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# Size at 50% maturity for Atlantic herring in the southern Gulf of St. Lawrence (NAFO 4T)

# Taille de 50% de maturité pour le hareng du sud du golfe Saint-Laurent (OPANO 4T)

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## ABSTRACT

DFO Fisheries Management Branch requested Science advice in November 2007 to determine whether the current 24.5 cm fork length size limit corresponded to the size at 50% maturity for the southern Gulf of St. Lawrence (sGSL) Atlantic herring stocks (NAFO 4T). The herring population in the sGSL consists of a spring and a fall spawner component. Herring samples from the annual herring acoustic surveys and the annual groundfish surveys from the years 1995 to 2006 were chosen for the analysis because they were considered to be unbiased for gear selectivity. Immature and mature classes were generated from gonad maturity data. We fitted logistic models to the observed proportion of mature fish at each length to determine the median fork length ($L_{50}$) at maturity for both the spring and the fall spawning components. We estimated confidence limits of $L_{50}$ alternatively by bootstrapping the observed number of mature and immature herring within each year and spawning group, both on non-weighted and weighted maturity data. There were no significant differences of the $L_{50}$ at maturity between sexes but some differences between areas. Inter-annual variations in $L_{50}$ was highly significant, thus the data were analysed by year. After considering both spawning groups separately, the differences in $L_{50}$ were not significant for most years and the data was combined. To determine the most appropriate $L_{50}$ values, the models were fitted to the weighted acoustic survey biological data and the confidence limits were obtained by bootstrap simulations. The mean fork length at maturity ($L_{50}$) for the southern Gulf of St. Lawrence Atlantic herring stocks for the years 1999-2006 is estimated at 23.5 cm.

## RÉSUMÉ

En novembre 2007, la Gestion des Pêches a demandé un avis scientifique afin de déterminer si la taille minimum limite actuelle de 24.5 cm à la fourche correspond à la taille de 50% de maturité pour le hareng du sud du golfe Saint-Laurent (sGSL) (OPANO 4T). La population de hareng dans le sud du golfe est constituée de deux composantes : une composante de reproducteurs de printemps et une de reproducteurs d'automne. Nous avons utilisé les données de deux relevés de recherche annuels, soit le relevé acoustique du hareng et le relevé des poissons de fond comme sources de données pour les analyses, ceux-ce étant considérés non biaisés par la sélectivité. Nous avons établi deux classes de maturité à partir des données sur la maturité des gonades des échantillons de poissons des deux composantes de reproducteurs ; juvénile et mature. Pour les deux composantes de reproducteurs, nous avons estimé la longueur à la fourche médiane de maturité ($L_{50}$) à partir de la proportion observée de poissons matures de chaque longueur à l'aide d'un modèle logistique. Nous avons calculé les limites de confiance de la $L_{50}$ en échantillonnant les données avec répétition pour chaque année (méthode bootstrap) et entre les deux composantes de reproducteurs, sur les données de maturité non-pondéres et pondérés. La $L_{50}$ n'était pas significativement différente entre les sexes mais il y avait certaines différences par zones géographiques. Les variations interannuelles de la $L_{50}$ étaient hautement significatives, et c'est pourquoi nous avons analysé les données en fonction de l'année. Après avoir étudié les deux groupes de reproducteurs séparément, nous avons conclu que les différences interannuelles de $L_{50}$ entre les deux groupes n'étaient pas significatives pour la plupart des années de la série chronologique, et nous avons décidé de combiner les données. Pour déterminer les valeurs les plus appropriées de la $L_{50}$, nous avons ajusté les modèles en fonction des données biologiques pondérées des relevés acoustiques et les limites de confiance ont été obtenues à l'aide de simulations bootstrap. La longueur à la fourche médiane à maturité ($L_{50}$) pour le hareng de l'Atlantique du sud du golfe Saint-Laurent est estimée à 23,5 cm pour la période entre 1999 et 2006.

# RATIONALE

By regulation and variation order, the current minimal landing size for Atlantic herring (*Clupea harengus harengus*) in the southern Gulf of St. Lawrence (sGSL) is 24.5 cm fork length. While the minimum size was originally put in place for market reasons, a science review in 1995 concluded that with the 24.5 cm fork length regulation in effect, purse seiners catch a very small proportion of immature herring (Claytor et al. 1996). In the regulations, a 10% catch of herring less than 24.5 cm is allowed and other management measures are taken when this level is exceeded.  In the 2007 herring seiner fishery, a higher proportion of herring less than 24.5 cm was caught than in previous years.  Science advice was requested by Fisheries Management in November 2007 to determine whether the 24.5 cm fork length size corresponded to the size at 50% maturity for the sGSL herring stocks (NAFO 4T). The Science advice was provided within a Canadian Science Advisory Secretariat (CSAS) Science Response document (DFO 2007). The methods and analysis used to generate that advice are described here in detail.

# INTRODUCTION

Atlantic herring in the sGSL are found in the area extending from the north shore of the Gaspé Peninsula to the northern tip of Cape Breton Island, including the Magdalen Islands (Fig. 1). Adults overwinter off the north and east coast of Cape Breton in NAFO areas 4T and 4Vn (Claytor 2001, Simon and Stobo 1983).

Herring are a pelagic species which form schools particularly during feeding and spawning periods. The herring population in the sGSL consists of two components, the spring spawner component (P) and the fall spawner component (A), with July 1$^{st}$ as a separation date. Spring spawning occurs primarily at depths less than 10m in April-May, but extends into June. Fall spawning occurs mainly from mid-August to October at depths of 5 to 20m. Eggs are attached to the bottom and large females can produce up to 360,000 eggs (Messieh 1988). First spawning occurs primarily at age four.

The sGSL herring is harvested primarily by an inshore fixed gear gillnet fleet (77% of the quota) and a mobile gear purse seine fleet (23% of the quota), both fishing in the NAFO area 4T (Fig. 1). The percentage of spring and fall spawner component in the catch varies according to season and gear type.  As a result, landings during the fall and spring fisheries have to be separated into the appropriate spring and fall spawning groups to determine if the Total Allowable Catch (TAC) for these groups were attained.

Annual acoustic surveys of early fall (September-October) concentrations of herring in the southern Gulf have been conducted since 1985 by the Science Branch of DFO. The surveys were usually concentrated in the areas of Chaleurs-Miscou and north of P.E.I. These areas are where NAFO Division 4T herring congregate in the fall. The survey design used random parallel transects within strata. Midwater trawl sampling was carried out wherever major concentrations were detected acoustically. Methods used are detailed in LeBlanc and Dale (1996).

Each September since 1971, a standardized research vessel bottom-trawl survey has been conducted by the Science Branch of DFO in the sGSL. The primary objective of this survey is to obtain abundance indices for the major groundfish resources in the area (Hurlbut et al. 2007). Herring samples were also taken during the survey.

## METHODS

For both the fishery and the research surveys, sampling for size distribution was done by measuring approximately 250 herring per sample and from these, sub-samples of individual herring were kept for the determination of biological characteristics in the laboratory; including total length, weight, sex, gonad weight, gonad maturity stage and otolith collection for ageing.

The following techniques were used to assign herring samples to either spring (P) or autumn (A) spawning components based on gonad maturity stages (Cleary et al. 1982). For immature herring (maturity stages 1 and 2), the season of hatching was based on the size at capture and visual examination of otolith characteristics (Messieh 1972). The spawning component assignment for juvenile herring corresponds to its hatching season. Mature adult herring with ripe or spent gonads (maturity stages 6 and 7) were assigned their maturity stage by visual laboratory examination of the gonads. Adult herring with non-ripe gonads (maturity stages 3, 4, 5 and 8) are assigned a maturity stage by using a gonadosomatic index (GSI) based on a discriminant function model. The GSI is based on the length of the fish and its gonad weight (McQuinn 1989). Assignment to a spawning component for adult herring was done by cross-referencing maturity stage and date of capture.

Samples from the annual acoustic survey of early fall (late September-October) concentrations of herring in the southern Gulf were considered unbiased for gear selectivity and sampled both immature and mature herring (Leblanc et al. 2007). The surveys were usually concentrated in the inshore areas of Chaleurs-Miscou, and north of P.E.I. (Fig. 2). The survey was conducted in the same areas and time of year than the peak activities in the seiner fishery (Fig. 3). Biological sampling was carried out wherever major concentrations were detected (Table 1). The sampling vessel used a Nordsea midwater trawl, with horizontal and vertical openings of 11 and 7 m respectively, a length of 36.2 m, and minimum mesh size of 4 cm in the codend.

The annual September groundfish bottom trawl survey also provided some herring biological samples (Table 1). During the last six years, herring were found primarily near shore in shallow waters, mostly west, north, and east of P.E.I., inshore of the Shediac Valley, in the Northumberland Strait and in St. Georges Bay (Fig. 4). The bottom trawl was considered non selective and sampled both immature and mature herring, although there were differences in catchability between day and night and the gear is designed primarily to sample demersal species (Hurlbut, et al. 2007). The range of herring lengths from samples of both research surveys were broader than the fishery length distributions, indicating that that the surveys provided better unbiased sampling of immature herring (Fig. 5).

For the analysis, the gonad maturity data of individual fish from the detail samples were pooled into mature or immature herring. Also, all total lengths of the individual fish from the detail samples were converted to fork length. The total length to fork length conversion was established from 2004 laboratory measurements (Fig 6). The equation used was: Fork length = (0.8973 * total length) + 0.032. The equivalence for a 24.5 cm fork length is 27.3 cm total length.

Acoustic and groundfish survey herring samples from the years 1995 to 2006 were examined (Tables 2 and 3). Logistic models were fitted to the proportion of mature fish at each length using a SAS procedure (PROC PROBIT) to determine the median fork length at maturity ($L_{50}$) for both the spring and the fall spawning components. $L_{50}$ is defined as the length at which 50% of individuals are mature and this value is generally used to describe the sexual maturity of fish stocks.

The analyses were first conducted using the observed (non-weighted) proportion of mature fish in the biological sampling, To avoid the possible effects of differences in the proportion of mature fish (e.g. mature fish tending to occur together) in the samples, the observations were weighted by the local abundance from the surveys (weighted). For the acoustic survey data, the observed proportion mature was weighted by the acoustic estimate of biomass at the location of sampling. For the groundfish survey, the observed proportion mature was weighted by the abundance index at the sampling location, divided by the stratified mean abundance in the same year.

SAS PROC PROBIT weights the contribution of each observation to the likelihood function by multiplying it by the value of the weight variable. The confidence limits of $L_{50}$ were found to be sensitive to the scale of the weight variable. For example, confidence intervals for $L_{50}$ using the biomass index (in thousands) were much smaller than when calculated using the biomass index scaled to a maximum of one. Therefore, the confidence limits of $L_{50}$ were estimated by bootstrapping the weighted number of mature and immature herring within each year and spawning group. The bootstraps were done by drawing random samples from the data with replacement 1000 times, performing an estimate of $L_{50}$ for each random draw. The adequacy of 1000 bootstraps was tested by increasing the number to 6000 on the spring herring component in the groundfish survey data. The results were similar between the two, thus 1000 bootstraps were deemed adequate.

The possible differences in $L_{50}$ between male and female herring were also examined by a similar graphing of results from the Chaleurs-Miscou acoustic survey samples of years with the greatest number of observations; 1998, 2000, 2001, 2005 and 2006.

To assess the effect of geographic differences in $L_{50}$, the acoustic survey data were divided into two sectors. Chaleur Bay (NAFO areas 4TM and 4TN) was separated from the area north of PEI. Graphical estimates of $L_{50}$ with confidence intervals were examined for the two areas in years with more than 700 fish biologically sampled from each area; these years being 2000, 2005 and 2006.

For each of the spawning components, the statistical significance of inter-annual variations in $L_{50}$ was tested by including a year effect in the statistical model and comparing the Chi-squared statistic associated with the year effect against 1000 analyses conducted with the data randomly assigned to year. The 95% confidence limits from the bootstrap analyses were derived from the 2.5 and 97.5 percentiles of the 1000 estimates of $L_{50}$ for each year.

After considering both spawning components separately, the differences in spawning component $L_{50}$ in a given year were not significant for most years of the time series. Therefore, the data for calculating the $L_{50}$ was combined to include both spawning components by year. It was also considered that combining the spawning components better reflects the species composition of the fall seiner fishery catch.

## RESULTS

The $L_{50}$ at maturity was not significantly different between sexes. The estimated $L_{50}$ for both male and female herring overlapped and are within the 95% confidence intervals (Fig. 7). All further analysis was done combining male and female herring.

The $L_{50}$ was significantly different between Chaleur Bay and north PEI areas for the years 2000 and 2005, but not in 2006. In all cases, the $L_{50}$ was lower in the north PEI area (Fig.

8). It was concluded that the use of data from both areas would be more appropriate to better cover the stock area. For the remaining analysis, both areas were combined.

Results of the logistic model maturity ogives from the acoustic survey data are presented for some years. For both the fall spawners (Fig. 9) and the spring spawners (Fig. 10), the resulting estimated $L_{50}$ varied between 22.5 and 25.0 cm. The year effect was highly significant ($P<0.001$) for both spawning groups and surveys. The weighting of each observation by the biomass estimate at the sampling location did not significantly change the $L_{50}$ estimates, but the error estimates varied from a minimal value close to the point estimate to large values depending on the scaling of the weighting. The two methods differed by less than 1 mm in estimated $L_{50}$. $L_{50}$ for fall spawners in 2003 were estimated at approximately 4 mm less by the weighted model. The weighted model reduced $L_{50}$ by approximately 2 mm for spring spawners in 2003 and 2004. Bootstrap simulation of $L_{50}$ at maturity with weighting provided similar estimates of $L_{50}$, with confidence intervals within ±1 mm (Table 2, Fig. 11).

$L_{50}$ estimates from the groundfish survey were completed on both non-weighted maturity data and data weighted by the biomass estimate of the stratum at location (Table 3). The maturity ogive for the groundfish survey data had a lower number of observations available in the $L_{50}$ range of sizes (Figs. 12 and 13). This is particularly true for the spring spawner component (Fig. 14). The estimated $L_{50}$ from the groundfish survey data are generally lower than the acoustic survey estimates, the resulting estimated $L_{50}$ varying between 22.0 and 23.5 cm. Bootstrap simulation of $L_{50}$ with weighting provided similar estimates of $L_{50}$, with confidence intervals within ±1 mm (Table 3, Fig. 14).

The logistic model maturity ogives representing the mean number of years that a herring can spawn in its lifespan (8 years) were chosen as the best representation of current information on maturity (1999-2006) from both surveys. The estimated $L_{50}$ from the groundfish survey data was lower at 220 mm, while the acoustic survey $L_{50}$ estimate was 235 mm (Figure 15). It was concluded that the groundfish survey undersamples the Chaleur area with fewer sets, and that fishing sets are generally in deeper waters than the depth in which herring are found at that time of year. The number of samples within the $L_{50}$ range in the groundfish survey data was lower than in the acoustic survey data. Therefore, only the weighted biological data from the acoustic survey were used to determine the most appropriate $L_{50}$ value for sGSL herring.

When averaged over the approximate number of years that a herring currently can spawn (eight years), the estimated $L_{50}$ for Atlantic herring combined spawning components sampled during the acoustic survey for the years 1999-2006 was estimated at 23.5 cm (Figure 16). The confidence limits of $L_{50}$ on the weighted observations were obtained by bootstrap simulations.

## DISCUSSION

By using the acoustic survey data, the main fall concentrations of herring were sampled during fall feeding and their migration from west to east of the sGSL. By weighting the data to local abundance, emphasis is placed on the main distribution of herring at the same time of year as the peak fall fishery activities occur, ensuring that the average $L_{50}$ estimate reflects the regional differences that were noted.

Changes in the exploitation profile of a fish stock to include a greater proportion of smaller fish could entail changes in the reference exploitation rate of the stock. Fishing has the potential to alter the evolution of phenotypic traits of fish, including the age or size of maturity

(Law 2000). Depending on the nature and intensity of the fishery, fish stocks may respond with $L_{50}$ declining over time. If one of the objectives of the fishery is to maintain large herring in the stock, a management strategy is required that ensures that herring survive to grow and spawn to a large size.

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Table 1. Biological sampling of fall and spring spawning herring in annual acoustic surveys and groundfish surveys. "n" signifies the number of samples taken; the number of fish biologically sampled (length, sex, maturity) is indicated in the columns "sampled".

| | Acoustic survey | | | Groundfish survey | | |
|---|---|---|---|---|---|---|
| | Fall spawners | Spring spawners | Samples | Fall spawners | Spring spawners | Samples |
| Year | sampled | sampled | n | sampled | sampled | n |
| 1995 | 209 | 435 | 13 | 645 | 321 | 22 |
| 1996 | 420 | 469 | 16 | 326 | 228 | 16 |
| 1997 | 559 | 334 | 17 | 917 | 401 | 26 |
| 1998 | 1422 | 1462 | 52 | 856 | 213 | 17 |
| 1999 | 694 | 449 | 22 | 440 | 190 | 23 |
| 2000 | 1085 | 358 | 26 | 453 | 145 | 16 |
| 2001 | 901 | 1035 | 35 | 524 | 152 | 21 |
| 2002 | 480 | 451 | 16 | 408 | 233 | 19 |
| 2003 | 454 | 473 | 18 | 243 | 62 | 11 |
| 2004 | 372 | 331 | 14 | 594 | 216 | 23 |
| 2005 | 2112 | 550 | 51 | 471 | 172 | 18 |
| 2006 | 984 | 310 | 26 | 345 | 94 | 13 |

Table 2. Acoustic survey estimates of $L_{50}$ and 95% confidence intervals for Atlantic herring samples. $L_{50}$ estimates based on non-weighted, weighted by biomass index, and bootstrap simulations are shown. (SPGP = spawning group, A = fall spawners, P = spring spawners, $L_{50}$ = fork length (mm) at 50% maturity, L_int and U_int = lower and upper 95% confidence intervals respectively)

| Year | SPGP | $L_{50}$ | L_int | U_int | SPGP | $L_{50}$ | L_int | U_int |
|---|---|---|---|---|---|---|---|---|
| without weighting | | | | | | | | |
| 1995 | A | 228.4 | 5.90 | 5.35 | P | 234.2 | 2.82 | 2.71 |
| 1996 | A | 237.5 | 2.70 | 2.71 | P | 233.7 | 2.37 | 2.43 |
| 1997 | A | 239.9 | 2.36 | 2.40 | P | 245.2 | 3.09 | 3.19 |
| 1998 | A | 230.2 | 1.43 | 1.38 | P | 236.7 | 1.66 | 1.71 |
| 1999 | A | 229.7 | 2.62 | 2.43 | P | 237.0 | 2.69 | 3.05 |
| 2000 | A | 230.4 | 2.13 | 2.04 | P | 232.8 | 2.84 | 2.98 |
| 2001 | A | 238.8 | 2.00 | 2.00 | P | 238.2 | 2.22 | 2.42 |
| 2002 | A | 234.9 | 3.60 | 3.87 | P | 235.3 | 2.79 | 2.87 |
| 2003 | A | 238.4 | 3.39 | 3.25 | P | 240.5 | 2.81 | 3.22 |
| 2004 | A | 233.7 | 2.58 | 2.32 | P | 249.4 | 5.38 | 8.28 |
| 2005 | A | 234.2 | 1.07 | 1.03 | P | 240.8 | 3.27 | 4.21 |
| 2006 | A | 233.3 | 1.99 | 1.89 | P | 229.8 | 3.01 | 3.23 |
| with weighting | | | | | | | | |
| 1995 | A | 229.0 | 19.11 | 14.32 | P | 234.2 | 7.99 | 6.97 |
| 1996 | A | 239.0 | 3.36 | 3.47 | P | 233.4 | 3.04 | 3.10 |
| 1997 | A | 239.0 | 2.92 | 2.93 | P | 245.8 | 3.96 | 4.04 |
| 1998 | A | 230.7 | 2.72 | 2.51 | P | 237.1 | 3.11 | 3.30 |
| 1999 | A | 230.8 | 3.65 | 3.28 | P | 237.4 | 3.60 | 4.28 |
| 2000 | A | 231.2 | 3.10 | 2.95 | P | 232.4 | 4.07 | 4.42 |
| 2001 | A | 238.1 | 5.88 | 5.91 | P | 238.1 | 7.07 | 9.35 |
| 2002 | A | 235.6 | 9.77 | 13.52 | P | 235.8 | 9.31 | 12.21 |
| 2003 | A | 234.2 | 7.66 | 6.10 | P | 237.2 | 5.64 | 6.30 |
| 2004 | A | 232.2 | 9.03 | 6.25 | P | 245.7 | 11.98 | 61.05 |
| 2005 | A | 234.5 | 3.26 | 2.87 | P | 240.2 | 7.87 | 16.81 |
| 2006 | A | 233.1 | 4.31 | 3.87 | P | 230.9 | 6.41 | 7.86 |
| bootstrap | | | | | | | | |
| 1995 | A | 229.2 | 0.17 | 0.17 | P | 234.1 | 0.08 | 0.08 |
| 1996 | A | 238.9 | 0.09 | 0.09 | P | 233.5 | 0.07 | 0.07 |
| 1997 | A | 238.9 | 0.07 | 0.07 | P | 245.8 | 0.09 | 0.09 |
| 1998 | A | 230.7 | 0.05 | 0.05 | P | 237.3 | 0.08 | 0.08 |
| 1999 | A | 230.8 | 0.09 | 0.09 | P | 237.4 | 0.09 | 0.09 |
| 2000 | A | 231.1 | 0.07 | 0.07 | P | 235.2 | 0.14 | 0.14 |
| 2001 | A | 238.0 | 0.06 | 0.06 | P | 238.5 | 0.07 | 0.07 |
| 2002 | A | 235.6 | 0.13 | 0.13 | P | 235.7 | 0.09 | 0.09 |
| 2003 | A | 234.2 | 0.14 | 0.14 | P | 237.3 | 0.12 | 0.12 |
| 2004 | A | 232.3 | 0.10 | 0.10 | P | 246.2 | 0.17 | 0.17 |
| 2005 | A | 234.5 | 0.04 | 0.04 | P | 240.3 | 0.11 | 0.11 |
| 2006 | A | 233.2 | 0.09 | 0.09 | P | 230.9 | 0.12 | 0.12 |

Table 3. Groundfish survey estimates of $L_{50}$ and 95% confidence intervals for Atlantic herring samples. $L_{50}$ estimates based on non-weighted, weighted by biomass index, and bootstrap simulations are shown. (SPGP = spawning group, A = fall spawners, P = spring spawners, $L_{50}$ = fork length (mm) at 50% maturity, L_int and U_int = lower and upper 95% confidence intervals respectively)

| Year | SPGP | $L_{50}$ | L_int | U_int | SPGP | $L_{50}$ | L_int | U_int |
|---|---|---|---|---|---|---|---|---|
| without weighting | | | | | | | | |
| 1995 | A | 228.1 | 4.24 | 3.45 | P | 237.0 | 4.40 | 3.99 |
| 1996 | A | 221.3 | 7.23 | 6.92 | P | 226.2 | -- | -- |
| 1997 | A | 228.1 | 3.35 | 2.89 | P | 246.0 | 7.92 | 11.36 |
| 1998 | A | 213.3 | 5.72 | 4.19 | P | 226.6 | -- | -- |
| 1999 | A | 215.9 | 6.60 | 5.14 | P | 231.5 | -- | -- |
| 2000 | A | 220.8 | 4.87 | 3.80 | P | 227.1 | 6.33 | 5.99 |
| 2001 | A | 215.1 | 6.09 | 4.64 | P | 216.4 | 24.60 | 11.73 |
| 2002 | A | 221.5 | 4.76 | 3.76 | P | 225.9 | 8.32 | 9.10 |
| 2003 | A | 190.3 | -- | -- | P | 229.0 | -- | -- |
| 2004 | A | 228.0 | 4.14 | 3.38 | P | 228.3 | 8.57 | 11.76 |
| 2005 | A | 220.0 | 7.18 | 5.16 | P | 238.8 | 17.34 | 11.49 |
| 2006 | A | 230.4 | 4.07 | 3.31 | P | 231.8 | -- | -- |
| with weighting | | | | | | | | |
| 1995 | A | 229.5 | 6.19 | 4.49 | P | 240.3 | 5.40 | 4.56 |
| 1996 | A | 228.6 | 10.09 | 9.35 | P | 226.0 | -- | -- |
| 1997 | A | 233.3 | 4.42 | 3.29 | P | 246.7 | -- | -- |
| 1998 | A | 215.0 | 5.42 | 3.59 | P | 226.5 | -- | -- |
| 1999 | A | 221.5 | 4.48 | 4.32 | P | 231.2 | -- | -- |
| 2000 | A | 224.3 | 3.03 | 2.54 | P | 227.5 | 4.46 | 4.39 |
| 2001 | A | 224.7 | 2.49 | 2.34 | P | 227.5 | 4.27 | 10.67 |
| 2002 | A | 209.6 | 9.39 | 6.19 | P | 221.8 | 16.14 | 10.50 |
| 2003 | A | 189.9 | -- | -- | P | 219.1 | 110.60 | 6.97 |
| 2004 | A | 231.4 | 3.53 | 3.12 | P | 224.6 | 17.72 | 5.40 |
| 2005 | A | 223.3 | 5.23 | 4.45 | P | 251.5 | 10.45 | 8.27 |
| 2006 | A | 230.9 | 2.90 | 2.63 | P | 228.7 | -- | -- |
| bootstrap | | | | | | | | |
| 1995 | A | 229.6 | 0.22 | 0.22 | P | 239.4 | 0.05 | 0.05 |
| 1996 | A | 228.0 | 0.32 | 0.32 | P | 225.6 | 0.11 | 0.11 |
| 1997 | A | 233.1 | 0.23 | 0.23 | P | 246.4 | 0.08 | 0.08 |
| 1998 | A | 215.0 | 0.34 | 0.34 | P | 225.3 | 0.08 | 0.08 |
| 1999 | A | 221.2 | 0.34 | 0.34 | P | 231.8 | 0.09 | 0.09 |
| 2000 | A | 224.3 | 0.15 | 0.15 | P | 227.7 | 0.11 | 0.11 |
| 2001 | A | 224.6 | 0.23 | 0.23 | P | 225.0 | 0.20 | 0.20 |
| 2002 | A | 210.1 | 0.35 | 0.35 | P | 221.9 | 0.09 | 0.09 |
| 2003 | A | 189.2 | 0.21 | 0.21 | P | 225.4 | 0.28 | 0.28 |
| 2004 | A | 231.4 | 0.19 | 0.19 | P | 225.4 | 0.09 | 0.09 |
| 2005 | A | 223.3 | 0.26 | 0.26 | P | 252.2 | 0.19 | 0.19 |
| 2006 | A | 231.0 | 0.14 | 0.14 | P | 233.6 | 0.21 | 0.21 |

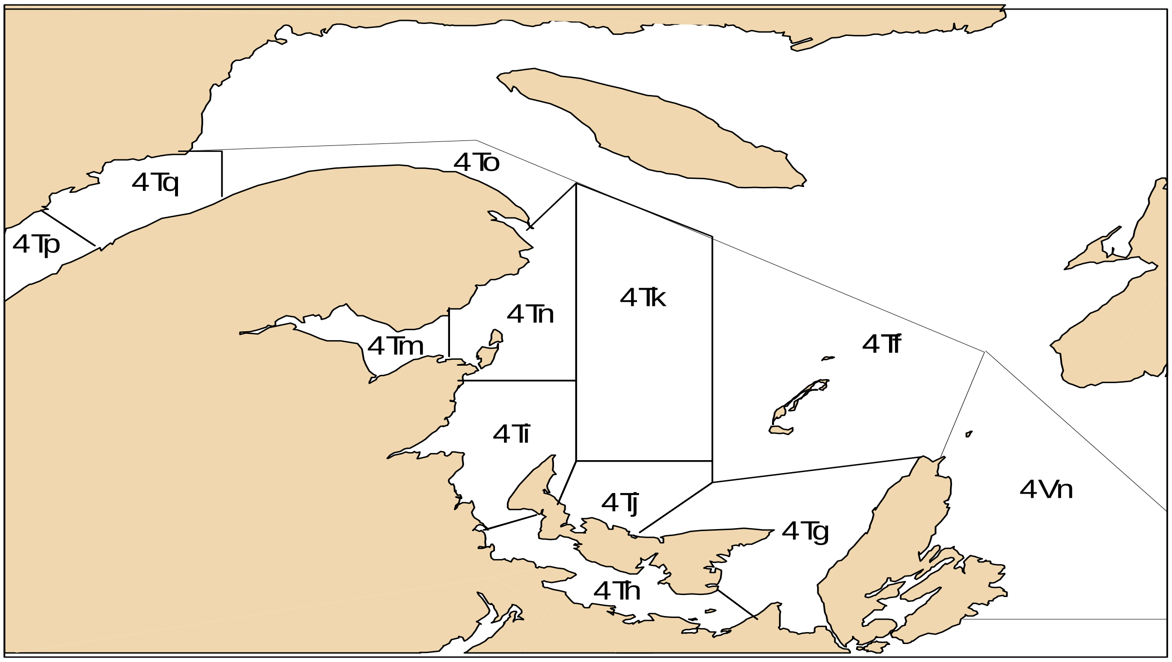


Figure 1. Northwest Atlantic Fisheries Organization (NAFO) 4T and 4Vn divisions and corresponding 4T unit areas.

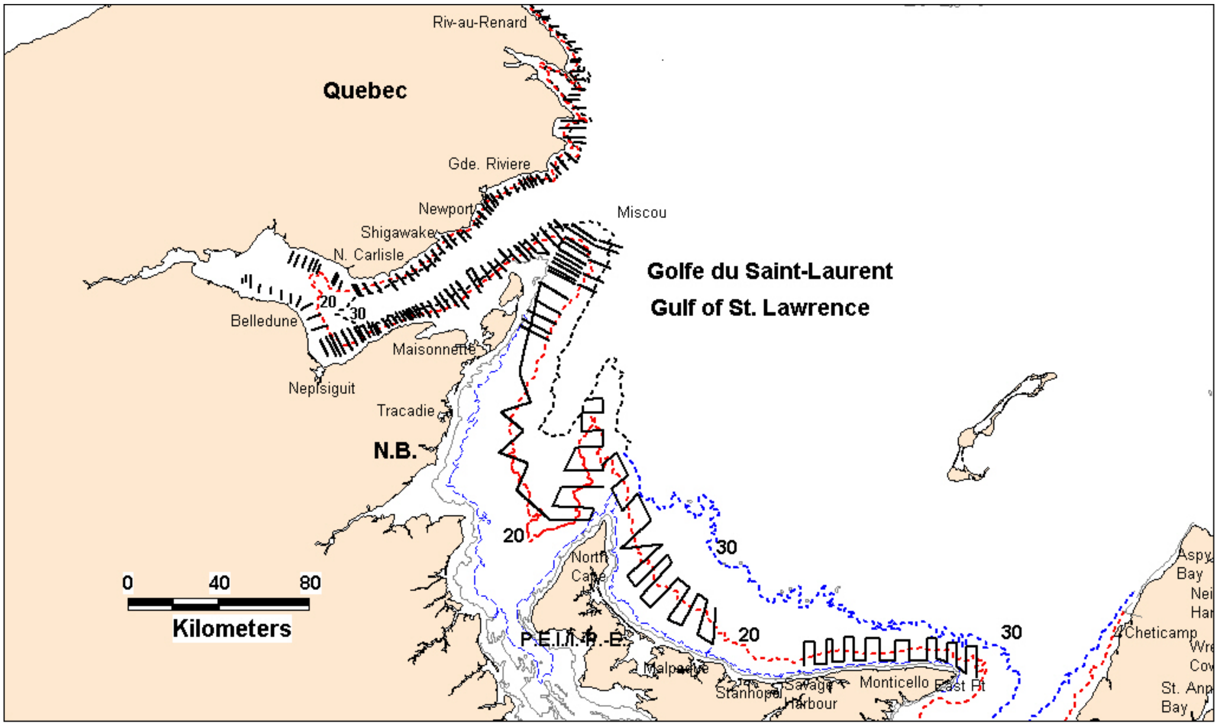


Figure 2. Transects (solid lines) surveyed during the 2006 acoustic survey for Atlantic herring in NAFO division 4T between September 23 and October 9, 2006. Dashed line represents water depth in fathoms.

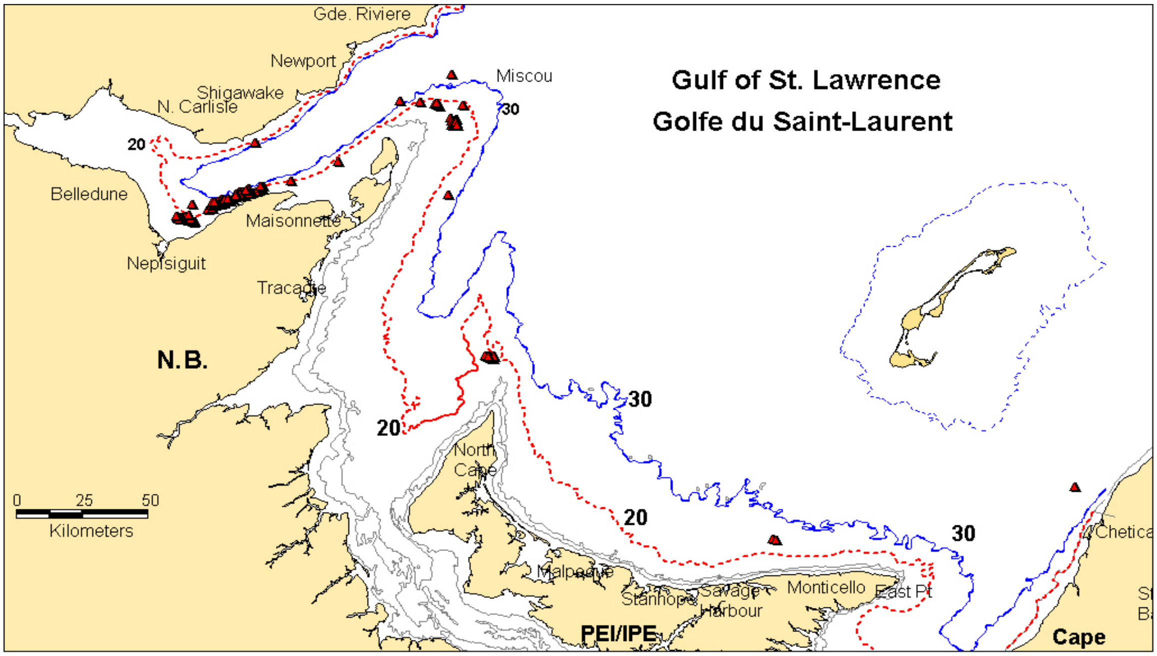


Figure 3. Location of sets (triangles) by large seiners under quota monitoring in the fall 2006 Atlantic herring fishery. Dashed lines represent water depth in fathoms.

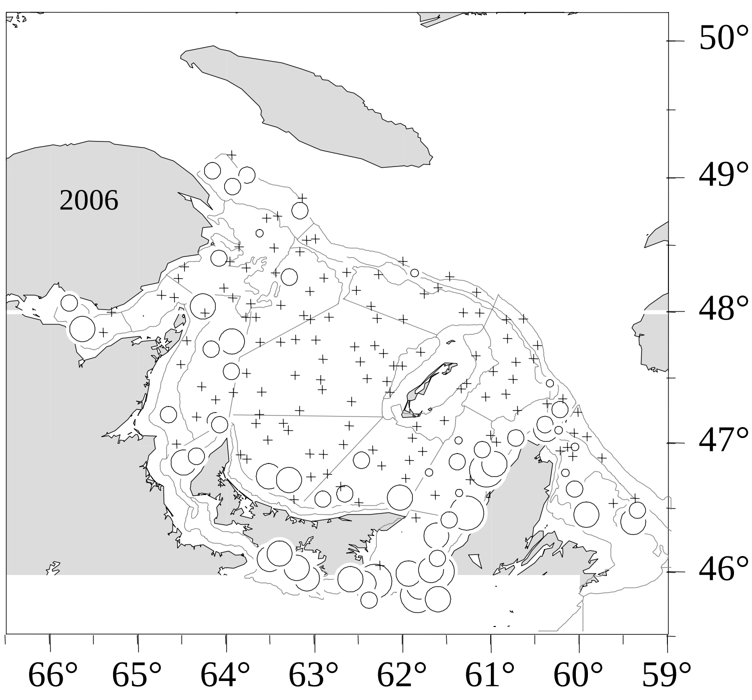


Figure 4. Atlantic herring catches in the 2006 southern Gulf of St. Lawrence September bottom-trawl survey. + indicates no herring catches. Circles indicate sets with catches, size of circle from smallest to largest indicates kilograms per set, respectively 0.1, 0.3, 1.7, 21 and 357+ kilograms.

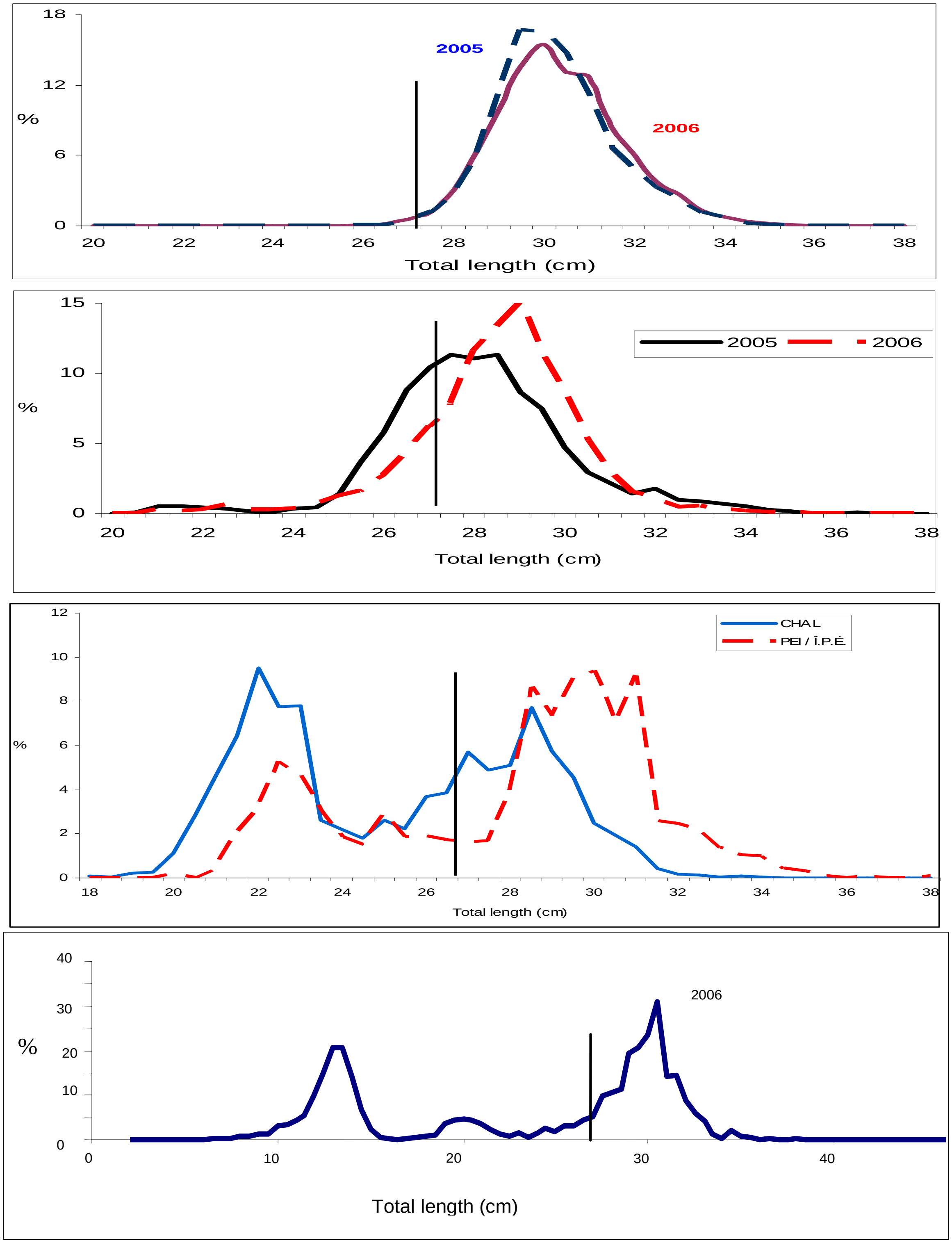


Figure 5. Length frequency distributions for Atlantic herring sampled in the 2005-06 fall gillnet fishery (first panel), the 2005-06 fall seiner fishery in Chaleurs-Miscou (second panel), the 2006 fall acoustic survey (third panel), and the 2006 groundfish survey (fourth panel). The solid vertical line indicates the current regulation minimum size of 27 cm total length (equivalent to 24.5 cm fork length).

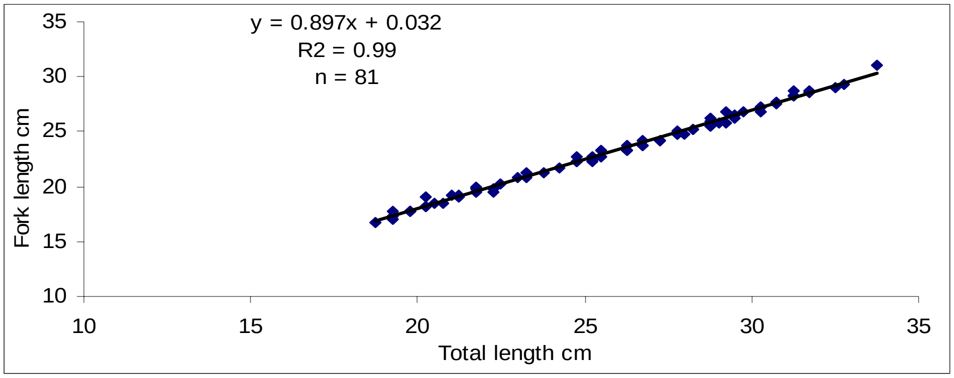


Figure 6. Total length to fork length linear relationship for Atlantic herring from laboratory measurements.

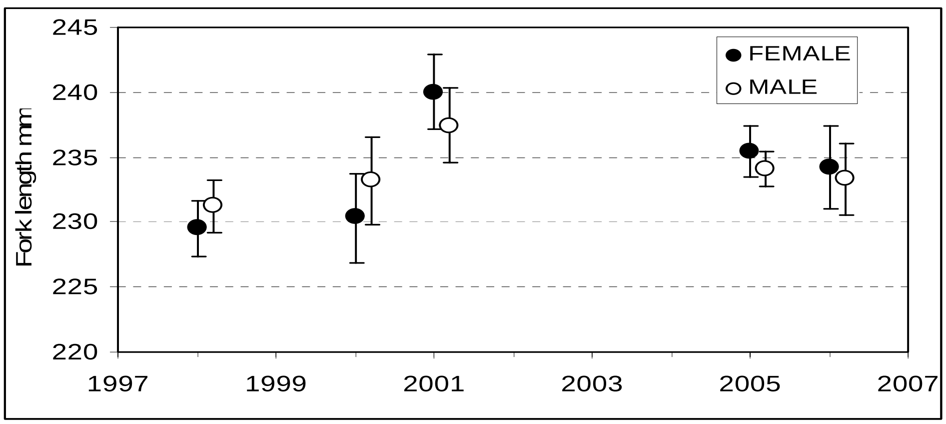


Figure 7. Estimated $L_{50}$ and 95% confidence intervals (bars) for Atlantic fall spawning herring sampled during the acoustic survey in Chaleurs-Miscou.

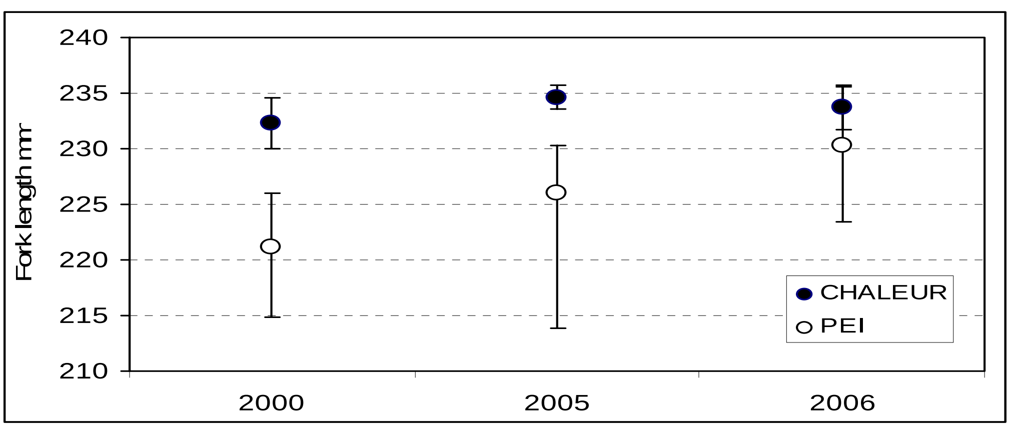


Figure 8. Estimated $L_{50}$ and 95% confidence intervals (bars) for Atlantic fall spawning herring sampled in two different areas during the acoustic survey.

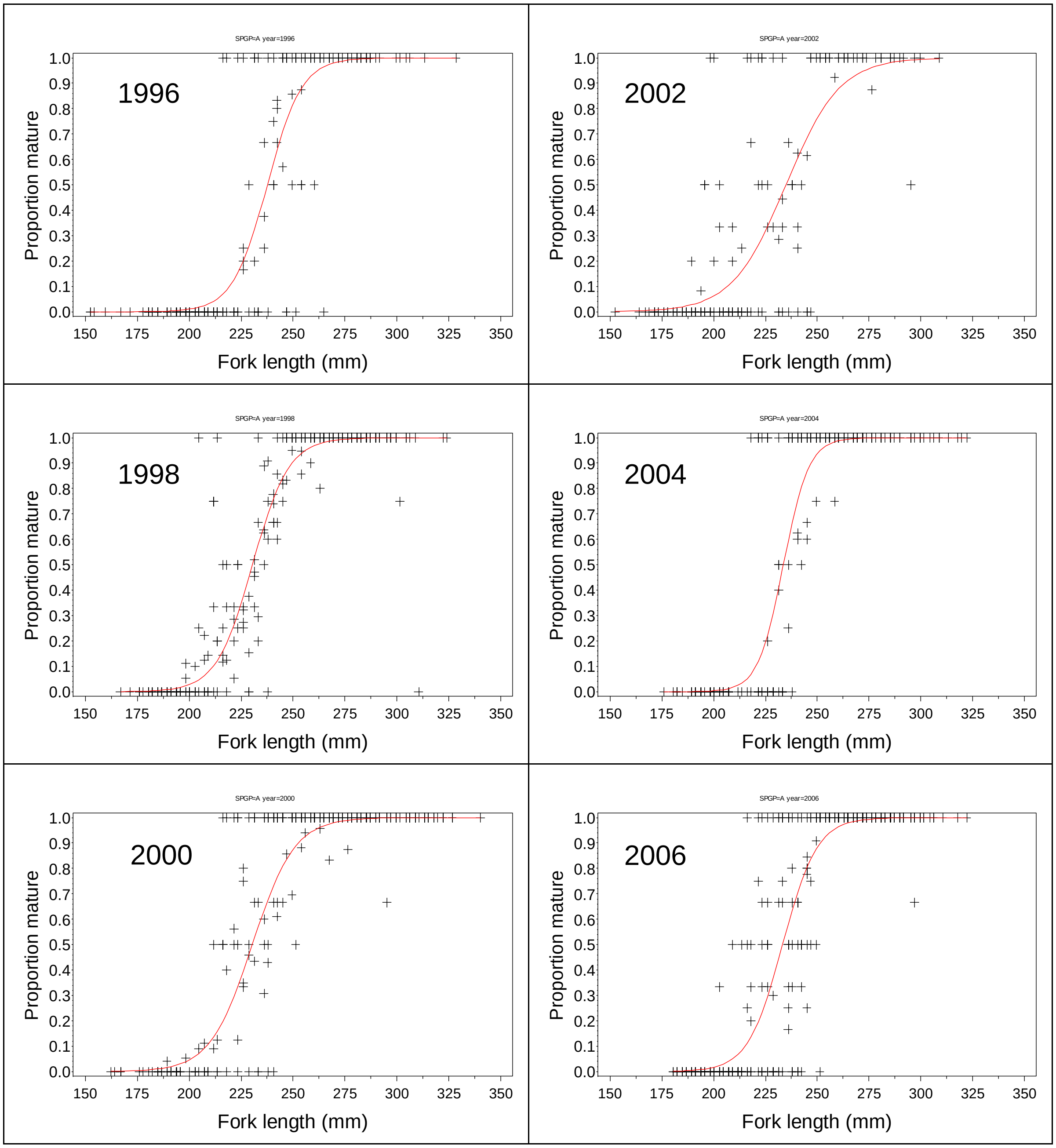


Figure 9. Fall spawning Atlantic herring maturity ogives from sampling done during the annual acoustic survey in Chaleur Bay and northern PEI.

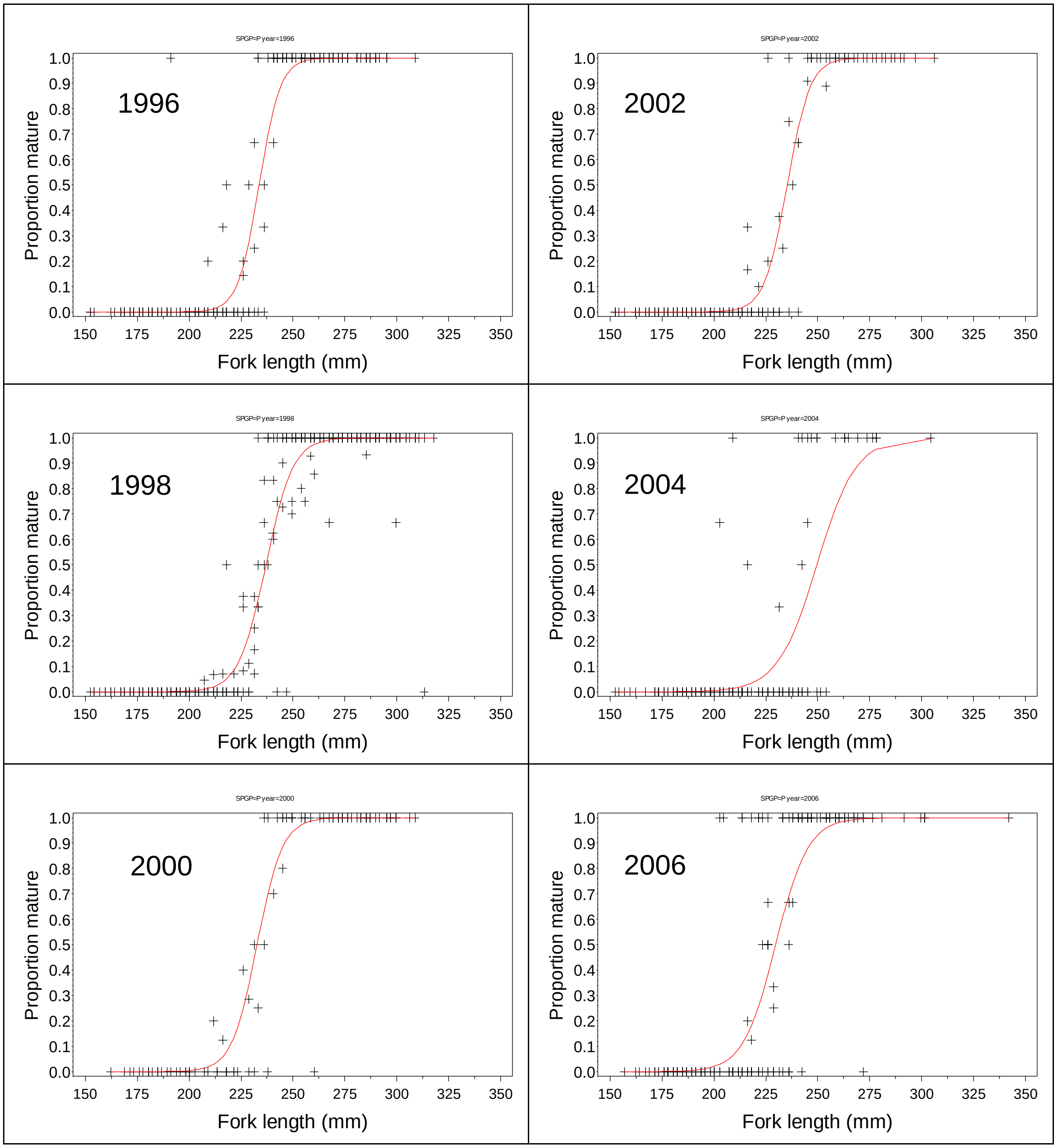


Figure 10. Spring spawning Atlantic herring maturity ogives from sampling done during the annual acoustic survey in Chaleur Bay and northern PEI.

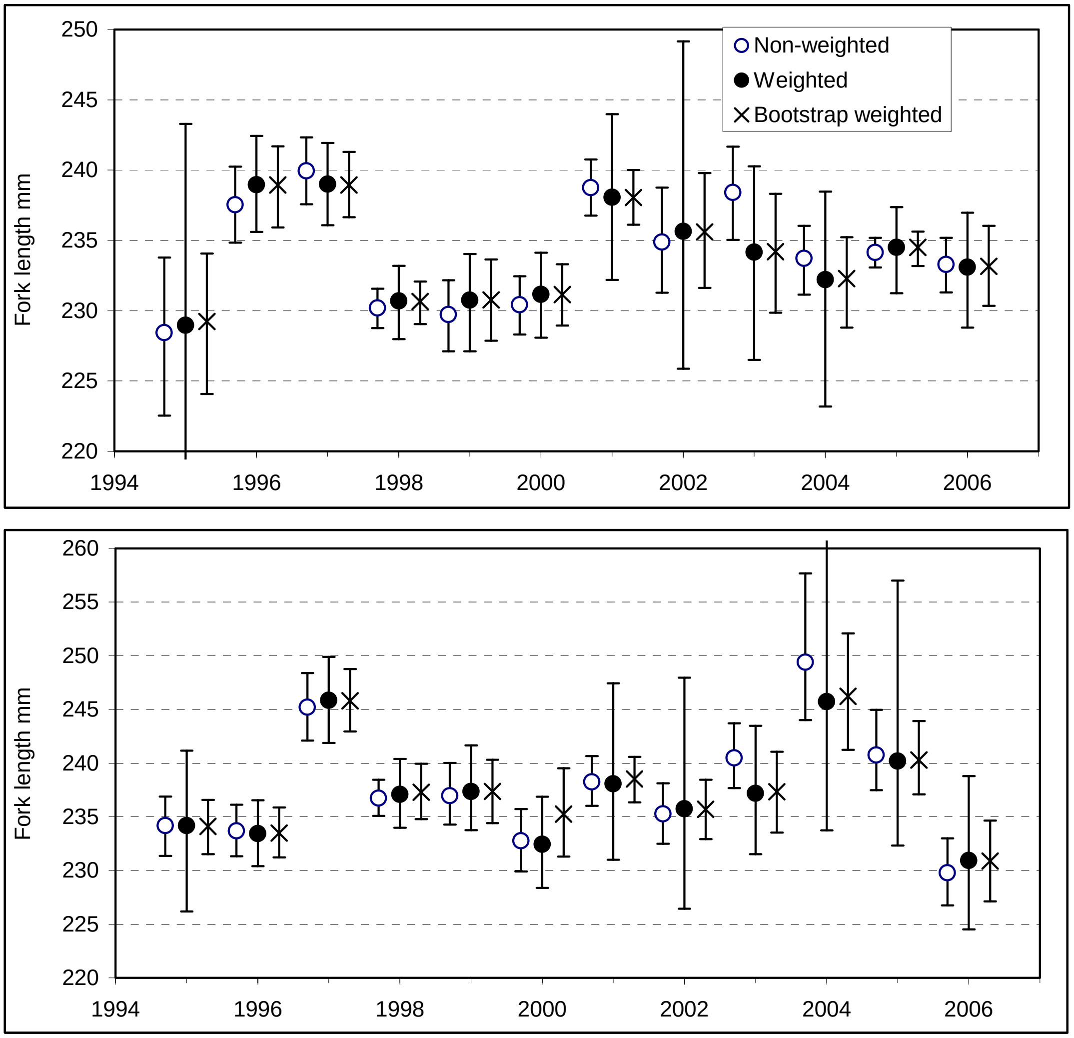


Figure 11. Estimated $L_{50}$ and 95% confidence intervals (bars) for fall (upper panel) and spring (lower panel) spawning Atlantic herring sampled during the acoustic survey in Chaleur Bay and north of Prince Edward Island.

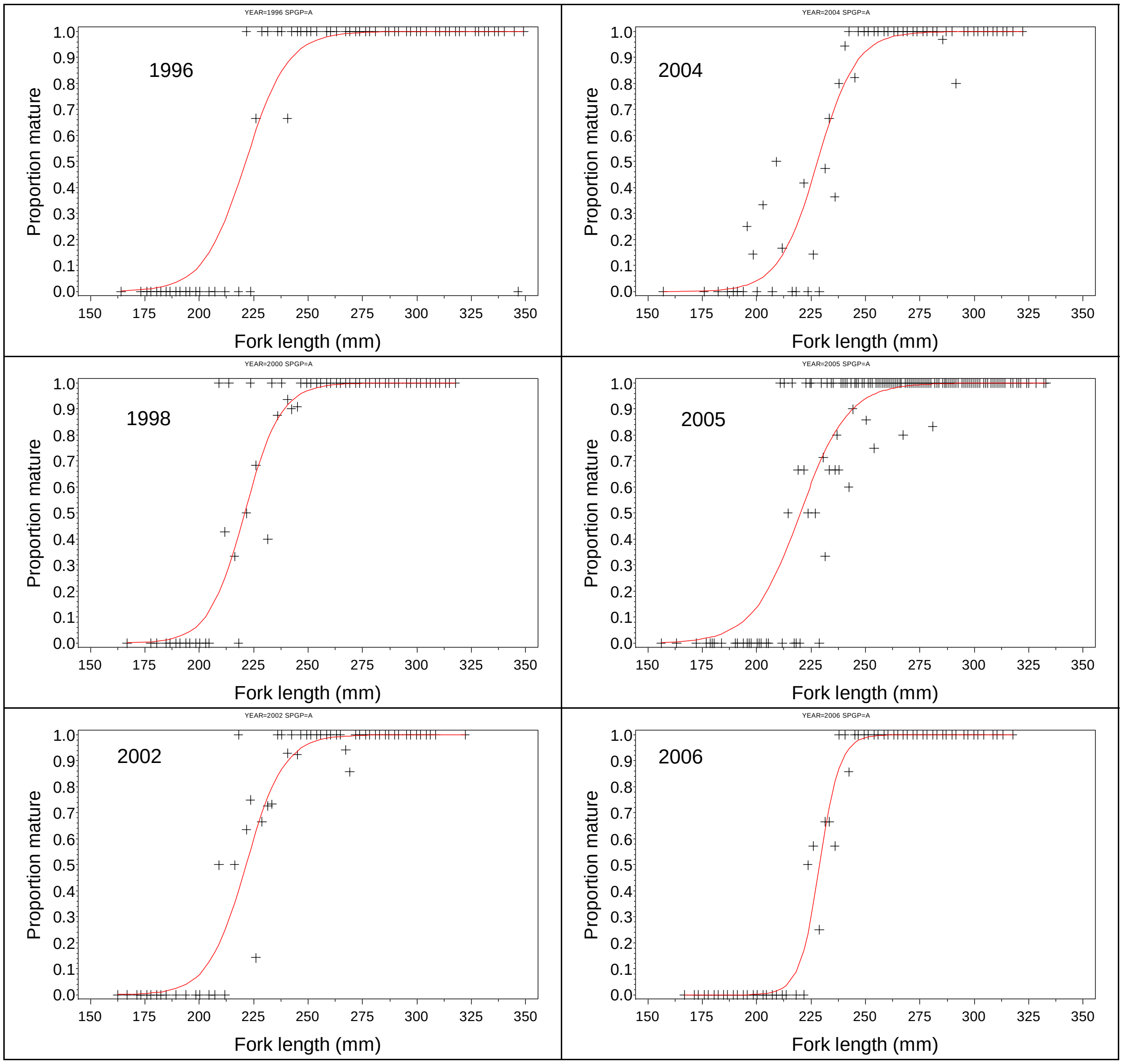


Figure 12. Fall spawning Atlantic herring maturity ogives from sampling done during the annual September groundfish survey in the southern Gulf of St. Lawrence.

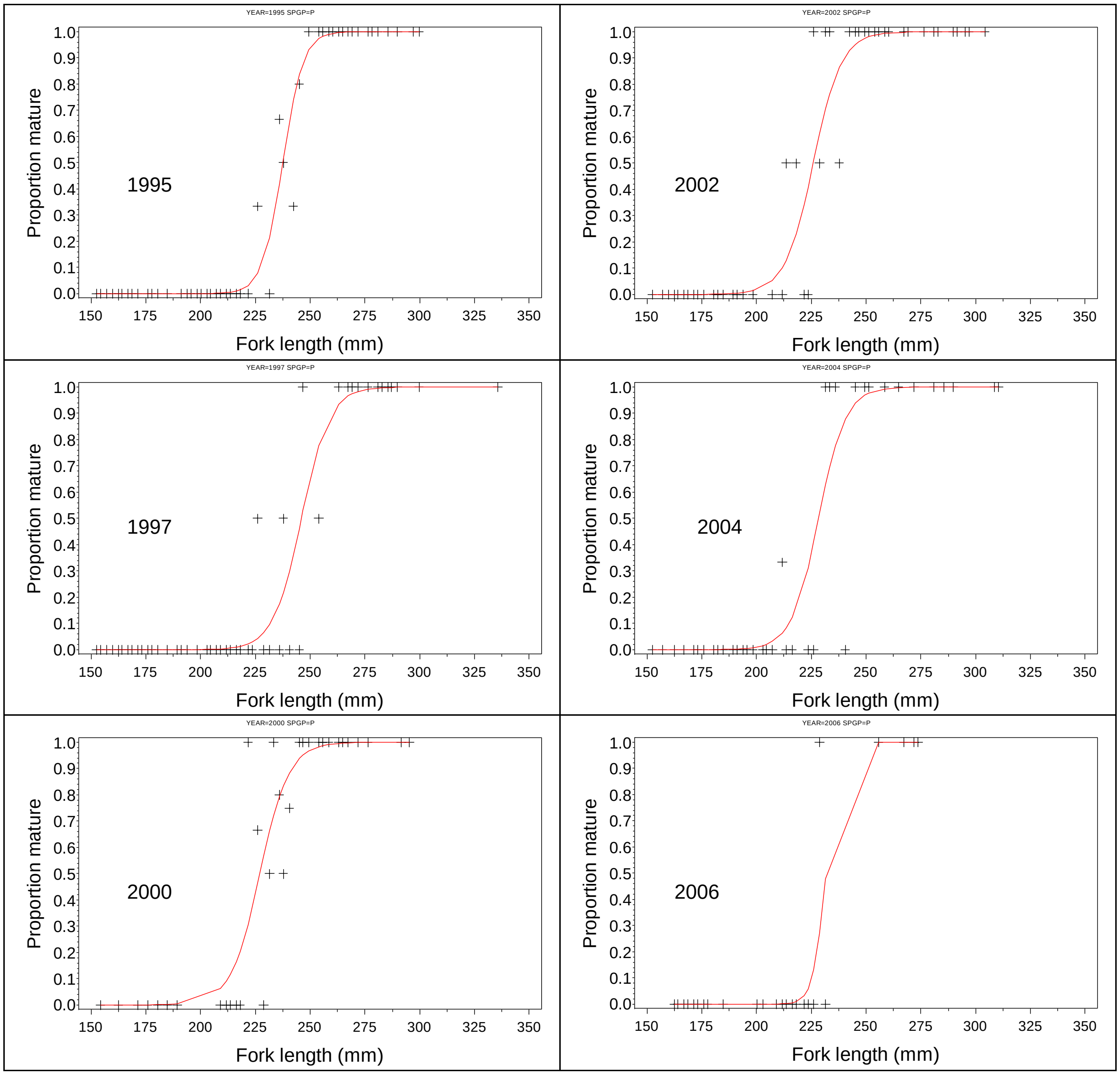


Figure 13. Spring spawning Atlantic herring maturity ogives from sampling done during the annual September groundfish survey in the southern Gulf of St. Lawrence.

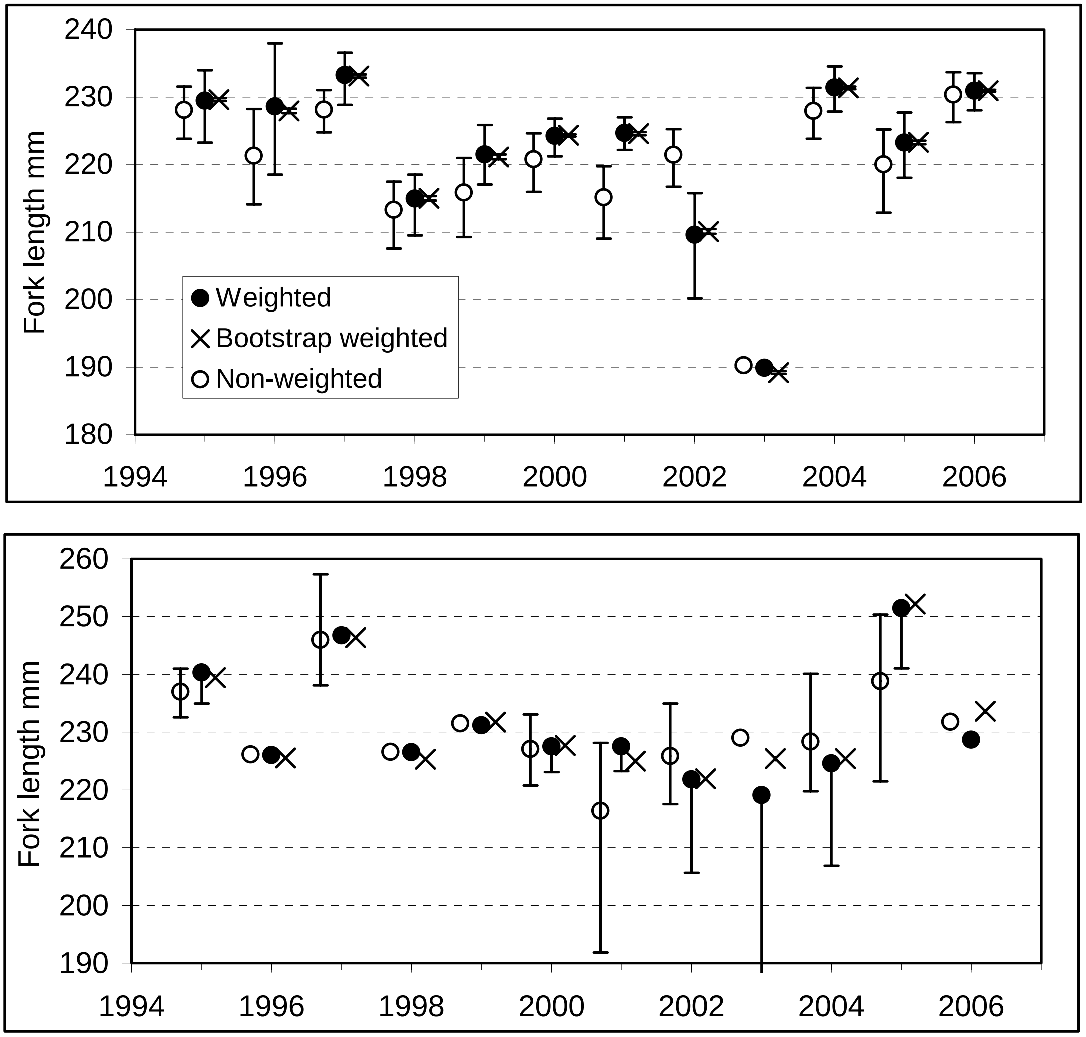


Figure 14. Estimated $L_{50}$ and 95% confidence intervals (bars) for fall (upper panel) and spring (lower panel) spawning Atlantic herring sampled during the annual September groundfish survey in the southern Gulf of St. Lawrence.

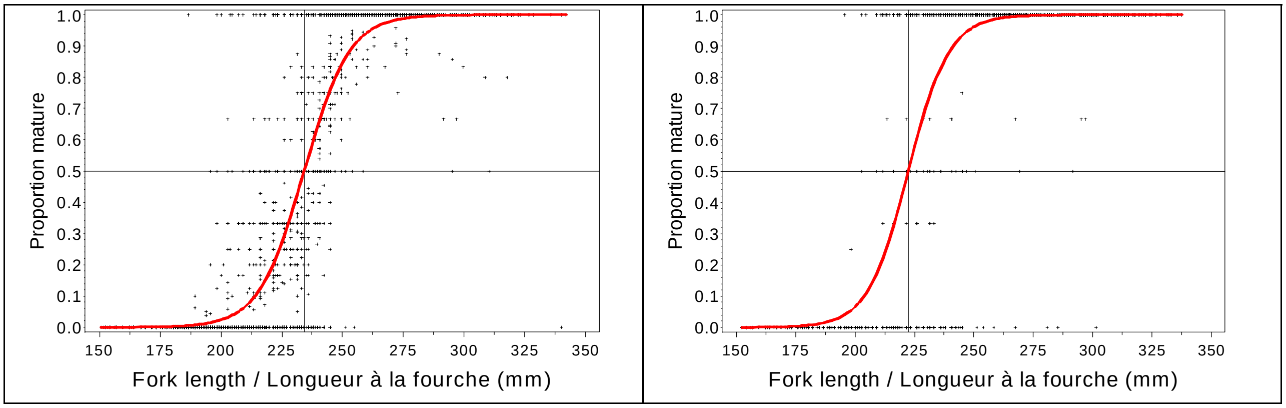


Figure 15. Maturity ogives for NAFO division 4T Atlantic herring combined spawning components sampled from 1999 to 2006 in the acoustic (left) and groundfish (right) surveys.

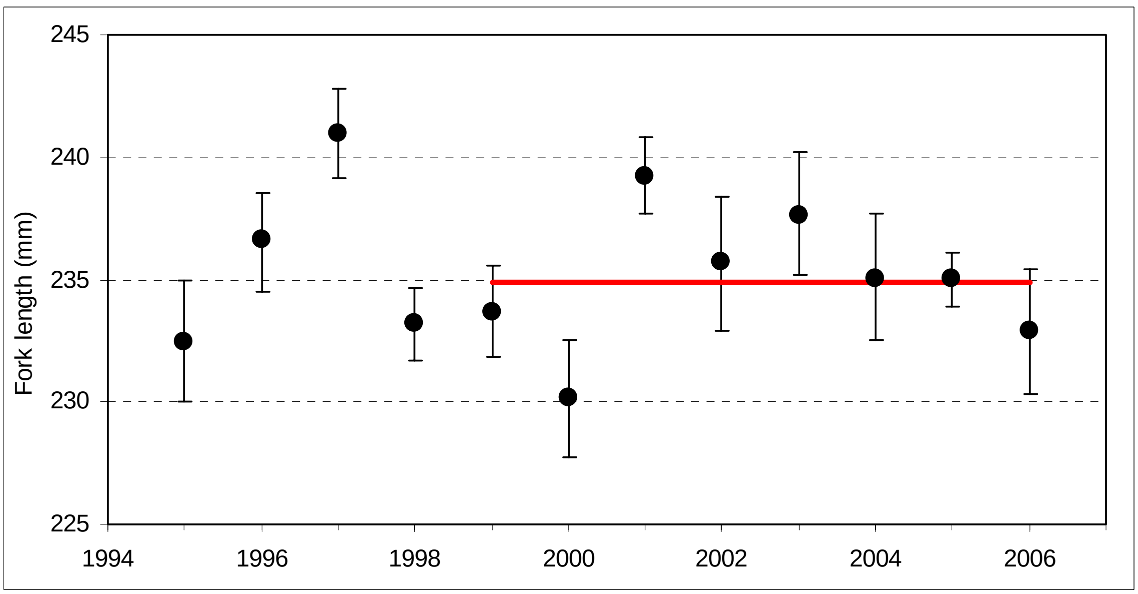


Figure 16. Estimated $L_{50}$ and 95% confidence intervals (bars) for Atlantic herring combined spawning components sampled during the acoustic survey in Chaleur Bay and north of Prince Edward Island. The horizontal line represents the 8-year $L_{50}$ average (1999-2006) estimated at 235 mm (23.5 cm) fork length.