West coast of Newfoundland capelin (*Mallotus villosus* M.) and Atlantic herring (*Clupea harengus harengus* L.) larval survey, part 8: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2008

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2011

Canadian Technical Report of Fisheries and Aquatic Sciences 2954

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Canadian Technical Report of

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Canadian Technical Report of

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WEST COAST OF NEWFOUNDLAND CAPELIN (*Mallotus villosus* M.) AND ATLANTIC HERRING (*Clupea harengus harengus* L.) LARVAL SURVEY, PART 8: ABUNDANCE ESTIMATES AND MARINE COMMUNITY ANALYSES OF THE DATA COLLECTED IN PARTNERSHIP WITH THE INDUSTRY (BARRY GROUP) IN JULY 2008

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Cat. No. Fs 97-6/2954E ISSN 1488-5379

This publication should be cited as follows:

Grégoire, F., W. Barry, J.-J. Barry, J. Barry, 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 8: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2008. Can. Tech. Rep. Fish. Aquat. Sci. 2954: ix + 56 pp.

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ABSTRACT

Grégoire, F., W. Barry, J.-J. Barry, J. Barry, 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 8: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2008. Can. Tech. Rep. Fish. Aquat. Sci. 2954: 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 2008 to measure the abundance and to describe the spatial distribution of eggs and larvae of the main fish species encountered. In the survey, eggs were most abundant in the CYT group (cunner [*Tautogolabrus adspersus*] and yellowtail flounder [*Limanda ferruginea*]), followed by Atlantic mackerel (*Scomber scombrus*) eggs and eggs from the CHW group (cod [*Gadus morhua*], haddock [*Melanogrammus aeglefinus*], and witch flounder [*Glyptocephalus cynoglossus*]) and the H4B group (hake [*Urophycis* spp.], fourbeard rockling [*Enchelyopus cimbrius*], and American butterfish [*Peprilus triacanthus*]). Among the larvae collected, the most abundant species were capelin (*Mallotus villosus*), cunner, radiated shanny (*Ulvaria subbifurcata*), Atlantic herring (*Clupea harengus*), and Atlantic mackerel. Compared to the survey conducted in the same area in 2007, and omitting St. George's Bay, the 2008 survey was characterized by a larger number of Atlantic mackerel eggs and capelin and Atlantic herring larvae and a decrease in cod and righteye flounder larvae. Generalized additive models (GAM) have shown that the abundance of eggs and larvae of the primary species sampled could be described using a smoothing function based on longitude, latitude, their interaction, water temperature, and the abundance of Atlantic mackerel eggs for larvae from this same species. From abundance measurements of all sampled larvae, cluster and ordination analyses revealed the presence of a spatial structure within the larval community. This was mainly characterized by capelin, cunner, and Atlantic herring.

RÉSUMÉ

Grégoire, F., W. Barry, J.-J. Barry, J. Barry, 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 8: Abundance estimates and marine community analyses of the data collected in partnership with the industry (Barry Group) in July 2008. Can. Tech. Rep. Fish. Aquat. Sci. 2954: 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 2008 dans le but de mesurer l'abondance et de décrire la distribution spatiale des œufs et des larves des principales espèces de poissons rencontrées. Lors du relevé, les œufs les plus abondants ont été ceux du groupe CYT (tanche-tautogue [*Tautogolabrus adspersus*] et limande à queue jaune [*Limanda ferruginea*]) suivi des œufs de maquereau bleu (*Scomber scombrus*) et des groupes CHW (morue franche [*Gadus morhua*], aiglefin [*Melanogrammus aeglefinus*] et plie grise [*Glyptocephalus cynoglossus*]) et H4B (merluches [*Urophycis* spp.], motelle à quatre barbillons [*Enchelyopus cimbrus*] et stromatée à fossette [*Peprilus triacanthus*]). Parmi les larves récoltées, les espèces les plus abondantes ont été le capelan (*Mallotus villosus*), la tanche-tautogue, l'ulvaire deux-lignes (*Ulvaria subbifurcata*), le hareng (*Clupea harengus*) et le maquereau bleu. Par rapport au relevé réalisé dans la même région en 2007, et en omettant la baie St. George, le relevé de 2008 a été caractérisé par un plus grand nombre d'œufs de maquereau et de larves de capelan et de hareng comparativement à une baisse pour les larves de morue et de plie. Des modèles additifs généralisés (GAM) ont démontré que l'abondance des œufs et des larves des principales espèces échantillonnées pouvait être décrite à l'aide de fonctions de lissage basées sur la longitude, la latitude, leur interaction, la température de l'eau et l'abondance des œufs de maquereau bleu dans le cas 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 au sein de la communauté larvaire. Cette dernière était principalement caractérisée par le capelan, la tanche-tautogue et le hareng.

1.0 INTRODUCTION

Larval surveys were conducted on the west coast of Newfoundland in July 2004, 2005, and 2007 to measure the abundance of eggs and larvae and to describe their spatial distribution. Eggs and larvae of a large number of fish species were identified during these surveys (Grégoire et al. 2005, 2006a, 2008a). Biodiversity measures have also shown that the larval community structure was characterized by a large number of scarce species and by more abundant commercial species concentrated in specific locations (Grégoire et al. 2006b, 2009a, 2009b). Compared to the 2004 and 2005 surveys, the 2007 survey was characterized by a decline in the abundance of most species encountered. The larval assemblages described in 2004 and 2005 were associated with capelin (*Mallotus villosus*) and cunner (*Tautogolabrus adspersus*), whereas those described in 2007 were characterized by cunner and righteye flounder (Pleuronectidae) (Grégoire et al. 2009b).

A fourth larval survey was conducted on the west coast of Newfoundland in July 2008 (Grégoire et al. 2009c). As in 2007, this survey's study area extended to St. George's Bay. The two most abundant egg groups were CHW (cod [*Gadus morhua*], haddock [*Melanogrammus aeglefinus*], and witch flounder [*Glyptocephalus cynoglossus*]) and CYT (cunner and yellowtail flounder [*Limanda ferruginea*]). Atlantic mackerel (*Scomber scombrus*) eggs were collected at all stations. Of the 16 species of larvae identified, the most abundant were capelin and cunner, followed by radiated shanny (*Ulvaria subbifurcata*), Atlantic herring (*Clupea harengus harengus*), fourbeard rockling (*Enchelyopus cimbrius*), and Atlantic mackerel. The spatial distribution of these eggs and larvae, their abundance, and biodiversity measurements are presented in this document.

2.0 MATERIAL AND METHODS

2.1 Study area and sampling procedures

The survey was conducted between 16 and 18 July 2008 aboard the *Ocean Leader*. The study area, located near the coast, was from south of Bonne Bay to St. George's Bay (Figure 1). A total of 46 stations were sampled using two bongo nets (Posgay and Marak 1980) with an opening of 61 cm and mesh size of 333 microns. Two General Oceanics flowmeters were fixed near the net openings 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%) (Hunter 1985) and the others in an ethanol solution (95%).

2.2 Laboratory analyses

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 to describe the development stages of Atlantic mackerel eggs. Egg and larva counts were standardized for volumes of 1,000 m^3 of water. Descriptive statistics were calculated for these values as well as for those collected in previous surveys.

2.3 Geostatistical abundance

Mean abundance data (n/1,000 m^3) of eggs and larvae from the main species encountered were estimated by ordinary kriging (Isaaks and Srivastava 1989). The choice of variogram model, semi-variance calculations, and kriging maps 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 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 when extreme abundance values had been previously excluded from the construction of the variograms. However, these values were reinserted in the data when preparing the kriging maps.

2.4 Temperature and abundance

The egg and larva 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 thermal preferences of 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 choice of variables and smoothing functions to keep was 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 determined according to the corresponding values of the factor of determination (r^2) and deviance (%). 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 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.

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 to determine if a sufficient number of stations were sampled. This procedure was applied on larva 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 observed if a very large number of stations had been sampled in the study area. The results from this approach were compared to the actual number of species observed.

The abundance and dominance of the larval species were examined using the DOMINANCE procedure (Clarke and Gorley 2006). For each station, the larvae were listed in decreasing order of abundance. Their cumulative relative abundance (i.e., the percentage of total abundance at a 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) and the following 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 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 of each index was calculated using a principal component analysis (PCA procedure; Clarke and Gorley 2006) applied to the standardized values 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 assemblage) 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). The SIMPER procedure calculates each species' contribution from a group to the similarity of the group, on condition that the latter contains at least two samples.

2.8.4 Non-metric multidimensional scaling (MDS)

Clarke and Warwick (2001) suggested that ordination 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), 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. Non-parametric multidimensional scaling was 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.

2.8.5 Similarity analyses between the 2007 and 2008 assemblages (ANOSIM and SIMPER)

The larval communities described in 2007 and 2008 were compared using a similarity analysis (ANOSIM procedure; Clarke and Gorley 2006). In the event of a significant difference, the SIMPER procedure was used to identify the species responsible for this difference.

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 in St. George's Bay. The last stations to be sampled were those located between Port-au-Port Bay and the Bay of Islands. Nets were damaged at station 3 and technical problems with the CTD probe occurred at stations 26 and 29. All stations were sampled during the day at depths between 8 and 65 m (Table 1). The volumes of filtered water varied between 171 and 653 m^3, averaging 393.5 m^3. The average tow duration was around 12 minutes.

3.2 Egg distribution and abundance

Atlantic mackerel eggs and eggs from the CHW and CYT groups were found at 45, 43, and 39 of the 45 stations sampled, respectively, compared to 31 stations for the H4B group (hake [*Urophycis* spp.], fourbeard rockling, and butterfish [*Peprilus triacanthus*]) (Table 2). American plaice (*Hippoglossoides platessoides*) and windowpane flounder (*Scophthalmus aquosus*) were only found at eight and six stations, respectively.

The CYT group was the most abundant, with an average of 7,713.4 eggs/1,000 m^3 (Table 3). It was followed by Atlantic mackerel and the CHW and H4B groups, with respective averages of 620.1, 421.2, and 274.2 eggs/1,000 m^3. An average of 15.6 eggs/1,000 m^3 was calculated for windowpane flounder and 1.8 eggs/1,000 m^3 for American plaice.

Eggs from group CYT were observed in very large numbers except at the stations located on the north side of St. George's Bay (Figure 3). Eggs from the CHW group were less abundant at the Port-au-Port Bay stations as opposed to eggs from the H4B group. Atlantic mackerel eggs were found in higher abundance in the southern part of the Bay of Islands as well as in St. George's Bay. Windowpane flounder eggs were primarily found in Port-au-Port Bay and St. George's Bay while American plaice were found in Bay of Islands and St. George's Bay.

3.3 Larval distribution and abundance

During the survey, 16 species or groups of species were sampled per station (Table 4). The most frequently found larvae at more than 30 stations, were capelin, Atlantic herring, radiated shanny, and cunner. They were followed by Atlantic mackerel, righteye flounder, and fourbeard rockling at 27, 23, and 22 stations. Other species were found at 16 stations or fewer.

The most abundant species were capelin and cunner with respective averages of 2,497 and 377 larvae/1,000 m^3, followed by radiated shanny, Atlantic herring, fourbeard rockling, and Atlantic mackerel with 97, 51, 47, and 46 larvae/1,000 m^3 (Table 5). Abundances varying between 2 and 14 larvae/1,000 m^3 were measured for the other species. For capelin, the highest abundances were measured at all stations in the Bay of Islands and Port-au-Port Bay while Atlantic herring and Atlantic mackerel larvae were most abundant at Bay of Islands and St. George's Bay stations. For the other species, the highest abundances were mostly measured at the Bay of Islands and St. George's Bay stations as well as at a few stations in Port-au-Port Bay.

3.4 Egg and larval abundances in 2004, 2005, 2007, and 2008

Among the commercial species, only righteye flounder and cod larvae showed a decrease in abundance between 2007 and 2008 (Appendix 1). A very significant increase was measured for Atlantic mackerel eggs and capelin larvae, with abundance values peaking in 2008. Atlantic herring larvae also increased in 2008. However, the 2008 value was lower than that measured in 2004. With the exception of capelin, measured abundances were all higher (or similar) in St. George's Bay than in the other bays combined.

With the exception of St. George's Bay, an increase in abundance was measured between 2007 and 2008 for eggs from the H4B and CYT groups, compared to a decrease for windowpane flounder and identical values for the CHW group and American plaice (Appendix 2). In 2008, eggs from the CHW group and windowpane flounder were more abundant than other species in St. George's Bay.

An increase in abundance was observed between 2007 and 2008 for radiated shanny, sand lance (*Ammodytes* spp.), snailfish (*Liparis* spp.), winter flounder (*Pseudopleuronectes americanus*), witch flounder, and yellowtail flounder, and there was a slight increase for fourbeard rockling (Appendix 3). Most of the species encountered in 2008 were less abundant at the St. George's Bay stations.

3.5 Abundance derived from geostatistics

The spatial variations of egg abundance, egg groups and larvae were all described using a spherical variogram (Table 6). For all the models, the r^2 values varied between 0.71 and 0.99 and no anisometry was recorded. No model could be defined for windowpane eggs and larvae or for winter, witch, and yellowtail flounder and Arctic shanny (*Stichaeus punctatus*) larvae due to low abundances 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. The abundance of Atlantic mackerel eggs was estimated at 599 eggs/1,000 m^3. The abundance of capelin larvae was estimated at 1,728 larvae/1,000 m^3 compared with abundances of 57 and 41 larvae/1,000 m^3 for Atlantic herring and Atlantic mackerel (Table 7, Figures 7A and 7B).

3.6 Temperature and abundance

Thermal preferences of eggs and egg groups showed few interspecific variations expect in terms of eggs from the H4B group, which are associated to warmer water (Figure 8A). Atlantic mackerel, cunner, and Atlantic herring larvae are also found in warmer water (Figure 8B). More pronounced variations were observed in the other larvae. For example, 50% of the radiated shanny abundances were observed at temperatures below 14.3°C compared to 16.1°C for fourbeard rockling larvae (Figure 8C). The latter as well as redfish larvae are associated with warmer water compared with flounder and radiated shanny larvae.

3.7 Generalized additive models (GAM)

Some non-significant *p* statistics (>0.05) and very low r^2 and deviance values were observed in American plaice eggs (0.13 and 25%), the CYT group (0.09 and 14%), cod (0.12 and 26%), radiated shanny (0.02 and 3%), and redfish (0.09 and 12%) larvae (Table 8). The highest values were measured in the H4B group (0.71 and 85%), Atlantic herring (0.62 and 78%), Atlantic mackerel (0.97 and 98%), and fourbeard rockling (0.93 and 99%) larvae.

For the H4B group, the smoothing function chosen is defined by the interaction between longitude and latitude (Table 8). Three smoothing functions were determined for Atlantic herring, longitude, latitude, and water temperature compared to water temperature and the abundance of eggs for the Atlantic mackerel larvae, and longitude and latitude and water temperature interaction for fourbeard rockling. For the H4B group, the highest abundance values, which were predicted by the smoothing function, were observed for the longitudes and latitudes associated with the southwestern part of the study area (Port-au-Port Bay and St. George's Bay) (Figure 9). There was an increase and a decrease, respectively, in the Atlantic herring larvae abundance for higher longitudes and latitudes (Figures 10A and 10B). A temperature increase would lead to an increase in the abundance of these larvae (Figure 10C). Temperature has an influence on the abundance of Atlantic mackerel larvae for values of over 16.5°C (Figure 11A). For Atlantic mackerel, the data show that the local abundance of larvae is strongly influenced by the abundance of eggs for egg abundances of more than 1,000 eggs/m^3 (Figure 11B). However, one should be cautious considering the small number of observed values for these high abundances. The two highest larva abundance values are associated with a significant increase in egg abundance. For fourbeard rockling larvae, the highest abundances were obtained at longitudes and latitudes associated with the southwest part of the study area (Figure 12). Temperatures ranging between 14.5°C and 16.5°C favour the presence of larvae from this species.

3.8 Accumulation and dominance plots

The total number of species that should be observed in the study area reaches a plateau at around 30 stations (Figure 13A). Reaching such a plateau means that the larval community was properly sampled during the survey. The survey was also characterized by a large number of stations with low dominance and a wide diversity of species (Figure 13B).

3.9 Biodiversity

The total number of species and the total number of larvae varied greatly among stations (Figures 14A and 14B). The four diversity indices presented similar values and variations (Figure 14C). The maximum number of species was observed at stations located in the Bay of Islands and Bonne Bay (Figure 15). The maximum number of larvae was observed in the same two areas and at a few stations in Port-au-Port Bay. The highest values from the four diversity indices were primarily observed at the stations in the Bay of Islands and St. George's Bay, and to a lesser extent at the Port-au-Port Bay stations.

There are strong correlations between the Fisher and Margalef indices and the Brillouin and Shannon indices (Figure 16A). These correlations are marked by the close occurrence of these indices in the reduced space defined by non-parametric multi-dimensional scaling (Figure 16B). This space is also characterized by 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 16C). The first two components (PC1 and PC2) explain 67% and 23%, 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 44% 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 (65% and 49% 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 17A). The *Pi* statistic was significantly different ($P<0.001$) than a distribution associated to this hypothesis (Figure 17B). Six groups of stations were determined using cluster analysis and the SIMPROF procedure (Figure 18A).

Capelin contributed more than 91% of the similarity of groups *b*, *c*, and *d* (Figure 19). Capelin and cunner contributed to the similarity of group *e* with respective values of 85 and 12%, compared to cunner, capelin, and Atlantic herring for group *f*, with respective contributions of 58, 28, and 5%. Finally, Atlantic herring, capelin, radiated shanny, and fourbeard rockling contributed 32, 26, 15, and 14% of the similarity of group *a*.

Groups of stations that were defined by cluster analysis occupy different positions in the space defined by the non-metric multidimensional scaling (Figure 18B). The species that contributed most to their respective group were identified when their abundance was superimposed on the corresponding stations (Figures 20A to 20E).

The stations belonging to certain groups defined by cluster analysis were observed at specific locations. This is the case for group *a*, with most stations located in St. George's Bay (Figure 21). The same occurred for groups *b*, *c*, *d*, and *e*, which were dominated by capelin, and the stations were for the most part located from Port-au-Port Bay to south of the Bay of Islands.

3.11 Similarity analyses

The ANOSIM procedure indicates that the larval assemblages described in 2007 and 2008 are statistically different ($P<0.0001$) (Figure 22A). Cunner, flounder, and Atlantic mackerel contributed respectively 50, 30, and 8% of the similarity measured in 2007 compared with 69, 11, and 8% for capelin, cunner, and Atlantic herring in 2008 (Figure 22B).

4.0 DISCUSSION

Compared to the survey conducted in 2007 (Grégoire et al. 2009b) and omitting St. George's Bay, a larger number of Atlantic mackerel eggs as well as capelin and Atlantic herring larvae were sampled in 2008 along with a decrease in cod and righteye flounder larvae. Eggs from groups CYT and H4B were more abundant, and there was a drop for windowpane flounder and similar values for the CHW group and American plaice. For the other larvae, higher abundances were measured for fourbeard rockling, radiated shanny, sand lance, snailfish, and winter, witch, and yellowtail flounder.

The larval assemblages described in 2008 were mainly characterized by capelin and cunner compared to cunner and righteye flounder in 2007. Cunner and capelin also characterized the assemblages described in 2004 and 2005 (Grégoire et al. 2009a). Cunner is by far the most abundant species in these four surveys. For the time being, 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 fifth survey was conducted in July 2009 following the same sampling pattern as the 2007 and 2008 surveys. Using the larvae preserved in ethanol, we also intended to analyze the daily growth of the main commercial species. This project will be put forward to better describe the marine ecosystem on the west coast of Newfoundland.

5.0 ACKNOWLEDGEMENTS

The authors would like to thank Dr. Jacques A. Gagné and Mr. Hugo Bourdages for the review of the report as well as the captain and crew of the *Ocean Leader* for their excellent collaboration.

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Table 1. Description of the stations and sampling of the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

STATION NUMBER	DATE (yyyy/mm/dd)	TIME (hh:mm) (NDT)	LONGITUDE °W (degrees minutes)	LATITUDE °N (degrees minutes)	DEPTH Station bottom (m)	Maximum sampled (m)	TOW DURATION (mm:ss)	VOLUME OF WATER FILTERED (m^3)
1	2008/07/16	11:51	58° 12'	49° 09'	125	39	11:47	513
2	2008/07/16	12:33	58° 12'	49° 12'	185	65	15:48	558
3*	2008/07/16	18:26	58° 12'	49° 27'	31	27	10:10	---
4	2008/07/16	17:33	58° 12'	49° 33'	60	48	13:36	473
5	2008/07/18	18:25	58° 18'	49° 06'	54	37	12:45	453
6	2008/07/16	13:21	58° 18'	49° 11'	137	60	18:50	653
7	2008/07/16	14:29	58° 18'	49° 15'	79	39	14:29	410
8	2008/07/16	15:18	58° 18'	49° 20'	29	27	10:39	422
9	2008/07/16	19:24	58° 18'	49° 27'	56	46	11:08	389
10	2008/07/16	21:25	58° 24'	49° 11'	58	38	10:43	391
11	2008/07/16	20:48	58° 24'	49° 15'	32	17	10:41	425
12	2008/07/16	15:56	58° 24'	49° 20'	45	28	10:53	433
13	2008/07/18	14:56	58° 30'	49° 03'	43	28	10:52	404
14	2008/07/18	17:16	58° 30'	49° 07'	87	51	13:35	221
15	2008/07/18	16:23	58° 30'	49° 12'	69	46	12:32	206
16	2008/07/18	11:55	58° 36'	48° 51'	38	27	11:50	441
17	2008/07/18	13:33	58° 36'	48° 57'	30	22	10:21	389
18	2008/07/18	14:19	58° 36'	49° 03'	42	28	11:34	418
19	2008/07/18	15:39	58° 36'	49° 07'	60	39	12:58	408
20	2008/07/18	8:43	58° 42'	48° 39'	27	20	10:31	401
21	2008/07/18	9:32	58° 42'	48° 45'	25	18	10:08	391
22	2008/07/18	11:19	58° 42'	48° 51'	14	8	10:20	395
23	2008/07/18	12:51	58° 42'	48° 57'	28	20	11:05	428
24	2008/07/18	8:02	58° 48'	48° 36'	20	18	10:48	427
25	2008/07/18	7:31	58° 48'	48° 39'	16	15	10:08	405
26	2008/07/18	6:59	58° 48'	48° 42'	15	10	10:12	396
27	2008/07/17	21:00	58° 48'	48° 48'	23	15	10.06	381
28	2008/07/18	10:43	58° 48'	48° 51'	40	29	11:50	430
29	2008/07/18	6:14	58° 54'	48° 39'	14	10	10:15	398
30	2008/07/17	20:21	58° 54'	48° 45'	25	16	10:51	402
31	2008/07/17	19:16	59° 06'	48° 39'	35	21	10:59	406
32	2008/07/17	17:58	59° 18'	48° 30'	52	34	12:07	358
33	2008/07/17	15:48	59° 06'	48° 28'	66	45	13:52	223
34	2008/07/17	14:07	58° 54'	48° 28'	66	39	12:40	264
35	2008/07/17	13:08	58° 42'	48° 30'	20	11	10:24	396
36	2008/07/17	12:31	58° 36'	48° 30'	35	19	10:40	412
37	2008/07/17	11:56	58° 36'	48° 27'	80	47	13:59	453
38	2008/07/17	16:58	59° 12'	48° 24'	85	52	13:32	203
39	2008/07/17	14:54	59° 00'	48° 24'	90	42	14:05	225
40	2008/07/17	10:35	58° 48'	48° 24'	40	27	11:43	344
41	2008/07/17	11:14	58° 42'	48° 24'	40	29	11:47	440
42	2008/07/17	6:26	59° 06'	48° 18'	97	50	14:10	171
43	2008/07/17	9:07	58° 54'	48° 18'	100	46	13:37	429
44	2008/07/17	9:48	58° 48'	48° 18'	40	25	11:37	438
45	2008/07/17	7:42	59° 00'	48° 12'	77	47	13:00	457
46	2008/07/17	8:25	58° 54'	48° 13'	22	15	11:04	425
Mean					53.3	31.3	11:58	393.5
Std. Dev.					35.5	14.5	1:47	92.0
Minimum					14	8	10:06	171
Maximum					185	65	18:50	653
n					46	46	46	45

* Damaged nets

Table 2. List of egg taxa from the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

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

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

Table 3. Abundance of eggs (number/1,000 m^3) from the samples collected during the capelin and Atlantic herring larval survey of July 2008 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	8	780	47	9 480	0	0
2	0	494	64	2 966	0	0
4	0	129	845	8	8	0
5	13	157	71	16 949	44	4
6	0	355	159	3 959	49	0
7	0	1 229	98	17 473	0	0
8	5	422	436	2 956	152	0
9	0	259	1 274	0	0	0
10	0	368	61	1 982	0	0
11	0	621	287	254	14	0
12	0	609	369	92	9	0
13	0	4 141	0	11 550	99	0
14	9	208	816	18	9	0
15	0	34	720	29	0	0
16	0	644	122	15 097	32	5
17	0	1 244	31	2 467	154	10
18	0	1 119	201	7 686	38	0
19	20	275	942	687	0	0
20	0	120	0	2 714	2 913	80
21	0	578	31	21 127	26	0
22	0	638	365	113 503	142	0
23	0	68	126	308	9	0
24	0	103	0	5 471	2 136	0
25	0	119	0	2 649	2 274	99
26	0	121	0	29 111	2 001	0
27	0	588	841	11 686	189	0
28	0	79	217	217	5	0
29	0	116	10	2 243	1 529	0
30	0	882	159	21 566	73	0
31	0	347	721	6 953	12	0
32	0	8	492	0	0	0
33	18	90	950	90	0	0
34	0	856	288	629	38	0
35	0	2 583	0	5 852	182	0
36	0	3 185	78	4 933	19	505
37	4	853	305	3 942	62	0
38	0	182	758	551	0	0
39	0	71	1 315	89	0	0
40	0	229	3 000	174	0	0
41	0	828	455	5 948	91	0
42	0	117	408	87	0	0
43	5	40	401	364	9	0
44	0	921	525	7 426	9	0
45	0	315	569	114	0	0
46	0	781	400	5 703	9	0
Mean	1.8	620.1	421.2	7 713.4	274.2	15.6
Std. Dev.	4.6	819.3	528.9	17 544.5	696.6	76.9
Minimum	0	8	0	0	0	0
Maximum	20	4 141	3 000	113 503	2 913	505
n	45	45	45	45	45	45

Table 4. List of larval taxa from the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

FAMILY	SPECIES	COMMOM NAME	STATION 1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ammodytidae	*Ammodytes* spp.	Sandlances	X		X								X											X	
Bothidae	*Scophthalmus aquosus*	Windowpane flounder				X	X						X	X											
Clupeidae	*Clupea harengus*	Atlantic herring	X	X	X	X		X	X	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									
Labridae	*Tautogolabrus adspersus*	Cunner	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
Osmoridae	*Mallotus villosus*	Capelin	X	X	X	X	X	X	X	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	X	X	X	X		
Pleuronectidae	Pleuronectidae	Righteye flounder				X			X	X		X	X			X	X	X	X	X					X
Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder		X	X	X		X			X														
Pleuronectidae	*Glyptocephalus cynoglossus*	Witch flounder	X	X	X		X				X			X	X								X	X	
Pleuronectidae	*Limanda ferruginea*	Yellowtail flounder		X		X								X	X									X	
Scombridae	*Scomber scombrus*	Atlantic mackerel	X	X	X	X		X			X		X	X			X	X			X		X	X	X
Scorpaenidae	*Sebastes* spp.	Redfishes														X	X							X	
Stichaeidae	*Stichaeus punctatus*	Arctic shanny																							
Stichaeidae	*Ulvaria subbifurcata*	Radiated shanny	X	X	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	TOTAL		**8**	**11**	**10**	**11**	**6**	**7**	**4**	**5**	**7**	**6**	**11**	**9**	**9**	**6**	**8**	**6**	**6**	**5**	**5**	**4**	**6**	**8**	**6**

FAMILY	SPECIES	COMMOM NAME	STATION 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	TOTAL
Ammodytidae	*Ammodytes* spp.	Sandlances								X											X					**6**
Bothidae	*Scophthalmus aquosus*	Windowpane flounder	X	X								X		X												**8**
Clupeidae	*Clupea harengus*	Atlantic herring	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X		**38**
Gadidae	*Gadus morhua*	Atlantic cod				X			X						X		X				X	X	X			**15**
Labridae	*Tautogolabrus adspersus*	Cunner	X	X	X		X	X			X		X	X		X		X	X							**30**
Liparidae	*Liparis* spp.	Snailfishes							X									X			X	X	X			**10**
Osmoridae	*Mallotus villosus*	Capelin	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X		**43**
Phycidae	*Enchelyopus cimbrius*	Fourbeard rockling	X	X			X	X				X									X					**22**
Pleuronectidae	Pleuronectidae	Righteye flounder	X			X	X		X					X	X	X	X	X		X		X	X			**23**
Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder		X							X		X						X							**9**
Pleuronectidae	*Glyptocephalus cynoglossus*	Witch flounder		X	X			X				X	X						X		X					**16**
Pleuronectidae	*Limanda ferruginea*	Yellowtail flounder									X	X	X													**8**
Scombridae	*Scomber scombrus*	Atlantic mackerel	X	X	X			X	X	X	X	X	X	X		X		X	X							**27**
Scorpaenidae	*Sebastes* spp.	Redfishes			X	X		X	X	X	X					X	X			X						**12**
Stichaeidae	*Stichaeus punctatus*	Arctic shanny												X												**1**
Stichaeidae	*Ulvaria subbifurcata*	Radiated shanny	X	X			X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X		**38**
	TOTAL		**8**	**9**	**6**	**5**	**6**	**8**	**7**	**6**	**8**	**8**	**7**	**7**	**5**	**7**	**5**	**7**	**7**	**3**	**8**	**6**	**6**	**3**		

Table 5. Abundance of larvae (number/1,000 m^3) from the samples collected during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

STATION	Arctic shanny	Atlantic herring	Atlantic mackerel	Capelin	Cod	Cunner	Fourbeard rockling	Radiated shanny	Redfish	Righteye flounder	Sand-lance	Snailfish
1	0	249	23	109	0	226	16	16	0	0	47	0
2	0	86	36	666	14	480	14	43	0	0	0	43
4	0	30	8	95	2	57	0	2	0	0	8	4
5	0	62	29	865	2	812	40	44	0	13	0	0
6	0	0	0	846	25	184	61	0	0	0	0	0
7	0	117	39	11 077	0	234	156	2 652	0	0	0	0
8	0	114	0	720	0	114	0	0	0	190	0	0
9	0	118	0	74	0	3	0	28	0	134	0	0
10	0	163	87	1 144	15	817	0	0	0	0	0	0
11	0	80	0	842	0	423	47	75	0	52	0	0
12	0	115	14	83	23	2 787	14	55	0	120	14	5
13	0	59	436	9 074	0	1 763	20	99	0	0	0	0
14	0	9	0	6 597	5	27	5	27	0	0	0	9
15	0	78	0	1 128	5	0	0	29	15	68	0	0
16	0	14	5	14 952	0	14	9	32	5	9	0	0
17	0	0	10	1 634	0	21	10	62	0	10	0	0
18	0	29	0	10 994	0	1 721	38	57	0	57	0	0
19	0	0	0	6 356	0	59	29	15	0	49	0	0
20	0	0	92	200	0	2 035	252	37	0	0	0	0
21	0	10	0	11 956	0	0	655	194	0	0	0	0
22	0	15	30	25 619	0	0	10	157	0	0	0	0
23	0	2	5	311	0	0	0	26	7	0	2	0
24	0	0	9	1 068	0	112	0	23	0	9	0	206
25	0	2	10	2 293	0	3 776	613	40	0	40	0	0
26	0	13	38	124	0	164	91	40	0	0	0	0
27	0	21	11	536	0	53	0	0	5	0	0	0
28	0	19	0	26	5	0	0	0	44	26	0	0
29	0	10	0	201	0	10	15	15	0	10	0	0
30	0	27	53	504	0	93	13	159	7	0	0	0
31	0	0	16	1 635	4	0	0	4	8	8	0	4
32	0	3	3	22	0	0	0	3	95	0	3	0
33	0	90	22	13	0	18	0	4	9	0	0	0
34	0	182	83	129	0	0	8	8	0	0	0	0
35	0	161	767	20	0	565	0	0	0	0	0	0
36	97	97	117	78	0	350	0	0	0	19	0	0
37	0	18	0	62	9	0	0	4	0	49	0	0
38	0	49	74	20	0	20	0	5	20	20	0	0
39	0	107	0	0	9	0	0	36	302	53	0	0
40	0	35	31	23	0	8	0	143	0	97	0	8
41	0	27	5	50	0	5	0	64	0	0	0	0
42	0	0	0	0	0	0	0	12	6	6	0	0
43	0	19	0	12	9	0	2	28	0	0	2	7
44	0	14	0	27	5	0	0	14	0	27	0	5
45	0	53	0	70	4	0	0	79	0	26	0	79
46	0	19	0	132	0	0	0	14	0	0	0	0
Mean	2.2	51.4	45.6	2 497.5	3.0	376.6	47.1	96.6	11.6	24.3	1.7	8.2
Std. Dev.	14.5	58.6	129.5	5 157.2	5.9	801.2	135.9	392.4	47.0	41.1	7.3	33.0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	97	249	767	25 619	25	3 776	655	2 652	302	190	47	206
n	45	45	45	45	45	45	45	45	45	45	45	45

Table 5. (Continued).

STATION	Windowpane flounder	Winter flounder	Witch flounder	Yellowtail flounder
1	0	0	16	0
2	0	29	21	7
4	0	68	19	0
5	13	9	0	18
6	12	0	61	0
7	0	59	0	0
8	0	0	0	0
9	0	0	0	0
10	0	41	20	0
11	0	0	0	0
12	9	0	0	0
13	20	0	198	40
14	0	0	23	14
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	35	0
23	0	0	2	37
24	0	0	0	0
25	40	0	0	0
26	10	5	8	0
27	0	0	116	0
28	0	0	0	0
29	0	0	0	0
30	0	0	27	0
31	0	0	0	0
32	0	0	0	0
33	0	13	0	22
34	15	0	8	61
35	0	20	20	20
36	39	0	0	0
37	0	0	0	0
38	0	0	0	0
39	0	0	0	0
40	0	0	0	0
41	0	14	23	0
42	0	0	0	0
43	0	0	30	0
44	0	0	0	0
45	0	0	0	0
46	0	0	0	0
Mean	3.5	5.7	13.9	4.9
Std. Dev.	9.1	15.0	34.9	12.6
Minimum	0	0	0	0
Maximum	40	68	198	61
n	45	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 2008 on the west coast of Newfoundland (Note: it was not possible to build variograms and apply kriging on the windowpane flounder egg data or on Arctic shanny and windowpane, winter, witch, and yellowtail flounder larva data; see text).

SPECIES	MODEL*	Nugget (C_0)	Sill (C_0 + C)	Range (A_0)	r^2	RSS: residual sum of square
EGGS						
American plaice	Spherical	0.01	23.68	19.2	0.88	1.16E+01
Atlantic mackerel	Spherical	185000	830200	21.3	0.99	6.61E+08
CHW	Spherical	700	138100	29.4	0.94	4.31E+08
CYT	Spherical	19700000	51870000	60.6	0.88	9.56E+13
H4B	Spherical	1000	703700	35.9	0.94	2.69E+10
LARVAE						
Atlantic herring	Spherical	833	3424	24.9	0.84	4.28E+05
Atlantic mackerel	Spherical	10	22650	22.0	0.82	8.68E+07
Capelin	Spherical	6820000	21360000	63.7	0.85	2.24E+13
Cod	Spherical	0.01	30	14.5	0.87	3.97E+01
Cunner	Spherical	100	214100	27.9	0.81	4.58E+09
Fourbeard rockling	Spherical	1	2765	19.8	0.87	4.47E+05
Radiated shanny	Spherical	1	2384	16.3	0.71	2.20E+06
Redfish	Spherical	0.10	63	22.1	0.76	5.30E+04
Righteye flounder	Spherical	28	1631	22.7	0.92	8.32E+07
Sandlance	Spherical	0.10	43	20.1	0.71	5.17E+02
Snailfish	Spherical	1	1644	27.2	0.75	9.60E+02

* 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 $h \leq A_0$, and $C0+C$ otherwise

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 2008 on the west coast of Newfoundland (Note: it was not possible to build variograms and apply kriging on the windowpane flounder egg data or on Arctic shanny and windowpane, winter, witch, and yellowtail flounder larva data).

	KRIGING			95% CONFIDENCE INTERVAL	
	Average	Std. Err.	CV	Lower Limit	Upper Limit
EGGS					
American plaice	2.09	0.51	0.24	1.09	3.10
Atlantic mackerel	598.78	104.25	0.17	394.46	803.11
CHW	461.53	51.45	0.11	360.68	562.37
CYT	5721.48	2296.29	0.40	1220.75	10222.21
H4B	181.26	72.31	0.40	39.53	322.98
LARVAE					
Atlantic herring	56.66	6.61	0.12	43.71	69.61
Atlantic mackerel	41.40	15.07	0.36	11.86	70.95
Capelin	1728.03	642.34	0.37	469.04	2987.01
Cod	2.88	0.59	0.21	1.72	4.04
Cunner	324.58	85.40	0.26	157.19	491.96
Fourbeard rockling	33.83	15.70	0.46	3.05	64.60
Radiated shanny	87.95	42.74	0.49	4.18	171.72
Redfish	13.31	4.73	0.36	4.03	22.59
Righteye flounder	30.01	4.05	0.14	22.06	37.96
Sandlance	1.81	0.67	0.37	0.49	3.13
Snailfish	4.94	3.89	0.79	-2.69	12.57

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 2008 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)	0.00	0.00	NA	0.13	25	23	257
		+ s(Lat)	5.48	1.54	0.196				
Atlantic mackerel	Gaussian	s(Long)	0.75	3.41	0.082	0.23	31	605180	696
		+ s(Temp)	3.42	3.02	0.036				
CHW	Gaussian	s(Long)	0.85	4.70	0.043	0.39	53	227770	652
		+ s(Temp)	8.45	2.82	0.016				
CYT	Gaussian	s(Long)	0.00	0.00	NA	0.09	14	304020000	964
		+ s(Lat)	2.10	2.19	0.123				
H4B	Gaussian	s(Long,Lat)	19.39	5.27	0.000	0.71	85	215930	638
LARVAE									
Atlantic herring	Gaussian	s(Long)	7.76	3.00	0.018	0.62	78	2335	446
		+ s(Lat)	7.23	2.32	0.056				
		+ s(Temp)	2.47	5.43	0.008				
Atlantic mackerel	Gaussian	s(Temp)	4.65	4.91	0.003	0.97	98	686	400
		+ s(E.Mackerel)	7.58	66.59	< 2e-16				
Capelin	Gaussian	s(Long,Lat)	5.71	2.31	0.057	0.24	35	24777000	855
Cod	Gaussian	s(Lat)	2.01	1.70	0.197	0.12	26	38	279
		+ s(Temp)	4.30	0.82	0.529				
Cunner	Gaussian	s(Lat)	0.93	7.84	0.009	0.18	22	586140	695
		+ s(Temp)	0.94	8.22	0.008				
Fourbeard rockling	Gaussian	s(Long,Lat)	26.80	9.39	0.001	0.93	99	6855.2	431
		+ s(Temp)	7.02	21.98	0.000				
Radiated shanny	Gaussian	s(Long)	0.42	0.71	NA	0.02	3	163770	640
		+ s(Lat)	0.00	0.00	NA				
Redfish	Gaussian	s(Long)	1.26	3.20	0.072	0.09	12	2216	455
Righteye flounder	Gaussian	s(Lat)	8.53	8.03	0.000	0.59	68	916.89	415
Sandlance	Gaussian	s(Long)	3.90	3.36	0.020	0.21	29	49	291
Snailfish	Gaussian	s(Lat)	7.92	2.86	0.018	0.37	56	1057	418
		+ s(Temp)	4.89	3.41	0.016				

* Generalized cross validation
** Akaike information criterion

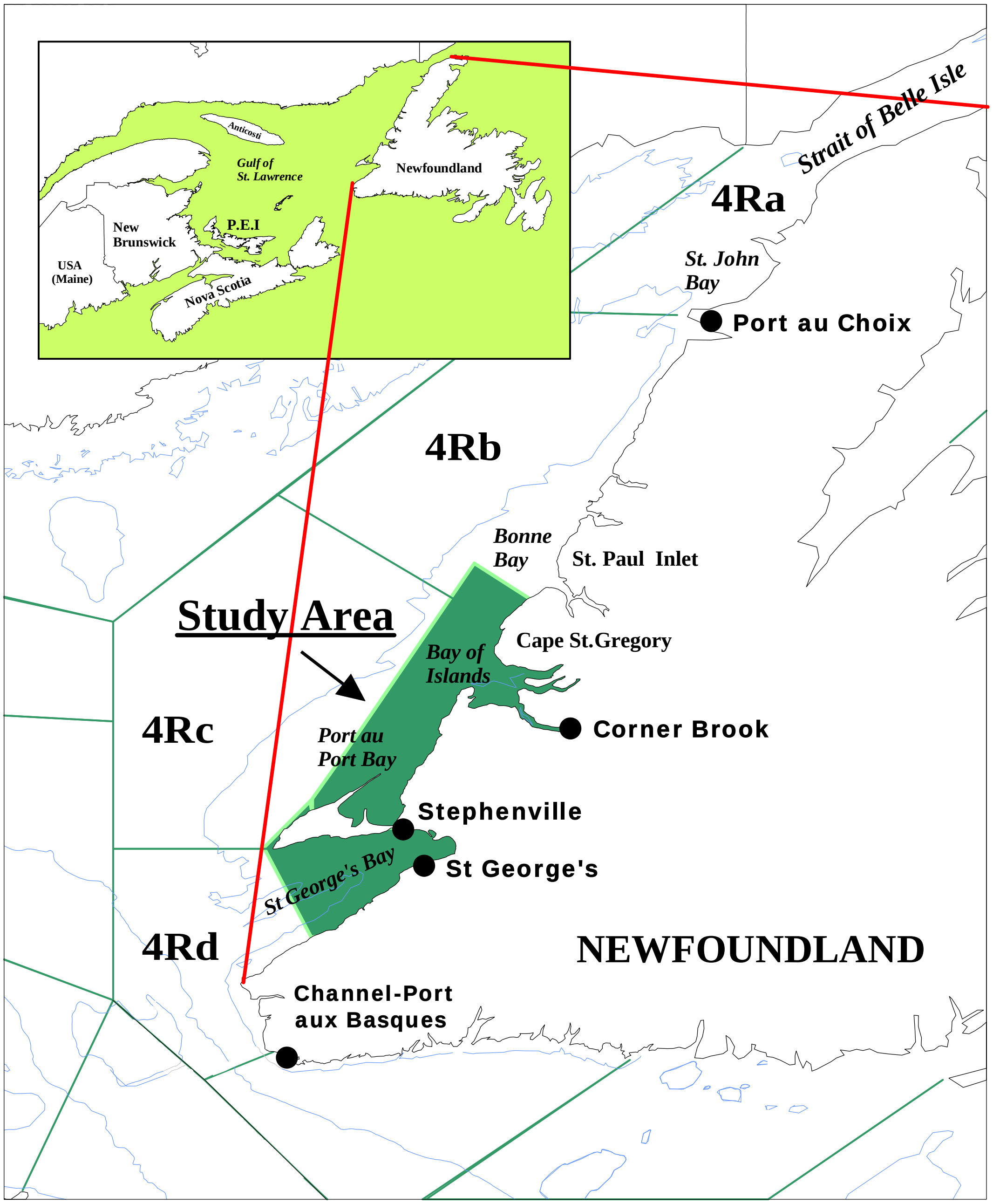


Figure 1. Map of the west coast of Newfoundland showing the study area and other locations mentioned in the document.

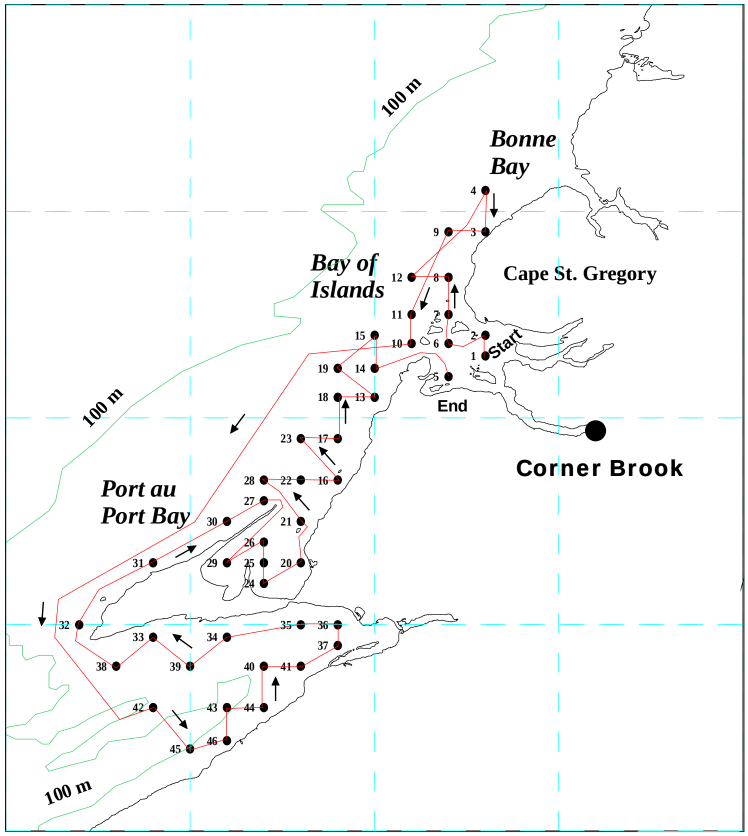


Figure 2. Map of the 46-station sampling grid of the capelin and Atlantic herring larval survey in July 2008 on the west coast of Newfoundland.

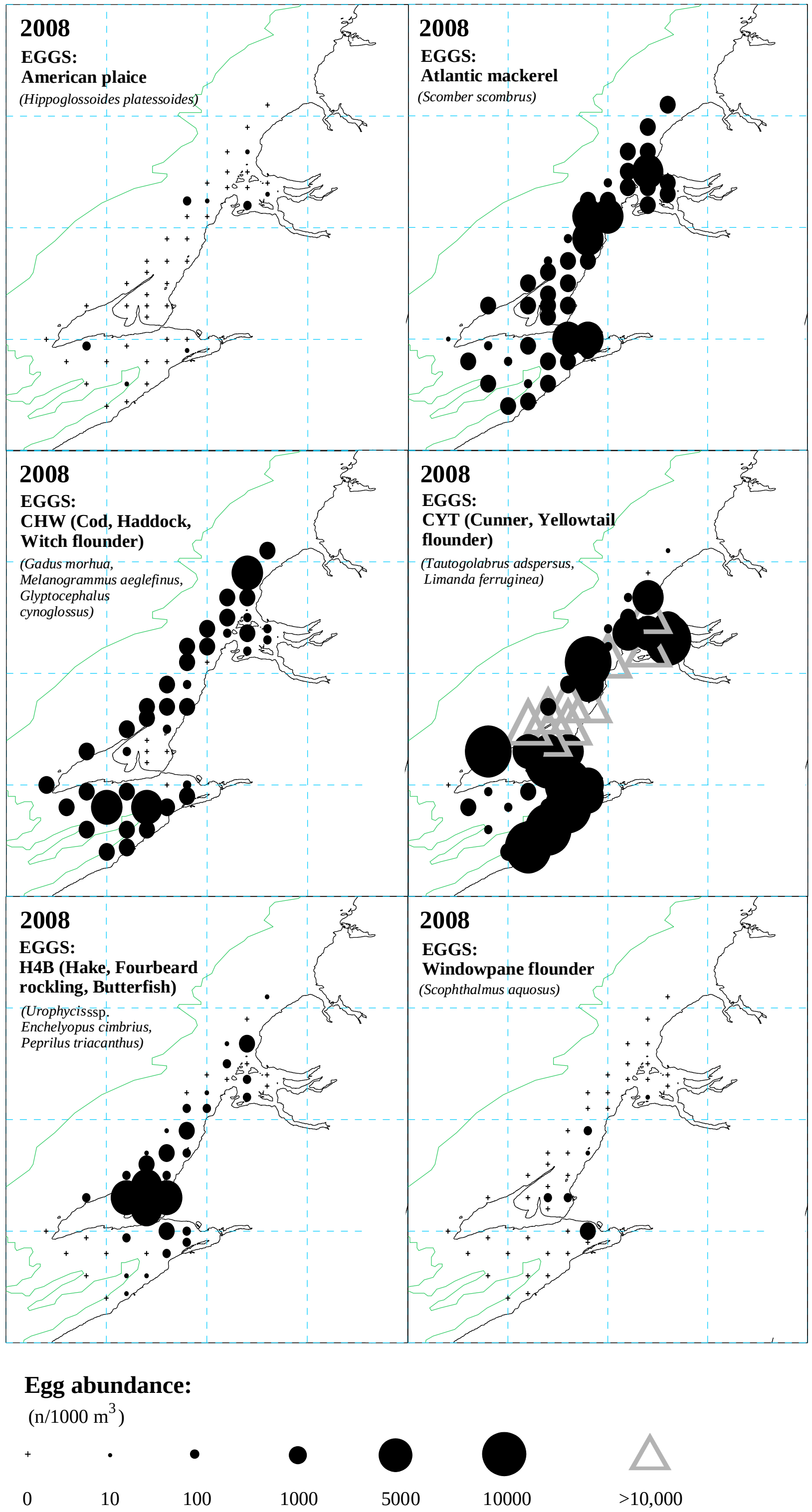


Figure 3. Maps of egg abundance (number/1,000 m^3) distributions from the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

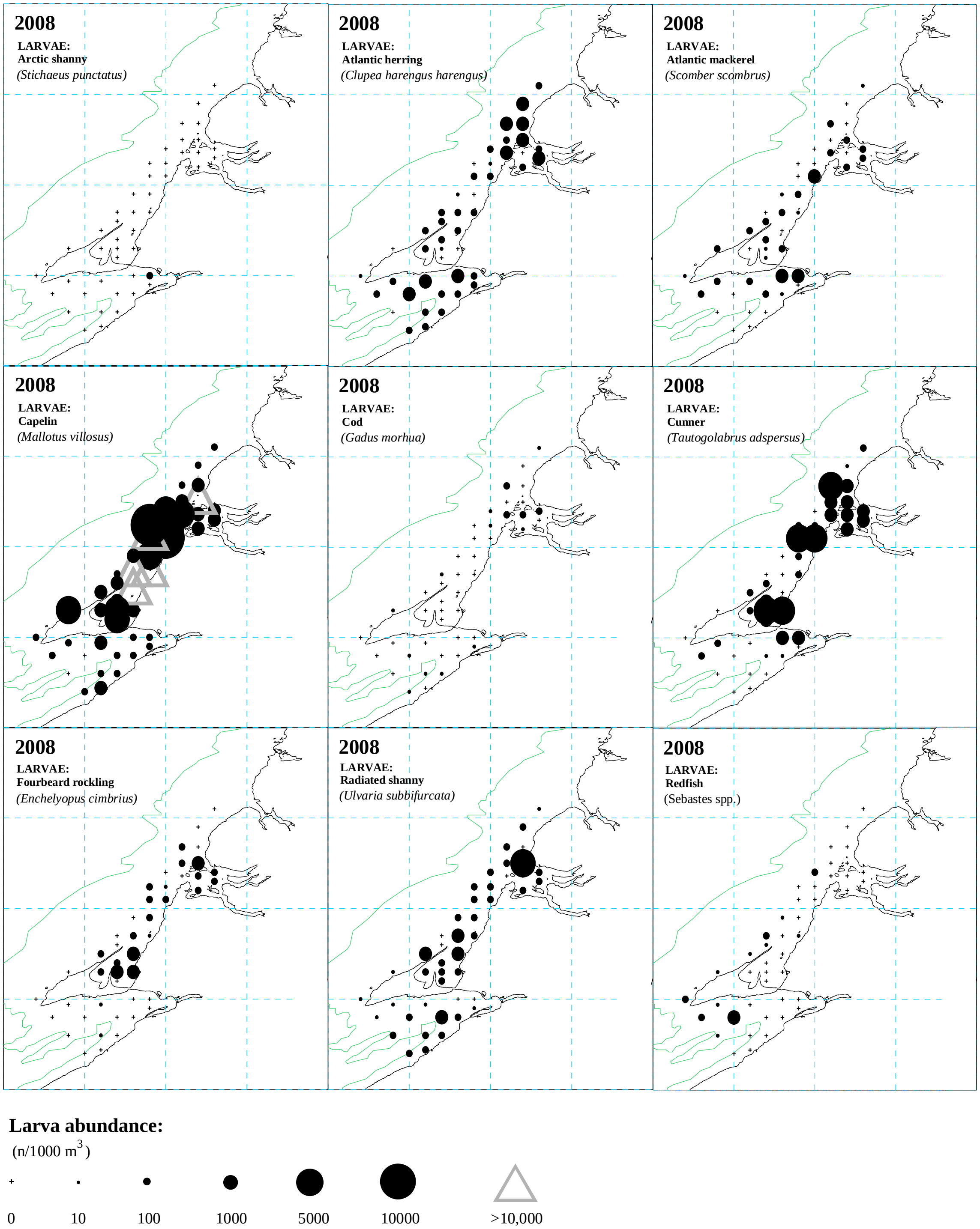


Figure 4. Maps of larval abundance (number/1,000 m^3) distributions from the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

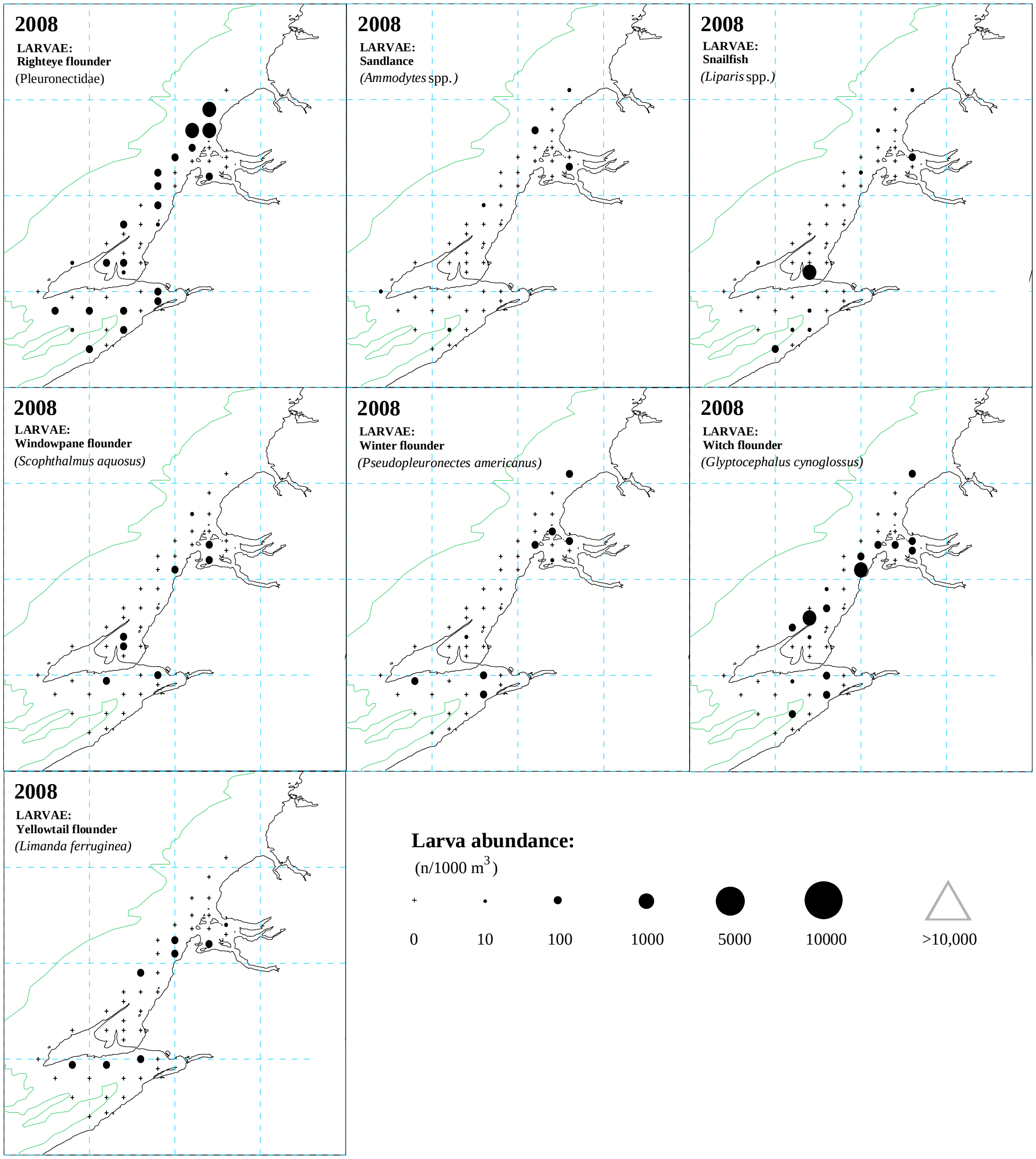


Figure 4. (Continued).

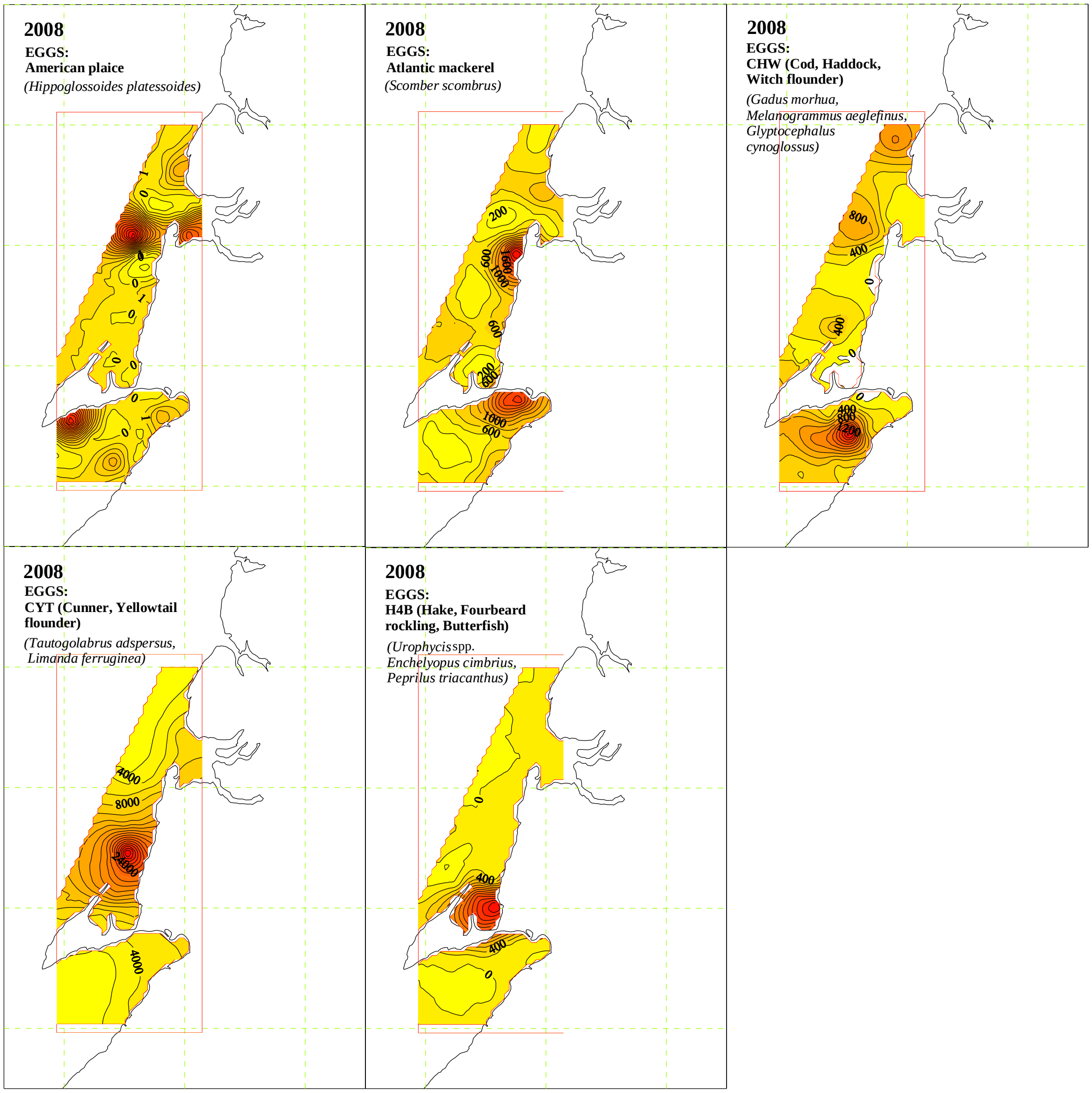


Figure 5. Abundance distribution maps (number/1,000 m^3) as derived by kriging of the eggs of some species sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland (Note: it was not possible to build a variogram and apply kriging on the windowpane flounder egg data).

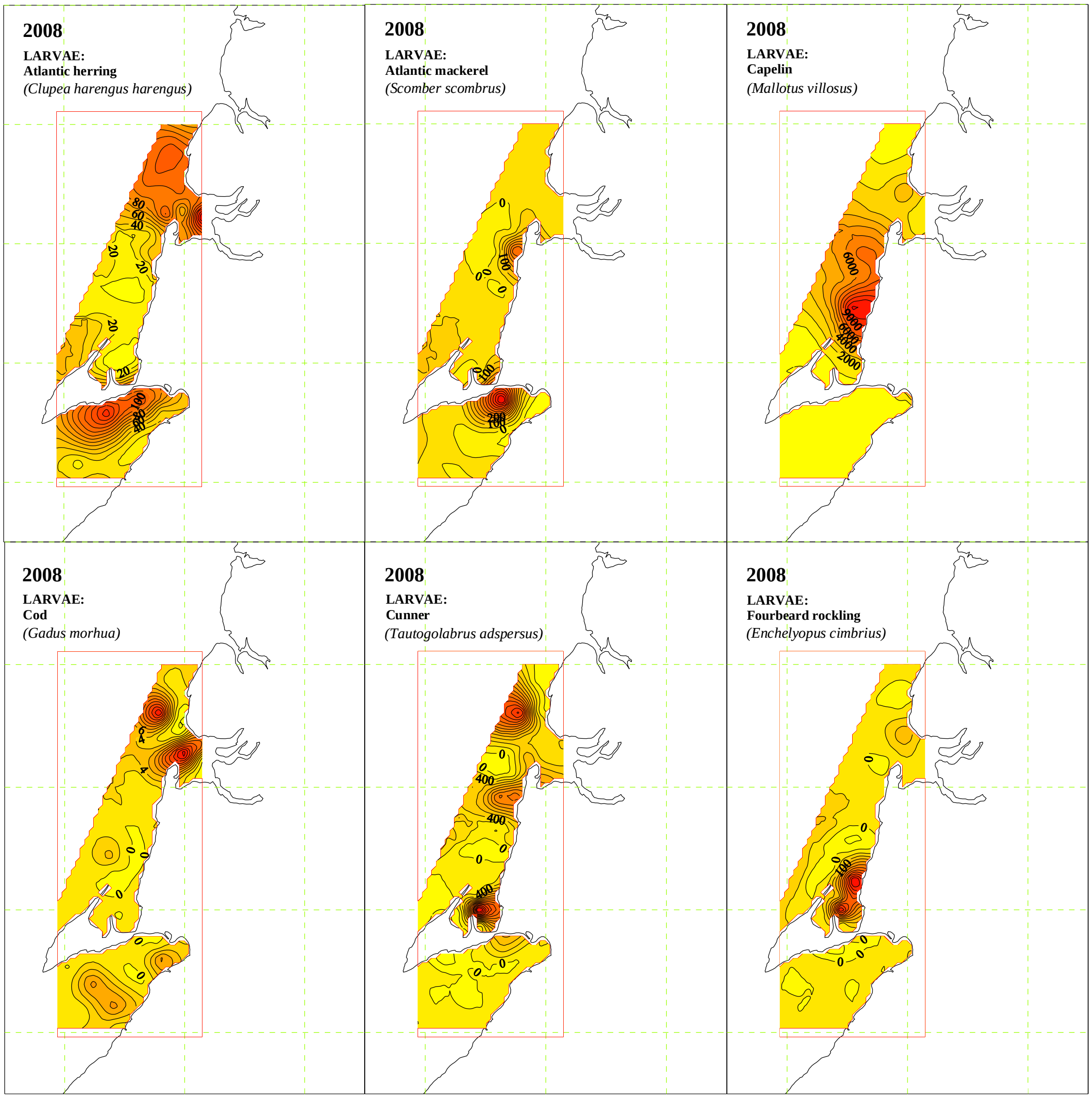


Figure 6. Abundance distribution maps (number/1,000 m^3) as derived by kriging of the larvae of some species sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland (Note: it was not possible to build variograms and apply kriging on Arctic shanny and windowpane, winter, witch, and yellowtail flounder larva data).

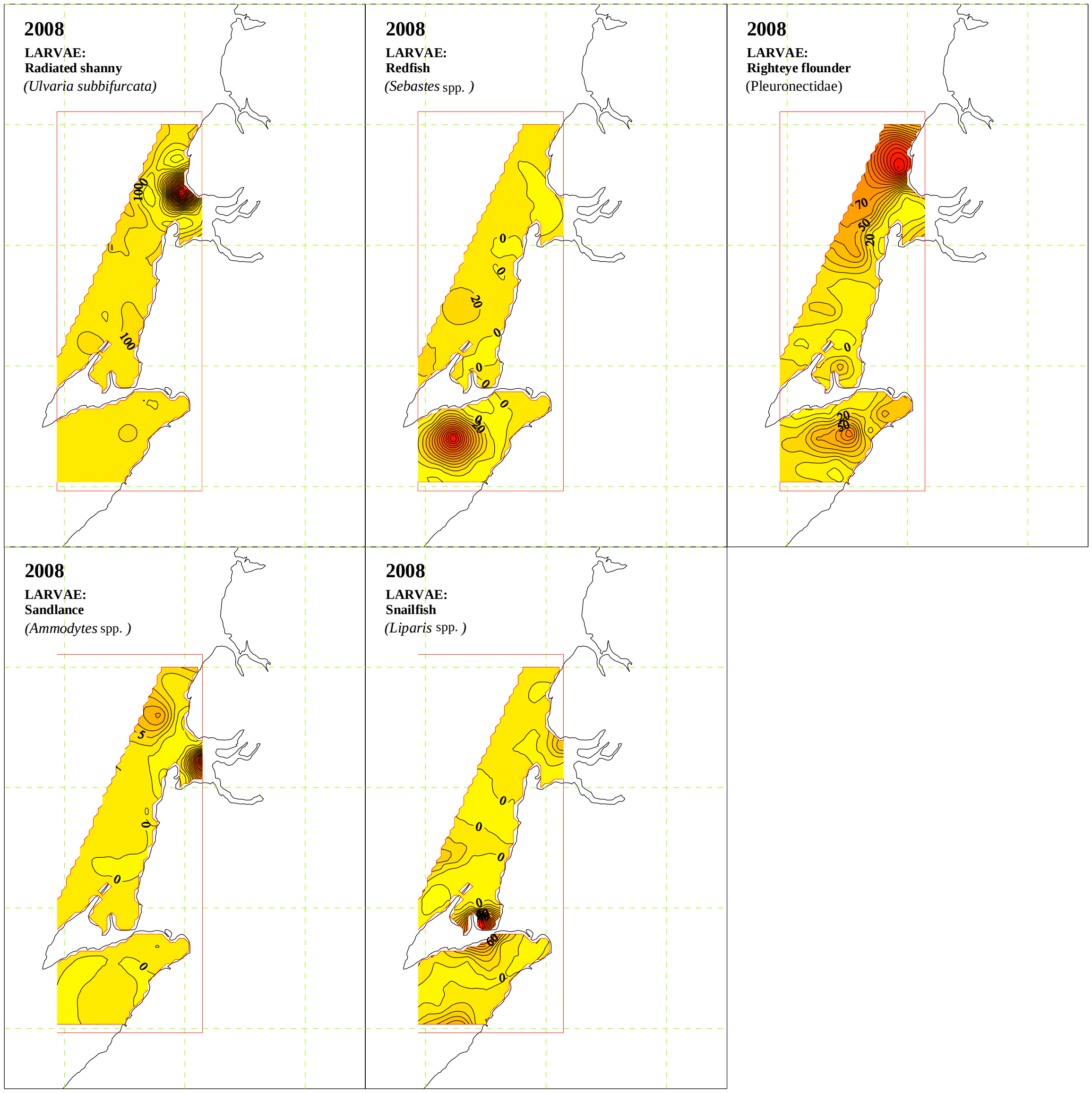
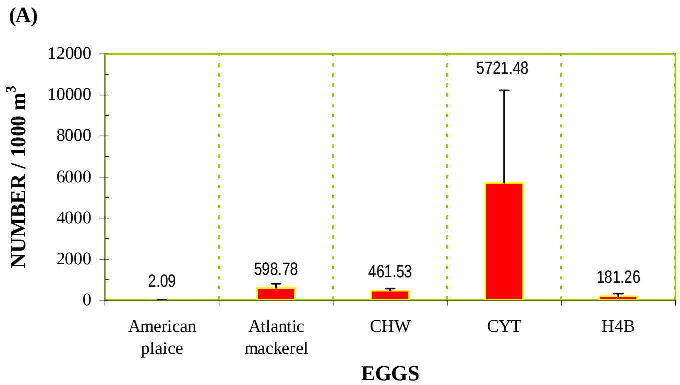


Figure 6. (Continued).



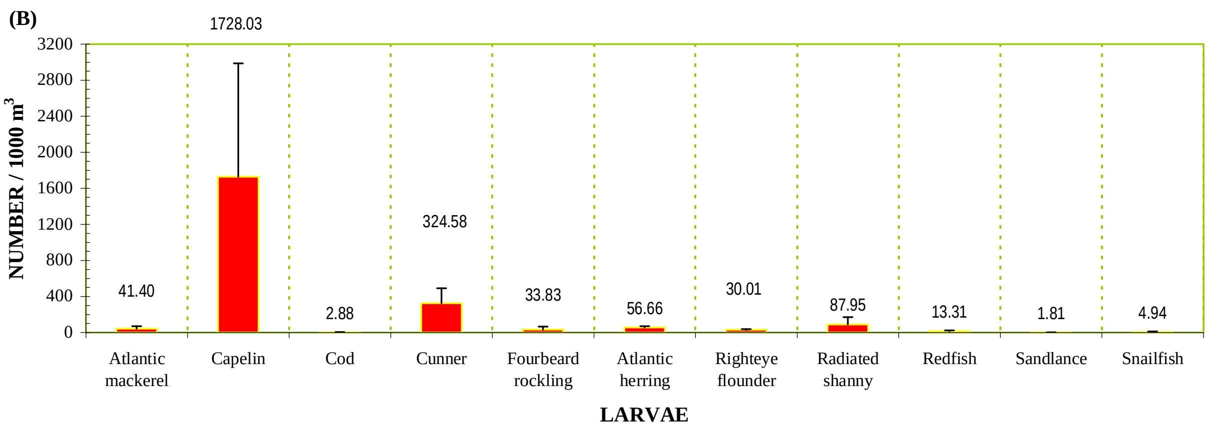


Figure 7. Mean abundance estimates (number/1,000 m^3) (with 95% confidence intervals) calculated by kriging of the eggs (A) and larvae (B) of some species sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

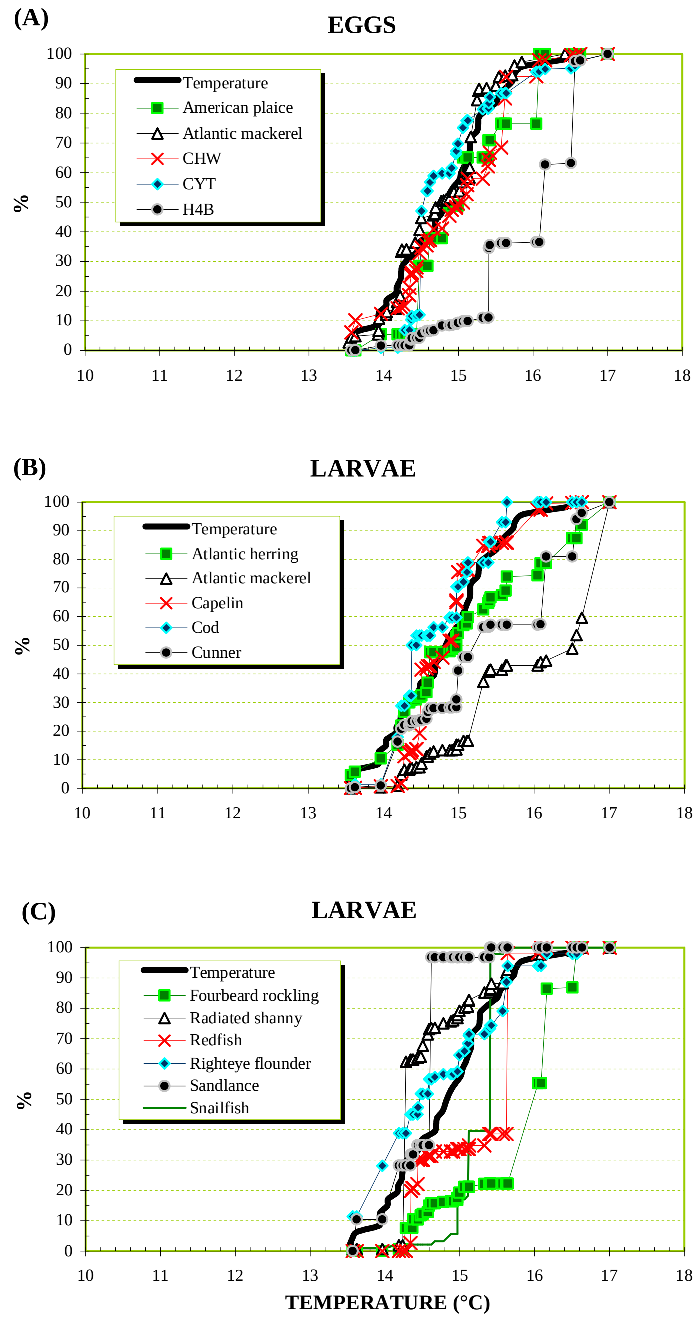


Figure 8. Cumulative curves of the abundance data of some eggs (A) and larvae (B and C) in relation to water temperature for the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

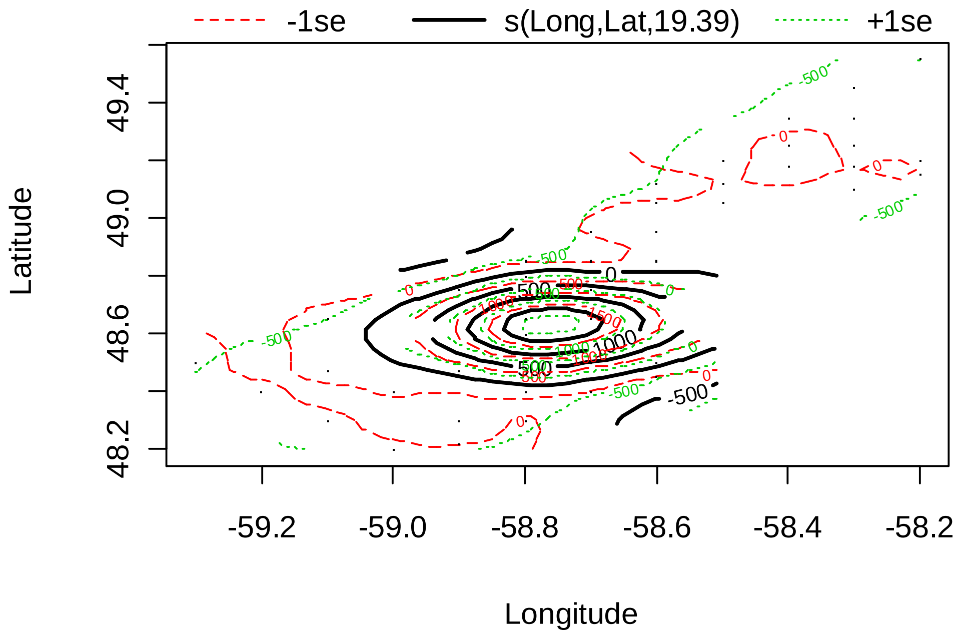


Figure 9. Smoothing function (with standard error) of the interaction between longitude and latitude on the H4B egg abundance data (number/1,000 m^3). The degrees of freedom was estimated at 19.39.

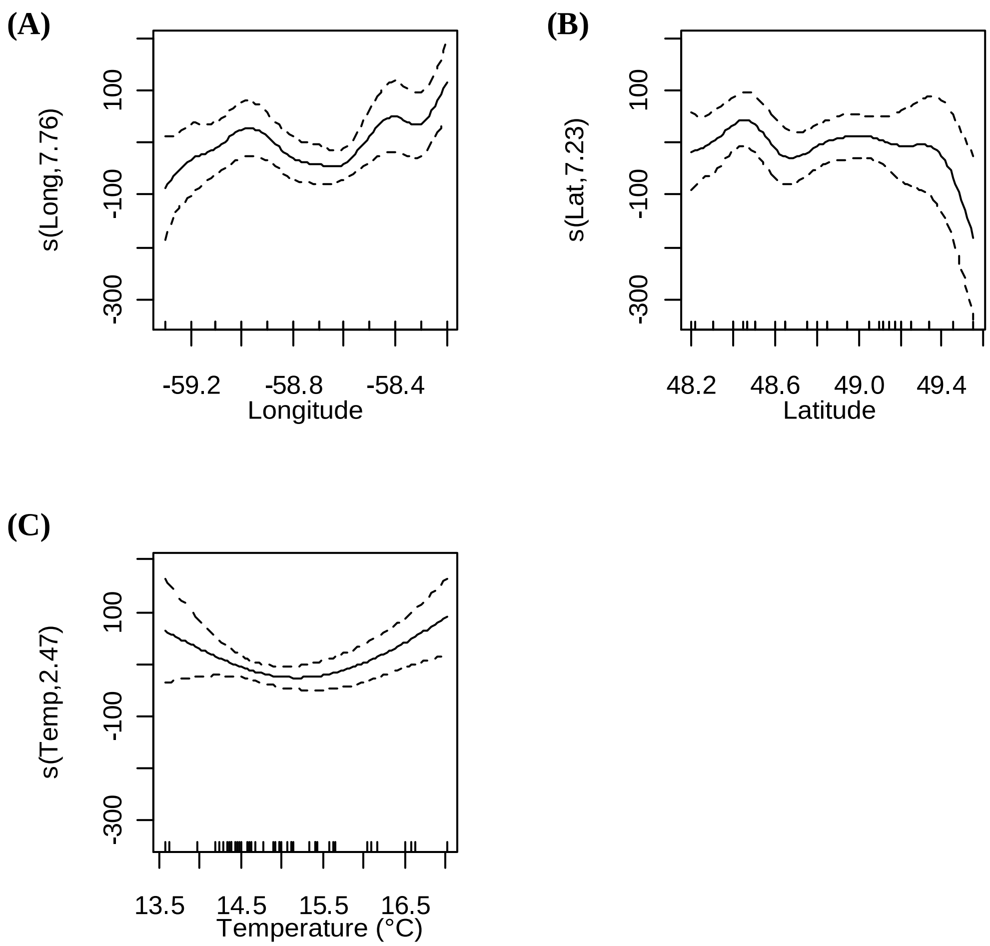
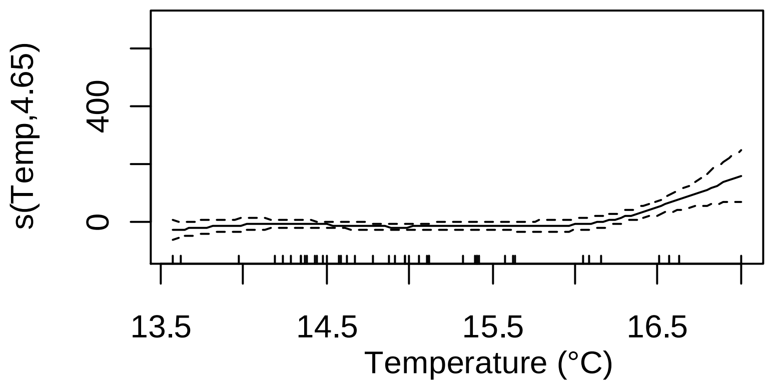


Figure 10. Smoothing functions between longitude (A), latitude (B), and temperature (°C) (C) on herring larva abundance data (number/1,000 m^3) (with 95% confidence intervals). Degrees of freedom were estimated at 7.76, 7.23, and 2.47, respectively. Vertical lines on the x-axes represent the observed longitude, latitude, and temperature values.

(A)



(B)

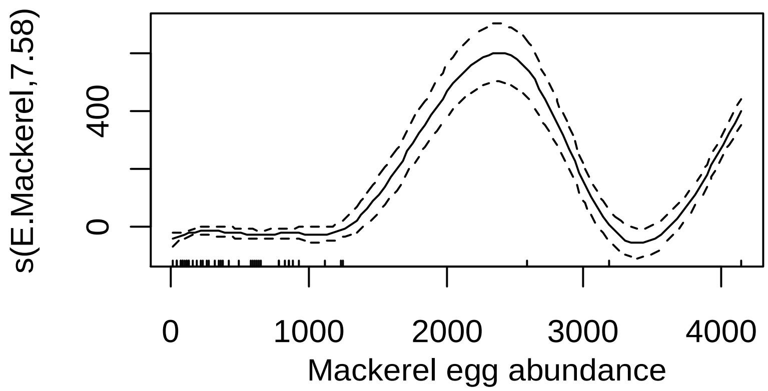
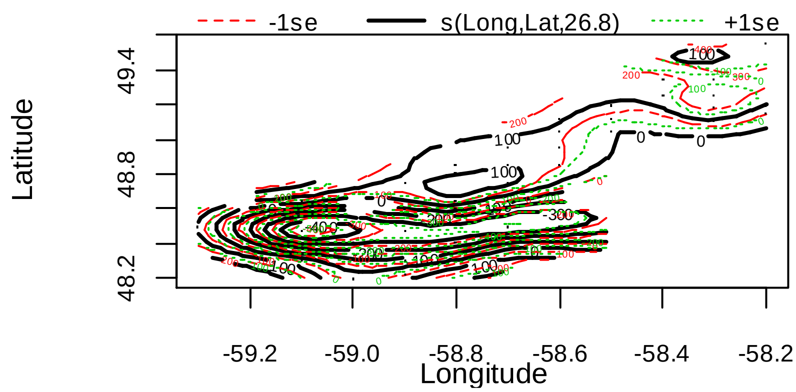


Figure 11. Smoothing functions between temperature (°C) (A) and Atlantic mackerel egg abundance (number/1,000 m^3) (B) on Atlantic mackerel larva abundance data (number/1,000 m^3) (with 95% confidence intervals). Degrees of freedom were estimated at 4.65 and 7.58, respectively. Vertical lines on the x-axes represent the observed temperature and Atlantic mackerel egg values.

(A)



(B)

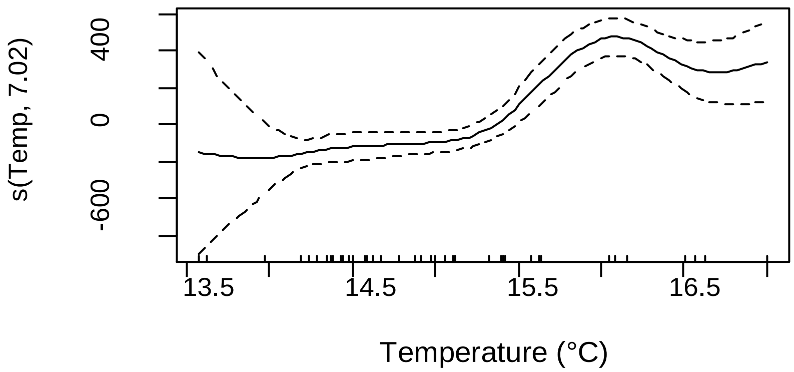


Figure 12. Smoothing functions of the interaction between longitude and latitude (with standard error) (A) and temperature (°C) (with 95% confidence intervals) (B) on the fourbeard rockling larva abundance data (number/1,000 m^3). Degrees of freedom were estimated at 26.8 and 7.02, respectively. Vertical lines on the x-axis represent the observed temperature values.

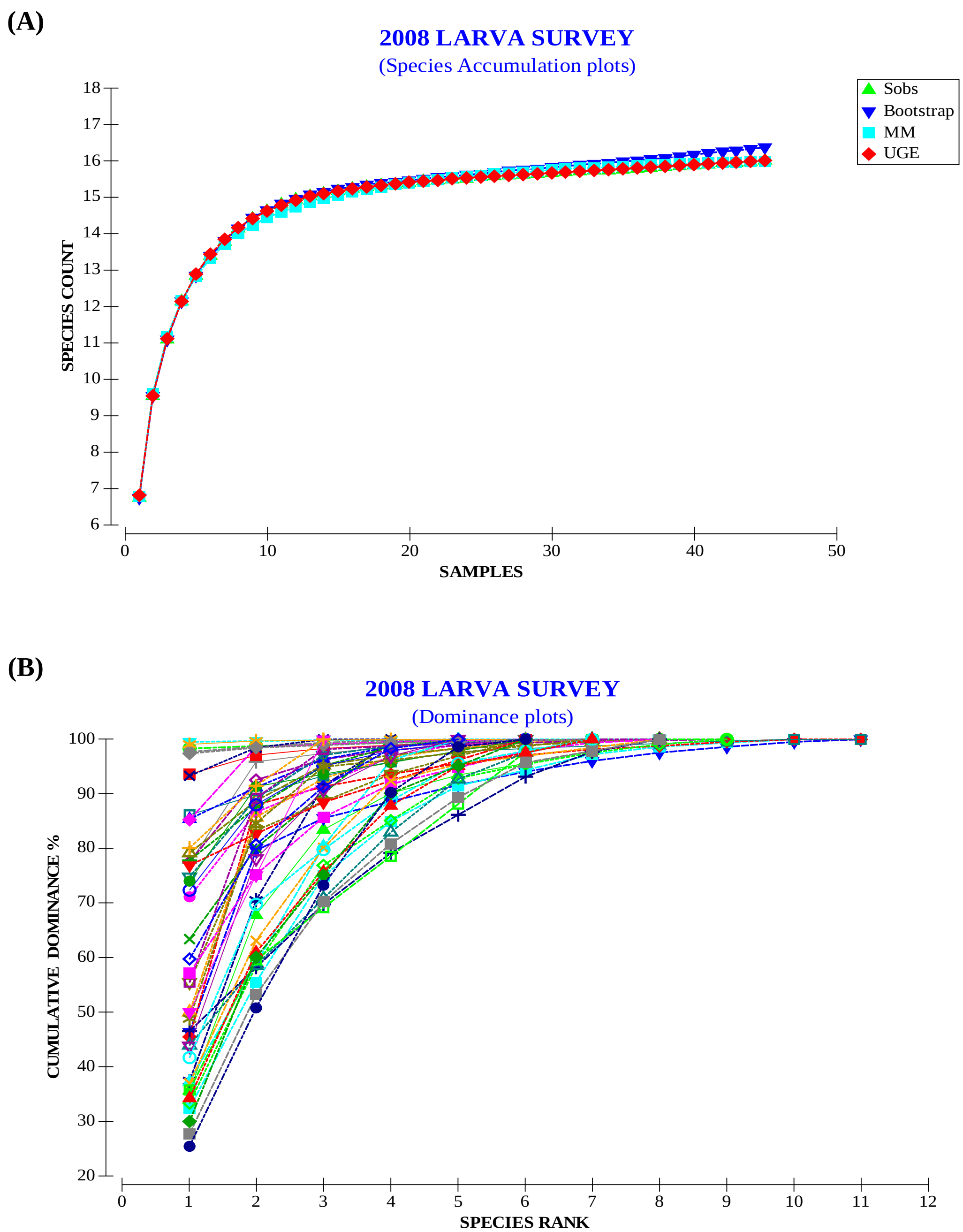


Figure 13. Species accumulation (A) and dominance (B) plots for the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland. In A, Sobs = observed data; bootstrap, MM, UGE = predicted data; see text for explanation. In B, the line–symbols represent the cumulative dominance and species rank of each station.

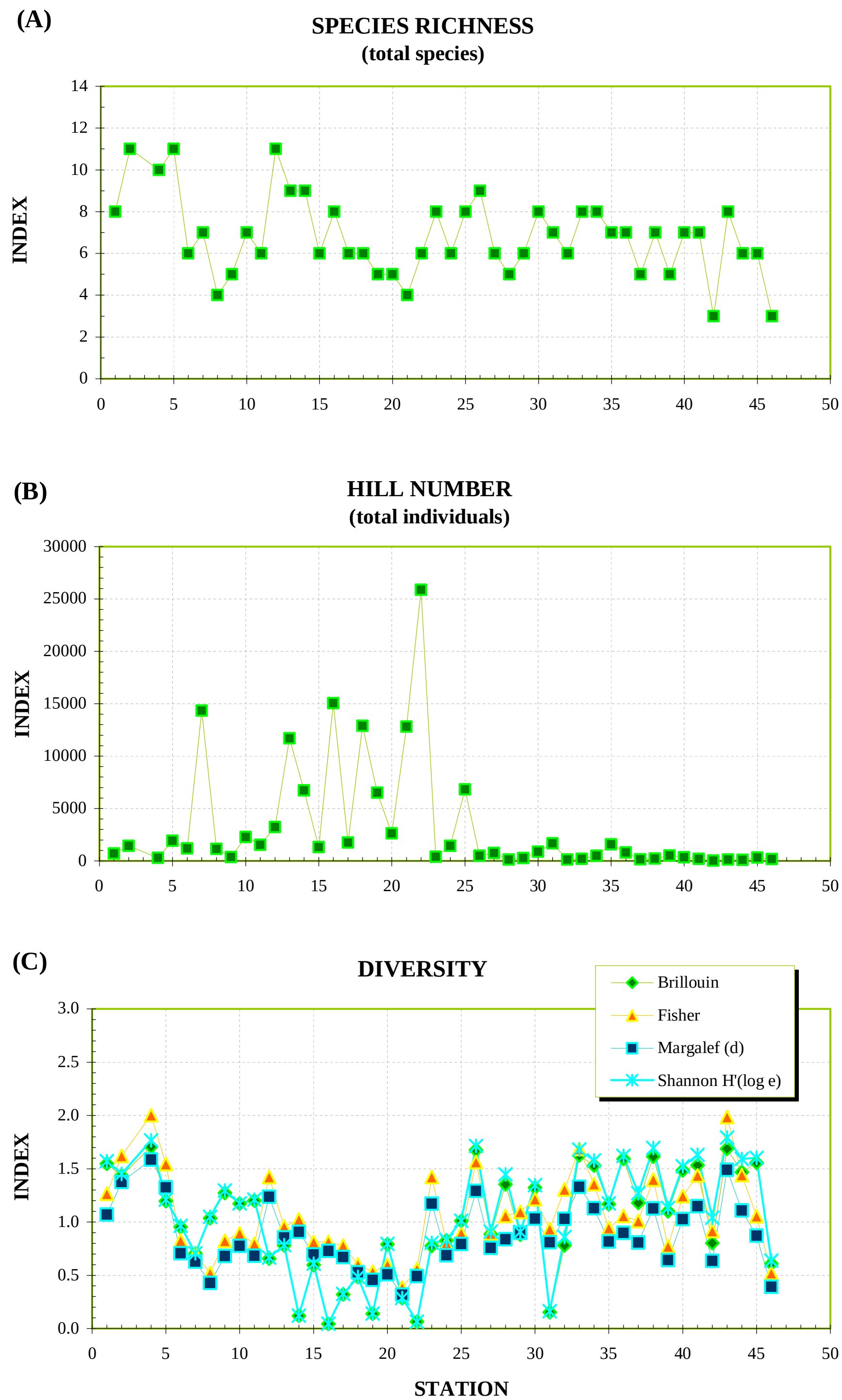


Figure 14. Total species (A), total individuals (B), and four diversity indices (C) calculated for the stations sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

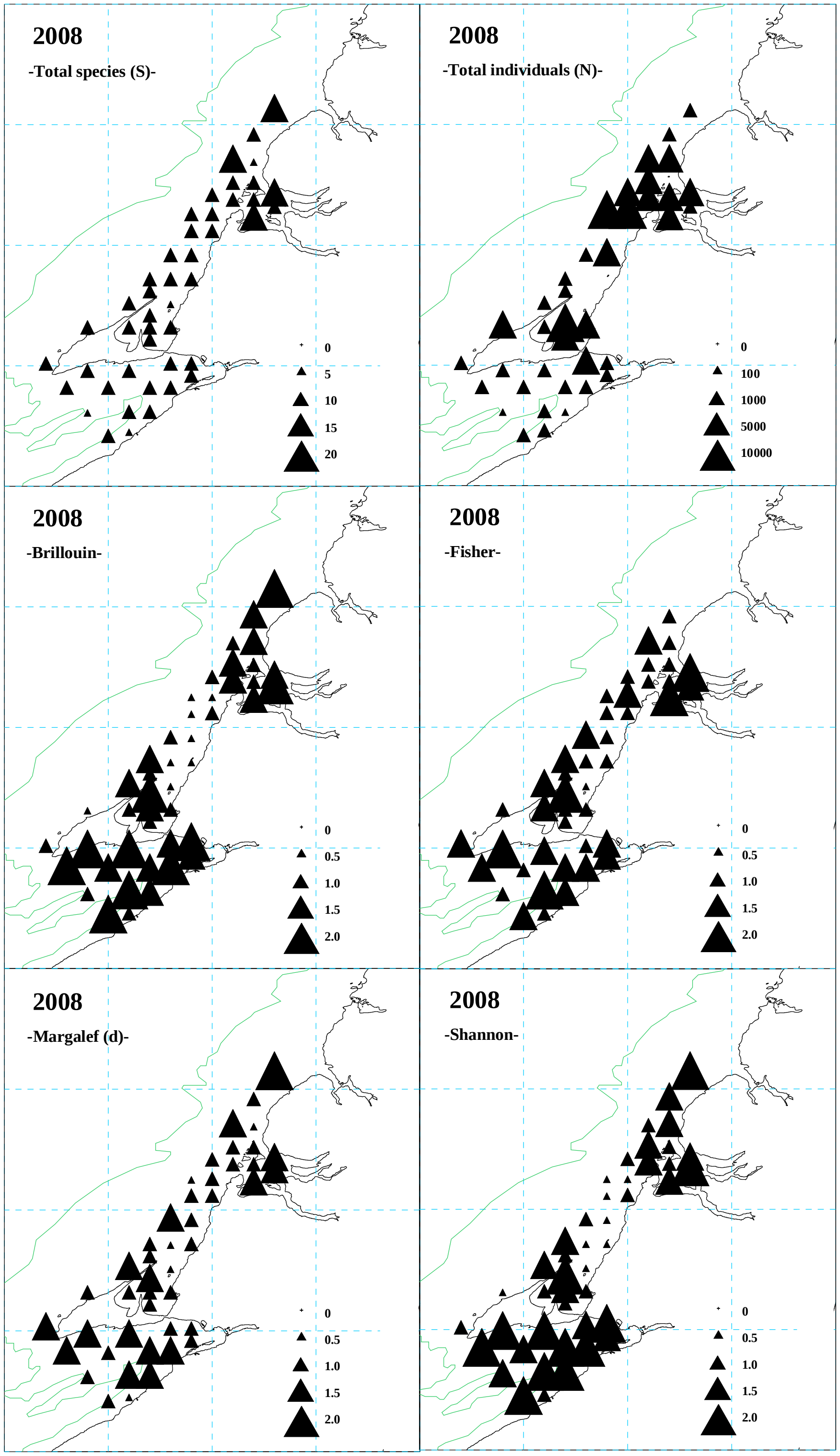
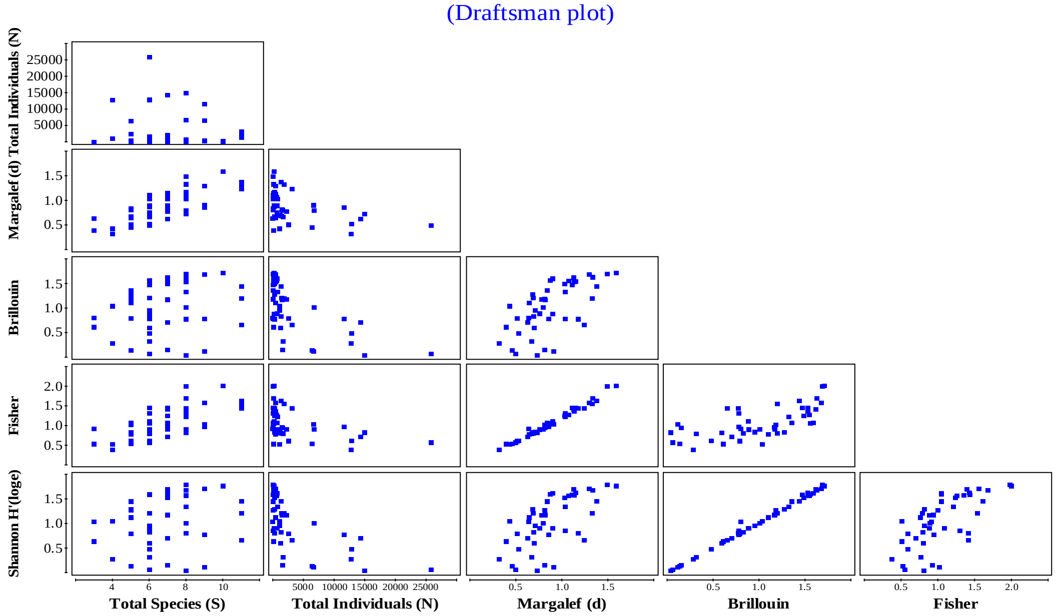


Figure 15. Maps showing distributions of total species, total individuals, and four diversity indices for the stations sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

(A)

2008 LARVA SURVEY

(Draftsman plot)



2008 LARVA SURVEY

(B)

(Non-Metric Multidimensional Scaling)

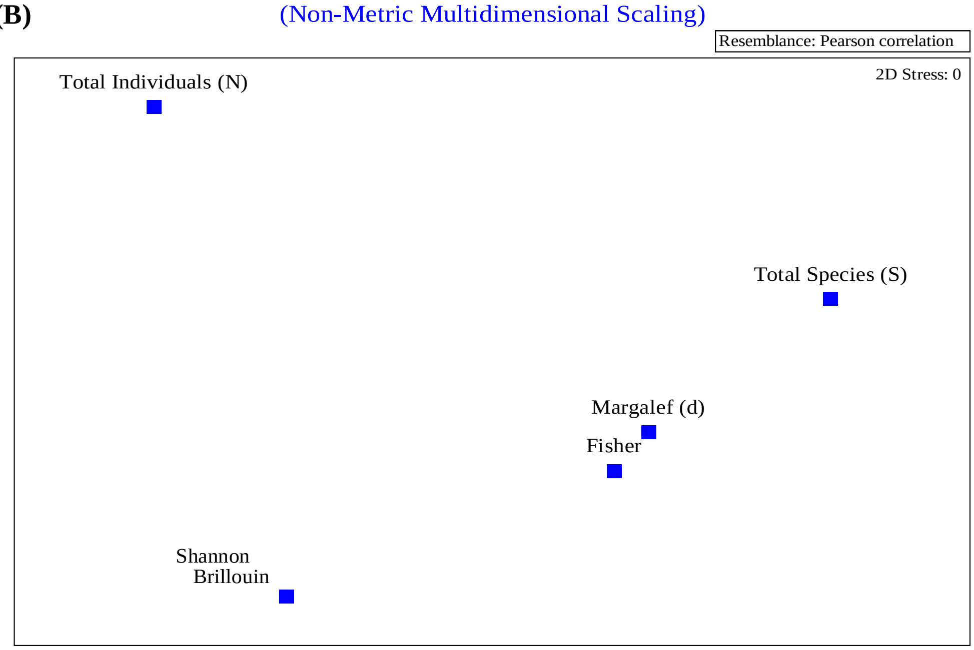
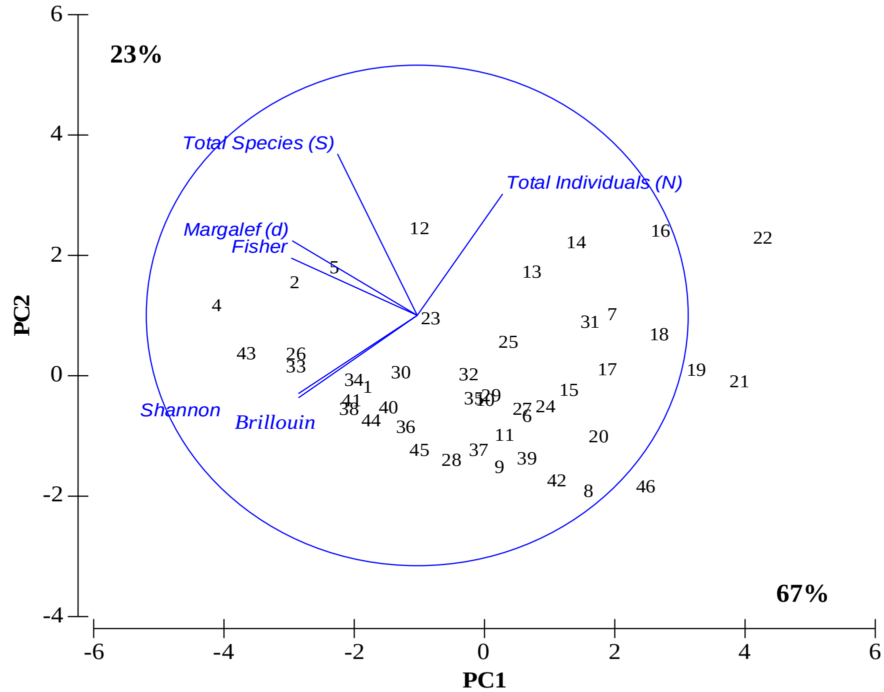


Figure 16. Draftsman (A), non-metric multidimensional scaling (B), and principal component analysis (PCA) (C) plots for the diversity indices calculated from the data collected during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

(C)

2008 LARVA SURVEY

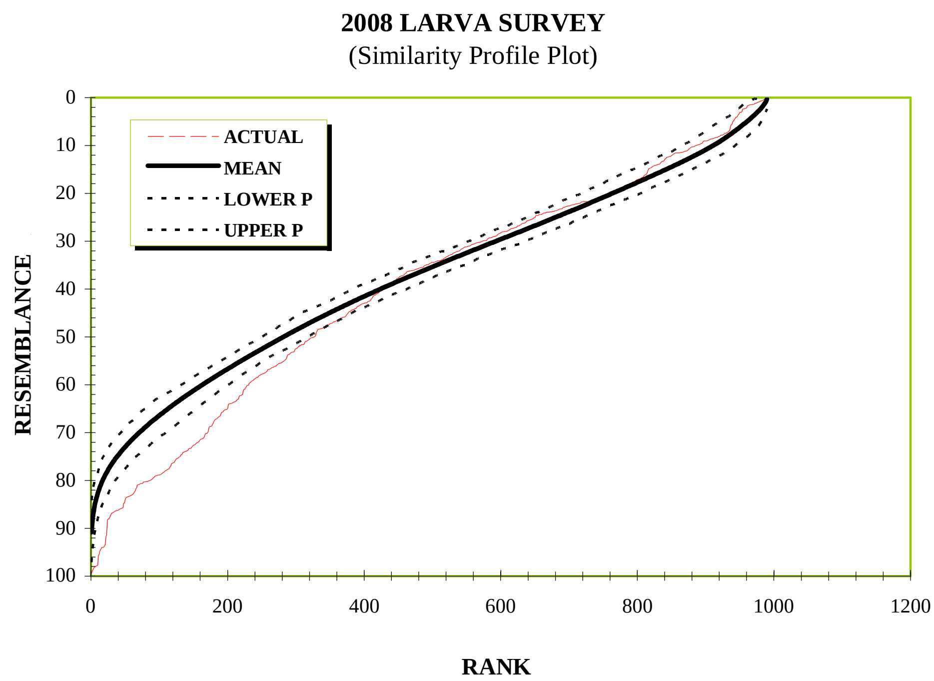
(Principal component analysis)



Variable	Eigenvectors	
	PC1	PC2
Total Species (S)	-0.294	0.646
Total Individuals (N)	0.315	0.486
Margalef (d)	-0.462	0.298
Brillouin	-0.439	-0.312
Fisher	-0.465	0.229
Shannon H'(log e)	-0.438	-0.329

Figure 16. (Continued).

(A)



(B)

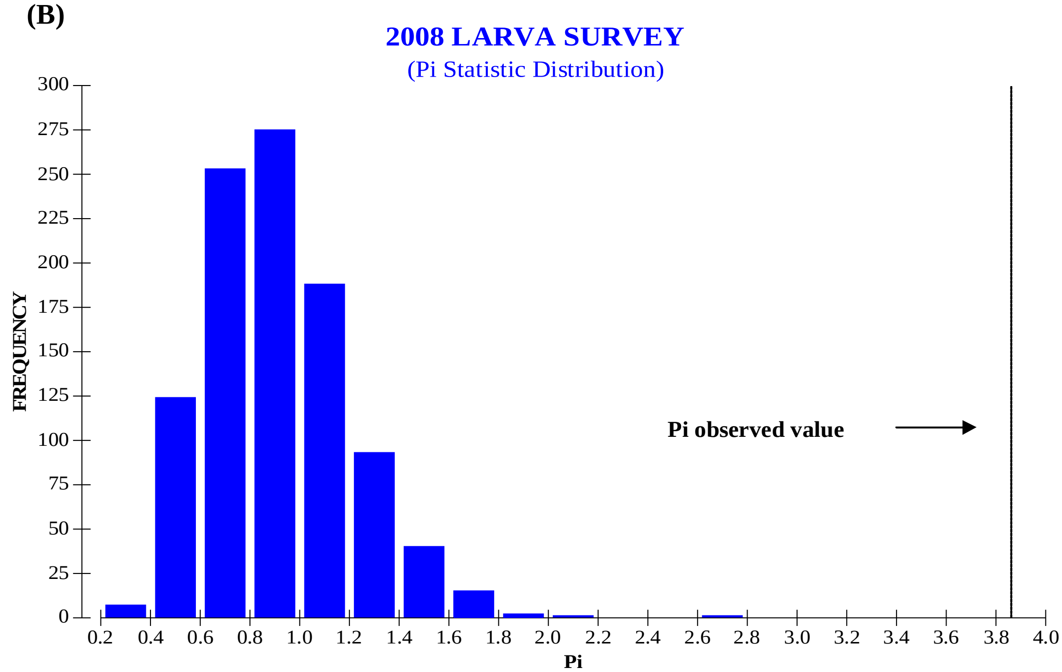
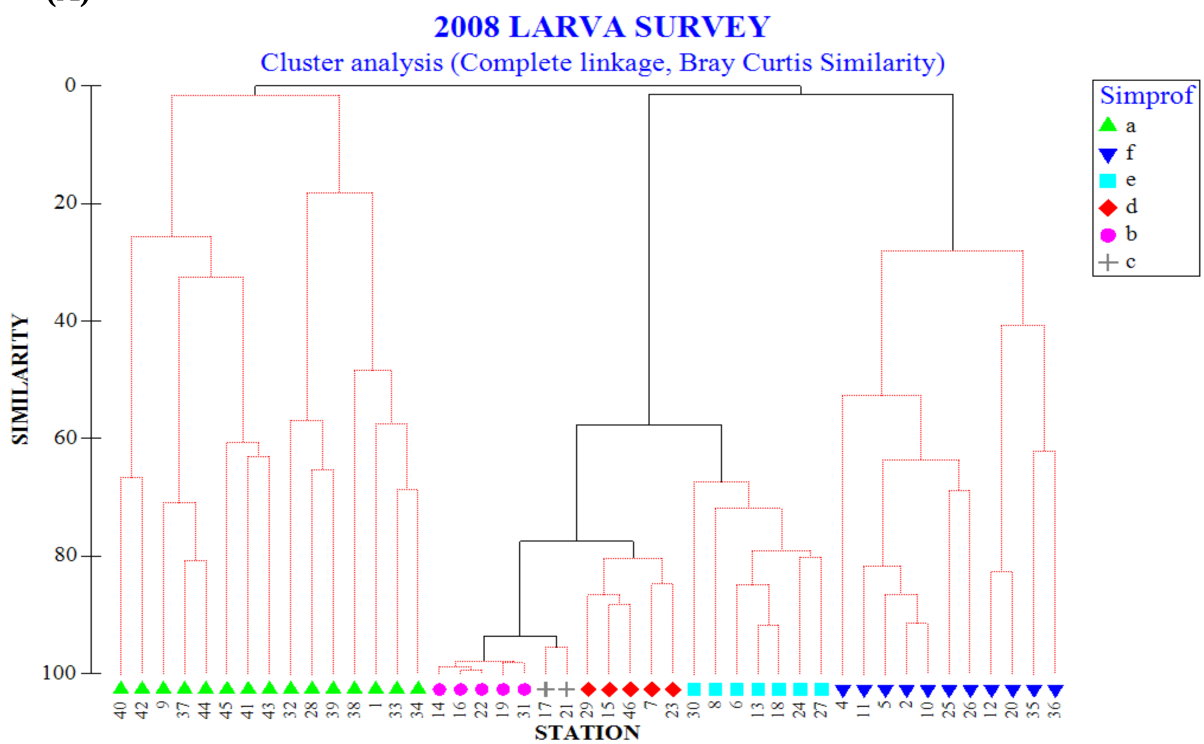


Figure 17. Similarity profile (A) and *Pi* statistic distribution (B) testing for evidence of internal group structure in the full set of stations sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland.

(A)



(B)

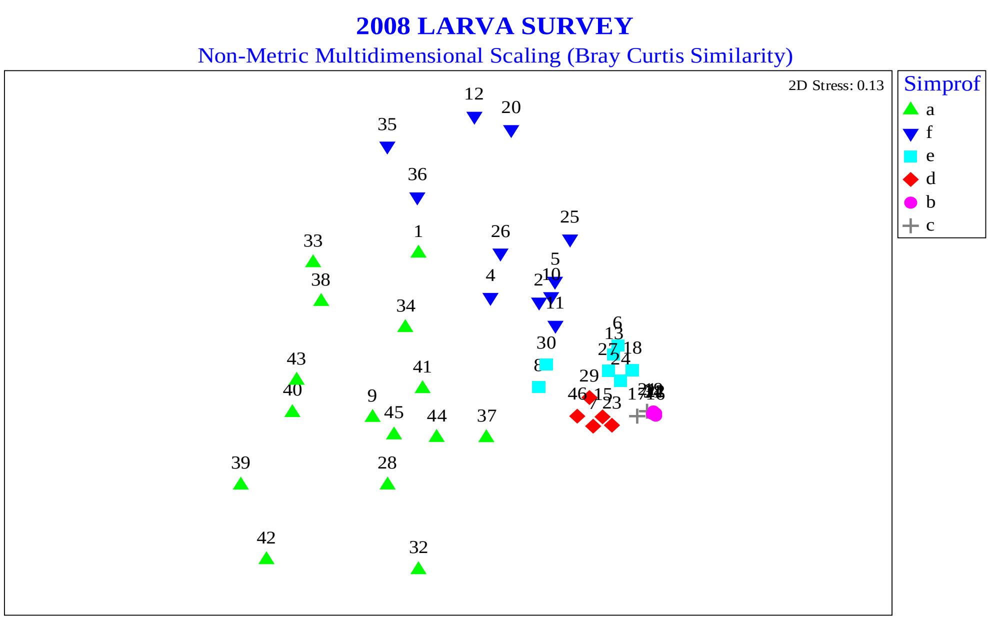


Figure 18. Results of the cluster analysis (A) and non-metric multidimensional scaling (B) applied on the Bray Curtis similarities calculated among the stations sampled during the capelin and Atlantic herring larval survey of July 2008 on the west coast of Newfoundland (groups of stations were defined by the SIMPROF procedure).

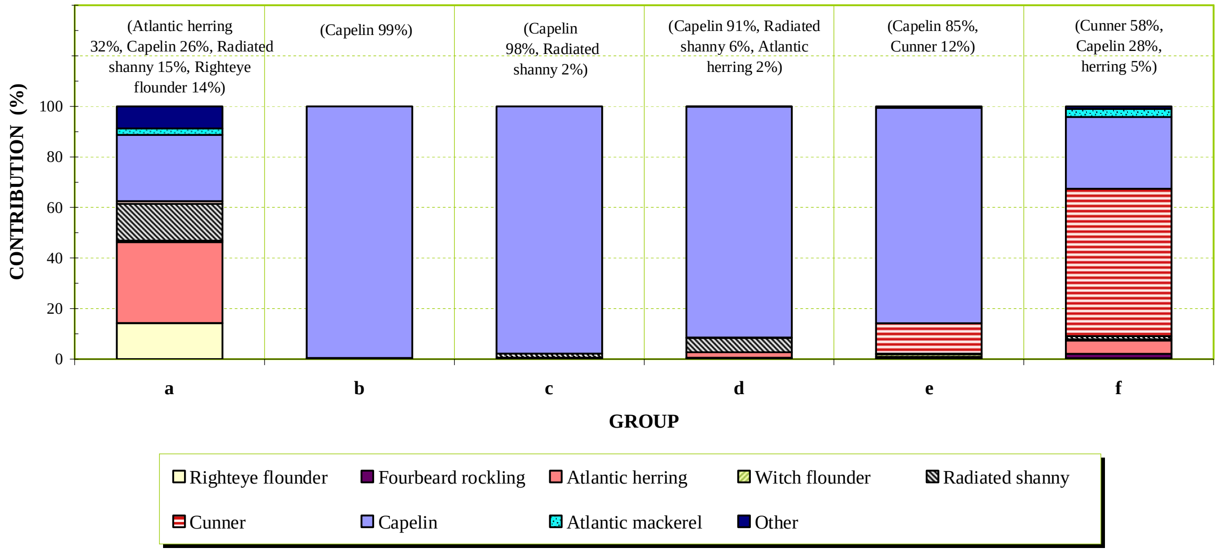


Figure 19. Relative contribution (%) of the main species of fish larvae to the similarity of each group of stations defined by cluster analysis.

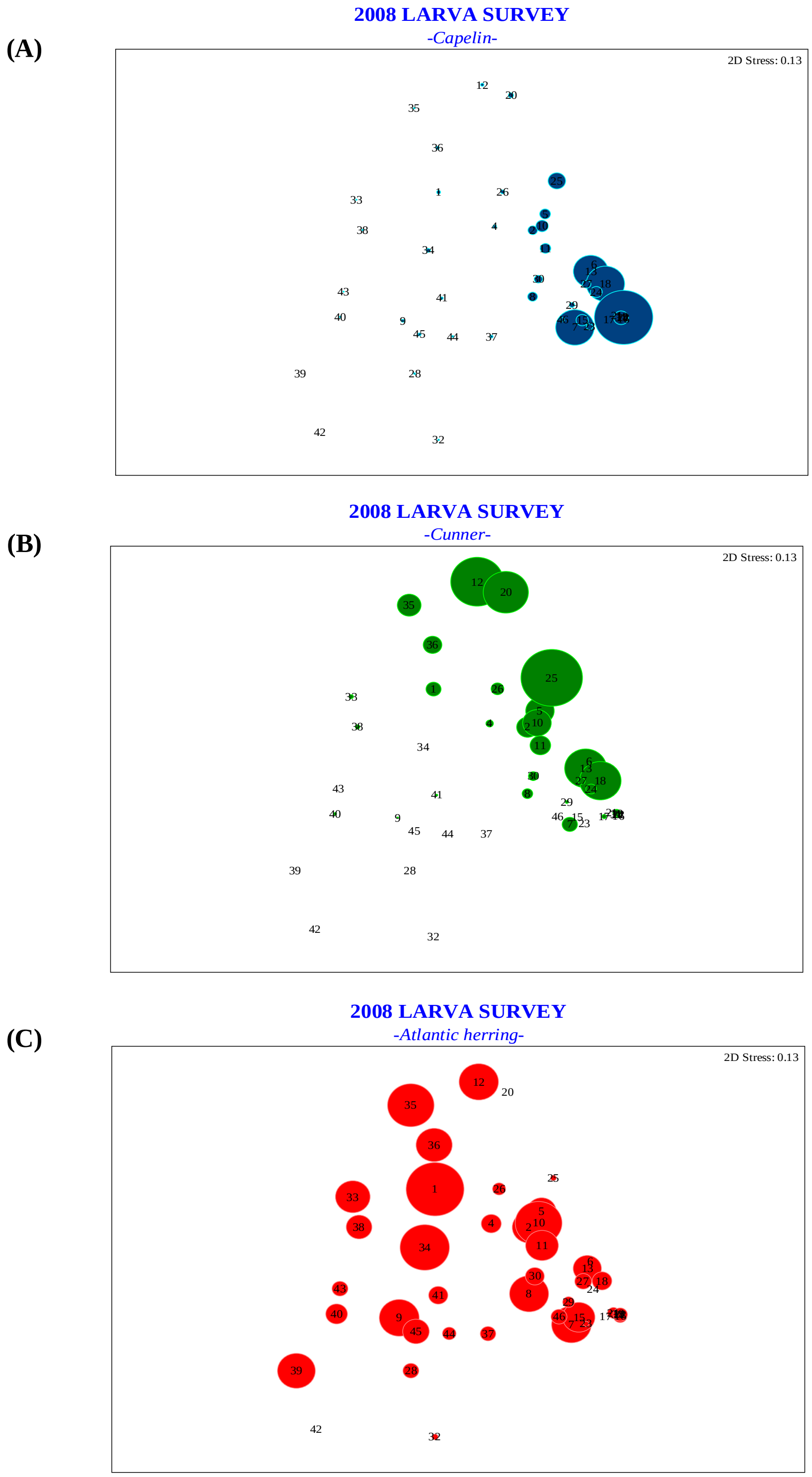
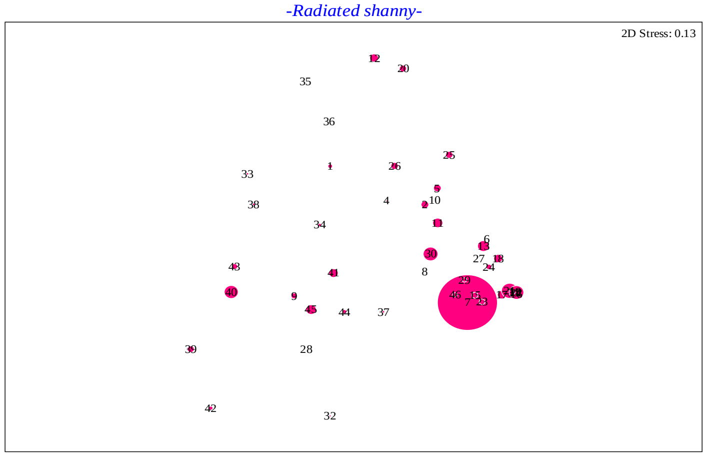


Figure 20. Non-metric multidimensional scaling showing the position and abundance (number/1,000 m^3) of the species with the greatest contribution (%) to their respective groups (A: capelin, B: cunner, C: Atlantic herring, D: radiated shanny, and E: righteye flounder).

(D)

2008 LARVA SURVEY

-Radiated shanny-



(E)

2008 LARVA SURVEY

-Righteye flounder-

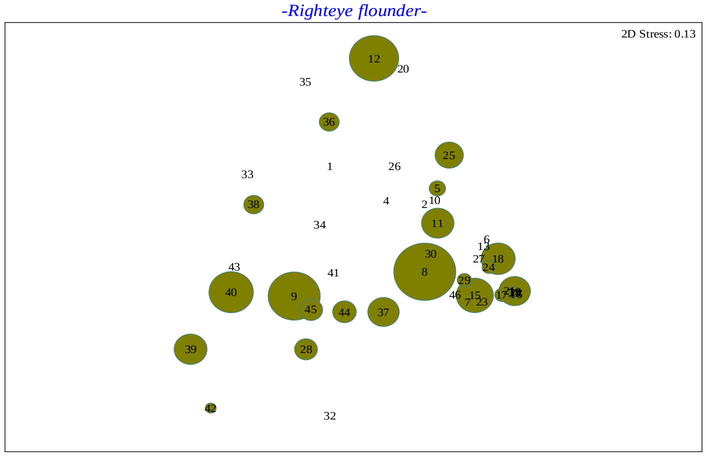


Figure 20. (Continued).

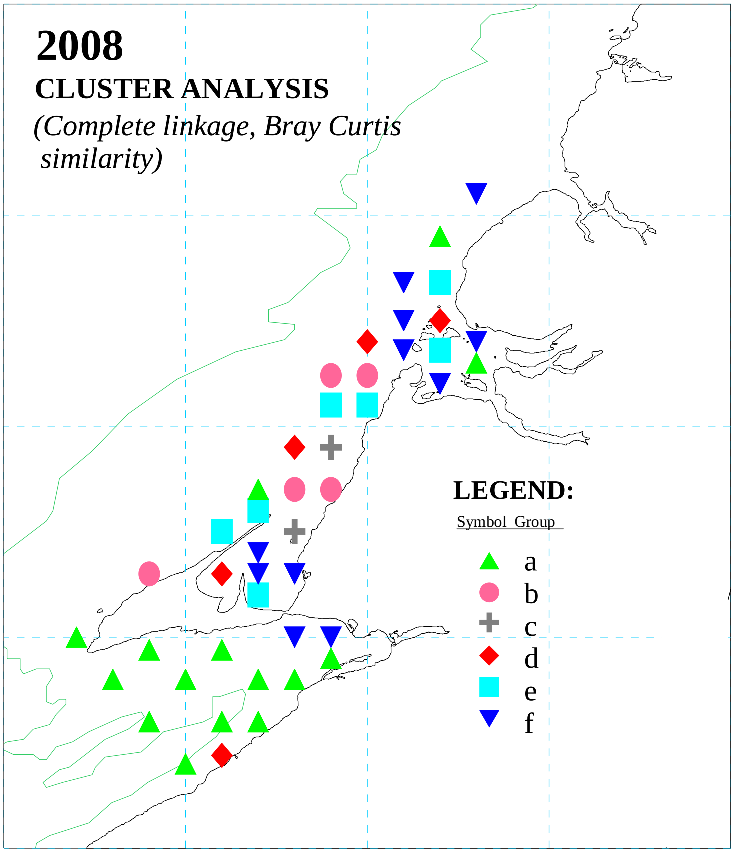
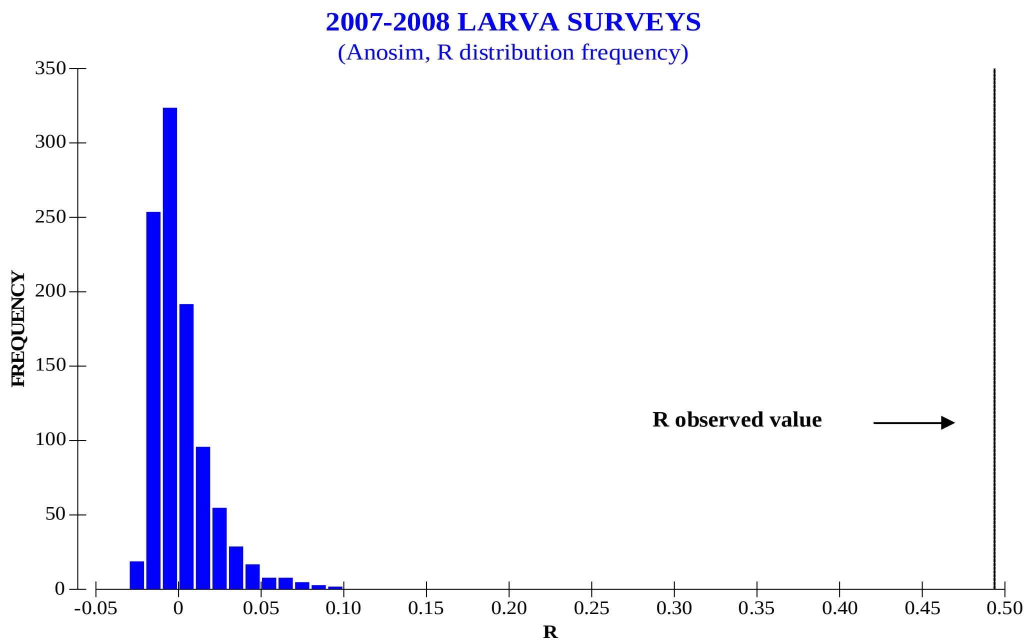


Figure 21. Map of the fish larval assemblages defined by the cluster analysis.

(A)



(B)

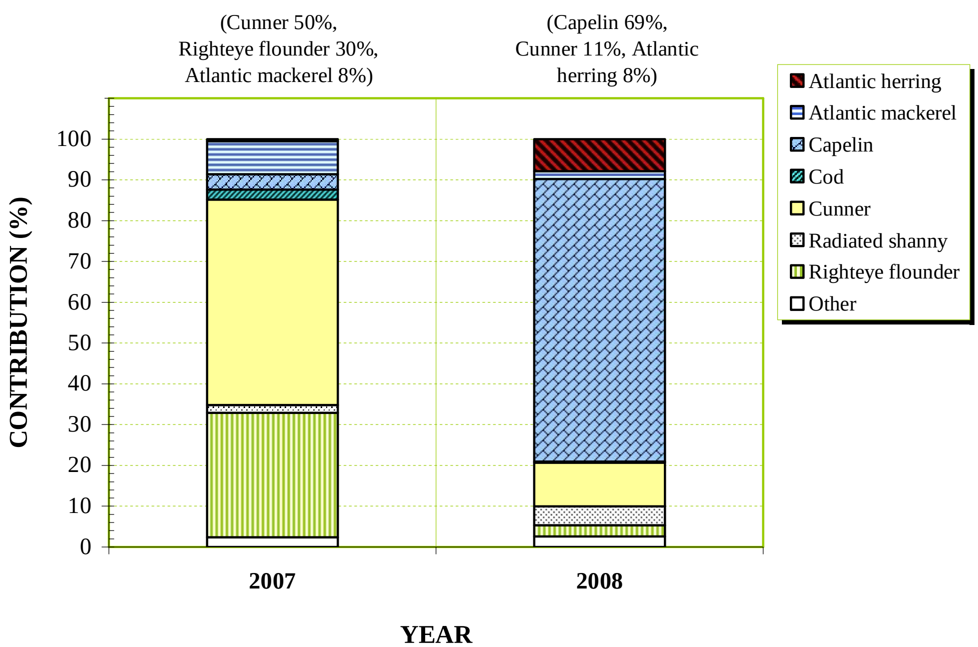
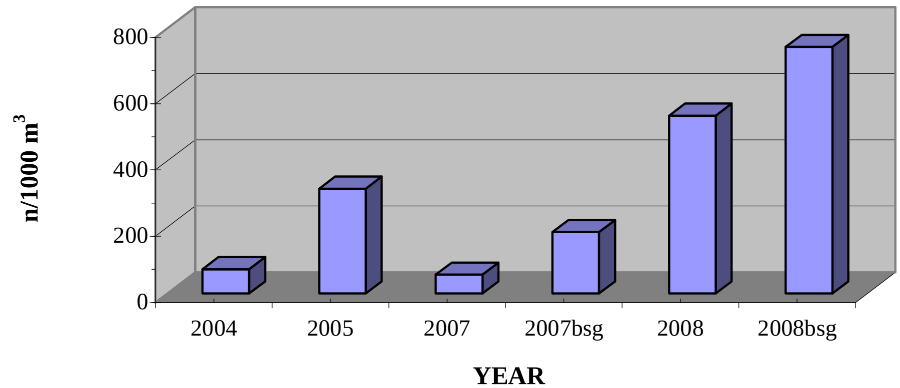


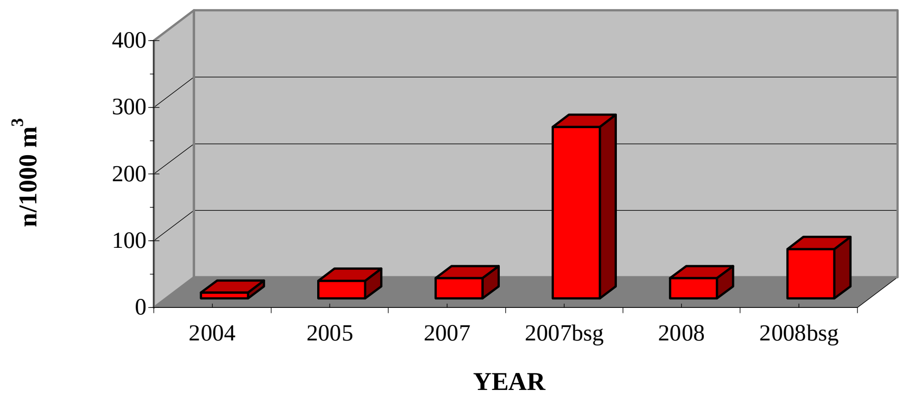
Figure 22. Results of the one-way ANOSIM procedure testing the null hypothesis that there are no larval assemblage differences between the groups of stations defined by cluster analyses and sampled in 2007 and 2008 (A) and relative contribution (%) of the main fish larvae to the similarity of each assemblage (B).

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 surveys of July 2004, 2005, 2007, and 2008 on the west coast of Newfoundland (note: bsg = St. George's Bay).

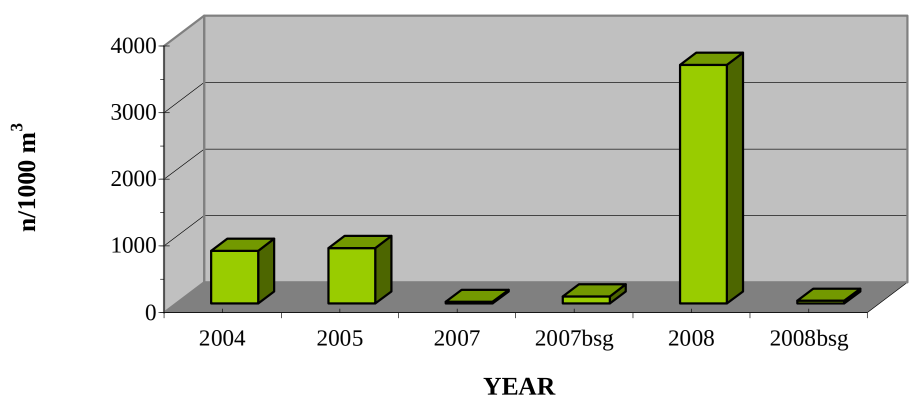
ATLANTIC MACKEREL -EGGS-
(*Scomber scombrus*)



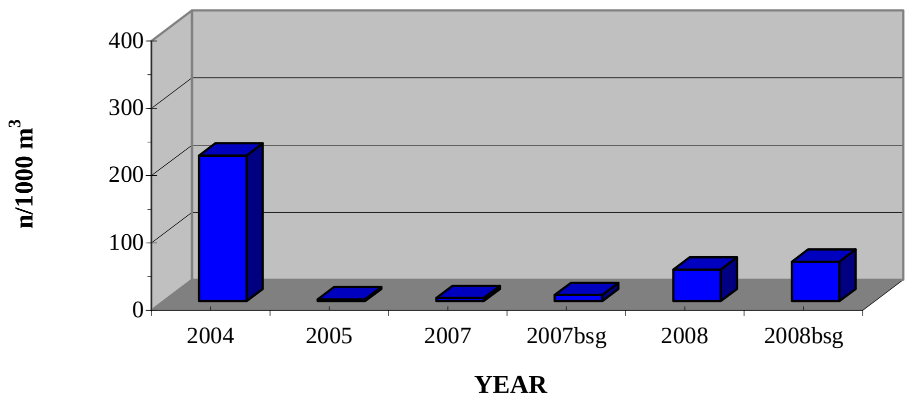
ATLANTIC MACKEREL -LARVAE-
(*Scomber scombrus*)



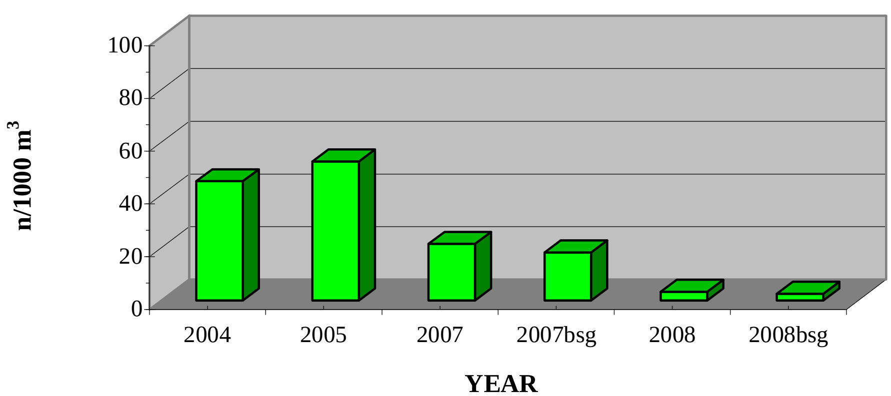
CAPELIN -LARVAE-
(*Mallotus villosus*)



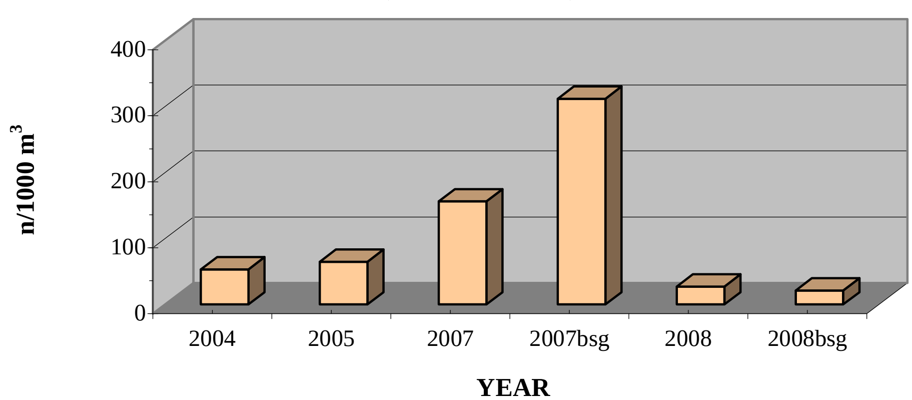
HERRING -LARVAE-
(*Clupea harengus harengus*)



COD -LARVAE-
(*Gadus morhua*)



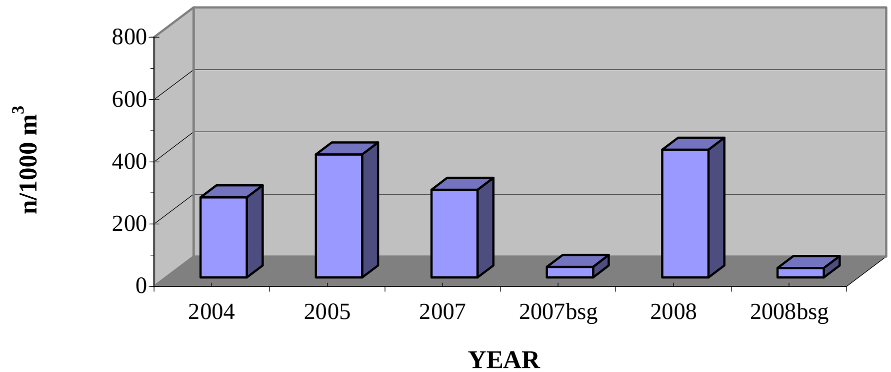
RIGHTEYE FLOUNDER -LARVAE-
(Pleuronectidae)



Appendix 2. Mean egg abundance (n/1,000 m^3) of the other species of fish sampled during the capelin and Atlantic herring larval surveys of July 2004, 2005, 2007, and 2008 on the west coast of Newfoundland (note: bsg = St. George’s Bay).

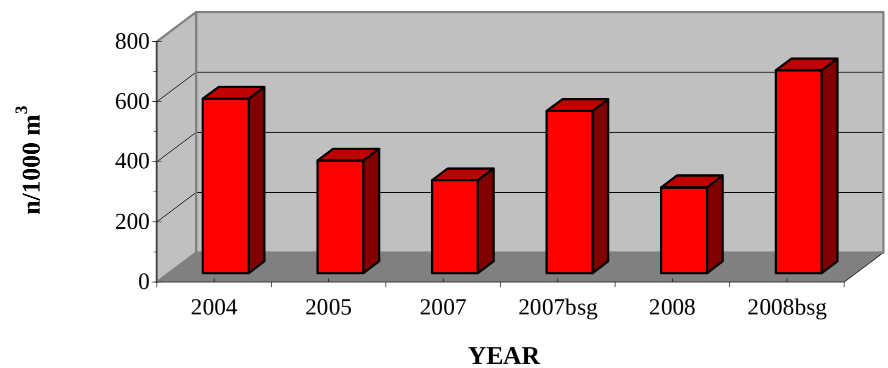
H4B -EGGS-

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



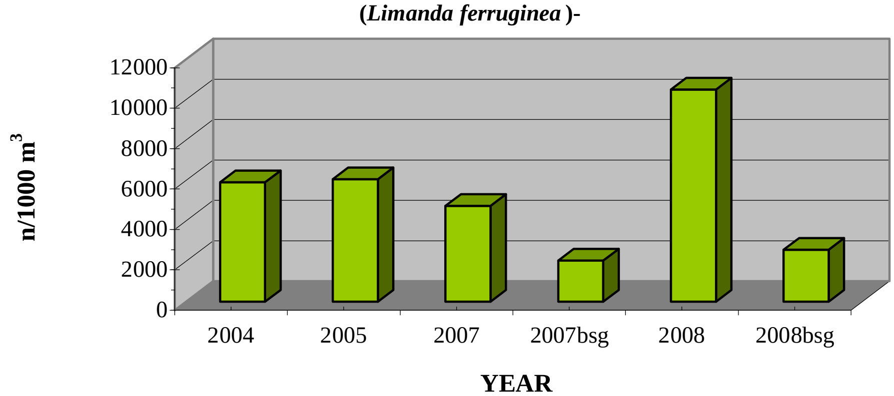
CHW -EGGS-

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

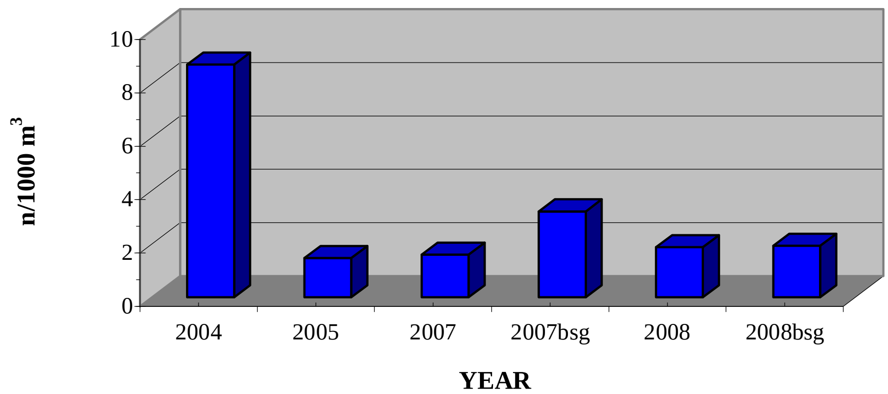


CYT -EGGS-

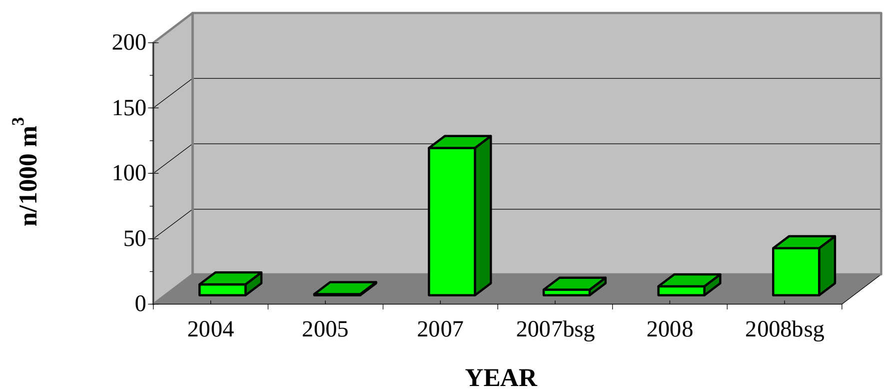
-Cunner (*Tautogolabrus adspersus*) and yellowtail flounder (*Limanda ferruginea*)-



AMERICAN PLAICE -EGGS-
(*Hippoglossoides platessoides*)

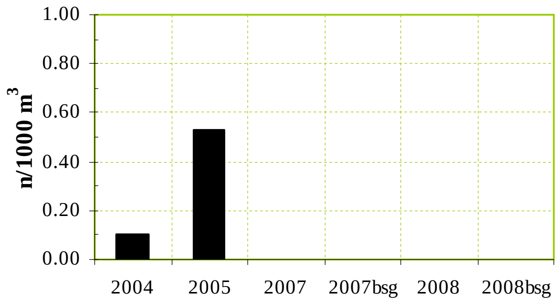


WINDOWPANE FLOUNDER -EGGS-
(*Scophthalmus aquosus*)

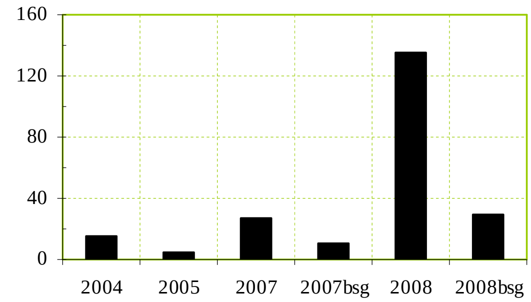


Appendix 3. Mean larval abundance (n/1,000 m^3) of the other species of fish sampled during the capelin and Atlantic herring larval surveys of July 2004, 2005, 2007, and 2008 on the west coast of Newfoundland (note: bsg = St. George's Bay).

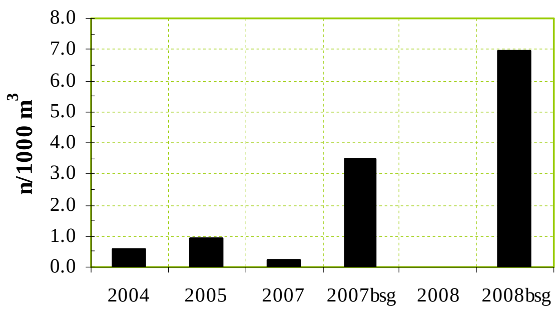
AMERICAN PLAICE
(*Hippoglossoides platessoides*)



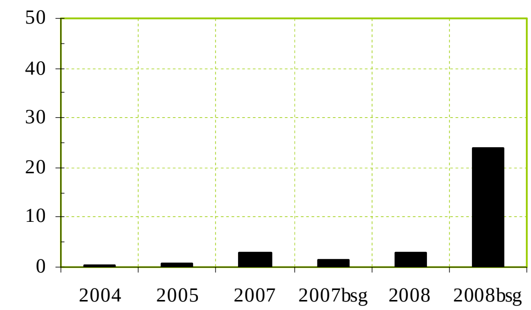
RADIATED SHANNY
(*Ulvaria subbifurcata*)



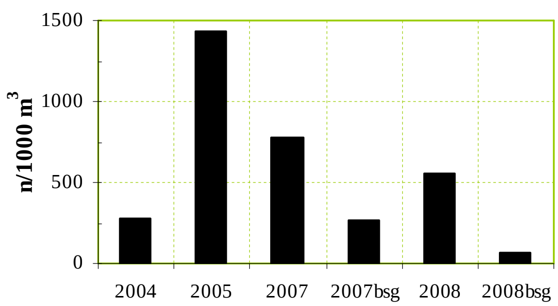
ARCTIC SHANNY
(*Stichaeus punctatus*)



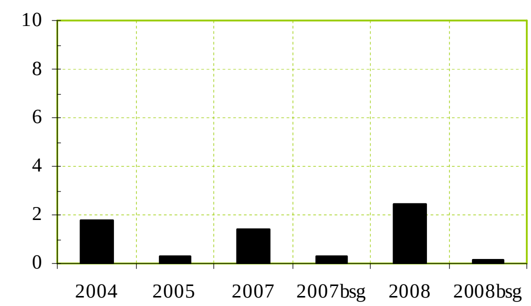
REDFISH
(*Sebastes* spp.)



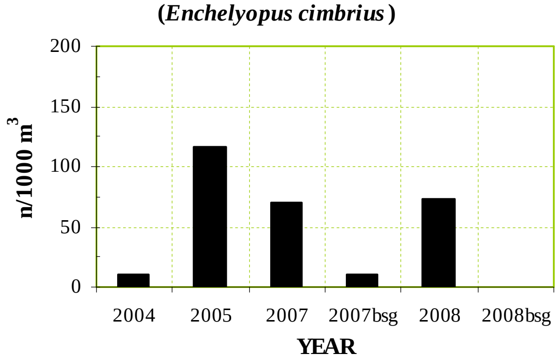
CUNNER
(*Tautogolabrus adspersus*)



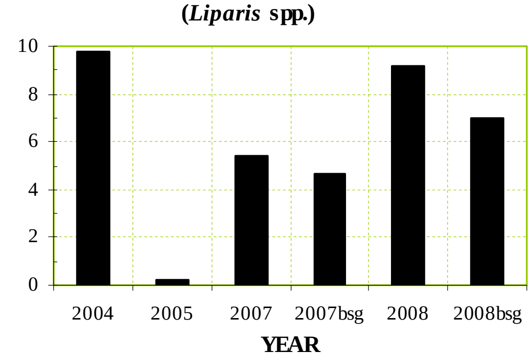
SANDLANCES
(*Ammodytes* spp.)



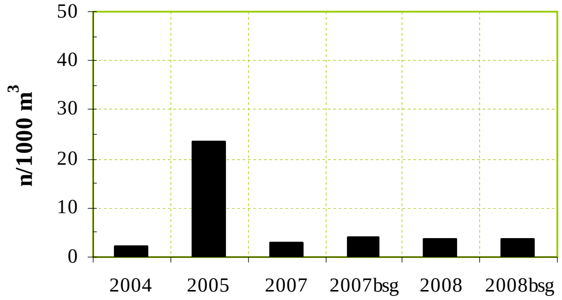
FOURBEARD ROCKLING
(*Enchelyopus cimbrius*)



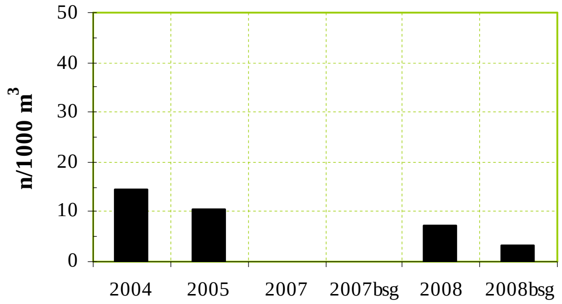
SNAILFISH
(*Liparis* spp.)



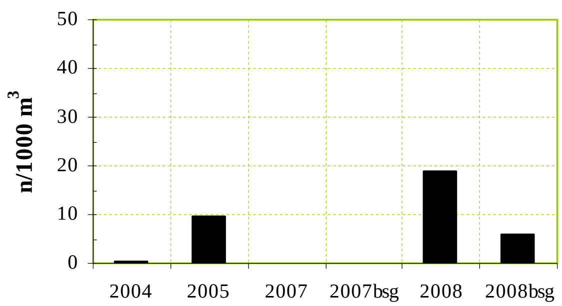
WINDOWPANE FLOUNDER
(*Scophthalmus aquosus*)



WINTER FLOUNDER
(*Pseudopleuronectes americanus*)



WITCH FLOUNDER
(*Glyptocephalus cynoglossus*)



YELLOWTAIL FLOUNDER
(*Limanda ferruginea*)