FM test datasets – dataset descriptions

This document provides detailed descriptions of each dataset, including the purpose of the associated survey or experiment, as well as the location and time of data collection. Information about the species, means of ground truthing and degree of certainty for species classification follows.

The platform carrying the sensors is described and illustrated by a figure. Each data file may contain data from one or several transducers or ping groups, and the structure of the data is described. A figure illustrates an example of an echogram from one cannel within the dataset.

Calibration procedure and calibration data are also described. Standard calibration methods and targets were used (Demer *et al.*, 2015), which involves several tungsten carbide (WC) calibration spheres with 6% cobalt binder. One or several calibration spheres of differing size were used to obtain calibration parameters across the bandwidth of the broadband pulse; calibration target sizes varied between different datasets. The different sphere sizes are referred to as, e.g., WC22 for a 22 mm diameter tungsten carbide sphere.

Finally, features in the data such as noise, usable depth ranges, faulty data channels etc., where applicable, are described.

For each dataset a table presents details of the echo sounder settings, including the following columns:

- **Channel Name:** Identifies the type and serial number of the WBT and the type of transducer.
- **Pulse Form:** Denotes the pulse form as either Continuous Wave (CW) indicating narrowband or Frequency Modulated (FM) indicating broadband.
- **Channel Number:** Each transducer and each pulse type pr transducer is given a channel number.
- **Transducer Frequency:** Represents the nominal frequency of the transducer.
- **Pulse Duration:** Refers to the duration of the transmitted pulse, measured in milliseconds (ms).
- **Sample Interval:** Describes the vertical resolution of the data, measured in meters (m).
- **Transmit Power:** Specifies the electrical power delivered to the transducer during transmission, measured in watts.
- **Slope:** Indicates the fraction of the pulse duration required for the transmitted signal to reach its full amplitude from zero.

- **Frequency Start:** Indicates the starting frequency of the transmitted broadband signal.
- **Frequency End:** Indicates the ending frequency of the transmitted broadband signal.

Test data: Mesopelagic organisms measured with a towed body deployed from RV Kronprins Haakon (T2019001)

The dataset originates from a research survey from Cape Verde to Bay of Biscay with the objective to investigate the large-scale distribution patterns of the acoustic scattering layers in the mesopelagic zone (Agersted et al., 2021).

The test data was collected 12.05.2019 in the North Atlantic Ocean (32°57'09.0"N 12°15'18.0"W) and contain backscatter from the organisms in the mesopelagic zone, including mesopelagic fish, crustaceans, squids, and jellyfish (Figure 1). A trawl sample was taken 9 hours prior to the towed body deployment, in the same area. 69 species were identified in the trawl sample and cyclothone species were the most abundant, comprising around 77% of the total counts. Ten most abundant species, by count, were (in that order): *Cyclothone braueri* (37.5 %), *Cyclothone microdon* (31.3 %), *Cyclothone Pseudopallida* (7.9 %), *Valenciennellus tripunctulatus* (2.5 %), L*obianchia dofleini* (2.5 %), *Argyropelecus hemigymnus* (1.5 %), Hygophum hygomii (1.3 %), 8. *Benthosema suborbitale* (1.3 %), 9. *Sternoptyx spp.* (1.2 %), and 10. Notoscopelus resplendens (1.0 %).

The MESSOR platform (Figure 2) was deployed from RV Kronprins Haakon, allowing the echosounders to obtain broadband acoustic backscatter observations at close range on individual scatterers at high depth. The MESSOR platform is a towed body developed to study plankton and other biological organisms in the mesopelagic zone (200 – 1000 m depth). During the data collection the MESSOR platform was towed from the ship in V-hauls from the surface to 1000 m depth, see details in (Agersted *et al.,* 2021) and (Khodabandeloo *et al.,* 2021).

The MESSOR platform is equipped with three Kongsberg EK80 WBT-Tube transceivers which can drive two transducers each, these were coupled to five echosounder transducers with nominal frequencies at 38, 70, 120, 200, and 333 kHz (ES38DD, ES70-7CD, ES120-7CD, ES200-7CD, and ES333-7CD), where the 38 kHz produced CW pulses of 0.5 ms pulse duration and the 70, 120 200 and 333 kHz produced FM pulses of 2 ms pulse duration, all five echosounders were pinging simultaneously. The transducers were mounted on a plate, with their surfaces flush against it, achieved by positioning them through appropriately sized holes. The exception was the 333 kHz transducer,

which was angled differently and oriented to face forward as an experiment to study avoidance. Details of the echo sounder settings are provided in Table 1.

The four lower frequency echosounders were calibrated with a tungsten carbide sphere with diameter of 38.1 mm (WC38.1). The calibration information for 333 kHz was not included. Calibration was done with MESSOR at 2 m depth in Cape Verde in May 2019 just before the data collection started.

The dataset is well suited for detecting individual scatterers. The 333 kHz channel should be disregarded.

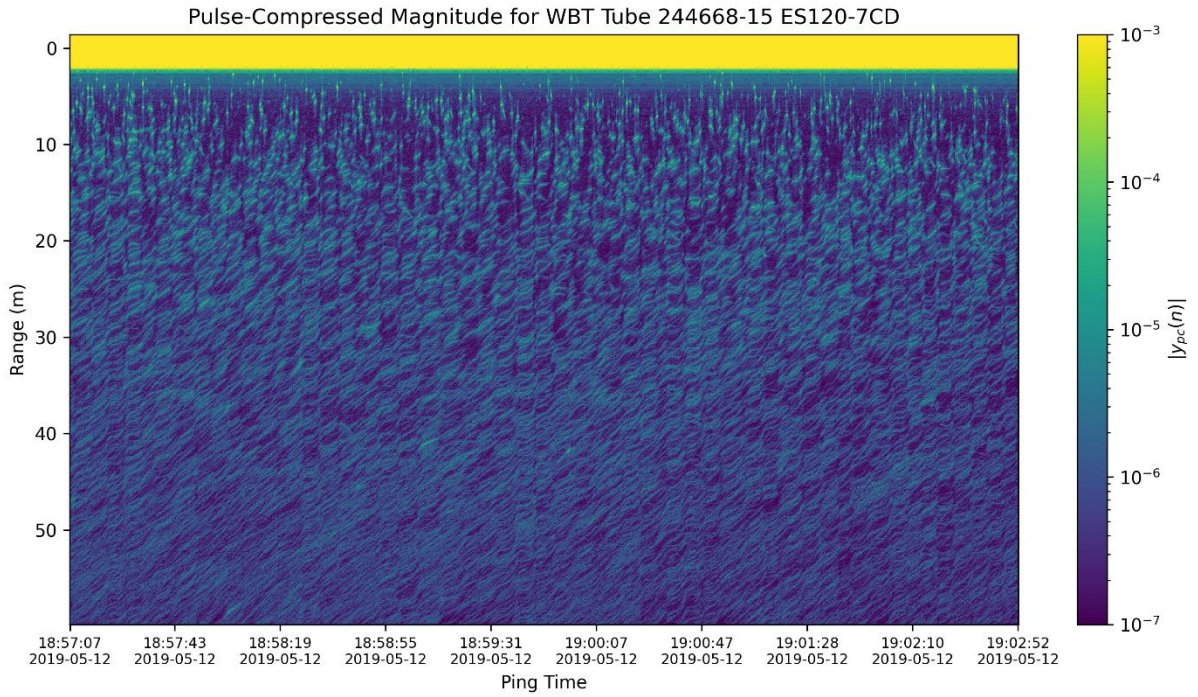

Figure 1: Example from T2019001 showing mesopelagic organisms measured with the MESSOR platform. The echogram shows data from the 120 kHz channel (93-155 kHz) recorded for 60 m range relative to the platform which was moving downwards from 522 to 557 m depth during the ca. 6 minutes of data. The color bar on the right indicates the magnitude of the pulse-compressed signal.

Figure 2: The towable echo sounder platform MESSOR developed for measurements in the mesopelagic zone. For the T2019001 dataset the position of the 333 kHz transduce was modified to be facing in a different angle, not shown in this picture. Photo: Kristian Rørhus Fjeld.

Table 1: Echo sounder settings for test dataset T2019001

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT Tube 253689-15 ES38D	CW	1	38000	0.512	0.012	100	0.50		
WBT Tube 244670-15 ES70-7CD	FM	2	70000	2.048	0.021	50	0.02	50000	80000
WBT Tube 244668-15 ES120-7CD	FM	3	120000	2.048	0.011	120	0.01	93000	155000
WBT Tube 244667-15 ES200-7CD	FM	4	200000	2.048	0.005	150	0.01	160000	260000
WBT Tube 244673-15 ES333-7CD	FM	5	333000	2.048	0.005	50	0.00	280000	450000

Test data: A layer of Atlantic herring (*Clupea harengus)* measured with keel-mounted echo sounders on RV G.O. Sars (T2020001)

The dataset originates from an experiment conducted during a research survey with the objective to estimate the difference in FM pulse backscatter from two distinct fish body size groups of Atlantic herring (*Clupea harengus*). The acoustic backscatter data of only one fish body size group is included for this test dataset.

The test dataset was collected on 23.11.2020 in Kvænangen Fjord in northern Norway (69°59'06.0"N 21°09'00.0"E). It contains measurements upon a layer of herring residing at around 25 m range (Figure 3). The species identification and average body length was determined by trawl sampling. Three trawl samples were conducted at the same location 12, 36 and 72 hours prior to the acoustic backscatter data acquisition; catch samples consisted purely of 30 cm long herring with little variation in size, further demonstrating that this large layer of herring was staying in the area over time.

Data was collected with the Kongsberg EK80 system on RV G.O. Sars (Figure 4), using six transceivers (WBT) coupled to six, keel-mounted transducers with nominal frequencies at: 18, 38, 70, 120, 200, and 333 kHz (ES18, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). Echosounder transducer depth was 8.5 m (drop-keel extended).

The echo sounders were operated with CW pulses of 0.5 ms pulse duration for the 18 kHz transducer, and with FM pulses of 2 ms pulse duration for 38, 70, 120, 200 and 333 kHz transducers, all with simultaneous pinging. Details of the echo sounder settings are provided in Table 2.

All echosounders were calibrated at the start of the research survey (19.11.2020) using the WC22 and WC57.2 spheres, for 333 kHz and the other echosounders, respectively. Note that the WC57.2 sphere is suboptimal for calibrating FM pulses for 120 and 200 kHz nominal frequency channels.

The bottom depth in the area was around 280 m, but data were recorded to 500 m range. The herring was too densely packed for detection of single individuals. The vessel speed was around 8-11 knots.

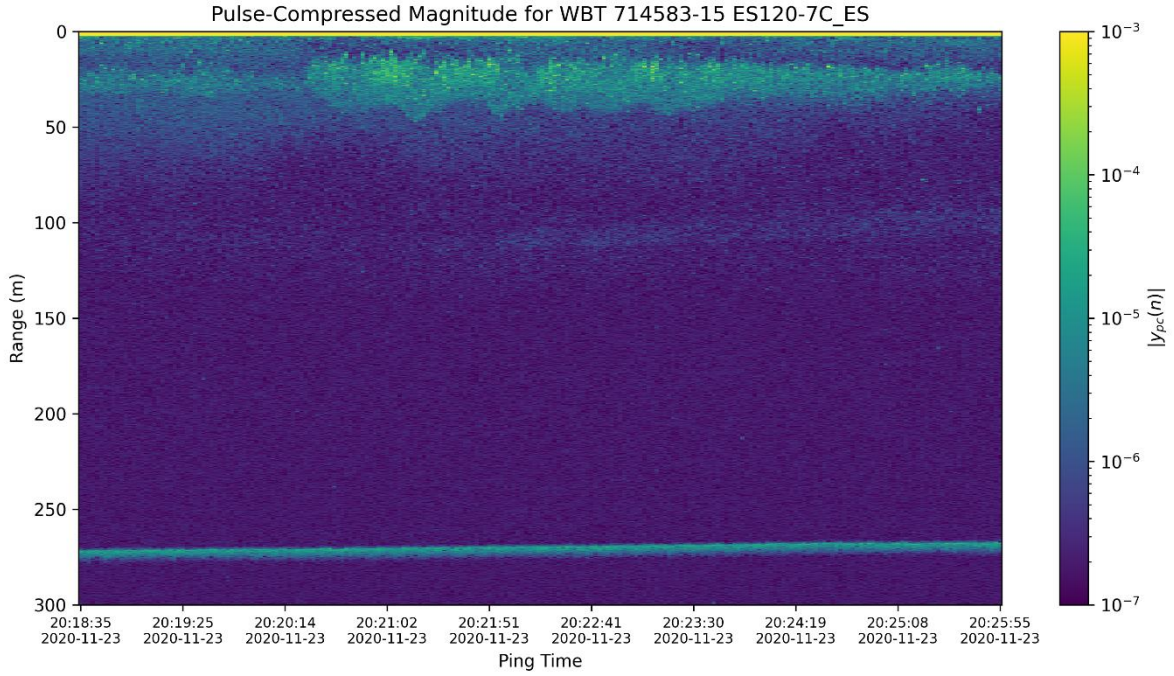

Figure 3: Example from T2020001 showing a layer of Atlantic herring (Clupea harengus) at 20-40 m range in Kvænangen Fjord (northern Norway), measured with RV G. O. Sars keel-mounted echosounders (8-11 knots vessel speed). The echogram shows ca. 7 minutes of data from the 120 kHz channel (91-160 kHz, frequency modulated up-sweep pulses, pulse-compressed). The bottom is seen at 280 m range. The color bar on the right indicates the magnitude of the pulse-compressed signal.

Figure 4: The research vessel G.O. Sars (built year 2003). Photo: Erlend Astad Lorentzen/Institute of Marine Research

Table 2: Echo sounder settings for test dataset T2020001

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 714581-15 ES18_ES	CW	1	18000	1.024	0.028	480	0.50		
WBT 714596-15 ES38-7_ES	FM	2	38000	2.048	0.043	400	0.06	34000	45000
WBT 714590-15 ES70-7C_ES	FM	3	70000	2.048	0.021	150	0.02	55000	90000
WBT 714583-15 ES120-7C_ES	FM	4	120000	2.048	0.011	100	0.01	91000	160000
WBT 714605-15 ES200-7C_ES	FM	5	200000	2.048	0.005	75	0.01	161000	260000
WBT 714597-15 ES333-7C_ES	CW	6	333000	1.024	0.024	40	0.01		

Test data: Atlantic herring (*Clupea harengus*) measured with an acoustic probe deployed from RV G.O. Sars (T2020002)

This dataset originates from the same research survey in the northern Norway as T2020001, measuring backscatter of Atlantic herring (*Clupea harengus*). The objective for this dataset was to do close range observations of individually resolved herring by means of a submersible echosounder rig (TS-probe).

The test data was collected on 21.11.2020 in Kvænangen Fjord (69°58'10.6"N 21°09'23.4"E) and contain close range measurements of Atlantic herring (Figure 5). The acoustic target identity was confirmed by mean of trawl sampling at the same location the morning before and the morning after the data collection with a pure catch of 30 cm average body length herring the morning before, and the same, but mixed with a small amount of Northern krill (*Meganyctiphanes norvegica*) the morning after.

The TS-probe (Figure 6) was lowered to 100 m depth from RV G.O. Sars hangar. The probe is equipped with four Kongsberg EK80 transceivers (WBT) placed in a water-tight cylinder. These are coupled to four plate-mounted transducers (facing downwards). The backside of the transducers is attached to the plate. Transceivers, transducers, and a swich unit were mounted inside the probe that is deployed into water. Power and communication with the probe in the water was achieved via electric/fibre-optic cable connected to a personal computer with EK80 software operated from onboard the vessel. The transducers have nominal frequencies at: 38, 70, 120, and 200 kHz (ES38DD, ES70-7CD, ES120-7CD, and ES200-7CD). The transducers were pinging simultaneously; the 38 kHz was operated with CW pulses at 0.5 ms pulse duration and the other echosounders were operated with FM pulses at 2 ms pulse duration. Details of the echo sounder settings are provided in Table 3.

TS probe echosounders were calibrated at the same location and date as this dataset; probe was deployed to 35 m depth during the calibration procedure. WC38.1 calibration target was used.

The dataset is well suited for analysing the scattering properties of individual herring. The TS-probe also has a 333 kHz transducer that was not used to collect this dataset.

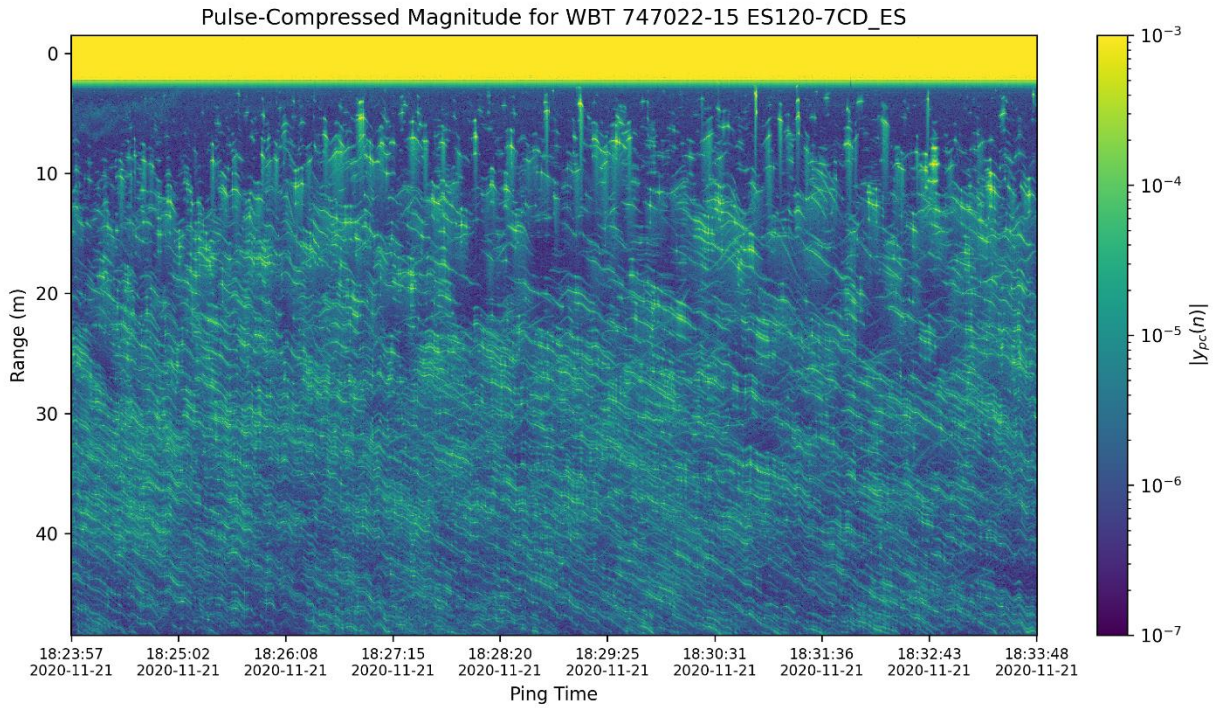

Figure 5: Example echogram from the 120 kHz channel (90-170 kHz, frequency modulated up-sweep pulses, pulse-compressed) of Atlantic herring (Clupea harengus) resolved as individual tracks. About 10 minutes of data are shown. The vertical axis on the left indicates the range (m) beneath the TS-probe, which was positioned at 100 m depth, projecting downwards. The color bar on the right represents the magnitude of the pulse-compressed signal.

Figure 6: The TS probe with four transducers mounted to project downwards, held by crane on its way into the water. Photo: Rokas Kubilius

Table 3: Echo sounder settings for test dataset T2020002.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 747008-15 ES38D_ES	CW	1	38000	0.512	0.01	400	0.50		
WBT 747015-15 ES70-7CD_ES	FM	2	70000	2.048	0.02	150	0.02	55000	90000
WBT 747022-15 ES120-7CD_ES	FM	3	120000	2.048	0.01	100	0.01	90000	170000
WBT 747019-15 ES200-7CD_ES	FM	4	200000	2.048	0.01	75	0.01	160000	260000

Test data: Lesser sandeel (*Ammodytes marinus*) measured with narrow-beam 200 kHz transducer deployed from MS Eros (T2020003)

The dataset originates from the annual acoustic-trawl sandeel abundance estimation survey in the North Sea. An experiment was conducted with the objective to obtain data on the broadband backscatter properties of individual Lesser sandeel (*Ammodytes marinus*).

The dataset was collected on 29.04.2020 in the North Sea (57°09'02.5"N 5°02'05.9"E) and contain close range measurements on sandeel (Figure 7). The sandeel school of interest was located by the ship's omnidirectional sonars and the vessel was positioned over the school, the ship was stopped and freely drifting during the data collection. The species was confirmed by a trawl sample taken 2 h after the acoustic dataset collection was concluded, in the same area. The catch was dominated by sandeel of ca. 11 cm total length.

For this experiment a single narrow-beamwidth transducer (ES200-3C) was lowered to 10 m depth over the side of the fishing vessel MS Eros that was rented to perform the research survey, projecting downwards, in an area with observations of several sandeel schools. The transducer was mounted in a protective metal frame hanging from a rope that was suspended over the railing by the ship's crane (Figure 8). The transducer was connected to a transceiver (Kongsberg EK80 WBT, placed on-board the ship) via 20 m transducer cable. The system was operated using EK80 software and a laptop personal computer. FM signals with 1 ms pulse duration were used. Details of the echo sounder settings are provided in Table 4.

The echosounder was calibrated in the harbour in Bergen (Norway) on 23.04.2020 at 2 m depth, 6 days before the data collection at sea. WC38.1 calibration target was used.

The dataset contain noise, most likely interference from the ship's instruments (echo sounders and sonar). The narrow beam width of the transducer, 3 deg., is an advantage for detecting and resolving single individuals in dense aggregations, but the commonly dense schools of sandeel makes it challenging. Data contains tracks of resolved as single individuals sandeels (albeit just barely) and sandeel school volume backscatter at 150-250 kHz.

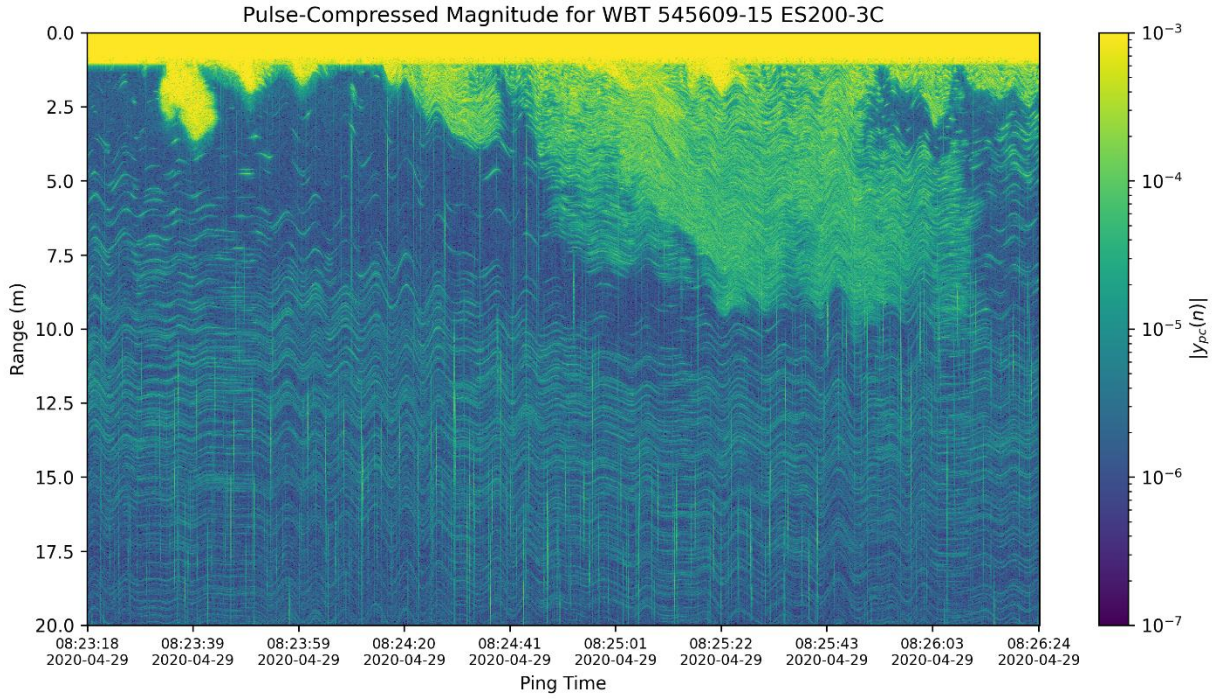

Figure 7: Example echogram (150-250 kHz, frequency modulated up-sweep pulses, pulse-compressed) showing Lesser sandeel (Ammodytes marinus) resolved as individual tracks on outskirts of a dense school at 0-9 m range. 3 minutes of data are shown. The vertical axis on the left represents range (m) beneath the transducer, which was positioned at about 10 m depth, projecting downwards. Noise from other instruments is visible. The color bar on the right represents the magnitude of the pulse-compressed signal.

Figure 8: The submersible, narrow beamwidth (3 degrees) transducer (ES200-3C) mounted in a protective metal housing. The transducer was deployed by a rope over the side of the ship to 10 m depth, operated via 20 m transducer cable connected directly to a transceiver (Kongsberg EK80 WBT), which in turn was connected to a personal computer operating EK80 software. Photo: T.N. Forland/R. Kubilius

Table 4 Echo sounder settings for test dataset T2020003.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 545609-15 ES200-3C	FM	1	200000	2.048	0.016	50	0.02	50000	88000

Test data: Northern krill (*Meganyctiphanes norvegica*) measured with a probe deployed from RV G.O. Sars (T2020008)

The data originates from the same research survey as T2020001 and T2020002 in Northern Norway from an opportunistic experiment with objective to measure the broadband backscatter from individual krill using a submersible echosounder rig (TS-probe).

This dataset was collected on 28.11.2020 in the fjord Balsfjord (69° 24.4203' N, 19° 2.0801' E) and contains measurements of individually resolved Northern krill (*Meganyctiphanes norvegica*) backscatter (Figure 9). Acoustic target identity was confirmed by a trawl sample taken at 50 m depth in the same area immediately after backscatter records; catch was dominated (>70 % by weight) by Northern krill (*Meganyctiphanes norvegica*), size distribution was not measured.

The same submergible echo sounder rig, the TS-probe (Figure 6) described in T2020002, was used, as deployed from RV G.O. Sars hangar. The TS-probe was deployed to 51 m depth (bottom depth 175 m) with echosounders (nominal frequency at 38, 70, 120, and 200 kHz) projecting downwards (data record range 40 m). The 38 kHz was operated with CW pulses of duration 0.512 ms. The 70, 120, and 200 kHz nominal frequency echosounders were operated with FM pulses of 2 ms duration, all transducers were pinging simultaneously. Details of the echo sounder settings are provided in Table 5.

All four echosounders were calibrated using a WC38.1 calibration sphere with probe deployed at 35 m water depth, in the same area, seven days prior to this dataset collection, c.f T2020002.

The research vessel was slowly drifting, at 0.7 knots, with ship dynamic positioning 'OFF'. Data was recorded during night-time/dark hours. The 38 kHz channel data is affected by noise, there are also some 'spike' noise in all channels.

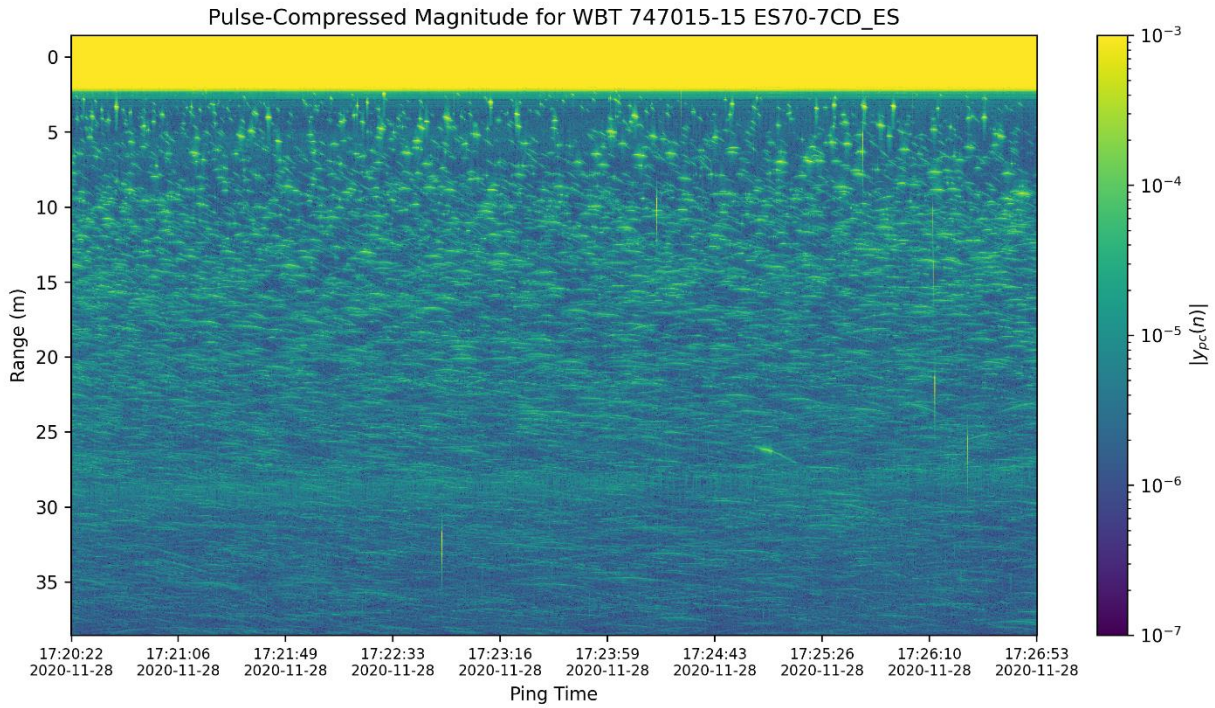

Figure 9: Example echogram from the 120 kHz channel (90-170 kHz, frequency modulated up-sweep pulses, pulse-compressed) of individual tracks dominated by Northern krill (Meganyctiphanes norvegica). About 6 minutes of data are shown. The vertical axis to the left indicates the range (m) beneath the TS-probe, which was positioned at 51 m depth, projecting downwards. Note that some 'spike' noise is present. The color bar on the right represents the magnitude of the pulse-compressed signal.

Table 5 Echo sounder settings for test dataset T2020008.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 747008-15 ES38D_ES	CW	1	38000	0.512	0.012	400	0.50		
WBT 747015-15 ES70-7CD_ES	FM	2	70000	2.048	0.021	150	0.02	55000	90000
WBT 747022-15 ES120-7CD_ES	FM	3	120000	2.048	0.008	100	0.01	90000	170000
WBT 747019-15 ES200-7CD_ES	FM	4	200000	2.048	0.005	75	0.01	160000	260000

Test data: 500 Atlantic salmon (*Salmo salar*) in a net pen with restricted surface access measured with upwards facing echo sounders (T2021001)

The dataset originates from a net pen experiment with the objective to measure changes in backscatter with time while the salmon (*Salmo salar*) was deprived from access to the surface, so swim bladder gradually deflated over time. Submerged aquaculture net pens can prevent salmon lice larvae infestation, but the salmon need access to air to refill the open swim bladder. The experiment simulated a submerged net pen with air supply failure.

500 salmon were kept in each of three 12x12x12 m^3 net pens. The datafiles from 16.03.2021 and 11.04.2021 represents backscatter from salmon with full swim bladder and after 3.5 weeks without access to air, respectively (Figure 10). The average fork length was 38 cm and 39 cm for the two periods, respectively.

The net pens were situated at Institute of Marine Research's floating aquaculture facility that was anchored to the shore in a fjord in Smørdalen, Matre (60°52'06.8"N 5°33'06.6"E). There was a small office building at the facility, which had electricity available through power outlets for computer and WBTs.

The transducers were placed beneath the net pens at about 24 m depth, facing upwards. One net pen was monitored with three transducers of 70, 120 and 200 kHz mounted on one gimballed transducer plate (ES70-7CD, ES120-7CD, ES200-7CD) whereas the two other fish holding net pens had an echo sounder gimbal with single 200 kHz transducer each (ES200-7CD) (Figure 11). 40 m long transducer cables were connected to five Kongsberg EK80 WBTs placed in waterproof suitcases close to the net pens with power supply from the facility and a common network switch, so all transducers recorded to the same datafile. The network switch was connected to a computer in the office house at about 100 m distance via a fibre cable.

Ping sequences of about 1 hour duration was used with sequential FM and CW pulse echosounder settings, changing setting every hour. The test dataset includes both settings. Five echosounders and two settings resulted in 10 channels of data in each file. The backscatter data of six channels originates from the same single net pen that was observed by 3 echo sounders operated at two sets of alternating settings. The backscatter data of four channels are from the two other net pens with two channels representing FM pulses with 2 ms pulse duration, and CW with 0.256 ms duration, respectively, for each of the two net pen. Details of the echo sounder settings are provided in Table 6.

All transducers and settings were calibrated with WC38.1 a few days prior to the experiment. Note that echosounder calibration was done outside the net pens without obstacles between the calibration target and the transducer while the fish backscatter was measured with the net pen netting being in-between the transducers and the fish targets.

In the echograms, the net pen floor echo can be seen at 12 m range and the sea surface echo at 24 m range. The area of interest is from about 12– 23 m range from the transducer. For the data from 11.04.2021 the submerged net to prevent fish from surface access is visible about 2 m below the surface (Figure 10). There is some acoustic noise in the dataset, it is thought to be originating from other instruments at the research facility.

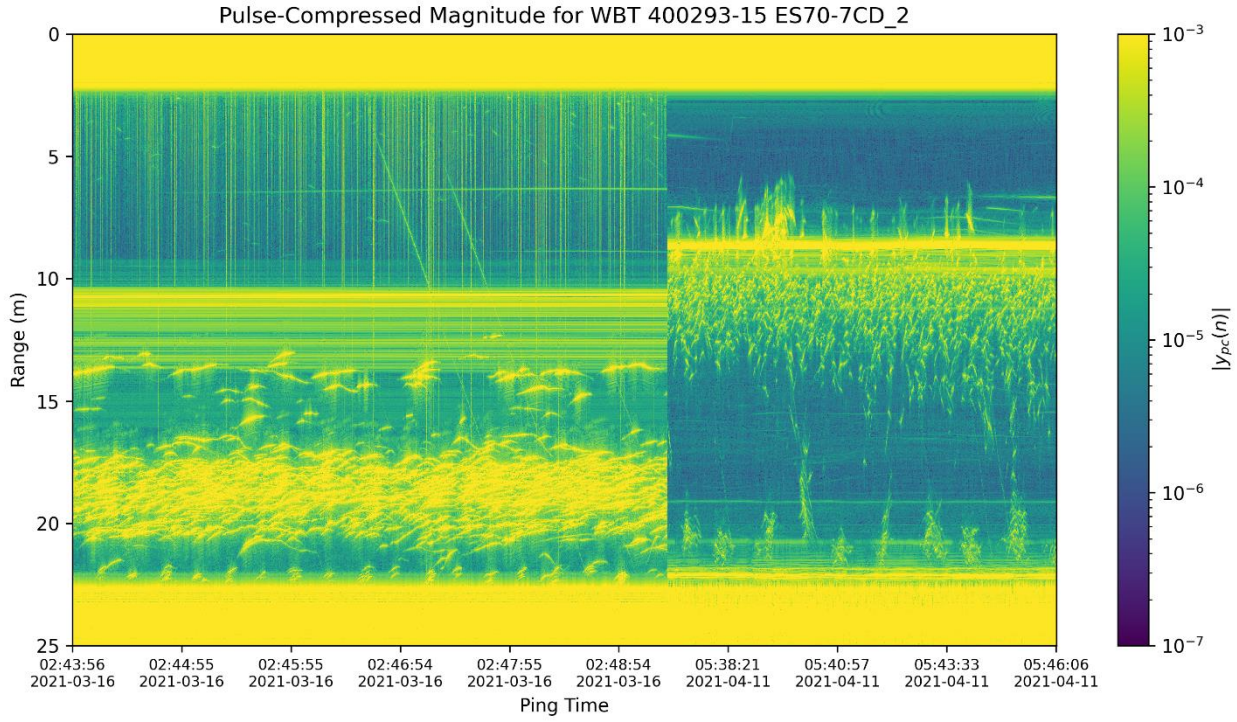

Figure 10: Echogram from T2021001 dataset from the 70 kHz channel with FM pulses (55-90 kHz, frequency modulated up-sweep pulses, pulse-compressed) showing salmon in the netpen before being deprived of access to air (left part), and after 3.5 weeks without access to air resulting in almost empty swimbladder and weaker backscatter (right panel). Echo sounder is under netpen looking upwards through the netpen floor (seen at about 10 m range). The area inside the netpen is from ca 12-23 m range. Reflection from the surface is seen at about 24 m range.

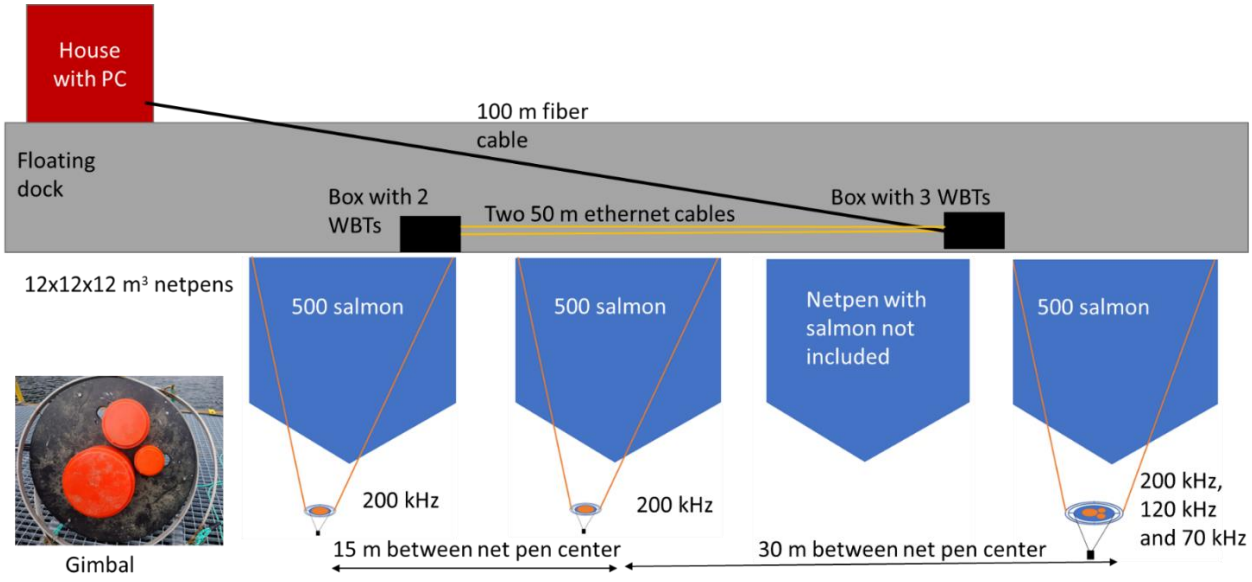

Figure 11:Experimental setup. Echo sounder gimbals with 1-3 transducers under three net pens with 500 salmon at a floating dock attached to the shore in a fjord in western Norway. A netting at about 2 m depth was used to deprive salmon from access to the surface to simulate a submerged net pen where the air supply has failed.

Table 6: Echo sounder settings for test dataset T2021001.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 400293-15 ES70-7CD_1	CW	1	70000	0.256	0.012	50	0.11		
WBT 400276-15 ES120-7CD_1	CW	3	120000	0.256	0.012	50	0.07		
WBT 400279-15 ES200-7CD_1	CW	5	200000	0.256	0.012	45	0.04		
WBT 545603-15 ES200-7CD_1	CW	7	200000	0.256	0.012	45	0.04		
WBT 400237-15 ES200-7CD_1	CW	9	200000	0.256	0.012	45	0.04		
WBT 400293-15 ES70-7CD_2	FM	2	70000	2.048	0.021	50	0.02	55000	90000
WBT 400276-15 ES120-7CD_2	FM	4	120000	2.048	0.011	50	0.01	90000	160000
WBT 400279-15 ES200-7CD_2	FM	6	200000	2.048	0.005	45	0.01	160000	260000
WBT 545603-15 ES200-7CD_2	FM	8	200000	2.048	0.005	45	0.01	160000	260000
WBT 400237-15 ES200-7CD_2	FM	10	200000	2.048	0.005	45	0.01	160000	260000

Test data: Mesopelagic organisms measured with a towed body deployed from RV G.O. Sars (T2021002)

This test dataset originates from a research survey with the objective of investigating the abundance, biomass and diversity of the acoustic scattering layers in the mesopelagic zone (200 – 1000 m depth), in the North Atlantic.

The test dataset was collected on 07.06.2021 at depth of 650 m in the North Atlantic (61°03'54.0"N 20°04'48.0"W) and contain backscatter from a variety of mesopelagic organisms (Figure 12). The acoustic measurements with MESSOR were carried out at about 18:30 UTC. Three trawls with two different openings were deployed for acoustic targe identity verification at two different water depths on the same day and in same area. The first trawl with 280 m mouth circumference 0 was deployed in V-haul to 971 m, at 03:30-06:30 UTC. Among the 4618 counts from the sub-sample from this trawl 65 species were identified, the most abundant species based on count of individuals were: *Cyclothone microdon* (22.9 %), Benthosema *glaciale* (17.8 %), *Sergestes atlanticus* (15.9 %), *Scopelogadus beanii* (9.1 %), and *Lampanyctus macdonaldi* (3.6 %). The second trawl with 134 m mouth circumference was deployed in V-haul to 1004 m, at 12:00-14:00 UTC. Among the 5837 counts from the sub-sample from this trawl 50 species were identified, the most abundant species based on count of individuals were: *Cyclothone microdon* (35.2 %), *Benthosema glaciale* (24.9 %), *Gnathophausia* (7.5 %), *Cnidaria* (5.3 %), and *Amphipoda* (4.3 %). The third haul with 280 m mouth circumference trawl was deployed in V-haul to 152 m at 23:00-24:00 UTC to sample organisms present in the upper water layers. Among the 574 counts from the sub-sample from this trawl, the most abundant (by count) taxa were: *Meganyctiphanes norvegica* (89.0 %), *Maurolicus muelleri* (7.3 %), Gonatus (2.6 %), and *Micromesistius poutassou* (0.5 %).

Data was collected from the MESSOR (Figure 2) platform deployed from the research vessel G.O. Sars in V-hauls from the surface to 1000 m depth. The configuration was similar to T2019001, i.e. five echosounder transducers of 38, 70, 120, 200 and 333 kHz nominal frequency, except that the 38 kHz transducer was replaced with 18 degrees beam width transducer (ES38-18DK-split) and the 333 kHz was facing in the same direction as the other transducers. All transducers were operated with 2 ms FM pulse duration, pinging simultaneously. Details of the echo sounder settings are provided in

Table 7.

Each transducer was calibrated with one calibration sphere, WC22 for 333 kHz and WC38.1 for the rest. Individual scatterers from the mesopelagic zone can be resolved in the acoustic backscatter data. The vessel speed was 4 knots during data collection with the MESSOR towed body. There is some acoustic noise in the backscatter data.

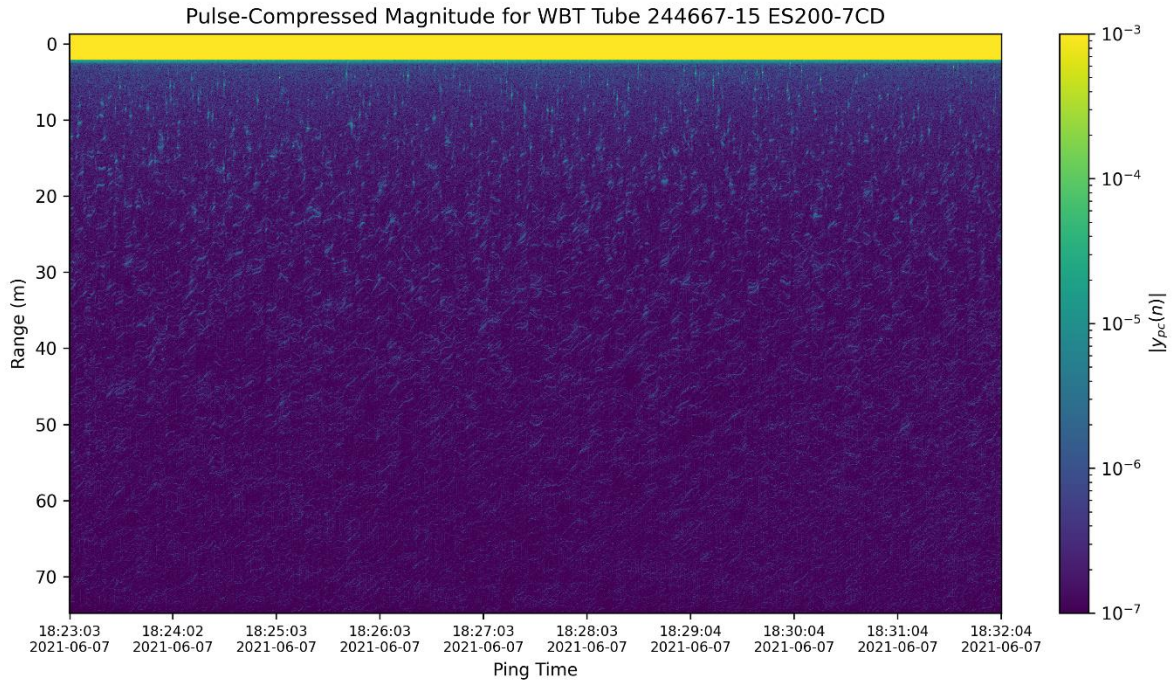

Figure 12: Example from T2021002 showing mesopelagic organisms measured with the MESSOR platform. The echogram shows 9 minutes of data from the 200 kHz channel (160-258 kHz) recorded for 75 m range relative to the platform which was at 650 m depth. The color bar represents the magnitude of the pulse-compressed signal.

Table 7: Echo sounder settings for test dataset T2021002.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT Tube 244670-15 ES70-7CD	FM	1	70000	2.048	0.016	50	0.02	50000	80000
WBT Tube 244673-15 ES333-7CD	FM	2	333000	2.048	0.005	50	0.00	280000	380000
WBT Tube 244667-15 ES200-7CD	FM	3	200000	2.048	0.005	135	0.01	160000	258000
WBT Tube 244668-15 ES120-7CD	FM	4	120000	2.048	0.011	80	0.01	90000	158000
WBT Tube 253689-7 ES38-18DK-Split	CW	5	38000	2.048	0.064	90	0.06		

Test data: Atlantic mackerel (*Scomber scombrus*) measured with keel-mounted echo sounders on MS Libas (T2021003)

This dataset originates from a fishing vessel during its voyage to fish Atlantic mackerel. The objective was to investigate the broad band acoustic backscatter data quality from a fishing vessel during its normal operation since the fishing fleet could potentially provide valuable data at low cost.

The test data was collected on 07.06.2021 in the Norwegian sea (61°07'12.0"N 1°23'06.0"E) and contain backscatter from dispersed Atlantic mackerel (*Scomber scombrus*) at about 15 m range followed by a mackerel school at about 15-25 m range (Figure 13). The species was verified by trawl sample immediately after the acoustic backscatter data collection. The average weight and fork length were 450 g and 37 cm, respectively.

The data was collected with the keel-mounted echo sounders on the fishing vessel MS Libas (Figure 14). The vessel was equipped with six echosounder transducers (ES18 ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). Echosounder transducer depth was about 6 m. The 18 kHz was operated with CW pulses of 1 ms pulse duration, while the 38, 70, 120, 200 and 333 kHz transducers were operated with FM pulses of 2 ms pulse duration. Details of the echo sounder settings are provided in Table 8.

The echosounder calibration took place in a fjord at the Libas home port located in Sotra close to Bergen, Norway, 25.06.2021. A WC57.2 calibration sphere was used to calibrate the 18, 38, and 70 kHz transducers, and a combination of the WC57.2 and WC35 was used to calibrate the 120 kHz nominal frequency transducer. All transducers were pinging simultaneously. The 200 kHz was calibrated using a WC35 sphere and the 333 kHz was calibrated with use of a WC22 sphere.

The vessel speed was about 5 knots during acoustic backscatter data collection. As expected, the acoustic backscatter data from the fishing vessel is more noisy than for a research vessel where effort has been made to reduce noise and interference between instruments. 200 kHz channel has some spike noise.

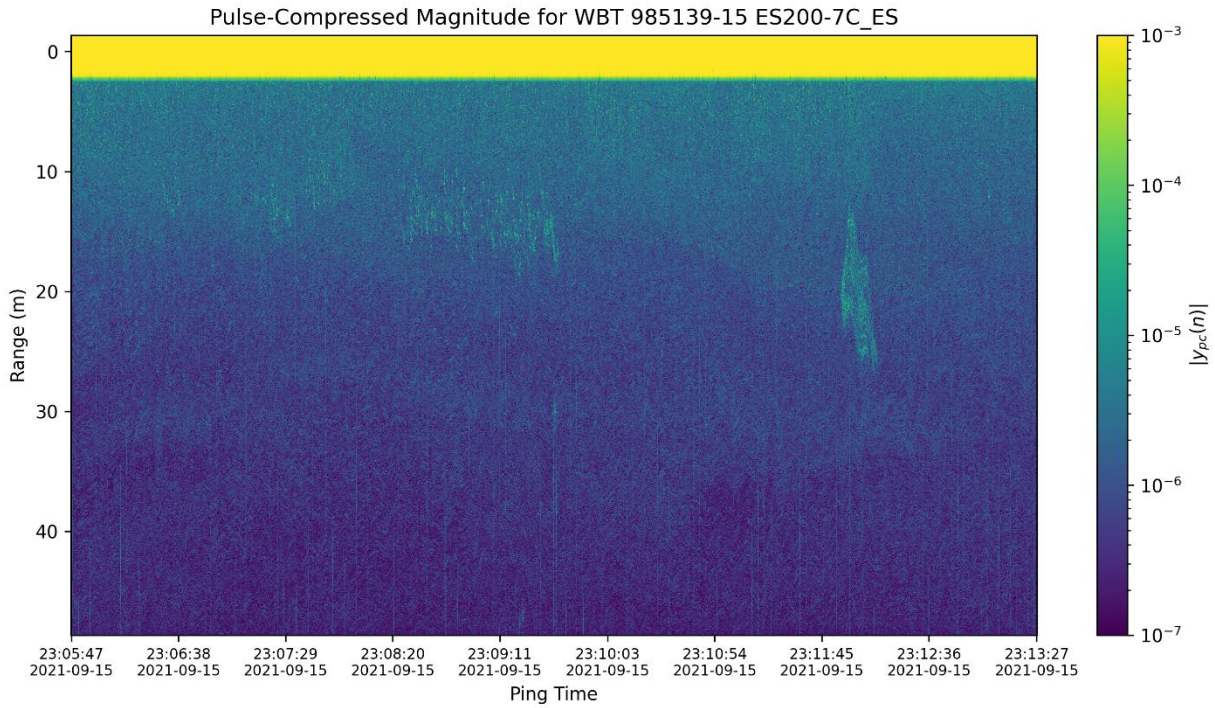

Figure 13: Example from T2021003 showing dispersed Atlantic mackerel (Scomber scombrus) at 15 m range (around 23:07-23:10 UTC) and a denser mackerel school at 20 m range (around 23:12 UTC), measured by a fishing vessel, MS Libas, during fisheries operations. The echogram shows about 8 minutes of data from the 200 kHz channel (160-260 kHz, frequency modulated up-sweep pulses, pulse-compressed). Note that data from a fishing vessel is more noisy than data from a research vessel. The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal.

Figure 14: The fishing vessel FV Libas (built year 2021). Photo: Liegruppen Fiskeri AS.

Table 8: Echo sounder settings for test dataset T2021003.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 145646-15 ES18_ES	CW	1	18000	1.024	0.028	300	0.50		
WBT 985128-15 ES38-7_ES	FM	2	38000	2.048	0.043	200	0.06	34000	45000
WBT 985136-15 ES70-7C_ES	FM	3	70000	2.048	0.016	75	0.02	45000	90000
WBT 985135-15 ES120-7C_ES	FM	4	120000	2.048	0.011	100	0.01	90000	160000
WBT 985139-15 ES200-7C_ES	FM	5	200000	2.048	0.005	105	0.01	160000	260000
WBT 985148-15 ES333-7C_ES	FM	6	333000	2.048	0.004	40	0.00	280000	450000

Test data: Bluefin tuna (*Thunnus thynnus*) measured with keel-mounted echo sounders on MS M. Ytterstad (T2021004)

The test data file originates from a survey in the Norwegian sea with the purpose of evaluating methods for detection and identification of bluefin tuna (*Thunnus thynnus*) in Norwegian waters.

The data was collected on 08.10.2021, offshore west coast of Norway (62°32'42.0"N 5°38'06.0"E) and contain backscatter from bluefin tuna (*Thunnus thynnus*) (Figure 15). The species was identified as bluefin tuna based on species-characteristic surface observations during daytime, the characteristic ‘soldier’ swimming formation, high swimming speed (4-7 knots) observed using sonar, and the strong backscatter indicating a large fish.

The fishing vessel FV M. Ytterstad (Figure 16) was equipped with five WBTs from the Kongsberg EK80 system and five keel mounted echosounders transducers (ES18, ES38B, ES70-7C, ES120-7C, and ES200-7C). Echosounder transducer depth was 8 m (drop-keel extended). The 18 and 38 kHz transducers were operated with CW pulses of

1 ms pulse duration, while the 70, 120 and 200 kHz were emitting FM pulses of 2 ms pulse duration. All transducers were pinging simultaneously. Details of the echo sounder settings are provided in Table 9.

A WC57.2 calibration sphere was used to calibrate the transducers, except for the 200 kHz which was calibrated by use of WC38.1 sphere. The echosounders were calibrated on 04.10.2021, four days prior to the data collection.

Tracks of bluefin tuna are visible on the echogram. Note that the 18, 70 and 120 kHz channels are affected by noise, probably originating from sonars which were operating as a tool to monitor bluefin tuna.

The vessel speed was about 2-3 knots during the acoustic backscatter data collection.

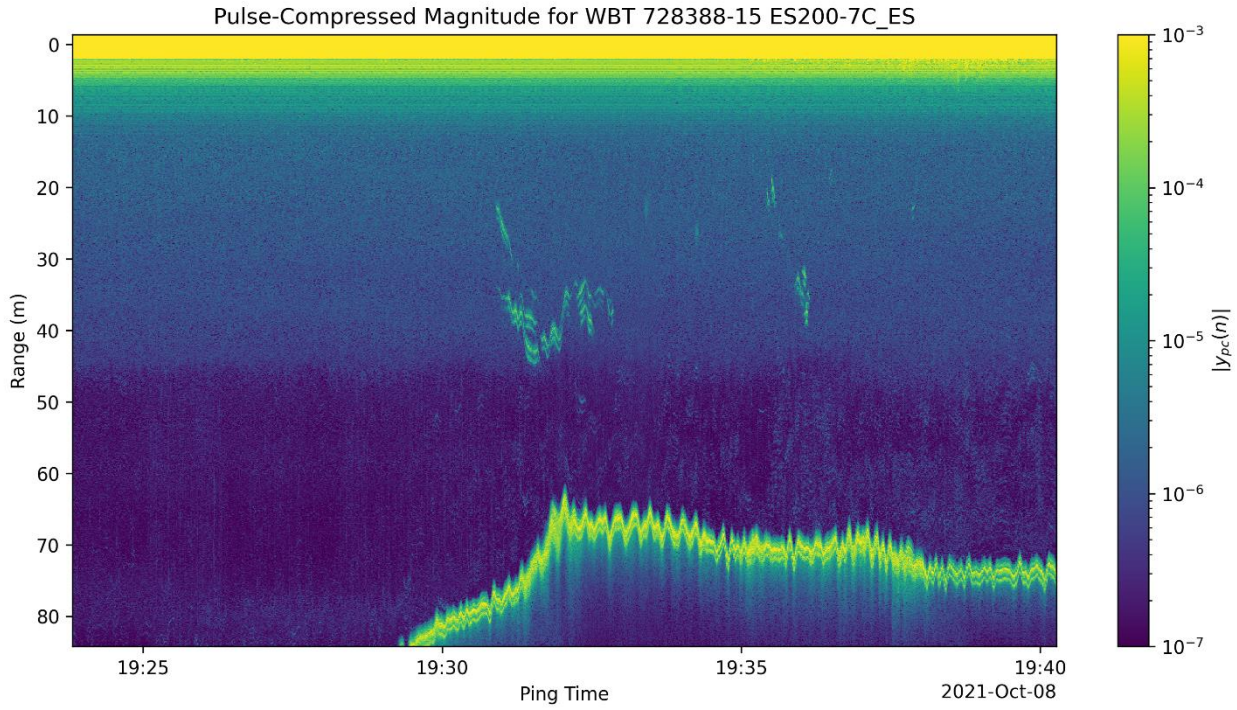

Figure 15: Example from T2021004 showing backscatter from bluefin tuna (Thunnus thynnus) measured from fishing vessel M. Ytterstad. The echogram shows data from the 200 kHz channel (160-260 kHz, frequency modulated up-sweep pulses, pulse-compressed) recorded for about 16 minutes. The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen at range around 70 m in the right part of the echogram.

Figure 16: The Fishing vessel FV M. Ytterstad (build year 2015). Photo: Ivan Reid

Table 9: Echo sounder settings for test dataset T2021004.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 145646-15 ES18_ES	CW	1	18000	1.024	0.028	300	0.50		
WBT 985128-15 ES38-7_ES	FM	2	38000	2.048	0.04	200	0.06	34000	45000
WBT 985136-15 ES70-7C_ES	FM	3	70000	2.048	0.016	75	0.02	45000	90000
WBT 985135-15 ES120-7C_ES	FM	4	120000	2.048	0.008	100	0.01	90000	160000
WBT 985139-15 ES200-7C_ES	FM	5	200000	2.048	0.005	105	0.01	160000	260000
WBT 985148-15 ES333-7C_ES	FM	6	333000	2.048	0.028	40	0.00	280000	450000

Test data: Haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) measured with keel- mounted echo sounders on MS Kings Bay (T2021005)

This test dataset on haddock and whiting stems from the annual North Sea sandeel survey, where broadband signals were briefly used and evaluated as a potential alternative to narrowband signals. During this period, high abundances of haddock and whiting were recorded using broadband signals.

The data were collected on 07.05.2021 in the North Sea (56°50'49.2"N 5°31'57.0"E) and include backscatter from haddock and whiting (Figure 17). The target species was first assumed to be haddock based on the characteristic school shape typically associated with haddock. Trawl catch taken in the same area and similar water depth, about 10 minutes after the acoustic backscatter data collection yielded a mix of haddock (*Melanogrammus aeglefinus)* and whiting (*Merlangius merlangus*) with 68.1% haddock and 31.6% whiting based on weight. The average fork lengths were 21.6 cm for haddock and 21.3 cm for whiting.

The data was collected by the keel-mounted echo sounders of the fishing vessel FV Kings Bay (Figure 18) which was chartered to conduct the survey. The vessel was equipped with five WBTs from the Kongsberg EK80 system, and five transducers with nominal frequencies of 18, 38, 70, 120 and 200 kHz (ES18, ES38-7, ES70-7C, ES120-7C, and ES200-7C). Echosounder transducer depth was 8 m (drop-keel extended). The 18 kHz and the 38-200 kHz transducers were operating with CW pulses of 1 ms pulse duration, and FM pulses of 2 ms pulse duration, respectively. Details of the echo sounder settings are provided in Table 10.

A WC57.2 calibration sphere was used to calibrate the 18, 38, 70, 120 kHz transducers. For the 200 kHz transducer a combination of WC38.1 and WC22 was used. The transducers were calibrated prior to the survey (21.04.2021) at Sandviksflaket just

outside Bergen, Norway. The vessel speed was 3-4 knots during acoustic backscatter data collection.

Individual targets were observed on the echogram. The blindsone close to the bottom is larger for FM pulse data than for CW pulse data which is a challenge for abundance estimation of fish species that tend to reside close to the bottom with FM pulses.

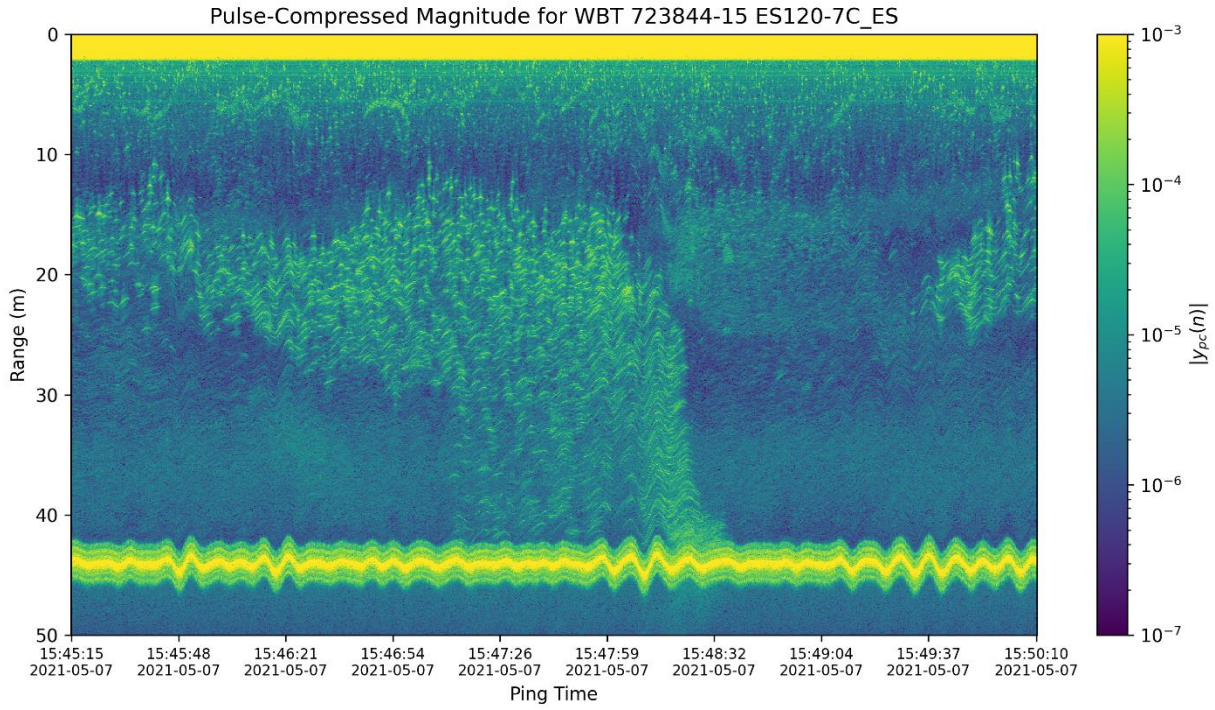

Figure 17: Example from T2021005 showing backscatter from haddock and whiting measured during the research cruise with FV Kings Bay. The echogram shows about 5 minutes of data from the 120 kHz channel (92-158 kHz, frequency modulated up-sweep pulses, pulse-compressed). The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen at range around 45 m.

Figure 18: Fishing vessel Kings Bay (build year 2013). Photo: Leif Nøttestad/Institute of Marine Research

Table 10: Echo sounder settings for test dataset T2021005.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 719182-15 ES18_ES	CW	1	18000	1.024	0.028	480	0.50		
WBT 990662-15 ES38-7_ES	FM	2	38000	2.048	0.085	200	0.06	34000	43000
WBT 723856-15 ES70-7C_ES	FM	3	70000	2.048	0.016	75	0.02	47000	88000
WBT 723844-15 ES120-7C_ES	FM	4	120000	2.048	0.011	100	0.01	92000	158000
WBT 723825-15 ES200-7C_ES	FM	5	200000	2.048	0.008	105	0.01	162000	258000

Test data: Zooplankton measured with keel-mounted echo sounders on RV Kristine Bonnevie (T2022001)

The test dataset originates from a scientific survey conducted to investigate the effect of acoustic signals from airguns used in a geophysical seismic survey on mortality and behaviour of zooplankton (Utne Palm *et al.,* 2022). The test dataset was collected by a research vessel operating concurrently with the seismic survey vessel which was operating the airgun array in the North Sea at the Ekofisk oil field.

The test dataset was collected on 30.04.2022 in the Nort Sea (56°40'00.4"N 3°09'57.7"E) and include a dense layer of mainly copepods (*Calanus finmarchicus*) at 15-20 m range (Figure 19).

Multinet sample content data showed that the layer at range 15-25 m was dominated (in number of individuals per m^3) by *Calanus finmarchicus* stage V. Echinoderm larvae dominated the layer at 0-15 m range in number of individuals per m^3. Layers at 5-25 m range also contained a significant number of *Aglantha digitale*. Layers at range 25-55 m contained a mix of several species, including *Calanus finmarchicus*. The vertical distribution of zooplankton was estimated using a 0.25 m^2 Hydrobios Multinet (180 µm mesh size), sampling in five discrete depth intervals (60-45, 45-30, 30-20, 20-10, and 10-0 m depth, but note that in this text it was reported as range from the transducers which were at 5.5 m depth (rounded for simplicity as range=depth – 5 m)).

RV Kristine Bonnevie's EK80 broadband transceivers (WBT) and keel-mounted transducers (ES18-11, ES38-7, ES120-7C, and ES200-7C), were used for the data collection (Figure 20). The echosounders were operated by emitting CW pulses of 1 ms duration for the 18 kHz transducer and emitting FM pulses of 2 ms duration for the 38, 120, and 200 kHz transducers. Details of the echo sounder settings are provided in Table 11.

Calibration of 18 kHz and 38 kHz was performed with WC57.2, the 120 kHz and 200 kHz with both WC38.1 and WC35. The calibrations were done on 01.05.2023, 9 months after the data collection. For the 120 and 200 kHz, a 4 ms pulse duration were used for the calibration (i.e. FM pulse duration is different in calibration versus the dataset).

The 120 kHz channel contains some noise (spikes) due to poor synchronization with the Teledyne Marine (150 kHz) Ocean Surveyor ADCP. The research vessel was stopped and freely drifting during the acoustic backscatter data collection.

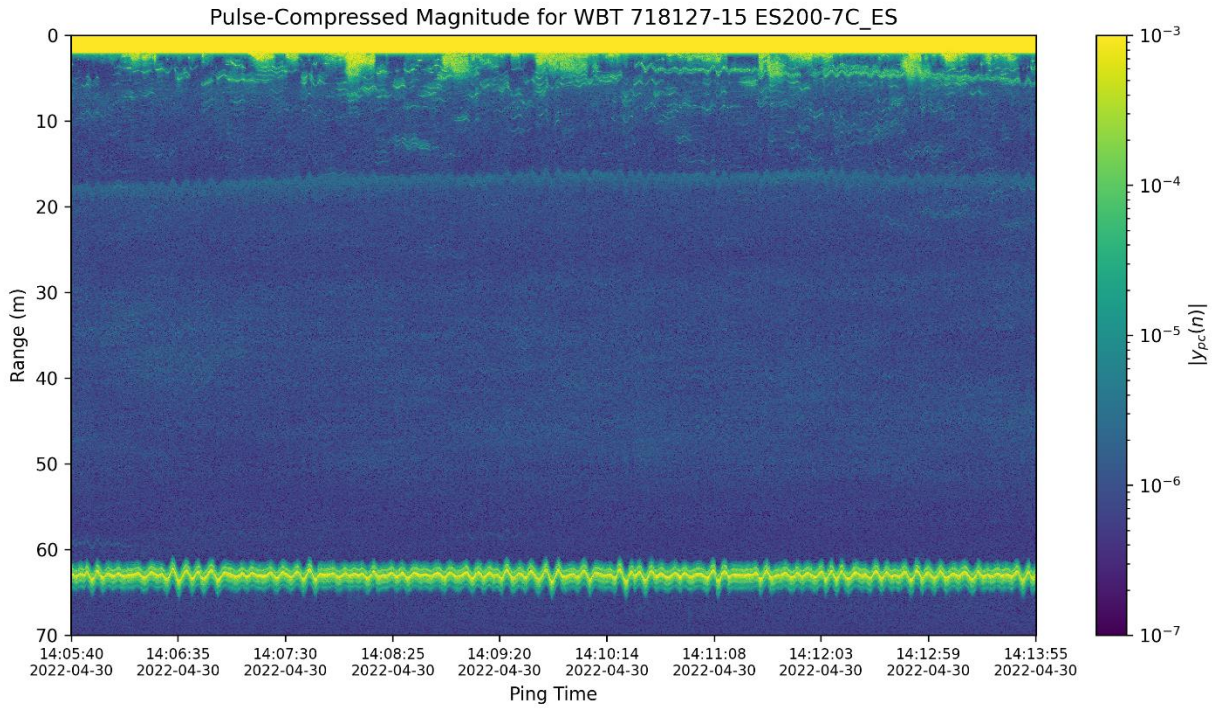

Figure 19: Example from T2022001 showing layers of plankton with a high-density concentration of mainly Calanus finmarchicus (by number) between 15-20 m range. The echogram shows data from the 200 kHz channel (162-258 kHz, frequency modulated up-sweep pulses, pulse-compressed) recorded for about 8 minutes. The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen at range around 65 m.

Figure 20. RV Kristine Bonnevie (build year 1993). Photo: Erlend Astad Lorentzen/Institute of Marine Research.

Table 11: Echo sounder settings for test dataset T2022001.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 719141-15 ES18_ES	CW	1	18000	1.024	0.028	480	0.50		
WBT 719148-15 ES38-7_ES	FM	2	38000	2.048	0.085	200	0.06	34000	43000
WBT 718119-15 ES120-7C_ES	FM	3	120000	2.048	0.011	100	0.01	92000	158000
WBT 718127-15 ES200-7C_ES	FM	4	200000	2.048	0.008	105	0.01	162000	258000

Test data: Pelagic fish and northern krill containing layers measured with keel-mounted echo sounders on RV G.O. Sars (T2023001)

The test dataset originates from a survey conducted to document potential changes in distribution patterns of marine organisms at the Hywind Tampen ocean wind farm site (Norwegian Sea) during the installation of the wind farm. This was the start of surveys and a data series to follow long term changes in the ecosystem at the wind farm site.

The test data was collected on 21.03.2023 in the Norwegian Sea (61°18'54.0"N 2°15'54.0"E) and include backscatter from three layers of different acoustic targets (Figure 21). A stereo camera trawl system, Deep vision (Rosen and Holst, 2013; Rosen *et al.,* 2013), was used between 01.45 and 02:50 UTC, about 6 hours before the acoustic backscatter dataset collection in the same area. It showed that the upper layer at 10-50 m range consisted of Atlantic herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*) and northern krill (*Meganyctiphanes norvegica*), the layer at 110 – 130 m range was consisting of blue whiting (*Micromesistius poutassou*) and muellers pearlside (Maurolicus muelleri) (120-140 m), while the layer at 170-180 m was dominated by blue whiting. The deepest layer was not sampled.

Data was collected from RV G.O. Sars (Figure 4) using six transceivers (WBT) from the Kongsberg EK80 system coupled to six, keel-mounted transducers with nominal frequencies at: 18, 38, 70, 120, 200, and 333 kHz (ES18, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). Echosounder transducer depth was 8.5 m (drop-keel extended).

The echosounders were operated by using CW pulses of 1 ms duration for the 18 and 38 kHz transducers, and FM pulses for the 70, 120, 200, and 333 kHz transducers with 2 ms pulse duration for the 70 kHz transducer and 4 ms for the rest, all pinging simultaneously. Details of the echo sounder settings are provided in Table 12.

The 18 and 38 kHz transducers were calibrated using a WC57.2 calibration sphere. The 70 kHz transducer was calibrated using a WC38.1 calibration sphere. The 120 kHz transducer was calibrated by combining WC38.1 and WC35 and for 200 kHz WC38.1, WC35 and WC25 calibration sphere were used. Finally, the 333 kHz transducer was calibrated with a WC20 and a WC22 sphere. The calibration was done on 27.11.2022, outside Tromsø, about 5 months before the dataset collection.

Noise is present on the 70 and 120 kHz channels, potentially originating from other acoustic instruments operated on the vessel. Survey speed was 9-10 knots.

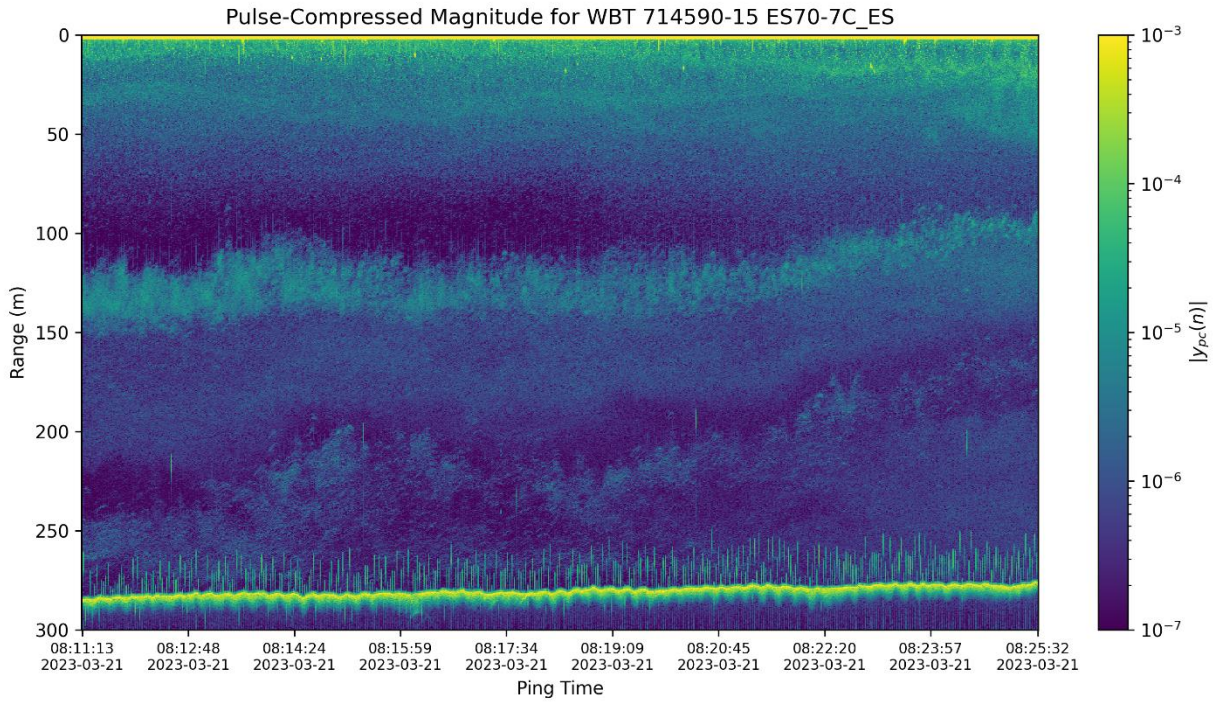

Figure 21: Example from T2023001 showing layers of fish and northern krill measured with keel mounted echo sounders from RV G.O. Sars. The echogram shows about 14 minutes of data from the 70 kHz channel (50-85 kHz, frequency modulated up-sweep pulses, pulse-compressed) The upper layer consisting of Atlantic herring (Clupea harengus), Atlantic mackerel (Scomber scombrus) and northern krill (Meganyctiphanes norvegica), the centre layer consisting of blue whiting (Micromesistius poutassou) and muellers pearlside (Maurolicus muelleri), the bottom layer was dominated by blue whiting. Noise from other instruments can be seen close to the bottom of the echogram for this channel. The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen at range around 290 m.

Table 12: Echo sounder settings for test dataset T2023001.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 714581-15 ES18_ES	CW	1	18000	1.024	0.028	800	0.50		
WBT 714596-15 ES38-7_ES	CW	2	38000	1.024	0.048	400	0.10		
WBT 714590-15 ES70-7C_ES	FM	3	70000	2.048	0.021	225	0.02	50000	85000
WBT 714583-15 ES120-7C_ES	FM	4	120000	4.096	0.011	100	0.01	95000	165000
WBT 714605-15 ES200-7C_ES	FM	5	200000	4.096	0.008	105	0.00	170000	260000
WBT 714597-15 ES333-7C_ES	FM	6	333000	4.096	0.005	40	0.00	280000	380000

Test data: Atlantic salmon (*Salmo salar*) in a net pen measured with upwards facing echo sounders (T2023002)

The test dataset is an extract from a net pen experiment where the objective was to measure the acoustic backscatter properties of Atlantic salmon (*Salmo salar*) of different body sizes. The test dataset includes backscatter data of only one fish size group.

The test data was collected on 03.08.2023 at the Norwegian Institute of Marine Research floating aquaculture facility that was anchored to the shore in Austevoll (60°05'18.8"N 5°16'00.1"E). The dataset contains measurements on 50 salmon swimming in an enclosed net pen, observed by echosounders from below (Figure 22). The 50 salmon were individually sampled from a source population (another net pen), anesthetized, and measured for body size and weight before being introduced to a 12x12x30 m net pen for the subsequent acoustic backscatter measurements (>24h between the fish handling and the start of the acoustic data collection). The mean body mass and length with one standard deviation of the salmon were 884 ± 134 grams and 415 ± 17 mm, respectively.

Five transducers with nominal frequencies of 38, 70, 120, 200 and 333 kHz (ES38-7, ES70-7CD, ES120-7CD, ES200-7CD, and ES333-7CD) were suspended at 25-meter depth inside the net pen in a gimbal system with the beams pointing upwards (Figure 23). Five Kongsberg EK80 WBTs were located inside a shipping container (doubling as experiment observation office) that was placed on the floating aquaculture platform right next to the fish-holding net pen; WBTs were connected to the transducers via 40 m long transducer cables. The measurement system, including laptop and switch, was powered from batteries to minimise noise from other instruments present on the research facility.

4 different pulse types were used during the acoustic backscatter data collection: CW pulses with 0.256 ms pulse duration, FM pulses with fast taper of 2 ms pulse duration, FM pulses with fast taper of 4 ms pulse duration, and FM pulses with slow taper of 2 ms pulse duration. All echosounders were operated with one of the 4 named echosounder settings and the setting was rotated every 15 minutes; all five transducers were pinging simultaneously. Details of the echo sounder settings are provided in Table 13.

The calibration of various frequencies and settings was conducted as follows: 38 kHz and 70 kHz CW and FM were both calibrated using WC38.1, 120 kHz CW was calibrated with WC38.1, while 120 kHz FM was calibrated with both WC38 and WC35. 200 kHz CW was calibrated using WC38.1, and 200 kHz FM was calibrated with WC38.1, WC35, and WC25. Lastly, 333 kHz CW was calibrated with WC22, and 333 kHz FM was calibrated with both WC22 and WC20. The calibration was done on 27.09.2023, almost two months after the data collection at the same location and with same echosounder installation setup and arrangement. Since the calibration files can only include one FM pulse setting at a time, four calibration files are included in the dataset.

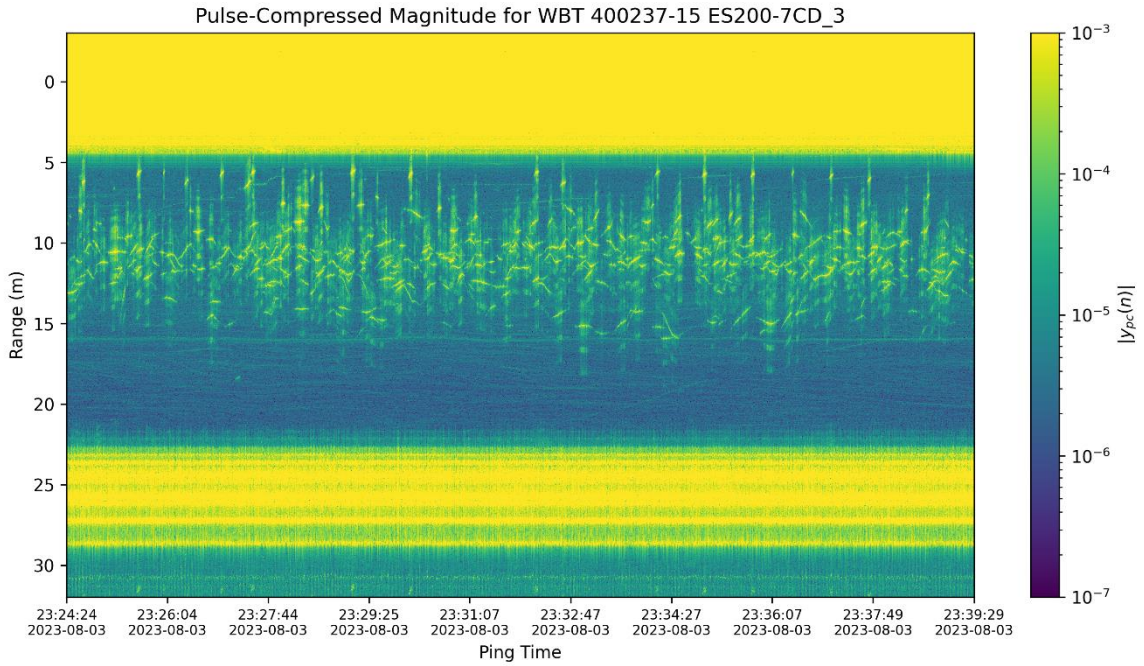

Figure 22: Example echogram showing backscatter from salmon (Salmo salar) in a net pen as observed from below by the 200 kHz channel (170-260 kHz, frequency modulated up-sweep pulses, pulse-compressed) for the pulsetype 4 ms with fast taper. The echo sounders were inside the net pen. The vertical axis to the left indicates the range (m) from the transducer and up. The surface is seen at 25 m range (NB. The echogram is upside down). The dataset lasts for about 70 minutes with about 15 minutes from each of four different acoustic pulse types. Data from one pulse type is shown in this figure. The color bar on the right represents the magnitude of the pulse-compressed signal.

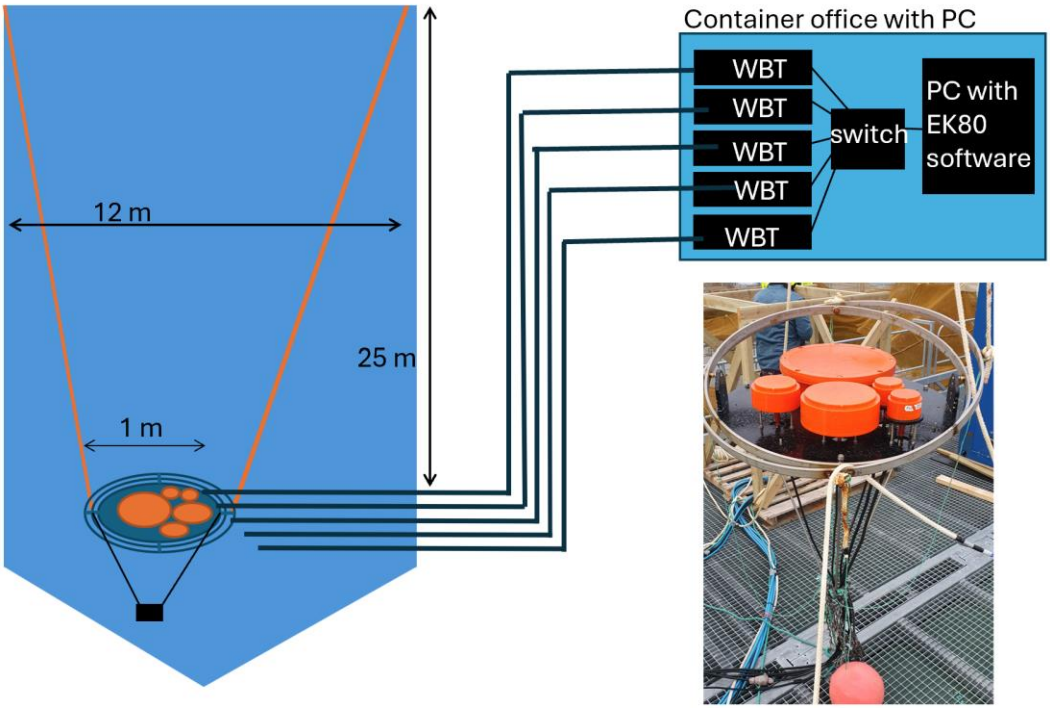

Figure 23: Echosounder setup schematic. The 5 transducers, suspended in the gimbal jig, were placed at 25 meters depth inside a net pen with 50 salmon.

Table 13: Echo sounder settings for test dataset T2023002.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. (kHz)
WBT 562910-15 ES38-7_1	CW	1	38000	0.256	0.008	200	0.40		
WBT 400276-15 ES70-7CD_1	CW	5	70000	0.256	0.012	75	0.11		
WBT 400293-15 ES120-7CD_1	CW	9	120000	0.256	0.012	75	0.06		
WBT 400237-15 ES200-7CD_1	CW	13	200000	0.256	0.012	105	0.04		
WBT 400279-15 ES333-7CD_1	CW	17	333000	0.256	0.008	40	0.02		
WBT 562910-15 ES38-7_2	FM	2	38000	2.048	0.043	200	0.06	34000	45000
WBT 400276-15 ES70-7CD_2	FM	6	70000	2.048	0.021	75	0.02	55000	85000
WBT 400293-15 ES120-7CD_2	FM	10	120000	2.048	0.011	75	0.01	95000	165000
WBT 400237-15 ES200-7CD_2	FM	14	200000	2.048	0.008	105	0.01	170000	260000
WBT 400279-15 ES333-7CD_2	FM	18	333000	2.048	0.005	40	0.00	280000	380000
WBT 562910-15 ES38-7_3	FM	3	38000	4.096	0.064	200	0.03	34000	45000
WBT 400276-15 ES70-7CD_3	FM	7	70000	4.096	0.021	75	0.01	55000	85000

WBT 400293-15 ES120-7CD_3	FM	11	120000	4.096	0.011	75	0.01	95000	165000
WBT 400237-15 ES200-7CD_3	FM	15	200000	4.096	0.008	105	0.00	170000	260000
WBT 400279-15 ES333-7CD_3	FM	19	333000	4.096	0.005	40	0.00	280000	380000
WBT 562910-15 ES38-7_4	FM	4	38000	2.048	0.043	200	0.50	34000	45000
WBT 400276-15 ES70-7CD_4	FM	8	70000	2.048	0.021	75	0.50	55000	85000
WBT 400293-15 ES120-7CD_4	FM	12	120000	2.048	0.011	75	0.50	95000	165000
WBT 400237-15 ES200-7CD_4	FM	16	200000	2.048	0.008	105	0.50	170000	260000
WBT 400279-15 ES333-7CD_4	FM	20	333000	2.048	0.005	40	0.50	280000	380000

Test data: Capelin (*Mallotus villosus*) measured with keel-mounted echo sounders on RV Johan Hjort (T2023004)

The test dataset originates from the annual demersal fish abundance assessment cruise around Lofoten islands (northern Norway), during which broadband signals were evaluated over a specified period. Significant quantities of capelin were detected by the echo sounders, presenting an opportunity to explore the broadband backscatter characteristics of this species.

The data were collected on 24.03.2023 in the northern part of the Norwegian Sea (70°04'08.4"N 17°37'37.2"E) and contain backscatter of individual capelin (*Mallotus villosus*) (Figure 24). Trawl sampling was used to verify the species about 10 minutes after the test dataset collection, and the catch consisted of 94% capelin by weight and 4 % being large Atlantic cod. Capelin average length was 17.3 cm.

The data were collected from RV Johan Hjort (Figure 25) which is equipped with six Kongsberg EK80 WBT transceivers and six the keel-mounted echo sounders (ES18, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). Echosounder transducer depth was 8 m (drop-keel extended). CW pulses with 1 ms duration were used for the 18 and 38 kHz transducer channels, while the 120, 200 and 333 kHz channels were using FM pulses with 4 ms pulse duration. Details of the echo sounder settings are provided in Table 14.

The 18 and 38 kHz were calibrated using copper spheres, Cu64 and Cu60, respectively. The 120 kHz transducer was calibrated with WC38.1 and WC35, the 200 kHz transducer with a combination of WC38.1, WC35 and WC25, and the 333 kHz transducer with a combination of a WC20 and a WC22 sphere. The CW pulse calibration (18 and 38 kHz) took place on 24.01.2022 and the FM calibration took place on 12.05.2022, that is approximately 14 and10 months prior to the survey, respectively.

This dataset contains distinct tracks of individual capelin that can be used to estimate the acoustic target strength as a function of acoustic frequency (TS(f)). Note that the data collection range was set to 500 m depth even if the bottom depth in the area was only about 80 m. There are some noise at 333 kHz nominal frequency channel data. The data were recorded at a survey speed of approximately 2.5-4 knots, which allowed for improved detection and resolution of single targets.

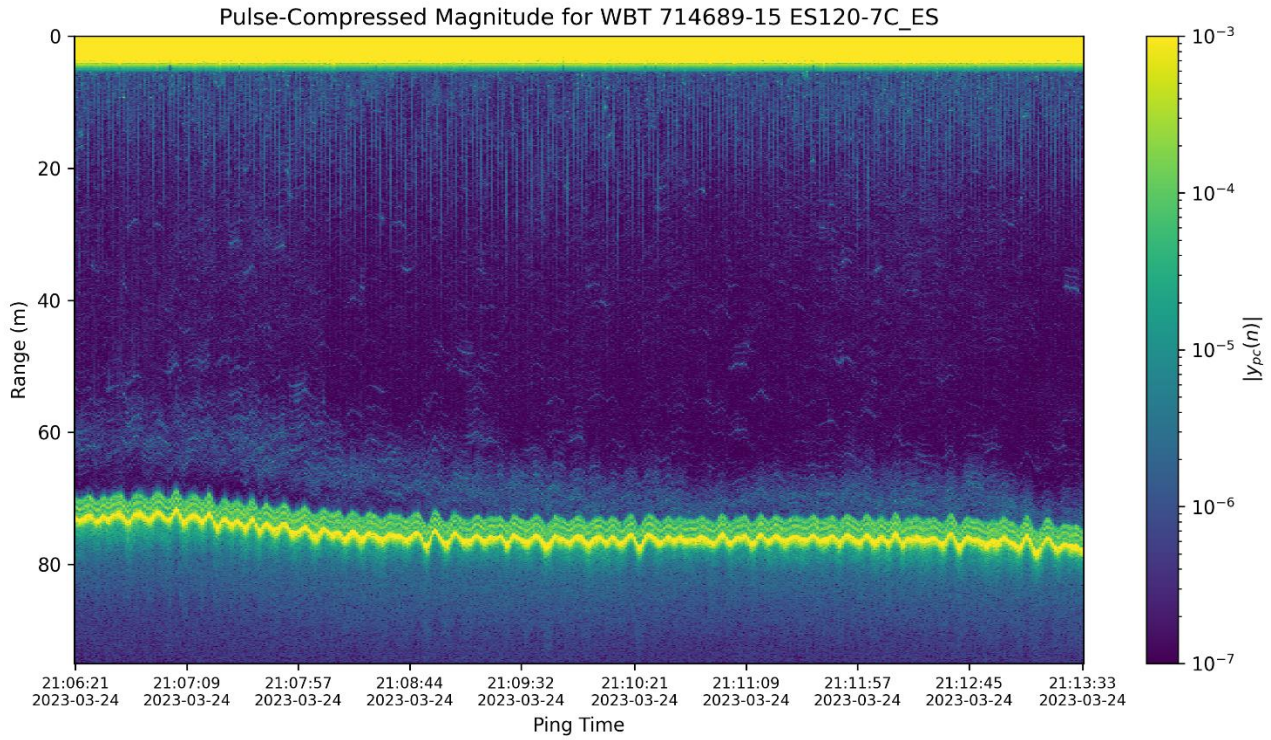

Figure 24: Example from T2023004 showing backscatter from individual capelin (Mallotus villosus) measured with the keel mounted echo sounders of RV Johan Hjorth. The echogram shows data from the 120 kHz channel (95-165 kHz, frequency modulated up-sweep pulses, pulse-compressed) for about 7 minutes. The vertical axis to the left indicates the range (m) beneath the transducer. The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen at range around 75 m.

Figure 25: The research vessel RV Johan Hjort (build year 1990). Photo: Ingunn.E. Bakketeig/Institute of Marine Research.

Table 14: Echo sounder settings for test dataset T2023004.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 145597-15 ES18_ES	CW	1	18000	1.024	0.028	750	0.50		
WBT 714699-15 ES38-7_ES	CW	2	38000	1.024	0.048	400	0.10		
WBT 714689-15 ES120-7C_ES	FM	3	120000	4.096	0.011	100	0.01	95000	165000
WBT 714677-15 ES200-7C_ES	FM	4	200000	4.096	0.008	105	0.00	170000	260000
WBT 714704-15 ES333-7C_ES	FM	5	333000	4.096	0.005	40	0.00	280000	380000

Test data: Atlantic cod (*Gadus morhua*) measured with keel- mounted echo sounders on RV Johan Hjort (T2023005)

The test dataset originates from the annual Lofoten area (northern Norway) demersal fish abundance assessment cruise like T2023004. The survey was conducted using CW pulses most of the time but recorded a subset of FM pulse data for test purposes to investigate if FM signals can be useful in identification of cod.

The data were collected on 25.03.2023 in the northern part of the Norwegian sea (69°51'46.4"N 17°36'46.1"E). Several individuals which are likely to be cod are visible close to the bottom in the echogram (Figure 26). The species was defined as Atlantic cod (*Gadus morhua*) based on expert evaluation, which relied on the acoustic target strength (TS) data and behaviour observed on the echograms in combination with the trawl sample content in the area, target identified by a scientist with long experience with Atlantic cod surveys.

The test data contain three files of selected echograms recorded between 03:00 and 07:53 UTC. Trawl sample catch at 05:44 UTC consisted of a catch with 49% Atlantic cod (*Gadus morhua*), 39% haddock *(Melanogrammus aeglefinus*), and 11% saithe (P*ollachius virens*) by weight. With average length 84 cm for the Atlantic cod, 50 cm for haddock and 55 cm for saithe. Another trawl sample at 08:00 UTC was dominated by European Plaice (82 %), Atlantic cod (12 %), haddock (3 %). Where the average length of European plaice, Atlantic cod and haddock were 41, 49 and 46 cm, respectively.

The data were collected from RV Johan Hjort (Figure 25) which is equipped with six Kongsberg EK80 WBT transceivers and six the keel-mounted echo sounders (ES18, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). CW pulses with 1 ms duration were used for the 18 and 38 kHz transducer channels, while the 120, 200 and 333 kHz channels were using FM pulses with 4 ms pulse duration. Echosounder transducer depth was 8 m (drop-keel extended). Details of the echo sounder settings are provided in Table 15.

18 and 38 kHz were calibrated with CW pulses using copper spheres, Cu64 and Cu60, respectively. The 120 kHz transducer was calibrated with WC38.1 and WC35, the 200 kHz transducer with a combination of WC38.1, WC35 and WC25, and the 333 kHz transducer with a combination of a WC20 and a WC22 sphere. The CW pulse calibration took place on 24.01.2022 and the FM pulse calibration took place on 12.05.2022 approximately 14 and10 months prior to the survey, respectively.

The survey speed was approximately 10, 9 and 2 knots for the three datafiles in the test dataset (see vessel speed data that is embedded in the raw files). The broadband backscatter (TS(f)) of individually resolved cod is available. This dataset also

demonstrates the challenges with the single target detection close to the sea bottom when FM pulses are used.

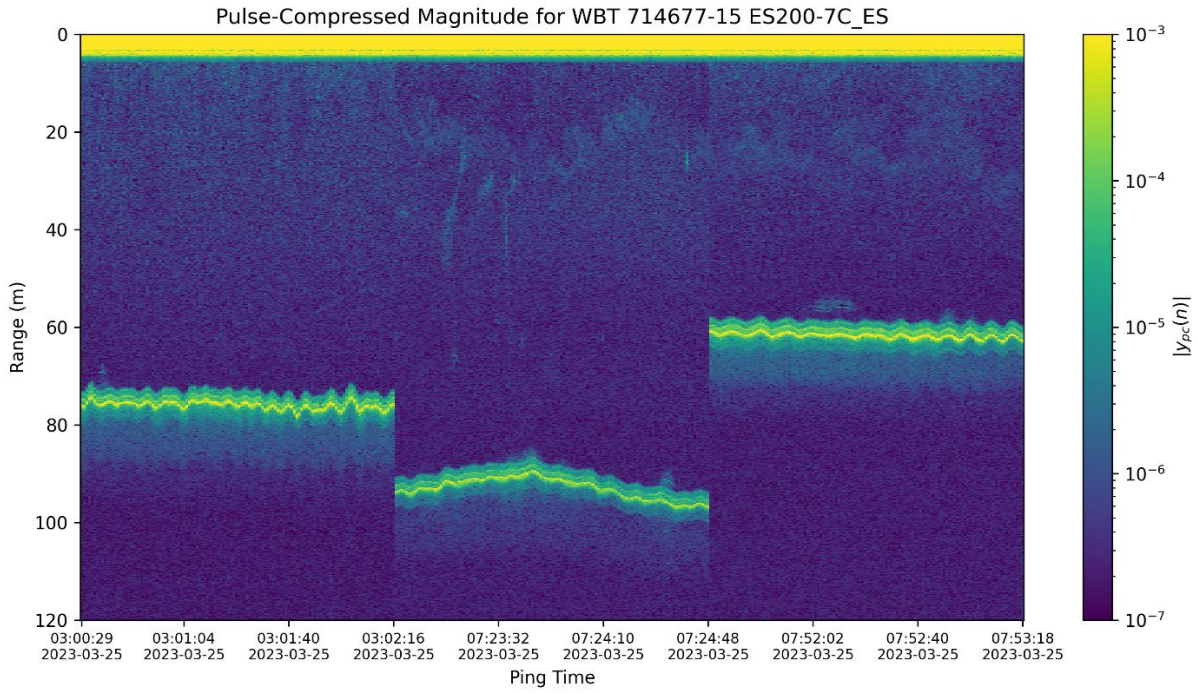

Figure 26: Example from T2023005 dataset, three selected files at different times during 5 hours, showing backscatter from individual cod (Gadus morhua) close to the bottom measured with the keel mounted echo sounders of RV Johan Hjorth. The echogram shows data from the 200 kHz channel (170-260 kHz, frequency modulated up-sweep pulses, pulse-compressed) for about 5.5 minutes The color bar on the right represents the magnitude of the pulse-compressed signal. The bottom is seen from about 60 to 100 m range.

Table 15: Echo sounder settings for test dataset T2023005.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 145597-15 ES18_ES	CW	1	18000	1.024	0.028	750	0.50		
WBT 714699-15 ES38-7_ES	CW	2	38000	1.024	0.048	400	0.10		
WBT 714689-15 ES120-7C_ES	FM	3	120000	4.096	0.011	100	0.01	95000	165000
WBT 714677-15 ES200-7C_ES	FM	4	200000	4.096	0.008	105	0.00	170000	260000
WBT 714704-15 ES333-7C_ES	FM	5	333000	4.096	0.005	40	0.00	280000	380000

Test data: Calibration sphere measured with keel-mounted echo sounders on RV G.O. Sars (T2023006)

The dataset was obtained from an experiment conducted during the echo sounder calibration prior to a research survey. Measurements on a target with known backscatter properties were made to test the echo sounder setup and the signal processing methods.

The data was collected on 25.11.2023 in a sheltered fjord in the north of Norway (69°54'36.0"N 21°17'20.4"E). The target was a tungsten carbide sphere of 38.1 mm diameter (WC38.1) suspended at 28 m depth under the ship by the 3-point motorised calibration rig, corresponding to 22 m range from the transduce (Figure 27). The dataset presented contains backscatter measurements of only WC38.1 calibration sphere. The WC38.1 was netted in 0.35 mm diameter nylon netting, suspended by the sphere own netting loop (2m long), i.e. the 3-point suspension rig lines do not loop through the netting of the sphere but rather form a single loop 2 m above the sphere and the sphere is freely suspended by its own suspension under that loop. No additional weights were used.

RV G.O. Sars (Figure 4) was equipped with six Kongsberg EK80 WBT transceivers and six keel-mounted echo sounders of the research vessel G.O. Sars (ES18-11mk2, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). Echosounder transducer depth was 6 m.

The dataset was collected with sequential pinging, alternating every second ping between FM and CW pulse settings and operating all channels simultaneously. For the FM pulse pings the 38 and 70 kHz transducers were using FM pulses with 2 ms pulse duration, while the 18, 120, 200 and 333 kHz channels were using FM pulses with 4 ms pulse duration. For CW pulses the pulse duration was 1 ms. The ping rate was about 4 pings per second. Details of the echo sounder settings are provided in Table 16.

The 38 kHz was calibrated with WC57.2, 70 kHz with WC38.1, 120 and 200 kHz was calibrated with WC38.1 and WC35, and 333 kHz was calibrated with WC22. The calibration was done immediately prior to the experimental dataset collection. The 18 kHz transducer was a prototype version with possibilities of FM pulse signals, but the transducer did not work as anticipated and it was not possible to calibrate it due its poor signal to noise ratio.

Measurements on a reference target, like a calibration sphere, but measured and processed like an acoustic target, where the backscatter can be calculated theoretically are useful to verify the data processing. The expected TS of the WC38.1 is about -39.2 dB re 1 m^2 for 200 kHz. The seawater properties between the transducer

and the calibration target (CTD profile) were measured at the location and prior to the dataset collection (the water column was well mixed with no strong layers evident).

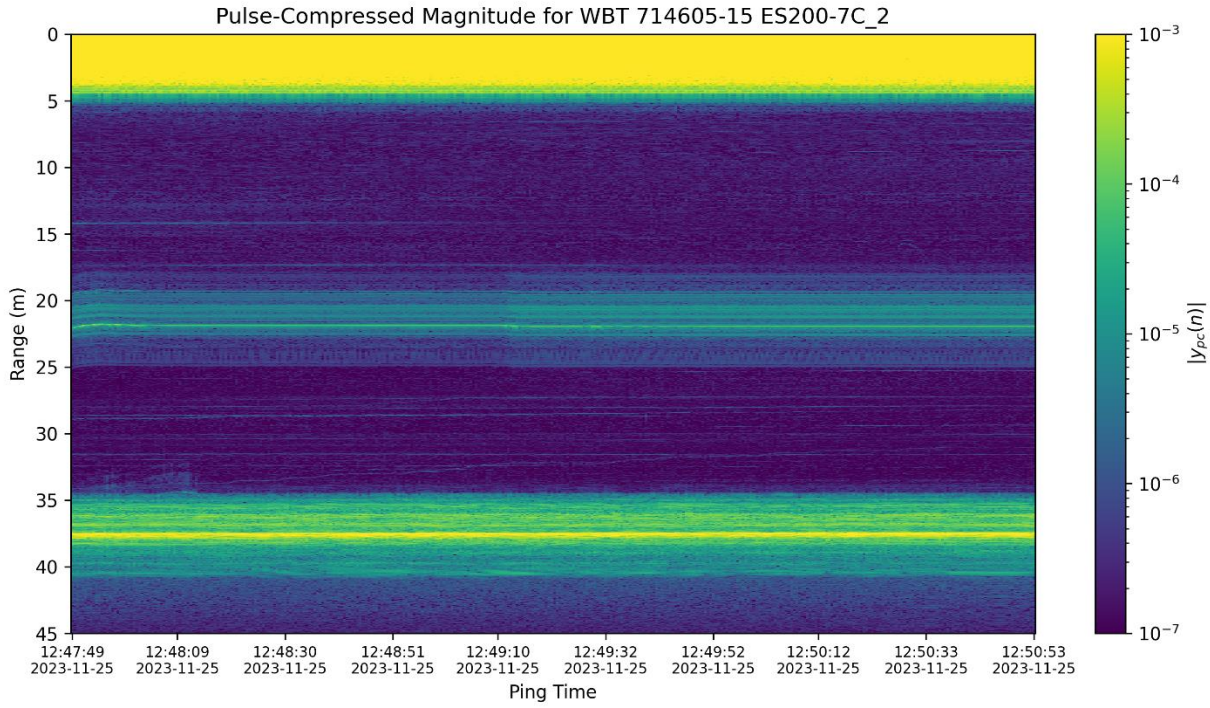

Figure 27: Example from T2023006 dataset showing backscatter from a calibration sphere, WC38.1. The echogram shows 3 minutes of data from the 200 kHz channel (170-260 kHz, frequency modulated up-sweep pulses, pulse-compressed) with the sphere at 22 m range from the transducer. The bottom is seen at about 38 m range. The color bar on the right indicates the magnitude of the pulse-compressed signal.

Table 16: Echo sounder settings for test dataset T2023006.

Channel Name	Pulse Form	Channel	Transducer Frequency (kHz)	Pulse Duration (ms)	Sample Interval (m)	Transmit Power (W)	Slope	Freq. Start (kHz)	Freq. End (kHz)
WBT 714581-15 ES18-11mk2_6	CW	1	18000	1.024	0.028	400	0.50		
WBT 714581-15 ES18-11mk2_7	FM	2	18000	4.096	0.043	400	0.50	12000	28000
WBT 714596-15 ES38-7_1	CW	3	38000	1.024	0.048	400	0.10		
WBT 714590-15 ES70-7C_1	CW	5	70000	1.024	0.048	225	0.03		
WBT 714583-15 ES120-7C_1	CW	7	120000	1.024	0.04	100	0.02		

WBT 714605-15 ES200-7C_1	CW	9	200000	1.024	0.032	105	0.01		
WBT 714597-15 ES333-7C_1	CW	11	333000	1.024	0.024	40	0.01		
WBT 714596-15 ES38-7_2	FM	4	38000	2.048	0.043	400	0.06	34000	45000
WBT 714590-15 ES70-7C_2	FM	6	70000	2.048	0.021	225	0.02	50000	85000
WBT 714583-15 ES120-7C_2	FM	8	120000	4.096	0.011	100	0.01	95000	165000
WBT 714605-15 ES200-7C_2	FM	10	200000	4.096	0.008	105	0.00	170000	260000
WBT 714597-15 ES333-7C_2	FM	12	333000	4.096	0.005	40	0.00	280000	380000