– Appendix 1 –

**Statistical Evaluation of VDAPP and RIFE at Gasoline Dispensing Facilities with Balance Phase II Enhanced Vapor Recovery Systems**

***DRAFT***

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## A. Introduction

The purpose of this appendix is to document a statistical evaluation of percent volume dispensed at positive pressure (VDAPP) and reverse idle flow emissions (RIFE) at gasoline dispensing facilities (GDFs) with balance Phase II enhanced vapor recovery (EVR) systems during different short- and long-term monitoring efforts. The goal of this evaluation is to identify VDAPP and RIFE values that can be used to calculate reasonably conservative seasonal and annual estimates of current regional and statewide emissions from positive pressure at balance GDFs.

It is necessary to identify values that do not under-estimate regional and statewide emissions because CARB staff will use the emission estimates to assess the significance of pressure driven emissions on attainment of National Ambient Air Quality Standards (NAAQS) for ozone. In addition, values specific to winter (November through February) are needed because prior studies found positive pressure conditions are more prevalent during the winter when wintertime, high Reid Vapor Pressure (RVP) gasoline is sold. Further, values specific to summer (March through October) are needed because attainment of the ozone NAAQS is a concern in several regions of the state during the summer.

A determination of whether or not pressure driven emissions could have a significant impact on standards attainment will inform CARB staff's recommendations for potential changes to EVR regulations and for State Implementation Plan (SIP) strategies to attain and maintain NAAQS. CARB staff's preliminary evaluations conducted before all monitoring activities were complete indicated pressure driven emissions do not significantly affect the State's and Air District-specific ozone SIP commitments. This evaluation makes use of completed data sets. CARB staff will use the results of this evaluation to update statewide and regional estimates of emissions from balance GDFs and the evaluation of the potential significance of the pressure driven emissions.

# B. Methodology

## 1. Data Collection

Between 2013 and 2018, CARB staff conducted two types of monitoring that resulted in the generation of extensive VDAPP compilations: periodic, short-term "Mega Blitz" (Blitz) monitoring at numerous balance GDFs, and long-term monitoring at a smaller number of balance GDFs.

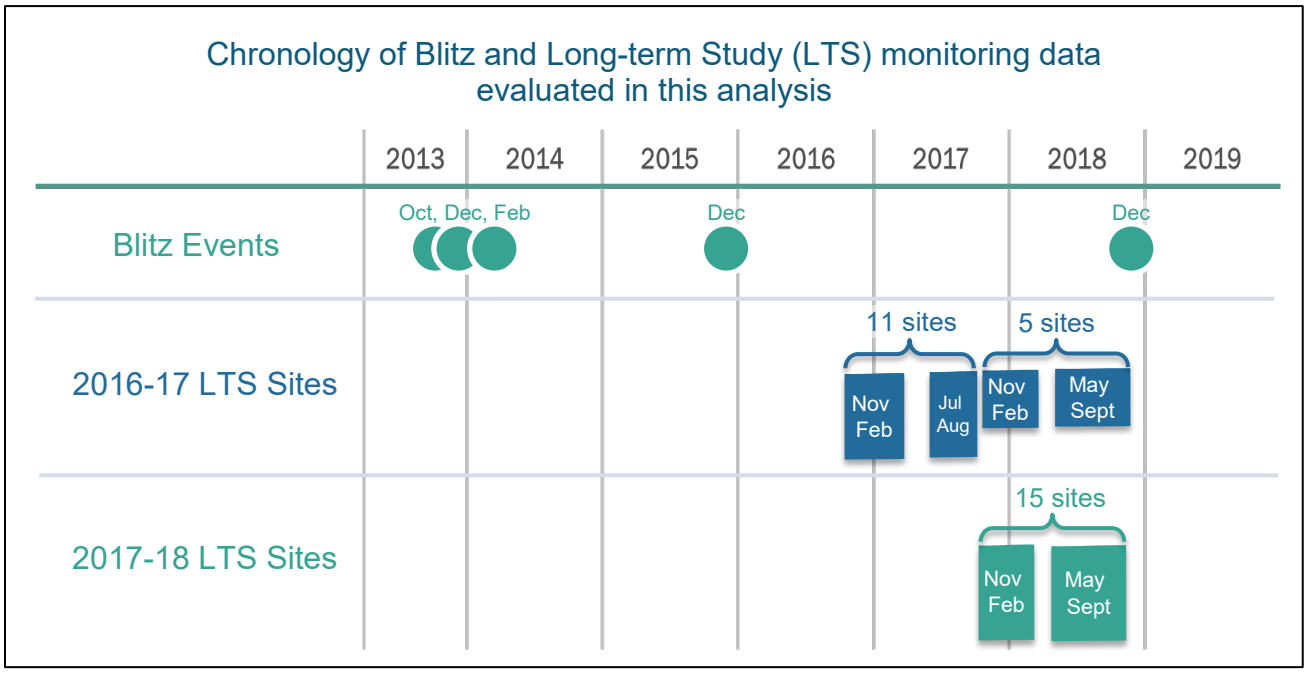
**Short-term "Mega Blitzes" (Blitz):** In-station diagnostic (ISD) system monitoring data were downloaded during the first two weeks of October 2013, December 2013, February 2014, December 2015, and December 2018. CARB staff used the pressure data to calculate a short-term (30-hour) VDAPP value for each balance GDF. Each Blitz monitoring event included from 77 to 108 balance GDFs. For the Blitz monitoring events, CARB selected GDFs with a variety of operating characteristics within defined geographic regions that collectively account for approximately 95 percent of the GDFs in California. CARB staff designed the site selection approach to produce monitoring data that can provide a relatively instantaneous "snap shot" of pressure conditions at the GDFs that, collectively, are representative of regional and statewide GDF operating conditions. CARB staff conducted Blitz monitoring in October 2013 to characterize conditions before high RVP (wintertime) gasoline is sold. CARB staff conducted Blitz monitoring in December 2013 and February 2014 because prior monitoring indicated overpressure conditions are more prevalent when high RVP gasoline is sold, typically reaching a maximum in December and declining through February. CARB staff conducted additional Blitz monitoring in December 2015 and December 2018 to evaluate long-term trends for the month that typically experiences the highest frequency of overpressure conditions.

The Blitz ISD system monitoring data enable the calculation of VDAPP but not RIFE. As described in the main body of this report, the ISD console does not store enough vapor flow meter totalizer data to produce a representative RIFE value.

**Long-term Study (LTS)**: CARB staff downloaded nearly continuous ISD system monitoring data between 2016 and 2018 from a subset of balance GDFs. The pressure data from this compilation can be used to calculate short-term (24-hour/daily) and long-term (weekly and seasonal) VDAPP values for each study site. Eight of the 11 GDFs first monitored in 2016-17 are all owned and operated by one company that volunteered its sites for long-term study. As described in the main body of this report, preliminary evaluations of the VDAPPs calculated for these sites indicated their distribution was substantially lower than the distribution of the 2013-2015 Blitz VDAPPs. As a result, for monitoring in 2017-18 CARB staff selected 15 additional GDFs that typically had higher 30-hour VDAPPs during the Blitzes. CARB staff continued to monitor several of the 2016-17 sites in 2017-18.

As described in the main body of this report, CARB staff installed equipment at the LTS sites that enabled the collection of data to support calculation of RIFE in addition to

VDAPP. The below chronology illustrates the timing of short-term Blitz monitoring events compared to the LTS monitoring efforts. Please refer to the main body of this report for a more detailed description of the monitoring efforts and VDAPP and RIFE calculation methods. Spreadsheets of all Blitz and LTS VDAPP and RIFE values are too large to include in this attachment; a Microsoft Excel file with the spreadsheets is available upon request.




## 2. Evaluation Methods and Results

The goal of this evaluation is to identify VDAPP and RIFE values that enable emission estimates for balance GDFs that meet the following objectives:

1. Represent the range of statewide GDF operating conditions
2. Represent current conditions
3. Characterize both winter and summer conditions
4. Do not under-estimate emissions

The Blitz monitoring events achieve goal #1 because they were designed to provide information representative of statewide GDF operating conditions and took place as recently as December 2018. However, the Blitz monitoring events provide information only for snapshots in time, not long-term measurements. Further, the October 2013 Blitz event was timed to provide a before/after comparison for when high RVP gasoline is sold, not to characterize VDAPP and RIFE throughout the summer season. Also, Blitz sites do not have the equipment necessary to generate the information needed to calculate RIFE. Consequently, the Blitz monitoring events can provide insight for

goals #2 and #3, but cannot be used by themselves to estimate statewide emissions if appropriate longer-term information is available.

In contrast, CARB staff designed the 2016-2018 Long Term Study (LTS) to provide seasonal emission estimates, including RIFE estimates. However, as noted earlier, preliminary evaluations indicated the 2016-17 LTS sites have substantially lower VDAPPs than the 2013-2015 Blitz VDAPPs. Additional evaluation is necessary to determine whether the 2017-18 LTS sites are representative of statewide conditions, or are biased high or low.

All tables and attachments are provided after the References (section E).

### a. VDAPP Evaluation Methods

To evaluate the statewide representativeness of the LTS sites, CARB staff compared LTS site VDAPPs to Blitz VDAPPs. To enable as direct a comparison as possible to the 30-hour VDAPPs generated by the Blitz monitoring events, CARB staff calculated 24-hour (daily) VDAPPs for each LTS site for the first two weeks of December, February, and October. Because preliminary evaluations indicated the 2016-17 LTS sites have substantially lower VDAPPs than the 2013-2015 Blitz VDAPPs, CARB staff evaluated different LTS site groupings and monitoring periods:

- All LTS sites: first two weeks of December 2017, February 2018, and October 2018
- The 15 sites initially monitored in 2016-17: first two weeks of December 2016 and 2017, February 2017 and 2018, and October 2016, 2017 and 2018
- The 15 sites added in 2017: first two weeks of December 2017, February 2017 and 2018, and October 2017 and 2018

CARB staff compared the Blitz and LTS VDAPPs using both qualitative and quantitative methods:

- Summary statistics (Attachment 1) generated using SAS Enterprise Guide version 7.1 and SAS 9.4 “Means Procedure”[1]
- Box plots (Attachment 2) and histograms (Attachment 3) generated using Microsoft Excel 2016[2]
- Four tests for normality—Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling—provided by SAS 9.4 “Univariate Procedure” (SAS code for the Univariate Procedure is in Attachment 4; procedure output is in Attachment 5)

[1] SAS Software version 9.4, 2002-2012, and SAS Enterprise Guide version 7.1, SAS Institute Inc., Cary, NC, USA.
[2] Microsoft Office Professional Plus 2016.

- Statistical comparisons of Blitz and LTS mean VDAPPs to determine if the means are significantly different using three tests provided by the SAS 9.4 "GLM Procedure" (Table 1 provides a summary of results; SAS code for the GLM procedure is in Attachment 4; procedure output is in Attachment 6):
    - Bonferroni (Dunn) t Tests (BON)
    - Scheffe's Test (SCHEFFE)
    - Tukey's Studentized Range (HSD) Test (TUKEY)

CARB staff evaluated the means of the Blitz and LTS VDAPPs, rather than 75$^{th}$ or 90$^{th}$ percentiles or other measures, because CARB staff needs to develop regional and statewide ROG emission estimates, versus focusing on emissions from just the GDFs with the highest emission rates. CARB staff also evaluated the means and distributions for the 66 sites common to all December Blitz events (2013, 2015, and 2018) to better understand inter-annual variability.

Because the histograms and normality testing indicate the VDAPPs are not normally distributed (i.e., the VDAPPs have a skewed distribution), VDAPP values were transformed (natural log transformation) before comparing their means. This transformation rendered the resulting data to be normally distributed, thus enabling staff to make use of methods based on normal distributions. VDAPP values equal to zero were replaced with 0.01% (half the lowest non-zero VDAPP value, 0.032%, rounded down to one significant figure) before transforming.

As discussed in the next section, given the results of the above evaluations, CARB staff further evaluated the LTS 2017-18 sites' VDAPPs. CARB staff compared the winter and summer means of LTS 2017-18 sites' VDAPPs to each other and to the mean VDAPP for each Blitz (Table 1 and Attachment 6).

Due to varying site conditions, the LTS 2017-18 sites have different amounts of weekly VDAPPs available and VDAPP variability. To assess whether sites with more data might have a substantial effect on mean VDAPP, CARB staff compared the mean of LTS 2017-18 sites' VDAPPs combined (the same values as those assessed in the above-mentioned analyses, Method 1 in Table 2) to the mean of site-specific means for winter and summer (Method 2 in Table 2).

### b. RIFE Evaluation Methods

CARB staff could not conduct as comprehensive an evaluation for RIFE because RIFE cannot be calculated from the Blitz monitoring data. Without RIFE values for the Blitz sites, it is not possible to evaluate the statewide representativeness of the available RIFE calculations. To identify reasonably conservative RIFE values for statewide emission estimates, CARB staff compared the winter and summer weekly RIFE means of the LTS 2016-17 sites to those of the LTS 2017-18 sites to determine if one set of sites has a significantly higher mean than the other (Table 1.G and Attachment 6).

Also, as done with the weekly VDAPP values, CARB staff compared the winter and summer means of LTS 2017-18 sites' RIFEs to each other to assess whether there is a significant seasonal difference (Table 1.H and Attachment 6).

CARB staff used the same methods for the RIFE evaluation as for the VDAPP evaluation described in section B.2.a. Because the histograms and normality testing indicate the weekly RIFE values are not normally distributed, CARB staff transformed the RIFE values (natural log transformation) before comparing their means. All RIFE values are greater than zero.

Due to varying site conditions, the LTS 2017-18 sites have different amounts of weekly RIFE values available and RIFE variability. To assess whether sites with more data might have a substantial effect on mean RIFE, CARB staff compared the mean of LTS 2017-18 sites' RIFEs combined (the same values as those assessed in the above-mentioned analyses) to the mean of site-specific means for winter and summer (Table 3).

# C. Discussion of Results

## 1. VDAPP Results

The summary statistics (Attachment 1.A) and box plots (Figure 1 in Attachment 2) indicate the distribution of the daily VDAPPs for the LTS 2016-17 sites in December, February and October are substantially lower than the December, February and October Blitz VDAPPs, respectively. The BON, SCHEFFE, and TUKEY tests all indicate the LTS 2016-17 sites' mean VDAPPs for December, February, and October are significantly lower than the Blitz means (Table 1.A and Attachment 6). These comparisons indicate the distribution and average of LTS 2016-17 VDAPPs are not comparable to Blitz VDAPPs and therefore are not representative of statewide conditions. Further, use of the LTS 2016-17 sites' VDAPPs would under-estimate statewide emissions from balance GDFs.

Conversely, the distribution and means of the daily VDAPPs for the LTS 2017-18 sites in December, February and October are comparable to or slightly higher than the December, February and October Blitz VDAPPs, respectively. The BON, SCHEFFE, and TUKEY tests all indicate the LTS 2017-18 sites' mean VDAPP for December is statistically no different from the Blitz mean for December 2015, and significantly higher than the Blitz means for December 2013 and December 2018. Similarly, the LTS 2017-18 sites' mean VDAPPs for February and October are statistically no different from the Blitz means for February 2014 and October 2013, respectively. These comparisons indicate the distribution and average of LTS 2017-18 VDAPPs are comparable to Blitz VDAPPs and therefore are representative of statewide conditions.

Further, use of the LTS 2017-18 sites' VDAPPs may neither under- nor over-estimate statewide emissions from balance GDFs in October (late summer season) and February (late winter season). Because the LTS 2017-18 sites' mean VDAPP is slightly but

significantly higher than the Blitz 2018 mean VDAPP, use of the LTS 2017-18 sites' VDAPPs may slightly over-estimate current statewide emissions from balance GDFs in December (early winter season). However, staff considers the potential over-estimate to be reasonably conservative because the LTS 2017-18 sites' mean VDAPP is statistically no different from the mean VDAPP for the December 2015 Blitz.

When the daily VDAPPs for the two sets of LTS sites are combined, the BON, SCHEFFE, and TUKEY tests all indicate the mean VDAPP for December 2017 is significantly higher than the mean VDAPP for the December 2013 Blitz, and statistically no different from the December 2015 and 2018 Blitzes (Table 1.B and Figure 2 in Attachment 2). However, the mean VDAPPs for the combined LTS sites for February 2018 and October 2018 are significantly lower than the Blitz means for February 2014 and October 2013, respectively. These comparisons indicate use of the combined LTS sites' VDAPPs would under-estimate statewide emissions from balance GDFs during the critical summer ozone season.

Because the above comparisons indicate the LTS 2017-18 sites' VDAPPs could provide a reasonably conservative estimate of statewide conditions, staff further evaluated the LTS 2017-18 sites' VDAPPs. Staff compared the winter and summer distributions and means of LTS 2017-18 sites' weekly VDAPPs to each other and to each of the Blitzes (Attachments 1, 2, and 6). The seasonal comparisons indicate the LTS 2017-18 sites' winter weekly VDAPPs mean is significantly higher than the summer weekly VDAPPs mean (Table 1.C and Figure 3 in Attachment 2), which is to be expected given the December and February Blitz means are significantly higher than the October Blitz mean (Table 1.D). The LTS sites' seasonal VDAPPs comparison confirms that statewide emissions from balance GDFs should be estimated separately for the summer and winter seasons.

In addition, as with the comparison of daily VDAPPs, the BON, SCHEFFE, and TUKEY tests all indicate the LTS 2017-18 sites' mean weekly VDAPP for the winter season is statistically no different from the Blitz mean for December 2015, and significantly but only slightly higher than the Blitz means for December 2013 and December 2018 (Table 1.E). The LTS 2017-18 sites' mean weekly VDAPPs for the summer season is slightly but statistically higher than the Blitz mean for October 2013. As illustrated in Figure 4.A, LTS 2017-18 sites' winter season weekly VDAPPs peaked in December; such a December peak was found in early, pre-Blitz monitoring efforts. Compared to the winter season, LTS 2017-18 sites' summer season weekly VDAPPs varied very little (Figure 4.B). Also, Figure 5 illustrates that weekly VDAPPs for the individual LTS sites have a variety of distributions. These comparisons and figures further indicate that the LTS 2017-18 sites encompass a range of operating conditions and are appropriate for providing VDAPP values that can enable reasonably conservative estimates of current summer and winter season emissions from balance GDFs.

Finally, the mean and distribution of VDAPPs for all sites monitored by the December 2015 Blitz event are significantly higher than those of the December 2013 and 2018

Blitz events, but are comparable to those of the 2017-18 long-term study sites (Table 1.E). In addition, the VDAPP means and distributions for the 66 sites common to the three December Blitz events (2013, 2015, and 2018) are not significantly different from each other (Table 1.E). These findings indicate statewide average annual VDAPPs have not significantly changed between 2013 and 2018.

For all means comparisons, the different statistical tests—Bonferroni, Scheffe, and Tukey—resulted in the same conclusions, which indicates the comparison results are robust.

Comparison of the mean of LTS 2017-18 sites' weekly VDAPPs combined (the same values as those assessed in the above-mentioned analyses, Method 1 in Table 2) to the mean of site-specific means (Method 2 in Table 2) indicates sites with more data might generate a low bias. The winter and summer Method 2 means of site-specific mean VDAPPs are slightly higher than the Method 1 means, and there is a relatively small absolute difference between the mean VDAPPs produced by Methods 1 and 2 (0.05%–0.8%). Consequently, Method 2 provides slightly higher (more conservative) values without being substantially different from Method 1 values. For this reason, CARB staff recommends Method 2 for estimating statewide emissions. Further, CARB staff recommends use of the back-transformed means of the natural log transformed VDAPP data to estimate seasonal statewide emissions because they are less influenced by outliers. Back-transforming the means is the correct step to take, as the original data were transformed to make use of the methods based on normal distributions.

## 2. RIFE Results

As noted in section C.1, the VDAPP evaluation results indicate the LTS 2017-18 sites are appropriate for providing VDAPP values that can enable reasonably conservative statewide estimates of current summer and winter season emissions from balance GDFs. Consequently, CARB staff recommends that the RIFE values associated with the LTS 2017-18 sites' VDAPPs be used to develop statewide estimates. The RIFE evaluation results support this recommendation.

The summary statistics (Attachments 1.B) and box plots (Figure 6 in Attachment 2) indicate the distributions of the 2017 summer weekly RIFEs for LTS 2016-17 sites is very similar to the mean of the 2018 summer weekly RIFEs for LTS 2017-18 sites, and the means comparison (Table 3.A and Attachment 6) indicate the means are not statistically different. In contrast, the summary statistics, box plots, and means comparison indicate the distribution and mean of 2017-18 winter weekly RIFEs for LTS 2017-18 sites are slightly but significantly higher than the distribution and mean of 2016-17 winter weekly RIFEs for LTS 2016-17 sites. This finding for RIFE mirrors the finding for VDAPP, and indicates the LTS 2017-18 sites are appropriate for providing RIFE values that can enable reasonably conservative statewide emission estimates.

As with VDAPP, the comparison of LTS 2017-18 sites' seasonal RIFE means indicates the winter mean RIFE is significantly higher than the summer mean RIFE (Table 3.B and Figure 6 in Attachment 2). This confirms that statewide emissions from balance GDFs should be estimated separately for the summer and winter seasons.

As illustrated in Figure 7.A (Attachment 2), LTS 2017-18 sites' winter season weekly RIFE peaked in December. Compared to the winter season, LTS 2017-18 sites' summer season weekly VDAPPs varied less (Figure 7.B).

Figure 8 (Attachment 2) illustrates that weekly RIFEs for the individual LTS sites have a variety of distributions. These comparisons and figures further indicate that the LTS 2017-18 sites encompass a range of operating conditions and are appropriate for providing both VDAPP and RIFE values that can enable reasonably conservative estimates of current summer and winter season emissions from balance GDFs.

Comparison of the mean of LTS 2017-18 sites' weekly RIFE combined (the same values as those assessed in the above-mentioned analyses, Method 1 in Table 4) to the mean of site-specific means (Method 2 in Table 4) indicates sites with more data might generate a low bias. The winter and summer Method 2 back-transformed means of site-specific mean RIFE are slightly higher than the Method 1 winter and summer means, and there is only a 0.001–0.005 lbs/kgal difference between the mean RIFEs produced by Methods 1 and 2. There is not a substantial difference in the resulting means for the two methods. For consistency with the VDAPP approach, CARB staff recommends Method 2 RIFE results for estimating statewide emissions.

## D. Recommendation

Based on the results of the statistical evaluations, CARB staff recommends using the following VDAPP and RIFE values to calculate reasonably conservative seasonal and annual estimates of current regional and statewide pressure driven emissions from balance GDFs:

| | VDAPP | RIFE |
|---|---|---|
| Winter: | 8.89% | 0.059 lbs/kgal |
| Summer: | 2.35% | 0.041 lbs/kgal |

These values are the back-transformed means of LTS 2017-18 site-specific mean weekly VDAPPs and RIFE during the winter (November 2017-February 2018) and summer (April-September 2018), respectively. CARB staff recommends these values because both qualitative and quantitative analytical methods indicate the LTS 2017-18 sites and the mean calculation method provide VDAPP and RIFE values that achieve the emission estimate objectives identified in section B.2 of this appendix.

Table 1: Summary of Comparisons of Blitz and LTS VDAPP Means Based on Natural Log Transformed VDAPPs [1]

| COMPARISON | | | | Are Means Significantly Different? | | |
|---|---|---|---|---|---|---|
| **Mean 1** | **Mean 1 VDAPP** (back-transformed) [1] | **Mean 2** | **Mean 2 VDAPP** (back-transformed) | Bonferroni (Dunn) t Tests | Scheffe's Test | Tukey's Studentized Range (HSD) Test |
| **A. LTS MEANS[2] COMPARED TO BLITZ MEANS[3]:** LTS Sites in 2016-17 and 2017-18 are evaluated separately | | | | | | |
| December LTS2017-18 Sites: 2017 | 8.17% | Dec Blitz 2013 | 3.86% | Yes | Yes | Yes |
| | | Dec Blitz 2015 | 6.85% | **No** | **No** | **No** |
| | | Dec Blitz 2018 | 5.64% | Yes | Yes | Yes |
| February LTS2017-18 Sites: 2018 | 5.36% | Feb Blitz 2014 | 4.14% | **No** | **No** | **No** |
| October LTS2017-18 Sites: 2018 | 1.38% | Oct Blitz 2013 | 1.08% | **No** | **No** | **No** |
| December LTS2016-17 Sites: 2016 | 1.87% | Dec Blitz 2013 | 3.86% | Yes | Yes | Yes |
| | | Dec Blitz 2015 | 6.85% | Yes | Yes | Yes |
| | | Dec Blitz 2018 | 5.64% | Yes | Yes | Yes |
| February LTS2016-17 Sites: 2017 | 0.5% | Feb Blitz 2014 | 4.14% | Yes | Yes | Yes |
| October LTS2016-17 Sites: 2017 | 0.13% | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| **B. LTS MEANS[2] COMPARED TO BLITZ MEANS[3]:** LTS Sites in 2016-17 and 2017-18 are combined for the most recent monitoring period | | | | | | |
| December LTS 2016-17 & 2017-18 Sites: 2017 | 5.50% | Dec Blitz 2013 | 3.86% | Yes | Yes | Yes |
| | | Dec Blitz 2015 | 6.85% | **No** | **No** | **No** |
| | | Dec Blitz 2018 | 5.64% | **No** | **No** | **No** |
| February LTS 2016-17 & 2017-18 Sites: 2018 | 2.30% | Feb Blitz 2014 | 4.14% | Yes | Yes | Yes |
| October LTS 2016-17 & 2017-18 Sites: 2018 | 0.57% | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| **C. COMPARISON OF LTS2017-18 SEASONAL MEANS OF WEEKLY VDAPPs** | | | | | | |
| LTS2017-18 Winter Weekly VDAPP | 8.06% | LTS2018 Summer Weekly VDAPP | 2.02% | Yes | Yes | Yes |
| **D. COMPARISON OF BLITZ EVENTS** [3] | | | | | | |
| Dec Blitz 2013 | 3.86% | Dec Blitz 2015 | 6.85% | Yes | Yes | Yes |
| | | Dec Blitz 2018 | 5.64% | **No** | **No** | **No** |
| | | Feb Blitz 2014 | 4.14% | **No** | **No** | **No** |
| | | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| Dec Blitz 2015 | 6.85% | Dec Blitz 2018 | 5.64% | **No** | **No** | **No** |
| | | Feb Blitz 2014 | 4.14% | Yes | Yes | Yes |
| | | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |

| COMPARISON | | | | Are Means Significantly Different? | | |
|---|---|---|---|---|---|---|
| **Mean 1** | **Mean 1 VDAPP** (back-transformed) (1) | **Mean 2** | **Mean 2 VDAPP** (back-transformed) | Bonferroni (Dunn) t Tests | Scheffe's Test | Tukey's Studentized Range (HSD) Test |
| Dec Blitz 2018 | 5.64% | Feb Blitz 2014 | 4.14% | **No** | **No** | **No** |
| | | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| Feb Blitz 2014 | 4.14% | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| Dec Blitz 2013 66 Sites | 6.04% | Dec Blitz 2015 66 Sites | 7.44% | **No** | **No** | **No** |
| | | Dec Blitz 2018 66 Sites | 5.72% | **No** | **No** | **No** |
| Dec Blitz 2015 66 Sites | 7.44% | Dec Blitz 2018 66 Sites | 5.72% | **No** | **No** | **No** |
| Dec Blitz 2013 66 Sites | 6.04% | Dec Blitz 2013 (all sites) | 3.86% | Yes | Yes | Yes |
| Dec Blitz 2015 66 Sites | 7.44% | Dec Blitz 2015 (all sites) | 6.85% | **No** | **No** | **No** |
| Dec Blitz 2018 66 Sites | 5.72% | Dec Blitz 2018 (all sites) | 5.64% | **No** | **No** | **No** |
| **E. COMPARISON OF LTS2017-18 SEASONAL MEANS OF WEEKLY VDAPPs TO BLITZ MEANS** | | | | | | |
| LTS2017-18 Winter Weekly | 8.06% | Dec Blitz 2013 | 3.86% | Yes | Yes | Yes |
| | | Dec Blitz 2015 | 6.85% | **No** | **No** | **No** |
| | | Dec Blitz 2018 | 5.64% | Yes | Yes | Yes |
| | | Feb Blitz 2014 | 4.14% | Yes | Yes | Yes |
| | | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |
| LTS2017-18 Summer Weekly | 2.02% | Dec Blitz 2013 | 3.86% | Yes | Yes | Yes |
| | | Dec Blitz 2015 | 6.85% | Yes | Yes | Yes |
| | | Dec Blitz 2018 | 5.64% | Yes | Yes | Yes |
| | | Feb Blitz 2014 | 4.14% | Yes | Yes | Yes |
| | | Oct Blitz 2013 | 1.08% | Yes | Yes | Yes |

(1) Because the histograms and normality testing indicate the VDAPPs are not normally distributed (i.e., the VDAPPs have a skewed distribution), VDAPP values were transformed (natural log transformation) before comparing their means. Means shown in this table are back-transformed from the mean of the natural log transformed values. See Attachment 1.A for the means of untransformed values.

(2) LTS VDAPP values are means of daily (24-hour) VDAPPs for the first two weeks of December, February and October.

(3) Blitz VDAPP values are means of 30-hour VDAPPs for the first two-three weeks of December, February and October.

Table 2: Site-specific mean VDAPPs by season for LTS 2017-18 sites

| WINTER | | | |
|---|---|---|---|
| **Site Code** | **# of Weekly VDAPPs** | **Site-Specific Mean of Weekly VDAPPs** | **Site-Specific Back-Transformed Mean of Weekly VDAPPs (1)** |
| 1 | 13 | 2.79% | 2.55% |
| 2 | 15 | 7.06% | 6.33% |
| 3 | 13 | 11.76% | 11.51% |
| 5 | 12 | 6.95% | 6.74% |
| 6 | 15 | 10.43% | 9.47% |
| 7 | 11 | 13.67% | 13.16% |
| 8 | 12 | 9.51% | 9.25% |
| 9 | 13 | 12.45% | 12.14% |
| 10 | 15 | 10.12% | 9.63% |
| 11 | 15 | 9.56% | 9.34% |
| 15 | 12 | 7.90% | 6.60% |
| 16 | 13 | 5.66% | 5.05% |
| 17 | 13 | 7.51% | 6.86% |
| 23 | 10 | 6.86% | 6.77% |
| 26 | 11 | 18.30% | 17.94% |
| **Mean Calculation Method 1:** Mean of all site weekly VDAPPs combined | | **9.29%** | **8.06%** |
| **Mean Calculation Method 2:** Mean of site-specific mean weekly VDAPPs | | **9.37%** | **8.89%** |
| **Percent Difference between Methods 1 & 2:** | | **0.9%** | **9.3%** |

| SUMMER | | | |
|---|---|---|---|
| **Site Code** | **# of Weekly VDAPPs** | **Site-Specific Mean of Weekly VDAPPs** | **Site-Specific Back-Transformed Mean of Weekly VDAPPs (1)** |
| 1 | 15 | 0.47% | 0.42% |
| 2 | 16 | 1.32% | 1.24% |
| 3 | 17 | 3.59% | 3.54% |
| 5 | 17 | 2.31% | 2.23% |
| 6 | 14 | 3.31% | 3.24% |
| 7 | 6 | 3.82% | 3.65% |
| 8 | 16 | 2.62% | 2.52% |
| 9 | 8 | 3.90% | 3.84% |
| 10 | 11 | 1.94% | 1.59% |
| 11 | 13 | 1.99% | 1.80% |
| 15 | 12 | 0.93% | 0.87% |
| 16 | 13 | 2.35% | 2.30% |
| 17 | 13 | 2.33% | 2.25% |
| 23 | 18 | 3.30% | 3.27% |
| 26 | 19 | 2.70% | 2.51% |
| **Mean Calculation Method 1:** Mean of all site weekly VDAPPs combined | | **2.41%** | **2.02%** |
| **Mean Calculation Method 2:** Mean of site-specific mean weekly VDAPPs | | **2.46%** | **2.35%** |
| **Percent Difference between Methods 1 & 2:** | | **2.1%** | **16%** |

(1) Because the histograms and normality testing indicate the VDAPPs are not normally distributed (i.e., the VDAPPs have a skewed distribution), VDAPP values were transformed (natural log transformation). Means shown in this column are back-transformed from the mean of the natural log transformed values.

Table 3: Summary of Comparisons of LTS Weekly RIFE Means [(1)]

| COMPARISON | | | | Are Means Significantly Different? | | |
|---|---|---|---|---|---|---|
| **LTS Mean 1** | **LTS Mean 1 RIFE** (back-transformed) [(1)] | **LTS Mean 2** | **LTS Mean 2 RIFE** (back-transformed) | Bonferroni (Dunn) t Tests | Scheffe's Test | Tukey's Studentized Range (HSD) Test |
| **A. LTS 2017-18 SITES' SEASONAL WEEKLY RIFE MEANS COMPARED TO LTS 2016-17 SITES** | | | | | | |
| LTS 2017-18 Sites: Winter 2017-18 | 0.054 | LTS 2016-17 Sites: Winter 2016-17 | 0.042 | Yes | Yes | Yes |
| LTS 2017-18 Sites: Summer 2018 | 0.040 | LTS 2016-17 Sites: Summer 2017 | 0.036 | No | No | No |
| **B. COMPARISON OF LTS2017-18 SITES' SEASONAL WEEKLY RIFE MEANS** | | | | | | |
| LTS 2017-18 Sites: Winter 2017-18 | 0.054 | LTS 2017-18 Sites: Summer 2018 | 0.040 | Yes | Yes | Yes |

(1) Because the histograms and normality testing indicate the RIFEs are not normally distributed (i.e., the RIFEs have a skewed distribution), RIFE values were transformed (natural log transformation) before comparing their means. Means shown in this table are back-transformed from the means of the natural log transformed values. See Attachment 1.B for the means of untransformed values.

Table 4: Site-specific mean RIFEs by season for LTS 2017-18 sites

| WINTER | | | |
|---|---|---|---|
| **Site Code** | **# of Weekly RIFEs** | **Site-Specific Mean of Weekly RIFEs** | **Site-Specific Back-Transformed Mean of Weekly RIFEs (1)** |
| 1 | 13 | 0.061 | 0.059 |
| 2 | 15 | 0.037 | 0.036 |
| 3 | 13 | 0.046 | 0.046 |
| 5 | 12 | 0.059 | 0.058 |
| 6 | 15 | 0.053 | 0.053 |
| 7 | 11 | 0.043 | 0.041 |
| 8 | 12 | 0.040 | 0.038 |
| 9 | 13 | 0.073 | 0.063 |
| 10 | 15 | 0.062 | 0.060 |
| 11 | 15 | 0.053 | 0.053 |
| 15 | 10 | 0.062 | 0.061 |
| 16 | 12 | 0.043 | 0.041 |
| 17 | 13 | 0.059 | 0.058 |
| 23 | 10 | 0.154 | 0.152 |
| 26 | 11 | 0.067 | 0.066 |
| **Mean Calculation Method 1:** Mean of all site weekly RIFEs combined | | **0.059** | **0.054** |
| **Mean Calculation Method 2:** Mean of site-specific mean weekly RIFEs | | **0.061** | **0.059** |
| **Percent Difference between Methods 1 & 2:** | | **3%** | **9%** |

| SUMMER | | | |
|---|---|---|---|
| **Site Code** | **# of Weekly RIFE** | **Site-Specific Mean of Weekly RIFEs** | **Site-Specific Back-Transformed Mean of Weekly RIFEs (1)** |
| 1 | 15 | 0.038 | 0.038 |
| 2 | 16 | 0.021 | 0.020 |
| 3 | 17 | 0.032 | 0.031 |
| 5 | 17 | 0.040 | 0.039 |
| 6 | 14 | 0.031 | 0.031 |
| 7 | 6 | 0.033 | 0.032 |
| 8 | 15 | 0.051 | 0.044 |
| 9 | 8 | 0.026 | 0.025 |
| 10 | 11 | 0.041 | 0.041 |
| 11 | 13 | 0.037 | 0.035 |
| 15 | 12 | 0.050 | 0.050 |
| 16 | 13 | 0.033 | 0.033 |
| 17 | 13 | 0.052 | 0.051 |
| 23 | 18 | 0.108 | 0.106 |
| 26 | 19 | 0.046 | 0.045 |
| **Mean Calculation Method 1:** Mean of all site weekly RIFEs combined | | **0.044** | **0.040** |
| **Mean Calculation Method 2:** Mean of site-specific mean weekly RIFEs | | **0.043** | **0.041** |
| **Percent Difference between Methods 1 & 2:** | | **-2%** | **3%** |

(1) Because the histograms and normality testing indicate the RIFEs are not normally distributed (i.e., the RIFEs have a skewed distribution), RIFE values were transformed (natural log transformation). Means shown in this column are back-transformed from the mean of the natural log transformed values.

## Attachments

Attachment 1: Summary Statistics

Attachment 2: Box Plots

Attachment 3: Histograms

Attachment 4: SAS Code

Attachment 5: Normality Tests

Attachment 6: Comparison of Means

Attachments 5 and 6 are too large to include in this appendix; separate Adobe Acrobat files are available upon request.

# Attachment 1: Summary Statistics

## Attachment 1.A: Blitz and Long-Term Study VDAPPs Summary Statistics

| VDAPP Source / Monitoring Month & Year | | | N | Mean | Min. | Max. | Lower Quartile (25th Pctl) | Median | Upper Quartile (75th Pctl) | 95th Pctl | Std Dev | Variance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blitz Monitoring | Dec | 2013 | 108 | 6.87% | 0.00% | 26.41% | 2.69% | 5.51% | 9.70% | 17.74% | 5.60% | 0.31% |
| | | 2015 | 91 | 9.37% | 0.34% | 42.72% | 4.02% | 7.29% | 12.54% | 25.02% | 7.46% | 0.56% |
| | | 2018 | 77 | 8.56% | 0.00% | 29.74% | 3.56% | 7.09% | 10.75% | 23.03% | 6.55% | 0.43% |
| | Feb | 2014 | 82 | 6.04% | 0.00% | 88.27% | 2.45% | 4.26% | 9.32% | 18.15% | 11.43% | 1.31% |
| | Oct | 2013 | 91 | 2.26% | 0.00% | 10.74% | 0.71% | 1.67% | 3.21% | 5.70% | 2.14% | 0.05% |
| Long Term Study (LTS): All Sites (Daily) | Dec | 2017 | 275 | 8.31% | 0.00% | 47.96% | 3.21% | 6.86% | 10.75% | 19.64% | 7.08% | 0.50% |
| | Feb | 2018 | 233 | 5.55% | 0.00% | 21.25% | 1.47% | 4.80% | 8.36% | 15.06% | 4.76% | 0.23% |
| | Oct | 2018 | 198 | 2.00% | 0.00% | 10.86% | 0.17% | 1.64% | 3.01% | 5.91% | 2.08% | 0.04% |
| LTS: 2016-17 Sites (Daily) | Dec | 2016 | 138 | 3.27% | 0.00% | 20.71% | 1.41% | 2.86% | 4.29% | 8.06% | 2.73% | 0.07% |
| | | 2017 | 65 | 2.27% | 0.00% | 10.75% | 1.04% | 1.78% | 2.78% | 5.34% | 1.90% | 0.04% |
| | Feb | 2017 | 135 | 1.76% | 0.00% | 8.38% | 0.20% | 0.96% | 2.91% | 6.01% | 1.92% | 0.04% |
| | | 2018 | 70 | 1.47% | 0.00% | 15.06% | 0.00% | 0.57% | 1.65% | 5.89% | 2.47% | 0.06% |
| | Oct | 2016 | 63 | 0.93% | 0.00% | 5.79% | 0.00% | 0.21% | 1.40% | 3.58% | 1.32% | 0.02% |
| | | 2017 | 84 | 0.66% | 0.00% | 3.44% | 0.00% | 0.31% | 1.04% | 2.62% | 0.84% | 0.01% |
| | | 2018 | 53 | 0.41% | 0.00% | 5.50% | 0.00% | 0.00% | 0.34% | 2.25% | 0.95% | 0.01% |
| LTS: 2017-18 Sites (Daily) | Dec | 2017 | 210 | 10.18% | 0.00% | 47.96% | 5.72% | 8.52% | 12.32% | 20.55% | 7.05% | 0.50% |
| | Feb | 2017 | 14 | 9.15% | 3.66% | 19.60% | 6.46% | 8.42% | 11.71% | 19.60% | 4.18% | 0.18% |
| | | 2018 | 163 | 7.30% | 0.00% | 21.25% | 4.19% | 6.50% | 9.77% | 16.09% | 4.43% | 0.20% |
| | Oct | 2017 | 14 | 1.39% | 0.38% | 2.96% | 0.86% | 1.31% | 1.65% | 2.96% | 0.70% | 0.00% |
| | | 2018 | 145 | 2.58% | 0.00% | 10.86% | 0.98% | 2.22% | 3.59% | 6.10% | 2.08% | 0.04% |
| LTS: 2016-17 Sites (Weekly) - Annual | Nov 2016-Feb 2017, Jul-Aug 2017 | | 180 | 2.33% | 0.02% | 6.49% | 6.47% | 0.91% | 1.97% | 3.47% | 5.48% | 1.62% |
| | Nov 2017-Feb 2018, May-Sep 2018 | | 133 | 1.37% | 0.00% | 6.02% | 6.02% | 0.45% | 1.12% | 2.05% | 3.29% | 1.10% |
| LTS: 2016-17 Sites (Weekly) - Summer | Jul-Aug 2017 | | 43 | 1.03% | 0.02% | 2.76% | 2.74% | 0.42% | 0.80% | 1.76% | 2.69% | 0.84% |
| | May-Sep 2018 | | 60 | 0.59% | 0.00% | 2.29% | 2.29% | 0.27% | 0.45% | 0.88% | 1.42% | 0.45% |

| VDAPP Source / Monitoring Month & Year | | N | Mean | Min. | Max. | Lower Quartile (25th Pctl) | Median | Upper Quartile (75th Pctl) | 95th Pctl | Std Dev | Variance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LTS: 2016-17 Sites (Weekly) - Winter | Nov 2016-Feb 2017 | 137 | 2.74% | 0.10% | 6.49% | 6.39% | 1.40% | 2.49% | 3.90% | 5.80% | 1.59% |
| | Nov 2017-Feb 2018 | 73 | 2.01% | 0.08% | 6.02% | 5.93% | 1.33% | 1.95% | 2.47% | 3.89% | 1.07% |
| LTS 2017-18 Sites (Weekly) - Annual | Nov 2017-Feb 2018, Apr-Sep 2018 | 401 | 5.72% | 0.08% | 23.53% | 2.35% | 3.61% | 8.44% | 14.86% | 4.74% | 0.22% |
| LTS 2017-18 Sites (Weekly) - Winter | Nov 2017-Feb 2018 | 193 | 9.29% | 1.10% | 23.53% | 6.02% | 8.68% | 11.87% | 18.38% | 4.54% | 0.21% |
| LTS 2017-18 Sites (Weekly) - Summer | Apr-Sep 2018 | 208 | 2.41% | 0.08% | 6.18% | 1.46% | 2.48% | 3.23% | 4.24% | 1.16% | 0.01% |

## Attachment 1.B: Long-Term Study Weekly RIFE (lbs/kgal) Summary Statistics

| RIFE Monitoring Period | N | Mean | Min. | Max. | Lower Quartile (25th Pctl) | Median | Upper Quartile (75th Pctl) | 95th Pctl | Std Dev | Variance |
|---|---|---|---|---|---|---|---|---|---|---|
| LTS 2016-17 Sites (Weekly): 2016-17 Winter | 131 | 0.046 | 0.021 | 0.199 | 0.033 | 0.040 | 0.047 | 0.094 | 0.023 | 0.0005 |
| LTS 2016-17 Sites (Weekly): 2017 Summer | 43 | 0.042 | 0.005 | 0.121 | 0.026 | 0.034 | 0.057 | 0.078 | 0.022 | 0.0005 |
| LTS 2017-18 Sites (Weekly): 2017-18 Winter | 190 | 0.059 | 0.024 | 0.194 | 0.043 | 0.053 | 0.064 | 0.125 | 0.029 | 0.0009 |
| LTS 2017-18 Sites (Weekly): 2018 Summer | 207 | 0.044 | 0.012 | 0.147 | 0.030 | 0.037 | 0.050 | 0.107 | 0.025 | 0.0006 |

# ATTACHMENT 2: Box Plots

**LEGEND**

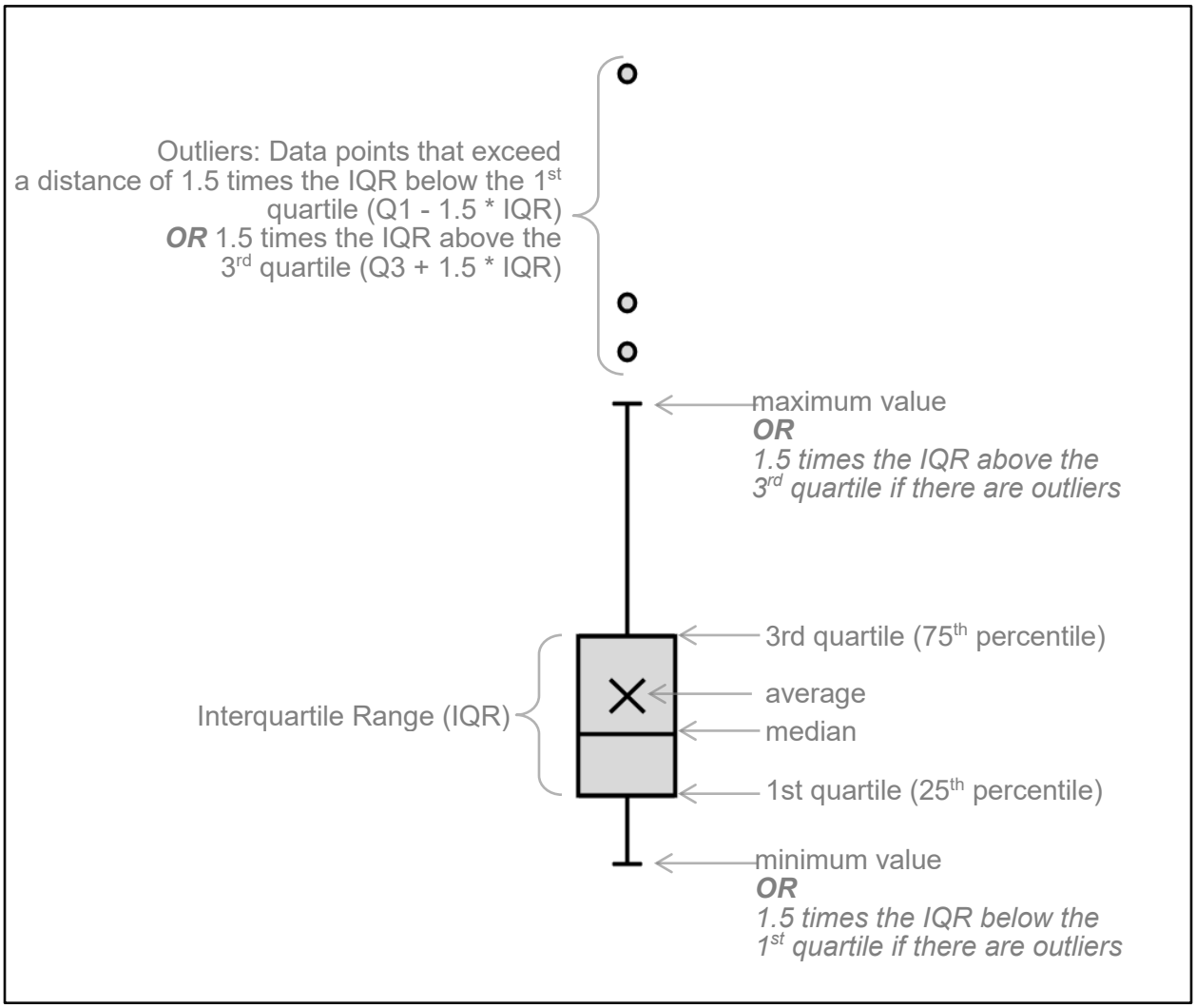


Figure 1: Box plot of Blitz 30-hour VDAPPs compared to LTS daily VDAPPs with 2016-17 and 2017-18 sites separated

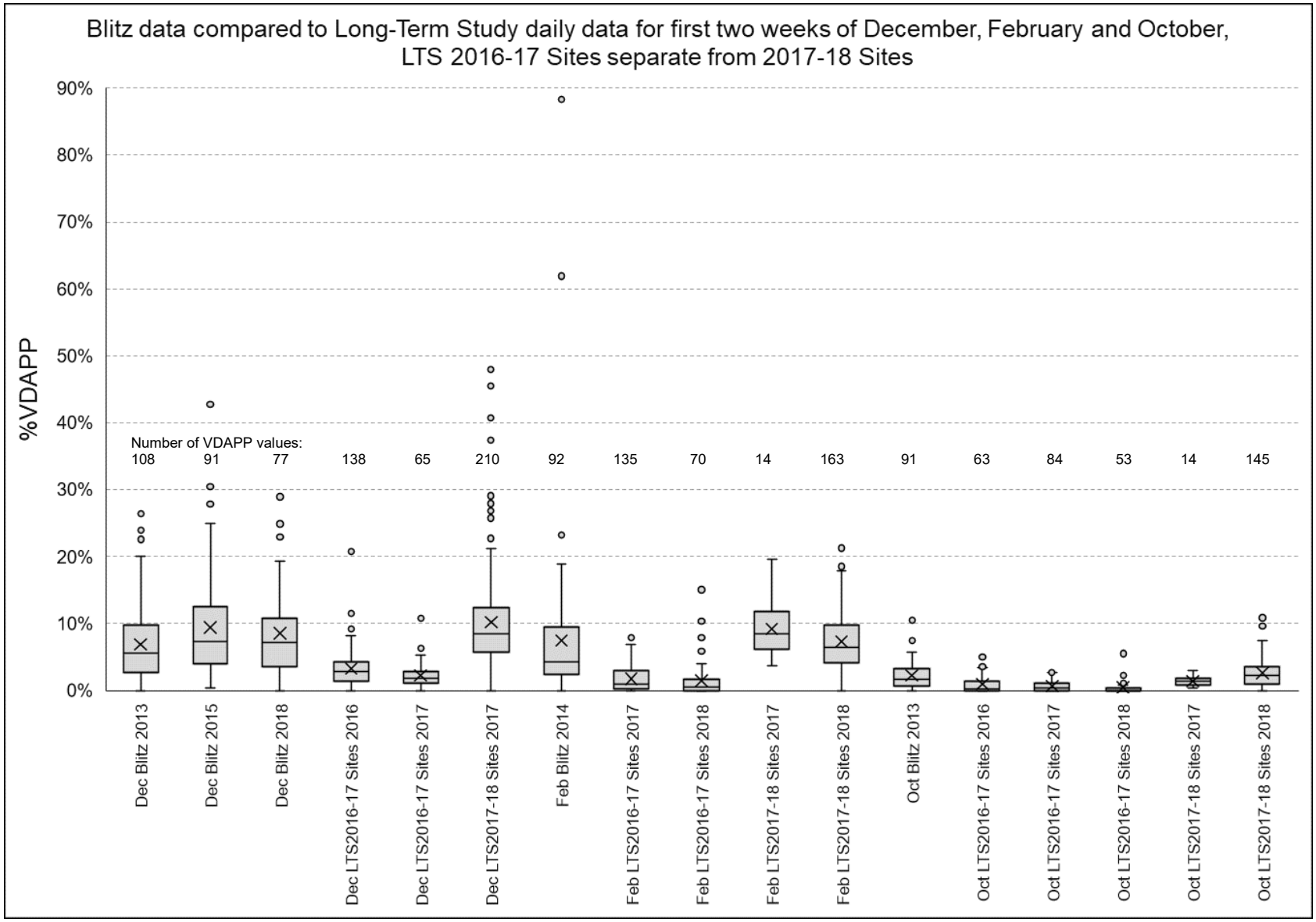


Figure 2: Box plot of Blitz 30-hour VDAPPs compared to LTS daily VDAPPs with 2016-17 and 2017-18 sites combined

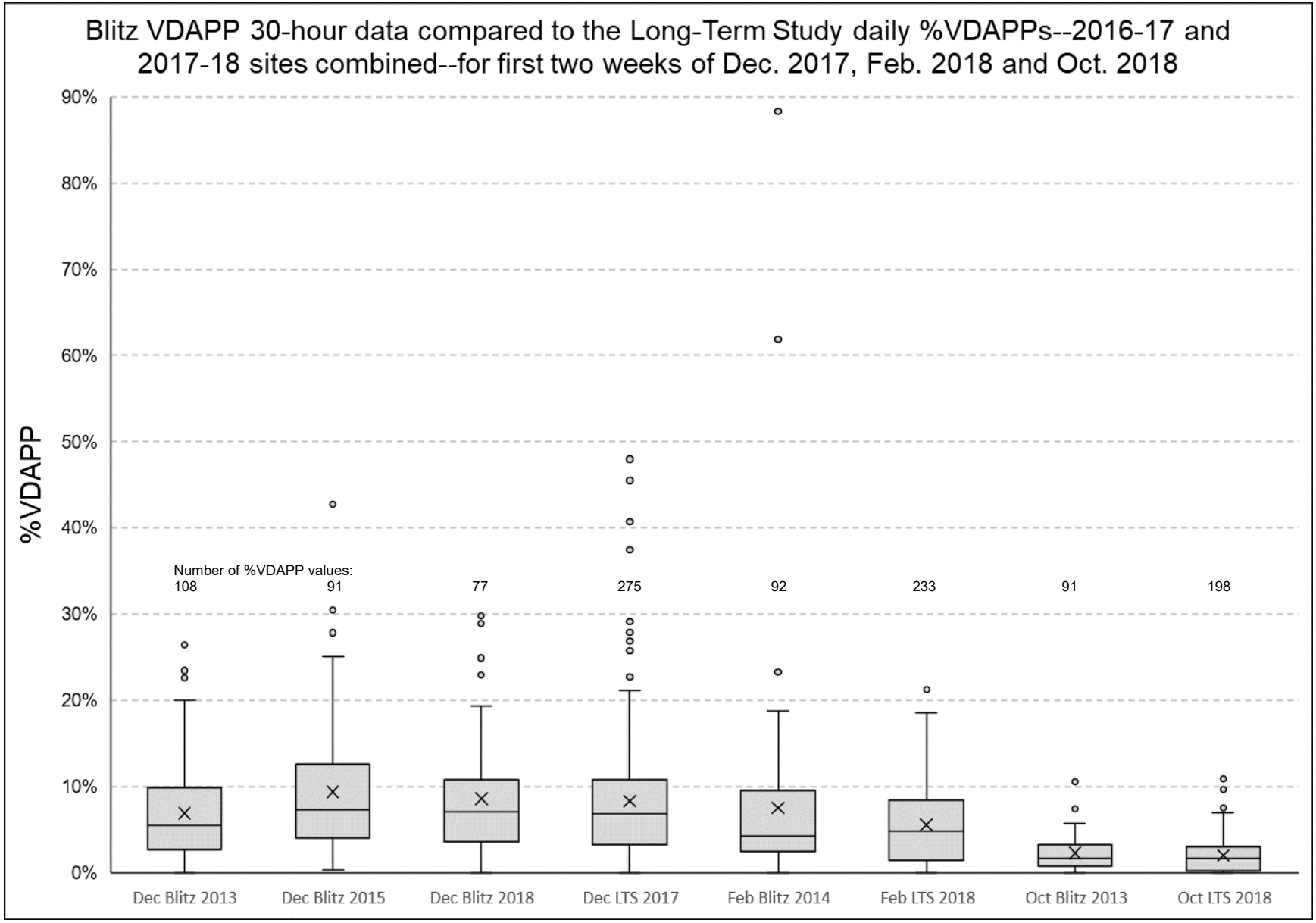


Figure 3: Box plot of Blitz daily VDAPPs and LTS 2017-18 sites weekly VDAPPs by season

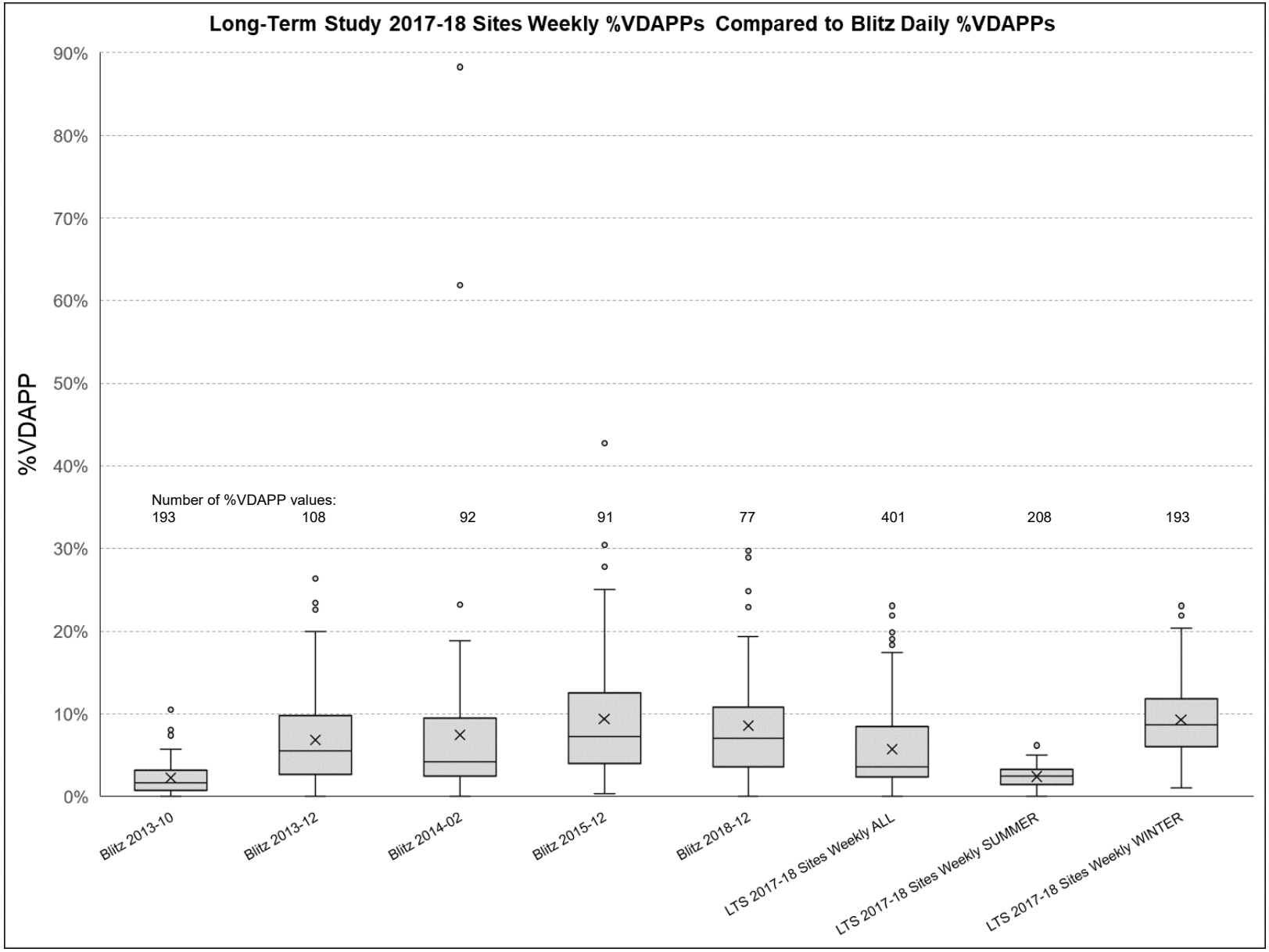
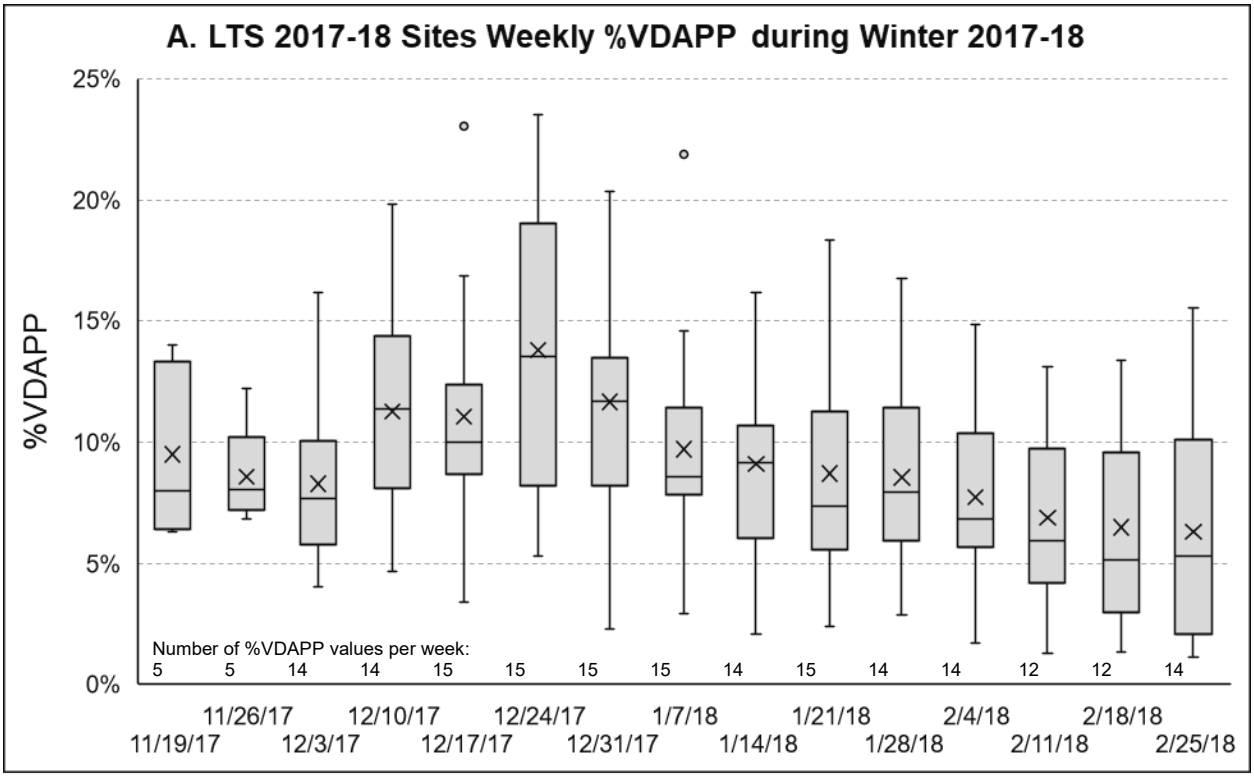


Figure 4: Box plots of weekly VDAPP for LTS 2017-18 sites by week



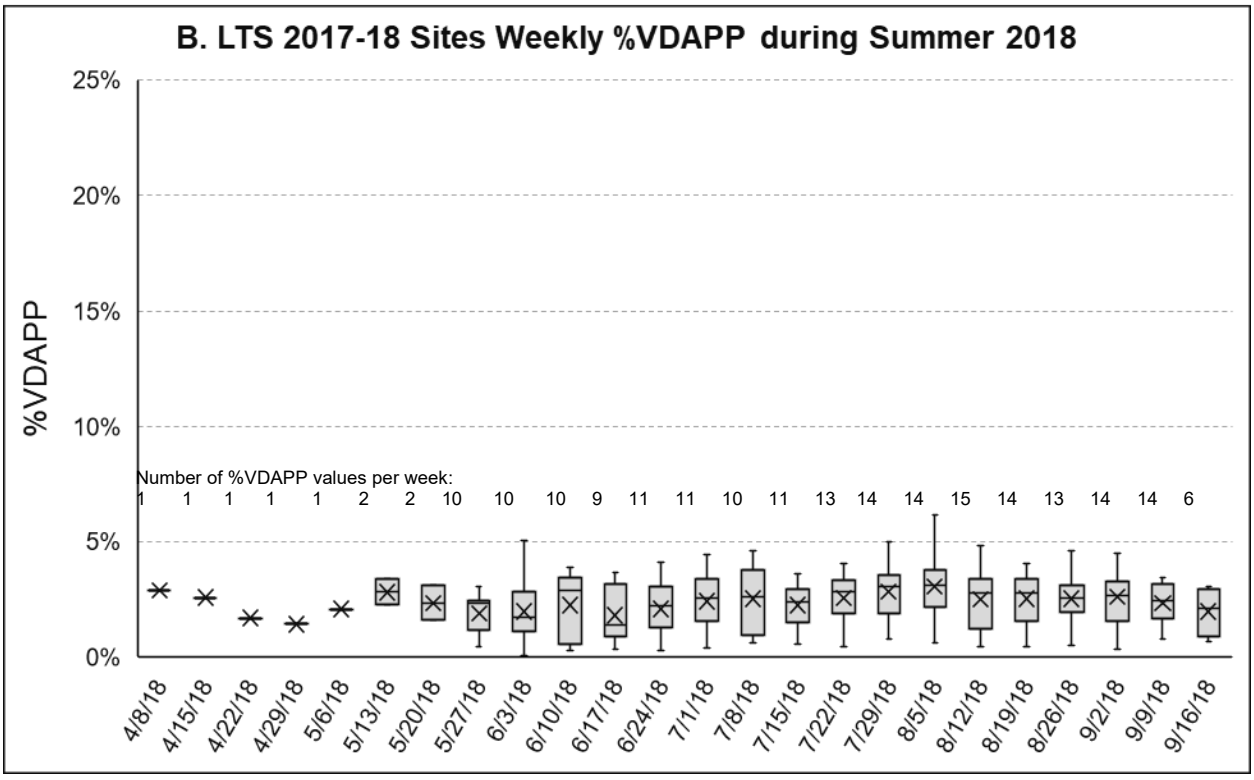
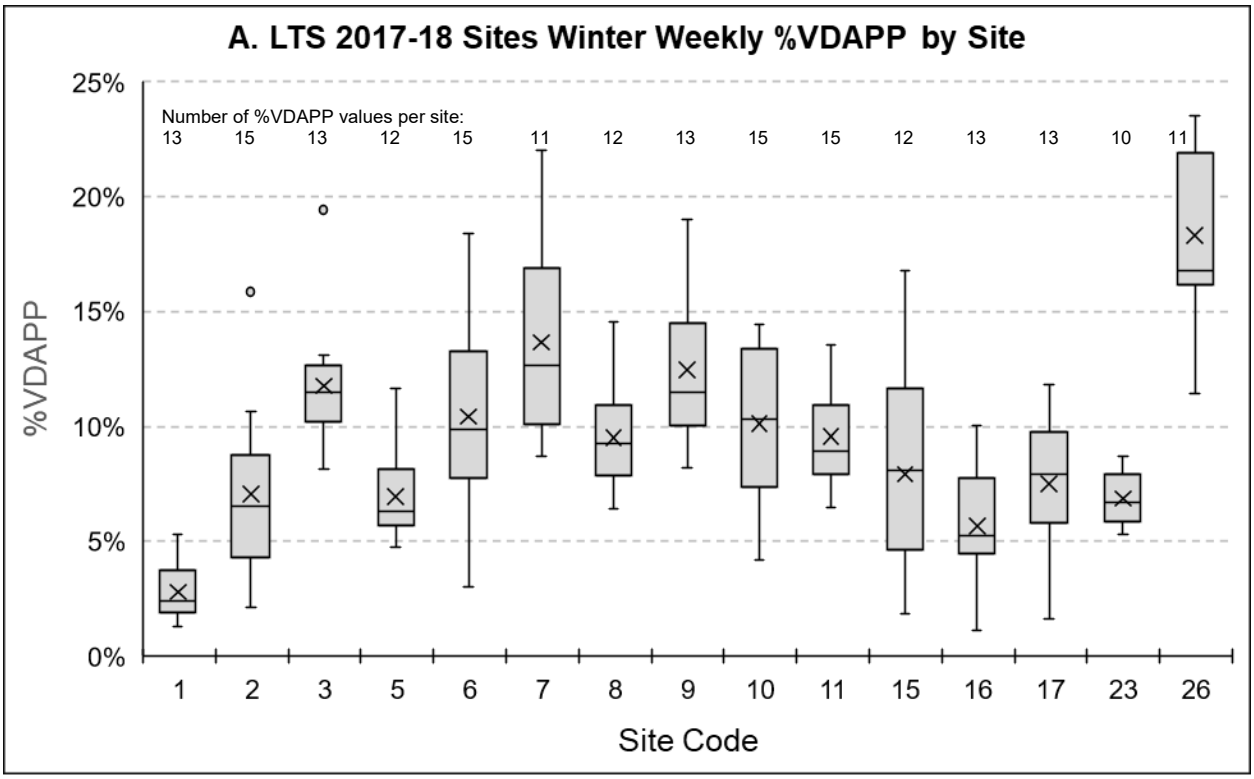



Figure 5: Box plots of weekly VDAPP for LTS 2017-18 sites by site



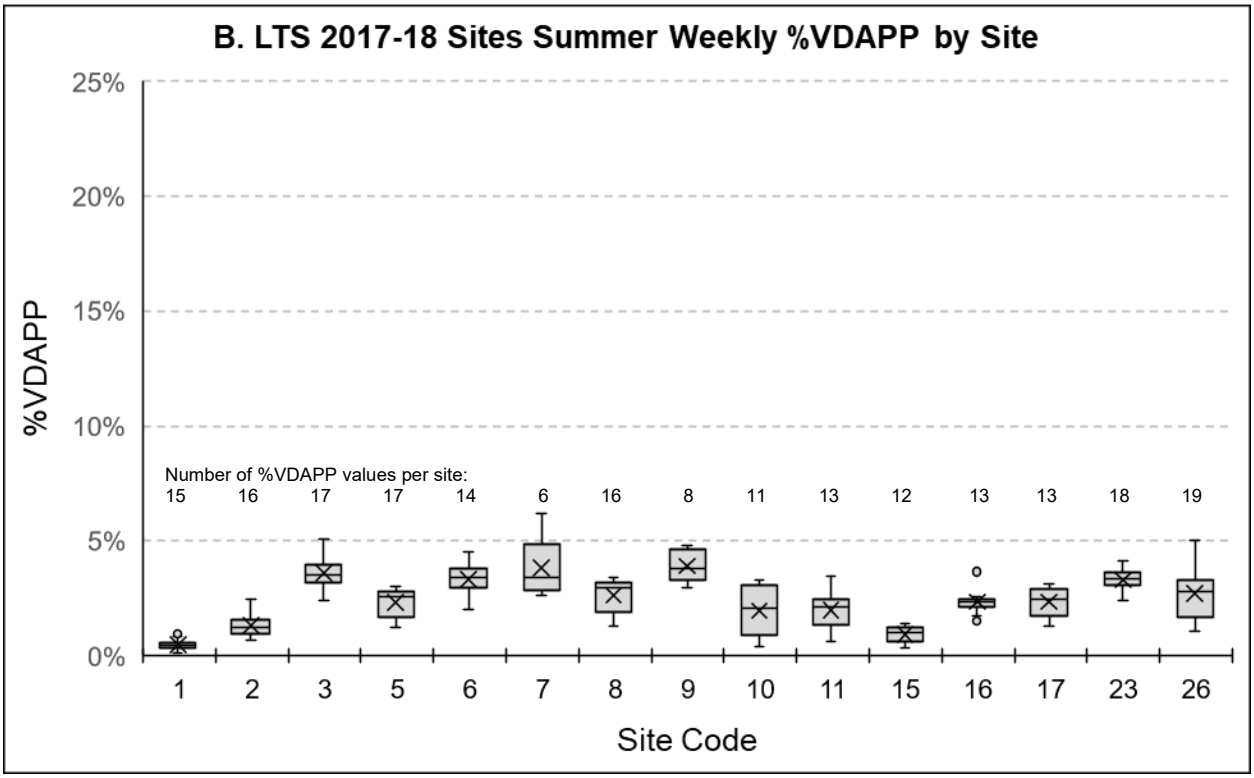



Figure 6: Box plot of LTS 2016-17 and 2017-18 sites weekly RIFE by season

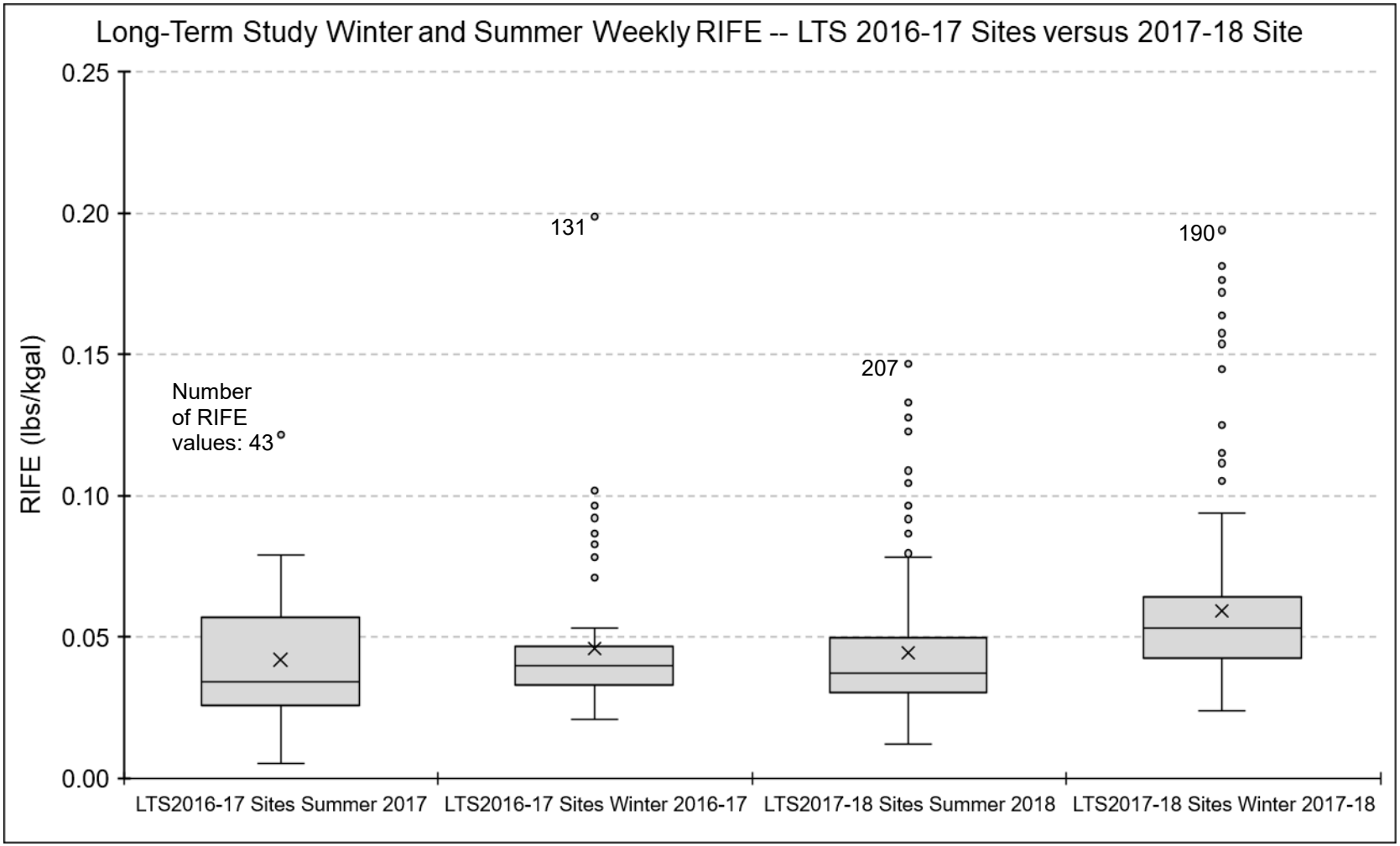


Figure 7: Box plots of weekly RIFE for LTS 2017-18 sites by week

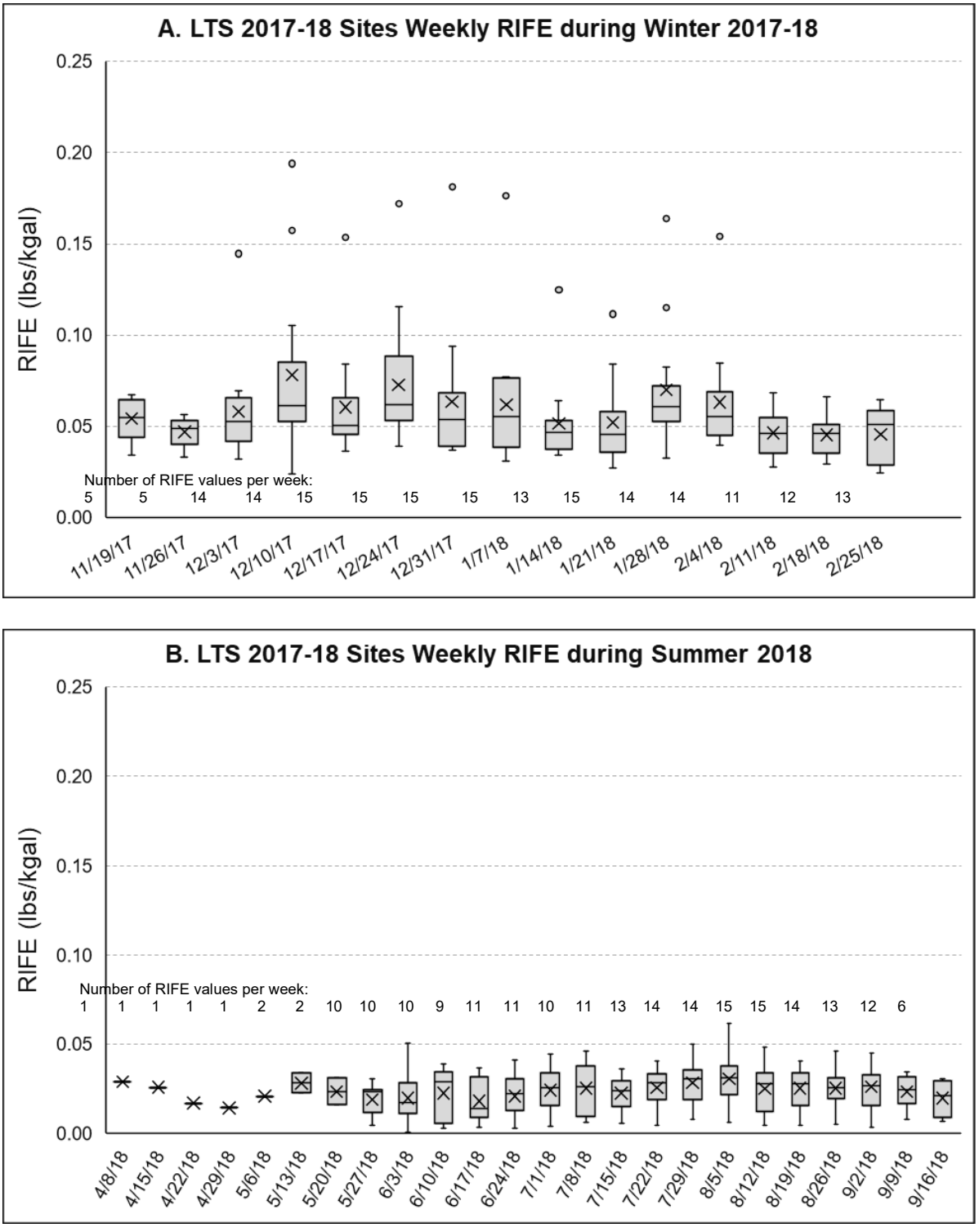
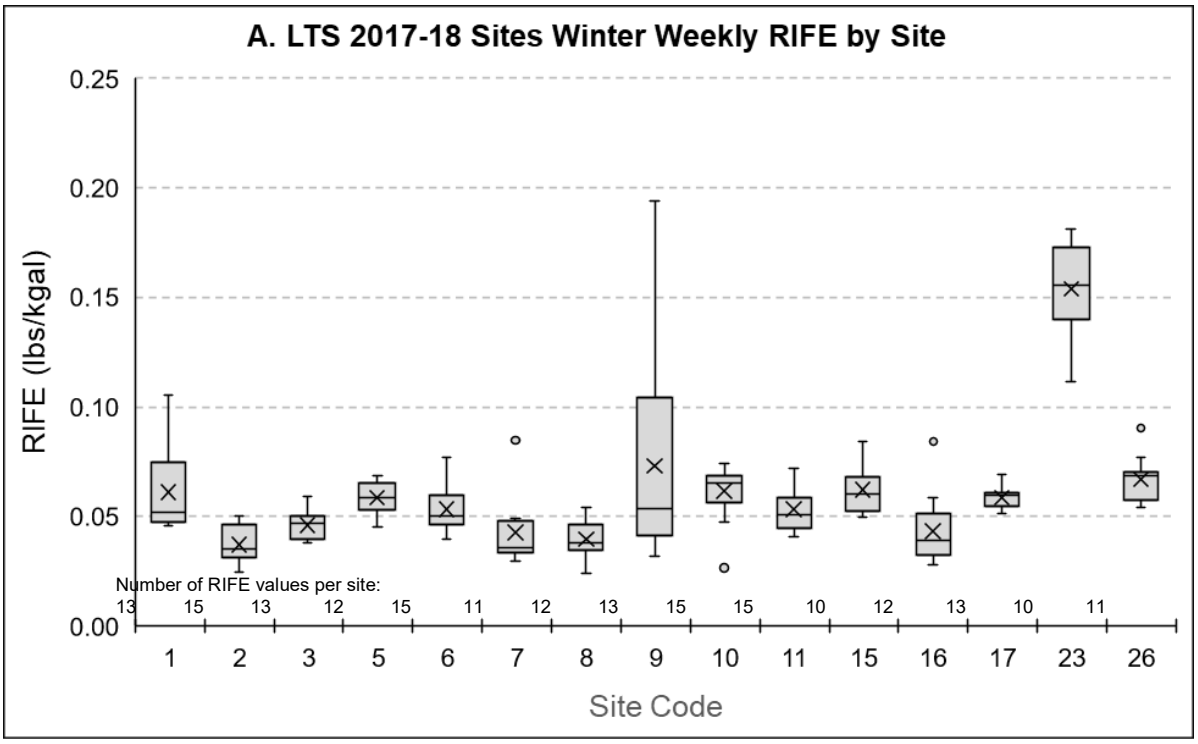
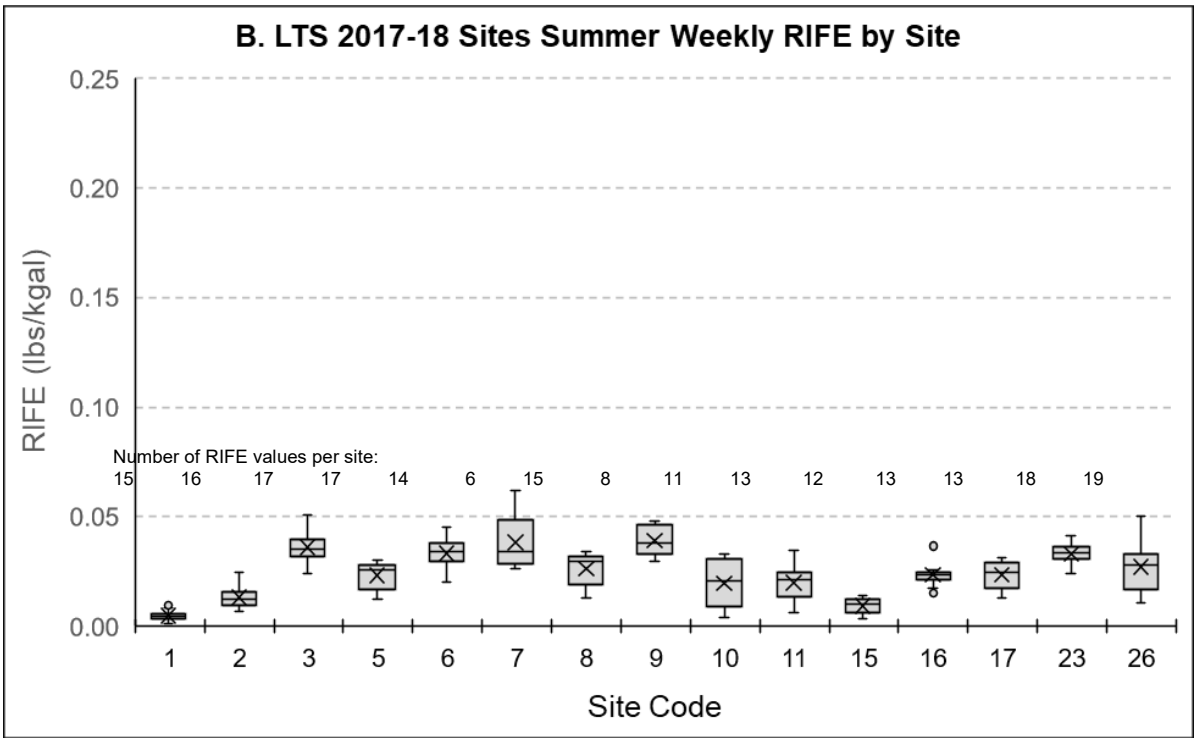


Figure 8: Box plots of weekly RIFE for LTS 2017-18 sites by site

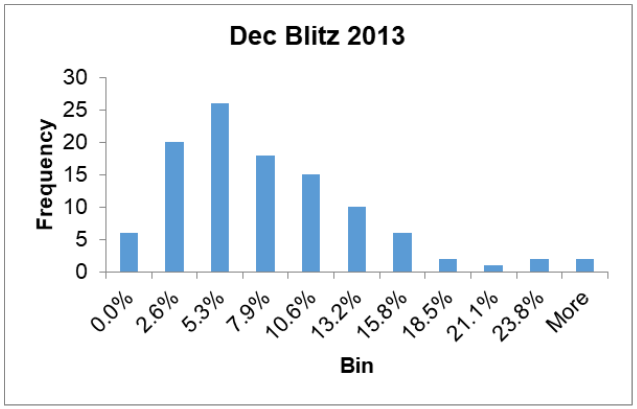


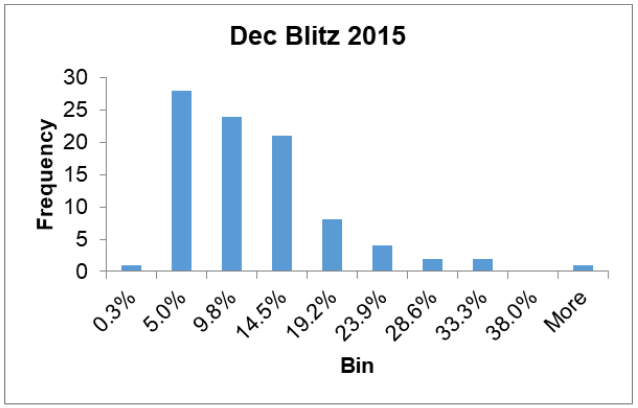



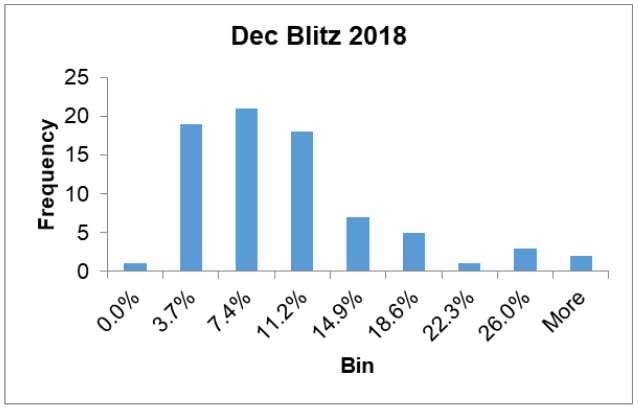
# ATTACHMENT 3: Histograms

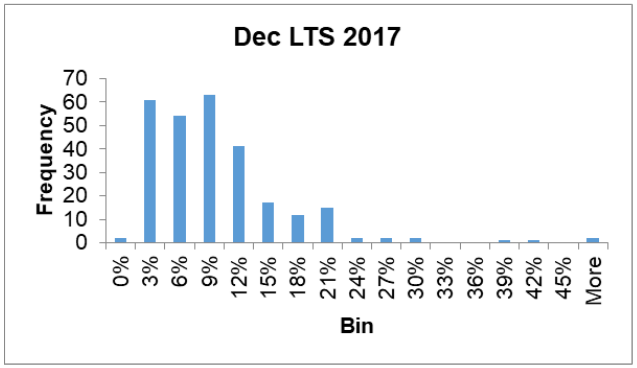
A. December Blitz 30-hour and LTS Daily VDAPPs
B. February Blitz 30-hour and LTS Daily VDAPPs
C. October Blitz 30-hour and LTS Daily VDAPPs
D. LTS 2017-18 sites weekly VDAPPs and RIFEs

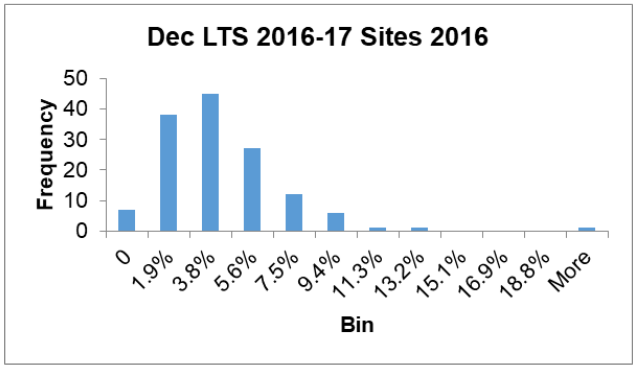
## A. December Blitz 30-hour and LTS Daily VDAPPs

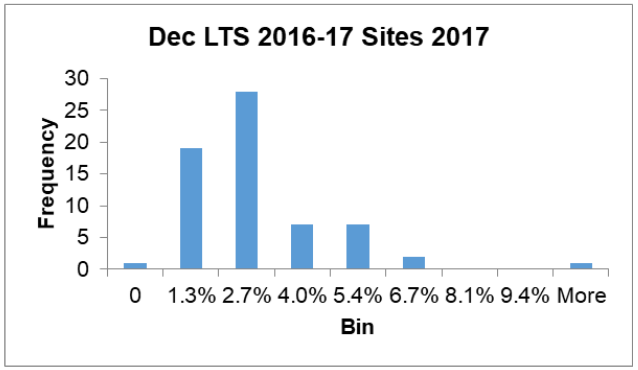


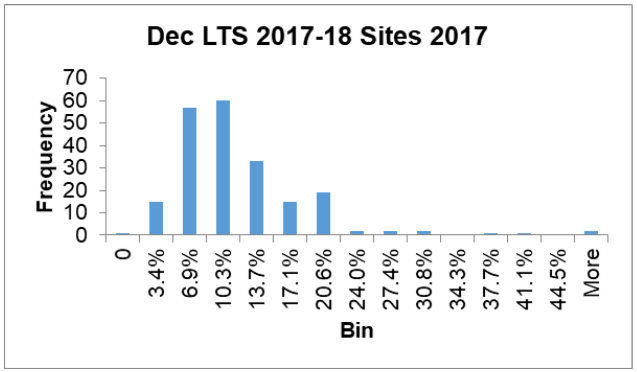



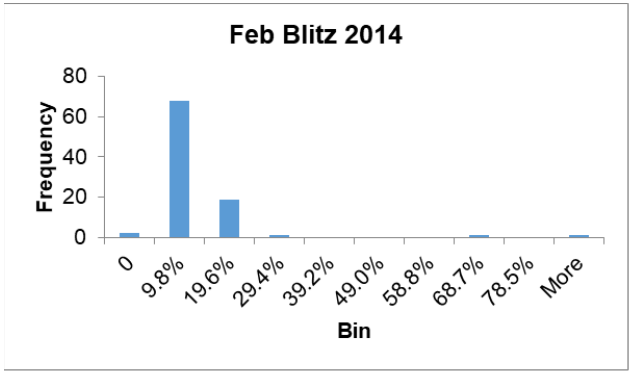



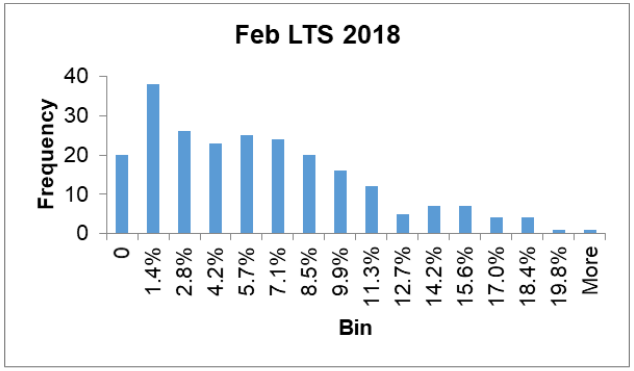



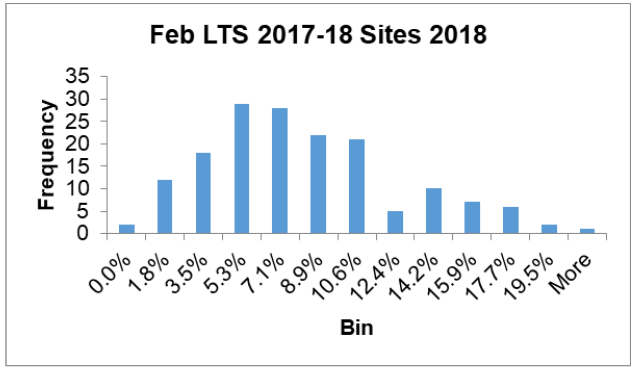



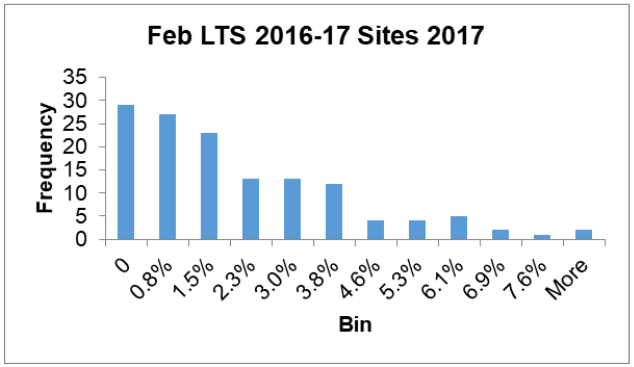



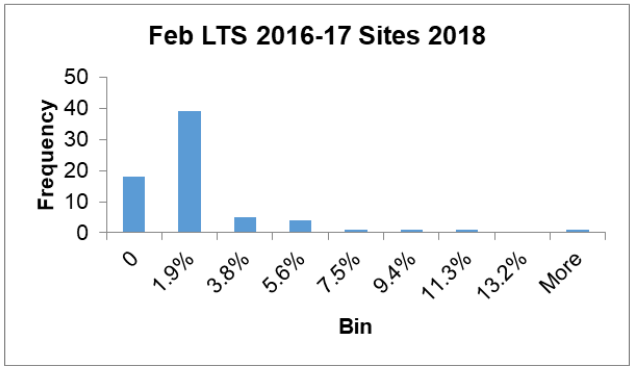
## B. February Blitz 30-hour and LTS Daily VDAPPs

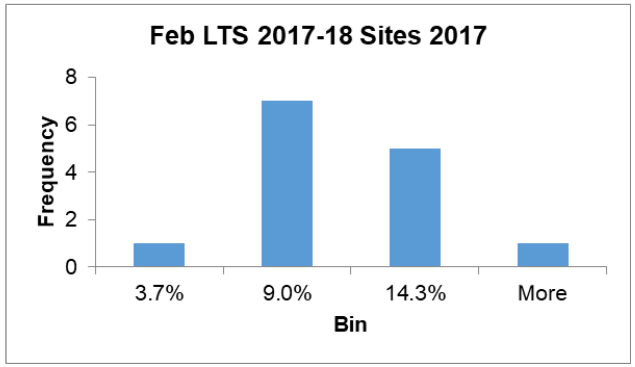


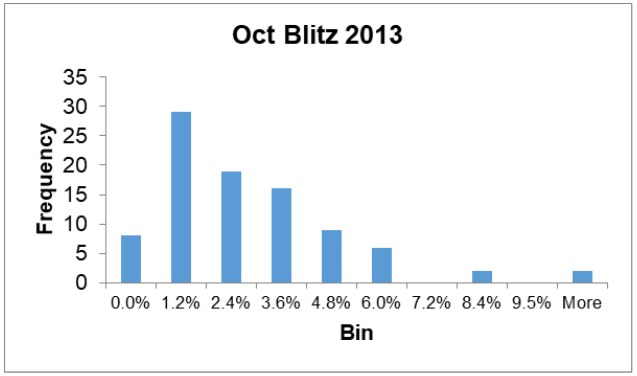



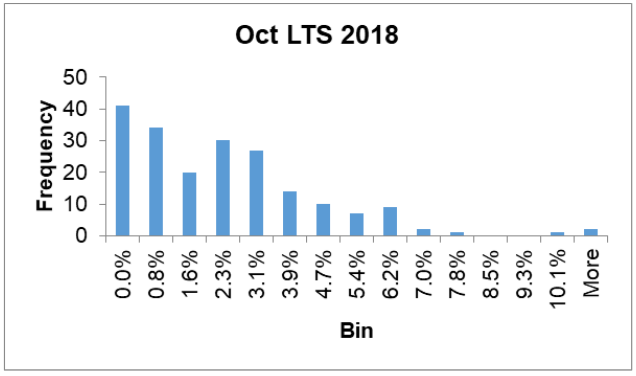



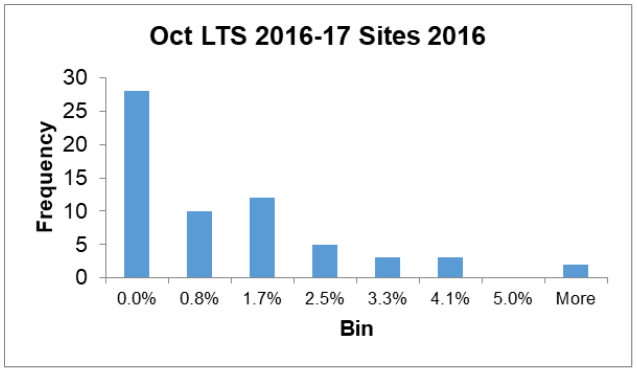



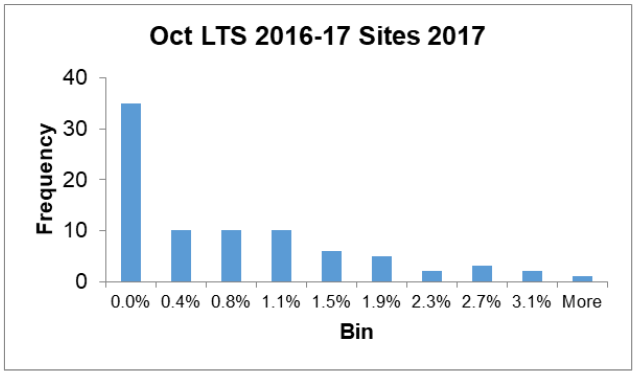



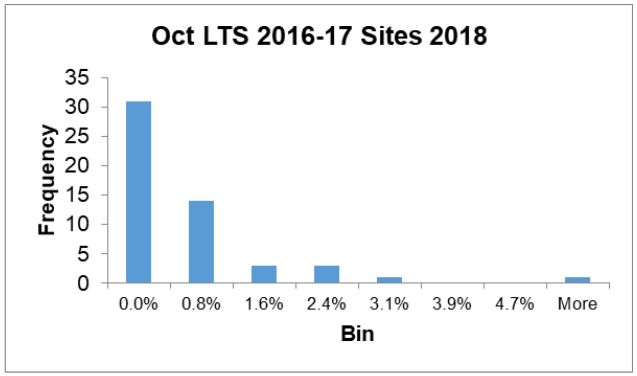
## C. October Blitz 30-hour and LTS Daily VDAPPs

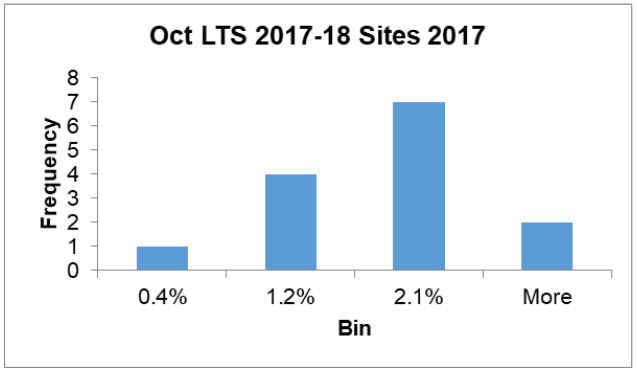


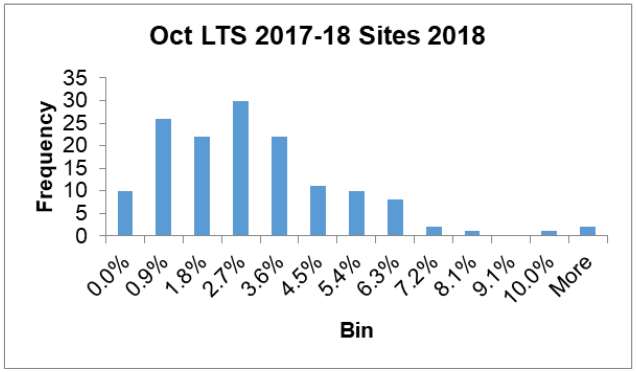



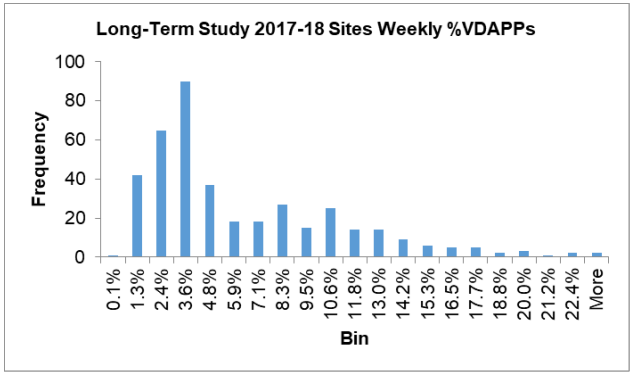



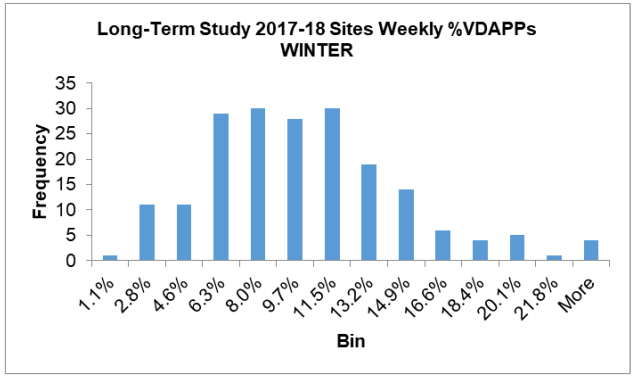



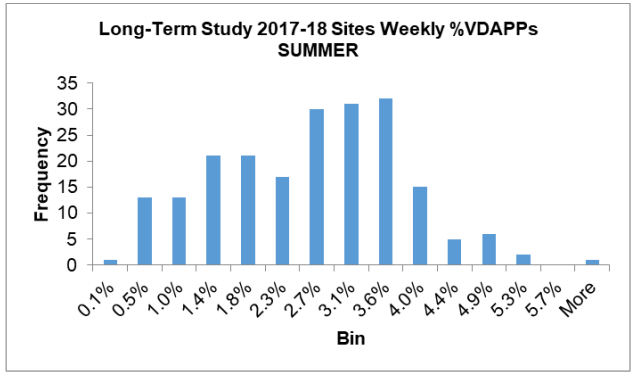



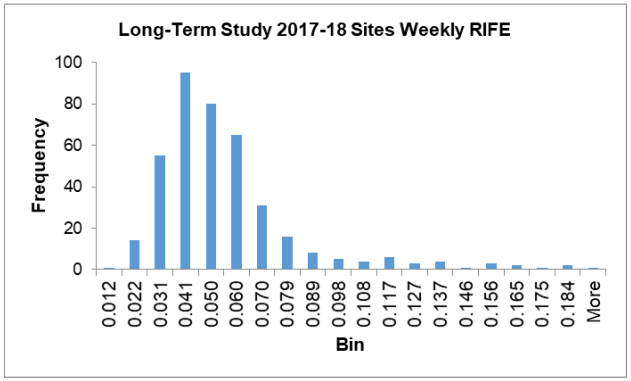



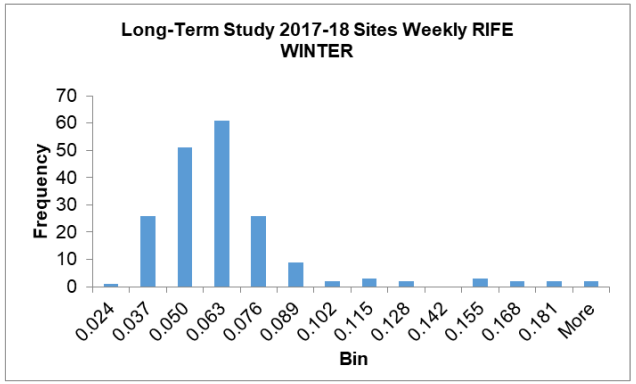
## D. LTS 2017-18 sites weekly VDAPPs and RIFEs

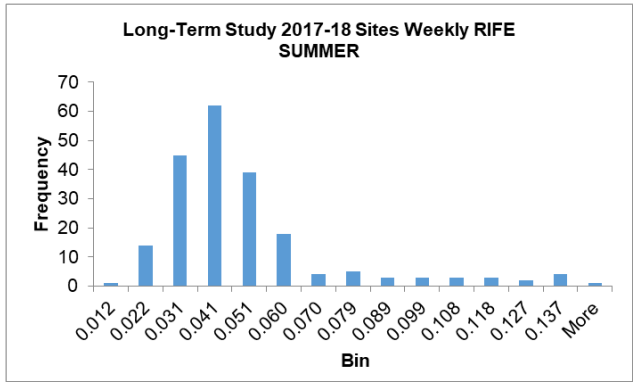


# ATTACHMENT 4: SAS Code

## A. Tests for Normality

```
title 'Test for Normality - LTS 2017-18 Sites Summer Weekly %VDAPPs';
ods graphics on;
ods select Moments TestsForNormality ProbPlot;
proc univariate data=work.weekly normaltest;
  var LTS1718_Summer_VDAPP;
  probplot LTS1718_Summer_VDAPP / normal(mu=est sigma=est)
                square
                odstitle = title;
  label LTS1718_Summer_VDAPP = 'Position LTS1718_Summer_VDAPP';
  inset mean std / format=6.4;
run;
```

## B. Comparison of Means

```
title 'Comparison of Mean VDAPPs for Blitz Events';
ods graphics on;
proc GLM data=Work.VDAPPs;
class B2013Dec_B2015Dec;
model LNVDAPP_B2013Dec_B2015Dec = B2013Dec_B2015Dec;
Means B2013Dec_B2015Dec / BON SCHEFFE TUKEY;
run;
ods graphics off;
```

# ATTACHMENT 5: Normality Tests

Attachment 5 provides the SAS 9.4 “Univariate Procedure” output with the results of the normality tests. The 56-page attachment is too large to include in this appendix file; a separate Adobe Acrobat file is available upon request.

# ATTACHMENT 6: Comparison of Means

Attachment 6 provides the SAS 9.4 "GLM Procedure" output with the results of the VDAPP and RIFE means comparisons. The 294-page attachment is too large to include in this appendix file; a separate Adobe Acrobat file is available upon request.

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