SURVEY REPORT FOR CRIMAC SFI 2023

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Summary (English):

This cruise report describes the objectives, methods, and preliminary results from the tasks carried out at the CRIMAC SFI survey. The survey was conducted on board RV G.O. Sars between November 15th (Tromsø) and November 21st (Tromsø); in the fjords around Tromsø, from Malangen to Kvænangen. The main objective was to test the Kongsberg Sounder capabilities, including noise testing, weather window testing and safe operations. Other tasks were broad banded calibration procedures, testing two new Kongsberg discovery transducers (18kHz and 333kHz), automated predictions from the deep vision system, and an experiment testing whether herring are affected from a whale deterring device or not (FHF project).

Summary (Norwegian):

Rapporten skildrar mål, metodar og førebels resultat frå oppgåvene utført under CRIMAC SFI toktet. Toktet vart gjennomført om bord på RV G.O. Sars frå 15. november (Tromsø) til 21. november (Tromsø); i fjordane rundt Tromsø, frå Malangen til Kvænangen. Hovudmålet var å testa Kongsberg USV Sounder, inkludert støytesting, testing av vêrvindauge og trygg drift. Andre oppgåver inkluderte kalibreringsprosedyrar for breidband, testing av to nye Kongsberg Discovery svingarar (18 kHz og 333 kHz), testing av prediksjon av Deep Vision sine maskinlæringsmodellar og innsamling av data for å testa om sild blir påverka av lyd som skremmer kval under fiskeri (FHF prosjekt).

Content

1 - Introduction

CRIMAC is a center of research-based innovation funded by the research council of Norway through their program for research-based innovation (SFI). Sustainable, healthy food production and clean energy production for a growing population are important global goals, and CRIMAC will contribute to these by obtaining accurate underwater observations of gas, fish, nekton and other targets. The data will be used in conjunction with CRIMAC data from other surveys to build a reference data set for optical and acoustic target classification. The classification libraries will be used for developing methods and products toward the fishing industry and marine science.

1.1 - Time period and area

The first leg was conducted between November 15th (Tromsø) and November 21st (Tromsø). The work was performed in the fjords around Tromsø, from Malangen to Kvænangen. The main objective was to test the Kongsberg Sounder capabilities, including noise testing, weather window testing and safe operations. The second leg was conducted between November 15th (Tromsø) and November 21st (Tromsø).

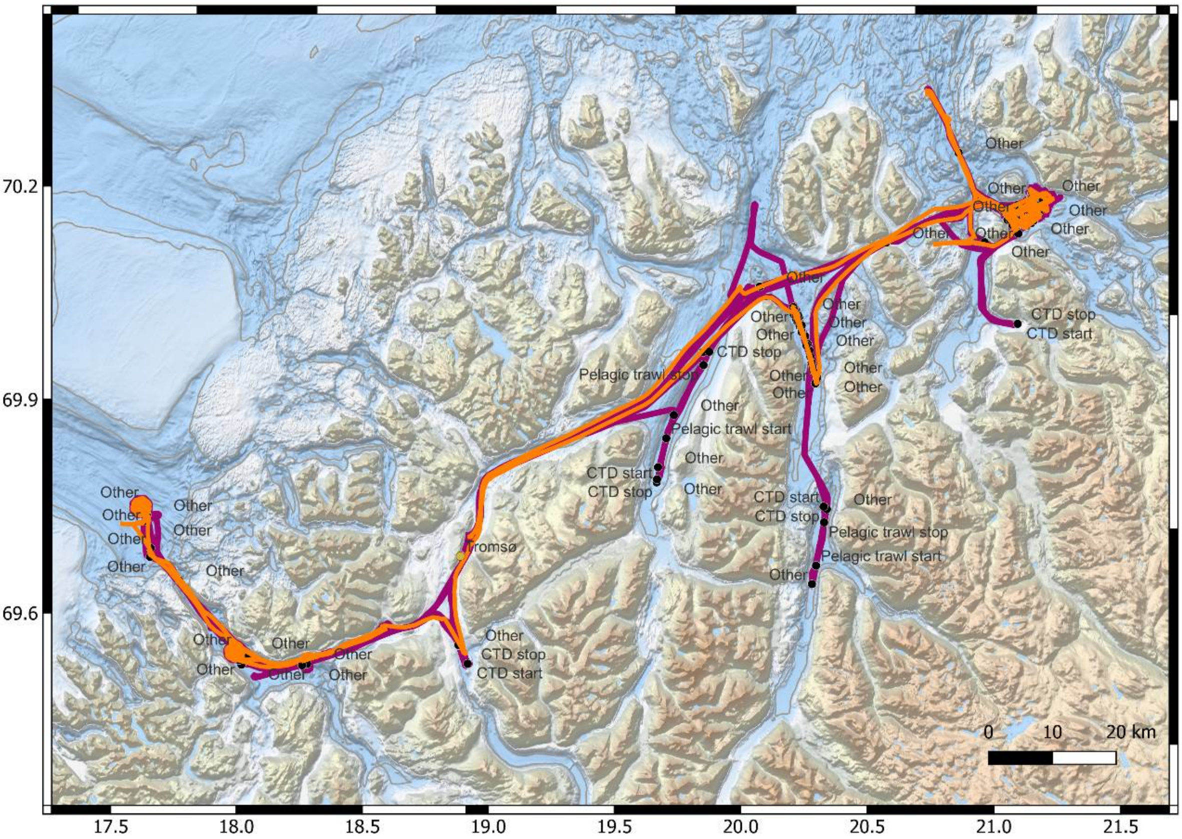


Figure 1 . Cruise track overview. Leg 1 in purple and leg 2 in orange.

1.2 - Timeline

Date	Task
14.11.2023	Mounting 18kHz BB transducer
15.11.2023	Loaded equipment, prepared for departure, prepared sounder operation
15.11.2023	Echosounder calibration of Frigg USV
16.11.2023	Testing Sounder operation, moving to Balsfjorden
16.11.2023	Echosounder calibration of GOS
17.11.2023	Testing emergency recovery protocols of Sounder
17.11.2023	Inshore noise estimate testing
18.11.2023	Moving offshore, offshore noise estimate
19.11.2023	Transit to Balsfjorden
19.11.2023	Sounder ADCP test
19.11.2023	Inshore noise estimates, fixed rpm
19.11.2023	Full scale emergency recovery and towing test up to 10 knots
19.11.2023	External interface test for autonomous operation
19.11.2023	Acoustic survey in Kvænangen
20.11.2023	Refueling Sounder, data transfer tests
20.11.2023	Acoustic survey in Kvænangen
21.11.2023	End of leg 1
21.11.2023	GOS bottom signal for noise testing
21.11.2023	GOS ADCP calibration
22.11.2023	Weather window closed
22.11.2023	Test 18kHz transducer in port
23.11.2023	Detect mesopelagic fish using deep vision in Ulsfjorden
23.11.2023	Pinger experiment
24.11.2023	Detect mesopelagic fish using deep vision in outer Ulsfjorden
24.11.2023	Pinger experiment
25.11.2023	Calibration experiment: One sphere covering all channels
25.11.2023	Pinger experiment
26.11.2023	End of leg 2

1.3 - Vessel details

The cruise was conducted with RV G.O. Sars (Figure 2 a) and the USV Frigg (Figure 2 b) operated by the Institute of Marine Research and Kongsberg Discovery, respectively.

RV G.O. Sars is 77.5 m length overall, has a m aximum speed of 17 knots and a c rew of 15 in addition to space for 30 scientific crew members including instrument technicians. The vessel is equipped with Kongsberg Maritime EK80 scientific broadband echosounders (operating at 18, 38, 70, 120, 200, and 333 kHz centre frequency) and a range of other sensors (sonars, ADCPs). The vessel is equipped to deploy a wide range of additional equipment (e.g. probes, towed vehicles, pelagic and demersal trawls). More information about the vessel can be found online (https://www.hi.no/resources/brosjyre-g.o.sars.pdf).

Figure 2 . (a) RV G.O. Sars (image credit: Institute of Marine Research) (b) USV Sounder platform (Image credit: Geir Pedersen, IMR).

USV Frigg is a uncrewed surface vehicle developed by Kongsberg Discovery (https://www.kongsberg.com/maritime/products/marine-robotics/uncrewed-surface-vehicle-sounder/). The USV is a multi-purpose unmanned surface vehicle with overall length 8 m and beam of 2.2m. The vessel weight is 4200kg. The vessel is equipped with a 125hp Steyr diesel engine. Means of communications through Maritime Broadband Radio and Iridium. The control system is delivered by maritime robotics (https://www.maritimerobotics.com/).

1.4 - Cruise participants

Table 1. Scientific crew for the two surveys

Scientific crew 1 st part (15.11 – 21.11)
Nils Olav Handegard (IMR) Joakim Skjefstad (IMR) Rolf Korneliussen (IMR) Mikal Samuelsen (IMR) Arne Johannes Holmin (IMR) Jan Arne Vågenes (IMR) Atle Totland (IMR) Alex de Robertis (NOAA) Espen Johnsen (IMR) Geir Pedersen (IMR) Maria Tenningen (IMR) Emeline Veit (Ifremer) Naig Le Bouffant (Ifremer) Kristian William Macdonald Gulaker (KD) Martin Johannes Nilsen (KD) Sakura Komiyama (UiB) Rabea Rogge (NTNU) Erik Schuster (IMR) Arne Johan Hestnes (KD)
Scientific crew 2nd part (21.11 – 26.11)
Nils Olav Handegard (IMR) Martin Dahl (IMR) Eyvind Ernstsen (IMR) Rolf Korneliussen (IMR) Ketil Malde (IMR) Ivar Wangen (KD) Lise Sivle (IMR) Geir Pedersen (IMR) Maria Tenningen (IMR) Nikolina Juraco (UiB) Vaneeda Allken (IMR) Rabea Rogge (NTNU) Erik Schuster (IMR) Guosong Zhang (IMR) Ahmet Pala (UiB) Changkyuo Choi (UiT)

2 - Calibration

Prior to the experiments the EK80 on RV G.O. Sars and USV Sounder were calibrated with IMR standard survey settings for both CW and FM (Table 1). Preliminary recommendations suggest FM pulses be calibrated using 2-3 spheres, where needed; and the results are merged using the EK80 software procedures. Calibrations were performed using the combination of calibration spheres and settings given in Table 2 , with some modifications as described under each sub-chapter.

Table 1 . IMR standard CW and FM settings for surveys and short-range measurements (TS-probe). indicates preliminary suggested bandwidth.*

Chanel	**Tr. type**	**Pulse shape**	**Bandwidth [kHz]**	**Taper**	**Pulse duration [ms]**	**Power [W]**
CW (Continuous Wave) Ping Group 1						
18-CW	ES18 mk2	CW	-	Fast	1.024	800
38-CW	ES38-7	CW	-	Fast	1.024	400
70-CW	ES70-7C	CW	-	Fast	1.024	225
120-CW	ES120-7C	CW	-	Fast	1.024	100
200-CW	ES200-7C	CW	-	Fast	1.024	105
333-CW	ES333-7C	CW	-	Fast	1.024	40
FM (Frequency Modulated) Ping Group 2						
18-FM	ES18 mk2	FM-Up	14-22*	Fast	2.048	400
38-FM	ES38-7	FM-Up	34-45	Fast	2.048	400
70-FM	ES70-7C	FM-Up	50-85	Fast	2.048	225
120-FM	ES120-7C	FM-Up	95-165	Fast	4.096	100
200-FM	ES200-7C	FM-Up	170-260	Fast	4.096	105
333-FM	ES333-7C	FM-Up	280-380	Fast	4.096	40
FM (Frequency Modulated) Ping Group TS-probe						
38-CW	ES38DD	CW	-		0.512	200
38-FM	ES38-18DK	FM-Up	35-45	Fast	2.048	100
70-FM	ES70-7CD	FM-Up	55-85	Fast	2.048	75
120-FM	ES120-7CD	FM-Up	95-165	Fast	2.048	70*
200-FM	ES200-7CD	FM-Up	170-260	Fast	2.048	105
333-FM	ES333-7CD	FM-Up	280-380	Fast	2.048	40

Table 2 . Calibration target choice for narrowband (CW) and broadband (FM) pulses of indicated nominal frequency echosounder (e.g., “70CW” - continuous wave pulses at 70 kHz nominal frequency).

		18CW	**18FM**	**38CW**	**38FM**	**70CW**	**70FM**	**120CW**	**120FM**	**200CW**	**200FM**	**333CW**	**333FM**
Sphere ID	BW (kHz)	**-**		**-**	**34-45**	**-**	**50-85**	**-**	**90-170**	**-**	**170-260**	**-**	**280-380**
IMR106	WC57.2	X	X	X	X								
IMR023	WC38.1					X	X	X	X	X	X		

IMR123	WC35								X		X		
IMR139	WC25										X		
IMR065	WC22											X	X
IMR008	WC20												X

The standard survey data directory ‘EK80_CALIBRATION’ was established containing three types of data: The EK80 calibration *.raw files , the calibration results *xml files and the post-calibration copy of the “ConfigSettings” folder containing the “TrList_calibration.xml”.

The target strength probe was not used during the survey, and a calibration of this equipment was therefore not performed.

2.1 - EK80 on RV G.O. Sars

G.O. Sars is equipped with six drop-keel mounted echosounders (Simrad EK80) capable of continuous wave (CW)/narrowband or frequency modulated (FM)/broadbanded pulse generation. These have nominal frequencies at 18, 38, 70, 120, 200, and 333 kHz.

Both the 18 and 333 kHz transducers were new and installed prior to the survey and had not been calibrated previously.

Ship echosounders were operated with both CW and FM acoustic pulses. Settings for these were chosen to conform with standard IMR settings, to avoid undesirable effects such as acoustic “crosstalk” in broadband data. This influenced the choice of the acoustic bandwidth, power, and pulse duration settings (Table 2). Standard CW pulse settings (Korneliussen et al., 2008) were used, but with reduced power to match the power setting of alternating CW / FM pulses.

Calibration plan and calibration data collection progress

1. Two anchors and bottom depth ≥40 m
2. CTD cast. Update EK80 ‘environment’ (average sound speed, temperature, and salinity between transducer and the calibration target depth).
3. Calibration starts with the largest sphere (WC57.2).
4. When using multiple spheres to calibrate the EK80 channel use largest sphere first (or, update TrList_calibration.xml with calibration data starting with the largest sphere),
5. Use 500 g weight to stabilise the smaller spheres (WC35-25-22-20), 4m between sphere and the weight (0.5mm nylon),
6. Sphere netting should have minimum 1 m long netting loop. (i.e., ≥1m between the triple winch suspension lines knots/loops and the calibration target),
7. Make a post-calibration copy of the TrList_calibration.xml file (save whole folder ‘ConfigSettings’ to the survey directory ‘EK80_CALIBRATION’),
8. The Table 3 top-down progression is based on the order of the calibration target deployment.

Table 3 . Ship EK80 calibration data collection log (16.11.2023) at calibration site near Tromsø. Data collection sequence is based on calibration sphere deployment order.

Chanel	Frequency [kHz]	Pulse shape	Pulse duration [ms]	Power [W]	Power taper	Beam mapping	Calibration target	EK80 Updated
18-CW	18	CW	1.024	800	Fast	Full	WC57.2	Yes, replace
18-FM	12-24	FM-Up	2.048	400	Fast	Full	WC57.2	Yes, replace
38-CW	38	CW	1.024	400	Fast	Full	WC57.2	Yes, replace
38-FM	34-45	FM-Up	2.048	400	Fast	Full	WC57.2	Yes, replace
70-CW	70	CW	1.024	225	Fast	Full	WC38.1	Yes, replace
70-FM	50-85	FM-Up	2.048	225	Fast	Full	WC38.1	Yes, replace
120-CW	120	CW	1.024	100	Fast	Full	WC38.1	Yes, replace
120-FM	95-165	FM-Up	4.096	100	Fast	Full	WC38.1	Yes, replace
200-CW	200	CW	1.024	105	Fast	Full	WC38.1	Yes, replace
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC38.1	Yes, replace
EC-150-3C	*150*	*CW*	*1.024*	*90*	*Fast*	*Full*	*WC38.1*	*Yes, replace*
EC-150-3C	*138-162*	*FM-Up*	*2.048*	*90*	*Fast*	*Full*	*WC38.1*	*Yes, replace*
120-FM	95-165	FM-Up	4.096	100	Fast	Full	WC35	Yes, MERGE
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC35	Yes, MERGE
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC25	Yes, MERGE
333-CW	333	CW	1.024	40	Fast	Full	WC22	Yes, replace
333-FM	280-380	FM-Up	4.096	40	Fast	Full	WC22	Yes, replace
333-FM	280-380	FM-Up	4.096	40	Fast	Full	WC20	Yes, MERGE

	All CW in PASSIVE	CW				PASSIVE record. 200pings. 700m record range. Ping rate 1/sec.		
	All FM in PASSIVE	FM-Up				PASSIVE record. 200pings. 700m record range. Ping rate 1/sec.		

Initially the ES18 mk2 was not calibrated (either in FM or CW) due to the high noise levels. The original plan was to calibrate the ES18 mk2 according to Table 1 and Table 2 , and perform additional calibrations with 1 and 4 ms FM up pulses in addition to 2 ms (which is assumed to be future standard setting), and full allowed bandwidth. In addition, two power settings would have been used for 2 ms, “low” and “high” power (400 and 800). Further we planned to compared SNR and noise at those combinations of settings and investigate the transducer performance drop at the outskirts of the band. The ES18 mk2 was calibrated later during the survey (25.11.2023) in a narrow frequency band (FM mode, 22-28 kHz) as this band was found to be reasonably clean (see chapter Modified 333 & 18 kHz).

Additionally, all echosounders were run simultaneous and sequentially in survey settings with a calibration target located within the acoustic beams. This was performed to collect a data set for evaluating whether simultaneous calibration of all channels could be performed, and to investigate the crosstalk between the ES18 mk2 (at 400 and 800 W) as the 18 kHz power will likely be the driving factors for crosstalk.

2.2 - EK80 on Sounder

The EK80 on the Sounder “Frigg” was calibrated in port (Tromsø, November 15-16). The USV was docked alongside GO Sars, and similar settings and spheres to the research vessel was used. The spheres were deployed with two lines (as opposed to three for the vessel) and manually moved along the vehicle to move the spheres through the beam. The echosounders were powered by the Sounder and a remote desktop was used to perform the calibrations.

Calibration plan and suggested calibration data collection progress (Table 4):

1. CTD cast. Update EK80 ‘environment’ (the average sound speed, temperature, and salinity between transducer and the calibration target depth),
2. Start with largest, WC57.2 sphere,
3. When using multiple spheres to calibrate the EK80 channel use largest sphere first (or, update TrList_calibration.xml with calibration data starting with the largest sphere),
4. Sphere netting should have minimum 1 m long netting loop (i.e., ≥1m between the triple winch suspension lines knots/loops and the calibration target),
5. Make a post-calibration copy of the TrList_calibration.xml file (save whole folder ‘ConfigSettings’ to the survey directory ‘EK80_CALIBRATION’),
6. Table 4 top-down progression is based on the order of calibration target deployment.

Due to challenging environment, i.e. other scatterers in the water column interfering with the signal from the sphere, all raw files had to be manually cleaned before updating the calibration values.

The echosounder beam of the EC150-3C was not calibrated, this was not possible due to the narrow beam in combination with short range to the sphere and seafloor.

Table 4 . USV EK80 calibration data collection log (15.11.2023) at calibration site near Tromsø. Data collection sequence is based on calibration target deployment. EC 150C was not calibrated.

Chanel	Frequency [kHz]	Pulse shape	Pulse duration [ms]	Power [W]	Power taper	Beam mapping	Calibration target	EK80 Updated
18-CW	18	CW	1.024	800	Fast	Full	WC57.2 *	Yes, replace
38-CW	38	CW	1.024	400	Fast	Full	WC57.2 *	Yes, replace
38-FM	34-45	FM-Up	2.048	400	Fast	Full	WC57.2 *	Yes, replace
70-CW	70	CW	1.024	225	Fast	Full	WC38.1	Yes, replace
70-FM	50-85	FM-Up	2.048	225	Fast	Full	WC38.1	Yes, replace
120-CW	120	CW	1.024	100	Fast	Full	WC38.1	Yes, replace
120-FM	95-165	FM-Up	4.096	100	Fast	Full	WC38.1	Yes, replace
200-CW	200	CW	1.024	105	Fast	Full	WC38.1	Yes, replace
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC38.1	Yes, replace
EC-150-3C	150	CW	1.024	90	Fast	Full	WC38.1	Yes, replace
EC-150-3C	138-162	FM-Up	2.048	90	Fast	Full	WC38.1	Yes, replace
120-FM	95-165	FM-Up	4.096	100	Fast	Full	WC35	Yes, MERGE
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC35	Yes, MERGE
200-FM	170-260	FM-Up	4.096	105	Fast	Full	WC25	Yes, MERGE
333-CW	333	CW	1.024	40	Fast	Full	WC22	Yes, replace
333-FM	280-380	FM-Up	4.096	40	Fast	Full	WC22	Yes, replace
333-FM	280-380	FM-Up	4.096	40	Fast	Full	WC20	Yes, MERGE
	All CW in PASSIVE	CW				PASSIVE record. 200pings. 700m record range. Ping rate 1/sec.		

	All FM in PASSIVE	FM-Up				PASSIVE record. 200pings. 700m record range. Ping rate 1/sec.		

3 - Modified 333 & 18 kHz transducers

3.1 - Objectives

A new broad banded 18 kHz transducer and a modified 333 kHz transducer were mounted in the instrument keel of RV G.O. Sars prior to the 2023001016 survey, and the objective was to test the performance of the two systems. The introduction of a new broadband 18 kHz transducer is important for, e.g., identifying mesopelagic fish, where the higher echosounder frequencies, like the 333 kHz, are useful for detection and categorisation of smaller organisms like zooplankton, such as the copepod *Calanus finmarcicus.*

3.2 - Methods

The new broadband 18 kHz transducer was the second in a pilot series of 3 units. The first 18-kHz transducer in this series performed well onboard the Kongsberg vessel RV “Echo”. The EK80/18kHz system was going to be extensively tested and verified during this survey.

The 333 kHz transducer had a modified grounding where the objective was to increase the EMC immunity. A shield termination to sea was introduced on the transducer to improve EMC immunity against interference and noise along the cable routing.

Both transducers were tested during the survey. Noise estimates and echosounder data were compared to the earlier versions of the transducers. The comparisons were both visual and based on noise estimation from the LSSS system.

3.3 - Preliminary results

The impression was that the new EK80/18kHz system had severe challenges appearing as ringing. The performance in CW was worse than the previous narrowband 18 kHz transducer when comparing data from this survey with the data from last year’s CRIMAC survey (Figure 3). The figure shows that the system performed worse than the original from the 2022 survey. We suspected that the apparent ringing could be caused by the tight fit between the hull and the transducer, and we lowered the transducer below the drop keel by using longer bolts allowing the transducer to hang freely below the keel. The problem remained. More work to investigate the causes are needed. The apparent ringing was less prominent at the higher frequency ranges of the transducer.

The increase in performance for the modified EK80/333kHz system was encouraging (Figure 3), with much less noise compared to the original installation. The probability density functions for the noise estimated from the LSSS system demonstrate a clear improvement in performance for the modified system (Figure 4). This is also seen from the echograms for the original (Figure 5) and modified (Figure 6) 333 kHz data, respectively. Although the maximum range of the 2022 data appears to be similar between the 2023 and 2022 examples, the 2022 example school is much stronger. There is also some noise that is not removed from the FM data, which is likely due to narrowband noise in the broadband signal.

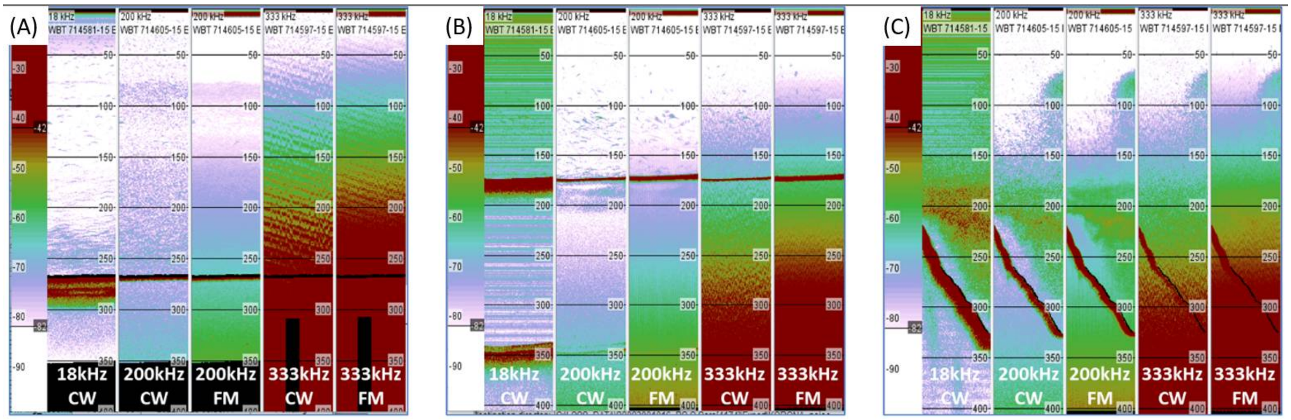
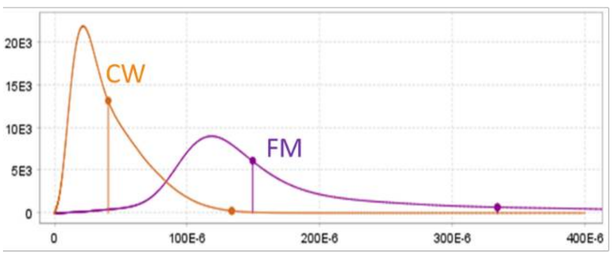
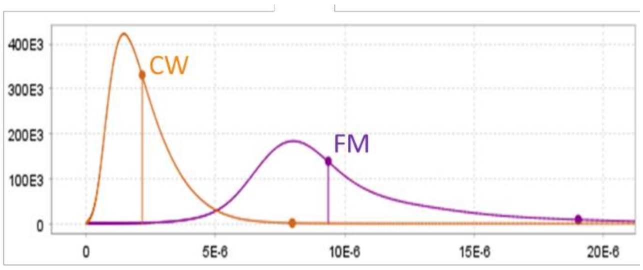


Figure 3 . Examples of unfiltered calibrated EK80 data from an earlier survey (A) compared to this survey (B, C) with RV «G. O. Sars», for surveys 2022115 (A) and 2023001016 (B, C), respectively. The colour-scales are similar between the examples (left column in figures). The five columns in each of subpanel, are the 18 kHz CW, 200 kHz CW, 200 kHz FM, 333 kHz CW, 333 kHz FM, respectively. Between surveys 2022115 (A) and 2023001016 (B, C) the 18 kHz transducer was changed from a narrowband transducer to a wideband transducer, while the 333 kHz transducer was modified with a different grounding (sea-water grounding). The noise in the 18 kHz was much less prominent in the 2022115 survey compared to the this survey, while the noise at 333 kHz was much improved after the modifications.



(a) Survey 2022115



(b) Survey 2023001016

Figure 4 . CW and FM noise estimates, respectively, from the original installation (a), and the modified installation (b). The curves are the probability-density-function for the noise, where the x-axis represents the strength of the noise. Thus, noise at 333-kHz were almost 20 times stronger in the 2022115 survey compared to the 2023001016 survey.

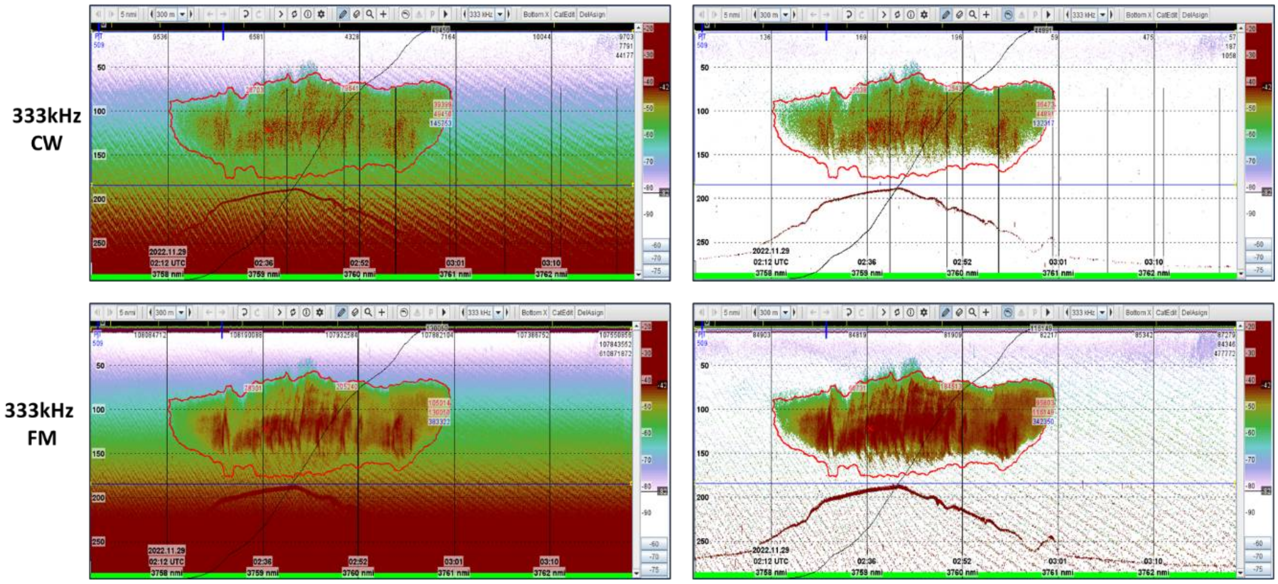


Figure 5 . Original, calibrated data at 333 kHz CW and FM from the 2022115 survey (left panels), and noise-corrected 333 kHz CW and FM data. Note that the school from the 2022115 survey is much stronger than the school from the 2023001016 survey.

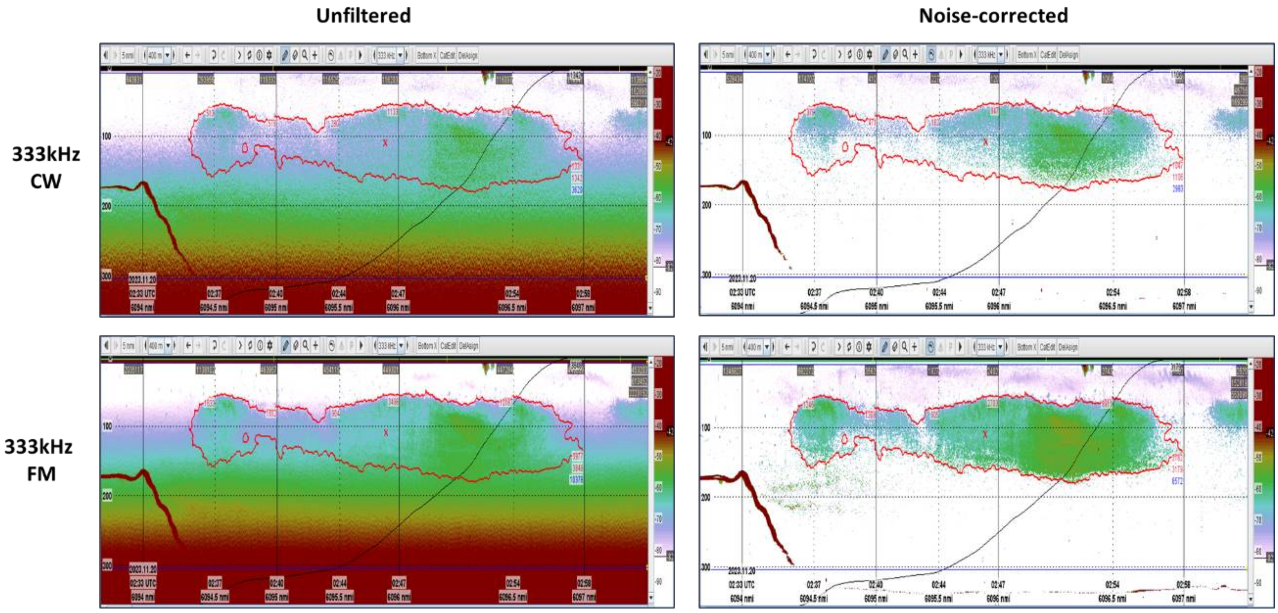


Figure 6 . Original, calibrated data at 333 kHz CW and FM from the 2023001016 survey (left panels), and noise-corrected 333 kHz CW and FM data.

4 - Acoustic data quality measurements on USV Frigg

4.1 - Objectives

The objective of this task was to assess the echosounder data quality from the USV Frigg in variable sea states and headings relative to the wind. Both noise from passive recordings and data quality based on masking from bubbles under the transducer were assessed.

4.2 - Methods

We collected both passive and active acoustic data to assess data quality at various sea states, different headings to the wind, and variable vessel speeds. Three different sites were chosen and ranged in sea state from sea state 2 to 4. The depth in the experiment areas ranged from 350 to 420 m (Table 5).

For sea state 2-3 and 4 an octagon pattern was chosen to cover 8 different headings to the wind (Figure 7 ab). For the sea state 2, a transect in and out the fjord was chosen (Figure 7 c), assuming that the wind did not affect the data quality at this sea state. An additional treatment was introduced for the latter, where the engine rpm was kept constant for a 5 minute-interval followed by a 5 minute-interval where the rpm was manually varied. The varying rpm range was similar to the rpm range during autonomous operation for the current speed control settings. The latter was included to assess whether there was any effect of varying the rpm on the noise levels, and particularly from propeller cavitation. We also measured the noise levels during the tow test, simulating the effect of operating the USV with the engine disengaged. We also tested the noise levels with the vessel stationary and running the engine with the propeller disengaged using RPMs like normal operation.

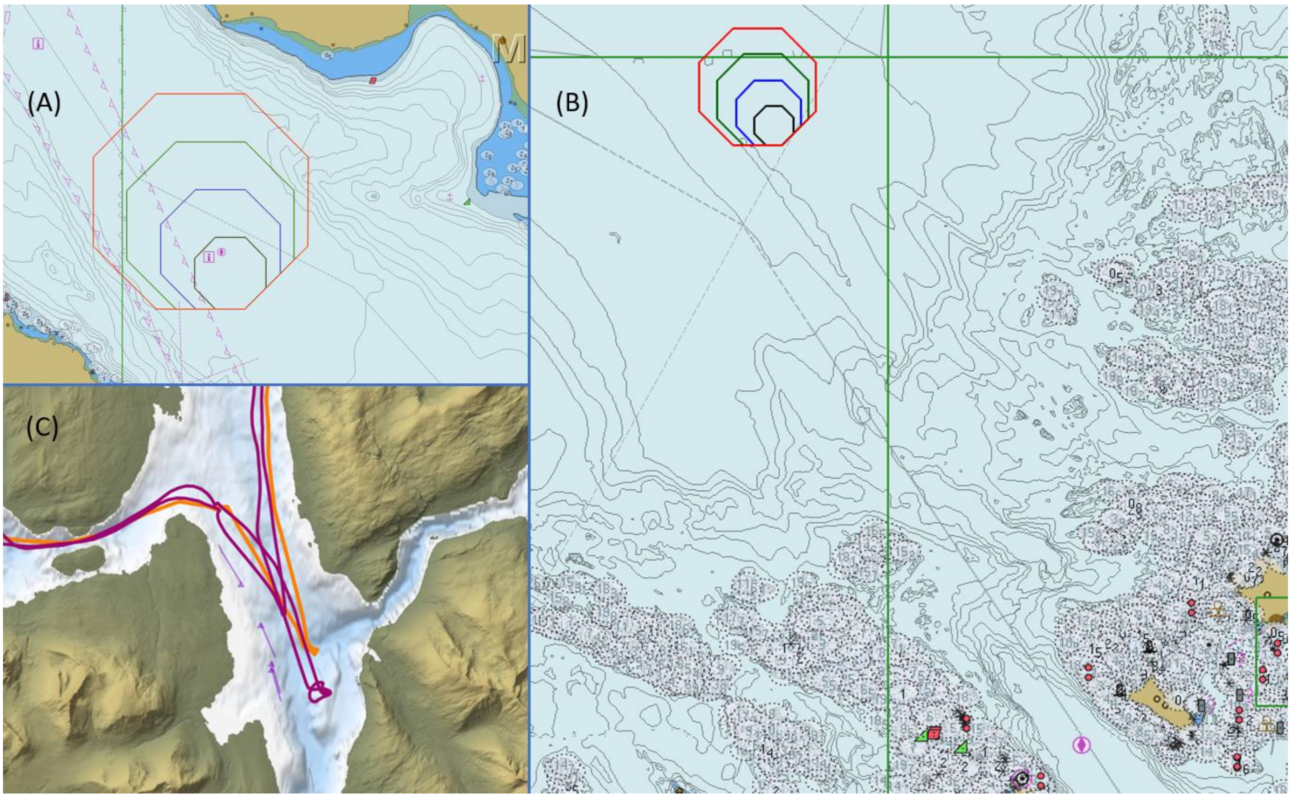


Figure 7 : (a,b) Octagons and (c) transect pattern for measuring data quality. Two locations were chosen for the octagon experiments, one in Malangen (a) for sea state 2-3 and one in Austerhola for sea state 4 (b). The largest and smallest octagon patterns were covered while cruising at 9 and 3 knots, respectively, and the others at 5 and 7, such that each side had a 4-minute duration. The full octagon patterns were repeated 3 times per location. (c) The transects in Lyngsfjorden. Each transect was covered while changing the vessel speed in steps of 3, 5, 7 and 9 knots, and while keeping the rpm constant and variable.

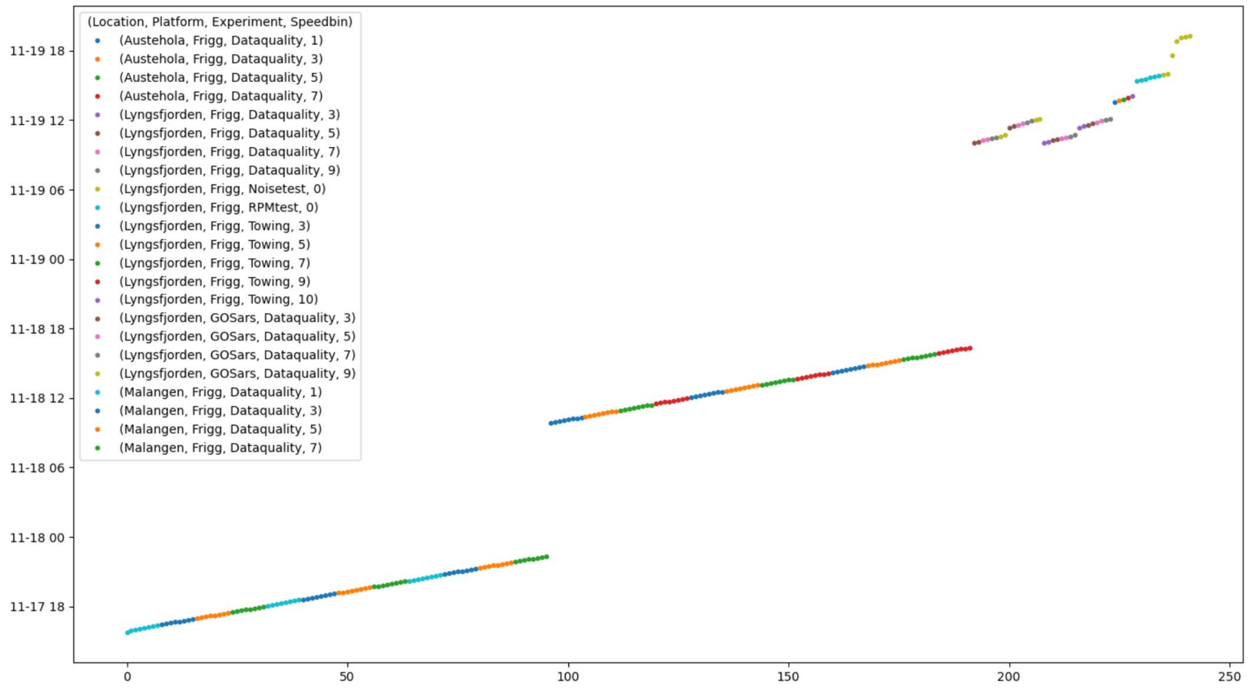


Figure 8 . The time for the location, platform, experiment and speed for each measurement.

Each transect or octagon pattern was repeated with four different vessel speeds (3, 5, 7 and 9 knots), and each leg of the octagon pattern had a duration of 4 minutes each. For the data collection in the calm state 5 minutes were used for each speed, allowing time for the speed to stabilize when changing speed. Each sequence covering the different headings to the wind and speed was repeated 3 times per sea state. After the completion of the octagon sequence in the outer region, Frigg was drifting while logging acoustic data (Austerhola, Frigg, Speed=0). The purpose was to estimate the amount of bubbles in the upper water column not caused by the platform. RV G.O. Sars covered the same transects as USV Frigg. This allowed us to compare the data quality metrics between RV G.O. Sars and USV Frigg.

Table 5 . Overview of the timing of depth, location and experiment for the different experiments.

Platform	Starttime	Stoptime	Depth	Sea state	Location	Experiment
Frigg	2023-11-17T15:53	22:26	380	2-3	Malangen	Dataquality
Frigg	2023-11-18T09:51	16:44	440	4	Austerhola	Dataquality
GOSars	2023-11-18T16:44	18:43	440	4	Austerhola	Dataquality
Frigg	2023-11-18T19:06	19:17	440	4	Austerhola	Dataquality
Frigg	2023-11-19T09:39	12:14	330	2	Lyngsfjorden	Dataquality
GOSars	2023-11-19T09:39	12:14	330	2	Lyngsfjorden	Dataquality
Frigg	2023-11-19T13:33	14:05	330	2	Lyngsfjorden	Towing
Frigg	2023-11-19T15:24	19:22	330	2	Lyngsfjorden	RPMtest, Noisetest
GOSars	2023-11-21T20:02	21:56	440	3	Austerhola	Dataquality
GOSars	2023-11-21T23:36	01:46	380	2-3	Malangen	Dataquality

Sensor data were logged at the platform during acquisition. These included GPS position, engine RPM, heave, tilt and roll, wind direction and wind speed. The sea state was taken from the RV G.O. Sars logbook, where the sea state is manually assessed by the personnel on the bridge. All systems were time synchronized, and echosounders on USV Frigg and RV G.O. Sars were calibrated in CW and FM using IMR standard settings (c.f. calibration table). The echosounder data were acquired using the EK80 “advanced sequencing”, where four ping groups were set up covering combinations of passive/active and CW/FM transmissions. Each group included all frequencies, but the 18 kHz transducer was included in the CW groups only since it lacks broadband capabilities. The combinations were (CW+FM)*4 + (2*CWpassive+2*FMpassive).

The passive noise estimates were estimated using the Korona module in LSSS for the different frequencies (Figure 9 and Figure 7). The noise estimates were provided for each frequency channel and platform as a function of time, and the time interval for each treatment (Figure 8) was used to assign the noise to the corresponding treatment. The data was merged using python and imported in R as a tibble and plotted using the tidyverse packages.

To compare the effect of the reduction in bottom echoes due to potential bubble sweep down caused by vessel motion, the bottom echoes were integrated for the transects in each location for both RV G.O. Sars and USV Frigg. The ratio between the transects are used as a proxy for bubble attenuation while noting that the echo integrated bottom signal is affected by tilt and roll of the transducer. The preliminary results must be interpreted with this in mind.

4.3 - Preliminary results

The raw noise estimates were exported from the LSSS system (Figure 9). The initial results show that the noise estimates are substantially higher and varies more for USV Frigg than for RV G.O. Sars. A more detailed view is provided when dividing the data based on sea state (location), vessel speeds, and platform (Figure 10). Much of the variability is explained by platform speed for USV Frigg. Towing the vehicle at the same speed intervals results in lower noise estimates (Figure 11). This suggests that the cause of the noise is associated with the propulsion system including the propeller, and the characteristics are typical for propeller cavitation. It is therefore likely that the propeller cavitation is causing the variability in noise that is related to the changing speeds.

The data quality is also affected by the sea state. The echogram from the USV during the Austerhola experiment in sea state 4 (Figure 12) show indications of bubble damping as well as increased noise for sea state 4 (Figure 12) compared to sea state 2-3 (Figure 13). The bottom echo recorded from G.O. Sars and USV Frigg for both areas was integrated and compared (Figure 14). For the sea state 4 the integrated backscatter from the bottom signal was lower from Frigg compared to G.O. Sars, and the difference was higher for the lower speed. Note that the echo integration was not corrected for transducer motion, and without adjusting for transducer motion we cannot conclude on the cause of the difference. For sea state 2-3 the difference was lower and consistent between different platform speeds.

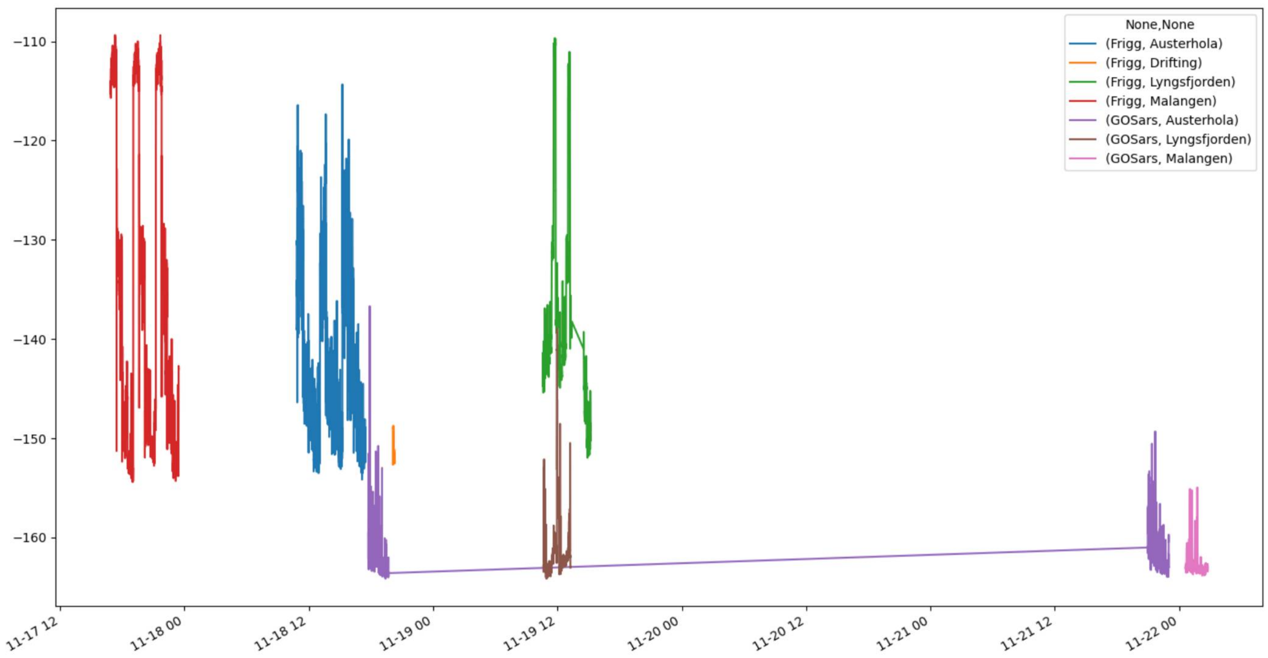


Figure 9 . Raw noise estimates for the 38 Hz channel as a function of time estimated using Korona, for each platform and location, respectively.

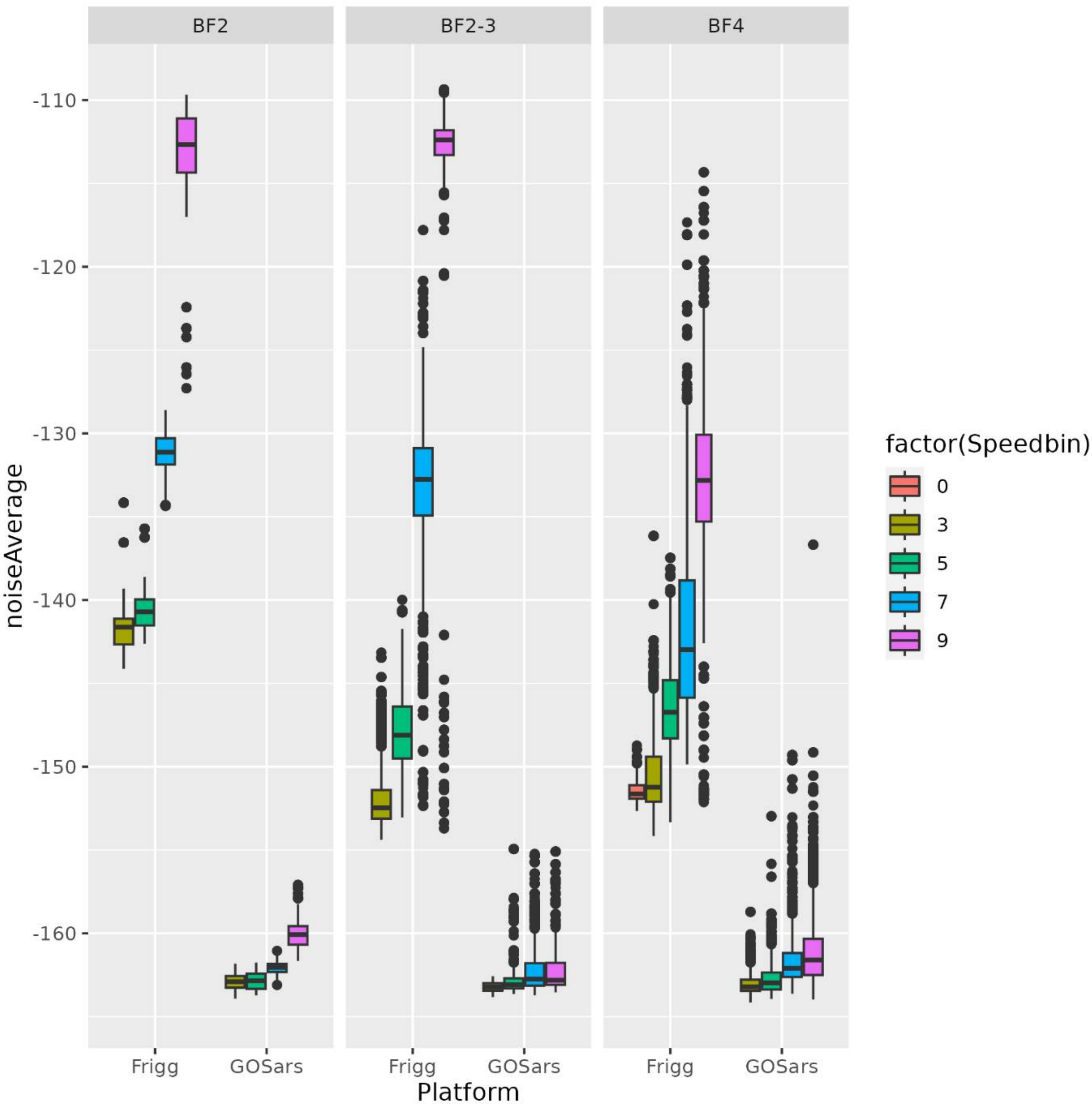


Figure 10 . The noise estimates grouped by sea-state, platform and platform speed.

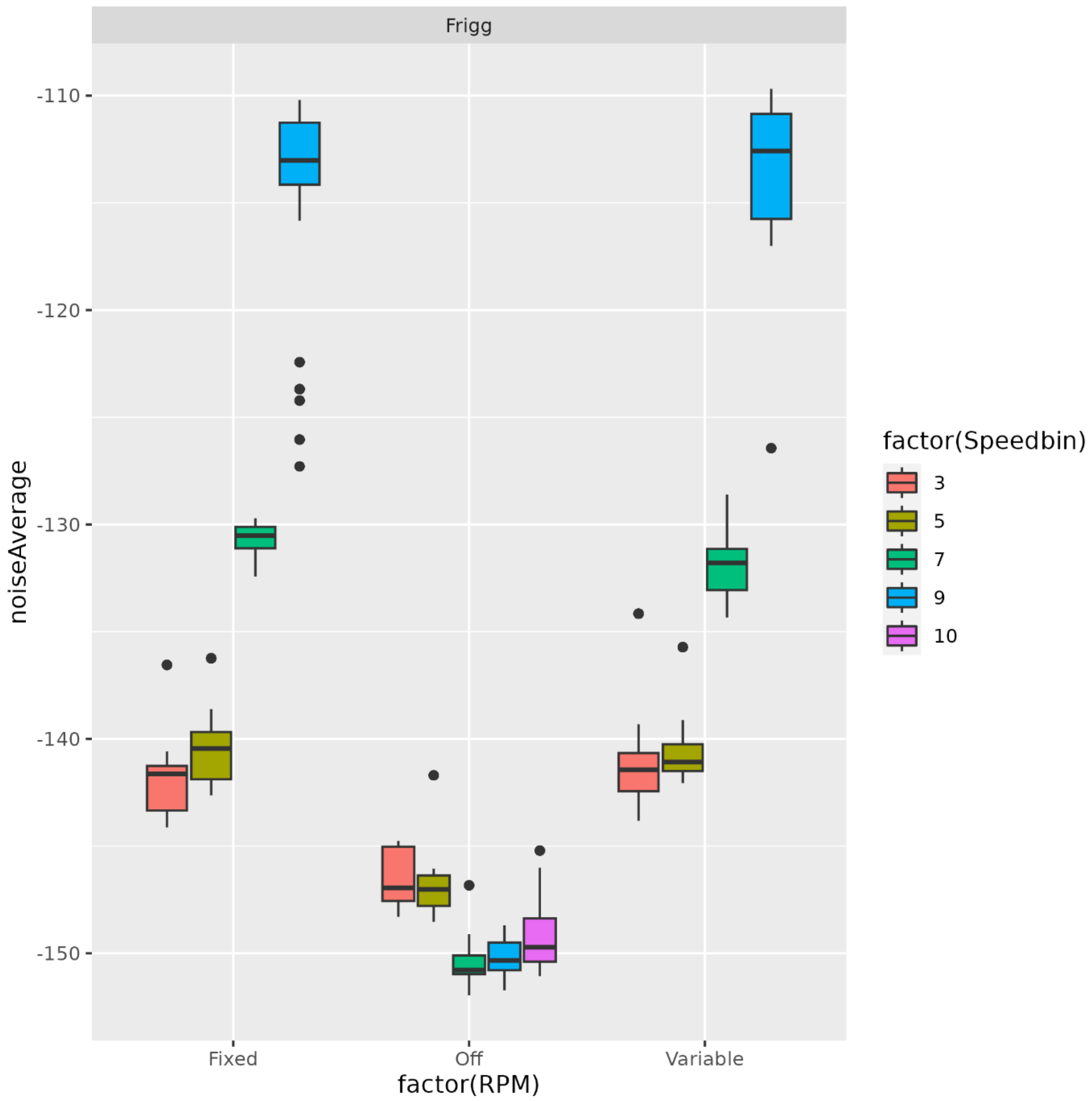


Figure 11 . The noise estimates for USV Frigg grouped by fixing the RPM (fixed), continuously varying the RPM (variable), and disenganging the propeller during towing (off).

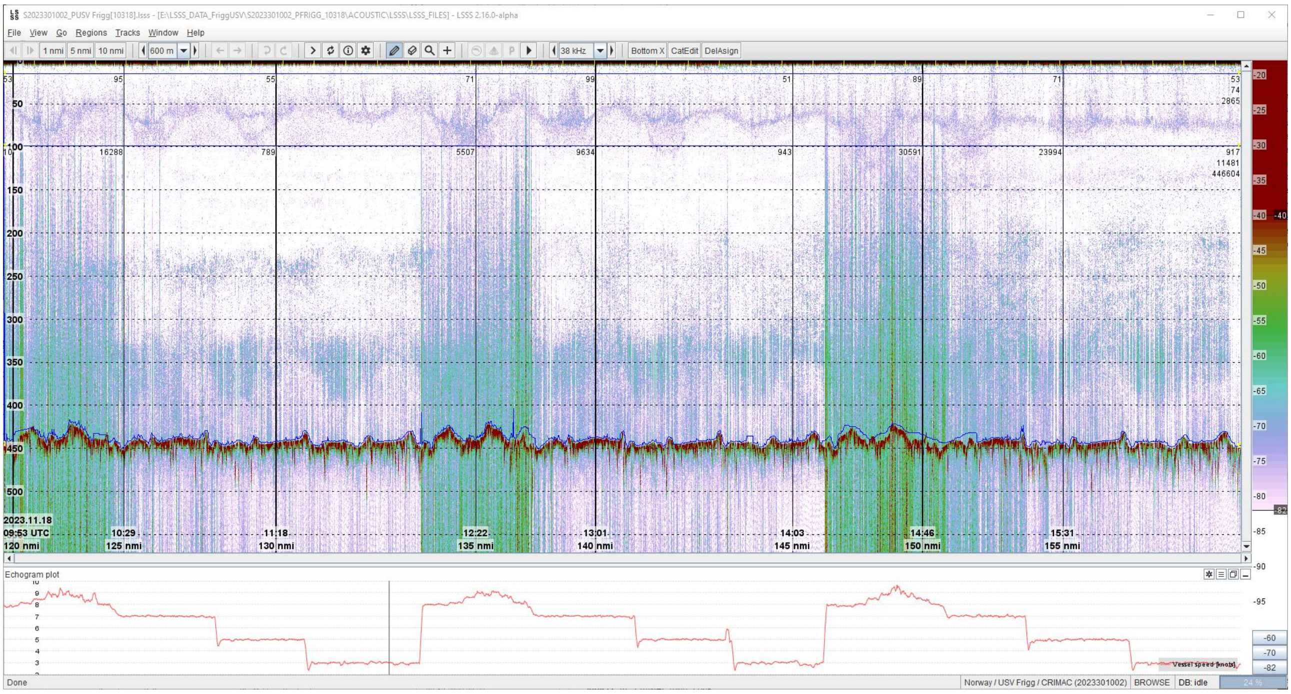


Figure 12 . Echogram from USV Frigg taken from the Austerhola octagon in BF4. Note the vertical stripes indicating loss of acoustic backscatter caused by bubble attenuation. The increased noise cause by increased speed is seen as the green "columns" in the echogram.

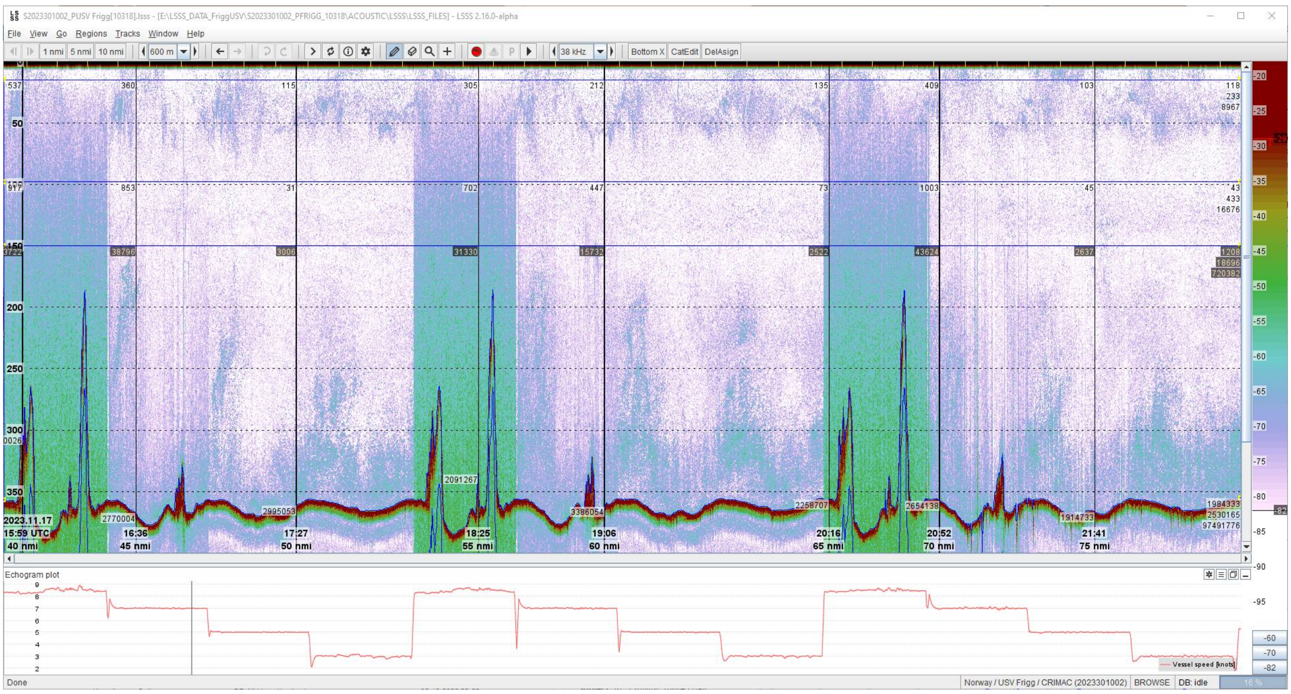


Figure 13 . Echogram from USV Frigg from the Malangen Octagon in BF 2-3. The increased noise cause by increased speed is seen as the green "columns" in the echogram.

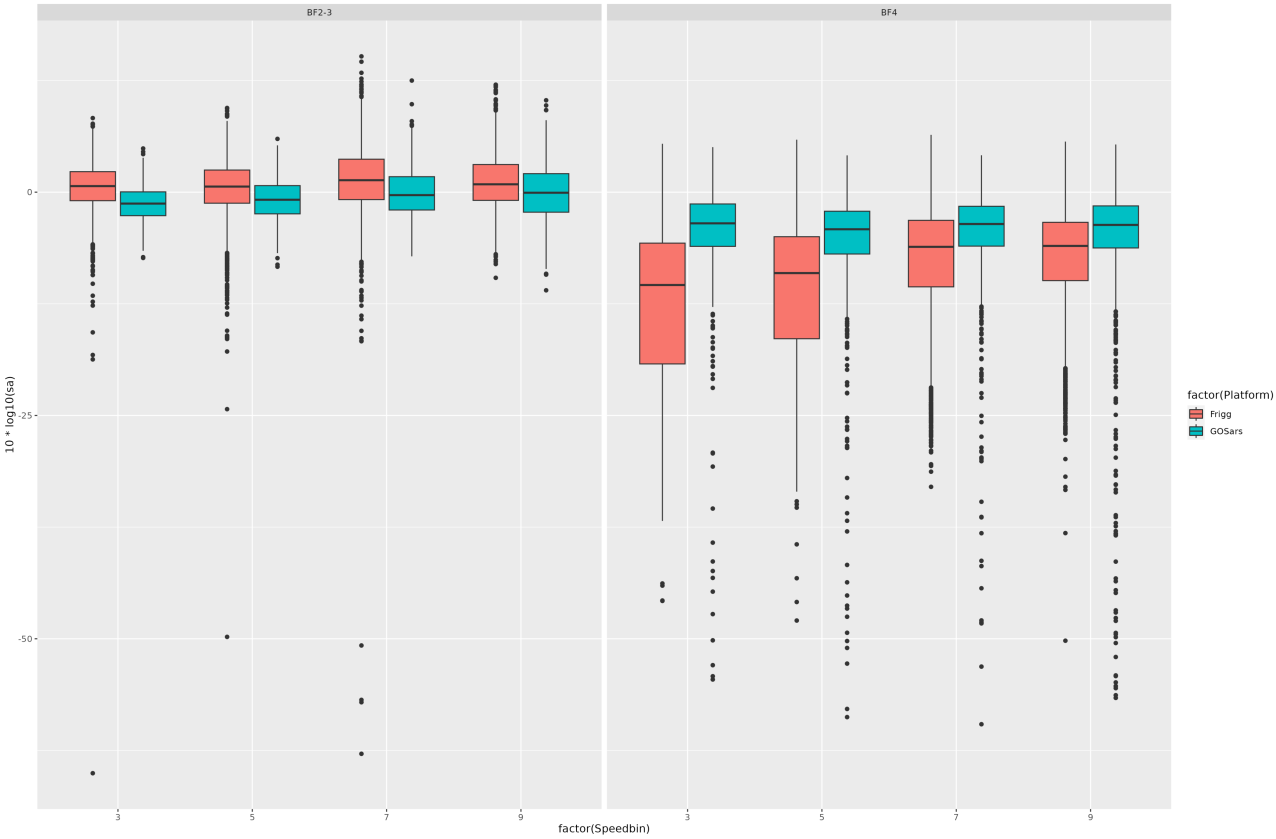


Figure 14 . The integrated bottom signal from the Malangen (BF2-3) and Austerhola (BF4) octagons, respectively.

5 - Automated sounder control and data quality

This task investigated whether the quality of the collected acoustic data could be increased by adjusting the navigation of the USV during operation. A controller was proposed that takes in bubble induced ping drop out as an input to adjust heading and speed of the vehicle USV Frigg.

5.1 - Objectives

Objective 1 : Quantify correlation between sea state, data quality and navigation.

To provide a justified control architecture, the model of correlation between input/observed parameters (sea state and data quality) and navigational control outputs (speed and heading) must be established.

Objective 2: Evaluate controller performance.

The objective was to evaluate the controller's performance in terms of reduced ping drop out and time increase. Further the metrics used for navigational accuracy (position), data quality estimation (ping drop out) and sea state (peak wave frequency, mean wind velocity) were evaluated in terms of robustness to tuning changes.

Objective 3: Identify platform-related challenges and weaknesses in the data sampling approach.

Since this work package takes an iterative approach, the purpose of this data set is also to identify issues in fundamental algorithm design, data logging and platform interface as early as possible.

5.2 - Methods

Algorithm The purpose of the algorithm is to provide a real-time feedback control loop, that outputs a desired speed and heading based on the observed ping dropout rate. The speed control is a PID controller, which scales a defined error signal at every timestep. The error signal is defined either as the difference of (1) the current ping dropout rate and a desired percentage drop out or (2) the sum of roll and pitch movement and a set threshold.

Platform Interface The command of the Sounder platform is executed via the Maritime Robotics backseat driver interface. The backseat driver is a command abstraction layer running on the on-board computer (OBS). It can be used to receive basic navigational information and transmit command signals to the platform via a TCP connection (cf. Maritime Robotics document MR2USV/D101).

5.3 - Preliminary Results

When testing the controller, two versions were used: One that took ping drop out as a control input, and one that acted on roll and pitch. No dropouts were observed during the experiments, so that the threshold for dropouts would either result in a constant maximum velocity (algorithm always detected no dropouts at high threshold) or minimum velocity (constant dropouts due to low threshold), cf. Figure 15 . When based on roll/pitch magnitude, the platform reacted reliably, reducing the attitude motion by velocity adaption as compared to no controller active, cf. Figure 16 .

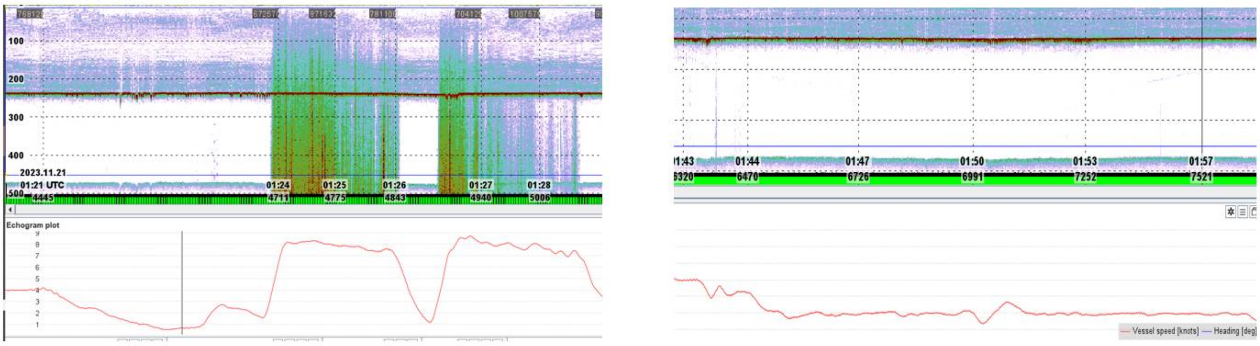


Figure 15 . Performance of the drop out advised algorithm at two different drop out thresholds of 25 and 20dB difference from global maximum.

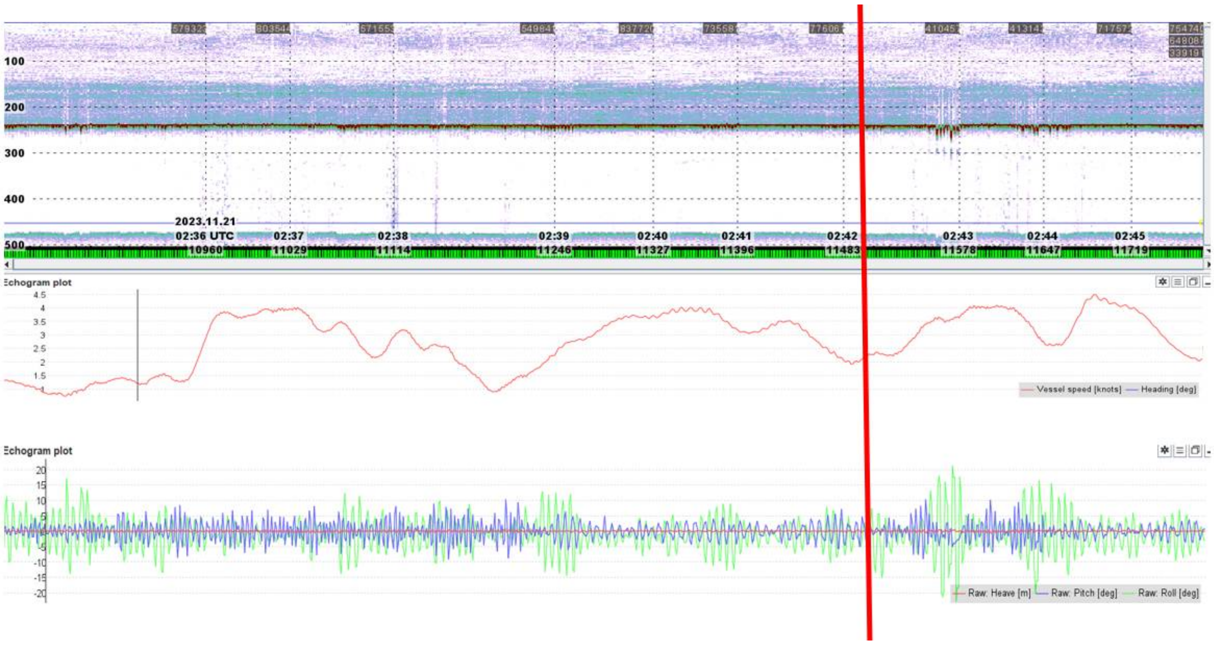


Figure 16 : Performance of the roll/pitch advised controller. The line indicates the change from controller active to inactive.

The main weaknesses in the controller design are observed to be: (1) Ping drop out as control input. The drop out threshold was observed to have a large impact and depend on the sea state, velocity range and platform. It further is a delayed input with an observed update delay of 5s, whereas roll and pitch information delay were less than a second. (2) Real-time echogram processing: Access to the echograms can (for now) only be facilitated on the same local machine as the EK80 software.

It was further evaluated whether taking in passive noise will benefit the stability of “data quality” as an indicator but was deemed to not be useful as a control input, since it does not depend on sea state or platform motion but rather on electrical and propeller noise.

6 - Broadband acoustic and Deep Vision trawl camera measurements of mesopelagic species

6.1 - Objective

The original objective was to use the 18 kHz broadband echosounder to measure mesopelagic species and validate species composition with image data from the Deep Vision trawl camera. The hypothesis was that the wide band covers the resonance frequencies of pearlside, *Maurolicus muelleri* , and can be used for sizing and distinction between species. The lantern fish *Benthosema glaciale* replaces its gas filled cavities with oil sacks, and we would like to see if we could detect this using BB sweeps around the operating frequency of this transducer. A new broadband 18 kHz echosounder from Kongsberg Discovery was installed at cruise start, but high noise levels (ringing) in the whole range prevented us from using it in broadband. The objective was then changed to collect data to describe the species composition in the fjords combining broadband acoustic methods and image data from trawl camera, focusing mainly on *Maurolicus and Benthosema* . Additional objectives were to test a newly developed image detection algorithm for mesopelagic species, implement it into the data pipeline on GO Sars and collect new training data.

6.2 - Method

Data were collected in Ullsfjord on the 23. November (between 09:46 and 15:20 UTC) and in Lyngsfjorden on the 24. November (between 13:00 and 16:00 UTC). This time of the year dawn is at 08:30 and dusk is at 14:20. Acoustic data were collected using the ship based Simrad EK80 wideband transceiver and six wideband split beam transducers ES18-11 (14 kHz single frequency), ES38B (34 – 45 kHz), ES70-7C (50 – 85 kHz), ES120-7C (95 – 165 kHz), ES200-7C (170 – 260 kHz) and ES330-7C (280 – 380) in transects along the mid fjord (Figure 17). Trawl samples were collected with the Harstad sampling trawl. The trawl is 84 m long, has 200 mm mesh in the wings and forepart and 60 mm mesh in the belly and aft sections. Thyborøn type 7a trawl doors were used. The trawl was equipped with a Scantrol Deep Vision camera system mounted in front of the cod end. Trawling was made with open codend and the Deep Vision recorded stereo images at a rate of 10 frames/second. Trawl geometry was monitored with sensors on the doors and headline and the trawl opening height was 17 – 19 m and door spread about 65 m. An external depth sensor was attached to the Deep Vision system. Long trawl hauls were made along the centre of the fjord, covering the same area as the acoustic transects, with stepwise trawling at different depths. The aim was to trawl minimum 15 minutes in each depth layer. The depths were selected based on the scattering layer depths as observed on the echosounder varying between 30 and 200 m.

The deep vision data were analysed using a newly developed machine learning algorithm for mesopelagic species. The detector is trained on Maurolicus, Gonatus, krill, Benthosema, Sergestes and Periphylla. The model uses a smaller scaling factor for predictions than the previous version developed for pelagic species (min image size=1000 instead of 800) (Allken *et al.* , 2021) . Different optimal score thresholds for different species were also used. These were determined empirically on a validation data set.

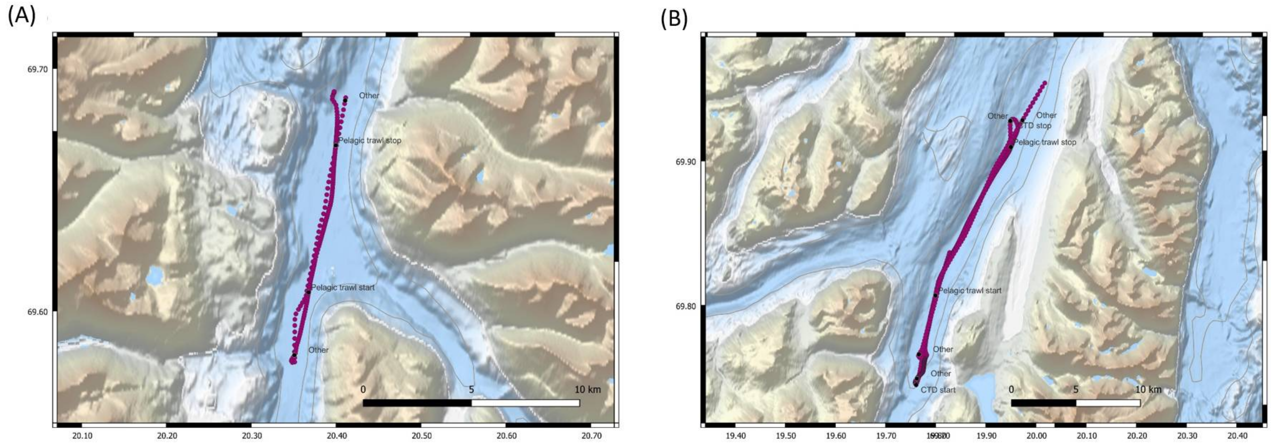
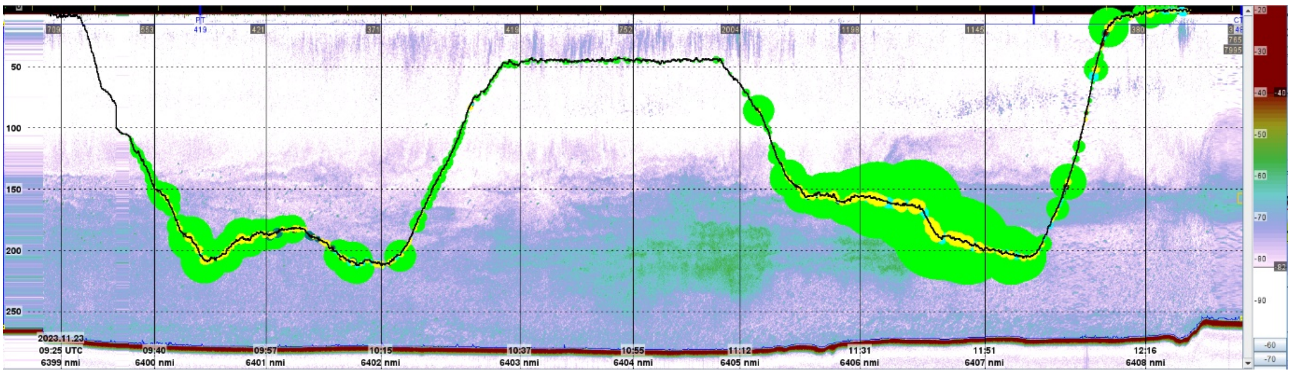


Figure 17 . Map of the two locations (A. Ullsfjorden and B. Lyngenfjorden).

6.3 - Preliminary results

We aimed for distinct layers of mainly, *Maurolicus* sp. and *Benthosema* to investigate if broadband data can be used to distinguish species and sizes. Small *Maurolicus* tend to be distributed near surface at daytime, while larger *Maurolicus* slightly deeper. *Benthosema* is typically at depths deeper than 300 m. At nighttime the *Benthosema* tend to migrate to shallower water. The scattering layers in Ullsfjord or Lyngenfjord were not distinct, but loosely distributed in the whole water column with highest densities from about 150 to seabed (~250 m). Balsfjord and Fugløysund west of Arnøya were also covered, but with no observations of clear mesopelagic layers. However, no clear layers of mesopelagic fish were discovered during the survey.

Echosounder data indicated that large quantities of krill were present in both fjords. This was confirmed by the results from deep vision image analyses. Krill dominated in the images (Figure 18). *Maurolicus* was also present in both fjords and perphylla and sergestes were present in Ullsfjord in smaller quantities. Other species not included in the algorithm were likely also present. A thermocline with rapid change in temperature and salinity was present at about 100 m in Ullsfjord and 150 m in Lyngenfjord (Figure 19).



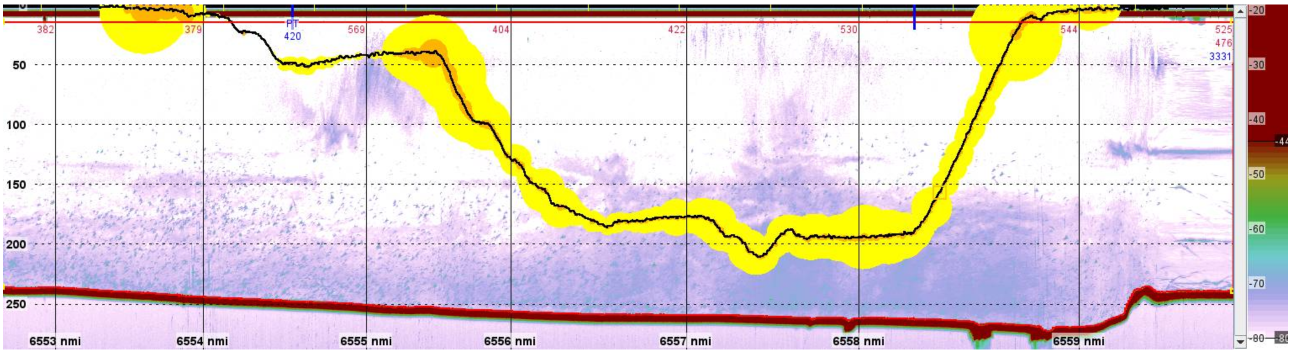


Figure 18 . Echograms and Deep Vision depth tracks during trawling. The colours along the trawl path indicate species and bubble size quantities estimated by the algorithm. Images are created in LSSS. Colour explanations can be found in Table 7 .

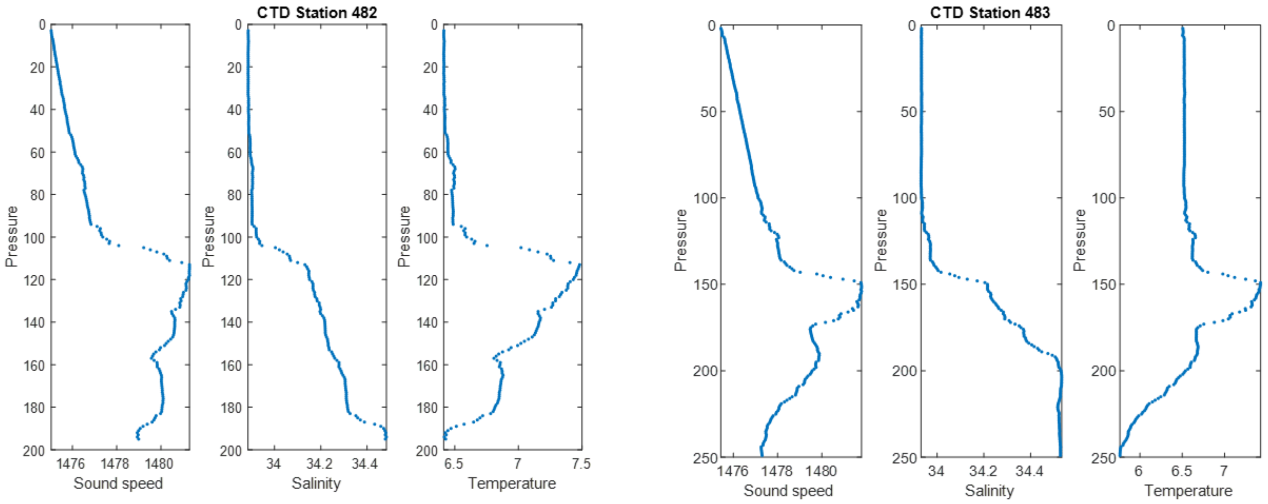


Figure 19 . CTD stations. Left: Ullsfjorden, right: Lyngenfjord.

Table 6 . Download and processing time of DV data in the two trawl hauls.

Station	Time taken				No images	Size in GB		Fraction active
	Download	**Postprocessing**	**Docker**	**Total**		Unprocessed	Processed	
20231123T0902Z	0:35:42	1:12:00	4:07:00	5:54:42	122329	22.8	45.4	0.53
20231124T1354Z	0:21:03	0:31:00	2:49:00	3:41:03	71256	13.4	25.4	0.6

Table 7 . Colours used for species in LSSS

Station	Maurolicus	Gonatus	Krill	Benthosema	Sergestes	Periphylla
20231123T0902Z	Yellow	Light green	Bright green	Dark red	Pale blue	Dark Blue
20231124T1354Z	Orange	Dark green	Yellow	Pale blue	Purple	Pink

7 - Comparison of acoustic densities measured from RV G.O. Sars and USV Frigg

7.1 - Objective

The objective of this task is to compare the measured acoustic density of herring during night between G.O. Sars and USV Frigg.

7.2 - Material and methods

An area of Kvænangen fjord that contained high densities of overwintering herring was chosen for the experiment. The area was chosen within the herring distribution area to avoid area conflicts with the commercial herring fishery and the gill net fishing activities in the fjord. The website “sildelaget.no” was used to study the herring fisheries, whereas the gill net activity information was downloaded from “fishinfo.no” as a redskap.gpx layer. Based on this we defined one stratum polygon for the first run (Figure 20), and another for the second run (Figure 21) using the OpenCPN software with a high resolution map downloaded from https://www.kartverket.no/. The surveys were carried out during night when the herring are distributed closer to the sea surface.

For each coverage, the R function surveyPlanner from the Rstox package was used to generate evenly distributed transects with random start position in a zig-zag pattern in the strata for RV G.O. Sars and USV “Frigg”. Table 8 shows the parameters used for the transect planning for each stratum and coverage by platform.

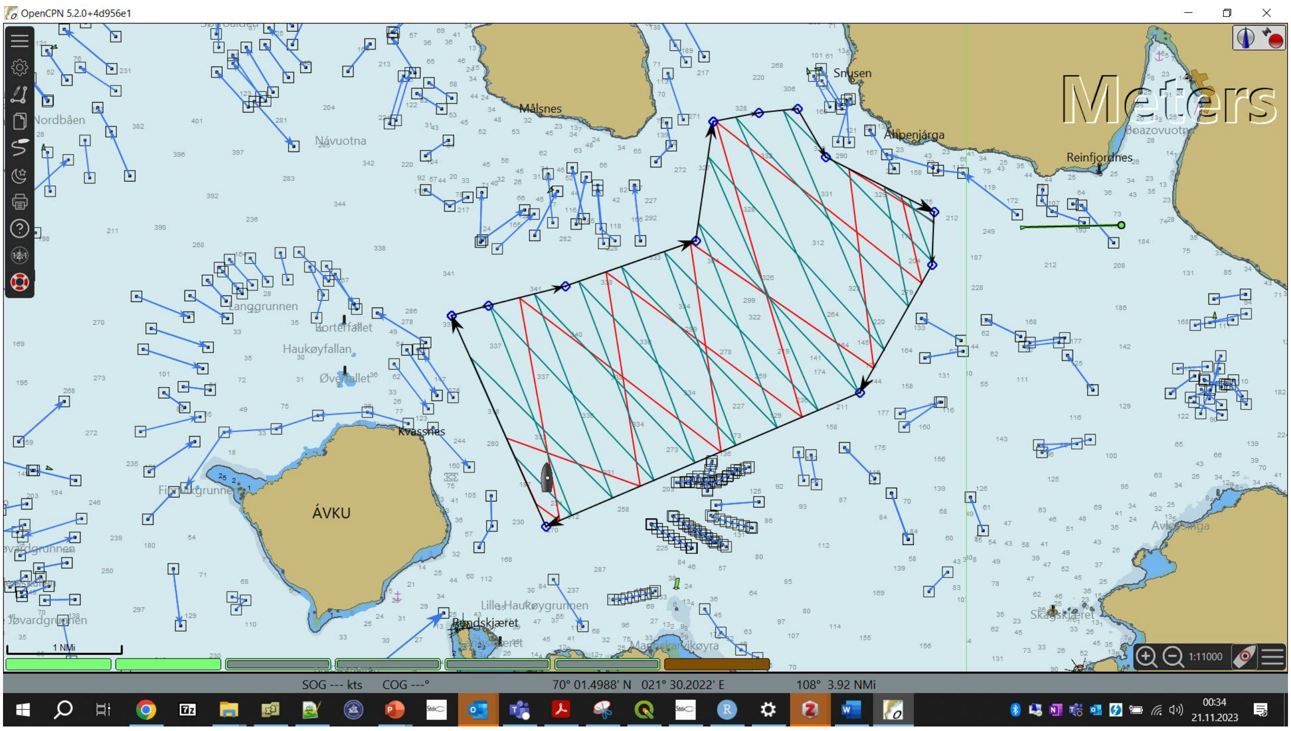


Figure 20 USV Frigg versus RV G.O. Sars experiment A. Planned transects of USV Frigg is marked as red, and the transects of G.O. Sars are depicted in green.

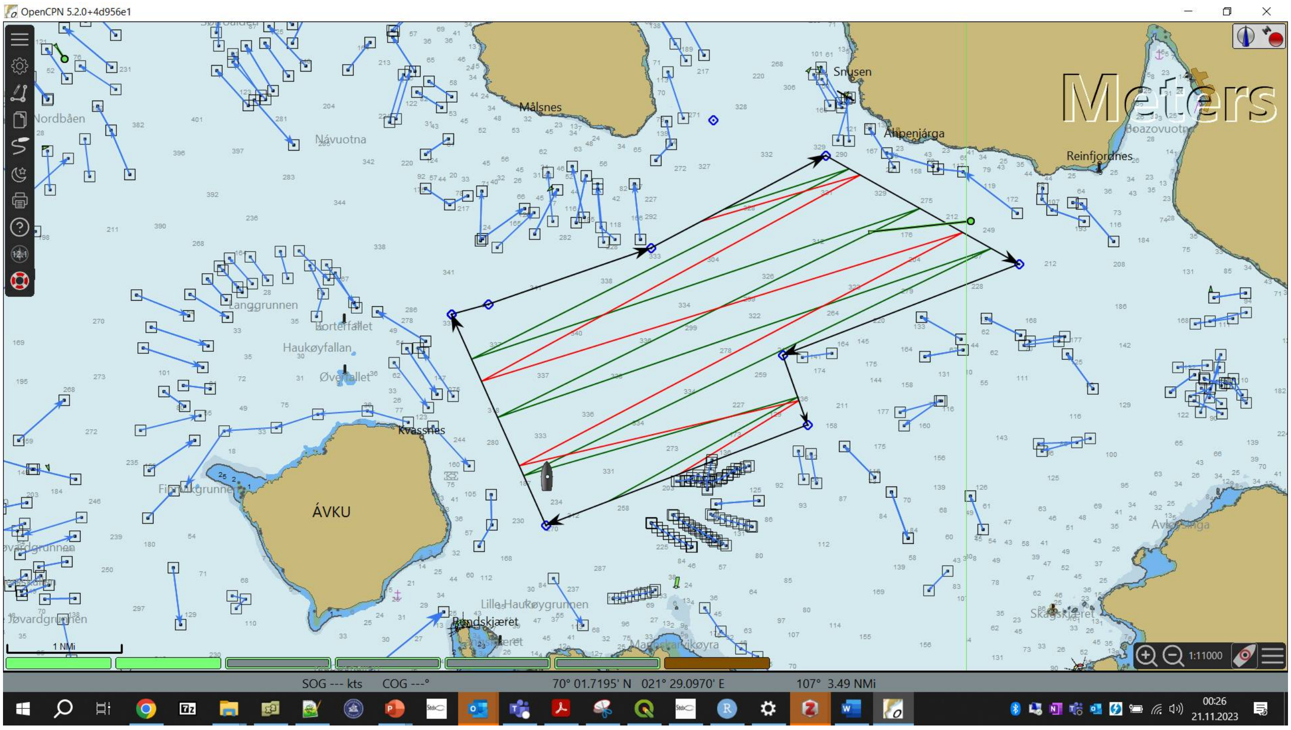


Figure 21 USV Frigg versus RV G.O. Sars experiment B. Planned transects of USV Frigg is marked as red, and the transects of G.O. Sars are depicted in green.

Table 8 . Overview of the parameters used to generate the transects in Rstox::surveyplanner.

Experiment	Survey	Platform	Speed (kt)	Bearing	Transect type	Return
A	1	G.O. Sars	9	Along	EqSpZZ	TRUE
A	2	Frigg	5	Along	EqSpZZ	TRUE
B	1	G..O Sars	7	Across	EqSpZZ	FALSE
B	2	Frigg	5	Across	EqSpZZ	FALSE

The echosounders on RV G.O. Sars and USV Frigg was operated using sequential pinging between FM and CW using IMR standard settings. The acoustic 38 kHz data was scrutinized using the LSSS system, and all backscatter above the integration threshold was assigned to herring. The data was exported to the ICES standard file format and imported into StoX (Johnsen *et al.* , 2019) . StoX 3.6.2 was used to make StoX projects for each of the surveys. The NMD Echosounder xml files produced in LSSS were imported into their respective StoX project. For the preliminary results the length distribution from 2020 was used, but biological information were collected from the catch sample lottery (https://www.sildelaget.no/no/kvoter-og-fangst/fangst/fangstproevelotteriet) that will be used to update the estimate after the cruise. The biomass was calculated using the standard acoustic target strength for herring (Foote, 1987) : TS = 20log L – 71.9. Based on these data, mean and 90%- confidence interval of biomass were estimated using standard baseline and bootstrap (*runs = 1000*) settings in StoX.

7.3 - Preliminary results

Visual inspection of the echograms shows that the depth distribution of the upper herring layer was distributed shallower below USV Frigg (Figure 22) than G.O. Sars (Figure 23). Also, the acoustic densities appear higher from the USV Frigg echograms compared to RV G.O. Sars. The NASC estimates from StoX were significantly larger using USV Frigg than RV G.O. Sars (two sample weighted t-test, p<0.005), and about 3.5 times higher for both for experiments (Figure 24).

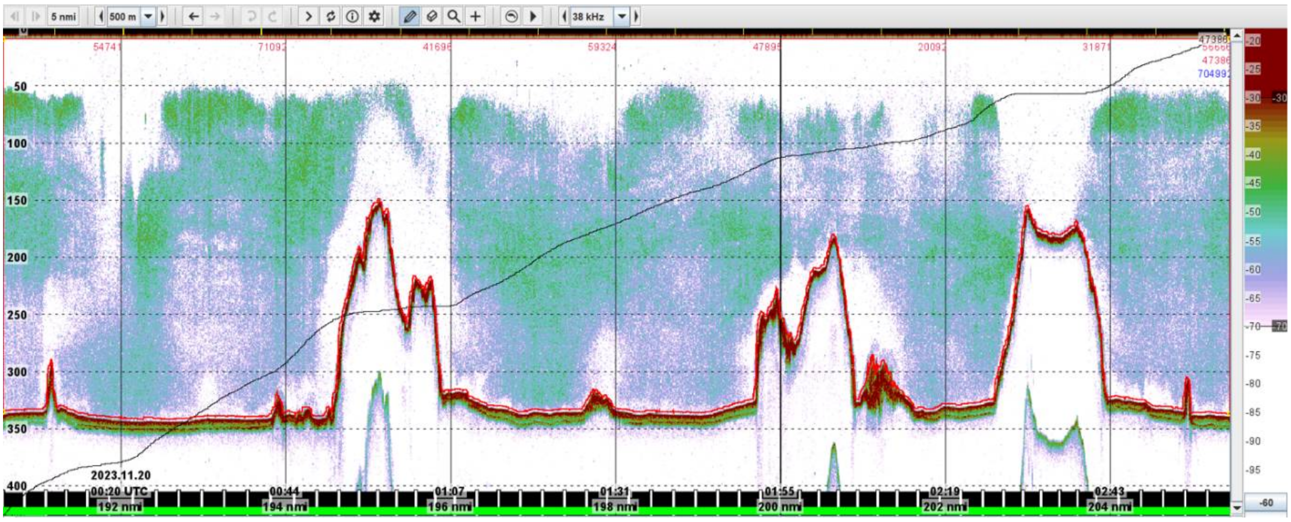


Figure 22 Echogram (38 kHz, CW) of herring layers monitored with USV Frigg during experiment A.

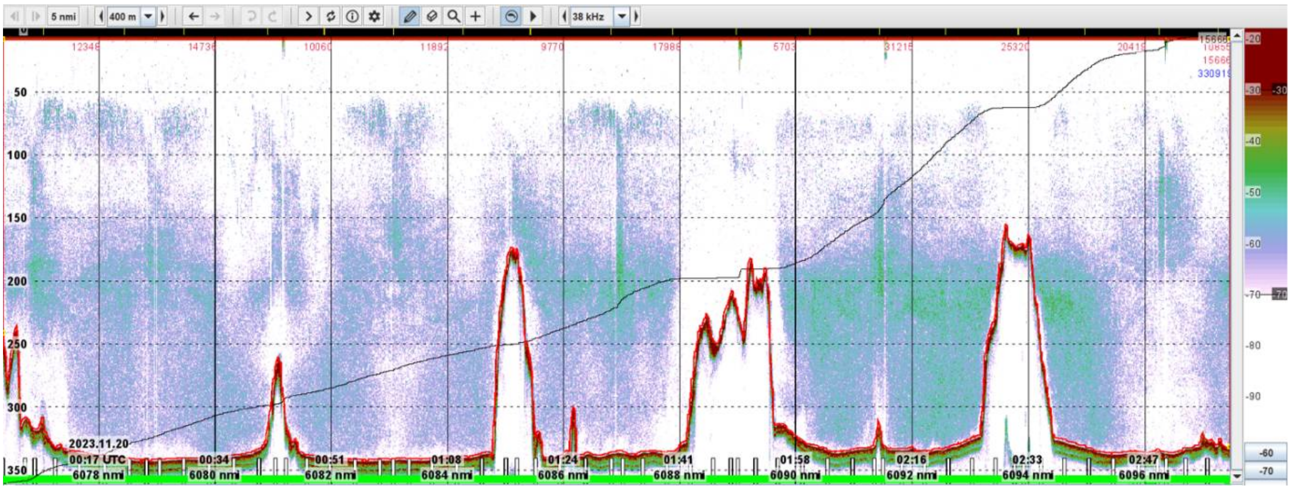


Figure 23 Echogram (38 kHz, CW) of herring layers monitored with RV G.O. Sars during experiment A.

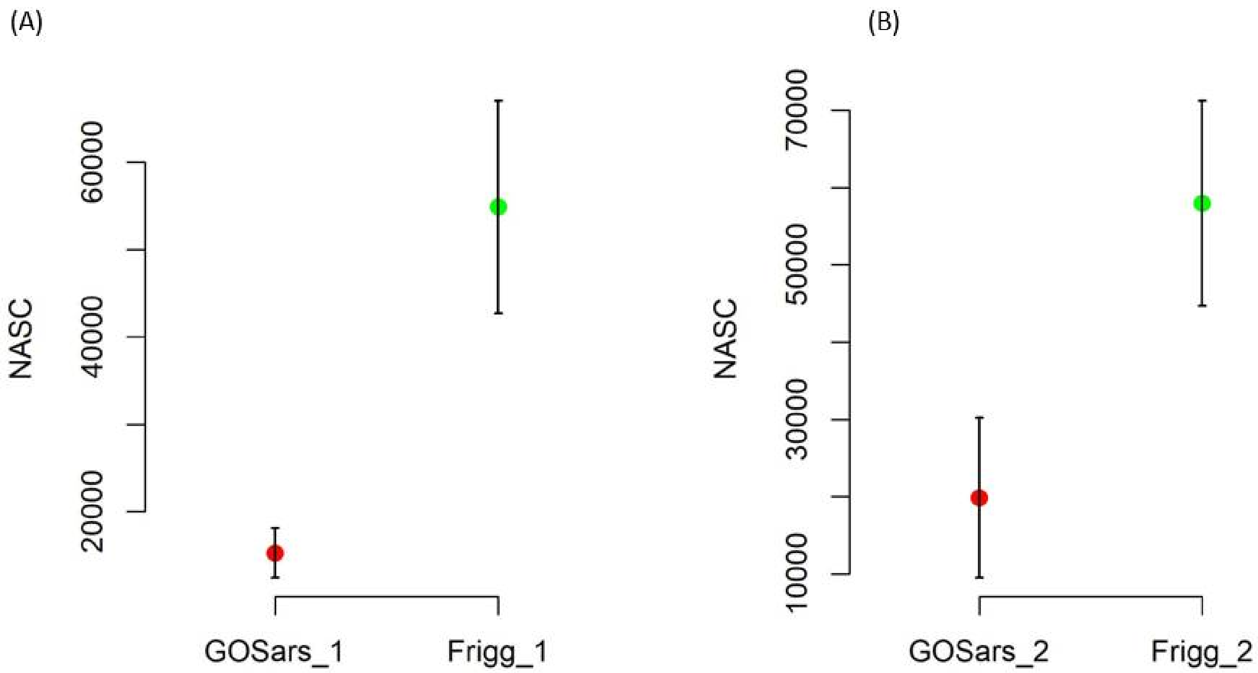


Figure 24 . Nautical area scattering coefficients by experiment (A, B) and platform. The centre value is the mean and the error bars indicate the 5- and 95% intervals.

8 - Testing whale scarer sounds on herring behaviour

8.1 - Objective

Norwegian catches of the pelagic species herring, mackerel and capelin are about 1 mill tons annually, and about 80% of these are caught using purse seines (Fiskeridirektoratet). This approach make the fish easily accessible for marine mammals and birds, and some species, such as killer whales, may follow fishing vessels in the search of “a free meal” (e.g. Vogel *et al.* , 2021) . This may create unfortunate incidents with whales getting entangled in the nets; with potential for both injury and even death for the animal and lost catches and gear for the fishermen (Bjørge *et al.* , 2023) . In the ongoing project “Kartlegging og testing av metoder for å redusere interaksjoner mellom fiskeri og hval”, it is tested whether sound can be used to keep whales away from ongoing fishing operations. The project results show a good deterrent effect on killer whales (Langstein, 2023) .

These sounds can be detected by herring, a species with good hearing due to a duct connecting its swimbladder to the inner ear (Enger, 1967) . If the herring respond to the sound signals, it may negatively affect the fishing operation. The objective of this task is to test whether the whale deterrent sounds affect the behaviour of herring or not.

8.2 - Methods

The TAST (target specific startle technology) system, developed by Genuswave LDT, transmits sound pulses that are of short duration and rise time with random intervals between transmitted pulses. Based on the published literature on this system (Götz and Janik, 2015; Langstein, 2023) , we generated sound sequences with the following properties:

- Each signal was 200 ms in duration
- Signal rise time was less than 5 ms
- Interval between pulses was random, varying from 1 to 40 seconds
- Signals were band passed white noise

The TAST system also randomizes the frequency bands within the sound sequence, however, in our experiment, we aimed at testing different frequency bands separately to assess if any frequency bands influenced herring behaviour. Consequently, we separated the sound clips into 4 different frequency band, each covering one octave:

Frequency band 1: 200-400 Hz

Frequency band 2: 400-800 Hz

Frequency band 3: 800-1600 Hz

Frequency band 4: 1600-3200 Hz

In addition to the TAST signals, we also played back recordings of killer whales. These sounds were recorded in Vestfjorden, Northern Norway in 2006, of killer whales feeding on overwintering herring. Recordings consisted both of calls and echolocation signals.

The playbacks were done with an underwater speaker (Lubell Labs LL1424HP) designed for Underwater Acoustic Deterrent Systems. It transmits within the frequency range of 200Hz - 9kHz, with maximum power at 600 Hz. Sound recordings, to monitor the sound level and proper output, were done with a sound trap 300 hydrophone from ocean instruments.

The sound source was lowered from a crane from the side of the ship to a depth of 15 m, limited by its cable length. A hydrophone was deployed 10 m below the source to measure the sound source level close to the source. A second hydrophone was lowered from a crane to 100 m depth, which was the assumed depth of the main herring layer, to measure the sound level received by the herring (c.f. Figure 25).

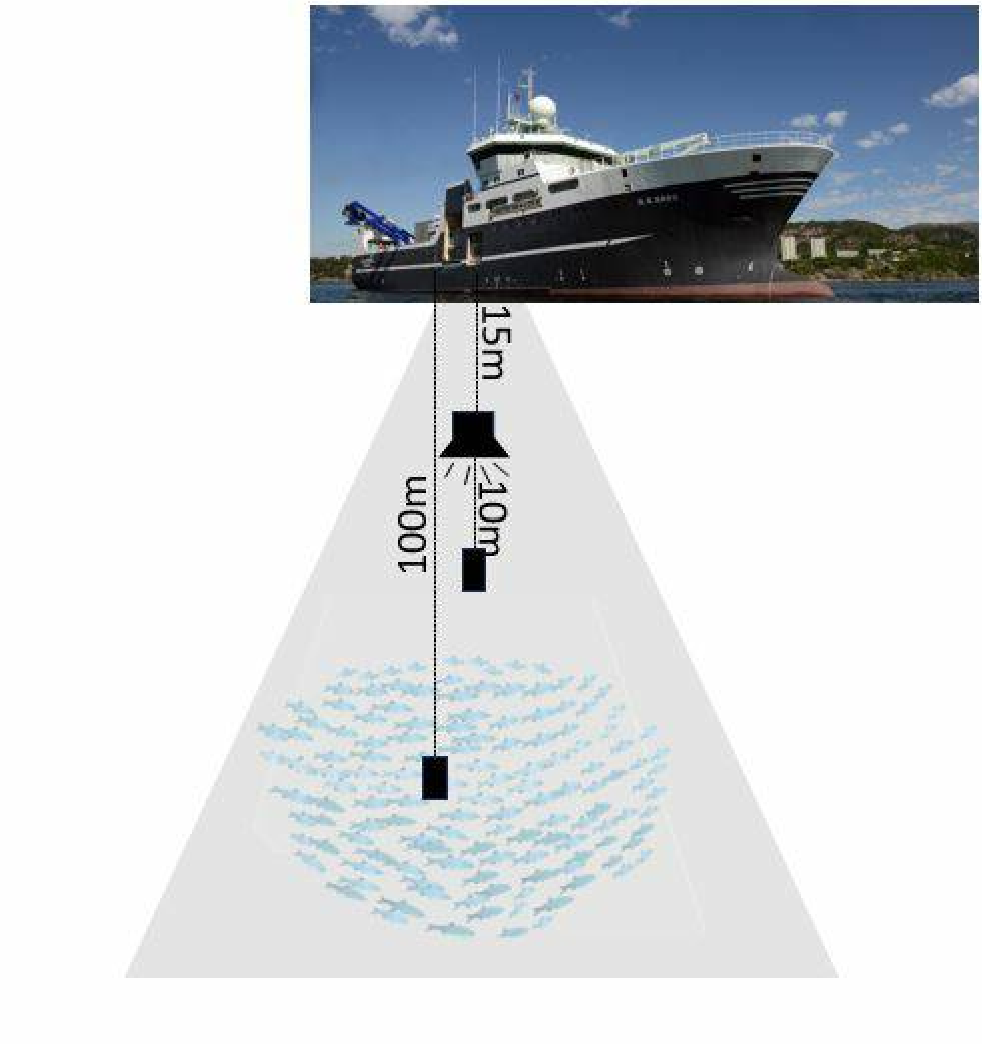


Figure 25 . Set up of sound source, hydrophones and echosounder.

The experiment was conducted as a block design, where each block consisted of a 10 min sequence of each of the 4 frequency bands. The order of the frequency bands within each block were randomized prior to start of the experiment. Also, a random selection of each of the 20 available clips were made for each frequency band.

Prior to start, we surveyed the area with echosounder and sonar to map herring distribution in the area. Once a suitable location was selected, the sound source and hydrophones were lowered. After deploying the instrument, we allowed the fish to acclimatize after any potential disturbance from the operation. The ship's main engine was turned off and the ship were drifting to avoid sound from the ship to disturb the fish. The 10 min sound sequences were played with 10 min no-sound control between, and we always started with a 10 min control.

After each block, we waited 1 h before starting the next exposure. During this period, the equipment was brought back on deck, and the ship relocated before the next block.

Observations of herring behaviour were conducted by the ships echosounder (EK80), measuring the density and depth structure of the herring layer, hence detecting potential vertical or horizontal avoidance behaviour.

8.3 - Preliminary results

The experiments were conducted over 3 days in November 2023, and a total of 10 blocks were conducted, and 4 playbacks of killer whale vocalisations (Table 9). All experiments were conducted in Kvænangen, which is the main overwintering area for the Norwegian Spring Spawning herring. Due to differences in wind conditions, the distance drifted during a block varied from 3500 m (block 2) to less than 100 m (block 6).

Table 9 . Overview of the experimental blocks. Treatment refers to the different frequency bands. Freq1 is the 200-400 Hz band, Freq 2 is the 400-800 Hz band, Freq3 is the 800-1600 Hz band, and Freq4 is the 1600-3200 Hz band.

Block	Treatment	Sound clip	Date	Start			Stop		
				Time (UTC)	Lat	Lon	Time (UTC)	Lat	Lon
1	Freq2	1	23.11.2023	20:03:00	70° 02.7970	21° 21.5581	20:13:00	70° 02.9382	21° 20.7925
1	Freq3	7	23.11.2023	20:23:00	70° 03.0985	21°20.1008	20:33:00	70° 03.2709	21° 19.54
1	Freq1	2	23.11.2023	20:43:00	70° 03.4353	21° 19.0100	20:53:00	70° 03.5889	21° 18.4655
1	Freq4	16	23.11.2023	20:53:00			21:03:00		
2	Freq1	2	23.11.2023	22:30:00	70° 03.0859	21° 22.4477	22:40:00	70° 03.19	21° 21.9587
2	Freq4	8	23.11.2023	22:50:00	70° 03.3286	21° 21.5122	23:00:00	70° 03.4410	21° 20.9601
2	Freq2	18	23.11.2023	23:10:00	70° 03.5412	21° 20.3905	23:20:00	70° 03.6914	21° 19.6117
2	Freq3	9	23.11.2023	23:30:00	70° 03.7905	21° 19.0820	23:40:00	70° 03.9084	21° 18.4711
3	Freq3	18	24.11.2023	01:10:00	70° 03.3241	21° 21.8073	01:20:00	70° 03.4261	21° 21.4238
3	Freq2	13	24.11.2023	01:30:00	70° 03.5580	21° 20.9224	01:40:00	70° 03.7007	21° 20.3202
3	Freq1	5	24.11.2023	01:50:00	70° 03.8491	21° 19.6970	02:00:00	70° 03.9847	21° 19.1156
3	Freq4	6	24.11.2023	02:10:00	70° 04.1054	21° 18.5046	02:20:00	70° 04.1952	21° 18.0275
4	Freq2	3	24.11.2023	03:56:09	70°03.3472	21°21.4728	04:06:16	70°03.4029	21°20.9631

4	Freq1	1	24.11.2023	04:16:08	70°03.4674	21°20.4649	04:26:08	70°03.5591	21°19.9779
4	Freq4	20	24.11.2023	04:36:05	70°03.6655	21°19.5003	04:46:04	70°03.7953	21°19.0285
4	Freq3	6	24.11.2023	04:56:03	70°03.9123	21°18.6263	05:06:00	70°04.0370	21°18.0839
5	Freq2	6	24.11.2023	20:45:00	70° 04.3129	21° 23.4295	20:55:00	70° 04.2872	21° 23.4212
5	Freq1	3	24.11.2023	21:05:00	70° 04.2755	21° 23.4195	21:15:00	70° 04.2776	21° 23.4207
5	Freq3	17	24.11.2023	21:25:00	70° 04.2808	21° 23.4604	21:35:00	70° 04.2776	21° 23.5203
5	Freq4	3	24.11.2023	21:45:00	70° 04.2595	21° 23.5755	21:55:00	70° 04.2372	21° 23.6494
6	Freq3	7	24.11.2023	23:05:00	70° 04.2952	21° 20.4899	23:15:00	70° 04.3001	21° 20.4454
6	Freq1	6	24.11.2023	23:25:00	70° 04.3073	21° 20.3982	23:35:00	70° 04.3025	21° 20.3737
6	Freq4	8	24.11.2023	23:45:00	70° 04.2903	21° 20.3883	23:55:00	70° 04.2757	21° 20.4327
6	Freq2	18	25.11.2023	00:05:00	70° 04.2692	21° 20.4910	00:15:00	70° 04.2579	21° 20.5165
	Killer whale playback		25.11.2023	00:25:00	70° 04.2170	21° 20.4412	00:35:00	70° 04.2006	21° 20.4163
7	Freq3	17	25.11.2023	01:30:00	70° 04.0957	21° 20.6217	01:40:00	70° 04.0862	21° 20.7318
7	Freq2	17	25.11.2023	01:50:00	70° 04.0751	21° 20.7987	02:00:00	70° 04.0615	21° 20.9004
7	Freq1	3	25.11.2023	02:10:00	70° 04.0464	21° 20.0210	02:20:00	70° 04.0319	21° 21.1081
7	Freq4	15	25.11.2023	02:30:00	70° 04.0234	21° 21.2236	02:40:00	70° 03.9966	21° 21.2825
8	Freq3	14	25.11.2023	04:05:00	70° 04.7295	21° 24.9886	04:15:00	70° 04.7220	21° 25.1773
8	Freq2	4	25.11.2023	04:25:00	70° 04.7221	21° 25.3613	04:35:00	70° 04.7040	21° 25.5132
8	Freq4	12	25.11.2023	04:45:00	70° 04.7003	21° 25.6642	04:55:00	70° 04.7080	21° 25.8766
8	Freq1	20	25.11.2023	05:05:00	70° 04.7098	21° 26.0699	05:15:00	70° 04.7080	21° 26.2897
	Killer whale playback		25.11.2023	05:25:00	70° 04.7161	21° 26.5306	05:35:00	70° 04.7161	21° 26.5306
9	Freq1	1	25.11.2023	17:39:00	70° 05.0908	21° 23.8230	17:49:00	70° 04.9905	21° 23.7241
9	Freq2	9	25.11.2023	17:59:00	70° 04.8974	21° 23.6813	18:09:00	70° 04.8974	21° 23.6813
9	Freq3	12	25.11.2023	18:30:00	70° 04.5597	21° 23.8611	18:40:00	70° 04.4537	21° 23.9663
9	Freq4	19	25.11.2023	18:50:00	70° 04.3389	21° 24.1216	19:00:00	70° 04.2412	21° 24.2885

	Killer whale playback		25.11.2023	19:10:00	70° 04.1648	21° 24.4727	19:20:00	70° 04.0471	21° 24.7151
10	Freq3	17	25.11.2023	20:35:00	70° 04.5601	21° 20.3392	20:45:00	70° 04.3959	21° 20.3567
10	Freq2	1	25.11.2023	20:55:00	70° 04.2276	21° 20.3804	21:05:00	70° 03.9715	21° 20.4941
10	Freq4	2	25.11.2023	21:15:00	70° 03.8923	21° 20.5425	21:25:00		
10	Freq1	6	25.11.2023	21:35:00	70° 03.6319	21° 20.7099	21:45:00	70° 03.5162	21° 20.8360
	Killer whale playback		25.11.2023	21:55:00	70° 03.4168	21° 20.9938	22:05:00	70° 03.3193	21° 21.1426

Before starting the experiments, the sound source was tested with all the frequency bands and levels measured with the hydrophones 10 m below the source and at 100 m depth. Based on these measurements the source level for the 4 frequency bands were calculated (Figure 26).

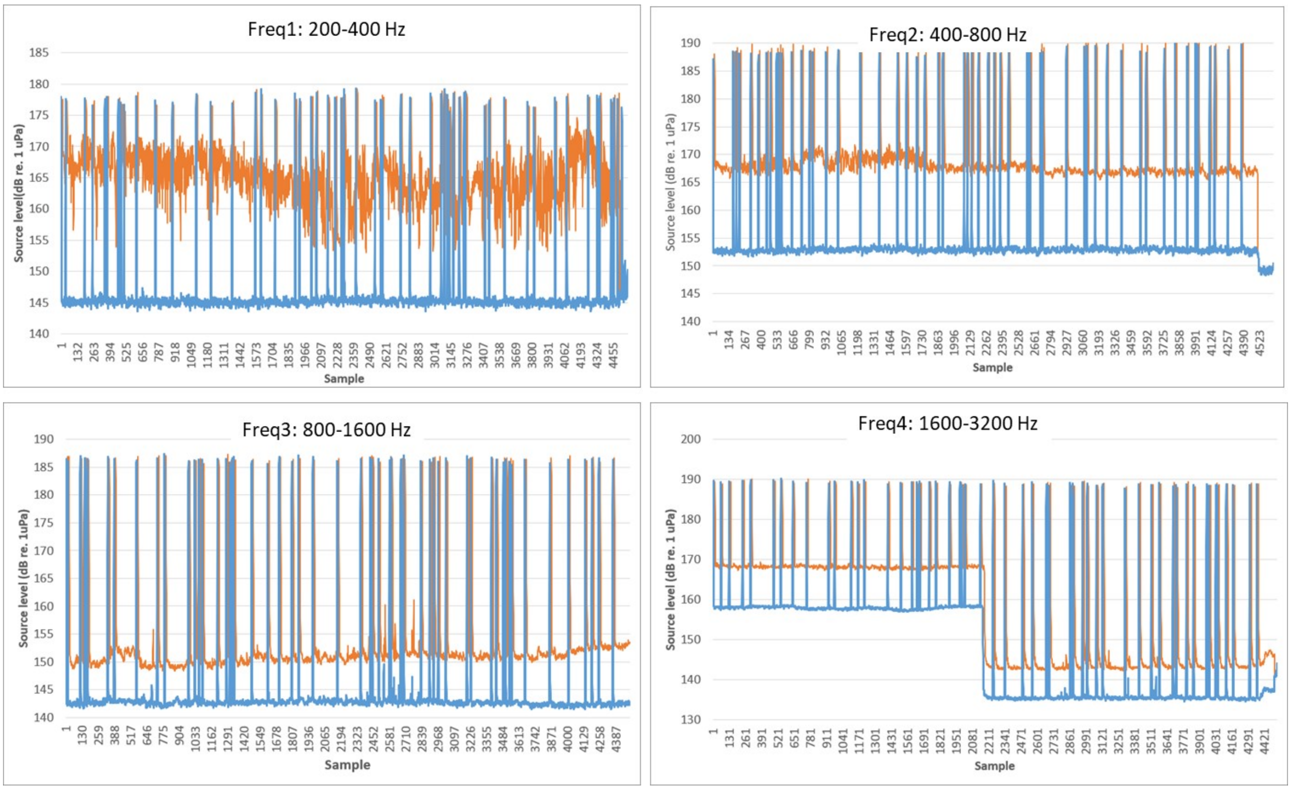


Figure 26 . Approximate source level for the 4 frequency bands. The blue curve is based on the measurements of the hydrophone 10 m below the source, the orange curve on the hydrophone at 100 m depth. In particular the hydrophone at 100 m depth show quite a lot of noise due to hydraulics and/or echosounder. This is particularly apparent for Freq 4 , where the hydraulics were turned off approximately midway into the measurement.

A preliminary screening of the echograms did not show any apparent reaction of the herring (c.f. Figure 27). Further, no apparent indication of a change in acoustic density could be determined from the preliminary screening, c.f. block 1 in Figure 28 .

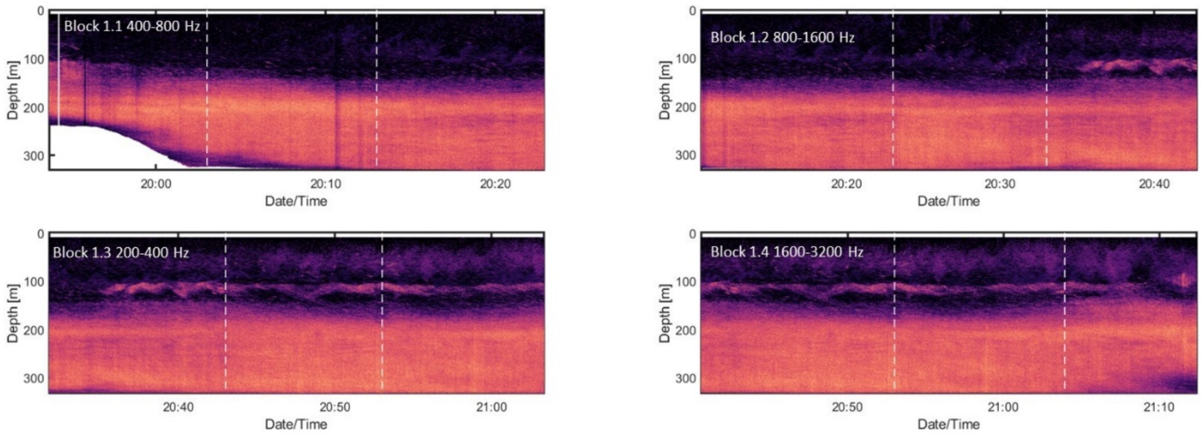


Figure 27 . Echogram for block 1. Dashed white lines indicate start and stop of the sound transmission.

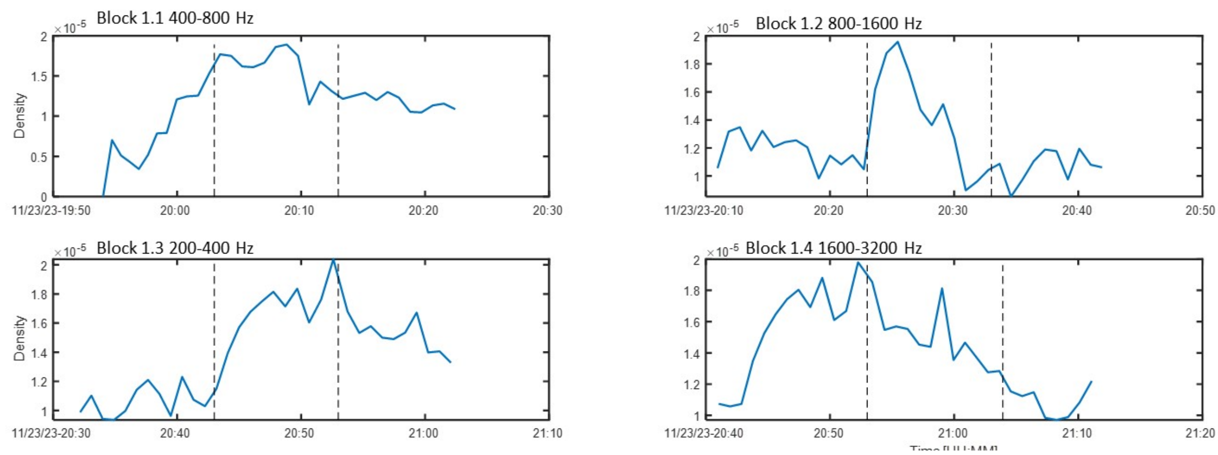


Figure 28 . Acoustic density as a function of time for block 1. Dashed lines indicate start and stop of sound transmission.

9 - Data organization

The data is organized in accordance with the IMR data organization procedure. In this section the placement of each data set is described as well as a short description of each individual data set. The headings are equal to the folders in the data structure.

The data from G.O. Sars is stored at IMRs secure data storage system under \cruise_data\2023\S2023001016_PGOSARS_4174

The USV Frigg uses a separate cruise number, and the data files from USV Frigg are placed under \cruise_data\2023\S2023301002_PFRIGG_10318\.

9.1 - ACOUSTIC DATA

The shipboard EK80 echosounder channels were calibrated 2023.11.15-11 prior to data acquisition. The EK80 echosounder channels onboard USV Sounder Frigg were also calibrated 2023.11.15 prior to data acquisition.

Ship-borne unprocessed EK80 data from FF G.O. Sars and USV Frigg was stored in accordance with the IMR data storage structure at \S2023001016_PGOSARS_4174\ACOUSTIC\EK80\EK80_RAWDATA and \S2023001016_PFRIGG_10318\ACOUSTIC\EK80\EK80_RAWDATA. There were several different strategies for collecting data, so that the content of the EK80 data files were not all the same: some contained CW-data only, some contained a mixture of CW and FM-data. They were, however, still all stored in the specified directory for each of the two surveys.

Due to the different content of the data, the processed data were not placed in a single directory, but were placed in a cluster of directories like …\ACOUSTIC\LSSS\KORONA_, i.e. directories like KORONA_Octagon1_GOSars_noise. Each of those directories contain the processing setup in the sub-directory “\copiedConfigFiles”.

The overall organizing of data from the survey is stored in the survey file localized at \ACOUSTIC\LSSS\LSSS_FILES. A survey-file keeps track of how the directories are organized, e.g. which Work-files to use, which KORONA-files to use and which preprocessing setup to use.

Files exported from LSSS fro RV G.O. Sars are placed in \S2023001016_PGOSARS_4174\ACOUSTIC\LSSS\EXPORT\EchogramPlot. Each of the data-files contain a prefix to identify its origin, and also a time-tag to identify which raw-data they are based on.

There are similar files from USV Frigg, but there is an additional directory \S2023301002_PFRIGG_10318\ACOUSTIC\LSSS\EXPORT\EchosounderData. The data in that directory are all at 38 kHz merged from its original raw datafiles.

Finally, data from the database are placed in directories like Reports_Survey1_Frigg, Reports_Survey2_Frigg or Reports_Survey1_GOSars, Reports_Survey2_GOSars. There would on an ordinary survey only be one directory per platform (named REPORTS), but here it was necessary to distinguish between the abundance estimation surveys of G.O. Sars and Frigg.

9.2 - StoX project

The Stox projects are placed under

\cruise_data\2023\S2023001016_PGOSARS_4174\CRUISE_DOCUMENTS

9.3 - BIOLOGY

9.3.1 - DEEP_VISION

The deep vision data is stored at:

\cruise_data\2023\S2023001016_PGOSARS_4174\BIOLOGY\CATCH_MEASUREMENTS\DEEP_VISION

9.4 - USV Frigg operator notes

During the USV Frigg operation, an operator_notes.txt file was used as notes between operators, handling the USV in 8-hour shifts. The document is located here:

\CRUISE_DOCUMENTS\OTHER_DOCUMENTS\operator_notes.txt

12.3 - USV Frigg Backseat control software

The backseat control software used to allow the USV to modify its course based on feedback from echosounder, as described earlier in this report, is stored here:

\CRUISE_DOCUMENTS\OTHER_DOCUMENTS\CONTROLSW*

12.4 - USV Frigg Vehicle control system

The topside operating software vehicle control system files are stored and includes mission execution files. Files are named “Sounder003.csv*” and are modified during the cruise:

\CRUISE_DOCUMENTS\OTHER_DOCUMENTS\VCS\VAR_LOG_VCS\Sounder003.csv*

These files does not contain a descriptive header; but contain the timestamp, latitude and longitude of the USV, as well as other meta-data transferred from the USV to the topside VCS software while operating.

Logfiles are also as generated by the Maritime Broadband Radio web interface (MBR). The files can be found here:

\CRUISE_DOCUMENTS\OTHER_DOCUMENTS\VCS\MBR_LOGS*.log

With the following headers:

Field 1: [SN] Unit serial number
Field 2: [S] Unix time in seconds either from boot or GPS
Field 3: [ms] Milliseconds after seconds

Field 4: [lat] GPS lat
Field 5: [lon] GPS lon
Field 6: [C] Temperature
Field 7: [mA] Input current
Field 8: [mV] Input voltage
Field 9: [MHz] Frequency MHz part
Field 10: [kHz] Frequency kHz part
Field 11: [Type] Product variant number
Field 12: [dB] Antenna element gain
Field 13: [Frames] RX Frames received OK
Field 14: [Frames] RX Frame errors
Field 15: [Frames] RX CRC 32 Errors
Field 16: [Frames] Frames relayed
Field 17: [Frames] TX Frames OK
Field 18: [Frames] TX frames dropped due to buffer overrun
Field 19: [Frames] TX rames dropped due to no link
Field 20: [Frames] TX frames dropped due to MAC Busy
Field 21: [Frames] TX Frames with missed ACK
Field 22: [kb/s] Total TX bandwidth to mac
Field 23: [kb/s] Total RX bandwidth from mac
Field 24: [Sites] Sites in following site table
Field 25+21*(n-1): Extra information about connection to designated site

Note that leaving the MBR to log indefinitely will result in the MBR web interface crashing with the firmware in use at the time. The MBR link will still work.

10 - References

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