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Results of the Atlantic mackerel (*Scomber scombrus* L.) egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009

Résultats du relevé des œufs de maquereau bleu (*Scomber scombrus* L.) réalisé sur le plateau néo-écossais et la côte sud de Terre-Neuve en 2009

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ABSTRACT

Using funds from the Larocque Scientific Program, a survey of Atlantic mackerel (*Scomber scombrus* L.) eggs was conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. The objectives of the survey were to describe the spatial egg distribution and to calculate the daily and total egg productions and the corresponding spawning biomass. The survey was also intended to test the hypothesis that a significant portion of the Canadian contingent of Atlantic mackerel could spawn in this region for some years. During the survey, Atlantic mackerel eggs were found in only 28 (30%) of the 93 stations sampled. The mean daily egg production per station was estimated at 0.162 eggs/m^2, which is much lower than the productions measured in the southern Gulf of St. Lawrence. Daily egg production and total egg production for the entire sampled area were estimated respectively at 3.322 x 10^{10} and 1.884 x 10^{12} eggs for a spawning biomass of only 2,576 t (2,141-3,010 t). Water temperatures varied between 4.8 and 11.7°C, with a mean of 8.8°C. Compared to similar temperatures, higher egg densities have been already measured in the southern Gulf of St. Lawrence. The survey results rule out the possibility that a significant portion of the Canadian contingent spawns on the Scotian Shelf and Newfoundland's South Coast. The results also suggest that the low egg densities measured in the southern Gulf of St. Lawrence since 2005 reflect a real decline in stock abundance.

RÉSUMÉ

À l'aide de fonds provenant du Programme scientifique Larocque, un relevé des œufs de maquereau bleu (*Scomber scombrus* L.) a été réalisé en 2009 sur le plateau néo-écossais et la côte sud de Terre-Neuve. Ce relevé avait pour objectifs de décrire la distribution spatiale des œufs et de calculer les productions quotidienne et totale d'œufs de même que la biomasse reproductrice correspondante. Le relevé avait aussi pour objectif de vérifier l'hypothèse qu'une portion importante du contingent canadien de maquereau bleu pourrait se reproduire dans cette région depuis quelques années. Lors du relevé, des œufs de maquereau bleu n'ont été retrouvés qu'à 28 (30 %) des 93 stations échantillonnées. La production journalière moyenne d'œufs par station a été estimée à 0,162 œufs/m^2 ce qui est de loin inférieur aux productions mesurées dans le sud du golfe du Saint-Laurent. La production journalière d'œufs pour toute la zone échantillonnée et la production totale ont été estimées respectivement à 3,322 x 10^{10} et 1,884 x 10^{12} œufs pour une biomasse reproductrice de seulement 2 576 t (2 141-3 010 t). Les températures de l'eau ont varié entre 4,8 et 11,7 °C pour une moyenne de 8,8 °C. Comparativement à des températures moyennes similaires, de plus fortes densités d'œufs ont déjà été mesurées dans le sud du golfe du Saint-Laurent. Les résultats du relevé excluent la possibilité qu'une portion importante du contingent canadien se reproduise sur le plateau néo-écossais et la côte sud de Terre-Neuve. Les résultats suggèrent aussi que les faibles densités d'œufs mesurées dans le sud du golfe du Saint-Laurent depuis 2005 reflèteraient une baisse réelle d'abondance.

1. INTRODUCTION

The southern Gulf of St. Lawrence has long been identified as the main spawning area of Atlantic mackerel (*Scomber scombrus* L.) in Canadian waters (Sette 1943, Arnold 1970). Exploratory ichthyoplankton surveys were conducted from the mid-1960s until the end of the 1970s (Grégoire and Lafleur 2006a; Grégoire and Faucher 2006b), and an index of the spawning biomass has been calculated since 1983 (Grégoire *et al*. 2008). This index fell sharply in the mid-1990s (DFO 2008) and commercial landings alone cannot fully explain this reduction. Although commercial landings showed a major increase during the 2000s (Grégoire *et al*. 2009), this increase happened after the abundance index fell sharply. It has therefore been suggested that this decrease in abundance was caused by a greater proportion of fish reproducing outside the southern Gulf of St. Lawrence.

Sette (1943) mentions that spawning can occur on the Scotian Shelf during the spring migration. In fact, mackerel eggs were sampled in St. Margaret's Bay, near Halifax, during an exploratory survey conducted in 1999 (Bernier et Lévesque 2000). Mackerel eggs and larvae were also sampled in a series of surveys conducted in partnership with the industry on the west coast of Newfoundland between 2004 and 2009 (Grégoire *et al*. 2012). These observations confirm that mackerel also spawns outside the southern Gulf of St. Lawrence.

An egg survey was conducted on the Scotian Shelf and Newfoundland's South Coast in June 2009, shortly before the regular annual southern Gulf of St. Lawrence egg survey. The objectives of this survey were to describe the spatial egg distribution and to calculate daily and total egg productions and the corresponding spawning biomass. The survey also had as an objective to test the hypothesis that a significant portion of the Canadian contingent of Atlantic mackerel could spawn on the Scotian Shelf and Newfoundland's South Coast for some years. The results of this survey are presented in detail in this document.

2. MATERIAL AND METHODS

2.1 SAMPLING AT SEA

The survey took place between June 2 and 17, 2009. Due to bad weather, the survey was conducted in three stages: from June 2 to 6 for stations 19.6 to 17.1, from June 7 to 12 for stations 16.4 to 8.5, and finally from June 13 to 17 for stations 8.6 to 7.6 (Figure 1). Poor weather conditions made it impossible to sample all planned stations.

Plankton sampling was carried out using two bongo nets (Posgay and Marak 1980). Each net had a diameter of 61 cm and a mesh size of 333 microns. Tows, which lasted a minimum of 10 minutes, were made following a sawtooth pattern (Hempel 1973) from the surface to a maximum of 50 m deep, or at 5 m from the bottom for the stations in shallow water. The volume of water filtered through the nets was measured using two flowmeters positioned in the net openings. Once on deck, the nets were rinsed with seawater. Samples from the portside nets were stored in a 4-5% formaldehyde solution (Hunter 1985), while those from the starboard nets were stored in 95% ethanol. A CTD probe (Sea-Bird SBE-19) was used before the bongo nets tows to measure water temperature and depth. Temperature profiles were presented in groups of at least 10 stations for greater ease of interpretation.

2.2 LABORATORY ANALYSES

The plankton samples were analysed in the fall of 2009. Samples were fractionated using Van Guelpen's beaker method (Van Guelpen *et al*. 1982). The eggs and larvae of all fish species were identified using the criteria in Fritzsche (1978), Elliott and Jimenez (1981) and Fahay (1983). Egg and larva counts for each separated fraction of the sample were reported as number per 1000 m^3 and number per m^2, taking into account the volume of water filtered (m^3) and the maximum depth sampled (m).

2.3 DATA ANALYSES

Total egg production (eggs of stages 1 and 5; Girard 2000) for the entire area sampled was used to calculate the spawning stock biomass according to the Total Egg Production Method (TEPM). This method is an adaptation of a model proposed by Saville (1977) and is defined as follows:

$$B = \frac{P \cdot A \cdot W}{S \cdot F \cdot R \cdot 10^6} \quad (1)$$

where :

P= Mean daily egg production (n/m^2) per station (kriged mean)
A= Surface of the area sampled ($2.0461 \times 10^{11} m^2$)
W= Mean weight (g) of a mackerel
S= Proportion of eggs spawned at the median date of the survey
F= Fecundity calculated following the model of Pelletier (1986)
R= Sex ratio (proportion of females)
10^6 = Correction factor for grams to tons

2.3.1 <u>Mean daily egg production</u> (P)

Egg abundances (n/m^2) at the sampling stations were converted into daily production as follows:

$$\frac{\text{Abundance (stages 1 and 5) } (n/m^2)}{\text{Incubation time (hr)}} \bullet 24 \text{ (hr)} \quad (2)$$

where the time of incubation (hr) was calculated according to the model of Lockwood *et al*. (1977) from the mean temperature (°C) in the first 10 m of water. The mean daily egg production per station (**P**) was calculated using the ordinary kriging. Variogram parameters and semivariance were calculated using GS^+ software (Robertson 1998). Kriging average and variance were calculated using the EVA II software (Petitgas and Lafont 1997).

2.3.2 <u>Surface of the area sampled</u> (A)

The surface of the area sampled (**A**), delimited by a contour polygon, was estimated (by EVA II) at $2.0461 \times 10^{11} m^2$. The daily egg production for the entire sampled area was defined as **PA**.

2.3.3 Proportion of eggs spawned daily (S)

The proportion of eggs spawned at the median date of the survey (**S**) was calculated using a logistic model describing daily changes in the gonadosomatic index (GSI). The model is defined as follows:

$$(3) \quad y = y_0 + \frac{a}{\left[1 + \left(\frac{x}{x_0}\right)^b\right]}$$

where y is the gonadosomatic index, x is the day and y_0, a, x_0 and b are the model parameters.

Daily GSI means were calculated from all biological samples collected during the 2009 fishing season. These same samples were used to calculate the mean weight of a mackerel (**W**), the female fecundity (**F**), and the sex ratio (**R**).

2.3.4 Total egg production (PA/S) and spawning biomass

The total egg production is defined as the product of the mean daily egg production per station (**P**) and the surface of the area sampled (**A**), divided by the proportion of eggs spawned at the median date of the survey (**S**). The total egg production was converted into spawning biomass using equation 1, considering the biological parameters (**W**, **F** and **R**) of the fish sampled.

3. RESULTS

3.1 ABUNDANCE OF EGGS AND LARVAE

Atlantic mackerel eggs were found in 28 (30%) of the 93 stations sampled. The mean abundance per station was estimated at 15.21 eggs/1000 m^3 and a maximum of 365.70 eggs/1000 m^3 was measured at station 9.3 (Table 1; Figure 1). This was also the station where all the stages of development were sampled. The most abundant eggs were those of stage 1 with an average of 7.98 eggs/1000 m^3. They were followed by stages 3, 5, 2, and 4 with respective averages of 2.61, 2.38, 2.11, and 0.14 eggs/1000 m^3. Mackerel larvae were found in only three stations with a mean abundance estimated at 0.16 larvae/1000 m^3. The mean egg abundance per station, expressed in number/m^2, was estimated at 0.75 eggs/m^2, with a maximum of 18.28 eggs/m^2 (Table 2). The mean abundance per station of stages 1 and 5 was 0.51 eggs/m^2, resulting in a mean daily egg production per station of 0.17 eggs/m^2 (Table 3).

3.2 TEMPERATURE PROFILES

Most of the stations presented a sharp decline in water temperature between the surface and about 50 m deep (Figure 2). This decline was more important for the stations located in the eastern part of the Scotian Shelf and in southern Newfoundland. For the deep-water stations, the temperature rose to 8°C and higher at depths of about 100 m.

Temperatures in the first 10 m ranged from 4.76 to 11.72°C for an average of 8.72°C (Table 3). For the same layer of water, incubation times ranged from 44.59 to 190.19 hr

for an average of 75.05 hr. The mean water temperature for the stations with eggs was 8.58°C, compared to 8.78°C for the stations where no eggs were found. No significant difference (t-test, $t=-0.73$, $p>0.05$) in water temperature was measured between these two groups of stations.

3.3 SPATIAL DISTRIBUTION

Most of the eggs were sampled along the coast in the area located between southwestern Nova Scotia and Georges Bank (Figures 3 and 4). Eggs were also sampled at the edge of the continental shelf. Mackerel larvae were found in stations 20.5 and 21.4 at the beginning of the survey, and in station 7.7 at the end (Figures 5A and 5B).

3.4 EGGS OF STAGES 1 AND 5

The egg distributions of stages 1 and 5 are presented in Figures 6A (n/1000 m^3) and 6B (n/m^2). The mean water temperature (0-10 m) at these stations ranged from 5.65 to 10.43°C (Figure 6C). Temperature was 7.67°C or lower in 5 of these stations, between 8.01 and 9.62°C in 18 stations, and 10.15°C or higher in five other stations. Daily egg production per station was less than 0.43 eggs/m^2 at 21 of the 28 stations. It ranged between 0.67 and 1.13 eggs/m^2 at four stations, and between 1.17 and 3.79 eggs/m^2 at three other stations (Figure 6D).

3.5 KRIGING

The spatial distribution of the daily egg production (eggs of stages 1 and 5) was modelled using a spherical variogram (Table 4; Figure 7). The mean daily egg production per station (**P**) at the median date of the survey was estimated at 0.162 eggs/m^2, while daily egg production (**PA**) for the entire sampled area (Figure 8) was estimated at 3.322×10^{10} eggs (Table 5).

3.6 GONADOSOMATIC INDEX AND PROPORTION OF EGGS SPAWNED DAILY

The gonadosomatic index reached a maximum on June 12 (day 163 of the year) (Figure 9A) and values less than 2% from June 22 (day 173). According to the logistic model, the proportion of eggs spawned at the median date of the survey (June 9.5, or day 160.5) was 0.0176 (Figure 9B).

3.7 TOTAL EGG PRODUCTION AND SPAWNING BIOMASS

Total egg production (**PA/S**) was estimated at 1.884×10^{12} eggs (Table 5). The proportion of females in the samples was 0.508, and the average weight of a fish and fecundity were estimated at 342.2 g and 492,810 eggs. The spawning biomass was estimated at only 2,576 t with 95% confidence upper and lower limits of 2,141 and 3,010 t (Table 5).

4. DISCUSSION AND CONCLUSION

One of the main objectives of the survey conducted on the Scotian Shelf and Newfoundland's South Coast was to evaluate the spawning biomass of Atlantic mackerel from these areas. No such survey had ever been conducted in the past. Mackerel eggs were sampled, but only at a few stations. The mean daily egg production per station, calculated at only 0.162 eggs/m^2, was much less than what was measured in 2009 in the southern Gulf of St. Lawrence (27.428 eggs/m^2; unpublished data) and on the west coast of Newfoundland (6.028 eggs/m^2; unpublished data).

The low egg production found on the Scotian Shelf and Newfoundland's South Coast could be explained by the lower water temperatures that were measured in these areas. For this survey, the mean water temperature was 8.7°C (0-10 m) compared to 10.8°C for the southern Gulf of St. Lawrence survey. However, for similar temperatures (8.5-9.0°C), more important egg productions have already been measured in the southern Gulf of St. Lawrence (Figure 10), which suggests that the production measured on the Scotian Shelf and Newfoundland's South Coast was unusually low.

Commercial fixed-gear catches along the Nova Scotia coast have fallen sharply in the last few years. They went from 6,681 t in 1995 to 2,647 t in 2007 (Grégoire *et al*. 2009), and later to 1,453 t and 666 t (preliminary) in 2009 and 2010 (F. Grégoire, unpublished data). In addition, Atlantic mackerel have almost disappeared from the multidisciplinary groundfish surveys that cover annually the whole Scotian Shelf (Grégoire *et al*. 2009). The lower numbers of Atlantic mackerel observed in this area may ultimately explain the low egg production measured during the survey. This suggests that mackerel egg production on the Scotian Shelf may have been higher in the late 1990s and early 2000s than in 2009. There is also indirect evidence that a substantial fraction of the very large 1999 year-class may have been spawned outside the traditional southern Gulf of St. Lawrence spawning area, possibly on the Scotian Shelf.

The very low egg production measured on the Scotian Shelf and Newfoundland's South Coast excludes the possibility that a significant portion of the Canadian contingent spawns in these areas. The results also suggest that the low egg production measured in the southern Gulf of St. Lawrence since 2005 reflect a real decline in abundance.

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Table 1. Atlantic mackerel eggs and larvae abundance (n/1000 m^3) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. Egg counts are grouped by development stage (Girard 2000).

CONS.	STATION	DATE (dd-mm)	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	NUMBER / 1000 m^3						
					EGGS						LARVAE
					STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL	
1	19.6	02-06	66° 20'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	20.5	02-06	66° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	4.72
3	21.4	03-06	67° 15'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	7.01
4	21.3	03-06	67° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	21.2	03-06	67° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	21.1	03-06	67° 15'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	20.1	03-06	66° 45'	42° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	19.2	03-06	66° 15'	42° 00'	0.00	0.00	0.00	0.00	3.24	3.24	0.00
9	19.1	03-06	66° 15'	41° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	18.1	04-06	65° 45'	41° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	18.2	04-06	65° 45'	42° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	18.3	04-06	65° 45'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	19.3	04-06	66° 15'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	20.2	04-06	66° 45'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	20.3	04-06	66° 45'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	20.4	04-06	66° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	19.5	05-06	66° 15'	43° 30'	29.00	10.88	7.25	0.00	3.63	50.75	0.00
18	19.4	05-06	66° 15'	43° 00'	259.57	3.29	0.00	0.00	0.00	262.85	0.00
19	18.4	05-06	65° 45'	43° 00'	17.38	2.90	0.00	0.00	11.58	31.86	0.00
20	18.5	05-06	65° 44'	43° 19'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	17.4	05-06	65° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	17.3	05-06	65° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	17.2	05-06	65° 15'	42° 30'	15.51	0.00	0.00	0.00	0.00	15.51	0.00
24	17.1	06-06	65° 15'	42° 01'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	16.4	07-06	64° 43'	43° 48'	12.93	0.00	0.00	0.00	12.93	25.86	0.00
26	16.3	08-06	64° 45'	43° 30'	3.33	0.00	0.00	0.00	6.66	9.98	0.00
27	16.2	08-06	64° 45'	43° 00'	3.70	3.70	0.00	0.00	0.00	7.40	0.00
28	15.2	08-06	64° 15'	43° 00'	21.00	0.00	0.00	0.00	0.00	21.00	0.00
29	15.3	08-06	64° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	15.4	08-06	64° 15'	44° 00'	68.41	31.58	10.53	0.00	0.00	110.51	0.00
31	15.5	08-06	64° 07'	44° 12'	16.83	0.00	0.00	0.00	5.61	22.45	0.00
32	14.5	08-06	63° 46'	44° 13'	57.69	16.97	0.00	0.00	0.00	74.66	0.00
33	14.4	08-06	63° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	12.4	09-06	63° 16'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	13.3	09-06	62° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	11.3	09-06	62° 15'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	10.2	09-06	61° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	10.1	09-06	61° 45'	43° 00'	3.77	0.00	0.00	0.00	0.00	3.77	0.00
39	11.1	09-06	62° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	13.1	09-06	62° 45'	43° 00'	6.33	0.00	0.00	0.00	0.00	6.33	0.00
41	12.2	09-06	63° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	14.2	10-06	63° 45'	43° 00'	3.11	3.11	0.00	0.00	0.00	6.23	0.00
43	14.3	10-06	63° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	12.3	10-06	63° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	13.2	10-06	62° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	11.2	10-06	62° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	10.3	10-06	61° 45'	44° 00'	3.96	0.00	0.00	0.00	0.00	3.96	0.00
48	10.4	10-06	61° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 1. (Continued).

CONS.	STATION	DATE (dd-mm)	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	NUMBER / 1000 m^3						
					EGGS						LARVAE
					STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL	
49	11.4	10-06	62° 15'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	13.4	11-06	62° 45'	44° 30'	25.92	0.00	0.00	0.00	0.00	25.92	0.00
51	11.5	11-06	62° 15'	44° 47'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	10.5	11-06	61° 45'	45° 00'	65.66	0.00	0.00	0.00	0.00	65.66	0.00
53	9.5	11-06	61° 15'	45° 00'	35.39	0.00	0.00	0.00	7.08	42.47	0.00
54	9.4	11-06	61° 15'	44° 30'	19.96	0.00	99.79	0.00	0.00	119.75	0.00
55	9.3	11-06	61° 15'	44° 16'	6.20	117.77	105.37	6.20	130.16	365.70	0.00
56	8.4	11-06	60° 45'	45° 00'	0.00	3.05	9.16	0.00	12.21	24.42	0.00
57	8.5	12-06	60° 45'	44° 30'	0.00	0.00	0.00	0.00	3.42	3.42	0.00
58	8.6	13-06	60° 44'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	7.5	13-06	60° 15'	45° 30'	17.45	0.00	0.00	0.00	4.36	21.82	0.00
60	6.5	13-06	59° 45'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	5.5	13-06	59° 15'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	5.4	13-06	59° 15'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	6.4	14-06	59° 45'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	7.4	14-06	60° 15'	45° 00'	0.00	0.00	0.00	0.00	3.99	3.99	0.00
65	7.3	14-06	60° 15'	44° 31'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	7.2	14-06	60° 15'	44° 07'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	6.2	14-06	59° 45'	44° 07'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	6.3	14-06	59° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	5.3	14-06	59° 15'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	4.2	14-06	58° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	4.3	15-06	58° 45'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	4.4	15-06	58° 45'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	3.4	15-06	58° 15'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	3.5	15-06	58° 15'	46° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	3.6	15-06	58° 15'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	3.7	15-06	58° 15'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	2.6	15-06	57° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	M	15-06	57° 15'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	N	16-06	57° 15'	47° 23'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	2.7	16-06	57° 45'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	3.8	16-06	58° 15'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	4.8	16-06	58° 45'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	5.9	16-06	59° 15'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	5.8	16-06	59° 15'	47° 00'	0.00	0.00	4.16	0.00	0.00	4.16	0.00
85	4.7	16-06	58° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	4.6	16-06	58° 45'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	4.5	17-06	58° 45'	46° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	5.6	17-06	59° 15'	46° 00'	6.69	0.00	0.00	0.00	0.00	6.69	0.00
89	6.6	17-06	59° 41'	45° 57'	6.87	3.43	0.00	0.00	0.00	10.30	0.00
90	6.7	17-06	59° 45'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	6.8	17-06	59° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	7.7	17-06	60° 15'	47° 00'	35.34	0.00	6.43	6.43	16.07	64.26	3.21
93	7.6	17-06	60° 15'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Min.:				0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average:				7.98	2.11	2.61	0.14	2.38	15.21	0.16
	Max.:				259.57	117.77	105.37	6.43	130.16	365.70	7.01

Table 2. Atlantic mackerel eggs and larvae abundance (n/m^2) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. Egg counts are grouped by stage of development (Girard 2000).

CONS.	STATION	DATE (dd-mm)	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	NUMBER / m^2						
					EGGS						LARVAE
					STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL	
1	19.6	02-06	66° 20'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	20.5	02-06	66° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.24
3	21.4	03-06	67° 15'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.35
4	21.3	03-06	67° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	21.2	03-06	67° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	21.1	03-06	67° 15'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	20.1	03-06	66° 45'	42° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	19.2	03-06	66° 15'	42° 00'	0.00	0.00	0.00	0.00	0.16	0.16	0.00
9	19.1	03-06	66° 15'	41° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	18.1	04-06	65° 45'	41° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	18.2	04-06	65° 45'	42° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	18.3	04-06	65° 45'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	19.3	04-06	66° 15'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	20.2	04-06	66° 45'	42° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	20.3	04-06	66° 45'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	20.4	04-06	66° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	19.5	05-06	66° 15'	43° 30'	1.31	0.49	0.33	0.00	0.16	2.28	0.00
18	19.4	05-06	66° 15'	43° 00'	12.98	0.16	0.00	0.00	0.00	13.14	0.00
19	18.4	05-06	65° 45'	43° 00'	0.87	0.14	0.00	0.00	0.58	1.59	0.00
20	18.5	05-06	65° 44'	43° 19'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	17.4	05-06	65° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	17.3	05-06	65° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	17.2	05-06	65° 15'	42° 30'	0.78	0.00	0.00	0.00	0.00	0.78	0.00
24	17.1	06-06	65° 15'	42° 01'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	16.4	07-06	64° 43'	43° 48'	0.65	0.00	0.00	0.00	0.65	1.29	0.00
26	16.3	08-06	64° 45'	43° 30'	0.17	0.00	0.00	0.00	0.33	0.50	0.00
27	16.2	08-06	64° 45'	43° 00'	0.18	0.18	0.00	0.00	0.00	0.37	0.00
28	15.2	08-06	64° 15'	43° 00'	1.05	0.00	0.00	0.00	0.00	1.05	0.00
29	15.3	08-06	64° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	15.4	08-06	64° 15'	44° 00'	3.42	1.58	0.53	0.00	0.00	5.53	0.00
31	15.5	08-06	64° 07'	44° 12'	0.84	0.00	0.00	0.00	0.28	1.12	0.00
32	14.5	08-06	63° 46'	44° 13'	2.88	0.85	0.00	0.00	0.00	3.73	0.00
33	14.4	08-06	63° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	12.4	09-06	63° 16'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	13.3	09-06	62° 45'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	11.3	09-06	62° 15'	44° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	10.2	09-06	61° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	10.1	09-06	61° 45'	43° 00'	0.19	0.00	0.00	0.00	0.00	0.19	0.00
39	11.1	09-06	62° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	13.1	09-06	62° 45'	43° 00'	0.32	0.00	0.00	0.00	0.00	0.32	0.00
41	12.2	09-06	63° 15'	43° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	14.2	10-06	63° 45'	43° 00'	0.16	0.16	0.00	0.00	0.00	0.31	0.00
43	14.3	10-06	63° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	12.3	10-06	63° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	13.2	10-06	62° 45'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	11.2	10-06	62° 15'	43° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	10.3	10-06	61° 45'	44° 00'	0.20	0.00	0.00	0.00	0.00	0.20	0.00
48	10.4	10-06	61° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. (Continued).

CONS.	STATION	DATE (dd-mm)	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	NUMBER / m^2						
					EGGS						LARVAE
					STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL	
49	11.4	10-06	62° 15'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	13.4	11-06	62° 45'	44° 30'	1.30	0.00	0.00	0.00	0.00	1.30	0.00
51	11.5	11-06	62° 15'	44° 47'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	10.5	11-06	61° 45'	45° 00'	2.95	0.00	0.00	0.00	0.00	2.95	0.00
53	9.5	11-06	61° 15'	45° 00'	1.77	0.00	0.00	0.00	0.35	2.12	0.00
54	9.4	11-06	61° 15'	44° 30'	1.00	0.00	4.99	0.00	0.00	5.99	0.00
55	9.3	11-06	61° 15'	44° 16'	0.31	5.89	5.27	0.31	6.51	18.28	0.00
56	8.4	11-06	60° 45'	45° 00'	0.00	0.15	0.46	0.00	0.61	1.22	0.00
57	8.5	12-06	60° 45'	44° 30'	0.00	0.00	0.00	0.00	0.17	0.17	0.00
58	8.6	13-06	60° 44'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	7.5	13-06	60° 15'	45° 30'	0.87	0.00	0.00	0.00	0.22	1.09	0.00
60	6.5	13-06	59° 45'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	5.5	13-06	59° 15'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	5.4	13-06	59° 15'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	6.4	14-06	59° 45'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	7.4	14-06	60° 15'	45° 00'	0.00	0.00	0.00	0.00	0.20	0.20	0.00
65	7.3	14-06	60° 15'	44° 31'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	7.2	14-06	60° 15'	44° 07'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	6.2	14-06	59° 45'	44° 07'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	6.3	14-06	59° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	5.3	14-06	59° 15'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	4.2	14-06	58° 45'	44° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	4.3	15-06	58° 45'	45° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	4.4	15-06	58° 45'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	3.4	15-06	58° 15'	45° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	3.5	15-06	58° 15'	46° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	3.6	15-06	58° 15'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	3.7	15-06	58° 15'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	2.6	15-06	57° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	M	15-06	57° 15'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	N	16-06	57° 15'	47° 23'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	2.7	16-06	57° 45'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	3.8	16-06	58° 15'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	4.8	16-06	58° 45'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	5.9	16-06	59° 15'	47° 24'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	5.8	16-06	59° 15'	47° 00'	0.00	0.00	0.21	0.00	0.00	0.21	0.00
85	4.7	16-06	58° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	4.6	16-06	58° 45'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	4.5	17-06	58° 45'	46° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	5.6	17-06	59° 15'	46° 00'	0.35	0.00	0.00	0.00	0.00	0.35	0.00
89	6.6	17-06	59° 41'	45° 57'	0.30	0.15	0.00	0.00	0.00	0.44	0.00
90	6.7	17-06	59° 45'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	6.8	17-06	59° 45'	47° 00'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	7.7	17-06	60° 15'	47° 00'	1.80	0.00	0.33	0.33	0.82	3.28	0.16
93	7.6	17-06	60° 15'	46° 30'	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Min.:				0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average:				0.39	0.10	0.13	0.01	0.12	0.75	0.01
	Max.:				12.98	5.89	5.27	0.33	6.51	18.28	0.35

Table 3. Mean water temperature (0-10 m) (°C), incubation time (hr), egg abundance (n/m^2) and daily egg production (n/m^2) (stages of development 1 and 5) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

CONS.	STATION	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	TEMPERATURE (°C) (MEAN 0-10m)	INCUBATION TIME (hr)	EGG STAGES 1 AND 5 (n/m^2)	
						ABUNDANCE	DAILY PRODUCTION
1	19.6	66° 20'	44° 00'	7.30	95.47	0.00	0.00
2	20.5	66° 45'	44° 00'	7.87	84.63	0.00	0.00
3	21.4	67° 15'	44° 00'	8.09	80.99	0.00	0.00
4	21.3	67° 15'	43° 30'	8.36	76.82	0.00	0.00
5	21.2	67° 15'	43° 00'	7.81	85.75	0.00	0.00
6	21.1	67° 15'	42° 30'	8.81	70.64	0.00	0.00
7	20.1	66° 45'	42° 00'	9.51	62.39	0.00	0.00
8	19.2	66° 15'	42° 00'	7.67	88.32	0.16	0.04
9	19.1	66° 15'	41° 30'	8.20	79.26	0.00	0.00
10	18.1	65° 45'	41° 30'	11.72	44.59	0.00	0.00
11	18.2	65° 45'	42° 00'	10.72	51.46	0.00	0.00
12	18.3	65° 45'	42° 30'	7.16	98.63	0.00	0.00
13	19.3	66° 15'	42° 30'	7.34	94.72	0.00	0.00
14	20.2	66° 45'	42° 30'	8.46	75.33	0.00	0.00
15	20.3	66° 45'	43° 00'	9.06	67.46	0.00	0.00
16	20.4	66° 45'	43° 30'	7.36	94.20	0.00	0.00
17	19.5	66° 15'	43° 30'	6.61	112.13	1.47	0.31
18	19.4	66° 15'	43° 00'	8.01	82.26	12.98	3.79
19	18.4	65° 45'	43° 00'	6.44	116.78	1.45	0.30
20	18.5	65° 44'	43° 19'	4.76	190.19	0.00	0.00
21	17.4	65° 15'	43° 30'	6.41	117.66	0.00	0.00
22	17.3	65° 15'	43° 00'	8.02	82.14	0.00	0.00
23	17.2	65° 15'	42° 30'	9.42	63.39	0.78	0.29
24	17.1	65° 15'	42° 01'	7.53	90.84	0.00	0.00
25	16.4	64° 43'	43° 48'	5.65	144.48	1.29	0.21
26	16.3	64° 45'	43° 30'	8.47	75.16	0.50	0.16
27	16.2	64° 45'	43° 00'	9.10	67.01	0.18	0.07
28	15.2	64° 15'	43° 00'	8.61	73.31	1.05	0.34
29	15.3	64° 15'	43° 30'	8.84	70.26	0.00	0.00
30	15.4	64° 15'	44° 00'	8.63	72.96	3.42	1.13
31	15.5	64° 07'	44° 12'	8.39	76.39	1.12	0.35
32	14.5	63° 46'	44° 13'	8.75	71.34	2.88	0.97
33	14.4	63° 45'	44° 00'	9.39	63.75	0.00	0.00
34	12.4	63° 16'	44° 00'	9.47	62.80	0.00	0.00
35	13.3	62° 45'	44° 00'	10.32	54.71	0.00	0.00
36	11.3	62° 15'	44° 00'	10.10	56.65	0.00	0.00
37	10.2	61° 45'	43° 30'	9.66	60.83	0.00	0.00
38	10.1	61° 45'	43° 00'	9.62	61.30	0.19	0.07
39	11.1	62° 15'	43° 00'	9.24	65.33	0.00	0.00
40	13.1	62° 45'	43° 00'	10.17	56.04	0.32	0.14
41	12.2	63° 15'	43° 00'	10.82	50.68	0.00	0.00
42	14.2	63° 45'	43° 00'	8.91	69.34	0.16	0.05
43	14.3	63° 45'	43° 30'	10.09	56.77	0.00	0.00
44	12.3	63° 15'	43° 30'	10.06	57.04	0.00	0.00
45	13.2	62° 45'	43° 30'	10.27	55.14	0.00	0.00
46	11.2	62° 15'	43° 30'	10.31	54.83	0.00	0.00
47	10.3	61° 45'	44° 00'	10.30	54.91	0.20	0.09
48	10.4	61° 45'	44° 30'	10.03	57.27	0.00	0.00

Table 3. (Continued).

CONS.	STATION	LONGITUDE °W (degrees-minutes)	LATITUDE °N (degrees-minutes)	TEMPERATURE (°C) (MEAN 0-10m)	INCUBATION TIME (hr)	EGG STAGES 1 AND 5 (n/m^2)	
						ABUNDANCE	DAILY PRODUCTION
49	11.4	62° 15'	44° 30'	10.02	57.39	0.00	0.00
50	13.4	62° 45'	44° 30'	8.58	73.68	1.30	0.42
51	11.5	62° 15'	44° 47'	9.44	63.16	0.00	0.00
52	10.5	61° 45'	45° 00'	8.75	71.39	2.95	0.99
53	9.5	61° 15'	45° 00'	8.45	75.52	2.12	0.67
54	9.4	61° 15'	44° 30'	10.15	56.24	1.00	0.43
55	9.3	61° 15'	44° 16'	10.22	55.58	6.82	2.94
56	8.4	60° 45'	45° 00'	8.12	80.51	0.61	0.18
57	8.5	60° 45'	44° 30'	8.20	79.24	0.17	0.05
58	8.6	60° 44'	45° 30'	6.82	106.67	0.00	0.00
59	7.5	60° 15'	45° 30'	8.14	80.11	1.09	0.33
60	6.5	59° 45'	45° 30'	7.91	83.97	0.00	0.00
61	5.5	59° 15'	45° 30'	7.63	88.99	0.00	0.00
62	5.4	59° 15'	45° 00'	8.52	74.51	0.00	0.00
63	6.4	59° 45'	45° 00'	8.66	72.60	0.00	0.00
64	7.4	60° 15'	45° 00'	8.48	75.12	0.20	0.06
65	7.3	60° 15'	44° 31'	9.02	67.96	0.00	0.00
66	7.2	60° 15'	44° 07'	9.69	60.55	0.00	0.00
67	6.2	59° 45'	44° 07'	8.62	73.18	0.00	0.00
68	6.3	59° 45'	44° 30'	8.98	68.50	0.00	0.00
69	5.3	59° 15'	44° 30'	8.63	72.93	0.00	0.00
70	4.2	58° 45'	44° 30'	8.73	71.64	0.00	0.00
71	4.3	58° 45'	45° 00'	8.64	72.78	0.00	0.00
72	4.4	58° 45'	45° 30'	8.77	71.05	0.00	0.00
73	3.4	58° 15'	45° 30'	8.45	75.52	0.00	0.00
74	3.5	58° 15'	46° 00'	8.45	75.53	0.00	0.00
75	3.6	58° 15'	46° 30'	8.46	75.33	0.00	0.00
76	3.7	58° 15'	47° 00'	9.21	65.77	0.00	0.00
77	2.6	57° 45'	47° 00'	8.53	74.31	0.00	0.00
78	M	57° 15'	47° 00'	8.08	81.07	0.00	0.00
79	N	57° 15'	47° 23'	8.10	80.84	0.00	0.00
80	2.7	57° 45'	47° 24'	8.41	76.14	0.00	0.00
81	3.8	58° 15'	47° 24'	6.65	111.10	0.00	0.00
82	4.8	58° 45'	47° 24'	8.73	71.70	0.00	0.00
83	5.9	59° 15'	47° 24'	8.74	71.50	0.00	0.00
84	5.8	59° 15'	47° 00'	8.92	69.21	0.00	0.00
85	4.7	58° 45'	47° 00'	8.03	82.00	0.00	0.00
86	4.6	58° 45'	46° 30'	8.85	70.05	0.00	0.00
87	4.5	58° 45'	46° 00'	8.96	68.75	0.00	0.00
88	5.6	59° 15'	46° 00'	8.63	73.04	0.35	0.12
89	6.6	59° 41'	45° 57'	7.47	92.04	0.30	0.08
90	6.7	59° 45'	46° 30'	9.95	58.03	0.00	0.00
91	6.8	59° 45'	47° 00'	9.99	57.62	0.00	0.00
92	7.7	60° 15'	47° 00'	10.43	53.78	2.62	1.17
93	7.6	60° 15'	46° 30'	11.05	48.98	0.00	0.00
	Min.:			4.76	44.59	0.00	0.00
	Average:			8.72	75.05	0.51	0.17
	Max.:			11.72	190.19	12.98	3.79

Table 4. Parameters of the isotropic variogram used for kriging the mean daily egg production (n/m^2) per station for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

YEAR	MODEL*	NUGGET (C0)	SILL (C0 + C)	RANGE (A_0)	R^2	RSS (residuals sum of square)
2009	Spherical	0.001	0.362	66.300	0.69	0.0006

* Spherical model $\gamma(h) = C0 + C\left[1.5\left(\frac{h}{A_0}\right) - 0.5\left(\frac{h}{A_0}\right)^3\right]$ if $h \le A_0$, and $C0+C$ otherwise

where *h* is a vector of distance having a value and a direction

*Table 5. Atlantic mackerel daily (**PA**) and total (**PA/S**) egg productions (n) and spawning biomass (t) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.*

SURFACE AREA (m^2)	DAILY EGG PRODUCTION	TOTAL EGG PRODUCTION	TOTAL EGG PRODUCTION METHOD (TEPM)		
	NUMBER (PA)	NUMBER (PA/S)	SPAWNING BIOMASS (t)	95% CONFIDENCE INTERVAL	
				Lower Limit	Upper Limit
2.046E+11	3.322E+10	1.884E+12	2 576	2 141	3 010

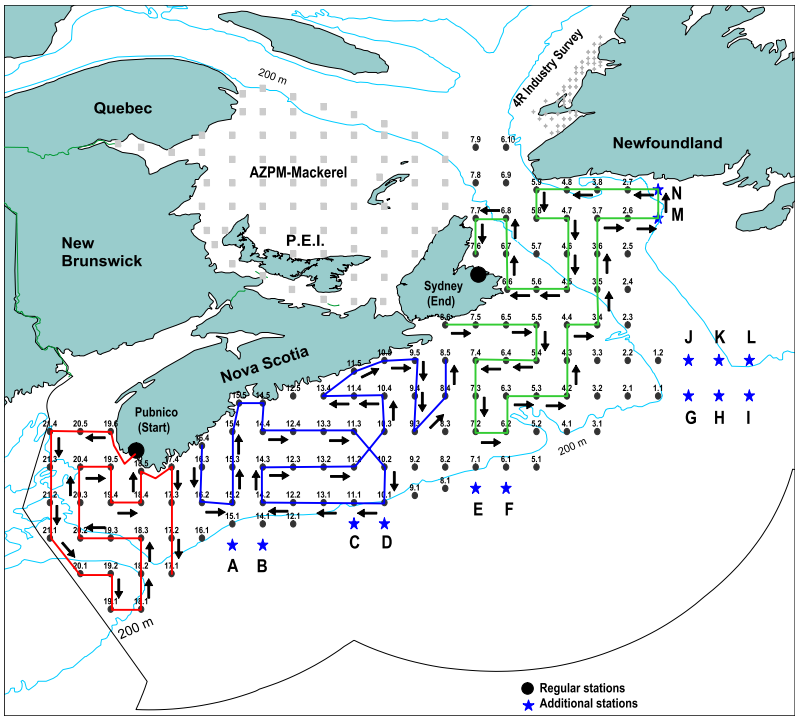

Figure 1. Map of the stations and sampling pattern of the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. The survey was conducted in three parts, each one is characterized by transects of a specific colour. Stations of the AZPM-Mackerel and Industry larval surveys conducted in the southern Gulf of St. Lawrence and on the west coast of Newfoundland are also indicated.

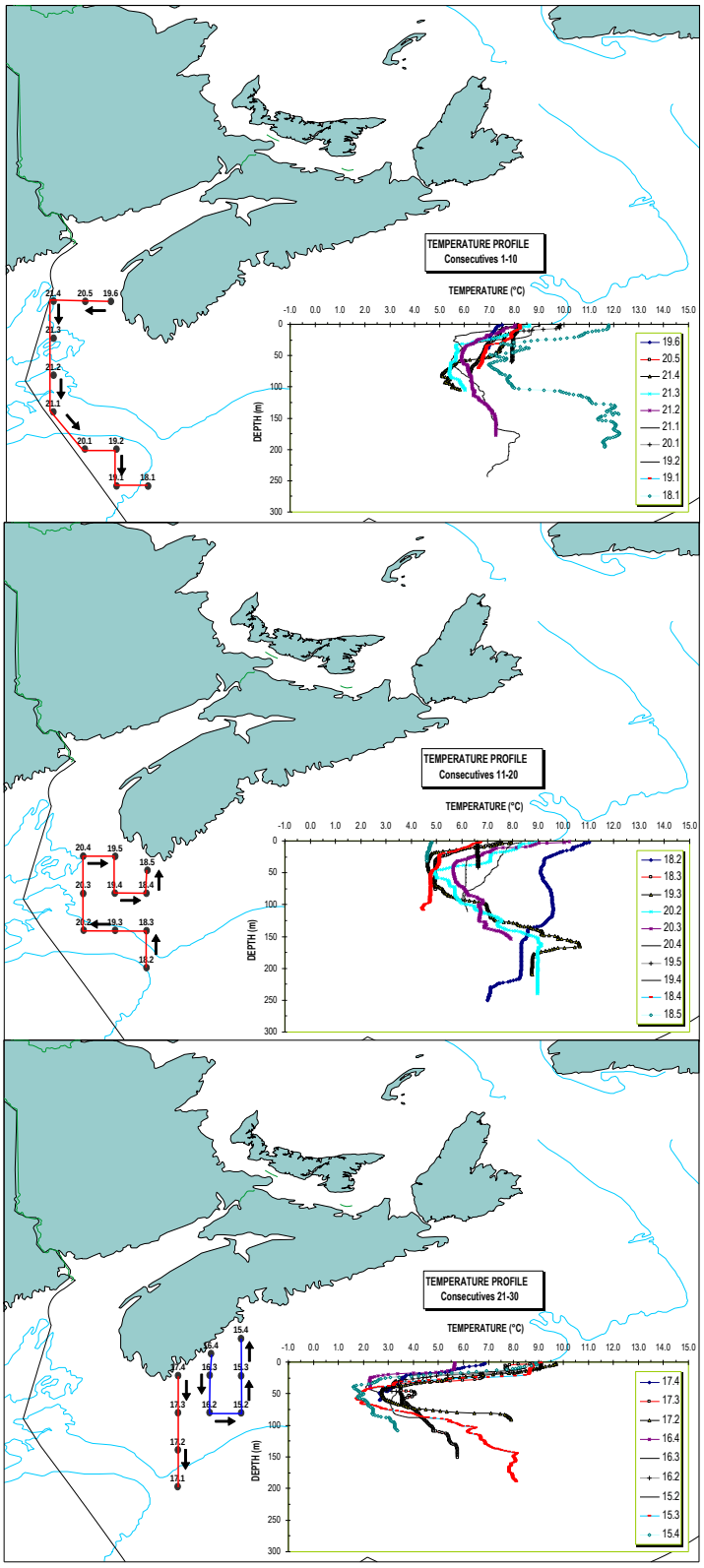

Figure 2. Water temperature (°C) profiles for different groups of stations sampled during the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

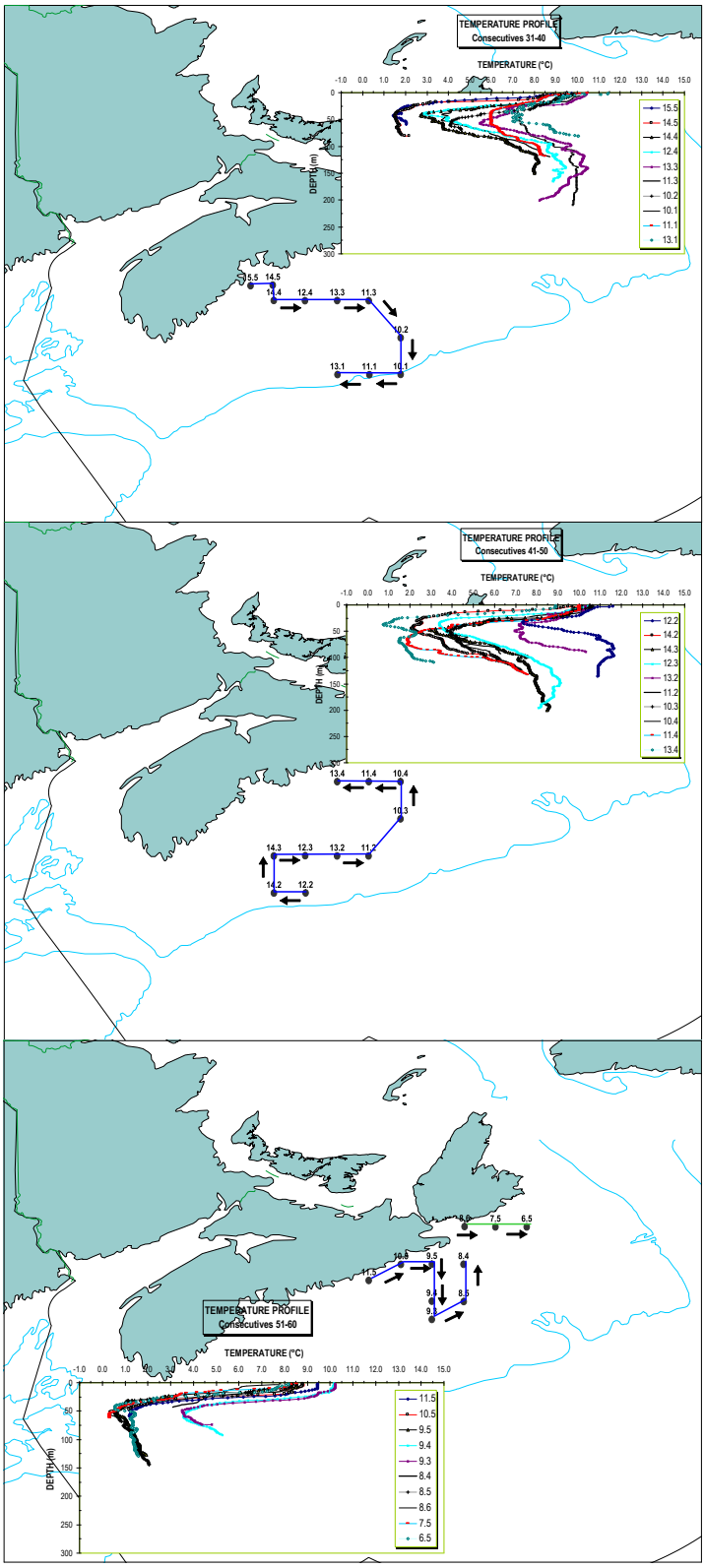

Figure 2. (Continued).

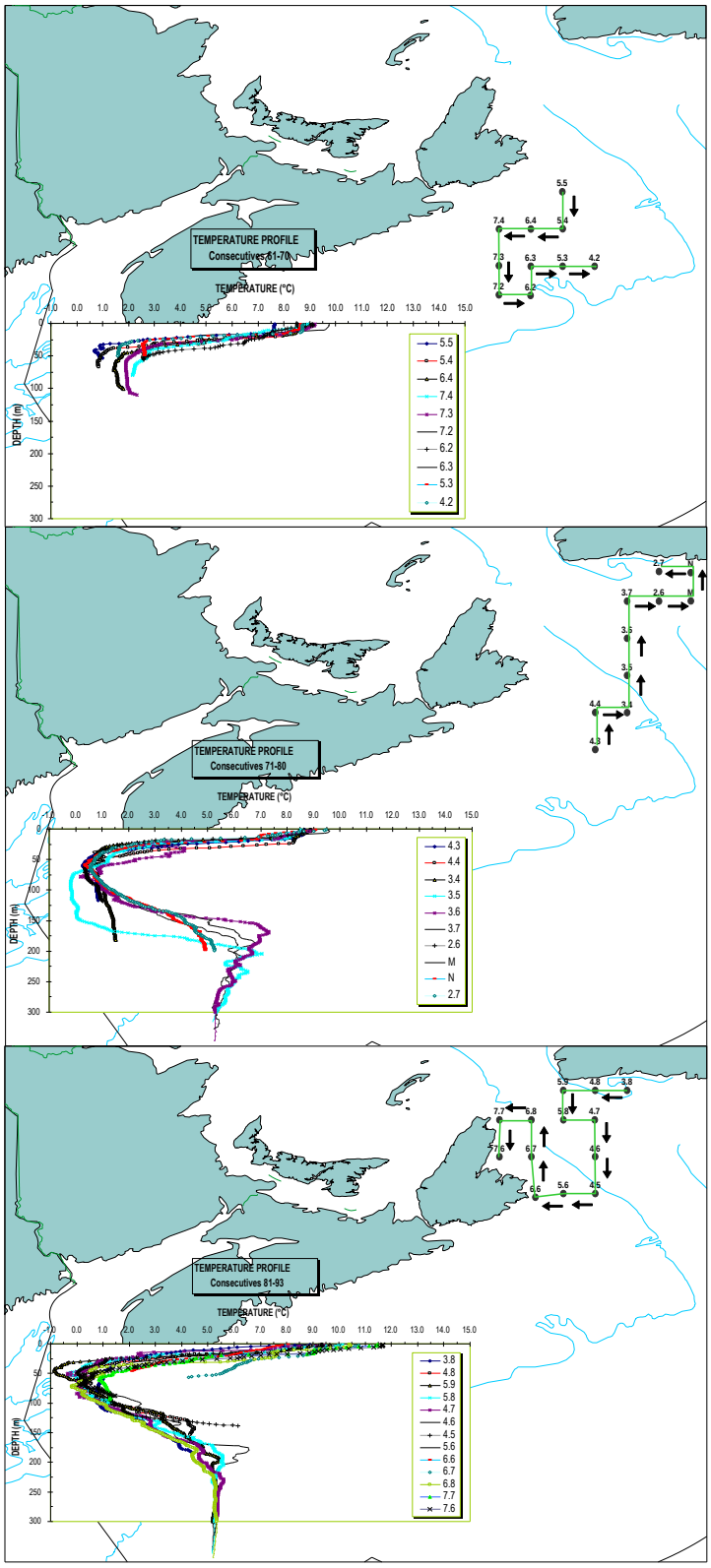

Figure 2. (Continued).

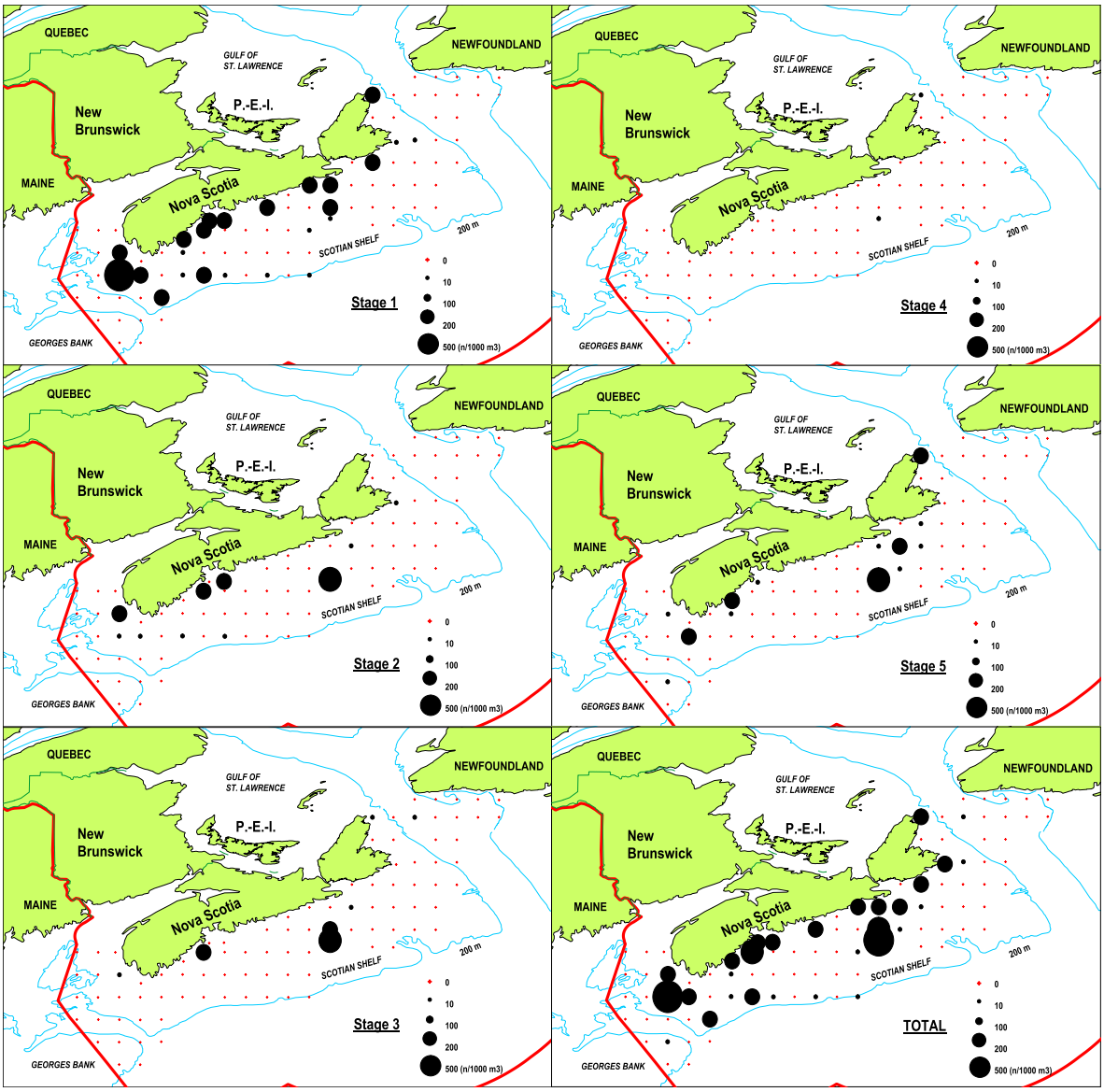

Figure 3. Atlantic mackerel egg distribution and abundance (n/1000m^3) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. Egg counts are grouped by development stage (Girard 2000).

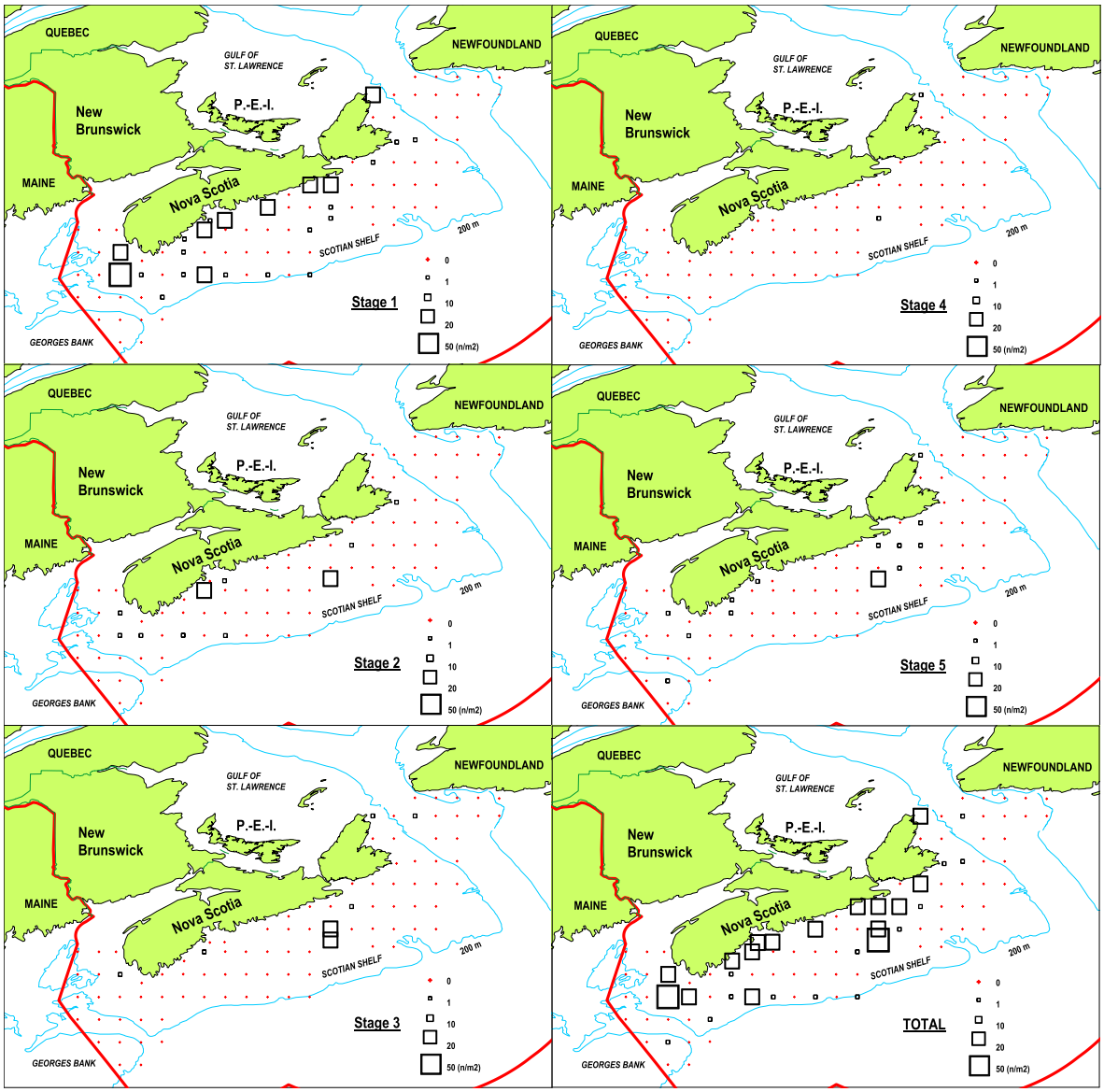

Figure 4. Atlantic mackerel egg distribution and abundance (n/m^2) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. Egg counts are grouped by development stage (Girard 2000).

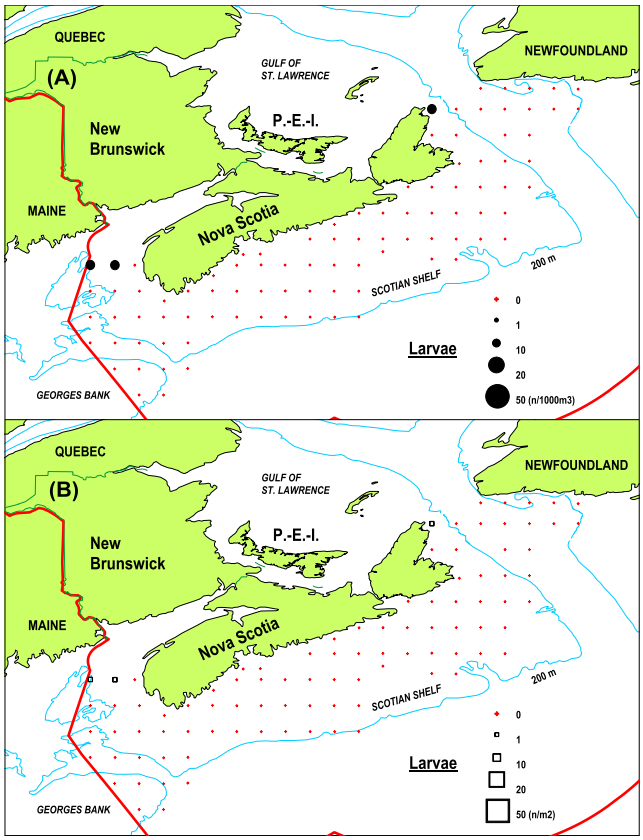

Figure 5. Atlantic mackerel larvae distribution and abundance in n/1000m^3 (A) and n/m^2 (B) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

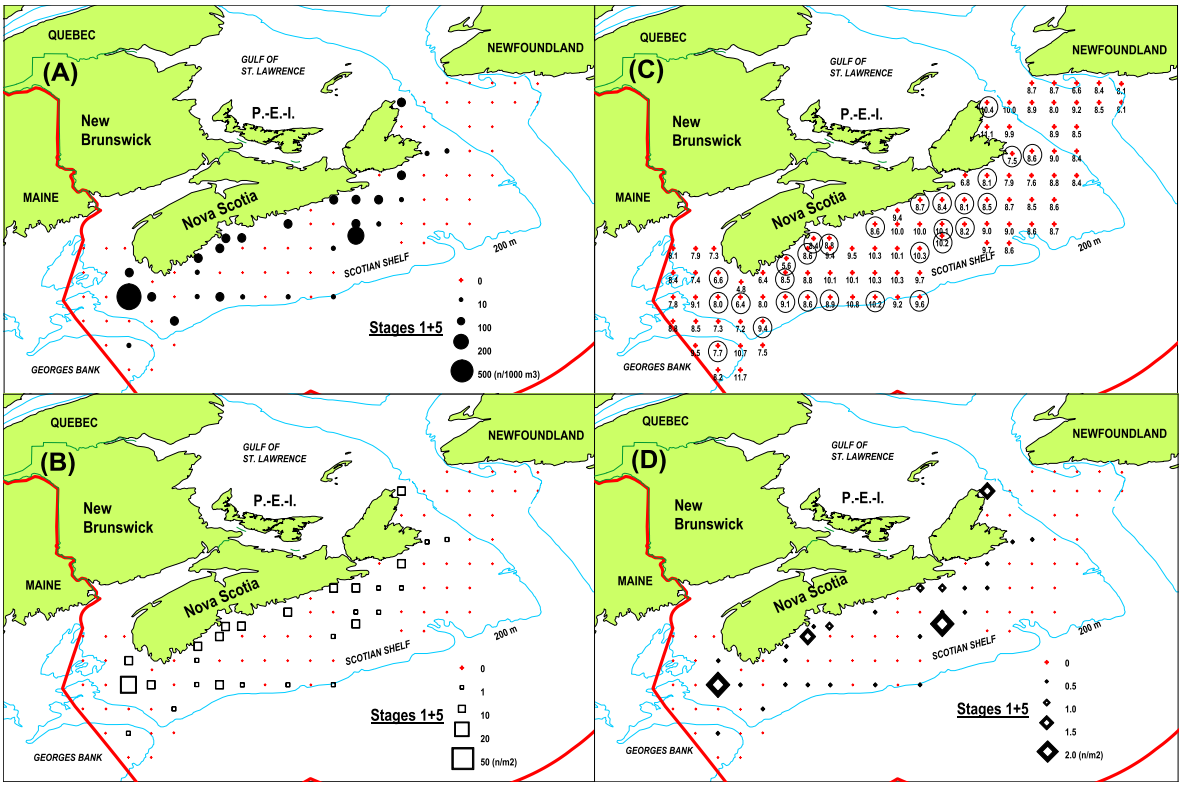

Figure 6. Atlantic mackerel egg (stages 1 and 5) distribution and abundance in n/1000m^3 (A) and n/m^2 (B), water temperature (°C) (mean 0-10 m) (C) (stations with eggs of stages 1 and 5 are indicated), and daily egg production (n/m^2) per station (D) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

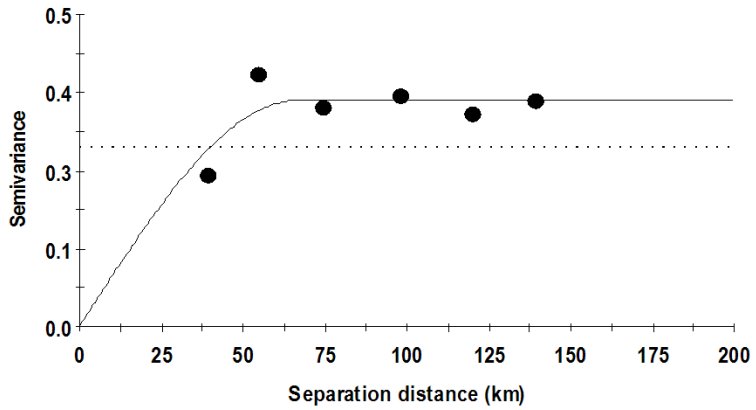

Figure 7. Isotropic variogram of the daily egg production (n/m^2) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

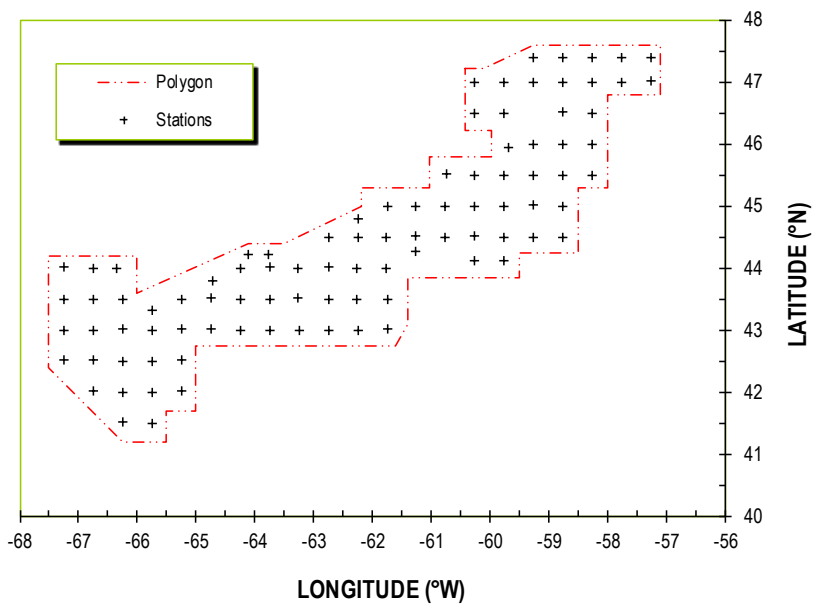

Figure 8. Contour polygon used to calculate the area sampled and to krige the mean daily egg production (n/m^2) for the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast in 2009.

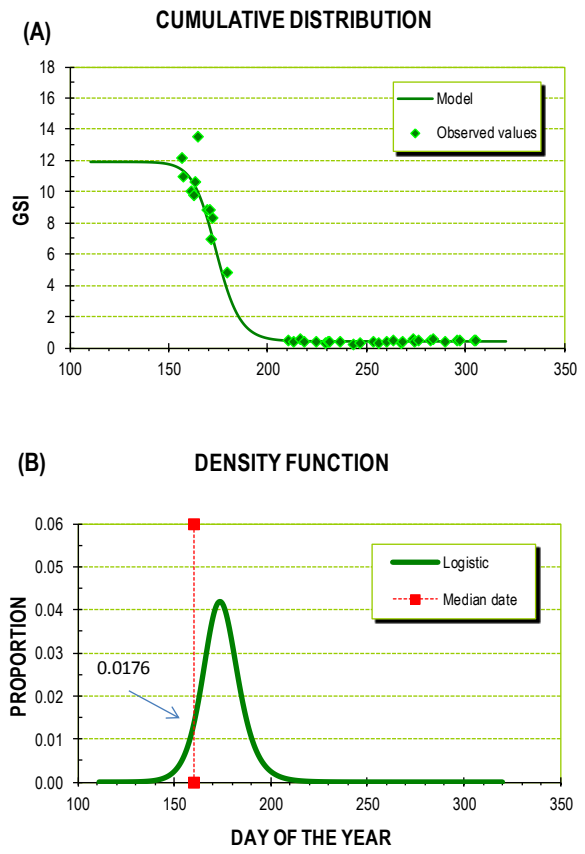

Figure 9. Gonadosomatic index (GSI) (observed and expected values) (A) and density function (B) describing the daily proportion of eggs spawned in Canadian waters in 2009 (in B, the median date of the egg survey conducted on the Scotian Shelf and Newfoundland's South Coast is indicated as the proportion of eggs spawned daily).

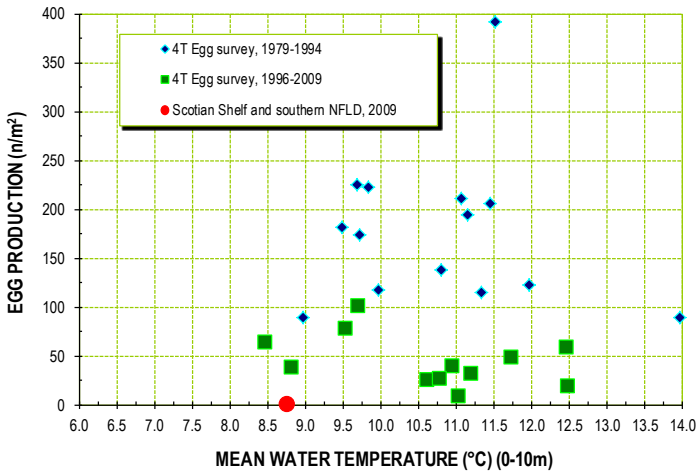

Figure 10. Relationship between the mean daily egg production (n/m^2) and water temperature (°C) (average, 0-10 m) for the southern Gulf of St. Lawrence (NAFO Division 4T) egg surveys conducted from 1979 to 2009 and the 2009 Scotian Shelf and Newfoundland's South Coast survey.