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Imputation of missing count data of recreational boat retrievals from remote camera surveys in the Perth Metropolitan region, Western Australia

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Executive Summary

In Western Australia (WA), remote cameras have been used to monitor boating activity at boat ramps since 2006 to assist in ongoing recreational fishing surveys. These monitoring schemes are useful tools to validate boating activity (defined here as the number of retrievals) and to corroborate estimates of recreational fishing effort obtained from other surveys. This is because remote cameras (also referred to as digital cameras) can provide complete coverage (i.e. 24 hours, 365 days) of boating activities. However, although efforts are continually made to service and maintain these cameras, outages (i.e. interruptions in camera operations) have been encountered and continue to occur. To provide accurate estimates of boating activity, an imputation process is required to adequately account for these gaps in the remote camera data.

This report summarises the imputation procedure and estimates of boating activity for the following six Perth Metropolitan ramps: Mindarie, Ocean Reef, Hillarys, Leeuwin, Woodman Point and Point Peron. Although this imputation process has recently been published in the scientific literature for one of the ramps (Leeuwin), there is a need to extend the analysis to the above six ramps, providing a comprehensive summary of boating activity. The proportion of missing data ranged from 0.05% to 60.69% across the ramps and survey years of 2011-12, 2013-14 and 2015-16. The highest percentage of missing data was observed for Mindarie in 2015-16, with a percentage of approximately 61%. Previous imputation approaches used by DPIRD were unable to deal with longer term outages. Therefore, an updated imputation approach was required that would enable boating activity to be estimated for previous surveys and also to assist in future camera monitoring where outages will likely occur. In this report, outages in the digital camera data were imputed using models driven by information on precipitation, temperature, humidity, wind speed (average and maximum), wind direction, and sea level pressure, in addition to season, day type and time of day.

Estimates of the number of powerboat retrievals have been provided across various stratification levels (such as type of day, seasonal, monthly and annual) for the six Perth metropolitan ramps, after applying the proposed imputation process. In general, there were no systematic trends in recreational boat retrievals within seasons, months and day type across the survey years. However, an increase in the annual total number of boat retrievals was observed across all ramps from 2011-12 to 2015-16. At Mindarie, an estimated total (with 95% confidence interval for imputed periods) of 12790(±5) boat retrievals was observed in 2011-12 and 22685(±344) in 2015-16. In 2013-14, a long outage occurred at Mindarie (~ 9 months), so imputation was not carried out. At Ocean Reef, estimated totals of 12846(±12), 14590(±199) and 20907(±165) were observed for 2011-12, 2013-

14 and 2015-16, respectively. At Hillarys, estimated totals of 27439(±151), 27512(±287) and 30653(±290) were observed for 2011-12, 2013-14 and 2015-16, respectively. Leeuwin was the least busy of the studied ramps with estimated totals of 12293, 13670(±181) and 16236(±112) for 2011-12, 2013-14 and 2015-16, respectively. Boating activity levels at Woodman Point were similar to Hillarys, with estimated totals of 25709(±95), 26726(±310) and 30431(±277) for 2011-12, 2013-14 and 2015-16, respectively. At Point Peron, estimated totals of 12779(±85), 17003(±169) and 19039(±174) were observed for 2011-12, 2013-14 and 2015-16 respectively. On average, ~77% of boat retrievals were observed between 05:00 and 16:00 across all ramps. This time span coincides with the scheduling of boat ramp surveys in the biological and rock lobster surveys. The technique outlined in this report has the ability to impute missing data from long-term camera outages and will support on-going monitoring of trends in recreational boating and fishing activity in WA.

1 Introduction

1.1 Background

Aspects of recreational fisheries management require effective monitoring to ensure sustainability. Digital cameras can enable long-term cost-effective monitoring of recreational boating activity at boat ramps or choke points (eg. the entrance of a marina) compared to other survey methods (such as on-site access point surveys) (Smallwood *et al.*, 2013). As the cameras can provide day and night coverage of boating activity, they provide reliable daily, seasonal and annual trends in boating activity, part of which involves fishing. The analysis of recreational boating activity data can also overcome some of the sampling challenges encountered from other survey methods in monitoring fishing effort (Steffe *et al.*, 2017; Hartill, 2015; Lancaster *et al*., 2016). For example, the analysis of 24-hour data on powerboat retrievals at a boat ramp can be used to extend the coverage of onsite recreational fishing surveys that are typically restricted to daylight hours (Steffe *et al.*, 2017; Taylor *et al.*, 2018; Ryan *et al*., 2017). However, sporadic interruptions of camera operations can result in the occurrence of significant gaps in the data. Camera outages occur as a result of technical faults, vandalism, theft, weather conditions such as temperature and humidity, lightning strikes, and flooding and environmental factors (Blight and Smallwood, 2015; Hartill *et al*., 2019), leading to the failure to provide complete data.

Dealing with missing data has been a subject of interest for researchers in many fields. This is because missing data require proper handling to ensure precision and reliability of estimates and indices. Missing data can cause serious defects such as biased estimates, irreproducibility and potential loss of statistical power. In WA, digital cameras have been used for monitoring boat- and shore-based recreational fishing activities since 2006, where information on the number of boat launches and retrievals at various boat ramps and choke points are collected. These data play key roles in validating and corroborating the results of other recreational fishing surveys (Steffe *et al*., 2017; Ryan *et al*., 2017) and enable other agencies and stakeholders to have reliable information on ramp usage across Western Australia. However, there is a need to deal with outages within the data. The previous imputation scheme used by the Western Australian Department of Primary Industries and Regional Development (DPIRD) is the mean substitution (Ryan *et al*., 2017) where missing observations are filled in by the average of the observed data. The technique possibly leads to underestimation of the standard errors and was not suitable for imputing longer-term gaps in the data. Therefore, the need to build imputation schemes are required which are especially tailored to the pattern and nature of missingness and the distributional characteristics of remote camera data.

1.2 Imputation and digital camera monitoring data

Elsewhere, imputation schemes have been applied in studies involving missing data on recreational boating and fishing effort monitored using digital cameras. van Poorten *et al*. (2015) developed a hierarchical Bayesian model to predict total angling effort in British Columbia, Canada (with the model accounting for three typical issues with camera effort) using a multiple imputation scheme. Missing camera effort data were imputed from the average effort from lakes in close proximity. In Hartill *et al*. (2016), a high degree of correlation between the number of trailer boats returning at three ramps in New Zealand informed the imputation of missing values for the one ramp where outages occurred, using observed counts of the other two ramps, which were in close proximity. The number of days with outages represented 7% of the entire survey days. In Hartill's study, generalized linear models (GLMs) were used in the imputation modelling scheme. Generally, GLMs fail to obtain estimates which reflect possible groupings in a given response variable, and perform relatively poorly in capturing the clustering effects within the boating activity data, especially for finer-scale datasets (Faraway, 2010). In both studies, nearby ramps and viewpoints were used as reference points; however, in instances where outages are persistent among ramps, the suitability of these imputation approaches may be compromised. Both studies recommended incorporating the effects of covariates such as environmental, climatic, oceanographic and other predeterminants of boating activity in the development of imputation scheme for data from digital camera monitoring.

1.3 Some influential factors of boating activities

Environmental conditions, including climatic variables, can predetermine human behaviour to some degree. For instance, wind strength and direction are linked to safe launching and retrieving of boats and fishing activity. Additionally, environmental conditions can inform both recreational and commercial fishers to maximize their catch (Soykan *et al*., 2014). Therefore, to an extent, it should be possible to characterize recreational boating and fishing effort (as a predetermined human behaviour) as a function of these environmental conditions (Kendall *et al*., 2021). Kendall *et al*., (2021) identified winds, waves, warm waters, and weekdays as influential predictors for recreational boating in the continental shelf of the Atlantic Ocean off the coast of Georgia, US. Soykan et al. (2014) found temperature, rainfall, tides, winds (direction, speed and gust), and sea surface variables to be significant predictors of fishing effort. Desfosses and Beckley (2015) reported day type (weekday or weekend), school holidays, time of day, wind direction and wind speed to significantly influence boat launching activities in Broome, Australia. Environmental and social factors affect the temporal variability of recreational boating activity and can play key roles

in building data imputation models, survey design and sampling schemes (Maynou and Sardà, 2001; Soykan *et al*., 2014; Steffe *et al.*, 2017). Therefore, there is a need to study several possible variables of influence, such as climatic, oceanographic, and social conditions, to capture the complex relationship structure of boating effort.

1.4 Objective

The objective was to develop a suitable imputation technique which draws inference on the support of climatic, oceanographic and some time-related stratification to "fill in" missing observations in data on recreational boat retrievals obtained via digital camera monitoring at six Perth Metropolitan ramps. The modelling challenges sought to be addressed included the formulation of imputation models with the ability to 1) capture the grouping effect of key temporal variables such as "season" on the number of powerboat retrievals; 2) allow for the explicit modelling of the variance-covariance structures, typical for correlated data which characterise the counts of boat retrievals; 3) sufficiently address any issues relating to over- and under- dispersion of the count data; and 4) account for any zero inflation in the data. The outcome of the imputation scheme is that complete summary statistics are presented for each of these ramps to provide researchers, managers and stakeholders with reliable information of ramp usage.

1.5 Structure of the report

The report is structured as follows; section 1 presents the background and the objective; section 2 presents the detailed methodology used in the treatment of missing observations in covariates and the remote camera data, section 3 presents the imputation results with associated summaries (i.e. monthly, seasonal, annual) for the six ramps, and section 4 provides the conclusions and recommendations for future research.

2 Methodology

2.1 General data description

The data for this project were obtained from DPIRD and the Bureau of Meteorology, Western Australia (WA). Data comprised counts of boat retrieval activities for three separate 12-month periods. These periods corresponded with state-wide surveys of boat-based fishing conducted from 01 March 2011 - 29 February 2012, 01 May 2013 - 30 April 2014 and 01 September 2015 - 31 August 2016 for the Perth Metropolitan area (see Figure 1). In the data processing stage, the data were aggregated to an hourly resolution. A zero value was recorded if there was no activity otherwise the number of boat parties returning to the ramp (eg. Hillarys) or leaving through specific choke point (eg. Ocean Reef) were recorded for the hour while NA was recorded if an outage was encountered for the hour. There were several instances of camera outages of varying duration (see Figure 19 in Appendix 1). Instances of missingness within an hour duration were aggregated. The data on observed activities and missingness were merged at "1 minute" resolution to enable the aggregation to the hour resolution. For a given hour, if there are observed activities and camera outages, the hour is considered incomplete and all data must be determined; therefore, the counts of the partially observed activities were censored. This decision was made because the imputation models built were supported by hourly blocks of covariates. In these hourly blocks, proportionate periods of outages in the camera data could not be determined for the covariates. Therefore, we chose to censor the data for the partially observed periods, and to subsequently use them to adjust the imputed values. For example, for a partially observed hour, if the imputed value is less than the partially observed count, the estimate was replaced by the partially available count. Table 1 shows the count and percentage of partially observed data that were censored. A more detailed description of the type of data collected and the procedure for reading the camera data is provided in Blight and Smallwood (2015).

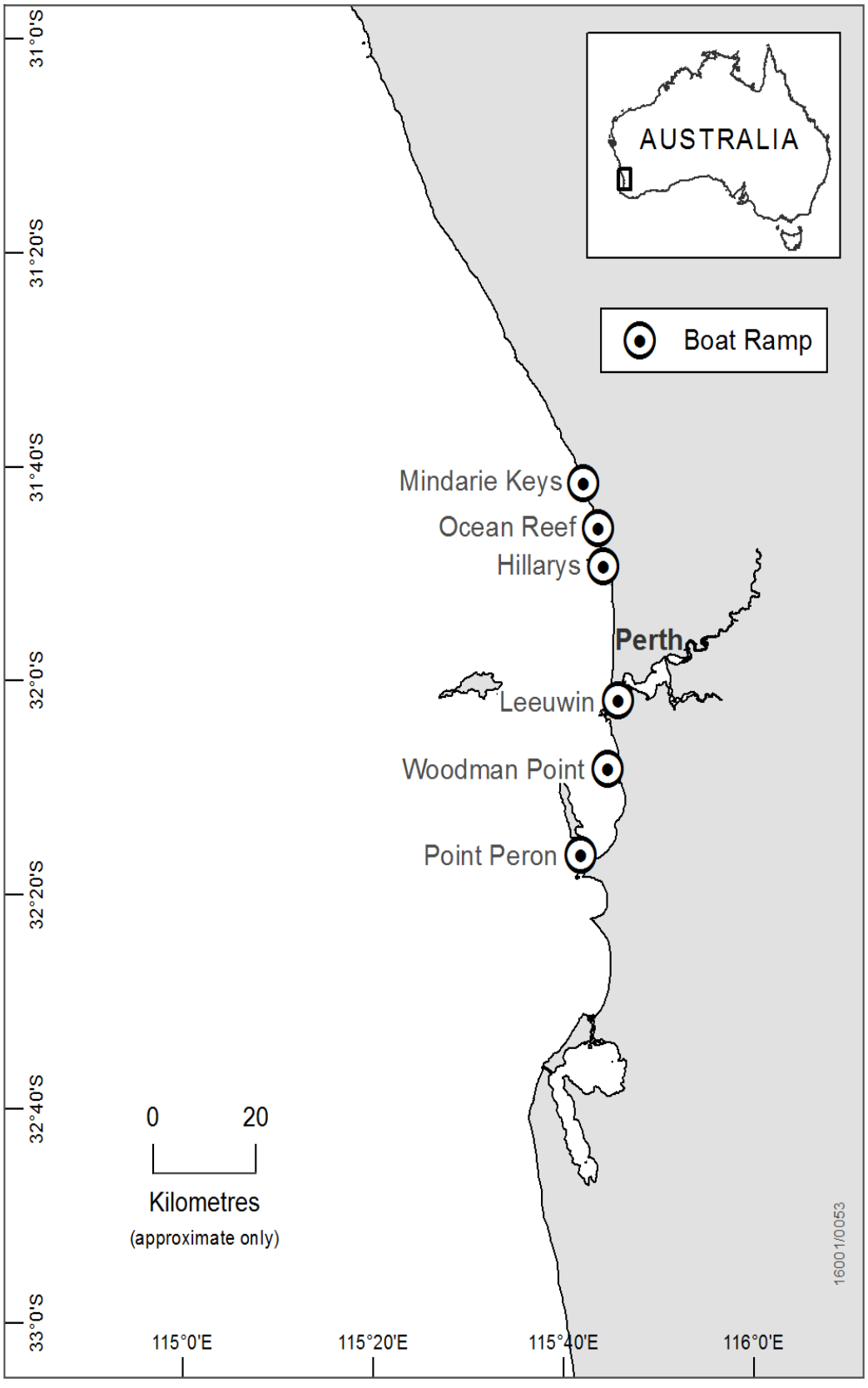

Figure 1: Study area showing the locations of the network of cameras for monitoring boating activity at boat ramps in the Perth Metropolitan region.

Table 1: The number and percentage of missing data and censored observations and the total powerboat retrievals recorded during censored periods.

Period	Ramp	Number of hours with an outage (% of all footage)	Number of hours missing partially (% of all outages)	Total censored retrievals
2011-12	Mindarie	26 (0.30%)	7 (26.92%)	0
	Ocean Reef	4 (0.05%)	4 (100%)	3
	Hillarys	818 (9.31%)	33 (4.03%)	42
	Leeuwin	–	–	–
	Woodman Point (Public)	296 (3.37%)	–	–
	Point Peron	567 (6.45%)	12 (2.12%)	3
2013-14	Mindarie[1]	NA	NA	NA
	Ocean Reef	2306 (26.32%)	20 (0.87%)	40
	Hillarys	2701 (30.83%)	8 (0.30%)	21
	Leeuwin	3217 (36.70%)	27 (0.84%)	13
	Woodman Point (Public)	1461 (16.68%)	33 (2.26%)	85
	Point Peron	528 (6.03%)	23 (4.36%)	8
2015-16	Mindarie	5331 (60.69%)	31 (0.58%)	52
	Ocean Reef	2176 (24.77%)	108 (4.96%)	260
	Hillarys	2106 (23.98%)	315 (14.96%)	139
	Leeuwin	1312 (14.94%)	–	–
	Woodman Point (Public)	2264 (25.77%)	56 (2.47%)	137
	Point Peron	514 (5.85%)	157 (30.54%)	536

The Bureau of Meteorology WA provided data on the following climatic and oceanographic conditions: precipitation, air temperature, humidity, wind speed, wind direction, speed of maximum wind gust and sea level pressure. The data were provided at hourly resolution, with the average hourly value provided for all variables except wind gust (maximum) (Table 2). Missing observations in the climate data were imputed using the methods described in Afrifa-Yamoah *et al.*, (2020a). Boating activities may be influenced by some temporal variables. Desfosses and Beckley (2015) identified the type of day, season and time of the day as significant determinants of the temporal variability in boating activities. For instance, more activities may be recorded on weekend and holidays than on working weekdays. To establish the effect of the day type on boating activities, the variable was included in the dataset. The variable was categorized as weekday

[1] Imputation was not carried out for Mindarie in 2013-2014 as there were insufficient data. Data were continuously missing for 9 months.

(Monday - Friday) and weekend/Public holidays (referring to Saturdays, Sundays and statutory holidays). Temperate Western Australia has four seasons, namely, summer, autumn, winter and spring. The effects of these seasons on boating activities are apparent (Desfosses and Beckley, 2015), and will be significant in assessing the covariance structure of the data. The possible autocorrelation of boating activities in the data can be addressed by studying the effect of the seasons. The varying effect of time of day on retrieval activities was also investigated using six temporal categories (Table 2).

Table 2: Study variables and their attributes

Variable	**Description**
Retrievals	hourly aggregated counts of powerboat retrievals.
Precipitation (Prec)	average hourly amount of rainfall (mm)
Temperature (Temp)	average hourly air temperature (℃)
Humidity (Hum)	average hourly levels of humidity (%)
Wind speed (WinS)	average hourly wind speed ($km.h^{-1}$)
Wind direction (Wsin and Wcos)	average hourly wind direction (true degrees trigonometrically transformed).
Wind gust (WinG)	maximum wind speed ($km.h^{-1}$)
Sea level pressure (SLP)	average sea level pressure (hPa)
Day type	weekday or weekend/public holiday
Season	summer (December – February) autumn (March – May) winter (June – August) spring (September – November).
Time of day	dawn (0100-0459) early morning (0500-0759) morning (0800-1159) afternoon (1200-1559) late afternoon (1600-1859) evening (1900-0059)

2.2 Imputation modelling

This section presents a brief description of the imputation scheme used for "filling-in" the missing data in the camera datasets (see Appendix 2). A detailed description of the method can be found in Afrifa-Yamoah *et al.*, (2019, 2020b). Data were assumed to be missing at random and the data generating process followed a generalized linear mixed model (GLMM). The zero-inflated Poisson (ZIP) model was found to be the most appropriate based on analysis conducted on the the Leeuwin boat ramp (Afrifa-Yamoah *et al.*, 2020b). The ZIP model was therefore applied to the digital camera data examined in this study. Some putative covariates may be seen as superfluous due to multicollinearity, however, the focus of imputation is not to use a parsimonious model but a "saturated" model. This is because there is no information about a missing value and thus one cannot determine "parsimony". Therefore, model selection is not of importance here. In addition, this study did not consider interactions among predictors. The technique did not impute missing observations with the direct estimates from the formulated model for the periods with missing values, but used the estimate as a guide to sample from the observed data with similar prediction scores. Thus, the unmeasured effect of interactions will minimally affect the imputation process. The decision to make the imputation models more dependent on the observed data was grounded in the assumption that data were missing at random, with the premise that some information about the missingness in the data could be inferred from the observed data under the guidance of some covariates. The fully-conditional specification multiple imputation scheme was used to carry out the imputation (see Afrifa-Yamoah *et al.*, 2020b). Even if there are only weak significant relationships between the covariates and the outcome variable, combining them effectively in an appropriate model setup can reveal useful patterns in the outcome variable.

The models were implemented in R (version 3.4.3, R Core Team 2016) using the packages *pscl* (version 1.5.2, Jackson, 2008; Zeileis, Kleiber and Jackson, 2008) and *glmmADMB* (version 0.8.2, Fournier *et al.*, 2012; Skaug *et al.*, 2015). The imputation schemes were carried out using the *mice* (version 2.14, van Buuren and Groothius-Oudshoorn, 2011) and *countimp* (version 1.0, Kleinke and Reinecke, 2013).

2.3 Uncertainty

The estimation of an unknown value is best reported in an interval and thus imputation estimates are subject to uncertainty. A 95% confidence interval (CI) is used to express the level of uncertainty for the total estimates imputed at various stratification levels. The standard error for the pooled estimate is also available to measure the level of variation within the multiple imputation.

3 Results

3.1 Overview

This section presents the summary of the imputations and associated uncertainties. For each ramp, annual and monthly expanded estimates of powerboat retrievals, with 95% confidence intervals are presented. Results for other stratification levels such as season, time of day and type of day are presented in Appendix 3. Diagrams depicting the outage patterns observed across the ramps for the survey periods are presented in Appendix 1.

3.2 Annual powerboat retrievals estimates

An increase in annual estimates of powerboat retrievals was observed for the three survey years in all the boat ramps (Figure 2), except for Mindarie. Due to the extended period of missing data at Mindarie in 2013-14 (nine continuous months of data missing), an annual estimate was not generated for this ramp as data from months in the same season could not be used to inform the imputation. The rate of increase was not uniform between the survey years. Typically, there was a higher percentage increase for the less busy ramps compared to the high intensity traffic ramps. For instance, between 2011-12 and 2015-16, there was an approximately 32% increase in recreational boat retrievals at the Leeuwin ramp, compared to approximately 12% at Hillarys for the same period of time. The percentage increase was highest for the Ocean Reef ramp between the years with an annual average of approximately 7%, followed by Point Peron with similar growth in activity. The 2013-2014 estimates compared to 2011-2012 estimates saw percentage increases of between 0.3% and 33% whereas the 2015-2016 estimates compared to 2013-14 estimates saw percentage increases of between 11% and 44% across the six boat ramps (see Tables 3-14). On average, approximately 77% of retrievals were observed between the hours of 05:00 and 16:00 across the region. This duration coincides with the times for boat ramp surveys in the biological and rock lobster surveys. Night-time recreational retrieval activity predominantly occurred at Leeuwin, where on average 61% of retrivals occurred between 05:00 and 16:00 across the study period. Leeuwin was the least busy ramp, with Woodman Point and Hillarys displaying similarities in boating traffic intensities and counts especially in the 2015-16 survey year, as the busiest ramps in the Perth Metropolitan Area. Both ramps recorded expanded estimates of over 30,000 powerboat retrievals in 2015-16. In 2015-16, Woodman Point observed the highest annual estimate of recreational boating activity, surpassing Hillarys which observed the highest annual estimates in both 2011-12 and 2013-14.

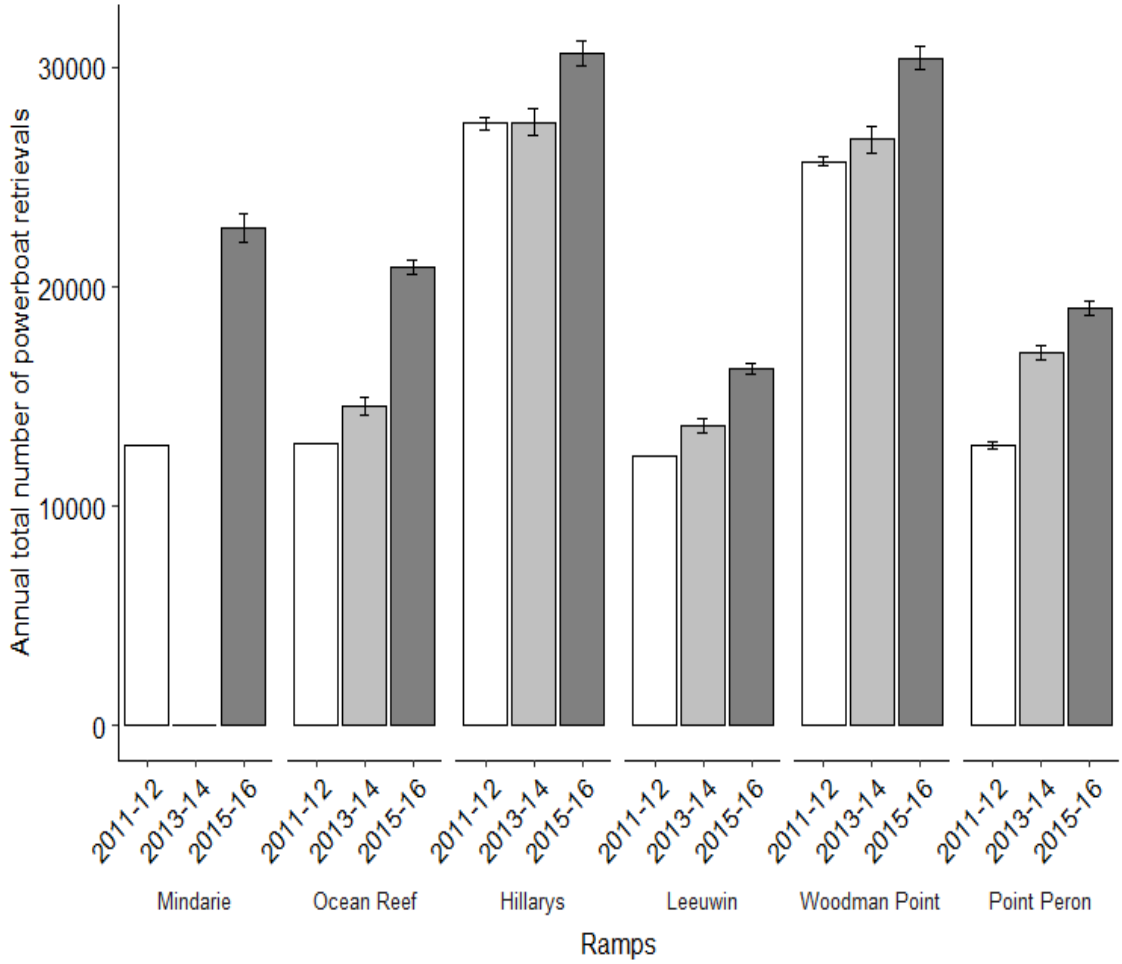

Figure 2: Comparison of estimates of total powerboat retrievals obtained from digital camera monitoring conducted as part of the state-wide survey of boat based fishing in the Perth Metropolitan area between 2011 and 2016. Error bars are the 95% confidence intervals of the annual total imputed estimates. All surveys were 12-months in duration with different start months.

3.3 Monthly estimates and distributions for the boat ramps

3.3.1 Mindarie

An annual estimate of 12790 powerboat retrievals was observed in 2011-12 survey year, with 0.16% of the estimate obtained via imputation (see Table 3). In terms of seasonal contributions, summer was the busiest period of retrieval activities accounting for 44.17% of the total estimate, followed by autumn (27.81%), spring (15.52%) and winter (12.50%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly activities were recorded in December, January and April, respectively (see Table 4). Of the total estimate obtained, 50.60% of activity was observed on weekdays with 49.40% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 83% of retrievals occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, there was a persistent outage for 9 months, in effect, imputation was not carried out. For the observed period, a total count of 5415 powerboat retrievals was observed.

In 2015-16, out of the 8784 hours of footage, 60.69% hours were missing due to camera outages. A complete outage was observed for the months of April, July and September (see Table 14 in Appendix 3). Therefore, estimates provided for those months are fully imputed and should be interpreted with caution. With the exception of the September estimate, estimates compared reasonably well to the estimates for the same periods in 2011-12 (see Table 4 and Figure 3). The September estimate for 2015-16 was 4-times higher than the estimate for the same period in the 2011-12 survey year, which may over-represent the anticipated increase in recreational boating activity. An annual total of 22685 powerboat retrievals was estimated, with 61.19% of the estimate obtained via imputation (see Table 3). Compared to the 2011-12 annual estimate, there was a 77.37% rise in recreational powerboat retrieval activities. Summer was the busiest season, contributing to 44.17% of the annual estimate, with autumn, spring, and winter accounting for 27.81%, 15.52% and 12.50% respectively. In terms of the busiest months, the top three were December, November and January, respectively (see Table 4). Activities on weekdays contributed 62.91% of the annual estimate (see Table 17 in Appendix 3). Approximately 86% of retrieval activities occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

Figure 3 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 4 presents a distibutional comparison of boating activities across month and survey years.

Table 3: Attributes, descriptive statistics and distributional characteristics of observed and imputed estimates of powerboat retrievals from the Mindarie digital camera.

Year	Remark	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	26 (0.30)	5504 (62.8)	1.5 (3.2)	3.90	24.48	12770
	Imputation	-	12 (46.2)	0.8 (0.9)	0.84	2.86	20±5
	Combined	-	5516 (62.8)	1.5 (3.2)	3.90	24.51	12790±5
2013-2014[2]	Observed	6670 (75.16)	7496 (85.9)	0.62 (2.6)	7.82	84.12	5415
	Imputation						
	Combined						
2015-2016	Observed	5331(60.69)	1933 (56.0)	2.5 (5.2)	3.12	14.00	8805
	Imputation	-	1602 (30.1)	2.6 (2.9)	1.20	3.73	13880±344
	Combined	-	3535 (40.2)	2.6 (4.0)	3.05	16.93	22685±344

Table 4: Monthly estimates of the number of powerboat retrievals (with the 95% confidence bounds) for Mindarie Boat ramp.

Year	Month	Total est. (±95% CI)	Year	Month	Total est. (±95% CI)
2011-2012	March ‘11	1190	2015-2016	March ‘16	1511±96
	April ‘11	1360±8		April ‘16	1311±113
	May ‘11	1007±2		May ‘16	1097±93
	June ‘11	417		June ‘16	696±45
	July ‘11	589		July ‘16	803±79
	Aug ‘11	593		Aug ‘16	604±47
	Sept ‘11	571±6		Sept ‘15	2572±154
	Oct ‘11	597		Oct ‘15	2024±103
	Nov ‘11	817		Nov ‘15	3025±91
	Dec ‘11	2974		Dec ‘15	3768±73
	Jan ‘12	1664		Jan ‘16	2714±144
	Feb’12	1011		Feb ‘16	2560±129

[2] Imputation was not carried out for Mindarie in 2013-2014 as there were insufficient data. Data were continuously missing for 9 months.

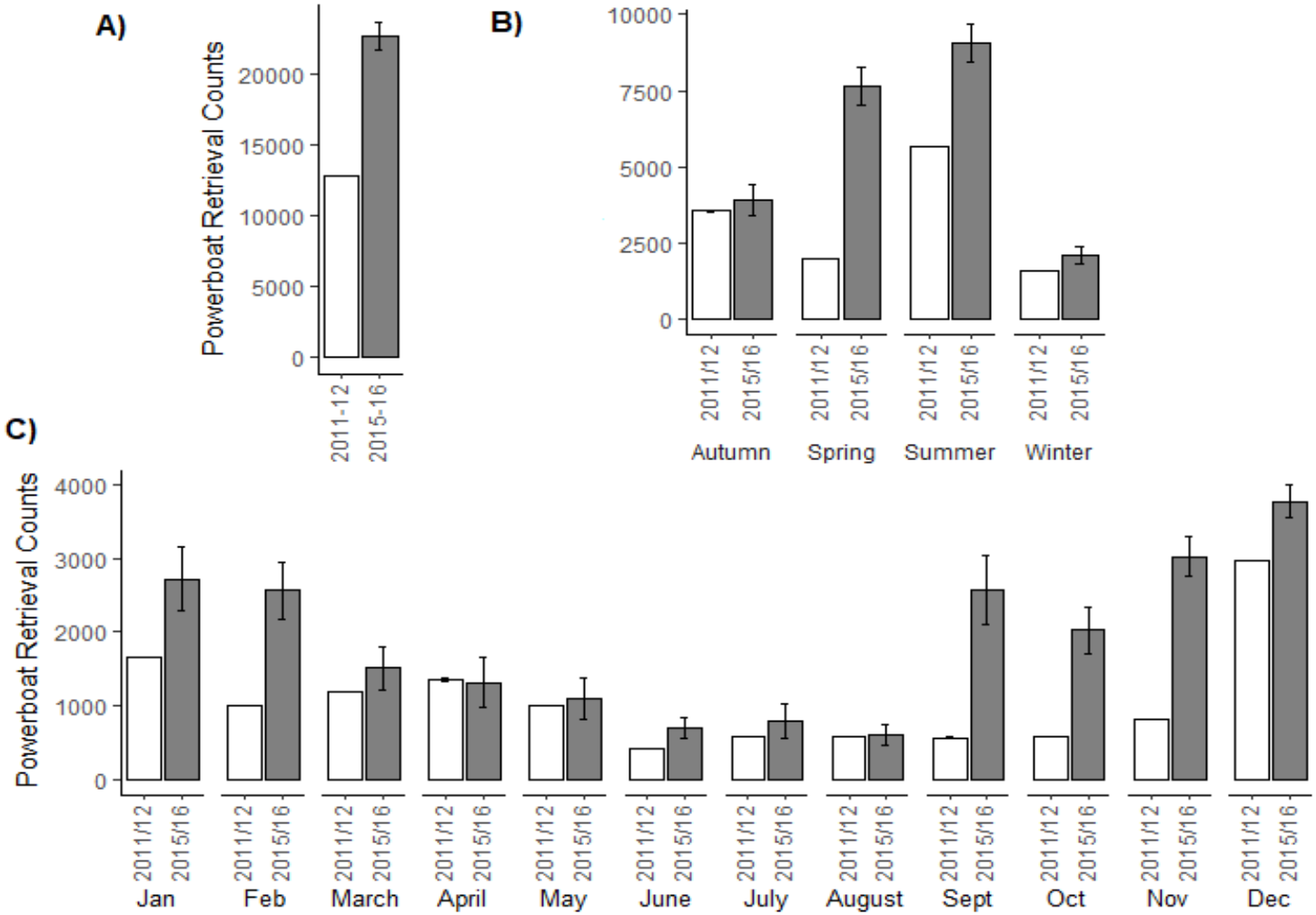

Figure 3: A) Total powerboat retrievals from Mindarie (Lat 31.692, Long 115.702) during 2011-12 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12 and 2015-16. C) Distribution of total powerboat retrievals by months across 2011-12 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

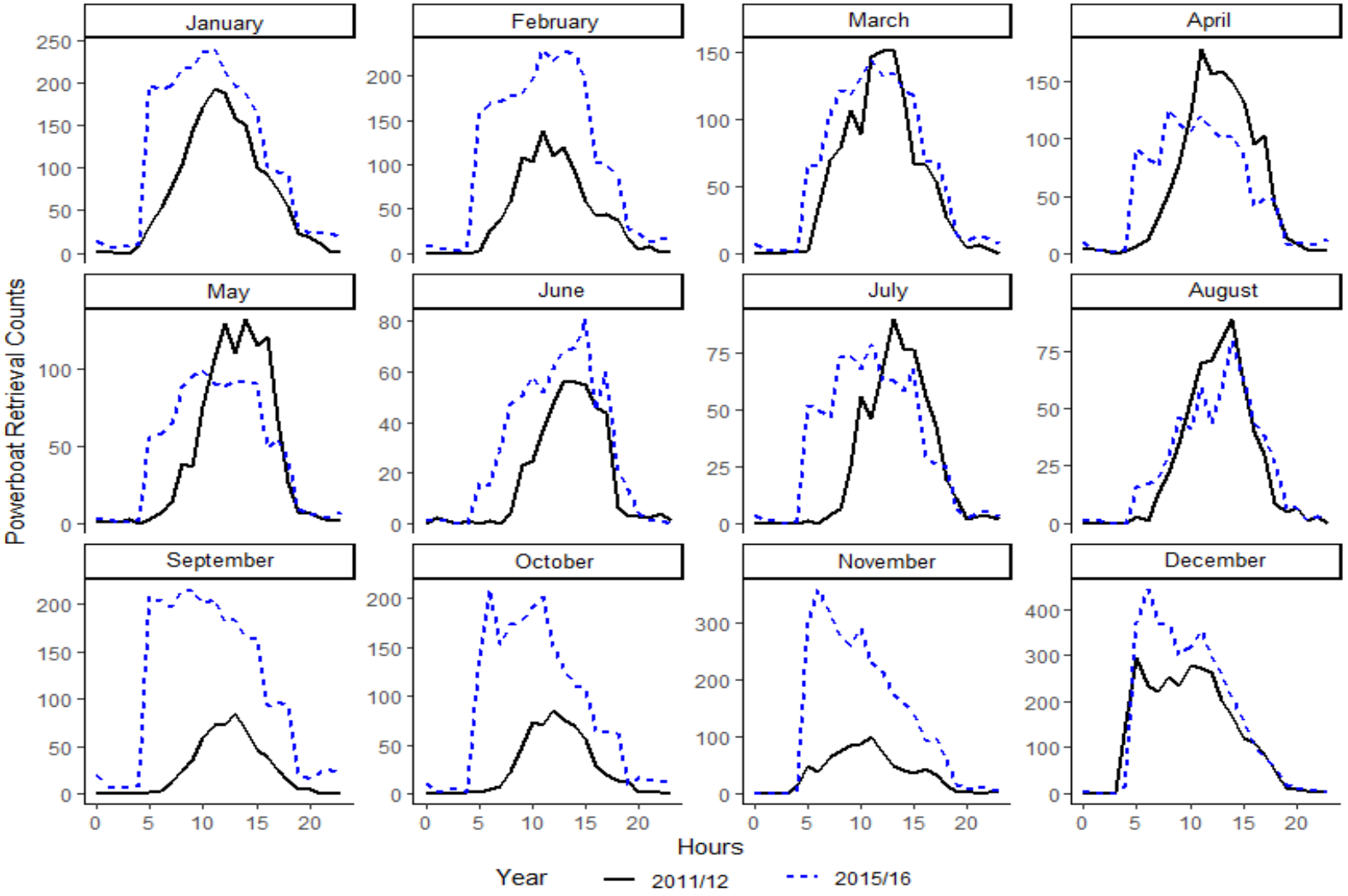

Figure 4: Hourly powerboat retrievals by month from Mindarie (Lat 31.692, Long 115.702) during 2011-12 and 2015-16.

3.3.2 Ocean Reef Boat ramp

An annual estimate of 12846 powerboat retrievals was observed in the 2011-12 survey year, with 0.12% of the estimate obtained via imputation for the 0.05% missing hours of the year (see Table 5). In terms of seasonal contributions, summer was the busiest period of retrieval activities accounting for 47.68% of the total estimate, followed by autumn (25.88%), spring (15.37%) and winter (11.07%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly activities were recorded in December, January and March respectively (see Table 6). Of the total estimate obtained, 43.40% was observed on weekdays with 56.60% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 83% of retrievals were observed between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, 26.32% of hours of camera footage were missing due to outages. The months of June, July and December were the most affected (see Table 14 in Appendix 3). An annual total of 14590 powerboat retrievals was estimated, with 30.57% of the estimate obtained via imputation (see Table 5). Compared to the 2011-12 annual estimate, there was a 13.58% rise in recreational powerboat retrieval activities. Summer was the busiest season, accounting for 38.66% of the annual estimate, followed by autumn (28.07%), spring (18.26%) and winter (15.01%) (see Table 16 in Appendix 3). December, January and February were the months of peak recreational boating activities (see Table 6). Weekdays accounted for 50.32% of the annual estimate, with the remaining 49.68% observed on weekends (including public holidays). Approximately 82% of retrievals occurred between the hours of 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2015-16, 24.77% of the hours of footage were missing. These outages mostly occurred in the months of March, April and July. An estimated annual total of 20907 recreational boating retrievals was obtained, of which 15.81% was determined via imputation. Compared to the 2011-12 and 2013-14 estimates, there was a 62.75% and 43.30% rise in recreational powerboat retrievals, respectively (see Table 5). Summer was the busiest season, contributing 44.37% of the annual estimate, with spring, autumn and winter accounting for 30.87%, 16.87% and 7.89% respectively. December, November and January were the months of peak recreational boating activities. Activities on weekdays contributed 58.43% of the annual estimate (see Table 17 in Appendix 3). Approximately 86% of retrieval activities occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

Figure 5 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 6 presents a distibutional comparison of boating activities across month and survey years. Notably, the density of distribution for November (and to some extent December) in 2015-16 is significantly higher and different to those for 2011-12 and 2013-14, with a shift of the peak retrievals observed around 6am (possibly due to the recreational rock lobster fishery).

Table 5: Attributes, descriptive statistics and distributional characteristics of observed and imputed estimates of powerboat retrievals from the Ocean Reef digital camera.

Year	Remark	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	4 (0.05)	5909 (67.3)	1.5 (4.0)	6.01	62.37	12831
	Imputation	-	2 (50.0)	3.8 (4.5)	0.21	1.28	15±12
	Combined	-	5911 (67.3)	1.5 (4.0)	6.01	62.32	12846±12
2013-2014	Observed	2306 (26.32)	4211 (65.2)	1.6 (4.2)	5.76	51.78	10130
	Imputation	-	766 (33.2)	1.9 (2.3)	1.89	7.98	4460±199
	Combined	-	4977 (56.8)	1.7 (3.8)	5.79	56.63	14590±199
2015-2016	Observed	2176 (24.77)	3903 (59.1)	2.7 (6.7)	5.33	42.90	17601
	Imputation	-	841 (38.6)	1.5 (1.7)	1.31	5.26	3306±165
	Combined	-	4744 (54.0)	2.4 (5.9)	6.03	55.09	20907±165

Table 6: Monthly estimate of the number of powerboat retrievals (with the 95% confidence bounds) for Ocean Reef Boat ramp

Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)
2011-2012	Mar ‘11	1245	2013-2014	Mar ‘14	1406±44	2015-2016	Mar ‘16	1440±95
	Apr ‘11	1151		Apr ‘14	1485		Apr ‘16	1215±108
	May ‘11	929		May ‘13	1205±90		May ‘16	873±16
	Jun ‘11	429		Jun ‘13	904±87		Jun ‘16	551±5
	Jul ‘11	472		Jul ‘13	614±68		Jul ‘16	676±63
	Aug ‘11	521		Aug ‘13	672		Aug ‘16	422±45
	Sep ‘11	503		Sep ‘13	316±10		Sep ‘15	846
	Oct ‘11	662		Oct ‘13	855		Oct ‘15	1681±10
	Nov ‘11	809		Nov ‘13	1493		Nov ‘15	3926±33
	Dec ‘11	2971		Dec ‘13	2314±136		Dec ‘15	4714±43
	Jan ‘12	1999±17		Jan ‘14	1823±33		Jan ‘16	2491±33
	Feb ‘12	1155		Feb ‘14	1503		Feb ‘16	2072

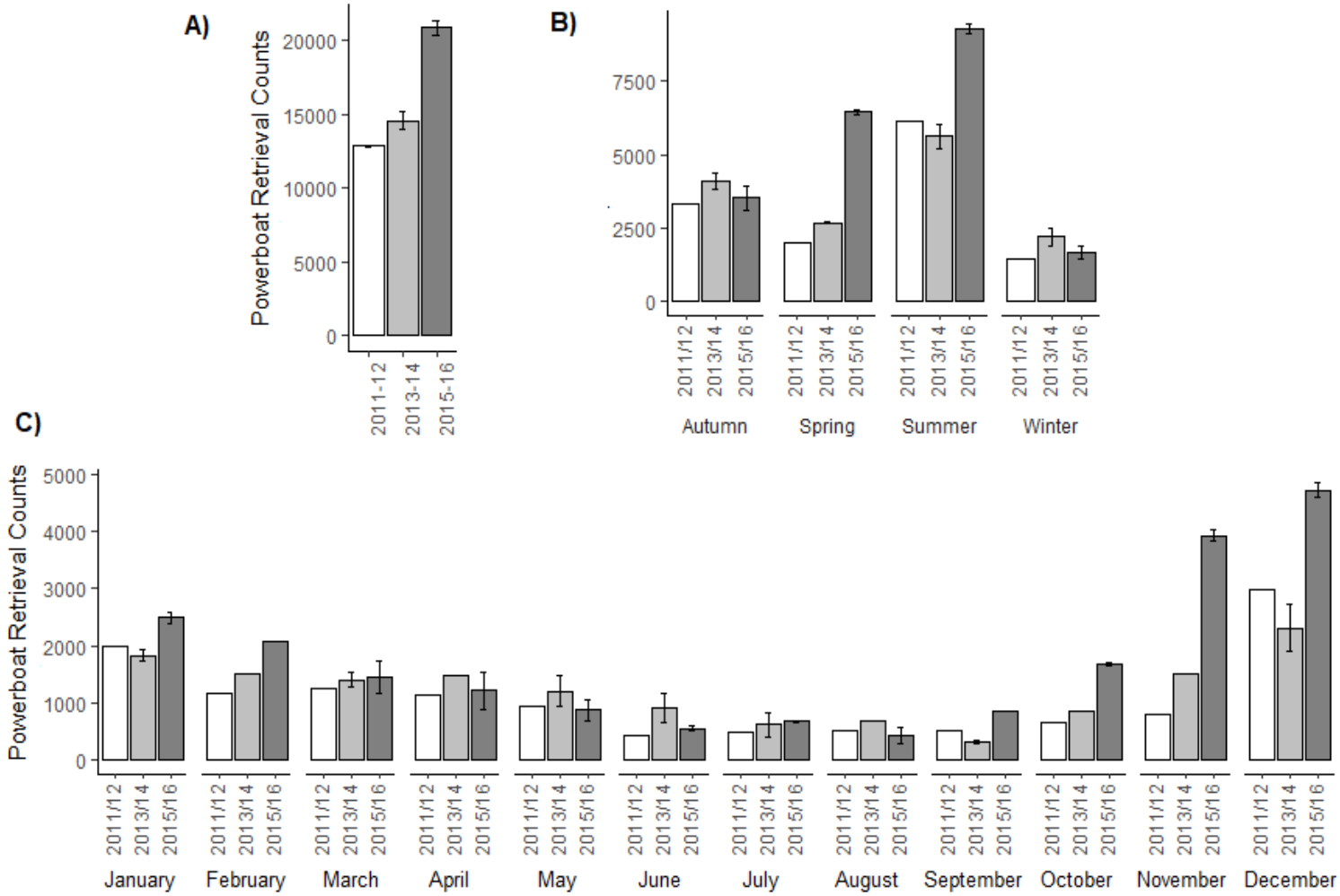

Figure 5: A) Total powerboat retrievals from Ocean Reef (Lat 31.762, Long 115.728) during 2011-12, 2013-14 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12, 2013-14 and 2015-16. C) Distribution of total powerboat retrievals by months across 2011-12, 2013-14 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

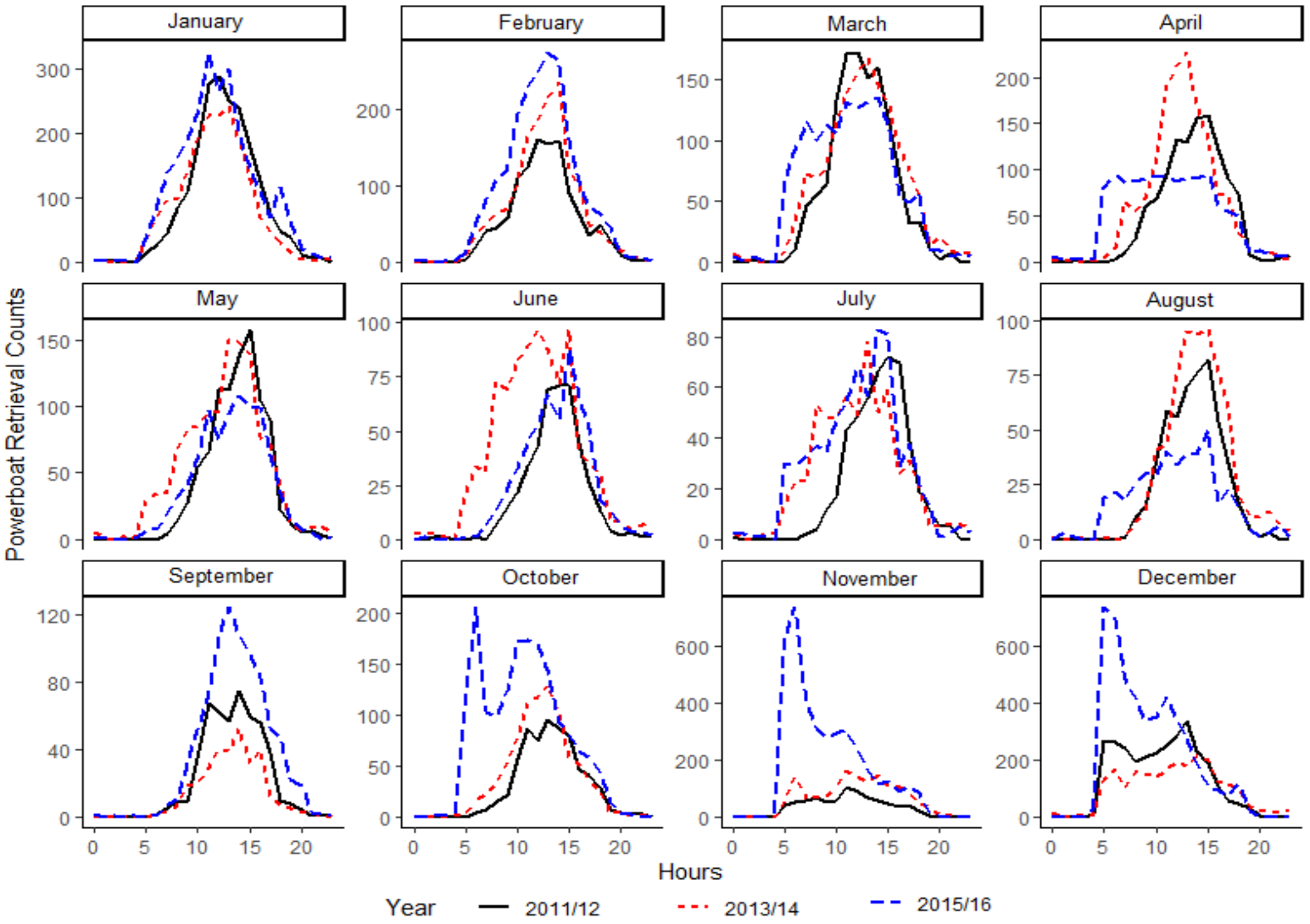

Figure 6: Hourly powerboat retrievals by month from Ocean Reef (Lat 31.762, Long 115.728) during 2011-12, 2013-14 and 2015-16.

3.3.3 Hillarys Boat ramp

An annual estimate of 27439 powerboat retrievals was observed in the 2011-12 survey year, with 8.58% of the estimate obtained via imputation for the 9.31% missing hours of the year (see Table 7). April and June were the months with most outages. In terms of seasonal contributions, summer was the busiest period of retrieval activities accounting for 40.45% of the total estimate, followed by autumn (26.60%), spring (16.86%) and winter (16.09%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly activities were recorded in December, January and March, respectively (see Table 8). Of the total estimate obtained, 49.26% was observed on weekdays with 50.74% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 79% of retrievals were observed between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, 30.83% of hours of camera footage were missing due to outages. The months of January, September and October were the most affected (see Table 14 in Appendix 3). An annual total of 27512 powerboat retrievals was estimated, with 34.58% of the estimate obtained via imputation (see Table 6). Compared to the 2011-12 annual estimate, there was a 0.27% rise in recreational powerboat retrievals. Summer was the busiest season, accounting for 35.97% of the annual estimate, followed by spring (25.65%), autumn (23.78%) and winter (14.60%) (see Table 16 in Appendix 3). December, January and October were the months of peak recreational boating activities (see Table 7). Weekdays accounted for 56.94% of the annual estimate, with the remaining 43.06% observed on weekends (including public holidays). Approximately 76% of retrievals occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2015-16, 23.98% of the hours of footage were missing. These outages mostly occurred in the months of March, April and May. An estimated annual total of 30653 powerboat retrievals was obtained, of which 23.63% was determined via imputation. Compared to the 2011-12 and 2013-14 estimates, there was a 11.71% and 11.42% rise in recreational powerboat retrievals, respectively (see Table 7). Summer was the busiest season, contributing 38.91% of the annual estimate, with spring, autumn and winter accounting for 27.71%, 23.17% and 10.21% respectively. December, November, and January were the months of peak recreational boating activities. Activities on weekdays contributed 58.60% of the annual estimate (see Table 17 in Appendix 3). Approximately 80% of retrieval activities occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

Figure 7 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 8

presents a distibutional comparison of boating activities across month and survey years. Similar to Ocean Reef, the density of distribution for November (and to some extent December) 2015-16 is significantly higher and different to those for 2011-12 and 2013-14, with a shift of the peak retrievals observed around 6am (possibly because of the recreational rock lobster fishery).

Table 7: Attributes, descriptive statistics and distributional characteristics of annual observed and imputed estimates of powerboat retrievals from the Hillarys digital camera.

Year	Remark	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	818 (9.31)	4060 (51.0)	3.1 (6.5)	4.03	25.53	25084
	Imputation	-	206 (25.2)	2.9 (3.1)	1.35	4.48	2355±151
	Combined	-	4266 (48.6)	3.1 (6.2)	4.10	26.93	27439±151
2013-2014	Observed	2701 (30.83)	3045 (50.3)	3.0 (5.7)	3.50	21.69	17997
	Imputation	-	556 (20.6)	3.5 (3.4)	1.02	3.52	9515±287
	Combined	-	3601 (41.1)	3.1 (5.1)	3.38	22.91	27512±287
2015-2016	Observed	2106 (23.98)	3381 (50.6)	3.5 (7.4)	3.85	22.34	23446
	Imputation	-	628 (29.8)	3.4 (3.8)	1.63	8.84	7244±290
	Combined	-	4009 (45.6)	3.5 (6.7)	3.98	25.19	30653±290

Table 8: Monthly estimate of the number of powerboat retrievals (with the 95% confidence bounds) for Hillarys Boat ramp

Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)
2011-2012	Mar ‘11	2660±23	2013-2014	Mar ‘14	2385	2015-2016	Mar ‘16	2561±184
	Apr ‘11	2516±85		Apr ‘14	2603±20		Apr ‘16	2589±125
	May ‘11	2124±22		May ‘13	1555		May ‘16	1953±141
	Jun ‘11	1724±122		Jun ‘13	1789		Jun ‘16	1017±1
	Jul ‘11	1317		Jul ‘13	953		Jul ‘16	1154±3
	Aug ‘11	1375		Aug ‘13	1274±55		Aug ‘16	958±13
	Sep ‘11	1242±2		Sep ‘13	2081±130		Sep ‘15	1623±37
	Oct ‘11	1587		Oct ‘13	2661±150		Oct ‘15	2330±4
	Nov ‘11	1796±3		Nov ‘13	2315±86		Nov ‘15	4541±6
	Dec ‘11	5130		Dec ‘13	4346±75		Dec ‘15	5457±115
	Jan ‘12	3546		Jan ‘14	3112±167		Jan ‘16	3539±10
	Feb ‘12	2422		Feb ‘14	2438		Feb ‘16	2931±87

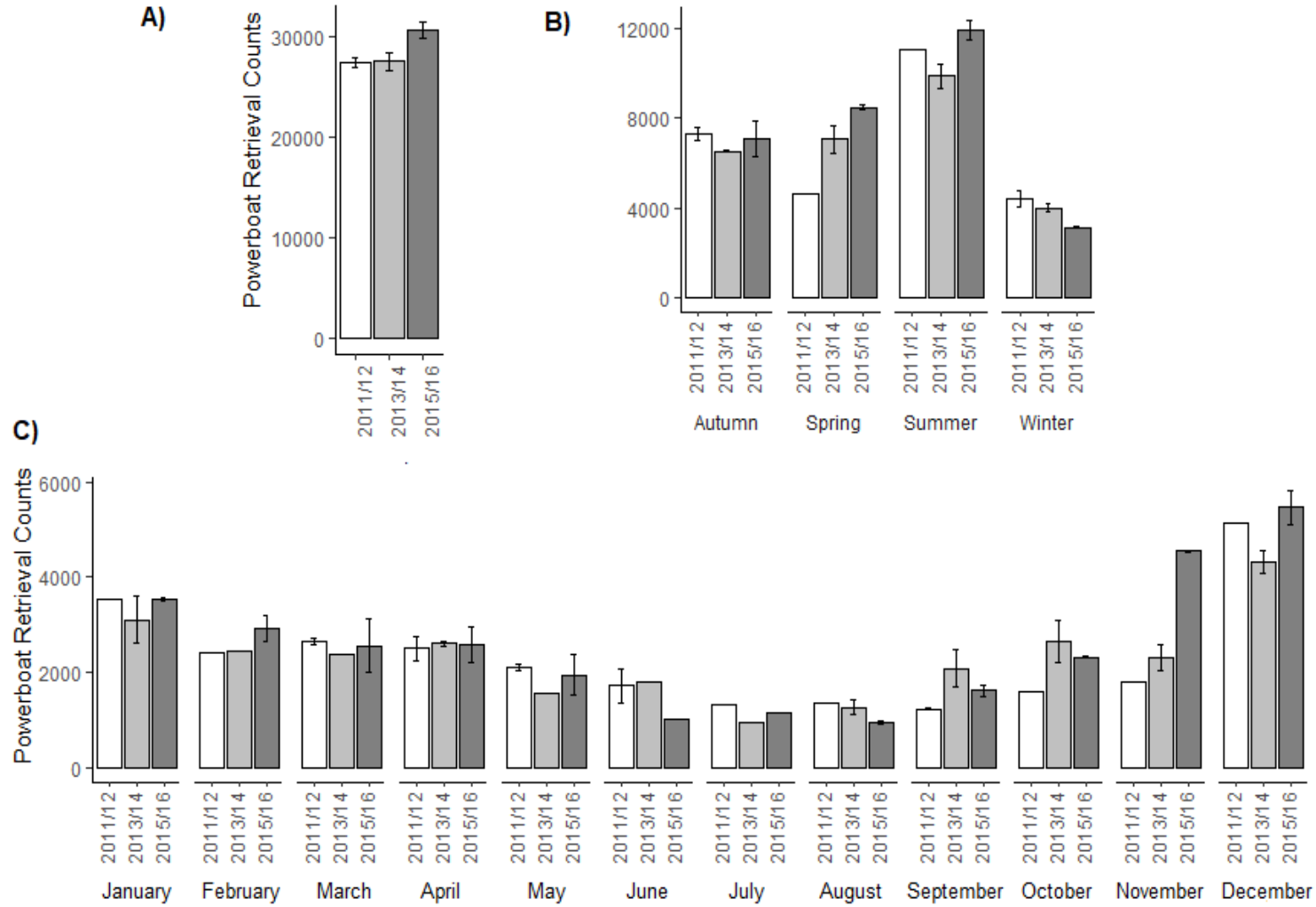

Figure 7: A) Total powerboat retrievals from Hillarys (Lat 31.822, Long 115.739) during 2011-12, 2013-14 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12, 2013-14 and 2015-16. C) Distribution of total powerboat retrievals by months across 2011-12, 2013-14 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

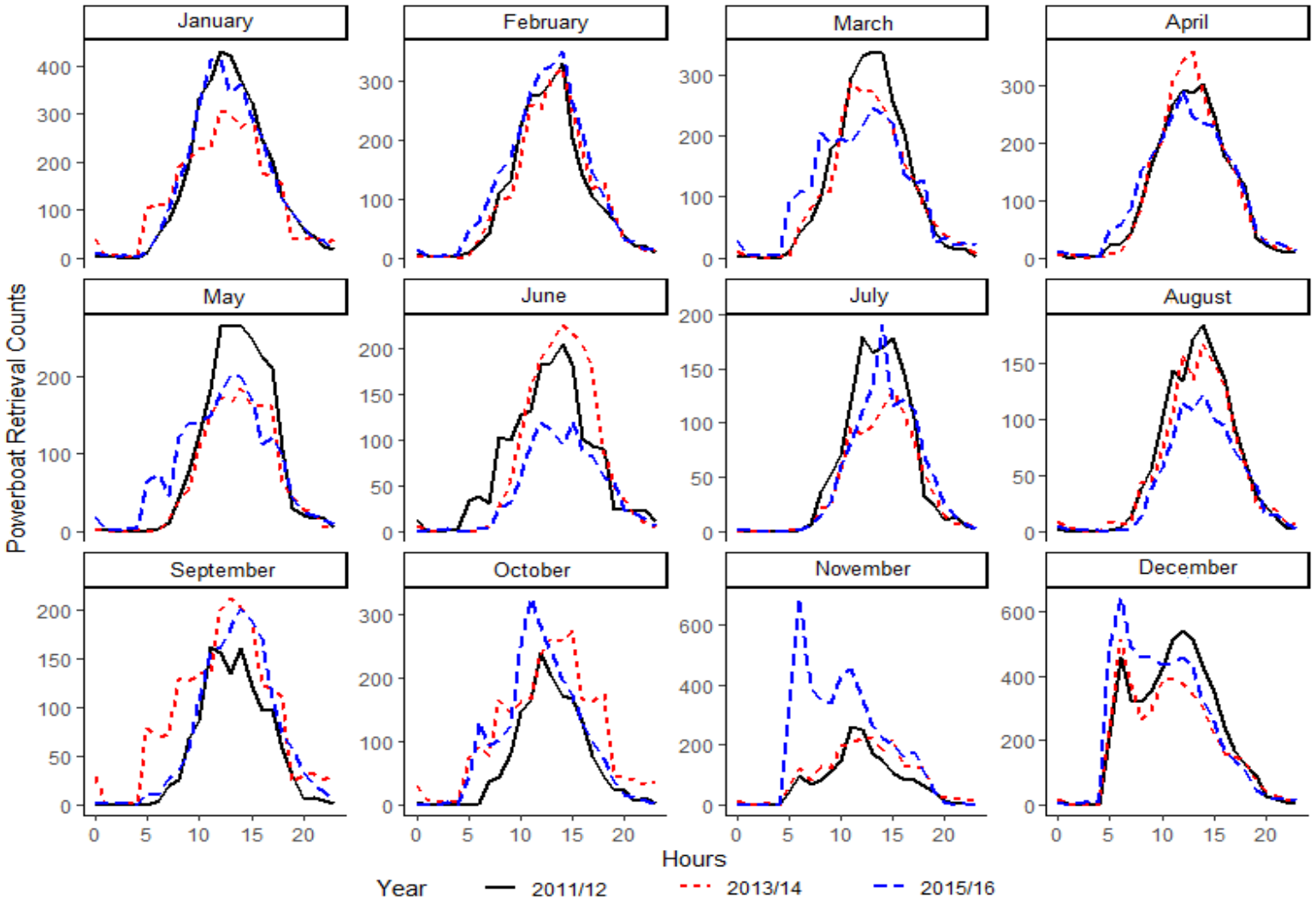

Figure 8: Hourly powerboat retrievals by month from Hillarys (Lat 31.822, Long 115.739) during 2011-12, 2013-14 and 2015-16.

3.3.4 Leeuwin Boat ramp

An annual estimate of 12293 powerboat retrievals was observed in the 2011-12 survey year, with no missing hours of the year (see Table 9). In terms of seasonal contributions, summer was the busiest period of retrieval activities accounting for 36.02% of the total estimate, followed by autumn (27.71%), winter (19.10%) and spring (17.17%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly retrievals were recorded in December, January and March, respectively (see Table 10). Of the total estimate obtained, 45.62% was observed on weekdays with 54.38% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 59% of retrievals were observed between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, 36.70% of hours of camera footage were missing due to outages. The months of January, August and September were most affected (see Table 14 in Appendix 3). An annual total of 13670 powerboat retrievals was estimated, with 59.91% of the estimate obtained via imputation (see Table 13). Compared to the 2011-12 annual estimate, there was a 11.20% rise in recreational powerboat retrievals. Summer was the busiest season, accounting for 32.79% of the annual estimate, followed by autumn (25.75%), spring (22.33%) and winter (19.13%) (see Table 16 in Appendix 3). December, January and February were the months of peak recreational boating activities (see Table 10). Weekdays accounted for 47.70% of the annual estimate, with the remaining 52.30% observed on weekends (including public holidays). Approximately 59% of retrievals were observed between the hours of 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2015-16, 14.94% of the hours of footage were missing. These outages mostly occurred in the months of August, September and October. An estimated annual total of 16236 powerboatr retrievals was obtained, of which 12.48% was determined via imputation. Compared to the 2011-12 and 2013-14 estimates, there was a 32.08% and 18.77% respective rise in recreational powerboat retrievals (see Table 9). Summer was the busiest season, contributing 36.69% of the annual estimate, with autumn, spring, and winter accounting for 24.17%, 23.74% and 15.39% respectively. December, January, and February were the months of peak recreational boating retrievals. Activities on weekdays contributed 51.51% of the annual estimate (see Table 17 in Appendix 3). Approximately 65% of retrieval activities occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

Figure 9 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 10 presents a distibutional comparison of boating activities across month and survey years.

Table 9: Attributes, descriptive statistics and distributional characteristics of observed and imputed estimates of powerboat retrievals from the Leeuwin digital camera.

Year	Remark	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	-	4808 (54.7)	1.4 (2.6)	3.19	16.27	12293
2013-2014	Observed	3217 (36.70)	2922 (52.7)	1.5 (2.7)	3.20	16.14	8190
	Imputation	-	706 (21.9)	1.7 (1.8)	2.25	10.45	5480±181
	Combined	-	3628 (41.4)	1.6 (2.4)	3.14	16.90	13670±181
2015-2016	Observed	1312 (14.94)	3589 (48.0)	1.9 (3.3)	3.12	15.75	14210
	Imputation	-	395 (30.1)	1.5 (1.8)	2.11	6.17	2026±112
	Combined	-	3984 (45.4)	1.8 (3.1)	3.22	14.03	16236±112

Table 10: Monthly estimate of the number of powerboat retrievals (with the 95% confidence bounds) for Leeuwin Boat ramp

Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)	Year	Month	Total estimates (95% CI)
2011-2012	Mar ‘11	1208	2013-2014	Mar ‘14	1285±4	2015-2016	Mar ‘16	1459±24
	Apr ‘11	1083		Apr ‘14	1289		Apr ‘16	1411±33
	May ‘11	1115		May ‘13	946		May ‘16	1055±27
	Jun ‘11	940		Jun ‘13	1027		Jun ‘16	790±3
	Jul ‘11	806		Jul ‘13	592±27		Jul ‘16	781±28
	Aug ‘11	602		Aug ‘13	996±67		Aug ‘16	928±74
	Sep ‘11	549		Sep ‘13	874±65		Sep ‘15	863±50
	Oct ‘11	802		Oct ‘13	1004±48		Oct ‘15	1401±42
	Nov ‘11	760		Nov ‘13	1175		Nov ‘15	1591±4
	Dec ‘11	1643		Dec ‘13	1622±96		Dec ‘15	2183±15
	Jan ‘12	1616		Jan ‘14	1494±99		Jan ‘16	2134±17
	Feb ‘12	1169		Feb ‘14	1366±57		Feb ‘16	1640±8

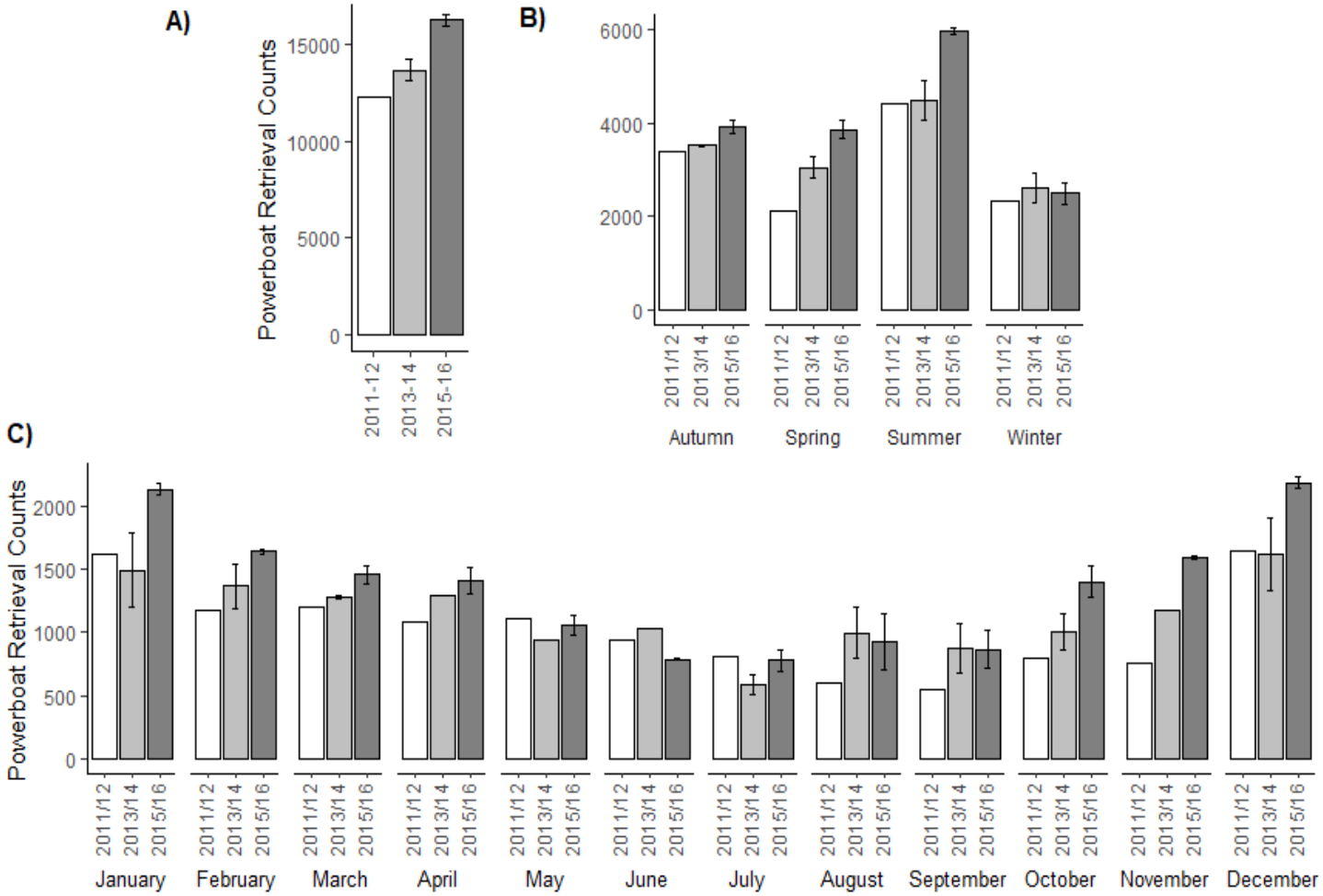

Figure 9: A) Total powerboat retrievals from Leeuwin (Lat 32.030, Long 115.762) during 2011-12, 2013-14 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12, 2013-14 and 2015-16. C) Distribution of total powerboat retrievals by months across 2011-12, 2013-14 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

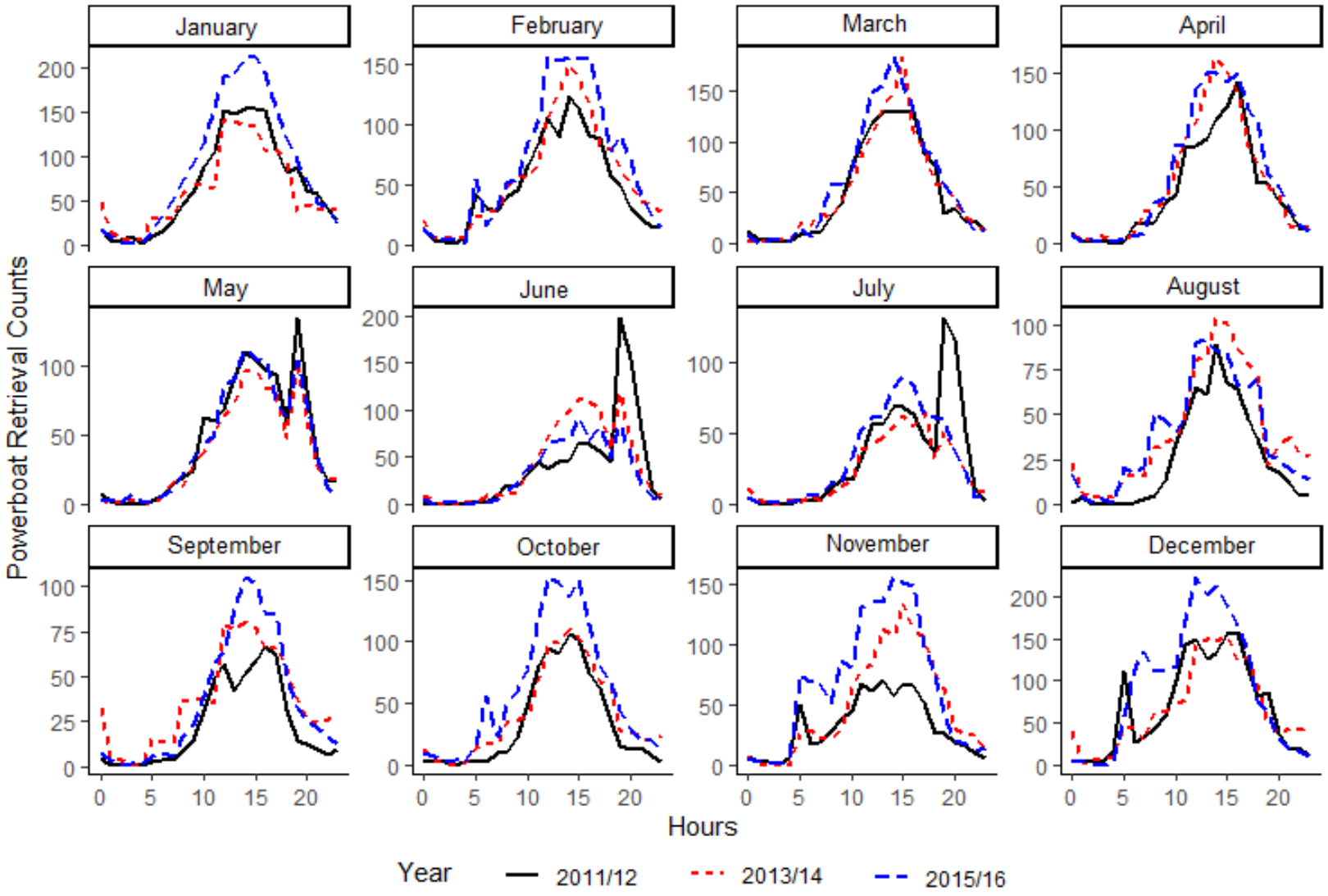

Figure 10: Hourly powerboat retrievals by month from Leeuwin (Lat 32.030, Long 115.762) during 2011-12, 2013-14 and 2015-16.

3.3.5 Woodman Point (Public)

An annual estimate of 24777 powerboat retrievals was observed in the 2011-12 survey year, with 3.76% of the estimate obtained via imputation for the 3.37% missing hours of the year (see Table 11). October was the month with the most outages. In terms of seasonal contributions, autumn was the busiest period of retrieval activities accounting for 32.05% of the total estimate, followed by summer (28.31%), spring (21.38) and winter (18.26%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly activities were recorded in January, March and April respectively (see Table 12). Of the total estimate obtained, 45.00% was observed on weekdays with 55.00% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 77% of retrievals were observed between the hours of 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, 16.68% of hours of camera footage were missing due to outages. The months of January and December were the most affected (see Table 14 in Appendix 3). An annual total of 26726 powerboat retrievals was estimated, with 28.03% of the estimate obtained via imputation (see Table 6). Compared to the 2011-12 annual estimate, there was a 3.96% rise in recreational powerboat retrievals. Summer was the busiest season, accounting for 36.71% of the annual estimate, followed by autumn (26.08%), winter (19.41%) and spring (17.81%) (see Table 16 in Appendix 3). December, January and April were respectively the months with the highest recreational boating activities (see Table 12). Weekdays accounted for 41.72% of the annual estimate, with the remaining 58.28% observed on weekends (including public holidays). About 69% of retrievals occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2015-16, 25.77% of the hours of camera footage were missing. These outages mostly occurred in the months of July, September and October. An estimated annual total of 30431 recreational boating retrievals was obtained, of which 23.93% was determined via imputation. Compared to the 2011-12 and 2013-14 estimates, there was a 18.37% and 13.86% rise in recreational powerboat retrievals, respectively (see Table 7). Summer was the busiest season, contributing 35.14% of the annual estimate, with spring, autumn and winter accounting for 26.78%, 26.21% and 11.87% respectively. December, November, and January were the months of peak recreational boating activities. Activities on weekdays contributed 50.45% of the annual estimate (see Table 17 in Appendix 3). Approximately 77% of retrieval activities occurred between 05:00 and 16:00 (see Table 15 in Appendix 3).

Figure 11 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 12 presents a distibutional comparison of boating activities across month and survey years.

Table 2: Attributes, descriptive statistics and distributional characteristics of observed and imputed estimates of powerboat retrievals from the Woodman Point (Public) digital camera.

Year	Remarks	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	296 (3.37)	4435 (52.3)	2.9 (6.3)	4.3	27.3	24777
	Imputation	-	56 (18.9)	3.2 (3.5)	1.89	7.54	932±95
	Combined	-	4491 (51.1)	2.9 (6.2)	4.3	27.7	25709±95
2013-2014	Observed	1461 (16.68)	3742 (51.3)	2.6 (5.6)	4.3	30.3	19234
	Imputation	-	249 (17.0)	3.7 (7.1)	3.0	12.78	7492±310
	Combined	-	3991 (45.6)	3.1 (6.2)	4.1	26.9	26726±310
2015-2016	Observed	2264 (25.77)	3240 (49.7)	3.6 (7.2)	3.8	22.0	23149
	Imputation	-	584 (25.8)	3.2 (4.5)	4.7	13.6	7282±277
	Combined	-	3824 (43.5)	3.5 (6.6)	4.0	25.5	30431±277

Table 3: Monthly estimate of the number of powerboat retrievals (with the 95% confidence bounds) for Woodman Point Boat ramp (Public).

Year	Month	Total estimate (95% CI)	Year	Month	Total estimate (95% CI)	Year	Month	Total estimate (95% CI)
2011-2012	Mar ‘11	2947±32	2013-2014	Mar ‘14	2292±32	2015-2016	Mar ‘16	2892±28
	Apr ‘11	2859±28		Apr ‘14	2795±14		Apr ‘16	3344±14
	May ‘11	2435±26		May ‘13	1883		May ‘16	1741±9
	Jun ‘11	1493±4		Jun ‘13	2391±10		Jun ‘16	1833±69
	Jul ‘11	1465		Jul ‘13	1229		Jul ‘16	1396±277
	Aug ‘11	1737		Aug ‘13	1567		Aug ‘16	1232±26
	Sep ‘11	2138		Sep ‘13	1349±32		Sep ‘15	2582±123
	Oct ‘11	1930±68		Oct ‘13	1517±63		Oct ‘15	2756±111
	Nov ‘11	1428		Nov ‘13	1893±27		Nov ‘15	2811±31
	Dec ‘11	1464		Dec ‘13	3870±120		Dec ‘15	4366±112
	Jan ‘12	3555		Jan ‘14	3611±136		Jan ‘16	3455±89
	Feb ‘12	2258		Feb ‘14	2329±36		Feb ‘16	2872

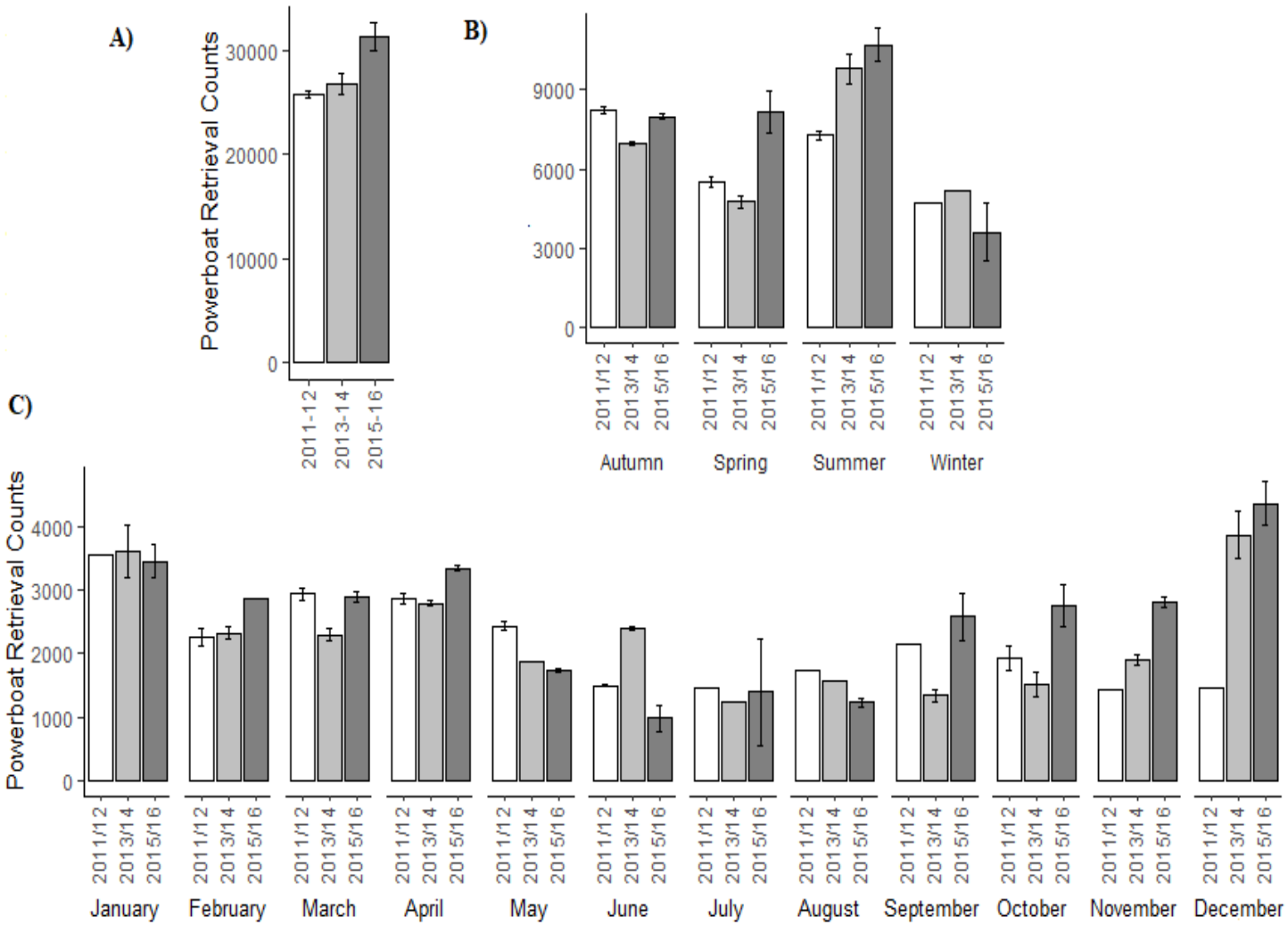

Figure 11: A) Total powerboat retrievals from Woodman Point (Lat 32.139, Long 115.762) during 2011-12, 2013-14 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12, 2013-14 and 2015-16. C) Distribution of total power boat retrievals by months across 2011-12, 2013-14 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

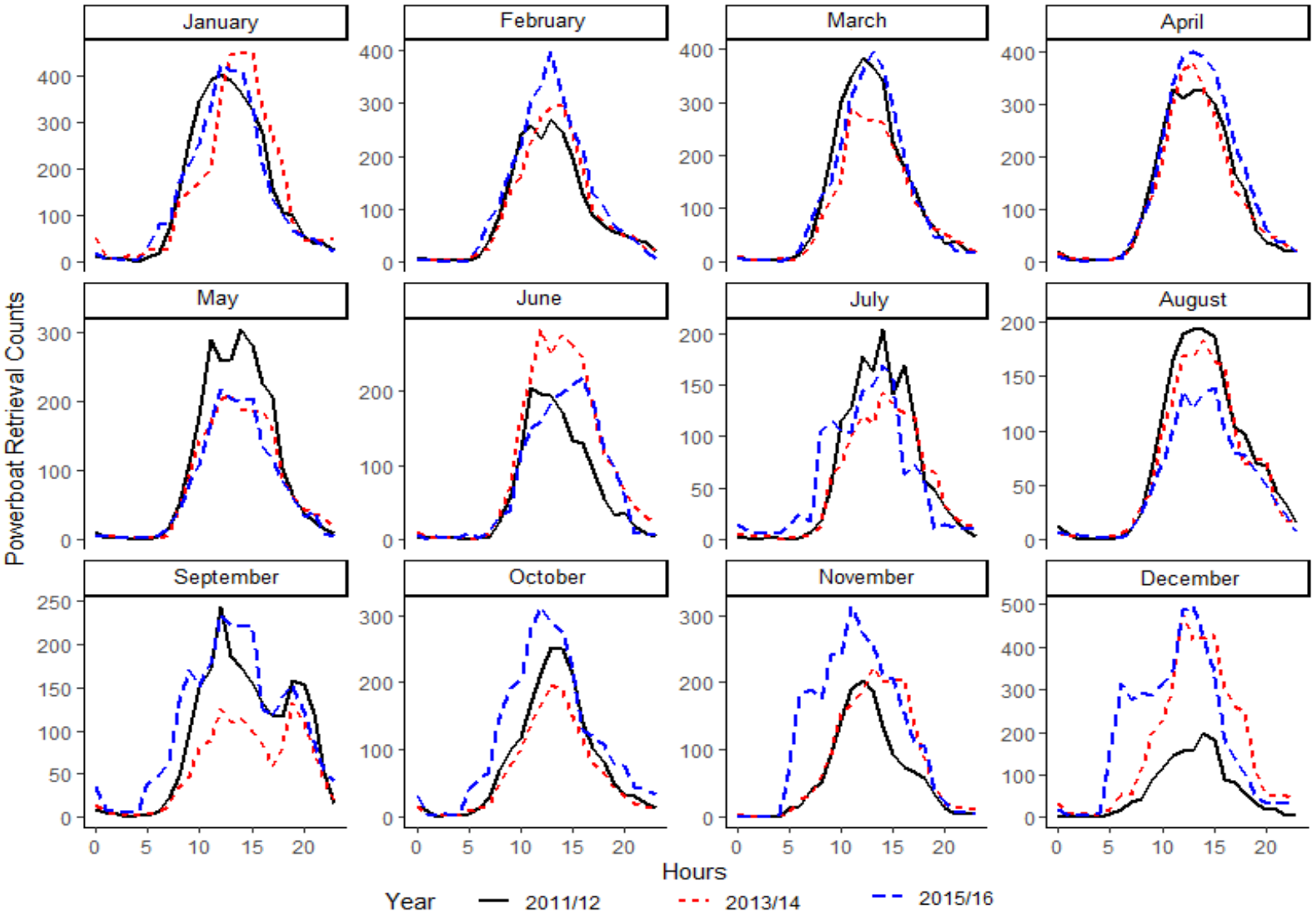

Figure 12: Hourly power boat retrievals by month from Woodman Point (Lat 32.139, Long 115.762) during 2011-12, 2013-14 and 2015-16.

3.3.6 Point Peron

An annual estimate of 12779 powerboat retrievals was observed in the 2011-12 survey year, with 8.73% of the estimate obtained via imputation for the 7.06% missing hours of the year (see Table 11). September, October and December were the months with most outages (see Table 15 in Appendix 3). In terms of seasonal contributions, summer was the busiest period of retrieval activities accounting for 40.93% of the total estimate, followed by autumn (26.71%), spring (19.60%) and winter (12.76%) (see Table 16 in Appendix 3 for detailed analysis). Highest monthly activities were recorded in December, January, and March respectively (see Table 12). Of the total estimate obtained, 47.10% was observed on weekdays with 52.90% observed during weekends (including public holiday) (see Table 17 in Appendix 3). Approximately 79% of retrievals were observed between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2013-14, 6.03% of hours of camera footage were missing due to outages. The month of May was most affected (see Table 14 in Appendix 3). An annual total of 17003 powerboat retrievals was estimated, with 7.01% of the estimate obtained via imputation (see Table 13). Compared to the 2011-12 annual estimate, there was a 33.05% rise in recreational powerboat retrievals. Summer was the busiest season, accounting for 39.79% of the annual estimate, followed by autumn (27.40%), spring (19.31%) and winter (13.50%) (see Table 16 in Appendix 3). December, January and April were the months of peak recreational boating activities (see Table 14). Weekdays accounted for 49.04% of the annual estimate, with the remaining 50.96% observed on weekends (including public holidays). Approximately 81% of retrievals were observed between 05:00 and 16:00 (see Table 15 in Appendix 3).

In 2015-16, 5.85% of the hours of footage were missing. These outages mostly occurred in the months of March, September and November. An estimated annual total of 19039 recreational boating retrievals was obtained, out which 7.30% was determined via imputation. Compared to the 2011-12 and 2013-14 estimates, there was a 48.99% and 11.98% respective rise in recreational powerboat retrievals, respectively (see Table 13). Summer was the busiest season, contributing 40.80% of the annual estimate, with spring, autumn and winter accounting for 27.37%, 21.55% and 10.27% respectively. November, December, and January were the months of peak recreational boating activities. Activities on weekdays contributed 58.44% of the annual estimate (see Table 17 in Appendix 3). Approximately 79% of retrieval activities occurred between 12:00 and 19:00 (see Table 15 in Appendix 3).

Figure 13 presents a comparative analysis of the trend in recreational boating activies across months and survey years. In terms of the hourly distribution of recreational boating activities, Figure 14 presents a distibutional comparison of boating activities across month and survey years. Similar to Ocean Reef and Hillarys, the density of distribution for November (and to some extent December) 2015-16 is significantly higher and different to those for 2011-12 and 2013-14, with a shift of the peak retrievals observed around 6am (possibly because of the recreational rock lobster fishery).

Table 13: Attributes, descriptive statistics and distributional characteristics of observed and imputed estimates of powerboat retrievals from the Point Peron digital camera.

Year	Remark	Num. of hours with outages (%)	Num. of zero counts (%)	Hourly Mean (SD)	Skewness	Kurtosis	Total est (± 95% CI)
2011-2012	Observed	620 (7.06)	5073 (62.1)	1.4 (3.1)	4.05	26.45	11664
	Imputation	-	177 (28.5)	1.8 (2.1)	2.33	11.29	1115±85
	Combined	-	5250 (59.8)	1.5 (3.0)	4.02	26.58	12779±85
2013-2014	Observed	528 (6.03)	4604 (55.9)	1.9 (4)	3.89	24.36	15805
	Imputation	-	118 (22.3)	2.3 (2.1)	0.96	3.14	1198±169
	Combined	-	4722 (53.9)	1.9 (3.9)	3.89	24.90	17003±169
2015-2016	Observed	514 (5.85)	4468 (54.0)	2.1 (4.3)	3.69	20.97	17649
	Imputation	-	86 (16.7)	2.7 (2.1)	0.60	2.89	1390±174
	Combined	-	4554 (51.8)	2.2 (4.2)	3.70	21.49	19039±174

Table 14: Monthly estimate of the number of powerboat retrievals (with the 95% confidence bounds) for Point Peron Boat ramp.

Year	Month	Total estimate (95% CI)	Year	Month	Total estimate (95% CI)	Year	Month	Total estimate (95% CI)
2011 - 2012	Mar ‘11	1470±3	2013-2014	Mar ‘14	1573±19	2015-2016	Mar ‘16	1721±108
	Apr ‘11	1155±5		Apr ‘14	1675		Apr ‘16	1529±11
	May ‘11	788		May ‘13	1410±162		May ‘16	854±44
	Jun ‘11	466		Jun ‘13	990±38		Jun ‘16	637
	Jul ‘11	523		Jul ‘13	532±1		Jul ‘16	697
	Aug ‘11	642±5		Aug ‘13	774±20		Aug ‘16	621
	Sep ‘11	822±51		Sep ‘13	639±35		Sep ‘15	1315±71
	Oct ‘11	841±37		Oct ‘13	1091±10		Oct ‘15	1505±62
	Nov ‘11	842		Nov ‘13	1554		Nov ‘15	2392±92
	Dec ‘11	2399±51		Dec ‘13	2754		Dec ‘15	3607±4
	Jan ‘12	2000±29		Jan ‘14	2398		Jan ‘16	2371±28
	Feb ‘12	964±5		Feb ‘14	1613		Feb ‘16	1790

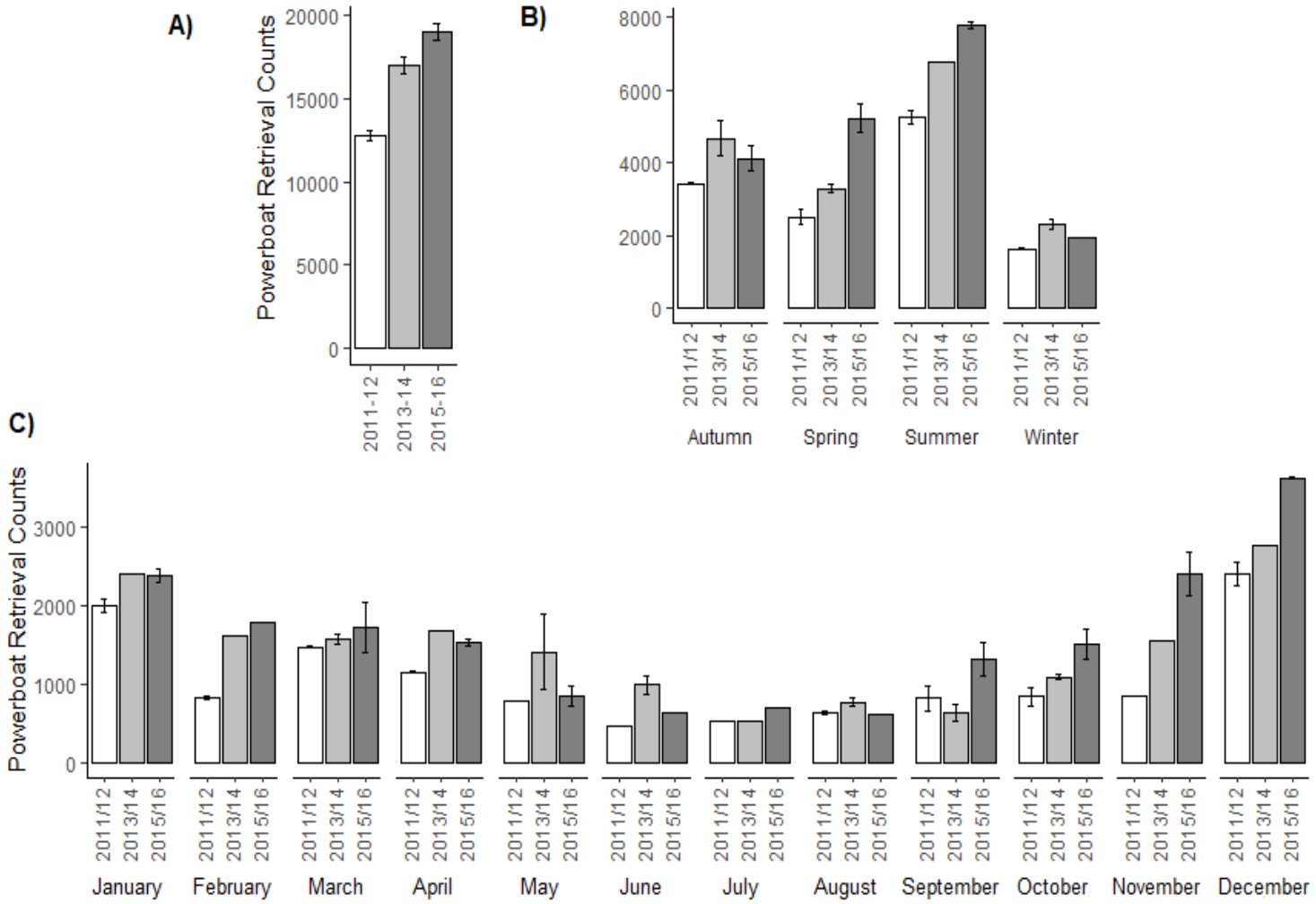

Figure 13: A) Total powerboat retrievals from Point Peron (Lat 32.271, Long 115.698) during 2011-12, 2013-14 and 2015-16. B) Distribution of total powerboat retrievals by seasons across 2011-12, 2013-14 and 2015-16. C) Distribution of total powerboat retrievals by months across 2011-12, 2013-14 and 2015-16. Error bars are 95% confidence intervals where data imputation was required for missing data.

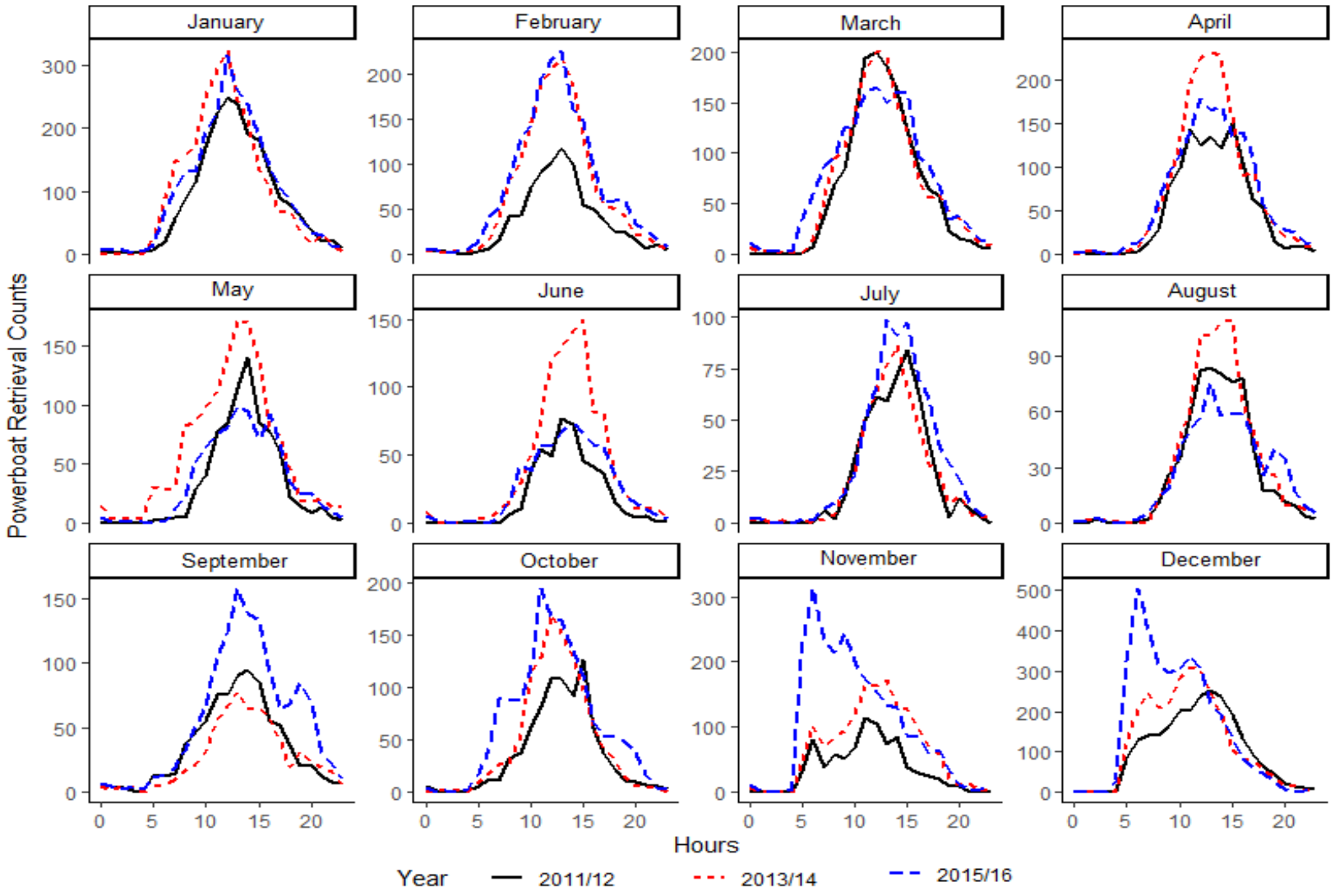

Figure 14: Hourly powerboat retrievals by month from Point Peron (Lat 32.271, Long 115.698) during 2011-12, 2013-14 and 2015-16.

3.4 Comparison with existing imputation method

Ryan *et al*., (2017) imputed data for short-term camera outages applying the extrapolation method in Wise and Fletcher (2013); however, data for periods of extended outages were not imputed (e.g. a two-month outage for Hillarys in 2013-14). In contrast, the current imputation method has the ability to impute missing observations from extended periods of camera outage. In instances where some data were missing within a given month (e.g. January 2013-14; Figure 15), the shapes of the distribution of the estimates obtained from the two methods suggest that the current method generally mimicked the observed data. Robust imputation models with the ability to uncover the relationship between variables to "fill-in" gaps of missing data with values that will fit the distribution of the powerboat retrievals are ideal.

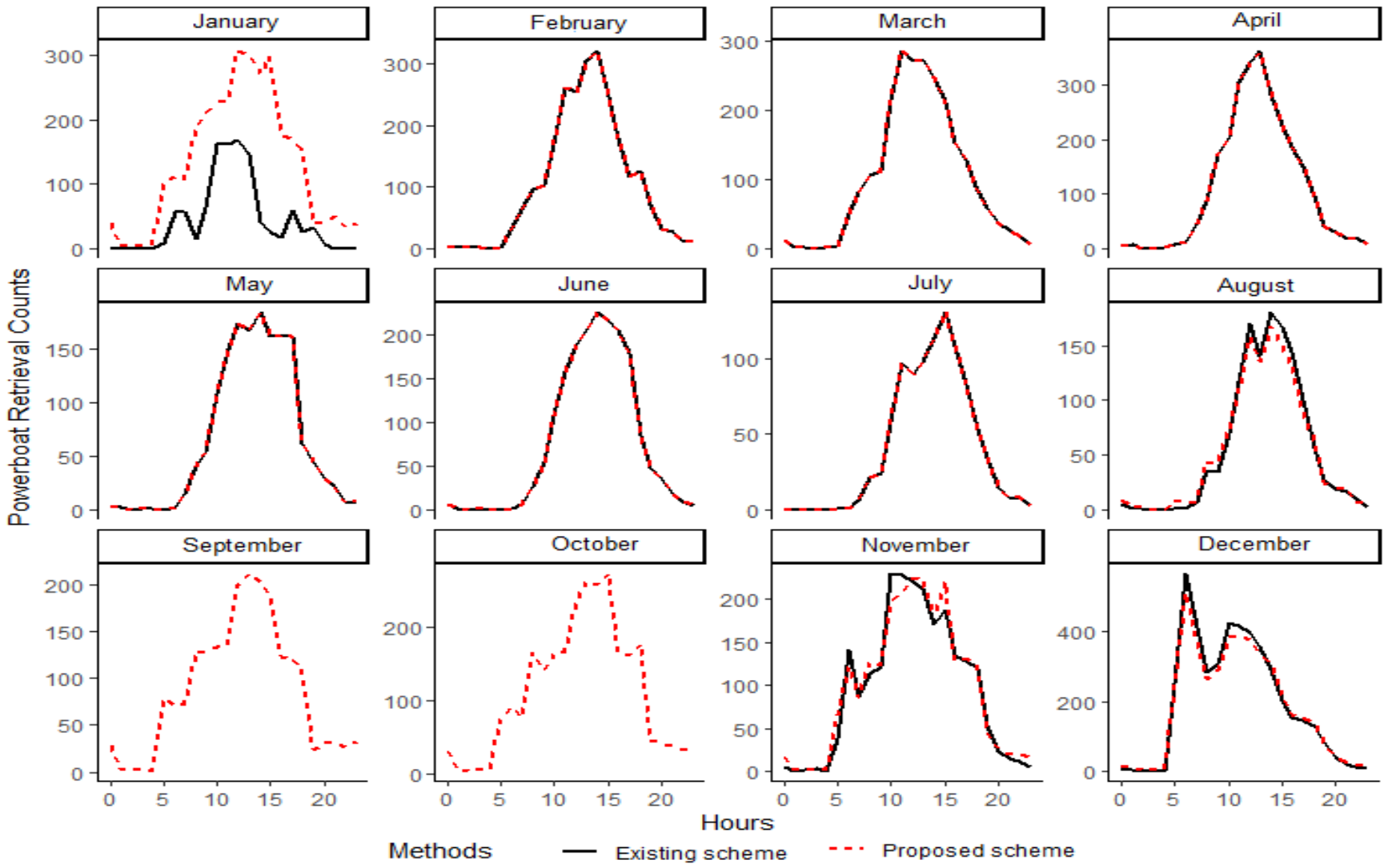

Figure 15: Hourly total powerboat retrievals at the Hillarys boat ramp during the 2013-2014 survey period. Missing data for the months of September and October were not imputed in Ryan et al. (2015). The existing scheme used is as described in Wise and Fletcher (2013). The proposed scheme imputed missing data according to the Bayesian sequential regression multiple imputation scheme.

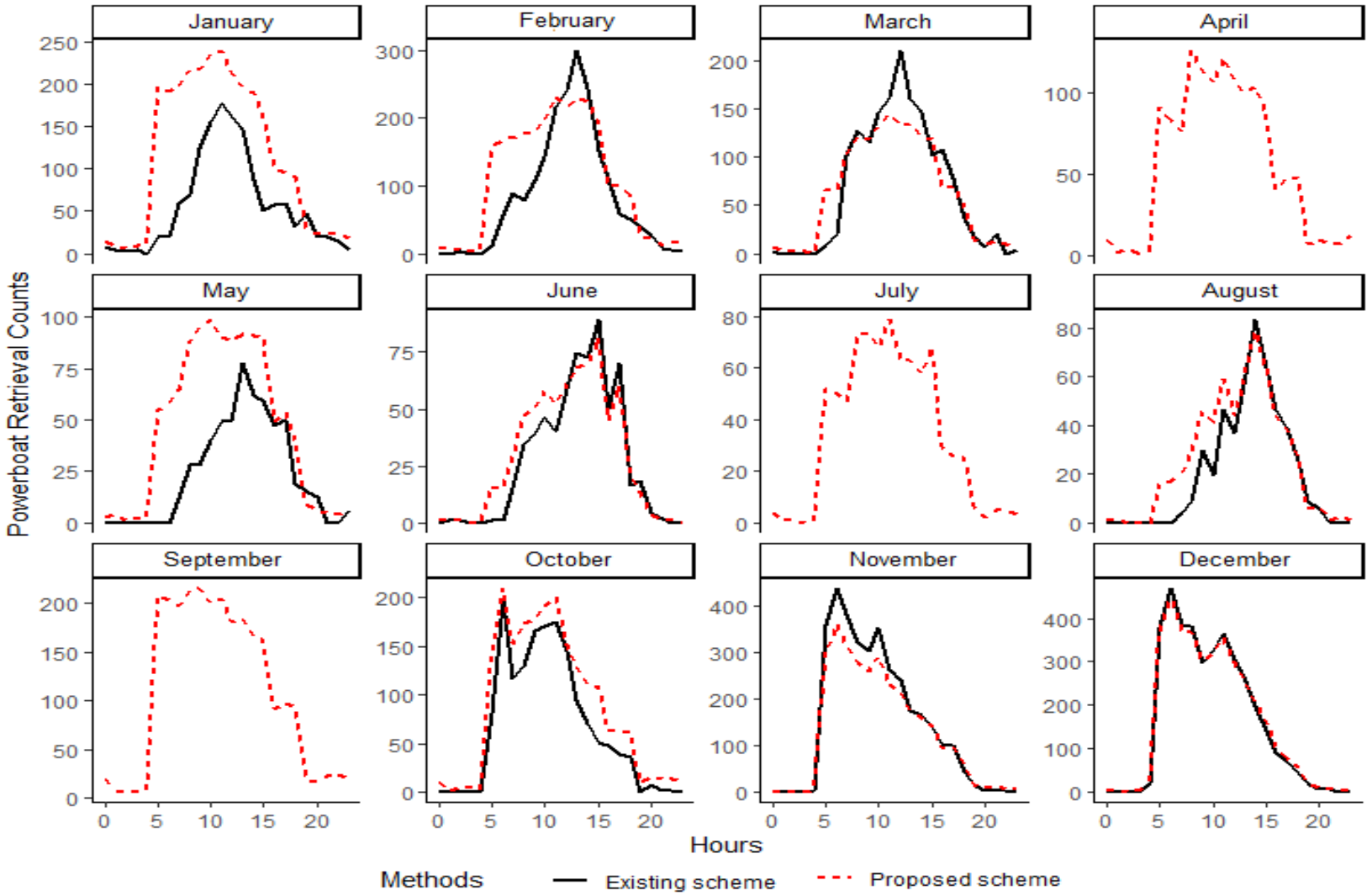

Figure 16: Hourly total powerboat retrievals at the Mindarie boat ramp during the 2015-2016 survey period. Missing data for the months of September, April and July were not imputed in Ryan et al. (2017). The existing scheme used is as described in Wise and Fletcher (2013). The proposed scheme imputed missing data according to the Bayesian sequential regression multiple imputation scheme.

4 Summary and recommendations for future surveys

4.1 Overview

This report presents estimates of powerboat retrievals from digital camera surveys at six boat ramps in the Perth Metropolitan area for the survey years 2011-2012, 2013-2014 and 2015-2016. Missing data were imputed under the assumption that data were missing at random, implying that inference could be drawn based on observed data and some useful covariates to obtain estimates to "fill-in" missing data. Climatic, oceanographic and time-related temporal variables were used as covariates in the imputation model building. The significance of climatic variables (including wind speed and direction, temperature), oceanographic variables (including sea level pressure) and time-related temporal strata (such as time of day, type of day and seasons) have been identified as predeterminants of recreational and commercial fishing activity (Soykan *et al*. 2014; Desfosses and Beckly, 2015; Kendall *et al*., 2021). However, it is important to note that these covariates were not directly associated with the missing mechanism and did not explicitly give any information on why the camera records were missing. In Afrifa-Yamoah *et al*., (2020b) and Afrifa-Yamoah (2021), the focus of the imputation models was to predict boating effort based on the collective contribution of all covariates, irrespective of the statistical significance of their coefficients. Zero-inflated Poisson mixed effect models were built on the fully-conditional specification multiple imputation framework to impute missing data (van Buuren and Groothuis-Oudshoorn, 2011; Klienke and Reinecke, 2013). Afrifa-Yamoah *et al*., (2020b) highlighted that the imputation framework does not impute missing data with the predicted values from the chain of equations formulated with the covariates. Their predicted values were only used as estimates to reveal the similarities and useful patterns within the outcome variable to guide reasonable random draws from the observed data to impute the missing data. The estimates of powerboat retrievals with their associated 95% confidence intervals have been provided.

Overall, there was an average increase of ~4% in the annual number of powerboat retrievals at Perth Metropolitan ramps. Our imputed estimates revealed higher levels of boating activity in summer compared to the other three seasons. However, there was no systematic trend withins months and seasons with respect to the three survey years. The busiest ramps (Woodman Point and Hillarys) observed over 30,000 retrievals in the 2015-16 fishing year. Between 2011 and 2016, the Ocean Reef ramp had observed the highest average yearly incease (~7%) in powerboat retrievals.

4.2 Recommendations

The challenges of missing data in remote camera studies can be mitigated with measures such as regular maintenance schedules, back-up power supplies for cameras, and installing cameras in close proximity to assist data sharing from surrounding ramps (Hartill *et al*., 2016); however, missing data cannot be completely eliminated. Comparison of our results with the estimates in Ryan *et al.,* (2013), Ryan *et al.,* (2015) and Ryan *et al.,* (2017) suggest that estimates obtained from the competing models were similar for relatively short durations. Re-analysis of the same dataset using the proposed imputation scheme has enabled the estimation of annual totals of the powerboat retrievals to be estimated (Figures 15 and 16). These annual estimates were previously lacking for some ramps due to extended outages. We therefore recommend an ongoing collection of auxiliary data, such as, climatic variables and other useful factors that influence boating activities, to support imputation inferences if required. However, there may be scenarios where the proposed method would not be effective in imputing extended outages. For instance, Mindarie in 2013-2014 experienced a continuous outage for 9-months.

While other studies have used data collected from adjacent digital cameras to account for a camera outage, this appears to be problematic in the Perth Metropolitan region because the traffic intensity of boating activity across ramps varies significantly. For instance, Hillarys and Ocean Reef are neighbouring ramps with different boat traffic intensities, with more activity occurring at the former ramp. Although an expansion factor could be applied based on data from the adjacent ramp, it must be guided by the trend over time, which is often difficult to observe in recreational fisheries because of data scarcity. Again, with regard to data sharing across months of years, there were no obvious trends in the estimates across the years. Generally, we could conclude that the months in summer were busier compared to the months in winter, however, there would always be the difficulty in establishing the relationship between the years and the magnitude of the difference in the estimates. There is also the issue of quantifying the proportion of non-fishing boating activity, which can only be determined from alternative/supplementary surveys. Recreational fisheries are dynamic, however, an attempt to establish such a relationship could be aided by time series analysis of adequately long historical data collected in a continuum. The data used in this study spanned a six-year period but had discontinuity gaps of 12-months in between. We recommend a posteriori sample size planning scheme for digital camera monitoring to enable a cost-effective continuous reading of the data, thus creating a useful database for comparison and extrapolative purposes. This would assist in validating and corroborating estimates from other recreational fishing surveys and could be used as an independent source for the estimation of fishing effort and catch rates (Afrifa-Yamoah *et al*., 2021; Steffe *et al*., 2008; van Poorten and Brydle, 2018).

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Appendix 1: Distributions of outage patterns

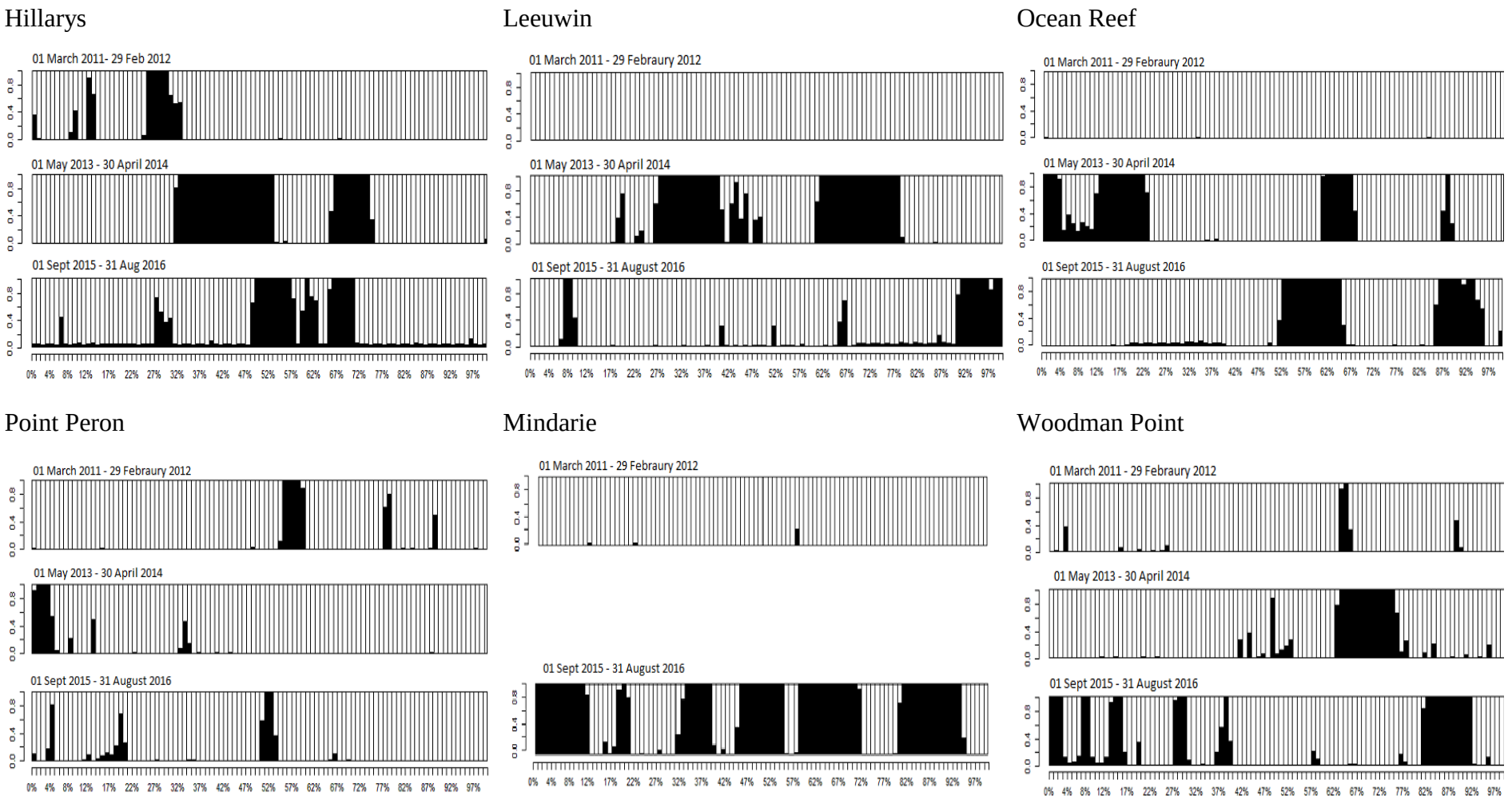

Figure 2: Distribution of the outage patterns. The black shades represent duration of outages and the white shades represent duration of no outages. The horizontal axes represent the percentage partition of the length of the data points (8784 hours for leap year and 8760 hours for non-leap year). The vertical axes represent the percentage of missing data in the percentage partition of the data points.

Appendix 2: Imputation modelling scheme

Information here is an extract from Afrifa-Yamoah *et al.*, (2020b). The imputation models were formulated to investigate the conditional distribution

$$P\left(Y^{mis}, \theta \middle| Y^{obs}, \boldsymbol{X}\right), \quad (1)$$

where θ represents the vector of unknown parameters of the model**.** Let y be a $n \times 1$ vector of observed outcomes

$$y = X\beta + Zv + \varepsilon, v \sim N(0, \psi_v), \varepsilon \sim N(0, \Sigma) \quad (2)$$

where X is a $n \times k$ matrix of covariates associated with the outcome y via β is the $k \times 1$ vector of fixed effects, and Z is a $n \times r$ matrix of variables associated with y via the $r \times 1$ vector of random effects v, , ψ_v is the $r \times r$ variance-covariance matrix of the random effects and ε is the $n \times 1$ error vector with $\Sigma = \sigma^2 I$. The posterior distribution of v given y under this model is $v|y \sim N(\psi_v Z^T (Z\psi_v Z^T + \Sigma)^{-1}(y - X\beta),\ \psi_v - \psi_v Z^T (Z\psi_v Z^T + \Sigma)^{-1} Z\psi_v)$ (Schafer and Yucel, 2002; Resche-Rigon and White, 2018).

The imputation was carried out as follows;

a) Estimate the model parameters, $\hat{\theta} = (\hat{\theta}_z, \hat{\theta}_c)$ and their variance covariance $S_{\hat{\theta}} = (S_{\hat{\theta}_z}, S_{\hat{\theta}_c})$ where $(\hat{\theta}_z, S_{\hat{\theta}_z})$ and $(\hat{\theta}_c, S_{\hat{\theta}_c})$ represent the estimates for the zero and the count parts respectively, by maximizing the log-likelihood of model (1) fitted to the available data.

b) Draw $\theta_z^* = (\beta_z^*, \psi_{v_z}^*, \sigma_z^*)$ using $N(\hat{\theta}_z, \hat{S}_{\theta_z})$, and compute the predicted probabilities for having a zero versus non-zero count. Missing observations with predicted probabilities assigned as zero counts are imputed with zeros.

c) For the non-zero counts, draw $\theta_c^* = (\beta_c^*, \psi_{v_c}^*, \sigma_c^*)$ using $N(\hat{\theta}_c, \hat{S}_{\theta_c})$, hence obtain $\psi_{v_c}^*$, and $\Sigma^* = \sigma^{*2} I$. Thus, $v^* \sim N(\psi_{v_c}^* Z^T \left(Z\psi_{v_c}^* Z^T + \Sigma^*\right)^{-1}(y - X\beta^*),\ \psi_{v_c}^* - \psi_{v_c}^* Z^T \left(Z\psi_{v_c}^* Z^T + \Sigma^*\right)^{-1} Z\psi_{v_c}^*)$ and $\varepsilon \sim N\left(0, \sigma_c^{*2}\right)$. These estimates were drawn using a Gibbs sampler (van Buuren and Groothuis-Oudshoorn, 2011; Kleinke and Reinecke, 2013)

d) Let $j = (1, \cdots, J)$ define the clustering levels, then for a missing observation, formulate $y_{ij}^* = x_{ij}\beta^* + z_{ij}v^* + \varepsilon_{ij}^*$.

e) Randomly draw from the observed data with y_{ij}^* in closest neighbourhood to the missing observation being imputed.

For each missing observation, the combined imputed estimates of the mean $\overline{\hat{Y}_i^{mis}}$ and variance $\widehat{Var}\left(\overline{\hat{Y}_i^{mis}}\right)$ were obtained as

$$\overline{\hat{Y}_i^{mis}} = \frac{\sum_{m=1}^{M} \hat{Y}_i^{mis}}{M} \tag{3}$$

$$\widehat{Var}\left(\overline{\hat{Y}_i^{mis}}\right) = \frac{\sum_{m=1}^{M} \widehat{Var}(\hat{Y}_{i,m}^{mis})}{M} + \frac{(M+1)}{M(M-1)} \sum_{m=1}^{M} \left(\hat{Y}_{i,m}^{mis} - \overline{\hat{Y}_i^{mis}}\right)^2 \tag{4}$$

where M denotes the total number of estimates for Y^{mis} in the imputation scheme and $\sum_{m=1}^{M}\left(\hat{Y}_{i,m}^{mis} - \overline{\hat{Y}_i^{mis}}\right)^2$ reflects the missing values estimation uncertainties (Rubin, 1987).

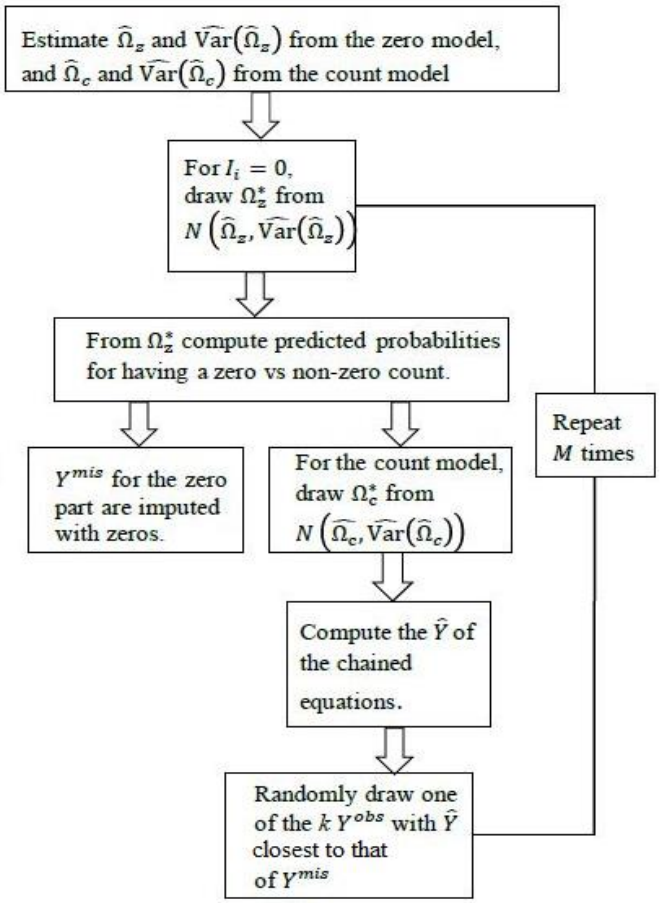

Figure 20: Flow chart of the proposed imputation scheme.

Appendix 3: Monthly, seasonal, time of day and type of day, relative missing proportion, imputed and observed totals for powerboat retrievals

Table 4: Monthly missing data proportions, imputed estimates and 95% confidence intervals and the overall monthly estimates for the three survey periods for the public ramps in Perth Metropolitan**.**

Ramp	Year	Month	Relative Prop. (% of all outages)	Tot. Imp. (95% CI)	Overall Total	Year	Month	Relative. Prop. (% of all outages)	Tot. Imp. (95% CI)	Overall Total	Year	Month	Relative Prop. (% of all outages)	Tot. Imp. (95% CI)	Overall Total
Mindarie	2011/12	Mar ‘11	-	-	1190						2015/16	Mar ‘16	0.09	957±96	1511±96
		April ‘11	0.12	5±8	1360±8							April ‘16	0.14	1311±113	1311±113
		May ‘11	0.12	2±2	1007±2							May ‘16	0.09	918±93	1097±93
		June ‘11	-	-	417							June ‘16	0.04	255±45	696±45
		July ‘11	-	-	589							July ‘16	0.14	803±79	803±79
		Aug ‘11	-	-	593							Aug ‘16	0.05	271±47	604±47
		Sept ‘11	0.76	13±6	571±6							Sept ‘15	0.14	2572±154	2572±154
		Oct ‘11	-	-	597							Oct ‘15	0.06	1182±103	2024±103
		Nov ‘11	-	-	817							Nov ‘15	0.05	874±91	3025±91
		Dec ‘11	-	-	2974							Dec ‘15	0.02	566±73	3768±73
		Jan ‘12	-	-	1664							Jan ‘16	0.10	2266±144	2714±144
		Feb ‘12	-	-	1011							Feb ‘16	0.08	1905±129	2560±129
Ocean Reef	2011/12	Mar ‘11	0.25	0	1245	2013/14	Mar ‘14	0.07	270±44	1406±44	2015/16	Mar ‘16	0.26	993±95	1440±95
		April ‘11	-	-	1151		April ‘14	-	-	1485		April ‘16	0.29	1175±108	1215±108
		May ‘11	-	-	929		May ‘13	0.19	934±90	1205±90		May ‘16	0.00	16±16	873±16
		June ‘11	-	-	429		June ‘13	0.22	750±87	904±87		June ‘16	0.00	3±5	551±5
		July ‘11	0.25	0	472		July ‘13	0.23	584±68	614±68		July ‘16	0.24	497±63	676±63
		Aug ‘11	-	-	521		Aug ‘13	-	-	672		Aug ‘16	0.16	306±45	422±45
		Sept ‘11	-	-	503		Sept ‘13	0.00	7±10	316±10		Sept ‘15	-	-	846
		Oct ‘11	-	-	662		Oct ‘13	-	-	855		Oct ‘15	0.00	5±10	1681±10
		Nov ‘11	-	-	809		Nov ‘13	-	-	1493		Nov ‘15	0.01	77±33	3926±33
		Dec ‘11	-	-	2971		Dec ‘13	0.26	1800±136	2314±136		Dec ‘15	0.02	139±43	4714±43
		Jan ‘12	0.50	15±17	1999±17		Jan ‘14	0.02	115±33	1823±33		Jan ‘16	0.01	128±33	2491±33
		Feb ‘12	-	-	1155		Feb ‘14	-	-	1503		Feb ‘16	-	-	2072
Hillarys	2011/12	Mar ‘11	0.04	77±23	2660±23	2013/14	Mar ‘14	-	-	2385	2015/16	Mar ‘16	0.34	2464±184	2561±184
		April ‘11	0.22	697±85	2516±85		April ‘14	0.00	23±20	2603±20		April ‘16	0.18	1222±125	2589±125
		May ‘11	0.02	47±22	2124±22		May ‘13	-	-	1555		May ‘16	0.21	1406±141	1953±141
		June ‘11	0.72	1526±122	1724±122		June ‘13	-	-	1789		June ‘16	0.01	3±1	1017±1
		July ‘11	-	-	1317		July ‘13	-	-	953		July ‘16	0.02	4±3	1154±3
		Aug ‘11	-	-	1375		Aug ‘13	0.08	363±55	1274±55		Aug ‘16	0.02	40±13	958±13
		Sept ‘11	0.00	4±2	1242±2		Sept ‘13	0.27	2081±130	2081±130		Sept ‘15	0.03	167±37	1623±37
		Oct ‘11	0	-	1587		Oct ‘13	0.28	2661±150	2661±150		Oct ‘15	0.02	13±4	2330±4
		Nov ‘11	0.00	4±3	1796±3		Nov ‘13	0.09	909±86	2315±86		Nov ‘15	0.02	54±6	4541±6
		Dec ‘11	-	-	5130		Dec ‘13	0.04	522±75	4346±75		Dec ‘15	0.09	1077±115	5457±115

		Jan ‘12	-	-	3546		Jan ‘14	0.25	2956±167	3112±167		Jan ‘16	0.02	22±10	3539±10
		Feb ‘12	-	-	2422		Feb ‘14	-	-	2438		Feb ‘16	0.06	735±87	2931±87
Leeuwin	2011/12	Mar ‘11	-	-	1208	2013/14	Mar ‘14	0.00	2±4	1285±4	2015/16	Mar ‘16	0.03	96±24	1459±24
		April ‘11	-	-	1083		April ‘14	-	-	1289		April ‘16	0.04	134±33	1411±33
		May ‘11	-	-	1115		May ‘13	-	-	946		May ‘16	0.05	114±27	1055±27
		June ‘11	-	-	940		June ‘13	-	-	1027		June ‘16	0.02	9±3	790±3
		July ‘11	-	-	806		July ‘13	0.04	133±27	592±27		July ‘16	0.10	145±28	781±28
		Aug ‘11	-	-	602		Aug ‘13	0.19	774±67	996±67		Aug ‘16	0.56	909±74	928±74
		Sept ‘11	-	-	549		Sept ‘13	0.19	814±65	874±65		Sept ‘15	0.09	277±50	863±50
		Oct ‘11	-	-	802		Oct ‘13	0.09	443±48	1004±48		Oct ‘15	0.08	253±42	1401±42
		Nov ‘11	-	-	760		Nov ‘13	-	-	1175		Nov ‘15	0.00	2±4	1591±4
		Dec ‘11	-	-	1643		Dec ‘13	0.18	1351±96	1622±96		Dec ‘15	0.00	14±15	2183±15
		Jan ‘12	-	-	1616		Jan ‘14	0.23	1494±99	1494±99		Jan ‘16	0.02	59±17	2134±17
		Feb ‘12	-	-	1169		Feb ‘14	0.08	469±57	1366±57		Feb ‘16	0.01	14±8	1640±8
Woodman Point (Public)	2011/12	Mar ‘11	0.11	95±32	2947±32	2013/14	Mar ‘14	0.02	57±23	2292±32	2015/16	Mar ‘16	0.01	74±28	2892±28
		April ‘11	0.02	39±28	2859±28		April ‘14	0.01	39±14	2795±14		April ‘16	0.00	12±14	3344±14
		May ‘11	0.05	43±26	2435±26		May ‘13	-	-	1883		May ‘16	0.00	2±9	1741±9
		June ‘11	0.00	1±4	1493±4		June ‘13	0.00	26±10	2391±10		June ‘16	0.08	293±69	1833±69
		July ‘11	-	-	1465		July ‘13	0.00	0	1229		July ‘16	0.33	1396±150	1396±150
		Aug ‘11	-	-	1737		Aug ‘13	-	-	1567		Aug ‘16	0.03	74±26	1232±26
		Sept ‘11	-	-	2138		Sept ‘13	0.02	70±32	1349±32		Sept ‘15	0.18	1561±123	2582±123
		Oct ‘11	0.67	583±68	1930±68		Oct ‘13	0.08	433±63	1517±63		Oct ‘15	0.16	1378±111	2756±111
		Nov ‘11	-	-	1428		Nov ‘13	0.03	105±27	1893±27		Nov ‘15	0.01	99±31	2811±31
		Dec ‘11	-	-	1464		Dec ‘13	0.28	2915±120	3870±120		Dec ‘15	0.12	1494±112	4366±112
		Jan ‘12	0.15	171±48	3555		Jan ‘14	0.51	3611±136	3611±136		Jan ‘16	0.08	899±89	3455±89
		Feb ‘12	-	-	2258		Feb ‘14	0.05	236±36	2329±36		Feb ‘16	-	-	2872
Point Peron	2011/12	Mar ‘11	0.00	1±3	1470±3	2013/14	Mar ‘14	0.00	7±19	1573±19	2015/16	Mar ‘16	0.51	613±108	1721±108
		April ‘11	0.00	2±5	1155±5		April ‘14	-	-	1675		April ‘16	0.00	4±11	1529±11
		May ‘11	-	-	788		May ‘13	0.75	992±162	1410±162		May ‘16	0.02	54±44	854±44
		June ‘11	-	-	466		June ‘13	0.12	84±38	990±38		June ‘16	-	-	637
		July ‘11	-	-	523		July ‘13	0.00	1±1	532±1		July ‘16	-	-	697
		Aug ‘11	0.00	3±5	642±5		Aug ‘13	0.01	15±20	774±20		Aug ‘16	-	-	621
		Sept ‘11	0.49	430±51	822±51		Sept ‘13	0.11	95±35	639±35		Sept ‘15	0.19	242±71	1315±71
		Oct ‘11	0.22	207±37	841±37		Oct ‘13	0.00	4±10	1091±10		Oct ‘15	0.05	108±62	1505±62
		Nov ‘11	-	-	842		Nov ‘13	-	-	1554		Nov ‘15	0.22	347±92	2392±92
		Dec ‘11	0.20	366±51	2399±51		Dec ‘13	-	-	2754		Dec ‘15	0.00	8±4	3607±4
		Jan ‘12	0.07	104±29	2000±29		Jan ‘14	-	-	2398		Jan ‘16	0.01	14±28	2371±28
		Feb ‘12	0.00	2±5	831±5		Feb ‘14	-	-	1613		Feb ‘16	-	-	1790

Table 5: Relative missing data proportions, imputed estimates and 95% confidence intervals and the overall monthly estimates for the three survey periods for the public ramps in Perth Metropolitan with respect to the time of the day.

Ramp	Year	Time	Relative Prop. (% of all outages)	Tot. Imp. (95% CI)	Overall Total	Year	Time	Relative Prop. (% of all outages).	Tot. Imp. (95% CI)	Overall Total	Year	Time	Relative Prop. (% of all outages).	Tot. Imp. (95% CI)	Overall Total
Mindarie	2011/	Dawn	0.15	0	210						2015/	Dawn	0.17	131±7	159±7
	2012	E. Morning	0.19	5±5	1364±5						2016	E. Morning	0.13	3094±253	5275±253
		Morning	0.08	3±5	4329±5							Morning	0.17	4607±244	7713±244
		Afternoon	0.12	7±7	4880±7							Afternoon	0.17	3962±228	6479±228
		L. Afternoon	0.12	3±5	1712±5							L. Afternoon	0.13	1511±118	2308±118
		Evening	0.35	2±1	295±1							Evening	0.25	575±34	751±34
Ocean	2011/	Dawn	0.25	0	21	2013/	Dawn	0.16	28±2	47±2	2015/	Dawn	0.16	20±2	94±2
Reef	2012	E. Morning	-	-	1179	2014	E. Morning	0.13	477±72	1467±72	2016	E. Morning	0.12	626±117	5279±117
		Morning	0.25	15±17	3561±17		Morning	0.18	1356±134	4240±134		Morning	0.17	924±111	6487±111
		Afternoon	-	-	5903		Afternoon	0.17	1752±182	6267±182		Afternoon	0.16	975±111	6298±111
		L. Afternoon	-	-	1882		L. Afternoon	0.12	594±81	2003±81		L. Afternoon	0.15	644±75	2254±75
		Evening	0.50	0	300		Evening	0.24	253±25	566±25		Evening	0.24	117±10	495±10
Hillarys	2011/	Dawn	0.17	9±1	45±1	2013/	Dawn	0.17	63±5	98±5	2015/	Dawn	0.28	101±6	133±6
	2012	E. Morning	0.13	168±54	1834±54	2014	E. Morning	0.12	924±127	2531±127	2016	E. Morning	0.11	951±189	4450±189
		Morning	0.27	670±95	7781±95		Morning	0.17	2422±160	7294±160		Morning	0.15	2180±199	9156±199
		Afternoon	0.16	967±125	12036±125		Afternoon	0.17	3683±213	11017±213		Afternoon	0.14	2506±205	10900±205
		L. Afternoon	0.12	379±75	4457±75		L. Afternoon	0.12	1644±138	4790±138		L. Afternoon	0.10	1023±126	4454±126
		Evening	0.24	162±31	1286±31		Evening	0.25	779±76	1782±76		Evening	0.21	446±63	1560±63
Leeuwin	2011/	Dawn	-	-	111	2013/	Dawn	0.17	111±7	170±7	2015/	Dawn	0.22	46±4	127±4
	2012	E. Morning	-	-	549	2014	E. Morning	0.13	338±34	675±34	2016	E. Morning	0.12	128±26	1011±26
		Morning	-	-	2215		Morning	0.17	918±81	2203±81		Morning	0.16	420±63	3160±63
		Afternoon	-	-	4483		Afternoon	0.16	1962±134	5252±134		Afternoon	0.15	759±93	6345±93
		L. Afternoon	-	-	2703		L. Afternoon	0.12	1149±103	3054±103		L. Afternoon	0.11	413±66	3540±66
		Evening	-	-	2232		Evening	0.25	1002±79	2316±79		Evening	0.23	420±63	2053±63
Woodman	2011/	Dawn	0.15	10±2	103±2	2013/	Dawn	0.16	86±8	184±8	2015/	Dawn	0.17	81±6	152±6
Point	2012	E. Morning	0.13	36±13	512±13	2014	E. Morning	0.13	160±28	509±28	2016	E. Morning	0.13	521±82	2060±82
(Public)		Morning	0.18	254±60	7190±60		Morning	0.17	1456±117	6038±117		Morning	0.17	2036±169	8337±169
		Afternoon	0.16	382±80	11248±80		Afternoon	0.16	3366±165	11932±165		Afternoon	0.16	3001±243	12921±243
		L. Afternoon	0.12	150±46	4387±46		L. Afternoon	0.13	1730±104	5304±104		L. Afternoon	0.12	1015±123	4543±123
		Evening	0.26	100±31	2269±31		Evening	0.25	694±72	2759±72		Evening	0.25	628±68	2418±68
Point	2011/	Dawn	0.16	11±2	44±2	2013/	Dawn	0.17	16±3	74±3	2015/	Dawn	0.15	17±4	124±4
Peron	2012	E. Morning	0.12	86±25	764±25	2014	E. Morning	0.12	102±56	1408±56	2016	E. Morning	0.13	183±87	2755±87
		Morning	0.17	303±56	3594±56		Morning	0.18	360±115	5101±115		Morning	0.21	436±110	5591±110
		Afternoon	0.17	440±71	5712±71		Afternoon	0.17	480±155	7302±155		Afternoon	0.20	507±121	6731±121
		L. Afternoon	0.13	169±40	1978±40		L. Afternoon	0.13	148±64	2178±64		L. Afternoon	0.11	155±59	2545±59
		Evening	0.25	106±18	687±18		Evening	0.24	92±27	940±27		Evening	0.19	92±38	1293±38

Table 6: Relative missing data proportions, imputed estimates and 95% confidence intervals and the overall monthly estimates for the three survey periods for the public ramps in Perth Metropolitan with respect to austral season.

Ramp	Year	Season	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total	Year	Season	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total	Year	Season	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total
Mindarie	2011/12	Autumn	0.23	7±7	3557±7						2015/16	Autumn	0.32	3186±175	3919±175
		Spring	0.77	13±6	1985±6							Spring	0.25	4628±206	7621±206
		Summer	-	-	5649							Summer	0.20	4737±206	9042±206
		Winter	-	-	1599							Winter	0.23	1329±102	2103±102
Ocean reef	2011/12	Autumn	0.25	0	3325	2013/14	Autumn	0.26	1204±100	4096±100	2015/16	Autumn	0.56	2251±139	3528±139
		Spring	-	-	1974		Spring	0.00	7±10	2664±10		Spring	0.01	82±34	6453±34
		Summer	0.50	15±17	6125±17		Summer	0.28	1915±139	5640±139		Summer	0.03	267±55	9277±55
		Winter	0.25	0	1422		Winter	0.45	1334±110	2190±110		Winter	0.40	806±77	1649±77
Hillarys	2011/12	Autumn	0.28	821±90	7300±90	2013/14	Autumn	0.00	23±20	6543±20	2015/16	Autumn	0.72	5092±262	7103±262
		Spring	0.00	8±6	4625±6		Spring	0.64	5651±216	7057±216		Spring	0.06	234±31	8494±31
		Summer	-	-	11098		Summer	0.29	3478±184	9896±184		Summer	0.17	1834±140	11927±140
		Winter	0.72	1521±122	4416±122		Winter	0.08	363±55	4016±55		Winter	0.05	47±10	3129±10
Leeuwin	2011/12	Autumn	-	-	3406	2013/14	Autumn	0.00	2±4	3520±4	2015/16	Autumn	0.12	344±48	3925±48
		Spring	-	-	2111		Spring	0.28	1257±81	3053±81		Spring	0.17	532±65	3855±65
		Summer	-	-	4428		Summer	0.48	3314±148	4482±148		Summer	0.03	87±23	5957±23
		Winter	-	-	2348		Winter	0.24	907±71	2615±71		Winter	0.68	1063±78	2499±78
Woodman Point (Public)	2011/12	Autumn	0.17	177±47	8241±47	2013/14	Autumn	0.03	96±27	6970±27	2015/16	Autumn	0.01	88±32	7977±32
		Spring	0.67	583±68	5496±68		Spring	0.13	608±74	4759±74		Spring	0.35	3038±169	8149±277
		Summer	0.15	171±48	7277±48		Summer	0.83	6762±184	9810±184		Summer	0.20	2393±142	10693±142
		Winter	0.00	1±4	4695±4		Winter	0.00	26±7	5187±7		Winter	0.43	1763±167	3612±167
Point Peron	2011/12	Autumn	0.00	3±6	3413±6	2013/14	Autumn	0.76	999±163	4658±163	2015/16	Autumn	0.53	671±115	4104±115
		Spring	0.71	637±63	2505±63		Spring	0.11	99±36	3284±36		Spring	0.46	697±130	5212±130
		Summer	0.28	472±59	5230±59		Summer	-	-	6765		Summer	0.01	22±26	7769±26
		Winter	0.00	3±5	1631±5		Winter	0.13	100±42	2296±42		Winter	-	-	1955

Table 7: Relative Missing data proportions, imputed estimates and 95% confidence intervals and the overall monthly estimates for the three survey periods for the public ramps in Perth Metropolitan with respect to type of day.

Ramp	Year	Day type	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total	Year	Day type	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total	Year	Day type	Miss. Prop.	Tot. Imp. (95% CI)	Overall Total
Mindarie	2011/12	Weekday	1	20±9	6472±9						2015/16	Weekday	0.70	8724±264	14272±264
		Weekend	-	-	6318							Weekend	0.30	5156±223	8413±223
Ocean Reef	2011/12	Weekday	0.5	0	5575	2013/14	Weekday	0.68	2861±157	7341±157	2015/16	Weekday	0.70	2028±121	12216±121
		Weekend	0.5	15±17	7271±17		Weekend	0.33	1599±124	7249±124		Weekend	0.30	1278±116	8691±116
Hillarys	2011/12	Weekday	0.64	1134±95	13517±95	2013/14	Weekday	0.68	6409±235	15665±235	2015/16	Weekday	0.65	3682±195	17964±195
		Weekend	0.36	1221±125	13922±125		Weekend	0.32	3106±164	11847±164		Weekend	0.35	3525±223	12689±223
Leeuwin	2011/12	Weekday	-	-	5608	2013/14	Weekday	0.71	2858±120	6521±120	2015/16	Weekday	0.67	1053±74	8363±74
		Weekend	-	-	6685		Weekend	0.29	2622±147	7149±147		Weekend	0.33	973±90	7872±90
Woodman Point (Public)	2011/12	Weekday	0.76	544±66	11568±66	2013/14	Weekday	0.62	2404±118	11151±118	2015/16	Weekday	0.74	4253±197	15351±197
		Weekend	0.24	388±76	14141±76		Weekend	0.38	5086±175	15575±175		Weekend	0.26	3029±211	15080±211
Point Peron	2011/12	Weekday	0.72	590±56	6019±56	2013/14	Weekday	0.73	914±153	8339±153	2015/16	Weekday	0.69	860±130	11127±130
		Weekend	0.28	525±71	6760±71		Weekend	0.27	284±73	8664±73		Weekend	0.31	530±119	7912±119