Salado Salamander Monitoring Final Report 2017

Peter Diaz and Mike Montagne
Texas Fish and Wildlife Conservation Office

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Acknowledgments

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Summary

The Texas Fish and Wildlife Conservation Office (TXFWCO) completed the 2017 monitoring schedule at the Salado Downtown Spring Complex and the Robertson Springs in Bell County under federal permit TE676811-9 and state permit SPR-0111-003. A total of 46 Salado salamanders were detected from Robertson Springs and the Downtown Spring Complex (DSC) in 2017. Most salamanders were captured, however, a few escaped after a visual observation before a photo or length could be taken. Of the remaining salamanders, 18 were considered adults (>30 mm) and 23 were considered juvenile. Seventeen salamanders were caught in drift nets and two salamanders were caught during the quadrat sampling. The remaining 27 were caught by actively searching. Salamanders were collected from eight different locations within the study area. The most salamanders captured this year by active searching and drift netting was from Robertson Springs, and within the Robertson Springs complex from five spring areas (Figure 1). Following Robertson Springs, Anderson Spring had 11, Big Boiling Spring had seven, and Side Spring had six salamanders detected.

There was a shift during 2017 from the Ludwigia spring zone producing more salamanders to Middle spring zone producing more this year as flows from Ludwigia began to subside. Flows at Robertson Springs were still strong at the beginning of the year, however, by July the flow at some of the spring orifices had dwindled or stopped entirely. Due to the loss of spring flow at some of these sites Robertson Springs was remapped in order to determine which spring outlets within the complex were more consistent. By July of 2017, seven individual springs had stopped flowing and the wetted area of the spring zones had shrunk compared to the areas in early 2016 (Figure 3).

Timed searches were conducted in February, May, June, September, and November. Quadrat searches were conducted in April and July. In addition to the DSC and the Robertson Springs sites, Solana Ranch was sampled in September, and Cowen Spring located in Sun City (Williamson County; Figure 1) was included in the quadrat sampling regime. Solana Ranch was added in order to collect genetic material for a future population genetics project. Cowen Spring was added to compare habitat and surface salamander counts with Robertson Spring.

Methods

A combination of timed searches and drift netting were conducted this year to document the occurrence of Salado salamanders within the study area. Sampling was conducted at three locations within the DSC (Anderson/Benedict, Big Boiling, and Side Spring). Little Bubbly was dry for most of the year, although it was searched when the spring was flowing in February. Critchfield Spring was also searched in February, but not examined the remaining part of the year. Sampling at Robertson Springs was conducted within the entire spring run. For each event at Anderson/Benedict, Big Boiling, and Robertson springs, the area was searched for approximately an hour usually with at least three people (Table 1). Drift netting was conducted this year at six different locations over the course of the year. There was one location at the DSC (Anderson Spring) and five nets set at Robertson Springs (Table 2). When a salamander was found, it was photographed and returned to the area where captured. All measurements were acquired using Image J software. Additionally, the software Wild ID was used to determine if any salamanders were recaptures using photographed head shots of the salamanders.

Quadrat searches were conducted at two locations twice in 2017. Cowen Spring is located within Sun City (Williamson County) and is not part of the normal monitoring schedule (Figure 1). Sampling at Cowen Springs was conducted to compare habitat and salamander surface counts between Cowen Spring and Robertson Springs, which has a more sporadic hydroperiod. We mapped Cowen Springs in March of 2017 (Figure 4, Table 4). From the Robertson and Cowen spring maps a stratified random study design for the quadrat searches was created. Quadrat searches were done in April and July at each location. Quadrat searches at Cowen and Robertson springs were conducted within five days of each other. Random points were selected within ArcGIS using XTools. Quadrat surveys were conducted using a ½ meter quadrat actively searched for 2.5 minutes. Depth ($1/10^{th}$ ft), flow (ft/s), temperature (C°), dissolved oxygen (mg/L), pH, conductivity (µs/cm), and total dissolved solids (g/L) were collected at each 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 coming out of the orifice does not mix with the spring run water. Spring areas were identified on the map and the total area was calculated for each. A total of 26 quadrats were sampled in April and a total of 35 quadrats were sampled in July at Cowen Spring. At Robertson Springs 41 quadrats were selected and were sampled each. The effort per spring was derived from the area of the spring, therefore, springs with a larger wetted area were surveyed more than smaller spring zones. In addition, ten surveys were added to the spring runs to examine differences between spring areas and spring run with respect to habitat and water chemistry. Data collected from quadrat surveys were analyzed using principal component analysis (PCA). Prior to analysis all data was z-scored.

Following a quadrat search, substrate was quantified by gridding out the spring zones and runs. Habitat at Robertson Springs was measured by running meter tape along the length of the spring run for 100 meters. Every five meters transects were created. The search area was quantified using a 1/3 m^2 quadrat. Substrate was identified every other 1/3 of a meter along each transect. At Cowen Spring the area was divided into four sections due to the non-linear fashion of the spring. The four sections were the backwater spring area, the Cowen Spring cobble and gravel run, the Cowen Creek mixing zone, and the main spring (Figure 4). Transects were created every two meters at Cowen Spring to maximize the amount of data collected as the spring area is much smaller than Robertson Springs.

Examination of the overall data set going back to 2015 will be completed in order to examine habitat associations and size distributions. Data will be grouped into quarterly blocks for size distribution analysis. The relative abundance of the salamanders will be calculated for each quarter based upon size classes. Size classes are from 0-19, 20-29, 30-39, 40-49, 50-59, 60-69 mm.

Results

A total of 46 Salado salamanders were detected from Robertson Springs and the DSC in 2017. Most salamanders were captured, however, a few escaped after a visual observation before a photo or length could be taken. Of the remaining salamanders 18 were considered adults (>30 mm) and 23 were considered juvenile. A total of 17 salamanders were captured using drift nets in the span of 1,359 days. Anderson Spring had the most drift net captures (n = 11) and catch per unit (CPUE) of 0.0251 salamanders per day, although the net was on the longest. Upper Ludwigia had a similar CPUE of 0.0204 salamanders per day. Drift net sampling at Upper Ludwigia was stopped when the spring dried up.

The remaining 27 salamanders were caught by actively searching, and were collected from eight different locations within Robertson Springs and DSC. The most salamanders captured this year by active searching was from Robertson Springs. Within Robertson Springs salamanders were captured from five spring areas (Figure 2). Water chemistry within the sampling area was within ranges of historical values (Table 3).

Downtown Spring Complex

In 2017, 25 salamanders were captured at the DSC. Timed searches yielded seven salamanders, and drift netting at Anderson Spring yielded 10 salamanders. One adult salamander was captured during the timed searches at Anderson Spring. This was the first adult captured at Anderson Spring. Other adults were captured from Side Spring over 2017, while no adults were captured within Big Boiling. Seven salamanders were captured at Big Boiling Spring, with 4 caught in May. The remaining salamanders were captured opportunistically during weekly net checking events. No recaptures were documented during 2017 from the DSC.

Robertson Springs

Twenty one salamanders were captured at Robertson Springs in 2017. Timed searches yielded seven salamanders. Seven salamanders were captured using drift nets and 7 salamanders were captured during opportunistic searches during weekly net checks. The Middle Spring zone yielded the most salamanders (n = 10). Ludwigia spring had seven, Creek, Beetle, and the Headwater springs all produced one salamander in 2017. As the year progressed, the flow at Robertson decreased. Salamander detections within Ludwigia decreased with flow.

The flow at Robertson Springs have been on the decline since the end of 2016. In June of 2016, the maximum flow of 6.15 m/sec was recorded, and the flow has steadily been decreasing. In April of 2017 the flow was 3.2 m/sec. Then in July, the flow was 1.11 m/sec, and finally in September the flow was 0.85 m/sec. Although salamanders have been captured as spring flows decrease, the main location yielding salamanders within Robertson Springs shifted to Middle Spring as the flow decreased. The flow at Middle Spring is still strong, however, the wetted area and the other smaller springs within the Middle Spring zone have dried up. The Headwater and Beetle springs stopped having detectable flow by August 31, 2017, but water is still flowing from the headwater section.

Quadrat Searches

Cowen and Robertson springs were selected for quadrat searches due to the potentially higher densities of salamanders. Quadrat sampling was conducted in April and July. A total of 101 quadrats were sampled and used for the PCA, with 54 quadrats from Cowen Spring and 47 from Robertson Springs. A total of 13 salamanders were detected using the quadrat method: 11

from Cowen Spring and two from Robertson Springs. This was the first collection of salamanders from Robertson Springs within sampled quadrats. In addition, one of the salamanders detected at Robertson Springs was found within a spring run quadrat, out of a spring zone.

Results from the PCA show a separation between the Robertson Springs and Cowen Spring sites along PC axis I (Figure 5). This division is driven by positive loadings of conductivity, total dissolved solids and temperature to negative loadings of flow and cobble (Table 5, Table 10). Therefore, at Robertson Springs there is higher flow, more cobble, with sand and mud/silt (MS) type habitats, and at Cowen Spring, conductivity, total dissolved solids, and temperature are higher with more gravel present. Robertson spring sites and spring run sites are more spatially separated than Cowen creek sites and Cowen spring sites. This indicates a larger change in habitat types between Robertson spring and run sites, than between Cowen creek and spring sites. The gradient along PC axis II shifts from positive loadings of pH, depth, and bedrock to negative loadings from gravel and flow.

Salamander occurrences were plotted in three of the quadrats within the graph. Only the lower left quadrat does not have a salamander occurrence. The lower left quadrat had the highest average values of flow present within the data set (Table 9). The upper left quadrat within the graph has two points that represent the detections at Robertson. On the positive side of the graph is where the Cowen Spring detections of the salamanders were plotted.

Sites were segregated by quadrat results from the PCA analysis to examine abiotic associations of observed salamanders. Abiotic values were averaged to provide trends from each quadrat. The most salamanders were captured in the lower right quadrat (n = 6). The lower right quadrat had the lowest average of dissolved oxygen, the highest conductivity, the lowest pH, the most gravel present, and an average of 0.42 ft/sec flow (Table 9).

Substrate types were assessed at each spring location to help understand any potential connection between salamander presence and absence. A total of 488 quadrats were examined at Robertson Springs (302) and Cowen Spring (186) (Table 6). Mud/silt substrates dominated at Robertson Springs (+50%), while gravel substrates were dominant at Cowen Spring (+40%).

Habitat Associations

A total of 81 salamanders have been captured since 2015. Most salamanders have been captured from cave conduits (n = 29; 35.80%; drift nets) followed by gravel substrates (n = 27;

33.33%), then cobble (n = 17; 20.99%) (Table 7). The most frequently associated aquatic vegetation was *Nasturtium* sp. (Watercress) with 25 salamanders (52.08%) detected within, followed by no vegetation (n = 10; 20.83%). The average flow where salamanders were detected (n = 11) during quadrat searches was 0.309 ft/sec. The average depth in the quadrats where salamanders were detected (n = 11) was 0.29 inches.

The relative abundance of salamanders examined quarterly showed that juvenile salamanders are present within the first and second quarters with the population shifting to larger salamanders over the third and fourth quarters (Figure 6 and Table 8).

Solana Ranch

Sampling for genetic material was accomplished on September the 5th, 2017. A total of 15 salamanders were collected at Solana Ranch Spring #1, from about a two m^2 area with cobble and gravel substrates with *Amblystegium* sp. (aquatic moss). Salamanders were photographed and returned to the location where they were collected. The average size of the salamanders collected was 50.76 mm. This is larger than the average size of salamanders collected from 2015 to 2017 from Robertson Springs and DSC (n = 75; 28.13 mm) and from Cowen (n = 10; 36.38 mm). All salamanders encountered at the Solana Ranch Spring #1 were adults.

Discussion

Monitoring in 2017 provided the highest number of detections within the entire study from the last three years. Determining the mechanisms for the increased detections is not possible, but a number of hypothesis could be examined. First, the hydroperiod of the springs along Robertson Springs has been constant since 2015, creating breakthrough within the subterranean environment allowing salamanders to populate the surface environment more freely. Second, the removal of the beaver dam from Robertson Springs in late 2015 lowered the water levels within the spring zones and spring runs, created a change in substrate dominance, and a subsequent colonization of salamanders was seen within Robertson Springs. Third, as the flows have been decreasing the amount of wetted area has decreased, thereby, causing a crowding effect and consolidating the salamanders within a smaller area potentially making them easier to collect.

The monitoring at Cowen Spring was extremely useful as a comparison to Robertson Springs. In 2016, 43 salamanders were detected at Cowen Spring during regular monitoring (Cambrian Environmental 2016). In the 2017 July event at Cowen there were 10 salamanders detected using the random quadrat approach. In 2016, Robertson Spring had 27 salamanders detected. This year there were 25 salamanders collected from the DSC and 21 collected at Robertson Springs. Although the numbers at Cowen Spring are higher, the collections within the DSC and Robertson Springs are higher than previously expected.

The potential mechanisms for why more salamanders are consistently found at Cowen Spring compared to Robertson Springs are more apparent following the monitoring events this year. As with Robertson Springs, Cowen Spring is adjacent to a creek, however, the depth within Cowen Spring is too shallow to allow large bodied predatory fish within the spring run. Habitat analysis showed that Cowen contained substantially more gravel than at Robertson Springs. Cowen Spring has large contiguous gravel and cobble sections. Within Robertson Springs the patches of gravel and cobble are separated by silt areas and a deeper main spring run. Finally, the hydroperiod is more consistent within Cowen Spring than at Robertson Springs, which has shown large fluctuations overtime.

Larger salamanders on average were found at the Solana Ranch Spring #1 than at Cowen or at Robertson springs. The spring at the Solana Ranch is on the edge of a hill that flows into a small creek. One reason for the average larger size of salamanders is that the Solana Ranch Spring #1 site may not be as susceptible to flooding as the Cowen and Robertson spring sites. This may provide time more time for salamanders to colonize the surface between disturbances. This spring was fenced off and no intrusions were allowed within the spring. The larger size of salamanders and the small area in which the salamanders were found indicate that the surface population at Solana Ranch is much more stable than at Cowen or Robertson springs.

Brune (2002) believed that the primary recharge for Robertson Springs and DSC was located in Williamson County adjacent to I-35 within Salado Creek, where there are large faults. If that is the case, genetic material from salamanders within these southern areas may be mixing with the populations present within Robertson Springs or the DSC. In addition, this would show that the populations within the study area are coupled with potential deleterious effects to water quality and quantity from the south.

Genetic analysis has been proposed for the 2018 monitoring season to examine genetic flow, population size, and the population size needed to maintain genetic diversity within captive programs. This type of work will solidify some of the hypothesis regarding gene flow and subsurface population sizes. More site visits to other springs in the area should be done to verify that the Robertson Springs and DSC sites are the most northern Salado salamander sites.

Understanding the life cycle of the Salado salamander is important in order to better manage the species. The results from the cumulative work over the last three years shows that most juvenile salamanders were captured in the first and second quarters. No gravidity was observed during the 2017 season. Bendik et al. (2017) showed that the largest proportion of the Jollyville Plateau salamanders were gravid during December. Pierce et al. (2014), found that there were two peaks within the population of Georgetown salamanders over the course of a year that had eggs present. One of these peaks was present in winter (around December) and the other around February or March. These results may explain why salamanders within the first and second quarter of our surveys are within the smaller size classes.

Habitat associations of the surface population seem to be similar to other Eurycea within the Edwards Plateau, with optimal habitat being cobble and gravel substrates. Surface population densities appear to be small, due to the absence of recaptures. In addition, 1/3 of the captures were collected from drift nets within our study area. These results show a potentially larger population of Salado salamanders present within the subterranean environment and low surface recruitment at the Robertson Springs site. One hypothesis is that the southern portions of the Salado salamander populations are robust and well established, therefore driving the juvenile salamanders into our study area to forage for food or find mates.

Overall, the Salado salamander population within the DSC and Robertson Springs appear to be stable although low in surface densities. Data suggests that salamanders are being driven from the aquifer in low densities (Diaz Final Report 2016, unpublished report). Based on these data, the reason for low surface densities may not have to do with available habitat or other anthropogenic stressors, but could be due to this species being on the fringe of *Eurycea* distribution within Texas.

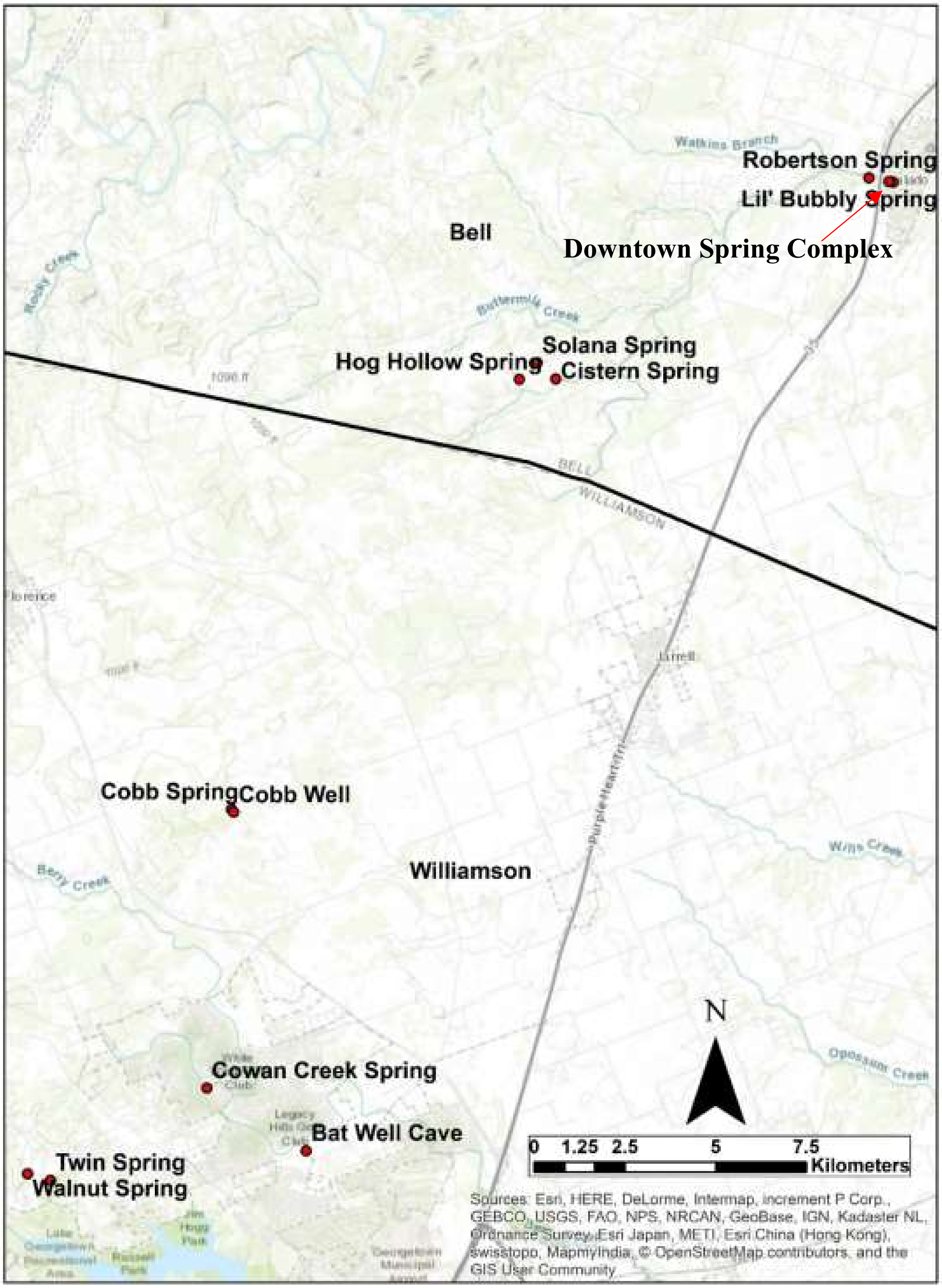

Figure 1. Map of *Eurycea* (salamanders) within the northern portion of the Edwards Aquifer.

Figure 2. Map of Robertson Springs taken from July of 2017. Yellow dots show locations where Salado salamanders have been capture. Red dots are other spring orifice. Light blue areas are the spring zones.

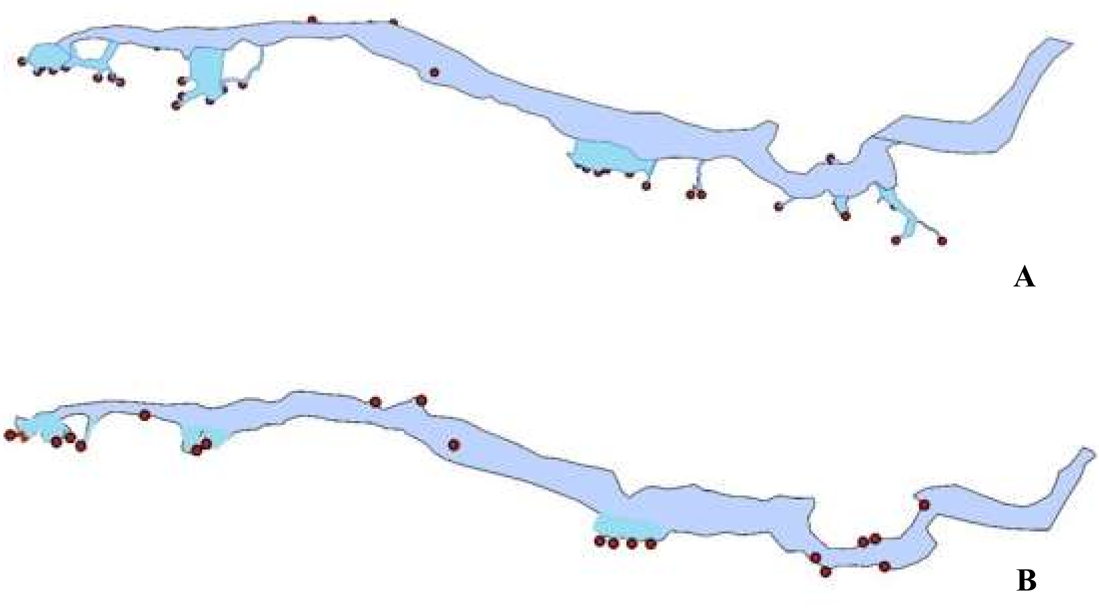

Figure 3. Mapping data collected at Robertson Springs in February of 2016 (A) and in July of 2017 (B). By July 2017, the wetted area of the spring zones has decreased and the overall number of spring orifice have decreased.

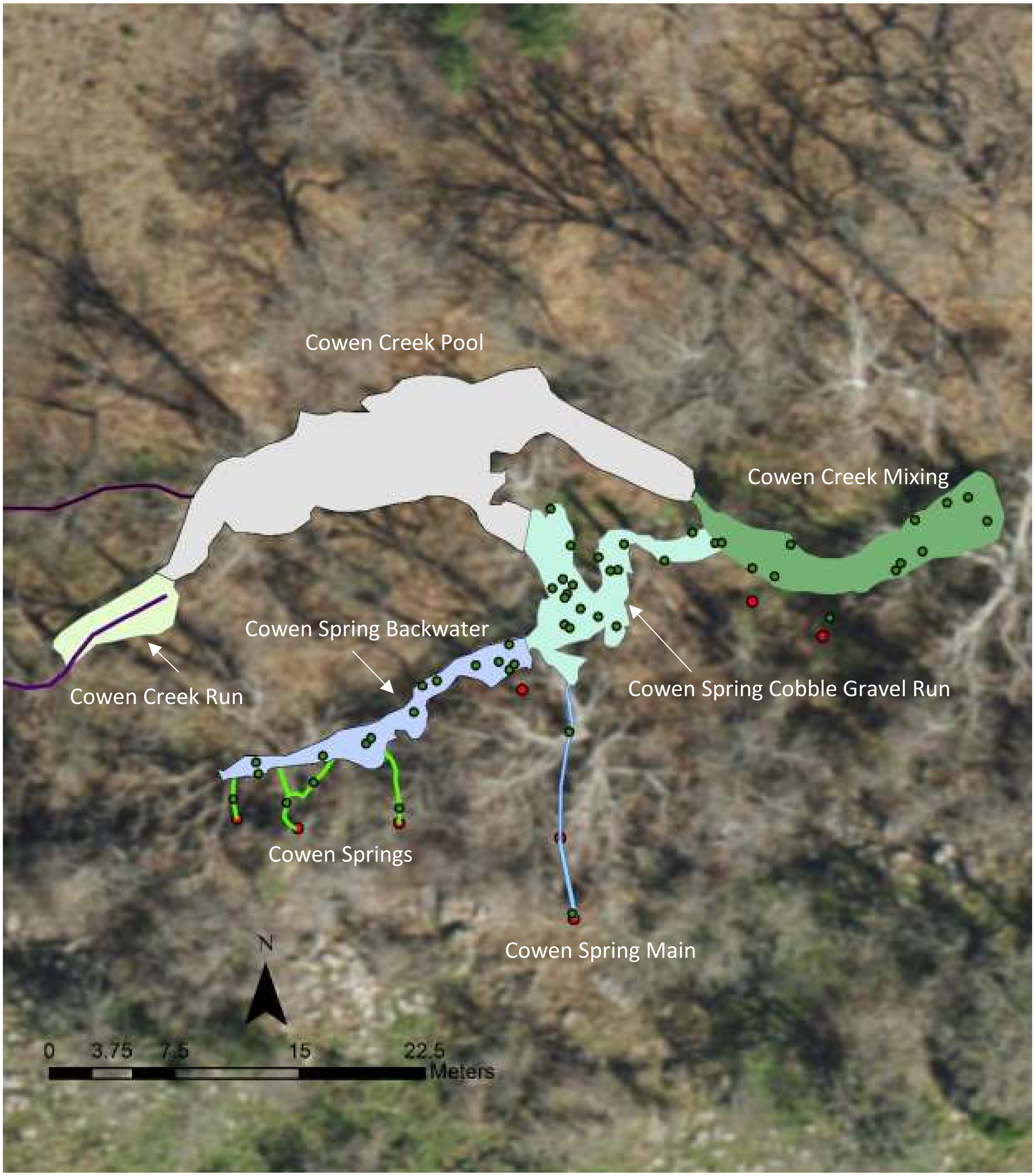

Figure 4. Map of Cowen Springs collected on March 23, 2017. The map is divided into zones of the creek and zones within the spring area. Green dots are randomly generated sampling locations and red dots are spring orifices.

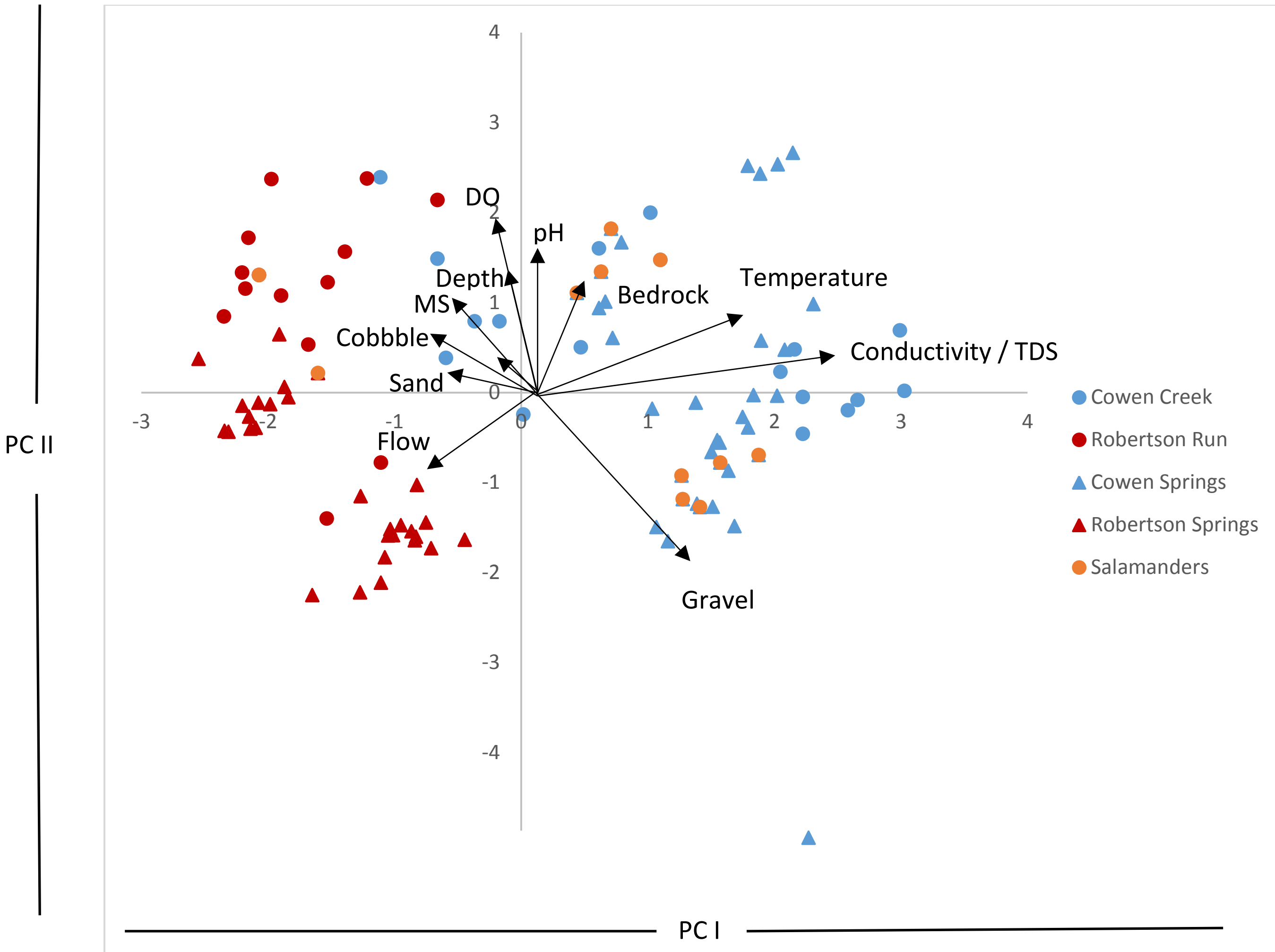

Figure 5. Results from principal components analysis at Cowen Spring and Robertson Springs with data collected during 2017. Abbreviations: DO = dissolved oxygen; TDS = total dissolved solids; MS = mud/silt.

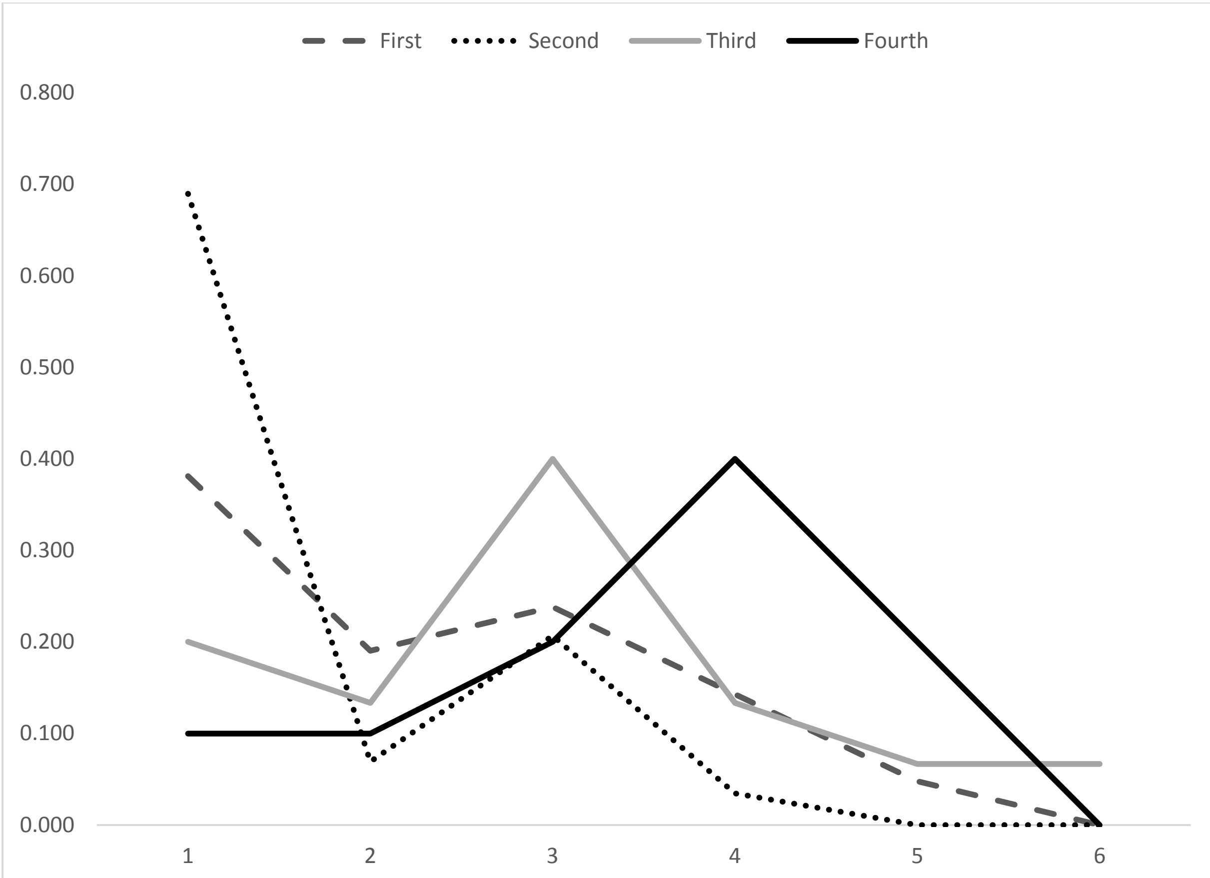

Figure 6. Relative abundance of size class for 75 Salado salamanders captured quarterly from 2015 - 2017 (1 = 10 - 19 mm; 2 = 20 - 29 mm; etc.).

Table 1. Timed searches conducted within the 2017 field season.

Location	Date	People	Time (min)	Total Time	Salamanders
Anderson	9-Feb	4	26	104	0
Critchfield	9-Feb	4	Mesohabitat	NA	0
Big Boiling	9-Feb	4	45	180	1
Little Bubbly	9-Feb	4	10	40	0
Side Spring	9-Feb	4	All	NA	0
Robertson	10-Feb	4	85	340	1
Anderson	4-May	3	50	150	1
Big Boiling	4-May	3	40	120	1
Side Spring	4-May	3	All	15	0
Robertson	4-May	3	80	240	1
Anderson	15-Jun	3	60	180	1
Big Boiling	15-Jun	3	55	165	1
Side Spring	15-Jun	3	All	NA	1
Robertson	15-Jun	3	96	288	3
Anderson	21-Sep	3	45	135	0
Big Boiling	21-Sep	3	36	108	0
Side Spring	21-Sep	3	All	NA	0
Robertson	21-Sep	3	85	255	0
Anderson	28-Nov	1	50	50	0
Big Boiling	28-Nov	1	30	30	0
Side Spring	28-Nov	1	All	NA	1
Robertson	29-Nov	1	90	90	2

Table 2. Drift netting conducted during the 2017 field season.

Spring	Location	Date Set	Date Removed	Salamanders	Days	CPUE/day
Anderson	DT Complex	10/26/2016	11/28/2017	10	398	0.0251
Headwater	Robertson	1/20/2017	8/31/2017	1	223	0.0044
Beetle	Robertson	1/20/2017	8/31/2017	1	223	0.0044
Upper Ludwigia	Robertson	1/20/2017	8/4/2017	4	196	0.0204
Creek	Robertson	5/11/2017	11/29/2017	1	202	0.0049
Middle	Robertson	7/21/2017	11/22/2017	0	117	0

Table 3. Water chemistry collected during timed searched monitoring.

Location	Date	Temperature	pH	Conductivity	DO	TDS
Anderson	9-Feb	20.43	7.14	595.80	7.58	0.3815
Big Boiling	9-Feb	20.79	7.09	591.80	7.63	0.3786
Little Bubbly	9-Feb	19.66	7.35	589.20	9.30	0.3775
Side Spring	9-Feb	20.44	7.23	595.20	7.55	0.3804
Robertson	9-Feb	28.81	NA	NA	7.83	NA
Anderson	4-May	20.72	6.91	587.40	7.31	0.376
Big Boiling	4-May	20.83	6.98	582.60	7.58	0.3733
Side Spring	4-May	20.84	7.00	582.90	7.61	0.3731
Robertson	4-May	20.81	7.05	578.10	7.75	0.3701
Anderson	21-Sep	20.95	6.88	590.00	7.19	0.3000
Big Boiling	21-Sep	20.89	6.98	589.40	7.71	0.3771
Side Spring	21-Sep	21.02	7.00	589.40	7.70	0.3772
Robertson	21-Sep	20.94	7.96	579.00	NA	0.3705
Anderson	29-Nov	20.89	7.00	580.40	7.79	0.3715
Big Boiling	29-Nov	20.86	7.05	585.40	7.60	0.3751
Side Spring	29-Nov	20.84	7.05	580.70	7.81	0.3715
Robertson	29-Nov	20.87	7.16	578.00	7.99	0.3000

Table 4. Results from post processing of mapping data collected July 17, 2017 from Robertson Springs and from March 23, 2017 at Cowen Springs.

Post Process Data	Robertson	Cowen
0-5cm	-	-
5-15cm	-	-
15-30cm	0.06%	0.93%
30-50cm	38.54%	40.88%
0.5-1m	45.40%	45.48%
1-2m	14.81%	12.15%
2-5m	1.19%	0.56%
>5m	-	-

Table 5. Loadings from principal components analysis

Variable	PC I	PC II
Temperature	0.386	0.210
Dissolved Oxygen	-0.075	0.470
Conductivity	0.556	0.107
pH	0.006	0.378
Total dissolved solids	0.555	0.106
Mud/Silt	-0.151	0.247
Sand	-0.151	0.048
Gravel	0.289	-0.474
Cobble	-0.199	0.159
Boulder	-0.074	0.093
Bedrock	0.088	0.297
Depth	-0.052	0.336
Flow	-0.207	-0.216

Table 6. Results from habitat assessment at Robertson and Cowen springs.

Robertson					Cowen			
		April		July		April		July
Substrate	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage
Mud/silt	92	58.23	77	53.47	9	13.84	26	21.48
Sand	10	6.33	14	9.72	3	4.62	1	0.82
Gravel	31	19.62	30	20.83	31	47.69	50	41.32
Cobble	5	3.16	9	6.25	15	23.08	29	23.96
Boulder	7	4.43	3	2.08	4	6.15	6	4.95
Bedrock	13	8.23	11	7.64	3	4.62	9	7.43
Total	158		144		65		121	
Rocks		27.22		29.17		76.92		70.25

Table 7. Results from captures of Salado salamanders from 2015 – 2017.

Substrate	Count	Percentage
Silt	2	2.47
Sand	2	2.47
Gravel	27	33.33
Cobble	17	20.99
Boulder	4	4.94
Cave Conduit	29	35.80
Vegetation	Count	Percentage
***Sagittaria* sp.**	1	2.08
***Nasturtium* sp.**	25	52.08
Filamentous Algae	3	6.25
***Ludwigia* sp.**	1	2.08
***Amblystegium* sp.**	3	6.25
***Hydrocotyle* sp.**	2	4.17
None	10	20.83
***Eleocharis* sp.**	1	2.08
Organic Debris	2	4.16

Table 8. Count and relative abundance data by size class for salamanders captured from 2015 to 2017.

Size Class	First	Second	Third	Fourth
1	8	20	3	1
2	4	2	2	1
3	5	6	6	2
4	3	1	2	4
5	1	0	1	2
6	0	0	1	0
Sum	21	29	15	10
1	0.381	0.690	0.200	0.100
2	0.190	0.069	0.133	0.100
3	0.238	0.207	0.400	0.200
4	0.143	0.034	0.133	0.400
5	0.048	0.000	0.067	0.200
6	0.000	0.000	0.067	0.000

Table 9. Average results from principle component analysis segregated by multivariate space (quadrats) and the number of salamanders captured within each section of multivariate space. Abbreviations: LL = lower left; UPL = upper left; LRT = lower right; UPRT = upper right; °C = temperature; DO = dissolved oxygen; µs/cm = conductivity; TDS = total dissolved solids; MS = mud/silt; GR = gravel; COB = cobble; BO = boulder; BED = bedrock; 1/10 = depth in tenths of feet.

Quadrat	°C	DO	µs/cm	pH	TDS	MS	Sand	GR	COB	BO	BED	Depth	Flow	Salamanders
LL	20.89	8.01	579.10	7.07	0.37	0.00	0.04	0.68	0.29	0.00	0.00	0.20	0.61	0
UPL	20.94	8.52	604.88	7.17	0.39	0.25	0.13	0.17	0.25	0.13	0.08	0.51	0.53	2
LRT	21.30	7.92	765.39	7.03	0.49	0.00	0.00	0.96	0.00	0.00	0.04	0.29	0.42	6
UPRT	21.73	8.38	763.75	7.14	0.49	0.09	0.00	0.36	0.27	0.09	0.18	0.36	0.17	5

Table 10. Average results from principle component analysis taken from 101 quadrats in 2017 segregated by site. Abbreviations: °C = temperature; DO = dissolved oxygen; µs/cm = conductivity; TDS = total dissolved solids; MS = mud/silt; GR = gravel; COB = cobble; BO = boulder; BED = bedrock; 1/10 = depth in tenths of feet.

Site	°C	DO	µs/cm	pH	TDS	MS	Sand	GR	COB	BO	BED	1/10	Flow	Salamanders
Robertson	20.96	8.14	579.04	7.09	0.37	0.13	0.09	0.43	0.26	0.06	0.04	0.32	0.53	2
Cowen	21.41	8.23	758.98	7.11	0.49	0.04	0.00	0.69	0.15	0.04	0.09	0.34	0.36	11

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