



## ASSESSMENT OF THE ATLANTIC MACKEREL STOCK FOR THE NORTHWEST ATLANTIC (SUBAREAS 3 AND 4) IN 2013



(Courtesy: M. Claude Nozères)

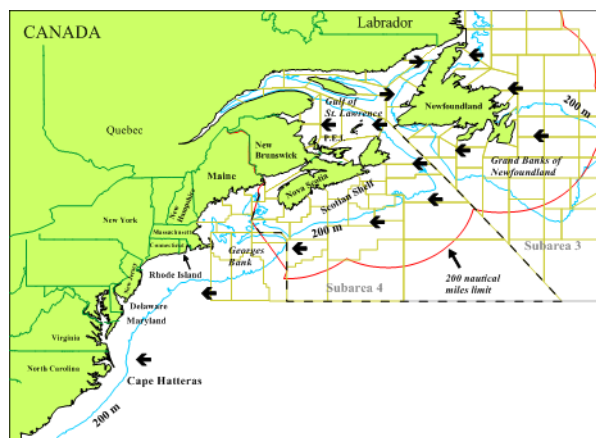


Figure 1. Distribution (←) of Atlantic mackerel (*Scomber scombrus* L.) in the Northwest Atlantic.

### Context:

Atlantic mackerel (*Scomber scombrus* L.) is found in the waters of the North Atlantic, from the Mediterranean to Norway, Iceland and the Faroe Islands in the east and from North Carolina to Newfoundland in the west (Figure 1). During spring and summer, Atlantic mackerel is found in inshore waters. From late fall and in winter, it is found deeper in warmer waters at the edge of the continental shelf. In the Northwest Atlantic, two main spawning areas characterize its distribution range. In Canadian waters, spawning occurs mainly in the southern Gulf of St. Lawrence during June and July. In American waters, spawning occurs during March and April between the coasts of Rhode Island and Virginia.

In the Maritime Provinces, Newfoundland and Quebec (NAFO subareas 3 and 4), over 15,000 commercial fishermen participate in the Atlantic mackerel fishery. This fishery occurs mainly along the coasts with gillnets, jiggers, handlines, seines (purse and "tuck") and traps. The type of gear used varies by region and time of year. Landings by Canadian fishermen were stable (average of 22,520 t per year) in the 1980s and 1990s. However, landings increased significantly in the early 2000s, reaching a historical high of 54,621 t in 2005. Landings averaged approximately 40,510 t per year between 2000 and 2010, before falling to 11,400 t, 6,468 t, and 7,431 t in 2011, 2012, and 2013, respectively. Canadian Atlantic mackerel landings are underestimated because commercial catches and catches for bait are not all recorded. Summer recreational catches are not recorded either. The spawning biomass of the Canadian mackerel contingent is evaluated using an analytical assessment calibrated by the abundance index from an egg survey conducted annually in the southern Gulf of St. Lawrence.

The last assessment of the Canadian Atlantic mackerel contingent was completed in April 2012. The Fisheries and Aquaculture Management Branch again requested a scientific advice on the Canadian mackerel contingent for the 2014 and 2015 seasons. The status of this contingent was reviewed at a meeting on March 4, 2014. This paper presents the results and conclusions from that meeting.

## SUMMARY

- Reported commercial landings in NAFO subareas 3 and 4 have decreased significantly in recent years. Between 2005 and 2010, they decreased from 54,621 t to 38,753 t before reaching 11,400 t in 2011, 6,468 t in 2012, and 7,431 t in 2013.
- US landings (commercial and recreational) in NAFO subareas 5 and 6 also decreased significantly in recent years. Between 2005 and 2010, they decreased from 43,220 t to 10,635 t before reaching 1,463 t in 2011, 6,019 t in 2012, and 5,250 t in 2013.
- Age at 50% maturity has varied little over the years. However, length at 50% maturity has varied and in most cases it is greater than the minimum authorized length of catch of 250 mm. The fact that catches may target immature fish represents an additional pressure for the stock.
- Mackerel condition in June and the gain in condition during summer, both apparently related to the temperature of the cold intermediate layer (CIL) and to the abundance and phenology of key copepod species, decreased since 2003 and 2009 respectively, the 2003 value being among the lowest of the series. Mackerel recruitment success appears to be favoured by high abundance and an early development of the copepod *Calanus finmarchicus*.
- The abundance index from the egg survey dropped significantly between 1993 and 1998. Following an increase caused by the arrival of the strong 1999 year-class, the index dropped again from 2002 to reach since 2005 the lowest values of the series, which reflects the collapse of the stock.
- A sequential population analysis calibrated with the abundance index from the egg survey indicates that the mackerel spawning biomass has been declining since the mid-2000s to reach in 2013 the historical minimum.
- According to the sequential population analysis, this decline in biomass was caused by fishing mortality levels several times higher than the historic sustainable levels. Two previous declines in the biomass associated with large increases in fishing mortality had not caused such a severe decline of the stock. It is likely that the stock is currently in a situation of recruitment overfishing.
- Given the critical situation of the stock, the priority is for its reconstruction: (1) According to the projections based on the average sustainable fishing mortality from the analytical assessment, annual catches in 2014 and 2015 should not exceed 800 t; (2) In the current situation of the stock, it is even more important to know and control the bait and recreational fisheries.

## INTRODUCTION

### Fishery

#### Historical overview

Following the arrival of a foreign fishery, Atlantic mackerel (*Scomber scombrus* L.) landings in the Northwest Atlantic (NAFO subareas 2 to 6) increased significantly from the end of the 1960s, reaching historical highs of over 250,000 t per year between 1970 and 1976. Atlantic

mackerel landings dropped considerably in 1977 with the introduction of the 200-nautical-mile exclusive economic zone (EEZ). However, as a result of agreements between the United States and the USSR in the early 1980s, they increased again to reach nearly 90,000 t in 1990 (Figure 2). Landings then dropped considerably as the US gradually reduced the quotas allocated to the USSR and closed the foreign fleet fishery completely in 1992. Landings of mackerel have experienced an increase of almost 400% between 2000 and 2006 due to the presence of a dominant year-class (1999) and a significant increase of the fishing effort. Landings of more than 100,000 t were reached in 2004 and 2006. Landings are decreasing since 2006, and in 2013 they were the lowest of the Canadian–US historical series.

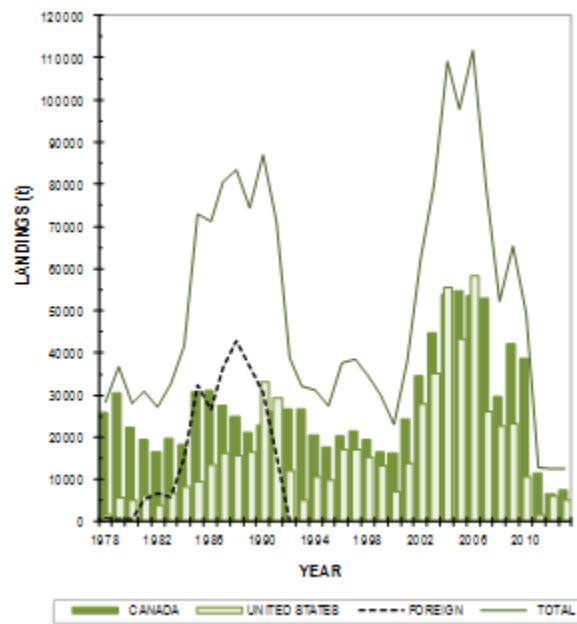


Figure 2. Annual Atlantic mackerel landings (t) for the Northwest Atlantic (NAFO subareas 2 to 6) since 1978 (first full year of the 200-nautical-mile exclusive economic zone –EEZ–).

Between 1987 and 2000, the total allowable catch (TAC) for the Northwest Atlantic was set at 200,000 t. Following the low biomass estimates from the 1996, 1998 and 2000 Canadian egg surveys, Canada lowered the TAC to 150,000 t between 2001 and 2009. In 2005, the US proposed values of more than 200,000 t for the 2006–2008 period. The TAC was lowered to 80,000 t following the 2009–2010 joint Canada-US assessment, and to 60,000 t following the 2010 Canadian Advisory Committee. Finally, following the 2012 Canadian Advisory Committee, the TAC for subareas 3 and 4 was set at 36,000 t to equal the US TAC despite a scientific advice that recommended annual catches not exceeding 9,000 t (DFO 2012).

### 2013 landings

For the Northwest Atlantic (NAFO subareas 2 to 6), Atlantic mackerel preliminary landings in 2013 totalled 12,681 t. These landings are of the same order of magnitude than those of 2011 and 2012 and represent a significant drop from the years prior to 2011 (Table 1). For Eastern Canada (NAFO subareas 3 and 4), preliminary landings in 2013 totalled 7,431 t, which are similar to those of 2011 and 2012 and also constitute a significant drop compared to previous years.

Table 1. Annual Atlantic mackerel landings (t) in NAFO subareas 2 to 6 between 1990 and 2013. Canadian landings for 2012 and 2013 are preliminary. Unlike the US, Canada does not record recreational fishery catches.

YEAR	CANADA		UNITED STATES			TOTAL
	Canadian vessels	Foreign vessels	Commercial	Recreational	Foreign	
1990	19 190	3 854	31 261	1 908	30 678	86 891
1991	24 914	1 281	26 961	2 439	15 714	71 309
1992	24 307	2 417	11 775	284	0	38 783
1993	26 158	591	4 666	600	0	32 015
1994	20 564	49	8 917	1 705	0	31 236
1995	17 706	0	8 468	1 249	0	27 424
1996	20 394	0	15 812	1 340	0	37 547
1997	21 309	0	15 403	1 737	0	38 449
1998	19 334	0	14 525	690	0	34 548
1999	16 561	0	12 031	1 335	0	29 927
2000	16 080	0	5 649	1 448	0	23 177
2001	24 429	0	12 340	1 536	0	38 305
2002	34 662	0	26 530	1 294	0	62 485
2003	44 736	0	34 298	770	0	79 804
2004	53 777	0	54 990	473	0	109 240
2005	54 621	0	42 187	1 032	0	97 840
2006	53 649	0	56 640	1 511	0	111 801
2007	53 016	0	25 547	584	0	79 147
2008	29 671	0	21 734	783	0	52 188
2009	42 231	0	22 635	603	0	65 470
2010	38 753	0	9 877	759	0	49 388
2011	11 400	0	531	932	0	12 863
2012 <sup>1</sup>	6 468	0	5 336	683	0	12 487
2013 <sup>1</sup>	7 431	0	4 408	842	0	12 681
<b>AVERAGE:</b>						
1990-1999	21 044	819	14 982	1 329	4 639	42 813
2000-2011	38 086	0	26 080	977	0	65 142

<sup>1</sup> Preliminary

Of the 7,431 t of Atlantic mackerel caught in Canadian waters in 2013, 5,145 t (69.2%) were landed in Newfoundland (Table 2). A total of 4,955 t (66.7%) were landed in Division 4R compared to 1,676 t (22.6%) in Division 4T (Table 3). The main fishing gear used included the small (<65' or 19.8 m) purse seine with 3,470 t (46.7%), the large (>65') purse seine with 1,519 t (20.4%), and handline with 1,279 t (17.2%) (Table 4).

Table 2. Annual Atlantic mackerel landings (t) by Canadian province since 2000. Landings for 2012 and 2013 are preliminary.

PROVINCE	YEAR														AVERAGE (2000-2011)
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 <sup>1</sup>	2013 <sup>1</sup>	
Nova Scotia	4 547	4 058	3 989	7 187	5 325	4 935	2 526	2 831	1 961	1 454	666	416	683	388	3 324
New Brunswick	972	2 199	2 182	1 734	1 398	1 047	1 499	1 426	1 205	1 762	1 260	903	524	111	1 466
Prince Edward Island	4 134	5 979	6 088	4 543	4 692	4 946	3 552	2 756	1 606	2 463	1 959	1 400	1 465	505	3 677
Quebec	2 022	3 212	4 421	4 597	1 979	1 221	1 818	1 750	1 863	2 316	1 709	1 345	1 177	1 282	2 354
Newfoundland	4 406	8 981	17 982	26 675	40 383	42 471	44 196	44 253	23 036	34 237	33 159	7 337	2 619	5 145	27 260
Not known	0	0	0	0	0	0	58	0	0.2	0.2	0.2	0	0	0	5
<b>TOTAL</b>	<b>16 080</b>	<b>24 429</b>	<b>34 662</b>	<b>44 736</b>	<b>53 777</b>	<b>54 621</b>	<b>53 649</b>	<b>53 016</b>	<b>29 671</b>	<b>42 231</b>	<b>38 753</b>	<b>11 401</b>	<b>6 468</b>	<b>7 431</b>	

<sup>1</sup> Preliminary

Table 3. Annual Atlantic mackerel landings (t) by NAFO division since 2000. Landings for 2012 and 2013 are preliminary.

DIVISION AND AREA	YEAR														AVERAGE (2000-2011)
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 <sup>1</sup>	2013 <sup>1</sup>	
2J <sup>2</sup>	13	0	0	0	0	0	0	26	0	0	0	0	78	0	3
3K	2 317	322	6 566	588	16 360	24 024	19 158	8 775	9 125	6 898	12 916	426	129	190	8 956
3L	55	10	3	0	59	4 068	7 960	10 340	4	39	830	61	3	0	1 953
3P	0	0	0	0	0	0	0	27	0	0	0	0	0	0	2
3O	20	273	162	149	79	238	266	360	166	5 387	5 541	1 544	149	0	1 182
4R	2 001	8 375	11 251	25 938	23 885	14 141	16 799	24 726	13 741	21 913	13 871	5 306	2 261	4 955	15 162
4S	0	16	2	0	0	35	76	19	23	64	123	107	304	245	39
4T	7 316	12 316	14 484	14 324	9 152	9 424	7 788	6 385	5 439	6 815	4 919	3 549	2 853	1 676	8 492
4V	576	125	308	60	13	126	222	370	111	55	7	2	150	141	164
4W	120	248	115	9	59	36	75	59	63	65	129	18	177	9	83
4X	3 663	2 743	1 771	3 669	4 169	2 529	1 304	1 928	1 000	980	416	389	365	215	2 047
5YZ <sup>3</sup>	1	0	0	0	0	0	0	0	0	16	0	0	0	0	1
Not known	0	0	0	0	0	0	2	0	0	0	0	0	0.2	0	0
Scotian Shelf	4 359	3 117	2 194	3 737	4 241	2 691	1 601	2 357	1 173	1 116	552	409	692	365	2 296
Gulf of St. Lawrence	9 317	20 707	25 737	40 262	33 037	23 600	24 663	31 129	19 203	28 792	18 913	8 962	5 418	6 876	23 693
East and south coasts of Newfoundland	2 405	605	6 731	737	16 498	28 330	27 384	19 529	9 295	12 324	19 288	2 031	359	190	12 096
<b>TOTAL</b>	<b>16 080</b>	<b>24 429</b>	<b>34 662</b>	<b>44 736</b>	<b>53 777</b>	<b>54 621</b>	<b>53 649</b>	<b>53 016</b>	<b>29 671</b>	<b>42 231</b>	<b>38 753</b>	<b>11 402</b>	<b>6 468</b>	<b>7 431</b>	

<sup>1</sup> Preliminary<sup>2</sup> Mackerel are occasionally caught in 2J (Labrador)<sup>3</sup> Caught in 5YZ but landed in subarea 4

For several years, 40% of the Canadian TAC has been allocated to large seiners (and before the last integrated fishery management plan, for all exploratory fishing) and 60% to small seiners, "tuck" seine and fixed gear such as traps, gillnets, lines and weirs. Large seiners caught only 11% of their allocation in 2013, compared to 27% for the other types of fishing gear (Table 5).

Table 4. Annual Atlantic mackerel landings (t) by fishing gear since 2000. Landings for 2012 and 2013 are preliminary.

GEAR	YEAR														AVERAGE (2000-2011)
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 <sup>1</sup>	2013 <sup>1</sup>	
Bottom trawl	1	3	5	0	2	1	7	7	0	1	1	1	3	5	2
Midwater trawl <sup>2</sup>	0	0	0	0	0	0	14	15	0	0	0	0	0	0	2
"Tuck" seine	0	0	0	0	2 460	845	2 696	3 982	1 718	3 019	3 428	1 066	240	266	1 601
Purse seine (PS) < 65'	3 431	4 518	10 833	11 686	25 338	28 232	29 161	26 731	15 659	20 552	20 688	4 501	1 926	3 470	16 777
Purse seine (PS) > 65'	492	3 579	6 074	14 645	11 612	5 065	6 011	8 686	5 178	9 015	7 024	1 191	448	1 519	6 548
Other seines	5	231	344	22	0	6 393	4 782	3 327	186	681	1 097	130	44	0	1 433
Gillnet	5 297	6 610	4 958	4 542	4 734	3 930	4 509	3 629	2 475	3 472	2 736	1 690	832	281	4 049
Trap	4 215	3 237	2 088	3 651	4 699	3 420	2 337	2 906	1 153	1 657	1 129	646	680	449	2 595
Longline	4	20	19	16	4	61	48	0	9	3	0	5	6	0	16
Handline	2 230	5 676	9 839	9 857	3 855	5 338	3 180	2 739	2 367	2 859	2 075	1 504	1 717	1 279	4 293
Jigger	90	200	129	9	694	1 118	877	321	62	0	0	0	1	0	292
Mechanized jigger	0	0	0	0	1	1	0	0	270	729	386	459	359	94	154
Weir	0	46	48	74	2	20	3	0	2	0	0	0	25	0	16
Other	311	308	326	217	363	191	2	651	549	157	160	180	60	56	285
Not known	6	0	0	18	12	4	22	23	43	88	31	26	129	13	23
<b>TOTAL</b>	<b>16 080</b>	<b>24 429</b>	<b>34 662</b>	<b>44 736</b>	<b>53 777</b>	<b>54 621</b>	<b>53 649</b>	<b>53 017</b>	<b>29 671</b>	<b>42 231</b>	<b>38 753</b>	<b>11 401</b>	<b>6 468</b>	<b>7 431</b>	

<sup>1</sup> Preliminary; <sup>2</sup> Midwater trawl, exploratory fishery in Nova Scotia

Table 5. Atlantic mackerel landings (t) and allocations (t and %) since 2000. Landings for 2012 and 2013 are preliminary.

ALLOC -ATION	GEAR	YEAR														AVERAGE (2000-2011)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 <sup>1</sup>	2013 <sup>1</sup>	
40%	Mid. trawl	0	0	0	0	0	14	15	0	0	0	0	0	0	2	
	PS >65'	492	3 579	6 074	14 645	11 612	5 065	6 011	8 686	5 178	9 015	7 024	1 191	448	1 519	6 548
	<b>Total</b>	<b>492</b>	<b>3 579</b>	<b>6 074</b>	<b>14 645</b>	<b>11 612</b>	<b>5 065</b>	<b>6 024</b>	<b>8 702</b>	<b>5 178</b>	<b>9 015</b>	<b>7 024</b>	<b>1 191</b>	<b>448</b>	<b>1 519</b>	<b>6 550</b>
40%	<b>TAC</b>	<b>40 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>30 000</b>	<b>16 000</b>	<b>16 000</b>	<b>14 400</b>	<b>14 400</b>	<b>28 500</b>
	% caught	1	12	20	49	39	17	20	29	17	30	44	7	3	11	24
60%	PS <65'	3 431	4 518	10 833	11 686	25 338	28 232	29 161	26 731	15 659	20 552	20 688	4 501	1 926	3 470	16 777
	Other	12 158	16 332	17 755	18 405	16 827	21 323	18 464	17 584	8 835	12 665	11 041	5 708	4 094	2 442	14 758
	<b>Total</b>	<b>15 589</b>	<b>20 850</b>	<b>28 588</b>	<b>30 091</b>	<b>42 164</b>	<b>49 555</b>	<b>47 625</b>	<b>44 316</b>	<b>24 493</b>	<b>33 217</b>	<b>31 729</b>	<b>10 209</b>	<b>6 020</b>	<b>5 912</b>	<b>31 536</b>
60%	<b>TAC</b>	<b>60 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>45 000</b>	<b>24 000</b>	<b>24 000</b>	<b>21 600</b>	<b>21 600</b>	<b>42 750</b>
	% caught	26	46	64	67	94	110	106	98	54	74	132	43	28	27	76
	<b>GRAND TOTAL</b>	<b>16 080</b>	<b>24 429</b>	<b>34 662</b>	<b>44 736</b>	<b>53 777</b>	<b>54 621</b>	<b>53 017</b>	<b>29 671</b>	<b>42 231</b>	<b>38 753</b>	<b>11 401</b>	<b>6 468</b>	<b>7 431</b>	<b>38 086</b>	
	<b>TOTAL TAC</b>	<b>100 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>75 000</b>	<b>40 000</b>	<b>40 000</b>	<b>36 000</b>	<b>36 000</b>		

<sup>1</sup> Preliminary

## ANALYSIS

### Description of catches

#### Age structure

The Atlantic mackerel age structure is mainly influenced by the periodic arrival of dominant year-classes. Such year-classes, as those of 1967, 1974, 1982, 1988 and 1999, completely dominated commercial catches for several years. For example, fish from the 1999 year-class contributed to 77% of all catches (in numbers) that were made between 2000 and 2004. The

abundance of this year-class started declining in 2005 and since then, the age structure of Atlantic mackerel is instead characterized by the quick capture of the new year-classes. This was the case for the 2003, 2005, 2007, 2008, and 2010 year-classes (Figures 3A and 3B), the relative importance of which was higher than the average (Figure 3C). The mean age of mackerel caught decreased between 1994 and 2000 (Figure 3D). It increased in the early 2000s with the arrival and aging of the 1999 year-class. The mean age increased slightly in 2011 before decreasing again in 2012. Values measured since 1997 are under historical average. In fact, very few old fish are present in the catches of recent years.

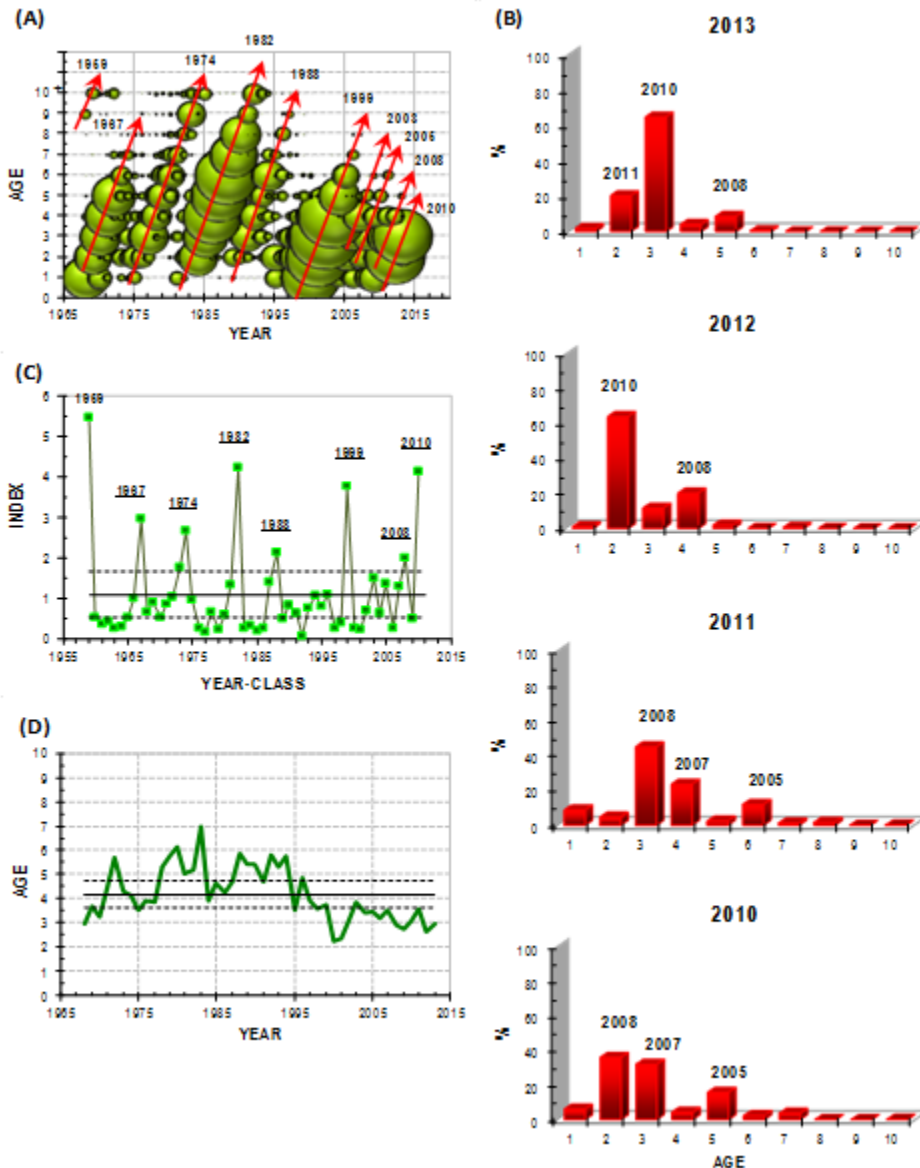


Figure 3. Catch-at-age in % (A and B) (dominant year-classes are indicated), Johnson index representing relative strength of year-classes (C), and mean age (D) of Atlantic mackerel catches from NAFO subareas 3 and 4 (horizontal lines in C and D represent the corresponding averages  $\pm 0.5$  x standard deviation).

### Length frequencies

Mackerel length frequencies are characterized by the occurrence of main modes that shift toward larger sizes over the years (Figure 4). These modes are associated with dominant year-classes and are observed in length frequencies from all fishing gear. However, the first year of detection of these year-classes in the length frequencies varies according to the selectivity of fishing gears. This is the case for the 2008 year-class which was observed as early as 2009 in length frequencies from line (4T) and seine (4R) fisheries, but only in 2011 for those of gillnet (4T).

In 2013, a slight increase in the mean length was observed in the catches of gillnet and seine fisheries compared to a decrease for the line fishery. Since the mid-2000, all these lengths remain below their respective historical averages. In 2013, the 2010 year-class was observed in the length frequencies of gillnet (4T), line (4T) and seine fisheries (4R) (Figure 4).

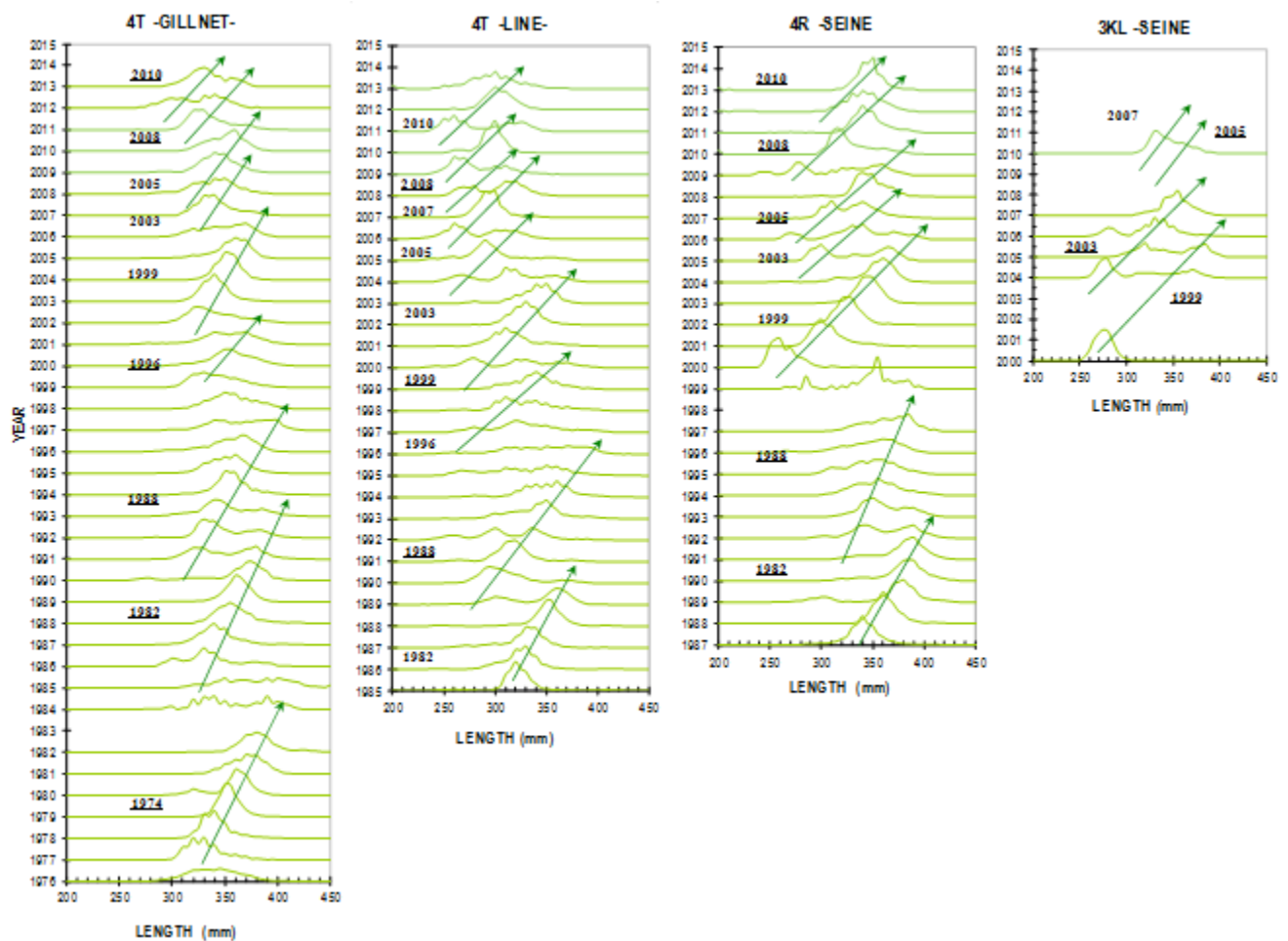


Figure 4. Annual length (mm) frequencies (%) of Atlantic mackerel caught with gillnets and lines in Division 4T and with seines in Divisions 3KL and 4R (the year-classes that dominated these fisheries are indicated).



## Resource status

### Biological indicators

The Fulton condition factor, measured in June, presented higher than average values (1973–2012) between 1973 and 1984 as well as in 1999, 2001, 2006 and between 2009 and 2012 (Figure 5). The index has been decreasing since 2009 and the 2013 value represents one of the lowest of the historical series. Annual variations in the condition are associated with those of the cold intermediate layer (CIL) temperature index, except since 2009.

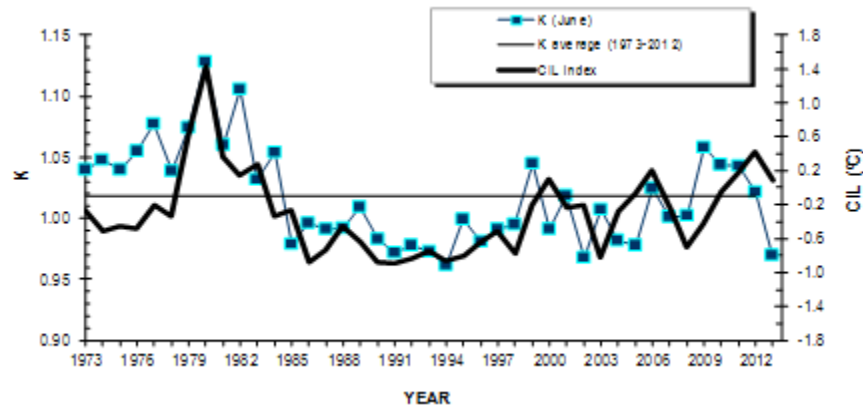


Figure 5. Fulton condition factor ( $K$ ) calculated from samples collected in June in NAFO subareas 3 and 4 since 1973 and temperature index ( $^{\circ}\text{C}$ ) of the cold intermediate layer, or CIL (P. Galbraith, DFO, MLI, pers. comm.). The mean condition factor for the 1973–2012 period is also indicated.

The proportion of mature fish at age has not varied much over the years (Figure 6A). The mean age at 50% maturity ( $A_{50}$ ) increased from 1.35 in the 1980s to 1.48 and 1.40 in the 1990s and 2000s. Between 2010 and 2013,  $A_{50}$  was 1.37 years (Figure 6B).

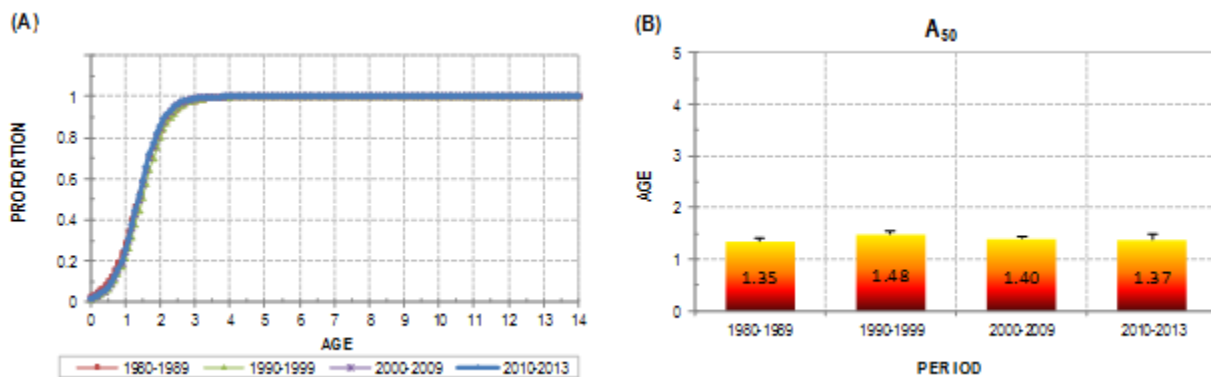


Figure 6. Proportion of mature fish at age calculated by period of years (A) and mean age at 50% maturity or  $A_{50}$  (B) (with confidence intervals at 95%) for Atlantic mackerel sampled in June in NAFO subareas 3 and 4 since 1980.

The proportion of mature fish at length has varied considerably over the years (Figure 7A). The mean length at 50% maturity ( $L_{50}$ ) decreased from 272.91 to 259.57 mm between the 1970s and 1980s (Figure 7B). This length was 266.17 mm in the 1990s, before reaching a minimum of 245.03 mm in the 2000s. Between 2010 and 2013,  $L_{50}$  was 263.76 mm.

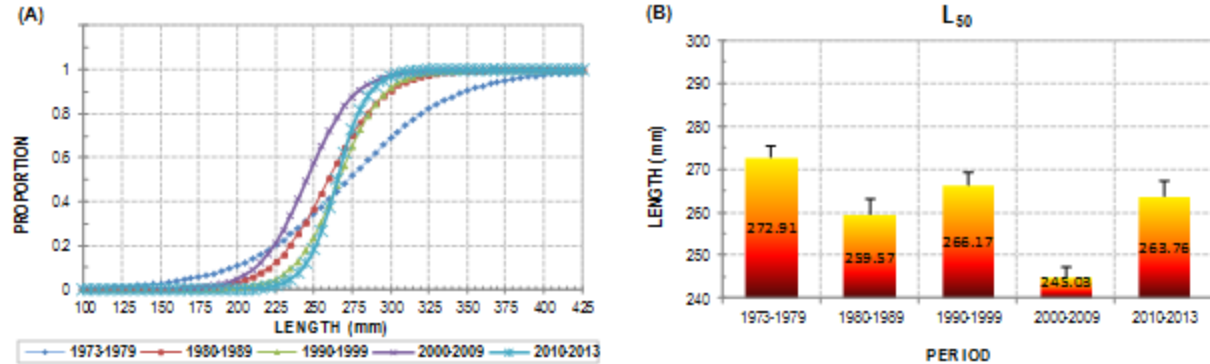


Figure 7. Proportion of mature fish at length calculated by period of years (A) and mean length at 50% maturity or  $L_{50}$  (B) (with confidence intervals at 95%) for Atlantic mackerel sampled in June in NAFO subareas 3 and 4 since 1973.

$L_{50}$  was greater than the minimum authorized length of catch of 250 mm for most of the years of the 1974–2013 period (Figure 8.) These results show that fishing pressure is exerted on immature fish. The increase in the minimum authorized length of catch and the application of the small fish protocol developed for mackerel would increase the reproductive potential by reducing this pressure.

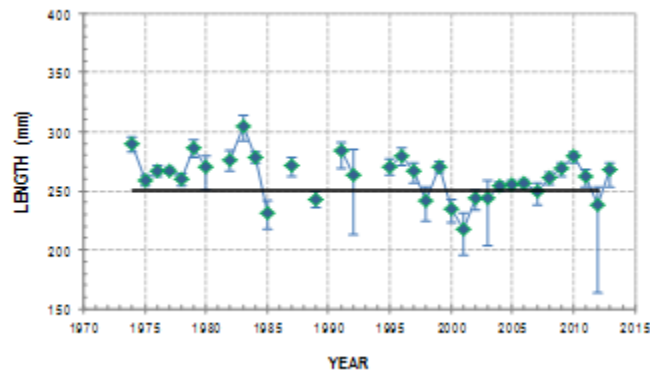


Figure 8. Annual length at 50% maturity or  $L_{50}$  (with 95% confidence intervals) of Atlantic mackerel in NAFO subareas 3 and 4 since 1973 (horizontal line indicates the minimum authorized length of catch of 250 mm).

### 2012 and 2013 egg surveys

During the 2012 and 2013 surveys, the highest egg densities ( $n/m^2$ ) were measured in the northwest part of the sampled area and in St. Georges Bay located between Nova Scotia and Cape Breton (Figures 9A and 9B). The densities measured in 2013 were generally higher than those in 2012. Water temperature (mean 0-10 m) was higher in 2012 (Figures 9C and 9D).

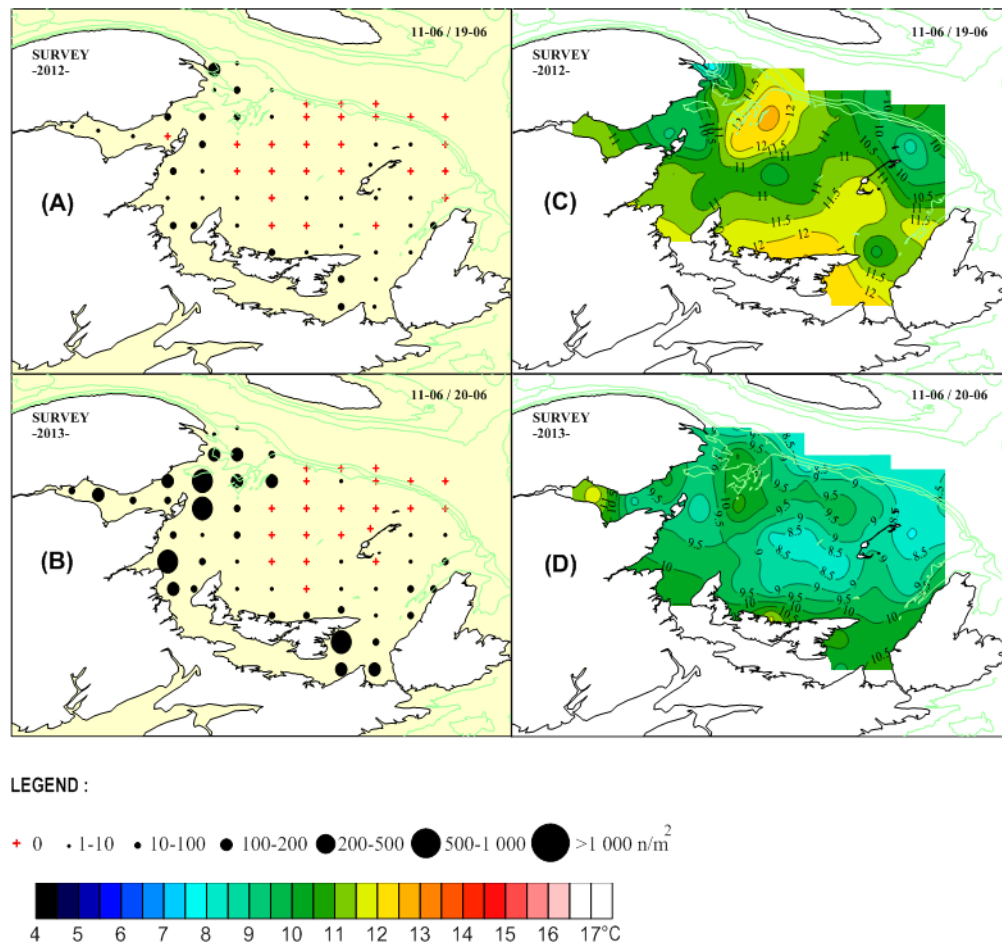


Figure 9. Atlantic mackerel egg (stages 1 and 5) densities ( $n/m^2$ ) distribution (A and B) and average water temperatures ( $^{\circ}C$ ) (mean 0–10 m) (C and D) measured during the 2012 and 2013 surveys in the southern Gulf of St. Lawrence.

### Abundance index

The abundance index from the egg survey has increased three times over the years due to the arrival of the dominant year-classes of 1982, 1988, and 1999 (Figure 10). The index fell sharply between 1993 and 1998. The lowest values of the series have been calculated since 2005. The index shows a very slight increase in 2013.

### Analytical assessment

An analytical assessment based on a sequential population analysis (SPA) was undertaken using the Canadian catch-at-age (1968–2013) and the abundance index from the southern Gulf of St. Lawrence egg survey (1996–2013). The diagnostic resulting from this analysis does not reveal any major adjustment problems. However, a slight retrospective pattern was observed for the abundance and fishing mortality estimates compared with no pattern for the total and spawning biomasses.

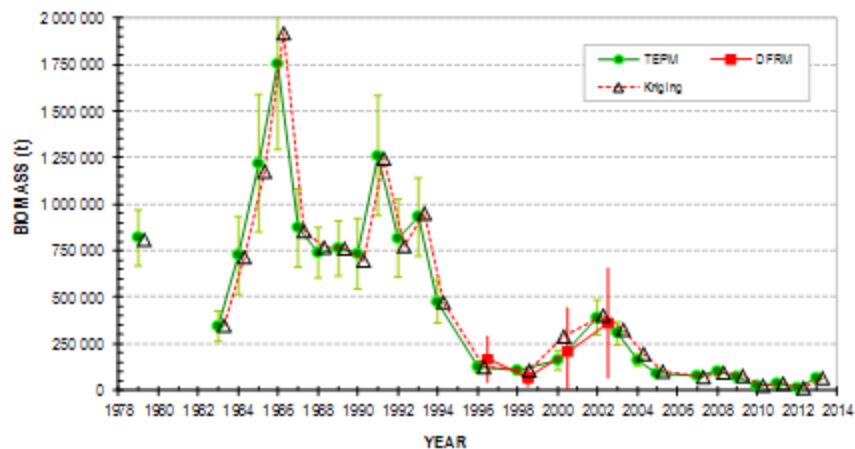


Figure 10. Abundance (t) index of Atlantic mackerel calculated using two approaches (TEPM: Total Egg Production Method; DFRM: Daily Fecundity Reduction Method) and two different techniques (stratified and kriging means) in the case of the first approach. No index was calculated in 2006 because the survey was conducted at the end of the spawning season.

The SPA results indicate the arrival of very strong year-classes in 1967, 1969, 1972, 1974, 1981, 1982, 1999, and 2003 (Figure 11). The abundance of all these year-classes were greater than the high recruitment level. More recently, the 2004, 2005, and 2008 year-classes presented an abundance greater than the medium recruitment level compared to 2013 which is just above the lower level.

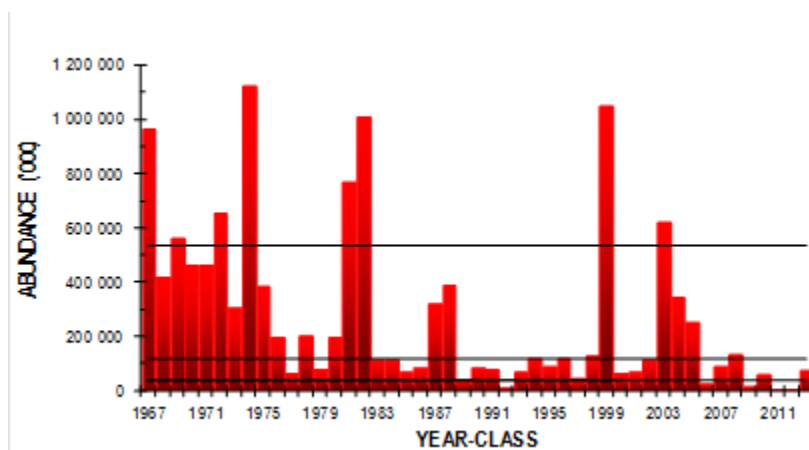


Figure 11. Estimation of Atlantic mackerel recruitment ('000) at age 1 in NAFO subareas 3 and 4 for year-classes from 1967 to 2013. Horizontal lines represent three levels of recruitment: low, medium, and high.

Annual fishing mortalities were stable (sustainable) between 1968 and 1992 (Figure 12). They then increased since 1993 to reach values above 0.50 at the end of the 1990s. Following a decrease in mortality in young age groups, a new increase was measured in the 2000s with maximum values reached in 2011. A decrease was observed in all year-classes in 2012 and 2013. However, mortalities calculated by age group remain high with values superior than 0.46.

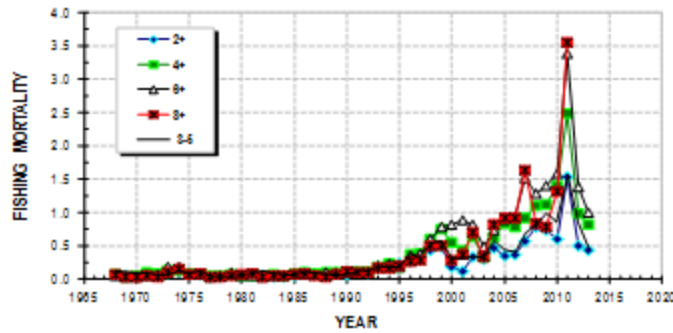


Figure 12. Atlantic mackerel annual fishing mortality in NAFO subareas 3 and 4 for various age groups from 1968 to 2013.

The significant increases in fishing mortality were accompanied by declines in the spawning and total biomasses (Figure 13). The lowest biomasses of the whole historical series were estimated in 2012 and 2013.

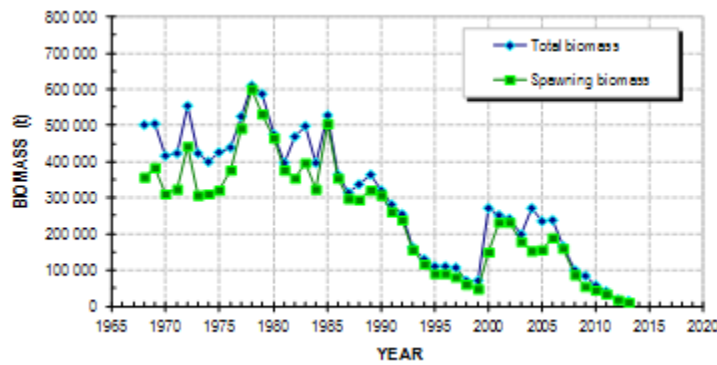


Figure 13. Total and spawning Atlantic mackerel biomasses (t) in NAFO subareas 3 and 4 for the 1968–2013 period.

The relationship between fishing mortality and spawning biomass indicates that the stock is currently in a critical situation (Figure 14).

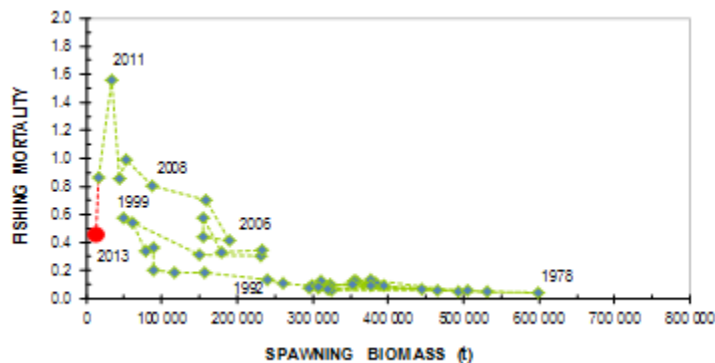


Figure 14. Relationship between fishing mortality and Atlantic mackerel spawning biomass (t) in NAFO subareas 3 and 4 for the 1968–2013 period (some years are indicated).

**Projections**

According to projections made at the level of the average fishing mortality of the 1968–1992 stability period ( $F=0.087$ ) and after applying an adjustment factor to the retrospective pattern observed for the abundances at age in 2014, spawning biomasses (SSB) at the beginning of 2015 and 2016 would be respectively 7,532 t and 9,045 t for catches in 2014 and 2015 of 662 t and 821 t (Figure 15).

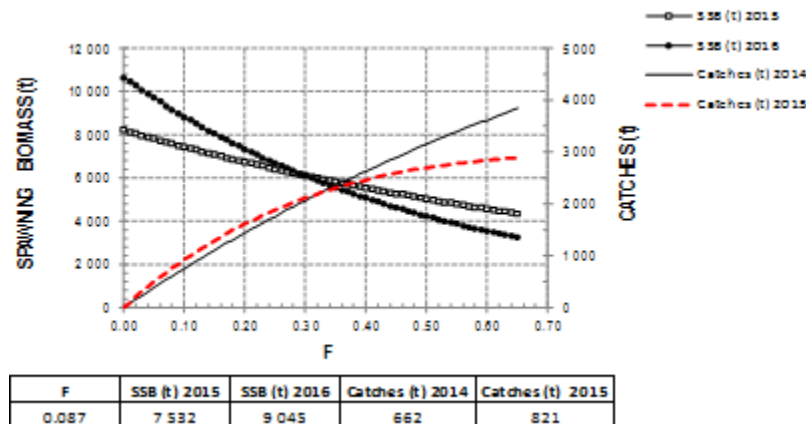


Figure 15. Projections of the spawning biomasses (t) at the beginning of 2015 and 2016 and catches (t) in 2014 and 2015 for fishing mortality of 0.087 which is associated to the 1968–1992 stability (sustainable) period. These projections were made by applying an adjustment factor to the retrospective pattern observed for the abundances at age in 2014.

From 2007 to 2009, the trajectory of the stock moved inside the "overfishing and not overfished" area (Figure 16). The trajectory subsequently remained in the "overfishing and overfished" area.

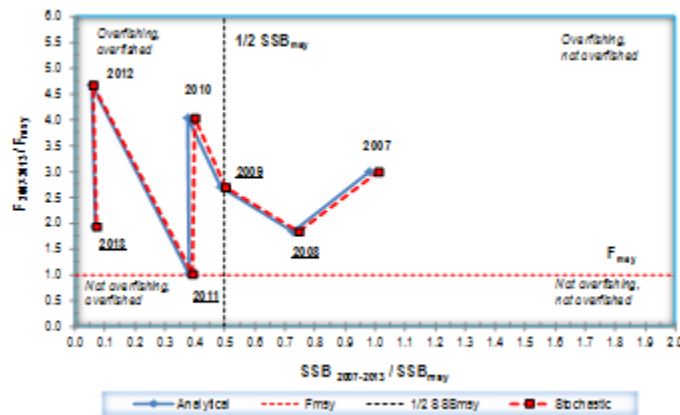


Figure 16. Status of the fishing mortality ( $F$ ) and spawning biomass ( $SSB$ ) (t) of the Atlantic mackerel in NAFO subareas 3 and 4 in 2013 and trajectory of the stock estimated since 2007 from the results of the retrospective analyses. Spawning biomasses at the maximum sustainable yield ( $msy$ ) were estimated by analytical and stochastic approaches.

## Ecosystemic considerations

A study on the synthesis of variables describing the variations of the physical environment and the zooplankton dynamics has identified two modes of spatial variability, a long-term mode (15-20 years) and a second short-term mode (5-10 years). This study also identified a strong link between environmental conditions, abundance variations, and the composition and seasonality of zooplankton species important for mackerel. The first mode of variability is strongly correlated to the warming of the environment and is characterized by the increasing abundance of *C. hyperboreus*, *Pseudocalanus* and *Temora* copepods, and a more early and late development of the first (spring) and second (fall) generations of the copepod *C. finmarchicus*. The second mode mainly illustrates the response of *Calanus* species of copepods and krill abundance and *Calanus* copepods phenology to variations in surface and cold intermediate layer temperature and sea-ice cover.

An analysis aimed at determining abrupt shifts in time series and applied on environmental variables identified sudden changes in environmental conditions in 1996-1997 and from 2009 to 2012. Such changes suggest abrupt transitions between separate environmental regimes.

Results of this analysis also show that variations in mackerel condition (K) and recruitment success ( $R_s$ ) are largely explained by environmental variability. Variations in abundance, species composition and phenology of key copepod species for the mackerel represent the most likely explanatory variables of variations in K and  $R_s$ , showing that adequate prey species in sufficient abundance and occurring at the right time for the mackerel dynamics. These results suggest that it would be important to incorporate the effect of environmental variation in the process of the mackerel assessment.

## Sources of uncertainty

### Unrecorded catches

Catches from the commercial fishery and sold directly between fishermen and from the bait fishery, which account for thousands of tons, are not all recorded in the DFO statistics. Catches of the recreational fishery, which is very popular in summer, are not recorded too. Because this activity is practised throughout Eastern Canada by many people including tourists – at wharf or aboard chartered vessels and almost commercially at some locations – the actual Atlantic mackerel catch statistics are largely underestimated. In view of future management of this activity (license, daily limits) and to improve fishery statistics as a whole, consideration should be given to developing methods for estimating all these catches. This recommendation has been issued for several years in the Advisory reports.

### Discards of small Atlantic mackerel

The discarding of Atlantic mackerel under the minimum authorized length of catch (250 mm) or below industry requirements is of concern. The extent of the discarding and the impact of this activity on the abundance of the year-classes at older ages are difficult to quantify. Measures such as the closure of the fishery or the relocation of fishing activities to reduce the impact of discarding on the abundance of future year-classes should be seriously considered.

## CONCLUSIONS AND ADVICE

The abundance index from the egg survey in the southern Gulf of St. Lawrence is at its lowest level. It's the same situation for the spawning biomass estimated from the analytical

assessment. Given the critical situation of the stock, the priority is for its reconstruction: (1) According to the projections based on the average sustainable fishing mortality from the analytical assessment, annual catches in 2014 and 2015 should not exceed 800 t; (2) In the current situation of the stock, it is even more important to know and control the bait and recreational fisheries.

## SOURCES OF INFORMATION

This Science Advisory Report is from the March 4, 2014 on the Assessment of the Atlantic Mackerel in subareas 3 and 4. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

DFO. 2012. [Assessment of the Atlantic Mackerel Stock for the Northwest Atlantic \(Subareas 3 and 4\) in 2011](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/031.

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