What Do Dolphins Do At Night?: Filling Knowledge Gaps in Night Time Range and Behaviour Activities of Chinese White Dolphins in Hong Kong

海豚在晚上做甚麼？：窺探本港海豚夜間行為及活動範圍之謎

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Project Title: What Do Dolphins Do At Night?: Filling Knowledge Gaps in Night Time Range and Behaviour Activities of Chinese White Dolphins in Hong Kong

Project Leader: Dr 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.

Signature: Project Leader, Dr Lindsay Porter
Date： 24 September 2019

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Attachments

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Executive Summary

This project proposed two objectives, both based on the ability to unambiguously detect the two different marine mammal species which occur within Hong Kong waters. The Indo-Pacific humpbacked dolphin (*Sousa chinensis*), locally known as the Chinese white dolphin (CWD) has an extensive vocal repertoire that includes, clicks, whistles, buzzes, squawks and creaks which range between 500Hz to 200kHz. Finless porpoise (*Neophocaena phocaenoides*) are also resident in Hong Kong waters and have a very restricted vocal repertoire that comprises narrow band, high frequency buzzes and clicks which range between 120-160kHz. The very different type of vocalisations emitted by the two species make it easy to aurally distinguish them and bespoke acoustic classifiers (that search acoustic data for the patterns of each species) make data extraction largely automated and very efficient. This project had two main aims; both based on acoustic monitoring. The first was to use traditional acoustic monitoring techniques, to conduct night time surveys of Hong Kong western waters and the second was to test a new acoustic monitoring system.

Night Time Surveys: much is known of the daylight occurrence of marine mammals in Hong Kong, however, neither dolphins nor porpoise 'sleep' so an understanding of their night time activities may be beneficial to management plans, particularly as Hong Kong waters are utilised, to various degrees, 24 hours a day, seven days a week. To address this data gap, night time acoustic surveys were conducted by vessel throughout Hong Kong western waters and data on species, time, location, vocalisation type and density, as well as other environmental parameters were recorded. It was challenging to configure marine mammal acoustic recording equipment to cope with Hong Kong's extremely noisy underwater environment, however, after some months of testing, an effective system was established. Surveys were largely conducted between 6pm and 6am, as well as several day time surveys so that comparisons between visual observations and acoustic detections could be made. A total of 2246 km of survey effort was completed and 162 dolphin and 216 finless porpoise detections were recorded. Differences between day and night dolphin habitat use are beginning to emerge, indicating that dolphins range more extensively throughout the Hong Kong habitat at night than they do during the day. Porpoise too seem to have differences in night time habitat use, but more data is required to discern any differences more clearly. Night time surveys will continue in 2019-20 and a more detailed analyses presented ta the completion of this two year project.

Real Time Acoustic Monitoring: stationary acoustic devices have been used globally to elucidate patterns of occurrence and fine scale habitat use of marine mammal species. In recent years, technological advances have allowed for the miniaturisation of acoustic recording equipment and data communication systems have diversified and become more widespread thus enabling the development of new marine mammal monitoring tools. A prototype real time acoustic monitoring system was tested and adapted for use in Hong Kong waters. Two models were tested, an autonomous buoy and a unit that can be attached to an existing navigational buoy or other marine structure. Two different communication systems were also configured that allowed the

real-time transmission of acoustic data from both acoustic device models; cellular network and wireless radio. Under different trial conditions, the acoustic devices remained sufficiently charged for four to eight weeks continuous deployment and were tested in eight different locations around Lantau Island. There wireless data transmission system worked without issue and data was relayed instantaneously to a base station. Configuring the system to use the local cellular network proved more challenging, however, after much testing, a suitable network provider was found, and acoustic data was reliably transmitted every two minutes. Even in the remotest part of Lantau waters, i.e., southern Soko Islands, data transmission over the chosen cellular network was problem free. Year one of this project was designated to testing both platforms and establishing reliable data transmission configurations. As the project progresses in 2019-20, longer term deployments solely for the purpose of marine mammal and marine park monitoring will be conducted.

This report provides a summary of available data collected during night time acoustic surveys and lists detections of both dolphins and porpoise. It provides the first acoustic detection rates for marine mammals from line transect surveys conducted at night and the emerging data reveals distinct diurnal patterns for Chinese white dolphin habitat use and less pronounced patterns for finless porpoise. As the work reported is part of a longer-term data set, more detailed analyses will be conducted at the completion of this project in 2020. This report also details the successful set up and trial of a new real time acoustic monitoring device which proved to work reliably throughout Hong Kong western waters. Two different types of data transmission systems were also established. As the project progresses, longer term deployments focused on collecting marine mammal data will be attempted.

What Do Dolphins Do At Night?: Filling Knowledge Gaps in Night Time Range and Behaviour Activities of Chinese White Dolphins in Hong Kong

1. Project Description

This project investigated the night-time acoustic activity of Chinese white dolphin (*Sousa chinensis*), and other species, in Hong Kong waters. The main aim of the project was to produce maps of the night-time occurrence and behavioural activity of dolphins. Day-time acoustic surveys were also conducted to calibrate visual observations with concomitantly collected acoustic data. The data was collected using multiple hydrophone arrays that were towed behind a small vessel that traversed the Lantau Island water area. Although some single hydrophone acoustic devices have been deployed on Hong Kong's sea bed (sometimes referred to as "static acoustic monitoring"), these only collect acoustic information from the immediate vicinity of the hydrophone station itself and, as such, provide data for fine scale habitat use of dolphins, and other soniferous marine species. Vessel-based acoustic surveys, however, have the potential to gather acoustic data from throughout the Hong Kong habitat and therefore, provide information on the dolphins range-wide occurrence. As anthropogenic activities occur, to varying degrees, 24 hours a day within Hong Kong waters, an understanding of the dolphins range wide 24-hour activity is useful information for management and conservation plans. Understanding a complete picture of habitat use patterns and behaviour also assists in understanding impacts to the dolphin population and how, potentially, to mitigate against any adverse effects.

The project was conducted throughout the known range of the Chinese white dolphin in Hong Kong waters, as identified by the 'Long Term Monitoring Programme of the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government'. This included the waters adjacent to the Third Runway System (3RS), the Marine Parks at Sha Chau and Lung Kwu Chau and the Brothers Island and western, southern and eastern Lantau waters. The acoustic data was collected from hydrophone arrays towed behind moving vessels and followed, where possible, the transect lines that the AFCD long term marine mammal monitoring surveys utilise. Additional surveys were conducted during daylight hours to provide a comparison between visual and acoustic data collection. Data on both resident species of marine mammals, the Chinese white dolphin and the finless porpoise (*Neophocaena phocaenoides*) were collected, as well as other soniferous species, e.g., croaker fishes (Sciaenids). The vocalisations of the two different cetacean species are quite distinctive and can be easily categorised. At final project completion (June 2020) it is anticipated that sufficient detection data will have been collected to conduct robust density analyses, for both species, using line transect methodology and spatial mapping techniques.

In addition, it was proposed to test a new autonomous and real-time acoustic detection unit as part of this project, so that the dolphin habitat, particularly Marine Protected Areas (MPA), could be monitored 24 hours a day with no delay in receiving the acoustic data. Initially, it was proposed to test the acoustic devices for six months during the first year of this project. It is planned to deploy a single system for a prolonged period during the second year of the project[1].

Therefore, this report summarises detections of both dolphins and porpoise and provides the first acoustic detection rates for line transect surveys at night. This first year of surveys thus provides an emerging understanding of dolphin, and porpoise, night time occurrence throughout western Hong Kong waters. As the work reported herein is part of a longer-term data set, more detailed analyses will be conducted at the completion of this project in 2020.

2. Completed activities against the proposed work schedule

This is a two-year project which proposed a work schedule to include two main components; night time acoustic surveys and the trialling and deployment of a real-time autonomous acoustic device.

Night time Acoustic Surveys: The work schedule proposed to conduct monthly night time surveys throughout Hong Kong western waters. As per the proposed schedule, night time surveys commenced in July 2018, however, as detailed in the interim report, initial analysis revealed that noise levels in some areas of Hong Kong were extraordinarily high and required the survey equipment and protocols to be revised and retested. Several months were dedicated to retesting and rebuilding of acoustic equipment and to locating quieter vessels than originally hired, so that as many external noise sources as possible could be minimised, in the already loud environment. With vessels and a suitable acoustic configuration established, and the initial day time calibration trials re-run, a full schedule of night time monthly surveys were resumed in January 2019. In April 2019, an at-sea incident resulted in the loss of equipment. A Hong Kong-Macau fast ferry did not give the survey vessel a sufficiently wide berth and as a result severed the hydrophone cable and damaged the topside electronics. Further, this “near miss” instigated a health and safety review within SMRU Hong Kong, and the University of St. Andrews, for all night time field activities. This resulted in a short cessation of fieldwork until new safety procedures were approved. Additional surveys were conducted in May to make up for this lost time and continued, without incident, until June 2019. In summary, night time surveys were conducted throughout the year, however, the period of additional testing and system reconfiguration resulted in less survey effort in those test months. Once a satisfactory vessel and hydrophone system configuration had been thoroughly tested, a full schedule of surveys resumed, and the entire Lantau habitat was surveyed at least once every month.

[1] The project proponent did not apply for a project extension to continue the deployment of the real time acoustic device into the second year of this project. As the main cost associated with this activity was to be provided by SMRU Hong Kong, it intended to continue deployments in the 2019-20 project period, with no cost implications to the original budget.

Realtime Acoustic Monitoring Device: devices were tested adjacent to both marine park areas in North Lantau between July 2018 and May 2019. Devices performed well although intermittent data transmission delays were noted in all areas when using the cellular network communications system. All common Hong Kong cellular network SIM cards were tested but all exhibited either delays or necessitated regular reboots to restart data transmission. In April 2019, a US-based cellular provider was tested which proved to transmit consistently, with only occasional delays of a few minutes. Thus, a 3G system was installed that successfully communicated, real-time data from the acoustic device to remote base stations. A wireless radio frequency communication system was also tested. In Hong Kong, the Office of the Communications Authority regulates all radio frequency band use and they provided guidance on wireless communication suitable for the acoustic device and the Hong Kong environment. The device was installed with radios that operated on the "Industrial, Scientific and Medical (ISM) Equipment" bandwidth (2.4GHz) which allowed real time data to be reliably transmitted from the acoustic device without issue.

In summary, night time surveys were conducted on schedule, after towed array systems were rebuilt and reconfigured and alternative vessels were deployed. There was an additional issue that paused survey for several weeks in early 2019. A real-time acoustic device was developed specifically for Hong Kong and deployed remotely in multiple areas around Lantau Island. Acoustic data was reliably transmitted via both the cellular network and wireless communications bandwidth. All deployments were relatively short term and a longer term deployment is planned for year two of the project.

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

3. Results

This is year one of a two-year project and part of this first year was dedicated to resolving issues caused by exceptionally high underwater noise levels. After project completion (June 2020), a more thorough analyses of all survey data will be provided. This, the first-year completion report, provides a summary of all data and preliminary observations of the first results as they emerge.

3.1. Survey Effort

A total of 2246km of survey effort was conducted which was dedicated to acoustic data collection, over an eight month period (July-August 2018 and January– June 2019). The survey area is divided into different blocks, following the AFCD long term monitoring programme survey methodology. These blocks are of different sizes and require different lengths of vessel effort to fully survey each area. Each block was surveyed at least once a month during active survey months, which resulted in each block having unequal total survey trackline. This report indicates if calculated rates or observations are based on individual block effort or total effort of the entire survey area. There was a total of 162 dolphin detections, approximately half of which (47%) were detected after sunset and before sunrise, a quarter of which were detected during daylight hours (25%) and the remaining (27%) were detected during the period one hour before sunset (transition), over the entire survey area (Table 1) By proportioning the survey effort in this way, both typical 'day time' encounters were recorded, as well as the transitional periods from day to night and night time itself. Therefore, the first year of survey obtained concomitant visual and acoustic data for dolphins which will be used to ground truth future analyses. There was a total of 216 finless porpoise detections, 37% detected during the day, 41 % at night and 22% during the one hour period before sunset (transition) (Table 2). Reliable visual detection of finless porpoise is notoriously inconsistent and acoustic detections alone will provide the basis for later porpoise density analyses. Encounter rates for dolphins ranged between 0 and 18 dolphins per 100 km, with a peak detection rate of 18.38 dolphin detections per 100 km in May 2019, based on total area effort. Finless porpoise were detected throughout the study period and porpoise detection rate varied between 0 and 19 porpoise detections per 100km, with a peak detection rate of 19.89 porpoise per 100km in January 2019 (Table 3). When detections are separated into different habitat sections, encounter rates (per 100 km) varied between 0 (East Lantau) and 24.49 dolphin detections per 100 km (West Lantau). For porpoise, detections per area varied between 0 and 26.82 detections per 100km (South East Lantau) (Table 4). During daylight hours, dolphins were recorded in both West and South Lantau and finless porpoise were recorded in South Lantau (Figure 1). During night time hours, the dolphins range extended to North East Lantau, North West Lantau and South Lantau, as well as West Lantau, as observed during daylight hours. The range of finless porpoise was extended into South East Lantau and East Lantau, as well as South Lantau (Figure 2).

Realtime acoustic monitoring devices were deployed in eight areas in November 2018 and April 2019. Site selection was based on proximity to marine protected areas (existing and proposed), shipping lanes and remoteness (Figure 3). The purpose of the deployments was to; 1) understand the difference between two different types of mounting platforms and; 2) to test two different data communication systems. The first platform trialled was an entirely independent system, where all electronics were contained in a buoy. This system was trialled in northern Lantau over a 10 day supervised period. The system functioned reliably, and the battery did not deplete. The second system is designed to be mounted on any existing platforms, e.g., piers, navigation and other shipping buoys, and has the option of adding an additional battery pack. This system operated on a nearshore platform and then from a fixed platform as sea for a continuous period of six weeks and the battery pack did not deplete. Two different modes of acoustic data transmission were also tested; cellular network and wireless radio frequency. Initially, there was considerable testing of different data transmission frequencies, i.e., transmit data every 2 minutes, 4 minutes, up to 30 minutes, across the cellular network system. All local providers proved to be inconsistent and required multiple system reboots to restart data transmission from the acoustic device. It took time to determine that the issue was the local SIM card configuration, and not the acoustic device system itself. No Hong Kong provider proved suitable for the type of data transmission required for the acoustic device. A network provider from the United States was then trialled and data transmission was immediately stabilised and it was possible to send data packages reliably every two minutes. This provider also had good coverage in the remoter southern areas of Hong Kong waters. Data transmission via wireless radio was straight forward, using the 2.4GHz bandwidth and no data transmission issues were encountered. Via wireless radio, data transmission was instantaneous. This deployment period was not intended to focus on marine mammal monitoring and instead used underwater speakers that played pre-recorded dolphin and porpoise sounds to test data transmission capability, although a sighting and concomitant acoustic detection of finless porpoise was recorded in South Lantau in April 2019. The initial findings of the deployment were presented at the 13th Western Pacific Conference on Acoustics (WESPAC 2018) and a paper was published in the conference proceedings (Appendix I).

Although only a preliminary investigation of the night time acoustic survey data has been performed, diurnal patterns of occurrence appear to be emerging for dolphins; there are detections throughout their known habitat during night time hours, however, day time occurrence appears to be restricted to West Lantau. For finless porpoise, it appears that their range extends further into the south and east of Lantau waters at night. Continued analysis will look more closely at the density of acoustic detections and relate this both to area and time, thus providing a more robust comparison of diurnal habitat use. Real time acoustic devices were trialled on two different platforms and using different data communication systems. Both systems were fine-tuned and stabilised for the Hong Kong environment and it is hoped to complete a long term deployment, focusing solely on marine mammal and underwater noise data collection, in year two of the project.

4. Evaluation of Project Effectiveness

The two objectives of this project were to:

Objective 1: Map the relative density, distribution and behaviour of the night-time occurrence of Chinese white dolphin (<u>Sousa chinensis</u>) in Hong Kong waters, from vessel based acoustic surveys
Vessel-based acoustic surveys were conducted in all Lantau habitat and both dolphins and porpoise were consistently detected throughout the survey period. There were challenges in fine tuning an acoustic system and survey methodology that was equally effective in noisy northern Lantau waters as well as elsewhere. In addition, an incident in the fast ferry lane necessitated the replacement of all acoustic equipment which interrupted surveys in April 2019. Simple investigation of the first years' dataset indicates that there are distinctive diurnal occurrence patterns for both dolphins and porpoise. Detailed spatial analyses will be conducted when the data set is completed in 2020. As such, this objective has been met for the first year of this project.

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

Real-time acoustic monitoring devices were tested adjacent to the Sha Chau Lung Kwu Chau Marine Park and the Brothers Marine Park, in North Lantau, and the proposed South Lantau Marine Park. Suitable system configurations were stabilised for two different types of data transmission. The deployment of the now stabilised system will continue into year two of this project. The initial objective of trialling a system that was stable and worked efficiently in Hong Kong Marine Park areas was achieved, although a longer term deployment was deferred until 2019-20. As such, this objective partially met in the first year of this project

Project Benefits

As yet, the benefits of this project are not fully realised as data collection will not be completed until 2020. What is becoming apparent, however, is that acoustic monitoring during night time periods provides new insights to dolphin behaviour and habitat use and assists in filling data gaps that are useful for management and conservation plans for this species. Acoustic monitoring tools have long been known to be the most effective means with which to monitor other porpoise species' which are difficult to observe (e.g., harbour porpoise, vaquita). This is the first project to consistently use towed acoustic arrays to map finless porpoise habitat use throughout their Lantau range and highlights the usefulness of this technique for collecting robust and verifiable datasets for a species which is challenging to detect visually (Figure 4)

Static acoustic monitoring devices that have been deployed on the seabed in Hong Kong, and elsewhere, have provided useful long term data however, if the device is lost or malfunctions this cannot be discerned until attempts are made to retrieve the device, at which point, the data may be already lost. As deployments may be up to six months in length, significant data gaps may result. If the real-time acoustic device malfunctions and data transmission stops, this will be discerned within several minutes. In such circumstances, the device can be remotely accessed from shore and if data transmission is not able to be restored via this option, then a team can be deployed to the device site and either the system is replaced or physical repairs are made. In Hong Kong, under normal weather conditions, a team could be deployed within hours and data loss would be minimal. In addition, real-time systems allow the monitoring of marine mammal activities as they happen, and periods of between 1 to 6 months do not have to pass before data can be retrieved. The benefits of being able to track the real time movements of marine mammals in important or sensitive areas allow for immediate actions to be taken, to improve dolphin and porpoise wellbeing in Hong Kong waters. As such, the real time and remote acoustic monitoring device which has been successfully trialled in Hong Kong is a useful addition to the suite of technology that researchers and management authorities can now use to monitor dolphins and porpoise in Hong Kong.

5. Summary and Next Steps

Acoustic surveys are conducted regularly, elsewhere, to map marine mammal species distribution, calculate population density and to elucidate patterns of occurrence both spatially and temporally. Vessel-based acoustic surveys are most useful for assessing spatial trends in distribution and, for year one of this project, the data indicates that there are differences between day and night time habitat use for Chinese white dolphin. In the last decade, based on day time visual observation studies, the number of dolphins sighted in eastern and northern Lantau waters has diminished. For this project, vessel based surveys, using an acoustic detection system, noted distinct differences between daylight and night time occurrence of dolphins, with dolphins having a greater range at night than during the day, i.e., most day time acoustic detections were restricted to Northwest and West Lantau whereas night time acoustic detections occurred throughout the habitat. This is year one of a longer term project and vessel based surveys will continue in 2019-20. Once the acoustic data collection phase is completed (June 2020), thorough analyses will be conducted and, depending on analyses outcomes, recommendations will be proposed that are based on the degree of diurnal behaviour observed and the factors that are most likely to drive differing habitat use. It is hoped that project conclusions will be presented to the Marine Mammal Conservation Working Group (MMCWG) of the Hong Kong SAR so that they might be considered as useful data for conservation and management plans. In addition, and hopefully after feedback from the MMCWG, and a paper of research finding will be developed after June 2020.

Static acoustic recorders (positioned either on the seabed or in the sea column) provide high resolution data useful for analysing temporal patterns of occurrence, or fine scale marine mammal habitat use. For offshore environments, this is often the most cost efficient way to obtain enough data to perform analyses with sufficient statistical power. Static acoustic recorders are most often archival in nature, that is, they store data on an internal hard drive until such time as the device can be retrieved and downloaded. As some deployments can last for 6 months or more, this means that any device that is lost or malfunctions is not discovered until after collection attempts and after data has been lost. Also, there is sometimes a need to have real-time acoustic surveillance, in instances where immediate mitigation action may be required, e.g., during seismic surveys, monitoring marine protected areas. Previously, these real-time acoustic systems required a substantial platform and personnel to monitor the system on site. A compact and remotely deployed acoustic monitoring system from which real-time data could be transmitted would resolve both the potential issue of data loss from static recorders and enable more efficient, and less costly, real-time acoustic monitoring system deployment. In recent years, the miniaturisation and increased proficiency of electronic hardware, as well as the proliferation of wireless data transmission systems, has led to the development of buoy-based, real time acoustic monitoring system. Two such buoyed systems were trialled in Hong Kong, a unit contained within a small buoy, that is deployed independently, and the other a unit that can be attached to an existing buoy or marine structure. Both performed well with batteries lasting between 4 to 8 weeks continuous use. In addition, two data communication systems were developed that worked effectively in Hong Kong, one which sent data instantaneously and one which sent data every 2 minutes. Now that both equipment configuration and data communication perform consistently in Hong Kong, as this project continues, a long term deployment of a real-time device is planned. A paper on the research applications of this real time acoustic system will be presented at the World Marine Mammal Conference in December 2019 and a paper of research finding will be developed after June 2020.

In summary, both vessel based acoustic surveys and real-time acoustic monitoring device deployment will continue as this project progresses into 2019-20. At the end of the project (June 2020) detailed analyses and conclusions will be presented, advice be will be sought from management groups in Hong Kong and papers will be prepared for peer-review.

Tables

Table 1 All Dolphin Acoustic Detections, July 2018-June 2019

Date	Time	Species	Area	Latitude	Longitude
2018/07/31	19:27:33	CWD	WL	22.26909	113.8678
2019/01/18	5:52:22	CWD	SL	22.19858	113.8617
2019/01/18	5:52:29	CWD	SL	22.19878	113.8615
2019/01/18	5:54:14	CWD	SL	22.19677	113.8583
2019/01/18	6:49:20	CWD	WL	22.20078	113.8394
2019/01/18	6:51:58	CWD	WL	22.20191	113.8408
2019/01/18	7:09:10	CWD	WL	22.21849	113.8244
2019/01/18	7:19:39	CWD	WL	22.22831	113.8260
2019/01/25	18:12:32	CWD	SEL	22.21751	113.9541
2019/01/25	18:12:58	CWD	SEL	22.21856	113.9539
2019/01/28	17:13:35	CWD	WL	22.23582	113.8348
2019/01/28	17:32:07	CWD	WL	22.25796	113.8489
2019/01/28	17:45:47	CWD	WL	22.26797	113.8573
2019/01/28	17:48:45	CWD	WL	22.26984	113.8651
2019/01/28	17:53:26	CWD	NWL	22.27964	113.8688
2019/01/28	17:53:52	CWD	NWL	22.28072	113.8687
2019/01/28	18:32:56	CWD	NWL	22.37149	113.8717
2019/01/28	18:33:27	CWD	NWL	22.37276	113.8717
2019/01/28	19:10:40	CWD	NWL	22.37518	113.8772
2019/01/28	19:50:29	CWD	NWL	22.29100	113.8769
2019/01/29	16:26:40	CWD	NWL	22.34934	113.8830
2019/01/29	16:28:15	CWD	NWL	22.35291	113.8838
2019/01/29	16:41:56	CWD	NWL	22.38230	113.8873
2019/01/29	17:02:34	CWD	NWL	22.38377	113.8981
2019/02/14	17:04:42	CWD	NEL	22.33157	114.0120
2019/02/14	17:05:30	CWD	NEL	22.33037	114.0103
2019/02/14	17:11:14	CWD	NEL	22.33358	114.0038
2019/02/19	17:43:17	CWD	WL	22.25273	113.8401
2019/02/19	17:48:05	CWD	WL	22.24534	113.8303
2019/02/19	17:52:26	CWD	WL	22.24238	113.8361
2019/02/19	18:01:30	CWD	WL	22.23536	113.8305
2019/02/19	18:43:55	CWD	WL	22.19286	113.8415
2019/02/19	19:03:51	CWD	WL	22.19214	113.8516
2019/02/27	4:21:39	CWD	NWL	22.39571	113.8867
2019/03/13	12:21:20	CWD	NWL	22.30755	113.8640
2019/03/13	12:52:44	CWD	NWL	22.29005	113.8781
2019/03/13	13:06:19	CWD	NWL	22.27874	113.8738
2019/03/13	13:06:25	CWD	NWL	22.27850	113.8738

Date	Time	Species	Area	Latitude	Longitude
2019/03/19	2:11:10	CWD	WL	22.26011	113.8501
2019/03/19	2:13:59	CWD	WL	22.26025	113.8490
2019/03/19	2:22:51	CWD	WL	22.25320	113.8437
2019/03/19	2:26:00	CWD	WL	22.25324	113.8353
2019/03/19	2:28:32	CWD	WL	22.24917	113.8314
2019/03/19	2:33:45	CWD	WL	22.24274	113.8354
2019/03/19	2:43:37	CWD	WL	22.23570	113.8300
2019/03/19	2:48:25	CWD	WL	22.23472	113.8321
2019/03/19	3:56:12	CWD	WL	22.23253	113.8241
2019/03/25	18:36:24	CWD	WL	22.21994	113.8337
2019/04/09	18:46:38	CWD	NWL	22.30917	113.8624
2019/04/09	20:57:21	CWD	WL	22.20002	113.8281
2019/04/09	21:01:11	CWD	WL	22.20116	113.8376
2019/04/09	21:15:55	CWD	WL	22.22024	113.8226
2019/04/09	21:28:43	CWD	WL	22.23670	113.8374
2019/05/07	2:16:07	CWD	WL	22.25232	113.8381
2019/05/07	2:37:21	CWD	WL	22.22283	113.8228
2019/05/07	2:53:20	CWD	WL	22.20007	113.8304
2019/05/07	2:56:35	CWD	WL	22.19867	113.8249
2019/05/07	3:01:06	CWD	WL	22.19022	113.8305
2019/05/07	3:10:08	CWD	WL	22.19105	113.8418
2019/05/07	3:11:48	CWD	WL	22.19288	113.8447
2019/05/07	3:18:59	CWD	WL	22.18257	113.8504
2019/05/07	3:29:17	CWD	WL	22.18470	113.8361
2019/05/07	3:31:25	CWD	WL	22.18810	113.8321
2019/05/07	3:53:32	CWD	WL	22.20933	113.8246
2019/05/07	4:05:32	CWD	WL	22.22669	113.8294
2019/05/07	4:09:06	CWD	WL	22.22912	113.8361
2019/05/07	4:14:45	CWD	WL	22.23943	113.8420
2019/05/07	4:16:58	CWD	WL	22.24336	113.8417
2019/05/07	4:22:59	CWD	WL	22.24659	113.8299
2019/05/07	4:26:34	CWD	WL	22.25353	113.8323
2019/05/07	4:33:31	CWD	WL	22.26018	113.8428
2019/05/07	4:37:51	CWD	WL	22.26002	113.8524
2019/05/07	4:41:30	CWD	WL	22.26500	113.8579
2019/05/09	18:05:13	CWD	WL	22.22735	113.8229
2019/05/09	18:06:17	CWD	WL	22.22497	113.8227
2019/05/09	18:28:16	CWD	WL	22.19354	113.8280

Date	Time	Species	Area	Latitude	Longitude
2019/05/09	18:32:38	CWD	WL	22.18479	113.8348
2019/05/09	19:18:50	CWD	WL	22.20987	113.8227
2019/05/16	17:44:47	CWD	NWL	22.37697	113.8974
2019/05/16	18:05:25	CWD	NWL	22.38818	113.8878
2019/05/20	3:50:44	CWD	SL	22.19178	113.8827
2019/05/20	4:45:13	CWD	SL	22.19184	113.9024
2019/05/20	5:49:19	CWD	SL	22.19166	113.9127
2019/05/21	1:54:42	CWD	WL	22.26959	113.8430
2019/05/21	2:00:58	CWD	WL	22.25898	113.8357
2019/05/21	2:13:58	CWD	WL	22.24032	113.8410
2019/05/21	2:14:52	CWD	WL	22.23818	113.8401
2019/05/21	2:23:00	CWD	WL	22.23144	113.8233
2019/05/21	2:24:18	CWD	WL	22.22891	113.8221
2019/05/21	2:29:22	CWD	WL	22.21841	113.8222
2019/05/21	2:39:13	CWD	WL	22.20541	113.8374
2019/05/21	2:41:40	CWD	WL	22.20120	113.8371
2019/05/21	2:46:47	CWD	WL	22.19941	113.8251
2019/05/21	3:28:18	CWD	WL	22.19430	113.8404
2019/05/21	3:29:19	CWD	WL	22.19529	113.8426
2019/05/21	3:48:14	CWD	WL	22.22577	113.8219
2019/05/21	3:48:32	CWD	WL	22.22654	113.8218
2019/05/21	3:49:26	CWD	WL	22.22725	113.8232
2019/05/21	3:49:41	CWD	WL	22.22709	113.8238
2019/05/21	3:54:22	CWD	WL	22.22399	113.8344
2019/05/21	3:54:39	CWD	WL	22.22458	113.8345
2019/05/21	4:00:42	CWD	WL	22.23605	113.8406
2019/05/21	4:04:36	CWD	WL	22.24260	113.8412
2019/05/21	4:09:44	CWD	WL	22.24572	113.8288
2019/05/21	4:14:35	CWD	WL	22.25600	113.8336
2019/05/21	4:20:07	CWD	WL	22.25934	113.8444
2019/05/22	9:47:17	CWD	WL	22.26940	113.8399
2019/05/22	9:57:44	CWD	WL	22.25276	113.8420
2019/05/22	10:13:53	CWD	WL	22.22088	113.8218
2019/05/22	10:32:10	CWD	WL	22.19708	113.8246
2019/05/22	10:34:02	CWD	WL	22.19224	113.8277
2019/05/22	10:38:56	CWD	WL	22.18507	113.8376
2019/05/22	10:42:17	CWD	WL	22.19091	113.8413
2019/05/22	10:49:09	CWD	WL	22.18795	113.8510
2019/05/22	10:52:17	CWD	WL	22.18029	113.8512
2019/05/22	10:59:02	CWD	WL	22.17733	113.8429
2019/05/22	11:09:22	CWD	WL	22.19294	113.8282

Date	Time	Species	Area	Latitude	Longitude
2019/05/22	11:15:13	CWD	WL	22.19437	113.8414
2019/05/22	11:22:54	CWD	WL	22.20874	113.8353
2019/05/22	11:40:51	CWD	WL	22.22709	113.8325
2019/05/22	11:47:36	CWD	WL	22.23927	113.8429
2019/05/22	11:52:53	CWD	WL	22.24386	113.8359
2019/05/22	11:57:18	CWD	WL	22.24717	113.8297
2019/05/22	12:02:59	CWD	WL	22.25906	113.8361
2019/05/23	17:55:17	CWD	NWL	22.37583	113.8873
2019/05/23	18:03:29	CWD	NWL	22.35557	113.8858
2019/05/23	18:06:00	CWD	NWL	22.35016	113.8826
2019/05/23	19:24:46	CWD	NWL	22.36209	113.9172
2019/05/23	19:25:27	CWD	NWL	22.36377	113.9169
2019/05/29	9:37:38	CWD	WL	22.21839	113.8231
2019/05/29	9:42:25	CWD	WL	22.21504	113.8337
2019/05/29	9:43:53	CWD	WL	22.21145	113.8353
2019/05/29	9:52:10	CWD	WL	22.20073	113.8279
2019/05/29	9:57:20	CWD	WL	22.19195	113.8271
2019/05/29	10:02:18	CWD	WL	22.18420	113.8354
2019/05/29	10:08:15	CWD	WL	22.19332	113.8449
2019/05/29	10:11:03	CWD	WL	22.19121	113.8500
2019/05/29	10:31:04	CWD	WL	22.19494	113.8343
2019/05/29	10:36:23	CWD	WL	22.19846	113.8433
2019/05/29	10:45:22	CWD	WL	22.20948	113.8277
2019/05/29	11:03:29	CWD	WL	22.23416	113.8382
2019/05/29	11:03:30	CWD	WL	22.23419	113.8382
2019/05/30	17:52:53	CWD	NWL	22.29438	113.8697
2019/06/19	16:23:59	CWD	SL	22.17630	113.8631
2019/06/19	16:36:13	CWD	SL	22.17650	113.8732
2019/06/19	17:00:48	CWD	SL	22.17927	113.8819
2019/06/19	17:01:52	CWD	SL	22.17652	113.8818
2019/06/20	17:09:49	CWD	NEL	22.32697	114.0049
2019/06/20	17:34:41	CWD	NEL	22.34172	113.9951
2019/06/20	17:39:48	CWD	NEL	22.33063	113.9956
2019/06/20	17:59:33	CWD	NEL	22.33943	113.9854
2019/06/23	17:56:44	CWD	WL	22.18496	113.8505
2019/06/23	17:58:02	CWD	WL	22.18181	113.8505
2019/06/23	18:04:17	CWD	WL	22.18122	113.8439
2019/06/23	18:08:06	CWD	WL	22.18607	113.8398
2019/06/23	18:08:41	CWD	WL	22.18734	113.8405

Date	Time	Species	Area	Latitude	Longitude
2019/06/23	18:13:02	CWD	WL	22.19417	113.8386
2019/06/23	18:28:38	CWD	WL	22.20865	113.8361
2019/06/23	18:33:28	CWD	WL	22.21000	113.8228
2019/06/23	18:41:00	CWD	WL	22.21892	113.8338
2019/06/23	19:03:36	CWD	WL	22.24334	113.8318
2019/06/23	19:15:11	CWD	WL	22.25820	113.8507

Table 2 All Finless Porpoise Acoustic Detections, July 2018-June 2019

Date	Time	Species	Area	Latitude	Longitude
2018/08/21	17:04:19	FP	EL	22.18753	114.0743
2018/08/21	17:15:56	FP	EL	22.21356	114.0734
2018/08/21	17:59:28	FP	EL	22.22897	114.0638
2018/08/22	15:32:06	FP	SEL	22.17297	113.9734
2018/08/22	17:56:40	FP	SL	22.17428	113.9382
2018/08/23	17:15:54	FP	SL	22.17683	113.9316
2018/08/23	17:26:59	FP	SL	22.15756	113.9279
2018/08/23	17:31:31	FP	SL	22.16572	113.9219
2018/08/23	17:34:08	FP	SL	22.17171	113.9221
2018/08/23	17:47:05	FP	SL	22.20136	113.9202
2018/08/23	18:05:28	FP	SL	22.16856	113.9215
2018/08/23	18:20:08	FP	SL	22.15062	113.9027
2019/01/18	02:41:13	FP	SL	22.18589	113.9321
2019/01/18	02:52:18	FP	SL	22.16001	113.9287
2019/01/18	02:54:10	FP	SL	22.15562	113.9289
2019/01/18	03:18:00	FP	SL	22.17329	113.9225
2019/01/18	03:47:54	FP	SL	22.16528	113.9208
2019/01/18	03:53:50	FP	SL	22.15293	113.9141
2019/01/18	03:54:12	FP	SL	22.15206	113.9139
2019/01/18	04:00:00	FP	SL	22.14970	113.9045
2019/01/18	04:06:10	FP	SL	22.16206	113.8965
2019/01/18	04:13:25	FP	SL	22.17919	113.8949
2019/01/18	04:14:11	FP	SL	22.18099	113.8948
2019/01/18	04:23:40	FP	SL	22.20362	113.8957
2019/01/18	04:38:15	FP	SL	22.18294	113.8890
2019/01/18	04:39:09	FP	SL	22.18074	113.8889
2019/01/18	05:18:36	FP	SL	22.20747	113.8797
2019/01/18	05:20:37	FP	SL	22.20551	113.8749
2019/01/18	05:33:50	FP	SL	22.17519	113.8723
2019/01/18	05:52:12	FP	SL	22.19823	113.8620
2019/01/23	12:57:14	FP	EL	22.25106	114.0825
2019/01/23	13:21:13	FP	EL	22.19395	114.0827
2019/01/23	13:25:20	FP	EL	22.18389	114.0824
2019/01/23	13:40:13	FP	EL	22.18157	114.0730
2019/01/23	13:54:57	FP	EL	22.21983	114.0738
2019/01/23	14:48:29	FP	EL	22.19463	114.0620
2019/01/23	14:53:39	FP	EL	22.18174	114.0621
2019/01/23	15:06:42	FP	EL	22.17817	114.0511
2019/01/23	15:14:19	FP	EL	22.19846	114.0514
2019/01/23	15:15:02	FP	EL	22.20039	114.0515

Date	Time	Species	Area	Latitude	Longitude
2019/01/23	15:24:27	FP	EL	22.22562	114.0509
2019/01/23	15:25:19	FP	EL	22.22793	114.0510
2019/01/23	15:33:06	FP	EL	22.24822	114.0516
2019/01/23	15:41:17	FP	EL	22.22884	114.0453
2019/01/23	15:54:34	FP	EL	22.19600	114.0438
2019/01/23	16:01:02	FP	EL	22.17997	114.0428
2019/01/23	16:07:51	FP	EL	22.16609	114.0367
2019/01/23	16:16:24	FP	EL	22.18242	114.0320
2019/01/23	16:21:28	FP	EL	22.19145	114.0270
2019/01/23	16:29:44	FP	EL	22.17460	114.0223
2019/01/23	16:29:56	FP	EL	22.17408	114.0223
2019/01/23	16:46:58	FP	SEL	22.19366	114.0127
2019/01/23	16:50:02	FP	SEL	22.20143	114.0130
2019/01/25	16:49:12	FP	SEL	22.18795	113.9785
2019/01/25	16:53:38	FP	SEL	22.17881	113.9832
2019/01/25	16:59:22	FP	SEL	22.16764	113.9793
2019/01/25	17:18:12	FP	SEL	22.20884	113.9732
2019/01/25	17:27:47	FP	SEL	22.21673	113.9637
2019/01/25	17:33:29	FP	SEL	22.20246	113.9642
2019/01/25	17:38:29	FP	SEL	22.18997	113.9645
2019/01/25	17:56:54	FP	SEL	22.17808	113.9537
2019/01/25	17:57:52	FP	SEL	22.18056	113.9538
2019/01/25	18:24:43	FP	SEL	22.19595	113.9450
2019/01/25	18:48:05	FP	SL	22.17733	113.9398
2019/01/25	18:53:10	FP	SL	22.18976	113.9393
2019/01/27	16:37:59	FP	SL	22.20706	113.9332
2019/01/27	16:38:58	FP	SL	22.20578	113.9310
2019/01/27	16:51:49	FP	SL	22.17419	113.9324
2019/01/27	16:57:04	FP	SL	22.16127	113.9321
2019/01/27	17:54:39	FP	SL	22.15643	113.8977
2019/01/27	19:17:04	FP	SL	22.16742	113.8687
2019/02/13	16:18:06	FP	SEL	22.21317	114.0000
2019/02/13	16:47:31	FP	SEL	22.17679	114.0025
2019/02/13	16:50:33	FP	SEL	22.18434	114.0025
2019/02/13	16:53:22	FP	SEL	22.19138	114.0027
2019/02/13	17:13:11	FP	SEL	22.19970	114.0125
2019/02/13	17:21:39	FP	SEL	22.17894	114.0126
2019/02/13	17:36:09	FP	EL	22.18212	114.0213
2019/02/13	17:38:00	FP	EL	22.18679	114.0215
2019/02/13	17:44:54	FP	EL	22.18954	114.0320
2019/02/13	17:48:16	FP	EL	22.18100	114.0320

Date	Time	Species	Area	Latitude	Longitude
2019/02/13	18:07:15	FP	EL	22.18952	114.0409
2019/02/13	18:09:30	FP	EL	22.19526	114.0415
2019/02/13	18:13:24	FP	EL	22.20514	114.0438
2019/02/13	18:18:07	FP	EL	22.21743	114.0446
2019/02/13	18:25:58	FP	EL	22.23746	114.0446
2019/02/13	18:37:01	FP	EL	22.23620	114.0511
2019/02/13	18:38:02	FP	EL	22.23366	114.0509
2019/02/13	18:44:38	FP	EL	22.21701	114.0520
2019/02/13	18:48:00	FP	EL	22.20857	114.0520
2019/02/13	19:06:40	FP	EL	22.18038	114.0616
2019/02/13	19:26:48	FP	EL	22.23220	114.0616
2019/02/13	19:29:14	FP	EL	22.23853	114.0617
2019/02/13	20:03:36	FP	EL	22.23533	114.0717
2019/02/13	20:12:10	FP	EL	22.21317	114.0722
2019/02/13	20:13:02	FP	EL	22.21093	114.0723
2019/02/13	20:55:05	FP	EL	22.24278	114.0813
2019/02/20	15:51:03	FP	SEL	22.19650	113.9761
2019/02/20	15:53:22	FP	SEL	22.20120	113.9796
2019/02/20	15:58:38	FP	SEL	22.21174	113.9838
2019/02/20	16:03:33	FP	SEL	22.22028	113.9758
2019/02/20	16:12:08	FP	SEL	22.20094	113.9739
2019/02/20	16:13:16	FP	SEL	22.19808	113.9738
2019/02/20	16:30:40	FP	SEL	22.17034	113.9644
2019/02/20	16:35:52	FP	SEL	22.18319	113.9647
2019/02/20	16:47:21	FP	SEL	22.21132	113.9645
2019/02/20	16:56:56	FP	SEL	22.21443	113.9543
2019/02/20	17:05:36	FP	SEL	22.19298	113.9541
2019/02/20	17:10:04	FP	SEL	22.18188	113.9542
2019/02/20	17:13:57	FP	SEL	22.17225	113.9541
2019/02/20	17:19:22	FP	SEL	22.16689	113.9462
2019/02/20	17:28:11	FP	SEL	22.18643	113.9438
2019/02/20	17:40:29	FP	SL	22.20967	113.9381
2019/02/20	17:43:17	FP	SL	22.20295	113.9382
2019/02/20	18:02:02	FP	SL	22.15596	113.9348
2019/02/20	18:03:16	FP	SL	22.15364	113.9332
2019/02/20	18:08:27	FP	SL	22.16304	113.9322
2019/02/20	18:13:17	FP	SL	22.17437	113.9327
2019/02/20	18:25:47	FP	SL	22.20370	113.9324
2019/02/20	18:28:16	FP	SL	22.20664	113.9373
2019/02/21	17:46:22	FP	SL	22.20166	113.8730
2019/02/21	18:01:55	FP	SL	22.17729	113.8826

Date	Time	Species	Area	Latitude	Longitude
2019/02/21	18:04:49	FP	SL	22.16958	113.8823
2019/02/21	18:15:07	FP	SL	22.15658	113.8925
2019/02/21	18:48:14	FP	SL	22.15990	113.8929
2019/02/21	19:12:39	FP	SL	22.20357	113.9010
2019/02/21	19:31:39	FP	SL	22.15847	113.8968
2019/02/21	19:37:34	FP	SL	22.14531	113.9075
2019/02/21	19:39:56	FP	SL	22.14608	113.9123
2019/02/21	19:44:22	FP	SL	22.14980	113.9154
2019/02/21	19:49:24	FP	SL	22.15606	113.9173
2019/02/21	20:23:34	FP	SL	22.20373	113.9205
2019/03/21	17:37:51	FP	SL	22.16420	113.8955
2019/03/21	17:38:11	FP	SL	22.16335	113.8956
2019/03/21	18:15:43	FP	SL	22.20986	113.8923
2019/03/26	16:05:55	FP	EL	22.24369	114.0823
2019/03/26	16:16:48	FP	EL	22.21659	114.0819
2019/03/26	16:27:15	FP	EL	22.19107	114.0810
2019/03/26	16:27:21	FP	EL	22.19083	114.0810
2019/03/26	17:04:01	FP	EL	22.22600	114.0717
2019/03/26	17:46:06	FP	EL	22.23352	114.0629
2019/03/26	17:50:58	FP	EL	22.22175	114.0635
2019/03/26	17:52:21	FP	EL	22.21843	114.0636
2019/03/26	19:13:50	FP	EL	22.20143	114.0432
2019/03/26	19:18:08	FP	EL	22.19072	114.0428
2019/03/26	19:43:19	FP	EL	22.19219	114.0292
2019/03/26	19:49:59	FP	EL	22.18144	114.0226
2019/03/26	20:02:49	FP	SEL	22.17484	114.0123
2019/03/26	20:13:33	FP	SEL	22.19915	114.0128
2019/03/28	16:41:55	FP	SEL	22.17938	114.0022
2019/03/28	16:54:29	FP	SEL	22.17374	113.9929
2019/03/28	17:20:53	FP	SEL	22.19178	113.9757
2019/03/28	17:28:33	FP	SEL	22.17567	113.9833
2019/03/28	17:39:28	FP	SEL	22.17496	113.9736
2019/03/28	17:40:49	FP	SEL	22.17831	113.9737
2019/03/28	17:51:45	FP	SEL	22.20587	113.9733
2019/03/28	18:03:43	FP	SEL	22.21272	113.9644
2019/03/28	18:06:46	FP	SEL	22.20504	113.9643
2019/03/28	18:10:38	FP	SEL	22.19527	113.9648
2019/03/28	18:17:24	FP	SEL	22.17815	113.9644
2019/03/28	18:25:56	FP	SEL	22.16537	113.9547
2019/03/28	18:30:40	FP	SEL	22.17638	113.9539
2019/03/28	18:35:47	FP	SEL	22.18940	113.9537

Date	Time	Species	Area	Latitude	Longitude
2019/03/28	18:42:05	FP	SEL	22.20543	113.9535
2019/03/28	18:53:49	FP	SEL	22.20156	113.9451
2019/03/28	18:56:16	FP	SEL	22.19536	113.9449
2019/03/28	19:00:58	FP	SEL	22.18345	113.9444
2019/03/28	19:05:39	FP	SEL	22.17174	113.9440
2019/03/28	19:11:16	FP	SL	22.15987	113.9397
2019/03/28	19:15:43	FP	SL	22.17039	113.9388
2019/03/28	19:20:38	FP	SL	22.18296	113.9389
2019/03/28	19:27:37	FP	SL	22.20058	113.9383
2019/03/28	19:34:15	FP	SL	22.20633	113.9333
2019/03/28	19:35:38	FP	SL	22.20309	113.9318
2019/03/28	19:41:20	FP	SL	22.18796	113.9317
2019/03/28	19:49:13	FP	SL	22.16826	113.9332
2019/03/28	19:51:01	FP	SL	22.16372	113.9330
2019/03/28	19:55:39	FP	SL	22.15246	113.9314
2019/03/28	20:22:14	FP	SL	22.19795	113.9225
2019/03/28	20:48:21	FP	SL	22.14907	113.9142
2019/03/28	20:52:13	FP	SL	22.14554	113.9070
2019/03/28	20:56:14	FP	SL	22.15115	113.8990
2019/03/28	21:00:38	FP	SL	22.15761	113.8918
2019/05/20	04:57:44	FP	SL	22.16702	113.8941
2019/05/20	05:10:34	FP	SL	22.15044	113.9105
2019/05/20	05:17:53	FP	SL	22.14972	113.9202
2019/05/20	05:22:01	FP	SL	22.15948	113.9199
2019/05/20	06:06:00	FP	SL	22.18492	113.9325
2019/05/20	06:10:25	FP	SL	22.17389	113.9317
2019/05/20	06:16:11	FP	SL	22.15952	113.9316
2019/06/17	16:13:18	FP	EL	22.21366	114.0835
2019/06/17	16:24:17	FP	EL	22.18814	114.0844
2019/06/17	16:58:43	FP	EL	22.21807	114.0712
2019/06/17	17:02:37	FP	EL	22.22720	114.0711
2019/06/17	17:47:39	FP	EL	22.22022	114.0620
2019/06/17	18:31:16	FP	EL	22.21232	114.0505
2019/06/17	19:01:38	FP	EL	22.20747	114.0432
2019/06/17	19:03:43	FP	EL	22.20199	114.0430
2019/06/17	19:12:10	FP	EL	22.17967	114.0418
2019/06/18	16:39:10	FP	SEL	22.21394	113.9556
2019/06/18	16:58:34	FP	SEL	22.17756	113.9443
2019/06/18	17:01:08	FP	SEL	22.17167	113.9445
2019/06/18	17:20:59	FP	SEL	22.19887	113.9542
2019/06/18	17:51:29	FP	SEL	22.17848	113.9649

Date	Time	Species	Area	Latitude	Longitude
2019/06/18	17:55:55	FP	SEL	22.16759	113.9646
2019/06/18	18:27:04	FP	SEL	22.21170	113.9832
2019/06/18	18:43:49	FP	SEL	22.17416	113.9832
2019/06/18	19:22:12	FP	SEL	22.18516	114.0034
2019/06/18	19:25:19	FP	SEL	22.17714	114.0032
2019/06/18	19:38:33	FP	SEL	22.18244	114.0120
2019/06/18	19:39:14	FP	SEL	22.18406	114.0119
2019/06/19	18:19:38	FP	SL	22.15601	113.9179
2019/06/19	18:21:52	FP	SL	22.16115	113.9201
2019/06/27	16:23:42	FP	EL	22.18643	114.0835
2019/06/27	16:24:49	FP	EL	22.18380	114.0831
2019/06/27	16:53:50	FP	EL	22.21428	114.0735

Table 3 Dolphin and Finless Porpoise Encounter Rate, per month (July 2018-June 2019)

Month	**Dolphin Detections**	**Porpoise Detections**	**Dolphin Encounter Rate (per 100km)**	**Porpoise Encounter Rate (per 100km)**
July	1	0	0.89	0.00
August	0	12	0.00	7.17
January	23	59	7.75	19.89
February	10	61	3.17	19.33
March	14	51	3.75	13.67
April	5	0	6.85	0.00
May	90	7	18.38	1.43
June	19	26	5.22	7.15

Table 4 Dolphin and Finless Porpoise Encounter Rate, per area (July 2018-June 2019)

Area	**Dolphin Detections**	**Porpoise Detections**	**Dolphin Encounter Rate (per 100km)**	**Porpoise Encounter Rate (per 100km)**
NEL	7	0	4.17	0.00
NWL	24	0	4.06	0.00
WL	119	0	24.49	0.00
SL	10	81	2.75	22.24
SEL	2	67	0.80	26.82
EL	0	68	0.00	17.42

Figures

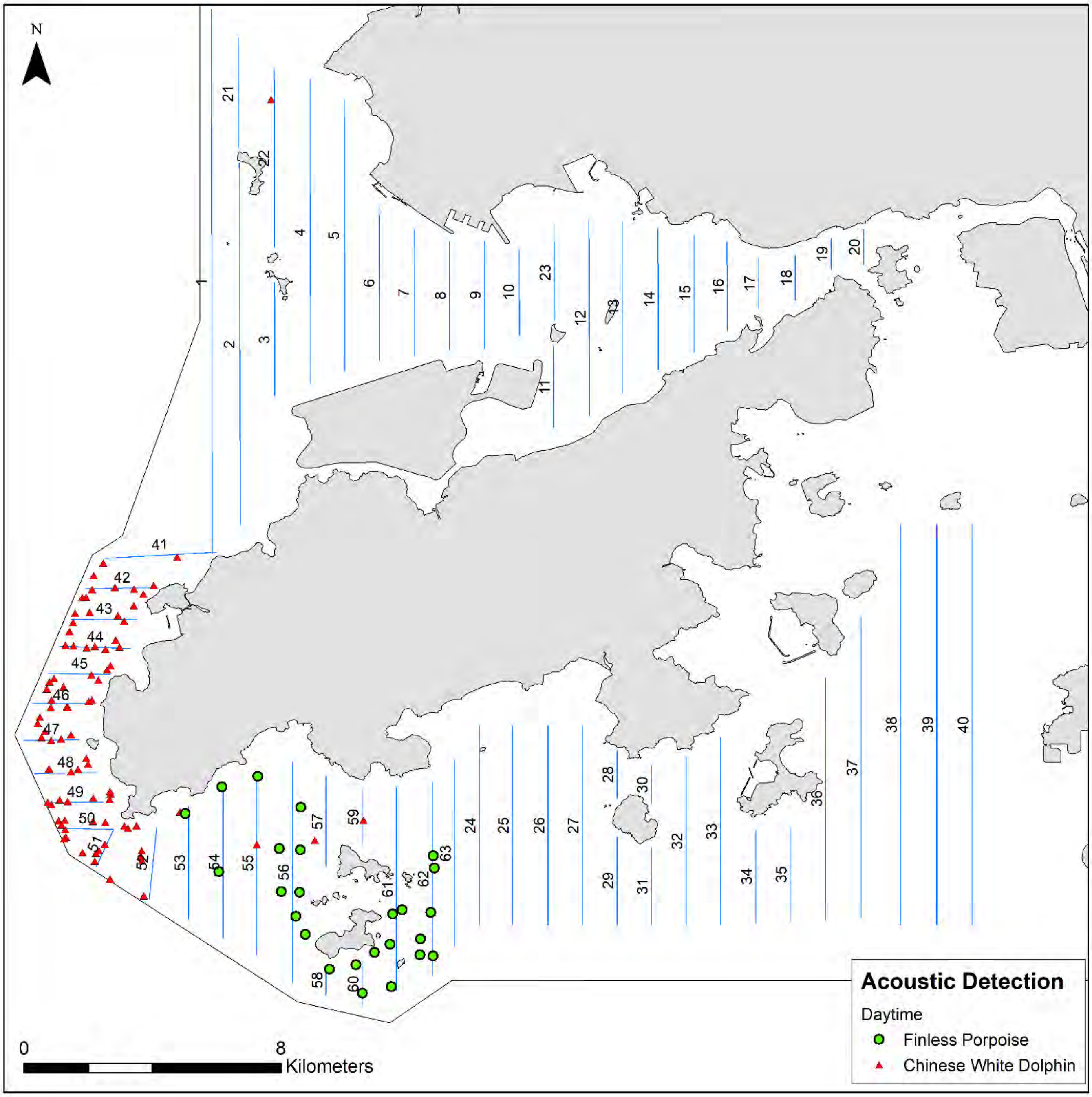

Figure 1 Day Time Acoustic Detections of Chinese White Dolphins and Finless Porpoise (July 2018-June 2019)

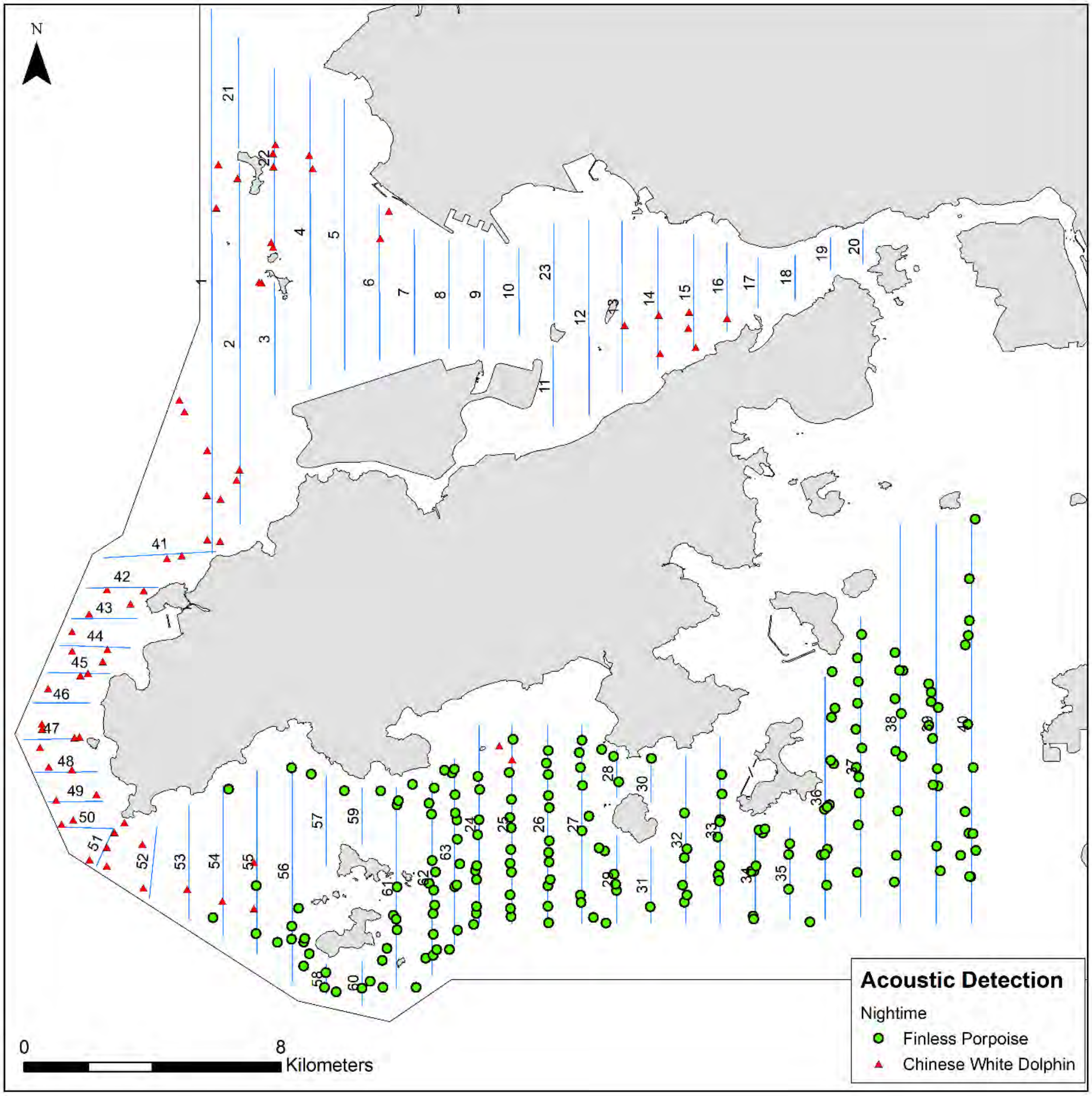

Figure 2 Night Time Acoustic Detections of Chinese White Dolphins and Finless Porpoise (July 2018-June 2019)

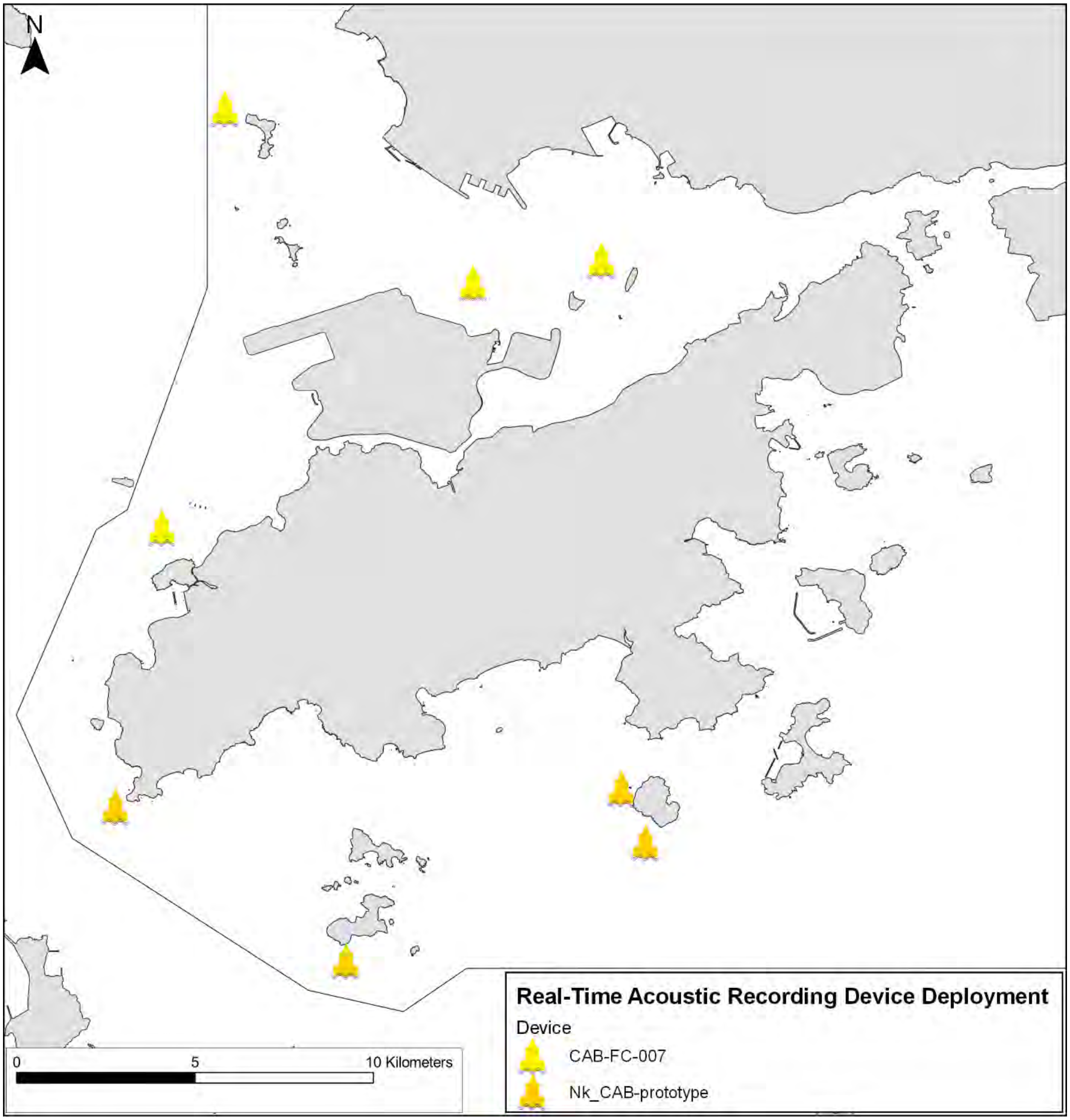

Figure 3 Real-Time Acoustic Device Deployment in Hong Kong (November 2018 and April 2019)

Figure 4 A Typically Cryptic Observation of a Finless Porpoise (Neophocaena phocaenoides) in Lantau Waters, Hong Kong.

MEEF201810

What do Dolphins do at Night?

Appendix I

Paper Presented at the 13th Western Pacific Conference on Acoustics

THE COASTAL ACOUSTIC BUOY: A NEW MITIGATION TOOL FOR MARINE MAMMAL MONITORING

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The Coastal Acoustic Buoy (CAB) represents a new generation of passive acoustic monitoring devices for marine mammal mitigation and underwater noise monitoring. A lightweight design allows CAB to be deployed by two people from a small boat using a small mooring to hold it in place (in depths up to 150 m), and its long battery life of 14 days minimizes deployment and recovery costs. Up to three channels and a sample rate up to 500 kHz provide flexibility and many options. In conjunction with PAMGaurd software, marine mammal echolocation clicks and whistles (or other tonal calls) can be identified with a suite of existing flexible detectors and classifiers to suit the needs of a variety of projects and species (from baleen whales to dolphins and porpoise). Noise modules can be implemented to measure ambient noise levels in rms, 0-peak, peak-peak and SEL across a customizable range of frequencies and time scales. These data (acoustic detections and noise measurements) can be sent in real time / near-real time. CAB can utilize either radio (2.4 GHz or 900 MHz) or cellular 3G communications, depending on the field site and local regulations. While processed data are sent during deployments, raw acoustic data can be stored onboard (1TB hard drive) for further analyses or auditing after retrieval. To date, CABs have been successfully deployed and tested in Hong Kong waters, to detect Indo-Pacific humpback dolphins (*Sousa chinensis*) and Washington State (USA) waters, to detect harbor porpoise (*Phocoena phocoena*) and orca (*Orcinus orca*). CAB can also measure underwater noise levels. The range of detection for each species depends on the source levels of the calls/clicks, the transmission loss at the study site and ambient noise levels.

1. Improvements to Passive Acoustic Monitoring

The difference in absorption of light and sound between water and air has strongly influenced the communications of marine mammals. Underwater, light is absorbed rapidly and scatters quickly, whereas sound travels significantly further than it does in air, therefore, acoustics play a vital role in the underwater communication of marine mammals [1]. In addition, the use of chemosenses is limited underwater, relative to air, by their poor dispersal rate [2]. As such, marine mammals use sound as their primary form of communication and may be heard over much greater distances underwater than they may be seen.

The detection of vocalising marine mammals, known as Passive Acoustic Monitoring (PAM), is an effective tool for gathering research data and is often used to augment visual surveys, which can be challenging in during periods of low visibility and poor weather [3]. Increased efforts to mitigate human activities on marine mammals has resulted from the many studies that have shown the detrimental effects of anthropogenic noise, that include behavioral changes, the masking of communication signals, physical injury and even mortality [4]. During activities producing intensive underwater sound, such as research sonar, pile driving, seismic surveys and shipping, real time PAM can be used to monitor for the presence of marine mammals thus allowing mitigation actions to take place.

As beneficial as PAM has been to advancing marine mammal science, it does have a suite of issues. Until recently, most platforms have been costly and challenging to deploy, e.g., large buoys and cabled hydrophones, and there are difficulties in managing roving systems, e.g., gliders, profiling floats. With stand-alone, systems, battery life and data communication present additional challenges, especially when real-time data are necessary.

The Coastal Acoustic Buoy (CAB) is cost effective and flexible, thus reducing and sometimes eliminating many of the difficulties that other PAM systems encounter when studying and monitoring marine mammals (Fig. 1). CAB can be installed, moved, and recovered by two people from a small boat without the need for specialised equipment and once installed, the batteries can last for 2-4 weeks, depending on the configuration, thus further reducing the costs associated with maintenance and upkeep. CAB is fully autonomous and has the capability to send marine mammal acoustic detection information in real-time to remote base stations while also archiving data on board the floating system.

2. CAB technology

St. Andrews Instrumentation Ltd. (SAIL) have developed and currently offer a 4-channel data acquisition board (DAQ) and Decimus hardware/software. The SAIL DAQ (http://www.sa-instrumentation.com/products/data-acquisition/) is able to digitise data up to 500 kHz with 16-bit precision and can be stacked to add additional, synchronised data channels. The Decimus system (http://www.sa-instrumentation.com/products/decimus/) is a low powered Linux processor with optimized PAMGuard software (https://www.pamguard.org/) modules that use audio data from the DAQ to measure underwater noise levels and to detect marine mammals vocalisations in real time.

The optimised detectors include a whistle/moan (Fig. 2) and echolocation click detectors (Fig. 3). This allows for the detection of a broad range of marine mammal species, from the lower frequency vocalisations of baleen whale to the high frequency clicks of porpoise (~150 kHz). Detectors are flexible, allowing for custom classifiers depending on local species, with user defined waveform variables such as sample length, energy bands, peak/mean frequency, and number of zero crossings. With three hydrophones, the Decimus system is also able to estimate bearings to echolocation clicks.

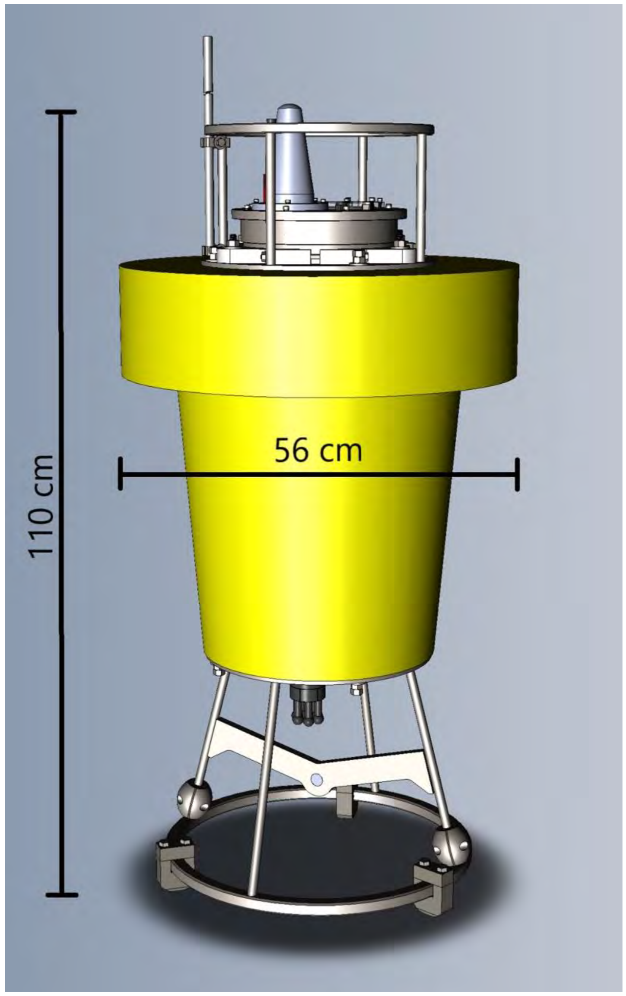

Figure 1. CAB mechanical drawing with dimensions

For the past two years SMRU Consulting have been developing CAB by integrating the SAIL Decimus and DAQ card into a lightweight buoy in collaboration with the Applied Physics Lab (APL), the University of Washington, USA. The CAB is 1.1 m in height, weighs less than 45 kg, and can be deployed in coastal waters of up to 50m depth. CAB can be easily deployed by two people in a small boat, thus minimising both the cost and the complexity of the deployment system. To date, 2.4 GHz and 900 MHz radios and the 3G cellular network have been used to transmit acoustic data from the CAB to a base station or server.

The CAB can function in two modes: baseline or mitigate. In baseline mode, data are sent to a server via cellular 3G at regular intervals (e.g. every 15 minutes) and are available within ~2 hours of collection. Batteries last up to ~4 weeks in this configuration. In mitigate mode, data are sent continuously via radio to a base station computer running PAMGuard software, and batteries will last up to ~2 weeks, due to the use of the radios. Detection data are stored on a server in baseline, on the base station computer in mitigate, and internally for both modes. Recordings of up to 100 kHz, and sample rates up to 250 kHz, can be scheduled to record directly on to the CAB system.

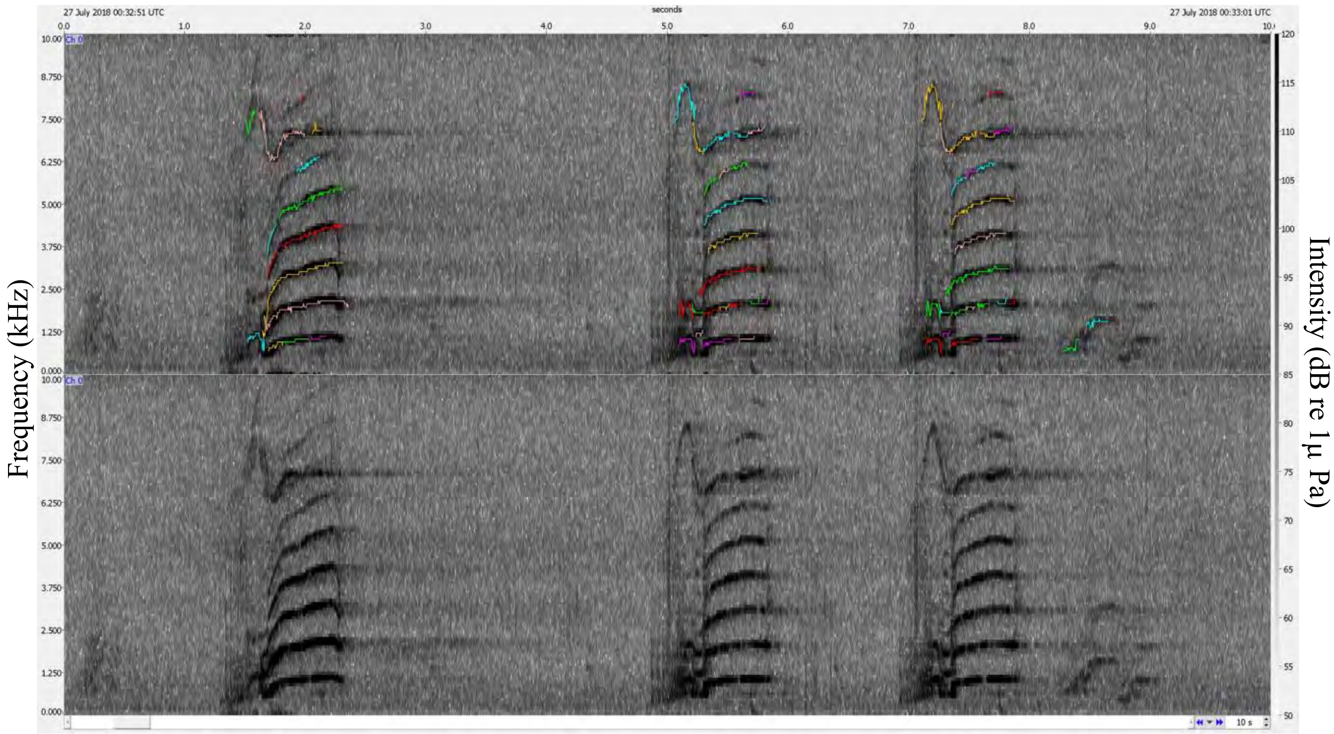

Figure 2. PAMGuard software showing an example whistle detection of an orca (*Orcinas orca*). Both the bottom and top panels show an FFT of the raw data while the top panel includes colored contours overlain automatically drawn in PAMGuard.

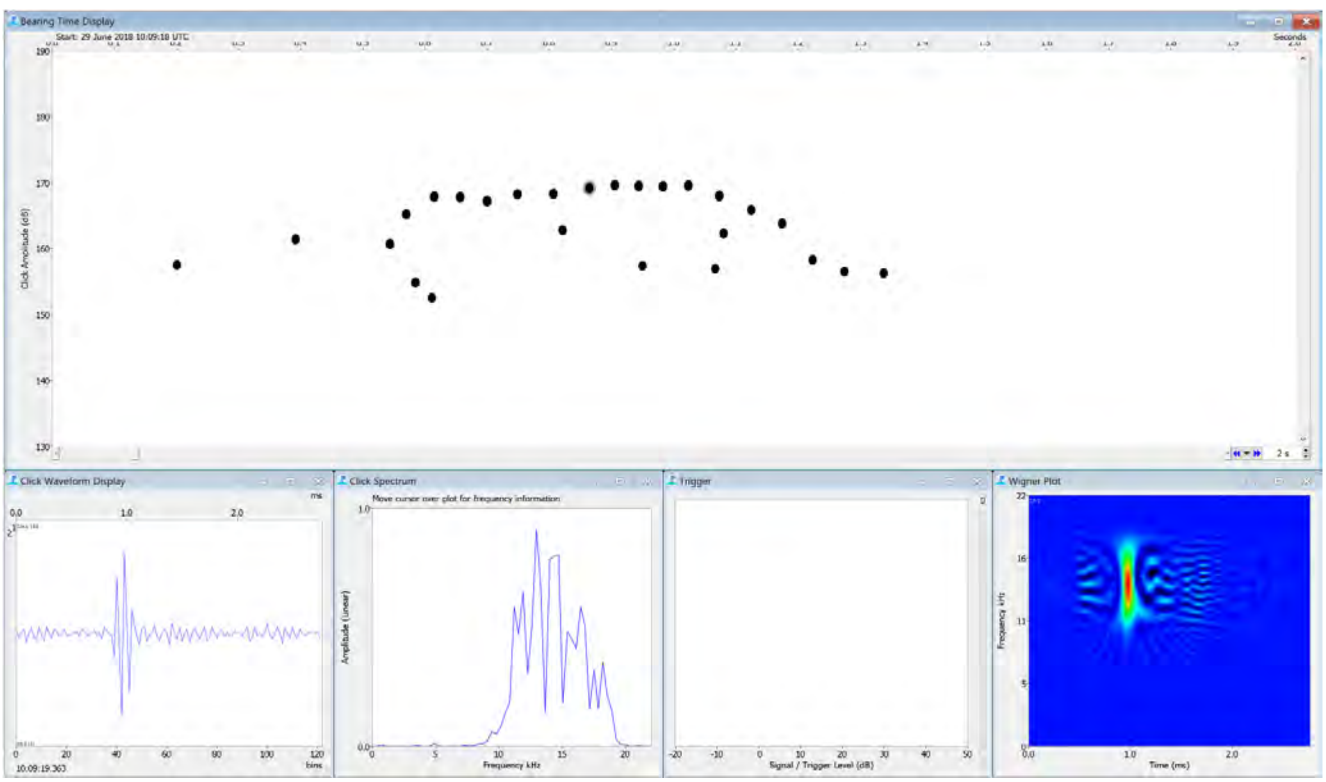

Figure 3. PAMGuard software showing an example click detection of an orca (*Orcinas orca*). The top panel shows all clicks as ovals within the time vs. amplitude domain. Bottom panels display the following from left to right: waveform, click spectrum, trigger (no trigger for this click), and a Wigner plot.

3. Applications

In recent years, the degree to which man's activities are affecting the marine environment has become better understood and, as such, more stringent regulations regarding the disturbance of marine mammals have been introduced. A host of countries have adopted limits to the amount of underwater noise that marine mammals might be exposed to and, if such limits are reached, then noise intensive activities may be required to temporarily shut down, if certain animals are present [5]. CAB is a cost effective and reliable tool for this type of mitigation due to its real-time monitoring capabilities. Further, it is often necessary to determine a baseline for underwater noise and marine mammal vocalising behaviour prior to the beginning of any activities, so that comparisons can be made to noise and behaviour during the activity period, a task CAB can complete using baseline mode. As marine mammal vocal detections do not rely on good light or suitably calm weather conditions, monitoring can continue during low visibility periods, as well as when cryptic or long-diving marine mammals are the subjects of interest [6]. Additionally, CAB also be used to verify underwater noise source levels from operations that have previously only been estimated by modelling techniques. Due to complicated properties of sound propagation underwater and the specificity of different equipment generating the noise, these source levels are often uncertain [5].

Activities that produce sudden and/or impulsive noises can be immediately detrimental to marine mammals, however, the shipping industry can present different risks to marine mammals by increasing overall background noise levels. Various studies indicate that an increase in vessel noise in areas in which marine mammals reside can affecting communication and feeding [7]. Studies involving ships reducing speed and altering routes are currently underway to better understand how to reduce impacts to marine mammal behavior [8]. For such trials, CAB can provide meaningful information, in the short term, on both noise level changes and associated marine mammal behavioural alteration when other, cabled or boat based systems are costly, manpower intensive and complex to deploy.

CAB can also be used as a tool for research studies into marine mammal abundance and communication, as well as noise level monitoring. In particular, the combined use of visual and acoustic research techniques greatly enhances the ability to collect quantitative and verifiable data on marine mammals as many species use sound as a primary means of communication, navigation and foraging [4]. To better understand marine mammal occurrence and behaviour, CAB provides a non-invasive platform with which to gather large volumes of data which allows for more accurate data analyses procedures.

To date, CAB has been tested in the San Juan Islands, Washington State, USA and in Hong Kong. In the USA, CAB was used on baseline mode and ran without issue for 99.9% of the deployment period during which both orcas (*Orcinas orca*) and harbor porpoise (*Phocoena phocoena*) were detected. In addition, vessel noises were measured from a myriad of vessels, ranging from small boats to ocean-going tankers. In Hong Kong, CAB successfully detected Indo-pacific humpback dolphins (*Sousa chinensis*) in high speed ferry lanes, where it would have been impossible to deploy vessels or visual observers due to the high risk nature of the traffic-intense environment. In both areas, deployment was in waters of current speeds of ~200 – ~300 cm/sec (~4 to ~6 knots) and in depths of ~30 m to ~ 20m in USA and Hong Kong, respectively.

4. Conclusion

CAB is a new PAM system that improves the capability of existing tools, as it has a greater flexibility of deployment, has multiple integrated functions, including real-time capability, and can significantly reduce deployment costs. Customizable parameters and a 500 kHz sample rate allow for detection of all species of vocalising marine mammals in real-time. It is a lightweight platform can be simply and cost effective transported, installed and re-positioned while a long battery life reduces maintenance costs.

The ability to communicate via 900 MHz and 2.4 GHz radios in addition to cellular 3G also provides additional flexibility.

In a world that is increasingly focused on marine health, industry and researchers alike are seeking better tools with which to better understand the impact of marine development projects on marine mammals and to mitigate against disturbance. In addition, CAB can be used to examine the effect of shipping on marine mammal behavior and ambient noise levels, simultaneously. Current studies which utilise PAM systems will also benefit from the increased flexibility that CAB provides, enabling an expansion of acoustic research. In summary, CAB has the potential to increase the feasibility of using PAM in a variety of applications, thereby dramatically increasing our understanding of marine mammals as well as providing an effective mitigation tool for industry.

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http://env.threerunwaysystem.com/en/meef/

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12 May 2020

To whom it may concern

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:-

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Dr Lindsay Porter
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