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Some results from spring acoustic surveys for capelin (*Mallotus villosus*) in NAFO Division 3L between 1982 and 2010

Certains résultats des relevés acoustiques du capelan (*Mallotus villosus*) effectués au printemps dans la division 3L de l'OPANO entre 1982 et 2010

Frances K. Mowbray

Fisheries and Oceans Canada
Science Branch
P.O. Box 5667
St. John's, NL A1C 5X1
Fran.Mowbray@dfo-mpo.gc.ca

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ABSTRACT

The spring NAFO Division 3L acoustic survey for capelin provides an index of abundance of 2J3KL capelin, as well as information on its distribution, biology and behavior. Spring capelin acoustic surveys have been conducted annually in 1982-1992, 1996, 1999-2005, and 2006-2010. The abundance of capelin has changed dramatically within this time series. Abundance peaked at nearly 7 million tonnes in the late 1980s, dropped an order of magnitude once in the early 1990s and again in 2010, with the 2010 biomass less than 1% of the historic levels (23,000 tonnes). Coincident with these changes have been shifts in distribution (to the north and toward the shelf break), as well as changes in the vertical distribution, depths of water occupied, and diel vertical migration patterns. 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.

RÉSUMÉ

Les relevés acoustiques du capelan effectués au printemps dans la division 3L de l'OPANO fournissent un indice de l'abondance du capelan dans la zone 2J3KL ainsi que des renseignements sur sa répartition, sa biologie et son comportement. Les relevés acoustiques du capelan effectués au printemps de 1982 à 1992, de 1996, de 1999 à 2005 et de 2006 à 2010 indiquent que l'abondance du capelan a considérablement changé au cours de cette série chronologique. L’abondance a culminé à près de 7 millions de tonnes vers la fin des années 1980 pour ensuite chuter d'un ordre de grandeur une fois au début des années 1990 et de nouveau en 2010. En 2010, la biomasse était inférieure à 1 % des niveaux historiques (23 000 tonnes). En même temps que ces changements, des variations liées à la répartition (au nord et vers le bord du plateau continental), à la répartition verticale, aux profondeurs occupées et aux habitudes migratoires verticales journalières sont survenues. 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 diminué, environ 10 fois plus de poissons d'âge 2 atteignant la maturité.

INTRODUCTION

The capelin (*Mallotus villosus*) stock inhabiting NAFO Divisions 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 Divisions 2J and 3K) in the fall of the year, moving southward 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), directed offshore acoustic surveys, annual offshore pelagic 0-group surveys, and to a lesser extent bycatch from offshore bottom trawl surveys.

Currently acoustic surveying is only realized on a portion of the stock area. From 1982 until 1991 the offshore acoustic surveys formed the primary basis of the capelin stock assessment. However in 1991, following a substantial decline in the spring offshore acoustic biomass accompanied by sudden changes in spawning behavior and migration, the reliability of offshore acoustic surveys was called into question.

From 1982-1993 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 Division 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 Divisions 2J and 3K. This survey was used to determine the size and number of maturing fish available for the following year.

Following the abrupt drop in spring and fall acoustic estimates in the early 1990s, the spring survey was briefly discontinued in 1993, in favor of an expanded fall survey covering all three divisions (1993-1994). No acoustic surveys were conducted in 1995. In 1996 only the spring 3L survey was conducted and no surveys were conducted in 1997 and 1998. Annual spring surveys were re-instated in 1999 and have occurred annually, with the exception of 2006. No dedicated acoustic fall surveys have occurred 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). This paper will document these changes and present results of a modeling exercise designed to capture some of the uncertainty resulting from these changes and integrate it into the subsequent biomass and abundance estimations. The resultant updated historic estimates are then presented in context with results from more recent surveys (2000-2010) in order to provide updated information on capelin biology as well as an index of capelin abundance for NAFO Divisions 2J3KL.

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 Division 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. 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 (depth-delimited) strata boundaries (Figure 1).

Transect design has also varied substantially over time. Prior to 1989, transects were laid out in equidistant parallel or zigzag patterns. From 1989 to 1992, 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 (RAP) a set of 'core' strata were designated. Stratum coverage, ranking of mean capelin density, and core status designation are given in Figure 1. Total annual areal coverage is shown in Figure 2.

BIOLOGICAL SAMPLING

Acoustic backscatter was attributed to species and biological characteristics were determined using catches from trawls. Targeted fishing sets were conducted as required to identify acoustic backscatter, and were also periodically conducted to confirm the absence of fish signal. A minimum of one set was conducted in every twelve hour period during all surveys. Prior to 1996 a large midwater 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 fewer large capelin >14 cm (Mowbray 2001). The bottom trawls have been fished both on the seabed and in the water column, targeting 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 to 120 minutes depending on the mode of deployment (bottom or midwater) and the intensity of the backscatter to be verified.

In all years the total number and weight of each species caught was recorded. Length, sex, and maturity was 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 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.

A detailed analysis of stomach contents was conducted for all preserved specimens. Until 2007, prey were categorized to group (e.g., copepods, amphipods, euphausids, etc), and lengths were recorded for up to 50 copepods, hyperiids, and euphausids. Since 2007, prey have been identified to species and stage where possible, but no lengths taken. Prey weight was recorded as damp weights in all years except 2007 when dry weights were recorded. Damp weights were converted to dry equivalents by dividing by 5. See Dalpadado and Mowbray (in press) for a fuller accounting of methods.

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 ”dead zone” 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 (s_a) 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, target strength (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. Target strength equations used are given in

Table 4. This process was repeated 1000 times for each horizontal bin 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

CAPELIN DISTRIBUTION

The distribution of capelin acoustic backscatter from 1988 to 2010 is presented in Figure 3. Detailed data on distribution from earlier years (1982-1987) can be found in Miller (1991). 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 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.

Capelin distribution patterns can be categorized in two periods: a) up to and including 1990, and b) 1991 onward. In the early period, capelin were pervasive throughout the survey area, extending to the bounds of the surveyed area in many cases. Capelin tended to be most dense west of 51ºW, 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 previously containing the largest biomass, capelin were subsequently 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 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 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.

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 is still prevalent in 2010. Mean depth at which capelin were found is presented in Figure 4. The deepest overall distribution of capelin occurred in the late 1990s and early 2000s. During this period capelin also tended to occupy areas with deeper waters and in closer proximity to the seabed. From 2007 to 2009 these patterns reverted somewhat, toward those of the 1980s but capelin still remained well below depths typical of the 1980s, and were distributed closer to the seabed.

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 1 capelin which usually range from 5 to 8 cm total length in May. Capelin age 2 and older, however, were well sampled by the gear.

Sizes of capelin taken in trawl samples ranged from 5 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%) (Figure 5). One of the most remarkable changes in the observed 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. However, since 1999 the percent of maturing age 2s increased to 58% peaking at 79% in 2005 (Figure 6). Similarly, the proportion of maturing age 3 fish increased from 67% to 92%. 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) (Figure 7).

The somatic condition of capelin (Fulton's K) is available only since 1996 (with the capability of weighing capelin at sea). Between 1996 and 2010 the mean somatic capelin condition fluctuated with an average value around 3.6, peaking in 2005 and poorest in 2009 (Figure 8). The percentage of roe of maturing female capelin is also available for the period 1996-2010. Gonad development closely tracks the somatic condition in most years, also 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 (Figure 8).

ABUNDANCE

Capelin abundance and biomass were calculated for the whole surveyed area using the Monte Carlo approach. 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 28 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 to 600 billion individuals (4-7 million tonnes) in the late 1980s to less than 30 billion (200 thousand tonnes) in the period from 1991 to 2005. This diminished biomass persisted despite an increase in the surveyed area from 1999 onward (Figure 2). Abundance increased slightly again from 2007 to 2009 with 22-29 billion (260-300 thousand tonnes) found, but fell again to less than 1% of the historic level in 2010 with only 2 billion fish (23 thousand tonnes) located (Figures 9 and 10). This latest drop was associated with a disappearance of capelin from all parts of its distribution, including areas which previously contained higher abundance. These temporal patterns in abundance were evident whether considering the entire survey area or only the core strata (Figure 11). This recent collapse appears to be due to the disappearance of the 2007 and 2008 year classes, similar to the 1991 survey collapse when the 1988 and 1989 year classes both disappeared. Despite these two outlying years, overall the abundance of age 3 (1983-2007) capelin was significantly correlated with the abundance of age 2 capelin in the preceding year and explained a good proportion of the variance ($P < 0.01$, $n = 18$, $R^2 = 0.61$) (Figure 12). This relation was even stronger when the two outlying cohorts (1988 and 2007) were removed from the analysis ($P < 0.01$, $n = 16$, $R^2 = 0.87$).

DISCUSSION / CONCLUSIONS

The abundance and distribution range of capelin in Division 3L were at a record low in 2010, despite good coverage of the entire survey area. 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 4-6 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 survey abundance never rebounded and the 'lost' capelin were never found. Abundance persisted at low levels despite repeating the survey a month later (to address timing/migration issues) and increasing the surveyed area (to address potential changes in distribution). Moreover, the age-disaggregated survey abundance indices, then and now, demonstrate a remarkable internal consistency, suggesting that the survey design is capable of tracking capelin abundance in all the other years.

In 2010, a second equally dramatic decline in abundance occurred. However, this time we have more information on coincident bottom-up processes. Although no direct evidence of starvation is available, the record poor capelin condition and delayed sexual maturation of fish found in 2009 may have foreshadowed unfavorable growth and survival of capelin during the fall and winter of 2009. Indices of physical and biological oceanography taken from the Atlantic Zone Monitoring Program (AZMP) program indicate that the water in 2009 was unusually cold and *Calanus* production (the main prey of capelin) was poor. The extent of the Cold Intermediate Layer (CIL) along standard transects off Bonavista and the southern Labrador shelf had been increasing since the mid 2000s, and in 2009 was at its second largest since 1994 (http://www.nafo.int/science/frames/ecosystem.html). At the same time the abundance of *Calanus* copepods along the Flemish Cap and Labrador transects had been declining since 2006.

It is clear that the full suite of factors influencing capelin abundance have yet to be elucidated. Earlier work on Northwest Atlantic capelin suggested that capelin cohort strength was influenced by environmental factors (water temperature and wind) during larval release (Carscadden et al. 2000). However these recent findings suggest that environmental factors may also be limiting at later life stages, particularly in relation to spawning. The observed relations between 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 by which these factors may moderate abundance, productivity and the order of magnitude changes observed in some cohorts, is yet unknown. The recent availability of secondary production time series, feeding data and continued capelin abundance monitoring will undoubtedly help in the search for an answer.

In the meanwhile, the results herein indicate that the current design and analysis of the spring capelin acoustic survey allows for the capture of most of the uncertainty surrounding the evolution in acoustic equipment and survey design while still allowing enough resolution to track cohorts and compare results over time. Consequently it should be considered a reliable index of abundance for the 2J3KL capelin stock.

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

	Sounders	Calibrations	Biology	Trawl gear
1988	EK400/HYDAS	Hydrophone	Abundant / immature	Diamond IX /
1989				
			Vertically migrating	Engels
1990				
1991	EK400/HDPS		Few / maturing Deep dwelling	
1992				
1993		Standard target		
1994	ES2000/HDPS			
				Campelen 1800 / some IYGPT
1995				
1996				
1997				
1998				
1999				
	EK500/CH1			
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007	EK500/Echoview			
2008				
2009				
2010				

Table 2. Acoustic systems used during the spring offshore capelin surveys between 1988 and 2010.

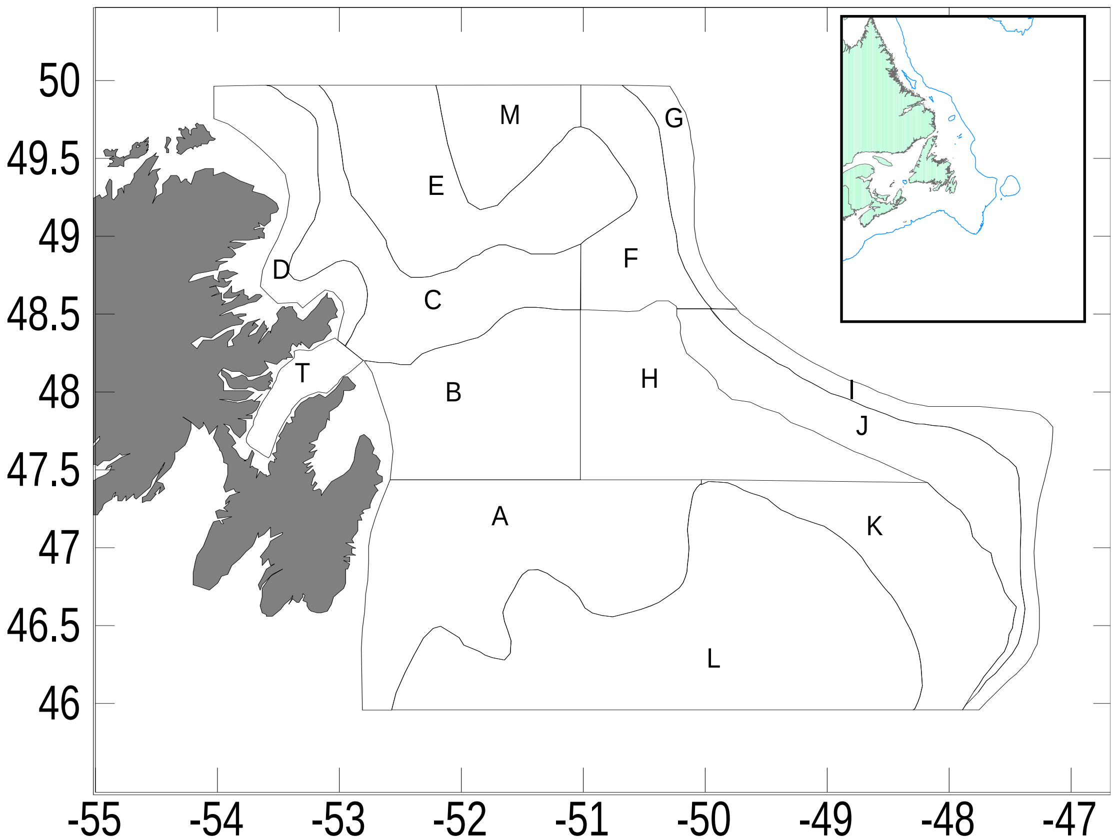
Period	**Echo-Sounder**	**Digitizer/ Recorder**	**Frequency (kHz)**	**Pulse length (msec)**	**Bandwidth (kHz)**
1988-1990	EK400	HYDAS	49	0.6	3.3
1991-1993	EK400	HDPS	49	0.6	3.3
1994-1996	ES2000	HDPS	38	0.8	2.5
1999-2005	EK500	CH1	38	1.0	3.8
2007-2008	EK500	Echoview	38	1.0	3.8

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

Variable	**Period**	**Range**	**Error distribution**
Calibration	1988-1992	Trip specific value +/- 1.5 dB	Uniform
	1996-2010	Trip specific value +/- 0.1 dB	Uniform
Detectability	1988-1990	0.46-1.0	Uniform
	1990-2010	0.60-1.0	Uniform
Length for Target Strength estimation	1988-2010	Mean length +/- one standard deviation (by stratum)	Normal
Spatial distribution	1988-2010	Random selection of one 100 m bin within each 2 km segment of survey track	

Table 4. Target strength (TS) 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 Strata (or equivalent)

	1988	1989	1990	1991	1992				1996			1999	2000	2001	2002	2003	2004	2005		2007	2008	2009	2010	Density rank	Core Strata
A																								11	X
B																								4	X
C																								1	X
D																								9	
E																								8	X
F																								7	X
G																								3	X
H																								5	X
I																								10	X
J																								2	X
K																								13	
L																								12	
M																								6	X
T																									

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. Ranking of mean density of capelin in each stratum (1999-2010) are also given, in addition to the list of strata considered 'core'.

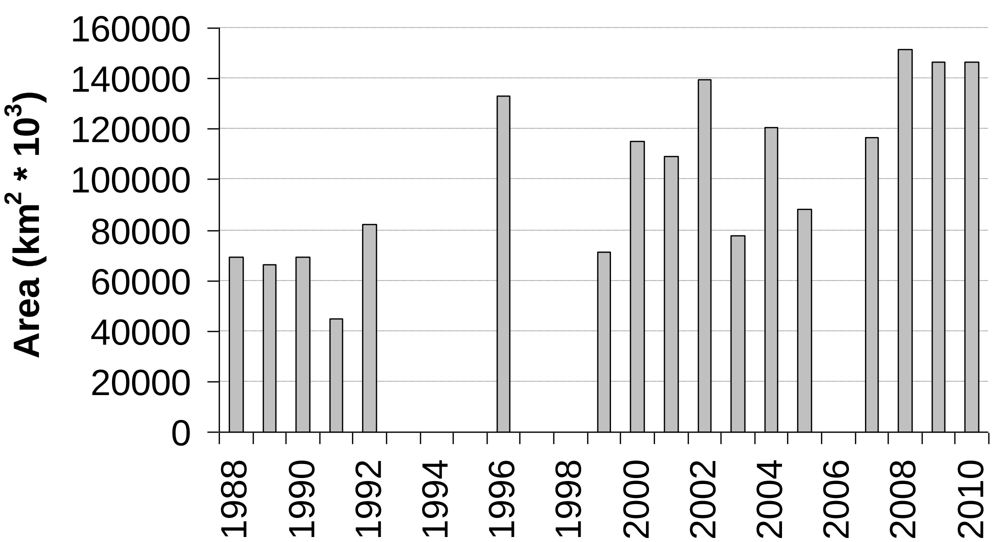


Figure 2. Surface area surveyed during Spring offshore acoustic survey 1988-2010.

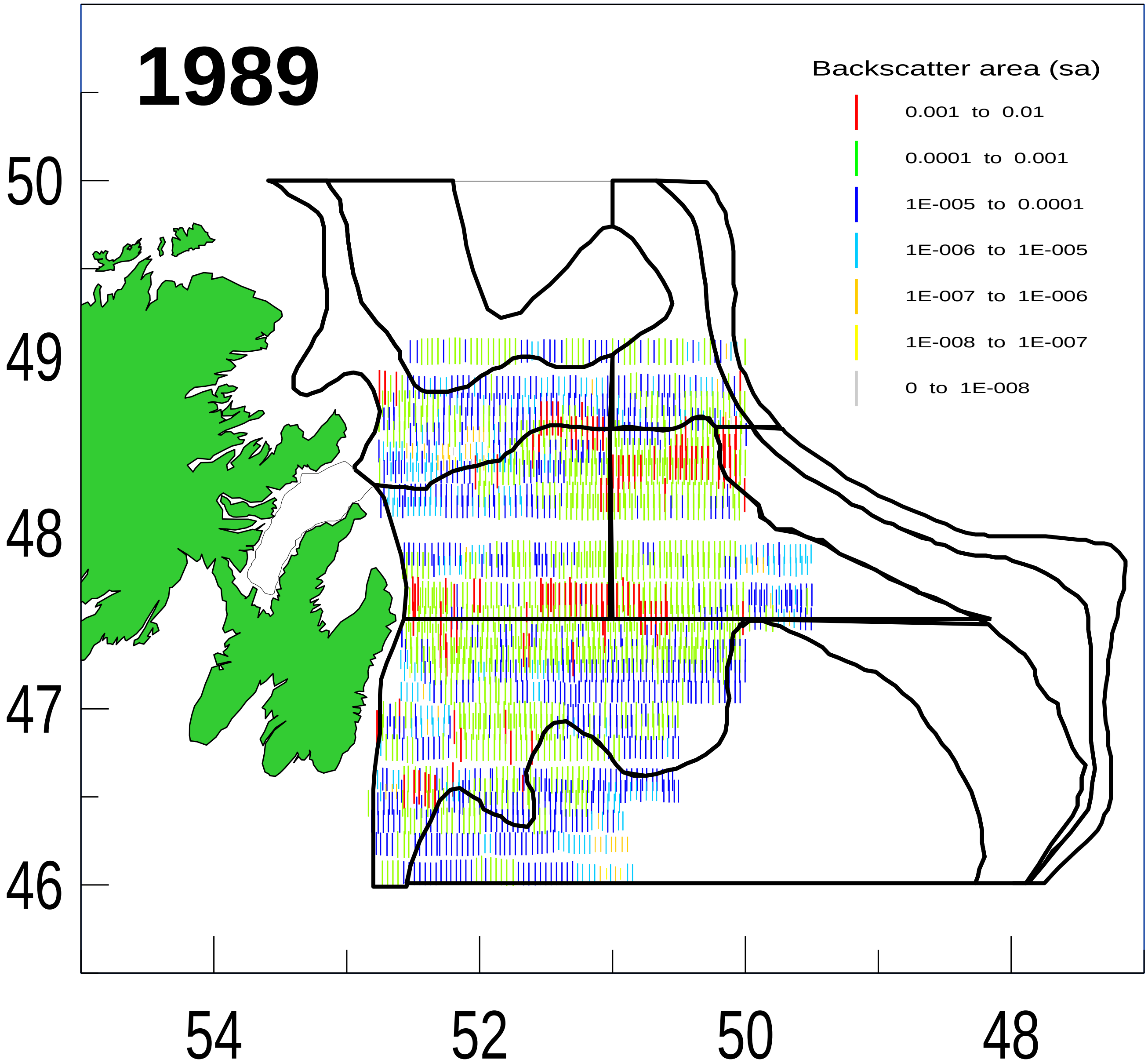
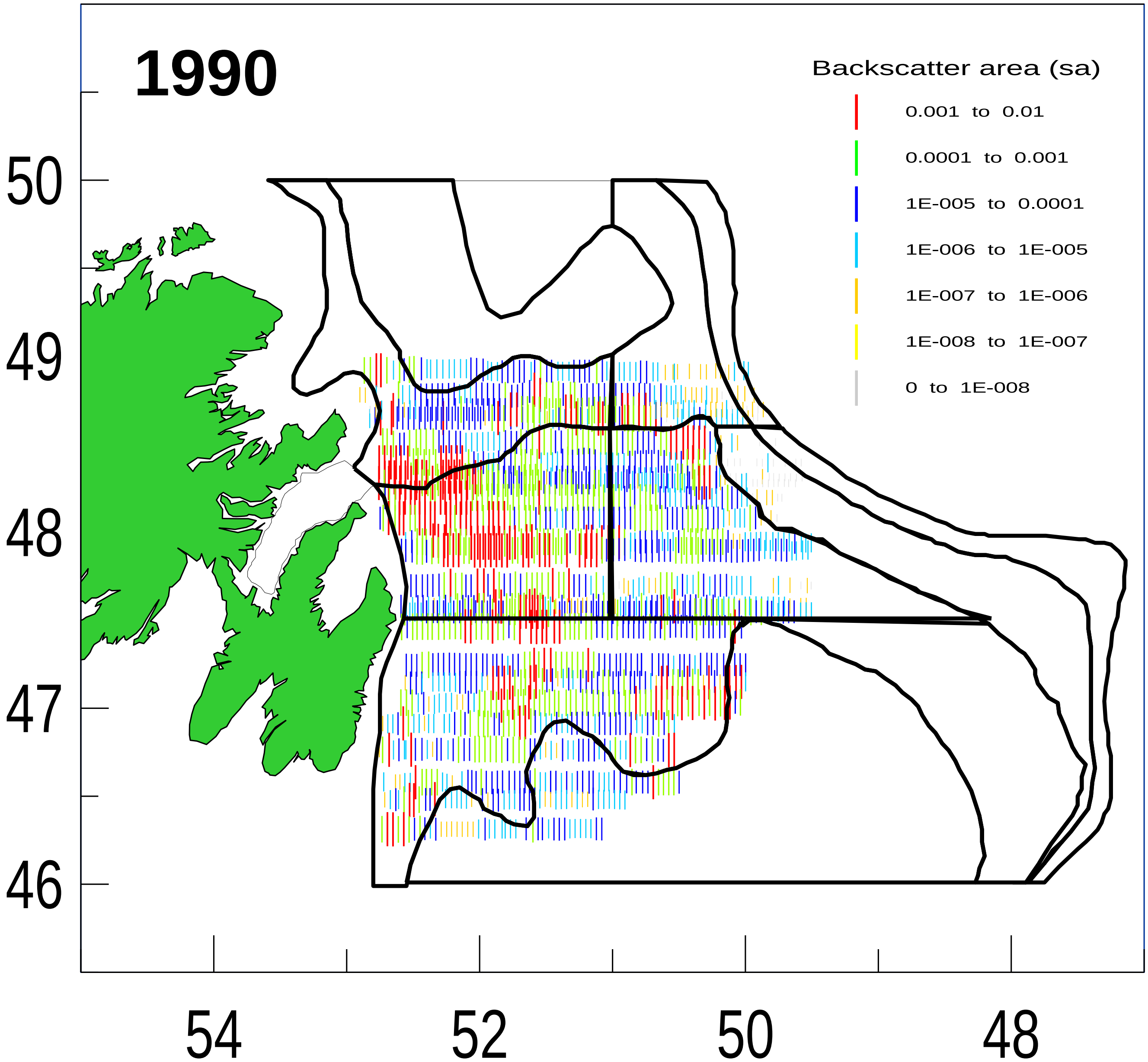


Figure 3. Distribution and intensity of capelin backscatter (s_a) during Spring acoustic surveys in NAFO Division 3L… (Continued).



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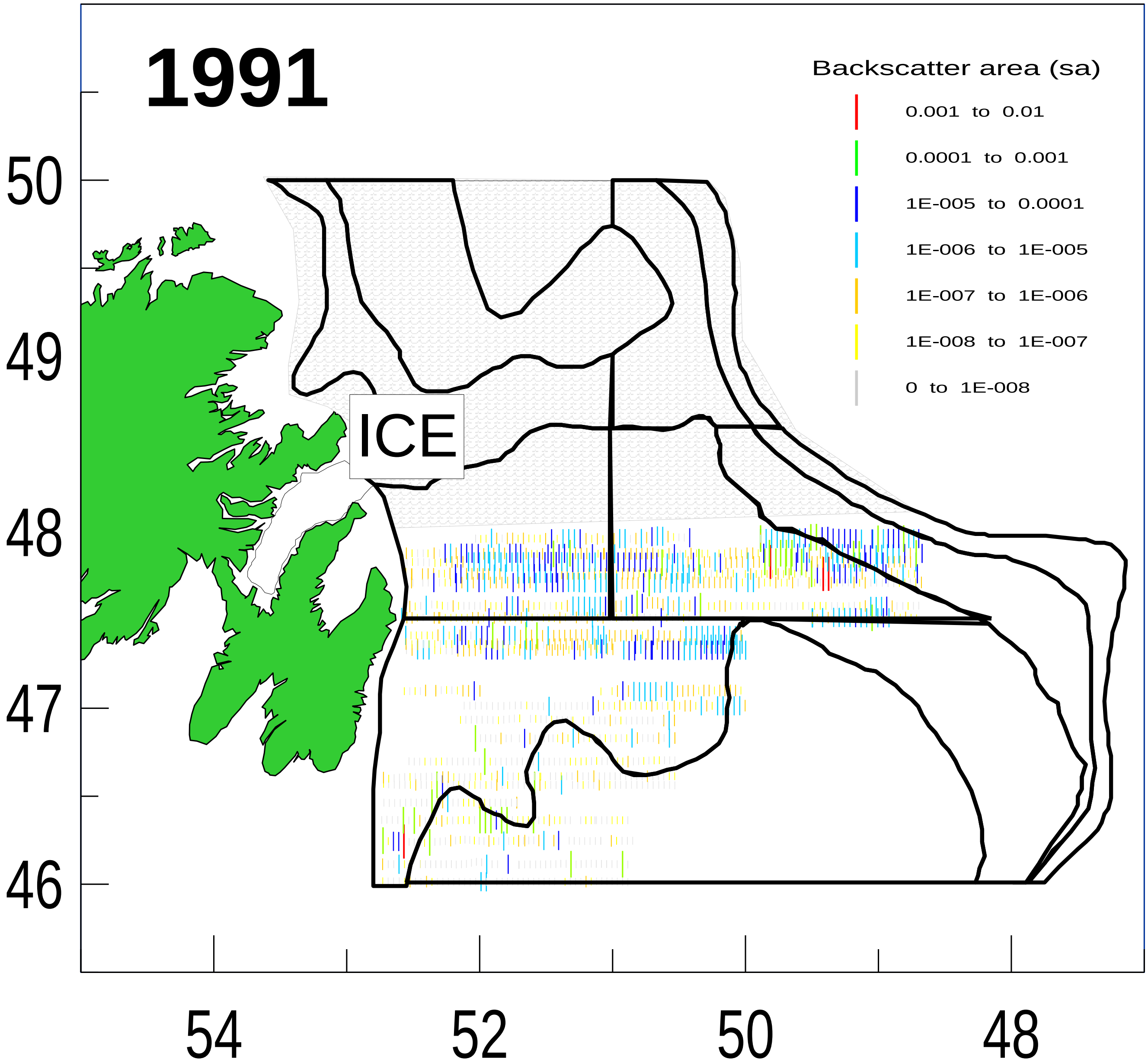

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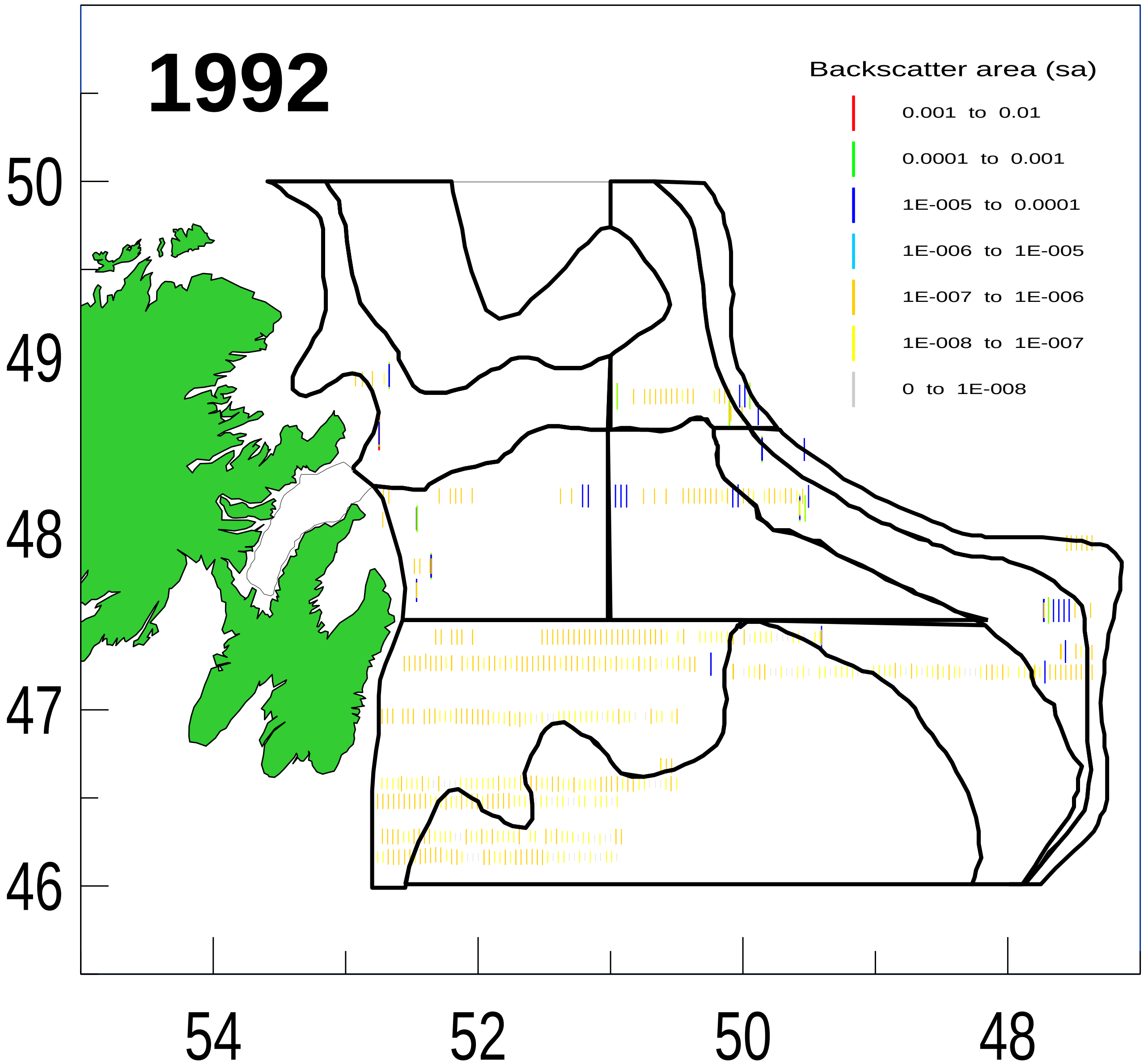

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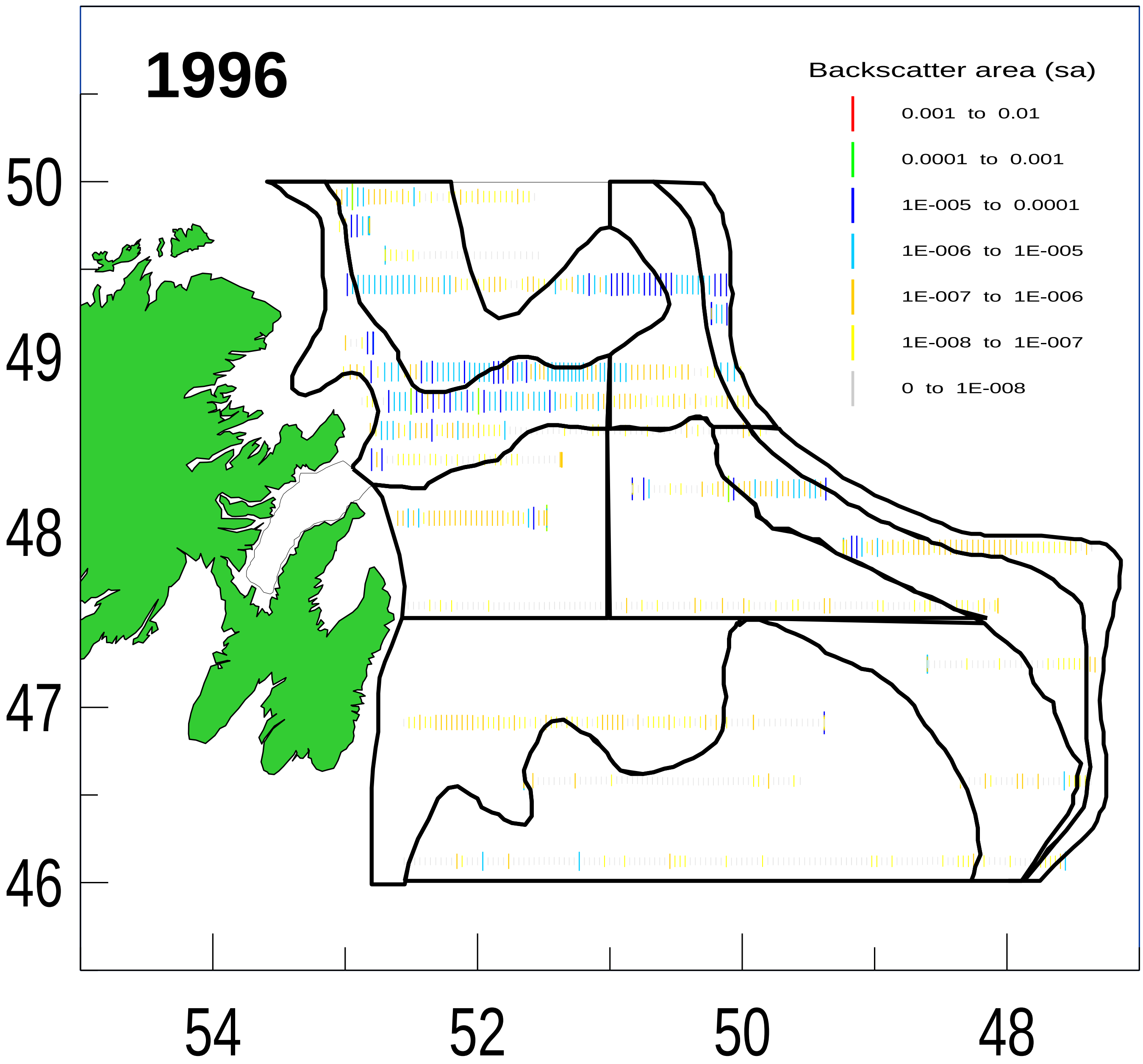

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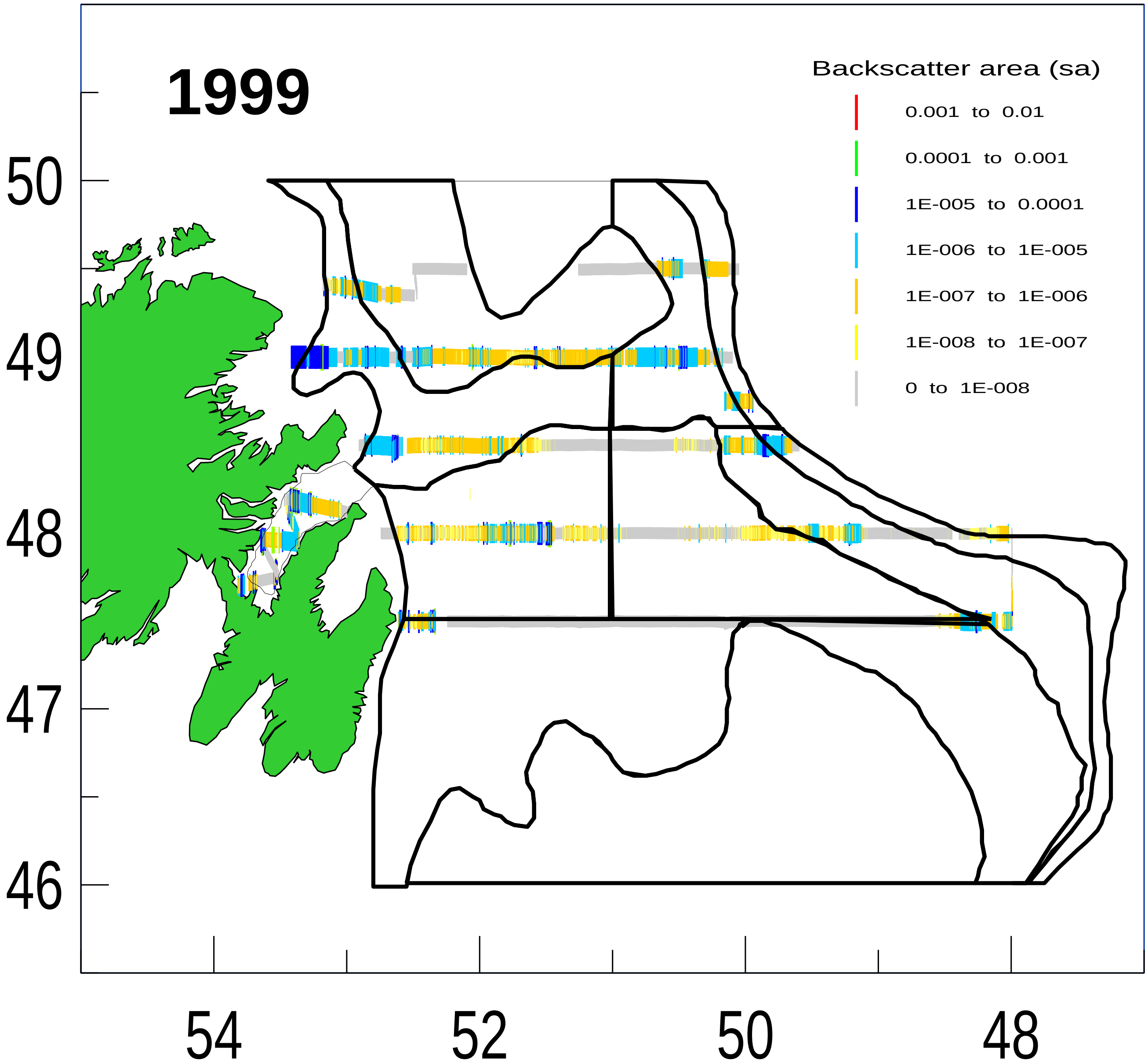

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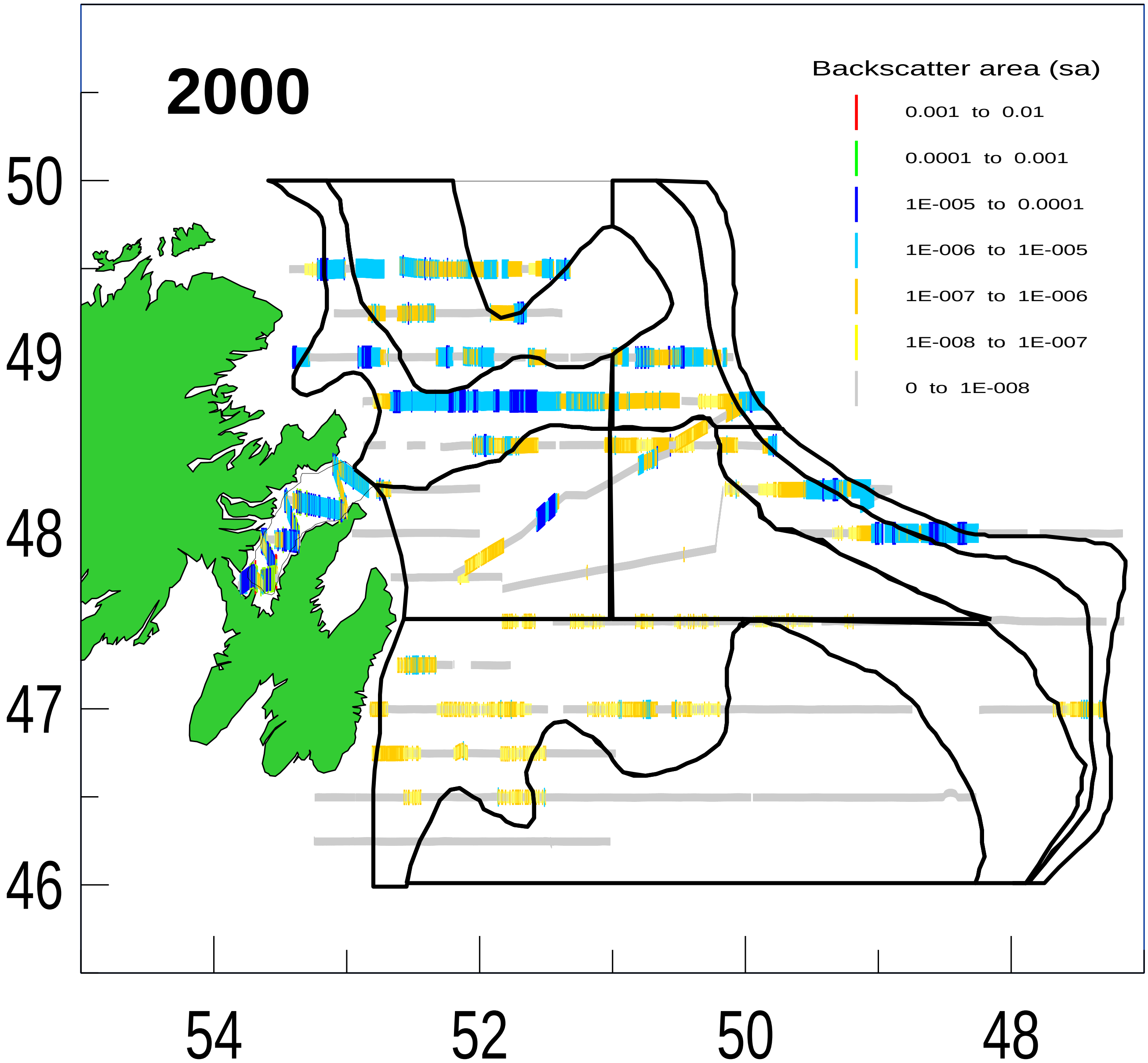

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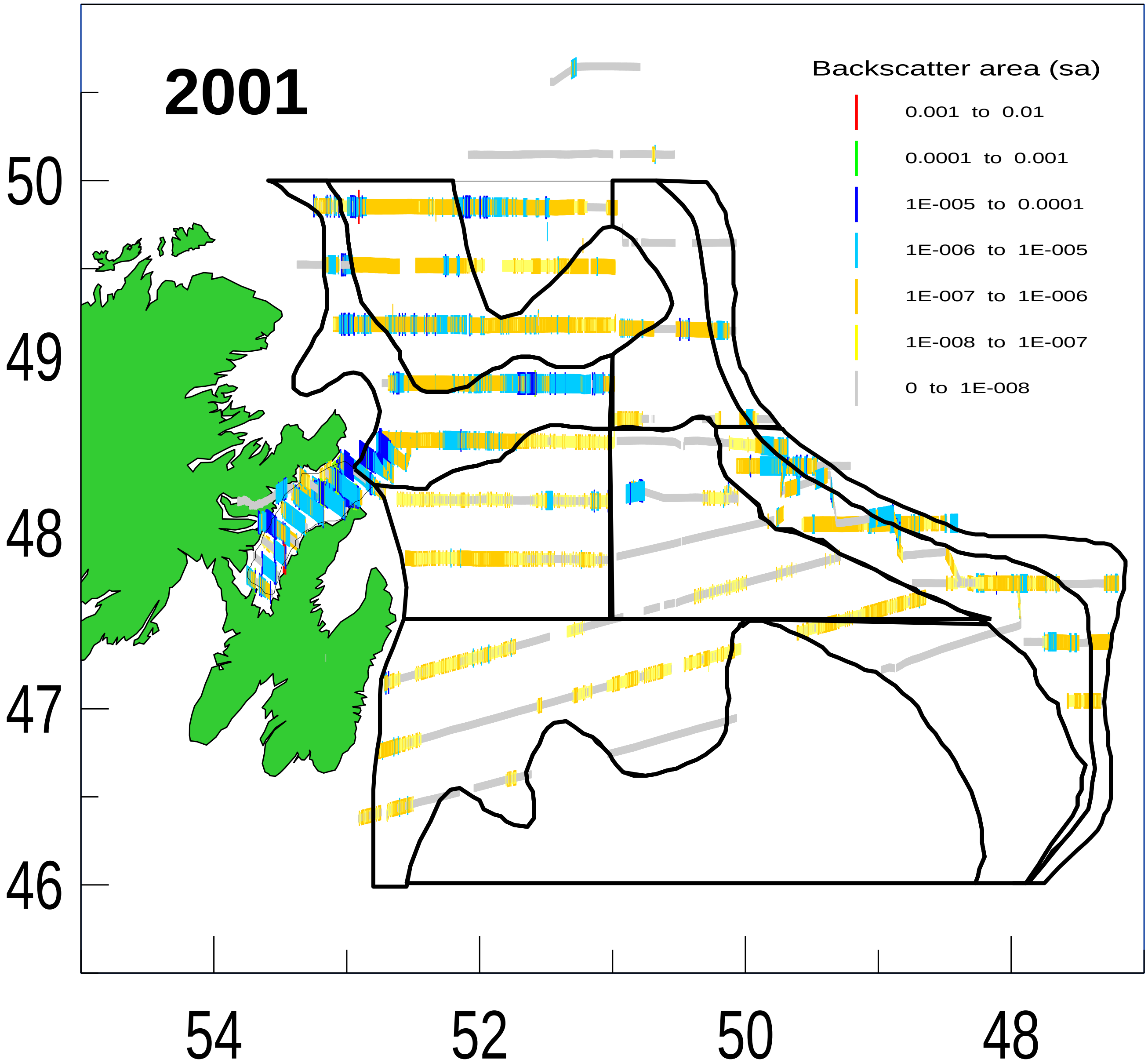


Figure 3. Distribution and intensity of capelin backscatter (s_a) during Spring acoustic surveys in NAFO Division 3L… (Continued).

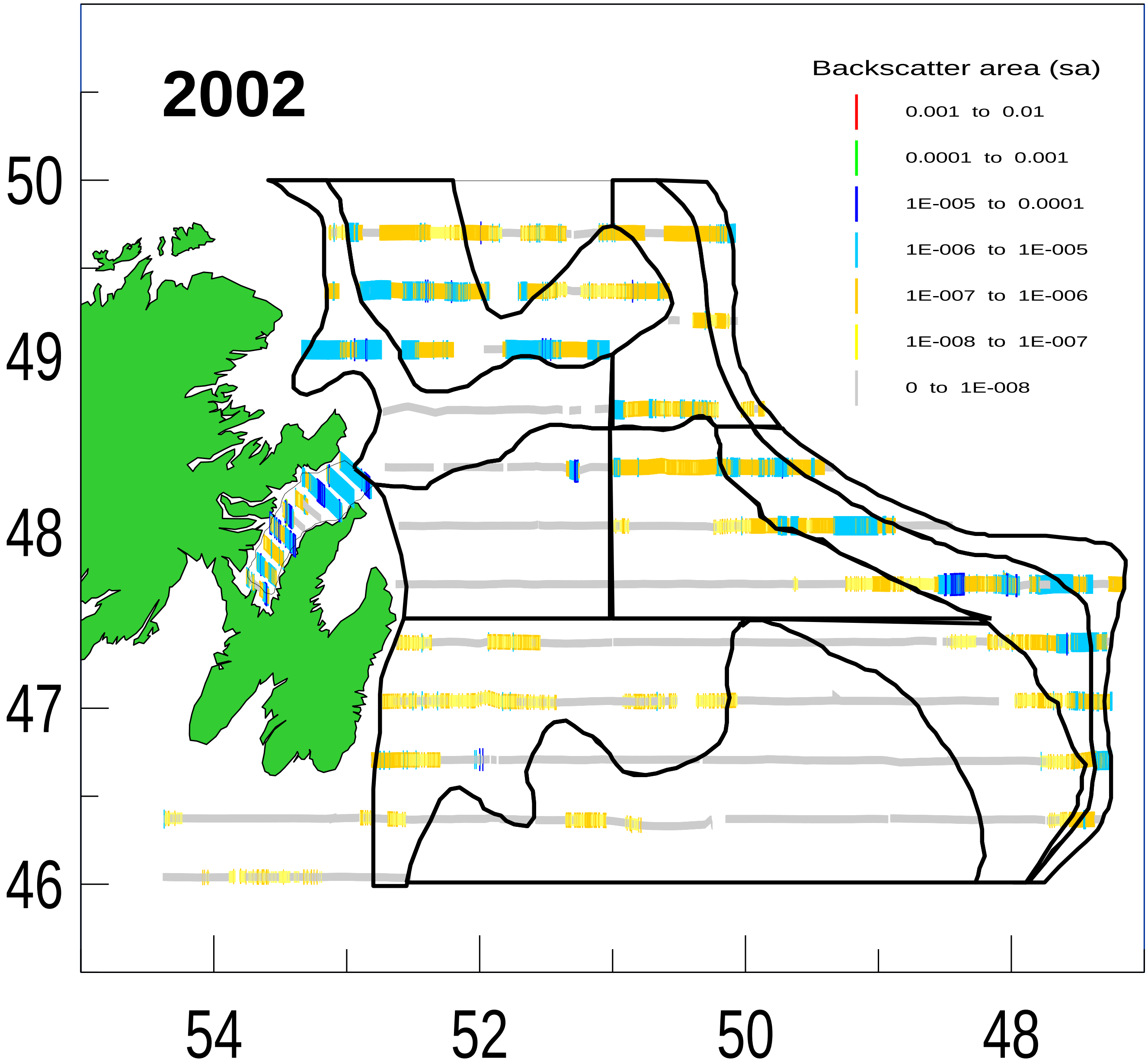


Figure 3. Distribution and intensity of capelin backscatter (s_a) during Spring acoustic surveys in NAFO Division 3L… (Continued).

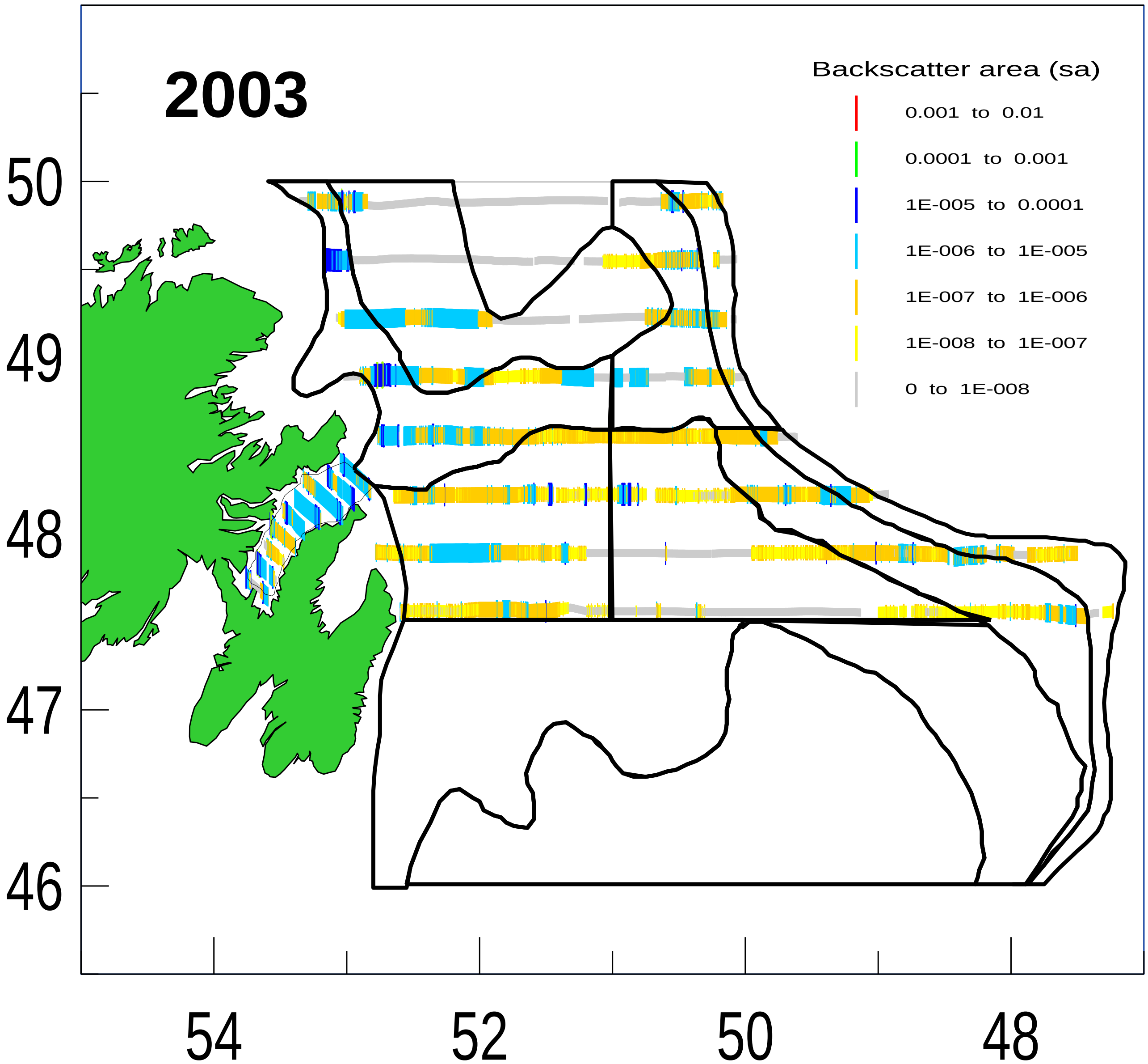
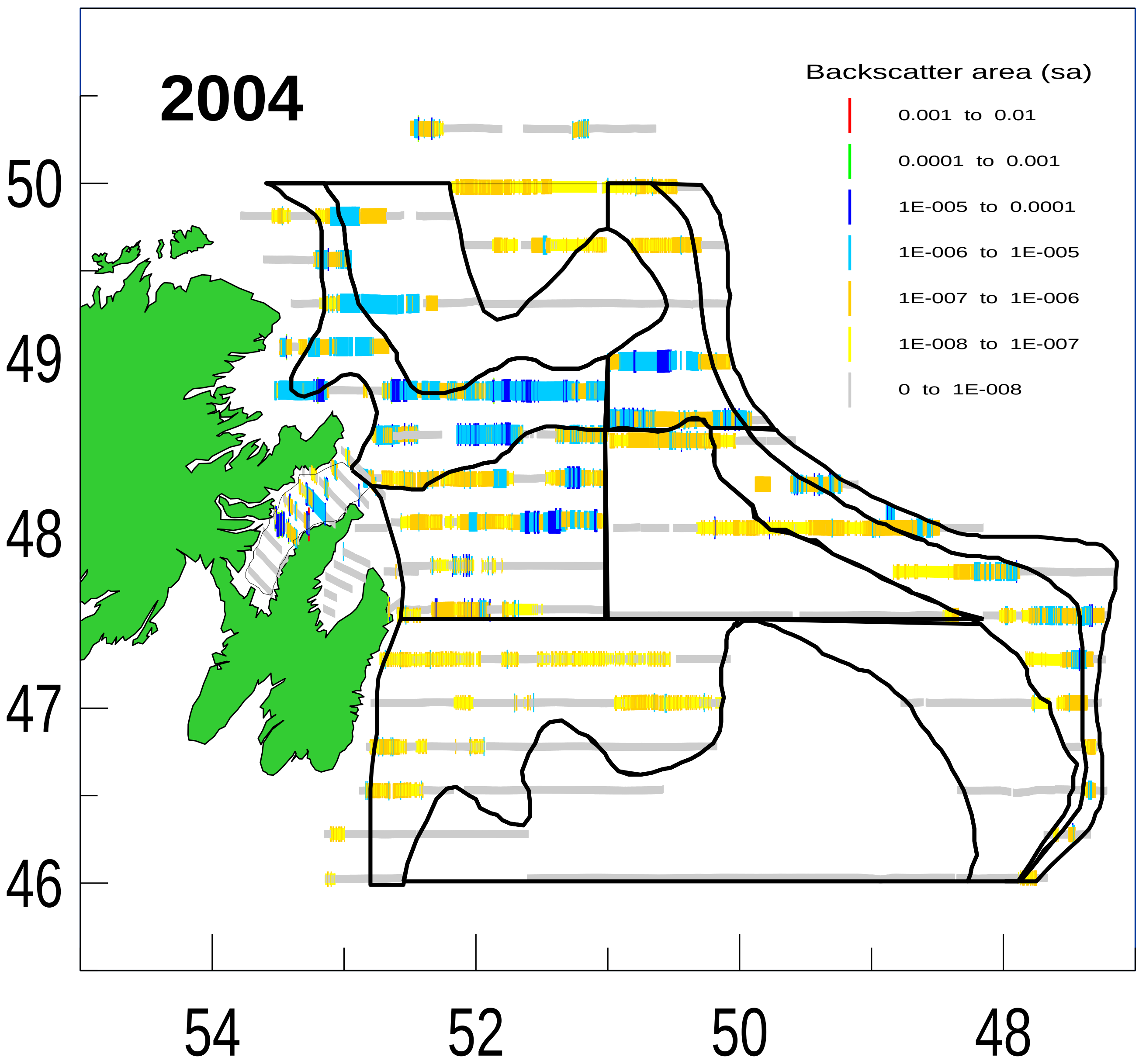


Figure 3. Distribution and intensity of capelin backscatter (s_a) during Spring acoustic surveys in NAFO Division 3L… (Continued).



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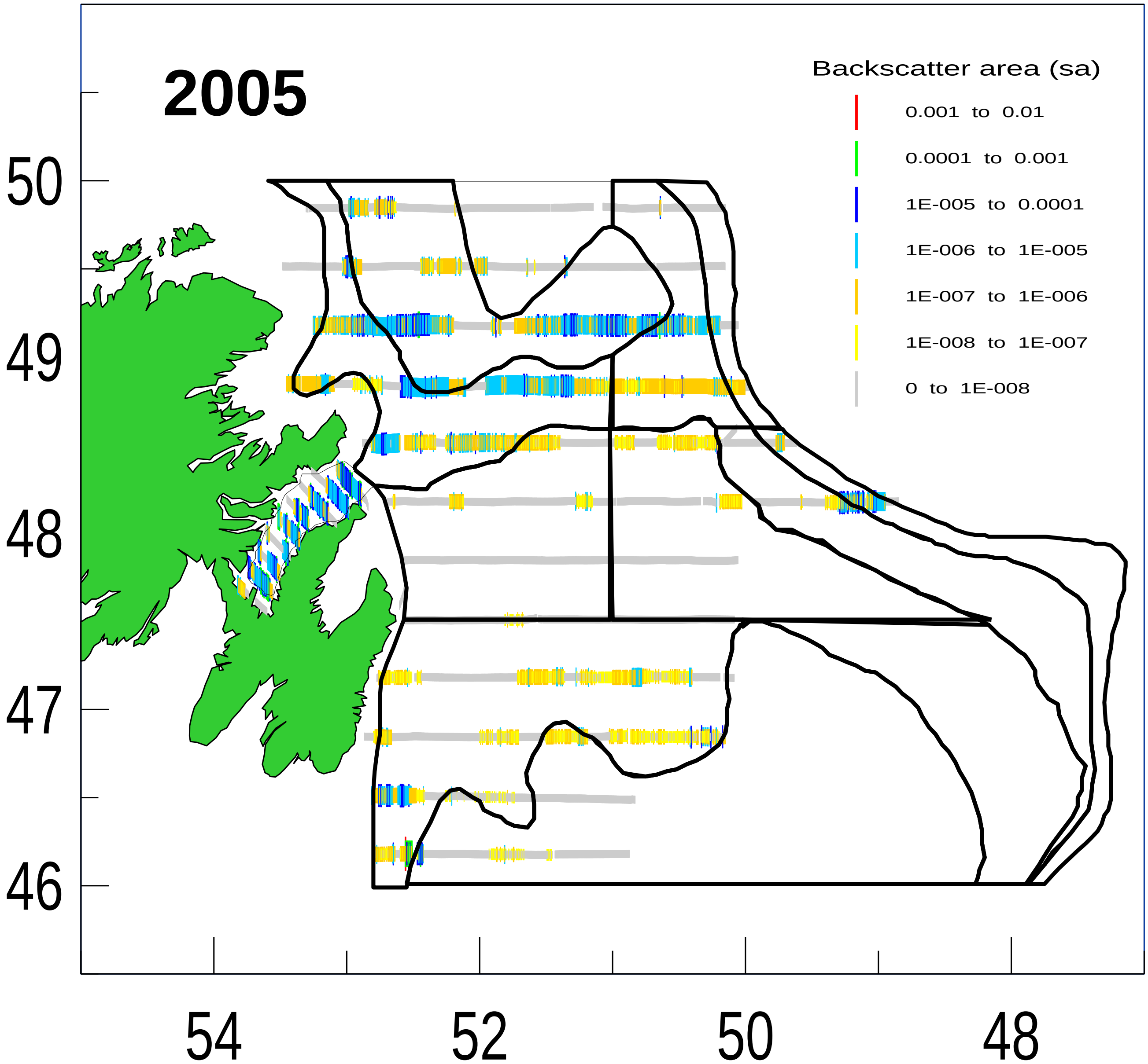

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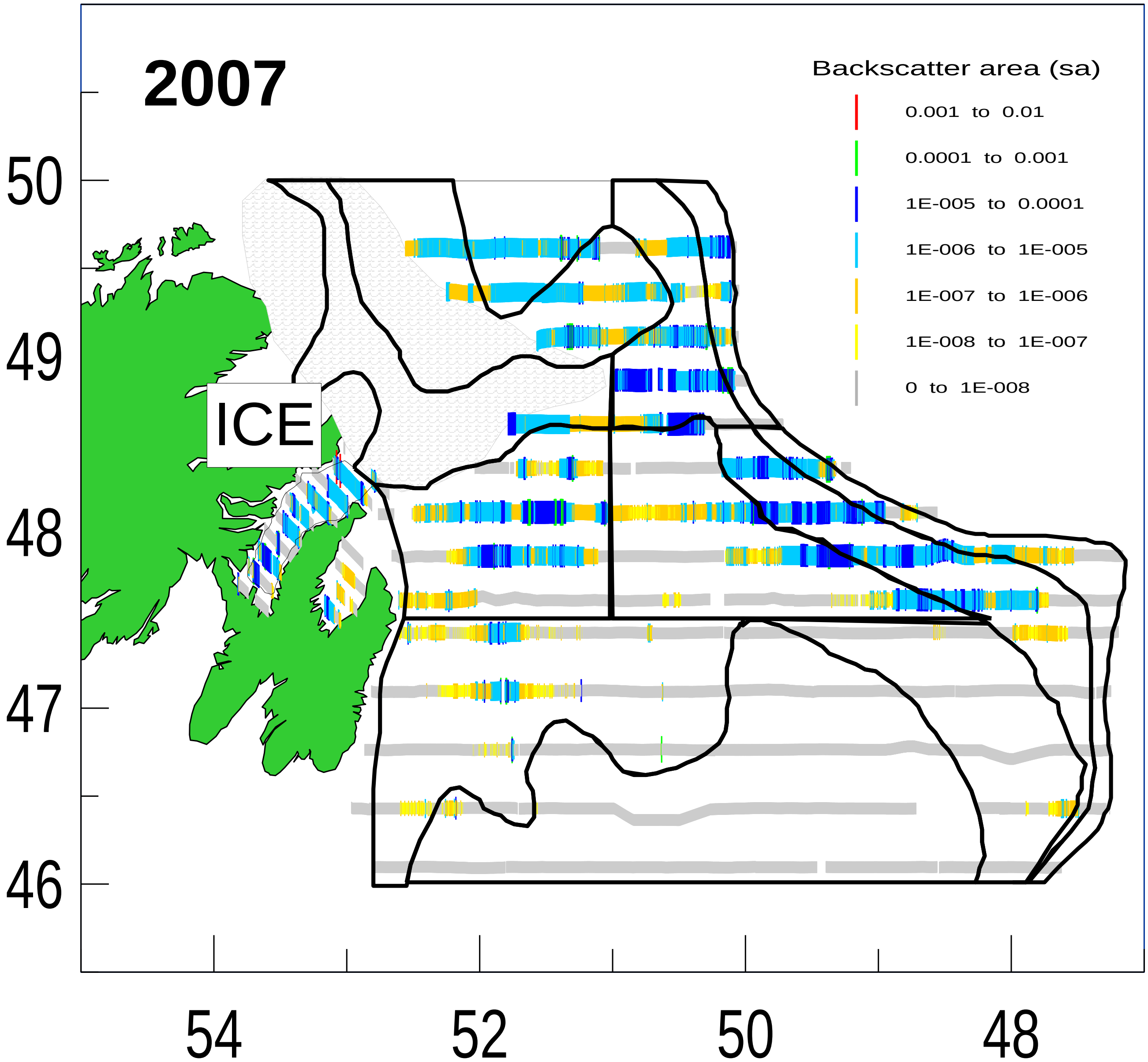

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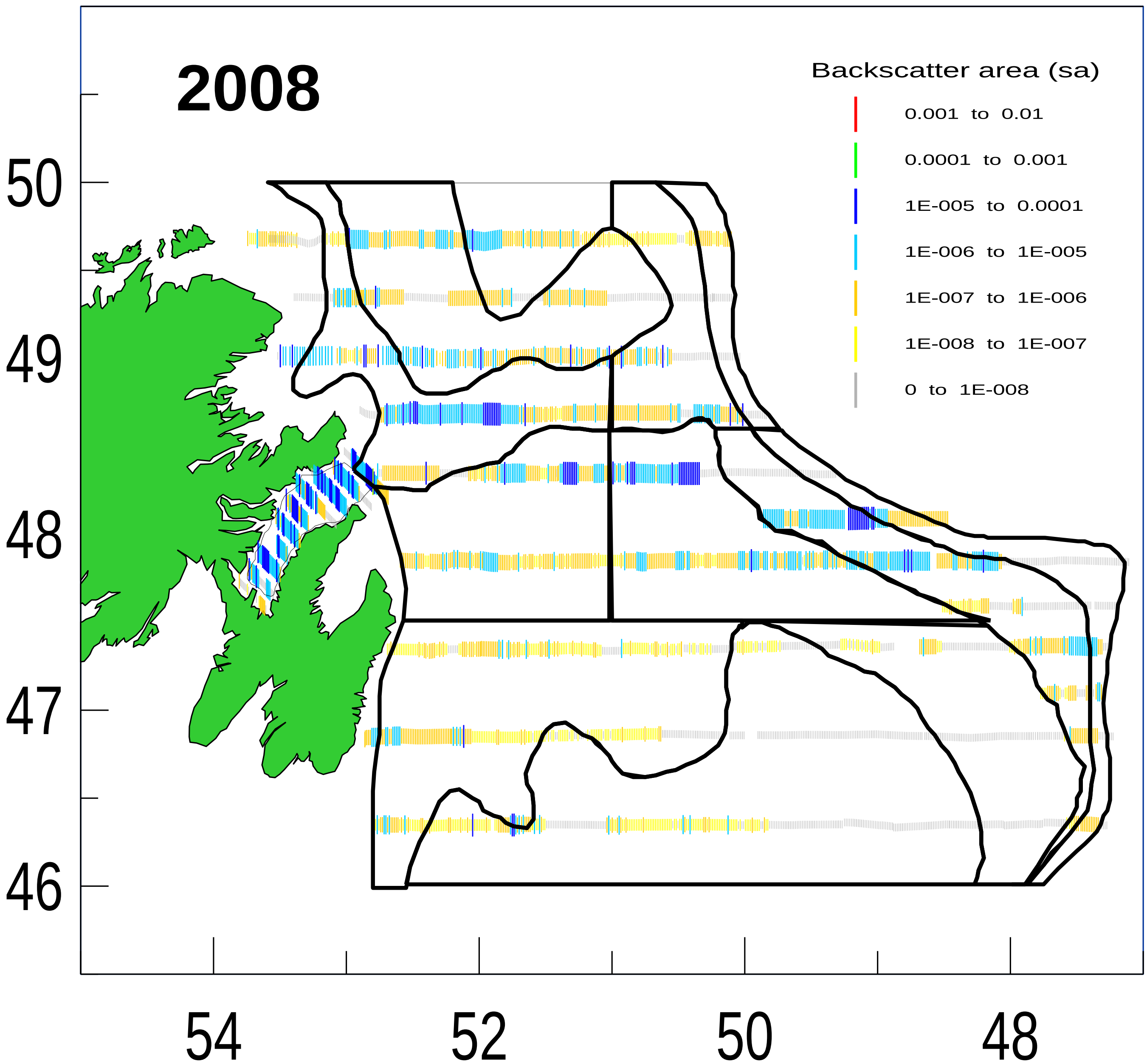

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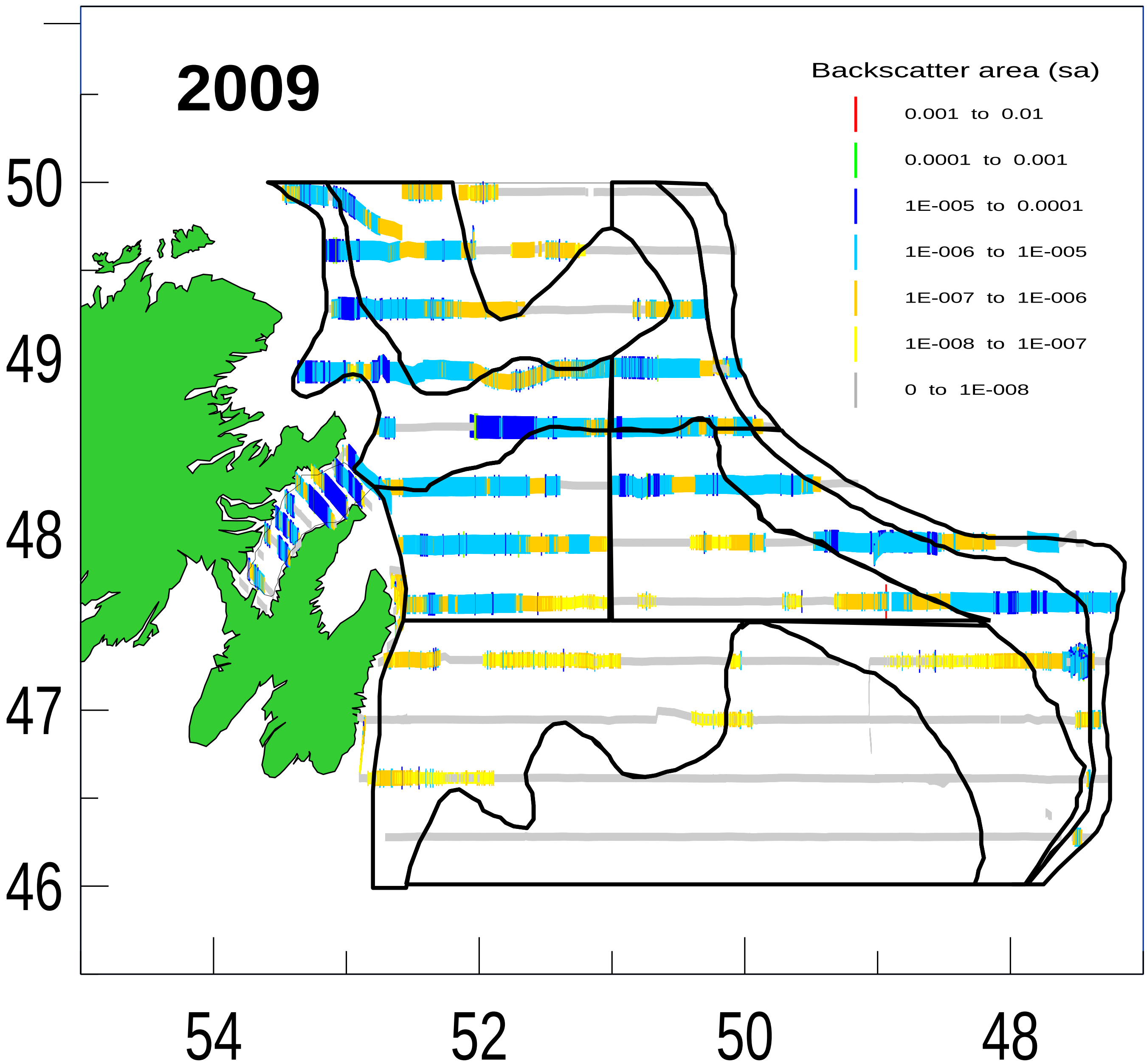

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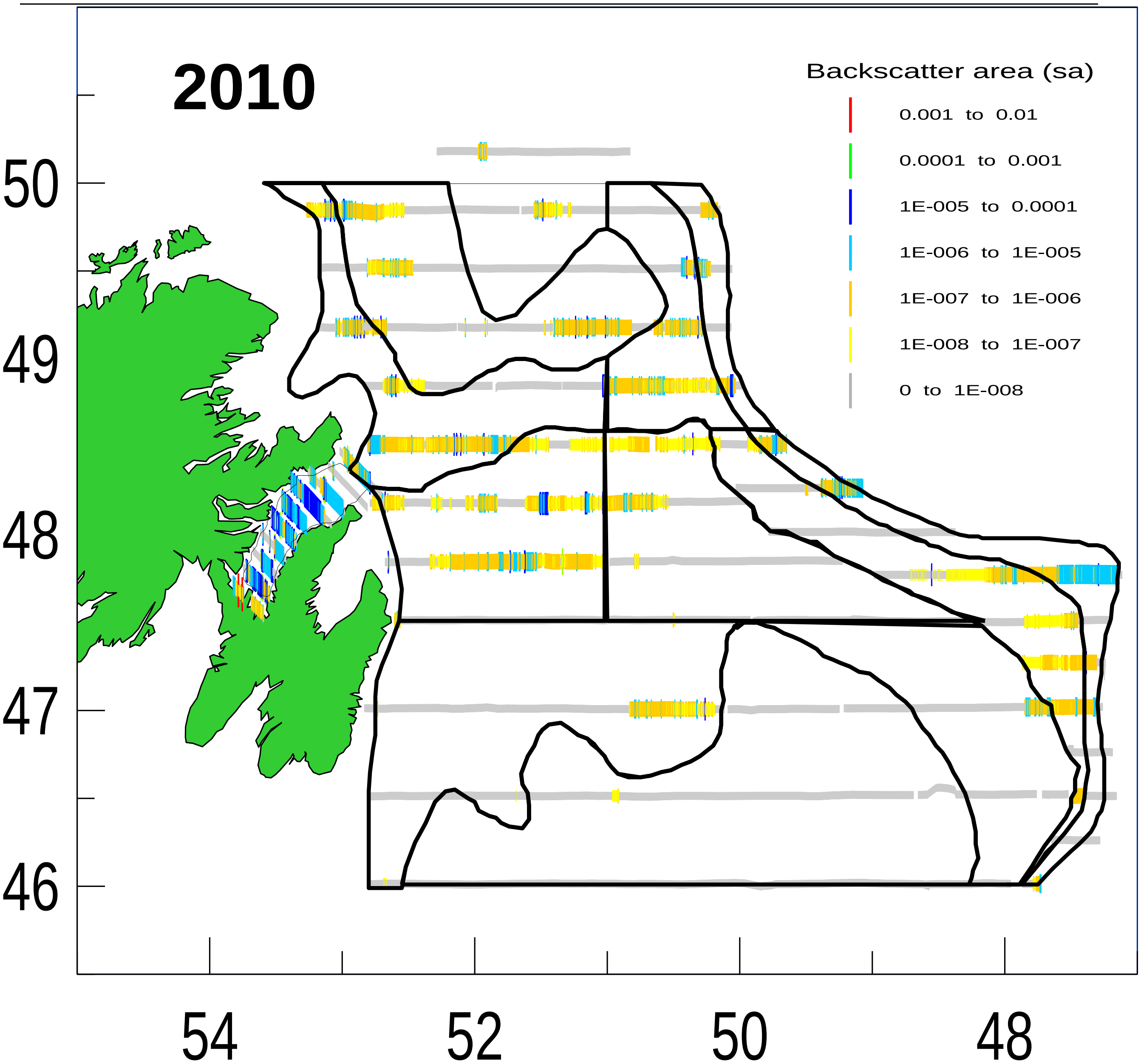

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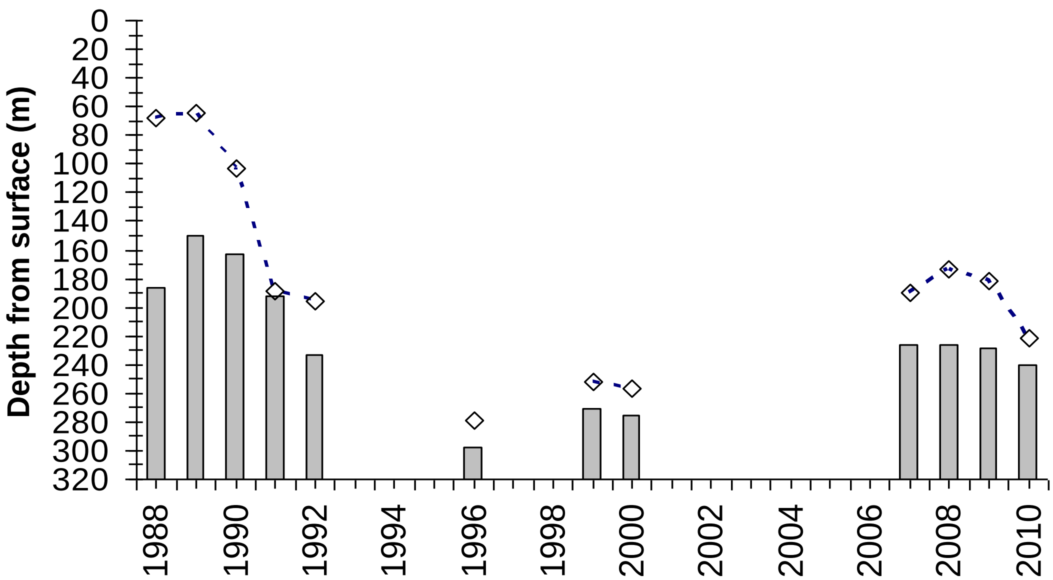

Figure 4. Mean weighted depth of capelin in survey area (diamonds) and mean weighted bottom depth where capelin were found (bars) 1988-2010.

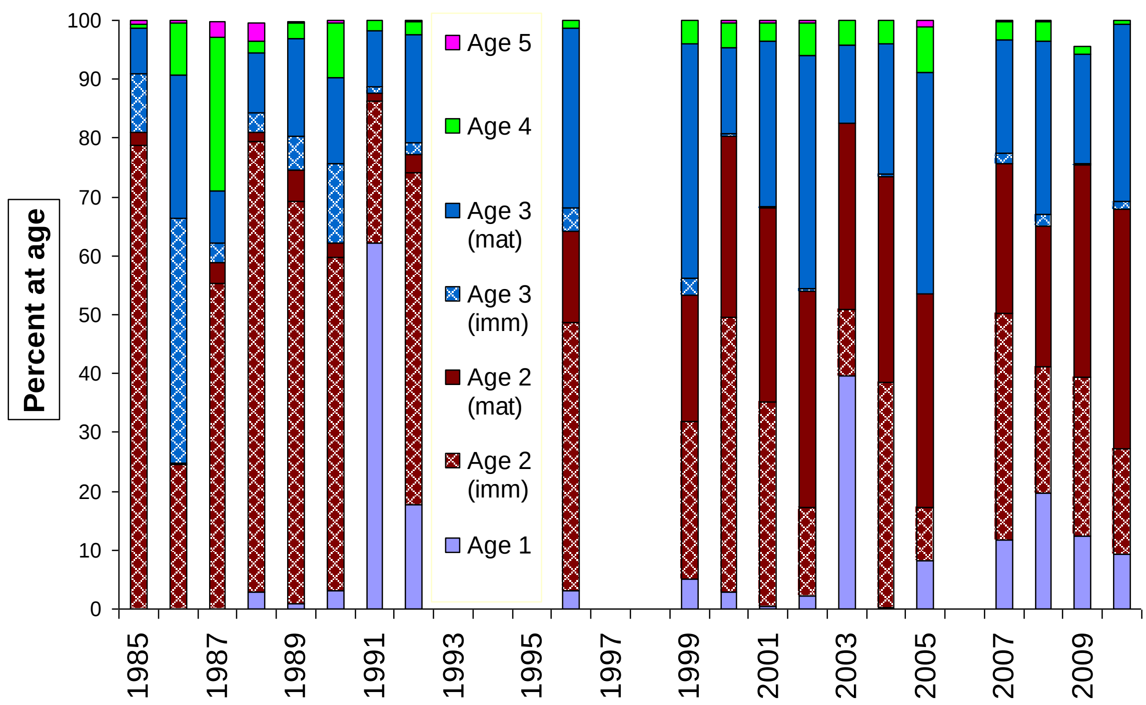

Figure 5. Age composition of capelin caught during Spring acoustic survey. Maturity stage is also indicated.

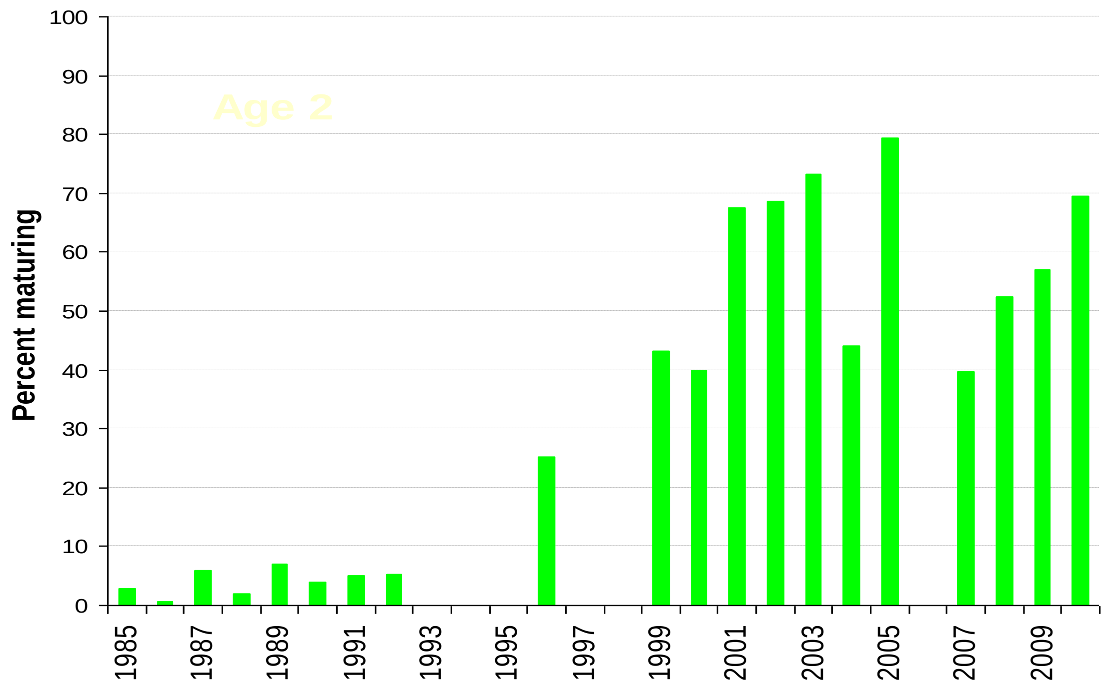

Figure 6. Proportion of maturing age 2 fish caught during Spring acoustic survey.

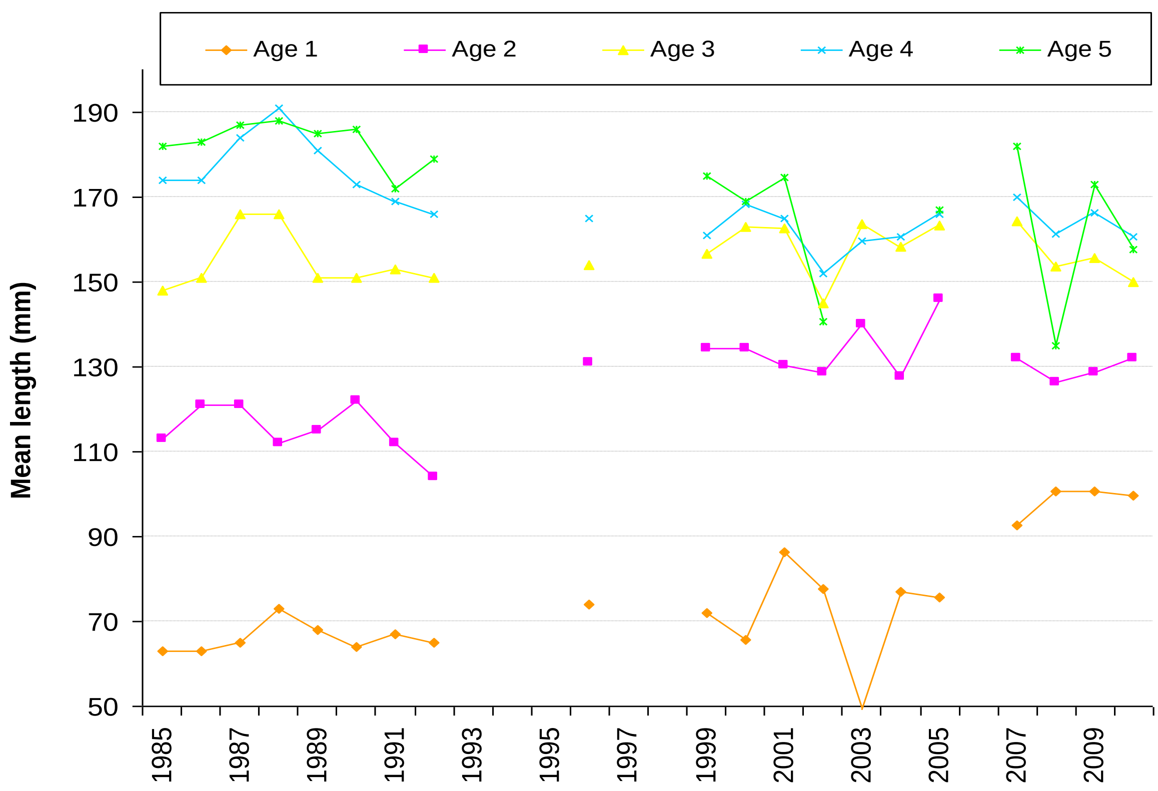

Figure 7. Mean length at age of capelin caught during Spring offshore acoustic survey.

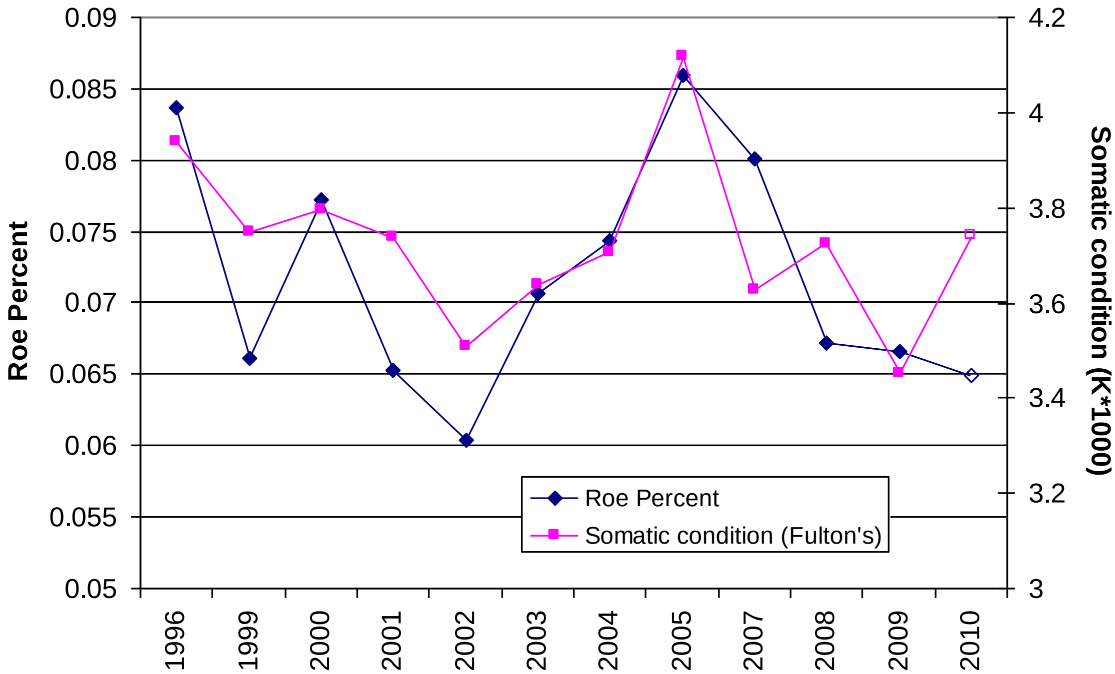

Figure 8. Mean roe content (%) and mean somatic condition of maturing female capelin caught during the Spring offshore acoustic survey.

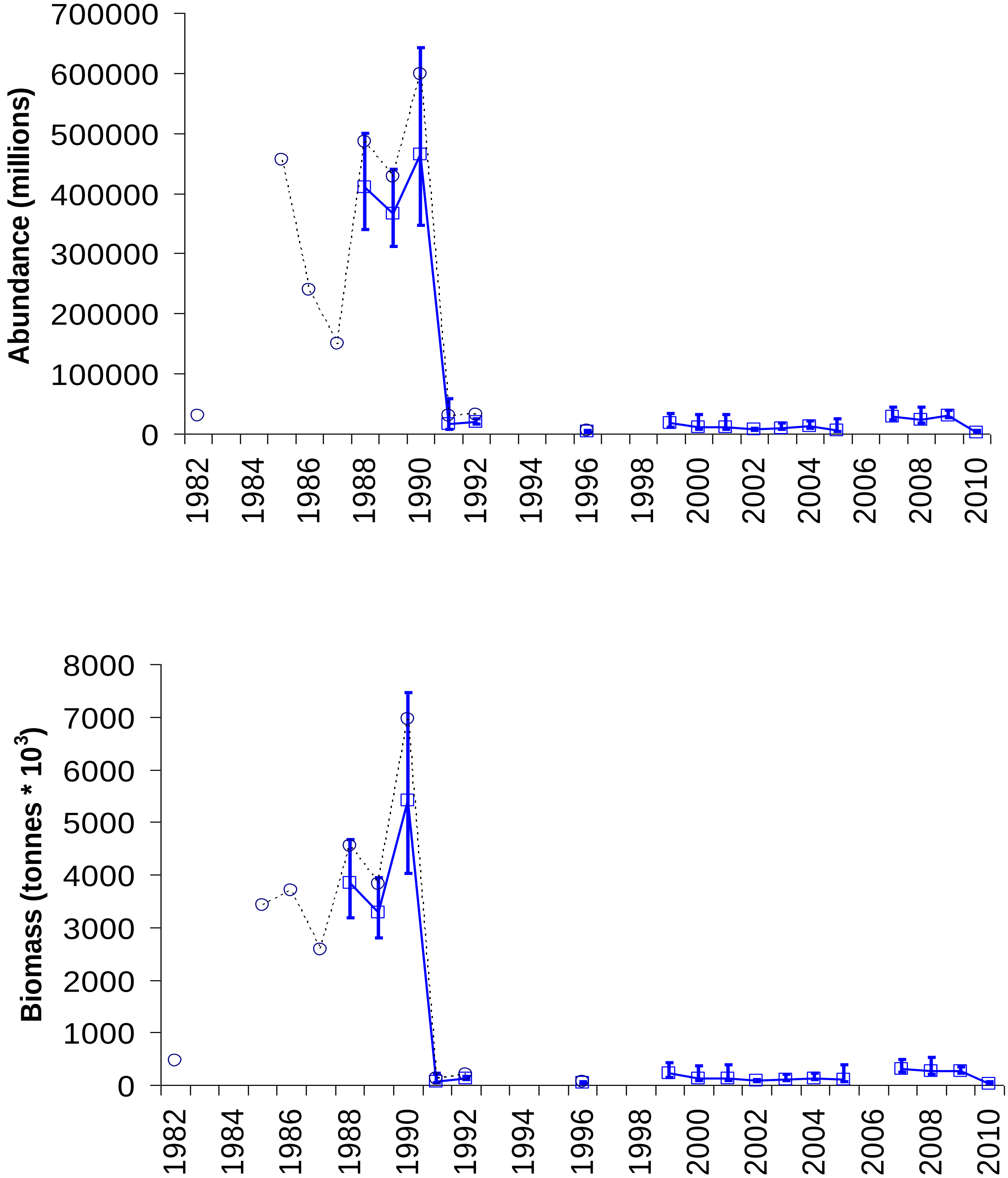

Figure 9. Abundance (upper) and biomass (lower) of capelin in area covered during Spring offshore acoustic surveys (1988-2010). Circles are estimates from Miller (1997). Squares are estimates derived using Monte Carlo simulation to estimate uncertainty. Median value is given bounded by the 5 and 95 percentiles.

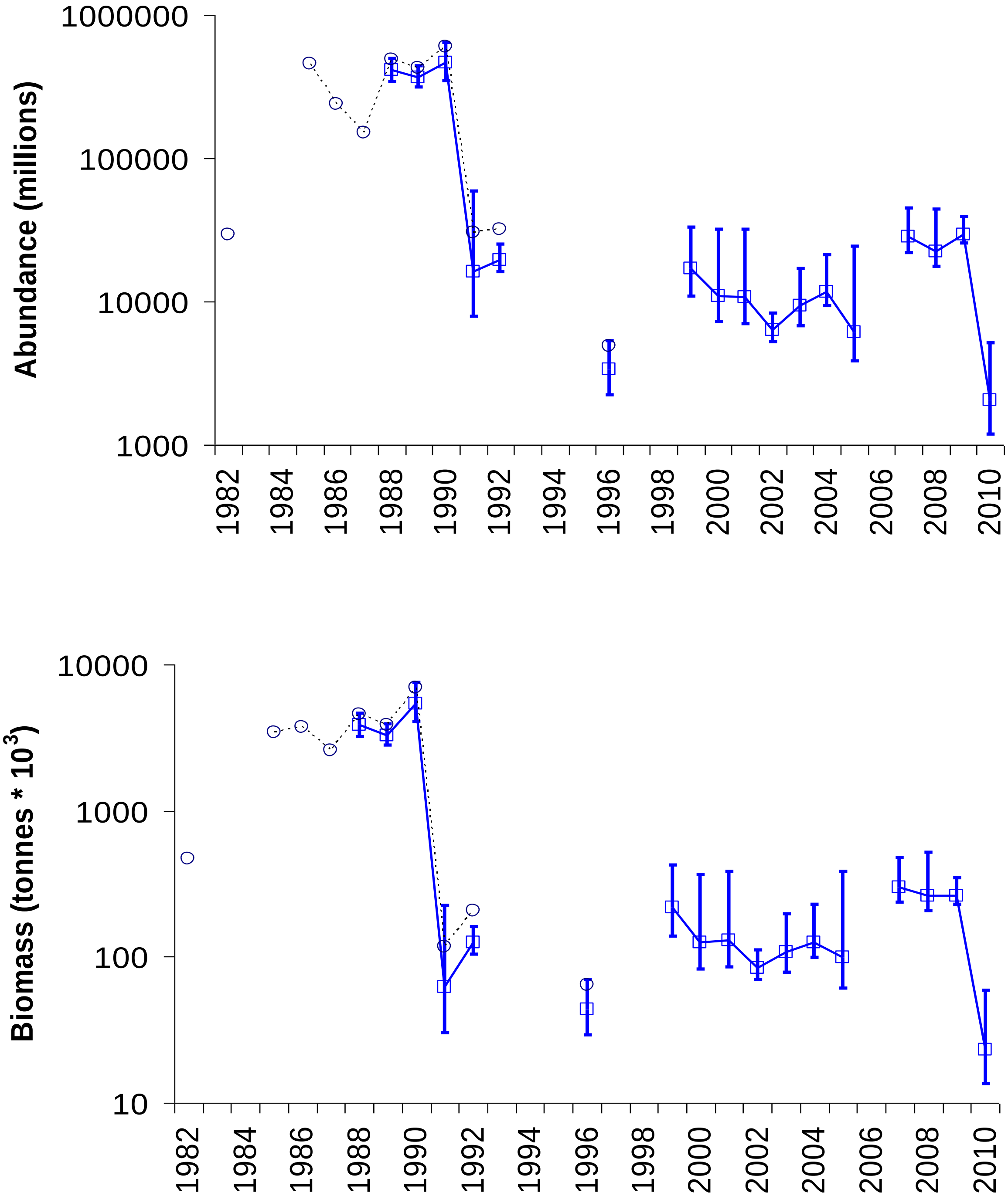

Figure 10. Log scaled presentation of Figure 9. Abundance (upper) and biomass (lower) of capelin in area covered during Spring offshore acoustic surveys (1988-2010) Circles are estimates from Miller (1997). Squares are estimates derived using Monte Carlo simulation to estimate uncertainty. Median value is given bounded by the 5 and 95 percentiles.

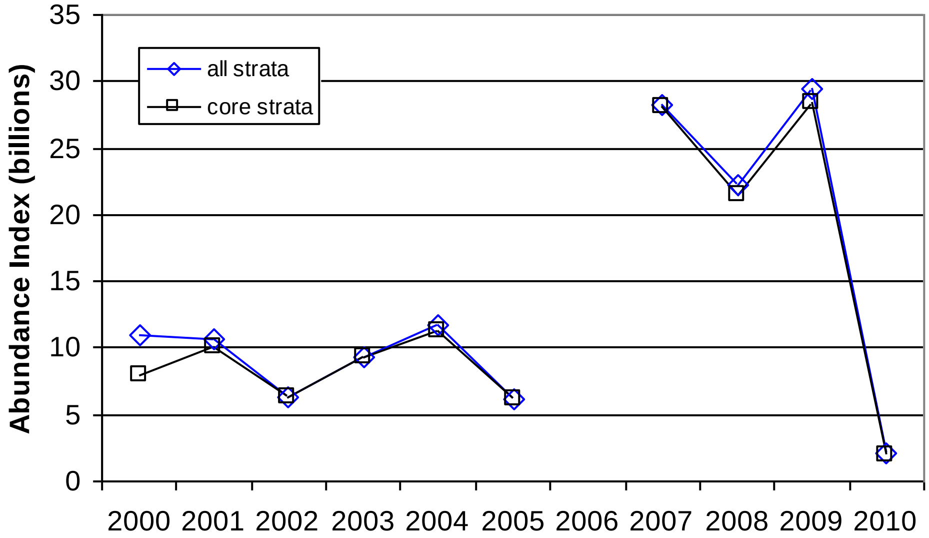

Figure 11. Total abundance of capelin in surveyed strata compared with core strata only.

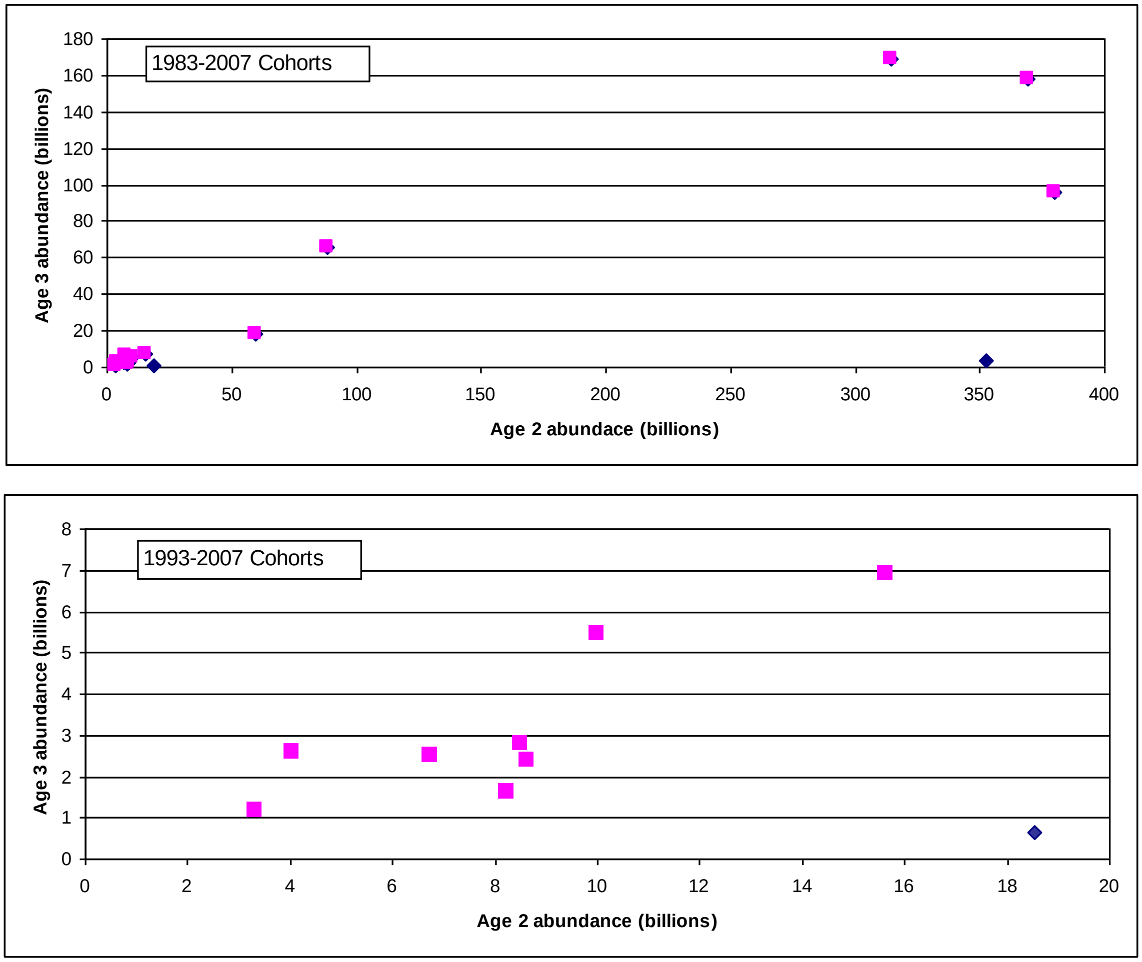

Figure 12. Correlation of age 2 and age 3 abundance for the full time series, 1983-2007 cohorts (upper panel), and for recent years only, 1997-2007 cohorts (bottom panel). Blue diamonds are cohorts which were identified as outliers.