West coast of Newfoundland capelin (*Mallotus villosus* M.) and Atlantic herring (*Clupea harengus harengus* L.) larval survey, part 6: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2007

F. Grégoire, W. Barry, J. Barry, C. Lévesque, J.-L. Beaulieu, and M.-H. Gendron

Department of Fisheries and Oceans
Science Branch
Maurice Lamontagne Institute
P.O. Box 1000, 850 Route de la Mer
Mont-Joli (Québec)
G5H 3Z4

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WEST COAST OF NEWFOUNDLAND CAPELIN (*Mallotus villosus* M.) AND ATLANTIC HERRING (*Clupea harengus harengus* L.) LARVAL SURVEY, PART 6: ABUNDANCE ESTIMATES AND MARINE COMMUNITY ANALYSES OF THE DATA COLLECTED IN PARTNERSHIP WITH THE INDUSTRY (BARRY GROUP) IN JULY 2007

François Grégoire[1], William Barry[2], Jim Barry[2], Charline Lévesque[1],
Jean-Louis Beaulieu[1], and Marie-Hélène Gendron[1]

[1]Department of Fisheries and Oceans
Science Branch
Maurice Lamontagne Institute
P.O. Box 1000, 850 Route de la Mer
Mont-Joli (Québec)
G5H 3Z4

[2]Barry Group, 415 Griffin Drive, Corner Brook, Newfoundland, A2H 3E9

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

Grégoire, F., W. Barry, J. Barry, C. Lévesque, J.-L. Beaulieu, and M.-H. Gendron. 2011. West coast of Newfoundland capelin (*Mallotus villosus* M.) and Atlantic herring (*Clupea harengus harengus* L.) larval survey, part 6: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2007. Can. Tech. Rep. Fish. Aquat. Sci. 2953: ix + 56 pp.

In partnership with the Barry Group in Corner Brook, a larval survey was conducted on the west coast of Newfoundland in July 2007 to measure the abundance and to describe the spatial distribution of eggs and larvae of fish species sampled, two of which were commercially significant, capelin (*Mallosus villosus*) and Atlantic herring (*Clupea harengus harengus*). The most abundant eggs were from the CYT (cunner [*Tautogolabrus adspersus*] and yellowtail flounder [*Limanda ferruginea*]), CHW (cod [*Gadus morhua*], haddock [*Melanogrammus aeglefinus*], and witch flounder [*Glyptocephalus cynoglossus*]), and H4B (hake [*Urophycis* spp.], fourbeard rockling [*Enchelyopus cimbrius*], and American butterfish [*Peprilus triacanthus*]) groups. Among the larvae collected, the most abundant species were cunner, flounder (Pleuronectidae), and Atlantic mackerel (*Scomber scombrus*) followed by capelin, fourbeard rockling, radiated shanny (*Ulvaria subbifurcata*), cod, and Atlantic herring. Compared to the survey conducted in 2005, and omitting St. George's Bay, the 2007 survey was characterized by a smaller number of Atlantic mackerel and capelin eggs and larvae. Egg groups CYT, CHW, and H4B, were also less abundant. The only increases in abundance were measured for windowpane (*Scophthalmus aquosus*) eggs, as well as radiated shanny, redfish (*Sebastes* spp.), sand lance (*Ammodytes* spp.), and snailfish (*Liparis* spp.) larvae. Generalized additive models (GAM) have shown that the abundance of eggs and larvae of most species sampled could be described using a smoothing function based on the interaction between the longitude and latitude of the stations. The abundance of Atlantic mackerel eggs and cod larvae have also been described by a second function based on water temperature. Finally, a last function based on the abundance of Atlantic mackerel eggs helped describe the abundance of larvae of this species. From abundance measurements of all sampled larvae, cluster and ordination analyses revealed the presence of a well-defined spatial structure within the larval community. This was mainly characterized by cunner and Flounder.

RÉSUMÉ

Grégoire, F., W. Barry, J. Barry, C. Lévesque, J.-L. Beaulieu, et M.-H. Gendron. 2011. West coast of Newfoundland capelin (*Mallotus villosus* M.) and Atlantic herring (*Clupea harengus harengus* L.) larval survey, part 6: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2007. Can. Tech. Rep. Fish. Aquat. Sci. 2953: ix + 56 pp.

En partenariat avec le Groupe Barry de Corner Brook, un relevé larvaire a été réalisé sur la côte ouest de Terre-Neuve en juillet 2007 afin de mesurer l'abondance et de décrire la distribution spatiale des œufs et des larves des poissons échantillonnés dont deux espèces d'importance commerciale, le capelan (*Mallosus villosus*) et le hareng (*Clupea harengus harengus*). Les œufs les plus abondants ont été ceux des groupes CYT (tanche-tautogue [*Tautogolabrus adspersus*] et limande à queue jaune [*Limanda ferruginea*]), CHW (morue [*Gadus morhua*], aiglefin [*Melanogrammus aeglefinus*] et plie grise [*Glyptocephalus cynoglossus*]) et H4B (merluches [*Urophycis* spp.], motelle à quatre barbillons [*Enchelyopus cimbrius*] et stromatée à fossette [*Peprilus triacanthus*]). Parmi les larves récoltées, les espèces les plus abondantes ont été la tanche-tautogue, la plie (Pleuronectidae) et le maquereau bleu (*Scomber scombrus*) suivies du capelan, de la motelle à quatre barbillons, de l'ulvaire deux-lignes (*Ulvaria subbifurcata*), de la morue et du hareng. Par rapport au relevé réalisé en 2005 et en omettant la baie St. George, le relevé de 2007 a été caractérisé par un moins grand nombre d'œufs et de larves de maquereau bleu et de capelan. Les œufs des groupes CYT, CHW et H4B ont aussi été moins abondants. Les seules hausses d'abondance ont été mesurées pour les œufs de turbot de sable (*Scophthalmus aquosus*) et les larves d'ulvaire deux-lignes, de sébaste (*Sebastes* spp.), de lançon (*Ammodytes* spp.) et de limace (*Liparis* spp.). Des modèles additifs généralisés (GAM) ont démontré que l'abondance des œufs et des larves de la plupart des espèces échantillonnées pouvait être décrite à l'aide d'une fonction de lissage basée sur l'interaction entre la longitude et la latitude des stations. Les abondances d'œufs de maquereau bleu et de larves de morue ont aussi été décrites par une seconde fonction basée sur la température de l'eau. Finalement, une dernière fonction basée sur l'abondance des œufs de maquereau bleu a permis de décrire l'abondance des larves de cette même espèce. À partir des mesures d'abondance de toutes les larves échantillonnées, des analyses de groupement et d'ordination ont démontré la présence d'une structure spatiale bien définie au sein de la communauté larvaire. Cette dernière était principalement caractérisée par la tanche-tautogue et la plie.

1.0 INTRODUCTION

Two larval surveys were conducted on the west coast of Newfoundland (Gulf of St. Lawrence) in July 2004 and 2005 in order to measure the abundance and to describe the spatial distribution of capelin (*Mallosus villosus*) and Atlantic herring (*Clupea harengus harengus*) larvae. Eggs and larvae of several other fish species were also identified during these surveys (Grégoire et al. 2005, 2006a). Biodiversity measures have shown that the larval community structure at the time of sampling was characterized by a large number of scarce species and by more abundant commercial species concentrated in specific locations (Grégoire et al. 2006b, 2009). Compared to the survey conducted in 2004, the 2005 survey was characterized by a significant decline in the abundance of Atlantic herring larvae and an increase in capelin and Atlantic mackerel (*Scomber scombrus*) larvae. The larval assemblages described in 2004 and 2005 were primarily characterized by capelin and cunner (*Tautogolabrus adspersus*). These two species alone accounted for 70% and 80% of the similarity associated with these assemblages.

A third larval survey was conducted on the west coast of Newfoundland in July 2007 (Grégoire et al. 2008a). Compared to the two previous surveys, this survey's study area extended to St. George's Bay. The most abundant egg groups were CYT (cunner and yellowtail flounder [*Limanda ferruginea*]) and CHW (cod [*Gadus morhua*], haddock [*Melanogrammus aeglefinus*], and witch flounder [*Glyptocephalus cynoglossus*]). Of the thirteen species of larvae identified, the most abundant were cunner, righteye flounder (Pleuronectidae), Atlantic mackerel, fourbeard rockling (*Enchelyopus cimbrius*), and capelin.

This study's three objectives were to calculate the abundance of eggs and larvae of all species sampled in 2007 using geostatistics, study their biodiversity by multivariate analysis techniques, and describe the possible links between their abundance, the geographical location of the stations, and water temperatures using generalized additive models (GAM).

2.0 MATERIAL AND METHODS

2.1 Study area and sampling procedures

The larval survey was conducted from 18 to 21 July 2007 aboard the *Ocean Provider*. The study area was located near the coast from south of Bonne Bay and into St. George's Bay (Figure 1). This area corresponds to the main capelin and Atlantic herring fishing sites. A total of 45 stations were sampled using two bongo nets (Posgay and Marak 1980) with an opening of 61 cm with mesh size of 333 microns. Two General Oceanics flowmeters were fixed near the opening of the nets in order to measure the volume of water filtered. The tows followed a saw-tooth pattern (Hempel 1973) between the surface and a maximum depth of 50 m, or down to 5 m off-bottom for shallower stations. A CTD probe (Sea-Bird Electronics, Inc., model SBE-19) was used to obtain salinity and temperature profiles. Samples from one of the nets were kept in a formaldehyde solution (4–5%) and the others in an ethanol solution (95%).

2.2 Laboratory analyses

To facilitate sorting, plankton samples were fractionated using the Van Guelpen beaker technique (Van Guelpen et al. 1982). The criteria used for identifying fish eggs and larvae are described in Fritzsche (1978), Elliott and Jimenez (1981), and Fahay (1983); Girard (2000) was used for describing the development stages of Atlantic mackerel eggs. Egg and larva counts were standardized for volumes of 1,000 m^3 of water.

2.3 Geostatistical abundance

Mean abundance data (n/1,000 m^3) of eggs and larvae from the primary species sampled were estimated by ordinary kriging (Isaaks and Srivastava 1989). The choice of variogram model, semi-variance calculations, and kriging map preparations were made using the GS^+ software (Robertson 1998). The final choice of variogram model was based on the following criteria: (a) the proportion of total variance explained by the variance associated with spatial structure, (b) the coefficient of determination, and (c) the reduced sum of squares measuring, as with the coefficient of determination, the model adjustment quality to the observed values (Robertson 1998). The kriging means and variances were calculated using EVA II (Petitgas and Lafont 1997). A correction was applied to these calculations for the extreme abundance values (Grégoire et al. 2006b).

2.4 Temperature and abundance

The abundance data (n/1,000 m^3) were studied according to water temperature (°C) (average in the first 10 metres) based on the approach proposed by Perry and Smith (1994). This approach helped describe the temperatures associated with the main species encountered.

2.5 Generalized additive models (GAM)

Different generalized additive models (GAM) (Hastie and Tibshirani 1990) were studied to describe the possible relationships between the abundance of eggs and larvae of the main species encountered and the following independent variables: (1) longitude (decimal-degree, expressed as negative values), (2) latitude (decimal-degree), (3) longitude and latitude interaction, (4) abundance of eggs of a species if the larvae of the same species were collected, and (5) average water temperature (°C) in the first 10 metres.

For a given model, the choices of independent variables and smoothing functions were based on the values of the *p* statistic compared to the 5% significance level. The "*mgcv*" library (Wood 2006, 2008) was chosen to test different GAM models. This library uses the generalized cross validation (GCV) method as amended by Wood (2006) to automatically determine the degree of smoothing applied to each independent variable. GCV and the Akaike information criterion (AIC) were also used to compare the different models. Model quality was measured using the coefficient of determination (r^2) and the percentage of deviance explained. The latter is defined as the percentage of the sum of squares explained by the model (Zuur et al. 2007). In R language (version 2.8.1) (R Development Core Team 2009), the first GAM model studied had the following form:

Model_1 = gam (Abundance ~ s(Longitude, bs="ts") + s(Latitude, bs="ts") + s(Temperature, bs="ts"), family=gaussian())

where s means that the smoothing choice was based on "spline," bs="ts" represents the type of smoothing used (*thin plate regression spline smoothers*), and family=gaussian if the function chosen to describe the distribution of the dependent variable is of normal type. The abundance data were extracted from an Excel file and inserted into the R environment using the "*xlsReadWrite*" function (Hans-Peter 2006).

2.6 Accumulation (ACCUM) and dominance (DOMINANCE) plots

The ACCUM procedure from the Primer software (version 6.1.6) (Clarke and Gorley 2006) was used on the larval abundance data to predict, with the use of three types of permutation (bootstrap, UGE, and MM; Colwell and Coddington 1994), the total number of species that should be observed if a very large number of stations had been sampled in the study area. The results from this procedure were compared to the actual total number of species observed.

The abundance and dominance of the different larval species were examined using the DOMINANCE procedure (Clarke and Gorley 2006). For each sampled station, the larvae were listed in decreasing order of abundance. The cumulative relative abundance (i.e., the percentage of total abundance at a given sampled station) was transferred to a graph based on the rank (x axis) expressed according to a logarithmic scale. Lower curves (stations) show lower dominance and a greater diversity of species.

2.7 Biodiversity measures (DIVERSE, DRAFTSMAN, PCA, and MDS)

The structure of the larval community was described based on the total number of species (S) and larvae (N) per station and the following four diversity indices: (1) Shannon (Legendre and Legendre 1998), (2) Brillouin (Brillouin 1956), (3) Fisher (Fisher et al. 1943), and (4) Margalef (Margalef 1951). These indices, which are among the most widely used, help measure different attributes of the larval community (Clarke and Warwick 2001). They were calculated and compared by pairings using the DIVERSE and DRAFTSMAN procedures (Clarke and Gorley 2006).

The relative distances between the diversity indices were measured using non-metric multi-dimensional scaling (MDS procedure; Clarke and Gorley 2006) applied to the correlation matrix (absolute values x 100). The relative significance between each index was calculated using a principal component analysis (PCA procedure; Clarke and Gorley 2006). The latter was applied to the standardized values from the indices to account for the scaling differences.

2.8 Marine community analyses

2.8.1 Similarity coefficient (RESEMBLANCE)

The Bray-Curtis (S_{jk}) similarity index was calculated for all possible station pairings using the RESEMBLANCE procedure (Clarke and Gorley 2006). This index is defined as follows:

$$S_{jk} = 100\left\{1 - \frac{\sum_{i=1}^{p}\left|y_{ij} - y_{ik}\right|}{\sum_{i=1}^{p}(y_{ij} + y_{ik})}\right\}$$

where y_{ij} represents the abundance (n/1,000 m^3) of species i at station j (i=1,2,…, p ; j=1,2,…, n) and y_{ik} is the abundance of species i at station k. As suggested by Clarke and Gorley (2006), the y_{ij} values were first standardized by dividing the abundance of a species at a given station by the sum of abundances of all species at this same station.

2.8.2 Hierarchical clustering (SIMPROF and CLUSTER)

The occurrence of a structure within the larval community (larval assemblages) was tested using permutations (SIMPROF procedure; Clarke and Gorley 2006). Groups of stations were defined using the Bray-Curtis similarity matrix by hierarchical cluster analyses (CLUSTER procedure; Clarke and Gorley 2006) according to average association (UPGMA) (Legendre and Legendre 1998). The significance of these groups considered *a priori* as non-structured was tested using SIMPROF.

2.8.3 Species contribution (SIMPER)

The significance of each larval species present in the groups defined by cluster analysis and by SIMPROF was calculated using the SIMPER procedure (Clarke and Gorley 2006). This procedure calculates each species' contribution from a group to the similarity of the group.

2.8.4 Non-metric multidimensional scaling (MDS)

Clarke and Warwick (2001) suggest that ordination techniques be applied in reduced space to the data that were previously used in a cluster analysis. Ordination in reduced space is also used in the presence of a regular gradient in an ecological community structure (McGarigal et al. 2000). According to Everitt (1978), the non-parametric multidimensional scaling represents the best ordination technique for describing in a small number of dimensions the complex relationships that may exist between members of an ecological community. The non-parametric multidimensional scaling was therefore applied to the similarity matrix using the MDS procedure (Clarke and Gorley 2006).

The abundance of species that have contributed the most to the similarity of station groupings defined by the CLUSTER and SIMPROF procedures were superimposed on the MDS procedure results.

3.0 RESULTS

3.1 Stations and sampling characteristics

The first stations to be sampled were the Bay of Islands stations and the stations south of Bonne Bay (Figure 2), followed by those located along the coast up to Port-au-Port Bay and St. George's Bay. The last stations to be sampled were those located offshore in the direction of the Bay of Islands. We could not sample station 22 due to lack of time and stations 5 and 28 due to technical problems with the temperature probe. All the other stations were sampled during the day at depths between 10 and 63 m (Table 1). The volumes of filtered water varied between 203 m^3 and 312 m^3, averaging 252.6 m^3. The average tow duration was around 11 minutes.

3.2 Egg distribution and abundance

Eggs from the CHW and CYT groups as well as Atlantic mackerel eggs were found at 43, 41, and 39 of the 45 stations sampled, respectively, compared to 28 stations for the H4B group (hake [*Urophycis* spp.], fourbeard rockling, and butterfish [*Peprilus triacanthus*]) (Table 2). American plaice (*Hippoglossoides platessoides*) and windowpane (*Scophthalmus aquosus*) were only found at 14 and 6 stations, respectively.

The CYT group was the most abundant, with an average of 4,587.0 eggs/1,000 m^3 (Table 3). It was followed by the CHW and H4B groups, with respective averages of 387.6 and 197.2 eggs/1,000 m^3. An average of 96.7 eggs/1,000 m^3 was calculated for Atlantic mackerel compared to 74.0 and 2.0 eggs/1,000 m^3 for American plaice and windowpane.

The highest abundance of CYT eggs was measured at stations near the coast and within the large bays (Figure 3), and the same was true for CHW eggs except for Port-au-Port Bay. Atlantic mackerel eggs were found in larger numbers in St. George's Bay and Port-au-Port Bay along with eggs from the H4B group and windowpane in Port-au-Port Bay. American plaice eggs were primarily found at stations in the Bay of Islands and a few stations in St. George's Bay.

3.3 Larval distribution and abundance

During the survey, between 3 and 10 larva species or groups of species were sampled per station (Table 4). The most frequently found larvae, at over 32 stations, were cunner, Atlantic mackerel, cod, and capelin, followed by fourbeard rockling and radiated shanny (*Ulvaria subbifurcata*) at 27 stations, Atlantic herring at 24 stations, and other species at 17 stations or fewer.

The most abundant species were cunner, flounder, and Atlantic mackerel, with 585, 201, and 103 larvae/1,000 m^3, respectively, followed by capelin, fourbeard rockling, radiated shanny, and cod, with 50, 48, 24, and 20 larvae/1,000 m^3 (Table 5). Abundances below 10 larvae/1,000 m^3 were measured for the other species, including Atlantic herring. Among the most abundant larvae, cunner was mostly found at the Bay of Islands and Port-au-Port Bay stations, compared to the St. George's Bay stations for Atlantic mackerel (Figure 4). Flounder abundance varied little from one station to another. For capelin and cod, the highest abundances were measured at the Bay of

Islands and St. George's Bay stations. Fourbeard rockling, Atlantic herring, and radiated shanny were mostly found at the St. George's Bay and Port-au-Port Bay stations.

3.4 Egg and larval abundances in 2004, 2005, and 2007

Among the main commercial species, only flounder larvae showed an increase in abundance between 2004 and 2007 (Appendix 1). In 2007, Atlantic mackerel eggs and larvae and capelin larvae were more abundant in St. George's Bay than in other bays while there was a slight decrease for cod and flounder larvae. Atlantic herring larvae were only abundant in 2004.

A slight decrease in abundance was measured between 2005 and 2007 for eggs from groups CHW, CYT, and H4B and a significant increase for windowpane flounder (Appendix 2). In 2007, eggs from the CHW group and from American plaice were more abundant in St. George's Bay than eggs from other species found in the other bays.

An increase in abundance was observed between 2004 and 2005 for most of the larvae of other species (Appendix 3). In 2007, their abundance was lower for stations in St. George's Bay. In addition, some of these larvae were not observed in 2007.

3.5 Abundance derived from geostatistics

The spatial variations of egg abundance and egg groups were described using spherical variograms (Table 6). For larvae, the exponential model was only used for cunner. For all the models, the coefficients of determination varied between 0.70 and 1.00 and no anisometry was recorded. No model could be defined for windowpane eggs and larvae or for Arctic shanny (*Stichaeus punctatus*) larvae due to low abundance and great distances between the stations where these species were encountered.

Kriging maps for eggs and egg groups (Figure 5) and larvae (Figure 6) illustrate well the abundance variations presented in Figures 3 and 4. The average abundances calculated by kriging (Table 7) were similar to the arithmetic averages (Tables 3 and 5). However, kriging considerably reduces estimate variability. For Atlantic mackerel eggs and larvae and for capelin and Atlantic herring larvae, the mean abundances were recorded at 93 eggs/1,000 m^3 and at 103, 46, and 7 larvae/1,000 m^3 (Table 7, Figures 7A and 7B).

3.6 Temperature and abundance

Similar temperature profiles were obtained for egg and larva abundances. For example, 50% of the egg abundances from group CYT were observed at temperatures below 14.4°C compared to 15.3°C for Atlantic mackerel eggs (Figure 8A). For larvae, the difference is between 14.4 and 15.1°C for cunner and Atlantic mackerel (Figure 8B) and between 14.2 and 15.3°C for snailfish and radiated shanny (Figure 8C).

3.7 Generalized additive models (GAM)

Most of the GAM models selected are characterized by a smoothing function of the interaction between the longitude and latitude of the stations (Table 8). A second function represented by water temperature was selected for the abundance of Atlantic mackerel eggs and cod and cunner larvae. Finally, a final function between the abundance of eggs and larvae was selected for Atlantic mackerel.

For eggs, the two best models are associated with the CYT group and Atlantic mackerel, with respective coefficients of determination of 0.90 and 0.64, and deviance explained of 96 and 72% (Table 8). These models indicate that the highest egg abundances were observed at the longitudes and latitudes associated with the southwest part of the area sampled (Figures 9 and 10A).

For fish larvae, the three best models are associated with cod, Atlantic mackerel, and redfish, with respective coefficients of determination of 0.94, 0.86, and 0.86, and deviance explained of 99, 95, and 93% (Table 8). The highest abundances of cod larvae are associated with the longitudes and latitudes of the two limits of the study area (Figure 11A). A sharp decline in the abundance of cod larvae is associated with temperatures between 13 and 14°C (Figure 11B). This decrease is followed by an increase up to 14.5°C. The effect of temperature varies little between 14.5 and 15.5°C. Abundance increases until about 16°C before decreasing thereafter. The highest abundances of Atlantic mackerel larvae are associated with the longitude and latitude corresponding to St. George's Bay and Port-au-Port Bay (Figure 12A). In addition, larva abundance is related to egg abundance (Figure 12B). Finally, the highest abundances of redfish larvae are associated with station positions located between St. George's Bay and Port-au-Port Bay (Figure 13).

3.8 Accumulation and dominance plots

The total number of species that should be observed in the study area reaches a plateau at around 35 stations (Figure 14A). Reaching such a plateau means that the larval community was properly sampled during the survey. It was also characterized by a large number of stations with low dominance and a wide diversity of species (Figure 14B).

3.9 Biodiversity

The number of species and the total number of larvae varied greatly from one station to another (Figures 15A and 15B). The four diversity indices presented similar values and variations (Figure 15C). The maximum number of species was observed at three stations located in the Bay of Islands and St. George's Bay (Figure 16). The maximum number of larvae was observed in the Bay of Islands and near the coast in St. George's Bay and Port-au-Port Bay. The highest values from the four diversity indices were observed at the stations in the Bay of Islands and St. George's Bay.

There are strong correlations between the Fisher and Margalef indices and the Brillouin and Shannon indices (Figure 17A). These correlations are marked by the close occurrence of these indices in the reduced space defined by non-parametric multi-dimensional scaling (Figure 17B). This space is also characterized by the occurrence of a linear gradient with limits associated to the total number of larvae (N) and species (S).

The strong correlations measured between the four diversity indices are also marked by the matching vectors defined by the principal component analysis (Figure 17C). The first two components (PC1 and PC2) explain 68% and 24% respectively of the total variance. With the exception of the total number of larvae, the contributions (eigenvector) from other indices to the first component were of relatively the same size (between 39% and 47%). These contributions are positive for the total number of larvae and negative for the other indices. The total number of larvae and the total number of species contributed most to the second component (69% and 48% respectively).

3.10 Cluster analysis, ordination, and species contribution

The similarity profile presented a larger amount of high values than what the larval community with no internal structure hypothesis predicted (Figure 18A). The *Pi* statistic was significantly different (P<0.001) than a distribution associated to this hypothesis (Figure 18B). Twelve groups of stations were determined using cluster analysis and the SIMPROF procedure (Figure 19A).

Flounder contributed to 70 and 83% of the similarity associated to groups *b* and *c* (Figure 20). Cunner and fourbeard rockling mostly contributed to the similarity of group *d*, with respective values of 70 and 29%. Cunner was also the species that contributed most in groups *e*, *h*, and *I*, with respective similarities of 93, 75, and 69%. Group *g* was characterized by capelin and flounder, with contributions of 47 and 27%, compared to flounder, cunner, and radiated shanny for group *k*, with contributions were 33, 26, and 29%. Finally, cunner and flounder contributed 45 and 30% of the similarity of group *l*. No species could be defined for groups *a* and *g* since they were only associated with one station (Clarke and Gorley 2006).

Groups of stations that were defined by cluster analysis occupy different positions in the space defined by the non-metric multidimensional scaling (Figure 19B). The species that contributed most to their respective group were identified when their abundance was superimposed on the corresponding stations (Figures 21A to 21F).

The stations belonging to certain groups defined by cluster analysis were observed at specific locations. This is the case for group *l*, with most stations located in St. George's Bay (Figure 22). The same occurred for groups *j* and *k*, present respectively in St. George's Bay and Port-au-Port Bay.

4.0 DISCUSSION

Compared to the survey conducted in 2005 (Grégoire et al. 2009) and omitting St. George's Bay, fewer Atlantic mackerel eggs and Altantic mackerel and capelin larvae were sampled in 2007. Eggs from groups CHW, CYT, and H4B were also less abundant in 2007. The only increases in abundance were measured for windowpane eggs and radiated shanny, redfish, sand lance, and snailfish larvae.

The larval assemblages described in 2007 were mainly characterized by cunner and flounder compared to cunner and capelin in 2004 and 2005 (Grégoire et al. 2006b and 2009). Cunner is by far the most abundant species in these three surveys. Cunner eggs are also sampled in the southern Gulf of St. Lawrence during the Atlantic mackerel abundance survey (F. Grégoire, unpublished data). They can be found for the most part in the southwest part of the sampled area and very near the coast. Their occurrence in coastal waters could explain the lack of catches by the northern Gulf of St. Lawrence multidisciplinary groundfish surveys. There is no information on the abundance of cunner in the Gulf of St. Lawrence, and few studies have examined the biological characteristics of this species and its potential as a commercial species.

The larval survey on the west coast of Newfoundland was conducted at the request of the industry and with their active collaboration. A fourth survey was conducted in July 2008 following the same sampling pattern as the 2007 survey. Using the larvae preserved in ethanol, it was also intended to analyze the daily growth of otoliths for the main commercial species. This project will be put forward to better describe the marine ecosystem on the west coast of Newfoundland.

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Table 1. Description of the stations and sampling of the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

STATION NUMBER	DATE (dd/mm/yyyy)	TIME OF DAY (hh:mm) (NDT)	LONGITUDE °W (degrees minutes)	LATITUDE °N (degrees minutes)	DEPTH Station bottom (m)	DEPTH Maximum sampled (m)	TOW DURATION (min:sec)	VOLUME OF WATER FILTERED (m^3)
1	21/07/2007	8:18	58° 12'	49° 09'	111	48	11:09	286
2	21/07/2007	5:49	58° 12'	49° 12'	160	63	12:34	279
3	20/07/2007	18:28	58° 12'	49° 27'	43	34	10:23	249
4	20/07/2007	17:39	58° 12'	49° 33'	61	56	11:08	277
5	18/07/2007	9:49	58° 18'	49° 06'	51	40	11:00	203
6	21/07/2007	6:32	58° 18'	49° 11'	135	61	11:56	292
7	21/07/2007	7:13	58° 18'	49° 15'	80	62	10:04	238
8	20/07/2007	19:35	58° 18'	49° 20'	37	30	10:26	251
9	20/07/2007	16:38	58° 18'	49° 27'	56	48	10:57	254
10	18/07/2007	10:28	58° 24'	49° 11'	64	52	10:28	207
11	20/07/2007	14:47	58° 24'	49° 15'	40	33	10:57	277
12	20/07/2007	15:32	58° 24'	49° 20'	47	33	10:34	262
13	20/07/2007	12:51	58° 30'	49° 03'	48	48	11:51	286
14	18/07/2007	11:19	58° 30'	49° 07'	88	51	11:19	216
15	20/07/2007	14:01	58° 30'	49° 12'	65	52	10:27	256
16	20/07/2007	11:17	58° 36'	48° 51'	42	33	10:48	268
17	18/07/2007	14:20	58° 36'	48° 57'	35	24	10:50	242
18	18/07/2007	13:22	58° 36'	49° 03'	44	33	09:58	208
19	18/07/2007	12:37	58° 36'	49° 07'	70	57	12:04	210
20	20/07/2007	9:23	58° 42'	48° 39'	34	28	09:56	245
21	20/07/2007	10:18	58° 42'	48° 45'	27	17	10:03	261
23	18/07/2007	15:05	58° 42'	48° 57'	31	16	10:07	248
24	20/07/2007	8:37	58° 48'	48° 36'	21	16	10:24	255
25	20/07/2007	8:02	58° 48'	48° 39'	23	17	10:21	262
26	20/07/2007	7:23	58° 48'	48° 42'	16	11	10:01	248
27	18/07/2007	17:15	58° 48'	48° 48'	29	16	10:03	249
28	18/07/2007	16:18	58° 48'	48° 51'	43	30	10:31	231
29	20/07/2007	6:37	58° 54'	48° 39'	15	10	10:24	242
30	18/07/2007	18:00	58° 54'	48° 45'	29	19	09:56	245
31	18/07/2007	19:19	59° 06'	48° 39'	43	28	11:10	258
32	19/07/2007	18:35	59° 18'	48° 30'	59	44	12:26	312
33	19/07/2007	6:00	59° 06'	48° 28'	68	47	10:23	244
34	19/07/2007	16:01	58° 54'	48° 28'	63	50	10:14	259
35	19/07/2007	14:47	58° 42'	48° 30'	44	35	11:08	269
36	19/07/2007	14:12	58° 36'	48° 30'	48	33	10:54	253
37	19/07/2007	13:38	58° 36'	48° 27'	89	55	10:14	241
38	19/07/2007	17:33	59° 12'	48° 24'	87	53	10:10	235
39	19/07/2007	6:55	59° 00'	48° 24'	91	50	11:20	256
40	19/07/2007	12:04	58° 48'	48° 24'	44	37	09:51	248
41	19/07/2007	12:49	58° 42'	48° 24'	47	41	10:34	256
42	19/07/2007	7:59	59° 06'	48° 18'	99	52	12:03	263
43	19/07/2007	10:29	58° 54'	48° 18'	104	52	11:47	266
44	19/07/2007	11:11	58° 48'	48° 18'	42	35	10:33	255
45	19/07/2007	9:02	59° 00'	48° 12'	85	54	10:30	249
46	19/07/2007	9:43	58° 54'	48° 13'	34	26	10:43	257
Mean					57.6	38.4	10:46	252.6
Std. Dev.					31.2	15.0	0:42	22.2
Minimum					15	10	9:51	203
Maximum					160	63	12:34	312
n					45	45	45	45

Table 2. List of egg taxa from the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

STATION	Atlantic Mackerel	H4B[1]	CHW[2]	CYT[3]	American Plaice	Windowpane flounder	TOTAL
1	X	X	X	X	X		5
2	X	X	X	X	X		5
3	X	X	X	X			4
4			X				1
5	X	X	X	X			4
6	X	X	X	X	X		5
7	X	X	X	X	X		5
8	X	X	X	X			4
9	X	X	X	X			4
10	X		X	X	X		4
11	X	X	X	X			4
12	X	X	X	X	X		5
13	X		X	X			3
14			X	X			2
15	X	X	X	X	X		5
16	X	X	X	X			4
17	X		X	X			3
18			X				1
19	X		X	X		X	4
20	X	X	X	X			4
21	X	X	X	X		X	5
23			X	X			2
24	X	X		X			3
25	X	X	X	X			4
26	X	X	X			X	4
27			X	X			2
28			X	X			2
29	X	X		X		X	4
30	X	X	X	X	X		5
31	X	X	X	X			4
32	X		X	X			3
33	X	X	X	X	X		5
34	X		X	X			3
35	X	X	X	X		X	5
36	X	X	X	X			4
37	X	X	X	X	X		5
38	X		X		X		3
39	X		X	X			3
40	X		X	X	X		4
41	X		X	X		X	4
42	X	X	X	X			4
43	X	X	X	X			4
44	X	X	X	X	X		5
45	X		X	X			3
46	X	X	X	X	X		5
TOTAL	39	28	43	41	14	6	

[1]H4B = hake, fourbeard rockling, and butterfish
[2]CHW = cod, haddock, and witch flounder
[3]CYT = cunner and yellowtail flounder

Table 3. Egg abundance (number/1,000 m^3) from the samples collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

STATION	American plaice	Atlantic mackerel	CHW (cod, haddock, witch flounder)	CYT (cunner, yellowtail flounder)	H4B (hake, fourbeard rockling, butterfish)	Windowpane flounder
1	7	38	105	5 628	21	0
2	7	18	107	573	14	0
3	0	60	40	1 673	64	0
4	0	0	802	0	0	0
5	0	153	138	9 182	118	0
6	3	41	548	1 699	7	0
7	4	17	42	613	17	0
8	0	60	119	2 804	8	0
9	0	20	1 101	102	8	0
10	5	5	377	1 788	0	0
11	0	18	159	404	14	0
12	8	31	443	138	15	0
13	0	42	196	10 419	0	0
14	0	0	416	18	0	0
15	4	27	1 187	1 750	4	0
16	0	67	119	17 143	60	0
17	0	12	157	3 176	0	0
18	0	0	942	0	0	0
19	0	5	639	19	0	5
20	0	106	33	5 546	881	0
21	0	115	77	10 209	245	92
23	0	0	101	89	0	0
24	0	121	0	376	877	0
25	0	229	8	580	1 007	0
26	0	129	4	0	517	259
27	0	0	417	3 628	0	0
28	0	0	285	233	0	0
29	0	310	0	24 087	4 235	2 912
30	8	16	409	35 311	41	0
31	0	70	334	39 499	248	0
32	0	48	576	1 358	0	0
33	8	147	1 073	860	49	0
34	0	366	1 404	39	0	0
35	0	271	175	3 416	30	30
36	0	435	103	1 249	229	0
37	12	183	274	316	91	0
38	9	89	876	0	0	0
39	0	63	461	8	0	0
40	8	97	888	113	0	0
41	0	441	523	4 992	0	31
42	0	23	706	46	15	0
43	0	53	395	546	4	0
44	4	377	518	15 826	31	0
45	0	12	8	529	0	0
46	4	35	156	432	19	0
Mean	2.0	96.7	387.6	4 587.0	197.2	74.0
Std. Dev.	3.4	121.4	365.7	8 829.7	661.0	434.5
Minimum	0	0	0	0	0	0
Maximum	12	441	1 404	39 499	4 235	2 912
n	45	45	45	45	45	45

Table 4. List of larval taxa from the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

			STATION																						
FAMILY	**SPECIES**	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**23**	**24**
Ammodytidae	*Ammodytes* spp.	Sandlances																						X	X
Bothidae	*Scophthalmus aquosus*	Windowpane flounder						X	X						X							X	X		
Clupeidae	*Clupea harengus*	Atlantic herring	X		X				X			X	X	X	X		X	X	X			X	X		
Gadidae	*Gadus morhua*	Atlantic cod	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X				
Labridae	*Tautogolabrus adspersus*	Cunner	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X
Liparidae	*Liparis* spp.	Snailfishes	X	X	X	X					X	X			X	X	X				X				
Osmeridae	*Mallotus villosus*	Capelin	X	X	X		X	X	X	X	X	X	X		X		X	X	X			X	X		
Phycidae	*Enchelyopus cimbrius*	Fourbeard rockling	X	X				X	X			X	X				X	X			X	X	X		X
Pleuronectidae	Pleuronectidae	Righteye flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Scombridae	*Scomber scombrus*	Atlantic mackerel	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X		X		X	X	
Scorpaenidae	*Sebastes* spp.	Redfishes	X	X			X		X		X								X	X				X	
Stichaeidae	*Stichaeus punctatus*	Arctic shanny						X																	
Stichaeidae	*Ulvaria subbifurcata*	Radiated shanny	X			X		X				X	X		X		X		X		X	X	X	X	X
	TOTAL		10	8	7	4	6	9	9	5	6	9	8	5	9	4	9	6	8	3	7	7	8	6	4

			STATION																						**TOTAL**
FAMILY	**SPECIES**	**COMMON NAME**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	
Ammodytidae	*Ammodytes* spp.	Sandlances			X	X				X													X		6
Bothidae	*Scophthalmus aquosus*	Windowpane flounder	X	X									X	X	X		X								11
Clupeidae	*Clupea harengus*	Atlantic herring			X	X		X	X	X	X			X	X	X			X	X		X			24
Gadidae	*Gadus morhua*	Atlantic cod			X	X		X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	35
Labridae	*Tautogolabrus adspersus*	Cunner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	41
Liparidae	*Liparis* spp.	Snailfishes								X		X	X			X	X		X		X				17
Osmeridae	*Mallotus villosus*	Capelin						X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	32
Phycidae	*Enchelyopus cimbrius*	Fourbeard rockling	X	X			X	X		X	X		X	X	X		X	X	X		X		X	X	27
Pleuronectidae	Pleuronectidae	Righteye flounder		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	43
Scombridae	*Scomber scombrus*	Atlantic mackerel	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	38
Scorpaenidae	*Sebastes* spp.	Redfishes						X	X	X						X	X					X			14
Stichaeidae	*Stichaeus punctatus*	Arctic shanny											X			X									3
Stichaeidae	*Ulvaria subbifurcata*	Radiated shanny		X	X	X		X	X	X	X	X		X			X			X	X	X		X	27
	TOTAL		4	6	7	6	3	9	8	10	8	7	9	9	8	8	10	5	8	6	8	8	7	7	

Table 5. Abundance of larvae (number/1,000 m^3) from the samples collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

STATION	Arctic shanny	Atlantic mackerel	Capelin	Cod	Cunner	Fourbeard rockling	Atlantic herring	Redfish	Righteye flounder	Radiated shanny	Sand-lance	Snailfish
1	0	24	52	17	3 836	21	21	17	112	28	0	14
2	0	21	68	21	1 117	21	0	21	72	0	0	7
3	0	80	40	28	2 413	0	4	0	676	0	0	4
4	0	0	0	79	0	0	0	0	188	7	0	51
5	0	20	217	39	1 498	0	0	5	39	0	0	0
6	7	31	45	27	185	21	0	0	96	14	0	0
7	0	17	59	13	756	17	4	4	151	0	0	0
8	0	32	12	8	526	0	0	0	143	0	0	0
9	0	20	4	20	0	0	0	8	197	0	0	8
10	0	5	24	19	203	19	5	0	116	29	0	10
11	0	14	36	29	382	14	11	0	72	11	0	0
12	0	61	0	65	92	0	4	0	970	0	0	0
13	0	28	42	14	378	0	4	0	147	21	0	14
14	0	0	0	83	28	0	0	0	46	0	0	37
15	0	39	12	16	273	16	4	0	62	31	0	4
16	0	30	37	0	358	37	4	0	202	0	0	0
17	0	8	8	4	83	0	4	4	50	29	0	0
18	0	0	0	96	0	0	0	10	154	0	0	0
19	0	14	0	10	86	5	0	0	81	33	0	10
20	0	0	8	0	171	86	4	0	24	4	0	0
21	0	134	61	0	5 396	238	11	0	222	15	0	0
23	0	20	0	0	101	0	0	8	16	4	12	0
24	0	0	0	0	611	329	0	0	0	4	4	0
25	0	15	0	0	2 289	702	0	0	0	0	0	0
26	0	53	0	0	969	420	0	0	24	8	0	0
27	0	185	0	16	265	0	24	0	104	345	16	0
28	0	0	0	9	95	0	26	0	190	61	9	0
29	0	0	0	0	190	66	0	0	8	0	0	0
30	0	33	12	8	131	16	4	4	368	147	0	0
31	0	35	12	12	62	0	31	31	132	124	0	0
32	0	122	13	0	83	6	10	45	32	6	16	6
33	0	336	37	49	237	25	12	0	639	25	0	0
34	0	120	42	19	339	0	0	0	270	8	0	8
35	45	743	45	15	691	52	0	0	401	0	0	4
36	0	787	79	20	553	32	20	0	79	8	0	0
37	0	337	233	29	191	4	37	0	341	0	0	0
38	4	166	0	21	459	0	13	9	281	0	0	4
39	0	141	20	16	242	8	0	8	250	8	0	8
40	0	85	85	0	226	4	0	0	242	0	0	0
41	0	480	277	8	491	8	16	0	281	0	0	16
42	0	95	4	23	0	0	27	0	349	15	0	0
43	0	4	60	4	15	4	0	0	60	19	0	26
44	0	51	275	4	86	0	4	4	447	31	0	0
45	0	152	68	44	64	8	0	0	650	0	4	0
46	0	105	269	4	144	4	0	0	74	31	0	0
Mean	1.2	103.1	50.1	19.8	584.8	48.5	6.7	4.0	201.3	23.7	1.3	5.1
Std. Dev.	6.7	175.4	77.5	23.1	1 039.1	130.4	9.8	8.9	207.1	57.1	3.9	10.2
Minimum	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	45	787	277	96	5 396	702	37	45	970	345	16	51
n	45	45	45	45	45	45	45	45	45	45	45	45

Table 5. (Continued).

STATION	Windowpane flounder	Broken larvae	Not identified
1	0	0	7
2	0	0	7
3	0	0	0
4	0	0	14
5	0	355	0
6	14	0	7
7	8	0	4
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	7	0	25
14	0	0	0
15	0	0	0
16	0	0	7
17	0	0	0
18	0	0	0
19	0	0	0
20	4	0	0
21	15	0	19
23	0	0	0
24	0	0	0
25	15	0	0
26	24	0	12
27	0	0	0
28	0	0	0
29	0	0	0
30	0	0	0
31	0	0	4
32	0	0	0
33	0	0	4
34	0	0	0
35	7	4	11
36	24	0	4
37	17	0	4
38	0	0	17
39	8	31	0
40	0	0	0
41	0	0	0
42	0	0	8
43	0	0	0
44	0	0	8
45	0	0	0
46	0	0	4
Mean	3.2	8.7	3.7
Std. Dev.	6.5	53.0	5.9
Minimum	0	0	0
Maximum	24	355	25
n	45	45	45

Table 6. Parameters of the isotropic variograms used to calculate the abundance estimates of eggs and larvae from the samples collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

SPECIES	MODEL*	Nugget (C_0)	Sill (C_0 + C)	Range (A_0)	r^2	RSS: residual sum of squares
EGGS						
American plaice	Spherical	0.08	9	18.7	0.75	5.88E+00
Atlantic mackerel	Spherical	3980	15920	45.6	0.83	1.22E+07
CHW	Spherical	9900	94790	37.5	1.00	4.48E+06
CYT	Spherical	100	49580	20.2	0.70	2.41E+08
H4B	Spherical	5300	59660	40.8	1.00	6.82E+05
LARVAE						
Atlantic herring	Spherical	0.10	93	21.6	0.92	2.17E+02
Atlantic mackerel	Spherical	100	37500	33.5	0.95	6.03E+07
Capelin	Spherical	1150	6244	31.5	0.98	1.16E+05
Cod	Spherical	305	610	61.7	0.76	2.08E+04
Cunner	Exponential	14600	69700	14.0	0.86	1.50E+08
Fourbeard rockling	Spherical	13490	26990	76.7	0.83	2.43E+07
Radiated shanny	Spherical	40	201	19.0	0.93	5.98E+02
Redfish	Spherical	0.01	22	19.0	0.83	5.60E+01
Righteye flounder	Spherical	2270	28650	31.7	0.84	8.32E+07
Sandlance	Spherical	0.01	10	18.9	0.88	5.16E+00
Snailfish	Spherical	0.10	62	17.6	0.75	9.60E+02

* Spherical model

$$\gamma(h) = \begin{cases} C0 + C\left[1.5\left(\frac{h}{A_0}\right) - 0.5\left(\frac{h}{A_0}\right)^3\right] & \text{if } h \le A_0 \text{, and } C0+C \text{ otherwise} \end{cases}$$

Exponential model

$$\gamma(h) = C0 + C\left[1 - \exp\left(-\frac{h}{A_0}\right)\right]$$

Table 7. Abundance estimates (number/1,000 m^3) of some eggs and larvae calculated by kriging from the samples collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

	KRIGING			95% CONFIDENCE INTERVAL	
	Average	**Std. Err.**	**CV**	**Lower Limit**	**Upper Limit**
EGGS					
American plaice	2.24	0.35	0.16	1.55	2.92
Atlantic mackerel	93.46	13.02	0.14	67.95	118.97
CHW	447.27	28.95	0.06	390.53	504.01
CYT	4453.19	22.10	0.01	4409.88	4496.51
H4B	220.27	22.09	0.10	176.98	263.56
LARVAE					
Atlantic herring	6.87	0.96	0.14	4.98	8.76
Atlantic mackerel	103.17	17.04	0.17	69.76	136.57
Capelin	45.56	8.23	0.18	29.42	61.69
Cod	19.06	2.99	0.16	13.20	24.91
Cunner	564.27	34.26	0.06	497.13	631.41
Fourbeard rockling	24.90	19.10	0.77	-12.52	62.33
Radiated shanny	21.85	6.46	0.30	9.20	34.51
Redfish	2.62	0.48	0.18	1.68	3.56
Righteye flounder	234.61	19.49	0.08	196.41	272.81
Sandlance	1.19	0.33	0.28	0.54	1.83
Snailfish	4.56	1.10	0.24	2.41	6.72

Table 8. Results of the ANOVA analyses on different generalized additive models applied on the abundance estimates (number/1,000 m^3) of some eggs and larvae collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

SPECIES	FAMILY	VARIABLE SMOOTHING FUNCTION	d.f.	F	p-value	R^2 (adjusted)	DEVIANCE EXPLAINED (%)	GCV*	AIC**
EGGS									
American plaice	Gaussian	s(Long,Lat)	4.31	0.81	0.536	0.06	15	13	232
Atlantic mackerel	Gaussian	s(Long,Lat)	8.36	3.11	0.009	0.64	72	7 140	503
		+ s(Temp)	0.97	8.23	0.008				
CHW	Gaussian	s(Long,Lat)	17.47	3.07	0.005	0.57	75	105 630	610
CYT	Gaussian	s(Long,Lat)	26.08	15.08	0.000	0.90	96	21 022 000	818
H4B	Gaussian	s(Lat)	6.73	2.61	0.029	0.28	39	402 330	677
LARVAE									
Atlantic herring	Gaussian	s(Long,Lat)	16.93	3.25	0.004	0.57	74	66	294
Atlantic mackerel	Gaussian	s(Long,Lat)	24.71	6.05	0.000	0.86	95	11 741	497
		+ s(E.Mackerel)	1.05	16.73	0.001				
Capelin	Gaussian	s(Long,Lat)	13.30	8.57	0.000	0.73	82	2 243	450
Cod	Gaussian	s(Long,Lat)	26.55	14.57	0.000	0.94	99	191	274
		+ s(Temp)	7.54	34.41	0.000				
Cunner	Gaussian	s(Lat)	2.14	5.96	0.005	0.31	40	906 930	713
		+ s(Temp)	3.62	4.92	0.004				
Fourbeard rockling	Gaussian	s(Long,Lat)	16.12	3.16	0.005	0.56	73	12 995	522
Radiated shanny	Gaussian	s(Long,Lat)	19.39	2.86	0.009	0.57	77	2 756	450
Redfish	Gaussian	s(Long,Lat)	20.68	11.84	0.000	0.86	93	24	244
Righteye flounder	Gaussian	s(Lat)	2.35	3.19	0.044	0.16	21	40 346	580
Sandlance	Gaussian	s(Long,Lat)	22.38	4.87	0.000	0.72	87	9	199
Snailfish	Gaussian	s(Long,Lat)	12.49	2.32	0.030	0.39	57	96	315

* Generalized cross validation
** Akaike information criterion

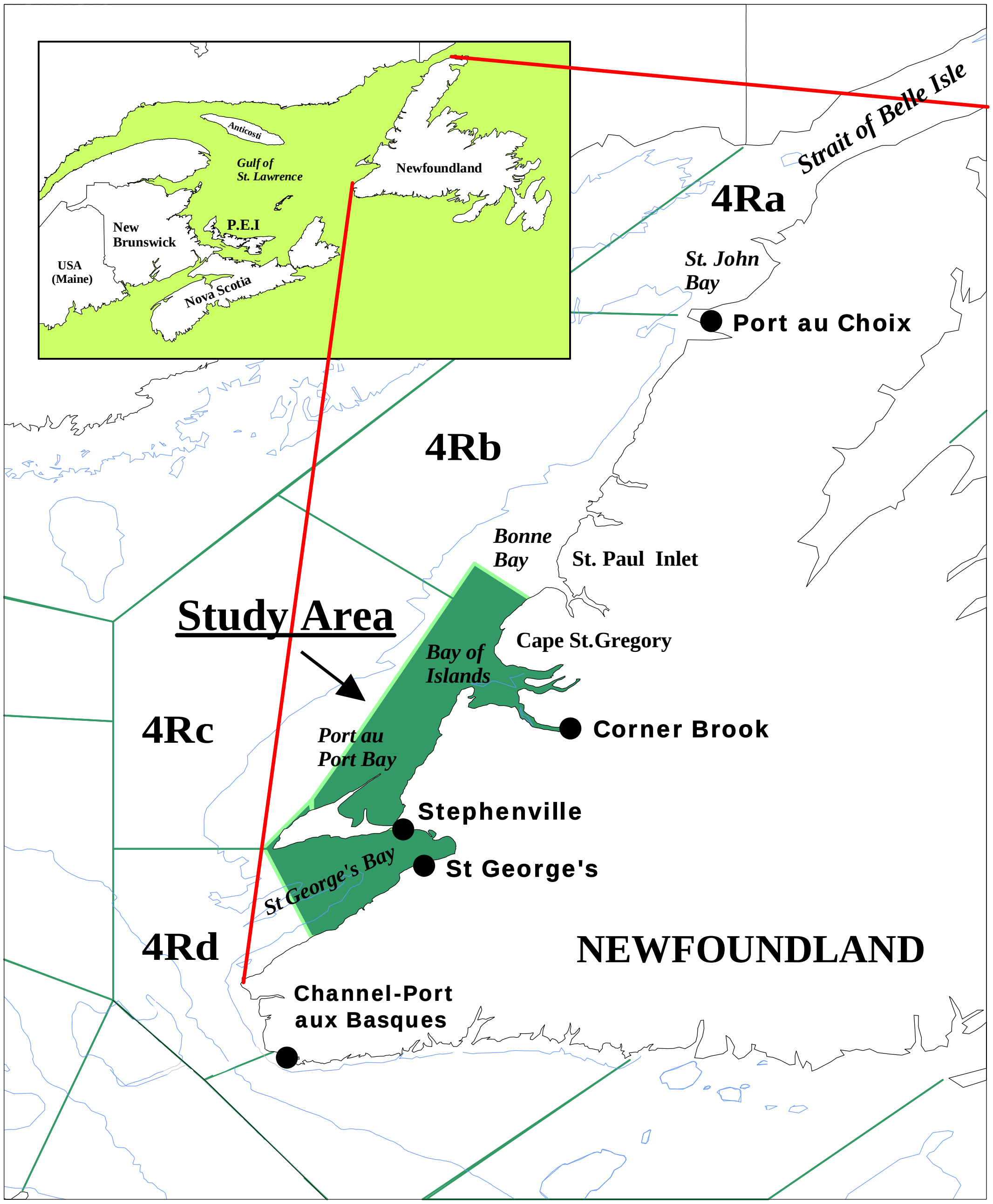


Figure 1. Map of the west coast of Newfoundland showing the study area and other locations mentioned in the document.

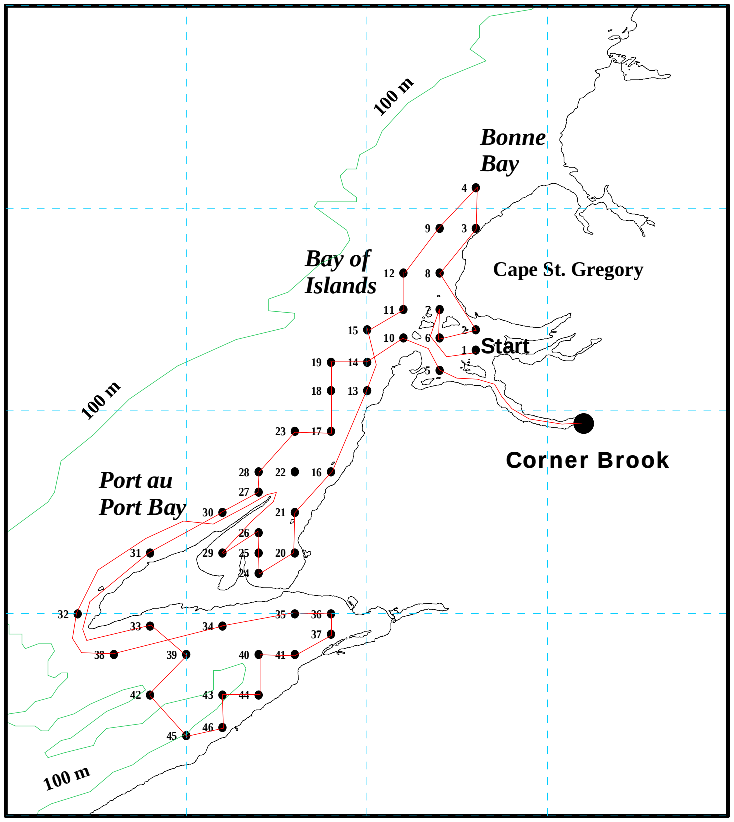


Figure 2. Map of the 45-station sampling grid of the capelin and Atlantic herring larval survey in July 2007 on the west coast of Newfoundland.

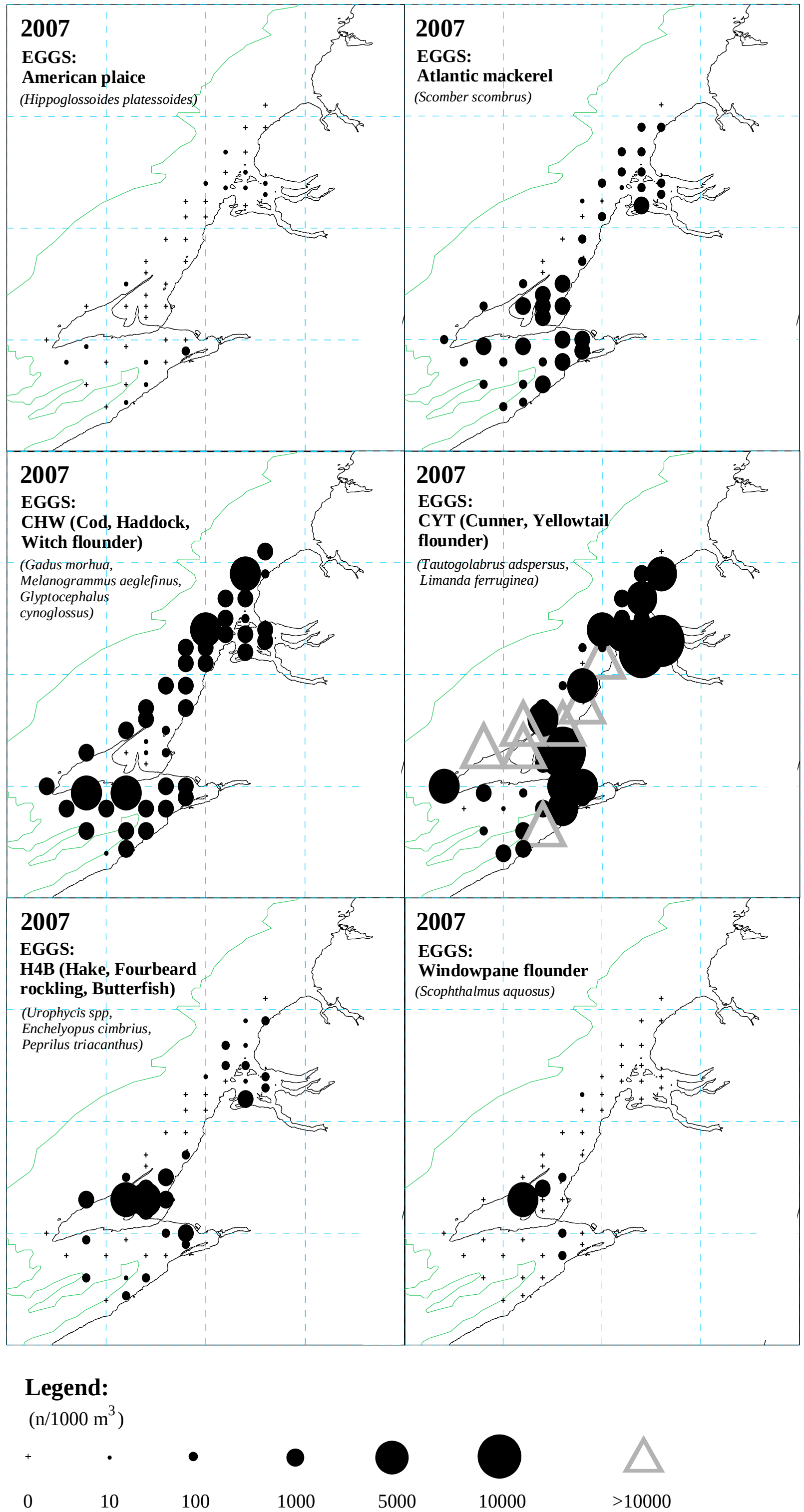


Figure 3. Maps of egg abundance (number/1,000 m^3) distributions from the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

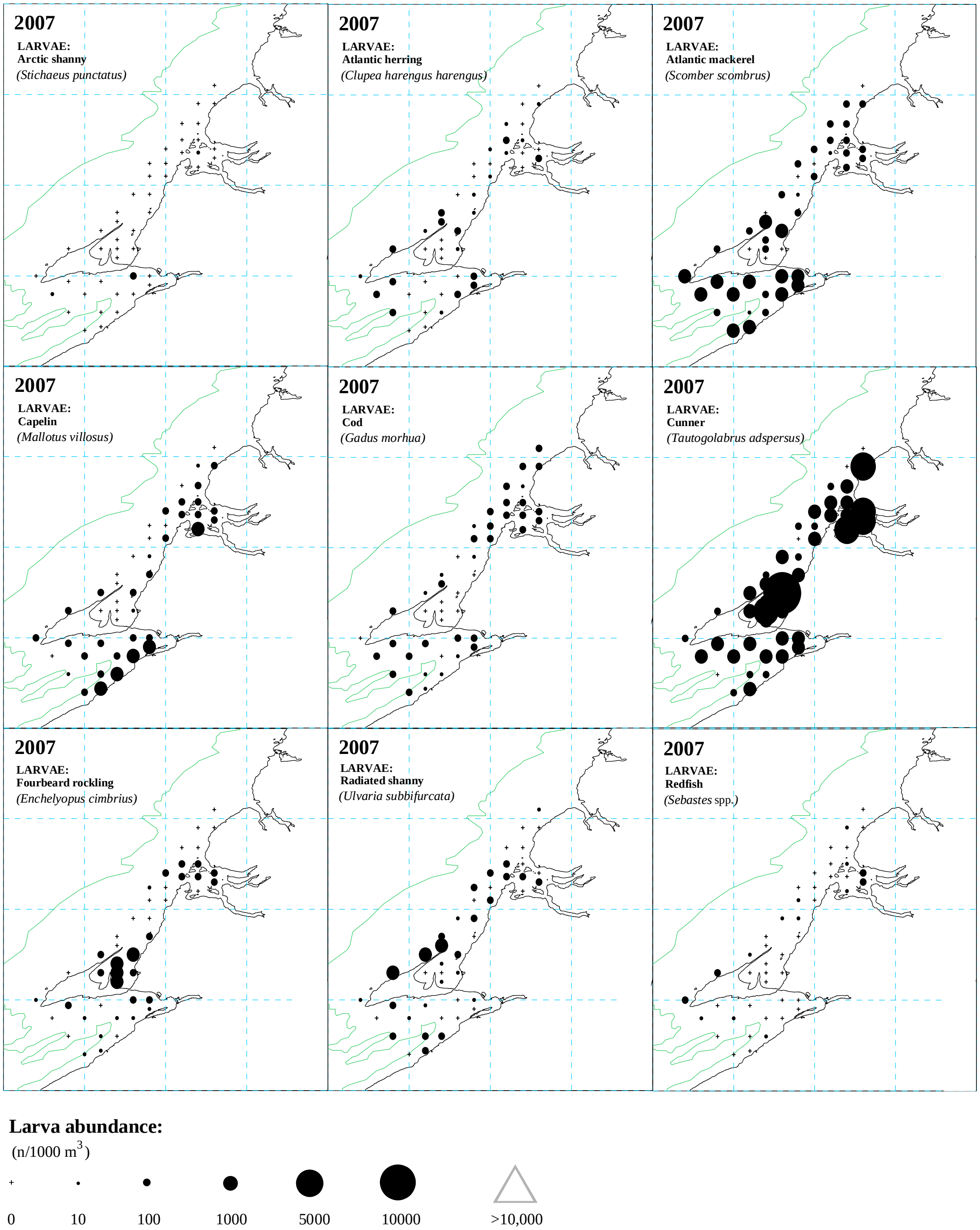


Figure 4. Maps of larval abundance (number/1,000 m^3) distributions from the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

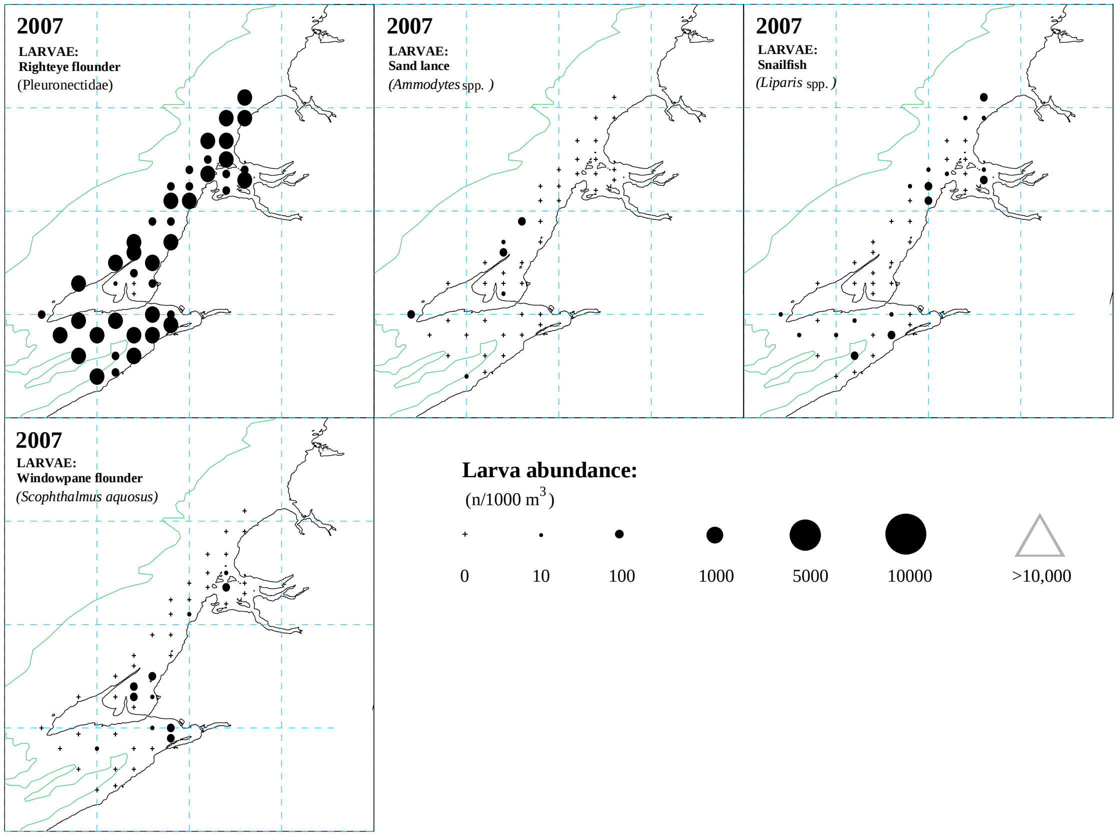


Figure 4. (Continued).

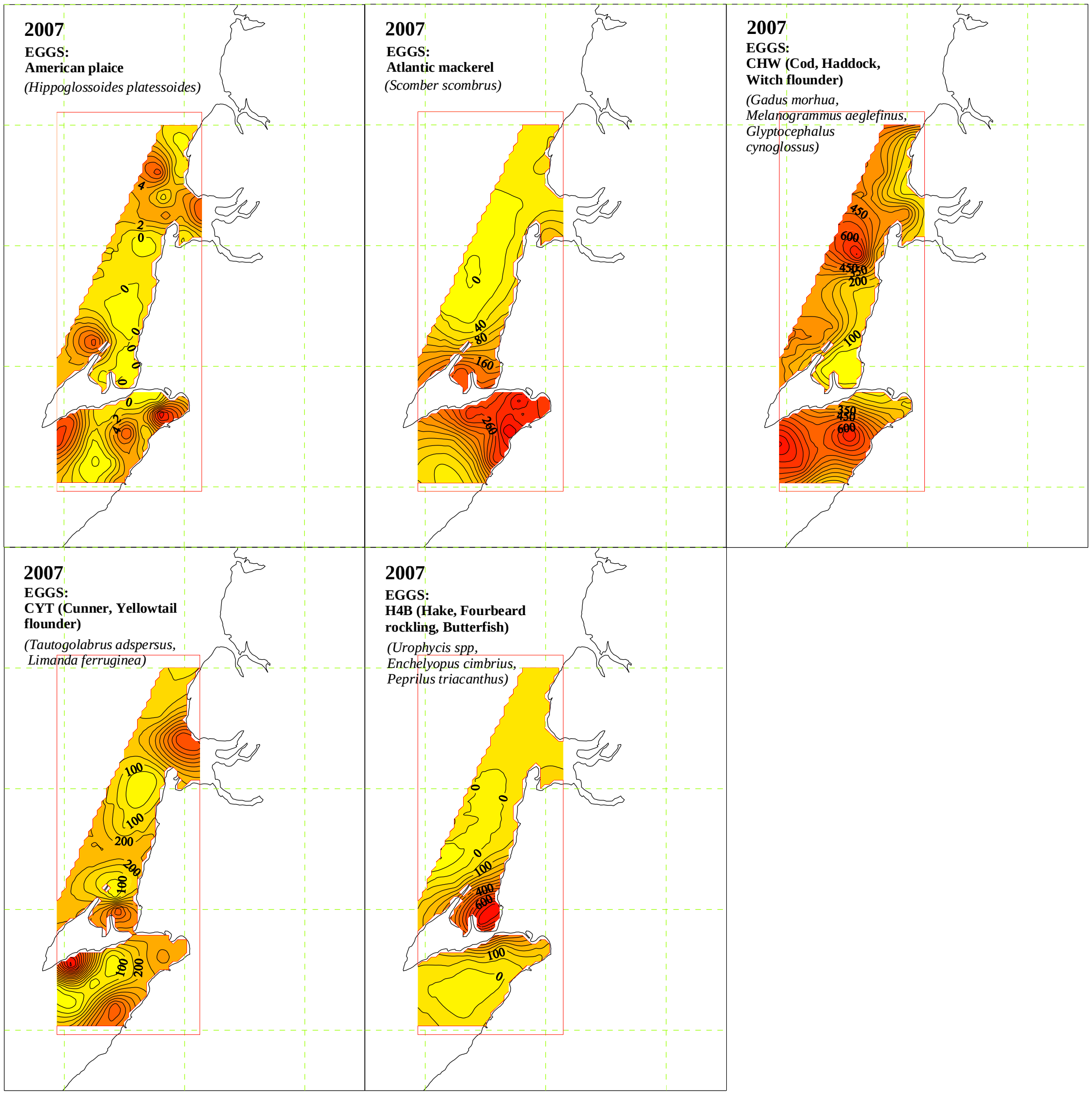


Figure 5. Abundance distribution maps (number/1,000 m^3) as derived by kriging of the eggs of some species sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland (Note: it was not possible to build a variogram and apply kriging on the windowpane flounder egg data).

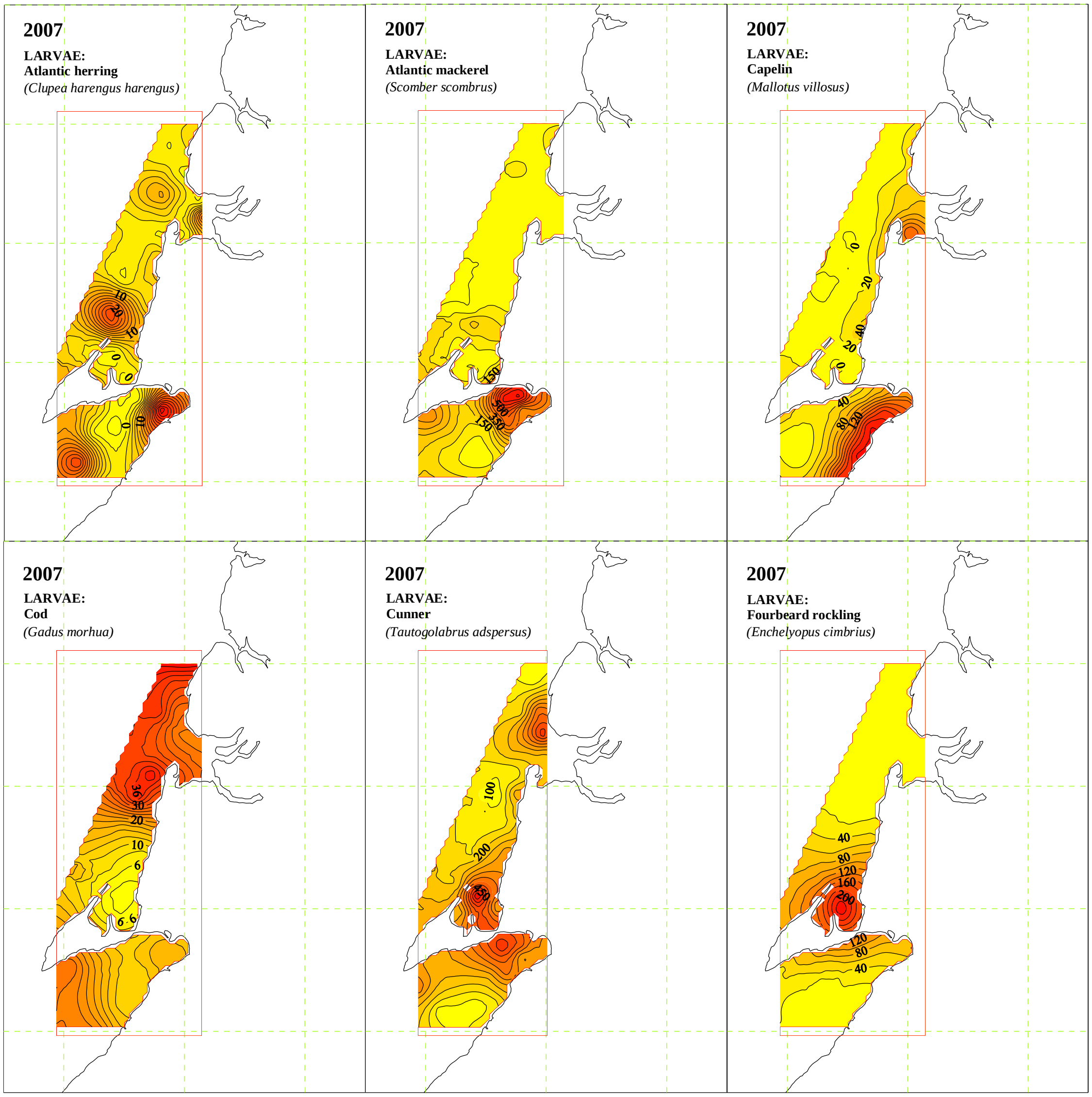


Figure 6. Abundance distribution maps (number/1,000 m^3) as derived by kriging of the larvae of some species sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland (Note: it was not possible to build a variogram and apply kriging on arctic shanny and windowpane flounder larva data).

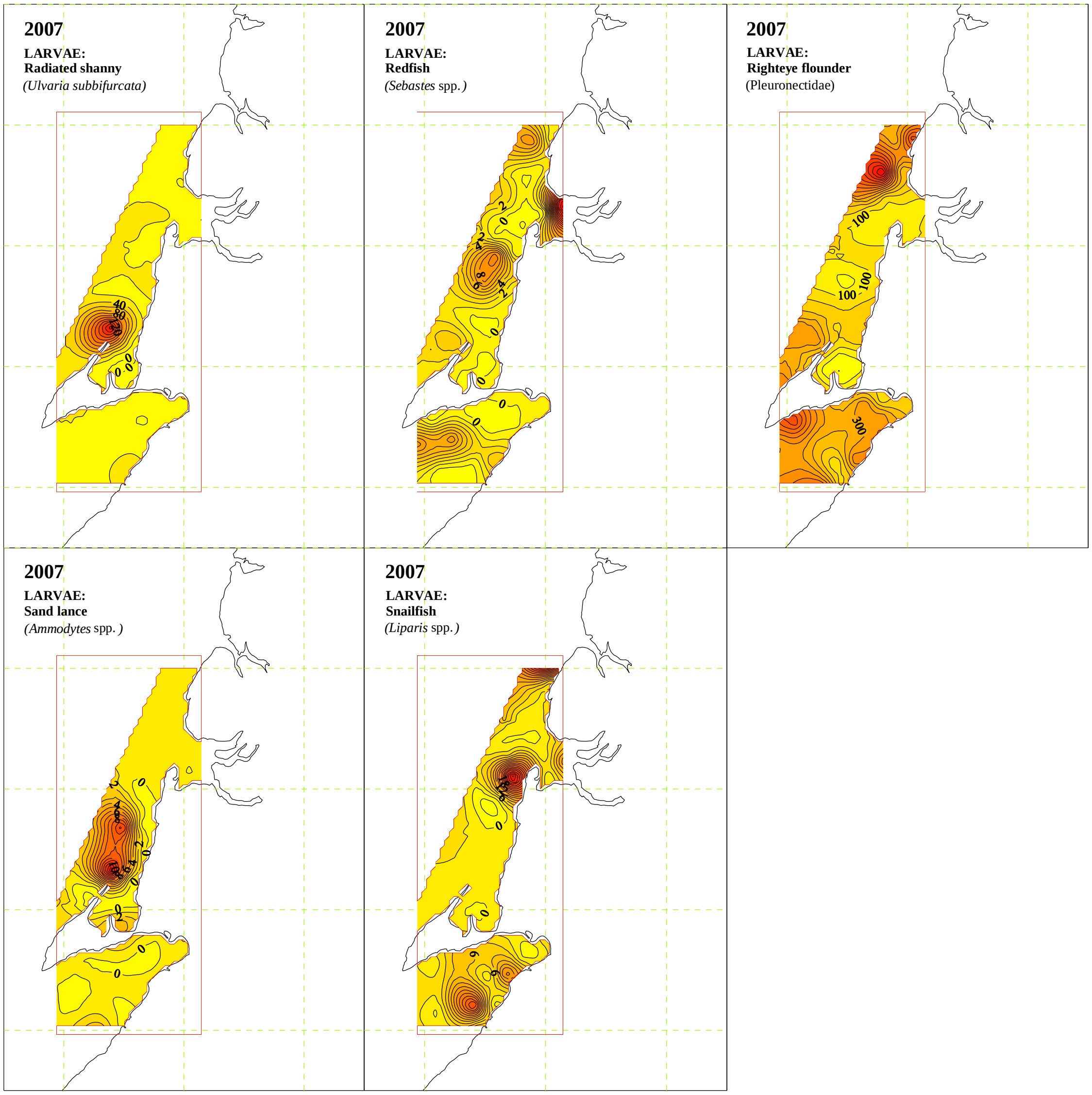


Figure 6. (Continued).

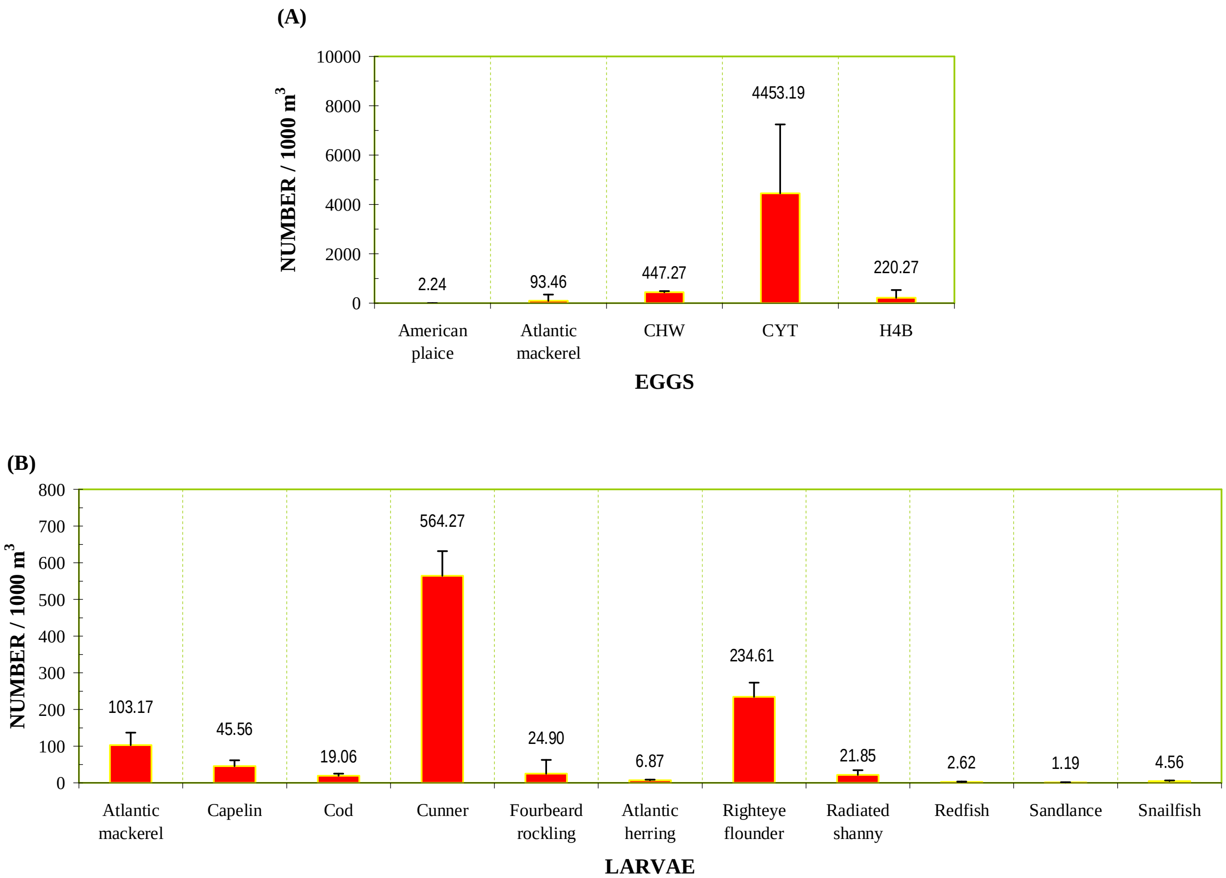


Figure 7. Mean abundance estimates (number/1,000 m^3) (with 95% confidence intervals) calculated by kriging of the eggs (A) and larvae (B) of some species sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

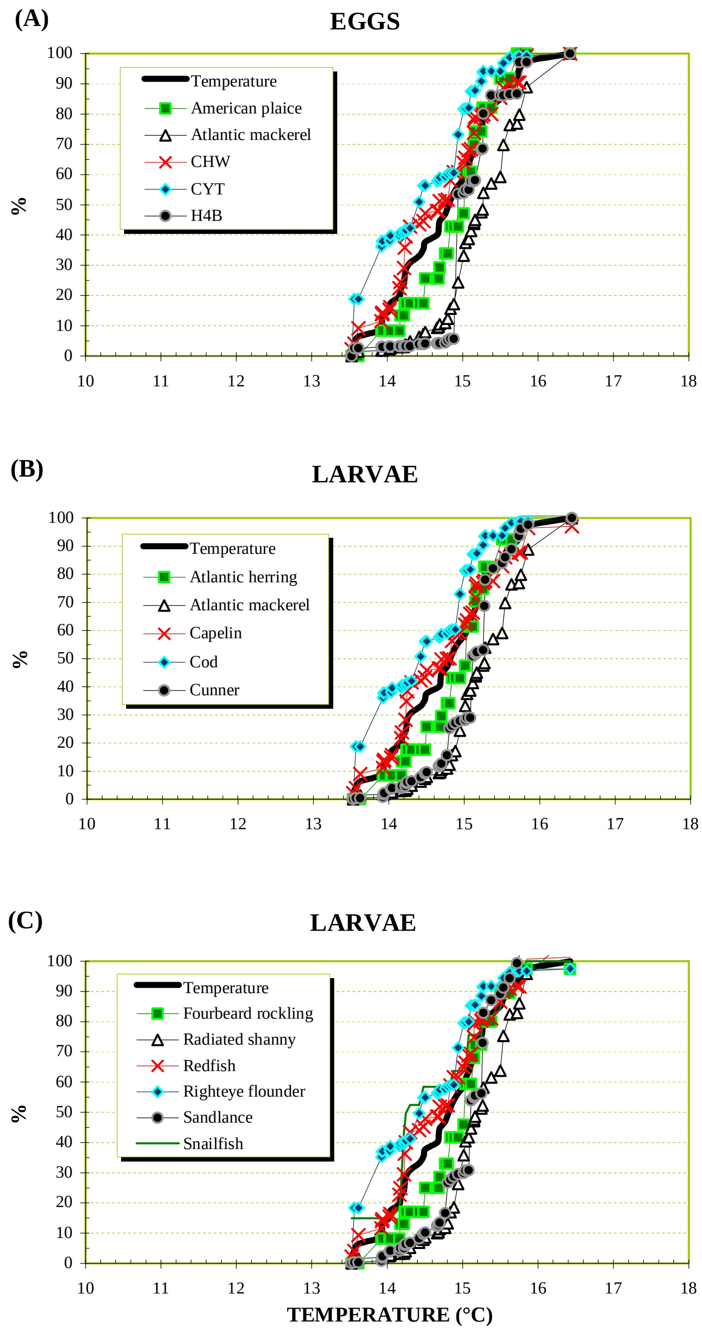


Figure 8. Cumulative curves of the abundance data of some eggs (A) and larvae (B and C) in relation to water temperature for the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

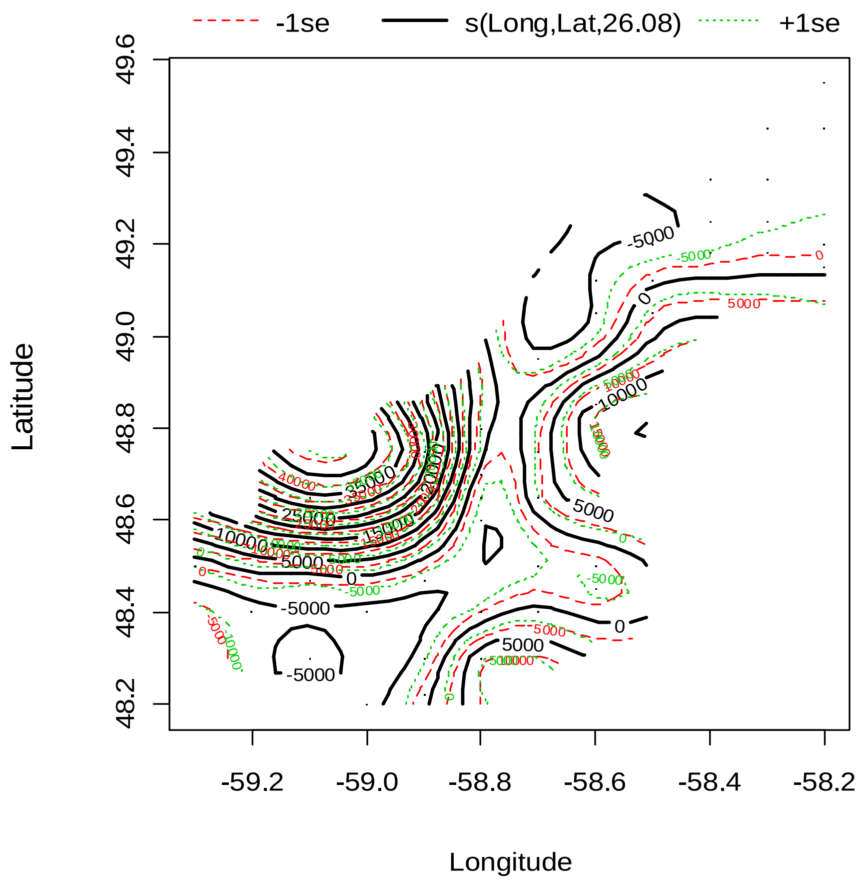
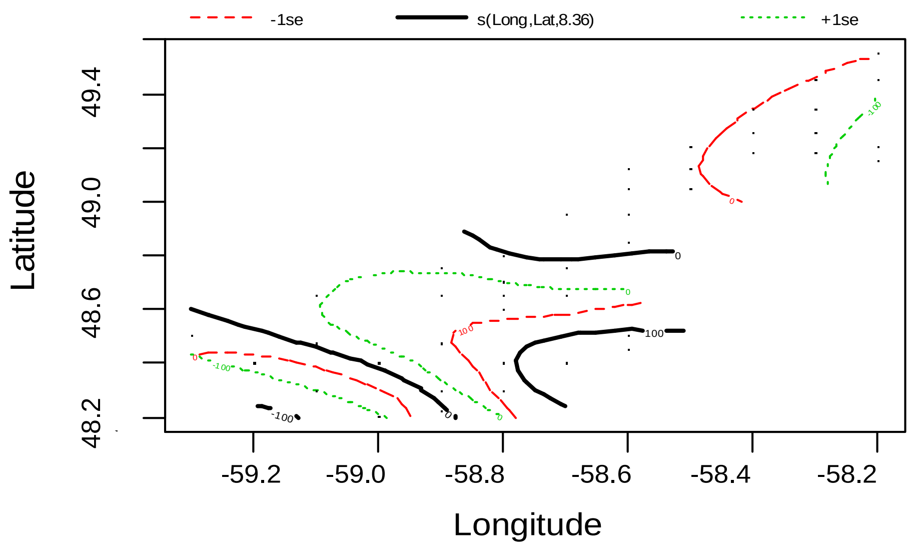


Figure 9. Smoothing function (with standard error) of the interaction between latitude and longitude on the CYT egg abundance data (number/1,000 m^3). Degrees of freedom was estimated at 26.08.

(A)



(B)

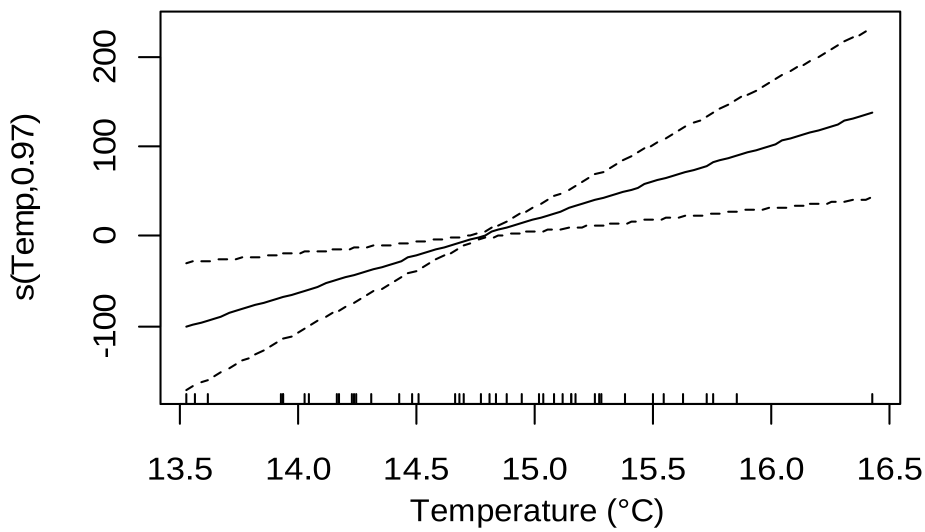


Figure 10. Smoothing functions of the interaction between latitude and longitude (with standard error) (A) and temperature (°C) (with 95% confidence intervals) (B) on the mackerel egg abundance data (number/1,000 m^3). Degrees of freedom were estimated at 8.36 and 0.97, respectively. Vertical lines on the x-axis in (B) represent observed temperature values.

(A)

(B)

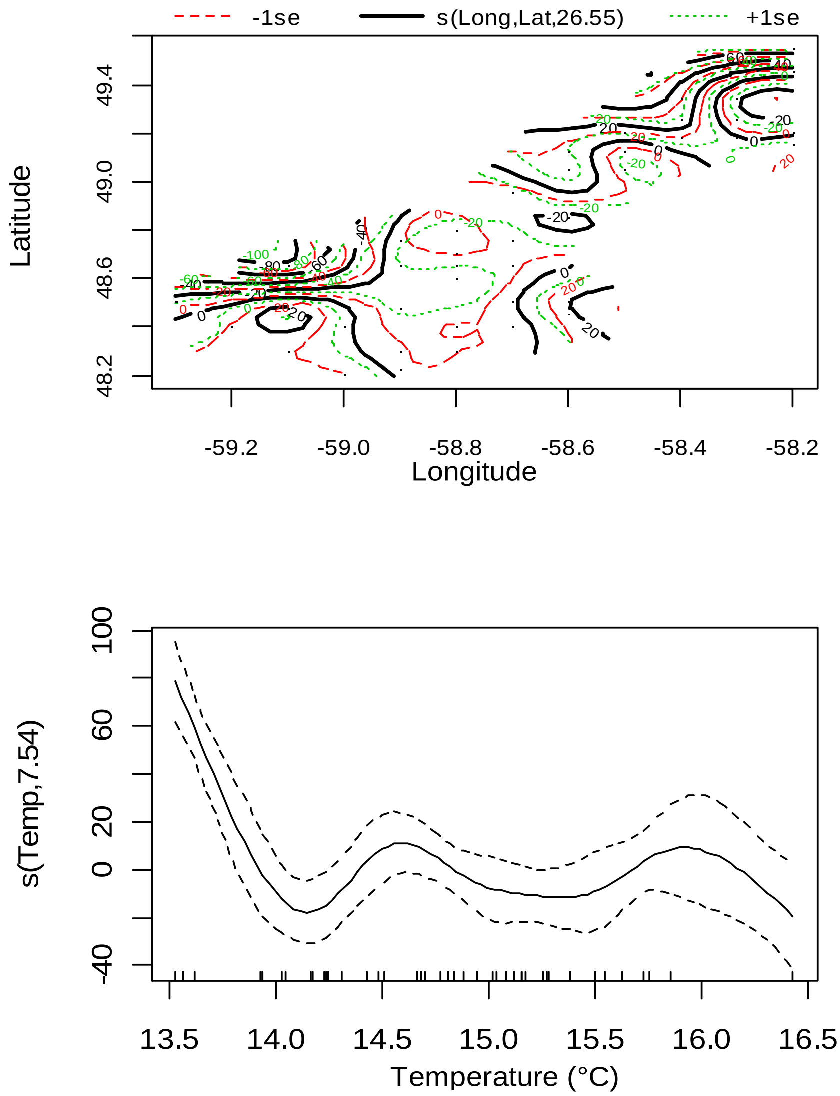
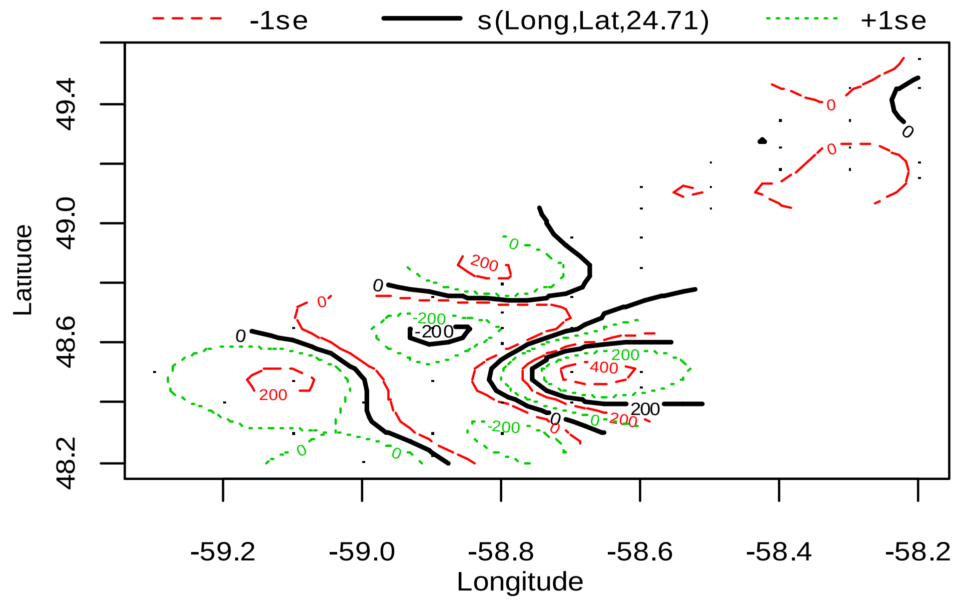


Figure 11. Smoothing functions of the interaction between latitude and longitude (with standard error) (A) and temperature (°C) (with 95% confidence intervals) (B) on the cod larva abundance data (number/1,000 m^3). Degrees of freedom were estimated at 26.55 and 7.54, respectively. Vertical lines on the x-axis in (B) represent observed temperature values.

(A)



(B)

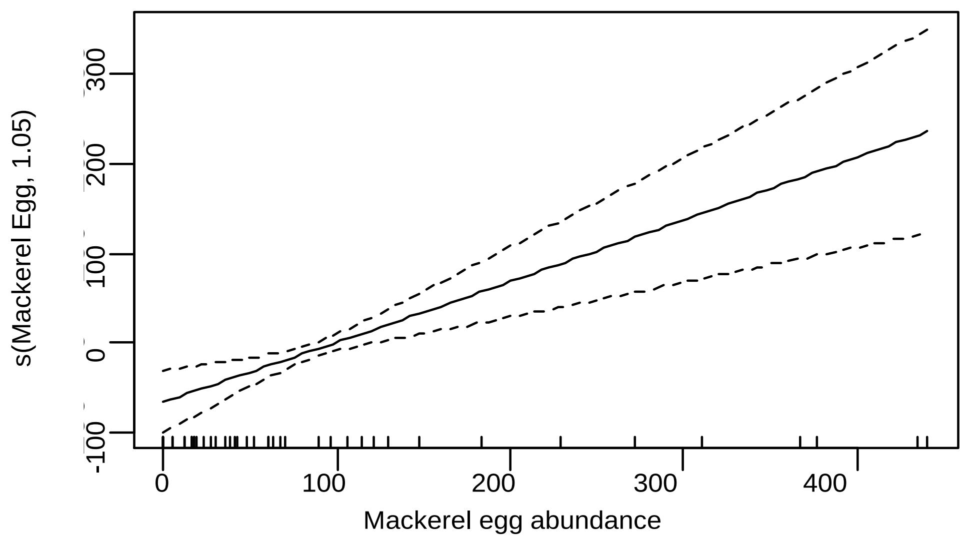


Figure 12. Smoothing functions of the interaction between latitude and longitude (with standard error) (A) and mackerel egg abundance (with 95% confidence intervals) (B) on the mackerel larva abundance data (number/1,000 m^3). Degrees of freedom were estimated at 24.71 and 1.05, respectively. Vertical lines on the x-axis in (B) represent observed egg abundance values.

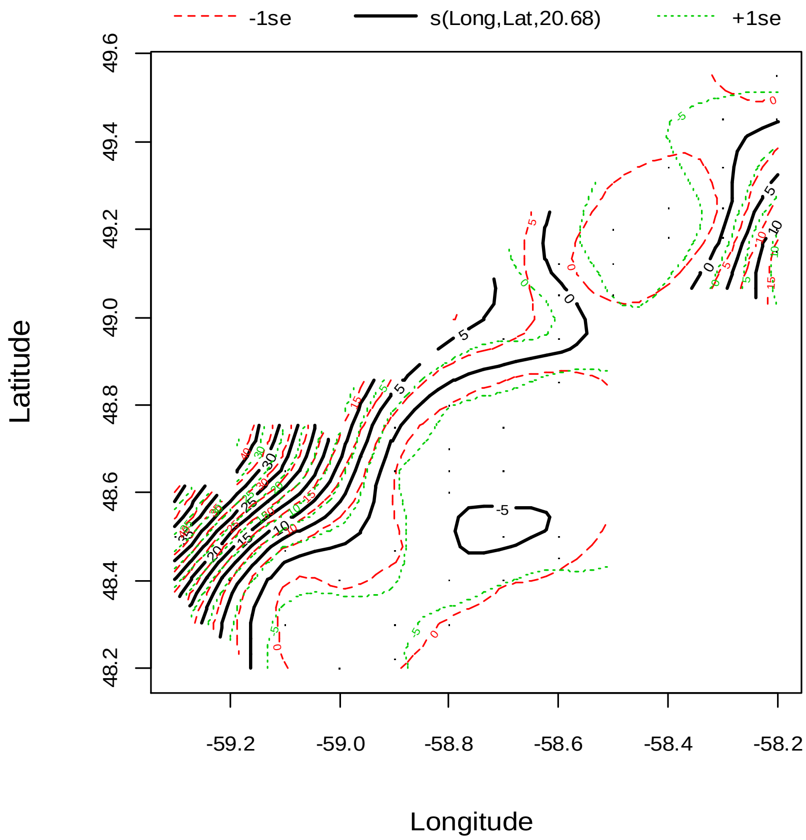
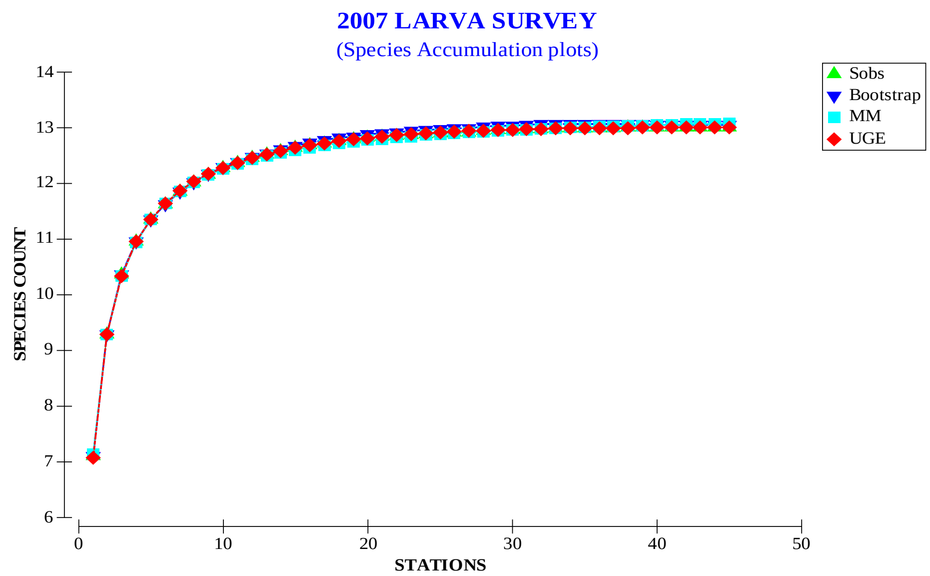


Figure 13. Smoothing function (with standard error) of the interaction between latitude and longitude on the redfish larva abundance data (number/1,000 m^3). Degrees of freedom was estimated at 20.68.

(A)



(B)

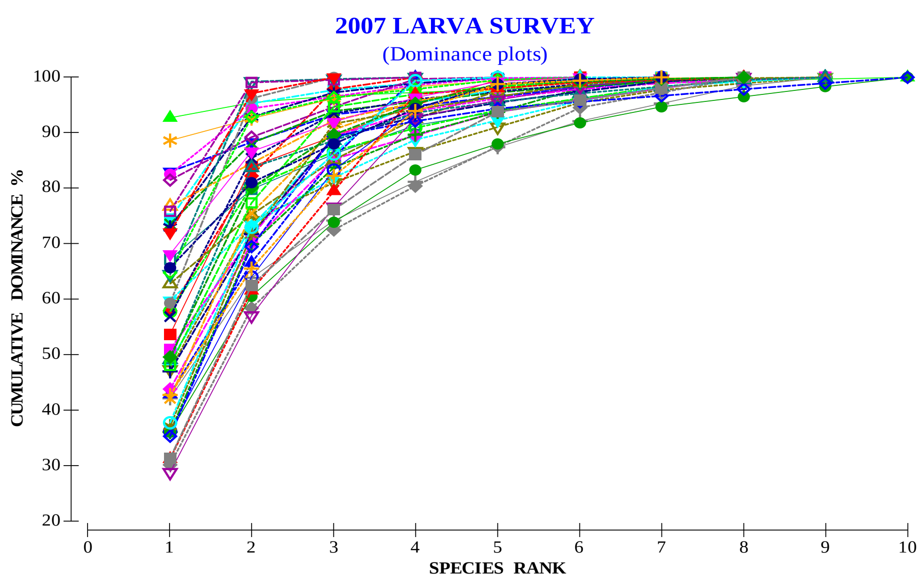


Figure 14. Species accumulation (A) and dominance (B) plots for the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland. In A, Sobs = observed data; bootstrap, MM, UGE = predicted data; see text for explanation. In B, the line-symbols represent the cumulative dominance and species rank of each station.

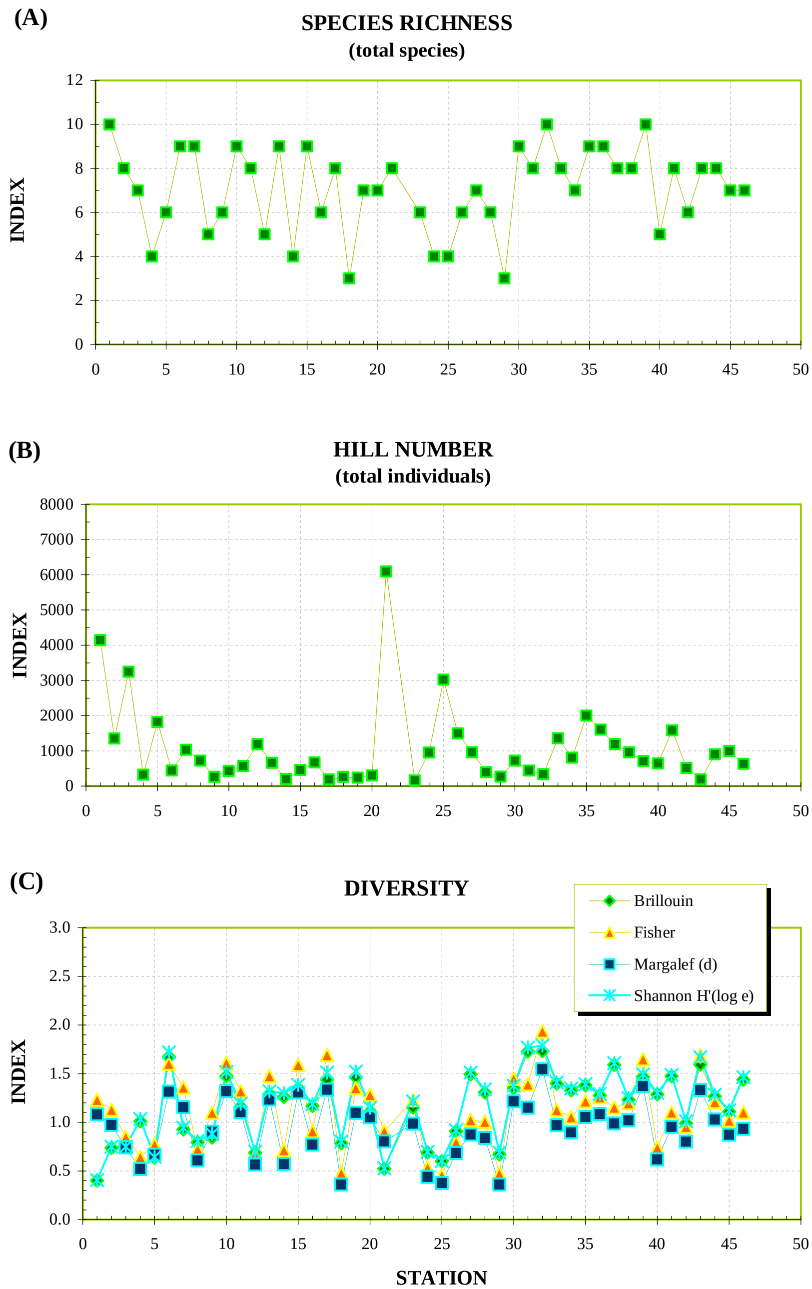


Figure 15. Total species (A), total individuals (B), and four diversity indices (C) calculated for the stations sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

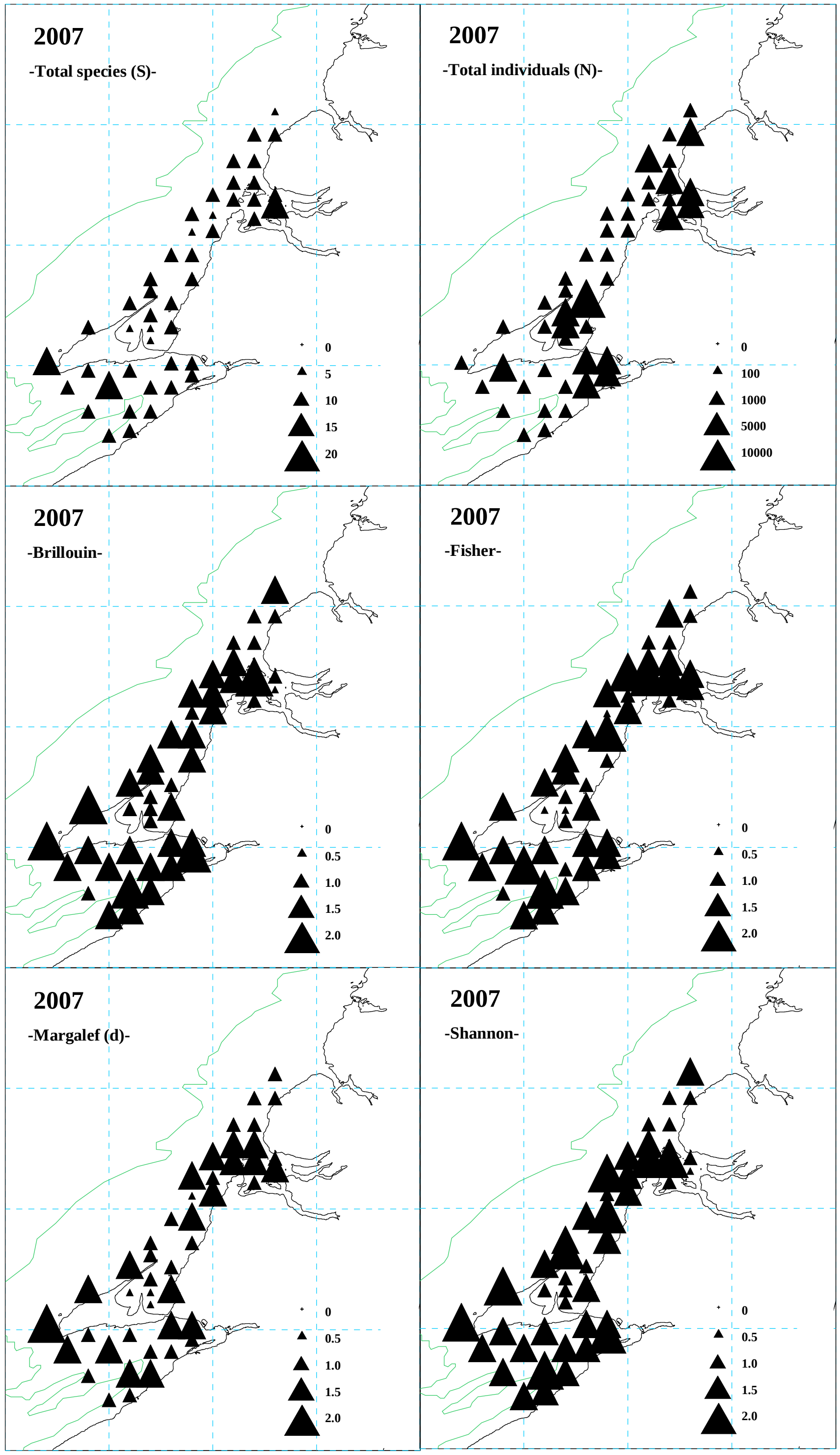
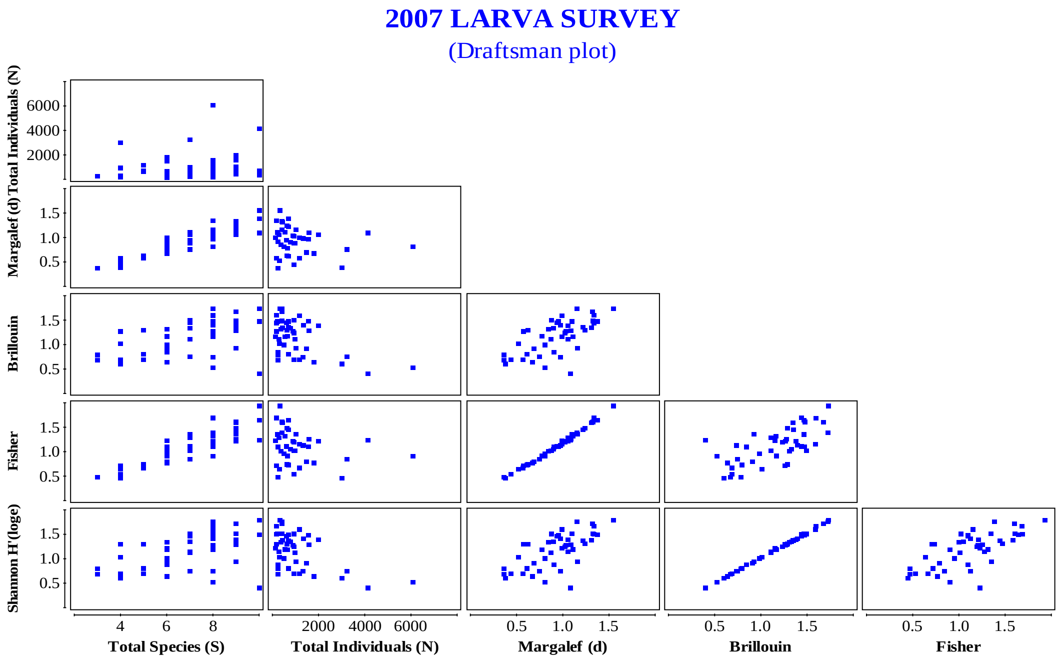


Figure 16. Maps showing distributions of total species, total individuals, and four diversity indices for the stations sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

(A)



(B)

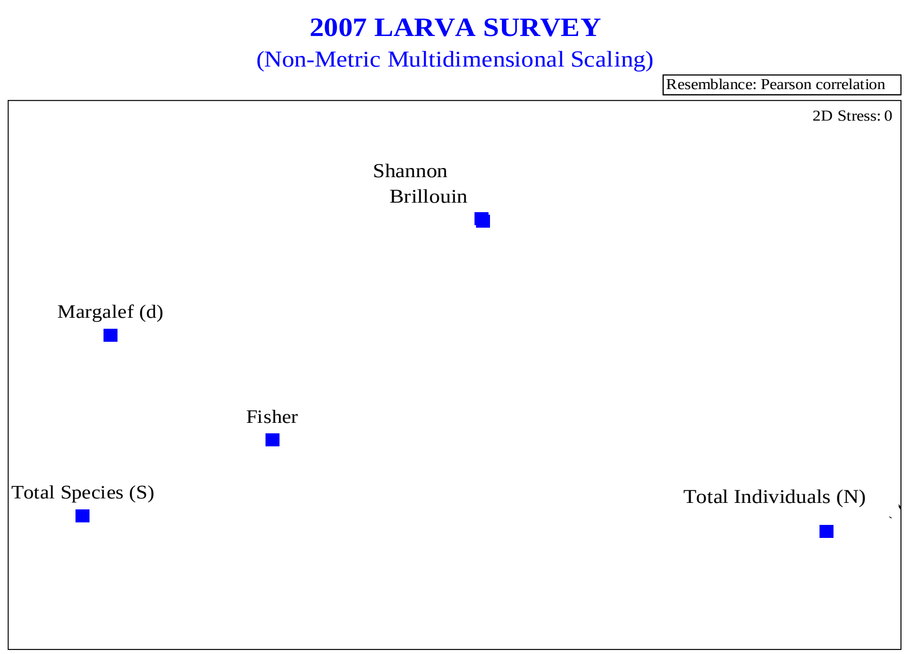
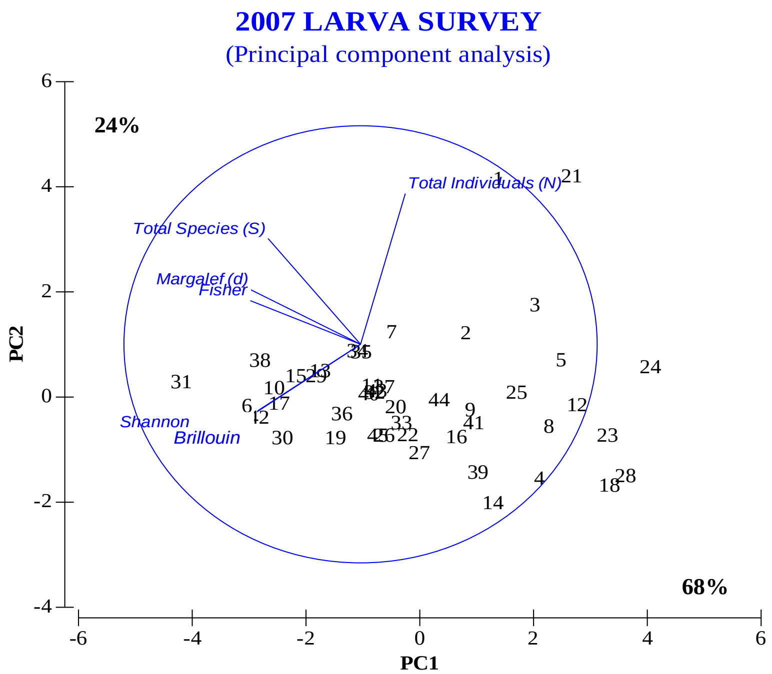


Figure 17. Draftsman (A), non-metric multidimensional scaling (B), and principal component analysis (PCA) (C) plots for the diversity indices calculated from the data collected during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

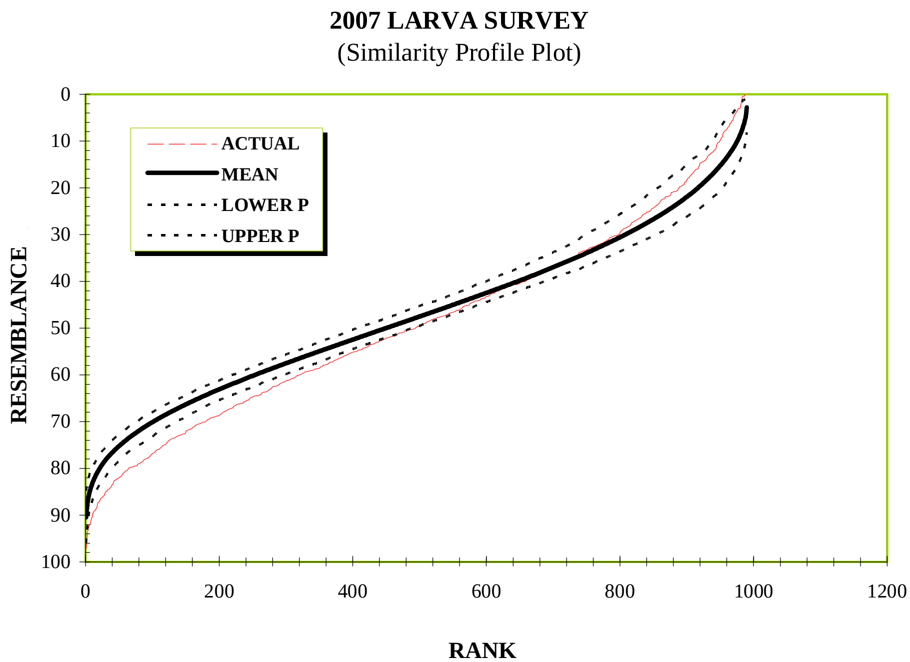
(C)



Variable	Eigenvectors PC1	PC2
Total Species (S)	-0.391	0.484
Total Individuals (N)	0.189	0.690
Margalef (d)	-0.463	0.249
Brillouin	-0.435	-0.304
Fisher	-0.466	0.200
Shannon H'(log e)	-0.437	-0.309

Figure 17. (Continued).

(A)



(B)

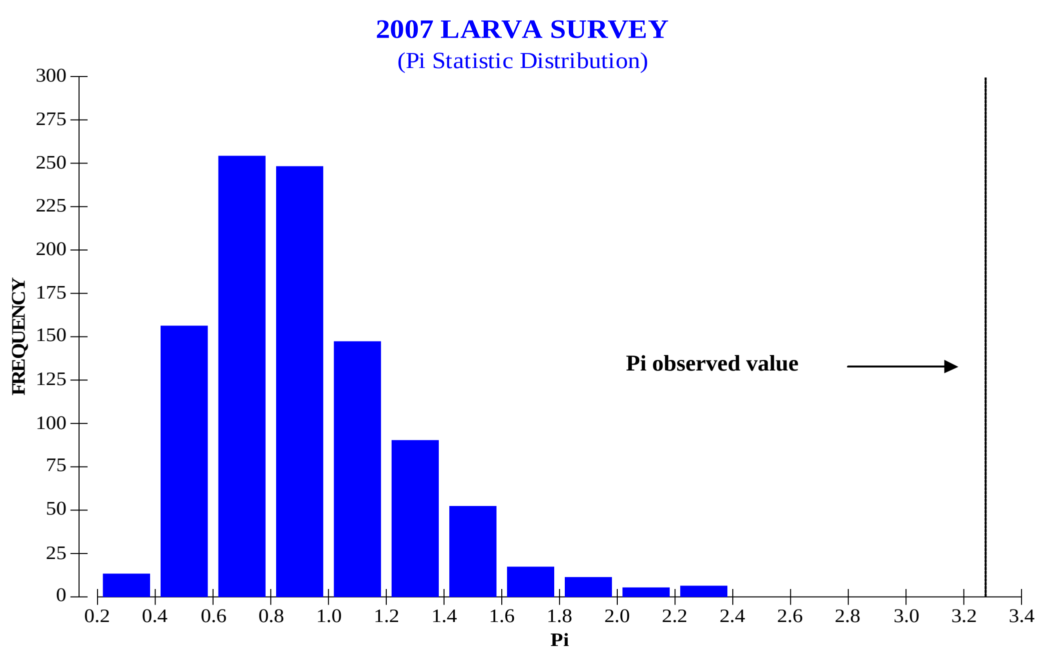


Figure 18. Similarity profile (A) and *Pi* statistic distribution (B) testing for evidence of internal group structure in the full set of stations sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland.

(A)

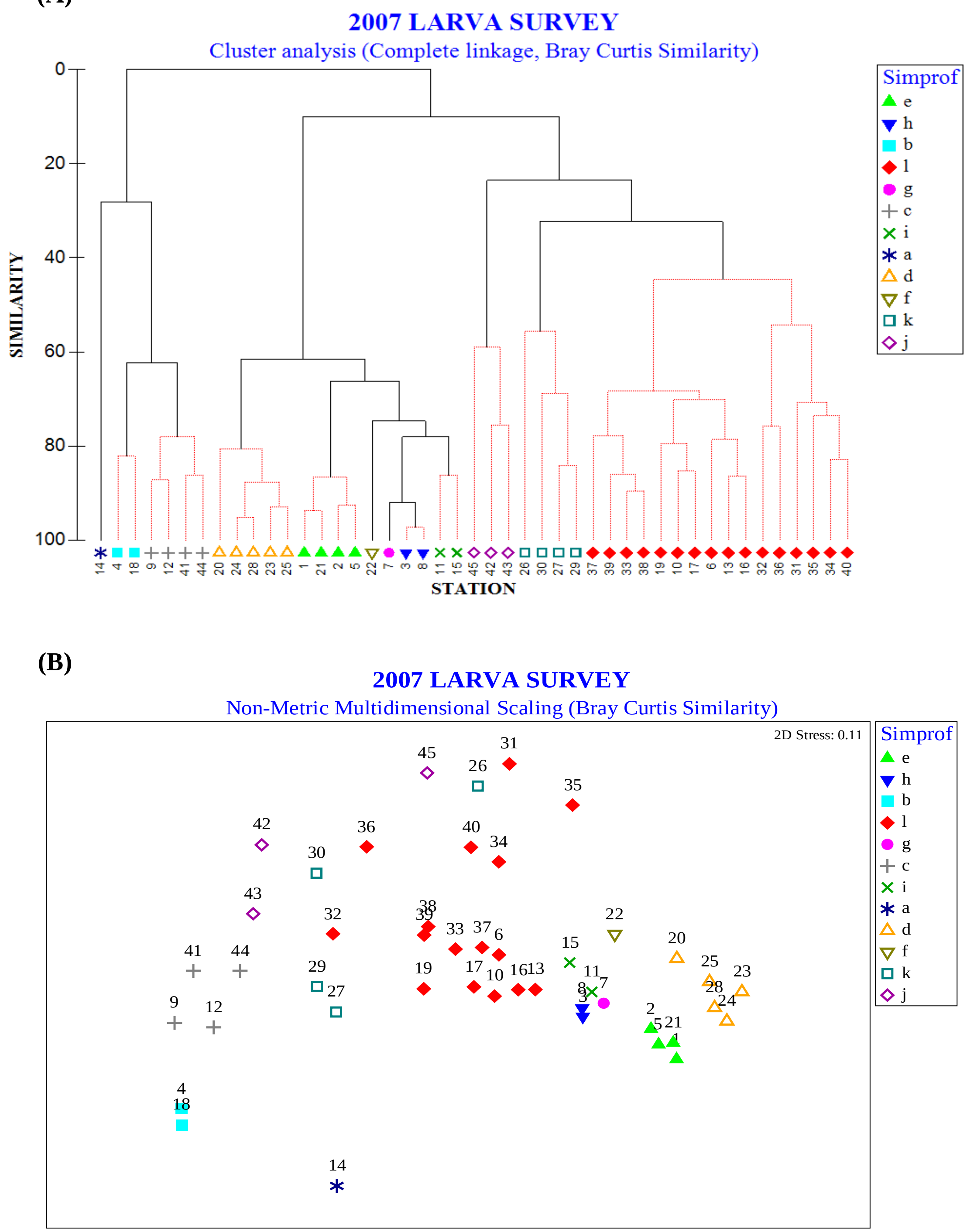


Figure 19. Results of the cluster analysis (A) and non-metric multidimensional scaling (B) applied on the Bray Curtis similarities calculated among the stations sampled during the capelin and Atlantic herring larval survey of July 2007 on the west coast of Newfoundland (groups of stations were defined by the SIMPROF procedure).

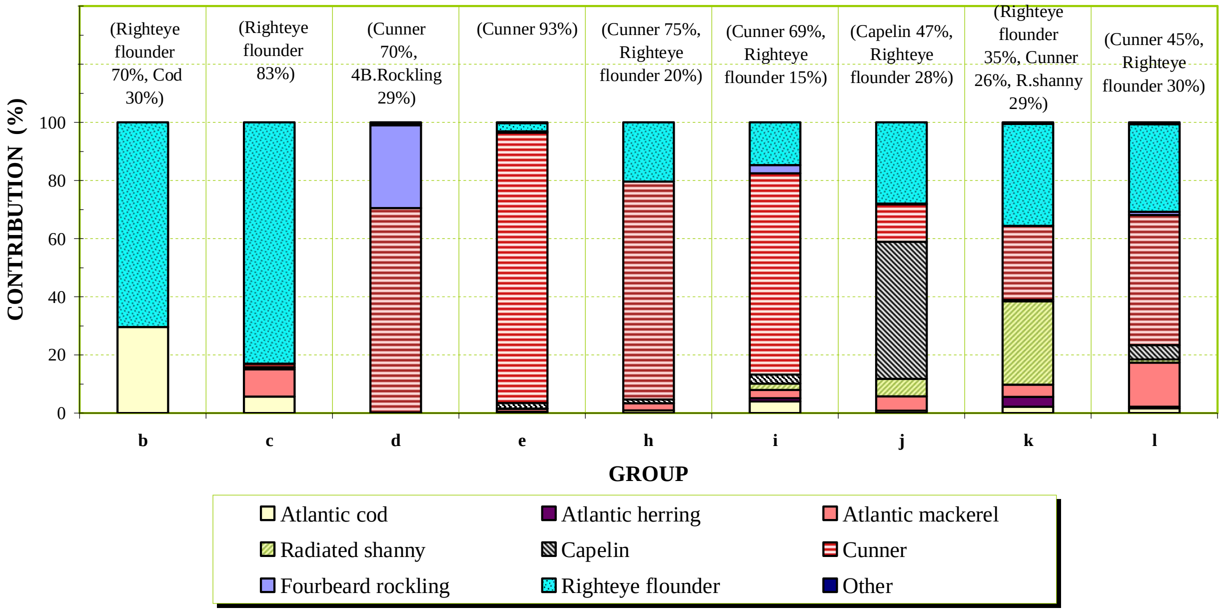


Figure 20. Relative contribution (%) of the main species of fish larvae to the similarity of each group of stations defined by cluster analysis.

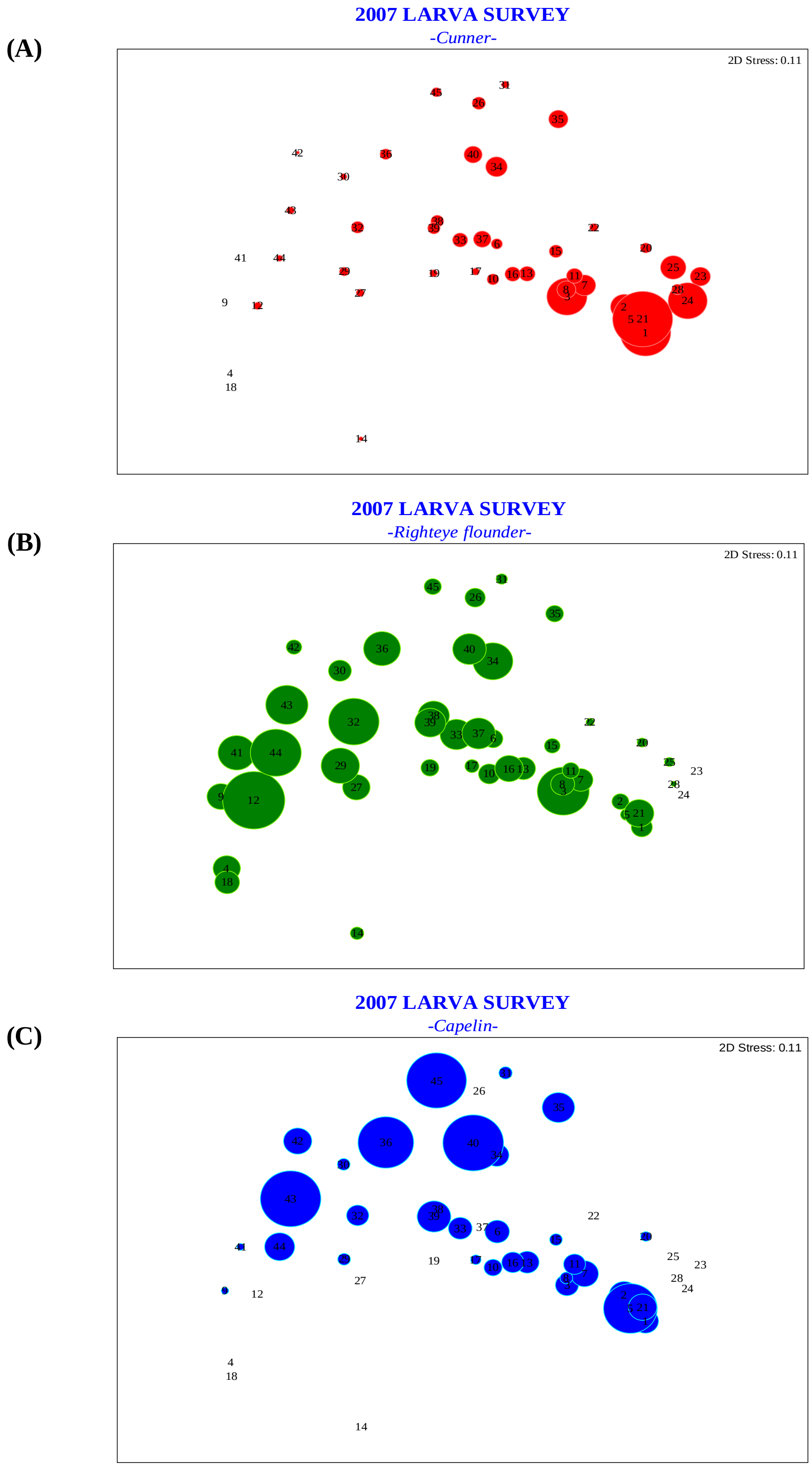
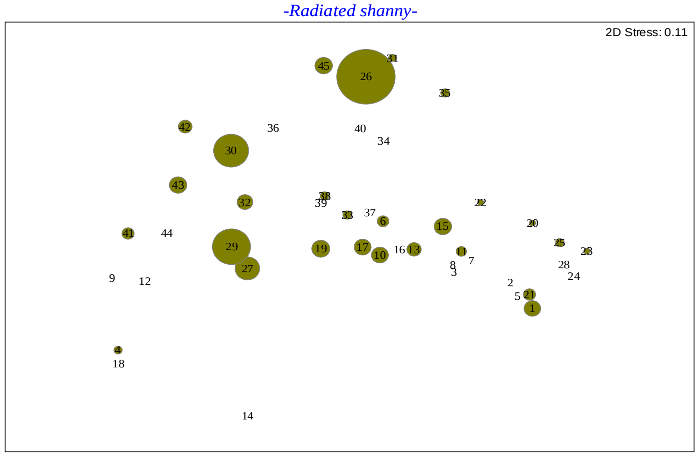


Figure 21. Non-metric multidimensional scaling showing the position and abundance (number/1,000 m^3) of the species with the greatest contribution (%) to their respective groups (A: cunner, B: righteye flounder, C: capelin, D: radiated shanny, E: fourbeard rockling, and F: cod).

(D)

2007 LARVA SURVEY

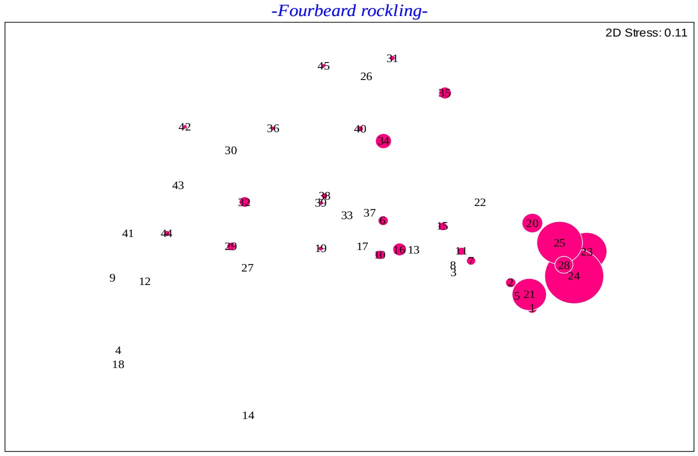
-Radiated shanny-



(E)

2007 LARVA SURVEY

-Fourbeard rockling-



(F)

2007 LARVA SURVEY

-Atlantic cod-

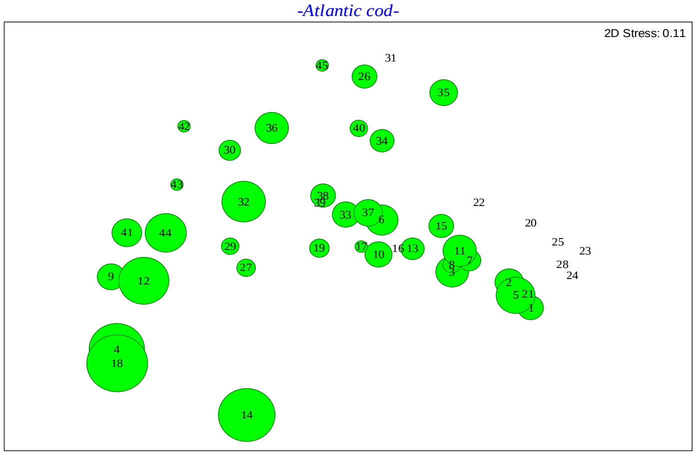


Figure 21. (Continued).

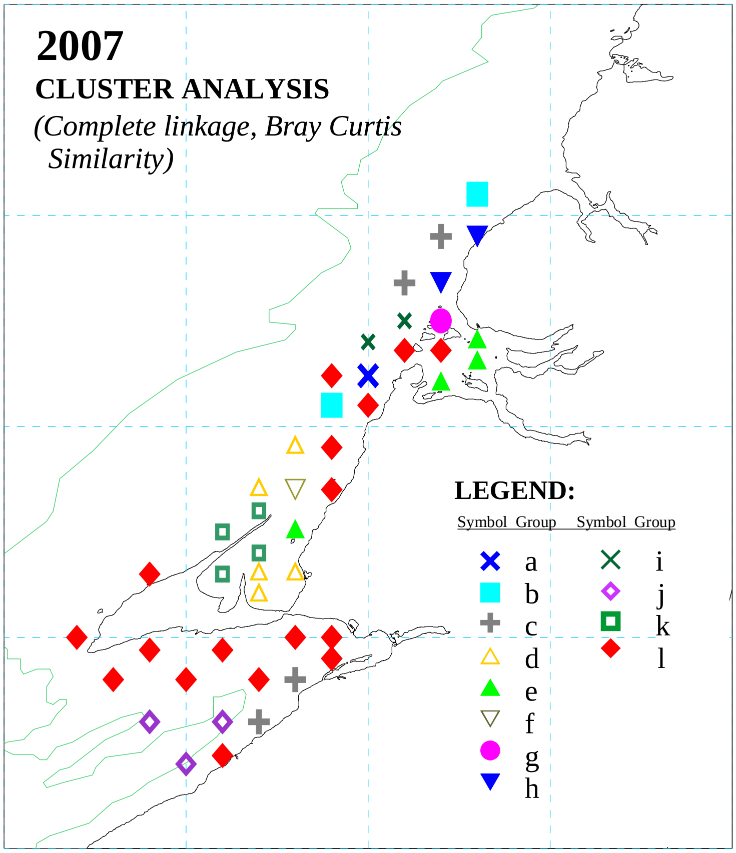
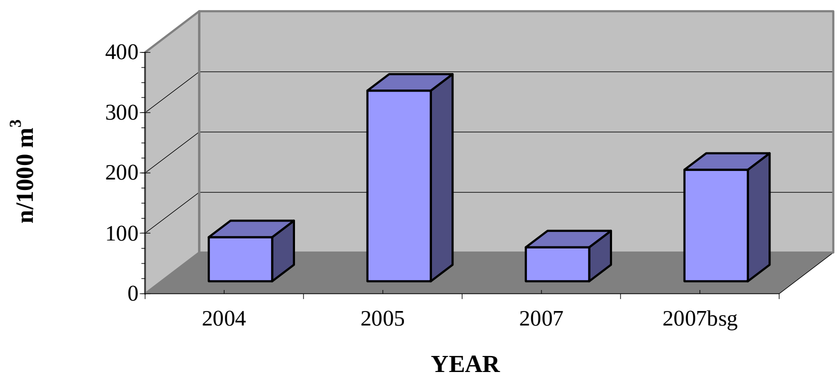


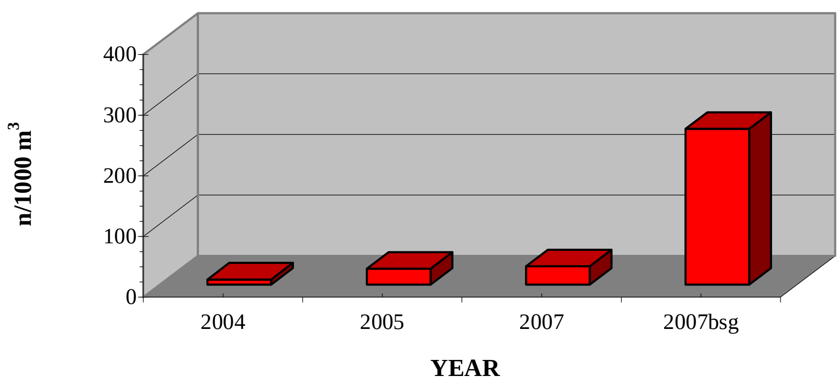
Figure 22. Map of the fish larval assemblages defined by the cluster analysis.

Appendix 1. Mean egg and larval abundance (n/1,000 m^3) of the main commercial fish species sampled during the capelin and Atlantic herring larval survey of July 2004, 2005, and 2007 on the west coast of Newfoundland (note: bsg = St. George's Bay).

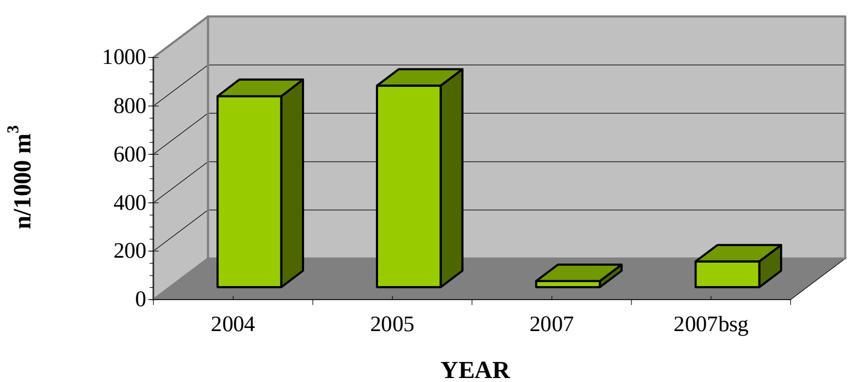
ATLANTIC MACKEREL -EGGS-
(*Scomber scombrus*)



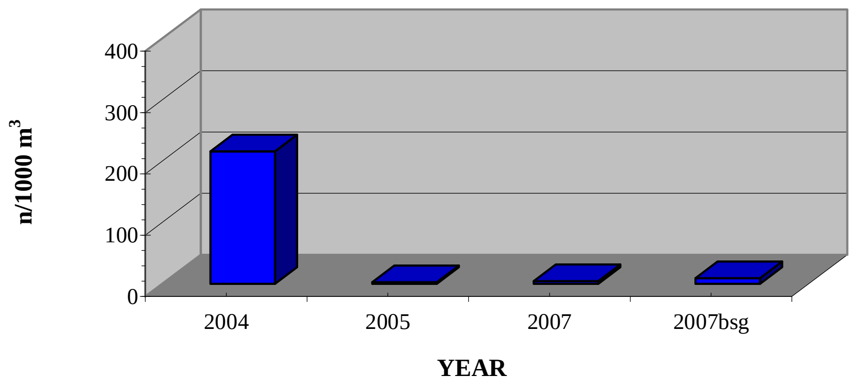
ATLANTIC MACKEREL -LARVAE-
(*Scomber scombrus*)



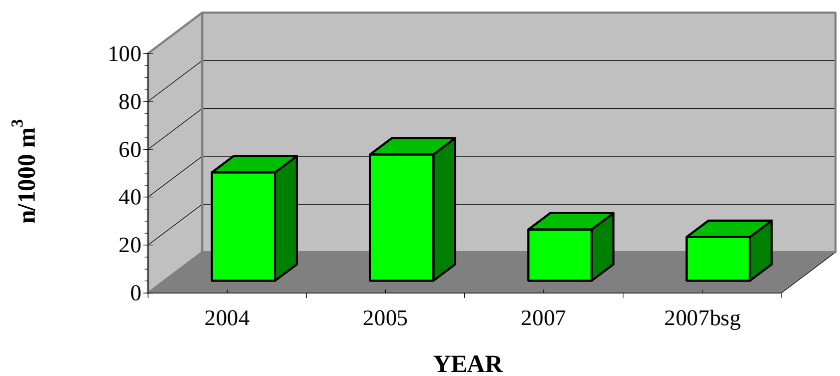
CAPELIN -LARVAE-
(*Mallotus villosus*)



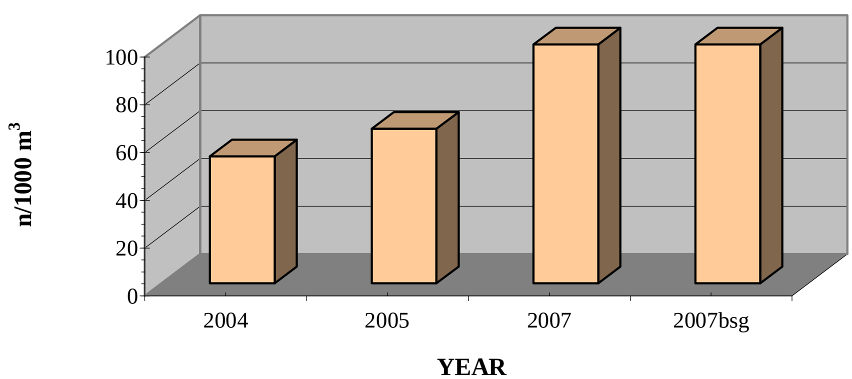
HERRING -LARVAE-
(*Clupea harengus harengus*)



COD -LARVAE-
(*Gadus morhua*)



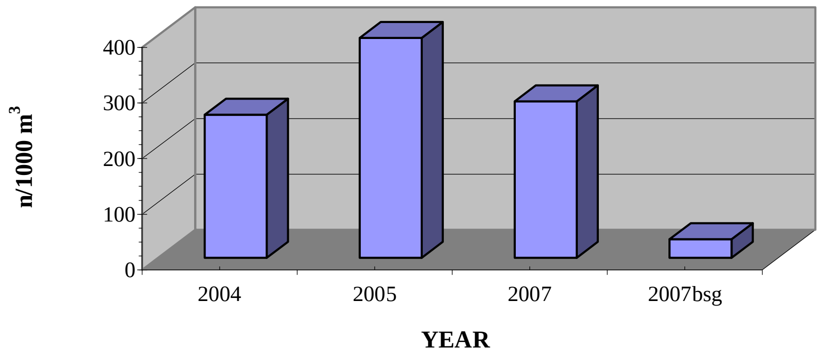
RIGHTEYE FLOUNDER -LARVAE-
(Pleuronectidae)



Appendix 2. Mean egg abundance (n/1,000 m^3) of the other fish species sampled during the capelin and Atlantic herring larval survey of July 2004, 2005, and 2007 on the west coast of Newfoundland (note: bsg = St. George's Bay).

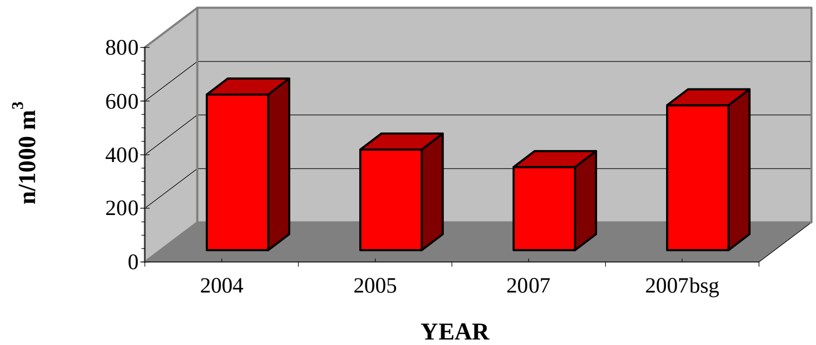
H4B

-Hake (*Urophycis* spp.), fourbeard rockling (*Enchelyopus cimbrius*), and butterfish (*Peprilus triacanthus*)-



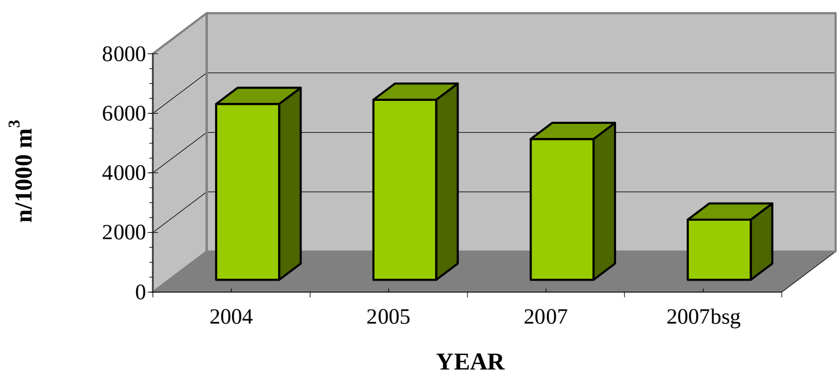
CHW

-Cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and witch flounder (*Glyptocephalus cynoglossus*)-

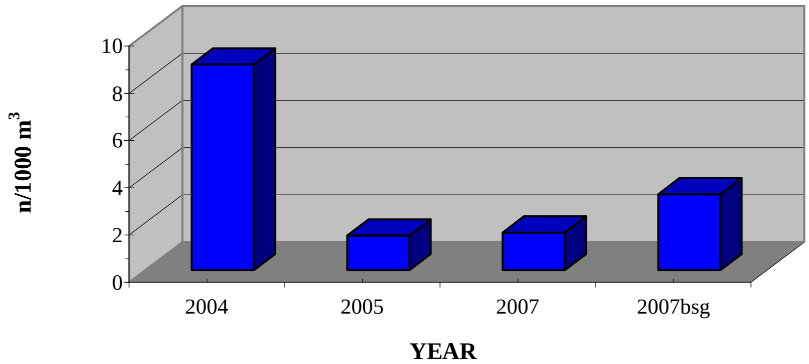


CYT

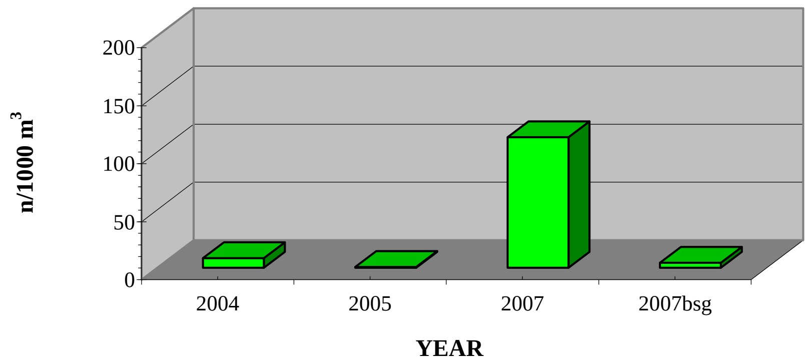
-Cunner (*Tautogolabrus adspersus*) and yellowtail flounder (*Limanda ferruginea*)-



AMERICAN PLAICE (Eggs)
(*Hippoglossoides platessoides*)

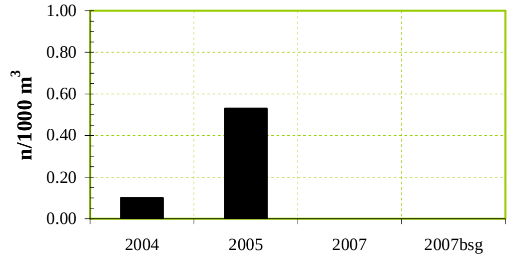


WINDOWPANE FLOUNDER (Eggs)
(*Scophthalmus aquosus*)

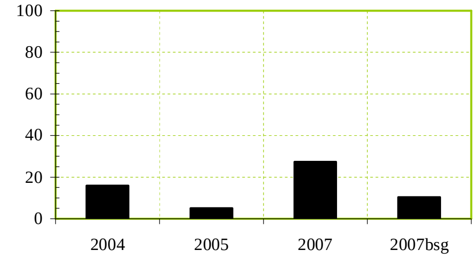


Appendix 3. Mean larval abundance (n/1,000 m^3) of the other fish species sampled during the capelin and Atlantic herring larval survey of July 2004, 2005, and 2007 on the west coast of Newfoundland (note: bsg = St. George's Bay).

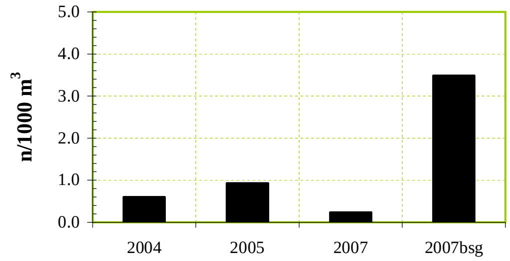
AMERICAN PLAICE
(***Hippoglossoides platessoides***)



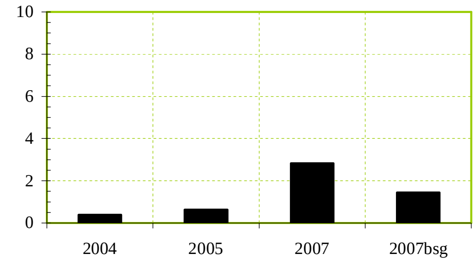
RADIATED SHANNY
(***Ulvaria subbifurcata***)



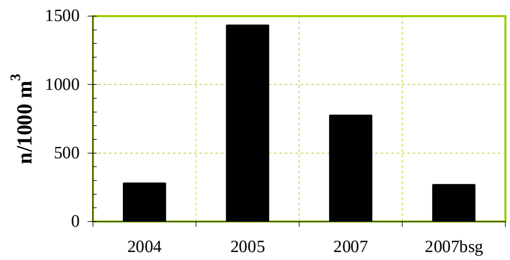
ARCTIC SHANNY
(***Stichaeus punctatus***)



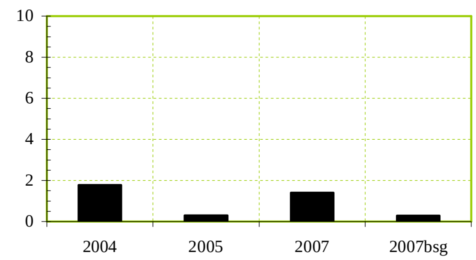
REDFISH
(***Sebastes* spp.**)



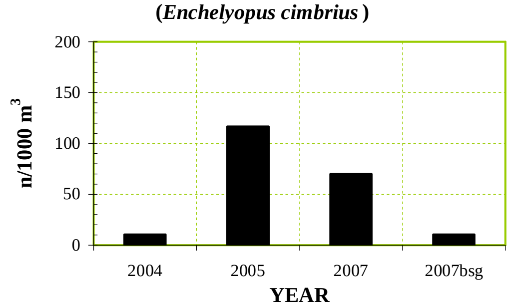
CUNNER
(***Tautogolabrus adspersus***)



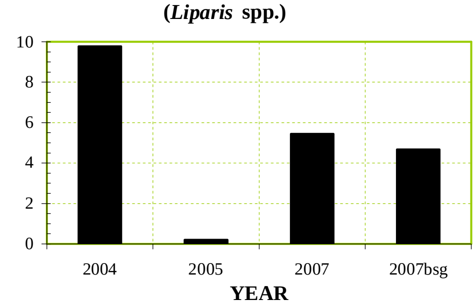
SANDLANCES
(***Ammodytes* spp.**)



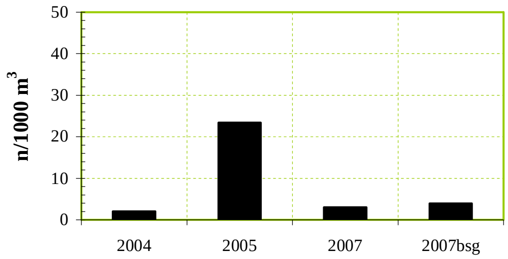
FOURBEARD ROCKLING
(***Enchelyopus cimbrius***)



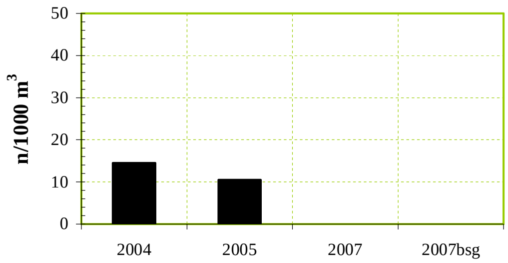
SNAILFISH
(***Liparis* spp.**)



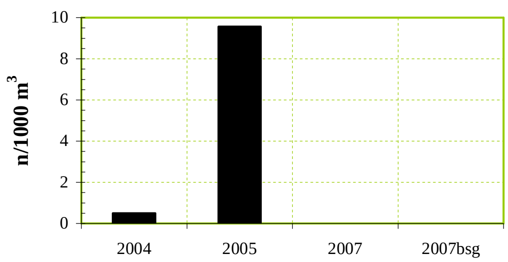
WINDOWPANE FLOUNDER
(*Scophthalmus aquosus*)



WINTER FLOUNDER
(*Pseudopleuronectes americanus*)



WITCH FLOUNDER
(*Glyptocephalus cynoglossus*)



YELLOWTAIL FLOUNDER
(*Limanda ferruginea*)