



Proposed Sampling Frequency for Barton Springs Salamanders Preliminary Analysis

DR-12-01
June 2012

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Abstract

The historical record of salamander counts at Barton, Eliza, Old Mill, and Upper Barton Springs was investigated to assess the impact of switching from monthly to bimonthly (every two months) sampling. Peak counts are probably missed under both the bimonthly and the current monthly sampling protocol. However, the periods of major increases and decreases in counts will still be identified if we switch to bimonthly sampling. With fewer data points we will need longer times periods or more nuanced analysis methods to show statistical significance. However, for the investigated analyses, the loss of data and the subsequent loss of significance would not have changed our reaction to the data. With an endangered species you need to take action when the trend of the data indicates a potential problem. You do not wait for significance. The ability to collect other information is likely to add more to our understanding of salamander dynamics than the maintenance of a monthly sampling protocol.

Introduction

Sampling has occurred monthly, with a few exceptions due to unsafe conditions, at all four salamander sites (Barton, Eliza, Old Mill, and Upper Barton Springs) if the site was not dry. Currently staff is overbooked and needs assistance from other teams/volunteers to complete the monthly sampling. Also there are additional items, such as prey abundance, which should be added to the sampling protocol. If sampling frequency could be decreased without loss of essential information, it would alleviate this situation.

I looked at the consequences if surveys had been conducted 6 times per year rather than 12 times. We wanted to know if peak counts would be missed with bimonthly sampling. Would summary statistics change dramatically? Would we lose statistical significance and be unable to statistically support important differences in counts relative to decision making processes. What other information should we have that is not currently gathered due to time constraints?

The duration of periods of peak juvenile counts is discussed. Then time series plots for total counts are presented, followed by summary statistics and a discussion of statistical significance levels under the reduced survey frequency. Then I discuss the value of collecting additional information rather than maintaining the current survey frequency. All data presented here is for the Barton Springs salamander and does not include the counts of the Austin blind salamander

Duration of Periods of Higher Counts

How long do counts stay high? If the period is less than two months then bimonthly sampling will miss some peaks entirely. The duration of the periods for high counts is similar those for the three size classes (< 1 inch, 1-2 inches and > 2 inches) (Figure 1). Thus we only need to investigate one size class. The smallest size class was chosen.

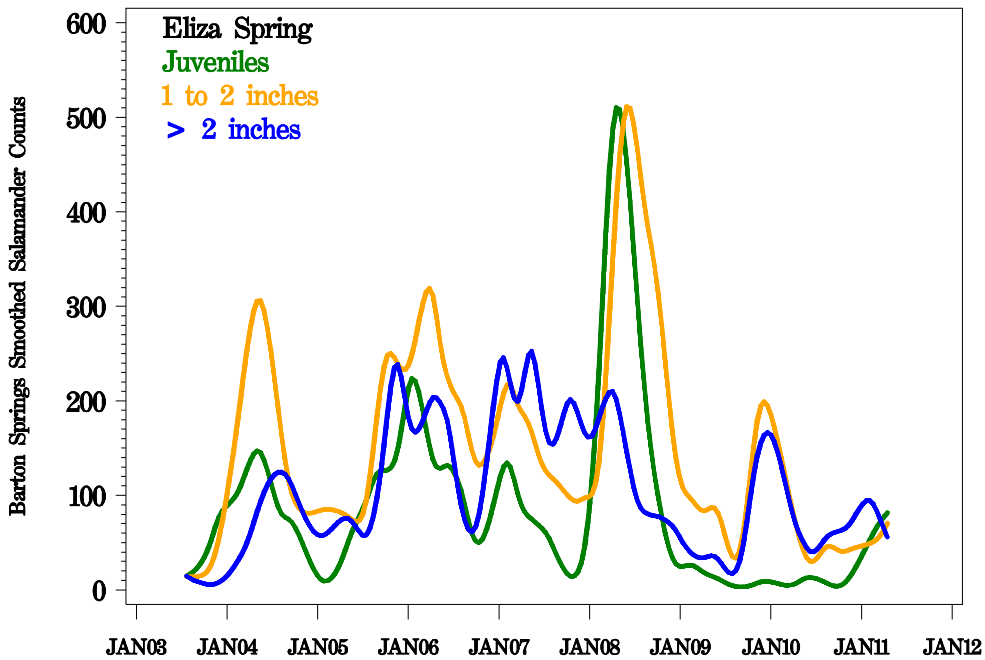
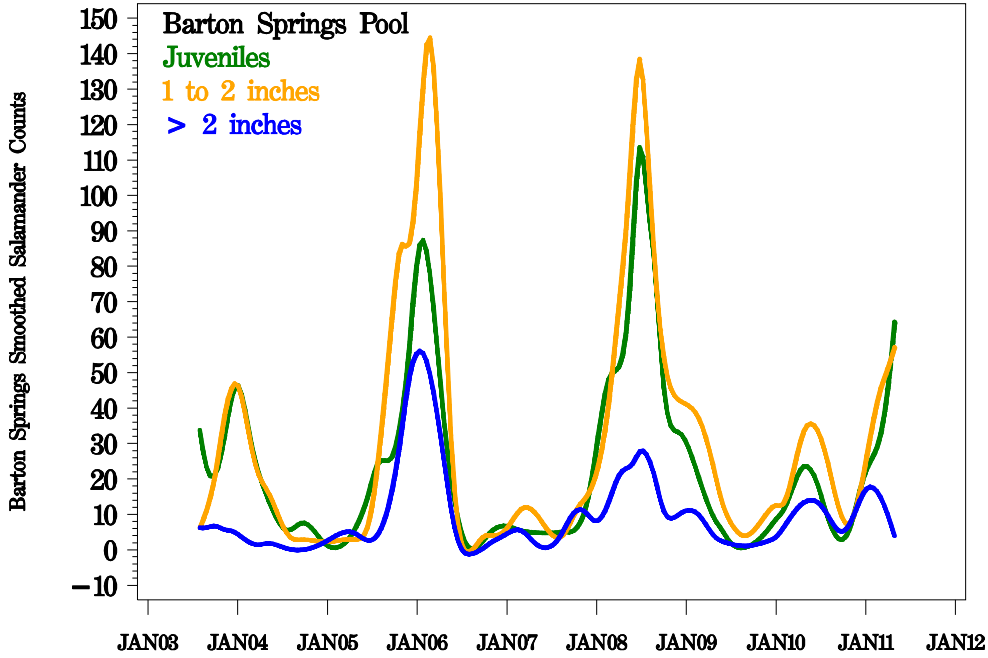


Figure 1. Smoothed counts of three size classes of Barton Springs salamanders at Eliza Spring and in Barton Springs Pool.

The duration of periods of higher juvenile counts was investigated by smoothing the count data using cubic splines with a smoothing factor of 20 and selecting all periods with counts greater than 10% of the maximum count for investigation. Starting and ending surveys for these periods were selected visually from the raw data (Figure 2) and the length of the period was determined.

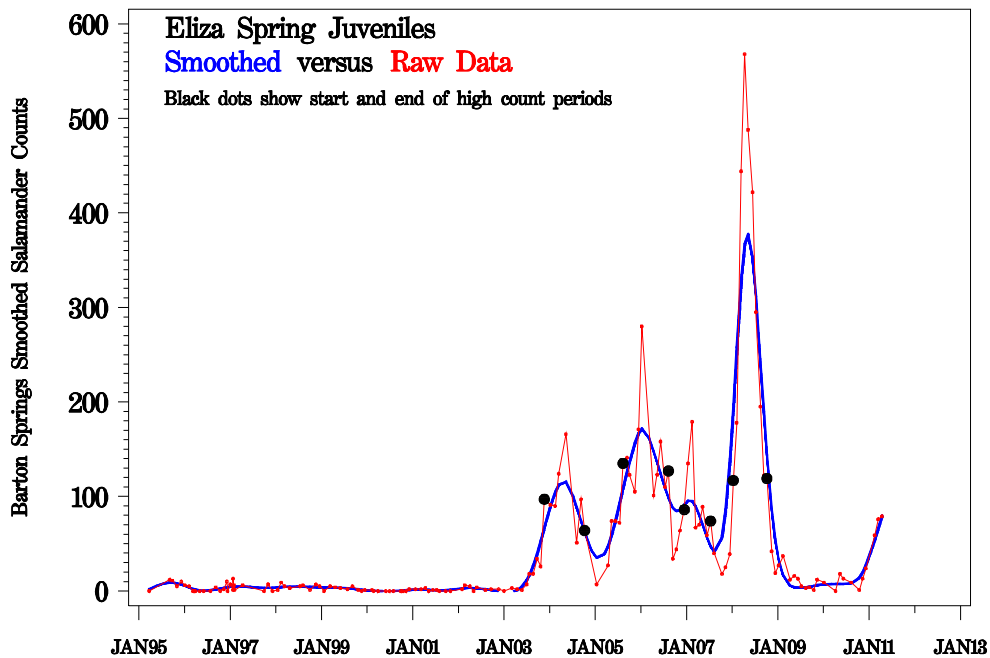
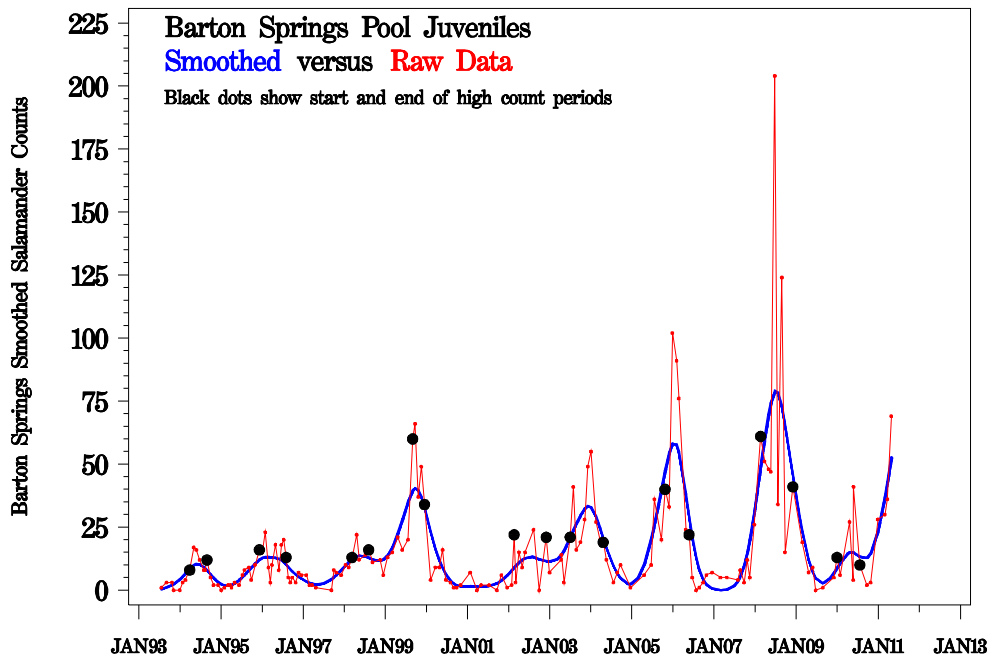


Figure 2a. Selection of peaks and start and end dates of periods of high juvenile counts. Comparison of smoothed data to survey counts

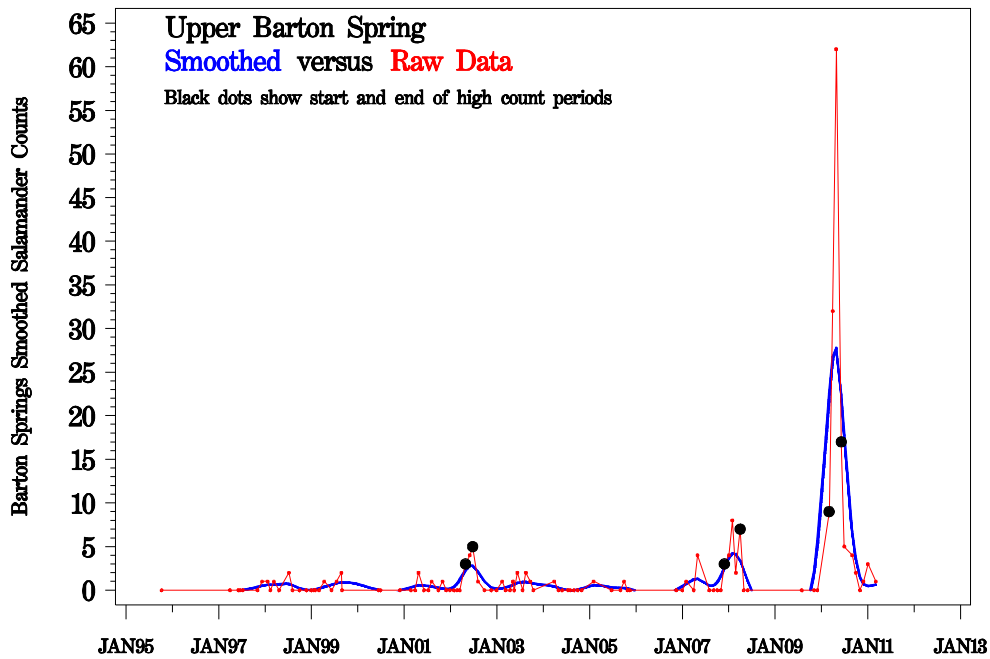
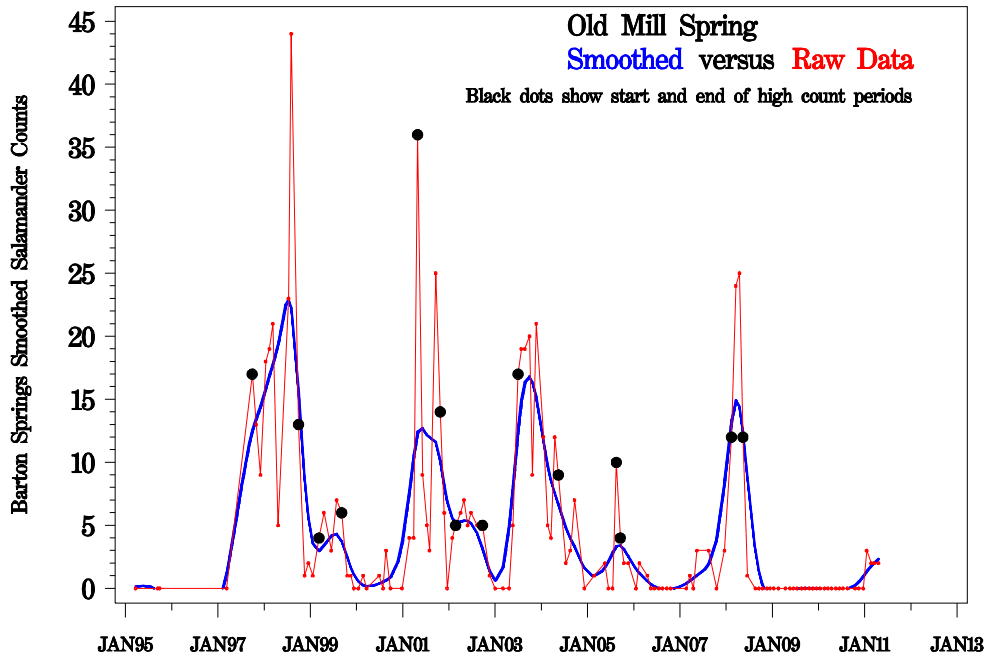


Figure 2b. Selection of peaks and start and end dates of periods of high juvenile counts. Comparison of smoothed data to survey counts

The average duration is 7 months and the shortest duration is two months (Table 1). Sampling every other month will pick up these increases in counts. The site with the shortest durations is Upper Barton Spring. This is because it goes dry at flows less than

40 cfs. If a better understanding of the surges in counts at Upper Barton is desired, sampling frequency could be increased from every other month to monthly whenever flows are decreasing and drop below 50 cfs.

Table 1. Duration of Peaks in Smoothed Juvenile Counts

Peaks in smoothed Juvenile Counts				
Site	Peak Date	Start Date	End Date	Duration (months)
Upper Barton Spring	26-Jun-02	30-Apr-02	26-Jun-02	2
	28-Feb-08	30-Nov-07	3-Apr-08	4
	Mean duration=3 months	29-Apr-10	4-Mar-10	8-Jun-10
Old Mill Spring	15-Jul-98	30-Sep-97	1-Oct-98	12
	2-Aug-99	12-Mar-99	7-Sep-99	6
	11-Jun-01	30-Apr-01	26-Oct-01	6
	31-May-02	24-Feb-02	24-Sep-02	7
	15-Oct-03	3-Jul-03	17-May-04	10
	22-Sep-05	18-Aug-05	19-Sep-05	2
Mean duration=7 months	24-Apr-08	14-Feb-08	15-May-08	3
Eliza Spring	5-May-04	21-Nov-03	7-Oct-04	11
	14-Jan-06	11-Aug-05	10-Aug-06	12
	2-Feb-07	15-Dec-06	13-Jul-07	7
	Mean duration=10 months	18-May-08	11-Jan-08	6-Oct-08
Barton Springs Pool	11-Jun-94	29-Mar-94	29-Aug-94	5
	20-Feb-96	8-Dec-95	2-Aug-96	8
	17-Jun-98	11-Mar-98	6-Aug-98	5
	20-Oct-99	2-Sep-99	16-Dec-99	3
	27-Jul-02	20-Feb-02	2-Dec-02	9
	31-Dec-03	3-Jul-03	22-Apr-04	9
	19-Jan-06	24-Oct-05	26-May-06	7
	20-Jul-08	21-Feb-08	4-Dec-08	9
Mean duration=7 months	5-Jun-10	31-Dec-09	22-Jul-10	7

Comparison of Two Survey Protocols

For decision making, we look at the data visually and we investigate it statistically for significant changes. The difference in visual presentations, under monthly and bimonthly survey protocols, is considered first followed by the effects on statistical significance.

Visual Comparison

Figure 3 compares the time series plots at Barton Springs Pool under the monthly and alternate months sampling frequencies. The bimonthly time series shows the same pattern as the original time series but misses the top of the highest peak. Whether we survey monthly or every other month, we will probably miss peak counts. More frequent sampling to determine peak counts is not an option as sampling disturbs the population. Therefore what we need to do is make sure we do identify each major period of increase/decrease in counts. (Note that the swings in counts may not be mirrored by changes in the populations as we do not know what is happening underground.) Examination of the plot shows that the durations of the count swings last many months. Table 2 lists the number of surveys under both survey protocols for the five periods with the highest counts in Barton Springs Pool. Even during the shortest period (in 2010)

there are enough surveys to characterize the period of expansion and contraction under the reduced frequency surveying protocol.

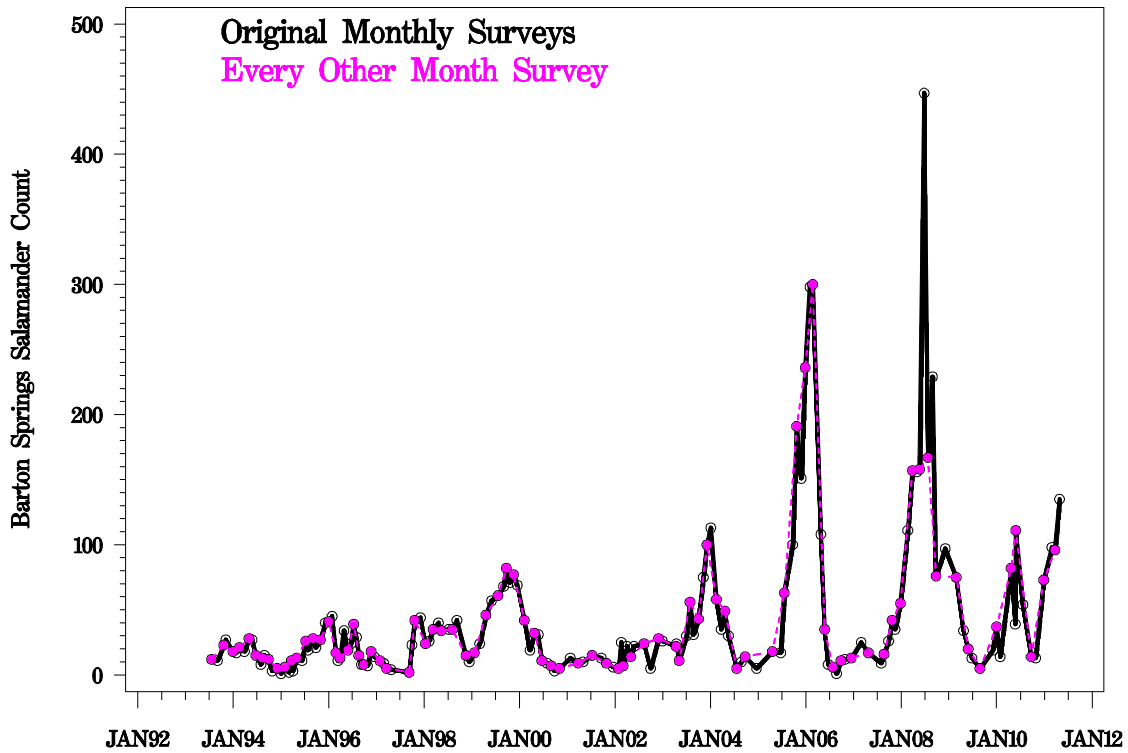


Figure 3. Comparison of the time series of counts of Barton Springs Salamanders in Barton Springs Pool from monthly surveys versus surveying every other month.

Table 2. Number of surveys during major increase/decrease periods under two surveying protocols in Barton Springs Pool

Major boom/bust periods	# of surveys under the monthly protocol	# of surveys – every other month protocol
1999	14	7
2003	11	5
2005	11	5
2008	18	9
2010	8	4

Figure 4 compares the time series counts at Eliza under both protocols. In this case there is very little difference in the two time series. The timing of the peak count in 2005-2006 looks earlier under the bimonthly month protocol, but the duration and size are similar.

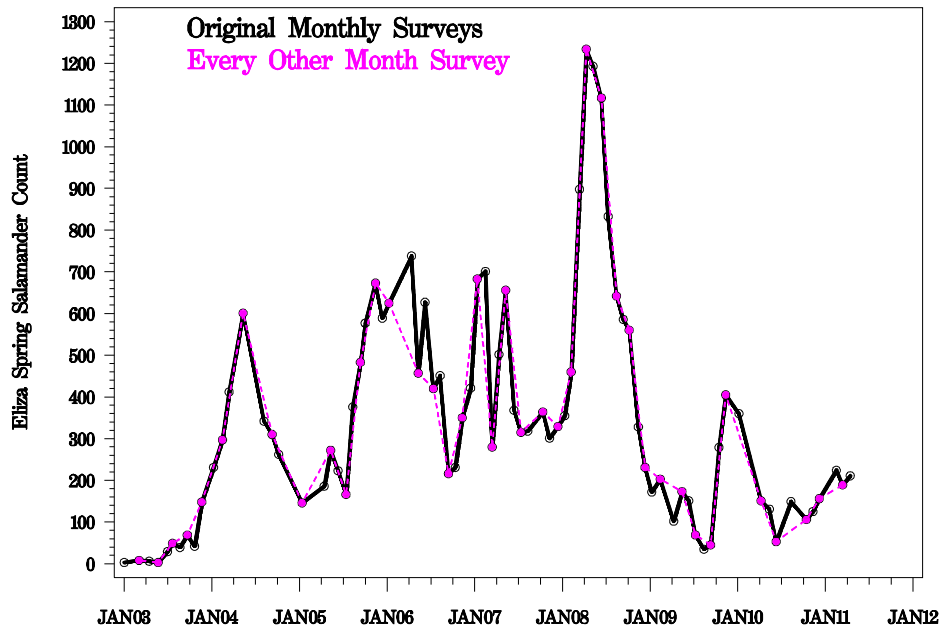


Figure 4. Comparison of the time series of counts of Baton Springs Salamanders in Eliza Spring from monthly surveys versus surveying every other month.

Figure 5 compares the time series in counts at Old Mill Spring under both protocols. As with the counts at Eliza, there is very little difference in the two time series.

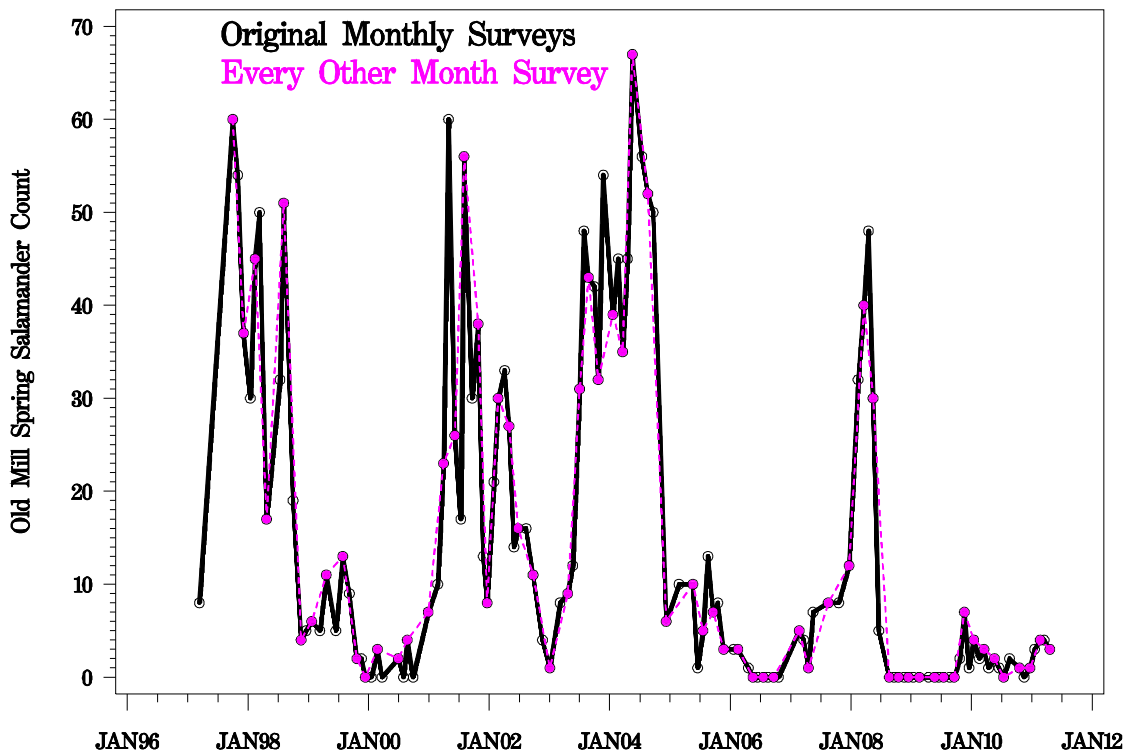


Figure 5. Comparison of the time series of counts of Baton Springs Salamanders in Old Mill Spring from monthly surveys versus surveying every other month:

Figure 6 compares the time series in counts at Upper Barton Spring under both protocols. The peak counts in 2010 would have been missed. That would have been a pity because that high count was interesting, but we would likely catch another high count sometime. However the timing of the count swings is well matched.

Examination of the plots of the juvenile counts shows that the missed peak counts in Figures 2 - 6 are almost entirely composed of juveniles. There have probably been other peaks of juveniles that we have missed. However we have some information relating to can the kinds of conditions that lead to large increases (and decreases) in juvenile counts. This, I think, is the important information, not the actual maximum count. Adding prey abundance to our set of collected parameters may shed more light on juvenile count swings than maintaining the current survey frequency.

Surveys could be done every 6 weeks with 8 surveys per year instead of 6. This will get you a few more samples for reaching statistical significance sooner, but is unlikely to capture much more in the way of juvenile peaks than the every other month protocol. Monthly surveying is not frequent enough for that.

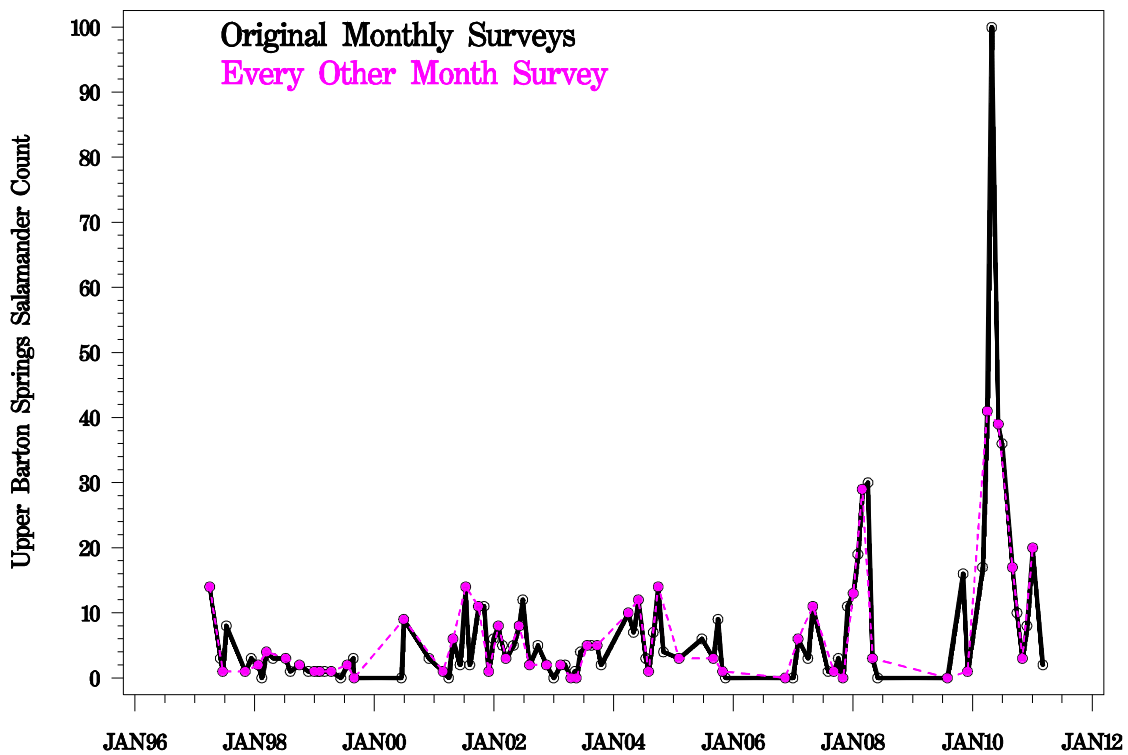


Figure 6. Comparison of the time series of counts of Baton Springs Salamanders in Upper Barton Spring from monthly surveys versus surveying every other month.

Statistical Analyses

While the time series are visually similar, what about the summary statistics? I calculated the summary statistics using two scenarios for the bimonthly sampling: sampling during even months or sampling during odd months. The mean, median, upper

and lower quartiles, the range and the variance for monthly and bimonthly sampling are shown in Table 3. Most of the values are very close. Those with large differences are highlighted. The major differences are found in the range and the variance when a high juvenile count was missed. The primary consequence is an increase in your confidence limits. The means do not change much, but your level of certainty about the mean decreases.

Table 3. Summary Statistics for monthly and bimonthly sampling

	Data	N	Mean			Median		
			Total	Adults	Juveniles	Total	Adults	Juveniles
Eliza	All	81	343	249	89	297	213	64
	Every other (odd)	41	344	253	87	301	238	59
	Every other (even)	40	343	245	91	289	209	70
Barton	All	170	43	25	17	24	13	9
	Every other (odd)	85	44	25	18	24	13	8
	Every other (even)	85	42	25	16	22	12	9
Old Mill	All	128	15	10	5	7	5	2
	Every other (odd)	64	15	9	6	6	3	2
	Every other (even)	64	15	10	5	7	5	2
Upper Barton	All	100	7	5	2	3	3	0
	Every other (odd)	50	8	5	2	3	3	0
	Every other (even)	50	7	5	2	3	3	0

	Data	N	The Upper Quartile			The Lower Quartile		
			Total	Adults	Juveniles	Total	Adults	Juveniles
Eliza	All	81	460	343	119	151	128	18
	Every other (odd)	41	451	338	122	151	132	18
	Every other (even)	40	472	344	115	150	101	17
Barton	All	170	43	26	20	12	6	3
	Every other (odd)	85	40	27	18	11	6	3
	Every other (even)	85	46	25	20	13	6	4
Old Mill	All	128	29	13	6	1	1	0
	Every other (odd)	64	26	11	6	1	1	0
	Every other (even)	64	29	16	6	2	1	0
Upper Barton	All	100	9	7	1	1	1	0
	Every other (odd)	50	8	7	1	1	1	0
	Every other (even)	50	10	7	1	1	1	0

	Data	N	Range			Variance		
			Total	Adults	Juveniles	Total	Adults	Juveniles
Eliza	All	81	1231	676	568	73384	31482	12135
	Every other (odd)	41	1190	675	488	70715	30892	11491
	Every other (even)	40	1231	671	568	78003	32860	13098
Barton	All	170	446	235	204	3553	1407	588
	Every other (odd)	85	446	235	204	4398	1488	847
	Every other (even)	85	298	224	102	2748	1342	334
Old Mill	All	128	67	58	44	332	173	62
	Every other (odd)	64	60	54	36	342	164	67
	Every other (even)	64	67	58	44	328	185	57

The question also arises as to the statistical significance of relationships between salamander counts and explanatory variables. What would reducing the frequency of sampling do to our ability to say that observed effects are statistically significant? Now, anytime you have fewer samples you will have less certainty in your results. However we will be surveying the salamanders as long as they are listed as endangered and we will take action (if possible) on effects that look like they are approaching significance without waiting for our type one error to be less than say 5%.

From the monthly surveys we determined that the relationship between dissolved oxygen 6 months prior and salamander counts was significant. This relationship is discussed here, not as an indication of its importance in understanding the salamander population levels, but merely to indicate what we would have concluded or done differently if sampling had been conducted less frequently. Table 4 shows the change in significance levels for surveys taken every month in Barton Springs Pool. R^2 is not high under either survey protocol. There are lots of other factors involved. The Pr>F increases as the number of surveys decreases, as expected. If you sampled only on alternate months your conclusions are no longer significant at the 0.05 level for juveniles and the total count. However the results are enough to tell you that something is probably going on and that with a few more data points you will probably be able to conclude that your regression is statistically significant for those two groups. If in addition you consider your data and notice that most of the apparent outliers are related to high flow periods, you can show significance during average and low flow periods. Also if you had surveyed 8 times per year rather than 12, all results would have remained significant at the 0.05 level.

Table 4. Significance Levels of Barton Springs Salamander Counts at Barton Springs Pool from 1993 – 2011 regressed on 6 month lagged DO

Salamander Group	Data	N	Pr>F	R square
Total	monthly	118	0.0079	0.0592
	every other month	59	0.0599	0.0607
Juvenile	all	118	0.0051	0.0656
	every other month	59	0.0935	0.0480
Adult (>1")	all	118	0.0190	0.0465
	every other month	59	0.0426	0.0707

At Eliza Spring the regression was significant only for juveniles (Table 5). There is substantially less data since only counts from 2004 are considered, as there was a major change in counts following habitat restoration in 2003. Dropping survey data from alternate months results in a major increase in Pr>F. As with the pool, the apparent outliers are collected under high flow conditions and the regression becomes significant for average and low flows for juveniles.

As a practical consideration, the loss of data and the subsequent loss of significance would not have changed our reaction to the data analysis. The studies that were initiated relative to dissolved oxygen and salamander survival would have still been done as well as the analyses relating dissolved oxygen and discharge at Barton Springs Thus I think that reducing survey frequency will not prevent us from determining other important factors for salamander survival in the future.

Table 5. Significance Levels of Eliza Spring Juvenile Salamander Counts from 2004 through 2011 regressed on 6 month lagged DO

Salamander Group	Data	N	Pr>F	R square
Juvenile	all	59	0.0408	0.0714
	every other month	29	0.1678	0.0646
	Every other month at average and low flows (<80 cfs)	20	0.0242	0.2291

The need for additional information.

Examination of the data collected to date has revealed one important omission; we do not have quantitative information on prey availability. Studies recently conducted by J. H. Gillespie indicate that the Barton Springs salamanders are preferential feeders on planaria, with amphipods and chironomids as second choice food items. We have some qualitative information on various prey species but the information is not adequate. We can not investigate the relationship between prey availability and population swings with out more quantitative data. To collect this data and I.D. the samples will take time and under the current survey protocol there is no available staff time, and in fact current surveys can not be completed by the salamander team without the addition of staff from other teams. I think that the addition of prey data with reduced frequency of salamander counts is likely to add more to our understanding of salamander count patterns than maintaining the current monthly frequency without adding the quantitative prey data.

There may be other information that we discover we need as more studies are done on the salamanders. With a protocol of surveying on alternate months, we will have the ability to start collecting the additional information as soon as the need for that information becomes apparent.

Conclusions

- Peak counts are probably missed under both the bimonthly and the current monthly sampling protocol. However, the periods of major increases and decreases in counts will not be missed if we switch to bimonthly sampling.
- There is not much difference in the impact of the count plots under the two sampling protocols. Underestimates of peak counts re the most obvious differences. However, regardless of our sampling frequency, we will miss the maximum counts.
- With fewer data points we will need longer times periods or more nuanced analysis methods to show statistical significance. However, for the investigated analyses, the loss of data and the subsequent loss of significance would not have changed our reaction to the data. With an endangered species you need to take action when the trend of the data indicates a potential problem. You do not wait for significance.
- The ability to collect other information is likely to add more to our understanding of salamander dynamics than the maintenance of a monthly sampling protocol.