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Assessment of the southern Gulf of St. Lawrence (NAFO Division 4T) stock of American plaice (*Hippoglossoides platessoides*), March 2016

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

While the American plaice stock in Division 4T of the Northwest Atlantic Fisheries Organisation was historically the most important flatfish fishery in the southern Gulf of St. Lawrence, it is now at low levels with little to no prospect of rebuilding to healthy levels in the next 5 years. The stock was assessed using a Virtual Population Analysis that estimated time-varying natural mortality. The current spawning stock biomass of the stock was estimated to be 55,023 t, which is 40% of the limit reference point of 139,134 t. Under current productivity conditions the spawning stock biomass is expected to decrease over the next 5 years under TACs of 0 t, 100 t or 250 t. The lack of rebuilding prospects stems from the elevated level of natural mortality experienced by the population.

Évaluation de la plie canadienne (*Hippoglossoides platessoides*) du sud du golfe du Saint-Laurent (division 4T de l'OPANO), mars 2016

RÉSUMÉ

Malgré qu'il ait supporté la plus importante pêche de poissons plats dans le Golfe du Saint-Laurent, le stock de plie canadienne de la division 4T de l'OPANO est maintenant à un niveau historiquement bas et n'a pratiquement aucune chance de se rétablir dans les 5 prochaines années. Le stock a été évalué à l'aide d'un modèle virtuel structuré par âge qui estime l'évolution temporelle de la mortalité naturelle. La biomasse du stock reproducteur est présentement estimée à 55 023 t, ce qui représente 40 % du point de référence limite de 139 134 t. Sous des conditions de productivités actuelles on s'attend à ce que la biomasse du stock reproducteur diminue au cours des 5 prochaines années sous un TAC de 0 t, 100 t ou 250 t. Les perspectives de reconstitution sont faibles dû aux niveaux élevés de mortalité naturelle subis par la population.

INTRODUCTION

American plaice (*Hippoglossoides platessoides*) is a righteye flounder whose distribution spans the North Atlantic Ocean. The species is split into two subspecies: *Hippoglossoides platessoides platessoides* Fabricius 1780 (American plaice) from the northwest Atlantic and *Hippoglossoides platessoides limandoides* Bloch 1786 (long rough dab) from the northeast Atlantic (Evseenko 2004). In the northwest Atlantic, the species ranges from 40°N in the United States to above the Arctic Circle. In Canadian waters, the species is divided in a number of different stocks and the current assessment is for the southern Gulf of St. Lawrence stock (NAFO Div. 4T; hereafter referred to as 4T).

American plaice in the southern Gulf of St. Lawrence was once an abundant resource and supported an extensive commercial fishery. In the 1980s, it was the most important commercial flatfish fishery in the Gulf of St. Lawrence. The resource then declined substantially during the 1990s and now supports a very modest fishery.

Early attempts at assessing the stock with a population model were unsuccessful because of the unreliability of the catch data (Landry 1986; Tallman and Sinclair 1988; Tallman and Sinclair 1989). This unreliability was related to a high rate of at-sea discarding of small plaice (Tallman 1991). A sequential population analysis was eventually evaluated to assess the stock (Tallman and Forest-Gallant 1990) but was not deemed scientifically appropriate by the committee reviewing the assessment. The first assessment that used a population model was in 2008, but it only assessed the population status back to 1993 because of the substantial at-sea discards which took place in the 1970s and 1980s (Morin et al. 2008). This population model assumed that natural mortality was constant over time since 1993.

Improvements were subsequently made to the analytical framework to make it scientifically suitable for the assessment of the stock over a longer time period. Changes included the estimation of the 1970s and 1980s at-sea discards (Tallman 1991) and the estimation of time trends in natural mortality. The last assessment of the stock (in 2012) used an age-structured approach and was implemented as a Virtual Population Analysis (VPA) to estimate the temporal trends in abundance, biomass and natural and fishing mortalities (Morin and LeBlanc 2012) and to define reference points for the stock (Morin et al. 2012).

Because of the dire state of the resource, the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) assessed the Designatable Unit (DU) called the Canadian Maritime Population of American plaice and determined its status as “threatened”. The 4T plaice stock was a component of this DU. A Recovery Potential Assessment (RPA) was conducted in order to inform stakeholders and management authorities of the future prospects of the three different American plaice stocks in this DU, including the southern Gulf stock (DFO 2011). The findings of the RPA for the NAFO 4T stock were that the population would continue to decline even if the fishing mortality was reduced to zero (i.e., if the stock was not fished).

In order to further guide management and conservation measures, a biomass limit reference point was developed for the stock (Morin et al. 2012). The southern Gulf stock was estimated to be highly depleted, with the spawning stock biomass below the limit reference point for 15 of the last 16 years considered.

The assessment described herein was presented at a Regional Advisory Process meeting in March 2016. The present document updates the stock assessment for the year 2016, using data up to 2015.

FISHERY

American plaice landings in NAFO Div. 4T ranged between 6,000 t and 12,000 t during the 1960s to the late 1980s (Table 1; Fig. 1). The reported landings do not account for the discarding that was a common practice in the mobile gear plaice fishery until 1993 (Morin 2012). Starting in 1993, the fishing effort on American plaice and the landings were greatly reduced because of the introduction of management measures (quota reduction and increased mesh size for mobile gear). The cod fishery was closed from 1993 to 1998 which also reduced the fishing effort on other groundfish stocks, including American plaice.

Since the closure of the cod fishery, American plaice landings have steadily declined and in recent years have been are their lowest historical level. Despite a current TAC of 250 t, total landings in 2015 have only reached 40 t (Table 1). The current exploitation of American plaice is mostly as by-catch in the witch flounder fishery by mobile gear off Cape Breton (NAFO Div. 4Tf) and the Greenland halibut fishery exploited by gillnetters off the Gaspe coast (NAFO Div. 4To; Fig. 2; top and bottom panels of Fig. 3). This can also be seen in the third panel of Figure 3 which shows that over 80% of landings in recent years came from seine and gillnets.

In recent years over 80% of fish were landed before the month of August, whereas historically this fishery extended into the fall months (second panel from the top in Figure 3).

COMMERCIAL FISHERY DATA

A critical input into the age-structured assessment methods presented herein is the commercial catch-at-age matrix for the southern Gulf of St. Lawrence. Estimates of discarded plaice are included in the catch-at-age matrix used in the population assessment models (Table 2).

Generation of catch-at-age matrix

Estimating the age composition of the commercial catch is an essential part of the assessment procedure. The weights of commercial landings are available for the different gear types used in the commercial fishery. Commercial catches are sampled at sea by observers and in landing ports by government technicians. Observers and port samplers both record information on the origin of their samples (the date, vessel, gear, and catch weight) before drawing a random sample of the catch to record the length composition of the catch. They also collect biological samples used for ageing. This allows the development of catch-at-length landings and age-length keys that are used to estimate the age composition of American plaice in the 4T fishery.

The estimation of the size and age composition of 4T American plaice catches usually takes into account differences due to seasonal growth and the potential size selectivity of commercial gear. For most of the time series, estimates have been made semi-annually, i.e., from January to July and from August to December and separately for the main gear types; otter trawls, seines and fixed gear (mainly gillnets and longlines combined). In recent years, the limited amount of landings (less than 100t annually) most of which have occurred as bycatch in other fisheries, has made it difficult to deploy samplers to landing ports or for observers to take samples at sea when plaice is not the targeted species. As a result, recent catch-at-length and catch-at-age are estimated by combining samples across all months of the year, or by grouping samples of trawls and seines.

For each year where commercial landings are available, the total landed weights by fishing gear type are summarized (Table 1). The catch-at-age matrix resulting from the above analytical steps can be found in Table 2.

ESTIMATES OF AT-SEA DISCARDS

An important amount of at-sea discarding of American plaice occurred in the 1970s and 1980s and must be accounted for in order to obtain a reliable estimate of the fishery removals that are subsequently used in the age-structured assessment models. The catch-at-age matrix (Table 2) was modified to include the discard estimates following the methods of Morin (2012).

The discard estimates were computed using the methodology first developed by Tallman (1991). This estimation assumes that the research survey catch-at-length is an unbiased estimate of the plaice population length structure across sizes that are captured in the mobile gear fishery. A theoretical catch of plaice is obtained by "fishing" the survey population. This is done by applying retention ogives for the dominant mesh size used in the commercial mobile gear fishery to the survey population-at-length. The theoretical catch is adjusted to the scale of the commercial catch-at-length across a range of non-discarded plaice lengths. The discarded length composition is obtained from the difference between the observed and estimated catch-at-length. This estimate is then separated into male and female plaice, based on sex ratios observed in the survey, then converted to discarded catch-at-age using the survey age-length keys for the same year.

RESEARCH SURVEY DATA

The Gulf Region of Fisheries and Oceans Canada has conducted a yearly research vessel (RV) bottom trawl survey in the Southern Gulf of St. Lawrence since 1971. The survey uses a stratified random sampling design and the stratum boundaries can be seen on Figure 4. The analyses presented here used the 24 strata consistently fished since 1971 (strata 415 to 439) and excludes the shallow strata that were added in 1984 (strata 401-403). The RV survey data used were corrected for the different vessels used and also for diel changes in catchability (Benoît and Swain 2003; Benoît 2006). Because of a mechanical failure to the survey vessel in 2003, an uncalibrated vessel was used and the survey coverage was limited. For these reasons, the survey indices from 2003 were not used in the present analyses.

Indices of plaice abundance and biomass increased to high levels in the mid to late 1970s (Fig. 5). Both indices then declined to levels similar to those observed in the early 1970s. Beginning in the early 1990s, both indices declined to the lowest levels observed and have remained at historically low levels despite showing some minor increases since 2012. Abundance and biomass declines were most severe for large plaice (≥ 30cm) of commercial harvest size (Fig. 6).

Sex-specific abundance and biomass indices indicate that small males were more abundant that small females during the 1970s and large females are consistently more common than large males (Fig. 7 and Fig. 8).

The geographic distribution of trawl survey catches for all individuals suggest that the stock is still widely distributed within the southern Gulf of St. Lawrence (Fig. 9). However, the distribution of higher densities of large individuals has contracted to the center of the stock area (Fig. 10). In the last 4 years, the distribution of small males and females has been consistent over the southern Gulf of St. Lawrence and while large individuals are dominated by females, large males have been observed more frequently in 2014 and 2015 (Fig. 11). The proportion of small individuals has increased since the 1970s and 1980s when such individuals were essentially absent from survey catches (Fig. 12). The length frequency of individuals captured has been generally stable in the 5 most recent years yet there has been a slight increase in the mean length in the last 2 years (Fig. 13).

GENERATION OF CATCH-AT-AGE MATRIX

The catch-at-age matrix from the trawl survey provides a fishery-independent temporal index that is used to fit the population dynamics models. This catch-at-age matrix is generated similarly to that of the commercial landings described previously. The length frequency of captures is used in conjunction with yearly age-length keys to generate the catch-at-age matrix of the survey data. The stratified mean number per tow by length group is first calculated for each year based on the survey design. Then, the length distribution is converted to the stratified mean number-at age per tow by applying an age-length key to the length distribution. Units are either mean number per tow or “trawlable abundance”. Trawlable abundance is the mean number per tow multiplied by the number of trawlable units in the survey area (a “trawlable unit” is the area swept by a standard tow). The resulting RV catch-at-age matrix can be found in Table 3.

GROWTH AND MATURATION

Growth

Ageing materials are collected as part of the sampling protocols on the RV survey which yields length and age measurements for thousands of American plaice individuals each year. These materials are processed in the laboratory and examined by trained technicians to obtain the age of sampled individuals. This procedure was validated to ensure that growth rings are produced each year and that ageing is accurate (Morin et al. 2013).

The commonly used von Bertalanffy growth model (von Bertalanffy 1934) was fitted to available length-at-age data from the RV survey. This three parameter model is defined as:

$$L_{s,a} = L_{\infty,s} * \left(1 - exp\left(-k_s\left(a - t_{0,s}\right)\right)\right) \qquad (1)$$

where $L_{s,a}$ is the length of an individual of sex s at age a, $L_{\infty,s}$ is the asymptotic length reached by individuals of sex s, k_s is the rate at which growth slows as individuals of sex s approach their asymptotic length and $t_{0,s}$ in the intercept of the model, representing the age (usually negative) when length would be zero for individuals of sex s. Not all age-length observations are independent and the model fitting must account for the stratification scheme of the survey, both in terms of the allocation of tows to the different survey strata and the fact that ageing materials are only collected for one individual per 1cm length bin and sex. Additionally, the weighting must factor in the estimated number of fish at each length and age in a given year. As such, the model was fitted using a weighted non-linear regression and used a weighting scheme that account for all the above factors (Sinclair et al. 2002):

$$w_{l,y,a} = \frac{N_{l,y,a}}{O_{l,y,a}\sum_l N_{l,y,a}} \qquad (2)$$

where $N_{l,y,a}$ is the survey estimate of the number of fish at length *l* in year *y* and age *a* and $O_{l,y,a}$ is the number of available otoliths at length *l* in year *y* and age *a*.

Because American plaice exhibits sexually dimorphic growth, the von Bertalanffy model was fitted separately for males and females (Fig. 14). Females have a larger asymptotic length but both sexes exhibit similar growth rates at early life stages. Additionally, there is evidence that the growth characteristics of American plaice have changed significantly over the last five decade (Morin et al. 2013). The same growth model presented above (equation 1) was fitted for decadal time periods. To ensure that individuals experiencing similar growth conditions are analysed together, the decadal model fits (Fig. 15) used the year of birth of individuals (the cohort year, which is the year of data collection minus the age of an individual). The resulting patterns in decadal growth indicate that the asymptotic length of both males and females decreased from the 1970s to the 1990s and has since stabilised at a much smaller length than at the earliest data collection period.

The paired observations of length and age collected during the annual trawl survey were used to generate the weight-at-age matrix used in the population model. Because the survey takes place in September of each year but the population model keeps track of the number of individuals on January 1st of each year, the average weight-at-age estimated from the survey data was adjusted accordingly. The weight-at-age matrix allows the population numbers to be converted into population biomass. The beginning of the year weight-at-age matrix used in the population model can be found on Table 5 and the temporal trends in weight-at-age for ages 6, 8, 10, and 12 can be found in Figure 16.

Maturation

The annual proportion of mature plaice since 1997 was obtained from logistic regressions applied to proportions of mature male and female plaice sampled in the RV survey (Table 6). The maturity stages for surveys before 1997 are currently undergoing review as they might be unreliable; therefore, we applied the median values of coefficients of logistic ogives of maturity since 1997 to the period 1976-1996. Maturity coding in recent years was also problematic leading to unreliable information for years 2013 to 2015. For this reason, the proportions mature-at-age for years 2012 to 2015 were set to those in 2012.

OTHER SOURCES OF DATA CONSIDERED

SENTINEL SURVEY DATA

An additional survey that is available to calibrate the population dynamics model started in 1994 in order to obtain an industry-based abundance index for Atlantic cod following the closure of the fishery in 1993 (Chouinard et al. 1999). The mobile gear sentinel survey (MS) was revised in 2003 and adopted the same stratified random sampling design that is used in the annual September ecosystem survey. The survey is conducted by a number of commercial vessels and is thoroughly described in Savoie (2012). The population biomass index derived from the mobile sentinel survey can be found on Figure 17. The index shows a steady decline since 2003 with some minor increases in 2004, 2011 and 2012. It has since stabilised to its lowest level over the last three years. For the 2003 to 2015 period, the rate of decline of the MS index is more pronounced than the RV index.

The MS catch-at-age matrix used in the model fitting can be found in Table 4. The catch-at-age matrix for this survey was generated with the same procedure as for the RV survey catch-at-age matrix. The length composition was derived from sampling in the sentinel survey, but the conversion to age composition was based on annual age-length keys in corresponding RV surveys.

POPULATION DYNAMICS MODEL

The NAFO 4T American plaice stock has been under scientific scrutiny since the 1980s. The stock was initially assessed qualitatively since there were a number of problematic aspects in the available data. The current assessment uses an age-structured population model to estimate the temporal trends in stock abundance and biomass, to estimate a lower limit reference point and to forecast the stock trajectories under different management options.

VIRTUAL POPULATION ANALYSIS (VPA)

Methods

As in previous assessments, we use a virtual population analysis (VPA) framework (Hilborn and Walters 1992) as an assessment model for the 4T American plaice stock.

The information that feeds into the virtual population analysis consists of the following:

- Commercial catch-at-age matrix, including estimated at-sea discards (Table 2),
- Beginning of the year weight-at-age matrix (Table 5),
- Proportion mature-at-age matrix (Table 6),
- RV catch-at-age matrix (Table 3), and
- Sentinel survey catch-at-age matrix (Table 4).

A number of different model formulations were evaluated during the assessment but only the most suitable version was used for the provision of scientific advice presented here. The model features, including the parameters to be estimated are as follows:

- Ages modelled: 4 to 16+ (13 age classes)
- Years considered: 1976 to 2015 (40 years)
- Estimated number of parameters: 144
    - Age-specific abundance in the last year of the model: 12 parameters
    - Yearly natural mortality in two age groups (4-9 years and 10+ years) estimated as a random walk: 80 parameters
    - RV catchability-at-age: 13 parameters
    - MS catchability-at-age: 13 parameters
    - Age-specific observation error variance for the RV survey: 13 parameters
    - Age-specific observation error variance for the MS survey: 13 parameters.

Independent time series of the instantaneous natural mortality (*M*) were estimated for ages 4-9 (*j = 1*) and ages 10+ (*j = 2*) as random walks:

$$M_{j,1} = M_{init_j}$$

$$M_{j,y} = M_{j,y-1}e^{Mdev_{j,y}} \quad (3)$$

where M_{init_j} is *M* in year 1 (1976). M_{init_j} and $Mdev_{j,y}$ are parameters estimated by the model. The *Mdev* parameters were assumed to be normally distributed with a mean of 0 and a standard deviation set at 0.075. Priors were supplied for M_{init_j}. These priors were normally distributed with means of 0.6 and 0.3 for American plaice aged 4-9 and 10+.

In the VPA model that was used, parameters were estimated by minimizing an objective function with the following components:

- a component for the discrepancy between observed and predicted values of the abundance indices at age, which were assumed to be log-normally distributed,
- a normal prior for the log *M* deviations, and

- a normal prior for the initial values of *M*.

All data analyses were conducted using the R language and environment for statistical computing (R Core Team, 2015) and the population dynamics model was implemented in AD Model Builder (Fournier et al. 2012).

Results

The model estimated age-specific abundance and its corresponding survey-derived estimates (corrected for survey catchability) can be found on Figure 18. The VPA estimates of age-specific abundance provide a good fit to both survey indices and indicate significant declines in the abundance of American plaice in the southern Gulf of St. Lawrence.

The residuals for the RV survey (Fig. 19) indicate that the model had a systematic overestimation of the abundance of individuals aged 11 and older in the late 1970s and early 1980s and an underestimation of the same age classes since the mid-2000s. Strong year classes born in 1994, 1999 and 2000 are also underestimated by the population model and appear as oblique series of solid dots in Figure 19. The residuals of the MS survey show that the population model underestimated the abundance of all ages in the first few years of the MS survey and overestimated the abundance of all ages in the last 3 years (Fig. 20). This was caused by the fact that in recent years the MS index declined faster than the RV index, and the fact that the population model will preferentially fit the RV survey indices because they span a longer time period.

The model estimate of the instantaneous rates of natural and fishing mortality for ages 4-9 and ages 10+ can be found on Figure 21. Natural mortality has been higher than fishing mortality for the entire time period of the assessment. Fishing mortality of individuals aged 10 and older peaked in 1991 and has decreased to a negligible level for the last 10 years. Natural mortality of individuals aged 4 to 9 is currently estimated to be lower than at earlier times while it has steadily increased to an elevated level for individuals aged 10 and older.

Retrospective analysis of the population model, showing the resulting estimates in spawning stock biomass, recruitment, natural mortality and fishing mortality obtained after removing one to five years of data can be found on Figure 22. The model had an important retrospective pattern in the estimates of natural mortality for American plaice age 10+ in the recent period, and a retrospective pattern in natural mortality of the 4-9 years age group over the entire time series. This produces large differences in the revised values of SSB, recruitment, and mortality rates through time.

Model estimates are obtained by running a Monte Carlo Markov Chain (MCMC) simulation on the fitted population model. The MCMC run consisted of 201,000 iterations with a burn-in period of 1,000 iterations and each 40 iterations was saved after the burn-in period, for a total of 5,000 MCMC estimates. The median value from the MCMC runs are used as the reported model estimates for model parameters, population abundance, population biomass, natural mortality and fishing mortality.

The estimated spawning stock biomass at the beginning of 2015 (the MCMC median) was 55,023 t. Since the last assessment in 2012 the spawning stock biomass has increased marginally (Fig. 23).

REFERENCE POINTS

Earlier attempts at establishing reference points defined a lower limit spawning stock biomass that represented the level where recruitment was half of the maximum level (Morin et al. 2012) .

The limit reference point (LRP) was re-estimated using the results of the new population dynamics model. We used the estimated spawning stock biomass (SSB) and recruitment (R) time-series (Fig. 24) to fit a Beverton-Holt stock-recruitment model. The recruitment time-series was matched with the spawning stock biomass that produced it (i.e., offset by a recruitment age of four years) and the following model was fitted to the available data:

$$R \sim Lognormal(\mu_t, \varepsilon)$$

$$\mu_t = log\left(\frac{\alpha SSB_t}{\beta + SSB_t}\right)$$

$$\varepsilon \sim N(0, \sigma^2) \tag{4}$$

where, α and β are the estimated parameters, and β represents the spawning stock biomass that yields half of the maximum recruitment, which was suggested as a limit reference point (Myers et al. 1994). The estimated LRP for American plaice in NAFO Div. 4T is 139,135 t (SE = 76,970 t) and the 2015 spawning stock biomass of 55,023 t is 40% of the LRP indicating that the stock is currently in the critical zone (Fig. 23 and Fig. 24). The 95th percentile of the estimated SSB from the population model has been below the LRP and the stock has been in the critical zone since 1993.

STOCK PROJECTIONS AND MANAGEMENT ADVICE

The fitted population models were used to predict the temporal evolution of the stock under different management options. We evaluated three 5-year stock projection scenarios:

- no catch (TAC of 0 t),
- a TAC of 100 t, and
- a TAC of 250 t.

Despite the almost insignificant level of fishing mortality experienced by the stock, its rebuilding prospects under current conditions are low because of the high level of natural mortality. Under current conditions, the SSB is expected to remain in the critical zone (with > 95% chance of being below B_{lim}) during 2016 to 2021 at all annual TAC options (Fig. 25).

STOCK STATUS INDICATORS

The NAFO 4T American plaice stock is currently assessed and managed on a five-year cycle. Indicators are needed to characterise stock status in years between assessments. The indicators suggested are the biomass indices obtained from the RV survey. These indices can have significant observation error and changes in stock biomass should not be inferred from annual estimates. Moving averages are therefore suggested, with a three-year moving average recommended for tracking American plaice stock biomass. Important changes in the indicator, e.g., a large change in the moving average from its value in the last assessment year would trigger a re-assessment before the five-year period has elapsed. Currently, the TAC for this stock is set to 250 t but has not exceeded 40 t for the last three years.

In order to implement this approach it is necessary to relate the LRP from its population scale in January to the scale of the RV index in September. This is done by scaling the biomass over the whole stock area to the scale of the RV index, which is either in trawlable biomass or in biomass per tow. Since the LRP is in spawning stock biomass units, a regression between the commercial size catch biomass (individuals ≥ 30cm) and the VPA-derived SSB estimates was used to relate the two variables. The slope of the regression was then used to convert the LRP estimate into its equivalent RV index in biomass per tow or in trawlable biomass. The resulting scaled LRP is 19.5 kg/tow or 33,770 t of trawlable biomass.

The three-year moving average will be computed annually for the next five years and an assessment will be triggered if its value increases beyond the scaled LRP or if its decline exceeds those predicted under a TAC of 250t.

CONCLUSIONS

The prospect for the rebuilding of the NAFO Div. 4T American plaice to a healthy level remains grim. The low levels of directed fishery catches of this stock and the small amount of bycatch in other fisheries are positive situations for rebuilding, but the high natural mortality experienced by this stock is hampering its recovery. A likely reason for the increased natural mortality is predation by grey seals (Swain and Benoît 2015).

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TABLES

Table 1. Yearly landings (tonnes) of American plaice in NAFO Division 4T by major gear type. Gear codes: OTB = unspecified otter trawls, OTB1 = side otter trawls, OTB2 = stern otter trawls SNU =seines, PTB =pair trawls, GNS =gillnets, LLS = longlines, LH =handlines, TAC = total allowable catch. Note that the 2015 landings data are preliminary. The numbers in parentheses represent the landings for "unspecified flounder".

Year	OTB	OTB1	OTB2	SNU	PTB	GNS	LLS	LH	OTHER	TOTAL	TAC
1960	6130 (1794)	0 (0)	0 (0)	1557 (516)	0 (0)	0 (0)	218 (73)	3 (0)	73 (22)	7981 (2405)	na
1961	4492 (1591)	0 (0)	0 (0)	1988 (708)	0 (0)	23 (8)	22 (8)	450 (158)	43 (20)	7018 (2493)	na
1962	2784 (878)	0 (0)	0 (0)	1294 (422)	0 (0)	0 (0)	49 (4)	465 (0)	0 (0)	4592 (1304)	na
1963	5007 (0)	0 (0)	0 (0)	1954 (0)	0 (0)	174 (0)	32 (0)	2 (0)	527 (0)	7696 (0)	na
1964	5724 (0)	0 (0)	0 (0)	1507 (0)	0 (0)	0 (0)	3 (0)	0 (0)	602 (0)	7836 (0)	na
1965	7782 (0)	0 (0)	0 (0)	1854 (0)	0 (0)	388 (0)	212 (0)	0 (0)	149 (0)	10385 (0)	na
1966	0 (0)	8066 (0)	581 (0)	2322 (0)	0 (0)	375 (0)	2 (0)	0 (0)	434 (0)	11780 (0)	na
1967	0 (0)	7237 (0)	211 (0)	1151 (0)	0 (0)	326 (0)	117 (0)	50 (0)	259 (0)	9351 (0)	na
1968	0 (0)	7900 (0)	237 (0)	911 (0)	0 (0)	298 (0)	4 (0)	36 (0)	182 (0)	9568 (0)	na
1969	0 (0)	5609 (0)	425 (0)	1418 (0)	0 (0)	421 (0)	58 (0)	17 (0)	244 (0)	8192 (0)	na
1970	29 (0)	5793 (0)	477 (0)	2241 (0)	0 (0)	439 (0)	79 (0)	7 (0)	136 (0)	9201 (0)	na
1971	0 (0)	4996 (0)	409 (0)	2884 (0)	0 (0)	876 (0)	21 (0)	9 (0)	318 (0)	9513 (0)	na
1972	14 (10)	4275 (595)	860 (3)	2576 (0)	0 (0)	286 (520)	73 (42)	11 (30)	199 (1)	8294 (1201)	na
1973	20 (0)	3087 (1091)	471 (0)	2744 (0)	0 (0)	241 (232)	73 (6)	1 (34)	268 (25)	6905 (1388)	na
1974	0 (0)	3556 (160)	585 (0)	3719 (0)	0 (0)	250 (375)	6 (6)	5 (6)	364 (55)	8485 (602)	na
1975	10 (32)	3207 (1628)	795 (0)	3897 (0)	0 (0)	217 (757)	14 (19)	0 (1)	303 (27)	8443 (2464)	na
1976	41 (1)	4098 (301)	2864 (0)	3395 (4)	0 (0)	225 (346)	2 (0)	6 (3)	562 (13)	11193 (668)	na
1977	35 (2)	4261 (121)	375 (0)	4013 (6)	0 (0)	242 (1013)	16 (0)	17 (1)	271 (20)	9230 (1163)	10000
1978	58 (0)	3651 (72)	889 (3)	3495 (19)	0 (0)	379 (601)	42 (0)	38 (0)	479 (69)	9031 (764)	10000
1979	83 (0)	3415 (91)	961 (4)	3719 (37)	0 (0)	721 (690)	9 (0)	17 (2)	1071 (17)	9996 (841)	10000
1980	1485 (0)	1809 (25)	558 (40)	3500 (78)	0 (0)	717 (0)	62 (0)	5 (0)	156 (616)	8292 (759)	10000
1981	1022 (0)	1311 (34)	290 (35)	3570 (49)	0 (0)	1084 (0)	98 (0)	2 (0)	457 (0)	7834 (118)	10000
1982	742 (10)	580 (60)	137 (1)	4124 (1)	0 (0)	805 (1)	94 (0)	5 (0)	55 (271)	6542 (344)	10000
1983	821 (0)	479 (0)	102 (0)	4095 (1)	0 (0)	494 (0)	76 (0)	10 (0)	17 (791)	6094 (792)	10000
1984	239 (0)	601 (14)	2582 (2)	3702 (13)	0 (0)	1905 (14)	386 (3)	25 (0)	159 (0)	9599 (46)	10000
1985	165 (0)	824 (0)	3027 (0)	3870 (0)	83 (0)	1007 (3)	404 (0)	29 (0)	81 (0)	9490 (3)	10000
1986	74 (0)	768 (0)	2125 (0)	3289 (0)	105 (0)	663 (0)	318 (0)	44 (0)	22 (0)	7408 (0)	10000
1987	50 (0)	1075 (0)	2101 (0)	3140 (0)	123 (0)	831 (0)	664 (0)	67 (0)	13 (0)	8064 (0)	10000
1988	84 (0)	540 (0)	2002 (0)	2842 (0)	0 (0)	957 (0)	484 (0)	33 (0)	47 (0)	6989 (0)	10000
1989	14 (0)	495 (0)	1602 (2)	2489 (30)	0 (0)	501 (0)	212 (0)	386 (0)	18 (4)	5717 (36)	10000
1990	9 (0)	677 (0)	1205 (0)	2259 (12)	4 (0)	474 (25)	240 (0)	26 (0)	13 (0)	4907 (37)	10000
1991	22 (0)	146 (0)	1232 (11)	3057 (2)	94 (0)	525 (18)	102 (6)	22 (0)	22 (0)	5222 (37)	10000
1992	19 (0)	175 (0)	1405 (9)	2793 (8)	174 (0)	537 (70)	70 (4)	14 (0)	11 (0)	5198 (91)	10000
1993	0 (0)	77 (0)	149 (9)	928 (0)	63 (0)	592 (1)	28 (2)	1 (0)	15 (0)	1853 (12)	5000
1994	1 (0)	4 (0)	274 (0)	1761 (15)	90 (0)	243 (0)	13 (0)	0 (0)	34 (0)	2420 (15)	5000
1995	0 (0)	1 (0)	347 (1)	1752 (4)	123 (0)	136 (0)	2 (0)	0 (0)	33 (0)	2394 (5)	5000

Year	OTB	OTB1	OTB2	SNU	PTB	GNS	LLS	LH	OTHER	TOTAL	TAC
1996	1 (0)	49 (0)	184 (0)	1019 (0)	99 (0)	42 (0)	1 (0)	0 (0)	11 (0)	1406 (0)	2000
1997	0 (0)	50 (0)	219 (0)	1318 (0)	124 (0)	56 (0)	2 (0)	1 (0)	17 (0)	1787 (0)	2500
1998	0 (0)	22 (0)	121 (20)	898 (5)	71 (0)	43 (0)	12 (0)	1 (0)	0 (0)	1168 (25)	1500
1999	0 (0)	0 (0)	254 (0)	1046 (0)	128 (0)	109 (0)	3 (0)	0 (0)	1 (0)	1541 (0)	2000
2000	0 (0)	0 (0)	205 (2)	1041 (1)	121 (0)	48 (0)	2 (0)	0 (0)	0 (0)	1417 (3)	2000
2001	0 (0)	0 (0)	147 (0)	869 (0)	139 (0)	32 (0)	3 (0)	0 (0)	0 (0)	1190 (0)	2000
2002	0 (0)	0 (0)	82 (0)	516 (0)	55 (0)	23 (0)	0 (0)	1 (0)	0 (0)	677 (0)	1000
2003	0 (0)	0 (0)	25 (0)	248 (0)	94 (0)	23 (0)	1 (0)	0 (0)	0 (0)	391 (0)	750
2004	0 (0)	0 (0)	52 (0)	298 (0)	11 (0)	38 (0)	1 (0)	0 (0)	0 (0)	400 (0)	750
2005	0 (0)	1 (0)	50 (0)	155 (0)	84 (0)	48 (0)	1 (0)	0 (0)	0 (0)	339 (0)	750
2006	0 (0)	0 (0)	102 (0)	233 (0)	92 (0)	35 (0)	1 (0)	0 (0)	11 (0)	474 (0)	750
2007	0 (0)	0 (0)	64 (0)	170 (0)	79 (0)	20 (0)	0 (0)	0 (0)	39 (3)	372 (3)	750
2008	1 (0)	25 (0)	16 (0)	66 (0)	0 (0)	40 (0)	0 (0)	0 (0)	23 (0)	171 (0)	500
2009	0 (0)	33 (0)	4 (0)	42 (0)	1 (0)	31 (0)	0 (0)	0 (0)	15 (0)	126 (0)	500
2010	0 (0)	0 (0)	32 (0)	84 (0)	0 (0)	30 (0)	0 (0)	0 (0)	0 (0)	146 (0)	500
2011	0 (0)	0 (0)	25 (0)	57 (0)	0 (0)	14 (0)	0 (0)	0 (0)	0 (0)	96 (0)	500
2012	0 (0)	1 (0)	24 (0)	21 (0)	0 (0)	22 (0)	0 (0)	0 (0)	0 (0)	68 (0)	250
2013	0 (0)	0 (0)	12 (0)	9 (0)	0 (0)	19 (0)	0 (0)	0 (0)	0 (0)	40 (0)	250
2014	0 (0)	0 (0)	1 (0)	11 (0)	0 (0)	20 (0)	0 (0)	0 (0)	0 (0)	32 (0)	250
2015	0 (0)	0 (0)	5 (0)	16 (0)	0 (0)	19 (0)	0 (0)	0 (0)	0 (0)	40 (0)	250
Mean	660 (77)	1409 (75)	552 (3)	1856 (34)	35 (0)	323 (83)	77 (3)	32 (4)	138 (35)	5082 (315)	na

Table 2. Estimated numbers caught at age (thousands) of 4T American plaice (landings + estimated discarded catch-at-age).

Year	Age													Total
	4	5	6	7	8	9	10	11	12	13	14	15	16+	
1976	1418	9985	19232	13687	7846	6583	5023	3096	3298	1523	813	498	1826	74828
1977	805	5121	11416	17458	10189	5077	3206	2073	2192	763	659	225	1078	60262
1978	435	2312	5365	10328	9658	3864	3285	2576	1403	1329	863	538	705	42660
1979	169	1293	3802	8043	11048	8310	4720	2687	1670	1101	1143	354	771	45111
1980	650	1990	4425	6890	7890	5922	3372	2334	2403	1812	1332	778	1067	40866
1981	254	527	1326	2206	2871	2789	2236	1857	1383	948	779	1225	2276	20676
1982	65	460	699	1539	3199	3247	3320	1950	1479	1059	810	423	1170	19420
1983	97	430	795	915	1435	1922	2122	2057	2001	1587	829	592	2155	16936
1984	251	638	1127	1823	1970	2386	3572	2671	2136	1166	1206	868	1885	21698
1985	204	811	985	1323	1939	1837	2424	3217	3438	2293	1793	1106	2130	23500
1986	243	442	1334	1582	1975	1814	1651	1844	2115	1900	1319	907	1714	18840
1987	306	1154	2293	3553	3508	2899	2994	2452	2602	1962	1946	1042	2359	29070
1988	134	572	1698	1617	2409	2251	1325	1295	1427	1307	1116	756	1962	17868
1989	242	948	1686	3358	3054	3133	2222	1429	1159	910	728	519	1326	20715
1990	373	1356	2168	2352	3529	2231	1874	1331	851	780	445	421	896	18606
1991	1046	3051	5156	6352	5321	6516	3903	3044	2242	1255	977	694	2004	41560
1992	450	1604	3521	4412	4494	2884	3391	1942	1359	663	544	368	895	26526
1993	305	1324	2150	2625	2719	1816	1052	1149	603	292	139	80	238	14492
1994	29	326	1051	1208	1066	855	722	449	423	222	130	81	197	6758
1995	9	55	347	874	980	964	917	713	488	438	208	179	301	6474
1996	30	78	238	599	584	482	536	393	261	190	170	63	122	3747
1997	15	43	201	383	772	896	851	590	480	258	167	118	110	4884
1998	19	82	137	444	456	528	570	271	285	181	90	83	84	3230
1999	43	79	330	365	894	758	761	497	355	153	76	37	26	4374
2000	32	91	155	327	284	634	500	511	449	296	151	127	86	3643
2001	50	70	246	352	441	322	576	342	390	265	143	96	76	3371
2002	15	78	136	216	248	211	205	226	161	121	83	53	61	1813
2003	5	11	119	130	154	135	137	77	76	61	22	21	15	964
2004	11	28	39	123	120	153	137	106	101	112	73	48	78	1129
2005	13	35	76	55	134	152	112	101	104	71	46	21	67	988
2006	7	4	55	135	93	200	170	164	177	124	62	60	130	1380
2007	3	13	51	79	113	109	140	134	106	73	94	59	62	1036
2008	0	1	5	11	39	60	41	40	25	33	38	18	28	341
2009	0	15	14	39	56	64	41	32	35	26	7	10	5	345
2010	1	18	10	30	35	37	62	89	25	34	25	18	56	441
2011	0	16	11	26	42	79	44	47	23	11	7	3	6	316
2012	0	1	13	17	23	36	33	23	30	13	6	4	7	208
2013	0	2	9	12	13	18	14	15	7	10	5	1	2	108
2014	5	6	16	15	6	11	13	7	3	5	2	1	0	93
2015	2	7	11	16	12	16	7	16	10	4	0	2	1	103

Table 3. Mean standardized catch-at-age (thousands) of American plaice from the annual southern Gulf of St. Lawrence research vessel trawl survey.

Year	Age												
	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	214058.4	334057.8	272193.9	128575.1	60418.2	55133.3	37303.7	26147.7	16548.1	9822.7	5184.6	2433.2	6073.5
1977	328983.9	461016.0	288626.1	199535.4	89602.6	36378.5	22614.7	13926.4	9200.1	6113.2	3010.8	2019.9	3199.3
1978	110773.3	149221.8	163888.4	164862.0	101538.6	35425.7	24380.3	12900.9	7142.2	8000.0	3228.7	2120.2	3555.5
1979	87366.6	233015.5	217342.5	252972.2	193230.2	89915.6	47804.3	26697.6	14453.9	9113.7	8475.5	4888.9	7247.7
1980	118365.1	137439.8	171148.2	123126.0	98884.0	52805.6	28119.2	18357.0	10901.8	7980.9	4095.1	1762.2	2481.6
1981	93931.2	124044.3	154963.2	164007.7	95497.9	63745.4	33480.1	16131.3	7444.8	4406.4	2635.5	1968.0	3406.8
1982	26817.0	53704.8	50697.5	76658.4	101998.6	50618.0	32518.6	12729.7	5701.7	2697.8	2990.0	1772.6	4714.2
1983	44881.7	55259.5	54190.8	40952.6	66386.1	64476.9	37412.7	37027.0	19375.6	7825.3	3821.9	2858.6	5606.5
1984	30484.9	40489.2	37634.0	33677.3	31366.9	28563.6	34057.7	12504.9	10701.2	4925.2	1878.1	1959.3	3450.0
1985	30075.1	53573.4	40627.5	23757.8	27040.1	20401.1	22730.5	24190.1	18289.6	11353.2	7695.6	4361.4	7911.8
1986	52862.6	52153.6	66171.7	46720.0	20665.7	24788.4	10177.2	13134.4	24164.2	14578.4	14381.2	9032.4	12453.0
1987	52658.6	75285.3	62796.0	63385.7	36842.0	30272.2	18756.5	13890.1	11859.9	4674.4	4818.0	2379.6	4380.4
1988	45295.0	55026.1	85884.5	55064.1	52975.1	32217.7	15999.9	11533.0	9682.6	8849.1	7488.1	3948.1	5041.0
1989	47233.6	65680.6	49765.4	54794.3	36164.1	22516.1	15486.3	7923.9	7429.3	5452.6	3896.2	2381.3	3671.4
1990	97825.6	135786.5	102730.1	53127.2	50106.1	28160.7	18182.3	12715.9	5885.0	4677.9	2018.1	2293.1	2210.1
1991	88483.7	110263.1	112333.1	77914.0	46718.3	44292.0	21699.8	14536.9	10118.4	4750.5	4470.4	3232.1	5763.9
1992	70192.4	79902.7	78054.0	51506.8	36096.6	18011.1	14545.5	7913.5	5589.2	3368.8	1981.8	1184.6	2184.2
1993	67691.8	67448.0	59672.8	45742.9	32138.2	18341.4	8603.5	8212.7	4024.2	2478.2	781.7	358.0	1578.9
1994	44669.0	74604.0	66234.0	52689.7	32976.9	20881.9	14006.0	6367.5	5974.9	2272.4	963.2	487.7	1048.0
1995	50569.5	40259.2	55968.6	39444.7	34299.8	21682.5	14927.7	8370.0	5082.5	2808.5	1086.0	681.4	529.2
1996	32101.8	58484.8	39553.6	38756.4	28887.0	21334.9	16444.4	7738.8	5936.8	2668.4	1715.5	946.0	584.5
1997	33684.2	19764.7	44245.3	20364.8	24750.4	13751.8	10619.9	6156.5	5001.3	3016.0	722.9	1131.0	579.3
1998	39264.8	40321.4	21267.5	31662.6	22068.2	19778.5	15827.0	7163.0	6409.0	2747.9	1177.7	779.9	332.0
1999	40267.8	29293.4	26405.4	14600.9	23422.3	11306.5	11712.9	5217.4	3372.2	1423.3	632.9	408.1	513.6
2000	30528.1	32828.2	24492.7	14901.8	13025.4	14194.5	9082.5	8501.5	4373.5	3176.8	1034.1	271.5	560.3
2001	30192.7	27045.2	30227.2	22088.9	16006.8	8086.4	12121.0	7605.7	8181.5	3979.2	1471.7	932.1	657.2
2002	18113.2	29926.3	23047.0	16070.8	16371.7	10277.5	5834.8	5075.6	3996.5	2189.4	1009.9	781.7	449.6
2003	na	na	na	na	na	na	na	na	na	na	na	na	na
2004	44454.6	40629.3	13027.2	18765.1	12492.8	12096.8	7916.9	4676.2	2894.9	2125.4	1601.4	1205.4	475.6
2005	32976.9	52907.6	40362.9	18154.7	19230.3	9163.8	9098.1	4875.0	3654.1	1791.6	1201.9	608.7	909.6
2006	34329.2	27987.7	46071.5	30789.3	12518.7	10630.3	7195.8	5917.8	5027.2	2113.3	1068.7	717.7	695.2
2007	24534.2	32842.0	33801.8	30258.4	19154.2	8773.0	8952.8	5724.1	3242.5	2078.7	1091.2	978.8	854.3
2008	31019.3	23915.1	40675.9	30566.2	50780.5	25302.1	10912.2	9203.6	4039.8	2943.3	1272.8	741.9	1891.9
2009	14479.8	21139.5	14324.2	21793.2	14979.6	18621.6	9724.1	3060.9	3035.0	1974.9	1046.3	435.8	520.5
2010	71835.3	29205.2	35565.7	21293.4	32134.7	16703.8	26983.0	12252.4	4939.0	3835.7	1672.3	1257.2	1537.4
2011	33846.8	51930.5	22868.9	20048.3	13314.2	16451.3	11560.7	13079.0	4875.0	2474.7	1438.8	971.9	985.7
2012	23769.9	27830.4	37812.2	18128.7	14033.6	9634.2	10836.1	9523.5	6434.9	3204.5	1563.3	1061.8	797.2
2013	44931.9	32491.0	34279.1	36610.3	22087.2	14806.7	10294.8	8504.9	5544.3	3936.0	2331.2	705.6	534.4
2014	48788.3	46714.8	40266.1	31296.0	21333.2	10421.0	5297.0	6163.4	3233.9	2383.0	1037.6	333.8	302.6
2015	41784.5	50458.9	40101.8	33478.4	29815.7	15299.5	10296.5	6270.6	5210.5	3726.7	2146.1	824.9	996.1

Table 4. Mean standardized catch-at-age (thousands) of American plaice from the annual southern Gulf of St. Lawrence sentinel survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
2003	6675	13459	7642	12482	9382	9819	7113	4387	2480	2328	1741	1442	614
2004	9975	17290	8482	13401	9935	10324	7428	4465	2696	2468	1818	1460	604
2005	6881	13617	12795	7057	8111	4033	4296	2622	2011	1084	640	396	609
2006	4771	6246	12775	10433	5036	4531	3346	3187	2523	1197	610	474	585
2007	2520	5842	8389	8474	6281	3279	3511	2471	1463	1010	522	479	457
2008	2580	2943	6437	5843	10985	6506	2866	2719	1389	991	541	261	785
2009	1243	3924	3760	7070	5435	7839	4742	1622	1598	1024	657	254	339
2010	3716	2056	3799	2629	4685	2881	4882	2597	1247	1067	533	372	624
2011	2712	8579	5563	6091	4854	6129	4522	5198	1992	1003	586	396	380
2012	1729	5198	11633	6699	6312	4408	5349	4654	3882	1899	813	591	500
2013	849	1541	2760	3853	2746	1970	1422	1249	899	640	406	237	140
2014	1390	2153	2475	2151	1546	837	457	545	291	247	109	64	66
2015	882	1952	2013	1951	1854	991	673	469	384	272	137	67	83

Table 5. Mean weight-at-age (kg) of American plaice from the annual southern Gulf of St. Lawrence research vessel trawl survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	0.047	0.081	0.131	0.197	0.257	0.306	0.337	0.446	0.518	0.759	0.733	0.895	1.656
1977	0.048	0.077	0.120	0.179	0.250	0.312	0.379	0.440	0.572	0.716	0.906	1.004	1.500
1978	0.039	0.071	0.100	0.147	0.212	0.301	0.357	0.466	0.566	0.671	0.944	0.960	1.544
1979	0.038	0.057	0.091	0.119	0.170	0.240	0.316	0.399	0.492	0.644	0.774	1.114	1.445
1980	0.053	0.066	0.089	0.129	0.172	0.233	0.312	0.403	0.522	0.604	0.802	1.000	1.451
1981	0.060	0.086	0.113	0.136	0.184	0.237	0.308	0.390	0.549	0.671	0.801	0.879	1.264
1982	0.064	0.095	0.119	0.144	0.169	0.220	0.279	0.366	0.508	0.659	0.812	0.903	1.194
1983	0.056	0.084	0.120	0.139	0.152	0.185	0.230	0.292	0.379	0.596	0.732	0.846	1.169
1984	0.056	0.083	0.108	0.135	0.153	0.172	0.201	0.246	0.302	0.385	0.590	0.753	1.190
1985	0.059	0.095	0.117	0.146	0.173	0.189	0.217	0.240	0.285	0.338	0.448	0.556	1.153
1986	0.062	0.094	0.132	0.160	0.191	0.213	0.245	0.256	0.268	0.294	0.337	0.413	0.729
1987	0.057	0.097	0.131	0.161	0.193	0.212	0.240	0.282	0.303	0.353	0.365	0.376	0.748
1988	0.045	0.082	0.119	0.154	0.182	0.215	0.227	0.268	0.293	0.344	0.417	0.515	0.865
1989	0.047	0.083	0.120	0.161	0.187	0.228	0.249	0.271	0.303	0.325	0.376	0.446	0.892
1990	0.055	0.092	0.129	0.169	0.209	0.228	0.270	0.285	0.333	0.357	0.416	0.465	0.871
1991	0.060	0.101	0.140	0.178	0.216	0.244	0.262	0.293	0.303	0.347	0.360	0.424	0.718
1992	0.066	0.105	0.143	0.178	0.211	0.238	0.269	0.287	0.318	0.332	0.339	0.379	0.541
1993	0.053	0.094	0.131	0.166	0.201	0.231	0.268	0.297	0.310	0.356	0.385	0.453	0.704
1994	0.053	0.086	0.128	0.165	0.200	0.227	0.255	0.299	0.312	0.334	0.385	0.442	0.627
1995	0.052	0.088	0.119	0.158	0.189	0.224	0.254	0.274	0.298	0.333	0.382	0.447	0.581
1996	0.051	0.080	0.119	0.150	0.189	0.218	0.245	0.280	0.296	0.327	0.384	0.431	0.600
1997	0.047	0.084	0.114	0.150	0.185	0.223	0.251	0.274	0.296	0.296	0.381	0.418	0.544
1998	0.041	0.075	0.112	0.147	0.182	0.218	0.247	0.270	0.307	0.329	0.351	0.377	0.607
1999	0.047	0.076	0.118	0.154	0.188	0.226	0.255	0.281	0.322	0.384	0.418	0.488	0.563
2000	0.053	0.086	0.119	0.167	0.197	0.228	0.253	0.275	0.329	0.396	0.486	0.528	0.666
2001	0.060	0.087	0.120	0.146	0.184	0.207	0.240	0.251	0.280	0.327	0.398	0.488	0.605
2002	0.046	0.088	0.118	0.150	0.170	0.198	0.228	0.261	0.270	0.319	0.359	0.405	0.491
2003	0.044	0.080	0.118	0.149	0.174	0.198	0.227	0.258	0.269	0.310	0.350	0.398	0.000
2004	0.042	0.073	0.118	0.149	0.179	0.198	0.226	0.254	0.268	0.302	0.341	0.390	0.443
2005	0.051	0.077	0.114	0.151	0.182	0.204	0.214	0.252	0.262	0.273	0.303	0.352	0.448
2006	0.052	0.084	0.108	0.143	0.170	0.198	0.223	0.225	0.255	0.282	0.298	0.340	0.462
2007	0.054	0.082	0.115	0.134	0.166	0.194	0.213	0.235	0.241	0.272	0.300	0.319	0.469
2008	0.055	0.080	0.107	0.134	0.157	0.192	0.209	0.235	0.259	0.256	0.320	0.307	0.412
2009	0.038	0.079	0.104	0.130	0.146	0.176	0.213	0.224	0.249	0.259	0.278	0.327	0.337
2010	0.046	0.071	0.106	0.126	0.151	0.164	0.186	0.217	0.224	0.248	0.253	0.281	0.332
2011	0.043	0.076	0.098	0.130	0.146	0.164	0.185	0.205	0.236	0.231	0.273	0.281	0.346
2012	0.037	0.064	0.095	0.118	0.148	0.161	0.181	0.191	0.233	0.260	0.253	0.284	0.329
2013	0.035	0.059	0.088	0.120	0.143	0.166	0.170	0.198	0.212	0.250	0.280	0.277	0.346
2014	0.043	0.073	0.104	0.131	0.152	0.184	0.215	0.209	0.236	0.276	0.293	0.342	0.469
2015	0.049	0.086	0.118	0.147	0.171	0.185	0.209	0.249	0.242	0.262	0.306	0.318	0.427

Table 6. Proportion American plaice mature-at-age in the annual southern Gulf of St. Lawrence research vessel trawl survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1977	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1978	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1979	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1980	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1981	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1982	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1983	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1984	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1985	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1986	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1987	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1988	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1989	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1990	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1991	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1992	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1993	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1994	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1995	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1996	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1997	0.280	0.360	0.430	0.510	0.590	0.670	0.740	0.790	0.840	0.880	0.910	0.930	0.963
1998	0.210	0.350	0.520	0.690	0.820	0.900	0.950	0.980	0.990	0.990	1.000	1.000	1.000
1999	0.290	0.420	0.560	0.690	0.790	0.870	0.920	0.950	0.970	0.980	0.990	0.990	1.000
2000	0.290	0.400	0.520	0.640	0.740	0.820	0.880	0.920	0.950	0.970	0.980	0.990	0.996
2001	0.260	0.320	0.390	0.460	0.530	0.600	0.670	0.730	0.780	0.820	0.860	0.890	0.936
2002	0.170	0.280	0.430	0.590	0.730	0.840	0.910	0.950	0.970	0.990	0.990	1.000	1.000
2003	0.285	0.410	0.550	0.685	0.795	0.880	0.930	0.960	0.975	0.990	0.990	1.000	1.000
2004	0.400	0.540	0.670	0.780	0.860	0.920	0.950	0.970	0.980	0.990	0.990	1.000	1.000
2005	0.280	0.380	0.480	0.590	0.690	0.770	0.840	0.890	0.920	0.950	0.970	0.980	0.991
2006	0.350	0.460	0.570	0.680	0.770	0.840	0.890	0.930	0.950	0.970	0.980	0.990	0.993
2007	0.440	0.580	0.710	0.810	0.880	0.930	0.960	0.980	0.990	0.990	1.000	1.000	1.000
2008	0.273	0.375	0.489	0.604	0.709	0.795	0.861	0.908	0.941	0.962	0.976	0.985	0.993
2009	0.285	0.372	0.467	0.566	0.659	0.741	0.809	0.863	0.903	0.933	0.954	0.968	0.984
2010	0.366	0.556	0.731	0.855	0.928	0.965	0.984	0.992	0.997	0.998	0.999	1.000	1.000
2011	0.213	0.349	0.515	0.678	0.807	0.892	0.943	0.970	0.985	0.992	0.996	0.998	0.999
2012	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2013	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2014	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2015	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994

Table 7. Age-specific yearly population size estimated from the virtual population analysis. Numbers are in thousand individuals and represent the population size on January 1st.

Year	Age												
	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	5506740	2652220	1173090	438765	158842	82742	48060	37834	18471	15033	4031	3766	13820
1977	5687200	2792990	1338690	581774	213077	75131	37410	32978	26712	11480	10357	2424	11642
1978	4750390	2660780	1303550	618819	260612	92934	31787	26477	24003	18991	8319	7532	9870
1979	3566170	2085690	1166900	568955	265090	108239	38330	22161	18601	17685	13799	5797	12622
1980	2068020	1534650	896789	499774	239743	107079	41333	26148	15155	13237	13016	9904	13575
1981	1546980	894092	662534	385075	211779	98677	42555	29682	18600	9854	8859	9108	16922
1982	995381	689958	398520	294700	170352	92613	42212	31591	21772	13450	6936	6300	17442
1983	887602	465655	322496	185985	136851	77568	41168	30300	23148	15834	9653	4745	17284
1984	898374	444016	232678	160800	92418	67475	37479	30441	21969	16405	11029	6846	14871
1985	767836	482793	238247	124277	85133	48265	34558	26088	21390	15255	11768	7541	14518
1986	1109410	436093	273695	134627	69625	46928	26059	24623	17377	13552	9802	7540	14245
1987	942724	647212	254148	158708	77369	39141	26019	18506	17240	11461	8721	6356	14394
1988	1213250	547233	374983	145865	89495	42296	20558	17034	11839	10756	6951	4902	12715
1989	1502750	687350	309647	211212	81449	48923	22300	14043	11468	7522	6825	4181	10690
1990	1552230	831825	379858	170201	114478	42861	24799	14084	8844	7229	4616	4271	9089
1991	1353110	839314	448943	203892	90359	59370	21574	15452	8558	5362	4314	2798	8074
1992	1853330	707240	436983	231237	102177	43513	26472	10877	7596	3774	2481	2021	4911
1993	1184940	945024	359621	220428	114860	48979	20184	13452	5112	3568	1782	1090	3239
1994	626644	602383	479663	181381	110263	56513	23641	10800	6866	2486	1831	920	2248
1995	614909	321048	308410	245023	92085	55746	28355	12556	5649	3491	1214	918	1551
1996	732099	315279	164574	157888	125018	46527	27906	14766	6317	2721	1584	512	1000
1997	531849	373713	160894	83848	80181	63412	23414	14827	7766	3255	1346	741	691
1998	1256420	270496	190046	81693	42378	40242	31626	12416	7825	3974	1624	628	632
1999	378876	634185	136480	95833	40926	21074	19945	17969	7019	4338	2176	877	609
2000	433112	196141	328306	70432	49362	20559	10377	11336	10357	3922	2475	1242	840
2001	374563	235802	106731	178647	38112	26671	10734	5877	6448	5904	2140	1378	1094
2002	218825	213116	134136	60554	101401	21361	14938	6021	3276	3583	3351	1179	1356
2003	1347140	124260	120970	76074	34228	57401	11974	8979	3508	1879	2098	1985	1462
2004	1634880	754275	69566	67644	42499	19051	32040	7303	5496	2111	1115	1281	2105
2005	500326	887251	409330	37726	36622	22977	10228	19934	4485	3359	1233	640	2019
2006	464545	279266	495228	228427	21018	20343	12714	6157	12090	2657	1996	717	1555
2007	291123	271658	163311	289564	133481	12221	11746	7279	3464	6910	1455	1116	1182
2008	328273	179632	167613	100729	178611	82275	7456	6218	3820	1787	3665	715	1149
2009	324474	209421	114595	106924	64251	113913	52440	3622	3017	1852	853	1768	881
2010	626214	203739	131485	71943	67108	40300	71476	25387	1733	1439	880	408	1274
2011	513185	376700	122546	79088	43254	40342	24214	36022	12748	857	702	427	798
2012	487549	295615	216982	70584	45538	24885	23179	12097	18008	6368	422	347	606
2013	572690	272604	165287	121312	39453	25445	13887	11206	5844	8703	3076	200	454
2014	670169	314567	149735	90782	66626	21661	13963	6503	5245	2736	4074	1439	305
2015	528392	366692	172117	81918	49662	36451	11844	6437	2997	2419	1260	1880	804

FIGURES

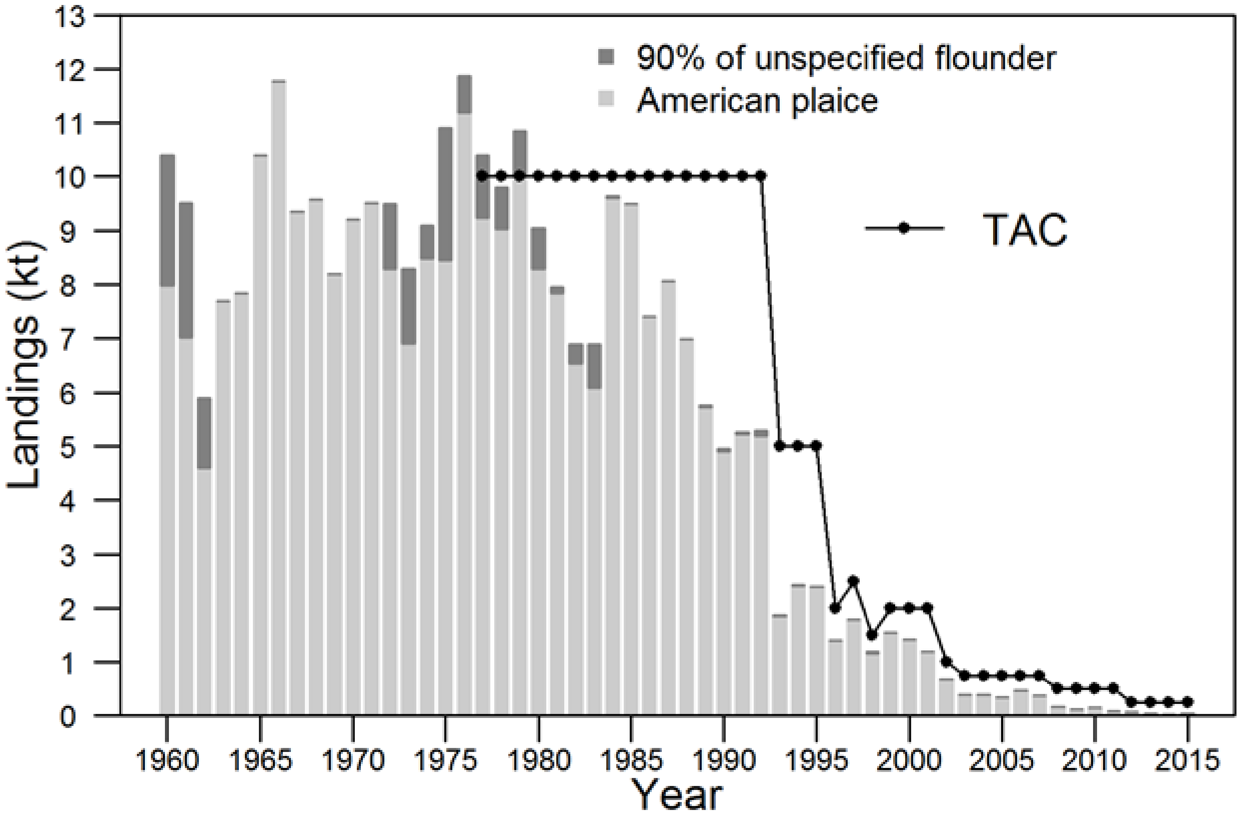

Figure 1. Reported annual landings of 4T American plaice and total allowable catch (TAC), 1960 to 2015. The landings estimates include at-sea discards during the 1970s and 1980s as well as 90% of landings marked as “unspecified flounder”.

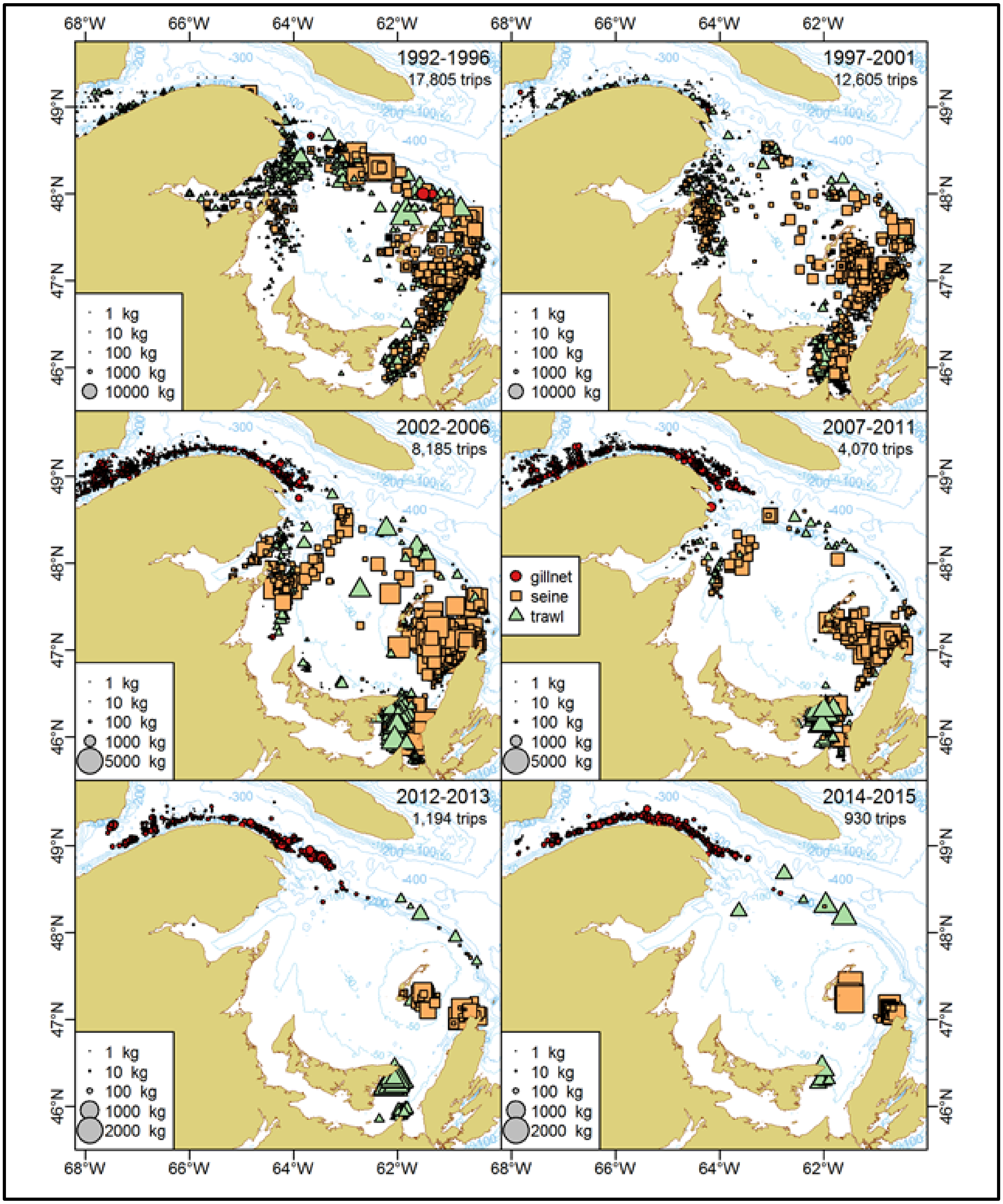

Figure 2. Geographic location of catches of American plaice by gear type in NAFO Div. 4T from 1992 to 2015. Catch locations are shown by 5-year blocks from 1992 to 2011 and by 2-year blocks from 2012 to 2015.

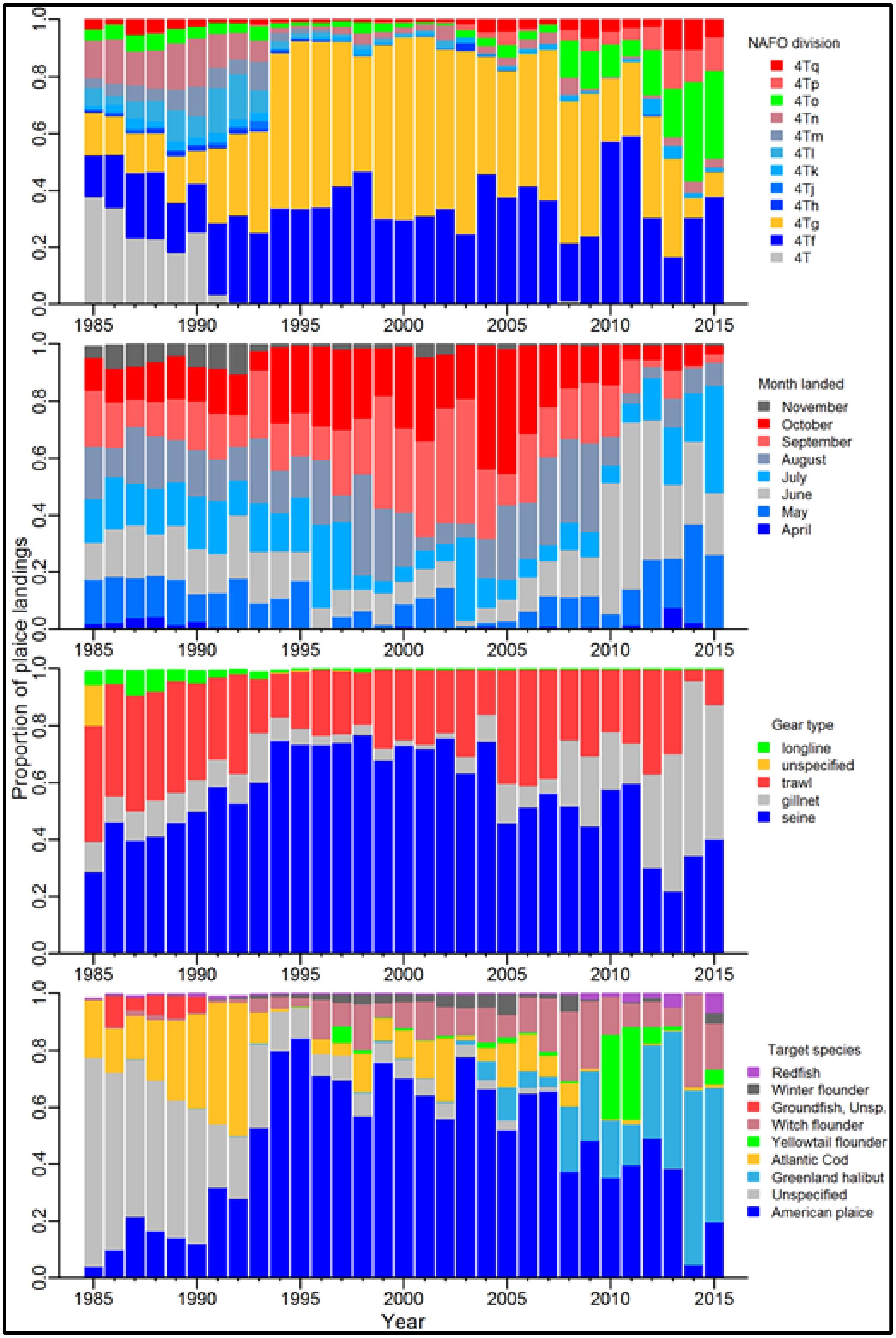

Figure 3. Proportion of annual American plaice landings by NAFO 4T subdivision (top panel), by month (second panel), by type of fishing gear (third panel) and by target species(lower panel) from 1985 to 2015.

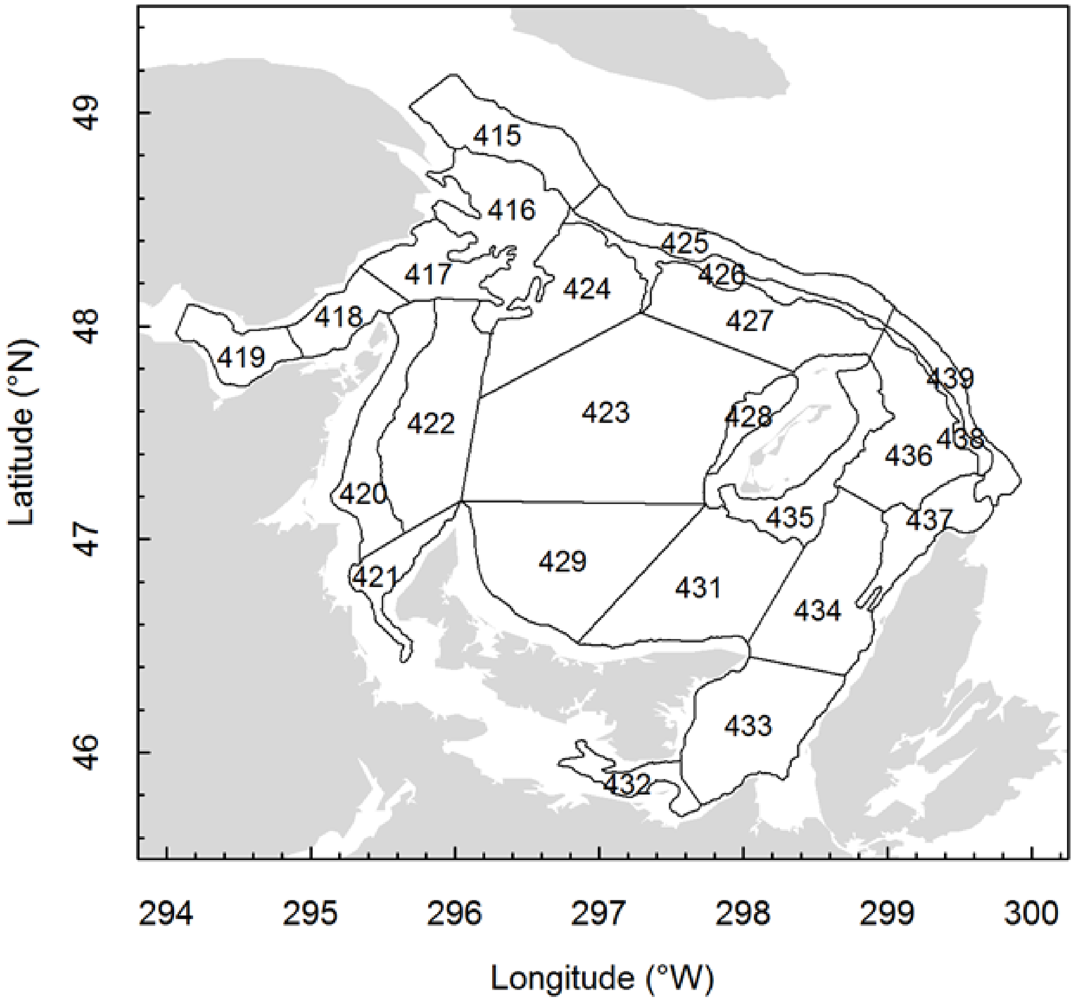

Figure 4. Map of the Southern Gulf of St. Lawrence showing the strata boundaries used during the annual Gulf Region September bottom trawl survey. Three coastal and shallow water strata added to the survey in 1984 were omitted from the analyses and are not shown on the map.

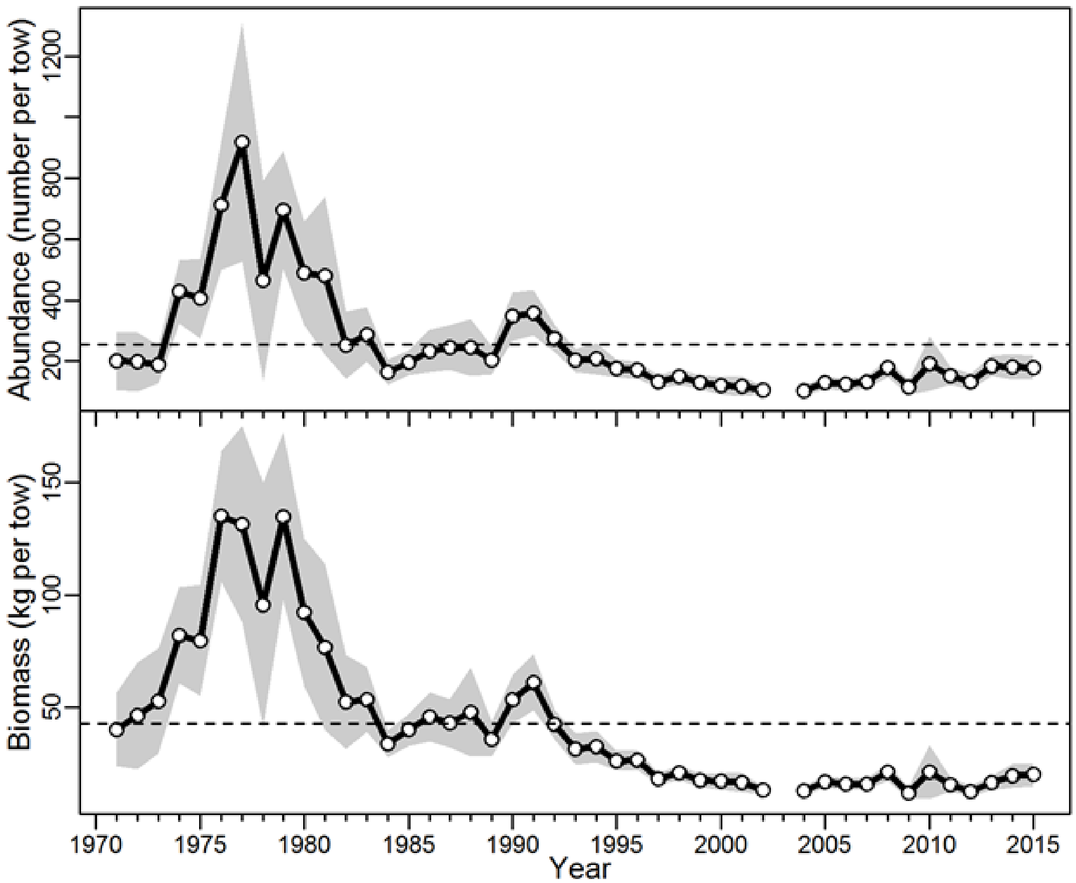

Figure 5. Survey abundance and biomass indices of plaice (top panel: stratified mean number per tow, bottom panel: stratified mean kilogram per tow), with horizontal line indicating mean of values obtained from 1971 to 2015.The indices presented on this figure include male and female individuals as well as undetermined sexes. Data from 2003 is omitted from the figure as an uncalibrated vessel was used in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

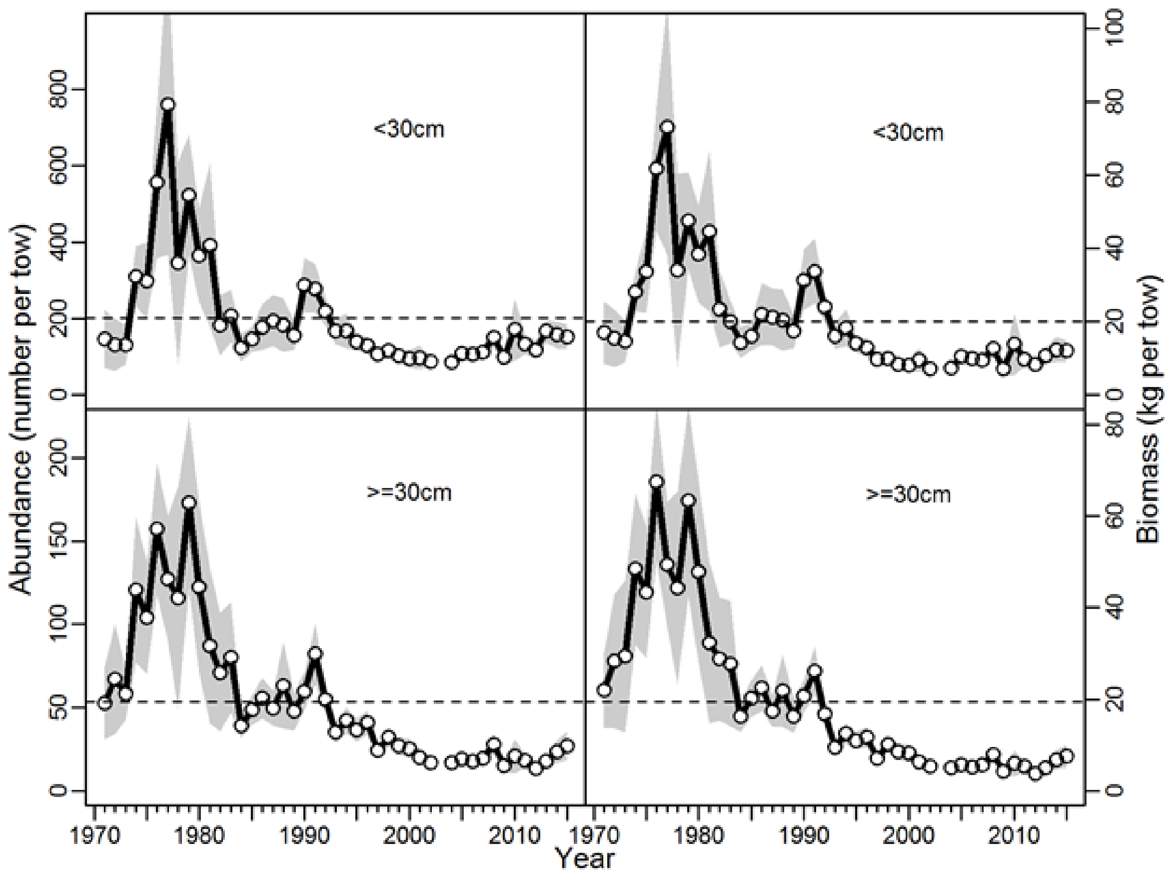

Figure 6. Survey abundance and biomass indices of plaice of length less than 30 cm (top panel) and greater than 30 cm (bottom panel). The left panel shows the stratified mean number per tow, with horizontal line indicating mean of values obtained from 1971 to 2015 and the right panel shows the stratified mean weight per tow, with horizontal line indicating mean of values obtained from 1971 to 2015. Data from 2003 is omitted from the figure as an uncalibrated vessel was used in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

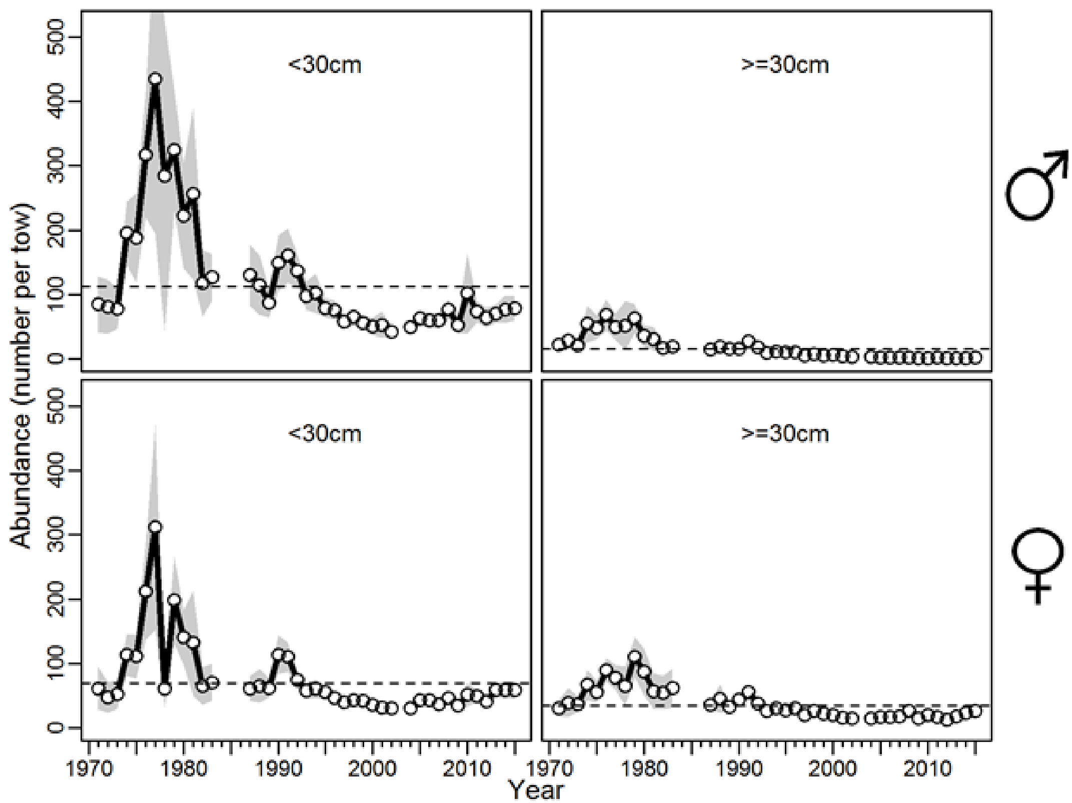

Figure 7. Survey abundance index of male and female plaice of length less than and greater than 30 cm, shown as the stratified mean number per tow, with horizontal line indicating mean of values obtained from 1971 to 2015. No estimates were available for 1984, 1985 and 1986 because no sex determination took place in those years. Data from 2003 is omitted from the figure as an uncalibrated vessel in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

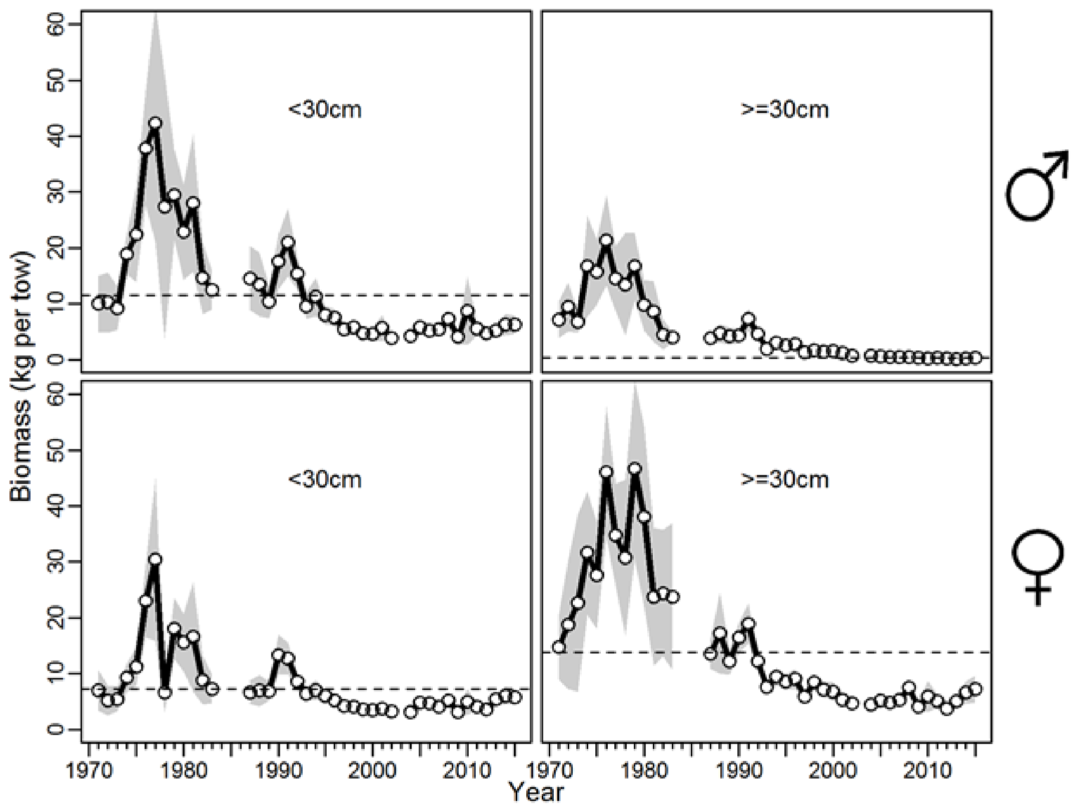

Figure 8. Survey biomass index of male and female plaice of length less than and greater than 30 cm, shown as the stratified mean kilogram per tow, with horizontal line indicating mean of values obtained from 1971 to 2015. No estimates were available for 1984, 1985 and 1986 because no sex determination took place in those years. Data from 2003 is omitted from the figure as an uncalibrated vessel in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

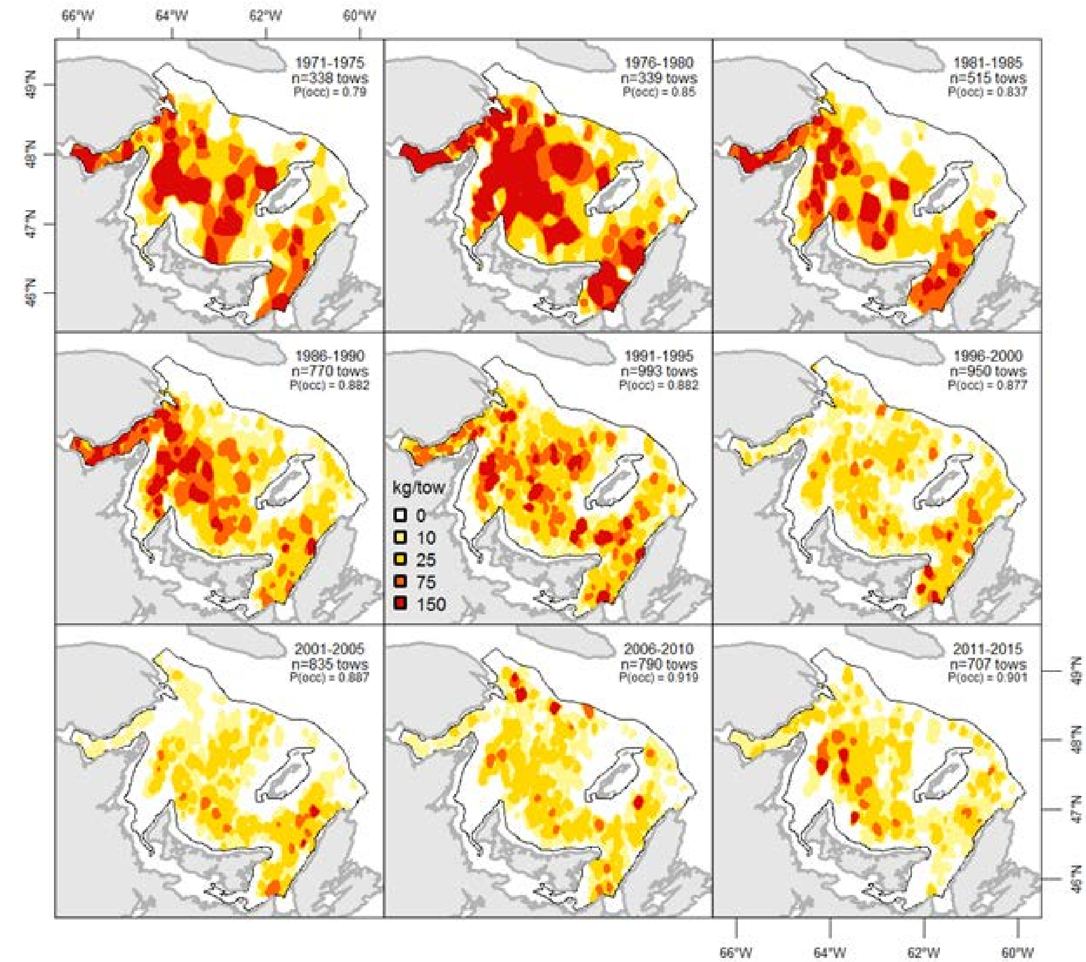

Figure 9. Distribution maps of American plaice catch biomass in the annual Southern Gulf of St. Lawrence trawl survey by 5-year periods.

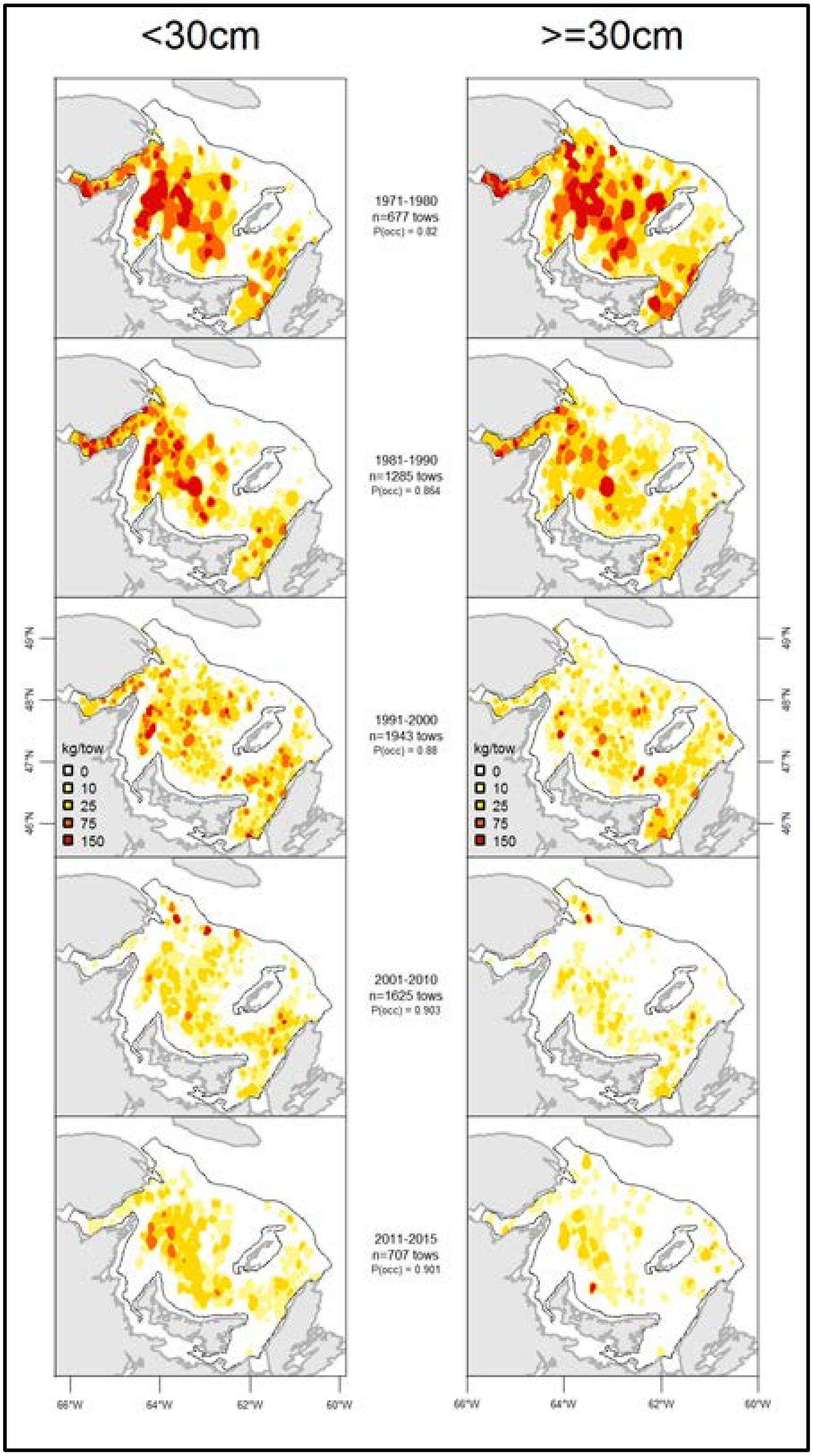

Figure 10. Distribution maps of American plaice catch biomass (individuals smaller than 30 cm in the left panel and individuals greater than 30 cm in the right panel) in the annual Southern Gulf of St. Lawrence trawl survey by 10-year periods (first 4 rows, 1971 to 2010) and 5-year period (last row, 2011-2015).

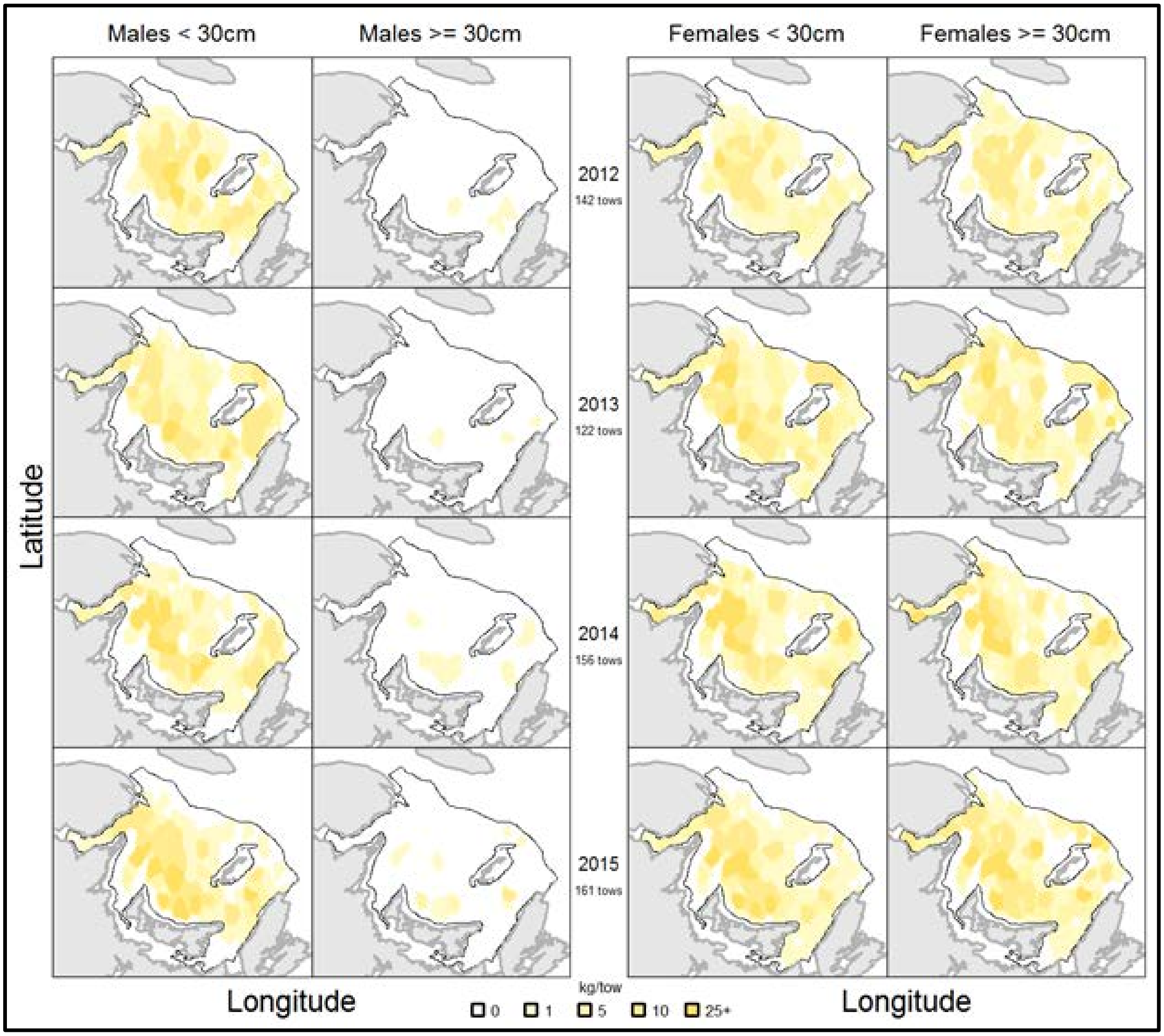

Figure 11. Distribution maps of American plaice catch biomass (kg per tow) in the annual Southern Gulf of St. Lawrence trawl survey over the last four years. Distribution maps for males appear in the two left columns and those for females appear in the two right columns. For each sex, the distribution of individuals smaller than 30 cm appear on the left and that of individuals greater than or equal to 30 cm appear on the right.

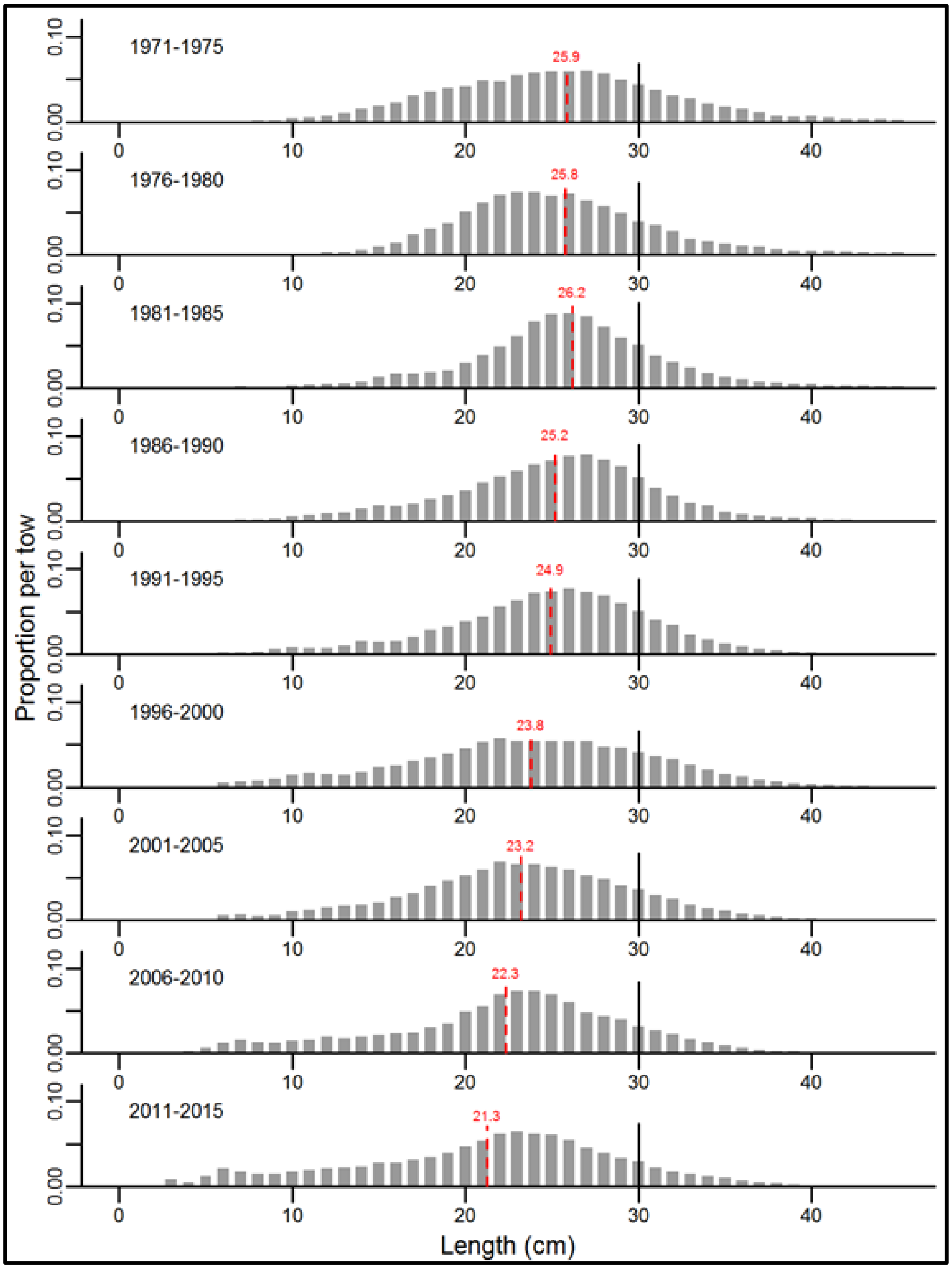

Figure 12. Length frequency of American plaice in the annual Southern Gulf of St. Lawrence trawl survey by 5-year periods. The mean length is shown as the red dashed vertical line and the solid line is the 30 cm minimum commercial size.

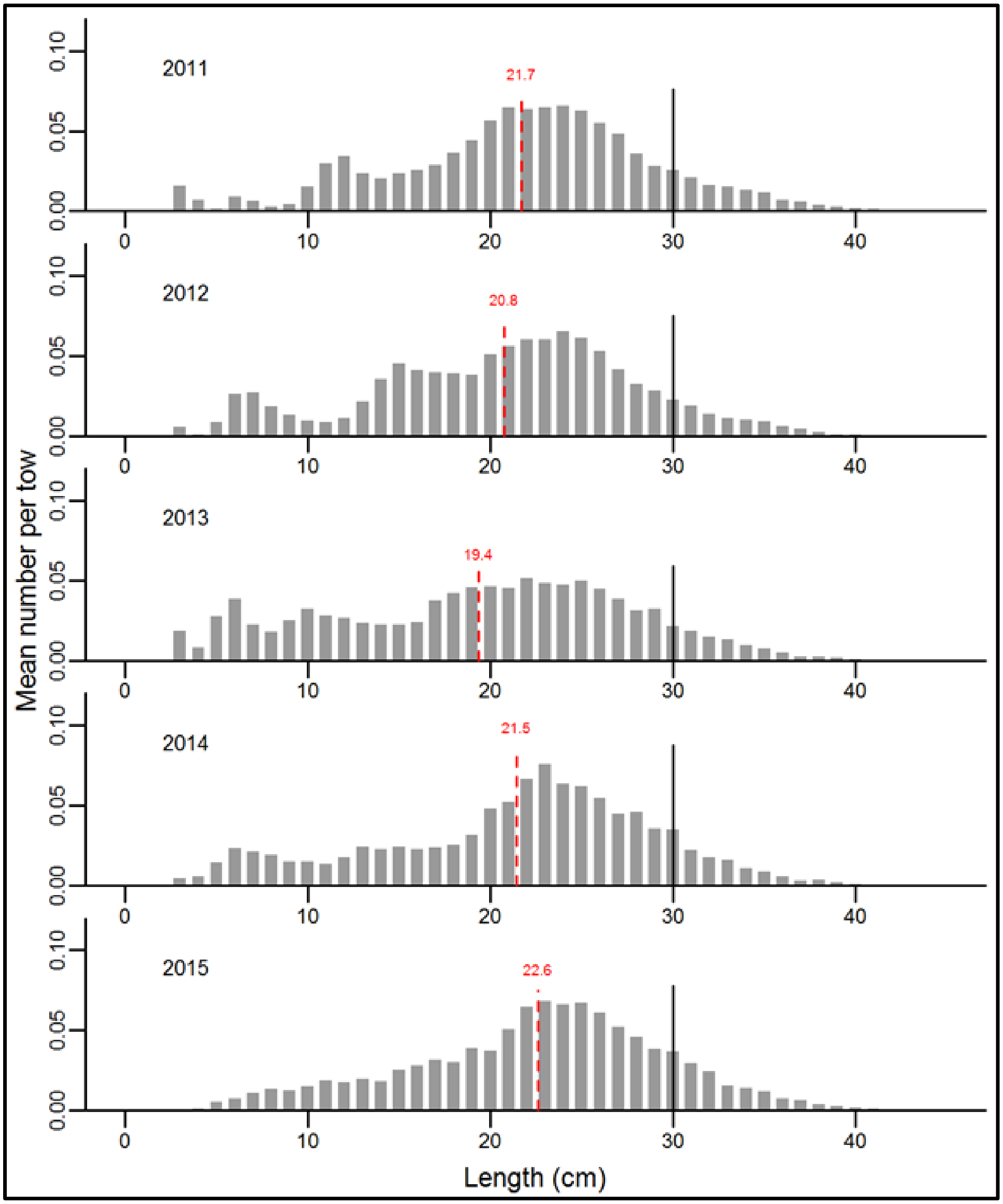

Figure 13. Length frequency of American plaice in the annual Southern Gulf of St. Lawrence trawl survey for the last available 5 years. The mean length is shown as the red dashed vertical line and the solid line is the 30 cm minimum commercial size.

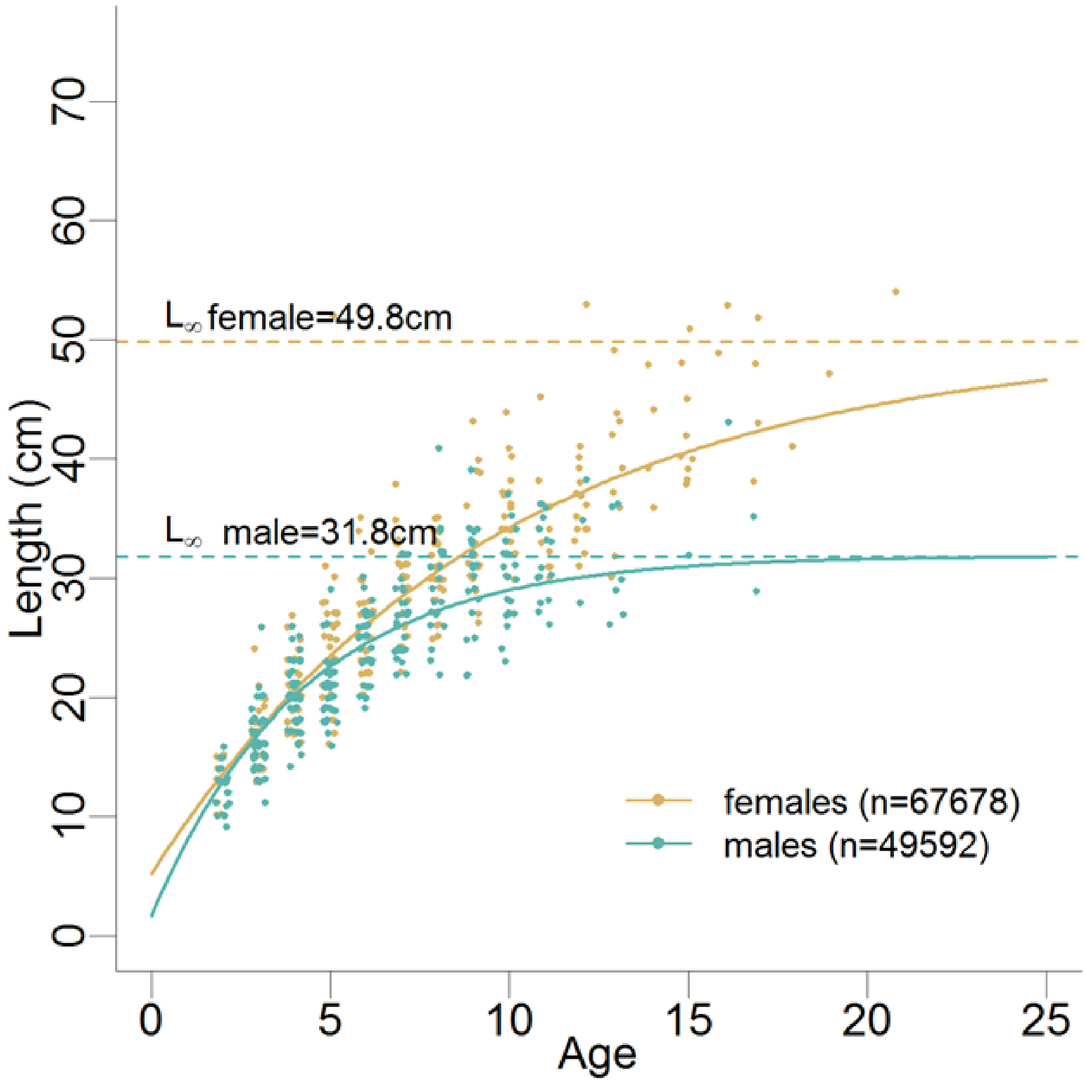

Figure 14. Growth of American plaice showing the relationship between length and age for individuals collected during the annual Southern Gulf of St. Lawrence trawl survey. A von Bertalanffy growth model was fitted separately for males and females. The points on the figure are 300 random age-length observations for each sex, the solid lines are the predicted lengths at age from the fitted growth models and the horizontal dashed lines are the asymptotic lengths for each sex. The age-length observations are jittered to ease visualisation.

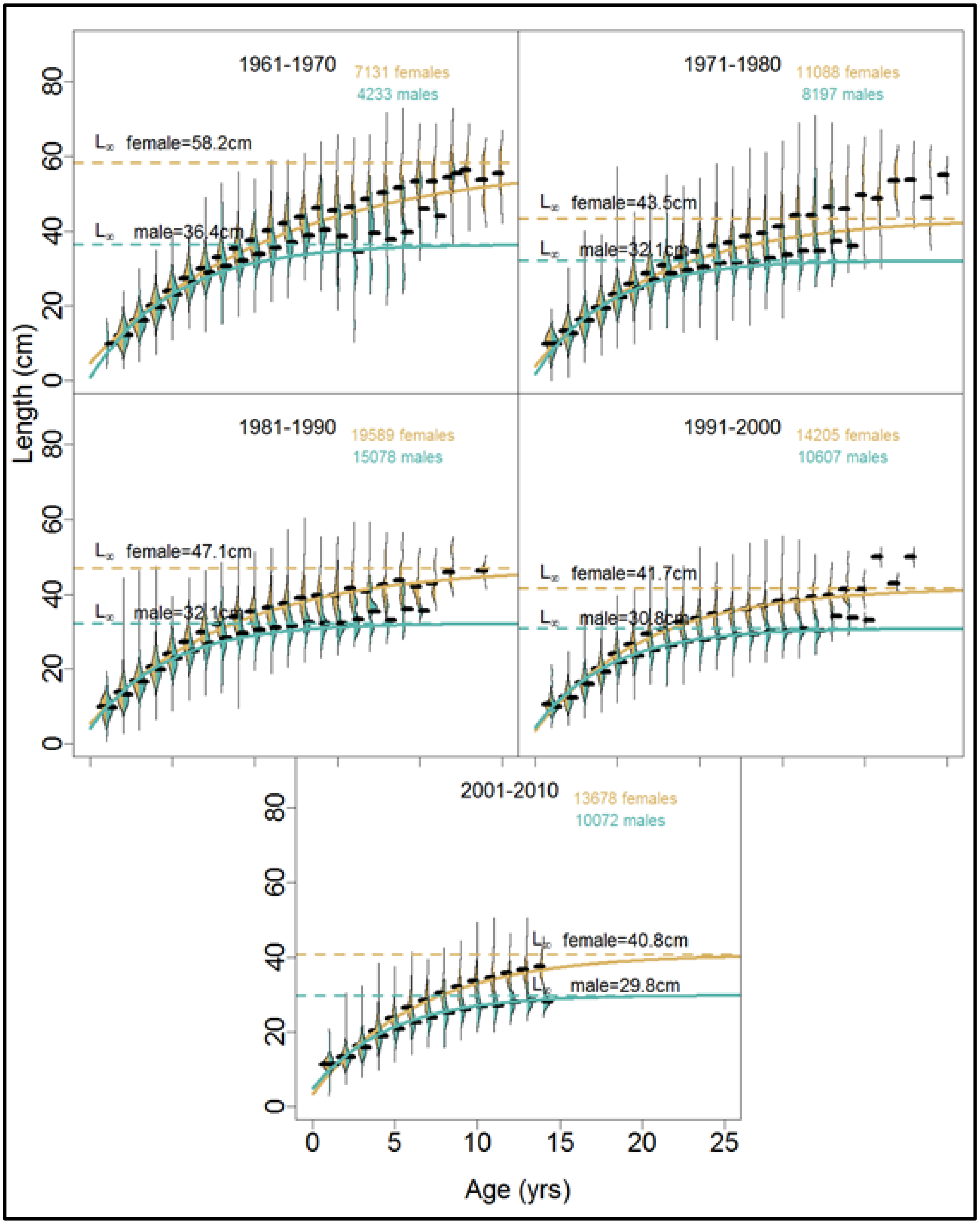

Figure 15. Growth of American plaice showing the relationship between length and age for individuals collected during the annual Southern Gulf of St. Lawrence trawl survey. A von Bertalanffy growth model was fitted separately for males and females born in the same year (cohort year) for different time decadal periods.

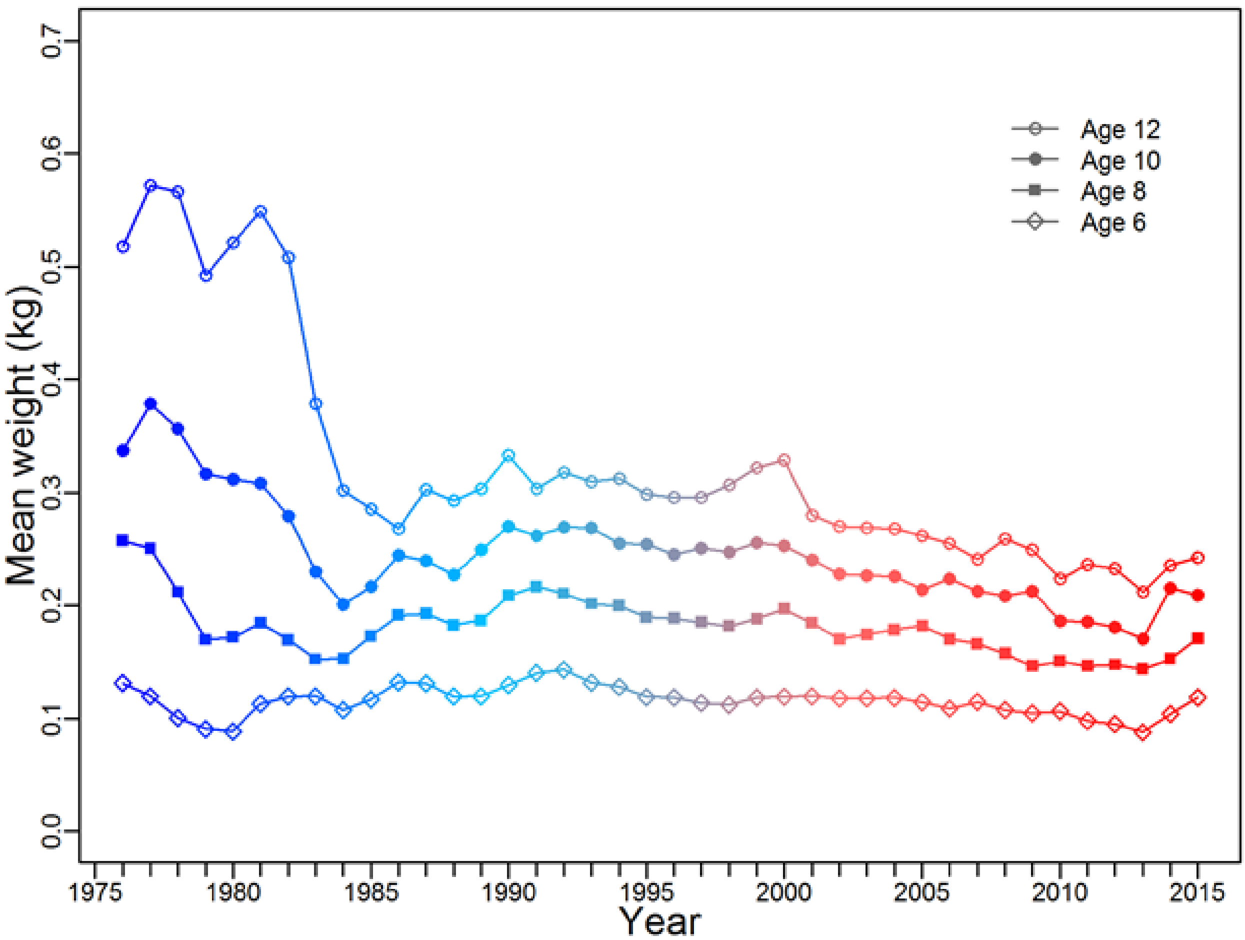

Figure 16. Mean weight-at-age (kg) of American plaice (sexes combined) for ages 6, 8, 10 and 12 years obtained from the annual southern Gulf of St. Lawrence September research vessel survey, 1976 to 2015.

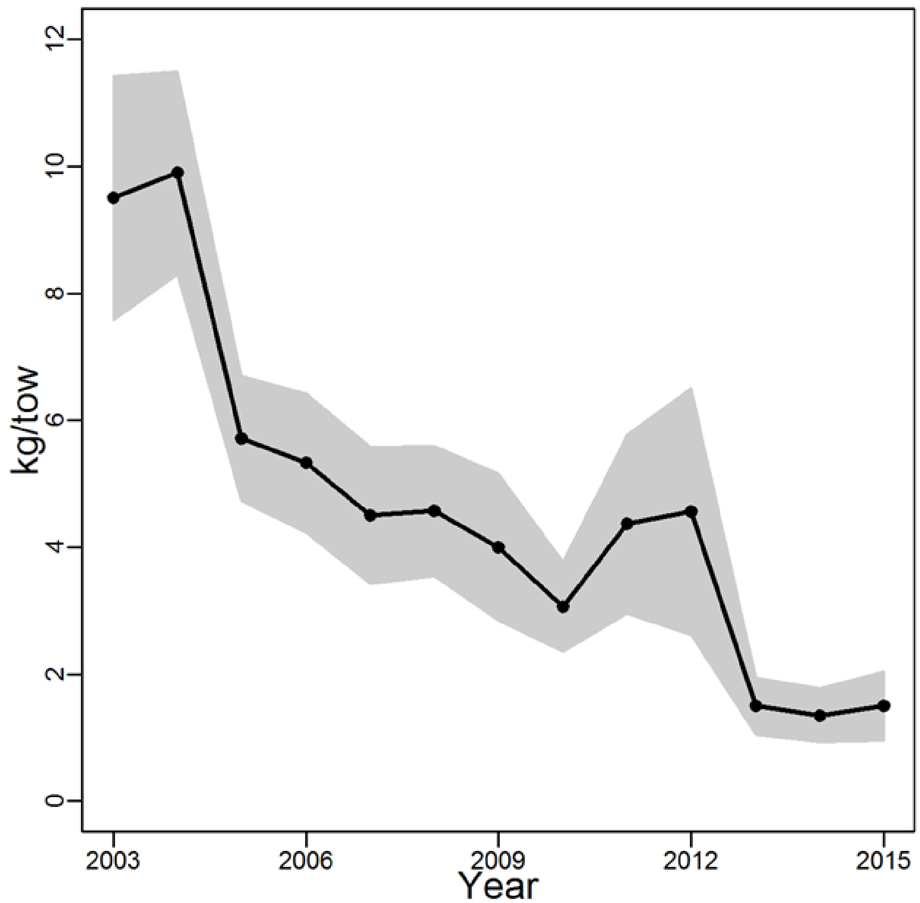

Figure 17. Mobile sentinel survey index (kg per tow) for American plaice in the southern Gulf of St. Lawrence, 2003 to 2015. The black line is the stratified mean estimate and the shading encompasses the 95% credibility interval of the estimates.

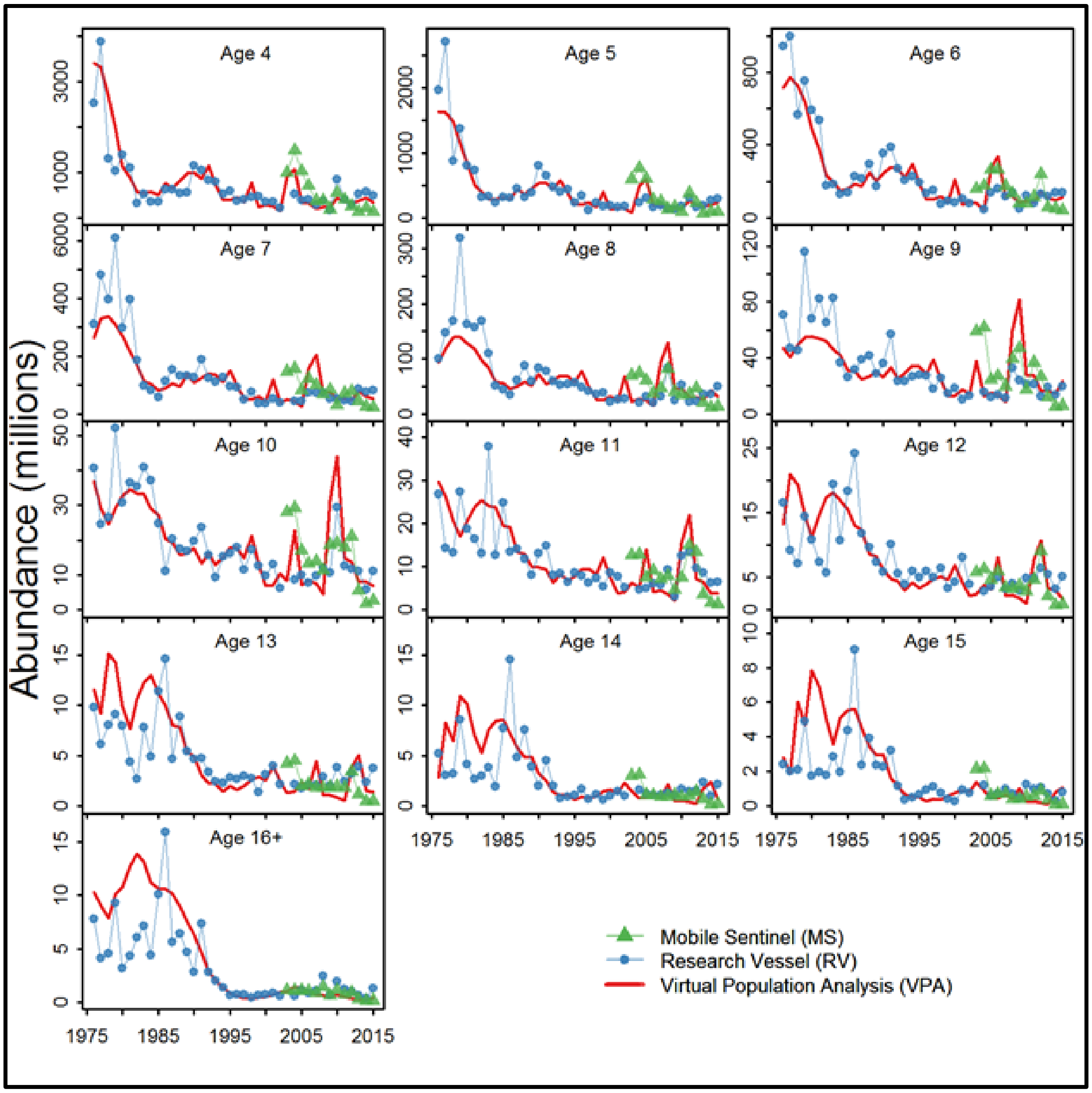

Figure 18. Comparison of population estimates for ages 4 to 16+ of American plaice from the VPA model (red lines) and the survey population estimates in January, corrected for catchability (RV survey: blue solid lines with blue dots, MS: survey: green solid lines with green triangles).

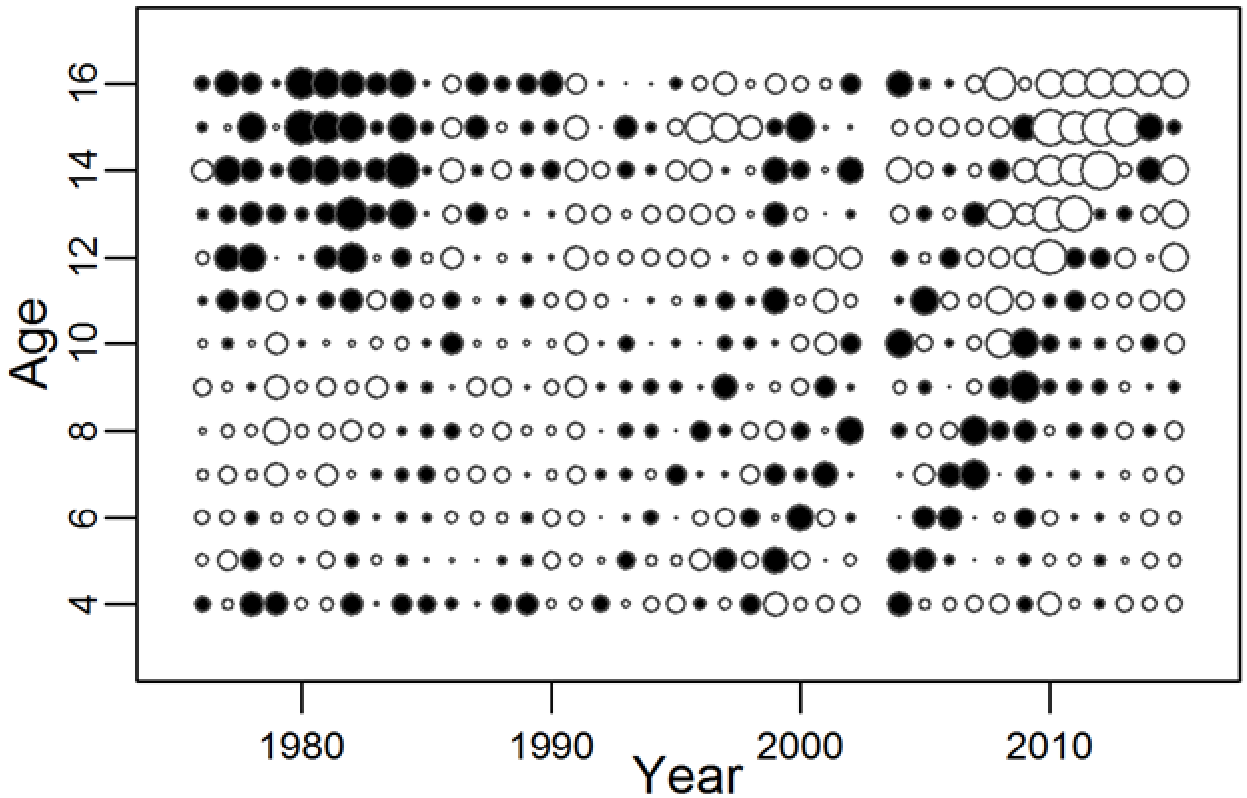

Figure 19. RV survey residual patterns for the VPA. Positive residuals (model abundance estimates exceeds q-corrected RV abundance) appear as open white dots and negative residuals (model abundance estimates are lower than q-corrected RV abundance) appear as black dots.

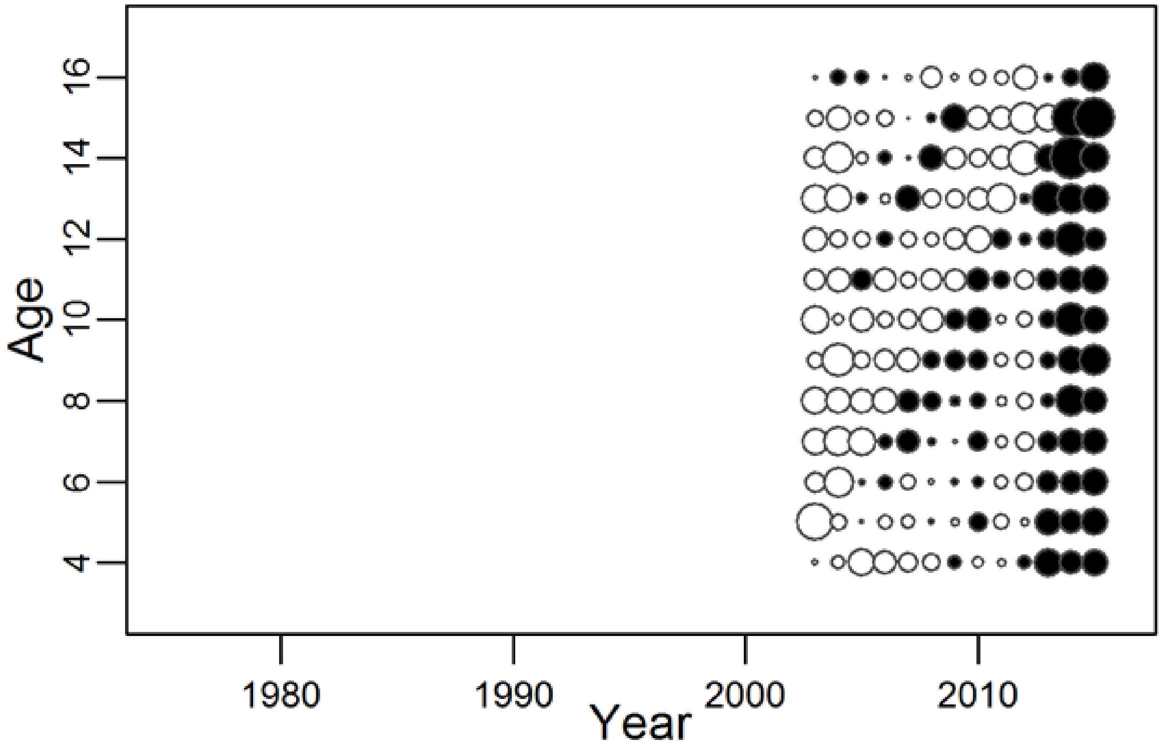

Figure 20. MS survey residual patterns for the VPA. Positive residuals (model abundance estimates exceeds q-corrected RV abundance) appear as open white dots and negative residuals (model abundance estimates are lower than q-corrected RV abundance) appear as black dots.

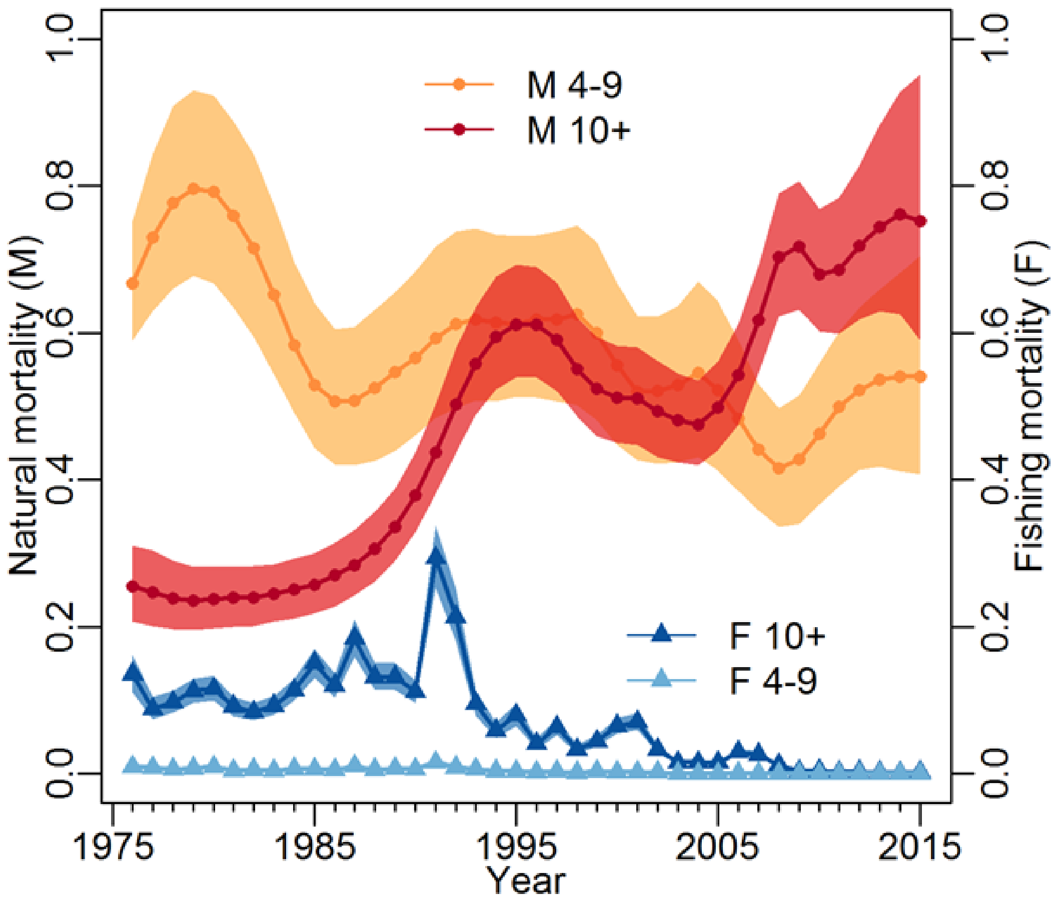

Figure 21. VPA estimates of the instantaneous rates of natural and fishing mortality for ages 4-9 and ages 10+. The solid lines and symbols are the median and the shading encompasses the 95% credibility interval of the estimates.

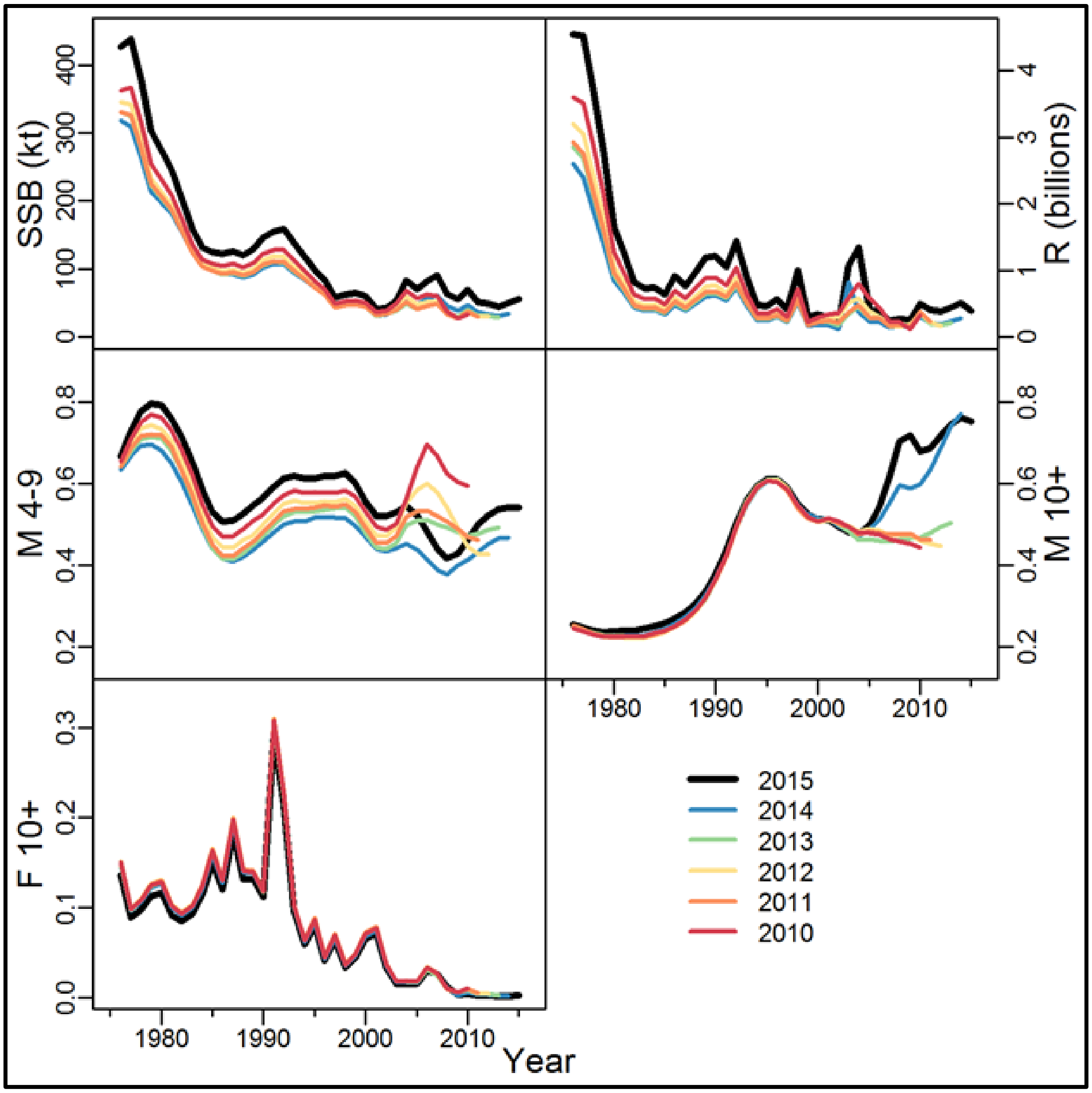

Figure 22. Retrospective analysis of population numbers from VPA showing estimates of spawning stock biomass (SSB, top left panel), recruitment (R, top right panel), natural mortality on ages 4-9 (M 4-9, middle left panel), natural mortality on ages 10+ (M 10+, middle right panel) and fishing mortality on ages 10+ (F 10+ bottom left panel) obtained from the full model and with one to five of the last years of data removed.

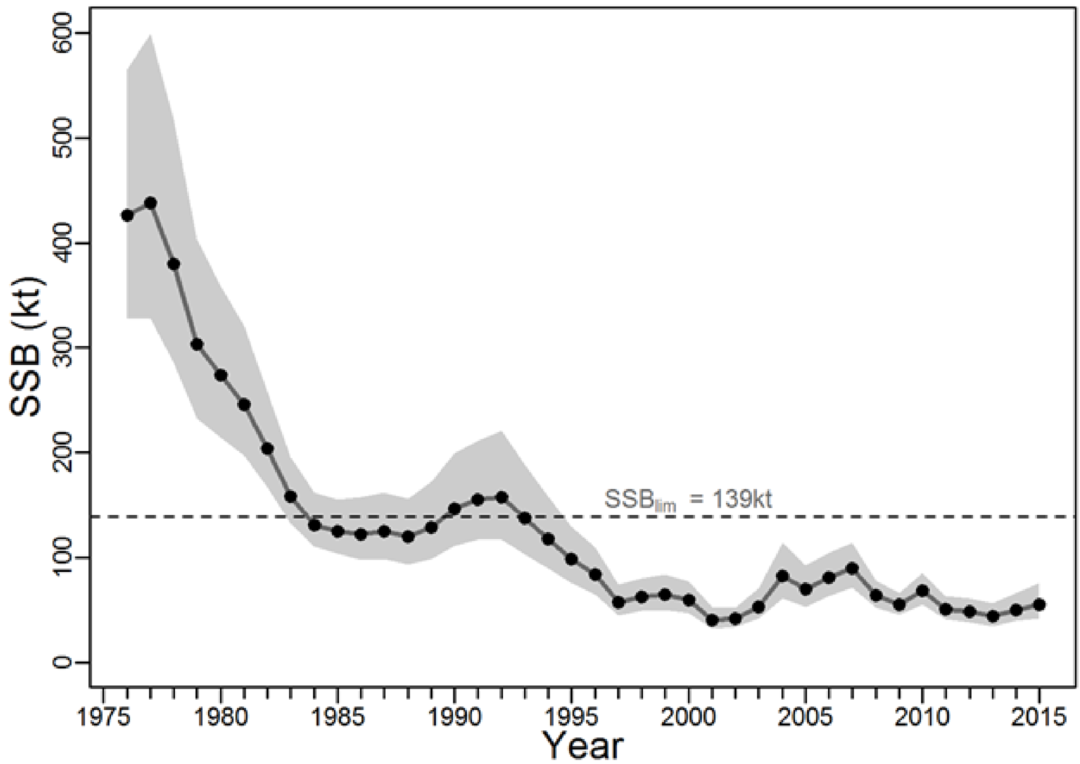

Figure 23. Estimates of yearly spawning stock biomass (SSB) from the virtual population analysis. The horizontal dashed line shows the lower limit reference point (B_{lim}) of 139 kt. The black line is the median and the shading encompasses the 95% credibility interval of the estimates.

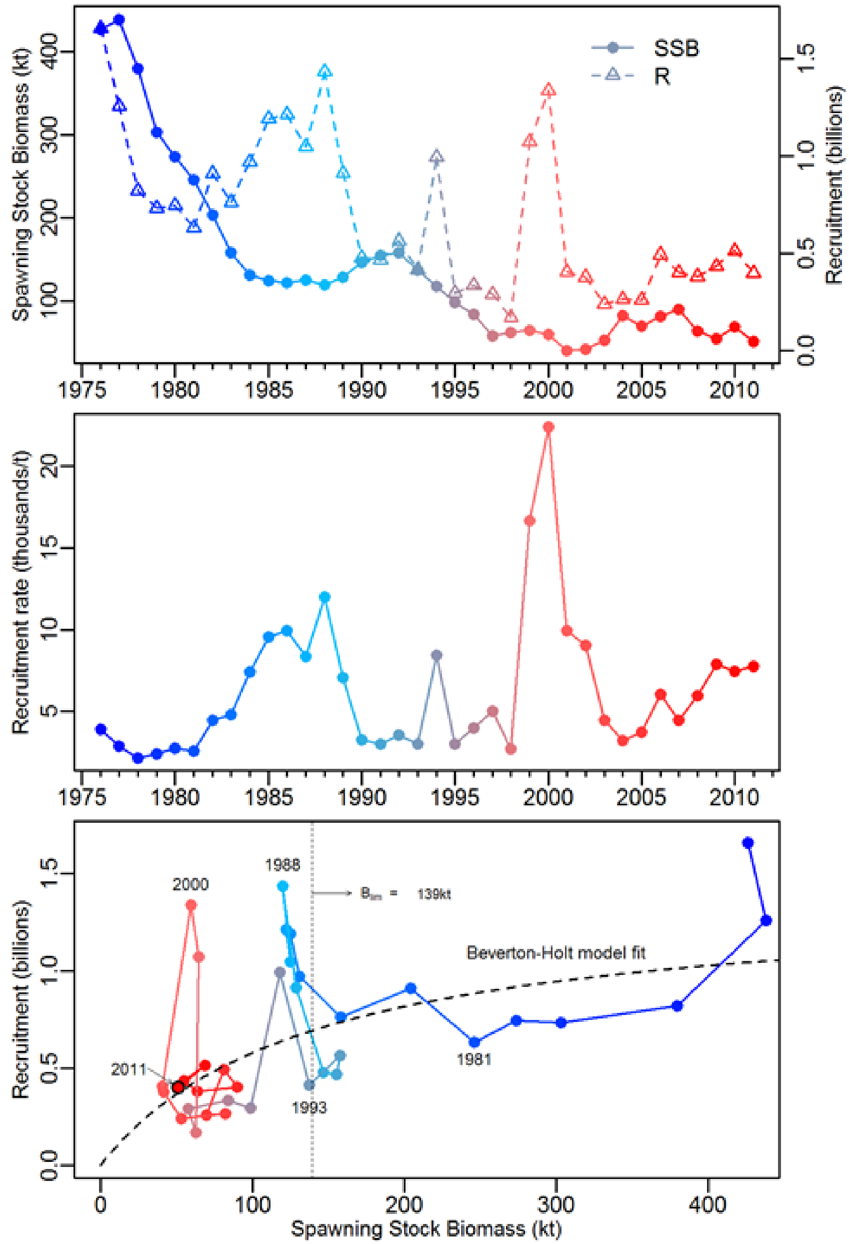

Figure 24. Stock and recruitment estimates from the VPA model. The top panel shows the time-series of spawning stock biomass and recruitment. The recruitment time-series is lagged to match the spawning stock that produced it (i.e., the age of recruitment).The time-series of recruitment rate, expressed as the number of recruits per unit of spawning stock biomass appears in the middle panel. The relationship between spawning stock and recruitment appears in the bottom panel. In all cases, the years are colour code from blue (early years) to red (recent years).

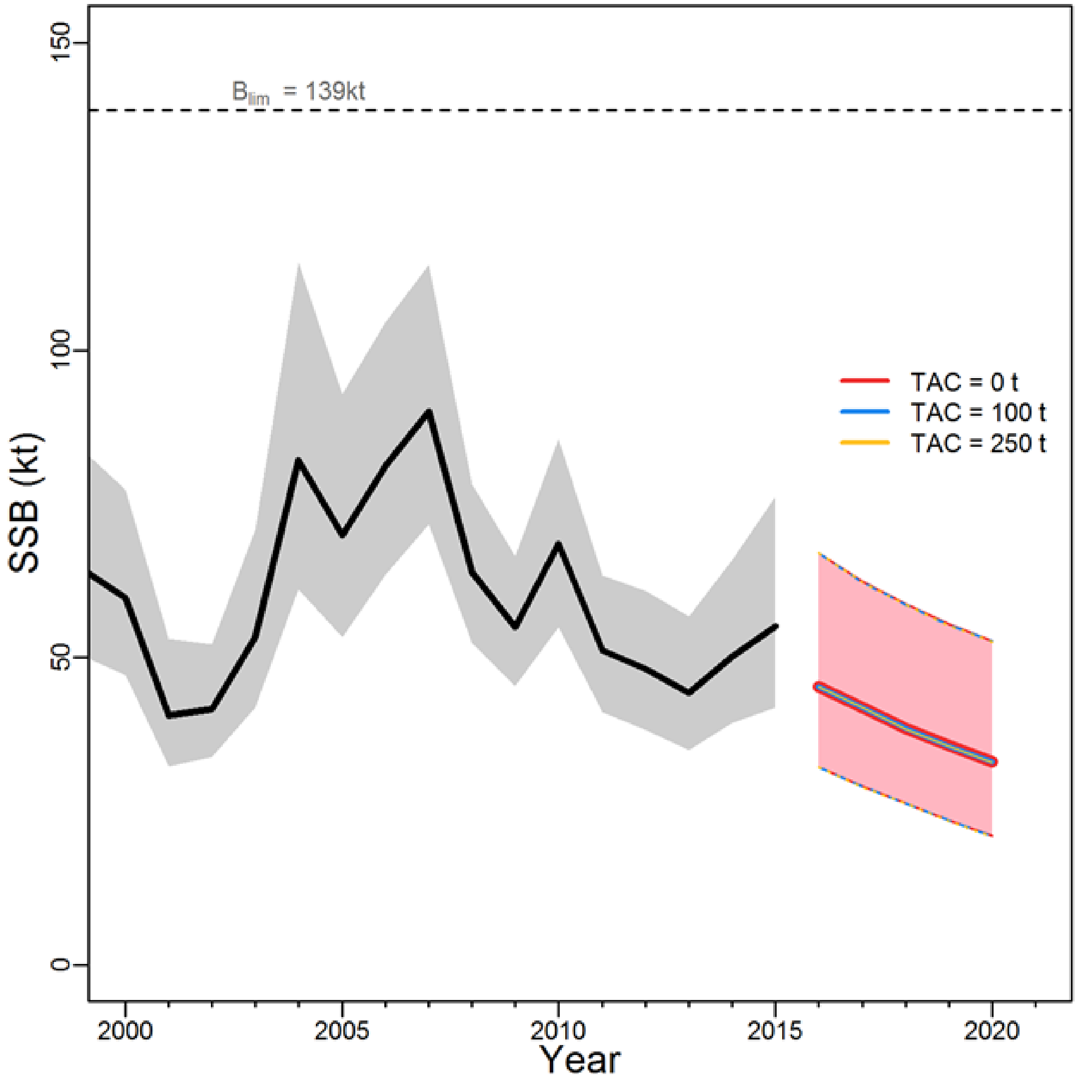

Figure 25. Ten-year stock projections of spawning stock biomass (SSB) under a TAC of 0 t, 100 t and 250 t under current levels of natural mortality. Note that the x-axis starts in year 2000 and that the y-axis has a smaller range that on previous figures showing estimates from 1976 to 2015. The black line is the median and the shading encompasses the 95% credibility interval of the estimates.