ASSESSMENT OF THE ATLANTIC MACKEREL STOCK FOR THE NORTHWEST ATLANTIC (SUBAREAS 3 AND 4) IN 2016

(Courtesy: Claude Nozères)

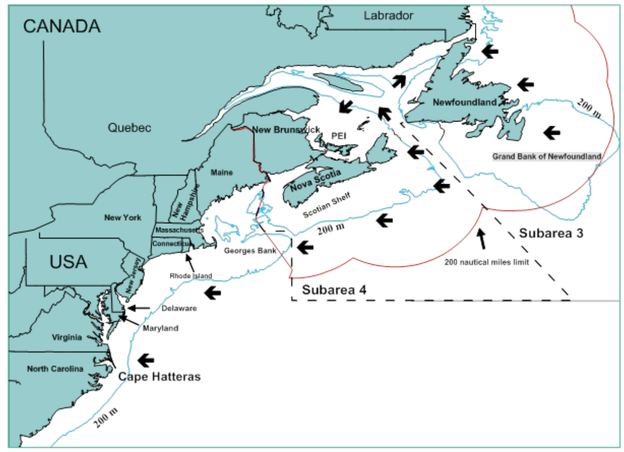

Figure 1. Distribution (←) of Atlantic mackerel (Scomber scombrus L.) in the Northwest Atlantic.

Context:

Atlantic mackerel (Scomber scombrus L.) is found in the waters of the Northwest Atlantic from North Carolina to Newfoundland (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. 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), several thousand commercial fishers participate in the Atlantic mackerel fishery. They fish mainly inshore using gillnets, jiggers, handlines, seines and traps, depending on the region and the time of year. Landings by Canadian fishers were stable and averaged 22,000 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. Average landings for 2006–2010 were 43,464 t. They then fell significantly to a historical low of 4,134 t in 2015.

Canadian Atlantic mackerel landings are underestimated because of unreported bait fishing. In addition, catches in the recreational fishery, which occurs during summer months all along the Atlantic coast, and the discards of small mackerel are not recorded.

The last assessment of the Canadian Atlantic mackerel contingent was completed in March 2014. The Fisheries and Aquaculture Management Branch has requested scientific advice on the Canadian Atlantic mackerel quota for the 2017 and 2018 fishing seasons.

SUMMARY

- Reported commercial landings in NAFO subareas 3 and 4 have decreased significantly in recent years. Between 2005 and 2013, they decreased from 54,621 t to 8,663 t before reaching 6,680 t in 2014 and 4,143 t in 2015. In 2016, the TAC of 8,000 t was reached.
- US landings (commercial and recreational) in NAFO subareas 5 and 6 also decreased significantly in recent years. Between 2005 and 2012, they decreased from 43,220 t to about 6,000 t and have remained at that level from 2013 to 2015.
- The issue of unrecorded catches has been investigated using a review of available data on bait needs and recreational fisheries, as well as an online survey aimed at mackerel fishermen. Both approaches show that total catches can reach 150% to 200% of declared catches, and that this ratio varies among regions and years.
- Following its increase in recent years, the length at 50% maturity has remained slightly above the minimum authorized length of 263 mm.
- The age structure in the fishery has contracted considerably since 2000 following the disappearance of fish older than 7 years. However, a slight improvement has been observed since 2013, with an increase of mackerel of ages 5 and 6.
- The abundance index from the egg survey in the southern Gulf reached its lowest level in 2012 (14,568 t), then slowly increased to 52,667 t in 2016. This value remains far below the abundance levels of over 750,000 t observed in the 1980s.
- A “censored” statistical catch-at-age model, calibrated with the abundance index from the egg survey and taking into account the uncertainty due to unrecorded catches, confirms that mackerel spawning biomass has declined due to high exploitation rates and reached its historical minimum in 2012 (20,000 t). According to the model, the 2016 spawning biomass was 40,000 t.
- The Limit Reference Point (LRP) for this stock is a proxy of 40%B_{msy} based on $F_{40\%}$ derived from a yield-per-recruit analysis. According to the censored model, stock abundance in 2016 was about 40% of the 103,000 t LRP.
- Model projections were used to quantify the risks associated with different catch scenarios. Considering that the stock is in the critical zone, total catches (declared + unreported) should be low enough to facilitate recovery.
- It is particularly important to fill gaps in the biological sampling of the commercial catch in some areas, to accelerate compiling of landing statistics and to improve data collection on unreported catches.

BACKGROUND

Historical overview

With the arrival of foreign fishing, Atlantic mackerel (*Scomber scombrus* L.) landings in the Northwest Atlantic (NAFO subareas 2 to 6) increased significantly starting in the late 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. However, as a result of agreements between the United States and the USSR in the early 1980s, they increased again to peak at near 90,000 t in 1990 (Figure 2). Landings then dropped considerably again as the US gradually reduced the mackerel quotas allocated to the USSR and closed the foreign fleet fishery completely in 1992.

Mackerel landings increased by nearly 400% between 2000 and 2006 due to the presence of a dominant year-class (1999) and a significant increase in fishing effort by small and large seiners on the east and west coasts of Newfoundland (divisions 3KL and 4R). Total landings exceeded 100,000 t in 2004 and 2006. Landings have been decreasing since 2006 and reached the lowest point of the Canadian–US historical series in 2015.

Between 1987 and 2000, the total allowable catch (TAC) for the Northwest Atlantic was 200,000 t. Following the low biomass estimates from the 1996, 1998 and 2000 egg surveys, Canada lowered the TAC to 150,000 t between 2001 and 2009. The TAC in subareas 3 and 4 was lowered to 80,000 t following the 2009–2010 joint Canada–US assessment, to 60,000 t following the 2010 Canadian Advisory Committee meeting, and to 36,000 t following the 2012 Canadian Advisory Committee meeting. Throughout this period, the Canadian TACs were never reached and therefore were not restrictive. In 2014, the TAC was set at 8,000 t, despite scientific advice recommending that annual catches not exceed 800 t (DFO 2014).

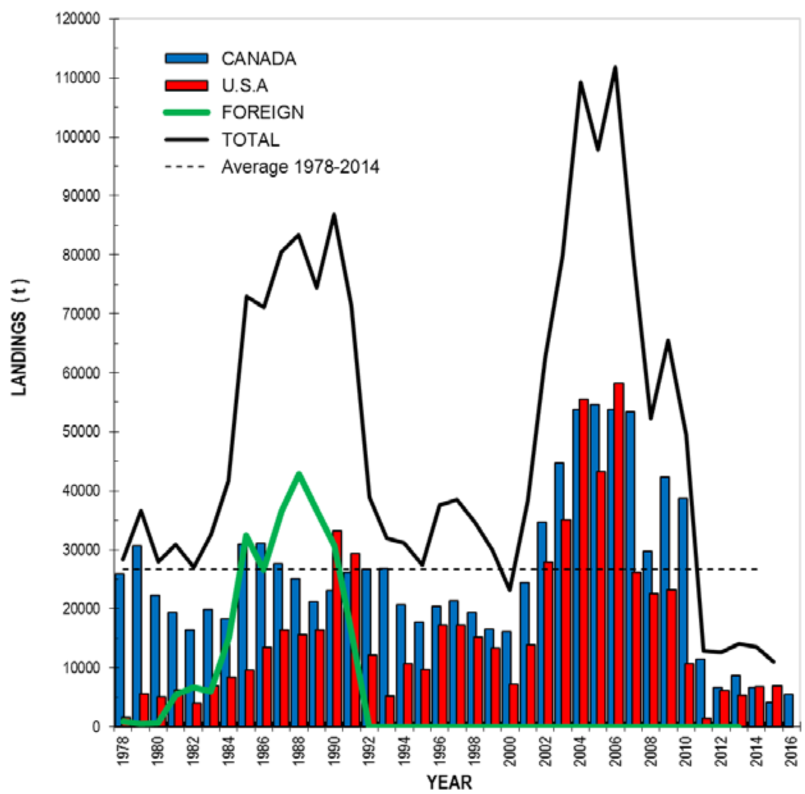

Figure 2. Annual Atlantic mackerel landings (t) in the northwest Atlantic (NAFO subareas 2 to 6) since 1978.

Landings 2014–2016

In eastern Canada (NAFO subareas 3 and 4), landings totalled 6,680 t in 2014 and 4,143 t in 2015 (Table 1). In 2015, landings were the lowest in the entire historical series (since 1960), and they have remained far below catch levels from 2001–2010. In 2016, the TAC of 8,000 t was reached for the first time (but landing statistics by region are still preliminary). In the United

States, landings have remained stable and below 6,000 t since 2012, but the numbers for 2016 are not yet available.

Table 1. Annual Atlantic mackerel landings (t) in NAFO subareas 2 to 6 from 2001 to 2016. The 2015 and 2016 Canadian landings are preliminary. Unlike the US, Canada does not record recreational fishery catches.

YEAR	CANADA	USA		TOTAL
	Canadian vessels	Commercial	Recreational	
2001	24,429	12,340	1,536	38,305
2002	34,662	26,530	1,294	62,485
2003	44,736	34,298	770	79,804
2004	53,777	54,990	473	109,240
2005	54,621	42,187	1,032	97,840
2006	53,649	56,640	1,511	111,801
2007	53,016	25,547	584	79,147
2008	29,671	21,734	783	52,188
2009	42,231	22,635	603	65,470
2010	38,753	9,877	759	49,388
2011	11,400	531	932	12,863
2012	6,582	5,333	668	12,487
2013	8,663	4,372	887	12,681
2014	6,680	5,905	788	13,373
2015 [1]	4,143	5,616	1,157	10,917
2016 [1]	5,357	N/A	N/A	N/A

[1] Preliminary

Of the 4,143 t of mackerel caught in Canadian waters in 2015, only 17% (700 t) were landed in Newfoundland; this percentage was on average 71% from 2001 to 2010 and 54% since 2011. However, in 2016, 4,513 t were landed in Newfoundland (more than half the commercial TAC), of which 1,710 t were in 4R and 2,803 t were in 3K, though there had been no significant landings in 3K since 2010 (Table 2). The main fishing gear used in 2015 was the handline (with 1,377 t out of 4,143 t), whereas in 2016 the main gear was the small purse seine with 3,657 t.

For several years, 40% of the Canadian TAC has been allocated to large seiners and 60% to small seiners, the "tuck-ring" seine, and fixed gear such as traps, gillnets, lines and weirs. Large seiners caught only 10% of their allocation in 2015 and 3% in 2016.

Table 2. Annual mackerel landings (t) by NAFO division since 2001. The 2015 and 2016 landings are preliminary.

DIVISION AND REGION	YEAR															
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015 [1]	2016 [1]
2J	0	0	0	0	0	0	0	0	0	0	0	78	4	0	0	0
3K	322	6,566	588	16,360	24,024	19,176	8,768	9,125	6,898	12,916	426	129	191	6	208	2,803
3L	10	3	0	59	4,068	7,960	10,673	4	39	830	61	3	0	25	54	0
3O	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0
3P	273	162	149	79	238	266	354	166	5,387	5,541	1,544	149	26	246	0	0
4R	8,375	11,251	25,938	23,885	14,141	16,874	24,782	13,741	21,913	13,871	5,306	2,261	4,909	3,155	438	1,710
4S	16	2	0	0	35	76	19	23	64	123	107	304	245	20	29	63
4T	12,316	14,484	14,324	9,152	9,424	7,785	5,763	5,439	6,815	4,919	3,549	2,866	2,748	2,389	2,242	750
4V	125	308	60	13	126	224	370	111	55	7	2	150	146	143	58	0
4W	248	115	9	59	36	75	59	63	65	129	18	177	17	220	186	0
4X	2,743	1,771	3,669	4,169	2,529	1,304	1,928	1,000	980	416	389	365	241	340	682	0
5YZ	0	0	0	0	0	0	0	0	16	0	0	0	0	0	245	0
Unknown	0	0	0	0	0	0	652	0	0	0	0	100	137	135	0	31
Scotian Shelf (4VWX5YZ)	3,117	2,194	3,737	4,241	2,691	1,603	2,357	1,173	1,116	552	409	692	403	703	1,172	0
Gulf of St. Lawrence (4RST)	20,707	25,737	40,262	33,037	23,600	24,735	31,129	19,203	28,792	18,913	8,962	5,431	7,902	5,564	2,710	2,523
Eastern and southern coasts of Newfoundland (2J3KLOP)	605	6,731	737	16,498	28,330	27,403	19,529	9,295	12,324	19,288	2,031	359	221	278	262	2,803
TOTAL	24,429	34,662	44,736	53,777	54,621	53,741	53,394	29,671	42,231	38,753	11,400	6,582	8,663	6,680	4,143	5,357

Unreported catches

Unreported catches are a significant issue for the mackerel fishery. This is because a large amount of commercial fishery catches sold directly to other fishers and the bait fishery for personal use are not accounted for in DFO statistics. Catches from the recreational fishery, which is very popular in the summer months, are not recorded either. Because this activity is practised throughout Eastern Canada by many people, including tourists (off wharves, on charter ships, and in a semi-commercial manner in certain places), the actual Atlantic mackerel catch statistics are largely underestimated. For many years, science advice on Atlantic mackerel has included a recommendation to improve statistics on the fishery overall, and to consider how to estimate these catches.

In this assessment, the issue of unreported catches was first examined by summarizing the available data on bait needs and recreational fisheries. The results of this exercise were used to estimate the approximate maximum unreported catches for each region and the variations in these catches over time. In addition, an informal internet survey aimed at all Canadian mackerel fishers was used to obtain their approximate estimates of the proportion of unreported catches (bait, discards, and recreational catches). There were 476 respondents in Quebec and the four Atlantic provinces who fished mackerel for bait or recreational or commercial purposes (Van Beveren et al. 2017). The results showed that over half of mackerel used for bait in 2016 were used in the lobster fishery, but mackerel was also used to bait other species, such as bluefin tuna (*Thunnus thynnus*), snow crab (*Chionoecetes opilio)* and Atlantic halibut (*Hippoglossus hippoglossus*). The recreational fishery, which generally uses a handline, can also be practiced semi-professionally with jiggers and gillnets, meaning it should not be overlooked. In addition, according to the respondents, 1.9% of catches were discarded, mainly because they were too small.

Both approaches (summary of bait needs and online survey) suggest that, due to its use as bait, the recreational fishery, and discards, total mackerel catches may be between 150% and 200% of reported catches, and that this percentage varies from province to province and over time.

ASSESSMENT

Age structure and length frequency of catches

Mackerel age structure is mainly influenced by the periodic arrival of dominant year-classes. Year-classes such 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 up to 77% of all catches (in numbers) made between 2000 and 2004. The abundance of this year-class decreased rapidly starting in 2004, and it did not persist in the population for as long as previous dominant year-classes (Figure 3). Since then, medium-sized new year-classes have been quickly caught in the fishery (e.g. 2003, 2005, 2007, 2008, and 2010), and the age structure in this fishery has considerably diminished since the 2000s due to the disappearance of fish over 7 years old. However, a slight improvement has been observed since 2013, with an increase in the abundance of 5- and 6-year-old mackerel (Figure 4).

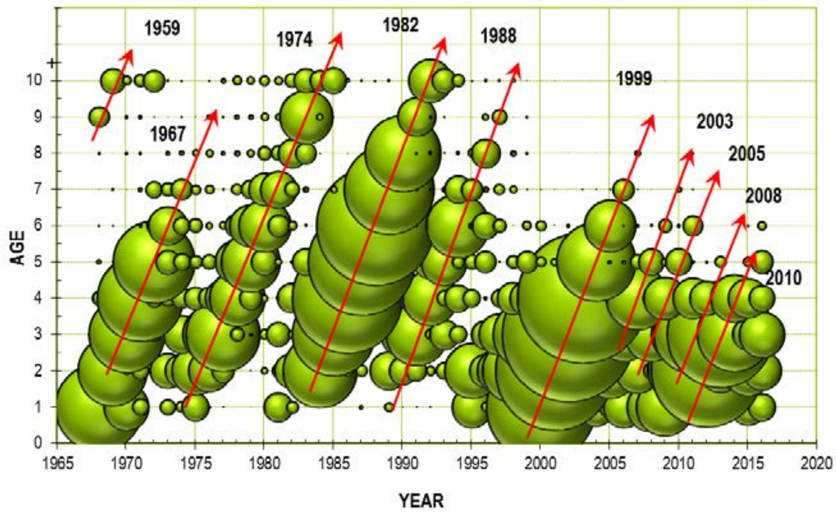

Figure 3. Catch-at-age in the commercial fishery (red arrows indicate dominant year-classes). The size of the circles is proportional to fish abundance.

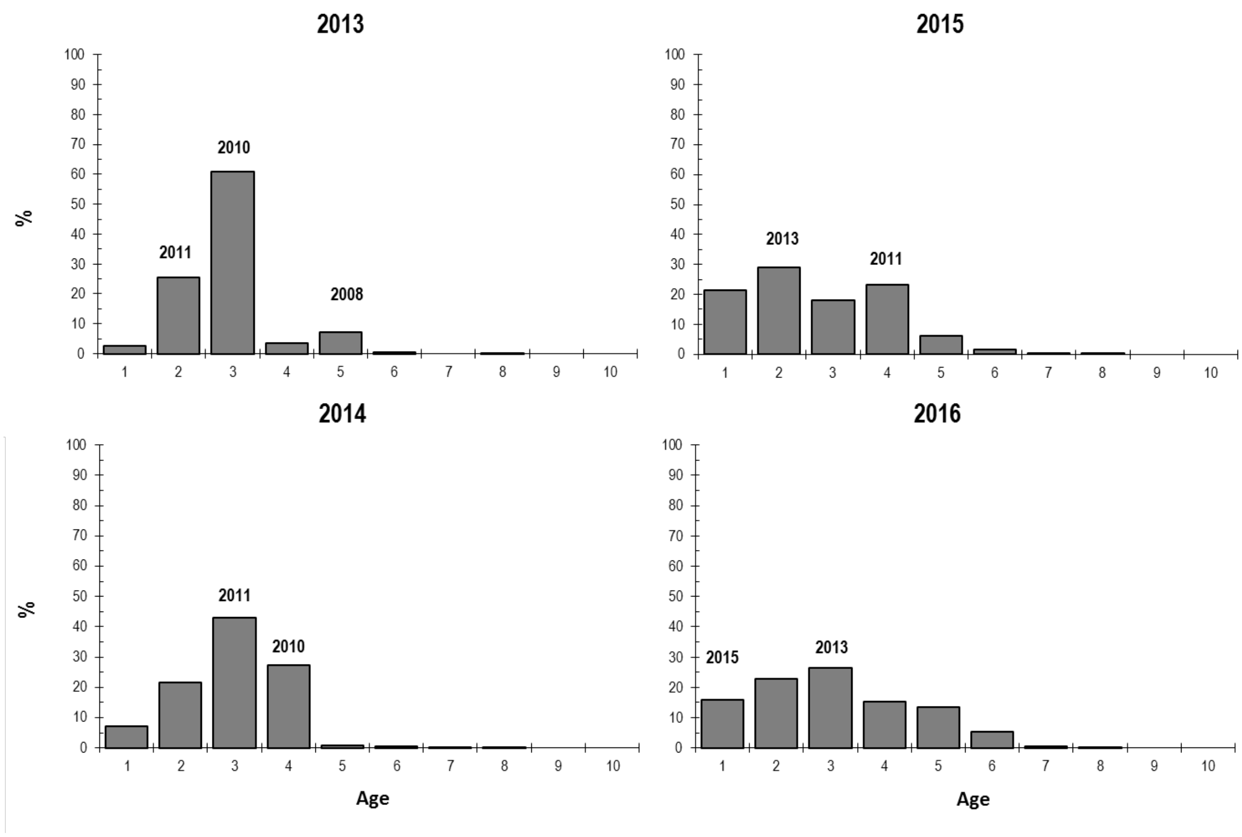

Figure 4. Proportion of year-classes in the commercial fishery (the dates above the bars indicate the progression of dominant year-classes).

Mackerel length frequencies are characterized by the occurrence of modes corresponding to dominant year-classes, which shift toward larger sizes over the years. These modes are observed in the length frequencies of all fishing gear. However, the first year these year-classes are detected in the length frequencies depends on the selectiveness of the fishing gear and therefore on the region. In 2016, a spike in the frequency of small fish was observed in 4R from mackerel in the 2015 year-class (Figure 5). This significant spike could indicate that recruitment was strong in 2015 and be an early sign of the entry of a large cohort in the fishery in 2017. This signal is also observed in catches in 4T to a lesser extent, but not in 3K or 4S.

Biological indicators

The proportion of mature fish at age has not varied much over the years. The average age at 50% maturity (A_{50}) was 1.40 in the 2000s and 1.39 between 2010 and 2015. However, the average length at 50% maturity (L_{50}) varied considerably over the years (Figure 6). L_{50} was over the minimum allowable catch size of 250 mm in most years from 1974–2013, suggesting that there was significant fishing pressure on immature fish. The increase in the minimum allowable catch length from 250 to 263 mm, which came into effect in 2014, and the application of a small fish protocol developed for mackerel, should increase the spawning potential by reducing this pressure. Following its increase in recent years, L_{50} has remained slightly above the minimum allowable catch length of 263 mm since 2013, which indicates that the current limit is still appropriate.

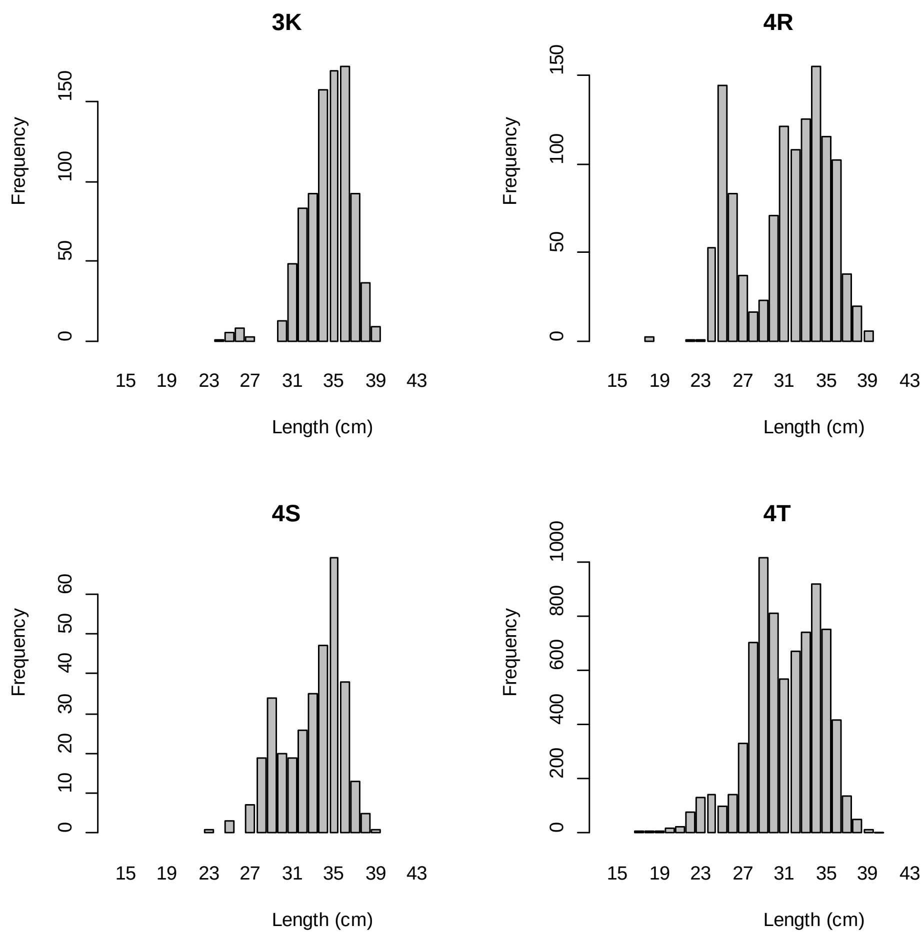

Figure 5. Length frequencies of mackerel caught in divisions 3K, 4S, 4R and 4T in 2016.

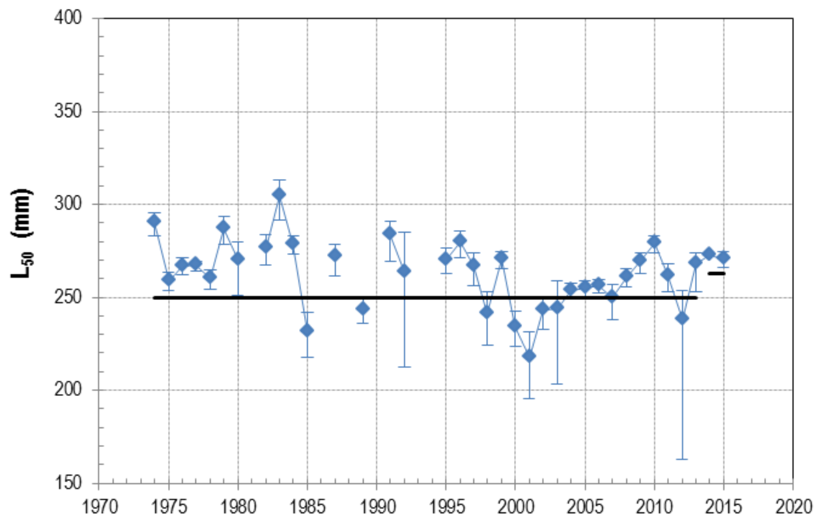

Figure 6. Length at 50% maturity (annual mean with 95% confidence intervals) of Atlantic mackerel in NAFO subareas 3 and 4 since 1973 (the horizontal line indicates the minimum allowable catch length, which was 250 mm until 2013 and 263 mm starting in 2014).

Egg survey and abundance index

Mackerel abundance is estimated using data from an egg survey that takes place annually at the main spawning site in the southern Gulf of St. Lawrence. In the 2013 and 2014 surveys, the highest egg densities (n/m^2) were found in the northwest part of the area sampled (Figure 7). In 2015 and 2016, egg distribution was broader, especially toward the centre and south of the survey area, but was not comparable to the very wide-ranging distributions observed in the 1990s.

Taking into account the water temperature, the incubation time, and the average weight and fecundity of females in biological samples, egg densities can be used to calculate a spawning biomass abundance index. This index increased significantly three times over the years due to the arrival of the 1982, 1988, and 1999 dominant year-classes (Figure 8). The index decreased significantly between 1993 and 1998 and again after 2002, reaching its lowest level in 2012 (14,568 t). It then rose slowly to 52,667 t in 2016. This value is still well below the abundance indices of over 750,000 t observed in the 1980s.

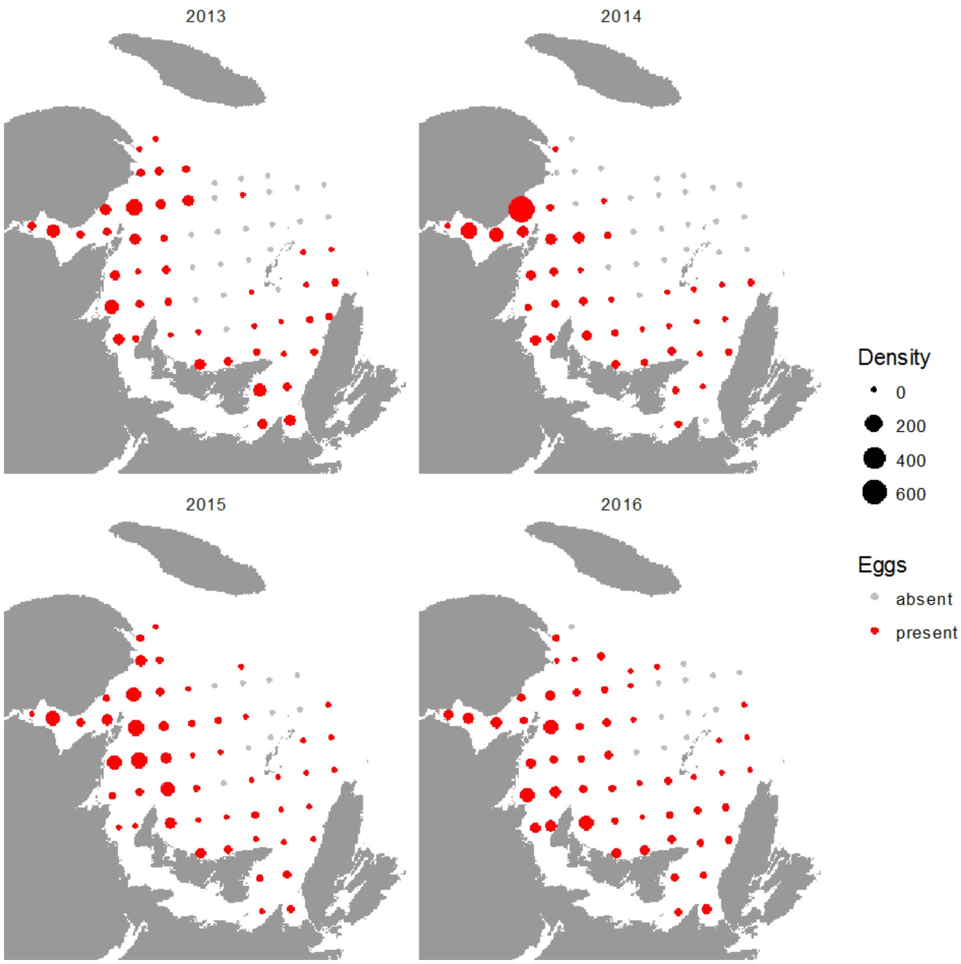

Figure 7. Distribution of mackerel egg (stages 1 and 5) densities (n/m^2) measured in surveys in the southern Gulf of St. Lawrence from 2013 to 2016.

In 2015 and 2016, five additional surveys were carried out in White and Notre-Dame bays on the northeast coast of Newfoundland (3K) following observations by industry of young mackerel in the area. These surveys were repeated several times over the summer to find potential additional spawning areas. However, no signs of mackerel spawning were detected in the samples, and the southern Gulf remains therefore the main spawning area taken into account in this assessment for subareas 3 and 4.

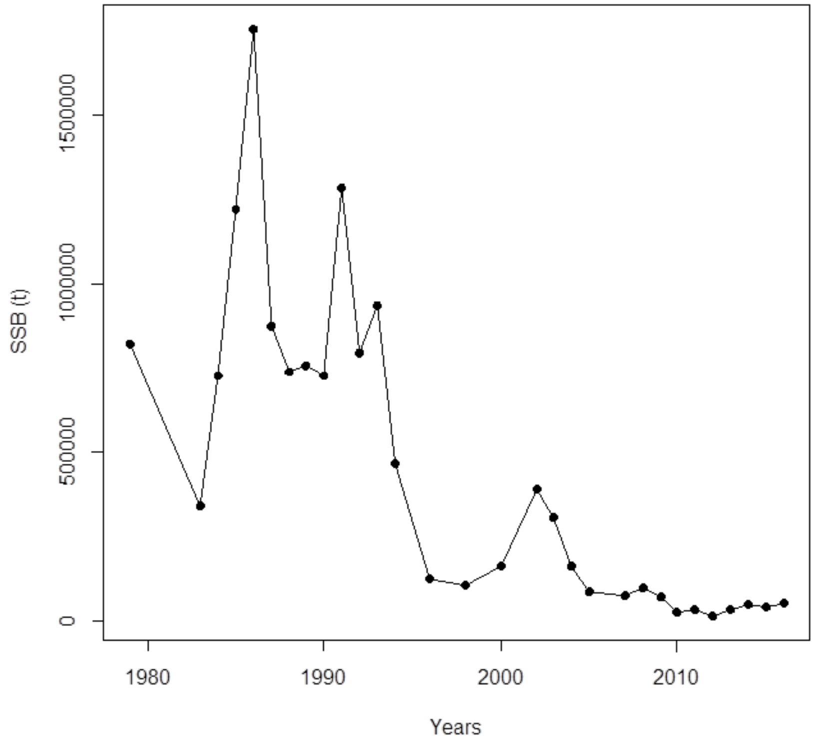

Figure 8. Mackerel spawning stock biomass abundance index calculated using the total egg production method, based on egg densities observed in the southern Gulf in June.

Analytical assessment

The 2012 and 2014 analytical assessments used only reported catches and were therefore suspected of underestimating the real size of the mackerel stock. A new model was developed specifically to address this gap for Atlantic mackerel. This censored catch-at-age statistical model uses a new approach where reported catches are explicitly considered to be biased and below total real catches. Total catches are estimated by the model based on the abundance index and catch-at-age data. To do this, an upper limit needs to be placed on additional catches. As much as possible, the maximum values for unreported catches were informed by available data on the bait fishing industry (the order of magnitude of which was confirmed by the results of the online survey).

This censored model, calibrated by the egg abundance index and taking into account the uncertainty due to unreported catches, confirmed that mackerel spawning biomass decreased due to high exploitation rates in the 1990s and 2000s and reached its historical minimum in 2012 (20,000 t). According to the model, the spawning biomass then slowly increased to approximately 40,000 t in 2016 (Figure 9a).

The model also suggests that additional catches (the difference between estimated total catches and reported catches) represented an average of 6,000 t over the past 10 years (Figure 9b).

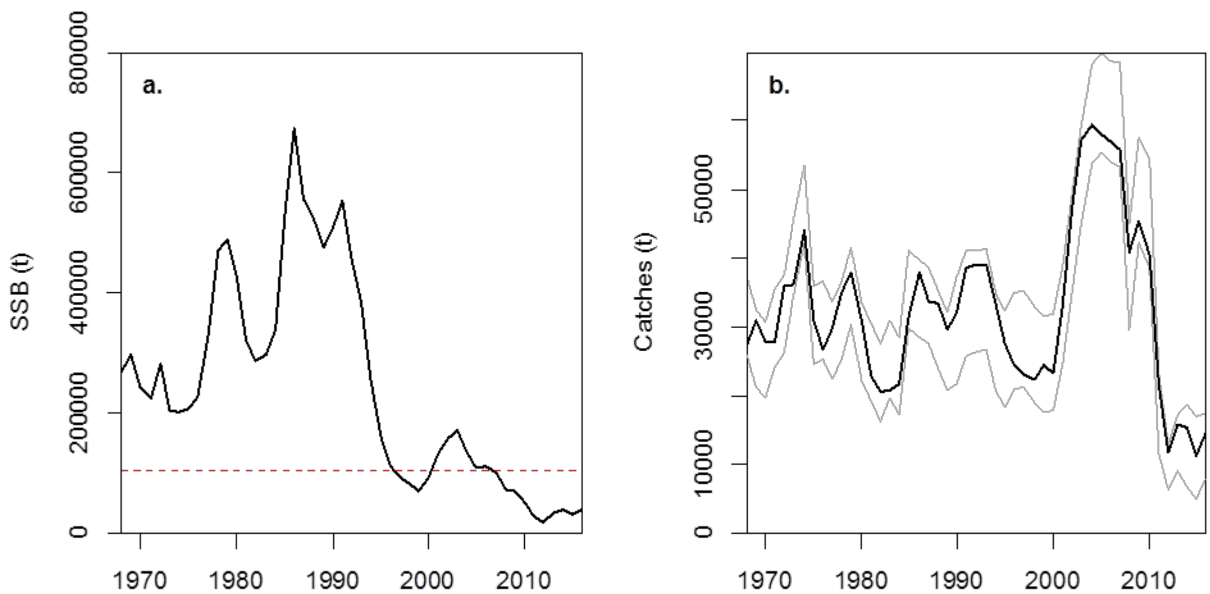

Figure 9. (a) Mackerel spawning stock biomass in NAFO subareas 3 and 4 for 1968–2016 estimated by a censored catch-at-age statistical model; dotted red line: limit reference point (b). Estimated catches for NAFO subareas 3 and 4. Lower grey line: lower limit of censored model (= reported catches); upper grey line: upper limit (based on bait needs and recreational fishery estimate); black line: total catches (reported + unreported) as estimated by the model.

In accordance with the Canadian framework for applying the precautionary approach, the limit reference point (LRP) for this stock is 40% of the biomass corresponding to the maximum sustainable yield (B_{msy}). However, since there is no clear stock-recruitment relationship observed for this pelagic stock, B_{msy} is based on an approximation of $F_{40\%}$ as obtained through a yield-per-recruit analysis. According to the statistical model, the LRP is equal to 103,000 t, and the stock in 2016 is about 40% of the LRP.

The censored model was also used to make three-year projections to estimate the impact of different total catch scenarios (reported + unreported) for 2017 and 2018. These projections use the average parameters for the past three years (e.g. weight-at-age, maturity) and random recruitment (which does not consider the possibility of an extreme recruitment event). Among other scenarios, these projections suggest that the probability of an increase in biomass is over 80% for total catches under 14,000 t per year (Table 3). The commercial TAC must take into account the uncertainty around real levels of unreported catches; the exact unreported catches are unknown, but they are estimated by the model to be about 6,000 t per year for 2011–2016. Thus, a TAC of 8,000 t (status quo) would result in an 81% probability of an increase in biomass and a 30% probability of reaching the LRP by 2019, assuming unreported catches are around 6,000 t in 2017 and 2018.

Table 3. Mackerel spawning biomass (SSB) and stock exploitation rate projections under different total catch scenarios (reported + unreported) calculated using a censored catch-at-age statistical model. For 2019, the table gives the probability of growth (SSB greater than in 2016) and the probability of exceeding the LRP of 103,000 t.

Reported + unreported catches (t)		2017		2018		2019		
2017	2018	SSB (t)	Expl. rate	SSB (t)	Expl. rate	SSB (t)	Prob. > 2016	Prob. > LRP
0	0	48,283	0.00	77,164	0.00	113,886	0.95	0.56
4,000	4,000	48,283	0.08	72,175	0.06	103,378	0.93	0.50
6,000	6,000	48,283	0.13	68,503	0.09	96,927	0.92	0.46
8,000	8,000	48,283	0.17	64,910	0.12	90,889	0.89	0.42
10,000	10,000	48,283	0.21	62,762	0.16	85,686	0.87	0.40
12,000	12,000	48,283	0.25	59,466	0.21	77,143	0.84	0.34
14,000	14,000	48,283	0.29	56,858	0.24	72,189	0.81	0.30
16,000	16,000	48,283	0.33	54,018	0.29	66,158	0.77	0.26
18,000	18,000	48,283	0.38	50,928	0.36	57,113	0.70	0.20
20,000	20,000	48,283	0.42	47,502	0.42	51,348	0.64	0.17
24,000	24,000	48,283	0.50	41,704	0.59	35,728	0.44	0.09
30,000	30,000	48,283	0.62	33,053	0.90	17,199	0.16	0.02

Sources of uncertainty

Unreported catches from the bait and recreational fisheries are still a significant source of uncertainty in the assessment of the mackerel stock. The censored statistical model, which accounts for the uncertainty in catches, was developed and used to propose a more realistic estimate of total catches, spawning biomass, and stock exploitation rates. However, this statistical tool cannot be used to predict future unreported catches and is not a substitute for the pressing need for better reporting of total catches in the mackerel fishery.

The discarding of small mackerel under the minimum allowable catch length (263 mm) is also a problem. 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.

There are several gaps in the biological sampling program of the commercial fishery, especially in the southern Gulf and the Maritimes. The low number of samples available in these areas, especially during the pre-spawning period, limits our ability to describe the spawning period and fish condition, which may affect the calculation of the abundance index based on the egg survey.

Significant recruitment episodes are difficult to detect in the scientific data (fishery sampling, egg survey) before the corresponding cohort reaches age 2. However, a spike in frequency of small fish corresponding to mackerel from the 2015 year-class was observed in the fishery in 4R in 2016. In addition, approximately half of fishers who answered the online survey reported that small mackerel were very abundant in 2016. These could be signs that recruitment was higher in 2015 than levels observed in recent years.

CONCLUSIONS AND ADVICE

The previous science advisory report (2014) was biased because it did not include estimates of unreported catches. This report contains the best possible estimates of unreported catches, obtained using a new statistical model, and therefore provides a more realistic spawning stock biomass estimate.

Based on the results of this assessment, the Atlantic mackerel stock in subareas 3 and 4 has reached its lowest historical level in 2012. The statistical model suggests that catch levelsin recent years have allowed for slow growth from 2013 to 2016, but that the stock is still in the critical zone. The catch-at-age data indicate a slight improvement in the age structure but no significant recruitment episode since 1999.

Based on the decision framework for the precautionary approach, when a stock is in the critical zone, conservation must be given priority, and management measures must promote growth. Exploitation from all sources must allow for a high probability of the stock growing out of the critical zone within a reasonable timeframe. Projections made using the statistical model, taking into account unreported catches, suggest for example that the probability of an increase in biomass is over 80% for total catches (reported plus unreported) under 14,000 t, which corresponds to a low risk of decline (5% to 25%) under the precautionary approach.

However, the commercial TAC must also take into account unreported catches, for which exact rates are unknown but estimated at several thousand tonnes per year. A TAC of 8,000 t (status quo compared to 2015–2016) would result in an 81% probability of an increase in biomass and a 30% probability of reaching the LRP by 2019, assuming unreported catches are around 6,000 t in 2017 and 2018.

It is also especially important to fill the gaps in commercial fishery sampling in certain sectors, to accelerate compilation of landing statistics, and to improve collection of data on unreported catches.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 8 and 9, 2017, regional meeting on the assessment of the Atlantic mackerel stock in subareas 3 and 4. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

DFO. 2014. Assessment of the Atlantic Mackerel Stock for the Northwest Atlantic (Subareas 3 and 4) in 2013. DFO Can. Sci. Advis. Sec., Sci. Advis. 2014/030

Van Beveren, E., Castonguay, M., Doniol-Valcroze, T., and Duplisea, D. 2017. Results of an informal survey of Canadian Atlantic mackerel commercial, recreational and bait fishers. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/029. v + 26 p.

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