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Porpoise and People: Using Local Environmental Knowledge and Fishing Community Cooperation to Map Bycatch Hotspots for Finless Porpoise (Neophocaena phocaenoides), in Hong Kong SAR

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Porpoise and People: Using Local Environmental Knowledge and Fishing Community Cooperation to Map Bycatch Hotspots for Finless Porpoise (*Neophocaena phocaenoides*), in Hong Kong SAR

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Introduction

Entanglement in fishing gear is the most commonly known cause of injury and/or death for cetaceans worldwide and likely contributes significantly to finless porpoise (*Neophocaena* spp.) mortality in Hong Kong waters. Although all commercial trawling was banned in Hong Kong in 2012, an extensive small scale fishing industry operates throughout local waters[1]. The fishing communities of Tai O and Cheung Chau operate in Hong Kong southern and southeastern waters, where high densities of finless porpoise occur seasonally between December and May. The impact of the current mortality level on the status of Hong Kong finless porpoise is unknown, however, with an estimated population size of fewer than 200 individuals (Jefferson and Moore, 2020; IWC, 2022) and an average of 29 stranded porpoise per year (2018-2022), the local population would appear to be under severe pressure (OPCF Strandings Programme[2]). As such, all measures to reduce mortality should be explored and expedited. The overarching aim of this project is to quantify the risk from bycatch in small scale fisheries by collecting systematic data on fishing effort and activities, in tandem with porpoise presence/absence data around active fishing gear. To obtain such data, the co-operation of fishermen is essential, not only to collect the data itself but also to find positive and collaborative solutions to minimise risk to porpoise. Between 2018-2019, researchers worked with several fishing communities to document local environmental knowledge and to test different tracking and acoustic monitoring devices and the mutual trust and respect established during this previous project was a key factor in the fishermen agreeing to install satellite tracking devices on their vessels full time and to independently deploy autonomous acoustic devices (AAD) onto active fishing gear, or on buoys set close to gear, to record finless porpoise vocalisations. With these data, and long-term information on porpoise distribution, it was possible to develop initial bycatch-risk maps for finless porpoise in Hong Kong southern waters.
This project had three core aims:

- To plot the fishing activities and movement patterns of fishermen who operate in the southern waters of Hong Kong using GPS tracking devices,
- To collaborate with fishermen to collect data on the occurrence of porpoise around active small scale fishing gear, using AAD and develop spatially explicit maps which quantify areas of highest fishing activity and porpoise occurrence, with the purpose of developing an action plan on how best to avoid overlap,
- To share the outcomes of this project with the wider conservation community in Hong Kong, elsewhere in Asia and globally via the International Whaling Commission Scientific and Conservation Committees.

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[1] https://www.hk-fish.net/en/
[2] https://www.opcf.org.hk/en/conservation-research/local-conservation-efforts/local-marine-life-stranding-investigation

This study's strategy was shared with marine mammal researchers at the University Malaysia Sarawak (UniMAS), Malaysia, who also work with fishing communities. It is planned to use the Hong Kong project as a framework for a similar study in Sarawak that will be initiated in early 2023. It is noted, however, that it may take some years to reach the same level of engagement, trust and cooperation as has grown in Hong Kong.

Methods

Data Collection

GPS Data

To understand fishing activity in southern Hong Kong waters, between 24th January 2022 and 24th March 2023, five (5) gill net and one (1) purse seine fishermen from Cheung Chau (Figure 1) were provided with GPS remote tracking devices: four (4) SPOT Traces and two (2) SPOT Gen4s (*SPOT LLC*, United States) (Table 1, Figure 2). Each device was mounted on a fishing vessel and programmed to record GPS coordinates every 2.5 minutes, which was the finest tracking resolution available from the service provider (SPOT). The devices were programmed to automatically start recording when they sensed movement, and as such, their operation was autonomous and not dependent on the fishermen. GPS data recorded from each device were downloaded wirelessly from the SPOT Mapping online interface on a monthly basis, then uploaded to R (v 4.0.3) (R Core Team 2020) and QGIS (v 3.16.11) (QGIS Development Team 2020) for processing and analysis. Battery levels were also monitored from the online interface and changed as needed by community liaison staff, typically every 8-12 weeks (Figure 3).

Acoustic Data

To understand the occurrence of finless porpoise around active fishing gear in southern Hong Kong waters, between 5th May and 30th September 2022, archival underwater acoustic recorders (SoundTrap ST300HF, *Ocean Instruments*, New Zealand) were given to two fishermen to deploy on active gillnets during their routine fishing trips (Figure 4). When deployed, SoundTraps were secured to the gillnet surface marker buoys using nylon rope and suspended underwater (Figure 5). Each SoundTrap consisted of a calibrated omnidirectional cylindrical hydrophone (20 Hz-150 kHz ± 3dB bandwidth), preamplifier and digital recorder (high-gain, 16-bit, 576 kHz sampling rate), which was programmed to record with a 50% duty cycle (1 minute in every 2 minutes). Due to memory constraints, these settings permitted a maximum recording duration of 7-14 days and SoundTraps were exchanged with the fishermen as needed to facilitate continuous recording coverage. Digitised recordings (WAV files) were downloaded from the SoundTraps using SoundTrap Host Software (*Ocean Instruments*, New Zealand), then uploaded to Raven Lite (v 2.0.3) (K. Lisa Yang Centre for Conservation Bioacoustics at the Cornell Lab of Ornithology 2022) and PAMGUARD (v 2.02) (Gillespie *et al*. 2009) for processing and analysis.

Data Processing and Analysis

Fishing Activity

Fishing activity was quantified from GPS data using speed, as previous studies[3] have indicated that net operation (i.e., setting and retrieval) requires vessels to be stationary or move at speeds below 8 km/h, which is notably slower than observed travel speeds that are typically in excess of 15 km/h. A discrete

[3] https://env.threerunwaysystem.com/en/meef/Completion-Report/MEEF2017009_Completion-Report.pdf

fishing trip was defined as a track that departed from and returned to Cheung Chau Typhoon Shelter (Figure 6) and recorded a minimum of 7.5 minutes (or three consecutive GPS coordinates) below 8 km/h.

To understand potential environmental drivers of fishing activity, GPS data were matched to environmental data using coordinates and timestamps; specifically, depth (m), tide height (m) and tidal state (high, ebb, low, flood). Depth (m) was estimated in QGIS from the DEPCNT, DEPARE, COALNE and LNDARE layers of the 2020 Hong Kong Electronic Navigational Chart (ENC). The ENC layers were used to create depth contours, which were subsequently used to generate a digital elevation model (DEM) of Hong Kong bathymetry using the *Interpolation* plugin. Tide height and tidal state were estimated in R from the Hong Kong Observatory (HKO) predicted tidal data[4].

To understand the spatial distribution and density of fishing activity, a quantitative grid analysis was conducted, similar to the analysis described in the Agricultural, Fisheries and Conservation Department (AFCD) Monitoring of Marine Mammals in Hong Kong Waters programme (e.g., AFCD 2022). For each 1 km by 1 km grid cell (Figure 6) that recorded fishing activity, the number of discrete fishing trips and the number of fishermen using the cell as a fishing ground, was calculated using R and mapped using QGIS.

Finless Porpoise Occurrence Around Fishing Gear

To quantify finless porpoise occurrence around fishing gear, acoustic recordings were first processed in Raven to obtain the exact set and retrieval timestamps of each SoundTrap deployed with a gillnet. These timestamps were used to obtain deployment locations from GPS data. Acoustic recordings from gillnet deployments were then analysed in PAMGUARD for the presence of finless porpoise vocalisations. The first stage of analysis involved identifying potential echolocation clicks using the Click Detector module, which was configured to trigger on any transient signal with energy rising more than 10 dB above background noise. Transient signals were classified as potential finless 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 were then manually reviewed for spectral features specific to Indo-Pacific finless porpoises (Goold & Jefferson 2002). To assist with this review, a click classifier with a peaked frequency of 100-155 kHz was used. A positive finless porpoise detection required a minimum of one click that met four criteria (Figure 7):

1) In the Click Spectrum, a peak frequency at 130-140 kHz or 142 kHz.
2) In the Click Spectrum, a frequency range between 110-160 kHz.
3) In the Click Waveform Display, a sinusoidal waveform that is smoothly enveloped (i.e., distinctly “diamond” or “kite-shaped”) that may be reflected.
4) In the Wigner Plot, a relatively flat, elliptical “beam” concentrated around 142 kHz and usually (but not always) around 100 µs between 50-200 µs.

Since SoundTraps were programmed to record 1 minute every 2 minutes, any 1 minute recording with a positive finless porpoise detection was considered to be a porpoise positive minute (PPM). Because the duration of gillnet deployments can vary considerably (depending on the location, depth, tidal conditions and target catch), the number of PPM was divided by the total number minutes recorded for each deployment to correct for effort and obtain the proportion of PPM. To understand the spatial distribution of porpoise occurrence around fishing gear, the proportion of PPM for each 1

[4] https://data.gov.hk/en/

km by 1 km grid cell (Figure 6) with acoustic recordings from a deployed gillnet was calculated using R and mapped using QGIS.

Overlap of Fishing Activity and Finless Porpoise Habitat

To quantify the overlap of fishing activity and finless porpoise habitat, fishing activity was overlaid with the location of finless porpoise sightings between 2017-2022 as published in the AFCD Monitoring of Marine Mammals in Hong Kong annual reports (AFCD 2017, 2018, 2019, 2020, 2021, 2022). Presence-absence of finless porpoises within each 1 km by 1 km grid cell (Figure 6) was used to determine whether only fishing activity, only finless porpoise sightings, or both fishing activity and finless porpoise sightings had been recorded.

Results

Fishing Activity

A total of 817 discrete fishing trips over 355 fishing days were recorded from the GPS devices between the 25th January 2022 and 24th March 2023 (Table 2). Spatially, fishing activity was recorded across southern Hong Kong waters, from the Soko Islands in the southwest to the Ninepin Group in the east, as well as northern Lantau waters around The Brothers Islands (Figure 8). The majority of fishing activity, as the number of fishing trips per km^2, was concentrated along the western side of Cheung Chau with relative hotspots in Admasta Channel (44-163 trips per km^2), western Shek Kwu Chau (79-104 trips per km^2), and around the typhoon shelter breakwater of Hei Ling Chau (57-72 trips per km^2). The relative fishing "footprint" of each fisherman varied considerably, ranging from 6 to 116 km^2 (Figure 9). Temporally, fishing activity was recorded every hour of the day (Figure 10). There was a slightly bimodal distribution in fishing activity, with the first peak at 06:00 (*n* of fishing trips = 301, 36.8%) and the second peak at 12:00 (*n* of fishing trips = 181, 22.2%). Fishing activity was recorded in depths ranging from 1.0 to 42.6 m, with the most fishing trips recorded in the 1 to 5 m depth range (*n* = 607, 74.3%) (Figure 11). With regards to tide variables, fishing activity was recorded in tide heights ranging from 0.12 to 2.62 m, with the most fishing trips recorded in the 1.0 to 1.5 m tide range (*n* = 469, 57.4%) (Figure 12); and in all tidal states, with the most fishing trips recorded during flood tides (*n* = 559, 68.4%). (Figure 13).

Finless Porpoise Occurrence Around Fishing Gear

There were 14 deployments of SoundTraps around active gillnets with a total duration of 73.2 hours (Table 5). On average, each deployment was 5.2 hours, though set times ranged from 0.4 to 17.8 hours. There were 2196 minutes of acoustic recordings, of which 308 were porpoise positive. SoundTraps were deployed around Cheung Sha, Pui O, northeast Cheung Chau, the West Lamma Channel and the southern waters between Shek Kwu Chau and Cheung Chau, covering 13 km^2 grid cells (Figure 14). Porpoise vocalisations were detected in 8 of the 14 deployments, with no clear spatial pattern. The proportion of PPM ranged from 0.03 to 0.42, with the highest recorded southeast of Shek Kwu Chau (0.42). Temporally, there were acoustic recordings from every hour of the day (Figure 15), though the proportion of PPM was highest at 00:00 (0.31), 01:00 (0.38) and 14:00 (0.33) (Figure 16).

Overlap of Fishing Activity and Finless Porpoise Habitat

When fishing activity was compared with finless porpoise sightings recorded between 2017-2022, fishing activity recorded during this project covered 210 km^2, finless porpoise sightings were recorded across 215 km^2, resulting in 75 km^2 of overlap between fishing activity and finless porpoise sightings

(Figure 17). The largest contiguous area of overlap occurred around Shek Kwu Chau, ranging from Tong Fuk on the southwestern coast of Lantau Island to the West Lamma Channel east of Cheung Chau (59 km^2). Areas of overlap with relatively high fishing activity were western Shek Kwu Chau and southwestern Cheung Chau (Figure 8, Figure 17). When compared with SoundTrap deployments, finless porpoise vocalisations were detected around gillnets in areas where they had not been sighted, namely northeast Cheung Chau (Figure 17).

Conclusion

Summary

- Fishing activity, even within fishing communities and between fishermen deploying the same fishing gear, is highly variable. The spatial "footprint" between the five gillnet fishermen differed markedly, ranging from 5 to 107 km^2. Spatially, fishing activity appeared to be concentrated in the coastal areas (within 1 km) northwest of Shek Kwu Chau and west of Cheung Chau. Temporally, fishing activity appeared to peak around 06:00. The majority of fishing activity occurred in shallow waters less than 5 m, typically during flood tides at around 1.0-1.5 m tide height.
- Finless porpoise vocalisations were detected in over half of gillnet deployments with SoundTraps. There were no clear spatial patterns in finless porpoise occurrence, though temporally, vocalisations appeared to peak between 00:00 and 02:00.
- Areas of relatively high fishing activity that overlapped with finless porpoise occurrence were northwestern Shek Kwu Chau and southwestern Cheung Chau. Notably, finless porpoises were detected acoustically from SoundTraps deployed on gillnets in areas that they had not been detected visually, which suggests that the overlap is likely greater than reported.

Study Caveats

- Fishing vessels, not fishing gear, were tracked. Consequently, the true spatio-temporal impact of fishing gear on finless porpoises is likely to have been underestimated, particularly for gillnets, given that their operation is not dependent on the presence of a fishing vessel. The results from SoundTrap deployments in this study, for example, indicate that gillnet fishermen from Cheung Chau regularly leave their gillnets overnight, spending only a fraction of the total deployment time in the fishing ground.
- The accuracy of using vessel speed as an indicator of fishing activity could be better improved through the use of remote time-lapse cameras to confirm fishing gear deployment.
- The AFCD Long-Term Marine Mammal Monitoring surveys, from which the 2017-2022 sightings data was derived, were not conducted in the fishing grounds between Cheung Chau and Hei Ling Chau, however, recent PAM studies show that this area is frequented by finless porpoises[5]. In addition, porpoise were detected around gillnets where they had not previously been sighted, as such, the overlap between fishing activities and finless porpoise presented here is an underestimate.
- The number of fishing vessels monitoring is small, ideally, 10% of vessels from each community should be monitored (~400 vessels in total).

Recommendations

[5] https://env.threerunwaysystem.com/en/meef/Completion-Report/MEEF2018010A_Completion-Report.pdf

Given the detection of finless porpoise in areas that are not monitored by the AFCD Monitoring of Marine Mammals in Hong Kong Waters programme, and the difficulty in sighting this cryptic species, the survey area for finless porpoise should be expanded and additional tools, that do not depend on sightability, should be used to obtain more comprehensive data on finless porpoise spatial and temporal occurrence. As such, the current visual line transect surveys that are being conducted by AFCD should consider including towed acoustic arrays as a more accurate means of detecting porpoise.

It would be useful to expand this study into Hong Kong eastern waters, where porpoise also occur. This area is sampled less frequently by the AFCD Monitoring of Marine Mammals in Hong Kong Waters programme and, as it is more exposed, sea states nearly always exceed Beaufort Sea State 2, making sightings conditions poor for porpoise. There has been very limited deployment of acoustic monitoring stations in this area so the true occurrence of finless porpoise in the area is not well understood, although records show that finless porpoise strandings do occur throughout Hong Kong eastern waters all year round. There are several fishing communities in this area so replicating this study model here would be useful, in addition to the long-term (year round) deployment of acoustic monitoring stations so that our understanding of porpoise presence/absence would improve and bycatch risk areas could be more accurately mapped. The engagement of new fishing communities may take time to achieve, however, this project shows that successful, multi-stakeholder awareness and management plans can be agreed by such an integrated, data collection approach.

Acknowledgements

Core funding for this study was provided by the Joanna Toole Foundation (https://joannatoolefoundation.org/). Launched in 2020 in memory of Joanna Toole, a passionate advocate for the protection of all animals, this project pays homage to Joanna's achievements over her short career in greatly reducing animal suffering and death around the world. The outcomes of the project are part of the mission to keep Joanna's legacy alive.

Additional funding and support was provided by WDC (https://uk.whales.org/), who was amongst the first to identify and detail the welfare impacts of fishing gear on individual porpoise, dolphins and whales. WDC provided overall guidance on how the research outcomes of this project could provide positive impacts to porpoise welfare. Funding was also provided by WWF and their guidance on local policy challenges was given by the WWF Hog Kong team (https://www.wwf.org.hk/en/).

This project would not have been successful without the dedication of the community liaison officers, YIP Sarah Hui and LAW Ka Kin, who worked with the communities throughout the covid-19 pandemic challenges in Hong Kong. Their contribution to bridging communications between the research team and the fishing community is highlighted and gratefully acknowledged.

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Tables

Table 1. GPS remote tracking devices provided to fishermen from Cheung Chau, Hong Kong, between 24th January 2022 and 24th March 2023.

Fisherman ID	Vessel Type	Fishing Community	Device
0-3190862	P4 (Gillnet)	Cheung Chau	SPOT Trace
0-3193808	P4 (Gillnet)	Cheung Chau	SPOT Trace
0-3178892	P4 (Gillnet)	Cheung Chau	SPOT Trace
0-3178470	P4 (Gillnet)	Cheung Chau	SPOT Trace
0-4148241	P4 (Gillnet)	Cheung Chau	SPOT Gen4
0-4141654	Purse Seine	Cheung Chau	SPOT Gen4

Table 2. Summary of fishing effort from fishermen from Cheung Chau, Hong Kong, between 24th January 2022 and 24th March 2023.

Year	Month	Number of Fishermen	Number of Fishing Days	Number of Fishing Trips
2022	January	5	7	19
	February	6	24	57
	March	5	28	78
	April	6	29	90
	May	5	29	60
	June	5	27	50
	July	4	23	47
	August	5	23	57
	September	6	28	69
	October	5	27	66
	November	5	25	54
	December	4	21	39
2023	January	4	24	46
	February	5	21	48

	March	4	19	37
	Total	**6**	**355**	**817**

Table 3. Summary of acoustic effort from SoundTraps deployed by fishermen from Cheung Chau, Hong Kong, between 24th January and 30th September 2022 on active gillnets.

Deployment ID	Fisherman ID	Fishing Gear Type	Deployment Start	Deployment End	Deployment Duration (min)	Latitude	Longitude	Depth (m)	Recording Duration (min)	Porpoise Positive Minutes (PPM)	Proportion PPM
1	0-3178470	Gillnet	2022-05-09 15:01:00	2022-05-09 15:28:00	27.0	22.22959	113.94361	-2.0	14	0	0
2	0-3178470	Gillnet	2022-05-10 04:15:00	2022-05-10 04:36:00	21.0	22.22979	113.94352	-2.0	11	0	0
3	0-3178892	Gillnet	2022-05-12 10:25:00	2022-05-12 13:56:00	211.0	22.23838	113.97161	-1.5	106	0	0
4	0-3178892	Gillnet	2022-05-20 13:34:00	2022-05-21 07:24:00	1070.5	22.18775	114.00223	-13.0	535	225	0.421
5	0-3178892	Gillnet	2022-05-26 04:27:00	2022-05-26 07:32:00	184.7	22.17371	113.97983	-13.4	92	0	0
6	0-3178892	Gillnet	2022-05-27 04:07:00	2022-05-27 05:40:00	93.0	22.17571	113.97772	-13.6	47	10	0.213
7	0-3178892	Gillnet	2022-05-28 04:24:00	2022-05-28 05:34:00	70.8	22.16766	114.01094	-11.2	35	11	0.314
8	0-3178892	Gillnet	2022-05-30 04:23:00	2022-05-30 05:32:00	68.1	22.17299	113.98459	-14.2	34	1	0.029

9	0-3178892	Gillnet	2022-06-01 04:38:00	2022-06-01 05:42:00	64.0	22.16793	114.03111	-11.3	32	1	0.031
10	0-3178892	Gillnet	2022-06-02 04:28:00	2022-06-02 05:36:00	68.7	22.19629	114.0584	-12.0	34	0	0
11	0-3178892	Gillnet	2022-06-03 04:27:00	2022-06-03 05:30:00	62.2	22.20992	114.06413	-10.0	31	0	0
12	0-3178892	Gillnet	2022-06-21 13:53:00	2022-06-22 05:16:00	923.0	22.22956	113.97727	-0.9	462	21	0.045
13	0-3178892	Gillnet	2022-07-06 15:39:00	2022-07-07 05:39:00	840.6	22.22295	114.07658	-9.5	420	18	0.043
14	0-3178892	Gillnet	2022-07-22 16:36:00	2022-07-23 04:02:00	687.0	22.22361	114.03495	-5.0	343	21	0.061

Figures

Figure 1. Examples of local P4 (left) and purse seine (right) fishing vessels in Hong Kong.

Figure 2. A fishing community liaison provides a fisherman with a SPOT Trace remote GPS tracking device on Cheung Chau, Hong Kong.

Figure 3. A researcher changes the batteries of a SPOT Trace on Cheung Chau, Hong Kong.

Figure 4. A researcher provides fishermen with SoundTrap ST300HFs to be deployed on active gillnets on Cheung Chau, Hong Kong.

Figure 5. A SoundTrap ST300HF prepared for deployment on active gillnets on Cheung Chau, Hong Kong.

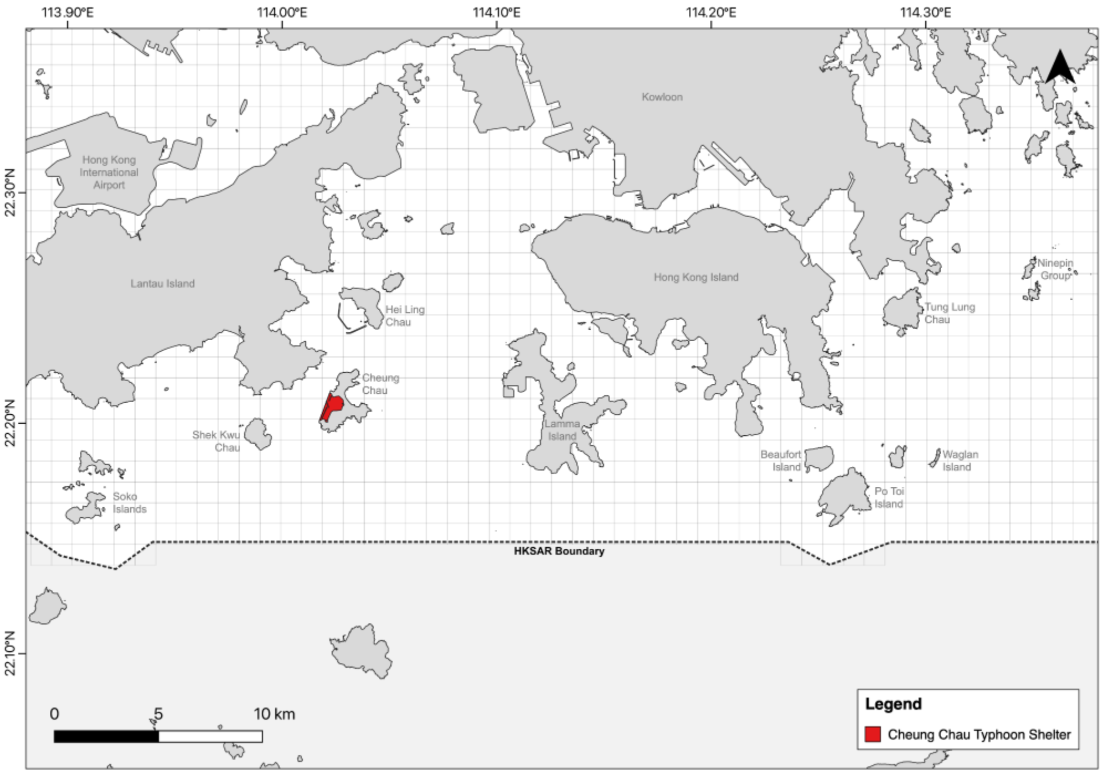

Figure 6. The study area encompassing southern Hong Kong waters.

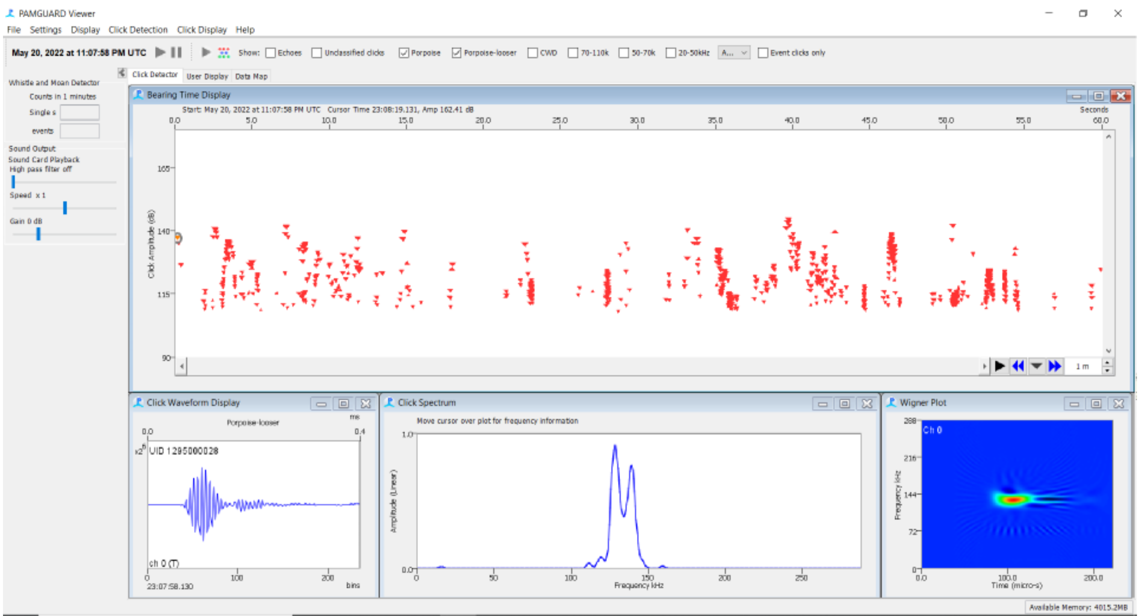

Figure 7. A screenshot of an Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) click detection in PAMGUARD.

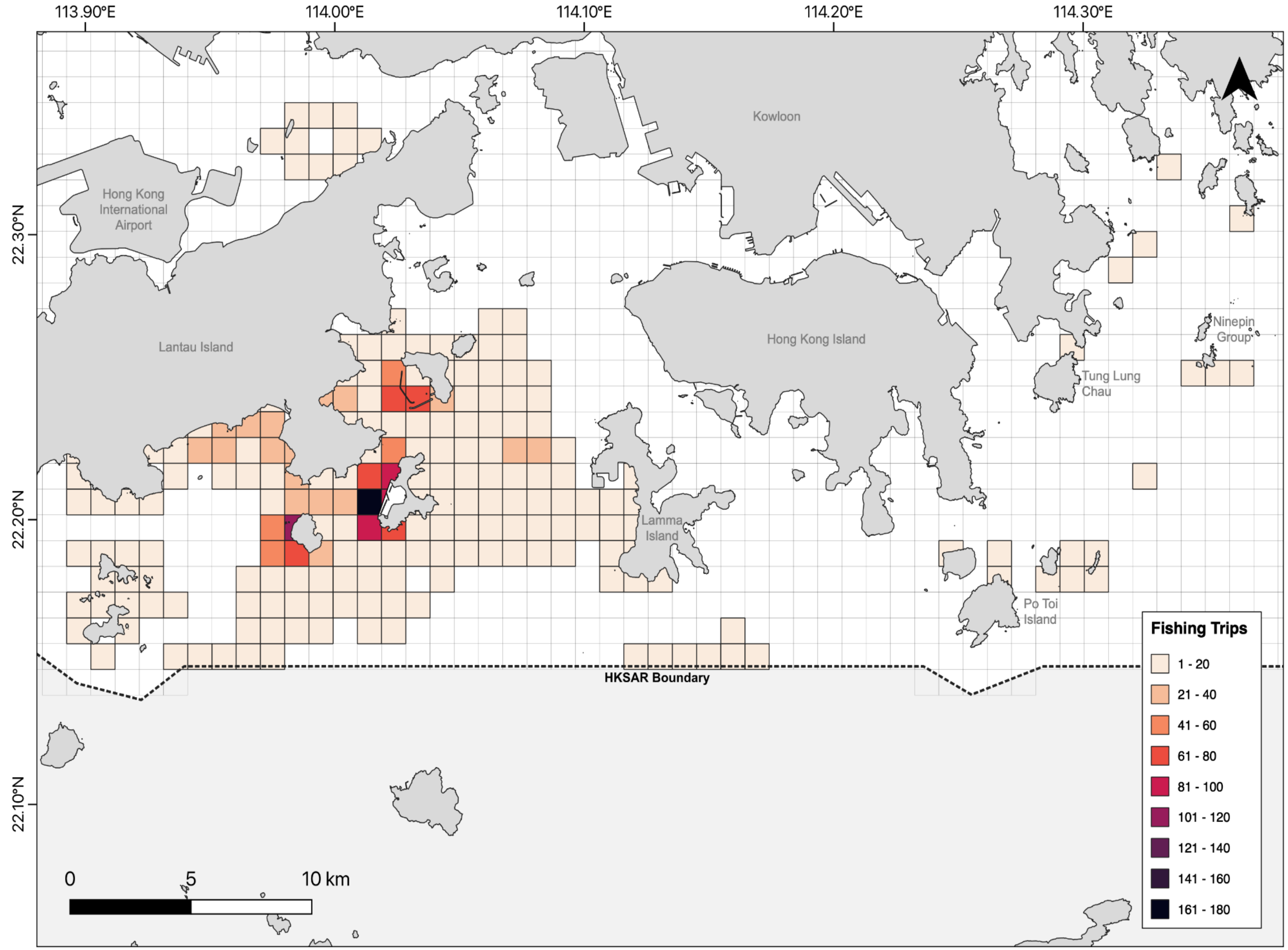

Figure 8. Fishing activity, as the number of discrete fishing trips per km^2, of fishermen (N = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

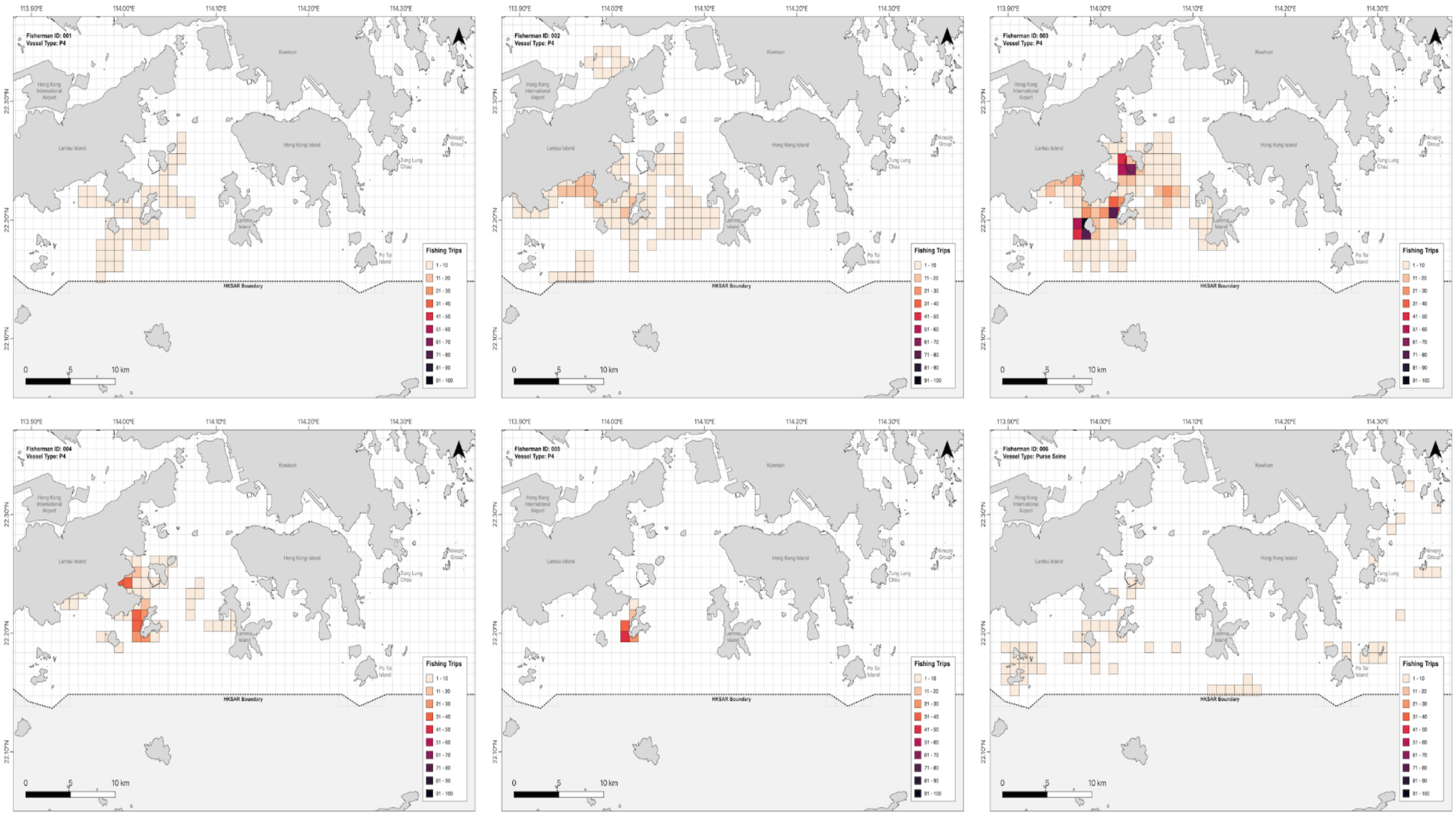

Figure 9. Fishing activity, as the number of discrete fishing trips per km^2, of individual fishermen (N = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

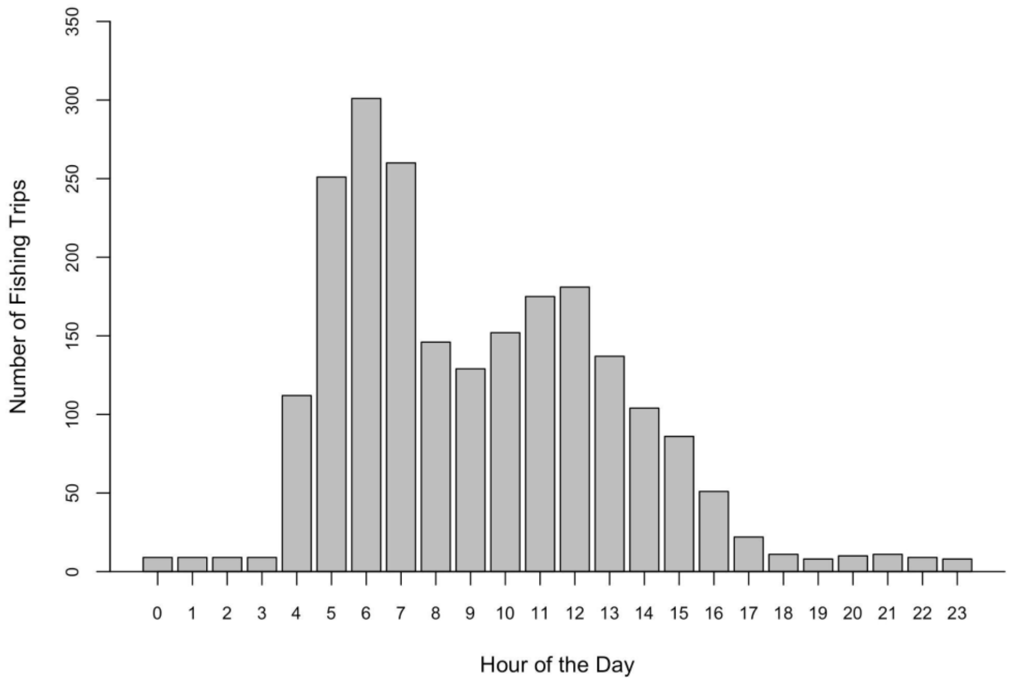

Figure 10. Fishing activity, as the number of discrete fishing trips per hour of the day, of fishermen (*N* = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

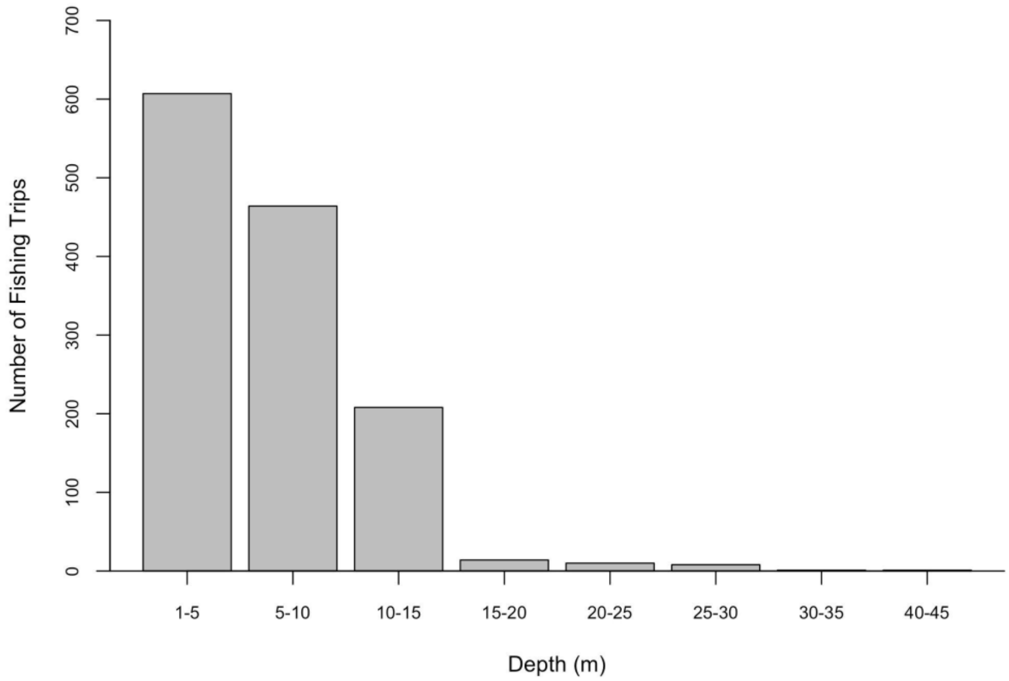

Figure 11. Fishing activity, as the number of fishing trips recorded across depth (m), of fishermen (*N* = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

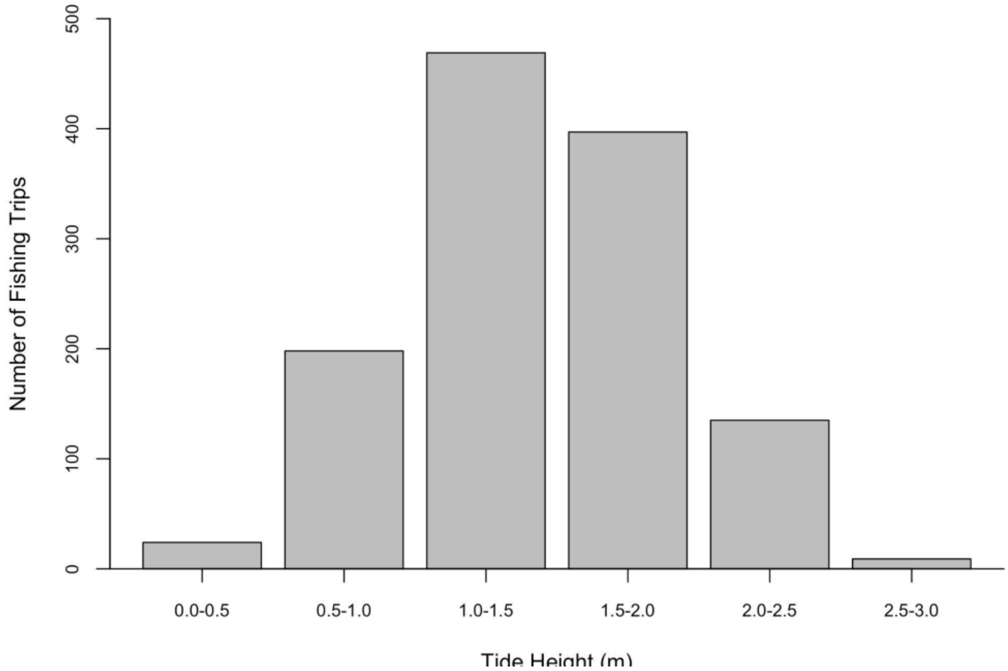

Figure 12. Fishing activity, as the number of fishing trips recorded across tide height (m), of fishermen (*N* = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

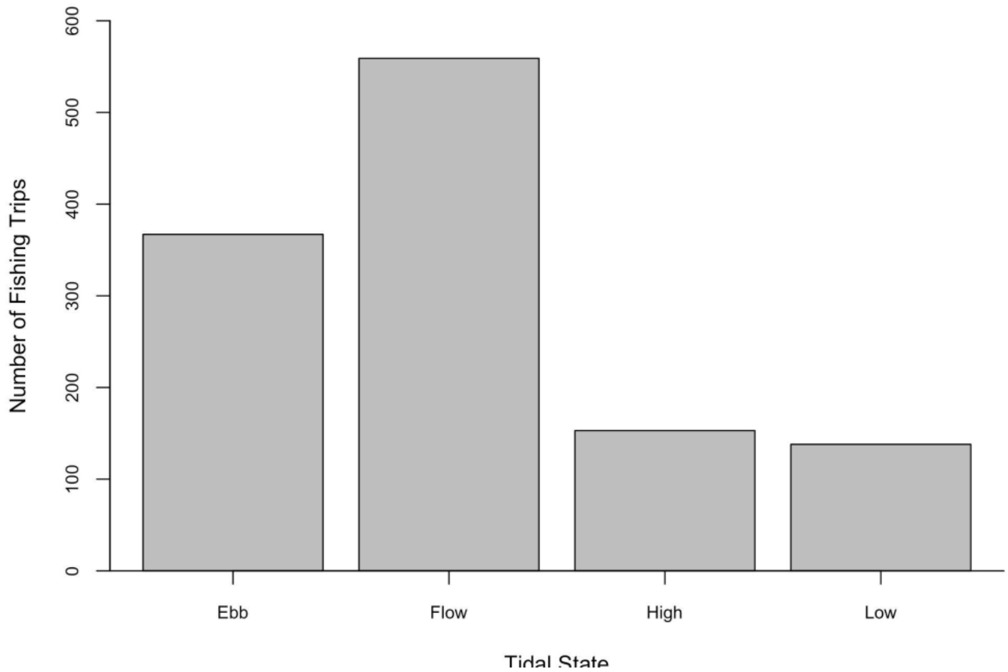

Figure 13. Fishing activity, as the number of fishing trips recorded across tidal state, of fishermen (*N* = 6) from Cheung Chau between 25th January 2022 and 24th March 2023.

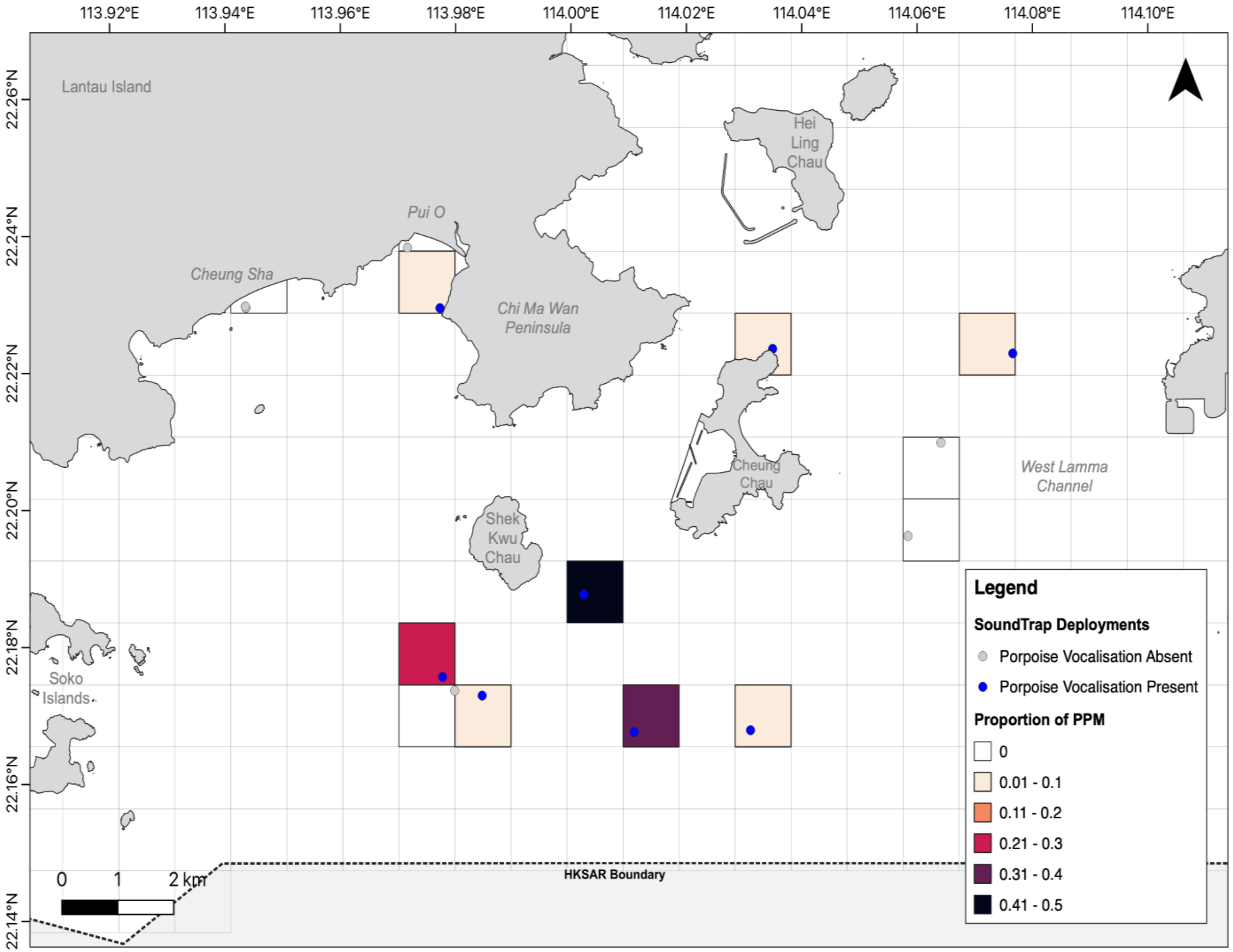

Figure 14. Location of SoundTrap deployments on active gillnets and the Proportion of Porpoise Positive Minutes (PPM) per km^2.

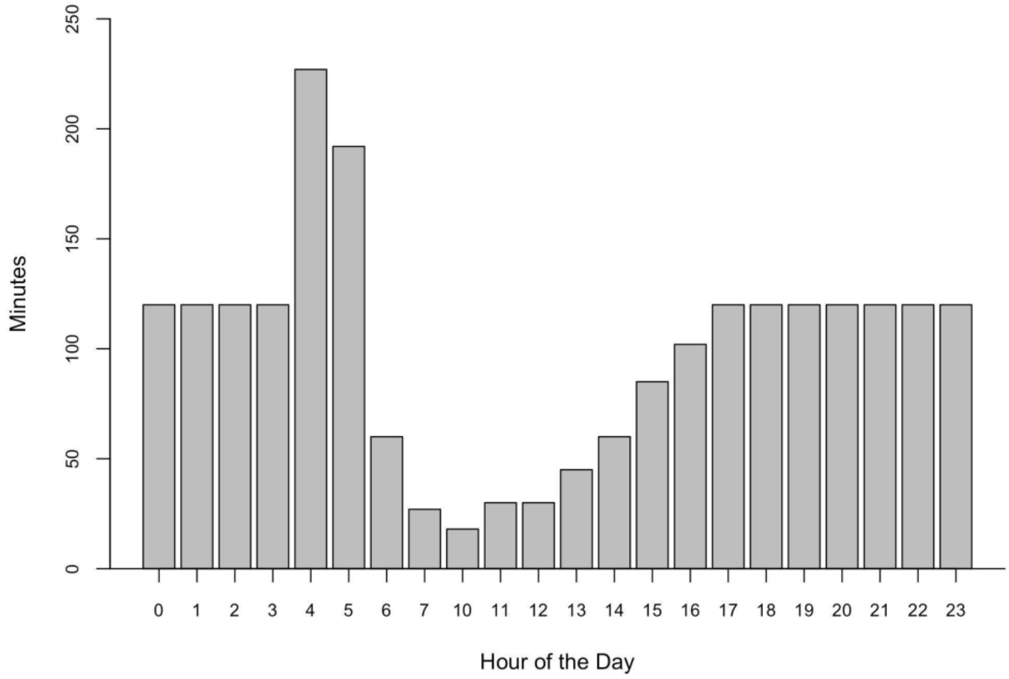

Figure 15. Minutes of acoustic recordings per hour of the day.

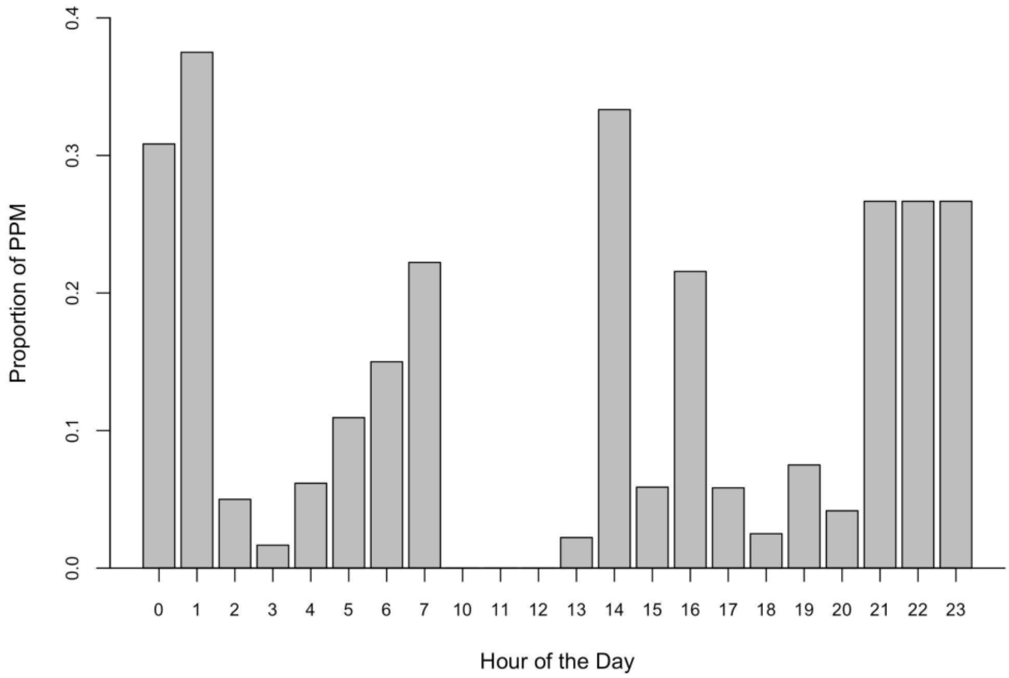

Figure 16. Proportion of Porpoise Positive Minutes (PPM) per hour of the day.

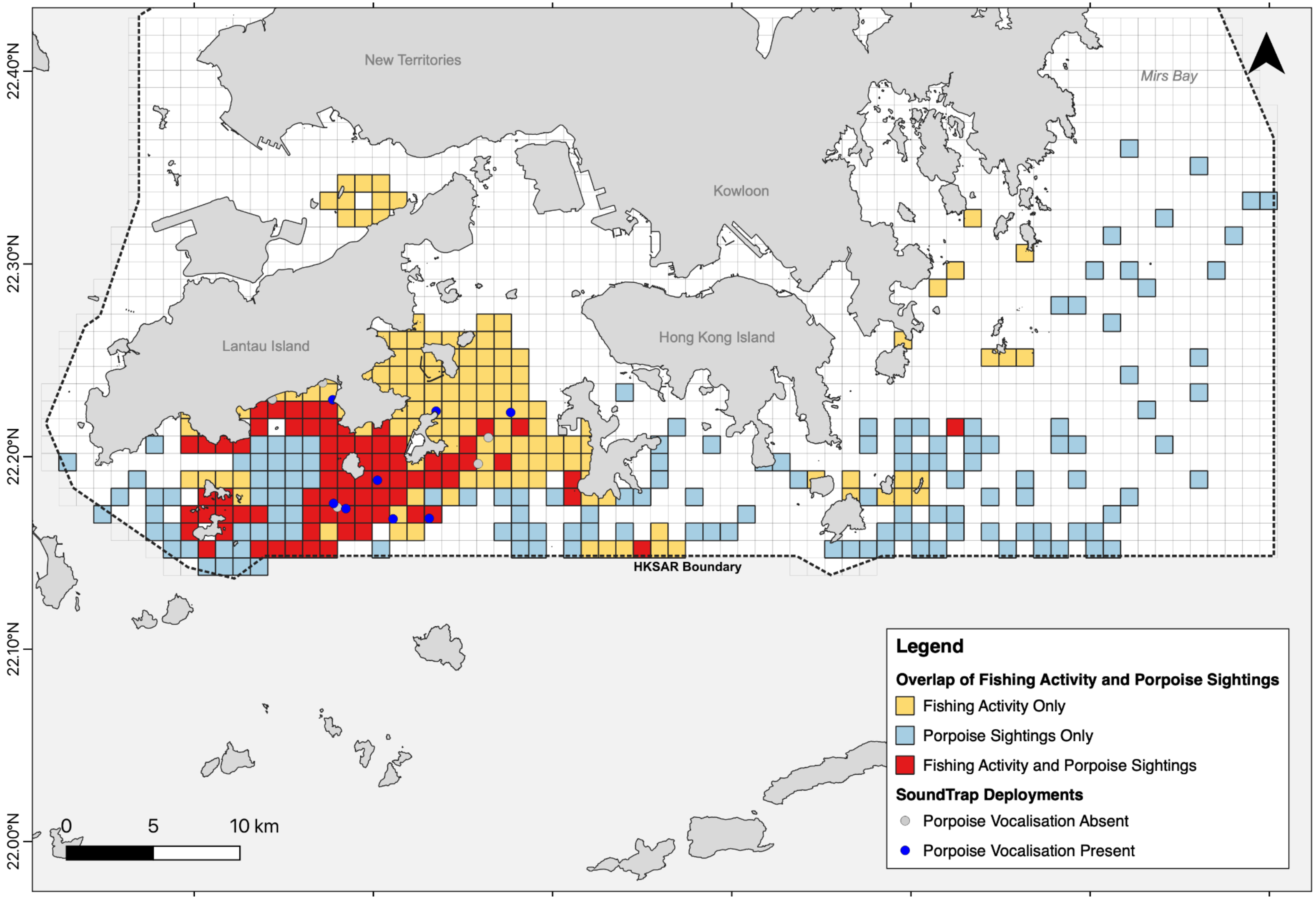

Figure 17. Overlap of fishing activity (25th January 2022 to 24th March 2023), SoundTrap deployments, and historical finless porpoise sightings (2017 to 2021).

Ethical Approval

No ethical approval process is in place in Hong Kong. All fishermen who participate in this project will provide their verbal consent (noting senior members of the Hong Kong fishing communities will have left the education system before entering high school and verbal agreements are commonplace, rather than written). Prior to each fisherman participating in this study a formal statement and agreement will be made, in the language most appropriate for the fisherman.

The statement will include:

- Title of the research study
- List of the investigators
- Description of the study and a structured discussion of the risks and benefits
- A list of the tasks associated with participation
- A statement that non-participation or withdrawal will not jeopardise any future or ongoing relationship with the research team specifically, or the organisation more broadly