PASSIVE ACOUSTIC MONITORING OF MARINE MAMMALS IN HONG KONG WATERS (2021-22)
(Contract Ref.: AFCD/SQ/315/20/C)

FINAL REPORT

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

As a continuation of previous passive acoustic monitoring (PAM) works, the present study funded by the Agriculture, Fisheries and Conservation Department of the Hong Kong SAR Government deployed F-POD and C-POD units among 12 locations within four marine parks (i.e. Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP), Brothers Marine Park (BMP), the Southwest Lantau Marine Park (SWLMP)), and the South Lantau Marine Park (SLMP)) as well as two “control” sites in West Lantau (WL). Covering the period from July 2021 to June 2022, the 12-month study aims to fill important data gaps on night-time usage of the western waters of Hong Kong by Chinese White Dolphins and Indo-Pacific Finless Porpoises, which is critically needed to provide a more complete picture of marine mammal occurrences especially within these marine protected areas over time.

During the study, the 12 F-POD units collected data from July 11th, 2021 to January 13th, 2022 for a combined total of 2,139.5 logged days. After visual validation, the detection positive minutes (DPMs) were assessed for dolphin and porpoise occurrences at each deployment location within and outside of the four marine parks. The results revealed that over 48,000 DPMs were recorded, of which 86.2% were from CWDs and 13.8% were from FPs. As with the C-POD data from previous years, most dolphin detections were from SWLMP and WL and both of these areas detected dolphins during about 80% of the logged days. The highest dolphin detections were at Peaked Hill, Shum Wat and Tai O, while the lower level was found at both BMP sites where near-zero detections were recorded. The temporal patterns of dolphin detections appear to vary with sites and diel phases, with some sites having higher detections during the day than at night while other sites had the opposite pattern.

From the same six-month deployment period, finless porpoises were only detected in SWLMP and SLMP, and most porpoise detections were from the SLMP area with both Tai A Chau sites having the greatest detection metrics. Kau Ling Chung was the only consistent and reliable site in SWLMP where porpoise detections were made in reasonable numbers. Porpoise detections had a more clearly defined temporal pattern of occurrence, with consistently more detections during the night regardless of site or season.

The long-term C-POD data collected since 2017 revealed a very clear and large decline in CWD overall and at most sites throughout the western waters of Hong Kong. In contrast, finless porpoise detections appear to have remained fairly constant and possibly have increased slightly over the years as dolphin numbers continue to decrease. At some sites, specific diel and seasonal patterns of occurrences appear to be maintained throughout multiple study periods and may be characteristic of the species at those sites.

During the four years from 2018 to 2021, C-POD DPMs and boat survey metrics correlated significantly but these correlations were not very strong nor consistent across sites. The significant correlations were not surprising as both DPM and boat survey metrics are related through the level of presence of animals. But the weakness of the correlation may be related to the differences in boat survey (covering a large area but for a much shorter period of time) and C-POD data collection (sampling a small area more or less continuously). A much larger portion of areas surveyed by boat to be covered by many more C-PODs would be needed in order to find a tighter correlation between the two sets of data.

The correlation between C-POD and F-POD dolphin detection varied greatly from being weak to moderately strong. Furthermore, the relationship between C-POD and F-POD dolphin detection levels were inconsistent and varied across sites, and where F-PODs recorded more DPMs, the increased detection were not consistently recorded at the same level across sites. Similarly, the correlation between C-POD and F-POD porpoise detection also varied, but C-PODs always had more detections than F-PODs, and generally the correlation coefficients for C-POD and F-POD data were higher than in the dolphin data. It is clear that there is no simple universal correction factor that can be applied across all sites for either species to allow direct comparison of C-POD and F-POD data sets. Analyses of larger data sets for each site and species would be required for further examination of correction factors to be applied.

In light of the findings of the present study, a list of recommendations was made on further studies for improving the overall understanding and conservation of marine mammals in Hong Kong’s waters.

行政摘要 (中文翻譯)

一項獲香港特別行政區政府漁農自然護理署資助、作為先前「被動水底聲音監察項目」的延伸研究於 2021 年 7 月至 2022 年 6 月期間展開，此為期 12 個月的研究項目於已成立的沙洲及龍鼓洲海岸公園、大小磨刀洲海岸公園、大嶼山西南海岸公園、南大嶼海岸公園、及西大嶼山區域的兩個參照點 (大澳及深屈) 共十二個監察點，分別放置名為 F-POD 及 C-POD 的水底監聽器，其主要目標是要填補有關中華白海豚及江豚於夜間使用香港西部水域的空白，藉此更全面掌握海洋哺乳類動物於西部水域各海岸公園的出沒情況。

在為期六個月的數據搜集期間 (即 2021 年 7 月 11 日至 2022 年 1 月 13 日)，12 個 F-POD 水底監聽器共搜集了 2,139.5 天的研究數據；經目測檢查後，研究員利用 DPM (註：每一分鐘內存有至少一次海豚卡嗒聲音調即為一個 DPM) 作為評估中華白海豚及江豚於四個海岸公園內外各監察點出沒程度的重要參數。在 2021-22 年度研究期間共錄得超過 48,000 個 DPM，其中 86.2%為中華白海豚發聲記錄、13.8%為江豚發聲記錄。正如之前研究所收集的 C-POD 數據顯示，大部份的中華白海豚發聲記錄均來自西大嶼山區域及大嶼山西南海岸公園，在這兩處分別約有八成的日數均錄得海豚的出沒記錄。其中，雞翼角、深屈及大澳均錄得最多海豚發聲記錄；反之，大小磨刀海岸公園內的兩個監察點均錄得極少的海豚發聲記錄。海豚發聲記錄在不同地點及日夜之間均有明顯差異，例如有部份監察點在日間錄得較多海豚出沒，但在另一些監察點卻出現相反情況。

在相同的六個月監察期內，江豚的發聲紀錄卻僅限於南大嶼海岸公園及大嶼山西南海岸公園之內，而且絕大部份於大鴉洲以南及以北的監察點錄得；在大嶼山西南海岸公園內，狗嶺涌是唯一持續錄得相當水平的監察點。與中華白海豚的情況不同，江豚在不同監察點及季度均於夜間錄得明顯較高的發聲水平。

自 2017 年開始搜集的 C-POD 長期數據顯示，中華白海豚的發聲記錄在整個西部水域及每個地區均清晰地呈現明顯下降趨勢；與此同時，江豚的發聲記錄水平反而相對平穩，甚至可能有輕微上升的趨勢，與中華白海豚的數據下降剛剛相反。此外，中華白海豚及江豚在個別監察點的晝夜出沒及季節性出沒情況，在不同年份都大致相若，有可能是牠們在這些監察點的特別出沒模式。

在 2018 至 2021 年的四個年度期間，中華白海豚及江豚的發聲記錄 (C-POD DPMs) 與船上調查的參數有明顯的關聯，但其相關性並不強烈、亦並非在每一個監察點穩定地出現。由於發聲記錄及船上調查參數均與海豚的出現程度相關，所以呈現明顯的關聯並非令人意外，但較弱的相關性卻可能源於兩種研究方法的基本差別，因為船上調查方法雖覆蓋大片海域但卻在每一處停留很少時間，水底聲

音監察方法雖定點覆蓋一小片海域但卻持續不分晝夜搜集數據。為要兩種研究方法搜集的數據達致更緊密的關聯，必須要投放更多的 C-POD，以更大幅度覆蓋船上調查的研究範圍。

將 C-POD 及 F-POD 的兩種數據作比較，發現兩者的海豚發聲記錄的相關性在不同監察點有明顯差別 (由微弱至中度強度不等)。F-POD 和 C-POD 的海豚數據關聯於不同監察點出現差異，沒有一致模式。有些情況 F-POD 錄得的海豚發聲水平較 C-POD 為高，但這現象並非穩定地以同一水平出現於其它監察點。同樣地，江豚的情況與中華白海豚相若 (兩者的關聯在不同監察點均各有差異)，但 C-POD 經常比 F-POD 錄得更多江豚發聲數據,並且江豚數據的相關系數均高於中華白海豚。此研究清楚顯示一個適用於各自兩個品種及所有監察點的簡單修正因子，以容許直接比較 C-POD 及 F-POD 的數據並不存在；要進一步了解所需的修正方法，需要為兩個品種及每個監察點搜集更大量的數據作詳細分析。

基於此研究項目的結果，研究員提出一系列的建議，作為未來研究方向的重要參考，這些建議有助加強我們對中華白海豚及江豚的認識及保護。

1. INTRODUCTION

An on-going research study on Chinese White Dolphins (CWD; also known as Indo-Pacific humpback dolphins, *Sousa chinensis*) and Indo-Pacific finless porpoises (FP, *Neophocaena phocaenoides*) has been conducted by the Hong Kong Cetacean Research Project (HKCRP) over the past two decades, and the study has been primarily funded by the Agriculture, Fisheries and Conservation Department (AFCD) as well as various government departments and non-governmental organizations (e.g., Hung 2020, 2021). One research component of this study is the application of passive acoustic monitoring (PAM) techniques to understand the diurnal pattern of dolphin and porpoise occurrences within their habitats around Lantau waters.

Past marine mammal monitoring and consultancy studies by HKCRP have shown the C-POD to be a reliable PAM system to detect the presence of CWD and FP by detecting and recording their click trains (e.g., Hung 2013, 2014). The successful deployment of C-POD units at numerous sites in the western waters of Hong Kong has also demonstrated a great potential for long-term PAM of CWD and FP where 24-hour monitoring is not feasible if only standard visual monitoring techniques (e.g., vessel-based line-transect surveys or shore-based theodolite tracking) were used. As a result, AFCD appointed the HKCRP research team in 2017-18 to undertake a PAM study using C-PODs on CWD at the existing Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP) and the Brothers Marine Park (BMP) in North Lantau waters. The study’s findings indicated that the C-POD data provided valuable information on the spatial, seasonal and diurnal activities of dolphins in the two marine parks that would not have been possible to obtain with visual research methods alone (Wang and Hung 2018). Subsequently, a series of PAM studies using C-PODs over three consecutive years (between 2018 and 2021) was funded by AFCD to further extend the coverage of the waters to include the Southwest Lantau Marine Park (SWLMP), the South Lantau Marine Park (SLMP) and outside the marine parks (i.e., two control sites in West Lantau, at Shum Wat and Tai O) to eliminate the vast gap between SCLKCMP and SWLMP. This series of PAM studies conducted at 12 deployment sites within and outside the four marine parks has yielded invaluable information on the 24-hour occurrence and habitat use of both CWD and FP in western waters of Hong Kong as well as provided an independent line of evidence of the great decline in dolphins in Hong Kong’s waters (Wang and Hung 2019, 2020, 2021).

Over the past few years, Chelonia Limited (the developer of C-POD) has been developing the F-POD, which is the next generation porpoise/dolphin click detector to succeed the C-POD. The C-POD is being phased out due to obsolescence of components as well as software that is no longer being supported. The F-POD has much greater capabilities than the C-POD and also addresses some of the short-comings of the C-POD that have been identified during the many years of research conducted by numerous scientists around the world. The F-POD has increased detection range and collects higher resolution data, which greatly improves click train detection. It also provides a great deal more information and allows easier examination of changes in the click rate within a train (or click-rate modulation), the purpose of which is suspected to be for communication. This kind of additional information will provide a better understanding of why the occurrence and behaviour of cetaceans may differ in areas. The F-POD system (including a new detection classifier, KERNO-F) has better sensitivity and superior performance in dolphin detection while also having lower rates of false positive detections so the need for time-consuming visual validation is reduced. Notably, in the 2020-21 PAM study conducted for AFCD, the HKCRP team acquired several F-POD units from Chelonia Limited to test the deployment of these units alongside C-POD units with supporting data analyses and interpretation by Mr. Nick Tregenza, the creator of both the C-POD and F-POD. The trial study has already shown promising results for the wider application of the F-POD as the eventual replacement of C-POD, but further work would still be needed to examine the real-world differences in the dolphin and porpoise detection capabilities between the F-POD and C-POD during the same deployment.

As a continuation of previous PAM works, the long-term PAM data collected during the present study within existing marine parks (i.e., BMP, SCLKCMP, SWLMP and SLMP) as well as outside of these marine parks (WL) in the western waters of Hong Kong will further fill important data gaps on night-time usage of these four areas by dolphins and porpoises. This is critically needed in order to provide a more complete picture of marine mammal occurrences within these marine parks over time. This project covers the 12-month study period from July 1st, 2021 to June 30th, 2022 and this final report is prepared and submitted to AFCD to summarize the findings of the project.

2. OBJECTIVES OF PRESENT STUDY

The main goal of the present study was to monitor the occurrence of CWD and FP within and outside the four marine parks in western waters of Hong Kong using both F-PODs and C-PODs. To achieve this main goal, several specific objectives were set for the present study. The first objective was to deploy F-PODs and C-PODs side-by-side to collect updated and long-term quality scientific data of CWD and FP within and outside the four marine parks (i.e., SCLKCMP, BMP, SWLMP, SLMP and WL). This objective was achieved through repeated periodic deployments, retrieval, data downloading and redeployments of pairs of F-POD and C-POD units at 12 sites during the six-month field work programme between July 2021 and January 2022.

The second objective was to analyze and assess the current occurrence, diurnal and seasonal utilization patterns of CWD and FP within and outside the four marine parks. This objective was achieved by experienced analysts utilizing dedicated computer programmes *FPOD.exe* and *CPOD.exe* that were developed by Chelonia Limited to carry out objective automated detection and identification of echolocation click trains produced by CWD and FP in the F-POD and C-POD (respectively) data obtained.

The third objective was to compile the long-term dataset using the C-POD data collected by AFCD since 2017, in order to carry out spatio-temporal analysis of the activities of CWD and FP in western waters of Hong Kong. This was achieved by examining the C-POD dataset (after data processing as above) accumulated since 2017. Basic statistics and comparisons of the dataset stratified by various combinations (and resolution levels) of spatio-temporal factors (e.g., location, season, time of day, etc.) will be used to explore the data before progressing to regression modelling to determine the main spatio-temporal factors (or combination of factors) that may best explain the observed patterns of detections of CWD and FP.

The fourth objective was to review and conduct suitable correlation analyses between the existing C-POD data and visual monitoring data from vessel-based line-transect surveys that were collected concurrently for AFCD since 2017. These concurrent studies provided independent data on relative occurrence and patterns of CWD (and FP) that can be examined for the level of congruence between the two data sets. A strong correlation between the two data sets not only increases confidence in observed trends but also allows for improved interpretation of acoustic data when vessel-based survey data may not be available (e.g., in low density areas). To achieve this objective, various (and appropriate) comparisons were conducted between the detection metrics obtained from C-PODs and density/abundance estimates (or possibly encounter rates if density/abundance estimates are not available) from vessel-based surveys for each area and across time. Various subsets of both data sets were examined to better understand the factors affecting the level of correlation between the two types of data (e.g., comparing only C-POD data obtained during the times when vessel-based survey was also being conducted in the location).

The fifth objective relates to changes in hardware and associated software. The unavoidable succession of the C-POD by the next generation F-POD is underway due to the obsolescence of hardware components of, and unsupported software used by, the C-POD. And although the F-POD provides superior sensitivity and accuracy for detecting cetacean acoustic activities (www.chelonia.co.uk/fpod_home_page.htm), such improvements preclude direct comparisons of F-POD data with those obtained previously using the C-POD. This objective was to better understand the relationship between the data collected by C-POD and F-POD, and to evaluate the feasibility of developing a calibration or correction factor between the two PAM systems so comparisons of data obtained from these systems may be facilitated. To achieve this objective, a C-POD/F-POD pair was deployed at each of the 12 sites to obtain data for a comparability analysis between side-by-side C-POD and F-POD units. Side-by-side deployments remove possible confounding factors that may be related to site differences. And under the different existing conditions at the 12 sites, factors (e.g., noise level) that may affect the level of differences between the two PAM systems can be examined so that a possible correction factor (or factors) can be developed to allow comparison of data obtained by the different devices. These results will be important for understanding how acoustic monitoring for temporal changes since 2017 (when PAM works began in the western waters of Hong Kong) can be transitioned from C-POD to F-POD equipment as seamlessly as possible.

The final objective was to make recommendations on necessary further studies, as well as feasible and practicable measures for conservation of marine mammals in light of the findings of the present study. This objective was achieved by a thorough review of results from the present PAM study on dolphin and porpoise occurrences within and outside the four marine parks, to determine any potential data gaps and additional research questions that may require further studies. Furthermore, the existing conservation measures for local marine mammals were also reviewed and assessed to determine whether the results of the present study can help to identify improvements to existing measures and/or guide in the designing and implementing of new measures to better conserve CWD and FP in Hong Kong’s waters.

3. METHODOLOGY

3.1. Deployments of C-PODs and F-PODs

The twelve locations for the deployments of side-by-side C-POD and F-POD pairs are the same sites as in the 2018-19, 2019-20 and 2020-21 PAM studies also funded by AFCD (Figure 1). These sites were selected to provide good spatial coverage of different parts of the four existing marine parks as well as two other sites outside the marine parks system, especially in areas known to have high dolphin or porpoise densities based on previous AFCD marine mammal monitoring studies (e.g., Hung 2020, 2021).

C-POD and F-POD pairs were deployed at two sites in each of the BMP (at Siu Ho Wan and Tai Mo To) and SCLKCMP (at Lung Kwu Chau N and Sha Chau SE). Three sites each were selected for the deployment of C-POD and F-POD pairs within the SWLMP (at Peaked Hill, Fan Lau and Kau Ling Chung) and SLMP (at Siu A Chau, Tai A Chau N and Tai A Chau S) (Figure 1). Two additional ("control") sites outside the four marine parks were also included as strategic locations to collect PAM data for the present study. The site near Shum Wat provides coverage of an area close to the Hong Kong Link Road (HKLR) alignment, which allows for the examination of dolphin occurrence near this infrastructure during its operational phase, in light of the concerns about dolphin movements near and across the bridge alignment. The site near Tai O has been consistently identified as a critical dolphin habitat (Hung 2008, 2022). This site has also been affected by dolphin-watching activities in the past decade so the diurnal pattern of dolphin occurrence at this strategic location may also shed light on the potential impacts of such activities. Moreover, the addition of these two sites near Tai O and Shum Wat fills a large spatial gap in acoustical knowledge between SCLKCMP and SWLMP.

Another important consideration for the current deployment locations was that C-POD units had already been deployed successfully at all of these locations previously and continuously over multiple years. Continuing to collect data at these sites allows for interannual comparisons to examine temporal changes in dolphin and porpoise occurrence. Another critical logistical consideration for the deployment locations is the confirmation by the professional dive team of the feasibility of deploying and securing the attachment frames and C-POD and F-POD units, since water depth, substrate type and water current could greatly affect the success of deployments for extended periods.

In late June 2021, HKCRP applied for and obtained a permit from the Country and Marine Parks Authority to undertake the scientific study within the marine parks. Subsequently, 12 pairs of C-POD and F-POD units were deployed with installed underwater frames (80 cm in height with a footprint of 0.8 m^2) on July 6-8, 2021 (first deployment), October 20-29, 2021 (second deployment) and January 11-13, 2022 (final deployment), with the help of a professional dive team. During each trip, HKCRP researchers were on board with the dive team for the retrieval and refurbishment of the C-POD and F-POD units. All units (except one pair of C-POD and F-POD) were successfully recovered, refurbished and redeployed at the 12 locations; the exception was the failure to recover the C-POD and F-POD units and their associated underwater frame at the Lung Kwu Chau N site during the first deployment.

However, suspicions of a systematic problem were raised when unusually low dolphin detections by all C-POD units were observed after processing of raw data. Two of these C-PODs were returned to the manufacturer for inspection, which revealed that the filter setting in the software of the C-PODs was incorrectly applied by the manufacturer and thus too many dolphin clicks were being filtered out (and lost). Unfortunately, it was not possible to troubleshoot the issue prior to the October retrieval/deployment and so the second (October 2021 to January 2022) deployment, using C-PODs with the incorrect filter setting, also resulted in the loss of the entire data set for the deployment. Corrections to the filter setting are easily performed and should resolve the C-POD issues for future deployment. However, it is still recommended (where logistically possible) that these corrected C-PODs be compared with C-PODs from an older lot to increase confidence in the performance of these newer units. Although it was very unfortunate that the six months of C-POD data for this study were lost, it was fortunate that the issue was discovered, can be resolved easily and the problematic data can be confidently omitted to prevent compromising future analyses with these unreliable data. Furthermore, because the C-PODs were paired with F-PODs, the study period will not be completely void of PAM data.

After opening each unit, the SD memory card was removed and locked, and all batteries and SD cards were replaced with new ones. Then the clock of each unit was re-calibrated before closing the lid, and subsequently the same unit was re-deployed and re-attached to the underwater frame immediately for another three months of deployment. At each location, the C-POD and F-POD units' serial numbers as well as the time and date of deployment were recorded. The final retrievals and data recovery occurred on January 11th to 13th, 2022, after another approximately three months of passive acoustic monitoring data collection. In this draft final report, the only new data from this study that will be analyzed and reported were obtained from the F-PODs for about six months because the C-POD data were unreliable (see above).

3.2. Analysis of F-POD data

Upon the retrieval and refurbishment of each F-POD unit, the SD card with the F-POD data was removed from the unit for data download. The data file was opened on the *FPOD.exe* software for further analyses by the data analyst Mr. Daniel Murphy. For detailed data analyses, the raw click data on the F-POD was first converted by the *FPOD.exe* software to “FP1” files. The click data were then processed using the KERNO-F classifier to identify click trains and their likely sources and reject weak boat sonar. [Note: in the progress reports of the current study, an earlier version of the KERNO-F was used; however, in this report, a much-improved final version of KERNO-F was used to reprocess all F-POD data in this study so specific numbers may be different from those in the progress reports].

The two resident cetacean species in Hong Kong’s waters can be differentiated with great confidence because the click trains of porpoises are characterized by clicks being narrow band, high frequency (NBHF), contain many cycles per click and are comparatively quiet when compared with dolphins. In contrast, dolphins produce shorter clicks (i.e., less cycles per click) but are broadband across the detection range and the clicks are in general also much louder than those produced by porpoises, so multi-path detections (when clicks that reflect off the water surface or other objects are detected again) are more likely to occur. The classified click trains were then recorded into a “FP3” file after processing.

The integrity of the data recorded was first checked, and the period of adequate deployment and correct operation was identified. Visual validation was then performed to assess the overall rate of false positive dolphin (and porpoise) detection positive minutes (DPMs) as identified by the KERNO-F classifier. This validation was based on examining the detail characteristics of clicks, multi-path clusters and click trains for a representative sample of all detections. Additional criteria based on the characteristics of the ambient noise regime could also be used, particularly in relation to boat sonar and sediment transport noise, which can generate a large number of ultrasonic “clicks”.

It should be emphasized that the level of false positives is not some consistent fraction of true positives, but is determined by the prevalence of the sources that are liable to be misclassified as dolphin or porpoise clicks, such as boat sonar and sediment transport noise. Moreover, it should be recognized that the cause of a substantial proportion of the “false positive dolphins” is actually true dolphins, but are rejected simply because they are not distinctive enough to meet the high stringency of these criteria. The same also applies to porpoise detections.

After visual validation, the detection positive minutes (DPMs) were assessed for dolphin and porpoise occurrences at each deployment site within the five areas, including four marine parks and one non-marine park. The DPM was used for calculating the total number of minutes where at least one click train was detected within a one-minute period in order to measure the amount of time at least one dolphin (or porpoise) was present in an area. Using DPM could eliminate (or at least greatly reduce) the possibility of counting individual click trains produced by more than one individual, as the number of individuals detected is unknown.

To identify the effects of location (either areas or specific sites within an area), season (wet or dry) and time of day (i.e., diel period) on occurrence, the F-POD data were also examined statistically. For the seasons, we based our groupings on the wet and dry monsoon seasons (with clear differences in monthly rainfall amounts over many years in the region according to data maintained by the Hong Kong Observatory) rather than the four solar/astronomical seasons (i.e., spring, summer, autumn, winter) because the former appears to be more biologically important to the local CWDs and FPs. However, the two methods of seasonal classification correspond closely with each other in Hong Kong (i.e., the wet season spanned from about April to September, which matches well with the solar spring and summer, and the dry season extended from about October to March, which represent autumn and winter).

For the diel periods, the hours of the day were separated into “day” and “night”, and six hours were omitted around the “transitional” periods when sunrise and sunset occurred (three hours each for sunrise and sunset). The omitted hours included the hours immediately preceding and following, as well as the hour in which sunrise/sunset occurred. The omission of the “transitional” periods helps to reduce the confounding issues of including possible different activity levels during transitional periods and autocorrelations between two periods of time being adjacent to one another.

All subsets of data, which were used in various comparisons to better understand the effects of location, season and diel period on dolphin and porpoise acoustic activity were examined for deviations from the assumptions of parametric analyses (i.e., distribution normality (Kolmogorov-Smirnov and Lilliefors tests) and variance homogeneity (Levene's test)). An overwhelming number of the subsets of the F-POD data used for analyses were either significantly different from a normal distribution or heteroscedastic (note: some subsets had too few data for the results to be reliable but they were assumed to be the same as the larger subsets of data) so non-parametric statistical methods were employed. When comparisons were made across two independent groups, we applied the Mann-Whitney U test and for multiple independent groups, the Kruskal-Wallis ranks ANOVA test was used. When comparisons were made between or across dependent groups (i.e., for repeated measures where pairs of data are available for the same sample, such as the comparisons of data obtained during the day vs. night for the same day, which was the sample), the Wilcoxon matched pairs test (for paired groups).. The Spearman's rank coefficient was used to determine the degree of correlation between two variables.

3.3. Spatio-temporal analysis of long-term C-POD on CWD and FP activities

The entire C-POD data set obtained from June 6th, 2017 to July 8th, 2021 was examined to better understand spatio-temporal factors that may be correlated with acoustic activity patterns of CWD and FP. The factors examined included: location (sites and study areas), season (dry/wet), time of day (day/night). The results of the analyses of C-POD data collected since 2017 were compared across the years to determine if any patterns changed or were consistent across years.

Regression modeling was also used to determine the spatio-temporal factors (or combinations of factors) that best explained the observed patterns of C-POD detections of CWD. The coding for the regression analyses in R was written by collaborating researcher, Dr. Timothy R. Frasier (St. Mary's University, Halifax, Nova Scotia, Canada). With continuous data (such as those collected using C-PODs), there is often autocorrelation issues (i.e., if dolphins were detected in one minute, there can be a higher likelihood that detections would be made in adjacent minutes). Garrod et al. (2018) demonstrated that using a coarser time scale to stratify data (e.g., Detection Positive Hour (DPH) or coarser) was effective in addressing autocorrelations. Furthermore, a coarser temporal resolution also reduces the underestimation of presence that can occur with finer time scales (Garrod et al., 2018). DPH data were obtained from DPM data but were only of twos states: 1 (present) and 0 (absent) and this detection record represented the predicted variable in binomial regression models while site, season, and diel phase were the categorical predictor variables.

A series of increasingly complex regression models were used to better understand the relationships between dolphin detections and the three predictor variables as well as all combinations of these variables. Models began most simply with single predictor variables and then progressed to various combinations of the three predictor variables, including a three-way interaction (site x season x diel phase). Akaike's Information Criterion (AIC) was used to determine the best model for explaining the data as well as assess how the models changed as different parameters were included. The general linear model (glm) function in R was used with the argument family = binomial (link = "logit") because the predicted variable (DPH) was binomial (R Core Team, 2019). Values were converted back to the original scale using the invlogit function of the arm package in R (v1.11-1; Gelman & Su, 2020).

3.4. Examining correlation between C-POD and vessel-based line-transect survey data

Both PAM and vessel-based surveys have been conducted concurrently in many locations throughout Hong Kong's waters since 2018. These two kinds of studies provide independent measures of relative occurrence and distribution patterns of CWD (and finless porpoise) that can be compared and the level of congruence between the two data sets can be examined. Strong correlation between the two data sets not only increases confidence in observed trends but may also allow better interpretation or extrapolation of acoustic data when vessel-based survey data are unavailable (e.g., in low density areas or even possibly at night).

Because C-POD data are generally not homoscedastic nor normal, nonparametric correlation analyses (using the Spearman's coefficient) were conducted between vessel-based line-transect survey and PAM data. These data were collected concurrently to determine the level of congruence between them at yearly and monthly levels of resolution. For yearly comparisons, three parameters calculated from the vessel-based survey data (Hung 2020, 2021, 2022) were used: abundance (only for CWD – see below), sightings per unit effort (SPUE) and "dolphins" (can be either dolphins or porpoises) per unit effort (DPUE). For comparisons on a monthly level, only SPUE and DPUE could be used because there were not enough sighting data to reliably calculate abundance for each month and for each survey area. Comparisons were conducted for each boat survey area (i.e., NEL, NWL, WL and SWL) as well as for all survey areas combined. However, because there were so few dolphin sightings (one sighting in five years) and minimum acoustic detections from the NEL area, this survey area was excluded from any further analyses. For finless porpoises, only SWL sites (i.e., Kau Ling Chung, Siu A Chau, Tai A Chau N and Tai A Chau S) were considered because finless porpoise detections were absent from (or were very rare in) the C-POD data from other sites. Furthermore, because abundance estimates from the vessel-based surveys were not available for finless porpoises, temporal trends in porpoise occurrence were only examined through their encounter rates (SPUE and DPUE).

C-POD data from 10 of the 12 C-POD deployment sites were included. Excluded were the NEL sites at Siu Ho Wan and Tai Mo To, where both visual sightings and C-POD detections were too few for meaningful analyses. There were three C-POD sites within the NWL (Lung Kwu Chau N, Shau Chau SE and Shum Wat) and WL (Tai O, Peaked Hill and Fan Lau) survey areas and four sites (Kau Ling Chung, Siu A Chau, Tai A Chau N and Tai A Chau S) within the SWL survey area. Because of the great variation in dolphin (and porpoise) occurrence across sites, if C-POD data were missing from any site, data from all sites in the respective survey area during that period were omitted from further analyses because that area would not be accurately represented. Also, acoustic detections are known to vary greatly across different days and throughout the day so comparing boat survey data with the entire continuous C-POD data set would confound the results. Boat surveys only record occurrences (determined visually) during the time in which the boat-based observers are searching for dolphins. The finest temporal resolution for the C-POD data was at the hourly level so the data used for the comparisons were filtered to include only the hours of the day during which visual boat surveys were also conducted in the area (for the monthly comparisons). The implicit assumption with this selection of data is that detections by all C-PODs within any survey area in the same hours during which boat-based surveys were conducted, is representative of the dolphins present in that survey area for boat-based observers to detect even if the survey boat may not have passed through all C-POD sites.

Logging times also varied greatly across C-PODs because of differences in deployment/retrieval times and stoppage (due to battery drainage or reaching memory capacity, etc.). Thus, the DPMs for all sites were adjusted (scaled) to correct for varying logging times so that datasets were comparable across all C-PODs.

The results from such comparisons across survey areas and time allowed for the evaluation of the degree of correlation in spatial and temporal patterns of CWD (and FP) as determined by the two methods of data collection, and allowed for the cross-validations of the detected temporal trends in CWD and finless porpoise occurrences using both research methods adopted by AFCD (i.e., visual and acoustic methods) for the long-term marine mammal monitoring programme in Hong Kong.

3.5. Compare C-POD and F-POD datasets to evaluate the feasibility of data calibration

Initially, the plan was to compare the current six months of data obtained from the paired C-POD/F-POD deployments at each site during this study as well as the additional data collected during the F-POD trials by HKCRP since January 2020. Such comparisons would help in understanding the differences between the two systems and determining possible correction factors that may be used to make the two data sets (i.e., obtained from C-POD and F-POD) more easily comparable for future analyses of trends in marine mammal detections across years, even if equipment capabilities changed over time. Understanding the different abilities of the devices is critical if earlier PAM data obtained from C-PODs are to be used in comparison with future data obtained from F-PODs (e.g., to examine long-term temporal changes).

However, due to an erroneous filter setting by the manufacturer, the C-PODs used in this study failed to detect dolphins properly. Thus, the entire six months of C-POD data obtained during this project were deemed unreliable and thus omitted from further analyses to avoid confounding issues. Consequently, the only data available for such paired CPOD/FPOD analyses were obtained between January and July 2020 (at four sites: Siu Ho Wan, Lung Kwu Chau N, Kau Ling Chung and Tai A Chau N) and from July 2020 to July 2021 (at seven sites: the four sites as before and Sha Chau SE, Tai O and Siu A Chau).

Missing data from either C-POD or F-POD for any time period (daily or hourly) resulted in the omission of that time period from the analyses. Furthermore, double zero values (i.e., no detections at both C-POD and F-POD) can influence the apparent correlation between datasets especially at sites where few detections are made. Therefore, time periods with no detections by both C-POD and F-POD were also omitted. Finally, because there were no C-POD detections at Sha Chau SE during the paired C-POD/F-POD deployment periods, this site was also excluded from all analyses. Non-parametric (i.e., Spearman's) correlation analyses on the paired C-POD and F-POD data were performed for each site separately as well as combined to examine the overall relationships between the two datasets regardless of location. Furthermore, the Wilcoxon matched pairs test was used to determine if the levels of DPMs recorded by the two kinds of PODs were significantly different.

4. RESULTS AND DISCUSSIONS

4.1. Summary of F-POD Data Collection (Current FPOD Study)

4.1.1. Number of logged days

The 12 F-POD units combined for a total of 2,139.46 logged days (i.e., the number of days the 12 F-PODs were on and recording during the study period) (Table 1). With the exception of the F-POD at Lung Kwu Chau N, all F-PODs functioned normally and the number of days logged by individual F-POD units varied from 186.83 (Tai O) to 190.97 (Tai Mo To). During the first deployment, the Lung Kwu Chau N unit was not recovered (and assumed lost) so there was a total of only 63.95 logged days at Lung Kwu Chau N. The minimal difference in the number of logged days across sites is reflected in the lack of time lost for all F-PODs (except at Tai O, where % time lost was 3.07); therefore, the F-PODs were recording constantly during deployment throughout the study period. Noise would be the primary reason for % time lost (see below) and also battery drainage, which would shorten the operating period of the F-POD.

4.1.2. Percentage of time lost

The amount of time lost is related to the minute click limit being reached (i.e., “maxed out”) so that no further clicks will be detected and recorded until the start of the next minute. The click limit per minute can be exceeded in noisy environments. The most common causes of such time loss for click detections include: loud boat sonar, sediment transport noise (caused by the collisions of small particles of sediments during movement), snapping shrimps and occasional storms or rougher sea conditions.

The percentage of time lost by the F-PODs at the 12 sites combined was only 0.27% (or 5.73 days) of the total 2,139.46 logged days, which is much lower than for C-PODs in previous years. The only site with any time lost was Tai O (3.07%) while all other sites had no time lost (Table 1). The near zero total time lost in the F-POD data is clear evidence of the superiority of the F-POD in filtering out noise compared with the C-POD. However, it is uncertain why Tai O was the only site with any time lost, especially because sites that are known to be noisier (e.g., Tai Mo To, Tai A Chau N, Sha Chau SE, etc.) had no time lost during this study.

Notably, boat sonar (generally around 18, 50 and 83 kHz) was detected during all of the deployment periods among the 12 sites (see examples in Figure 2). Both boat sonar and sediment transport noise were detected by F-PODs and appeared to be the main sources of broadband ultrasonic noise.

4.1.3. False positives

The overall rate of false positive dolphin DPM, as identified by the KERNO-F encounter classifier, was assessed using visual validation. During the study period, false positive dolphin DPM was low at 0.46% overall. Site specific false positive rates varied from 0.00% (Siu Ho Wan, Tai Mo To, Lung Kwu Chau N, Sha Chau SE, Fan Lau, Kau Ling Chung, Siu A Chau, Tai A Chau N and Tai A Chau S) to 1.50% (Tai O and Peaked Hill). Only one other site (Shum Wat) had a non-zero % false positives (Shum Wat) (Table 1). Given these very low levels of false positives and that a considerable proportion of the false positives may actually be dolphin clicks (that were rejected because they failed to meet the stringent criteria of the validation process), there was no need to adjust for the false positives.

Visual validation to assess the site-specific rate of false positives in the porpoise DPMs identified by the KERNO-F encounter classifier found no (0.00%) false positives for all SWLMP and SLMP sites. Rates of false positives were not possible to calculate for the other sites because there were no porpoise detections (Table 1). The absence of false positives provided great confidence of the recorded porpoise detections.

4.2. Acoustic Detections of CWD and FP (Current FPOD Study)

After visual validation, the DPMs were assessed for dolphin and porpoise occurrences at each deployment location within the five areas (i.e., four marine parks and WL). Summaries of the data obtained from the 12 F-PODs deployed along with detection statistics for dolphins and porpoises are shown in Table 1 (also see Figures 3-9). All detections were assumed to belong to CWD or FP because these are the only two resident cetacean species in Hong Kong’s waters and all other cetaceans are extremely rarely observed in these waters (see Jefferson and Hung 2007). Of 48,257 total detection positive minutes (DPMs), 41,588 (or 86.18%) were from dolphins and 6,669 (or 13.82%) were from porpoises.

4.2.1. Acoustic detections of Chinese White Dolphins

Comparison of dolphin occurrence among sites and areas

The activity of CWDs, as measured by the proportion of all logged days with one or more detections (DPD% of logged days), varied greatly among the 12 deployment sites, from a low of 1.03% of 190.93 logged days (Siu Ho Wan) to 100.00% of 188.01 logged days (Peaked Hill) (Table 1). The other sites were somewhere in between these minimum and maximum values: 3.61% of 190.97 logged days (Tai Mo To), 6.31% of 187.93 logged days (Tai A Chau S), 17.55% of 190.94 logged days (Sha Chau

SE), 27.36% of 187.93 logged days (Siu A Chau), 50.50% of 187.94 logged days (Tai A Chau N), 61.02% of 188.04 logged days (Kau Ling Chung), 78.39% of 188.00 logged days (Fan Lau), 81.54% of 63.95 logged days (Lung Kwu Chau N), 84.07% of 186.83 logged days (Tai O) and 88.17% of 188.00 logged days (Shum Wat). Comparing across the five areas, BMP had the lowest value at 2.32% of 381.90 logged days while WL had the highest at 86.13% of 374.83 logged days. The values for the other areas were: 28.06% of 563.80 logged days (SLMP), 33.60% of 254.89 logged days (SCLKCMP), and 79.80% of 564.04 logged days (SWLMP).

Similarly, the mean DPM per day metric also varied widely between 0.03 at Siu Ho Wan and 143.27 at Peaked Hill, while all the other sites followed a similar general pattern as with the DPD% of logged days (with some minor differences in rank orders): Tai Mo To (0.04), Tai A Chau S (0.12), Sha Chau SE (0.73), Siu A Chau (0.91), Kau Ling Chung (6.21), Tai A Chau N (6.59), Lung Kwu Chau N (15.08), Tai O (16.12), Fan Lau (16.79) and Shum Wat (25.37) (Table 1). Considering the five areas, mean DPM per day followed a similar pattern as with DPD% of logged days, except SWLMP had a higher value than WL (in increasing order: BMP (0.03), SLMP (2.54), SCLKCMP (4.33), WL (20.76) and SWLMP (55.42)). Thus, the area with the highest mean DPM per day (SWLMP) was >1,847 times higher than the lowest (BMP).

Overall, the 12 sites can be classified into four general groups based on similar DPM metrics: Peaked Hill (highest levels of dolphin DPM metrics and much higher than any other site); Fan Lau, Tai O, Lung Kwu Chau N and Shum Wat (moderate to high levels); Kau Ling Chung and Tai A Chau N (moderate levels); Siu A Chau, Sha Chau SE, Tai A Chau S, Siu Ho Wan, and Tai Mo To (low to extremely low levels). With few exceptions, the rank orders of the areas and sites were generally consistent with those found in the C-POD data obtained in 2019-20 and 2020-21.

Not surprisingly, statistical analyses (Kruskal-Wallis ranks ANOVA test) showed significant differences in daily DPM among the five areas ($H (4, N=2152) = 880.22$, $p<<0.001$) and all pairwise comparisons (except between SCLKCMP and SLMP) between areas were significantly different from each other. These results strongly support that for further examinations of sites as well as diel and seasonal patterns, data for the five different areas should be analyzed separately to prevent areas with large numbers of detections overwhelming areas with many fewer detections.

Mann-Whitney U tests were used to determine if the two sites within each of the BMP, SCLKCMP and WL areas differed from each other with regards to daily dolphin

DPMs, while Kruskal-Wallis ranks ANOVA tests were used to examine the three sites within SWLMP and SLMP. The two BMP sites were not statistically different from each other ($U=17955$; $p=0.095$) but statistical differences were found between the two sites within the SCLKCMP ($U=1686.5$, $p<<0.0001$; with Lung Kwu Chau N having more DPMs than Sha Chau SE) and WL ($U=15262.5$, $p<0.05$; with Shum Wat having more DPMs than Tai O). The sites within the SWLMP showed significant differences ($H (2, N=567) = 316.39$, $p<<0.001$) and all pairwise comparisons of the three sites were also significantly different: Peaked Hill vs. Fan Lau (z' value = 13.36, $p<<0.0001$); Peaked Hill vs. Kau Ling Chung (z' value = 16.75, $p<<0.0001$) and Fan Lau vs. Kau Ling Chung (z' value = 3.39, $p<0.005$). Among the three sites within the SWLMP, Peaked Hill had the largest number of CWD detections while Kau Ling Chung had the lowest. The sites within the SLMP were also significantly different ($H (2, N=567) = 34.06$, $p<<0.001$) from each other as shown by pairwise comparisons of the three sites (except one): Siu A Chau had significantly more CWD detections than Tai A Chau N (z' value = 5.07, $p<<0.0001$) but was not different from Tai A Chau S (z' value = 1.91, $p=0.17$) and Tai A Chau N had significantly more CWD detections than Tai A Chau S (z' value = 3.16, $p<0.005$).

These PAM results are completely consistent with the findings of visual surveys in the past five years where dolphin density was consistently the highest in SWLMP, followed by WL and then SLMP, SCLKCMP and BMP (which had the fewest, by far) (Hung 2021, 2022). However, if the F-POD at Lung Kwu Chau N was not lost during the first deployment, SCLKCMP would likely have had more detections than SLMP. The 2021-22 F-POD data were also completely consistent with C-POD data obtained in 2019-20 and 2020-21 with regards to relative spatial differences in CWD detections across the areas.

It is also interesting to note that only moderate levels of dolphin DPMs were detected at the Shum Wat and Tai O sites in the present study when compared to the relatively high levels detected at the adjacent, nearby site of Peaked Hill, even though the waters near Tai O Peninsula and Shum Wat have been consistently identified as important dolphin habitats with high dolphin occurrence in the past (e.g., Hung 2008, 2022). The unexpected relatively lower level of acoustic detections at Tai O could be related to the deployment location, which was constrained by diving logistics, as the F-POD unit had to be deployed in the inner bay of Tai O to avoid the strong current at the outer western edge of Tai O Peninsula where most dolphins have been encountered during visual surveys. The deployment location at Tai O also overlapped with the traveling route of the dolphin-watching speedboats (also known as “wala-wala”) and other boats that leave frequently from the port of the fishing village throughout the day, which may also reduce dolphin occurrence at or near this deployment site during the day time. At Shum Wat, deployment site choice was not the issue because it was the same site for C-PODs in previous years, when detection levels were much higher than in more recent years. The reason(s) for the much lower levels of detection when compared with Peaked Hill may be due to higher levels of past (and more recent) human disturbance near Shum Wat (e.g., continuing degradation of habitat by ongoing construction related to the airport expansion, the construction of the Hong Kong-Zhuhai-Macau Bridge, suspected smuggling activities by mainland Chinese vessels in this area (mostly anchored during the day but likely active during the night time)). Close monitoring of the lower and declining trend in dolphin occurrence at Shum Wat should be continued.

Comparison of dolphin occurrence between seasons

With data missing from Lung Kwu Chau N during the first deployment, it was not possible to compare across the two (wet and dry) seasons at this site. For all other sites, Siu Ho Wan, Tai Mo To, Sha Chau SE, Siu A Chau and Tai A Chau S always ranked amongst the sites with the lowest CWD detections, with Siu Ho Wan always having the lowest values for all detection metrics (including no detections recorded during the first deployment (most of which was comprised of wet season days). Peaked Hill always had the highest (by far) detection metrics in both seasons. Shum Wat, Tai O and Fan Lau always had the next highest detection metrics that were similar to each other and their rank order varied depending on the metric and season. Kau Ling Chung and Tai A Chau N had values that were below the above sites but well above those in the lowest group but their rank order varied between the deployments and metrics examined. The F-POD array detected dolphins at every site during the study period (except at Siu Ho Wan during the first deployment).

Because F-POD recording times differed greatly among sites (e.g., F-POD loss or stoppage due to malfunction or battery drainage due to excessive noise), DPM counts can be affected by the number of data logging days. Thus, DPD% of logged days and mean DPM/day are better metrics for comparisons across sites because differences in effort are considered. Discrepancies between the rank order of sites based on DPD% of logged days as compared to mean DPM/day suggest that at different sites, dolphins may differ in how long they remained at a site, their group size or their rate of production of detectable sounds (e.g., mean DPM/day may be inflated if dolphins spent a greater amount of time foraging and thus emitting more clicks and more often at some sites). Repeated consistent discrepancies between these two metrics over a longer period may help to shed insight into the behaviour of the dolphins at each site as well as the importance of each site to the dolphins. Coupling F-POD data with visual observations of dolphin behaviour would also help to further understand the reasons for the discrepancies observed in these two acoustic parameters. It may also be possible and interesting to investigate individual click trains detected by F-PODs to identify feeding attempts. However, this type of work is presently quite labour-intensive and time-prohibitive so full analyses of the data for feeding attempts will only be possible when automated detection of feeding click trains is available. The newly available F-POD with its associated software, which is still being refined, shows some promise for accomplishing some of the automated data processing needed for such studies.

When comparing areas using the metrics that accounted for effort (i.e., DPD% of logged days and mean DPM/day), SWLMP had all the highest values for mean DPM/day in both deployments (and thus overall) whereas WL had the highest values DPD% logged days in both deployments (and overall). SLMP had the next highest mean DPM/day and DPD% of logged days during the first deployment but SCLKCMP had the next highest values for these two metrics in the second deployment. Overall, SCLKCMP had higher values for these two metrics than SLMP. BMP had clearly the lowest values for all deployments and overall. The rank order of the areas was the same as observed in C-POD data from 2019-20 and 2020-21 with the exception that in the current study, the DPD% logged days were highest for WL (rather than for SWLMP as in past years).

There were clear seasonal differences in the daily CWD DPM metrics across all areas and all sites with the dry season having higher values for both metrics (see Figures 3-7, Table 2). Meaningful statistical analyses were not possible for BMP (due to insufficient detections) and SCLKCMP (due to lost equipment during the first (wet season) deployment period). Significantly more detections were found at WL ($U=8250.5$, $p<<0.0001$) and SWLMP ($U=25407$, $p<<0.0001$) but no differences were found at SLMP ($U=37574.5$, $p=0.196$) (Table 2). For four of the 12 sites (Siu Ho Wan, Tai Mo To, Lung Kwu Chau N and Tai A Chau S), there were too few to no detections for meaningful analyses. For the remaining eight sites, seven had significantly higher metrics during the dry season (Sha Chau SE ($U=3643.5$, $p<0.001$), Shum Wat ($U=2383.5$, $p<<0.0001$), Tai O ($U=1699$, $p<<0.0001$), Peaked Hill ($U=1587$, $p<<0.0001$), Fan Lau ($U=1779$, $p<<0.0001$), Kau Ling Chung ($U=2380$, $p<<0.0001$) and Tai A Chau N ($U=3379$, $p<0.005$)) while the higher detections during the dry season at Siu A Chau was not significant statistically ($U=3999.5$, $p=0.153$). The current F-POD study is consistent with the C-POD data of 2020-21 where the dry season had higher detections, which is different from that observed in 2019-20. Currently, it is uncertain which season pattern of occurrence is most common and this can only be determined with more years of data.

Finally, the regular bursts of activity observed in C-POD data every 1.5-2 months from July 12th, 2019 to April 12th, 2020 (see Figure 5 in Wang and Hung 2020) were observed neither in the 2020-21 C-POD study (Wang and Hung 2021) nor in the current F-POD data. Thus, the regular bursts observed in 2019-20 were likely a coincidental pattern rather than of any biological importance.

4.2.2. Acoustic detections of Finless Porpoises

Comparison of porpoise occurrence among sites and areas

Porpoises were primarily detected at the sites in SLMP and SWLMP (but very few detections were made at Peaked Hill and Fan Lau and only during the second deployment) (Table 1; Figures 8-9). The activity of porpoises at sites where they are not rare events, as measured by DPD% of logged days, varied greatly among deployment sites, from a low of 26.20% (Kau Ling Chung) to 73.66% (Tai A Chau N) of logged days with at least one detection. The other two sites were somewhere in between these minimum and maximum values: Siu A Chau (51.05%) and Tai A Chau N (72.08%). The other porpoise DPM metrics (counts and mean DPM/day) also showed the same ordering of sites from low to high values except that Tai A Chau S had a slightly higher DPD% of logged days than Tai A Chau N (Table 1). Statistical comparisons of porpoise detections between SWLMP and SLMP using the Mann-Whitney U test showed significant differences between the areas with regards to daily DPMs, with SLMP having much higher levels of detections ($U=67668.5$; $p<<0.001$). Thus, further analyses of sites as well as diel and seasonal patterns within these areas were conducted separately. The most interesting pattern observed was the overall general decrease in porpoise detections as latitude increased among these sites although the correlation was not perfect (see Section 4.2.4).

The Kruskal-Wallis ranks ANOVA test was used to examine the three sites within the SLMP area (for SWLMP, porpoise detections were really only recorded at Kau Ling Chung). The three sites within SLMP were significantly different from each other ($H(2, N=567) = 38.81$, $p<<0.0001$) and pairwise comparisons showed that Siu A Chau had significantly fewer DPMs than either Tai A Chau N (z’ value = 5.21, $p<<0.0001$) or Tai A Chau S (z’ value = 5.38, $p<<0.0001$) but Tai A Chau N and Tai A Chau S were not significantly different from each other (z’ value = 0.17, $p=1.00$). This pattern of occurrence within SLMP was the same that was observed by the 2020-21 C-POD study (see Wang and Hung 2021).

The general pattern of decreasing porpoise daily DPMs with increasing latitude was consistent with previous PAM studies (Wang and Hung 2019, 2020, 2021) as well as the findings of visual surveys where porpoise density is the highest in the Tai A Chau region and porpoises rarely occurred in the SWLMP region north of Fan Lau and are absent in WL, BMP and SCLKCMP. In fact, visual surveys have never detected any porpoise occurrence to the north of Fan Lau in the past 20+ years, until an extremely rare sighting of a lone porpoise was recently made just to the west of Fan Lau Peninsula in March 2021 (Hung 2021). Porpoise detections at Fan Lau and Peaked Hill in the present study (and only during the second deployment) were clearly rare events but similarly rare events have been recorded by C-PODs at Fan Lau and Peaked Hill in 2018-19 and 2020-21 and at Fan Lau in 2019-20 (Wang and Hung 2019, 2020, 2021). With so few detections, it is uncertain if porpoises actually produced these click trains because it is possible that dolphins may be capable of periodically producing click trains that resemble porpoises (Cosentino et al. 2018; Wang and Hung 2018, 2019, 2020, 2021). No porpoises were detected at Peaked Hill in 2019-20 while in this F-POD study, only 8 and 19 DPMs were recorded at Peaked Hill and Fan Lau, respectively, which further confirmed the rarity (and the likely biological insignificance) of these events. However, continued monitoring is prudent and it may be possible to determine if, and how often, CWDs produce porpoise-like clicks by conducting a study that specifically couples land-based theodolite tracking of dolphins around a deployed F-POD.

<u>Comparison of porpoise occurrence across different seasons</u>

Considering the entire study period, Tai A Chau N and S had the highest porpoise detections regardless of DPM metrics. Tai A Chau N had higher DPM counts and mean DPM/day but Tai A Chau S had a slightly higher DPD% of logged days). Siu A Chau had the next highest values for the DPM metrics and Kau Ling Chung had the lowest (Table 1). When looking across the different seasons, the rank orders of the sites were somewhat similar with a few exceptions: Siu A Chau had higher values for DPM counts and mean DPM/day than the Tai A Chau sites during the wet season (July to October) but this was reversed during the dry season deployments (October to January), when Siu A Chau always had lower metrics than both Tai A Chau sites (Figure 9). Kau Ling Chung was the only SWLMP site with a meaningful number of detections for analyses and comparison (Figure 8). Kau Ling Chung had lower values of DPM metrics than all three SLMP sites overall as well as during the dry season. However, during the wet season, DPM count and mean DPM/day for Kau Ling Chung were higher than at both Tai A Chau sites (but lower than Siu A Chau) but DPD% logged days remained lower than all SLMP sites. Because the current study only included part of the dry and wet seasons, comparison with previous C-POD data (which includes data from the entire year) may be misleading and should not be conducted until F-POD data from an entire year is available.

Discrepancies between the rank order of sites with regards to DPD% of logged days and mean DPM/day suggests that at different sites, porpoises may differ in how long they remained at a site, their group size or their rate of production of detectable sounds (e.g., mean DPM/day may be inflated if porpoises spent a greater amount of time foraging and thus emitting more clicks and more often at some sites). Repeated consistent discrepancies in these metrics over a longer period may help to shed light on the behaviour of porpoises at these sites and the importance of these sites to porpoises. Although coupling F-POD data with visual observations of porpoise behaviour would help to further understand the reasons for the acoustic discrepancies observed, this may be more challenging for porpoises because of the difficulty in observing them visually. It may also be possible and interesting to investigate individual click trains detected by the F-PODs to identify feeding attempts. However, this type of work is presently quite labour-intensive and time-prohibitive so full analyses of the F-POD data for feeding attempts will only be possible when automated detection of feeding click trains is available. The newly available F-POD with its associated software, which is still likely to be refined, shows some promise for accomplishing some of the automated data processing needed for such studies.

When comparing the areas using the metrics that accounted for effort (i.e., DPD% of logged days and mean DPM/day), it was clear that SLMP had the highest values by far (Table 1). For the sites, Tai A Chau N and S had higher detection metrics in the second deployment (dry season) while Siu A Chau and Kau Ling Chung had higher metrics in the first deployment (wet season), which was similar to the pattern found in the 2020-21 C-POD study.

Overall, it was clear that porpoise detection metrics were higher in the dry season (the rare porpoise detections recorded at Fan Lau and Peaked Hill also occurred during the dry season) than the wet season (Figures 8-9). For SLMP, there were clearly more daily porpoise DPMs during the dry season compared with the wet season (SLMP: $U=31003$, $p<<0.0001$) (Table 2). When comparing within the sites, significantly more daily DPMs were found during the dry season at both Tai A Chau sites (Tai A Chau N ($U=1840$, $p<<0.0001$) and Tai A Chau S ($U=2900$, $p<<0.0001$)). In contrast, the other two sites had significantly more daily DPMs during the wet season: Siu A Chau (U=3568, p<0.05) and Kau Ling Chung (U=3255, p<<0.0001) (Table 2; Figure 8-9). For Peaked Hill and Fan Lau, all detections were recorded in the dry season but too few detections were available for meaningful statistical analyses. The distinct seasonality of porpoise occurrence in SLMP as shown in the acoustic data is consistent with the visual monitoring data obtained in the past two decades, which demonstrated that the peak season of porpoise occurrence in South Lantau waters is between December and May (Hung 2008, 2021, 2022).

4.2.3. Diel Patterns in CWD and FP Occurrences

The F-POD data from the present study provided some novel information on the 24-hour activity pattern of the local dolphins (over a large spatial scale) and porpoises. The data revealed some clear differences in diel peak activity periods during different times of the day and at different sites for both dolphins and porpoises.

Diel patterns of dolphin occurrence

For BMP sites, there were too few detections for meaningful analyses and for SCLKCMP, the F-POD at Lung Kwu Chau N was lost during the first (wet season) deployment so analyses are limited for that site as well as the area. When considering the entire study period, there were strong overall diel patterns at different areas and sites. There were significantly more dolphin DPMs at night than during the day at SCLKCMP (T=520.5, z=4.80, p<<0.0001), WL (T=16614.5, z=3.802, p<<0.001) and SLMP (T=4202.5, z=2.272, p<0.05) (Table 3 and Figures 10-14 and 18-20). In contrast, SWLMP had the reverse pattern with significantly more DPMs in the day than at night (T=20821.5, z=9.795, p<<0.0001) (Table 3 and Figures 15-17). For SCLKCMP, it was not possible to examine diel patterns during the wet season because the F-POD at Lung Kwu Chau N was lost; during the dry season, the same pattern with significantly more detections at night was observed. Both WL and SWLMP also had the same general patterns of high and low diel acoustic activities as the entire 6-month study period regardless of the season. However, for SLMP, the overall pattern of significantly more detections during the night time was only reflected during the dry season while the wet season had significantly more detections in the day time (Table 3 and Figure 19).

When considering the full 6-month data set, only three sites had significantly higher detections at night than during the day time: Sha Chau SE (Wilcoxon T=38.5, z=3.480, p<<0.001), Shum Wat (Wilcoxon T=2511, z=5.995, p<<0.0001) and Tai A Chau N (Wilcoxon T=38.5, z=3.480, p<<0.001). The other five sites with sufficient detections for meaningful analyses all had more detections in the day time but two sites did not have significantly more: Tai O (Wilcoxon $T=4740$, $z=1.352$, $p=0.176$), Peaked Hill (Wilcoxon $T=3590$, $z=7.154$, $p \ll 0.0001$), Fan Lau (Wilcoxon $T=3012.5$, $z=3.574$, $p<0.0005$), Kau Ling Chung (Wilcoxon $T=752.5$, $z=6.335$, $p \ll 0.0001$), Siu A Chau (Wilcoxon $T=375$, $z=1.808$, $p=0.071$) and Tai A Chau N (Wilcoxon $T=1215$, $z=3.350$ $p<0.001$) (Table 3). For both BMP sites, Lung Kwu Chau N (due to loss of F-POD during the first (wet season) deployment) and Tai A Chau S, there were insufficient detections for meaningful analyses (except for Lung Kwu Chau N during the dry season). The most common diel pattern found in the current F-POD data set (i.e., more CWD detections during the day) was the opposite of the pattern observed in past C-POD data sets.

For the areas which had sufficient data for analyses of the diel patterns separately for wet and dry seasons, all showed the same general diel pattern as for the entire study period, except SLMP during the wet season, which had the opposite pattern than observed for the entire data set (Table 3). Therefore, the general diel pattern of occurrence did not seem to be overly affected by season. All sites also followed the same patterns as its respective area and where they did not (Tai O and Siu A Chau – all data), the opposite pattern observed was not statistically significant (Table 3).

Considering all the results together, it is clear that some strong diel patterns exist in CWD DPMs. In the C-POD data of previous years, the general pattern for most sites during both seasons was higher DPMs during the night but the pattern was reversed in the SWLMP sites. This interesting pattern reversal was also observed previously in other sites (e.g., Lung Kwu Chau N during the wet season in 2017-18 (Wang and Hung 2018) and at several sites in 2018-19, especially during the dry season (Wang and Hung 2019)). In the current study with F-PODs, the reverse pattern was most commonly observed but this may be at least partially due the lack of data from BMP sites and missing data from Lung Kwu Chau N. Regardless, the biological reasons for these diel differences and at different sites should be investigated further in future years when more data become available, particularly for the SWLMP sites where the atypical pattern appears to occur most often, including in the current F-POD data set.

<u>Diel patterns of porpoise occurrence</u>

When considering the full six-month data set, there were significantly more DPMs during the night than the day at SWLMP (Wilcoxon $T=221$, $z=5.012$, $p \ll 0.0001$) (Table 4), but it is important to note that Peaked Hill and Fan Lau had very few detections so the SWLMP pattern is more or less reflecting the Kau Ling Chung pattern (Wilcoxon $T=35$, $z=5.446$, $p<<0.0001$) (Figures 21-23). Thus, conclusions about the diel patterns about porpoises in this area need to be made cautiously. Significantly higher night time DPMs were also observed in the wet and dry seasons for SWLMP (Wilcoxon $T=21$, $z=4.544$, $p<<0.0001$ and Wilcoxon $T=102$, $z=2.090$, $p<<0.0001$, respectively) and Kau Ling Chung (Wilcoxon $T=21$, $z=4.544$, $p<<0.0001$ and Wilcoxon $T=0$, $z=3.180$, $p<0.05$, respectively). The highest level of porpoise DPMs at SWLMP occurred roughly from about 20:00 to 06:00. The latter part of the larger peak was also observed during the wet season (Figure 22) while the diel pattern during the dry season was more or less the same except that the large peak of activity ended at 03:00 and there were several small peaks of activity throughout the day (Figure 23).

At SLMP, a similarly clear overall diel pattern with more porpoise DPMs at night than during the day (Wilcoxon $T=15312$, $z=7.169$, $p<<0.0001$) was also observed (Table 4 and Figure 24). The general diel pattern observed at SLMP was consistent regardless of seasons, with the highest activity being from about 19:00-20:00 to about 06:00-07:00 (Figures 24-26). The SLMP pattern of significantly higher DPMs at night was also reflected at all three sites: Siu A Chau (Wilcoxon $T=693$, $z=4.971$, $p<<0.0001$), Tai A Chau N (Wilcoxon $T=2057$, $z=4.633$, $p<<0.0001$) and Tai A Chau S (Wilcoxon $T=2708.5$, $z=2.909$, $p<0.005$) (Table 4). When the diel patterns of porpoise DPMs were analyzed separately for wet and dry seasons, SLMP showed significantly more DPMs at night in both wet and dry seasons (Wilcoxon $T=2413.5$, $z=4,387$, $p<<0.0001$ and Wilcoxon $T=5563.5$ $z=5.715$, $p<<0.0001$, respectively) (Table 4). The diel patterns of all sites within SLMP were the same with night having significantly more DPMs regardless of season but this was not significant at Tai A Chau N and Tai A Chau S during the wet season (Wilcoxon $T=342$, $z=1.582$, $p=0.114$ and Wilcoxon $T=414$, $z=0.945$, $p=0.345$, respectively) (Table 4).

The consistent, clear diel patterns in porpoise DPMs observed at both the SWLMP and SLMP areas (with many more DPMs during the night hours) (Table 4 and Figures 21-26) was also observed in the 2020-21 C-POD study but this pattern was inconsistent in studies before 2020-21. Specifically, porpoise detections at SWLMP did not show clearly higher detections at night than during the day in the past. More data are needed (especially for SWLMP) to understand the observed change in diel patterns but seasonality does not appear to change observed diel patterns.

4.2.4. Spatial and Temporal Overlaps in CWD and FP Occurrences

Both CWD and FP were detected by the F-PODs at SWLMP and SLMP sites but only a very few porpoise detections were made at Peaked Hill and Fan Lau (and only during the second deployment). Nevertheless, Peaked Hill and Fan Lau sites were included in the site-specific comparisons of descriptive statistics between dolphin and porpoise detections because limited porpoise detections have also been made by C-PODs at these sites in previous years and so they provide additional comparative sites where both species have been detected.

Comparisons of the detection metrics (DPM counts, DPD% of logged days, mean DPM/day) of both species at the sites that recorded both species, showed a general inverse correlation between the two species. While there was a general decrease in porpoise DPM metrics with increasing latitude, the opposite was also generally true with increasing CWD detections until Peaked Hill, where dolphin detections were at the maximum (Figures 27-29). However, the relationship was not followed tightly by Tai A Chau N, which had higher porpoise DPMs and mean DPM/day than Tai A Chau S and higher CWD detections (all metrics) than at Siu A Chau. There was also minimal temporal overlap in CWD and FP detections when examined at the temporal resolution of an hour (i.e., there were relatively fewer hours in which both CWD and FP were detected) and there was a strong inverse correlation between dolphin DPMs and porpoise DPMs (i.e., hours with higher dolphin DPMs had fewer porpoise DPMs and vice versa) (Spearman's $r = -0.745$, $p << 0.0001$) (Figure 30). This strong inverse relationship pattern between dolphin and porpoise detections was consistently found for both areas (SWLMP and SLMP) as well as for Kau Ling Chung and all three sites within SLMP, and were similar to the patterns found in 2018-19, 2019-20 and 2020-21 (Wang and Hung 2019, 2020, 2021). The low level of spatio-temporal overlap between the two species that was observed at the hourly level of temporal resolution will almost certainly be even more obvious if examined at an even higher level of temporal resolution.

4.3. Long-term Spatio-temporal Patterns in C-POD Detections of CWD and FP

Summaries of the basic C-POD metrics for dolphins and porpoises obtained from 12 sites since 2017 are shown in Tables 5 and 6 (also see Figures 31-37). Unfortunately, a faulty filter setting by the manufacturer of the new C-PODs that were deployed from July 2021 to January 2022 resulted in unreliable data and thus not included in any further analyses so the data examined here only extend to early July 2021. All detections were assumed to belong to CWD or FP because these are the only two resident cetacean species in Hong Kong's waters and all other cetaceans are extremely rarely observed in these waters (see Jefferson and Hung 2007).

In 2017-18, C-PODs were deployed at only six sites and all within the BMP or SCLKCMP areas so there were little chance of detecting porpoises. Furthermore, of the three sites within each area for which C-PODs were deployed in 2017-18, no further deployments were made at one site in each area (i.e., Spoon Island and Lung Kwu Chau S). For the two sites in each of the BMP and SCLKCMP that became long-term deployment sites (i.e, Lung Kwu Chau N, Sha Chau SE, Siu Ho Wan and Tai Mo To), a total of 21,596 CWD detection positive minutes (DPMs) were made in 2017-18 during 1,466.8 logged days. Because only four of the 12 long-term sites were sampled in 2017-18, comparing the metrics from all detections combined with later years is not very instructive. However, because the same sites (and areas) in 2017-18 were also used for collecting data from 2018-21, these sites and areas could be compared across the study periods.

From 2018-21, C-PODs at the 12 long-term deployment sites recorded 311,346 total DPMs during a total of 12,246.9 logged days. Of these DPMs, 220,977 (or 70.97%) were from dolphins and 90,370 (or 29.03%) were from porpoises. Examining the year-to-year changes in the relative composition of the overall total DPMs, the % CWD DPMs went from 76.98% (2018-19) to 76.41% (2019-20) and then dropped sharply to 55.84% (2020-21). Mirroring these proportions were the porpoise DPMs which changed from 23.02% (2018-19) to 23.39% (2019-20) and then a large increase to 44.16% (2020-21).

4.3.1. Acoustic detections of Chinese White Dolphins

Because there was great variability in the amount of data collection effort (i.e., logged days) across time and locations due to various reasons, comparisons across study periods were best made using metrics that accounted for such variation in effort rather than simple counts (i.e., DPMs). The proportion of all logged days with one or more detections (DPD% of logged days) and mean DPM/day are two metrics that can be used for such comparisons. Overall DPD% of logged days for all sites combined was near 100% for every study period and changed little across the study periods (Table 5), which indicated that the 12 C-POD sites were sufficient to record at least one DPM every day across all sites. However, this coarseness of spatial examination may be of limited interest.

When looking at the trends on finer spatial scales (areas or sites), it was clear that DPD% of logged days decreased at most areas and sites across the study periods. All areas showed continued year-over-year declines in DPD% of logged days in the data available for each area. This was the same pattern with mean DPM/day with the exception of WL, which showed a slight increase in 2020-21 (from 2019-20 but still well below 2018-19 levels) after a larger decline from 2018-19 to 2019-20. For almost all sites (Siu Ho Wan, Tai Mo To, Lung Kwu Chau N, Sha Chau SE, Shum Wat, Tai O, Kau Ling Chung, Siu A Chau, Tai A Chau N and Tai A Chau S), continuing declines in DPD% of logged days were observed. Peaked Hill and Fan Lau had the highest values and both showed a slight increase from 2018-19 to 2019-20 before a minimal decrease in 2020-21. At Tai A Chau S, DPD% of logged days declined greatly from 2018-19 to 2019-20 and then increased slightly in 2020-21 but well below the level of 2018-19.

With regards to mean DPM/day, almost all sites showed year-over-year decreases. The exceptions included: a negligible increase at Sha Chau SE from 2017-18 to 2018-19 before declining greatly to zero (in 2020-21); Tai O, Peaked Hill and Tai A Chau S all showed considerable relative decreases from 2018-19 to 2019-20 before increasing again in 2020-21 (when Tai O and Peaked Hill recorded the highest mean DPM/day); Kau Ling Chung was little changed across the study periods but 2019-20 had the highest value; Siu A Chau increased from 2018-19 to 2019-20 before dropping to a very low level in 2020-21 (see Table 5). Overall, the lowest values of DPM metrics occurred in 2020-21.

The decline in CWD detections can be seen in the long-term plots of DPMs over time for most sites (Figures 31-35) and statistical analyses confirmed that the decreases in CWD DPMs were statistically significant for most sites (Table 7 and Figures 38-42).

<u>Comparison of dolphin occurrence between seasons</u>

When comparing across the years, there was no consistent seasonal pattern that applied for all sites and areas (Table 8). SCLKCMP and WL consistently had more DPMs in the dry season than during the wet season whereas SLMP had consistently more DPMs in the wet season. For BMP and SWLMP, the seasonal patterns were different during different study periods. When examining the sites, only Lung Kwu Chau N and Shum Wat had consistent seasonal patterns across all study periods whereas the seasonal patterns for the other sites varied with study period. The reason(s) for the changing patterns across study periods at some sites and areas is uncertain and need more research. As well, the reason(s) for some sites and areas having different seasonal patterns is also uncertain and need to be better understood.

4.3.2. Acoustic detections of Finless Porpoises

Because there was great variability in the amount of data collection effort (i.e., logged days) across time and locations due to various reasons, comparisons across study periods were best made using metrics that accounted for such variation in effort rather than simple counts (i.e., DPMs). DPD% of logged days and mean DPM/day can be used for such comparisons. Overall DPD% of logged days for all sites combined changed little across the study periods with a slight increase in 2020-21 (Table 6). This suggest that the C-PODs at the six (primarily four) sites where finless porpoises have been recorded were sufficient to record at least one DPM almost every day. However, the results of this coarseness of spatial examination may be of limited interest.

When looking at the trends on finer spatial scales (areas or sites), it was clear that for the two areas (i.e., SWLMP and SLMP) and for most sites (Peaked Hill, Fan Lau, Siu A Chau and Tai A Chau S), DPD% of logged days decreased from 2018-19 to 2019-20 before increasing again in 2020-21. At Kau Ling Chung, DPD% of logged days increased from 2018-19 to 2019-20 and then more or less stayed the at the same level in 2020-21 while at Tai A Chau N, the levels increased year-over-year. With regards to mean DPM/day, both areas and almost all sites showed the same pattern observed in the DPD% of logged days metric where levels decreased from 2018-19 to 2019-20 before increasing in 2020-21. Fan Lau and Siu A Chau were exceptions to this general pattern where the mean DPM/day increased year-over-year at Fan Lau and at Siu A Chau, it decreased year-over year (see Table 7 and Figures 43-44). Overall, the highest values of the DPM metrics were in 2020-21 (Table 6), which is the opposite of the observed DPM metrics for CWD.

Unlike the clear declines in CWD detections over the years, overall porpoise detections have not noticeably changed too much (Figures 36-37). There are some indications of declines at Siu A Chau but at the same time increased detections were made at Tai A Chau N and it was not clear if there has been any net change at Tai A Chau S after three study periods (Figure 44). More years of data are required to determine the long-term trajectory of porpoise occurrence.

Comparison of porpoise occurrence across different seasons

Because there were too few finless porpoise detections at Peaked Hill, comparisons across study periods were not possible. For all the other sites and areas, the seasonal patterns observed were consistent across all study periods. Only at Siu A Chau, was there more detections during the wet season than the dry, which is the opposite of all other sites (as well as the areas) (see Table 9). Finless porpoises appear to have more defined seasonal patterns than CWD. The reason(s) for the reversed seasonal patterns at Siu A Chau is uncertain and needs more research. Overall, many more detections of finless porpoises occurred during the dry season periods, which is consistent with the boat-based visual survey data.

4.3.3. Diel Patterns in CWD and FP Occurrences

The C-POD data provided some novel information on the 24-hour activity pattern of the local dolphins and porpoises over a large spatial scale and across multiple study periods. The data revealed some clear differences in diel peak activity periods during different times of the day and at different sites for both dolphins and porpoises and some were maintained across study periods (Tables 10-12 and Figures 45-59 (for CWD) and Tables 13-15 and Figures 60-65 (for finless porpoises)).

Diel patterns of dolphin occurrence

For BMP, there were very few detections in later study periods to observe diel patterns clearly. However, even so, it appeared that most of the CWD activity occurred during low light periods from about 18:00 to about 06:00 with some minor activity during the day time and this was generally consistent across the study periods (Figures 45). The number of DPMs were significantly more at night than during the daytime (Tables 10) and regardless of season (Tables 11 and 12; Figures 50 and 55), this pattern remained the same (although in 2019-20, DPMs at night were not significantly greater than the day time during the dry season).

At SCLKCMP, activity was more broadly distributed across the 24-hour period with a more notable decrease in activity between about 13:00 and 18:00 and this general diel pattern also appeared to be fairly consistent across the study periods with minor differences (Figure 46). Overall, there were more DPMs at night than during the daytime with the exception of the wet season in 2017-18 where the reverse pattern was observed (although it was not significant) (Tables 10-12; Figures 46, 51 and 57).

The general diel pattern observed at WL was also maintained across the study periods where most of the activity occurred from about 18:00 to 08:00 with a low activity period during the day time (from about 09:00 to 17:00) but in 2020-21, there seemed to be an expanded period of high activity from about 01:00 to 07:00 (Figure 47). For all study periods and regardless of season, there were significantly more DPMs at WL during the night time than the day (Tables 10-12; Figures 52 and 57). Similarly, the diel pattern at SWLMP also seemed to be broadly consistent across the study periods with the highest level of activity being in the morning with another peak of activity being later in the afternoon (the exact timing slightly different across study periods) (Figure 48). For all study periods, the DPMs in the day time were higher than at night (Tables 10), which was the opposite of the more common pattern with more DPMs at night. The wet and dry season patterns were also noticeably different (Figures 53 and 58).

Only at SLMP, was the general diel pattern for the area inconsistent across the study periods. For 2018-19 and 2019-20, a similar pattern with the lowest activity occurring between about 05:00 and 09:00 and the shapes of the activity during the other hours were roughly similar for these two study periods. However, in 2020-21, the shape of the highest activity periods was very different than in previous years even though the lowest activity hours were still around the same time (roughly from about 05:00-06:00 to about 09:00-10:00) (see Table 10 and Figure 49). Similar inconsistent diel patterns over time were also observed during the wet season (Table 11 and Figure 54) but not during the dry season (Table 12; Figure 59).

With respect to sites, Siu Ho Wan, Tai Mo To, Sha Chau SE and Tai A Chau S (although this last site had a lack of DPMs in 2020-21 and in the dry season of 2019-20) all had more DPMs at night than the day for all study periods regardless of season. In contrast, Peaked Hill also was consistent across study periods regardless of seasons but with more DPMs in the day time (Tables 10-12). With the exception of one or two inconsistencies in the diel pattern that was observed during a specific study period and season, Lung Kwu Chau N, Tai O, Siu A Chau and Tai A Chau N had primarily more DPMs at night than during the day time while Kau Ling Chung had more during the day time. Fan Lau had the least predictable diel pattern of all sites.

Considering all the results together, it is clear that some strong diel patterns existed in CWD DPMs. The overall general pattern was that DPMs were higher during the night regardless of season and this was maintained across study periods. However, it was also clear that for some sites, the pattern was reversed regardless of season (e.g., Peaked Hill) and across the study periods. The reason for the reversed pattern at Peaked Hill is interesting and should be studied further as should the occasional reversed patterns at other sites during some study periods and seasons. Continued monitoring of these sites with different (consistent and fluid) patterns may allow an understanding of the factors leading to such differences.

<u>Diel patterns of porpoise occurrence</u>

The predominant diel pattern throughout the study periods (and regardless of seasons) for each area and site in which porpoises were detected had more DPMs during the night than day time, with a few exceptions (see Tables 13-15). However, none of the few exceptions (with more DPMs during the day than night) was statistically significant. At SWLMP, the diel patterns in 2018-19 and 2020-21 were similar but the pattern in 2019-20 noticeably different from the other study periods (Figure 60). In general, the highest level of activity occurred from about 21:00 to 06:00. Although the wet season diel patterns for all three study periods were roughly similar (except for a peak of activity at about 12:00-13:00 in 2019-20) (Figure 62), only the dry season of 2020-21 had a pattern that was similar to the overall general pattern (Figure 64). At SLMP, the diel patterns observed during each of the study periods were strikingly similar to each other with the greatest activity level occurring from about 20:00 to 06:00 (Figure 61). This pattern was also observed during the wet season for all study periods (Figure 63) and the dry season in 2019-20 whereas the dry seasons of the other study periods only showed slight indications of the general pattern (Figure 65).

With respect to sites, Siu A Chau and Tai A Chau S had more DPMs at night than the day for all study periods regardless of season (Tables 13-15). Only Kau Ling Chung in 2019-20 had more overall DPMs during the day time. During the wet season, all sites had more DPMs at night than the day time (Table 14). However, in the 2018-19 dry season, Kau Ling Chung and Tai A Chau N had more (but not significantly so) DPMs in the day time. Kau Ling Chung also had more (again not significantly so) DPMs during the day in the 2019-20 dry season (see Table 15).

Considering all the results together, it is clear that finless porpoise DPMs are overwhelmingly higher at night than in the day time. Whether this indicates that porpoises are more acoustically active at night or more finless porpoises are present in these regions at night require more research that specifically addresses this question. The reversal of diel patterns at Kau Ling Chung and Tai A Chau N during the dry season is interesting and more data are needed to determine if these observations are seen in future years and may be of biological importance.

4.3.4. Regression Modeling Results (for one year of CWD data)

C-POD data for this analysis were obtained from 12 sites between June 25th, 2018 and July 5th, 2019. A total of 6,274,620 minutes were logged across the 12 C-PODs, of which 103,846 had at least one detection recorded (DPM). However, the number of DPMs varied greatly across sites, seasons and diel phases (see Wang and Hung, 2019).

When the predictor variables were examined individually, only site appeared to be significantly related to the patterns of detection ($p<0.001$) (Figure 66), while neither season nor diel phase alone significantly explained the observed detections. However, all pairwise interactions as well as three-way interactions were significant. Model 6 (which included three-way interactions as well as all pairwise interactions and individual variables) had the lowest AIC value but it was only marginally lower than that of model 5, which included only pairwise interactions in addition to the individual variables (Table 16). The effect of season on the probability of detections varied greatly across sites and diel phases. For most sites (i.e., Siu Ho Wan, Lung Kwu Chau N, Tai O, Peaked Hill, Fan Lau, Kau Ling Chung and Siu A Chau), the highest numbers of DPMs occurred during the wet season. Various hydrological parameters (e.g., temperature, salinity, turbidity and rainfall amounts) differ seasonally and even though they may be correlated with dolphin occurrence in Hong Kong's waters, the most important determinant of dolphin distribution within the PRE is the availability of prey (Hung, 2008; Pine et al., 2017), which is likely affected by these parameters more directly than the CWD. The effect of diel phase on the probability of dolphin detections also differed significantly across sites and seasons within each site. Some sites (e.g., Sha Chau SE, Shum Wat, Tai O and Siu A Chau) showed clear diel differences while other sites (e.g., Lung Kwu Chau N and Tai A Chau S) had relatively consistent detections throughout the day.

The results of the present analyses for a single year of data further supported the patterns observed in earlier simpler analyses. However, these results still need to be interpreted cautiously until more data can be analysed to determine if the current patterns observed are consistent across years. An analysis including all C-POD data obtained since 2017 is ongoing. Such a large data set is unwieldy for desk-top computing abilities and may require a mainframe supercomputer.

4.4. C-POD vs. Boat-based Survey Data

4.4.1. Yearly Comparisons

For the yearly comparisons for CWD, there were only four years (2018 to 2021) for which both DPM and boat survey data were available. Thus, statistical analyses would not be meaningful because even an additional data point (year) can heavily influence any observed relationship. However, graphical examination was performed to provide some cautious initial insights into the overall (all areas combined) relationship between DPM and boat-based survey metrics as well as area-by-area differences in these data. When looking at all areas combined, DPUE, SPUE and DPM seemed to have similar year-to-year patterns. However, abundance was clearly much lower in 2018 compared with 2019 and there was a slight increase from 2020 to

2021 (Figure 67). In NWL, all metrics seemed to follow a similar pattern except DPM continued to decline from 2020 to 2021 while the boat-based metrics increased (Figure 68). In WL, all metrics showed similar patterns from 2019 to 2021 but DPM was much higher in 2018 than in 2019, which was different from all boat survey metrics (Figure 69). In SWL, the overall patterns were similar across all metrics with a couple of differences; the decrease in DPMs after 2019 was more pronounced than for the boat survey metrics and unlike all the other metrics, SPUE had minimal change across the years (Figure 70).

To better understand the relationships between DPM and the boat-based survey metrics (abundance, SPUE and DPUE), correlation analyses were conducted on all data points from each survey area together (thus, 12 data points for each of the analyses of DPM versus each boat-based metric) (see Figure 71). DPUE and DPM had the highest and statistically significant correlation (Spearman's r=0.943; p<<0.001). Both SPUE and abundance also had significant correlations with DPM but the Spearman's correlation coefficient was lowest for abundance and DPM (r=0.728; p<0.01) while SPUE and DPM (r=0.916; p<0.001) was similar to DPUE and DPM. The lower correlation between DPM and abundance may be because abundance is an estimate of the total number of dolphins in an area while DPM is an index of occurrence (much like DPUE and SPUE) but not necessarily the number of different individuals present. Increasing the number of years of data will improve confidence in the reliability of any relationships found and may also allow similar correlation analyses within each area (if sufficient data were available).

For porpoises (in SWL, the only survey area where porpoises were recorded in significant numbers), the same scarcity of data points (n=4 years) precluded meaningful statistical analyses to be performed. An examination of the data showed that the year-over-year pattern of DPMs resembled much more closely the DPUE pattern than that for SPUE (Figure 72). Increasing the number of years of data will further improve our understanding of the relationships between these kinds of data.

4.4.2. Monthly Comparisons

For the monthly comparisons, CWD abundance estimates were not available so correlation analyses were performed for DPM versus CWD SPUE and DPM versus CWD DPUE. In NWL, both DPM and SPUE and DPM and DPUE were significantly correlated even though the correlation coefficients were not large (Spearman's r=0.567, p<<0.001 and Spearman's r=0.564, p<<0.001, respectively) (Figure 73). Similarly in WL, both comparisons were also significant but with low correlation coefficients

(Spearman's r=0.430, p<0.05 and Spearman's r=0.389, p<0.05, respectively) (Figure 74). In contrast, neither DPM and SPUE nor DPM and DPUE in SWL were significantly correlated (Spearman's r=0.028, p=0.87 and Spearman's r=0.062, p=0.72, respectively) (Figure 75).

For porpoises, both DPM-SPUE and DPM-DPUE were significantly correlated but similarly, the correlation coefficients were not high and almost identical to each other (Spearman's r=0.522, p<0.005 and Spearman's r=0.517, p<0.005, respectively) (Figure 76).

Clearly, the correlations between CWD and finless porpoise DPM data and boat-based survey metrics were significantly different (from no correlation) at the annual and monthly levels for all areas, except SWL where CWD monthly DPM was not significantly correlated with either SPUE or DPUE. SWL is also the survey area where the diel occurrence pattern of CWD was reversed (i.e., more detections during the day time than at night) compared with all other survey areas. The reason for this discrepancy at SWL maybe caused by the limited CWD detections during some deployment periods at some sites (e.g., Tai A Chau N and S), which may have a large influence on any correlations that may exist at other sites and be reflected by the lack of significant correlations for the survey area (which of course includes all sites together).

4.5. C-POD vs. F-POD

4.5.1. CWD Hourly Data

At all sites (except Siu A Chau), the Spearman's correlation coefficient (r) for C-POD and F-POD DPMs were significantly different from zero but the r values varied greatly and were weak: Tai A Chau N (r=0.120, p<0.05), Lung Kwu Chau N (r=0.180, p<<0.0001), Siu Ho Wan (r=0.298, p<0.05), Tai O (r=0.339, p<0.01), and Kau Ling Chung (r=0.345, p<0.01). Siu A Chau had the lowest r value between the C-POD and F-POD DPMs at 0.024, which was not significantly different from no correlation (p=0.664). When the data from all sites were combined, Spearman's r was very low at 0.127 even though it was significantly different from no correlation (p<<0.0001) (Figure 77). Examining the slopes from simple linear correlations provides a general understanding of the relationship between the C-POD and F-POD data even though these data did not follow parametric characteristics. The slopes also varied greatly across sites: Siu A Chau = 0.080, Tai A Chau N = 0.225, Siu Ho Wan = 0.325, Tai O = 0.532, Lung Kwu Chau N = 1.000 and Kau Ling Chung = 1.019. For all data combined, the slope was 0.546. These values show that for most sites (except at Kau Ling Chung), F-PODs recorded more DPMs (from 1.9 to 12.5 times more) than

C-PODs. At Lung Kwu Chau N, both C-POD and F-POD recorded about the same levels of DPMs while at Kau Ling Chung, the C-POD recorded slightly (about 2%) more DPMs than the F-POD. When all data were considered, F-PODs recorded about 1.8 times more CWD DPMs than C-PODs.

4.5.2. CWD Daily Data

The correlations between C-POD and F-POD data were all significant. However, the Spearman's r values varied greatly across sites and for most sites were not very strong. Siu Ho Wan had the lowest r value (0.401, p<0.01) and Tai O had the highest (r=0.798, p<0.01). The other sites were in between these minimum and maximum values: Siu A Chau (r=0.501, p<<0.0001), Tai A Chau N (r=0.523, p<<0.0001), Kau Ling Chung (r-0.706, p<0.01) and Lung Kwu Chau N (r=0.712, p<0.01). When the data from all sites were combined, the correlation between C-POD and F-POD data was also significant but again not very strong (r=0.575, p<0.01) (Figure 78). The slopes from simple linear correlations varied greatly across sites: Siu Ho Wan = 0.352, Tai A Chau N = 0.389, Tai O = 0.433, Siu A Chau = 0.444, Lung Kwu Chau N = 0.702 and Kau Ling Chung = 1.099. For all data combined, the slope was 0.468. These values show that for most sites (except at Kau Ling Chung), F-PODs recorded more DPMs (from 1.4 to 2.8 times more) than C-PODs. At Kau Ling Chung, the C-POD recorded slightly (about 10%) more DPMs than the F-POD. When all data were considered together, F-PODs recorded about 2.1 times more DPMs than C-PODs.

4.5.3. FP Hourly Data

At the three sites with porpoise detections (i.e., Kau Ling Chung, Siu A Chau and Tai A Chau N), the correlation between C-POD and F-POD porpoise DPMs were significantly different from zero but as also seen with CWD data, the r values varied greatly and were weak: Siu A Chau (r=0.240, p<<0.0001), Kau Ling Chung (r=0.352, p<<0.0001) and Tai A Chau N (r=0.737, p<0.01). When the data from all sites were combined, Spearman's r was 0.546 and significantly different from no correlation (p<0.01) (Figure 79). The slopes from simple linear correlations also varied greatly across sites: Siu A Chau = 0.912, Tai A Chau N = 1.302 and Kau Ling Chung = 1.317. For all data combined, the slope was 1.244. These values show that for Tai A Chau N and Kau Ling Chung, C-PODs recorded about 30% more porpoise DPMs than F-PODs while at Siu A Chau, the F-POD recorded 10% more porpoise DPMs than the C-POD. When all sites were considered, C-PODs recorded about 24% more porpoise DPMs than F-PODs.

4.5.4. FP Daily Data

The correlations between C-POD and F-POD porpoise data were all significant. However, the Spearman's r values varied greatly across sites: Siu A Chau had the lowest r value (0.593, $p<<0.0001$) and Kau Ling Chung had the highest ($r=0.813$, $p<0.01$) with Tai A Chau N having an intermediate r value (0.764, $p<0.01$). When the data from all sites were combined, the correlation between C-POD and F-POD FP data was also significant ($r=0.770$, $p<0.01$) (Figure 80). The slopes from simple linear correlations also varied greatly across sites: Tai A Chau N = 0.834, Siu A Chau = 1.084 and Kau Ling Chung = 1.886. For all data combined, the slope was 0.998. These values show that for Siu A Chau and Kau Ling Chung, C-PODs recorded about 8% and 89%, respectively, more porpoise DPMs than F-PODs. At Tai A Chau N, the C-POD recorded about 1.2 times more porpoise DPMs than the F-POD and when all data were considered together, C-PODs and F-PODs recorded about the same number of porpoise DPMs.

4.5.5. Potential Correction Factor

In general, F-PODs detected significantly more CWD DPMs than C-PODs (except at Lung Kwu Chau N and Kau Ling Chung, both of which had significantly higher detections by C-PODs than F-PODs) (Table 17). In contrast, finless porpoises showed an opposite pattern where C-PODs consistently logged significantly more detections than F-PODs at all sites where porpoises were recorded (Table 18). However, because of the great variation in the correlations observed in the C-POD and F-POD CWD DPM data across sites (including reversed relationships, which were also indicated by the slopes observed from simple linear correlations), there was no simple universal correction factor that was applicable to all sites to convert C-POD data to F-POD data (or vice versa). Thus, comparing past C-POD data with future F-POD data to better understand long-term trends in detections does not appear to be straightforward. Whether site specific correction factors exist will require analysis of much more paired C-POD/F-POD data from each site before confident correction factors can be determined.

4.5.6. Percentage of False Positive

For all four paired C-POD/F-POD deployment periods, the F-POD data had much lower rates of false positives regardless of sites or species (ignoring the cases where both C-POD and F-POD had 0.00% false positives). The four paired deployment periods at six sites with CWD detections and three sites with porpoise detections resulted in a total of 36 possible % false positive comparisons for C-PODs and F-PODs. For only five of the 23 F-POD CWD false positive calculations (one site, Tai A Chau N, was missing F-POD data during the final deployment period) were there any false positives. Of these, four had a false positive rate of 1.00% and one had 2.00% (Tai O during the last deployment period) with an overall mean of 0.26% (see Table 19). In contrast, 13 of 24 calculations for C-PODs registered CWD false positives and the rates varied from 1.00% to as high as 40.00% (at Lung Kwu Chau N during the first deployment period) with an overall mean of 7.77%. For porpoises, only two of the possible 11 F-POD calculations (Tai A Chau N, was missing F-POD data during the final deployment period) resulted in false positive rates and both were at 1.00%. The overall mean false positive rate for F-POD was 0.18%. In contrast, for C-PODs, there were false positives at all sites during all deployments (i.e., 12). The rates varied from 1.00% to 56.00% (at Kau Ling Chung during the second deployment) with an overall mean of 8.33% (see Table 20). The relative false positive rates of C-PODs and F-PODs were not consistent (i.e., occasions where C-PODs had high rates were not reflected by high rates in F-PODs). Overall, the overall mean % false positives in CWD detections by C-PODs (7.77%) was about 30 times higher than the mean for F-PODs (0.26%). Similarly, the overall mean % false positives for porpoise detections by C-PODs was about 46 times higher than for F-PODs.

5. SUMMARY OF MAIN FINDINGS

5.1. Current Deployment of C-POD/F-POD pairs

The deployment and retrieval of C-POD and F-POD pairs were successful at most sites. However, the first deployment at Lung Kwu Chau N resulted in equipment loss. Furthermore, a factory filter-setting for all C-PODs deployed during the entire study period was set incorrectly and thus all C-POD data collected were unreliable and omitted from analyses (note: this factory setting has been fixed and so the newly acquired C-PODs are now functioning properly). There was minimal variability in noise levels across sites with all sites, except one (Tai O), having no time lost in F-POD recordings. Even Tai O had minimal time lost (of 3.07%). However, because this was the first year in which F-PODs were used, it is not possible to determine if overall noise levels in the waters of Hong Kong have decreased over the years to a particularly quiet period (current) or if F-POD noise filters are so proficient that even under noisy conditions, little logging time would be lost (which would preclude examination of the relative noisiness across sites). Only with data from more years can this question be answered.

The recently-released final version of the KERNO-F classifier produced extremely low levels of false positives for both dolphin and porpoise detections. For the CWD, only four sites registered false positives and none had more than 3% and no sites had any false positive detections of FPs. Another major component of the low level of false positive species identifications hinges on the assumptions that all dolphin detections belonged to CWDs and all porpoise detections belonged to FPs. For Hong Kong's waters, this assumption is very well supported by over 20 years of visual observations and some initial direct cross-referencing of DPMs with visual observations from line-transect vessel surveys and shore-based theodolite tracking. However, there is some evidence that dolphins are capable of producing NBHF clicks that are similar to porpoises. This may explain some of the unexpected detections that were classified as porpoise in sites where porpoises have never been observed over 20 years of visual surveys (e.g., Peaked Hill and Fan Lau during the current study and other sites in previous C-POD studies – see Wang and Hung (2020, 2021)).

5.2. Current F-POD data

About 48,000 DPMs were recorded, of which 86.18% were from CWDs and 13.82% were from FPs. As with the C-POD data from previous years, most CWD detections were from SWLMP and WL and both of these areas detected dolphins during about 80% or more of the logged days. The highest CWD detections were at Peaked Hill, Shum Wat, Fan Lau and Tai O. The lowest dolphin detection level was found at Siu Ho Wan and Tai Mo To (BMP sites) where near-zero DPMs were recorded. The temporal patterns of dolphin detections appear to vary with sites and diel phases. Some sites had higher detections during the day than at night while other sites had the opposite pattern. Even though this diel pattern at each site was usually the same during the wet and dry seasons, there were a few sites that did not follow the same pattern. Although atypical, the higher detections during the day were not unusual because similar patterns were seen in the previous year at SWLMP sites but more data in future years are needed (and accumulating) to determine the consistency of the atypical pattern at certain sites over time.

Finless porpoises were only really detected in SWLMP and SLMP, and most FP detections were from the SLMP area with both Tai A Chau sites always having the greatest detection metrics. Siu A Chau had the next highest values followed distantly by Kau Ling Chung, which had the lowest metrics (not considering the sites with rare porpoise detections – i.e., Peaked Hill and Fan Lau). Kau Ling Chung was the only consistent and reliable site in SWLMP where FP detections were recorded in reasonable numbers. In contrast to CWDs, FP detections had a more clearly defined temporal pattern of occurrence with consistently more detections during the night regardless of site or season.

At sites where both species were detected, there appeared to be little spatio-temporal overlap. Comparing all sites with detections of both species, there was a strong inverse relationship between the two species for all DPM metrics. While FP detections generally decreased with increasing latitude of the sites, CWD detections increased. Examining the degree of spatio-temporal overlap of the two species at an even higher temporal resolution (i.e., less than one hour) will certainly result in further separation. However, the fineness of the temporal resolution selected for the present study should be biologically meaningful to both species.

5.3. Long-term C-POD data and factors

The long-term C-POD data collected since 2017 revealed some interesting long-term patterns of occurrence in both CWD and porpoises. There is a very clear and large decline in CWD overall and at most sites (and areas) throughout the waters of Hong Kong. At some sites, CWD detections have continued to remain high even as detections at other sites have declined dramatically. At some sites, the CWD detections have dropped to zero from earlier years when detections were much higher. Comparing with PAM data that were obtained at some sites well prior to 2017 showed the declines to be even greater than during the last few years. In contrast, finless porpoise detections appear to have remained fairly constant and possibly have increased slightly over the years as CWD numbers continue to decrease. At some sites, specific diel and seasonal patterns of occurrences appear to be maintained throughout multiple study periods and may be characteristic of the species at those sites.

5.4. C-POD vs. boat survey data

C-POD DPMs and boat survey metrics correlated significantly but these correlations were not very strong nor consistent across sites. The significant correlations were not surprising as both DPM and boat survey metrics are related through the level of presence of animals. The lower correlation coefficient between DPMs and abundance as compared with the per-unit-effort metrics (DPUE and SPUE) was likely due to abundance being an estimate of the number of individuals present rather than a metric that is directly calculated from detection with no extrapolation to a larger area (like DPM, DPUE and SPUE). Furthermore, the weakness of the correlation may be related to the differences in boat survey and C-POD data collection. In the former, a large amount of water is sampled but for a much shorter period of time whereas with C-POD, a small area is sampled more or less continuously. As such, these two sampling methods are not likely to reflect each other but are more likely to provide different information. For C-POD and boat survey data to be tightly correlated with each other, many more C-PODs are needed to sample a much larger portion of the areas surveyed using a boat (and then only using the data obtained by the C-PODs during the period in which the boat survey is being conducted). Even so, general patterns (e.g., direction and degree of change) in the trends in abundance and occurrence should be reflected in both kinds of data even if they may not be strongly correlated to one another.

5.5. C-POD vs. F-POD data

Overall, the correlation between C-POD and F-POD CWD DPM data were significantly different from zero, which was not surprising as both PODs are detecting the presence of animals. However, the correlation coefficients varied greatly from being weak to moderately strong. Furthermore, the relationships between C-POD and F-POD CWD detection levels were inconsistent and varied greatly across sites (including patterns at some sites that were in the opposite direction – i.e., F-PODs did not record more CWD DPMs than C-PODs at all sites) and where F-PODs recorded more DPMs, the increased detections were not consistently at the same level across sites. Similarly, C-POD and F-POD porpoise DPMs were also variable but C-PODs always had more detections than F-PODs and the correlation coefficients for C-POD and F-POD data were, in general, higher than in the CWD data. As a consequence of these results, it is clear that there is no simple universal correction factor that can be applied across all sites (for either species) to allow direct comparison of C-POD and F-POD data sets. Whether there are corrections factors that can be applied within specific sites will require analyses of larger data sets for each site and species.

A clear result of the comparison between C-POD and F-POD data was that the false positive rates were much lower for F-PODs than C-PODs regardless of site (or species), which demonstrates the superiority of the F-POD over the C-POD in reducing false positive detections and thus further increasing the confidence of the detection data obtained from using F-PODs.

6. RECOMMENDATIONS

The final objective of the present PAM study is to make recommendations on necessary further studies for the conservation of CWDs and FPs within the marine parks in light of the findings of the present study. In order to make these recommendations, the results from the present PAM study on their occurrences among the four marine parks are thoroughly reviewed to identify any potential data gaps and additional research questions that can be addressed by further studies. A number of recommendations are made for consideration in the future (notably some of these will require much more time, resources or data while others can be undertaken immediately):

- The PAM monitoring programme should be continued and be used to compliment the long-term visual monitoring of dolphins and porpoises in Hong Kong's waters, as such programme provides important information about the usage of areas by cetaceans during times when visual observations cannot be conducted. For sites that are known to be noisy (e.g., Tai Mo To, Tai A Chau N, Tai A Chau S), more frequent retrieval and redeployments (i.e., shorter deployment times) may help to reduce lengthy periods of missing data. The F-POD, with increased battery life, increased data storage capacity and the ability to set duty cycles rather than being 'on' all the time, has provided solid proofs in the present study with many abilities to reduce potentially long periods of missing data (see below) from noisy sites. Even in the current F-POD deployments, just its noisy filtering abilities alone has resulted in more or less no logging time loss during the about 3 months of deployment periods so maybe sufficient without needing to employ further options to reduce POD stoppage time. However, the dependence on PAM alone risks losing large amounts of data when equipment is lost or unexpected failures occur (equipment malfunctions or there are systematic issues in the equipment – e.g., a faulty filter setting in the 2021-22 C-PODs rendered about 6 months of data useless). On the other hand, dependence on visual monitoring will result in no information about the cetaceans during times of low-light and poor marine conditions. Therefore, the ideal approach would implement both PAM and visual monitoring at the same time as complementary to both sets of monitoring data..

- Long-term series of F-POD monitoring data from the same sites should be collected for the examination of temporal changes over years, especially as construction and other human activities changes. For example, dolphin activities could decrease further as construction activities continue at the third runway expansion site and Tung Chung East New Town Development reclamation sites, respectively, in the near future. Long-term PAM is also important to better understand the response of dolphins when certain threats change in intensity or prevalence (e.g., stoppage of HSF service due to public health concerns over COVID-19; the completion of current development projects). In addition, previous sites with historic C-POD data (e.g., Lung Kwu Chau S, Lung Kwu Tan) should again be considered for C-and F-POD deployments in the near future to increase spatio-temporal coverage and confirm the wide-spread decline in dolphin occurrences over the years.

- The visual monitoring data (line-transect vessel survey or shore-based theodolite tracking data) near F-POD sites could be compared with the F-POD data in greater detail to better understand the relationship between dolphin (and porpoise) presence, numbers and behaviour with F-POD detection metrics (see Nuutilla et al. 2013; Brookes et al. 2013). Visual data can also be used to determine the level of false negative results (i.e., the non-detection of an animal when actually present). Even though broad-band recorders can reduce the non-detection of dolphins that are not producing echolocation clicks because they can also detect dolphins that are only whistling, there still is an unknown level of false negatives (i.e., silent animals or animals that made sounds in a direction away from the recorder so was not detected or classified as a detection) that must be determined. The importance of false negatives has been overlooked because of the greater focus on understanding false positives. Having a better understanding of false negatives will contribute greatly to understanding the two cetacean species in Hong Kong's waters.

- Examination of DPM relationships with other environmental changes (such as tidal phases, current flow and direction, and more complex interactions between solar, lunar, tidal, current and/or seasons) should be further expanded in the future (e.g., Gallus et al. 2012; Wang et al. 2015).

- The F-POD data can be further analyzed for indications of foraging behaviour to better understand where and when this important biological activity may be taking place (e.g., Shaffield et al. 2016). Although there are no automated classifiers for detecting foraging behavior in the click trains recorded, strategic sampling of the dataset can result in a smaller, manageable subset of data that may still accurately represent the complete dataset. The feasibility of manually extracting foraging click trains can be examined.

- It is possible to examine the influence of certain kinds of noises on the acoustic activity of CWD by coupling F-PODs with broad-band acoustic recorders that can record noises and levels. In this way, the amount of DPMs in the presence and absence of certain identifiable noises and their levels (e.g., shipping, construction activities) may be quantified and examined in a gradient designed study of impacts (see Bailey et al. 2014).

- The full C-POD data set since 2017 can be combined into a much larger regression modelling analysis conducted in this report to better understand year-over-year differences in the factors that influence detections of CWD. The same can be conducted on finless porpoise data as well.

- Wherever possible and practical, paired C-POD and F-POD deployments should be continued to increase the data set in order to allow analyses to better understand if there are site-specific correction factors that can be applied to convert C-POD data to permit comparison with F-POD data. Furthermore, having a long-series of C-POD data that overlaps across several years with F-POD data may provide a clearer understanding of the rates of changes in detections by both kinds of PODs as well as boat survey data. Although, such comparison may not result in absolute numbers in cetaceans, multiple lines of evidence of similar trends would provide strong information of the level of change observed. If both kinds of PODs and the boat survey data accurately represent the local animals, then appropriate metrics of each study method should be able to detect the same rate of change in the local animals.

7. ACKNOWLEDGEMENTS

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Table 1. Summary data statistics on detection of Chinese White Dolphins and Indo-Pacific Finless Porpoises as recorded by F-PODs from July 6th, 2021 to January 13th, 2022 for each area (Brothers Marine Park (BMP), Sha Chau & Lung Kwu Chau Marine Park (SCLKCMP), West Lantau (WL), Southwest Lantau Marine Park (SWLMP) and the planned South Lantau Marine Park (SLMP) and each site within these areas. (Note: "Logged Days": no. logged days the C-POD was on and recording; "DPD% of Days": detection positive days as a percentage of logged days; DPM: detection positive minutes, minutes where at least one dolphin click train was detected; "% Time Lost": percentage of time lost because the minute click limit has been reached and no subsequent data could be recorded for that minute; * the F-POD of the first deployment at Lung Kwu Chau N was lost (along with the accompanying C-POD) so there were not data during this period)

			Chinese White Dolphins				Finless Porpoises			
Site / Area	**Logged Days**	**% Time Lost**	**DPD% of Days**	**DPM**	**Mean DPM/Day**	**% False Positive DPM**	**DPD% of Days**	**DPM**	**Mean DPM/Day**	**% False Positive DPM**
BMP	381.90	0.00	2.32	13	0.03	0.00	0.00	0	0.00	-
*SCLKCMP	254.89	0.00	33.60	1104	4.33	0.00	0.00	0	0.00	-
WL	374.83	1.53	86.13	7780	20.76	1.25	0.00	0	0.00	-
SWLMP	564.04	0.00	79.80	31259	55.42	0.43	12.23	872	1.55	0.00
SLMP	563.80	0.00	28.06	1432	2.54	0.00	65.60	5797	10.28	0.00
SIU HO WAN	190.93	0.00	1.03	5	0.03	0.00	0.00	0	0.00	-
TAI MO TO	190.97	0.00	3.61	8	0.04	0.00	0.00	0	0.00	-
*LUNG KWU CHAU N	63.95	0.00	81.54	964	15.08	0.00	0.00	0	0.00	-
SHA CHAU SE	190.94	0.00	17.55	140	0.73	0.00	0.00	0	0.00	-
SHUM WAT	188.00	0.00	88.17	4769	25.37	1.00	0.00	0	0.00	-
TAI O	186.83	3.07	84.07	3011	16.12	1.50	0.00	0	0.00	-
PEAKED HILL	188.01	0.00	100.00	26936	143.27	1.50	3.68	8	0.04	0.00
FAN LAU	188.00	0.00	78.39	3156	16.79	0.00	6.83	19	0.10	0.00
KAU LING CHUNG	188.04	0.00	61.02	1167	6.21	0.00	26.20	845	4.49	0.00
SIU A CHAU	187.93	0.00	27.36	171	0.91	0.00	51.05	1187	6.32	0.00
TAI A CHAU N	187.94	0.00	50.50	1238	6.59	0.00	72.08	2536	13.49	0.00
TAI A CHAU S	187.93	0.00	6.31	23	0.12	0.00	73.66	2074	11.04	0.00
Totals:	**2139.46**	**0.27**		**41588**	**19.44**	**0.46**		**6669**	**3.12**	**0.00**

Table 2. Values of U statistics for comparing differences in F-POD daily DPMs for Chinese White Dolphins and Indo-Pacific Finless Porpoises during wet and dry seasons using the Mann-Whitney U test for: BMP, SCLKCMP, WL, SWLMP and SLMP and all sites within these areas. (Note: red font = significant at the α=0.05 level; blue font = reverse pattern; * too few dolphin or porpoise detections for meaningful comparison; ** due to lost equipment during the first deployment, comparison between seasons cannot be performed.

	Chinese White Dolphins			Indo-Pacific Finless Porpoises		
Areas	**U-values**	**p-values**	**direction**	**U-values**	**p-values**	**direction**
*BMP	-	-	-	-	-	-
**SCLKCMP	-	-	-	-	-	-
WL	8250.5	<<0.0001	dry > wet	-	-	-
*SWLMP	25407.0	<<0.0001	dry > wet	-	-	-
SLMP	37574.5	0.196	dry > wet	31003.0	<<0.0001	dry > wet
Sites						
*SIU HO WAN	-	-	-	-	-	-
*TAI MO TO	-	-	-	-	-	-
**LUNG KWU CHAU N	-	-	-	-	-	-
SHA CHAU SE	3643.5	<0.001	dry > wet	-	-	-
SHUM WAT	2383.5	<<0.0001	dry > wet	-	-	-
TAI O	1699.0	<<0.0001	dry > wet	-	-	-
*PEAKED HILL	1587.0	<<0.0001	dry > wet	-	-	-
*FAN LAU	1779.0	<<0.0001	dry > wet	-	-	-
KAU LING CHUNG	2380.0	<<0.0001	dry > wet	3255.0	<<0.0001	wet > dry
SIU A CHAU	3999.5	0.153	dry > wet	3568.0	<0.05	wet > dry
TAI A CHAU N	3379.0	<0.005	dry > wet	1840.0	<<0.0001	dry > wet
*TAI A CHAU S	-	-	-	2900.0	<<0.0001	dry > wet

Table 3. Wilcoxon T statistics for comparing differences in F-POD hourly DPM of Chinese White Dolphins in day vs night for all data and only during the wet and dry seasons for SCLKCMP, WL, SWLMP and SLMP and all sites within these areas. (Note: red font = significant at the α=0.05 level; blue font = reverse pattern; * too few detections for meaningful comparison; ** the Lung Kwu Chau N F-POD was lost during the first (wet season) deployment.

	All			Wet Season			Dry Season		
Sites or Areas	**T-values**	**p-values**	**direction**	**T-values**	**p-values**	**direction**	**T-values**	**p-values**	**direction**
*BMP	-	-	-	-	-	-	-	-	-
**SCLKCMP	520.5	<<0.0001	night > day	-	-	-	481	<<0.0001	night > day
WL	16614.5	<<0.001	night > day	2843.0	0.098	night > day	5758	<<0.001	night > day
SWLMP	20821.5	<<0.0001	day > night	1933.5	<<0.0001	day > night	9204	<<0.0001	day > night
SLMP	4202.5	<0.05	night > day	243.5	<0.0005	day > night	932.5	<<0.0001	night > day
*SIU HO WAN	-	-	-	-	-	-	-	-	-
*TAI MO TO	-	-	-	-	-	-	-	-	-
**LUNG KWU CHAU N	-	-	-	-	-	-	254	<<0.001	night > day
SHAU CHAU SE	38.5	<<0.001	night > day	1.0	0.144	night > day	31.0	<0.005	night > day
SHUM WAT	2511	<<0.0001	night > day	475.5	<0.005	night > day	844	<<0.0001	night > day
TAI O	4740	0.176	day > night	730	0. 792	day > night	1782	0.902	day > night
PEAKED HILL	3590	<<0.0001	day > night	248.5	<<0.0001	day > night	1517.5	<0.0005	day > night
FAN LAU	3012.5	<0.0005	day > night	419.5	<0.01	day > night	1135	<0.01	day > night
KAU LING CHUNG	752.5	<<0.0001	day > night	40.5	<<0.0001	day > night	377.5	<<0.0001	day > night
SIU A CHAU	375	0.071	day > night	0	<0.0005	day > night	195	0.627	night > day
TAI A CHAU N	1215	<0.001	night > day	145.5	<0.05	day > night	166.5	<<0.0001	night > day
*TAI A CHAU S	-	-	-	-	-	-	-	-	-

Table 4. Wilcoxon T statistics for comparing differences in F-POD hourly DPM of Indo-Pacific Finless Porpoises in day vs night for all data and only during the wet and dry seasons for SWLMP and SLMP and all sites within these areas. (Note: red font = significant at the α=0.05 level; * very few detections were recorded at Peaked Hill and Fan Lau).

	All			Wet Season			Dry Season		
Sites or Areas	T-values	p-values	direction	T-values	p-values	direction	T-values	p-values	direction
*SWLMP	221	<<0.0001	night > day	21	<<0.0001	night > day	102	<0.05	night > day
SLMP	15312.0	<<0.0001	night > day	2413.5	<<0.0001	night > day	5563.5	<<0.0001	night > day
KAU LING CHUNG	35	<<0.0001	night > day	21	<<0.0001	night > day	0	<0.05	night > day
SIU A CHAU	693	<<0.0001	night > day	146	<<0.0001	night > day	231	<0.01	night > day
TAI A CHAU N	2057	<<0.0001	night > day	342	0.114	night > day	759	<<0.0001	night > day
TAI A CHAU S	2708.5	<0.005	night > day	414	0.345	night > day	1043.5	<0.01	night > day

Table 5. Summary of basic metrics for Chinese White Dolphin C-POD detections from June 2017 to July 2021 (blue font indicates values that were recalculated after omitting data from sites that were not used after the 2017-18 study period).

	2017-18					2018-19					2019-20					2020-21			
Site or Area	**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**		**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**		**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**		**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**
BMP	752.7	23.00	1535	2.03		700.1	15.13	586	0.84		673.3	3.52	123	0.18		675.3	2.64	71	0.11
SCLKCMP	714.1	67.55	20061	27.94		696.9	65.69	11403	16.36		739.2	58.46	6457	8.74		707.4	38.81	5486	7.76
WL	-	-	-	-		740.0	80.51	22567	30.50		743.9	73.80	10098	13.57		711.9	67.78	10683	15.01
SWLMP	-	-	-	-		1110.0	90.19	60180	54.22		1032.5	88.35	47561	46.07		803.7	79.90	30521	37.98
SLMP	-	-	-	-		955.8	45.80	7172	7.50		943.3	27.54	6842	7.25		1013.6	13.95	1227	1.21
SIU HO WAN	386.0	24.73	1175	3.04		380.0	17.71	465	1.22		371.0	3.20	78	0.21		353.9	3.35	56	0.16
TAI MO TO	366.7	21.17	360	0.98		320.1	12.05	121	0.38		302.4	3.91	45	0.15		321.4	1.85	15	0.05
LUNG KWU CHAU N	360.5	98.65	19094	52.60		316.9	96.56	10359	32.69		370.9	88.92	5965	16.08		353.5	77.65	5486	15.52
SHA CHAU SE	353.6	35.84	967	2.72		380.0	39.95	1044	2.75		368.3	27.79	492	1.34		353.9	0.00	0	0.00
SHUM WAT	-	-	-	-		370.0	77.27	16203	43.79		372.0	66.76	4847	13.03		355.9	59.17	2416	6.79
TAI O	-	-	-	-		370.0	83.75	6364	17.20		372.0	80.85	5251	14.12		355.9	76.40	8267	23.23
PEAKED HILL	-	-	-	-		370.0	95.94	34546	93.38		291.6	98.64	22921	78.62		168.0	98.26	17607	104.83
FAN LAU	-	-	-	-		370.0	92.48	21444	57.96		371.9	94.15	19770	53.15		277.9	90.39	8789	31.62
KAU LING CHUNG	-	-	-	-		370.0	82.15	4190	11.32		369.0	74.36	4870	13.20		357.8	63.13	4125	11.53
SIU A CHAU	-	-	-	-		370.0	63.90	5428	14.67		371.9	48.92	6149	16.53		345.1	18.90	448	1.30
TAI A CHAU N	-	-	-	-		302.9	38.14	1301	4.30		287.2	25.03	677	2.36		328.2	18.38	716	2.18
TAI A CHAU S	-	-	-	-		282.9	30.33	443	1.57		284.2	2.09	16	0.06		340.2	4.65	63	0.19
Totals	1466.8	97.85	21596	14.72		4202.8	100.0	101908	24.25		4132.4	100.0	71081	17.20		3911.7	99.44	47988	12.27

Table 6. Summary of basic metrics for finless porpoise C-POD detections from July 2018 to July 2021 (blue font indicate values that may be rare events or potentially unreliable data).

	2018-19					2019-20					2020-21			
Site or Area	**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**		**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**		**Logged Days**	**DPD% of Days**	**DPM**	**Mean DPM/Day**
SWLMP	1110.0	16.49	3272	2.95		1032.5	16.19	2265	2.19		803.7	23.66	4430	5.51
SLMP	955.8	77.90	27204	28.46		943.3	73.45	19682	20.86		1013.6	85.37	33517	33.07
PEAKED HILL	370.0	10.16	75	0.20		291.6	0.00	0	0.00		168.0	8.72	27	0.16
FAN LAU	370.0	2.14	14	0.04		371.9	0.53	17	0.05		277.9	5.65	71	0.26
KAU LING CHUNG	370.0	37.16	3183	8.60		369.0	44.76	2248	6.09		357.8	44.67	4332	12.11
SIU A CHAU	370.0	72.20	7972	21.55		371.9	69.42	5635	15.15		345.1	77.07	5008	14.51
TAI A CHAU N	302.9	69.41	6419	21.19		287.2	71.29	5257	18.30		328.2	86.45	13732	41.84
TAI A CHAU S	282.9	94.43	12813	45.29		284.2	80.92	8790	30.93		340.2	92.73	14777	43.43
Totals:	2065.8	93.55	30476	14.75		1975.8	93.87	21947	11.12		1817.2	97.21	37947	20.88

Table 7. Year-over-year comparisons using the Wilcoxon paired test for annual deployments (standardized to the same calendar dates across years) at all sites in 2017-18 (where available), 2018-19, 2019-20 and 2020-21. (Note: red font – significant at the α=0.05 level); blue font – increasing detections from earlier year(s); * - no porpoise detections in 2019-20)

	Chinese White Dolphin			Finless Porpoise		
Sites	**direction**	**T-values**	**p-values**	**direction**	**T-values**	**p-values**
SIU HO WAN	2017-18 > 2018-19	3283	<0.0005	-	-	-
	2017-18 > 2019-20	664.5	<<0.0001	-	-	-
	2017-18 > 2020-21	304	<<0.0001	-	-	-
	2018-19 > 2019-20	593	<<0.0001	-	-	-
	2018-19 > 2020-21	422	<<0.0001	-	-	-
	2019-20 > 2020-21	154	0.170	-	-	-
TAI MO TO	2017-18 > 2018-19	1208.5	<0.001	-	-	-
	2017-18 > 2019-20	362	<<0.0001	-	-	-
	2017-18 > 2020-21	72	<<0.0001	-	-	-
	2018-19 > 2019-20	248	<0.01	-	-	-
	2018-19 > 2020-21	100.5	<<0.0001	-	-	-
	2019-20 > 2020-21	33	0.070	-	-	-
LUNG KWU CHAU N	2017-18 > 2018-19	10875.5	<<0.0001	-	-	-
	2017-18 > 2019-20	6031	<<0.0001	-	-	-
	2017-18 > 2020-21	6081.5	<<0.0001	-	-	-
	2018-19 > 2019-20	9609	<<0.0001	-	-	-
	2018-19 > 2020-21	4603.5	<<0.0001	-	-	-
	2019-20 > 2020-21	22951.5	<0.0005	-	-	-
SHA CHAU SE	2017-18 ~ 2018-19	10130.5	0.463	-	-	-
	2017-18 > 2019-20	6687	<0.005	-	-	-
	2017-18 > 2020-21	229.5	<<0.0001	-	-	-
	2018-19 > 2019-20	6454.5	<<0.0001	-	-	-
	2018-19 > 2020-21	254	<<0.0001	-	-	-
	2019-20 > 2020-21	153.5	<<0.0001	-	-	-
SHUM WAT	2018-19 > 2019-20	10036	<<0.0001	-	-	-
	2018-19 > 2020-21	4506	<<0.0001	-	-	-
	2019-20 > 2020-21	18453	<0.005	-	-	-
TAI O	2018-19 > 2019-20	24744	<0.05	-	-	-
	2018-19 < 2020-21	28974	0.706	-	-	-
	2019-20 < 2020-21	24669	<0.01	-	-	-
*PEAKED HILL	2018-19 > 2019-20	20235.5	0.929	2018-19 > 2019-20	0.00	<<0.0001
	2018-19 < 2020-21	6718.5	0.144	2018-19 > 2020-21	111.5	0.420
	2019-20 < 2020-21	6452.5	<0.05	2019-20 < 2020-21	0.00	<0.001
FAN LAU	2018-19 > 2019-20	28246	<0.05	2018-19 < 2019-20	14.0	0.169
	2018-19 > 2020-21	12848	<<0.0001	2018-19 < 2020-21	42	<0.05
	2019-20 > 2020-21	14036.5	<<0.0001	2019-20 < 2020-21	20.5	<0.01
KAU LING CHUNG	2018-19 > 2019-20	12921.5	<<0.0001	2018-19 > 2019-20	9668.5	0.204
	2018-19 < 2020-21	22965	0.101	2018-19 < 2020-21	9994	0.437
	2019-20 < 2020-21	12305	<<0.0001	2019-20 < 2020-21	10203	<0.01

Table 7. (cont'd)

Sites	Chinese White Dolphin			Finless Porpoise		
	direction	T-values	p-values	direction	T-values	p-values
SIU A CHAU	2018-19 < 2019-20	15744.5	<0.01	2018-19 > 2019-20	18672.5	<0.001
	2018-19 > 2020-21	4035	<<0.0001	2018-19 > 2020-21	19837	<0.001
	2019-20 > 2020-21	2499.5	<<0.0001	2019-20 > 2020-21	24379.5	0.755
TAI A CHAU N	2018-19 > 2019-20	3996.5	<0.01	2018-19 > 2019-20	10209	0.064
	2018-19 > 2020-21	1746.5	<<0.0001	2018-19 < 2020-21	8495.5	<<0.0001
	2019-20 > 2020-21	1435	<0.05	2019-20 < 2020-21	6780.5	<<0.0001
TAI A CHAU S	2018-19 > 2019-20	137.5	<<0.0001	2018-19 > 2019-20	8441	<<0.0001
	2018-19 > 2020-21	181	<<0.0001	2018-19 > 2020-21	12549.5	<0.01
	2019-20 < 2020-21	51	0.609	2019-20 < 2020-21	11723	<0.0005

Table 8. Seasonal patterns of Chinese White Dolphin occurrence at each area and site from 2017 to 2021.

	Study Periods			
Site or Area	**2017-18**	**2018-19**	**2019-20**	**2020-21**
BMP	dry>wet p<0.0005	wet>dry p<<0.0001	dry>wet p=0.883	-
SCLKCMP	dry>wet p<<0.0001	dry>wet p=0.425	dry>wet p=0.492	dry>wet p<<0.0001
WL	-	dry>wet p<<0.0001	dry>wet p<<0.0001	dry>wet p<<0.0001
SWLMP	-	wet>dry p<<0.0001	wet>dry p=0.0106	dry>wet p<<0.0001
SLMP	-	wet>dry p<<0.0001	wet>dry p<<0.0001	wet>dry p<0.005
Siu Ho Wan	dry>wet p=0.32	wet>dry p<<0.0001	wet>dry p=0.945	-
Tai Mo To	dry>wet p<0.0005	wet>dry p=0.559	dry>wet p=0.887	-
Lung Kwu Chau N	dry>wet p<<0.0001	dry>wet p=0.026	dry>wet p<0.001	dry>wet p<<0.0001
Sha Chau SE	dry>wet p<<0.0001	dry>wet p=0.194	wet>dry p=0.0023	-
Shum Wat	-	dry>wet p<<0.0001	dry>wet p<<0.0001	dry>wet p<<0.0001
Tai O	-	wet>dry p=0.049	dry>wet p<<0.0001	dry>wet p<<0.0001
Peaked Hill	-	wet>dry p<<0.0001	wet>dry p<<0.0001	dry>wet p<<0.0001
Fan Lau	-	wet>dry p<<0.0001	wet>dry p<<0.0001	dry>wet p=0.789
Kau Ling Chung	-	dry>wet p<<0.0001	wet>dry p=0.173	dry>wet p<<0.0001
Siu A Chau	-	wet>dry p=0.120	wet>dry p<<0.0001	wet>dry p=0.202
Tai A Chau N	-	dry>wet p<<0.0001	wet>dry p<<0.0001	dry>wet p<<0.0001
Tai A Chau S	-	dry>wet p<<0.0001	wet>dry p=0.012	-

Table 9. Seasonal patterns of finless porpoise occurrence at each area and site from 2018-2021.

	Study Periods		
Site or Area	**2018-19**	**2019-20**	**2020-21**
SWLMP	dry>wet p<<0.0001	dry>wet p=0.0048	dry>wet p<0.0005
SLMP	dry>wet p<<0.0001	dry>wet p<<0.0001	dry>wet p<<0.0001
Peaked Hill	dry>wet p=0.260	-	-
Fan Lau	dry>wet p=0.713	dry>wet p<0.001	-
Kau Ling Chung	dry>wet p<<0.0001	dry>wet p<<0.0001	dry>wet p<0.0005
Siu A Chau	wet>dry p=0. 054	wet>dry p=0.018	wet>dry p<0.005
Tai A Chau N	dry>wet p<<0.0001	dry>wet p<<0.0001	dry>wet p<<0.0001
Tai A Chau S	dry>wet p=0.024	dry>wet p<<0.0001	dry>wet p<<0.0001

Table 10. Diel patterns of Chinese White Dolphin occurrence at each area and site from 2017-2021.

	Study Periods			
Site or Area	**2017-18**	**2018-19**	**2019-20**	**2020-21**
BMP	night>day p<<0.0001	night>day p<<0.0001	night>day p=0.0067	-
SCLKCMP	night>day p=0.399	night>day p=0.026	night>day p=0.0056	night>day p<<0.0001
WL	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
SWLMP	-	day>night p<<0.0001	day>night p<<0.0001	day>night p<0.001
SLMP	-	night>day p=0.120	day>night p=0.483	night>day p<<0.0001
Siu Ho Wan	night>day p<<0.0001	night>day p<0.0005	night>day p=0.047	-
Tai Mo To	night>day p<0.0005	night>day p<0.01	night>day p=0.050	-
Lung Kwu Chau N	night>day p=0.699	night>day p=0.798	night>day p=0.247	night>day p<<0.0001
Sha Chau SE	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001	-
Shum Wat	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Tai O	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Peaked Hill	-	day>night p<<0.0001	day>night p<<0.0001	day>night p<<0.0001
Fan Lau	-	day>night p=0.053	day>night p=0.329	night>day p<0.05
Kau Ling Chung	-	night>day p=0.884	day>night p<<0.0001	day>night p<<0.0001
Siu A Chau	-	night>day p=0.108	day>night p=0.488	night>day p=0.769
Tai A Chau N	-	night>day p=0.646	night>day p=0.696	night>day p<<0.0001
Tai A Chau S	-	night>day p=0.384	night>day p=0.500	-

Table 11. Diel patterns of Chinese White Dolphin occurrence during the wet season at each area and site from 2017-2021.

	Study Periods			
Site or Area	**2017-18**	**2018-19**	**2019-20**	**2020-21**
BMP	night>day $p<0.0001$	night>day $p=0.0016$	night>day $p=0.0033$	-
SCLKCMP	day>night $p=0.073$	night>day $p=0.0058$	night>day $p=0.708$	night>day $p<<0.0001$
WL	-	night>day $p<<0.0001$	night>day $p=0.0057$	night>day $p<0.005$
SWLMP	-	day>night $p<<0.0001$	day>night $p<<0.0001$	day>night $p<<0.0001$
SLMP	-	day>night $p=0.002$	day>night $p=0.0293$	night>day $p=0.722$
Siu Ho Wan	night>day $p<0.00005$	night>day $p=0.002$	night>day $p=0.043$	-
Tai Mo To	night>day $p=0.357$	night>day $p=0.327$	night>day $p=0.028$	-
Lung Kwu Chau N	day>night $p<0.001$	night>day $p=0.124$	night>day $p=0.307$	night>day $p<<0.0001$
Sha Chau SE	night>day $p=0.028$	night>day $p=0.0003$	night>day $p=0.0023$	-
Shum Wat	-	night>day $p<<0.0001$	night>day $p<<0.0001$	night>day $p<0.005$
Tai O	-	day>night $p=0.651$	night>day $p=0.608$	night>day $p=0.379$
Peaked Hill	-	day>night $p<<0.0001$	day>night $p<<0.0001$	day>night $p<<0.0001$
Fan Lau	-	day>night $p<<0.0001$	day>night $p=0.019$	night>day $p=0.954$
Kau Ling Chung	-	day>night $p=0.004$	day>night $p<<0.0001$	day>night $p<<0.0001$
Siu A Chau	-	day>night $p=0.012$	night>day $p=0.060$	night>day $p=0.210$
Tai A Chau N	-	day>night $p=0.018$	night>day $p=0.202$	night>day $p=0.221$
Tai A Chau S	-	night>day $p=0.338$	night>day $p=0.500$	-

Table 12. Diel patterns of Chinese White Dolphin occurrence during the dry season at each area and site from 2017-2021.

	Study Periods			
Site or Area	**2017-18**	**2018-19**	**2019-20**	**2020-21**
BMP	night>day p<<0.0001	night>day p<0.001	night>day p=0.308	-
SCLKCMP	night>day p<<0.0001	night>day p=764	night>day p=0.0012	night>day p<<0.0001
WL	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
SWLMP	-	day>night p=0.108	day>night p=0.546	day>night p=0.836
SLMP	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Siu Ho Wan	night>day p<0.0001	night>day p>0.050	night>day p=0.345	-
Tai Mo To	night>day p<0.005	night>day p=0.008	night>day p=0.500	-
Lung Kwu Chau N	night>day p<0.005	day>night p=0.186	night>day p=0.024	night>day p<<0.0001
Sha Chau SE	night>day p<0.00005	night>day p=0.0003	night>day p<<0.0001	-
Shum Wat	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Tai O	-	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Peaked Hill	-	day>night p=0.117	day>night p=0.011	day>night p=0.159
Fan Lau	-	night>day p=0.010	night>day p=0.112	night>day p<0.005
Kau Ling Chung	-	night>day p=0.048	day>night p=0.702	day>night p<0.05
Siu A Chau	-	night>day p<<0.0001	night>day p<0.001	night>day p<0.01
Tai A Chau N	-	night>day p=0.174	night>day p=0.015	night>day p<<0.0001
Tai A Chau S	-	night>day p=0.633	-	-

Table 13. Diel patterns of finless porpoise occurrence at each area and site from 2018-2021.

	Study Periods		
Site or Area	**2018-19**	**2019-20**	**2020-21**
SWLMP	night>day p=0.083	day>night p=0.691	night>day p<<0.0001
SLMP	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Kau Ling Chung	night>day p=0.013	day>night p=0.567	night>day p<<0.0001
Siu A Chau	night>day p<<0.0001	night>day p<<0.0001	night>day p<0.05
Tai A Chau N	night>day p=0.315	night>day p<<0.0001	night>day p<<0.0001
Tai A Chau S	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001

Table 14. Diel patterns of finless porpoise occurrence during the wet season at each area and site from 2018-2021.

	Study Periods		
Site or Area	**2018-19**	**2019-20**	**2020-21**
SWLMP	night>day p=0.0009	night>day p=0.192	night>day p<0.005
SLMP	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Kau Ling Chung	night>day p<<0.0001	night>day p=0.359	night>day p<0.005
Siu A Chau	night>day p<<0.0001	night>day p<<0.0001	day>night p<0.001
Tai A Chau N	night>day p=0.009	night>day p<<0.0001	night>day p<<0.0001
Tai A Chau S	night>day p=0.012	night>day p<<0.0001	night>day p<<0.0001

Table 15. Diel patterns of finless porpoise occurrence during the dry season at each area and site from 2018-2021.

	Study Periods		
Site or Area	**2018-19**	**2019-20**	**2020-21**
SWLMP	day>night p=0.73	day>night p=0.875	night>day p<0.001
SLMP	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001
Kau Ling Chung	day>night p=0.97	day>night p=0.990	night>day p<0.005
Siu A Chau	night>day p=0.0011	night>day p<<0.0001	day>night p=0.966
Tai A Chau N	day>night p=0.843	night>day p<<0.0001	night>day p<0.0005
Tai A Chau S	night>day p<<0.0001	night>day p<<0.0001	night>day p<<0.0001

Table 16. Models of increasing complexity in predictor variable(s) and their Akaike's Information Criteria (AIC) values.

Model	Predictor Variable(s)	AIC Value
Model 1	Site	71160.62
Model 2	Season (wet/dry)	74347.98
Model 3	Diel Phase (day/night)	74349.11
Model 4	Location + Season + Diel Phase	71159.49
Model 5	Location + Season + Diel Phase + Location x Season + Location x Diel Phase + Season x Diel Phase	71014.41
Model 6	Location + Season + Diel Phase + Location x Season + Location x Diel Phase + Season x Diel Phase + Location x Season x Diel Phase	71008.62

Table 17. Site specific (as well as all sites combined) comparisons of the relative levels of Chinese White Dolphin DPMs obtained from paired F-POD and C-POD deployments at the hourly and daily levels of temporal resolution. The directions of the relative DPMs recorded and the p-values for the Wilcoxon matched pairs tests are shown.

Sites	Hourly (DPMs)	Daily (DPMs)
Siu Ho Wan	F-POD > C-POD p<<0.0001	F-POD > C-POD p<<0.0001
Lung Kwu Chau N	F-POD < C-POD p<<0.0001	F-POD < C-POD p<<0.0001
Tai O	F-POD > C-POD p<0.01	F-POD > C-POD p<0.01
Kau Ling Chung	F-POD < C-POD p<0.01	F-POD < C-POD p<0.01
Siu A Chau	F-POD > C-POD p<<0.0001	F-POD > C-POD p<<0.0001
Tai A Chau N	F-POD > C-POD p<0.01	F-POD > C-POD p<<0.0001
All sites combined	F-POD > C-POD p<0.01	F-POD > C-POD p<<0.0001

Table 18. Site specific (as well as all sites combined) comparisons of the relative levels of finless porpoise DPMs recorded by paired F-POD and C-POD at the hourly and daily levels of temporal resolution. The directions of the relative DPMs recorded and the p-values for the Wilcoxon matched pairs tests are shown.

Sites	Hourly (DPMs)	Daily (DPMs)
Kau Ling Chung	F-POD < C-POD p<0.01	F-POD < C-POD p<0.01
Siu A Chau	F-POD < C-POD p<0.01	F-POD < C-POD p<<0.0001
Tai A Chau N	F-POD < C-POD p<0.01	F-POD < C-POD p<<0.0001
All sites combined	F-POD < C-POD p<0.01	F-POD < C-POD p<0.01

* There were no FP detections by either the C-POD or F-POD at the Sha Chau SE site.

Table 19. Comparison of % false positive Chinese White Dolphin detections in the DPM data obtained from paired C-POD and F-POD deployments.

	Deployment Periods										
	Jul/20-Oct/20			**Oct/20-Jan/21**			**Jan/21-Apr/21**			**Apr/21-Jul/21**	
Site	**CPOD**	**FPOD**		**CPOD**	**FPOD**		**CPOD**	**FPOD**		**C-POD**	**FPOD**
Siu Ho Wan	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00
Lung Kwu Chau N	**40.00**	0.00		**39.00**	1.00		**16.00**	1.00		0.00	0.00
Tai O	**13.00**	1.00		**9.00**	0.00		**9.00**	1.00		**7.39**	2.00
Kau Ling Chung	**18.00**	0.00		**10.00**	0.00		**16.00**	0.00		0.00	0.00
Siu A Chau	**4.88**	0.00		0.00	0.00		0.00	0.00		**3.09**	0.00
Tai A Chau N	0.00	0.00		**1.00**	0.00		0.00	0.00		0.00	-

C-POD false positive rate for Chinese white dolphins: overall mean = 7.77%; SD=11.48%

F-POD false positive rate for Chinese white dolphins: overall mean = 0.26%; SD=0.54%

(i.e., false positive rate of the C-POD is about 30 times higher than F-POD for CWD detection).

Table 20. Comparison of % false positive finless porpoise detections in the DPM data obtained from paired C-POD and F-POD deployments.

	Deployment Periods										
	Jul/20-Oct/20			**Oct/20-Jan/21**			**Jan/21-Apr/21**			**Apr/21-Jul/21**	
Site	**CPOD**	**FPOD**		**CPOD**	**FPOD**		**CPOD**	**FPOD**		**C-POD**	**FPOD**
Kau Ling Chung	**3.00**	0.00		**56.00**	0.00		**3.00**	0.00		**4.00**	0.00
Siu A Chau	**2.00**	0.00		**3.00**	0.00		**3.00**	0.00		**1.00**	0.00
Tai A Chau N	**10.00**	1.00		**11.00**	0.00		**2.00**	1.00		**2.00**	-

C-POD false positive rate for Chinese white dolphins: overall mean = 8.33%; SD=15.34%

F-POD false positive rate for Chinese white dolphins: overall mean = 0.18%; SD=0.40%

(i.e., false positive rate of the C-POD is about 21 times higher than F-POD for FP detection).

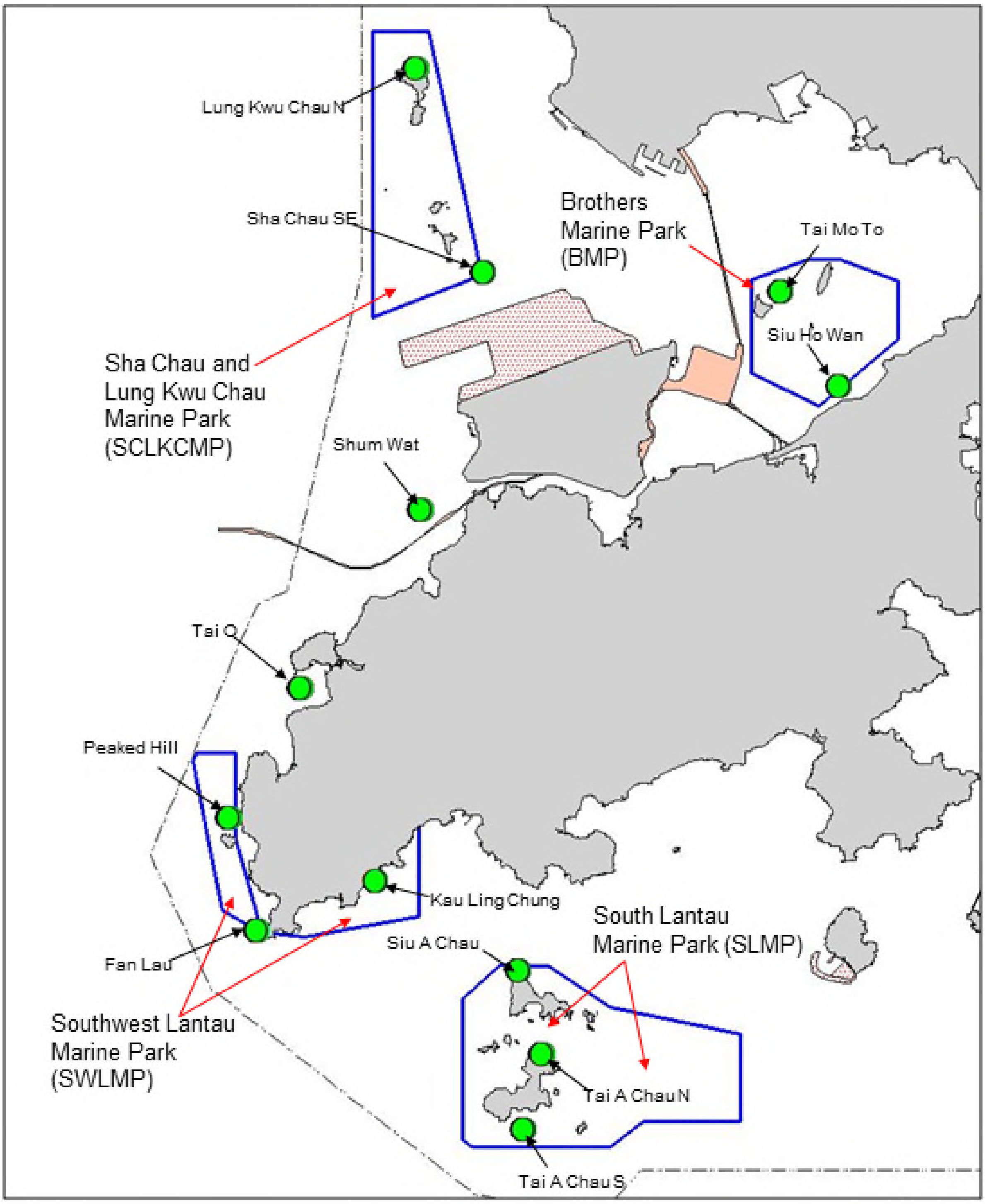


Figure 1. Locations (green dots) for deployment of 12 pairs of C-POD and F-POD units within four existing marine parks (BMP, SCLKCMP, SWLMP and SLMP), and outside of these marine parks in WL (Shum Wat and Tai O). Existing marine parks are outlined in blue.

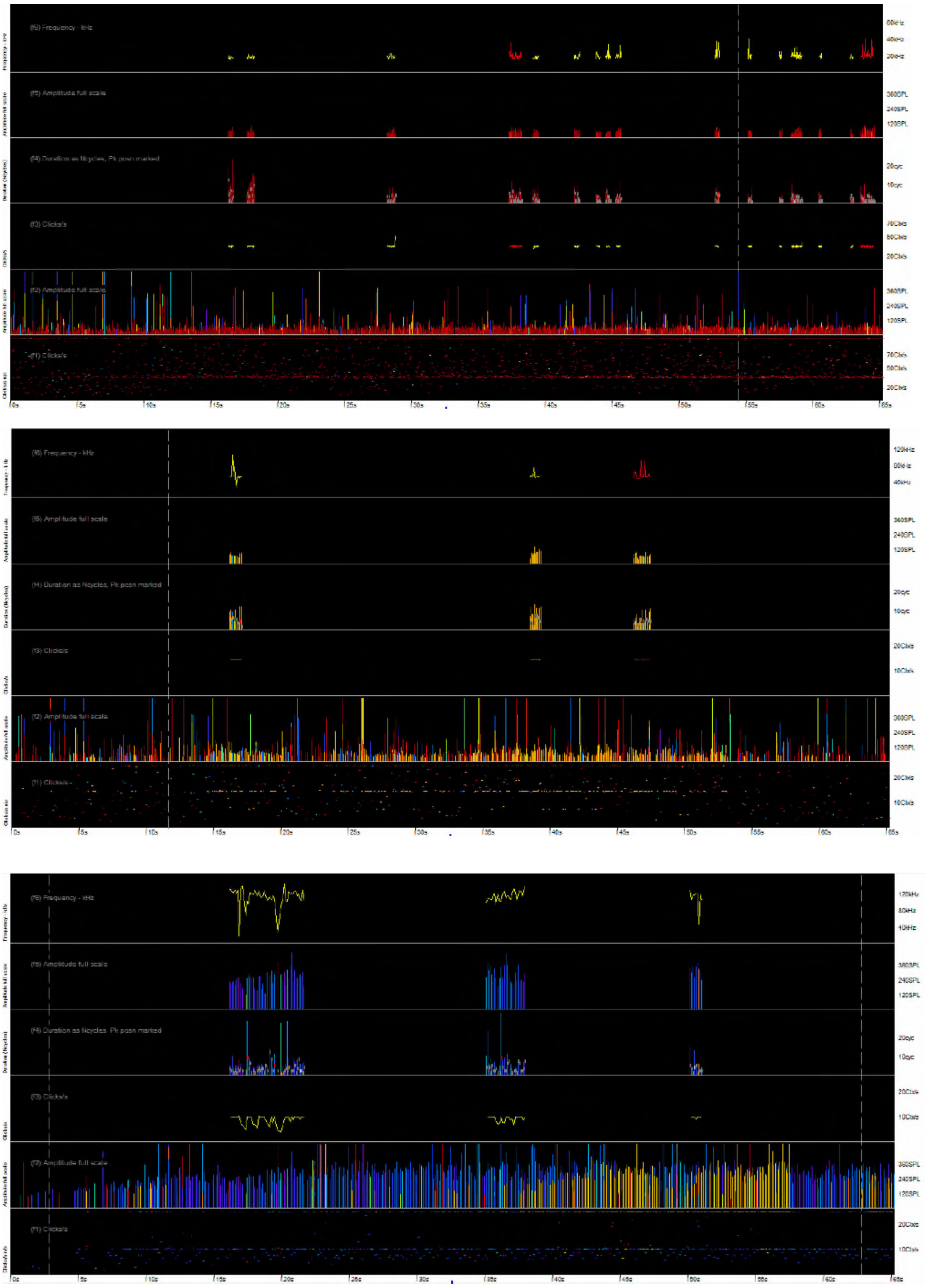


Figure 2. High resolution click details of an example of 18 kHz (top), 50kHz (centre) and 83kHz (bottom) boat sonar found in the F-POD data at Siu Ho Wan. In each example series, the graphs represent (from top to bottom): click amplitude (FP3 file); click duration (i.e., number of cycles per click) (FP3 file); clicks per second (FP3 file); click amplitude (FP1 file); clicks per second (FP1 file). The FP3 files were filtered for boat sonar detections and the FP1 files shows all clicks, unfiltered.

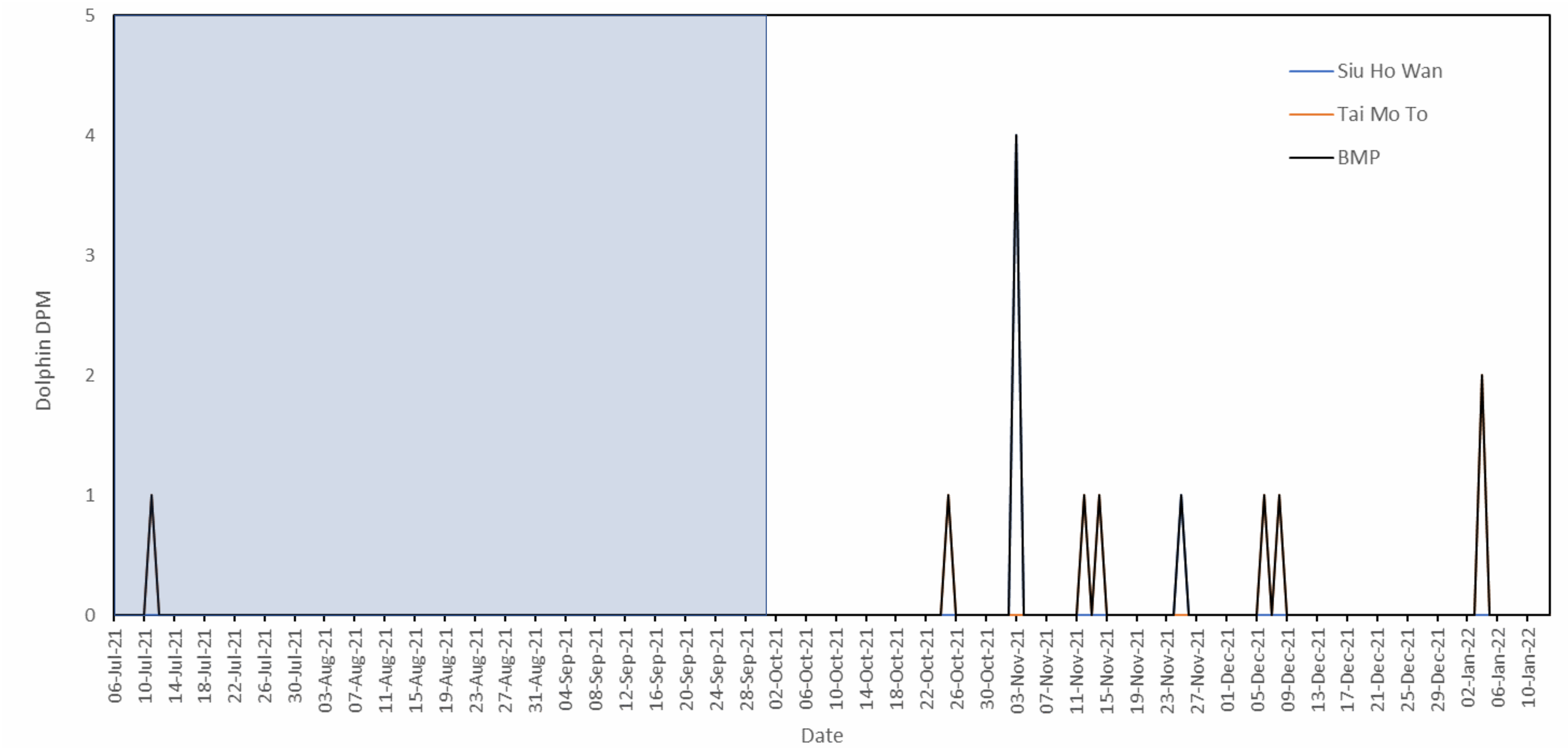


Figure 3. Dolphin DPM per day in the BMP area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

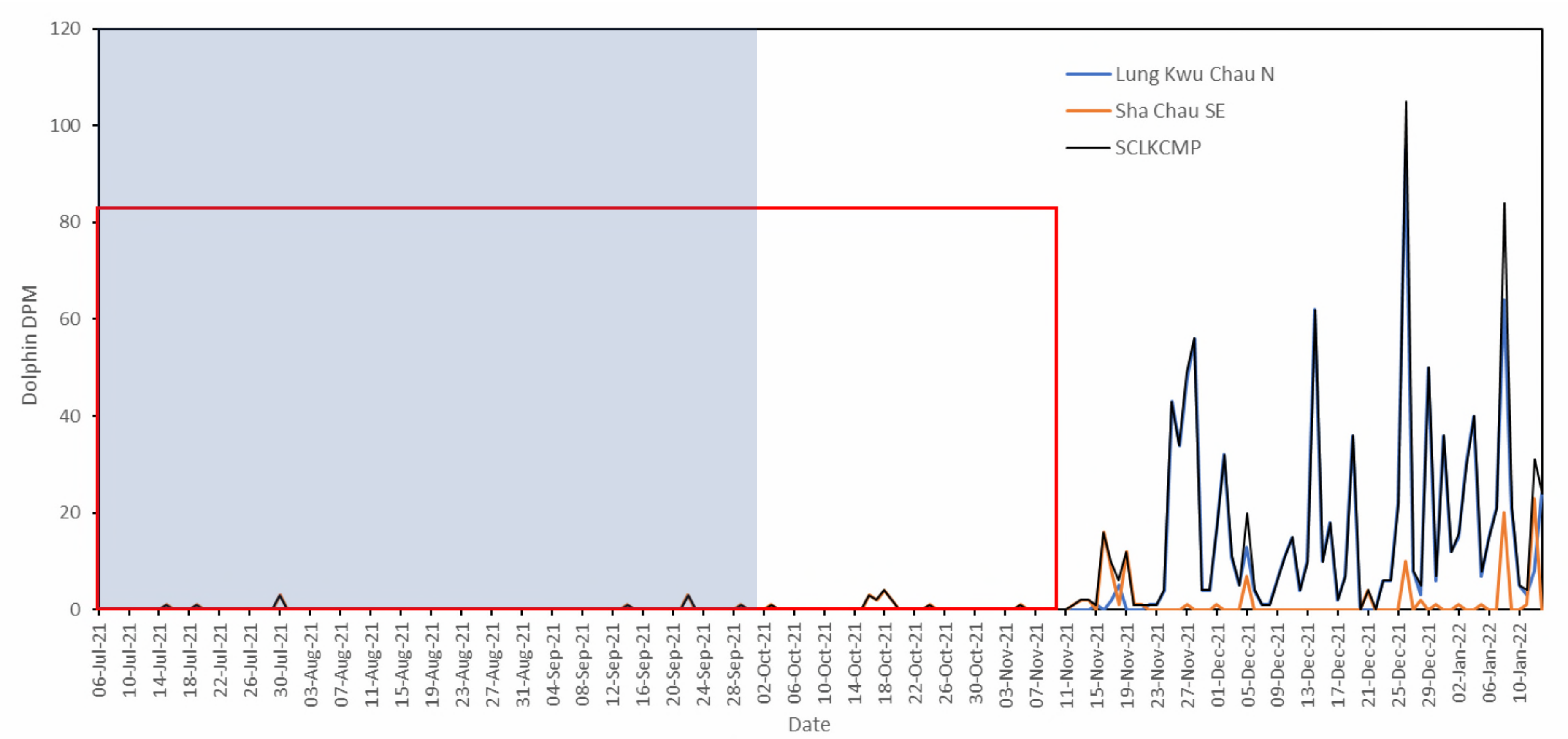


Figure 4. Dolphin DPM per day in the SCLKCMP area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively). Note: the F-POD at Lung Kwu Chau N was lost during the first deployment (red box) so no data were collected.

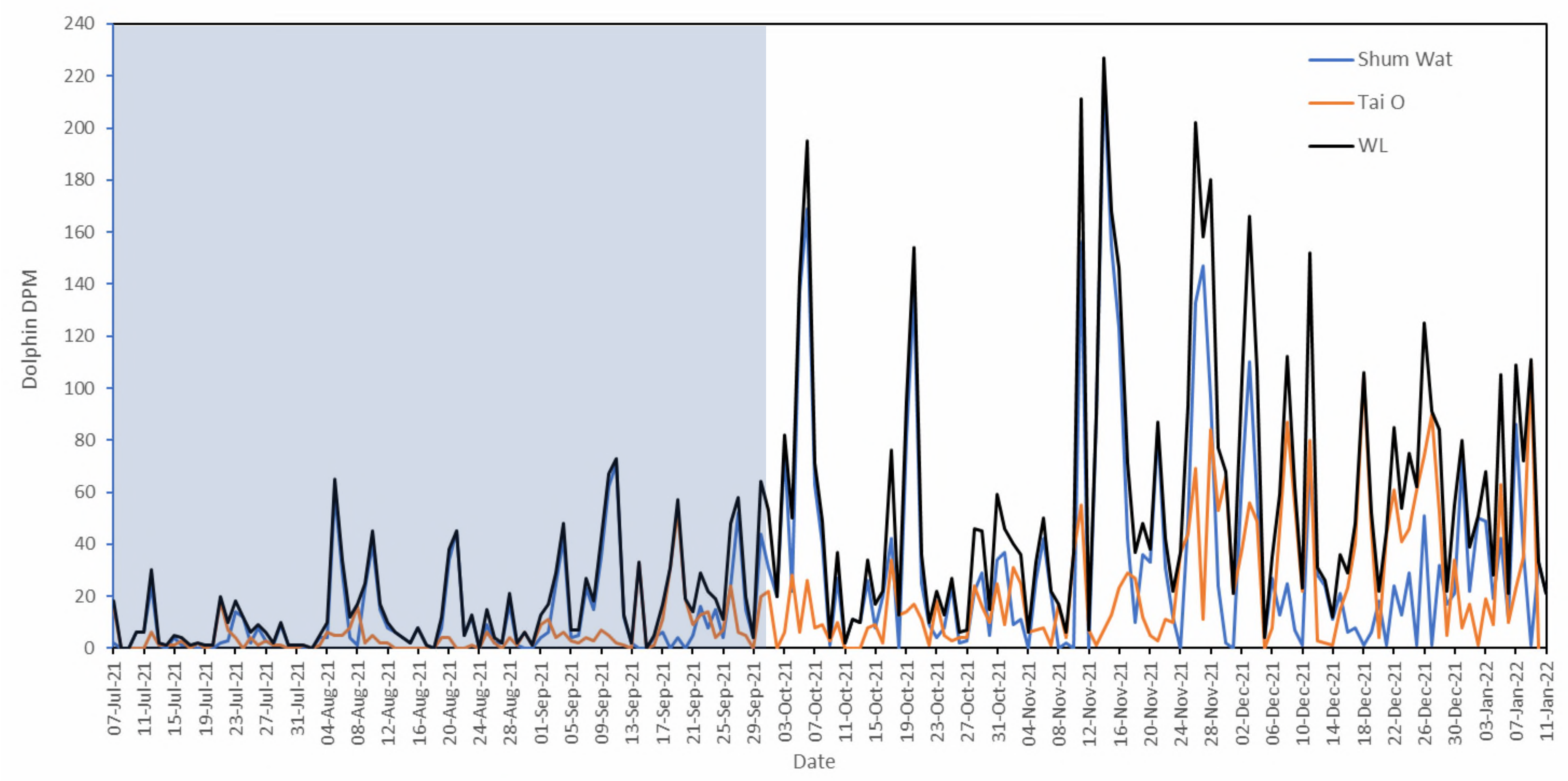


Figure 5. Dolphin DPM per day in the WL area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

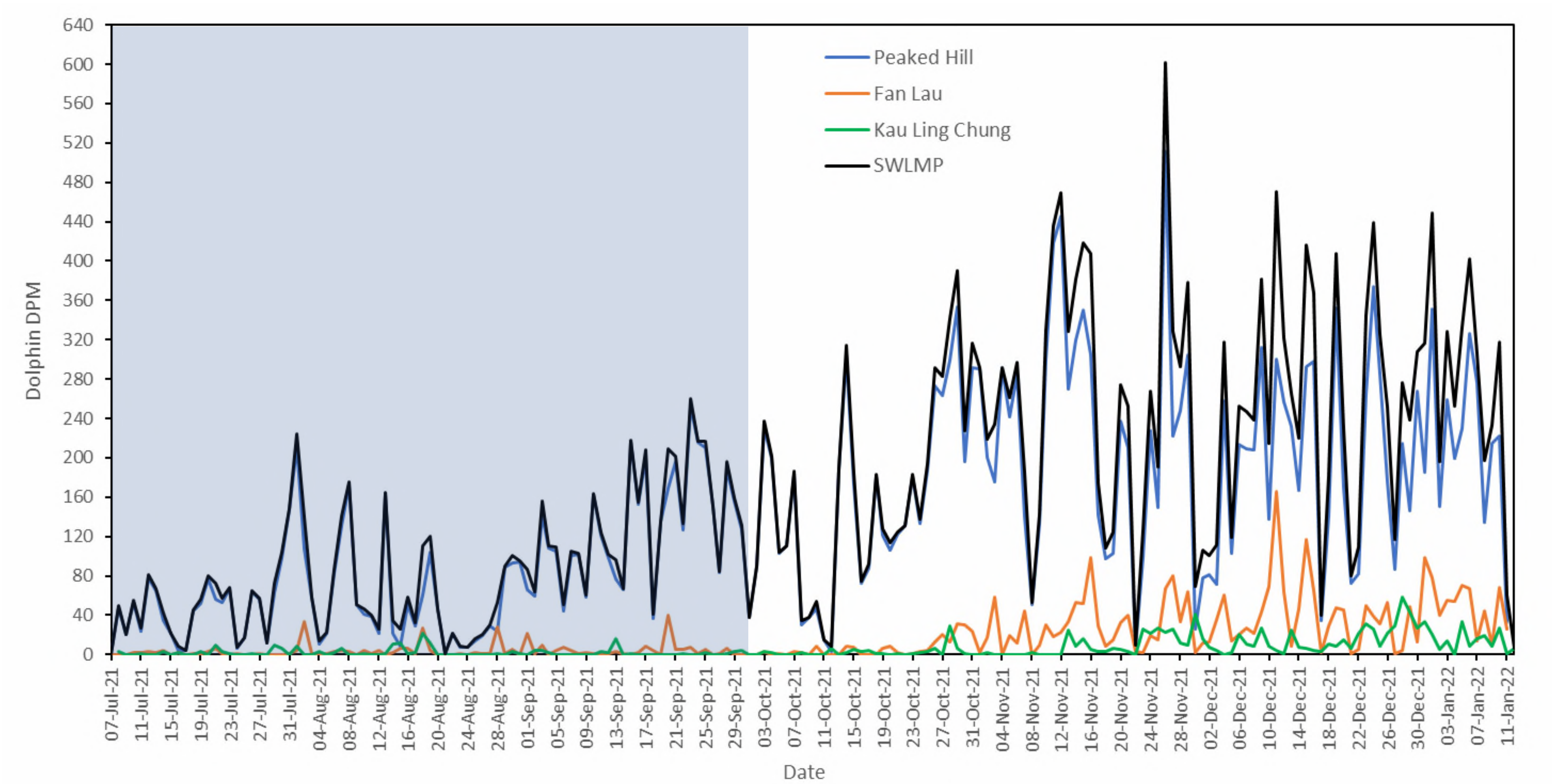


Figure 6. Dolphin DPM per day in the SWLMP area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

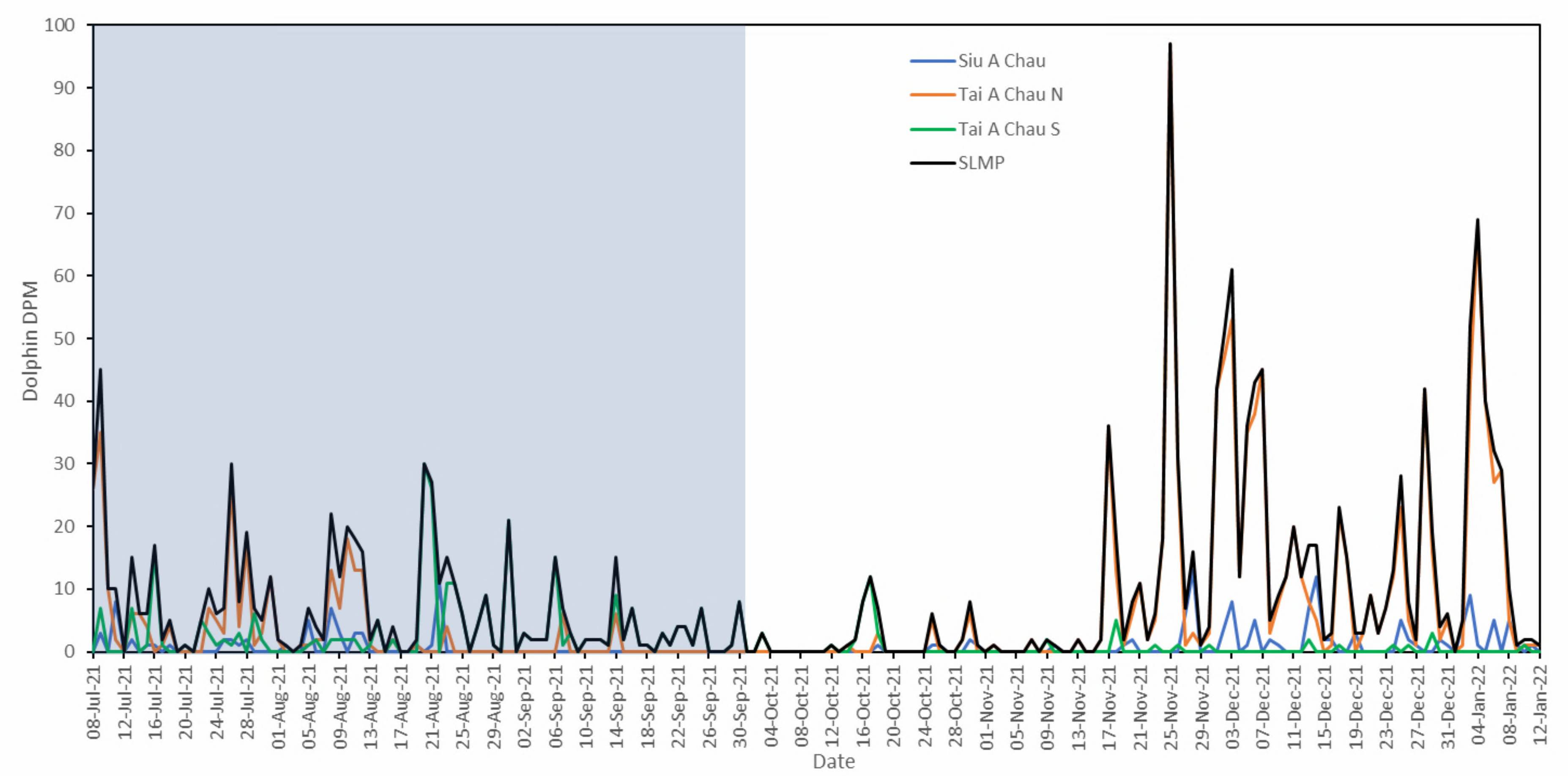


Figure 7. Dolphin DPM per day in the SLMP area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

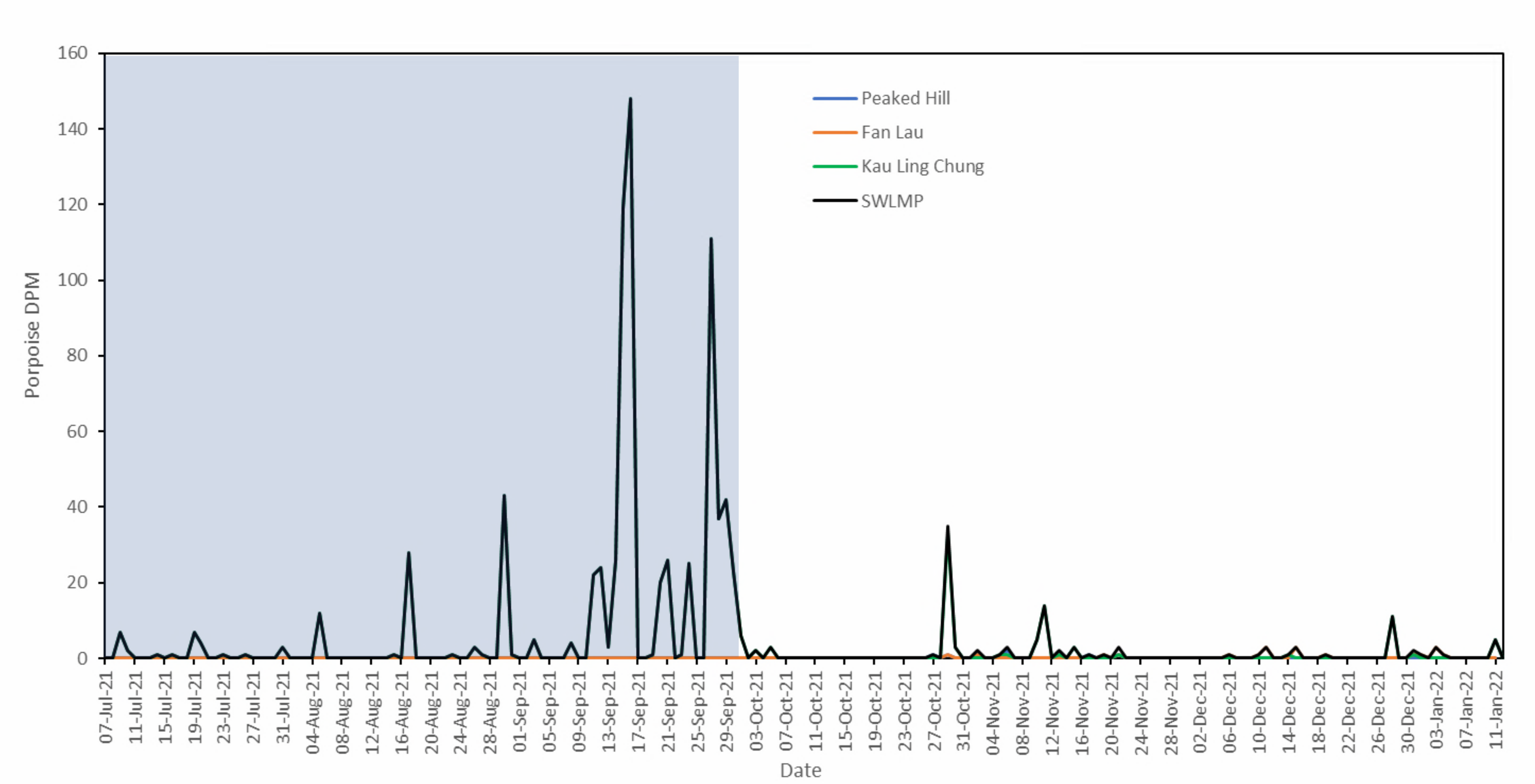


Figure 8. Porpoise DPM per day in the SWLMP area as recorded by F-PODs from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

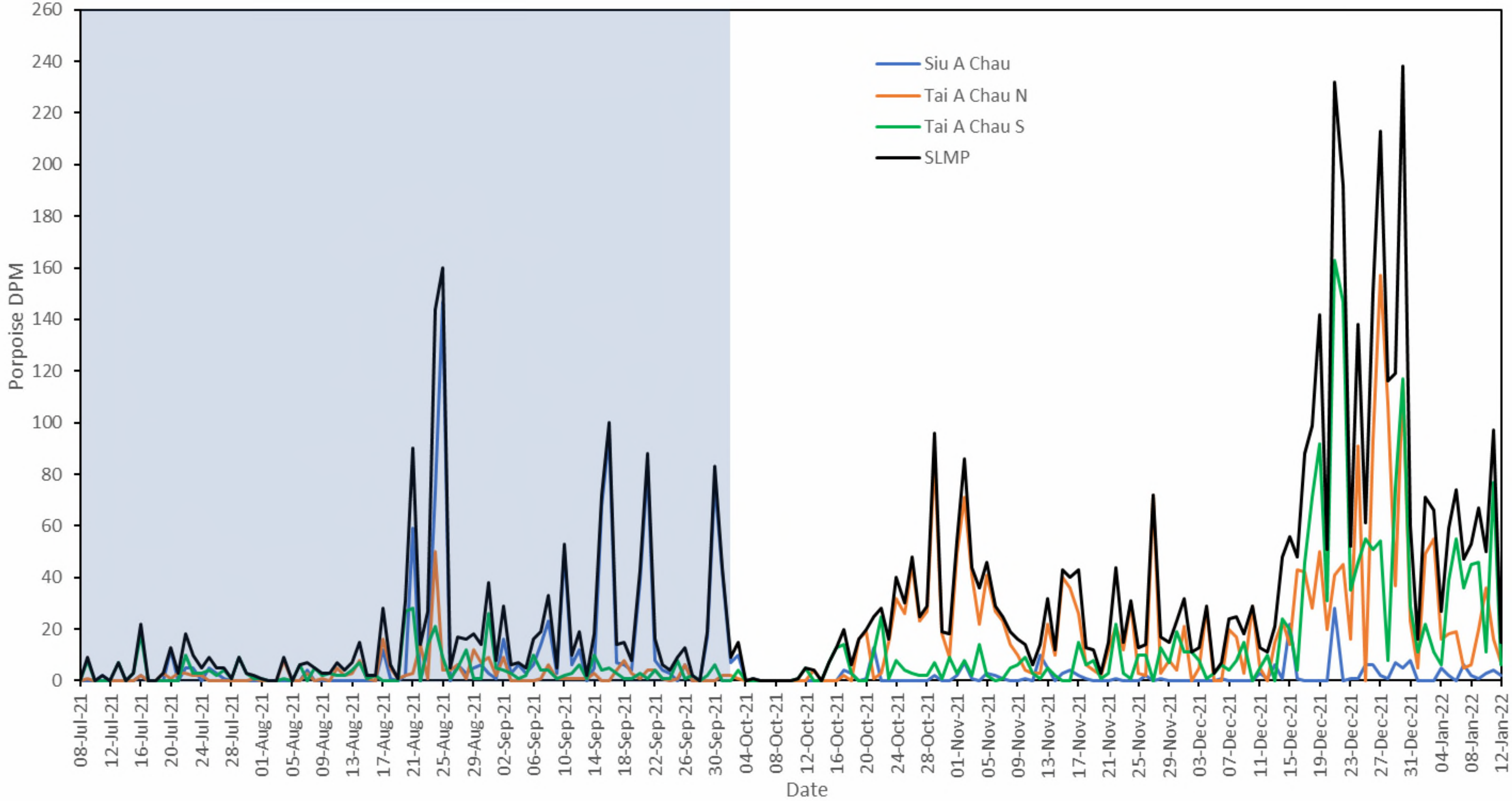


Figure 9. Porpoise DPM per day in the SLMP area as recorded by F-POD units from July 2021 to January 2022 (the shaded and unshaded areas represent the wet and dry seasons, respectively).

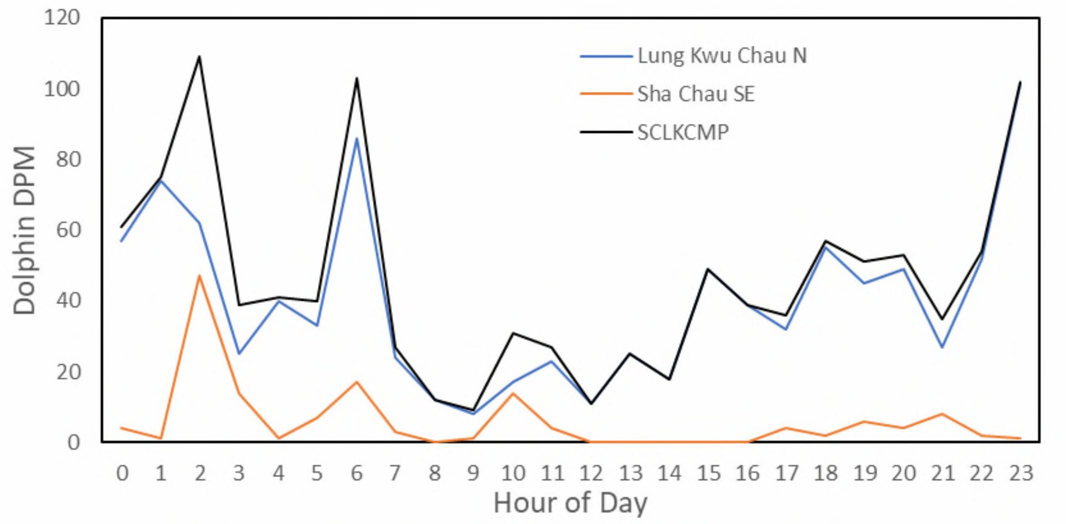


Figure 10. Dolphin DPM diel pattern at SCLKCMP from July 2021 to January 2022.

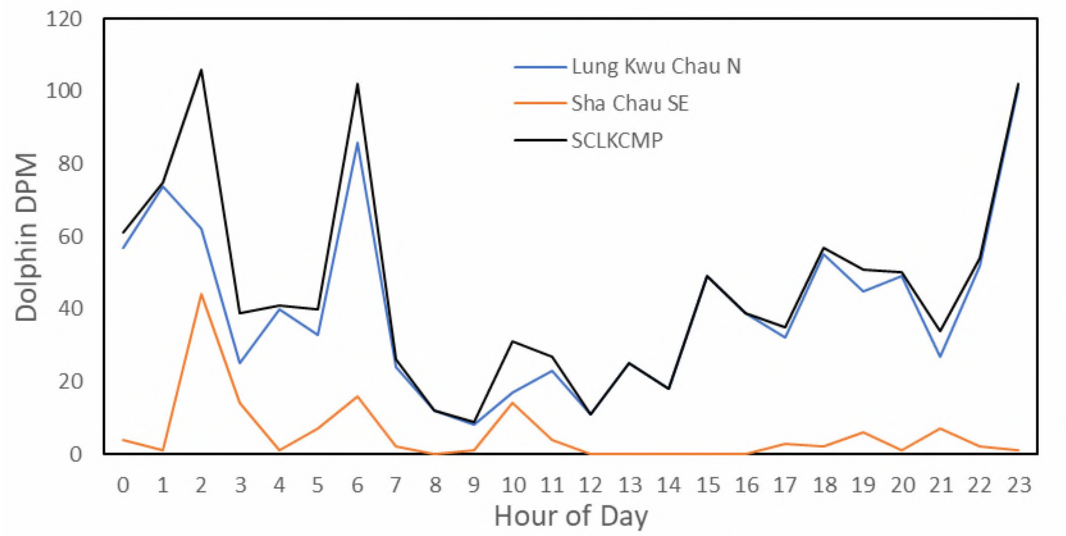


Figure 11. Dolphin DPM diel pattern at SCLKCMP in the dry season (October 2021 to January 2022).

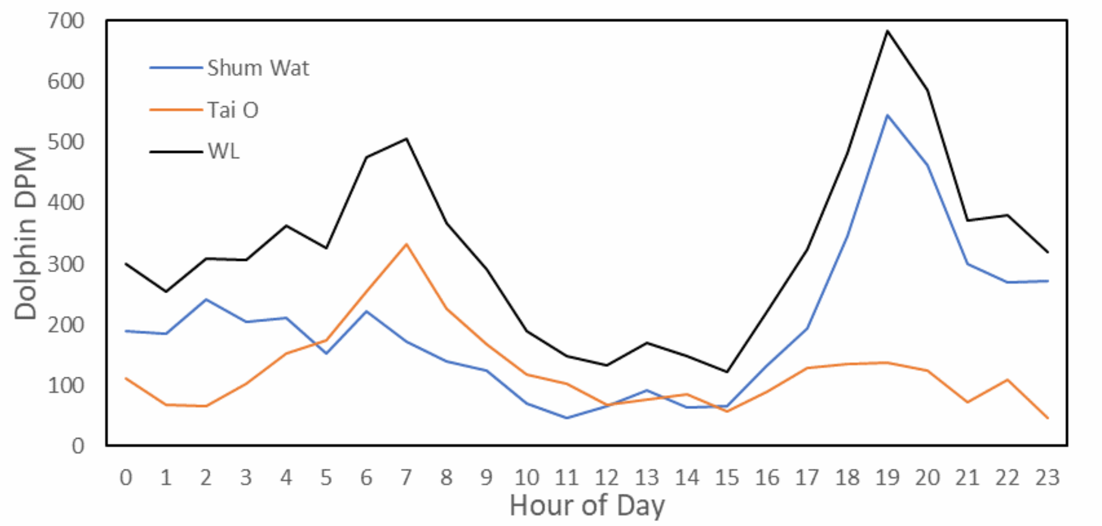


Figure 12. Dolphin DPM diel pattern at WL from July 2021 to January 2022.

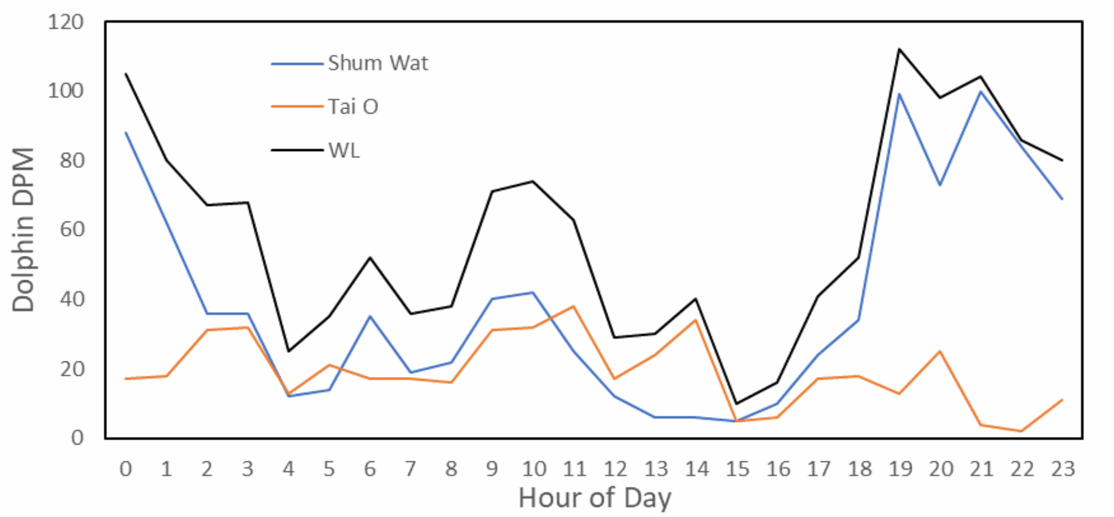


Figure 13. Dolphin DPM diel pattern at WL in the wet season (July-September 2021).

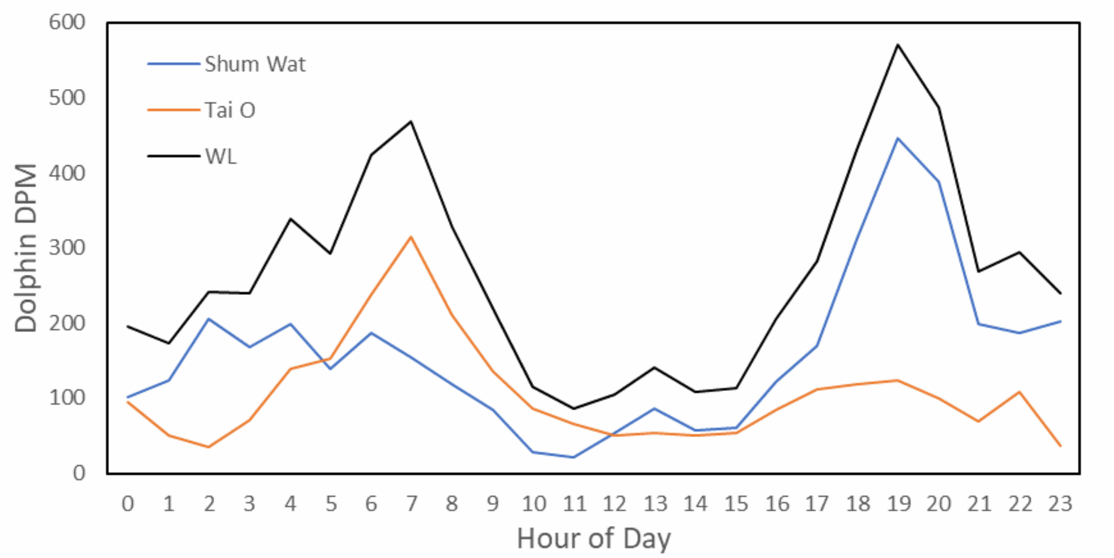


Figure 14. Dolphin DPM diel pattern at WL in the dry season (October 2021-January 2022).

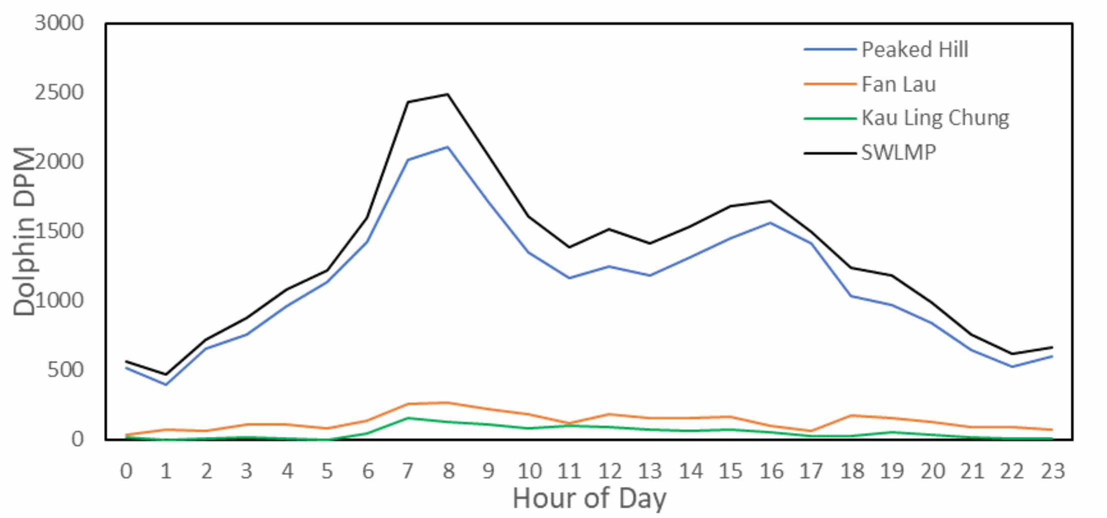


Figure 15. Dolphin DPM diel pattern at SWLMP from July 2021 to January 2022.

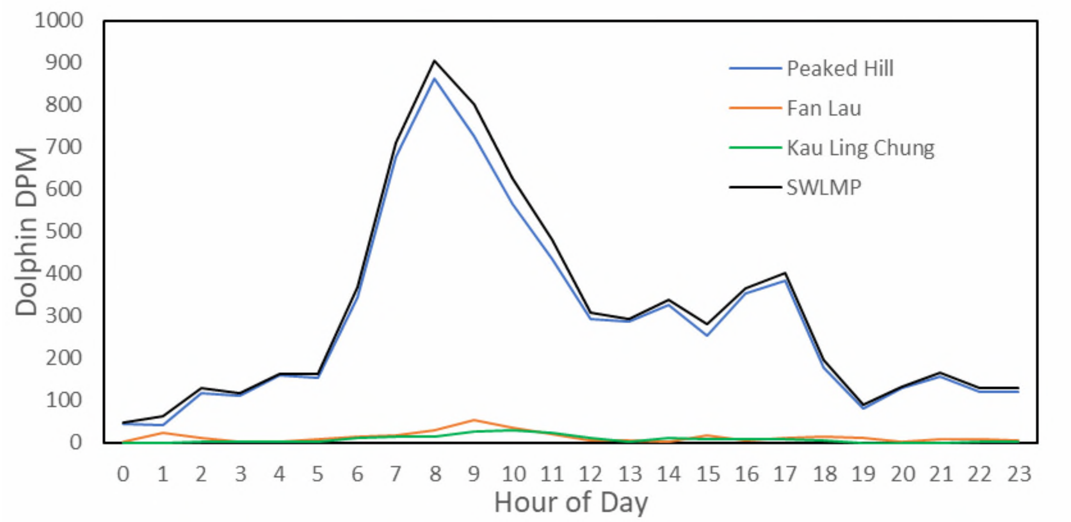


Figure 16. Dolphin DPM diel pattern at SWLMP in the wet season (July-October 2021).

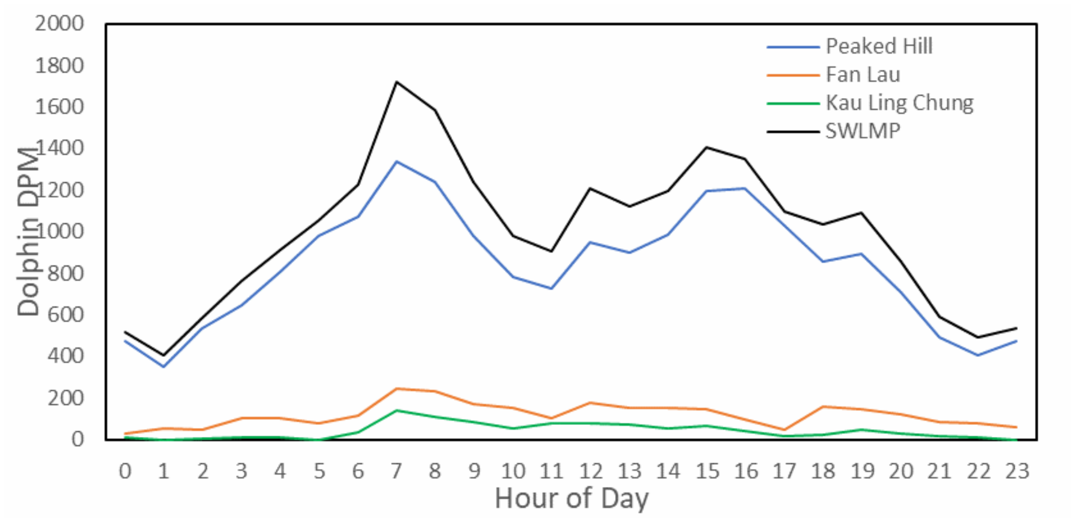


Figure 17. Dolphin DPM diel pattern at SWLMP in the dry season (Oct 2021-Jan 2022).

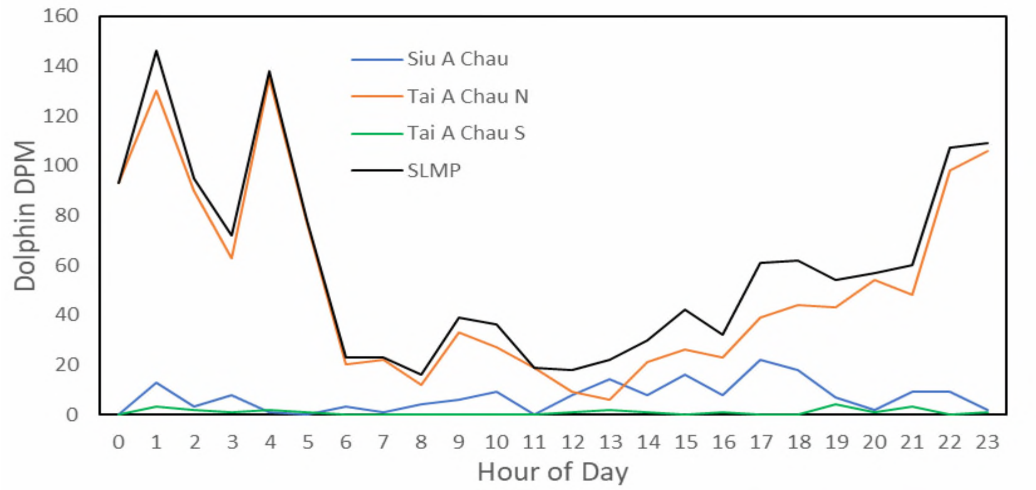


Figure 18. Dolphin DPM diel pattern at SLMP from July 2021 to January 2022.

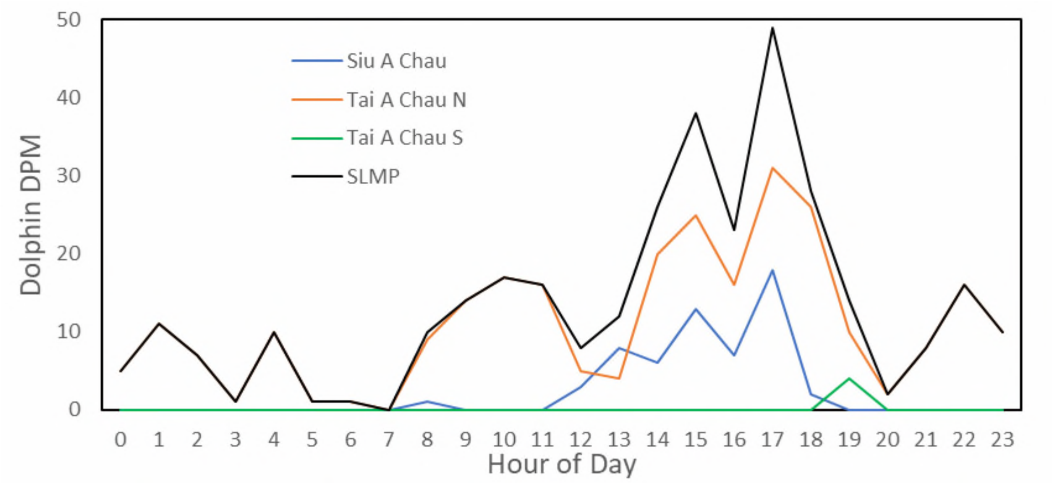


Figure 19. Dolphin DPM diel pattern at SLMP in the wet season (July-September 2021).

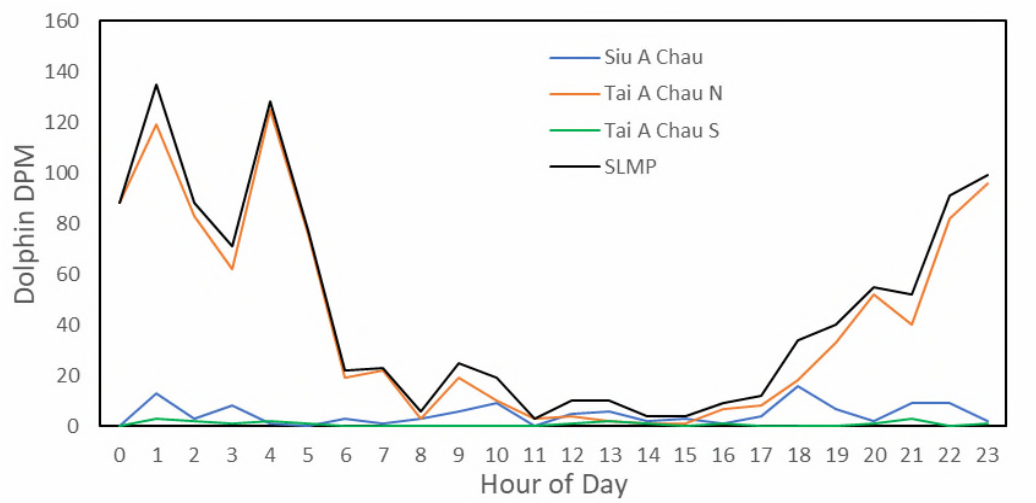


Figure 20. Dolphin DPM diel pattern at SLMP in the dry season (Oct 2021-Jan 2022).

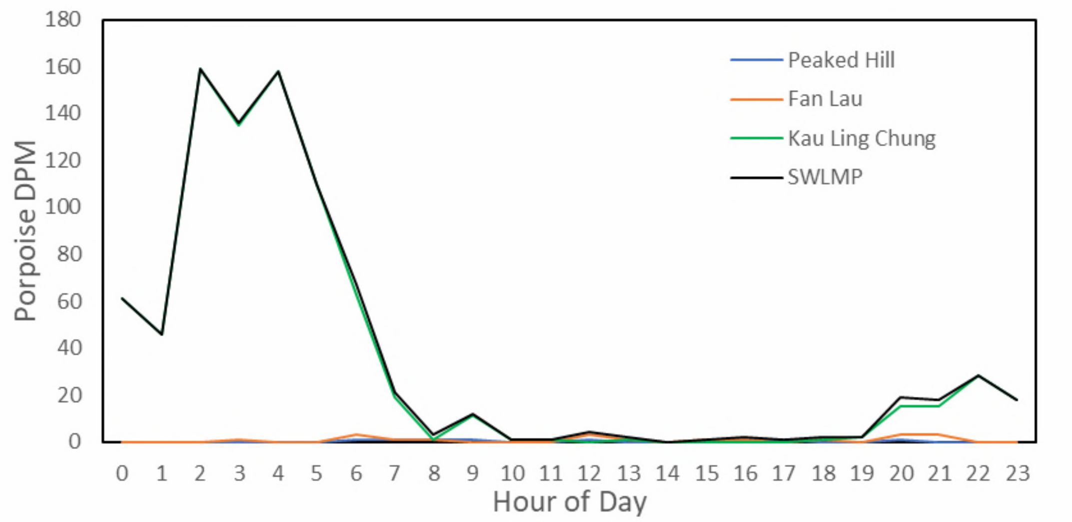


Figure 21. Porpoise DPM diel pattern at SWLMP from July 2021 to January 2022.

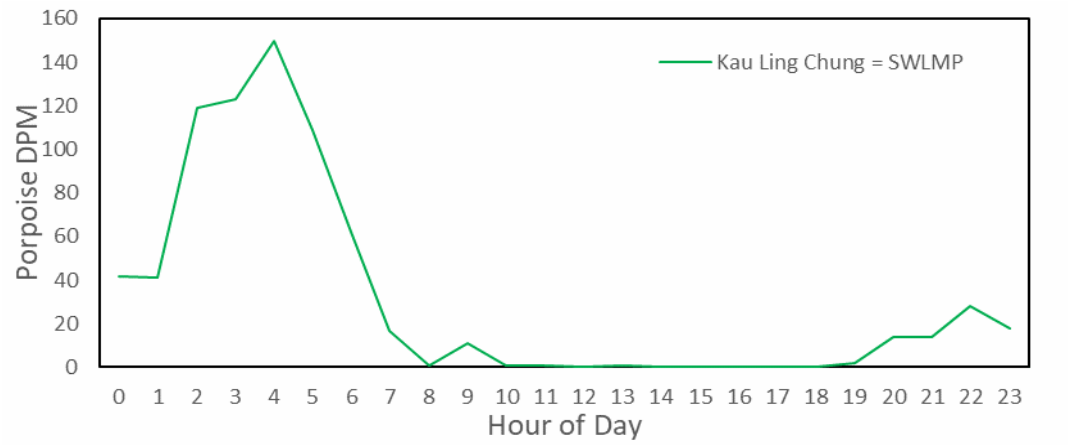


Figure 22. Porpoise DPM diel pattern at SWLMP (porpoises were only recorded at Kau Ling Chung) in the wet season (July-September 2021).

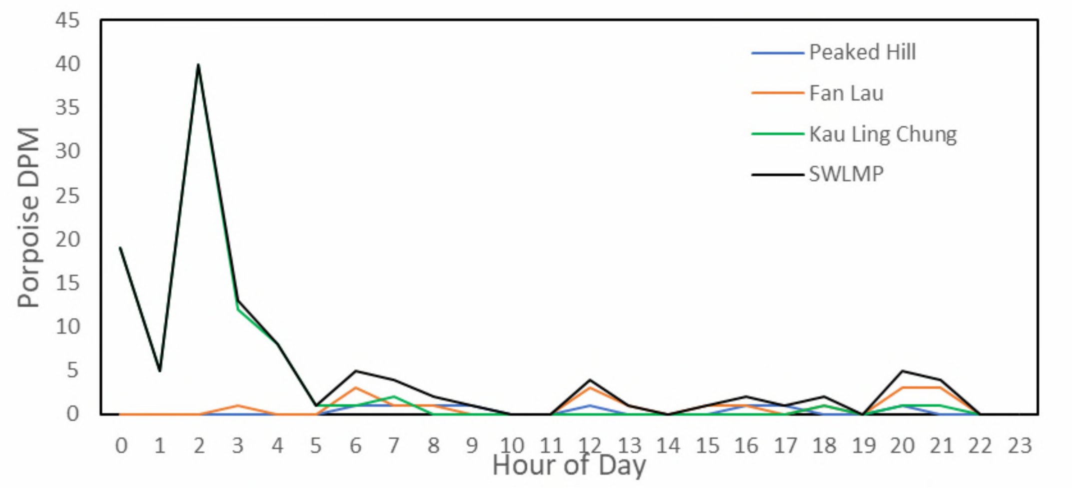


Figure 23. Porpoise DPM diel pattern at SWLMP in the dry season (Oct 2021-Jan 2022).

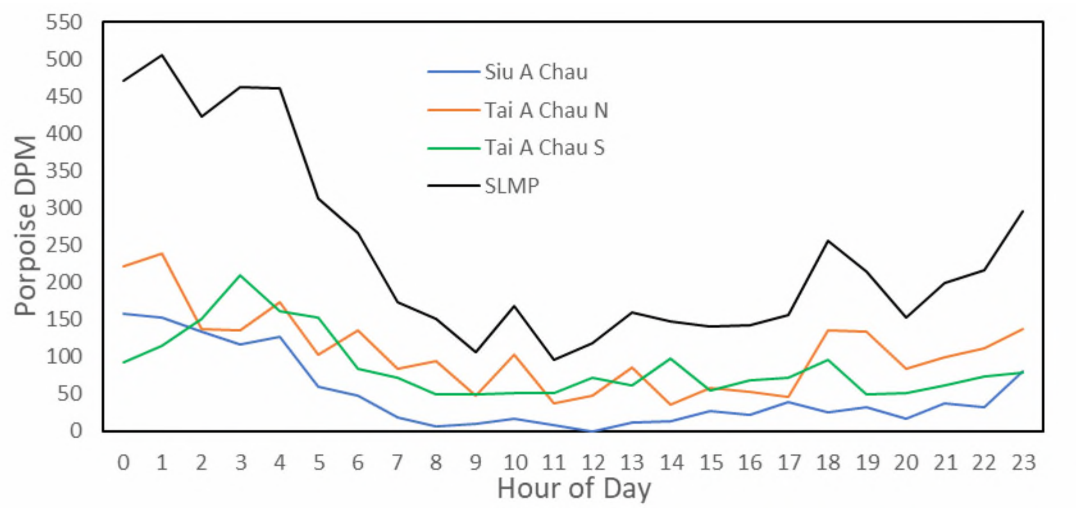


Figure 24. Porpoise DPM diel pattern for SLMP area from July 2021 to January 2022.

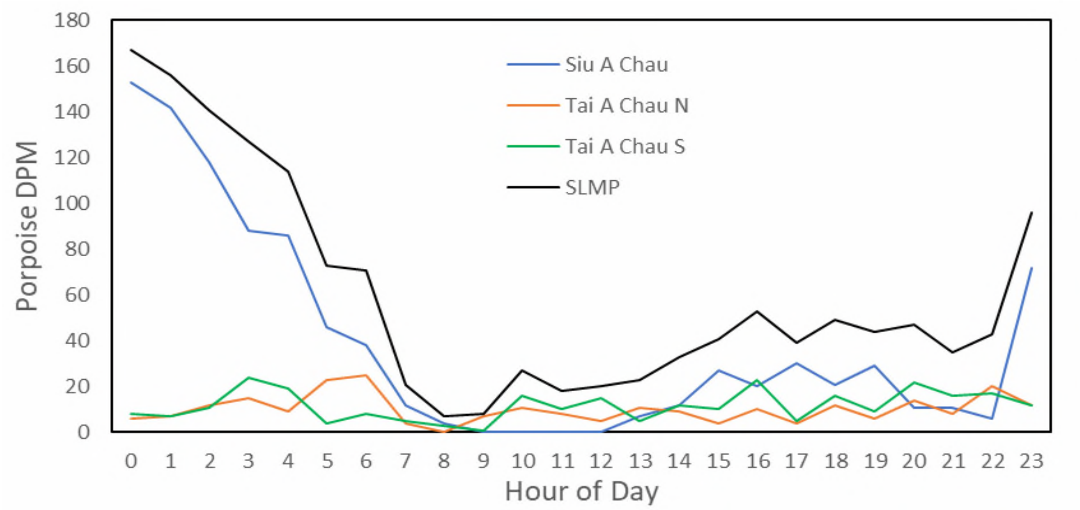


Figure 25. Porpoise DPM diel pattern at SLMP in the wet season (July-September 2021).

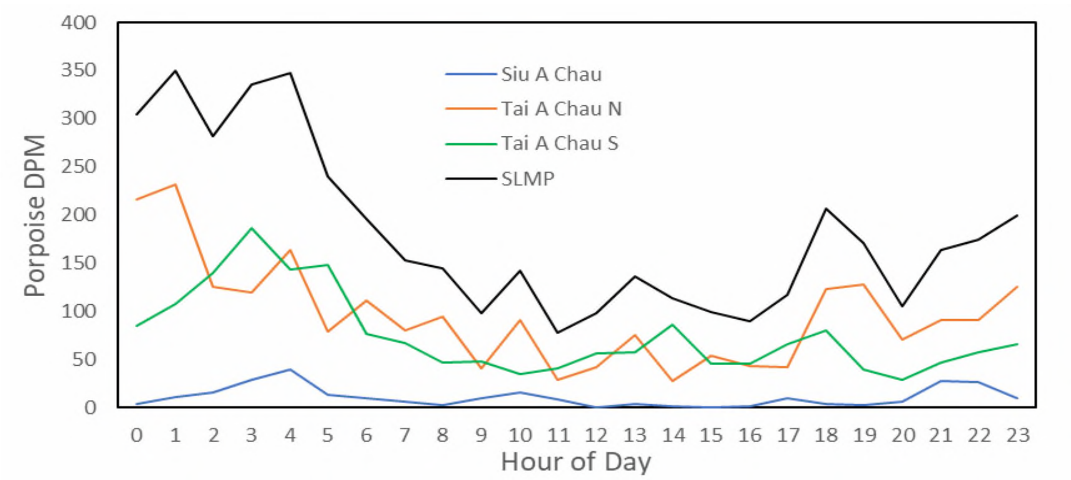


Figure 26. Porpoise DPM diel pattern at SLMP in the dry season (Oct 2021-Jan 2022).

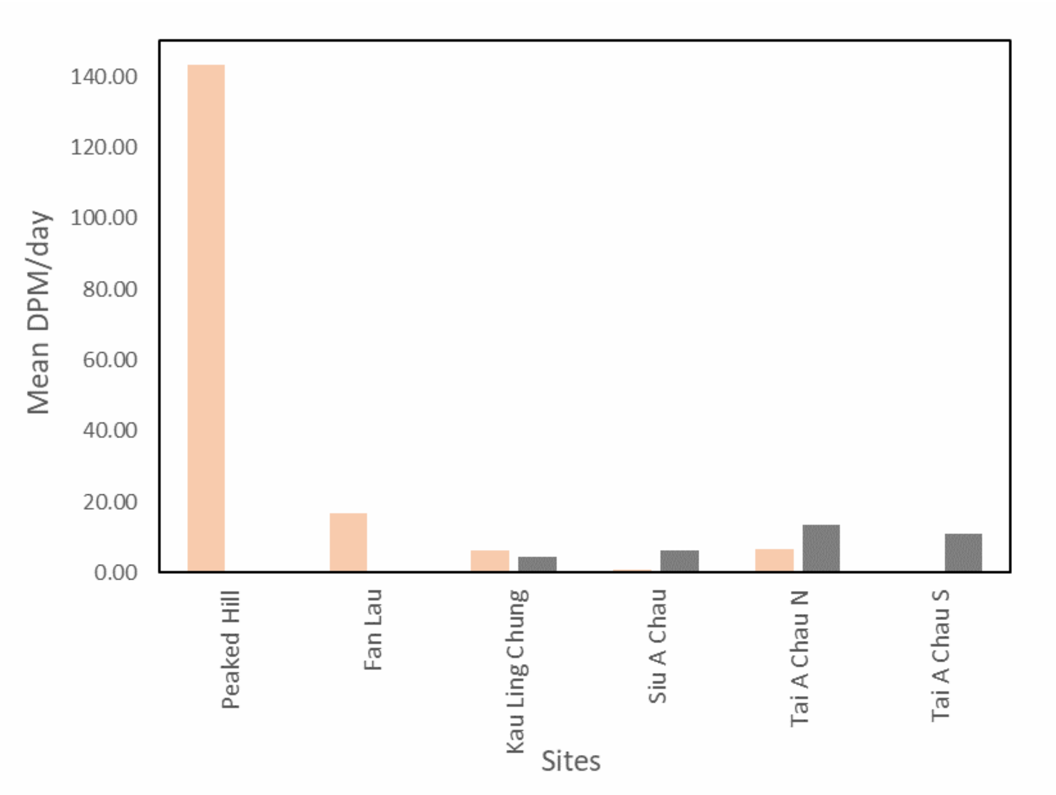


Figure 27. Comparison of the mean DPM/day for dolphins (pink) and porpoises (grey) at the sites where both species were recorded between July 2021 to January 2022.

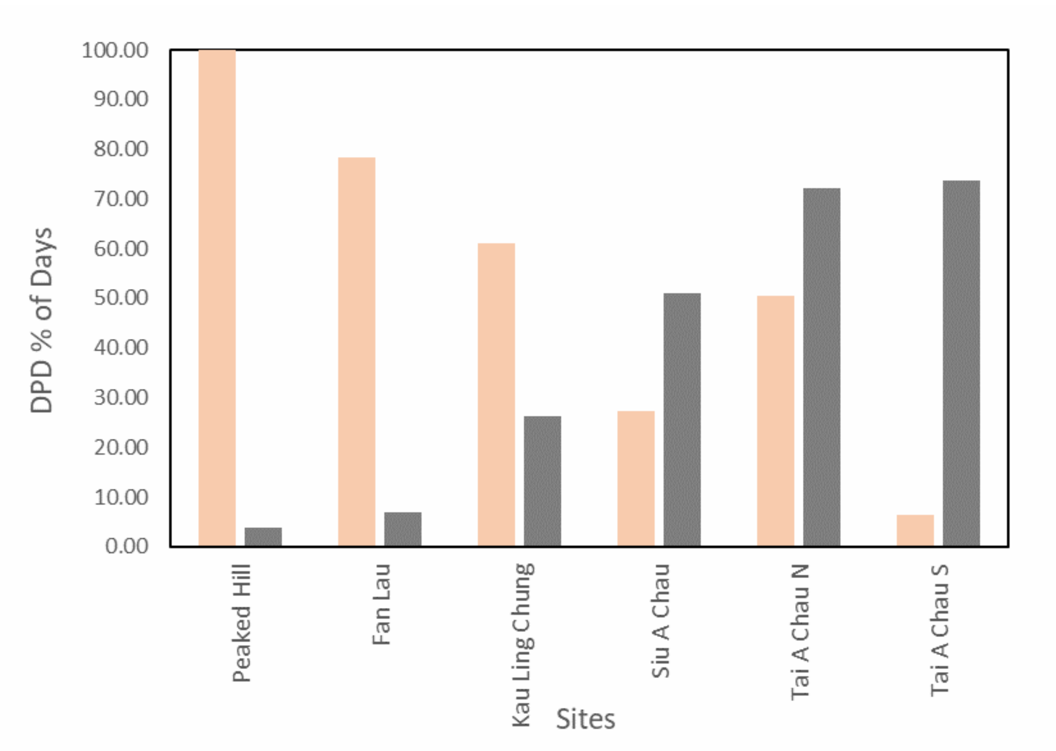


Figure 28. Comparison of the DPD % of days for dolphins (pink) and porpoises (grey) at the sites where both species were recorded between July 2021 to January 2022.

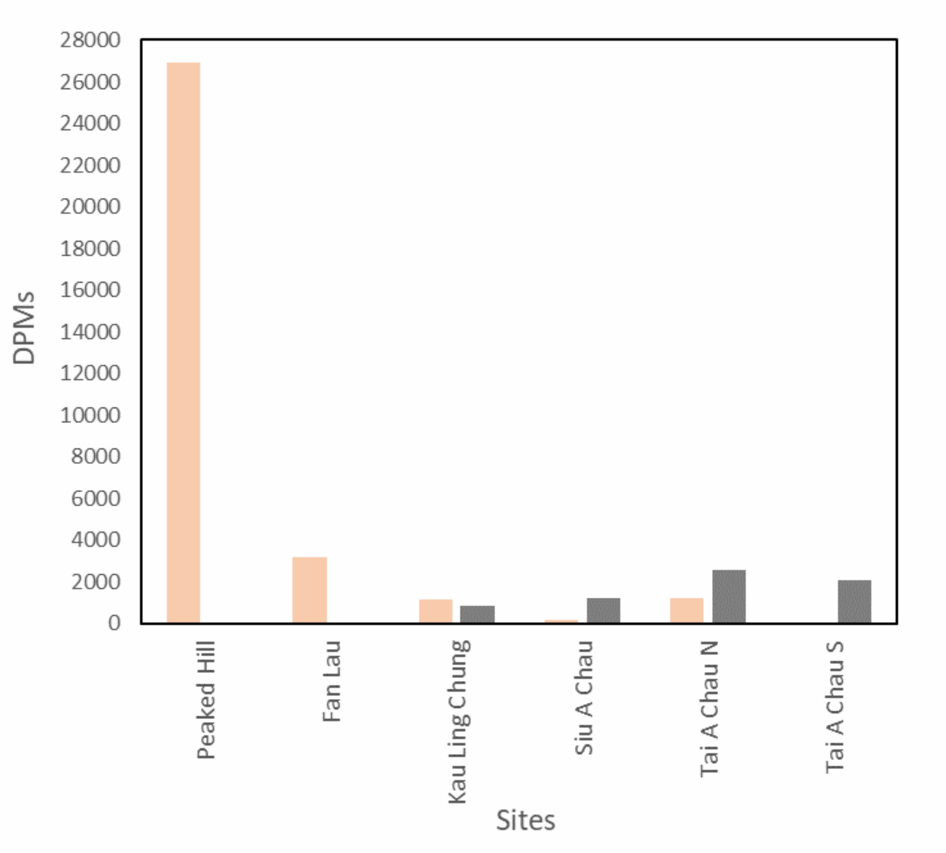


Figure 29. Comparison of dolphin (pink) and porpoise (grey) DPMs at sites where both species were recorded between July 2021 to January 2022.

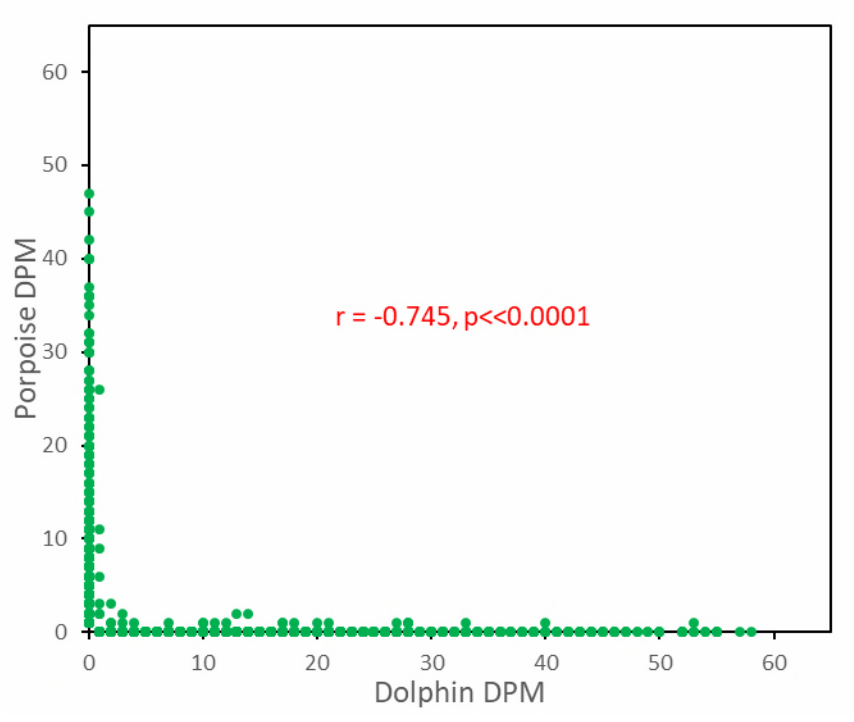


Figure 30. Inverse relationship between hourly porpoise and dolphin DPMs using all data from sites where both species were detected from July 2021 to January 2022.

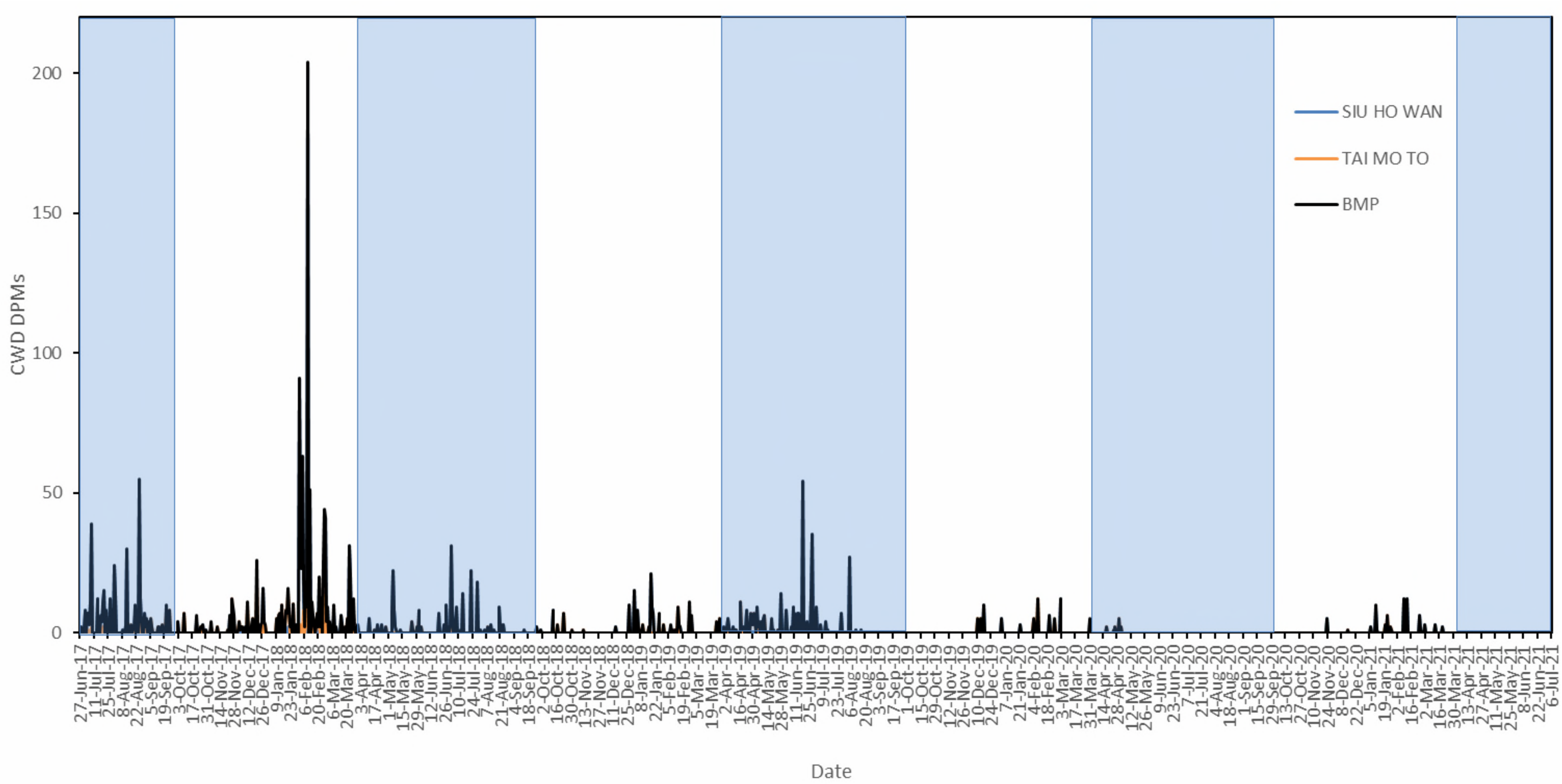


Figure 31. Chinese White Dolphin DPMs recorded by C-PODs from 27 June 2017 to 06 July 2021 at BMP sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

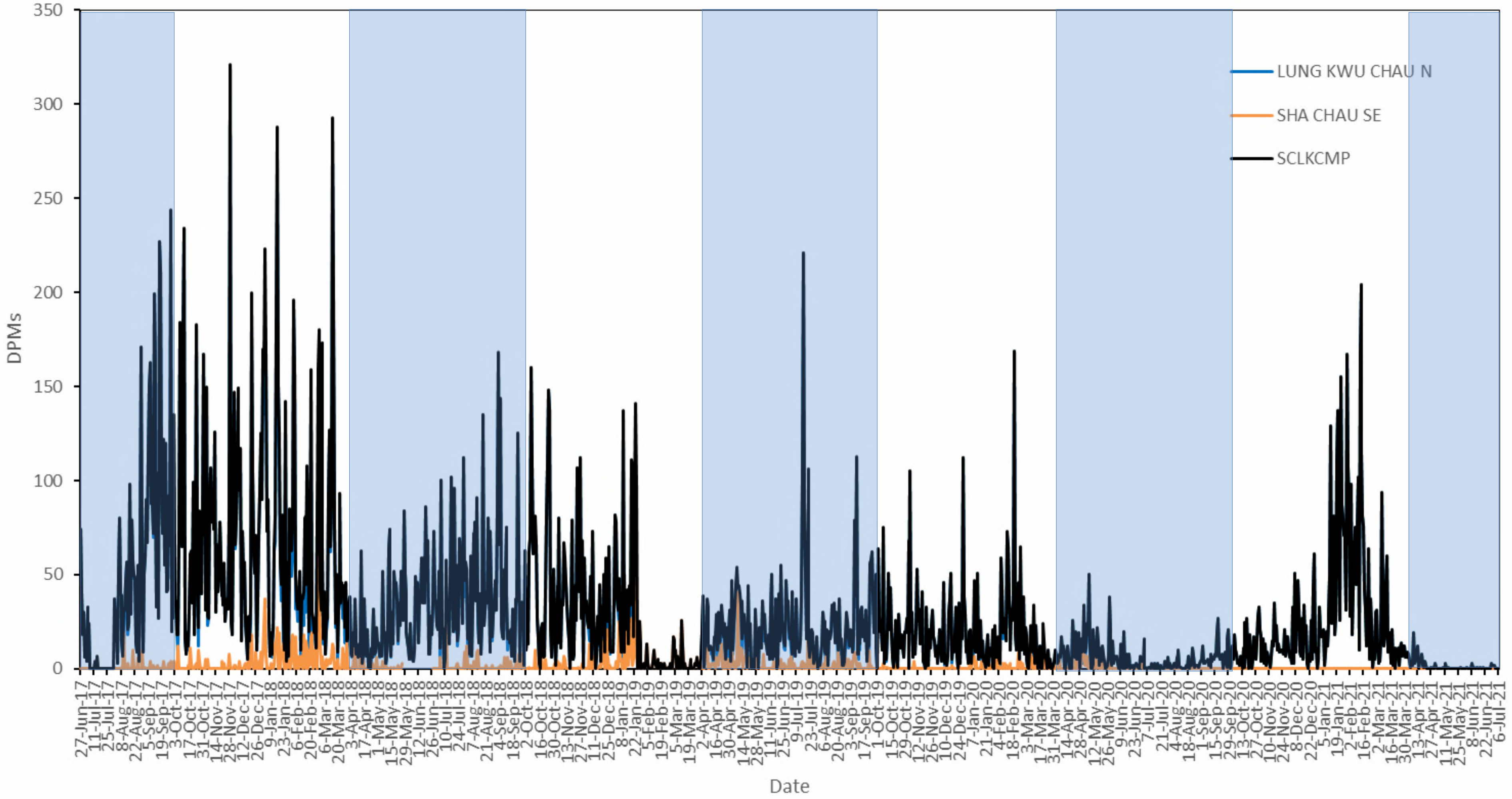


Figure 32. Chinese White Dolphin DPMs recorded by C-PODs from 27 June 2017 to 06 July 2021 at SCLKCMP sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

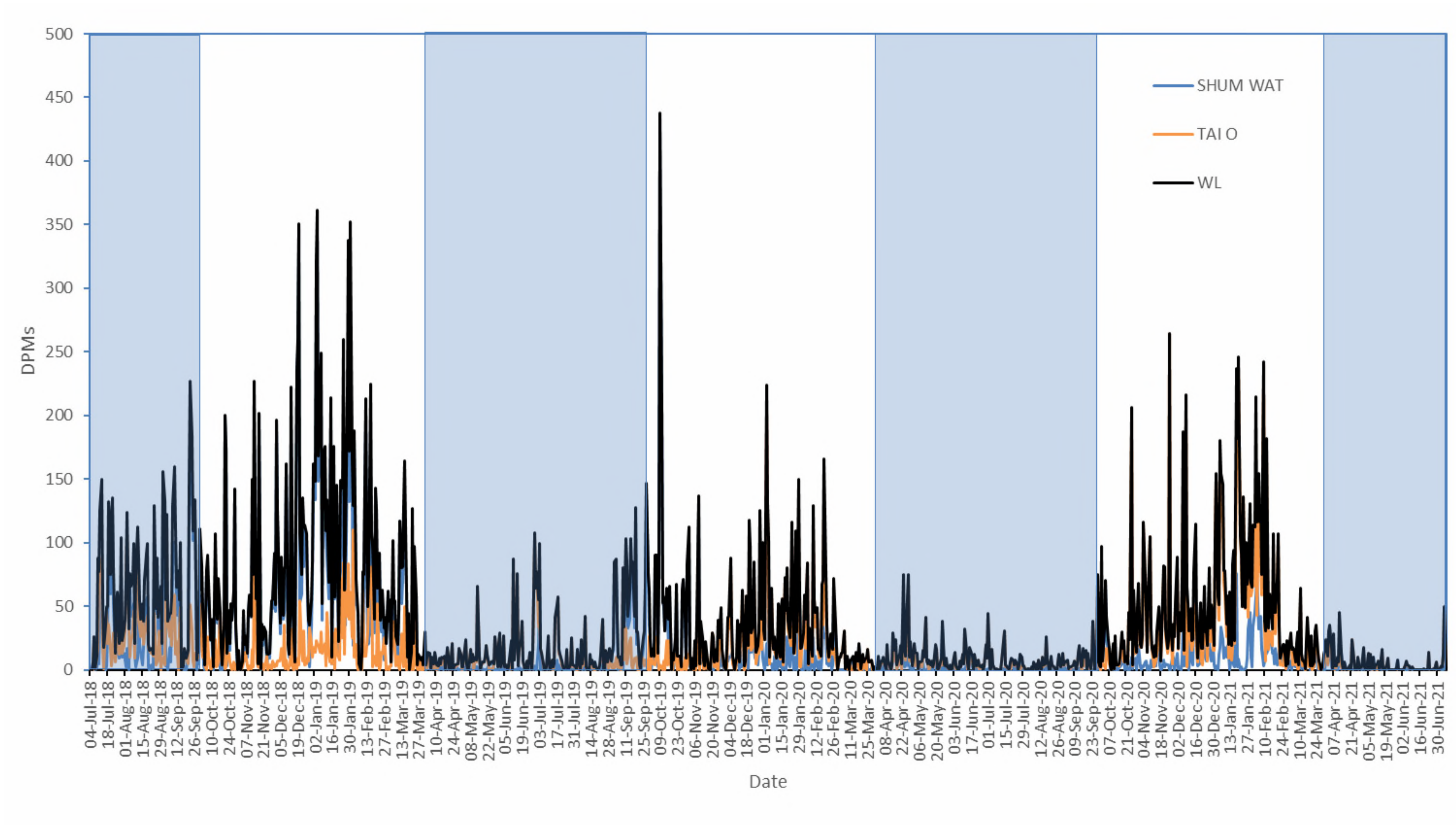


Figure 33. Chinese White Dolphin DPMs recorded by C-PODs from 04 July 2018 to 07 July 2021 at WL sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

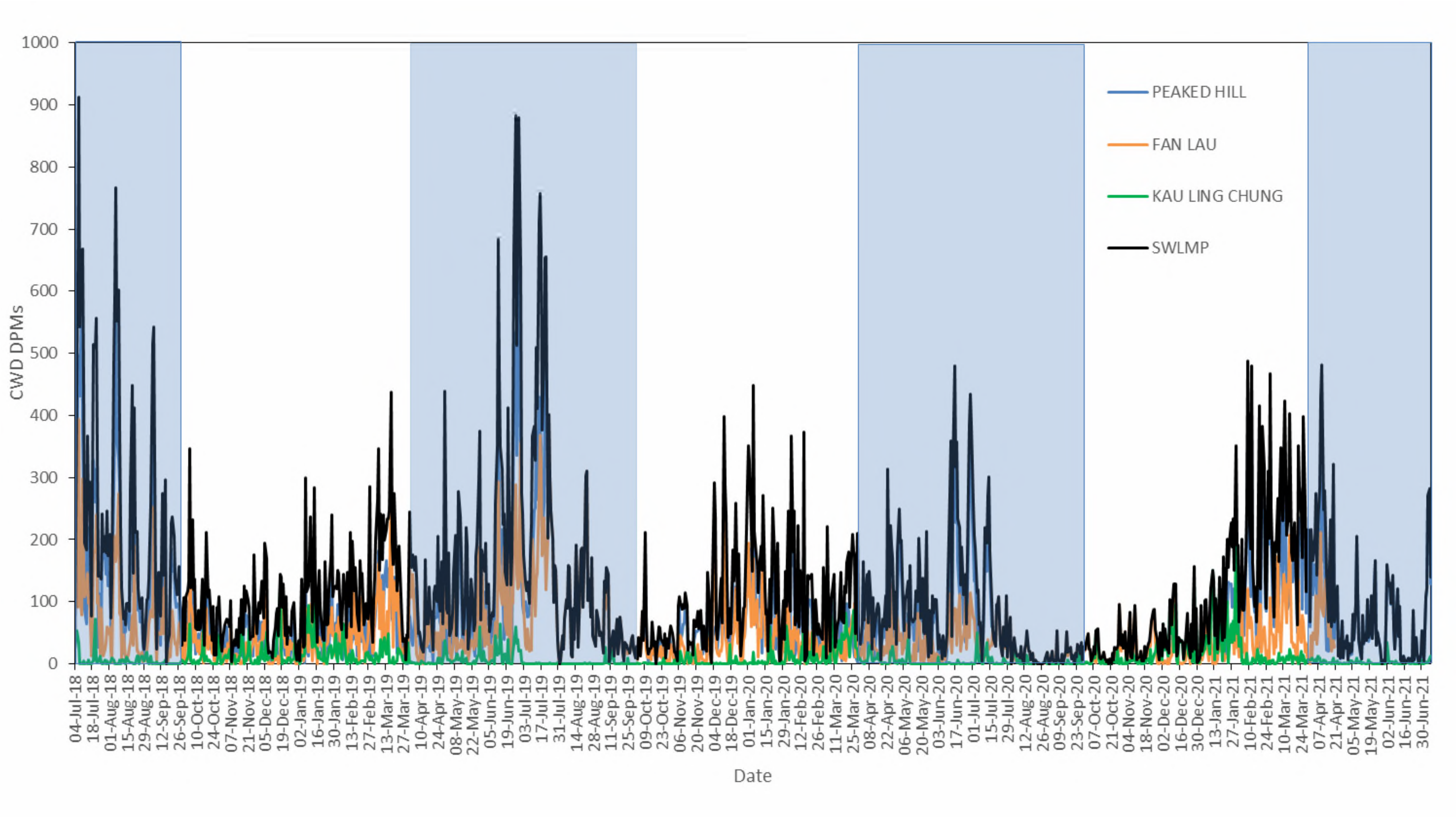


Figure 34. Chinese White Dolphin DPMs recorded by C-PODs from 04 July 2018 to 07 July 2021 at SWLMP sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

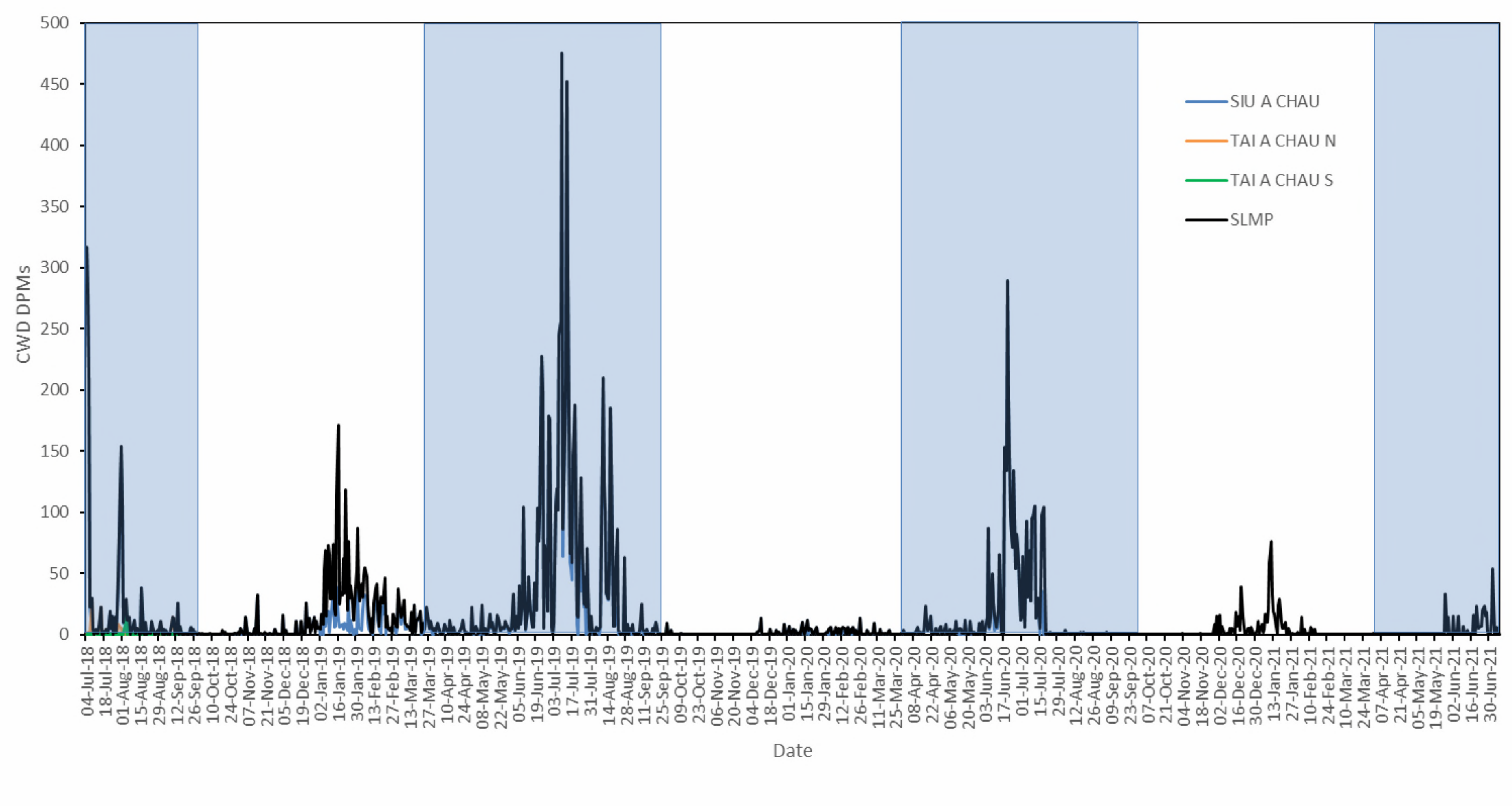


Figure 35. Chinese White Dolphin DPMs recorded by C-PODs from 04 July 2018 to 08 July 2021 at SLMP sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

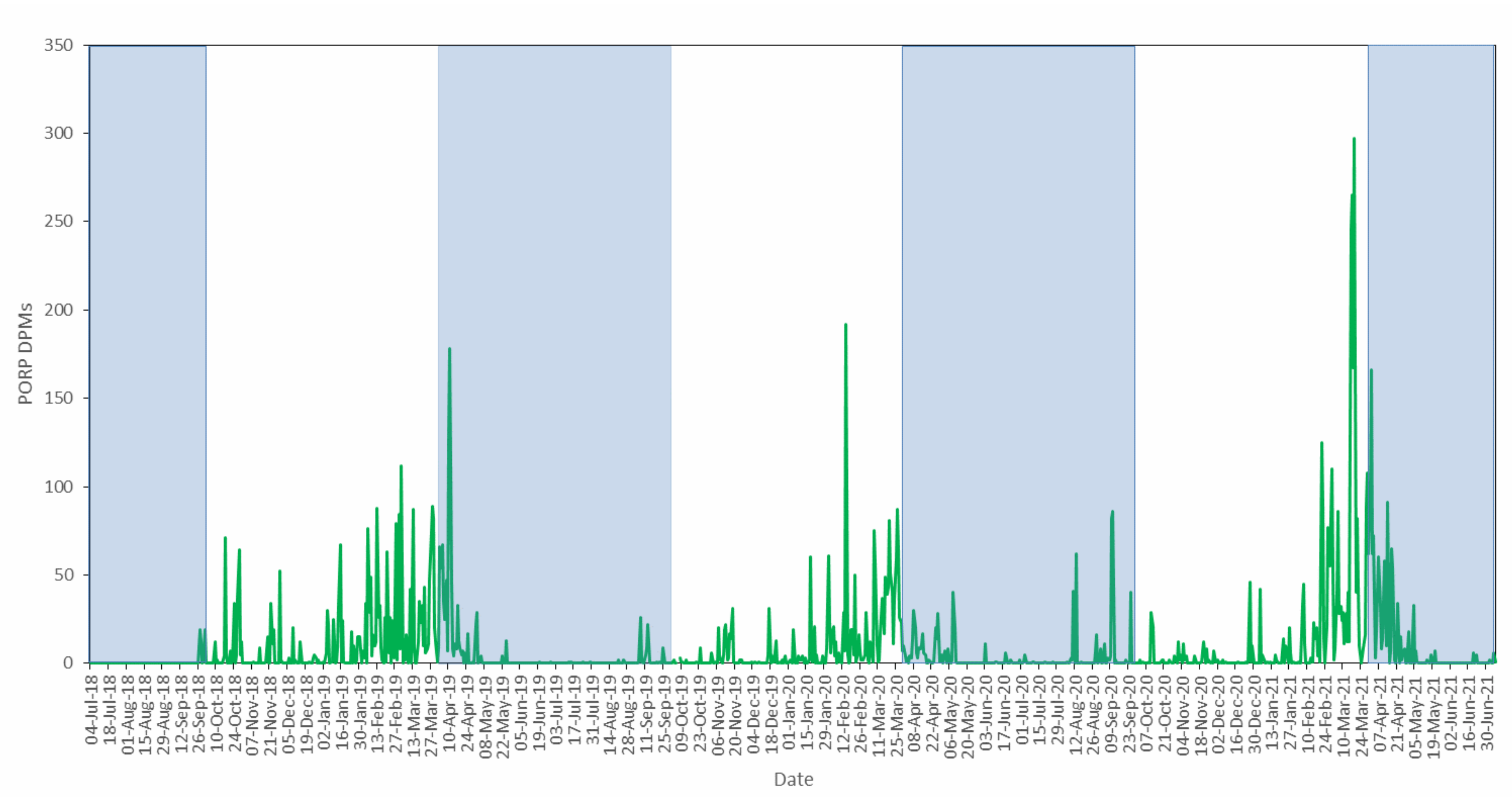


Figure 36. Finless porpoise DPMs recorded by C-PODs from 04 July 2018 to 07 July 2021 at Kau Ling Chung (all other sites had too few DPMs for graphing). The shaded and unshaded areas represent the wet and dry season periods, respectively.

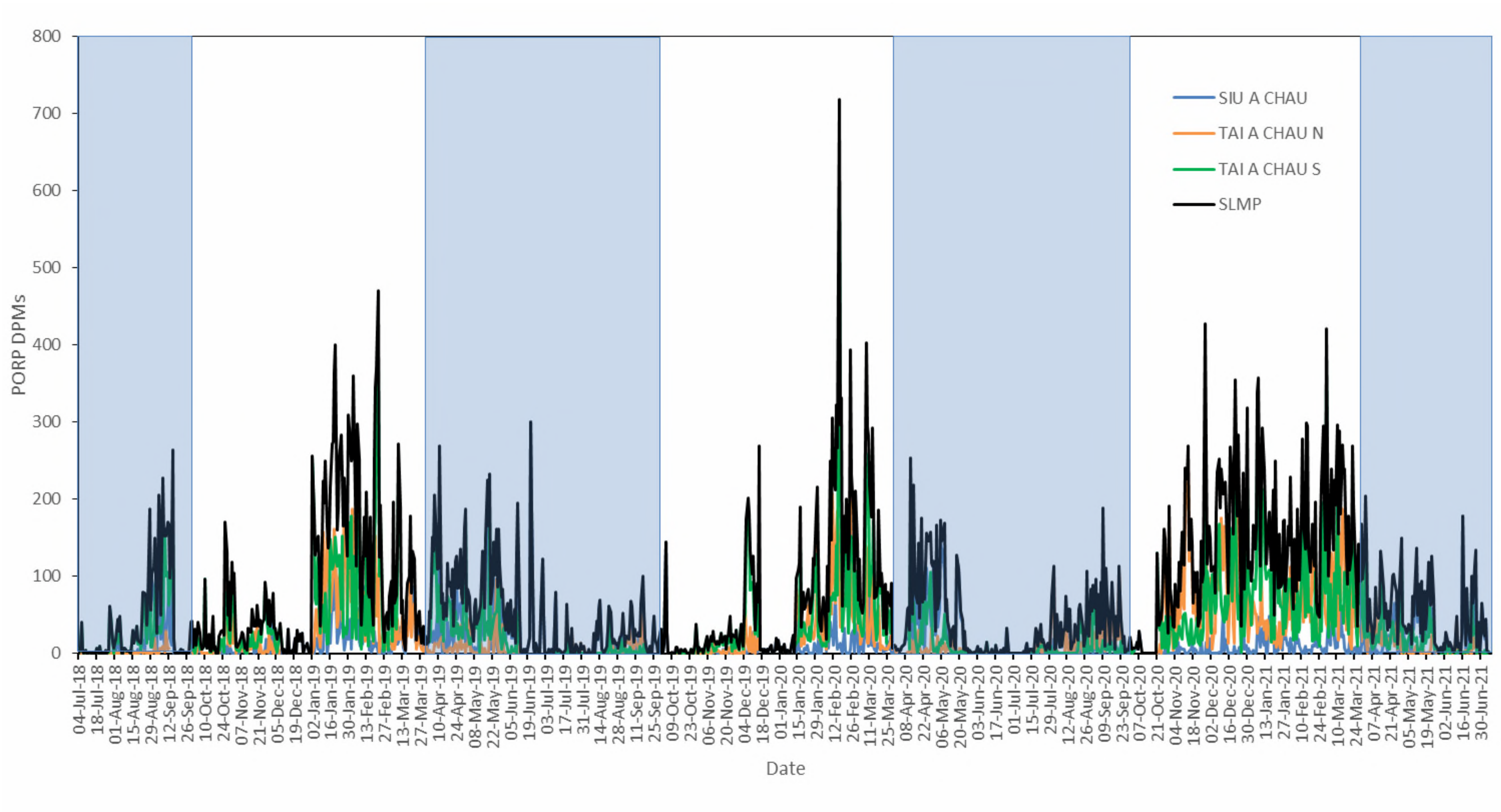


Figure 37. Finless porpoise DPMs recorded by C-PODs from 04 July 2018 to 08 July 2021 at SLMP sites. The shaded and unshaded areas represent the wet and dry season periods, respectively.

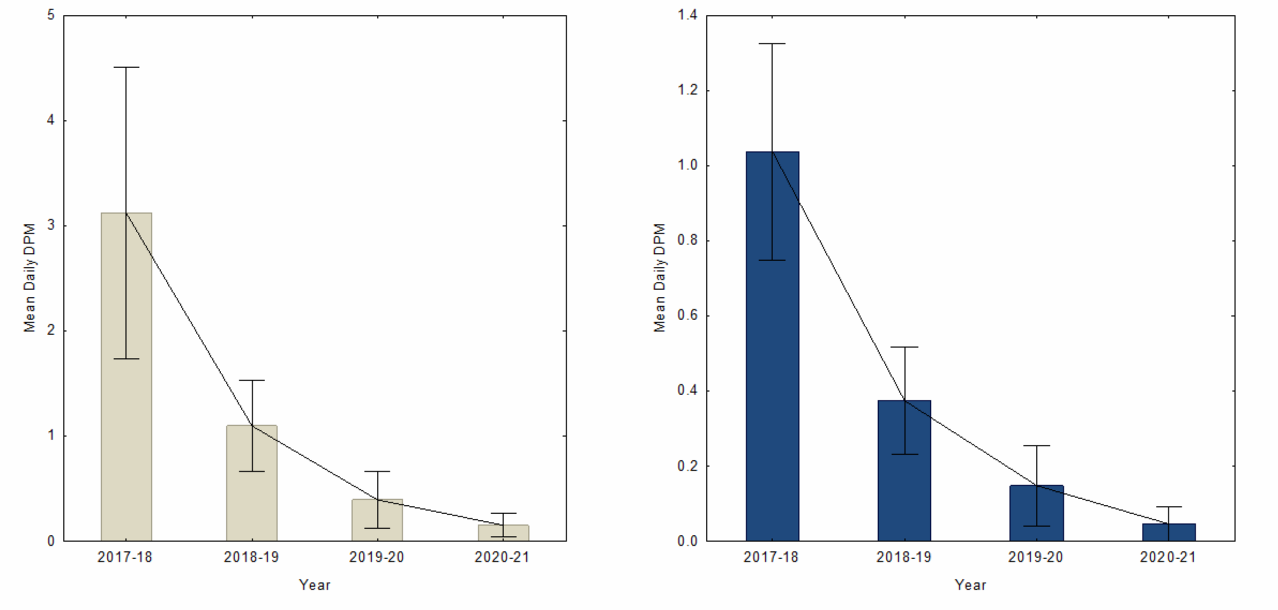


Figure 38. Dolphin mean daily DPMs at Siu Ho Wan (left) and Tai Mo To (right) for the last four (~12 month long) study periods (2017-18, 2018-19, 2019-20 and 2020-21). Each period was significantly lower than the preceding period (except 2019-20 and 2020-21). Error bars represent 95% confidence intervals.

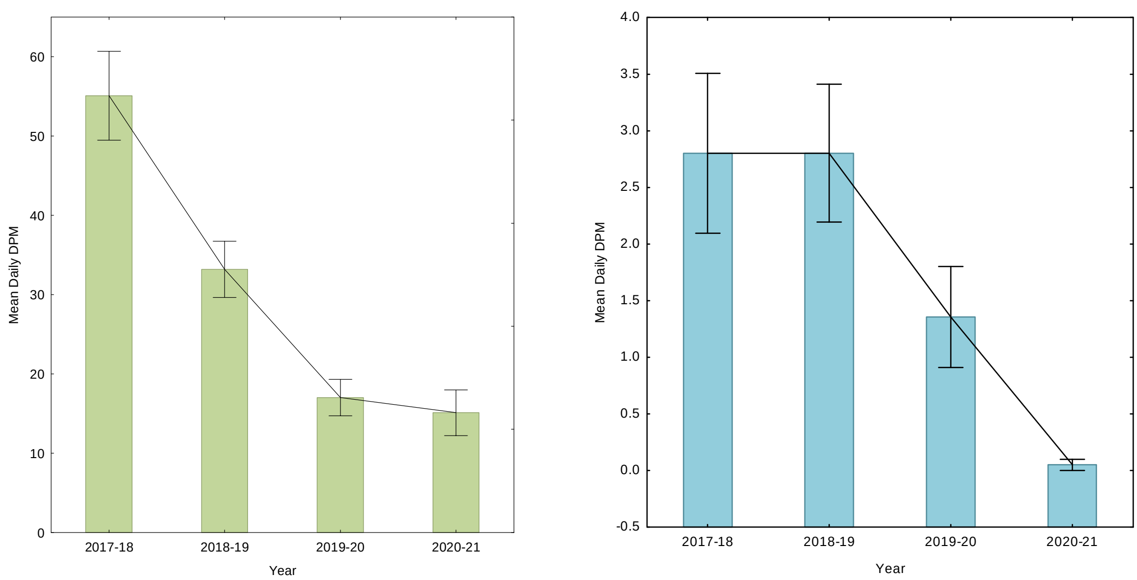


Figure 39. Dolphin mean daily DPMs at Lung Kwu Chau N (left) and Sha Chau SE (right) for the last four (~12 month long) study periods (2017-18, 2018-19, 2019-20 and 2020-21). For Lung Kwu Chau N, each period was significantly lower than the preceding period(s). For Sha Chau SE, 2020-21 was significantly lower than all other periods, 2019-20 was significantly lower than 2017-18 and 2018-19 but 2017-18 and 2018-19 did not differ from each other. Error bars represent 95% confidence intervals.

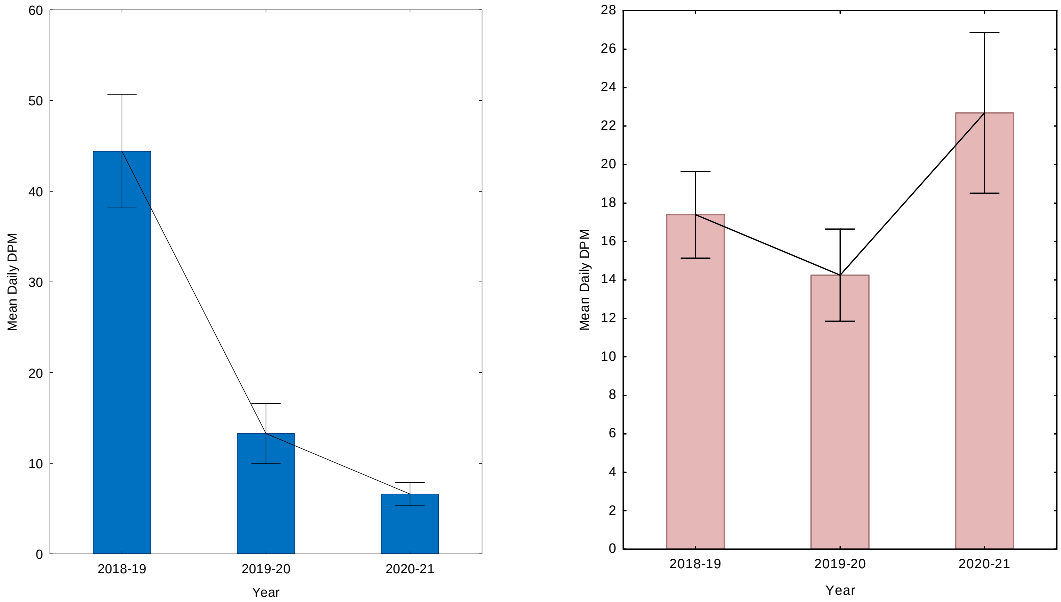


Figure 40. Dolphin mean daily DPMs at Shum Wat (left) and Tai O (right) for the last three (~12 month long) study periods (2018-19, 2019-20 and 2020-21). At both sites, 2019-20 was significantly lower than in 2018-19. At Shum Wat, 2020-21 was significantly lower than 2019-20 while at Tai O, 2020-21 was significantly higher than 2019-20. Error bars represent 95% confidence intervals.

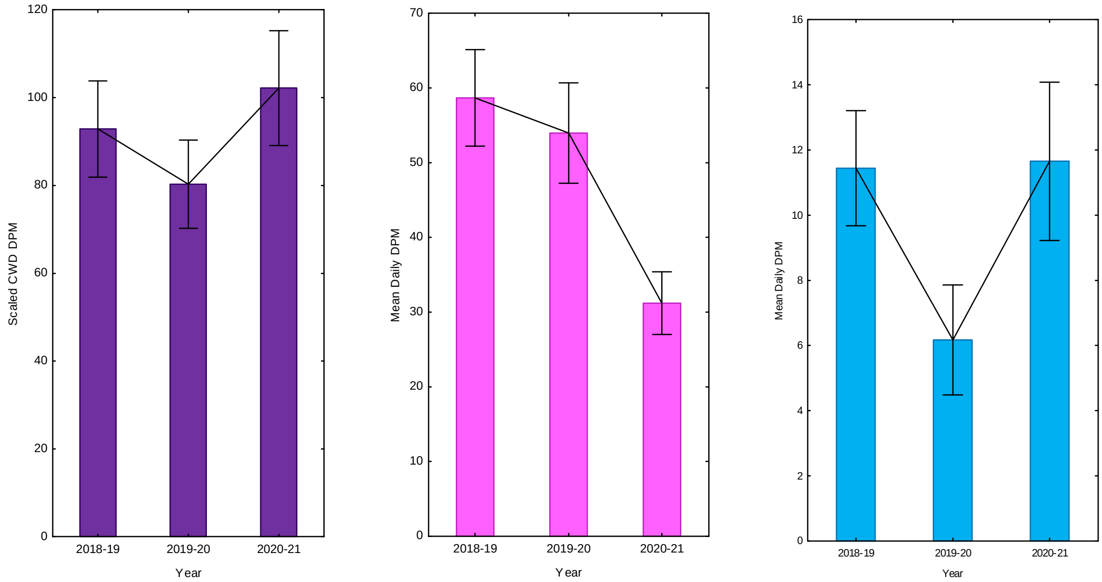


Figure 41. Dolphin mean daily DPMs at Peaked Hill (left), Fan Lau (centre) and Kau Ling Chung (right) for the last three (~12 month long) study periods (2018-19, 2019-20 and 2020-21). At Peaked Hill, only 2020-21 differed significantly from 2019-20 but at Fan Lau and Kau Ling Chung, all periods differed significantly from the previous period. Error bars represent 95% confidence intervals.

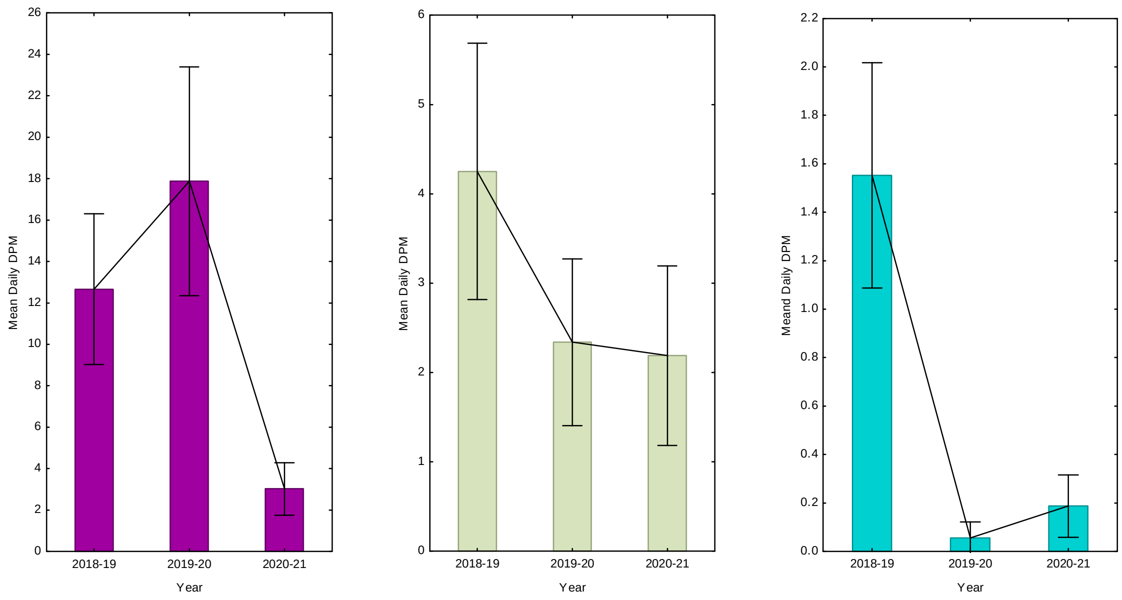


Figure 42. Dolphin mean daily DPMs at Siu A Chau (left), Tai A Chau N (centre) and Tai A Chau S (right) for the last three (~12 month long) study periods (2018-19, 2019-20 and 2020-21). For all sites, all periods differed significantly from each other, except 2019-20 and 2020-21 at Tai A Chau S. Error bars represent 95% confidence intervals.

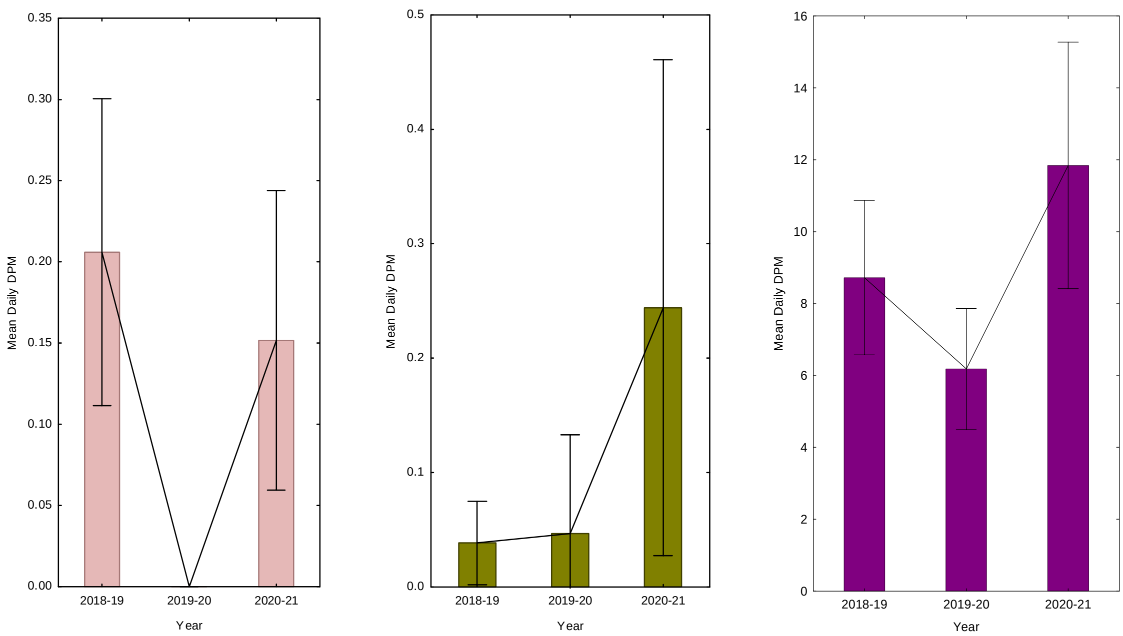


Figure 43. Porpoise mean daily DPMs at Peaked Hill (left), Fan Lau (centre) and Kau Ling Chung (right) for the last three (~12 month long) study periods (2018-19, 2019-20 and 2020-21). For Peaked Hill, all periods differed significantly from the previous period. At Fan Lau and Kau Ling Chung, 2018-19 did not differ from 2019-20 but 2019-20 differed significantly from 2020-21. Error bars represent 95% confidence intervals.

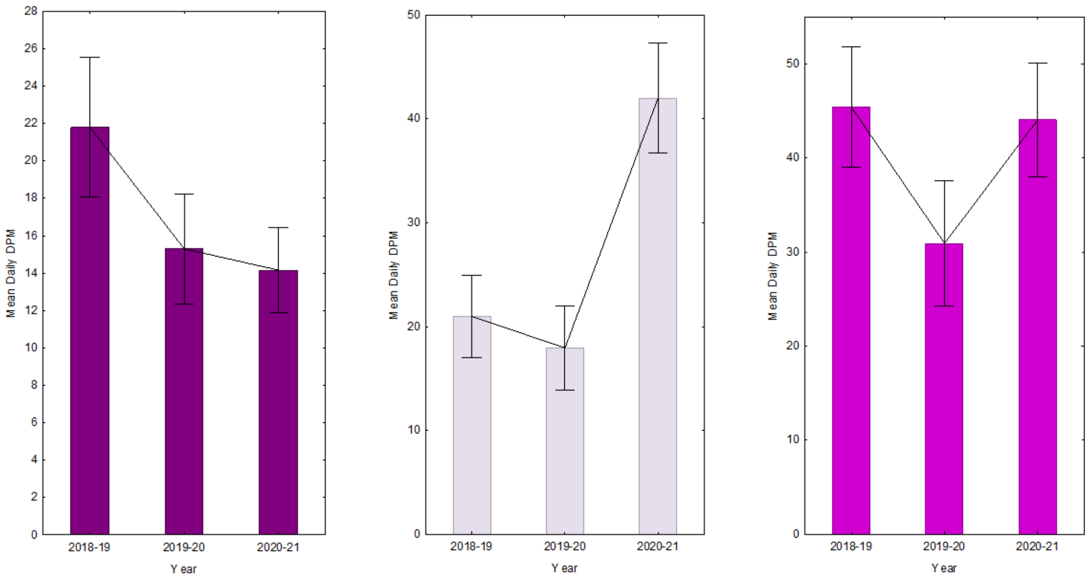


Figure 44. Porpoise mean daily DPMs at Siu A Chau (left), Tai A Chau N (centre) and Tai A Chau S (right) for the last three (~12 month long) study periods (2018-19, 2019-20 and 2020-21). At Siu A Chau, 2018-19 was significantly higher than 2019-20. At Tai A Chau N, 2020-21 was significantly higher than 2019-20. At Tai A Chau S, all periods differed significantly from each other. Error bars represent 95% confidence intervals.

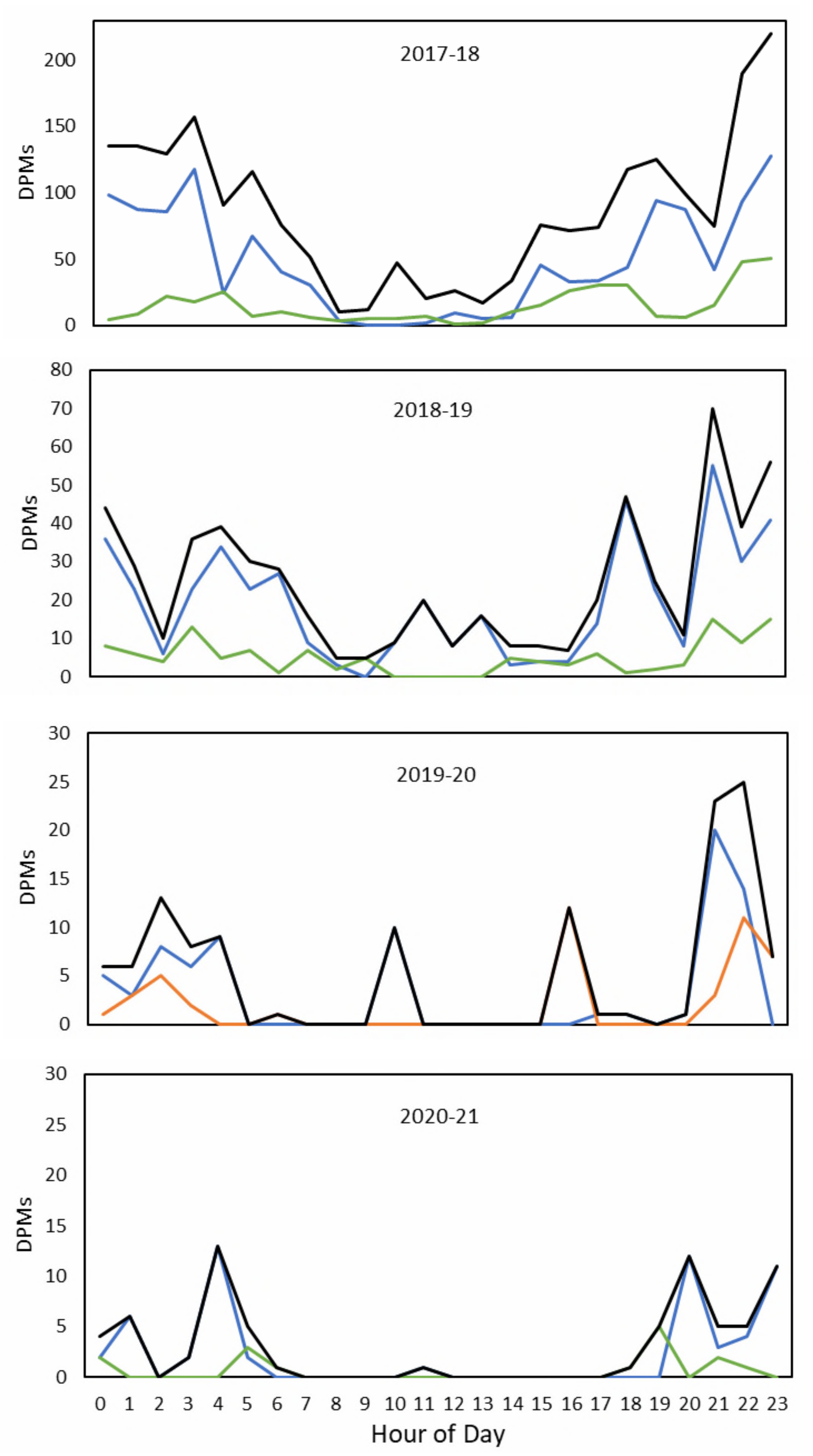


Figure 45. Dolphin DPM diel patterns at BMP for four study periods from 2017 to 2021 (black = BMP; blue = Siu Ho Wan; Orange = Tai Mo To).

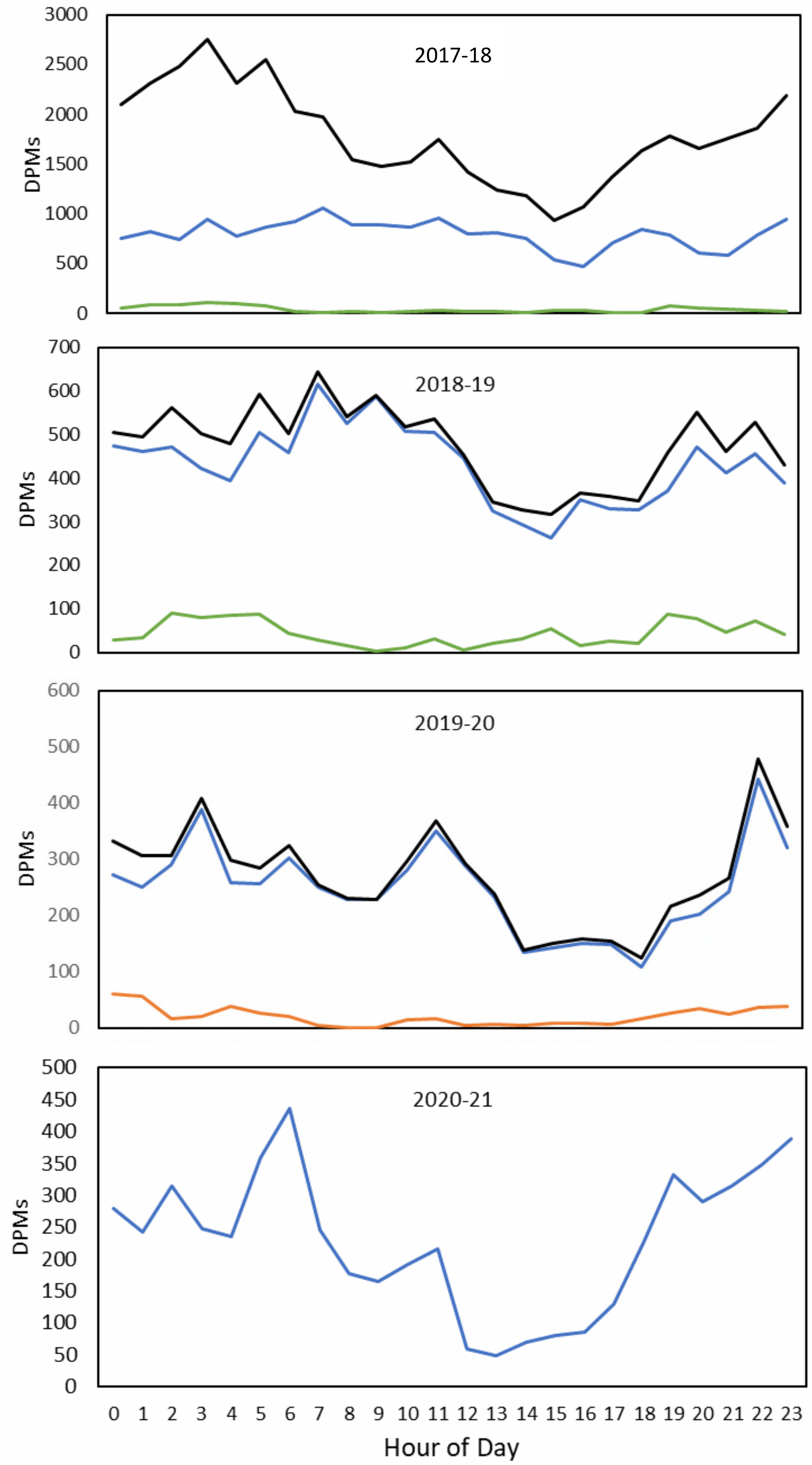


Figure 46. Dolphin DPM diel patterns at SCLKCMP for four study periods from 2017 to 2021 (black = SCLKCMP; blue = Lung Kwu Chau N; Orange = Sha Chau SE).

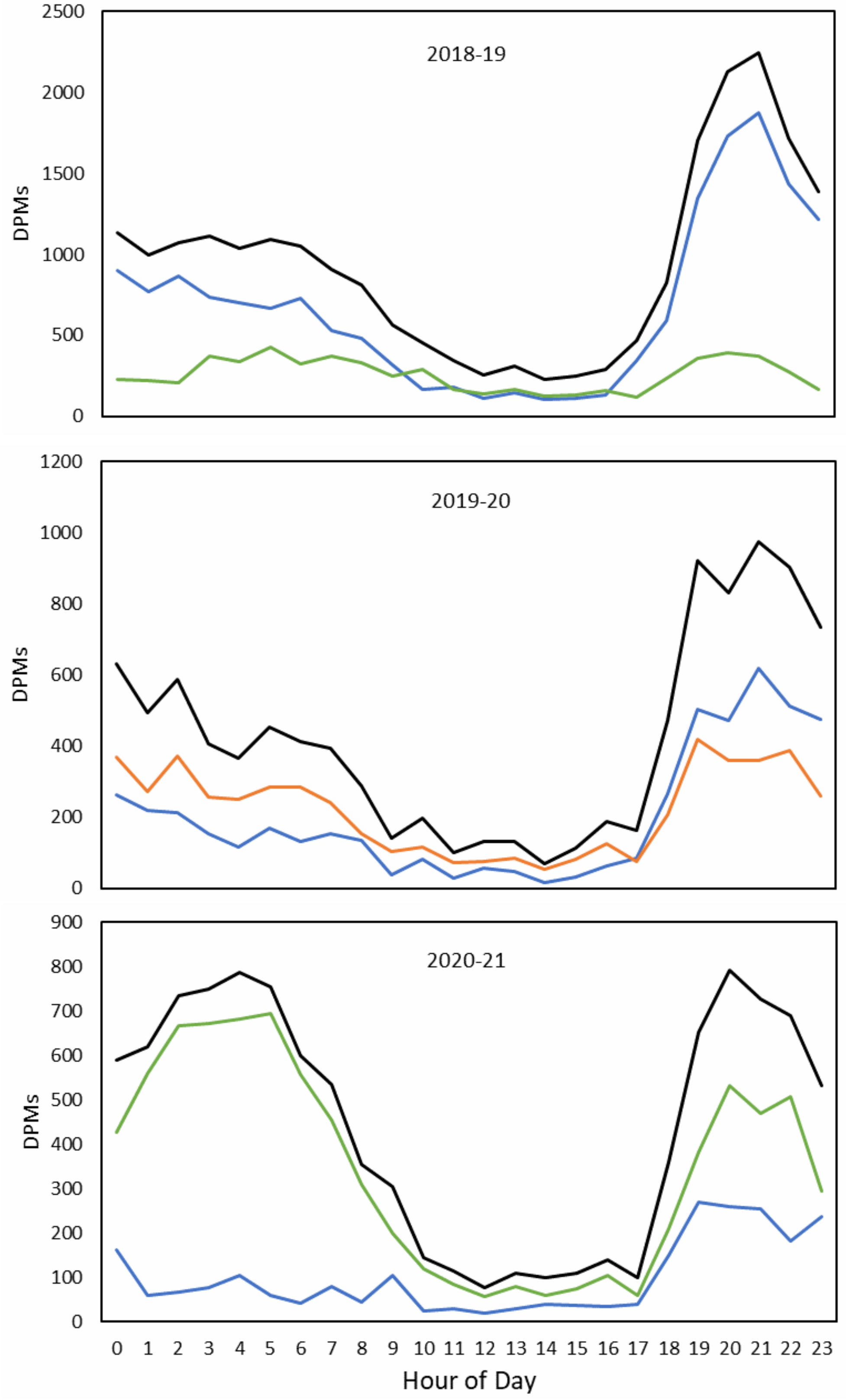


Figure 47. Dolphin DPM diel patterns at WL for three study periods from 2018 to 2021 (black = WL; blue = Shum Wat; Orange = Tai O).

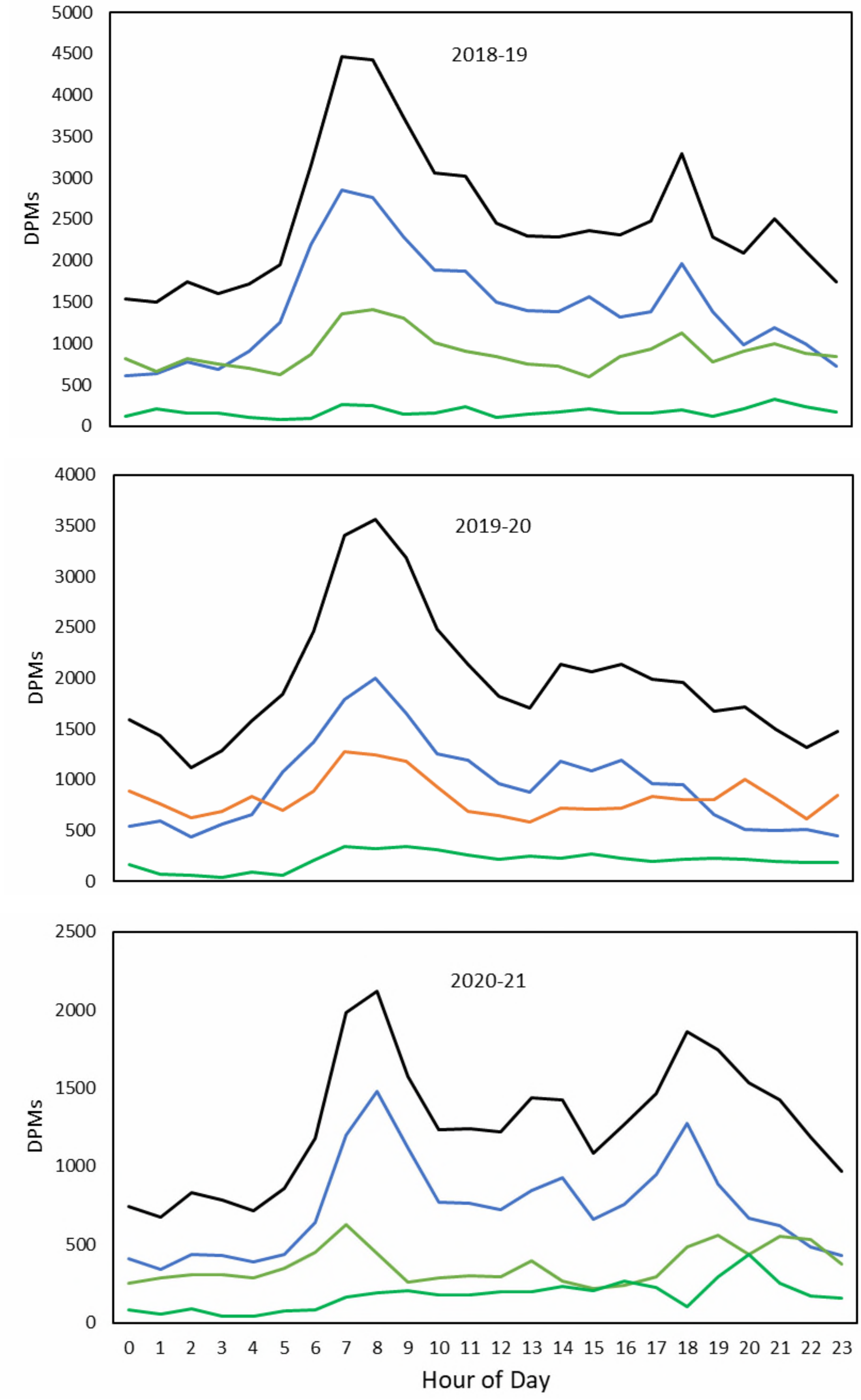


Figure 48. Dolphin DPM diel patterns at SWLMP for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

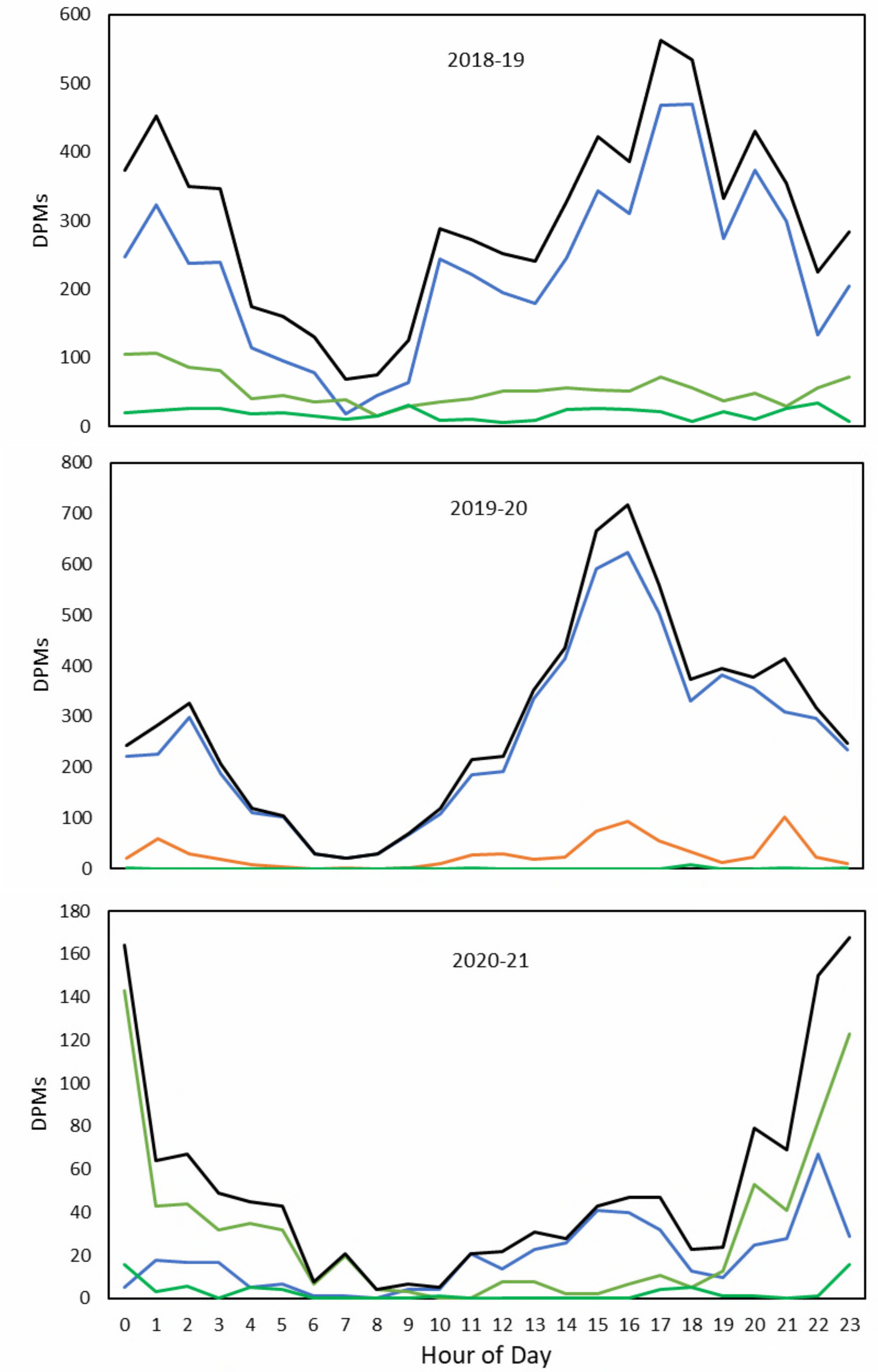


Figure 49. Dolphin DPM diel patterns at SLMP for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

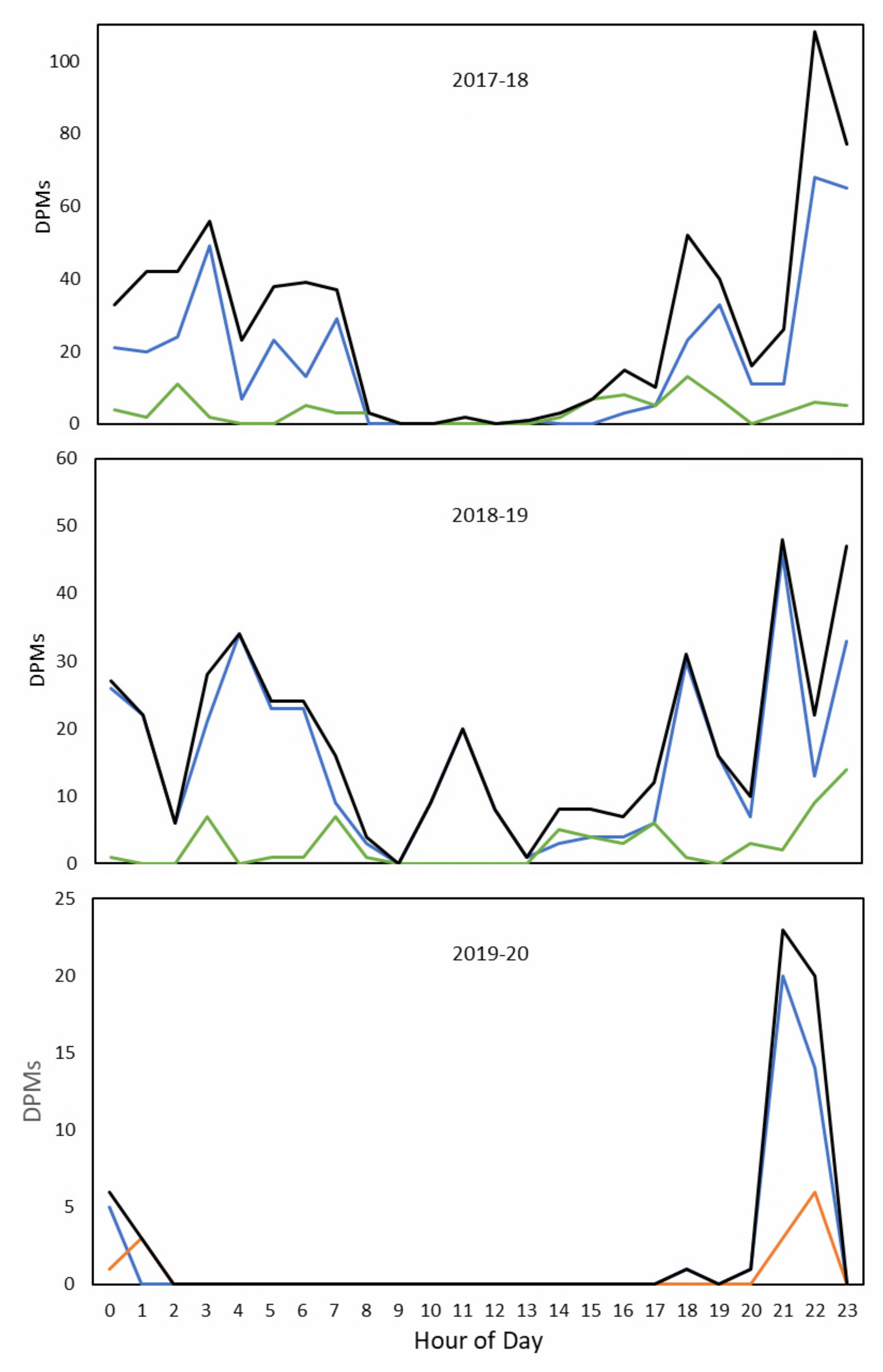


Figure 50. Dolphin DPM diel patterns at BMP during the wet season for four study periods from 2017 to 2020; there were no DPMs during the wet season of 2020-21 (black = BMP; blue = Siu Ho Wan; Orange = Tai Mo To).

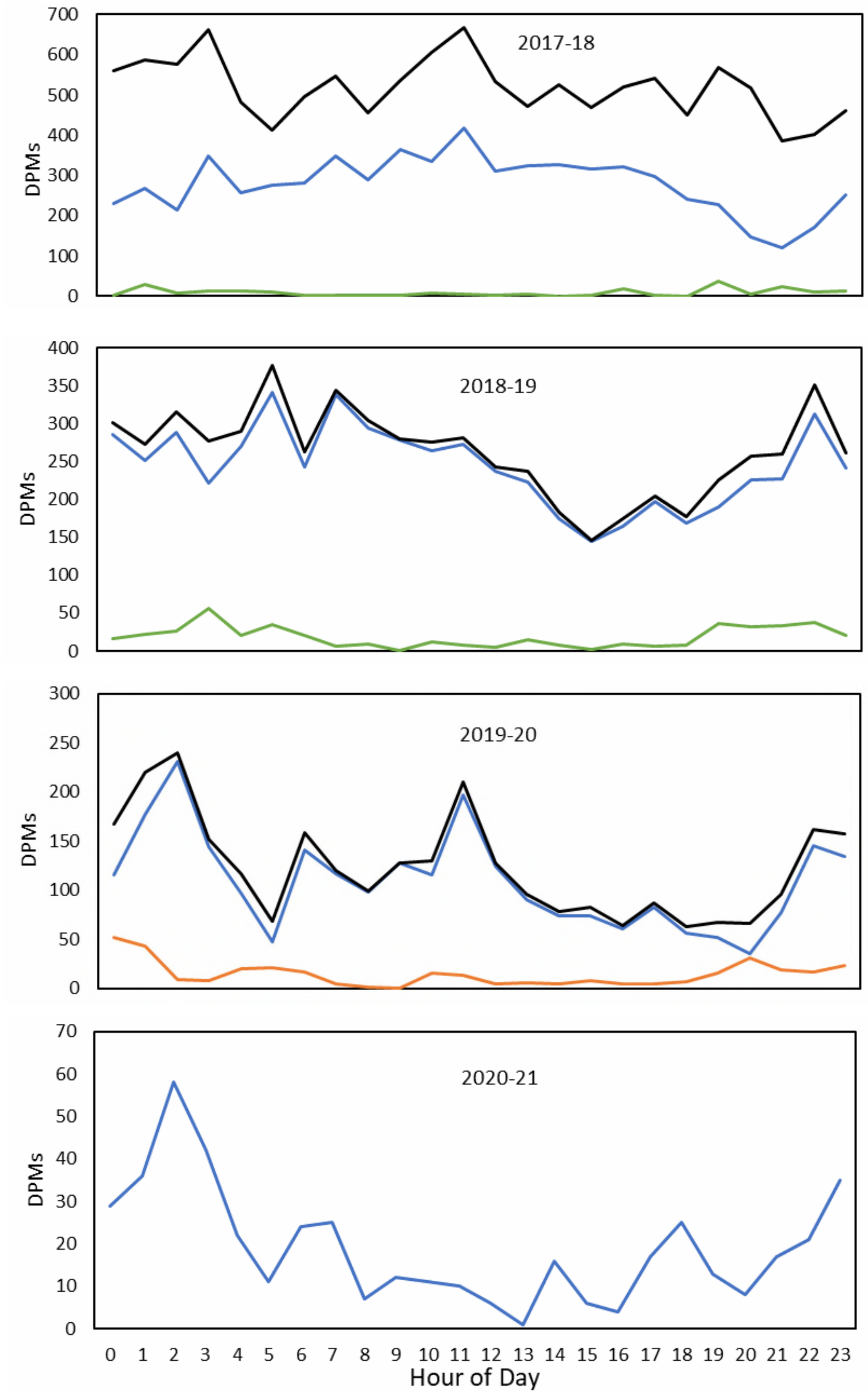


Figure 51. Dolphin DPM diel patterns at SCLKCMP during the wet season for four study periods from 2017 to 2021 (black = SCLKCMP; blue = Lung Kwu Chau N; Orange = Sha Chau SE).

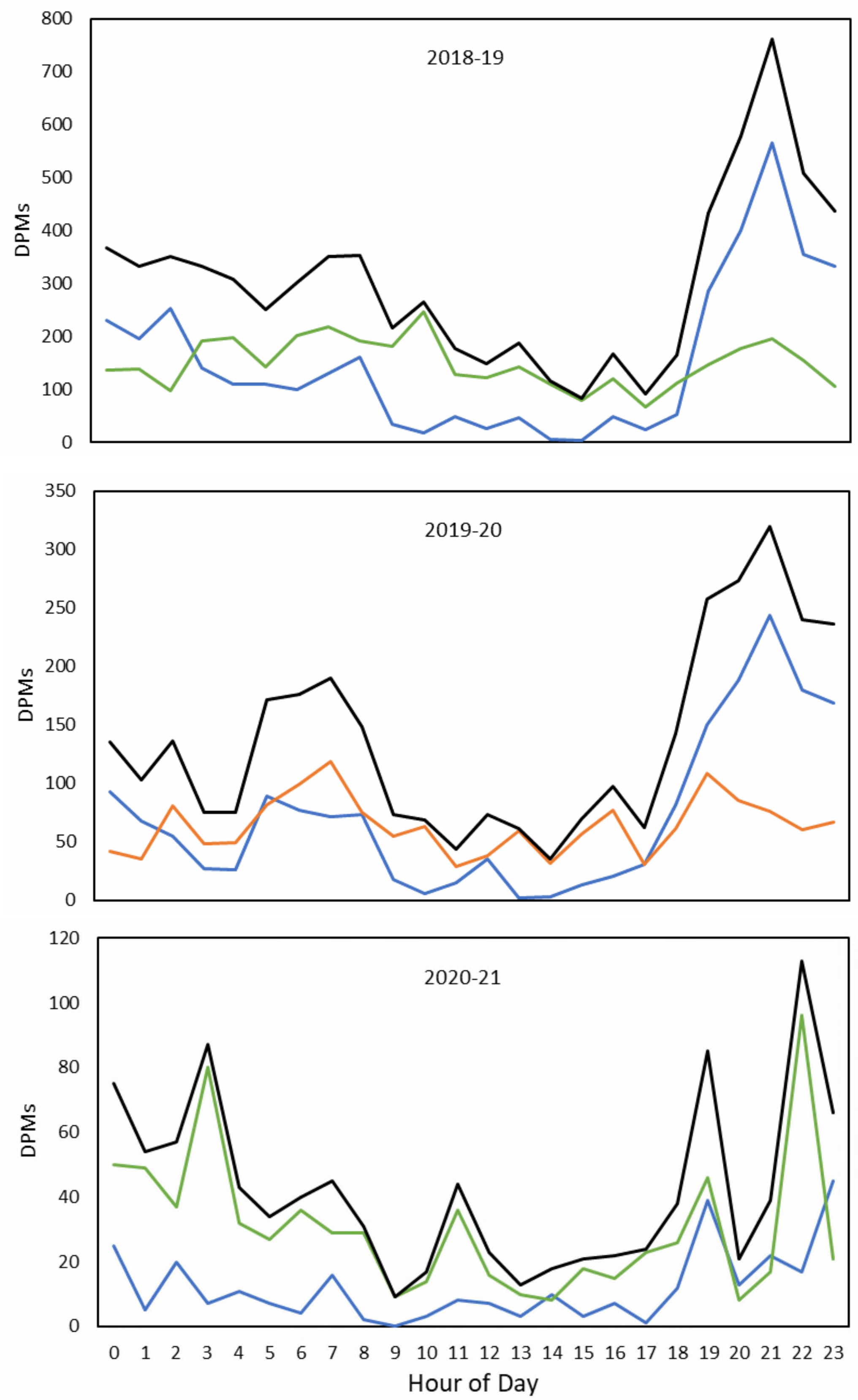


Figure 52. Dolphin DPM diel patterns at WL during the wet season for three study periods from 2018 to 2021 (black = WL; blue = Shum Wat; Orange = Tai Mo To).

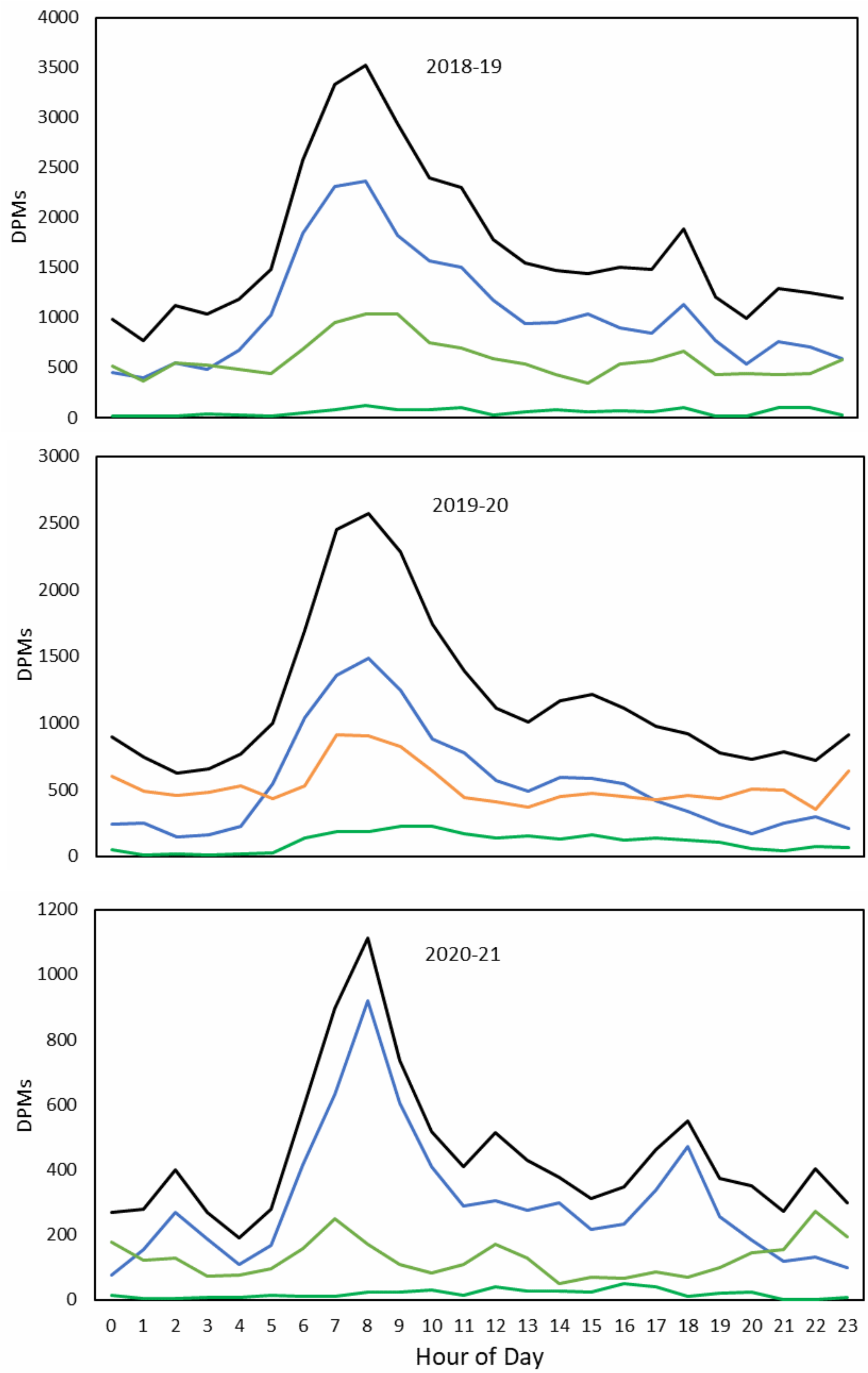


Figure 53. Dolphin DPM diel patterns at SWLMP during the wet season for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

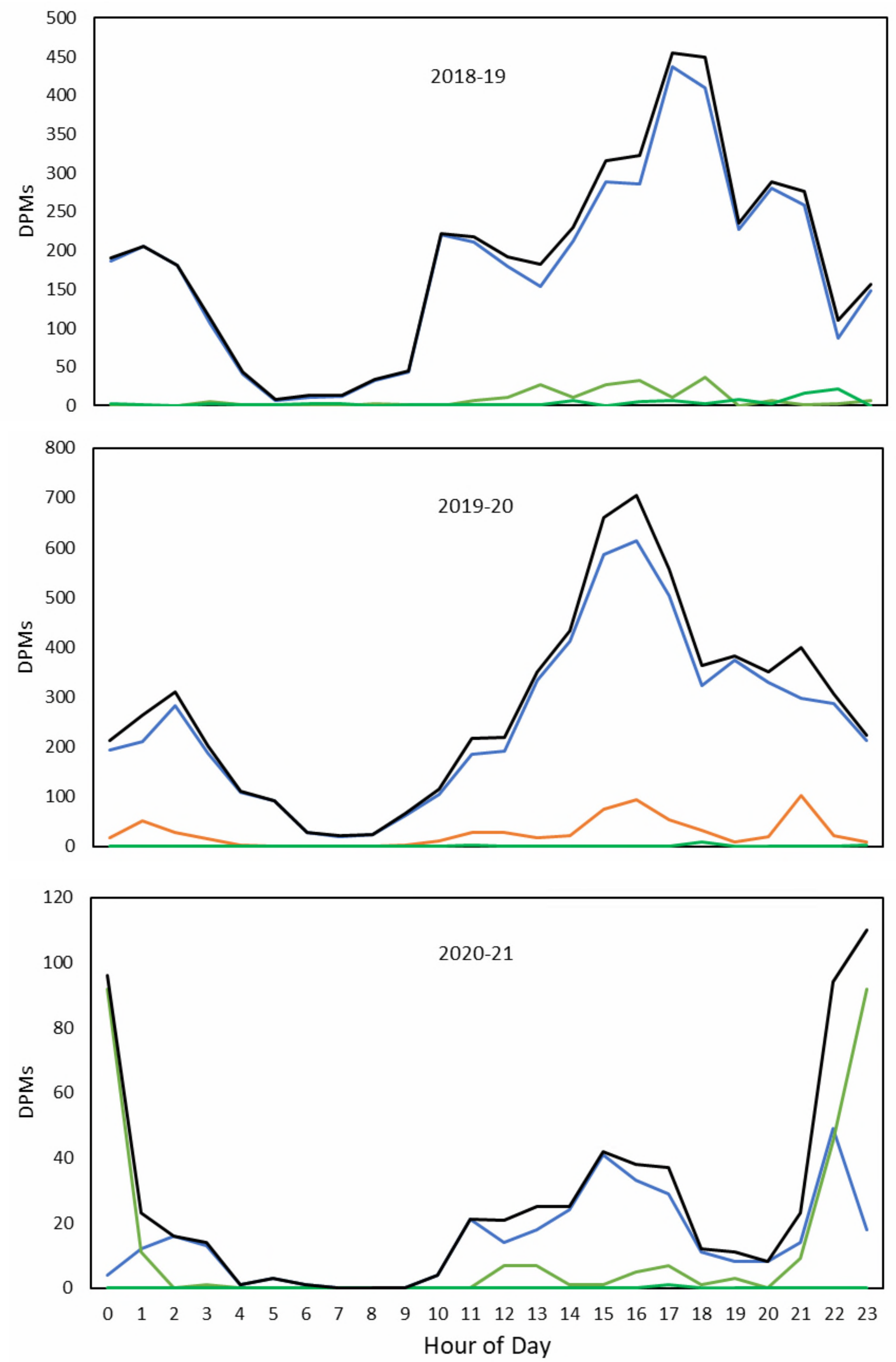


Figure 54. Dolphin DPM diel patterns at SLMP during the wet season for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

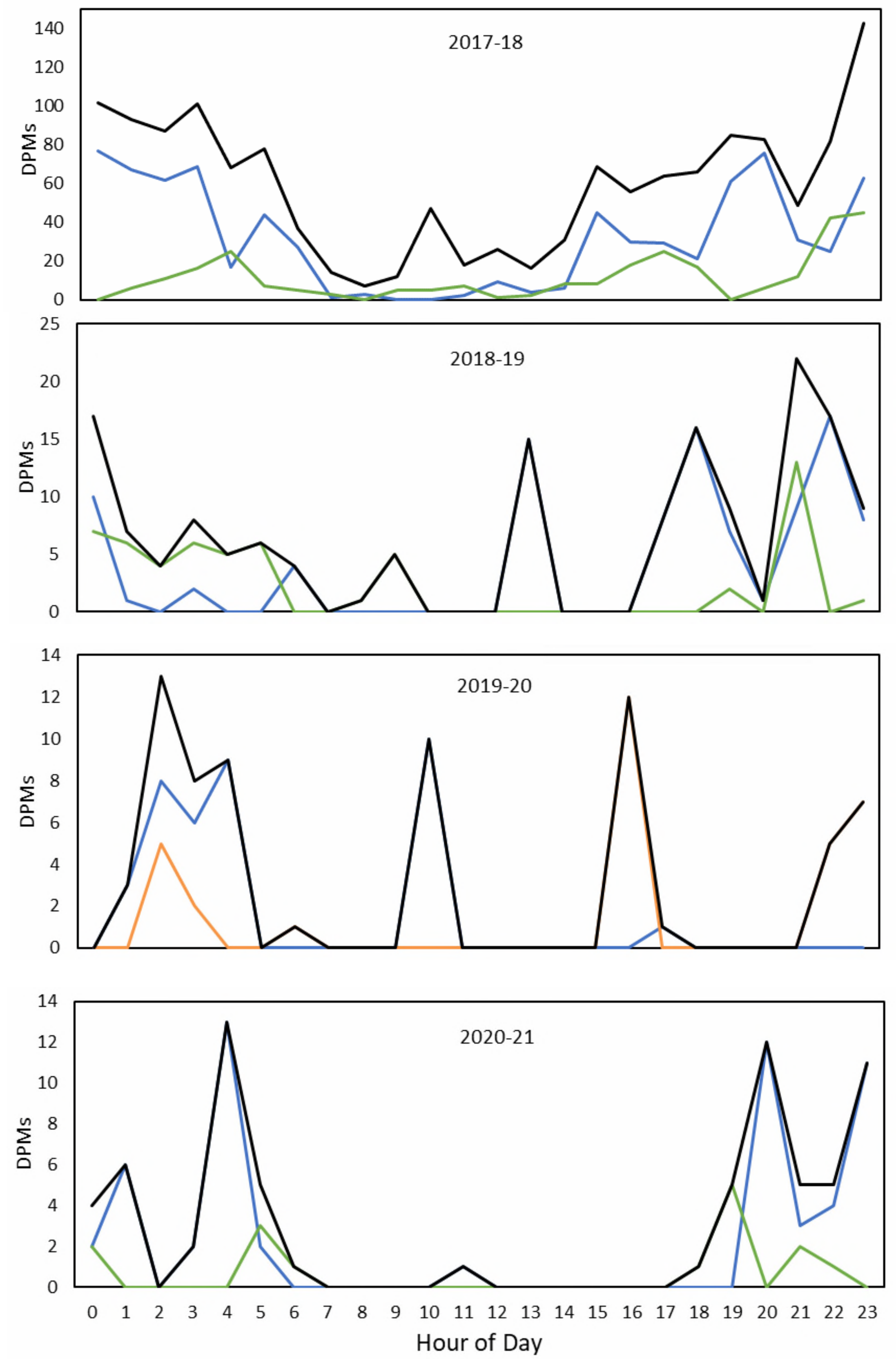


Figure 55. Dolphin DPM diel patterns at BMP during the dry season for four study periods from 2017 to 2021 (black = BMP; blue = Siu Ho Wan; Orange = Tai Mo To).

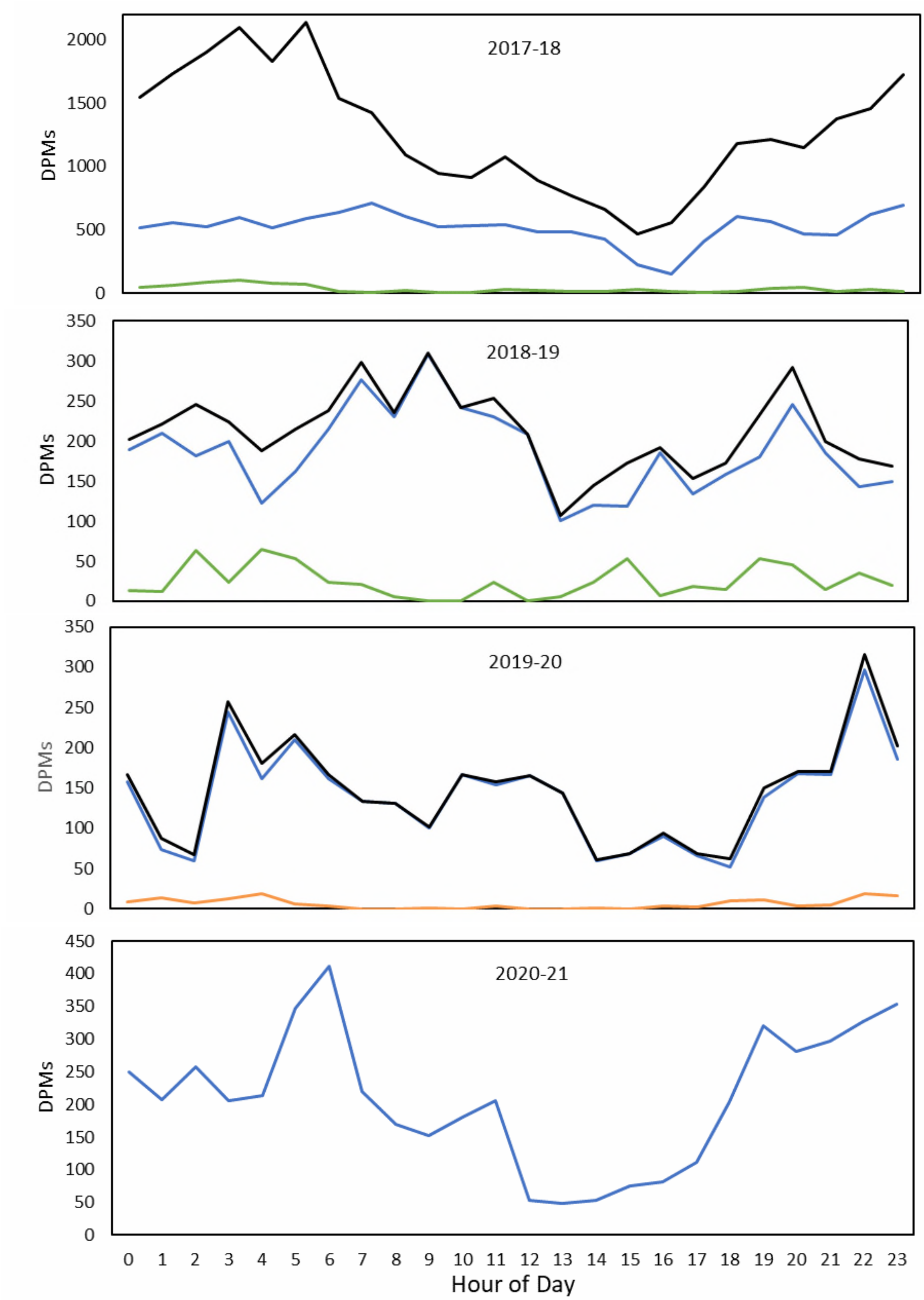


Figure 56. Dolphin DPM diel patterns at SCLKCMP during the dry season for four study periods from 2017 to 2021 (black = SCLKCMP; blue = Lung Kwu Chau N; Orange = Sha Chau SE).

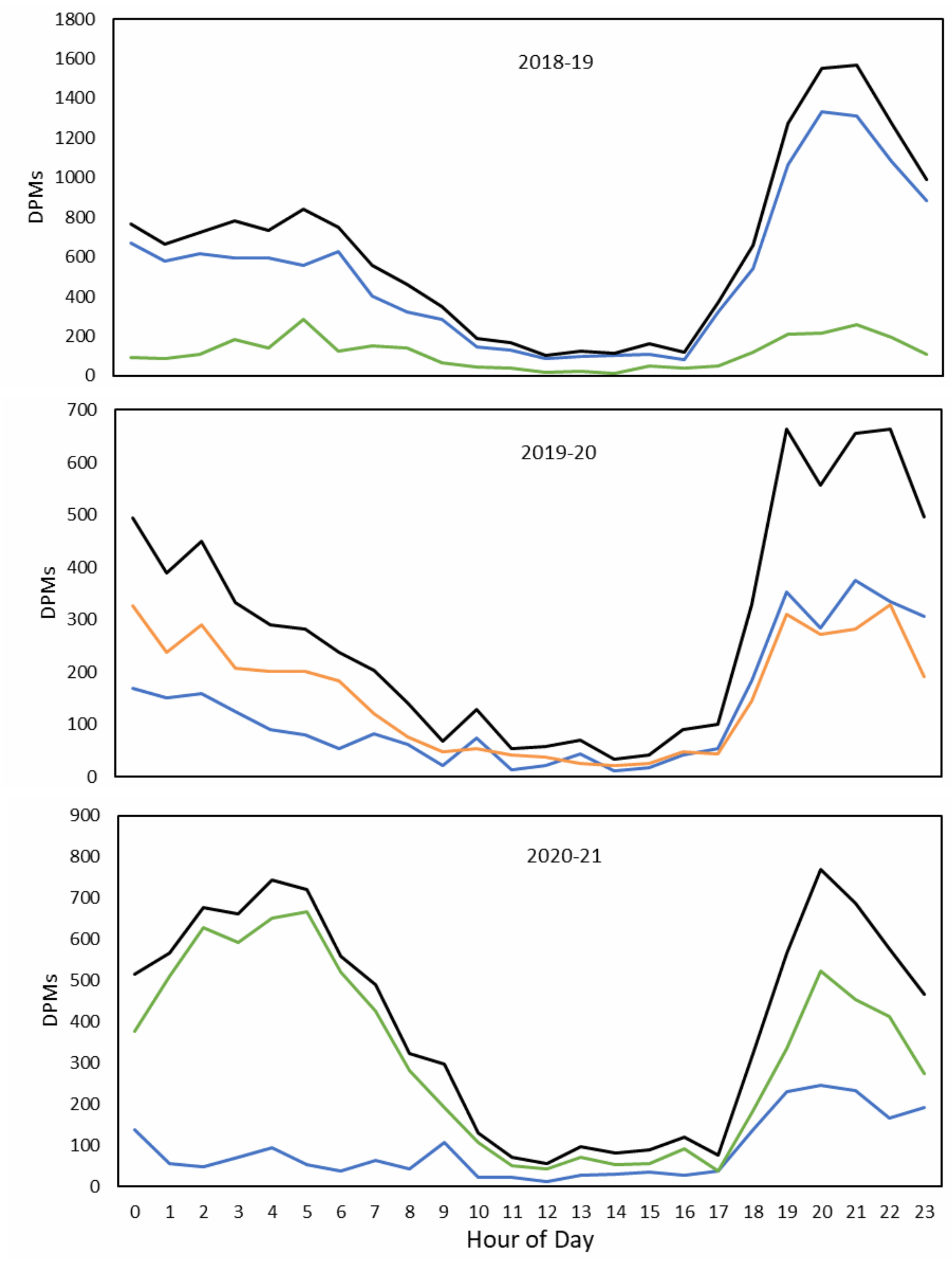


Figure 57. Dolphin DPM diel patterns at WL during the dry season for three study periods from 2018 to 2021 (black = WL; blue = Shum Wat; Orange = Tai O).

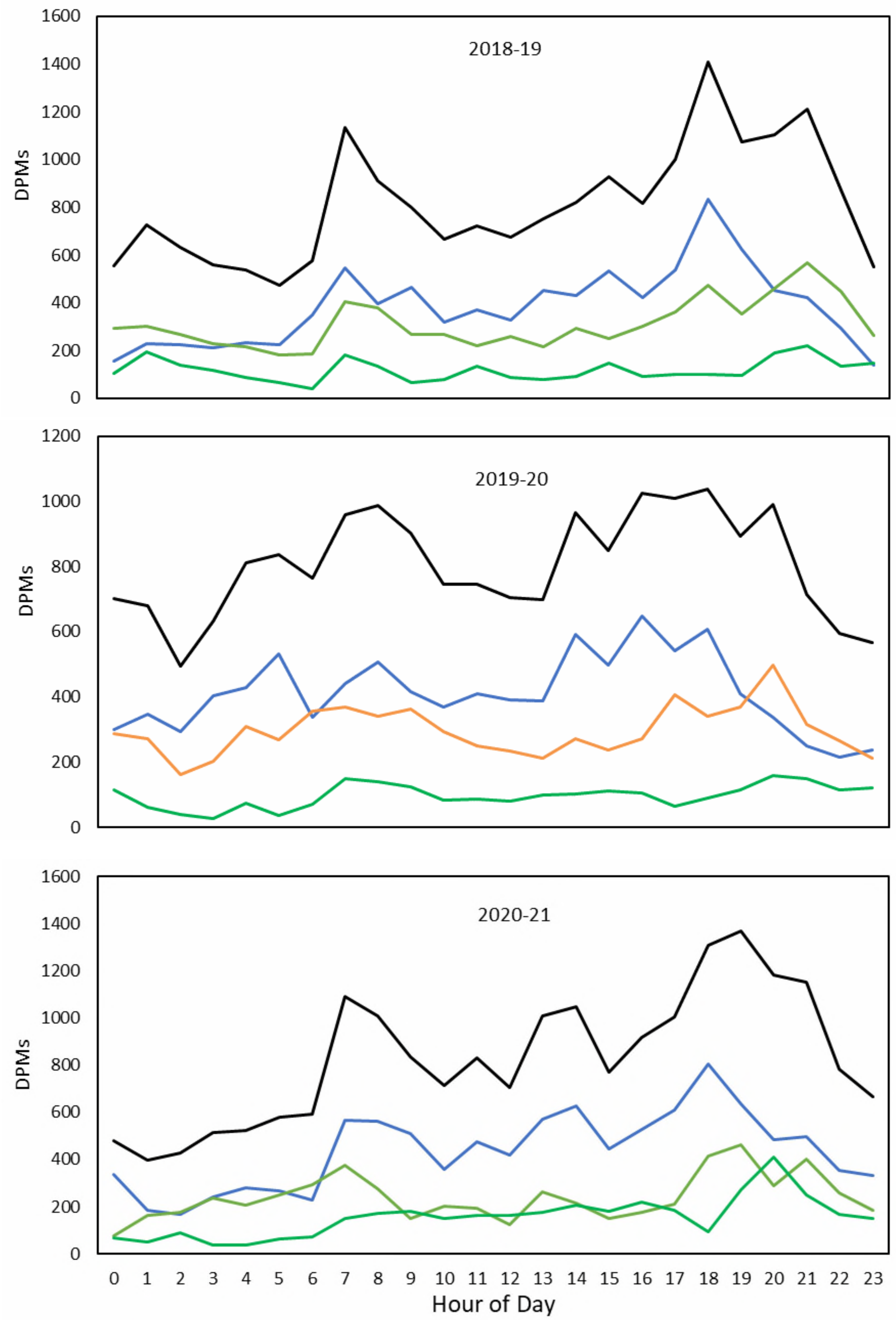


Figure 58. Dolphin DPM diel patterns at SWLMP during the dry season for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

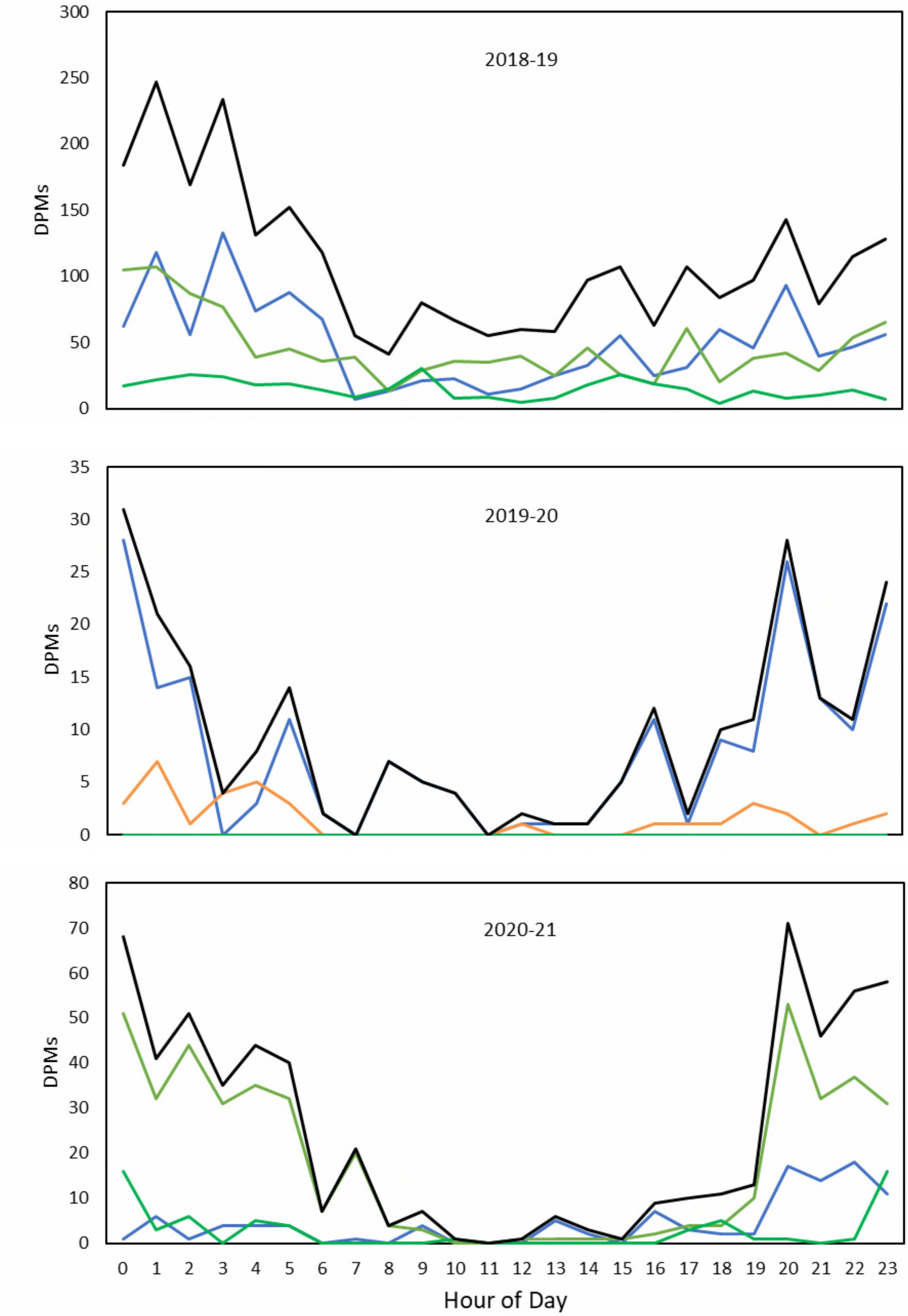


Figure 59. Dolphin DPM diel patterns at SLMP during the dry season for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

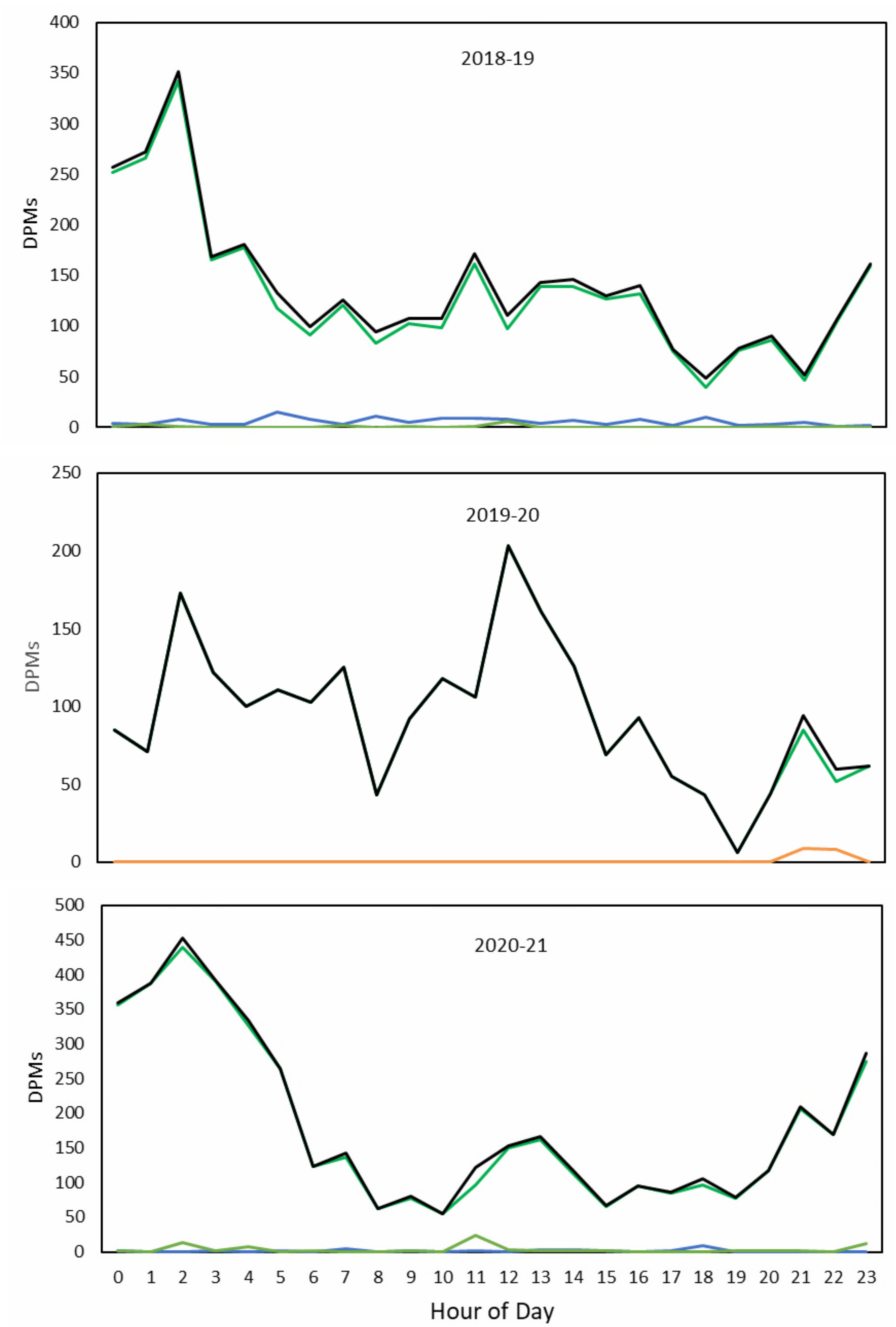


Figure 60. Porpoise DPM diel patterns at SWLMP for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

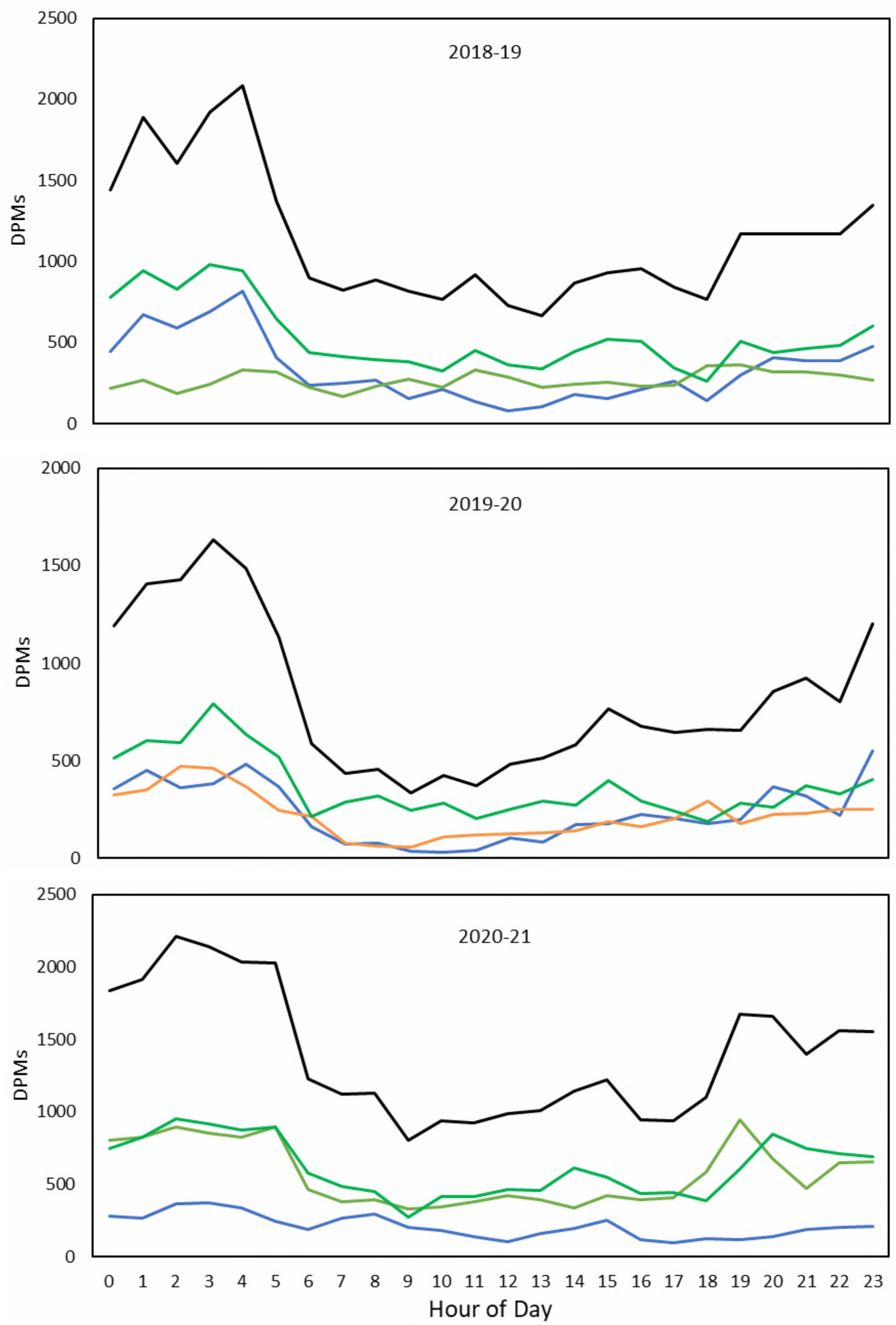


Figure 61. Porpoise DPM diel patterns at SLMP for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

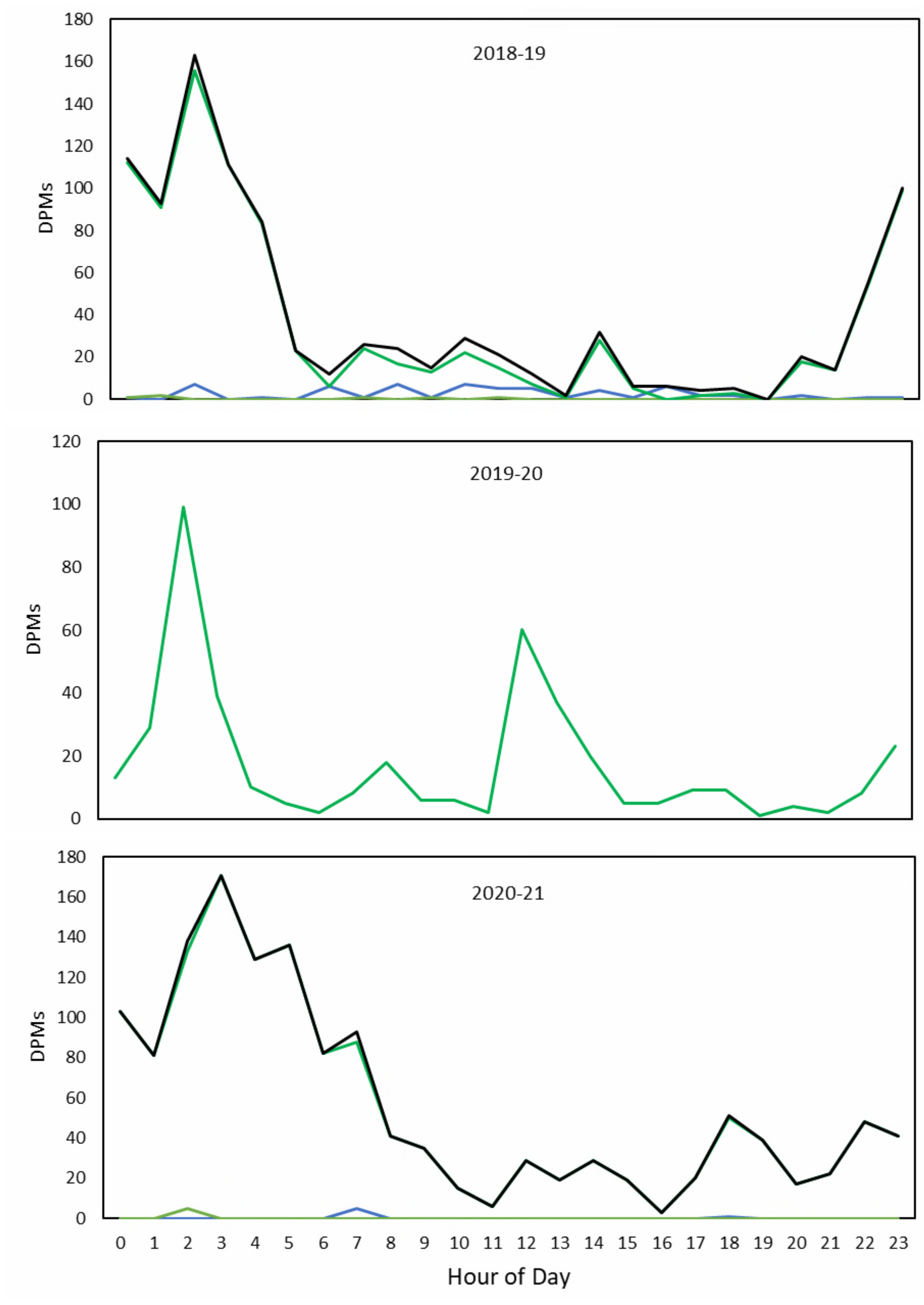


Figure 62. Porpoise DPM diel patterns at SWLMP during the wet season for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

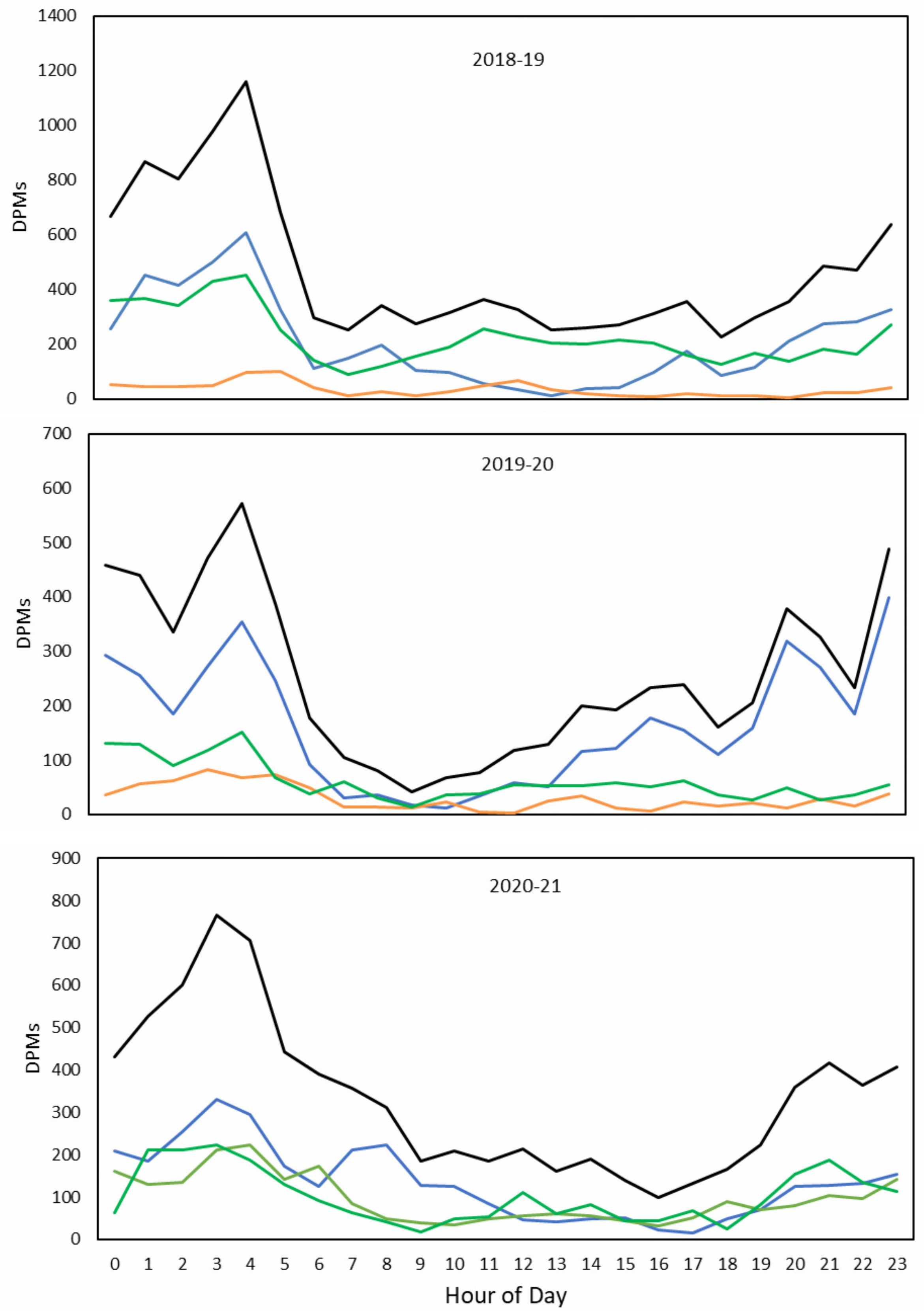


Figure 63. Porpoise DPM diel patterns at SLMP during the wet season for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

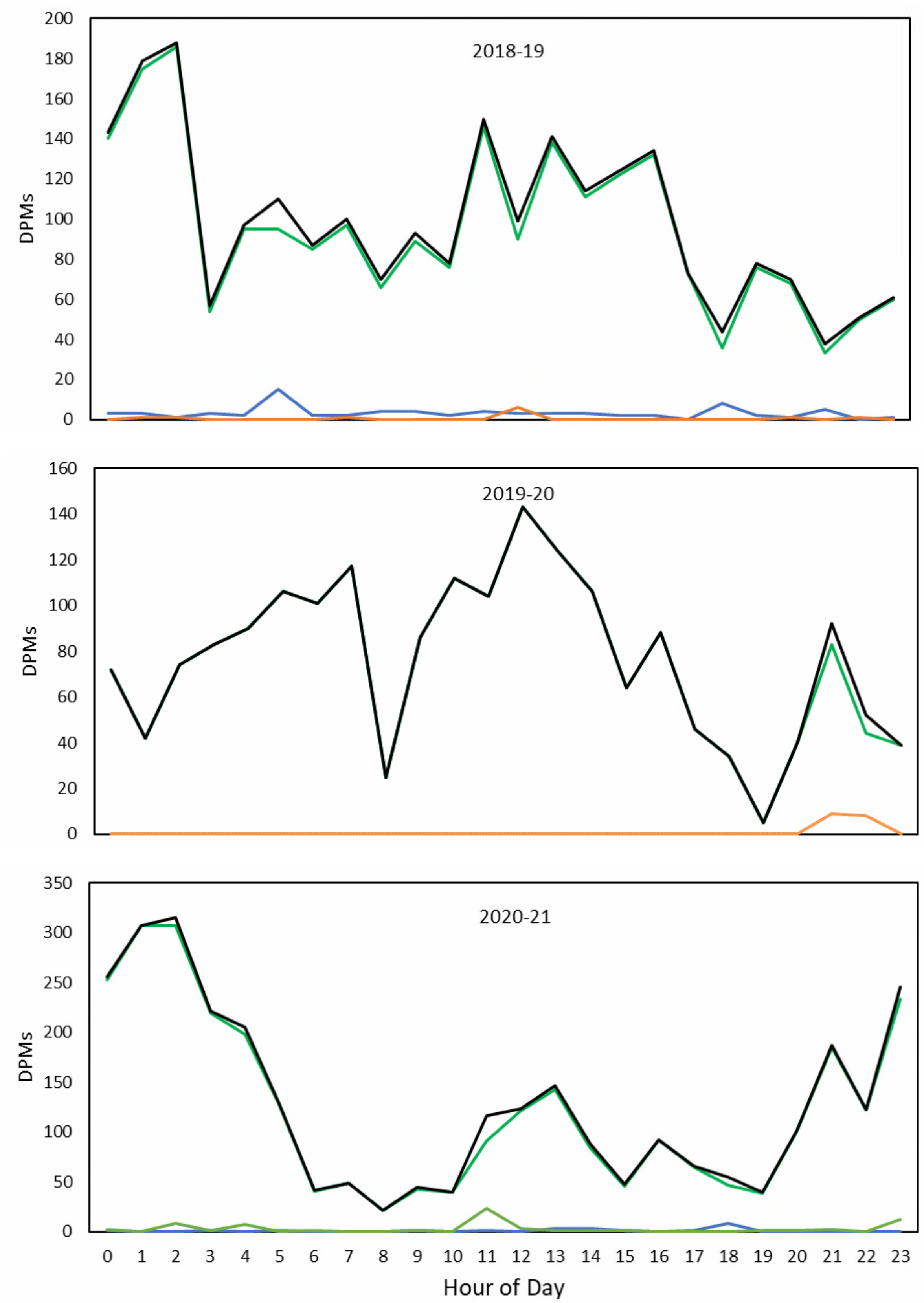


Figure 64. Porpoise DPM diel patterns at SWLMP during the dry season for three study periods from 2018 to 2021 (black = SWLMP; blue = Peaked Hill; orange = Fan Lau; green = Kau Ling Chung).

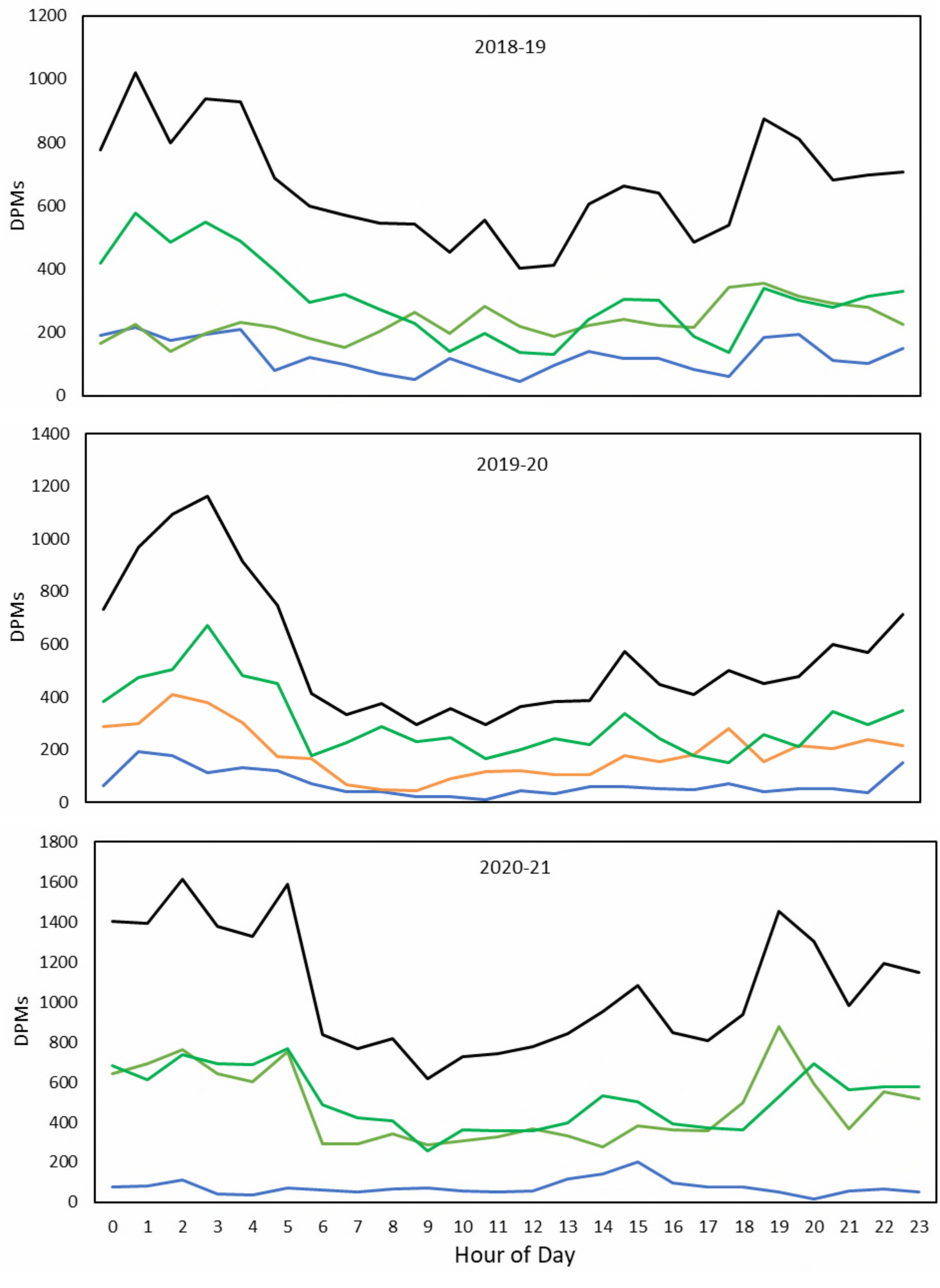


Figure 65. Porpoise DPM diel patterns at SLMP during the dry season for three study periods from 2018 to 2021 (black = SLMP; blue = Siu A Chau; orange = Tai A Chau N; green = Tai A Chau S).

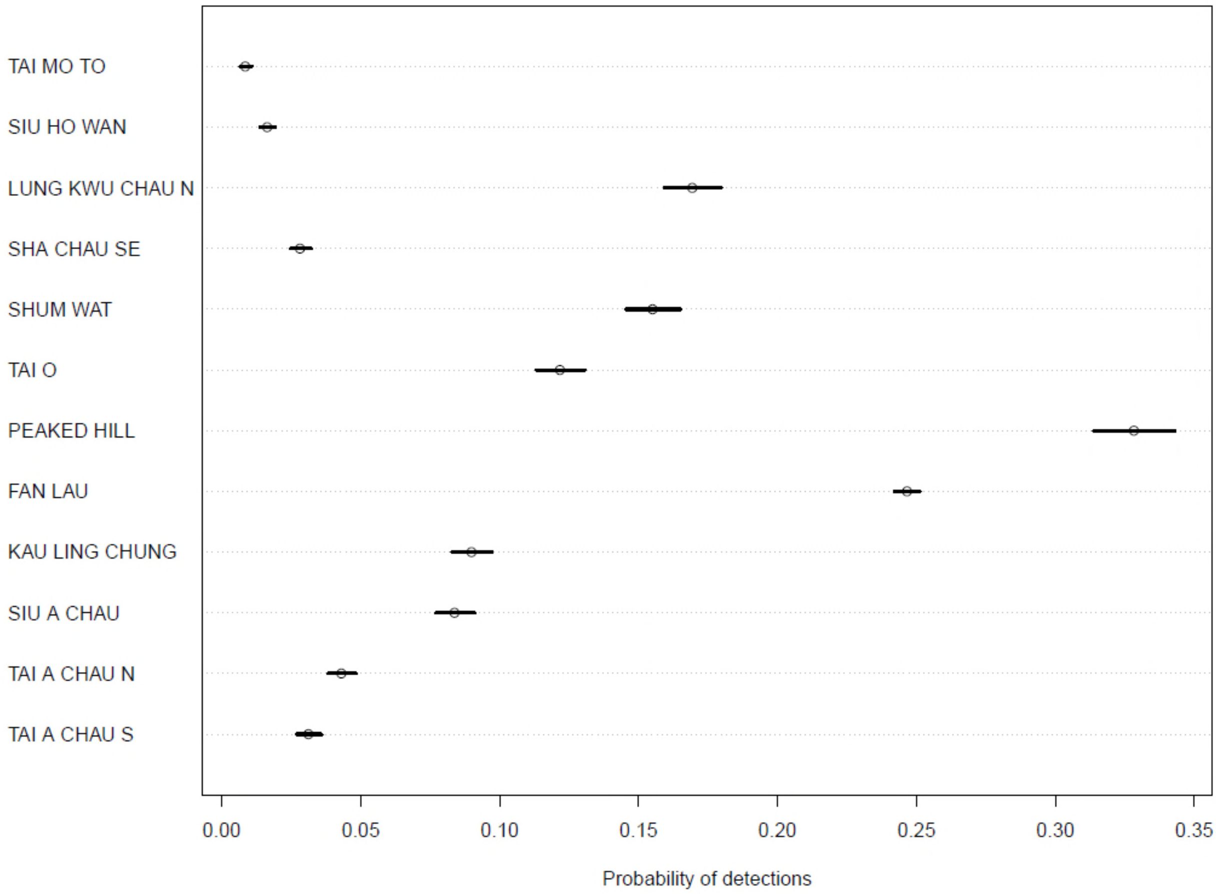


Figure 66. The probability of dolphin detection varied greatly across sites (based on model 1, where location was the only predictor variable). The mean and two standard deviations from the mean are shown by the open circles and solid bars, respectively.

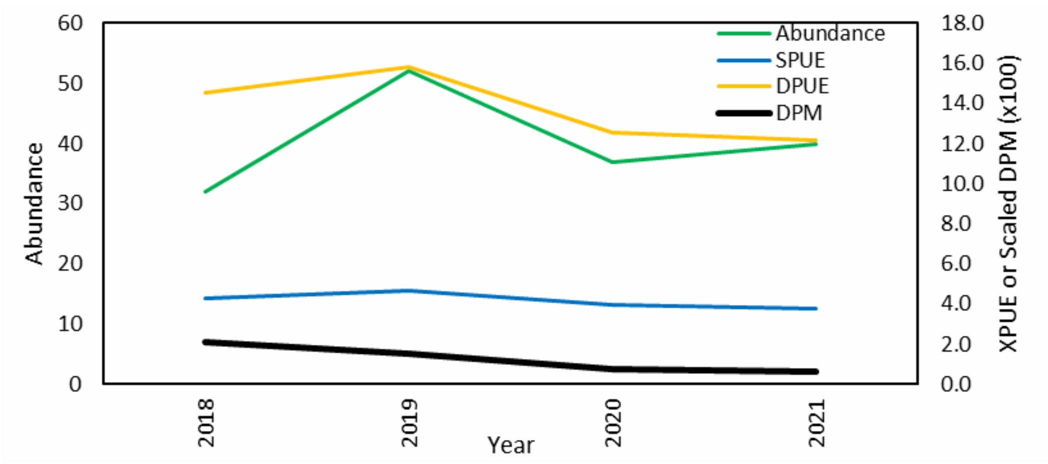


Figure 67. Comparison of annual C-POD data (DPM) and boat-based survey metrics (abundance, SPUE and DPUE) for Chinese White Dolphins for all survey areas combined.

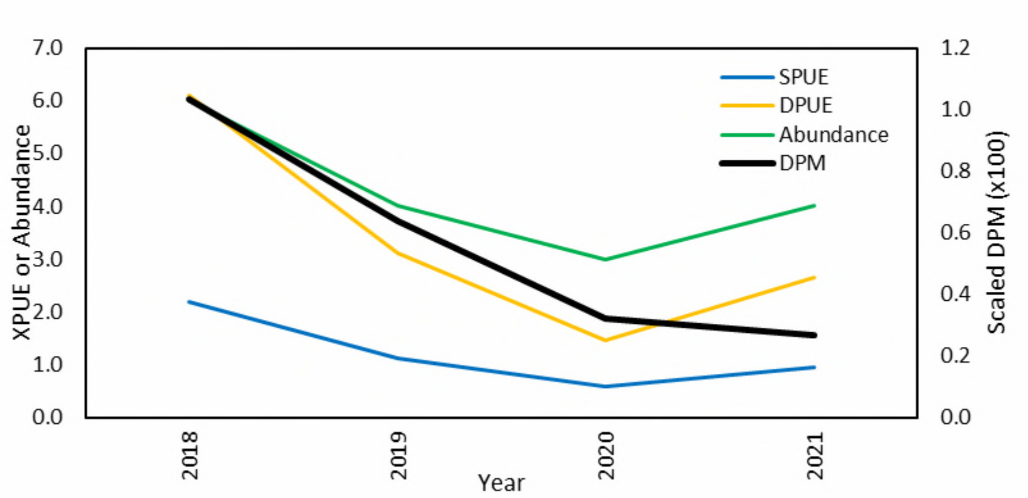


Figure 68. Comparison of annual C-POD data (DPM) and boat-based survey metrics (abundance, SPUE and DPUE) for Chinese White Dolphins in the NWL survey area.

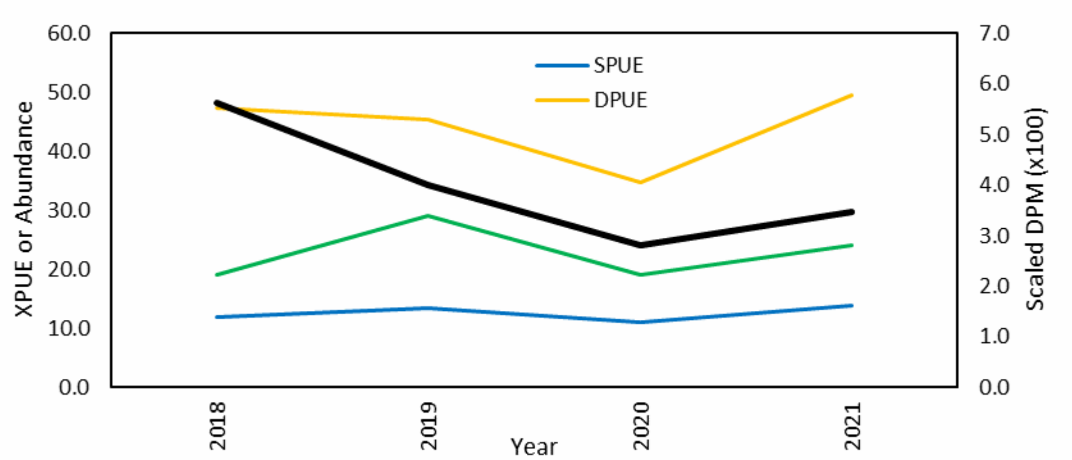


Figure 69. Comparison of annual C-POD data (DPM) and boat-based survey metrics (abundance, SPUE and DPUE) for Chinese White Dolphins in the WL survey area.

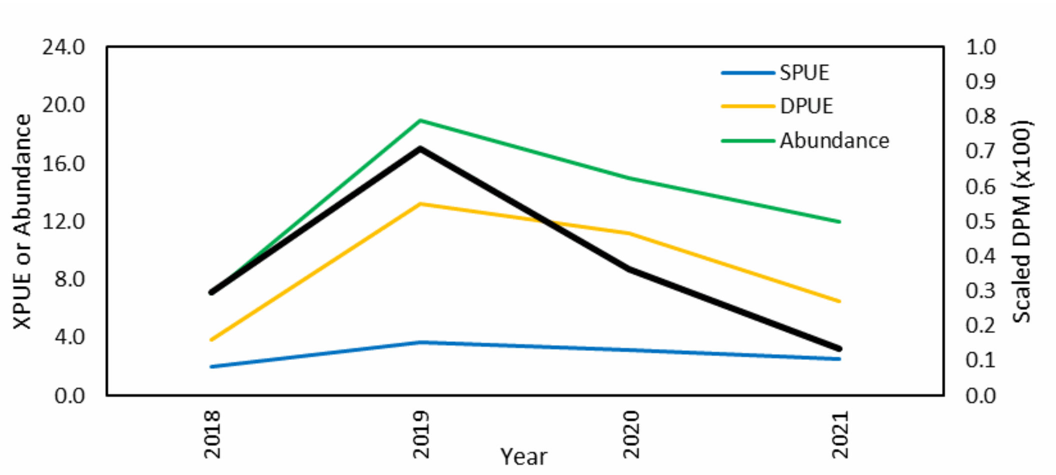


Figure 70. Comparison of annual C-POD data (DPM) and boat-based survey metrics (abundance, SPUE and DPUE) for Chinese White Dolphins in the SWL survey area.

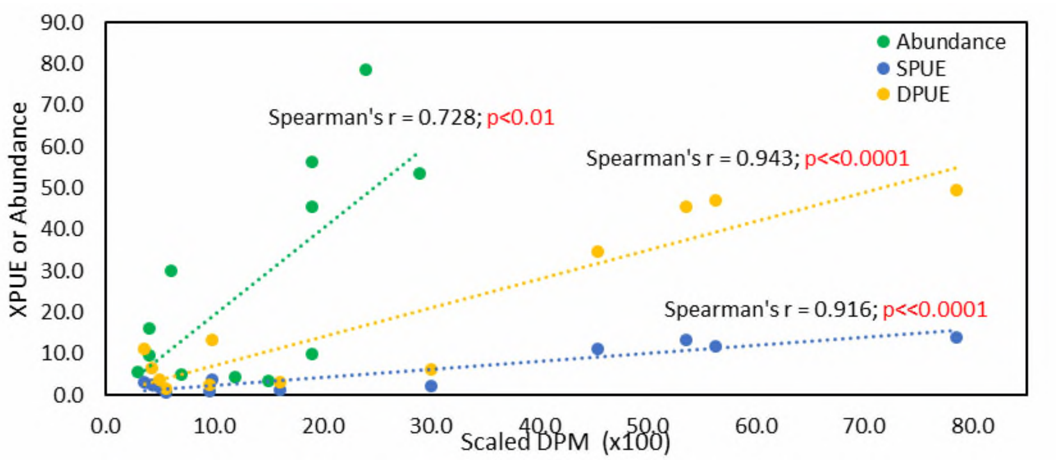


Figure 71. Correlations between annual Chinese White Dolphin C-POD (DPM) data and boat-based survey metrics for all survey areas combined.

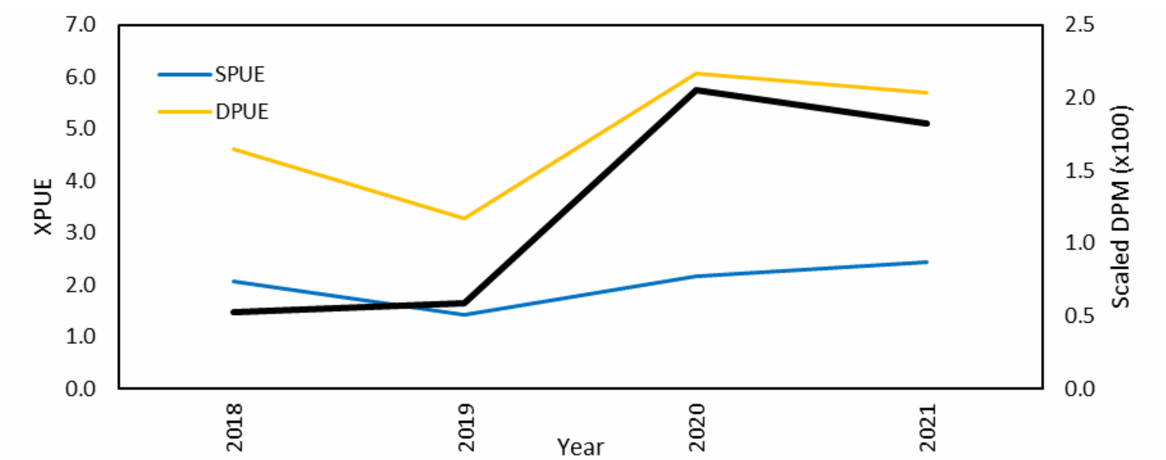


Figure 72. Comparison of annual C-POD data (DPM) and boat-based survey metrics (abundance, SPUE and DPUE) for finless porpoises in the SWL survey.

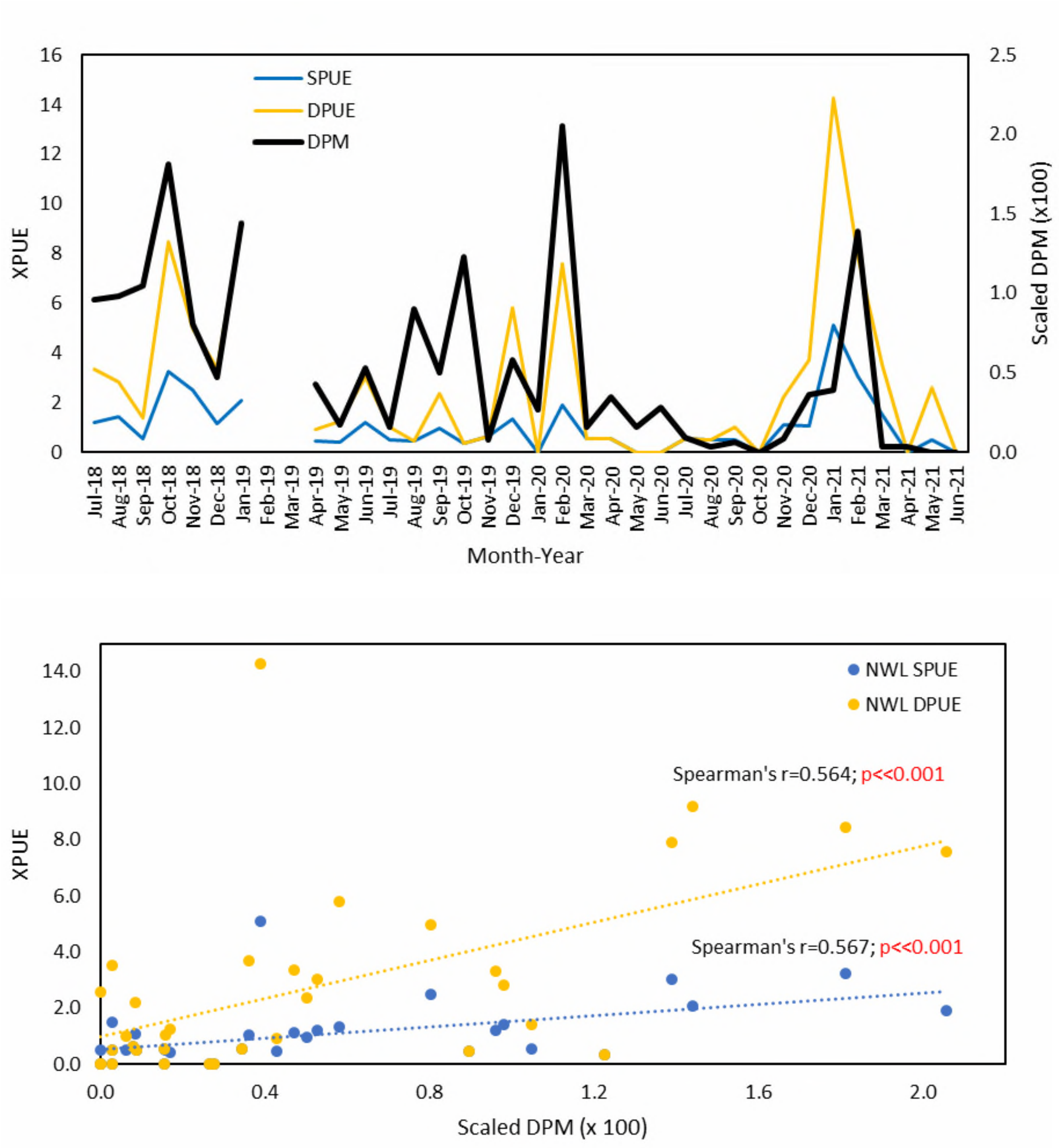


Figure 73. Comparison of monthly C-POD data (DPM) and boat-based survey metrics (SPUE and DPUE) (top) and the correlations between monthly DPMs with SPUE and DPUE (bottom) for Chinese white dolphins in the NWL survey area.

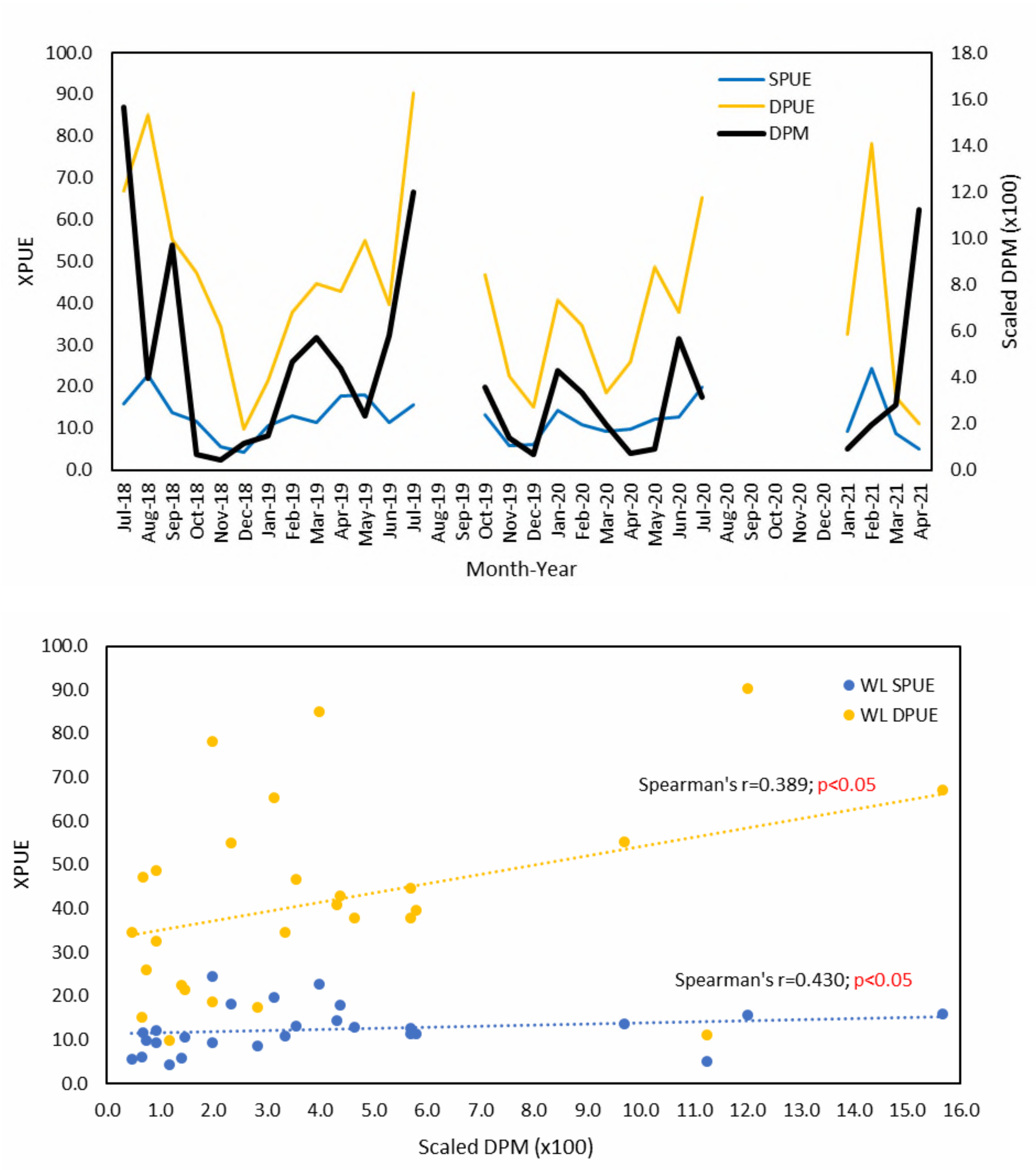


Figure 74. Comparison of monthly C-POD data (DPM) and boat-based survey metrics (SPUE and DPUE) (top) and the correlations between monthly DPMs with SPUE and DPUE (bottom) for Chinese white dolphins in the WL survey area.

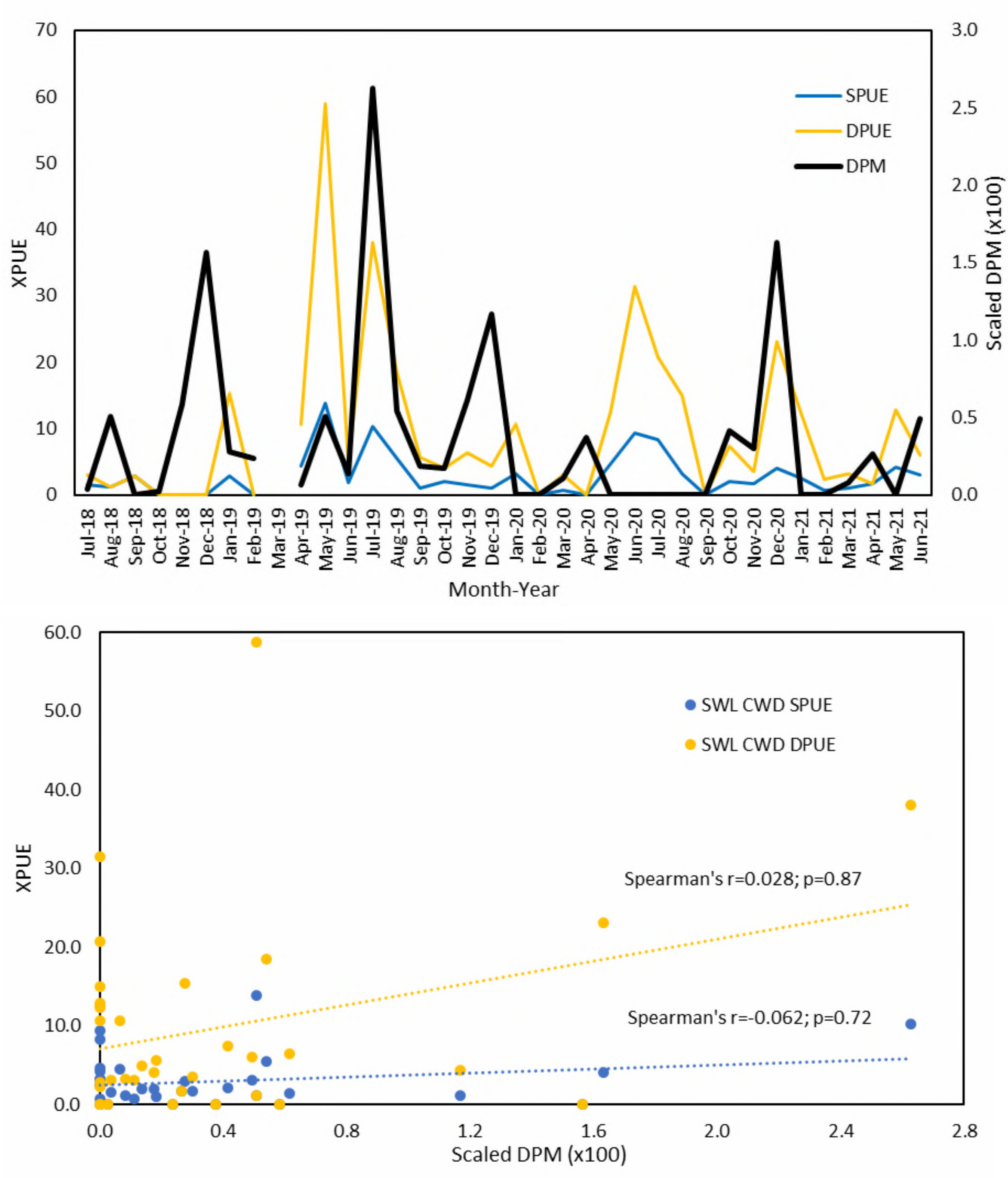
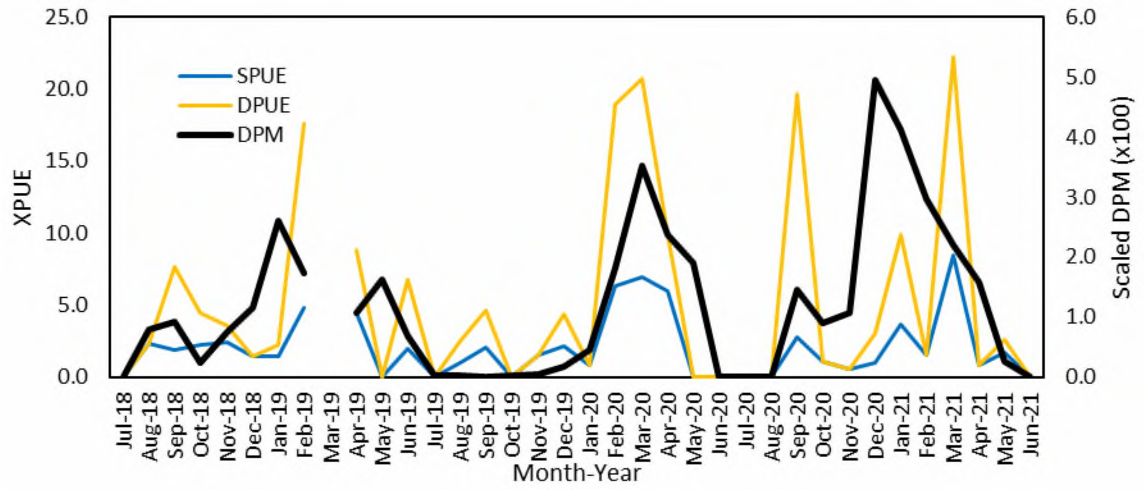


Figure 75. Comparison of monthly C-POD data (DPM) and boat-based survey metrics (SPUE and DPUE) (top) and the correlations between monthly DPMs with SPUE and DPUE (bottom) for Chinese white dolphins in the SWL survey area.



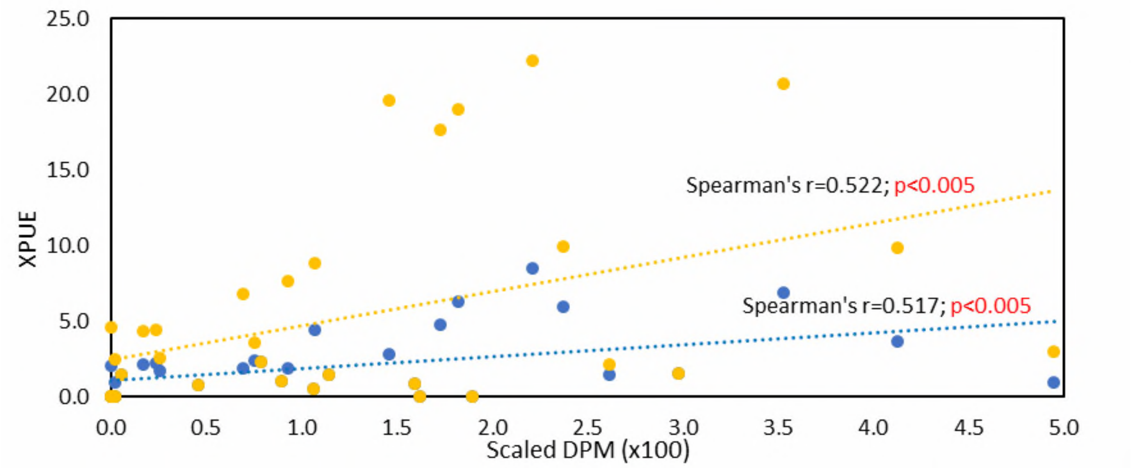


Figure 76. Comparison of monthly C-POD data (DPM) and boat-based survey metrics (SPUE and DPUE) (top) and the correlations between monthly DPMs with SPUE and DPUE (bottom) for finless porpoises in the SWL survey area.

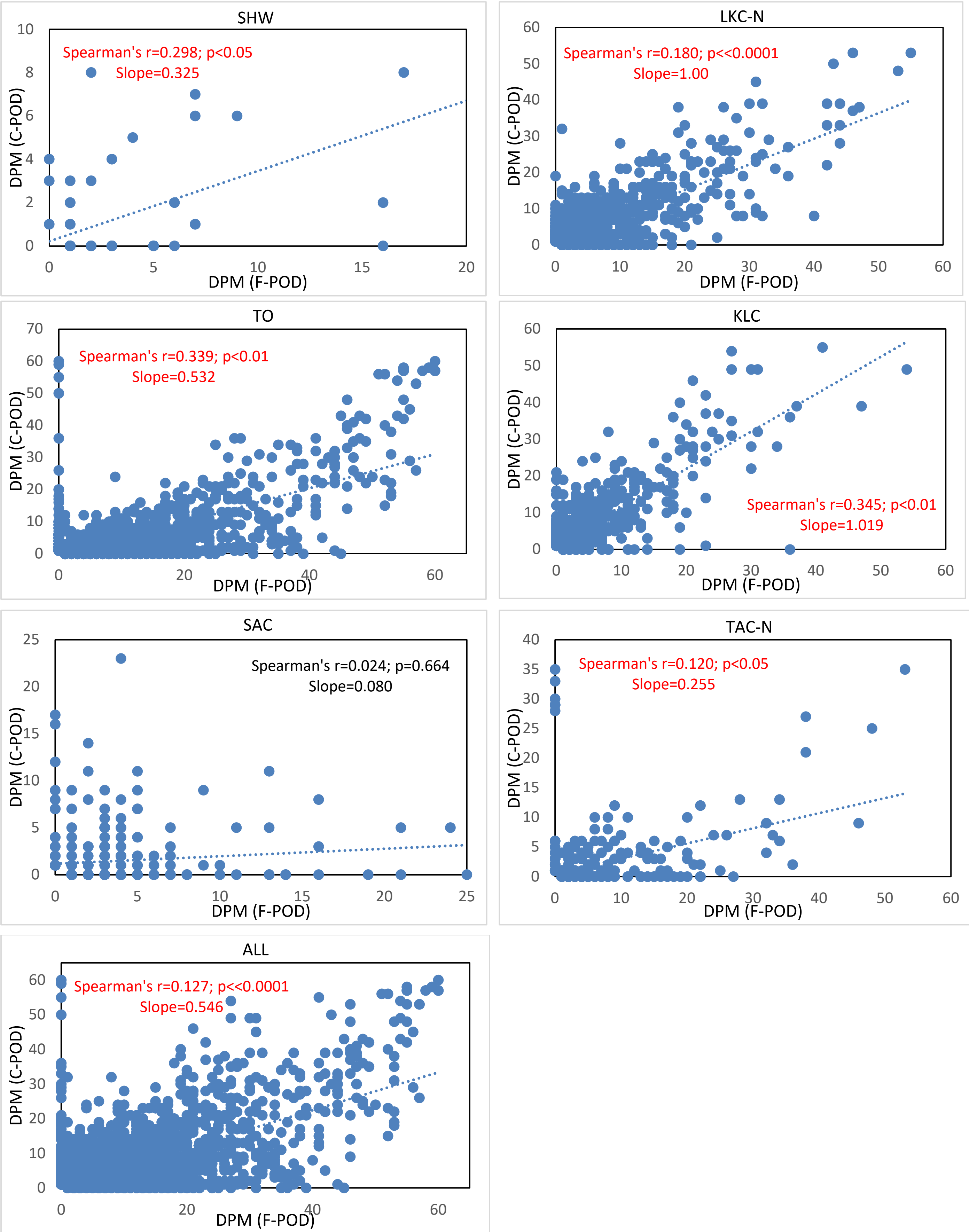


Figure 77. Comparison of Chinese white dolphin hourly DPM data obtained from paired C-POD/F-POD deployments from 2020 to 2021 for each site: Siu Ho Wan (SHW), Lung Kwu Chau N (LKC-N), Tai O (TO), Kau Ling Chung (KLC), Siu A Chau (SAC), Tai A Chau N (TAC-N) and all sites combined (ALL). The slopes shown were from simple linear correlations.

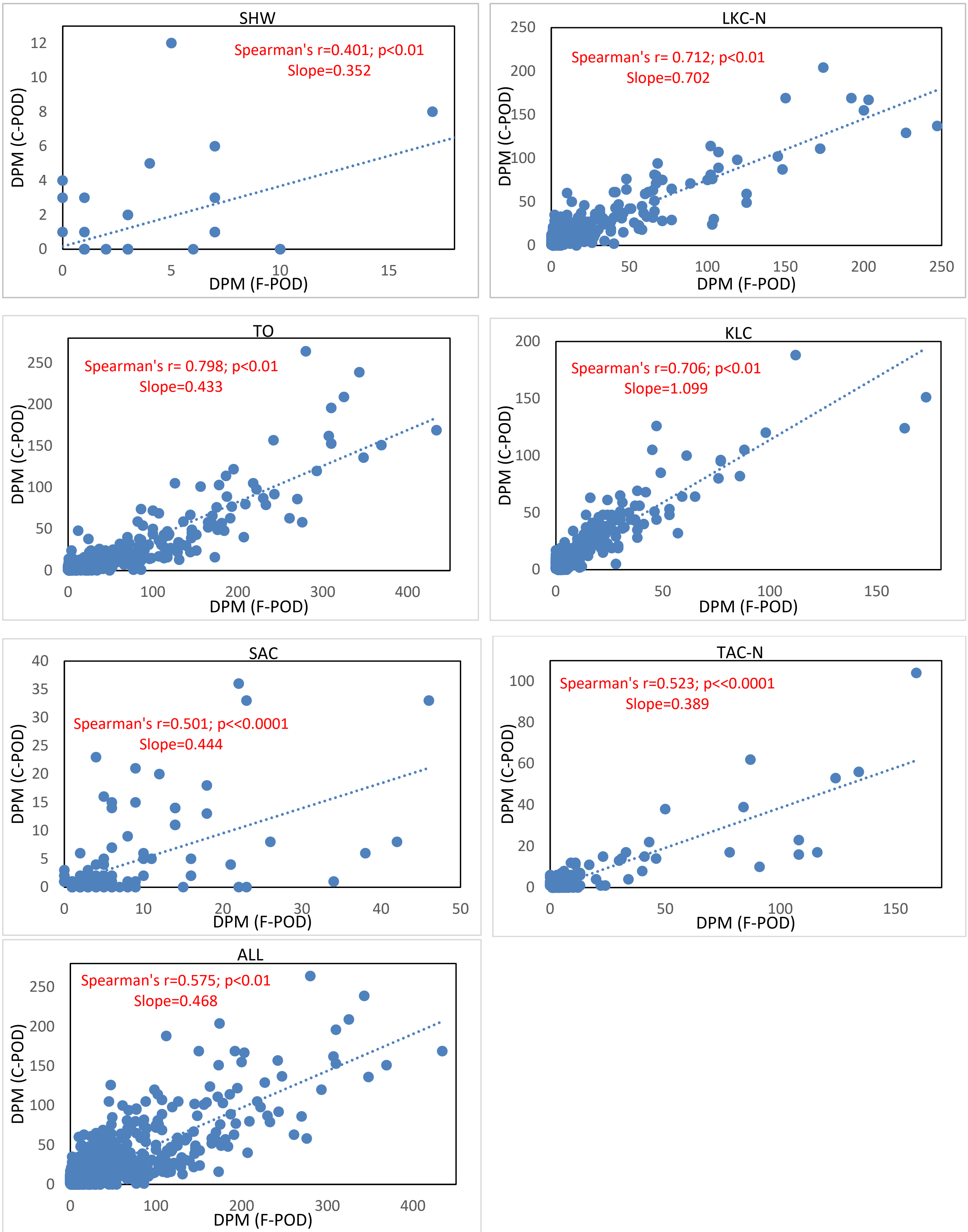


Figure 78. Comparison of Chinese white dolphin daily DPM data obtained from paired C-POD/F-POD deployments from 2020 to 2021 for each site: Siu Ho Wan (SHW), Lung Kwu Chau N (LKC-N), Tai O (TO), Kau Ling Chung (KLC), Siu A Chau (SAC), Tai A Chau N (TAC-N) and all sites combined (ALL). The slopes shown were from simple linear correlations.

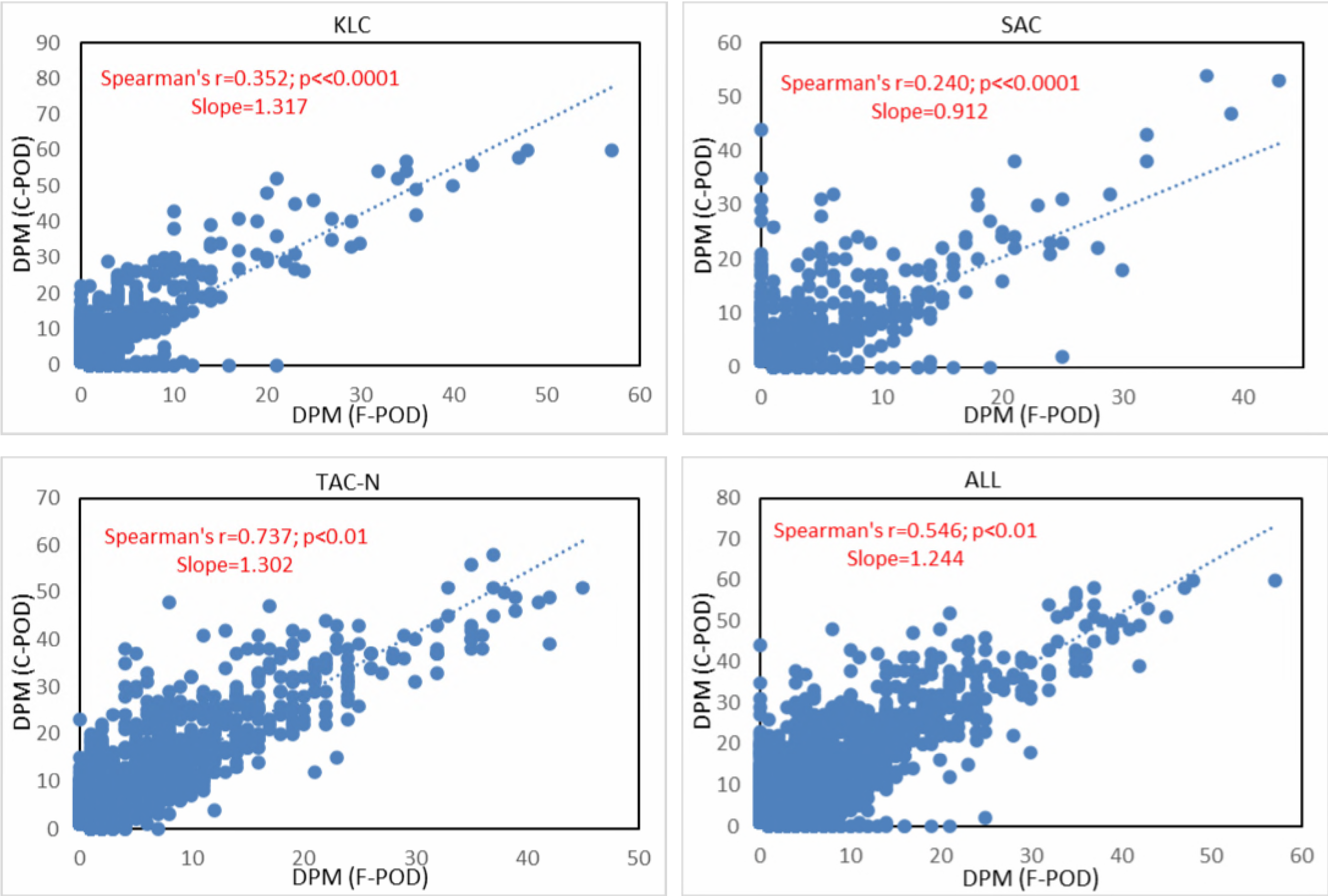


Figure 79. Comparison of finless porpoise hourly DPM data obtained from paired C-POD/F-POD deployments from 2020 to 2021 for each site: Kau Ling Chung (KLC), Siu A Chau (SAC), Tai A Chau N (TAC-N) and all sites combined (ALL). The slopes shown were from simple linear correlations.

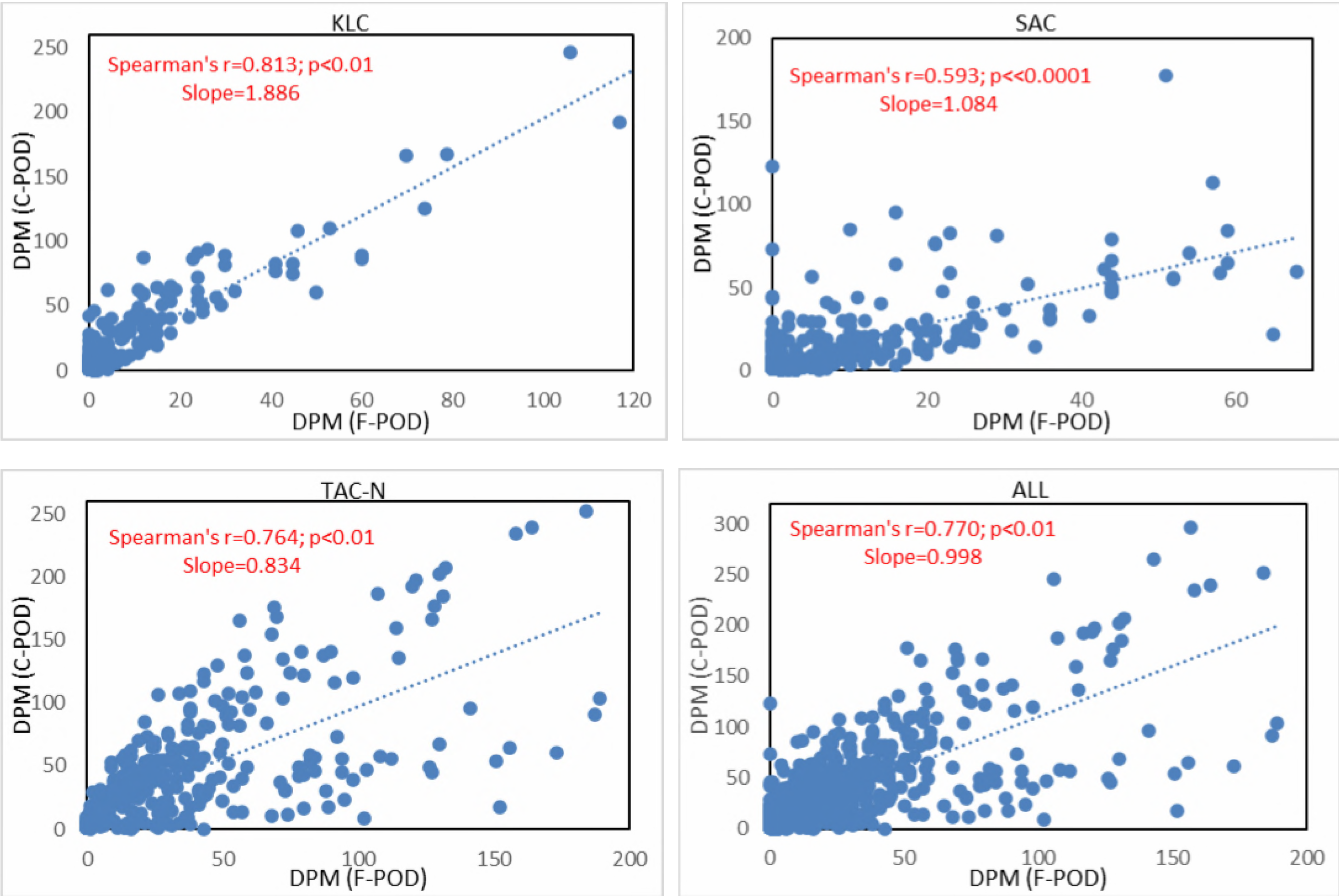


Figure 80. Comparison of finless porpoise daily DPM data obtained from paired C-POD/F-POD deployments from 2020 to 2021 for each site: Kau Ling Chung (KLC), Siu A Chau (SAC), Tai A Chau N (TAC-N) and all sites combined (ALL). The slopes shown were from simple linear correlations.