ISSN 1893-4536 (online)

RAPPORT FRA HAVFORSKNINGEN

Nr. 41-2016

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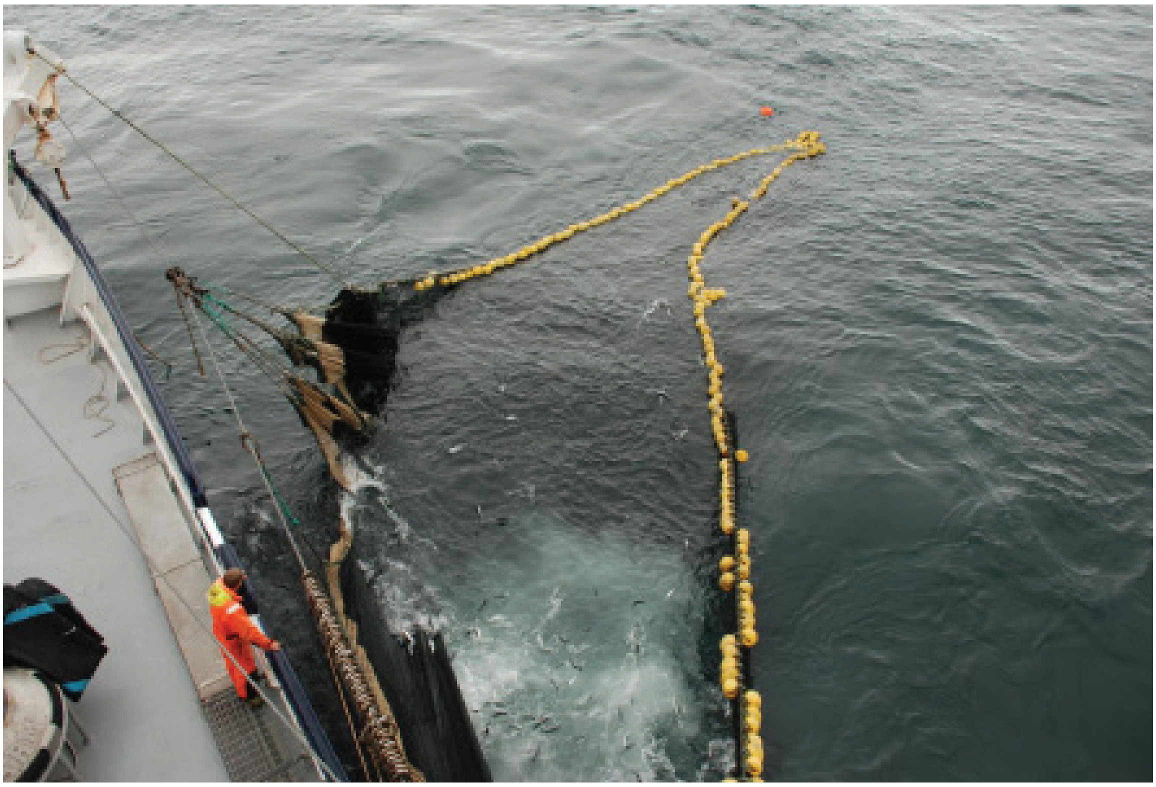

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INSTITUTE OF MARINE RESEARCH

Survey report from
the CODFUN 2016114 Barents Sea survey
5.-11. oktober 2016

By
Georg Skaret, Edda Johannesen,
Johanna Fall, and Øyvind Fiksen

Innhold

Background and aim

The survey is part of the project "The cod – capelin interaction in the Barents Sea: spatial dynamics in predator prey overlap and functional response (CODFUN)" funded by the Norwegian Research Council (NRC project number 243676/E40).

The CODFUN project was motivated by the need to update and improve the current formulation of the functional response of cod used in the capelin assessment model. The functional response is the relationship between the feeding rate of individual predators and density of prey. Functional response, together with density of predators and prey is used to calculate natural mortality. In all natural environments, there is spatial heterogeneity in densities of prey and predators and their overlap. This heterogeneity becomes a very important determinant of natural mortality due to predation. The aim of the CODFUN project is to quantify and explain spatial heterogeneity in the capelin-cod interaction at different spatial scales in the Barents Sea.

The aim of the survey was to study spatial variation at the scale of individual cod and capelin schools. We aimed at quantifying attack rates of cod on capelin using acoustics, and to estimate proportion of successful attacks using stomach samples from trawl catches and handline. Furthermore, we aimed to relate variation in attack rates to variation in capelin densities and light conditions.

Material and methods

Survey area and sampling

The CODFUN survey was planned to start in Tromsø and work its way northwards ending in Longyearbyen. The survey was according to plan starting directly after the Joint IMR PINRO ecosystem survey ended (late September) and planned to use results from this survey to find a suitable area with capelin schools and occurrence of cod. The chances of finding a good location for the investigations seemed good, since the project was initiated when both the capelin and cod stocks were at high levels and had a wide distribution. However, some inconveniences created challenges: First, we were given Tromsø both as port of both departure and arrival which shortened down our available time for doing field work in the right areas. Second, the ecosystem survey coverage of the most relevant study area took place 1 month earlier than usual. We therefore relied on information from the Russian and Norwegian cod fishing fleet in combination with own ship acoustics for finding a suitable study area. Third, the capelin stock in 2016 was at a very low level, and distribution was scattered. On a very positive note, the vessel and its crew provided extra ship time so we could leave port in the evening of the 4. October instead of the morning of the 5. October. In total, we used ca. 70 % of the ship hours transiting or searching for a suitable study area, leaving around 30%, or ca. 50 hours for investigations. The short time available in combination with the novelty of the approach and methods to study interactions, the survey can be considered as a pilot for further studies. Two areas were chosen for the investigations (Figures 1 and 2). Both areas contained a mixture of polar cod and capelin in addition to cod, but Area 2 had a higher proportion of capelin and was chosen as the main study area.

Area 1 was sampled with ship acoustics, CTD, pelagic and demersal trawl, whereas Area 2 was sampled with CTD, WP2, demersal trawl, pelagic trawl, ship acoustics and TS probe (Table 1).

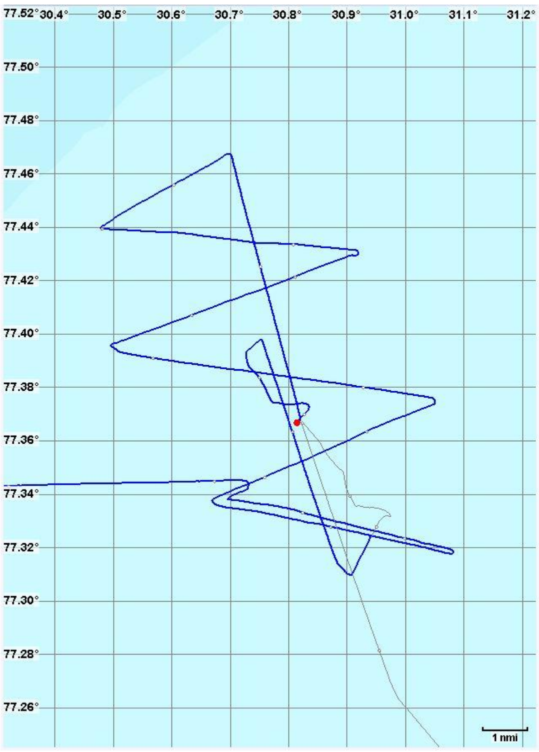

Figure 1. First area of investigation including cruise tracks. The acoustic recordings indicated a significant aggregation in this area. One pelagic trawl, one demersal trawl and one CTD was set out. The pelagic trawl catch was dominated by polar cod, while the demersal trawl catch included approximately 50% of both polar cod and capelin in addition to cod. The area was abandoned due to the high dominance of polar cod.

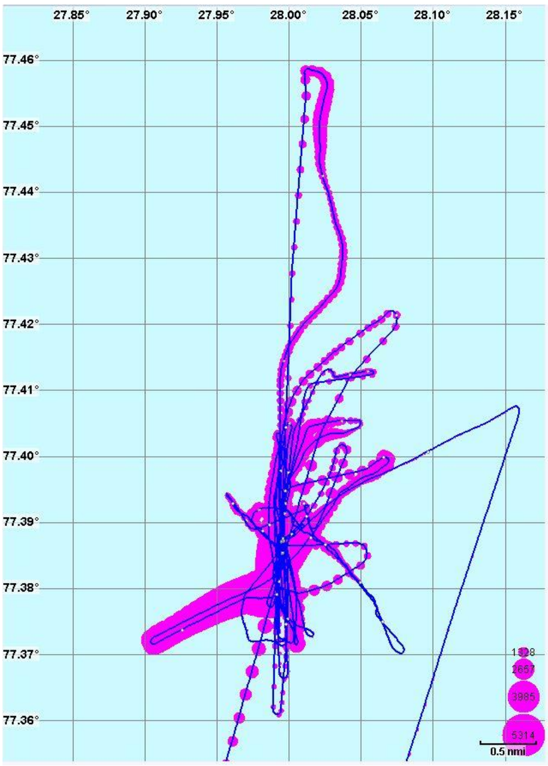

Figure 2. Second area of investigation with cruise tracks in blue, and acoustic backscatter Nautical Area Backscattering Coefficient (NASC; m^2nmi^{-2}) values in purple. The acoustic recordings indicated a significant aggregation, and the trawl catches revealed both capelin and polar cod, with capelin dominating. This was chosen as the main area of investigation.

Biological sampling

Trawl sampling

Standard trawls for Barents Sea surveys were used: Harstad trawl (pelagic), Åkra Trawl (pelagic) and Campelen trawl (demersal).

All cod from the catches were length measured and the catch number and weight was recorded. Stomach samples were taken from a maximum of 50 cod from each station, together with information on individual weight, sex, liver weight and gonadal state. Digestion stage, length (if possible) and weight of prey recorded to the species level if possible were recorded for each cod stomach sample.

Standard procedures for sampling of capelin used at the ecosystem survey was used here (100 length measurements, 30 recordings of sex, condition and weight). In addition simplified stomach analysis was carried out for 10 individuals. Capelin stomachs were weighed and the volume percentage of each prey category of the total was judged.

Thirty polar cod from each catch were length measured and stomach content was analysed for 10 individuals from 3 stations using the same procedure as for capelin.

The total number of capelin and polar cod in the catch were calculated from the weight of the subsample. The rest of the cod was subsampled and sorted into crude categories that was weighed. Total weight of the categories was calculated from the proportion of the catch that was subsampled.

The number of stomachs sampled, the proportion of empty stomachs and main prey is given in Table 2.

Handline fishing

Attempts were made to sample cod using handline while the vessel was lying still and operating the TS-probe (see section below). If this was successful we would potentially have cod samples very close in time and space to the cod we observed acoustically. However, no cod was caught, possibly due to the extremely low temperatures (-1 – 2 °C) in the research area.

Marine mammal observations

Marine mammal observations were undertaken for approximately 1.5 hours each day, depending on weather conditions. During the three days, 12 whales where observed; 7 confirmed humpback whales, and the remaining 5 unconfirmed but likely to be the same species (Table 3). Two thirds of the observations were made in area 2, the main survey area. The observations should be treated as qualitative due to the simplified methodology.

Acoustic sampling

Target strength (TS) probe

Set-up

The TS probe was applied primarily as an attempt to quantify cod attacks on capelin based on acoustic target tracking. The TS probe could also provide valuable information about the prey such as densities, schooling tendencies and possibly individual behavior based on target tracking. The TS probe is designed to be submerged for close range acoustic recordings at different depths. In our set-up we applied four Simrad wideband transducers operating at center frequencies of 38, 70, 120 and 200 kHz. We also brought a stereo camera system, but one of the three optical cables of the vessels' operating winch was malfunctioning, and the stereo camera was removed. A Gopro camera with associated red light source was mounted on the frame of the TS-probe and recorded video, but no fish was captured on video within the ca. 2 m visible range.

Calibration

The TS-probe was calibrated on all frequencies. The 38 kHz was calibrated over the entire bandwidth using a 60 mm cupper sphere, and the 70 kHz using a 38.1 mm wolfram carbide sphere also covered the entire bandwidth. Attempts were made twice to calibrate the 120 and 200 kHz using the 22 mm WC sphere, but sphere was not detected. A new trial using the 38.1 mm WC sphere was successful, but the calibration does not cover the entire bandwidth so the result was merged with old calibration.

Application

Some trial and error experimenting with the TS probe was done during the course of the investigations. First, all frequencies were run with sequential pinging to avoid interfering signals between frequencies (Gavin Macaulay, pers. comm.). The sequential pinging applied on four frequencies resulted in a ping rate much lower than desired for target tracking. 70 kHz was therefore selected and tried separately, since the bandwidth should cover well both fish and macroplankton targets. When the 70 kHz malfunctioned, we switched to 120 kHz since the 38 kHz transducer was limited to operate at the narrow bandwidth of 34-42 kHz (Table 4). With a few exceptions when several frequencies were run in sequence, we applied the 120 kHz uniquely.

The TS-probe can be applied either while the vessel is drifting or while it is Dynamic Positioning system (DP). In a first attempt, we applied the TS-probe while the vessel was drifting, in order to avoid possible disturbance of the fish and that you cover a greater area. The disadvantage is then that the vessels moves which makes the target tracking more difficult, and that you drift off from the defined location. Drifting speed was approximately 1 knot. In the proceeding attempts, the TS probe was applied on a selected location with good recordings while the vessel was at DP. Except from a signal when the propellers first started, there were no obvious indications of influence on fish behavior of the DP. In the last two attempts, the probe was applied while the vessel was drifting, the aggregations at the selected location had then either disappeared or were very thin.

Hull mounted echo sounders

Simrad echo sounders operating the 6 frequencies 18, 38, 70, 120, 200 and 333 were logged continuously during small scale surveying and trawling. When the TS probe was operated only the 18 kHz was active to avoid interference. Echo sounder data during the mini surveying were scrutinized on all frequencies.

Sonars

We wanted to log sonar data in order to possibly describe changes in aggregating behavior of the prey of the capelin. Data were logged from the SX90 sonar, but conditions for recording capelin schools with sonar were difficult due to the deep distribution. The MS70 quantitative multi beam sonar malfunctioned.

Other sampling

Light measurements

Since the surface irradiance is an environmental variable that is measured in the weather station but not stored on current monitoring routines in GO Sars, we brought a separate instrument to measure surface light irradiance during the cruise, the LI-1400. The radiation sensor was mounted on the starboard side railing on top of the bridge, with a connecting cable to the bridge. Light (PAR) was also measured in the CTD stations, to estimate light attenuation in the vertical. Note that the sensitivity of the sensor on the CTD station is not high enough to measure light below about 0.1 umol photons m^{-2} s^{-1}. Surface light and attenuation coefficients will be used to calculate ambient radiance and the role of light in generating the behavior observed in the acoustics, and to evaluate the role of light in the functional response, gut fullness and foraging success of cod on capelin.

Preliminary results and overview of activities

Temperature and salinity profiles

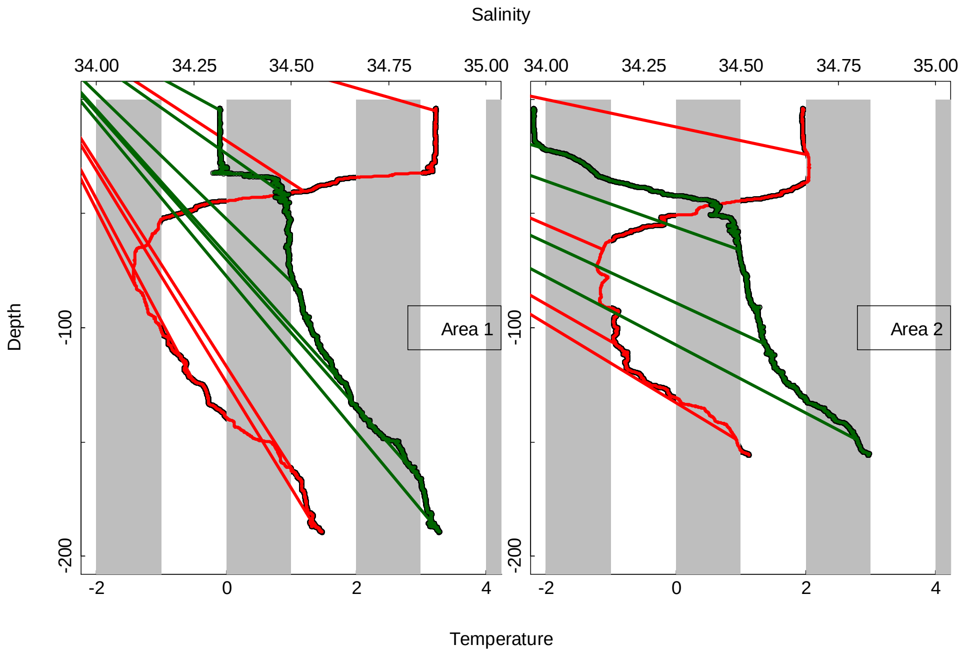

Fig. 3. Temperature (red) and salinity (green) profiles from the two study locations.

Diel variation in acoustic backscatter

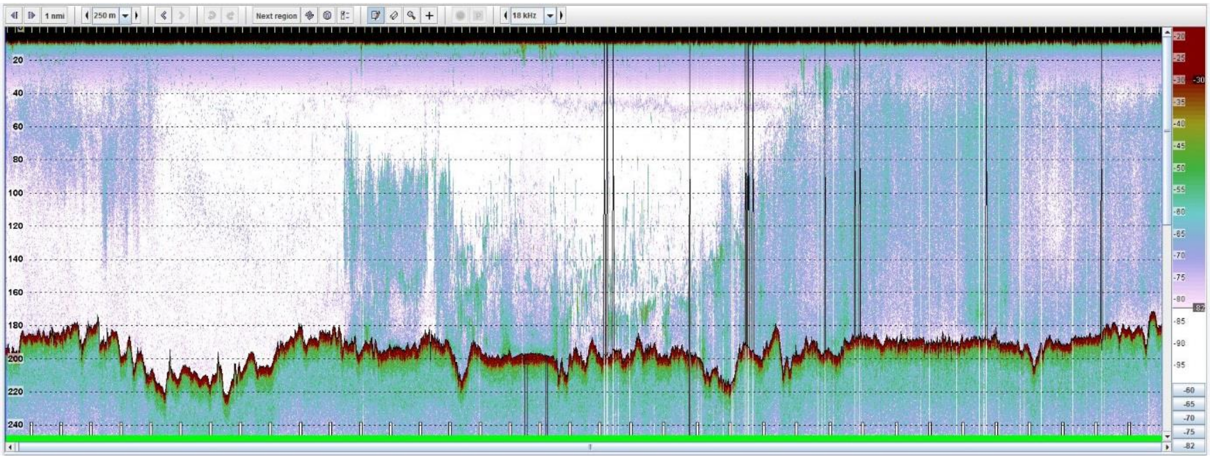

Fig. 4. Hull mounted 18 kHz, 24 h echogram showing backscatter resolved over time (not distance), start ca. 00.00 UTC on the 07.10.2016.

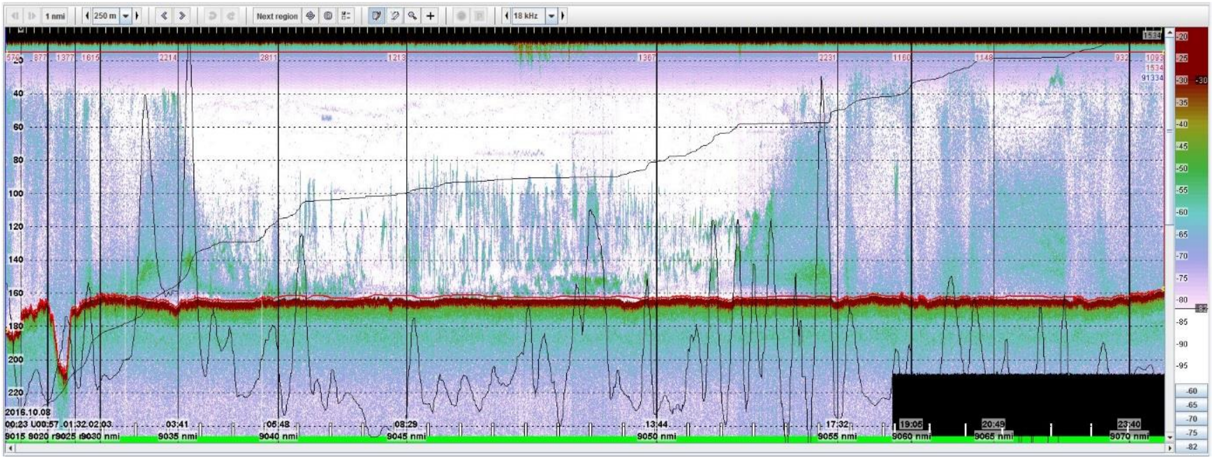

Fig. 5. Hull mounted 18 kHz, 24 h echogram showing backscatter resolved over time (not distance), start ca. 00.00 UTC on the 08.10.2016.

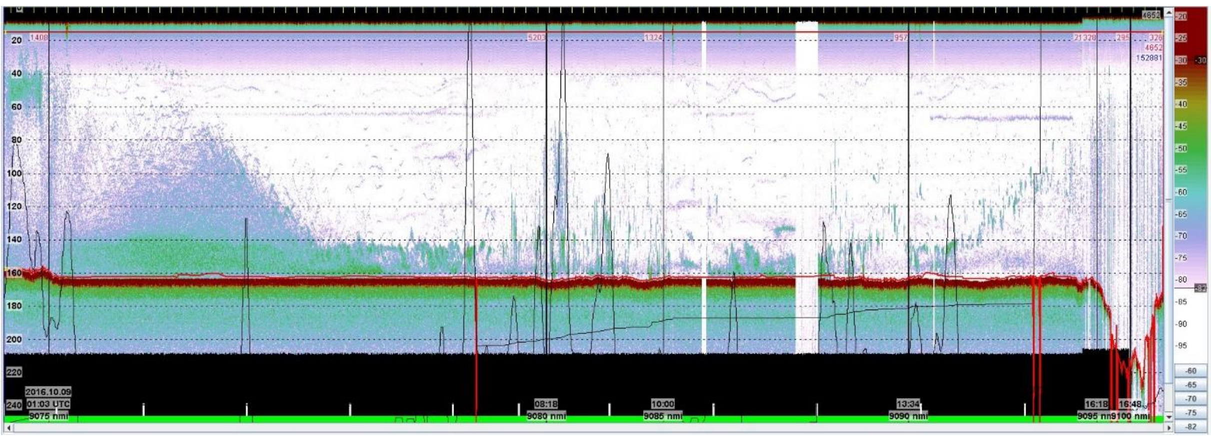

Fig. 6. Hull mounted 18 kHz, 16 h echogram showing backscatter resolved over time (not distance), start ca. 00.00 UTC on the 09.10.2016.

Detailed echograms extracted from periods lying still

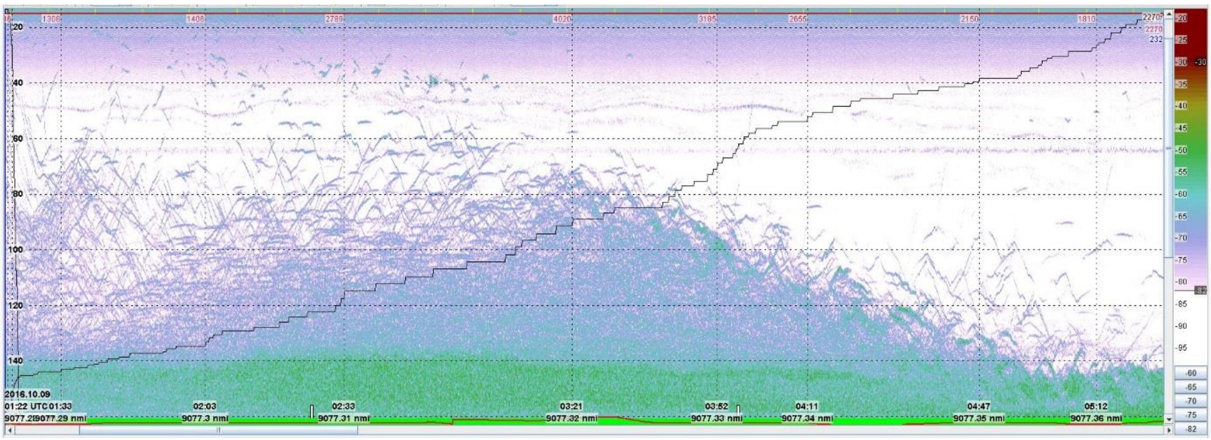

Fig. 7. Hull mounted 18 kHz echogram showing ca. 2 h period at the break of dawn.

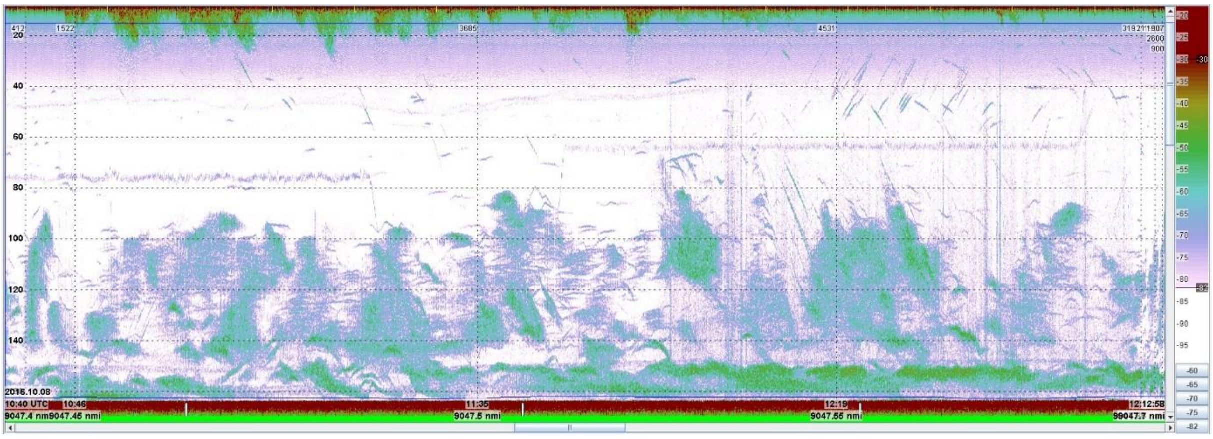

Fig. 8. Hull mounted 18 kHz daytime

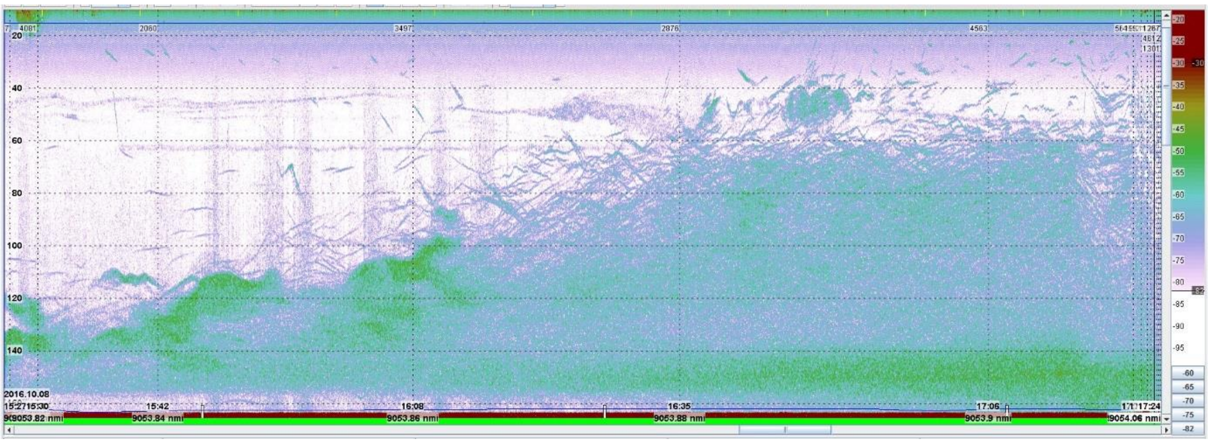

Fig. 9. Hull mounted 18 kHz dusk.

Echogram from TS-probe

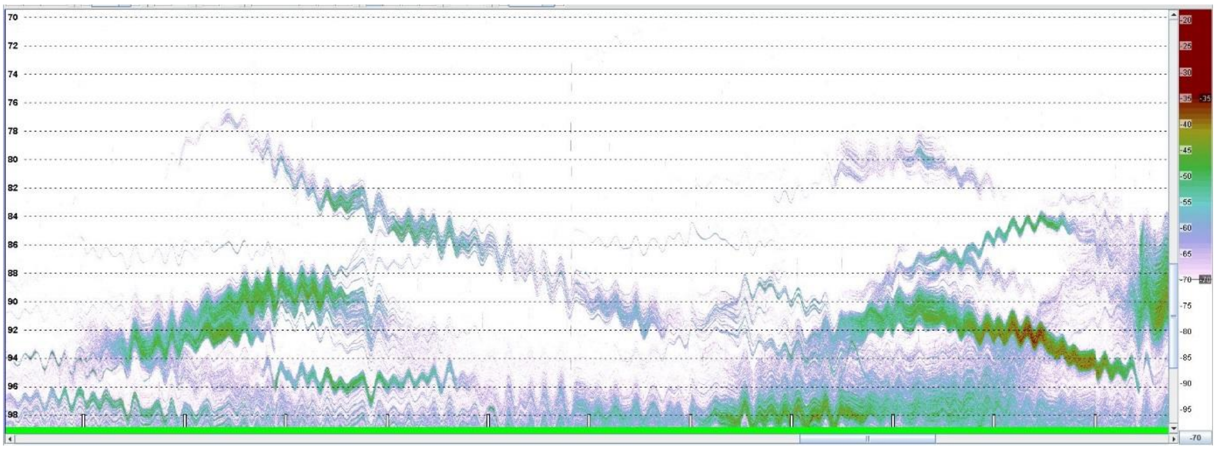

Fig. 10. TS-probe echogram showing 120 kHz used in chirp mode. Echogram displays a 5-min period in the morning close to the bottom and likely displays cod and capelin. The impressions of wavy movements are due to the continuous movements of the vessel.

Light conditions

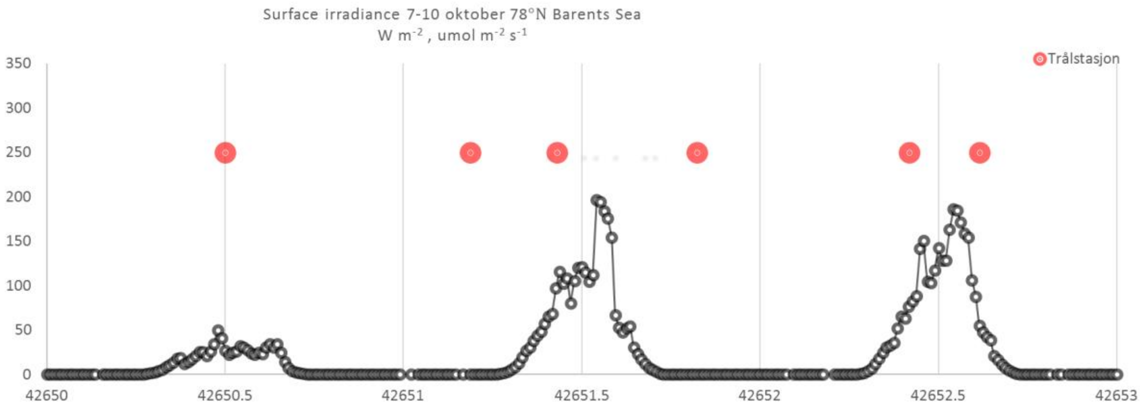

Fig. 11. Results from daily surface irradiation measurements (integrated over 15 min intervals), and the timing of trawl stations.

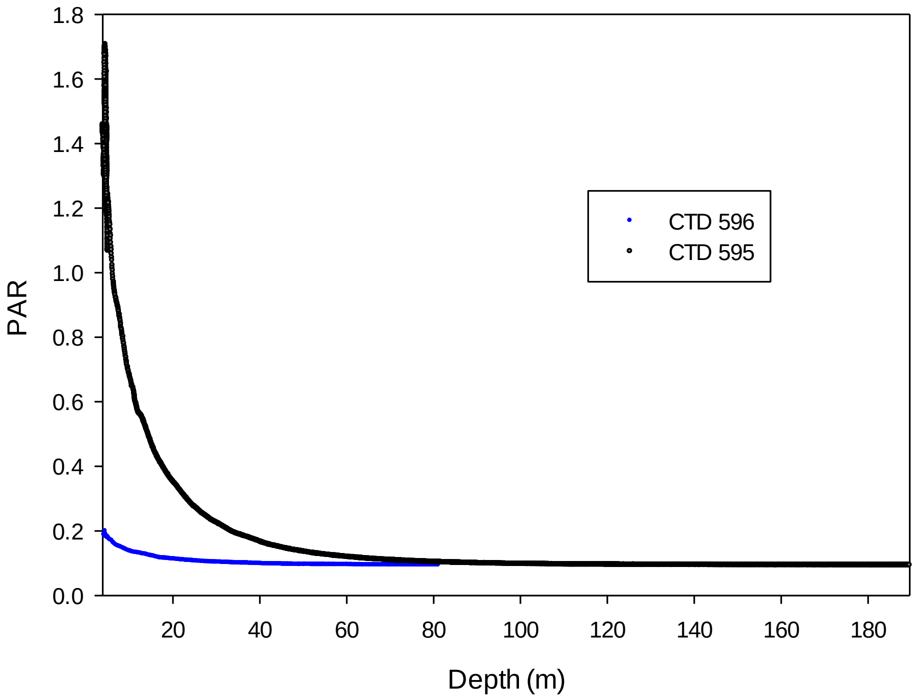

Fig. 12. The raw data of PAR from the two CTD-stations. Note that the sensitivity of the sensor is not sufficient to measure light below about 0.1 umol photons m^{-2} s^{-1}.

Table 1. Time line of activities

Area	Date	UTC	Activity	**Comment**
1	07.oct	08:13	Harstad trawl 3 min tow, no 75001	large school dominated by polar cod, only 10 of the capelin caught were length measured
1	07.oct	10:00	Campelen trawl tow 15 min, no 75002	
1	07.oct	10:59	CTD	
2	08.oct	02:30	Campelen trawl tow 20 min no 75003	dense school near bottom
2	08.oct	04:00	Harstad trawl tow 15 min, no 75004	dense small schools at 50 m, descends to 100 meter=trawl depth
2	08.oct	04:48	CTD	
2	08.oct	04:57	WP2	
2	08.oct	06:36	TS	Try different settings, drift ca 1 hour, 70 khz malfunction
2	08.oct	08:20	Campelen trawl tow 15 min, no 75005	
2	08.oct	09:50	TS probe ended 12:51	Used DP, fishing with hand line but no catch, sampling from: 60 m (probe) to the bottom, 120 kHz
2	08.oct	13:26	Harstad trawl tow 3 min, no 75006	Short haul, Highly concentrated schools near bottom, almost exclusively capelin
2	08.oct	14:49	Harstad trawl, tow 8 min, no 75007	Higher up in the water column, loose aggregation, mixture of capelin and polar cod
2	08.oct	15:43	TS probe until 17:17	Used DP, sampling from: 60 m (probe) to the bottom, 120 kHz
2	08.oct	17:44	Campelen trawl tow 15 min, no 75008	
2	08.oct	19:35	Harstad trawl tow 15 min. no 75009	hal på registrering nær bunn, men mindre tett enn på dagtid, blanding polartorsk lodde
2	08.oct	20:50	TS probe	
2	08.oct	23:07	Åkratrawl, tow 3 min, no 75010	Ca 50 meter to catch pelagic cod, capelin and polar cod, but no cod. Problems setting out and taking in the trawl
2	09.oct	01:29	TS probe	Used DP, sampling from: 60 m (probe) to the bottom, 120 kHz
2	09.oct	08:01	Campelen trawl, tow 16 min, no 75011	
2	09.oct	09:20	Harstad trawl, tow 16 min, no 75012	
2	09.oct	10:23	TS probe	Both drift and DP
2	09.oct	12:46	Campelen trawl, tow 15 min, no 75013	
2	09.oct	13:56	TS probe	Used DP, sampling from: 60 m (probe) to the bottom, 120 kHz

Table 2. Overview of the number of stomachs analysed per species group. Frequency of empty stomachs as well as frequency of stomachs containing main prey groups.

	Cod	Capelin	Polar cod
No stomachs	300	118	29
Empty	45	66	0
Krill	21	24	7
Calanus	0	2	5
Themisto	0	5	1
Unident. crustaceans	1	24	14
Polar cod	124	0	0
Capelin	233	0	1
Other	21	0	0
unidentified	11	0	4

Table 3. Marine mammal observations during the CODFUN survey.

Date	Area	Time (UTC)	Latitude (N)	Longitude (E)	BSS	Activity	Species	Number (ind)	Distance (m)
07-10-2016	1	7:13	77° 24’	30° 46’	7	Back, blow	Humpback	2	1015
07-10-2016	1	7:18	77° 24’	30° 46’	7	Back, blow	Humpback	1	903
07-10-2016	1	7:29	77° 24’	30° 46’	7	Back	Humpback	1	516
08-10-2016	2	8:15	77° 23’	27° 58’	4	Blow	Humpback	3	1587
09-10-2016	2	10:55	77° 22’	28° 00’	3	Blow	Large whale	5	3212

Table 4. Settings used for the collection of acoustic data with the TS-probe.

Center frequency	Start freq range	End freq range	Pulse length	Power	Ping rate
38	34	42	2.048	Max	Max
70	50	95	2.048	Max	Max
120	95	160	1.024	Max	Max
200			1.024	Max	Max

Table 5. List of Participants

Name:	Role	Institution
Georg Skaret	Cruise leader	IMR. Pelagic fish
Edda Johannesen	Assistent cruise leader night	IMR, Ecosystem processes
Ronald Pedersen	Acoustics	IMR, Oceanography
Asgeir Steinsland	Instrument	IMR, Electronic instrument
Ole Sverre Fossheim	Instrument	IMR, Electronic instrument
Johanna Fall	Researcher, marine mammals	IMR, Ecosystem processes
Per Fauchald	Researcher, sea birds	NINA
Øyvind Fiksen	Researcher	UIB
Göran Englund	Researcher	Umeå University
Harald Gjøsæter	Fish lab 06-12	IMR. Demersal fish
Ørjan Sørensen	Fish lab 12-06	IMR. Pelagic fish
Inger Marie Beck	Fish lab 06-12	IMR, Ecosystem processes
Fish lab 12-06	Fish lab 12-06	IMR, Ecosystem processes