Dolphins of the Kelp - SAERI / Darwin Initiative Project

A Precursory Assessment of Dolphin Attendance Patterns by Acoustic C-pod Click Detectors;

1.0 Deployments

Three C-pods were deployed for a total of 4 deployment periods within the Manybranch Harbour focal area on West Falkland; 2019 Inside, 2020 Channel and 2088 Outside. Deployment locations of the C-pods are given in Figure 1 and deployment periods in Table 1.

An additional two C-pods were deployed outside and further from the entrance, however these were lost following a gale during the first deployment, and no data was recovered.

The remaining three C-pods were recovered, downloaded and replaced in the same positions during each service visit with the whole operation taking approximately one hour in each location.

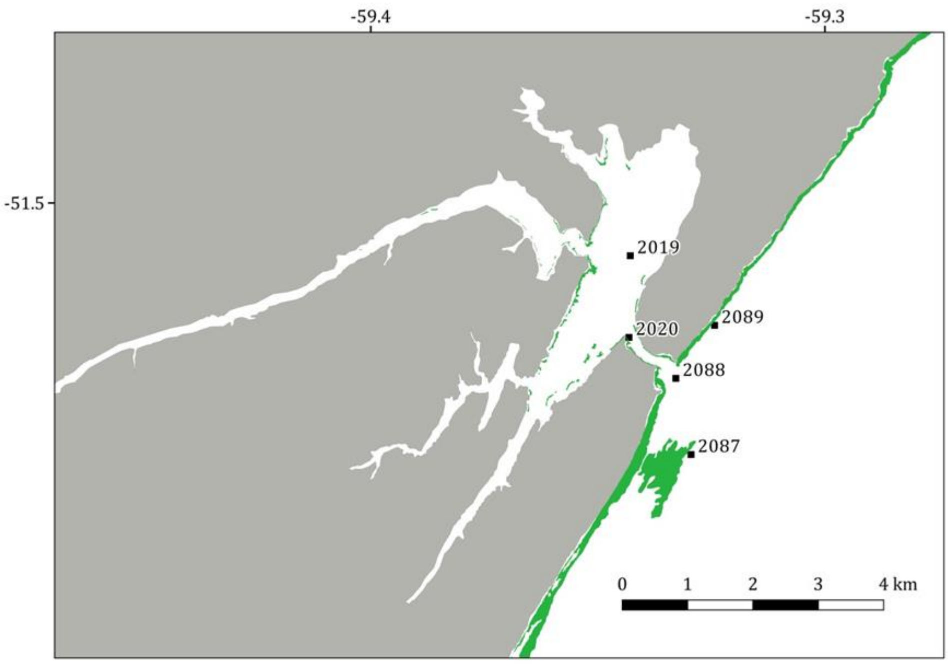


Figure 1: Location of the three deployed C-pods at Manybranch. CP2019 inside the harbour, CP2020 within the entrance channel and CP2088 outside nearshore.

2.0 Data Analysis

In looking at attendance patterns only full 24 hour periods were considered. Partial days on deployment and recovery were excluded from analysis. The reasons were two-fold. Firstly dolphins were attracted and drawn into the area during recovery and deployment operations due to the presence and activity of the vessel. This may have caused higher levels of detection that could skew data away from uninfluenced behaviour and attendance patterns. Secondly parameter metrics that apply a daily average would not represent a full 24 hour period. Given that retrieval and deployment on the same day often only resulted in the loss of 15 minutes of recording the deployment periods could have been stitched together (and were initially) however due to the former consideration and evidence of increased dolphin attendance on service visit days it was decided to exclude the full 24-hours of each service day.

The clipping of outputted data files is detailed in Table 2. This gave a sample size of;

- 423 days at each location for daily metrics
- 10,152 hours at each location for diurnal hourly metrics.

Table 1: Deployment periods and location of C-pods over 4 deployments.

C-pod	**2088**		**2020**		**2019**	
Location	**Outside**		**Channel**		**Inside**	
	Date	Time	Date	Time	Date	Time
Deployment 1						
Start	15/04/2017	18:14	15/04/2017	18:34	15/04/2017	18:41
Deployed	16/04/2017		16/04/2017		16/04/2017	
End	11/07/2017	09:48	11/07/2017	10:46	11/07/2017	11:30
Deployment 2						
Start	11/07/2017	10:28	11/07/2017	11:13	11/07/2017	11:42
End	15/11/2017	08:42	15/11/2017	09:35	15/11/2017	10:43
Deployment 3						
Start	15/11/2017	09:00	15/11/2017	09:53	15/11/2017	11:02
End	23/03/2018	08:03	23/03/2018	09:16	23/03/2018	10:15
Deployment 4						
Start	23/03/2018	08:19	23/03/2018	09:28	23/03/2018	10:30
End	17/06/2018	10:07	17/06/2018	10:56	17/06/2018	11:22

Table 2: The clipping of data files to full 24-hour periods

Start / End	Date	Time [1]	Periods Deleted
Deployment 1			
Start	17/04/2017	00:59	15/04/2017 pm 16/04/2017 all
End	10/07/2017	23:59	11/07/2017 am
Deployment 2			
Start	12/07/2017	00:59	11/07/2017 pm
End	14/11/2017	23:59	15/11/2017 am
Deployment 3			
Start	16/11/2017	00:59	15/11/2017 pm
End	22/03/2018	23:59	23/03/2018 am
Deployment 4			
Start	24/03/2018	00:59	23/03/2018 pm
End	16/06/2018	23:59	17/06/2018 am
Sampled and analysed durations at each location, each location clipped to same n at each location			
Total Day Units (n)	423		
Total Hour Units (n)	10,152		

[1] End of 1st Sampling Period and End of Last Sampling Period

2.1 Data Analysis & Filter Selection

C-Pods do not record full broadband waveform data but record only key signal parameters for each noise event, this gives long data and battery autonomy and minimises servicing. The acoustic events can then be processed through a proprietary algorithm to assign the identified click trains to each of four "species type" classes with an associated certainty of High, Moderate or Low (though it should be noted that these are relative and clicks assigned as Low are still usually robust data). *C-pod Ver. 2.044* (Chelonia, 2014) Kerno Click Train Classifier was used to analyse the raw click data in the deployment CP1 files and create the outputted CP3 files used in subsequent analyses. This identifies and assigns click data with H/M/L probability to:

- Narrowband High Frequency "Porpoise Type" (NBHF),
- Broadband "Dolphin" Type,
- Other Cetacean Types, and
- Sonar.

The standard default settings for click train analysis were utilised.

The raw data summary for each deployment of each C-Pod is given in Table 3.

2.1 Narrow Band High Frequency (NBHF), High and Moderate Certainty

Commerson's dolphins (and Peale's dolphins) are an NBHF species. Subsequent analysis only outputted data for NBHF, with the NBHF filter applied.

It can be seen from Table 2 that inclusion of "low" assigned probability would in some cases double the level of data available and hence the strength of any analysis. However, whilst past deployments have shown the reliability of the low assignation in the Falklands, it is usually recommended that a manual check of 10% of automatically identified click trains in the low probability range is undertaken to check and verify for false positives. Given time-constraints for initial analysis this was not performed and hence to be conservative low assignations were excluded from analysis and only High and Moderate assigned click trains utilised. This was also felt to be safest given the increased occurrence of non-NBHF signals within the low probability classes, as these were not expected this may signify some incorrect assignations in the Low classification (in the Falklands there is no inshore boating and hence there should be no sonar signals, and both inshore occurring dolphin species are "NBHF porpoise type", so there should be no broader band "Dolphin Type" signals).

Subsequent analysis only outputted data for NBHF with High and Moderate certainty, with the NBHF-Hi +Mod filter applied.

2.3 Detection Positive Minutes

A detection positive minute (DPM) is the count of any minute with at least one detected NBHF click of High or Moderate probability within that minute, a DPM may relate to just 1 click in that 1-minute period or 100 clicks in that 1-minute period. DPMs have been found to be a reliable metric for the study of occurrence / attendance that excludes interpretation complications such as utilising number of clicks that may be complicated by group size or activity behaviour. The metric has been shown to be the most representative for study of presence / occurrence.

Other detection positive time periods are possible, for example detection positive 10-minutes (DP10m) may be used to smooth data in some instances, however for the initial analysis DPM was used in all analysis.

3.0 Results Seasonal Variation in Occurrence (DPM / Day by Location and by Season and Month)

Each C-pod was located in the same location on each subsequent deployment and hence C-pod and location may be taken as the same with;

- CP 2019 Inside
- CP 2088 Outside
- CP 2020 Channel

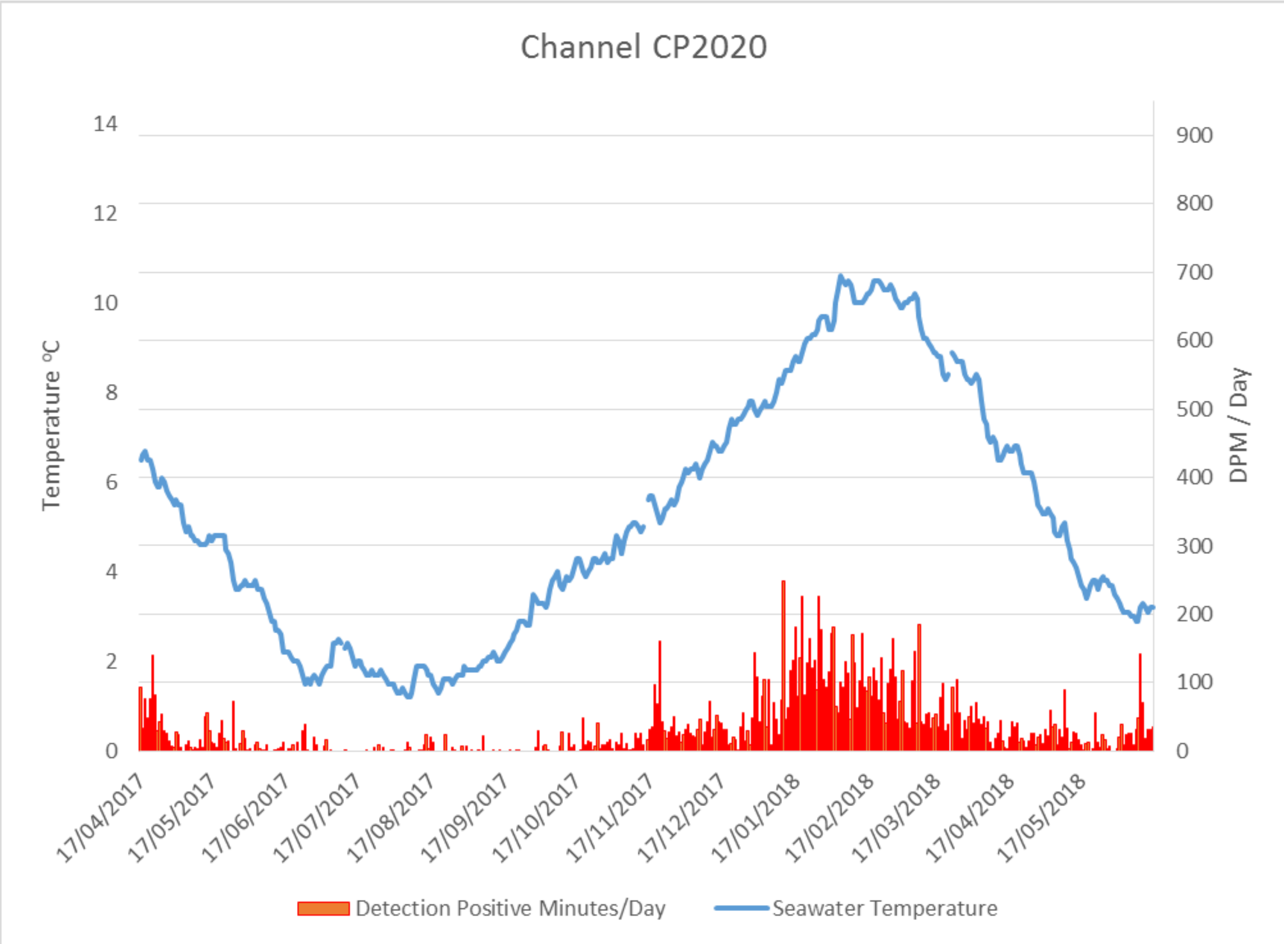
The total DPM within a calendar day 24 hour period at each location are plotted in Figure 2, along with the daily mean seawater temperature at deployment depth. The mean, standard errors, upper and lower confidence interval limits and median values for each location, and for each seasonal period within each location are given in Table A1 (Appendix A) along with the results of a Kruskal Wallis Sum Rank test on significant differences between locations and seasons. The results are plotted in Figures A1, A2, A3, A4 (Appendix A). DPM data was extremely skewed (Figure A5, Appendix A) and non-normal with a high proportion of zero and low counts (especially during the winter seasons) and simple non-normal non-parametric tests were utilised to test for differences and association.

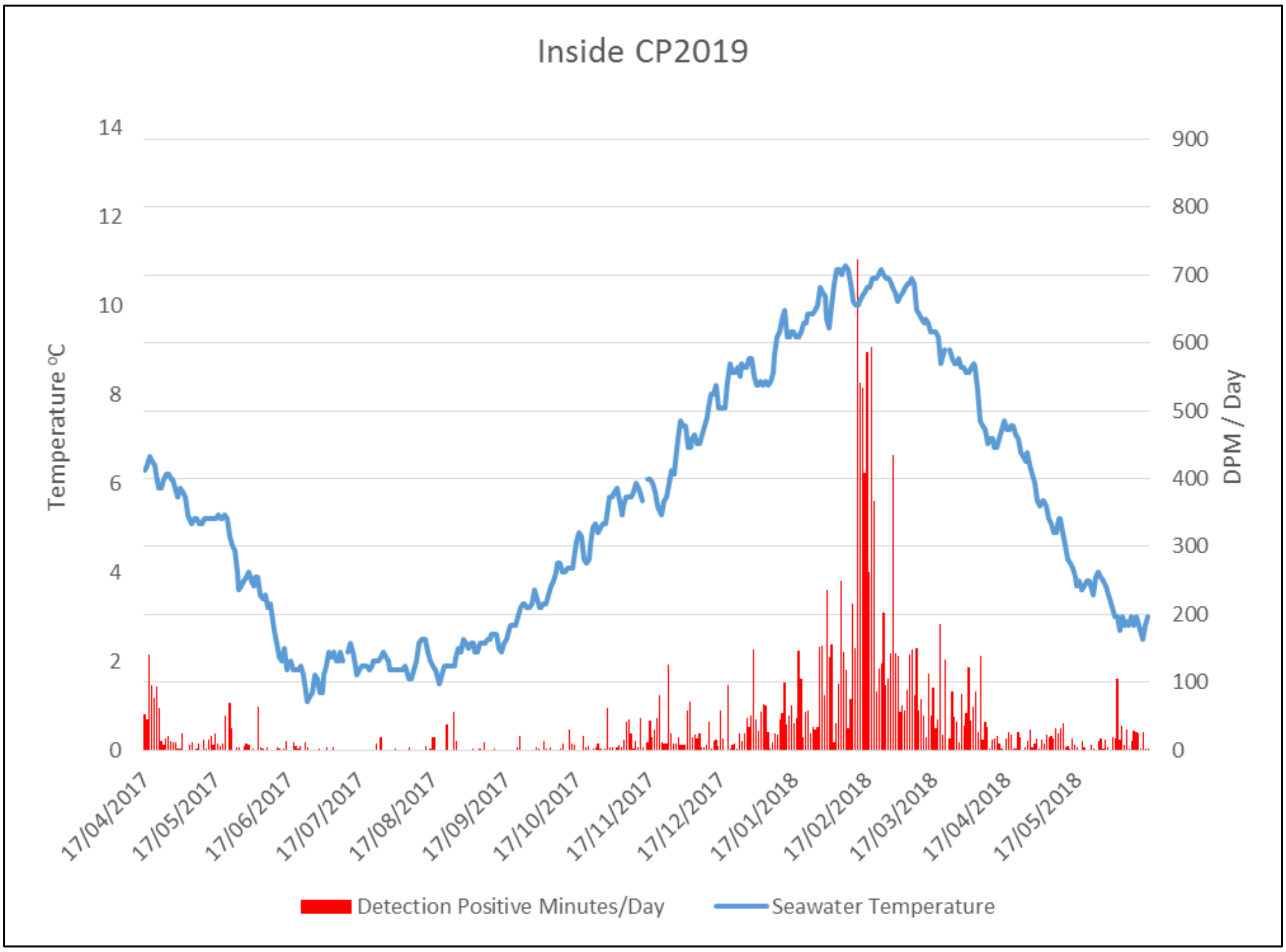
Table 3: Selected click data for species classes for each deployment and location and overall detection positive minutes.

Deployment	C-Pod	Total Clicks in CP1 file	Total Clicks in CP3 file identified as of High & Moderate Probability							Additional NBHF Low	Additional Dolphins Low	NBHF only Detection Positive Minutes		Mins On
			NBHF Hi	NBHF Mod	NBHF Total	"Broadband" Dolphins	Other Cetaceans	Sonar	Un-classed			DPM H/M	DPM H/M/L	
Dep1	2019	5055964	25796	58816	83970	0	0	0	642	50186	12468	1208	1826	124850
Dep2	2019	6125084	14190	29112	42680	0	0	0	622	36734	15642	700	1048	182822
Dep3	2019	9349631	290340	577334	867443	0	0	0	231	422302	4155	11969	17794	184274
Dep4	2019	6410588	18204	52721	70884	0	0	0	41	77291	17230	1964	3371	123893
Dep1	2088	5727894	27941	77599	91787	5398	0	0	8355	125861	3892	2559	5003	123861
Dep2	2088	5286029	50101	106970	152384	2414	0	0	2273	138439	3433	2864	5361	182775
Dep3	2088	13380966	171274	556875	727974	0	0	0	175	892691	239	18737	31429	184264
Dep4	2088	3036113	45092	131984	175420	0	0	0	1656	206565	5	5117	9789	123949
Dep1	2020	6887445	20385	48590	68593	0	0	0	382	84215	3778	1550	3230	124813
Dep2	2020	4542962	8330	16841	23421	12	0	0	1738	39529	2041	686	1655	182783
Dep3	2020	9654211	70676	211150	281255	180	0	0	391	454448	1744	9523	21045	184284
Dep4	2020	4748932	27214	71546	98632	24	0	0	104	122937	1561	2510	5414	123929

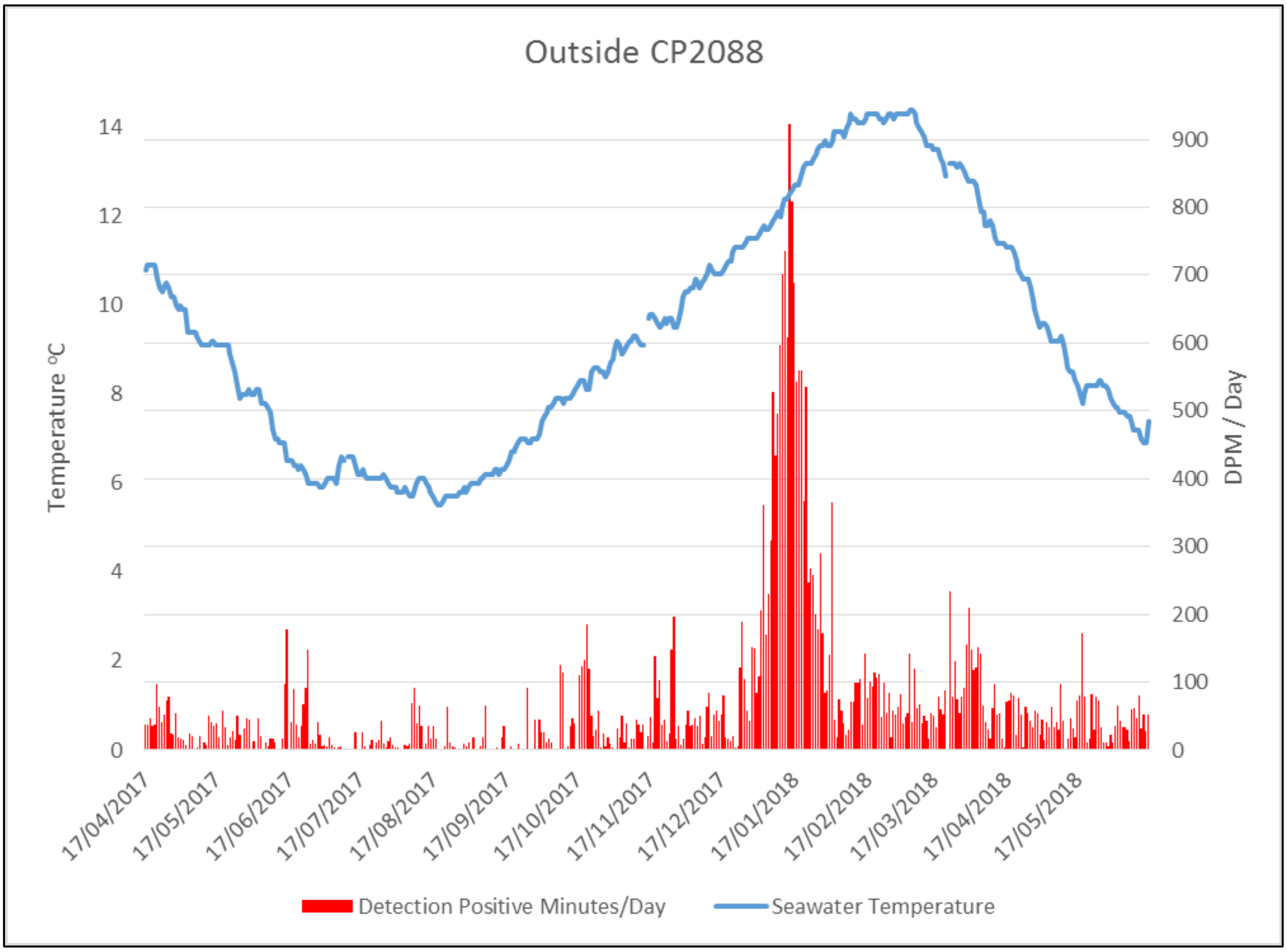
3.1 Daily DPM through deployment

Figure 2: Daily detection positive minutes and daily average temperature recorded at each of the three deployed locations over the 423 complete 24-hour days of the deployments. Data is plotted on the same scale between locations. It should be noted that the whilst range, trend and relative temperature values are considered correct, the absolute temperature values of the "Outside" deepwater C-pod read 4°C higher than the other 2 units. This will be corrected in subsequent analysis once calibration figures are available (in the interim attendance association to temperature was conducted separately for each location).





Inside CP2019
Temperature °C
DPM / Day
14
12
10
8
6
4
2
0
900
800
700
600
500
400
300
200
100
0
17/04/2017
17/05/2017
17/06/2017
17/07/2017
17/08/2017
17/09/2017
17/10/2017
17/11/2017
17/12/2017
17/01/2018
17/02/2018
17/03/2018
17/04/2018
17/05/2018
Detection Positive Minutes/Day
Seawater Temperature



Outside CP2088
Temperature °C
DPM / Day
14
12
10
8
6
4
2
0
900
800
700
600
500
400
300
200
100
0
17/04/2017
17/05/2017
17/06/2017
17/07/2017
17/08/2017
17/09/2017
17/10/2017
17/11/2017
17/12/2017
17/01/2018
17/02/2018
17/03/2018
17/04/2018
17/05/2018
Detection Positive Minutes/Day
Seawater Temperature

3.2 DPM/day by season and month

Additional seasonal analysis of DPM/day are presented in Appendix A, including by proportion of daylight / night length,-determined by the astronomical equinoxes giving two 6 month periods, 6-months with longer day-length vs 6-months with longer night-length. These were further subdivided by astronomical summer and winter solstices giving; Spring, Summer, Autumn and Winter periods. These seasonal periods are summarised in Table 4.

All analyses provided significant differences between location and between the temporal season periods.

Table 4: Seasonal periods determined by astronomical equinoxes and solstices

Year			
Daylight Predominates **> Day-Length** Spring Equinox – Autumn Equinox 23rd Sept – 19th March		Dark Predominates **> Night-Length** Autumn Equinox – Spring Equinox 20th March – 22nd Sept	
Spring Spring Equinox – Summer Solstice 23rd Sept – 20th Dec	**Summer** Summer Solstice – Autumn Equinox 21st Dec – 19th March	**Autumn** Autumn Equinox to Winter Solstice 20th March – 20th June	**Winter** Winter Solstice to Spring Equinox 21st June – 22nd Sept

Monthly median values of DPM/day and range are given in Figures 3, 4, & 5 for each location. Corresponding values are given in Table A2 (Appendix A). The figures clearly indicate that within each location there was a summer peak that was significantly different.

Since repeated pair-wise post hoc analysis to define between which paired periods or months the significant differences may exist may give rise to risk of Type I errors this was not conducted, however whether the notch of the box-plots overlaps between months gives an indication of probable significant difference.

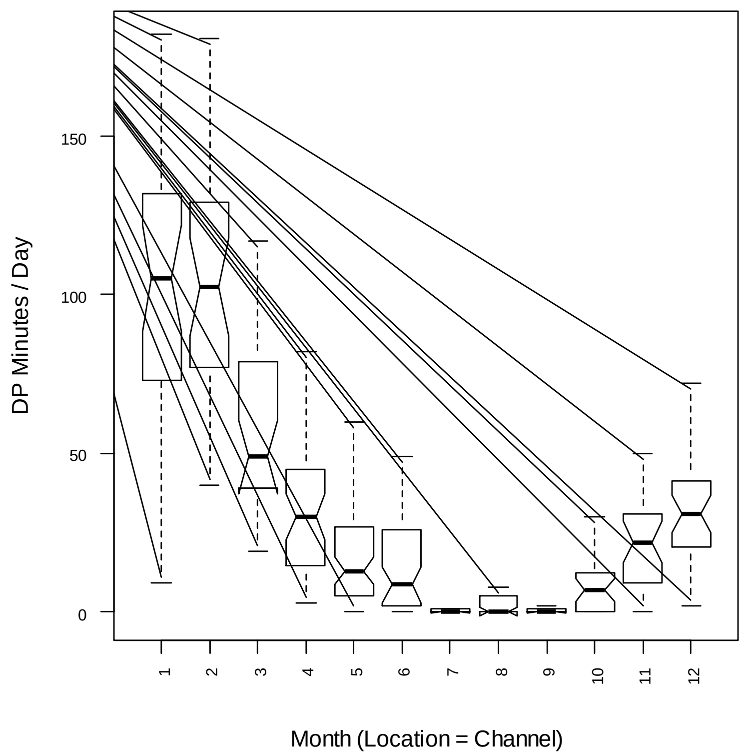


Figure 3: Channel deployment location, Median detection positive minutes / day by month. Outliers have been excluded.

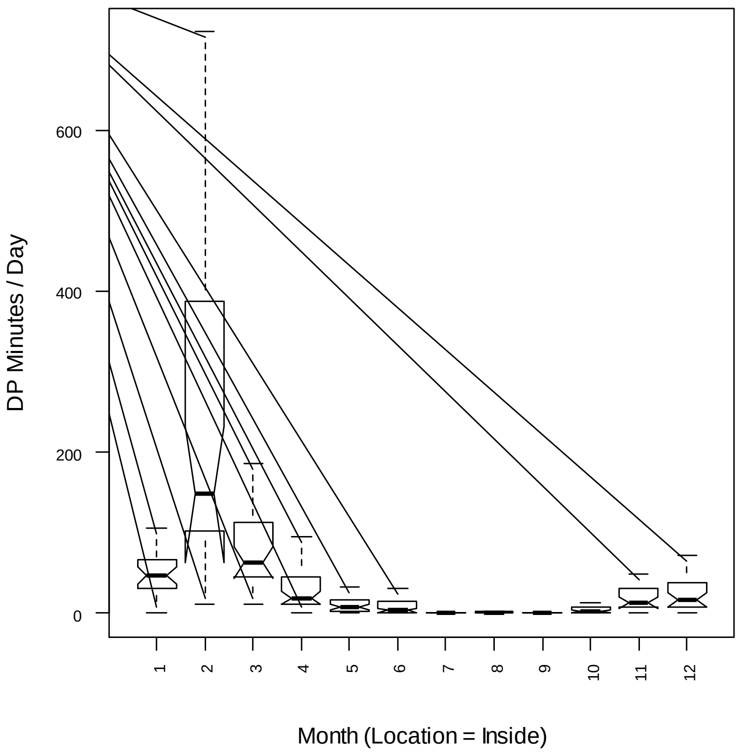


Figure 4: Inside harbour deployment Median detection positive minutes / day by month. Outliers have been excluded.

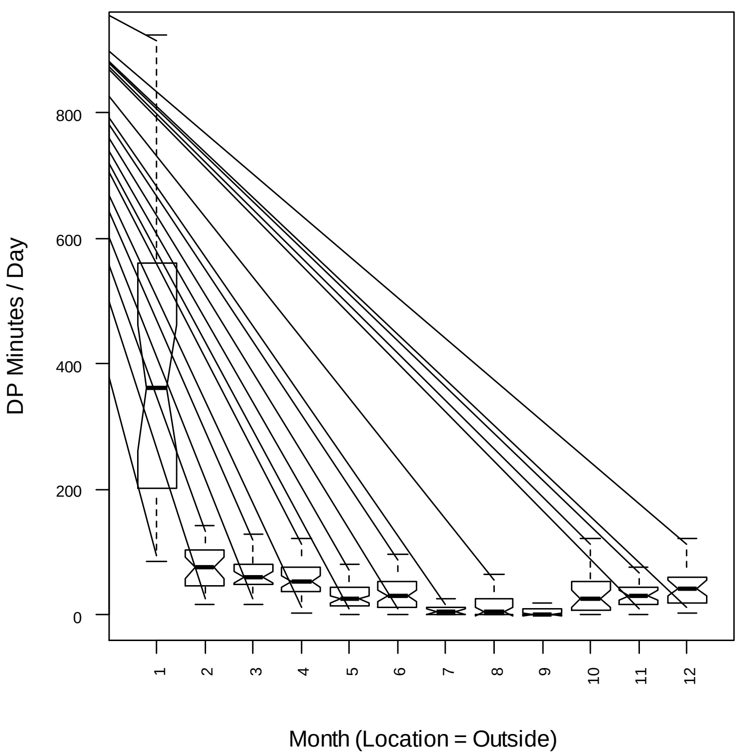


Figure 5: Outside entrance Median DPM/day by month. Outliers have been excluded.

3.3 Inter-annual Variation in Occurrence (DPM/Day)

Whilst two over-winter periods were available to compare occurrence between years, unfortunately only one peak summer period was recorded. Due to the low occurrence rates over winter and the incomplete year coverage it was decided not to conduct inter-annual comparisons at this time.

3.4 Sea Temperature as a determinant to Occurrence (DPM vs. Temp)

Sea temperature is linked to season and may be a driver of marine productivity. All locations showed the same range (the difference in degrees between minimum to maximum temperatures) and the same seasonal pattern in temperature. However, Outside “deepwater-C-pod 2088” read 4^{o}C higher than the other two units across the range. The intention will be to scale-correct temperature data from this unit once a calibration to true temperature is possible. For the moment as the error appears equal across the range and on a location by location basis the trend and correlation (though not the line equation) between occurrence and temperature should still be valid. The doubt in POutside temperature readings does however mean that all data cannot be pooled and that the relationship must be tested on a location by location basis and not between locations.

Taking all locations together daily DPM / day was positively correlated to temperature (Kendall's rank correlation; z = 27.483, p-value < 2.2e-16, tau is not equal to 0, tau = 0.5270894), however as stated due to errors between Outside CP2088 (which showed higher temperatures and coincidentally also had higher occurrence that may lead to a higher correlation when grouped to two C-pods with lower temperatures and lower occurrence) and the two inshore C-pods the analysis was undertaken for each location separately. Data for each location are presented in Figures 6, 7, & 8 and significances of the correlations in Table 5.

Table 5: Significance of non-parametric correlation between DPM and Sea Temperature at each location

Kendall's rank correlation Alternative hypothesis: true tau is not equal to 0		
Channel	Inside	Outside
z = 17.855, p-value < 2.2e-16 tau 0.5964737 Highly Significant Correlation	z = 16.946, p-value < 2.2e-16 tau 0.5729402 Highly Significant Correlation	z = 12.994, p-value < 2.2e-16 tau 0.4294158 Highly Significant Correlation

A two-tailed (negative or positive) correlation test was undertaken, however graphing and context would suggest a positive correlation with peak occurrence in summer with higher temperatures and marine productivity. Each of the three locations showed a positive correlation

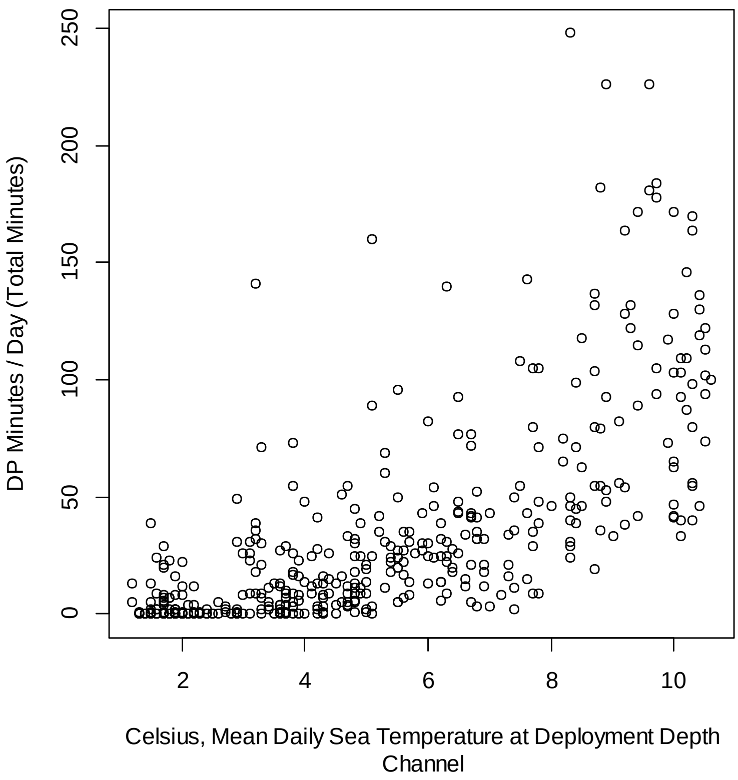


Figure 6: Detection positive minutes / Day against sea temperature at the Channel deployment position

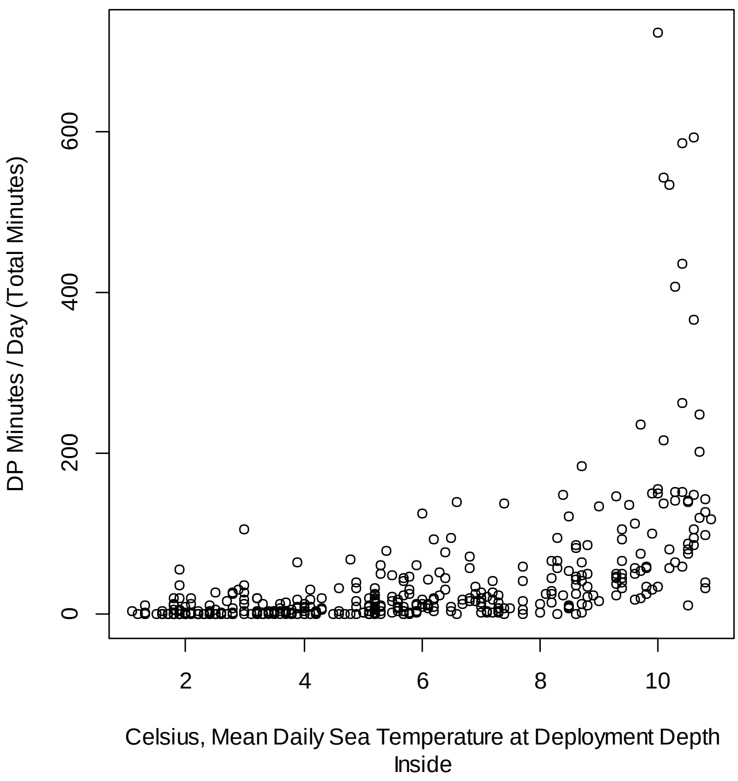


Figure 7: Detection positive minutes / Day against sea temperature at the Inside harbour deployment position

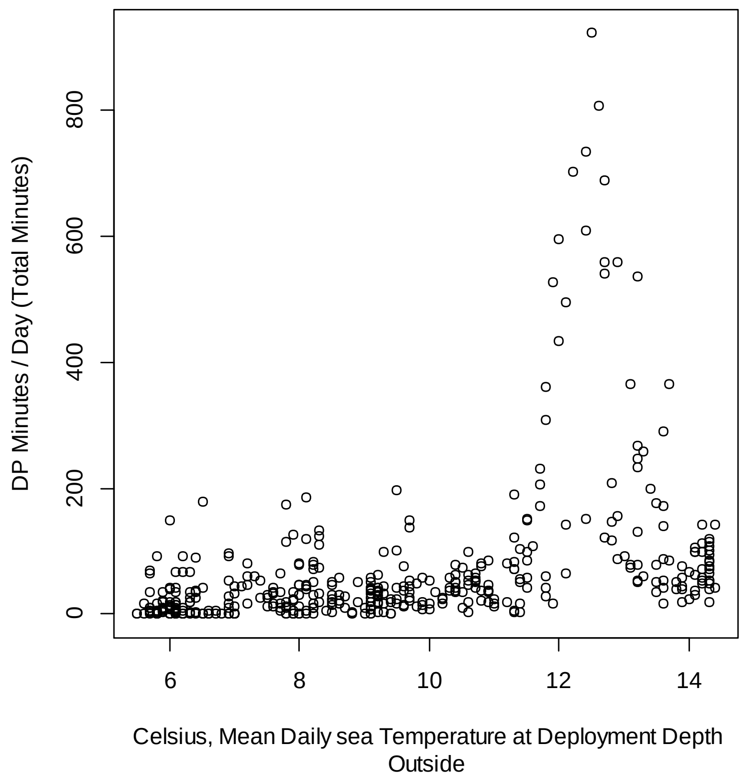


Figure 8: Detection positive minutes / Day against sea temperature at the Outside inshore deployment position

4.0 Diurnal Occurrence Patterns

Occurrence and utilisation of an area may follow diurnal patterns of utilisation based upon diurnal light cycles or tidal cycles. This may be due to visibility, availability or the movements and dispersal of prey species.

C-pod analysis does allow the calculation of tidal cycles but works off fixed period cycles and this may not correspond with local tidal periods and may become out of synch. It is advisable that tidal times are inputted from local tide tables and phases subdivided from these on a daily basis. Tidal cycles will also move relative to day-light cycles and there may be an interaction between the two. Due to time constraints tide-cycles were not analysed.

Similarly daily hourly occurrence may be based upon solar cycles using sunrise, solar midday, and sunset periods. These times vary daily through the year on a cycle, and hence the same hour of the day may have a different significance in winter than in summer as regards daylight and solar intensity. The +/- proportional relationship to sunrise-solar midday-sunset was not measured or analysed. Rather for simplicity only the 24-hour period of the day was taken by monthly periods through the year.

Nevertheless, using dpm/hour by hour of the day, at each of the three locations analysed separately, patterns were observed. These diurnal patterns changed through the year by season and location.

Figure B1 (Appendix B) shows the median DPM /hour by hour through the complete deployment. It should be noted that the complete deployment encompasses two low occurrence winter periods and only one higher occurrence summer period, thus biasing median results towards lower winter occurrence levels. However, the results do suggest a pattern. Inside there is a peak between 06:00 and 17:00 with few observations outside this period, whilst outside showing higher overall attendance rates shows a slight dip through the middle of the day, suggesting a possible move inwards. Variance is high and results should be treated with caution. This results from the high proportion of 0 or detection negative periods and a small number of high detection positive outliers, indicative especially in winter of a fairly low density area with infrequent detection positive events.

To avoid the issue of bias caused by considering the whole deployment with unequal repetition of seasonal periods the diurnal pattern of attendance were considered by season (Summer and Winter, as the two extremes of high and low attendance respectively) and by month.

Figures B2 & B3 (Appendix B) show the diurnal attendance patterns for summer and winter.

In the summer peak both the channel and inside locations sowed a trend towards higher occurrence through the middle of the day declining overnight. Outside occurrence was higher through-out the 24-hour period, but showed a dip in the approx. sunrise to midday period, perhaps indicating a movement of some animals inshore to the harbour to coincide with the inside and channel peaks, and a subsequent increase in the afternoon, evening and night. The significance of these hourly differences is given in Table B1 and the hourly values in Table B2. With the exception of Inside Winter (very low occurrence and almost absent) all diurnal patterns showed a significant difference between at least one hour and another.

Winter diurnal patterns are harder to discern and less significant (Inside Winter was the only seasonal period with non-significant differences between hours, largely due to the total absence of animals). The clearest pattern is the higher occurrence outside, where at least in the distribution of outliers suggests greater activity at night.

Diurnal patterns by month are shown in Figures B4 to B15 (Appendix B). Perhaps the two most interesting are the peak months of January & February. Referring to previous daily occurrence rates the peak in attendance occurs outside in January, with occurrence inside in this same period still low, peak occurrence inside does not occur until into February. Diurnal hourly attendance shows a strong peak outside in mid-afternoon having increased through the morning. Peaks inside and in the Channel are less pronounced. However into February once overall occurrence inside has increased a corresponding depression in diurnal hourly rates through the middle of the day is observed. This would suggest a movement of some animals from outside to inside through the day and exiting to deeper outside waters through the later afternoon and evening.

A similar pattern of daylight peak inside and daylight depression with higher night values outside follows for March and April

Through the winter months due to the generally low occurrence patterns are not discernible and for the inside and channel locations tend not to be significant (Table B1, Appendix B). Outside winter levels are higher with a continued slight suggested bias to night-time. Levels start to change in October and again increase in November and December.

5.0 Discussion

5.1 Moorings

The mooring configurations deployed within shallow water utilising the shallow water buoyant C-pods proved to be satisfactory. C-pods maintained a near vertical orientation throughout the deployments with only limited or no movement or dragging of the mooring out of position.

Deep-water C-pods are negatively buoyant and hence require a different configuration with buoyancy above to maintain the vertical orientation of the unit. This requires a slightly more complex mooring configuration that is perhaps more susceptible to kelp entanglement and dragging in severe weather. At the outset the compromise between mooring and anchor weight to allow deployment by hand from a RIB whilst being sufficiently heavy and robust to remain anchored in severe weather was recognised. With hindsight the loss of two units during the 1st deployment would suggest that hand-recoverable moorings (that in practise limits the ground anchor weight and chain that may deployed) are too light with respect to the conditions that may be encountered in the Falklands and especially the additional loading that drifting kelp may exert on the mooring when fouled. During gales many tonnes of kelp fronds may be detached by waves and wind and drift both along the seabed and water surface, these are tenacious and can become wrapped around units and moorings increasing the load and resistance on the mooring.

In future consideration should be given to increasing budgets to allow deployment from larger vessels with fixed decks and windlass to allow automated hauling of larger ground weights, or the mounting of a plywood forward deck to a RIB with hand winch; or mounting automatic release units to ground weights to dispense with surface buoy mooring configurations. Each of these methods would allow moorings of greater weight to be deployed.

Increased allowance for the mooring configuration would also allow bespoke non-snagging mounting blocks and lighter ”slippy” sheathed lines to be used to reduce mooring load from kelp entanglement.

The deepwater C-Pods also showed evidence of galvanic corrosion and certified plastic securing bands and tensioner should be used in the future.

Finally the deep-water C-Pod was deployed upside down across all 4 deployments. This should not be significant to results as it was consistent across all 4 deployments and maintained its vertical alignment (horizontal alignment can create quadrant blind-spots caused by the body of the unit). This was human error and the risk would have been that in the event of battery leakage it would have drained into the electronic workings of the unit.

5.2 Sampling and Locational Considerations to Interpretation

NBHF signals are rapidly attenuated in water and have a limited range of detection. Lower frequency sounds can be recorded at kilometres distance, however the full likely detection distance for NBHF species is limited to 200m, and no more than 400m for possible detection.

This means that C-pods are in effect a randomly placed 200m radial sample point. This is true for the Inside and Outside deployments that sample a 200m radial circle in a larger area. However, the channel width is less than 200m in breadth and hence the Channel deployment is perhaps acting more like an electronic gate. Animals almost have to pass through the sample area and be recorded moving in and out. If they are transiting through the channel then they will be recorded (but maybe only for 1 or 2 minutes depending on speed of transit) before then dispersing in the larger area of the inner harbour, but prolonged detection positive minutes may not occur if they are not paused and foraging but transiting along the channel. This may then give different occurrence patterns, if acting as a gate in the channel we may expect more uniform consistent occurrence (more regular and shorter inter-occurrence time durations between successive encounters) but for short periods, versus an inside location that may be more infrequent as more dispersed animals move in a larger area but with occasional longer periods of attendance if active in the sampled area for foraging or socialising. This possible, though uncertain, dynamic should be borne in mind when interpreting the data patterns.

The loss of the two outer deepwater C-pods during the first instalment was unfortunate. The one remaining Outside deployment was very close inshore and almost within the entrance to the Channel and perhaps does not represent a true “Outside” near-shore deployment and certainly does not assist in defining the boundaries of a possible wider winter dispersal. The two additional alongshore deployments may have given additional insights.

Further additional deepwater C-pods (with reference to the mooring limitations detailed above) across a wider near-shore area should be a consideration of future programmes along with a possible winter repeat island-wide survey to better define the distribution of animals during the austral winter period.

5.3 Occurrence

A distinct summer peak in occurrence is shown at all locations. This corresponds to findings of the repeated visual transect surveys in the focal areas, however as the time series provided by C-pods is continuous this gives a greater temporal resolution to the peak periods.

Whilst the summer peak and lower winter occurrence occurs across the three sites, the Inside site is the most distinct with the almost complete absence of animals inside during the winter months. The Outside site whilst showing a summer peak a month earlier (before animals start to move back in and utilise the Inside area) shows an on average higher rate through the entire year and 24 hour periods. However, that the outside site is still depressed over winter does suggest that the range of animals is greater over winter and not so intensively focussed in the inshore highly productive areas, and that the greater limits of winter range have still to be determined. More constant movement over a wider area in smaller groups is also suggested by the concurrent visual surveys.

Diurnal patterns are also evident that are not available through visual surveys. The diurnal patterns are most evident during the summer months where there appears to be the suggestion of a movement into the shallow inshore Inside areas through the daylight hours and a depressed occurrence during hours of darkness. This may suggest a visual component to foraging in shallow waters. The diurnal pattern (differences between hour of the day) in both the channel and inside was significant during the summer months but was not significant during the winter when animals were largely absent.

The pattern was perhaps not so pronounced outside, but due to higher on average occurrence throughout the year it was however significant in both summer and winter. There was generally higher occurrence through the 24-hour period on average and only in the peak months of Inside summer usage is there perhaps a slight daylight depression and increase in darkness occurrence Outside to reflect a daily inward movement. This is not evident in January however which relates to the summer outside peak but before animals have moved Inside. Inside summer peak occurs a month later in February with a sudden and rapid increase from the previous month.

The use of detection positive periods (minutes, 10-minutes most usually) is considered a robust metric across many studies and is thought to accurately reflect occurrence. Whilst NBHF emit click vocalisations fairly consistently and continuously certain activity such as active foraging and prey approach (a click buzz of rapidly decreasing inter-click interval) can increases the rate and hence number of clicks. Likewise larger group size may increase the likelihood of more clicks, both due to more animals and the chance that one is pointing directly at the unit (signals are highly directional). Use of total clicks is a less reliable as a measure of occurrence but can suggest activity if investigated at smaller temporal scales. Detection positive minutes smooths this effect as a single click within the defined period (likely if present due to the constant regular clicking) will register as a detection positive period, whilst 100 clicks (perhaps from a feeding buzz or a large group) will also register as a detection positive period. It thus provides a more stable metric for presence / absence, though it does not necessarily tell us anything about density or number, merely area occurrence.

A great deal of further analysis can still be done with the existing data. Tide cycles, timing in cycle relative to Spring and Neap tides, timing of occurrence relative to sunrise, solar midday and sunset (+/-) may all further elucidate patterns of occurrence.

5.4 Additional Analysis

An initial review of the data has been conducted using High and Moderate NBHF signals to define detection positive minutes.

The level of data could be increased by inclusion of Lower certainty signals. This would significantly increase power but should only be undertaken once there has been a visual validation of the reliability of the Low signals with manual checking of perhaps 10% of click trains in this category.

Variation of the detection positive period such as to detection positive 10 minutes may also help smooth data and increase positives which could help reduce the skewed-tail distribution of the data.

Investigation of total clicks, inter-click intervals and proportion of accelerating feeding buzzes may all suggest differences in area usage over just occurrence.

5.5 Future Research

Species Seperation

Whilst the current study was conducted in an area of only Commerson's dolphin know occurrence, both Commerson's and Peale's have similar NBHF acoustics. Further investigation and consultation with experts in the field should be conducted to ascertain if there may be a means to separate the two species within the NBHF C-pod assignation. At present both species would be categorised as the same NBHF which could reduce the utility of C-pod data in overlap sympatric areas where both species are known to be present.

Detection function and Abundance

Data at present provides information on occurrence but not abundance. The calculation of a detection function for C-pods has been undertaken for Harbour Porpoise (utilising animal tracking relative to the unit position on the same timelines and matching detections) which has allowed data to be utilised to estimate abundance through radial sampling. This may be complicated in the Falklands with Commerson's due to the number of animals and difficulty in tracking a known or closest animal. However the ability to estimate abundance would greatly increase the utility of the units across a range of studies and applications.

Impact Studies

C-pods have been shown to be particularly useful in quantifying the impacts of coastal developments such as dredging, pile-driving, seismic and wind-farm

Before, after, control, impact (BACI) monitoring programmes utilising a number of stations equally distributed between the impact area and a nearby reference area can show differences in occurrence patterns before during and after activities and the time-lapse until occurrence returns to normal. Mean waiting times, defined as the period between 2 consecutive encounters of echolocation activity, is a particularly valuable metric that can show the length of temporary exclusion from an area during and following activities, relative to the average periodicity prior to commencement. This is especially relevant to activities such as pile driving or other anthropogenic noise that can be accurately time-stamped on the same timeline as the C-pod and gives a fine temporal scale to monitoring impacts. This approach is widely used in Europe during the construction of offshore windfarms.

Appendix A

Seasonal

Addition Data Outputs

Table A1: Mean, Standard Error, Upper and Lower Confidence Interval limits and median values for each location

	Factors											
All (Figure A2)	**Channel**				**Inside**				**Outside**			
Mean DPM/day	33.36				37.16				68.67			
Standard Error +/-	2.13				3.97				5.84			
Upper CI	35.49				41.13				74.51			
Lower CI	31.23				33.19				62.84			
Median	17				10				36			
Significance	Kruskal-Wallis Rank Sum Test: chi-squared = 77.9, df = 2, p-value < 2.2e-16. **At least one significant difference in location of median between Locations**											
Equinox – Equinox (Figure A3)	**>Day Length** Sept 23 – 19 Mar		**>Night Length** Mar 20 - 22 Sept		**>Day Length** Sept 23 – 19 Mar		**>Night Length** Mar 20 - 22 Sept		**>Day Length** Sept 23 – 19 Mar		**>Night Length** Mar 20 - 22 Sept	
Mean DPM/day	55.26		17.61		68.09		14.90		115.00		35.34	
Standard Error +/-	4.10		1.54		8.67		1.72		12.73		2.50	
Upper CI	59.36		19.15		76.76		16.62		127.73		37.84	
Lower CI	51.16		16.07		59.42		13.17		102.27		32.84	
Median	38		8		26		4		51		22.5	
Significance	Kruskal-Wallis chi-squared = 72.731, df = 1, p-value < 2.2e-16 **Significant Difference**				Kruskal-Wallis chi-squared = 70.793, df = 1, p-value < 2.2e-16 **Significant Difference**				Kruskal-Wallis chi-squared = 47.43, df = 1, p-value = 5.701e-12 **Significant Difference**			
Equinox – Solstice – Equinox – Solstice (Figures A4 & A5)	**Spring** 23 Sept 20 Dec	**Summer** 21 Dec 19 Mar	**Autumn** 20 Mar 20 Jun	**Winter** 21 Jun 22 Sept	**Spring** 23 Sept 20 Dec	**Summer** 21 Dec 19 Mar	**Autumn** 20 Mar 20 Jun	**Winter** 21 Jun 22 Sept	**Spring** 23 Sept 20 Dec	**Summer** 21 Dec 19 Mar	**Autumn** 20 Mar 20 Jun	**Winter** 21 Jun 22 Sept
Mean DPM/day	20.25	89.88	26.294	3.56	15.86	119.73	22.45	2.68	41.26	187.91	47.27	16.04
Standard Error +/-	2.57	5.74	2.17	0.75	2.46	15.24	2.56	0.82	4.58	22.41	3.38	2.55
Upper CI	22.82	95.62	28.46	4.31	18.32	134.97	25.02	3.50	45.84	210.32	50.65	18.59
Lower CI	17.68	84.14	24.12	2.81	13.40	104.49	19.89	1.86	36.69	165.50	43.89	13.49
Median	13	82	18	0	7.000000	66	12.5	0	30.5	100	38.5	6.5
Significance	Kruskal X^2= 220.54, df = 3, p-value < 2.2e-16 **Significant Difference**				Kruskal X^2 = 206.23, df = 3, p-value < 2.2e-16 **Significant Difference**				Kruskal X^2 = 147.29, df = 3, p-value < 2.2e-16 **Significant Difference**			

Table A2: Monthly mean, standard error, upper and lower confidence interval and median for each location by month

Month	Statistics	Channel	Inside	Outside
January (01)	Mean DPM/day	108.65	62.06	397.97
	Standard Error +/-	10.63	9.10	42.15
	Upper CI	119.28	71.17	440.12
	Lower CI	98.01	52.96	355.82
	Median	105	47	362
February (02)	Mean DPM/day	106.46	241.39	85.29
	Standard Error +/-	7.57	37.63	12.30
	Upper CI	114.03	279.02	97.59
	Lower CI	98.89	203.76	72.99
	Median	102.5	147.5	76
March (03)	Mean DPM/day	62.80	77.60	74.40
	Standard Error +/-	6.89	8.52	8.02
	Upper CI	69.69	86.12	82.42
	Lower CI	55.91	69.08	66.38
	Median	49	62	60.5
April (04)	Mean DPM/day	35.80	34.27	63.66
	Standard Error +/-	4.19	5.58	6.34
	Upper CI	39.98	39.85	69.99
	Lower CI	31.61	28.69	57.32
	Median	30	18.5	54
May (05)	Mean DPM/day	18.74	11.52	33.00
	Standard Error +/-	2.40	1.68	3.78
	Upper CI	21.14	13.20	36.78
	Lower CI	16.34	9.83	29.22
	Median	13	7.5	26
June (06)	Mean DPM/day	16.52	10.93	37.89
	Standard Error +/-	3.61	2.83	5.52
	Upper CI	20.13	13.77	43.41
	Lower CI	12.91	8.10	32.37
	Median	8.5	3	31
July (07)	Mean DPM/day	1.53	1.27	8.70
	Standard Error +/-	0.65	0.75	1.84
	Upper CI	2.18	2.01	10.54
	Lower CI	0.89	0.52	6.86
	Median	0	0	5.5
August (08)	Mean DPM/day	4.23	5.19	17.90
	Standard Error +/-	1.26	2.26	4.45
	Upper CI	5.49	7.45	22.35
	Lower CI	2.96	2.94	13.45
	Median	0	0	6
September (09)	Mean DPM/day	1.47	1.57	11.00
	Standard Error +/-	0.77	0.81	3.94
	Upper CI	2.23	2.37	14.94
	Lower CI	0.70	0.76	7.06
	Median	0	0	1
October (10)	Mean DPM/day	9.84	6.35	45.06
	Standard Error +/-	2.23	2.23	9.09
	Upper CI	12.07	8.58	54.15
	Lower CI	7.61	4.13	35.98
	Median	7	2	26
November (11)	Mean DPM/day	28.28	23.38	43.59
	Standard Error +/-	6.12	5.04	8.71
	Upper CI	34.39	28.42	52.30
	Lower CI	22.16	18.34	34.87
	Median	22	12	31
December (12)	Mean DPM/day	33.42	27.74	54.65
	Standard Error +/-	4.61	5.80	8.26
	Upper CI	38.03	33.55	62.91
	Lower CI	28.81	21.94	46.38
	Median	31	17	43
Significant Difference between at least one month an another ?		Kruskal-X^2 = 278.5, df = 11, $p < 2.2e-16$. **Significant**	Kruskal-X^2 = 257.47, df = 11, $p < 2.2e-16$ **Significant**	Kruskal-X^2 = 206.82, df = 11, $p < 2.2e-16$ **Significant**

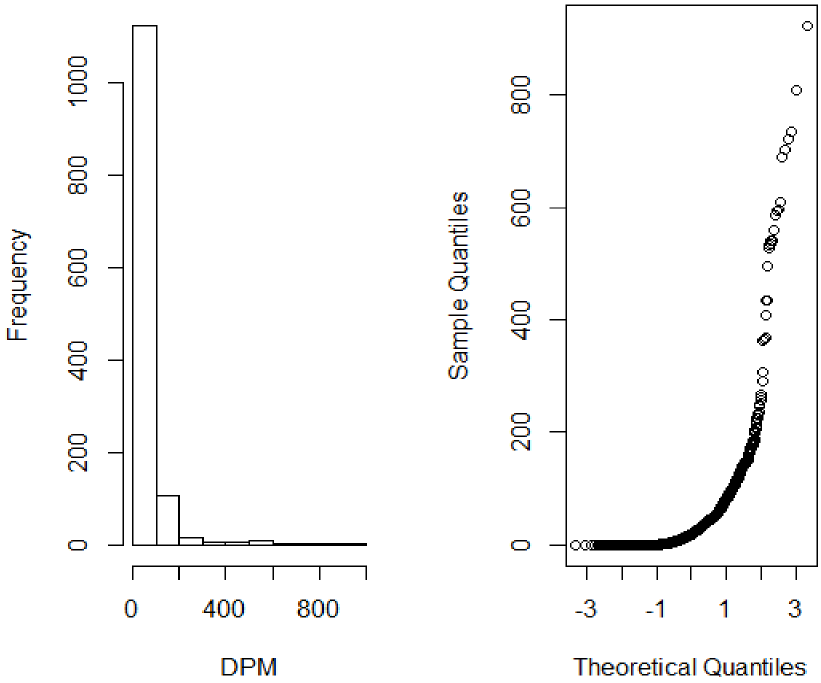
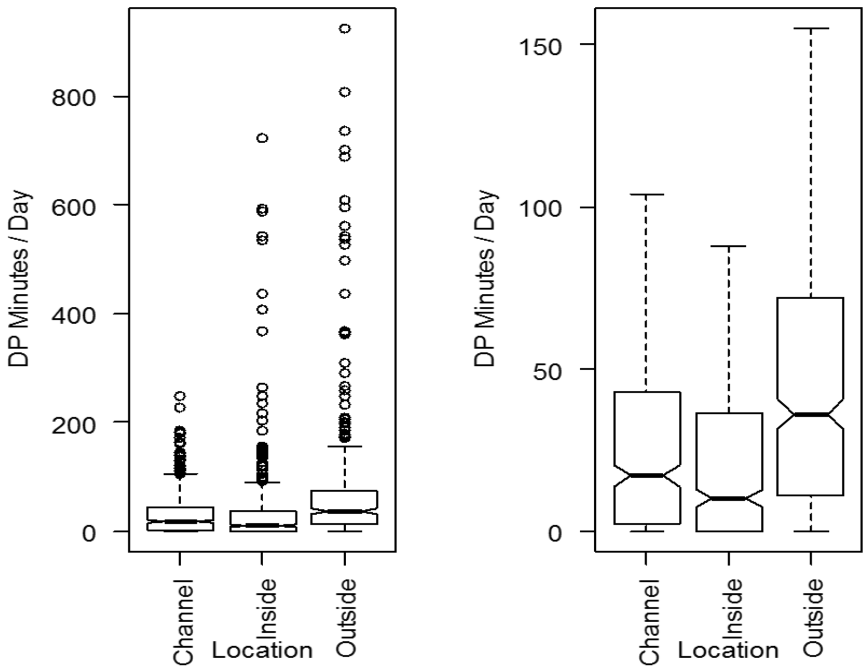


Figure A1: Histogram of daily DPM frequencies showing the skewed and non-normal distribution of data.



Figures A2: Median Detection Positive Minutes / Day by C-Pod Location, with and without data point outliers. It can be observed that the approximate level of significance, represented by the notch, do not overlap and that each location is likely significant from each other, although the accompanying Kruskal Wallis Rank Sum Test only tests for at least one significant difference between median location.

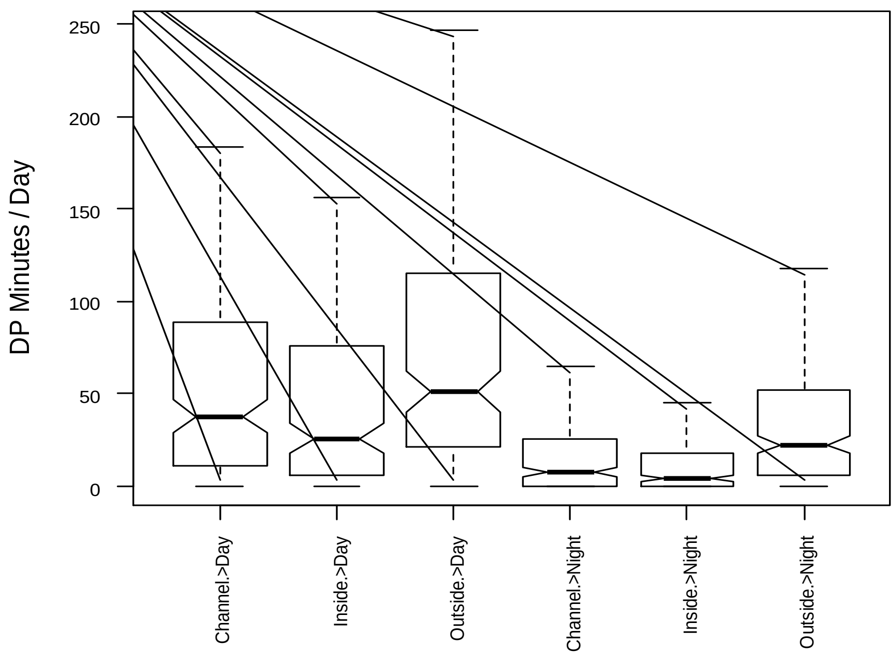


Figure A3: Median Detection Positive Minutes / Day by Location and Day Length (defined by the equinoxes and whether day-length or night-length is greater). Outlier data points are excluded for clarity.

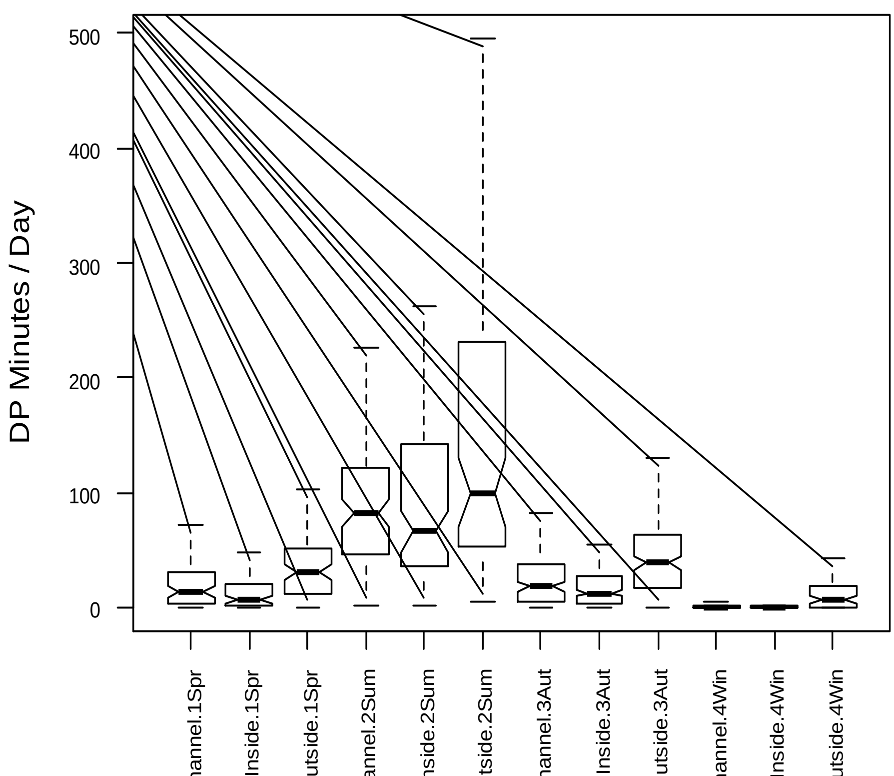


Figure A4: Median detection positive minutes / day by location and astronomical season (defined by solar equinoxes and solstices) for all locations and seasons. Outlier data pints are excluded for clarity.

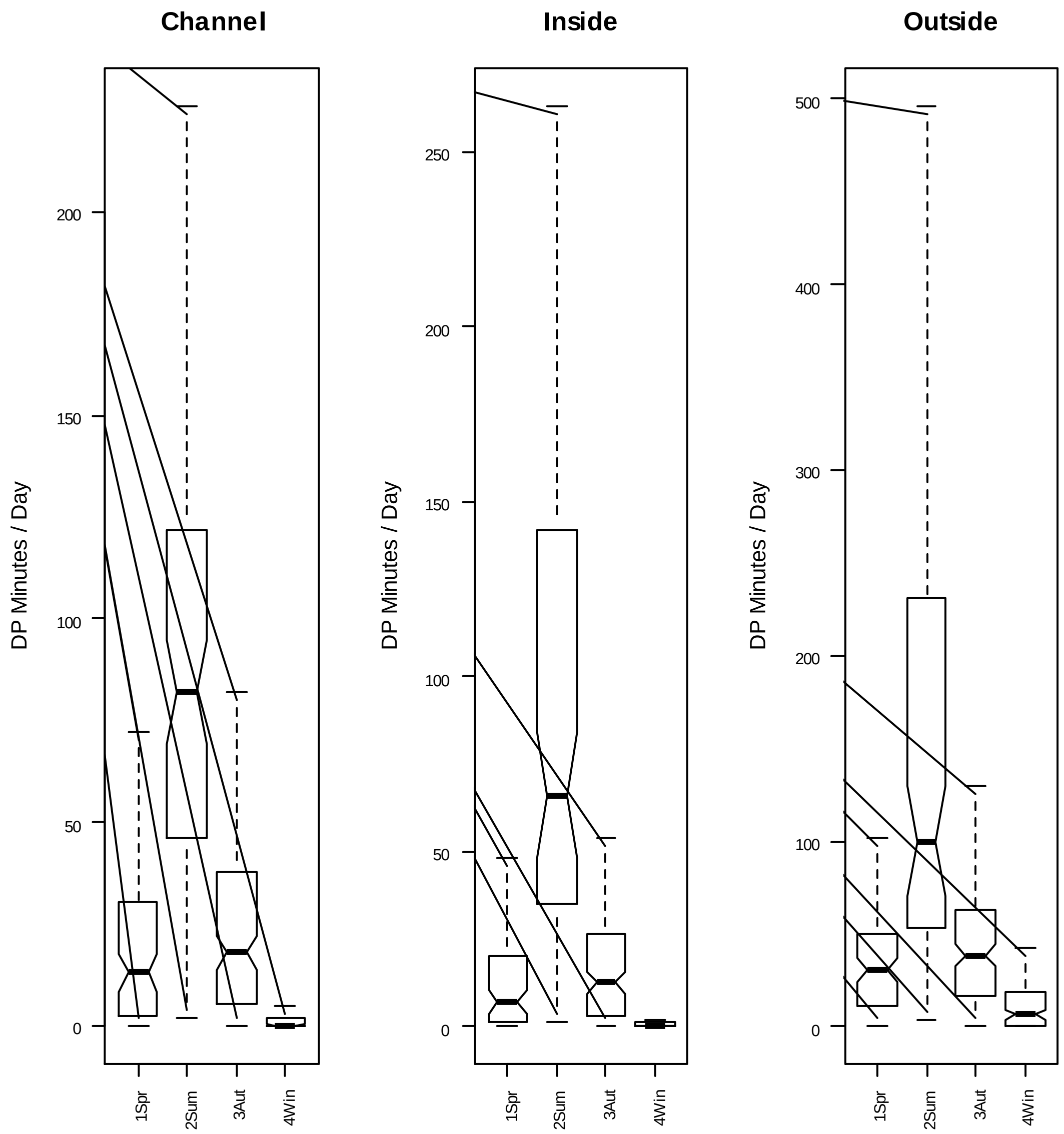


Figure A5: Median detection positive minutes / day by astronomical season defined by solar equinoxes and solstices (1-Spring, 2-Summer, 3-Autumn and 4-Winter) for each location. Note different y-axis scales are used between locations to better stretch and show notch overlap between seasonal attendance rates. Outlier data points are excluded for clarity.

Appendix B

Diurnal Patterns of Occurrence

Additional Data Outputs

Table B1: Significance of diurnal hourly median differences for each month at each location

Period of Diurnal Hourly Observations	**Kruskal-Wallis Rank Sum Test – Chi Squared** At least one significance between median DPM/Hr and distribution of DPM/Hour at each location individually. (Note: This is not testing between the diurnal distributions between locations but only that there is at least one significant difference between hourly rates within a location) Statistically "significant" as P < 0.05 and statistically "highly significant" as P < 0.001 Non-Significant Results Highlighted		
Season	**Channel**	**Inside**	**Outside**
Summer	X^2 = 209.91, df = 23, P < 2.2e-16 Highly Significant	X^2 = 321.4, df = 23, P < 2.2e-16 Highly Significant	X^2 = 52.138, df = 23, P = 0.0004791 Highly Significant
Winter	X^2 = 45.567, df = 23, P = 0.003385 Significant	X^2 = 13.994, df = 23, P = 0.9271	X^2 = 96.953, df = 23, P = 4.706e-11 Highly Significant
Month	**Channel**	**Inside**	**Outside**
January (1)	X^2 = 112.23, df = 23, P = 1.018e-13 Highly Significant	X^2 = 68.214, df = 23, P = 2.288e-06 Highly Significant	X^2 = 104, df = 23, P = 2.854e-12 Highly Significant
February (2)	X^2 = 75.834, df = 23, P = 1.48e-07 Highly Significant	X^2 = 178.09, df = 23, P < 2.2e-16 Highly Significant	X^2 = 58.892, df = 23, P = 5.515e-05 Highly Significant
March (3)	X^2 = 73.363, df = 23, P = 3.64e-07 Highly Significant	X^2 = 258.78, df = 23, P < 2.2e-16 Highly Significant	X^2 = 122.2, df = 23, P = 1.667e-15 Highly Significant
April (4)	X^2 = 35.616, df = 23, P = 0.04513 Significant	X^2 = 32.629, df = 23, P = 0.08776	X^2 = 67.505, df = 23, P = 2.934e-06 Highly Significant
May (5)	X^2 = 32.152, df = 23, P = 0.09702	X^2 = 42.53, df = 23, P = 0.00787 Significant	X^2 = 56.794, df = 23, P = 0.0001095 Highly Significant
June (6)	X^2 = 16.261, df = 23, P = 0.8439	X^2 = 31.118, df = 23, P = 0.1199	X^2 = 78.597, df = 23, P = 5.35e-08 Highly Significant
July (7)	X^2 = 21.912, df = 23, P = 0.5256	X^2 = 22.318, df = 23, P = 0.5011	X^2 =43.578, df = 23, P = 0.00591 Significant
August (8)	X^2 = 31.166, df = 23, P = 0.1188	X^2 = 14.584, df = 23, P = 0.9089	X^2 = 53.691, df = 23, P = 0.0002951 Highly Significant
September (9)	X^2 = 25.767, df = 23, P = 0.312	X^2 = 13.184, df = 23, P = 0.9479	X^2 = 24.848, df = 23, P = 0.3582
October (10)	X^2 = 52.973, df = 23, P = 0.0003696 Highly Significant	X^2 = 53.415, df = 23, P = 0.0003218 Highly Significant	X^2 = 36.402, df = 23, P = 0.03751 Significant
November (11)	X^2 = 89.687, df = 23, P = 8.023e-10 Highly Significant	X^2 = 33.552, df = 23, P = 0.07192	X^2 = 51.635, df = 23, P = 0.0005596 Highly Significant
December (12	X^2 = 77.669, df = 23, P = 7.54e-08 Highly Significant	X^2 = 49.621, df = 23, P = 0.001033 Significant	X^2 = 34.073, df = 23, P = 0.0641

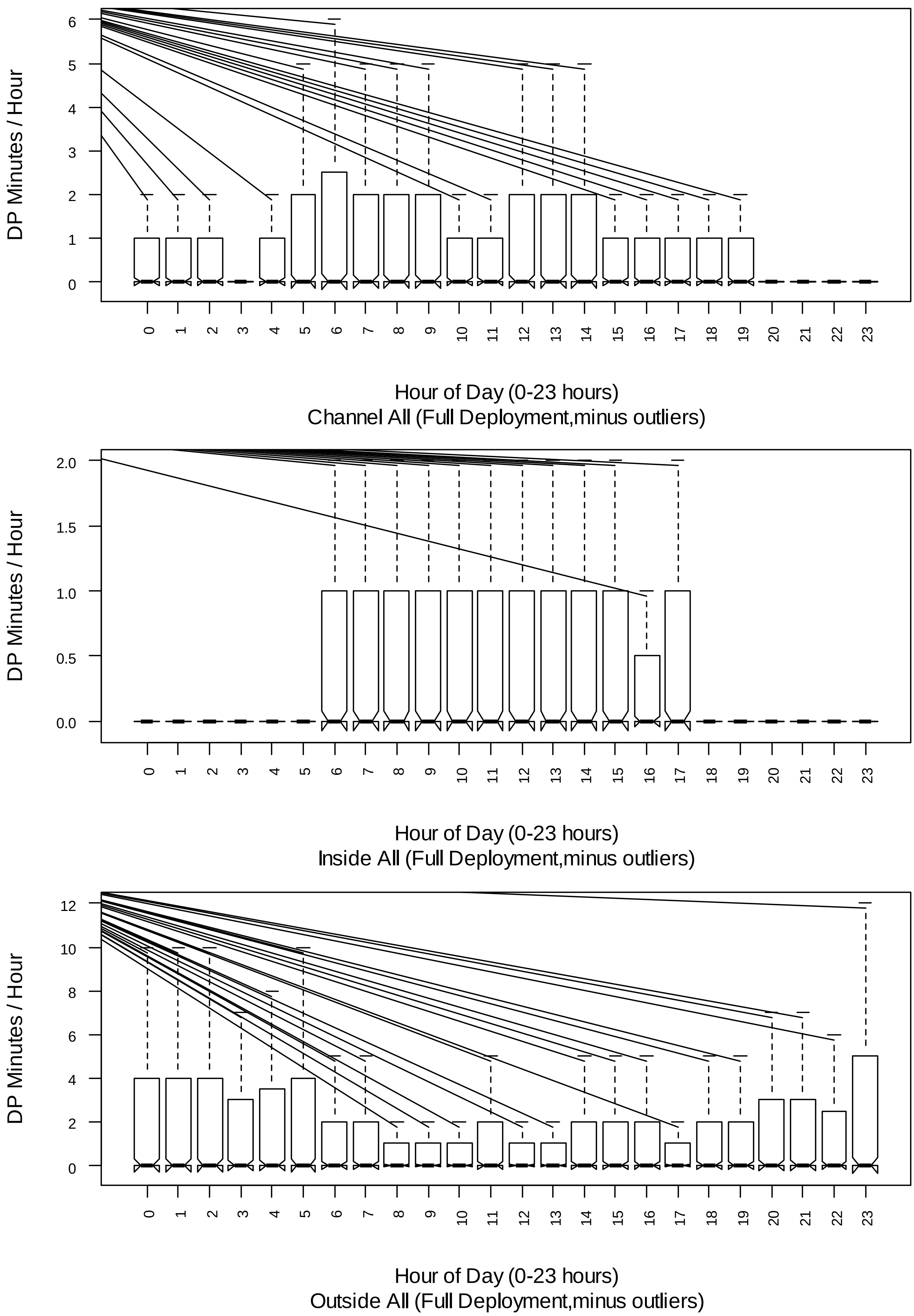
Table B2(a): Mean, standard error and median for the Summer and Winter periods at each location, 00:00 – 12:00.

Hour & Statistic	Channel		Inside		Outside	
	Summer	Winter	Summer	Winter	Summer	Winter
00 (00:00 – 00:59)						
Mean	2.83	0.33	1.85	0.08	7.44	1.51
± S.E	0.47	0.15	0.37	0.04	0.96	0.46
Median	1	0	0	0	3	0
01 (01:00 – 01:59)						
Mean	2.88	0.40	1.66	0.20	6.07	1.44
± S.E	0.53	0.25	0.34	0.13	0.88	0.49
Median	0	0	0	0	3	0
02 (02:00 – 02:59)						
Mean	3.10	0.05	1.30	0.10	6.83	1.30
± S.E	0.49	0.04	0.39	0.06	0.92	0.53
Median	1	0	0	0	3	0
03 (03:00 – 03:59)						
Mean	1.85	0.39	1.66	0.10	4.74	1.24
± S.E	0.35	0.21	0.40	0.06	0.70	0.39
Median	0	0	0	0	2	0
04 (04:00 – 04:59)						
Mean	2.36	0.32	1.52	0.38	4.39	1.63
± S.E	0.39	0.17	0.31	0.24	0.53	0.45
Median	1	0	0	0	3	0
05 (05:00 – 05:59)						
Mean	3.17	0.39	1.70	0.05	5.54	1.32
± S.E	0.48	0.17	0.34	0.04	0.82	0.35
Median	1	0	0	0	3	0
06 (06:00 – 06:59)						
Mean	4.29	0.38	2.78	0.24	5.22	0.77
± S.E	0.48	0.22	0.56	0.13	0.99	0.28
Median	3	0	1	0	1	0
07 (07:00 – 07:59)						
Mean	4.71	0.02	5.15	0.08	5.99	0.29
± S.E	0.66	0.02	1.00	0.04	1.21	0.14
Median	2	0	2	0	1	0
08 (08:00 – 08:59)						
Mean	5.12	0.12	8.30	0.06	7.19	0.10
± S.E	0.66	0.05	1.28	0.05	1.48	0.05
Median	3	0	3	0	1	0
09 (09:00 – 09:59)						
Mean	4.93	0	8.72	0.04	7.48	0.18
± S.E	0.62	0	1.30	0.02	1.42	0.13
Median	3	0	3	0	1	0
10 (10:00 – 10:59)						
Mean	5.42	0.10	9.08	0.06	8.01	0.03
± S.E	0.66	0.07	1.33	0.05	1.42	0.02
Median	3	0	3	0	2	0
11 (11:00 – 11:59)						
Mean	5.16	0.01	9.33	0.01	8.10	0.29
± S.E	0.64	0.01	1.46	0.01	1.47	0.23
Median	3	0	3	0	1	0

Table B2(b): Mean, standard error and median for the Summer and Winter periods at each location, 12:00 – 24:00.

Hour & Statistic	Channel		Inside		Outside	
	Summer	Winter	Summer	Winter	Summer	Winter
12 (12:00 – 12:59)						
Mean	4.52	0.06	8.22	0.08	8.85	0.17
± S.E	0.48	0.03	1.43	0.05	1.60	0.79
Median	3	0	2	0	2	0
13 (13:00 – 13:59)						
Mean	5.42	0	9.51	0.04	9.64	0.05
± S.E	0.61	0	1.62	0.03	1.61	0.04
Median	4	0	3	0	2	0
14 (14:00 – 14:59)						
Mean	5.81	0	8.36	0.01	11.65	0.05
± S.E	0.68	0	1.35	0.01	1.71	0.04
Median	3	0	2	0	4	0
15 (15:00 – 15:59)						
Mean	5.09	0.03	6.82	0.11	10.79	0.14
± S.E	0.68	0.02	1.23	0.09	1.60	0.10
Median	3	0	2	0	4	0
16 (16:00 – 16:59)						
Mean	4.45	0.12	8.43	0.04	10.92	0.09
± S.E	0.63	0.06	1.65	0.03	1.61	0.07
Median	2	0	2	0	3	0
17 (17:00 – 17:59)						
Mean	3.88	0.02	7.84	0.01	10.46	0.13
± S.E	0.55	0.02	1.61	0.01	1.59	0.08
Median	2	0	2	0	4	0
18 (18:00 – 18:59)						
Mean	3.39	0.01	6.66	0.01	9.81	0.10
± S.E	0.53	0.01	1.41	0.01	1.66	0.07
Median	2	0	1	0	3	0
19 (19:00 – 19:59)						
Mean	2.62	0.01	4.00	0.06	9.47	0.43
± S.E	0.44	0.01	0.98	0.06	1.58	0.19
Median	1	0	0	0	2	0
20 (20:00 – 20:59)						
Mean	2.70	0.08	1.26	0.51	10.56	0.52
± S.E	0.41	0.04	0.30	0.33	1.70	0.24
Median	1	0	0	0	3	0
21 (21:00 – 21:59)						
Mean	2.15	0.22	1.61	0.26	8.80	1.38
± S.E	0.33	0.11	0.36	0.15	1.36	0.38
Median	1	0	0	0	3	0
22 (22:00 – 22:59)						
Mean	1.72	0.31	2.01	0	3.71	1.08
± S.E	0.35	0.20	0.45	0	0.55	0.31
Median	0	0	0	0	2	0
23 (23:00 – 23:59)						
Mean	2.33	0.15	1.97	0.12	6.24	1.57
± S.E	0.45	0.06	0.41	0.08	0.88	0.56
Median	0	0	0	0	3	0

Figure B1: Full deployment (including 2 winter periods and 1 summer period) diurnal DPM / hour at each location



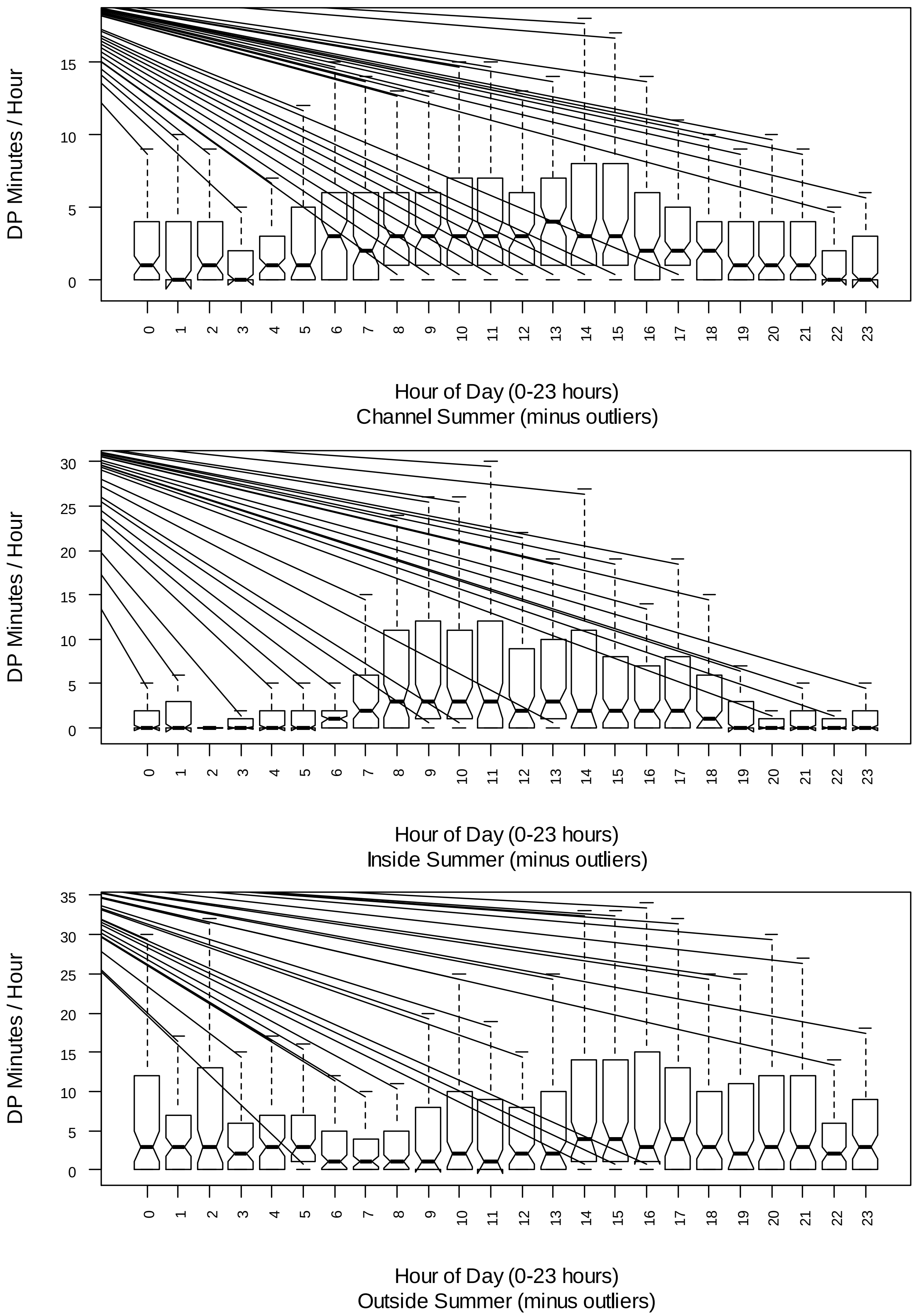
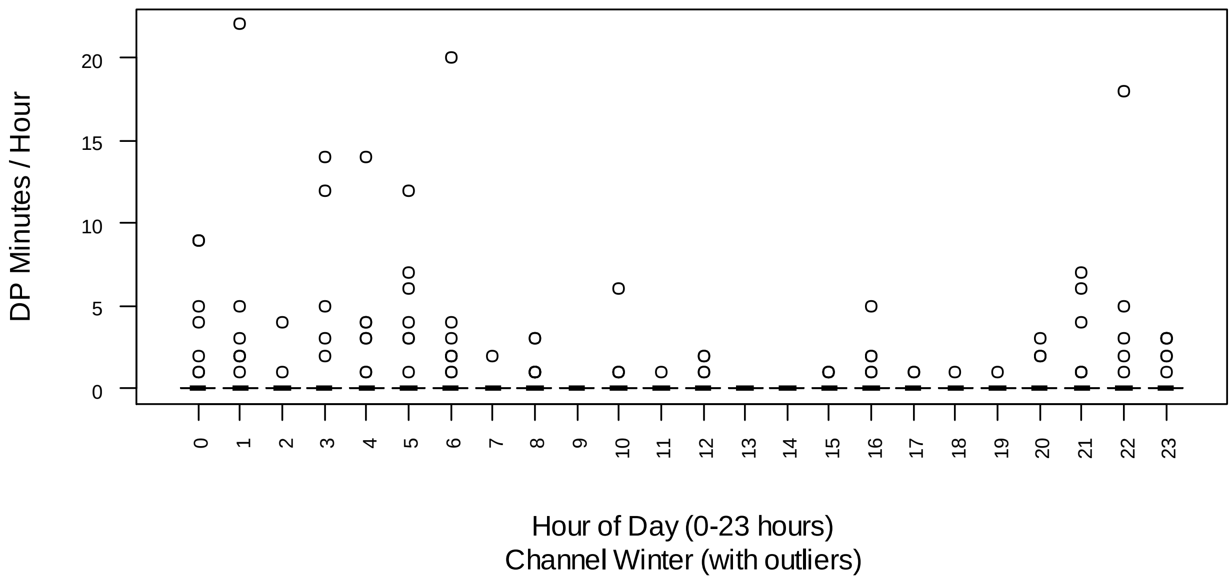
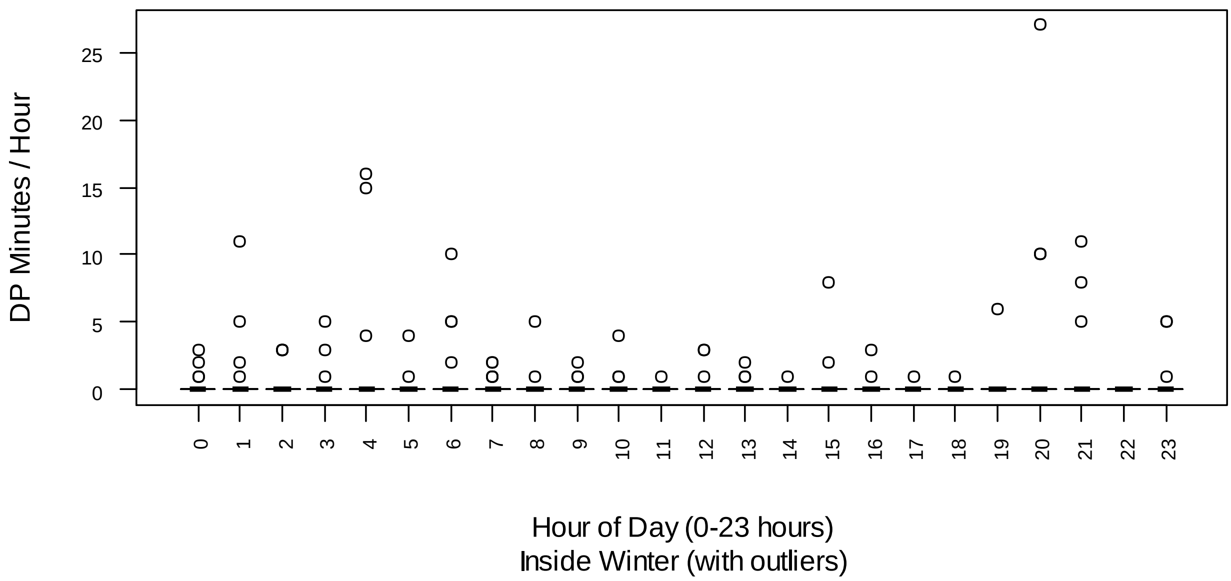


Figure B2: Diurnal DPM / hour during summer period (21st Dec – 19th Mar) at each location

Figure B3: Diurnal DPM / hour during winter period (21st Jun – 22nd Oct) at each location





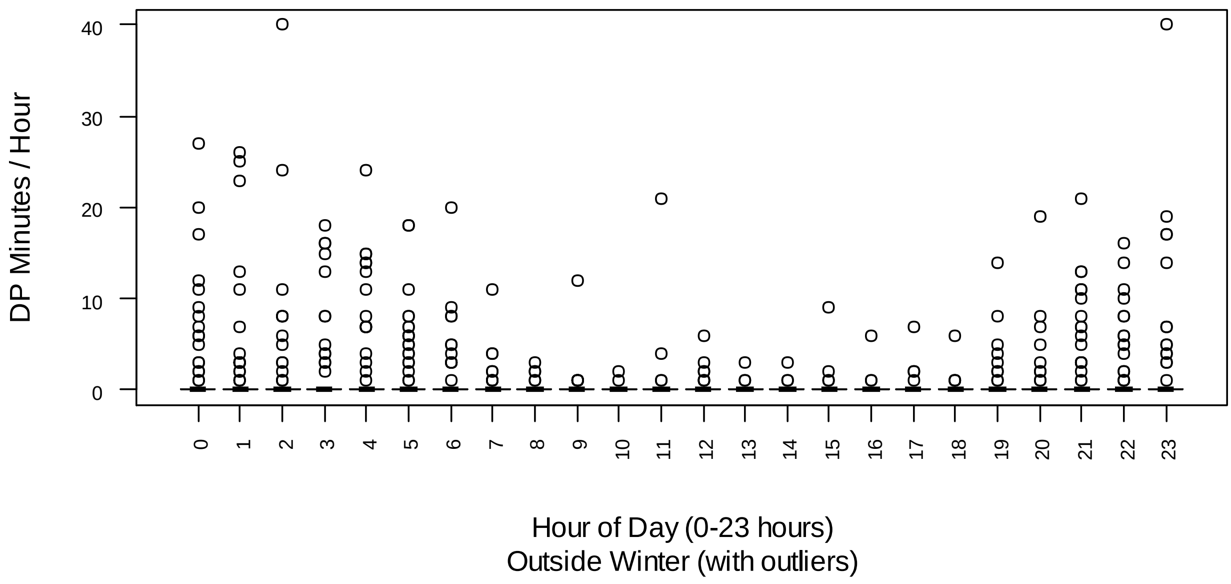


Figure B4: Diurnal DPM / hour during January at each location

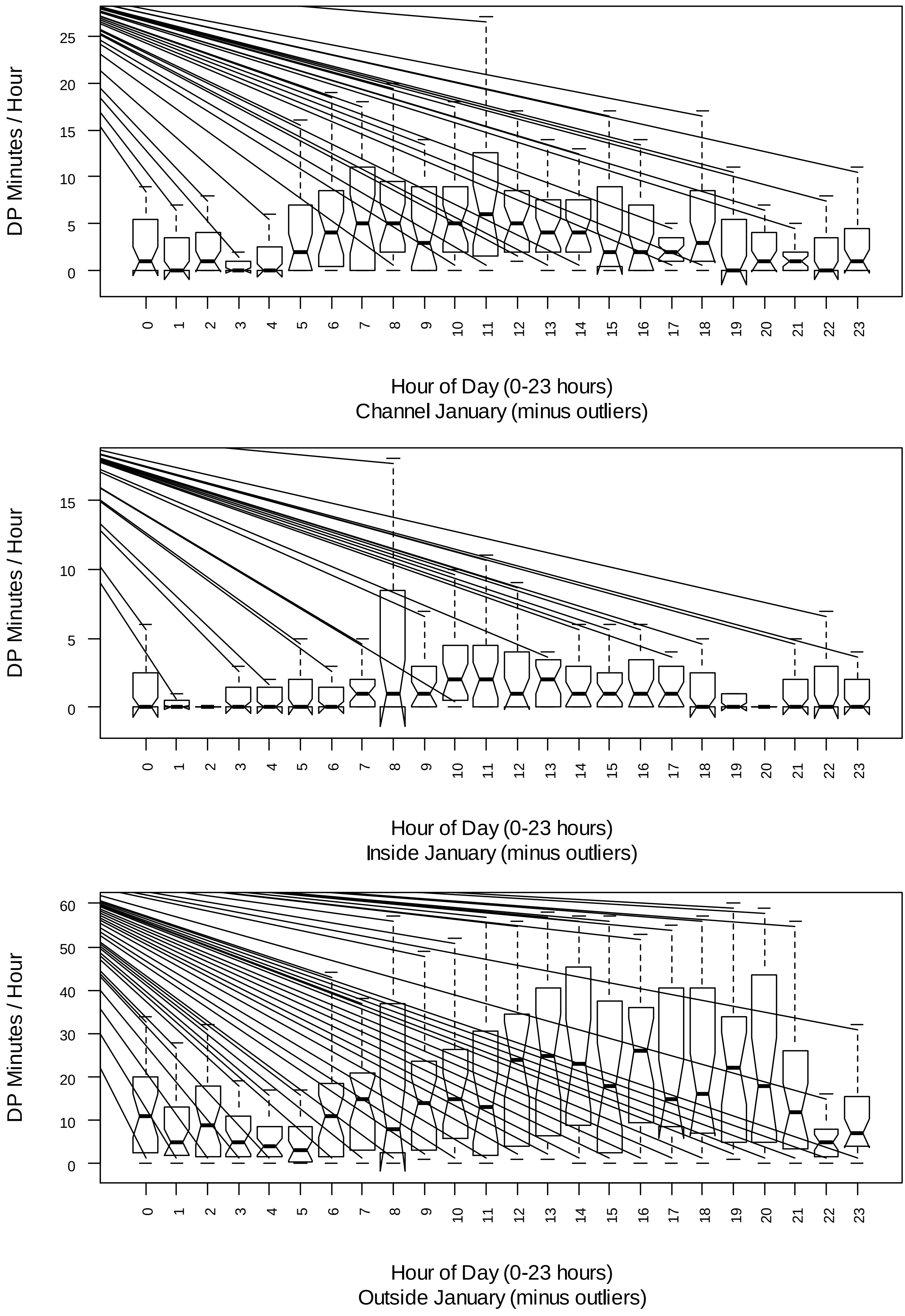
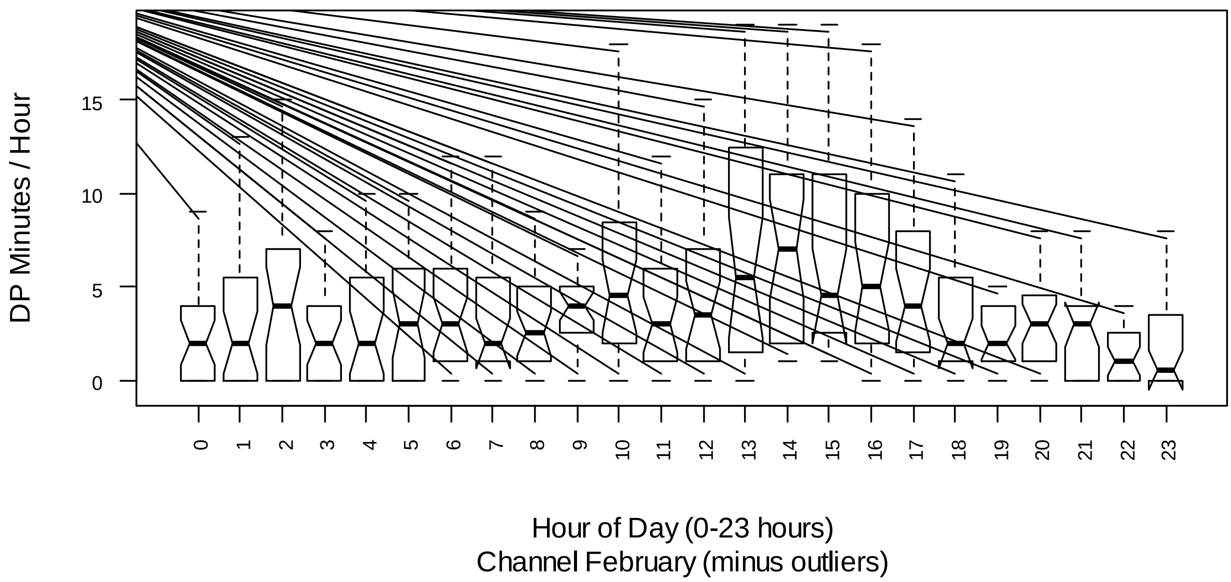
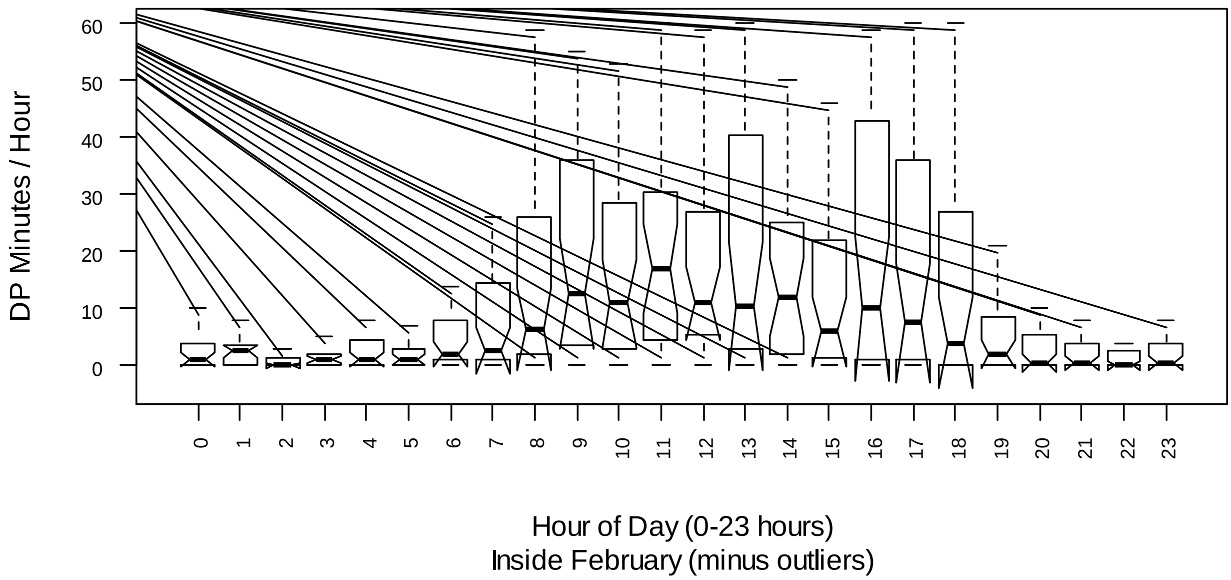


Figure B5: Diurnal DPM / hour during February at each location





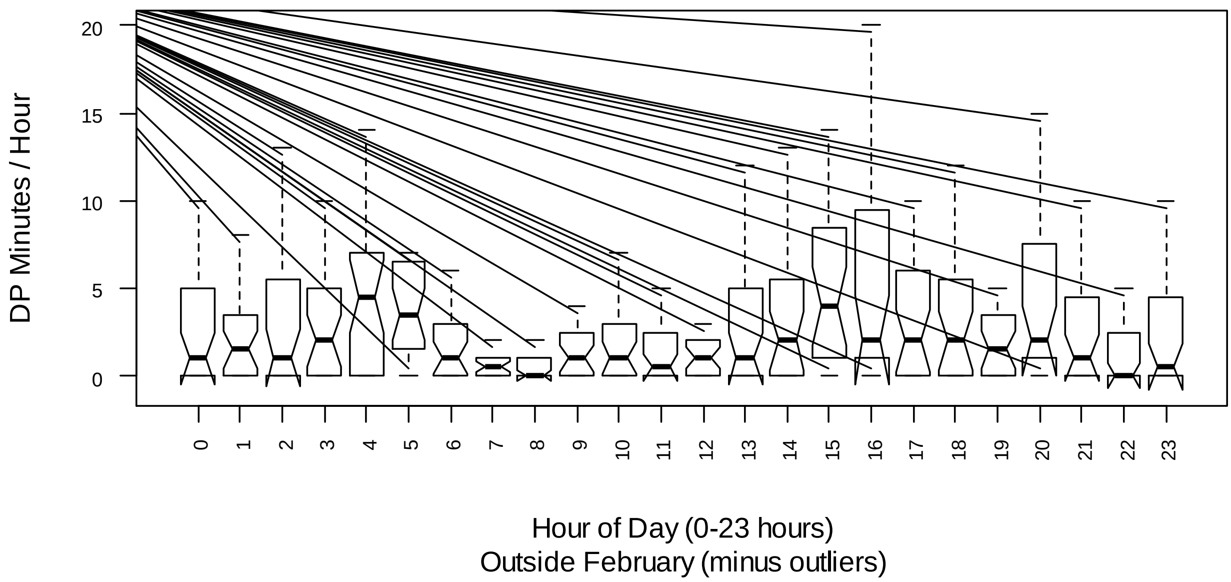
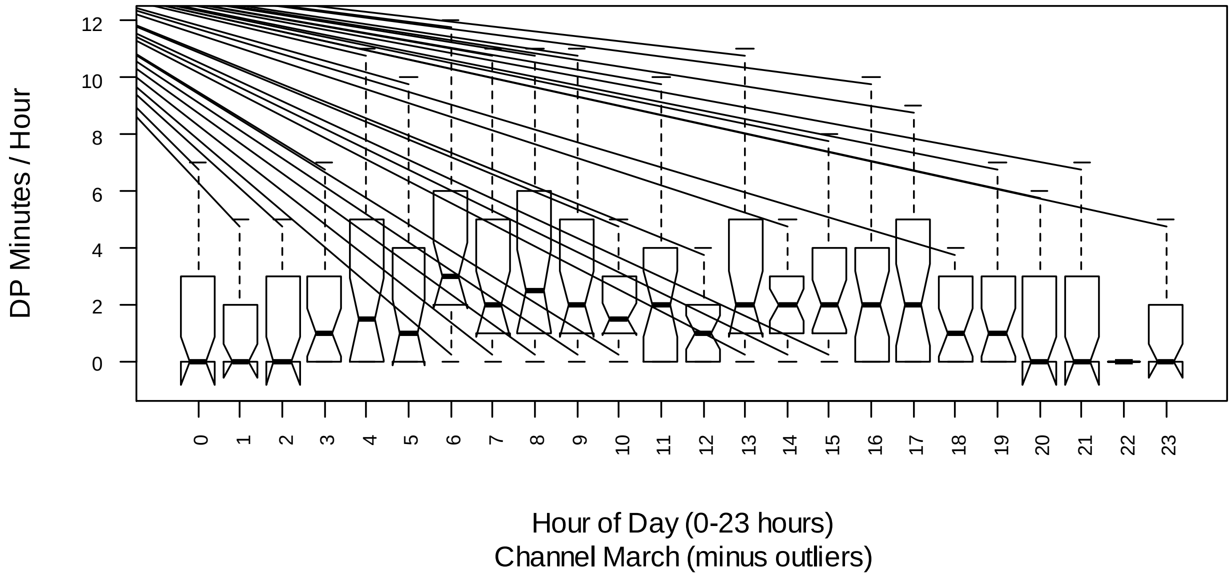
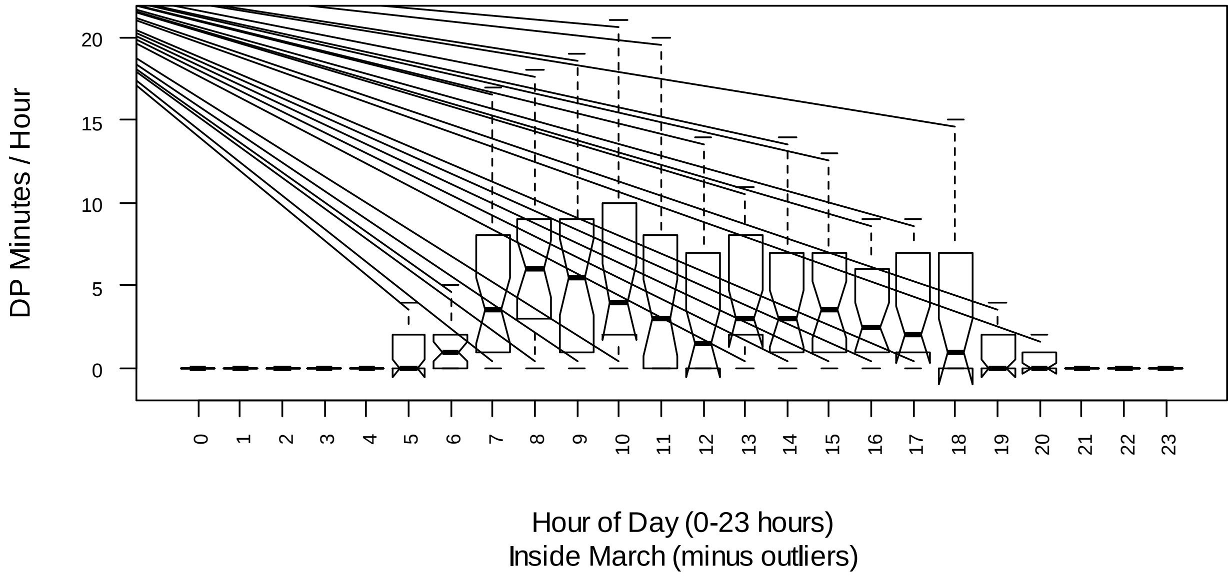


Figure B6: Diurnal DPM / hour during March at each location





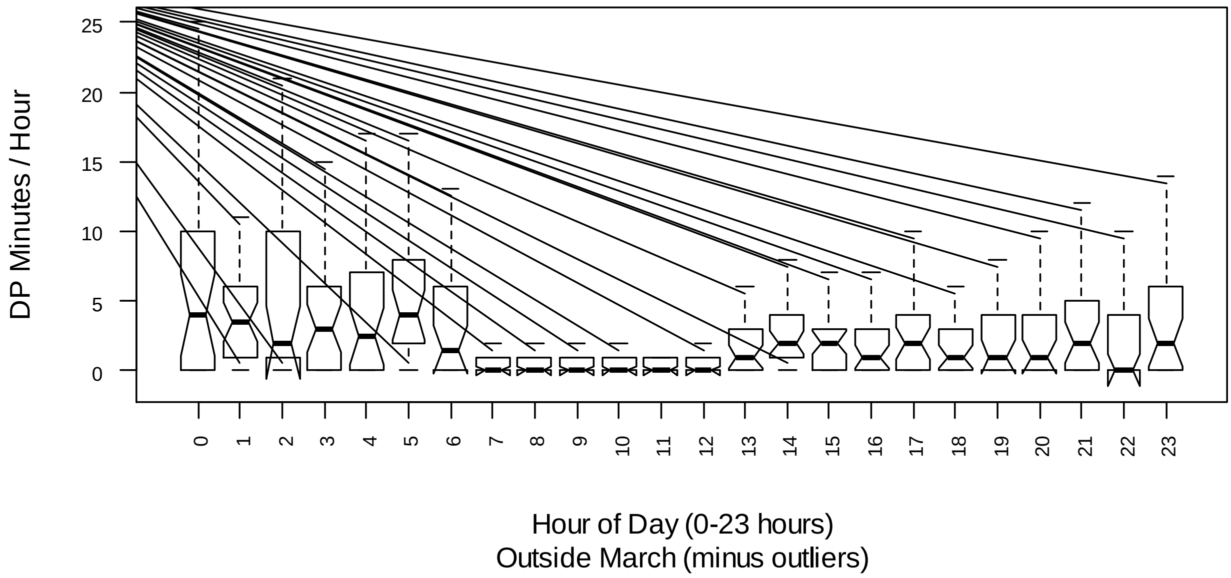
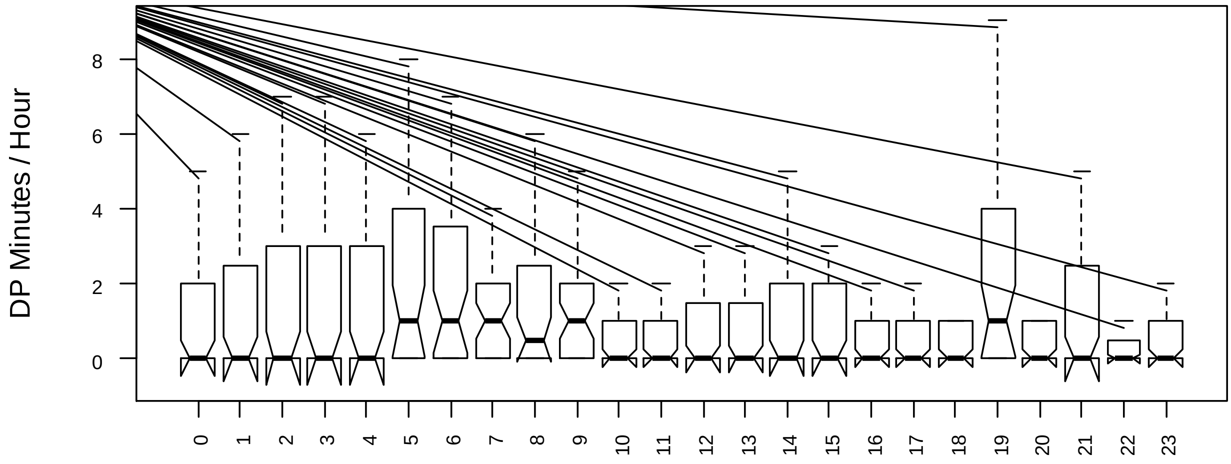
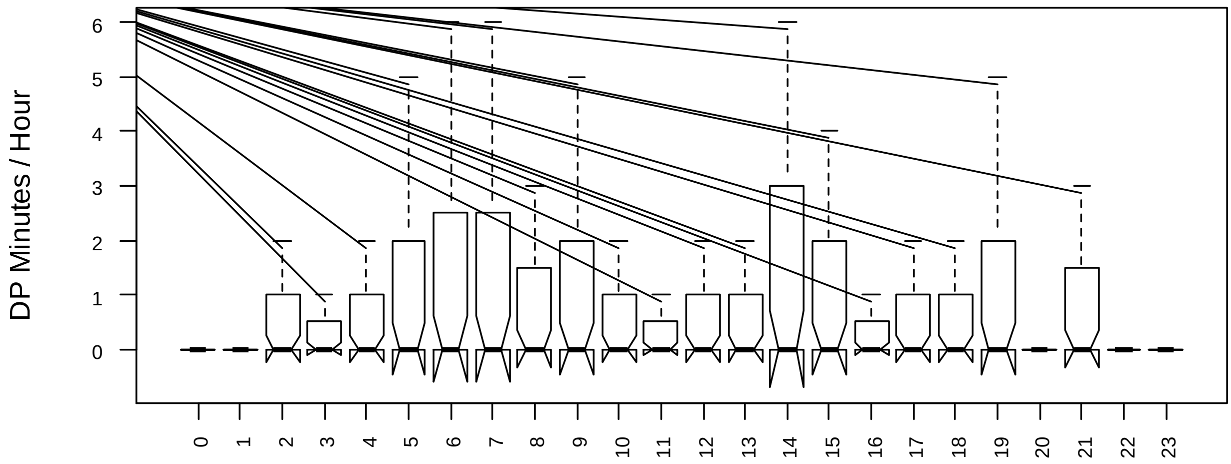


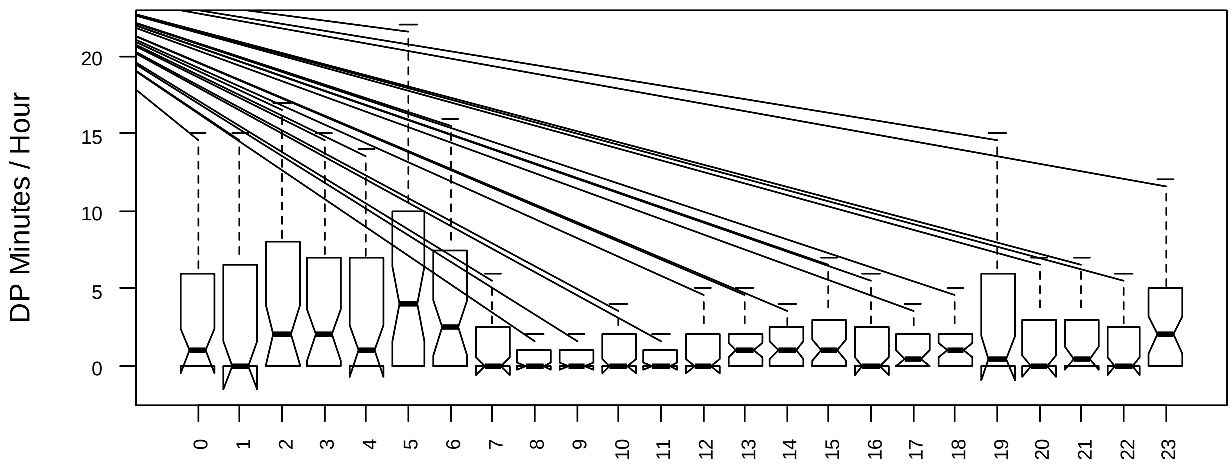
Figure B7: Diurnal DPM / hour during April at each location



Hour of Day (0-23 hours)
Channel April (minus outliers)

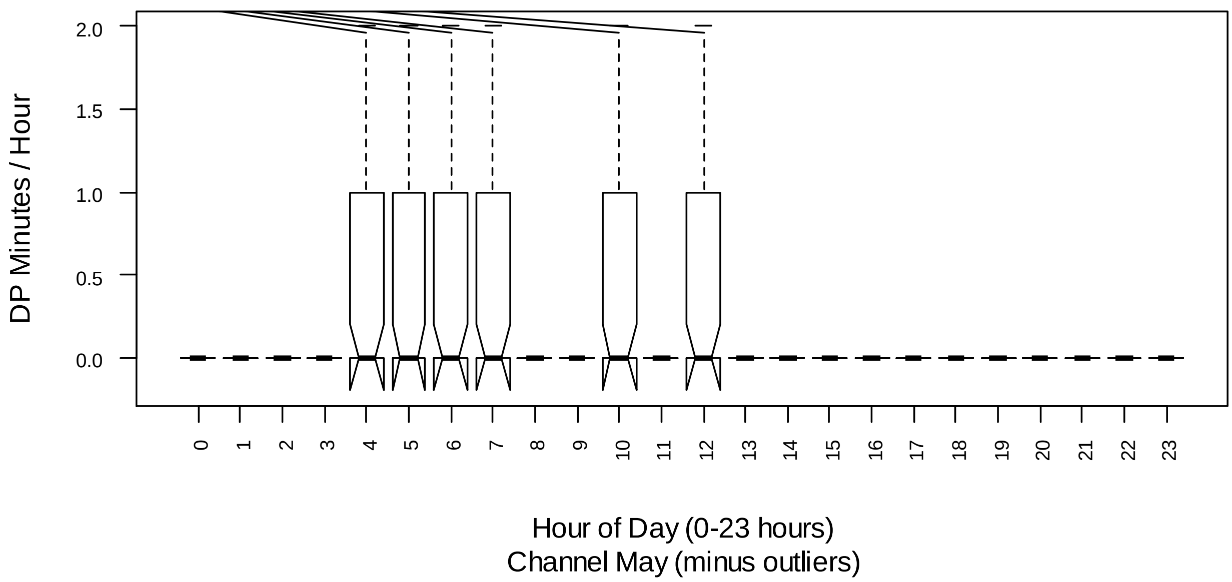


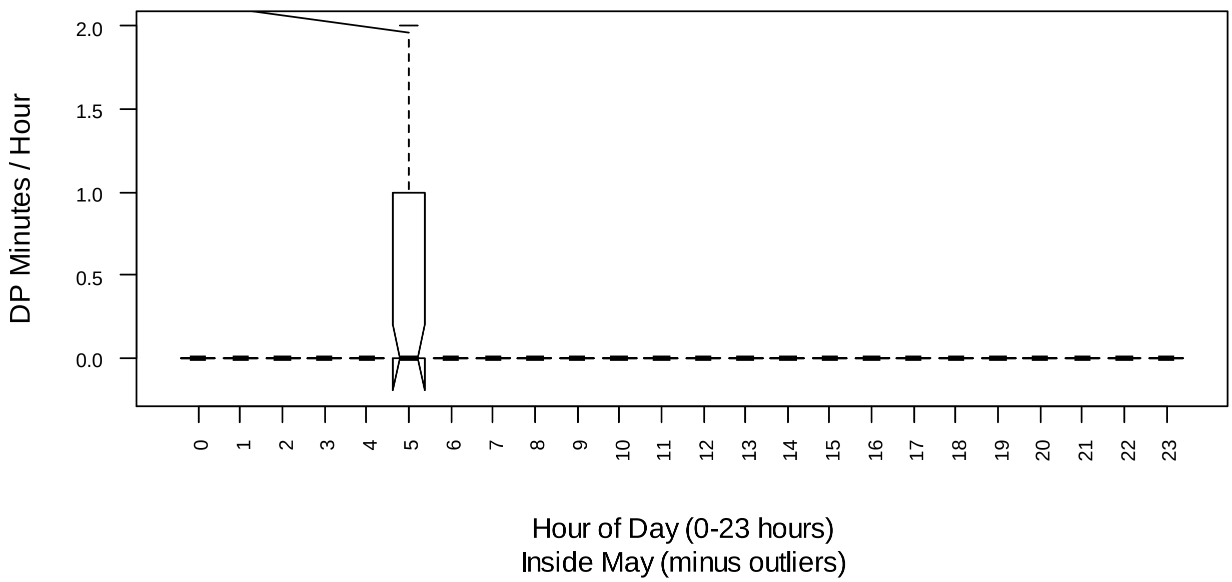
Hour of Day (0-23 hours)
Inside April (minus outliers)



Hour of Day (0-23 hours)
Outside April (minus outliers)

Figure B8: Diurnal DPM / hour during May at each location





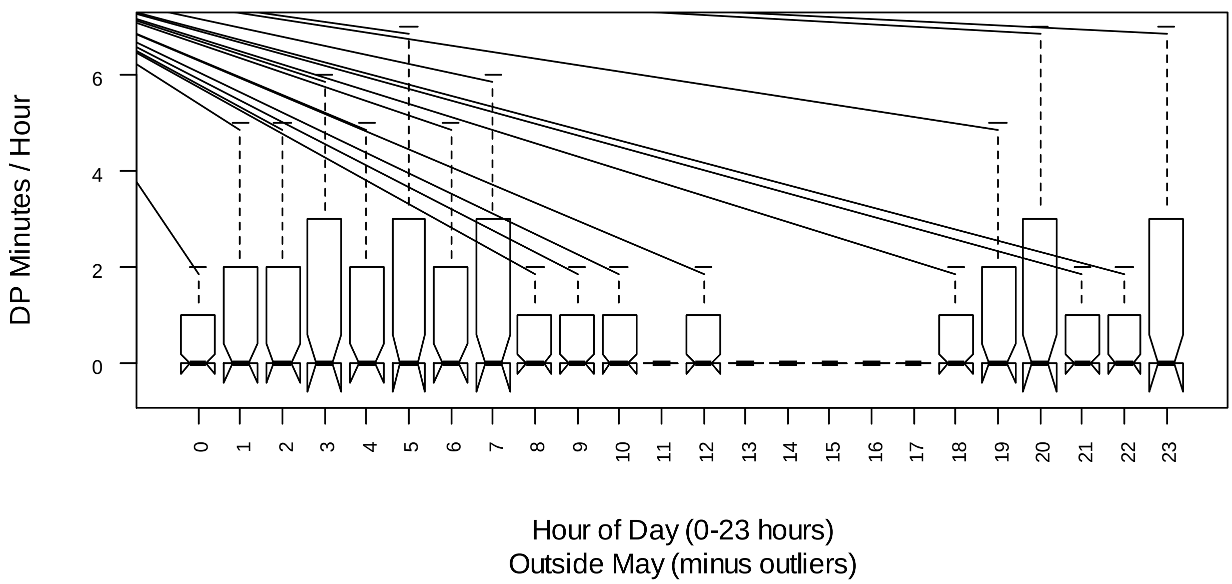
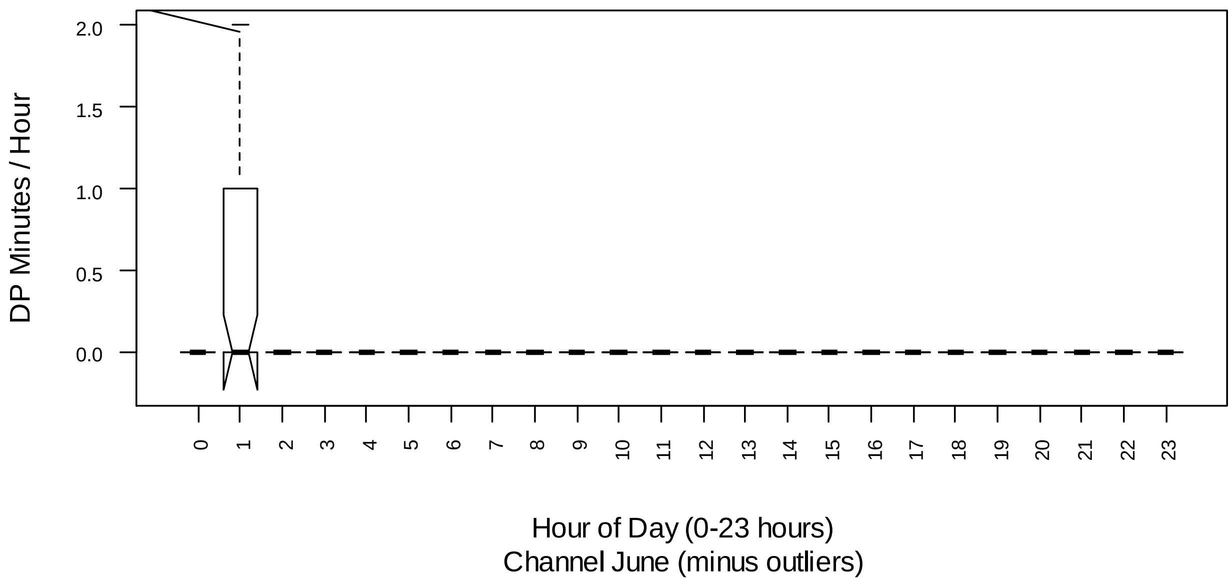
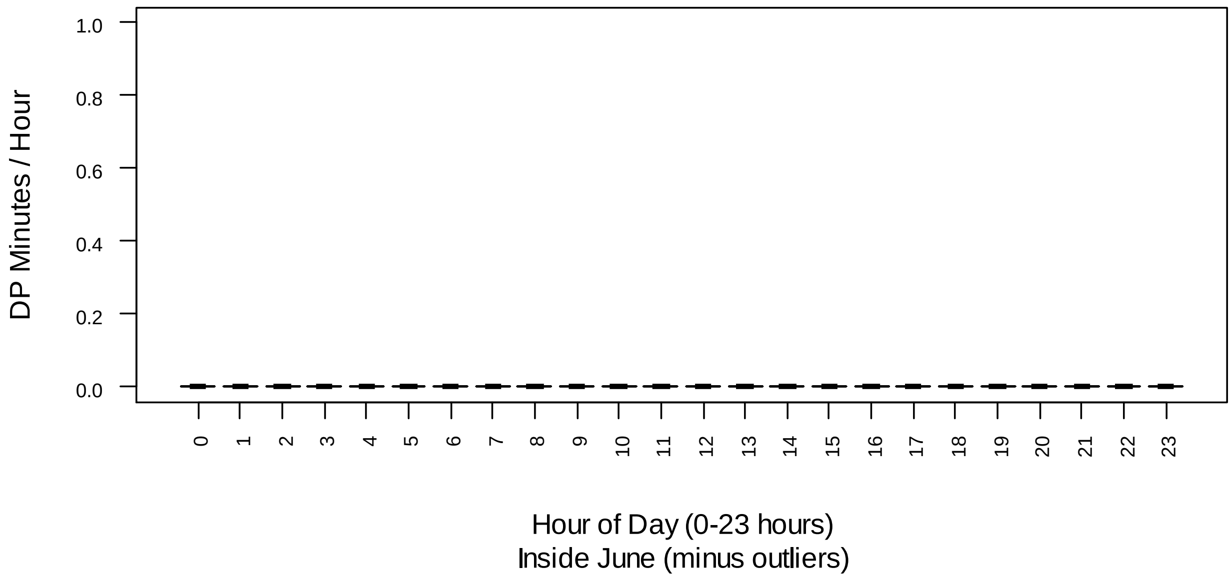


Figure B9: Diurnal DPM / hour during June at each location





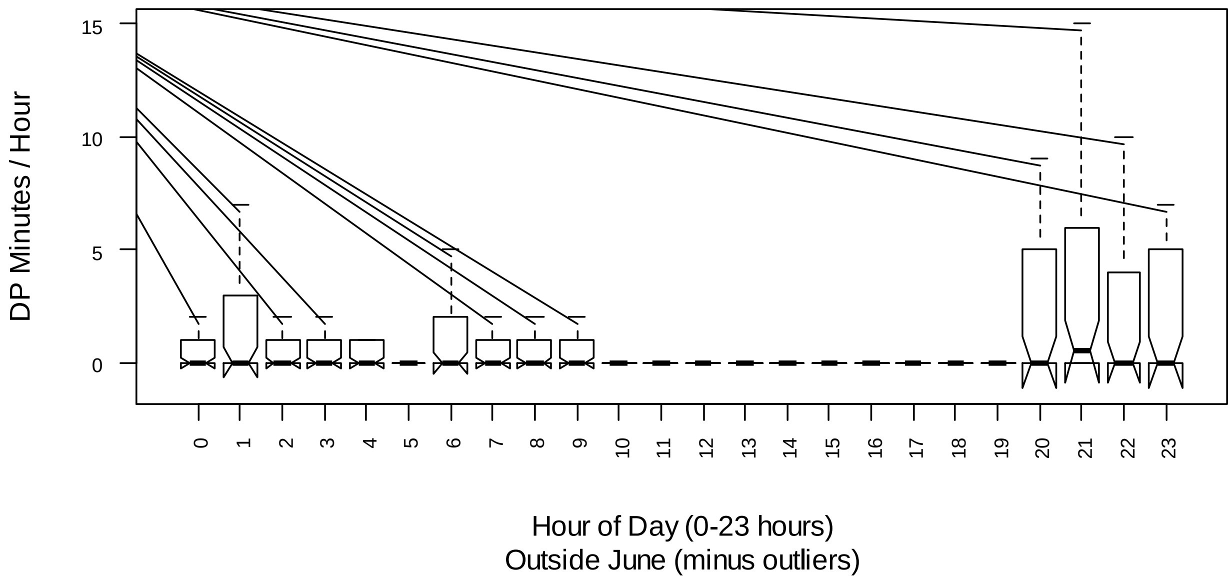
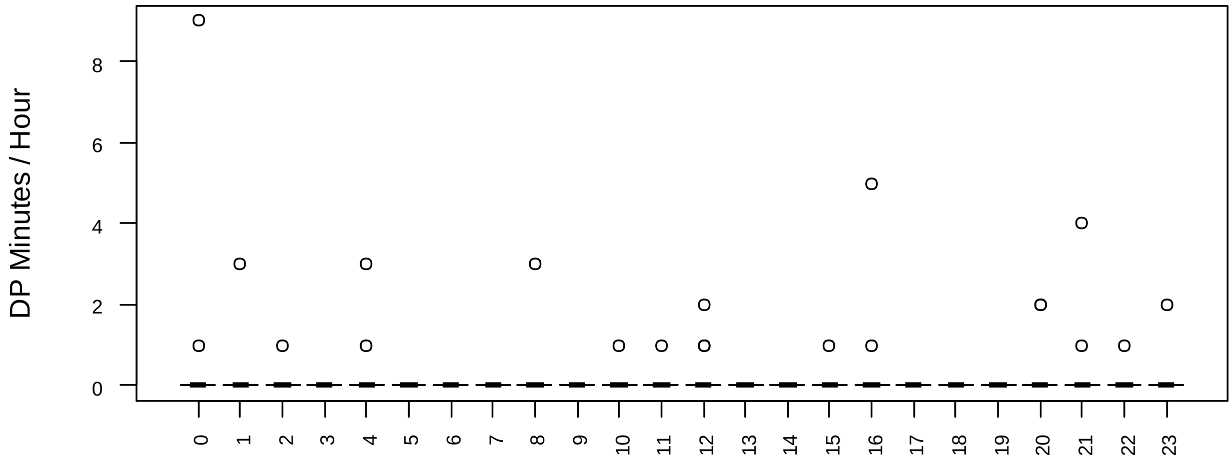
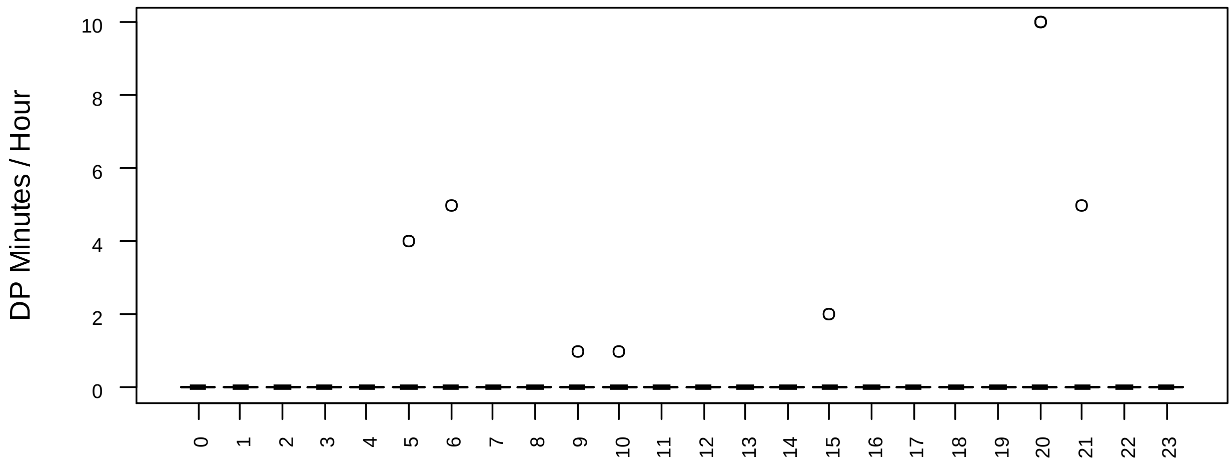


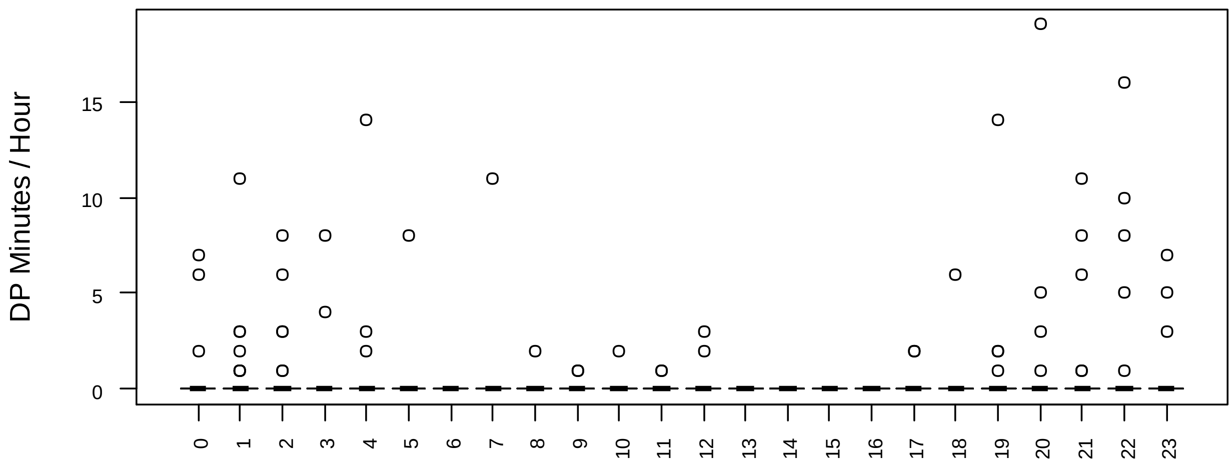
Figure B10: Diurnal DPM / hour during July at each location



Hour of Day (0-23 hours)
Channel July (with outliers)

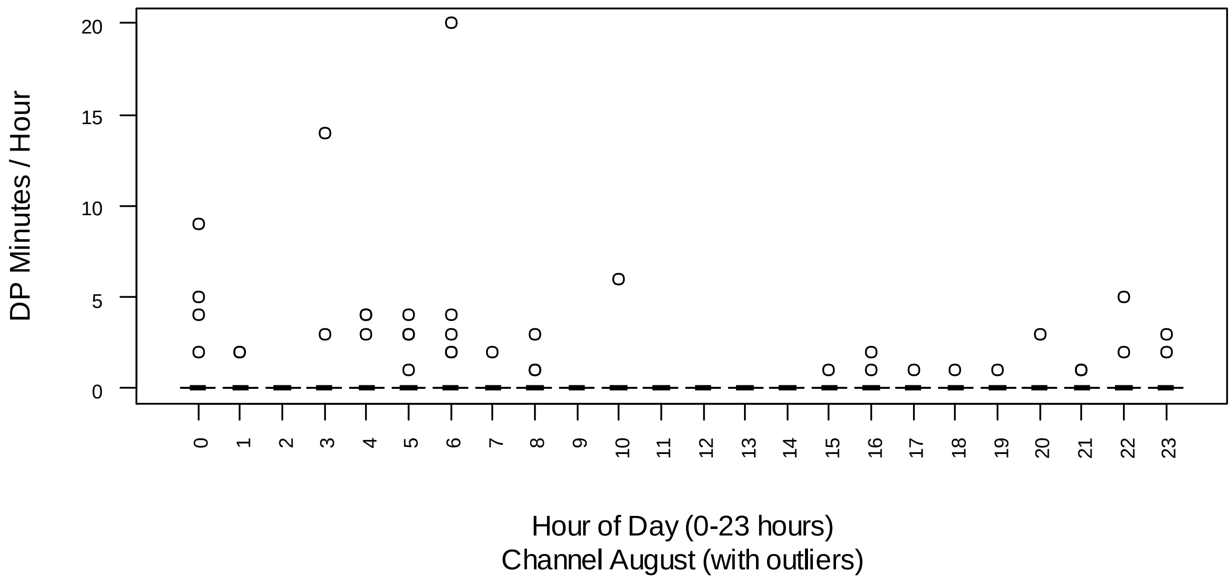


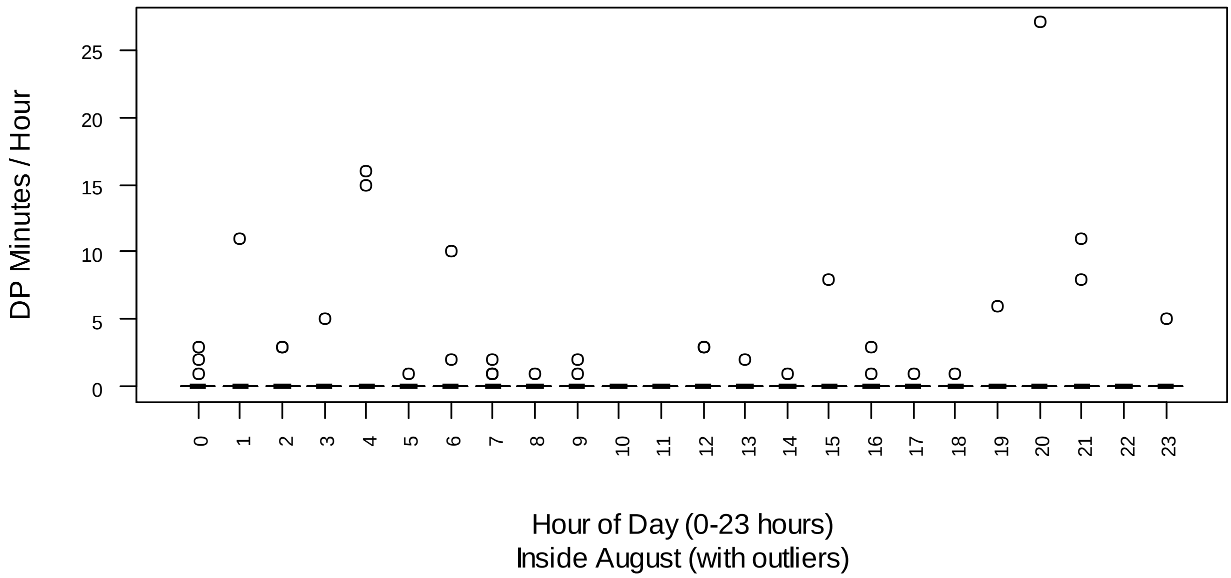
Hour of Day (0-23 hours)
Inside July (with outliers)

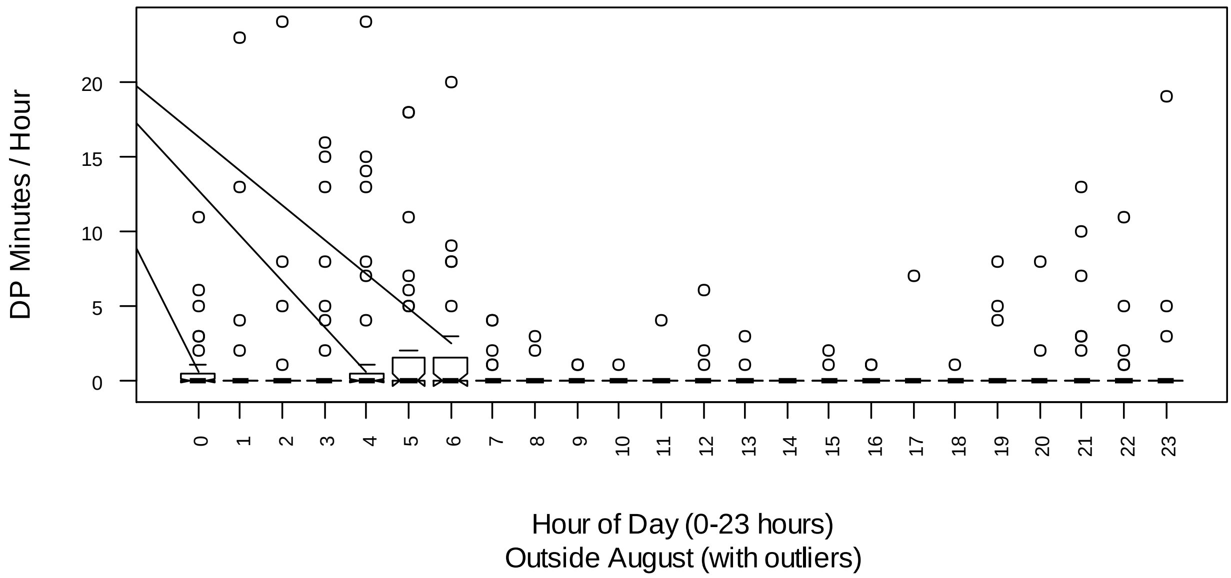


Hour of Day (0-23 hours)
Outside July (with outliers)

Figure B11: Diurnal DPM / hour during August at each location







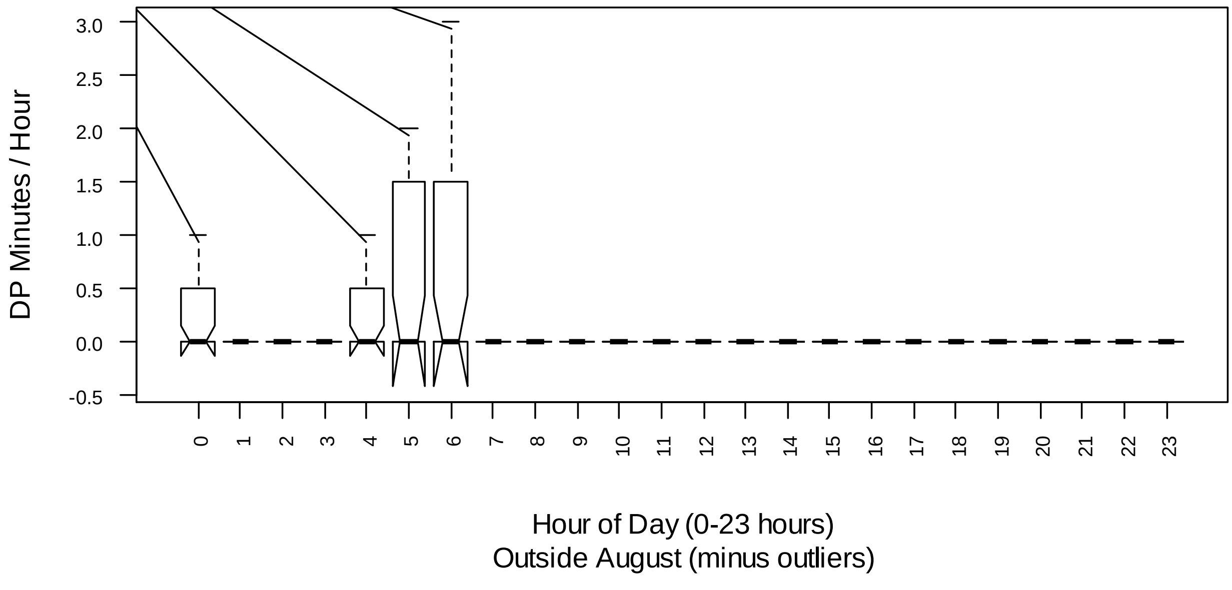
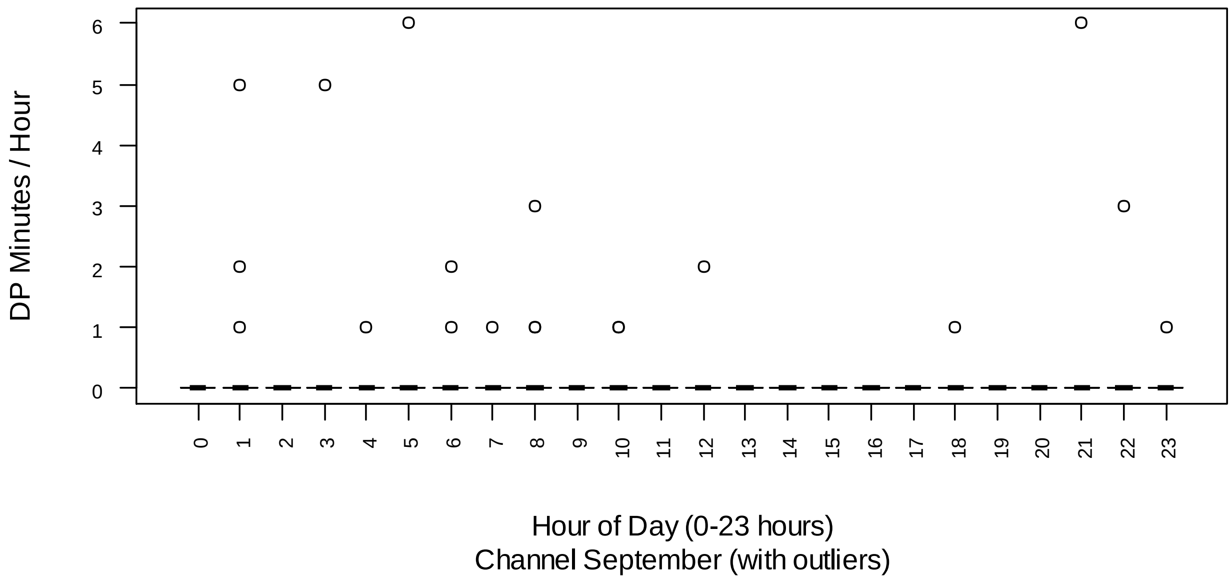
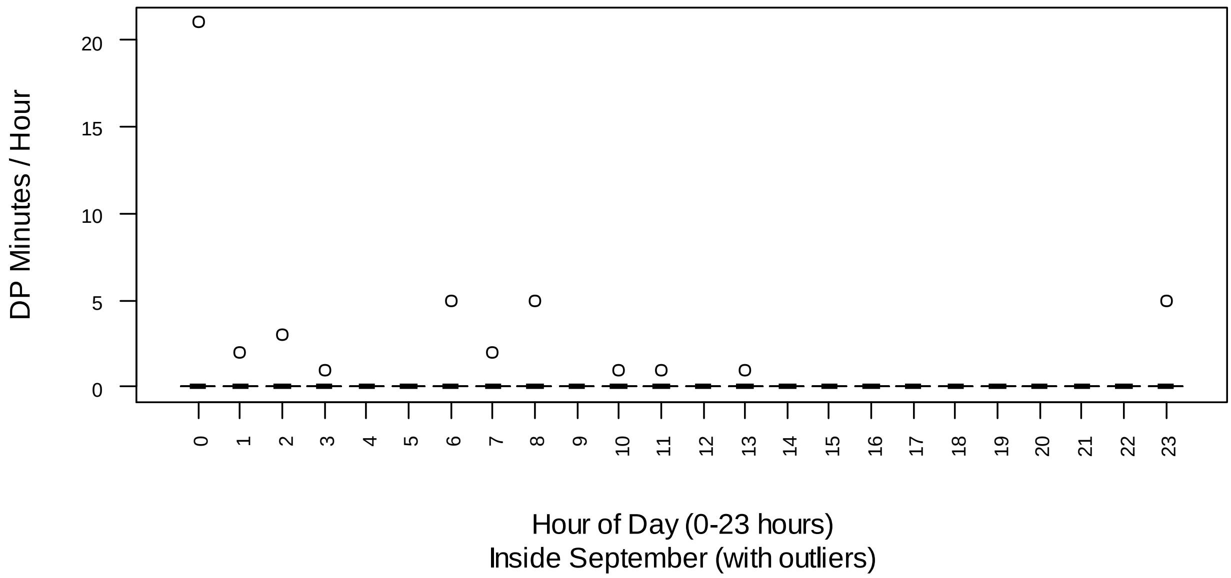

DP Minutes / Hour
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Hour of Day (0-23 hours)
Outside August (minus outliers)

Figure B12: Diurnal DPM / hour during September at each location





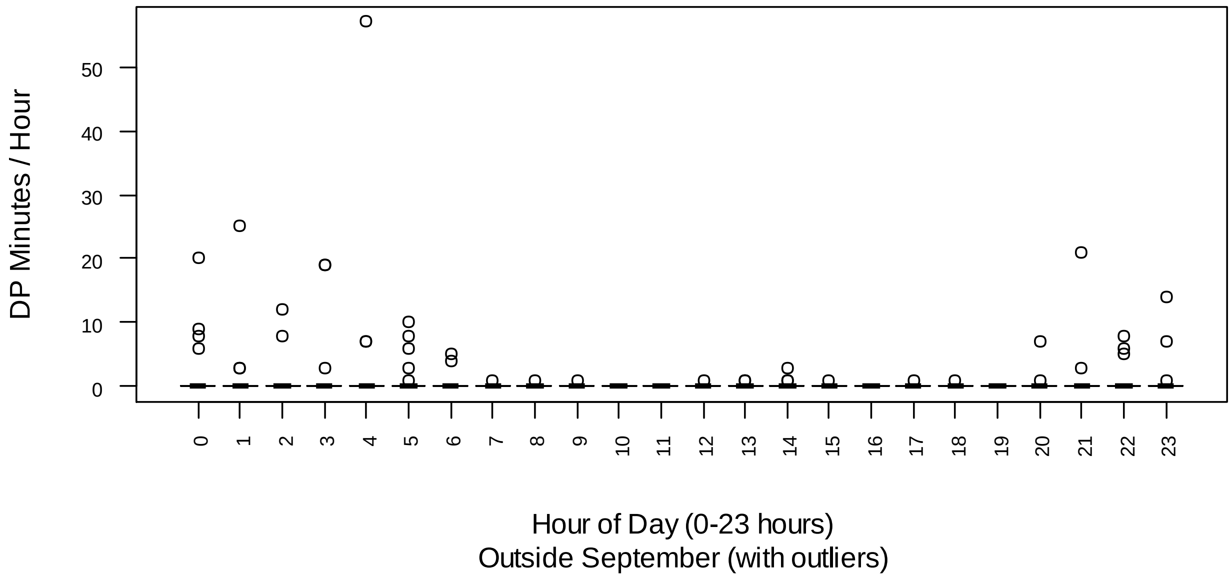
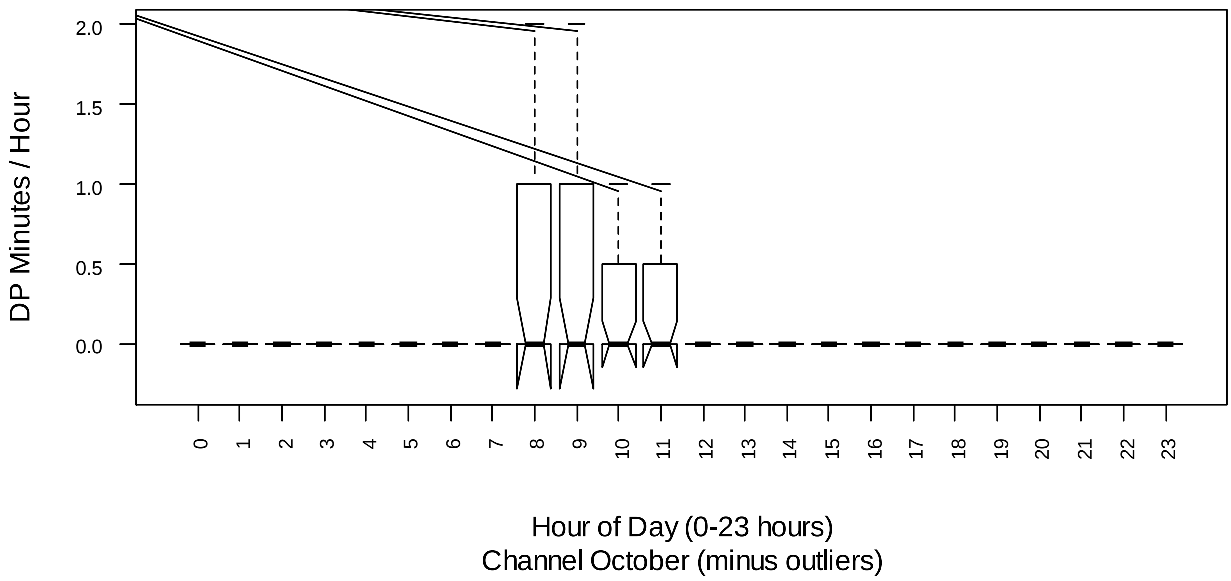
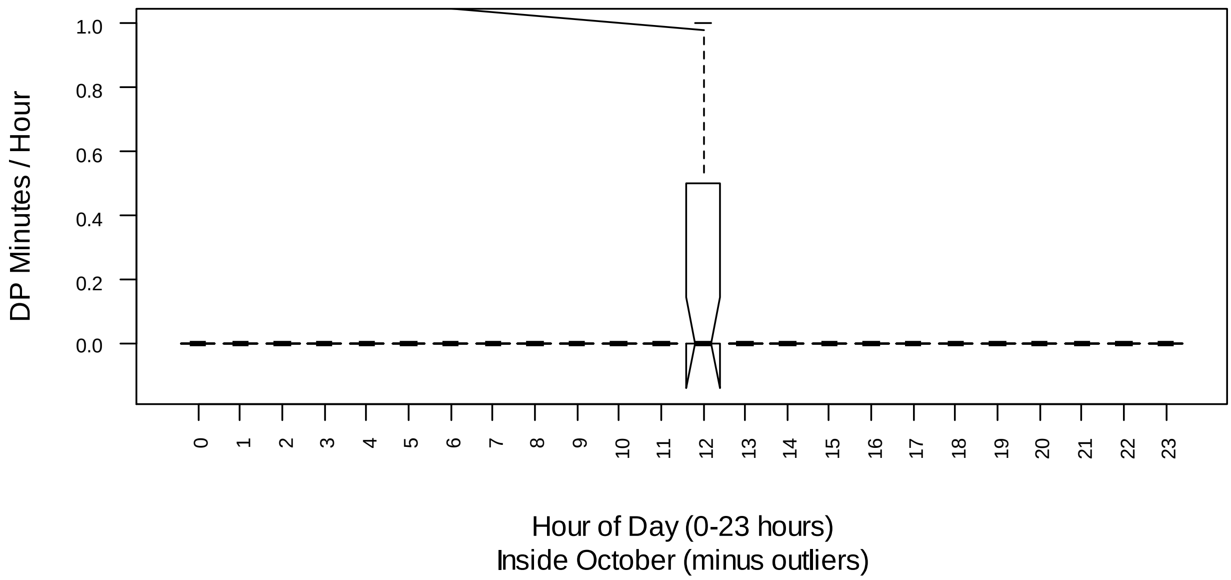
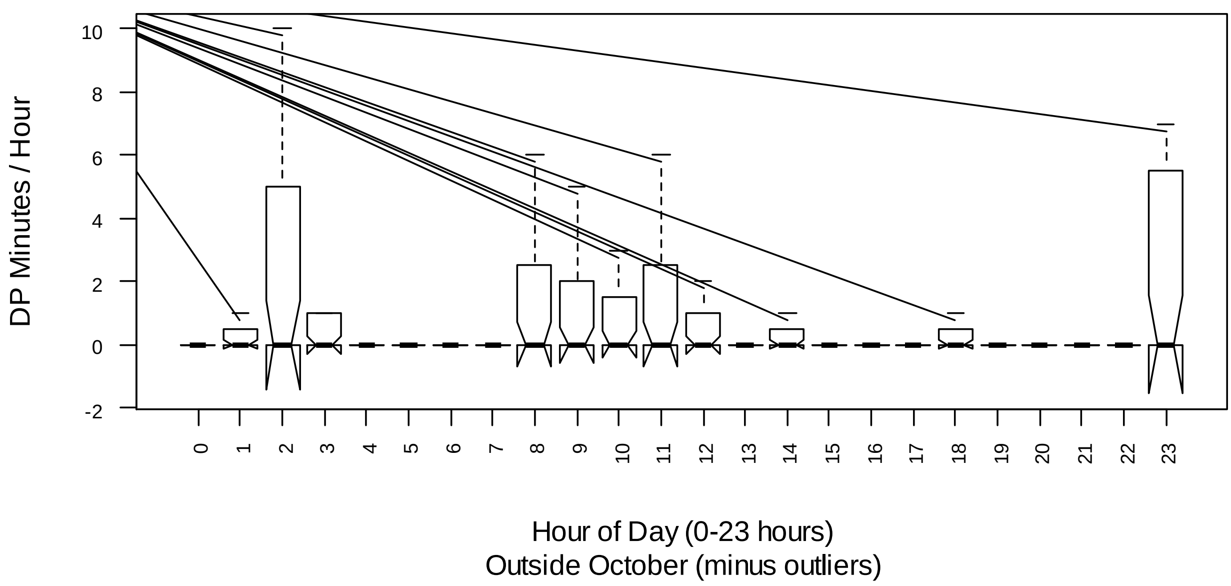
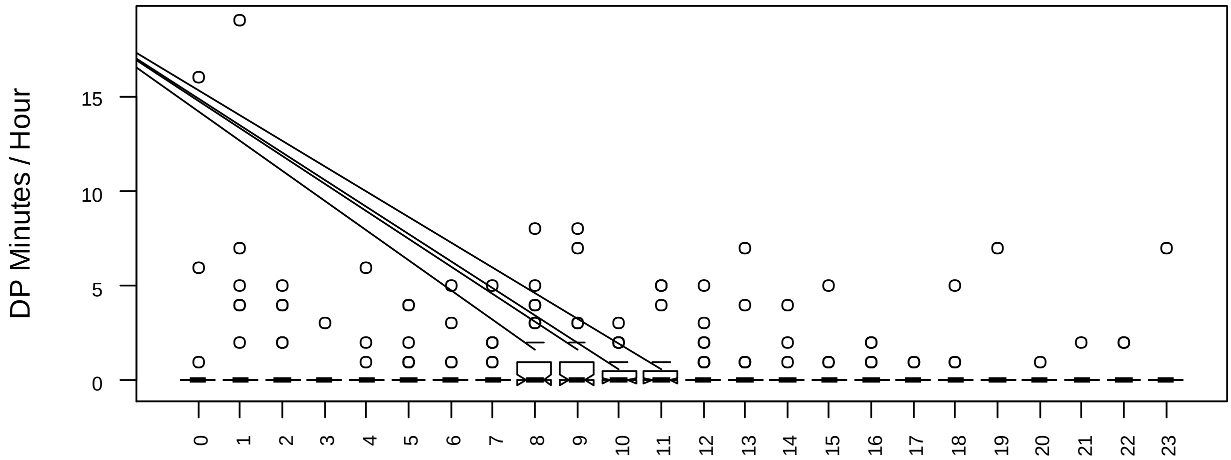


Figure B13: Diurnal DPM / hour during October at each location

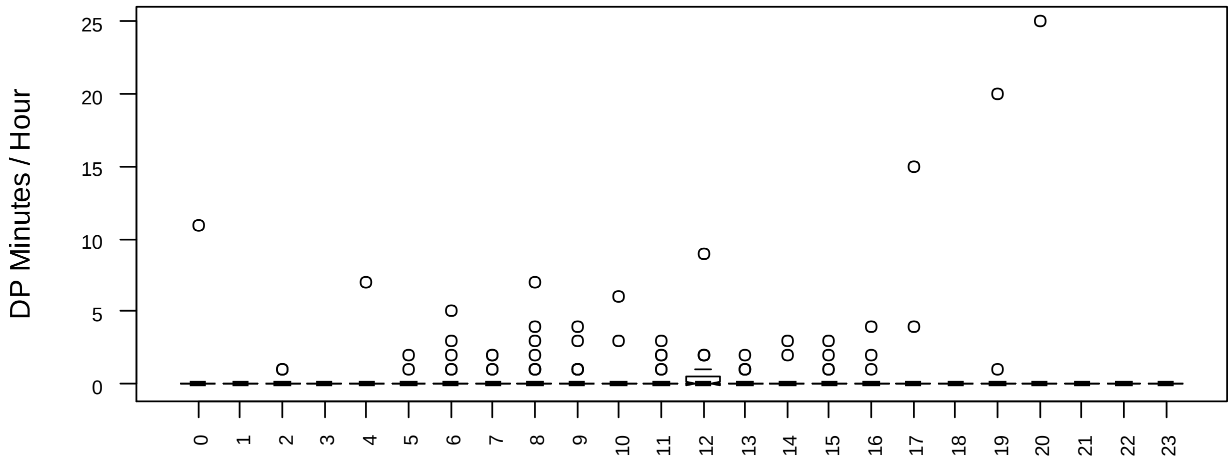




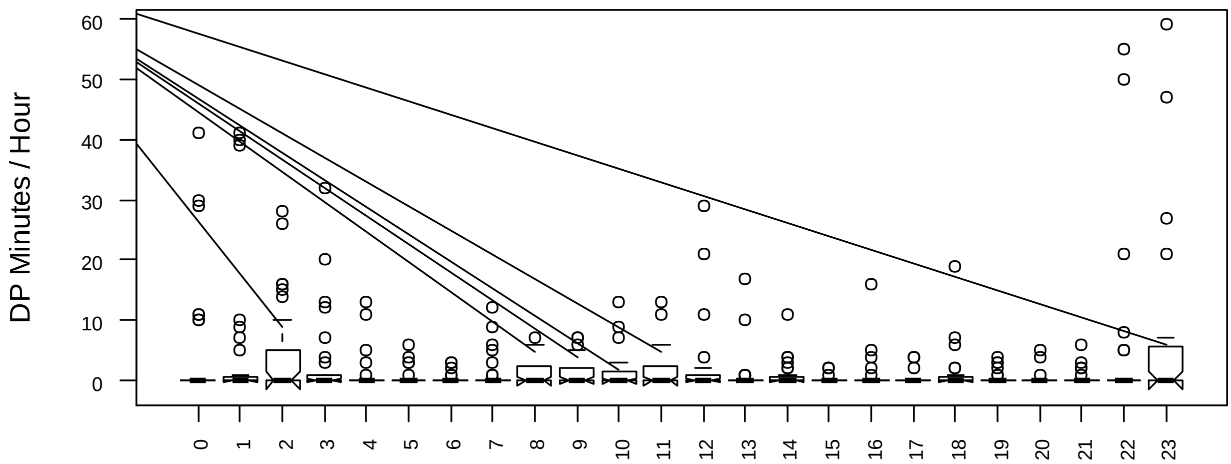




Hour of Day (0-23 hours)
Channel October (with outliers)

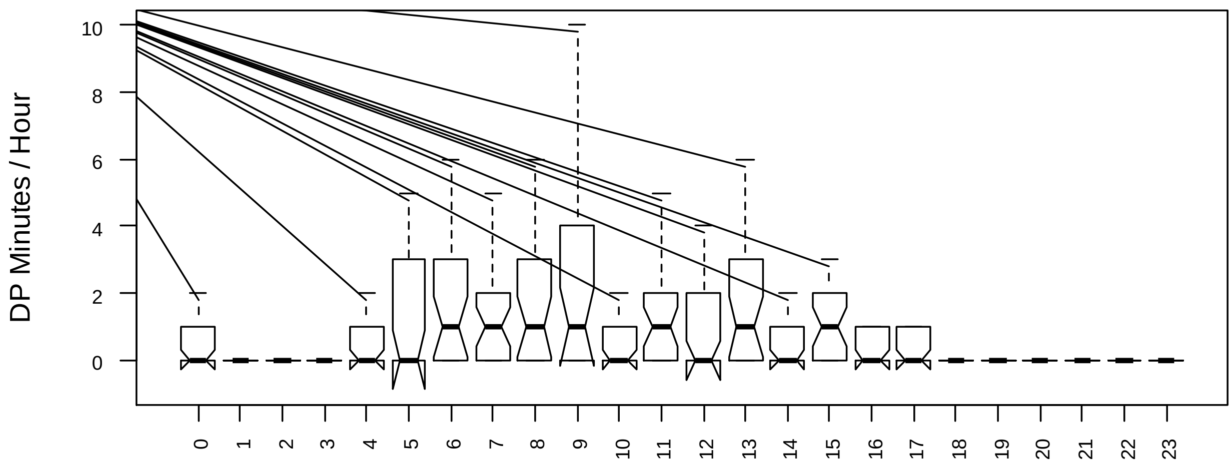


Hour of Day (0-23 hours)
Inside October (with outliers)

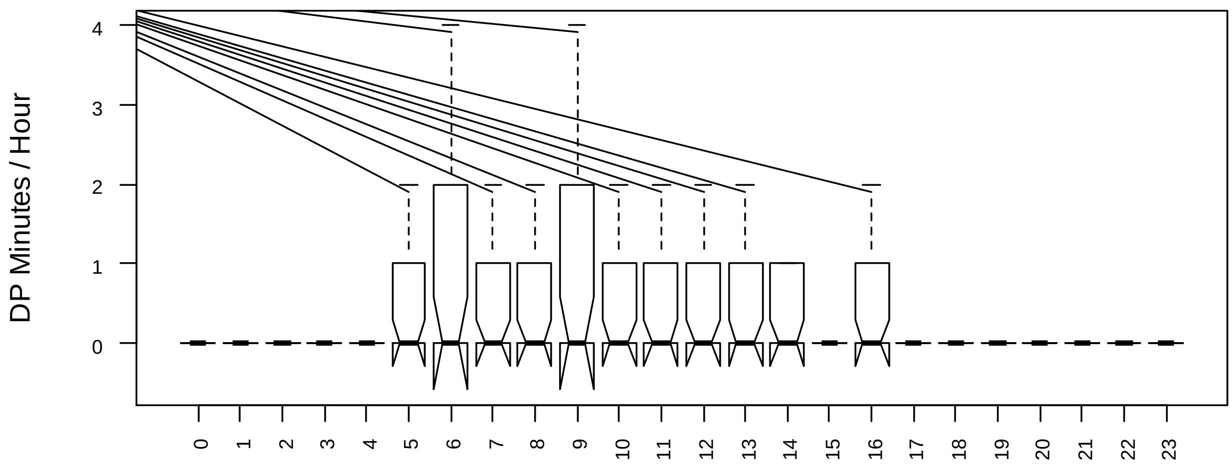


Hour of Day (0-23 hours)
Outside October (with outliers)

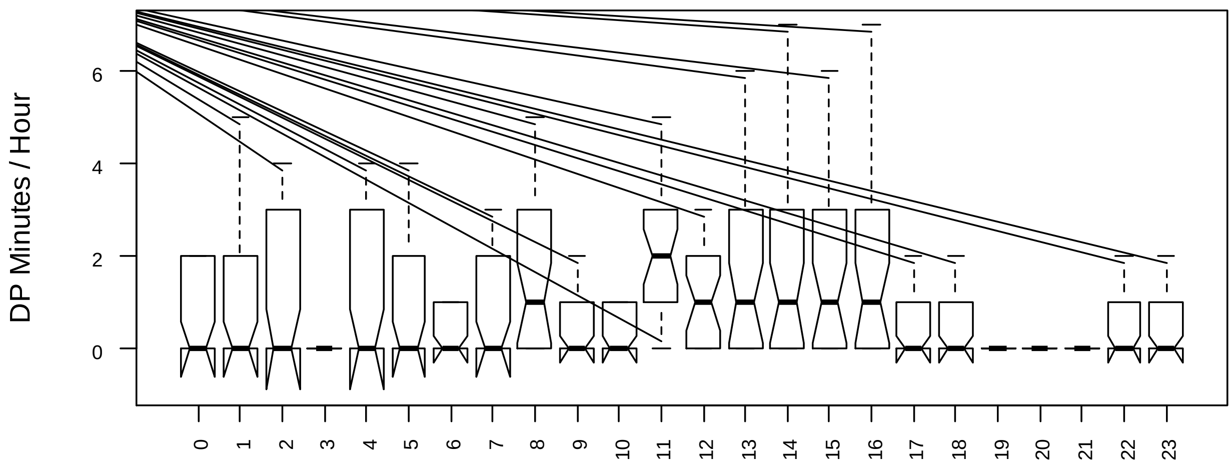
Figure B14: Diurnal DPM / hour during November at each location



Hour of Day (0-23 hours)
Channel November (minus outliers)

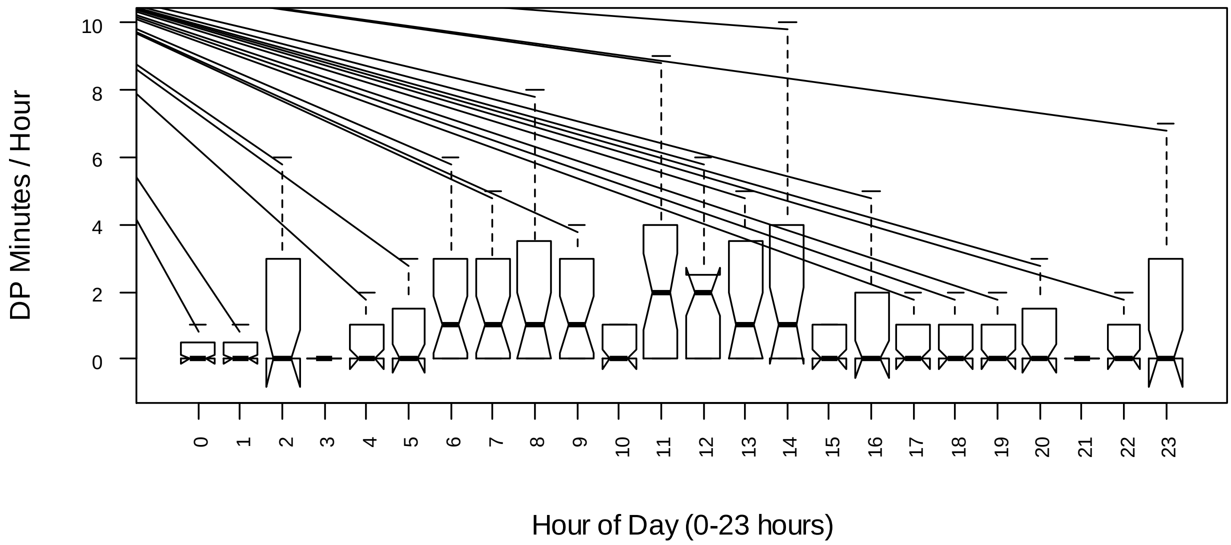


Hour of Day (0-23 hours)
Inside November (minus outliers)

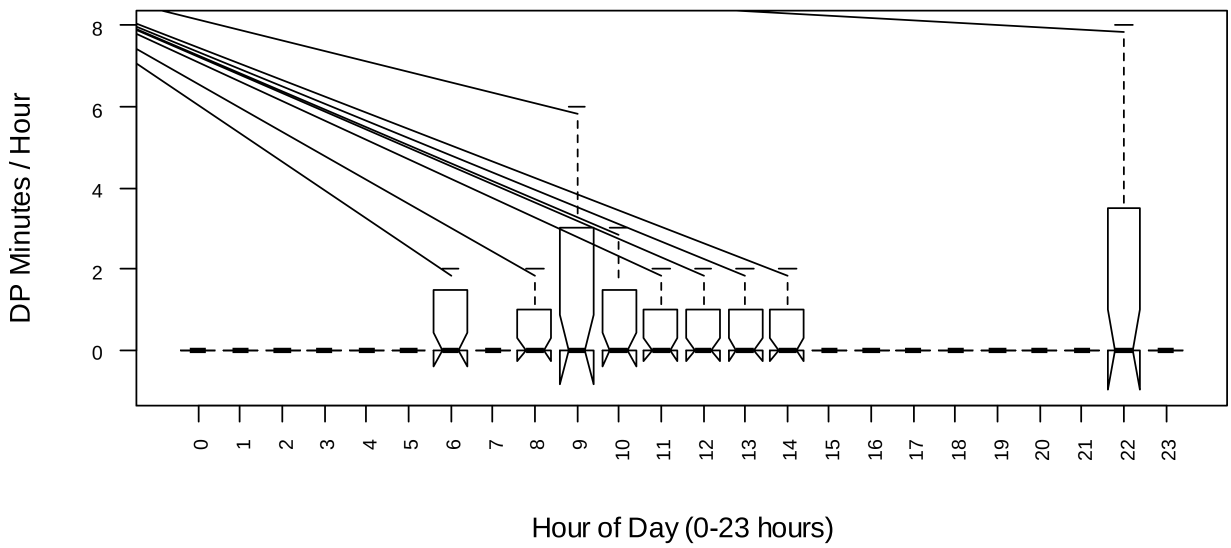


Hour of Day (0-23 hours)
Outside November (minus outliers)

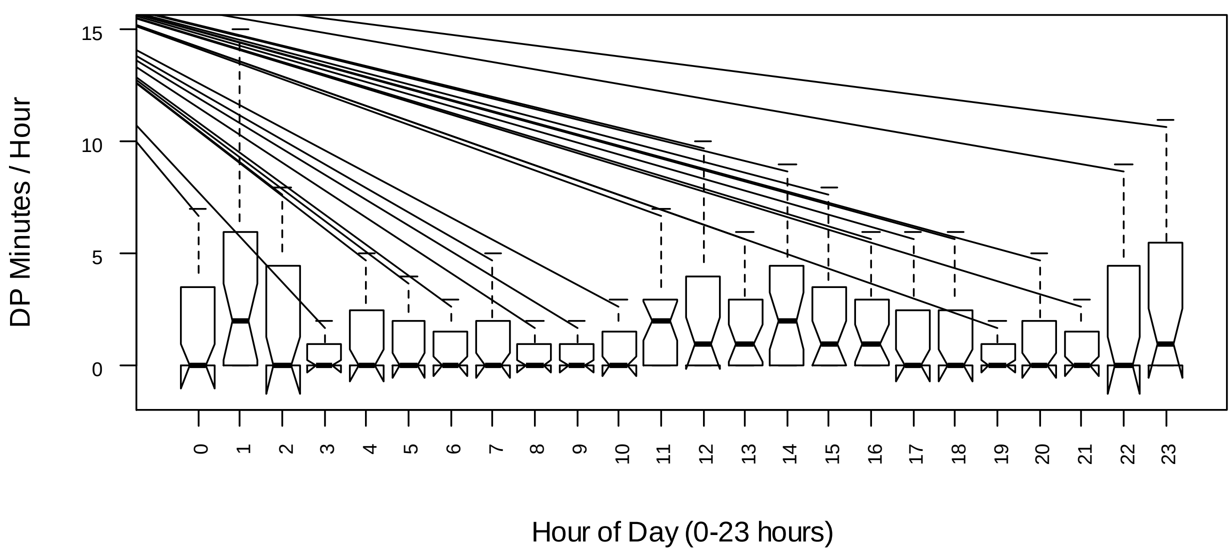
Figure B15: Diurnal DPM / hour during December at each location



Channel December (minus outliers)



Inside December (minus outliers)



Outside December (minus outliers)