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Survey report /Institute of Marine Research

Joint survey report: M/S “Libas” 20.01–14.02.2009 (survey nr: 2009803) and MS ”Eros” 20.01–14.02.2009 (survey nr: 2009804)

Methodology for assessment of the capelin spawning migration in the Barents Sea, spring 2009

Metodiske undersøkelser av loddens gytevandring i Barentshavet i våren 2009
(engelsk m/norsk sammendrag)

Elena Eriksen, Geir Odd Johansen, Sigurd Tjelmeland, Hector Peña and Jaime Alvarez

Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway

Sammendrag (Summary in Norwegian)

Denne rapporten oppsummerer resultatene fra et akustisk tokt for å teste ut metodikk for kartlegging og mengdeberegning av gyteinnsiget til lodde i Barentshavet vinteren 2009. Målsetningene for årets tokt var: mengdeberegning av gytelodde samt kartlegging av utbredelsen av moden og umoden lodde. Kartlegge utbredelse av ungsild med tanke på blanding av ungsild og lodde som problem for akustisk mengdeberegning. Estimere akustisk målstyrke for lodde i gyteperioden. Estimere vandringshastighet og retning for gytelodde med sonar som støtte for akustisk mengdeberegning. Toktet ble avsluttet tidligere enn planlagt p.g.a. manglende lisensen for toktgjennomføring i RØS. Toktet ble gjennomført av M/S ”Eros” (20/1–14/2 2009), M/S ”Libas” (20/1–14/2 2009). Toktet dekket et område sør for 75˚N, mellom 18 og 36˚Ø i perioden 20/1–6/2 2009, samt langs kysten av Norge, mellom øst for 17˚Ø i perioden 6–14/02 2009. Under det kommersielle fisket om bord på M/S ”Libas” (14–25/2 og 16–21/3.2009) ble biologiske prøver tatt av gyteklar lodde, loddeegg ble kunstig befruktet og tatt på land for senere studier av embryoutviklingen og eggdødelighet under ulike temperatur- og forurensningsforhold.

Under toktet ble det målt gradvis avtagende temperatur på 50 meters dyp fra vest (5–6.5 °C) mot øst (3–4.5 °C) og fra sør mot nord innenfor toktområdet. Temperaturen langs bunnen varierte på samme måte, men var noe lavere i sentrale og nordliges områder. Varmere vannmasser (4.5–6.5 °C) ble observert fra bunn til overflate langs Norskekysten, med de høyeste temperaturene i vest.

I første periode av toktet ble lodde observert nær bunnen i blanding med annen fisk i nesten hele toktområdet. 3 år gammel lodde dominerte både i vest og øst, men i øst var det også innslag av 1, 2, 4 og 5 år gammel lodde. Pelagiske loddestimer dominert av 3-åringer ble observert i det vestlige området. Disse stimene vandret sørvestover mot Norskekysten. Nesten all lodden var i spesialstadium 4, og rognprosenten var ca 6 % av kroppsvekten. I det østlige området ble lodde registrert i et blandet pelagisk lag sammen med krill, reker og 1-årig torsk og hyse. Dette laget var dominert av umoden lodde i et område mellom ca 73°N–74N and 30°Ø–36°Ø.

I løpet av andre periode ble lodde vanligvis observert nær bunnen i et blandet lag sammen med større (> 15 cm) fisk som ungsild, hyse, torsk, uer og andre arter. Her dominerte 3 år gamle hunner. Nesten all lodden var i spesialstadium 4, som i periode 1, og eggprosenten varierte mellom 8 % i vest og 10 % i øst. Pelagiske stimer av ungsild ble observert i den sørvestre delen av toktområdet.

Pålitelige bestandsanslag for gytelodde avhenger av å være på rett sted til rett tid. Dette året ble gyteloddebestanden trolig sterkt underestimert. Dette kan skyldes flere forhold som kan ha virket sammen. Mulige forklaringer omfatter for tidlig start av toktet, begrenset områdedekning og tidlig start av loddefisket. Det akustiske bestandsanslaget for gytelodde i 2009 er 100 000 tonn, merk at dette er et underestimat kun basert på det norske toktet.

Summary

This report presents the results from an acoustic survey to test methodology for mapping and abundance estimation of the capelin spawning stock during spawning migration in the Barents Sea in winter 2009. The objectives was: acoustic abundance estimation and mapping the distribution of the spawning migration of capelin and immature capelin; mapping the distribution of juvenile herring to assess the mixture of capelin and juvenile herring as a problem for acoustic abundance estimation of capelin; estimation of acoustic target strength of capelin in the spawning period. Estimate speed and direction of the spawning migration of capelin towards the coast with sonar, so that this can be implemented as a correction factor in the acoustic abundance estimation. The survey was finished earlier than planned due to lack of license to cover areas in the Russian Exclusive Economic Zone. The survey was conducted with MS “Eros” (20 January–14 February), MS “Libas” (20 January–14 February). The survey covered the area south of 75˚N, between 18 and 36˚E during the first period (20 January–06 February) and an area along the Norwegian coast, east of 17˚E during the second period (06–14 February). During the commercial fishery onboard “Libas”, (period 1: 14–24 February, and period 2: 15–20 March) biological samples were taken from pre-spawning capelin during period 2, and eggs were artificial fertilized for later investigation of embryo development during different temperature conditions and egg development under pollution.

During this survey the temperature in 50 m depth decreased gradually from west (5–6.5 °C) to east (3–4.5 °C) and from south to north in the survey area. The temperature near the bottom decreased in the same way, but was lower in the central and northern parts. Along the Norwegian coast, warmer water masses (4.5–6.5 °C) were observed from the bottom to the surface, with highest temperature in the west.

In the first period of the survey capelin were observed near the bottom in mix with other fish throughout the survey area. In the western area, this capelin was dominated by 3 years old individuals. This year class also dominated in the eastern area, but 1, 2, 4 and 5 years old individuals also occurred. In the pelagic, capelin were also observed in schools dominated by 3 years old individuals in the western area. The schools migrated in south-eastern direction towards the Norwegian coast. Almost all capelin was in special stadium 4 and egg percentage was approximately 6% of the body weight. In the eastern area capelin were observed in a pelagic mixed layer with krill, shrimp and 1 year old cod and haddock. Immature capelin dominated this layer in an area between approximately 73°N–74°N and 30°E–36°E. During the second period, the capelin were generally observed near the bottom mixed with larger (>

15 cm) fish like young herring, haddock, cod, redfish and other species. The capelin was dominated by 3 years old females. Almost all capelin was in special stadium 4, like in period 1, and egg percentage of body weight varied between 8% in west and 10% in east. Pelagic schools of young herring were observed in the south-western part of survey area.
Reasonable abundance estimation of the capelin spawning migration depends on being at the right place at the right time. This year, the spawning stock of Barents Sea capelin was most probably largely underestimated. There are several possible explanations of this, and they might all have acted in concert. This includes the early start of the survey, limited coverage of the area, and early start of the capelin fishery. The acoustic abundance estimate of spawning capelin in 2009 is 100 000 tons. Note that this is an underestimate, only based on the Norwegian survey.

Innhold

1 Introduction

This survey is part of an ongoing activity aiming investigating whether a winter survey can be implemented in the management of capelin in order to adjust the quota set in the autumn. The specific objectives of the survey were:

- Acoustic abundance estimation of the spawning migration of capelin winter 2009
- Map the distribution of the spawning migration of capelin and immature capelin
- Map the distribution of juvenile herring to assess the mixture of capelin and juvenile herring as a problem for acoustic abundance estimation of capelin.
- Estimate speed and direction of the spawning migration of capelin towards the coast with sonar, so that this can be implemented as a correction factor in the acoustic abundance estimation
- Obtain acoustic target strength (TS) estimates of capelin during the spawning migration
- To study capelin embryo development and egg mortality during different temperature conditions and under pollution

Abundance indices were calculated based on acoustic registrations with echo sounder combined with biological samples. Note that the survey is aimed at development of methodology, so the abundance estimates are preliminary and not suited for assessment of the spawning stock in the Barents Sea. The coverage of the total spawning stock represents a major challenge for obtaining reliable stock estimates for assessment, and lack of coverage in Russian zone may considerably influence results.

2 Execution and methodology

The survey was conducted in the period 20. January–14.February 2009 with the commercial vessel MS ”Eros” LIVA, M-60-HØ (survey number: 2009804, serial numbers: 72001–72037), starting in Tromsø and ending in Tromsø, and the commercial vessel MS ”Libas” LMQI, H-5-F (survey number: 2009803, serial numbers: 72101–72132), starting in Kirkenes and ending in Kirkenes. The survey covered the area south of 75˚N between 17˚30’ and 36˚10’E during the first period (20. January–06.February) and an area along the Norwegian coast, between 18˚30’E and to 34˚E during second period (06–14.February) (Figure 1 and Table1). MS ”Eros” covered the western part while MS ”Libas” covered the eastern part of surveyed area. The south eastern part of the Barents Sea was not covered due to lack of license to enter the Russian Exclusive Economic Zone, also leading to an earlier termination of the survey.

Scientists from IMR obtained biological samples of pre-spawning capelin at MS “Libas” during the fishery to carry out embryological experiment with artificially fertilised capelin eggs. During the first period of the fishery (14–25/2), capelin eggs were not ready to be fertilised because the capelin gonads was not ripe. Only during the second period (16–21/3), ripe pre-spawning capelin were found for embryological investigations.

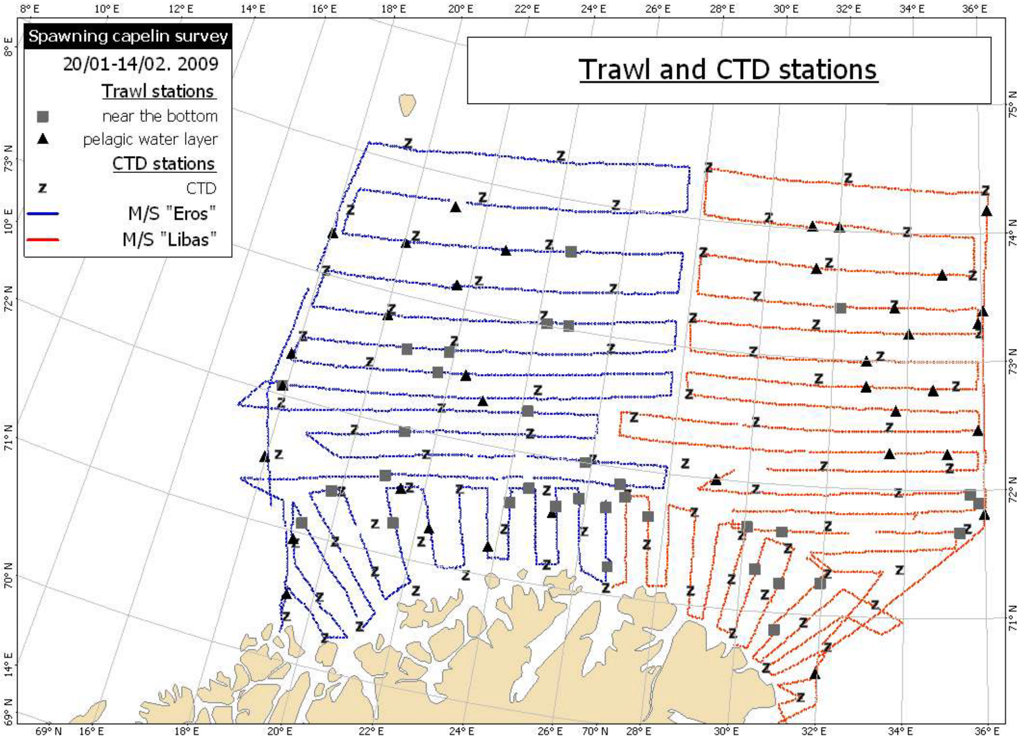

Figure 1 Course lines, CTD stations and trawl hauls for MS “Eros” (blue line) and MS “Libas” (red line).

Table 1. Timing and coverage of the capelin spawning survey 2009. Reference log numbers represents sailed nautical miles, and are given for future reference.

Covered area	**Vessel**	**Date**	**Period**	**Number of trawl stations**	**Number of CTD stations**	**Reference log**
Northern area (74° 30’N -71°N and 17°30’E - 28°E)	MS ”Eros”	20/01–06/02.2009	**1**	22	29	1212-5855
Northern area (74° 30’N -71° 20’N and 28°E - 36° 10’E)	MS ”Libas”	20/01–06/02.2009	**1**	24	41	5164 – 3802
Norwegian coastal area (71° 40’N -70° 20’N and 19°E - 27°10’E)	MS ”Eros”	06/02–14/02.2009	**2**	15	23	8518-7829
Norwegian coastal area (71° 40’N -69° 50’N and 27°E - 34°10’E)	MS ”Libas”	06/02–14/02.2009	**2**	8	22	7359-1352

2.1 Physical oceanography

Salinity (‰) and temperature (ºC) was measured with a transportable STD/CTD probe SD204 (SAIV A/S, Bergen). The probe was lowered and heaved with a mechanical winch and the interval for data registration was set to 1 per 2 sec. Data from the upcast was used, as the probe seemed to need some time in the water to stabilize. Samples were taken at regular intervals, and in combination with biological samples. At MS "Libas" a total of 63 stations were sampled, of which 1 was unsuccessful due to malfunction of the probe. At MS "Eros" a total of 52 stations were sampled, of which 2 was unsuccessful due to malfunction of the probe.

2.2 Biological samples

Biological samples were taken with a pelagic capelin trawl with opening circumference of 952 m at MS ”Libas” and a small herring pelagic trawl with opening circumference of 608 m at MS ”Eros”. To avoid excessive catch, the trawl was cut with a 3 m incision in the longitudinal direction, about 3 m from the end of codend. A total of 37 hauls were taken at MS "Eros", and 32 hauls at MS "Libas" (Table 1).

Length (down to nearest ½ cm), weight (down to nearest 1 g) and sex were recorded for maximum 100 individuals of capelin and young herring from each trawl sample. In addition individual measures of age and special maturation stadium was taken from 25 randomly selected individuals of capelin and herring. Relative gonad weight (gonad %) for the individually measured female capelin was measured as (total gonad weight/total individual weight) × 100. Stomach samples were taken from 10 randomly selected individuals of capelin and frozen for diet analyses on shore after the survey (see sections 2.8 and 3.7).

2.3 Echo sounder registrations

Acoustic data was recorded continuously by the vessels acoustic systems. Data was recorded at 5 frequencies (18, 38, 70, 120 and 200 kHz) with SIMRAD split-beam transducers. The range of the echosounder was set to 500 m, and pulse length was 1024 µs. Calibration of all frequencies was done prior to the survey. Acoustic abundance of fish was recorded as nautical area scattering coefficient (s_A) (m^2/n.mi.^{2}), and stored as ER60 raw files (*.raw). The acoustic data recorded at 38 kHz were scrutinised in the Large Scale Survey System[1]. The following acoustic categories were used (priority in parentheses): capelin (1), herring (1), bottom fish (3), and others organisms (3). In addition the category plankton (3) was used at MS "Eros". The results were stored for each nautical mile with a vertical resolution of 10 m. Echo integration stopped at 0.5 m above the acoustic bottom registration, threshold for volume backscattering strength (S_v) was set to -82 dB. Acoustic recordings from the other frequencies were stored for multi-frequency analysis of capelin and herring.

2.4 Acoustic abundance estimation of capelin

Nautical area scattering coefficient (s_A) (m^2/n.mi.^{2}) from the scrutinised echosounder data along acoustic transects is used as input to the acoustic abundance estimation of capelin and herring. The relation between acoustic target strength (*TS*), individual length in cm (*L*) and back scattering cross section (σ) is given as:

$TS = 10\log(\frac{\sigma}{4\pi}) = 19.1\log L - 74.0$, which gives: $\sigma = 5 \cdot 10^{-7} \cdot L^{1.91}$. The number of fish is calculated for standard 1 by 2 degrees WMO squares as:

$N(L) = \frac{\overline{s_A} A n(L)}{\sum_{Min.length}^{Max.length} n(L)\sigma(L)}$, where $\overline{s_A}$ is the mean s_A-value in the square, A is the area of the square in square nautical miles and n(L) the observed length distribution from samples in the square.

The TS-relation used is the same as the one used during surveys in the autumn. However, conditions during the winter (swimming behavior, fatness, sexual development, depth of registrations) are different in the winter from the conditions in the autumn. This may constitute a major source of error in the estimate, and makes it difficult to compare winter and autumn results. Comparable estimates requires TS measurements in both periods at various depths, which has not been accomplished yet. The abundance estimation has been performed with the program Recap, see www.assessment.imr.no/Bifrost/capelinResampling.htm for a description of the program. Here, also a comparison between the present abundance estimate and autumn estimates is

[1] Korneliussen, R. J., Ona, E., Eliassen, I., Heggelund, Y., Patel, R., Godø, O.R., Giertsen, C., Patel, D., Nornes, E., Bekkvik, T., Knudsen, H. P., Lien, G. 2006. The Large Scale Survey System - LSSS. Proceedings of the 29th Scandinavian Symposium on Physical Acoustics, Ustaoset 29 January – 1 February 2006.).

given. Note that migration during the survey poses a problem for abundance estimation of capelin, especially during the pre-spawning period. Note also that the abundance estimates under no circumstance are absolute measures, but must be treated as indices for the spawning stock.

2.5 Sonar measurements of migration

The methodology for school tracking was based on the description in Eriksen *et.al* (2008) [2]. Basically this methodology included criteria for sonar setup, school tracking, processing of tracks, identification of tracking errors and calculation of migration speed and direction of each of the tracked capelin schools. The school track analyses were done using the Geographical Information System (GIS) Arcmap ver 9.3 software. Additional data from sonar screen-dumps during the tracking was also recorded to support the analyses of the tracking.

During the cruise reported here, no data was recorded from the Furuno current indicator model CI-35 (fishery doppler current meter) available in the vessel.

Note that the school tracking activity during the survey was not a major activity in the survey design this year, as it was during the cruise in 2008. Therefore the time available for this activity was reduced compared to the previous year.

All data from the survey are stored in external hard discs (Elena Eriksen, Research group pelagic fish, Institute of Marine Research, Bergen, Norway). Biological data and Acoustic data from the echosounders are also stored in databases at Institute of Marine Research.

2.6 Capelin feeding during spawning migration

Capelin cannibalism was observed during the survey, and therefore stomach samples were collected on board MS "Libas". Stomach samples will be investigated at the lab after the survey and data and results stored along with the rest of the data from the survey (Padmini Dalpadado, Research group Plankton, Institute of Marine Research, Bergen, Norway)

[2] Eriksen E., Johansen G.O., Pedersen G., Peña H., Svellingen I., and Tjelmeland S. 2008. Methodology for assessment of the capelin spawning migration in the Barents Sea, spring 2008. Cruise report/Institute of Marine Research/ ISSN 1503-6294/Nr.8 – 2008.

2.7 Embryological studies of capelin eggs during different temperature conditions and under pollution.

During the first period of the fishery onboard MS “Libas” (14–25/2), capelin eggs were not ready to be fertilised because the capelin gonads was not ripe. Only during the second period (16–21/3), ripe pre-spawning capelin were found for embryological investigations. Biological samples were taken from 77 female and 77 male pre-spawning capelin. Biological measurements were taken according to the procedure described in chapter 2.2 “Biological samples”, except from sample size which was 77 for each sex.

The embryological experiments were divided in two parts: the first parts aimed at investigating egg development and mortality under different temperature regimes, and the second parts aimed at investigating egg development and mortality under different pollution regimes. Male and female were stripped for sperm and eggs. Before stripping, the fish was cleaned and dried with paper towel. Eggs, followed by sperm from one single pair of capelin were stripped onto a glass slide. Some sea water was added and the glass slides were allowed to rest for 10–15 minutes to allow fertilisation. The glass slides were rinsed, first with fresh sea water, followed by sterilized sea water. The quality of the eggs was checked, and single eggs from the same glass slide where embryological development had started were placed in separate compartments in the same NUNC plate (25 eggs from a capelin pair in each NUNC plate). 154 NUNC plates (one plate from each capelin pair) were taken for each of the two temperatures in the experiment, resulting in a total of 3850 eggs from 77 capelin pairs. For the pollution experiments, 2 NUNC plates from each of 2 capelin pairs were taken for each of the three pollution concentrations and control in the experiment, resulting in a total of 400 eggs from 2 capelin pairs.

The eggs used for analyses of temperature effects were placed in sterilized sea water, and the NUNC plates were placed in a refrigerator (Termax KB8182) at 5 °C and 8 °C (varying by 0.1 °C in both). The eggs used for analyses of pollution effects were placed in sea water with three different constant concentrations of oil platform production water (4%, 1% and 0.1%) in a refrigerator (Termax KB8182) at 5 °C (varying by 0.1 °C). At intervals of 2 days the sterilized and polluted waters were changed in the NUNC plates. Samples were taken at regular intervals during the incubation period, and the eggs were observed under binocular at 1-5 X magnifications.

3 Results and discussion

This year, the spawning stock of Barents Sea capelin was most probably largely underestimated. There are several possible explanations of this, and they might all have acted in concert. The timing of the survey was decided from the main purpose of investigations, i.e. to provide an estimate of the capelin spawning stock before the Norwegian-Russian Fisheries Commission has settled the quotas (preliminary in March) and the fishery starts. Thus, the timing was decided from the management's point of view, not the biological. Consequently this year's survey started too early with respect to the timing of the spawning migration of capelin.

Area of coverage was reduced due to lack of permission to enter the REEZ. To conduct the survey in REEZ an application for permission to enter the zone must be sent 6 months in advance. The application was sent 20 June 2008 (i.e. before the deadline) but without a vessel name. The vessel name can't be provided until the Norwegian-Russian Fisheries Commission has settled the quotas, and the tender procedure for rental of vessels have been finished, both which was done in October 2008. The application for permission including vessel names could therefore not be resent until 28 October 2008.Therefore coverage of REEZ was impossible with commercial vessels.

The capelin fishery was opened almost simultaneously as this survey. During the survey the fishery activity took place in the area that was not covered by our vessels. During the first part of survey when the survey covered the northern part of the survey area, the fishery took place south of our vessels. During the second part of the survey, the fishery activity took place north of our vessels. It is therefore possible that the fishery caught the immigrating capelin before it reached the surveyed area along the coast. Therefore the fishery activity may have influence uncertainties in the spawning biomass estimate.

3.1 Physical oceanography

The temperature in 50 m depth decreased gradually from west to east and from south to north in the surveyed area. The temperature near the bottom decreased in the same way, but was lower in the central and northern parts. Along the Norwegian coast, warmer water masses were observed from the bottom to the surface, with highest temperature in the west (Figure 3).

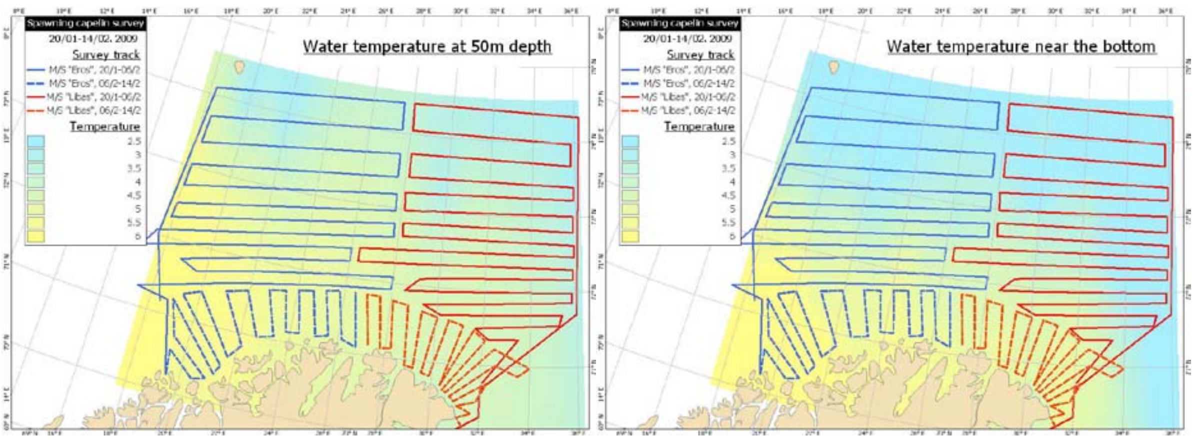

Figure 3. Average temperature (°C) in 50 m depth (A) and near the bottom (B) from MS “Eros” and MS “Libas” 20 January–14 February. Course tracks shown for MS “Libas” (red line) and MS “Eros” (blue line).Solid line represents the first period, and hatched line the second period of the survey.

3.2 Distribution and biology of capelin and young herring

Mature capelin was distributed along the bottom mixed with other fish species in a wide area in the eastern and southern parts of the Barents Sea. Schools of capelin were observed in the north-western part, migrating in south-eastern direction towards the Norwegian coast (see Figure 10 in section 3.5). Most of the sonar observations of schools were from outside the survey tracks, and were therefore excluded from the acoustic estimates and distribution maps. Schools of young herring were observed in the south-western part of survey area. Immature and mature capelin also occurred in a pelagic mixed layer together with krill, shrimp and 1 and 2 years old haddock and cod in the eastern an area.

To reflect the main pattern in vertical distribution, the trawl catches of capelin were divided into two groups: the first representing schools and layers in the upper water masses (10–100 m), the second the mixed registration of capelin and other fish species near the bottom (~20–70 m from the bottom) (Figure 5).

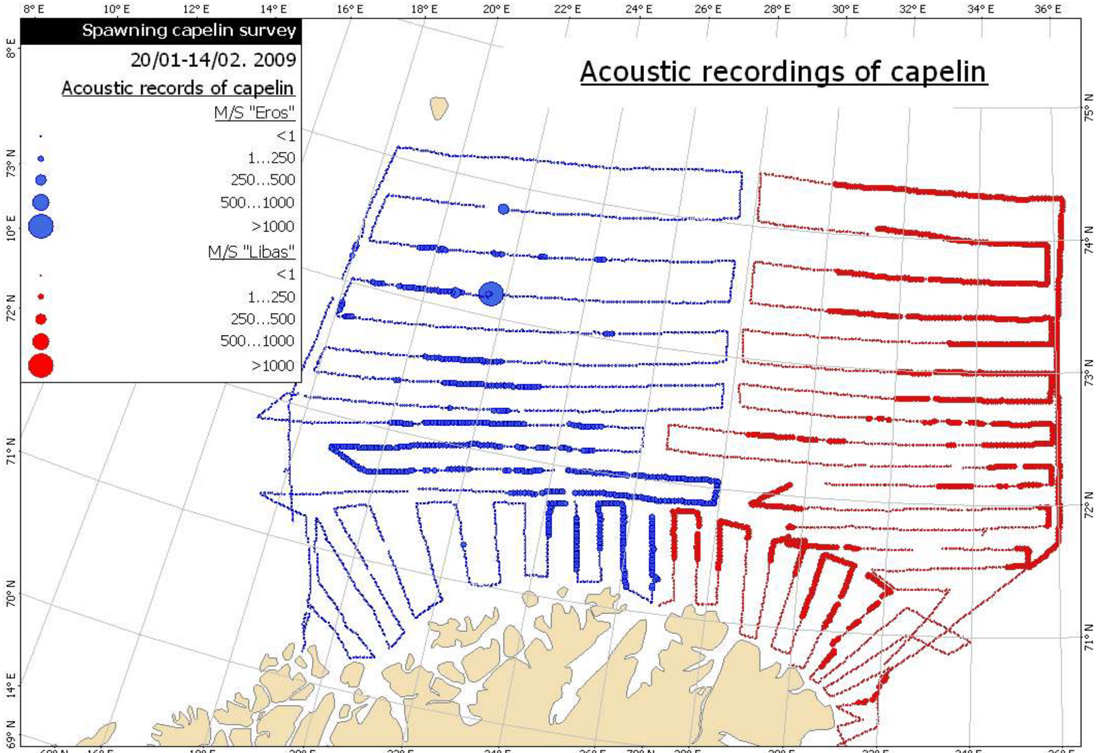

Figure 4. Acoustic recordings of capelin from MS “Eros” and MS “Libas” 20 January–14 February 2009. Course tracks included in the acoustic abundance estimation are indicated. Size of dots indicates level of nautical area scattering coefficient (s_A) (m^2/n.mi.^{2}).

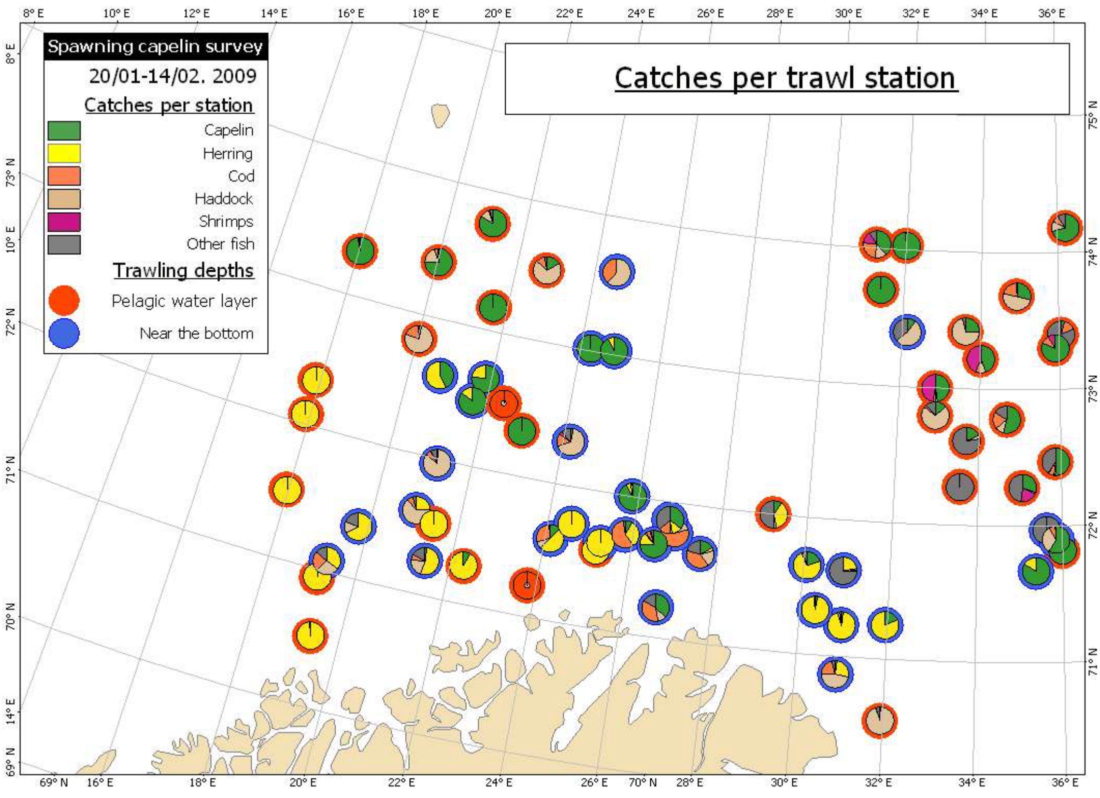

Figure 5. Trawl catches per station divided in different fish species and depth groups. Pelagic catches indicated by red circle, and catches taken near the bottom indicated by blue circle.

The body length of immature capelin (1–3 years old) varied between 5 and 12.5 cm. while that of mature capelin (2–5 years old) varied between 13 and 21 cm. Mean length, weight and special maturation stadium by different age group is presented in Table 3. The length and age composition of capelin varied between periods and areas and the details are presented separately below.

Table 3. Biological parameters of capelin in different periods and areas; mean length in cm ($\overline{L}$), mean weight in g ($\overline{w}$), special stadium for capelin (Ss), and mean gonad percent (Gonad %).

Age/ periods	$\overline{L}$					$\overline{w}$					Ss					Gonad %
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	
1 west			17.6	18.2	17.8			25.5	28.9	25.0			3.7	3.9	4.0	6
1 east	6.5	10.0	15.6	17.5	18.5	1.0	2.8	16.0	24.2	28.7		1.4	3.8	4.0	4.0	5
2 west		14.2	17.0	18.0			13.0	22.3	28.1			4.0	3.8	4.0		8
2 east		12.8	16.5	17.3	17.5		7.0	20.4	23.6	25.0		3.0	4.0	4.0	4.0	10

3.2.1 Period 1 (20.01–06.02.2009)

The capelin observed near the bottom in mix with other fish in the western area, was dominated by 3 years old individuals (Figure 6). Females were as usual smallest and the body length varied between 14 and 18cm, while the body length of males varied from 16 to 21cm.

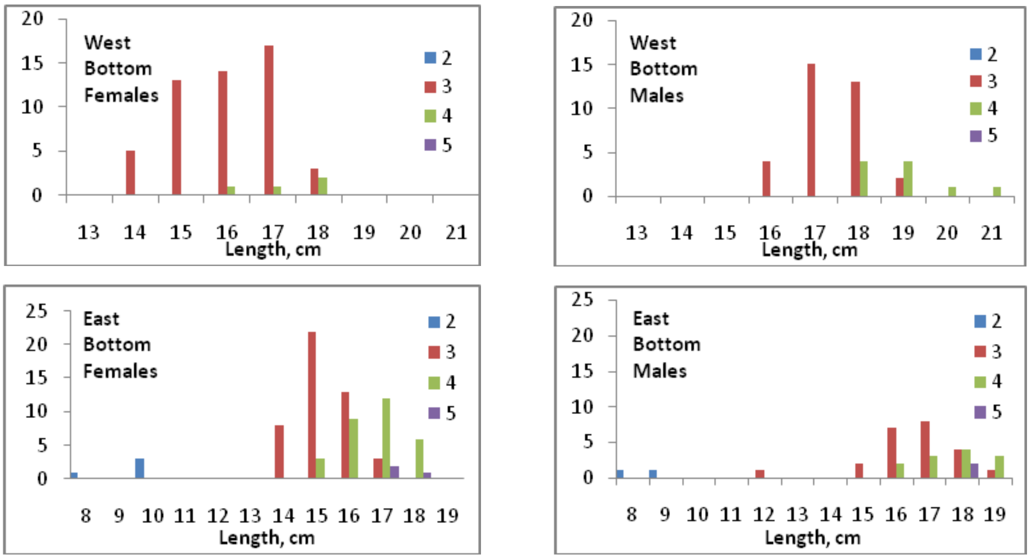

Figure 6. Body length and age composition of capelin near the bottom in the western (M/S “Eros”) and eastern (M/S “Libas”) areas during the period 1 (20.01-06.02.2009). Y axis shows number of capelin in each age and length group in the sample.

In the eastern area the capelin was dominated by 3 year old individuals (Figure 6) like in the west, but 1, 2, 4 and 5 years old individuals also occurred in the samples. In this area, the samples were dominated by females, and the length of females and males was almost the same.

In the pelagic in the western part of the survey area, capelin were also observed in schools dominated by 3 years old individuals. Few 4 but no 5 or 2 years old individuals were observed. Females were as usual smaller than males, and the body length of females varied between 14 and 18 cm, while the length of males varied between 16 and 20cm (Figure 7).

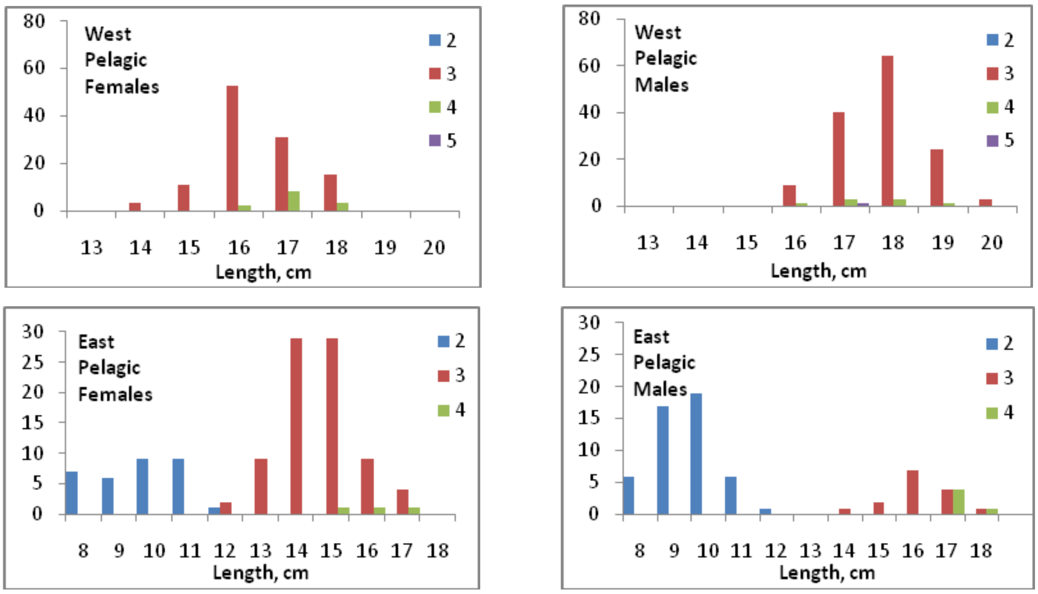

Figure 7. Body length and age composition of capelin in the pelagic in the western (M/S "Eros") and eastern (M/S "Libas") areas during the period 1 (20.01-06.02.2009). Y axes shows percentage of age and length groups in samples. Y axis shows number of capelin in each age and length group in the sample.

Almost all capelin was in special stadium 4 within a scale between 1 (immature) and 6 (spawning) and 7 (spent). Percentage of eggs was low, approximately 6% of the body weight. The capelin observed in the pelagic mixed layer with krill, shrimps and 1 year old cod and haddock in the eastern part of the survey area was distributed as shown in Figure 8. Immature capelin dominated this layer in an area between approximately 73°N–74°N and 30°E–36°E. Females dominated the catches and this capelin were 1–2 years old with males and females of similar size in special stadium 1 and 2 (Figure 7). The mature capelin in this layer was 3 and 4 years old and was in special stadium 4. Percentage of eggs was low, approximately 5% of the body weight.

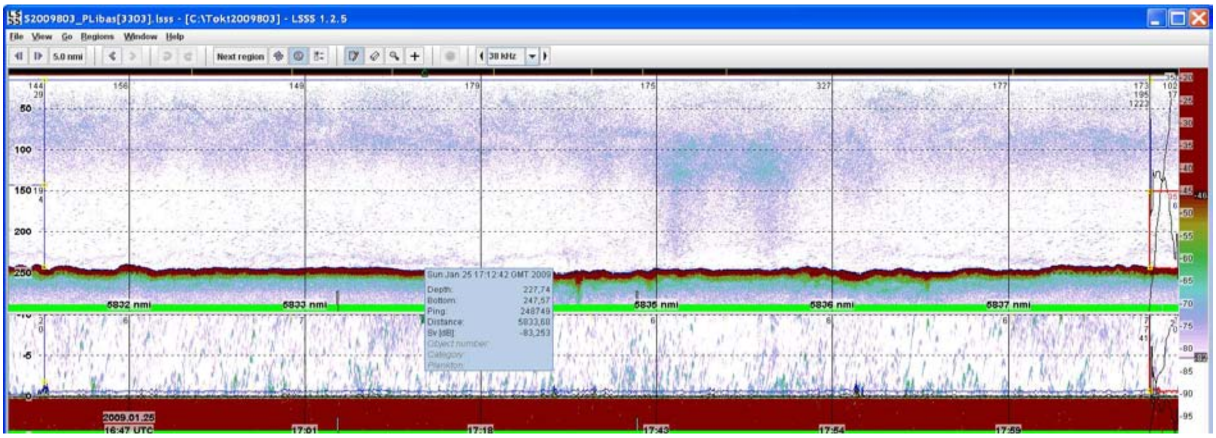

Figure 8. Echogram from station nr 10, taken by M/S ”Libas”, showing typical mix in pelagic layer in the eastern part of survey area.

3.2.2 Period 2 (06–14.02.02.2009)

During the last week of the first period and several days in the start of the second period, weather condition were bad due to storm, and no schools of capelin were observed. During the storm capelin was observed near the bottom mixed with other fish or as plain capelin concentrations. During period 2 the capelin were generally observed near the bottom mixed with larger (> 15 cm) fish like young herring, haddock, cod, redfish and other species. The capelin were dominated by 3 years old females. In the western part a few 2 year old capelin were observed and their maturation level were lower than for older fishes (Figure 9).

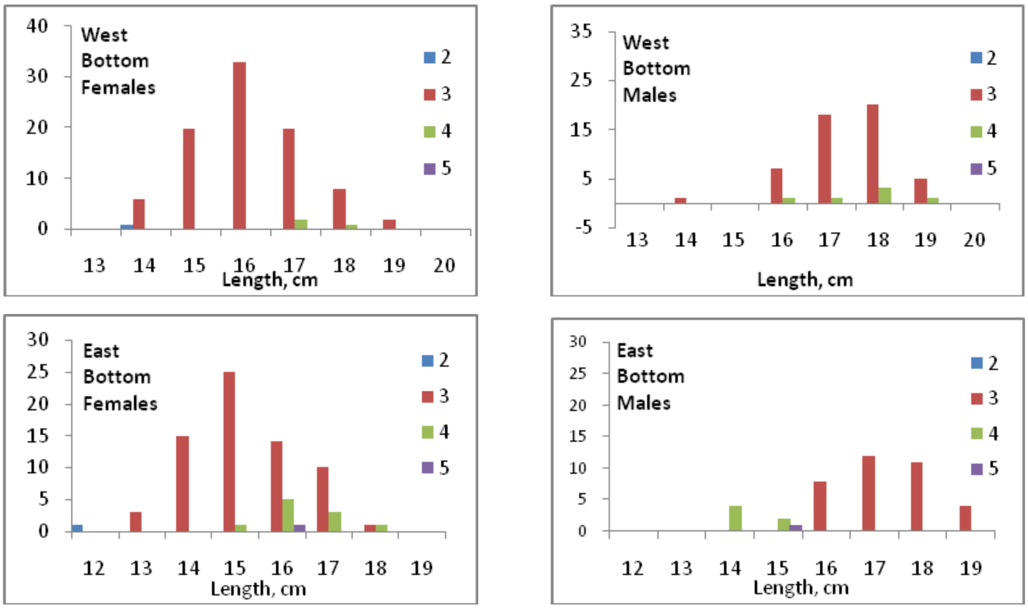

Figure 9. Body length and age composition of capelin near the bottom in the western (M/S “Eros”) and eastern (M/S “Libas”) areas during the period 2 (06–14.02.02.2009). Y axes shows percentage of age and length groups in samples. Y axis shows number of capelin in each age and length group in the sample.

Almost all fish were in special stadium 4, like in period 1. Egg percentage of body weight was higher than in period 1, but still low, and varied between 8% in west and 10% in east. This means that the capelin had some time left (weeks) before the start of spawning. Schools of young herring were generally observed in the pelagic.

3.3 Abundance indices of capelin spawning stocks

Table 4 shows the acoustic abundance estimate of capelin, based on the same TS-value as used in the autumn.

The abundance estimate showed about 100 000 tonnes of mature capelin, completely at odds with the prognosis from October 2008, which gives an expectation value of about 0.5 million tonnes by April 1 2009. Should this estimate have been used in the management, there would be no fishery in 2009. Clearly the survey missed the main capelin concentrations completely, or the capelin for some unknown reason did not mature as expected or were subject to an unprecedented high natural mortality in October-January.

Table 4. Abundance estimate of capelin

Length, cm	Age / Year class 1 2008	2 2007	3 2006	4 2005	5 2004	Number, 10^6	Biomass, 10^3 t	Mean weight, g.
6.5-7.0	503.2	0.0	0.0	0.0	0.0	503.2	0.5	1.0
7.0-7.5	162.1	69.0	0.0	0.0	0.0	231.0	0.0	0.0
7.5-8.0	144.6	76.8	0.1	0.0	0.0	221.5	0.0	0.0
8.0-8.5	0.0	221.8	0.0	0.0	0.0	221.8	0.4	2.0
8.5-9.0	0.0	211.6	8.4	0.0	0.0	220.0	0.4	2.0
9.0-9.5	0.0	179.0	25.3	0.0	0.0	204.3	0.0	0.0
9.5-10.0	0.0	276.0	8.4	0.0	0.0	284.4	0.7	2.5
10.0-10.5	0.0	292.7	59.0	0.0	0.0	351.7	0.9	2.5
10.5-11.0	0.0	172.4	16.9	0.0	0.0	189.3	0.6	3.3
11.0-11.5	0.0	66.0	222.7	0.0	0.0	288.7	1.2	4.0
11.5-12.0	0.0	71.5	8.3	0.0	0.0	79.8	0.0	0.0
12.0-12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
12.5-13.0	0.0	8.8	214.6	0.0	0.0	223.3	0.0	0.0
13.0-13.5	0.0	0.0	48.4	0.0	0.0	48.4	0.0	0.0
13.5-14.0	0.0	0.0	461.8	0.0	0.0	461.8	5.2	11.3
14.0-14.5	0.0	0.0	507.6	0.0	0.0	507.6	5.7	11.3
14.5-15.0	0.0	0.0	999.5	0.0	0.0	999.5	11.2	11.3
15.0-15.5	0.0	0.0	687.3	46.7	0.0	734.0	10.1	13.8
15.5-16.0	0.0	0.0	983.0	35.4	0.0	1018.4	16.8	16.5
16.0-16.5	0.0	0.0	456.2	60.2	0.0	516.4	9.6	18.5
16.5-17.0	0.0	0.0	418.8	84.4	2.5	505.6	10.7	21.2
17.0-17.5	0.0	0.0	503.5	163.4	0.0	666.9	14.8	22.2
17.5-18.0	0.0	0.0	342.8	61.8	5.4	409.9	8.6	21.0
18.0-18.5	0.0	0.0	229.0	27.0	5.7	261.7	0.0	0.0
18.5-19.0	0.0	0.0	148.5	37.3	3.9	189.6	6.1	32.0
19.0-19.5	0.0	0.0	336.7	30.9	1.0	368.6	0.0	0.0
19.5-20.0	0.0	0.0	327.5	4.2	0.0	331.7	0.0	0.0
20.0-20.5	0.0	0.0	3.9	2.0	0.0	5.9	0.0	0.0
20.5-21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.0-21.5	0.0	0.0	0.0	0.7	0.0	0.7	0.0	0.0
Abundance, 10^6	809.9	1645.5	7018.1	553.9	18.5	10046.0		
Mean length, cm	7.0	9.5	15.8	17.2	18.1	14.1		
Biomass, 10^3 tonnes	0.5	3.1	89.5	10.2	0.3		103.6	
Mean weight, g	0.6	1.9	12.7	18.5	15.7	10.3		

3.4 Acoustic target strength measurements of capelin

The report of analyses will come later after analyzing of collected data. All data stored in external hard disk (Egil Ona, Research group observation methodology, Institute of Marine Research, Bergen, Norway)

3.5 Migration towards the spawning grounds

Suitable tracking data were obtained from only 4 capelin schools, observed on 23 January 2009, approximately 200 nautical miles northwest of Nordkapp centred in 73˚48’6 ’’N and 21˚11’12’’E. The schools tracks are show in figure 10 and the results of the tracking analysis are summarised in Table 4.

In general the capelin school were tracked during a short time period (< 2 min), and only one school was tracked for more than 5 minutes. The general direction of the schools was to the east-southeast, with a speed between 0.7 and 2.5 knots. Due to the low number of schools detected during the survey by both vessels, it was not possible to do any further analysis.

Table 4. Results of tracked data for herring and capelin schools onboard MS “Eros”, during January 2009. ID is a label for school number. Latitude and longitude are the geographical coordinates of the central position of the track (decimal degrees), Time in UTC, School course (degrees), distance travelled during the track (m), elapsed time in the tracking (minutes) and school speed (knots).

ID	Latitude	Longitude	Time	Date	Course	Distance	Time	Speed
S1	73.80138	21.18364	08:12:10	23.02.09	77	186	8.4	0.72
S2	73.7939	21.22421	10:07:04	23.02.09	121	64	1.3	1.57
S3	73.79255	21.22455	10:08:53	23.02.09	109	76	1.7	1.45
S4	73.7823	21.22105	10:16:17	23.02.09	144	104	1.4	2.50

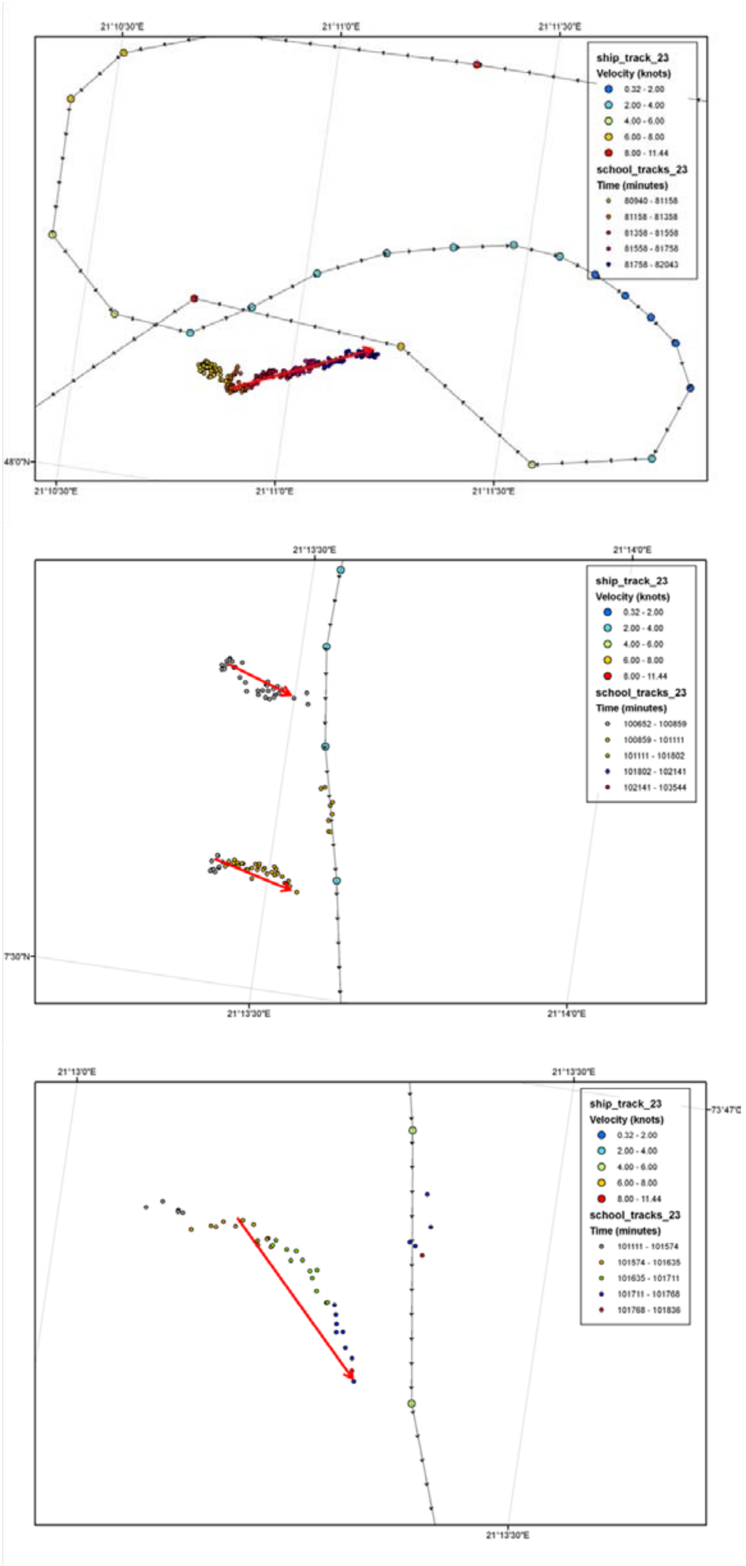

Figure 10. Capelin schools tracks from data collected onboard “MS” Eros, 23 January 2009. The colours of the dots indicate time during the tracking. The track of the vessel is plotted as a continuous black line, with arrows showing the vessel direction and dots showing the vessel speed. Red arrows indicate the general swimming direction of the schools.

3.6 Embryological studies of capelin eggs during different temperature conditions and under pollution.

The report of these analyses will come later after the experiments on embryologic development of egg and mortality of larvae are terminated and all data are collected and analyzed. All data will be stored in external hard disk (Elena Eriksen, Research group fish distribution, Institute of Marine Research, Bergen, Norway)

4 Conclusions and future recommendations

Research vessels are equipped with advanced instruments with effective internal communication between the different units. IMR has now developed a suite of equipment making the system at rental commercial vessels similar to the one at the research vessels. This setup was used onboard both MS "Eros" and MS "Libas", and the experience was that the rented commercial vessels, equipped with drop keel in addition to this setup, fitted perfectly to the task of acoustic abundance estimation and other acoustic sampling.

Reasonable abundance estimation of the capelin spawning migration depends on being at the right place at the right time. It is difficult to predict were the main spawning concentrations will hit the coast based on experience from earlier surveys. The timing for estimating the spawning stock was not correct this year, compared to the previous years. Both the Norwegian and Russian surveys seemed to miss the main immigration of spawning capelin. The Norwegian survey along the coast started too early, while the Russian survey offshore in the eastern part started too late. The occurrence of capelin in the mixed species layer at the bottom during survey period poses some interesting questions about how the capelin approaches the coast. If this is a general trait early in the spawning period, more attention should be directed towards the mapping of this mixed layer both offshore and closer to the coast. The link between migration routes and the autumn/winter distribution of capelin, as well as bathymetry and temperature conditions should also be studied to test if migration is limited or guided by these biological and physical factors.

Area of coverage of area is important for pre-spawning stock estimation, and lack of Russian parts of coverage may have crucial influence on stock estimation.

The area covered by the survey is important as parts of the feeding area of juvenile herring in the Barents Sea. The acoustic recordings of capelin and herring are quite similar, and difficult to separate. The main herring concentrations were found in the western and southern parts along the Norwegian coast, an area without capelin registrations this year.

A method for sonar estimation of migration speed and direction is established, and similar studies as the one presented here can be done in the future. The data sampled at this cruise are valuable as a first approach towards describing the small scale migration patterns in spawning capelin. A general impression of the migration speed and direction of capelin is obtained.

Currently, the capelin quota is determined by forward modelling of a multispecies model taking into account the autumn survey abundance estimate and estimated predation by cod during winter. This survey is part of a series of surveys from 2005 and 2007–2009, exploring the potential of obtaining abundance estimates of the spawning stock of capelin as a basis for setting fishing quotas. To fulfil this aim, we need to obtain reliable estimates early in the spawning season, so the fishermen can get the catches before the capelin is spent. The dynamic properties of the spawning migration make this task difficult. Two possible strategies are proposed to fulfil this task:

1. Instead of aiming at abundance estimates of the total spawning stock, we can estimate the stock in a predefined geographical area and time, suggested in cooperation with the fishermen. The quota based on the model described above can be adjusted if the abundance in this area is above a certain limit. For the time being, it is not clear if this strategy is compatible with the current exploitation rules.
2. If a quota based is recommended based on the modelling, this can be viewed as preliminary. Then several commercial vessels can be used to assess the spawning stock before the quota is set, and fishing can commence.

We thank the technical staff onboard MS “Eros” and MS “Libas” for their invaluable assistance during the survey. We also like to send our sincere gratitude to the skippers and crews onboard MS “Eros” and MS “Libas” for their goodwill and effort during the survey. Their contribution to the excellent working conditions for the scientific staff was immense and much appreciated. The cooperation between them and the scientific staff was flawless, and their expertise and experience was an important success factor for the survey. The exchange of experience between fishermen and researchers experienced at such surveys is educating and inspiring, and represents a valuable asset from surveys with rented commercial vessels.

5 Participants

5.1 Abundance estimation part

Participants	Research group	Time	Vessel	Responsibility
Elena Eriksen	439 Trophic interactions	20/1–6/2	MS ” Libas”	Cruise coordinator/leader
Jaime Alvarez	433 Pelagic fish	6/2–14/2	MS ”Libas”	Cruise leader
Geir Odd Johansen	439 Trophic interactions	6/2–14/2	MS ” Eros”	Cruise leader
Egil Ona	431 Observation methodology	20/1–6/2	MS ”Eros”	Cruise leader
Ingvald Svellingen	431 Observation methodology	20/1–6/2	MS ”Eros”	TS measurements
Hector Pena	431 Observation methodology	6/2–14/2	MS ”Libas”	Sonar
Lage Drivenes	620 Electronic equipment	20/1–14/2	MS ”Eros”	Equipment/data storage
Reidar Johannesen	620 Electronic equipment	6/2–14/2	MS ”Eros”	Equipment/data storage
Jarle Kristiansen	620 Electronic equipment	6/2–14/2	MS ”Libas”	Equipment/data storage
Andreas Nieuwejaar	620 Electronic equipment	6/2–14/2	MS ”Libas”	Equipment/data storage
Ronald Pedersen	431 Oceanography	20/1–6/2	MS ”Libas”	Equipment/data storage
Helga Gill	433 Pelagic fish	6/2–14/2	MS ”Libas”	Biological sampling
Eilert Hermansen	433 Pelagic fish	6/2–14/2	MS ”Eros”	Biological sampling
Jan de Lange	433 Pelagic fish	20/1–6/2	MS ”Libas”	Biological sampling
Elna Meland	433 Pelagic fish	20/1–6/2	MS ”Libas”	Biological sampling
Jan Henrik Nilsen	433 Pelagic fish	20/1–6/2	MS ”Eros”	Biological sampling
Jostein Røttingen	433 Pelagic fish	6/2–14/2	MS ”Libas”	Biological sampling
Bjørn Vidar Svendsen	433 Pelagic fish	20/1–6/2	MS ”Eros”	Biological sampling
Øyvind Tangen	433 Pelagic fish	6/2–14/2	MS ”Eros”	Biological sampling

5.2 Biological and embryological sampling

Participants	Research group	Time	Vessel	Responsibility
Elena Eriksen	439 Trophic interactions	14–25/2	MS ”Libas”	Embryological sampling
Andrey Shadin	Unestablished	14–25/2	MS ”Libas”	Embryological sampling
Jaime Alvarez	433 Pelagic fish	16–21/3	MS ”Libas”	Biological sampling
Andrey Shadin	Unestablished	16–21/3	MS ”Libas”	Embryological sampling