Eyes in the Sky: Using UAV imagery to monitor Hong Kong's dolphins and to conduct a school citizen science programme

天空之眼：利用無人機監察香港海洋哺乳動物

MEEF 2021014

Final Report

SEAMAR

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Final Report
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SEAMAR

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Declaration

Reference Number: MEEF2021014

Project Title: Eyes in the Sky: Using UAV Imagery to Monitor Hong Kong's dolphins and to conduct a school citizen science programme

Project Leader: Lindsay Porter

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

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

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

1. Do not deal with, and are not in any way associated with, any country or organisation or activity which is or may potentially be relevant to, or targeted by, sanctions administered by the United Nations Security Council, the European Union, Her Majesty's Treasury-United Kingdom, the United States Department of the Treasury's Office of Foreign Assets Control, or the Hong Kong Monetary Authority, or any sanctions law applicable;

2. Have not used any money obtained from the Marine Ecology Enhancement Fund or the related Top-up Fund (and any derived surplus), in any unlawful manner, whether involving bribery, money- laundering, terrorism or infringement of any international or local law; and

3. Have used the funds received (and any derived surplus) solely for the studies or projects which further the MEEF Objectives and have not distributed any portion of such funds (including any derived surplus) to members of the Recipient Organisation or the public.

Signature: ____________________

Lindsay Porter, Project Leader

Date: 1 May 2024

Contents

Executive Summary

This project aimed to assess the use of Unmanned Aerial Vehicle (UAV), often called 'drones', as a new tool to collect imagery suitable to estimate the density of Indo-Pacific humpback dolphin (also called Chinese White dolphin) and finless porpoise (*Neophocaena phocaenoides*). Several different UAV models and cameras attachments were compared for functionality and ease of use and compared these to the logistics required and data outputs derived from vessel-based surveys also aimed at estimating cetacean density. A student citizen science programme was also developed, that was rolled out in various forms to students who were participating in the International Baccalaureate (IB) syllabus, with a particular focus on science students.

The project had three main objectives:

- Assess the use of different UAV and camera systems to estimate dolphin population density.
- Conduct a cost-benefit analysis to determine if the use of UAV can provide comparable or better data to augment the long-term marine mammal monitoring programme of cetaceans in Hong Kong.
- Pilot a school citizen science project that enables students to participate in real-world science by learning UAV piloting skills (in a controlled environment) and analysing imagery obtained from research field surveys.

Between November 2021 and June 2022, a total of 17 systematic surveys were conducted, comprising 5 surveys that were synchronous UAS and vessel line transects and 12 surveys that only UAS transect surveys were conducted.

Vessel line-transect surveys were conducted in West Lantau (WL) and 69.4 km of survey track were completed, in ideal survey conditions. Seven (7) groups of humpback dolphins were sighted, equating to an encounter rate of **0.101 dolphin groups km^{-1}**.

Aerial surveys were conducted in Northeast Lantau (NEL), Northwest Lantau (NWL), West Lantau (WL) and South Lantau (SL), during which 28,938 images were collected over a total of 2,087.9 km of UAV effort. In total, the spatial coverage of the aerial surveys was 81.6 km^2. These surveys recorded seventeen (17) humpback dolphin and thirty three (33) finless porpoise groups. Slightly more than half of the humpback dolphin sightings were recorded at the surface (52.9%) and the rest were sighted subsurface (47.1%). Both 'on the surface' and 'sub surface' sightings were included in encounter rate ad density estimations.

The majority of humpback dolphin sightings occurred in WL (15), and the other two sightings were in SL. Encounter rates ranged from **0.003 dolphin groups km^{-1}**, in SL (area 1) to **0.017 dolphin groups km^{-1}** in WL. The number of sightings ($SPSE_U$) detected per 100 units of aerial survey effort was greatest around Wong Fa Pai (**0.43-0.57**) in WL and the area between Fan Lau and Lo Kei Wan in SL (**0.5**). The number of animals ($DPSE_U$) detected per 100 units of aerial survey effort was greatest at Peaked Hill in WL (**0.17**).

Thirty three (33) finless porpoise groups were recorded, of which, 63.6% were below the surface, 18.2% were at the surface and 18.2% were at mixed positions within the water column. All sightings, regardless of location in the water column, were included in encounter rate and density estimations. Finless porpoise occurred only in SL and encounter rates ranged from **0.022 – 0.227 porpoise groups km^{-1}**. Sighting density ($SPSE_U$) was greatest to the south of Tai A Chau in SL (**2.3-3.5**), as was individual porpoise density ($DPSE_U$) (**7.5**).

During aerial-only surveys, that is, when the vessel was not conducting concurrent line transect surveys, 32 sightings were made by crew or observers who were not operating the UAV, of which 25 were of humpback dolphins and 7 were of finless porpoises. These sightings were considered opportunistic and were not included in any density or encounter rate analysis, as the vessel itself was not 'on effort '

An infrared camera was tested on bottlenose dolphins held under human care at Ocean Park, Hong Kong. In addition, an infrared camera, that could simultaneously record infrared as well as full spectrum imagery, was used opportunistically to gather video footage during dolphin and porpoise encounters, while the larger UAV was taking still imagery for density mapping. A comparison of normal versus infrared footage, for bottlenose and humpback dolphins and finless porpoise, showed that the infrared imagery showed only parts of the bottlenose dolphins filmed and only occasionally filmed parts of the humpback dolphins filmed. Infrared imagery did not capture finless porpoise bodies at all, but did show porpoise 'fluke prints' when they dived below the surface.

A cost benefit analysis of UAV versus aerial surveys concluded that the main advantages of UAV as a tool for cetacean surveys are:

- imagery data obtained can be archived for later evaluation,
- imagery data can be independently verified,
- locational data is more accurate
- group size estimates are more accurate.

In addition, experienced observers are not required on the vessel and weather conditions are less likely to limit sightability of cetaceans, particularly as both species in this study could also be detected when they were below the surface

The main disadvantages of UAV surveys were the short flight time per battery pack and the time to charge battery packs while on the water, e.g., a vessel with generator is required. Also, in hot weather, battery pack performance was considerably reduced. In Hong Kong, no fly zones limited the area in which surveys could be conducted, thus not all the dolphin's known habitat could be surveyed by UAV. Initial image analysis was labour intensive and required considerable development and testing of methods to decrease the time required to review images. In addition, the density estimates derived from UAV surveys were directly comparable with those obtained from vessel based visual surveys. Overall, both methods had advantages, however, for line transect surveys, UAV can conduct more trackline per survey day (dramatically increasing survey effort and sightings data) and the data gathered (imagery) can be viewed multiple times and can be independently verified. Archived imagery has the potential to be used in future studies as well.

The school citizen science programme included several year levels enrolled in the International Baccalaureate (IB) programme and, as such, multiple projects and activities were developed appropriate for different year groups and curriculum expectations. Datasets derived from this and other MEEF projects (MEEF2018010 and MEEF2020005) were provided to Year 13 students to use in their Internal Assessment (IA); Year 12 students participated in activities to complete the Group 4 Project part of the syllabus and; Year 2 students were provided information relevant to the Biology component of the IB syllabus. Students were also provided practical experience with multiple UAV models, as well as practical experience using a UAV simulator. Some students also worked with the project data beyond the academic year and learned more scientific analysis skills, on a voluntary basis.

This project was completed successfully, although the time it took to analyse the imagery was longer than anticipated. The data derived from this and previous MEEF projects contributed to the learning goals of Hong Kong students. This project also catalysed the development of a new UAV with a longer flying range and led to the development of improved AI-based analysis of UAV imagery.

Project Title and Brief Description of the Project

Project Title

Eyes in the Sky: Using UAV Imagery to Monitor Hong Kong's dolphins and to conduct a school citizen science programme.

Brief Description

The main aim of this was to assess the use of Unmanned Aerial Vehicle (UAV), often called 'drones', as a new tool to collect imagery suitable to estimate the density of Indo-Pacific humpback dolphin (also called Chinese White dolphin). This project assessed the use of different UAV and different cameras and conducted a cost benefit analysis of data collected by UAV versus vessel-based surveys. This project was also developed into a student citizen science programme, that was rolled out in various forms to all ages of students, from Kindergarten to Senior Years, with a particular focus on secondary school science students.

The project had three main objectives:

1) Assess the use of different UAV and camera systems to estimate dolphin population density.

2) Conduct a cost-benefit analysis to determine if the use of UAV can provide comparable or better data to augment the long-term marine mammal monitoring programme of Hong Kong.

3) Pilot a school citizen science project that enables students to participate in real-world science by learning UAV piloting skills (in a controlled environment) and analysing imagery obtained from research field surveys.

Completed Activities Against the Proposed Work Schedule

Of the 10 activities proposed for the one year duration of the Project (Table 1), two were completed between July and December 2021 and eight (8) were completed between January and August 2022.

Activity 1: Drone purchase and camera trials (on land)
Status: Complete

Four UAVs were ordered in July (2021) and delivered between August and November: a DJI Mavic 2 Pro; a DJI Mavic 2 Enterprise; an Autel Evo II Dual; and a DJI Matrice 300 with a Zenmuse H20 camera. These UAVs fell under three different classes: (1) an inexpensive, fully integrated UAV (< 2 kg), i.e., the DJI Mavic 2 Pro; (2) a professional, somewhat modifiable UAV (<2kg), i.e., the DJI Mavic 2 Enterprise and the Autel Evo II; and (3) a commercial-grade, fully customisable UAV (2-25 kg), i.e., the DJI Matrice 300. Two of the UAVs, the DJI Mavic 2 Enterprise and the Autel Evo II, possessed thermal imaging sensors.

To assess the capabilities of each UAV, both office and land-based trials were conducted in August 2021, as scheduled, and extended into September as it took some time for all equipment to arrive. Land-based field trials were conducted at Lung Kwu Tan, during which each UAV was flown by each team member, launching-landing procedures were agreed upon, and test flights were conducted in the northern part of the Sha Chau Lung Kwu Chau Marine Park.

To assess the capabilities of the thermal imaging sensors on the DJI Mavic 2 Enterprise and the Autel Evo II Dual, a trial was conducted with the bottlenose dolphins at Ocean Park, to better understand which parts of dolphin anatomy are thermally detectable and to provide a more detailed insight to dolphin behaviour to drone technicians, who are not biologists

Activity 2: Submit test flight results and flight plan to CAD
Status: Complete

At project onset, the team contacted the Civil Aviation Department (CAD) for advice on UAV limitations and potential issues flying close to Hong Kong international Airport and the Hong Kong maritime border. The CAD provided guidance on conduct over ships and shipping lanes, detailed typical flight pattern sand activities of low flying Government aircraft in western Lantau. Test flights were submitted to CAD to improve their understanding of planned research survey conduct. CAD also advice on how to complete a flight manual that complied to Hong Kong rules. Initially, CAD offered o send staff to advise the project team directly onboard, however, increasingly stricter covid restrictions were put in place as the project progressed and it was not possible to take additional personnel onboard

Activity 3: Conduct field surveys
Status: Complete

Surveys were originally scheduled between September and November 2021 and February and April 2022 (Table 1). Due to inclement weather and a delay in the delivery of some UAV equipment, the start of fieldwork was delayed until October 2021 and extended to June 2022 (Table 2). Surveys were halted in February 2022 due to restrictions during the fifth wave of COVID-19, however, fieldwork resumed in March 2022, following revised government guidelines on workplace practises.

In late October and early November 2021, surveys focused on trialling best practices for flying a UAV over water, launching and landing a UAV from a vessel (Figure 1), delineating the "No Fly Zone" (NFZ) around Hong Kong International Airport (HKIA) in western Lantau, testing parameters for aerial line transect surveys (e.g. altitude, speed, battery endurance) and confirming that dolphins (and finless porpoise) could be unambiguously identified from aerial imagery taken at the maximum permissible altitude for UAV in Hong Kong (90 m) (Figure 2, Figure 3). In total, two (2) trial surveys were completed successfully (Table 3). Two (2) further trial surveys were conducted in northern Lantau waters in January 2022 and March 2022 following changes to the boundary of the NFZ around HKIA (Table 3).

Systematic vessel and aerial line transect surveys commenced in late November 2021 and continued until June 2022, covering the known range of dolphins in Hong Kong, as identified in the AFCD Marine Mammal Monitoring Programme (AFCD 2021) - specifically, Northeast Lantau (NEL), Northwest Lantau (NWL), West Lantau (WL) and South Lantau (SL) (referred to as Southwest Lantau in the Marine Mammal Monitoring Programme) (Figure 4). The study area encompassed the waters adjacent to the Third Runway System (3RS), as well as The Brothers Marine Park (TBMP), Sha Chau and Lung Kwu Chau Marine Park (SCLKCMP), Southwest Lantau Marine Park (SWLMP) and South Lantau Marine Park (SLMP). In total, 17 line transect survey days were completed successfully (Table 3).

Vessel line transect surveys were conducted as described in the AFCD Marine Mammal Monitoring Programme (AFCD 2021). A 21.9 m twin-engine motor yacht was used as a research vessel, which travelled at a constant speed of approximately 9 knots, and had a viewing platform 5 m above sea level with an unobstructed 360° view. Two observers searched the area ahead of the vessel with the naked eye between 270° and 90° (in relation to the bow at 0°) aided by 7x50 marine binoculars with an in-built digital compass. A data recorder inputted standard effort and environmental data (i.e. prevailing weather conditions, Beaufort sea state, swell and glare) into an MS Access database using IFAW

Logger 2010[1] software. Logger 2010 was also used to record the vessel's GPS position, heading and speed every 10 seconds. Observers and data recorders rotated every 30 minutes to prevent observer fatigue. Survey design followed line transect "closing" mode in Buckland et al. (2001). Upon sighting cetaceans, search effort was paused and standard sighting data (i.e. location, time, distance, bearing and heading) were recorded. Distance was estimated by eye (noting the marine mammal survey team regularly take part in distance estimation training at sea). Bearing to and heading of the dolphins (or porpoise) were determined from the marine binoculars' in-built digital compasses. Once these data had been confirmed, the vessel then left the transect and approached the cetaceans to confirm species, group size and group composition, as well as collect photo-identification images using DSLR cameras and video footage of behaviour using a UAV. One of three UAV were used interchangeably, each with with different cameras capable of recording visible light (VL) and/or infra-red (IR): a DJI Mavic 2 Pro (VL), a DJI Mavic 2 Enterprise (VL and IR), and an Autel Evo II (VL and IR) (Figure 5). To minimise potential disturbance to cetaceans and avoid collision with the UAV conducting aerial line transect surveys (see below), UAV for behavioural observation were flown at altitudes no lower than 30 m and no higher than 50 m. Each video had GPS timestamps and coordinates embedded in the image metadata, permitting them to be georeferenced. Group size was reported as "minimum", "maximum" and "best" estimates. For humpback dolphin group composition, four age classes were distinguished based on external appearance, colouration and body size: adult, subadult, juvenile, and calf (Jefferson 2000; Hung and Jefferson 2004; Chan and Karczmarski 2017). Adults were mostly solid pink with dark spots, at least 2.5 m in length with robust bodies and a well-developed dorsal ridge. Calves were solid dark grey, two-thirds the length of an adult and always in close association with an adult. Juveniles were a solid light grey without spots, at least 2 m in length, noticeably less robust and often swimming independently. Dolphins with an external appearance between juveniles and adults, with a predominantly grey cast or dense spotting, were classified as subadults. For finless porpoise, four classes have been also distinguished based on external appearance, colouration and body size (Jefferson et al. 2002), however, due to their cryptic nature many of these identifiers (e.g. pectoral fins, forehead shape, lip pigmentation) cannot be observed reliably in free-ranging animals. Consequently, only two age classes were used for group composition: adult and calf. Adults were dark grey, almost black, and at least 1.5 m in length. Calves were lighter in colour, less than 1 m in length and always in close association with an adult. Once all the relevant data were recorded, the vessel returned to the point it departed the transect and search effort was resumed.

Aerial line transect surveys were conducted concurrently with vessel surveys using a DJI Matrice RTK 300 carrying a Zenmuse H20 camera payload with a 4.5 mm f/2.8 lens. Observer search effort was paused as and when needed to permit the UAV to land on, and launch from, the vessel. One pilot monitored the UAV using a controller whilst a second pilot followed the UAV by eye, aided by 7x50 marine binoculars, to monitor the surrounding airspace for potential hazards (e.g. birds, helicopters, other UAV). The UAV was kept within line-of-sight and within 2.5 km of the vessel. The DJI Pilot 2 app was used to generate transects within the study area based on a series of parameters: image side overlap (10%), image frontal overlap (10%), speed (15 m/s) and altitude (90 m). These parameters provided an on-ground image resolution of 3.1 cm per pixel. Each image was 4056 x 3040 pixels, resulting in an on-ground image surface area of 0.01 km^2 (125.7 x 94.2 m). Parameters were chosen to maximise coverage whilst minimising flight time and the number of battery exchanges. Due to a safety feature in the DJI Pilot 2 app, line transect length was restricted

[1] Logger 2010 software available from http://www.marineconservationresearch.co.uk/.

to 5 km and survey areas had to be partitioned to accommodate this limitation (Figure 6). Survey areas were partitioned in QGIS (v 3.22) (QGIS Development Team 2021) and imported into the DJI Pilot 2 app as KML files. The DJI Pilot 2 app was also used to configure the Zenmuse H20 camera to capture timed-interval images along each transect and ensure complete coverage of each survey area (Figure 7). The camera was configured with automatic exposure and shutter speed to avoid motion blur. Each image had GPS timestamps and coordinates embedded in the metadata, permitting them to be georeferenced.

In addition to systematic vessel and aerial line transect surveys, two (2) dedicated focal follow surveys were conducted to collect video footage of behaviour using the Matrice RTK 300 so that it could be compared with the DJI Mavic 2 Pro, DJI Mavic 2 Enterprise and Autel Evo II (Table 3). Focal follow surveys were conducted using the same research vessel as the line transect surveys, in areas of known high-density for dolphins (and finless porpoise), namely western Lantau waters and the Soko Islands. Search effort, environmental conditions and sighting data were recorded using Logger 2010. Upon sighting cetaceans, photo-identification images and video footage were also recorded as described above for vessel line transect surveys.

Limitations on the number of staff permitted onboard the research vessel at any one time from March 2022 onwards meant that systematic vessel and aerial line transect surveys could no longer be conducted concurrently. Given the objectives of this project, priority was given to aerial line transect surveys, and as a result, only aerial line transect surveys were conducted from March 2022 onwards (Table 3). During these surveys, however, any cetaceans sighted opportunistically by the pilot and co-pilot, and/or the relief team, were recorded as described for vessel line transect surveys using Logger 2010.

Activity 4: Analyse data and review procedures
Status: Complete

Data analysis was originally scheduled for two periods between December 2021 and January 2022 and May and June 2022 (Table 1). As a larger than anticipated volume of aerial imagery was generated, data analysis had to be conducted throughout the entire project period (Activity 3) from October 2021 to July 2022 (and beyond) (Table 2). Overall, 28,938 UAV images were analysed.

The objectives of data analyses were to:

1) Determine whether UAV-mounted infra-red (IR) cameras are capable of detecting wild, free-ranging cetaceans in Hong Kong waters
2) Calculate cetacean encounter rates using UAV imagery from aerial line transect surveys
3) Map cetacean distribution and density using UAV imagery from aerial line transect surveys
4) Compare group size and composition of cetacean sightings from observers and UAV imagery where concurrent aerial and vessel line transect surveys were conducted

To determine whether UAV-mounted IR cameras were capable of detecting cetaceans, concurrent VL and IR imagery taken during systematic line transect surveys using the Mavic 2 Enterprise and Autel Evo II were compared (Figure 8).

To calculate encounter rates from aerial line transect surveys, UAV images were first graded on environmental conditions, specifically glare and sea state, both of which influence the likelihood of detecting cetaceans (Figure 9). Since manual grading can be time-consuming and inconsistent, grading was semi-automated using the countcolors package (Hooper et al. 2020) in R v 4.2 (R Core Team 2022) by quantifying the percentage of pixels in each image, referred to as image fraction (%), that were compromised by sun glitter or white caps (i.e. white in colour). A spherical range with a reference RGB triplet of 1,1,1 and a search radius of 50% (0.50) was used after various trials with different parameters (Figure 10). UAV images were then reviewed manually for the presence of cetaceans (Figure 11). For each image with cetaceans, the minimum, maximum and best estimate for the number of animals, number of adults, number of calves, position in the water column and identification certainty were extracted. Position in the water column was classified as: Surface = animal has broken the surface of the water; Subsurface = animal is below the surface of the water; and Mixed = multiple animals are at different positions in the water column (for images containing more than one animal). Identification certainty was graded as: 1 = Certain; 2 = Partial, using sequential images; and 3 = Uncertain, because the animal is obscured or in an awkward orientation. Due to the 10 % side and frontal overlap between images, some animals were visible across sequential images and/or transects. To avoid double counting animals, all images with cetaceans were geo-referenced and visualised in QGIS using the Vertical Photo Placer[2] plugin. "Frontal" resights (i.e. across sequential images) were readily detected based on the location of animals, the time interval between images (5-6 seconds), as well as the average swimming speed of humpback dolphins (3.6-7.2 km/h) (Jefferson & Karczmarski 2001) and finless porpoise (4.6 km/h) (Akamatsu et al. 2002). Images with cetaceans that overlapped laterally (i.e. across transects) were marked as "side" resights. Only images that were not frontal or side resights and had an identification certainty of 1 were used for subsequent analyses. Encounter rate was calculated per survey area as the number of sightings divided by the total distance surveyed by the UAV. In addition to cetaceans, the presence of vessels (including vessel wake and vessel shadows), coastlines, islands, landmarks (e.g. safe water marks), miscellaneous objects (e.g. surface marker buoys, gill nets, marine debris), algal blooms (i.e. "red tides") and other animals (e.g. fish, birds) were also recorded.

To map distribution and density from aerial line transect surveys, and to make aerial detection densities broadly comparable with published vessel detection densities, a quantitative grid analysis was conducted as described in the AFCD Monitoring of Marine Mammals in Hong Kong Waters reports (e.g. AFCD 2021). For each 1 km by 1 km grid that was surveyed, the number of sightings ($SPSE_U$) and animals ($DPSE_U$) detected per 100 units of aerial survey effort were calculated using the following formulae:

$$SPSE_U = \frac{(S_U / E_U) \, x \, 100}{SA}$$

$$DPSE_U = \frac{(D_U / E_U) \, x \, 100}{SA}$$

S_U = *total number of sightings from UAV imagery*
D_U = *total number of animals from UAV imagery*
E_U = *total units of UAV survey effort*
SA = *proportion of sea area*

Units of survey effort were defined as the number of times a grid cell was surveyed, such that a grid cell that had been surveyed 10 times was considered to have 10 units of survey effort. For grid cells partially covered by land, the percentage of sea area was calculated using QGIS. $SPSE_U$ and $DPSE_U$ values were calculated for each grid cell using R and mapped using QGIS.

[2]Available at: https://verticalphotoplacer.github.io/VerticalPhotoPlacer/

Activity 5: Interim Report
Status: Complete

The Interim Report was completed and submitted in March 2022.

Activity 6: Liaise AFCD preliminary results and incorporate comments
Status: Complete

No in person meetings were conducted during the project period, however, online discussion on project concept and preliminary results allowed AFCD to better understand both the advantages and challenges of UAV surveys in Hong Kong as these were the first systematic surveys to use UAV in Hong Kong. Comments on how best to compare density estimated between survey types were incorporated during the final analysis steps.

Activity 7: Cost-benefit analysis
Status: Complete

The cost-benefit analysis was originally scheduled between May and June 2022 (Table 1), however, as surveys were extended until June 2022 (Activity 3), it was completed in July 2022 (Table 2).

Cost/Benefit

UAV

- Data are archival and independently verifiable.
- Data are not limited to what the observers record in-situ.
- Sightings and encounters are always evidenced with imagery.
- Still aerial images do not permit behavioural data to be collected (however, UAV video footage provides significantly more observational capacity than vessel-based observations).
- Vessel-based observers can laterally scan a larger area more than a downward-facing UAV camera (i.e. spatial coverage is more efficient).
- Locations of sightings are more accurate and precise, as the exact coordinates of individual animals are recorded in the metadata of each image.
- Access to an electrical power source is integral to data collection when surveying relatively large areas due to the battery life constraints of (quadcopter) UAVs.
- UAV battery performance is significantly affected by ambient temperatures. Flight times were noticeably shorter and battery charge times noticeably longer when ambient temperatures exceeded 30°C.
- Data collection in-situ is not dependent on experienced marine mammal observers, as the detection and identification of cetacean species is performed post-hoc.
- Labour costs of data analysis (i.e. image review) are higher, due to the sheer volume of imagery generated per survey (though this can be ameliorated by automation).
- There are limitations, both legal and logistical, on UAV operation (e.g. altitude restrictions, HKIA NFZ).

Vessel-Based Observers

- Data are not archival and cannot be independently verified.
- Data are limited to what the observers record in-situ.
- Sightings and encounters are not always evidenced with imagery.
- Direct observation of animals permits behavioural data to be collected (however, UAV video footage provides significantly more observational capacity than vessel-based observations).

- Vessel-based observers can laterally scan a larger area more than a downward-facing UAV camera (i.e. spatial coverage is more efficient).
- Locations of sightings are estimated by vessel-based observers, the accuracy and precision of which is highly dependent on training, experience, and environmental conditions.
- Access to an electrical power source is not integral to data collection.
- Observer performance is not significantly affected by ambient temperatures.
- Data collection in-situ must be performed by experienced marine mammal observers, as the ability to search, detect and identify cetacean species is highly dependent on training and experience.
- Labour costs of data analysis (i.e. photo-identification) are lower, as they are not as time consuming.
- Vessels are not limited by NFZs.

Activity 8: School citizen science project
Status: Complete

The school citizen science project was originally scheduled to occur between September and December 2021 with Year 13 students (Table 1), however, the participating school International College Hong Kong (ICHK), requested that the collaboration be extended to June 2022 so that the whole school could be included (Table 2).

In September 2021, a presentation was given to Year 13 students on resident marine mammal species in Hong Kong waters. The presentation was followed by a field trip in October 2021, in which the students were invited to participate in a trial survey (see Activity 3). Subsequently, between October and December 2021, datasets derived from MEEF projects (this project plus MEEF2018010 and MEEF2020005) were provided to Year 13 students that had participated in the presentation and field trip as part of their Internal Assessment (IA).

In May 2022, a presentation was given to Year 2 students on anthropological impacts on humpback dolphins and their habitat in Hong Kong waters (Figure 12).

In June 2022, a workshop was held for Year 12 students as part of their IB Group 4 Project syllabus. The workshop involved presentations on the application of UAVs in marine mammal science (Figure 13) and the operation of UAVs (Figure 14), as well as practical experience using a UAV simulator (Figure 15) and in the field (Figure 16). This was followed by an interactive Q&A session where students were given access to datasets derived from MEEF projects (this project plus MEEF2018010 and MEEF2020005) and encouraged to develop their own scientific questions (Figure 17). The results of the workshop were published by the students as an Instagram page (@ichk_seamar).

All educational material used in the presentations, work produced by the students and imagery from student activities Appendix 5.

Activity 9: Evaluation contribution to secondary school science students
Status: Complete

This project contributed directly to secondary school students as the information provided and activities organised contributed directly to formal aspects of the school curriculum. For Year 13 students, data derived from this and other MEEF projects were used by the students to complete Internal Assessments (IA), which are a compulsory task for International Baccalaureate (IB) students to assess their level in relation to objectives set out in the Diploma Programme (DP). For Year 12 students, the workshop and activities were held contributed to the Group 4 Project which is an essential component of the IB syllabus that emphasises the collaborative and interdisciplinary nature of scientific inquiry. For Year 2 students, the information provided contributed to several aspects of the IB Biology Syllabus, including 'Conservation and Biodiversity', 'Adaptation to Environment', Stability and Change' and 'Climate Change'.

Activity 10: Final Report
Status: Complete

Results

Between November 2021 and June 2022, there were 17 systematic survey days, of which 5 were concurrent aerial-vessel line transect surveys and 12 were aerial-only line transect surveys (Table 3).

For vessel surveys, there was 69.4 km (4.4 hours) of vessel-based observer effort in WL (Table 5). Overall, there were 7 on-effort sightings of humpback dolphins, resulting in an encounter rate of 0.101 km^{-1}. On-effort sightings were all made in Beaufort sea state ≤3. From aerial-only and focal follow surveys, 32 opportunistic sightings were recorded, of which 25 were of humpback dolphins and 7 were of finless porpoises (Table 6; Figure 18).

For aerial surveys, there was 2,087.9 km (62.3 hours) UAV effort in NEL, NWL, WL and SL, which yielded 28,938 images (Table 7). The total length of the aerial transects was 946.7 km and the total spatial coverage of the aerial images was 81.6 km^2. Of the 28,938 aerial images, 28,235 were suitable for semi-automated environmental grading (i.e. not compromised by vessels, vessel wake or land). Image fractions for these images ranged from 0.0% to 10.5% (Figure 19), though the majority of images (42.9%) had an image fraction of ≤2% and only a minority had an image fraction ≥ 10% (Table 8; Figure 20). Overall, there were 17 sightings of humpback dolphins (Table 9). Image fractions for these sightings ranged from 0.003 to 3.6%, though the majority (88.2%, n = 15) had an image fraction between 0-2%. In terms of position in the water column, 52.9% (9) sightings were of humpback dolphins at the surface and 47.1% (8) were of subsurface animals. Humpback dolphin sightings were predominantly in WL (15), though there were sightings in SL1 (1) and SL2N (1) (Figure 21). Encounter rates ranged from 0.003 km^{-1} (SL1) to 0.017 km^{-1} (WL) (Table 7). Sighting density ($SPSE_U$) was greatest around Wong Fa Pai (0.43-0.57) in WL and between Fan Lau and Lo Kei Wan in SL (0.5) (Figure 22). Density of humpback dolphins ($DPSE_U$) was greatest southwest of Peaked Hill (0.17) (Figure 22). There were 33 sightings of finless porpoises (Table 9). Image fractions for these sightings ranged from 0 to 4.8%, though the majority (87.9%, n = 29) had an image fraction between 0-2%. In terms of position in the water column, 63.6% (21) of sightings were of finless porpoises below the surface of the water, 18.2% (6) were of animals at the surface, and 18.2% (6) were of animals at mixed positions in the water column. Finless porpoise sightings were predominantly in SL3S (25), though there were also sightings in SL2S (5) and SL3N (3) (Figure 21). Encounter rates ranged from 0.022 km^{-1} (SL3N) to 0.227 km^{-1} (SL3S) (Table 7). Sighting density ($SPSE_U$) was greatest south of Tai A Chau (2.3-3.5), which was also reflected in the density of finless porpoises ($DPSE_U$) (7.5) (Figure 23).

Comparison of humpback dolphin sightings from concurrent line transect surveys in WL revealed that vessel-based observers recorded 7 on-effort sightings of 9 animals over 4 days, whereas UAV imagery recorded 5 sightings of 6 animals over 2 days (Table 9). Notably, however, 2 of the sightings recorded by vessel-based observers were north of Tai O, within range of the HKIA NFZ, where the UAV was not able to survey (Figure 24). Excluding these two sightings, the total number of animals sighted and their age composition (6 adults) between aerial and vessel line transect surveys was the same. Although UAV imagery did not record sightings on 3 of the concurrent line transect survey days, vessel-based observers also missed 1 sighting that was recorded from UAV imagery (Table 9).

A review of concurrent VL and IR footage revealed that IR cameras are likely not reliable enough to be used to detect wild, free-ranging cetaceans in Hong Kong waters, as the visibility of cetaceans was highly variable (Figure 25).

Evaluation of Project Effectiveness

Objective 1: This objective will be achieved by successfully capturing images of dolphins from each UAV model that are concurrent with, at least some, sightings logged by visual observers during vessel-based line transect surveys. Project effectiveness will be evaluated by the establishment of a UAV imagery catalogue of dolphins and porpoise sightings, each sightings group size and the measured distance of each sighting from the transect line. For Chinese white dolphin, 60 sightings will be sufficient data from which to estimate abundance with a good level of confidence. A comparison of the concurrent vessel-based sightings and UAV derived sightings will allow an assessment of the efficiency of each method, taking into consideration the sighting conditions for each survey. The establishment of a UAV database and critical assessment of each data collection method will be submitted to a scientific journal and the publication of this paper will be an indicator of the project's academic research value. The expected environmental benefits of this aim will be to provide new techniques that are more accurate with regards to establishing Chinese white dolphin population status and that provide a permanent and independently verifiable record of sightings.

This objective has been achieved by successfully capturing aerial imagery and footage of humpback dolphins concurrently with sightings by observers from vessel line transect surveys. Overall, 28,938 images (and 8 hours of video footage) were captured using four UAV models: a DJI Mavic 2 Pro, a DJI Mavic 2 Enterprise, an Autel Evo II and a Matrice RTK 300. Although the minimum number (60) of humpback dolphin sightings required to estimate abundance was not reached, a UAV sightings database has been established that contains 17 UAV sightings of humpback dolphins and 33 UAV sightings of finless porpoises.

Objective 2: This objective will be achieved by completing a cost benefit analysis once the results of UAV survey efficiency are determined. If the UAV surveys provide better results than vessel-based line transect surveys, this will benefit the environment by providing better data upon which to base management plans. If UAV line transect surveys provide comparable results to vessel–based line transect surveys at a lower cost, then long term monitoring work can be planned with a smaller budget therefore, releasing more funds to implement management action and increasing support for positive conservation outcomes. The cost benefit analysis will be developed in conjunction with AFCD and submitted to the Marine Mammal Conservation Working Group. The impact of this aim will be indicated by the degree to which the cost benefit report conclusions are considered by management authorities.

This objective has been achieved for the given models of UAV trialled. The major limitation to using UAV technology, with the models used, was that battery power was limited as recharging had to occur every 20 to 40 minutes. It was not possible, even with 4 sets of batteries, to maintain the recharging-flying-recharging cycle throughout the day. Ultimately, the battery recharging could not keep up with the flying time. Overall, the 28,938 images obtained provided an excellent sightings record, which is not usually achieved during line transect surveys. The man hours required to analyse these images exceeded typical line transect conduct and analysis time, however, automated detection and AI will considerably reduce image analysis time.

Objective 3: This objective will be achieved by successfully completing the ten-week programme and by the contribution the programme makes to the year marks of the participating students. In addition, the proposed presentation and discussions of the pilot programme at the annual teachers' conference following the study will provide a basis upon which further projects might be developed for Hong Kong. curriculum. The environmental benefit of this outcome will be an increased awareness and the development of practical and analytical skills for aspiring Hong Kong scientists and environmental resource managers and verified scientific contribution to ongoing research programmes.

This objective has been achieved as well as could be expected, given that covid restrictions prevented some in person meetings, e.g., the teachers conference. The participating students did complete a variety of projects which did contribute to their final examination marks and, for younger students, a diverse range of projects were submitted as part of their course work. Two students remained working with SEAMAR during 2022 and beyond and the school programme continued (see MEEF2022014).

Summary and Way Forward

Summary

- Overall, the results of this project suggest that UAV and vessel line transect surveys for estimating abundance, density and distribution are complementary.
- The main limitation of UAV line transect surveys (using quadcopter UAVs) are the flight time, range and battery life constraints of commercially available models (e.g. Matrice RTK 300).
    - Surveys using UAVs (specifically quadcopter UAVs) may be more applicable when the purpose of data collection is to understand cetacean distribution at relatively small spatial scales (e.g. Southwest Lantau Marine Park).
    - The main advantage is the collection of highly accurate and precise, spatially-explicit, archival data that can be independently verified post-hoc.
    - Relatively small UAVs (e.g. Mavic 2 Pro) are invaluable for recording subsurface behaviours that would otherwise be missed from a vessel platform.
    - Surveys using observers on vessel platforms may be more applicable when the purpose of data collection is to understand cetacean distribution and habitat use at relatively large spatial scales (e.g. South Lantau).
    - The main limitation is the experience and training required to collect accurate and precise, spatially-explicit data in-situ.
- Results suggest that UAV surveys may be particularly effective at detecting finless porpoises, as the majority of finless porpoise UAV sightings (81.8%) were of animals that were below the surface of the water, compared to less than half (47.1%) of humpback dolphin UAV sightings.

Way Forward

- Optimisation of parameters (e.g. image overlap, speed) used to generate line transects in the DJI Pilot 2 app, as these may be species-specific (i.e. differ between humpback dolphins and finless porpoises).
- Development of a custom image review programme (e.g. in Python or R) to help standardise image processing and data extraction, as well as to optimise the accuracy of the data extracted. For example, the programme could extract the exact GPS coordinates of each animal in each image. In turn, this could be used to semi-automate the identification of sequential "resight" images.
- Development of an automated cetacean detection algorithm to significantly reduce data processing time.
- Refinement of the semi-automated environmental grading criteria to account for non-environmental conditions that compromise UAV image coverage (e.g. vessels, vessel wake, land), other environmental conditions (e.g. sediment, algal blooms) and the distribution of glitter or white caps within the image (e.g. concentrated versus scattered).
- Expansion of the survey area to include finless porpoise habitat, as the preliminary results of this Project indicate UAV platforms may be particularly effective at detecting finless porpoises, which are often difficult to detect by observers from vessel platforms due to their small size, dark colouration and cryptic behaviour.
- Overcome the flight time, range and battery life limitations of commercially available quadcopter UAVs (e.g. Matrice RTK 300) by testing the use of custom-built fixed-wing UAVs.
- Continuation of concurrent aerial and vessel line transect surveys to permit the full comparison of the two modalities.

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Tables

Table 1. Proposed timeline of activities.

Item	Activities	Project Period											
		Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
1	Drone Purchase and Camera Trials (land)	■	■										
2	Submit test flight results and Flight Plan to CAD			■									
3	Conduct Field Surveys			■	■	■			■	■	■		
4	Analyse data, review procedures						■	■			■	■	
5	Interim Report						■						
6	Liase AFCD preliminary results/incorporate comments							■	■				
7	Cost Benefit Analysis											■	■
8	School Citizen Sciencie Project			■	■	■	■						
9	Evaluation Contribution to Secondary School Science Students												■
10	Final Report												■

Table 2. Achieved timeline of activities.

Item	Activities [Revised]	Project Period											
		Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
1	Drone Purchase and Camera Trials (land)		■	■	■	■							
2	Submit test flight results and Flight Plan to CAD								■				
3	Conduct Field Surveys				■	■	■	■		■	■	■	■
4	Analyse data, review procedures*						■	■			■	■	
5	Interim Report						■						
6	Liase AFCD preliminary results/incorporate comments												
7	Cost Benefit Analysis												■
8	School Citizen Sciencie Project			■	■	■	■					■	■
9	Evaluation Contribution to Secondary School Science Students												■
10	Final Report*												■
	* Field surveys were delayed and image analysis took considerably longer than anticipated. Subsequently, both analysis time and report writing extended beyond the originally anticipated date of completion												

Table 3 Summary of surveys.

Date	Survey Block	Survey Type	Notes
2021-10-07	NA	School Field Trip	ICHK Y13
2021-10-28	NA	Test	Established UAV launch and landing protocols, UAV survey parameters, detectability of cetaceans at various altitudes and NFZ in WL
2021-11-05	NA	Test	
2021-11-25	WL	Line Transect (Concurrent Vessel-Aerial)	NA
2021-12-06	WL	Line Transect (Concurrent Vessel-Aerial)	NA
2021-12-10	WL	Line Transect (Concurrent Vessel-Aerial)	NA
2021-12-15	WL	Line Transect (Concurrent Vessel-Aerial)	NA
2022-01-13	WL	Line Transect (Concurrent Vessel-Aerial)	NA
2022-01-14	NA	Test	Established NFZ in NEL and NWL
2022-01-19	SL1	Line Transect (Aerial Only)	NA
2022-01-20	SL2N	Line Transect (Aerial Only)	NA
2022-03-02	WL	Line Transect (Aerial Only)	NA
2022-03-15	SL1	Line Transect (Aerial Only)	NA
2022-03-16	NA	Test	Re-established NFZ in NEL and NWL
2022-03-17	SL3N, SL3C, SL3S	Line Transect (Aerial Only)	NA
2022-03-18	NA	Focal Follow	NA
2022-04-12	SL3N, SL3C, SL3S	Line Transect (Aerial Only)	NA
2022-04-13	SL2N, SL2S	Line Transect (Aerial Only)	NA
2022-04-21	SL1	Line Transect (Aerial Only)	NA
2022-04-22	WL	Line Transect (Aerial Only)	NA
2022-05-04	NWLS	Line Transect (Aerial Only)	NA
2022-05-30	NEL	Line Transect (Aerial Only)	NA
2022-06-23	NWLN	Line Transect (Aerial Only)	NA
2022-06-24	NA	Focal Follow	NA

Table 4. Summary of effort during vessel line transect surveys.

Survey Block	Sea State	Total Effort (km)	Total Effort (hr)	Humpback Dolphin	
				Sightings	Animals
WL	1	12.2	0.8	2	3
	2	34.2	2.1	4	4
	3	15.9	1.0	1	2
	4	7.1	0.4	0	0
Total		**69.4**	**4.4**	**7**	**9**

Table 5. Sightings from vessel line transect surveys.

Sighting ID	Datetime (HKT)	Survey Type	Latitude	Longitude	Survey Block	Effort	Species	Group Size	Group Composition				Behaviour
									Adults	Sub-adults	Juveniles	Calves	
1	2021-11-25 14:48:25	Line Transect (Vessel-Aerial)	22.26749	113.8676	WL	Opp	*Sousa chinensis*	1	0	1	0	0	Foraging
2	2021-12-06 10:19:22	Line Transect (Vessel-Aerial)	22.25922	113.8527	WL	Opp	*Sousa chinensis*	1	0	1	0	0	Travelling
3	2021-12-06 13:36:37	Line Transect (Vessel-Aerial)	22.2089	113.832	WL	On	*Sousa chinensis*	1	1	0	0	0	Unknown
4	2021-12-06 13:44:36	Line Transect (Vessel-Aerial)	22.21822	113.8232	WL	Opp	*Sousa chinensis*	3	3	0	0	0	Travelling
5	2021-12-06 15:07:10	Line Transect (Vessel-Aerial)	22.24241	113.8336	WL	On	*Sousa chinensis*	1	1	0	0	0	Travelling
6	2021-12-10 10:18:08	Line Transect (Vessel-Aerial)	22.25635	113.85	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
7	2021-12-10 11:52:27	Line Transect (Vessel-Aerial)	22.19277	113.8442	WL	Opp	*Sousa chinensis*	3	3	0	0	0	Multiple
8	2021-12-10 12:23:10	Line Transect (Vessel-Aerial)	22.19077	113.8413	WL	On	*Sousa chinensis*	2	2	0	0	0	Foraging
9	2021-12-10 12:49:40	Line Transect (Vessel-Aerial)	22.21091	113.8212	WL	Opp	*Sousa chinensis*	5	5	0	0	0	Travelling
10	2021-12-10 13:03:24	Line Transect (Vessel-Aerial)	22.2275	113.8291	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Unknown
11	2021-12-10 13:29:12	Line Transect (Vessel-Aerial)	22.23768	113.8398	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
12	2021-12-10 14:43:34	Line Transect (Vessel-Aerial)	22.24621	113.8295	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Travelling
13	2021-12-10 15:11:35	Line Transect (Vessel-Aerial)	22.2606	113.8468	WL	On	*Sousa chinensis*	2	1	0	1	0	Foraging
14	2021-12-10 15:20:59	Line Transect (Vessel-Aerial)	22.26312	113.8493	WL	Opp	*Sousa chinensis*	5	2	2	1	0	Multiple
15	2021-12-15 10:28:48	Line Transect (Vessel-Aerial)	22.22026	113.8344	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Travelling
16	2021-12-15 11:03:55	Line Transect (Vessel-Aerial)	22.19405	113.8444	WL	Opp	*Sousa chinensis*	4	4	0	0	0	Foraging
17	2021-12-15 12:03:48	Line Transect (Vessel-Aerial)	22.19224	113.8422	WL	On	*Sousa chinensis*	1	1	0	0	0	Foraging
18	2021-12-15 12:36:20	Line Transect (Vessel-Aerial)	22.21824	113.8262	WL	On	*Sousa chinensis*	1	1	0	0	0	Unknown
19	2022-01-13 10:31:23	Line Transect (Vessel-Aerial)	22.21839	113.8338	WL	Opp	*Sousa chinensis*	3	1	2	0	0	Multiple
20	2022-01-13 11:05:25	Line Transect (Vessel-Aerial)	22.19601	113.8431	WL	Opp	*Sousa chinensis*	2	2	0	0	0	Foraging
21	2022-01-13 14:34:19	Line Transect (Vessel-Aerial)	22.26928	113.8523	WL	On	*Sousa chinensis*	1	1	0	0	0	Travelling
22	2022-01-19 10:37:10	Line Transect (Aerial)	22.21403	113.8346	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
23	2022-01-19 11:57:57	Line Transect (Aerial)	22.17389	113.8638	SL	Opp	*Sousa chinensis*	10	7	2	1	0	Multiple
24	2022-01-19 14:16:11	Line Transect (Aerial)	22.17916	113.8737	SL	Opp	*Sousa chinensis*	4	2	1	1	0	Travelling
25	2022-01-20 10:49:21	Line Transect (Aerial)	22.20077	113.8846	SL	Opp	*Sousa chinensis*	2	2	0	0	0	Foraging
26	2022-01-20 11:11:58	Line Transect (Aerial)	22.19941	113.8683	SL	Opp	*Sousa chinensis*	2	2	0	0	0	Socialising
27	2022-01-20 11:51:57	Line Transect (Aerial)	22.19333	113.8545	SL	Opp	*Sousa chinensis*	6	5	0	1	0	Multiple
28	2022-03-02 13:47:53	Line Transect (Aerial)	22.21659	113.8332	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
29	2022-03-02 14:08:25	Line Transect (Aerial)	22.21939	113.834	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Multiple
30	2022-03-02 14:32:16	Line Transect (Aerial)	22.22639	113.8336	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
31	2022-03-02 14:41:57	Line Transect (Aerial)	22.22799	113.836	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Multiple
32	2022-03-02 14:50:27	Line Transect (Aerial)	22.23425	113.8395	WL	Opp	*Sousa chinensis*	2	1	0	1	0	Multiple
33	2022-03-15 12:21:15	Line Transect (Aerial)	22.18504	113.8698	SL	Opp	*Neophocaena phocaenoides*	3	3	0	0	0	Travelling
34	2022-03-15 14:48:44	Line Transect (Aerial)	22.19134	113.9021	SL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
35	2022-03-15 15:25:44	Line Transect (Aerial)	22.17713	113.9292	SL	Opp	*Neophocaena phocaenoides*	30	10	0	0	10	Other
36	2022-03-17 14:47:35	Line Transect (Aerial)	22.15899	113.9187	SL	Opp	*Neophocaena phocaenoides*	5	5	0	0	0	Foraging
37	2022-03-17 15:23:30	Line Transect (Aerial)	22.15381	113.9156	SL	Opp	*Neophocaena phocaenoides*	10	10	0	0	0	Multiple
38	2022-03-18 11:26:59	Focal Follow	22.26549	113.8478	WL	Opp	*Sousa chinensis*	4	2	1	1	0	Multiple
39	2022-03-18 11:56:23	Focal Follow	22.24897	113.8359	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Foraging
40	2022-03-18 12:21:45	Focal Follow	22.23479	113.8337	WL	Opp	*Sousa chinensis*	6	6	0	0	0	Foraging
41	2022-03-18 13:11:19	Focal Follow	22.22987	113.8304	WL	Opp	*Sousa chinensis*	5	5	0	0	0	Foraging
42	2022-03-18 13:33:34	Focal Follow	22.21942	113.8322	WL	Opp	*Sousa chinensis*	3	2	1	0	0	Multiple
43	2022-03-18 14:29:50	Focal Follow	22.19351	113.8464	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Travelling
44	2022-03-18 15:20:19	Focal Follow	22.19707	113.8922	SL	Opp	*Neophocaena phocaenoides*	2	2	0	0	0	Unknown
45	2022-03-18 15:36:46	Focal Follow	22.18704	113.9179	SL	Opp	*Neophocaena phocaenoides*	3	3	0	0	0	Unknown
46	2022-03-18 15:55:18	Focal Follow	22.1785	113.9292	SL	Opp	*Neophocaena phocaenoides*	14	14	0	0	0	Other
47	2022-04-22 10:36:37	Line Transect (Aerial)	22.22616	113.8365	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Unknown
48	2022-04-22 13:29:16	Line Transect (Aerial)	22.21499	113.8315	WL	Opp	*Sousa chinensis*	1	1	0	0	0	Multiple
49	2022-04-22 14:37:33	Line Transect (Aerial)	22.23079	113.8364	WL	Opp	*Sousa chinensis*	8	7	0	1	0	Other
50	2022-06-24 11:26:40	Focal Follow	22.1887	113.8662	SL	Opp	*Sousa chinensis*	4	3	0	1	0	Multiple
51	2022-06-24 12:01:58	Focal Follow	22.18503	113.8625	SL	Opp	*Sousa chinensis*	10	9	0	1	0	Multiple
52	2022-06-24 12:31:22	Focal Follow	22.19138	113.8526	SL	Opp	*Sousa chinensis*	12	12	0	0	0	Foraging
53	2022-06-24 13:17:26	Focal Follow	22.20285	113.8405	WL	Opp	*Sousa chinensis*	6	3	0	2	1	Travelling

Table 6. Summary of UAV effort during aerial line transect surveys.

Survey Block	Survey Area (km2)	Transect Length (km)	Total Number of Times Surveyed	Total Effort (km)	Total Effort (hr)	Total Number of Images Taken	Humpback Dolphin			Finless Porpoise		
							Sightings	Animals	Encounter Rate (km-1)	Sightings	Animals	Encounter Rate (km-1)
NEL	12.1	130.1	1	130.8	3.8	1,708	0	0	0.000	0	0	0.000
NWLN	13.8	142.8	1	143.6	4.6	1,842	0	0	0.000	0	0	0.000
NWLS	8.4	97.3	1	97.8	3.0	1,279	0	0	0.000	0	0	0.000
WL	10.7	145.6	7	862.9	29.4	12,545	15	19	0.017	0	0	0.000
SL 1	8.4	102.7	3	309.6	8.3	4,443	1	1	0.003	0	0	0.000
SL2N	8.5	92.1	2	151.2	3.7	1,936	1	1	0.007	0	0	0.000
SL2S	7.4	82.2	1	82.6	1.9	1,057	0	0	0.000	5	11	0.061
SL3N	5.7	67.5	2	135.6	3.3	1,757	0	0	0.000	3	4	0.022
SL3C	2.2	31.9	2	63.7	1.5	909	0	0	0.000	0	0	0.000
SL3S	4.4	54.5	2	110.2	2.8	1,462	0	0	0.000	25	43	0.227
Total	**81.6**	**946.7**	**22**	**2,087.9**	**62.3**	**28,938**	**17**	**21**	**0.008**	**33**	**58**	**0.016**

Table 7. Distribution of image fraction for UAV images obtained from aerial line transect surveys.

Image Fraction	Number of UAV Images*	Percentage of UAV Images
0-2%	12,115	42.91
2-4%	6,525	23.11
4-6%	4,999	17.70
6-8%	3,696	13.09
8-10%	872	3.09
>10%	28	0.10
Total	**28,235**	**100.00**

* not compromised by vessels, vessel wake or land

Table 8. UAV sightings from aerial line transect surveys.

Sighting ID	Datetime (HKT)	Survey Type	Latitude	Longitude	Survey Block	Species	Group Size	Group		Position	Image Fraction
								Adult	Calf		
1	2021-11-25 11:59:58	Line Transect (Vessel-Aerial)	22.24268083	113.8366946	WL	*Sousa chinensis*	1	1	0	Surface	3.626
2	2021-12-15 11:35:59	Line Transect (Vessel-Aerial)	22.19382497	113.8451058	WL	*Sousa chinensis*	1	1	0	Surface	0.004
3	2021-12-15 12:56:54	Line Transect (Vessel-Aerial)	22.22333608	113.8287859	WL	*Sousa chinensis*	2	2	0	Sub-surface	0.003
4	2021-12-15 12:57:00	Line Transect (Vessel-Aerial)	22.22333586	113.8296179	WL	*Sousa chinensis*	1	1	0	Sub-surface	0.004
5	2021-12-15 13:08:40	Line Transect (Vessel-Aerial)	22.22638897	113.8303018	WL	*Sousa chinensis*	1	1	0	Surface	0.005
6	2022-01-19 12:57:37	Line Transect (Aerial)	22.17623988	113.8643826	SL1	*Sousa chinensis*	1	1	0	Surface	2.375
7	2022-03-02 14:23:50	Line Transect (Aerial)	22.22802727	113.8343155	WL	*Sousa chinensis*	1	1	0	Surface	0.465
8	2022-03-02 14:25:32	Line Transect (Aerial)	22.22887516	113.8251531	WL	*Sousa chinensis*	1	1	0	Sub-surface	0.378
9	2022-03-02 14:29:08	Line Transect (Aerial)	22.23048083	113.8248194	WL	*Sousa chinensis*	1	1	0	Sub-surface	0.035
10	2022-03-02 14:42:58	Line Transect (Aerial)	22.23227011	113.8307478	WL	*Sousa chinensis*	1	1	0	Surface	0.152
11	2022-03-02 14:44:19	Line Transect (Aerial)	22.23311616	113.8390842	WL	*Sousa chinensis*	1	1	0	Surface	0.044
12	2022-03-02 14:49:14	Line Transect (Aerial)	22.23481511	113.8301533	WL	*Sousa chinensis*	1	1	0	Surface	0.012
13	2022-03-02 15:38:40	Line Transect (Aerial)	22.24754319	113.8366643	WL	*Sousa chinensis*	1	1	0	Sub-surface	0.004
14	2022-03-17 10:58:41	Line Transect (Aerial)	22.20396841	113.8994361	SL3N	*Neophocaena phocaenoides*	1	1	0	Sub-surface	4.415
15	2022-03-17 11:27:43	Line Transect (Aerial)	22.19018344	113.9038351	SL3N	*Neophocaena phocaenoides*	2	2	0	Mixed	4.781
16	2022-03-17 12:29:39	Line Transect (Aerial)	22.18854861	113.9214298	SL3N	*Neophocaena phocaenoides*	1	1	0	Surface	1.854
17	2022-03-17 15:04:39	Line Transect (Aerial)	22.14894069	113.9205362	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.886
18	2022-03-17 15:04:50	Line Transect (Aerial)	22.14741788	113.9205363	SL3S	*Neophocaena phocaenoides*	1	1	0	Surface	0.846
19	2022-03-17 15:04:56	Line Transect (Aerial)	22.14666341	113.9205363	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.831
20	2022-03-17 15:07:41	Line Transect (Aerial)	22.14998825	113.9194368	SL3S	*Neophocaena phocaenoides*	3	2	1	Mixed	0.918
21	2022-03-17 15:22:04	Line Transect (Aerial)	22.14133291	113.9183375	SL3S	*Neophocaena phocaenoides*	2	1	1	Surface	1.284
22	2022-03-17 15:24:06	Line Transect (Aerial)	22.15050472	113.9172382	SL3S	*Neophocaena phocaenoides*	2	1	1	Sub-surface	0.916
23	2022-03-17 15:33:08	Line Transect (Aerial)	22.14623061	113.9139394	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.619
24	2022-03-17 15:33:48	Line Transect (Aerial)	22.140895	113.9139405	SL3S	*Neophocaena phocaenoides*	2	2	0	Sub-surface	0.327
25	2022-03-17 15:33:54	Line Transect (Aerial)	22.14023422	113.9139398	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.835
26	2022-03-17 15:40:26	Line Transect (Aerial)	22.14970433	113.910642	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.722
27	2022-03-17 15:43:57	Line Transect (Aerial)	22.14640708	113.9095421	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.029
28	2022-03-17 15:53:16	Line Transect (Aerial)	22.14944711	113.9084431	SL3S	*Neophocaena phocaenoides*	3	2	1	Sub-surface	0.040
29	2022-03-17 15:54:47	Line Transect (Aerial)	22.15600191	113.9073441	SL3S	*Neophocaena phocaenoides*	1	1	0	Surface	0.106
30	2022-03-17 15:55:26	Line Transect (Aerial)	22.15066916	113.9073438	SL3S	*Neophocaena phocaenoides*	3	3	0	Sub-surface	0.086
31	2022-03-17 15:56:17	Line Transect (Aerial)	22.14381275	113.9073442	SL3S	*Neophocaena phocaenoides*	1	1	0	Surface	0.022
32	2022-03-17 15:58:19	Line Transect (Aerial)	22.15297086	113.9062444	SL3S	*Neophocaena phocaenoides*	3	3	0	Sub-surface	0.006
33	2022-03-17 16:02:09	Line Transect (Aerial)	22.14968247	113.9040461	SL3S	*Neophocaena phocaenoides*	3	3	0	Mixed	0.005
34	2022-03-17 16:03:40	Line Transect (Aerial)	22.15192047	113.9029467	SL3S	*Neophocaena phocaenoides*	1	1	0	Surface	0.007
35	2022-03-17 16:04:20	Line Transect (Aerial)	22.14657219	113.9029472	SL3S	*Neophocaena phocaenoides*	2	2	0	Mixed	0.004
36	2022-03-17 16:04:25	Line Transect (Aerial)	22.14583163	113.9029472	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.003
37	2022-03-17 16:06:06	Line Transect (Aerial)	22.15014205	113.9018474	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.001
38	2022-03-17 16:07:40	Line Transect (Aerial)	22.1532335	113.900748	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.000
39	2022-03-17 16:11:41	Line Transect (Aerial)	22.15608216	113.8985492	SL3S	*Neophocaena phocaenoides*	4	4	0	Mixed	0.002
40	2022-03-17 16:14:54	Line Transect (Aerial)	22.15419161	113.8974486	SL3S	*Neophocaena phocaenoides*	2	3	0	Sub-surface	0.019
41	2022-03-17 16:15:22	Line Transect (Aerial)	22.15648258	113.8974489	SL3S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.006
42	2022-04-13 13:14:16	Line Transect (Aerial)	22.17734516	113.8767652	SL2S	*Neophocaena phocaenoides*	3	3	0	Mixed	0.966
43	2022-04-13 13:16:04	Line Transect (Aerial)	22.17126808	113.875666	SL2S	*Neophocaena phocaenoides*	2	2	0	Sub-surface	0.110
44	2022-04-13 13:21:27	Line Transect (Aerial)	22.17812302	113.8734672	SL2S	*Neophocaena phocaenoides*	4	3	1	Sub-surface	3.890
45	2022-04-13 13:26:03	Line Transect (Aerial)	22.15648258	113.8974489	SL2S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	0.108
46	2022-04-13 14:27:50	Line Transect (Aerial)	22.15648258	113.8974489	SL2S	*Neophocaena phocaenoides*	1	1	0	Sub-surface	4.682
47	2022-04-13 15:23:25	Line Transect (Aerial)	22.19745341	113.8874788	SL2N	*Sousa chinensis*	1	1	0	Sub-surface	0.301
48	2022-04-22 12:41:02	Line Transect (Aerial)	22.21021372	113.8268738	WL	*Sousa chinensis*	4	4	0	Sub-surface	0.252
49	2022-04-22 14:44:23	Line Transect (Aerial)	22.23396363	113.8388278	WL	*Sousa chinensis*	1	1	0	Surface	0.391
50	2022-04-22 14:44:44	Line Transect (Aerial)	22.2347413	113.8400441	WL	*Sousa chinensis*	1	1	0	Sub-surface	1.321

Table 9. Comparison of on-effort vessel and UAV sightings from concurrent line transect surveys.

Date	Vessel					UAV				
	Number of Sightings	Adult	Sub-Adult	Juvenile	Calf	Number of Sightings	Adult	Sub-Adult	Juvenile	Calf
2021-11-25	0	0	0	0	0	1	1	0	0	0
2021-12-06	2	2	0	0	0	0	0	0	0	0
2021-12-10	4	3	0	1	0	0	0	0	0	0
2021-12-15	2	2	0	0	0	5	5	0	0	0
2022-01-13	1	1	0	0	0	0	0	0	0	0
Total	**9**	**8**	**0**	**1**	**0**	**6**	**6**	**0**	**0**	**0**

Figures

Figure 1. Landing the DJI Matrice RTK 300 on a vessel platform at sea.

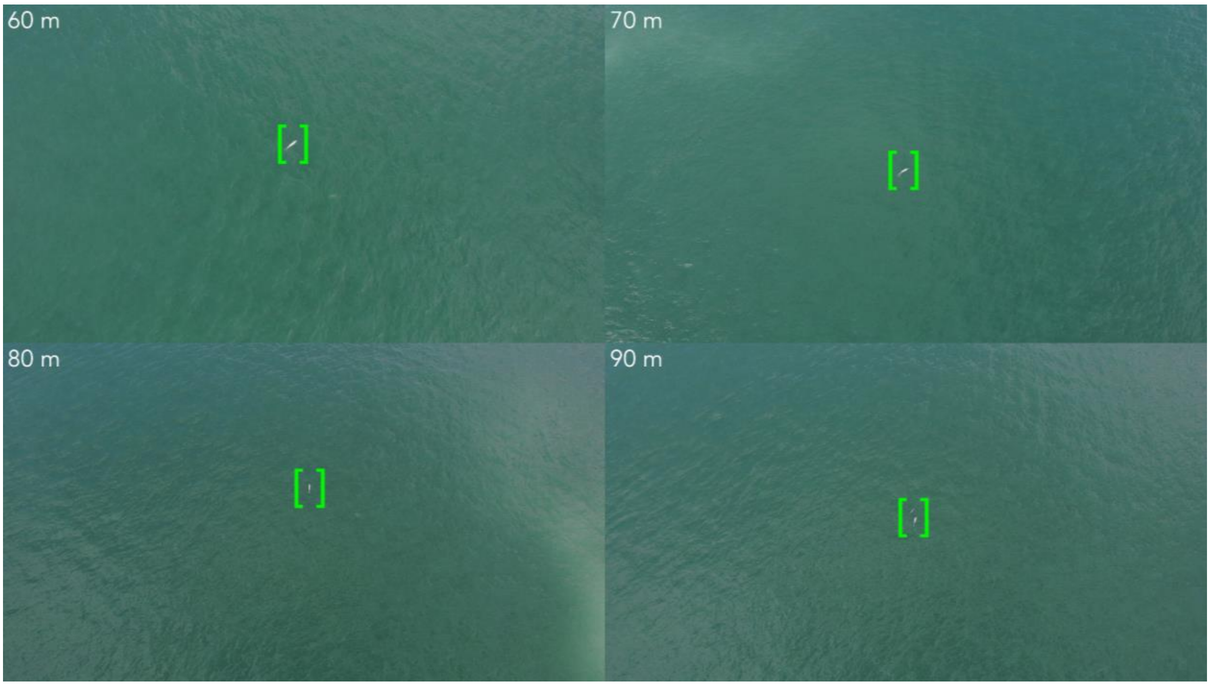


Figure 2. Aerial imagery of Indo-Pacific humpback dolphins (*Sousa chinensis*) taken from the DJI Matrice RTK 300 at 60, 70, 80 and 90 m altitudes.

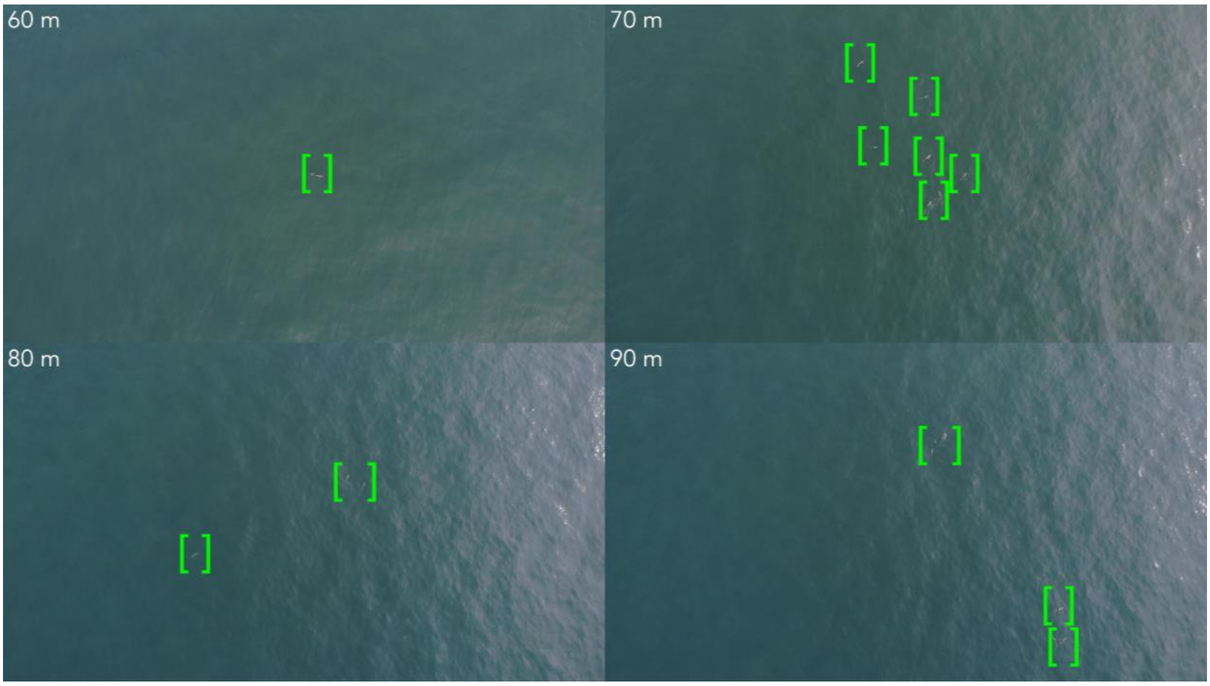


Figure 3. Aerial imagery of Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) taken from the DJI Matrice RTK 300 at 60, 70, 80 and 90 m altitudes.

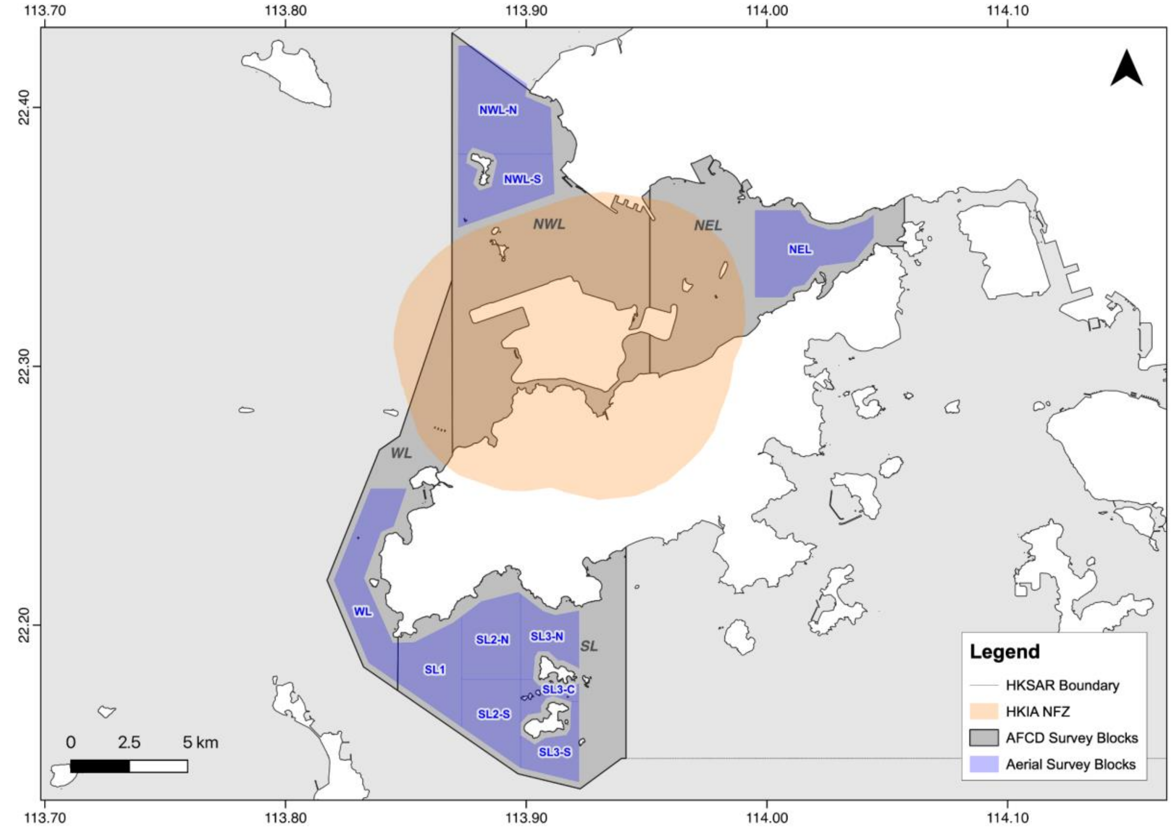


Figure 4. Study area for the systematic vessel and aerial line transect surveys.

Figure 5. The Unmanned Aerial Vehicles (UAV) used during systematic surveys: DJI Matrice RTK 300 (top), DJI Mavic 2 Pro (left) and an Autel Evo II (right). Not pictured: DJI Mavic 2 Enterprise.

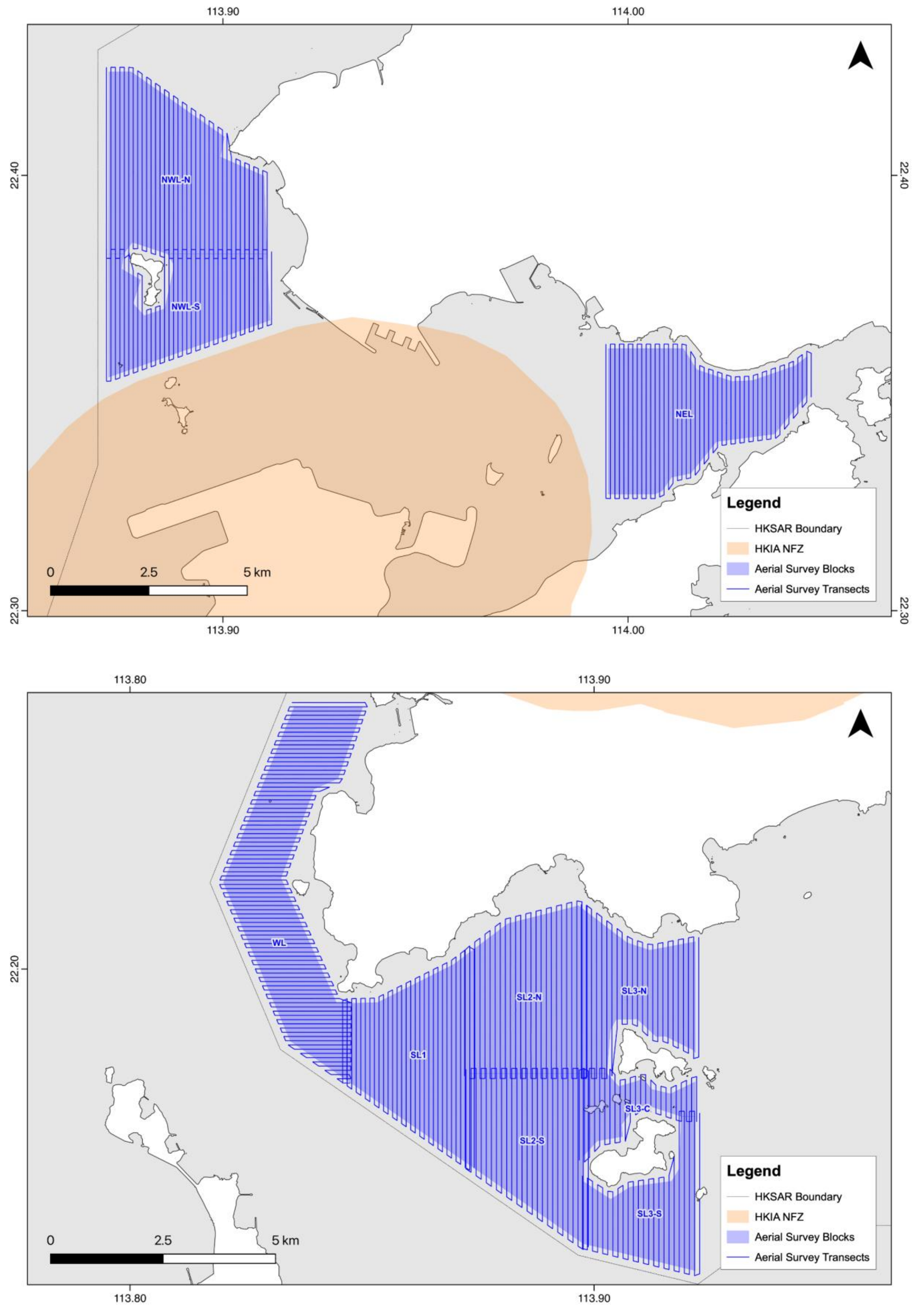


Figure 6. Aerial line transects in northern (top) and southern (bottom) Lantau.

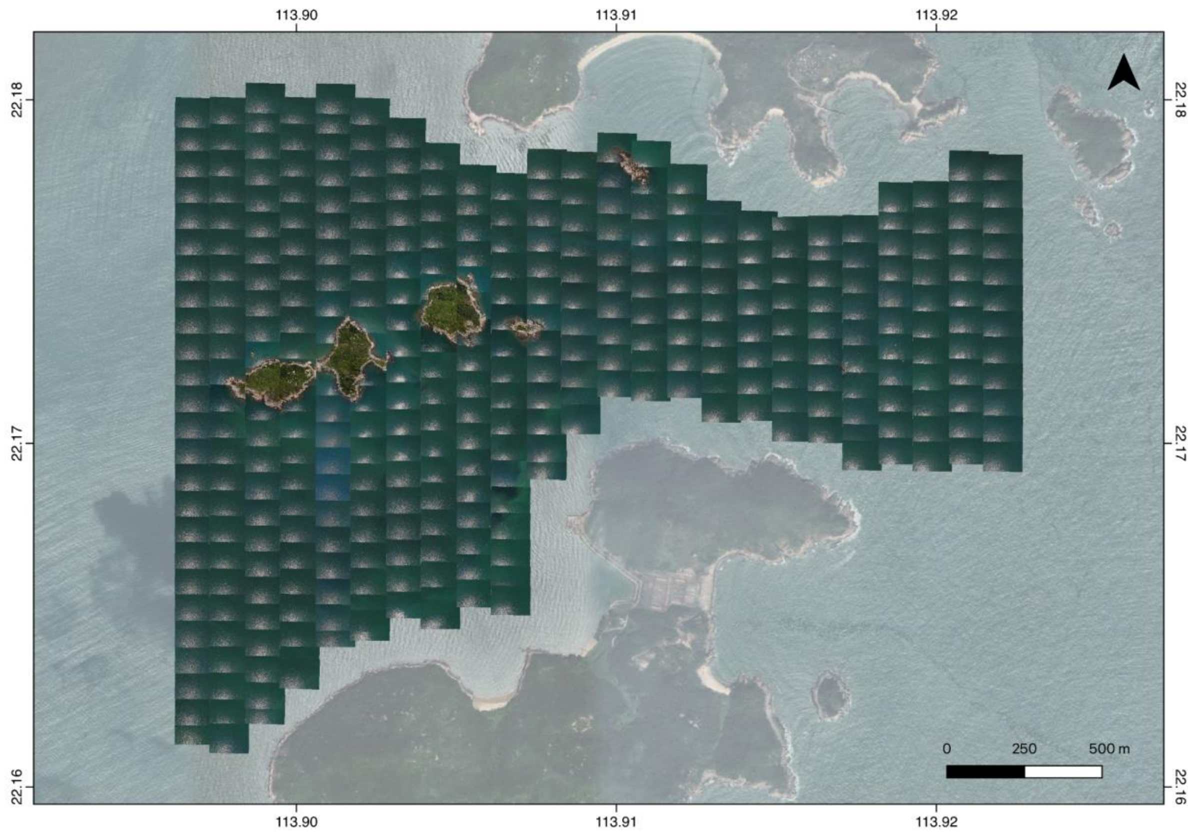


Figure 7. Example of timed-interval images taken from the Soko Islands using the Zenmuse H20 camera payload mounted on the Matrice RTK 300 during aerial line transect surveys. Altitude above ground = 90 m. Image side overlap = 10%. Image frontal overlap = 10%.

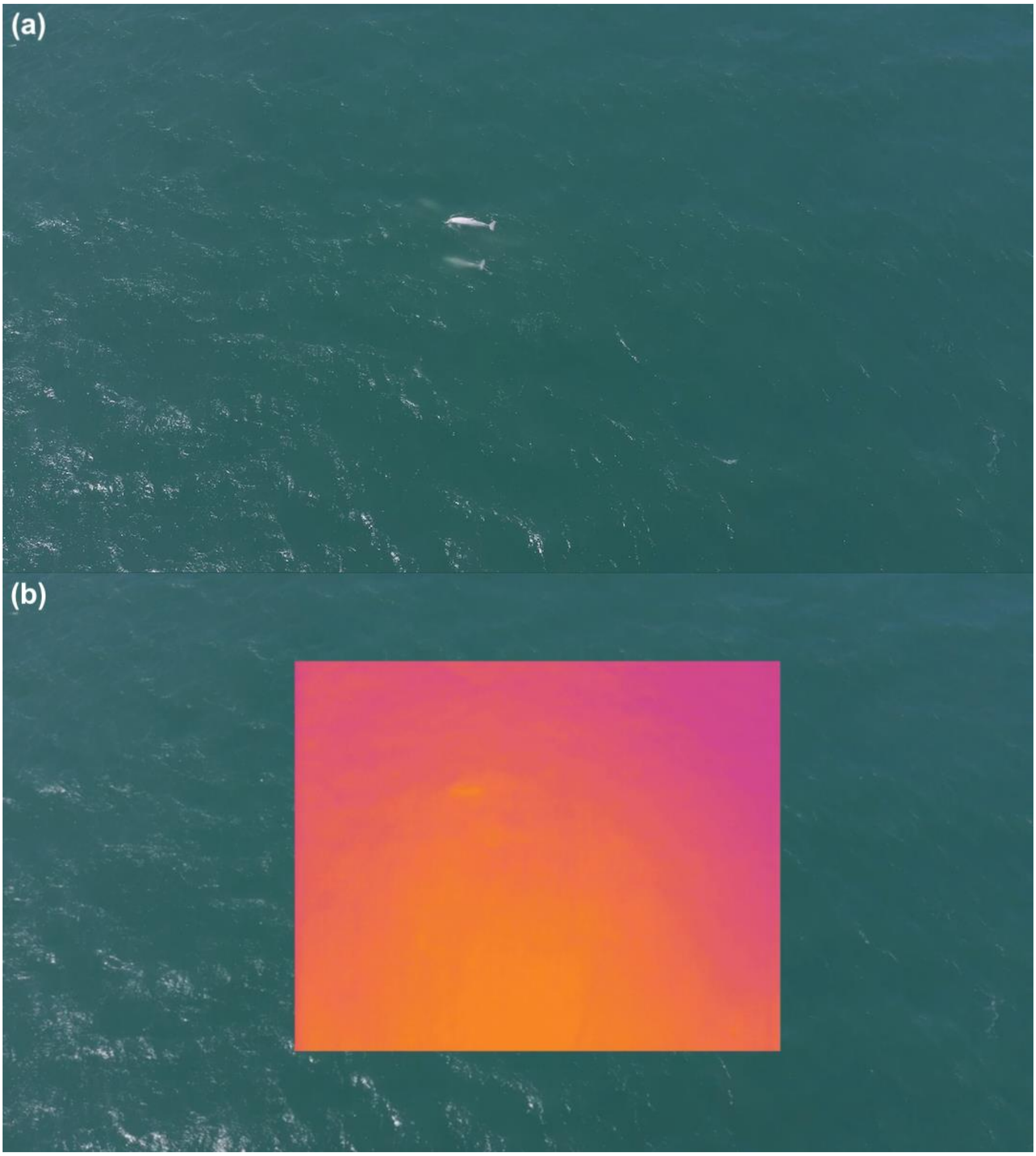


Figure 8. Comparison of **(a)** visible light (VL) imagery (top) and **(b)** composite infra-red (IR) imagery (bottom) taken from an Autel Evo II of Indo-Pacific humpback dolphins (*Sousa chinensis*).

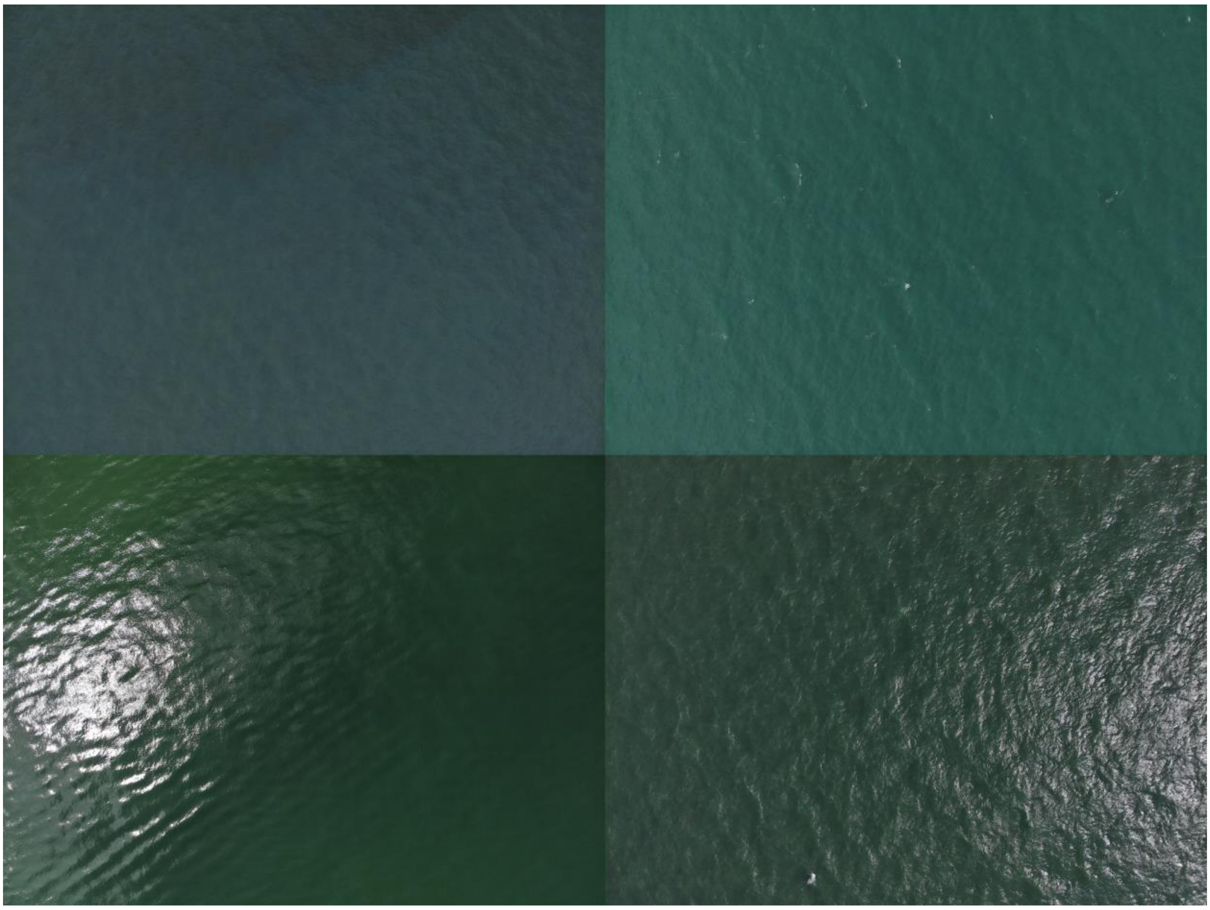


Figure 9. Varying glare and sea state conditions present in UAV images.

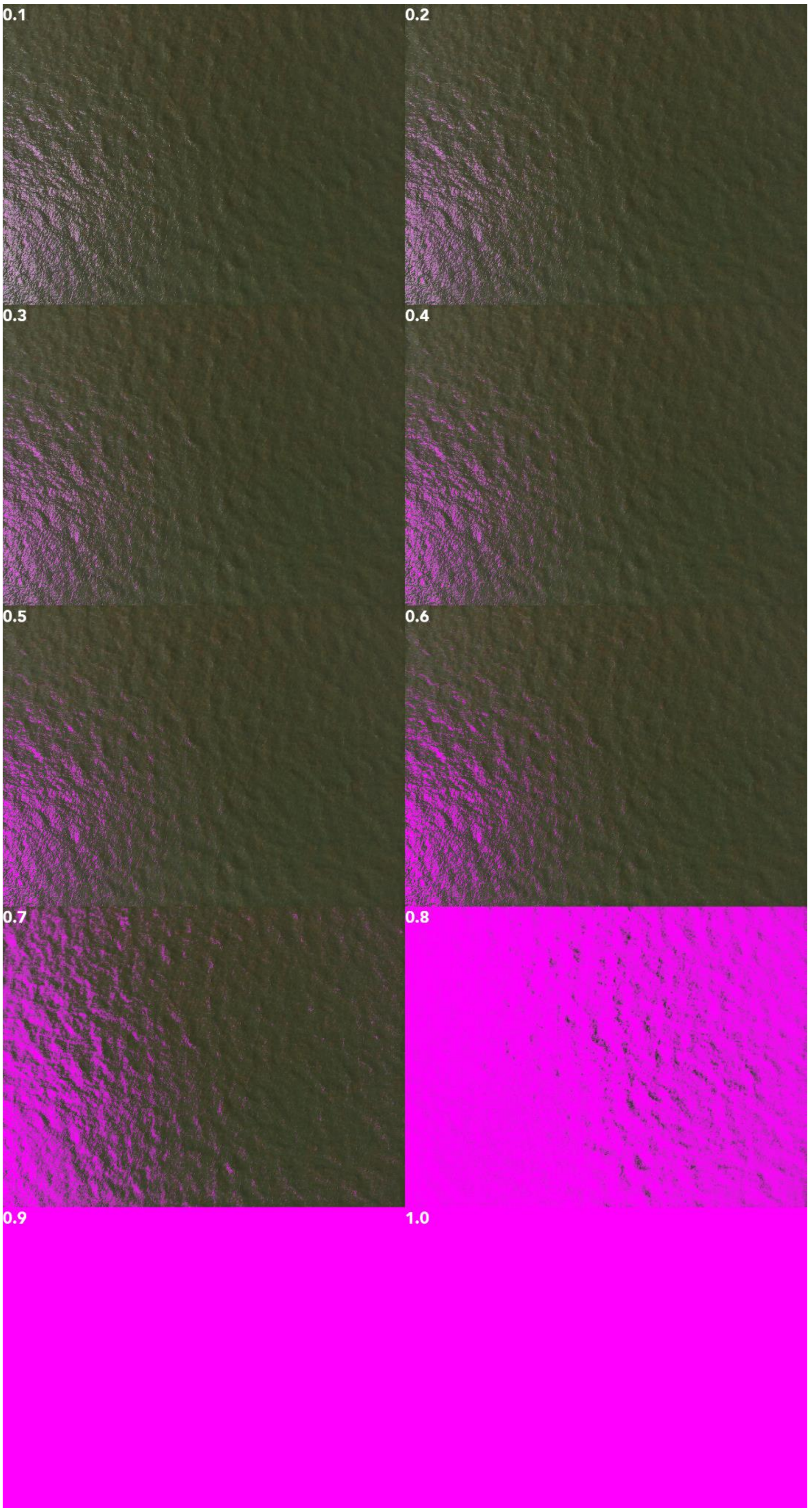


Figure 10. countcolor trials in R using varying spherical search radii (with a reference RGB triplet of 1,1,1) ranging from 0.1 to 1.0.

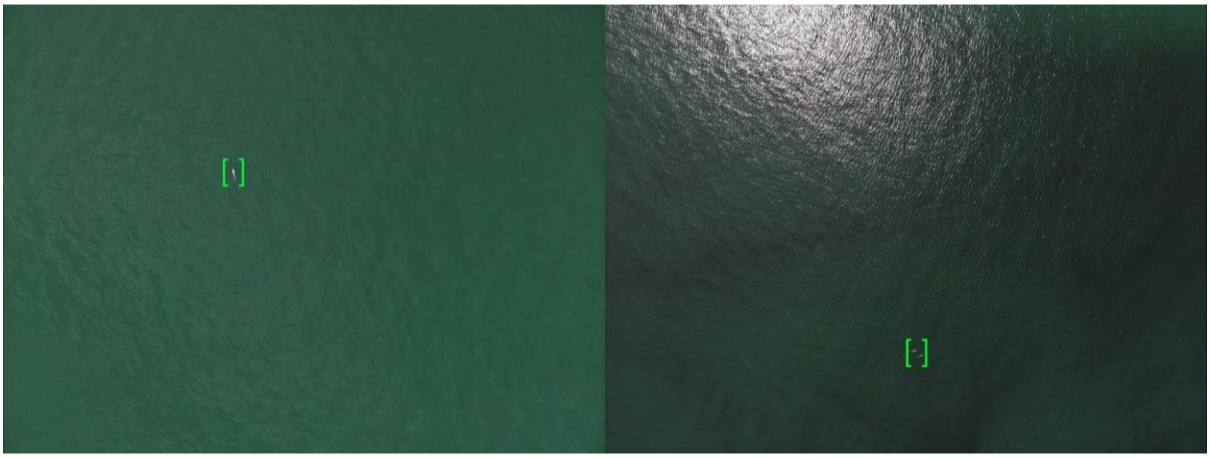


Figure 11. Aerial line transect imagery with Indo-Pacific humpback dolphins (*Sousa chinensis*) (left) and Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) (right).

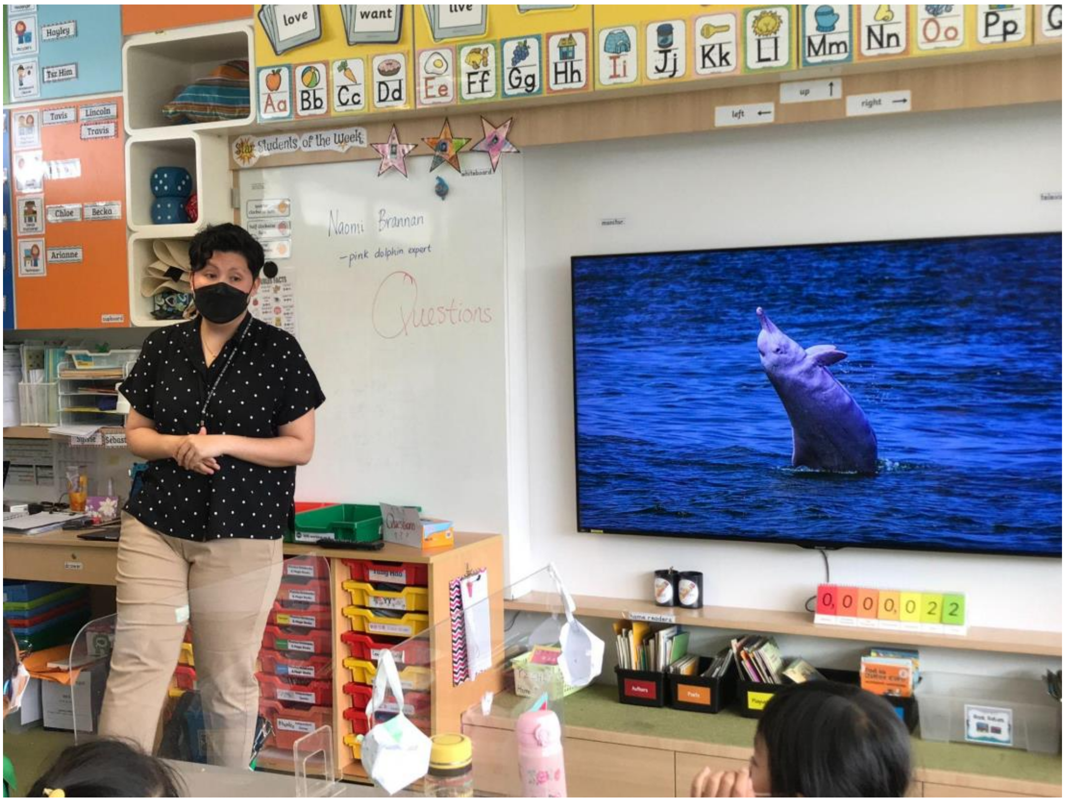


Figure 12. Presentation given to Year 2 ICHK students on the anthropological images on humpback dolphins and their habitat in Hong Kong waters in May 2022.

Figure 13. Presentation on the application of UAVs in marine mammal science during a workshop given to Year 12 ICHK students as part of their IB Group 4 Project syllabus.

Figure 14. Presentation on the operation of UAVs during a workshop given to Year 12 ICHK students as part of their IB Group 4 Project syllabus.

Figure 15. Practical experience using a UAV simulator during a workshop given to Year 12 ICHK students as part of their IB Group 4 Project syllabus.

Figure 16. Practical experience in the field during a workshop given to Year 12 ICHK students as part of their IB Group 4 Project syllabus.

Figure 17. Interactive Q&A session during a workshop given to Year 12 ICHK students as part of their IB Group 4 Project syllabus.

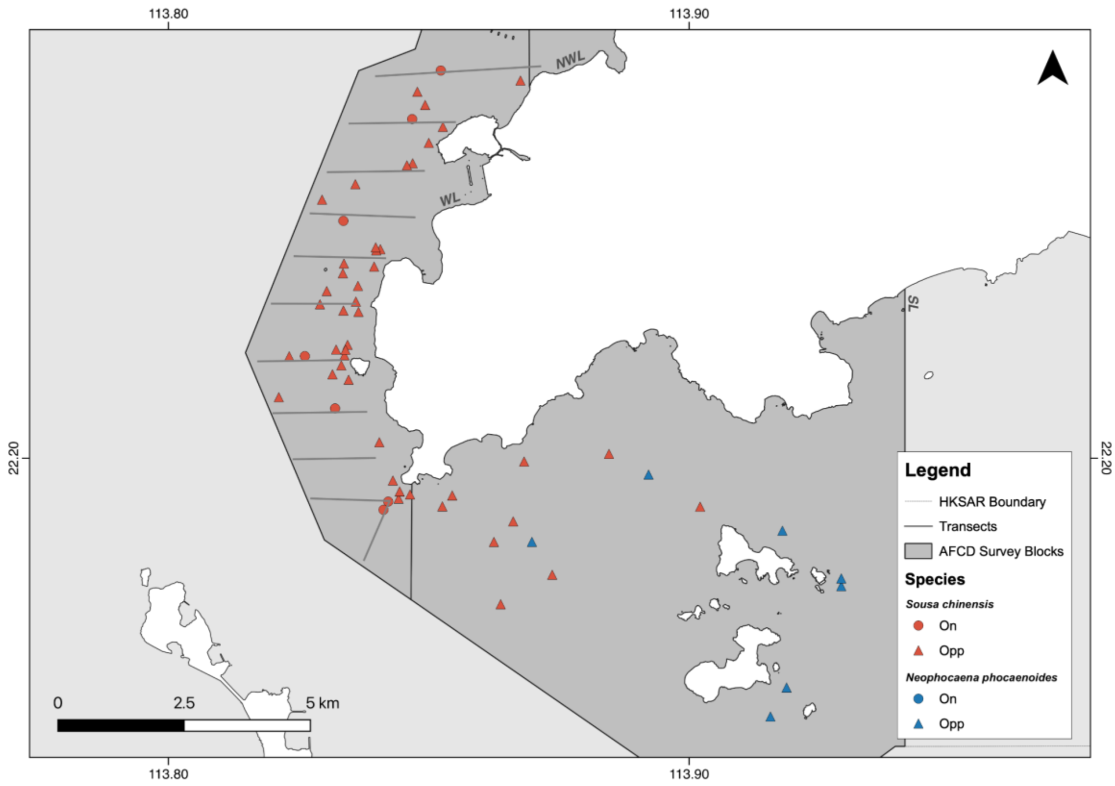


Figure 18. Vessel-based observer sightings of Indo-Pacific humpback dolphins (*Sousa chinensis*) and Indo-Pacific finless porpoises (*Neophocaena phocaenoides*).

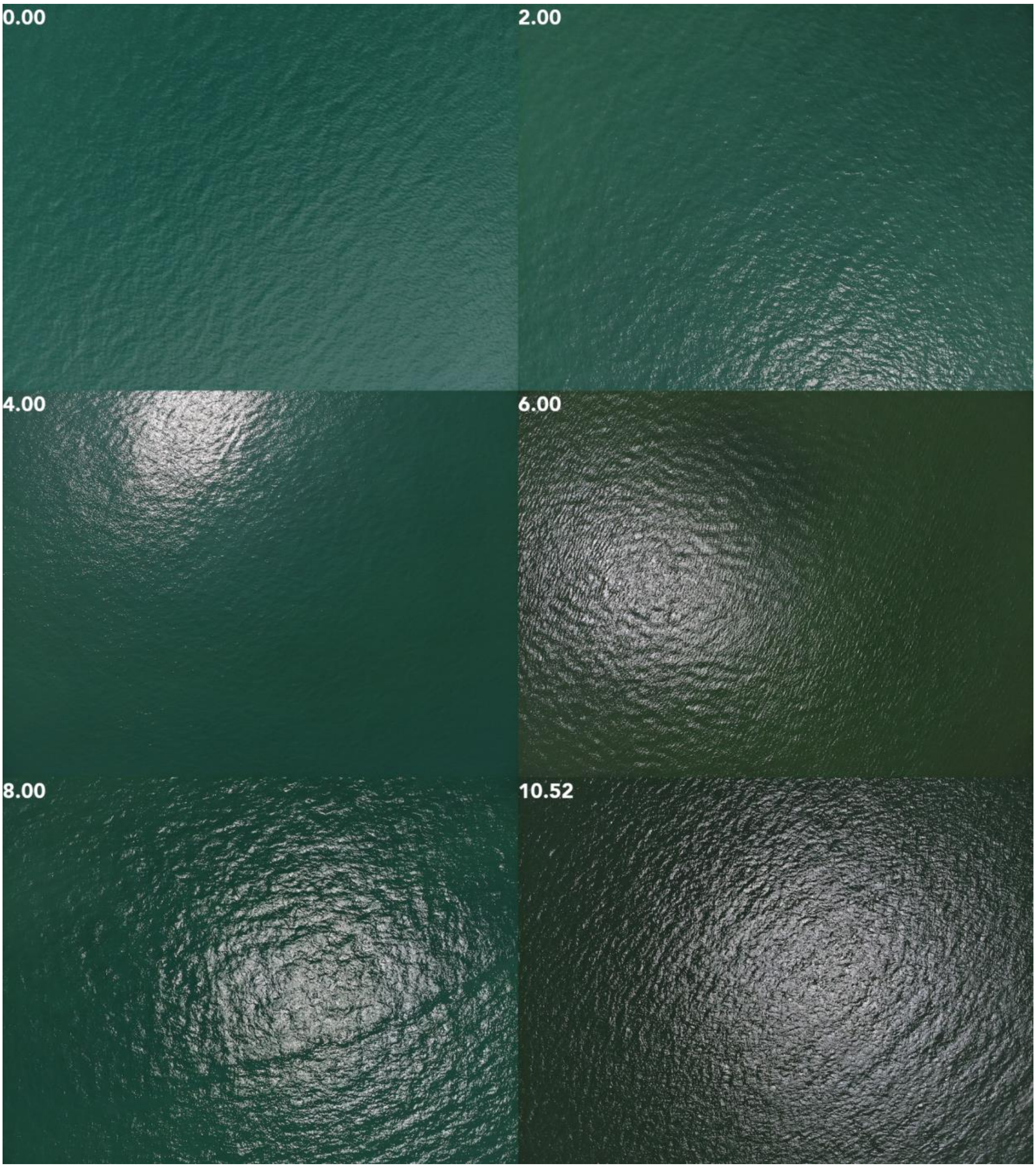


Figure 19. UAV images obtained from aerial line transect surveys with varying image fractions (%).

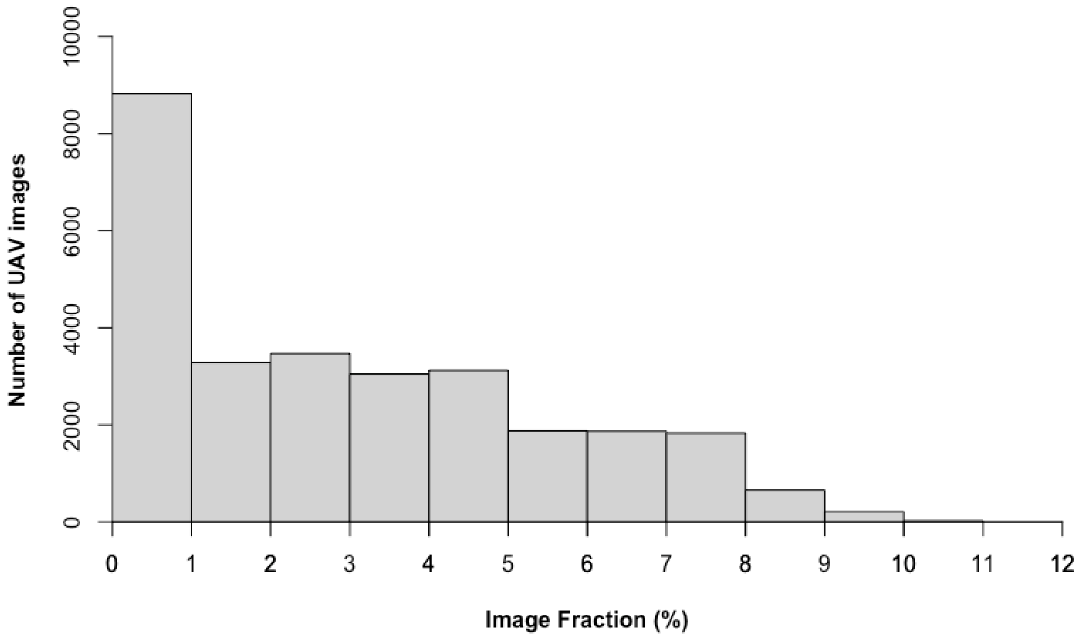


Figure 20. Distribution of image fraction (%) for UAV images obtained from aerial line transect surveys (*N* = 28,235).

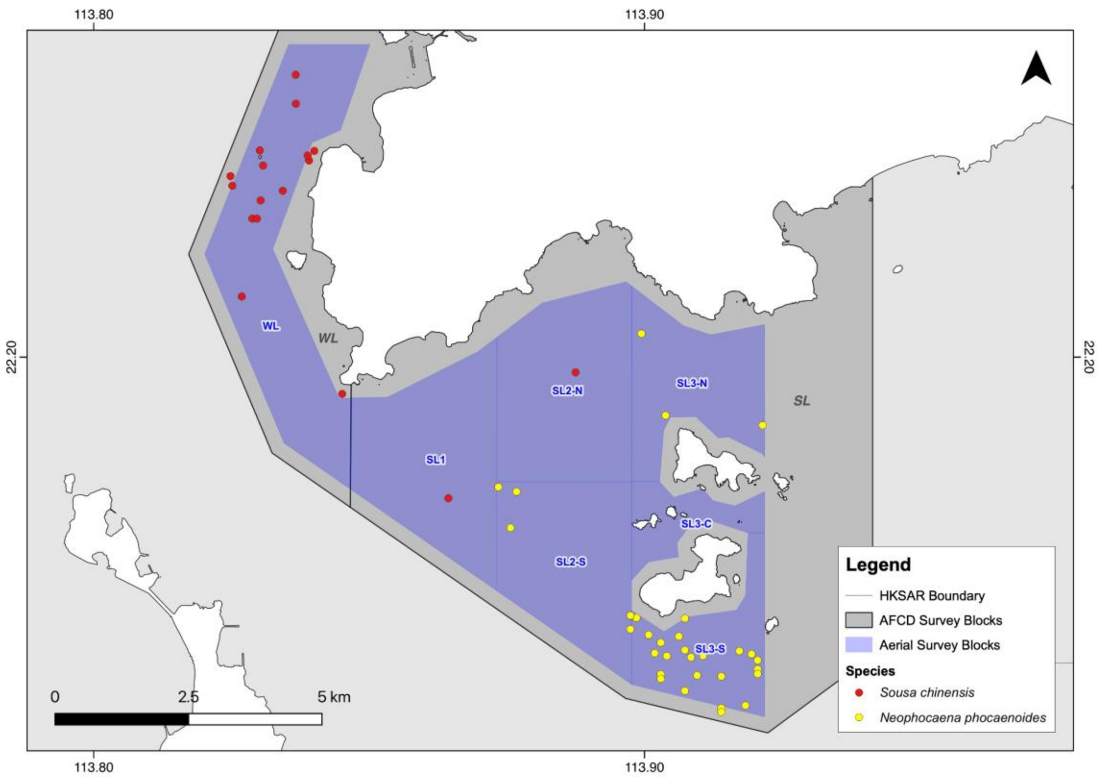
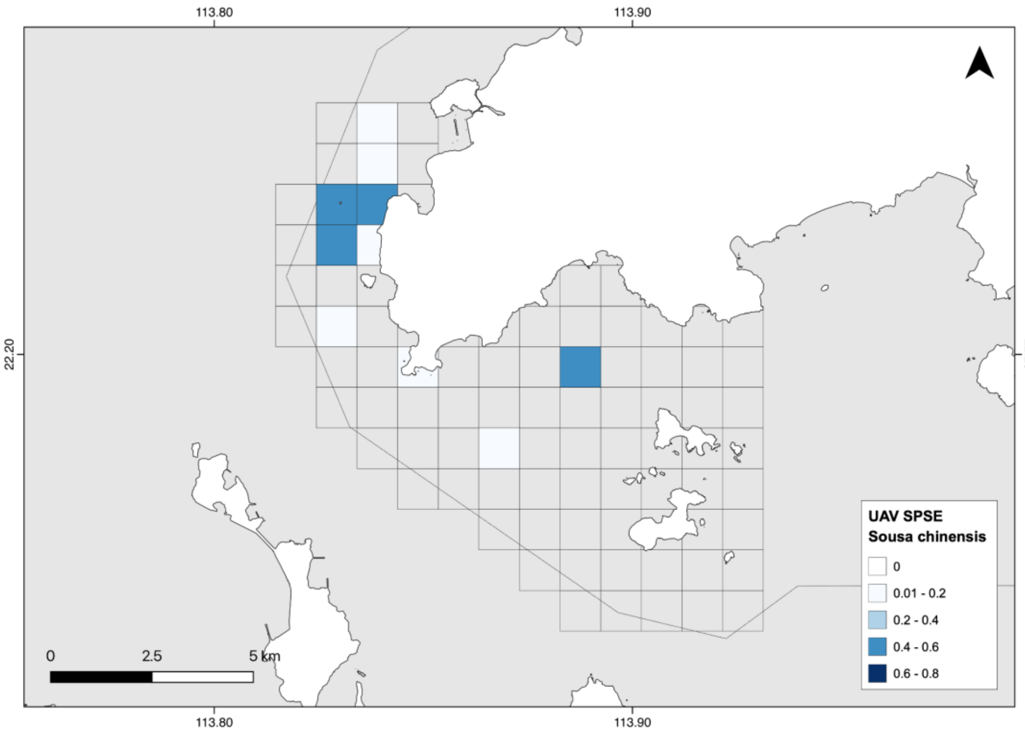


Figure 21. UAV sightings from aerial line transect surveys of Indo-Pacific humpback dolphins (*Sousa chinensis*) and Indo-Pacific finless porpoises (*Neophocaena phocaenoides*).



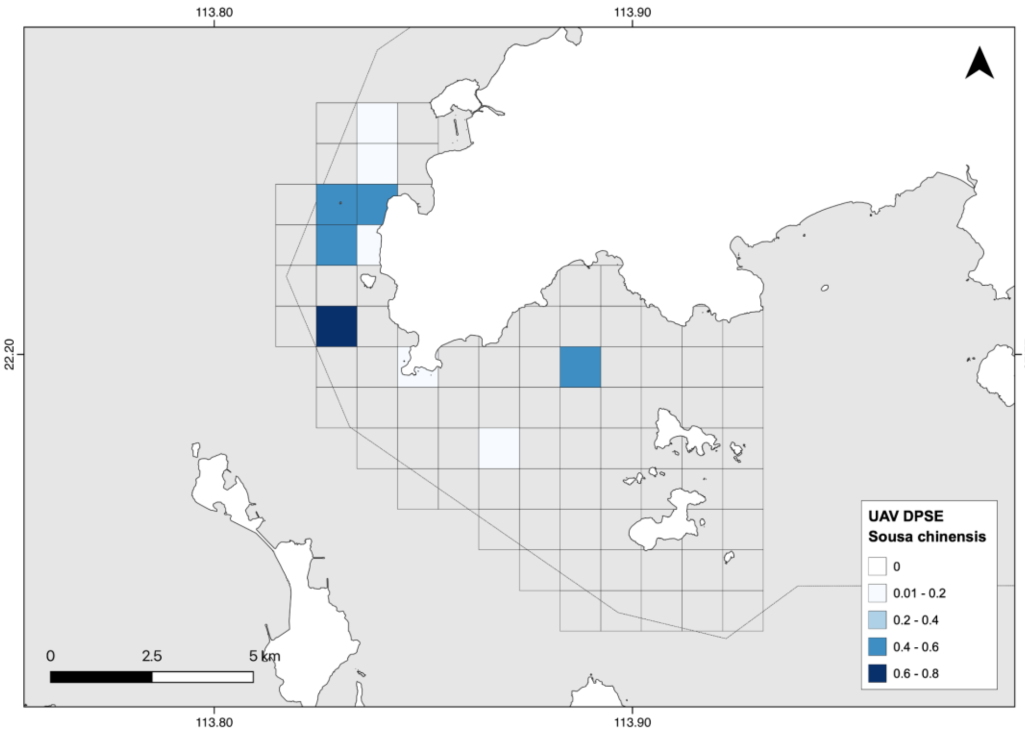


Figure 22. UAV sighting ($SPSE_U$) and animal ($DPSE_U$) from aerial line transect surveys of Indo-Pacific humpback dolphins (*Sousa chinensis*).

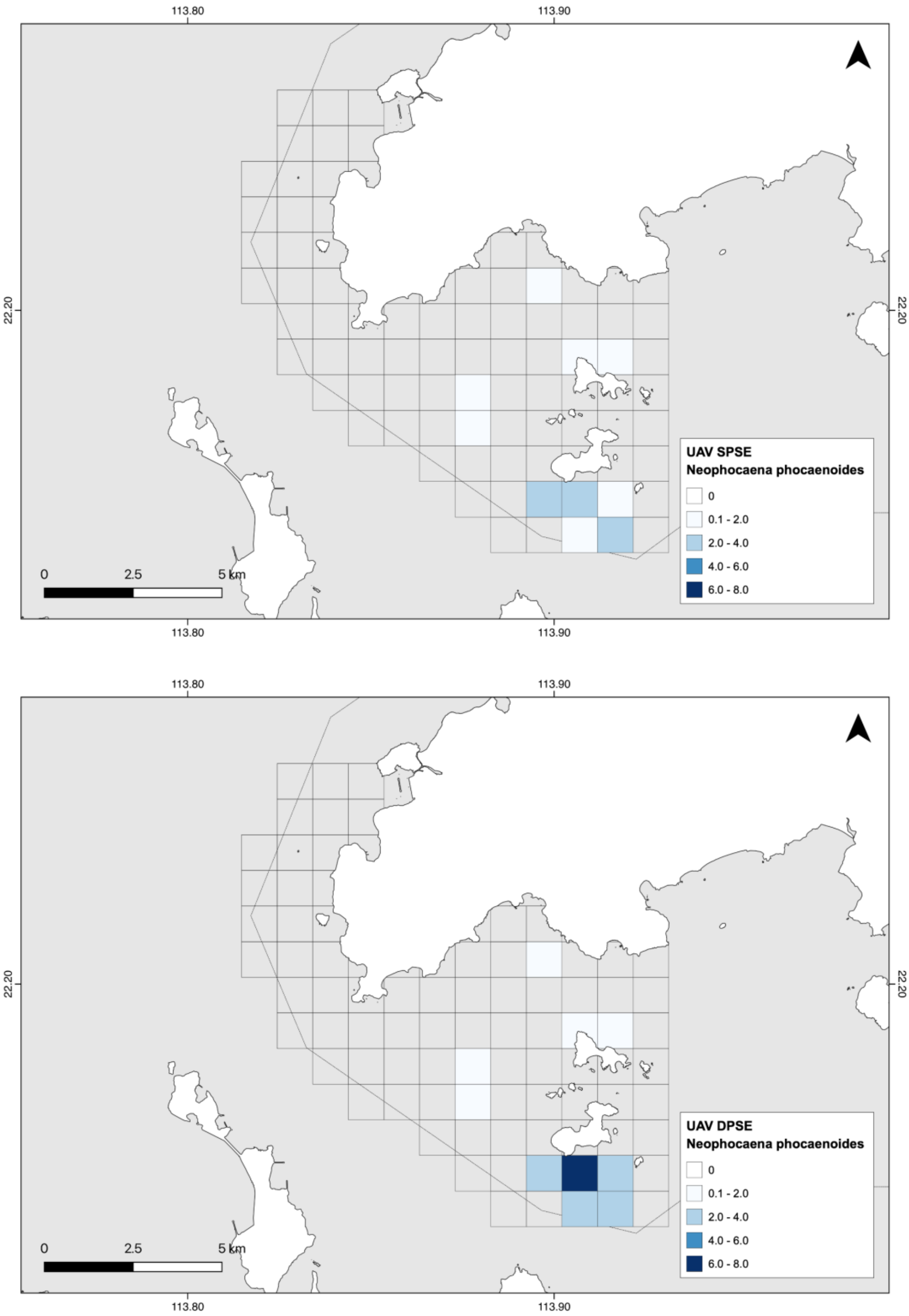


Figure 23. UAV sighting ($SPSE_U$) and animal ($DPSE_U$) from aerial line transect surveys of Indo-Pacific finless porpoises (*Neophocaena phocaenoides*).

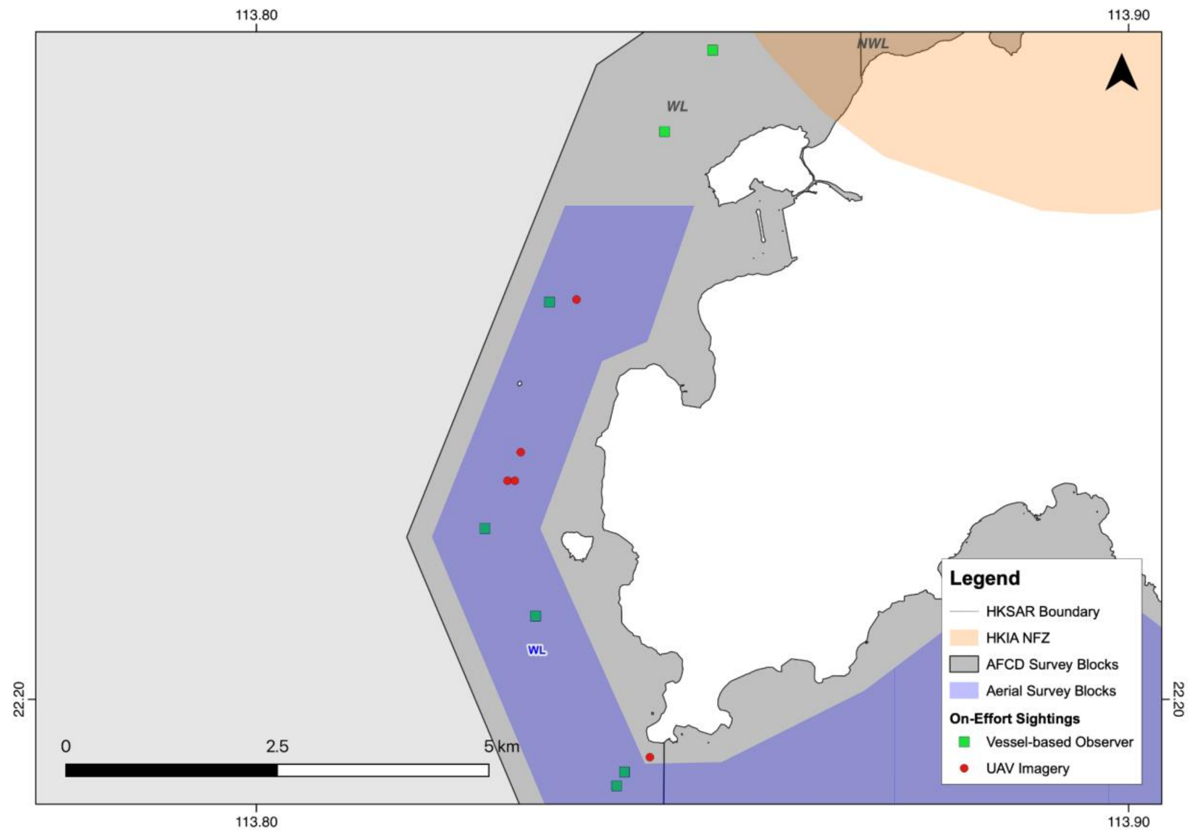


Figure 24. Comparison of on-effort sightings of Indo-Pacific humpback dolphin (*Sousa chinensis*) during concurrent vessel and aerial line transect surveys (*N* of survey days = 5).

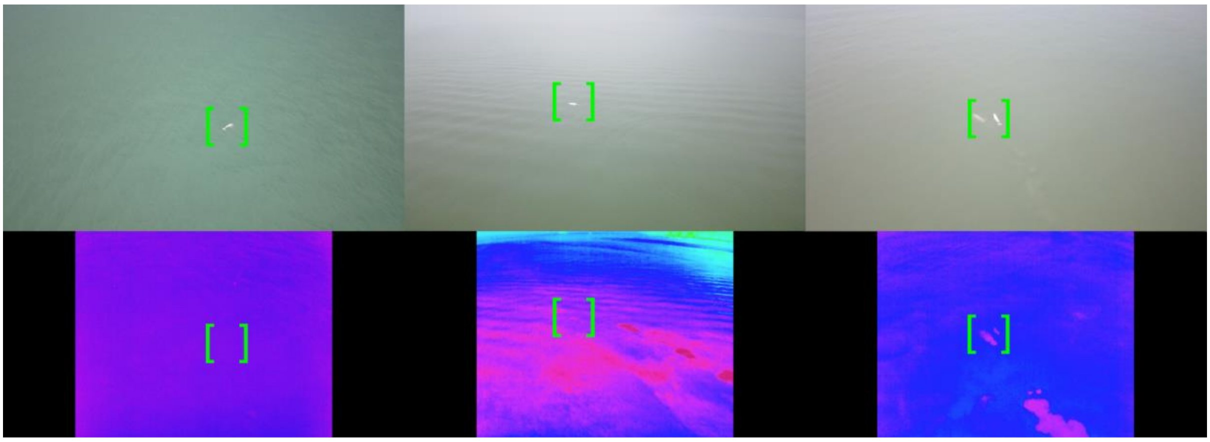


Figure 25. Comparison of visible light (VL) and infrared (IR) imagery for the detection of Indo-Pacific humpback dolphins (*Sousa chinensis*).

Appendices

Appendix 1. Statement of Accounts.

Statement of Accounts is not disclosed due to confidentiality reasons.

Appendix 2. Project assets (transferred to MEEF2022014)

Project assets are not disclosed due to confidentiality reasons.

Appendix 3. Staff Attendance Record
Staff Attendance Record is not disclosed due to confidentiality reasons.

Appendix 3. Staff Attendance Record (con'd)
Staff Attendance Record is not disclosed due to confidentiality reasons.

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

No new staff were recruited.

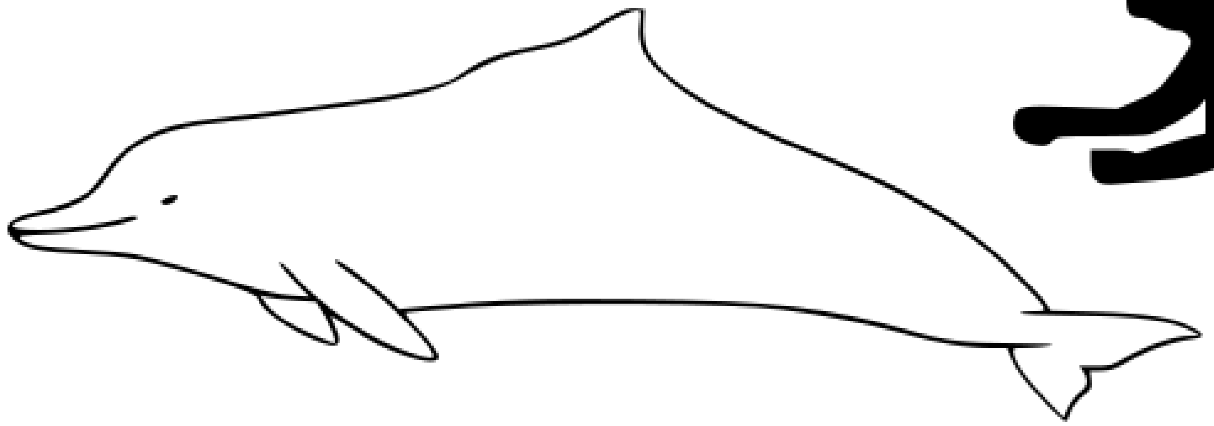
Appendix 5. Educational material used in presentations and workshops for Activity 8 and student projects.
Student projects are not disclosed.

Studying Hong Kong's Dolphins and Porpoise

SEAMAR

Project

Background



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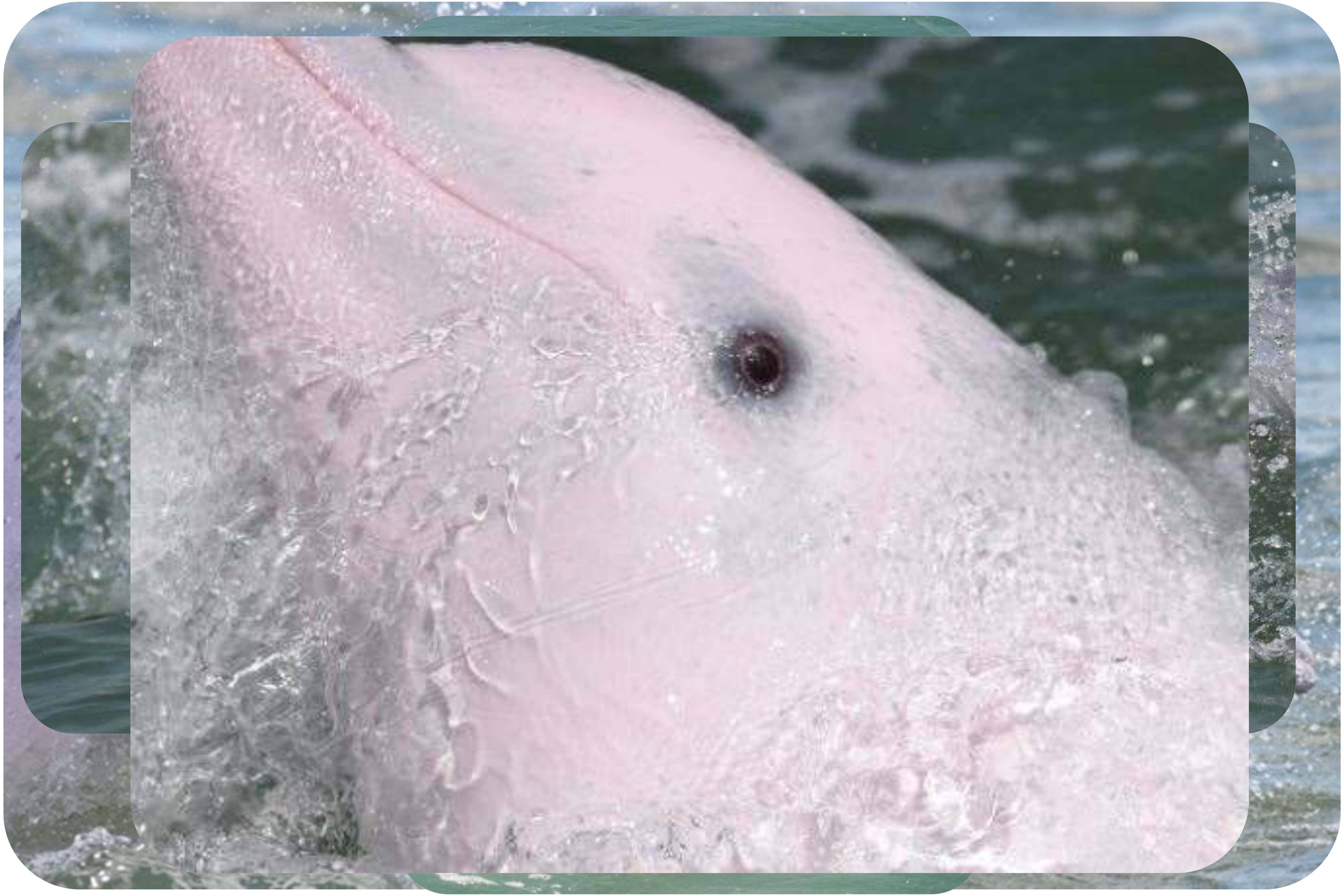
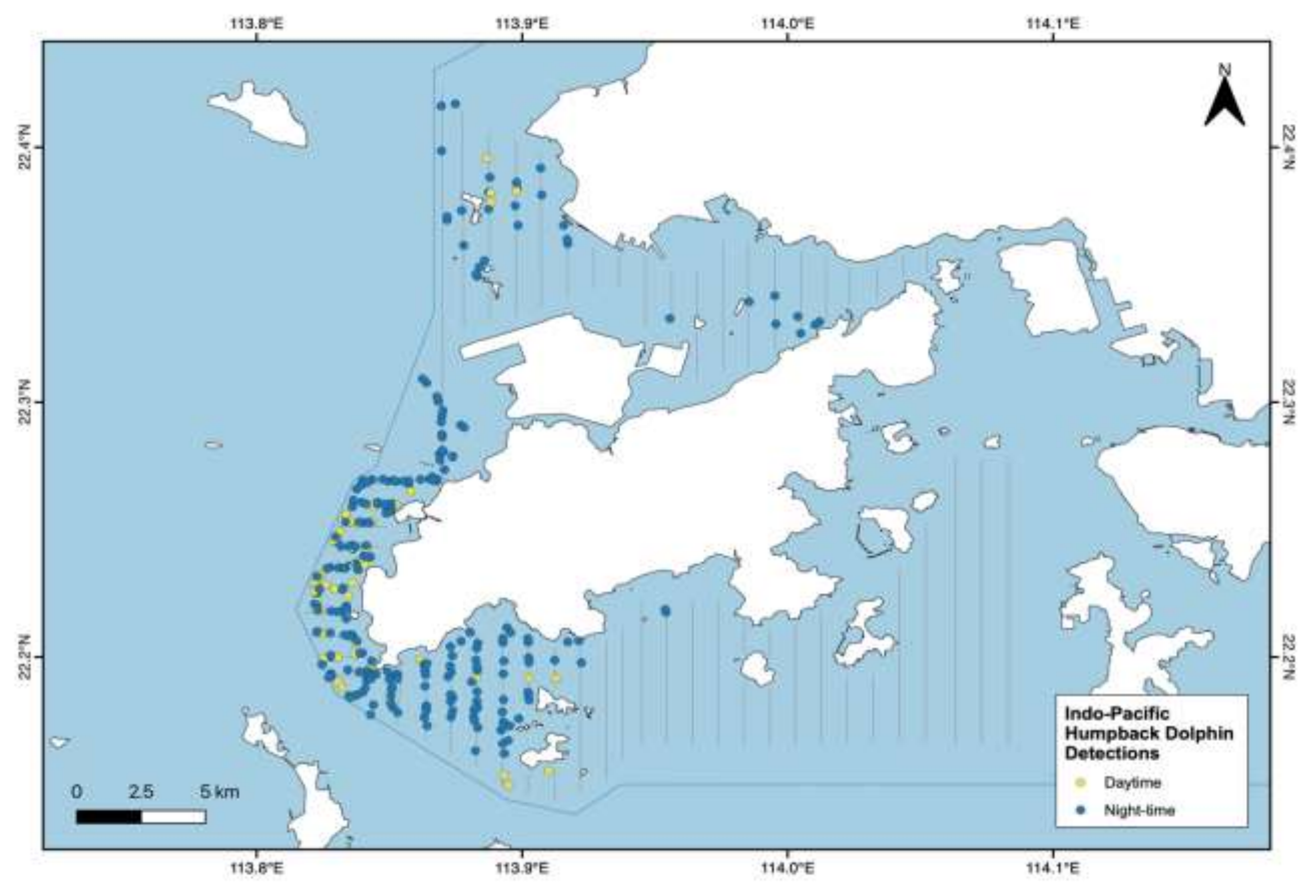


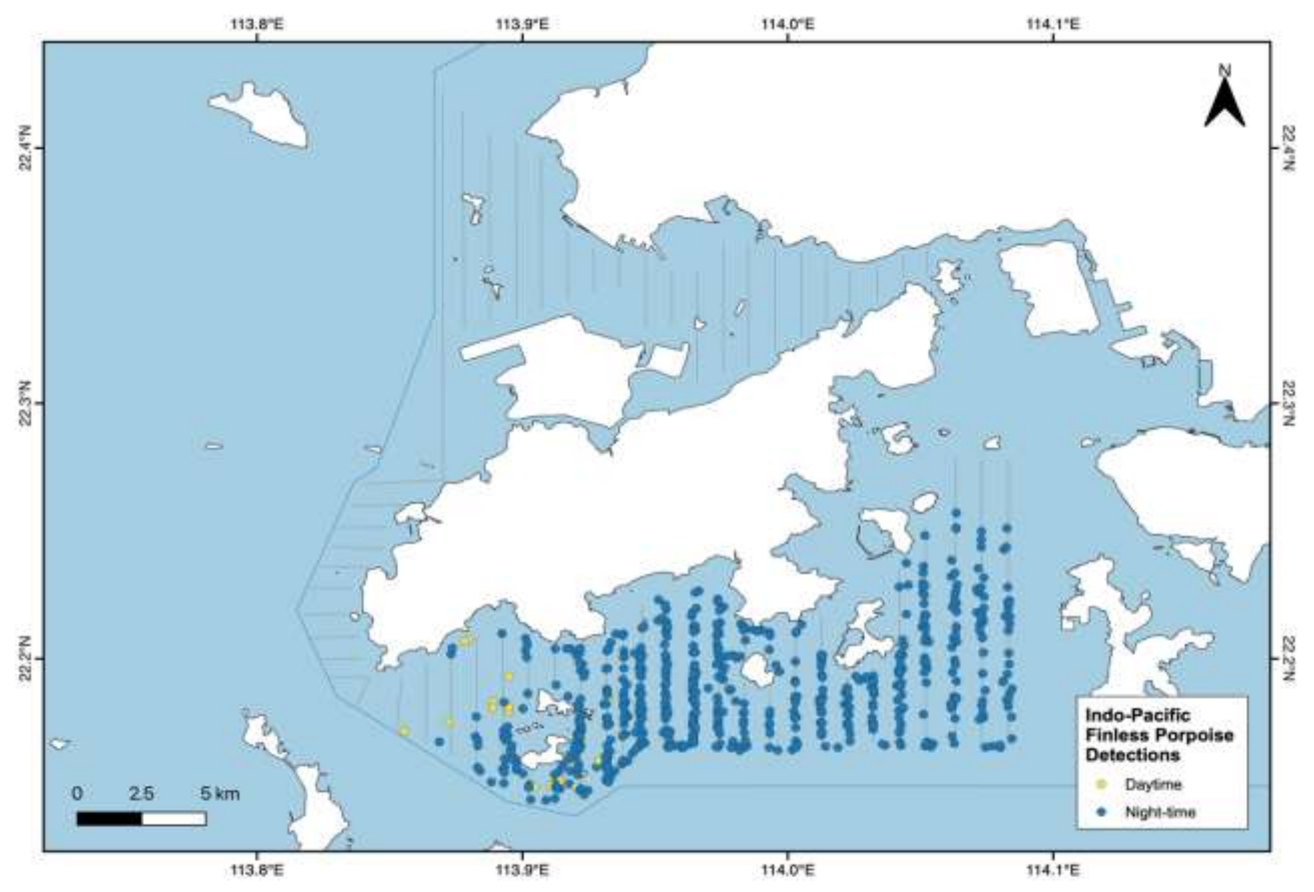
SEAMAR

SEAMAR

Project

Background





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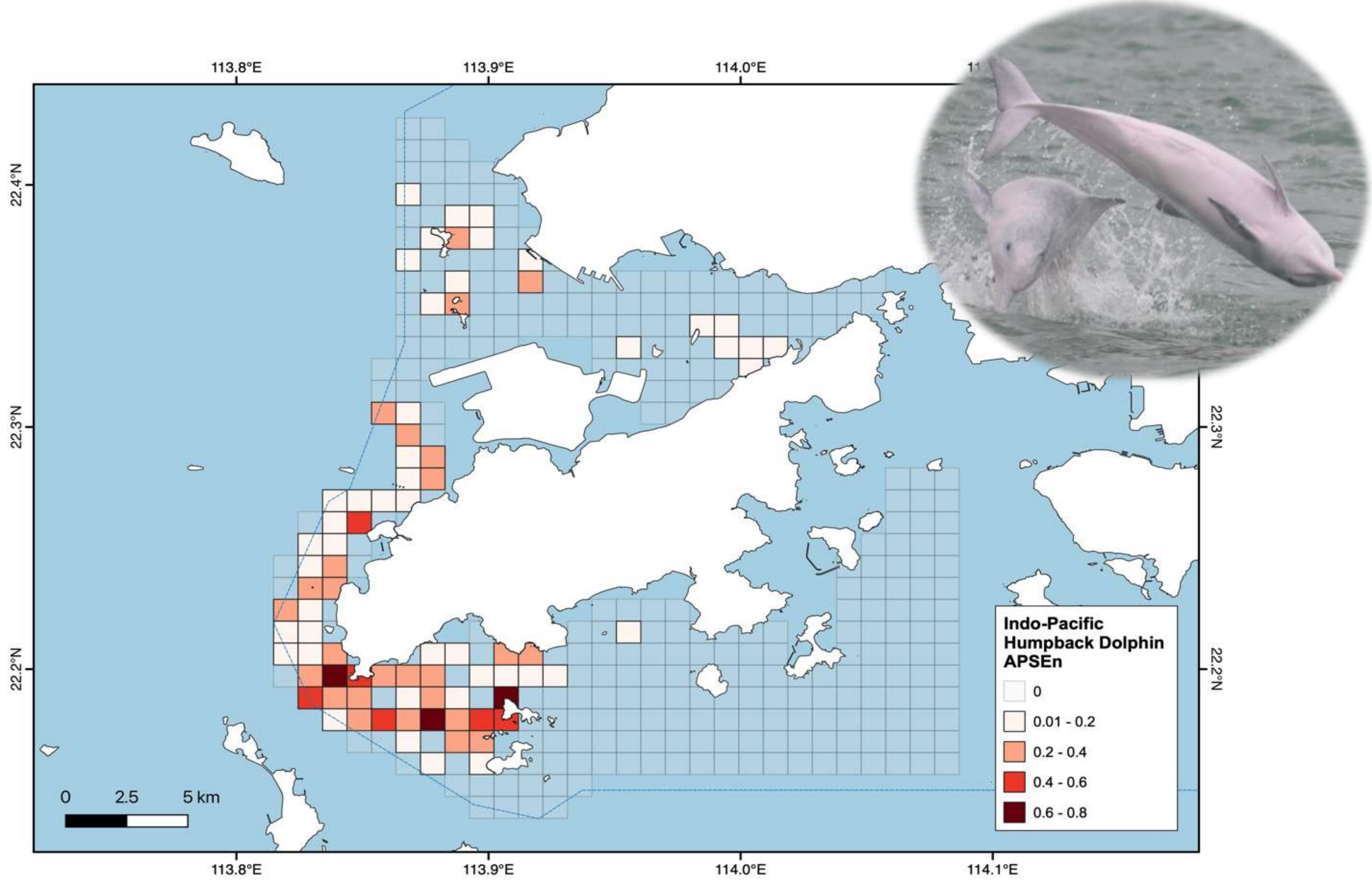
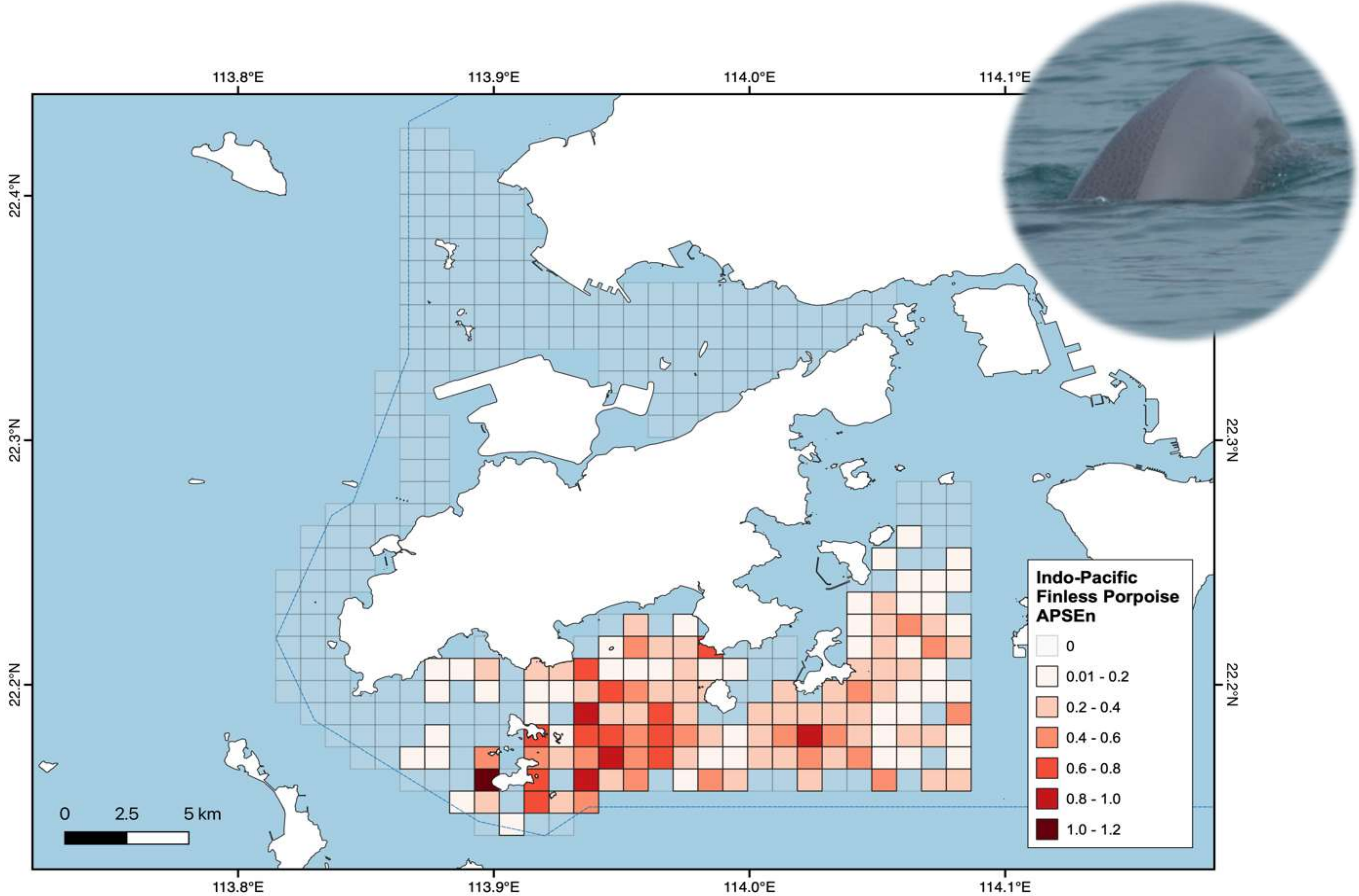


113.8°E
113.9°E
114.0°E
114.1°E
22.4°N
22.3°N
22.2°N
0
2.5
5 km
Indo-Pacific Humpback Dolphin APSEn
0
0.01 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8

SEAMAR


113.8°E
113.9°E
114.0°E
114.1°E
22.4°N
22.3°N
22.2°N
0
2.5
5 km
Indo-Pacific
Finless Porpoise
APSEn
0
0.01 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1.0
1.0 - 1.2

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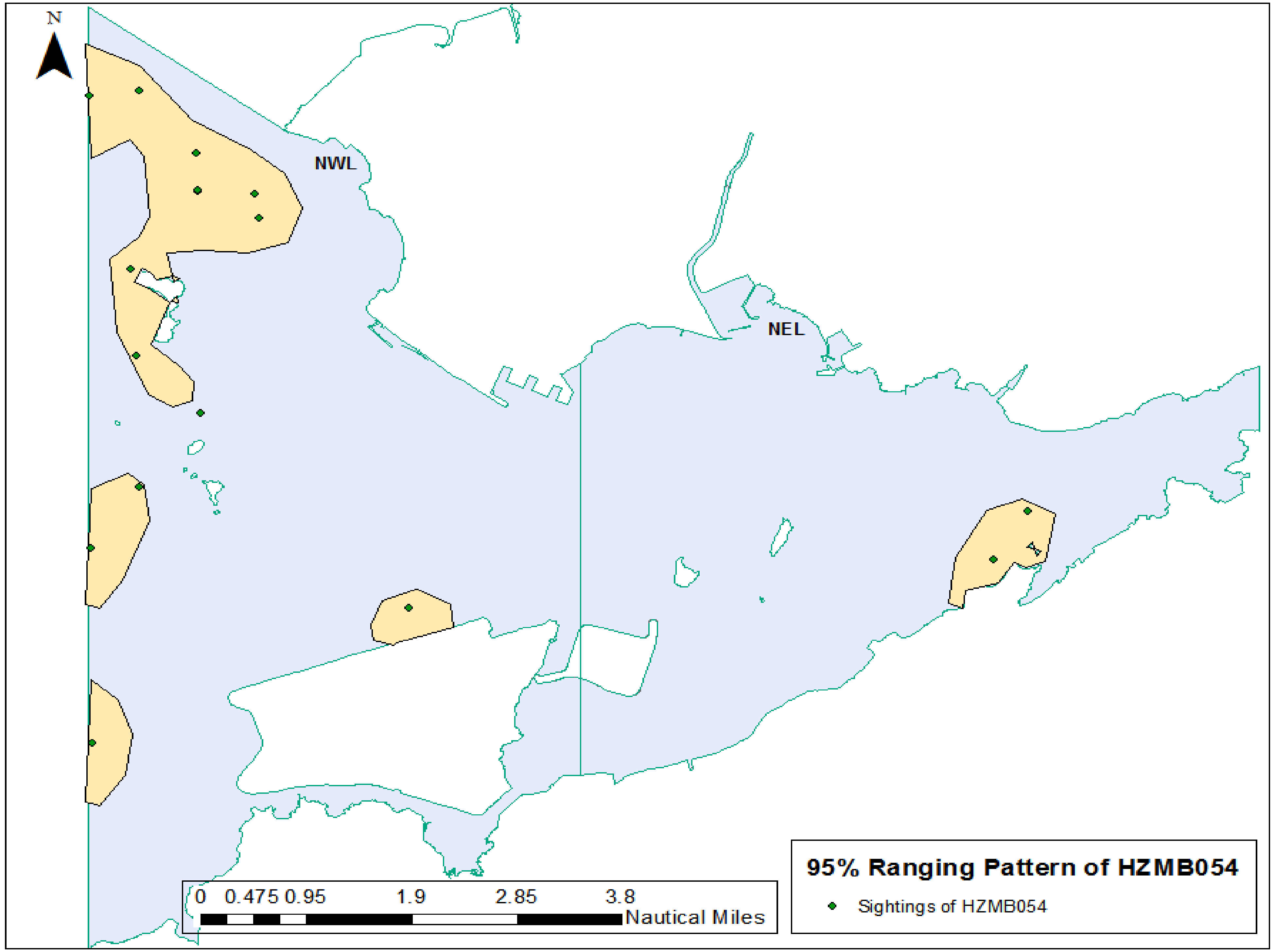
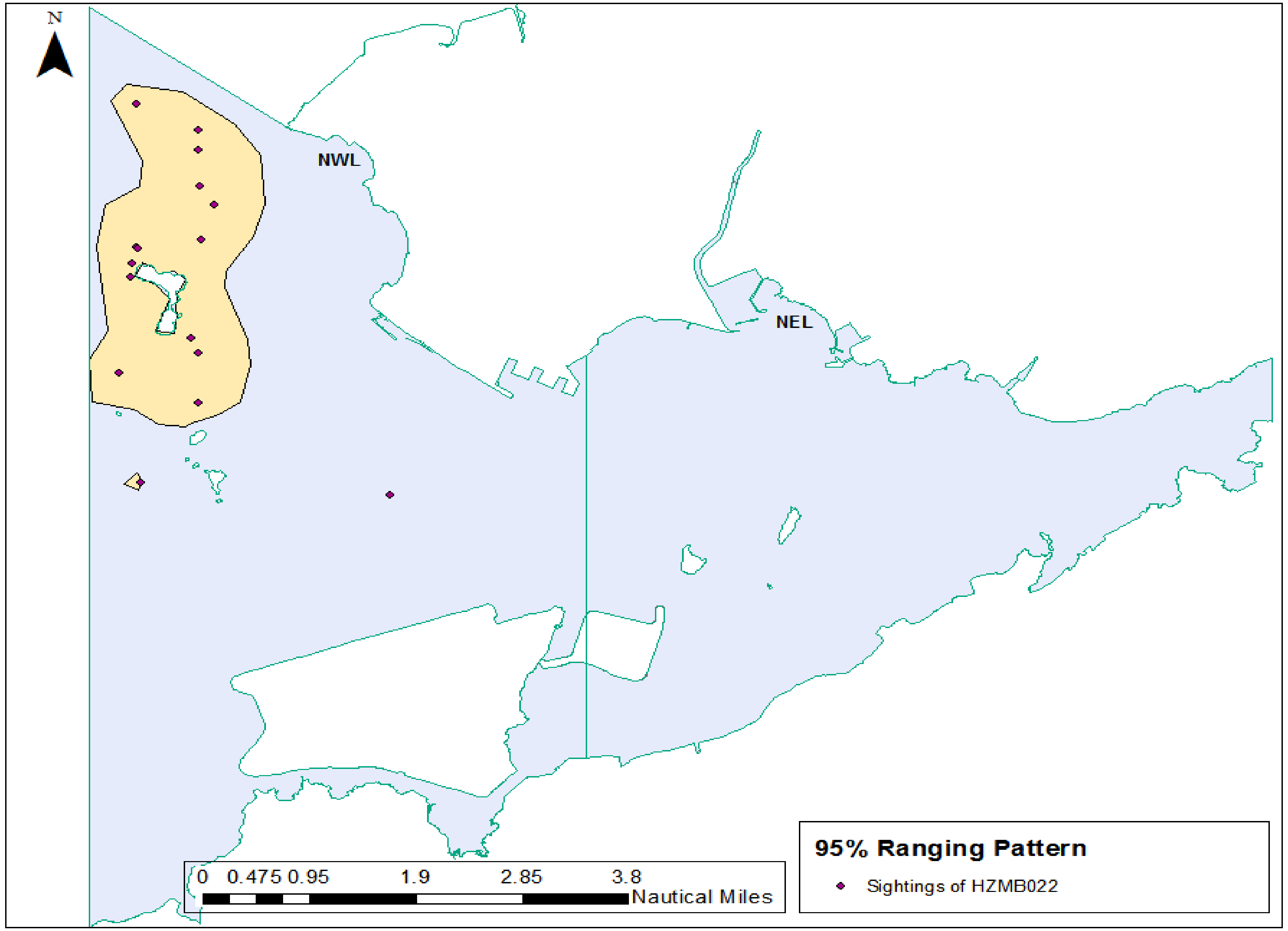

N
NWL
NEL
0 0.475 0.95 1.9 2.85 3.8
Nautical Miles
95% Ranging Pattern of HZMB054
Sightings of HZMB054

SEAMAR


N
NWL
NEL
0 0.475 0.95 1.9 2.85 3.8
Nautical Miles
95% Ranging Pattern
Sightings of HZMB022

SEAMAR

SEAMAR

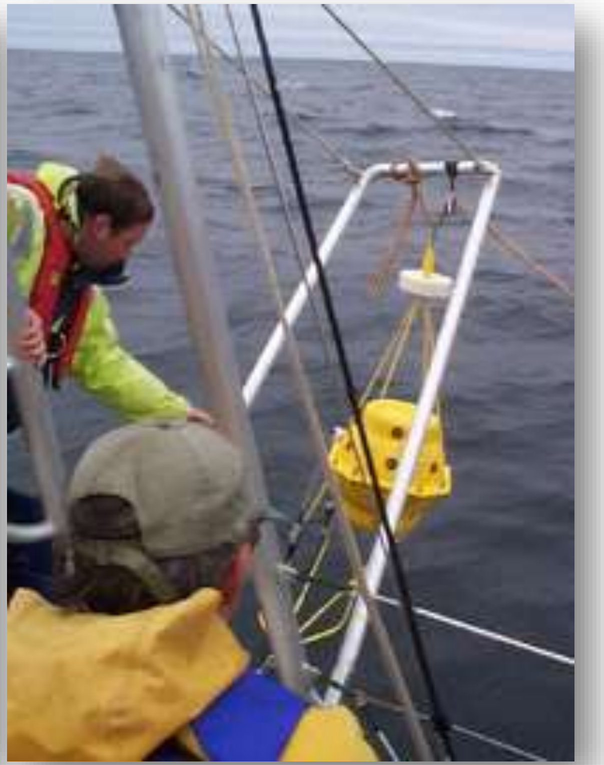
What is Passive Acoustic Monitoring (PAM)?

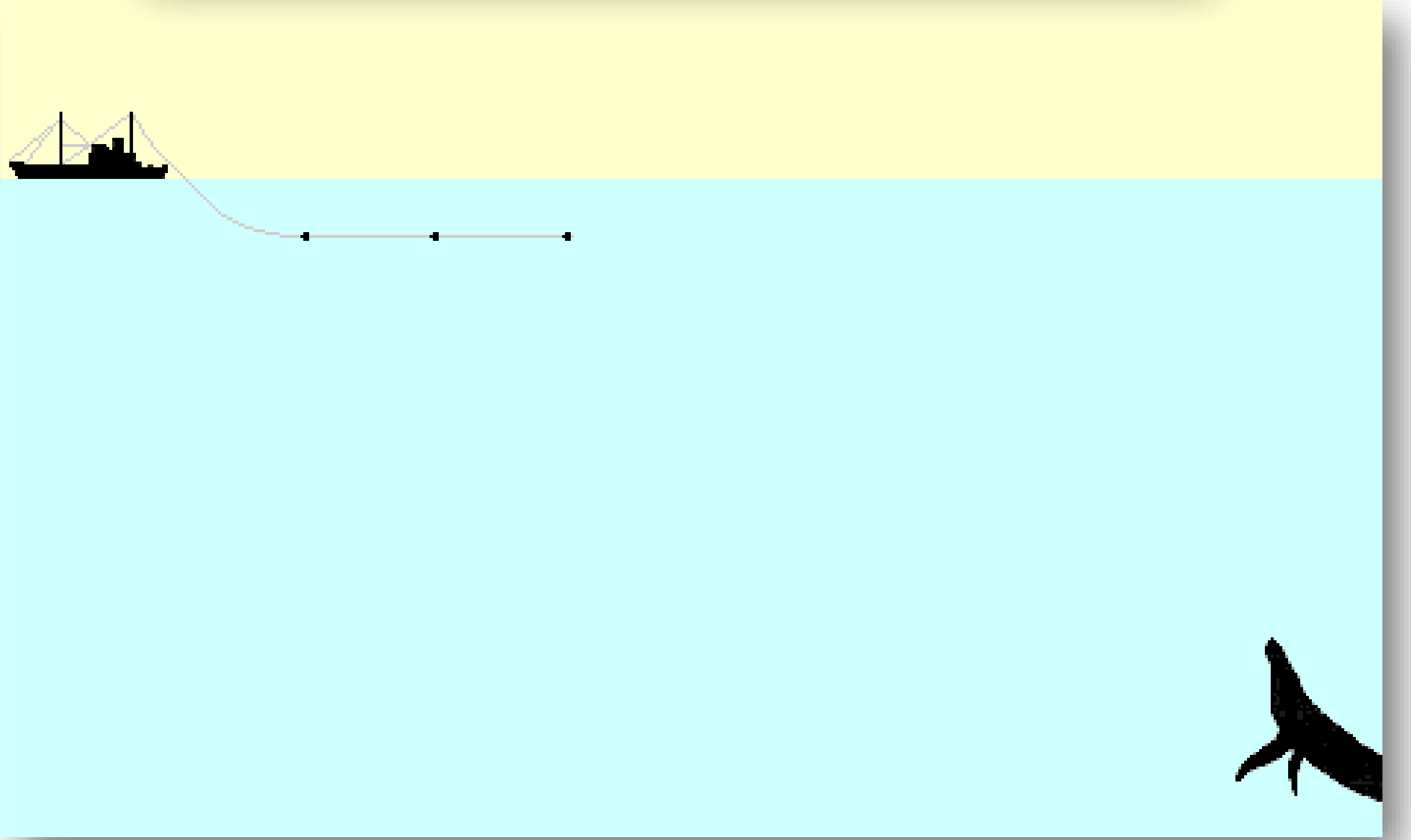
- Studying marine mammals is inherently challenging, as they are highly mobile, often occupy vast areas, and are only visible for brief periods of time at the surface.
- Visual methods are weather and light-dependent and costly
- Access to the area is an issue
- **Passive Acoustic Monitoring (PAM)** uses technology to listen for these vocalisations

SEAMAR

PAM

Systems





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PAM

Systems

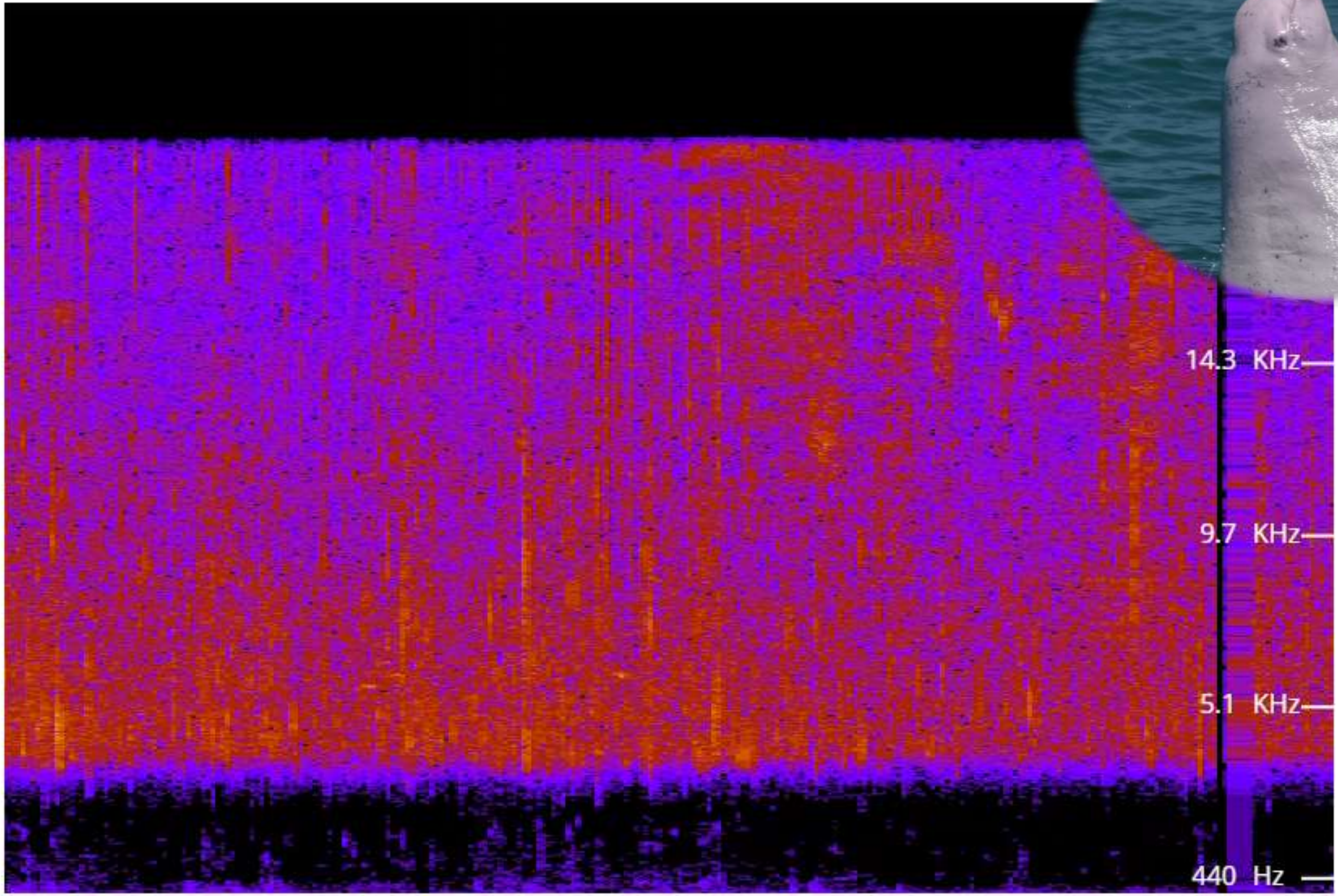
SEAMAR

Passive

Acoustic Monitoring

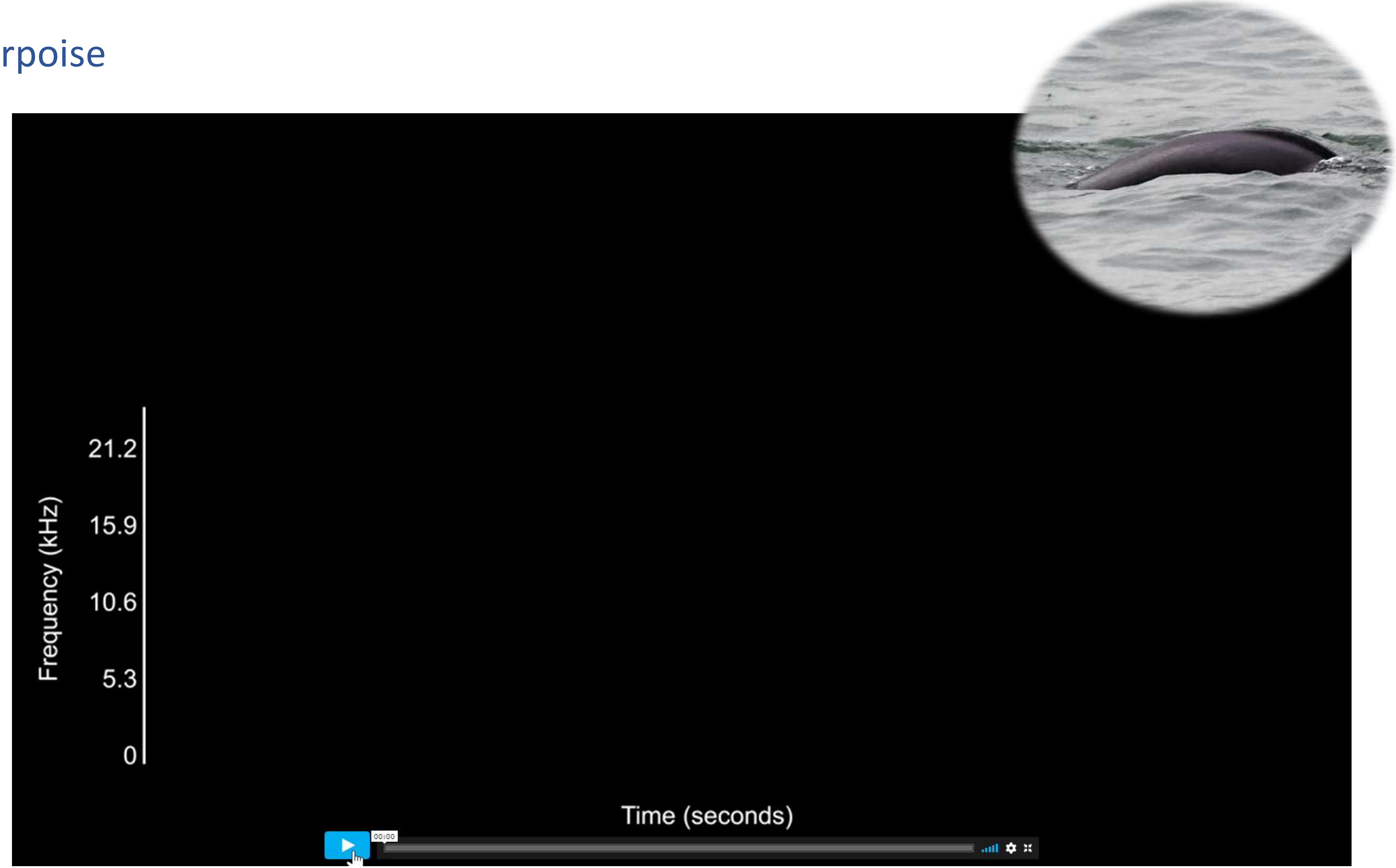
SEAMAR

Chinese White Dolphin



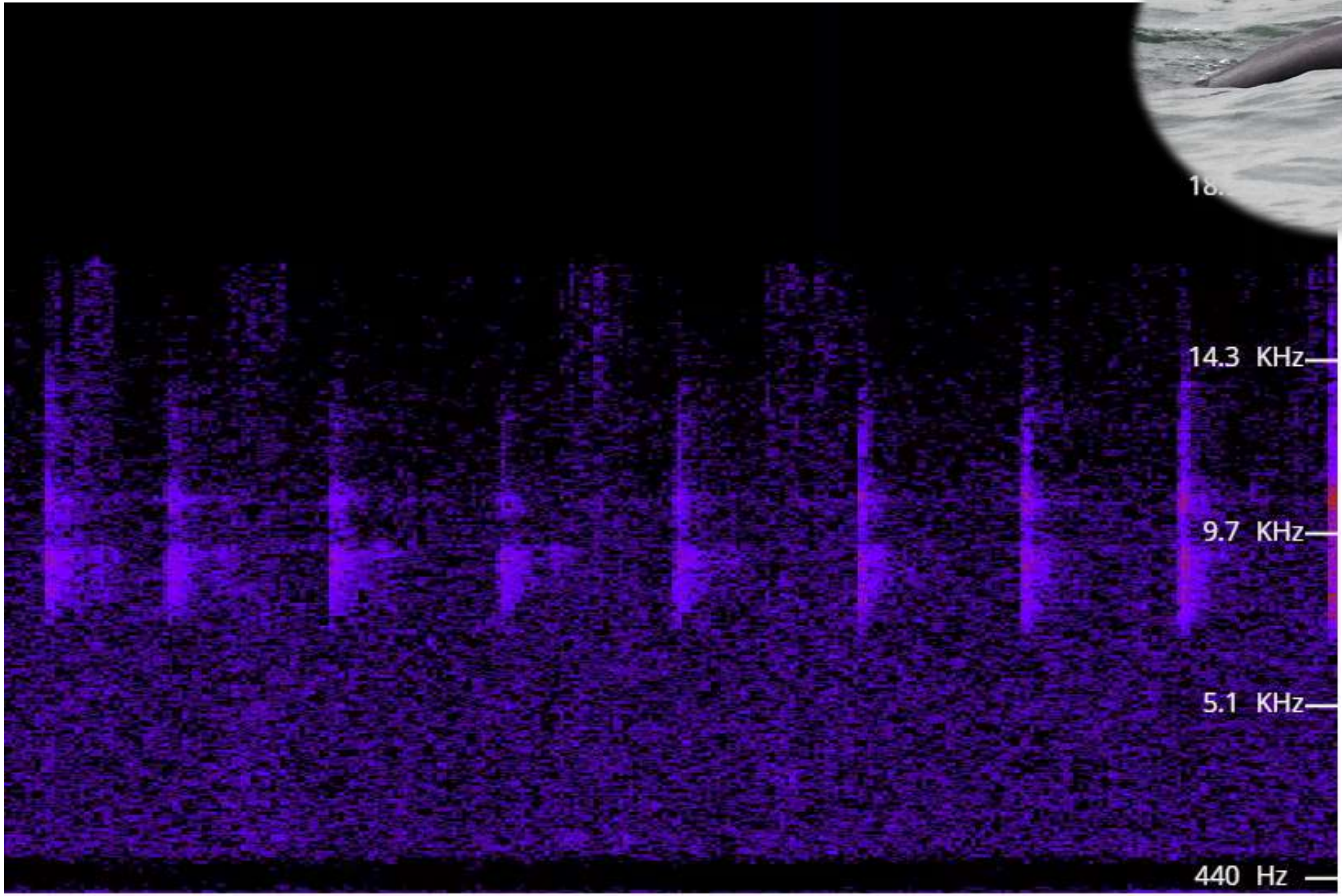
SEAMAR

Finless Porpoise



SEAMAR

Finless Porpoise (slow)



SEAMAR

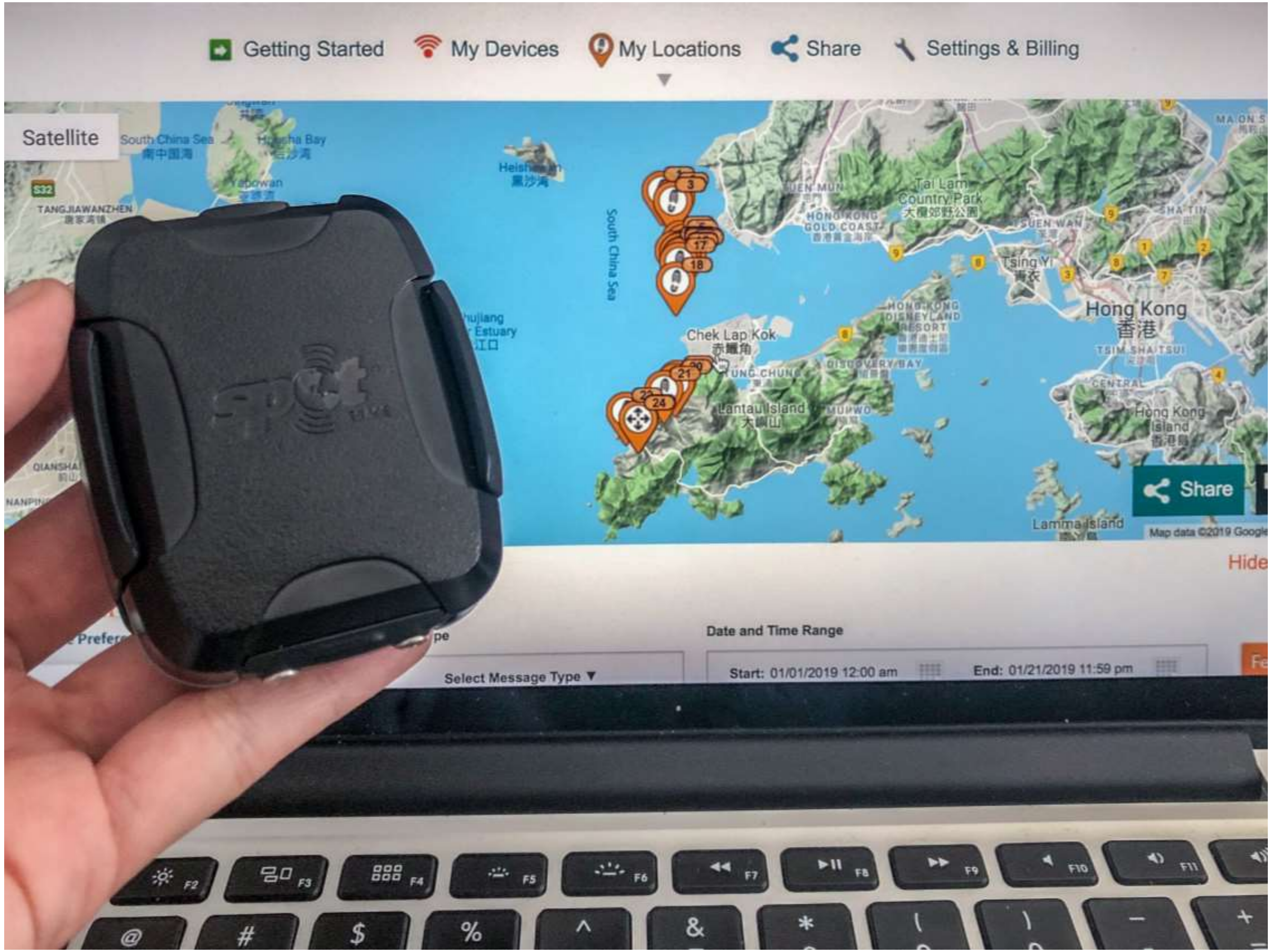

OCEANSASIA

How will you study
Hong Kong's dolphins and porpoise?

SEAMAR

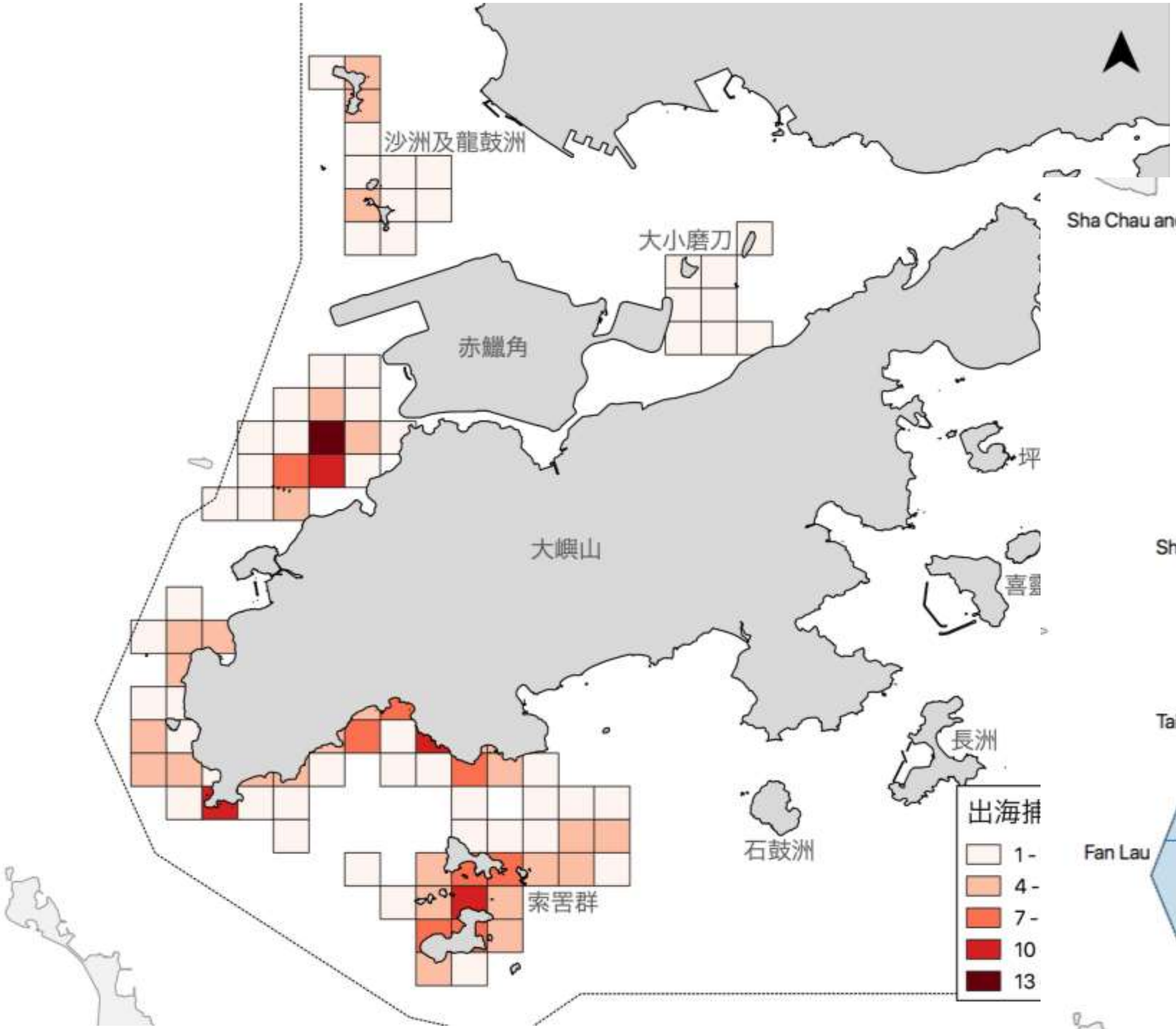
SEAMAR

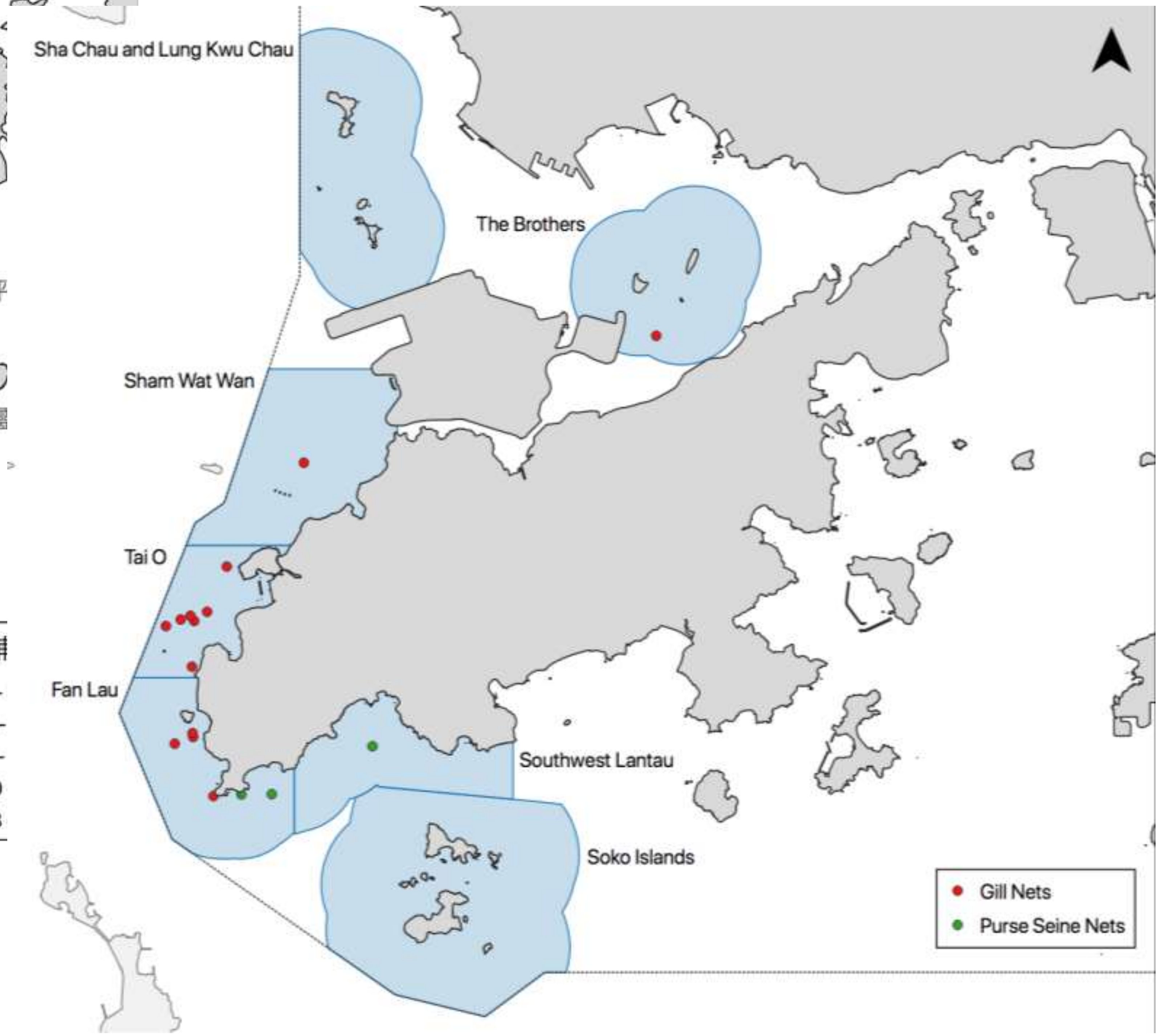
Assessing Threats



SEAMAR

Assessing Threats





SEAMAR

What is a marine mammal?

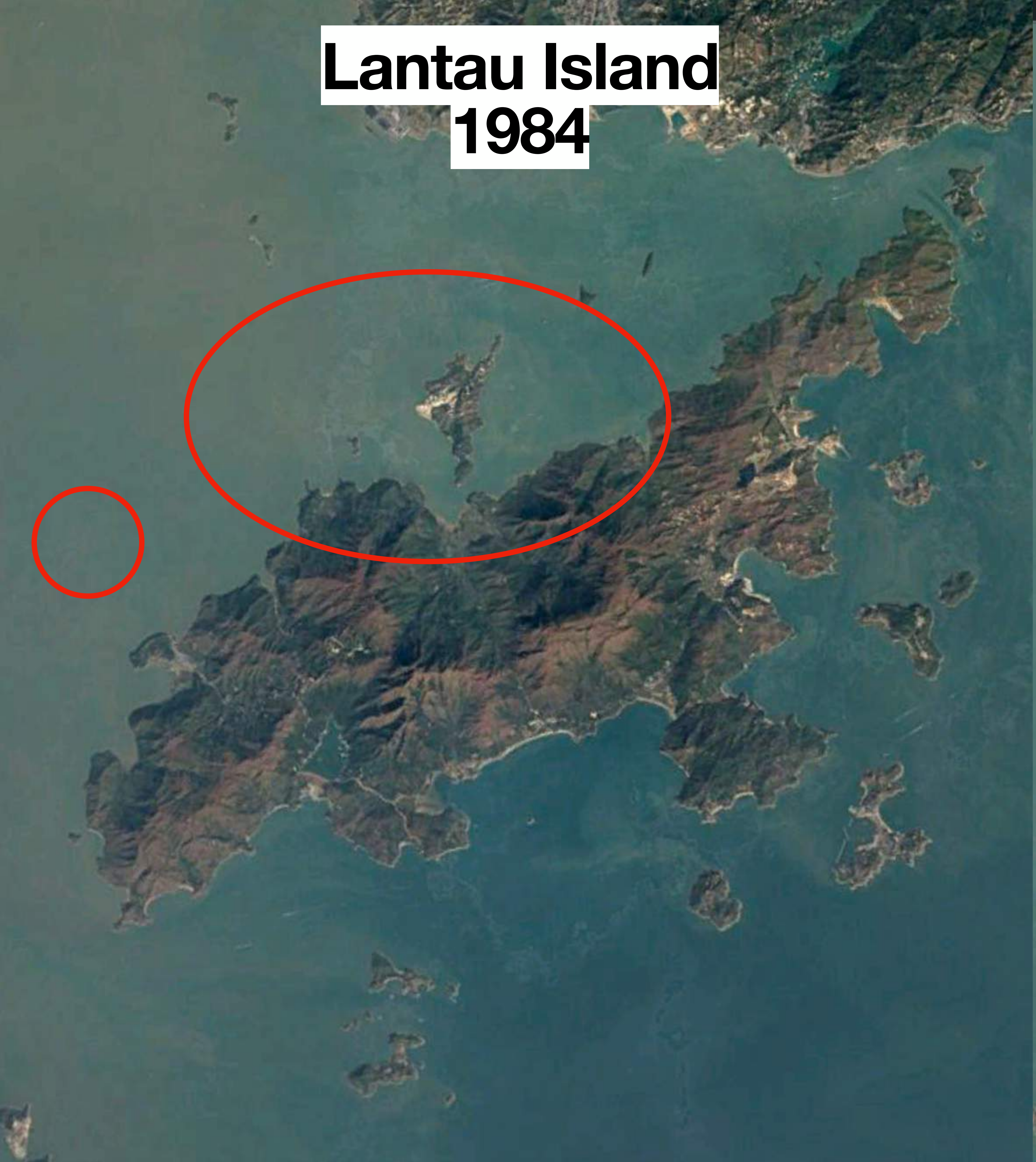
- Live in the **sea**
- Breathe **air**
- Make **milk** to **nurse** their **young**
- Have **hair**


Indo-Pacific
humpback
dolphin

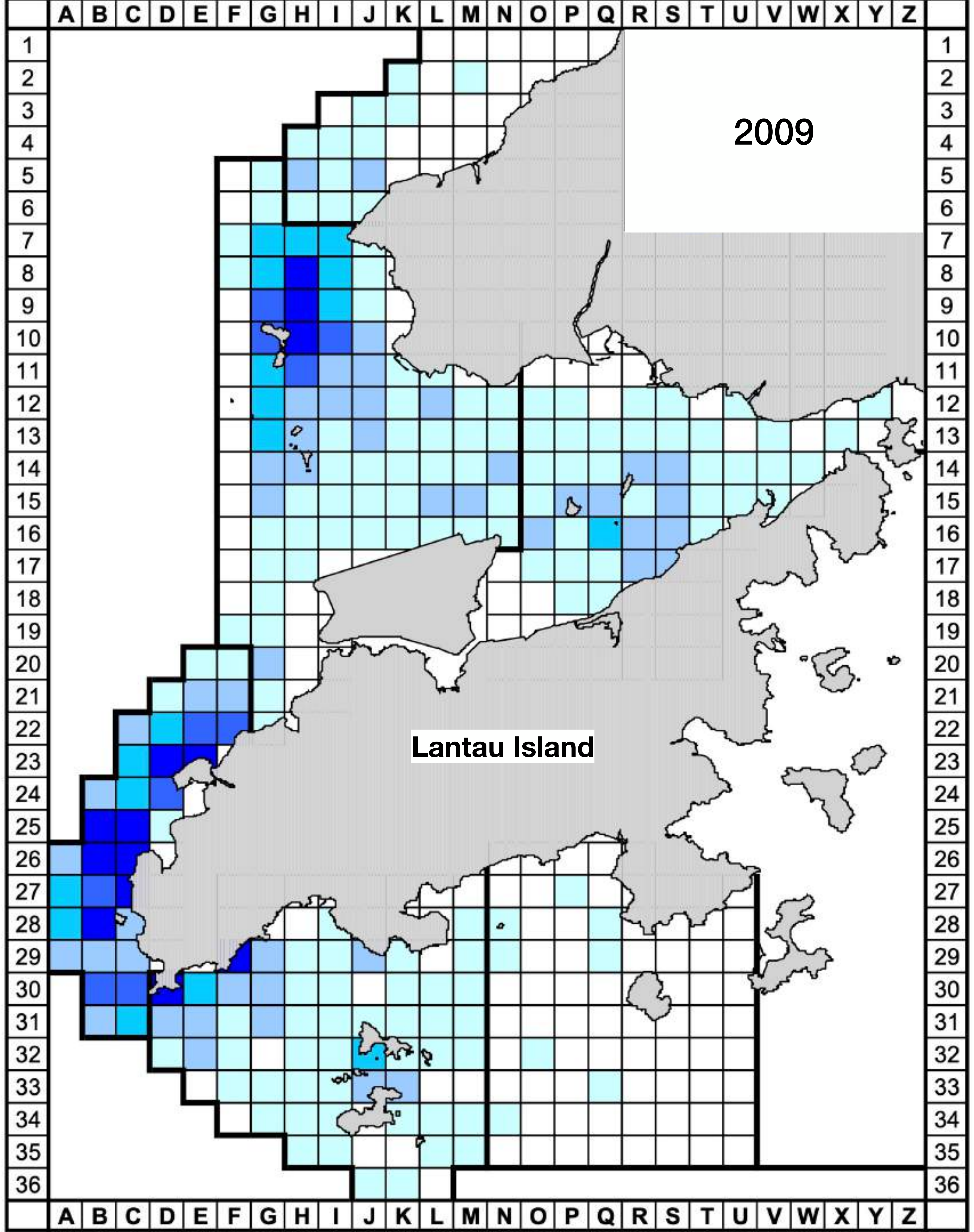

1-2 years old
2-4 years old
4-8 years old
8-10 years old
10-25 years old
+25 years old

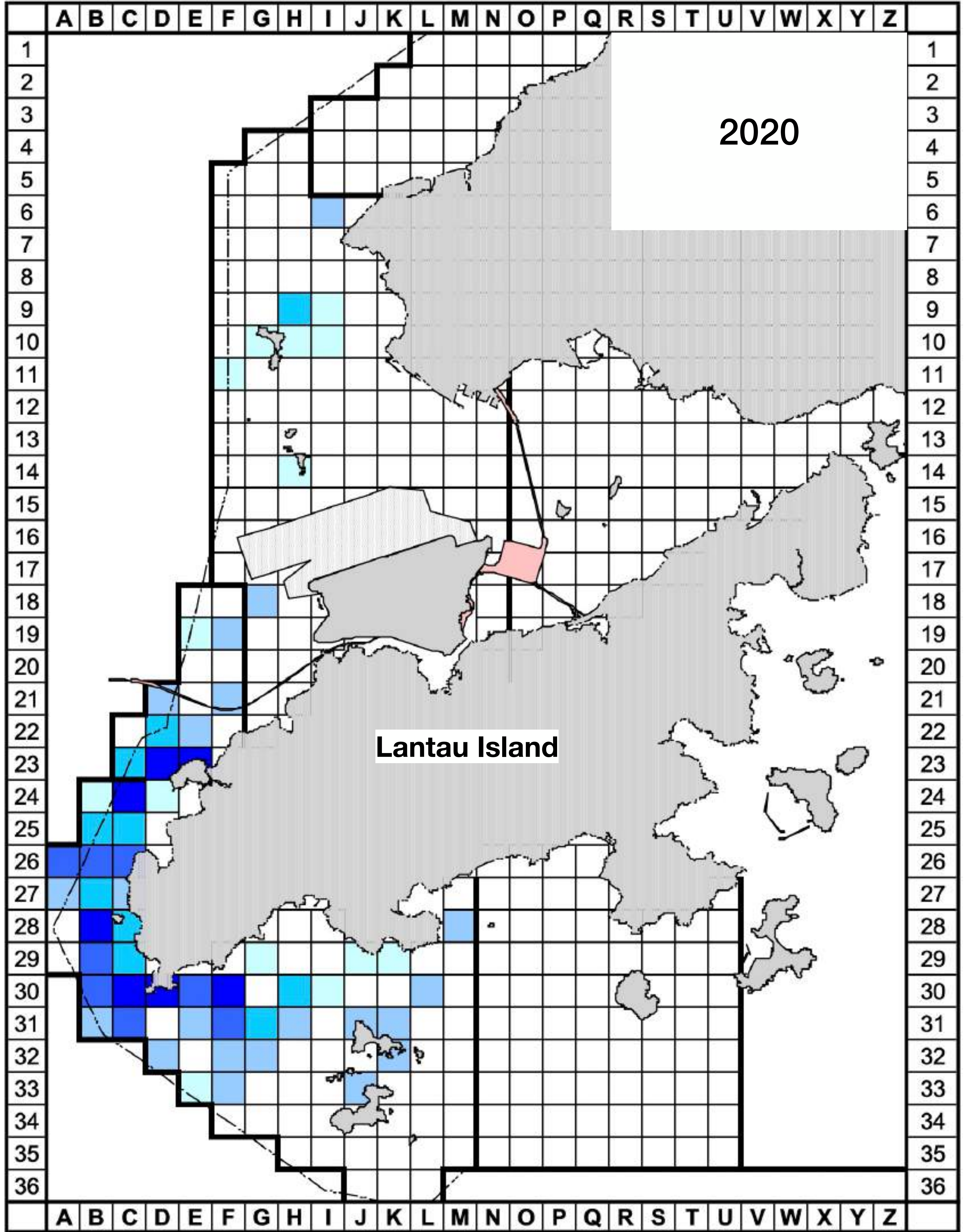

20 kg
1.6 meters
70 kg
300 kg
3.2 metres

Pearl River Estuary
(Freshwater)
New Territories
Lantau Island
Hong Kong Island
South China Sea
(Seawater)


Lantau Island
1984


Lantau Island
2020

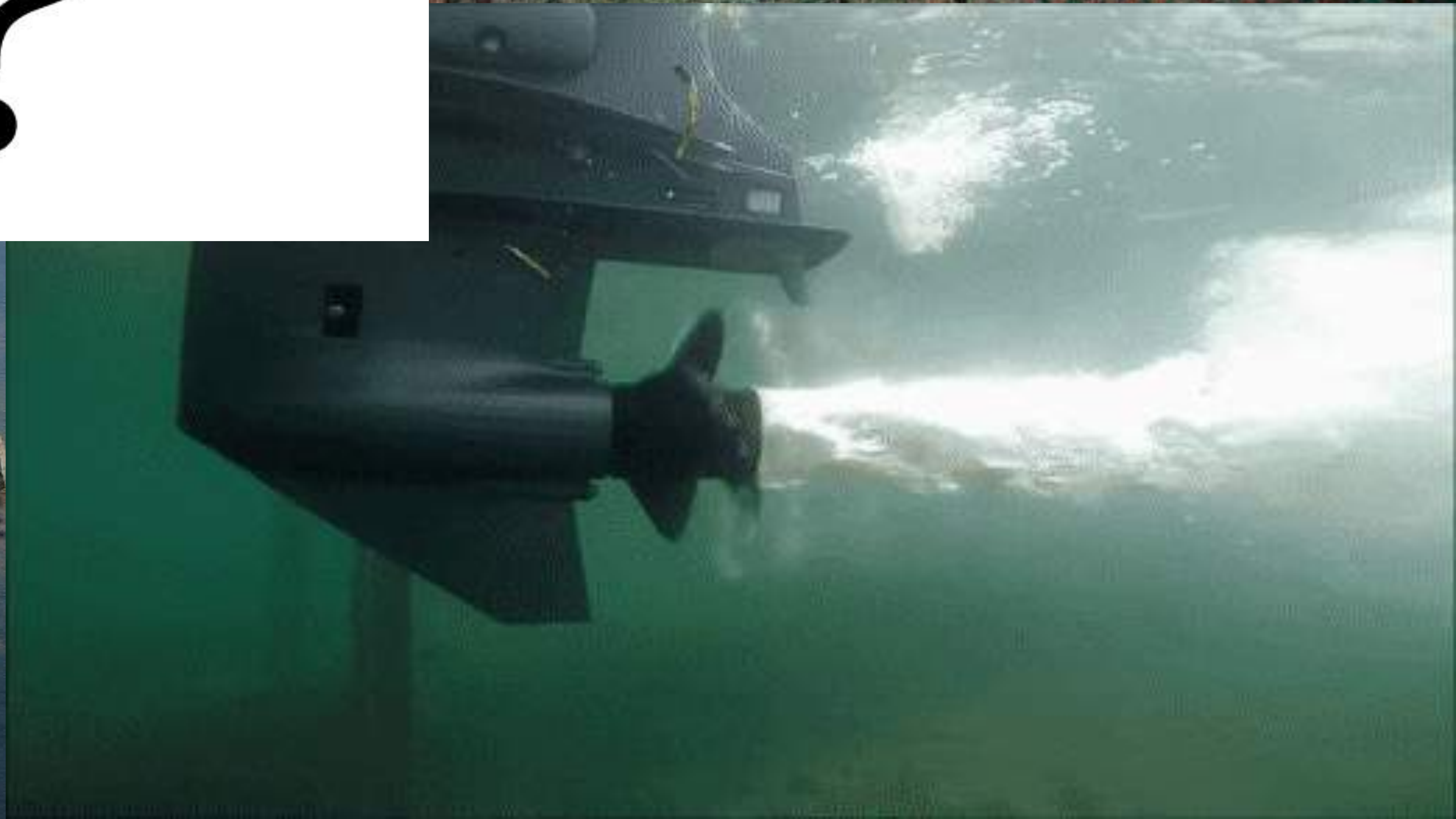

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1–36
2009
Lantau Island


A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1–36
2020
Lantau Island

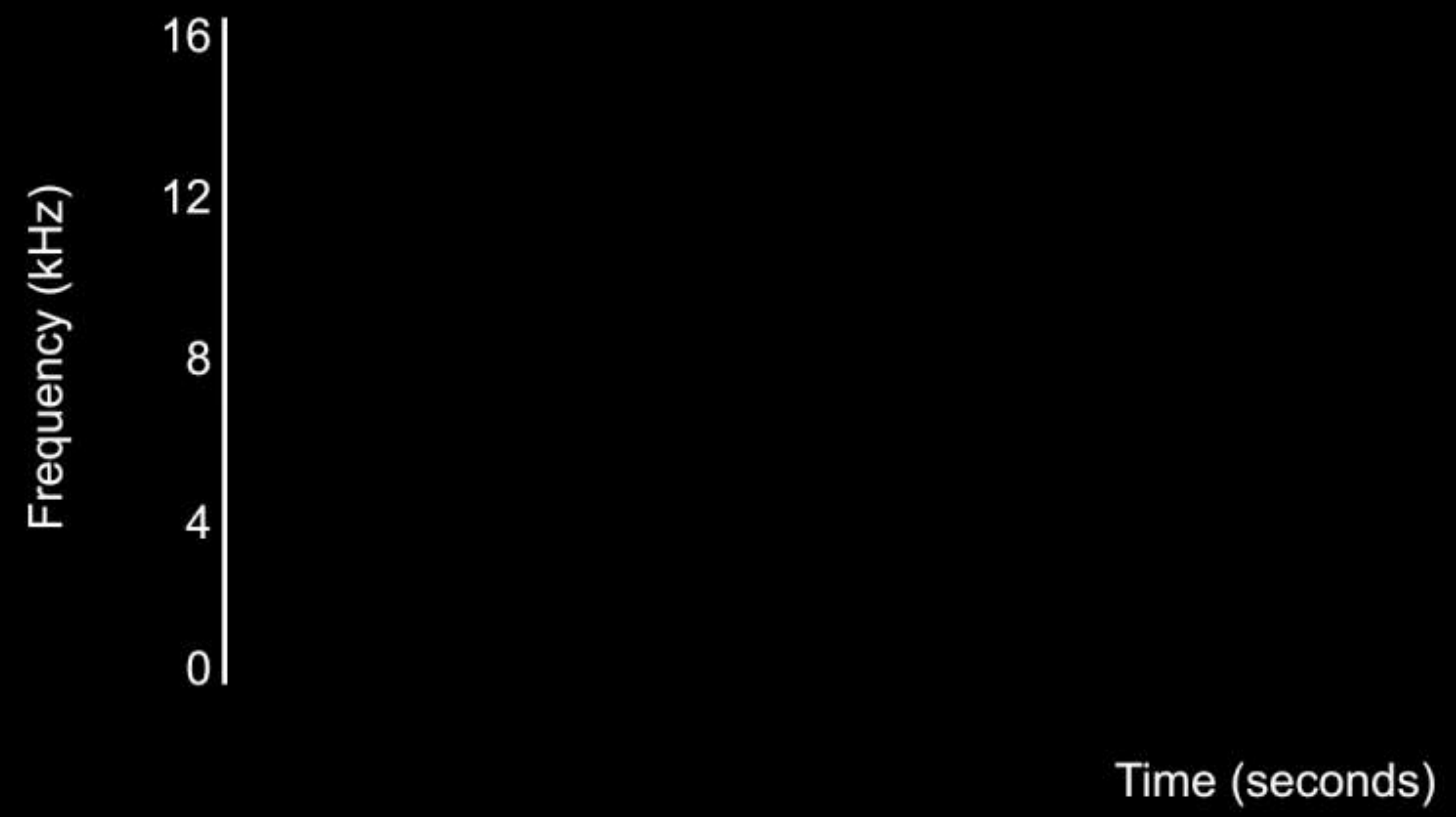
?

?

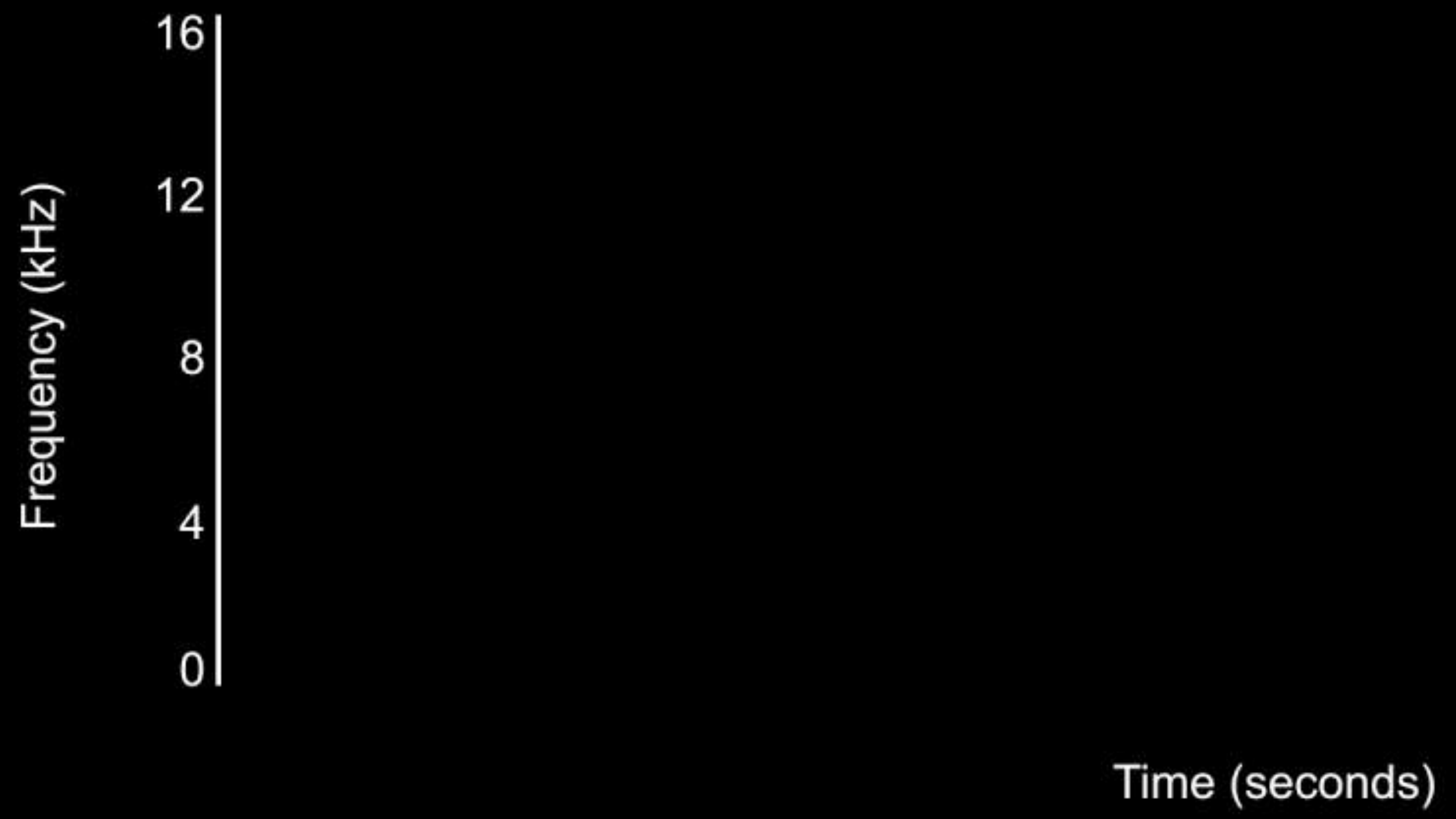

?

Can you guess the underwater sound?



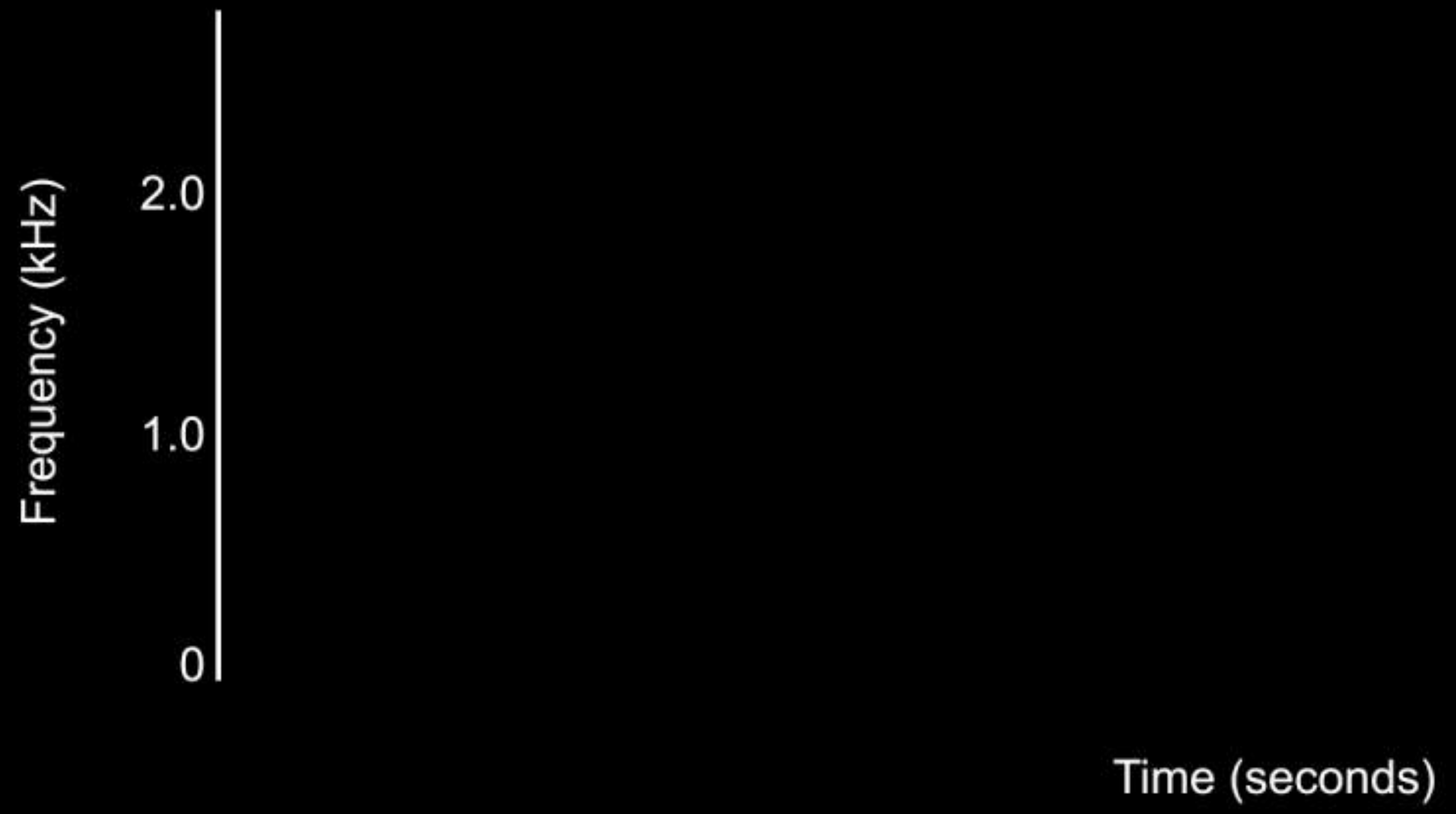
Can you guess the underwater sound?



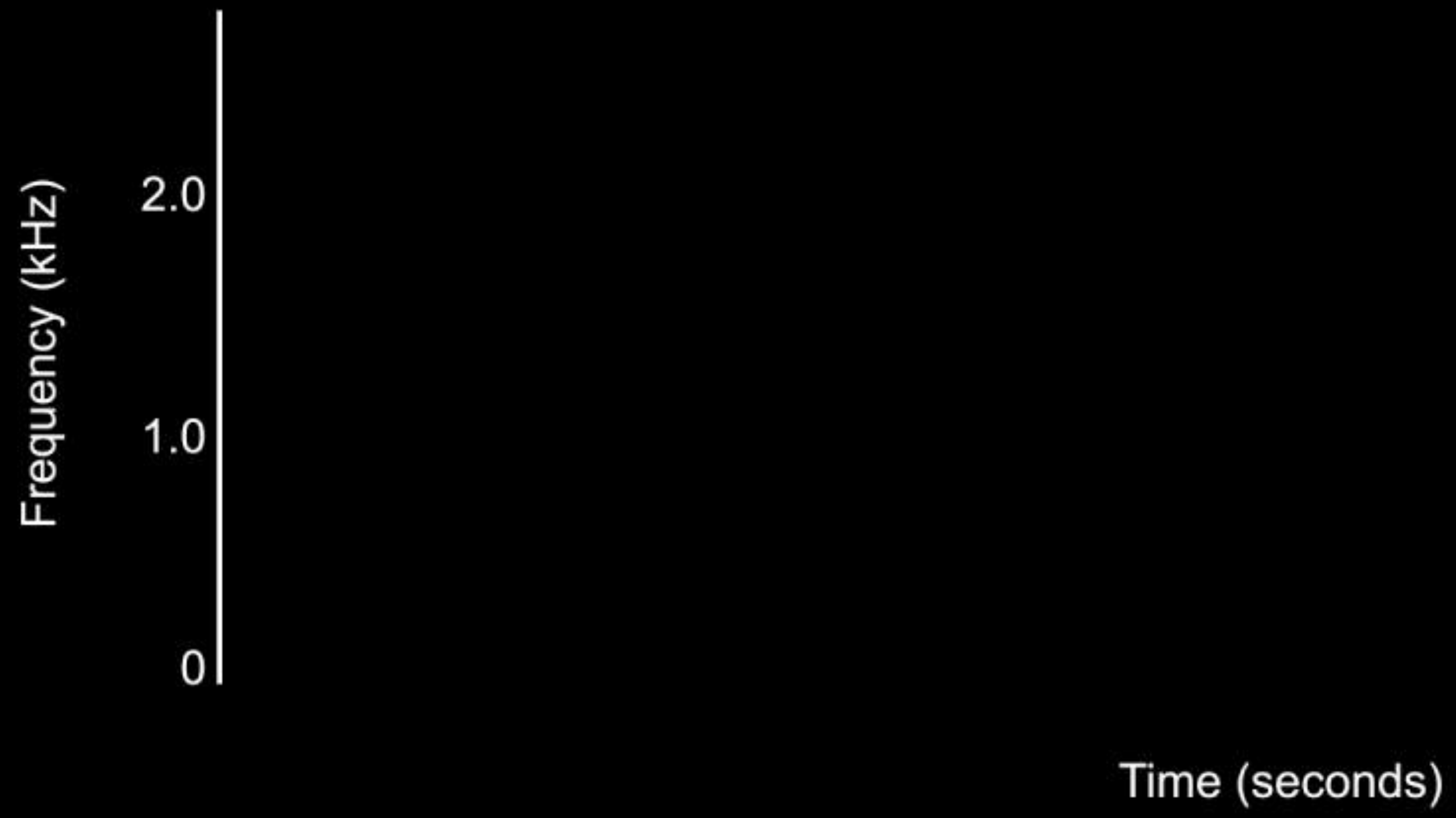
Humpback Dolphin

Frequency (kHz)
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Time (s)

Can you guess what animal this is?

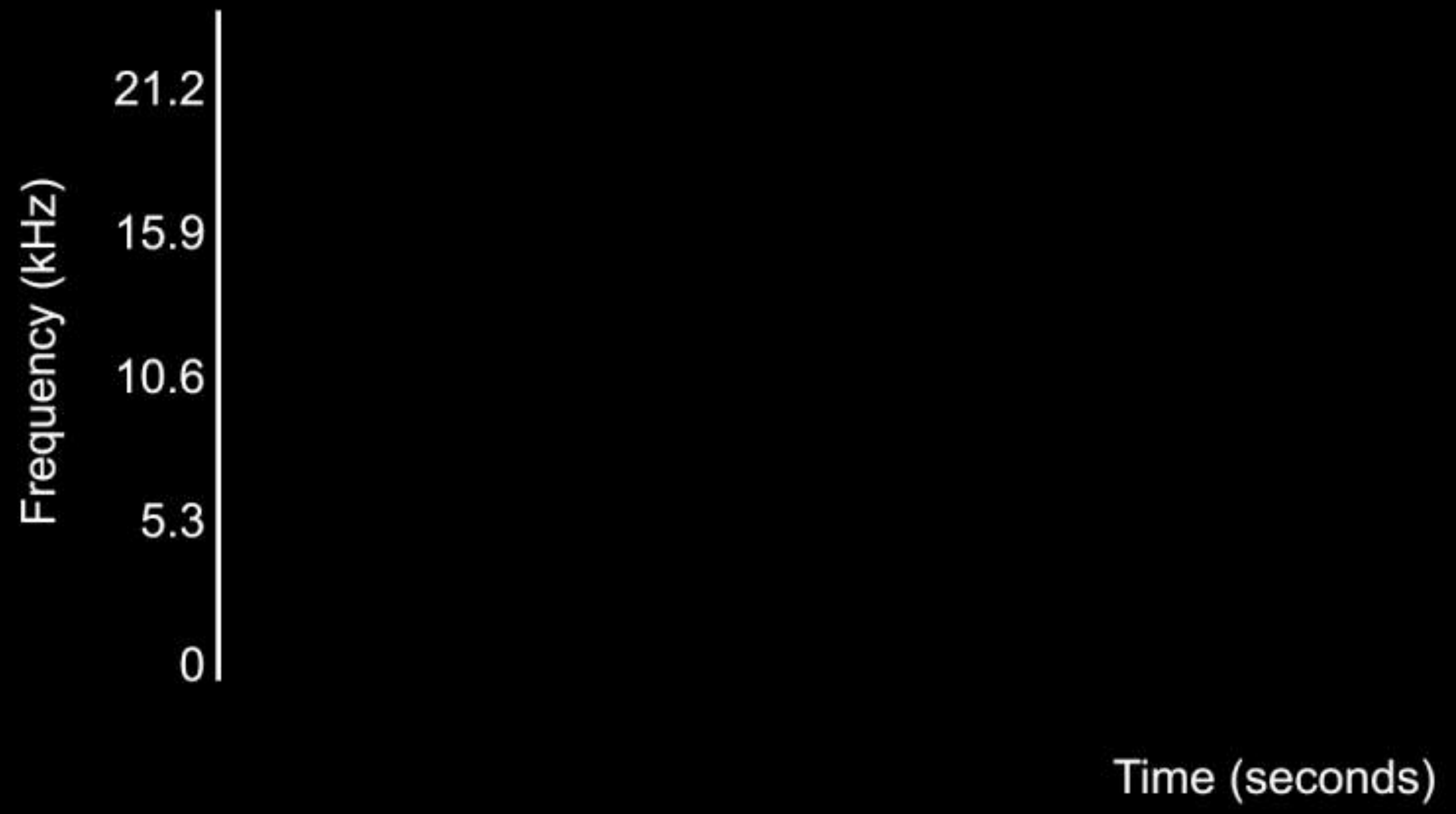


Can you guess what animal this is?

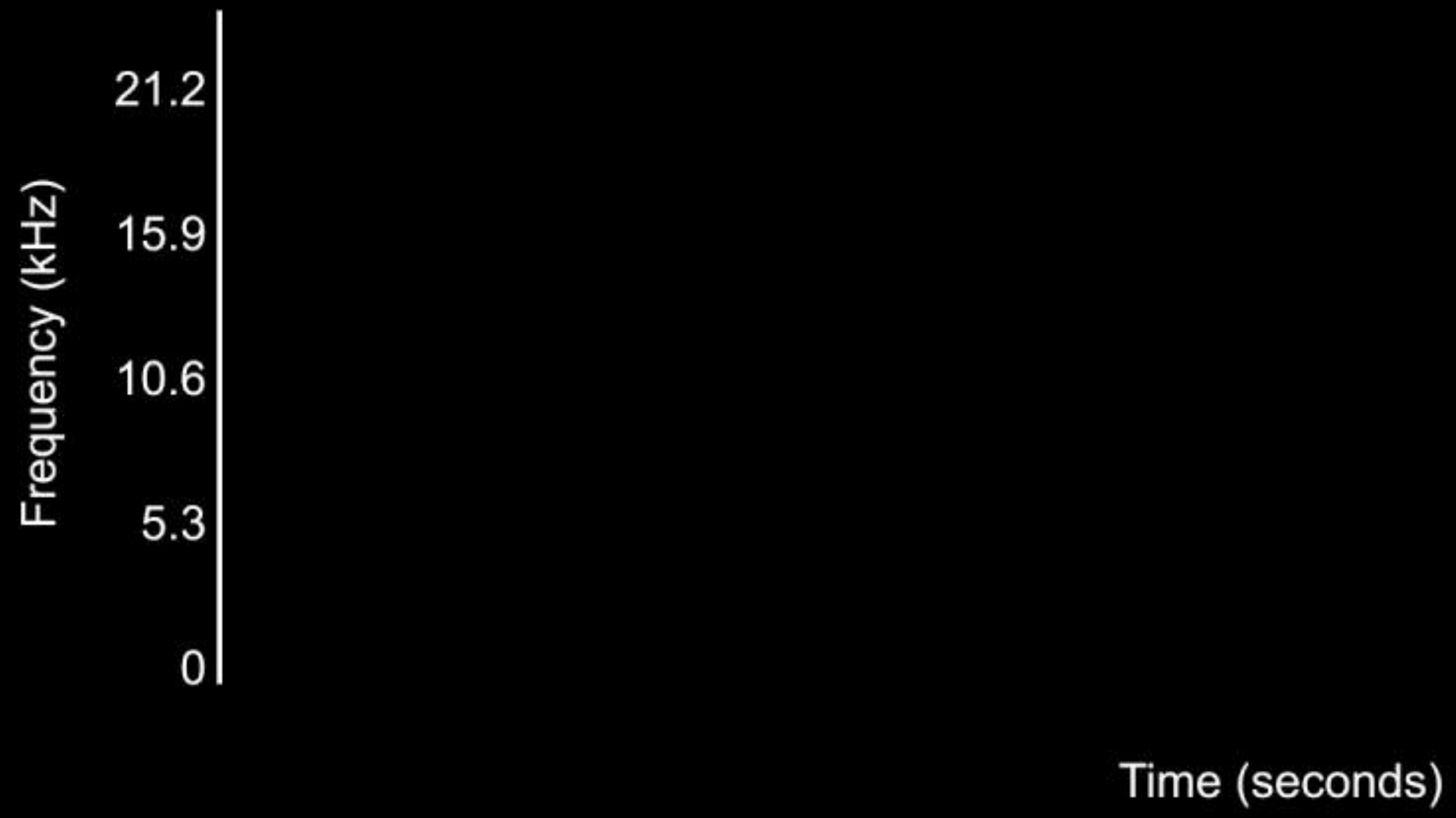


Shrimp

Can you guess what animal this is?

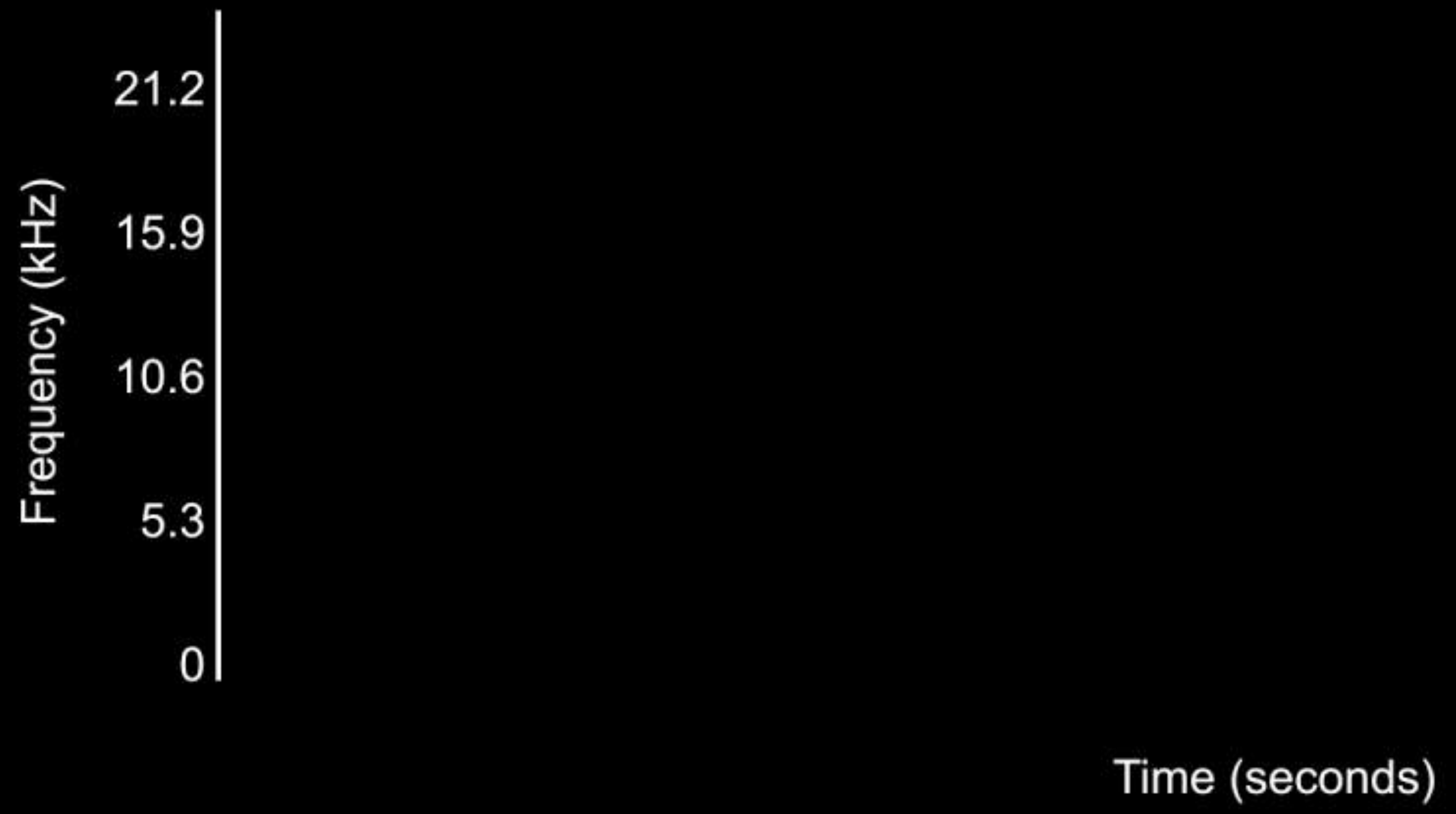


Can you guess the underwater sound?

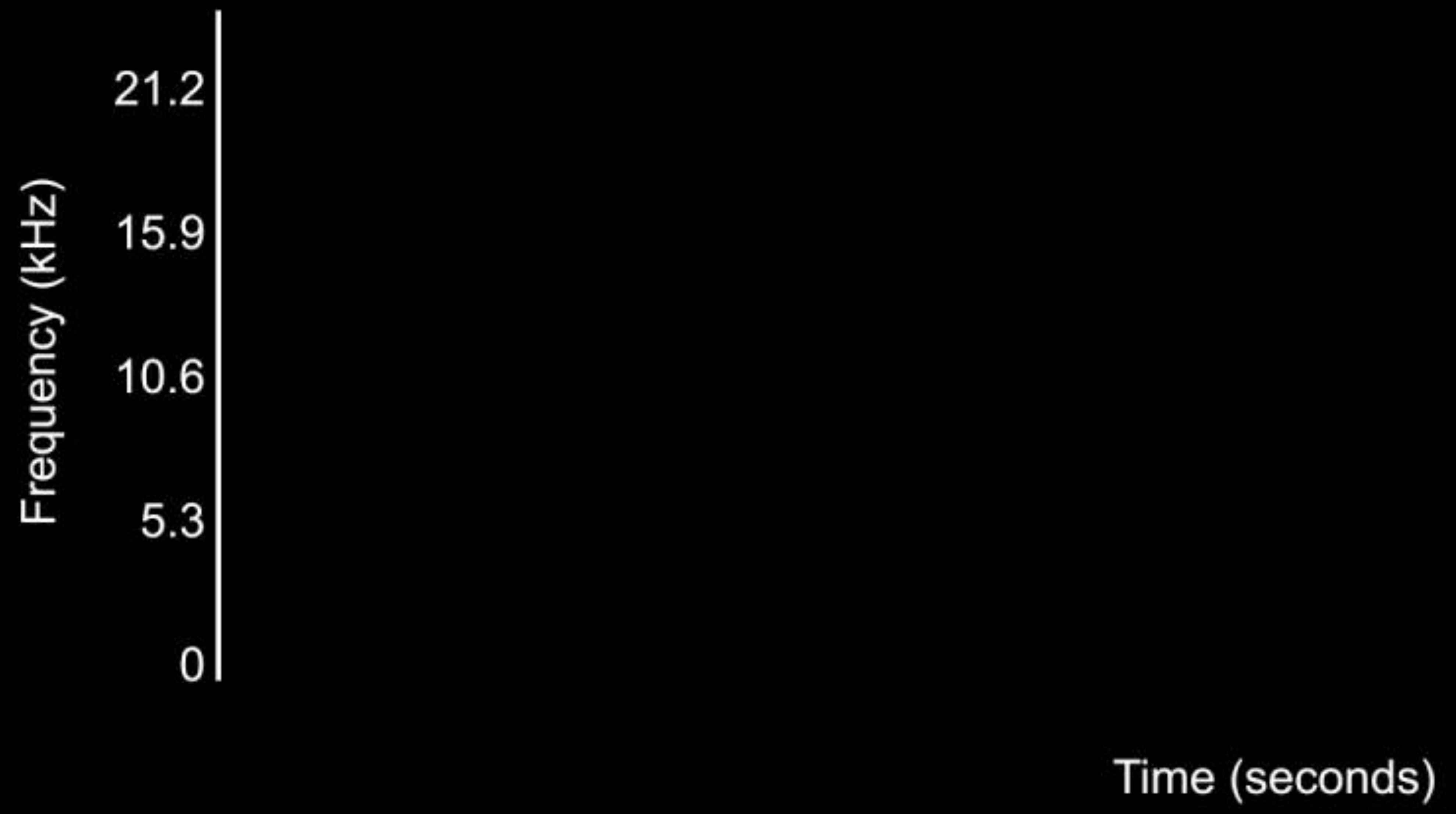


Sea Urchin

Can you guess what animal this is?



Can you guess the underwater sound?



Lobster

Can you guess what animal this is?

Discovery of *Sound in the Sea*

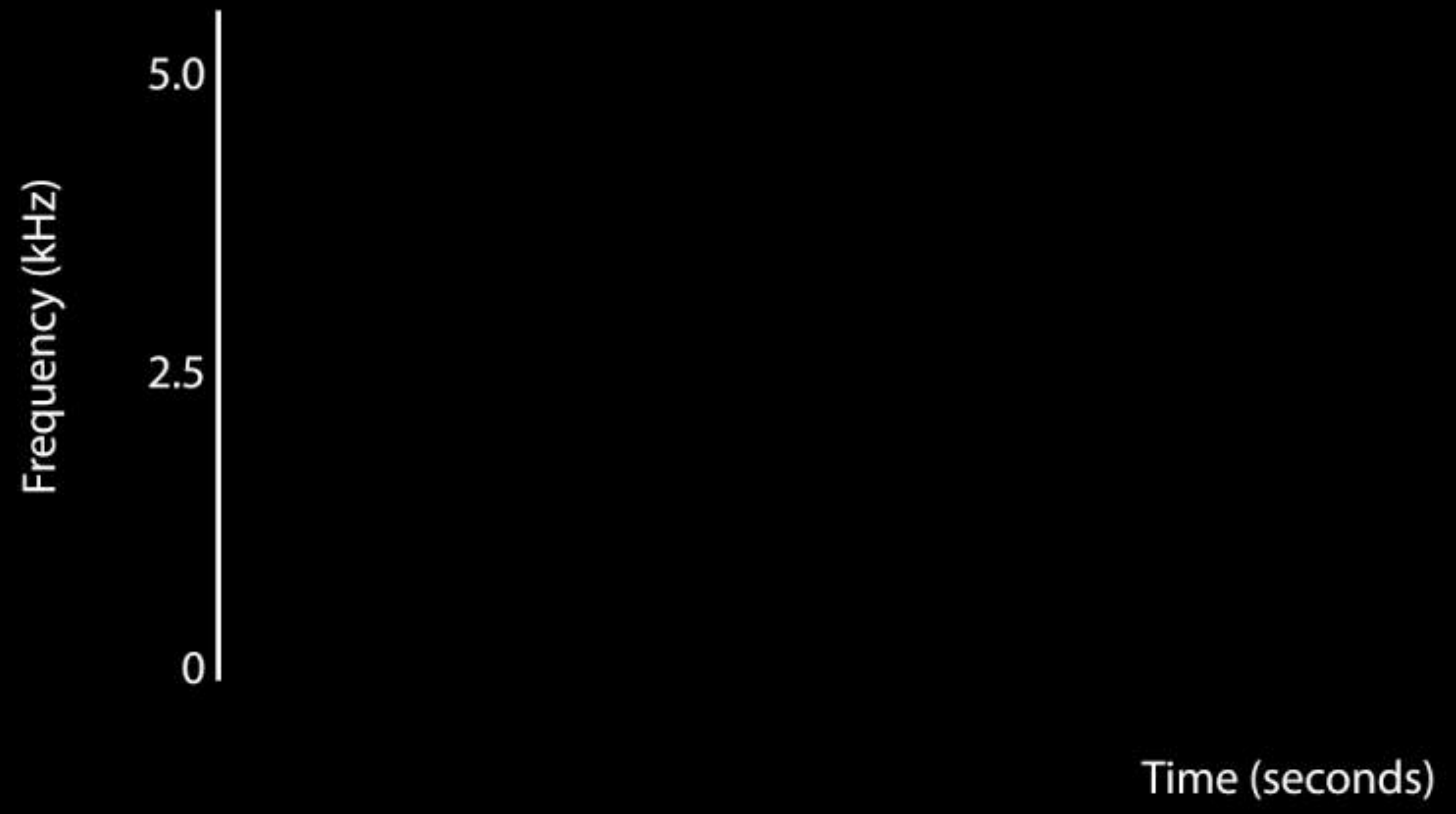
?

Can you guess what animal this is?

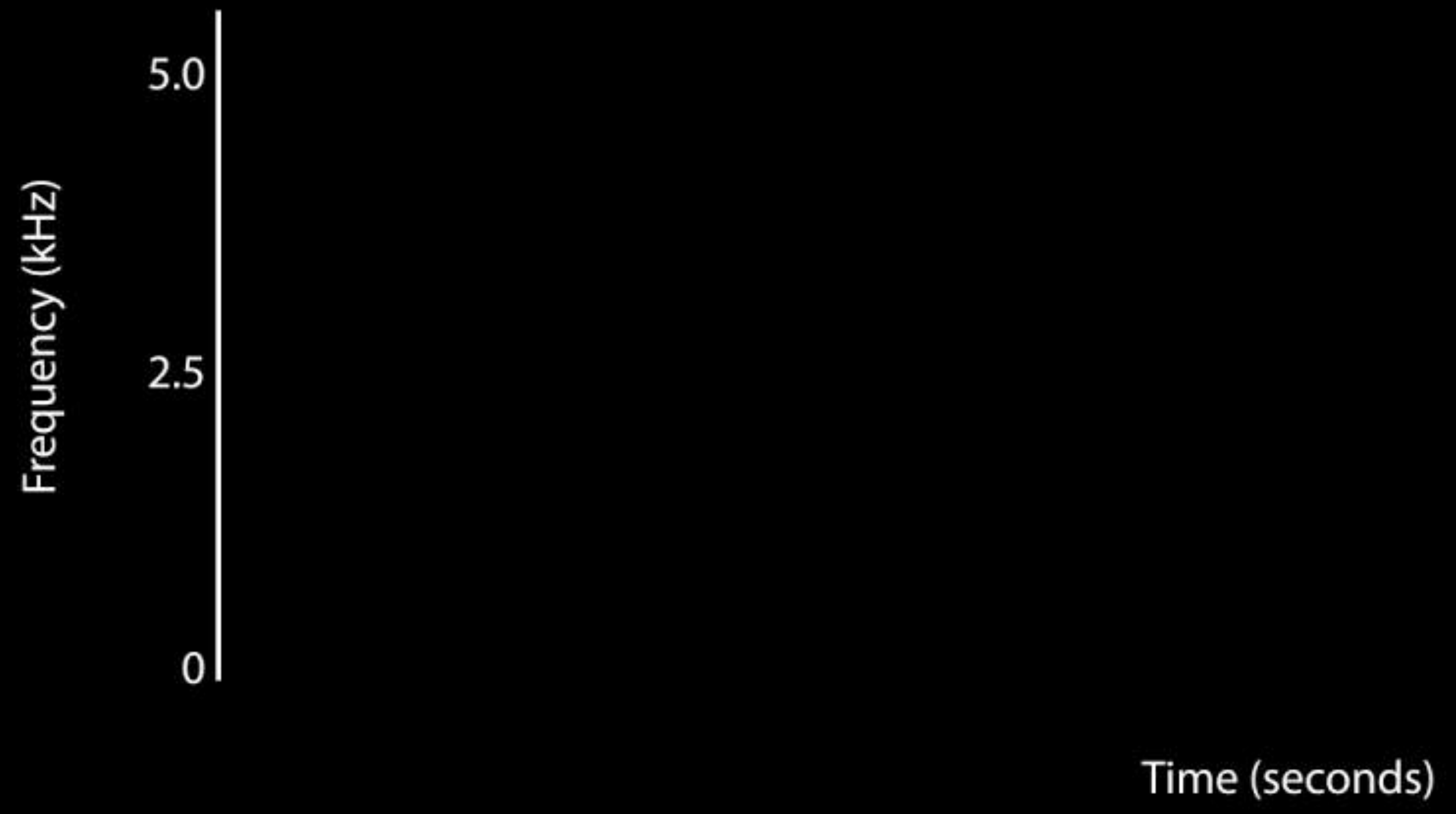
Discovery of *Sound in the Sea*

Fish (Croaker)

Can you guess the underwater sound?

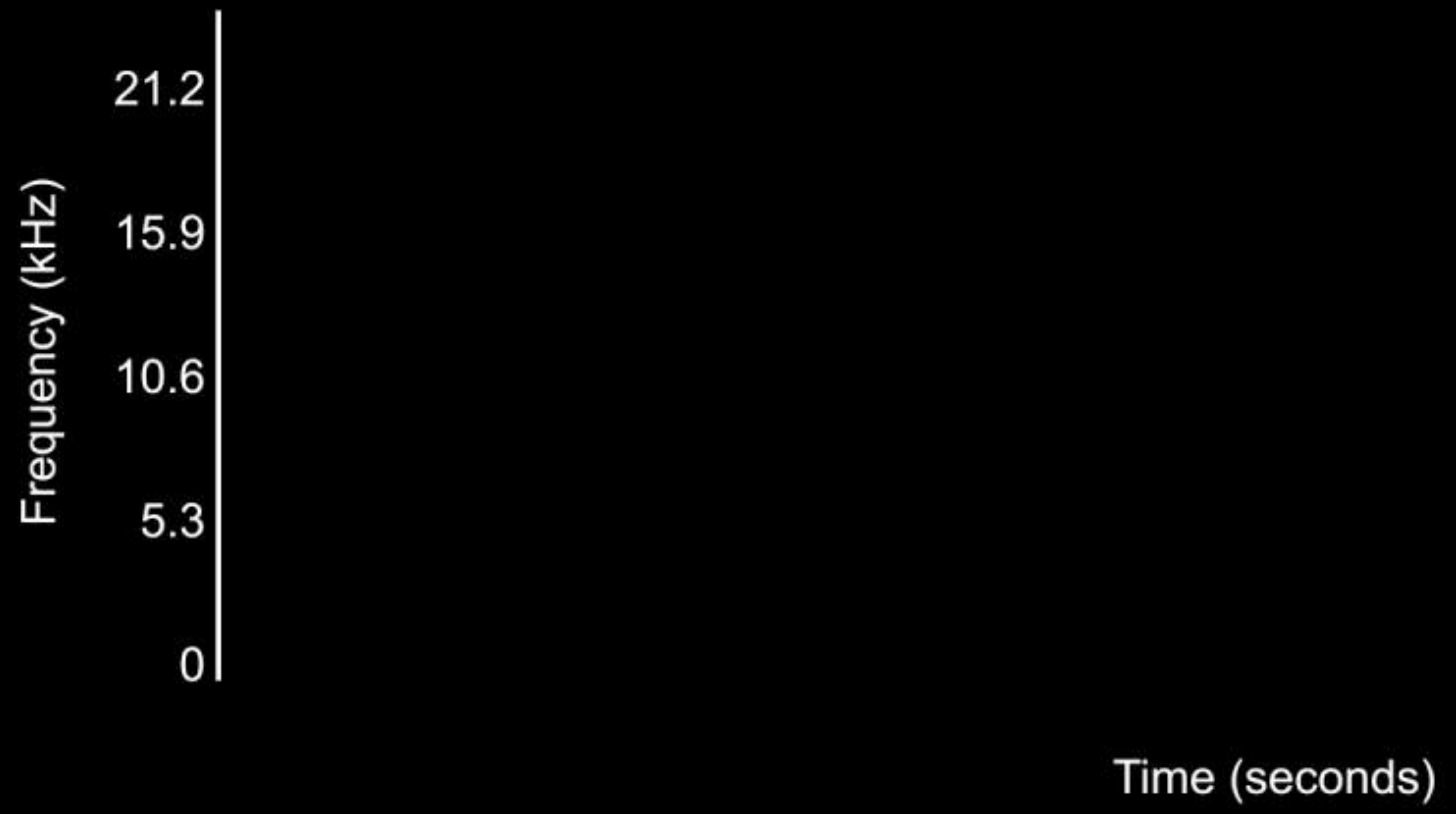


Can you guess the underwater sound?



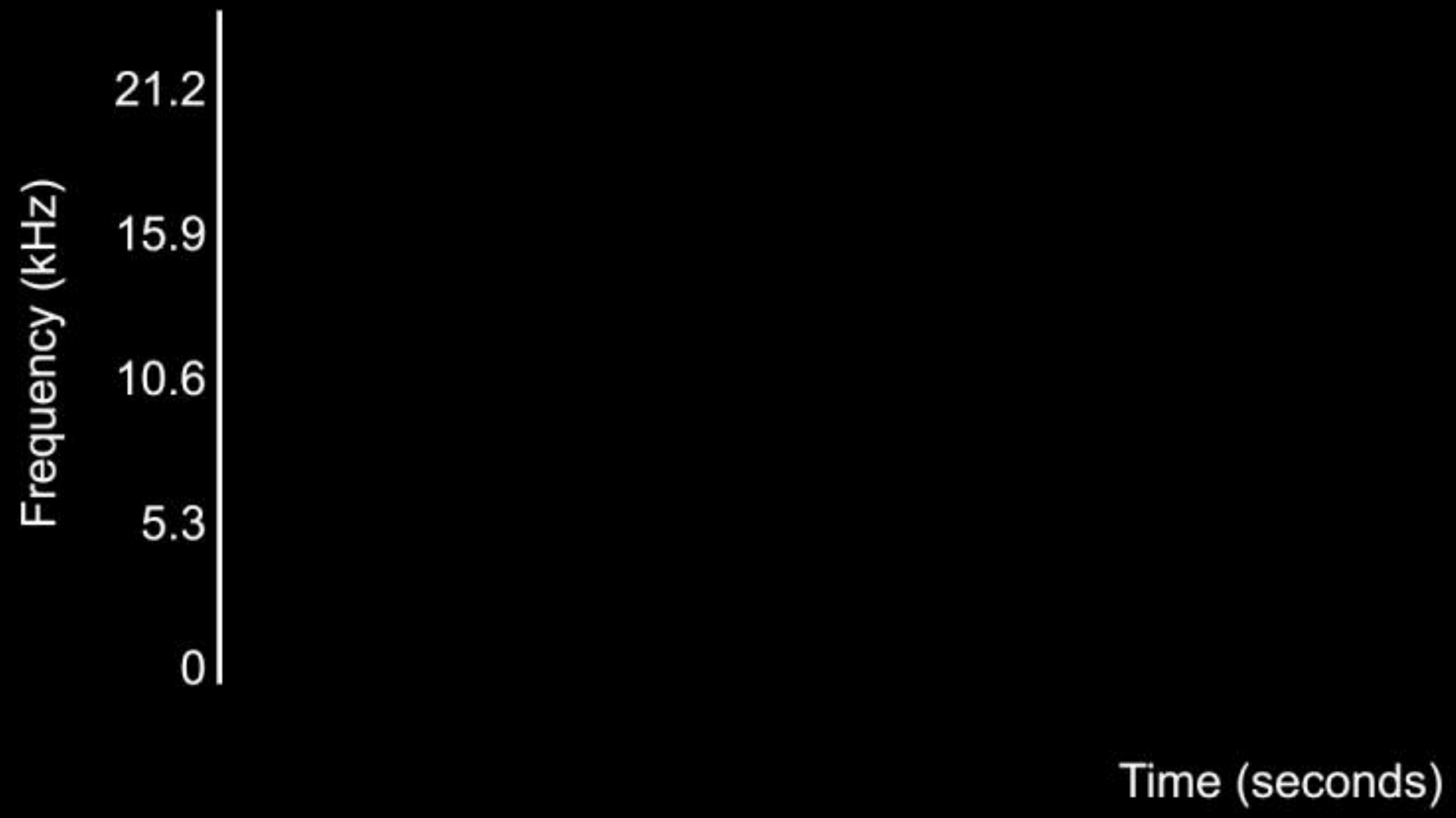
Lighting

Can you guess the underwater sound?



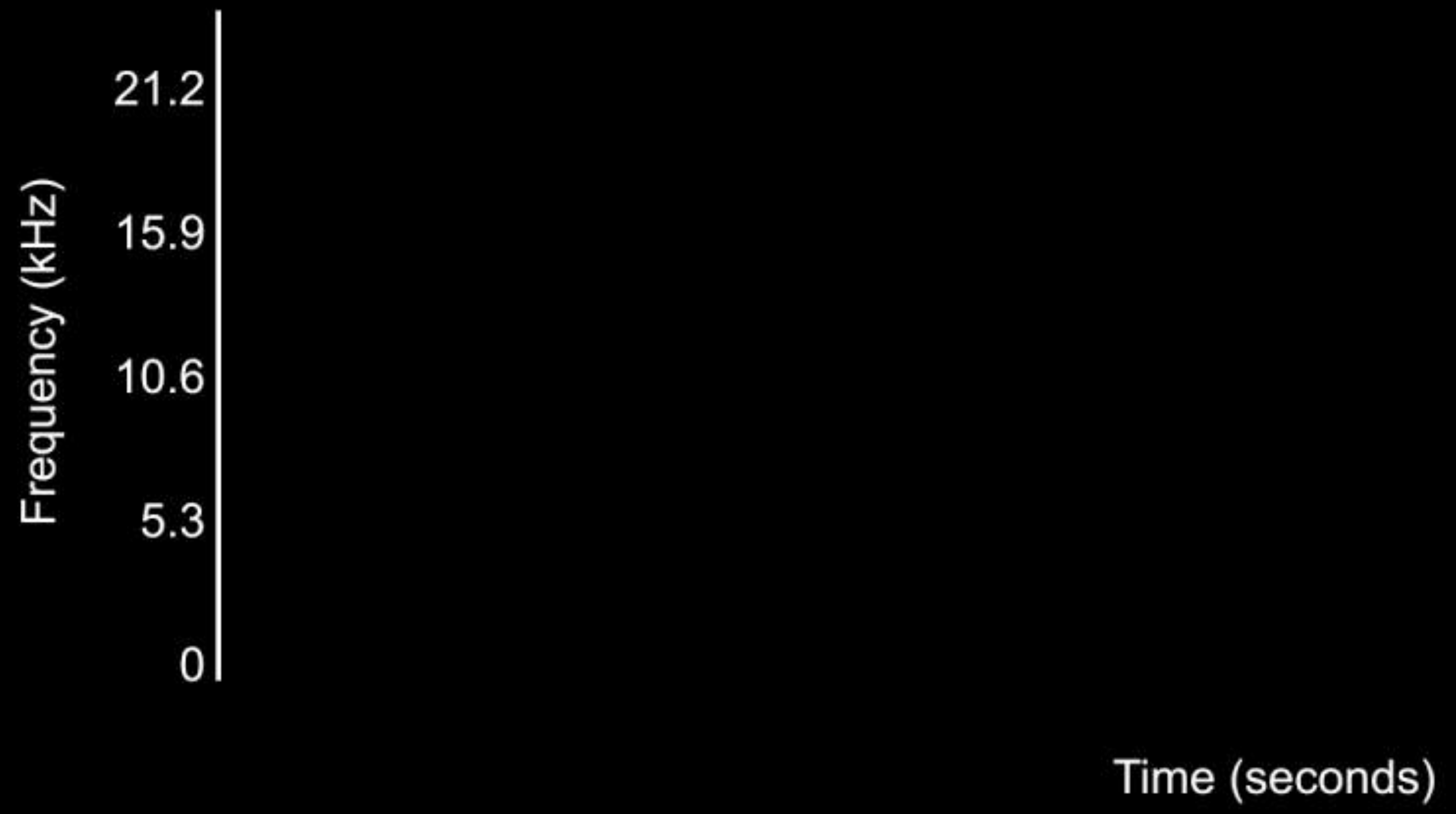
?

Can you guess the underwater sound?

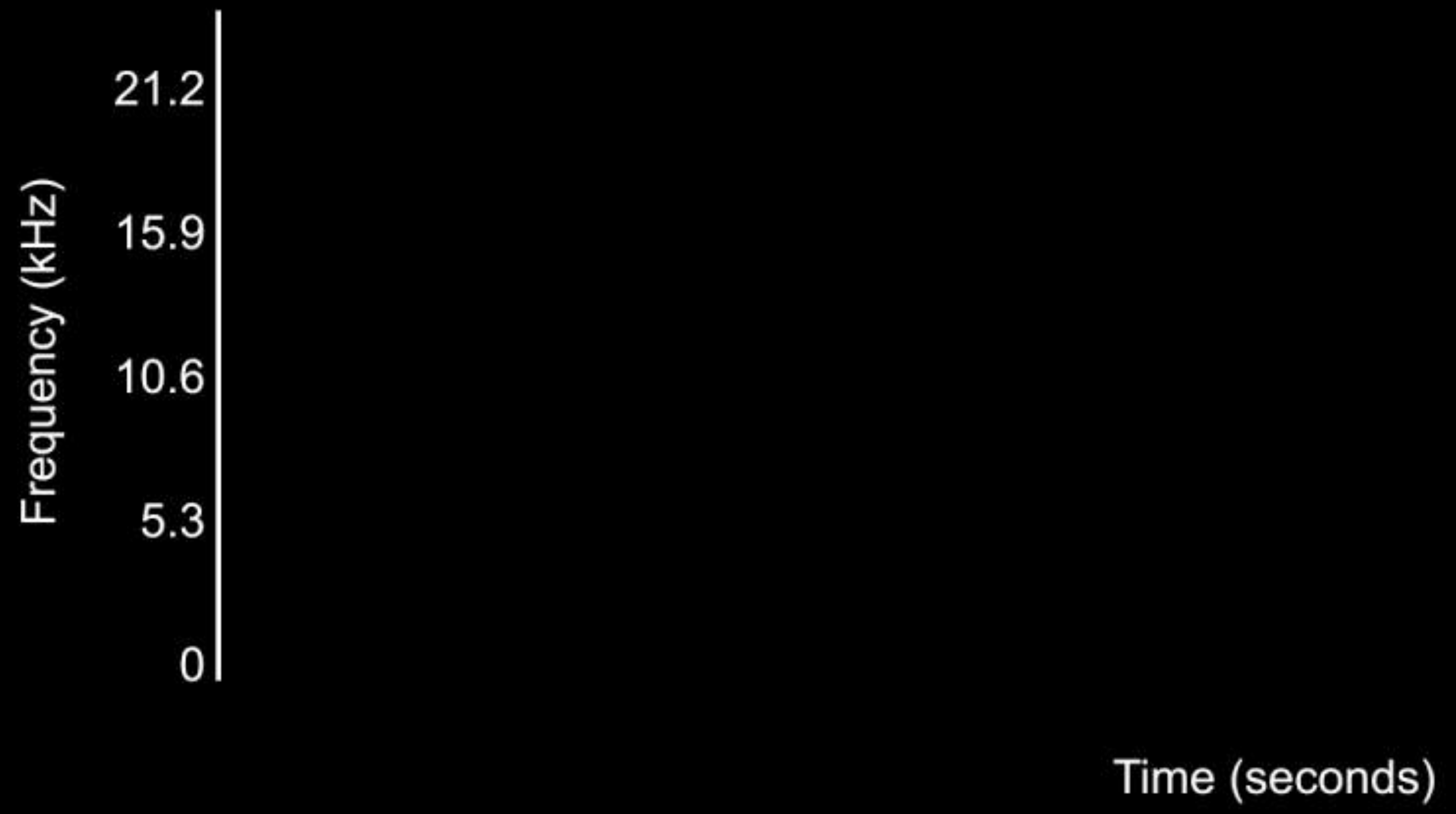


Waves

Can you guess the human activity?

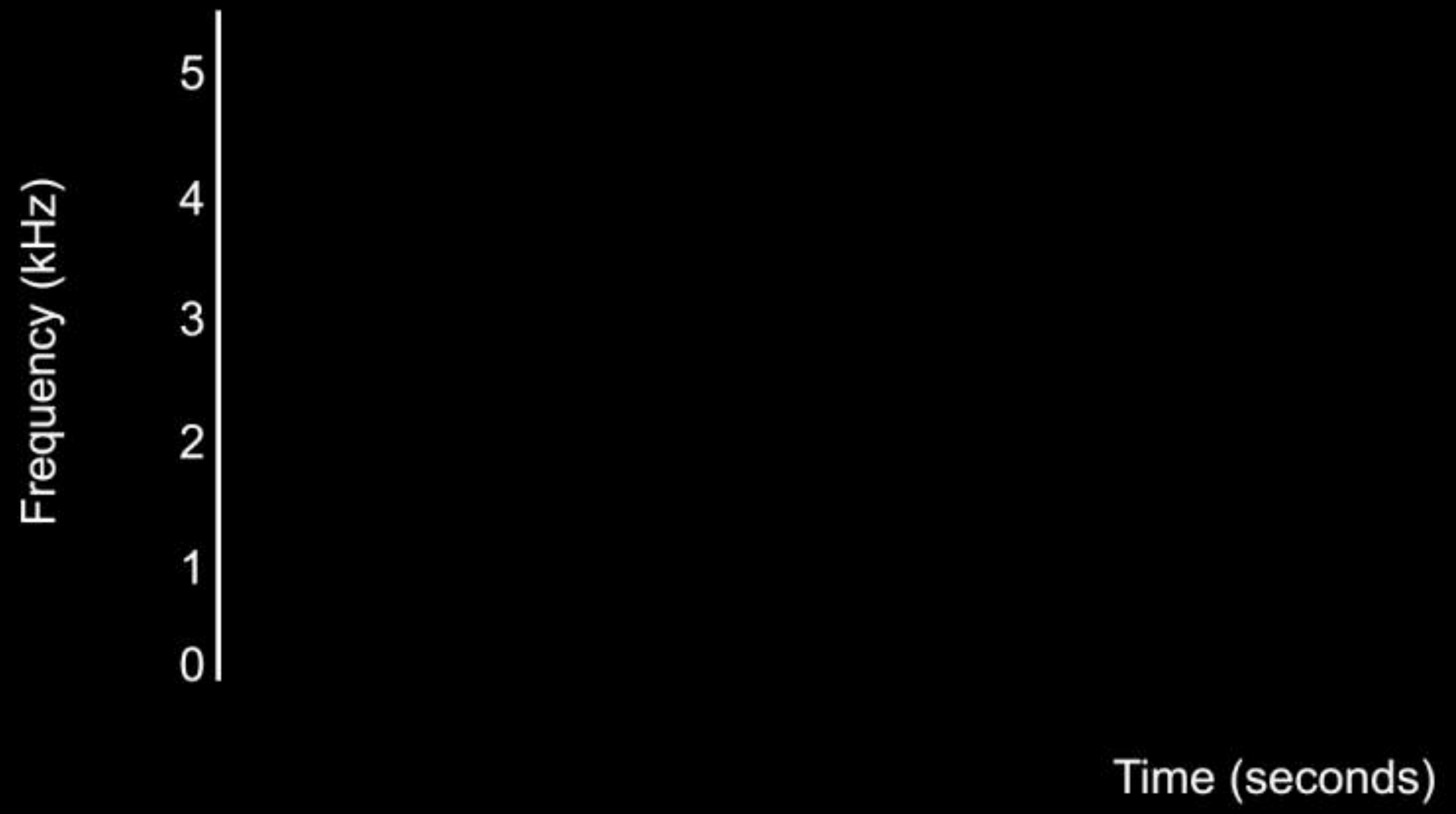


Can you guess the human activity?

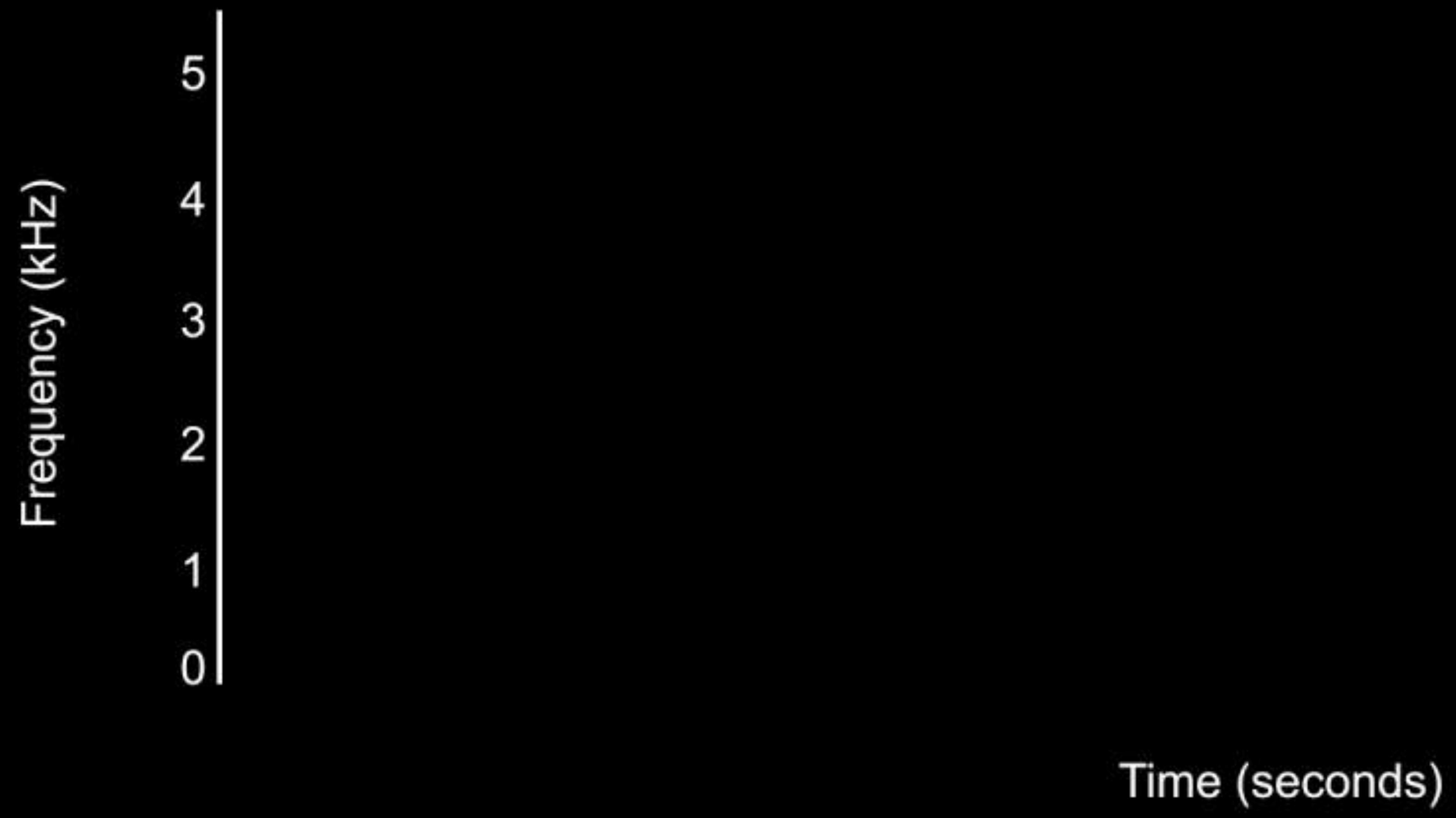


SCUBA Diver

Can you guess the human activity?



Can you guess the human activity?

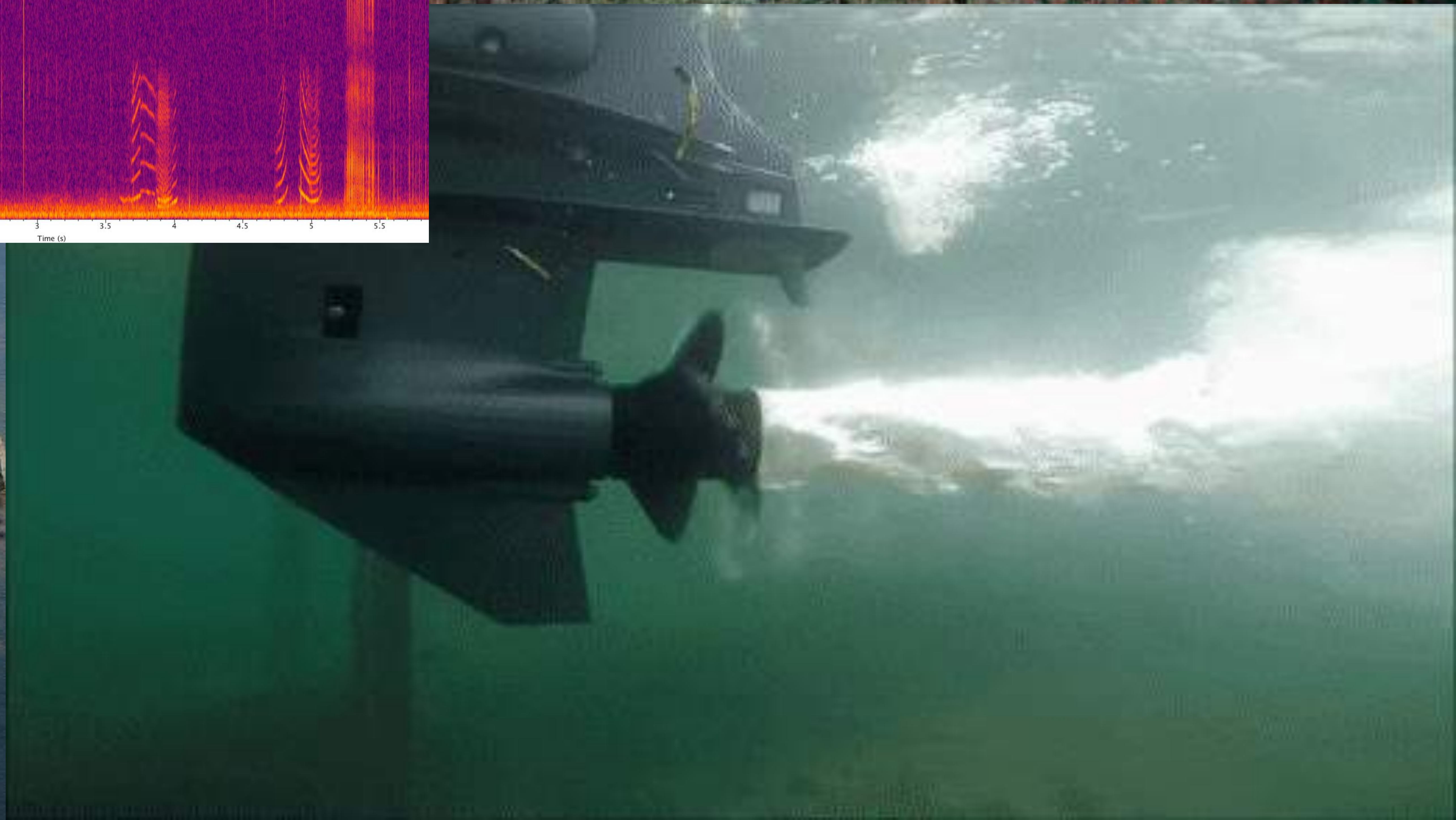


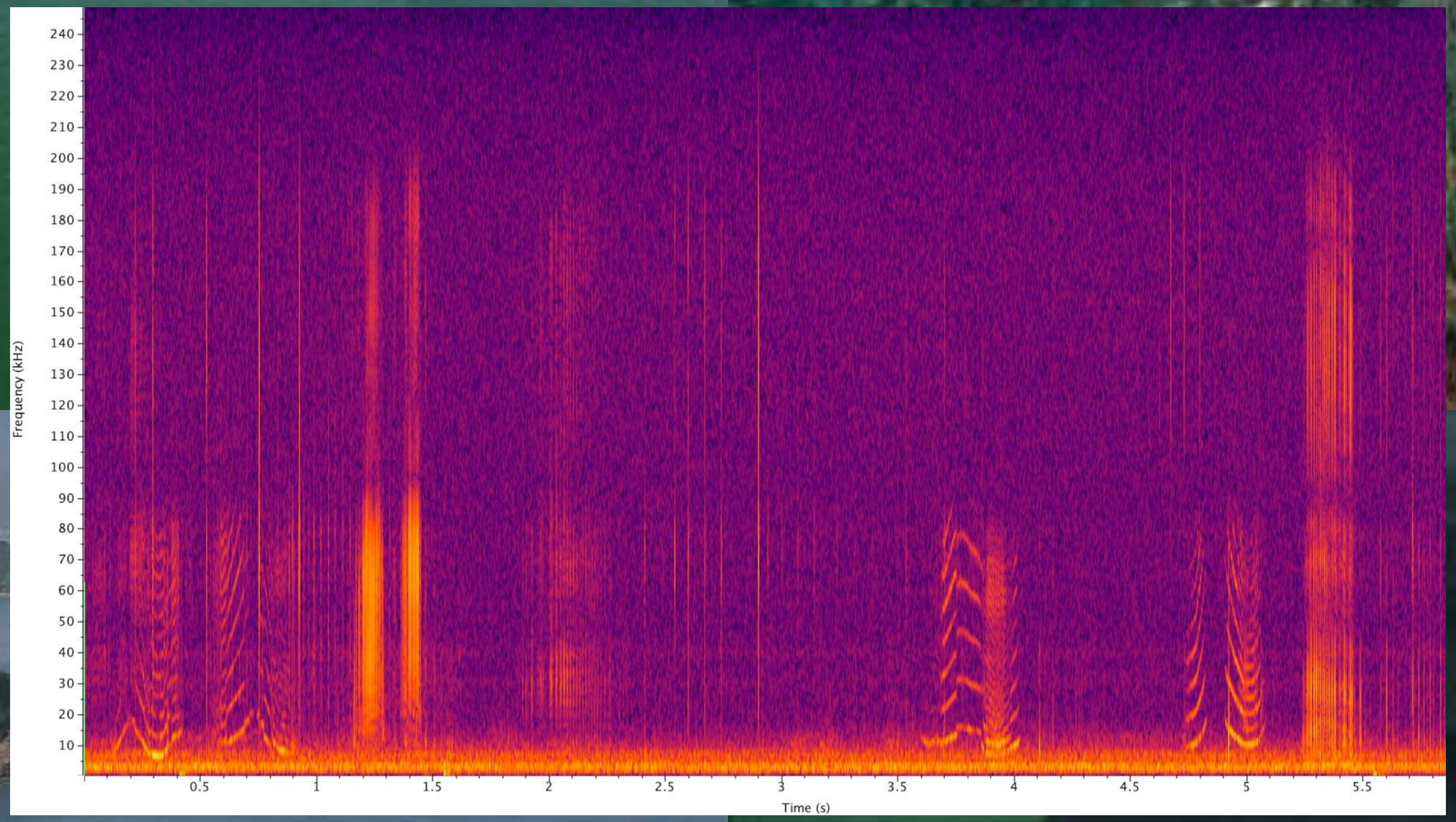
Container Ship

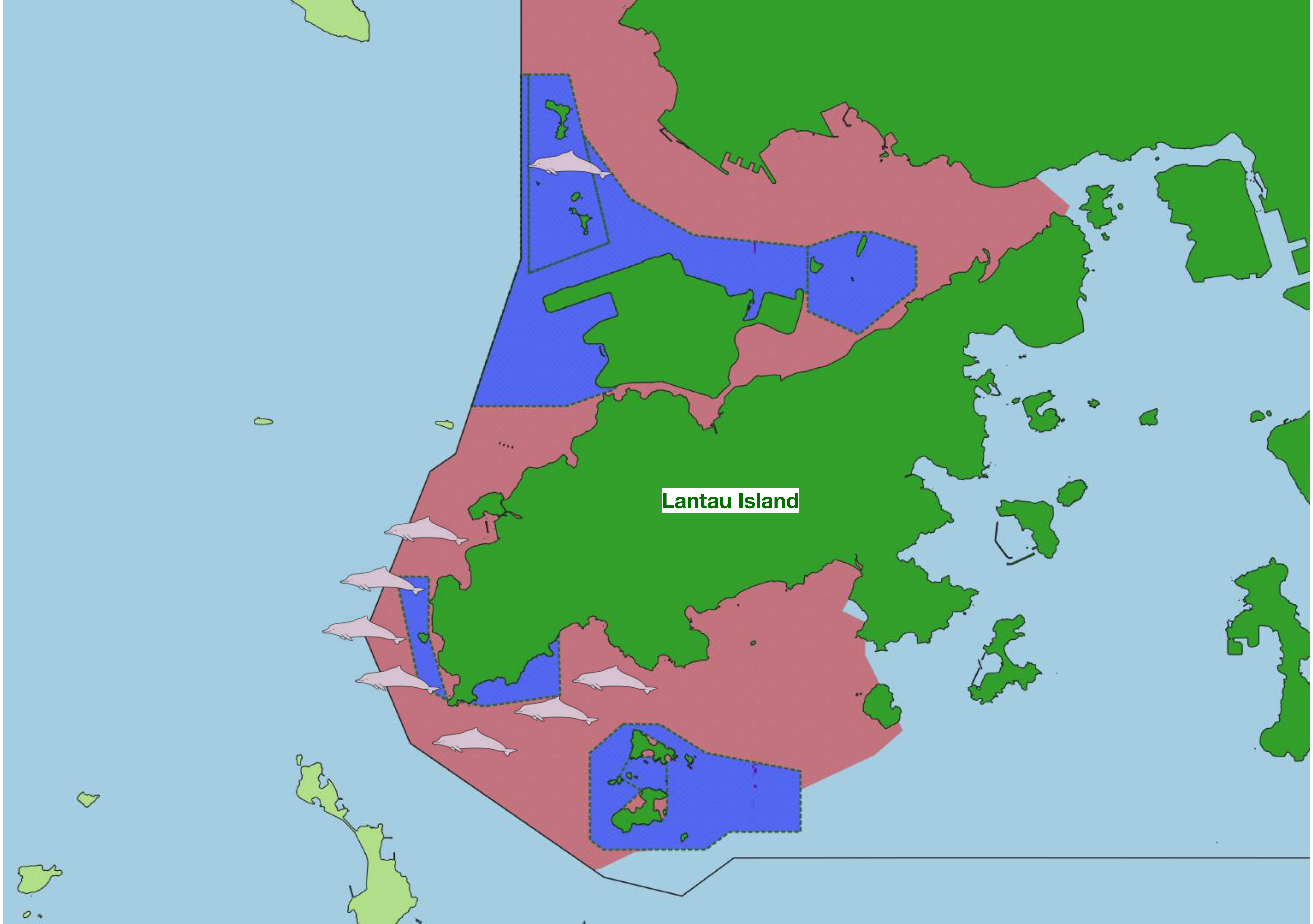
16
12
8
4
0
Frequency (kHz)
Time (seconds)
5
4
3
2
1
0
Frequency (kHz)
Time (seconds)
5
4
3
2
1
0
Frequency (kHz)
Time (seconds)
5
4
3
2
1
0
Frequency (kHz)
Time (seconds)

Discovery of *Sound in the Sea*

dosits.org




Frequency (kHz)
Time (s)
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5


Lantau Island

CETACEANS FROM THE AIR

THE USE OF DRONES IN CETACEAN RESEARCH

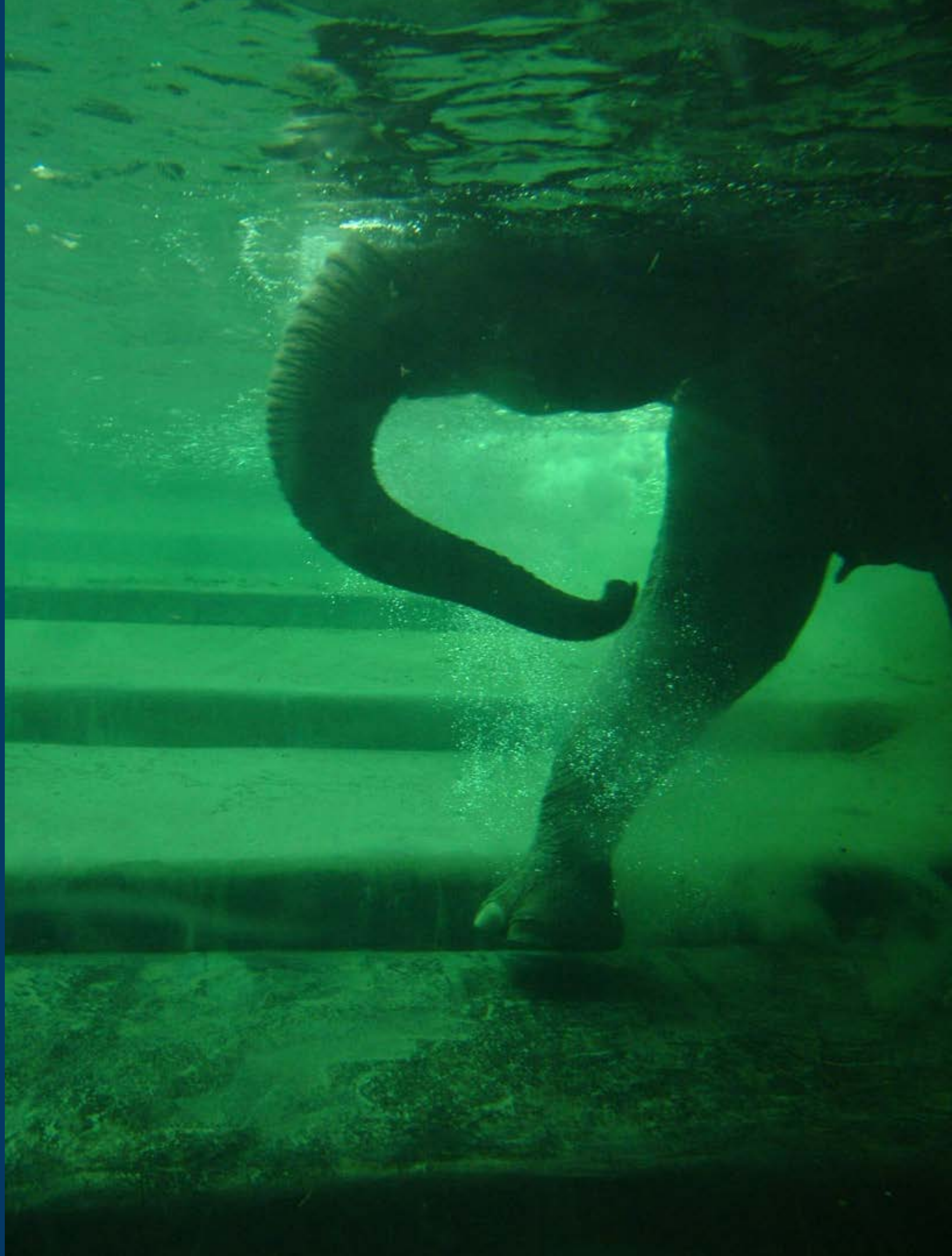
SEAMAR

CHALLENGES OF STUDYING CETACEANS

“Imagine you study elephants.

Now imagine you live at the bottom of a watering hole and are only able to observe them when they come to drink. You have to infer everything you can - about their life history, behaviour, physiology - from the briefest underwater glimpse of a trunk.

Where do you start? How do you start?”

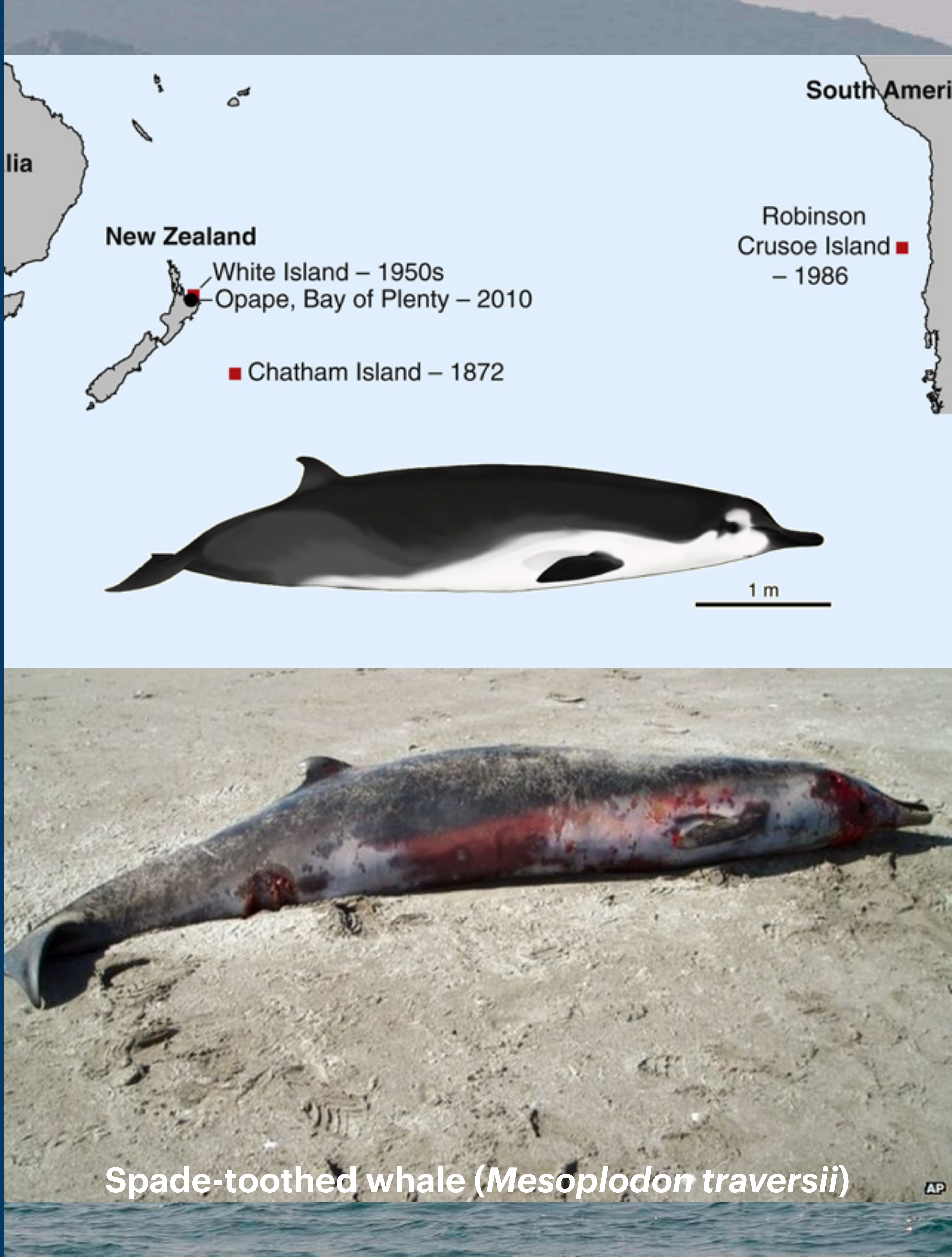


CHALLENGES OF STUDYING CETACEANS

Wild, free-living cetaceans are:

- **Difficult to observe**
- **Difficult to access** (laterally and vertically)
- **Difficult to follow** (spatially and temporally)
- **Difficult to detect** (cryptic and mobile)

Given all these challenges... How do we study them?



Spade-toothed whale (*Mesoplodon traversii*)

METHODS FOR STUDYING CETACEANS

1. Visual
2. Acoustic
3. Telemetry
4. Biopsy
5. Capture

Individual -> Population -> Species

VISUAL

- Actively searching for cetaceans
- Used to understand population abundance, density, distribution, habitat use, behaviour and life history
- Searches can be land-based, boat-based or aerial
- Allows longitudinal studies of populations

ACOUSTIC

- Passively listening for cetaceans
- Used to understand population abundance, density, distribution, habitat use and behaviour
- Deployment methods include static, drifting or towed
- Allows longitudinal studies of populations

TELEMETRY

- Attaching a sensor to an individual
- Attachment methods include suction cup, dart, bolts (i.e. invasive)
- Used to collect information on location, orientation, speed, depth, respiration, heart rate and immediate environment
- Data is used to understand behaviour and habitat use of an individual

BIOPSY

- Sampling skin and blubber from an individual
- Sampling methods involve pole-mounted or crossbow darts (i.e. invasive)
- Used to collect information on sex, reproductive status, genetics, stable isotopes and contaminant loads
- Data is used to understand the health status of an individual

CAPTURE

- Sampling blood and morphometrics from an individual
- Capture methods involve nets, sedation, restraint and handling (i.e. *very* invasive)
- Used to collect information on serology, toxicology and body condition
- Data is used to understand the health status of an individual

WHERE ARE THE GAPS?

????

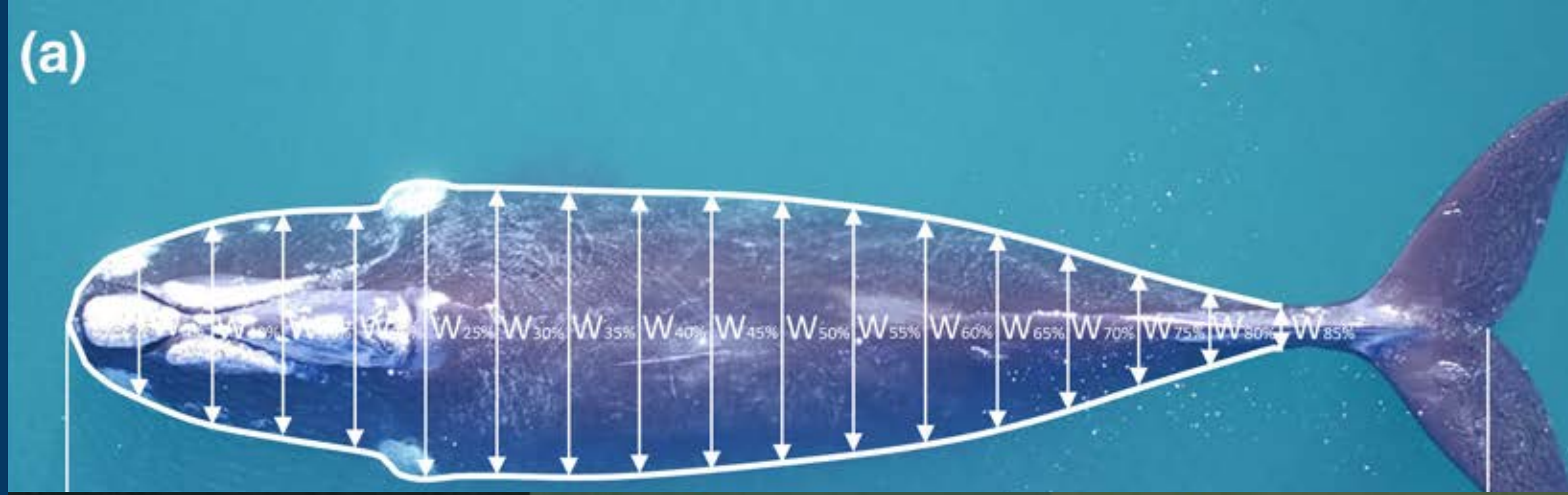
METHODS	TRADE-OFF	METHODS
Visual	POPULATION versus INDIVIDUAL	Telemetry
Acoustic	Large-scale verses fine-scale	Biopsy
	Non-invasive versus Invasive	Capture
	External metrics versus Internal metrics	

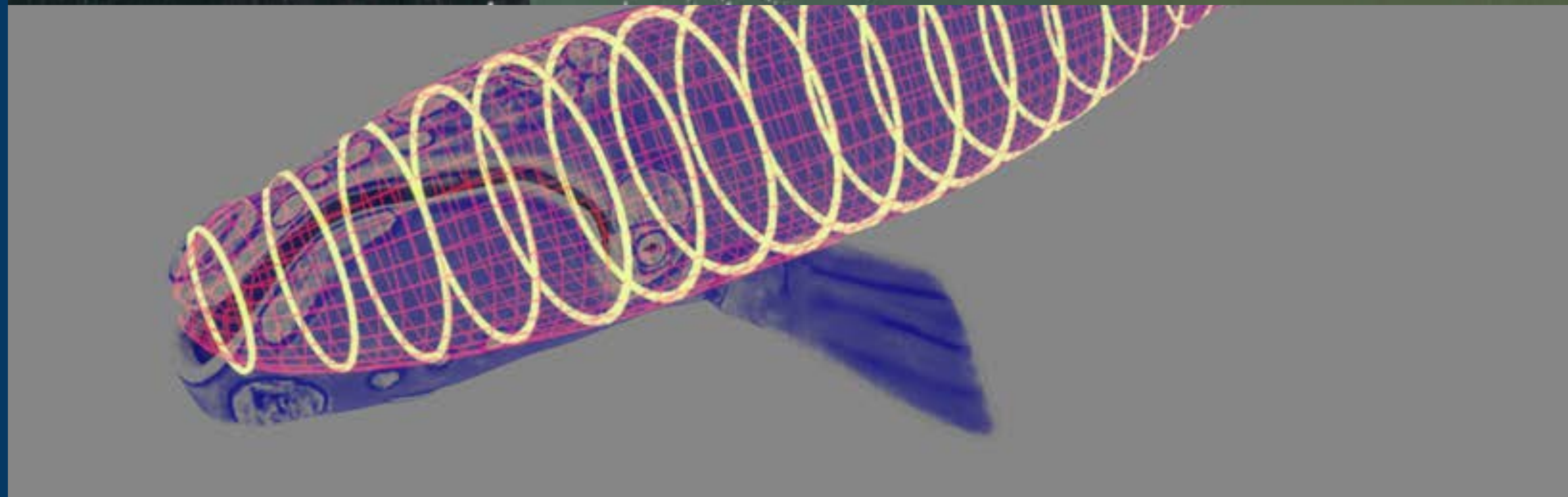
How do we link individual-level impacts to population-level impacts?

Costly
Specialist
INVASIVE

HOW DO DRONES BRIDGE THESE GAPS?

- Population abundance, density, distribution (visual, acoustic)
- Habitat use and behaviour (telemetry)
- Reproductive status (biopsy)
- SnotBot! (biopsy)
- Morphometrics and volumetrics (capture)
- Body condition (capture)






dji
ENTERPRISE
Tagging Whales From
Above With Drones

HOW ARE DRONES USED IN HONG KONG?

- Population abundance, density, distribution (visual, acoustic)
- Habitat use and behaviour (telemetry)
- Reproductive status (biopsy)
- SnotBot! (biopsy)
- Morphometrics and volumetrics (capture)
- Body condition (capture)


APPLYING DRONES
IN RESEARCH
SEAMAR

APPLYING DRONES IN RESEARCH

Drones are a tool that we apply to achieve a research objective

- *What is the research objective?*
- *What data is needed to achieve the objective?*
- *What tool can feasibly collect these data accurately and precisely?*


General aerial photography and video
360 aerial panoramas
Orthomosaic maps
Digital elevation model (DEM)
Elevation contours
3D point cloud (LiDAR)
Thermal imagery and mapping
Air, gas and water sampling
... and more!

APPLYING DRONES IN RESEARCH

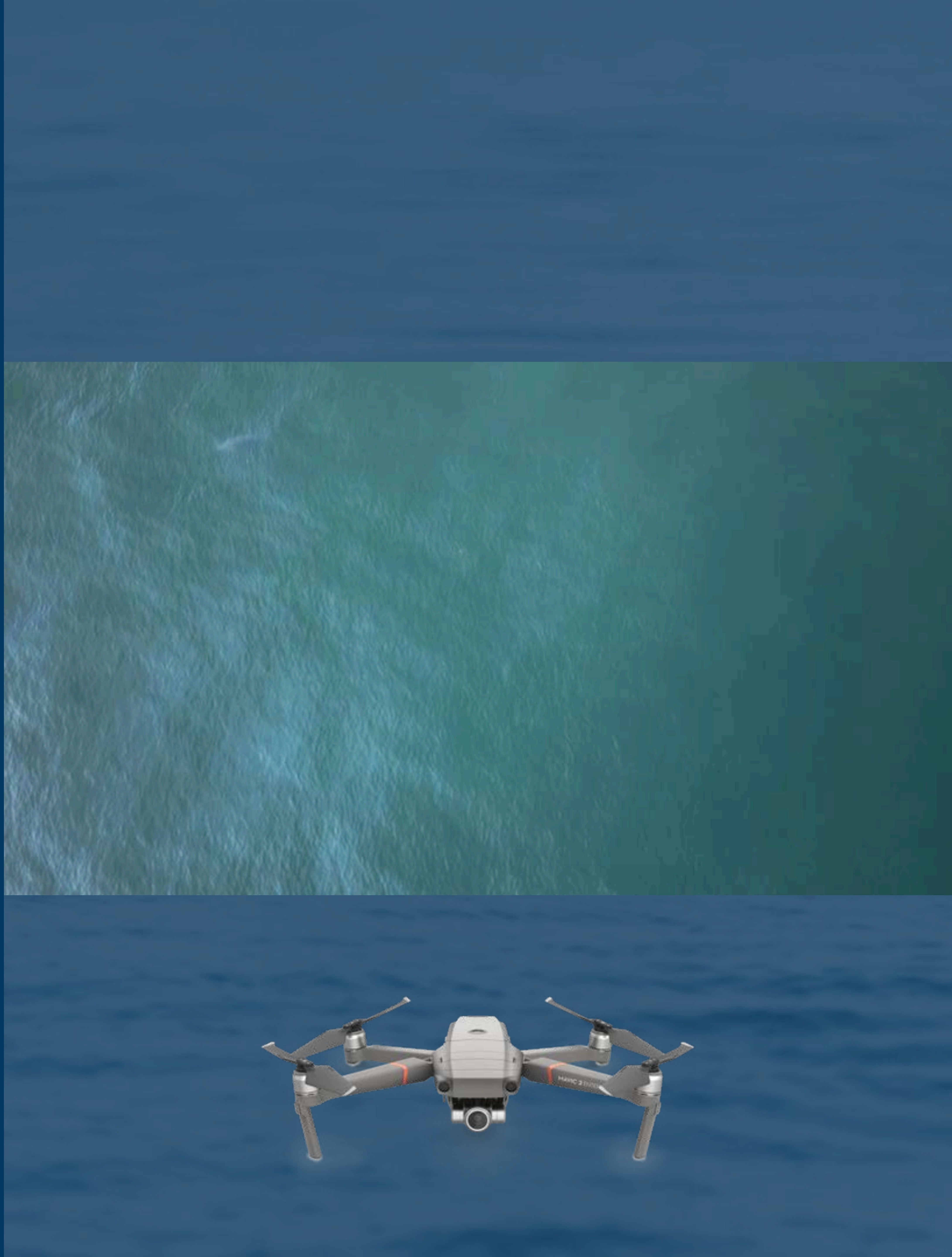
IMPORTANT CONSIDERATIONS

- Capabilities of the drone
- Capabilities of the payload
- Characteristics of target
- Launch and landing
- Topography
- Local laws and regulations

DRONE STUDY EXAMPLE 1

FINLESS PORPOISE

- Research Objective:
  - Ethogram of finless porpoises in Hong Kong waters
- Data:
  - High-definition video footage of a small (~1.8 m) highly mobile subject in a small area (< 100 m^2)



DRONE STUDY EXAMPLE 2

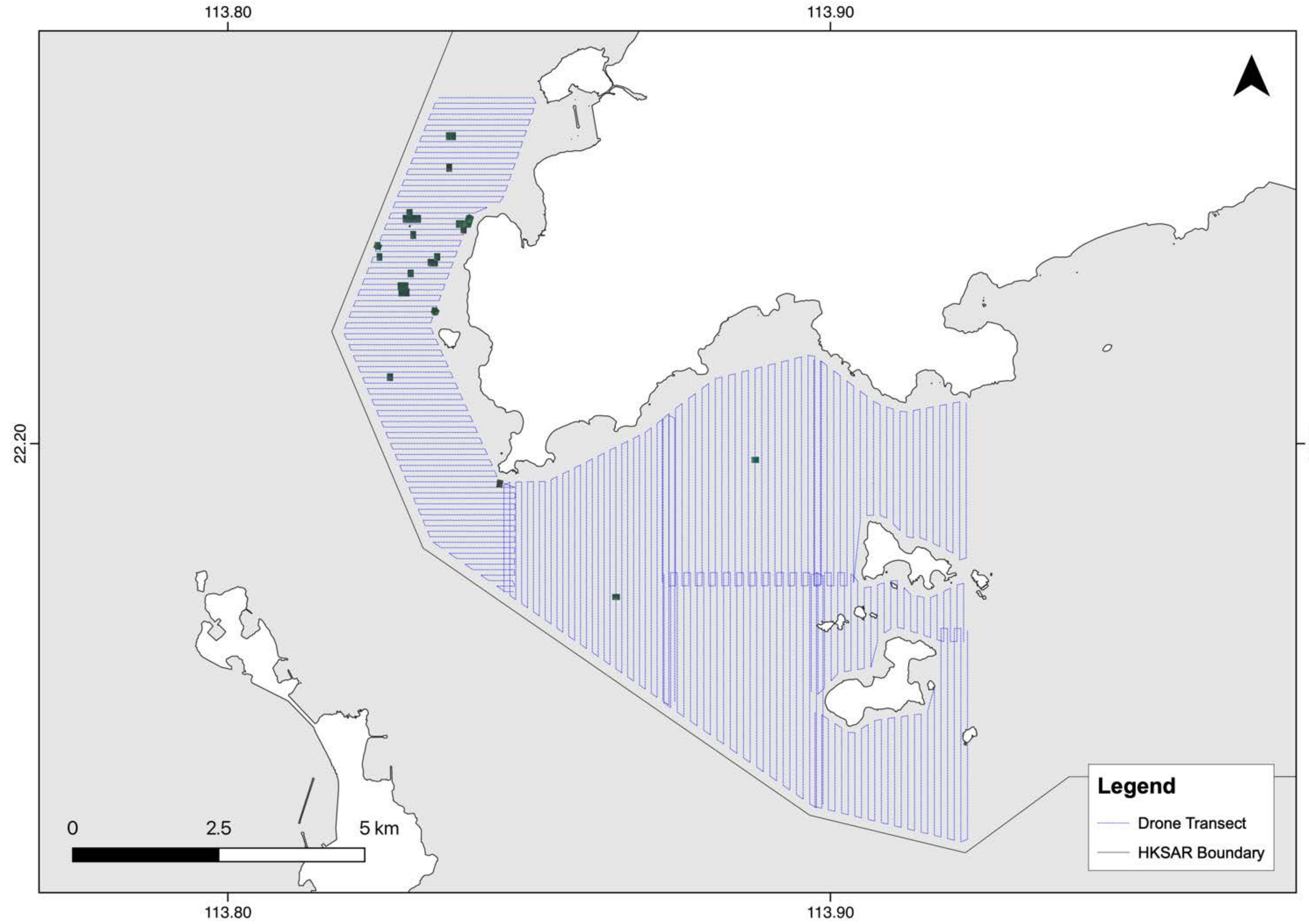
MARINE LITTER

- **Research Objective:**
  - Composition, density and distribution of marine litter at the Soko Islands
- **Data:**
  - High-resolution geo-referenced imagery capable of detecting *very* small (< 1 m) static objects in a medium area (< 5 km²)

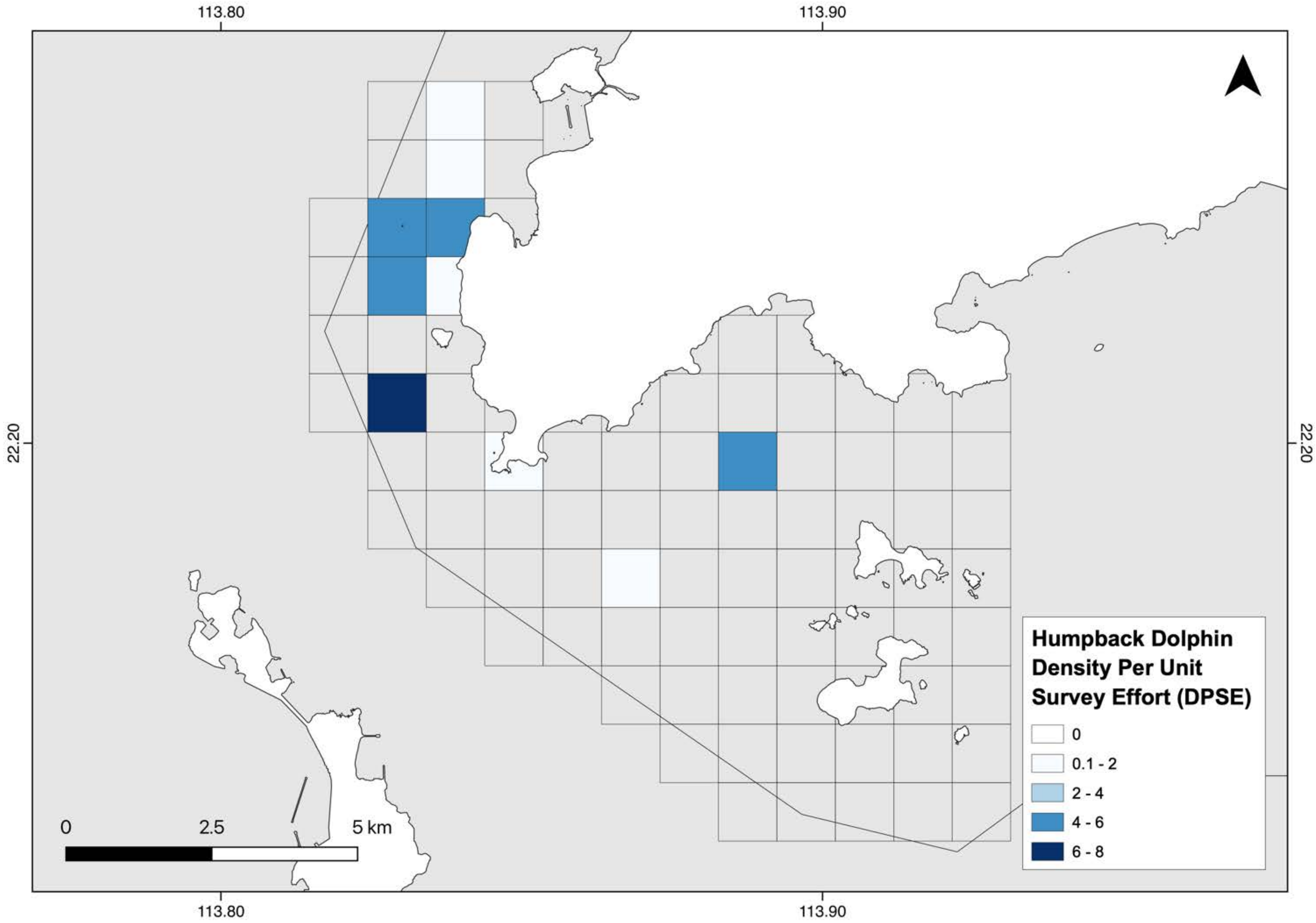
DRONE STUDY EXAMPLE 3

HUMPBACK DOLPHINS

- Research Objectives:
  - Density and distribution of humpback dolphins in Hong Kong waters
- Data:
  - High-resolution geo-referenced imagery capable of detecting small (~2.8 m) highly mobile subjects in a large area (> 100 km^2)



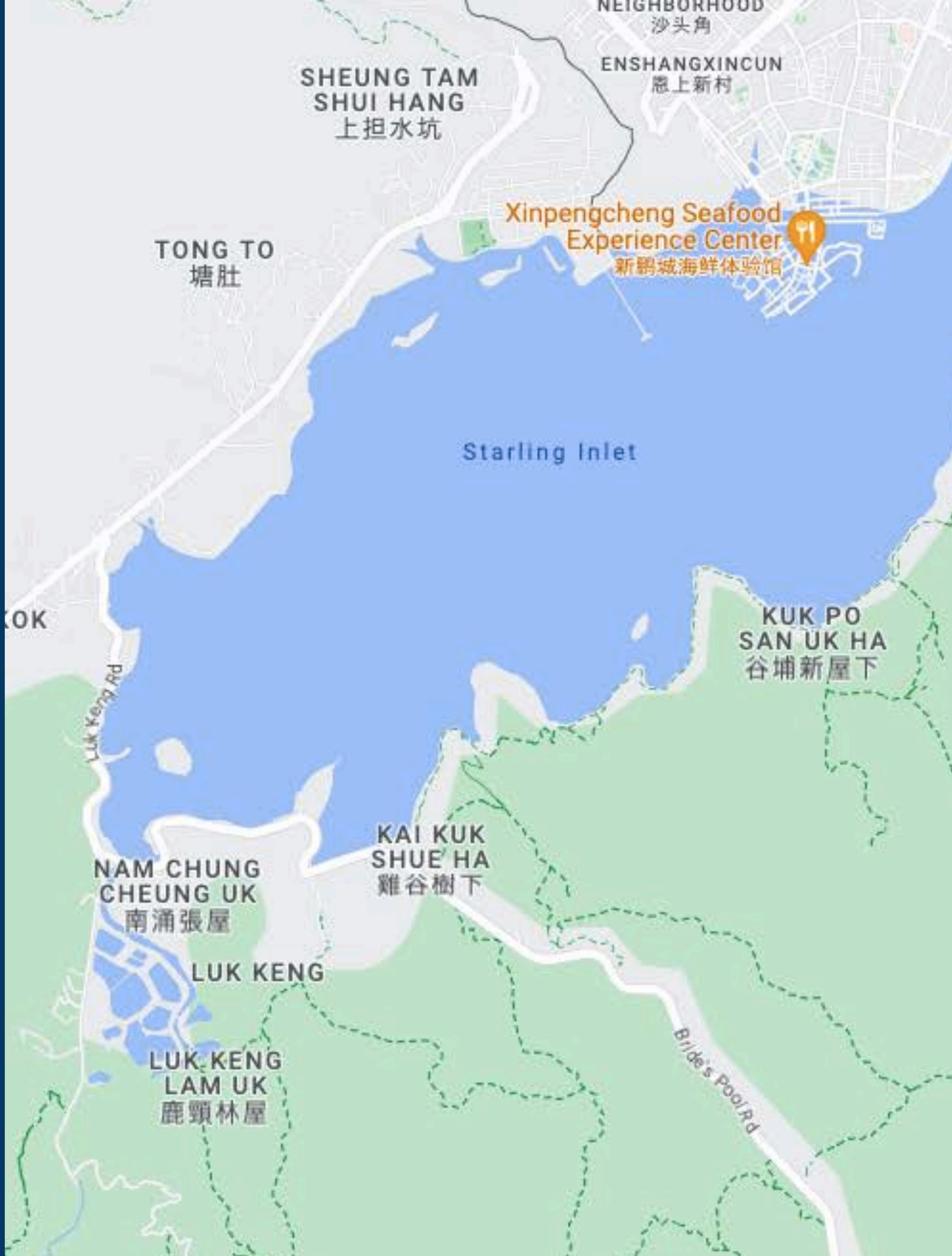
113.80
113.90
22.20
22.20
0
2.5
5 km
113.80
113.90
Legend
Drone Transect
HKSAR Boundary

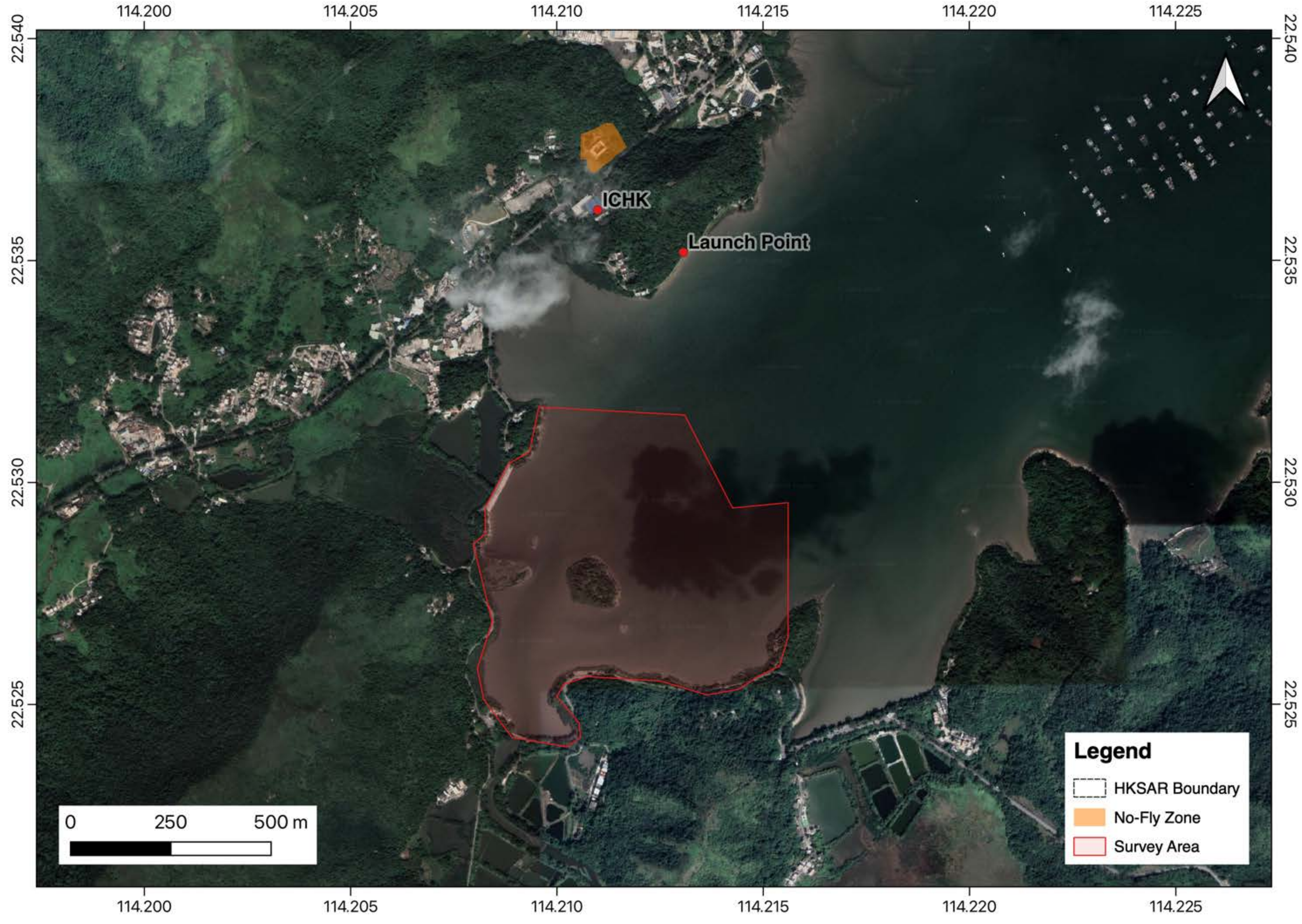

113.80
113.90
22.20
22.20
113.80
113.90
Humpback Dolphin Density Per Unit Survey Effort (DPSE)
0
0.1 - 2
2 - 4
4 - 6
6 - 8
0
2.5
5 km

DRONE PRACTICAL

COASTAL EROSION IN STARLING INLET

- **Research Objective:**
    - Produce a baseline orthomosaic map to document coastal erosion in Starling Inlet
- **Data:**
    - High-resolution geo-referenced imagery capable of detecting topographic details in a large area




114.200
114.205
114.210
114.215
114.220
114.225
22.540
22.535
22.530
22.525
ICHK
Launch Point
Legend
HKSAR Boundary
No-Fly Zone
Survey Area
0
250
500 m

HOW WILL YOU APPLY DRONES?

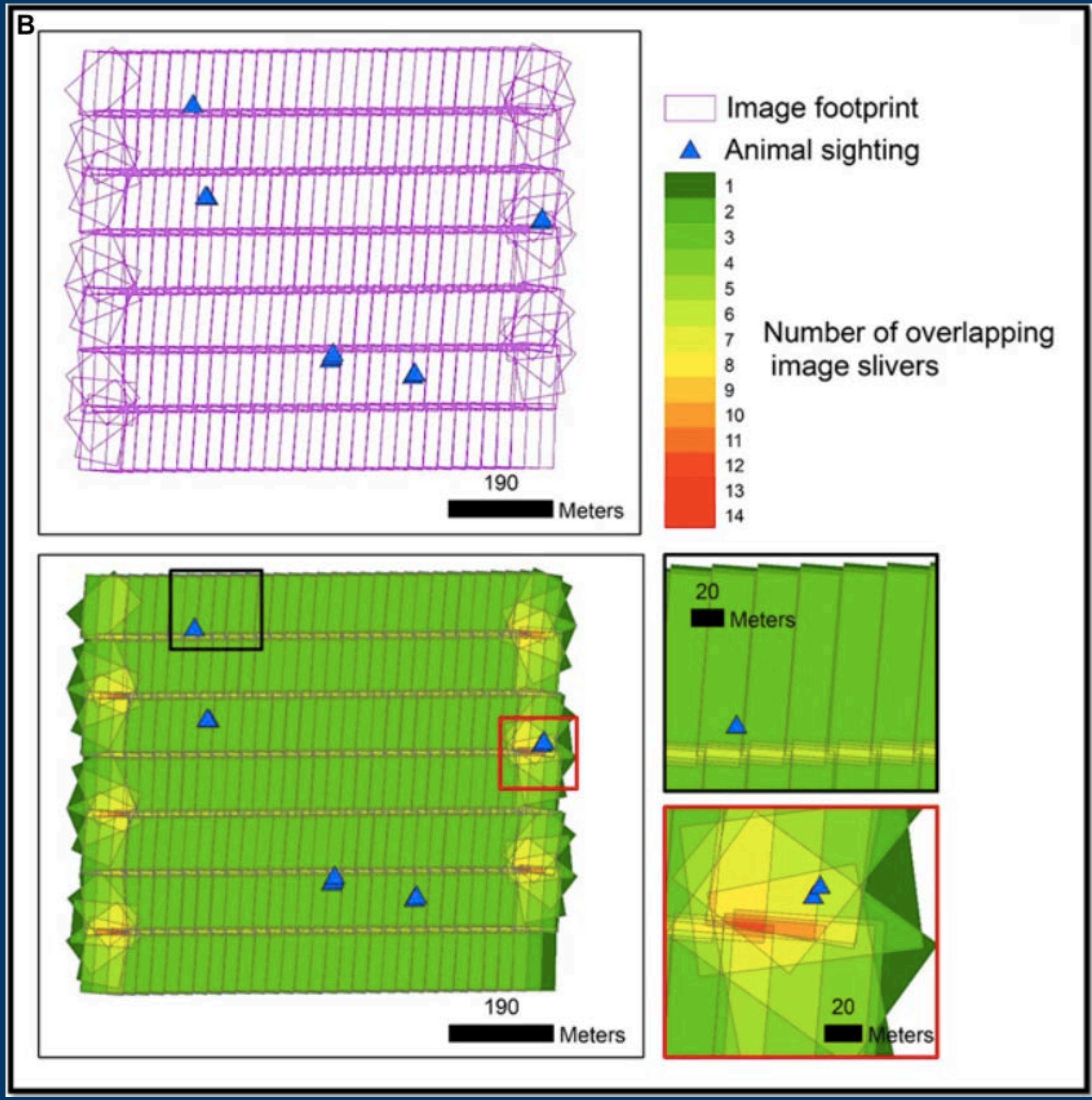
SEAMAR


EXTRAS
SEAMAR

HOW TO DESIGN A DRONE STUDY

CONSIDERATIONS: FLIGHT PARAMETERS

- Frontal overlap
- Side overlap
- Altitude
- Speed
- Ground sampling distance (GSD)
  - Image size
  - Sensor size
  - Focal length



Cleguer et al. 2021. A novel method for using small unoccupied aerial vehicles to survey wildlife species and model their density distribution. Frontiers in Marine Science, 8: 640338.