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Recent spring offshore acoustic survey results for capelin, *Mallotus villosus*, in NAFO Division 3L

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The spring NAFO Division 3L acoustic survey for capelin provides indices of biomass and abundance of 2J3KL capelin, in addition to information on capelin distribution, biology and behavior. Spring capelin acoustic surveys have been conducted annually in 1982-92, 1996, 1999-2005 and 2006-12. The biomass of capelin found during the survey has changed dramatically within this time series, peaking at 7 million tonnes in the late 1980s, dropping an order of magnitude in the early 1990s and again in 2010 to an all-time low of 23,000 t. However during the last two years the survey biomass has rebounded to levels more consistent with those of the late 2000s (206,000–210,000 t). Coincident with these changes in biomass have been shifts in the spatial distribution of capelin, initially to the north and toward the shelf break, though returning in 2011 and 2012 to spatial distributions more reminiscent of those seen during the 1980s. On-going changes have occurred in capelin vertical distribution with capelin distributed in areas with deeper water, in closer proximity to the bottom and exhibiting decreased diel vertical migration. Age composition and size structure have also changed over time with the current index comprised of mainly ages 2 and 3 fish, while ages up to 5 were present historically. The age at maturation has also decreased with approximately 10 times more age 2 fish maturing, a trend which continues over the last 2 years.

Résultats des relevés acoustiques du capelan (*Mallotus villosus*) effectués au printemps, au large, dans la division 3L de l'OPANO

RÉSUMÉ

Les relevés acoustiques du capelan effectués au printemps dans la division 3L de l'OPANO fournissent des indices de la biomasse et de l'abondance du capelan dans la zone 2J3KL ainsi que des renseignements sur sa répartition, sa biologie et son comportement. Ces relevés acoustiques ont été réalisés chaque année de 1982 à 1992, en 1996, de 1999 à 2005, et de 2006 à 2012. La biomasse du capelan déterminée par les relevés a changé énormément pendant la série chronologique. À un sommet de 7 millions de tonnes à la fin des années 1980, elle a chuté d'un ordre de grandeur au début des années 1990, et encore une fois en 2010 pour atteindre un creux record de 23 000 tonnes. Cependant, selon les relevés des 2 dernières années, la biomasse du capelan a rebondi à des niveaux correspondant plus ou moins à ceux de la fin des années 2000 (de 206 000 à 210 000 tonnes). En étroite concordance avec ces changements à la biomasse, on a constaté une modification de la répartition spatiale du capelan, d'abord vers le nord et le rebord continental. Cependant, en 2011 et 2012, la population est revenue à une répartition spatiale plus similaire à celle qu'elle avait dans les années 1980. Des changements continus ont été constatés dans la répartition verticale du capelan, les poissons étant répartis plus près du fond, dans des zones où l'eau plus profonde, et démontrant une diminution de la migration verticale journalière. La composition par âge et la structure par taille ont également changé avec le temps, l'indice actuel comprenant principalement des poissons d'âge 2 et 3. Par le passé, on retrouvait des poissons d'âge 5. L'âge de maturation a également chuté, environ 10 fois plus de poissons d'âge 2 atteignant la maturité. Cette tendance se poursuit depuis 2 ans.

BACKGROUND

The capelin (*Mallotus villosus*) stock inhabiting NAFO Div. 2J3KL spend most of their adult life in offshore waters. Historically the center of this distribution changed seasonally with capelin generally found further north (NAFO Div. 2J and 3K) in the fall of the year, moving southward along the shelf break before turning in to spawn along the northeast Newfoundland coast in the spring and early summer.

Over the years, a number of indices have been used to describe the abundance and distribution of capelin off Newfoundland. These include: inshore data series which have typically concentrated on capelin abundance at or around the time of spawning (aerial surveys, inshore commercial fishery catch rates, egg depositions), annual offshore pelagic O-group surveys, distribution of bycatch from offshore bottom trawl surveys, and most important directed offshore acoustic surveys.

From 1982 to 1993 two acoustic surveys were conducted each year. The first survey of the year was conducted in the month of May and covered the majority of Div. 3L, an area of particular importance for juvenile capelin. The main objective of this survey was to furnish an estimate of immature capelin that would be recruiting to the spawning population in the following year. A second survey was conducted during the month of October in Div. 2J and 3K. This survey was used to determine the size and number of maturing fish available for the following year. Together these surveys formed the main basis of the stock assessment. However, following a dramatic decline in the spring offshore acoustic biomass accompanied by sudden changes in spawning behaviour and migration, the reliability of offshore acoustic surveys as indices of abundance was called into question.

In an attempt to address these concerns in 1993 the spring survey was briefly discontinued in favor of an expanded fall survey covering all of 2J3KL (1993-94). Unfortunately this change did not resolve the issue. No acoustic surveys were conducted in 1995 and only the spring 3L survey was conducted in 1996. There were no surveys were conducted in 1997 and 1998. Since 1999 spring surveys have been conducted annually (with the exception of 2006), but fall surveys have not been undertaken since 1994.

Over the history of these acoustic surveys changes have occurred which may impact survey results and comparability. These included changes in the acoustic technology used, calibration techniques, fish biology and sampling gear used (Tables 1 and 2). In the previous assessment (Mowbray 2012) a methodology was established to incorporate variability associated with these changes into the calculation of confidence around the survey estimates. This paper presents an update of spring acoustic results for 2011 and 2012 and places them in context with previous spring acoustic surveys.

METHODS

SURVEY DESIGN

Spring surveys for capelin have historically been conducted in the month of May, however in two years (1992 and 2003) the survey was also repeated a second time in June. Surveys were conducted primarily in NAFO Div. 3L and since 1996 also in the lower portion of 3K (<50ºN). A stratified survey design was pursued each year, although the stratum boundaries and areas covered have changed over time. Prior to 1999, strata were generally rectangular and extended from the coastline across the shelf, but not as far as the shelf break. Since 1999 stratum have been depth-delimited. The methodology and original strata for each survey from 1982 to 1996 are presented in annual stock assessment documents (Miller 1985, 1991, 1992, 1997). In order to facilitate inter-annual comparisons of survey effort, spring survey tracks for years since 1988 are mapped into the post-1999 stratum boundaries (Fig. 1).

Transect design has also varied substantially over time. Prior to 1989, transects were laid out in equidistant parallel or zigzag patterns. From 1989 to1992, randomly spaced parallel transects were surveyed following protocols set out in O'Boyle and Atkinson (1989). A randomly spaced transect design was thought preferable as it would allow for calculation of variance on abundance estimates based on transect means. However a decline in offshore capelin densities and distribution patterns lead researchers to revert to the equidistant parallel line design in 1993, as it was felt that this design would have the greatest probability of intersecting capelin aggregations. In the post-1999 survey design, the start point of the initial transect is randomly generated for each survey.

In the 1980s and early 1990s, transects were allocated within each stratum at a rate of one per 10 nautical miles of latitude. In subsequent years, it was decided that survey intensity was less important than maximal area coverage. In particular, there was interest in expanding the survey area northward and to the deep shelf edge waters. Consequently, transect spacing was increased to 15-30 nautical miles, and sampling intensity (effort) was adjusted in each stratum depending on its expected density ranking (based on the previous year's survey findings) and upon total time available for the survey.

Comparing acoustic estimates among years is challenging. Shelf break strata, which have contained relatively high densities in the last decade, were not previously surveyed. Following recommendations from the 2008 capelin Regional Advisory Process a set of 'core' strata were designated. Stratum coverage, ranking of mean capelin density and core status designation are given in Fig. 1. Total annual areal coverage is shown in Fig. 2.

BIOLOGICAL SAMPLING

Acoustic backscatter was attributed to species and biological characteristics were determined using echogram characteristics and catches from trawls. Targeted fishing sets were conducted as required to investigate the species composition of the acoustic backscatter, and were also periodically conducted to confirm the absence of fish signal. A minimum of one set was conducted in every 12 hour period during all surveys. Prior to 1996 a large mid-water trawl (Diamond IX) was used to collected biological samples. Since 1996 both mid-water (IYGPT) and bottom trawls (Campelen 1800) have been used. Length-based selectivity corrections were made to all IYGPT catches to produce Campelen equivalents, as the IYGPT trawl catches significantly more small capelin (<10 cm) and relatively less large capelin >14 cm (Mowbray 2001). The bottom trawls have been fished both on the seabed and in the water column, targeting the observed backscatter. The switch to bottom trawls allowed for more thorough sampling of the bottom zone in the 1990s when the capelin tended to aggregate very near the seabed. The duration of fishing sets ranged from 15 to120 minutes depending on the mode of deployment (bottom or mid-water) and the intensity of the backscatter to be verified.

In all years the total number and weight of each species caught was recorded. Total length, sex, and maturity were recorded for a maximum of 200 randomly selected capelin from each catch. Additional detailed sampling was conducted on two capelin of each sex per 0.5 cm length group. This included records of round weight, gonad weight, and stomach fullness as well as removal of otoliths for aging. Since 1999 stomachs have been removed from each fish subjected to detailed sampling from one set per stratum. From 1999 to 2007 stomachs were preserved in 10 % formalin but since 2008 stomachs have been preserved by freezing. Since 1999, length measurements have also been recorded for all other potential acoustic targets including Arctic cod, Atlantic cod, Atlantic herring, redfish, and sand lance.

DETECTABILITY

Changes in vertical migration patterns may affect the availability of fish to acoustic sampling. This can result from fish moving above the "effectively ensonified" portion of the water column, staying within the bottom "deadzone" or by dispersal to such a degree that capelin cannot be detected or separated from background noise. In order to address these concerns, mesoscale studies investigating diel differences in capelin detectability were conducted in two years, 1987 (Miller, unpublished data) and 1999 (Mowbray 2001). During these studies a small block (approximately 18.5*14.8 km) was repeatedly surveyed with equidistant parallel lines and the resultant backscatter integrated in 100 m horizontal bins. The mean area backscattering coefficient (sa) of capelin on a transect was calculated each time the transect was surveyed. Minimum detectability was calculated as the ratio between the minimum and maximum average capelin s_a over the mesoscale survey area within a given 24-hour period.

ESTIMATION OF UNCERTAINTY

A Monte Carlo technique was used to provide a robust estimate of capelin abundance and determine the related uncertainty by incorporating potential variability derived from four factors: calibration values (associated with technological advances), target strength (resulting from variations in length composition and catchability), acoustic detectability (resulting from variations in vertical migration) and spatial variability. A re-sampled population of capelin areal density estimates was derived for each stratum in the following manner. To address issues of spatial autocorrelation the track was divided into consecutive 2 km segments. For each 2 km segment, the species s_a value was randomly selected from one of the twenty candidate 100 m horizontal bins. This value was then transformed into capelin density by incorporating randomly selected values for three parameters: calibration correction factor, TS (derived from a range of lengths), and a detectability correction. Ranges and distribution types from which these values were chosen are given in Table 3. This process was repeated 1000 times for each 2 km segment within each stratum. The median value of the resultant distribution was then used to estimate the areal density of fish in each stratum while the 5^{th} and 95^{th} percentiles were used as upper and lower confidence limits.

RESULTS

SPATIAL DISTRIBUTION OF CAPELIN

The distribution of capelin acoustic backscatter from 2007 to 2012 is presented in Fig. 3. Detailed data on distribution from earlier years (1982-87) can be found in Miller (1991) and from

1988 to 2011 in Mowbray (2012). Loss of survey time in 2003 and 2005 meant that not all strata could be covered these years, and heavy spring ice coverage limited the area available to the survey in 1991, 1992 and 2007. Ice coverage was also extensive in 2009, but the vessel was able to work around the ice and survey the entire area. Survey coverage in 2011 and 2012 comprised all strata with above average transect density.

Capelin distribution patterns can be categorized into three time periods: a) up to and including 1990, b) from 1991 through 2010 and c) 2011 and 2012. In the early period, capelin were pervasive throughout the surveyed area, extending to the bounds of the area in several cases. Capelin tended to be most dense west of 51W, east of St. John's and on the western portion of the northern Grand Banks. However, starting in 1991 these patterns changed. Overall densities declined remarkably throughout the surveyed area. More capelin were found in Stratum C, north of the most densely populated areas in previous surveys. In the stratum off the Avalon Peninsula, which had previously contained the largest biomass, capelin were at very low densities or altogether absent. Once the survey was expanded eastward in 1996 it was found that capelin densities along the shelf break were nearly as high as those in the peak inshore strata, though still an order of magnitude below those seen in the 1980s. Indirect evidence from bottom trawl catches and cod stomach analyses indicated that capelin were probably not prevalent on the shelf break in the 1980s (Lilly 1992). However, this cannot be determined with certainty as the bottom trawl surveys during which the cod stomachs were gathered occurred 2-4 weeks after the capelin acoustic surveys. Increased densities of capelin to the north and along the shelf break remained fairly constant until 2010 when overall densities declined once again. This resulted in even fewer capelin present in the western portion of the survey area in addition to large areas where capelin were entirely absent. During surveys in 2011 capelin distribution was still reminiscent of the 1990s and 2000s with the highest densities occurring off Trinity and Bonavista bays, but with the relative density of capelin in the near shore strata (A) increased. Distributions in 2012 were much more typical of those found in the late 1980s, with the highest densities occurring in stratum A and lower densities present along the shelf break. Densities were also higher than usual in the southwest corner of the survey area, an area which historically contained older maturing capelin.

VERTICAL DISTRIBUTION

Capelin vertical distribution information is available for a number of years. Historically capelin underwent diel vertical migrations in all portions of the surveyed area. However, starting in the spring of 1991, these patterns changed suddenly with capelin remaining much deeper in the water column throughout the day (Mowbray 2002). This disruption in vertical migration was still prevalent in 2010. However, in 2011 a move toward greater diel migrations were observed in some areas. The mean weighted depth at which capelin were found is presented in Fig. 4. The deepest overall distribution of capelin occurred in the late 1990s and early 2000s with depths in 2011 and 2012 the shallowest observed since 1990. The proximity of capelin to the seabed has not changed remarkably in the last two decades. During the last 2 years capelin have also moved to occupy shallower waters, after having moved into deeper waters during the 1990-2010 periods.

BIOLOGICAL CHARACTERISTICS

Capelin are regularly sampled throughout the acoustic surveys. The trawls most extensively used to collect these samples (Diamond IX and Campelen) are biased against the smaller sized fish, in particular those less than 10 cm. This has resulted in a poor representation in catches of age one capelin which usually range from 5 to 8 cm total length in May. Hower, capelin age 2 and older are well sampled by the gear.

Sizes of capelin taken in trawl sets ranged from 5 cm to 20 cm and were composed of ages 1 through 6, although ages 5 and 6 were present in only a few years. In most years, age 2 fish accounted for the majority of fish caught (mean 58 %) followed by age 3 (26 %) (Fig. 5). One of the most remarkable changes in the composition of capelin was the proportion of maturing age 2 capelin. During surveys from 1985 to 1992 an average of 4 % of age 2 capelin were maturing. Since 1999, the percent of maturing age 2 fish has increased to 58 % peaking at 79 % in 2005 (Fig. 6). Accordingly during the same period the proportion of maturing age 3 fish increased from 67 % to 92 %. The proportion of maturing age 2 fish in 2012 was the lowest recorded since 1999 (37 %). Decreased age at maturity has been associated with increased size at age for younger (age 1 and 2) capelin, while the size of older capelin has remained stable (age 3) or declined (ages 4 and 5) (Fig. 7).

The somatic condition of capelin (Fulton's K) is available only since 1996 (with the capacity of weighing capelin at sea). Between 1996 and 2012 the mean somatic capelin condition fluctuated with an average value around 3.6, peaking in 2005 and poorest in 2009 (Fig. 8). There was no change in condition during the last two years.

The roe content (% body weight) of maturing female capelin is also available for the period 1996-2012. Gonad development (Fig. 8) closely tracks the somatic condition in most years, peaking in 2005 (which coincided with earlier spawning at Bellevue Beach, an important, annually monitored inshore spawning site) ,and poorest in 2009, which was a year of near record late spawning. Gonad development in 2011 and 2012 approached the highest values in the series and were likewise associated with earlier spawning at Bellevue Beach (Nakashima and Mowbray, 2014).

Stomach fullness was recorded for all fish which were subjected to detailed sampling. Stomach fullness was assigned a value of 0 is empty, 1 for ¼ full, 2 for ½ full, 3 for ¾ full and 4 for full. Interannual trends in stomach fullness compared well across different size groups. Stomach fullness was highest for all size groups during 1988 and 1989 and lowest in 2000 (Fig. 9).

ABUNDANCE

Capelin abundance and biomass with confidence intervals were calculated for the whole surveyed area using a Monte Carlo approach. As previously noted (Mowbray 2012), estimates derived using the new simulation approach and a length-based target strength were well correlated with those previous published by Miller (1985, 1991, 1997), although slightly lower. During the 30 year time series, some dramatic changes in abundance and biomass have occurred. Both abundance and biomass dropped by more than an order of magnitude from 400-600 billion individuals (4-7 million t) in the late 1980s to less than 30 billion (200,000 t) in the period from 1991 to 2005. This diminished biomass persisted despite an increase in the surveyed area from 2000 onward (Fig. 2). Abundance increased slightly again from 2007 to 2009 with 22-29 billion (260,000-300,000 t) found, but fell in 2010 to less than 1 % of the historic level with only 2 billion fish (23,000 t) located (Figs. 10 and 11). This latest drop was associated with a disappearance of capelin from all parts of its distribution, including areas which previously contained higher abundance. This recent collapse includes the disappearance of two year classes (2007 and 2008), as occurred with the 1991 survey when the 1988 and 1989 year classes disappeared. Abundance during in 2011 and 2012 was 19 and 23 billion (210,000 and 206,000 t) respectively, a level nearing those recorded during 2007-09. Estimates of capelin in the core strata tracked well those from the entire survey area in nearly all years (Fig. 11). The small deviation in 2012 was due to the presence of a significant amount of capelin in stratum L in this year.

Over the years the surveys have demonstrated remarkable internal consistency. The abundance of age 3 (1983-2009 cohorts) capelin was significantly correlated with the abundance of age 2 capelin in the preceding year and explained 60 % of the variance ($P<0.01$, $n=18$, $R2=0.60$) (Fig. 12). This relationship holds true within periods of high (1983-90) and low abundance (1991-2012). Cohort tracking of fish ages one to five indicate a survey/availability effect has occurred only twice within the time series (1990 and 2010) and that it affects all ages when it occurs (Fig. 13).

DISCUSSION/CONCLUSIONS

The abundance and distribution range of capelin in Div. 3L were at a record low in 2010, despite good coverage of the entire survey area. However, in the last two years abundance has rebounded to levels near those of the late 2000s. The first time this index underwent such a dramatic decline was in 1991. At that time there was considerable doubt that the findings accurately reflected the state of the stock. There were several reasons for these concerns: a) inshore abundance indices (Bellevue Beach egg deposition, aerial survey estimates, catch rates) did not demonstrate the same dramatic declines; b) ice limited the survey coverage; c) water temperatures were at record lows; d) spawning activity was delayed by 4 to 6 weeks and the size of spawners declined sharply, and e) the timing of capelin migrations or migration route patterns appeared to have changed. Consequently, a mismatch between the survey and the availability of capelin seemed plausible. However, the overall survey abundance never rebounded and the ‘lost' capelin were never found. Indices of abundance persisted at low levels despite repeating the survey a month later to address timing/migration issues and increasing the area surveyed to address potential changes in distribution.

In 2010, a second equally dramatic decline in abundance occurred. In both circumstances the abundance of at least two cohorts (age 2 and 3) dropped precipitously with the age 2 fish re-appearing in greater numbers in the following year. Mowbray (2012) had hypothesized that the disappearance of capelin in 2010 may have been a result of unfavorable survival related to the record poor capelin condition and delayed sexual maturation of capelin in the preceding year. However, the re-appearance of the 2007 and 2008 cohorts in the 2011 survey disproves this theory. Instead, it is likely that capelin were not fully available to, or detected by the survey. There was no evidence from the survey itself that the fish were simply missed, or schooling particularly densely so as to be able to evade detection with by survey transect pattern. Nor did the spatial distribution of the capelin found in the 2010 survey include any areas of high densities near the survey boundaries, as might be seen if the fish were just outside the survey area. However it was noted that distributions within the survey area had shifted with the highest densities relocated to the shelf break, suggesting a major change in the use of habitat. Catches during the spring bottom trawl survey in the same and adjacent areas to the south, mirrored the acoustic survey results with low capelin densities throughout the survey area. Likewise fall bottom trawl catches the preceding fall did not show any unusual distribution patterns. However spring bottom trawl survey catches did not decline quite as dramatically as did the acoustic survey densities[1]. Although the capacity of bottom trawl surveys to track pelagics species such as capelin are limited, this observation would lead to question whether a larger proportion of capelin may have been within the acoustic deadzone and consequently evaded detection. However, the information presented on the vertical distribution in 2010 suggests that capelin were not closer to the seabed, but in fact were on average higher than in the preceding year.

[1] Mowbray, F.K. 2013. Incidental catches of Capelin (Mallotus villosus) in DFO bottom trawl surveys (1995-2012) and the offshore shrimp fishery (1995-2011). Unpublished manuscript.

This leaves only the supposition that the majority of the stock was not within the surveyed area. Episodic occurrences of capelin outside their normal distribution range have been previously documented for this stock. Frank et al. (1996) reported the appearance of capelin at two distant locations (the Flemish Cap and Scotian Shelf) in response to anomalous hydrographic conditions (unusual cold) in the early 1990s. However, environmental conditions in 2010 were neither excessively warm nor cold. Neither is it apparent that the capelin that remained within the area suffered any decline in condition or disruption of spawning. However the low densities recorded in the spring bottom trawl survey in addition to fishers observations of abundance declines suggest that the capelin were in fact away from their normal area of distribution during both spring and early summer periods.]

It is clear that the full suite of factors influencing capelin abundance and distribution have yet to be elucidated. Earlier work on Northwest Atlantic capelin suggested that cohort strength was influenced by environmental factors (wind and water temperature) during larval release (Leggett et al. 1984; Carscadden et al. 2000). However recent findings suggest that environmental factors may also be limiting at later life stages, particularly in relation to spawning. The observed relationships among capelin size, condition and timing of spawning within the last 15 years are suggestive of within-year, or previous year environmental effects on capelin. But, the exact mechanism(s) by which these factors may moderate abundance, productivity and the order of magnitude changes observed in some cohorts, is yet unknown. Moreover the manner in which oceanographic variation effects capelin distributions remains unclear. The recent availability of secondary production time series, feeding data, and continued monitoring of annual capelin abundances will undoubtedly help in answering these questions.

In the meanwhile, the results herein indicate that the year classes of capelin which will be forming the main portion of the catches in 2013 are both strong relative to the last two decades and that several of the aspects of spring distribution, migration and behaviour are slowly returning to those more characteristic of the periods of high abundance during the late 1980s.

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Table 1. Timelines of change in acoustic technology, fishing gear and biology.

Year	Echo-Sounder	Calibration	Biology	Trawl Gear
1988	EK400/HYDAS	Hydrophone	Abundant/Immature Vertically migrating	Diamond IV / Engels
1989				
1989				
1990				
1991	EK400/HDPS		Few/Maturing/ Deep dwelling	
1992				
1993		Standard target		
1994	EK2000/HDPS			
1995				Campelen 1800/ Some IYGPT
1996				
1997				
1998				
1999	EK2000/HDPS			
2000				
2001				
2002				
2003				
2994				
2005				
2006				
2007	EK5000/Echoview			
2008				
2009				
2010				
2011				
2012	EK60/ Echoview			Some vertical migration coastally

Table 2. Acoustic systems used during the spring offshore capelin acoustic surveys between 1988 and 2012.

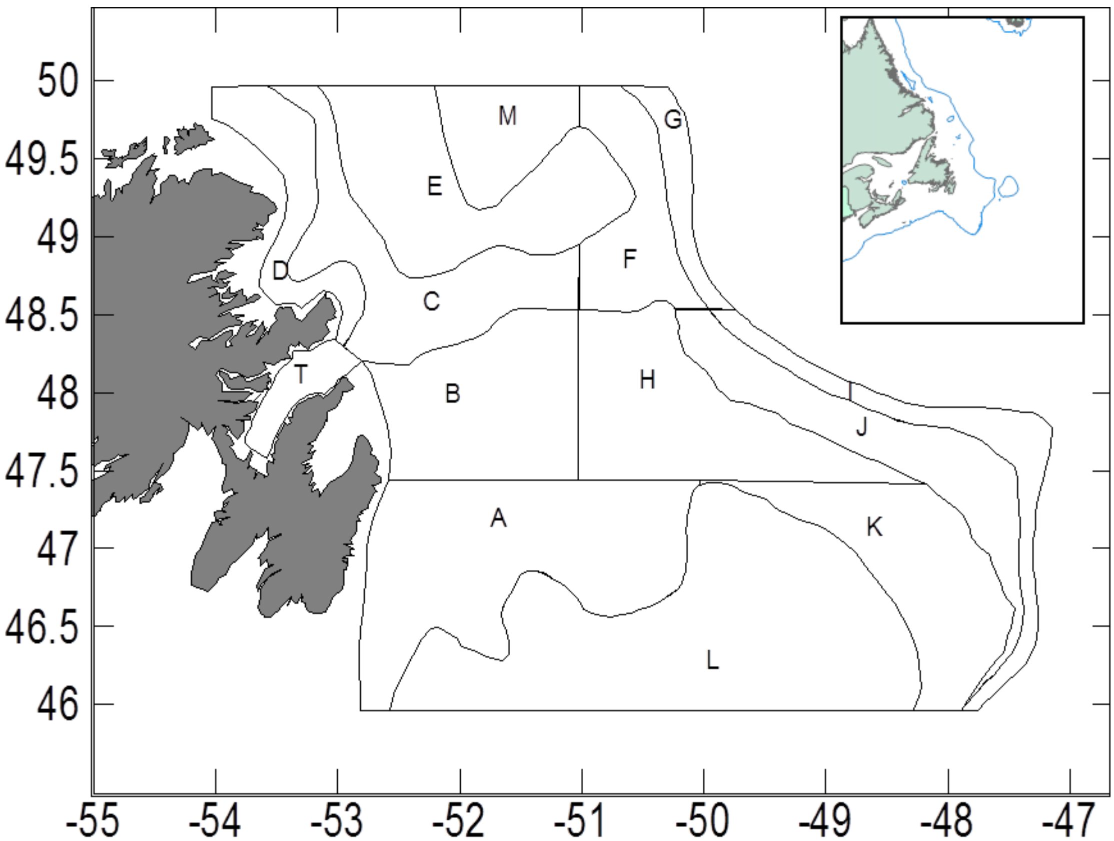
Period	Echo-Sounder	Digitizer/ Recorder	Frequency (kHz)	Pulse length (msec)	Bandwidth (kHz)
1988-90	EK400	HYDAS	49	0.6	3.3
1991-93	EK400	HDPS	49	0.6	3.3
1994-96	ES2000	HDPS	38	0.8	2.5
1999-2005	EK500	CH1	38[1]	1.0	3.8
2007-11	EK500	Echolog	38	1.0	3.8
2012	EK60	Echolog	38[2]	1.0	3.8

Table 3. Values and error distributions used for Monte Carlo simulation of uncertainty.

Variable	Period	Range	Error distribution
Calibration	1988-92	Trip specific value +/- 1.5 dB	Uniform
	1996-2012	Trip specific value +/- 0.1 dB	Uniform
Detectability	1988-90	0.46-1.0	Uniform
	1990-2012	0.60-1.0	Uniform
Length for Target Strength estimation	1988-2012	Mean length +/- one standard deviation (by stratum)	Normal
Spatial distribution	1988-2012	Random selection of one 100 m bin within each 2 km segment of survey track	

Table 4. Target strength equations used for scaling and partitioning backscatter.

Species	TS equation
Capelin	20 log L- 73.1
Atlantic Cod	20 log L- 67.5
Arctic Cod	21.8 log L - 72.7



Standard Stratum (2001-2012)

	1988	1989	1990	1991	1992				###			1999	2000	2001	2002	2003	2004	2005		2007	2008	2009	2010	2011	2012	Core Strata
A																										X
B																										X
C																										X
D																										
E																										X
F																										X
G																										X
H																										X
I																										X
J																										X
K																										
L																										
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Figure 1. Map of survey area showing boundaries of depth-delimited strata used since 1999 (Upper). Lower table gives information on the frequency and degree of strata coverage. Blocks shaded green were fully surveyed, blocks shaded yellow were partially covered and red blocks were not surveyed. Strata considered to be part of the core area are indicated with an X.

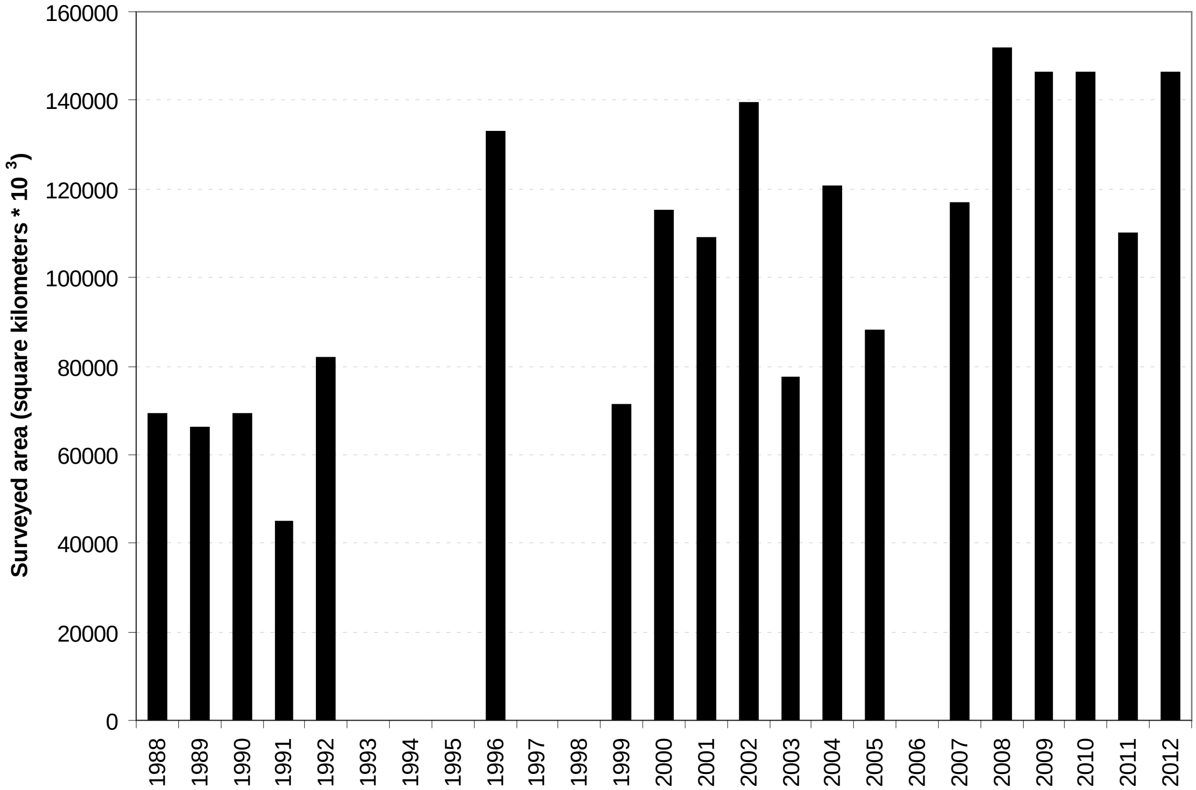


Figure 2. Surface area surveyed during spring offshore acoustic survey 1988-2012.

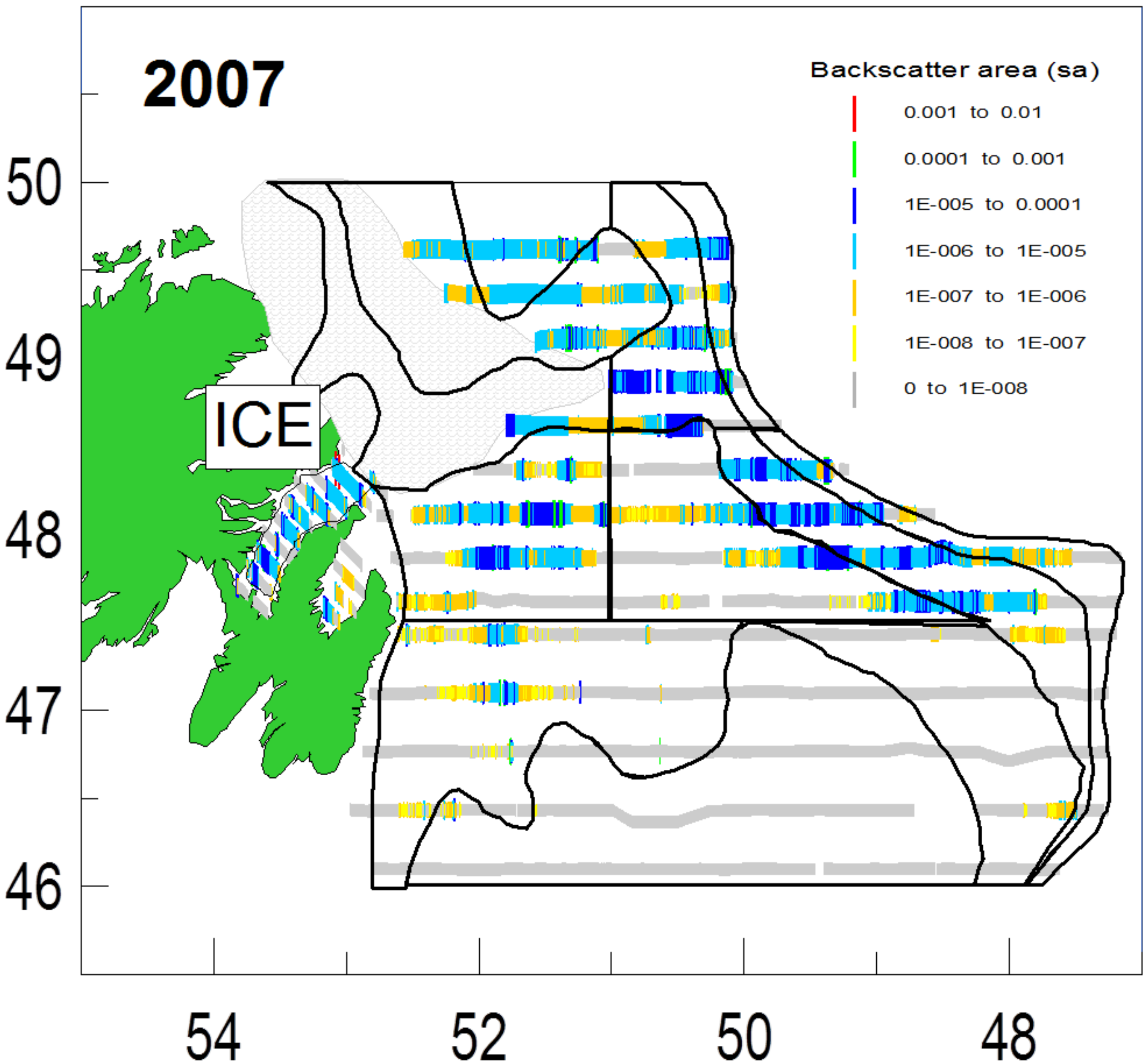


Figure 3. Distribution and intensity of capelin backscatter (sa) during spring acoustic surveys in NAFO Division 3L from 2007-12.

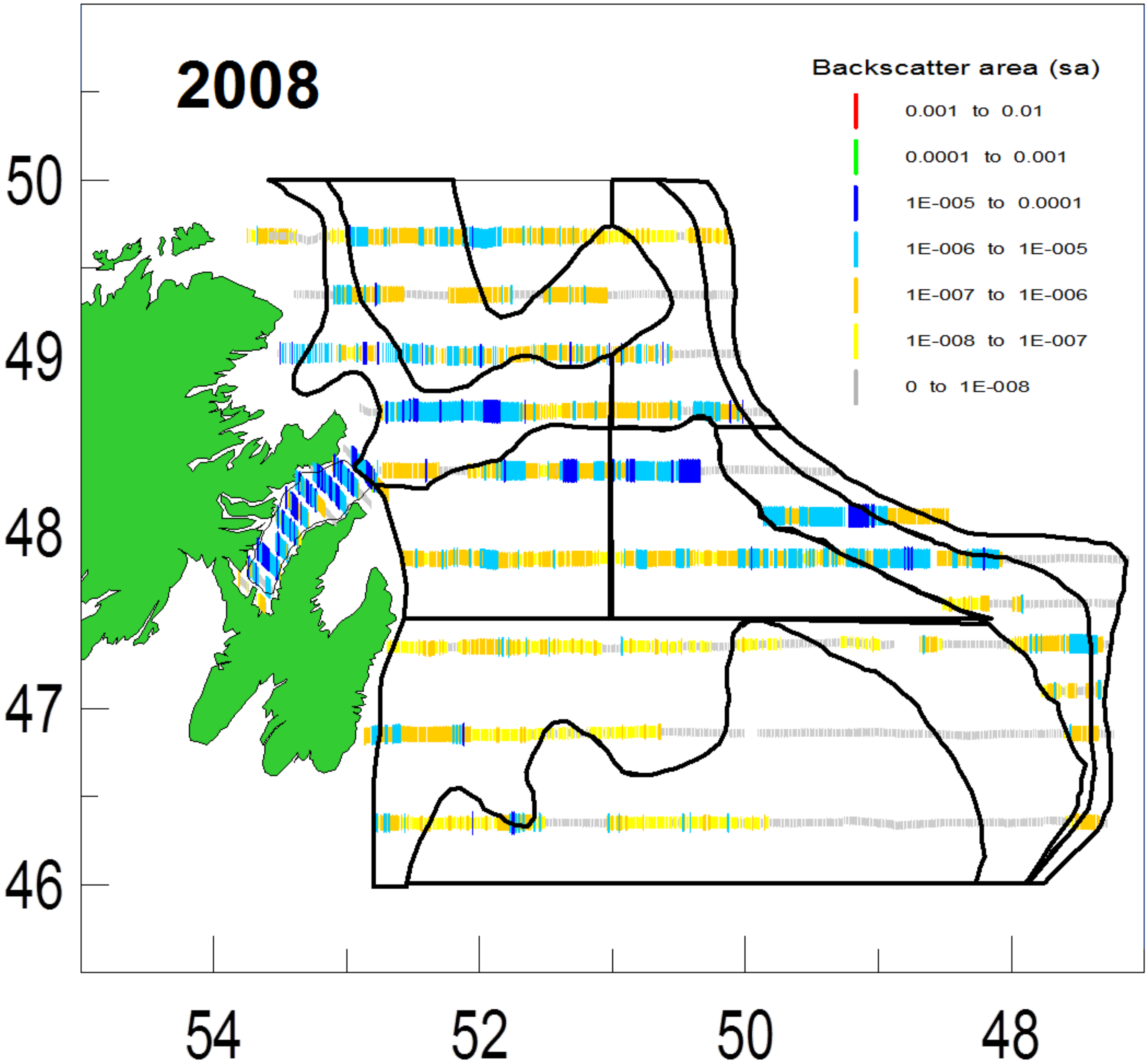


Figure 3. (Cont'd.)

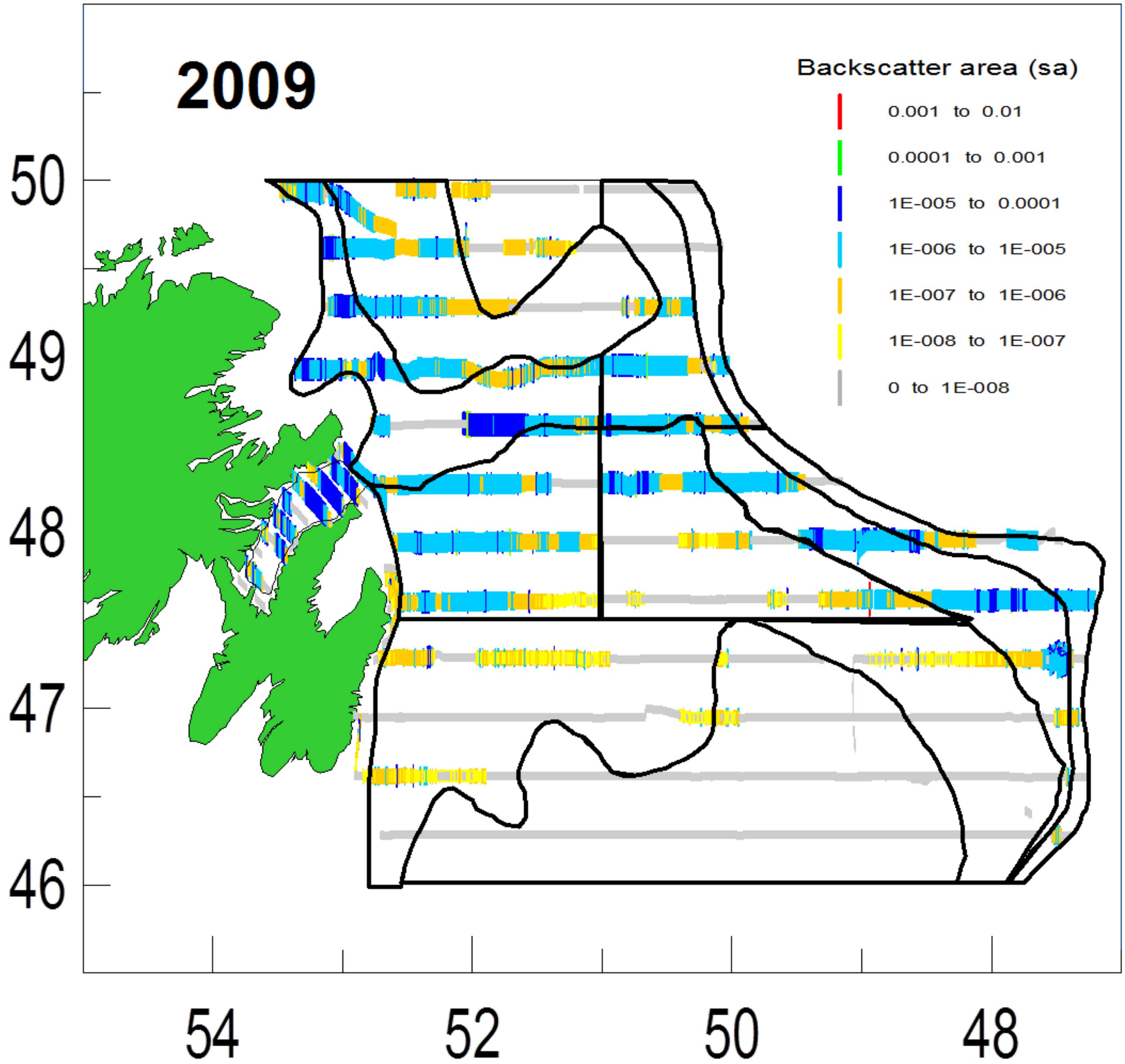


Figure 3. (Cont'd.)

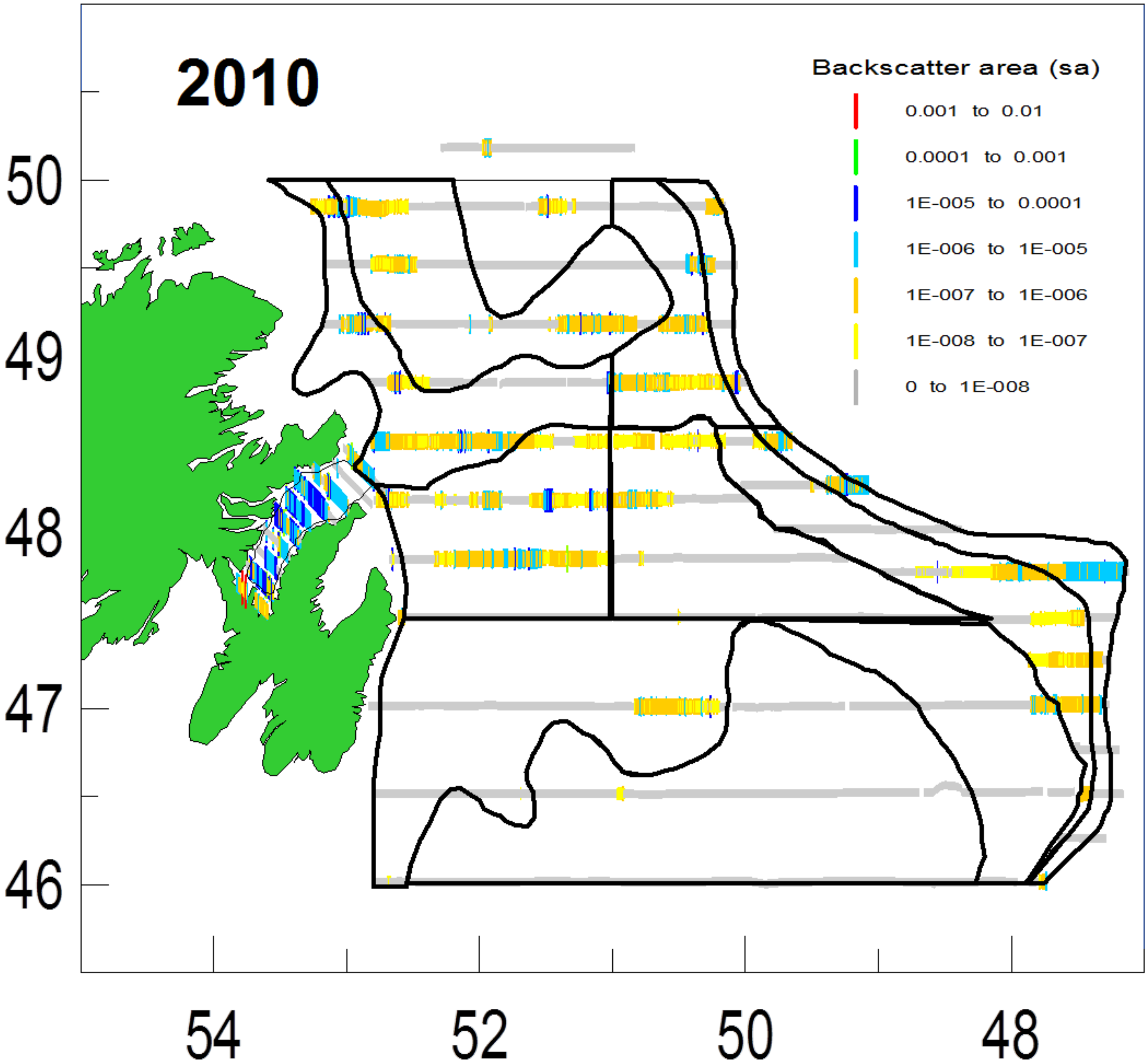


Figure 3. (Cont'd.)

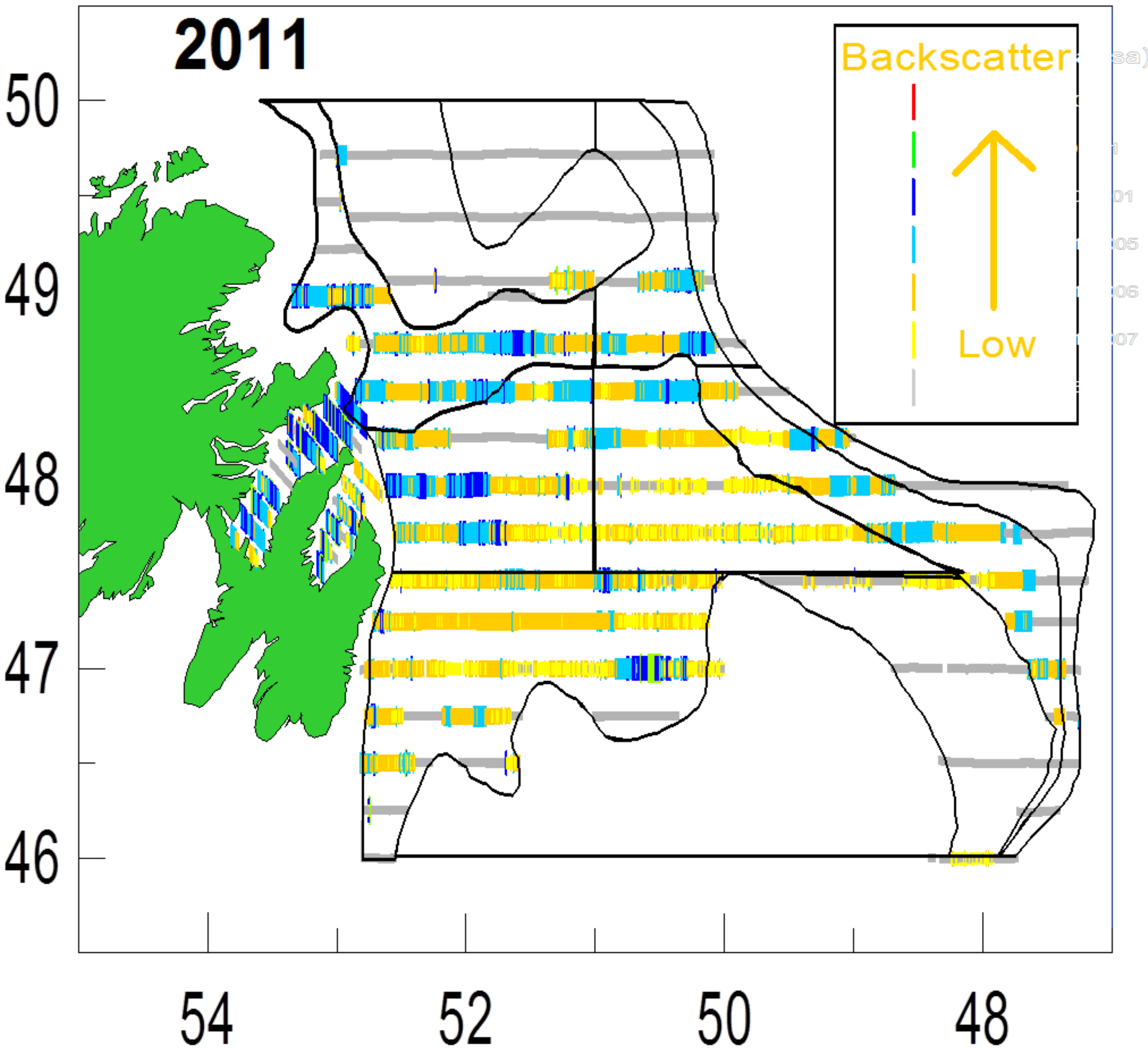


Figure 3. (Cont'd.)

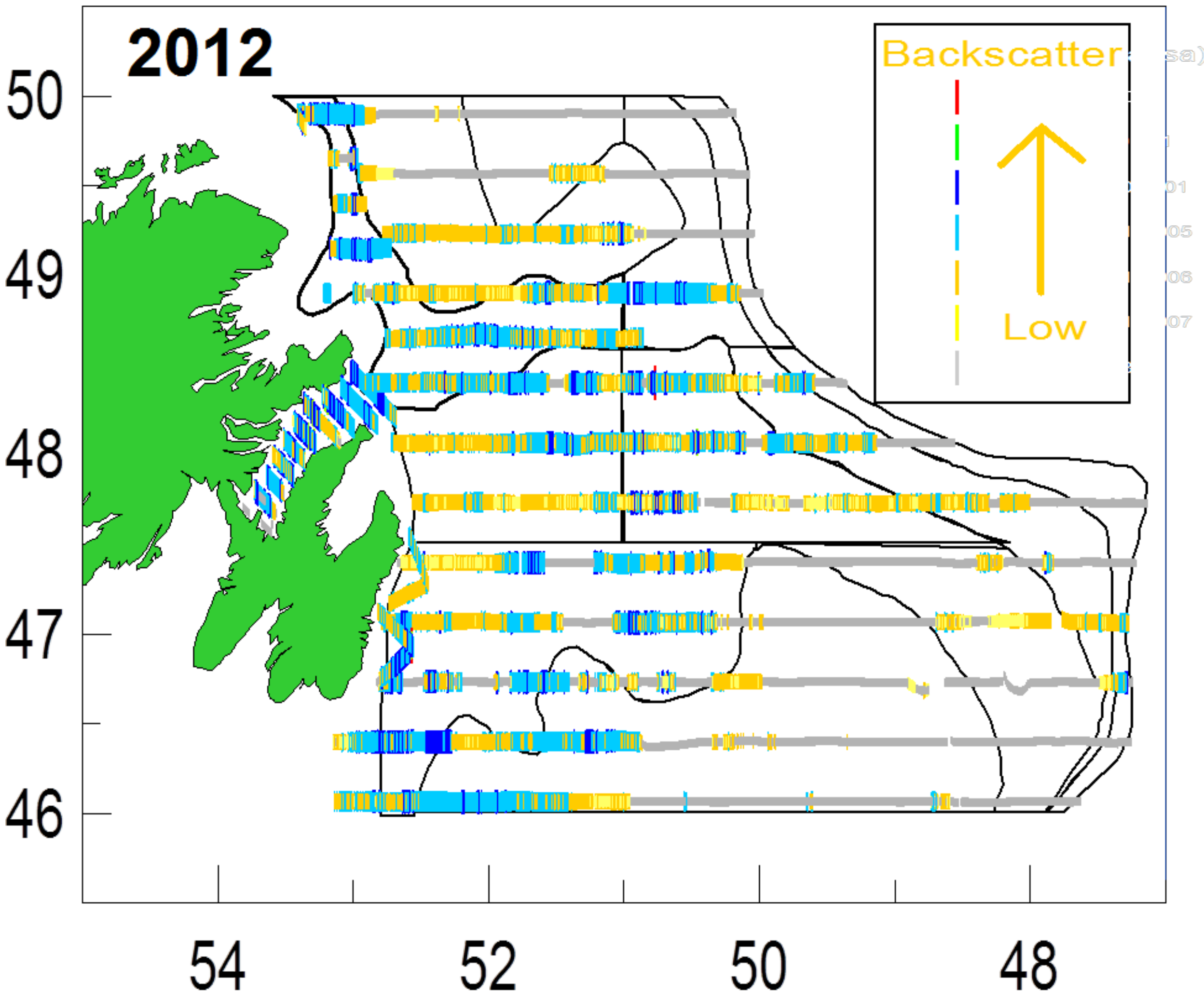


Figure 3. (Cont'd.)

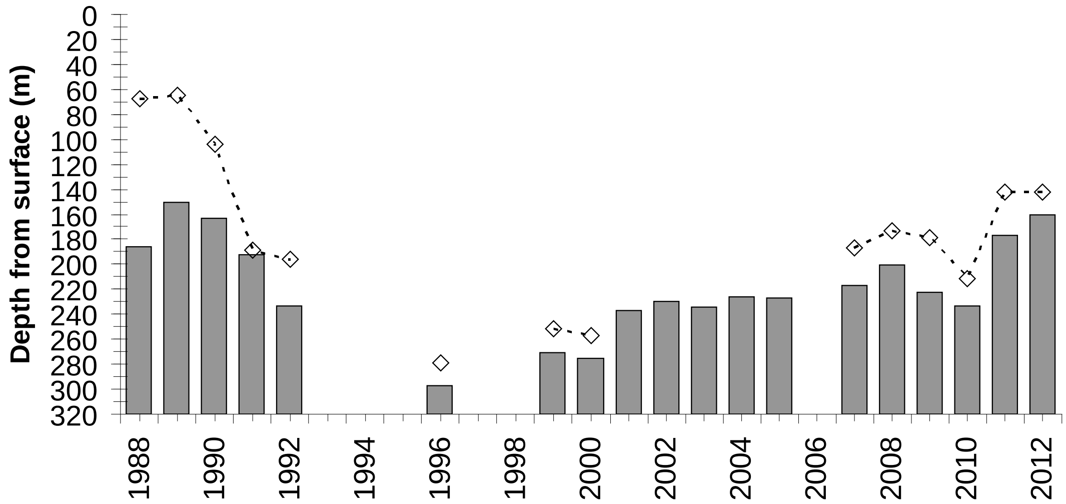


Figure 4. Mean weighted depth of capelin in survey area (diamonds) and mean bottom depth where capelin were found (bars) 1988-2012.

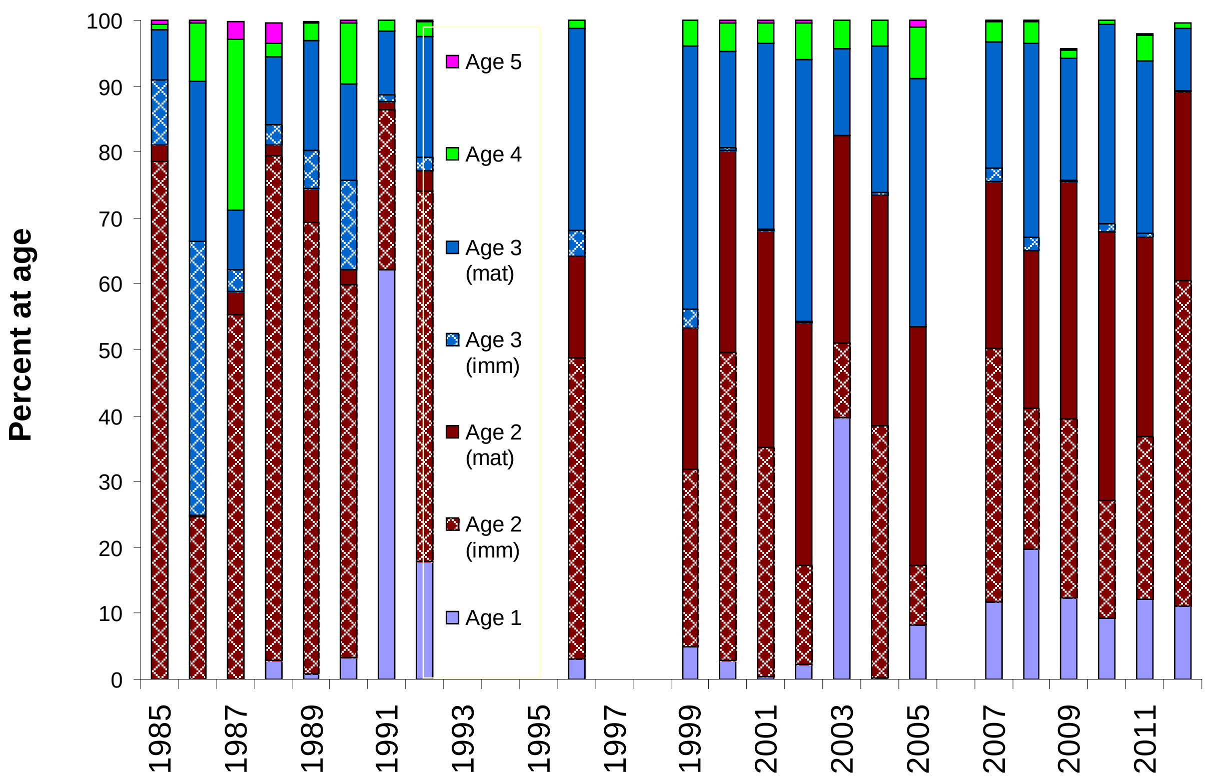


Figure 5. Age composition of capelin caught during spring acoustic survey. Maturity stage is also indicated.

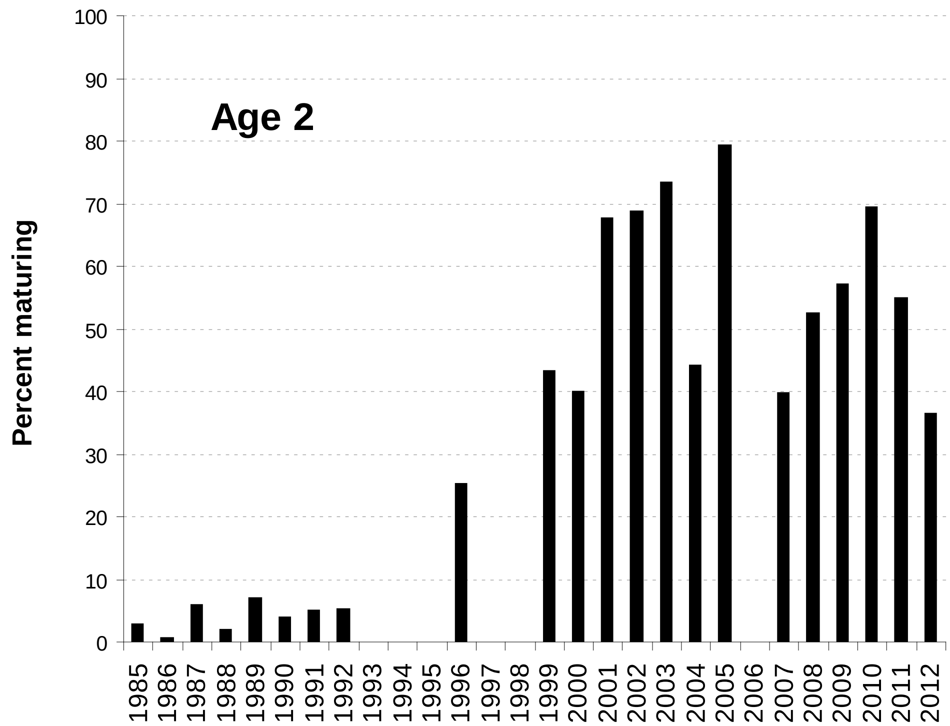


Figure 6. Proportion of age two fish caught during spring acoustic survey which were maturing.

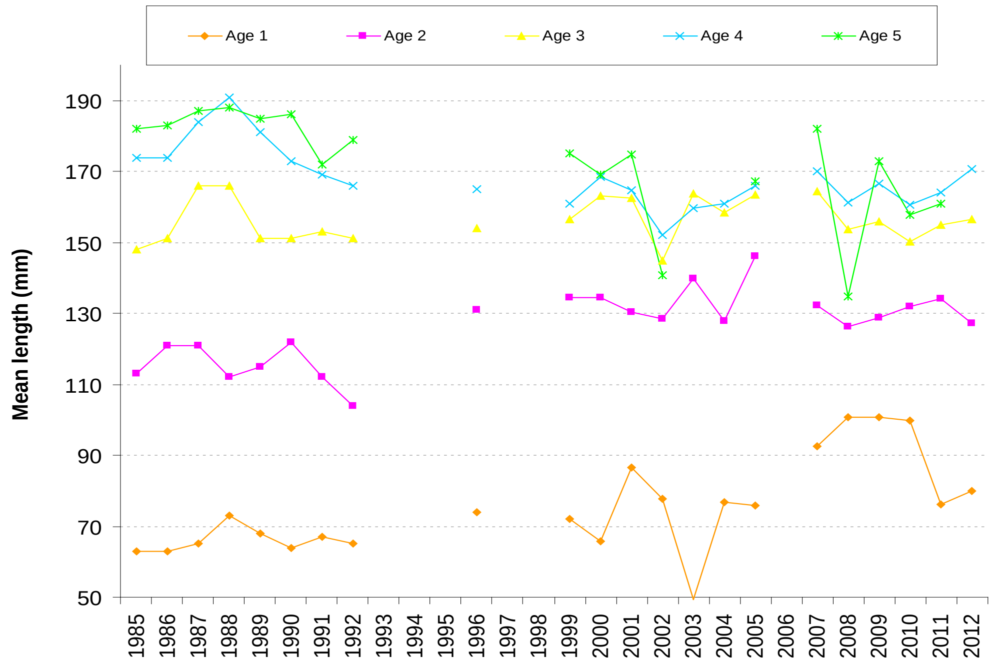


Figure 7. Mean length at age of capelin caught during spring offshore acoustic survey.

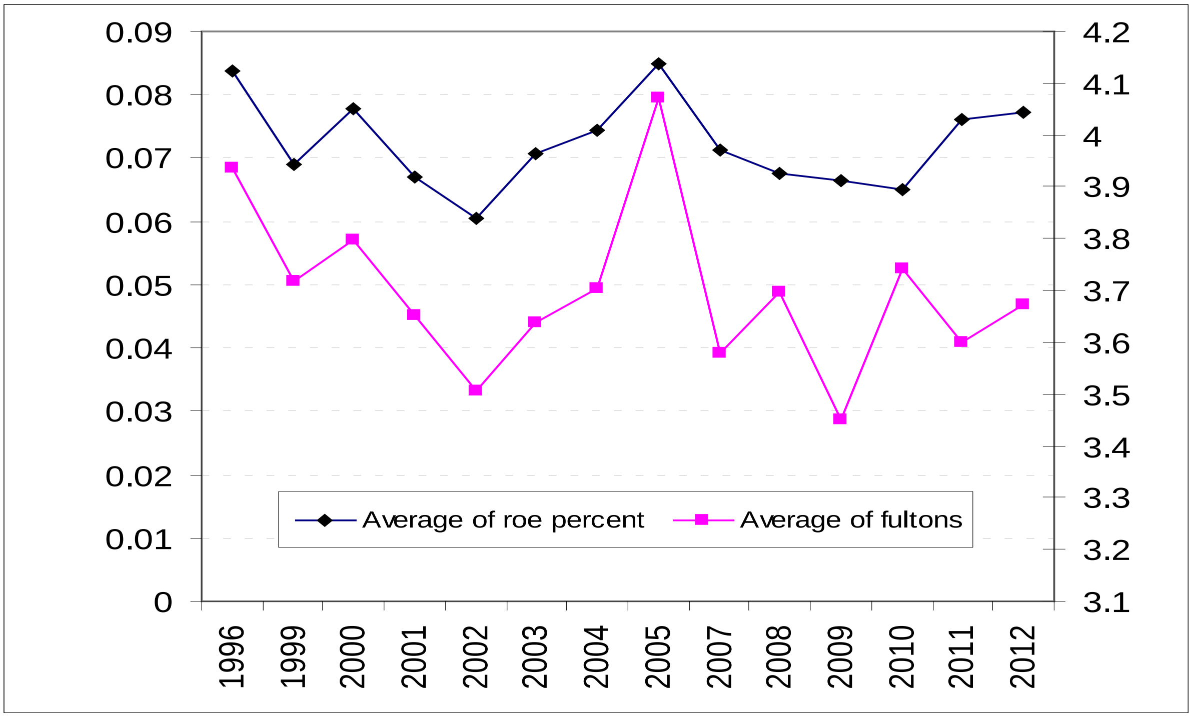


Figure 8. Mean roe content (%) and mean somatic condition of maturing female capelin caught during the Spring offshore acoustic survey.

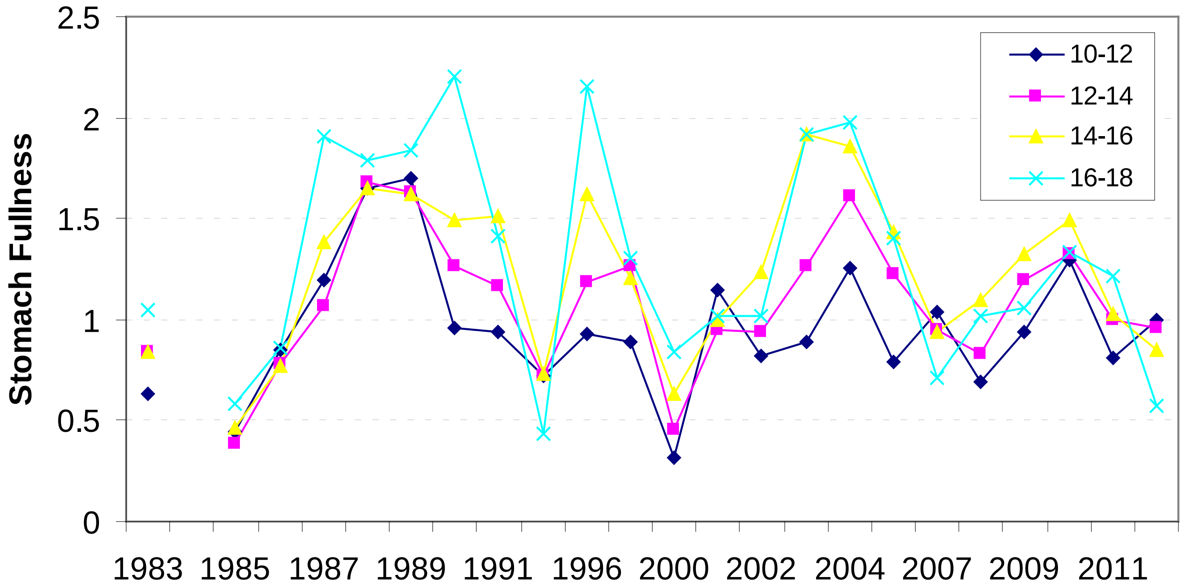


Figure 9. Mean stomach fullness of capelin caught during the spring offshore acoustic surveys.

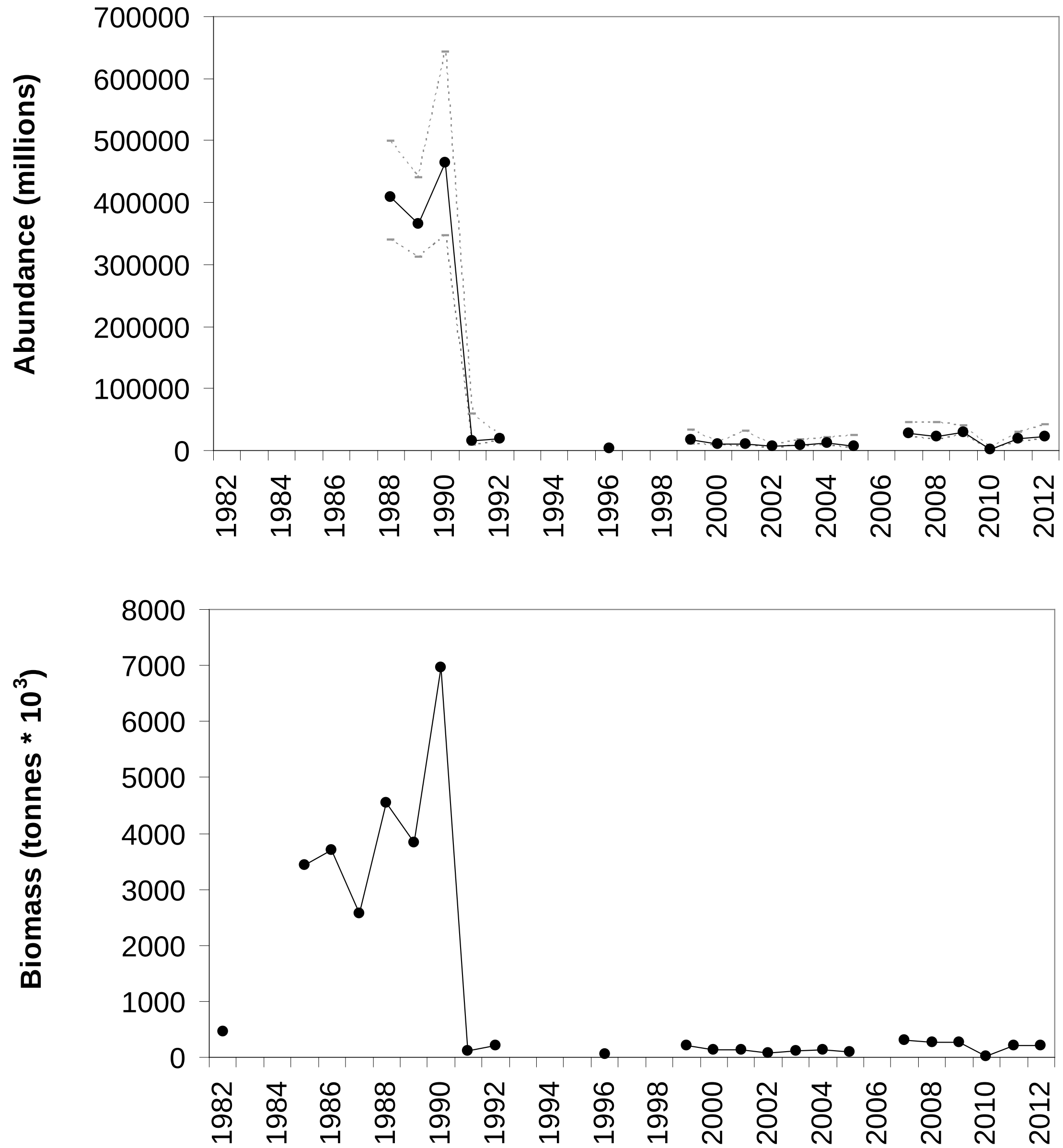


Figure 10. Abundance (upper) and biomass (lower) of capelin in area covered during spring offshore acoustic surveys (1988-2012). Circles are estimates from Miller (1996). Squares are estimates derived using MonteCarlo simulation to estimate uncertainty. Median value is given bounded by the 5 and 95 percentiles for abundance only (upper panel).

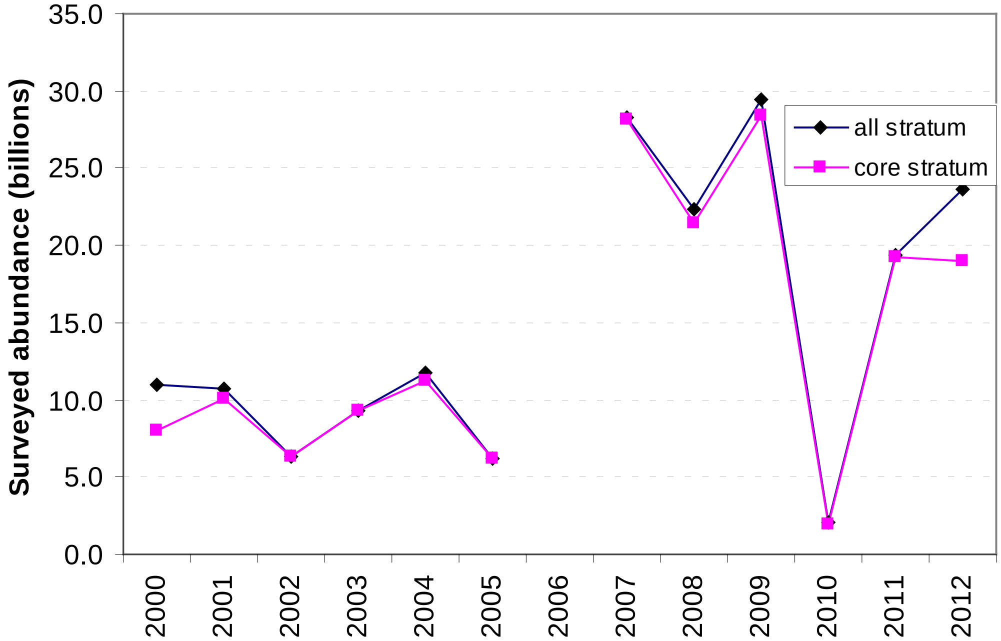


Figure 11. Abundance of capelin in core strata in contrast with all stratum. Data are only presented for the years since 2000 when the survey area covered was expanded.

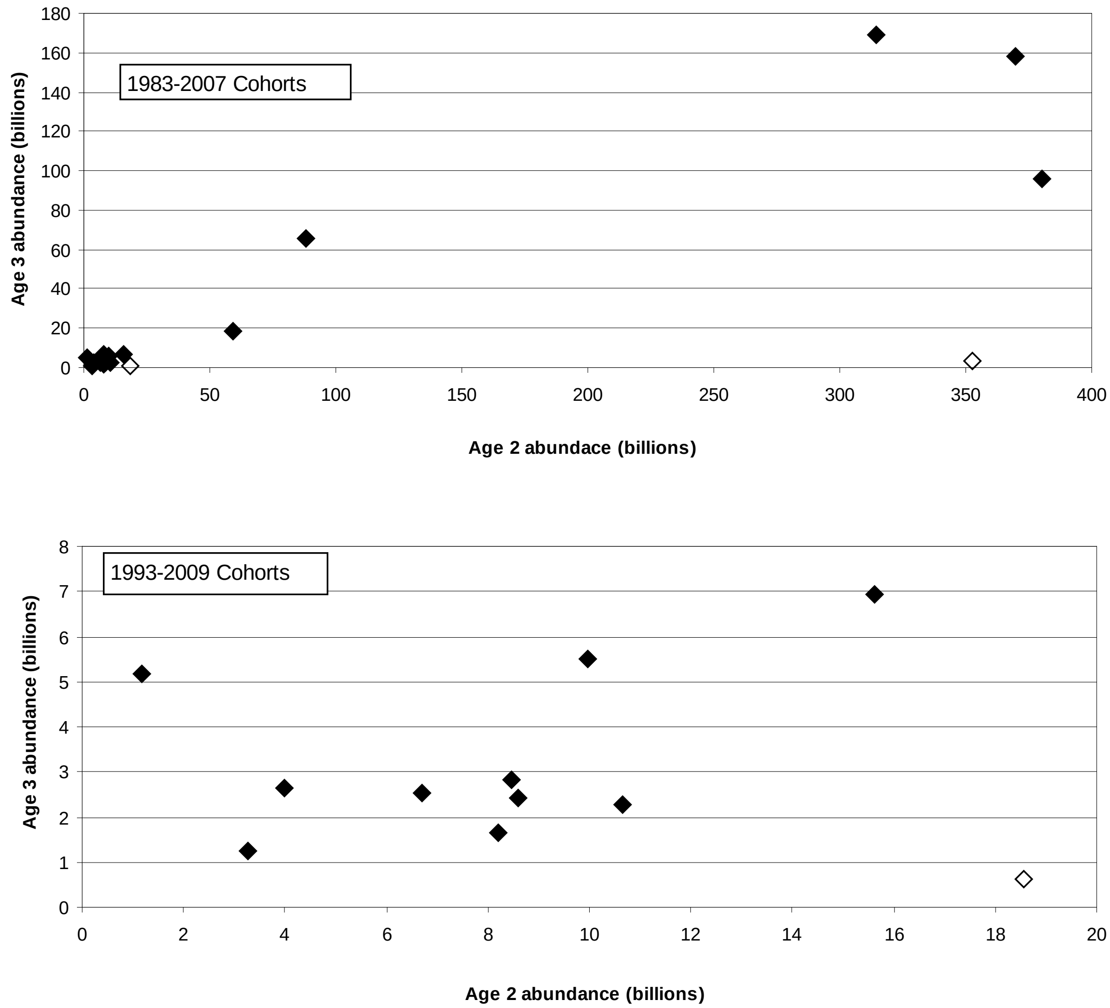
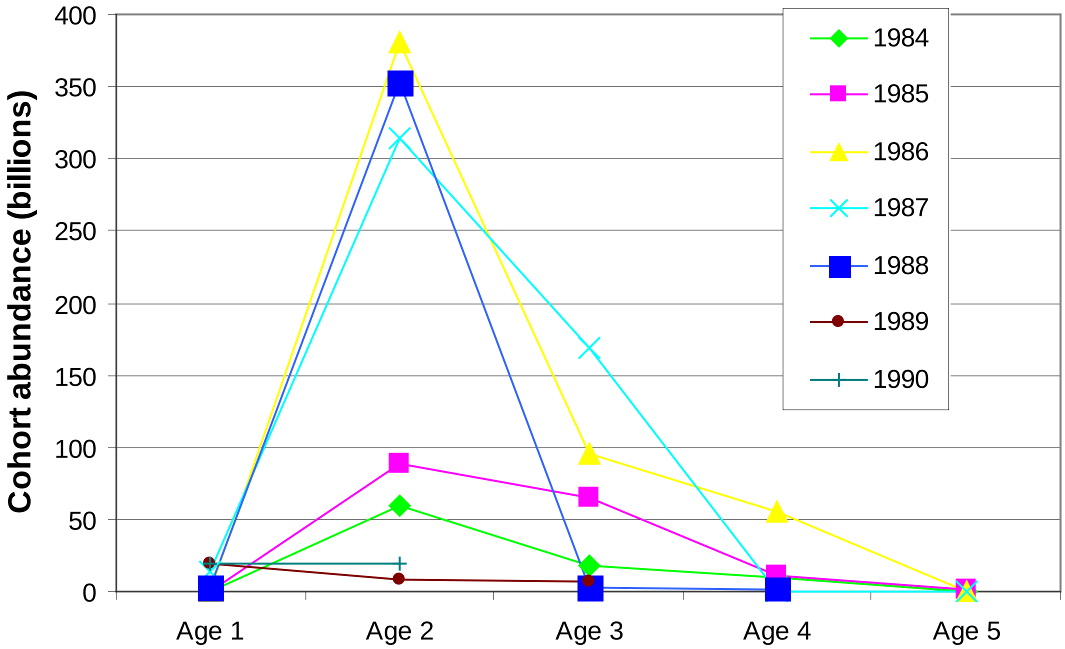


Figure 12. Correlation of age 2 and age 3 abundance for the full time series, 1983-2009 cohorts (upper panel), and for recent years only, 1997-2009 cohorts (bottom panel). Empty symbols are cohorts which were identified as outliers.



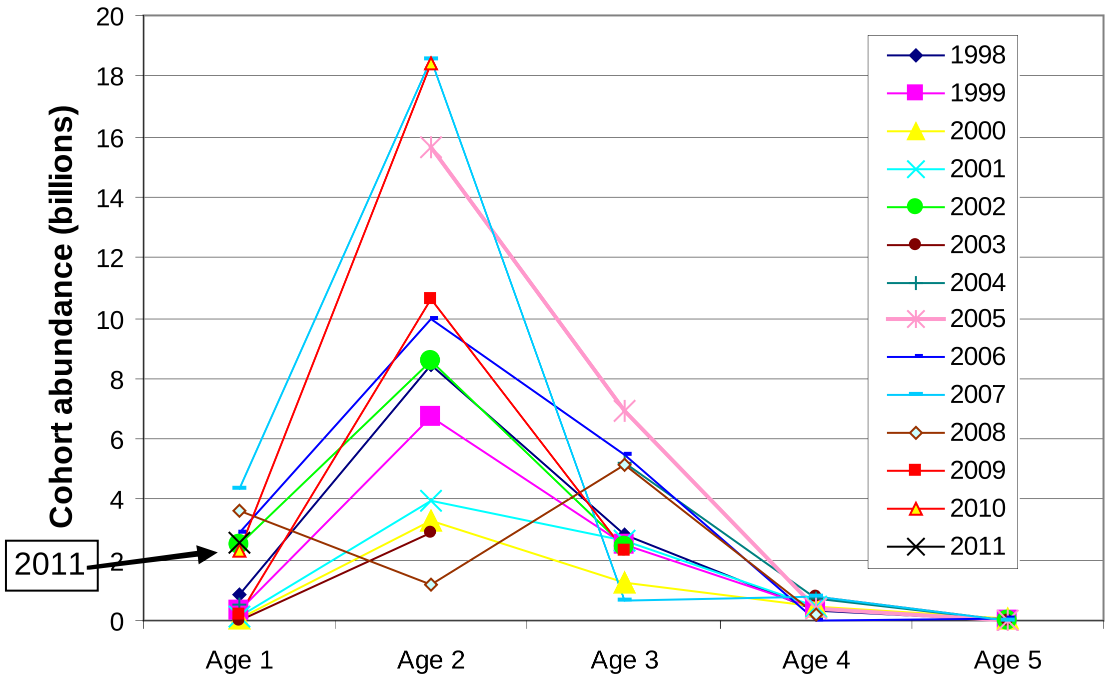


Figure 13. Cohort abundance at age during surveys between 1984 and 1990 (upper) and 1998-2012 (lower).