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High-resolution acoustic recordings of wild free-ranging short-beaked common dolphins for etho-acoustical and repertoire studies

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Abstract. Dolphins are highly vocal cetaceans with a complex acoustic repertoire. These marine mammals rely heavily on sound for critical activities: echolocation clicks for navigation and prey detection, whistles for social communication, and pulsed sounds for less well-documented purposes. Understanding their acoustic behaviour is essential for insights into their ecology, social structure, and responses to anthropogenic noise. However, to date, there has been a lack of open-access datasets of acoustic recordings of wild free-ranging short-beaked common dolphins (*Delphinus delphis*) coupled with observational data. Here, we present a new dataset (https://doi.org/10.5281/zenodo.14637674, Lehnhoff, 2025a) of high-resolution acoustic recordings of (*D. delphis*) observed in various behavioural states, including foraging, travelling, socializing, milling, and attraction to the boat. The dataset was collected in the northern Bay of Biscay, France, in the summers of 2020 to 2022 during surveys conducted as part of the DOLPHINFREE project. Audio recordings were made during opportunistic encounters using two devices: a single high-quality hydrophone (sampling rate 512 kHz and bit depth 32 bits) and a compact array of four hydrophones (256 to 512 kHz and 16 to 24 bits) for localization purposes. The dataset comprises over 400 min of unedited audio recordings of *D. delphis* accompanied by visual observations. In total, we identified about 68 000 echolocation clicks, 4600 whistle contours, and more than 350 pulsed sounds. This comprehensive resource is invaluable for detailed studies of the acoustic repertoire of (*D. delphis*), coupled with behavioural studies or analyses of the directionality of their acoustic emissions.

1 Introduction

This data descriptor makes available a bio-acoustic dataset of audio recordings of wild free-ranging short-beaked common dolphins (*Delphinus delphis*) collected at sea. These recordings are accompanied by visual observations, providing a comprehensive contextual framework for each file. Comparable audio datasets are available for other delphinid species (e.g. Di Nardo et al., 2023). However, to date, there has been a lack of open-access datasets of acoustic recordings of *D. delphis*.

Short-beaked common dolphins emit sounds that are similar to those of other delphinid species. These acoustic signals can usually be divided into three main categories: echolocation clicks, whistles, and rapid sequences of clicks (or pulsed sounds, often referred to as buzzes and/or burst pulses; Jones et al., 2020).

Echolocation clicks are short (typically $< 100\,\mu s$), broadband (ranging from 20 kHz to over 150 kHz, Henderson et al., 2012) pulses used primarily for navigation, prey detection, and object recognition (Au, 1993; Tyack, 1986; Norris et al., 1961). For *D. delphis*, these clicks have been the most frequently observed when the animals are travelling (e.g. Henderson et al., 2012).

Whistles are narrowband, frequency-modulated tonal sounds (usually between 5 and 25 kHz) that are thought to be used for inter-individual communication (Caldwell and Caldwell, 1968; Au and Hastings, 2008), individual identification (signature whistles, Sayigh, 1992), and coordination of group movements (Lammers and Au, 2003; Branstetter et al., 2012). The whistle repertoire of *D. delphis* is well-described (e.g. Ansmann et al., 2007; Pagliani et al., 2022). However, there have been recent advances with formal identification of signature whistles for this species (Fearey et al., 2019; Cones et al., 2023; Agafonov et al., 2024), showing the importance of these signals in social interactions.

Pulsed sounds (Herman and Tavolga, 1980), including burst pulses and buzzes, are rapid sequences of clicks whose function remains a subject of debate (Ridgway et al., 2015). The classification of these sounds can be complex, as they form a graded continuum between clicks and whistles (Murray et al., 1998). Usually, their categorization is based on an inter-click interval (ICI) (Martin et al., 2019). Buzzes are characterized by very short ICIs and high repetition rates and are typically associated with the terminal phase of prey capture (Wisniewska et al., 2014; Ridgway et al., 2015), while burst pulses are more variable and are frequently observed during close-range social interactions such as agonistic or intimate encounters (Overstrom, 1983; Lammers et al., 2006).

The dataset that we provide is extracted from audio recordings collected during surveys at sea made for the DOLPHINFREE project off the coast of Penmarc'h, Brittany, France, in 2020, 2021, and 2022. The aim of this project was to create a bio-inspired acoustic signal to reduce the risk of fishery by-catch of *D. delphis* (Lehnhoff et al., 2022). To that end, surveys were conducted in order to visually and acoustically assess the behavioural responses of wild free-ranging common dolphins to the bio-inspired acoustic signal (co-created by the University of Montpellier and IFREMER) emitted by version 1 of the CETASAVER-DOLPHINFREE beacon (OCTech).

These surveys generated a large number of acoustic recordings made with and without the activation of the beacon, with the presence or absence of a fishing net, and with dependence on the behavioural state of the dolphins (i.e. foraging, travelling, socializing, milling, or being attracted to the boat), in order to assess the acoustic activities of the animals under different conditions. Only the acoustic recordings collected before the beacon was turned on are made available, as (i) the DOLPHINFREE signals are protected by intellectual property rights (property of the University of Montpellier and IFREMER) and, (ii) in order to deliver data that are not dependent on the activation of the device, the study of the natural behaviour of the dolphins during the different states cited above is enabled.

The study of the sounds emitted by cetaceans represents a field of research with numerous applications, including the investigation of social interactions, behavioural patterns, localization (including trajectory reconstruction), and the identification of these animals (e.g. Caldwell and Caldwell, 1968; Overstrom, 1983; Poupard et al., 2019; Halkias et al., 2013). With this dataset, we hope to provide high-quality audio recordings of free-ranging short-beaked common dolphins, which should be of interest for the study of the acoustic repertoire of these animals, their acoustic behaviours, and the directionality of their acoustic emissions.

2 Material and surveys

2.1 Study area

Non-systematic scientific surveys were conducted at sea from semi-rigid pneumatic boats carrying observers off the coast of Penmarc'h, Brittany, France (see Fig. 1). The area was chosen as it is locally known for its frequent sightings of free-ranging dolphins, which have been observed just a few nautical miles off the coast, thereby facilitating opportunistic encounters. In addition, the occurrence of dolphin strandings in the area (Peltier et al., 2020) contributed to the selection of this site. Surveys were performed during the periods 11–17 July 2020, 9–18 July 2021, and 16–24 July 2022. They were only conducted when the weather conditions allowed sightings of the dolphins and identification of their behaviours under windy conditions ≤ 10 kn and with a swell ≤ 1 m.

2.2 Acoustic devices

Two types of devices were used to make acoustic recordings: (i) a single Ocean Sonics icListen HF hydrophone and (ii) a custom-made compact four-hydrophone tetrahedral array (TETRA). The objective of the audio monitoring using the HF hydrophone was to record the acoustic signals emitted by dolphins at close range from the observation boat. These signals could then be correlated directly with visual observation of the behaviours of the dolphins. The recordings made using TETRA were dedicated to the study of the angular movements of the dolphins during the surveys. As these devices were not designed for the same purposes, they were often deployed during different recording sequences.

2.2.1 Main hydrophone

The Ocean Sonics icListen HF hydrophone (see Appendix B2 for the technical details) was used during sur-

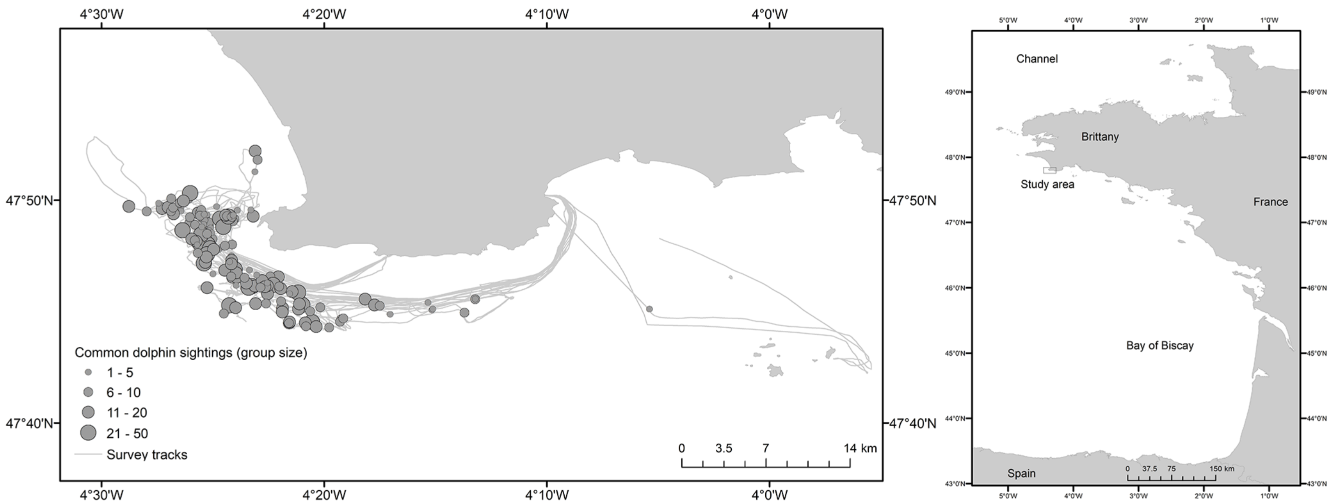

Figure 1. Map of dolphins encountered during the 2020, 2021, and 2022 DOLPHINFREE surveys conducted at sea off the coast of Penmarc'h, Brittany, France.

veys at sea in order to record short-beaked common dolphin acoustic signals. This high-frequency hydrophone was used to record sounds in one channel, with a sampling rate of 512 kHz and an audio bit depth of 32 bits. When the observation boat was stationary (engine off), this hydrophone was deployed from one side of the boat and positioned at −3 m under water. These procedures allow for high-quality sampling of the raw acoustic signals in the vicinity of the boat.

2.2.2 Compact hydrophone array

A custom-made prototype of a compact array of four hydrophones was deployed during the surveys. The device (TETRA, Fig. 2) has a tetrahedral shape, with one hydrophone at each of its apexes: one CR3 spherical hydrophone with a linear frequency range of up to 180 kHz and three SQ26 cylindrical hydrophones with satisfactory responses up to 50 kHz (see Appendices B3 and B4 for the technical details). The array is made of PVC tubes joined by 3D-printed parts and connected to a QHB motherboard made by the SMIoT laboratory (Barchasz et al., 2020) at the University of Toulon, France (technical specifications are available online at https://sabiod.lis-lab.fr/pub/QHB.pdf, last access: 1 April 2025).

This array was used in 2021 and 2022 to record audio in four channels at 256 to 512 kHz with a bit depth of 16 to 24 bits, depending on the survey sessions. Its materials and size (about 90 cm in length) make it a compact, portable, and practical device. Once in the water, it is left to drift freely under a buoy at −3 m under water and is monitored by observers on board. Consequently, when both recording devices were deployed, audio recordings made with TETRA might differ from those from the icListen hydrophone due to the distance between the two devices. It should also be noted that this version of TETRA was an initial prototype, which has since been improved in subsequent versions (see Glotin et al., 2024).

2.3 Survey design

During the surveys, two to three people were present on board to navigate, to deploy the acoustic equipment, and to take notes on the visual observations made of the observed groups of dolphins (see Fig. 3). A group of dolphins was defined as any number of the animals observed within five body lengths of another that was conspecific, moving, and behaving in the same manner (Shane, 1990; Stockin et al., 2008; Filby et al., 2013). The distances of each group of dolphins from the boat were initially estimated using rangefinder binoculars (Bushnell Fusion 10 × 42) that enabled visual observers to get accustomed to estimating distances at sea. Once the observers were used to estimating distances, the binoculars were set aside as this allowed for quicker visual observations, which was a more pragmatic approach.

The DOLPHINFREE surveys required a group of dolphins to show a constant behavioural state (defined in Table 1) for at least 1 min of observation, meaning that the observers waited until the dolphins presented a homogeneous behavioural state before starting to record. As soon as this condition was met, the boat was stopped and the engine and sonar were switched off. Then, the recording devices were set: the icListen hydrophone at −3 m from one of the sides of the boat and the TETRA antenna at −3 m under a buoy left to drift from the other side of the boat. However, it should be noted that the TETRA antenna was only deployed when drift conditions enabled the observers on board to maintain visual contact with the buoy.

As stated in the Introduction section, only the recordings made before the emission of signals by the DOLPHINFREE acoustic beacon are available here. However, other signals

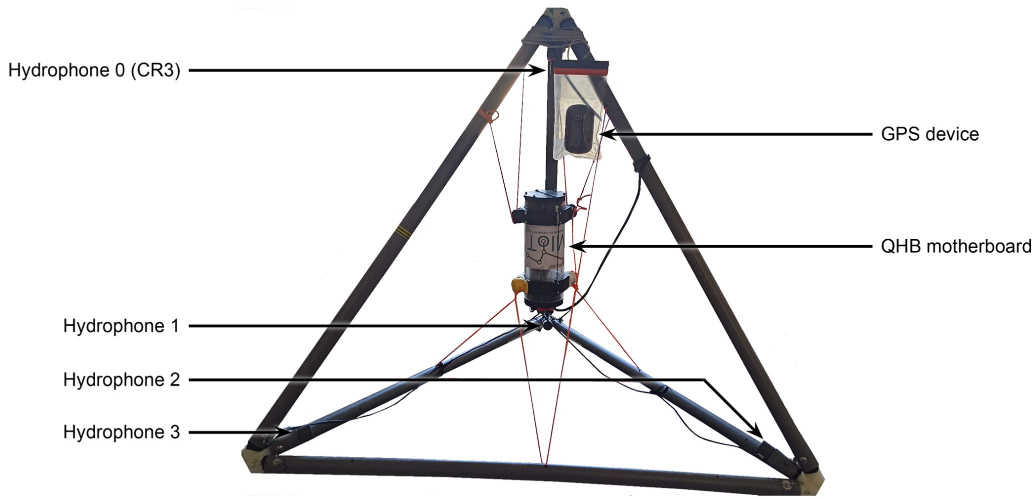

Figure 2. Annotated photo of the TETRA antenna used during the 2021 and 2022 surveys of the DOLPHINFREE project. TETRA's sides are ≈ 90 cm in length. Photograph taken by Loïc Lehnhoff before the surveys.

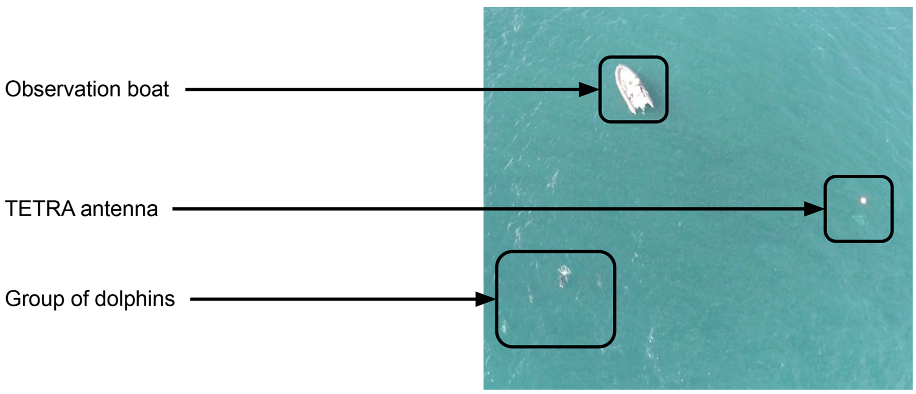

Figure 3. Experimental layout during the DOLPHINFREE surveys. Image captured by a DJI Phantom drone piloted by Bastien Mérigot.

were tested during part of the surveys: classical music pieces and whistles of orcas. The audio recordings of these sequences are fully available. In addition, during some surveys, a fishing net was set under water to simulate the conditions under which by-catch occurs. The distribution of audio files according to the behaviour observed and the presence or absence of a fishing net is presented in Fig. 4. Four fishing nets were utilized in the course of the surveys. While they do not constitute an exhaustive sample of all the existing nets deployed by fishers, they still represent a diverse sample of fishing gear. The technical specifications of these nets are provided in Appendix B1.

3 Data and methods

This section describes the files and data types that will be found in the dataset (https://doi.org/10.5281/zenodo.14637674, Lehnhoff, 2025a) that is made available.

3.1 Observation notes

Observation data were collected manually during the surveys, following a custom-made data table (see Appendix A). Then, notes were standardized and associated with each audio file independently. These visual observations are available as .xlsx files, distinct for each year and acoustic recording device. Each file contains the values described in Table 2. Animals within a group often exhibited the same behavioural state (as defined in Table 1). Behavioural states were relatively easy to identify and distinguish from each other. However, in some cases, the dolphins may have changed their behaviour within the observational window, exhibited different behavioural states within the same group, or displayed two different states simultaneously (notably attraction to the boat and socializing during our surveys). To take these cases into account, the behavioural states were recorded as a percentage of the behaviours observed each minute. In addition, each observation was associated with the name of the observer to help identify potential biases.

Table 1. Definitions of the behavioural states of common dolphins recorded in 2020, 2021, and 2022, according to Van Canneyt et al. (2006), Berg Soto et al. (2013), and Filby et al. (2013) from Lehnhoff et al. (2022).

State	Definition
Foraging	Dolphins were involved in any effort to pursue, capture, and/or consume prey, as defined by observations of two or more of the following: fish chasing, erratic movements at the surface, multi-directional diving, coordinated deep diving, and rapid circle swimming. Prey and hunting birds were often observed at the surface.
Travelling	Dolphins engaged in persistent, directional movement, making noticeable headway along a specific compass bearing. Group spacing varied and individuals swam with short (< 20 s), relatively constant dive intervals.
Socializing	The animals were involved in active surface behaviour (frequent surfacing and breaching) that included physical interactions among group members and sometimes aerial behaviour.
Milling	Dolphins showed little movement, tended to remain in the same place, and either spent time floating at the surface or surfaced asynchronously.
Attraction	Dolphins came towards the boat and swam at a distance of a few metres along it, following its direction.

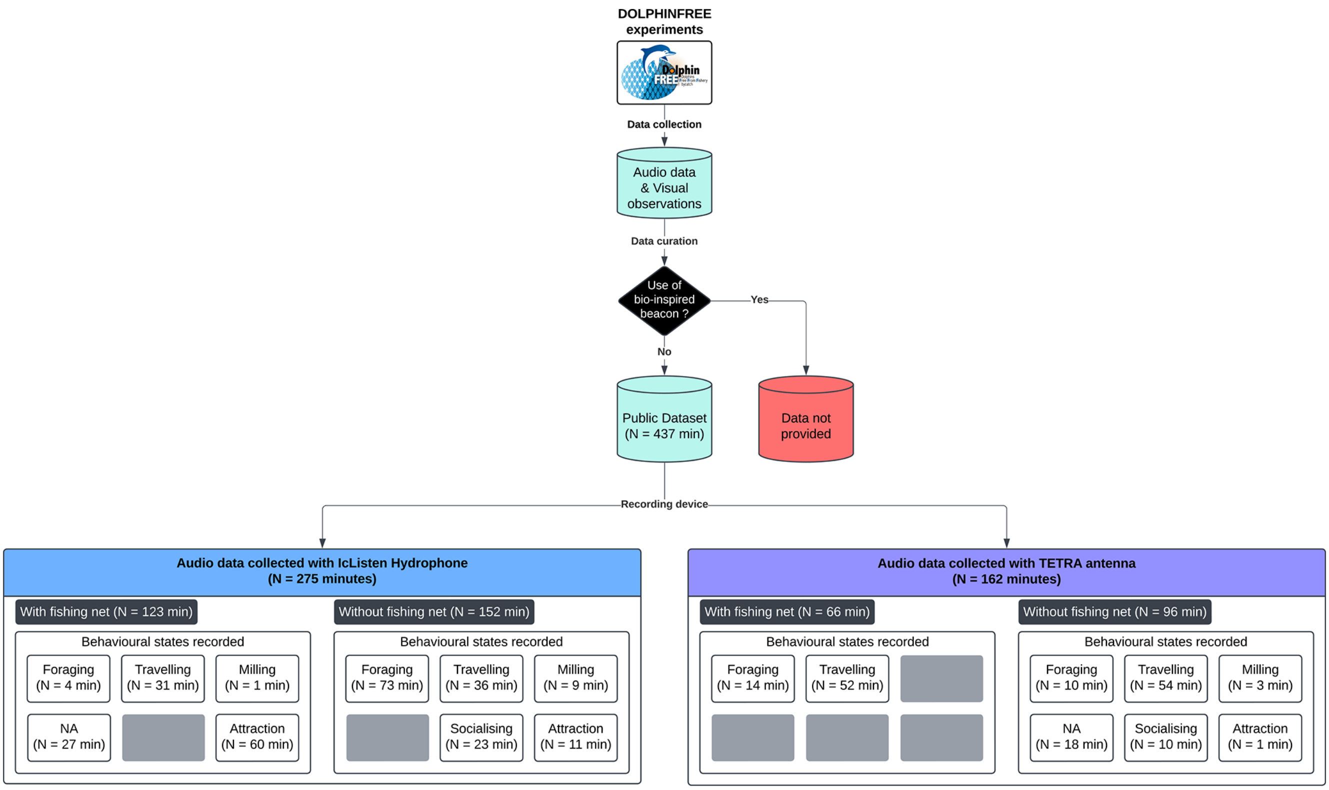

Figure 4. Diagram illustrating the distribution of data collected as part of the DOLPHINFREE surveys, with a focus on the data made available depending on the presence of a fishing net and the observed behavioural state of the dolphins.

Table 2. Descriptions of the column headers in the visual observation data (XLSX) files.

Column name	Meaning	Value format
audio_file	Name of the .wav file	[date]_[time].wav
datetime_utc	Start date and time of recording	YYYY-MM-DD HH:MM:SS
observers	Names of observers taking notes	firstname_lastname
ID_group	Identification number of a group of dolphins	Integer
ID_sequence	Identification number of each survey sequence	Integer
group_size	Number of individuals in a group	Integer
fishing_net	Presence or absence of a fishing net	“present” or “absent”
fishing_net_type	When present, the type of fishing net deployed	“type_of_net ”
percent_[behaviour]	Percentage of observed behaviour as defined in Table 1	Integer
behavioural_event	Special behavioural events	jumps, spy-hopping, etc.
distance	Distance from the boat to the closest visible dolphin	Integer
group_clustering	Aspect of the spacing between the individuals	“compact” or “scattered”
direction	General direction in which the group is heading	“continuous” or “variable”
speed	Average speed of the animals (slow/fast threshold: $\approx$ 10 kn)	“slow”, “variable”, or “fast”.
diving_time	Average diving time of the animals (normal/long threshold: 2 min)	“normal”, “variable”, or “long”
activation_sequence	Experimental treatment (relative to the emission of signals)	“before”, “during”, “after”, or “control”
signal	Type of signal loaded into the emitter	See the `signal_codes.txt` file.
sonar_noise	Indicates whether a sonar was unintentionally recorded	0 (no) or 1 (yes)
special_observations	Any additional observation	Notes

3.2 Audio files

These are raw files obtained from the recording of wild free-ranging short-beaked common dolphins during the DOLPHINFREE surveys. There are 275 unedited 1 min files of audio recordings made using the icListen hydrophone. These files have a sampling rate of 512 kHz with 32-bit resolution in one channel.

As TETRA is a custom-made device, we experimented with different configurations of its QHB motherboard, leading to audio recordings made with varying parameters. Overall, 117 files are available, which in total add up to 162 min of audio data. Files obtained from the TETRA antenna were recorded in four channels (corresponding to its four hydrophones) and have varying sampling rates (256 or 512 kHz), bit-depth resolutions (16 to 24 bits), and durations (15 to 120 s).

For the acoustic data recorded by both recording devices, we recommend the application of a high-pass filter for the study of echolocation clicks in order to avoid background noises (such as waves and boat engines), as both devices were deployed only a few metres below the water surface. Visual observations confirmed the presence of dolphins in all of the recordings provided. These data contain a wide panorama of the signals that short-beaked common dolphins can produce: echolocation clicks, whistles, pulsed sounds, and probable bi-phonations (Jones et al., 2020).

3.3 Whistle contour annotation

The shapes of whistles can be linked to specific behaviours and contexts (Lehnhoff et al., 2022) or directly to individuals (i.e. signature whistles; Caldwell and Caldwell, 1965). However, the extraction of whistle contours represents a challenging task for which a variety of automated methods have been developed, e.g. using modelling (Halkias and Ellis, 2006; Roch et al., 2011), pitch-tracking (Baumgartner and Mussoline, 2011), or deep-learning (Conant et al., 2022; Li et al., 2023) techniques.

We used a semi-automated method (Lehnhoff et al., 2025a) to annotate the contour of whistles from audio recordings made using the IcListen hydrophone. The spectrograms used for the annotations were generated using the following parameters: a 96 000 Hz sampling rate, a 1024-sample (11 ms) frame size, and a 512-sample (5 ms) hop length on a linear frequency scale. These annotations were then manually verified and corrected using https://gitlab.lis-lab.fr/loic.lehnhoff/PyAVA (last access: 1 April 2025) (Lehnhoff, 2022), a custom-made annotation tool for whistle contours. These results are made available as .json files in the `Whistle_annotations` folder within the dataset.

3.4 Other data

A `README.md` file is available in the parent folder of the dataset and describes the structure of the dataset, with usage notes and links to academic papers produced using its data.

The `Tetra\Hydro_coordinates` folder contains the .csv files giving the measured coordinates of the four hydrophones of the tetrahedral antenna in 2021 and 2022. These coordinates are needed to determine the angle of arrival of the signals detected using the hydrophones.

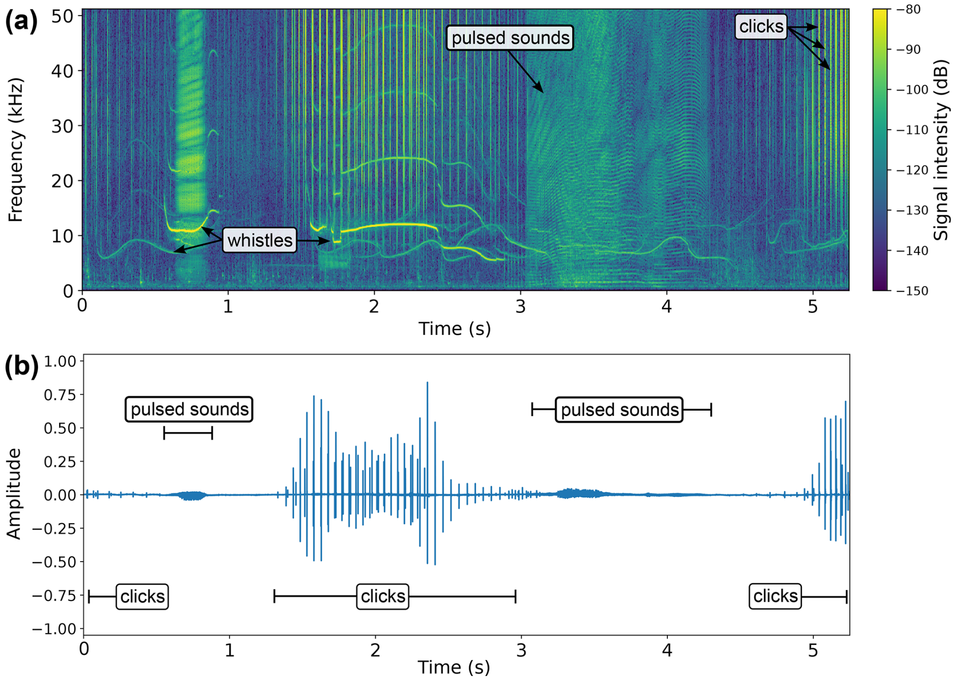

Figure 5. Spectrogram **(a)** and waveform **(b)** extracted from audio recording "SCW1807_20200713_064400.wav". **(a)** Arrows point to the representative signals. **(b)** Segments show the time span of click-like sounds. The annotations indicate only some of the signals emitted by short-beaked common dolphins that are visible in the spectrogram.

4 Results and output data

Some analyses have already been conducted of this dataset and been published, reviewed, or submitted as three different scientific papers. These papers show an increase in the acoustic activity of common dolphins in response to the DOLPHINFREE bio-inspired acoustic signal (Lehnhoff et al., 2022), characterize the features of whistles (Lehnhoff et al., 2025a), and identify signature whistles in the whistling repertoire of these animals (Lehnhoff et al., 2025b). However, it should be noted that the dataset made available here is slightly different than the one used in our previous analyses (due to the exclusion of audio recordings containing DOLPHINFREE signals).

From these works, the technical quality of the dataset is supported by manual and automatic detections of dolphin signals in audio recordings. A standard Teager–Kaiser click detector coupled with a data projection to exclude false-positive detections (Lehnhoff et al., 2022) was used to confirm the presence of echolocation clicks in most files. A semi-automatic detector of whistles was also applied to extract contour coordinates of whistles (Lehnhoff et al., 2025a) with manual validation of the detections. In total, we confirm the presence of about 68 000 echolocation clicks, 4600 whistles, and 350 pulsed sounds in the provided audio data recorded with the icListen hydrophone (Lehnhoff et al., 2022, 2025a).

The distribution of dolphin signals across the recordings is quite heterogenous. Figure 5 shows the different signals that can be found in the audio files made available. In addition, we show the magnitude spectrum of a sample of echolocation clicks recorded by the icListen hydrophone at 512 kHz, revealing the broadband nature of these clicks (see Fig. 6).

4.1 Two-dimensional localization

TETRA's recordings (four channels; see Fig. 7) can be used to determine the time difference of arrival (TDoA) of echolocation clicks at the hydrophones of the antenna, also enabling the estimation of the angle of arrival (AoA) of these clicks. A validation sequence test to evaluate the errors made in the estimation of the AoAs was conducted. DOLPHINFREE signals were emitted from the boat and recorded by the TETRA antenna at different angles around it.

The position of the antenna relative to the observation boat was determined by two GPS devices: one located on the observation boat and the other attached to the TETRA antenna buoy. Then, with the audio recordings, the DOLPHINFREE signals were used to estimate AoAs from TDoAs. A comparison of the values estimated by these two methods is shown in Fig. 8. It highlights that there are only a few deviations in the estimation of AoAs using TETRA compared to GPS measurements (on average, 0.15 radians (8.6°) for the azimuths and 0.08 radians (4.4°) for the elevation angles). However, since calibrations were performed by recording the DOLPHINFREE signal, the corresponding audio recordings are not publicly available.

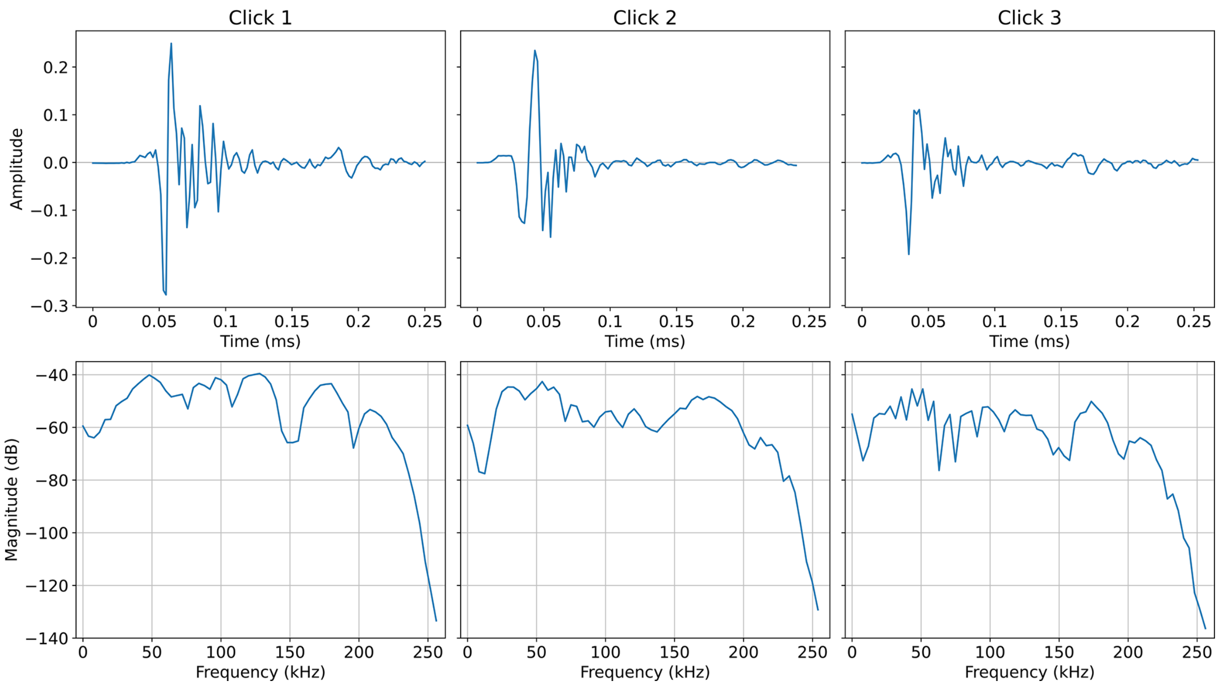

Figure 6. Waveforms and magnitude spectra of three echolocation clicks selected randomly in audio file "SCW1807_20200713_064400.wav".

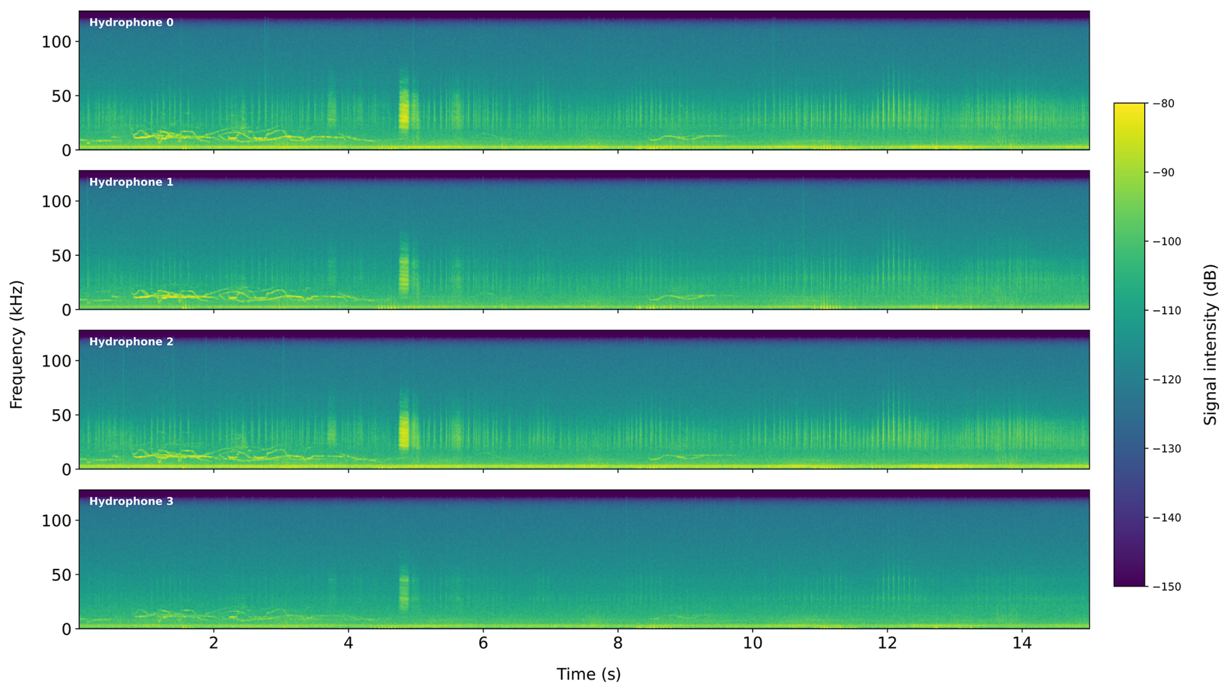

Figure 7. Spectrogram extracted from audio recording "20210709_135634UTC+2_V12.wav" collected with the TETRA antenna. Hydrophone 0 is a CR3, and the other hydrophones are SQ26.

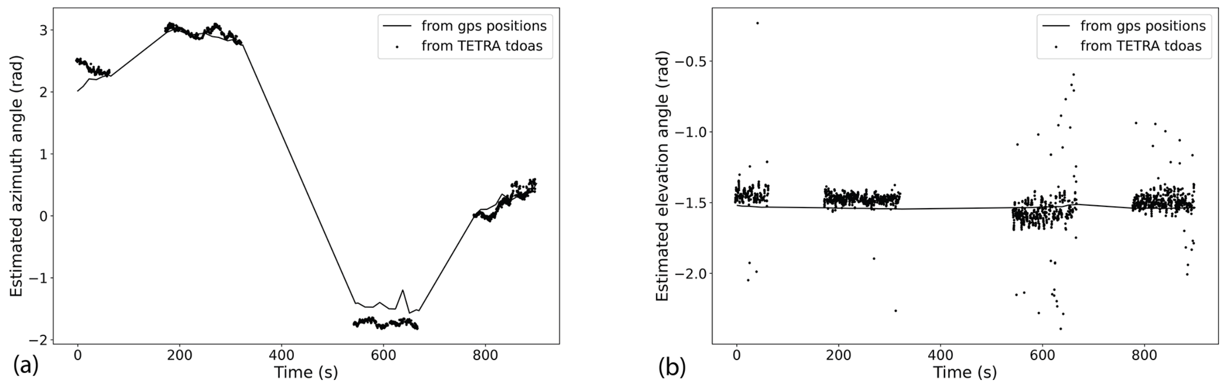

Figure 8. Angular comparison of azimuths **(a)** and elevation **(b)** between GPS references and TETRA estimates during a calibration experiment. The emitter's elevation is interpolated from the immersion depth of the TETRA antenna.

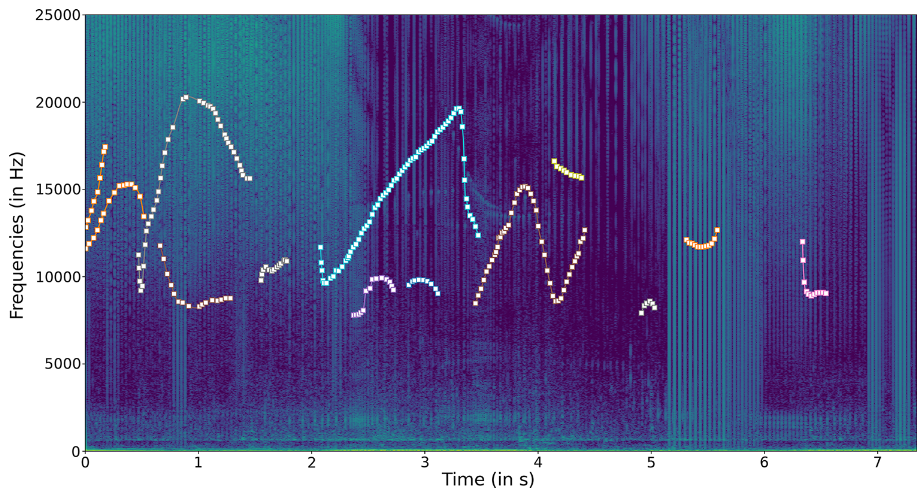

Figure 9. Screenshot showing the whistle contour annotations of audio file "SCW1807_20200712_090400.wav".

4.2 Whistle contours

Whistle contours were determined using DYOC (Lehnhoff et al., 2025a), a deep-learning tool made for whistle contour annotation and developed using parts of this dataset. Then, contours were cleaned manually using PyAVA at https://gitlab.lis-lab.fr/loic.lehnhoff/PyAVA (last access: 1 April 2025), a custom-made annotation tool in Python. An example of the results is shown in Fig. 9.

In total, 4637 annotated whistle contours were verified and are provided as .json files (dictionaries) with the audio recordings. In each file, different keys correspond to different whistle contours, with points represented as lists of time–frequency coordinates. This dataset provides ground truths that could be used to study the short-beaked common dolphin whistle repertoire and to train and/or test performances of models for the extraction of whistle contours.

5 Code and data availability

The data described in this paper can be accessed at https://zenodo.org/records/14637675 (last access: 1 April 2025) under https://doi.org/10.5281/zenodo.14637674 (Lehnhoff, 2025a). Reuse of this dataset is facilitated by several scripts available at https://gitlab.lis-lab.fr/dolphinfree-experiments (Lehnhoff, 2025b).

The decision to publish only a part of the collected data was prompted by the presence of signals protected by intellectual property.

6 Conclusions

Overall, this open-access dataset is the first to provide high-quality recordings of free-ranging short-beaked common dolphins (*Delphinus delphis*) across multiple observed behavioural states. It comprises over 400 min of acoustic data collected from wild animals at sea, including approximately 68 000 echolocation clicks, 4600 whistles, and 350 pulsed sounds. The combination of recordings made from a single hydrophone and a tetrahedral array of hydrophones, along with detailed behavioural annotations and manually validated whistles, offers a rich resource for acoustic repertoire analysis, behavioural research, and sound source localization.

This dataset represents a significant step forward in documenting and understanding the etho-acoustics and ecology of a widely distributed but understudied species. By providing both contextual behavioural data and high-resolution acoustic recordings, the dataset can support a wide range of future research, including investigations into the links between vocalizations and specific behaviours, development of automated detection and classification tools, and comparative studies across species and habitats. Ultimately, this dataset has the potential to enhance passive acoustic monitoring techniques and deepen our understanding of cetacean communication systems.

Appendix A: Observation table

Visual observations were written down by observers on board using the following table document (Fig. A1).

Date : **Observation plateform :** **Observers :**

TIME	GROUP	SEQUENCE		PINGER		NET	GENERAL BEHAVIOUR					INT.	SPECIFIC BEHAVIOUR					DIST.	NUM.	SPACE	DIR.	SPEED	DIVE TIME	BOATS	NOTES
HH:MM	# ID	# seq	pinger 1: pre- (off) 2: on 3 : post-	type	Orientat-ion	Yes (1) No (0)	Travel. %	Forag. %	Soc. %	Mill. %	Attrac. %	Response intensity to pinger **0, 1, 2**	Simult. surfacing %	Active surfacing %	Blows %	Dive %	Others (Jump, Lobtail, Spyhopping) %	Observers to dolphin group (m)	Number of dolphins in group	Group spacing: **C**ompact. **S**cattered	Direction of the group: **V**ariable **C**ontinuous	**S**low (<10 kt) **F**ast (>10 kt)	**S**td. <2 min **V**ariable **L**ong >2 min	Number of boats present in a 1 NM radius	**Additional observations** (including sudden change in direction, speed and/or dive time, etc.). Start/End time of pinger transmission; hydrophone launch.

Figure A1. Document used to record visual observations during the surveys.

Appendix B: Technical details

B1 Fishing nets

During the DOLPHINFREE surveys, four nets were utilized to mimic the setting of a fishing net under water by professional fishers. They were all set from the surface and weighted with lead weights. These nets are described in Table B1.

Table B1. Descriptions of the fishing nets used during the DOLPHINFREE surveys.

Name	Net type	Material	Mesh size	Net size ($H \times W$)
trammel	Monkfish trammel net	Nylon	220 mm	2×4 m
white_trawl	Trawl netting	Reinforced nylon	12 mm	2×4 m
green_trawl	Trawl netting	Polyethylene	40 mm	2×4 m
large_net	Entangling net	Nylon	136 mm	3×20 m

B2 icListen HF hydrophone

The icListen HF hydrophone is produced by © Ocean Sonics. Its specifications are available on their website (https://oceansonics.com/documents/icListen_FULL_specsheet.pdf?_t=1731942062, last access: 1 April 2025). In the following figures, we report the hydrophone specifications provided by the manufacturer.

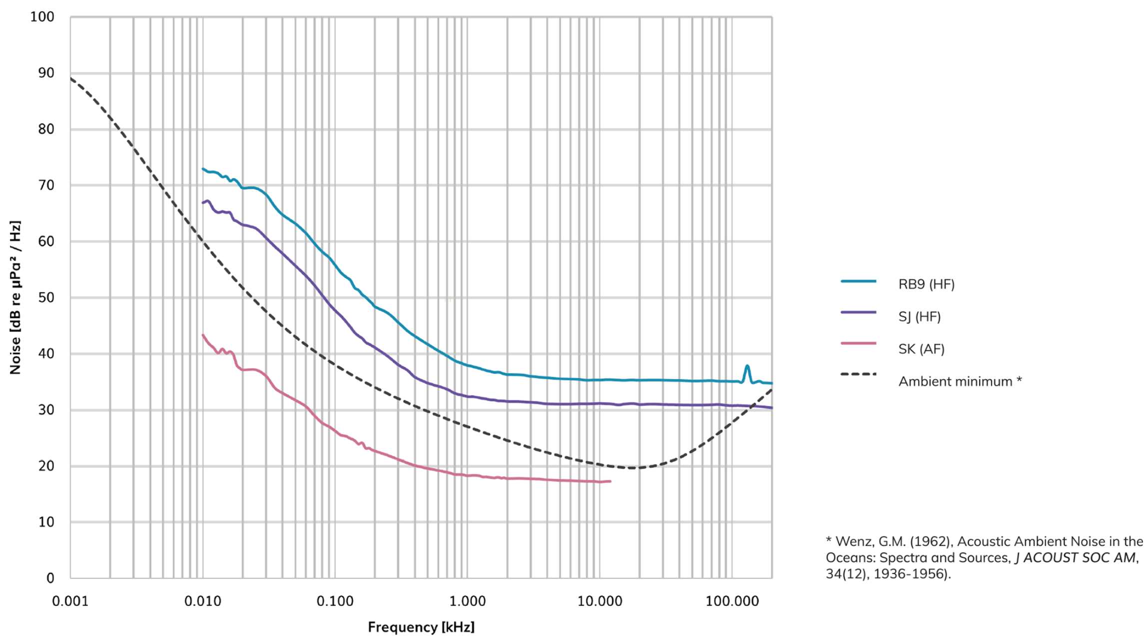

Figure B1. Noise spectrum levels of the different icListen HF hydrophones, provided by © Ocean Sonics. The SJ model (purple) was the one used in this study.

	SJ	RB	SK	Units
SIGNAL PERFORMANCE				
Low Frequency Cutoff	10	10	10	Hz
±3 dB Bandwidth	200	200	12.8	kHz
Usable Bandwidth	200	200	12.8	kHz
Maximum Data Sample Rate	512	512	32	ksps
Minimum Data Sample Rate	1	1	1	ksps
Resolution	24	24	24	bits
Minimum Self Noise	32	36	17	dB re μPa²/Hz
Peak Input Level (μPa)	180	184	168	dB re μPa
Peak Input Level (Volts)	6	6	6	dBV
Voltage Sensitivity	-173	-177	-162	dB re V/μPa

Figure B2. Signal performance table of the different icListen HF hydrophones, provided by © Ocean Sonics. The SJ model (purple) was the one used in this study.

B3 CR3 hydrophone

The CR3 hydrophone is produced by Cetacean Research™. Its specifications are available on their website (https://www.cetaceanresearch.com/hydrophones/cr3-hydrophone/index.html, last access: 1 April 2025). In the following figures and tables, we report the hydrophone specifications provided by the manufacturer.

Table B2. CR3 hydrophone specifications, provided by Cetacean Research™.

Parameter	Value
Linear frequency range (±3 dB)	0.0004 to 180 kHz
Usable frequency range (+3/ − 12 dB)	0.0001 to 240 kHz
Transducer sensitivity	−207 dB re 1 V μPa^{-1}
Sound pressure level (SPL)-equivalent self-noise at 1 kHz	54 dB re 1 μPa/$\sqrt{\text{Hz}}$
Maximum operating depth	980 m
Operating temperature range	−40 to 90 °C
Capacitance	6.7 nF
Dimensions	50 mm L × 18 mm diameter

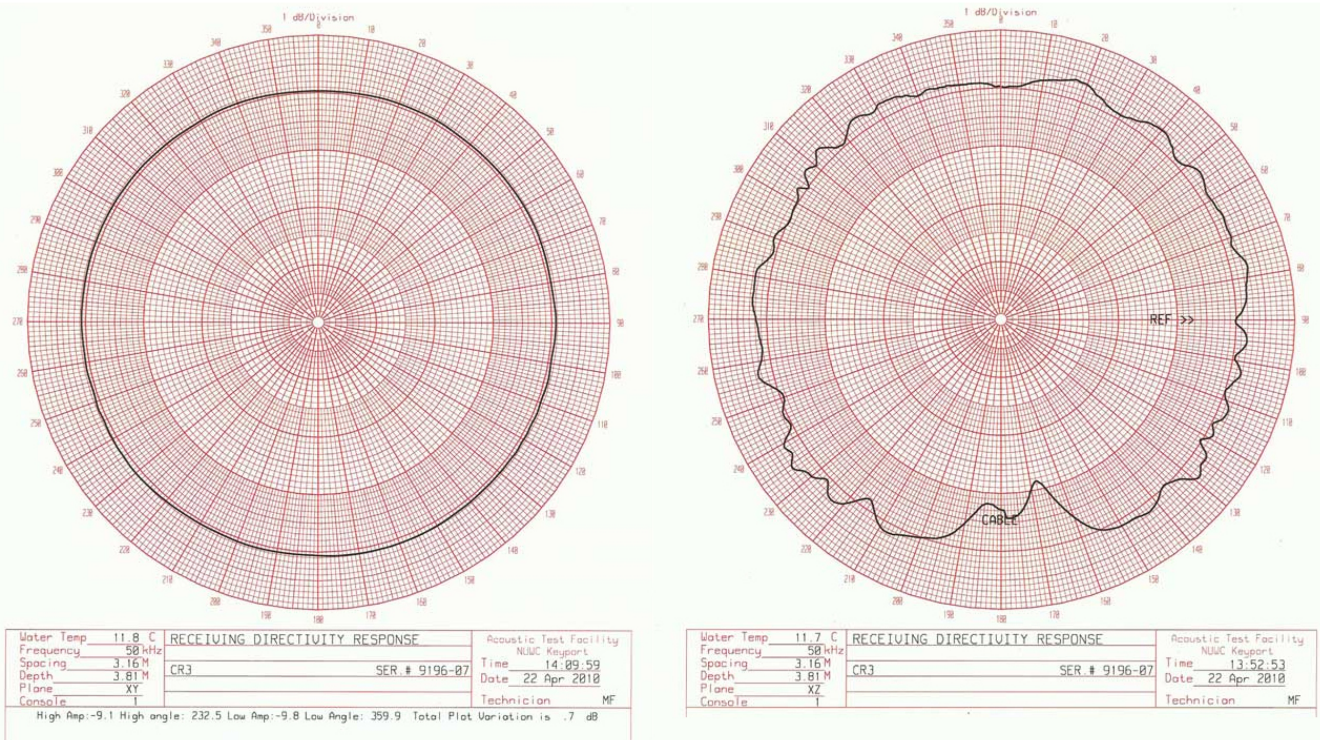

Figure B3. Horizontal (left panel) and vertical (right panel) beam patterns of the CR3 hydrophone, provided by Cetacean Research™.

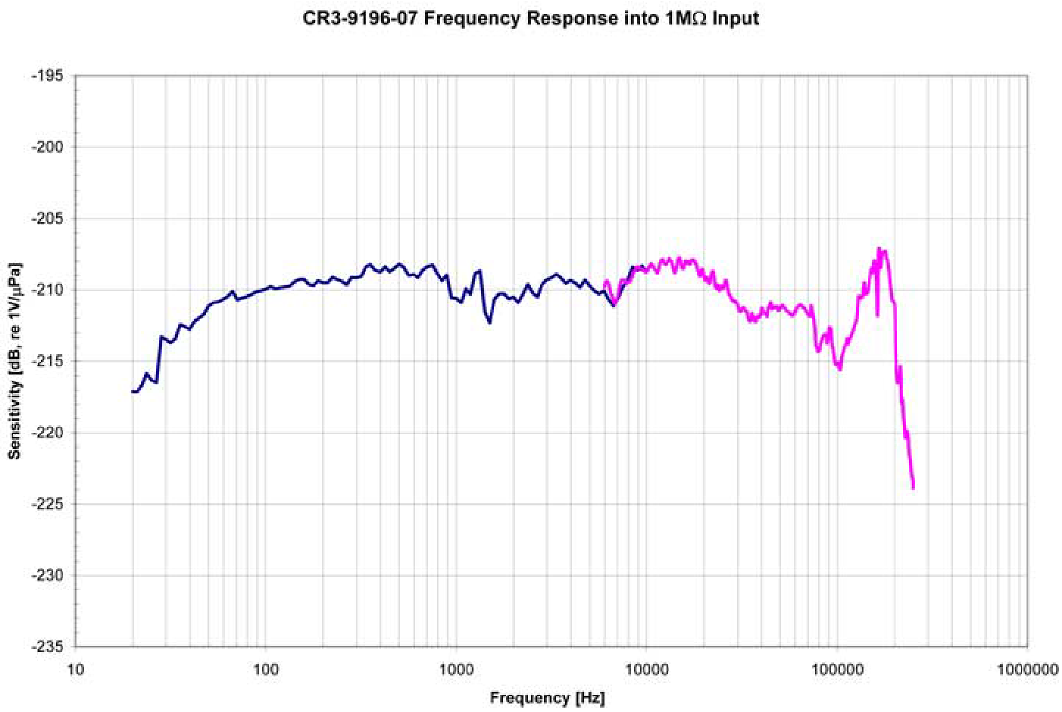

Figure B4. Frequency response of the CR3 hydrophone, provided by Cetacean Research™.

B4 SQ26 hydrophone

The SQ26 hydrophone is provided by Cetacean Research™. Its specifications are available on their website (https://www.cetaceanresearch.com/hydrophones/sq26-01-hydrophone/index.html, last access: 1 April 2025). In the following figures and tables, we report the hydrophone specifications provided by the manufacturer.

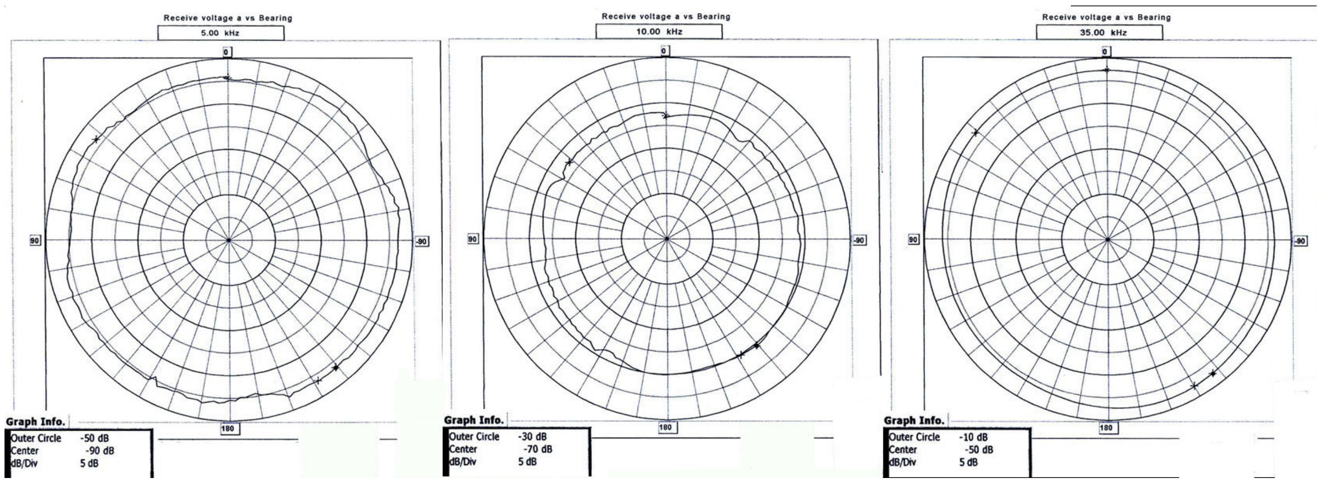

Figure B5. Horizontal beam pattern at 5 kHz (left panel), 10 kHz (centre panel), and 35 kHz (left panel) of the SQ26 hydrophone, provided by Cetacean Research™.

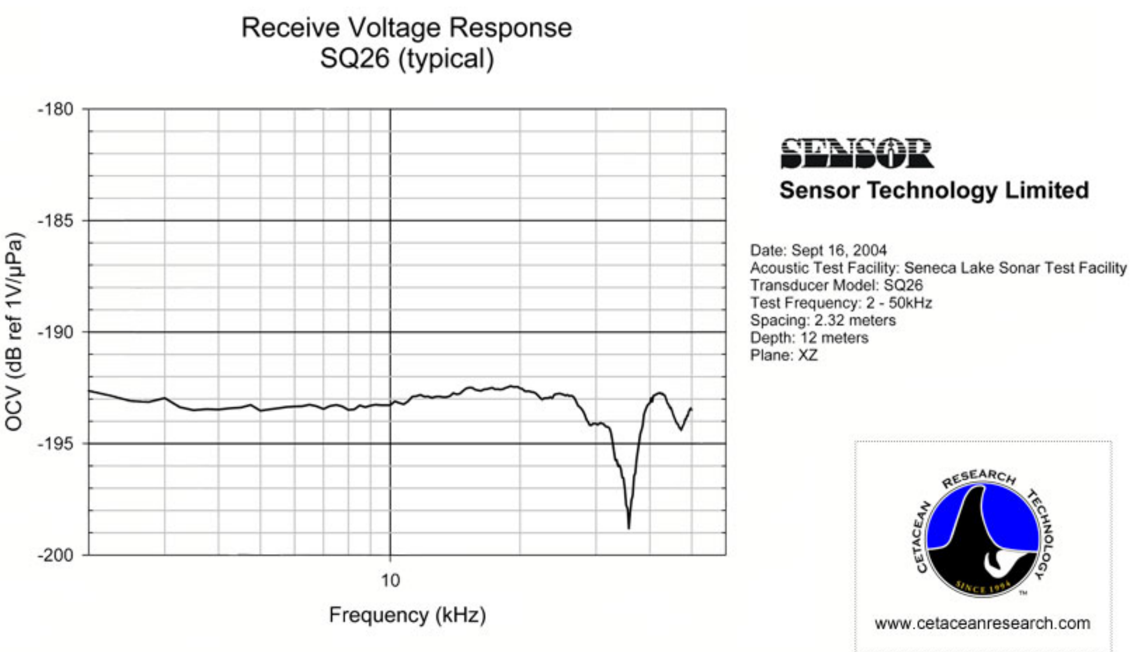

Figure B6. Frequency response of the SQ26 hydrophone, provided by Cetacean Research™.

Table B3. SQ26 hydrophone specifications, provided by Cetacean Research™.

Parameter	Value
Linear frequency range (±1 dB)	0.001 to 28 kHz
Usable frequency range (+3/ − 12 dB)	0.001 to > 50 kHz
Transducer sensitivity	−193.5 dB re 1 V µPa^{-1}
SPL-equivalent self-noise at 1 kHz	54 dB re 1 µPa/$\sqrt{\text{Hz}}$
Maximum operating depth	Down to 2000 m
Operating temperature range	−30 to 60 °C
Capacitance	1.4 nF
Dimensions	25.4 mm L × 25.4 mm diameter

Author contributions. Conceptualization: BM, HG, and LL. Methodology: BM, HG, LL, YLG, EM, and OVC. TETRA design: HG. Code and formal analysis: LL, HG, and BM. Validation and supervision: BM and HG. Data curation: BM and LL. Writing – original draft preparation: LL. Figures: LL and OVC. Data acquisition and writing – review and editing: all of the authors. Project administration: BM. Project funding acquisition: BM and HG. All of the authors reviewed the manuscript.

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