Salado Salamander Monitoring
Final Report 2016

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Figure 1. Flowing water, cobble substrates and the aquatic plant, *Justicia americana* in the Robertson spring run.

Summary

The Texas Fish and Wildlife Conservation Office (TXFWCO) completed the 2016 monitoring at the Salado Spring Complex and the Robertson Springs in Bell County under federal permit TE676811-9 and state permit SPR-0111-003. The TXFWCO created a map of the springs in early 2016 as basis to conduct surveys in a stratified random fashion. Surveys for salamanders were completed in January, April, June, September and October. Transect surveys, time search surveys, and quadrat surveys were completed this year to examine different sampling techniques and their efficiency and productivity. A total of 20 visits were conducted in 2016. A total of 27 salamanders, 11 juveniles (< 30 mm) and 16 adults, were collected and documented. Only seven salamanders (one adult) were captured in 2015.

Data collected from the different types of surveys at Robertson Springs clearly show that timed searches provided more detections of salamanders, likely due to low salamander population densities present at the sites. However, the quadrat searches provide valuable information as to available habitat, water chemistry differences at each spring site as well as between the spring run and spring source sites. In addition, drift netting at certain springs was productive in capturing salamanders without large amounts of personnel time.

A total of 34 salamanders were captured from the all combined sampling events. A modified Wentworth scale was used to describe substrate. The designation of “cave conduit” was applied to salamanders caught within a drift net. The two dominant substrates were gravel and “cave conduit” with 19 and 11 occurrences respectively (Table 2). These are some of the first captures of Salado salamanders from cave conduit type areas. The drift net captures are strong evidence for the presence of a large proportion of the Salado salamander population being present subsurface. Salado salamanders are more often captured in the lower section, particularly *Ludwigia* spring (subset of Robertson Springs), suggesting a more stable hydroperiod (duration a body of water has water present) for the lower springs compared to the upper section of the spring run which drys out periodically.

The goals for 2017 are: to continue habitat association surveys using quadrats surveys for the salamanders, begin work on a refugium within the downtown complex, collect genetic material when possible from the downtown spring complex, and continue to explore different methods to capture salamanders at different locations. The creek was not examined for potential transient or permanent resident salamanders in 2016, but will be attempted in 2017.

Methods

At the beginning of the year, a map was made of the survey areas in order to facilitate random stratified sampling of the spring run at Robertson Springs. Data was collected on a Trimble Nomad with an XT Pro receiver. This data was then post processed using Pathfinder Office. Accuracy of collected data points is presented in Table 2. Data was collected in WGS 1984 datum. Primary and secondary substrates were categorized using a modified Wentworth scale (Table 1). Flow was assessed and given a categorical value ranging from one to four. All data collected is presented in Table 3.

Table 1. Modified Wentworth scale used to quantify substrates at spring opening during the mapping event.

Code	Classification	Size (mm)
0	Organics	Organic Debris
1	Clay	<0.004
2	Silt	0.004 - 0.062
3	Sand	0.062 - 1.0
4	Course Sand	1.0 - 2.0
5	Very Small Gravel	2.0 - 4.0
6	Small Gravel	4.0 - 8.0
7	Medium Gravel	8.0 - 16.0
8	Large Gravel	16 -32
9	Rubble	32 - 64
10	Small Cobble	64 - 128
11	Large Cobble	128 - 256
12	Small Boulder	256 - 512
13	Medium Boulder	512 - 1024
14	Large Boulder	>1024
15	Bedrock	Solid Substrate

In order to determine the efficiency and productivity of each method, sampling for Salado salamanders was conducted using three different methods: transect surveys, timed searches, and quadrat sampling in conjunction with drift netting orifices along the springs runs during all methods. Timed searches were conducted with at least three people for a minimum of 30 minutes, providing a total of ~1.5 people hours. The timed searches were conducted at Big Boiling, Anderson / Benedict, and at Robertson springs. Surveys at Critchfield Spring and the side spring were conducted using either mesohabitat or surveying the entire area, respectively.

Due to the higher probability of encountering salamanders (based on previous data), only quadrat and transect surveys were conducted at Robertson Springs. Transect surveys were conducted in the same method as the previous year, by running a meter tape and sampling along the tape every x number of meters (dependent upon site) and then sampling across the entire stretch of the transect from bank to bank. Quadrat surveys were conducted using a random stratified design and a ½ meter quadrat. The spring run was divided into spring areas and run (or mixed zone) areas. A spring area was defined as the area where the water emerging from the orifice does not mix with the spring run water. Spring areas were identified on the map and their areas were quantified. A total of 36 quadrats were sampled from the spring areas. The amount of effort expended per spring was derived from the area of the spring, therefore, springs with a larger wetted area were surveyed more often. In addition, ten surveys were added to the spring run to examine differences between spring areas and the spring run with respect to habitat and water chemistry. At each quadrat depth, flow, temperature, conductivity, pH, dissolved oxygen, total dissolved solids, substrate, and percent vegetation were recorded. Data collected from quadrat surveys were z-scored and analyzed using principal component analysis in R using the "princomp" function. Associated with the quadrat search discharge was measured at the outflow of the spring run. Discharge was collected by dividing the outflow area by 25 and then taking a reading evenly across the mouth of the outflow.

If a salamander was found, it was photographed and returned to the area where captured. All salamanders captured were reported to Texas Parks and Wildlife Department in the Texas Natural Diversity Database, allowing for the capture to be recorded and the data made available for other researchers or studies. All measurements were acquired using Image J software. Additionally, The software Wild ID was used to determine if any salamanders were recaptures.

The passive sampling is an important component for the monitoring of these salamanders due to the small surface population present at most sites. Drift nets were placed over the spring orifice (Figure 2), left in place and checked weekly. Nets were set on October 26, 2016 at Anderson and Beetle springs at the Robertson property and left indefinitely to collect salamanders for genetic material. When the nets were examined, the entire sample was stored in 95% EtOH and taken back to the lab where the contents were sorted and enumerated under a compound microscope. Rates for salamanders and prey densities were calculated as *x* per day.

Following the removal of a beaver dam during late 2015and into early 2016, available habitat was quantified by gridding out the spring run. Habitat was measured by running meter tape along the length of the spring run for 100 meters. At every five meters, transects were sampled and quantified using a 1/3 m^2 quadrat. Substrate was identified along transect within the first quadrat (0-0.3m) and then alternated every 0.3 m thereafter. A minimum of 165 measurements of substrates were made for each available habitat determination.

Figure 2. Drift nets placed on spring orifices to collect salamanders and examine prey densities

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Water quality data was collected at each site during the course of a survey using a Hydrotech compact DS 5 meter. Water quality measurements were collected from each spring and averaged for each site. Measured parameters included: temperature, dissolved oxygen, pH, conductivity, and total dissolved solids. To examine contaminant loads present at Robertson Springs and the downtown complex, passive samplers were used collect data. The samplers collect organochlorines, polybrominated diphenyl ethers, polychlorinated biphenyl, and polycyclic aromatic hydrocarbons. These samplers were left in place for 34 (Robertson Sp.) and 37 (Stagecoach Inn cave) days.

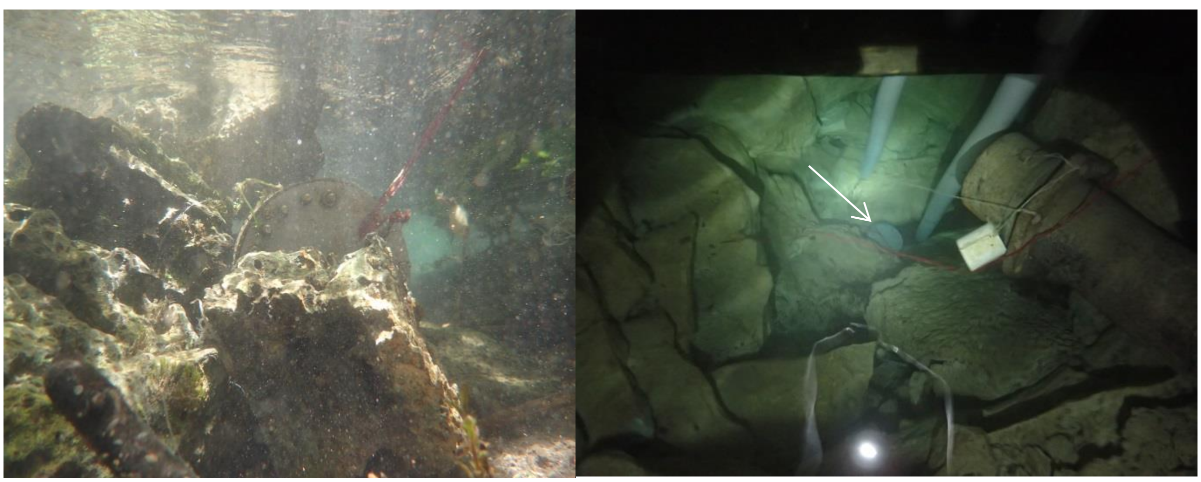

Figure 3. Passive water samplers left in place at Robertson Spring and Stagecoach Inn cave to collect contaminants.

Results

Mapping

Mapping of Robertson Springs was conducted on February 4th 2016, and 31 spring openings were identified (Figure 4). There were three types of spring openings present: seeps (alluvial), orifice and upwellings. The orifice type were the most common. The most common substrates encountered at spring orifices were gravel (n = 18) followed by silt (n = 9). Following post processing, the GIS data was most in the 0.5-1 m range for the accuracy of collected spatial data (Table 2).

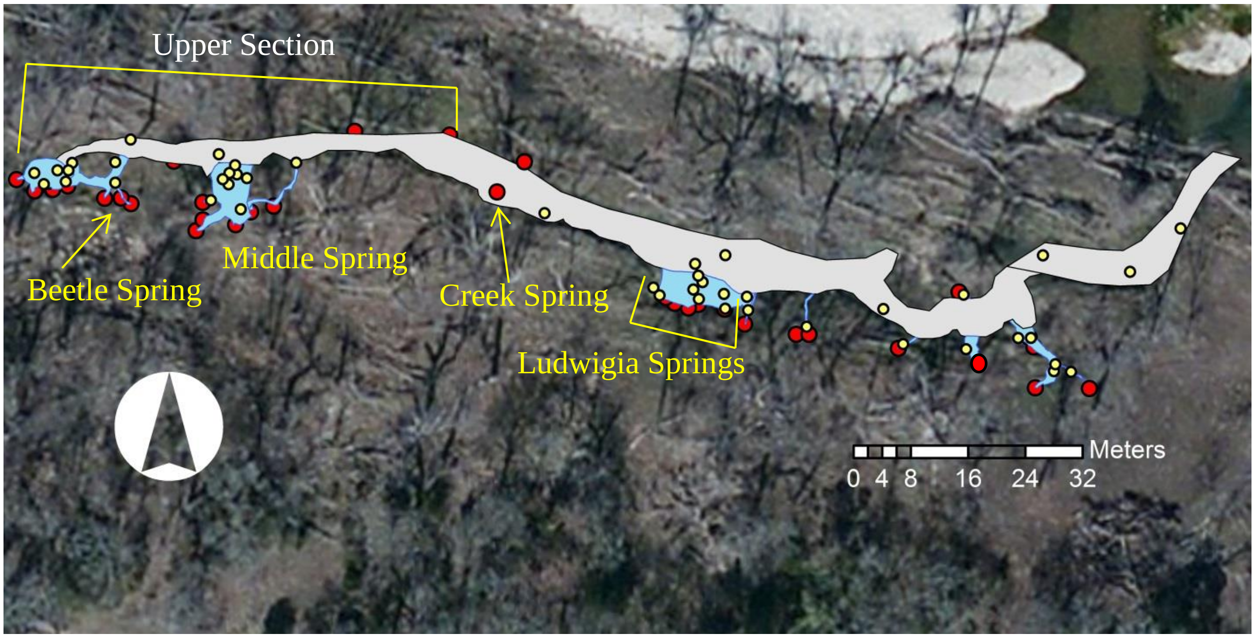

Figure 4. Map of Robertson Springs showing spring areas and spring openings. Red dots are spring openings. Yellow dots are quadrat sites. Light blue areas are spring areas. The purple is the spring run.

Table 2. Output from Pathfinder Office following post processing of data collected from February 4th 2016 at Robertson Springs. Showing accuracy of spatial data collected.

Range	Percentage
0-5cm	-
5-15cm	-
15-30cm	3.53%
30-50cm	33.27%
0.5-1m	41.54%
1-2m	20.58%
2-5m	1.08%
>5m	-

Table 3. Data from Robertson Springs mapping event on February 4th 2016.

Number	Location	Spring Type	Primary Substrate	Secondary Substrate	Flow
1	Robertson	orifice	2 silt	5 gravel very small	1
2	Robertson	orifice	2 silt	1 clay	1
3	Robertson	orifice	2 silt	1 clay	2
4	Robertson	orifice	6 gravel small	8 gravel large	3
5	Robertson	orifice	6 gravel small	1 clay	3
6	Robertson	orifice	6 gravel small	5 gravel very small	2
7	Robertson	orifice	6 gravel small	5 gravel very small	2
8	Robertson	orifice	5 gravel very small	7 gravel medium	3
9	Robertson	orifice	5 gravel very small	7 gravel medium	2
10	Robertson	orifice	5 gravel very small	7 gravel medium	2
11	Robertson	orifice	5 gravel very small	7 gravel medium	1
12	Robertson	orifice	5 gravel very small	7 gravel medium	3
13	Robertson	upwelling	5 gravel very small	3 sand	4
14	Robertson	upwelling	2 silt	3 sand	2
15	Robertson	alluvial	2 silt	1 clay	1
16	Robertson	alluvial	2 silt	0 organics	1
17	Robertson	upwelling	8 gravel large	5 gravel very small	1
18	Robertson	orifice	5 gravel very small	6 gravel small	1
19	Robertson	orifice	0 organics	2 silt	1
20	Robertson	seep	0 organics	2 silt	1
21	Robertson	seep	0 organics	2 silt	1
22	Robertson	upwelling	7 gravel medium	10 cobble small	4
23	Robertson	orifice	2 silt	6 gravel small	2
24	Robertson	orifice	2 silt	5 gravel very small	2
25	Robertson	orifice	2 silt	5 gravel very small	2
26	Robertson	orifice	7 gravel medium	10 cobble small	3
27	Robertson	orifice	7 gravel medium	10 cobble small	3
28	Robertson	orifice	7 gravel medium	10 cobble small	2
29	Robertson	seep	7 gravel medium	10 cobble small	2
30	Robertson	orifice	7 gravel medium	5 gravel very small	3
31	Robertson	orifice	7 gravel medium	5 gravel very small	4

Salamanders

Downtown Spring Complex

No salamanders were captured this year at the downtown spring complex either by active searching or by passive sampling. The drift net on Anderson Spring was set on October 26, 2016 and has not been disturbed, however, it has not captured any salamanders.

Table 4. Dates and time searched for Big Boiling, Anderson/Benedict, Critchfiled and the side springs.

Date	Big Boiling Minutes	Anderson/Benedict Minutes	Critchfield Mesohabitat	Side Spring All
4/14/2016	120	150		
6/7/2016	80	150	Searched	Searched
6/27/2016	75	-		
9/7/2016	120	150	Searched	Searched
10/26/2016	90	150		Searched
Salamanders	0	0	0	0

Robertson

Neither transect nor quadrat surveys at Robertson Springs detected salamanders, though timed surveys and passive sampling with drift nets was successful at this site (Table 5). A total of 27 salamanders were collected and documented (Table 6). There were 11 juveniles (< 30 mm) and 16 adults captured in 2016. Only seven salamanders were captured (one adult) in 2015. The dominant substrate at the sites of salamander collection consisted of gravel and “cave conduit” (drift nets). Salamanders collected on the surface tended to be associated with watercress (*Nasturtium* sp.). Fifteen salamanders out of the 27 were collected within this vegetation.

Although the quadrat sampling did not result in the capture of any salamanders, the benefits were seen from a statistical point of view due to the random stratified sampling design regarding abiotic parameters (substrate, depth, flow, etc). Results from the first quadat event are not shown since it was not stratified, just a random sample of the entire system. Distinctions were observed between the spring run and the spring areas and between sampling events in June and September of 2016 (Figure 5A). The discharge for in June was 6.15 m/sec and for September, 4.67 m/sec. The principal component analysis explains the mechanisms for the separation of these mesohabitats. The analysis explains 57% of the variance by principal component axis two (PCII) (Table 8). Principal component axis one (PC I) explains 35% of the variance and PC II explains the other 22%. Principal component axis I has a gradient from negative loadings for conductivity, total dissolved solids and pH to positive loadings for flow (although very low loading for flow). Principal component axis II has a gradient from negative loadings for flow and pH to positive loadings for vegetation and temperature. Therefore, sites along the PC I axis that are on the left side (negative) of the axis have lower conductivity, pH, total dissolved solids and lower flow than sites present on the right side (positive) of PC I. Although other parameters were measured such as mud and silt these parameters were not significant enough to have loadings on either the first and second PC axis (Table 7). The changes in discharge may explain the separation of sites by time period (Figure 5B).

Table 5. Sampling events at Robertson springs.

Date	Survey Type	Time (min)	Salamanders
1/29/2016	Transect	-	0
2/4/2016	Timed	120	2
2/4/2016	Drift Net	2280	1
2/26/2016	Transect	-	0
3/1/2016	Drift Net	10080	3
3/1/2016	Timed	165	1
3/24/2016	Quadrat	-	0
3/24/2016	Timed	150	6
3/31/2016	Drift Net	10080	3
6/7/2016	Quadrat	-	0
6/7/2016	Timed	150	2
8/4/2016	Drift Net	7200	0
8/12/2016	Drift Net	4320	1
8/18/2016	Drift Net	8640	1
9/8/2016	Quadrat	-	0
10/27/2016	Timed	180	1

Table 6. Salamanders captured from 2016 sampling events.

Location	Date	Location	Size (mm)	Primary Substrate	Secondary Substrate	Vegetation
Robertson Spring	2/4/2016	130 meters	14	Silt	Silt	Sagittaria
Robertson Spring	2/4/2016	Ludwigia Sp	16	Cave Conduit	Cave Conduit	-
Robertson Spring	2/4/2016	Ludwigia Sp	31	Gravel	Sand	Watercress
Robertson Spring	3/1/2016	Ludwigia Sp	55.5	Gravel	Gravel	-
Robertson Spring	3/1/2016	Creek Spring	43.6	Cave Conduit	Cave Conduit	-
Robertson Spring	3/1/2016	Creek Spring	42.2	Cave Conduit	Cave Conduit	-
Robertson Spring	3/1/2016	Creek Spring	11.72	Cave Conduit	Cave Conduit	-
Robertson Spring	3/24/2016	Ludwigia Sp	23.15	Gravel	Gravel	Watercress
Robertson Spring	3/24/2016	Ludwigia Sp	30.93	Gravel	Gravel	Watercress
Robertson Spring	3/24/2016	Ludwigia Sp	22.95	Gravel	Gravel	Watercress
Robertson Spring	3/24/2016	Ludwigia Sp	18.29	Gravel	Gravel	Watercress
Robertson Spring	3/24/2016	Ludwigia Sp	18.67	Gravel	Gravel	Watercress
Robertson Spring	3/31/2016	Ludwigia Sp	33.28	Gravel	Gravel	Watercress
Robertson Spring	3/31/2016	Ludwigia Sp	20.09	Gravel	Gravel	Watercress
Robertson Spring	3/31/2016	Ludwigia Sp	37.16	Gravel	Gravel	Watercress
Robertson Spring	3/31/2016	Beetle Spring	17.22	Cave Conduit	Cave Conduit	-
Robertson Spring	3/31/2016	Creek Spring	32.23	Cave Conduit	Cave Conduit	-
Robertson Spring	3/31/2016	Ludwigia Upper	49.91	Cave Conduit	Cave Conduit	-

Robertson Spring	6/7/2016	Ludwigia Sp	12.69	Gravel	Gravel	Watercress
Robertson Spring	6/7/2016	Ludwigia Sp	33.84	Gravel	Gravel	Watercress
Robertson Spring	8/9/2016	Ludwigia Sp	21.61	Gravel	Gravel	Watercress
Robertson Spring	8/9/2016	Ludwigia Sp	37.55	Gravel	Gravel	Watercress
Robertson Spring	8/9/2016	Ludwigia Sp	40	Gravel	Gravel	Watercress
Robertson Spring	8/12/2016	Ludwigia Sp	60.4	Boulder	Gravel	-
Robertson Spring	8/12/2016	Ludwigia Upper	53.72	Cave Conduit	Cave Conduit	-
Robertson Spring	8/18/2016	Creek Spring	35	Cave Conduit	Cave Conduit	-
Robertson Spring	10/27/2016	Ludwigia Sp	25.05	Gravel	Gravel	Watercress

Table 7. Loadings from principal component analysis taken from quadrat sampling from Robertson Springs examining the spring run and spring areas.

	PC I	PC II
Temp	-0.322	0.372
DO		0.395
cond	-0.538	-0.189
ph	-0.495	-0.205
tds	-0.538	-0.188
Mud/silt		0.132
Sand		
Gravel		
Cobble	0.125	
Bedrock		
Vegetation	-0.146	0.394
Depth		0.483
Flow	0.112	-0.415

Table 8. Proportion of variance explained by principal component analysis from random stratified sampling of mesohabitats along Robertson Springs.

	PC I	PC II
Standard deviation	1.73	1.37
Proportion of Variance	0.35	0.22
Cumulative Proportion	0.35	0.57

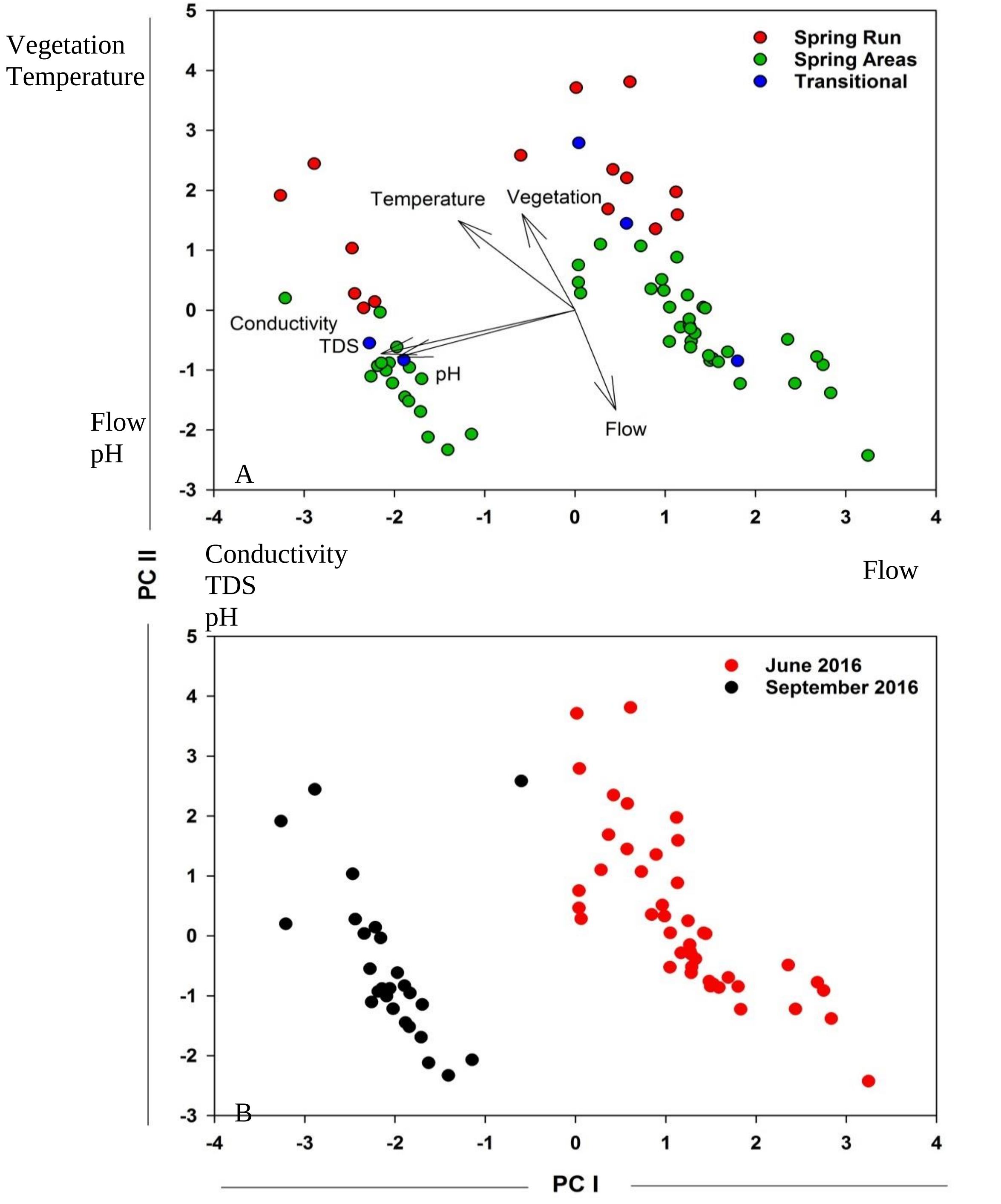

Figure 5. Principal component analysis results from stratified random sampling using quadrats along Robertson Springs run and spring areas from June and September 2016. Figure 5A shows the results of the PCA and figure 5B shows the separation of sites by sampling event.

Habitat Availability

The habitat at Robertson Springs was the primary focus in 2016 (Figure 6). Habitat was quantified four times during the year (Table 9). The substrates present seem to be reaching equilibrium as shown by the last two sampling events. Sand substrates have increased fairly consistently over the course of the year. This may be due to the types of sediment being dislodged from the associated subterranean environment and drifting out of the spring sources.

Table 9. Habitat availability at Robertson springs following removal of a beaver dam.

	12/10/2015	12/17/2015	1/29/2016	2/26/2016	6/27/2016	9/21/2016
Days	Before Dam	7	21	77	189	273
Mud/Silt	92.55	64.36	68.48	58.56	55.62	47.93
Sand	0.00	2.48	6.06	4.42	7.69	14.79
Gravel	4.97	5.94	10.30	17.13	20.12	20.71
Cobble	1.24	3.47	3.03	4.97	6.51	3.55
Boulder	1.24	0.00	2.42	0.55	3.55	2.96
Bedrock	0.00	14.36	9.70	14.36	6.51	7.96
Sum of Rocks	7.45	9.41	15.76	22.65	36.69	35.76

Figure 6. Robertson Spring before and after the removal of a beaver dam.

Surface Recruitment

Drift nets were set 23 times at Robertson springs over the course of the year. Springs were divided into an upper section and a lower section. Any springs above Creek Spring were designated within the upper section (Figure 4). There were ten sampling events at the upper section and 13 in the lower section. The total average recruitment for the entire spring run was 0.078 salamanders per day. The upper section had a rate of 0.021 salamanders per day, while the lower section had 0.122 salamanders per day. Creek spring had the highest rate for any of the springs sampled (Table 10). Creek spring also was rated as the highest discharge during the mapping event.

Table 10. Salamander rates from individual springs sampled using drift nets at Robertson Springs.

	Upper Spring	Beetle Spring	Mid Spring	Creek Spring	Ludwigia Springs--Upper	Ludwigia Springs--Mid	Ludwigia Springs--Lower
Days Set	11	46	44	21	16	12	16
Number of Sallies	0	3	1	5	2	0	0
Rate	0	0.065	0.022	0.238	0.125	0	0

Water Quality

Water quality was measured two different ways during this study. Using the HydroTech sonde basic water quality parameters were collected at the time of each visit. The values have been averaged and are presented in Table 11. There were no values exceeding any ecological limits set by federal or state organizations taken from the dissolved oxygen, temperature, pH, conductivity or turbidity.

Table 11. Average water quality data collected over 2016.

	Benedict/Anderson	Big Boiling	Robertson	Side Spring off Little	Critchfield
Temperature	20.85	20.78	20.70	20.79	20.71
Dissolved Oxygen	6.92	7.57	7.40	7.37	7.31
pH	6.95	7.07	7.06	7.02	6.77
Conductivity	579.23	578.47	563.05	569.40	567.40
Total Dissolved Solids	0.36	0.37	0.36	0.36	0.36

The second type of water quality sampling included the placement of a semipermeable membrane device to collect contaminants at two sites (Stage Coach Inn Cave Conduit and Robertson Springs). These results are presented in Table 12. A more detail list is provided in the appendix (A1). There was an issue this year with the Robertson Springs site. The polycyclic aromatic hydrocarbons are likely degraded within this sample. If the sampler is exposed to sunlight then the more volatile chemicals have the chance to degrade either to below the detection limit, or to lower levels then present within the system. Although this may be the case, the PAHs this year were higher than any other year, and were similar between Stagecoach Inn cave and the Robertson Springs sample (426 pg/L and 470 pg/L respectively). The Stagecoach Inn cave sample was not influenced by solar degradation due to the fact that it was within a cave. Both sites sampled during 2016 had many overlapping and similar amounts of contaminants. Both samples are still within the second quartile based on the relationship between contaminant loadings and impervious cover scores from other salamander sites across the Edwards Plateau. Again this year, none of the individual contaminants detected are above any state or federal standards for freshwater.

Table 12. List of contaminants sampled for in 2014, 2015 and 2016 in the study area along with quartiles from other springs within the Edwards Aquifer Zone at salamander sites. The table is broken into two major parts. The upper section displays the number of contaminants present by category, while the lower section displays the amount within each category in pg/L.

Contaminant	**Stage Coach Inn Cave 2016**	**Robertson Spring 2016**	**Stage Coach Inn Cave 2015**	**Robertson Spring 2015**	**Robertson Spring 2014**	**1st Quartile**	**2nd Quartile**	**3rd Quartile**
Organochlorines (#)	11	8	13	11	5	4	7	11
Polychlorinated biphenlys (#)	0	0	0	0	0	0	0	1
Polybrominated diphenyl ethers (#)	5	6	9	9	0	0	0	1
Polycyclic aromatic hydrocarbons (#)	3	3	2	6	2	2	7	14.5
Organochlorines (pg/L)	175.5	139.3	339.6	628.1	75.9	88	302	707
Polybrominated diphenyl ethers (pg/L)	102.6	113.9	162.3	898.1	0	0	0	15
Polycyclic aromatic hydrocarbons (pg/L)	426	470	12.8	197	324	321	1188	2741
Impervious Cover (%)	6.25	6.25	6.25	6.25	6.25	6	17	23
Total Number of Contaminants	19	17	24	26	7	12	19	32
Total Amount (pg/L)	704.19	723.25	514.7	1723.2	399.9	208	563	2262

Prey Base

All invertebrates captured within the drift nets were taken back to the lab for sorting and enumeration. Most of the samples have been completed. While all orifices had the presence of stygobionts (cave adapted organisms that live in the aquatic area of caves) within the samples, Creek spring had the highest count of stygobionts within the samples. This year the blind dytiscid was sent off to Kelly Miller (University of New Mexico) for description and publication. The hope is to name the blind Dytiscidae after the matriarch of the Robertson family, Ruth. Also, the Ostracoda (seed shrimp) is in review now for publication and has been proposed as a new genus and species (*Schornikovcandona bellensis***)**. This species was named after a scientist who has contributed to the Ostracoda field throughout his life. This seed shrimp has also been collected at the downtown spring complex.

Figure 7. Pictures of *Schornikovcandona bellensis* (upper left) and the blind dytiscidae collected from the Salado area. The upper right and the lower left are photos of the larvae.

Discussion

Mapping of the spring proved useful for surveys and understanding the contributions of spring orifices to the overall discharge. Mapping will be conducted again in 2017 and when changes to the system occur, such as a lowering of the water table. Throughout the year other openings appeared, however, these were low in discharge and mainly would have been designated as seeps.

The quadrat surveys will continue throughout 2017, to attempt to detect if the salamanders are colonizing the springs following the beaver dam removal. Although no salamanders were captured within the frame work of the quadrat sampling, more salamanders overall were collected at Robertson Springs. The habitat appears to be stabilizing naturally now that the beaver dam has been removed. This may provide less disturbance throughout the year within their optimal habitat.

The changes in discharge appear to have affected the distribution of sites within multivariate space (Figure 5B). It is unknown at this time how this may effect salamander densities as none were detected during either event. The discharge decreased between the two events and probably affected the flow of the springs.

At this time, Ludwigia springs seems to be the best potential surface habitat for the salamanders to colonize. Within Ludwigia springs, there are five major spring openings. The upper section of these springs have proven to be the most productive for capturing salamanders. It is unknown if these springs follow the same path underground. I would speculate that they are originated from different flow paths all discharging into Salado Creek. Monitoring of these sites will continue.

Creek spring has been the most productive when sampling with drift nets. In addition to more salamanders captured there the flow was categorized as a four, the highest rating, for Robertson during the mapping event. More stygobionts have been captured from this spring. Given the lower elevation in relationship to the other springs, this spring has the potential to be sampled during drought years with traps or nets placed within the orifice. This spring appears to be an offshoot of a larger conduit or cave system that is heading towards Salado creek.

Three years of contaminant data has been collected from Robertson and two years from Stagecoach Inn. The data has been fairly consistent and has shown the low levels of contaminants within the springs, although higher for the amount of impervious cover present. The reason for higher averages is due to more organochlorines and PBDEs present within the Salado area than other springs around the Edwards Plateau. Sampling of contaminants should be postponed until other changes within the area occur such as increases in impervious cover or an event such as a toxic spill.

Future efforts will include continued monitoring at the downtown complex and at Robertson Springs. Habitat availability and quadrat sampling will be conducted at Cowen Springs in Williamson County and compared to Robertson Springs. These sampling events will be conducted within the same week to assure similar conditions. Genetic material will continue to be collected for future population genetics. Habitat restoration will also be a major focus in the upcoming year at Critchfield Springs.

Appendix

A1: List of contaminants from 2016 sampling season. Highlighted area may be lower than present at site due to solar degredation.

CERC Site #			Site 1	Site 2
Site Identification	MDL	MQL	Stagecoach Inn Cave	Robertson #2
Organochlorine Pesticides	pg/L	pg/L	pg/L	pg/L
Trifluralin	0.10	0.52	**15** [a]	**52**
Hexachlorobenzene (HCB)	0.36	1.8	<0.36 [b]	<0.36
Pentachloroanisole (PCA)	0.38	1.9	<0.38	*0.89* [c]
Tefluthrin	0.60	3.0	<0.60	<0.60
alpha-Benzenehexachloride (a-BHC)	4.7	23	<4.7	<4.7
Lindane	6.8	34	*31*	*27*
beta-Benzenehexachloride (b-BHC)	4.7	23	*18*	*18*
Heptachlor	0.45	2.3	<0.45	<0.45
delta-Benzenehexachloride (d-BHC)	2.5	13	<2.5	<2.5
Dacthal	1.8	9.2	**12**	<1.8
Chlorpyrifos	0.52	2.6	**83**	**25**
Oxychlordane	0.38	1.9	**6.8**	*0.54*
Heptachlor Epoxide	1.1	5.6	<1.1	<1.1
trans-Chlordane	0.40	2.0	**5.3**	*1.5*
trans-Nonachlor	0.39	2.0	<0.39	<0.39
o,p'-DDE	0.37	1.9	<0.37	<0.37
cis-Chlordane	0.40	2.0	**2.3**	<0.40
Endosulfan	22	110	<22	<22
p,p'-DDE	0.37	1.8	**4.9**	**6.2**
Dieldrin	0.95	4.8	**4.8**	<0.95
o,p'-DDD	0.36	1.8	**3.9**	<0.36
Endrin	0.91	4.5	<0.91	**6.1**
cis-Nonachlor	0.37	1.9	<0.37	<0.37
o,p'-DDT	0.37	1.9	*0.95*	<0.37
p,p'-DDD	0.36	1.8	*0.85*	<0.36
Endosulfan-II	46	230	<46	<46
p,p'-DDT	0.39	1.9	*1.7*	**3.0**
Endosulfan Sulfate	32	160	<32	<32
p,p'-Methoxychlor	9.4	17	<9.4	<9.4
Mirex	0.50	2.5	<0.50	<0.50
cis-Permethrin	2.5	12	<2.5	<2.5
trans-Permethrin	1.1	5.3	<1.1	<1.1

PCBs				
Total PCBs	79	390	<79	<79
PBDEs				
PBDE-28	0.36	1.8	0	**2.5**
PBDE-47	0.47	2.3	**8.1**	**5.7**
PBDE-66	0.47	2.3	<0.47	*0.81*
PBDE-85	0.83	4.2	*1.8*	**4.4**
PBDE-99	0.83	4.2	**7.1**	**4.5**
PBDE-100	0.83	4.2	*0.89*	<0.83
PBDE-153	1.7	8.3	*7.8*	**17**
PBDE-154	1.7	8.3	<1.7	<1.7
PBDE-183	3.2	16	**77**	**79**

CERC Site #			Site 1	Site 2
Site Identification	MDL	MQL	Stagecoach Inn Cave	Robertson #2
PAHs	pg/L	pg/L	pg/L	pg/L
Naphthalene	140	680	<140 [a]	*270* [b]
Acenaphthylene	28	140	<28	<28
Acenaphthene	20	100	<20	<20
Fluorene	14	72	<14	<14
Phenanthrene	12	62	<12	<12
Anthracene	11	53	<11	<11
Fluoranthene	4.5	23	<4.5	<4.5
Pyrene	4.2	21	<4.2	<4.2
Benz[a]anthracene	3.6	18	<3.6	<3.6
Chrysene	3.7	18	<3.7	<3.7
Benzo[b]fluoranthene	3.6	18	<3.6	<3.6
Benzo[k]fluoranthene	3.7	19	<3.7	<3.7
Benzo[a]pyrene	3.9	20	<3.9	<3.9
Indeno[1,2,3-cd]pyrene	4.6	23	<4.6	<4.6
Dibenzo[a,h]anthracene	4.1	21	<4.1	<4.1
Benzo[g,h,I]perylene	5.0	25	<5.0	<5.0
Benzo[b]thiophene	530	2600	<530	<530
2-methylnaphthalene	47	230	*91*	*130*
1-methylnaphthalene	47	230	*55*	*70*
Biphenyl	42	210	<42	<42
1-ethylnaphthalene	14	71	<14	<14
1,2-dimethylnaphthalene	18	92	<18	<18
4-methylbiphenyl	17	85	**280**	**270**
2,3,5-trimethylnaphthalene	6.1	30	<6.1	<6.1

1-methylfluorene	5.6	28	<5.6	<5.6
Dibenzothiophene	14	72	<14	<14
2-methylphenanthrene	6.2	31	<6.2	<6.2
9-methylanthracene	5.0	25	<5.0	<5.0
3,6-dimethylphenanthrene	3.9	20	<3.9	<3.9
2-methylfluoranthene	3.8	19	<3.8	<3.8
Benzo[b]naphtho[2,1-d]thiophene	4.1	21	<4.1	<4.1
Benzo[e]pyrene	4.0	20	<4.0	<4.0
Perylene	3.7	18	<3.7	<3.7