

Appendix D: Marine Mammal Monitoring

**Acoustic monitoring of Hector's dolphins within Lyttelton Harbour: progress report #3,
Styles Group, April 2018**

19 March 2018

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Dear Jared,

RE: Acoustic monitoring of Hectors dolphins within Lyttelton Harbour: progress report # 3

Introduction

Styles Group has been engaged by the Lyttelton Port Company to analyse the acoustic data collected using four CPOD click detectors from four sites within Lyttelton Harbour. The aim of the monitoring is to establish baseline presence and behaviours of endangered Hectors dolphin, *Cephalorhynchus hectori*, for the eventual comparison with detections during, and after, the proposed dredging works over a two year period. This brief reports on the data collection and processing completed to date. These will be updated quarterly as data continues to come in until the monitoring completion late 2018.

CPOD Deployment Sites

Four CPOD units have been deployed within Lyttelton Harbour at sites MM1 (43 deg 33.815 S, 172 deg 45.851 E), MM2 (43 deg 35.933 S, 172 deg 4.755 E), MM3 (43 deg 36.332 S, 172 deg 50.867 E) and MM4 (43 deg 34.430 S, 172 deg 53.438 E). A map showing these locations is provided in [Figure 1](#) below. The water depth during deployment was 9.5m at monitoring site MM1, 14m at site MM2, 15m at site MM3 and 20m at site MM4.

The acoustic monitoring started on 27 January 2017 and batteries and SD cards are swapped monthly with new ones before the units are immediately re-deployed on the same mooring. The data analysed thus far covers the period between 27 January 2017 and 7 February 2018.



CPOD Performance and Data Processing

Pod data was uploaded to cpod.exe software (Chelonia Ltd, UK) and scanned for any metadata warnings, the maximum click count per minute, patterns in the time-series and the overall spectra to determine possible contamination issues via tides, weather events, vessels and non-target biological sources (such as snapping shrimp). An example of a time-series is provided in [Figure 2](#). Our analysis of the data confirms that the performance of the pod was acceptable adequate.

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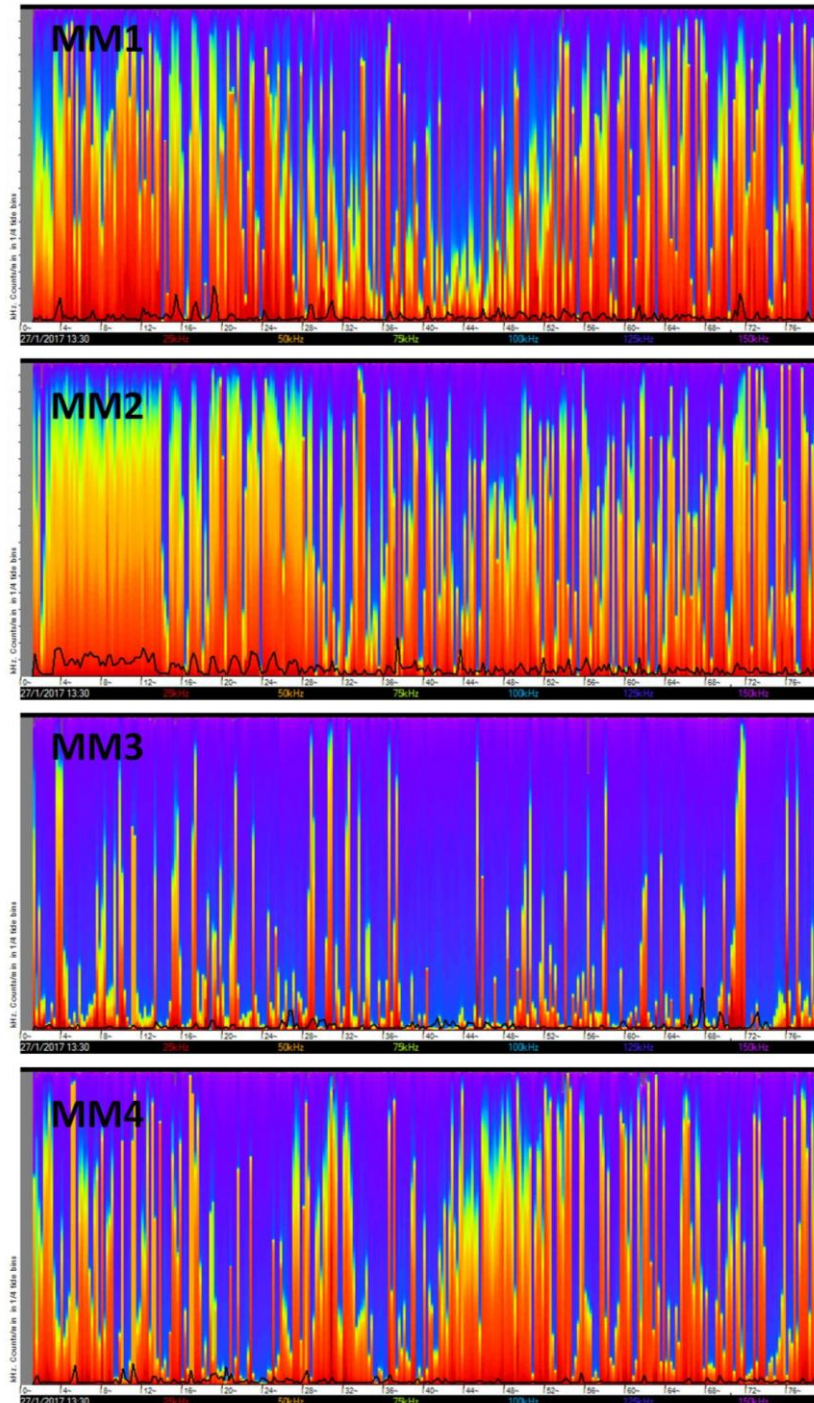


Figure 2: Time series of the raw data before any filters were applied. These plots depict the entire first deployment at each site, with the deployment day along the x-axis. The y-axis is the number of unfiltered clicks that were logged (shown by the black line plot overlaying the colour spectrum) and the colour spectrum represents frequency (from below 25 kHz (red) to 150 kHz (pink)). Incoherence between time series plots from each monitoring site and the absence of any cyclic patterns in the unfiltered clicks show minimal tidal interference from currents on the performance of the units but high levels of low frequencies at the shallower sites MM1 and MM2 compared to the deeper MM3 and MM4 sites.

Following all checks and scans, the main parameter used to quantify spatio-temporal variation in dolphin activity near each monitoring site was Detection Positive Minutes (DPM) or Detection Positive Hours (DPH). The DPM is the number of minutes that contained at least one dolphin click train across the day or hour, while the DPH is the number of hours per day that contained at least one dolphin click train.

Autocorrelation (the correlation between data points of the same variable based on related factors) in the DPM metric was assessed to determine the most appropriate time-interval during the analyses. This was done using the 1-min DPM counts and following the formula for the autocorrelation at lag k from Box et al. (2016) as follows:

Similarly, the *autocorrelation* at lag k is

$$\begin{aligned}\rho_k &= \frac{E[(z_t - \mu)(z_{t+k} - \mu)]}{\sqrt{E[(z_t - \mu)^2]E[(z_{t+k} - \mu)^2]}} \\ &= \frac{E[(z_t - \mu)(z_{t+k} - \mu)]}{\sigma_z^2}\end{aligned}$$

since, for a stationary process, the variance $\sigma_z^2 = \gamma_0$ is the same at time $t + k$ as at time t . Thus, the autocorrelation at lag k , that is, the correlation between z_t and z_{t+k} , is

$$\rho_k = \frac{\gamma_k}{\gamma_0} \quad (2.1.6)$$

which implies, in particular, that $\rho_0 = 1$.

with the number of values for the lag series being limited to 1000 of the number of bins (Tollit et al 2011). Values were then plotted in a correlogram with the horizontal limits (set using $\pm 1.96 * (2/\sqrt{N}) * \text{ones}(1,2)$) representing the approximate 0.05 p-values. Since the resulting autocorrelation was observed up to 29 minutes across all sites, the DPM per hour was the shortest time period used for statistical analyses.

DPM per hour and day, along with DPH per day, were exported and plotted. Diurnal variation in the DPM per hour and DPH was tested using a Kruskal-Wallis ANOVA, after confirming the required assumptions, while a non-parametric two-way Scheirer-Ray-Hare model was used to test the interaction between factors Site x Month. When a statistically significant interaction was found, Dunn's pairwise comparisons were used to determine which groups differed from each other. Preliminary observations of foraging behaviours were quantified by inter-click intervals, train durations and the number of clicks per train, and differences between monitoring sites for each deployment period were tested using the Kruskal-Wallis model. Feeding buzzes were identified as fast click trains with a minimum inter-click interval (ICI) of <10 ms (Carlström 2005; Verfuß 2009; Nuuttila et al. 2013) and the ratio of feeding buzzes to non-feeding buzzes were quantified and plotted (Nuuttila et al. 2013).

Summary of Analysed Data

Pooled across all sites and deployments, approximately 34,200 hours of data have been recorded. No physical problems with either the CPOD units or mooring systems were reported, however a date-stamp issue was corrected for data obtained from site MM2 from Deployment 2, and sites MM3 and MM4, Deployment 6. Those date-stamp issues were due to a misalignment of the date format between the units and software, and the format was corrected during the post-processing. Of those 34,200 hours, 10,642 hours contained at least one Hector's dolphin detection. The daily ratio of minutes with no detections to minutes containing at least a single detection is plotted in **Figure 3**.

All figures are attached in Appendix B.

Detection Positive Hours (DPH)

While dolphins were detected most days during all months (**Figure 4, 5**), there was significant variation in the DPH data between months and sites ($H_{40} = 677.20$, $P < 0.001$). Differences in the monthly DPH were recorded in all sites ($P < 0.05$) (**Figure 6**), with higher DPH during the warmer spring and summer months (between September and March) at all sites (MM1 ($H_{11} = 255.35$, $P < 0.001$), MM2 ($H_{11} = 239.50$, $P < 0.001$), MM3 ($F_{10,311} = 18.00$, $P < 0.001$) and MM4 ($H_{11} = 176.40$, $P < 0.001$). The highest median DPH from each site over the year (occurring in December and January) was 19 DPH at MM1; 21 DPH at MM2; 18.4 DPH at MM3¹; and 20 DPH at MM4. From early autumn (March onwards), median DPH begin to decrease with the lowest detection rates by late winter (August) (median of 3 DPH at MM1; 5 DPH at MM2²; 11 DPH at MM3; and 6 DPH at MM4). Throughout the year, median DPH over each month varied the least at MM3 compared to the other sites, however the highest median DPH over the year during January was at MM2, followed by MM4.

Detection Positive Minutes (DPM)

Summed across all days per month, the total median DPM per 24 hour period was generally highest during January and gradually fell each month thereafter at sites MM1 and MM2, while MM3 and MM4 showed less change coming into winter compared to MM1 and MM2 (**Figure 7**). Broken down into DPMs per hour, diel patterns were generally seen at all sites (**Figure 8, 9**). However, depending on the seasons, said patterns varied between sites. For example, most activity was recorded between 19:00hrs and 07:00hrs (the following day) at MM1 during late summer (February and March). However, by late winter (August), diel patterns at MM1 were not recorded at all, before a peak in DPM was recorded again during the early morning (02:00hrs – 04:00hrs) during January. Contrastingly, at site MM3, diel patterns remained nearly year-round (as November and December showed similar DPMs throughout a 24-hr period). Generally, DPMs were higher during the night periods inside the harbour (sites MM1 and MM2) and during the day outside the harbour at site MM3. The more offshore site of MM4 generally showed

¹ DPH value from December, since no data were collected from MM3 during January 2018.

² DPH value from July, since no data were collected from MM2 during August).

higher DPMs during the night (particularly during mid-spring through summer (October through January)).

Potential Behaviours

Differences in the median ICIs, click train durations and the number of clicks per train were recorded from all deployments (all Kruskal-Wallis tests returned P values under 0.05) (**Figures 10 through 21**). Focusing on ICIs as a proxy for foraging behaviours, the shortest median ICIs were recorded from within the harbour (sites MM1 and MM2) during February ($H_3 = 6871.13$, $P < 0.001$), however this trend was reversed by May with sites MM1 and MM2 showing longer ICIs (median ICIs of 23905 μs and 26927 μs , respectively) compared to the outer sites MM3 and MM4 (with median ICIs of 19945 μs and 17780 μs , respectively) ($H_3 = 1209.26$, $P < 0.001$).

Feeding- to non-feeding buzzes ratios also varied by month (**Figures 22 through 25**). During February, the number of feeding buzzes detected was highest at all sites; possibly suggesting that no particular area was a preferential foraging ground during late summer. However, while the number of feeding buzzes decreased going into autumn, a higher ratio of feeding- to non-feeding buzzes was clearly seen at site MM1, first suggesting that the area may hold some importance for foraging compared to the other sites during that period. However, the feeding ratios at site MM1 continued to decrease through the winter months, while sites MM3 and MM4 outside the harbour remained fairly consistent through winter and into autumn. By August, feeding activity detected at site MM1 was below 10%, approximately half the ratio seen at site MM3 (at 18.5%). During the winter months and early spring, site MM1 within the inner harbour recorded the lowest feeding activity (below 10% of their time spent foraging). At site MM2, no data were collected during August; however foraging buzzes were detected less than 10% of the time during September, and gradually increased again from October (which differed from site MM1 where feeding activity did not begin increasing above 10% until January). Outside the harbour, the proportion of detections containing feeding buzzes remained between 12 and 19 % during the winter months. These data suggest dolphins forage more often outside the harbour (around sites MM3 and MM4) during the winter, but forage more often inside the harbour (around site MM1) and the harbour entrance (around site MM2) during the summer. During the spring months (October-December), foraging activity around MM2 is detected more often compared to all other sites.

Dolphins' spent between 6.2 % and 36 % of their time at the MM1 site foraging, compared to 9-35% at site MM2, 12-30% at site MM3 and 10-24% at site MM4 (Figure 22). Thus, the majority of click trains detected were not related to foraging activity and, coupled with the lower presence during autumn and winter, the area around site MM1 might not be critical foraging ground for dolphins, but rather supplementary to the area as a whole. During the winter and spring months, the area around site MM1 does not appear critical foraging habitat, however this is not the case for the area around site MM2 and beyond the harbour entrance, with detection rates of foraging buzzes increasing from October. However, the amount of data collected to date would not support this as a conclusion since it would be based on a single year only and this will be revised after more data is collected.

Summary

The data presented herein serves as a snapshot of the data collected to date. As additional data continues to be collected, the statistical results above may change.

Notwithstanding, the results collected thus far do indicate spatio-temporal variations in the habitat use by Hector's dolphins around Lyttelton Harbour. Highest dolphin detection rates were recorded at site MM3, outside Port Levy, which was also an important day-time habitat. The data collected to-date shows dolphin presence within Lyttelton Harbour (represented by site MM1) is generally highest between 15:00hrs and 08:00hrs the following day. While detection rates inside Lyttelton Harbour were less compared to the coastal sites near the entrance (represented by sites MM2 and MM3), the highest proportion of feeding buzzes were detected at site MM1 during the summer and autumn months compared to the other sites. By winter, foraging activity is below 10%, compared to 18.5 and 13.2% at sites MM3 and MM4, respectively. Overall, dolphins' spent between 6% and 36% of their time at the MM1 site foraging, compared to 9-35% at site MM2, 12-30% at site MM3 and 10-24% at site MM4. Therefore, these data suggest that the dolphins are currently foraging over a wider area with none of the monitoring sites being critical foraging habitat. However, this is based on a single year of data and that should be taken into account when using these data for planning.

I trust that this information is satisfactory. Please do not hesitate to contact me should you have any queries or require any further information.

Kind regards,



Matthew K. Pine, Ph.D. MASNZ.
Marine Scientist & Consultant
Styles Group

References

- Box GEP, Jenkins GM, Reinsel GC. 2016. Time Series Analysis: Forecasting and Control. 5th ed. Englewood Cliffs, NJ: Prentice Hall, pg 25.
- Carlström J. 2005. Diel variation in echolocation behavior of wild harbor porpoises. Marine Mammal Science 21(1): 1-12.
- Nuuttila HK, Meier R, Evans PGH, Turner JR, Bennell JD, Hiddink JG. 2013. Identifying foraging behaviour of wild bottlenose dolphins (*Tursiops truncatus*) and harbor porpoises (*Phocoena phocoena*) with static acoustic dataloggers. Aquatic Mammals 39(2): 147-161.

Tollit D, Wood J, Broome J, Redden A. 2011. Detection of marine mammals and effects monitoring at the NSPI (OpenHydro) turbine site in the Minas Passage during 2010. SMRU Consulting Ltd & Acadia University (SMRU Rpt # NA0410BOF, Acadia Publication # 101).

Verfuß UK, Miller LA, Pilz PKD, Schnitzler HU. 2009. Echolocation by two foraging harbour porpoises (*Phocoena phocoena*). The Journal of Experimental Biology 212(6): 823-834.

Appendix A: Metadata

Deployment	Start Date	End Date	Number of hours recorded (hrs)			
			Site MM1	Site MM2	Site MM3	Site MM4
1	28/01/2017	09/03/2017	968.15	966.65	965.85	957.57
2	09/03/2017	01/04/2017	550.23	545.78	550.88	553.95
3	01/04/2017	07/05/2017	864.42	864.97	864.57	863.85
4	07/05/2017	08/06/2017	766.87	767.37	766.77	767.22
5	08/06/2017	05/07/2017	649.78	664.97	672.27	672.17
6	05/07/2017	01/08/2017	648.95	643.87	626.50	626.53
7	01/08/2017	04/09/2017	814.37	NaN	814.22	814.57
8	04/09/2017	19/10/2017	893.83	1084.42	1080.15	1080.33
9	19/10/2017	10/11/2017	524.53	521.00	524.85	524.47
10	10/11/2017	5/12/2017	599.25	598.60	598.70	598.75
11	5/12/2017	4/01/2018	716.80	722.25	721.92	722.32
12	4/01/2018	7/02/2018	821.60	819.93	NaN	816.43

Table 1: Start and end dates for each deployment and number of hours recorded from each monitoring site per deployment. No data were obtained from MM2 during Deployment 7 due to technical issue that has since been resolved. No data were obtained from MM3 during Deployment 12 due to missing unit that has since been replaced.

Appendix B: Figures

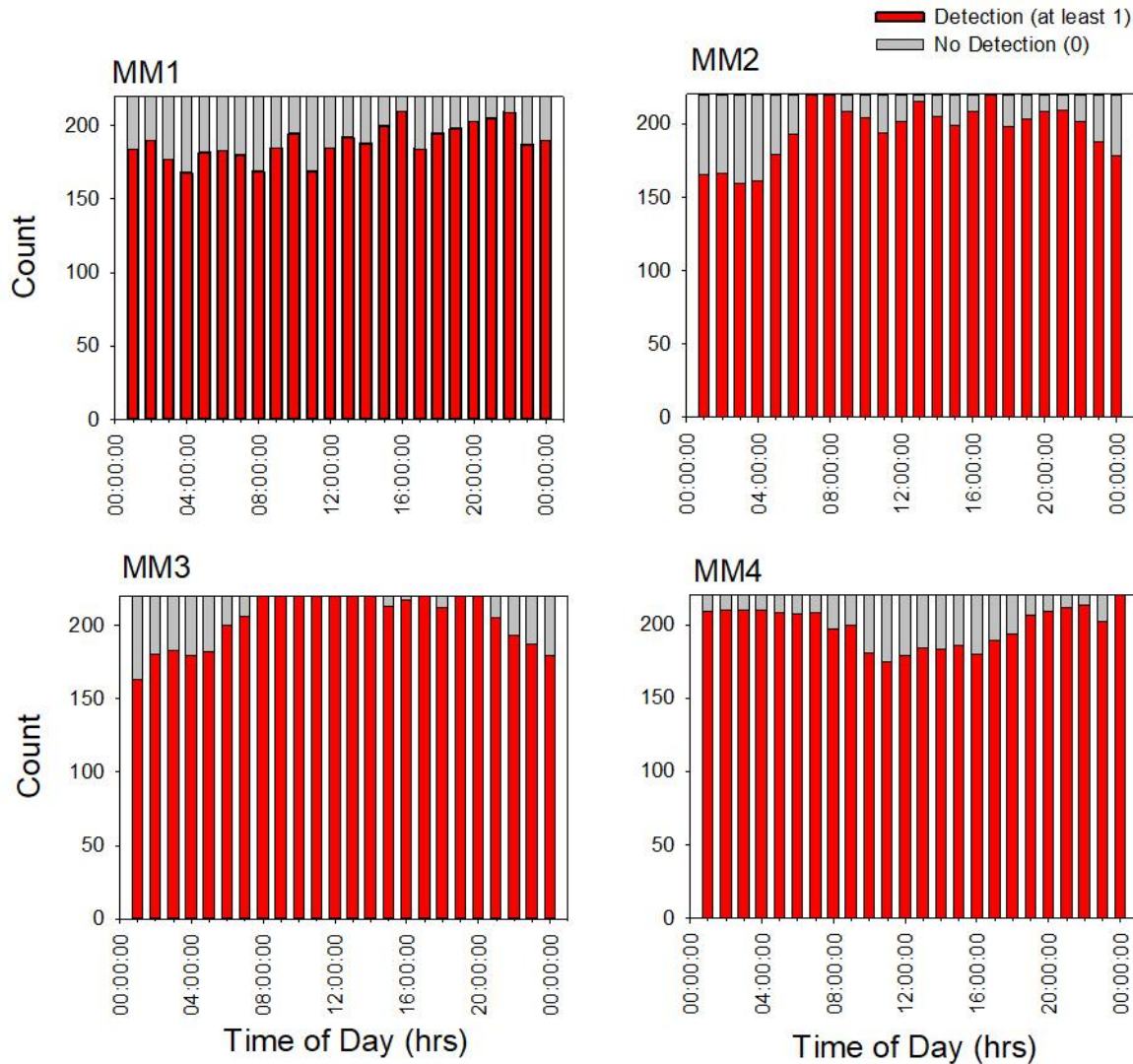


Figure 3: Proportion of days (220 per site, except MM2 with 187 days) that contained at least one DPM for each hour (i.e. a detection, shown by the red bars), and that contained zero DPMs (i.e. no detections were made during that hour, shown by the grey bars). 50% of hours containing detections are only seen at site MM3 between 07:00hrs and 21:00hrs.

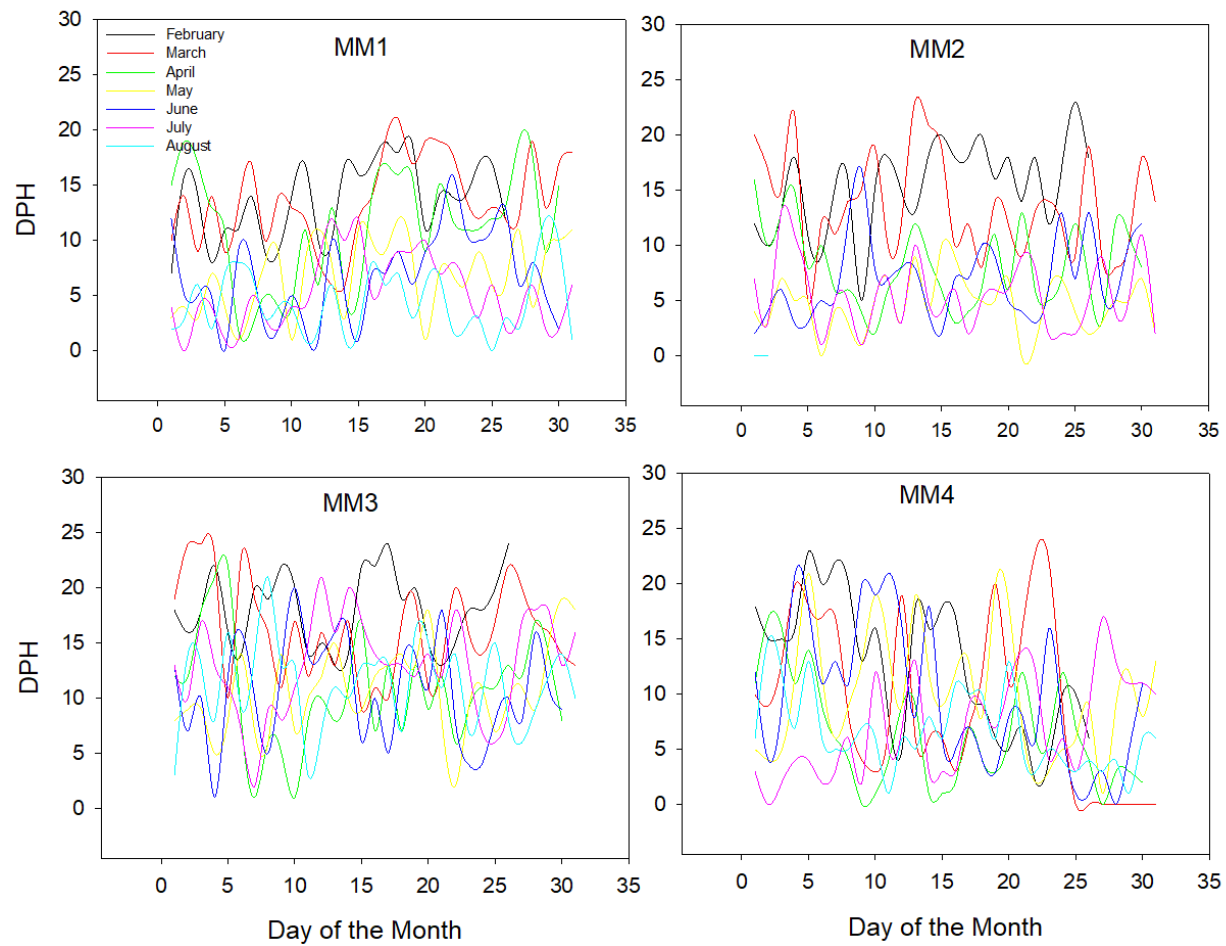


Figure 4: Summed DPH over each day between February and August 2017 for monitoring sites MM1, MM2, MM3 and MM4.

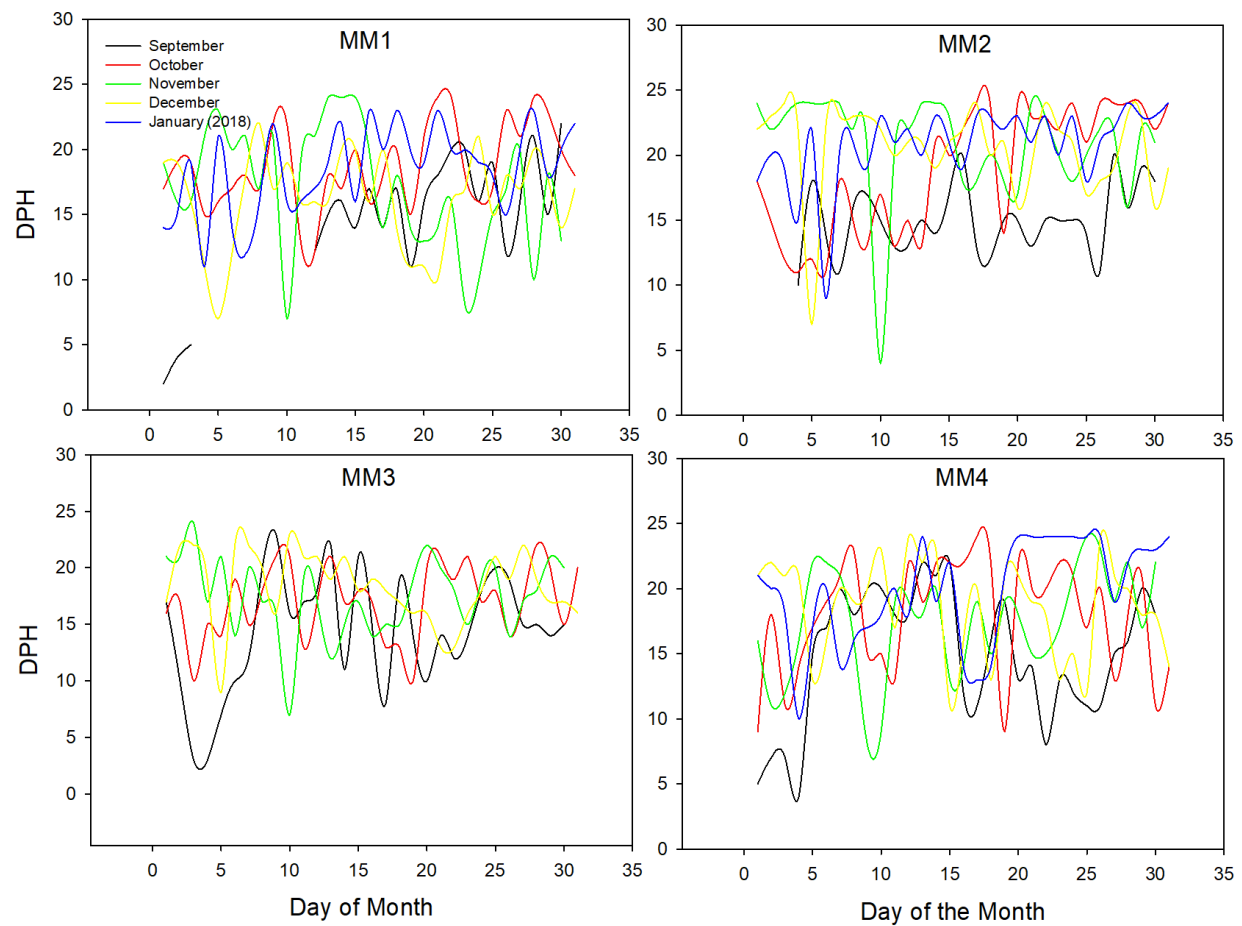


Figure 5: Summed DPH over each day between September 2017 and January 2017 for monitoring sites MM1, MM2, MM3 and MM4.

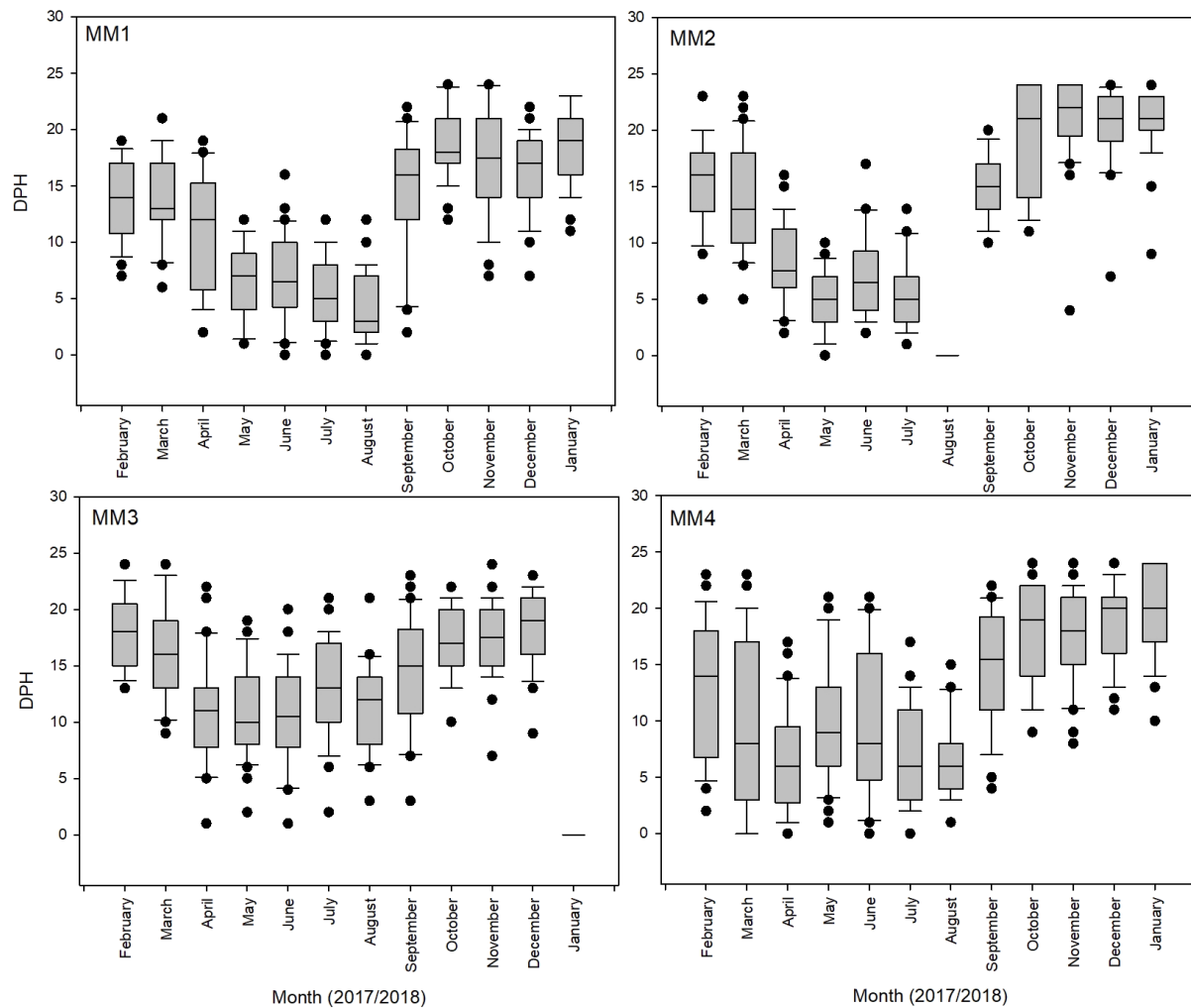


Figure 6: Box plots showing the variation in the summed DPH per day between February 2017 and January 2018.

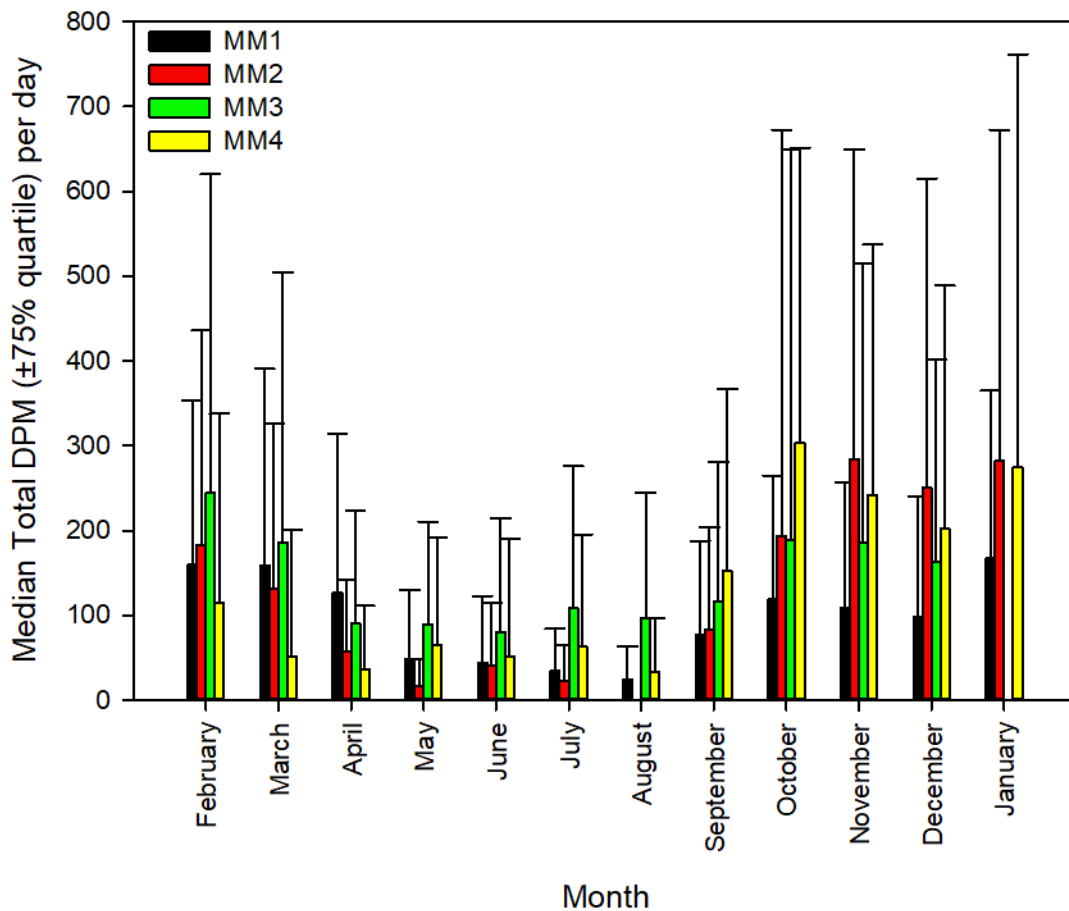


Figure 7: Median DPMs ($\pm 75\%$ quartile) recorded at each monitoring site between February 2017 and January 2017. Medians and quartiles were calculated from the DPM per 60mins summed over each day of the month (i.e. total DPM for that day and thus $n=30$ or $n=31$).

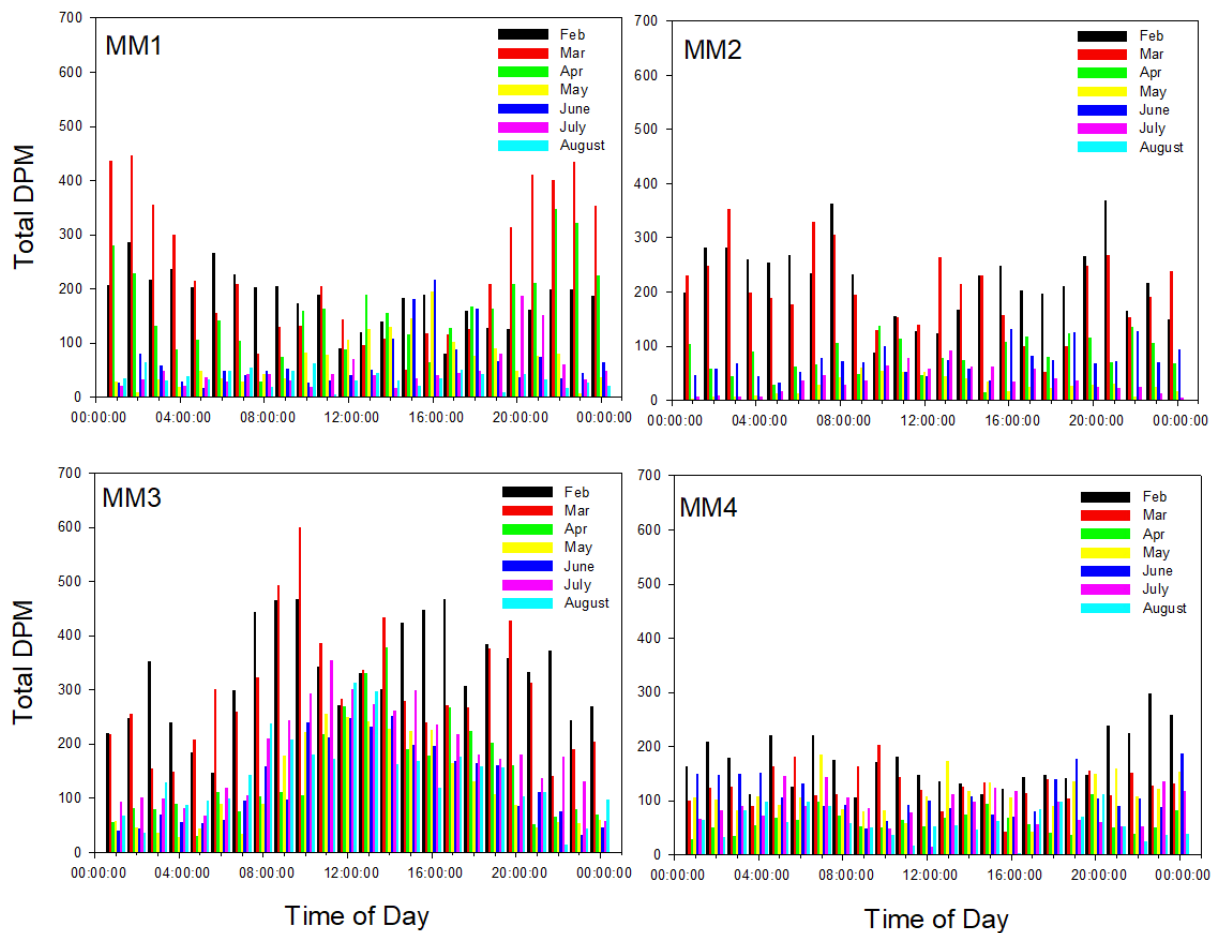


Figure 8: Total DPM per hour (summed over all days per month, n=30 or n=31) for each hour of the day for all sites between February and August 2017.

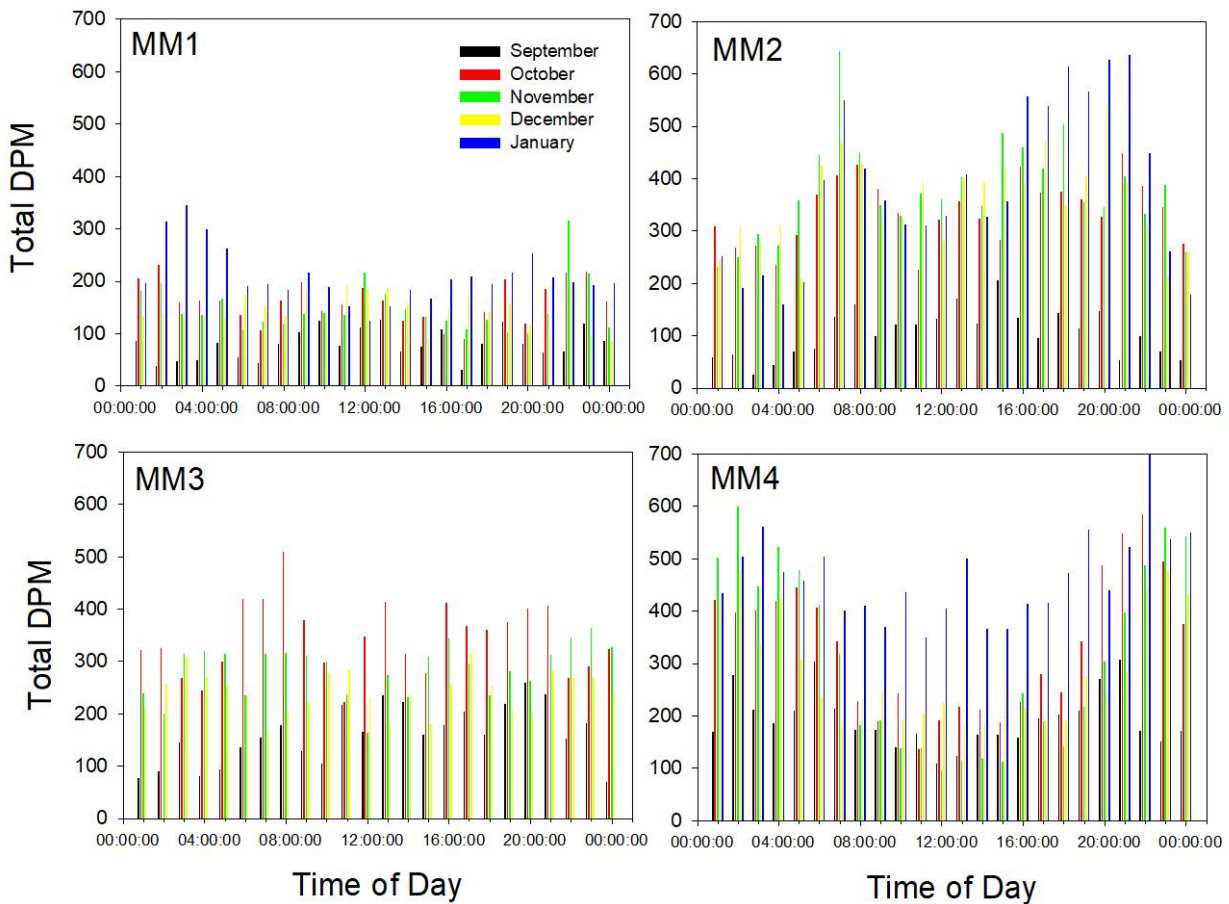


Figure 9: Total DPM per hour (summed over all days per month, n=30 or n=31) for each hour of the day for all sites between September 2017 and January 2018. No data were collected from site MM3 during January 2018 as the unit was lost.

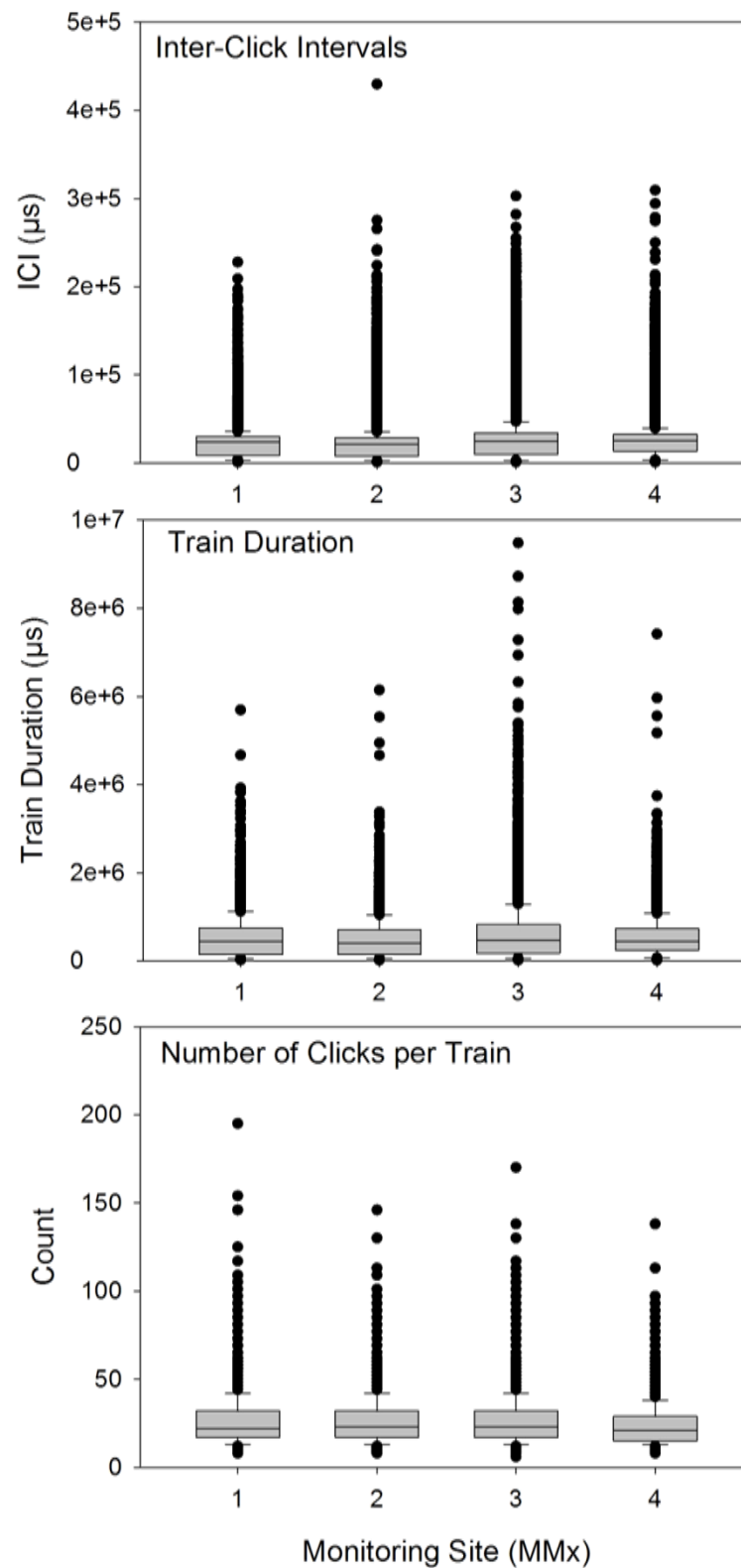


Figure 10: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the first deployment (28 Jan – 9 Mar 2017).

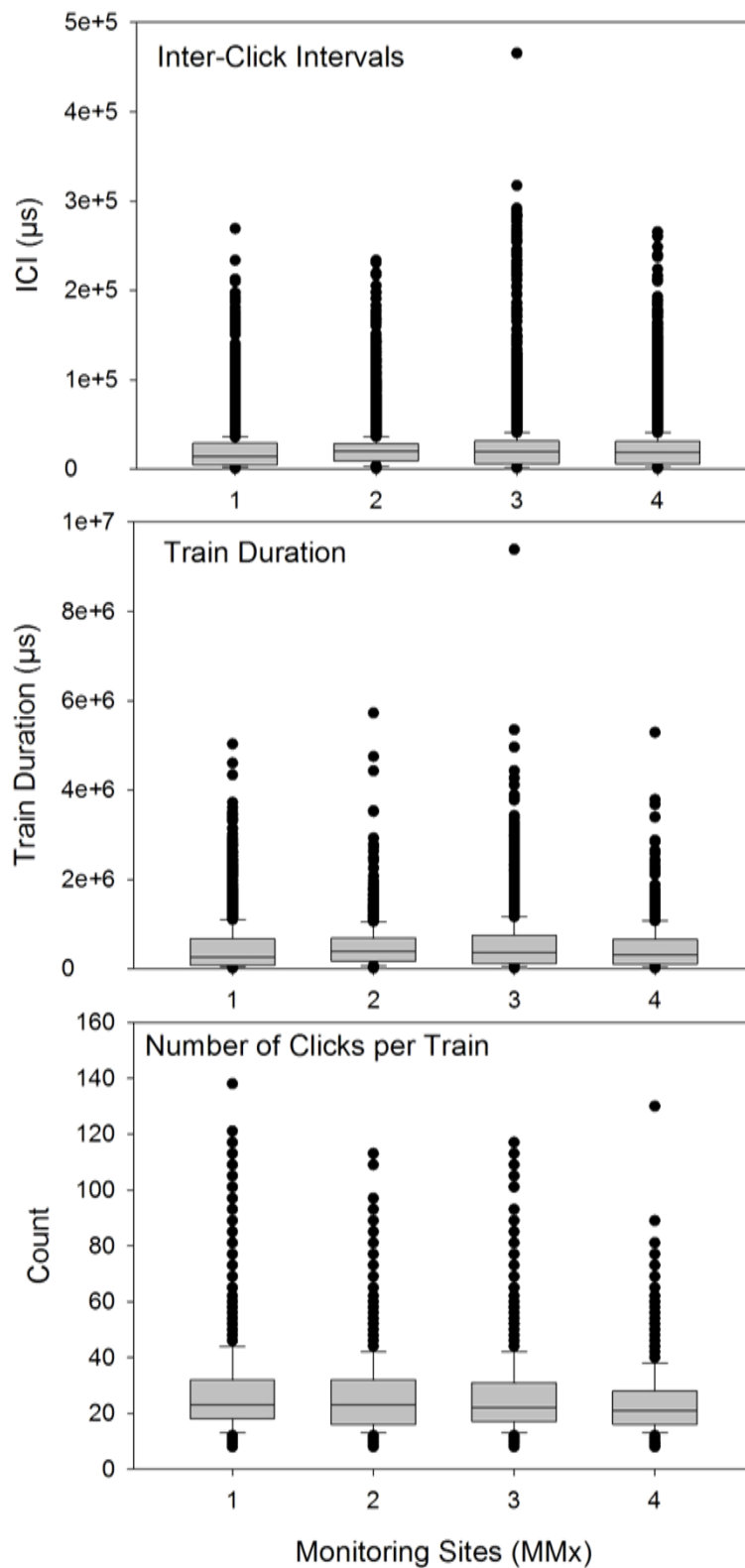


Figure 11: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the second deployment (9 Mar – 1 Apr 2017).

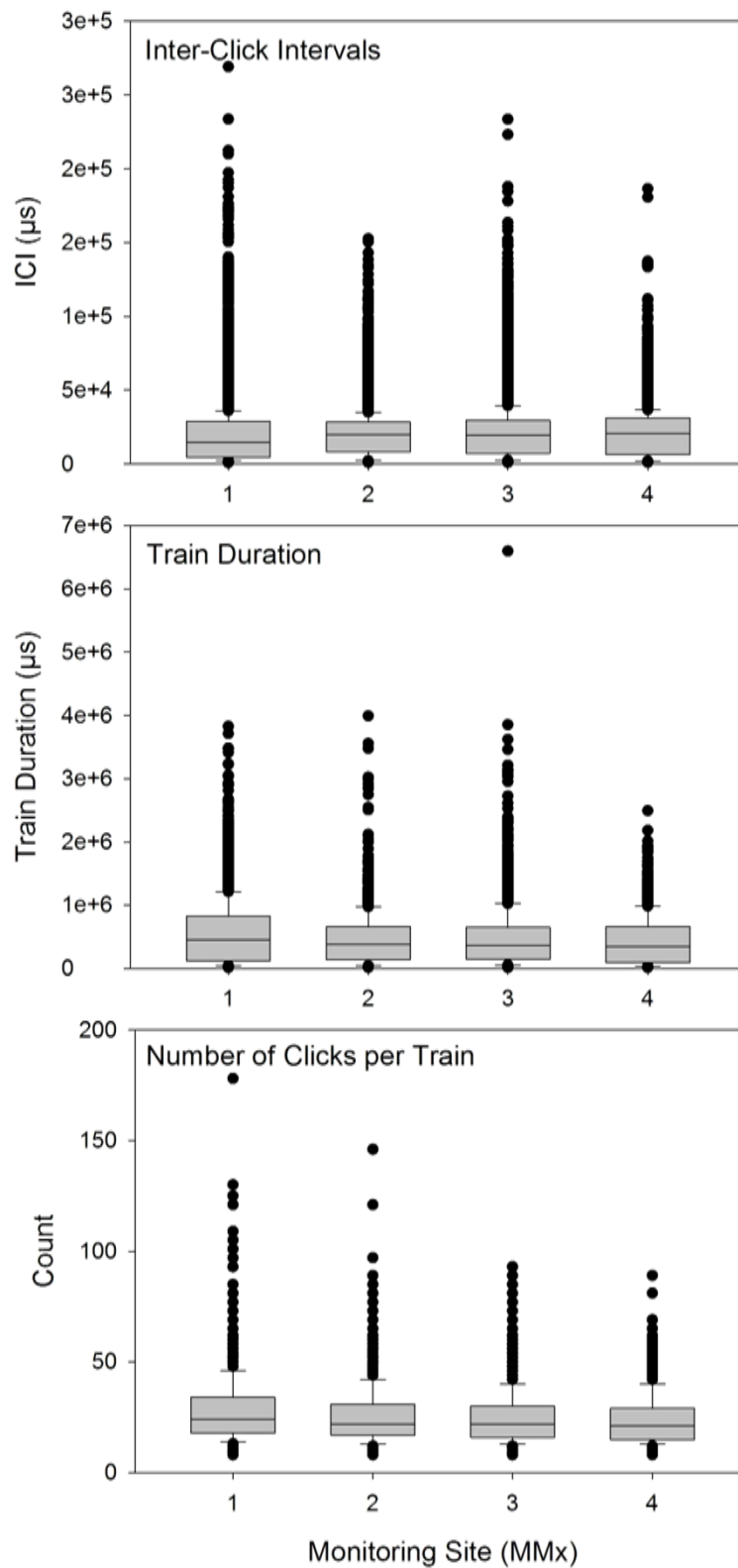


Figure 12: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the third deployment (1 Apr – 7 May 2017).

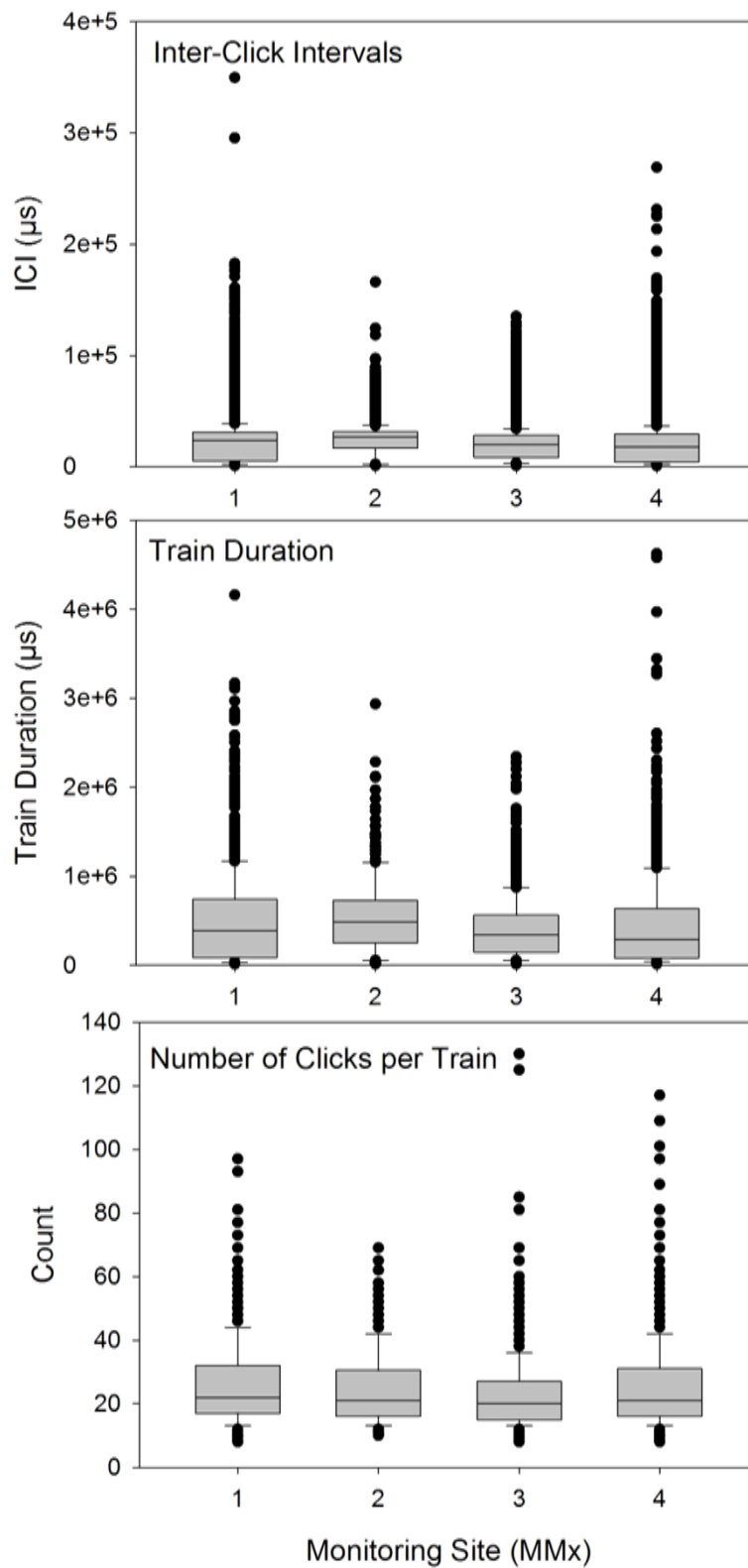


Figure 13: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the fourth deployment (7 May – 8 June 2017).

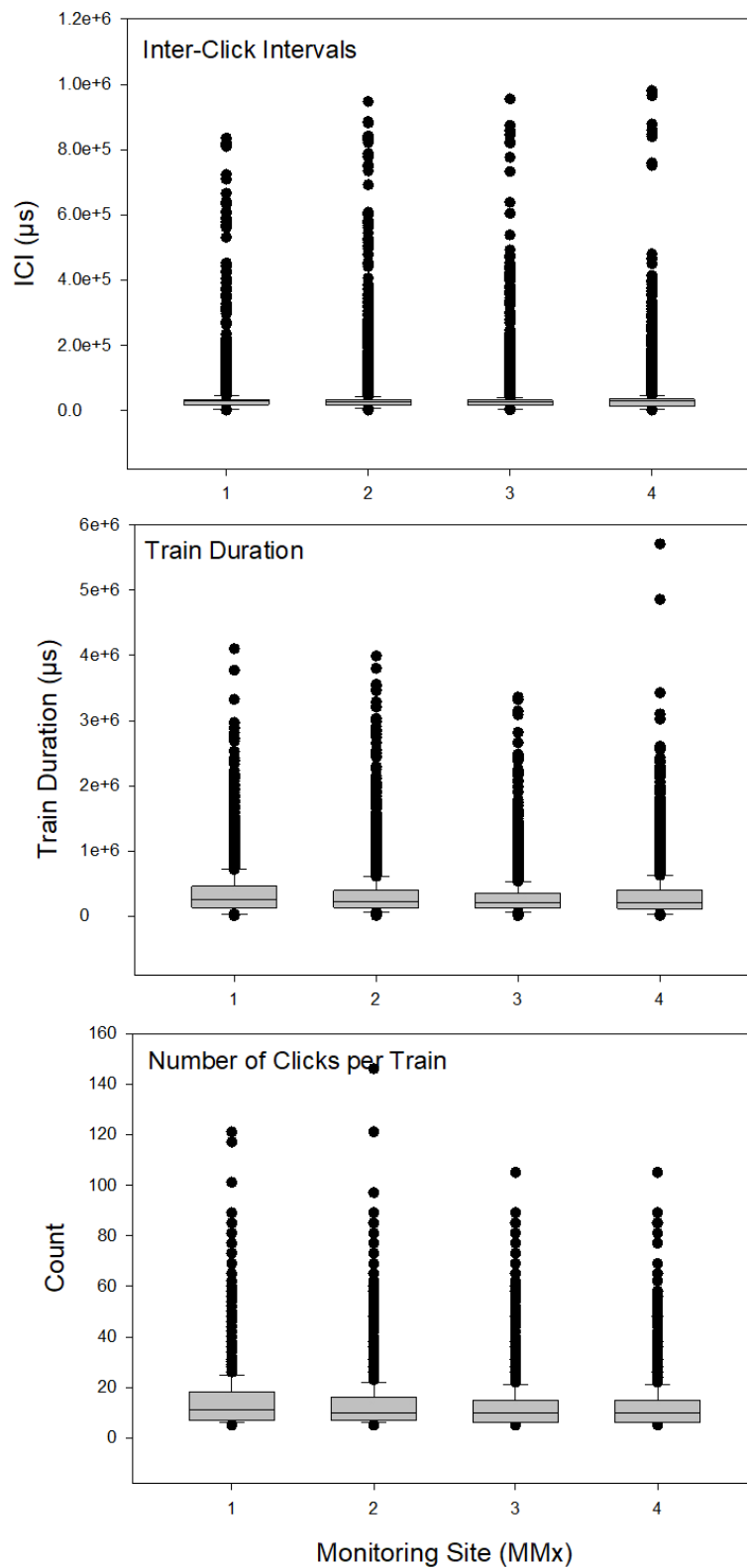


Figure 14: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the fifth deployment (8 June – 5 July 2017).

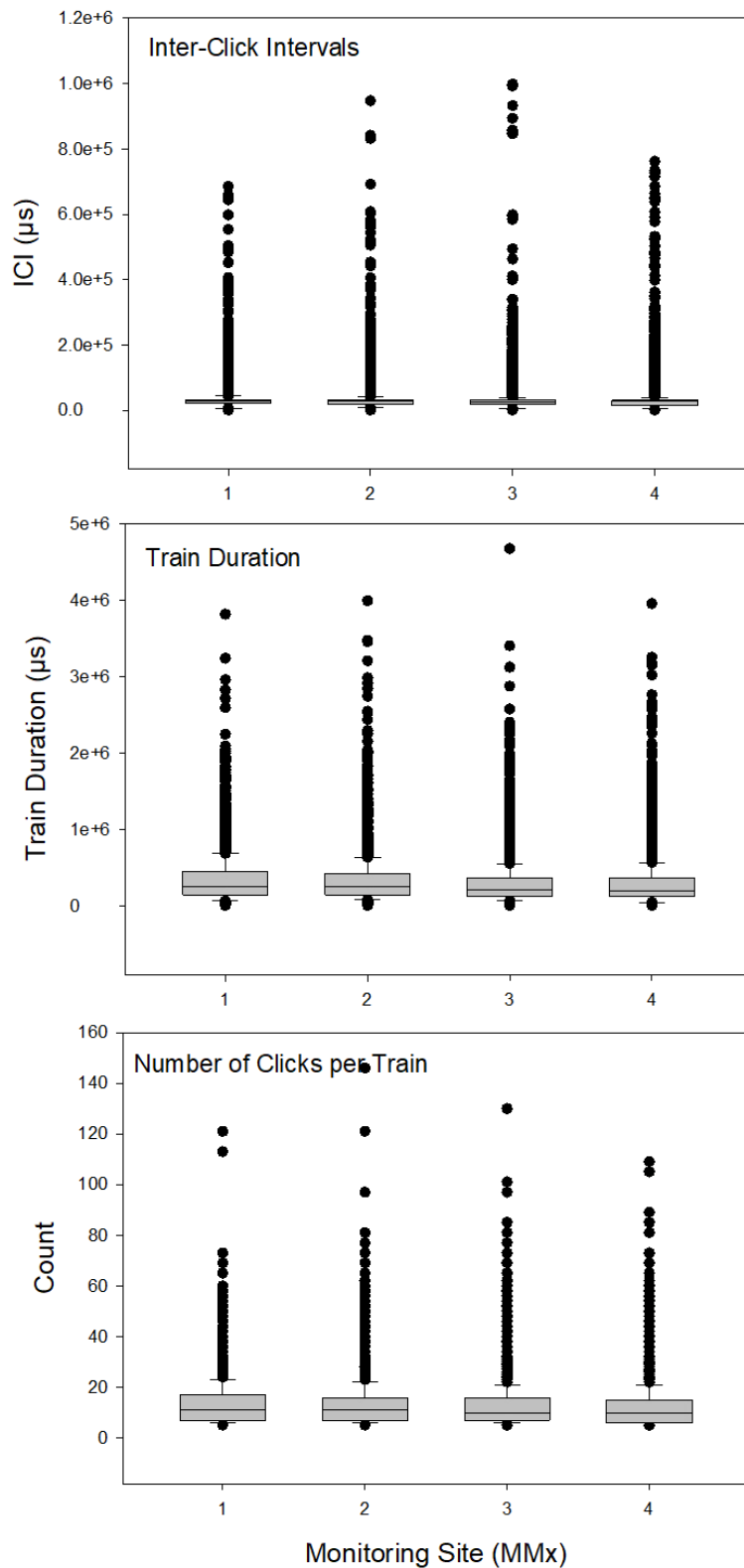


Figure 15: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the sixth deployment (5 July – 1 August 2017).

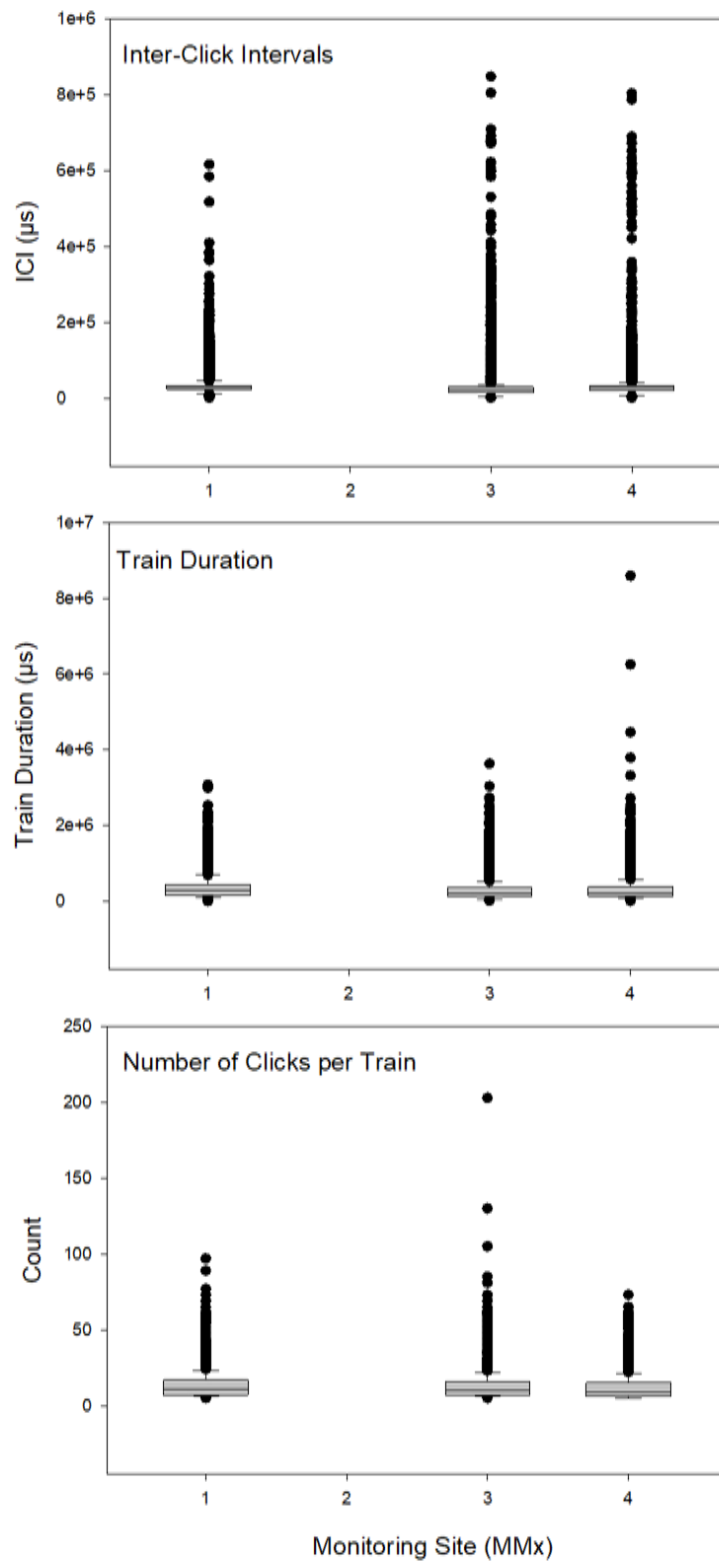


Figure 16: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the seventh deployment (1 August – 4 September 2017).

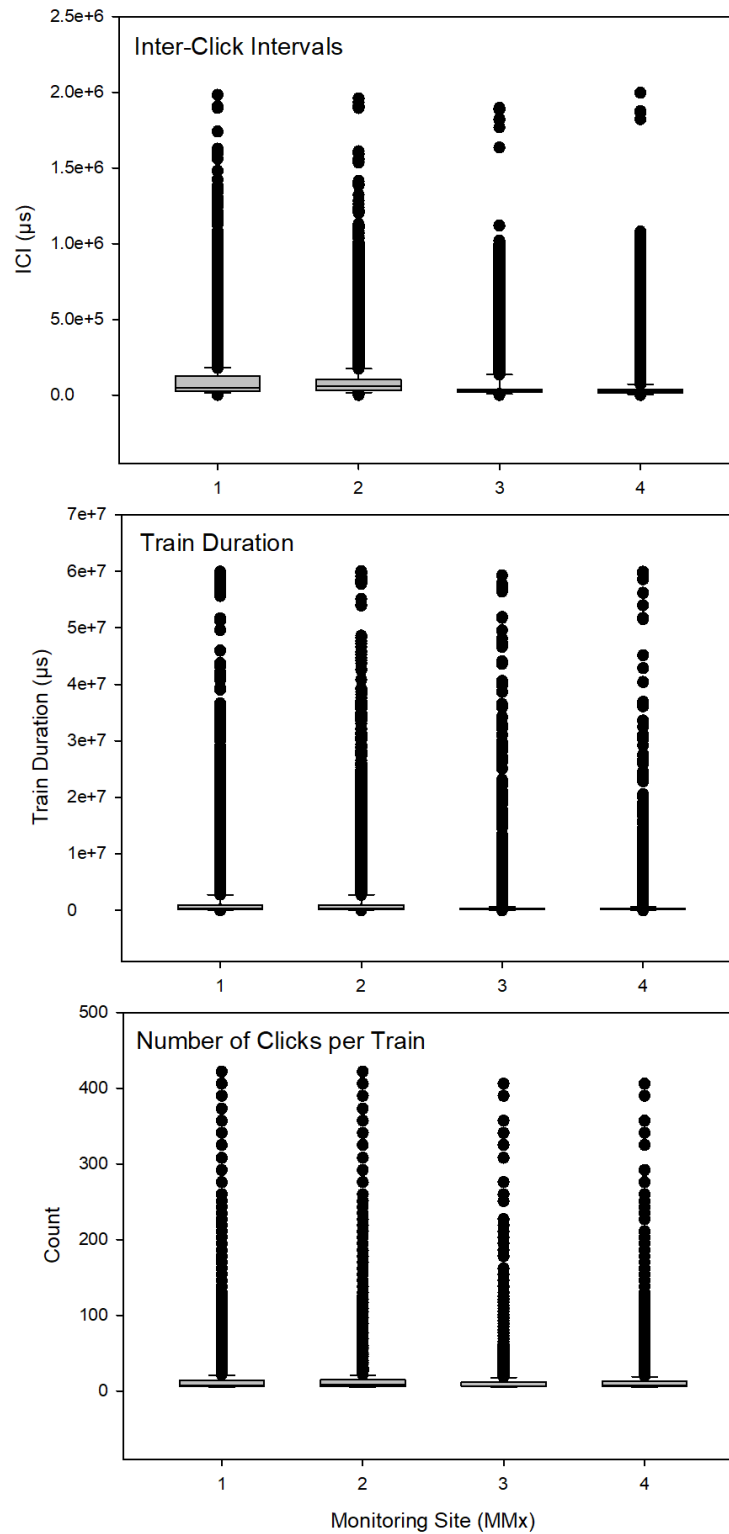


Figure 17: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the eighth deployment (4 September – 19 October 2017).

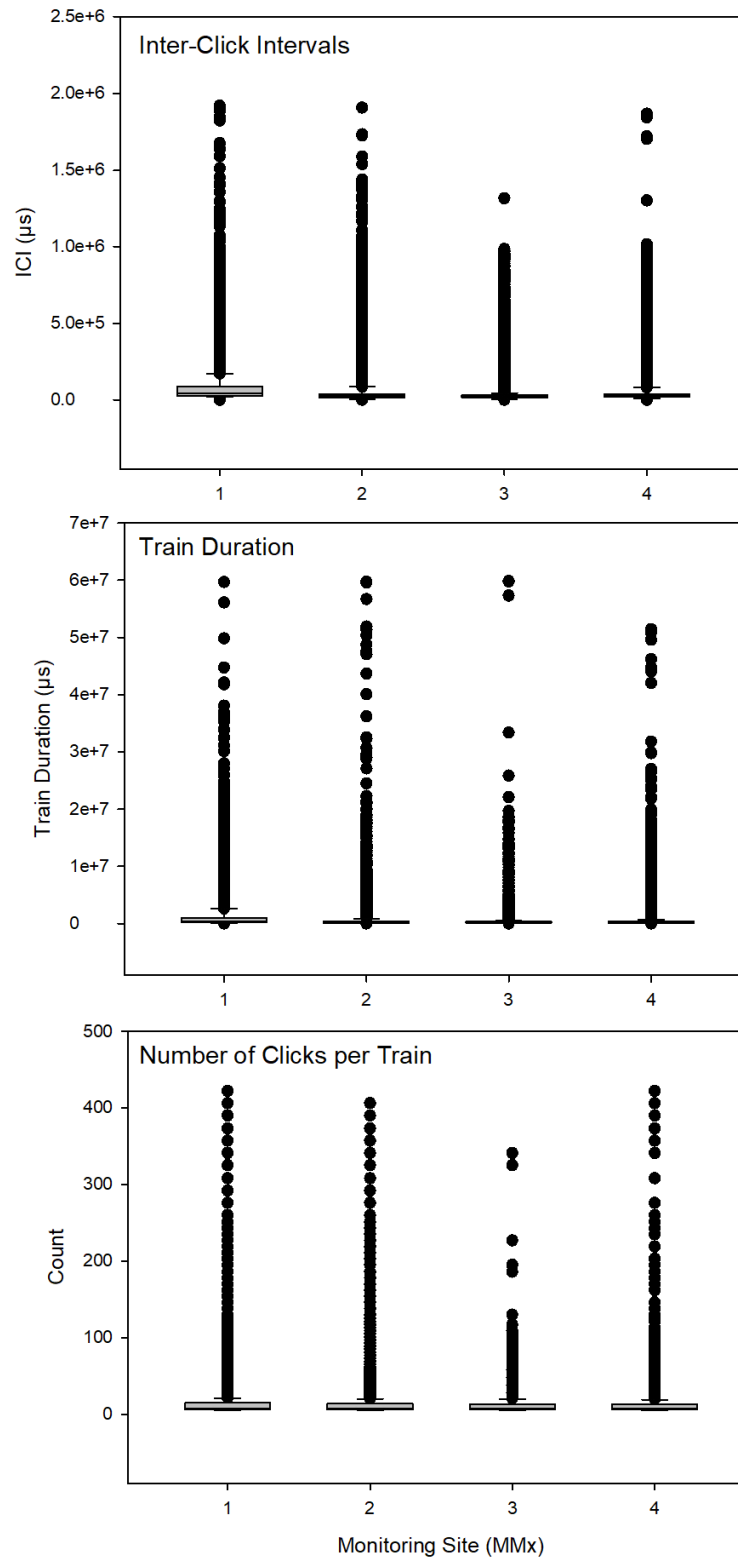


Figure 18: Box plots showing the variation in inter-click intervals (ICIs), train durations and number of clicks per train for the ninth deployment (19 October – 10 November 2017).