Appendix Q Passive Acoustic Monitoring Report

吉寶西格斯－振華聯營公司
KEPPEL SEGHERS - ZHEN HUA JOINT VENTURE

Passive Acoustic Monitoring Report

Revision History

B	Revision based on IEC's comments	19 February 2020
A	First Submission	10 January 2020
Rev.	**DESCRIPTION OF MODIFICATION**	**DATE**

CONTENTS

1. INTRODUCTION

1.1 Under the EM&A Manuel for the Integrated Waste Management Facility (IWMF) [EP/SP/66/12], there is a requirement for various monitoring for marine mammals in south Lantau waters. The marine mammal monitoring programme focuses on finless porpoise (Neophocaena phocaenoides) as the Project Site has been identified as a hotspot for this species. The Chinese white dolphin (Sousa chinensis) rarely occurs in this area, however, all detections of this species are also recorded. The general aim of all marine mammal monitoring is to assess impacts to marine mammals as predicted in the Environmental Impact Assessment (EIA). The marine mammal monitoring programme will be conducted during all phases of the project. The data for this report was gathered during the construction period (Phase I). This report details the collection and analyses of a passive acoustic monitoring (PAM) study. The Environmental Monitoring and Audit (EM&A) Manual for this project details the PAM studies to be conducted, at three (3) sites, during peak porpoise period (December to May) and for a duration of no less than 30 days during all phases of the project. It was noted prior to the start of this study that it was not possible to deploy a PAM system in the exact location used in the baseline study for one site, Shek Kwu Chau, as the ongoing IWMF construction meant that seabed modifications were ongoing in that area. A new PAM site, adjacent to the original PAM site at Shek Kwu Chau was identified. Acoustic data analyses methods are described in the EM&A Manual and in more detail in the baseline PAM study report. The results from this study, impact phase monitoring, were compared to the baseline study and, in addition, reference was made to the AFCD long-term marine mammal monitoring programme reports and other published information on finless porpoise.

2. METHODOLOGY

2.1 Three PAM systems were deployed for thirty (30) plus days during peak porpoise season. The purpose of the deployment was to gain an insight of fine scale habitat use by finless porpoise. An autonomous acoustic recorder (archival data) was selected that was able to record the distinctive high frequency sounds produced by finless porpoise, as well as other marine mammal vocalisations. Acoustic data analyss were conducted using PAMGuard software (Gillespie et al, 2008). High frequency finless porpoise clicks are easily distinguished from other marine mammal species that may occur, e.g., Chinese white dolphin or other delphinids, as well as manmade high frequency sound sources, such as boat sonar emissions. Two PAM systems were deployed at controls sites, at different distances from the IWMF construction area (Pui O Wan and Tai A Chau) and a third system was deployed within the IWMF construction area (Shek Kwu Chau). Multiple PAM systems were deployed at each site to minimise the risk of PAM units being lost/malfunctioning. One system was lost, at Shek Kwu Chau, however, data gathered from the back up unit was approved and has been included in these analyses. As such, the EM&A remit was fulfilled, as more than 30 days of PAM data was gathered from each of three sites during peak porpoise season during the construction phase of IWMF (**Figure 1**).

2.2 "Soundtraps" were archival acoustic devices chosen as the best option for this study, as they can record 24-hour underwater activity of all marine mammal species, and underwater noise levels, via an omnidirectional hydrophone with a frequency range of 20Hz to 150kHz (Appendix I). These specifications are comparable to the CPOD, which was used during the PAM baseline study. Therefore, the Soundtrap can collect the same type of data the CPOD does, as well as additional parameters. There are differences between the two devices, the CPOD is large (80cm) and floats within the water column whereas the Soundtrap is much smaller and lighter (20cm and less than 500g) and is not required to float, allowing it to be safely secured in a fixed position, either on the seabed or other solid structures, without the risk of it 'floating' into fishing gear (moving and static) or boat propellers. With regards to analyses, Soundtraps collect comprehensive and complete acoustic files (wav format) whereas CPODs are restricted to brand specific file formats that can only be analysed in one way. The complete files collected by Soundtraps can be analysed to produce the same "Detection Positive Minute (DPM)" parameters that CPODs can, as well as myriad other measurements. The more compact size and secure mooring system, in addition to being able to conduct the same analyses as that presented in the PAM baseline study, made this the most convenient PAM archival device to deploy for this study.

2.3 Once each Soundtrap was retrieved, the data, in compressed wav file format, was downloaded and inflated. The data was then processed using PAMGuard software, which was configured to detect "clicks" with energy in the 2kHz to 150kHz band. Two different click classifiers were used, one with very strict criteria which has a high confidence of identifying a click correctly, and a second which has slightly more flexible criteria, to assess clicks that may have been distant or not directed towards the device. These classifiers were designed specifically for Hong Kong finless porpoise. In addition, a dolphin click classifier and a dolphin whistle detector were also used to process the data, so that the presence of Chinses white dolphin could be determined. Similar to the CPOD inbuilt classifier, these are automated analyses and the resultant positively identified detections must be visually checked by expert acoustic technicians. Periods of high ambient noise or corrupted data segments were also determined at this stage in the process and, if present, were eliminated from the dataset. Acoustic detections identified by the software were confirmed by viewing the first identified 'click' in each one minute slot, to ensure that peak frequency, inter-click intervals (ICI) and duration characteristics conformed to what has been established for finless porpoise clicks. These characteristics were analysed via varies graphs that are displayed in PAMguard when a particular click is selected (**Figure 2**). Once the first identified click in every minute was visually confirmed, this became a 'detection positive minute' (DPM). If there were no clicks recorded in any given minute, this was classified as detection negative. This analysis was conducted twice, using the highly accurate classifier as well as the more flexible classifier. The full dataset for each recorder was analysed by two experienced analysts. The first performed confirmation checking of the automatically identified clicks for the entire dataset. The second analyst then reviewed the dataset for any potential discrepancies and assessed any ambiguous detections. If any discrepancies were noted, both analysts reviewed the original sound file and resolved any issue. The resultant dataset was thus an analysis of every recorded minute of data, with the date and time of all detection positive minutes were tabulated. This dataset was also subject to independent review. This dataset was then sub-sampled to graph DPM per calendar day for each site. The data were then further sampled to graph DPM for each hour, to investigate the presence of diurnal vocalisation patterns. These graphs could then be directly compared to the baseline data of the same parameters for each site.

3. RESULTS

3.1 Summary of data collection, including errors and data loss, and comparison to the baseline study.

3.1.1 A total of 121.9 days of recordings were obtained, combining the data from the three deployment sites. This is slightly more than the baseline study, which obtained 99.01 days of useable data. This difference in study duration must be accounted for when comparing results. This study had 0% false positive DPM, compared to the baseline study which had 0%, 1% and 2% at Shek Kwu Chau, Tai A Chau and Pui O Wan, respectively. As such, false positives were deemed to be negligible in both studies. Time lost due to device malfunction, corrupted data, high levels of underwater noise (that may mask marine mammal vocalisations) or "truncated recordings"[1] was 0% for all sites for this study, compared to the baseline study which noted time lost as 1%, 2% and 31.87% for Shek Kwu Chau, Tai A Chau and Pui O Wan, respectively. For sites Shek Kwu Chau and Tai A Chau, the loss noted during the baseline study is negligible, however, the considerable time lost during the baseline study at Pui O Wan (more than 30% of each minute recorded) is significant and must be considered when comparing this site across the two studies.

Note 1: In CPODs, acoustic recordings stop when predefined "click limits" are reached, as occurred in the baseline study. This is not a feature of Soundtrap recorders, so no data was lost in this way.

3.1.2 For the baseline study, the DPM for each site was 11,160 (Shek Kwu Chau), 16,089 (Tai A Chau) and 3645 (Pui O Wan), totalling 30,894 DPM across all three sites, compared to DPMs of 4740 (Shek Kwu Chau), 7725 (Tai A Chau) and 23,986 (Pui O Wan), totalling **36,451 DPM**, for the impact phase study. As the impact phase study was longer than the baseline study, it is not appropriate to directly compare total counts of DPM, however, the DPM rate (the average number of detections per day) for each site can be more directly compared. During the baseline study, Shek Kwu Chau averaged **338.2 DPM** per day compared to **124.8 DPM** per day, during the cimpact phase study. This shows a decrease in the daily average of porpoise detection at Shek Kwu Chau. During the baseline study, Tai A Chau averaged **487.6** DPM per day compared to **179.7 DPM** per day, during the impact phase study. This shows a decrease in the daily average of porpoise detection at Tai A Chau. During the baseline study, Pui O Wan averaged **98.5 DPM** per day compared to **557.8 DPM** per day, during the impact phase study. This shows a significant increase in the daily average of porpoise detections at Pui O Wan (**Table 1**).

3.1.3 During the baseline study, Chinese white dolphins were detected for 8 DPM at Shek Kwu Chau, 21 DPM at Tai A Chau and not at all at Pui O Wan. During this study, Chinese white dolphin were recorded on one day at Pui O Wan (13/05/2019) and only for 1 DPM. As Chinese white dolphin are not the focal species of these studies and did not occur often in the area, no more reference will be made to Chinese white dolphin in this report.

3.2 Daily Patterns of Porpoise Occurrence

3.2.1 For Shek Kwu Chau, the baseline study noted an "astonishing decline in porpoise activity" (from 150 DPM to 4 DPM over 4 days) concomitant with the start of site preparation activities for IWMF. The impact phase study recorded a relatively low level of porpoise activity, with an average daily occupancy of 8.7%, which fluctuated between 1.0% and 26.3%. The peaks in occurrence did not appear to be related to site activities, e.g., did not occur over weekends, although an in-depth assessment of specific site activities was not made. When it is considered that a 97% decrease in DPM was recorded during the baseline study as site preparation activities started, the overall decline in the daily average of DPM between the baseline and this study is not unexpected. The overall trend, although weak, is of decreasing use of the Shek Kwu Chau study site as the study progressed, again this is not unexpected as the PAM monitoring took place between March and April, when the peak season for porpoise in Hong Kong is more than half way through and porpoise occurrence, in general, is slowly declining (**Figure 3**).

3.2.2 For Tai A Chau, the baseline study noted a consistently high occurrence of porpoise at this site, compared to the two other sites. Fluctuations of between <200 DPM total per day to 1000 total DPM per day were noted during the baseline study, with no particular trend. For the impact phase study, there was a higher occupancy of this site, compared to Shek Kwu Chau, with an average daily occupancy of 12.5%, which fluctuated between 2.1% and 26.3%. Although the daily average DPM between the two studies was different, both showed large fluctuations in daily occurrence. The peaks in occurrence did not appear to be related to environmental changes for either study, although an in-depth assessment of influencing parameters, such as tide or salinity, was not made. When it is considered that the PAM deployment for this study occurred later in the peak porpoise season compared to the baseline study (April cf. February), this may account for the overall fewer detections. In addition, it must also be considered that the AFCD long term marine mammal monitoring programme for Hong Kong has suggested that porpoise have been in decline in Hong Kong waters for some time and these data may be a reflection of an overall general population decline. The overall trend, although weak, is of decreasing use of the Tai A Chau study site as the study progressed. This is not unexpected as the PAM monitoring took place between March and April, when the peak season for porpoise in Hong Kong is more than half way through and porpoise occurrence in general is slowly declining (**Figure 4**).

3.2.3 The most marked difference between baseline and impact phase monitoring is noted at the Pui O Wan PAM site. During the baseline study, the Pui O Wan site was initially highly used (during the first 13 days of the study) but then occurrence dropped dramatically (>400 DPM total per day to ~50 total DPM per day). This trend was not consistent across the baseline study and, as noted previously, the data derived from this deployment was compromised due to significant data loss (>30% of each minute's data was lost). It is therefore difficult to draw direct comparisons between a full and a partial dataset, however, the trends between the two studies are quite different. During baseline, the Pui O Site showed a sudden decline in detections, whereas the impact phase monitoring showed a gradual decline in detection rate, consistent with the other two sites monitored during this study. There was a higher finless porpoise occupancy of this site, compared to both other sites, during the impact phase, with an average daily occupancy of 38.7%, which fluctuated between 6.3% and 75.0%. This site is close to the IWMF construction site and perhaps the apparent increase in this site's use, compared to the baseline study, is an indication that porpoise that may have used the Shek Kwu Chau site were displaced to the waters of Pui O Wan. It is noted that the seasonal timing of the baseline (Feb-March) and the impact phase (March-April) PAM study overlapped, so the comparatively lower use of Pui O Wan during the baseline monitoring cannot be attributed to the generally accepted seasonal decline in porpoise as the peak period progresses. Much of the comparison between the baseline study and the impact phase study at this specific site, is confounded by the data loss issue during the baseline, however, what is clear is that during the impact phase study period, finless porpoise occupied the Pui O Wan site considerably more than the other two sites. It is noted that Pui O Wan is closer to the IWMF construction area than Tai A Chau. The overall occupancy trend at Pui O Wan is of a marked decrease in use as the monitoring progressed. This is not unexpected as the PAM monitoring took place between March and April, when the peak season for porpoise in Hong Kong is nearing an end and, as is shown in the AFCD long term marine mammal monitoring, seasonal declines in porpoise do occur (**Figure 5**).

3.3 Diurnal Patterns of Porpoise Occurrence

3.3.1 During the baseline study, all three sites showed diurnal occurrence of finless porpoise, that is, porpoise were more likely to be detected during night-time hours. At Shek Kwu Chau, occurrence during the baseline study peaked between 2am and 5am, whereas, the peak in occurrence at Tai A Chau and Pui O Wan was at midnight.

3.3.2 During the impact phase study, both Shek Kwu Chau and Pui O Wan showed significant diurnal activity, as was also noted in the baseline study. At Shek Kwu Chau, detections peaked between 9pm and 4am (**Figure 6**) and, at Pui O Wan, detections peaked between 8pm and 3am (**Figure 7**). There was very weak evidence of diurnal activity patterns at Tai A Chau, with only a suggestion of a possible peak in detections at 11pm, compared to the midnight peak noted during the baseline study (**Figure 8**). This lack of a pattern may be due to a difference in environmental parameters between the two study years, e.g., it has been noted that salinity significantly impacts finless porpoise occurrence and increased freshwater outflow from the Pearl River Estuary directly effects the Tai A Chau area. In addition, the limited number of detections from this site during impact phase monitoring may be insufficient to show clear patterns.

4. DISCUSSION

4.1 The EIA for the IWMF construction work predicted that marine mammals, in particular finless porpoise, would be displaced from the area immediately adjacent to construction activities. There has not been strong evidence for this during the impact phase vessel-based line-transect monitoring, however, comparisons between baseline and impact phase studies for both theodolite tracking and PAM do show, overall, fewer porpoise detections. As the area in which the line transect monitoring is conducted results in very few visual encounters (both historical and current data clearly show this) there is low power to detect any significant changes in porpoise occurrence, making it difficult to assess EIA predictions with certainty. Both theodolite tracking and PAM studies involve considerably more survey effort and therefore, more data is recorded and trends can be more easily discerned. The theodolite tracking (both baseline and impact phase monitoring) at Shek Kwu Chau showed a decline in porpoise detections concomitant with site activities. A comparison of the PAM data obtained during baseline and impact monitoring is not as clear cut. The PAM site immediately adjacent to IWMF construction activities, Shek Kwu Chau, was utilised by finless porpoise every day of the study and diurnal behaviour, typical of this species, was clearly detected. The Shek Kwu Chau area did appear to be used less often when compared to the baseline study, thus going some way to support the EIA predictions. Pui O Wan, the control site closest to the IWMF (~2.5km) recorded the greatest rate of daily porpoise detections during impact phase monitoring and distinct diurnal activity patterns were recorded, suggesting that porpoise were behaving as normal. There was considerably more activity at Pui O Wan during impact phase monitoring when compared to baseline monitoring, suggesting, perhaps, porpoise were displaced from the adjacent Shek Kwu Chau site. This difference, however, may also be due to different environmental or other anthropogenic factors between the two study periods. Further, the significant data loss from the Pui O Wan site during the baseline study may be confounding data comparison. Tai A Chau, some 9km distant from the IWMF site, showed no difference in porpoise detections related to start up site preparation activities at IWMF during the baseline study. There were, however, considerably less detections at Tai A Chau during impact phase monitoring, when compared to baseline monitoring, even though the area is most likely outside the impact zone of IWMF construction activities. In addition, there was no clear indication of diurnal behavioural patterns at Tai A Chau. The reduction in finless porpoise detections at Tai A Chau is contrary to EIA predictions and further analyses should be conducted to assess what other factors might be driving this apparent decline.

4.2 The PAM archival system survey could be used to study habitat use by finless porpoise (Neophocaena phocaenoides). Serveral such automated static porpoise detectors (e.g. CPODs, Soundtraps) could be deployed on the seabed (mounted on blocks / frameworks) and would archive any porpoise acoustic clicks. During baseline surveys, CPOD was installed on a high profile "A" frame seabed mount. Theses frames are not suitable for use in exposed areas and CPODs are also tethered "free floating" devices which, again, may be problematic to use in exposed areas as the tether may tangle or break and excessive motion may disrupt the collection of data as CPODs only record when vertical – not when horizontal as they might be in a current. Soundtraps will be used instead of CPODs, as these devices are smaller, more robust and can be fixed directly onto a frame, thus nothing is free floating in the water column. Soundtraps archive sound, like CPODs do, and the data can be analysed in the same way as CPODs. The soundtraps would be mounted on small storm proof seabed frames, which can be deployed quickly by divers using lift bags.

4.3 Overall, the PAM study showed that porpoise continue to consistently utilise the Shek Kwu Chau habitat immediately adjacent to the IWMF construction activities, although to a lesser degree than that prior to construction activities. In addition, the Pui O Wan site, which is 2.5km away from the IWMF construction area, was also consistently utilised during the impact phase PAM study. A continued assessment of fine scale habitat use, particularly through PAM which yields large quantities of data, would allow a more comprehensive assessment of the EIA predictions.

5. REFERENCES

5.1 Agriculture, Fisheries and Conservation Department (AFCD) 2018. Annual Marne Mammal Monitoring Programme April 2017-March 2018) The Agriculture, Fisheries and Conservation Department, Government ofthe Hong Kong SAR.

http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

5.2 Agriculture, Fisheries and Conservation Department (AFCD) 2017. Annual Marne Mammal Monitoring Programme April 2016-March 2017) The Agriculture, Fisheries and Conservation Department, Government of the Hong Kong SAR.

http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

5.3 Agriculture, Fisheries and Conservation Department (AFCD) 2016. Annual Marne Mammal Monitoring Programme April 2015-March 2016) The Agriculture, Fisheries and Conservation Department, Government of the Hong Kong SAR.

http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

5.4 Agriculture, Fisheries and Conservation Department (AFCD) 2015. Annual Marne Mammal Monitoring Programme April 2014-March 2015) The Agriculture, Fisheries and Conservation Department, Government of the Hong Kong SAR.

http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

5.5 Agriculture, Fisheries and Conservation Department (AFCD) 2014. Annual Marne Mammal Monitoring Programme April 2013-March 2014) The Agriculture, Fisheries and Conservation Department, Government of the Hong Kong SAR.

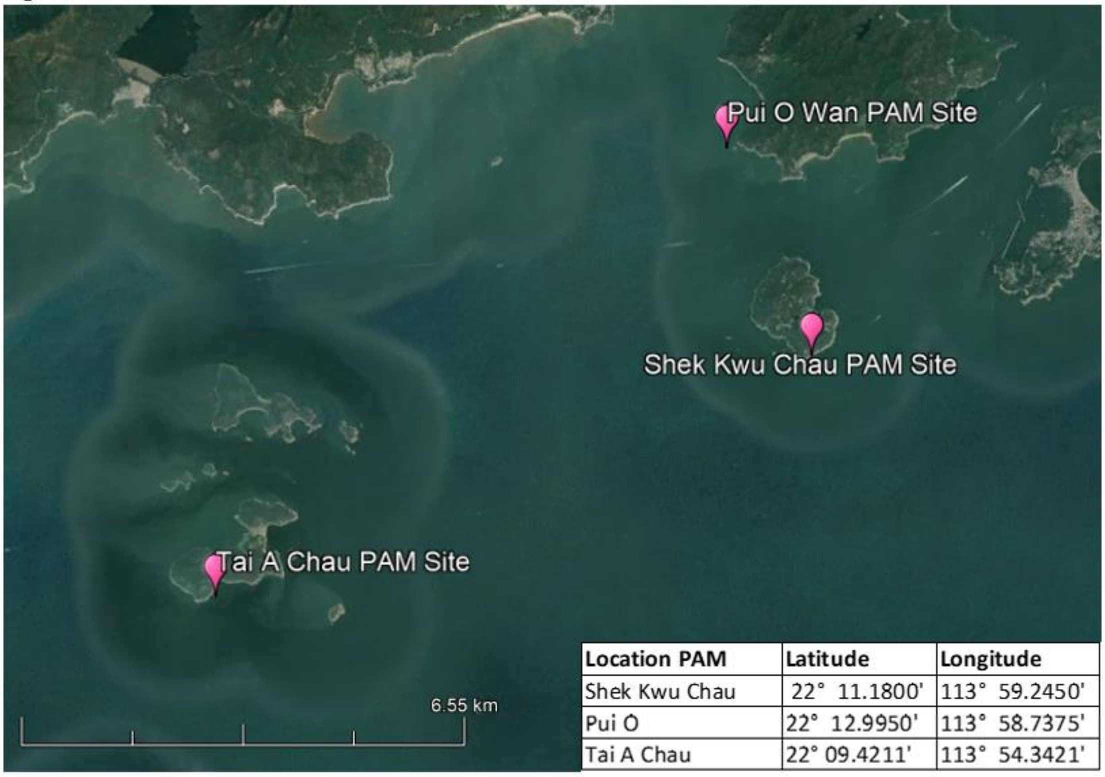
http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

5.6 Agriculture, Fisheries and Conservation Department (AFCD) 2013. Annual Marne Mammal Monitoring Programme April 2012-March 2013) The Agriculture, Fisheries and Conservation Department, Government of the Hong Kong SAR.

http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi.html

6. FIGURES AND TABLES

Figure 1 The Location of the PAM Sites during Impact Phase Monitoring (March - May 2019)



Location PAM	Latitude	Longitude
Shek Kwu Chau	22° 11.1800'	113° 59.2450'
Pui O	22° 12.9950'	113° 58.7375'
Tai A Chau	22° 09.4211'	113° 54.3421'

Figure 2 Using PAMGuard software, marine mammal vocalisations can be automatically detected by using inbuilt or bespoke classifiers. Here is an example of a finless porpoise click train, with corresponding click waveform and click spectrum graphs and a Wigner Plot, confirming the typical charcteristics of porpoise clicks

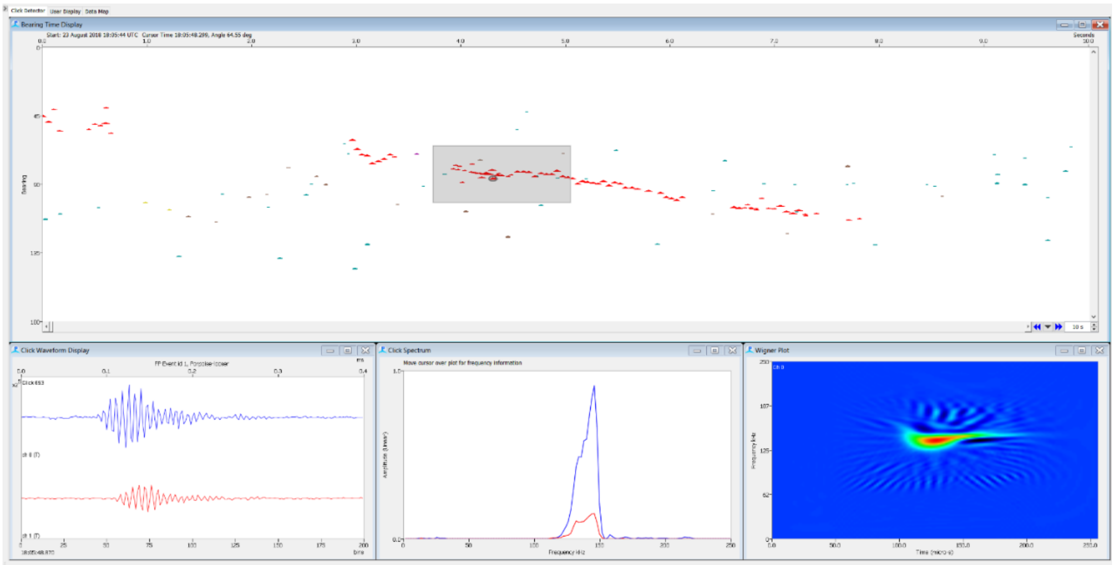


Figure 3 The Daily Rate of Detection Positive Minutes (DPM) for Finless Porpoise (Neophocaena phocaenoides) at Shek Kwu Chau, 5th March - 11th April 2019

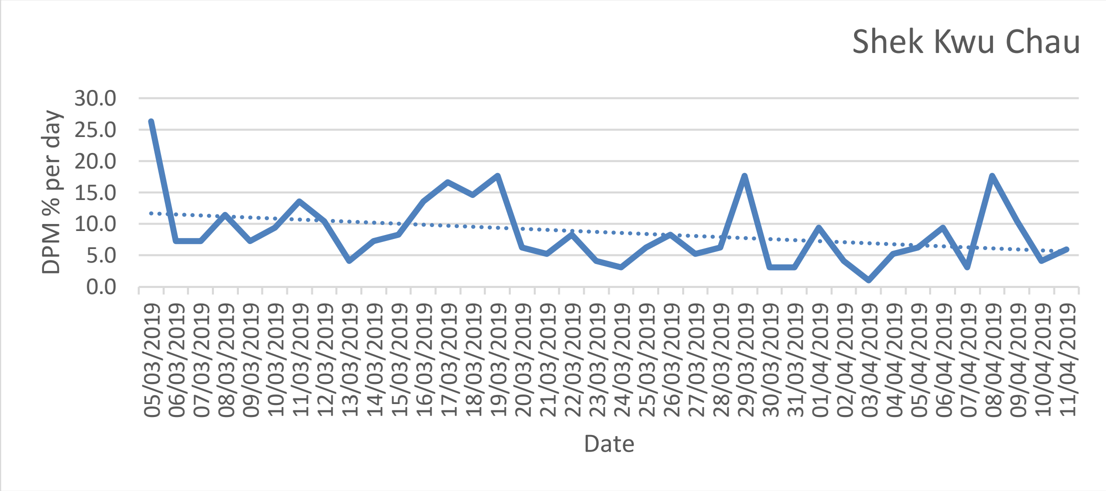


Figure 4 The Daily Rate of Detection Positive Minutes (DPM) for Finless Porpoise (Neophocaena phocaenoides) at Tai A Chau, 11th April – 23rd May 2019

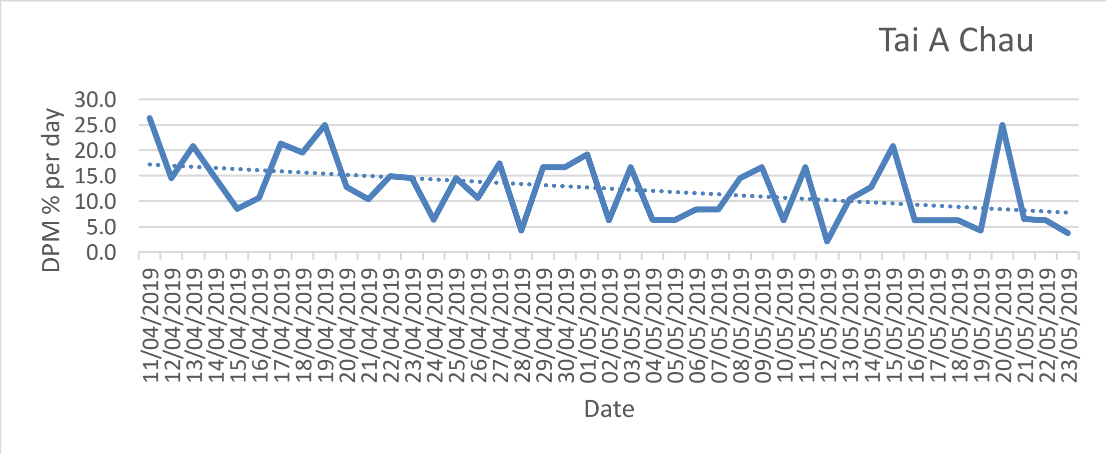


Figure 5 The Daily Rate of Detection Positive Minutes (DPM) for Finless Porpoise (Neophocaena phocaenoides) at Pui O Wan, 11th April - 23rd May 2019

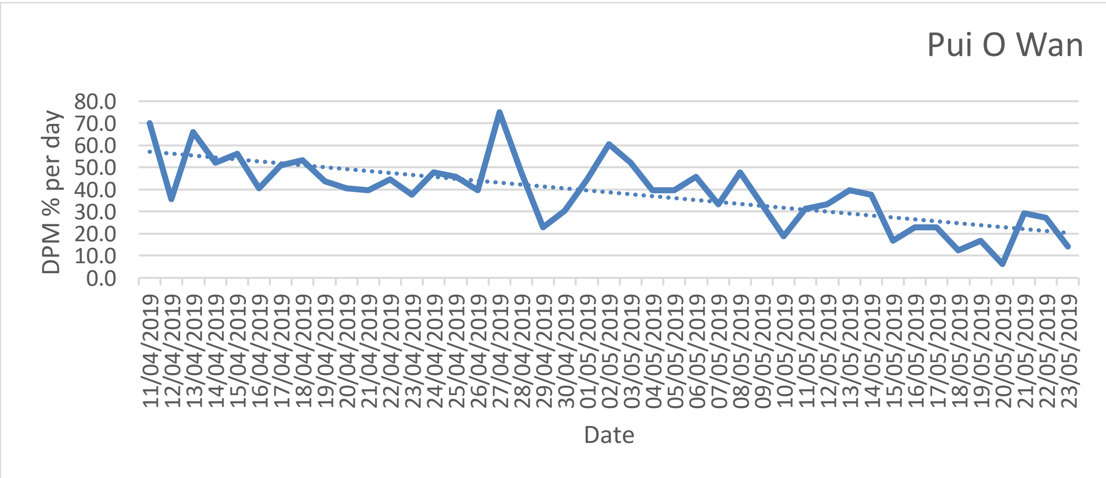


Figure 6 Finless Porpoise (Neophocaena phocaenoides) Diurnal Detection Patterns at Pui O Wan, 11th April - 23rd May 2019

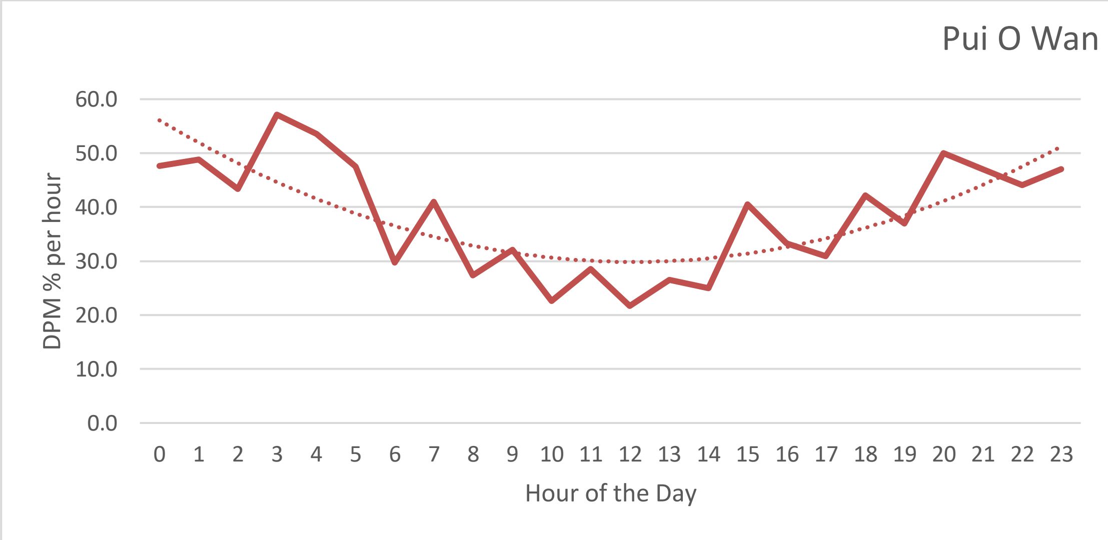
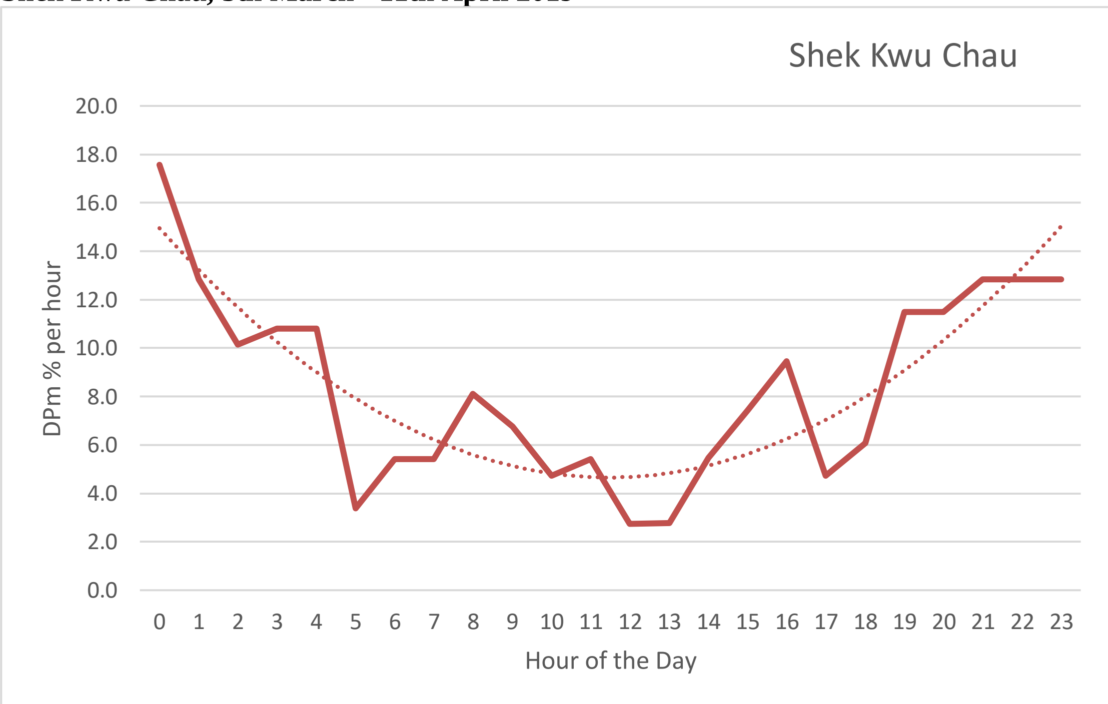


Figure 7 Finless Porpoise (Neophocaena phocaenoides) Diurnal Detection Patterns at Shek Kwu Chau, 5th March - 11th April 2019



Date	Time	Weather	Beaufort Sea State	Visibility	Fix Type	Group Number	Group Size	Behaviour	Horizontal	Vertical	Latitude	Longitude
01/03/2019	12:45:25	Fair	1	Good > 5KM	Finless Porpoise	1	1	Traveling	170.0541	267.3245	N 22° 11.1	113° 59.4

Figure 8 Finless Porpoise (Neophocaena phocaenoides) Diurnal Detection Patterns at Tai A Chau, 11th April - 23rd May 2019

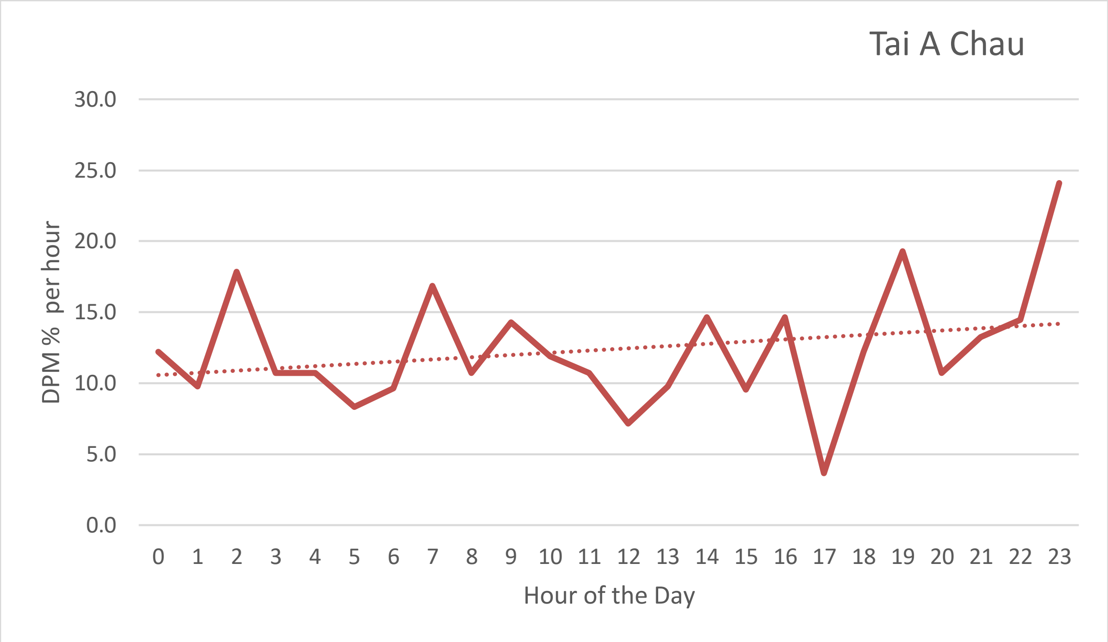


Table 1 Summary Statistic Comparison of Baseline (2018) and Impact Phase (2019) Passive Acoustic Monitoring, South Lantau, Hong Kong SAR

Baseline data									
Site	**Unit ID**	**Start**	**End**	**Days**	**DPD % Days**	**Total DPM**	**DPM /Day**	**% False Positive DPM**	**Time Lost %**
Shek Kwu Chau	2891	2018/02/09	2018/03/13	32.11	100	11160	338.2	0.0	1.00
Tai A Chau	2868	2018/02/09	2018/03/13	32.5	100	16089	487.6	1.0	2.00
Pui O Wan	2891	2018/03/13	2018/04/17	34.85	97.3	3645	98.5	2.0	31.87
Total				99.01		30894	312.0		
Impact Phase									
Site	**Unit ID**	**Start**	**End**	**Days**	**DPD % Days**	**Total DPM**	**DPM /Day**	**% False Positive DPM**	**Time Lost %**
Shek Kwu Chau	IWMF_BU_20190305_01	2019/03/05	2019/04/11	37.91	100	4740	124.8	0.0	0
Tai A Chau	IWMF_20190411_02	2019/04/11	2019/05/23	41.94	100	7725	179.7	0.0	0
Pui O Wan	IWMF_20190411_01	2019/04/11	2019/05/23	42.02	100	23986	557.8	0.0	0
Total				121.9		36451	299.1		

APPENDIX 1

www.OceanInstruments.co.nz
ENGINEERING SERVICES FOR MARINE SCIENCE

SoundTrap 300 Digital Sound Recorders

STD & HF models

Key features:

- **Industry leading audio fidelity**
- **Very low self-noise**
- **60 kHz and 150 kHz bandwidth models**
- **Up to 13 days continuous recording on internal battery**
- **Up to 70 days continuous with optional external battery (3 x D cell)**
- **Simple operation with IR remote control**
- **Sealed, low maintenance, flood proof housing**
- **Selectable high pass filter for high energy sites or towing**
- **Sensors for temperature and acceleration**
- **Fast USB offload**

The SoundTrap 300 series are compact self-contained underwater sound recorders for ocean acoustic research. The STD model is intended for general aquatic noise measurements with a working frequency range of 20 Hz to 60 kHz. While the HF model offers 20 Hz to 150 kHz bandwidth for high frequency bioacoustic measurements. Both feature very low self-noise, ensuring beautiful recordings in even the quietest places.

Their internal battery enables continuous recording for up to 13 days, or 56 days on a 10 minute per hour duty cycle. For longer deployments simply plug in the optional external battery pack for up to 70 days continuous recording. 128 GB of internal memory coupled with lossless audio compression provide storage for up to 65 days continuous recording at 36 kHz.

Data offload and battery recharge are done via a high quality wet plug. The housing therefore never needs opening, thereby eliminating the usual worries about o'ring maintenance and moisture ingress. Weighing less than 500 g in air, hydrophone deployment has never before been so easy.

Output files are in the industry standard WAV format. Ancillary sensors are included for logging temperature and tri-axial acceleration. The included software offers flexible deployment options for sample rate, gain control, filtering, delayed start and duty cycle. Plus the included water proof IR remote control makes for convenient in-the-field ad hoc measurements. Each instrument is supplied with a calibration certificate and features self-calibration checks for confirmation of performance in the field.

Detailed Specifications

Bandwidth	**STD model**	20 Hz - 60 kHz ± 3dB
	HF model	20 Hz - 150 kHz ± 3dB
Self-noise	Better than sea-state 0 (100 Hz - 2 kHz)	
	STD model Less than 34 dB re 1 µPa above 2 kHz	
	HF model Less than 37 dB re 1 µPa above 2 kHz	
Gain	Two gain settings - Low noise and high dynamic range.	
	Maximum level before clipping approx. 186 dB re 1 µPa	
High Pass Filter	400 Hz selectable high pass for high energy sites	
Sample rates	**STD model**	288, 144, 96, 48 & 36 kHz
	HF model	576, 288, 192, 96 & 72 kHz
ADC	16-bit SAR	
Calibration	Factory OCR calibration certificate	
	Self-calibration check	
	Pistonphone coupler available	
Control	Waterproof IR remote control for manual record start/stop.	
Ancillary sensors	Temperature - 0.1°C precision, 1°C uncalibrated accuracy in water	
	Acceleration – For detecting orientation, or cable strum / platform vibration.	
	Tri-axial accelerometer, +/- 8g, Sampling up to 1 Hz	
Memory	128 GB. Lossless audio compression provides 3 to 4 times compression, thereby allowing for up to 512 GB of wav file storage.	
Internal battery	An internal rechargeable battery provides power for up to 13 days continuous operation	
External battery	The optional external battery housing takes 3 x D cell batteries, and provides up to 70 days continuous operation.	
Connectivity	Wet pluggable connector for connection to GPS or radio telemetry.	
Maximum depth	500m (Extended depth version available on request)	
Dimensions:	200mm L x 60mm D (excluding connector dummy)	
Weight	Approx. 500g in air