500 cfs critical flow requirement.

g. A flow of 500 cfs supports between 93 and 100 percent of the maximum available spawning habitat for the Blue Sucker. A flow of 300 cfs (which is generally consistent with the new criteria in the table above) would support at least 86% of the maximum available spawning habitat for the Blue Sucker. (*See* Tab 3, 2008 Instream Flow Guidelines Report, p. 79 Table 4.9.)

h. LCRA is currently participating with the TPWD in a study to assess the Blue Sucker. Collection and tagging of Blue Sucker was conducted December 15-17, 2014. The collections were at locations containing adult Blue Sucker habitat (typically fast-flowing areas near bedrock outcrops and boulders) that had also been used in an assessment in 2004. Blue Suckers were collected and tagged in similar numbers in 2014 as in 2004 as shown in Table 2. The 2014 sampling event also collected 7 juvenile Blue Sucker (one at La Grange and six at Altair). Preliminary estimates are that the fish are two years old. These are the first juvenile fish collected in the Colorado River and indicate reproductive success in recent years.

Table 2. Adult Blue Sucker fish collected and tagged

Location	2004	2014
Bastrop	5	12
Smithville	2	0
La Grange	6	13
Columbus	5	1
Altair	13	10

i. LCRA routinely performs water quality monitoring of the lower Colorado River. Tables 3, 4 and 5 present water quality data collected since 2000 when flows were below 350 cfs. Water quality standards are consistently met (with few exceptions) when flow is at or near 300 cfs.

Table 3. Water Quality Data for Webberville Reach, 1428

Date	Flow	Temp	DO	pH	Chloride	Sulfate	E coli	TDS
Standard		*95.00*	*6*	*6.5 - 9*	*100*	*100*	*126*	*500*
2/2/2000	324	55.38	9.63	7.43	66	64	20	352
12/10/2001	302	58.26	9.86	7.68	30	35	1110	249
12/5/2005	294	58.46	9.75	7.98	59	46	35	343
2/1/2006	331	60.55	8.65	7.71	57	49	13	322
12/4/2006	260	54.86	9.3	7.9	56	48	75	335
12/2/2008	210	55.40	9.6	7.9	67	54	30	361
2/3/2009	193	55.40	12.9	8	72	60	23	372
12/7/2010	335	55.22	9.9	8	50	46	44	334
6/5/2012	347	87.98	8.6	8.4	69	89	32	399
10/4/2012	302	76.28	8.4	8.1	57	50	25	326
12/3/2012	233	70.16	6.2	7.8	80	68	9	420
2/11/2013	203	64.04	7.4	7.6	87	77	43	428
4/8/2013	335	71.42	5.8	7.7	67	69	91	387
10/8/2013	340	76.82	9.5	8	58	60	34	333
4/1/2014	237	71.78	7.8	8.1	78.7	76.3	44	431
8/13/2014	255	87.80	7.5	8	67.9	68.5	32	384

Table 4. Water Quality Data for Bastrop Reach, 1434

Date	Flow	Temp	DO	pH	Chloride	Sulfate	E coli	TDS
Standard		*95*	*6*	*6.5 - 9*	*100*	*100*	*126*	*500*
2/2/2000	324	50.34	13.18	8.44	54	55	10	311
12/10/2001	302	57.18	10	7.73	24	34	2380	227
12/5/2005	294	55.98	10.69	8.23	52	46	29	339
2/1/2006	331	59.20	9.26	7.89	51	45	37	286
12/4/2006	260	51.26	10.3	8	46	43	16	273
12/2/2008	210	53.42	10.8	8.1	67	55	8	359
2/3/2009	193	51.80	12.5	8.6	70	60	8	366
12/7/2010	335	53.24	11.3	8.6	51	47	7	338
6/5/2012	347	89.06	10.9	8.9	70	95	26	404
10/4/2012	302	74.84	7.8	8.1	40	39	100	255
12/3/2012	233	68.72	9.2	8.3	77	69	19	413
2/11/2013	203	63.50	9.2	8.2	86	80	34	430
4/8/2013	335	69.80	7	8	50	53	70	315
10/8/2013	340	77.00	10.4	8.2	61	66	27	349
4/1/2014	237	71.24	6.6	8	79.7	77.9	39	431
8/13/2014	255	89.42	9.3	8.5	75.3	78.7	32	402

Table 5. Water Quality Data for Columbus Reach, 1402

Date	Flow	Temp	DO	pH	Chloride	Sulfate	E coli	TDS
Standard		*95*	*5*	*6.5 - 9*	*100*	*100*	*126*	*500*
12/3/2008	266	58.46	9.4	8.1	59.8	54.5	66	311
2/4/2009	254	53.60	10.4	8.5	61.9	55.1	2	366
12/8/2010	334	53.42	10.8	8.5	49.7	49.3	66	346
12/6/2011	332	53.24	9.7	8	67.3	77.5	240	387
8/8/2012	137	88.34	5.9	8.8	50.7	56.2	17	302
12/4/2012	242	70.16	8	8.5	68.9	60.4	1000	363
2/12/2013	242	61.70	11.7	8.4	73.8	74.1	15	399
8/7/2013	340	88.88	8.5	9	56.3	44	26	304
10/8/2013	343	74.84	9.3	8.2	26.8	31.1	49	211
12/10/2013	246	48.54	11.65	8.02	48.4	68	37.3	372
2/11/2014	314	48.97	12.18	9.02	70.3	88.8	29.8	421
4/1/2014	297	74.48	8.7	8.7	75.2	79.5	11	396
8/13/2014	200	88.52	7.2	8.6	58.3	64.1	51	337

"In my opinion, maintaining flows at 300 cfs maintains an acceptable balance between protecting environmental flow needs for the Blue Sucker and other firm water needs because there should not be a significant impact on the Blue Sucker or water quality."

Further affiant sayeth not.

Bryan Cook

BRYAN COOK, AFFIANT

SWORN TO AND SUBSCRIBED before me on the 19th day of December, 2014.

TABETHA JASKE
Notary Public, State of Texas
My Commission Expires
January 11, 2018

Notary Public in and for the State of Texas

My Commission Expires: 1-11-2018

Tab 1

Bryan P. Cook

Lower Colorado River Authority
P. O. Box 220
Austin, TX 78767-0220

EDUCATION

Master of Public Affairs, December 2004
LBJ School of Public Affairs
The University of Texas at Austin
Professional Report: "Freshwater Inflows To Matagorda Bay"

Master of Science, May 1998
Aquatic Biology
Southwest Texas State Univ.
Thesis: "Seasonal and Longitudinal Variation in Nitrate and Chlorophyll *a* in a Central Texas Reservoir"

Bachelor of Science, December 1995
Major: Resource and Environmental Studies, Minor: Biology
Southwest Texas State Univ.

SUMMARY

Seventeen years experience in collection and analysis of water quality and biological data, evaluation and development of riverine and estuarine environmental flow recommendations, with past five years overseeing these activities as a supervisor. Excellent writing and public speaking skills. Experience as liaison in technical and public stakeholder processes, as primary internal expert for environmental flows and water quality processes within the Colorado River system, and as expert witness in legal and regulatory proceedings. Success with funding and project management of water quality grants. Exceptional skills in operation of water quality data sondes, flow meters, boat operation, and biological collection devices in estuarine and freshwater ecosystems.

PROFESSIONAL EXPERIENCE

LOWER COLORADO RIVER AUTHORITY, AUSTIN, TEXAS — Jan. 1998 - PRESENT

Water Quality Supervisor — *Jan. 2009 – Present*

- Conduct and review complex biological and water quality evaluations, including estimating water needs for the environment and environmental impacts of water supply strategies.
- Supervise, coordinate, and direct activities of staff related to the Clean Rivers Program
- Manage the Clean Rivers Program grant and other team grants
- Review and comment on state water quality permit applications filed in the Colorado River Basin
- Represent LCRA with water quality related stakeholder groups
- Provide written expert testimony in support of LCRA's position in legal proceedings.

Senior Aquatic Scientist — Jan. 2005 – Jan 2009

- Conduct and review complex biological and water quality evaluations, including estimating water needs for the environment and environmental impacts of water supply strategies.
- Prepare reports and provide recommendations for solutions to water supply and management issues.
- Interpret results from water quality and water quantity models simulating all aspects (physical, chemical, and biological) of the Colorado River system- including watersheds, tributaries, rivers, reservoirs, and estuary systems.
- Convey information to internal and external customers and provide expertise to upper management regarding statewide water policy issues and Lower Colorado River Authority (LCRA) operations.
- Serve as the primary internal expert and liaison with state resource agencies for environmental flows and water quality processes within the lower Colorado River Basin.
- Provide written expert testimony in support of LCRA's position in legal proceedings.
- Manage federal Clean Water Act 319 grant contracts.
- Selected and graduated from Leadership LCRA 2006, a year long leadership development program.

Aquatic Scientist *II* Sep. 2000 -Jan. 2005

- Expanded the long-term fixed station water quality monitoring program in Matagorda Bay.
- Developed statistical relationships between freshwater inflows, salinity, and species abundance in Matagorda Bay.
- Participated and provided recommendations for environmental flows in LCRA's Water Management Plan process.
- Designed and implemented intensive chemical, biological, and habitat monitoring program targeting watersheds throughout the Lower Colorado River basin.
- Prepared final reports and presented data at statewide conferences and to the general public.

Watershed Protection Coordinator II *Aug. 1999 - Sep. 2000*

- Designed and implemented water quality monitoring programs to assess stormwater treatment ponds.
- Conducted stormwater monitoring, analyzed runoff data and evaluated success of best management practices for federal Clean Water Act 319 Grants.
- Performed chemical and biological assessments throughout the lower Colorado River basin supporting the Texas Clean Rivers Program.

Environmental Coordinator l Jan. 1998 - Aug. 1999

- Conducted stormwater monitoring to support federal Clean Water Act 319 grants.
- Analyzed water quality samples to determine runoff quality from innovative best management practices.
- Prepared quarterly progress reports for grants.
- Assisted with routine water quality monitoring and data analysis.

SOUTHWEST TEXAS STATE UNIVERSITY, SAN MARCOS, TEXAS Jan. 1997 - Dec. 1997

Zoology Teaching Assistant

- Taught principals of taxonomy, anatomy, and physiology to underclassmen.
- Prepared lesson plans and administered examinations.

CITY OF AUSTIN, ENVIRONMENTAL SERVICES, AUSTIN, TEXAS Feb. 1994 - Jan. 1997

Professional Intern

- Prepared technical reports to staff and supervisors summarizing development trends and applicable ordinances.
- Researched developments over environmentally sensitive zones.
- Performed on-site inspections of land development projects.

SKILL SUMMARY

- Monitoring and analysis of estuarine and freshwater ecosystems
- Ability to communicate with technical and non-technical audiences
- Quantitative and multivariate analysis of chemical and biological data
- Managing water quality grants
- Operations of water quality, flow, and biological monitoring equipment
- Knowledge of State water quality standards

Blue Sucker Life History Studies Summary Report

Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker

Prepared for

Lower Colorado River Authority

and San Antonio Water System

Prepared by

BIO-WEST, Inc.
1812 Central Commerce Court
Round Rock, TX 78664-8546

OCTOBER 2007

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Acronyms and Abbreviations

CFS	Cubic Feet Per Second
DO	Dissolved Oxygen
GPS	Global Positioning System
HSC	Habitat Suitability Criteria
LCRA	Lower Colorado River Authority
LSWP	LCRA-SAWS Water Project
SAWS	San Antonio Water System
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
USGS	United States Geological Survey
WUA	Weighted Usable Area

1.0 INTRODUCTION

The blue sucker (*Cycleptus elongatus*) is a wide-ranging catostomid fish native to large rivers in the Mississippi River Basin and large Western Gulf Slope drainages of Louisiana and Texas. It has been documented from northern Wisconsin, central Montana, and Pennsylvania southwest to central Texas. A sister species, the southeastern blue sucker (*Cycleptus meridionalis*), has recently been recognized from Gulf Slope drainages east of the Mississippi in Alabama, Mississippi, and Louisiana (Burr and Mayden 1999). In addition, recent genetic analyses has suggested that populations in the Rio Grande drainage of Texas, New Mexico, and Mexico are divergent from other *C. elongatus* populations, and a formal species description is currently being conducted for this species (Bessert 2006).

Blue suckers are a rather large long-lived fish that obtain total lengths over 800 mm (32 inches) and weights over 4,000 g (8.8 lbs.). Southeastern blue suckers are thought to live up to 33 years based on opercular bone aging (Peterson et al. 1999), and have been known to migrate large distances upstream during annual spring spawning migrations (Mettee et al. 2003, Peterson et al. 2000). Blue suckers inhabit relatively deep, high-velocity rapids over firm substrates such as cobble and bedrock and feed on aquatic invertebrates – mainly Trichopteran and Dipteran larvae (Rupprecht and Jahn 1980, Moss et al. 1983). Although they were once an important part of commercial catches from the Mississippi River, abundance of blue suckers has declined in many areas due to reservoir construction which blocks migration routes and limits availability of high-velocity rapids habitats (Rupprecht and Jahn 1980, Mettee et al. 2003). Due to such impacts, the population status of blue suckers is somewhat questionable and they are considered threatened or endangered throughout much of their range (Peterson et al. 2000).

In Texas, blue suckers exhibit a rather sparse and disjunctive distribution. Disregarding the recently recognized Rio Grande species, specimens have been confirmed from the Colorado River in central Texas, and the Sabine and Neches Rivers in the eastern part of the state. However, several large rivers located in between those mentioned lack confirmed reports of blue suckers (Burr and Mayden 1999). The disjunctive distribution of blue suckers within the state and the lack of data on confirmed populations have led to its listing as a threatened species by the state of Texas.

Given the limited information on blue sucker populations in Texas and the potential for impacts to the lower Colorado River blue sucker population as a result of the LSWP, an effort was made to gather data on movement, migration, habitat use, and general life history of blue suckers within the lower Colorado River. This report provides a summary of all activities associated with this task, and a discussion of subsequent results.

2.0 MOVEMENT AND MIGRATION

2.1 Tagging

Thirty blue suckers (486-705 mm TL) were collected by boat electrofishing from five pre-selected riffle locations within the lower Colorado River. Riffle locations were selected because previous sampling by LCRA biologists and others had identified blue suckers in these areas. Thirteen blue suckers were collected and implanted with radio transmitters at a riffle site near Altair (Colorado County), four at a site near Columbus (Colorado County), six at a site near LaGrange (Fayette County), two at a site near Smithville (Bastrop County), and five at a site near Bastrop (Bastrop County) (Figure 2.1).

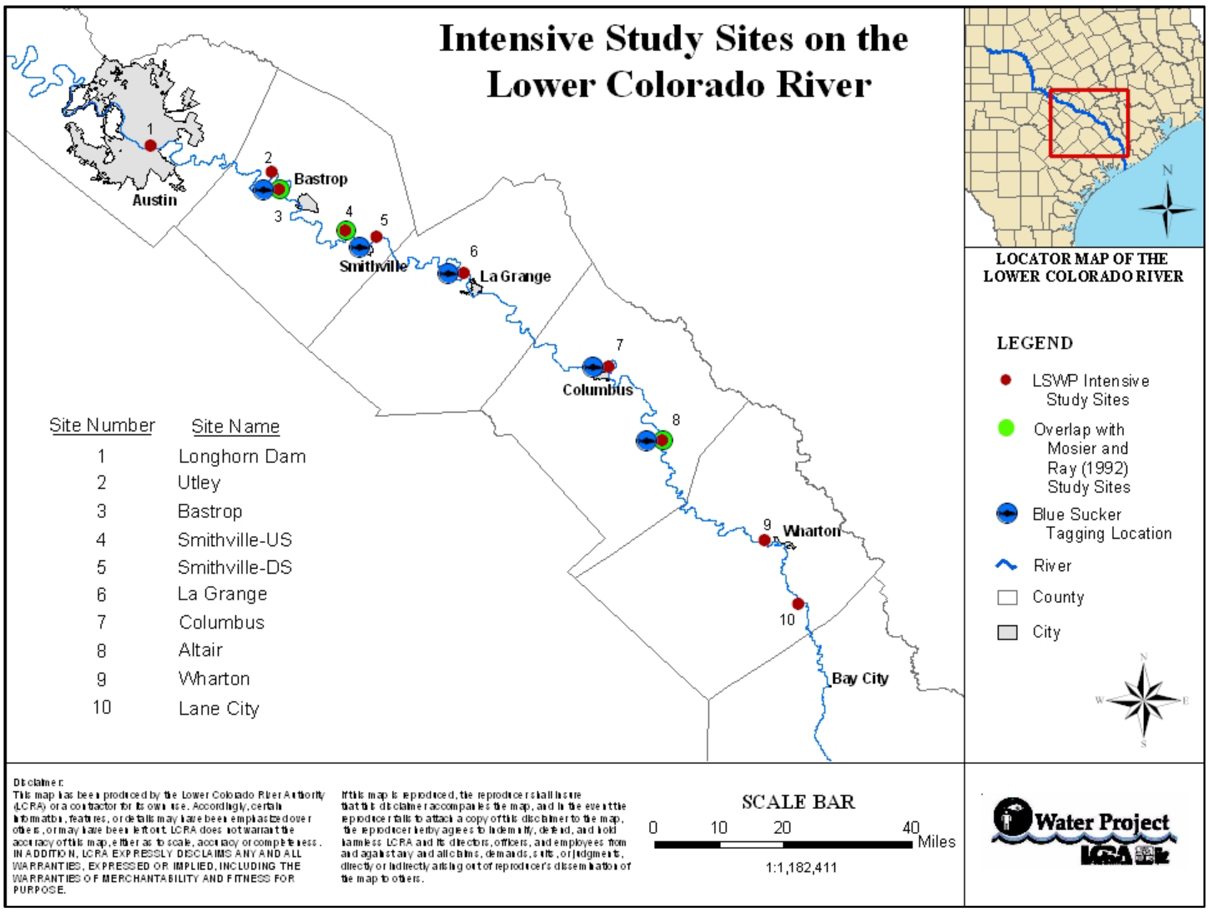


Figure 2.1 – Map showing tagging locations of blue suckers in the Colorado River, Texas.

Once captured, fish were held in a flow-through holding tank set in the river until time of surgery. Total length (mm) and weight (g) of each fish was measured, and the abdominal area was gently squeezed in an attempt to expel milt or eggs and thus determine sex of the fish (Table 2.1, Figure 2.2). Individuals which did not readily expel gametes, and for which gonads were not obvious during surgery, were recorded as sex unknown.

Table 2.1 - Date, location, length, weight, sex, and tag frequency of 30 blue suckers implanted with radio transmitters in the lower Colorado River, Texas.

Location[1]	GPS Coord.[2]	Date	Total Length (mm)	Weight (g)	Sex	Frequency
Columbus	14 R 737896 3289952	10/19/2004	642	2722	F	149.320
Columbus	14 R 737896 3289952	10/19/2004	486	680	U	149.340
Columbus	14 R 737896 3289952	10/19/2004	535	1134	U	149.360
Columbus	14 R 737896 3289952	10/19/2004	524	1134	U	149.380
Altair	14 R 751808 3272345	10/20/2004	556	3175	U	149.400
Altair	14 R 751808 3272345	10/20/2004	555	1588	M	149.420
Altair	14 R 751808 3272345	10/20/2004	705	4536	F	149.440
Altair	14 R 751808 3272345	10/20/2004	521	1134	U	149.460
Altair	14 R 751808 3272345	10/20/2004	596	1814	M	149.480
Altair	14 R 751808 3272345	10/20/2004	655	2722	M	149.500
Altair	14 R 751808 3272345	10/20/2004	584	2041	U	149.520
Altair	14 R 751808 3272345	10/20/2004	667	3175	M	149.540
Altair	14 R 751808 3272345	10/20/2004	605	2495	F	149.560
Altair	14 R 751808 3272345	10/20/2004	686	4082	F	149.580
Altair	14 R 751808 3272345	10/20/2004	558	2268	M	149.600
Altair	14 R 751808 3272345	10/20/2004	665	2948	M	149.620
Altair	14 R 751808 3272345	10/20/2004	596	2495	M	149.640
La Grange	14 R 702322 3314482	10/21/2004	610	2722	M	149.660
La Grange	14 R 702322 3314482	10/21/2004	601	2041	M	149.680
La Grange	14 R 702322 3314482	10/21/2004	665	3402	M	149.700
La Grange	14 R 702322 3314482	10/21/2004	685	4082	F	149.720
La Grange	14 R 702322 3314482	10/21/2004	668	3629	F	149.740
La Grange	14 R 702322 3314482	10/21/2004	651	2948	M	149.760
Smithville	14 R 677445 3321657	10/22/2004	670	3175	M	149.780
Smithville	14 R 677445 3321657	10/22/2004	621	2268	M	149.800
Bastrop	14 R 656632 3336236	10/27/2004	693	3856	F	149.820
Bastrop	14 R 656632 3336236	10/27/2004	646	2722	M	149.840
Bastrop	14 R 656632 3336236	10/27/2004	676	3175	M	149.860
Bastrop	14 R 656632 3336236	10/27/2004	600	2381	M	149.880
Bastrop	14 R 656632 3336236	10/27/2004	607	2268	M	150.180

[1]All fish captured in the Colorado River, Texas.

[2]All GPS Coordinates in UTM Nad 83.

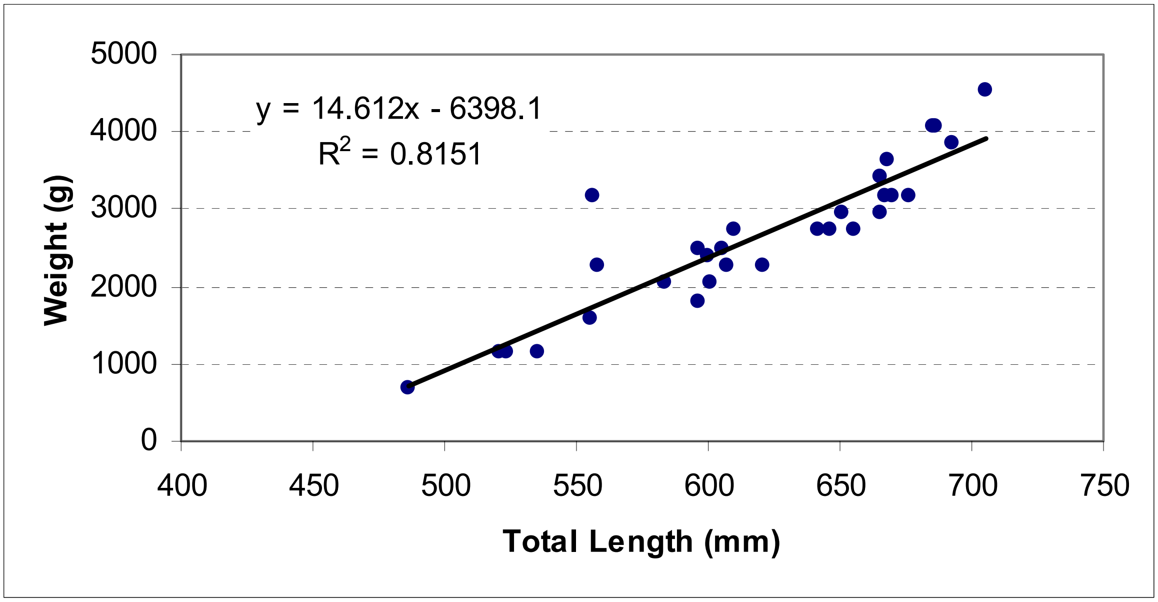


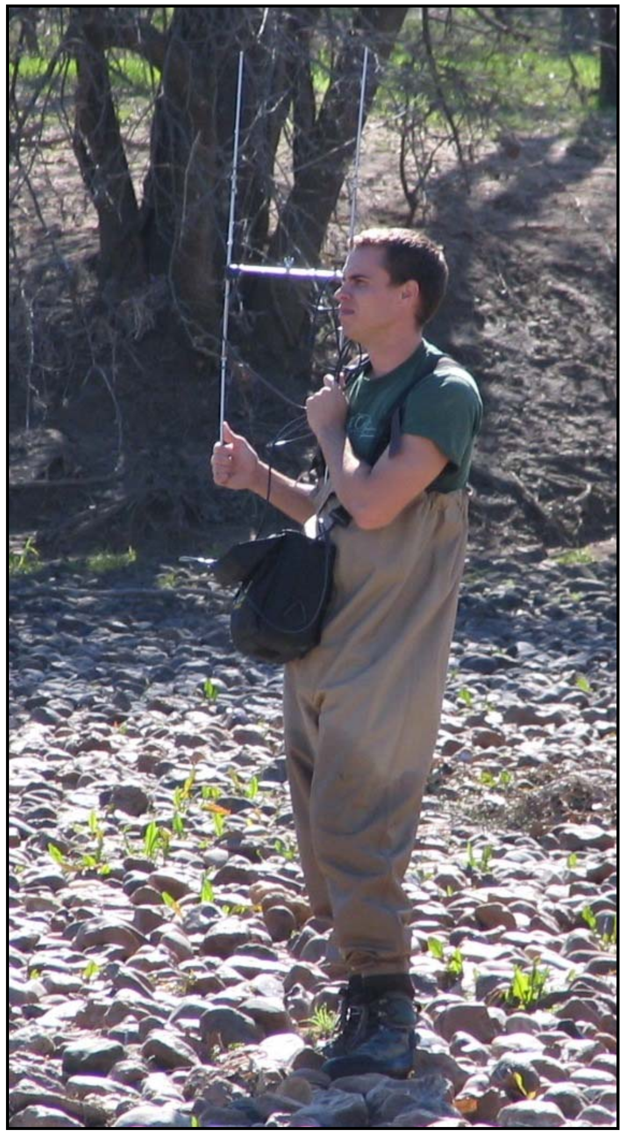
Figure 2.2 – Length-weight relationship for 30 blue suckers collected from the lower Colorado River, Texas.

Immediately before surgery, each fish was placed into a 100 quart ice chest containing a mixture of river water and clove oil as an anesthetic. Once fish became docile and lost equilibrium, a sharp scalpel was used to make a small 2-cm incision immediately behind the left pelvic fin. A 16-gram radio transmitter (LOTEK model #MBFT_3A, frequency range: 149.320-150.180) was then placed inside the peritoneal cavity of the fish, and the incision was closed with surgical sutures leaving the antennae exposed. Scissors were then used to remove a small clip from the anal fin of each fish for later genetic analysis (see section 3.4). A small Floy anchor tag was inserted near the dorsal fin of each fish to aid in identification. After surgery, iodine was used to disinfect surgical wounds, and fish were placed into a separate flow-through recovery tank in the river. Once fish had fully recovered (at least 45 minutes in recovery tank) they were released back into the river near the site of capture.

2.2 Tracking

Movement of tagged fish was monitored from time of release through 2007 by frequent mobile tracking excursions using an SRX_400 Telemetry Receiver (Lotek Wireless, Inc.) and an H-antenna. This receiver emits an audible signal of varying intensity to indicate proximity to the transmitter frequency being scanned. Most tracking was conducted by boat, with one person driving and one person operating the telemetry receiver and antennae. Once a signal was detected, an effort was made to get as close as possible to examine specific habitat use of tagged fish (see section 3.0). A strong audible signal at a low gain setting indicated close proximity to the tag. A GPS waypoint was then taken at the exact location of strongest signal strength using a handheld GPS unit (Garmin GPSMap 60CSx), and notes on date, time, general location, habitat, and confidence in location were recorded.

Mobile tracking was also conducted by fixed-wing aircraft on several occasions. When tracking by aircraft, the H-antennae was securely fastened to the wing of a small plane and the cord was run inside the cockpit to a person monitoring the receiver. To reduce the effects of engine noise on detection of audible signals, headphones were worn during aircraft tracking excursions. An experienced pilot then flew as low as possible along the river corridor. Although tracking by aircraft did not allow for specific microhabitat measurements, it was a more time efficient method to cover large expanses of river and provide general locations of tagged fish.



In addition to mobile tracking excursions, a fixed station receiver was established just upstream of the Altair tagging location at the LCRA's Eagle Lake Pumping Facility. A continuously monitoring telemetry receiver connected to two stationary antennas, one facing the river on each end of the facility, allowed detection of any tagged fish that passed by this facility. Data from this receiver was then downloaded to a laptop computer every 3-4 months.

2.2.1 2005

Tracking efforts from release (October 2004) through December 2005 resulted in 255 observations of tagged blue sucker locations. Results demonstrate that in spring 2005, several tagged fish made large upstream spawning migrations. In fact, 77% of fish considered alive at the end of the year had moved more than 1.2 miles from their initial tagging locations. Seven fish traveled over 100 miles upstream during spring 2005 (Table 2.2). The longest migration documented was a male blue sucker (149.640) that moved approximately 167 miles from the Altair riffle complex to the mouth of Onion Creek. As discussed in section 3.2, three fish that made large upstream migrations led the study team to a spawning aggregation of approximately 50 blue suckers congregated just downstream of Longhorn dam, which blocks further upstream migration.

Table 2.2 - Longest distances moved by radio-tagged blue suckers in 2005.

Tag #	Tagging Site	Sex	Distance Traveled (miles)	Farthest Upstream Point
149.640	Altair	male	167	Onion Creek
149.380*	Columbus	n/a	148	Low-Head Decker Lake Diversion Dam
149.420	Altair	male	139	Utley Site
149.660*	La Grange	male	115	Longhorn Dam
149.480	Altair	male	108	2.0 Miles Upstream of Upstream Smithville Site
149.600	Altair	male	106	Upstream Smithville Site
149.400	Altair	male	105	Upstream Smithville Site
149.720*	La Grange	female	87	Between Webberville and Utley
149.800*	Smithville	male	82	Longhorn Dam
149.860*	Bastrop	male	56	Longhorn Dam

* denotes fish that returned to their home riffles

Interestingly, the majority of these fish (65%) returned to within 0.6 miles of their initial tagging location during late spring and early summer 2005. For example, fish 149.380 traveled 148 miles upstream from the Columbus riffle to the Decker Lake Diversion Dam in early March, and then returned to the Columbus riffle by August. As a result of upstream spawning migrations and subsequent return trips downstream, several tagged fish moved 200-300 miles during the course of the year.

Differences in movement patterns were observed between male and female blue suckers. Of the male blue suckers tagged, 87% moved more than 1.2 miles during 2005, whereas only 50% of females migrated. Of the females that migrated, 100% returned to their home riffle by the end of the summer; however, only 57% of males returned.

Results suggest that males may be more mobile than females; however, more data are needed to confirm this observation.

During tracking activities in 2005, three tags were recovered from the river bottom. Two of these tags never exhibited any substantial movement; however, one tag (149.480) made a large upstream migration from its tagging site near Altair to Smithville in May, and was then recovered near La Grange in October 2005. In addition, four other tags had not moved in several return visits and were thought to be dead or shed as of December 2005. One tag (149.540) was not relocated during 2005. Despite this, 15 months after tagging 22 of 30 (73%) tags were still considered to be in live fish at the beginning of 2006.

2.2.2 2006

Tracking efforts from January to December 2006 resulted in 69 observations of tagged blue sucker locations. Movement patterns in 2006 were substantially different from those observed in 2005. Of the 15 live fish located in spring 2006, no large upstream migrations were observed. The largest upstream movement documented was fish 149.420 which was located approximately 1.9 miles upstream from its previous location. Nine fish which made upstream migrations in spring 2005 showed little to no upstream movement in spring 2006. Four fish which had stayed near their home riffles in spring 2005 did the same in 2006. Fish 149.800 moved several miles downstream in spring 2006.

Most movement documented the previous year corresponded to upstream spawning migrations in early spring, and resulting return trips in late spring and summer. Since no large upstream migrations were observed in spring 2006, tagged blue suckers moved very little over the course of the year. Over the entire year, only three fish moved distances of greater than 10 miles, all in a downstream direction.

One tagged fish (149.580) was recaptured at the Altair riffle with the help of LCRA biologists and electrofishing equipment in February 2006 (16 months after tagging). The fish was in good health, and the surgery wound had healed well. The small Floy tag placed near the fish's dorsal fin during surgery was no longer present. This fish was subsequently released unharmed, and was relocated several times after being recaptured.

Radio-tagged blue sucker (149.580) recaptured in February 2006

Four more tags were recovered in 2006, bringing the total number of recovered tags to seven. Additionally, five tags were considered to be dead or shed by the end of the year because they had not moved in several return visits. Tag 149.540 had still not been located since release. The remaining 17 tags were still considered to be in live fish at the beginning of 2007.

2.2.3 2007

Tracking efforts in 2007 resulted in 12 observations of tagged blue sucker locations. As expected, decreasing battery power in tags and increasing mortality/shedding rates negatively influenced tracking success. Additionally, extremely high flows prevented tracking during early summer 2007.

Again, no large migrations were observed in 2007. Five tagged fish thought to be alive were relocated in spring 2007 in or near their home riffle. Three of these fish had exhibited upstream migrations in 2005, whereas two of them had not moved substantial distances from their home riffle during the course of the study.

The final tracking session was conducted in August 2007. Although tracking success was low due to tag failure/shedding and higher than normal flows, several tags were located which were thought to be in live fish. Again, most fish moved little from their home riffles during the course of 2007.

2.2.4 Movement Summary

Twenty-nine tags were relocated at least twice since release in October 2004. One tag (149.540) was never relocated and is thought to have malfunctioned. From the remaining 29 tags there were 337 total observations over a 34 month period (Table 2.3). Several tags were located over 10 times during the course of the study. Although several tags were eventually shed (seven were recovered), this is to be expected given the high-velocity rocky habitats occupied by blue suckers. Recovered tags often exhibited twisted and mangled antennas, suggesting that they had perhaps become tangled in the substrate and thus pulled from the fish’s body. Despite the number of shed tags, overall tag retention was good and tracking data provided extremely valuable information on movement of blue suckers in the lower Colorado River.

Table 2.3 - Number of relocations and final status of each radio-tagged blue sucker.

Tagging Location	Frequency	Sex	Number of Observations	Final Status
Columbus	149.320	F	10	Dead or shed
Columbus	149.340	U	11	Tag recovered
Columbus	149.360	U	7	Dead or shed
Columbus	149.380	U	12	Alive
Altair	149.400	U	8	Dead or shed
Altair	149.420	M	9	Unknown
Altair	149.440	F	22	Alive
Altair	149.460	U	8	Dead or shed
Altair	149.480	M	6	Tag recovered
Altair	149.500	M	2	Dead or shed
Altair	149.520	U	8	Tag recovered
Altair	149.540	M	0	Unknown
Altair	149.560	F	9	Unknown
Altair	149.580	F	20	Alive
Altair	149.600	M	10	Unknown
Altair	149.620	M	18	Alive
Altair	149.640	M	11	Dead or shed
La Grange	149.660	M	11	Tag recovered
La Grange	149.680	M	9	Tag recovered
La Grange	149.700	M	12	Tag recovered
La Grange	149.720	F	15	Alive
La Grange	149.740	F	16	Unknown
La Grange	149.760	M	12	Alive
Smithville	149.780	M	14	Alive
Smithville	149.800	M	13	Alive
Bastrop	149.820	F	15	Tag recovered
Bastrop	149.840	M	8	Unknown
Bastrop	149.860	M	17	Alive
Bastrop	149.880	M	10	Unknown
Bastrop	150.180	M	14	Alive

In summary, movement patterns of tagged blue suckers differed substantially between years. During the first year of tracking (2005) most tagged fish made large upstream spawning migrations in early spring and the majority returned downstream by the end of summer. However, in the following two years (2006 and 2007) no large spawning migrations were observed. For example, Figure 2.3 demonstrates movement of fish 149.720 throughout the study period.

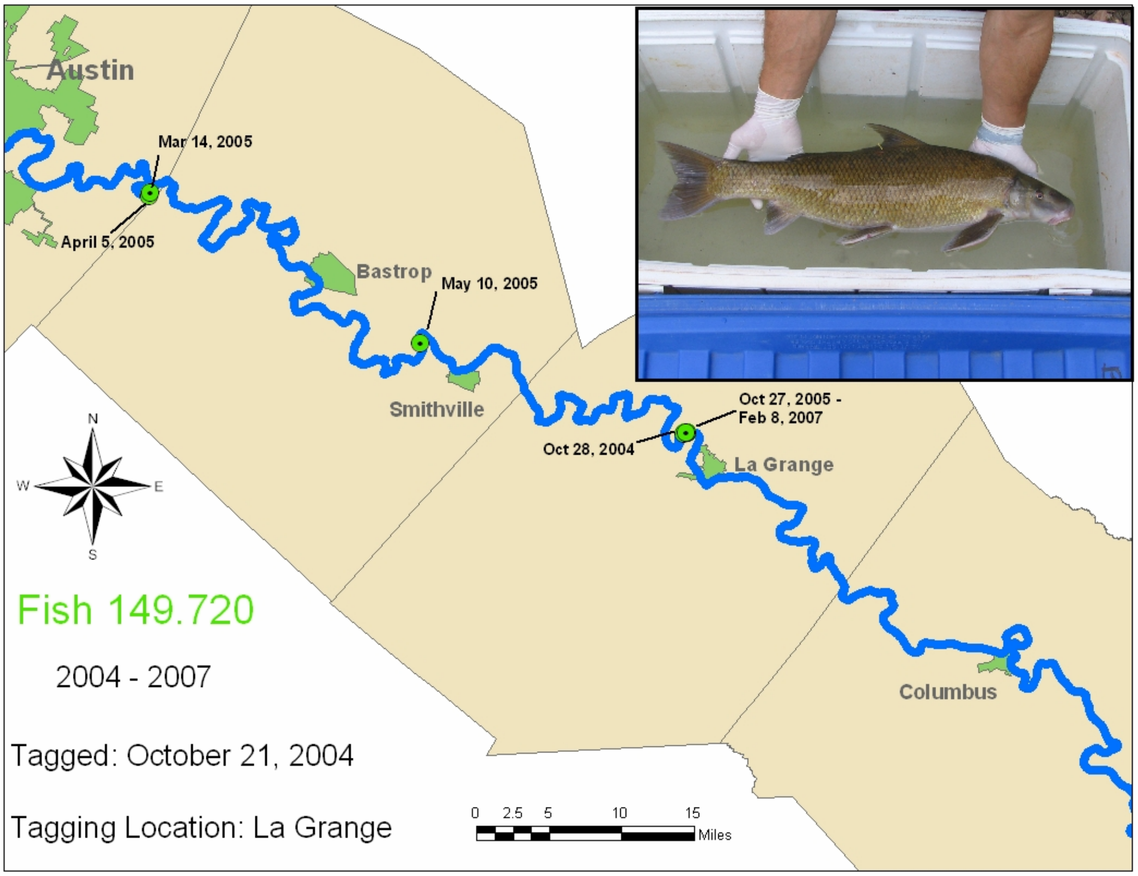


Figure 2.3 – Movement of fish 149.720 in the lower Colorado River, Texas.

Differences in movement patterns of tagged blue suckers among years were most likely a result of significantly different flows during spawning periods (Table 2.4). Large precipitation events in late winter and early spring 2005 led to consistently high flows throughout this period, whereas drier conditions in 2006 resulted in much lower flows. In 2007, flows were low throughout much of the early spring (i.e., February), but were punctuated by high flow events in January and March.

Table 2.4 - Average monthly discharge at Austin, Bastrop, and Columbus for January through April 2005-2007.

USGS Stream Gage	Average Monthly Discharge (cfs)			
	January	February	March	April
Winter/Spring 2005				
Austin (08158000)	2,154	2,274	5,719	2,183
Bastrop (08159200)	2,400	2,759	6,740	2,874
Columbus (08161000)	3,063	4,614	7,367	3,179
Winter/Spring 2006				
Austin (08158000)	188	209	456	965
Bastrop (08159200)	350	374	711	1,267
Columbus (08161000)	369	416	663	1,134
Winter/Spring 2007				
Austin (08158000)	431	214	354	354
Bastrop (08159200)	2,212	423	1,636	849
Columbus (08161000)	3,498	519	3,309	1,806

3.0 HABITAT USE AND LIFE HISTORY

Tracking data not only provided information on movement and migration of blue suckers, but also allowed the study team to monitor habitat use of tagged blue suckers. This data is summarized in section 3.1. Tagged blue suckers also led the study team to numerous spawning aggregations during the course of the study. A summary of spawning observations from these areas is provided in section 3.2. To provide further information on life history, the project team sampled extensively for larval and juvenile blue suckers. A summary of activities and subsequent results associated with this task are provided in section 3.3.

3.1 Adult Habitat Use

When tracking was conducted by boat, an effort was made to get as close as possible to examine specific habitat use of tagged fish. This was usually done by wading into the area with the receiver and antenna in hand until the strongest signal strength was observed. Often, as the study team would close in on a tagged fish, signal strengths would suddenly become weaker as the fish moved away from the area. Once the best estimate of a fish's initial location was obtained, a GPS point was taken, and habitat measurements were collected. Depth, velocity, and dominate substrate were recorded. Water depth (ft) and velocity (ft/s) were measured using a Marsh-McBirney Flowmate Model 2000 portable flowmeter and incremental wading rod at five points representing the center and the corners of a hypothetical square encompassing the tagged fish's initial location. Dominant substrate was classified at each point as silt, sand, gravel, cobble, boulder, or bedrock following the standard Wentworth scale based on particle size. Occasionally, water depth and velocity were too high to allow for specific habitat measurements.

Habitat data (depth, velocity, and dominate substrate) collected in the immediate area of blue suckers located during tracking activities demonstrates that adult blue suckers occupy relatively deep, high-velocity habitats similar to those reported in the literature. Depths ranged from 1.4 – 8.0 feet (average = 3.4), and velocities ranged from 0.2 – 4.8 feet/second (average = 2.4). Substrates in areas where blue suckers were present were most commonly bedrock (41%), gravel (33%), and cobble (16%), and occasionally boulder (9%) and sand (2%) (Figure 3.1).

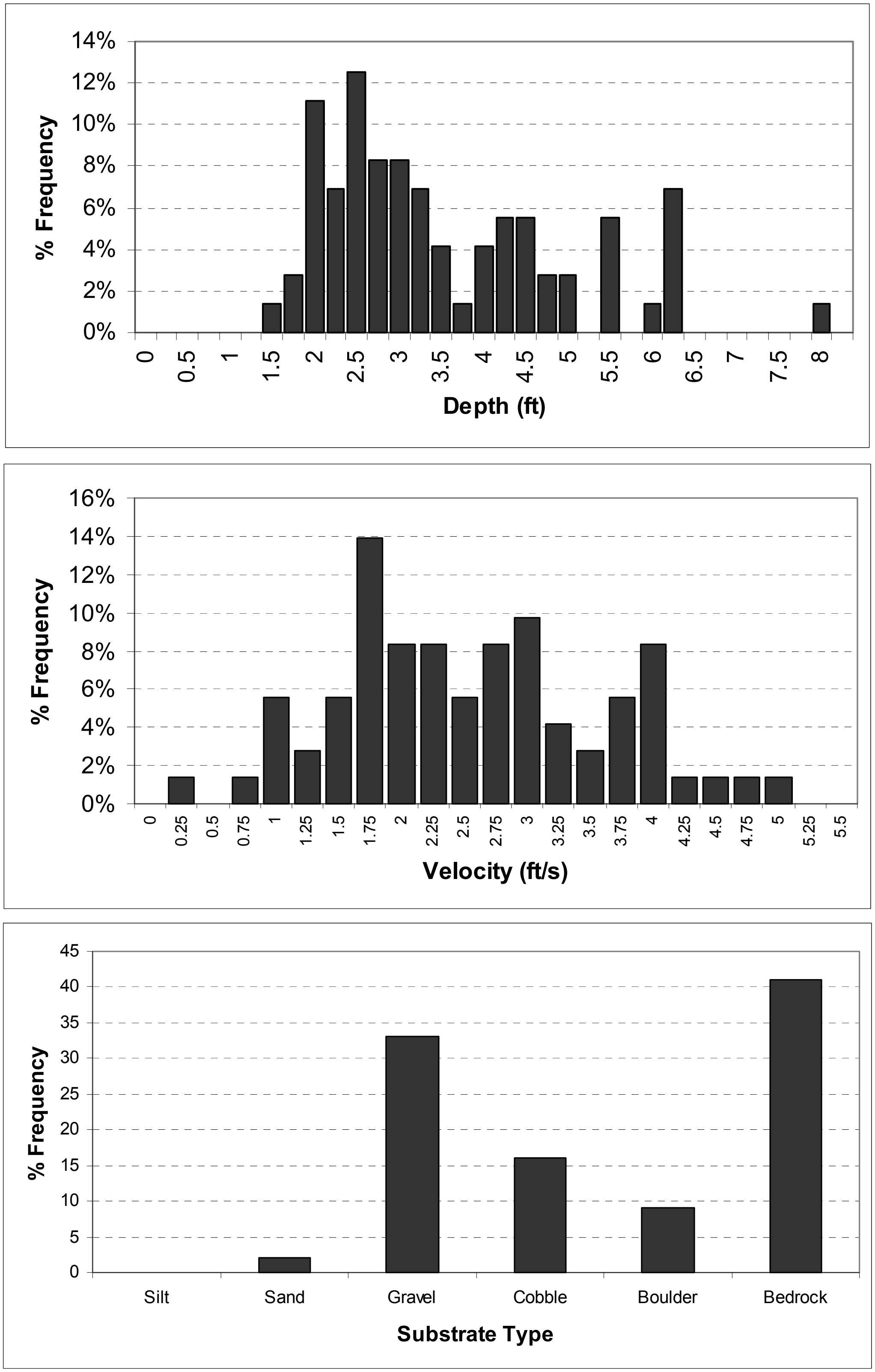


Figure 3.1 – Distributions of depth (ft), velocity (ft/s), and dominant substrate in locations of tagged blue suckers.

3.2 Spawning Observations

Several blue sucker spawning sites were identified by the project team over the course of the study. Detailed depth, velocity, and substrate measurements were taken at each site. The following is a description of study sites identified each year, and a summary of overall results.

3.2.1 2005

On March 13, 2005 three tagged blue suckers (149.660, 149.800, and 149.860) led the study team to a spawning aggregation of 40-50 adult blue suckers immediately below Longhorn Dam. Coincidentally, this occurred on a day in which water was being held in Town Lake for a regatta race and the 7,000+cfs that had been occurring in the river downstream was reduced to <1,000 cfs for about a six hour period. The three tagged blue suckers (originally tagged in three different riffle complexes) had moved between 55 and 115 river miles to this area just below Longhorn Dam. Spawning behavior was first discovered at 1:30 pm and continued until a large amount of water was released at 5:20 pm (when the race was over) at which time the flows became too high to observe fish. The USGS gage indicated that discharge was between 770 cfs and 910 cfs during this time period. Water temperature was approximately 16 °C. Spawning behavior exhibited by this congregation of blue suckers included vigorous splashing and the dorsal region of the fish breaching the water surface in several areas. Pictures and video were recorded to document the spawning behavior.

As discharge below Longhorn Dam was >7,000 cfs during the entire following week, the project team had to wait until the following weekend when regatta races again allowed for brief but significant reductions in flow at the spawning location. The spawning habitat was thus revisited on Saturday, March 19, 2005 to evaluate if spawning behavior of blue suckers was still taking place. On this date, only 10 to 15 adult blue suckers remained in the area (including one radio-tagged fish), and the project team did not observe any spawning activity. Detailed velocity, depth, and substrate measurements were collected because flows (780 cfs to 975 cfs) were similar to that of the previous week when spawning activity was evident. Pictures and underwater video of blue suckers were again collected to document the observations. The underwater footage taken on March 19, 2005 included numerous close (<2 ft. distance) observations of adult fish, which were very docile and not readily disturbed by the observer and underwater video camera. Evidence of cleared areas of substrate was also documented with video and still images. The spawning area contained large boulders, cobble, and bedrock substrates. Depth measurements in the specific areas of spawning were fairly shallow (0.5 – 2.5 ft.), and velocities low (0.3 – 1.8 ft/s) compared to data recorded from radio-tagged adults collected during other times of the year. Included were several deeper holes (2.5-3.0 ft) that were absent of the filamentous algae growing in the shallower areas.

3.2.2 2006

Discharge during late winter and early spring of 2006 was much lower than in 2005 (see Table 2.4), and thus presented the study team with much more favorable conditions for spawning observations. Previous observations of spawning blue suckers on the

Colorado River by the study team and others had been made in early March. Therefore, in early February 2006 the project team initiated tracking efforts to determine the current location of all radio-tagged fish in the river, with the additional goal of documenting any potential spawning aggregations. These efforts led to documentation of three blue sucker spawning sites as described below.

The first spawning site was located on February 8, 2006, when the project team tracked a radio-tagged blue sucker (149.620) to a small aggregation (≥ 5 individuals) of adult blue suckers within the Altair riffle complex. Although the water was too turbid to accurately assess exact behaviors, the fish were congregated in a confined area (≈ 5 m x 10 m) of decreased velocity immediately below a ledge in the middle of the riffle with high-velocity chutes on both sides. The substrate in the area was dominated by bedrock, but also contained small amounts of gravel and cobble. Water temperature at the time was 15 °C. Upon closer examination hundreds of milky white eggs (≈ 2–4 mm diameter) were found attached to the underside of large cobble–sized rocks in the area. Depths in the area ranged from 1.0-2.0 feet, and mean velocity ranged from 0.3-2.7 ft/s.

Altair spawning site

On February 9, 2006, another aggregation of approximately 20 adult blue suckers was documented while searching for radio-tagged fish at the La Grange riffle. The fish were tightly congregated in a relatively small, high-velocity area near the head of the riffle with a mixed substrate of bedrock, gravel, and cobble. Depths in the area ranged from 1.5-2.3 feet, and mean velocities ranged from 0.6-3.3 ft/s. Water temperature at the time was 16 °C. Again, hundreds of milky-white eggs, identical to those collected at Altair, were found on the substrate in the area near the aggregation and immediately downstream. The project team collected several of these eggs for verification, and several minutes of underwater video were taken in an attempt to capture spawning behavior. Although no spawning was actually witnessed, the project team observed the aggregation for approximately one hour in which time most of the fish moved little from their initial location. Similar to the spawning aggregation documented in 2005, fish were fairly docile and were not readily disturbed by the observers.

Spawning site at La Grange

Blue sucker eggs

The third confirmed spawning location of 2006 was documented at a riffle complex within the Utley intensive model site on February 14. Although no fish were observed at this location, eggs identical to those found at Altair and La Grange were collected from the substrate along a fast, shallow, cobble riffle near the upstream end of the site. Several eggs were collected for verification, and habitat measurements were taken in the area of egg deposition. Eggs were scattered over a relatively broad area in depths ranging from 0.7-1.1 feet, and velocities of 0.6-1.1 ft/s. Immediately downstream of the egg deposition site, depths increased to approximately 4 feet. The water temperature at the time was 12 °C.

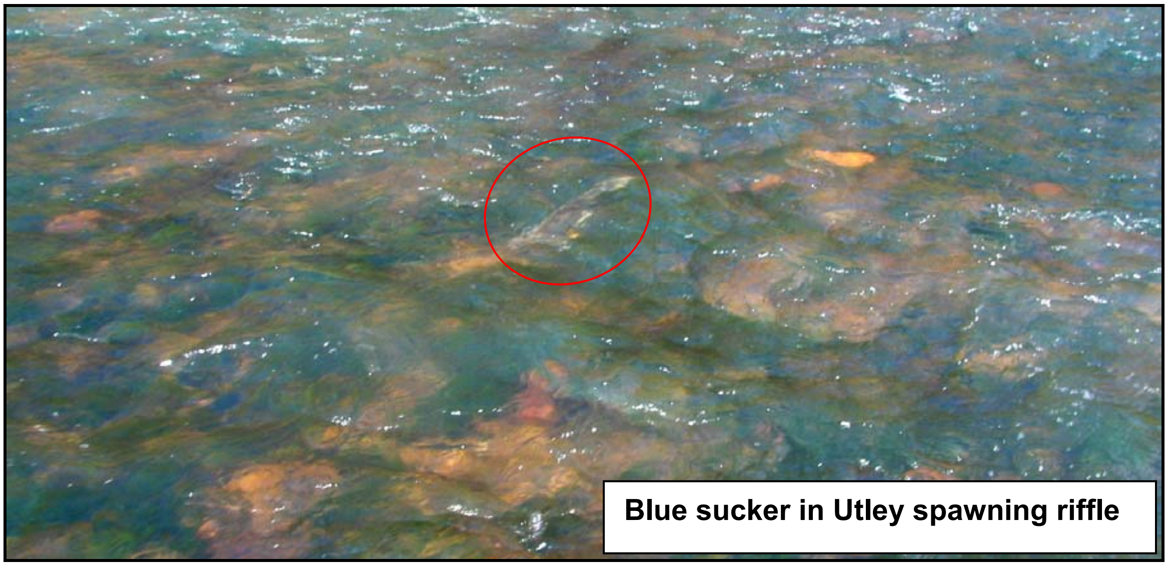
Eggs collected by the study team at La Grange and Utley were brought back to the BIO-WEST laboratory for verification. Visual examination of these eggs corresponded well with descriptions in the literature. Eggs collected at Utley were sent to Mike Bessert at the University of Nebraska for official verification. Mr. Bessert's PhD project describes population genetics of the blue sucker complex. Using both microsatellite and mitochondrial DNA markers, he confirmed that the eggs were in fact blue sucker embryos.

3.2.3 2007

Again in 2007, the study team initiated tracking efforts in early February with the goal of documenting spawning aggregations. Efforts in 2007 identified five spawning areas. Spawning was documented at the three previously discovered sites in the river near Altair, La Grange, and Utley, as well as a new site near Smithville. Additionally, reports from a local fisherman led to documentation of a spawning site in Onion Creek just upstream of its confluence with the Colorado River. The details of each spawning aggregation are documented below.

On February 7, 2007 the study team documented spawning blue suckers at the Utley riffle (in the same location as eggs were found in 2006). Approximately 50 adult blue suckers were congregated in a shallow riffle area over small to large cobble. Fish were seen forming tight congregations and vigorously rolling over, around, and between one another. This was often accompanied by splashing from the dorsal or caudal fin of the fish breaching the waters surface. Eggs similar to the ones found the previous year were discovered attached to cobble-sized stones immediately downstream of the observed spawning congregations. Depths in the area ranged between 0.9 and 1.3 feet, and velocities ranged from 2.1 to 3.1 feet/second. Water temperature at the time was 15 °C.

In an effort to confirm if blue sucker eggs were hatching, drift nets were placed below the spawning site at Utley five days after spawning activity was observed. Several newly hatched larval fish were collected in the drift nets immediately below the spawning site over the next few days. Section 3.3 provides a more detailed description of methods and results associated with larval sampling efforts.



Blue sucker in Utley spawning riffle

On the morning of February 8, 2007 the study team located a new spawning area at a riffle just downstream of the boat ramp in Smithville. Although only 4 adult blue suckers were witnessed at the time, eggs were abundant in the area. The area of egg deposition consisted of a fast shallow riffle over gravel, cobble, and bedrock substrates. Depths in the area ranged from 0.7 to 1.3 feet, and velocities ranged from 0.4 to 4.4 feet per second. Water temperature at the time was 15 °C.

Later that day a spawning aggregation was documented at the previously discovered spawning site near La Grange. Approximately 100 adult blue suckers were observed exhibiting spawning behavior over fast bedrock chutes, and eggs were collected in the immediate area. Depths ranged from 1.4 to 2.6 feet, and velocities ranged from 2.3 to 5.1 feet per second. Water temperature at the La Grange riffle was 15 °C.

The following day (February 9, 2007) blue sucker eggs were discovered at the previously identified spawning area near Altair. Although no spawning fish were witnessed in this location, habitat measurements were taken around the egg deposition site. Depths ranged from 0.9 to 2.4 feet, and velocities ranged from 0.4 to 4.8 feet per second over a gravel and bedrock substrate.

Information provided by a local fisherman led to discovery of another spawning location near the mouth of Onion Creek on February 22, 2007. A local fisherman reported to the study team that he had witnessed 30-100 blue suckers engaged in spawning activity at a small riffle approximately 200 yards upstream of the mouth of Onion Creek on February 20, 2007. Two days later when the project team visited the location, blue sucker eggs were found on the substrate. Although no blue suckers were witnessed by the study team, measurements were taken in the area of egg deposition since flows in the creek had changed little over the previous two days. Depths in the area ranged from 0.6 to 1.9 feet, and velocities ranged from 0.8 to 3.8 feet per second. Eggs were deposited over clay bedrock and gravel, and the water temperature in the area was 15 °C.

Onion Creek

Later the same day the study team encountered another congregation of spawning blue suckers while tracking at Smithville. Approximately 50 to 60 feet (within the same riffle complex) from the original egg deposition site identified a few days earlier was a large congregation of 20-30 adult blue suckers (including tagged fish 149.780). Again, spawning behavior was witnessed and eggs were collected from the substrate. Depths ranged from 1.0-1.6 feet, and velocities ranged from 1.9-6.0 feet per second. Substrate in the area consisted of gravel, cobble, and bedrock. Water temperature at the time was 18 °C.

3.2.4 Spawning Summary

Over the course of the study the project team identified seven different spawning areas either by witnessing spawning activity or by collection of blue sucker eggs. At three of these sites spawning was documented in 2006 and 2007. Table 3.1 provides a brief summary of spawning observations made throughout the study period.

Table 3.1 - Summary of blue sucker spawning observations by the study team on the lower Colorado River from 2005-2007.

	2005	**2006**	**2007**
Time	**March**	**February**	**February**
Location	**Below Longhorn Dam**	**Utley** **Bastrop** **La Grange** **Altair**	**Onion Creek** **Utley** **Smithville** **La Grange** **Altair**
Observations	**Spawning Activity** **3 tagged fish from 3 different riffles traveled 56 to 115 miles**	**Spawning Activity** **Eggs found**	**Spawning Activity** **Eggs Found** **Larval Fish Collected**

Habitat data collected at blue sucker spawning sites differed slightly between years (Figure 3.2). However, as more data were collected and more spawning sites were identified under various flow conditions (1 site in 2005, 3 sites in 2006, 5 sites in 2007) the project team achieved a more accurate assessment of spawning blue sucker habitat. Overall, results demonstrate that spawning habitat is considerably shallower but fairly similar in velocity to common adult habitats (Figure 3.3). Depths at spawning sites averaged 1.4 feet (range: 0.6-2.6), and velocities averaged 2.5 ft/s (range: 0.3-6.0). In addition, spawning substrates differed slightly from those used during other times of the year, and consisted mainly of cobble (38%), followed by bedrock (37%), and gravel (25%). Water temperatures observed during spawning surveys ranged from 12-18 °C; however, water temperatures were close to 15 °C when most actual spawning behavior was observed.

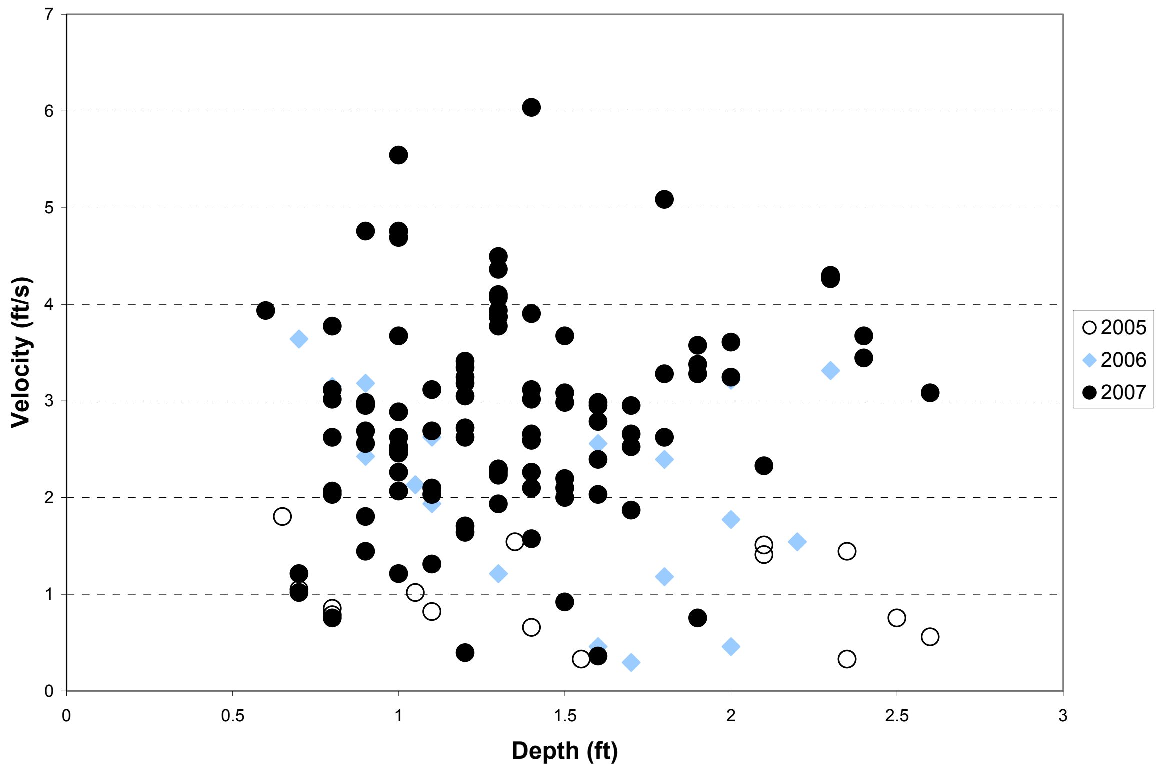


Figure 3.2 – Scatterplot of depths and velocities recorded at sites of blue sucker spawning activity in the lower Colorado River during 2005, 2006, and 2007.

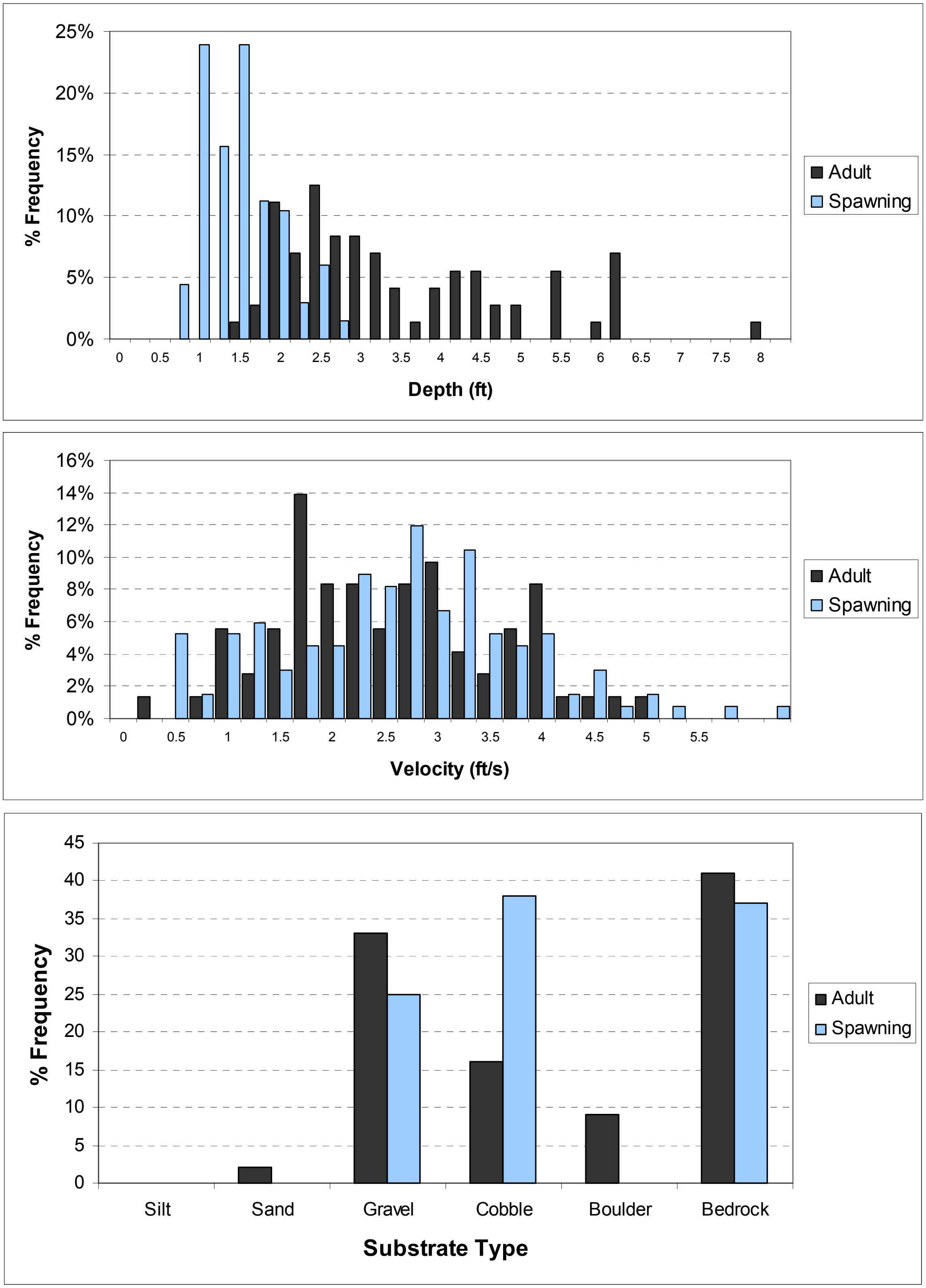


Figure 3.3 – Depth, velocity, and substrate used by spawning blue suckers in early spring (blue) and by adult blue suckers the remainder of the year (black).

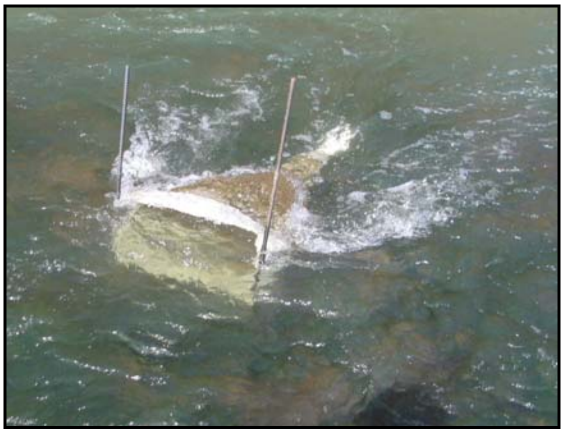
3.3 Larval/Juvenile Observations

Little information is available regarding the early life history of blue suckers because of the scarcity of larval and juvenile blue suckers collected by researchers (Morey and Berry 2003). Although a few recent studies have predictably documented larval blue suckers in near-channel backwaters (Fisher and Willis 2000, Adams et al. 2006), most studies conducted on the species have yielded few, if any, juveniles. Inability to capture juvenile blue suckers has often been attributed to the behavior and habitat affinities of the species which make sampling difficult and inefficient (Morey and Berry 2003). Unfortunately, collections from the Colorado River exhibit the same trend as previous studies and are dominated by large individuals. This section provides a summary of the activities and results associated with larval and juvenile blue sucker sampling.

Extensive efforts by the project team aimed specifically at collection of larval and/or juvenile blue suckers began in spring 2005. After documentation of the spawning aggregation below Longhorn Dam in early March 2005 (see section 3.2) flows in the river were extremely high (>5,000 cfs) for several weeks. Sampling for juvenile blue suckers was initiated as soon as flows receded to levels amenable for sampling. In the late spring and summer of 2005 nine sampling trips were dedicated specifically to capturing juvenile blue suckers (Table 3.2). Despite extensive sampling using a variety of techniques, no juvenile blue suckers were captured in 2005.

Larval/juvenile sampling was reinitiated shortly after spawning was documented in early spring 2006. Flows during spring 2006 were much lower than the previous year and allowed for larval sampling shortly after spawning was observed. Beginning on March 9, the project team began sampling with standard larval fish techniques such as small-mesh larval seines and light traps. Initially sampling was focused near and downstream of known egg deposition sites; however, eventually a wide variety of habitats were sampled throughout the river. Given the fast initial growth rates of blue suckers (Moss et al. 1983), efforts switched to sampling for juvenile blue suckers in summer 2006. From July through November 2006 a variety of techniques (e.g., seines, boat electrofishing, barge electrofishing, Fyke nets) were used in multiple locations in an attempt to capture juvenile blue suckers (Table 3.2). Unfortunately, no juvenile blue suckers were captured in 2006.

The project team continued larval/juvenile sampling in spring 2007. Identification of blue sucker eggs in 2006 and 2007 provided confirmation that spawning was occurring in the lower Colorado River. Therefore, early efforts in 2007 focused on using fine-mesh, stationary, drift nets set immediately downstream of known egg deposition sites to determine if eggs were hatching. Spawning blue suckers were documented at Utley on February 7, 2007 (see section 3.2), and given that blue sucker eggs hatch approximately 6 days following fertilization (Semmens 1985), drift nets were placed immediately below the Utley spawning site on February 12, 2007. These nets were then checked once a day for the following three days and all contents were removed and brought back to the BIO-WEST laboratory for further examination. Examination of drift net contents led to identification of several small larval fish approximately 10 mm or less total length, as well as a number of blue sucker eggs which had been dislodged from the rocks upstream. All eggs were placed in an aquarium with river water, and observed for hatching. One larval fish was collected from the aquarium and combined with the other larval fish collected in drift nets. Visual identification was difficult because of the size and condition of the fish collected; however, given that they were collected immediately downstream of a riffle where blue sucker spawning was observed and eggs were confirmed only a few days earlier, the study team is confident that they represent larval blue suckers. Although an attempt was made to confirm this with molecular techniques, DNA extractions from the larvae were unsuccessful.



Now confident that spawning was occurring and fish were hatching, efforts to document juvenile blue suckers continued in April 2007. On April 3-5, 2007, sampling was conducted using seines, experimental gill nets, and a backpack electrofisher near the spawning site in Onion Creek, and near Webberville, La Grange, and Altair. At each site, three experimental gill nets were set out overnight, and one day was spent sampling with seines and the backpack electrofisher. Following the April sampling event, high flows prevented juvenile sampling in late spring and early summer 2007. The next sampling trip was conducted on September 28, 2007 using boat and barge electrofishing techniques. Despite considerable effort, no juvenile blue suckers were observed.

In addition to efforts directed specifically at capturing juvenile blue suckers, the project team has conducted considerable larval/juvenile sampling while on the river for telemetry tracking activities. The team has also spent extensive time on the river collecting fish during habitat guild sampling (over 8,000 fish collected) and biological validation sampling (≈5,000 fish collected) related to the habitat modeling portion of this project. Through these efforts, the project team has gained extensive knowledge of habitat preferences for the entire lower Colorado River fish assemblage, including other Catostomid species (i.e., river carpsucker, smallmouth buffalo, and gray redhorse). The team has also collected and observed numerous adult blue suckers and has gained extensive insight into their habitat preferences. Unfortunately, lack of juvenile blue suckers in Colorado River collections has not allowed for quantification of their habitat affinities, and prompts concern regarding recruitment success of the species.

Table 3.2 - Dates, locations, and techniques used during larval/juvenile blue sucker sampling trips on the lower Colorado River, Texas between May 2005 and Oct. 2007.

Date	Location/Reach	Techniques Used
May 18, 2005	Webberville	Seines, Backpack electrofisher
May 19, 2005	Longhorn Dam	Seines, Backpack electrofisher
July 28, 2005	Smithville	Seines, Backpack electrofisher, Otter trawl
August 1, 2005	Webberville to Utley	Seines, Boat electrofisher
August 2, 2005	Downstream of Columbus	Seines, Otter trawl
August 3, 2005	Columbus	Seines, Otter trawl
August 4, 2005	La Grange	Seines, Boat electrofisher, Snorkeling
August 23, 2005	Utley to Bastrop	Seines
August 24, 2005	Downstream of Altair	Seines
March 9, 2006	La Grange	Seines, Boat electrofisher, Barge electrofisher
March 22, 2006	Utley	Seines, Light traps
March 31, 2006	Bastrop	Seines
April 4, 2006	Altair	Seines
April 5, 2006	Columbus	Seines
July 31, 2006	Utley to Bastrop	Seines, Boat electrofisher, Barge electrofisher
August 1, 2006	Upstream of Smithville	Seines, Boat electrofisher, Barge electrofisher
September 27, 2006	Altair	Seines, Fyke net, Cast net
September 28, 2006	Columbus	Seines, Fyke net, Cast net
November 29, 2006	Altair	Seines, Fyke net, Boat electrofisher, Barge electrofisher
April 3, 2007	Onion Creek to Webberville	Seines, Gill nets, Backpack electrofisher
April 4, 2007	La Grange	Seines, Gill nets, Backpack electrofisher
April 5, 2007	Altair	Seines, Gill nets, Backpack electrofisher
September 28, 2007	Webberville	Boat electrofisher, Barge electrofisher
October 1, 2007		Seines, Gill nets, Hoop nets, Boat electrofisher, Barge electrofisher

3.4 Genetics

Genetic samples were taken in the form of fin clips from the blue suckers caught during the tagging collection effort in the fall of 2004. A 1-3 cm^2 section of the soft tissue of the anal fin was taken from each fish after surgery was performed, and subsequently placed into a vial containing 95% ethanol for preservation. Fin clips were collected from all tagged fish at each site where sampling of blue suckers occurred (Altair, Bastrop, Columbus, La Grange, and Smithville). Upon completion of the tagging portion of the study, all genetic samples were sent to Mike Bessert at the University of Nebraska for analysis, where he was working on his PhD project assessing population genetics of blue suckers.

Throughout the study, the project team has stayed in contact with Dr. Bessert, who has now completed his dissertation. His molecular analyses suggest that the Rio Grande blue sucker population is genetically divergent, should be recognized as a separate species (a formal species description is currently being written), and is in need of special conservation concern. Based on his results he speculates that blue suckers, range-wide, are not terribly threatened. However, in addition to the Rio Grande species some local blue sucker populations are of concern--mainly those which are isolated by dams or occurring in disjunct drainages such as the Sabine River and Colorado River in Texas.

The major concern for the Colorado River population is reduced allelic richness. Allelic richness is a measure of genetic diversity, and scores from the Colorado River (4.521) are the lowest out of 27 drainages examined (range-wide mean = 6.870). Reduced genetic diversity could signify some type of recent founding event or population bottleneck. However, a more detailed analysis of the Colorado River population is needed to gain insight into the causes of this apparent reduced diversity.

4.0 SUMMARY

Radio-telemetry data indicate that spawning migration of blue suckers in the lower Colorado River is strongly tied to discharge, and is likely initiated by high flows. During high flows in early spring 2005, most tagged blue suckers made large upstream spawning migrations. However, during lower flows in spring 2006 and most of spring 2007 no spawning migrations were observed. Differences in migration patterns and discharge between years proffer one of two possible conclusions. Lower flows observed in spring 2006 and most of spring 2007 could have physically limited the normal spawning migrations of blue suckers due to the low water levels. Alternatively, higher discharge in spring 2005 could have resulted in inundation of normal spawning areas throughout the river, and thus forced a mass upstream migration to search for more suitable spawning habitat. Given that spawning was observed in several locations throughout the river in 2006 and 2007, and that high pulse events in 2007 should have allowed for migrations yet none were observed, the second alternative seems more feasible. However, even if large migrations only occur during high flow years when normal spawning areas are inundated, their importance to the population should not be overlooked. During years of lower flow blue suckers in the lower Colorado River evidently move little from their "home" riffle, and likely spawn with other members of the same riffle sub-population. Therefore, high flow years may serve as important dispersal mechanisms needed to stimulate gene flow between distant sub-populations from various riffle complexes. This is especially important given the reduced genetic diversity suggested by Dr. Bessert's molecular analyses.

Spawning activity of blue suckers in the lower Colorado River takes place at water temperatures similar to those reported elsewhere (12-18°C). However, as expected, spawning seems to take place earlier in the Colorado River than in more northern latitudes. Blue suckers spawn in late April and May at temperatures of 13-23°C in Kansas, Missouri, and the upper Mississippi River (Rupprecht and Jahn 1980, Moss et al. 1983, Vokoun et al. 2003). Mettee et al. (2003) noted peak spawning activity for southeastern blue suckers in the Alabama River was in late March at temperatures of 15-17°C, which corresponds well with other reports from the same region (Semmens 1985, Peterson et al. 1999). We documented spawning activity of blue suckers in central Texas in early February through early March depending mainly on water temperature. For example, spawning activity witnessed February 7-9, 2007 (water temp. ≈ 15°C) was followed by a severe cold front that dropped daytime high air temperatures from near 70°F to near 40°F for 3-4 days. During this period, water temperature dropped several degrees, and spawning activity ceased. However, after several days of warm weather and a subsequent increase in water temperature spawning was again witnessed on February 22, 2007 (18°C).

Although spawning was documented on several occasions, eggs were confirmed in 2006, and hatching was observed in 2007, no juvenile blue suckers were collected during the study. Previous researchers in other systems have had similar difficulty in collecting juvenile blue suckers due to the habitat affinities of the species (Morey and Berry 2003). Regardless, lack of juveniles in recent collections elicits concern regarding recruitment success of this state-threatened species in the lower Colorado River.

Habitat data collected during blue sucker telemetry efforts was used to create habitat suitability criteria (HSC) for use in the aquatic habitat modeling portion of the study. Development of HSC allowed the project team to model changes in habitat in relation to discharge for both spawning blue suckers and non-spawning adults. In addition, HSC were developed for five other habitat guilds consisting of up to eight species each (BIO-WEST 2007). Developing a flow regime that provides some habitat for each guild throughout the year promotes a healthy and diverse fish assemblage. As for blue suckers, specific habitat affinities demonstrate that maintenance of at least some deep, high-velocity rapids throughout the year is important for their continued success. However, perhaps even more important, especially given recruitment concerns expressed above, is maintenance of adequate amounts of spawning habitat in early spring months.

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Tab 3

Lower Colorado River, Texas Instream Flow Guidelines

Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker

Prepared for

Lower Colorado River Authority

and San Antonio Water System

Prepared by

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March 31, 2008

EXECUTIVE SUMMARY

The lower Colorado River downstream of Austin has been impacted by human activity for more than 100 years and there are currently diversions, return flows, low water dams, agriculture up to the banks, and other structural and non-structural modifications. Nevertheless, the river continues to support a diverse aquatic and riparian environment. This environment relies on the quality, quantity, and timing of water moving through the lower Colorado River basin. A major alteration to the natural flow regime of the lower Colorado River occurred with the completion of Buchanan and Mansfield Dams (1937 and 1940, respectively). The LCRA-SAWS Water Project (LSWP) also has the potential to alter characteristics of the flow regime, and thus, the Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker Study was conducted. This study was developed to assess potential impacts or benefits resulting from the LSWP and address the environmental principles applied to the project.

Two of the environmental principles incorporated into the LSWP contract relate directly to the lower Colorado River aquatic and riparian environment. They specify that before LSWP implementation, studies must show that the project (1) "protects and benefits the lower Colorado River watershed and the Lower Colorado River Authority (LCRA) Service Area, including municipal, industrial, agricultural, recreational, and environmental interests"; and (2) "provides for instream flows no less protective than those included in the LCRA Water Management Plan (WMP) for the Lower Colorado River Basin, as approved by the Texas Commission on Environmental Quality." Additionally, the Texas Instream Flow Program (TIFP) has a legislative mandate (Senate Bill 2) to identify instream flow conditions that support a "sound ecological environment", which is described as "…a functioning ecosystem characterized by intact, natural processes, resilience, and a balanced, integrated, and adaptive community of organisms comparable to that of the natural habitat of a region." (TIFP Draft 2006). The respective resource agencies participating in the TIFP have participated in this study since its inception.

Streamflow acts as a "master" variable that directly and indirectly influences the full range of riverine resources and functions, including hydrology and hydraulics, biology (aquatic and riparian), geomorphology, and water quality. Intensive biological and physical data collection activities associated with these key study components were completed in 2004-2007. A detailed description of these activities can be found in BIO-WEST 2004, 2005, 2006, 2007. Chapter 2 provides an overview of each river study component while Chapters 3 and 4 document how study results were used to develop instream flow guidelines for the lower Colorado River.

In order to meet the environmental principles set forth for the LSWP and remain consistent with the TIFP objectives to conserve biodiversity and maintain biological integrity, the project team followed the recommendations of the NRC (2005) which has subsequently been endorsed by the TIFP (TIFP Draft 2006). The integration process involves four components of the hydrologic regime: subsistence flows, base flows, high flow pulses, and overbank flows. Hydraulic and habitat modeling, sediment transport analysis, and water quality modeling were used to support the development of subsistence and base flow guidelines. Pulse, channel maintenance and overbanking flow recommendations were based on sediment transport analysis conducted during this study and a hydrologic analysis of existing and pre-1940 flow regimes.

To establish instream flow guidelines, physical habitat times series were computed based on two flow scenarios. These included the existing condition (1975 to 2004) and pre-1940 (from 1898 at Austin and from 1916 at Columbus through 1939). The existing flow scenario was included in the habitat time series analysis because 1) the field data (physical and biological) used for the hydraulic and habitat models, sediment transport analysis, and baseline riparian conditions were all collected under the existing flow regime, and 2) the present day geomorphic conditions, riparian zone, water chemistry, aquatic habitat, and biological resources have all been imprinted by the existing flow regime. Additionally, the water quality and biological data collected by LCRA over the past decade reflect good water quality and diverse biological communities. Therefore, an examination of the existing flow regime was deemed necessary to evaluate the potential for maintaining similar conditions. The pre-1940 "natural" flow scenario was included to be consistent with the guidance of the TIFP and Natural Flow paradigm. Even though the data collected for this study was done under the existing flow regime, using natural flow conditions as a reference for comparison often provides insight into the ecological variability of riverine systems.

An evaluation of the hydrology, habitat time series modeling results, sediment transport analyses, and water quality results indicated that the pre-1940 flow regime is different from the existing flow regime. A detailed description of these differences is provided in Section 4.2.3. The TIFP (TIFP Draft 2006) proposes, "The goal of ensuring a 'sound ecological environment' has been equated to maintaining the ecological integrity and conserving the biological diversity of riverine ecosystems. In order to meet these goals, the Agencies recognize the importance of maintaining the natural habitat diversity, hydrologic character, and water quality of river systems." For the ecological advantages discussed in Section 4.2.3 and to be consistent with the goals of the TIFP, the pre-1940 time period was selected to be used for the development of instream flow guidelines. Hardy et al. (2006) states, "Utilizing the characteristics of the natural flow regime as a "template" is widely accepted and applied at the international level …."

Instream flow recommendations for five categories (subsistence, base, pulse, channel maintenance, and overbank flows) specific to the LSWP are recommended for the lower Colorado River (Table ES.1). The subsistence flow recommendations represent minimum conditions at which water quality is maintained at acceptable levels and aquatic habitats are expected to resemble those found during extreme conditions in a more natural setting. The base flow recommendations provide a range of suitable conditions with the goal of maintaining year to year variability and the ecological functions associated with this level of variability. Pulse flows provide a myriad of ecological functions including but not limited to nutrient and organic matter exchange, limited channel maintenance, flushing, vegetation scouring, and seed dispersal. Channel maintenance flows provide for the maintenance of channel capacity, while also flushing accumulated fine sediments from important gravel bar and riffle habitats, and scouring accumulated sediments from pool habitats. Overbank flows inundate low floodplain areas adjacent to the river providing for lateral floodplain and riparian connectivity, floodplain maintenance and nutrient deposition, and recruitment of organic material and woody debris.

Table ES.1. Instream Flow Guidelines for the lower Colorado River specific to the LSWP.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AUSTIN REACH												
Subsistence	50	50	50	50	50	50	50	50	50	50	50	50
BASTROP REACH												
Subsistence	208	274	274	184	275	202	137	123	123	127	180	186
Base-DRY	313	317	274	287	579	418	347	194	236	245	283	311
Base-AVERAGE	433	497	497	635	824	733	610	381	423	433	424	450
COLUMBUS REACH												
Subsistence	340	375	375	299	425	534	342	190	279	190	202	301
Base-DRY	487	590	525	554	966	967	570	310	405	356	480	464
Base-AVERAGE	828	895	1,020	977	1,316	1,440	895	516	610	741	755	737
WHARTON REACH												
Subsistence	315	303	204	270	304	371	212	107	188	147	173	202
Base-DRY	492	597	531	561	985	984	577	314	410	360	486	470
Base-AVERAGE	838	906	1,036	1,011	1,397	1,512	906	522	617	749	764	746

COLORADO RIVER DOWNSTREAM OF AUSTIN	
PULSE FLOWS	
Base	MAGNITUDE (2,000 to 3,000 cfs); FREQUENCY (8–10 times annually); DURATION (3–5 days)
High	MAGNITUDE (@ 8,000 cfs); FREQUENCY (2 Events in 3 year period); DURATION (2–3 days)
CHANNEL MAINTENANCE	MAGNITUDE (27,000 - 30,000 cfs); FREQUENCY (1 Event in 3 years); DURATION (3 days)
OVERBANK	MAGNITUDE (> 30,000 cfs); FREQUENCY and DURATION (Naturally Driven)

As discussed in Chapter 4, the Austin Reach has a subsistence flow recommendation whereas the Bastrop, Columbus, and Wharton reaches have proposed monthly regimes for subsistence and two levels of base flow. Pulse flows, channel maintenance flows and overbanking flows are currently the same amongst reaches.

The LSWP instream flow recommendations represent an ecologically balanced approach that takes into account hydrology, biology, geomorphology, and water quality with the goal of supporting a sound ecological environment in the lower Colorado River. The project team concurs with the TIFP and acknowledges that a critical component of all recommendations for this project is a long-term monitoring program to evaluate the effectiveness of the LSWP instream flow guidelines. In conjunction with long-term monitoring, adaptive management will be a vital component to assist in ensuring the success of the environmental principles associated with the LSWP and goals of the TIFP.

Table 4.9. Percent of maximum available habitat per month per reach for LSWP Subsistence Flow recommendations.

BASTROP REACH

Month	SUBSISTENCE Discharge (cfs)	Percent of Maximum Available Habitat						
		Rapid - Adult Blue Sucker	Spawning Blue Sucker	Deep Pools	Deep Run	Pools/Edges/ Backwaters	Shallow Runs	Riffles
January	**208**	16%	84%	60%	84%	91%	99%	89%
February	**274**	25%	91%	64%	88%	88%	100%	94%
March	**274**	25%	91%	64%	88%	88%	100%	94%
April	**184**	13%	82%	58%	83%	92%	99%	87%
May	**275**	26%	91%	64%	88%	88%	100%	94%
June	**202**	16%	N/A	59%	84%	91%	99%	88%
July	**137**	7%	N/A	55%	81%	94%	98%	83%
August	**123**	5%	N/A	54%	80%	95%	98%	81%
September	**123**	5%	N/A	54%	80%	95%	98%	81%
October	**127**	5%	N/A	54%	80%	94%	98%	82%
November	**180**	13%	N/A	58%	83%	92%	99%	86%
December	**186**	13%	N/A	58%	83%	92%	99%	87%
Annual Average		14%	88%	59%	83%	92%	99%	87%

COLUMBUS REACH

Month	SUBSISTENCE Discharge (cfs)	Percent of Maximum Available Habitat						
		Rapid - Adult Blue Sucker	Spawning Blue Sucker	Deep Pools	Deep Run	Pools/Edges/ Backwaters	Shallow Runs	Riffles
January	**340**	16%	88%	58%	89%	94%	99%	97%
February	**375**	19%	90%	59%	90%	93%	99%	98%
March	**375**	19%	90%	59%	90%	93%	99%	98%
April	**299**	12%	86%	56%	88%	95%	100%	96%
May	**425**	24%	93%	61%	91%	92%	98%	99%
June	**534**	33%	N/A	64%	93%	88%	96%	100%
July	**342**	16%	N/A	58%	89%	94%	99%	97%
August	**190**	5%	N/A	51%	82%	97%	99%	88%
September	**279**	10%	N/A	55%	87%	95%	100%	95%
October	**190**	5%	N/A	51%	82%	97%	99%	88%
November	**202**	5%	N/A	52%	83%	96%	99%	89%
December	**301**	12%	N/A	56%	88%	95%	100%	96%
Annual Average		14%	89%	57%	87%	94%	99%	95%

WHARTON REACH

Month	SUBSISTENCE Discharge (cfs)	Percent of Maximum Available Habitat						
		Rapid - Adult Blue Sucker	Spawning Blue Sucker	Deep Pools	Deep Run	Pools/Edges/ Backwaters	Shallow Runs	Riffles
January	**315**	N/A	N/A	40%	79%	91%	100%	96%
February	**303**	N/A	N/A	39%	78%	92%	100%	96%
March	**204**	N/A	N/A	34%	73%	96%	99%	88%
April	**270**	N/A	N/A	37%	77%	93%	100%	94%
May	**304**	N/A	N/A	39%	78%	92%	100%	96%
June	**371**	N/A	N/A	42%	80%	89%	99%	97%
July	**212**	N/A	N/A	35%	73%	96%	99%	89%
August	**107**	N/A	N/A	29%	66%	99%	97%	77%
September	**188**	N/A	N/A	34%	72%	97%	99%	87%
October	**147**	N/A	N/A	32%	70%	98%	98%	83%
November	**173**	N/A	N/A	33%	71%	97%	99%	86%
December	**202**	N/A	N/A	34%	73%	96%	99%	88%
Annual Average		N/A	N/A	36%	74%	95%	99%	90%

REB Tab 4

THE POWER TO MAKE A DIFFERENCE.

Instream Flows for the Lower Colorado River

Reconciling Traditional Beneficial Uses With
the Ecological Requirements of the
Native Aquatic Community

Lower Colorado River Authority

FINAL REPORT

June 1992

Instream Flows for the Lower Colorado River:

Reconciling Traditional Beneficial Uses With
the Ecological Requirements of the
Native Aquatic Community

Prepared by:

Doyle T. Mosier and Russell T. Ray

Lower Colorado River Authority
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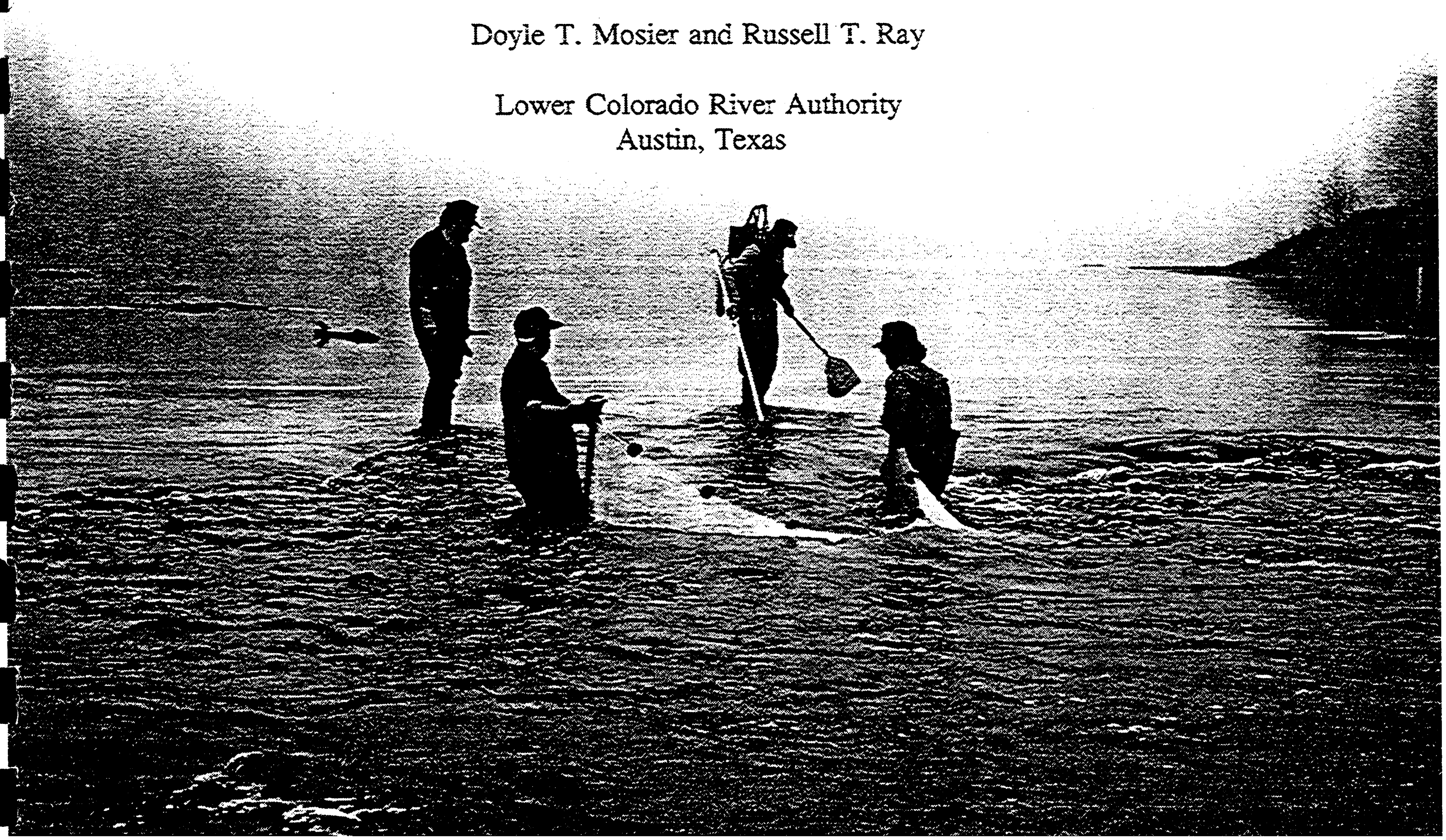

LOWER COLORADO RIVER AUTHORITY
INSTREAM FLOW STUDY

EXECUTIVE SUMMARY

The impact of reservoir construction and subsequent management strategies for economically beneficial uses on the native aquatic communities of impacted streams is increasingly becoming an area of concern for natural resource managers. Reservoirs built for flood control, hydropower and water supply are operated in such a manner as to alter the natural flow regimes of the impounded stream. Consequently, these activities may have a substantial impact on the structure of the natural community assemblages of rivers and streams.

As mandated in the 1988 adjudication of the Lower Colorado River Authority's (LCRA) water rights in the lower segment of the Colorado River, the LCRA and the Texas Parks and Wildlife Department (TPWD) performed a cooperative study to investigate the instream flow needs of the fish community native to the Colorado River downstream of Austin. This study provides the basis for a series of flow recommendations designed to mitigate the impacts of LCRA's water management strategies on the aquatic community of the Colorado River.

The following schedule of flows takes into consideration the water quality and physical habitat requirements of the fish community native to the Colorado River.

Subsistence and critical flows: Since all City of Austin wastewater plants discharge into the Colorado River downstream of Highway 183, return flows of treated effluent bypass the Austin gage, effectively dewatering parts of the river immediately downstream of Longhorn Dam when no releases are being made from the dam. Flows of less than ten cfs have been common at this gage during the non-irrigation season although flows are substantially higher immediately downstream. Although this segment does not have the capacity to support a balanced, natural community due to its proximity to the dam, a minimum flow should be maintained in this reach. A review of historical flow records indicate that flows seldom fell below 50 cfs during dry periods before impoundment by the Highland Lakes. It is recommended that a flow of at least **46 cfs** be maintained at the Austin gage at all times. This is the 7Q10 (the seven-day average low flow expected to occur every ten years) for the Austin gage based on the period of record prior to impoundment by the Highland Lakes (1898 to 1940). Maintenance of low flows at the Austin gage will require the City of Austin to alter operational procedures at Longhorn Dam to avoid pulsed discharges from the dam's automatic gates.

A mean daily discharge of greater than **120 cubic feet per second** as measured at the Bastrop Gage should be maintained at all times except March, April, and May (critical flow months) in order to provide adequate water quality conditions in the Colorado River. This is a minimum flow based on the Texas Water Commission's standard of a daily average of greater than five milligrams per liter dissolved oxygen and meets the criteria for the high quality aquatic habitat designation in segment 1402 and 1428. Model simulations indicate that this discharge will provide a minimum daily average of greater than six mg/l dissolved oxygen throughout most of segment 1428. This recommendation is based on the assumption that the City of Austin will maintain an effluent quality at or above current levels and amend their TWC permits to require that they meet those standards in the future. Minimum flow recommendations should be considered subject to revision as predictive capabilities are improved.

The seasonally adjusted target flow recommendations given below are largely adequate to meet the critical flow requirements for the target species during the spawning season. However, until more information on the flow requirements of the Blue Sucker (*Cycleptus elongatus*) during critical periods are available, it is recommended that flow be maintained at or above **500 cfs** at Bastrop for a continuous period of not less than six weeks during the months of March, April, and May. Further studies on the life history of the Blue Sucker in the Colorado River are needed.

Subsistence and critical flows are classified as a non-interruptible demand on water resources and instream flows should be maintained at or above these levels at all times.

Target flows: A schedule of flows that provides an optimal range of habitat complexity to support a well balanced, native aquatic community was determined for each study reach. These flow regimes are considered an optimal range and should be maintained whenever water resources are adequate but should be classified as an interruptible demand subject to curtailment when water resources become limited during drought periods. Since native fish species are adapted to normal seasonal variations in flow regimes, target flows were adjusted monthly to emulate the annual cycle. It is interesting to note that the composite optimal flows are roughly equivalent to the historic median flows prior to impoundment. The following recommended target flows are based on the Bastrop study reach since this segment contains suitable habitat for the Blue Sucker (*Cycleptus elongatus*), listed as a threatened (protected nongame) species by the Texas Parks and Wildlife Department. Since diversions for irrigation have the potential to reduce flows significantly in the lower reaches, flows should be monitored at Eagle Lake and Egypt to assure that target flows for those reaches are also met (Attached Table).

Maintenance flows: Periodic spates of high flows are needed to prevent siltation and dense macrophyte growth. It is presumed that these flows would be provided by natural rainfall events but may occasionally require dam releases in excess of generation capacity for short periods. Frequency and duration of maintenance flows will be determined by examination of historical data on flow regimes and macrophyte growth patterns. Macrophyte studies are in progress.

These recommendations represent a balanced approach to instream flow requirements that take into account both natural flow regimes and water quality conditions needed to support a healthy, diverse native fish community downstream of Austin and should provide a strong technical foundation for the development of instream flow policy for the Lower Colorado River.

Schedule of Recommended Flows for the Colorado River Downstream of Austin:

Month	Subsistence/Critical Flows (cfs)		Target Flows (cfs)		
	Austin	Bastrop	Bastrop	Eagle Lake	Egypt
January	46	120	370	300	240
February	46	120	430	340	280
March	46	500	560	500[a]	360
April	46	500	600	500[a]	390
May	46	500	1030	820	670
June	46	120	830	660	540
July	46	120	370	300	240
August	46	120	240	200	160
September	46	120	400	320	260
October	46	120	470	380	310
November	46	120	370	290	240
December	46	120	340	270	220

[a] Since target flow at Eagle Lake (based on overall community habitat availability) were insufficient to meet Blue Sucker (*Cycleptus elongatus*) spawning requirements during March and April, target flows were superseded by critical flow recommendations for this reach.

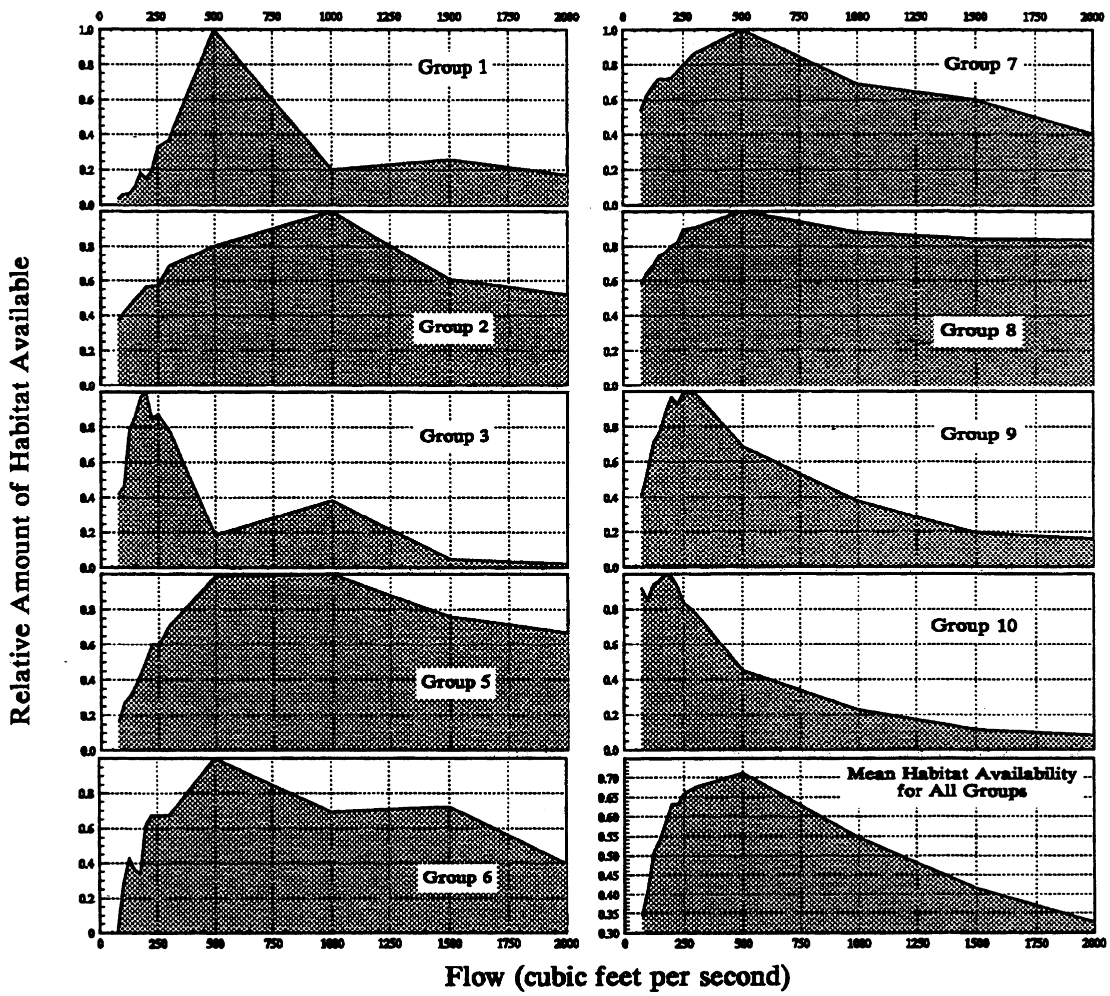

Figure 16. Relative habitat availability for fundamental habitat groups at Bastrop.

Smithville: The Smithville study reach contained habitat for all functional guilds except sandy runs (Group 4, spawning *Macrhybopsis aestivalis*) and adult blue suckers (Group 6). Habitat availability was more consistent over a wider range of flows for most guilds (Figure 17). Target flows were not dominated by requirements for a specific fundamental group.

Several *Cycleptus elongatus* were observed spawning in this study reach at the head of the rock outcrop that forms a section control (XSEC 7889) on March 9, 1989 at a flow of 225 cfs. Spawning occurred over a large cobble/boulder bottom contiguous to a bedrock outcrop in one foot of water at a velocity of 1.6 feet per second. The eggs appeared to be broadcast and drifted into the riffle immediately downstream of the spawning site.

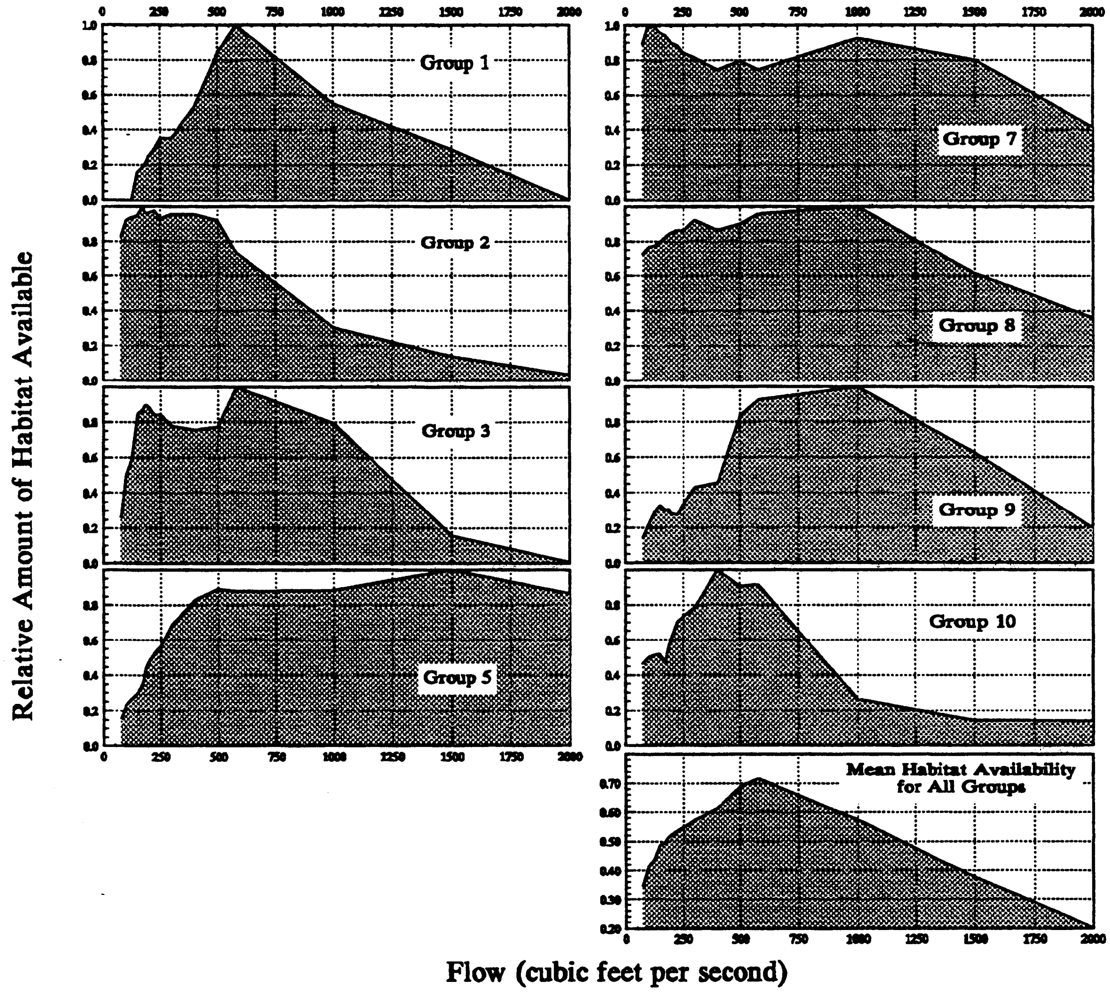

Figure 17. Relative habitat availability for fundamental habitat groups represented at Smithville.

Eagle Lake: One of the most extensive rock outcrops between Austin and the Gulf of Mexico is located in this study reach and appears to provide significant spawning habitat for the blue sucker. In February 1990, numerous tuberculate *Cycleptus elongatus* males in spawning condition were observed in the rapids and gravid females were collected in the pools immediately downstream. Since no females were observed in the rapids and no spent females were collected during this time, it is assumed that spawning had not commenced. Target flow to maintain community diversity at Eagle Lake was 400 cfs (Figure 18).

Egypt: The Egypt study reach lacked suitable habitat for *Cycleptus elongatus* adults but all other habitat groups were represented (Figure 19). This segment was the only one that included significant habitat for *Macrhybopsis aestivalis* spawning. A decrease in target flow (325 cfs) was for Eagle Lake due to differences in physical habitat availability.