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Analytical assessment of the Atlantic Mackerel (*Scomber scombrus* L.) in NAFO Subareas 3 and 4 in 2011

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Foreword

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ABSTRACT

A sequential population analysis (SPA) was performed on the Atlantic mackerel (*Scomber scombrus* L.) component that spawns in the southern Gulf of St. Lawrence. The input parameters to this analysis were the data from the commercial fishery from the 1968–2011 period and the index of the spawning biomass from the egg surveys conducted since 1996. Despite high CV for some of the estimated parameters, the SPA presented no major retrospective pattern. The SPA revealed that the last two year-classes of high level of recruitment were those of 1999 and 2003 and that the year-classes that appeared over the last years were of medium and low level. Following a stability period (1968–1992), fishing mortalities reached very high values in the during the years 2000 and in particular for the older fish with exploitation rates varying between 50 and 80%. Total and spawning biomasses are decreasing since the mid-2000s and the last years values are near the minimum historic reached in 1999. Reference points were calculated from the SPA results and the biological data from the commercial sampling. Their evolution over the years indicates that there were overfishing since 2003. Given the average sustainable exploitation level of the 1968–1992 period, spawning biomasses projections for 2012, 2013, and 2014 would be of 62 218 t, 64 462 t, and 64 181 t, respectively, and projected catches for 2012 and 2013 would reached 8 785 t and 8 636 t. Given that stock abundance should not increase in the short term (absence of strong recruitment according to the SPA), the fishing mortality rates over the next few years should be lower compared to that of 2011. Therefore, in order to bring back fishing mortality to the average sustainable exploitation level of the 1968–1992 period, catches in 2012 and 2013 should not exceed 9,000 t.

Évaluation analytique du maquereau bleu (*Scomber scombrus* L.) des sous-régions 3-4 de l'OPANO en 2011

RÉSUMÉ

Une analyse séquentielle de population (ASP) a été réalisée sur la composante de maquereau bleu (*Scomber scombrus* L.) se reproduisant dans le sud du golfe du Saint-Laurent. Les paramètres d'entrée à cette analyse étaient les données de la pêche commerciale de la période 1968–2011 et l'indice de la biomasse reproductrice des relevés des œufs réalisés depuis 1996. Malgré des CV élevés pour certains des paramètres estimés, l'ASP n'a présenté aucun patron rétrospectif majeur. L'ASP a révélé que les deux dernières classes d'âge de niveau de recrutement élevé étaient celles de 1999 et 2003 et que celles qui sont apparues au cours des dernières années étaient de niveau moyen et faible. Suite à une période de stabilité (1968–1992), les mortalités par la pêche ont été très élevées au cours des années 2000 et en particulier chez les poissons âgés avec des taux d'exploitation de 50 à 80 %. Les biomasses totales et reproductrices sont à la baisse depuis le milieu des années 2000 et les valeurs des dernières années sont près du minimum historique qui a été atteint en 1999. Des points de références ont été calculés à partir des résultats de l'ASP et des données biologiques provenant de l'échantillonnage commercial. Leur évolution au cours des ans indique qu'il y aurait eu surpêche depuis 2003. Selon le niveau d'exploitation soutenable moyen de la période 1968–1992, les biomasses reproductrices projetées pour 2012, 2013 et 2014 seraient respectivement de 62 218 t, 64 462 t et 64 181 t et les captures projetées pour 2012 et 2013 atteindraient 8 785 t et 8 636 t. Étant donné que l'abondance du stock est à un niveau très bas et qu'il ne devrait pas augmenter à court terme (absence d'un fort recrutement selon l'ASP), les mortalités par la pêche des prochaines années devraient être réduites par rapport à celle de 2011. Par conséquent, pour ramener la mortalité par la pêche au niveau moyen soutenable de la période 1968–1992, les captures de 2012 et de 2013 ne devraient pas dépasser 9 000 t.

1. INTRODUCTION

In eastern Canada, it is generally known that the Atlantic Mackerel (*Scomber scombrus* L.) spawns mainly in the southern Gulf of St. Lawrence (NAFO Division 4T) (Sette 1943, Arnold 1970). This is the reason why an egg survey was conducted in this area with the goal of calculating a spawning biomass index. According to the survey, the index was very high between 1984 and 1994 with annual values that could exceed 500 000 t (Grégoire *et al*. 2013a). During the same period, annual landings averaged 24 441 t (Grégoire *et al*. 2013b). This significant gap between the abundance index and landings has always been a major impediment to using sequential population analysis (SPA) because SPA can only reconstruct cohorts accurately if the instantaneous rate of natural mortality (M) is low with respect to the fishing mortality rate (F) (Hilborn and Walters 1992; Mertz and Myers 1997).

The Atlantic Mackerel spawning biomass index experienced a sharp decrease beginning in 1996 (no survey in 1995), coinciding with a significant increase in commercial landings (Grégoire *et al*. 2013b). This study suggests that these new abundance and landing levels can enable the use of an SPA.

The purpose of this study was to develop and carry out an SPA on the Canadian component of the Atlantic Mackerel commercial fishery data by using the spawning biomass from egg surveys conducted since 1996 as a calibration index.

2. MATERIAL AND METHODS

2.1. DATA SOURCE

2.1.1 Catch-at-age

The Canadian catch-at-age has been updated (Grégoire *et al*. 2013b) so that the period covered by the SPA runs from 1968 to 2011 and includes ages 1 to 10^{+} (Tables 1 and 2). Commercial line fishery and sport fishing discard data are not recorded and neither are certain catches used as bait (e.g.: for personal use or direct sales at sea between fishers).

2.1.2 Weights at age

The weights at age of commercial catches (mid-year) (Table 3) were updated and used to convert the catch-at-age, expressed as a number, into the biomass (t) of the catch-at-age (Table 4). The catch-at-age biomass (the annual total of all age classes) was compared with commercial landings to detect possible grouping or weighting errors in the calculation of the catch-at-age. The weights at age were converted to the weights at age at the beginning of the year (January 1) (Table 5) using the Rivard method, version 2.0 (NOAA Fisheries Toolbox 2009a). Lastly, the biomass for the different age classes was calculated by multiplying the weights at age at the beginning of the year by the numbers at age (abundances) from the SPA.

2.1.3 Maturity-at-age

The annual proportions of maturity-at-age (Table 6) were calculated from 1974 and onwards using biological data from the analysis of commercial samples collected during the spawning season (June and July). The proportions of maturity-at-age were adjusted using the SAS LOGISTIC procedure (SAS Institute 2008). Since the data series for catch-at-age begins in 1968, the values for maturity-at-age in 1974 were applied to the period 1968-1973. The spawning biomass-at-age was calculated by multiplying the annual proportions of maturity-at-age by the respective values for biomass-at-age.

2.1.4 Spawning biomass index

The annual spawning biomass index values from the egg survey are presented in Table 7. No surveys were conducted in 1995 and 1997 and partial surveys were conducted in 1999 and 2001. The results from these surveys were not used in this study; neither were those from the 2006 survey, which was conducted at the end of the spawning season.

2.2. FORMULATION OF THE ANALYTICAL ASSESSMENT

The analytical assessment was performed using the ICA (Integrated Catch at Age) software, version 1.2 (Patterson and Melvin 1995), which is commonly used in the assessments of Atlantic Mackerel from the Northeast Atlantic. ICA allows for the use of an abundance index not disaggregated by age like the one from the egg survey. Various formulations were tested and the one finally selected is shown in Table 8. The selection of this formulation was based on the examination of residuals (values and patterns) and CVs (smaller values) at age of the estimated parameters. These parameters are the annual fishing mortality between 2006 and 2011, selectivity at age for ages 1 to 9 (set to ages 3 and 9), abundance at ages 1 to 9 in 2011 and abundance at age 9 between 2006 and 2010.

2.3. RETROSPECTIVE PATTERN

The presence of a retrospective pattern was examined for the period 2007-2011 for fishing mortality (average of ages 3-5 weighted by the corresponding abundances), total population ('000) for ages 1-10$^+$, recruitment ('000) (age 1), and total biomass (t) and spawning biomass (t).

2.4. SHORT-TERM PROJECTIONS

Projections of catches were made for two years (2012 and 2013) from abundances at age (1-10$^+$) estimated at the beginning of 2012 using SPA. Catches ($C_{t,a}$) were projected using Baranov's equation (Haddon 2011), which is defined as follows:

$$C_{t,a} = \left(\frac{F_{t,a}}{F_{t,a} + M}\right) N_{t,a} \left(1 - e^{-(M + F_{t,a})}\right)$$

where $\boldsymbol{F_{t,a}}$ is the instantaneous fishing mortality rate (average of ages 3-5 weighted by the corresponding abundances) at time $\boldsymbol{t}$ and age $\boldsymbol{a}$, $\boldsymbol{M}$, natural mortality, set to 0.20 and $\boldsymbol{N_{t,a}}$, abundance by age at the beginning of the year. Baranov's equation assumes that the instantaneous fishing mortality rate and natural mortality rate are constant throughout the year and that their effect on the population is simultaneous (Type II fishery, Ricker 1980). Projected catches were converted into tonnes using the mean weights at age (mid-year) from 2010 and 2011.

Abundances $N_{t+1,a+1}$ at the beginning of 2013 and 2014 were estimated using the following equation:

$$N_{(t+1,a+1)} = N_{t,a} \left(e^{-(M + F_{t,a})}\right)$$

These abundances were converted into spawning biomass (t) using the 2010 and 2011 mean weights at age (on January 1) and mean proportions of maturity at age in 2010 and 2011. Note that the abundances at age 1 at the beginning of 2013 and 2014 correspond to the 2010 and 2011 mean abundance of recruits (age 1). Finally, following the results of the SPA, the projections were made using the mean sustainable level of fishing mortality for the period 1968-1992.

2.5. REFERENCE POINTS

Fishing mortality reference points were calculated using a yield-per-recruit analysis and the YPR procedure, version 2.7.2 (NOAA Fisheries Toolbox 2009b). The input parameters were selectivity, weights, proportions of maturity at age, as well as natural mortality. Selectivity at age was calculated using fishing mortalities computed by SPA between 2008 and 2011. Natural mortality was set to 0.2 and the weights and proportions of maturity-at-age correspond to the averages for the period 2008-2011.

The following reference points were selected: $F_{0.1}$, F_{max}, and $F_{40\%}$ which, according to Clark (1993) and Mace (1994), is a proxy for F_{msy}. Two other reference points, spawning stock biomass providing maximum sustainable yield (SSB_{msy}) and maximum sustainable yield (*msy*) were calculated analytically and using a random approach.

2.5.1 Analytical approach

In the analytical approach, SSB_{msy} is calculated by multiplying the recruits at age 1 (average of year-classes from 1967 to 2011) by the spawning stock biomass per recruit (*SSB/R*) at$F_{40\%}$. In the analytical approach, *msy* is calculated by multiplying these recruits by the yield per recruit (*YPR*) at $F_{40\%}$.

2.5.2 Random approach

SSB_{msy} and *msy* as well as the total biomass (as an indicator) were randomly calculated based on projections using the AGEPRO procedure (NOAA Fisheries Toolbox 2009c). These projections were calculated with a 100-year outlook with $F_{40\%}$ as the annual harvest strategy. After a few years, the projections stabilized and SSB_{msy} and *msy* were defined as the respective averages for the 2024-2112 period. In the projections, recruits were calculated using an empirical cumulative function (AGEPRO, model 14) rather than a standard stock-recruitment model whose relationship is predetermined (e.g.: Beverton-Holt and Ricker). The empirical cumulative function generates recruits assuming that their distribution is stationary and independent of stock size.

2.5.3 Stock trajectory based on fishing mortality and spawning biomass status

Stock trajectory (2002–2011) was described by monitoring the annual relationships between fishing mortality and $F_{40\%}$, and spawning biomass and SSB_{msy}. The trajectory is projected using a figure divided into four areas: (1) "*being overfished and overfished*", (2) "*being overfished and not overfished*", (3) "*not being overfished and not overfished*", and (4) "*not being overfished and overfished*." This approach is based on the one used by NOAA (National Oceanic and Atmospheric Administration) for stocks along the U.S. east coast. (e.g.: Northeast Fisheries Science Center 2008).

3. RESULTS

3.1. ANALYTICAL ASSESSMENT

3.1.1 Diagnostics

Diagnostics of the parameters estimated by the SPA are presented in Table 9. The coefficients of variation (CV) are high for the fishing mortality in 2011, abundances at ages 1, 2, 8 and 9 in 2011 and abundances at age 9 in 2006 and 2010. For all other parameters, the average CV calculated by SPA is 39%. There are no specific patterns in the residuals of the logarithms of the catchability coefficients for the separable period (2006–2011) of the SPA (Figure 1A). The highest residuals were obtained in 2008 and 2010 (Figure 1B) and at ages 8 and 9 (Figure 1C).

3.1.2 Retrospective analyses

The fishing mortalities at ages 3-5 show a slight retrospective pattern (Figure 2A). The pattern is less pronounced for abundances (Figure 2B), recruits (Figure 2C) and total biomass (Figure 2D). However, the total biomass exhibits small deviations for two of the four years that were back-calculated. There is no retrospective pattern in the spawning biomass.

3.1.3 Abundance and recruitment

Until the late 1990s, the pattern of annual abundances was characterized by the periodic presence of very strong year-classes which remained in the population for several years (Table 10, Figure 3A). Since the early 2000s, the abundance patterns have instead been characterized by a presence of less significant year-classes. For the same period, the total abundance decreased and there were few older fish (6^+) (Figure 3B).

In descending order, the largest year-classes at ages 1 and 2 occurred in 1982, 1999, 1974, 1967 and 2003 (Figures 4A and 4B). The abundance of these year-classes was higher than the high recruitment level. The year-classes that appeared between 1967 and 1975 were instead characterized by abundances that are higher than medium or high recruitment levels. With the exception of the year-classes 1981, 1982, 1987, 1988 and 1999, those that appeared between 1976 and 2001 were lower in abundance than the average recruitment levels. Finally, in the year-classes that occurred after 2002, abundances at ages 1 and 2 were characterized by high to medium levels of recruitment with the exception of year-classes 2006, 2009 and 2010, which exhibited low levels.

3.1.4 Partial recruitment

Partial recruitment has changed little since the early 2000s with values at or near 1 after having reached the maximum value (Figure 5A). The maximum value was observed for age 4 in 2010 and age 5 in the preceding years. A sharp drop in partial recruitment occurred after the maximum value (less than 1) was reached in 1970 and 1980.

3.1.5 Fishing mortality

Fishing mortality changed little between 1968 and 1992, with an average value of 0.124 (Table 11, Figure 5B). After 1992, fishing mortality gradually increased for all age groups and very high values between 1 and 2 were attained in the 2000s, especially for older fish (6^+). Fishing mortality has been declining among all age groups since 2008. From 1968 to 1992, exploitation rates were below 20% (Figure 5C). Between 2000 and 2008, exploitation rates of older fish (6^+) ranged from 50% to 80% and have dropped among all age groups since 2008.

3.1.6 Total and spawning biomass

Between 1968 and 1984, total biomass (Table 12) and spawning biomass (Table 13) remained stable between 200 000 t and 400 000 t (Figure 5D). This was followed by a clear downward trend with historical low levels in 1998 and 1999. The biomass increased between 1999 and 2001 after the arrival of the strong 1999 year-class, and remained between 150 000 t and 200 000 t until 2006 but has been declining since.

3.1.7 Recruitment rate

The highest recruitment rate was produced by the 1999 year-class (Figure 6A). The same year the spawning biomass was at its lowest level. The 1982 and 1974 year-classes produced the second- and third-highest recruitment rates respectively.

3.1.8 Relationship between recruits, fishing mortality and spawning biomass

The relationship between recruits and spawning biomass does not show any particular pattern (Figure 6B). The strong year-classes of 1974 and 1982 were produced when the spawning biomass was at average abundance levels while the 1999 year-class emerged when the stock was at its lowest level. Also, very few recruits were produced when the spawning biomass was at its highest level.

Until the early 1990s, fishing mortality was approximately 0.2 for a spawning biomass between 200 000 t and 400 000 t (Figure 6C). The spawning biomass declined rapidly until 1995 without major changes in fishing mortality. Subsequently, fishing mortality and spawning biomass both showed a sharp increase in 2000 and 2001 with the arrival of the strong 1999 year-class. Spawning biomass declined again starting in 2004, while mortality remained high until 2009 before decreasing rapidly until 2011.

3.2. REFERENCE POINTS

The inputs for the yield-per-recruit (YPR) analysis (Figure 7) are presented in Table 14. Reference points $F_{0.1}$, F_{max}, and $F_{40\%}$ were estimated to be 0.270, 0.767 and 0.222 respectively (Table 15). At $F_{40\%}$, the yield-per-recruit and spawning biomass per recruit would be 0.186 and 0.821. At an average recruitment level (170 626 x 10^3) and at $F_{40\%}$, *msy* and SSB_{msy} would be 31 672 t and 140 081 t (Table 16) using the analytical approach, and 30 026 t and 132 808 t (Figures 8A and 8B) using the random approach. According to the same projections, the total biomass would be 188 103 t (Figure 8C).

3.3. STOCK TRAJECTORY

The relationship between fishing mortality measured in 2011 and $F_{40\%}$ (F_{msy}) was set to 0.7 and the relationship between spawning biomass and SSB_{msy} was set to 0.515 and 0.543 for the analytical and random methods (Table 16). From 2002 to 2007, the stock trajectory shifted from the "*not being overfished and not overfished*" range to the "*being overfished and not overfished*" range (Figure 9). It was in the "*being overfished and overfished*" range from 2008 to 2010 and finally in the "*not being overfished and overfished*" range in 2011. According to these results, the stock has been overfished since 2003.

3.4. LANDING PROJECTIONS FOR 2012 AND 2013

Spawning biomass projections for the beginning of 2012, 2013 and 2014 were estimated at 62 218 t, 64 462 t and 64 181 t (Table 17). According to the average sustainable exploitation level of the 1968–1992 period (F = 0.124), catch projections for 2012 and 2013 would be 8 785 t and 8 636 t.

4. DISCUSSION AND CONCLUSION

This analytical assessment represents the first time the Canadian component of the Atlantic Mackerel has been examined. Although there were no major retrospective patterns, some of the parameters estimated by SPA have high CVs as do some catchability coefficients. We are still working on the on formulation of the SPA and will pay special attention to the values assigned to natural mortality during the next assessment. Nevertheless, this SPA lends credibility to the egg index for the 2000s which tended to be discounted because of its low values.

Reference points calculated using the two estimation methods provide similar results, increasing confidence in the validity of the values. However, the reference points were estimated for informational purposes only. As with stock trajectory monitoring, they did not undergo a peer review focused exclusively on the Precautionary Approach. However, they represent a starting point for developing this type of approach.

According to the SPA, the arrival of strong year-classes resulted in an increase in biomass or that the biomass remained at the same level. The sharpest drop in biomass occurred between 1992 and 1999 when the strong 1982 year-class was in decline with fish aged 10 years and older. It therefore seems that biomass levels are linked not only to the strength of the year-classes but also their frequency. The last strong year-class is the one from 1999 and recent year-classes are characterized by medium or low recruitment levels.

Given that stock abundance is not expected to increase in the short term (lack of strong recruitment according to the SPA), the fishing mortality levels the in the coming years should be lower compared to the mortality level in 2011. As a result, to bring this rate back to the mean sustainable level of 1968 to 1992, catches from 2012 and 2013 should not exceed 9 000 t.

The Canadian component of Atlantic Mackerel is now at a very low abundance level. For the time being, it may not be subject to recruitment overfishing because similar levels of abundance, measured at the end of the 1990s were followed by the arrival of the strong 1999 year-class.

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TABLES

Table 1. Catch-at-age ('000) of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1968	**43 062**	7 157	10 343	7 393	2 819	1 349	721	1 658	**10 425**	97
1969	5 692	**26 359**	18 057	2 027	929	855	1 099	440	462	**9 656**
1970	20 277	3 654	**33 584**	8 047	2 496	451	425	1 578	1 645	4 335
1971	7 156	7 389	1 702	**35 931**	7 620	1 753	2 203	1 526	1 879	5 517
1972	1	136	4 401	5 541	**24 826**	4 975	5 248	77	546	6 833
1973	9 176	20 624	9 649	9 333	13 972	**22 293**	8 317	2 771	837	1 603
1974	8 618	24 340	26 703	14 602	12 594	12 417	**15 377**	4 053	1 714	1 749
1975	**14 206**	24 905	13 049	11 636	7 052	7 526	5 456	**3 917**	825	581
1976	1 686	**21 171**	27 110	10 982	7 740	3 868	4 922	3 977	**3 123**	1 165
1977	740	7 136	**22 566**	11 319	3 683	2 570	809	1 443	897	**1 721**
1978	2	182	3 831	**14 733**	11 575	6 358	3 157	1 649	1 402	2 497
1979	204	480	1 189	6 615	**17 202**	12 321	5 590	2 282	1 702	2 457
1980	6	1 455	2 156	1 463	5 087	**9 833**	6 148	2 692	1 604	1 998
1981	6 145	2 836	5 143	1 183	1 656	4 669	**7 743**	3 309	1 595	1 892
1982	2 145	5 899	1 609	5 004	715	1 609	2 623	**4 828**	1 549	2 504
1983	**244**	1 622	2 459	915	4 012	478	946	3 119	**7 770**	3 601
1984	60	**19 774**	14 060	1 413	781	1 551	339	479	2 022	**5 640**
1985	357	511	**23 790**	12 844	1 252	656	2 197	289	551	7 605
1986	363	4 282	3 259	**40 844**	11 522	933	485	635	117	1 915
1987	1 291	3 118	3 358	2 288	**27 133**	5 692	232	183	83	716
1988	117	703	1 028	1 932	2 481	**24 769**	4 493	227	131	572
1989	**2 399**	8 862	1 276	937	1 541	575	**20 957**	2 693	369	781
1990	390	**6 222**	9 737	1 457	888	966	639	**16 765**	923	277
1991	646	6 106	**17 808**	9 560	1 212	762	1 052	849	**10 964**	557
1992	628	2 627	3 014	**14 148**	8 630	1 411	733	1 048	884	**11 142**
1993	117	4 900	8 493	4 497	**13 011**	7 686	1 660	651	699	6 882
1994	672	231	3 896	5 905	2 856	**13 672**	5 977	929	244	2 925
1995	10 603	14 206	698	4 674	4 093	1 768	**5 757**	2 281	203	590
1996	2 505	8 050	7 052	1 013	5 380	6 519	1 622	**7 094**	1 806	893
1997	**5 083**	11 823	10 923	4 604	638	3 709	3 081	545	**4 212**	785
1998	1 927	**18 525**	9 977	9 560	4 291	505	2 432	2 024	412	**1 472**
1999	1 348	4 463	**14 625**	7 509	4 698	2 049	478	681	663	354
2000	**28 460**	2 689	1 800	**5 465**	2 869	2 941	458	65	195	371
2001	8 215	**60 111**	11 234	2 482	**4 184**	842	870	144	33	371
2002	6 088	3 832	**70 334**	6 047	2 275	**2 136**	538	407	48	73
2003	3 763	4 381	5 832	**73 840**	8 480	1 123	**1 199**	32	5	0
2004	**27 524**	24 574	6 017	4 753	**56 010**	2 457	1 322	**606**	9	0
2005	17 391	**42 971**	24 381	4 007	3 807	**40 391**	1 680	746	**81**	45
2006	**31 651**	14 756	**41 630**	21 769	3 765	1 917	**17 117**	448	36	**0**
2007	2 968	**31 233**	22 784	**43 885**	11 105	2 471	1 328	**4 819**	39	7
2008	23 622	8 120	**25 964**	8 655	**12 703**	1 631	633	218	**1 033**	9
2009	**38 026**	24 443	6 613	**28 416**	6 363	**9 425**	358	127	5	**482**
2010	5 402	**31 923**	28 384	3 829	**13 988**	2 033	**3 286**	83	1	132
2011	1 715	922	**8 702**	4 565	479	**2 323**	252	**355**	19	30

Table 2. Catch-at-age (%) of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1968	**<u>50.65</u>**	8.42	12.16	8.69	3.32	1.59	0.85	1.95	**<u>12.26</u>**	0.11
1969	8.68	**<u>40.20</u>**	27.54	3.09	1.42	1.30	1.68	0.67	0.71	**<u>14.72</u>**
1970	26.51	4.78	**<u>43.91</u>**	10.52	3.26	0.59	0.56	2.06	2.15	5.67
1971	9.85	10.17	2.34	**<u>49.44</u>**	10.48	2.41	3.03	2.10	2.59	7.59
1972	0.00	0.26	8.37	10.54	**<u>47.21</u>**	9.46	9.98	0.15	1.04	12.99
1973	9.31	20.92	9.79	9.47	14.17	**<u>22.61</u>**	8.44	2.81	0.85	1.63
1974	7.05	19.92	21.86	11.95	10.31	10.16	**<u>12.59</u>**	3.32	1.40	1.43
1975	**<u>15.93</u>**	27.93	14.64	13.05	7.91	8.44	6.12	**<u>4.39</u>**	0.92	0.65
1976	1.97	**<u>24.69</u>**	31.62	12.81	9.03	4.51	5.74	4.64	**<u>3.64</u>**	1.36
1977	1.40	13.49	**<u>42.67</u>**	21.40	6.96	4.86	1.53	2.73	1.70	**<u>3.26</u>**
1978	0.00	0.40	8.44	**<u>32.46</u>**	25.50	14.01	6.96	3.63	3.09	5.50
1979	0.41	0.96	2.38	13.22	**<u>34.38</u>**	24.62	11.17	4.56	3.40	4.91
1980	0.02	4.48	6.65	4.51	15.68	**<u>30.31</u>**	18.95	8.30	4.94	6.16
1981	16.99	7.84	14.22	3.27	4.58	12.91	**<u>21.41</u>**	9.15	4.41	5.23
1982	7.53	20.71	5.65	17.57	2.51	5.65	9.21	**<u>16.95</u>**	5.44	8.79
1983	**<u>0.97</u>**	6.45	9.77	3.64	15.94	1.90	3.76	12.39	**<u>30.87</u>**	14.31
1984	0.13	**<u>42.88</u>**	30.49	3.06	1.69	3.36	0.74	1.04	4.38	**<u>12.23</u>**
1985	0.71	1.02	**<u>47.53</u>**	25.66	2.50	1.31	4.39	0.58	1.10	15.19
1986	0.56	6.65	5.06	**<u>63.47</u>**	17.90	1.45	0.75	0.99	0.18	2.98
1987	2.93	7.07	7.62	5.19	**<u>61.54</u>**	12.91	0.53	0.42	0.19	1.62
1988	0.32	1.93	2.82	5.30	6.81	**<u>67.94</u>**	12.32	0.62	0.36	1.57
1989	**<u>5.94</u>**	21.94	3.16	2.32	3.81	1.42	**<u>51.89</u>**	6.67	0.91	1.93
1990	1.02	**<u>16.26</u>**	25.45	3.81	2.32	2.52	1.67	**<u>43.81</u>**	2.41	0.72
1991	1.30	12.33	**<u>35.96</u>**	19.31	2.45	1.54	2.12	1.71	**<u>22.14</u>**	1.12
1992	1.42	5.93	6.81	**<u>31.96</u>**	19.50	3.19	1.66	2.37	2.00	**<u>25.17</u>**
1993	0.24	10.08	17.48	9.25	**<u>26.77</u>**	15.82	3.42	1.34	1.44	14.16
1994	1.80	0.62	10.44	15.83	7.66	**<u>36.65</u>**	16.02	2.49	0.65	7.84
1995	23.63	31.66	1.56	10.42	9.12	3.94	**<u>12.83</u>**	5.08	0.45	1.31
1996	5.97	19.20	16.82	2.42	12.83	15.55	3.87	**<u>16.92</u>**	4.31	2.13
1997	**<u>11.20</u>**	26.04	24.06	10.14	1.41	8.17	6.79	1.20	**<u>9.28</u>**	1.73
1998	3.77	**<u>36.23</u>**	19.51	18.70	8.39	0.99	4.76	3.96	0.81	**<u>2.88</u>**
1999	3.66	12.11	**<u>39.67</u>**	20.37	12.74	5.56	1.30	1.85	1.80	0.96
2000	**<u>62.81</u>**	5.93	3.97	**<u>12.06</u>**	6.33	6.49	1.01	0.14	0.43	0.82
2001	9.28	**<u>67.93</u>**	12.70	2.80	**<u>4.73</u>**	0.95	0.98	0.16	0.04	0.42
2002	6.63	4.18	**<u>76.63</u>**	6.59	2.48	**<u>2.33</u>**	0.59	0.44	0.05	0.08
2003	3.81	4.44	5.91	**<u>74.85</u>**	8.60	1.14	**<u>1.21</u>**	0.03	0.01	0.00
2004	**<u>22.33</u>**	19.93	4.88	3.86	**<u>45.44</u>**	1.99	1.07	**<u>0.49</u>**	0.01	0.00
2005	12.83	**<u>31.71</u>**	17.99	2.96	2.81	**<u>29.81</u>**	1.24	0.55	**<u>0.06</u>**	0.03
2006	**<u>23.78</u>**	11.09	**<u>31.28</u>**	16.36	2.83	1.44	**<u>12.86</u>**	0.34	0.03	**<u>0.00</u>**
2007	2.46	**<u>25.89</u>**	18.89	**<u>36.38</u>**	9.21	2.05	1.10	**<u>3.99</u>**	0.03	0.01
2008	28.60	9.83	**<u>31.44</u>**	10.48	**<u>15.38</u>**	1.97	0.77	0.26	**<u>1.25</u>**	0.01
2009	**<u>33.28</u>**	21.39	5.79	**<u>24.87</u>**	5.57	**<u>8.25</u>**	0.31	0.11	0.00	**<u>0.42</u>**
2010	6.07	**<u>35.84</u>**	31.87	4.30	**<u>15.71</u>**	2.28	**<u>3.69</u>**	0.09	0.00	0.15
2011	8.86	4.76	**<u>44.94</u>**	23.58	2.47	**<u>12.00</u>**	1.30	**<u>1.83</u>**	0.10	0.15

Table 3. Weight (kg) of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	**AGE**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1968	**<u>0.148</u>**	0.241	0.335	0.425	0.506	0.576	0.634	0.683	**<u>0.722</u>**	0.753
1969	0.131	**<u>0.214</u>**	0.300	0.382	0.456	0.520	0.574	0.618	0.654	**<u>0.683</u>**
1970	0.107	0.179	**<u>0.253</u>**	0.324	0.389	0.444	0.491	0.530	0.562	0.587
1971	0.110	0.181	0.256	**<u>0.327</u>**	0.391	0.446	0.494	0.532	0.564	0.589
1972	0.123	0.210	0.300	0.386	**<u>0.464</u>**	0.533	0.590	0.638	0.677	0.733
1973	0.113	0.189	0.269	0.345	0.414	**<u>0.473</u>**	0.524	0.565	0.600	0.628
1974	0.111	0.190	0.273	0.352	0.425	0.487	**<u>0.541</u>**	0.585	0.621	0.649
1975	**<u>0.104</u>**	0.176	0.252	0.326	0.393	0.451	0.500	**<u>0.540</u>**	0.573	0.600
1976	0.097	**<u>0.168</u>**	0.244	0.316	0.382	0.440	0.489	0.530	**<u>0.563</u>**	0.590
1977	0.114	0.198	**<u>0.288</u>**	0.375	0.454	0.524	0.582	0.631	0.671	**<u>0.703</u>**
1978	0.192	0.285	0.425	**<u>0.463</u>**	0.509	0.582	0.625	0.659	0.673	0.697
1979	0.190	0.272	0.531	0.567	**<u>0.579</u>**	0.603	0.652	0.714	0.752	0.769
1980	0.146	0.376	0.548	0.609	0.617	**<u>0.635</u>**	0.672	0.705	0.781	0.743
1981	0.114	0.315	0.523	0.577	0.643	0.660	**<u>0.674</u>**	0.707	0.723	0.756
1982	0.152	0.340	0.541	0.606	0.666	0.743	0.737	**<u>0.722</u>**	0.719	0.740
1983	**<u>0.098</u>**	0.257	0.479	0.593	0.628	0.659	0.712	0.709	**<u>0.705</u>**	0.727
1984	0.098	**<u>0.162</u>**	0.338	0.525	0.625	0.657	0.696	0.715	0.705	**<u>0.709</u>**
1985	0.203	0.393	**<u>0.399</u>**	0.505	0.601	0.742	0.767	0.779	0.840	0.866
1986	0.163	0.306	0.435	**<u>0.436</u>**	0.520	0.671	0.784	0.800	0.856	0.844
1987	0.214	0.309	0.405	0.483	**<u>0.506</u>**	0.599	0.701	0.785	0.888	0.892
1988	0.203	0.398	0.467	0.502	0.549	**<u>0.579</u>**	0.670	0.732	0.795	0.876
1989	**<u>0.169</u>**	0.329	0.450	0.545	0.619	0.618	**<u>0.660</u>**	0.753	0.810	0.884
1990	0.280	**<u>0.331</u>**	0.416	0.534	0.620	0.628	0.676	**<u>0.678</u>**	0.724	0.863
1991	0.251	0.336	**<u>0.435</u>**	0.478	0.564	0.627	0.644	0.724	**<u>0.712</u>**	0.816
1992	0.184	0.297	0.408	**<u>0.449</u>**	0.508	0.552	0.616	0.672	0.678	**<u>0.694</u>**
1993	0.180	0.280	0.361	0.446	**<u>0.489</u>**	0.547	0.607	0.664	0.699	0.724
1994	0.232	0.371	0.384	0.461	0.554	**<u>0.549</u>**	0.594	0.643	0.714	0.714
1995	0.197	0.300	0.435	0.488	0.532	0.607	**<u>0.616</u>**	0.661	0.738	0.799
1996	0.224	0.333	0.433	0.535	0.543	0.595	0.647	**<u>0.684</u>**	0.729	0.845
1997	**<u>0.240</u>**	0.375	0.448	0.524	0.594	0.601	0.635	0.757	**<u>0.700</u>**	0.751
1998	0.157	**<u>0.273</u>**	0.412	0.517	0.577	0.603	0.665	0.666	0.721	**<u>0.716</u>**
1999	0.186	0.298	**<u>0.439</u>**	0.509	0.569	0.649	0.703	0.719	0.730	0.769
2000	**<u>0.208</u>**	0.328	0.409	**<u>0.488</u>**	0.564	0.610	0.658	0.674	0.697	0.704
2001	0.139	**<u>0.280</u>**	0.401	0.475	**<u>0.562</u>**	0.625	0.668	0.693	0.758	0.775
2002	0.161	0.294	**<u>0.389</u>**	0.464	0.498	**<u>0.607</u>**	0.637	0.666	0.671	0.696
2003	0.207	0.314	0.387	**<u>0.490</u>**	0.554	0.667	**<u>0.726</u>**	0.828	0.839	0.680
2004	**<u>0.212</u>**	0.281	0.394	0.480	**<u>0.554</u>**	0.593	0.661	**<u>0.754</u>**	0.682	0.680
2005	0.110	**<u>0.306</u>**	0.385	0.466	0.520	**<u>0.618</u>**	0.654	0.698	**<u>0.708</u>**	0.665
2006	**<u>0.204</u>**	0.316	**<u>0.429</u>**	0.482	0.544	0.569	**<u>0.655</u>**	0.679	0.667	**<u>0.679</u>**
2007	0.206	**<u>0.308</u>**	0.427	**<u>0.503</u>**	0.582	0.629	0.665	**<u>0.711</u>**	0.767	0.692
2008	0.175	0.293	**<u>0.416</u>**	0.497	**<u>0.536</u>**	0.612	0.644	0.587	**<u>0.724</u>**	0.733
2009	**<u>0.208</u>**	0.316	0.416	**<u>0.495</u>**	0.580	**<u>0.605</u>**	0.675	0.612	0.707	**<u>0.775</u>**
2010	0.148	**<u>0.348</u>**	0.431	0.527	**<u>0.575</u>**	0.661	**<u>0.652</u>**	0.602	0.716	0.667
2011	0.188	0.293	**<u>0.428</u>**	0.491	0.565	**<u>0.574</u>**	0.704	**<u>0.649</u>**	0.650	0.710

Table 4. Catch-at-age biomass (t) of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE										TOTAL
	1	2	3	4	5	6	7	8	9	10^+	
1968	**<u>6 373</u>**	1 725	3 465	3 142	1 426	777	457	1 132	**<u>7 527</u>**	73	**26 097**
1969	746	**<u>5 641</u>**	5 417	774	424	444	631	272	302	**<u>6 595</u>**	**21 247**
1970	2 170	654	**<u>8 497</u>**	2 607	971	200	209	836	924	2 545	**19 613**
1971	787	1 337	436	**<u>11 749</u>**	2 979	782	1 088	812	1 060	3 249	**24 280**
1972	0	29	1 320	2 139	**<u>11 519</u>**	2 651	3 097	49	370	5 009	**26 183**
1973	1 037	3 898	2 596	3 220	5 785	**<u>10 545</u>**	4 358	1 566	502	1 007	**34 513**
1974	957	4 625	7 290	5 140	5 352	6 047	**<u>8 319</u>**	2 371	1 064	1 135	**42 300**
1975	**<u>1 477</u>**	4 383	3 288	3 793	2 771	3 394	2 728	**<u>2 115</u>**	473	349	**24 773**
1976	164	**<u>3 557</u>**	6 615	3 470	2 957	1 702	2 407	2 108	**<u>1 758</u>**	688	**25 425**
1977	84	1 413	**<u>6 499</u>**	4 244	1 672	1 346	471	910	602	**<u>1 210</u>**	**18 453**
1978	0	52	1 628	**<u>6 821</u>**	5 892	3 700	1 973	1 087	944	1 740	**23 838**
1979	39	131	631	3 751	**<u>9 960</u>**	7 430	3 645	1 629	1 280	1 889	**30 384**
1980	1	547	1 181	891	3 139	**<u>6 244</u>**	4 131	1 898	1 253	1 485	**20 770**
1981	701	893	2 690	683	1 065	3 082	**<u>5 219</u>**	2 339	1 153	1 430	**19 254**
1982	326	2 006	870	3 032	476	1 195	1 933	**<u>3 486</u>**	1 114	1 853	**16 292**
1983	**<u>24</u>**	417	1 178	543	2 520	315	674	2 211	**<u>5 478</u>**	2 618	**15 976**
1984	6	**<u>3 203</u>**	4 752	742	488	1 019	236	342	1 426	**<u>3 999</u>**	**16 213**
1985	72	201	**<u>9 492</u>**	6 486	752	487	1 685	225	463	6 583	**26 447**
1986	59	1 310	1 418	**<u>17 808</u>**	5 992	626	381	508	100	1 617	**29 818**
1987	276	963	1 360	1 105	**<u>13 729</u>**	3 409	162	144	74	639	**21 862**
1988	24	280	480	970	1 362	**<u>14 341</u>**	3 010	166	104	501	**21 239**
1989	**<u>405</u>**	2 916	574	511	954	356	**<u>13 832</u>**	2 028	299	690	**22 563**
1990	109	**<u>2 059</u>**	4 051	778	551	607	432	**<u>11 367</u>**	668	239	**20 861**
1991	162	2 052	**<u>7 746</u>**	4 570	684	478	677	615	**<u>7 806</u>**	454	**25 244**
1992	116	780	1 230	**<u>6 352</u>**	4 384	779	452	704	599	**<u>7 734</u>**	**23 130**
1993	21	1 372	3 066	2 006	**<u>6 362</u>**	4 204	1 008	432	489	4 986	**23 946**
1994	156	86	1 496	2 722	1 582	**<u>7 506</u>**	3 550	597	174	2 090	**19 960**
1995	2 089	4 262	304	2 281	2 177	1 073	**<u>3 546</u>**	1 508	150	471	**17 861**
1996	561	2 681	3 054	542	2 921	3 879	1 049	**<u>4 852</u>**	1 317	755	**21 610**
1997	**<u>1 220</u>**	4 434	4 894	2 412	379	2 229	1 956	413	**<u>2 948</u>**	590	**21 475**
1998	303	**<u>5 057</u>**	4 111	4 943	2 476	305	1 617	1 348	297	**<u>1 054</u>**	**21 509**
1999	251	1 330	**<u>6 420</u>**	3 822	2 673	1 330	336	490	484	272	**17 408**
2000	**<u>5 920</u>**	882	736	**<u>2 667</u>**	1 618	1 794	301	44	136	261	**14 359**
2001	1 142	**<u>16 831</u>**	4 505	1 179	**<u>2 352</u>**	526	581	100	25	287	**27 528**
2002	980	1 127	**<u>27 360</u>**	2 806	1 133	**<u>1 296</u>**	343	271	32	51	**35 399**
2003	779	1 376	2 257	**<u>36 182</u>**	4 698	749	**<u>870</u>**	27	4	0	**46 941**
2004	**<u>5 835</u>**	6 905	2 371	2 282	**<u>31 029</u>**	1 457	874	**<u>457</u>**	6	0	**51 216**
2005	1 913	**<u>13 149</u>**	9 387	1 867	1 980	**<u>24 961</u>**	1 099	521	**<u>57</u>**	30	**54 964**
2006	**<u>6 457</u>**	4 663	**<u>17 859</u>**	10 493	2 048	1 091	**<u>11 212</u>**	304	24	**<u>0</u>**	**54 150**
2007	611	**<u>9 620</u>**	9 729	**<u>22 074</u>**	6 463	1 554	883	**<u>3 426</u>**	30	5	**54 396**
2008	4 134	2 379	**<u>10 801</u>**	4 302	**<u>6 809</u>**	998	408	128	**<u>748</u>**	7	**30 713**
2009	**<u>7 909</u>**	7 724	2 751	**<u>14 066</u>**	3 691	**<u>5 702</u>**	242	78	4	**<u>374</u>**	**42 539**
2010	799	**<u>11 109</u>**	12 234	2 018	**<u>8 043</u>**	1 344	**<u>2 142</u>**	50	0	88	**37 827**
2011	322	270	**<u>3 724</u>**	2 241	271	**<u>1 333</u>**	177	**<u>230</u>**	12	21	**8 604**

Table 5. Weights at age (kg) on January 1st of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1968	**0.123**	0.216	0.314	0.410	0.499	0.577	0.642	0.698	**0.702**	0.753
1969	0.112	**0.178**	0.269	0.358	0.440	0.513	0.575	0.626	0.668	**0.683**
1970	0.082	0.153	**0.233**	0.312	0.386	0.450	0.505	0.552	0.589	0.587
1971	0.080	0.139	0.214	**0.288**	0.356	0.417	0.468	0.511	0.547	0.589
1972	0.099	0.152	0.233	0.314	**0.390**	0.457	0.513	0.561	0.600	0.733
1973	0.087	0.153	0.238	0.322	0.400	**0.469**	0.529	0.577	0.619	0.628
1974	0.088	0.147	0.227	0.308	0.383	0.449	**0.506**	0.554	0.592	0.649
1975	**0.082**	0.140	0.219	0.298	0.372	0.438	0.494	**0.541**	0.579	0.600
1976	0.068	**0.132**	0.207	0.282	0.353	0.416	0.470	0.515	**0.551**	0.590
1977	0.072	0.139	**0.220**	0.303	0.379	0.447	0.506	0.556	0.596	**0.703**
1978	0.161	0.180	0.290	**0.365**	0.437	0.514	0.572	0.619	0.652	0.697
1979	0.135	0.229	0.389	0.491	**0.518**	0.554	0.616	0.668	0.704	0.769
1980	0.099	0.267	0.386	0.569	0.592	**0.606**	0.637	0.678	0.747	0.743
1981	0.066	0.215	0.444	0.562	0.626	0.638	**0.654**	0.689	0.714	0.756
1982	0.117	0.197	0.413	0.563	0.620	0.691	0.697	**0.698**	0.713	0.740
1983	**0.076**	0.198	0.404	0.566	0.617	0.663	0.727	0.723	**0.713**	0.727
1984	0.049	**0.126**	0.295	0.502	0.609	0.642	0.677	0.714	0.707	**0.709**
1985	0.165	0.196	**0.254**	0.413	0.562	0.681	0.710	0.736	0.775	0.866
1986	0.118	0.249	0.414	**0.417**	0.512	0.635	0.763	0.783	0.817	0.844
1987	0.157	0.224	0.352	0.458	**0.470**	0.558	0.686	0.785	0.843	0.892
1988	0.160	0.292	0.380	0.451	0.515	**0.541**	0.634	0.716	0.790	0.876
1989	**0.121**	0.258	0.423	0.505	0.557	0.583	**0.618**	0.710	0.770	0.884
1990	0.256	**0.237**	0.370	0.490	0.581	0.624	0.646	**0.669**	0.738	0.863
1991	0.231	0.307	**0.380**	0.446	0.549	0.624	0.636	0.700	**0.695**	0.816
1992	0.149	0.273	0.370	**0.442**	0.493	0.558	0.622	0.658	0.701	**0.694**
1993	0.125	0.227	0.327	0.427	**0.469**	0.527	0.579	0.640	0.685	0.724
1994	0.204	0.258	0.328	0.408	0.497	**0.518**	0.570	0.625	0.689	0.714
1995	0.152	0.264	0.402	0.433	0.495	0.580	**0.582**	0.627	0.689	0.799
1996	0.173	0.256	0.360	0.482	0.515	0.563	0.627	**0.649**	0.694	0.845
1997	**0.225**	0.290	0.386	0.476	0.564	0.571	0.615	0.700	**0.692**	0.751
1998	0.114	**0.256**	0.393	0.481	0.550	0.599	0.632	0.650	0.739	**0.716**
1999	0.140	0.216	**0.346**	0.458	0.542	0.612	0.651	0.692	0.697	0.769
2000	**0.179**	0.247	0.349	**0.463**	0.536	0.589	0.654	0.688	0.708	0.704
2001	0.096	**0.241**	0.363	0.441	**0.524**	0.594	0.638	0.675	0.715	0.775
2002	0.115	0.202	**0.330**	0.431	0.486	**0.584**	0.631	0.667	0.682	0.696
2003	0.178	0.225	0.337	**0.437**	0.507	0.576	**0.664**	0.726	0.748	0.680
2004	**0.177**	0.241	0.352	0.431	**0.521**	0.573	0.664	**0.740**	0.752	0.680
2005	0.065	**0.255**	0.329	0.429	0.500	**0.585**	0.623	0.679	**0.731**	0.665
2006	**0.166**	0.186	**0.362**	0.431	0.504	0.544	**0.636**	0.666	0.682	**0.679**
2007	0.173	**0.251**	0.367	**0.465**	0.530	0.585	0.615	**0.682**	0.722	0.692
2008	0.130	0.246	**0.358**	0.461	**0.519**	0.597	0.637	0.625	**0.718**	0.733
2009	**0.161**	0.235	0.349	**0.454**	0.537	**0.570**	0.643	0.628	0.644	**0.775**
2010	0.105	**0.269**	0.369	0.468	**0.534**	0.619	**0.628**	0.638	0.662	0.667
2011	0.170	0.208	**0.386**	0.460	0.546	**0.575**	0.682	**0.651**	0.626	0.710

Table 6. Proportions of maturity-at-age of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes). Proportions were calculated from commercial samples collected in June. Given the absence of data, the proportions from 1974 were applied to the years 1968-1973.

YEAR	AGE									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10⁺**
1968	**0.288**	0.495	0.705	0.853	0.934	0.972	0.988	0.995	**0.998**	0.999
1969	0.288	**0.495**	0.705	0.853	0.934	0.972	0.988	0.995	0.998	**0.999**
1970	0.288	0.495	**0.705**	0.853	0.934	0.972	0.988	0.995	0.998	0.999
1971	0.288	0.495	0.705	**0.853**	0.934	0.972	0.988	0.995	0.998	0.999
1972	0.288	0.495	0.705	0.853	**0.934**	0.972	0.988	0.995	0.998	0.999
1973	0.288	0.495	0.705	0.853	0.934	**0.972**	0.988	0.995	0.998	0.999
1974	0.288	0.495	0.705	0.853	0.934	0.972	**0.988**	0.995	0.998	0.999
1975	**0.163**	0.857	0.995	1.000	1.000	1.000	1.000	**1.000**	1.000	1.000
1976	0.204	**0.785**	0.981	0.999	1.000	1.000	1.000	1.000	**1.000**	1.000
1977	0.049	0.841	**0.998**	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
1978	0.429	0.907	0.992	**0.999**	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.368	0.593	0.785	0.902	**0.958**	0.983	0.993	0.997	0.999	1.000
1980	0.231	0.972	1.000	1.000	1.000	**1.000**	1.000	1.000	1.000	1.000
1981	0.123	0.984	1.000	1.000	1.000	1.000	**1.000**	1.000	1.000	1.000
1982	0.015	0.995	1.000	1.000	1.000	1.000	1.000	**1.000**	1.000	1.000
1983	**0.378**	0.654	0.854	0.948	0.983	0.994	0.998	0.999	**1.000**	1.000
1984	0.010	**0.503**	0.990	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
1985	0.402	0.879	**0.988**	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.422	0.847	0.974	**0.996**	0.999	1.000	1.000	1.000	1.000	1.000
1987	0.442	0.815	0.961	0.993	**0.999**	1.000	1.000	1.000	1.000	1.000
1988	0.395	0.904	0.980	0.996	0.999	**1.000**	1.000	1.000	1.000	1.000
1989	**0.349**	0.992	1.000	1.000	1.000	1.000	**1.000**	1.000	1.000	1.000
1990	0.283	**0.937**	0.998	1.000	1.000	1.000	1.000	**1.000**	1.000	1.000
1991	0.216	0.881	**0.995**	1.000	1.000	1.000	1.000	1.000	**1.000**	1.000
1992	0.229	0.807	0.977	**0.997**	1.000	1.000	1.000	1.000	1.000	**1.000**
1993	0.229	0.807	0.977	0.997	**1.000**	1.000	1.000	1.000	1.000	1.000
1994	0.229	0.807	0.977	0.997	1.000	**1.000**	1.000	1.000	1.000	1.000
1995	0.242	0.733	0.959	0.995	0.999	1.000	**1.000**	1.000	1.000	1.000
1996	0.195	0.736	0.970	0.997	1.000	1.000	1.000	**1.000**	1.000	1.000
1997	**0.132**	0.830	0.985	0.999	1.000	1.000	1.000	1.000	**1.000**	1.000
1998	0.068	**0.925**	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
1999	0.117	0.766	**0.988**	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	**0.459**	0.908	0.991	**0.999**	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.430	**0.929**	0.996	1.000	**1.000**	1.000	1.000	1.000	1.000	1.000
2002	0.306	0.949	**0.999**	1.000	1.000	**1.000**	1.000	1.000	1.000	1.000
2003	0.241	0.953	0.999	**1.000**	1.000	1.000	**1.000**	1.000	1.000	1.000
2004	**0.138**	0.855	0.995	1.000	**1.000**	1.000	1.000	**1.000**	1.000	1.000
2005	0.088	**0.624**	0.966	0.998	1.000	**1.000**	1.000	1.000	**1.000**	1.000
2006	**0.253**	0.847	**0.989**	0.999	1.000	1.000	**1.000**	1.000	1.000	**1.000**
2007	0.081	**0.922**	0.999	**1.000**	1.000	1.000	1.000	**1.000**	1.000	1.000
2008	0.210	0.793	**0.982**	0.999	**1.000**	1.000	1.000	1.000	**1.000**	1.000
2009	**0.029**	0.854	0.999	**1.000**	1.000	**1.000**	1.000	1.000	1.000	**1.000**
2010	0.025	**0.615**	0.990	1.000	**1.000**	1.000	**1.000**	1.000	1.000	1.000
2011	0.325	0.836	**0.982**	0.998	1.000	**1.000**	1.000	**1.000**	1.000	1.000

Table 7. Spawning biomass index (t) of Atlantic Mackerel calculated from the egg surveys conducted in the southern Gulf of St. Lawrence since 1996. No surveys were conducted in 1997 and partial surveys were conducted in 1999 and 2001. The 2006 survey began at the end of the spawning season so these results are not taken into account in this assessment.

YEAR	BIOMASS INDEX (t)
1996	123 464
1997	----
1998	105 801
1999	----
2000	161 573
2001	----
2002	389 007
2003	307 091
2004	162 802
2005	87 959
2006	----
2007	76 532
2008	99 631
2009	73 743
2010	25 960
2011	35 714

Table 8. Input parameters and final formulation used for the ICA (Integrated Catch at Age) assessment of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011.

ASSESSMENT FORMULATION

Input parameters		
First year		1968
Last year		2011
Number of years for separable constraint		6
Constant selectivity pattern		S1(2006–2011)
S to be set to oldest age		1.25
Age range		$1\text{-}10^{+}$
Natural mortality		0.2
Proportion of M and F before spawning		0.5
Reference age for the separable constraint		3
Youngest age for calculating the F reference value		4
Oldest age for calculating the F reference value		10
Compress final population		No
Calibration index		
Egg survey		
Year		1996–2011
	Abundance index	Absolute
Weighting of the model		
Relative weights in catch-at-age		1
Survey index weighting		1
Model a stock-recruitment relationship		No
Parameters to be estimated		27
Number of observations		66

Table 9. Diagnostics of the final formulation used for the ICA (Integrated Catch at Age) assessment of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011.

YEAR	**FISHING MORTALITY**	**CV (%)**	**95% CONFIDENCE INTERVAL**		**- SD**	**+ SD**
			Low. Lim.	Up. Lim.		
2006	0.403	30	0.224	0.728	0.299	0.545
2007	0.490	28	0.279	0.862	0.368	0.654
2008	0.582	28	0.335	1.011	0.439	0.771
2009	0.540	31	0.294	0.993	0.396	0.737
2010	0.361	43	0.155	0.842	0.234	0.556
2011	0.137	60	0.042	0.446	0.075	0.250
AGE	**SELECTIVITY BY AGE**	**CV (%)**	**95% CONFIDENCE INTERVAL**		**- SD**	**+ SD**
			Low. Lim.	Up. Lim.		
1	0.353	40	0.159	0.782	0.235	0.530
2	0.537	37	0.257	1.123	0.369	0.783
3	1		Reference Age Set to:			
4	1.390	35	0.699	2.765	0.979	1.974
5	1.751	33	0.916	3.347	1.258	2.437
6	2.313	30	1.261	4.245	1.697	3.153
7	2.923	28	1.656	5.159	2.187	3.906
8	4.092	23	2.588	6.470	3.239	5.169
9	1		Oldest Real Age Set to:			
AGE	**2011 POPULATION ('000)**	**CV (%)**	**95% CONFIDENCE INTERVAL**		**- SD**	**+ SD**
			Low. Lim.	Up. Lim.		
1	39 396	93	6 271	247 485	15 426	100 611
2	22 338	69	5 710	87 379	11 138	44 799
3	89 217	47	34 909	228 008	55 276	143 998
4	36 980	45	15 164	90 181	23 466	58 276
5	3 495	49	1 330	9 184	2 135	5 722
6	9 094	47	3 580	23 098	5 652	14 631
7	1 090	52	390	3 045	645	1 841
8	822	57	268	2 523	464	1 457
9	34	76	7	155	16	74
AGE	**POPULATION AGE 9 ('000)**	**CV (%)**	**95% CONFIDENCE INTERVAL**		**- SD**	**+ SD**
			Low. Lim.	Up. Lim.		
2006	98	68	25	375	49	194
2007	92	53	32	264	53	158
2008	1 019	49	382	2 716	618	1 680
2009	16	54	5	48	9	28
2010	8	63	2	29	4	15

Table 10. Population at age ('000) on January 1st of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
1968	**573 440**	143 370	78 620	33 740	31 060	55 230	49 170	10 500	**115 960**	1 080
1969	218 830	**430 650**	110 920	55 050	20 980	22 880	44 000	39 610	7 100	**148 490**
1970	275 230	174 030	**328 800**	74 560	43 240	16 340	17 960	35 030	32 030	84 410
1971	212 060	207 050	139 180	**238 920**	53 790	33 150	12 970	14 320	27 260	80 040
1972	236 110	167 160	162 850	112 410	**163 250**	37 180	25 560	8 630	10 350	129 550
1973	211 520	193 310	136 730	129 360	87 040	**111 300**	25 950	16 200	7 000	13 410
1974	271 630	164 890	139 680	103 240	97 490	58 680	**71 070**	13 790	10 770	10 990
1975	**674 860**	214 610	113 080	90 330	71 370	68 470	36 870	**44 360**	7 650	5 390
1976	209 590	**539 700**	153 260	80 820	63 470	52 080	49 270	25 280	**32 790**	12 230
1977	49 540	170 080	**422 760**	101 080	56 280	44 990	39 150	35 900	17 110	**32 830**
1978	17 600	39 890	132 810	**325 760**	72 550	42 750	34 520	31 320	28 090	50 040
1979	49 980	14 410	32 490	105 270	**253 410**	48 980	29 280	25 410	24 160	34 870
1980	25 280	40 740	11 360	25 530	80 220	**191 960**	29 030	18 940	18 750	23 350
1981	55 520	20 690	32 040	7 360	19 580	61 090	**148 290**	18 240	13 080	15 520
1982	197 010	39 920	14 380	21 600	4 960	14 540	45 810	**114 420**	11 960	19 330
1983	**900 170**	159 360	27 370	10 330	13 190	3 420	10 450	35 140	**89 320**	41 400
1984	69 640	**736 780**	129 010	20 190	7 630	7 200	2 370	7 710	25 950	**72 390**
1985	52 940	56 960	**585 370**	92 950	15 260	5 540	4 500	1 630	5 880	81 110
1986	27 380	43 020	46 170	**457 790**	64 530	11 360	3 950	1 720	1 080	17 630
1987	29 820	22 090	31 360	34 860	**337 970**	42 460	8 460	2 790	840	7 260
1988	163 470	23 250	15 280	22 650	26 480	**252 230**	29 640	6 720	2 120	9 270
1989	**274 720**	133 730	18 400	11 580	16 800	19 440	**184 180**	20 220	5 290	11 210
1990	49 130	**222 760**	101 490	13 910	8 640	12 370	15 400	**131 900**	14 130	4 240
1991	88 650	39 870	**176 760**	74 320	10 080	6 270	9 250	12 030	**92 890**	4 720
1992	62 850	72 000	27 150	**128 660**	52 230	7 160	4 450	6 630	9 080	**114 500**
1993	9 320	50 890	56 570	19 510	**92 590**	34 990	4 590	2 980	4 480	44 140
1994	59 950	7 530	37 250	38 670	11 930	**64 080**	21 740	2 270	1 850	22 230
1995	84 480	48 480	5 950	26 980	26 340	7 200	**40 170**	12 430	1 030	2 990
1996	61 430	59 610	26 940	4 250	17 880	17 880	4 310	**27 700**	8 130	4 020
1997	**89 860**	48 030	41 550	15 720	2 570	9 810	8 800	2 070	**16 310**	3 040
1998	33 450	**68 990**	28 700	24 210	8 740	1 530	4 710	4 440	1 210	**4 320**
1999	71 870	25 650	**39 840**	14 560	11 270	3 330	800	1 690	1 830	980
2000	**753 700**	57 620	16 980	**19 520**	5 230	5 020	910	230	780	1 480
2001	52 580	**591 380**	44 750	12 280	**11 080**	1 730	1 500	330	130	1 450
2002	45 110	35 650	**429 990**	26 550	7 820	**5 320**	660	450	140	220
2003	136 700	31 450	25 730	**288 720**	16 300	4 360	**2 450**	70	20	190
2004	**361 980**	108 520	21 800	15 830	**170 050**	5 790	2 560	**930**	30	120
2005	116 900	**271 540**	66 760	12 450	8 690	**89 000**	2 540	920	**230**	130
2006	**264 340**	80 050	**183 620**	32 820	6 600	3 710	**36 790**	590	100	**180**
2007	35 830	**187 700**	52 770	**100 440**	15 340	2 670	1 200	**9 260**	90	20
2008	158 630	24 670	**118 090**	26 460	**41 600**	5 320	700	230	**1 020**	20
2009	**195 480**	105 750	14 770	**54 030**	9 650	**12 290**	1 130	100	20	**1 070**
2010	30 990	**132 270**	64 780	7 050	**20 890**	3 070	**2 890**	190	10	400
2011	39 400	22 340	**89 220**	36 980	3 500	**9 100**	1 090	**820**	40	210
2012	79 200	30 730	16 990	**63 680**	25 020	2 250	**5 420**	600	**380**	170

Table 11. Fishing mortality at age of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1968	**<u>0.086</u>**	0.057	0.156	0.275	0.105	0.027	0.016	0.191	**<u>0.104</u>**	0.104
1969	0.029	**<u>0.070</u>**	0.197	0.041	0.050	0.042	0.028	0.012	0.074	**<u>0.074</u>**
1970	0.085	0.023	**<u>0.119</u>**	0.127	0.066	0.031	0.026	0.051	0.058	0.058
1971	0.038	0.040	0.014	**<u>0.181</u>**	0.169	0.060	0.207	0.125	0.079	0.079
1972	0.000	0.001	0.030	0.056	**<u>0.183</u>**	0.159	0.256	0.010	0.060	0.060
1973	0.049	0.125	0.081	0.083	0.194	**<u>0.249</u>**	0.432	0.208	0.141	0.141
1974	0.036	0.177	0.236	0.169	0.153	0.265	**<u>0.271</u>**	0.389	0.192	0.192
1975	**<u>0.024</u>**	0.137	0.136	0.153	0.115	0.129	0.178	**<u>0.102</u>**	0.126	0.126
1976	0.009	**<u>0.044</u>**	0.216	0.162	0.144	0.085	0.117	0.190	**<u>0.111</u>**	0.111
1977	0.017	0.047	**<u>0.061</u>**	0.132	0.075	0.065	0.023	0.045	0.060	**<u>0.060</u>**
1978	0.000	0.005	0.032	**<u>0.051</u>**	0.193	0.179	0.106	0.060	0.057	0.057
1979	0.005	0.037	0.041	0.072	**<u>0.078</u>**	0.323	0.236	0.104	0.081	0.081
1980	0.000	0.040	0.234	0.065	0.072	**<u>0.058</u>**	0.265	0.170	0.099	0.099
1981	0.130	0.164	0.194	0.195	0.098	0.088	**<u>0.059</u>**	0.222	0.144	0.144
1982	0.012	0.177	0.131	0.294	0.173	0.130	0.065	**<u>0.048</u>**	0.154	0.154
1983	**<u>0.000</u>**	0.011	0.104	0.103	0.406	0.167	0.105	0.103	**<u>0.101</u>**	0.101
1984	0.001	**<u>0.030</u>**	0.128	0.080	0.120	0.270	0.171	0.071	0.090	**<u>0.090</u>**
1985	0.008	0.010	**<u>0.046</u>**	0.165	0.095	0.140	0.760	0.216	0.109	0.109
1986	0.015	0.116	0.081	**<u>0.103</u>**	0.219	0.095	0.145	0.517	0.127	0.127
1987	0.049	0.169	0.125	0.075	**<u>0.093</u>**	0.160	0.031	0.075	0.115	0.115
1988	0.001	0.034	0.077	0.099	0.109	**<u>0.114</u>**	0.182	0.038	0.070	0.070
1989	**<u>0.010</u>**	0.076	0.080	0.093	0.107	0.033	**<u>0.134</u>**	0.159	0.080	0.080
1990	0.009	**<u>0.031</u>**	0.112	0.123	0.120	0.090	0.047	**<u>0.151</u>**	0.075	0.075
1991	0.008	0.184	**<u>0.118</u>**	0.153	0.142	0.144	0.134	0.081	**<u>0.139</u>**	0.139
1992	0.011	0.041	0.130	**<u>0.129</u>**	0.201	0.244	0.200	0.191	0.113	**<u>0.113</u>**
1993	0.014	0.112	0.181	0.292	**<u>0.168</u>**	0.276	0.504	0.274	0.188	0.188
1994	0.012	0.034	0.122	0.184	0.305	**<u>0.267</u>**	0.359	0.592	0.156	0.156
1995	0.149	0.388	0.138	0.211	0.187	0.314	**<u>0.172</u>**	0.225	0.244	0.244
1996	0.046	0.161	0.339	0.304	0.400	0.509	0.531	**<u>0.330</u>**	0.280	0.280
1997	**<u>0.064</u>**	0.315	0.340	0.387	0.319	0.533	0.483	0.340	**<u>0.333</u>**	0.333
1998	0.066	**<u>0.349</u>**	0.479	0.565	0.766	0.450	0.824	0.687	0.467	**<u>0.467</u>**
1999	0.021	0.212	**<u>0.513</u>**	0.824	0.608	1.100	1.051	0.579	0.505	0.505
2000	**<u>0.043</u>**	0.053	0.124	**<u>0.367</u>**	0.908	1.009	0.799	0.374	0.323	0.323
2001	0.189	**<u>0.119</u>**	0.322	0.251	**<u>0.533</u>**	0.759	0.995	0.636	0.331	0.331
2002	0.161	0.126	**<u>0.198</u>**	0.288	0.384	**<u>0.577</u>**	2.034	2.961	0.452	0.452
2003	0.031	0.166	0.286	**<u>0.329</u>**	0.835	0.332	**<u>0.764</u>**	0.678	0.336	0.336
2004	**<u>0.088</u>**	0.286	0.361	0.399	**<u>0.447</u>**	0.623	0.825	**<u>1.213</u>**	0.408	0.408
2005	0.179	**<u>0.191</u>**	0.510	0.435	0.650	**<u>0.683</u>**	1.254	2.024	**<u>0.495</u>**	0.495
2006	**<u>0.142</u>**	0.217	**<u>0.403</u>**	0.561	0.706	0.933	**<u>1.179</u>**	1.650	0.504	**<u>0.504</u>**
2007	0.173	**<u>0.263</u>**	0.490	**<u>0.682</u>**	0.859	1.134	1.433	**<u>2.006</u>**	0.613	0.613
2008	0.206	0.313	**<u>0.582</u>**	0.809	**<u>1.019</u>**	1.346	1.701	2.381	**<u>0.727</u>**	0.727
2009	**<u>0.191</u>**	0.290	0.540	**<u>0.750</u>**	0.945	**<u>1.249</u>**	1.578	2.209	0.675	**<u>0.675</u>**
2010	0.127	**<u>0.194</u>**	0.361	0.501	**<u>0.632</u>**	0.834	**<u>1.054</u>**	1.476	0.451	0.451
2011	0.048	0.074	**<u>0.137</u>**	0.191	0.240	**<u>0.317</u>**	0.401	**<u>0.561</u>**	0.172	0.172

Table 12. Total biomass (t) at age of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE										TOTAL
	1	2	3	4	5	6	7	8	9	10+	
1968	**84 869**	34 552	26 338	14 340	15 716	31 812	31 174	7 172	**83 723**	813	**330 509**
1969	28 667	**92 159**	33 276	21 029	9 567	11 898	25 256	24 479	4 643	**101 419**	**352 392**
1970	29 450	31 151	**83 186**	24 157	16 820	7 255	8 818	18 566	18 001	49 549	**286 954**
1971	23 327	37 476	35 630	**78 127**	21 032	14 785	6 407	7 618	15 375	47 144	**286 920**
1972	29 042	35 104	48 855	43 390	**75 748**	19 817	15 080	5 506	7 007	94 960	**374 509**
1973	23 902	36 536	36 780	44 629	36 035	**52 645**	13 598	9 153	4 200	8 421	**265 899**
1974	30 151	31 329	38 133	36 340	41 433	28 577	**38 449**	8 067	6 688	7 133	**266 300**
1975	**70 185**	37 771	28 496	29 448	28 048	30 880	18 435	**23 954**	4 383	3 234	**274 836**
1976	20 330	**90 670**	37 395	25 539	24 246	22 915	24 093	13 398	**18 461**	7 216	**284 263**
1977	5 648	33 676	**121 755**	37 905	25 551	23 575	22 785	22 653	11 481	**23 079**	**328 108**
1978	3 379	11 369	56 444	**150 827**	36 928	24 881	21 575	20 640	18 905	34 878	**379 825**
1979	9 496	3 920	17 252	59 688	**146 724**	29 535	19 091	18 143	18 168	26 815	**348 832**
1980	3 691	15 318	6 225	15 548	49 496	**121 895**	19 508	13 353	14 644	17 349	**277 026**
1981	6 329	6 517	16 757	4 247	12 590	40 319	**99 947**	12 896	9 457	11 733	**220 793**
1982	29 946	13 573	7 780	13 090	3 303	10 803	33 762	**82 611**	8 599	14 304	**217 771**
1983	**88 217**	40 956	13 110	6 126	8 283	2 254	7 440	24 914	**62 971**	30 098	**284 368**
1984	6 825	**119 358**	43 605	10 600	4 769	4 730	1 650	5 513	18 295	**51 325**	**266 669**
1985	10 747	22 385	**233 563**	46 940	9 171	4 111	3 452	1 270	4 939	70 241	**406 818**
1986	4 463	13 164	20 084	**199 596**	33 556	7 623	3 097	1 376	924	14 880	**298 763**
1987	6 381	6 826	12 701	16 837	**171 013**	25 434	5 930	2 190	746	6 476	**254 534**
1988	33 184	9 254	7 136	11 370	14 538	**146 041**	19 859	4 919	1 685	8 121	**256 106**
1989	**46 428**	43 997	8 280	6 311	10 399	12 014	**121 559**	15 226	4 285	9 910	**278 408**
1990	13 756	**73 734**	42 220	7 428	5 357	7 768	10 410	**89 428**	10 230	3 659	**263 991**
1991	22 251	13 396	**76 891**	35 525	5 685	3 931	5 957	8 710	**66 138**	3 852	**242 335**
1992	11 564	21 384	11 077	**57 768**	26 533	3 952	2 741	4 455	6 156	**79 463**	**225 095**
1993	1 678	14 249	20 422	8 701	**45 277**	19 140	2 786	1 979	3 132	31 957	**149 320**
1994	13 908	2 794	14 304	17 827	6 609	**35 180**	12 914	1 460	1 321	15 872	**122 188**
1995	16 643	14 544	2 588	13 166	14 013	4 370	**24 745**	8 216	760	2 389	**101 434**
1996	13 760	19 850	11 665	2 274	9 709	10 639	2 789	**18 947**	5 927	3 397	**98 956**
1997	**21 566**	18 011	18 614	8 237	1 527	5 896	5 588	1 567	**11 417**	2 283	**94 707**
1998	5 252	**18 834**	11 824	12 517	5 043	923	3 132	2 957	872	**3 093**	**64 447**
1999	13 368	7 644	**17 490**	7 411	6 413	2 161	562	1 215	1 336	754	**58 353**
2000	**156 770**	18 899	6 945	**9 526**	2 950	3 062	599	155	544	1 042	**200 491**
2001	7 309	**165 586**	17 945	5 833	**6 227**	1 081	1 002	229	99	1 124	**206 434**
2002	7 263	10 481	**167 266**	12 319	3 894	**3 229**	420	300	94	153	**205 420**
2003	28 297	9 875	9 958	**141 473**	9 030	2 908	**1 779**	58	17	129	**203 523**
2004	**76 740**	30 494	8 589	7 598	**94 208**	3 433	1 692	**701**	20	82	**223 558**
2005	12 859	**83 091**	25 703	5 802	4 519	**55 002**	1 661	642	**163**	86	**189 528**
2006	**53 925**	25 296	**78 773**	15 819	3 590	2 111	**24 097**	401	67	**122**	**204 202**
2007	7 381	**57 812**	22 533	**50 521**	8 928	1 679	798	**6 584**	69	14	**156 319**
2008	27 760	7 228	**49 125**	13 151	**22 298**	3 256	451	135	**738**	15	**124 157**
2009	**40 660**	33 417	6 144	**26 745**	5 597	**7 435**	763	61	14	**829**	**121 666**
2010	4 587	**46 030**	27 920	3 715	**12 012**	2 029	**1 884**	114	7	267	**98 566**
2011	7 407	6 546	**38 186**	18 157	1 978	**5 223**	767	**532**	26	149	**78 972**

Table 13. Spawning biomass (t) at age of Atlantic Mackerel in NAFO subareas 3 and 4 from 1968 to 2011 (numbers in bold and underlined represent abundant year-classes).

YEAR	AGE										TOTAL
	1	2	3	4	5	6	7	8	9	10+	
1968	**24 442**	17 103	18 568	12 232	14 679	30 922	30 800	7 136	**83 556**	812	**240 250**
1969	8 256	**45 619**	23 460	17 938	8 935	11 564	24 953	24 357	4 634	**101 317**	**271 033**
1970	8 481	15 420	**58 646**	20 606	15 710	7 052	8 713	18 473	17 965	49 499	**220 566**
1971	6 718	18 551	25 119	**66 642**	19 644	14 371	6 330	7 580	15 344	47 096	**227 396**
1972	8 364	17 376	34 443	37 012	**70 749**	19 262	14 899	5 478	6 993	94 865	**309 442**
1973	6 884	18 085	25 930	38 069	33 656	**51 171**	13 435	9 107	4 192	8 413	**208 941**
1974	8 683	15 508	26 884	30 998	38 699	27 777	**37 987**	8 027	6 675	7 125	**208 363**
1975	**11 440**	32 370	28 354	29 448	28 048	30 880	18 435	**23 954**	4 383	3 234	**210 547**
1976	4 147	**71 176**	36 685	25 514	24 246	22 915	24 093	13 398	**18 461**	7 216	**247 850**
1977	277	28 321	**121 511**	37 905	25 551	23 575	22 785	22 653	11 481	**23 079**	**317 139**
1978	1 450	10 311	55 993	**150 676**	36 928	24 881	21 575	20 640	18 905	34 878	**376 236**
1979	3 495	2 324	13 543	53 839	**140 562**	29 033	18 957	18 088	18 150	26 815	**324 806**
1980	853	14 889	6 225	15 548	49 496	**121 895**	19 508	13 353	14 644	17 349	**273 759**
1981	779	6 413	16 757	4 247	12 590	40 319	**99 947**	12 896	9 457	11 733	**215 138**
1982	449	13 505	7 780	13 090	3 303	10 803	33 762	**82 611**	8 599	14 304	**188 207**
1983	**33 346**	26 785	11 196	5 807	8 143	2 240	7 426	24 889	**62 971**	30 098	**212 900**
1984	68	**60 037**	43 169	10 600	4 769	4 730	1 650	5 513	18 295	**51 325**	**200 155**
1985	4 320	19 677	**230 760**	46 893	9 171	4 111	3 452	1 270	4 939	70 241	**394 833**
1986	1 883	11 150	19 562	**198 798**	33 522	7 623	3 097	1 376	924	14 880	**292 815**
1987	2 821	5 563	12 205	16 720	**170 842**	25 434	5 930	2 190	746	6 476	**248 926**
1988	13 108	8 365	6 993	11 325	14 523	**146 041**	19 859	4 919	1 685	8 121	**234 939**
1989	**16 203**	43 645	8 280	6 311	10 399	12 014	**121 559**	15 226	4 285	9 910	**247 832**
1990	3 893	**69 088**	42 135	7 428	5 357	7 768	10 410	**89 428**	10 230	3 659	**249 398**
1991	4 806	11 802	**76 506**	35 525	5 685	3 931	5 957	8 710	**66 138**	3 852	**222 912**
1992	2 648	17 257	10 822	**57 595**	26 533	3 952	2 741	4 455	6 156	**79 463**	**211 624**
1993	384	11 499	19 952	8 675	**45 277**	19 140	2 786	1 979	3 132	31 957	**144 780**
1994	3 185	2 254	13 975	17 773	6 609	**35 180**	12 914	1 460	1 321	15 872	**110 543**
1995	4 027	10 661	2 482	13 100	13 999	4 370	**24 745**	8 216	760	2 389	**84 750**
1996	2 683	14 610	11 315	2 267	9 709	10 639	2 789	**18 947**	5 927	3 397	**82 281**
1997	**2 847**	14 949	18 335	8 229	1 527	5 896	5 588	1 567	**11 417**	2 283	**72 638**
1998	357	**17 422**	11 824	12 517	5 043	923	3 132	2 957	872	**3 093**	**58 140**
1999	1 564	5 855	**17 280**	7 411	6 413	2 161	562	1 215	1 336	754	**44 551**
2000	**71 957**	17 161	6 882	**9 516**	2 950	3 062	599	155	544	1 042	**113 868**
2001	3 143	**153 830**	17 873	5 833	**6 227**	1 081	1 002	229	99	1 124	**190 440**
2002	2 222	9 947	**167 099**	12 319	3 894	**3 229**	420	300	94	153	**199 678**
2003	6 820	9 411	9 948	**141 473**	9 030	2 908	**1 779**	58	17	129	**181 572**
2004	**10 590**	26 072	8 546	7 598	**94 208**	3 433	1 692	**701**	20	82	**152 944**
2005	1 132	**51 849**	24 829	5 790	4 519	**55 002**	1 661	642	**163**	86	**145 673**
2006	**13 643**	21 426	**77 906**	15 803	3 590	2 111	**24 097**	401	67	**122**	**159 167**
2007	598	**53 302**	22 510	**50 521**	8 928	1 679	798	**6 584**	69	14	**145 004**
2008	5 830	5 732	**48 241**	13 137	**22 298**	3 256	451	135	**738**	15	**99 833**
2009	**1 179**	28 538	6 138	**26 745**	5 597	**7 435**	763	61	14	**829**	**77 300**
2010	115	**28 308**	27 641	3 715	**12 012**	2 029	**1 884**	114	7	267	**76 093**
2011	2 407	5 472	**37 499**	18 121	1 978	**5 223**	767	**532**	26	149	**72 175**

Table 14. Input data from the yield-per-recruit (YPR) analysis. The selectivity data (partial recruitment) were calculated using the fishing mortalities from the analytical assessment (ICA).

AGE	SELECTIVITY[1]	NATURAL MORTALITY[2]	POPULATION WEIGHT (kg)[3]	CATCH WEIGHT (kg)[3]	SPAWNING POPULATION WEIGHT (kg)[3]	MATURE FRACTION[4]
1	0.2886	1	0.142	0.180	0.142	0.147
2	0.4392	1	0.240	0.313	0.240	0.775
3	0.8175	1	0.366	0.423	0.366	0.988
4	1.0000	1	0.461	0.503	0.461	0.999
5	1.0000	1	0.534	0.564	0.534	1.000
6	1.0000	1	0.590	0.613	0.590	1.000
7	1.0000	1	0.648	0.669	0.648	1.000
8	1.0000	1	0.636	0.613	0.636	1.000
9	0.9796	1	0.663	0.699	0.663	1.000
10	0.9796	1	0.721	0.721	0.721	1.000

1 Calculated using Fs (3-5), 2008–2011 mean
2 Factor of 1 applied to 0.2
3 2008–2011 mean
4 Canadian data (June), 2008–2011 mean

Table 15. Results of the yield-per-recruit (YPR) analysis (F at 40% is considered a proxy for F_{msy}).

	PARAMETERS				
	F	**Yield-Per-Recruit**	**SSB Per Recruit**	**Total Biomass Per Recruit**	**Mean Age**
F-0	0	0	2.052	2.436	5.517
F-0.1	0.270	0.197	0.717	1.052	2.947
F-Max	0.767	0.226	0.285	0.574	2.040
F at 40%	0.222	0.186	0.821	1.163	3.154

Table 16. Exploratory biological reference points: MSY and SSB_{msy} were calculated analytically by carrying out a yield-per-recruit (YPR) analysis and random bootstrap projections (AGEPRO). The recruits and selectivity data (partial recruitment) used in YPR and AGEPRO are from the results of the analytical assessment (ICA).

RECRUITS ('000) (1967–2011 mean)	**ANALYTICAL**		**RANDOM**		**$F (3\text{-}5)_{2011} \div F_{msy}$**	**$SSB_{2011} \div SSB_{msy}$**	
	MSY (t)	SSB_{msy} (t)	MSY (t)	SSB_{msy} (t)	Analytical	Analytical	Random
170 626	31 672	140 081	30 026	132 808	0.700	0.515	0.543

Table 17. Input parameters and results from predictions of spawning biomass and catches for Atlantic Mackerel in NAFO subareas 3 and 4 from 2012 to 2014.

PARAMETERS AND RESULTS	**AGE**										**TOTAL**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Abundance beginning of 2012 ('000)	79 200	30 730	16 990	63 680	25 020	2 250	5 420	600	380	170	
Catches in 2012 ('000)	8 389	3 255	1 800	6 745	2 650	238	574	64	40	18	
Natural mortality in 2012 ('000)	13 530	5 250	2 902	10 879	4 274	384	926	102	65	29	
Abundance beginning of 2013 ('000)	35 195 [1]	57 281	22 225	12 288	46 057	18 096	1 627	3 920	434	275	
Catches in 2013 ('000)	3 728	6 067	2 354	1 302	4 878	1 917	172	415	46	29	
Natural mortality in 2013 ('000)	6 012	9 786	3 797	2 099	7 868	3 091	278	670	74	47	
Abundance beginning of 2014 ('000)	35 195 [1]	25 455	41 429	16 075	8 887	33 310	13 088	1 177	2 835	314	
Catch-at-age weight (mid-year) 2010–2011 mean	0.168	0.321	0.430	0.509	0.570	0.618	0.678	0.626	0.683	0.689	
Weight of the population at age (January): 2010–2011 mean	0.138	0.239	0.378	0.464	0.540	0.597	0.655	0.645	0.644	0.689	
Maturity-at-age*:* 2010–2011 mean	0.175	0.726	0.986	0.999	1	1	1	1	1	1	
Instantaneous rate of natural mortality (M)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
Instantaneous fishing mortality rate (F)[2]	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	
Spawning biomass at age (t)											
Beginning of 2012	1 906	5 317	6 324	29 518	13 511	1 343	3 550	387	245	117	62 218
Beginning of 2013	847	9 912	8 273	5 696	24 871	10 803	1 066	2 526	279	189	64 462
Beginning of 2014	847	4 404	15 420	7 451	4 799	19 886	8 572	759	1 826	216	64 181
Catches (t)											
2012	1 409	1 043	773	3 433	1 511	147	389	40	27	12	8 785
2013	626	1 944	1 011	662	2 781	1 184	117	260	31	20	8 636

[1] 2010–2011 mean; [2]1968–1992 mean (ages 3–5)

FIGURES

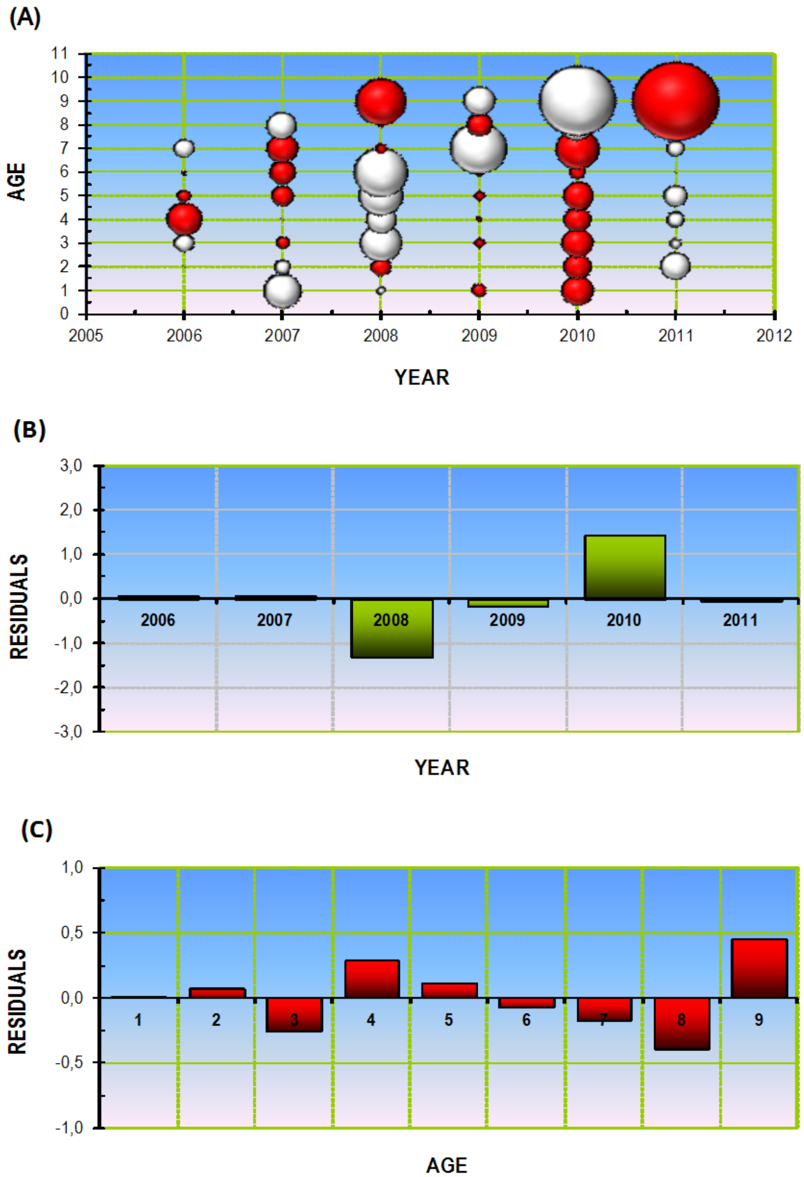


Figure 1. Diagnostics of the analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) Residuals of the logarithms of the catchability by year and age (negative values are blank), (B) total annual residuals and (C) total residuals at age.

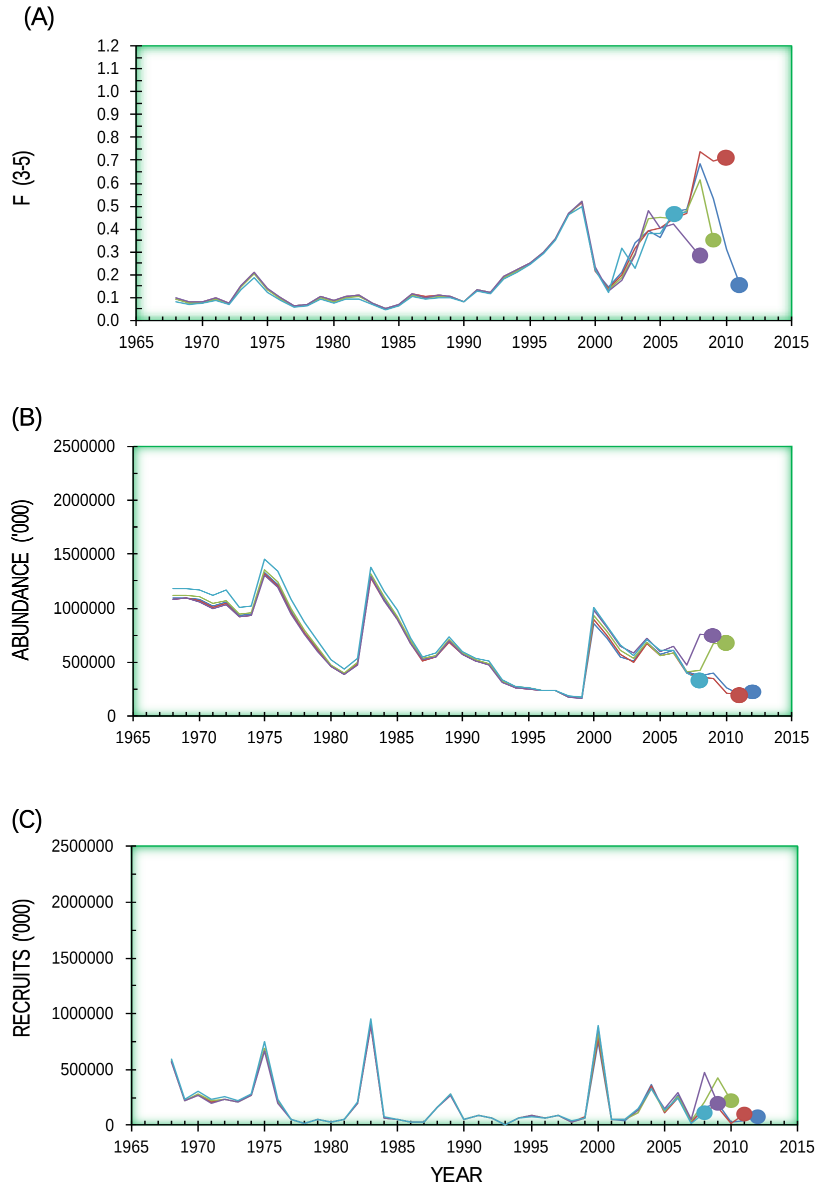


Figure 2. Retrospective analyses of the analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) fishing mortality (ages 3-5 weighted by the corresponding abundances), (B) population at ages 1 to 10^+ ('000), (C) recruits at age 1 ('000), (D) total biomass (t) and (E) spawning biomass (SSB) (t).

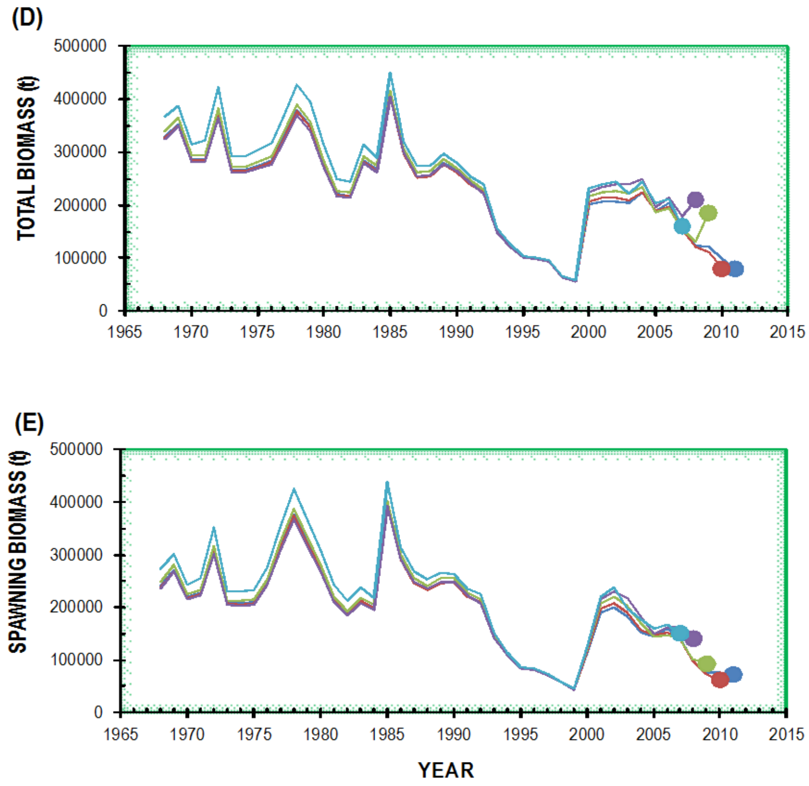
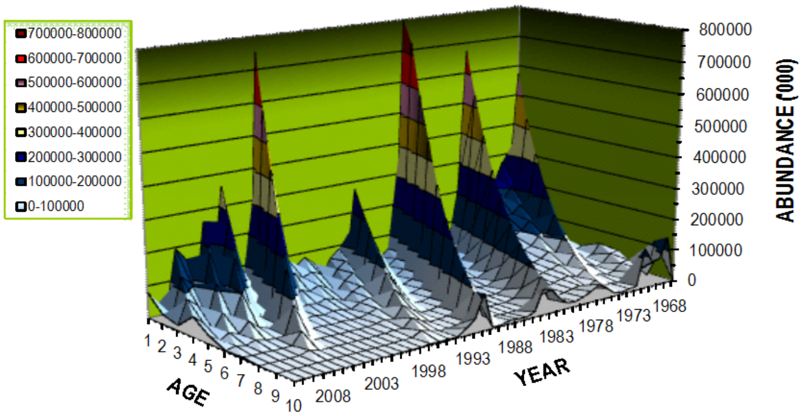


Figure 2. (Continued).

(A)



(B)

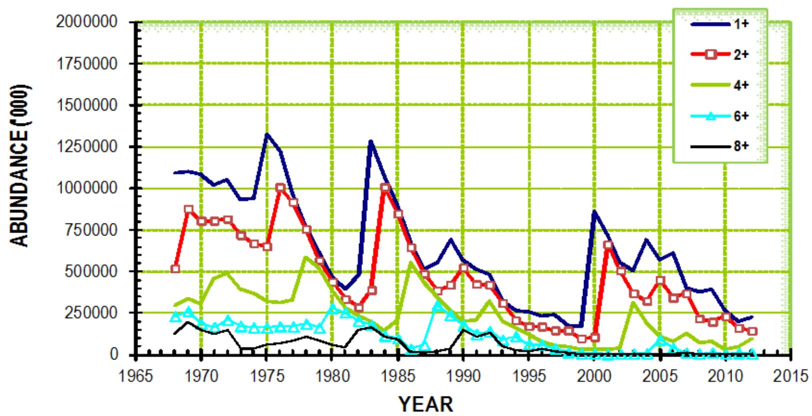


Figure 3. Analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) annual abundance of different year-classes ('000) and (B) annual abundance ('000) of age groups plus.

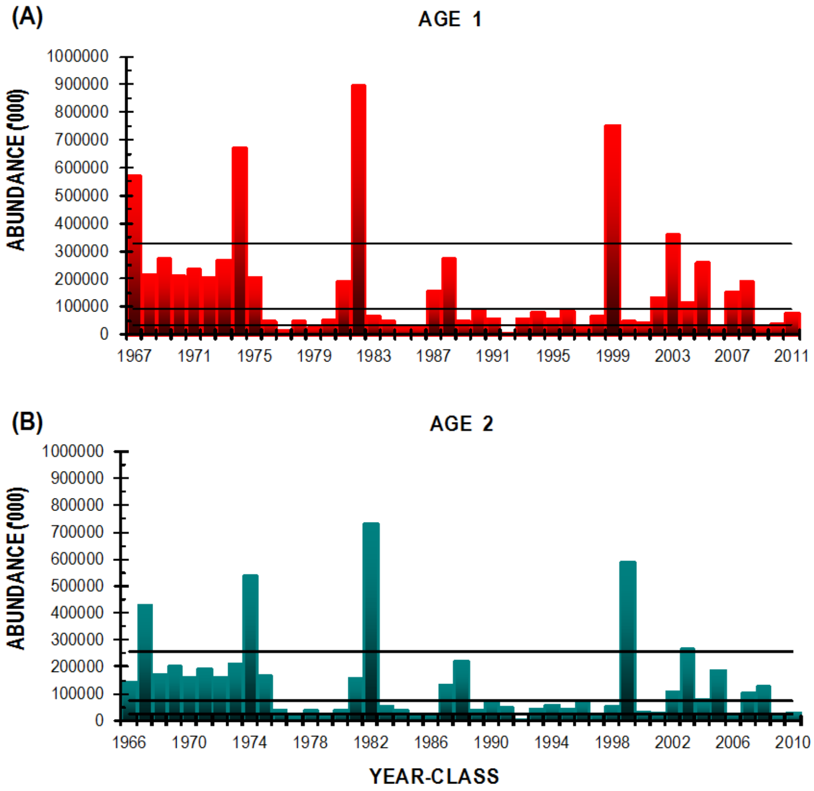


Figure 4. Analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) recruits at age 1 ('000) and (B) recruits at age 2 ('000). The horizontal lines represent three recruitment levels: low, medium and high.

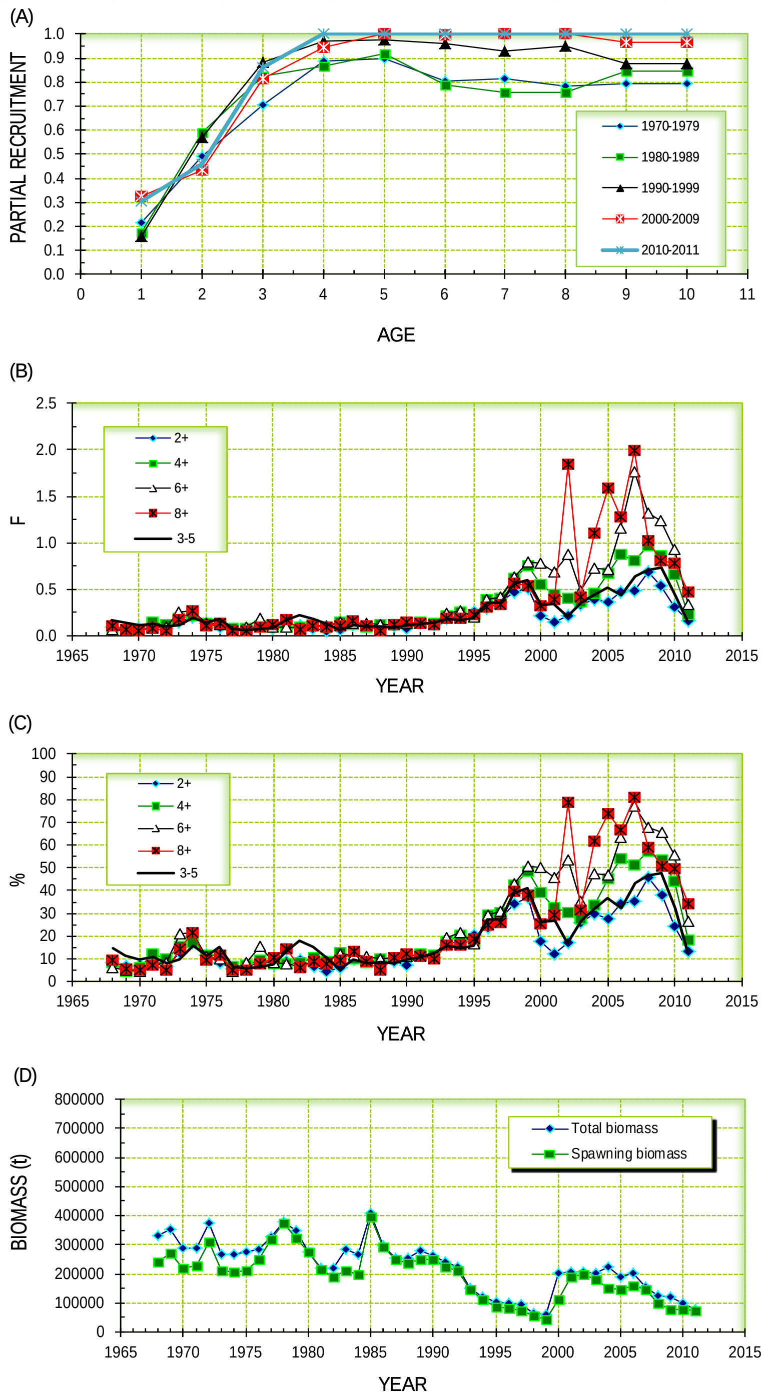


Figure 5. Analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) partial recruitment for different decades, (B) fishing mortality for age groups plus and the mean of ages 3-5, (C) exploitation (%) by fishery for age groups plus and the mean of ages 3-5, and (D) total biomass (t) and spawning biomass (t).

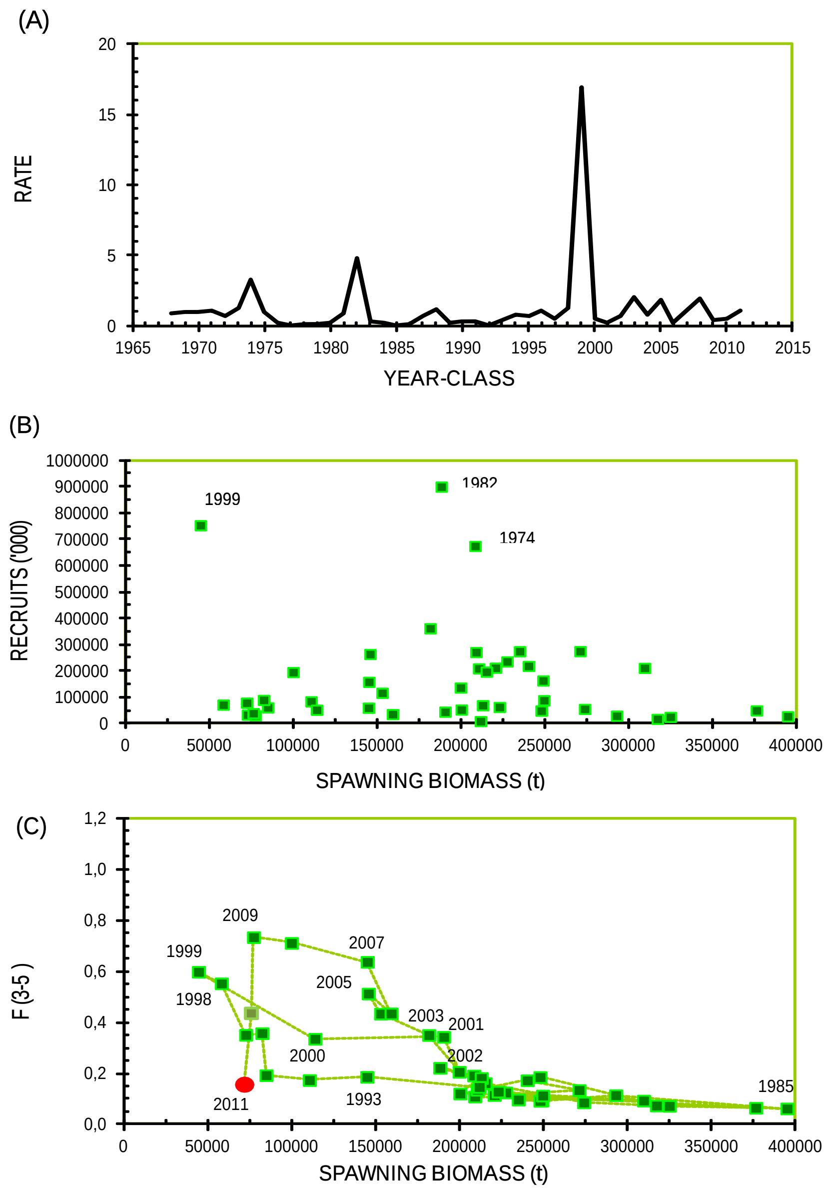


Figure 6. Analytical assessment (ICA) of Atlantic Mackerel in NAFO subareas 3–4: (A) recruitment rate, (B) relationship between recruits ('000) and spawning biomass (t) and (C) relationship between fishing mortality at ages 3-5 (weighted by the corresponding abundances) and spawning biomass (t) (some years are indicated).

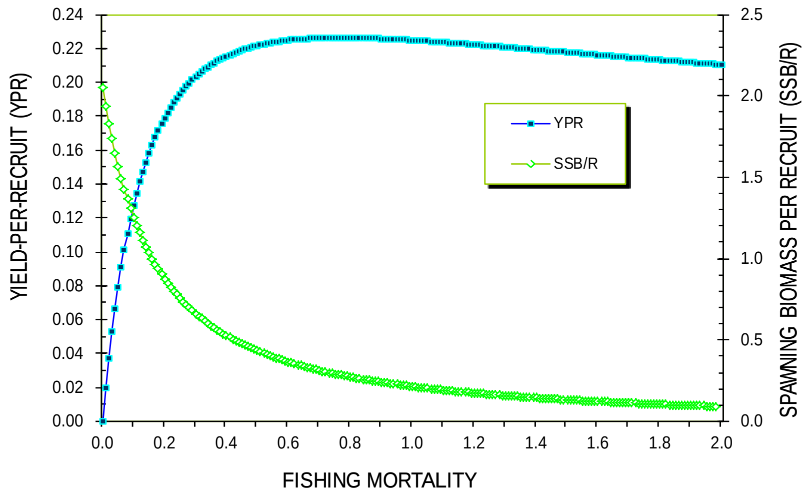


Figure 7. Analyses of yield and spawning biomass per recruit for Atlantic Mackerel in NAFO subareas 3–4: ($F_{0.1}$ = 0.258, F_{max} = 0.819 and F at 40 % = 0.217).

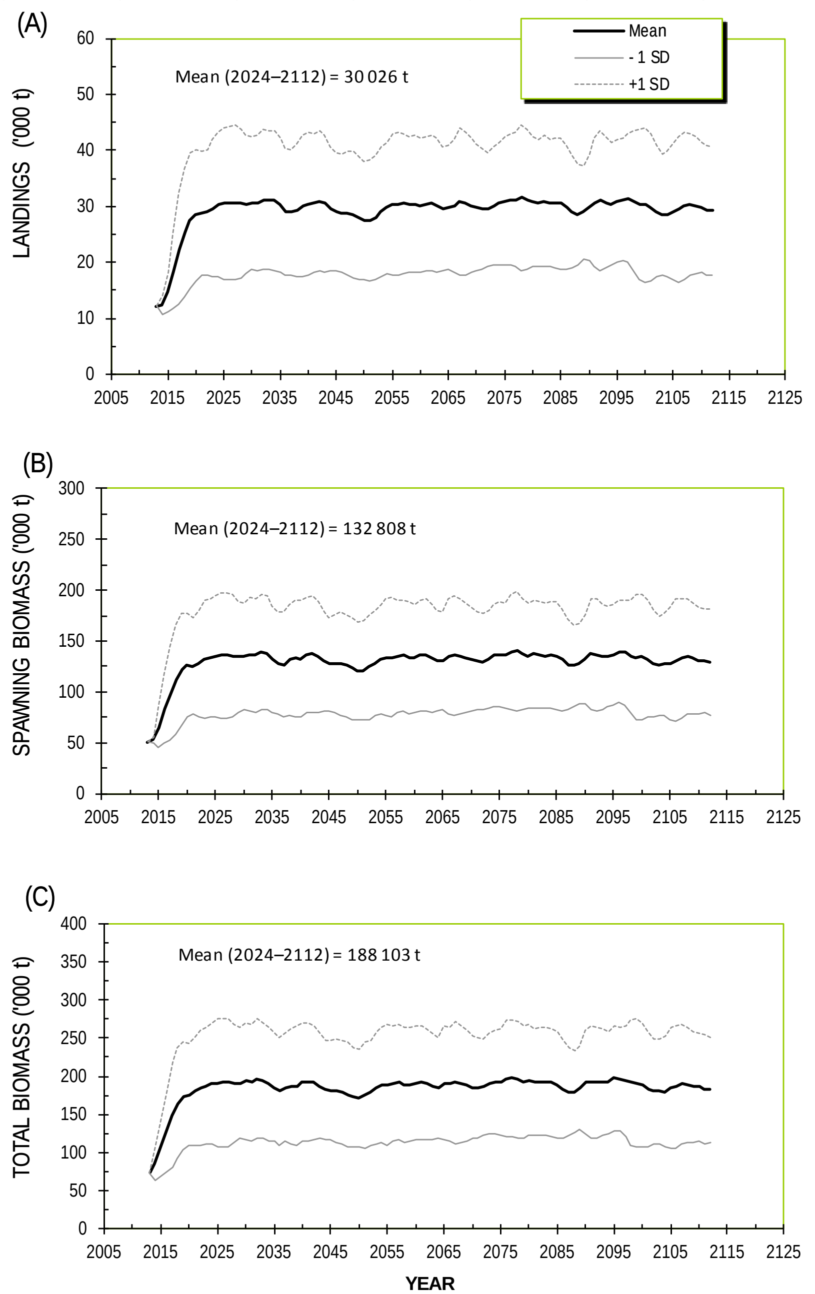


Figure 8. Random bootstrap projections (AGEPRO) of: (A) landings ('000 t), (B) spawning biomass (SSB) ('000 t) and (C) total biomass ('000 t) with the value of F set to 40% as harvest strategy. MSY and SSB_{msy} in (A) and (B) represent the mean of the projected values for the period 2024-2112.

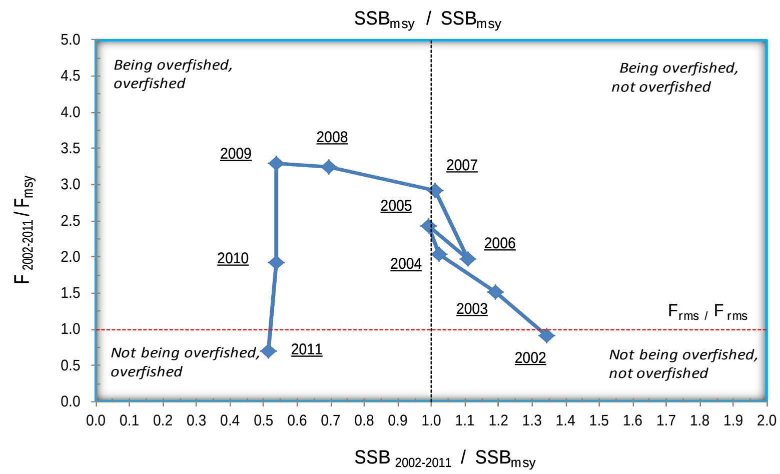


Figure 9. Status of fishing mortality (F) and spawning biomass (SSB) (t) of Atlantic Mackerel in NAFO subareas 3–4 in 2011 and estimated trajectory since 2002.