2016-2018 Fecal Coliform Bacteria for Streams in Mason County in the South Puget Sound Watershed

Final Report
Prepared by:
Squaxin Island Tribe- Erica Marbet
Field Data Collection- Joe Puhn
GIS- Brian McTeague

For: Mason County and other stakeholders

Contents

Executive Summary

The Squaxin Island Tribe Natural Resources Department collects a monthly grab sample for fecal coliform bacteria at the mouths of 18 freshwater streams in Mason County (Figure 1 through Figure 5). These streams are in Washington State Department of Ecology's (ECY) Water Resource Inventory Area (WRIA) 14 (Kennedy-Goldsborough), in the South Puget Sound watershed. These sampling efforts began in 2004 to ensure monitoring of freshwater inputs to shellfish beds in the County. The Tribe collects all samples on the same day and delivers them for processing to ECY's Manchester Environmental Laboratory. The Tribe's sampling is covered under Quality Assurance Project Plan approved by the Environmental Protection Agency in December 2017. The reporting in this document is an update with 2016 to 2018 data added on.

To give a general assessment of each stream over the years, we have assigned a letter grade. We did this by looking at the range of bacteria concentrations in our samples and ranking each stream (see Standards). The rest of the report gives details on bacterial concentrations for all streams.

The following are a set of "letter grades" for monitored creeks:

A-Coulter, South Fork Goldsborough, Schumocher

A~- Johns, Deer, Malaney, Sherwood

B- Cranberry, Goldsborough, Mill

C- Campbell, Uncle Johns, Shelton, Little, Hurley, Skookum

D- Unnamed "TR24", "RVP1"

Most Mason County WRIA 14 streams, that we sample, have satisfactory bacteria levels for water quality. Here we offer potential explanations, based on our professional experience and existing studies, for levels of bacteria that we found. Streams with an A grade are in watersheds with human low population density and often the presence of cold, clean groundwater. Moving from letter grade A to A- to B, there is a greater proximity of humans to the stream, or there is a greater concentration of wildlife and livestock animals. When residential lots and small farms fill an area, wildlife are concentrated into the open spaces that are left, and those are often near streams. For streams with a C grade, the concentration of wildlife, humans, and livestock increases. For example, Skookum Creek has more intensive livestock presence in the valley farms, but the casino campus is there as well. Shelton Creek has the highest density of humans and pets and associated urban street waste with direct storm drain connections to the creek itself. Streams with a D are associated with livestock, but such high bacterial concentrations are not necessarily easy to pin down to just that source.

Standards

We have applied the Washington State fresh water standard to these data (WAC 173-201a-200(2)(b)).

Table 1. Washington State WAC173-201a-200 (2)(b), Water Contact Recreation Bacteria Criteria in Fresh Water, Primary Contact

Fresh Water Standard *Source-WAC 173-201a-200 (2)(b)*	Fecal coliform organism levels must not exceed a geometric mean value of **100** colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding **200** colonies/100 mL.

Geometric Mean versus Arithmetic Mean-

Where ***a*** is a fecal coliform concentration for each sample and ***n*** is the number of samples collected.

Arithmetic Mean(average)

$$AM = \frac{a_1 + a_2 + a_3 + \ldots + a_n}{n}$$

Geometric Mean

$$GM = \sqrt[n]{a_1 a_2 a_3 \ldots a_n}$$

Geometric mean is used to summarize all sample data without being heavily influenced by extreme values and is standard for analyzing water quality results. Arithmetic mean, however, is very influenced by extreme values and may not accurately describe a water body's water quality.

"Not more than 10 percent of all samples exceeds 200 colonies/100 mL"- This is also called the "**90th Percentile**". In other words, 10 percent of the samples' concentrations fall above this value (200 colonies/100mL), and 90 percent fall below the value. In this case the regulation states that if the value of the 90th percentile is greater than 200 colonies/100mL, then that stream has exceeded the threshold for water quality standards as it relates to primary contact (recreational use). To be precise, we used the "estimated 90th percentile", which is listed in Appendix I. Detailed Definition of the *Estimated* 90th Percentile.

Letter Grades

We developed letter grades as a way to rank these sites for water quality and communicate with the public. We built the grades based on the range of bacterial concentrations from our sample data.

- **A** Geometric mean not greater than 20, estimated 90th percentile not greater than 140
- **A-** Geometric mean not greater than 30, estimated 90th percentile not greater than 180
- **B** Geometric mean not greater than 40, estimated 90th percentile not greater than 200
- **C** Geometric mean not greater than 200, estimated 90th percentile not greater than 500
- **D** Geometric mean not greater than 250, estimated 90th percentile not greater than 2500

Units are colonies per 100 mL.

Results and Discussion

Table 2 is a summary of geometric means and 90th percentiles over 16 years at listed sites. They generally fall into groups by letter grade (as described in Standards). Figure 6 is a raw time series plot of fecal coliform concentrations and example locations. Figure 7, Figure 8, and Figure 9 are plots of rolling geometric means and estimated 90th percentiles. Note that the year 2015 had higher bacterial concentrations than other years.

A-**Coulter, South Fork Goldsborough, Schumocher** – Generally clean, almost "background conditions". There are fewer people and domesticated animals in these watersheds. Geometric mean not greater than 20, estimated 90th percentile not greater than 140 colonies per 100 mL.

A$^-$- **Johns, Deer, Malaney, Sherwood** – Though these streams still have fairly low fecal coliform concentrations, human and animal populations are larger. Geometric mean not greater than 30, estimated 90th percentile not greater than 180 colonies per 100 mL.

B- **Cranberry, Goldsborough, Mill-** Density of humans and domesticated animals is larger in the watershed, and wildlife are concentrated in patches of undeveloped land. Geometric mean not greater than 40, estimated 90th percentile not greater than 200 colonies per 100 mL.

C- **Campbell, Uncle Johns, Shelton, Little, Hurley, Skookum-** For all but Shelton Creek, causes of higher bacterial concentrations include septic systems and livestock. Shelton, Little, and Skookum creeks also have transient human waste, pet waste, and bacteria associated with garbage from streets and parking lots. Geometric mean not greater than 200, estimated 90th percentile not greater than 500 colonies per 100 mL.

D- **Unnamed "TR24", "RVP1"**- Both of these streams have livestock in close proximity. Geometric mean not greater than 250, estimated 90th percentile not greater than 2500 colonies per 100 mL.

Table 3 is a coarse calculation of bacterial load. The bacterial load of a stream is the concentration of bacteria multiplied by the volume of discharge of the stream. The Tribe monitors discharge at six streams and pays the US Geological Survey to monitor discharge at Goldsborough Creek. Streams with high concentrations of bacteria may have low discharges, and so their bacterial load is still low. Streams with low bacterial concentrations that have higher discharges may still have a high bacterial load. Goldsborough Creek is a good example of that. Bacterial loads are greatest during storms. Again, even if the bacterial concentration is low, the discharge very high. Furthermore, surface runoff flows from more of the watershed during storms, thereby accessing bacteria stored on the land surface that had previously been stationary.

In the future we will be doing some storm based sampling of bacteria in order to see how concentrations change on the rising and falling end of storm hydrographs.

Maps

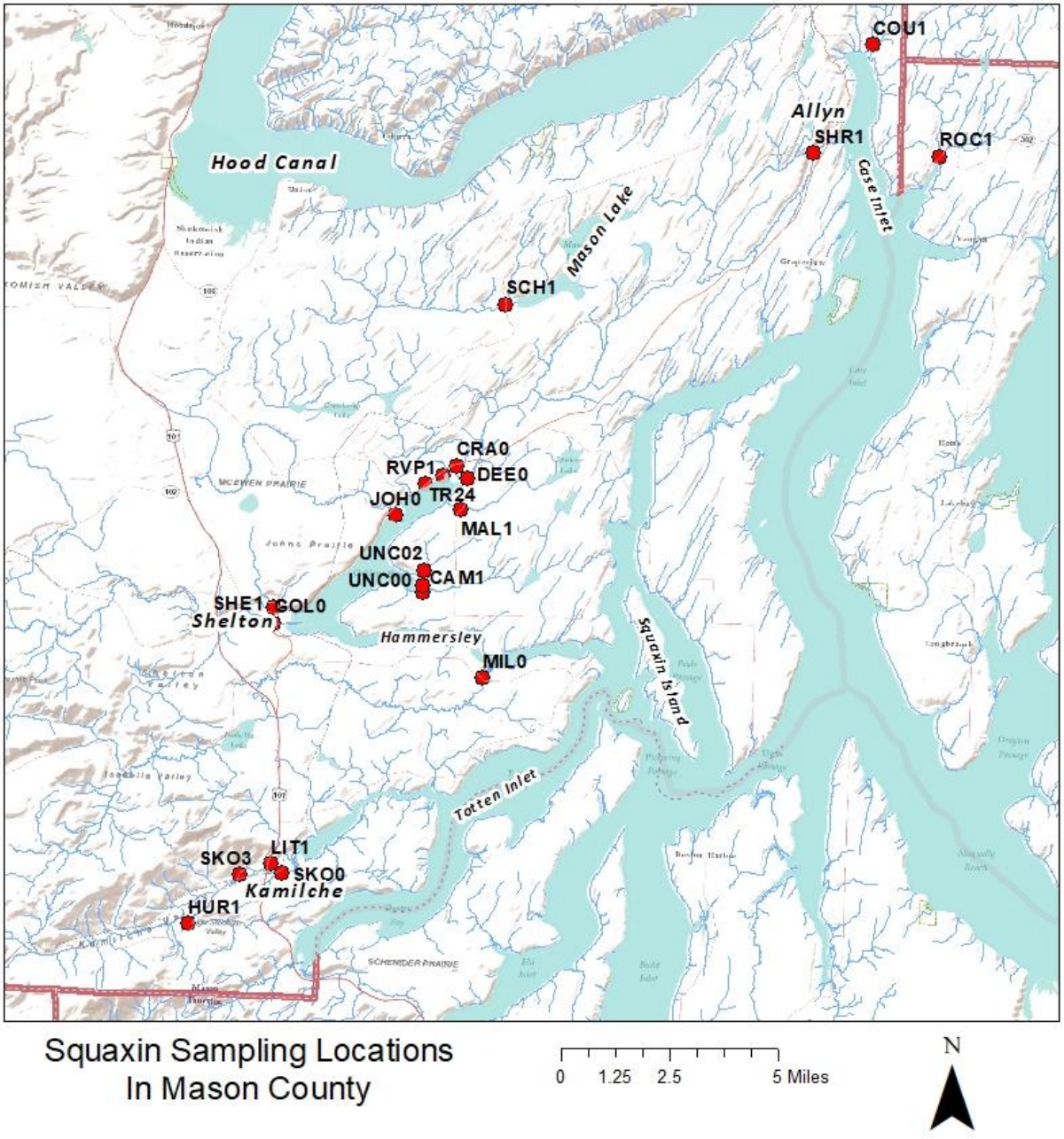

Figure 1. Squaxin Island Tribe ambient sampling. See details in following pages. Includes these creeks: Coulter (COU1), Sherwood (SHR1), Schumocher (SCH1), Cranberry (CRA0), unnamed (RVP1), unnamed (TR24), Johns (JOH0), Deer (DEE0), Malaney (MAL1), Uncle Johns (UNC00 and UNC002), Campbell (CAM1), Shelton (SHE1), Goldsborough (GOL0), South Fork Goldsborough (GOLS3), Skookum (SKO0 and SKO3), Little (LIT1), and Hurley (HUR1). Rock Creek (ROC1) has historical data. However it is outside Mason County, and did not sample it in the 2016-2018 period.

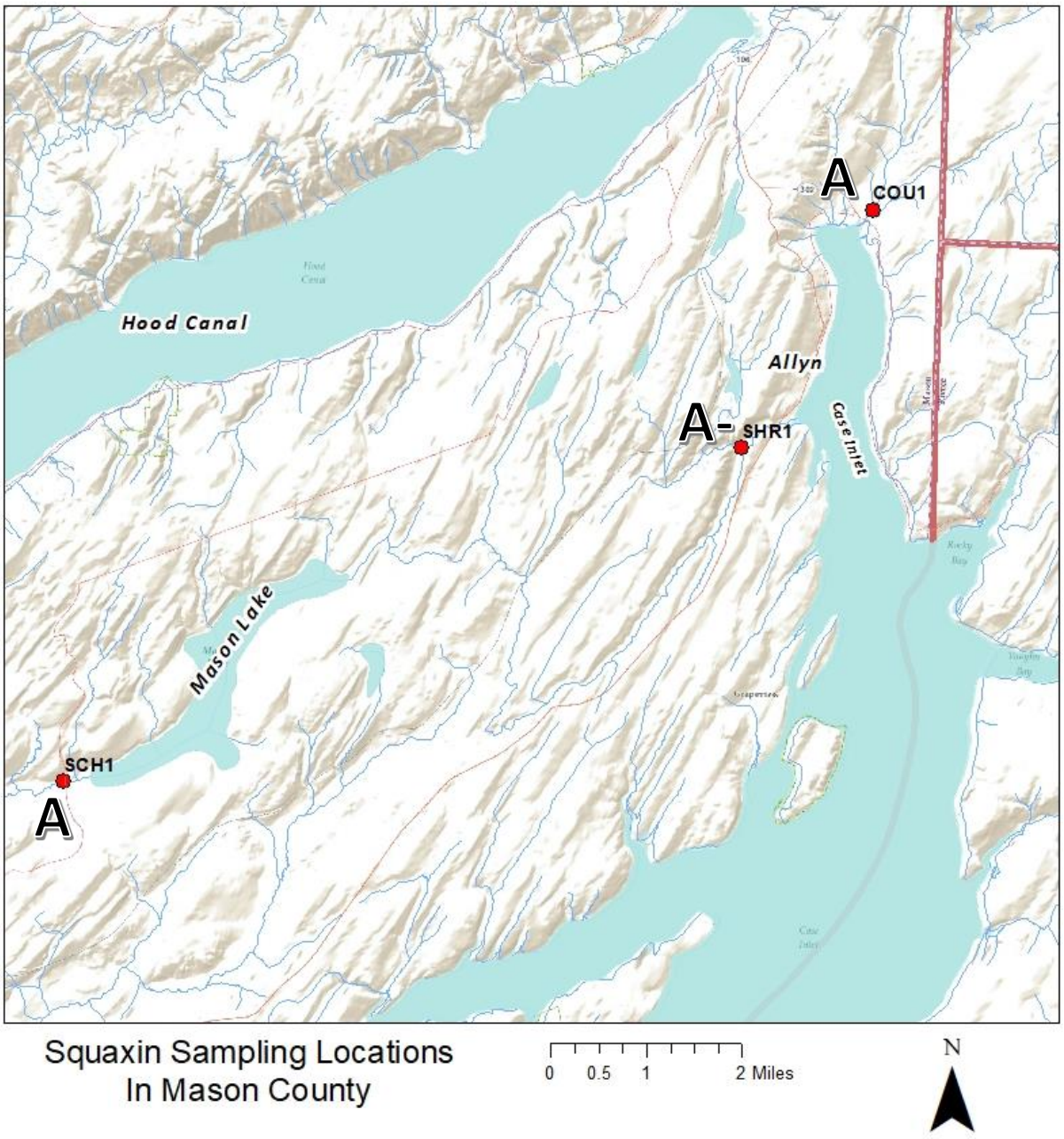

Figure 2. North Mason County- Includes these creeks: Coulter (COU1), Sherwood (SHR1), Schumocher (SCH1). Each creek has a letter grade next to it.

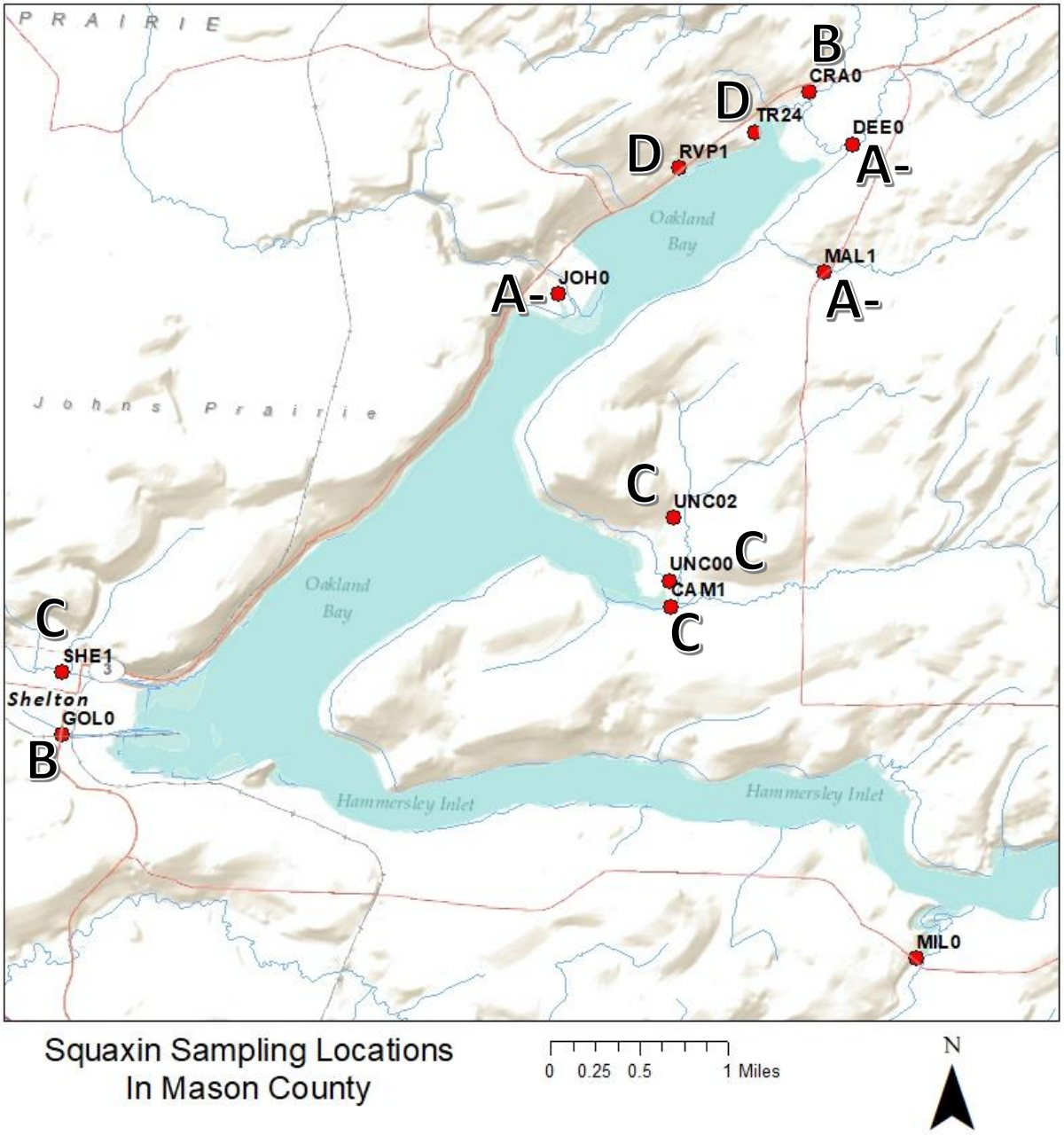

Figure 3. Oakland Bay area- Includes these creeks: Cranberry (CRA0), unnamed (RVP1), unnamed (TR24), Johns (JOH0), Deer (DEE0), Malaney (MAL1), Uncle Johns (UNC00 and UNC002), Campbell (CAM1), Shelton (SHE1), Goldsborough (GOL0). Each creek has a letter grade next to it.

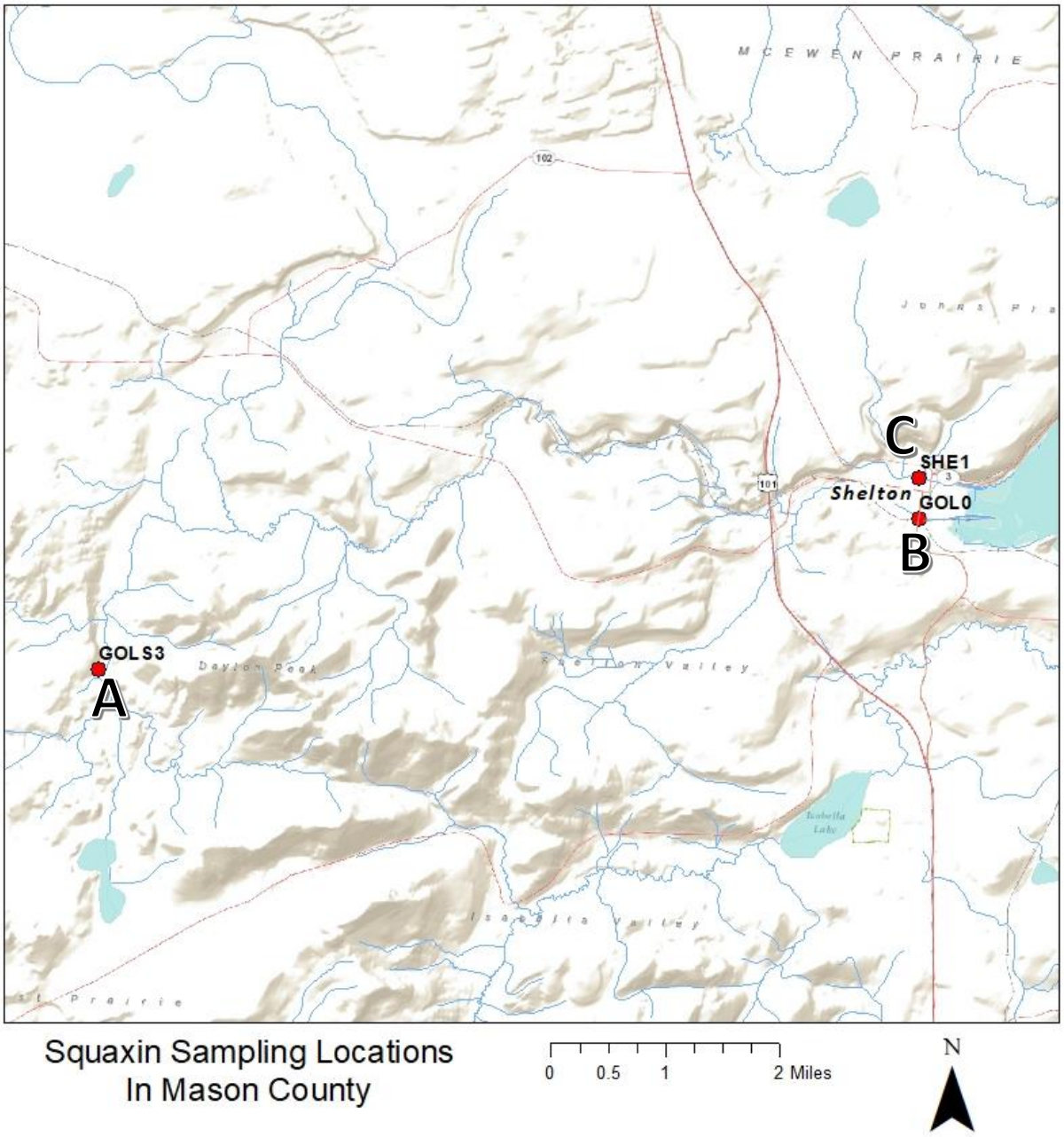

Figure 4. Includes these creeks: Shelton (SHE1), Goldsborough (GOL0), South Fork Goldsborough (GOLS3). Each creek has a letter grade next to it.

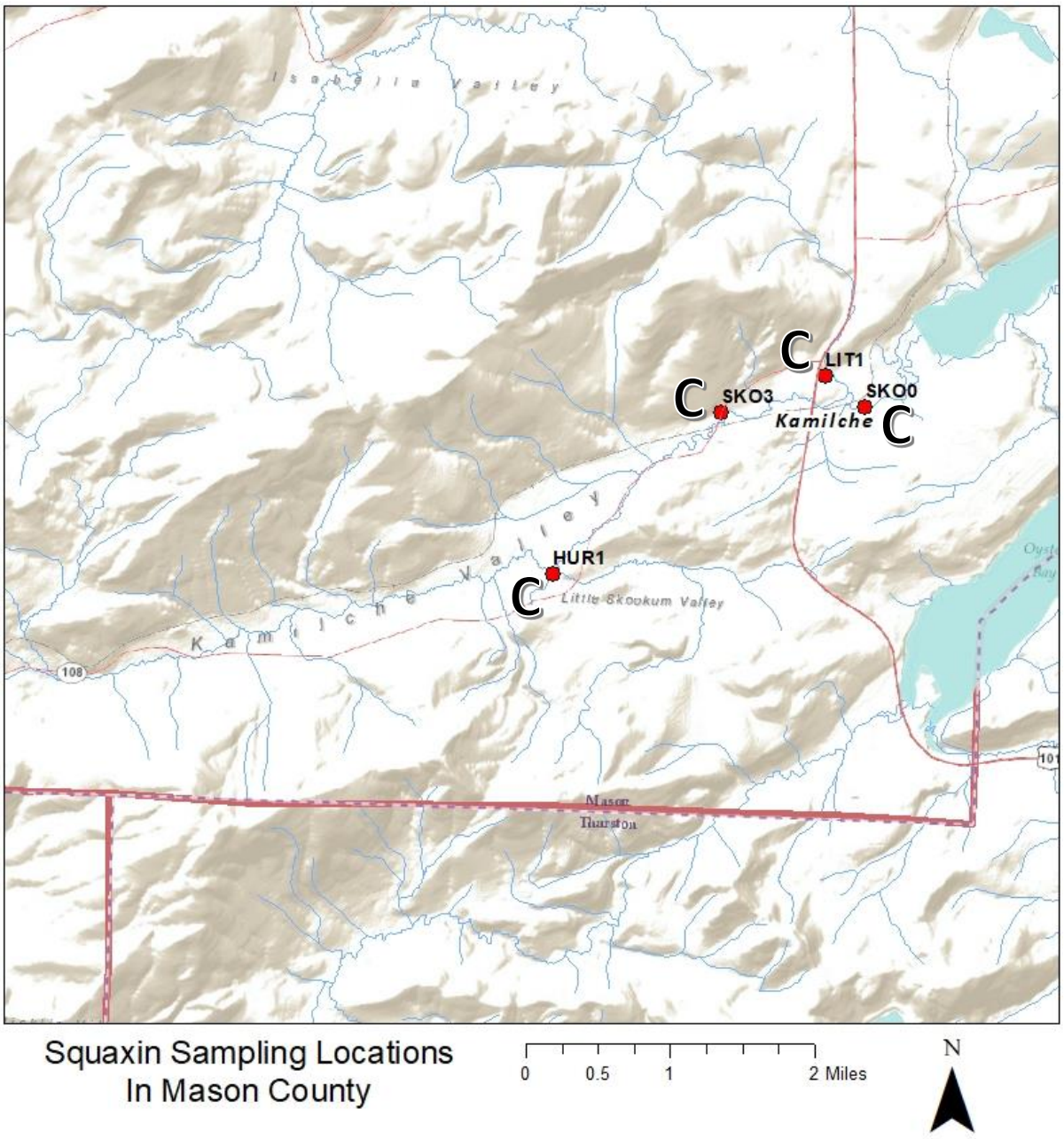

Figure 5. Includes these creeks: Skookum (SKO0 and SKO3), Little (LIT1), and Hurley (HUR1). Each creek has a letter grade next to it.

Figures and Tables

Table 2. Statistical summary of fecal coliform concentration at Squaxin Island Tribe sampling sites (# of colonies per 100 ml). Geometric means and estimated 90th percentiles boxed in red have exceeded the threshold standard concentrations described on page 3.

		Geometric Mean							90th Percentile						
	Site	2004-2012	2013	2014	2015	2016	2017	2018	2012	2013	2014	2015	2016	2017	2018
Campbell 1	CAM1	22	15	31	28	69	79	53	142	54	107	116	172	271	144
Coulter 1	COU1		11	17	18	12	16	17		55	52	89	42	55	80
Cranberry 0/1	CRA0/1	38	12	10	26	32	21	23	157	85	52	129	191	122	94
Deer 0	DEE0	22	21	20	26	19	29	22	113	102	93	95	60	125	74
Goldsborough 0	GOL0	27	29	26	25	25	30	42	120	100	88	101	81	149	99
SF Goldsborough 3	GOLS3					15	13	20					44	85	137
Hurley 1	HUR1	46	12	20	63	20	24	60	279	72	155	222	108	102	318
Johns 0/1	JOH 0/1	14	9	15	23	14	21	19	59	31	44	70	27	59	54
Little 1	LIT1	32	10	22	52	27	21	27	185	94	125	317	91	109	63
Malaney 1	MAL1	28	17	21	26	17	27	22	172	131	128	101	45	121	139
Mill 0	MIL0	17	12	32	32	28	27	27	70	25	152	72	62	107	80
Rocky 1	ROC1		21	18	36					214	58	71			
RV Park 1	RVP1					38	181						122	2034	
Schumocher 1	SCH1					7	13						26	60	
Shelton 1	SHE1	71	63	53	88	56	95	94	449	340	140	235	228	362	358
Sherwood 1	SHR1		16	18	29			26		59	39	64			114
Skookum 0	SKO0	45	26	41	72	31	50	48	275	56	156	165	113	232	215
Skookum 3	SKO3	45	28	36	53	33	63	48	231	108	89	104	162	220	125
TR24	TR24	69	25	28	116		144	194	1012	261	372	854		782	621
Uncle Johns 0	UNC00	55	21	42	82	92	60	69	324	72	181	450	478	346	216
Uncle Johns 2	UNC02		17	36	76	53				65	125	299	233		

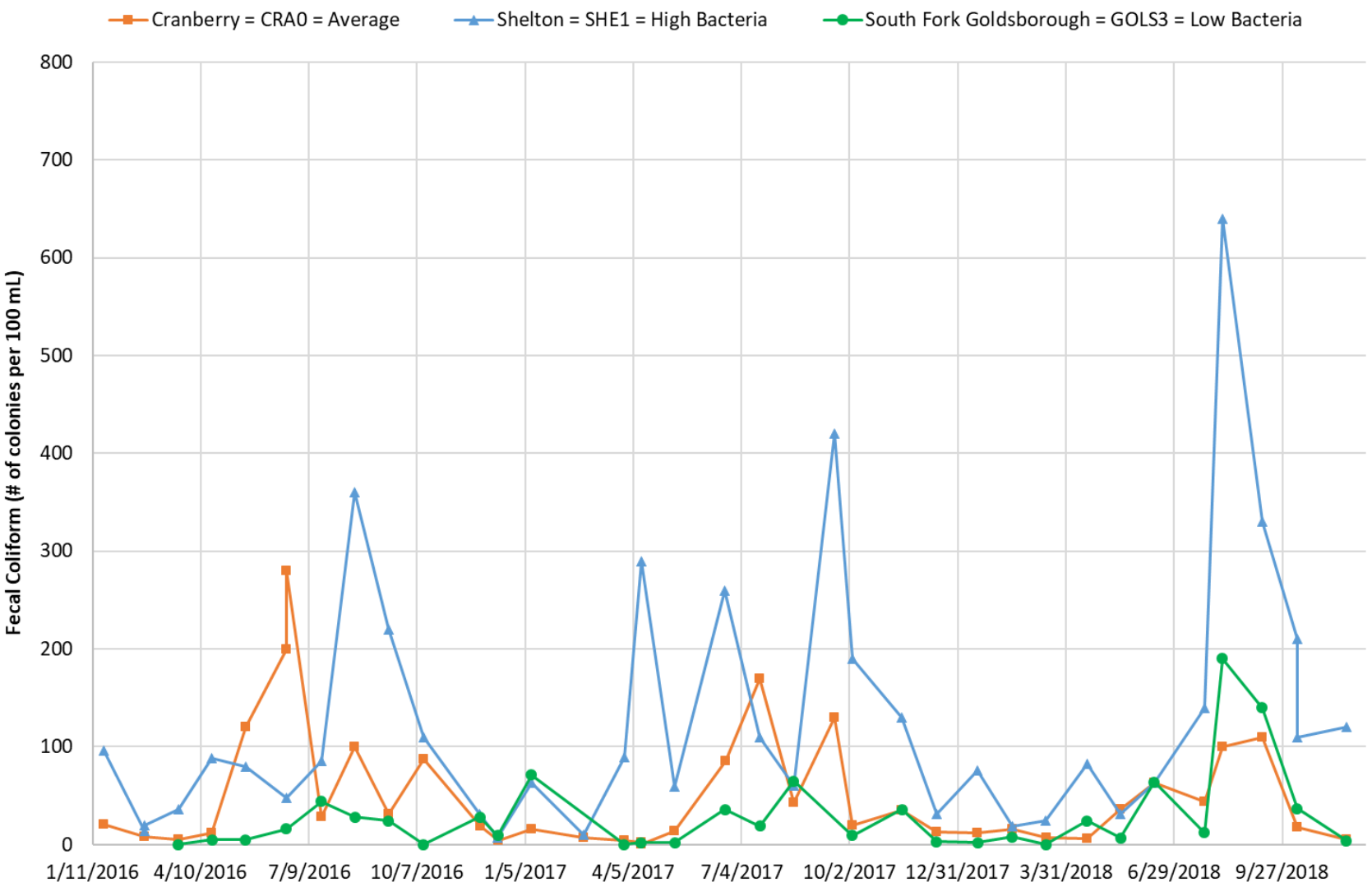

Figure 6. Plot of fecal coliform concentration of monthly grab samples at three creeks, representing different conditions. Creeks like Cranberry and Shelton generally have higher counts during the summer months.

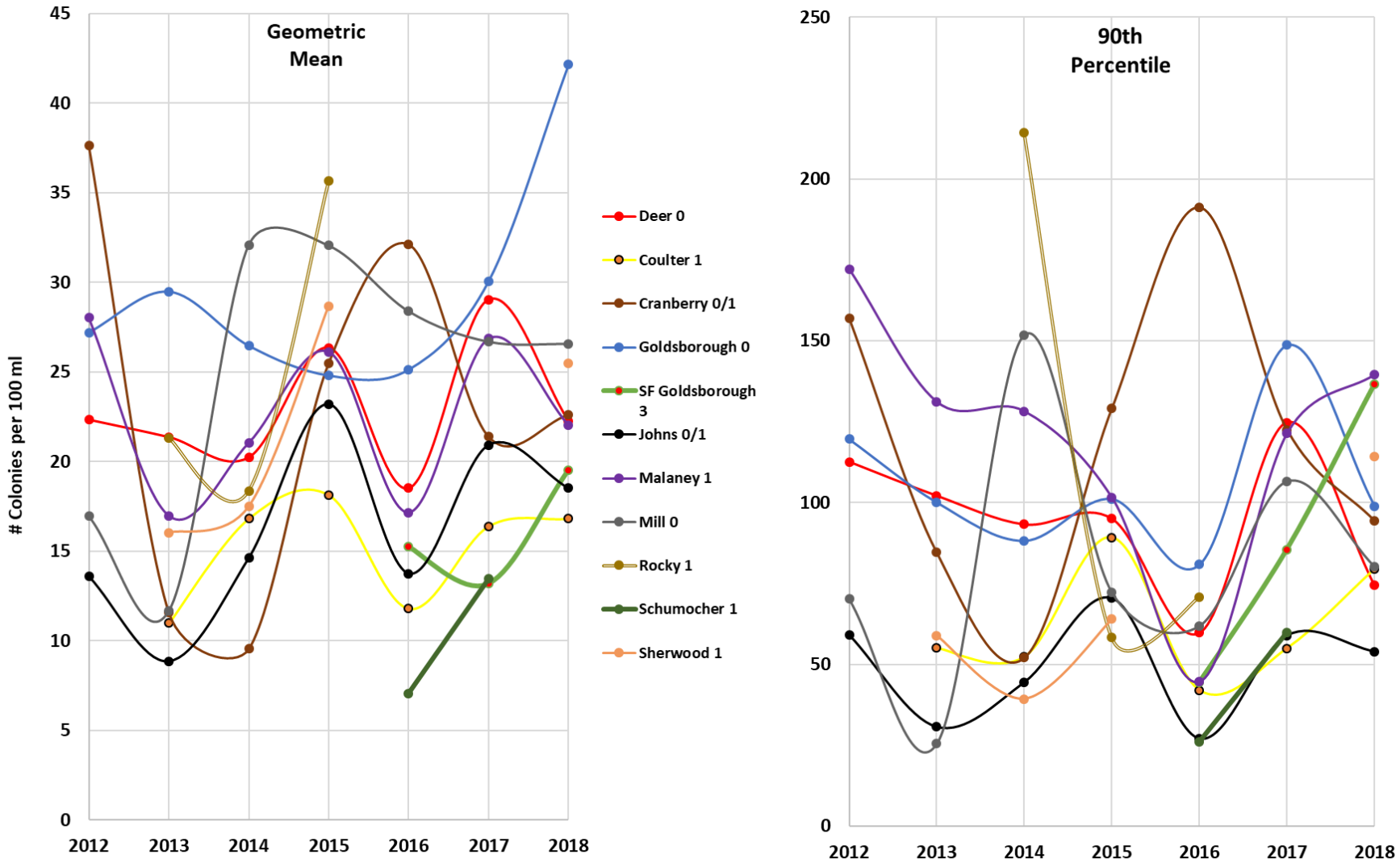

Figure 7. Of sampled creeks, these have lower fecal coliform concentrations. Geometric means did not exceed the state regulatory threshold of 100 colonies per 100 ml. Only Rocky Creek exceeded the estimated 90th percentile of 200 colonies per 100 ml.

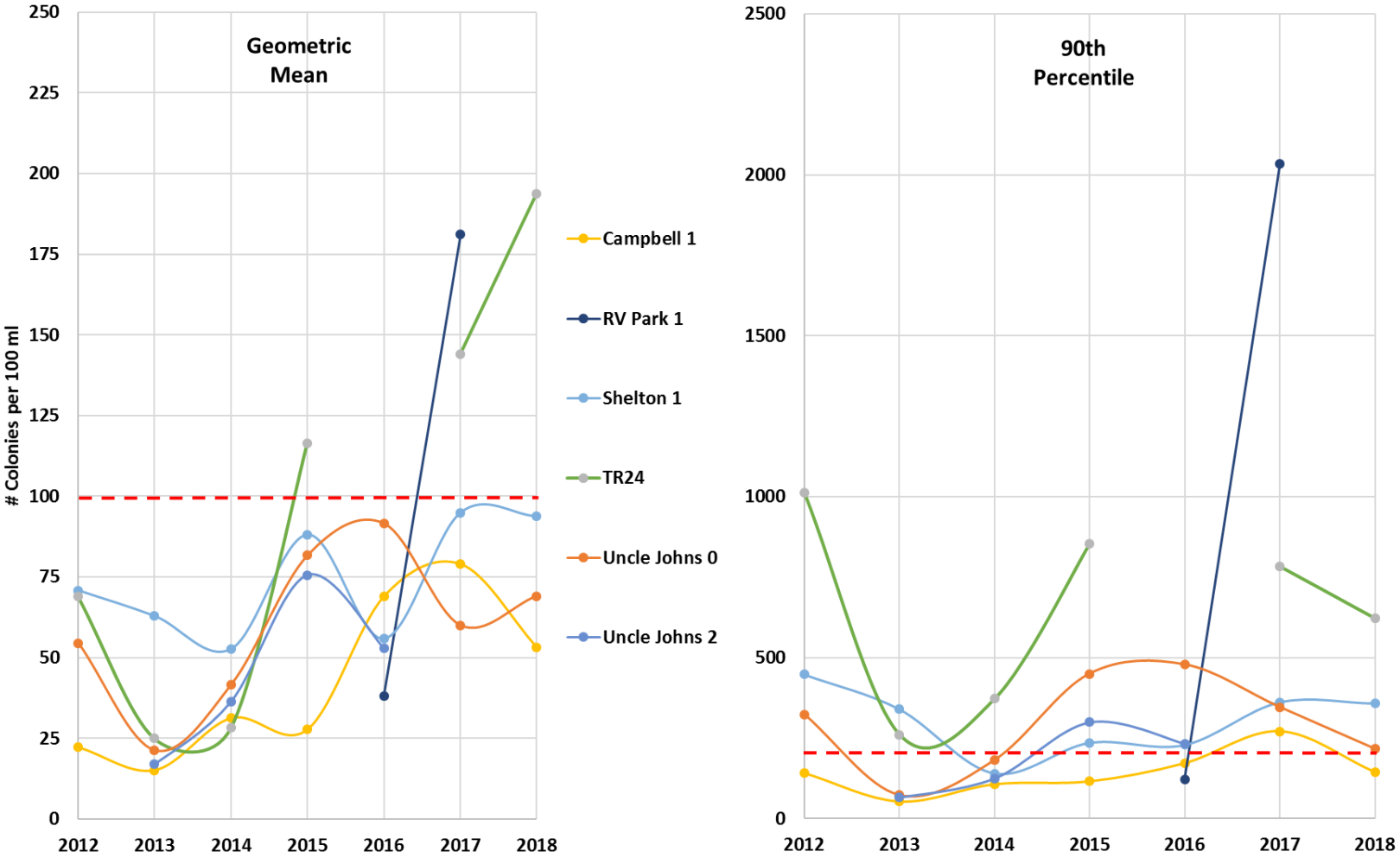

Figure 8. Of sampled creeks, these have higher fecal coliform concentrations. Geometric means approached and exceeded the state regulatory threshold of 100 colonies per 100 ml. All creeks exceeded the estimated 90th percentile of 200 colonies per 100 ml

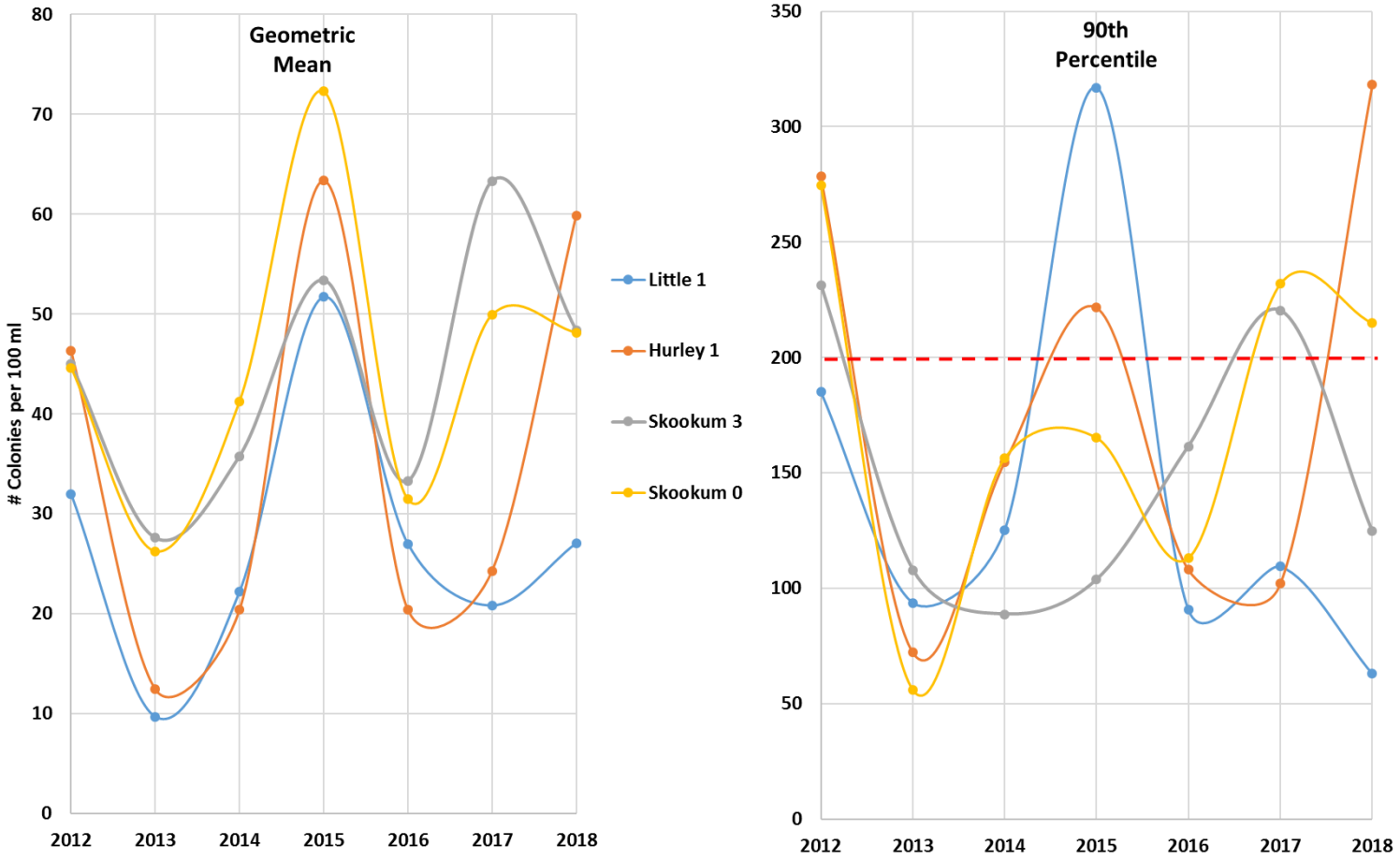

Figure 9. Of sampled creeks, the Skookum watershed and tributaries have higher fecal coliform concentrations, though geometric means did not exceed state regulatory threshold of 100 colonies per 100 ml. All creeks exceeded the estimated 90th percentile of 200 colonies per 100 ml.

Table 3. Bacterial load calculations from seven creeks that have long term gaging stations. Green indicates low smaller loads, yellow indicates moderate loads, and red indicates higher loads.

Average Flow, Average Concentrations	**Geometric Mean of Fecal Coliform**	**Mean Annual Flow**	**Mean Daily Load**
Location	**# of colonies per 100 mL**	**cfs**	**billion colonies per day**
Coulter at Hwy. 302 (COU1)	15	36	1.3
Cranberry at Hwy. 3 (CRA 0/1)	25	39	2.4
Goldsborough at Hwy. 3 (GOL0)	32	162	12.7
Johns 1 at Hwy. 3 (JOH0/1)	18	43	1.9
Mill at Hwy. 3 (Flow, MIL2), and at Arcadia Rd. (Bacteria, MIL0)	27	66	4.4
Sherwood at Sherwood Creek Road *=(SHR1)	26	67	4.3
Skookum at Hwy. 101 (Flow, SKO1), and at Hwy. 108 (Bacteria, SKO0)	48	54	6.4
Low Flow, High Concentrations, as in summer	**90th Percentile of Fecal Coliform**	**7-day Low Flow**	**Load during 7-day Low Flow**
Location	**# of colonies per 100 mL**	**cfs**	**billion colonies per day**
Coulter at Hwy. 302 (COU1)	59	13	1.9
Cranberry at Hwy. 3 (CRA 0/1)	136	6	2.0
Goldsborough at Hwy. 3 (GOL0)	109	35	9.4
Johns 1 at Hwy. 3 (JOH0/1)	47	7	0.8
Mill at Hwy. 3 (Flow, MIL2), and at Arcadia Rd. (Bacteria, MIL0)	83	11	2.2
Sherwood at Sherwood Creek Road *=(SHR1)	114	9	2.4
Skookum at Hwy. 101 (Flow, SKO1), and at Hwy. 108 (Bacteria, SKO0)	187	1	0.7
High Flow, Average Concentrations, as during floods	**Geometric Mean of Fecal Coliform**	**Max Daily Flow**	**Max Daily Load**
Location	**# of colonies per 100 mL**	**cfs**	**billion colonies per day**
Coulter at Hwy. 302 (COU1)	15	695	26
Cranberry at Hwy. 3 (CRA 0/1)	25	602	37
Goldsborough at Hwy. 3 (GOL0)	32	1419	111
Johns 1 at Hwy. 3 (JOH0/1)	18	254	11
Mill at Hwy. 3 (Flow, MIL2), and at Arcadia Rd. (Bacteria, MIL0)	27	595	39
Sherwood at Sherwood Creek Road *=(SHR1)	26	709	45
Skookum at Hwy. 101 (Flow, SKO1), and at Hwy. 108 (Bacteria, SKO0)	48	839	99

Appendix I. Detailed Definition of the *Estimated* 90th Percentile

Determining the 90th percentile, as described in the Standards section, is a matter of ranking sample values and finding the bacterial concentration below which 90% of the samples fall.

The ***estimated*** 90th percentile is a calculation based on the shape of the normal distribution curve, assuming that the log of bacterial concentration is normally distributed.

Arithmetic mean of $\log_{10}$ of fecal coliform concentrations is equal to the **geometric mean** of those concentrations.

Where **a** = fecal coliform concentration (# of colonies per 100 mL) of a sample, mean is the mean the $\log_{10}$ of the sample set, stdev is standard deviation of $\log_{10}$ of the sample set, and 1.28 is the Z statistic for the normal distribution at 90th percentile

$$90th\ \% = 10^{(mean(\log_{10} \boldsymbol{a}) + 1.28 \times stdev(\log_{10} \boldsymbol{a}))}$$

The math formula in Excel is:

90th percentile =10^(AVERAGE(*LOG10 OF DATA ARRAY*)+1.28*(STDEV(*LOG10 OF DATA ARRAY*)))

Appendix II. Quality Control of Squaxin Island Tribe Fecal Coliform Sampling

A single blank and as single duplicate were taken on each day of sampling, occurring once a month. Samples were processed at WA Dept. of Ecology's Manchester Lab. The large relative percent difference is due to the variability of fecal coliform bacteria distribution in streams. We are looking for changes in order of magnitude as indicators of changes in bacterial concentration in streams. As an example, Hurley Creek has a 64% difference between duplicates 10/4/17. The duplicate values are 17 and 33 colonies per 100 ml. However, those two values are in the same order of magnitude. If the first measurement were 17, and the second were 170 col/100 ml, then there would be cause for concern. But 17 and 33 col/100 ml are essentially the same concentration.

Duplicates Analysis, 2016-2018 Fecal Coliform (# of colonies per 100 mL)

Site	Date	Sample	Sample Duplicate	Relative % Difference
HUR1	1/20/2016	7	5	33%
SHE1	2/23/2016	14	20	35%
SCH1	3/22/2016	2	0	200%
COU1	4/19/2016	5	4	22%
DEE0	5/17/2016	20	29	37%
CRA0	6/20/2016	200	280	33%
LIT1	7/19/2016	22	19	15%
LIT1	8/16/2016	57	47	19%
LIT1	9/13/2016	87	76	13%
SKO3	10/12/2016	51	60	16%
LIT1	11/28/2016	33	22	40%
HUR1	12/13/2016	13	14	7%
JOH0	1/10/2017	29	16	58%
CLA2	2/22/2017	0	2	200%
LIT1	3/28/2017	12	10	18%
CRA0	4/11/2017	2	0	200%
SKO3	5/9/2017	77	65	17%
DEE0	6/20/2017	71	49	37%
JOH0	7/19/2017	31	31	0%
DEE0	8/16/2017	57	49	15%
HUR1	10/4/2017	17	33	64%
CLA2	11/14/2017	15	10	40%
LIT1	12/13/2017	5	8	46%
LIT1	2/14/2018	32	24	29%
HUR1	3/14/2018	65	69	6%
SKO3	4/17/2018	35	29	19%
LIT1	6/12/2018	35	25	33%
SKO0	7/24/2018	170	160	6%
TR24	8/8/2018	320	630	65%
MIL0	9/10/2018	9	6	40%
SHE1	10/9/2018	210	110	63%
HUR1	11/19/2018	240	220	9%

**Null values were given a zero.*