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Distribution and intensity of acoustic backscatter of key species identified in the 2008 fall bottom trawl survey in NAFO Divisions 2J3KLNO

Distribution et intensité de la radiodiffusion acoustique d'espèces clés identifiées lors du relevé d'automne au chalut de fond de 2008 dans les divisions 2J3KLNO de l'OPANO

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ABSTRACT

This study investigated the suitability of using the acoustic and catch data gathered during bottom trawl surveys conducted in Newfoundland and Labrador waters (NAFO Div. 2J3KLNO). The main goal is to improve abundance and distribution estimates of key fish species of the shelf ecosystem, in particular for small pelagic forage fish species. First, we describe the methodology used for acoustic data collection and editing, fish species identification and problems encountered. Next, we compare the acoustic estimates (backscattering coefficient, s_a) for different fish species with the catch data from the 2008 fall bottom trawl tows. We also present acoustic estimation along the survey tracks. The integrated analysis of acoustic and catch data was successful in (i) detecting and differentiating among several groups of organisms across the continental shelves of Newfoundland and Labrador, including zooplankton, pelagic (capelin and sandlance) and demersal fish (cod, redfish, myctophids), (ii) providing proxy estimates of density and distribution for different groups of fish, (iii) identifying the role of factors such as geographic location and bathymetry, which seem to affect the distribution pattern of the various fish groups.

RÉSUMÉ

Cette étude a examiné la pertinence d'utiliser les données acoustiques et les données sur les prises recueillies pendant les relevés au chalut de fond effectués dans les eaux de Terre-Neuve-et-Labrador (divisions 2J3KLNO de l'OPANO). L'objectif principal est d'améliorer les estimations d'abondance et de distribution d'espèces clés de poissons dans l'écosystème de la plateforme, en particulier les petites espèces de poissons pélagiques fourragères. En premier lieu, nous décrivons la méthodologie utilisée pour la collecte et la vérification des données acoustiques, l'identification des espèces de poissons et les problèmes éprouvés. Ensuite, nous comparons les estimations acoustiques (coefficient de radiodiffusion, s_a) des différentes espèces de poissons avec les données sur les prises des traits de chalut de fond de l'automne 2008. Nous présentons également l'estimation acoustique le long des traces laissées par le relevé. L'analyse intégrée des données acoustiques et sur les prises a permis de i) détecter et de faire une distinction entre plusieurs groupes d'organismes dans l'ensemble des plateformes continentales de Terre-Neuve-et-Labrador, incluant les zooplanctons, des poissons pélagiques (capelan et lançon) et des poissons démersaux (morue, sébaste, myctophidae); ii) fournir des estimations indirectes de la densité et de la distribution de différents groupes de poissons; iii) déterminer le rôle de facteurs tels que l'emplacement géographique et la bathymétrie, qui semblent influer sur le modèle de distribution de divers groupes de poissons.

INTRODUCTION

Acoustic data have been collected around the clock during the fall multi-species bottom trawl survey in NAFO Div. 2J3KLNO since 2008 (Fig. 1). The acoustic program is conducted under the Ecosystem Research Initiative (NAFC, DFO) and in collaboration with the Centre for Fisheries Ecosystem Research (Marine Institute, MUN).

In this report we present the methodological approach used for the acoustic data collection, editing, integration and analysis. Proxy estimates of fish density and distribution (i.e., area backscattering coefficient [s_a]) are given for several species and groups of organisms in the surveyed area during 2008. The geographic distribution of acoustic backscatter estimates for different fish species are compared with the catch data from bottom trawl tows. Issues and problems encountered during the editing and processing of the acoustic data are highlighted. Finally, we propose several approaches for assessing functional relationships between acoustic and catch data. Our ultimate goal is to combine these two data sources, to improve the accuracy and precision of abundance and distribution estimates of key species of the Newfoundland and Labrador continental shelf ecosystem, particularly for small pelagic forage fish species.

MATERIAL AND METHODS

Acoustic data were collected during the annual stratified random bottom trawl survey of NAFO Div. 2J3KLNO. The 2008 survey was conducted using three research vessels over a total of fourteen survey legs conducted between October 3 and December 24 (Table 1). During the overall survey a total of 560 fishing stations were occupied. Station locations were randomly selected within depth and area delimited strata (Doubleday 1981). Near 1700 hours of single frequency acoustic data were collected during the survey from a hull-mounted split beam 38 kHz transducer coupled with either a Simrad EK500 or EK60 echo-sounder.

Data were collected continuously along the vessel track, both during and between fishing tows, to a depth of 550 m. The vessels proceeded from station to station as per previous years so as to occupy all the survey stations in the most efficient manner possible. Acoustic data were collected and analyzed in conjunction with bottom trawl catches for all tows in waters less than 500 m. Fishing tows were conducted for 15 minutes at a speed of 3 knots, covering a distance of 0.75 n.m., whereas the vessel speed between fishing tow stations varied according to the sea and weather conditions (5-10 knots). The distance between tow stations was also variable, resulting from the random scheme used to select stations.

Catch compositions were used to assist in the interpretation and verification of species contributing to the acoustic signal and to determine the biological characteristics of the fish and invertebrate components including length, weight, age, sex and maturity stage. In addition, at each station fishing tow start and end time, depth, light level, wind direction and force were recorded, and the temperature of the water column was profiled using a trawl mounted CTD (Seabird 19). Metrics of the trawl geometry (clearance from seafloor, doorspread, headrope and footrope depth) and bearing were measured continuously using gear-mounted sensors (Scanmar). Wire tension was controlled by an auto-trawl system, which helped maintaining a constant tension and keeping the trawl in an optimal position. Together, these systems were used in real time for correcting trawl asymmetry.

Prior to acoustic data processing and analysis, data from the trawl sensors were retrieved and synchronized with the GPS data from the vessel track. Tow depth and trawl wire length were used to estimate the trawl distance from the vessel. The overlap of vessel and trawl tracks was confirmed by plotting their relative locations as generated by the Scanmar monitoring system and vessel GPS. Acoustic data were selected from the actual area where the trawl fished (from gear touchdown to liftoff), as well from the transect segment between fishing tow stations.

The acoustic data (echograms) were edited manually using Echoview software (Myriax Ltd). The editing procedure sought to maximize data utility while quantifying its limitations. A number of factors affected acoustic data quality during the surveys, these included: bubble attenuation, loss of bottom tracking due to surface turbulence (rough weather, vessel propellers), and interference from other active acoustic devices like the vessel sounder and Scanmar trawl sensors (white noise). Bubble attenuation in particular may manifest itself in a variety of manners. At times bubble attenuation occurs in clusters of pings so as the entire water column will appear as a void, possibly even attenuating signal from the bottom. But, these groups of pings might be interspersed with others where the echogram quality is good. In this case only the data from the sections with clustered bubble attenuation were marked as bad data. When noise or clustered bubble attenuation was very frequent (more than 75 % of the pings in a section) the entire section was classified as bad data. Bubble attenuation also occurred in a milder form whereby acoustic echoes can de discerned in the water column and from bottom, but the strength of that signal has been reduced. In this case the pings were not classified as bad data but the overall data quality and suitable usage was flagged (see below). Scanmar trawl sensors were also common sources of white noise. However, the latter was only evident when the trawl approached or moved away from the seafloor (i.e., prior and subsequent to the fishing tow), and was easily detected and edited out from the echogram. Note that all acoustic data from the four Teleost legs were classified as bad data due to continuous backscatter interference from the vessel’s depth sounder which was left in active mode both while surveying and fishing.

All echograms were categorized by the analyst as usable for quantitative or qualitative purposes. This consisted of visually assessing the missing acoustic signal in the water column resulting from bubble attenuation (clustered and dispersed) and white noise level, as well as the reliability of the bottom detection. Acoustic data were labeled as (1) good for quantification, (2) useful for presence and absence only, and (3) no useful data. Bottom detection was also labeled as (4) reliably picked, (5) too spotty to be reliable and (6) exceeded echogram depth. Only echograms with acoustic data classified as (1) and (4) were used for quantitative analysis, whereas all but (3) and (6) were considered useful for qualitative purposes.

Seafloor depth was automatically picked for each ping as the depth of the maximum volume-backscattering strength (Sv, dB), back-stepped to -48 dB. Manual adjustments to the bottom pick line were conducted when necessary (e.g., noisy or missing acoustic signal resulting in loss of bottom tracking, bottom pick deeper than the true seafloor). Echo-traces (e.g., echo shapes and colors) and target strength (TS) of single fish were used to separate backscatter from the seafloor and other organisms (e.g., shrimp, zooplankton), and together with the information from the catch data (i.e., percentage of various species in catch weight), were used for partitioning the ‘biological’ s_a among the various species or groups of species (used when speciation was not possible). Based on these data, s_a was classified in 6 speciated (capelin, sandlance, herring, cod, redfish and myctophids) and 4 unspeciated categories (shrimp, demersal fish, pelagic fish and zooplankton). Backscatter of uncertain origin was labeled unclassified s_a. The location of each fishing tow was also identified in the echogram as an analysis region and classified as ‘fishing tow’. This facilitated extraction of data from fishing tows only.

Acoustic backscatter was integrated by category and cell. Cells were bounded by 100 m elementary distance sampling units (EDSUs) and 10 m surface referenced layers. All cells with s_a greater than 0.0001 m^2/m^2 were manually checked for errors/outliers (e.g., bottom pick errors, noisy spikes) and erroneous large values were manually corrected or removed.

Backscatter assigned to the different categories can be readily expressed as biomass (via areal fish density) when population or stock-specific TS relationships are available. In the case of unspeciated categories, the acoustic data is mainly useful for qualitative purposes (presence/absence). But eventually it would be possible to follow temporal trends in s_a, and potentially in changes in relative abundance of organisms within these categories. With representative sampling of the water column (e.g., pelagic and plankton tows), it would be possible to further partition the s_a from many of the unspeciated categories into specific ones.

RESULTS

Acoustic data were successfully collected during 10 survey legs, and used for quantitative assessment of capelin, sandlance, cod, redfish, and myctophids in the study area. All good data (flagged either for quantitative or qualitative purposes) were used to map distribution of the species listed above, in addition to zooplankton, unspeciated pelagic and demersal fish. No further analysis were pursued for herring and unspeciated shrimp at this time due to the very small number of observations in the former (<0.02 % of acoustic classifications), and difficulties in applying visual criteria to species classification and the lack of TS information for the latter.

Near 2.2 million integration cells containing acoustic backscatter of biological origin were identified during the survey (both data collected at and between fishing tows stations). Half of the data were classified as unspeciated zooplankton, whereas between 11-14 % were classified either as redfish, myctophids or capelin, and the remaining classifications comprised between 1-5 % each (Table 2). The percentage of good pings in each 100 m integration bin was examined. Sixty percent of the bins contained 100 % good data (useful for estimating indices of abundance and distribution), and only 9 % of the intervals contained more than 50 % bad data (Fig. 2a). Furthermore, acoustic data were available for 98 % of the fishing tows (excluding those from the Teleost legs). The amount of usable data reached 100 % in half of the tows, and in only 5 % of tows was the ratio between good and bad data less than 50 % (Fig. 2b).

The geographic distribution of the acoustic backscatter (s_a) indicates that over 50 % of EDSUs in the southern portion of the study area (Grand Bank - Div. 3LNO) were deemed as 100 % good/useful data, however the quality of the acoustic data tended to decline further north in Div. 2J3K (Fig. 3). This result will likely be repeated in subsequent years as the survey generally starts in October with one vessel in the north (Div. 2G or 2J) and the other in Div. 3NO, working toward the center to finish Div. 3KL in mid to late December. Given that the weather tends to poorer further north, and deteriorates as the fall progresses, the impact of poor weather on acoustic data is likely to be highest in Div. 2J3KL. Consequently, it would be expected that the strength of acoustic and catch data relationship varies according to the area, as well as the period when the survey is conducted. How such relationship as well others (e.g., fish avoidance, diel effects of fish distribution on acoustic and catch data) can be quantified and used in determining data quality is the focus of an ongoing study (Mello et al., in preparation).

Whole water column backscatter (s_a) is presented for capelin, sandlance, redfish, and Atlantic cod in Figures 4-7. Most species were distributed in small, dense aggregations in areas adjacent to the Grand Bank, with species distributions overlapping in many cases. Capelin acoustic backscatter predominated in Div. 2J and 3K in both shallower (<200 m) and deeper waters (200-500 m). In Div. 3LNO the prevalence of either capelin or sandlance varied according to depth, with capelin in deep waters along the shelf edge, and sandlance in shallow waters over the Grand Bank. Further north (Div. 2J and 3K), the backscatter distribution for all categories tended to be more dispersed through the shelf, showing mostly low values (low densities), except in the case of (i) cod in the Bonavista Corridor (Div. 3K), which were found aggregated in a few areas, (ii) capelin in the Southern Labrador and the Northeast Newfoundland Shelves, with a near-shore distribution pattern and (iii) myctophids, which where found all along the continental shelf slope (depth >400 m) as relatively dense and continuous layers of fish (Fig. 8). For the unspeciated s_a categories, zooplankton had a distribution pattern similar to that observed for capelin and sandlance, that is higher densities and gregarious distribution in the southern areas, and lower densities and scattered distribution further north, whereas unspeciated pelagic and demersal fish showed the latter pattern across the study area (Figs. 9-11).

The whole water column acoustic backscatter estimates for demersal fish (from areas adjacent to the trawl transect segment) are in good agreement with those from catch data, both in terms of relative density and geographic distribution. The largest catches were observed along the shelf slope for redfish (Div. 2J3KNO), and in the Bonavista Corridor for cod (Figs. 6-7). For pelagic fish, there was a noticeable correspondence between catch and acoustic data for sandlance (relative density and distribution), particularly in the eastern portion of the Grand Bank (Div. 3LO), as well for capelin in terms of distribution (Div. 2J3KL), but the relationship was less evident in terms of relative densities, except on the Northeast Newfoundland Shelf in Div. 3K (Figs. 4-5). There were no notable relationships between catch and acoustic backscatter for myctophids (Fig. 8).

DISCUSSION

The integrated analysis of acoustic and catch data was successful in detecting and differentiating among several types of organisms across the continental shelves of Newfoundland and Labrador, including zooplankton, pelagic and demersal fish, as well providing proxy estimates of density and distribution for different groups of fish. Observations were in good agreement with the general understanding regarding the distribution and structure of the main fish stocks in the study area, including capelin and sandlance (Lilly and Simpson 2000; Mowbray 2002), as well as cod and redfish (Rose et al. 2000; Power 2003; Morin et al. 2004; Mello and Rose 2009*a*; Rose et al. 2011).

Acoustic and trawl data have been used together to assess the abundance and distribution of pelagic and demersal fish stocks since the 1960’s (Kelso et al. 1974; Mais 1974; Dalen and Smedstad 1979; Hylen et al. 1986; Aglen et al. 1999; Bez et al. 2007; von Szalay and Somerton 2009). A major benefit of this approach is the ability to expand the knowledge about the sampled populations over the whole study area (e.g., vertical distribution), hence minimizing errors and biases from survey estimates, which are due to sampling gear characteristics, and species-specific traits like diel migrations, herding and other behavioral characteristics (Godø and Wespestad 1993; Aglen et al. 1999; von Szaley et al. 2007; Yule et al. 2008).

For combined acoustic-trawl surveys, fish detectability by an echosounder within the dead zone (region near the seafloor where fish cannot be resolved acoustically) or the blind zone (unsampled water layer above the transducer) is an important source of uncertainty in acoustics estimation (Ona and Mitson 1996; McQuinn et al. 2005; Mello and Rose *2009b*; Totland et al. 2009). Likewise, differences in fish availability during tows (e.g., pelagic fish to bottom trawl) may effectively compromise sampling strategies based on trawling data alone and its usefulness for stock assessment (Aglen 1996; Hjellvik et al. 2002, 2007; De Roberts and Wilson 2006; Stockwell et al. 2006; Yule et al. 2007).

Several methods have been proposed to improve the reliability of acoustic-trawl survey indices. For instance, in the case of data recorded at the tow stations, the main focus is to determine the relationship between abundance and distribution indices and the factors which affect these relations (Ona et al. 1991; Krieger et al. 2001; Beare et al. 2004; Godø et al. 2004; Bouleau and Bez 2005; von Szalay et al. 2007). The purpose of this exercise is to validate the hypothesis that fishing and acoustic gears are measuring the same fraction of the stock. Once this relationship can be established, the next step would be to correlate the acoustic data recorded during fishing tows with the acoustic data recorded between tow stations (Bez et al. 2007; von Szalay and Somerton 2009).

Our study constitutes the first step towards developing an approach for combining and incorporating acoustic and bottom trawl survey catch data into the stock assessment routine of demersal and pelagic fish and potentially other species (e.g., zooplankton) inhabiting Newfoundland and Labrador waters. The next step will focus on assessing statistical relationships between survey catch and acoustic estimation of fish density and distribution on a tow by tow basis, followed by the development of predictive models of density and distribution patterns to the survey transect segments between fishing tow stations. Considering that fishing tows often sample a small fraction of a statistical stratum (typically a few of hundreds of km^2), and that acoustic data can be recorded continuously through the study area, the approach proposed in this study could represent a cost-effective way to maximize the sampling rate during surveys, improving the estimates based on catch data, and the information used in stock assessment.

Finally, a critical aspect for ecosystem-based fisheries management (EBFM) is the ability to detect and quantify changes in ecosystem carrying capacity, and combined acoustic-trawl surveys can become effective analytical tools to gather the information necessary for the long-term integrated assessment of key components of the Newfoundland and Labrador marine ecosystem.

REFERENCES

Aglen, A. 1996. Impact of fish distribution and species composition on the relationship between acoustic and swept-area estimates of fish density. ICES J. Mar. Sci. **53**: 501-505.

Aglen, A., Engås, A., Huse, I., Michalsen, K., and Stensholt, B.K. 1999. How vertical fish distribution may affect survey results. ICES J. Mar. Sci. **56**: 345-360.

Beare, D.J., Reid, D.G., Greig, T., Bez, N., Hjellvik, V., Godø, O.R., Bouleau, M., van der Kooij, J., Neville, S., and Mackinson, S. 2004. Positive relationships between trawl and acoustic data. ICES CM 2004/R:24.

Bez, N., Reid, D., Neville, S., Vérin, Y., Hjellvik, V., Gerritsen, H.D. 2007. Acoustic data collected during and between bottom trawl stations: consistency and common trends. Can. J. Fish. Aquat. Sci. **6**4: 166-180.

Bouleau, M., and Bez, N. 2005. Using a Markov-type model to combine trawl and acoustic data in fish surveys. *In* Geostatistics for environmental application. *Edited by* P. Renard, H. Demougeot-Renard, and F. Froidevaux. Springer, Berlin. pp. 111-123.

Dalen, J., and Smedstad, O.M. 1979. Acoustic method for estimating absolute abundance of young cod and haddock in the Barents Sea. ICES CM 1979/G:51.

De Roberts, A., and Wilson, C.D. 2006. Walleye pollock respond to trawling vessels. ICES J. Mar. Sci. **63**: 514-522.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Counc. Stud. No. 2.

Godø, O.R., and Wespestad, V.G. 1993. Monitoring changes of abundance of gadoids with varying availability to trawl and acoustic surveys. ICES J. Mar. Sci. **50**: 39-51.

Godø, O.R., Hjellvik, V., Greig, T., and Beare, D. 2004. Can subjective evaluation of echograms improve correlation between bottom trawl and acoustic densities? ICES CM 2004/R:23.

Hjellvik,V., Godø, O.R.V., and Tjøstheim, D. 2002. Diurnal variation in bottom trawl survey catches: does it pay to adjust? Can. J. Fish. Aquat. Sci. **59**: 33-48.

Hjellvik, V., Tjøstheim, D., and Godø, O.R. 2007. Can the precision of bottom trawl indices be increased by using simultaneously collected acoustic data? The Barents Sea experience. Can. J. Fish. Aquat. Sci. **64**: 1390-1402.

Hylen, A., Nakken, O., and Sunnanå, K. 1986. The use of acoustic and bottom trawl surveys in the assessment of north-east cod and haddock stocks. *In* A Workshop on Comparative Biology, Assessment and Management of Gadoids from the North Pacific and Atlantic Oceans, June 1985. *Edited by* M. Alton, Seattle, Washington. pp 473-498

Kelso, J.R.M., Pickett, E.E., and Dowd, R.G. 1974. A digital echo-counting system used in determining abundance of freshwater pelagic fish in relation to depth. J. Fish. Res. Board Can. **31**: 1101-1104.

Krieger, K., Heifetz, J., and Ito, D. 2001. Rockfish assessed acoustically and compared to bottom trawl catch rates. Alaska Fish. Res. Bull. **8**: 71-77.

Lilly, G.R., and Simpson, M. 2000. Distribution and biomass of capelin, Arctic cod and sandlance on the Northeast Newfoundland Shelf and Grand bank as deduced from bottom-trawl surveys. DFO Can. Stock Assess. Sec. Res. Doc. 2000/091.

Mais, K.F. 1974. Pelagic fish survey in the California current. Fish. Bull. **162**: 1-79.

McQuinn, I.H., Simard, Y., Stroud, T.W.F., Beaulieu, J.-L., and Walsh, S.J. 2005. An adaptive, integrated "acoustic-trawl" survey design for Atlantic cod (*Gadus morhua*) with estimation of the acoustic and trawl dead zones. ICES J. Mar. Sci. **62**: 93-106.

Mello, L.G.S., and Rose, G.A., 2009a. An acoustic-trawl survey of offshore over-wintering northern cod, February- March 2008. DFO Can. Stock Assess. Sec. Res. Doc. 2009/099.

Mello, L.G.S., and Rose, G.A. 2009b. The acoustic dead zone: theoretical vs. empirical estimates, and its effect on density measurements of semi-demersal fish. ICES J. Mar. Sci. **66**: 1364-1369.

Morin, B., Methot, R., Sevigny, J.-M., Power, D., Branton, B., and McIntyre, T. 2004. Review of the structure, the abundance and distribution of *Sebastes mentella* and *S. fasciatus* in Atlantic Canada in a species at risk context. DFO Can. Stock Assess. Sec. Res. Doc. 2004/058.

Mowbray, F.K. 2002. Changes in the vertical distribution of capelin (*Mallotus villosus*) off Newfoundland. ICES J. Mar. Sci. **59:** 942-949.

Ona, E., and Mitson, R.B. 1996. Acoustic sampling and signal processing near the seabed: the deadzone revised. ICES J. Mar. Sci. **53**: 677-690.

Ona, E., Pennington, M., and Voelstad, J.H. 1991. Using acoustics to improve the precision of bottom trawl indices of abundance. ICES CM 1991/D:13.

Power, D. 2003. Distribution of redfish in NAFO Divisions 3LNO based on Canadian research surveys from 1991-2002. NAFO SCR Doc. 03/60.

Rose, G.A., Nelson, R.J., and Mello, L.G.S. 2011. Isolation or metapopulation: whence and whither the Smith Sound cod? Can. J. Fish. Aquat. Sci. **68**: 152-169.

Rose, G.A., deYoung, B., Kulka, D.W., Goddard, S.V., and Fletcher, G.L. 2000. Distribution shifts and overfishing the northern cod *Gadus morhua*): a view from the ocean. Can. J. Fish. Aquat. Sci. **57**: 644-663.

Stockwell, J.D., Yule, D.L., Gorman, O.T., Isaac, E.J., and Moore, S.A. 2006. Evaluation of bottom trawl as compared to acoustics to assess adult lake herring (*Coregonus artedi*) abundance in Lake Superior. J. Great Lakes Res. **32**: 280-292.

Totland, A., Johansen, G.O., Godø, O.R., Ona, E., and Torkelsen,T. 2009. Quantifying and reducing and surface blind zone and the seabed dead zone using new technology. ICES J. Mar. Sci. **66**: 1370-1383.

von Szalay, P.G., Somerton, D.A., and Kotwicki, S. 2007. Correlating trawl and acoustic data in the eastern Bering Sea: A first step toward improving biomass estimates of walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*)? Fish. Res. **86**: 77-83.

von Szalay, P.G., and Somerton, D.A. 2009. A comparison of acoustic backscatter between a trawling and a free-running vessel for eastern Bearing Sea walleye pollock (*Theragra chalcogramma*). Fish. Res. **96**: 223-229.

Yule, D.L., Adams, J.V., Stockwell, J.D., and Gorman, O.T. 2008. Factors affecting bottom trawl catches: implications for monitoring the fishes of Lake Superior. N. Am. J. Fish. Manag. **28**: 109-122.

Yule, D.L., Stockwell, J.D., Schreiner, D.R., Evrard, L.M., Balge, M., and Hrabik, T.R. 2007. Can pelagic forage fish and spawning cisco (*Coregonus artedi*) biomass in the western arm of Lake Superior be assessed with a single summer survey? Fish. Res. **96**: 39-50.

Table 1. Information on vessels, legs, date and number of tows conducted during the fall 2008 multi-species bottom trawl survey in NAFO Divisions 2J3KLNO.

Vessel	Survey leg	Date	No. of tow
Teleost	817	Oct 4-9	35
	818	Oct 11-18	37
	820	Nov 7-10	21
	821	Nov 23-24	10
W. Templeman	835	Oct 3-6	23
	836	Oct 14-20	48
	837	Oct 24-Nov 3	81
	838	Nov 6-15	86
	839	Nov 21-Dec 1	69
	840	Dec 4-11	33
	841	Dec 19-21	19
A. Needler	867	Nov 1-2	10
	868	Nov 6-13	49
	869	Nov 26-Dec 7	39
Total			560

Table 2. Overall number and percentage of acoustic classification per category recorded during the fall 2008 bottom trawl survey in NAFO Divisions 2J3KLNO. The number of observations refers to the summation of acoustic classifications per integration bin (100 m long x 10 m deep cell in echograms).

Category	Observation	
	No.	%
Capelin	228157	11
Cod	29548	1
Myctophids	260337	12
Redfish	305457	14
Shrimp	116020	5
Sandlance	38012	2
Herring	40	0.002
Unspecified demersal	23375	1
Unspecified pelagic	60241	3
Unspecified zooplankton	1098706	51
Unclassified	6160	0.3
Total	2166053	

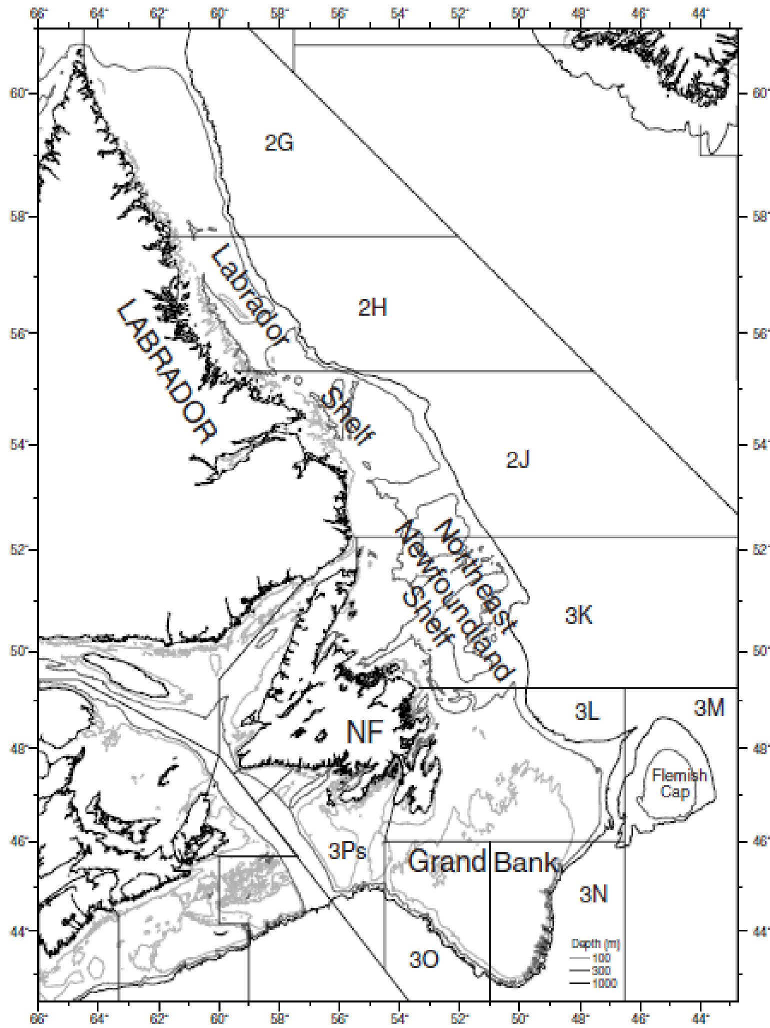

Figure 1. NAFO fisheries management Divisions of the Northwest Atlantic Ocean, bathymetry and areas cited in the text.

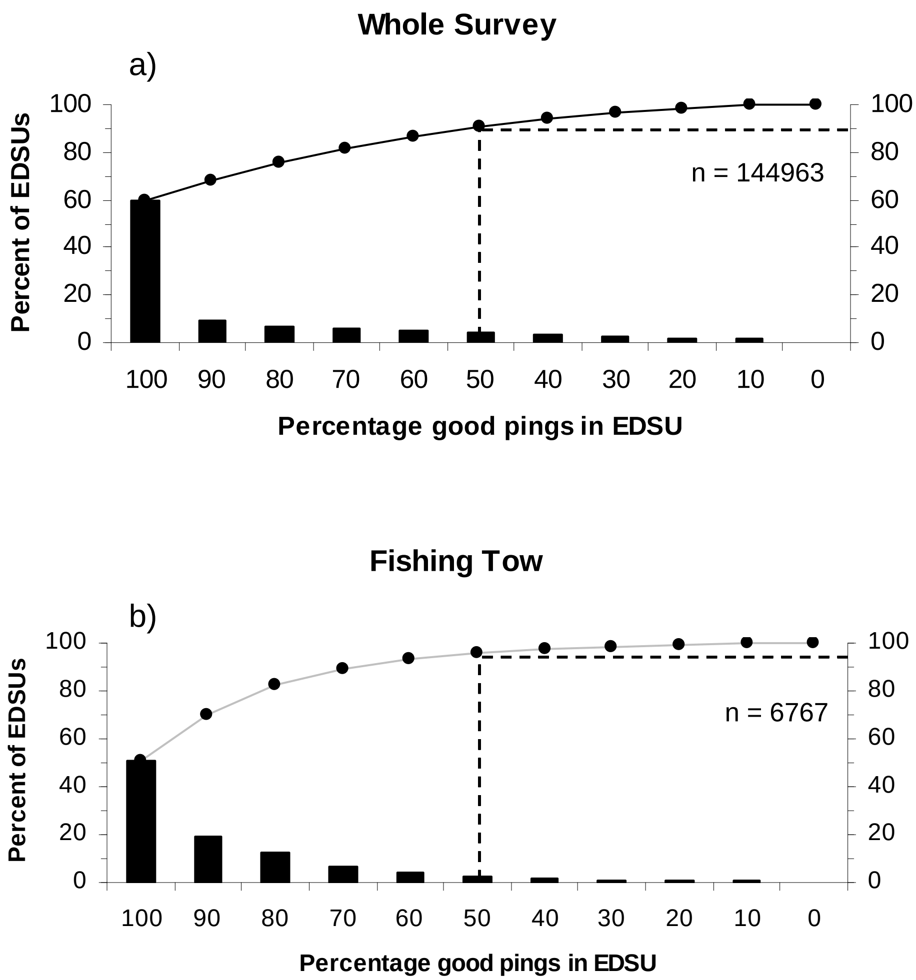

Figure 2. Proportion of the acoustic data used for quantitative and distribution estimation in (a) the study area and (b) fishing tows.

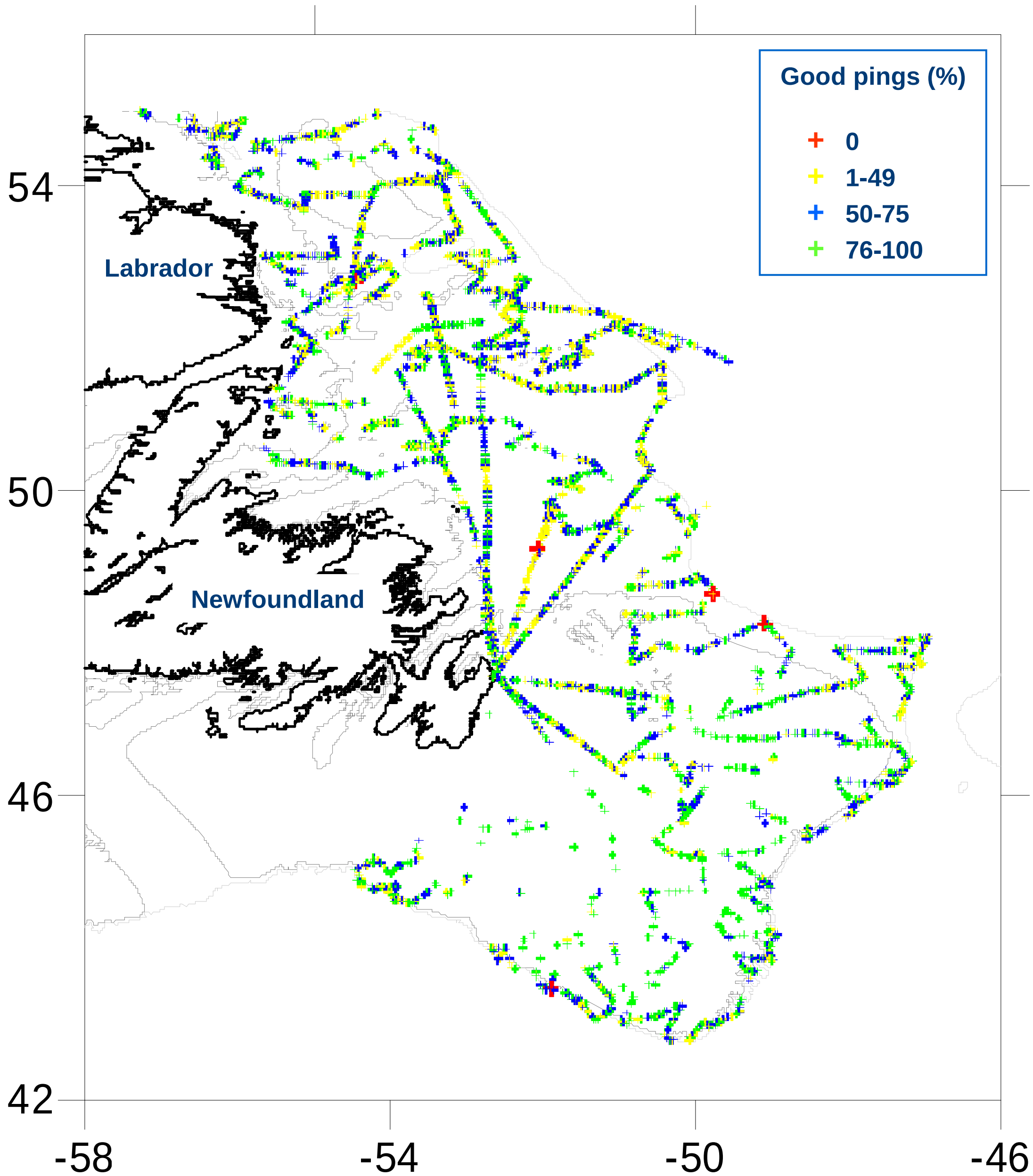

Figure 3. Geographic distribution of s_a estimation according to the data quality classification (good pings %).

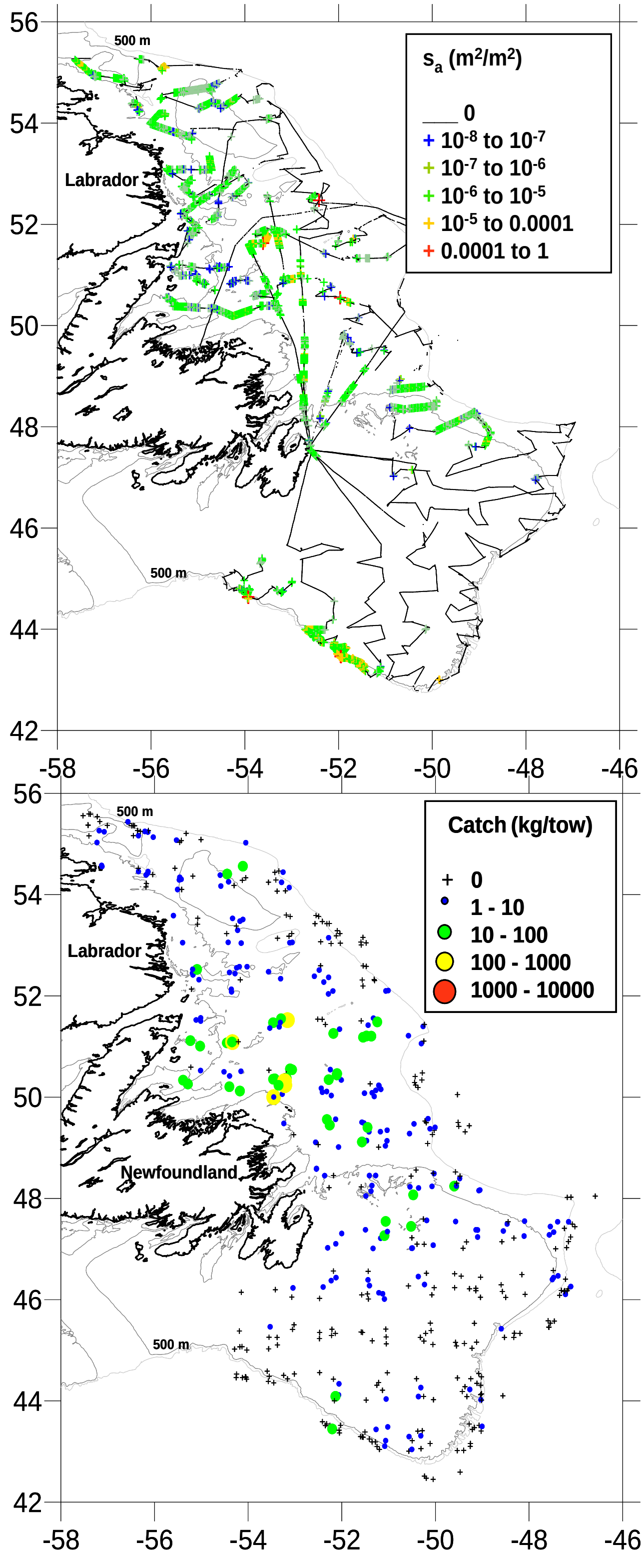

Figure 4. Distribution of s_a attributed to capelin (upper panel) and catch weight per tow (lower panel) from the 2008 fall bottom trawl survey.

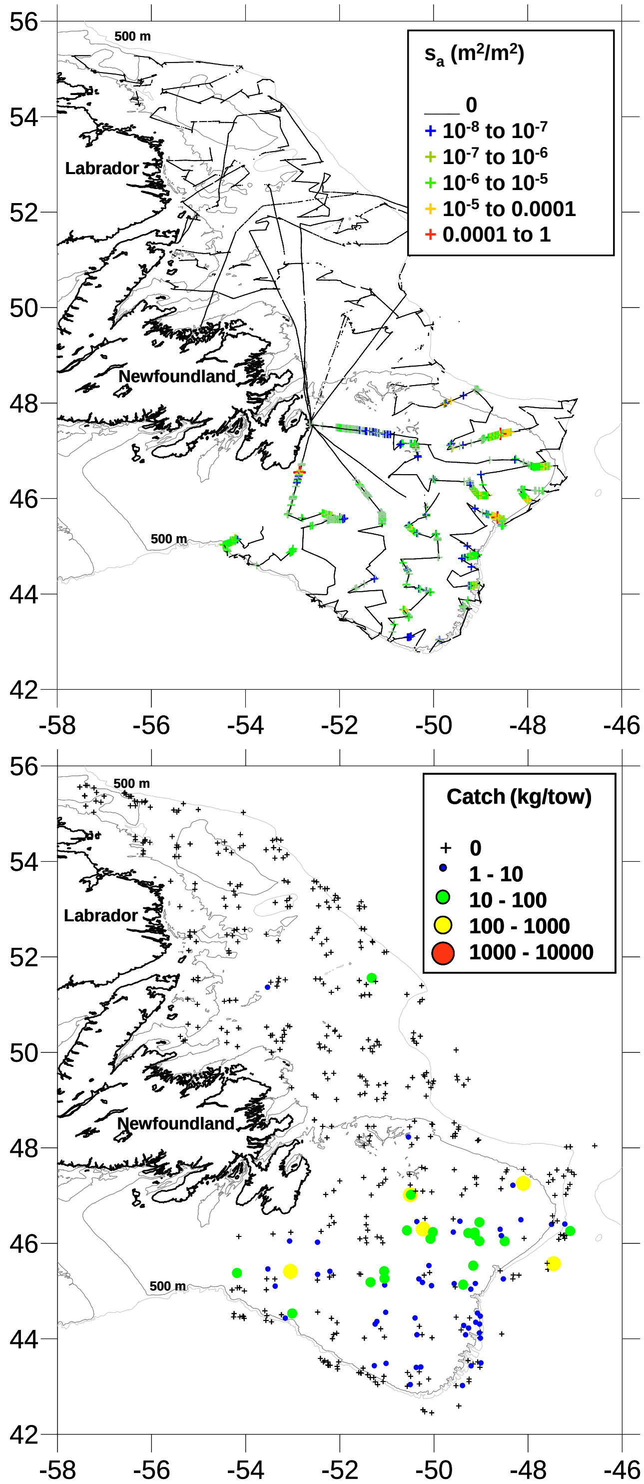

Figure 5. Distribution of s_a attributed to sandlance (upper panel) and catch weight per tow (lower panel) from the 2008 fall bottom trawl survey.

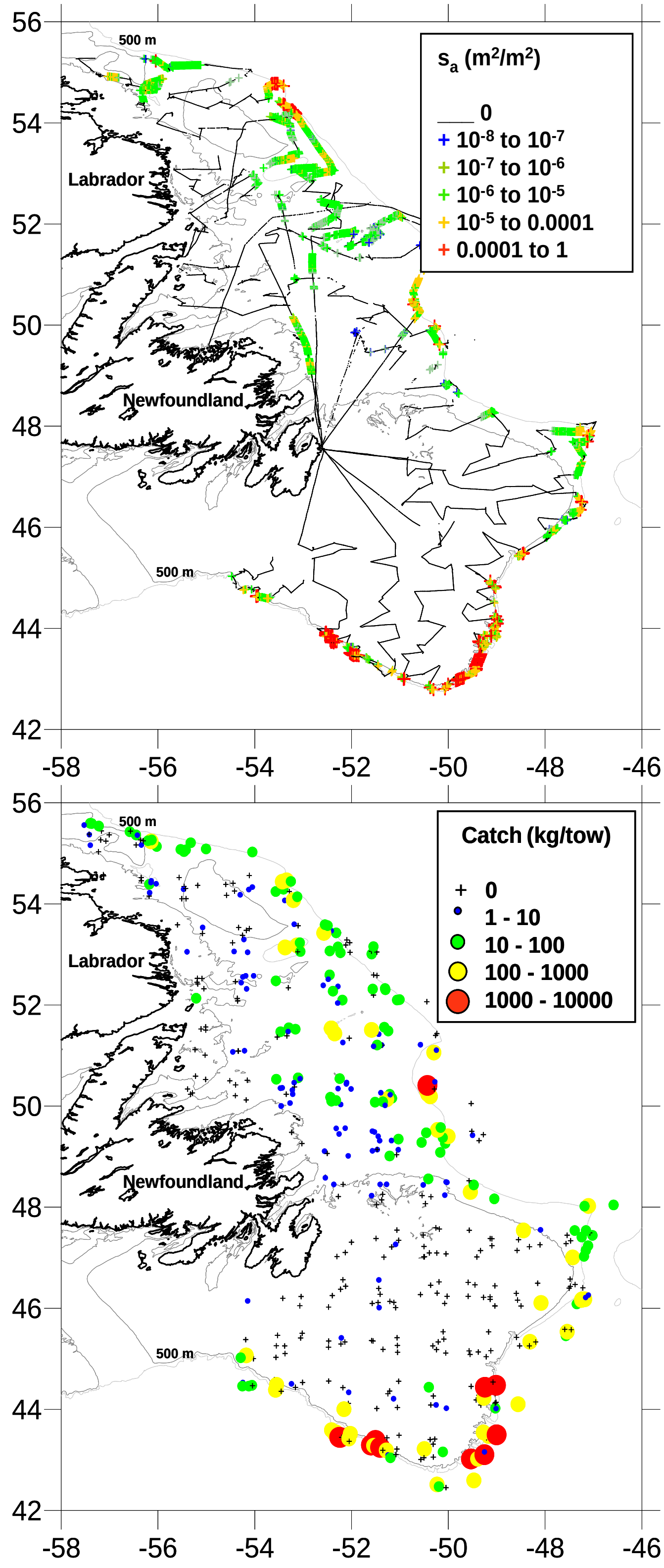

Figure 6. Distribution of s_a attributed to redfish (upper panel) and catch weight per tow (lower panel) from the 2008 fall bottom trawl survey.

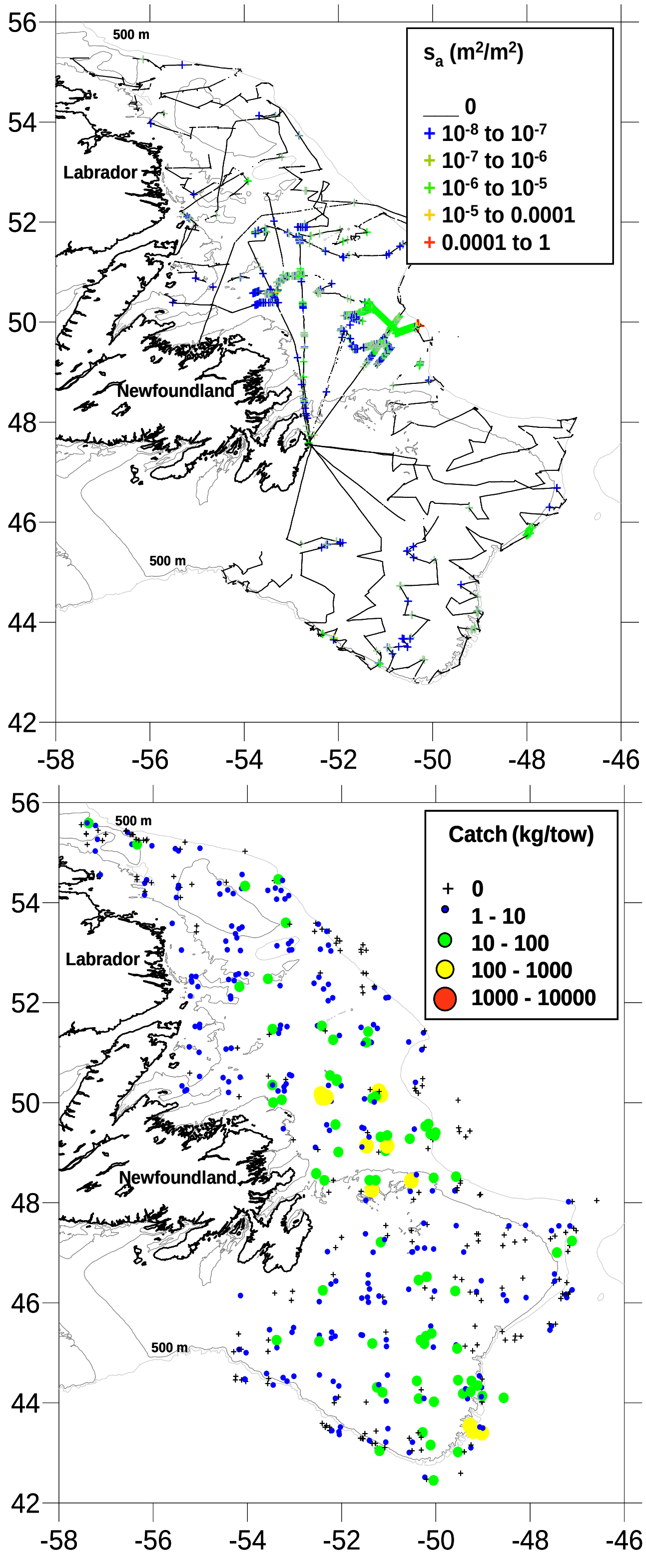

Figure 7. Distribution of s_a attributed to cod (upper panel) and catch weight per tow (lower panel) from the 2008 fall bottom trawl survey.

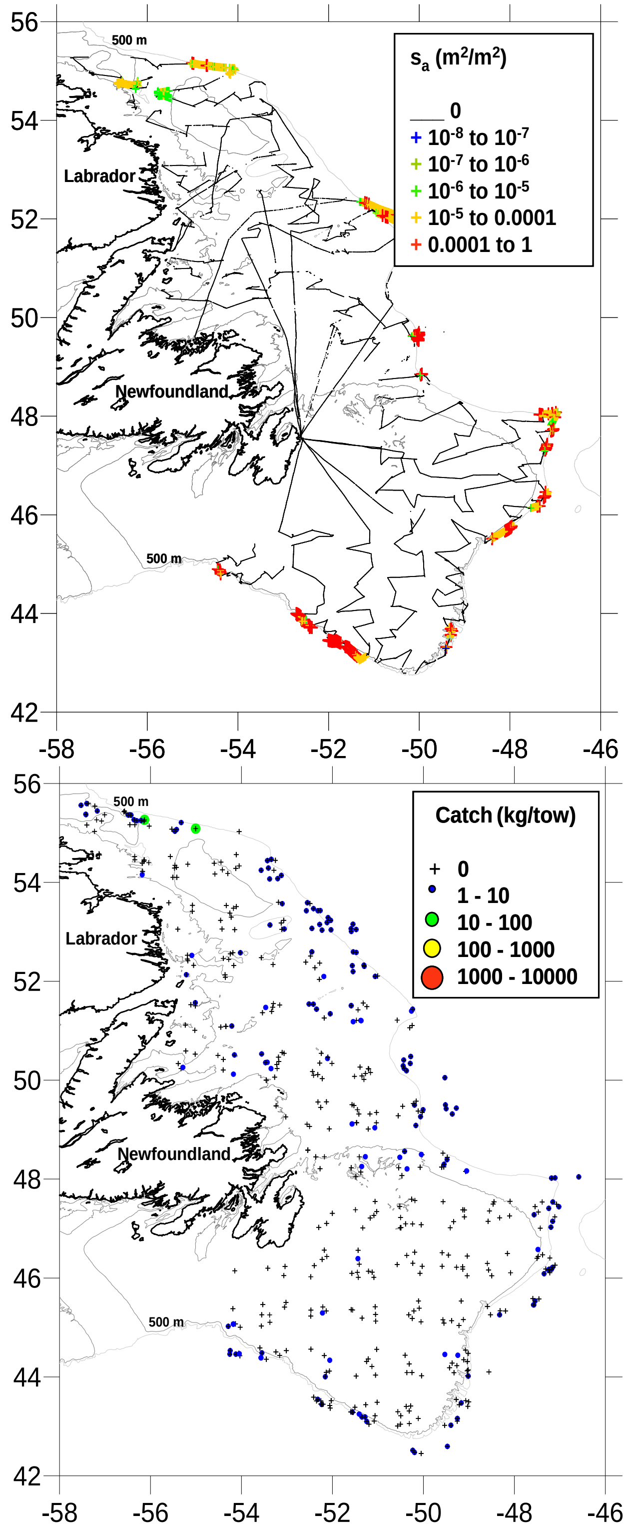

Figure 8. Distribution of s_a attributed to myctophids (upper panel) and catch weight per tow (lower panel) from the 2008 fall bottom trawl survey.

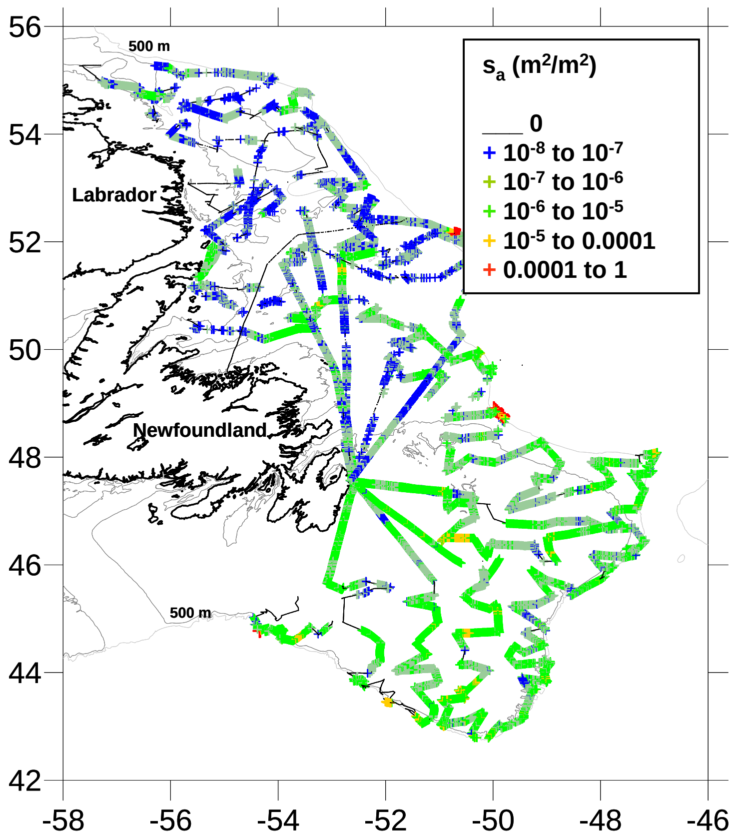

Figure 9. Distribution of s_a attributed to unspecified zooplankton from the 2008 fall bottom trawl survey. No catch data are available.

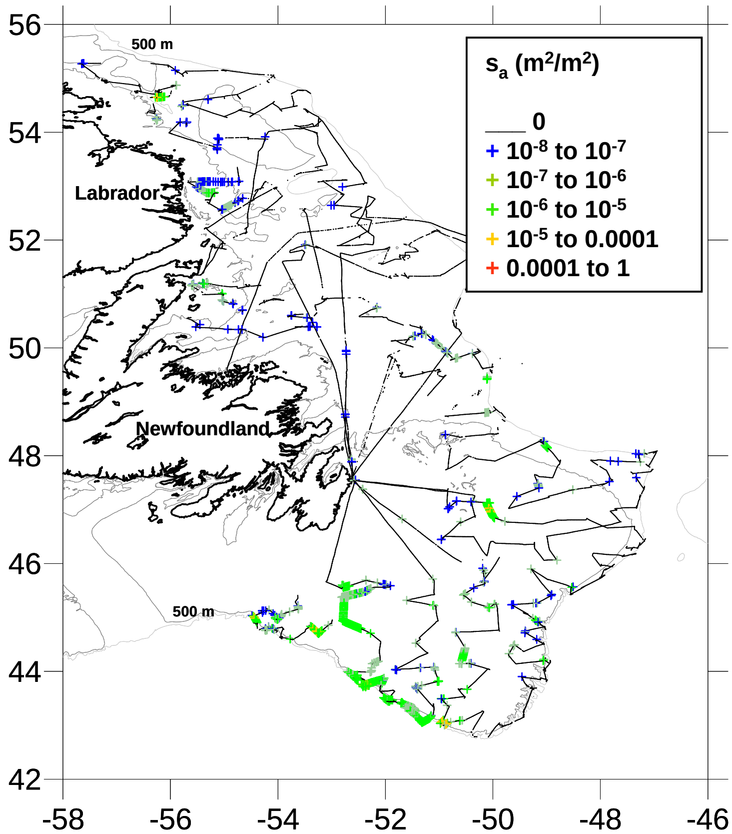

Figure 10. Distribution of s_a attributed to unspeciated pelagic fish from the 2008 fall bottom trawl survey.

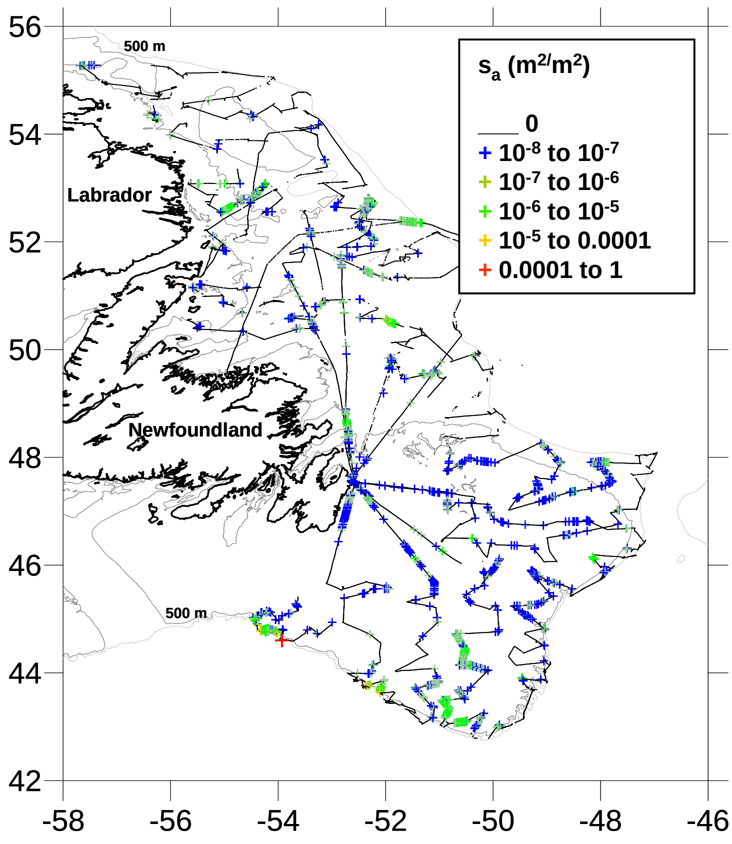

Figure 11. Distribution of s_a attributed to unspeciated demersal fish from the 2008 fall bottom trawl survey.