Using new tools to monitor human behaviour in critical dolphin habitat and marine protected areas

如何利用新工具於海豚重要棲息地及海洋保護區監測人類活動

MEEF 2020005A

Final Report

SEAMAR

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Final Report

December 2022

Submitted to Marine Ecology Enhancement Fund (MEEF)
Project Number MEEF2020005A

Southeast Asia Marine Mammal Research (SEAMAR)
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Declaration

Reference Number: MEEF2020005A

Project Title: Using new tools to monitor human behaviour in critical dolphin habitat and marine protected areas

Project Leader: Lindsay Porter

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.

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.

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 Fund (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 Organisation or the public.

Signature: ______________________

Lindsay Porter, Project Leader

Date: ___01/12/2022___________

Contents

Executive Summary

In Hong Kong, a ban on commercial trawling came into effect in December 2012. The purpose of the ban was to conserve the fisheries resources in Hong Kong waters and promote the sustainable development of the Hong Kong fisheries industry. Healthy fisheries are critical to marine mammal survival in Hong Kong. Previous studies that included both direct observation and interviews with local fishermen, indicated that illegal trawlers regularly operate in Hong Kong waters at night. As these vessels operate without lights, they are not easily 'seen' but can be detected acoustically by the distinctive underwater sound of the trawl vessel. This project used underwater acoustic monitoring devices, usually deployed to record marine mammals, to monitor vessel activity at night, with the aim of better understanding the extent of any unlawful practises, such as trawling. Both static underwater listening stations and hydrophones deployed from a moving vessel were used to record the underwater soundscape. In addition, sound propagation models developed to monitor marine protected areas elsewhere were also assessed, and modified, for use in Hong Kong waters. These monitoring and analytical tools were an efficient means of mapping vessel activities, including trawling and speed boats, believed to be trafficking goods illegally across Hong Kong's maritime border. The data from surveys towing passive acoustic monitoring (PAM) equipment mapped the spatial overlap between illegal activities and marine mammals. The use of static PAM devices provided detailed information on daily vessel activities within three of Hong Kong's marine protected areas. The objective of deploying the static devices was to test the ability of these devices to document the frequency, duration and driving factors of vessel activities in marine park areas.

This study, in its entirety, was conducted between January and October 2021. This report details activities during the period 1 July– 31 October 2021 and summarises the data gathered. This report also includes analyses and discussion of the data gathered between 1 January and 31 October 2021. The report detailing the data collection phase is detailed in project MEEF2020005.

This study was conducted during the start of the Covid-19 pandemic and, as such, Hong Kong's maritime border was closed. This restriction did not inhibit project fieldwork activities and static acoustic devices were deployed at Yuen Chau, in the South Lantau Marine Park (SLMP), proposed at time of research, now designated; Peaked Hill, in the South West Lantau Marine Park (SWLMP) and; Tai Mo To, in The Brothers Marine Park (TBMP). This fieldwork was conducted between February and June 2021 and analysis of these data was conducted between July – October 2021. A total of 65.7 days (1576 hours) of acoustic recordings was available to be analysed.

Between July-October 2021, vessel surveys recorded 59 marine mammal acoustic events (25 Chinese white dolphin; 34 finless porpoise) and 86 acoustic events attributed to vessels, of which 23 were either definitely, or most likely, conducting unlawful activities (12 active trawlers and 11 unlit, speed boats travelling across the Hong Kong maritime border). Dolphins were detected in Northwest Lantau (NWL), West Lantau (WL) and South Lantau (SL), including Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP), SWLMP and SLMP. Finless porpoise were detected in Southeast Lantau (SEL) SL and SLMP. Illegal trawling activities (usually single trawlers) were documented in SL. Speedboats were encountered in NWL, WL and SL. Trawlers were encountered throughout the survey period and speed boats were encountered in July, September and October.

For MEEF2020005 and MEEF 2020005A combined, the vessel surveys recorded 207 marine mammal acoustic events (75 Chinese white dolphin; 132 finless porpoise) and 326 acoustic events attributed to vessels, of which 144 were either definitely, or most likely, conducting unlawful activities (22 active trawlers and 122 unlit, speed boats travelling across the Hong Kong maritime border). Dolphins were detected in NWL, WL, SL and SEL, all Marine parks, except TBMP. Finless porpoise were detected in SL and SEL, including SLMP. Illegal trawling activities (usually single trawlers) were documented in SL, SEL and WL, including within SLMP and SWLMP. Speedboats were encountered in NEL, NWL, SL and WL, including SCLKCMP, SWLMP and TBMP. Trawlers were only absent during the months of the South China Sea-wide ban on trawling activity, whereas speed boats were encountered throughout the entire survey period (January – October 2021).

The vessel data recorded from the static PAM devices were classified into five different behaviours: a travelling vessel, some distance from the recording device location (TB), a travelling vessel, close to the recording device location(TA), a travelling vessel, close to the recording device, that changed direction or speed (TA + M), the closest point of vessel approach to the recorder location (CPA) and a change in direction or speed of vessel as it was at the closest point of approach (CPA + M). Three classes of vessel were categorised, based on sound source levels: small sized, outboard powered vessels, e.g., RHIB, P4 fishing boats, medium sized, inboard powered vessels, e.g., tugs and trawlers, and large vessels, tankers and container ships. Vessel activity, of all types, was highest in the SLMP and lowest in TBMP. SWLMP and TBMP showed peaks in vessel activity on Mondays and Tuesdays, whereas activity in SLMP was highest at the weekend. SWLMP and TBMP had a peak in activity between 17:00 and 18:00 and TBMP typically had another peak at 21:00, followed by further activity between 23:00 and 03:00. SLMP had a peak in activity between 11:00-13:00. There was some association between vessel occurrence and tidal phase, typically flood phase, however, a longer time series of data is required to better understand this potential relation

From both the spatial dataset (towed array surveys) and the temporal dataset (static devices), the following conclusions and recommendations were made, noting the short deployment time of the static stations and the short window of time these deployments provided insight to:

- Illegal trawling activities occur predominantly in Hong Kong's southwestern waters, where they overlap directly with both humpback dolphin and finless porpoise presence within and around SLMP.
- Speed boats likely conducting unlawful activities were predominantly detected in Hong Kong's north-western waters, where they overlap directly with humpback dolphin presence within and around SCLKCMP.
- Patrols of the TBMP would be most effective in the early evening between Saturdays and Tuesdays.
- Patrols of the SWLMP would be most effective in the early evening between Saturdays and Tuesdays.
- Patrols of SLMP would be most effective at midday and at the weekends
- A static device was not deployed in SCLKCMP, where most of the speed boat activity was detected by the vessel surveys, so the ability of a static device to detect speed boat underwater noise signals should be assessed specifically in that area.

It is suggested that if static PAM stations are to be used for future monitoring, a longer deployment in each area would be required to better assess long-term patterns in vessel activity in marine parks. In addition, a static device was not deployed in SCLKCMP, where most of the speed boat activity was detected by the vessel surveys, so the ability of a static device to detect speed boat underwater noise signals should be assessed specifically in that area.

During the time of the study, data on detected night-time activities were provided to law enforcement agencies although this was not the original expectation of the project. This study aimed to assess the suitability of various acoustic monitoring tools to provide quantitative data on compliance with fisheries and habitat protection policies in Hong Kong. In addition, the study assessed a novel means of monitoring and categorising vessel activity, as well as a marine mammal occurrence, and modified models for use in Hong Kong. This project has demonstrated the usefulness of these tools and preliminary data suggests that they have the potential to improve the efficiency of marine protected area monitoring.

The final goal of this project was to provide a report to management authorities, detailing the potential use of these various tools and how they might assist in better understanding vessel activities, particularly illegal activities, in critical dolphin and porpoise habitat.

Project Title and Brief Description of the Project

Project Title

Using New Tools to Monitor Human Behaviour in Critical Dolphin Habitat and Marine Protected Areas.

Brief Description

In Hong Kong, a ban on commercial trawling came into effect in December 2012. The purpose of the ban was to conserve the fisheries resources in Hong Kong waters and promote the sustainable development of the Hong Kong fisheries industry. Healthy fisheries are critical to the dolphins, and other marine mammals, survival in Hong Kong. Illegal trawlers operate at night without lights so are not easily 'seen' but are readily heard by the distinctive underwater sound of the trawl nets. Acoustic devices usually deployed to detect marine mammals were assessed and modified so as to provide an efficient means of (a) informing management authorities of unlawful activities and (b) mapping the overlap between marine mammals and various vessel activities, particularly illegal activities, such as trawling, which pose risk to dolphins and porpoise from direct injury or death and from impoverishing their prey resources.

Objectives

Test the feasibility of multiple passive acoustic monitoring devices to document the frequency, duration and driving factors of human activities, particularly illegal trawling events, in critical marine mammal habitat and Hong Kong Marine Park Areas.

Provide a summary report to management authorities with a detailed analysis of human activities in both critical marine mammal habitat and Marine Park Areas so that management and enforcement activities can be informed and adapted, if required.

Completed Activities Against the Proposed Work Schedule

The project and its activities were conducted between July -October 2021, during which eight (8) activities were scheduled (Table 1A. Timeline of completed activities for MEEF2020005A (July – October 2021)) The workplan for the period January – October 2021 is included for reference (Table 1B).

Activity 1: Towed PAM Surveys
Status: Completed for this period (and continued from January-June 2021)

For details, please refer to Appendix 5.

Activity 2: Static PAM Deployment
Status: Complete

For details, please refer to Appendix 6.

Activity 3: Visual Mapping of Vessels at Static Sites
Status: Completed for this period (and continued from January-June 2021)

Activity 4: Data Collection: Sound propagation model
Status: Completed for this period (and continued from January-June 2021)

Activity 5: Data Collection: existing datasets/environment
Status: Complete

Activity 6: Data Analyses

Status: Complete

For details, please refer to Appendix 7

Activity 7: Discussion Management Authorities
Status: Completed

Activity 8: Final Report
Status: Completed

Results

Static PAM Stations

Between January and October 2021, SoundTraps were deployed at Yuen Chau, Peaked Hill and Tai Mo To for 65.7 days resulting in 1576 hours of acoustic recordings (Table 2). On average, there were 26 days and 630 hours recorded at each PAM station with the exception of Peaked Hill, where a SoundTrap error resulted in only 12.8 days and 307.4 hours being recorded. *For details, please refer to* Appendix 7.

Acoustic Surveys

Between January and October 2021, 22 surveys were conducted resulting in 1234.0 km of survey effort and 83.2 hours of acoustic recordings (Table 3). The majority of this effort was between 18:00 and 20:00 (Figure 1).

There were 207 acoustic events, of which 75 were of Chinese white dolphins and 132 were of finless porpoise (Table 3, Appendix 8). Dolphins were detected in Northwest Lantau (NWL), West Lantau (WL), South Lantau (SL) and Southeast Lantau (SEL), as well as Sha Chau Lung Kwu Chau Marine Park (SCLKCMP), Southwest Lantau Marine Park (SWLMP) and South Lantau Marine Park (SLMP) (Figure 2). Finless porpoise were only detected in SL, SEL and SLMP (Figure 2). There were no cetacean detections in Northeast Lantau (NEL) or The Brothers Marine Park (TBMP).

There were 326 vessel encounters (Appendix 9), of which 22 involved vessels that were "definitely" conducting illegal activities, such as active trawlers (Figure 3a); and 122 that were "likely" conducting illegal activities, such as high-powered speed boats travelling at >50 kt into and out of Hong Kong waters, often without navigation lights (Figure 3b). It is noted that it was not possible to identify individual vessels at night, such that a single trawler operating in an area may have been "encountered" multiple times throughout a survey. Trawlers were encountered predominantly in SL (n = 18), as well as within SLMP (n = 7) (Figure 4). Typically, trawlers were almost exclusively encountered alone; there was only one encounter involving a pair of trawlers. Trawlers were not encountered in January nor, not unsurprisingly, between May to July, which is the annual fishing moratorium period in the South China Sea. Speed boats were encountered predominantly in NWL (n = 112), as well as within SCLKCMP (n = 10) and TBMP (n = 1) (Figure 4). Similar to trawlers, speed boats were almost exclusively encountered alone, though the number of vessels per encounter ranged between to 30 vessels. Speed boats were encountered in every month that NWL was surveyed (January, March, May, July and September).

Evaluation of Project Effectiveness

The **major outcomes** of this project are a) to document vessel behaviour, determine the frequency and location of unlawful activities, such as illegal trawling, and investigate the factors that influence such activities b) provide new insights to authorities on the effectiveness of management actions and c) assess the feasibility of using acoustic tools to assist conservation initiatives.

Objective 1 (as stated in the project proposal). *This objective will be achieved by successfully deploying towed and static acoustic equipment throughout the project period and analysing the collected data. Additional visual observations of vessel traffic around the static acoustic recorders will provide data on vessel size and activity that will inform acoustic models. Recordings of marine mammals will also be logged and mapped. The overlap of marine mammal occurrence and undesirable vessel activities will be summarised and direct risk assessed. On completion and appropriate approvals, the acceptance of a scientific paper in a peer reviewed journal shall be an indicator of this projects academic research value.*

Objective 1 has been achieved by successfully deploying towed and static acoustic equipment throughout the project period and analysing the collected data. Visual observations of vessel traffic around the static acoustics recorders have also been integrated. The overlap of marine mammal occurrence and undesirable vessel activity has been summarised, indicating that:

- Illegal trawling activities occur predominantly in Hong Kong's southwestern waters, where they overlap directly with both humpback dolphin and finless porpoise presence within and around SLMP.
- Illegal speed boats are active predominantly in Hong Kong's northwestern waters, where they overlap directly with humpback dolphin presence within and around SCLKCMP.

Objective 2 (as stated in the project proposal). *This objective will be achieved by reporting to management authorities, detailing the acoustic modelling, vessel location and behaviour, and the factors that influence vessel occurrence, will allow the feasibility of this method as a potential monitoring and management tool to be assessed. The evaluation of results and recommendations for future use by the appropriate management authorities shall be an indicator of this works conservation management value.*

Objective 2 will be achieved in full once this report and the attached report to government has been reviewed and approved by the MEEF Committee. This objective has been achieved in part as during the survey work, incidents of illegal activity were provided to law enforcement agencies.

Summary and Way Forward

This project was catalysed by a previously funded MEEF project that logged several vessel activities in marine parks, and other areas, that were likely illegal and could potentially negatively impact both dolphins and porpoise. The use of towed array PAM surveys, during a project that focused on night-time activities of dolphins and finless porpoise, had identified trawling activity, by its characteristic underwater signature, noting that trawling has been banned in Hong Kong waters for more than a decade. The means to investigate these clandestine activities in more detail, relied on novel sound modelling propagation techniques that had only just been pioneered for the Great Barrier Reef Marine Park, Australia. This project, therefore, had two data collection components, the towed array surveys that were conducted throughout Lantau waters and the static PAM stations, that were located in marine park areas. The towed array surveys recorded 144 vessels (44% of all vessels detected) conducting, or highly likely to be conducting, illegal activities. Detections of active trawlers were made predominantly in SL waters, including within the SLMP, but occurred only in some months. Notably there was no trawling activity detected during the annual fishing moratorium in the South China Sea (May-July). Speed boats, believed to be involved in the cross-border trafficking of goods and people, were detected in NWL, including within SCLKCMP. These vessels were encountered throughout the study period. The towed array PAM surveys provided acoustic data on dolphins, porpoise and vessel activity from throughout the Lantau habitat, at night, and highlighted areas of overlap in SL (trawlers and porpoise) and NWL (high-speed small vessels). Marine park monitoring via the deployment of static acoustic monitoring devices provided a very detailed picture of marine park use over 24 hour periods. The analyses included the identification of several vessel activity types, as well as vessel activity in relation to time of day and tidal cycles. Much of the static device data analyses centred on the testing of detectors that had been developed elsewhere to monitor vessel behaviour to assess if these models were suitable for use in each Hong Kong marine protected area. The static devices indicated that TBMP had the lowest overall vessel activity, whereas SLMP had the highest vessel activity. TBMP and SWLMP had peaks in activity on Mondays and Tuesdays and night-time activities peaked at 21:00 and between 00:00 and 03:00, in TBMP and SWLMP, respectively. Overall, data from the towed array surveys indicated that SCLKCMP should be patrolled more actively during night-time hours, and TBMP and SWLMP should be subject to evening patrols, between Saturdays and Tuesdays, to overlap with most vessel activity. SLMP should be patrolled at midday and at weekends. It is noted that the static PAM deployments were short, and did not occur in the SCLKMP, and extending the deployment time and area coverage would capture more detailed patterns of marine park use by vessels, thus allowing both seasonal patterns and environmental variables, to be better understood. As such, the static device monitoring protocols were able to define activities and vessel classes within, and outside, marine park areas thus providing a new means to focus active management.

The use of both static and towed PAM techniques proved to be effective tools for monitoring vessel activities in and adjacent to marine parks and, although it took much longer than anticipated to analyse the complex soundscape of Hong Kong's underwater habitat, these models have now been adapted to monitor Hong Kong's busy waterways. During and subsequent to this project being conducted, management and enforcement authorities have substantially increased patrolling and monitoring of the Lantau habitat. These acoustic tools could, therefore, provide a low cost means to monitor activities and marine mammals in marine protected areas in the long term, to gauge the effectiveness and longevity of this increased patrolling effort. This may assist management authorities to assess different patrol strategies and, if some illegal activities return to the more remote waters of Hong Kong, will provide detailed vessel activity data upon which the authorities can act.

This project was conducted at a time when illegal activities in Hong Kong waters were perceived to be escalating and real-time information on observed activities was provided to the authorities by the project proponents. In this way, this project is believed to have already contributed to the larger effort to reduce illegal activities in Hong Kong waters.

Tables

Table 1A. Timeline of completed activities for MEEF2020005A (July – October 2021)

Item	Activities	Jul-21	Aug-21	Sep-21	Oct-21
1	Towed PAM Surveys	🟦	🟦	🟦	🟦
2	Static PAM Deployment	🟦			
3	Visual Mapping of Vessels at Static Sites	🟦			
4	Data Collection for sound propagation models	🟦			
5	Data Collection: existing datasets/environment		🟦	🟦	
6	Data Analyses	🟦	🟦	🟦	
7	Discussion Management Authorities		🟦		🟦
8	Final Report				🟦

Table 1B. Timeline of completed activities for MEEF2020005 and MEEF2020005A (January – October 2021).

Item	Activities	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21
1	Towed PAM Surveys	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
2	Static PAM Deployment	🟦						🟦			
3	Visual Mapping of Vessels at Static Sites	🟦			🟦			🟦			
4	Data Collection for sound propogation models	🟦						🟦			
5	Data Collection: existing datasets/environment	🟦	🟦						🟦	🟦	
6	Data Analyses	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
7	Interim Report				🟦						
8	Discussion Management Authorities		🟦			🟦			🟦		🟦
9	Final Report						🟦				🟦

Table 2. Summary of static PAM station effort.

Site	Marine Park	Deployment Date	Retrieval Date	Recording Hours	Recording Days
Yuen Chau	SLMP	2021-02-02	2021-03-01	637.4	26.6
Peaked Hill	SWLMP	2021-03-25	2021-04-07	307.4	12.8
Tai Mo To	TBMP	2021-05-26	2021-06-21	631.2	26.3
Total				**1576.0**	**65.7**

Table 3. Summary of acoustic survey effort and acoustic events by survey area.

Month	Surveys	NEL			NWL			SEL			SL			WL		
		Effort (km)	Acoustic Events		Effort (km)	Acoustic Events		Effort (km)	Acoustic Events		Effort (km)	Acoustic Events		Effort (km)	Acoustic Events	
			CWD	FP		CWD	FP		CWD	FP		CWD	FP		CWD	FP
January	4	27.7	0	0	72.8	7	0	35.7	0	17	65.2	8	10	25.6	6	0
February	2	0.0	0	0	0.0	0	0	35.7	0	14	66.2	3	17	0.0	0	0
March	2	27.4	0	0	70.7	1	0	0.0	0	0	3.9	0	0	24.9	5	0
April	2	0.0	0	0	0.0	0	0	35.4	0	11	67.7	0	17	0.0	0	0
May	2	26.1	0	0	72.1	0	0	0.0	0	0	4.0	1	0	26.0	3	0
June	2	0.0	0	0	0.0	0	0	33.2	2	4	63.5	14	8	0.0	0	0
July	2	26.7	0	0	71.8	3	0	0.0	0	0	3.7	1	0	25.2	5	0
August	2	0.0	0	0	0.0	0	0	32.8	0	3	62.1	6	18	0.0	0	0
September	2	28.3	0	0	70.5	4	0	0.0	0	0	6.4	1	0	26.3	5	0
October	2	0.0	0	0	0.0	0	0	33.4	0	3	62.9	0	10	0.0	0	0
Total	**22**	**136.1**	**0**	**0**	**358.0**	**15**	**0**	**206.2**	**2**	**52**	**405.7**	**34**	**80**	**128.0**	**24**	**0**

Figures

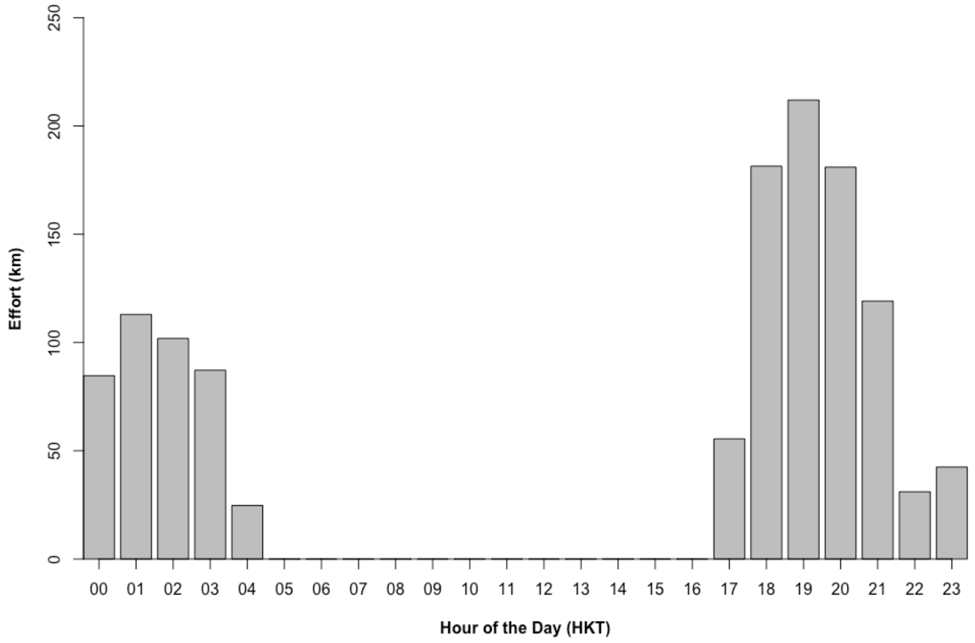

Figure 1. Summary of acoustic survey effort (km) by survey area.

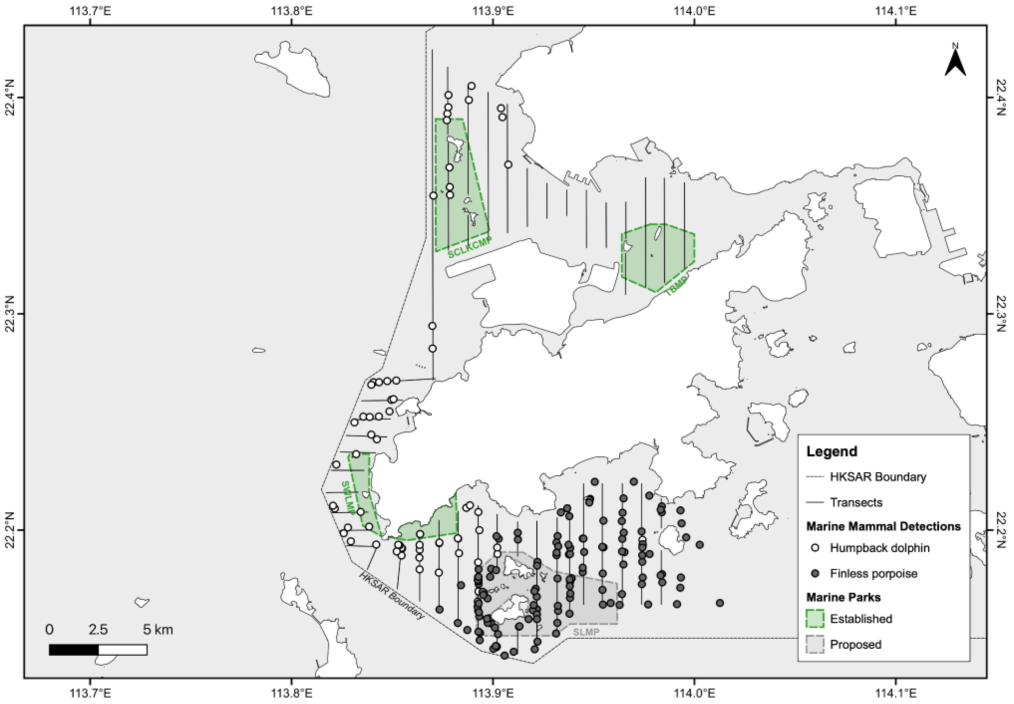

Figure 2. Indo-Pacific humpback dolphin (*Sousa chinensis*) and Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) acoustic events detected during acoustic surveys between January and October 2021.

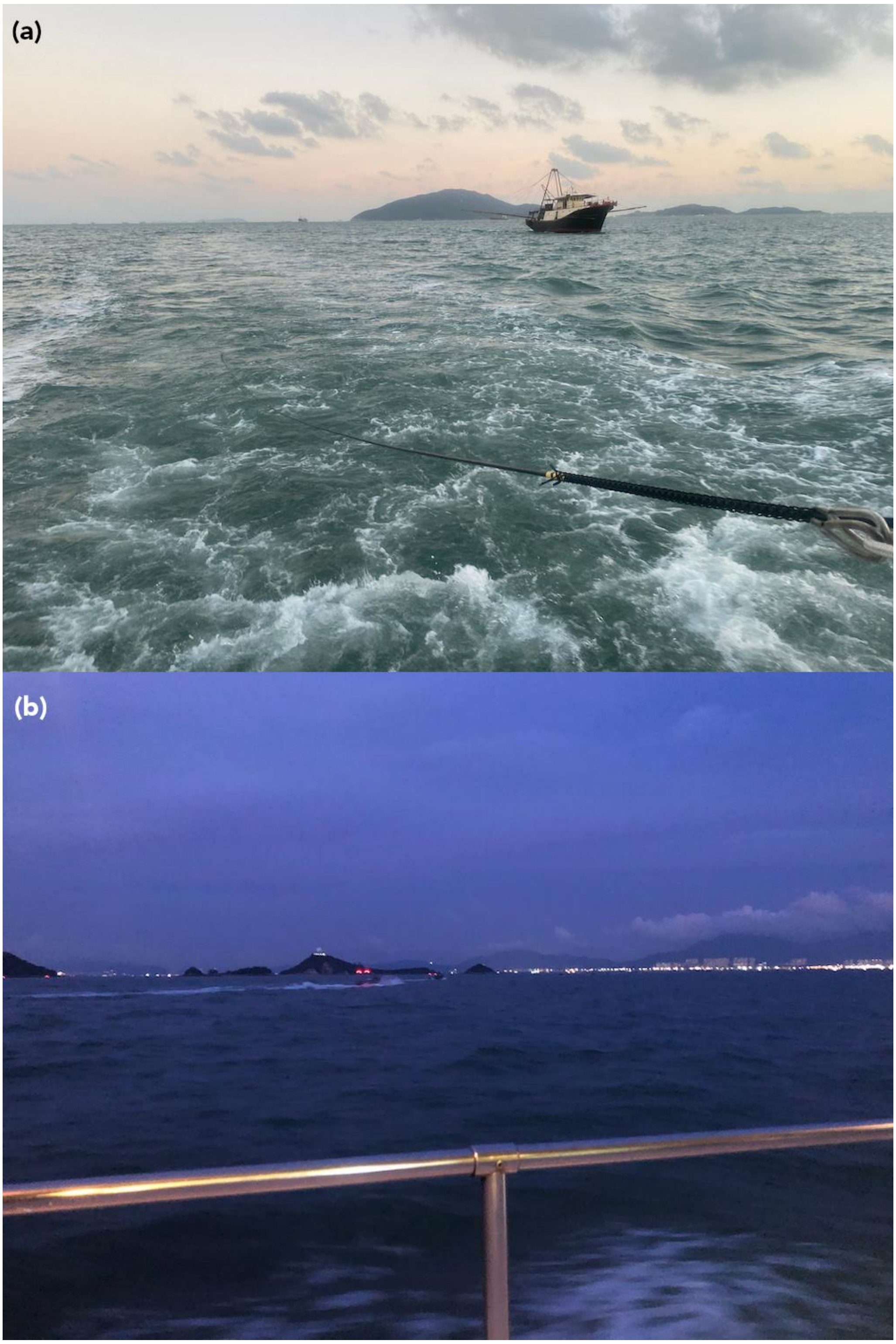

Figure 3. Examples of vessels definitely conducting illegal activities, such as **(a)** active trawlers, and likely conducting illegal activities, such as **(b)** high-powered speed boats.

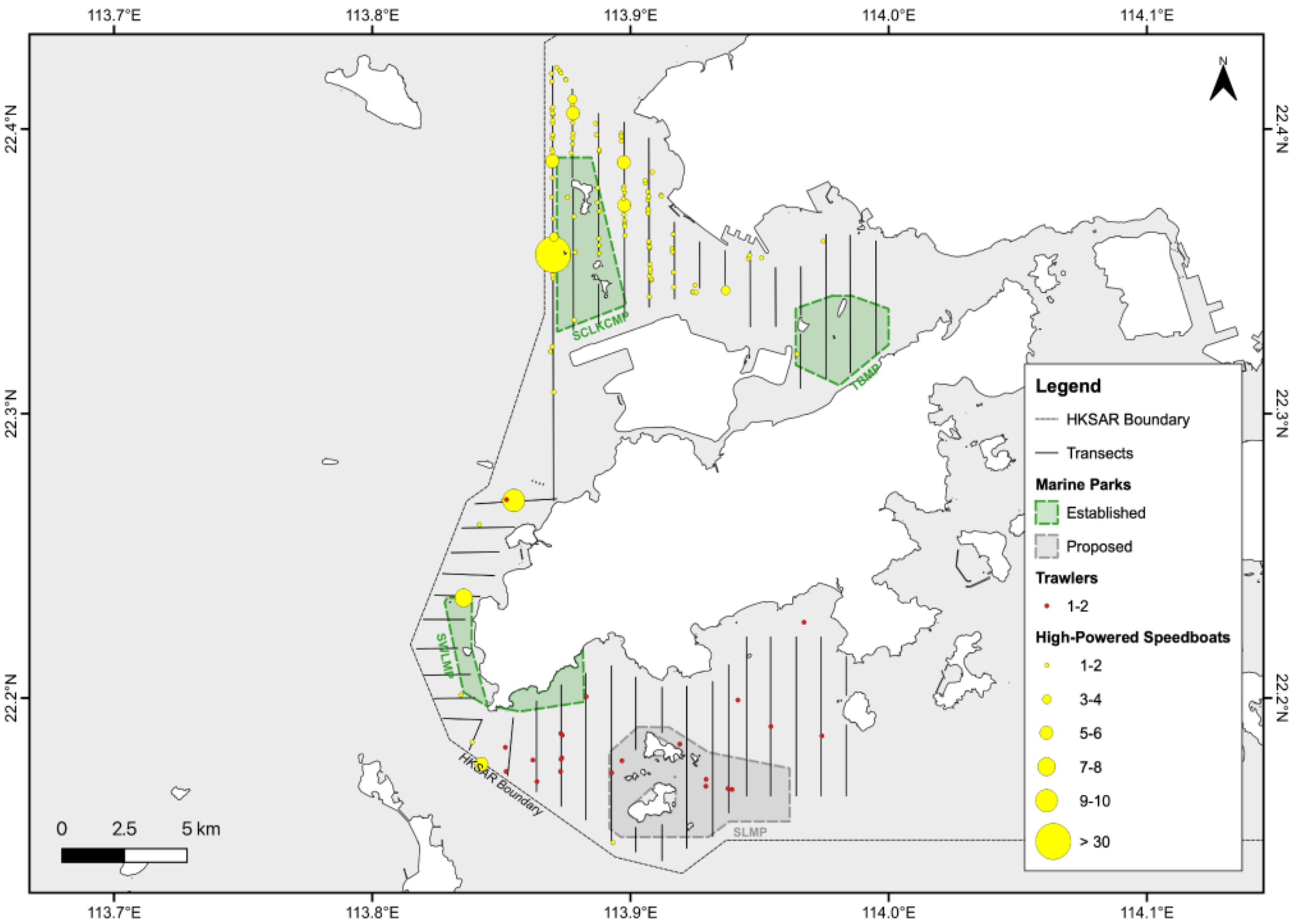

Figure 4. The number of vessels encountered conducting illegal activities, i.e., active trawlers and high-powered speed boats, during acoustic surveys between January and October 2021.

Appendices

Appendix 1. Audited statement of accounts.

Audit Report MEEF2020005 (July – October 2021)

Audited statement of accounts are not disclosed due to confidentiality reasons.

Appendix 2. Project assets.

List of project assets are not disclosed due to confidentiality reasons.

Appendix 3. Staff attendance record.

Staff attendance record are not disclosed due to confidentiality reasons.

Appendix 4. Recruitment record for all project staff employed under the project enclosed as an appendix to the completion report in accordance with the recruitment plan.

Recruitment record are not disclosed due to confidentiality reasons.

Appendix 5. Methods for *Activity 1: Towed PAM Surveys*.

Study Area

The study area encompassed the waters adjacent to the Third Runway System (3RS), as well as The Brothers Marine Park (TBMP), Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP), South West Lantau Marine Park (SWLMP) and South Lantau Marine Park (SLMP) (Figure 1).

Data Collection

Night-time acoustic data were collected using monthly line transect surveys across the known range of Chinese white dolphins (CWD) around Lantau Island (Figure 2), as identified in the AFCD Marine Mammal Monitoring Programme Report (AFCD 2020). During surveys, a cabled hydrophone array was towed 80 m behind a research vessel travelling at 9 knots (Figure 3). The arrays were custom-built, consisted of two elements, and had a frequency response of 20 Hz to 200 kHz with ± 10 dB sensitivity. Two different array configurations were used: (1) a liner-cast array (*Seiche*, United Kingdom) and (2) a linear oil-filled array (*Vanishing Point Marine*, United Kingdom). Analogue acoustic signals were passed through a 100 Hz high-pass filter 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). 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.

Where possible, all hardware was powered by 12 V DC batteries to reduce electrical noise in the acoustic system. When 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 for surveys: (1) a 21.9 m twin-engine motor yacht and (2) a 17.5 m single-engine motor yacht. Various combinations of research vessels cabled hydrophone arrays and DAQ cards were used throughout the study period (July-October 2021) which are detailed in Table 1A. For reference, the combinations of research vessels cabled hydrophone arrays and DAQ cards that were used for the entire study period (MEEF2020005 and MEEF2020005A combined) are included (Table 1B). Surveys were conducted by two PAM operators (excluding the research vessel captain and crew) working in 1-hour shifts to monitor the cabled hydrophone array, listen to the acoustic output and input relevant survey data into PAMGuard (Figure 4). Upon hearing engine noise on the hydrophone, the PAM operator would confirm (to the best of their ability) the number and approximate location of the vessel relative to the research vessel. These vessel "encounters" were then classified into six categories: *Cargo*, *Construction*, *Fishing*, *Government*, *Passenger*, *Pleasure* and *Other* (Table 2). For *Fishing* vessels, activity was also noted, specifically whether they were transiting or fishing. To ensure equal coverage over a 12-hour night cycle, surveys were conducted between 16:00-22:00 or 22:00-04:00.

Data Processing and Analysis

Acoustic recordings from towed hydrophone array surveys were processed and analysed using PAMGuard. Recordings were reviewed continuously for the presence of dolphin vocalisations, specifically echolocation clicks and whistles. The first stage of processing involved identifying individual clicks and whistles using automated detectors in PAMGuard. For clicks, the Click Detector in PAMGuard was configured to trigger on any transient signal with energy rising more than 10 dB above background noise. Transient signals were classified as potential dolphin clicks if they had a peak frequency between 20-50 kHz, 50-70 kHz, 70-110 kHz or 28-130 kHz; or as potential porpoise clicks if they had a peak frequency between 100-150 kHz and total energy in the peak was ≥ 6 dB higher than the 40-90 kHz and 170-210 kHz bands. Potential clicks identified by the detector were then manually reviewed by an analyst for spectral and temporal features, such as peak frequency, frequency range and interclick interval (ICI) specific to CWD and finless porpoise to confirm species presence. To assist with this review, click classifiers were used with different peaked frequencies: 30-50 kHz, 50-70 kHz and 70-110 kHz for CWD; and 100-155 kHz for finless porpoise. A positive CWD click detection required a minimum of one click train (i.e. four successive clicks) that met three criteria: (1) a peak frequency of 20-40 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) (Figure 5). A positive finless porpoise click detection required a minimum of one click that met three criteria: (1) a peak frequency of 130-140 kHz; (2) a frequency range of 110-160 kHz (Goold and Jefferson 2002); and (3) a clear sinusoidal waveform that was smoothly enveloped (Figure 6). For whistles, the Whistle and Moan detector in PAMGuard was configured to trigger potential whistles using a set of parameters (Table 3). Potential whistles were reviewed visually by inspecting spectrogram contours (Figure 7). Where necessary, whistles were also reviewed aurally by playing back at original speed. A positive CWD whistle detection required a whistle contour that had a constant frequency and an upsweep, downsweep, convex, concave, multiple or “chirp” shape, as described by Ruxton (2002). Once identified, individual clicks and whistles were grouped into an acoustic event, which was defined as all confirmed vocalisations occurring within a time window of 60 seconds. Vocalisations separated by more than this time window were assumed to be from separate individuals or groups.

Both acoustic events and vessel “encounters” were paired with GPS using their respective date-time stamps in R 4.0.3. (R Core Team 2020) and mapped using QGIS 3.16. (QGIS Development Team 2020).

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Tables

Table 1A. Summary of research vessel, hydrophone array and DAQ card combinations used throughout the study period (July-October 2021).

Survey Date	Survey Start (UTC)	Survey End (UTC)	Hydrophone	DAQ	Sampling Rate	Survey Area	Research Vessel
2021-07-22	2021-07-22 09:10:19	2021-07-22 13:35:47	Seiche SM2073	NI	500	SL,WL,NWL	Twin Engine
2021-07-26	2021-07-26 10:05:02	2021-07-26 13:17:38	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-08-10	2021-08-10 17:03:16	2021-08-10 20:18:09	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-08-17	2021-08-17 16:40:20	2021-08-17 20:31:52	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-09-07	2021-09-07 09:51:56	2021-09-07 14:27:55	Seiche SM2073	NI	500	SL,WL,NWL	Twin Engine
2021-09-08	2021-09-08 09:52:56	2021-09-08 13:13:15	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-10-20	2021-10-20 09:59:34	2021-10-20 13:57:59	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-10-25	2021-10-25 09:20:00	2021-10-25 12:12:38	Seiche SM2073	NI	500	SL,SEL	Twin Engine

Table 1B. Summary of research vessel, hydrophone array and DAQ card combinations used for MEEF2020005 and MEEF2020005A combined (January – October 2021).

Survey Date	Survey Start (UTC)	Survey End (UTC)	Hydrophone	DAQ	Sampling R	Survey Are	Research Vessel
2021-01-15	2021-01-15 10:46:44	2021-01-15 13:54:57	Seiche SM2073	NI	500	WL,NWL	Twin Engine
2021-01-21	2021-01-21 09:19:39	2021-01-21 13:47:53	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-01-22	2021-01-22 09:15:50	2021-01-22 12:37:32	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-01-27	2021-01-27 09:54:49	2021-01-27 14:19:09	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-02-22	2021-02-22 16:16:08	2021-02-22 20:08:16	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-02-25	2021-02-25 15:40:34	2021-02-25 19:23:00	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-03-01	2021-03-01 14:49:24	2021-03-01 18:15:24	Seiche SM2073	NI	500	SL,WL,NWL	Twin Engine
2021-03-04	2021-03-04 15:40:18	2021-03-04 19:52:38	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-04-12	2021-04-12 16:31:11	2021-04-12 20:31:27	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-04-13	2021-04-13 16:42:21	2021-04-13 20:20:38	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-05-04	2021-05-04 10:04:19	2021-05-04 12:03:01	Seiche SM2073	NI	500	SL,WL	Twin Engine
2021-05-13	2021-05-13 10:45:05	2021-05-13 16:48:50	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-06-02	2021-06-02 10:05:02	2021-06-02 13:56:30	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-06-03	2021-06-03 09:35:47	2021-06-03 13:10:35	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-07-22	2021-07-22 09:10:19	2021-07-22 13:35:47	Seiche SM2073	NI	500	SL,WL,NWL	Twin Engine
2021-07-26	2021-07-26 10:05:02	2021-07-26 13:17:38	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-08-10	2021-08-10 17:03:16	2021-08-10 20:18:09	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-08-17	2021-08-17 16:40:20	2021-08-17 20:31:52	Vanishing Point Serial Stereo	SAIL	500	SL,SEL	Single Engine
2021-09-07	2021-09-07 09:51:56	2021-09-07 14:27:55	Seiche SM2073	NI	500	SL,WL,NWL	Twin Engine
2021-09-08	2021-09-08 09:52:56	2021-09-08 13:13:15	Seiche SM2073	NI	500	NWL,NEL	Twin Engine
2021-10-20	2021-10-20 09:59:34	2021-10-20 13:57:59	Vanishing Point Serial Stereo	SAIL	500	SL	Single Engine
2021-10-25	2021-10-25 09:20:00	2021-10-25 12:12:38	Seiche SM2073	NI	500	SL,SEL	Twin Engine

Table 2. Categories and types of vessels.

Category	Type
Cargo	Container
	Dry Carrier
	Fish Carrier
	Liquid Carrier
Construction	Crane Barge
	Dredger
	Dumb Lighter
	Flat-top Barge
	Hopper Barge
	Pilot Boat
	Pelican Barge
	Tug
Fishing	Pair Trawler
	Stern Trawler
	Shrimp Trawler
	Hang Trawler
	Long liner
	Purse seiner
	Cage trapper
	P4
Government	AFCD
	Customs and Excise
	Marine Police
Passenger	
Pleasure	Junk
	Motorised Yacht
	Sailing Yacht
Other	

Table 3. PAMGuard Whistle and Moan detector parameters.

Maximum Frequency	Connection Type	Minimum Length	Minimum Total Size	Crossing / Joining	Maximum Cross Length	Median Filter Length	Subtraction Constant	Threshold
24 kHz	8 sides and diagonals	10 slices	20 pixels	Re-link	5 slices	61	0.02	8 dB

Figures

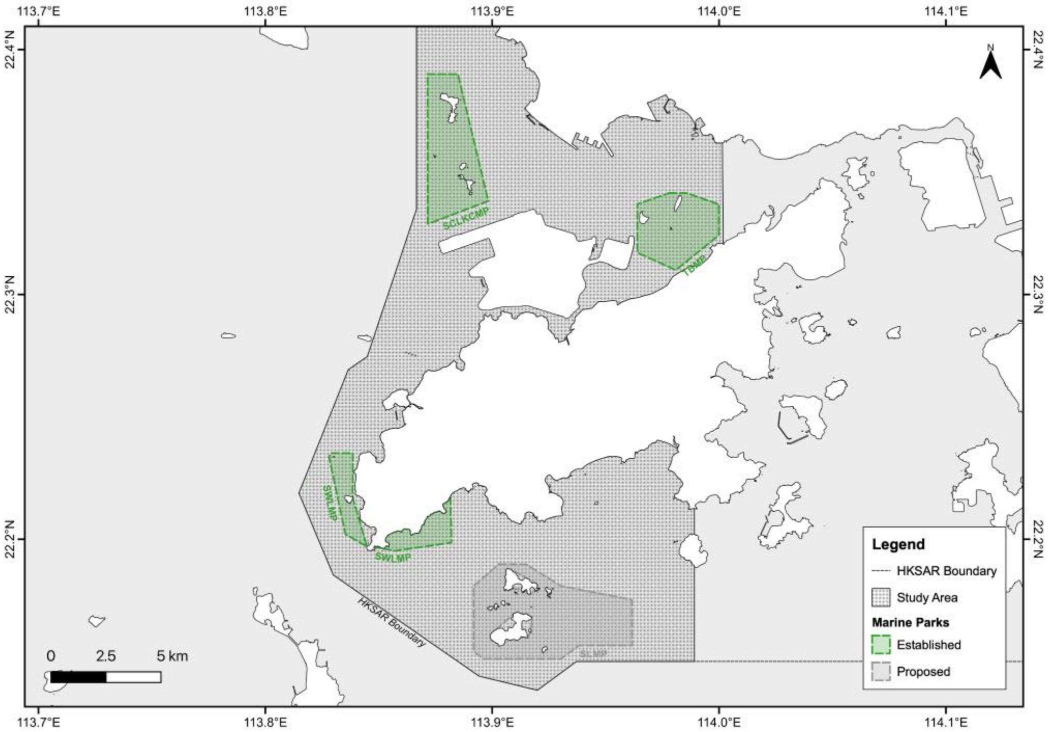

Figure 1. The study area encompassing The Brothers Marine Park (TBMP), Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP), Southwest Lantau (SWLMP) and South Lantau Marine Park (SLMP).

Figure 2. Line transects and survey areas (NEL, NWL, WL, SL, and SEL) for acoustic surveys.

Figure 3. The cabled hydrophone array (*Seiche*, United Kingdom) being deployed from the research vessel near the Soko Islands. An active illegal trawler operating in Hong Kong waters can be seen in the background.

Figure 4. A PAM operator monitoring the cabled hydrophone array, listening to the acoustic output and inputting relevant survey data into PAMGuard.

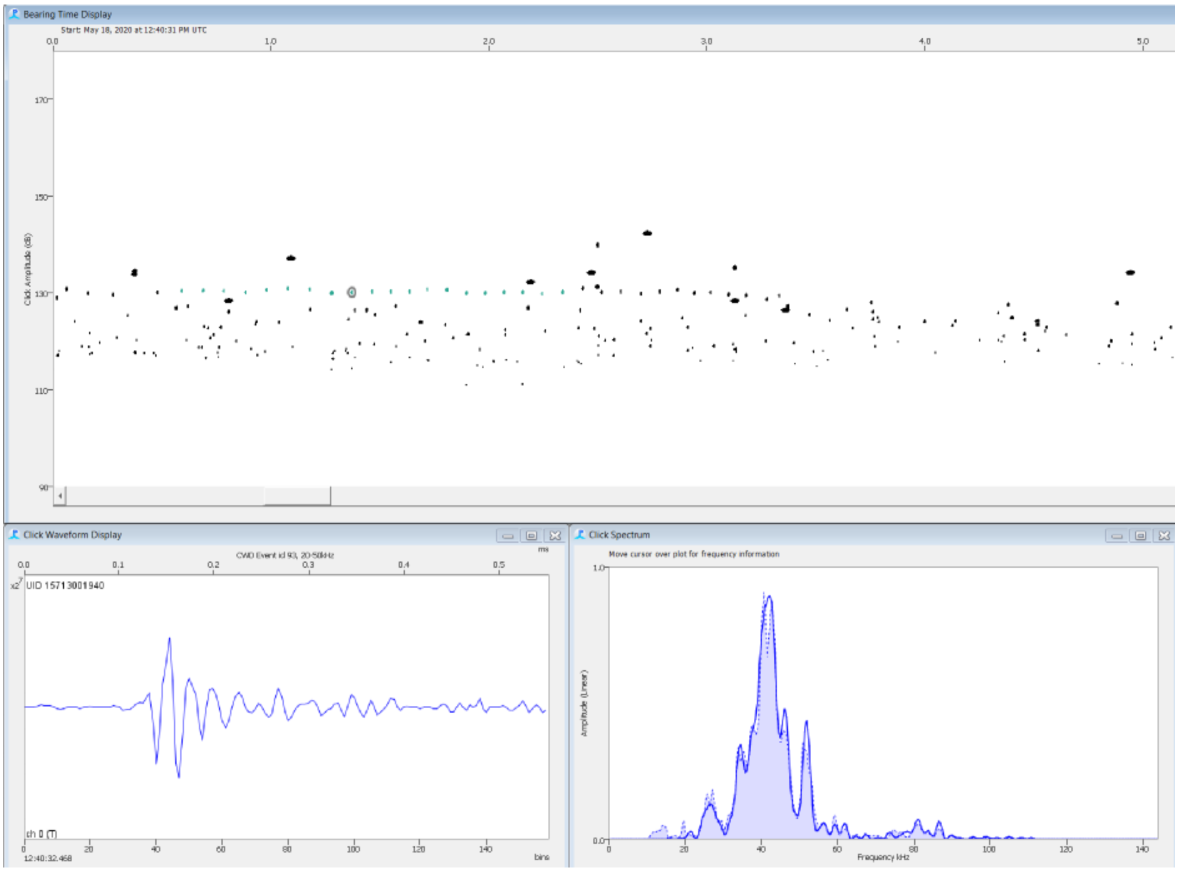

Figure 5. A typical CWD click (*Sousa chinensis*) identified in PAMGuard.

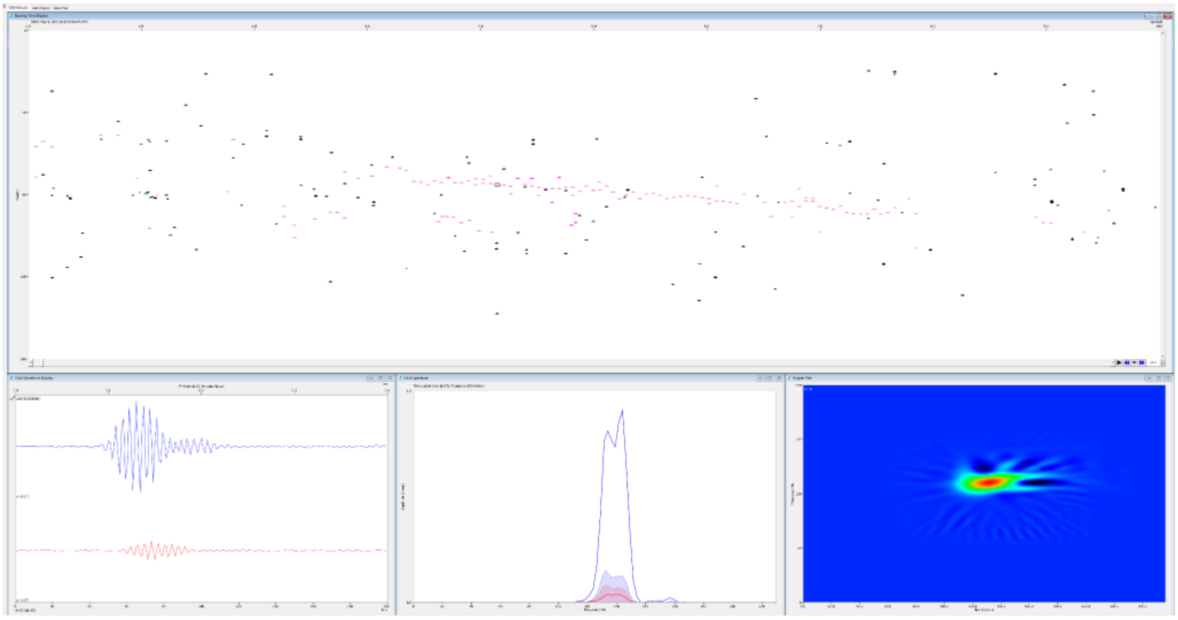

Figure 6. A typical Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) click identified in PAMGuard.

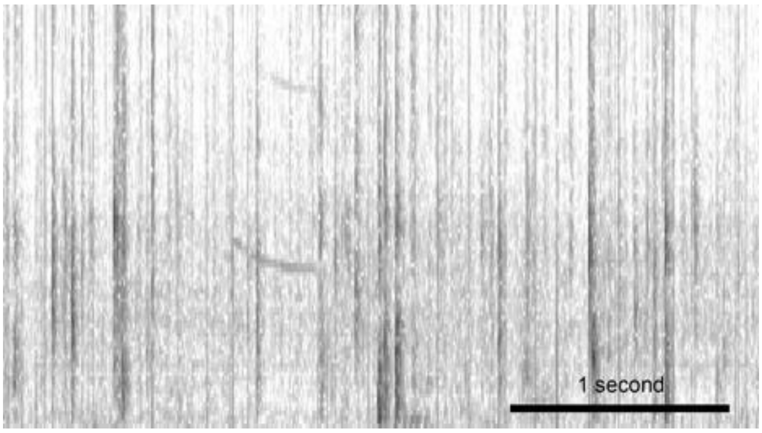

Figure 7. Spectrogram of a typical CWD (*Sousa chinensis*) whistle contour.

Appendix 6. Methods for *Activity 2: Static PAM Deployment*.

Data Collection

To investigate vessel presence within marine parks in Hong Kong waters, three PAM stations were established at Tai Mo To (Coordinates: 22.334133, 113.971083; Depth: 7 m) within TMBP; Peaked Hill (Coordinates: 22.219117, 113.836317; Depth: 6 m) within SWLMP; and Yuen Chau (Coordinates: 22.1727, 113.905283; Depth: 5 m) within SLMP (Figure 1). Each PAM station consisted of a 15 cm deep, 50 kg circular concrete platform with a 30 cm iron beam that permitted the attachment of archival underwater acoustic recorders (SoundTrap ST300 HF, *Ocean Instruments*, New Zealand) by divers (Figure 2). Each SoundTrap consisted of a calibrated, omnidirectional cylindrical hydrophone, preamplifier and digital recorder, which were set to record continuously at a sampling rate of 48 kHz, providing an effective recording bandwidth of 20 Hz to 24 kHz. Because these settings permitted a maximum recording duration of 13 days, two SoundTraps were deployed together (with the first SoundTrap triggered to start recording immediately and the second SoundTrap 13 days after the deployment date) to ensure a minimum of 21 days' coverage at each PAM station.

During deployment, SoundTraps at each PAM station were calibrated to permit transmission loss modelling as described in Kline et al. (2020). A rigid-hulled inflatable boat (RHIB) motored, at a constant speed of 10 kt, in three circles and an "X" centered on the PAM station (Figure 3), deviating where necessary to avoid nearby islands. The radii of the three circles were 250 m, 500 m and 1000 m, respectively. Two different RHIBs were used for the calibration: *Hato* (a 6.5 m RHIB with a single Suzuki 140 hp 4-stroke engine) at the Peaked Hill PAM station; and *Seawolf* (a 4.8 m RHIB with a single Mercury 60 hp 4-stroke engine) at the Yuen Chau and Tai Mo To PAM stations. A handheld GPS (Garmin GPSMAP 78S, *Garmin*, United States) was used to record timestamped calibration tracks, which provided known distances of the RHIB to the SoundTrap.

References

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Figures

Figure 1. Static PAM stations established in The Brothers Marine Park (TBMP) at Tai Mo To, Southwest Lantau Marine Park (SWLMP) at Peaked Hill and South Lantau Marine Park (SLMP) at Yuen Chau.

Figure 2. A diver preparing to deploy at SoundTrap ST300 HF (*Ocean Instruments*, New Zealand) at the Peaked Hill static PAM station in Southwest Lantau Marine Park (SWLMP).

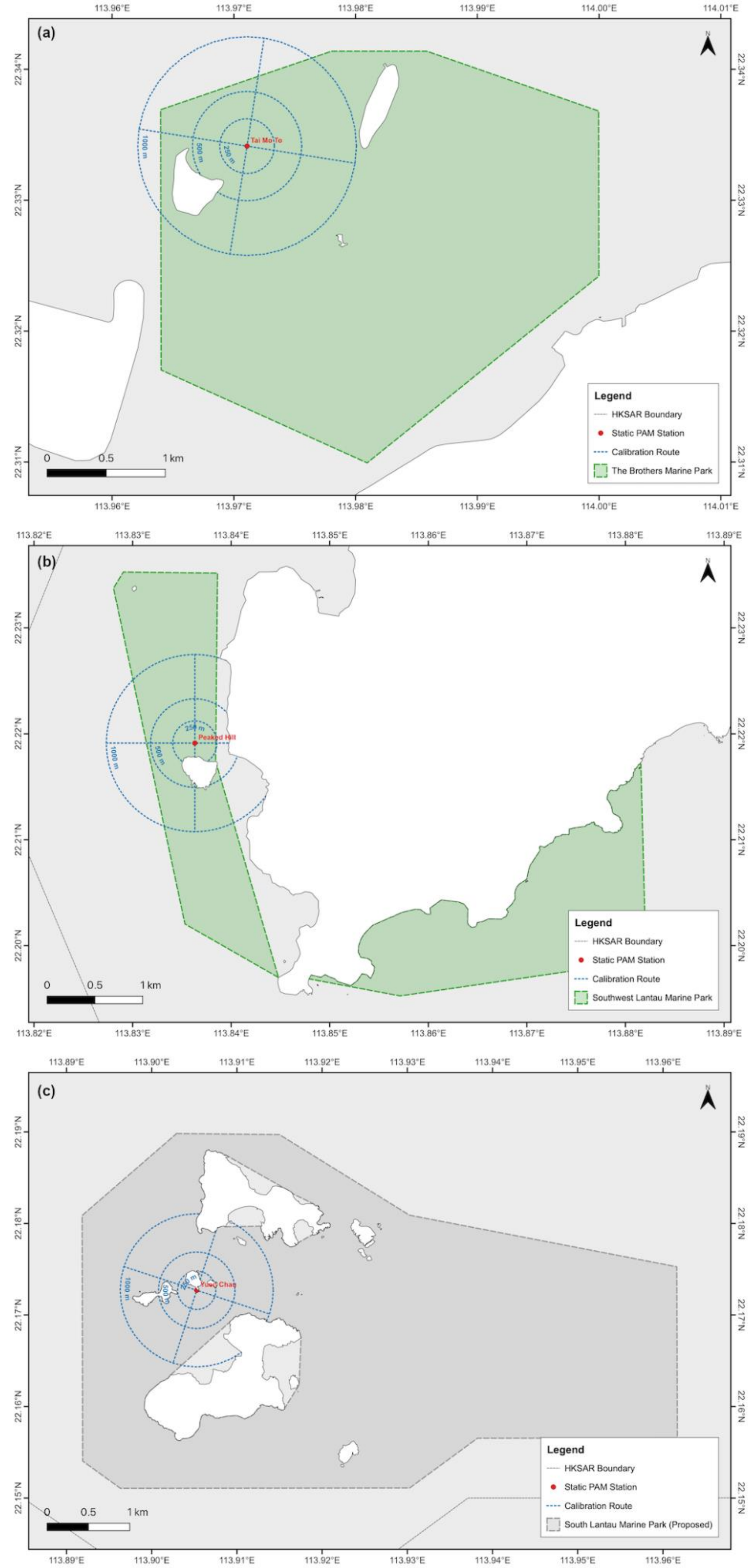

Figure 3. Calibration tracks of the **(a)** Tai Mo To, **(b)** Peaked Hill and **(c)** Yuen Chau static PAM stations.

Appendix 7. Results for *Activity 6: Data Analyses* for static PAM deployments at Yuen Chau (SLMP), Peaked Hill (SWLMP) and Tai Mo T (TMBP).

Acoustic monitoring of vessel activity in three Marine Protected Area, Hong Kong SAR

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Introduction

The marine environments of Hong Kong are home to an extensive range of marine resources. These ecosystems are threatened by anthropogenic influence such as vessel traffic, unregulated fishing, and other illegal activity. Marine protected areas (MPAs) are designated marine areas in which management efforts are taken for the purposes of ocean conservation and management. Currently, 5% of Hong Kong waters are designated or planned to be established as MPAs by 2023 and are essential for long-term viability of marine resources (WWF Hong Kong, 2021).

Passive acoustic monitoring (PAM) has previously been found to be a useful tool for assessing vessel presence in marine environments (McCordic et al., 2020). For this project, we examine the use of PAM to monitor vessel presence in MPAs in Hong Kong, where extractive activities are restricted. These MPAs are located within marine parks that provide important habitats and feeding resources of the threatened Chinese white dolphin and other marine species (McCook et al., 2019).

Successful management of MPAs relies on effective enforcement and compliance. Therefore, monitoring of vessel movement within these areas is important to achieve management goals (McCook et al., 2019). Utilizing PAM in marine environments allows us to analyze vessel movement within and surrounding a given area (Howe et al., 2019). Understanding the patterns and behaviours of vessel movement in these areas is useful in determining the likelihood of potential illegal activity at a given time.

Analysis of these data may be advantageous to protecting biodiversity and long-term viability of marine resources within each respective MPA. The remote and autonomous nature of this monitoring technique is not limited by environmental factors such as weather or daylight (Kline et al., 2020). Therefore, this method provides valuable information to complement other monitoring methods such as manned patrols and aerial surveillance (Read et al., 2019). These data show us patterns of vessel use over time, indicating the highest likelihood of when illegal activity may occur. This provides insight into possible management and enforcement conditions to reduce noncompliance. In conjunction with other monitoring methods, this technique can aid in enforcement practices and lead to an increase in overall compliance.

For this study, acoustic recorders were deployed at three sites within Hong Kong waters. Yuen Chau (YCH) falls within the South Lantau Marine Park. This park was proposed by the government of Hong Kong in 2020 and designated as this study was underway (Government of the Hong Kong Special Administrative Region, 2020). Peaked Hill (PKH) lays within the Southwest Lantau Marine Park, designated in April 2020 (AFCD, 2021). Tai Mo To (TMT) is located within The Brothers Marine Park, designated in December 2016 (AFCD, 2021) (Fig. 1).

Methods

Site description and recording effort

SoundTrap 300 STD acoustic recorders (Ocean Instruments, Inc.) were deployed within three MPAs near Hong Kong Harbor (Fig. 1). At YCH, two recorders were deployed on 02 February 2021. The first (YCH D1) recorded for a total of 17 days from 02 February 2021 – 18 February 2021. The second acoustic recorder at this site was programmed to delay recording until 15 February to maximize total recording time. This second deployment (YCH D2) recorded from 15 February 2021 – 01 March 2021 for a total of 15 days. At PKH, two recorders were initially deployed in a similar configuration as YCH; however, the second deployment failed, resulting in a single deployment (PKH D1) lasting 14 days from 25 March 2021 – 07 April 2021. For TMT, two recorders were similarly deployed on 26 May 2021. The first deployment (TMT D1) recorded from 26 May 2021– 08 June 2021, and the second deployment (TMT D2) was programmed to start on 08 June 2021 and recorded until 21 June 2021. All sites are shallow (YCH = 5 meters, PKH = 6 meters, TMT = 5 meters) and are situated near small islands (Table 1; Fig. 1).

Table 1: Summary of recording effort.

Site	Location	Depth (m)	Recording Dates	N Days	Full System Sensitivity (dB re 1 V/μPa)
Yuen Chau	22.1727 N 113.9053 E	5	D1: 02 Feb. – 18 Feb. 2021	17	-172.7
			D2: 15 Feb. – 01 Mar. 2021	15	-172.5
Peaked Hill	22.2191 N 113.8363 E	6	D1: 25 Mar. – 07 Apr. 2021	14	-172.4
Tai Mo To	22.3341 N 113.9711 E	5	D1: 26 May – 08 Jun. 2021	13	-172.4
			D2: 08 Jun. – 21 Jun. 2021	13	-172.8

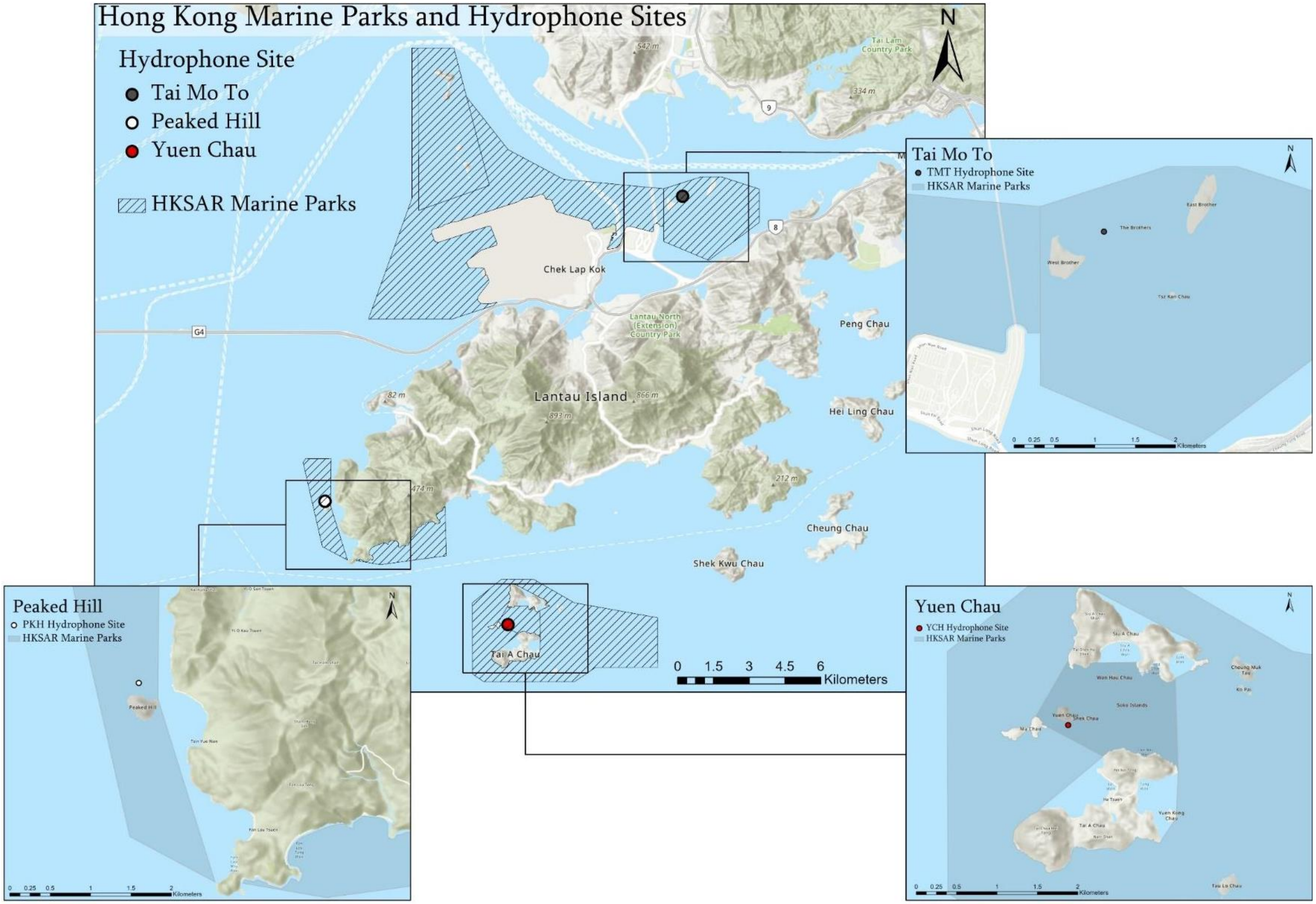

Figure 1: Deployment locations within Hong Kong marine park boundaries: Peaked Hill (bottom left, white circle) within Southwest Lantau Marine Park, Yuen Chau (bottom right, red circle) within the South Lantau Marine Park, and Tai Mo To (top left, black circle) within The Brothers Marine Park.

Propagation modeling

In order to estimate the distance of unknown vessels to the recorder, the deployment vessel completed calibration tracks similar to those described in Kline et al. (2020). After deploying the recorder, the vessel drove in three circles centered on the recorder location with radii of approximately 250m, 500m, and 1000m as well as an "X" pattern centered on the recorder. The route included deviations when necessary to account for nearby islands. Timestamped GPS locations were provided for these tracks to provide known distances from the recorder to the vessel that could be associated with measured received levels from the same vessel at those times. According to the passive sonar equation (Eq. 1),

$$(\boldsymbol{Eq.1})\ RL = SL - TL$$

received level (RL, dB re 1µPa) is equivalent to the source level (SL, dB re 1µPa at 1m) minus any transmission loss (TL, dB re 1µPa). A geometric model of TL is further defined by the distance between the source and receiver (r) as well as coefficients of spreading loss (a) and absorption of sound by the surrounding medium (α) (Eq. 2).

$$(\boldsymbol{Eq.2})\ TL = \left(alog_{10}(r) + \alpha(r)\right)$$

The GPS locations taken around the recorders by the patrol boats allowed estimations of SL and TL at each site based on the known range of the vessels to the recorders at particular times. These locations were partitioned into main sub-tracks and transit sub-tracks that contained points which corresponded to times in the recordings. GPS locations were separated into three inner, middle, and outer sub-tracks at roughly 250, 500, and 1000 m, respectively, from the recorders. Additionally, two transit sub-tracks of inner-middle and middle-outer were specified to provide intermediate distances.

Using ArcGIS Pro, the ranges between each GPS location for the deployment vessel and recorder were calculated. For each main and transit sub-track at each site, 15 to 20 GPS patrol boat locations were selected at intervals respective to each sub-track's sample size (i.e., the number of GPS points in each sub-track). This resulted in 110 location selections for YCH, 141 location selections for PKH, and 146 location selections for TMT. Raven Pro 2.0 was used to view spectrograms of recordings concurrent with each of the sampled GPS locations. Using a padding of 2.5 seconds on either side of each location's timestamp in the acoustic data, five-second sound clips were generated, annotated with the calculated ranges of each sample track location to the recorder, and exported. Any sample locations that overlapped the data captured in another sound clip were removed from analysis.

The software MATLAB (R2017a, The MathWorks Inc.) was then used to calculate the peak frequency (Hz) and RL centered on the peak frequency of each sound clip. Peak frequencies were manually verified in Raven Pro 2.0 to ensure they belonged to the deployment vessel and did not result from other sound sources. In cases where the peak frequency resulted from a different source (e.g., cetacean calls or fish grunts), the sample was removed from the following analysis.

MATLAB was used to fit a regression curve for each site based on Eq. 3 for each GPS location's RL and range. The fit was parameterized with SL, a, and α as unknowns. Model fit was assessed using the Curve-Fitting App in MATLAB, and outliers were removed where necessary to preserve a plausible range of parameter values. The resulting equations provided estimates of the SL of the patrol boat and empirically derived models of TL in the environments for each site that were used to estimate probable ranges of discrete vessel events based on size classes and simulated SLs.

$$(\boldsymbol{Eq.3})\ RL = SL - \left(a log_{10}(r) + \alpha(r)\right)$$

Detecting unknown vessels

Using the Ship Detector Remora attached to Triton software (version 1.93.20160524), potential vessel passages were automatically selected from a long-term spectral average (LTSA) of each deployment. The ship detector within the Triton software has been successful in detecting vessels in other datasets (Kendall et al., 2020); however, this is the first time it was used for these sites. Thus we conducted a hybrid methodology using the results from the detector with a manual review of the data to examine whether the detector's performance was sufficient for this project.

The detector uses a long-term spectral average (LTSA) as the base for detecting vessels. The LTSA for each deployment was computed using 5s/48Hz bin averages. Detections were recorded and stored if specific criteria were met regarding amplitude, duration, relative frequency components, and signal-to-noise ratio of the detected sound to the background noise. To remain consistent with previous protocols for manual review (see Kline et al., 2020), we adjusted detection parameters to exclude vessels which only contained low-frequency components in the vessel signature ($\leq$ 500 Hz). Detection parameters were also adjusted to avoid false positive detections from fish chorusing. In addition to detecting events of interest, the ship detector classified each detection as 'ship' or 'ambient' based on relative frequency components.

For all potential vessel detections, we used Raven Pro 2.0 (Center for Conservation Bioacoustics, 2014) to review spectrograms at a finer time and frequency resolution to confirm presence or absence of a vessel as well as to obtain more precise start and end times to calculate duration of any vessels. For any intervals without vessel noise occurring between two similar signatures, if the interval lasted longer than 1.5 minutes, the original vessel signature was split into two discrete vessels. Fine-scale spectrograms were also used to assign vessel behaviour based on probable distance from the recorder and presence of potential maneuvers indicated by discrete changes in frequency or amplitude of the vessel signatures (Kline et al., 2020) (Table 2).

To assess detector performance, recall (ability to correctly select either 'ship' or 'ambient' events fitting the detection parameters) and precision (ability to correctly identify true vessel events as 'ship') were calculated as follows: Recall = N True Detections / N Total True Events; Precision = N True Detections / N Total Ship Detections (Baumgartner et al., 2019). For YCH D1, after running the detector, we manually reviewed the LTSA calculated in Triton to look for any vessel signatures that may have been missed by the detector. Potential vessels found during this step were compared against the start and end times of automated detections to determine if they were new vessels. Any new vessels were reviewed using spectrograms in Raven Pro 2.0 as described above to determine start and end times as well as vessel behaviour. Precision was calculated for all deployments following manual review of detected events.

Table 2: Definitions of vessel behaviours

Behaviour	Description	Spectrogram characteristics
TB	Distant transit	Consistent horizontal frequency bands without any abrupt changes in frequency or amplitude; visible harmonics and subharmonics up to ~2 kHz
TA	Close transit	Consistent horizontal frequency bands without any abrupt changes in frequency or amplitude; visible harmonics and subharmonics continue above ~2 kHz
TA + M	Close transit with a maneuver	Portions of vessel signature contain consistent horizontal frequency bands; at least 1 abrupt change in frequency or amplitude; visible harmonics and subharmonics continue above ~2 kHz
CPA	Closest point of approach	Distinctive Doppler-related U-shape of frequency bands at any point during vessel signature indicating close approach to the recorder; no other notable changes in frequency or amplitude
CPA + M	CPA with a maneuver	Distinctive Doppler-related U-shape of frequency bands at any point during vessel signature indicating close approach to the recorder; at least 1 abrupt change in frequency or amplitude

Determining vessel presence within MPA boundaries

For discrete vessels with unknown parameters detected by the recorders at each site, around ten seconds of relatively "clean" (i.e., containing little biological noise) selections of vessel noise were taken from times where the signal of vessel noise was greater than that of surrounding background noise, including biological noise. Vessels often did not have ten consecutive seconds of clean data; in these cases, multiple selections greater than one second were made in different parts of the vessel's spectrogram. When vessels did not have any periods of clean data due to overlapping biological sounds (e.g., fish chorusing throughout original vessel selection) or the acoustic signature was hard to distinguish due to a low signal-to-noise ratio, selections were not made, and that vessel was eliminated from the size class and range analysis. Selections were made where it was assumed the vessel was making its closest point of approach (i.e., the lowest portion of the "bath tub" for CPAs and times of greatest estimated acoustic pressure for other behaviour classes). These selections were exported as sound clips.

Each vessel sample sound clip was run through custom-made MATLAB scripts that calculated peak frequency and peak RL. As with the deployment vessel clips used to model the TL parameters, peak frequencies were manually checked in Raven Pro 2.0 to ensure that the script was not selecting other sources. For TMT, peak frequency values were restricted to the frequency range of a single TOL band centered on 125 Hz (range 113 – 141 Hz). Correct samples with the highest peak RLs were selected for each vessel to be used for further analysis. In some instances, the script was unable to generate accurate peak frequencies for any of the samples taken; these were eliminated from further range and vessel size class analysis. The correct samples selected in this step were then used to calculate SLs.

Using SLs and vessel types reported in the literature (Barlett and Wilson, 2002; Hatch et al., 2008), SLs were separated into three categories: small (vessels such as RHIBs and small outboard boats), medium (vessels such as trawlers and yachts), and large (vessels such as cargo and cruise ships) (Table 3). Each vessel category corresponds with a range of SLs (small = 125–150 dB re 1 µPa/Hz, medium = 151–170 dB re 1 µPa/Hz, large = 171–180 dB re 1 µPa/Hz). Since we cannot directly measure SL values from unknown vessels, plausible SL values were modelled at each range based on the measured RL values for each vessel along with the modelled TL equation. For each RL, the SL of simulated hypothetical vessels was calculated every 10 meters from 1 to the maximum detection range of the loudest medium-sized vessel (170 dB re 1 µPa/Hz). The maximum detection range was calculated by rearranging the passive sonar equation (Eq. 4a) and estimating TL when signal excess (SE) equaled zero (Eq. 4b). To estimate the range at which TL would result in RL being equal to background noise levels (NL) and therefore undetectable (signal-to-noise ratio = 0), the range parameter (r) in the modeled TL equation was solved for using the SL of medium-sized vessels and the 50th percentile of ambient noise levels (NL_{50}) in the third-octave level (TOL) band containing the majority of peak frequency values of vessel sample sound clips (Eq. 4c). NL_{50} was measured from in-situ recordings across the deployment duration with custom MATLAB scripts.

$$(\boldsymbol{Eq.4a})\ SE = SL - TL - NL$$
$$(\boldsymbol{Eq.4b})\ TL = SL - NL$$
$$(\boldsymbol{Eq.4c})\ a\log_{10}(r) + \alpha(r) = 170\ dB - NL_{50}$$

Table 3: Vessel size classes (small, medium, and large) and length ranges with examples of vessel types attributed to each class, recorded source level ranges, and literature contributing to these data.

Class	**Size (m)**	**Examples**	**dB re 1 µPa/Hz Range**	**Source**
Small	≤ 7.0	RHIBs, small outboard engines	125–150	Barlett and Wilson (2002)
Medium	7.1–40	Fishing boats, trawlers, yachts, tugs	151–170	Hatch et al. (2008)
Large	41–250	Cruise ships, tankers, cargo ships	171–180	Hatch et al. (2008)

Since directionality is unknown using a single recorder, the representative distance from an acoustic recorder to the park boundary was calculated as the mean of distances measured between the recorder and the park boundary or nearest point of land at 45 degree intervals (8 measurements; mean = 1201 meters for YCH, 679 meters for PKH, 1512 meters for TMT).

Vessels that travel within the MPA boundaries are more likely to be medium and small vessel classes (Kline et al., 2020). Using the probability of all three size classes inflates the probability that a vessel will be categorized as outside of the park, as the large vessel class is almost always found to be outside of the park. Therefore, the probability of a vessel being inside of YCH or PKH was calculated only with small and medium size class probabilities. In order to determine whether a discrete vessel of small or medium size would be inside of the marine park, the probability (P_{in}) was computed using Eq. 5, where N is the number of vessels defined by size class and inside or outside the park boundary.

$$(Eq. 5)\ P_{in} = \frac{N_{small\ in} + N_{medium\ in}}{N_{small\ in} + N_{small\ out} + N_{medium\ in} + N_{medium\ out}}$$

A vessel was categorized as inside of the park if Pin ≥ 0.75. To determine the probability of an individual vessel size class being inside the park (Pclass in), the number of SLs within the park for each vessel class (small and medium) was divided by the total number of SLs that occurred inside and outside of the park for that class (Eq. 6).

$$(Eq. 6)\ P_{class\ in} = \frac{N_{class\ in}}{N_{class\ in} + N_{class\ out}}$$

Tidal influence on vessels within park boundaries

To determine any influence of tides on vessel presence within park boundaries, we assigned each vessel to one of four tidal phases based on hourly tide heights from Shek Pik (YCH and PKH) and Chek Lap Kok (TMT) (Hong Kong Observatory): ebb, flood, high, and low. The Hong Kong region experiences semi-diurnal mixed tides, and we classified tidal phase based on the trend in tidal height between successive hours. The ebb phase is represented by successive hours of decreasing height, while the flood phase is represented by successive hours of increasing height. High and low tide were determined as instances of a switch in the height trend from flood to ebb or ebb to flood, respectively. This approach accounts for any irregular intervals between multiple ebb and flood cycles per day as well as high and low tides of different heights within the same day.

Results

Detector Performance

Within the first deployment period (D1) at Yuen Chau, the vessel detector identified 278 events. Upon manual review, it was found that the detector correctly identified 229 unique vessels and 4 ambient events. The detector incorrectly identified 15 ambient events as vessel noise. It also identified 30 vessel signatures as ambient events. An additional 389 vessels were found via manual review of the LTSA for a total of 626 vessel signatures (Table 4). Detections used to measure detector performance include vessels under 500 Hz, which are not used in further analysis throughout this report.

These data have a recall value of 0.353, indicating that the detector was able to recall or detect 35.3% of acoustic events throughout the recording. Of the recalled events, the detector was found to be relatively precise (precision = 0.939) in accurately identifying vessel signatures or ambient events.

Table 4: Detection matrix for automated ship detector used in Yuen Chau deployment 1 (YCH D1). The predicted condition indicates the number of events the detector identified as either "ship" or "ambient", and the true condition indicates the number of events identified by manually reviewing the detections and the LTSA.

YCH D1				
		True Condition		
		Ship	Ambient	Total
Predicted Condition	Ship	229	15	244
	Ambient	397	4	--
	Total	626	n/a	--

For the purposes of this study, manual review of the LTSA was only performed for YCH D1 to analyze detector performance, and any additional vessels discovered during manual review of the LTSA are not included in analyses beyond detector performance. This step was not included in the analysis of the second deployment at Yuen Chau (YCH D2), the deployment at Peaked Hill (PKH), or either deployment at Tai Mo To (TMT). Precision values were high across all deployments (range 0.939 – 0.997), indicating that the detector accurately identified a high percentage of events as ships (Table 5).

For YCH D2, a total of 213 vessels were identified via the detector in combination with manual review. In addition, a total of 347 vessels were identified during the deployment period at Peaked Hill via the vessel detector in combination with manual review, 12 of which are under 500 Hz and not included in analysis. For TMT D1, a total of 325 unique vessels were identified via the detector and manual review, including two vessels under 500 Hz which are not included in analysis. For TMT D2, a total of 355 vessels were identified via the detector and manual review, including 9 vessels under 500 Hz which are not used in analysis throughout this report.

Table 5: Precision values of events detected using the automated ship detector throughout each deployment. PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2.

	True Positive	**False Positive**	**Precision**
YCH D1	229	15	0.939
YCH D2	163	9	0.948
PKH D1	307	10	0.968
TMT D1	338	1	0.997
TMT D2	416	2	0.995

Patterns of Vessel Presence

Consistent vessel presence occurred over each deployment at all sites. During the first deployment at Yuen Chau (YCH D1) (02 Feb. 2021 – 18 Feb. 2021), vessel signatures were detected on each consecutive day of the first deployment (17/17 days present = 100%, N = 237 vessels) (Fig. 2). The majority of vessels detected during this deployment are classified as TA+M (N = 128, 54.0%). The second most frequent behaviour is TB (N = 64, 27.0%); followed by CPA+M (N = 22, 9.28%), TA (N = 21, 8.86%), and the least frequent behaviour present is CPA (N = 2, 0.844%) (Table 6).

During the second deployment at Yuen Chau (YCH D2) (14 Feb. 2021 – 01 Mar. 2021), vessel signatures were also present on each consecutive day (15/15 days present = 100%, N = 193 vessels) (Fig. 2). YCH D2 followed the same pattern of vessel presence as YCH D1. The vessel signatures are dominated by the TA+M behavioural category (N = 111, 57.5%). The second most frequent behaviour is TB (N = 40, 20.7%); followed by TA (N = 25, 13.0%), CPA+M (N = 14, 7.3%) and the least frequent category is CPA (N = 3, 1.6%) (Table 6).

At Peaked Hill (PKH D1), vessel signatures were detected on each consecutive day of the first deployment (25 Mar. 2021 – 07 Apr. 2021) (14/14 days present = 100%, N = 335 vessels) (Fig. 2). The behavioral patterns at PKH D1 are primarily driven by the CPA+M category (N = 137, 40.9%). This deployment observed similar occurrences of the behaviours CPA (N = 56, 16.7%), TA+M (N = 55, 16.4%), and TB (N = 52, 15.5%). The least frequent behaviour that occurred is TA (N = 35, 10.4%) (Table 6).

During the first deployment at Tai Mo To (TMT D1) (26 May 2021 – 08 June 2021), vessel presence was observed on each consecutive day (14/14 days present = 100%, N = 323) (Fig. 2). The behavioral patterns of this deployment are driven by the CPA+M vessel category (N = 94, 29.1%). This deployment observed equal occurrences of CPA and TA+M vessel signatures (N = 68, 21.1% each). The next most frequent behaviour was TB (N = 52, 16.1%) The least frequent behaviour observed at TMT D1 is TA (N = 41, 12.7%) (Table 6).

During the second deployment at Tai Mo To (TMT D2) (08 June 2021 – 21 June 2021), vessel presence was observed on each consecutive day (14/14 days present = 100%, N =346) (Fig. 2). Like TMT D1, the behavioral patterns of this deployment are driven by CPA+M vessel signatures (N = 89, 25.8%). This is followed by CPA (N = 85, 24.6%). The next most frequently observed vessel signatures are TB (N = 63, 18.2%) and TA+M (N = 61, 17.6%). Like TMT D1, the least frequently observed behavioral category at TMT D2 is TA (N = 48, 13.9%) (Table 6).

Despite a smaller overall duration range at TMT D1 and TMT D2 (0.396 – 490 min and 0.435 – 485 min, respectively) than at YCH D1, YCH D2 (0.505 – 376 min and 1.05 – 548 min, respectively) and PKH D1 (0.980 – 570 min), longer periods of vessel duration were observed at TMT D1 and TMT D2 (median = 41.7 and 45.0 min, respectively) than at YCH D1, YCH D2 (median = 16.2 and 17.5 min, respectively) and PKH D1 (27.4 min). The results reflect a duration median for TA+M at PKH greater than twice that of both YCH D1 and YCH D2 despite a smaller duration range at PKH D1 than YCH D1 and YCH D2.

Table 6: Summary of vessel behaviours and duration during each deployment at each site.

	Behaviour	**N Vessels**	**Duration Range (minutes)**	**Duration Median (Minutes)**
YCH D1	**CPA**	2	3.34 – 8.85	6.10
	CPA+M	22	1.97 – 138	17.8
	TA	21	1.90 – 74.0	15.3
	TA+M	128	0.505 – 376	18.7
	TB	64	1.20 – 293	15.2
	Total	237	0.505 – 376	16.2
YCH D2	**CPA**	3	12.5 – 47.9	17.4
	CPA+M	14	1.91 – 95.4	13.0
	TA	25	1.41 – 94.7	16.2
	TA+M	111	1.05 – 548	16.9
	TB	40	1.52 – 199	18.8
	Total	193	1.05 – 548	17.5
PKH D1	**CPA**	56	1.43 – 116	9.38
	CPA+M	137	1.55 – 570	29.1
	TA	35	1.63 – 85.0	21.9
	TA+M	55	1.38 – 213	41.6
	TB	52	0.980 – 262	31.5
	Total	335	0.980 – 570	27.4
TMT D1	**CPA**	68	1.12 – 168	30.6
	CPA+M	94	0.824 – 490	34.4
	TA	41	3.96 – 255	48.4
	TA+M	68	1.65 – 433	37.4
	TB	52	0.396 – 367	43.0
	Total	323	0.396 – 490	41.7
TMT D2	**CPA**	85	0.815 – 390	35.7
	CPA+M	89	0.435 – 485	50.5
	TA	48	3.78 – 441	46.8
	TA+M	61	0.783 – 340	37.5
	TB	63	6.15 – 355	47.5
	Total	346	0.435 – 485	45.0

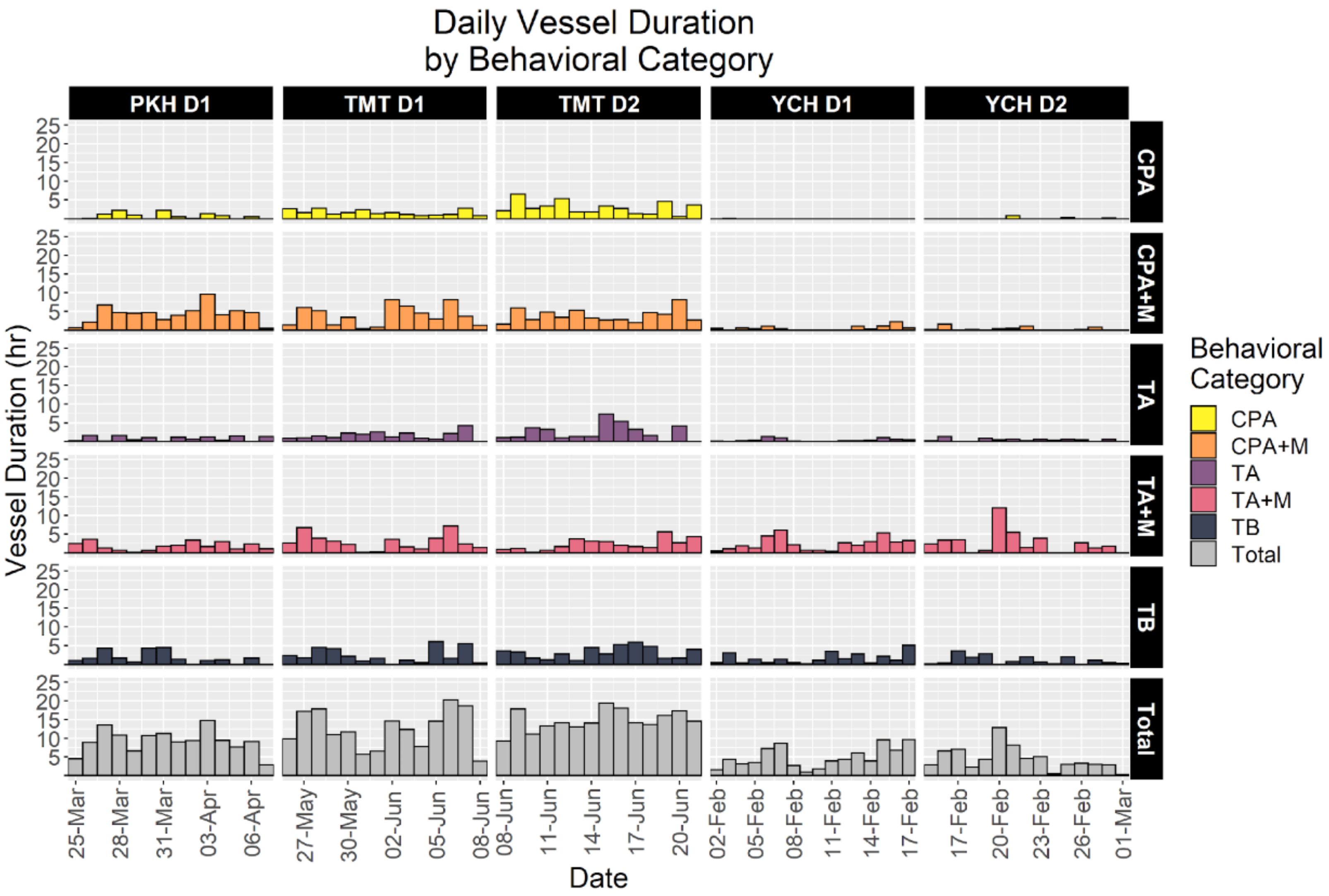

Figure 2: Daily vessel duration (hour) separated by behavioral category at each deployment at each site. PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Weekday Vessel Presence

Yuen Chau

During YCH D1, the highest number of total vessels occurred on Sundays (N = 40, 16.8%). Fridays and Saturdays also had higher vessel activity (N = 37, 15.6% and N = 36, 15.2%, respectively). The lowest number of vessels occurred on Thursdays and Tuesdays (N = 25, 10.5% and N = 32, 13.5%, respectively) (Fig. 3). On Sundays during YCH D1, when the highest number of vessels was recorded, TA+M vessel signatures accounted for 65.0% of total vessels.

During YCH D2, the highest number of vessels occurred on Tuesdays and Saturdays (N = 36, 18.7% each day), followed by Sundays (N = 35, 18.1%). The fewest amount of vessels was recorded on Wednesdays (N = 15, 10.4%) (Fig. 3). TA+M vessel signatures accounted for 69.4% of total vessels on Saturdays, when the highest number of vessels was recorded.

Peaked Hill

At PKH D2, the highest percentage of vessels per day occurred on weekends (N = 77, 23.0% Sundays and N = 66, 19.7% Saturdays), followed by Fridays (N = 55, 16.4%). The fewest number of vessels occurred on Wednesdays (N = 26, 7.8%), followed by Tuesdays (N = 34, 10.1%) (Fig. 3). These weekday trends are driven by CPA and CPA+M vessel signatures. On Sundays, when the highest number of vessels was recorded, CPA and CPA+M vessel signatures accounted for 32.4% and 29.9% of total vessels.

Tai Mo To

During TMT D1, the highest number of vessels was recorded on weekends (N = 60, 18.6% on both Sundays and Saturdays) (Fig. 3). The fewest number of vessels was recorded on Tuesdays and Wednesdays (N = 36, 11.2% each). An equal number of vessels was observed on Thursdays and Fridays (N = 41, 12.7%). These weekday trends are driven by TA+M and CPA+M vessel signatures. On Sundays, TA+M and CPA+M vessel signatures accounted for 30.0% and 26.7% of observed vessels, respectively. On Saturdays, TA+M and CPA+M vessel signatures accounted for 26.7% and 25.0% of observed vessels, respectively.

During TMT D2, the highest number of vessels was observed on Fridays (N = 58, 16.8%), followed by weekend days (N = 57, 16.5% Saturdays and N = 44, 12.7% Sundays). An equal number of vessels occurred on Mondays and Thursdays (N = 48, 13.9% each), followed by Wednesdays (N = 47, 13.6). The fewest number of vessels were observed on Tuesdays (N = 44, 12.7%) (Fig 3). These weekday trends are driven by CPA+M vessel signatures. On Fridays, when the highest number of vessels was recorded, CPA+M vessel signatures accounted for 37.9 of total vessels.

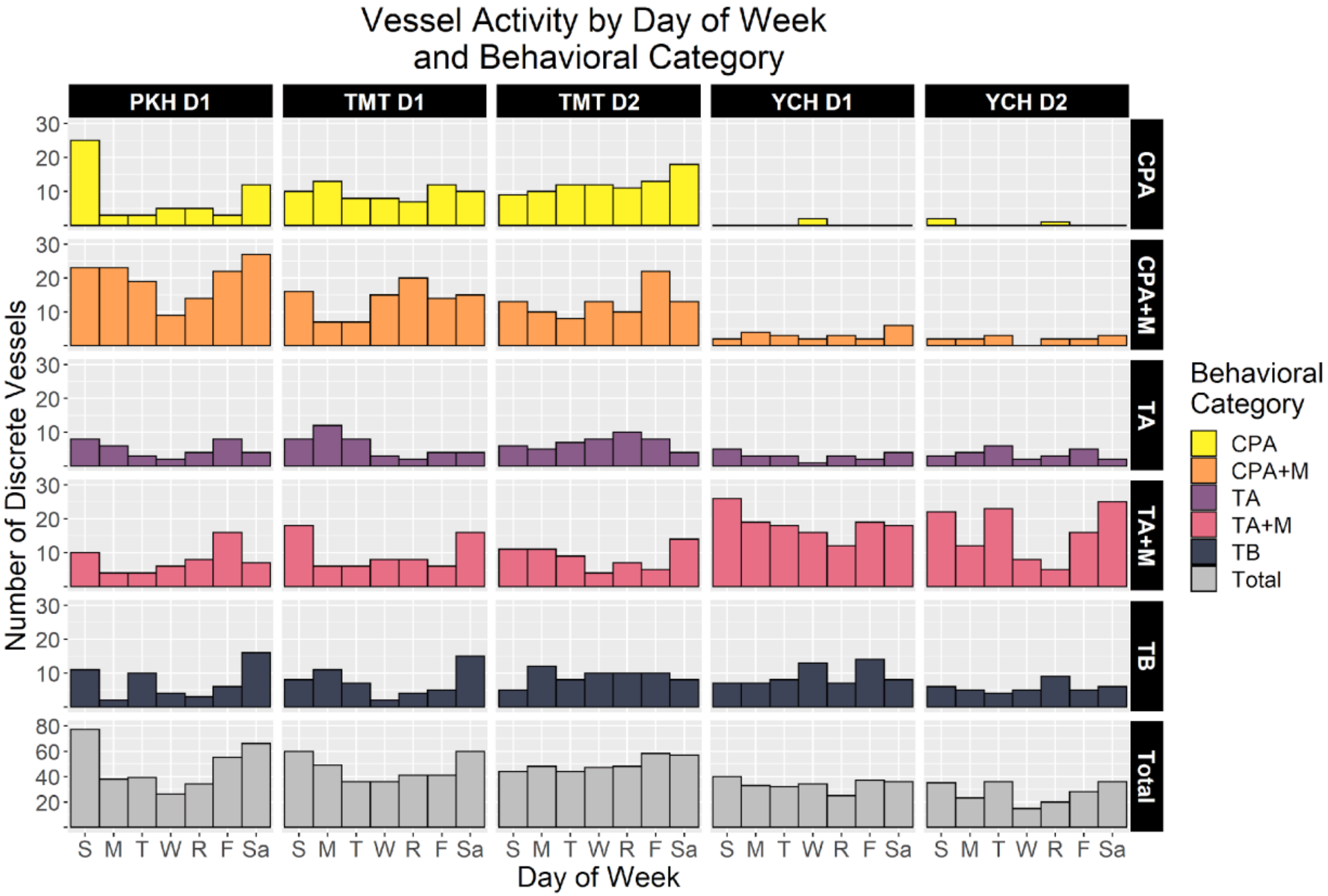

Figure 3: Vessel activity by day of week and behavioral category over each deployment at each site. PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Diel Vessel Presence

Yuen Chau

At YCH D1, vessel presence was highest between the late morning and early afternoon, from 10:00 – 15:00 HKT (N = 19, 8.0%; N= 24, 10.1%; N = 20, 8.4%; N = 20, 8.4%; N = 14, 5.9%; N = 21, 8.9% for each respective hour). TA+M vessel signatures followed consistent diel patterns and represent the primary influence in these diel patterns for total vessel presence across all behaviours (10:00 N = 14, 73.6%; 11:00 N = 14, 58.3%; 12:00 N = 15, 75.0%; 13:00 N = 8, 40.0%; 14:00 N = 10, 71.4%; 15:00 N = 15, 71.4%). At YCH D1, vessel presence was lowest in the late evening and nighttime hours, at 19:00 (N = 3, 1.3%) and 21:00 – 23:00 HKT (N = 2, 0.8%; N = 3, 1.3%; N = 2, 0.8% for each respective hour) (Fig. 4).

A similar pattern is seen in YCH D2, in which the highest number of vessels are present from 09:00 HKT – 15:00 HKT. (N = 22, 11.4%; N = 13, 6.7%; N = 24, 12.4%; N = 19, 9.8%; N = 20, 10.4%; N = 12, 6.2%; N = 11, 5.7% for each respective hour). Like YCH D1, these diel patterns are driven by TA+M vessel signatures (09:00 N = 13, 59.1%; 10:00 N = 7, 53.8%; 11:00 N = 15, 62.5%; 12:00 N = 11, 57.9%; 13:00 N = 14, 70.0%; 14:00 N = 8, 66.7%; 15:00 N = 9, 81.8%). Similar to YCH D1, vessel presence at YCH D2 was lowest in the evening and night hours, at 18:00 (N = 1, 0.5%; and 22:00 – 00:00 (N = 1, 0.5% each) (Fig. 4).

Peaked Hill

At PKH D1, the most frequent number of vessels was observed at 17:00 HKT (N = 33, 9.9%) and 05:00 (N = 28, 8.4%) (Fig. 7). The fewest number of vessels was observed at 22:00 HKT (N = 3, 0.9%). CPA and CPA+M vessel presence followed consistent diel patterns and drive the diel patterns for total vessel presence across all behaviours. At 17:00 HKT, when total vessel presence was highest, CPA vessel signatures accounted for 30.3% of all vessels. CPA+M vessel signatures accounted for 33.0% of all vessels at 17:00 HKT. CPA and CPA+M vessel signatures were most frequently present at 17:00 HKT, (N=10 and N=11, respectively) and 05:00 HKT (N = 11 and N = 15, respectively). Both CPA and CPA+M vessel signatures were absent between 20:00 – 23:00 HKT (Fig. 4).

Tai Mo To

At TMT D1, vessels were most frequently observed at 04:00 HKT (N = 22, 6.8%), followed by 06:00 and 17:00 HKT (N = 20, 6.2% each). Vessels were least frequently observed at the nighttime hours of 23:00 HKT – 03:00 HKT (N = 7, 2.2%; N = 5, 1.5%; N = 5, 1.5%; N = 7, 2.2%; N = 6, 1.9% for each respective hour). CPA+M vessel signatures followed consistent diel patterns and drive the diel patterns for total vessel presence across all behaviours (Fig. 4). At 04:00 HKT, when vessels were most frequently observed, CPA+M vessel signatures account for 40.9% of total vessel presence (N = 9).

At TMT D2, vessels were most frequently observed at 18:00 HKT (N = 22, 6.4%), followed by 05:00 and 17:00 HKT (N = 21, 6.1% each). Vessels were least frequently observed at 22:00 HKT (N = 7, 2.0%), followed by 01:00 and 19:00 HKT (N = 8, 2.3% each). CPA vessel signatures drive diel patterns for total vessel presence across all behaviours (Fig. 4). At 18:00 HKT, when vessels were most frequently observed, CPA vessel signatures account for 50% of total vessel presence (N = 11).

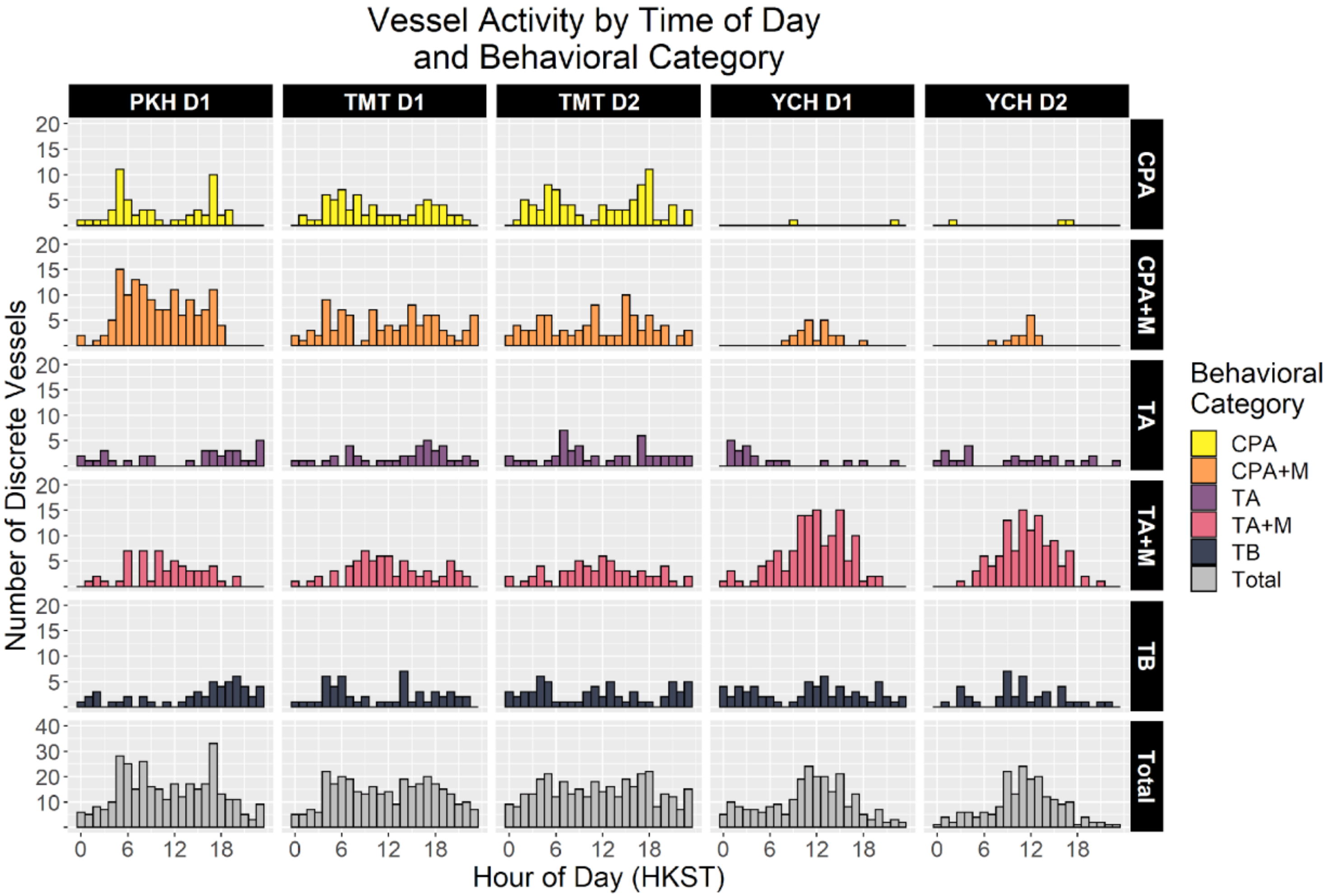

Figure 4: Counts of vessel signatures per hour separated by behavioral category each deployment at each site. Hourly presence counts reflect the start time of each vessel signature. Times are reported in local time (Hong Kong Time (HKT), UTC+8). PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Propagation modeling and detection range

The following transmission loss (TL) equations were fit using empirical RL data from the calibration tracks made at YCH. PKH, and TMT (Eq. 5, Fig. 5).

$$(\boldsymbol{Eq.5a})\ TL_{YCH} = 21.1((r)) + 0.0001r$$
$$(\boldsymbol{Eq.5b})\ TL_{PKH} = 19.4((r)) + 0.0001r$$
$$(\boldsymbol{Eq.5c})\ TL_{TMT} = 13.8((r)) + 0.002r$$

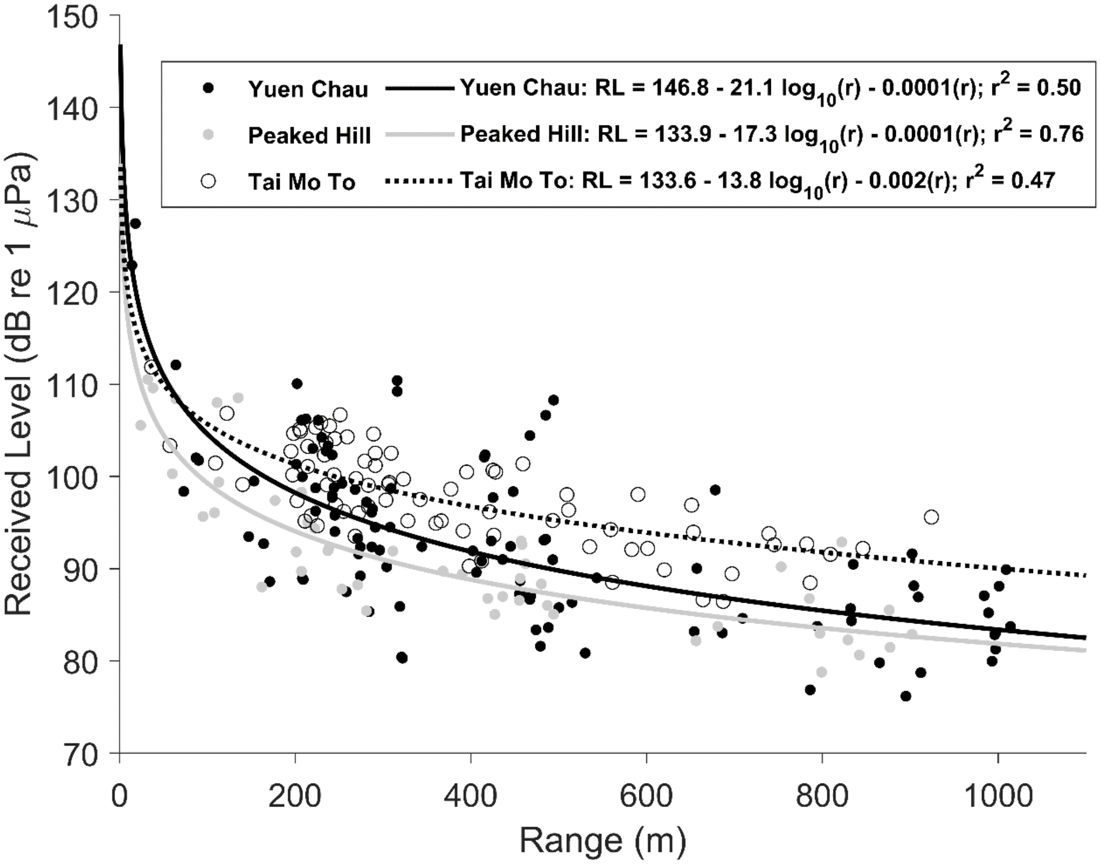

Figure 5: Regression line of received levels measured from acoustic recordings versus deployment vessel ranges taken from GPS points taken from Yuen Chau (YCH: black), Peaked Hill (PKH: gray), and Tai Mo To (TMT: open circles, dotted line).

Based on the median peak frequency from vessels with clean selection samples (YCH D1: 178 Hz, YCH D2: 155 Hz, PKH: 159 Hz), we used ambient noise levels from the TOL band centered on 160 Hz for both sites. The median peak frequency of TMT was 116 Hz, so for that site we used ambient noise levels from the TOL band centered on 125 Hz. Median ambient noise levels were highest in TMT (D1: NL_{50} = 101.1 dB re 1µPa; D2: NL_{50} = 101.0 dB re 1µPa), followed by YCH (D1: NL_{50} = 88.4 dB re 1µPa; D2: NL_{50} = 87.8 dB re 1µPa) and PKH (NL_{50} = 83.2 dB re 1µPa). Noise level affects maximum detection distance for a representative medium-sized vessel (SL =

170) with a peak frequency within the respective TOL band, and TMT D1 had the shortest detection distance (TMT D1: 5.9 km; TMT D2: 6.0 km; YCH D1: 6.7 km; YCH D2: 7.2 km; PKH: 22.7 km).

Total Vessel Presence within Park Boundaries

Across all deployments, the majority of vessels were estimated to occur outside of the MPA boundaries (Pin ≥ 0.75: range 3.1 – 44.2% inside park boundaries) (Table 7). These estimates assume vessels with SL ranging between 125 – 170 dB re 1 µPa. If all vessels were assumed to be small vessels with SL ranging from 125 – 150 dB re 1 µPa, then the majority of vessels in both YCH and PKH would be estimated to occur within park boundaries (Psmall in ≥ 0.75: range 82.7 – 97.2% inside park boundaries). At TMT, a smaller proportion of vessels was estimated within the park boundaries even if vessels were assumed to belong to the small size class (Psmall in ≥ 0.75: D1: 40.5 %; D2: 44.7% inside park boundaries). Since we do not have information regarding vessel size or SL for each signature, the more conservative estimates of vessels with overall Pin ≥ 0.75 are reported below; however, counts of vessels with Psmall in ≥ 0.75 can be found in Table 7.

Yuen Chau

Of the 237 total vessels detected within YCH D1, 218 (92.0%) were able to be used for propagation analysis. Of the usable vessels, 72 individual vessels (33.0%) were categorized as likely to be inside (Pin ≥ 0.75) the Yuen Chau park boundary (Table 7). The majority of vessels likely be within the park were classified as TA+M (N = 48, 66.7% of vessels inside the park, 82.8% of usable TA+M vessels) (Fig. 6). There were 19 vessels within CPA+M category categorized as likely to be within the park boundary (30.6% of vessels inside the park, 86.4% of 22 usable CPA+M vessels). Together, the two behavioral categories including a maneuver represent 93.1% of all vessels estimated to be within the park boundaries (N = 67/72). A single CPA vessel was estimated to occur within the park, while a small proportion of usable TA and TB vessels occurred inside the park (TA: N = 1, 5.2% of usable TA vessels; TB: N = 3, 5.8% of usable TB vessels).

In YCH D2, 181 of the total 193 vessels (93.7%) were usable for propagation analysis. Of these, 80 vessels (44.2%) were estimated to be within the park boundaries (Table 7). As in YCH D1, the TA+M category represented the highest number of vessels within the park (N = 58, 72.5% of vessels inside the park, 54.2% of usable TA+M vessels) followed by CPA+M (N = 13, 16.3% of vessels inside the park, 92.3% of usable CPA+M vessels) (Fig. 6). Vessels with a maneuver comprised 88.8% of all vessels estimated to occur within park boundaries (N = 71/80). All CPA vessels occurred within the park boundaries (N = 3, 3.8% of vessels inside the park). The TA and TB behaviours followed a similar pattern as YCH D1 with only a small proportion estimated to occur within the park boundaries (TA: N = 4, 5.0% of vessels inside the park, 16.0% of usable TA vessels; TB: N = 2, 2.5% of vessels inside the park, 6.3% of usable TB vessels).

Peaked Hill

In PKH, 312 of the total 335 vessels (93.1%) were usable for propagation analysis. Of those, 38 were estimated to occur within the park boundaries (12%) (Table 7). The CPA+M behaviour represented the highest proportion of these vessels (N = 26, 19.7% of usable CPA+M vessels, 68.4% of vessels inside the park), followed by CPA and TA+M which were each represented by 5 vessels (13.2% of vessels inside the park; CPA: 9.6% of usable CPA vessels; TA+M: 9.1% of usable TA+M vessels) (Fig. 6). There were two TA vessels within the park (6.9% of usable TA vessels, 5.3% of vessels inside the park), and none of the 44 usable TB vessels were estimated to occur within the park boundaries.

Tai Mo To

Most vessels in TMT were usable for propagation analysis (D1: N = 262, 81.1% of all vessels; D2: N = 284, 82.1% of all vessels) (Table 7) (Fig. 6). In TMT D1, 8 vessels (3.1%) were estimated to occur within park boundaries, and the CPA behaviour was represented more than any other behaviour (N = 4). The remaining 4 vessels primarily included vessels with maneuvers (CPA+M: N = 2; TA+M: N = 1) as well as a single TA vessel. TMT D2 was primarily represented by CPA (N = 6, 46.2%) and CPA+M (N = 5, 38.4%) vessels which comprised 84.6% of all vessels inside the park. There were no TA+M vessels estimated within the park boundaries during TMT D2, and there were no TB vessels during either deployment (Fig. 6).

Table 7: Summary of vessel presence and vessels at each recording site estimated to occur within the park boundaries surrounding Yuen Chau and Peaked Hill.

Deployment	**Behaviour**	**Original N vessels**	**N Usable Vessels**	$P_{small\ in} \geq 0.75$	$P_{in} \geq 0.75$
YCH D1	**CPA**	2	2	2	1
	CPA+M	22	22	22	19
	TA	21	19	16	1
	TA+M	128	124	124	48
	TB	64	51	43	3
	Total	237	218	207	72
YCH D2	**CPA**	3	3	3	3
	CPA+M	14	14	14	13
	TA	25	25	24	4
	TA+M	111	107	107	58
	TB	40	32	28	2
	Total	193	181	176	80
PKH D1	**CPA**	56	52	52	5
	CPA+M	137	132	130	26
	TA	35	29	22	2
	TA+M	55	55	42	5
	TB	52	44	12	0
	Total	335	312	258	38
TMT D1	**CPA**	68	57	30	4
	CPA+M	94	80	41	2
	TA	41	32	14	1
	TA+M	68	56	13	1
	TB	52	37	8	0
	Total	323	262	106	8
TMT D2	**CPA**	85	69	43	6
	CPA+M	89	82	40	5
	TA	48	43	24	2
	TA+M	61	47	16	0
	TB	63	43	4	0
	Total	346	284	127	13

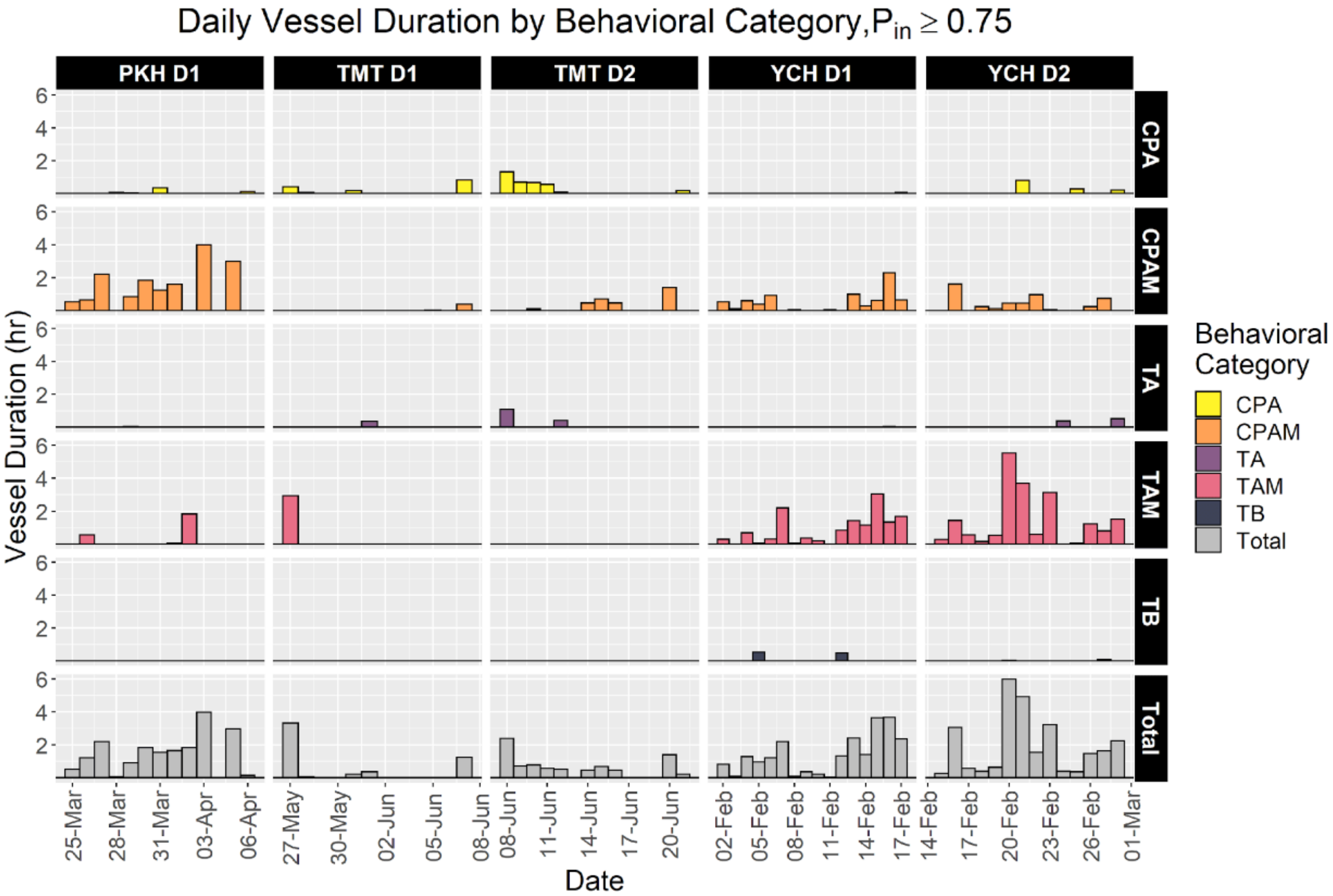

Figure 6: Daily vessel duration (hour) of vessels estimated within park boundaries (Pin ≥ 0.75) separated by behavioral category. PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Weekday Vessel Presence within Park Boundaries

Yuen Chau

In YCH D1, most vessels occurred on the weekends, with Sunday showing slightly higher vessel presence (Saturday: N = 14, 19.4%; Sunday: N = 13, 18.1%) (Fig. 7). All 13 vessels on Sundays included a maneuver, and 12 were the TA+M behaviour. On Saturdays, there were 5 CPA+M vessels and 9 TA+M vessels. Vessel presence was fairly consistent across weekdays, although the beginning of the week showed slightly higher presence than the end of the week.

YCH D2 exhibited a similar pattern as YCH D1 with most vessels occurring on the weekends (N =20, 25.0% each day) (Fig. 7). Vessel activity on weekdays varied, with Tuesdays (N = 14, 17.5%) and Fridays (N = 11, 13.8%) showing the highest number of vessels. Patterns of vessel activity throughout the week were primarily driven by TA+M vessels, which comprised the majority of vessels relative to any other behaviours on most days of the week.

Peaked Hill

PKH had the highest number of vessels within the park boundaries on Saturdays (N = 8, 21.1%) and the lowest number on Sundays (N = 2) (Fig. 7). All vessels on Saturdays were CPA+M (N = 8). The fewest vessels occurred on Sunday, with 2 CPA vessels and no instances of other behaviours. Of the weekdays, Monday had the highest number of vessels (N = 7, 18.4%), followed by Thursdays and Fridays (N = 6, 15.8% each day). Most vessels during the week were CPA+M vessels (N = 18, 64.3% of 28 weekday vessels).

Tai Mo To

In TMT D1, Mondays had the highest number of vessels (N = 3, 37.5%), and Thursdays represent a slight second peak in activity (N = 2, 25.0%) (Fig. 7). There were no vessels estimated within the park boundaries on Sundays or Wednesdays. During D2, Tuesdays showed the highest vessel presence (N = 3, 15.4%), with relatively consistent presence on the remaining days of the week (range 1 – 2 vessels) (Fig. 7). Vessel behaviour did not show a clear association with weekday patterns during either deployment.

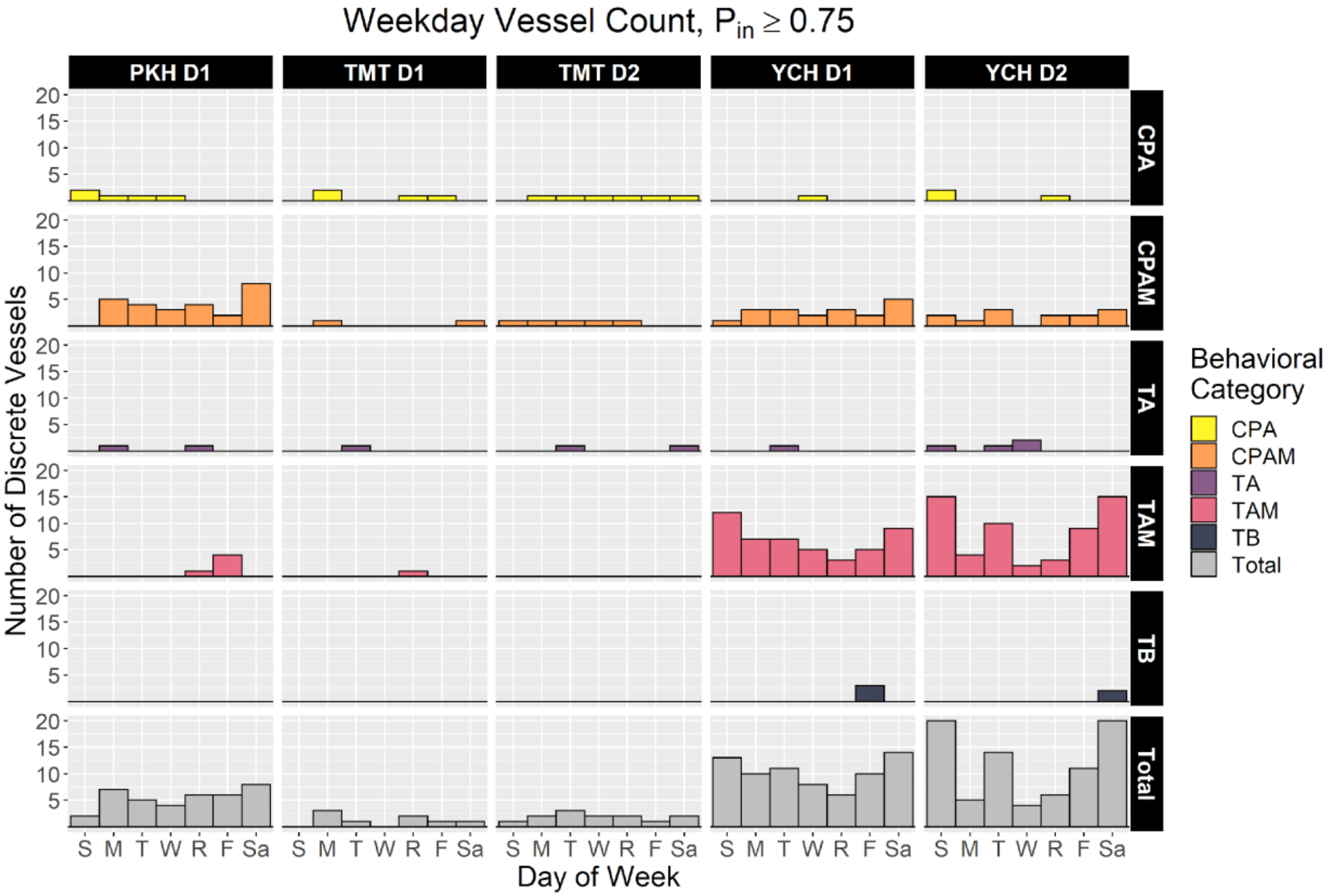

Figure 7: Vessel activity by day of week and behavioral category of vessels estimated within park boundaries (Pin ≥ 0.75). PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Diel Vessel Presence within Park Boundaries

Yuen Chau

Vessels in YCH D1 were most prevalent in the evening, with the highest number of vessels in a single hour occurring at 11:00 (N = 11, 15.3%) (Fig. 8). TA+M vessels comprised the majority of vessels in that hour (N = 7, 63.6%), with the remaining 4 vessels represented by the CPA+M behaviour. The highest number of CPA+M vessels occurred at 13:00, where the 10 total vessels included 5 CPA+M vessels, 4 TA+M vessels, and a single TB vessel. A secondary peak in vessel activity occurred at 17:00 with 6 TA+M vessels (8.3%). No vessels occurred inside the park boundaries between 20:00 – 04:00, and vessels were infrequent in the morning (range: 1 – 5 vessels, 05:00 – 09:00).

In YCH D2, vessels showed a similar pattern as the first deployment with the majority of vessels occurring during the hours of 11:00 (N = 13, 16.3%) and 12:00 (N = 15, 18.8%) (Fig. 8). In D2, there were more vessels in the morning, including 8 vessels (10.0%) at 09:00 (range: 2 – 4 vessels, 05:00 – 08:00). As in YCH D1, there was a secondary peak in activity at 17:00 (N = 6, 7.5%) and no vessels between 20:00 – 01:00.

Peaked Hill

In PKH, the highest number of vessels in a single hour occurred at 17:00 (N = 8, 21.1%), with all behaviours except TB represented (Fig. 8). Although CPA+M vessels were the most prevalent overall, they showed relatively consistent presence across hours of the day (range: 0 – 3 per hour). The majority of all vessels (N = 32, 84.2%) occurred between sunrise and sunset (06:21–18:36), although there was a slight peak in vessel activity in the early morning represented by 3 CPA+M vessels at 04:00. No vessels occurred between 19:00 – 01:00.

Tai Mo To

In TMT D1, the majority of vessels inside the park occurred between 20:00 – 00:00 HKT (N = 5, 62.5%), including the three vessels with a maneuver (CPA+M: 20:00 and 23:00, N = 1 each hour; TA+M: 21:00, N = 1). The three remaining vessels were all CPA vessels and were present between 10:00 – 13:00 HKT. In TMT D2, vessels were more evenly distributed throughout daylight hours, with most vessels between sunrise (05:39 – 05:40 HKT) and sunset (19:01 – 19:10 HKT) (N = 12 vessels, 92.3%, 06:00 – 18:00 HKT). The highest number of vessels for any given hour occurred at 18:00 HKT (N = 4, 30.7%), and the majority of these were CPA vessels (N = 3).

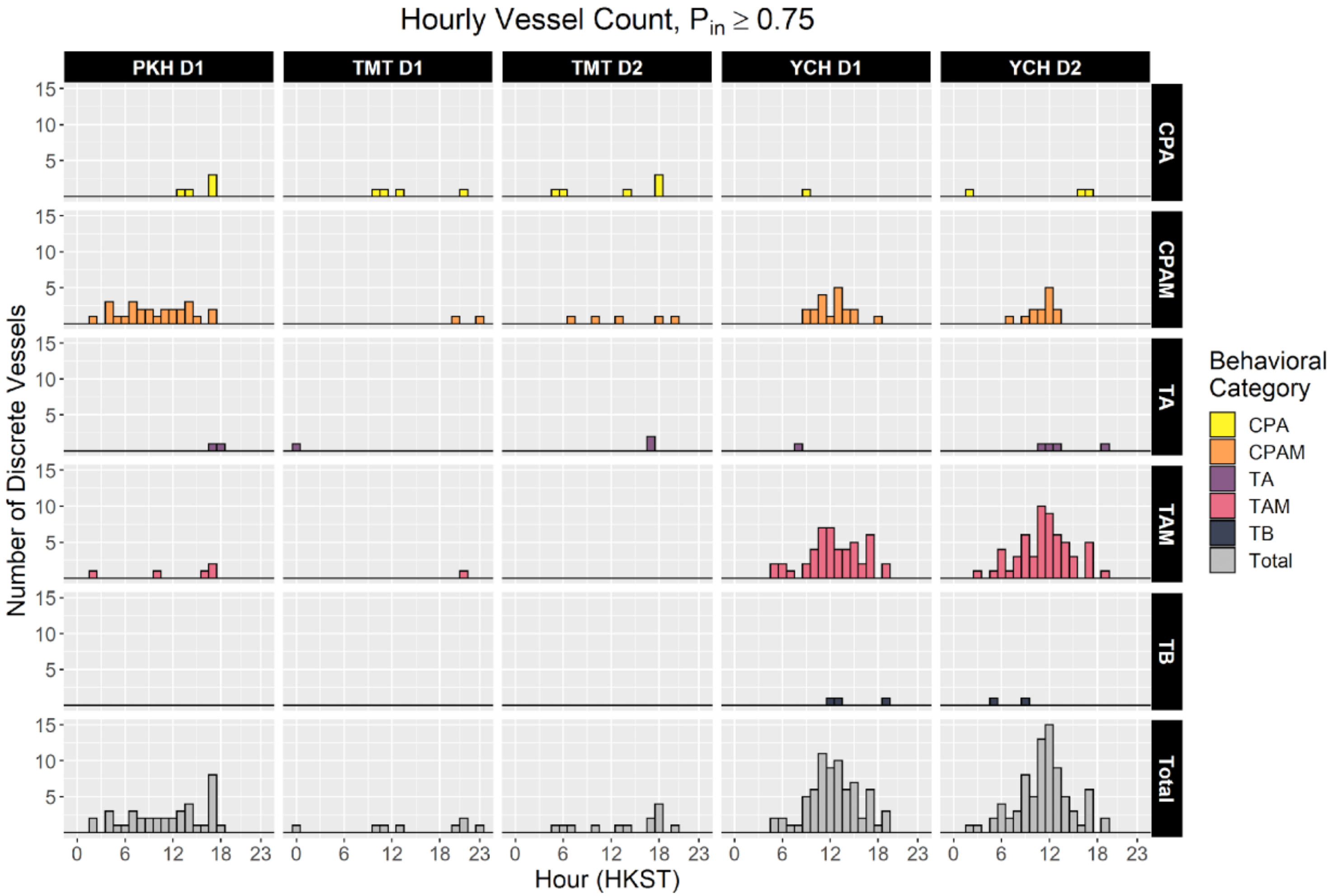

Figure 8: Counts of vessel signatures estimated within park boundaries (Pin ≥ 0.75) per hour separated by behavioral category. Hourly presence counts reflect the start time of each vessel signature. Times are reported in local time (Hong Kong Time (HKT), UTC+8). PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Tidal Influence on Vessel Presence within Park Boundaries

In all deployments, the majority of vessels inside the park boundaries ($P_{in} \geq 0.75$) occurred during either the ebb or flood phases of the tide, with the fewest vessels transiting during slack water periods near high and low tide times (Table 8, Fig. 9). In YCH D1, most vessels occurred during the flood tide (N = 37), and TA+M vessels were the most prevalent during that phase (N = 21), followed by CPA+M vessels (N = 13). YCH D2 showed the same relationship with tidal phase as YCH D1, with the majority of vessels occurring during flood tide (N = 58, 72.5%) and most of those vessels including a maneuver (TA+M: N = 41; CPA+M: N = 12).

For PKH, the highest proportion of vessels occurring during the ebb phase relative to other phases (N = 16, 42.1%) (Fig. 9). In PKH, this pattern was driven primarily by the CPA+M behaviour (N = 10). The flood phase also represented increased vessel activity, with 12 vessels (31.6%) occurring during this phase. As with the ebb tide, CPA+M vessels comprised the majority of vessels during the flood phase (N = 10, 75.0% of flood phase vessels).

TMT showed a similar pattern to YCH with the highest proportion of vessels occurring during the flood tide (D1: N = 4, 50%; D2: N = 6, 46.2%). Vessel behaviour did not show a clear association with tidal phase during either deployment at TMT.

Table 8: Summary of vessel activity by tidal phase at all sites.

Deployment	Behaviour	Ebb	Flood	High	Low
YCH D1	**CPA**	0	1	0	0
	CPA+M	3	13	3	0
	TA	0	1	0	0
	TA+M	10	21	11	6
	TB	1	1	1	0
	Total	14	37	15	6
YCH D2	**CPA**	0	2	0	1
	CPA+M	0	12	1	0
	TA	0	2	0	2
	TA+M	9	41	4	4
	TB	1	1	0	0
	Total	10	58	5	7
PKH D1	**CPA**	3	0	1	1
	CPA+M	10	9	1	6
	TA	1	1	0	0
	TA+M	2	2	1	0
	TB	0	0	0	0
	Total	16	12	3	7
TMT D1	**CPA**	1	1	2	0
	CPA+M	1	1	0	0
	TA	0	1	0	0
	TA+M	0	1	0	0
	TB	0	0	0	0
	Total	2	4	2	0
TMT D2	**CPA**	1	4	0	1
	CPA+M	1	2	1	1
	TA	1	0	0	1
	TA+M	0	0	0	0
	TB	0	0	0	0
	Total	3	6	1	3

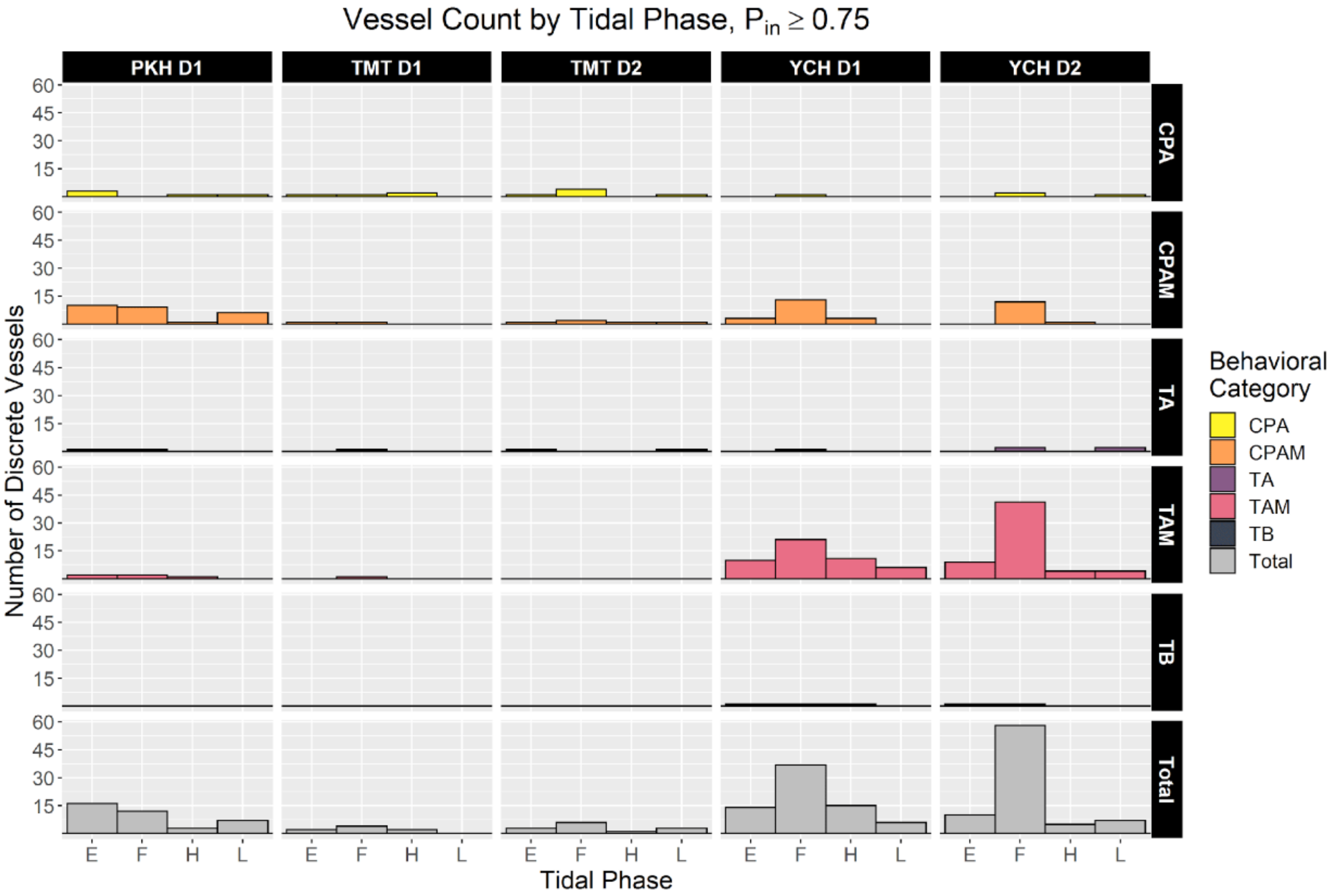

Figure 9: Counts of vessel signatures estimated within park boundaries (Pin ≥ 0.75) separated by behavioral category occurring within four tidal phases. E = ebb tide, F = flood tide, H = high tide, L = low tide. PKH D1 = Peaked Hill deployment 1, TMT D1 = Tai Mo To deployment 1, TMT D2 = Tai Mo To deployment 2, YCH D1 = Yuen Chau deployment 1, YCH D2 = Yuen Chau deployment 2. CPA = closest point of approach, M = maneuver, TA = close transit, TB = distant transit.

Discussion and Recommendations

Patterns of vessel presence

Across all three sites, vessel passages including a maneuver represented the highest proportion of activity. Vessels were logged primarily on weekends and between sunrise and sunset in all MPAs. Most detected vessels were estimated to occur outside of the park, although the relative proportion of vessels within the park boundaries varied according to site and vessel behaviour. TMT showed the lowest proportion of vessels estimated to occur within the park boundaries, and YCH showed the highest. In all deployments, CPA, CPA+M, and TA+M vessels were more likely to occur within park boundaries, while TA and TB vessels were more likely to represent vessels transiting outside the MPAs.

Weekday patterns of activity within the park boundaries remained relatively consistent with those of all detected vessels. There were some notable differences, however, particularly within the PKH and TMT sites. At both of these sites, the subset of vessels within the park showed a high proportion of activity on Mondays and Tuesdays compared to the pattern seen with all vessels of increased presence on the weekends. YCH vessels within the park still showed the most activity on weekends but exhibited a more exaggerated secondary peak in activity on Tuesdays.

Diel patterns of activity varied among sites, and this variation was more pronounced in the subset of vessels estimated to occur within the park boundaries. YCH showed peak activity within the park during midday (11:00 – 13:00), while PKH and TMT D2 both had the highest proportion of vessels in the early evening (17:00 – 18:00). TMT D1 showed a somewhat later peak in activity at 21:00 and was the only site with vessels occurring within the park boundaries overnight (23:00 – 03:00).

Of the vessels occurring within the MPA boundaries, most were present during either the ebb or flood phases of the tidal cycle. This association was most apparent in YCH, which had the highest proportion of vessels in a single tidal phase—flood phase—compared to the other sites. All sites are comparably shallow (range 5 – 6 meters), so it is possible that vessels are taking advantage of changing water levels for transit within the MPA. PKH was the only site with higher vessel presence during ebb tide, and it would be worth further investigation to determine how tidal currents during various phases at this site might differentially affect feasibility of vessel transit compared to YCH and TMT. It is important to note, however, that for this analysis no distinction was made between the heights or durations of mixed high and low tides within a single day.

Detector performance and analytical approach

Using a detector along with manual review of an LTSA provides an efficient, semi-automated method of detecting vessels in a long-term acoustic recording. Due to the potential for geographic and temporal variability of ambient noise, we recommend the more detailed hybrid approach whenever recorders are deployed in a new site or a new time of year. Using the hybrid approach will allow managers to determine the feasibility of using fully automated or semi-automated methods for a particular set of environmental conditions.

Although the detector alone was not able to find the majority of vessel signatures in YCH D1, the high precision of the detector improves overall efficiency of analyses, particularly given the frequent nature of vessel passages in urban areas. Given the large sample of vessels detected in these sites, we are confident that the temporal patterns reported here are representative of vessel activity.

Compared to applying a standard transmission loss model to both sites, using a tailored approach that incorporates MPA size as well as ambient noise conditions provides more accurate estimates of vessels within the park. For example, the number of vessels estimated to occur within PKH may have been overestimated if the analysis did not account for the smaller park size and larger maximum detection distance relative to YCH.

Recommendations for monitoring

Based on these results, we primarily recommend tailoring the timing of patrols based on site-specific temporal patterns in vessel activity. For TMT and PKH, early evening patrols between Saturdays – Tuesdays would have the most overlap with vessel activity as reported here. In YCH, monitoring should focus on vessel activity during mid-day and on weekends. Secondarily, the ebb and flood phases of the tidal cycle contain the majority of vessels within all parks and may be beneficial as a focus area for monitoring. Since the timing of the tide shifts across days, it is difficult to determine the primary factor affecting vessel activity on a diel scale (i.e., daylight versus tidal phase), and both factors should be considered until additional data are available. Results concerning weekday activity at all MPAs suggest some consistent patterns but should be interpreted cautiously due to the short duration of the deployments providing few examples of representative weekdays.

Additional recordings would be valuable at these sites to solidify conclusions regarding vessel activity as it relates to weekday, and future recordings could also be used to determine longer-term temporal patterns (e.g., seasonality). Depending on management goals, recorders deployed simultaneously in multiple locations within a single MPA could also improve monitoring within MPAs that have irregularly shaped boundaries.

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Appendix 8. Indo-Pacific humpback dolphin (*Sousa chinensis*) and Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) acoustic events from acoustic surveys.

Event ID	Event Start (UTC)	Event End (UTC)	Latitude	Longitude	Survey Area	Species
1	2021-01-15 11:05:57	2021-01-15 11:06:11	22.201575	113.838513	WL	CWD
2	2021-01-15 11:09:20	2021-01-15 11:09:43	22.208395	113.834278	WL	CWD
3	2021-01-15 11:54:22	2021-01-15 11:54:22	22.254895	113.848615	WL	CWD
4	2021-01-15 11:56:35	2021-01-15 11:59:13	22.2602433	113.849513	WL	CWD
5	2021-01-15 12:05:23	2021-01-15 12:05:24	22.268355	113.840667	WL	CWD
6	2021-01-15 12:06:27	2021-01-15 12:08:30	22.2683783	113.843407	WL	CWD
7	2021-01-15 12:20:03	2021-01-15 12:22:30	22.2839633	113.869992	NWL	CWD
8	2021-01-15 12:23:48	2021-01-15 12:25:24	22.294405	113.869893	NWL	CWD
9	2021-01-15 13:37:39	2021-01-15 13:39:04	22.367655	113.878403	NWL	CWD
10	2021-01-15 13:41:38	2021-01-15 13:42:20	22.3585933	113.87852	NWL	CWD
11	2021-01-15 13:43:21	2021-01-15 13:43:21	22.3549667	113.878658	NWL	CWD
12	2021-01-21 09:20:14	2021-01-21 09:20:35	22.1915283	113.854868	SL	CWD
13	2021-01-21 09:22:00	2021-01-21 09:22:10	22.1882433	113.854587	SL	CWD
14	2021-01-21 09:44:36	2021-01-21 09:49:31	22.181815	113.863555	SL	CWD
15	2021-01-21 09:49:10	2021-01-21 09:49:31	22.1908983	113.863597	SL	CWD
16	2021-01-21 10:52:07	2021-01-21 10:52:08	22.2102933	113.88677	SL	CWD
17	2021-01-21 10:53:08	2021-01-21 10:53:08	22.2114533	113.888537	SL	CWD
18	2021-01-21 10:56:16	2021-01-21 10:56:17	22.20835	113.892742	SL	CWD
19	2021-01-21 11:00:40	2021-01-21 11:02:25	22.1999467	113.893252	SL	CWD
20	2021-01-21 11:18:44	2021-01-21 11:25:23	22.1645367	113.892365	SL	FP
21	2021-01-21 11:34:48	2021-01-21 11:36:19	22.1568117	113.899088	SL	FP
22	2021-01-21 11:41:11	2021-01-21 11:43:49	22.1683967	113.8973	SL	FP
23	2021-01-21 12:24:58	2021-01-21 12:43:31	22.1728433	113.921205	SL	FP
24	2021-01-21 12:44:46	2021-01-21 12:52:32	22.1448683	113.92071	SL	FP
25	2021-01-21 12:54:27	2021-01-21 13:02:06	22.1633617	113.921815	SL	FP
26	2021-01-22 09:16:41	2021-01-22 09:18:07	22.1613117	113.938007	SL	FP
27	2021-01-22 09:24:30	2021-01-22 09:29:00	22.176075	113.938305	SL	FP
28	2021-01-22 09:31:17	2021-01-22 09:38:39	22.18874	113.937728	SL	FP
29	2021-01-22 09:40:57	2021-01-22 09:42:15	22.20642	113.937917	SL	FP
30	2021-01-22 09:55:09	2021-01-22 09:58:55	22.1961033	113.944577	SEL	FP
31	2021-01-22 10:03:07	2021-01-22 10:08:17	22.1805533	113.94458	SEL	FP

32	2021-01-22 10:16:10	2021-01-22 10:18:11	22.1655167	113.954578	SEL	FP
33	2021-01-22 10:19:51	2021-01-22 10:22:45	22.172325	113.954373	SEL	FP
34	2021-01-22 10:23:54	2021-01-22 10:28:34	22.1799133	113.954508	SEL	FP
35	2021-01-22 10:30:20	2021-01-22 10:35:13	22.192055	113.954442	SEL	FP
36	2021-01-22 11:10:12	2021-01-22 11:18:02	22.1897717	113.965283	SEL	FP
37	2021-01-22 11:33:41	2021-01-22 11:45:58	22.178065	113.974333	SEL	FP
38	2021-01-22 12:04:42	2021-01-22 12:07:52	22.2159217	113.9776	SEL	FP
39	2021-01-22 12:10:56	2021-01-22 12:10:57	22.2082317	113.983812	SEL	FP
40	2021-01-22 12:23:38	2021-01-22 12:34:51	22.1889083	113.977745	SEL	FP
41	2021-01-22 12:41:54	2021-01-22 12:44:51	22.1657167	113.991373	SEL	FP
42	2021-01-22 12:49:32	2021-01-22 12:53:18	22.17805	113.993303	SEL	FP
43	2021-01-22 13:00:42	2021-01-22 13:04:47	22.1966233	113.995927	SEL	FP
44	2021-01-22 13:08:06	2021-01-22 13:09:14	22.209105	113.99309	SEL	FP
45	2021-01-22 13:24:39	2021-01-22 13:30:10	22.1932067	114.002643	SEL	FP
46	2021-01-22 13:49:33	2021-01-22 14:13:17	22.1662633	114.012673	SEL	FP
47	2021-01-27 11:22:11	2021-01-27 11:22:12	22.390905	113.904707	NWL	CWD
48	2021-01-27 11:23:31	2021-01-27 11:28:18	22.395	113.903985	NWL	CWD
49	2021-02-22 16:16:17	2021-02-22 16:21:21	22.1917717	113.854568	SL	CWD
50	2021-02-22 16:44:39	2021-02-22 16:46:52	22.1931417	113.863573	SL	CWD
51	2021-02-22 17:17:08	2021-02-22 17:22:08	22.156995	113.882532	SL	FP
52	2021-02-22 18:01:59	2021-02-22 18:11:39	22.1850733	113.89263	SL	CWD
53	2021-02-22 18:14:17	2021-02-22 18:20:16	22.16007	113.89319	SL	FP
54	2021-02-22 18:23:02	2021-02-22 18:26:07	22.1450817	113.900212	SL	FP
55	2021-02-22 18:27:11	2021-02-22 18:28:36	22.1518333	113.902475	SL	FP
56	2021-02-22 18:31:46	2021-02-22 18:37:54	22.1592033	113.898137	SL	FP
57	2021-02-22 18:43:48	2021-02-22 18:47:23	22.18209	113.899122	SL	FP
58	2021-02-22 18:51:08	2021-02-22 19:15:45	22.1960033	113.902832	SL	FP
59	2021-02-22 19:29:31	2021-02-22 19:31:31	22.1553417	113.912903	SL	FP
60	2021-02-22 19:40:52	2021-02-22 19:46:13	22.1483983	113.922085	SL	FP
61	2021-02-22 19:59:22	2021-02-22 20:05:44	22.1852883	113.922098	SL	FP
62	2021-02-25 15:46:02	2021-02-25 15:55:02	22.1626433	113.932335	SL	FP
63	2021-02-25 15:59:37	2021-02-25 16:02:32	22.1883767	113.931572	SL	FP
64	2021-02-25 16:04:11	2021-02-25 16:07:55	22.1972233	113.932072	SL	FP

65	2021-02-25 16:09:44	2021-02-25 16:19:15	22.20818	113.933728	SL	FP
66	2021-02-25 16:23:40	2021-02-25 16:24:44	22.19169	113.938335	SL	FP
67	2021-02-25 16:30:12	2021-02-25 16:31:58	22.1777033	113.939092	SL	FP
68	2021-02-25 16:34:35	2021-02-25 16:47:44	22.168595	113.938252	SL	FP
69	2021-02-25 16:56:30	2021-02-25 16:58:43	22.1898583	113.945275	SEL	FP
70	2021-02-25 16:59:49	2021-02-25 17:02:33	22.196075	113.944913	SEL	FP
71	2021-02-25 17:09:31	2021-02-25 17:11:22	22.214435	113.948247	SEL	FP
72	2021-02-25 17:13:37	2021-02-25 17:15:20	22.2223067	113.950538	SEL	FP
73	2021-02-25 17:31:12	2021-02-25 17:45:24	22.19202	113.954882	SEL	FP
74	2021-02-25 17:58:11	2021-02-25 17:58:14	22.1840983	113.96476	SEL	FP
75	2021-02-25 18:04:29	2021-02-25 18:07:59	22.1959433	113.964208	SEL	FP
76	2021-02-25 18:10:48	2021-02-25 18:11:12	22.2080133	113.964357	SEL	FP
77	2021-02-25 18:38:20	2021-02-25 18:39:43	22.193525	113.974342	SEL	FP
78	2021-02-25 18:42:10	2021-02-25 18:45:08	22.1853333	113.97412	SEL	FP
79	2021-02-25 19:03:59	2021-02-25 19:05:49	22.1796017	113.983933	SEL	FP
80	2021-02-25 19:22:36	2021-02-25 19:23:26	22.2109783	113.983837	SEL	FP
81	2021-02-25 19:30:55	2021-02-25 19:38:30	22.2031133	113.993647	SEL	FP
82	2021-02-25 19:45:46	2021-02-25 19:51:22	22.1733183	113.99301	SEL	FP
83	2021-03-01 15:56:16	2021-03-01 15:56:32	22.2419833	113.842325	WL	CWD
84	2021-03-01 15:58:01	2021-03-01 15:59:12	22.24415	113.839575	WL	CWD
85	2021-03-01 16:04:38	2021-03-01 16:05:39	22.249795	113.831218	WL	CWD
86	2021-03-01 16:06:48	2021-03-01 16:06:53	22.25247	113.83564	WL	CWD
87	2021-03-01 16:08:10	2021-03-01 16:08:11	22.2523133	113.838782	WL	CWD
88	2021-03-04 16:08:05	2021-03-04 16:13:27	22.3988083	113.888015	NWL	CWD
89	2021-04-12 17:06:49	2021-04-12 17:06:51	22.1632467	113.873452	SL	FP
90	2021-04-12 17:52:49	2021-04-12 17:59:50	22.1744833	113.884108	SL	FP
91	2021-04-12 18:07:39	2021-04-12 18:12:19	22.15244	113.893535	SL	FP
92	2021-04-12 18:15:44	2021-04-12 18:17:26	22.16606	113.892915	SL	FP
93	2021-04-12 18:21:45	2021-04-12 18:21:45	22.1769633	113.892818	SL	FP
94	2021-04-12 18:24:21	2021-04-12 18:35:24	22.181875	113.89285	SL	FP
95	2021-04-12 18:51:13	2021-04-12 18:55:24	22.1971867	113.901758	SL	FP
96	2021-04-12 18:59:17	2021-04-12 19:01:43	22.1814617	113.901567	SL	FP
97	2021-04-12 19:05:27	2021-04-12 19:11:06	22.1714733	113.894812	SL	FP

98	2021-04-12 19:12:11	2021-04-12 19:17:32	22.1570933	113.897382	SL	FP
99	2021-04-12 19:20:26	2021-04-12 19:32:34	22.1419483	113.905777	SL	FP
100	2021-04-12 19:33:40	2021-04-12 19:35:17	22.1588183	113.917688	SL	FP
101	2021-04-12 19:36:31	2021-04-12 19:52:06	22.1637883	113.920368	SL	FP
102	2021-04-12 19:55:13	2021-04-12 20:13:49	22.1956183	113.91239	SL	FP
103	2021-04-12 20:23:20	2021-04-12 20:36:08	22.1632817	113.9217	SL	FP
104	2021-04-13 16:42:42	2021-04-13 16:44:13	22.1521483	113.931368	SL	FP
105	2021-04-13 17:03:50	2021-04-13 17:42:29	22.1942617	113.931552	SL	FP
106	2021-04-13 17:52:30	2021-04-13 17:55:07	22.18261	113.944553	SEL	FP
107	2021-04-13 18:08:19	2021-04-13 18:22:18	22.2139967	113.947982	SEL	FP
108	2021-04-13 18:24:55	2021-04-13 18:31:46	22.20433	113.95485	SEL	FP
109	2021-04-13 18:49:02	2021-04-13 18:58:25	22.1653767	113.962882	SEL	FP
110	2021-04-13 19:09:15	2021-04-13 19:09:15	22.2041417	113.963968	SEL	FP
111	2021-04-13 19:14:31	2021-04-13 19:15:47	22.2146767	113.964828	SEL	FP
112	2021-04-13 19:21:10	2021-04-13 19:25:10	22.2223817	113.969933	SEL	FP
113	2021-04-13 19:37:06	2021-04-13 19:41:42	22.1919	113.97419	SEL	FP
114	2021-04-13 19:51:32	2021-04-13 19:53:52	22.1655783	113.977027	SEL	FP
115	2021-04-13 19:59:34	2021-04-13 20:03:01	22.1758033	113.984067	SEL	FP
116	2021-04-13 20:19:52	2021-04-13 20:21:45	22.2094333	113.983278	SEL	FP
117	2021-05-04 10:06:21	2021-05-04 10:52:23	22.1901133	113.852202	SL	CWD
118	2021-05-04 10:30:31	2021-05-04 10:30:32	22.1947717	113.82942	WL	CWD
119	2021-05-04 10:35:48	2021-05-04 10:35:49	22.2011717	113.827978	WL	CWD
120	2021-05-04 10:51:34	2021-05-04 10:51:35	22.2099317	113.82144	WL	CWD
121	2021-06-02 09:56:42	2021-06-02 09:57:56	22.1981433	113.863778	SL	CWD
122	2021-06-02 10:00:36	2021-06-02 10:00:36	22.1981433	113.863778	SL	CWD
123	2021-06-02 10:01:49	2021-06-02 10:04:17	22.1981433	113.863778	SL	CWD
124	2021-06-02 10:43:37	2021-06-02 10:46:20	22.1939667	113.873325	SL	CWD
125	2021-06-02 11:00:39	2021-06-02 11:00:39	22.1960567	113.882703	SL	CWD
126	2021-06-02 11:04:10	2021-06-02 11:04:12	22.1893033	113.88312	SL	CWD
127	2021-06-02 11:34:00	2021-06-02 11:37:59	22.1625833	113.892675	SL	CWD
128	2021-06-02 11:39:04	2021-06-02 11:40:53	22.17161	113.892802	SL	CWD
129	2021-06-02 11:41:02	2021-06-02 11:41:03	22.1750667	113.892847	SL	FP
130	2021-06-02 11:41:08	2021-06-02 11:41:24	22.1752417	113.892847	SL	CWD

131	2021-06-02 11:41:46	2021-06-02 11:41:46	22.17633	113.892762	SL	FP
132	2021-06-02 11:41:54	2021-06-02 11:42:52	22.1765417	113.892713	SL	CWD
133	2021-06-02 11:42:52	2021-06-02 11:42:53	22.1781933	113.8926	SL	FP
134	2021-06-02 11:42:53	2021-06-02 11:46:04	22.1782233	113.892602	SL	CWD
135	2021-06-02 12:14:28	2021-06-02 12:16:00	22.19193	113.902113	SL	CWD
136	2021-06-02 12:16:01	2021-06-02 12:17:34	22.188925	113.902222	SL	CWD
137	2021-06-02 12:40:29	2021-06-02 12:40:32	22.1458317	113.901725	SL	CWD
138	2021-06-02 13:36:11	2021-06-02 13:37:14	22.1835217	113.921898	SL	FP
139	2021-06-02 13:44:03	2021-06-02 13:45:40	22.1691617	113.921735	SL	FP
140	2021-06-03 09:48:21	2021-06-03 09:52:25	22.1775883	113.932043	SL	FP
141	2021-06-03 09:55:55	2021-06-03 09:56:05	22.1924833	113.932403	SL	FP
142	2021-06-03 10:17:21	2021-06-03 10:20:20	22.1932217	113.937513	SL	FP
143	2021-06-03 11:02:48	2021-06-03 11:03:20	22.2127367	113.947822	SEL	FP
144	2021-06-03 11:20:46	2021-06-03 11:30:09	22.1922467	113.954318	SEL	FP
145	2021-06-03 11:56:09	2021-06-03 12:00:37	22.1988033	113.96494	SEL	FP
146	2021-06-03 12:24:56	2021-06-03 12:24:57	22.1954883	113.974232	SEL	CWD
147	2021-06-03 12:26:23	2021-06-03 12:26:26	22.1927967	113.974285	SEL	CWD
148	2021-06-03 12:51:07	2021-06-03 12:53:06	22.1790433	113.983235	SEL	FP
149	2021-07-22 09:09:19	2021-07-22 09:15:17	22.1929867	113.853625	SL	CWD
150	2021-07-22 09:29:08	2021-07-22 09:29:31	22.1933083	113.84201	WL	CWD
151	2021-07-22 09:36:45	2021-07-22 09:36:45	22.1985533	113.825883	WL	CWD
152	2021-07-22 10:08:34	2021-07-22 10:09:20	22.2302833	113.822215	WL	CWD
153	2021-07-22 10:13:09	2021-07-22 10:14:13	22.2350933	113.832062	WL	CWD
154	2021-07-22 10:44:20	2021-07-22 10:45:39	22.2672167	113.839583	WL	CWD
155	2021-07-22 12:03:29	2021-07-22 12:03:52	22.392495	113.877347	NWL	CWD
156	2021-07-22 12:04:53	2021-07-22 12:06:12	22.3894667	113.87707	NWL	CWD
157	2021-07-26 10:21:03	2021-07-26 10:21:13	22.3689833	113.907615	NWL	CWD
158	2021-08-10 17:08:26	2021-08-10 17:08:28	22.1872433	113.86344	SL	CWD
159	2021-08-10 17:35:22	2021-08-10 17:41:36	22.1803233	113.873105	SL	CWD
160	2021-08-10 17:42:55	2021-08-10 17:42:56	22.194245	113.873363	SL	CWD
161	2021-08-10 17:59:31	2021-08-10 17:59:35	22.1961817	113.882532	SL	CWD
162	2021-08-10 18:22:55	2021-08-10 18:26:07	22.1537433	113.887248	SL	FP
163	2021-08-10 18:27:43	2021-08-10 18:28:26	22.1529633	113.89278	SL	FP

164	2021-08-10 18:35:35	2021-08-10 18:37:04	22.166905	113.892453	SL	CWD
165	2021-08-10 18:41:14	2021-08-10 18:43:14	22.1769767	113.89242	SL	FP
166	2021-08-10 19:24:58	2021-08-10 19:26:36	22.1709267	113.895588	SL	CWD
167	2021-08-10 19:33:41	2021-08-10 19:36:50	22.1548667	113.90097	SL	FP
168	2021-08-10 19:38:12	2021-08-10 19:38:12	22.146145	113.9019	SL	FP
169	2021-08-10 19:42:14	2021-08-10 19:43:30	22.14369	113.910245	SL	FP
170	2021-08-10 19:49:49	2021-08-10 19:51:05	22.1555017	113.913148	SL	FP
171	2021-08-10 19:54:40	2021-08-10 19:56:43	22.1629517	113.919812	SL	FP
172	2021-08-17 17:01:28	2021-08-17 17:01:28	22.1610217	113.921798	SL	FP
173	2021-08-17 17:02:30	2021-08-17 17:05:16	22.1588067	113.92185	SL	FP
174	2021-08-17 17:16:10	2021-08-17 17:17:21	22.1570683	113.931957	SL	FP
175	2021-08-17 17:20:07	2021-08-17 17:25:54	22.1649417	113.932228	SL	FP
176	2021-08-17 17:32:14	2021-08-17 17:33:12	22.1895867	113.931618	SL	FP
177	2021-08-17 17:43:05	2021-08-17 17:46:20	22.2100417	113.93685	SL	FP
178	2021-08-17 17:53:46	2021-08-17 17:53:46	22.1888933	113.938237	SL	FP
179	2021-08-17 17:59:06	2021-08-17 17:59:30	22.177215	113.938095	SL	FP
180	2021-08-17 18:00:32	2021-08-17 18:00:32	22.17408	113.938142	SL	FP
181	2021-08-17 18:02:09	2021-08-17 18:06:20	22.1706383	113.938412	SL	FP
182	2021-08-17 19:04:33	2021-08-17 19:04:33	22.166235	113.958422	SEL	FP
183	2021-08-17 19:09:02	2021-08-17 19:11:32	22.1703567	113.964057	SEL	FP
184	2021-08-17 19:58:27	2021-08-17 20:02:04	22.1749783	113.973925	SEL	FP
185	2021-09-07 09:51:30	2021-09-07 09:52:12	22.193225	113.852962	SL	CWD
186	2021-09-07 10:36:11	2021-09-07 10:36:11	22.21128	113.820592	WL	CWD
187	2021-09-07 11:17:13	2021-09-07 11:20:17	22.2525283	113.843328	WL	CWD
188	2021-09-07 11:21:22	2021-09-07 11:28:35	22.2605367	113.850617	WL	CWD
189	2021-09-07 11:32:58	2021-09-07 11:32:58	22.2688867	113.847498	WL	CWD
190	2021-09-07 11:34:29	2021-09-07 11:36:55	22.2691517	113.851968	WL	CWD
191	2021-09-07 12:11:03	2021-09-07 12:13:43	22.3546167	113.870415	NWL	CWD
192	2021-09-07 12:47:04	2021-09-07 12:47:48	22.4010783	113.877895	NWL	CWD
193	2021-09-07 12:49:33	2021-09-07 12:49:34	22.3954767	113.877832	NWL	CWD
194	2021-09-07 13:55:51	2021-09-07 13:56:14	22.4053083	113.889327	NWL	CWD
195	2021-10-20 11:45:22	2021-10-20 11:48:09	22.17834	113.8928	SL	FP
196	2021-10-20 11:54:01	2021-10-20 11:55:34	22.16201	113.893	SL	FP

197	2021-10-20 12:01:31	2021-10-20 12:02:27	22.14905	113.8934	SL	FP
198	2021-10-20 12:07:12	2021-10-20 12:11:47	22.14637	113.9014	SL	FP
199	2021-10-20 12:14:20	2021-10-20 12:16:36	22.15896	113.897	SL	FP
200	2021-10-20 12:20:10	2021-10-20 12:22:08	22.16998	113.8952	SL	FP
201	2021-10-20 12:25:19	2021-10-20 12:26:47	22.17837	113.8986	SL	FP
202	2021-10-20 12:49:26	2021-10-20 12:51:06	22.19877	113.9123	SL	FP
203	2021-10-20 13:07:04	2021-10-20 13:08:30	22.17174	113.9206	SL	FP
204	2021-10-20 13:10:36	2021-10-20 13:12:11	22.16531	113.9202	SL	FP
205	2021-10-25 11:10:21	2021-10-25 11:10:37	22.1901	113.9641	SEL	FP
206	2021-10-25 11:32:30	2021-10-25 11:32:38	22.18833	113.9741	SEL	FP
207	2021-10-25 11:36:54	2021-10-25 11:37:12	22.19936	113.9738	SEL	FP

Appendix 9. Encounters with active trawlers from acoustic surveys.

Encounter ID	Encounter UTC	Category	Type	Count	Latitude	Longitude	Survey Area
1	2021-01-15 12:34:36	Other	High-powered speedboat	1	22.32355167	113.8697533	NWL
2	2021-01-15 12:45:22	Other	High-powered speedboat	1	22.35362333	113.870475	NWL
3	2021-01-15 12:48:36	Other	High-powered speedboat	2	22.36221167	113.8714583	NWL
4	2021-01-15 12:53:27	Other	High-powered speedboat	1	22.376065	113.8694733	NWL
5	2021-01-15 12:57:20	Other	High-powered speedboat	1	22.38712333	113.8692817	NWL
6	2021-01-15 12:59:24	Other	High-powered speedboat	1	22.39288	113.8695133	NWL
7	2021-01-15 13:00:43	Other	High-powered speedboat	1	22.39662833	113.8697483	NWL
8	2021-01-15 13:07:59	Other	High-powered speedboat	1	22.41669167	113.8695617	NWL
9	2021-01-15 13:08:49	Other	High-powered speedboat	1	22.41947833	113.86937	NWL
10	2021-01-15 13:10:39	Other	High-powered speedboat	1	22.42165	113.87141	NWL
11	2021-01-15 13:11:29	Other	High-powered speedboat	1	22.42049333	113.87253	NWL
12	2021-01-15 13:11:54	Other	High-powered speedboat	1	22.419605	113.8731567	NWL
13	2021-01-15 13:13:13	Other	High-powered speedboat	1	22.41742167	113.874885	NWL
14	2021-01-15 13:13:21	Other	High-powered speedboat	2	22.41726667	113.8750283	NWL
15	2021-01-15 13:16:58	Other	High-powered speedboat	3	22.41050333	113.8775367	NWL
16	2021-01-15 13:18:12	Other	High-powered speedboat	1	22.408265	113.87764	NWL
17	2021-01-15 13:19:29	Other	High-powered speedboat	5	22.405525	113.8777517	NWL
18	2021-01-15 13:21:07	Other	High-powered speedboat	1	22.40221667	113.87767	NWL
19	2021-01-15 13:22:45	Other	High-powered speedboat	1	22.39838167	113.87774	NWL
20	2021-01-15 13:23:28	Other	High-powered speedboat	1	22.39684333	113.877675	NWL
21	2021-01-15 13:24:31	Other	High-powered speedboat	1	22.39479833	113.8776433	NWL

22	2021-01-15 13:33:38	Other	High-powered speedboat	1	22.37605833	113.8756617	NWL
23	2021-01-15 13:36:56	Other	High-powered speedboat	1	22.36927333	113.878195	NWL
24	2021-01-15 13:42:31	Other	High-powered speedboat	1	22.35673667	113.8785683	NWL
25	2021-01-15 13:53:13	Other	High-powered speedboat	1	22.33286833	113.8782567	NWL
26	2021-01-27 10:05:14	Other	High-powered speedboat	1	22.35628167	113.8878283	NWL
27	2021-01-27 10:06:21	Other	High-powered speedboat	1	22.359125	113.887885	NWL
28	2021-01-27 10:07:14	Other	High-powered speedboat	1	22.36150167	113.8876983	NWL
29	2021-01-27 10:11:58	Other	High-powered speedboat	1	22.37422	113.8871667	NWL
30	2021-01-27 10:13:50	Other	High-powered speedboat	1	22.37936167	113.8872417	NWL
31	2021-01-27 10:21:59	Other	High-powered speedboat	2	22.40193167	113.8864983	NWL
32	2021-01-27 10:33:29	Other	High-powered speedboat	1	22.38862	113.8984867	NWL
33	2021-01-27 10:38:29	Other	High-powered speedboat	1	22.377725	113.8976417	NWL
34	2021-01-27 10:40:37	Other	High-powered speedboat	6	22.37325833	113.8976183	NWL
35	2021-01-27 10:42:01	Other	High-powered speedboat	2	22.36993333	113.8974933	NWL
36	2021-01-27 11:05:03	Other	High-powered speedboat	1	22.34688167	113.9080783	NWL
37	2021-01-27 11:05:15	Other	High-powered speedboat	1	22.347295	113.9080383	NWL
38	2021-01-27 11:06:15	Other	High-powered speedboat	1	22.34993333	113.907835	NWL
39	2021-01-27 11:06:27	Other	High-powered speedboat	1	22.35088333	113.9076883	NWL
40	2021-01-27 11:07:14	Other	High-powered speedboat	1	22.35248333	113.9075017	NWL
41	2021-01-27 11:15:02	Other	High-powered speedboat	2	22.37069167	113.9068683	NWL
42	2021-01-27 11:15:27	Other	High-powered speedboat	1	22.37211167	113.9068217	NWL
43	2021-01-27 11:16:31	Other	High-powered speedboat	1	22.37502333	113.9067133	NWL
44	2021-01-27 11:17:38	Other	High-powered speedboat	1	22.37802667	113.9066183	NWL

45	2021-01-27 11:18:46	Other	High-powered speedboat	1	22.38099	113.9058617	NWL
46	2021-01-27 11:18:54	Other	High-powered speedboat	1	22.38188	113.9055967	NWL
47	2021-01-27 11:29:20	Other	High-powered speedboat	2	22.38492167	113.90847	NWL
48	2021-01-27 11:33:01	Other	High-powered speedboat	1	22.37672333	113.911835	NWL
49	2021-01-27 11:33:14	Other	High-powered speedboat	2	22.37638333	113.9119817	NWL
50	2021-01-27 11:39:43	Other	High-powered speedboat	1	22.36306833	113.9164467	NWL
51	2021-01-27 11:50:16	Other	High-powered speedboat	1	22.35811167	113.9161017	NWL
52	2021-01-27 11:50:42	Other	High-powered speedboat	1	22.35683167	113.91626	NWL
53	2021-01-27 11:53:51	Other	High-powered speedboat	1	22.34964667	113.9165533	NWL
54	2021-01-27 11:56:09	Other	High-powered speedboat	1	22.34448833	113.91679	NWL
55	2021-01-27 11:59:23	Other	High-powered speedboat	1	22.342705	113.9239633	NWL
56	2021-01-27 12:00:33	Other	High-powered speedboat	2	22.34513667	113.9249783	NWL
57	2021-01-27 13:19:32	Other	High-powered speedboat	1	22.36063667	113.9746483	NEL
58	2021-02-22 18:41:26	Fishing	Trawler	1	22.177965	113.896728	SL
59	2021-02-25 16:19:11	Fishing	Trawler	1	22.1992683	113.941612	SL
60	2021-02-25 17:32:19	Fishing	Trawler	1	22.1899833	113.954395	SEL
61	2021-02-25 18:21:07	Fishing	Trawler	1	22.22665	113.96722	SEL
62	2021-02-25 18:41:34	Fishing	Trawler	1	22.1866967	113.974133	SEL
63	2021-03-01 16:27:16	Fishing	Trawler	1	22.2697817	113.852007	WL
64	2021-03-01 17:34:56	Other	High-powered speedboat	1	22.40697667	113.8695683	NWL
65	2021-03-04 15:58:05	Other	High-powered speedboat	2	22.37112833	113.8880517	NWL
66	2021-03-04 16:05:48	Other	High-powered speedboat	1	22.39214833	113.887855	NWL
67	2021-03-04 16:06:03	Other	High-powered speedboat	1	22.39269	113.8879133	NWL

68	2021-03-04 16:16:21	Other	High-powered speedboat	1	22.39834667	113.896415	NWL
69	2021-03-04 16:16:37	Other	High-powered speedboat	1	22.39742	113.896465	NWL
70	2021-03-04 16:17:33	Other	High-powered speedboat	1	22.39578833	113.8965283	NWL
71	2021-03-04 16:21:36	Other	High-powered speedboat	1	22.38687167	113.8969417	NWL
72	2021-03-04 16:30:00	Other	High-powered speedboat	1	22.36779	113.8976667	NWL
73	2021-03-04 16:30:19	Other	High-powered speedboat	1	22.36668667	113.8977017	NWL
74	2021-03-04 16:30:31	Other	High-powered speedboat	1	22.36629167	113.8977067	NWL
75	2021-03-04 16:30:47	Other	High-powered speedboat	1	22.36577333	113.8977433	NWL
76	2021-03-04 17:33:34	Other	High-powered speedboat	1	22.34262833	113.9244133	NWL
77	2021-03-04 17:34:02	Other	High-powered speedboat	1	22.34258667	113.92548	NWL
78	2021-03-04 17:50:41	Other	High-powered speedboat	3	22.34328833	113.936905	NWL
79	2021-03-04 18:08:44	Other	High-powered speedboat	1	22.35448167	113.9456783	NWL
80	2021-03-04 18:09:25	Other	High-powered speedboat	1	22.35558	113.94612	NWL
81	2021-03-04 18:28:53	Other	High-powered speedboat	1	22.32090167	113.9644833	NEL
82	2021-04-12 16:57:09	Fishing	Trawler	1	22.1781767	113.8622	SL
83	2021-04-12 17:15:52	Fishing	Trawler	1	22.17894	113.87343	SL
84	2021-04-12 17:20:27	Fishing	Trawler	1	22.1875083	113.873047	SL
85	2021-04-13 17:35:06	Fishing	Trawler	1	22.1681417	113.937783	SL
86	2021-05-13 11:16:48	Other	High-powered speedboat	1	22.34748333	113.870025	NWL
87	2021-05-13 11:17:11	Other	High-powered speedboat	1	22.34862833	113.8699083	NWL
88	2021-05-13 11:20:17	Other	High-powered speedboat	30	22.35589333	113.8700317	NWL
89	2021-05-13 11:22:39	Other	High-powered speedboat	3	22.36210667	113.8703433	NWL
90	2021-05-13 11:25:05	Other	High-powered speedboat	1	22.36849833	113.8701133	NWL

91	2021-05-13 11:31:07	Other	High-powered speedboat	1	22.382845	113.869805	NWL
92	2021-05-13 11:33:28	Other	High-powered speedboat	1	22.388415	113.8697383	NWL
93	2021-05-13 11:33:39	Other	High-powered speedboat	6	22.388735	113.8697233	NWL
94	2021-05-13 11:35:02	Other	High-powered speedboat	1	22.39198667	113.869865	NWL
95	2021-05-13 11:37:20	Other	High-powered speedboat	1	22.39769667	113.8698183	NWL
96	2021-05-13 11:37:27	Other	High-powered speedboat	1	22.39790333	113.8698083	NWL
97	2021-05-13 11:38:56	Other	High-powered speedboat	1	22.40204167	113.8698067	NWL
98	2021-05-13 11:39:24	Other	High-powered speedboat	1	22.40297833	113.8698817	NWL
99	2021-05-13 11:40:05	Other	High-powered speedboat	1	22.40492833	113.869885	NWL
100	2021-05-13 11:40:16	Other	High-powered speedboat	1	22.40531333	113.8698467	NWL
101	2021-05-13 11:40:22	Other	High-powered speedboat	1	22.40552833	113.8698333	NWL
102	2021-05-13 11:41:07	Other	High-powered speedboat	1	22.40760167	113.8699	NWL
103	2021-05-13 12:01:06	Other	High-powered speedboat	1	22.39156833	113.877165	NWL
104	2021-05-13 13:00:39	Other	High-powered speedboat	1	22.39791167	113.88675	NWL
105	2021-05-13 13:13:45	Other	High-powered speedboat	6	22.38828833	113.8974367	NWL
106	2021-05-13 13:17:34	Other	High-powered speedboat	1	22.37977	113.8975067	NWL
107	2021-05-13 13:18:05	Other	High-powered speedboat	2	22.37888167	113.8974067	NWL
108	2021-05-13 13:19:32	Other	High-powered speedboat	1	22.37553167	113.8973183	NWL
109	2021-05-13 13:25:13	Other	High-powered speedboat	1	22.362585	113.89783	NWL
110	2021-05-13 13:41:25	Other	High-powered speedboat	1	22.34105167	113.9073767	NWL
111	2021-05-13 13:44:11	Other	High-powered speedboat	1	22.34824167	113.9073933	NWL
112	2021-05-13 13:47:50	Other	High-powered speedboat	1	22.35813	113.9073517	NWL
113	2021-05-13 13:47:55	Other	High-powered speedboat	1	22.35835167	113.9073717	NWL

114	2021-05-13 13:48:02	Other	High-powered speedboat	1	22.35861667	113.90741	NWL
115	2021-05-13 13:48:42	Other	High-powered speedboat	1	22.36010667	113.9071167	NWL
116	2021-05-13 13:48:46	Other	High-powered speedboat	1	22.36023833	113.907085	NWL
117	2021-05-13 13:48:53	Other	High-powered speedboat	1	22.36050667	113.90703	NWL
118	2021-05-13 13:52:29	Other	High-powered speedboat	2	22.37040833	113.906905	NWL
119	2021-05-13 13:53:00	Other	High-powered speedboat	2	22.37168	113.9069167	NWL
120	2021-05-13 13:54:34	Other	High-powered speedboat	1	22.37610167	113.9070183	NWL
121	2021-05-13 13:54:39	Other	High-powered speedboat	1	22.37628833	113.907065	NWL
122	2021-07-22 10:39:54	Other	High-powered speedboat	2	22.260985	113.8415167	WL
123	2021-07-22 10:48:38	Other	High-powered speedboat	1	22.269535	113.8508183	WL
124	2021-07-22 10:49:56	Other	High-powered speedboat	10	22.269455	113.8548233	WL
125	2021-07-22 11:08:30	Other	High-powered speedboat	1	22.30755167	113.8703717	NWL
126	2021-07-26 11:36:30	Other	High-powered speedboat	1	22.35481	113.950815	NWL
127	2021-08-17 18:03:36	Fishing	Trawler	1	22.1678083	113.939357	SL
128	2021-09-07 09:55:55	Fishing	Trawler	1	22.1826333	113.851568	SL
129	2021-09-07 09:59:41	Fishing	Trawler	1	22.1741417	113.851797	SL
130	2021-09-07 10:03:48	Other	High-powered speedboat	6	22.17679667	113.8422983	SL
131	2021-09-07 10:08:06	Other	High-powered speedboat	2	22.18451	113.8387117	WL
132	2021-09-07 10:24:38	Other	High-powered speedboat	2	22.20107	113.834285	WL
133	2021-09-07 10:59:14	Other	High-powered speedboat	8	22.23521667	113.8354067	WL
134	2021-09-07 11:59:38	Other	High-powered speedboat	1	22.32184	113.868985	NWL
135	2021-10-20 10:01:31	Fishing	Trawler	2	22.17059	113.8638	SL
136	2021-10-20 10:32:25	Fishing	Trawler	1	22.1869	113.8736	SL

137	2021-10-20 10:36:55	Fishing	Trawler	1	22.17849	113.8731	SL
138	2021-10-20 10:39:18	Fishing	Trawler	1	22.17415	113.8729	SL
139	2021-10-20 11:17:07	Fishing	Trawler	1	22.20048	113.8829	SL
140	2021-10-20 11:47:48	Fishing	Trawler	1	22.17372	113.8927	SL
141	2021-10-20 12:01:23	Other	High-powered speedboat	2	22.14916	113.8932	SL
142	2021-10-20 13:00:05	Fishing	Trawler	1	22.18381	113.9191	SL
143	2021-10-25 09:34:03	Fishing	Trawler	1	22.17139	113.9293	SL
144	2021-10-25 09:35:02	Fishing	Trawler	1	22.16898	113.9292	SL