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An acoustic-trawl survey of offshore over-wintering northern cod, February-March 2007

Un relevé acoustique et par chalut de la morue de Terre-Neuve en hiver, février-mars 2007

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ABSTRACT

A dedicated hydroacoustic/bottom trawl survey was conducted during the winter 2007 off southern Labrador and Eastern Newfoundland (NAFO Div. 2J3KL). The survey objectives included determining the distribution, abundance and biological traits of Atlantic cod (*Gadus morhua*) and the results indicated that most fish were found in two main regions adjacent to the Bonavista Corridor (NAFO 3KL) and Hawke Channel (NAFO 2J). The fish were highly aggregated at these locations and found in the demersal zone at depths ranging between 400-550 m. These fish were predominantly of younger (3-5 years old) - smaller size-classes (24-55 cm), although several larger fish (70-87 cm) were caught in the Bonavista Corridor. The remaining areas were characterized by low abundance levels, including most of NAFO 3L. Biomass estimates (using acoustic data) over the surveyed areas were approximately 2,600 t (3L), 4,000 t (2J) and 17,000 t (3K). The survey design and sampling strategies were effective in detecting fish and area coverage, and particularly suitable to assess cod abundance when most fish are found aggregated over small regions of the offshore.

RÉSUMÉ

Un relevé hydroacoustique au chalut de fond a été réalisé durant l'hiver 2007 au large du sud du Labrador et à l'est de Terre-Neuve (OPANO, div. 2J,3KL). Le relevé avait pour objectif de déterminer la distribution, l'abondance et les caractéristiques biologiques de la morue franche (*Gadus morhua*) et les conclusions ont révélé que la plupart des poissons évoluaient dans deux grandes zones adjacentes au corridor de Bonavista (OPANO, div. 3KL) et au chenal Hawke (OPANO, div. 2J). On a observé une forte concentration de poissons dans ces zones et à des profondeurs oscillant entre 400 et 550 mètres. La majorité de ces poissons étaient jeunes (de trois à cinq ans) et appartenaient à des catégories de plus petites tailles (entre 24 et 55 cm), bien que plusieurs gros poissons (de 70 à 87 cm) aient été pris dans le corridor Bonavista. Un niveau d'abondance bas caractérisait les autres zones, y compris la majeure partie de la division 3L de l'OPANO. Les estimations de la biomasse (à partir des données du relevé acoustique) dans les zones sondées s'établissaient à environ 2 600 tonnes (3L), 4 000 tonnes (2J) et 17 000 tonnes (3K). La conception de l'enquête et les stratégies d'échantillonnage ont été efficaces pour la détection du poisson et la zone de couverture, et elles convenaient particulièrement bien à l'évaluation de l'abondance de la morue lorsque la plupart des poissons étaient concentrés dans de petites zones au large.

INTRODUCTION

In 2003 a bilateral agreement between the federal and provincial Governments was formed for developing recovery and management strategies of cod stocks in Newfoundland and Labrador (Anon. 2005). One of the mandates of the Canada-NL action team for cod recovery was to improve knowledge of the current status of cod stocks adjacent to Newfoundland and Labrador. Within this framework, two dedicated winter hydroacoustic/bottom trawl surveys have been conducted in 2007 and 2008 in a collaborative effort between the Department of Fisheries and Oceans (NAFC) and the Fisheries Conservation Group (Memorial University). The survey goals included determining the distribution and abundance of Atlantic cod on the outer shelf and upper slope off southern Labrador, Eastern Newfoundland and Northern Grand Bank (46^o-54^oN).

In this report we present the results of the 2007 survey, including estimates of biomass and biological characteristics of cod over-wintering in the offshore, from Hawke Channel to the Nose of the Grand Bank (NAFO Div. 2J3KL).

MATERIAL AND METHODS

The 2007 survey was conducted between February 28 and March 19 from the CCGS Teleost. The vessel was equipped with a calibrated Simrad EK 500 echosounder with a hull-mounted 38 kHz transducer. Fishing sets were conducted using a Campelen 1800 bottom trawl fished at 3 knots for 10-15 minutes. Vertical profiles of temperature and salinity at fishing stations were obtained using a trawl mounted CTD profiler.

The acoustic survey was conducted on the outer edge of the continental shelf following a systematic triangular grid track, limited by depth (<700 m) and run at 6-9 knots during both day and night time periods (Fig. 1). The triangular design was considered to the better than the parallel design because transect length was in most cases less than five times the average inter-transect spacing (MacLennan and Simmonds 1992). Transect and inter-transect length were chosen primarily as a function of the size and shape of the study area boundaries (approximately 900 km long and an average width of 3 km) and the time allocated for the survey.

Fishing tows were conducted within and around detected fish aggregations (17 tows) as well as in areas of low or undetected acoustic signal (8 tows) in NAFO 3K and 3L. In NAFO 2J only two tows were conducted successfully (both at detected aggregations) due to compact sea ice concentration in the area at the time of the survey. Catch data were used to verify species composition of the acoustic signal and for biological information, including total length (cm) and weight (kg), maturity stage and age structure of cod (through otoliths reading by DFO-NAFC personnel). Stomachs were also collected for future diet analysis.

Acoustic data (echograms) were edited manually and integrated using the visual editing software EchoView (SonarData Pty Ltd) to determine an area backscattering coefficient or ABC (m^2/m^2) of cod in each 100 m section of survey transect. Echogram editing consisted in identifying and separating cod from other fish species based on echo traces (e.g. shape, color intensity) and target strength (TS) of single fish. In a few cases, it was not possible to separate cod from other fish species (mainly red fish, *Sebastes sp.*) based on visual or acoustic properties of detected echoes. In such cases, catch data from the fishing tow (i.e. the proportions of cod in tow relative to the other species) conducted along or adjacent to the particular transect were applied to the partitioning of the echo traces in question during the echo-integration procedures using EchoView.

ABC values were converted to density (kg/m^2) using the equations:

TS (kg) = -11.26 x Log (TL) - 13.67 (Rose 2003)

and

$$\text{density (kg/m}^2\text{)} = ABC/10^{TS(kg)/10}$$

where *TS* is acoustic target strength (dB) and *TL* is total length (cm).

Fish density estimates obtained along the cruise tracks were then averaged (binned) over an area equivalent to 2 minutes of latitude by 4 minutes of longitude according to Mello and Rose (2005). The estimates were also adjusted to include undetectable fish in the acoustic deadzone, i.e. the region near the seabed where fish cannot be acoustically resolved (see Ona and Mitson 1996) based on a linear extrapolation of fish density in the 5 measurable meters above the acoustic bottom over the estimated deadzone for each 100 m horizontal bin. The deadzone depth (*dz*) for the EK 500 echosounder with the SIMRAD 38 kHz transducer (7^o power beam angle using 1 ms pulses) was estimated as:

$$dz = BSz + \left(2404 * \frac{d\tan^4\theta}{\theta^2}\right) + \frac{C\tau}{4}$$

where *BSz* is the backstep range (average of 0.5 m over the detected bottom), *d* is the mean depth of the bin (m), *C* is the average sound speed (m/s) through the water column, τ is the transmitted pulse width (1 ms) and θ is the half power beam angle of the transducer (3.5 ^{o}). At depths of 350-450 m, the *dz* for this survey was estimated to range from 1.85-2.42 m.

Data gathered during acoustic surveys are often spatially correlated as the result of samples being recorded continuously along the transect, specially in the case when the targeted species is found highly aggregated over a few areas, as typically observed with cod in NAFO Divisions 2J3KL during winter in both inshore (Rose 2003) and offshore areas (Kulka et al. 1995; Wroblewski et al. 1995).

Spatial correlation was confirmed in acoustic data and modeled as auto-correlation using geostatistical analysis and incorporated into the estimation procedure by weighting the sample values with the appropriate variogram model (Matheron 1963). The geostatistical analysis consisted of detecting trends in data distribution (e.g. a directional influence in fish density related to bathymetry), evaluating stationarity, estimation of empirical variograms, fitting a theoretical variogram model and calculating fish density and the associated standard error (SE) surfaces using ordinary kriging (Matheron 1971) as an interpolation method. When detected trends were modeled using first or second order polynomials and removed from the dataset. Once removed, the statistical analysis was performed on the residuals or the short-range variation component of the surface. Subsequently, trends were added back before the final surfaces were created in order to produce meaningful predictions. The spatial stationarity (isotropy) assumption implies a process with a constant mean and with the variance defined only as a function of distance and not location (Cressie 1993). Directional variograms were used to check for the presence of anisotropy in variograms. In all cases directional influences were detected and anisotropical variograms were calculated and incorporated into the kriging model used to estimate fish density surfaces.

The estimator of the variogram used was:

$$\gamma(h) = \frac{1}{2n} \sum_{i=1}^{x} \{z(x_i) - z(x_i + h)\}^2$$

where n is the set of all pair-wise distances $z(x_i)$ and $z(x_i + h)$ in a two dimensional plan and h is the scalar distance between two measurements.

Empirical variograms were then fitted with appropriate theoretical variogram models. In all cases, spherical models with a nugget term (micro-scale variations of data that are not described by spatial scale) provided the best fit. The model used was:

$$\gamma(h) = c\left[\frac{3|h|}{2a} - \frac{|h|^3}{a^3}\right], \qquad \text{for } |h| < a$$

$$\gamma(h) = c\ , \qquad \text{for } |h| \geq a$$

where c is the sill of the variogram $\gamma(h)$ representing the maximum level of variability in data measurements and a is the range of the variogram $\gamma(h)$ and represents the distance at which data are no longer correlated. The nugget model used was:

$\gamma(h) = 0$ for $h = 0$

$\gamma(h) = c$ for $|h| > 0$

Cross-validation was used prior to producing the final fish density surfaces in order to assess the accuracy and precision of model predictions. For all data points, the technique sequentially omits a data point, predicting its value using the remaining data and then comparing the measured and predicted values. The calculated statistics include the '1:1' line and the line of 'best fit' (regression lines using the observed and predicted values, respectively) based on the cross-validation scatter plotter, and mean error distribution.

Kriging predictions were computed as:

$$Z(V) = \sum_{i=1}^{N} \lambda_i Z(x_i)$$

where $Z(V)$ is the estimate of fish density at an unsampled point, N is the number of samples, λ_i is the weight attributed to sample x_i. The kriging output included fish density and SE surfaces of the surveyed area per NAFO Division. Additional details on geostatistical cod density indices are given in Mello and Rose (2005).

Cod biomass estimates in NAFO Div. 2J3KL were obtained by multiplying the kriged fish density index (mean fish density (kg/m^2) of interpolated surfaces) by the surveyed area in each NAFO Division.

RESULTS

Approximately 1300 nmi of acoustic transects were run from Hawke Channel (NAFO 2J) to the Nose of the Grand Bank (NAFO 3L). The depth range surveyed varied from 180 m to 680 m, but mostly between 280-430 m (Fig. 2). Median surveyed depths were 380 m in 2J, 375 in 3K and 300 m in 3L.

A total of 25 fishing tows were conducted through the study area (Fig. 1) and 3032 cod were caught (Table 1). The largest catches (up to 650 fish/tow) were consistently obtained in the Bonavista Corridor region, located at the NAFO Div. 3KL boundary and depths ranging between 400-430 m. Several other fish and invertebrates species were also caught during tows (Appendix 1).

Cod length frequency varied considerably among NAFO Divisions (Fig. 3). In 2J and 3K, length frequencies displayed a bimodal distribution, with peaks at 24 cm and 47 cm in 2J, and 36 cm and 51 cm in 3K, whereas in 3L, the distribution was unimodal, peaking at 34 cm. The mean length of cod caught in 2J was 35 cm (SD = 9 cm), 50 cm (SD = 9 cm) in 3K and 37 cm (SD = 12 cm) in 3L. Several larger fish (70-87 cm) were caught during the survey, particularly in 3K. A total of 281 fish were aged, most were 3-5 years old (Fig. 4). Modal age of samples was 3 in both 2J and 3L and 4 in 3K, and up to 9% of the fish aged were 6-7 years of age (mostly in 3KL). Most male and female cod caught in NAFO 2J3KL were immature or in maturing condition (Table 2).

It is likely that the variability associated to the maturity stage, stomach fullness and physiological condition of individual fish (e.g. size, density and relative position of the various organs and tissues) will have an effect on the acoustic properties measured, in particular the target strength of ensonified fish (Ona 1990). This study has not been designed to deal with these sources of uncertainty and it is considered here as a component of the variability inherent to acoustic abundance estimates.

The CTD casts obtained during fishing tows throughout the study area show a stratified water column with a cold upper layer, varying from -1.7 to 1.7 ^oC at the surface and from 1 to 2.3 ^oC at the thermocline depth (100-200 m), followed by a steady increase in temperature with depth, reaching between 3 and 4 ^oC at depths greater than 300 m (Fig. 5).

In terms of acoustic data analysis, the distribution of the area backscattering coefficient (ABC) in relation to depth indicate that most of the acoustic signal (used here as a proxy for fish density) were detected at depths ranging from 400-500 m in 2J and 3L and 350-550 m in 3K (Fig. 6). The geostatistical analysis showed evidence of spatial correlation in fish density distribution throughout the study area. Overall there was a good fit of theoretical to empirical variograms (Fig. 7). Variogram range varied between 8-53 nmi and was higher in 2J than in 3KL. Variogram sill varied between 2.7 $(kg/m^2)^2$ in

2J and 3K and 3.1 $(kg/m^2)^2$ in 3L and the nugget effect between 1 $(kg/m^2)^2$ in 3L to 2.2 $(kg/m^2)^2$ in 3K (Table 3).

The cross-validation analysis suggests that the models used provide reasonably accurate predictions as indicated by the line of best fit following the 1:1 line (i.e. measured values) very closely (Fig 8). As well as, the regression line for error plots (measured and predicted values) tended to be close to zero in all cases, suggesting that the predictions are unbiased.

The prediction map of cod density using ordinary kriging indicated that the highest densities (0.002-0.01 kg/m^2) were located in the region adjacent to the Bonavista Corridor in 3K, followed by the inner region of Hawke Channel (2J) whereas much lower densities (<0.0001 kg/m^2) were observed elsewhere, including most of 3L (Fig. 9). Cod aggregations in these regions were typically found in the demersal zone (up to 25 m above the bottom), each aggregation spanning up to 5-6 nmi (Fig. 10). Overall, the prediction SE map exhibited mostly low values (Fig. 11), indicating that the kriging models used had good predictive capability. High SE values were mostly limited to high-density areas and along the boundaries of the estimated map. Such patterns are expected due to the large variability in density values within short distances from around high-density locations in the former, and the reduced number of neighboring samples used for predicting fish density at unsampled locations in the latter.

The fish density index was highest in 3K (0.001 kg/m^2), reached 0.0003 kg/m^2 in 2J and was lowest in 3L (0.0001 kg/m^2). These density estimates include average deadzone corrections of + 22%, 20% and 10% in NAFO 2J3KL, respectively. Accordingly, cod biomass estimates within the surveyed area ranged from near 17,000 t in 3K and 4,000 t in 2J to 2,600 t in 3L (Table 4).

DISCUSSION

Acoustic survey data gathered during the winter 2007 on the outer shelf and upper slope off southern Labrador, Eastern Newfoundland and Northern Grand Bank show that most cod were aggregated within two main regions, the Bonavista Corridor (NAFO 3KL) and Hawke Channel (NAFO 2J) within the demersal zone, at depths ranging from 400 to 550 m, and coinciding with the warmest water layer found throughout the study area. The observations indicate that both regions are primary locations for cod in winter. The remaining areas of the continental shelf edge were characterized by low abundance levels, including most of the surveyed areas in 3L. The fish found were predominantly of small size (<60 cm) and young age (3-5 years old).

Bottom trawl surveys covering the shelf edge were conducted by the DFO in the fall (DFO 2007) and although the overall abundance estimates during most of the time series since 1994 are compatible with those of this winter acoustic survey, the fall surveys did not find cod aggregations. Comparisons of the two seasonal surveys suggest that cod aggregated in the Bonavista Corridor and Hawke Channel in winter but dispersed out of these areas during summer and fall. Such behavior is consistent with the historical post-spawning feeding migrations of this stock (Templeman 1974; Lear 1984) and migration routes (Rose 1993), which take cod from their overwintering areas in deep water near the edge of the banks and channels to spawning areas in shallower waters in springtime, then to inshore feeding grounds in summer and back offshore in fall.

In conclusion, the above findings indicate that of the area surveyed most cod biomass is presently found in a few regions of the offshore during winter, which is consistent with the historical over-wintering distribution pattern of the cod stock in NAFO Div. 2J3KL. The acoustic-bottom trawl survey design and sampling strategy proved to be effective in terms of detecting fish and covering a large area, and is likely the best approach in terms of accuracy and precision of estimates, time and cost effectiveness that can be used to assess rebuilding cod abundance when most fish are found highly aggregated over small regions.

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Table 1. Cod catch per fishing tow during the winter 2007 (February 28-March 19) hydroacoustic/bottom trawl survey conducted in NAFO Divisions 2J3KL. Tow duration ranged from 10 minutes (Set # in bold) to 15 minutes.

Set #	NAFO		
	2J	3K	3L
1		259	
2		114	
3		5	
4		7	
5		1	
6		3	
7		3	
8		1	
9		19	
10	25		
11	67		
12			61
13			11
14			0
15			1
16			23
17			108
18		142	
19		259	
20		180	
21		295	
22		98	
23		368	
24		650	
25		332	

Table 2. Maturity stage frequencies of cod sampled during the winter 2007 hydroacoustic/bottom trawl survey conducted in NAFO Divisions 2J3KL. Maturity stages were identified using the visual classification criteria provided by Morrison (1990).

Sex	Maturity Stage	NAFO		
		2L	3K	3L
Male	Immature	16	183	44
	Spent L		3	
	Mat P	26	475	18
	Partly Spent	8		
	Spent P		5	
	Spent L-Mat P no milt		7	
	Spent L-Mat P with milt		3	1
Female	Immature	34	326	53
	Spent L		11	
	Mat AP	8	373	15
	Mat BP		3	1
	Spent P		15	5
Unknown	Unknown		1327	64

Table 3. Variogram model parameters computed for the winter 2007 acoustic cod density estimates in NAFO Divisions 2J3KL. One decimal degree of latitude = 60 nmi.

NAFO	Sill $(fish/m^2)^2$	Range (decimal degree) Major	Minor	Nugget $(fish/m^2)^2$	Anisotropy Direction (degree)	Lag Size (decimal degree)	Number of Lags
2J	2.77	0.89	0.46	1.59	73.2	0.07	12
3K	2.76	0.27	0.16	2.24	54	0.03	8
3L	3.11	0.19	0.14	1.03	279	0.02	9

Table 4. Abundance index and biomass estimates within the areas surveyed during winter 2007 in NAFO Divisions 2J3KL.

NAFO	Mean Fish Density (SD) (kg/m^2)	Area $(x10^{10}\ m^2)$	Biomass (t)
2J	0.0003 (0.0004)	1.36	4085
3K	0.001 (0.002)	1.68	16831
3L	0.0001 (0.0002)	2.57	2574

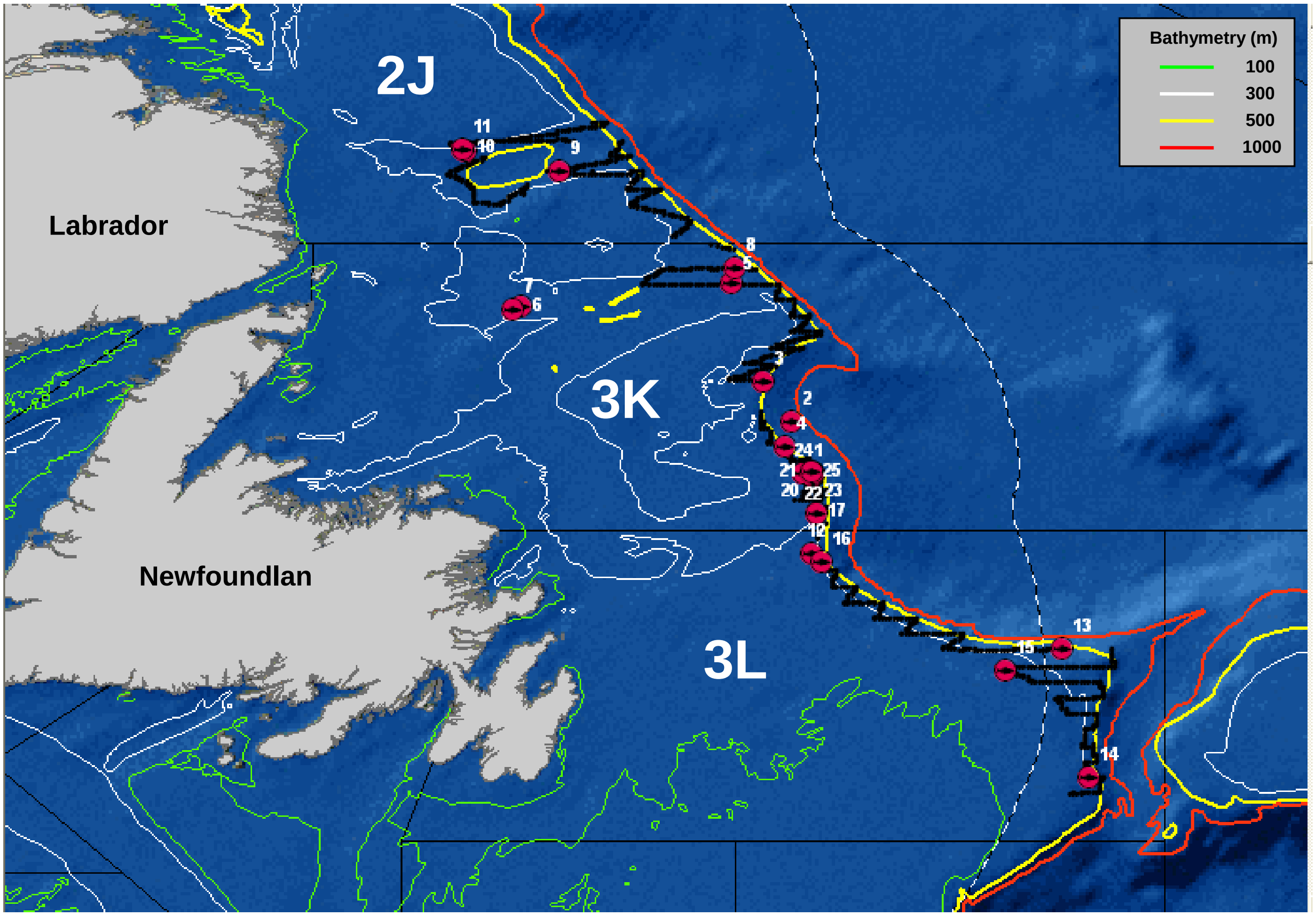

Figure 1. Track (black dots) and fishing tows (red circles # 1-25) of the winter 2007 cod hydroacoustic/bottom trawl survey conducted on the outer shelf and upper slope off southern Labrador, Eastern Newfoundland and Northern Grand Bank (NAFO Divisions 2J3KL).

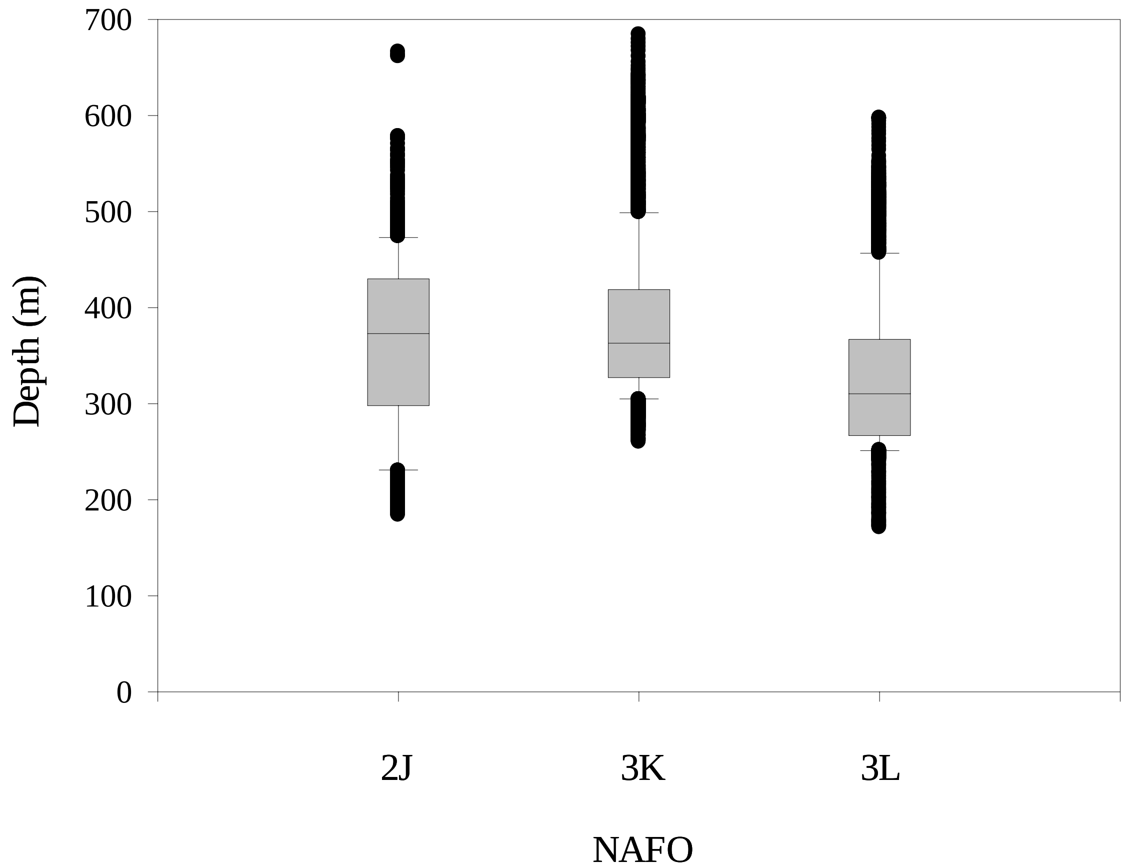

Figure 2. Depth range surveyed acoustically during the winter 2007. The box-plot graph shows the 25th and 75th percentiles (box lower and upper limits), the median (line inside the box), and the 10th and 90th percentiles (lower and upper limits of T-bars), with values beyond this range represented by black dots.

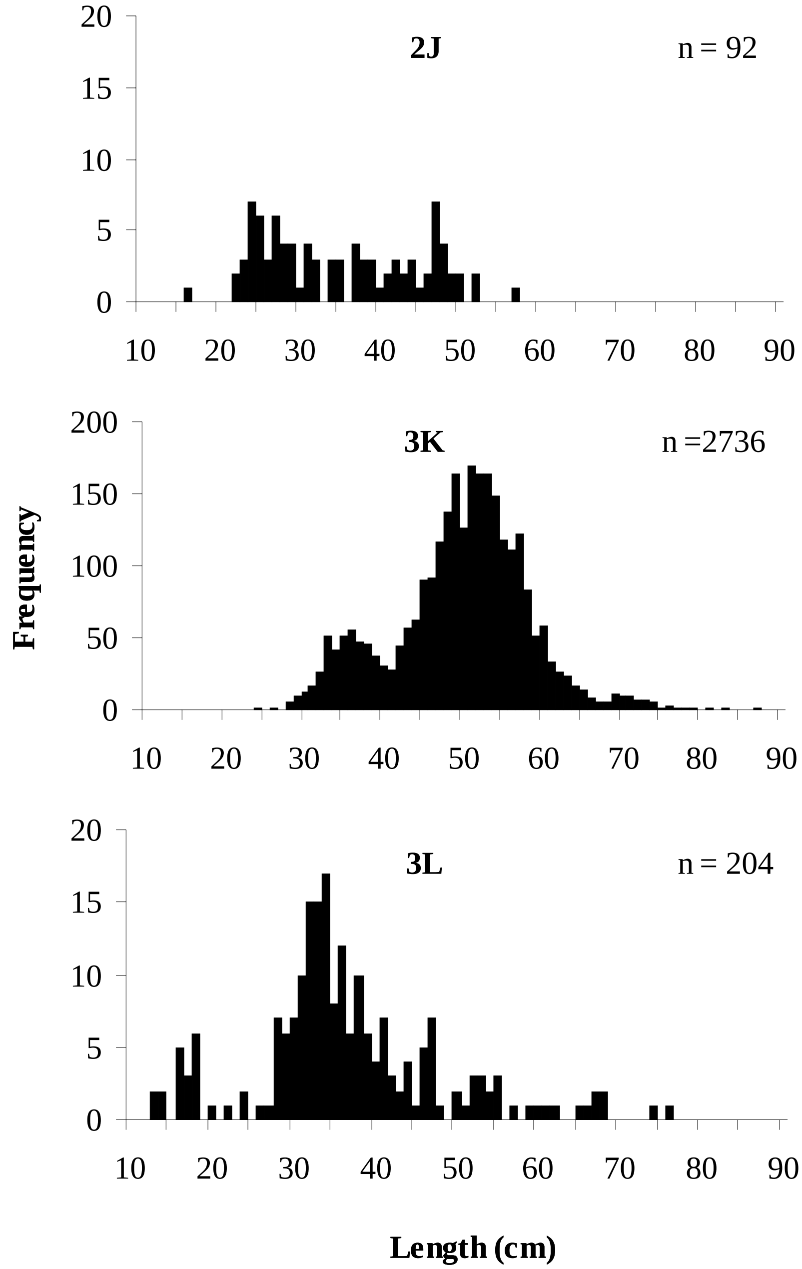

Figure 3. Length frequency distribution of cod caught during the winter 2007 survey in NAFO Divisions 2J3KL.

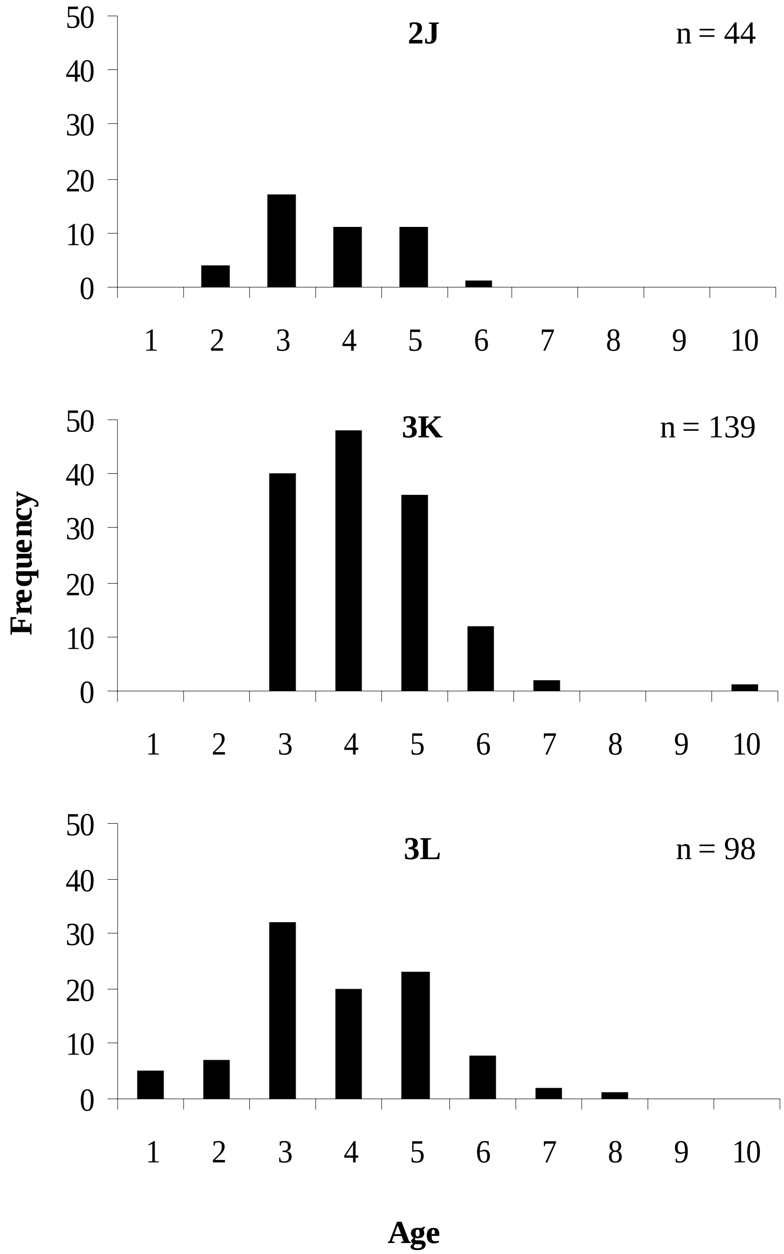

Figure 4. Age frequency distribution of cod caught during the winter 2007 survey in NAFO Divisions 2J3KL.

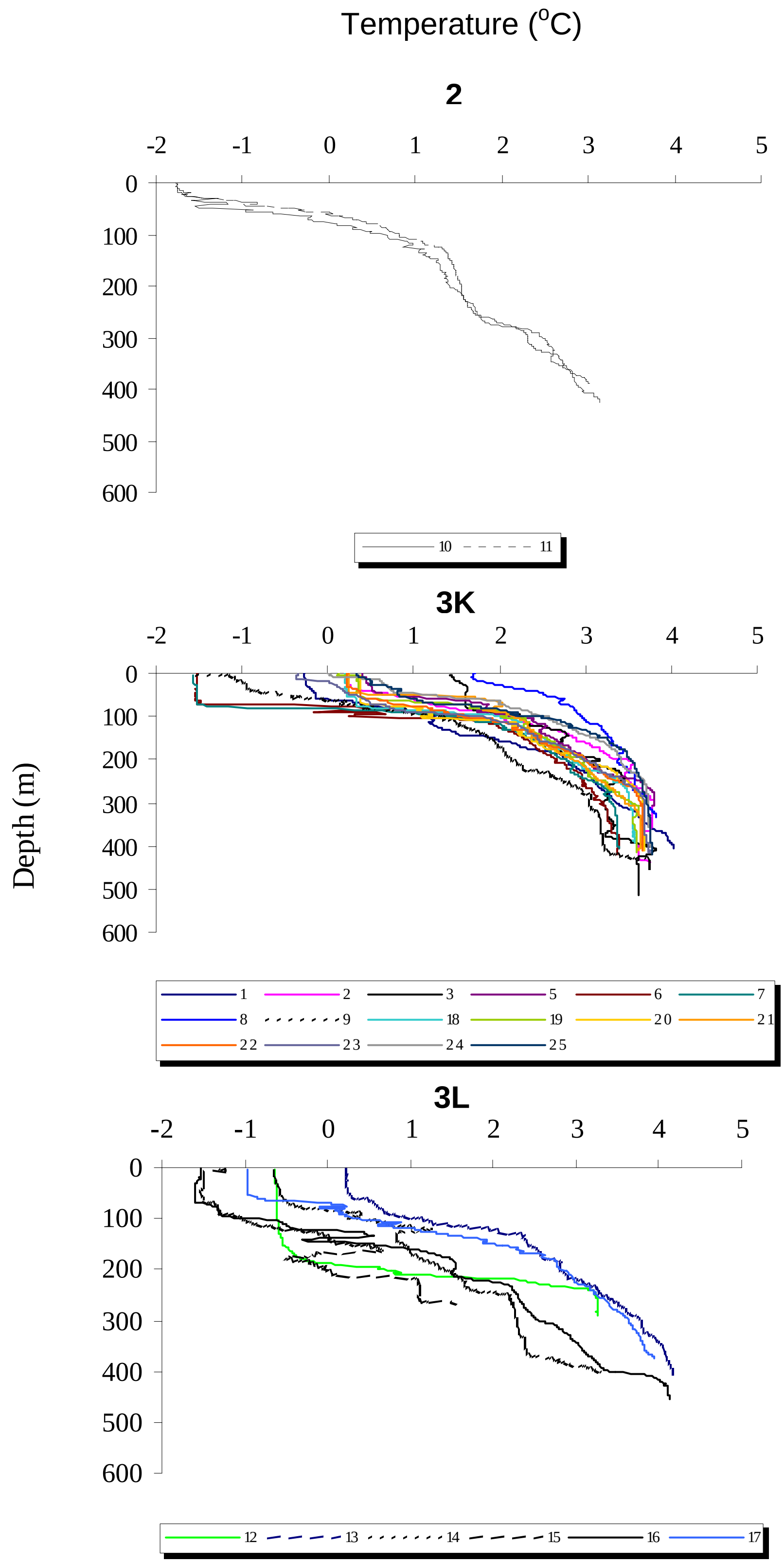

Figure 5. Temperature profile of the water column recorded in winter 2007 during fishing tows (1-25) in NAFO Divisions 2J3KL. No data available for tow 4.

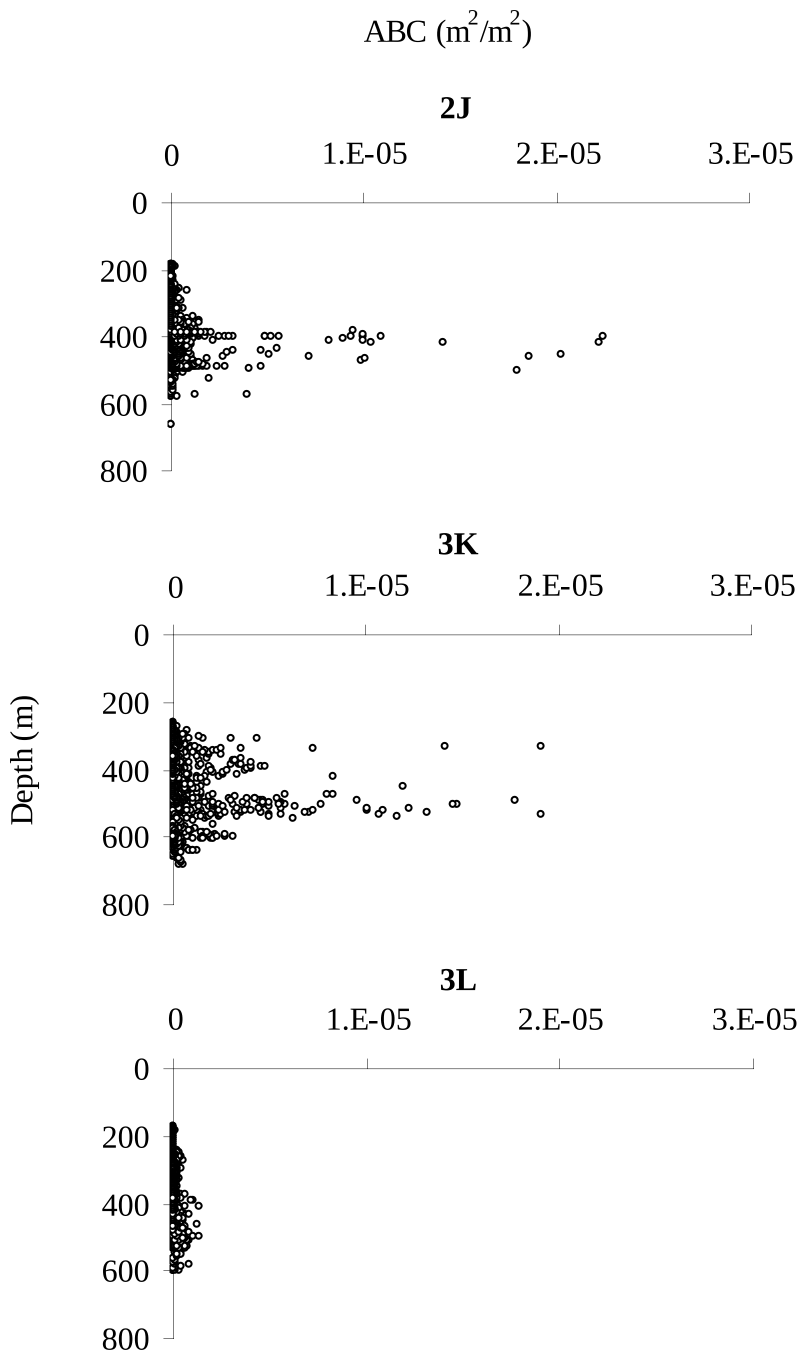

Figure 6. Distribution of the area backscattering coefficient (ABC) of acoustic data from the winter 2007 survey in relation to depth in NAFO Divisions 2J3KL.

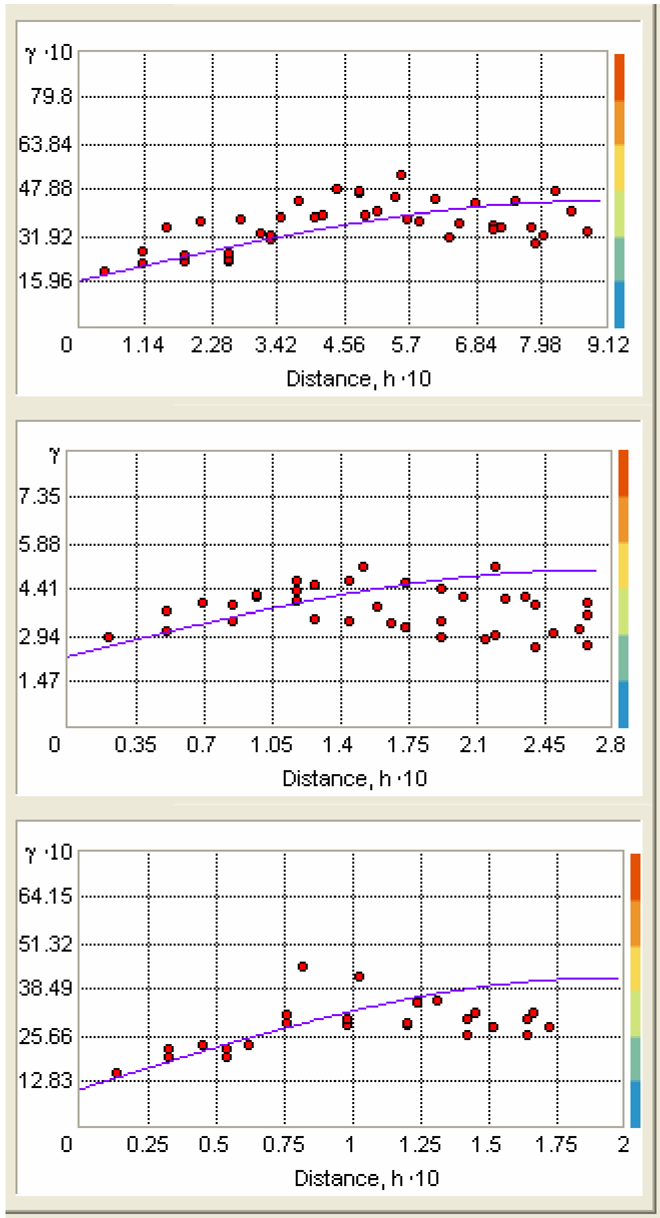

Figure 7. Empirical (dot) and theoretical (line) variogram models computed for the main direction of anisotropy (see Table 2) of acoustic cod density estimates in NAFO Divisions 2J (top), 3K (middle) and 3L (bottom panel) during the winter 2007.

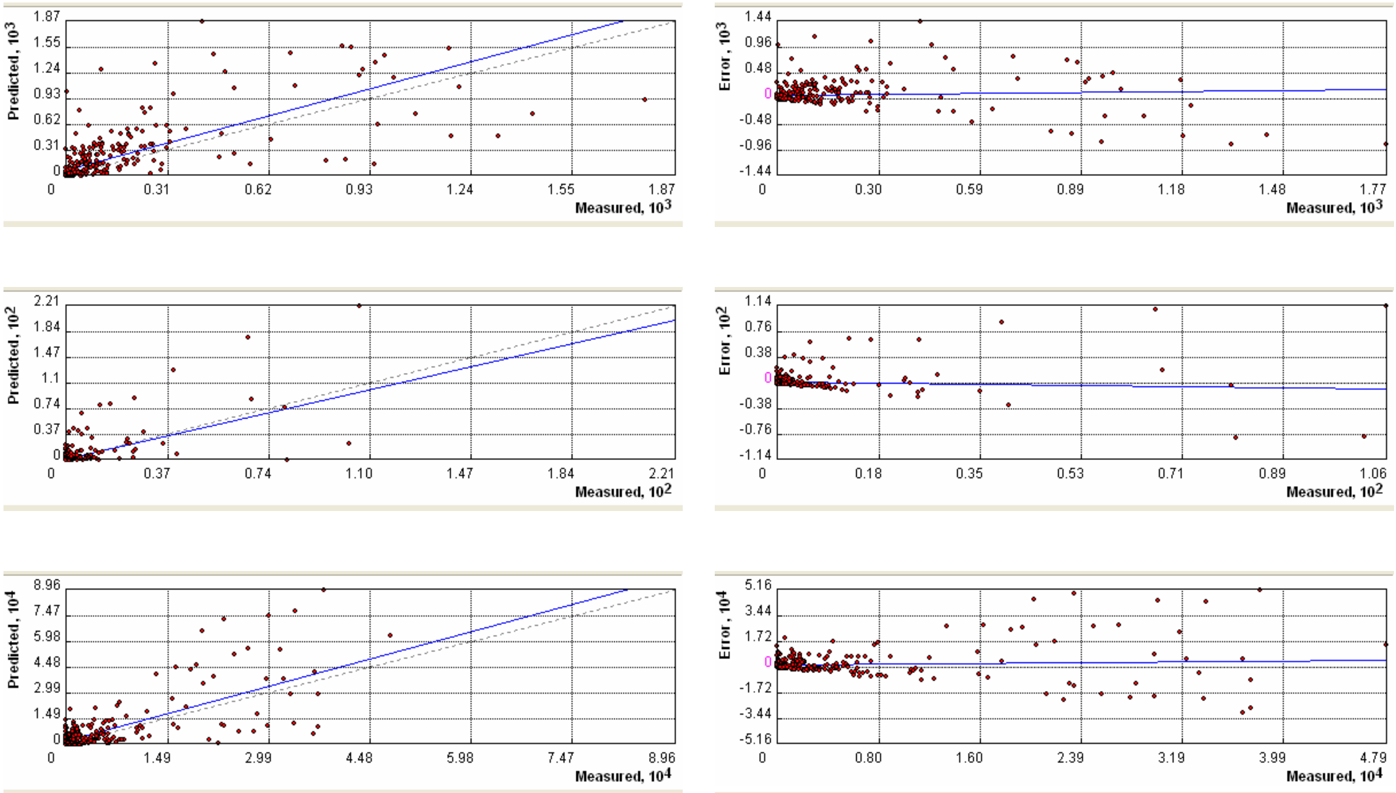

Figure 8. Results of the cross-validation analysis used to develop models for predicting cod density (left panels) and standard error (SE) maps (right panels) in NAFO Divisions 2J (top), 3K (middle) and 3L (bottom panels) during the winter 2007. Lines: dashed (1:1 or measured values) and blue (best fit).

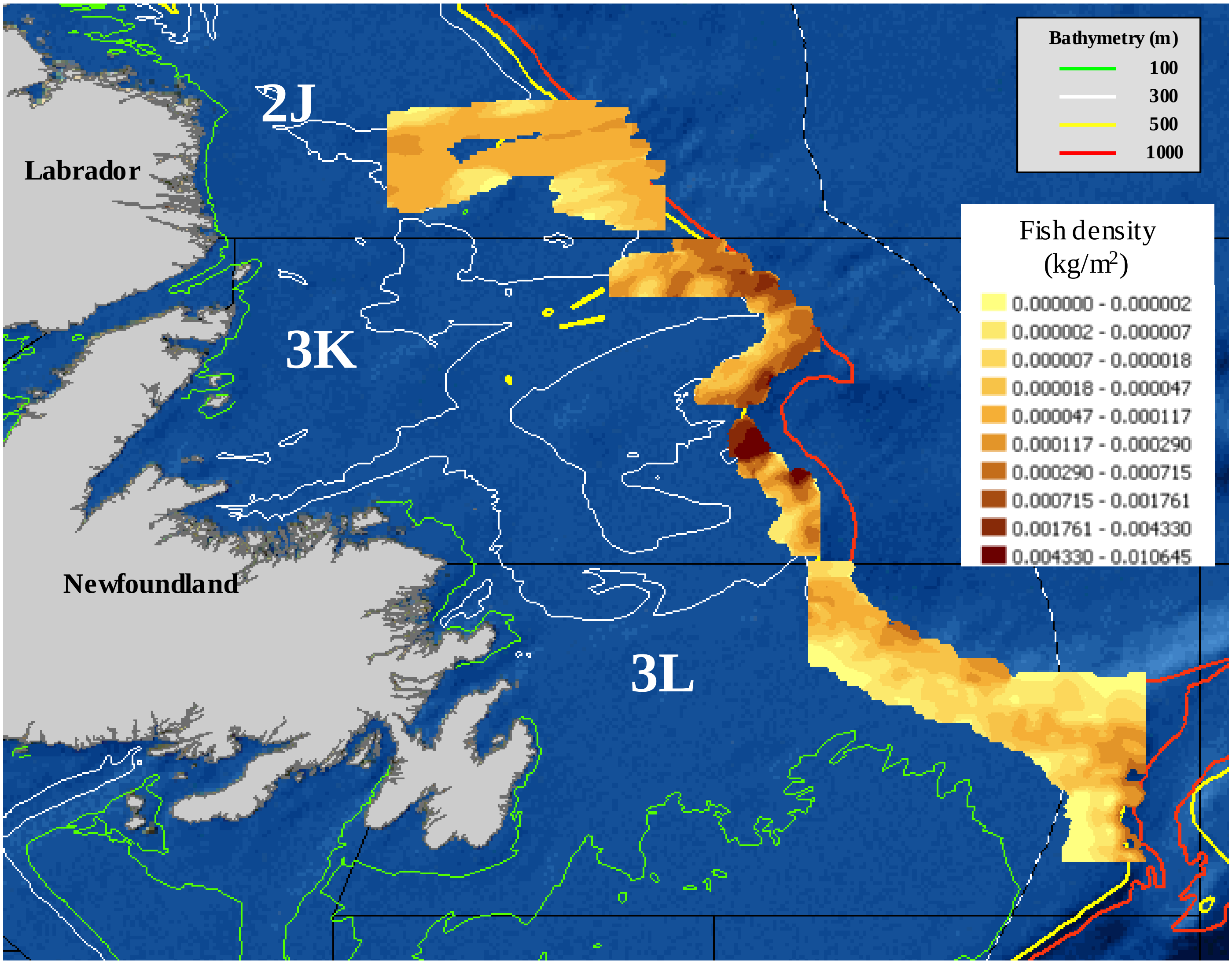

Figure 9. Prediction map of cod density in NAFO Divisions 2J3KL during the winter 2007 survey using ordinary kriging.

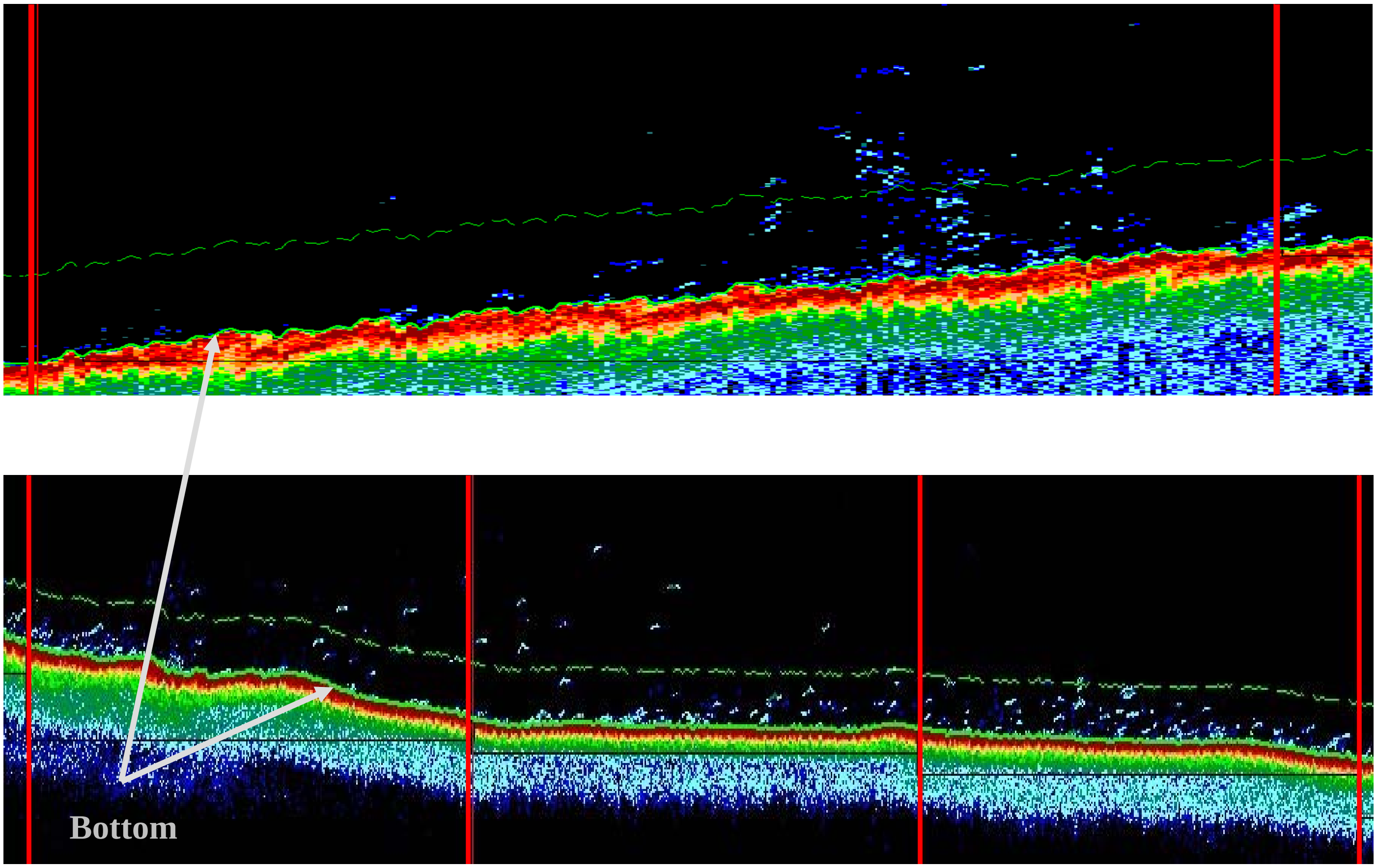

Figure 10. Echograms showing cod aggregations in the Bonavista Corridor (top) and Hawke Channel (bottom) as recorded during the winter 2007 survey. Echogram TS colour scale varies from -13 dB (orange) to -71 dB (blue). Distance between vertical red lines = 1 nmi, and bottom to dashed green line offset = 25 m.

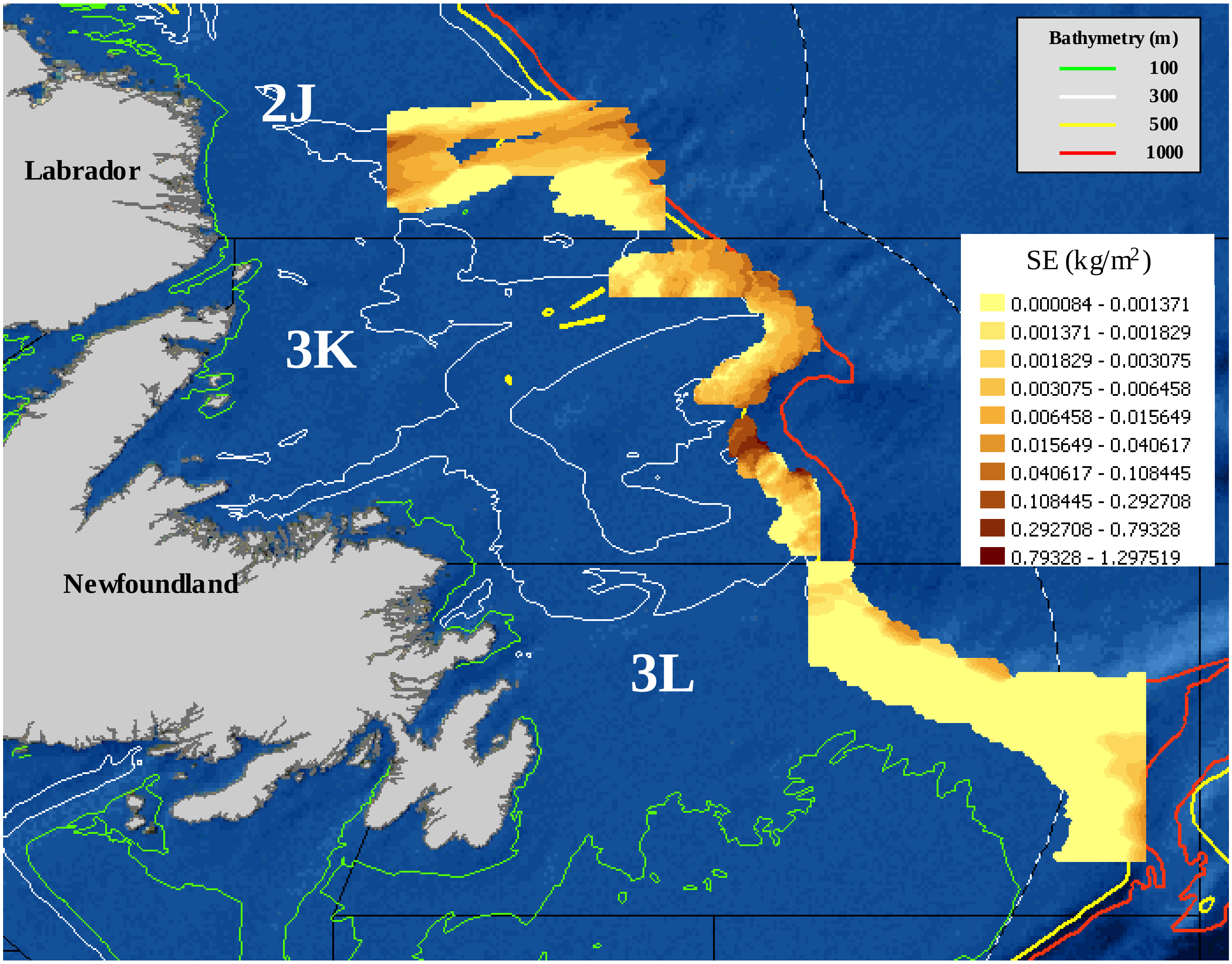

Figure 11. Prediction standard error map (SE) of cod density estimates in NAFO Divisions 2J3KL during the winter 2007 survey using ordinary kriging.

Appendix 1. Results of fishing tows conducted during the winter 2007 hydroacoustic/bottom trawl survey in NAFO Divisions 2J3KL. Superscript: [1] = Family, [2] = Order, [3] = Class, NA = not applicable.

Name		Catch weight (kg) Tow #																								
Common	Scientific	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Skates										0.1																
Thorny skate	Raja radiata	7.1	6.8	11.2	7.8	2.5		2.1			1.1	0.4	39.7	8.8		15.3	21.5		24.3		5.2			13.2	12	
Smooth skate	Raja senta																		0.8							
Spinytail skate	Raja spinicauda				0.8				0.1																	
Atlantic herring	Clupea harengus								0.2				1.7			0.1										
Capelin	Mallotus villosus					27.6			44.2							3										
Lantern fish	Myctophidae[1]					0.1								0.1												
Barracudinas	Paralepididae[1]		0.1	0.1	0.1		0.1			0.5	0.4	0.1							0.2			0.5			0.4	0.5
Scaled lancetfish	Notolepis rissoi kroyeri																0.1	0.1			1.2					
Longnose eel	Synaphobranchus kaupi			0.1	0.4																					
Large scale tapirfish	Notacanthus nasus																	2.2								
Atlantic cod	Gadus morhua	255	43.1	7.8	8.8	0.2	4.6	2.3	1.4	10.9	13.6	29.8	30.1	5.2		1	40.2	39.7	126.2	302	180.3	332.1	98.4	438.7	825.5	367.6
Longfin hake	Urophycis chesteri			0.1						0.1				2.3			0.1									
White hake	Urophycis tenuis									0.1																
Threebeard rockling	Gaidropsarus sp.			0.1			0.1									0.8										
Fourbeard rockling	Enchelyopus cimbrius												0.2	0.1												
Roughhead grenadier	Macrourus berglax	0.2	0.8	1.8	2.1												1.1		0.2		0.3		4.6		0.9	0.1
Common grenadier	Nezumia bairdi		0.1	4.1	6	0.2				4.8				3.8			0.7									
Broadhead wolffish	Anarhichas denticulatus	1.1																	6.6							
Striped wolffish	Anarhichas lupus					2			0.1				22.7			0.9	5.8	3.8								
Spotted wolffish	Anarhichas minor		1.5		2.4				0.1				0.1					3.4				1.7	2.7		3.3	
Fourline snakeblenny	Eumesogrammus praecisus															0.8										
Snake blenny	Lumpenus lumpretaeformis					0.3																				
Eelpouts	Zoarcidae[1]	0.6		5.2	6.1	0.1	0.1			1.7	0.1					5.3	3.6	1						1		
Esmark's eelpout	Lycodes esmarki													0.9												
Vahl's eelpout	Lycodes vahlii												0.4	6.7								2.8				1.5
Wolf eel	Lycenchelys sp.															0.2										
Redfish	Sebastes mentella	15.7	110	283.7	785	14.8			2.2	19.9	3.2	0.6	8.55	18.3	6800	0.2	44.8	138.4	360.8	126.3	52	175.5	180.4	116.8	197	78.8
Hookear sculpin	Artediellus sp.					0.2					0.1		1.9	0.7												
Arctic hookear sculpin	Artediellus uncinatus																	0.1								
Mailed sculpin	Triglops sp.					0.6				0.1		0.1	0.2			0.8										
Arctic deepsea sculpin	Cottunculus microps							0.1																		
Spatulate sculpin	Icelus spatula						0.1	0.1								0.1										
Northern alligatorfish	Agonus decagonus						0.1	0.1		0.5	0.2	0.1	0.5			0.8										
Common alligatorfish	Aspidophoroides monopterygius					0.1						0.1	0.2													
Common lumpfish	Cyclopterus lumpus		1.2				0.6		5.5	0.3						4.6	0.43		5.3					0.9		
Seasnail	Liparidae[1]					0.1																				
American plaice	Hippoglossoides platessoides	1.5	0.9	6.1	3.1	0.7	2.1	0.3		0.5	0.5	0.2	1.4	13.5		2	31	15.1	15.9	9.9	7.2	12.2	14	17.6	3.5	14.8
Witch flounder	Glyptocephalus cynoglossus			0.2										0.2			0.2		0.5			1.7		2		
Turbot	Reinhardtius hippoglossoides	3	30.6	60	34.6	1	53.2	27	6.1	178.5	4.4	5.2	24.2	7.6		2	18	2.2	4.7	3.9	7.2	11	8	2.5	4.5	4.4
Invertebrates	NA	6.1	13.7	10.1	2.8	7.4			5.2	0.1			17.5	10.3			0.2		1.9	2.5	4.4		3.6	11.5	9	0.5
Jellyfish	Scyphozoa[3]																					8.5				
Sea anemone	Actinaria[2]													234.5					16.8			10.5				
Cephalopod	Cephalopoda[3]									0.1		0.1														
Octopus	Octopoda[2]				0.07																					
Shrimp (all shrimp)	Decapoda[2]						34.35	53	277		3.4	4	68.5	1.6									0.1			
Sea star	Asteriidae[1]										0.2															
Deepsea coral	German rubiformis								0.1																	
Deepsea coral	Capnella sp.								0.1																	
Snow crab (male)	Chionoecetes opilio						0.7		1.4		0.2															
Snow crab (female)	Chionoecetes opilio								0.4																	