What Do Dolphins Do At Night?

海豚在晚上做甚麼?:窺探本港海豚夜間行為及活動範圍之謎

MEEF2018010A Final Report

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Declaration

Reference Number: MEEF2018010A

Project Title: What Do Dolphins Do At Night?: Filling knowledge gaps in night time range and behaviour activities of Chinese white dolphins in Hong Kong

Project Leader: Derek Watson

I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorisation has been obtained in respect of information owned by third parties.

I hereby irrevocably declare, warrant and undertake to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that I myself, and the Organisation:-

1. *do not deal with, and are not in any way associated with, any country or organisation or activity which is or may potentially be relevant to, or targeted by, sanctions administered by the United Nations Security Council, the European Union, Her Majesty's Treasury-United Kingdom, the United States Department of the Treasury's Office of Foreign Assets Control, or the Hong Kong Monetary Authority, or any sanctions law applicable;*
2. *have not used any money obtained from the Marine Ecology Enhancement Fund or the related Top-up Find (and any derived surplus), in any unlawful manner, whether involving bribery, money-laundering, terrorism or infringement of any international or local law; and*
3. *have used the funds received (and any derived surplus) solely for the studies or projects which further the MEEF Objectives and have not distributed any portion of such funds (including any derived surplus) to members of the recipient organization or the public.*

Signature: ____________________

Derek Watson, Project Leader

Date: 5 February 2021

Any opinions, findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.

Contents

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Executive Summary

The Indo-Pacific humpback dolphin (*Sousa chinensis*), known locally as the Chinese white dolphin (CWD), has been studied in Hong Kong through a long-term monitoring programme by the Agricultural, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government since the early 1990s. This monitoring programme focuses on visual line transect surveys that provide excellent data on the daytime occurrence, distribution and habitat usage of CWDs. However, given that CWDs are known to occur day and night in both Hong Kong and the Pearl River Estuary, there remain significant gaps in our understanding of their night-time distribution and habitat usage. Addressing these gaps is a priority, since construction activities related to large infrastructure projects within the dolphins' habitat occur, to varying degrees, 24 hours a day. Understanding the full impact of these activities, and how to mitigate potentially adverse impacts, requires knowledge of the dolphins' diel movements and behaviours. Accordingly, the overall aim of this multi-year project was to better understand the night-time occurrence, distribution and habitat usage of CWDs in Hong Kong waters by using passive acoustic monitoring (PAM) systems. Specifically, the objectives were to:

(1) Map the relative density, distribution and behaviour of the night-time occurrence of CWDs in Hong Kong waters from vessel-based acoustic surveys.
(2) Trial a real-time remote acoustic monitoring buoy for dolphins in Marine Park Areas of Hong Kong.

To map the distribution and density of the night-time occurrence of CWDs, a quantitative grid analyses was conducted (as described in the AFCD Marine Mammal Monitoring Programme) to calculate the number of night-time acoustic detections per 100 units of survey effort ($ASPE_N$). The night-time behaviour of CWDs could not be mapped, as preliminary analyses revealed that the vocalisations needed to differentiate behavioural states were difficult to isolate from background noise underwater. Instead, the relationship between night-time occurrence and environmental variables was investigated using Generalised Additive Models (GAMs) to understand fine-scale influences in distribution. CWD presence was modelled against effort, lunar phase, tidal height, temperature, turbidity, pH, suspended solids, depth and slope.

From Year 1 (2018-19) and Year 2 (2019-20) of the project, 100 towed hydrophone array surveys were conducted over 98 survey days, with over 350 hours of acoustic data recorded. There were 304 CWD detections in northern, western and southern Lantau waters from The Brothers Marine Park to Sha Chau and Lung Kwu Chau, Tai O Peninsula, Fan Lau Peninsula, and the Soko Islands. The distribution of night-time detections corresponded to the distribution of daytime sightings. Notably, however, CWDs were detected acoustically at night in areas where they were not detected visually during the day – specifically, The Brothers Marine Park. The highest number of detections was recorded in West Lantau (WL), but coverage (the number of 1 km^2 grid cells that were CWD-positive) was highest in South Lantau (SL). Density analyses revealed three "hotspots", where $APSE_N$ values were highest, around Fan Lau Peninsula, between Fan Lau Peninsula and the Soko Islands, and northeast of Siu A Chau. GAMs indicated that CWD night-time presence was affected by effort, lunar phase, tidal height, temperature, turbidity and pH. Presence was greater during the new moon and the last phases of the lunar cycle (i.e., last quarter and waning crescent); during extreme low tides (less than 0.5 m); at lower temperatures; at 10 ntu; and at a pH of 8.1. A real-time acoustic buoy – the Coastal Acoustic Buoy (CAB) – was deployed between 26th March 2020 and 1st April 2020 in the proposed South Lantau Marine Park. Over 143 hours of acoustic data were recorded from which there were 16 Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) detections. Although no dolphin vocalisations and only one porpoise event was detected, CAB ran smoothly and continuously, demonstrating its capabilities and potential for longer term deployments.

The objectives of the project were, on the whole, achieved within the proposed timeframe. Based on the outcomes, three recommendations were made: to improve the detection of lower frequency CWD vocalisations from towed hydrophone arrays; update existing CWD acoustic ethograms by conducting detailed behavioural observations and making concurrent acoustic recordings; and identify prey species' vocalisations (specifically, sciaenids) from data collected for this project, so that their distribution and density may be mapped in relation to CWD distribution and density.

1. Project Description

The Indo-Pacific humpback dolphin (*Sousa chinensis*), known locally as the Chinese white dolphin (CWD), has been studied in Hong Kong through a long-term monitoring programme by the Agricultural, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government since the early 1990s (Jefferson et al. 2009). This monitoring programme focuses on visual line transect surveys that provide excellent data on the daytime occurrence, distribution and habitat usage of CWDs (e.g., Hung 2020). However, given that CWDs are known to occur day and night in both Hong Kong (Munger et al. 2016) and the Pearl River Estuary (Wang et al. 2015; Pine et al. 2017), there remain significant gaps in our understanding of their distribution and habitat usage. Addressing these gaps is a priority, since construction activities related to large infrastructure projects within the dolphins' habitat occur, to varying degrees, 24 hours a day. Understanding the full impact of these activities, and how to mitigate potentially adverse impacts, requires knowledge of the dolphins' diel movements and behaviours. Accordingly, the overall aim of this multi-year project was to better understand the night-time occurrence, distribution and habitat usage of CWDs in Hong Kong waters.

Passive acoustic monitoring (PAM) is one of the few tools that can be used to study cetacean activity at night. Like visual methods, PAM systems can be used to collect spatio-temporal data on a species' occurrence, distribution and habitat usage. For example, towed hydrophone arrays deployed during line transect surveys have been used to understand spatial trends across large areas (e.g., Yack et al. 2013; Norris et al. 2017; Gridley et al. 2020). Similarly, static hydrophone stations or buoys deployed in an area of interest can be used to understand temporal trends at a specific site (e.g., Wang et al. 2015; Guan et al. 2015; Munger et al. 2016; Pine et al. 2017). Unlike visual methods, however, PAM systems are not limited by daylight, poor visibility or inclement weather, and are capable of recording continuous data over long periods of time. The vocal repertoire of CWDs in Hong Kong (Ruxton 2002), the Pearl River Estuary (Goold and Jefferson 2004; Sims et al. 2011) and southern China (Wang et al. 2013) has been well-documented, making them ideal candidates for PAM that are readily detectable and identifiable. Additionally, different CWD vocalisations have been associated with different behavioural states (Ruxton 2002), and thus can be used to discern habitat use.

This report summarises activities conducted in Year 2 (2019-20) of the project MEEF2018010A, combined with data gathered during Year 1 (2018-19). Over the course of the project, night-time towed hydrophone array surveys were conducted across the known range of CWDs in Hong Kong waters. Supplementary daytime towed hydrophone array surveys, with concurrent visual observation, were also conducted to calibrate acoustic detections with sightings. Since the range of CWDs overlaps with Indo-Pacific finless porpoise (*Neophocaena phocaenoides*), acoustic detections of finless porpoises were also identified and analysed. The vocalisations of finless porpoises are similarly well-documented (Goold and Jefferson 2002) and easily distinguished from CWD vocalisations. The specific objectives of this project were to:

(1) Map the relative density, distribution and behaviour of the night-time occurrence of CWD in Hong Kong waters from vessel-based acoustic surveys.
(2) Trial a real-time remote acoustic monitoring buoy for dolphins in Marine Park Areas of Hong Kong.

1.1. Completed Activities Against Proposed Work Schedule

The project and its activities were conducted between July 2019 and June 2020 (Table 1). Acoustic surveys were conducted as timetabled and added to the data collected from Year 1 of this multi-year project (July 2018 – June 2019). In the period between July 2019 and June 2020 (Year 2), 55 night and 2 day surveys were conducted. These were combined with surveys from Year 1 so that survey effort totalled ninety (90) night-time acoustic surveys and ten (10) daytime acoustic surveys, completed between July 2018 and June 2020 (Table 2, Appendix I). A real-time acoustic buoy – the Coastal Acoustic Buoy (CAB)[1] – was tested in various locations during Year 1 of the project. However, a longer term deployment was delayed to Year 2 as issues with 4G data transmission were not resolved during Year 1. A real-time CAB system was deployed within the proposed South Lantau Marine Park between 26th March 2020 and 1st April 2020. An interim report was submitted on 23rd of December 2019. This current report is the final report for the multi-year project.

2. Methodology

2.1. Night-time Towed Hydrophone Surveys

Night-time acoustic data were collected using towed hydrophone line transect surveys across the known range of CWDs around Lantau Island (Figure 1), as identified in the AFCD Marine Mammal Monitoring Programme (Hung 2020). The study area encompassed the waters adjacent to the Third Runway System (3RS), the Marine Parks at The Brothers Islands, Sha Chau and Lung Kwu Chau and Southwest Lantau and the proposed South Lantau Marine Park (Figure 2). For each survey, a

[1] http://www.smruconsulting.com/products-tools/cab/

hydrophone array was towed approximately 50 to 80 m behind a research vessel travelling at 8-9 knots. The arrays were custom-built, consisted of two elements, and had a frequency response of 20 Hz to 200 kHz with $\pm$ 10 dB sensitivity. Two different array configurations were used: (1) a linear resin-cast array (*Seiche*, United Kingdom) and (2) a linear oil-filled array (*Vanishing Point Marine*, United Kingdom). Analog acoustic signals were passed through a 100 Hz high-pass filer and converted into a digital signal at a sampling rate of 500 kHz using a data acquisition (DAQ) card. Two custom-built DAQ cards were used: (1) SAIL (*SA Instrumentation*, United Kingdom) and (2) National Instrument USB 6251 (*National Instruments*, United States). The digitized output was sent to a laptop running Windows 7 for signal processing, recording and display using PAMGuard 1.15 software (Gillespie et al. 2008; available at: http://www.pamguard.org/). GPS (Digital Yacht GPS 150 DualNav Sensor; Aadhaar Globalsat BU 353 S4 G Star IV GPS Receiver) and AIS (Digital Yacht AIS100 PRO Dual Channel AIS Receiver) units were connected to PAMGuard via the laptop, permitting the simultaneous recording of acoustic, GPS and AIS data. Weather conditions (e.g., Beaufort Sea state) were monitored continuously throughout surveys and also recorded in PAMGuard. Where possible, all acoustic hardware was powered by 12 V DC batteries to reduce electrical noise in the recording system. Where hardware had to be powered by a ship-board generator, a cable was placed in the water to ground the acoustic system. Two different research vessels were used: (1) a 21.9 m twin-engine motor yacht and (2) a 13.1 m single-engine wooden junk. Various combinations of research vessels, hydrophone arrays and DAQ cards were used throughout the study period, which are detailed in Appendix I.

Surveys were conducted by two PAM operators, excluding the research vessel captain and crew, working in 1-hour shifts to monitor the hydrophone array and record relevant data into PAMGuard. To ensure equal coverage over a 12-hour night cycle, surveys were conducted between 16:00 and 22:00 or 22:00 and 04:00 (Hong Kong time). For surveys that started at 16:00, opportunistic visual data were collected whilst there was enough light to support visual observation.

2.2. Daytime Towed Hydrophone Surveys

Daytime acoustic data were collected with concurrent visual observations to calibrate detections and sightings. Visual data were collected using methodology comparable to the AFCD Marine Mammal Monitoring Programme (Hung 2020). Daytime surveys were conducted by two observers, one data recorder and one PAM operator. Observers searched the area ahead of the research vessel between 270° and 90° (in relation to the bow at 0°) aided by 7 x 50 *Steiner* marine binoculars. The data recorder relayed data such as effort, weather and sightings to the PAM operator, who logged data into PAMGuard whilst monitoring the hydrophone array. To minimise fatigue, observers and data recorders rotated positions every 30 minutes. Acoustic data were collected as described in section *2.1. Night-time Towed Hydrophone Surveys*. To increase the likelihood of simultaneous detections and sightings, daytime surveys were conducted in areas of known high dolphin density – i.e., western and southern Lantau waters.

2.3. Data Processing and Analysis

Acoustic data were post-processed using PAMGuard. Ultimately, only echolocation clicks were used for CWD analyses, because preliminary processing revealed lower frequency vocalisations such as whistles were difficult to isolate from background noise. Hong Kong has a noisy underwater environment, with much of the sound concentrated in the lower frequency that whistles occur (Wursig and Greene 2002), it is likely these vocalisations were “masked” (Sims et al. 2011), making clicks the most reliable indicator of CWD presence. Unfortunately, clicks were not suitable for differentiating CWD behavioural states, as they have been associated with multiple behaviours, e.g., foraging, milling, resting, travelling and socialising (Fang et al. 2015). Consequently, clicks could not be used to discern habitat use. Finless porpoises do not produce whistles, but rather narrow-band high-frequency echolocation clicks (Goold and Jefferson 2002), which were used as indicators of finless porpoise presence. A click detector was configured in PAMGuard to detect CWD and finless porpoise clicks with energy in the 22- 250 kHz band. A 4th-order Butterworth 12 kHz high-pass digital pre-filter was first applied to remove low frequency noise. A 4th-order Butterworth 22 kHz high-pass trigger filter was then applied to detect sounds that were 10 dB above background noise level. Clicks detected by the click detector were manually reviewed for spectral features and click characteristics such as peak frequency and inter-click interval (ICI) specific to CWDs and finless porpoises. A large volume of non-marine mammal clicks was detected by the click detector from both biological (e.g., shrimp) and anthropogenic (e.g., vessel) sources, which quickly became time-intensive to manually review. As a result, species presence was not evaluated continuously but rather in 5-minute bins, which was the average time it took the research vessel to travel 1 km of track line. To assist with species identification, four click classifiers were used with different peaked frequencies: (1) 30-50 kHz, (2) 50-70 kHz and (3) 70-110 kHz for CWD, and (4) 100-155 kHz for finless porpoises. For CWDs, presence within a bin required one click train (i.e. four successive clicks) that met three criteria: (1) a peak frequency of 20-40 kHz or 60-80 kHz, (2) a frequency range of 10.7 kHz to 200 kHz, and (3) an ICI of 10-145 ms (Goold and Jefferson 2004, Li et al. 2012, Sims et al. 2011, Berg Soto et al. 2014, Fang et al. 2015). For finless porpoises, presence within a bin required one click that met two criteria: (1) a peak frequency of 130-140 kHz and (2) a frequency range of 110-160 kHz (Goold and Jefferson 2002). Once species presence was established within a bin, the date and time of the first click and whether there was only one or more than one click was recorded before moving on to review the next bin. Sightings were paired with detections if they started or ended within the same bin. Detections were then paired with GPS data and assigned survey areas that corresponded to survey areas defined in the AFCD Marine Mammal Monitoring Programme: Northeast Lantau (NEL), Northwest Lantau (NWL), West Lantau (WL), South Lantau (SL)[2], Southeast Lantau (SEL)[3] and East Lantau (EL) (Figure 2).

Quantitative Grid Analysis

To map the relative distribution and density of CWDs and finless porpoises, and to make night-time detections broadly comparable with published daytime sighting densities (sightings per 100 units of survey effort or SPSE), a quantitative grid analysis was conducted as described in the AFCD Marine Mammal Monitoring Programme. For each 1 km by 1 km grid cell that was surveyed (Figure 1), the number of night-time on-effort acoustic detections per 100 units of survey effort ($APSE_N$) was calculated using the following formulae:

$$APSE_N = \frac{(A/E) \times 100}{SA}$$

A = total number of on-effort acoustic detections
E = total units of survey effort
SA = percentage of sea area

Units of survey effort were defined as the number of times a grid cell was surveyed, such that a grid cell that had been surveyed 10 times was considered to have 10 units of survey effort. For grid cells partially covered by land, percentage of sea area was calculated using QGIS (QGIS Development Team 2020). $APSE_N$ values were calculated for an entire one-year period in 2019, which were then compared with published on-effort sightings per 100 units of survey effort (*SPSE*) within the same one-year period (Hung 2020).

Generalised Additive Models (GAMs)

Since different CWD vocalisations could not be used to discern habitat use, the relationship between night-time occurrence and environmental variables was investigated using Generalised Additive Models (GAMs) to understand fine-scale influences in distribution. For CWDs (and finless porpoises), a binomial GAM (with a logit link) was fitted using the *mgcv* package (Wood 2006) in R 3.6.1. (R Core Team 2019), with night-time presence within a grid cell as the response variable. For each grid cell, effort and environmental variables were calculated for each survey using R and QGIS. Effort was defined as the total distance travelled (m) within the grid cell. Environmental variables included weather, lunar, tidal, water quality and bathymetry data. Beaufort Sea state was extracted from observations recorded in PAMGuard during surveys. Lunar data such as the proportion of lunar illumination (%) and lunar phase (rad) were determined using the *lunar* package (Lazaridis 2014) in R. Lunar phase in radians was converted into degrees, such that one lunar cycle corresponded to 360° and each of the eight lunar phases corresponded to 45° degrees – i.e., new moon was 0° to 45°, waxing crescent was 45° to 90°, first quarter was 90° to 135°, etc. Tidal data such as the tidal state, tidal height (m) and tidal range (m) were extracted from predicted tidal data from the Hong Kong Observatory (HKO) (available at: https://data.gov.hk/en/). Since tides can vary widely in Hong Kong waters, tidal data were taken from different stations across the study area. Grid cells in NEL were paired with data from Ma Wan; NWL from Chek Lap Kok (East); WL from Tai O; SL from Shek Pik; and SEL and EL from Cheung Chau. Water quality data were extracted from the Third Runway System (3RS) (available at: http://env.threerunwaysystem.com/en/data_search_WQ.php) and the Integrated Waste Management Facility (IWMF) (available at: https://iwmfhk.com/en/ema_data.php?cate=water) monitoring stations (Figure 3). Water quality indices extracted for analyses included water temperature (°C), salinity (ppt), turbidity (ntu), PH, dissolved oxygen (DO mg/L) and suspended solids (SS mg/L). Surveyed cells were paired with water quality indices from the closest station and sampling date using the *RANN* package

[2] The Southwest Lantau survey area in the AFCD Marine Mammal Monitoring Programme.
[3] The easternmost section of the Lamma survey area in the AFCD Marine Mammal Monitoring Programme.

(Arta et al. 2019) in R. Indices for each monitoring station and sample date were sample- and depth-averaged. Depth (m) was extracted from the DEPCNT, DEPARE, COALNE and LNDARE layers of the 2018 Hong Kong Electronic Navigational Chart (HKENC) using QGIS. Depth contours were used to generate a digital elevation model (DEM) of depth using the *Interpolation* plugin, from which the seabed slope could be calculated using the *GDAL* plugin. Both depth and slope were averaged across each surveyed grid cell. Temporal variables were also calculated, which included year, month, day of year, hour of day and season. Season was determined by month, wherein the "wet season" referred to the months between April and October and the "dry season" referred to the months between November and March (Mott MacDonald 2015).

Nine environmental variables were ultimately used for the GAMs, upon checking for covariance: effort, lunar phase (in degrees, fitted using a cyclic cubic spline), tidal height, temperature, turbidity, PH, suspended solids, depth and slope. The final models were:

CWD Presence-Absence ~ s(Effort) + s(Lunar Phase) + factor (Tidal Height) + s(Temperature) + s(Turbidity) + s(pH) + s(Suspended Solids) + s(Mean Depth) + s(Mean Slope)

FP Presence-Absence ~ s(Effort) + s(Lunar Phase) + factor (Tidal Height) + s(Temperature) + s(Turbidity) + s(pH) + s(Suspended Solids) + s(Mean Depth) + s(Mean Slope)

Relationships were considered statistically significant at $p = 0.05$.

3. Results

Between July 2018 and February 2020, 100 surveys were conducted over 98 survey days with 351.7 hours and 5064.1 km of survey effort (Table 2). The majority of this effort was between 17:00 to 21:59 and 00:00 to 03:59 (Hong Kong time) (Table 3). Overall, there were 962 unique on-effort detections, of which 304 were of CWDs (Figure 4, Table 4) and 658 were of finless porpoises (Figure 5, Table 4). There were 30 sightings, of which 28 were of CWDs and 2 were of finless porpoises (Table 5). Twenty-six (26) of these sightings had concurrent acoustic detections; based on these data, it was estimated that CWDs and finless porpoises were acoustically detectable in the waters around Lantau Island up to 750 m and100 m, respectively.

3.1. Quantitative Grid Analysis

Indo-Pacific humpback dolphins

CWDs were detected in northern, western and southern Lantau waters from The Brothers Marine Park to Sha Chau and Lung Kwu Chau Marine Park, Tai O Peninsula, Fan Lau Peninsula and the Soko Islands (Figure 4). The distribution of night-time detections corresponded to the distribution of daytime sightings published in the AFCD Marine Mammal Monitoring Programme reports between July 2018 and February 2020 (Hung 2019, 2020). Notably, however, CWDs were detected at night around The Brothers Marine Park in NEL where they have not been sighted during the day since before April 2018 (Hung 2017). Of the 356 unique 1 km^2 grid cells that were surveyed, 91 were positive for CWD acoustic detections. The majority of these grid cells were in SL (33), followed by WL (30), NWL (20), NEL (7) and SEL (1). Distribution based on visual sightings was comparable (during the same period between July 2018 and February 2020) with 78 CWD-positive grid cells in SWL (33), WL (28), NWL (15), and SEL (2) (Hung 2019, 2020). The highest number of acoustic detections were recorded in WL (165), followed by SL (89) and NWL (45). A similar pattern was observed in the visual data, with the highest number of sightings recorded in WL (155), followed by SWL (77) and NWL (17) (Hung 2019, 2020). There were very few acoustic detections in NEL (8) and SEL (2), and no detections in EL.

CWD night-time detection density in 2019 was highest around Fan Lau Peninsula ($ASPE_N$ = 0.5-0.643), between Fan Lau Peninsula and the Soko Islands ($ASPE_N$ = 0.5-0.75), northeast of Siu A Chau ($ASPE_N$ = 0.432-0.625), followed by west of Tai O Peninsula ($ASPE_N$ = 0.475) (Figure 6). This pattern was not wholly reflected in the daytime sighting densities for 2019, which was highest along the west coast of Lantau Island, between Fan Lau Peninsula and Tai O Peninsula, but relatively lower northeast of Siu A Chau and the area between Fan Lau Peninsula and the Soko Islands (Hung 2020). It is noted that $APSE_N$ and SPSE values are not directly comparable, and it is only possible to compare the differences in the relative patterns of density between daytime sightings and acoustic detections.

Indo-Pacific finless porpoise

Finless porpoises were detected in southern Lantau and eastern Lamma waters, ranging from Fan Lau Peninsula to the East Lamma Channel (Figure 5). Finless porpoise detections did not overlap with CWD detections, except in the Soko Islands, as documented previously (Jefferson 2000; Jefferson et al. 2002; Jefferson and Hung 2004). Similar to CWDs, finless porpoises were acoustically detected at night in all areas that they were visually sighted during the day in the AFCD Marine Mammal Monitoring Programme reports between July 2018 and February 2020 (Hung 2019, 2020), but with a broader coverage. Of the 356 unique 1 km^2 grid cells that were surveyed, 152 were positive for finless porpoise detections. The majority of these grid cells were in EL (58), followed by SEL (53) and SL (41). In contrast, coverage based on visual sightings was less than half, with 76 finless porpoise-positive grid cells in SEL (41), SWL (23) and EL (11) (Hung 2019, 2020). The highest number of acoustic detections were recorded in SEL (271), followed by SL (210) and SL (194). A similar pattern was observed in the visual data, with the highest number of sightings recorded in SEL (75), SWL (43) and EL (13) (Hung 2019, 2020). There were no finless porpoise detections in NEL, NWL or WL. Finless porpoise night-time detection density in 2019 was highest west of Tai A Chau ($ASPE_N$ = 1.147), east of the Soko Islands ($ASPE_N$ = 0.818-1) and south of Cheung Chau ($ASPE_N$ = 0.818) (Figure 7). Daytime sighting densities for 2019 were also highest east of the Soko Islands, but relatively lower west of Tau A Chau and south of Cheung Chau.

3.2. Generalised Additive Models (GAMs)

Indo-Pacific humpback dolphins

The final model explained 17% of deviance (R^2 (adj) = 0.093). CWD night-time occurrence was significantly related to effort, lunar phase, tidal height, temperature, turbidity and pH (Table 6). As expected, occurrence increased the greater the distance travelled within each grid cell, levelling off at 2000 m, suggesting this is the minimum amount of effort needed to sample a grid cell effectively (Figure 8a). In relation to lunar phase, occurrence was highest during the new moon (0°-45°), the last quarter (270°-315°) and the waning crescent moon (315°-360°), and was lowest during the first quarter (90°-135°) and the waxing gibbous moon (135°-180°) (Figure 8b). In relation to tidal height, occurrence was highest during extreme low tides less than 0.5 m and lowest during extreme (for Hong Kong) high tides more than 2.5 m (Figure 8c). Across the range of observed temperatures (17.6-30.8°C), occurrence was highest at colder temperatures and decreased at warmer temperatures (Figure 8d). In relation to water quality, occurrence was highest at 10 ntu and pH 8.1, though the relationships with turbidity and pH were not significant beyond 13 ntu and pH 8.6 (Figure 8e-f).

Indo-Pacific finless porpoise

The final model explained 28% of deviance (R^2 (adj) = 0.198). Finless porpoise night-time occurrence was significantly related to effort, lunar phase, tidal height, temperature, turbidity, depth and slope (Table 6). As with CWD occurrence, finless porpoise occurrence increased the greater the distance travelled within each grid cell. Unlike CWD occurrence, however, finless porpoise occurrence did not level off, suggesting the minimum amount of effort needed to sample a grid cell effectively was not reached (Figure 9a). In relation to lunar phase, occurrence was highest during the new moon (0°-45°) and the last quarter (270°-315°), and was lowest during the waxing gibbous moon (135°-180°) (Figure 9b). The relationship with tidal height was only significant at tides higher than 1.0 m, with occurrence slightly greater at tides more than 2 m (Figure 9c). The relationship with temperature was significant across the range of observed temperatures, but curiously, there was a sinusoidal relationship that peaked at 22°C and 30°C and troughed at 18°C and 27°C (Figure 9d). In relation to turbidity, occurrence was relatively stable below 6 ntu, beyond which the relationship was not significant – likely due to the fewer observations at turbidities greater than 10 ntu (Figure 9e). In relation to bathymetry, occurrence was greatest in areas that were flat and moderately shallow, between 10-15 m (Figure 9f-g).

3.3. Real-Time Acoustic Buoy Deployment

A real-time acoustic buoy developed by SMRU Consulting – the Coastal Acoustic Buoy (CAB) – was deployed between 26th March and 1st April 2020 at the proposed South Lantau Marine Park. A total of 143 hours and 48 minutes of recordings were made, which were compressed to 22.79 GB of acoustic data within CAB. The acoustic data were further compressed into 157 MB of processed data, which was sent to a server in the United Kingdom via a 3G network. Processed data included results from a custom-built click detector and classifier, whistle detector and long-term spectral average.

Porpoise were detected between Porpoise were detected between 2020-03-26 22:56:03 and 2020-03-26 23:08:01 (Hong Kong time), during which 16 clicks were identified by CAB. Unexpectedly, an unidentified radio noise jammed recordings between 2020-03-26 23:48:31 and 2020-03-26 00:00:00 (Hong Kong time). This was solved by re-configuring the deployment arrangement of the hydrophone.

CAB operated continuously throughout the deployment period, with only minor modifications needed. The click detector configuration was modified to lower false click detection on 2020-04-28 07:49:32 (Hong Kong time) to reduce the workload on the system. This was done by increasing the click detector threshold from 18 dB to 20 dB and decreasing the trigger filter order from 7 to 4. The click detector was again modified on 2020-05-01 04:00:00 (Hong Kong time) to further lower false click detection, by increasing the click detector threshold from 20 dB to 22 dB, increasing the pre-filter order to 7 and narrowing the triggerfilter to 50-170 kHz. Following these modifications, the rate of false click detections decreasedsignificantly. Although no dolphin vocalisations were detected and only one porpoise event was detected, CAB ran smoothly and continuously, proving its capability and potential for longer-term deployments.

4. Evaluation of Project Effectiveness

The overall aim of this multi-year project was to better understand the night-time occurrence, distribution and habitat usage of CWDs in Hong Kong waters. It was proposed this would be achieved in two objectives, which were, on the whole, achieved.

Objective 1: Map the relative density, distribution and behaviour of the night-time occurrence of CWDs in Hong Kong waters from vessel-based acoustic surveys.

This objective was achieved within the timeframe of the project, with the exception of mapping the night-time behaviour of CWDs. As explained in Section 2.3 of this report (*Data Processing and Analysis*), analyses were limited to echolocation clicks. This was because preliminary processing revealed the lower frequency vocalisations used to differentiate behavioural states were difficult to isolate from background noise, which was not anticipated. Despite efforts to extract these vocalisations, it was ultimately decided that they were not reliable enough to indicate CWD behaviour, let alone CWD presence. Instead, an alternative analysis using GAMs to understand fine-scale environmental influences in the night-time occurrence of CWDs was successfully conducted.

Objective 2: Trial a real-time remote acoustic monitoring buoy for dolphins in Marine Park Areas of Hong Kong.

This objective was also achieved within the timeframe of the project. A real-time acoustic buoy developed by SMRU Consulting, known as the Coastal Acoustic Buoy (CAB), was successfully deployed at the proposed Soko Islands Marine Park. The CAB was able to record over 134 hours of data and detect finless porpoises remotely, demonstrating its feasibility, capability and potential for monitoring marine mammals in Hong Kong waters.

5. Summary and Way Forward

The CWD has been studied in Hong Kong through a long-term monitoring programme by the AFCD since the early 1990s. This monitoring programme focuses on visual line transect surveys that provide excellent data on the daytime occurrence, distribution and habitat usage of CWDs. However, given that CWDs are known to occupy Hong Kong waters day and night, there remain significant gaps in our understanding. Addressing these knowledge gaps is a priority, since anthropogenic activities within the dolphins' habitat occur, to varying degrees, 24 hours day. The overall aim of the project MEEF2018010A "What do dolphins do at night?" was therefore to understand the night-time distribution and density of CWDs in Hong Kong waters by using PAM systems. Between Year 1 (2018-19) and Year 2 (2019-20), towed hydrophone array surveys were conducted across the known range of CWDs. Results from this project demonstrated that the night-time distribution of CWDs corresponded to known daytime distributions, and that notably, CWDs were detected acoustically at night in areas where they were not sighted visually during the day. Density analyses indicate three potential "hotspots" at night-time, two of which did not correspond to observed daytime density hotspots. Further analyses indicated that there were fine-scale environmental influences of the presence and distribution of CWD, such as lunar phase, tidal height, water temperature, turbidity and pH. Additionally, a real-time acoustic buoy was deployed in the proposed South Lantau Marine Park to demonstrate their feasibility, capability and potential for remotely monitoring marine mammals in Hong Kong waters. Based on the findings of this project, the following recommendations are proposed:

Recommendation 1: Improve the detection of lower frequency CWD vocalisations from towed hydrophone array acoustic recordings.

Understanding the night-time behaviour and habitat use of CWDs is contingent on the ability to identify different CWD vocalisations.

Recommendation 2: Update existing ethograms for CWDs (e.g., Ruxton 2002) with current technology.

Understanding the night-time behaviour and habitat use of CWDs is contingent on understanding the context of different vocalisations. This could be achieved by conducting detailed behavioural observations, ideally using a drone to record aerial footage, concurrently with acoustic recordings.

Recommendation 3: Identify sciaenid vocalisations from towed hydrophone array acoustic recordings and map their distribution and density in relation to CWD distribution and density.

Stomach content analyses of stranded CWDs in Hong Kong have revealed that soniferous sciaenid fish are the most important prey for this species (Barros et al. 2004). Furthermore, data from static hydrophone stations in the Pearl River Estuary have indicated that the distribution of CWDs is associated with the distribution of sciaenid calls and choruses (Pine et al. 2017). Unfortunately, the distribution and density of fish (particularly sciaenids) within Hong Kong waters is poorly understood and data are scarce. Given that prey is likely to be the primary driver of CWD distribution and density, as opposed to environmental influences, it would be worthwhile to map the distribution and density of sciaenids using data collected for this project. Individual fish vocalisations and fish choruses, presumed to be sciaenids, were heard frequently and consistently during towed hydrophone array surveys, making this analysis highly feasible.

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Figures

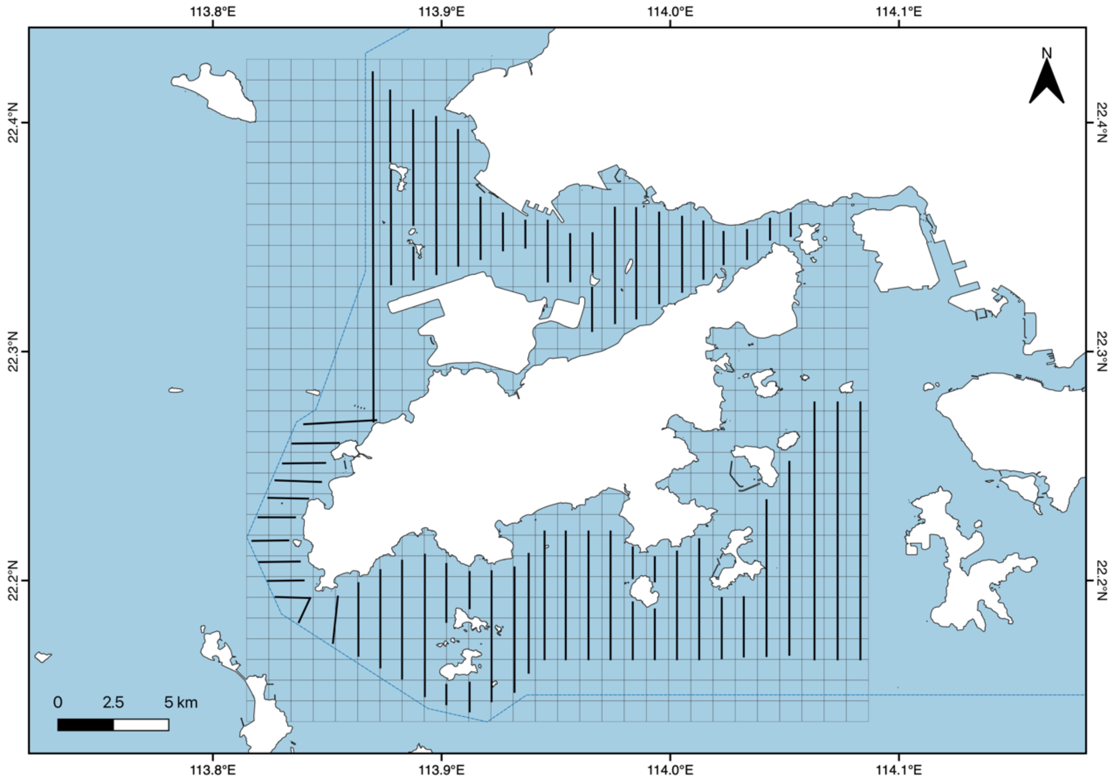

Figure 1. Survey area in the waters surrounding Lantau, including line transects and AFCD 1 km by 1 km grid cells.

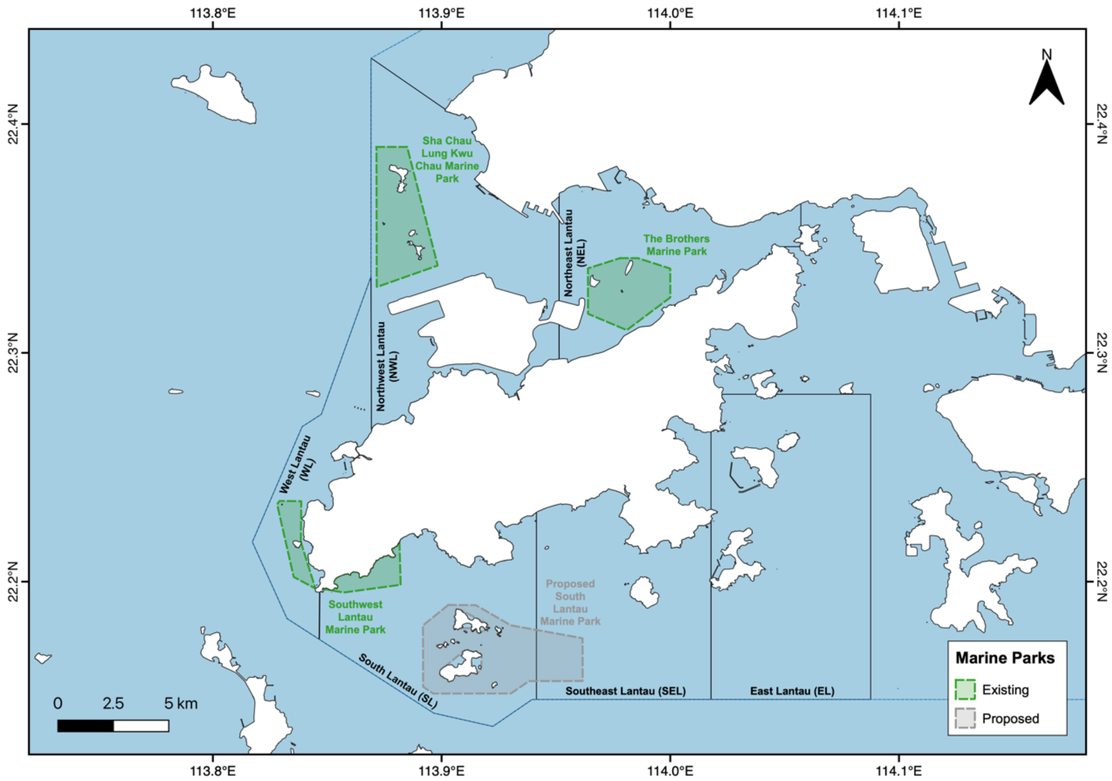

Figure 2. Survey area in the waters surrounding Lantau, including marine parks, proposed marine parks and AFCD survey blocks.

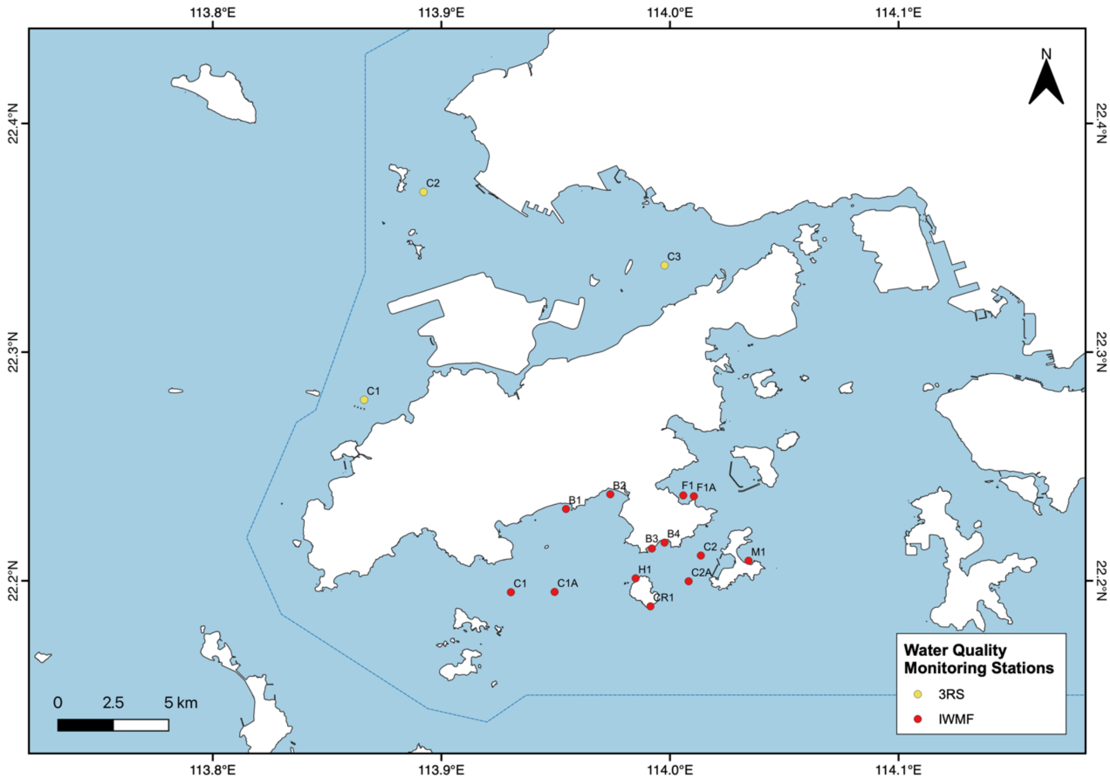

Figure 3. Locations of water quality monitoring stations managed by the Third Runway System (3RS) and Integrated Waste Management Facility (IWMF) from which water quality indices were sourced.

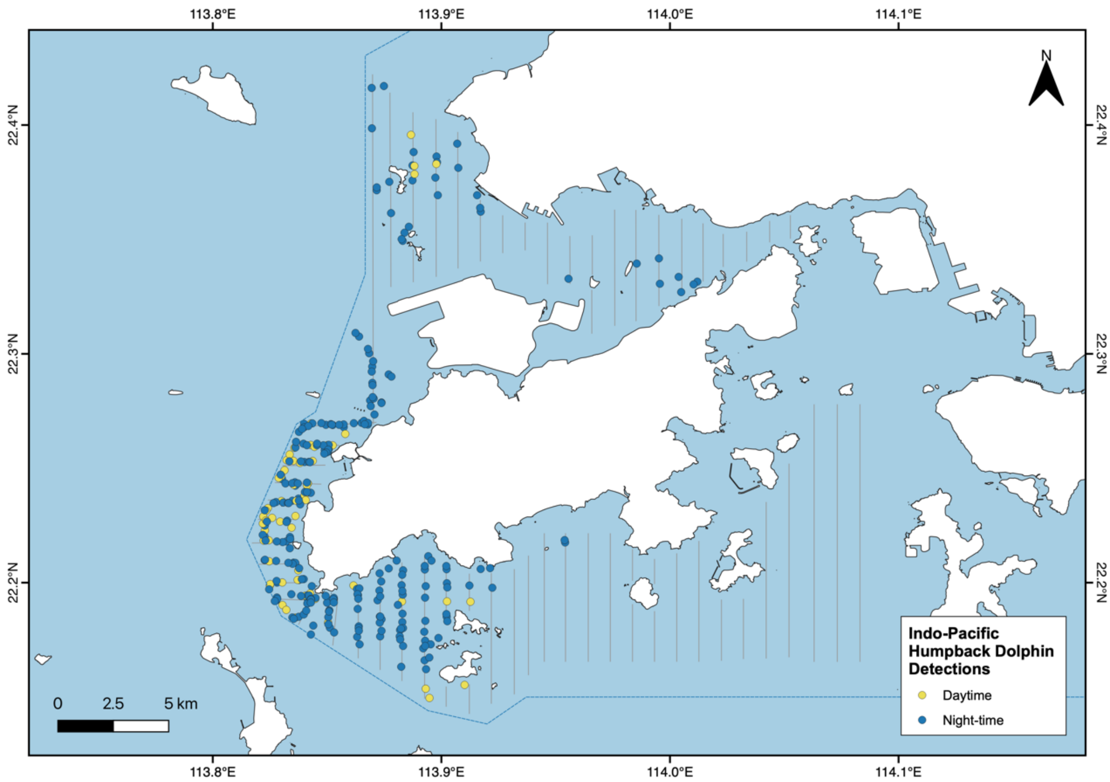

Figure 4. Acoustic detections of Indo-Pacific humpback dolphins (*Sousa chinensis*) between July 2018 and February 2020, from both day- and night-time surveys.

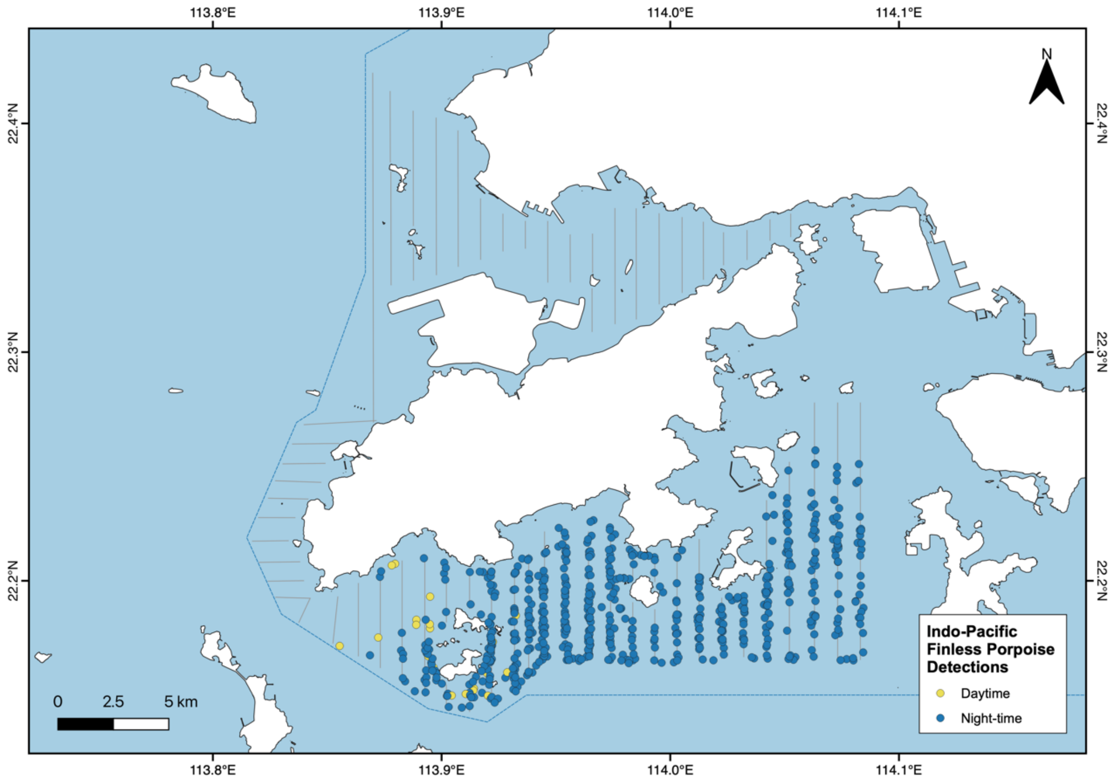

Figure 5. Acoustic detections of Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) between July 2018 and February 2020, from both day- and night-time surveys.

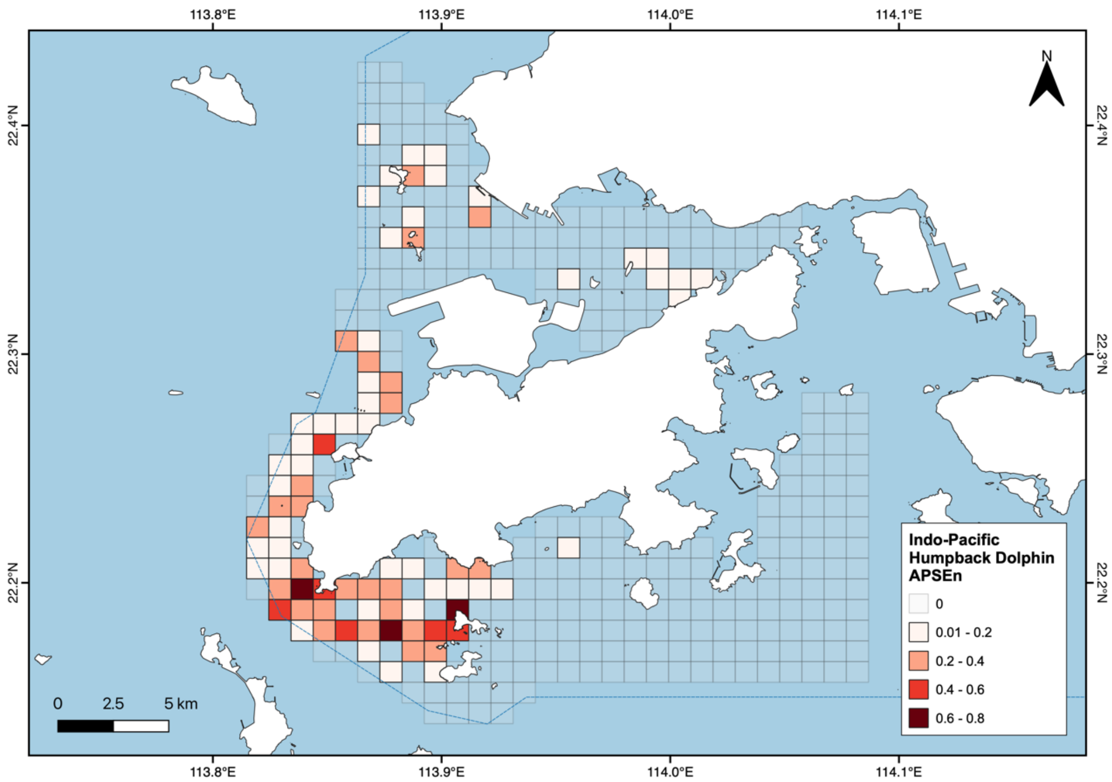

Figure 6. Night-time acoustic detection density of Indo-Pacific humpback dolphins (*Sousa chinensis*) in 2019. $APSE_N$ represents the number of on-effort acoustic detections per 100 units of survey effort.

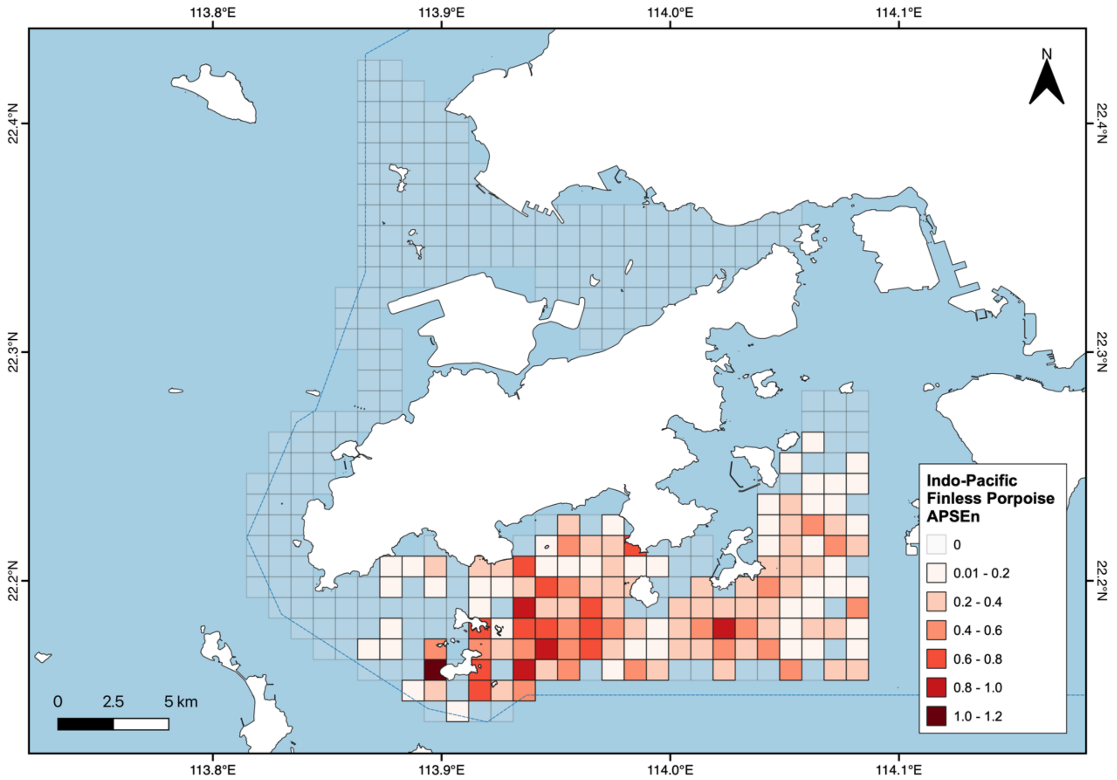

Figure 7. Night-time acoustic detection density of Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) in 2019. $APSE_N$ represents the number of on-effort acoustic detections per 100 units of survey effort.

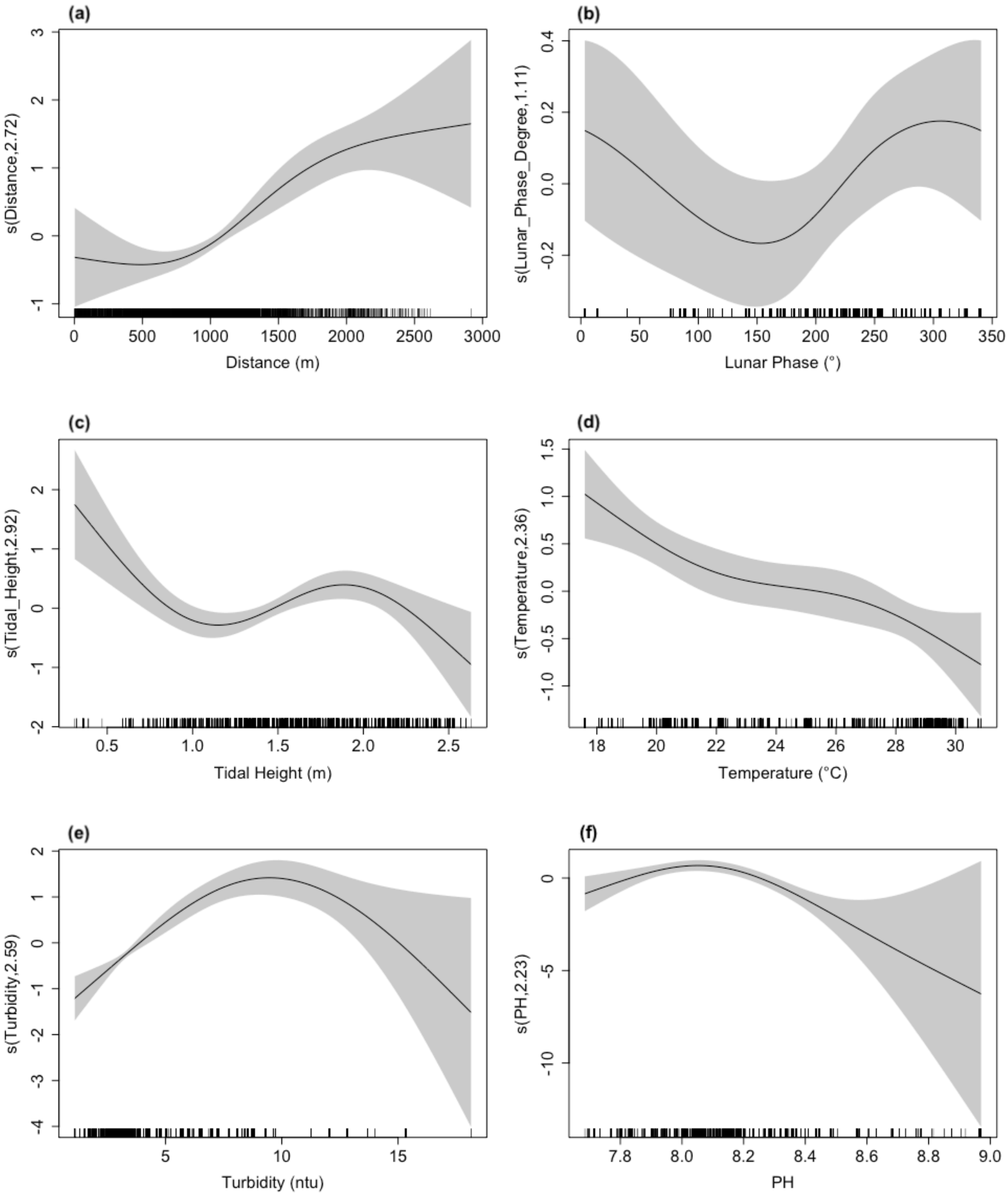

Figure 8. GAM plots for significant smoothed terms for Indo-Pacific humpback dolphins (*Sousa chinensis*) presence.

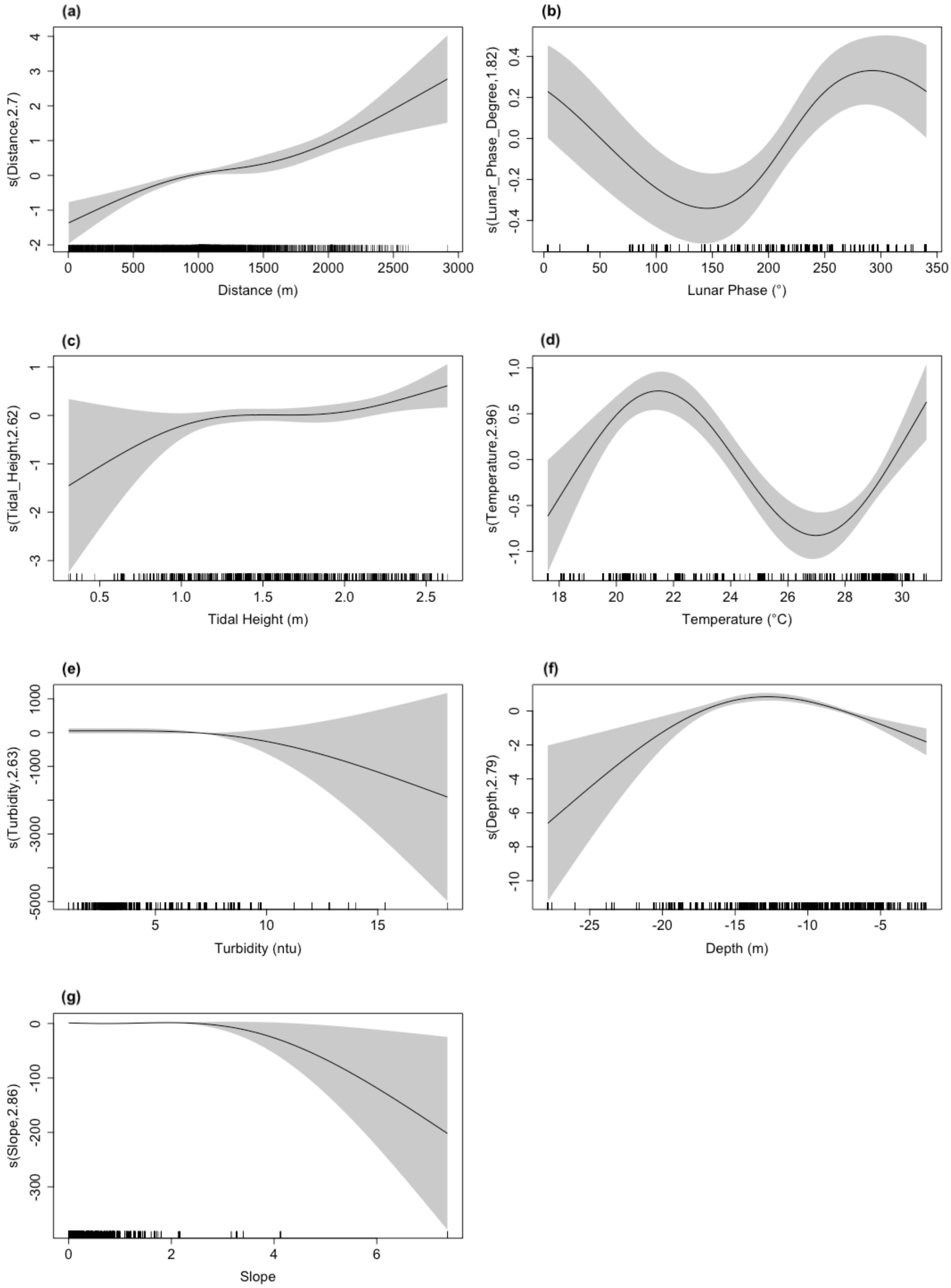

Figure 9. GAM plots for significant smoothed terms for Indo-Pacific finless porpoise (*Neophocaena phoecaenoides*) presence.

Tables

Table 1. Timeline of completed activities.

Items	Activities	Year 1 (July 2018-June 2019)											
		Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Night Time Acoustic Surveys	■	■					■	■	■	■	■	■
2	Day Time Acoustic Surveys							■	■	■		■	■
3	Deployment Real-Time Acoustic Device												
4	Interim Report						■						
5	Final Report (and publication preparation)											■	■
6	Presentations of research findings												■
Items	**Activities**	**Year 2 (July 2019-June 2020)**											
		Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Night Time Acoustic Surveys	■	■	■	■	■	■	■	■				
2	Day Time Acoustic Surveys		■										
3	Deployment Real-Time Acoustic Device									■			
4	Interim Report						■						
5	Final Report (and publication preparation)											■	■
6	Presentations of research findings												■

Table 2. Total acoustic survey effort by survey type.

Survey Type	Number of Surveys	Duration (hr)	Distance (km)
Night	90	317.7	4536.7
Day	10	34	527.5

Table 3. Total acoustic survey effort by hour of the day. All times Hong Kong time.

Hour	Start	End	Number of Surveys	Duration (hr)	Distance (km)
12AM	00:00:00	00:59:59	32	19.6	317.1
1AM	01:00:00	01:59:59	45	39.3	640.5
2AM	02:00:00	02:59:59	44	40.7	660.6
3AM	03:00:00	03:59:59	40	27.6	451.2
4AM	04:00:00	04:59:59	14	6.4	100.7
5AM	05:00:00	05:59:59	3	2.1	32.9
6AM	06:00:00	06:59:59	2	0.3	4.6
7AM	07:00:00	07:59:59	0	0	0
8AM	08:00:00	08:59:59	0	0	0
9AM	09:00:00	09:59:59	4	0.6	9.3
10AM	10:00:00	10:59:59	5	4.1	66.0
11AM	11:00:00	11:59:59	7	6.7	106.1
12PM	12:00:00	12:59:59	7	6.8	106.7
1PM	13:00:00	13:59:59	9	7.7	123.4
2PM	14:00:00	14:59:59	8	4.8	72.0
3PM	15:00:00	15:59:59	4	2.7	39.1
4PM	16:00:00	16:59:59	9	2.8	31.2
5PM	17:00:00	17:59:59	36	24.7	306.4
6PM	18:00:00	18:59:59	43	40.4	517.1
7PM	19:00:00	19:59:59	44	43.1	557.2
8PM	20:00:00	20:59:59	44	37.1	470.4
9PM	21:00:00	21:59:59	33	25.5	316.8
10PM	22:00:00	22:59:59	13	5.2	74.2
11PM	23:00:00	23:59:59	8	3.6	60.6

Table 4. Summary of acoustic detections.

Species	Survey Type	Acoustic-Only Detections	Acoustic Detections with Visual Sightings
Chinese white dolphin	Night	230	13
	Day	46	15
Finless porpoise	Night	635	0
	Day	21	2

Table 5. Summary of visual sightings. All times Hong Kong time.

Sighting ID	Survey Type	Effort	Sighting Start	Sighting End	Species	Distance (m)	Angle	Heading	Number of Animals	Behaviour	Associated Acoustic Detection
1	Day	On	2019-01-18 10:53:52	2019-01-18 11:03:00	FP	100	NA	NA	2	Unknown	Y
2	Day	On	2019-01-18 12:38:24	2019-01-18 12:44:57	FP	100	NA	240	1	Unknown	Y
3	Day	On	2019-01-18 13:51:35	2019-01-18 14:17:25	CWD	100	NA	NA	1	Feeding	Y
4	Day	On	2019-01-18 14:23:30	2019-01-18 14:26:11	CWD	96	145	NA	1	Travelling	N
5	Day	On	2019-01-18 14:49:17	2019-01-18 14:54:14	CWD	54	37	NA	3	Feeding	Y
6	Day	On	2019-01-18 15:19:47	2019-01-18 15:26:43	CWD	310	11	NA	4	Feeding	Y
7	Day	On	2019-03-19 10:11:26	2019-03-19 10:17:24	CWD	100	176	NA	1	Feeding	Y
8	Day	On	2019-03-19 10:26:59	2019-03-19 10:32:44	CWD	100	143	90	6	Travelling	Y
9	Day	On	2019-03-19 10:42:31	2019-03-19 10:47:39	CWD	400	261	90	2	Multiple	Y
10	Day	On	2019-03-19 11:55:33	2019-03-19 11:58:22	CWD	750	NA	NA	3	Multiple	Y
11	Day	On	2019-05-07 11:06:12	2019-05-07 11:07:54	CWD	85	344	334	1	Travelling	Y
12	Day	On	2019-05-07 12:06:33	2019-05-07 12:08:15	CWD	270	116	NA	2	Travelling	Y
13	Day	On	2019-05-07 12:36:45	2019-05-07 12:37:37	CWD	120	132	NA	1	Feeding	Y
14	Day	On	2019-05-07 14:07:56	2019-05-07 14:08:46	CWD	45	5	270	1	Travelling	N
15	Day	Off	2019-05-07 14:41:51	2019-05-07 14:44:05	CWD	210	NA	NA	2	Feeding	N
16	Day	On	2019-05-21 10:28:22	2019-05-21 10:29:54	CWD	600	300	270	1	Travelling	Y
17	Day	On	2019-05-21 11:27:15	2019-05-21 11:27:53	CWD	400	67	170	2	Travelling	Y
18	Day	On	2019-05-21 11:49:18	2019-05-21 11:50:05	CWD	50	215	45	1	Travelling	Y
19	Day	On	2019-05-21 11:52:59	2019-05-21 11:53:33	CWD	400	150	180	1	Travelling	N
20	Day	On	2019-05-21 12:00:27	2019-05-21 12:01:28	CWD	500	100	90	1	Travelling	Y
21	Night	On	2019-05-22 18:41:15	2019-05-22 18:43:05	CWD	65	NA	NA	1	Unknown	Y
22	Night	On	2019-05-22 18:54:10	2019-05-22 18:56:14	CWD	90	NA	NA	1	Travelling	Y
23	Night	On	2019-05-29 17:43:13	2019-05-29 17:45:27	CWD	80	NA	NA	2	Travelling	Y
24	Night	On	2019-08-22 18:23:36	2019-08-22 18:26:04	CWD	115	NA	NA	4	Surface active behaviour	Y
25	Night	On	2020-01-08 17:55:34	2020-01-08 17:56:19	CWD	263	NA	NA	2	Unknown	Y
27	Night	On	2020-02-04 17:48:27	2020-02-04 17:52:07	CWD	215	NA	NA	1	Feeding	Y
26	Night	On	2020-02-04 17:54:30	2020-02-04 17:58:58	CWD	64	178	184	1	Feeding	Y
28	Night	Off	2020-02-05 17:07:08	2020-02-05 17:21:02	CWD	400	NA	NA	1	Feeding	Y
29	Night	On	2020-02-05 17:24:49	2020-02-05 17:26:08	CWD	407	210	108	3	Travelling	Y
30	Night	Off	2020-02-12 18:02:54	2020-02-12 18:15:58	CWD	350	NA	NA	1	Feeding	Y

Table 6. GAM summary statistics for smoothed terms.

Response Variable	Dependent Variables	edf	df	*F*-statistic	*p*-value
CWD night-time occurrence	**Effort**	**2.715**	**2.939**	**55.22**	**<0.001**
	Lunar Phase (°)	**1.112**	**2**	**3.65**	**0.033**
	Tidal Height (m)	**2.925**	**2.994**	**19.506**	**<0.001**
	Temperature (°C)	**2.364**	**2.703**	**24.595**	**<0.001**
	Turbidity (ntu)	**2.588**	**2.863**	**75.056**	**<0.001**
	pH	**2.232**	**2.532**	**19.557**	**<0.001**
	Suspended Solids (mgl)	1.005	1.01	1.176	0.282
	Depth (m)	2.388	2.755	7.414	0.100
	Slope (°)	1	1	0.107	0.743
Finless porpoise night-time occurrence	**Effort**	**2.699**	**2.93**	**63.044**	**<0.001**
	Lunar Phase (°)	**1.817**	**2**	**16.34**	**<0.001**
	Tidal Height (m)	**2.624**	**2.885**	**9.553**	**0.025**
	Temperature (°C)	**2.96**	**2.998**	**56.818**	**<0.001**
	Turbidity (ntu)	**2.635**	**2.865**	**19.418**	**<0.001**
	pH	2.614	2.898	8.12	0.088
	Suspended Solids (mgl)	2.803	2.97	6.595	0.119
	Depth (m)	**2.786**	**2.962**	**71.785**	**<0.001**
	Slope (°)	**2.862**	**2.981**	**28.68**	**<0.001**

Appendices

Appendix I. Summary of surveys conducted between July 2018 and February 2020. All times Hong Kong time.

Survey ID	Survey Date	Hydrophone	DAQ	Survey Start	Survey End	Survey Duration (hr)	On Effort Duration (hr)	On Effort Distance (km)	Survey Block	Survey Type	Research Vessel
MEEF_ACOUSTICS_20180708	2018-07-08	Seiche SM3553	NI	2018-07-08 11:12:00	2018-07-08 15:33:00	4.3	4.3	53.1	WL	Trial	Motor yacht
MEEF_ACOUSTICS_20180730	2018-07-30	Seiche SM3553	NI	2018-07-31 00:45:00	2018-07-31 06:15:00	5.5	5.4	86.4	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20180731	2018-07-31	Seiche SM3553	SAIL	2018-08-01 01:41:00	2018-08-01 03:27:00	1.8	1.7	25.9	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20180821	2018-08-21	Seiche SM3553	SAIL	2018-08-22 00:07:00	2018-08-22 04:00:00	3.9	3.7	63	EL	Night	Motor yacht
MEEF_ACOUSTICS_20180822	2018-08-22	Seiche SM3553	SAIL	2018-08-22 22:02:00	2018-08-23 02:11:00	4.2	3.1	51.7	SEL,SL	Night	Motor yacht
MEEF_ACOUSTICS_20180823	2018-08-23	Seiche SM3553	SAIL	2018-08-24 01:03:00	2018-08-24 04:00:00	2.9	2.9	46.8	SL	Night	Motor yacht
MEEF_ACOUSTICS_20190118	2019-01-18	Seiche SM3553	SAIL	2019-01-18 10:33:00	2019-01-18 15:19:00	4.8	4.1	65.9	SL,WL	Day	Motor yacht
MEEF_ACOUSTICS_20190123	2019-01-23	Seiche SM3553	SAIL	2019-01-23 20:45:00	2019-01-24 01:38:00	4.9	4.9	81.8	EL,SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190125	2019-01-25	Seiche SM3553	SAIL	2019-01-26 00:38:00	2019-01-26 03:01:00	2.4	2.4	39	SEL,SL	Night	Motor yacht
MEEF_ACOUSTICS_20190127	2019-01-27	Seiche SM3553	SAIL	2019-01-28 00:39:00	2019-01-28 03:29:00	2.8	2.8	47.2	SL	Night	Motor yacht
MEEF_ACOUSTICS_20190128	2019-01-28	Seiche SM3553	SAIL	2019-01-29 00:20:00	2019-01-29 03:54:00	3.6	3.6	58.7	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190129	2019-01-29	Seiche SM3553	SAIL	2019-01-30 00:19:00	2019-01-30 03:38:00	3.3	3.3	54.2	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20190213	2019-02-13	Seiche SM3553	SAIL	2019-02-14 00:21:00	2019-02-14 05:09:00	4.8	4.8	80.7	EL,SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190214	2019-02-14	Seiche SM3553	SAIL	2019-02-15 00:19:00	2019-02-15 03:16:00	3	3	47.9	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190219	2019-02-19	Seiche SM3553	SAIL	2019-02-20 01:18:00	2019-02-20 03:03:00	1.8	1.8	29.4	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190220	2019-02-20	Seiche SM3553	SAIL	2019-02-20 23:38:00	2019-02-21 02:26:00	2.8	2.8	46	SEL,SL	Night	Motor yacht
MEEF_ACOUSTICS_20190221	2019-02-21	Seiche SM3553	SAIL	2019-02-22 01:15:00	2019-02-22 04:20:00	3.1	3.1	46.1	SL	Night	Motor yacht
MEEF_ACOUSTICS_20190227	2019-02-27	Seiche SM3553	SAIL	2019-02-27 09:57:00	2019-02-27 14:08:00	4.2	4.2	69.6	NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190312	2019-03-12	Seiche SM3553	SAIL	2019-03-13 00:06:00	2019-03-13 03:45:00	3.6	3.6	58.3	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190313	2019-03-13	Seiche SM3553	SAIL	2019-03-13 17:15:00	2019-03-13 21:49:00	4.6	4.6	72.6	NWL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190319	2019-03-19	Seiche SM3553	SAIL	2019-03-19 09:48:00	2019-03-19 12:50:00	3	2.8	43.1	WL	Day	Motor yacht
MEEF_ACOUSTICS_20190321	2019-03-21	Seiche SM3553	SAIL	2019-03-22 01:18:00	2019-03-22 03:00:00	1.7	1.7	26.3	SL	Night	Motor yacht
MEEF_ACOUSTICS_20190325	2019-03-25	Seiche SM2073	SAIL	2019-03-26 01:28:00	2019-03-26 03:32:00	2.1	2.1	33.3	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190326	2019-03-26	Seiche SM2073	SAIL	2019-03-26 23:52:00	2019-03-27 04:21:00	4.5	4.5	72.9	EL,SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190328	2019-03-28	Seiche SM2073	SAIL	2019-03-29 00:31:00	2019-03-29 04:50:00	4.3	4.3	72.7	SEL,SL	Night	Motor yacht
MEEF_ACOUSTICS_20190409	2019-04-09	Seiche SM2073	SAIL	2019-04-10 01:15:00	2019-04-10 06:01:00	4.8	4.8	73.2	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190507	2019-05-07	Seiche SM2073	SAIL	2019-05-07 09:53:00	2019-05-07 14:38:00	4.7	4.7	71.2	SL,WL,NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190509	2019-05-09	Seiche SM2073	SAIL	2019-05-10 01:25:00	2019-05-10 03:56:00	2.5	2.5	40.6	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190516	2019-05-16	Seiche SM2073	SAIL	2019-05-17 01:25:00	2019-05-17 04:14:00	2.8	2.8	45.5	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190520	2019-05-20	Seiche SM2073	SAIL	2019-05-20 11:04:00	2019-05-20 14:18:00	3.2	3.2	53.6	SL	Day	Motor yacht
MEEF_ACOUSTICS_20190521	2019-05-21	Seiche SM2073	SAIL	2019-05-21 09:43:00	2019-05-21 13:37:00	3.9	3.9	60.9	SL,WL,NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190522	2019-05-22	Seiche SM2073	SAIL	2019-05-22 17:36:00	2019-05-22 20:08:00	2.5	2.5	42.2	SL,WL	Night	Motor yacht

MEEF_ACOUSTICS_20190523	2019-05-23	Seiche SM2073	SAIL	2019-05-24 01:04:00	2019-05-24 03:36:00	2.5	2.5	42.6	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190527	2019-05-27	Seiche SM2073	SAIL	2019-05-27 11:12:00	2019-05-27 14:09:00	2.9	2.9	47.9	NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190529	2019-05-29	Seiche SM2073	SAIL	2019-05-29 16:54:00	2019-05-29 19:25:00	2.5	2.5	41.2	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190530	2019-05-30	Seiche SM2073	SAIL	2019-05-31 01:27:00	2019-05-31 04:44:00	3.3	3.3	49.6	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190617	2019-06-17	Seiche SM2073	SAIL	2019-06-17 23:45:00	2019-06-18 03:40:00	3.9	3.9	63.7	EL	Night	Motor yacht
MEEF_ACOUSTICS_20190618	2019-06-18	Seiche SM2073	SAIL	2019-06-19 00:43:00	2019-06-19 03:52:00	3.1	3.1	51.7	SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190619	2019-06-19	Seiche SM2073	SAIL	2019-06-20 00:15:00	2019-06-20 03:40:00	3.4	3.4	57.6	SL	Night	Motor yacht
MEEF_ACOUSTICS_20190620	2019-06-20	Seiche SM2073	SAIL	2019-06-21 00:30:00	2019-06-21 03:27:00	3	3	46.2	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190623	2019-06-23	Seiche SM2073	SAIL	2019-06-24 01:53:00	2019-06-24 03:36:00	1.7	1.7	28.5	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190625	2019-06-25	Seiche SM2073	SAIL	2019-06-26 02:24:00	2019-06-26 04:11:00	1.8	1.8	29.2	SL,WL	Night	Motor yacht
MEEF_ACOUSTICS_20190626	2019-06-26	Seiche SM2073	SAIL	2019-06-26 13:11:00	2019-06-26 15:26:00	2.3	2.3	37.6	NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190627	2019-06-27	Seiche SM2073	SAIL	2019-06-27 23:47:00	2019-06-28 03:42:00	3.9	3.9	65.1	EL	Night	Motor yacht
MEEF_ACOUSTICS_20190708	2019-07-08	Seiche SM2073	SAIL	2019-07-09 00:52:00	2019-07-09 04:01:00	3.2	3.2	48.5	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190709	2019-07-09	Seiche SM2073	SAIL	2019-07-10 00:49:00	2019-07-10 02:19:00	1.5	1.5	24.1	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190710	2019-07-10	Seiche SM2073	SAIL	2019-07-10 23:23:00	2019-07-11 01:59:00	2.6	2.6	41.3	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190715	2019-07-15	Seiche SM2073	SAIL	2019-07-16 00:48:00	2019-07-16 04:04:00	3.3	3.3	53.7	SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190716	2019-07-16	Seiche SM2073	SAIL	2019-07-16 23:50:00	2019-07-17 03:52:00	4	4	65.6	EL	Night	Motor yacht
MEEF_ACOUSTICS_20190718	2019-07-18	Seiche SM2073	SAIL	2019-07-19 00:53:00	2019-07-19 03:53:00	3	3	50.9	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190722	2019-07-22	Seiche SM2073	SAIL	2019-07-23 00:40:00	2019-07-23 03:58:00	3.3	3.1	52	SEL	Night	Motor yacht
MEEF_ACOUSTICS_20190728	2019-07-28	Seiche SM2073	SAIL	2019-07-29 00:15:00	2019-07-29 03:34:00	3.3	3.3	55.1	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190806	2019-08-06	Vanishing Point Serial Stereo (50m)	SAIL	2019-08-06 13:20:00	2019-08-06 16:28:00	3.1	3.1	32.9	SL	Day	Wooden junk
MEEF_ACOUSTICS_20190813	2019-08-13	Vanishing Point Serial Stereo (50m)	SAIL	2019-08-13 17:40:00	2019-08-13 22:15:00	4.6	4.6	43.6	EL	Night	Wooden junk
MEEF_ACOUSTICS_20190815	2019-08-15	Seiche SM2073	SAIL	2019-08-16 01:22:00	2019-08-16 04:31:00	3.2	3.2	47.2	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190816	2019-08-16	Seiche SM2073	SAIL	2019-08-17 00:14:00	2019-08-17 03:23:00	3.1	3.1	49.2	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190822	2019-08-22	Vanishing Point Serial Stereo (50m)	SAIL	2019-08-22 17:44:00	2019-08-22 21:50:00	4.1	4.1	43.7	SL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20190823	2019-08-23	Vanishing Point Serial Stereo (50m)	SAIL	2019-08-23 17:11:00	2019-08-23 22:10:00	5	5	51	SEL,EL	Night	Wooden junk
MEEF_ACOUSTICS_20190828	2019-08-28	Seiche SM2073	SAIL	2019-08-28 13:13:00	2019-08-28 15:59:00	2.8	2.8	44.8	NWL	Day	Motor yacht
MEEF_ACOUSTICS_20190916	2019-09-16	Seiche SM2073	SAIL	2019-09-16 18:48:00	2019-09-16 22:21:00	3.6	3.6	58.5	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20190917	2019-09-17	Vanishing Point Serial Stereo (50m)	SAIL	2019-09-17 17:23:00	2019-09-17 22:02:00	4.7	4.7	51.3	EL	Night	Wooden junk
MEEF_ACOUSTICS_20190918	2019-09-18	Vanishing Point Serial Stereo (50m)	SAIL	2019-09-18 17:01:00	2019-09-18 20:40:00	3.6	3.6	39.2	SEL,EL	Night	Wooden junk
MEEF_ACOUSTICS_20190919	2019-09-19	Seiche SM2073	SAIL	2019-09-19 18:07:00	2019-09-19 21:02:00	2.9	2.9	46.4	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20190924	2019-09-24	Seiche SM2073	SAIL	2019-09-25 00:01:00	2019-09-25 02:53:00	2.9	2.9	43.7	NEL	Night	Motor yacht
MEEF_ACOUSTICS_20190925	2019-09-25	Vanishing Point Serial Stereo (50m)	SAIL	2019-09-25 16:53:00	2019-09-25 21:56:00	5.1	5.1	53.9	SEL,SL	Night	Wooden junk
MEEF_ACOUSTICS_20190927	2019-09-27	Vanishing Point Serial Stereo (50m)	SAIL	2019-09-27 17:33:00	2019-09-27 21:28:00	3.9	3.9	41.7	SL	Night	Wooden junk
MEEF_ACOUSTICS_20191003	2019-10-03	Vanishing Point Serial Stereo (50m)	SAIL	2019-10-03 17:22:00	2019-10-03 22:09:00	4.8	4.8	51.1	EL	Night	Wooden junk
MEEF_ACOUSTICS_20191004	2019-10-04	Vanishing Point Serial Stereo (50m)	SAIL	2019-10-04 17:31:00	2019-10-04 21:45:00	4.2	4.2	48.7	SL	Night	Wooden junk
MEEF_ACOUSTICS_20191010	2019-10-10	Vanishing Point Serial Stereo (50m)	SAIL	2019-10-10 16:45:00	2019-10-10 21:15:00	4.5	4.5	51.1	EL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20191011	2019-10-11	Vanishing Point Serial Stereo (50m)	SAIL	2019-10-11 17:25:00	2019-10-11 20:30:00	3.1	3.1	35.3	SL,SEL	Night	Wooden junk

MEEF_ACOUSTICS_20191015_01	2019-10-15	Seiche SM2073	SAIL	2019-10-15 19:19:00	2019-10-15 22:59:00	3.7	3.7	59.5	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191016_01	2019-10-16	Seiche SM2073	SAIL	2019-10-16 17:04:00	2019-10-16 20:08:00	3.1	3.1	46.9	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20191017	2019-10-17	Seiche SM2073	SAIL	2019-10-17 17:01:00	2019-10-17 20:05:00	3.1	3.1	41	NEL	Night	Motor yacht
MEEF_ACOUSTICS_20191107	2019-11-07	Vanishing Point Serial Stereo (100m)	SAIL	2019-11-07 16:31:00	2019-11-07 20:48:00	4.3	4.3	50.9	EL	Night	Wooden junk
MEEF_ACOUSTICS_20191111	2019-11-11	Seiche SM2073	NI	2019-11-11 18:23:00	2019-11-11 21:27:00	3.1	3.1	49	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191112	2019-11-12	Seiche SM2073	NI	2019-11-12 18:22:00	2019-11-12 21:20:00	3	3	45.9	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191114	2019-11-14	Vanishing Point Serial Stereo (100m)	SAIL	2019-11-14 16:31:00	2019-11-14 21:31:00	5	5	61.3	EL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20191119	2019-11-19	Seiche SM2073	NI	2019-11-19 18:13:00	2019-11-19 20:57:00	2.7	2.7	47.4	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191121	2019-11-21	Vanishing Point Serial Stereo (100m)	SAIL	2019-11-21 17:31:00	2019-11-21 21:44:00	4.2	4.2	49.6	SL	Night	Wooden junk
MEEF_ACOUSTICS_20191128	2019-11-28	Vanishing Point Serial Stereo (100m)	SAIL	2019-11-28 17:10:00	2019-11-28 21:56:00	4.8	4.8	52.3	SL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20191202	2019-12-02	Seiche SM2073	NI	2019-12-03 00:07:00	2019-12-03 03:03:00	2.9	2.9	47.7	NEL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191203_01	2019-12-03	Vanishing Point Serial Stereo (100m)	SAIL	2019-12-03 17:15:00	2019-12-03 21:45:00	4.5	4.5	51	EL	Night	Wooden junk
MEEF_ACOUSTICS_20191203_02	2019-12-03	Seiche SM2073	NI	2019-12-04 00:30:00	2019-12-04 03:09:00	2.6	2.6	44	NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191204_01	2019-12-04	Vanishing Point Serial Stereo (100m)	SAIL	2019-12-04 16:40:00	2019-12-04 22:09:00	5.5	5.5	61	EL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20191204_02	2019-12-04	Seiche SM2073	NI	2019-12-04 17:16:00	2019-12-04 20:03:00	2.8	2.8	46.6	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20191210	2019-12-10	Vanishing Point Serial Stereo (100m)	SAIL	2019-12-10 17:51:00	2019-12-10 21:41:00	3.8	3.8	42.8	SL	Night	Wooden junk
MEEF_ACOUSTICS_20191211	2019-12-11	Vanishing Point Serial Stereo (100m)	SAIL	2019-12-11 17:21:00	2019-12-11 21:58:00	4.6	4.6	50.2	SL, SEL	Night	Wooden junk
MEEF_ACOUSTICS_20200108	2020-01-08	Seiche SM2073	NI	2020-01-08 17:03:00	2020-01-08 20:06:00	3.1	3.1	51.9	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20200109	2020-01-09	Seiche SM2073	NI	2020-01-09 17:53:00	2020-01-09 21:50:00	4	4	65.9	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20200110	2020-01-10	Seiche SM2073	NI	2020-01-11 00:37:00	2020-01-11 03:00:00	2.4	2.4	40.9	NEL	Night	Motor yacht
MEEF_ACOUSTICS_20200113	2020-01-13	Vanishing Point Serial Stereo (100m)	SAIL	2020-01-13 17:01:00	2020-01-13 21:45:00	4.7	4.7	50.3	EL	Night	Wooden junk
MEEF_ACOUSTICS_20200114	2020-01-14	Vanishing Point Serial Stereo (100m)	SAIL	2020-01-14 16:42:00	2020-01-14 20:51:00	4.1	4.2	44.8	EL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20200116	2020-01-16	Vanishing Point Serial Stereo (100m)	SAIL	2020-01-16 18:21:00	2020-01-16 22:36:00	4.3	4.3	49.8	SL	Night	Wooden junk
MEEF_ACOUSTICS_20200124	2020-01-24	Vanishing Point Serial Stereo (100m)	SAIL	2020-01-24 17:01:00	2020-01-24 21:21:00	4.3	4.3	51.2	SL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20200204	2020-02-04	Seiche SM2073	NI	2020-02-04 17:51:00	2020-02-04 21:26:00	3.6	3.6	58.8	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20200205	2020-02-05	Seiche SM2073	NI	2020-02-05 17:22:00	2020-02-05 20:45:00	3.4	3.4	55.6	SL,WL,NWL	Night	Motor yacht
MEEF_ACOUSTICS_20200206	2020-02-06	Seiche SM2073	NI	2020-02-06 17:47:00	2020-02-06 21:31:00	3.7	3.7	62.7	NWL,NEL	Night	Motor yacht
MEEF_ACOUSTICS_20200210	2020-02-10	Vanishing Point Serial Stereo (100m)	SAIL	2020-02-10 17:25:00	2020-02-10 22:09:00	4.7	4.7	50.4	EL	Night	Wooden junk
MEEF_ACOUSTICS_20200211	2020-02-11	Vanishing Point Serial Stereo (100m)	SAIL	2020-02-11 16:44:00	2020-02-11 22:19:00	5.6	5.6	60.7	EL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20200212	2020-02-12	Vanishing Point Serial Stereo (100m)	SAIL	2020-02-12 18:17:00	2020-02-12 22:00:00	3.7	3.7	42.6	SL	Night	Wooden junk
MEEF_ACOUSTICS_20200217	2020-02-17	Vanishing Point Serial Stereo (100m)	SAIL	2020-02-17 17:22:00	2020-02-17 21:59:00	4.6	4.6	50.3	SL,SEL	Night	Wooden junk
MEEF_ACOUSTICS_20200515	2020-05-15	SoundTrap	N/A	2020-05-15 10:02:02	2020-05-15 15:01:50	4.9	4.9	49.2	SEL,SL,WL	Day	Wooden junk