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ASSESSMENT OF THE ATLANTIC MACKEREL STOCK FOR THE NORTHWEST ATLANTIC (SUBAREAS 3 AND 4) IN 2006

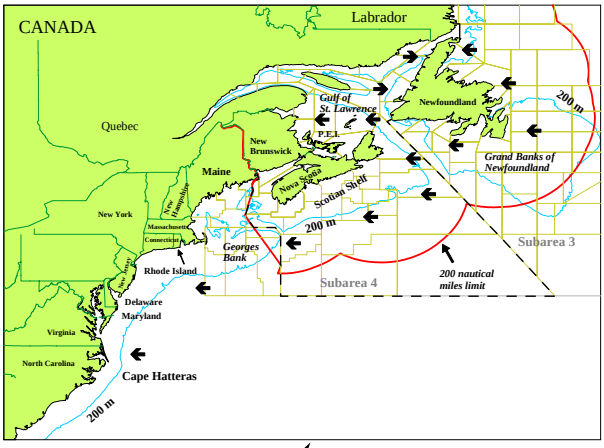

Figure 1. Distribution (←) of Atlantic mackerel (Scomber scombrus L.) in the Northwest Atlantic. The dotted line indicates the borders between Subareas 3 and 4 of the Northwest Atlantic Fisheries Organization (NAFO).

Context

Atlantic mackerel (Scomber scombrus L.) is found in the waters of the North Atlantic, from the Mediterranean to Norway in the east and from North Carolina to Newfoundland in the west. During spring and summer, 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 intense spawning areas characterize its distribution range. In Canadian waters, spawning mainly occurs in the southern Gulf of St. Lawrence during the months of June and July. This spawning period is preceded by a long migration that begins early in spring in the Gulf of Maine and Georges Bank area. In American waters, spawning occurs during the months of 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 mackerel fishery. They fish mainly inshore using gillnets, jiggers, handlines, purse seines and traps. The type of gear used varies according to the region and time of the year. Landings reported by Canadian fishermen have been rather stable from one year to the next and have averaged around 22,000 t per year since the early 1980s. However, there has been a significant increase since the early 2000s, reaching a record high of 54,279 t in 2005. This upsurge is mostly due to the marked increase of landings by small seiners on the east coast of Newfoundland (Divisions 3K and 3L). The occurrence of mackerel in this area in such remarkable quantities is unusual. Bait fishermen in the Gulf of St. Lawrence are not required to fill a logbook, and since there is no dockside monitoring for mackerel, their catch may go unrecorded, as is the case for the recreational fishery, which occurs during summer months all along the Atlantic coast.

Mackerel abundance in the Gulf of St. Lawrence is calculated using data collected from an egg survey. This survey, unique in the Northwest Atlantic, is also used to perform annual monitoring of oceanographic conditions and of plankton community abundance and diversity in the southern Gulf of St. Lawrence.

SUMMARY

- Mackerel landings in NAFO Subareas 3 and 4 have increased significantly in recent years, shifting from 13,383 t in 2000 to an all-time high of 54,279 t in 2005. Canadian preliminary landings for the 2006 fishing season totalled 38,155 t.

- Essentially, this upsurge is explained by the marked increase of catches by small seiners on the east coast of Newfoundland (Divisions 3K and 3L). The occurrence of mackerel in such large numbers is unusual there.

- From 2004 to 2006, landings by American commercial fishermen increased from 54,939 t to 58,117 t, and landings from the north-west Atlantic as a whole (NAFO Subareas 2-6), dropped from 108,819 t to 96,272 t. Only during the 1970s' offshore fishery were tonnages higher than these values recorded.

- The actual proportion of TAC that is caught could very well be higher than we think because of unrecorded landings. Furthermore, catches in American waters of mackerel that come from the Gulf of St. Lawrence are not included in Canadian landings.

- Since the early 2000s, Canadian landings have been greatly dominated by fish from the 1999 year-class. The relative significance of this year-class quickly dropped in 2005-2006 in favour of the 2003 year-class.

- According to the egg survey in the southern Gulf of St. Lawrence, a significant drop in spawning biomass was recorded between 2002 and 2005. This drop in abundance could be the result of particular environmental conditions (cold waters) that have been occurring for a few years in the mackerel's traditional spawning area. A decrease in landings in the southern Gulf is also associated to this drop in biomass.

- The 2006 egg survey was conducted towards the end of the spawning season as shown by the daily egg production curve, the high water temperatures and the occurrence of larvae at almost every station. Consequently, the results of this survey cannot be used to calculate the biomass of mackerel that spawned in 2006 in the southern Gulf of St. Lawrence.

- Despite the uncertainties associated with the fishery statistics and egg survey results, it appears that the strong 1999 year-class no longer contributes to the fishery or to the spawning stock. Therefore, the 2007 catches will likely not exceed those of recent years and the TAC, which is much higher than the highest recorded catches, should be brought back down to 50,000 t. However, it is highly unlikely that catches of this size will be maintained if post-1999 year-classes are of average abundance.

INTRODUCTION

Species Biology

General

Atlantic mackerel (*Scomber scombrus* L.) belong to the order Perciform, family Scombridae, and genus *Scomber*. The family Scombridae is distributed widely throughout the world's tropical and temperate ocean waters and includes a large number of species, the most famous of which being tuna and bonitos. Among the three *Scomber* genus species, Atlantic mackerel has the most northerly distribution. Atlantic mackerel is also the only species of the *Scomber* genus without a swim bladder, requiring it to swim continually in order to maintain its hydrostatic balance. This biological feature along with its high swim speed helps it change position rapidly, making it difficult to catch compared with other pelagic fish species. During its long annual migrations, mackerel sometimes travel in very dense schools, especially in spring and fall. The schools are composed of similar-size individuals travelling at the same speed. These schools would allow mackerel to escape their prey more easily while also helping them feed.

Spawning

Though some spawning does take place along the coasts of Nova Scotia during spring migrations, the mackerel that frequent Canadian waters (NAFO Subareas 3 and 4) mostly spawn in the southern Gulf of St. Lawrence (Figure 1), in June and July. The largest concentrations of eggs are found in waters south of the Laurentian Channel, west of the Magdalen Islands. At the peak of the spawning period, water temperature varies between 10° C and 12° C, and at these temperatures, egg incubation time lasts around one week. Spawning is described as multiple because each female spawns several times, and asynchronous because it can occur at any time of day or night. Spawning occurs near the surface and during incubation, eggs are found floating in water layers above the thermocline. On hatching, young mackerel measure about 3 mm. They then go through three development phases: (1) yolk sac, (2) larvae, (3) juvenile. The first phase lasts a few days, and the second about two months. The second phase is characterized by the disappearance of the yolk sac and the appearance of fins. At 50 mm, larvae transforms into juveniles that form into schools. Some of these schools are found near the coast, which indicates that juveniles migrate from spawning grounds towards the coast. Not much is known about what proportion of the juvenile population participates in this migration, nor about what roles these inshore habitats play in determining juvenile growth and survival.

Growth

Mackerel are a very fast-growing species. By the end of their second year (age 1+), average length and weight (somatic) can reach 257 mm and 197 g respectively (Figures 2A and 2B). Growth not only varies from one year to another, but also from one year-class to another. For example, growth was slower for abundant year-classes of 1967, 1974, 1982, 1988 and 1999 (Figure 3). These same year-classes can be identified in the distributions of mean length at year and at age (Figure 4).

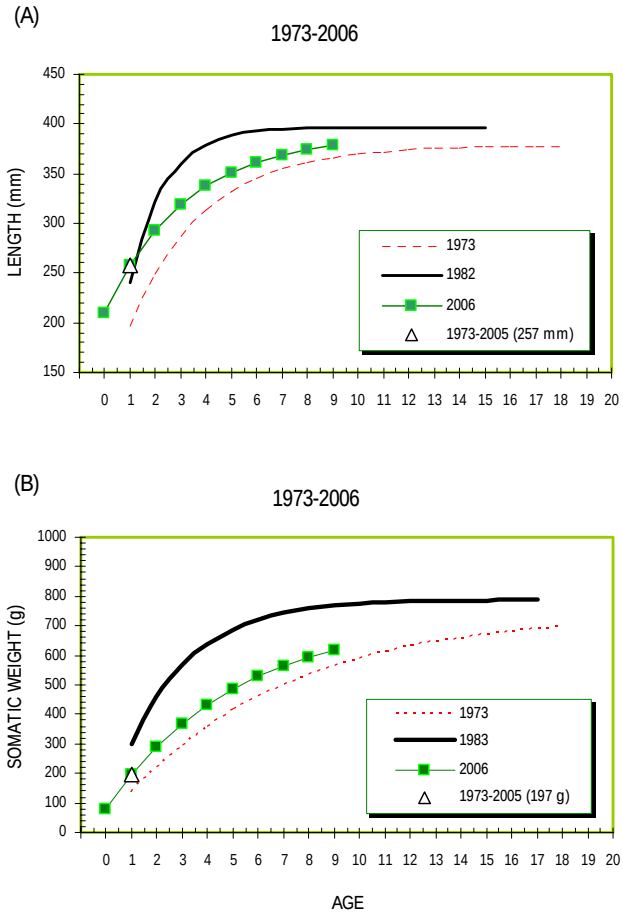

Figure 2. Mean annual length (mm) (A) and weight (g) (B) at age calculated using commercial samples collected in NAFO Subareas 3 and 4 since 1973. The highest and slowest growth years are indicated as well as mean length and weight at one year for all the data (1973-2005).

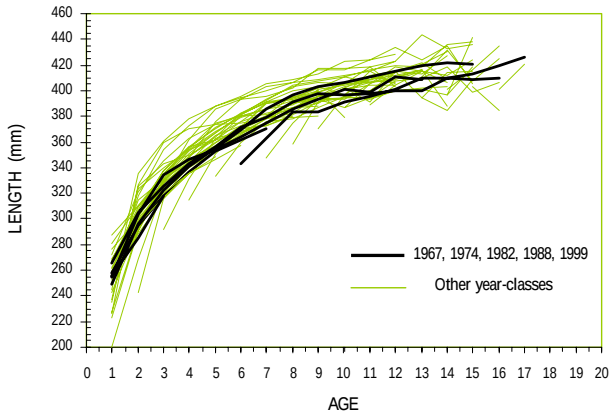

Figure 3. Mean length (mm) at age and per year-class calculated using commercial samples collected in NAFO Subareas 3 and 4 since 1973. The five most significant year-classes that have dominated the fishery over recent years are indicated with bold lines.

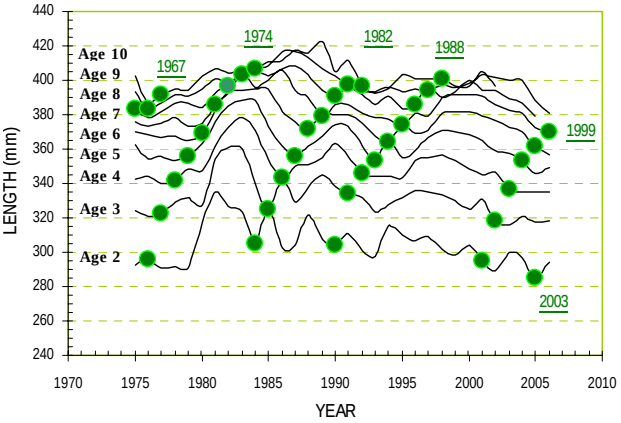

Figure 4. Mean length (mm) calculated per age group using commercial samples collected in NAFO Subareas 3 and 4 since 1973. Ages are indicated as well as year-classes which dominated the fishery over recent years.

Maturity

Compared with other fish species, mackerel reach sexual maturity early in life. For example, the size at which 50% of the fish are mature, or L_{50}, was only 251.4 mm in 2006 (Figure 5A), and all fish above 340 mm were mature. L_{50} varies according to year (Figure 5B) and year-class (Figure 5C). Since 2000, the annual L_{50} values have been below or slightly above the minimum legal catch size of 250 mm.

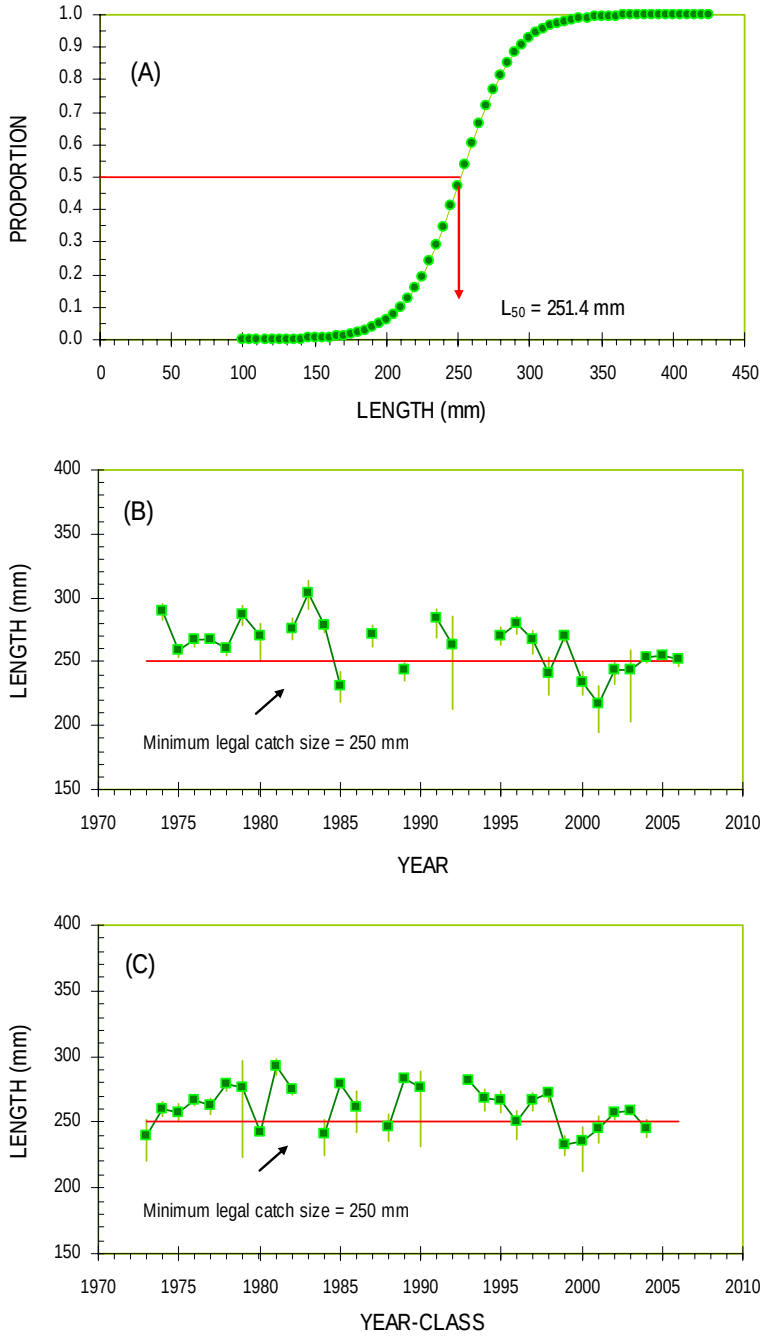

Figure 5. Mean proportion of mature fish at length in 2006 (A) and mean L_{50} values calculated per year (B) and per year-class (C) using commercial samples collected in June and July in NAFO Subareas 3 and 4 since 1973 (L_{50} represents the size at which 50% of the fish are mature; vertical lines represent 95% confidence intervals). The current minimum legal catch size is 250 mm.

At one year, less than 40% of mackerel are mature, and all of them are mature at age 4+ (Figure 6). Sexual maturity at age also varies from one year to the next. In 2006, the proportion of mature fish at age was higher than in 2004 and 2005, but lower than 2000-2003.

Prey and Predators

Data collected in the mid-1980s showed that mackerel in the Northern Gulf of St. Lawrence (Divisions 4RS) fed mainly on small (< 5 mm; mostly copepods, small planktonic crustaceans) and large (≥ 5 mm; mostly euphausiids, hyperiid amphipods and chaetognaths) zooplankton (Figure 7). New estimates derived in the mid-1990s indicate that small and large zooplankton were still mackerel main prey (83 % of their diet). However, capelin (*Mallotus villosus*) made up nearly 15% of the mackerel diet. In the early 2000s, small and large zooplankton proportion continued to drop, accounting for only 75% of the mackerel diet, while northern shrimp (*Pandalus borealis*) and capelin reached 14% and 4% of the total respectively.

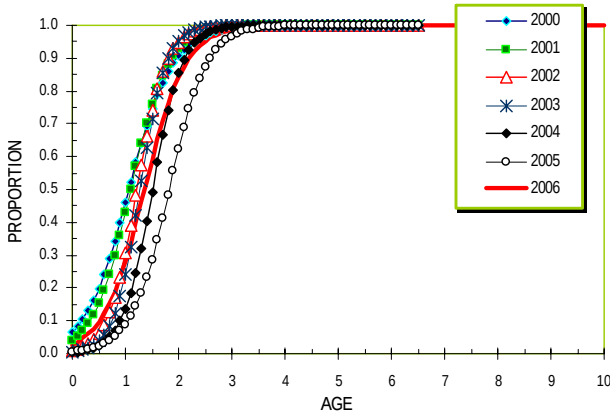

Figure 6. Mean proportion of mature fish at age calculated during the 2000s using commercial samples collected in June and July in NAFO Subareas 3 and 4.

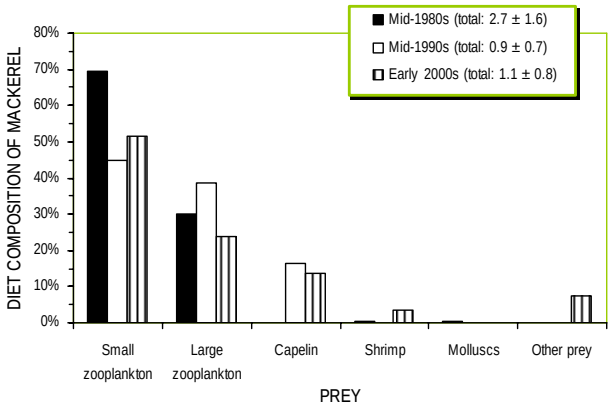

Figure 7. Mackerel diet composition (%) in the Northern Gulf of St. Lawrence from the mid-1980s to the early 2000s. Total annual consumption by mackerel in t km^{-2} yr^{-1} is presented in the legend.

As shown by the results of different models of the Northern Gulf of St. Lawrence marine ecosystem, the main cause of mortality for mackerel is predation (Figure 8A). In the early 1980s, the principal predators were cetaceans, large cod (*Gadus morhua*), and large demersals (Figure 8B). In the middle of the 1990s and in the early 2000s, cetaceans were still the main predators of mackerel in the Northern Gulf. The same models showed that fishery related mortalities gradually increased during these three periods, from 2% on total mortalities in the early 1980s to 15% in the mid-1990s, and finally to 30% in the early 2000s.

The Fishery

Historical Overview

Mackerel landings in the Northwest Atlantic (NAFO Subareas 2-6) reached significant values in the early 1970s; from 300,000 t to 400,000 t per year (Figure 9). Landings then dropped considerably in 1977 with the introduction of the 200-nautical-mile economic exclusion zone (EEZ). Owing to agreements between the United States and the USSR, landings increased again in the early 1980s, peaking at 86,891 t in 1990. In the ensuing years, landings dropped considerably as the United States gradually reduced their mackerel quotas,

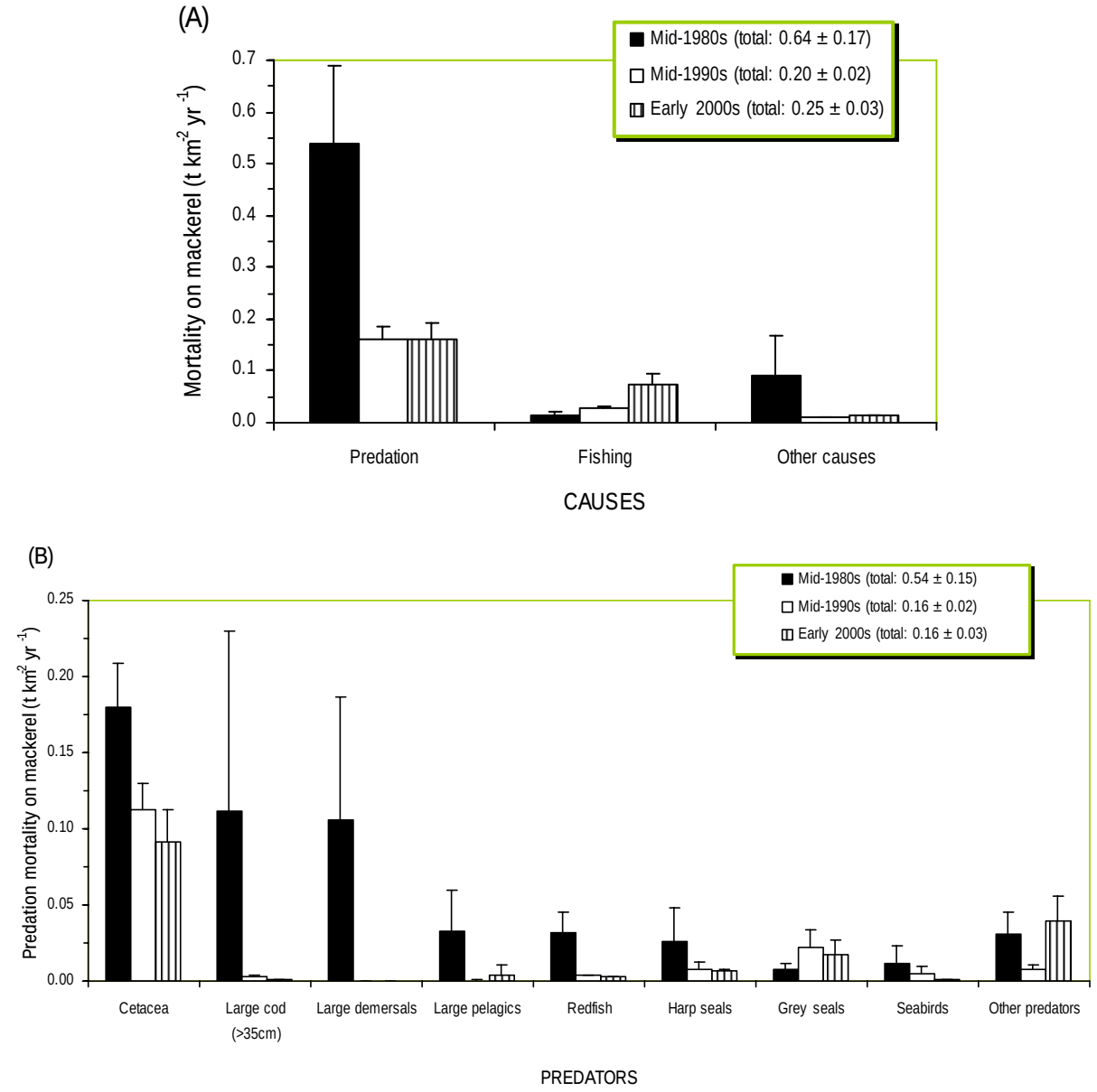

Figure 8. Main causes of mortality (t km^{-2} yr^{-1}) (A) and detail of predation related mortality (B) for Atlantic mackerel according to different models of the Northern Gulf of St. Lawrence marine ecosystem from the mid-1980s to the early 2000s (from Savenkoff et al. 2005).

which was followed by a complete closure of foreign fishery in 1992. Since the early 2000s, catches have been increasing again due to an abundant year-class (1999) and a considerable increase in fishing effort on this species.

Since 1987, Canada has proposed that the 200,000 t TAC for the entire Northwest Atlantic be divided equally with the United-States. Following the low biomass estimates from the 1996, 1998 and 2000 egg surveys, the Canadian portion of the TAC was lowered from 100,000 t to 75,000 t in 2001.

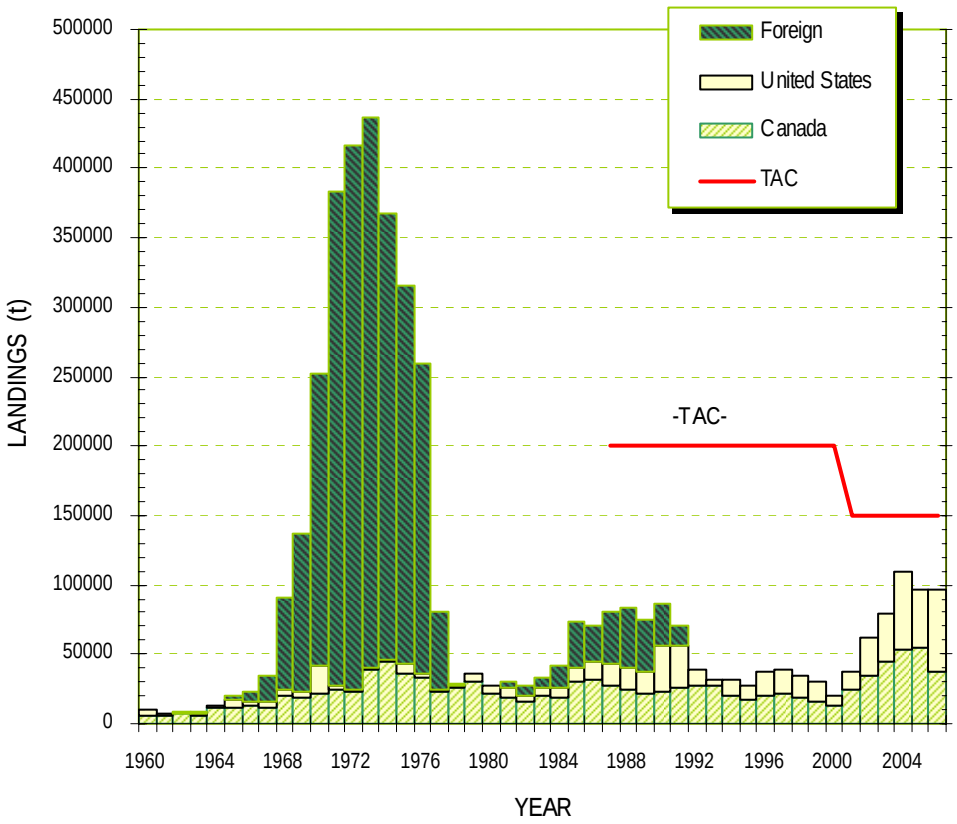

Figure 9. Annual landings (t) of Atlantic mackerel and TAC (t) for the Northwest Atlantic (NAFO Subareas 2-6). Since 1987, Canada has proposed that the TAC be divided equally with the United-States; in 2001, the Canadian portion of the TAC was lowered from 100,000 t to 75,000 t.

Landings in 2006

In 2006, reported mackerel landings in Eastern Canada (NAFO Subareas 3 and 4) totalled 38,155 t, compared with 53,365 t in 2004 and 54,279 t in 2005 (Table 1). Landings in 2006 should be higher because not all the fishery data from New Brunswick, Prince Edward Island and Nova Scotia has been accounted for. U.S. commercial landings reached 58,117 t in 2006, which represents an increase with 2005 of about 17,000 t. Recreational landings in the United States (chartered trips) weren't available at the time of the assessment, but totalled 1,042 t in 2005, compared with an annual average of 1,243 t. No foreign vessels are reported to have fished in U.S. waters since 1992. For the entire Northwest Atlantic (NAFO Subareas 2-6), mackerel landings would have totalled 96,272 t in 2006 (Table 1). Only in 2004 and 2005 was a higher tonnage recorded (with landings of 108,819 t and 96,338 t, respectively) and during the 1970s offshore fishery.

Of the 38,155 t of mackerel caught in Canadian waters in 2006, 34,884 t or 78% were landed in Newfoundland (Table 2), i.e. 14,967 t and 5,541 t in Divisions 3K and 3L respectively, and 14,375 t in Division 4R (Table 3). The two main fishing gears were the small (<65' or 19.8 m) and large (>65') purse seine, 28,970 t and 5,985 t each, followed by the trap and jiggers with respective landings totalling 1,128 t and 1,091 t (Table 4).

Table 1. Annual Atlantic mackerel landings (t) between 1990 and 2006 in NAFO Subareas 2 to 6.

YEAR	CANADA		UNITED STATES			TOTAL
	Canadian vessels	Foreign vessels	Commercial	Recreational	Other countries	
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	344	0	38 843
1993	26 158	591	4 666	540	0	31 955
1994	20 564	49	8 877	1 705	0	31 195
1995	17 706	0	8 479	1 249	0	27 434
1996	20 394	0	16 137	1 416	0	37 947
1997	21 309	0	15 400	1 735	0	38 444
1998	19 334	0	14 415	670	0	34 419
1999	16 561	0	12 026	1 335	0	29 922
2000	13 383	0	5 646	1 448	0	20 477
2001	23 857	0	12 336	1 538	0	37 731
2002	34 402	0	26 452	1 286	0	62 140
2003	44 475	0	34 292	724	0	79 491
2004	53 365	0	54 939	515	0	108 819
2005	54 279	0	41 017	1 042	0	96 338
2006*	38 155	0	58 117		0	96 272
AVERAGE						
1990-2005	27 137	512	20 292	1 243	2 900	52 085
1995-2005	29 006	0	21 922	1 178	0	52 106

* Preliminary

Table 2. Annual Atlantic mackerel landings (t) by Canadian province (NAFO Subareas 3 and 4) since 1995.

PROVINCE	YEAR												AVERAGE
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*	(1995-2005)
Nova Scotia	6 681	5 517	5 669	4 562	4 797	4 546	4 058	3 989	7 187	5 325	4 935	1 431	5 206
New Brunswick	2 206	2 684	1 990	1 682	1 373	972	2 199	2 182	1 734	1 398	1 047	30	1 770
Prince Edward Island	2 518	4 018	6 693	6 784	3 842	4 134	5 886	6 181	4 543	4 692	4 946	276	4 931
Quebec	3 382	4 317	5 769	4 066	5 104	1 711	2 904	4 095	4 380	1 618	1 035	1 536	3 489
Newfoundland	2 919	3 857	1 188	2 149	1 445	2 020	8 810	17 955	26 631	40 333	42 315	34 884	13 602
Not known	0	0	0	91	0	0	0	0	0	0	0	0	8
TOTAL	17 706	20 394	21 309	19 334	16 561	13 383	23 857	34 402	44 475	53 365	54 279	38 155	29 006

* Preliminary

Table 3. Annual Atlantic mackerel landings (t) by NAFO Division (Subareas 3 and 4) since 1995.

DIVISION AND REGION	YEAR												AVERAGE
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*	(1995-2005)
3K	11	3	0	0	0	0	322	6 566	588	16360	24024	14967	4 352
3L	11	0	0	0	0	0	10	3	0	59	4068	5541	377
3P	90	60	8	65	7	19	102	135	105	30	82		64
4R	2 807	3 794	1 181	2 175	1 438	2 001	8 375	11 251	25938	23885	14141	14375	8 817
4S	30	9	1	1	2	0	16	2	0	0	35	76	9
4T	8 184	11 358	15 358	12 739	10 562	7 005	11 915	14 251	14106	8790	9238	1740	11 228
4V	1 475	1 591	838	554	762	576	125	308	60	13	126	222	584
4W	622	1 182	716	138	127	120	248	115	9	59	36	32	307
4X	4 477	2 398	3 208	3 662	3 663	3 663	2 743	1 771	3669	4 169	2 529	1 202	3 268
Scotian Shelf (4VWX)	6 574	5 170	4 762	4 355	4 552	4 358	3 117	2 194	3 737	4 241	2 691	1 456	4 159
Gulf of St. Lawrence (4RST)	11 021	15 161	16 540	14 914	12 002	9 006	20 306	25 504	40 044	32 676	23 414	16 191	20 054
East and South coasts of Newfoundland (3KLP)	112	63	8	65	7	19	434	6 704	693	16 449	28 174	20 508	4 793
TOTAL	17 706	20 394	21 309	19 334	16 561	13 383	23 857	34 402	44 475	53 365	54 279	38 155	29 006

* Preliminary

Table 4. Annual Atlantic mackerel landings (t) by gear type in NAFO Subareas 3 and 4 since 1995.

GEAR	YEAR												AVERAGE
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*	(1995-2005)
Bottom trawl	59	68	92	9	12	1	3	5	0	2	1	7	23
Midwater trawl**	0	0	0	0	0	0	0	0	0	0	0	15	0
'Tuck'' seine	0	0	0	0	0	0	0	0	0	2 448	6 393		804
Purse seine < 65'	1 415	1 853	801	1 406	1 044	1 348	4 443	10 833	11 668	25 334	28 212	28 970	8 032
Purse seine > 65'	1 312	1 782	315	167	304	492	3 579	6 074	14 645	11 612	5 065	5 985	4 122
Other seines	0	0	9	0	0	0	227	0	0	0	845	184	98
Gillnet	4 481	6 420	6 657	7 638	5 128	5294	6 554	5 000	4 541	4 734	3 929	772	5 489
Trap	4 728	3 821	3 889	3 999	4 057	3 920	0	2 073	3 628	4 690	3 330	1 128	3 467
Longline	0	0	0	7	3	3	20	18	13	3	59	0	12
Handline	899	1 231	3 029	1 998	569	90	160	169	9	694	1 119		906
Jigger	3 823	4 708	6 204	3 651	5 435	2 229	5 676	9 839	9 856	3 843	5 296	1 091	5 506
Weir	177	0	1	141	8	0	3 148	48	74	2	20	3	329
Other	812	510	313	320	0	5	0	344	40	2	4	1	214
Not known	0	0	0	0	0	0	46	0	0	0	6	0	5
TOTAL	17 706	20 394	21 309	19 334	16 561	13 383	23 857	34 402	44 475	53 365	54 279	38 155	29 006

* Preliminary

** Exploratory fishery in Nova Scotia

For several years, 40% of the TAC has been allocated to vessels (purse seiners or trawlers) over 65' (or for all exploratory fishing), and 60% to small purse seiners and gear such as traps, gillnets, lines and weirs. In the first case, nearly 20% of the quota was reached in 2006 (Table 5). In the second case, 71% of the quota was reached in 2006, compared with 93% in 2004 and 109% in 2005. The quota was exceeded (4,214 t) for the first time since the 1987 introduction of a TAC for mackerel in Subareas 3 and 4. The excess was caused by Newfoundland small purse seiners catches, which on their own totalled 28,212 t (Table 5).

Table 5. Landings (t) and quotas (t) of Atlantic mackerel for NAFO Subareas 3 and 4 since 1995.

GEAR	YEAR												AVERAGE
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*	(1995-2005)
-- QUOTA 40% --													
Midwater trawl	0	0	0	0	0	0	0	0	0	0	0	15	0
Purse senne >65'	1 312	1 782	315	167	304	492	3 579	6 074	14 645	11 612	5 065	5985	4 122
Quota	*40 000*	*40 000*	*40 000*	*40 000*	*40 000*	*40 000*	*30 000*	*30 000*	*30 000*	*30 000*	*30 000*	*30 000*	
%	3.28	4.45	0.79	0.42	0.76	1.23	11.93	20.25	48.82	38.71	16.88	19.95	13
-- QUOTA 60% --													
Purse senne <65'	1 415	1 853	801	1 406	1 044	1 348	4 443	10 833	11 668	25 334	28 212	28 970	8 032
Other	14 980	16 760	20 193	17 762	15 213	11 543	15 835	17 495	18 162	16 419	21 002	3 186	16 851
Total	16 394	18 612	20 995	19 168	16 257	12 891	20 278	28 328	29 830	41 753	49 214	32 156	24 884
Quota	*60 000*	*60 000*	*60 000*	*60 000*	*60 000*	*60 000*	*45 000*	*45 000*	*45 000*	*45 000*	*45 000*	*45 000*	53 182
%	27.32	31.02	34.99	31.95	27.10	21.49	45.06	62.95	66.29	92.78	109.36	71.46	50
TOTAL	17 706	20 394	21 309	19 334	16 561	13 383	23 857	34 402	44 475	53 365	54 279	38 155	

* Preliminary

ANALYSIS

Description of catches

Catch at age

Since the early 2000s, a very large proportion of fish from the 1999 year-class has dominated mackerel landings (Figure 10). Between 2001 and 2004, fish from this year-class have accounted for 45% to 77% of all catches in number (Figure 11). Predominance such as this has never been observed before among year-classes sampled since 1968, i.e. since Canada began collecting biological data on mackerel. However, the relative importance of this year-class dropped quickly in 2005 and 2006 in favour of the 2003 year-class, which accounted for 32% of all catches in 2005 and 35% in 2006.

Length frequencies

In 2006, the mean length and weight of fish from the 1999 year-class was respectively 374 mm and 665 g. Fish from this year-class have been observed since 2000 in the annual length frequencies derived from sampling of the commercial line fishery in Division 4T and the

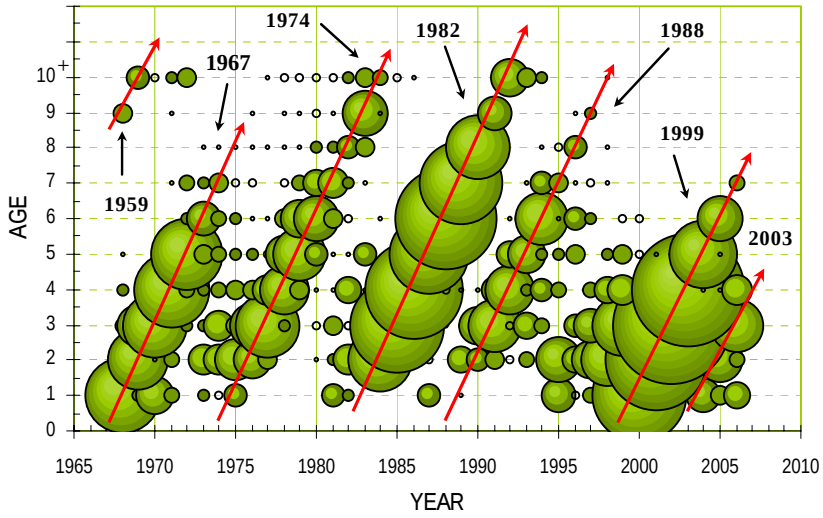

Figure 10. Catch at age (%) of Atlantic mackerel from NAFO Subareas 3 and 4 for the period between 1968 and 2006 (the year-classes that dominated the fishery over several years are indicated; the 10+ age group represents all fish older than 10 years old).

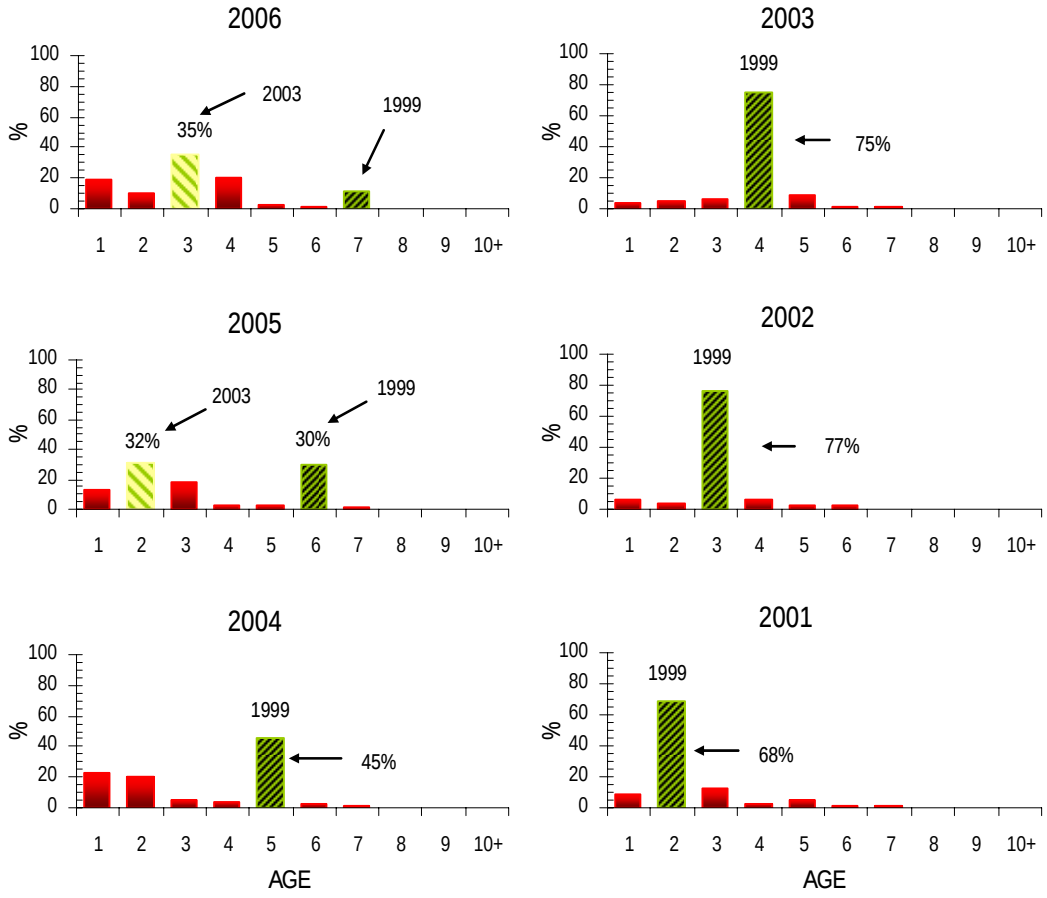

Figure 11. Catch at age (%) of Atlantic mackerel from the 1999 year-class since 2001, and from the 2003 in 2005 and 2006.

commercial purse seine fishery in Divisions 3K and 4R (Figure 12). However, these fish have only been observed since 2002 in the length frequency distributions for the gillnet fishery due to this fishing gear's greater selectivity.

In 2006, the mean length and weight of fish from the 2003 year-class was 331 mm and 434 g, respectively. These fish have been observed since 2004 in the annual length frequencies derived from sampling of the commercial line fishery in Division 4T and the commercial purse seine fishery in Division 3K, and since 2005, in the purse seine fishery in 4R.

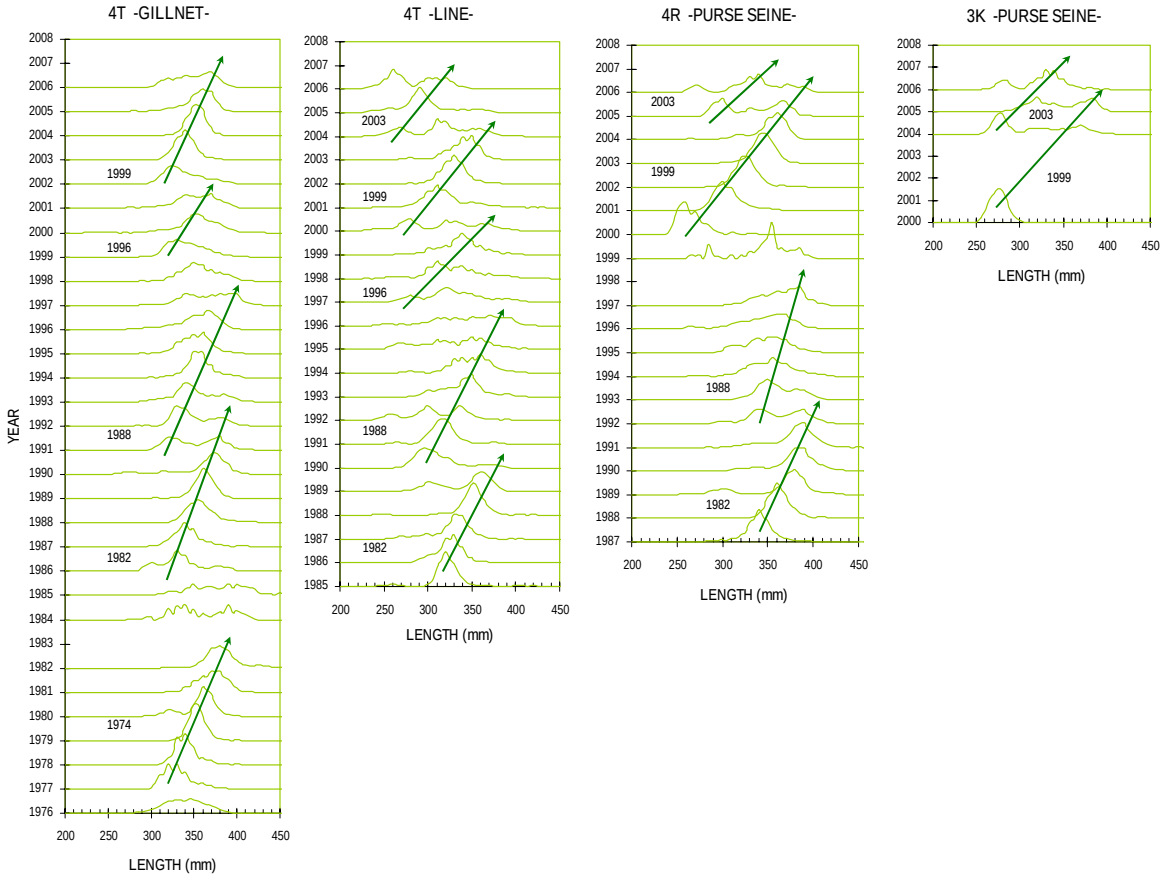

Figure 12. Annual length (mm) frequencies (%) of mackerel caught with gillnets and lines in Division 4T and with purse seines in Divisions 3K and 4R (the year-classes that dominated these fisheries are indicated).

Resource Status

1999 year-class

The 1999 year-class comes from a year when spawning took place earlier in the season than usual. This early spawning was deduced from the mean daily values of the gonado-somatic index, which stood at only 5% at the beginning of June 1999 in the Southern Gulf, compared to a mean value of 12% in the other years (Figure 13). Several fishermen also mentioned that the mackerel had arrived earlier in the Gulf of St. Lawrence in 1999. Samples from bottom trawl

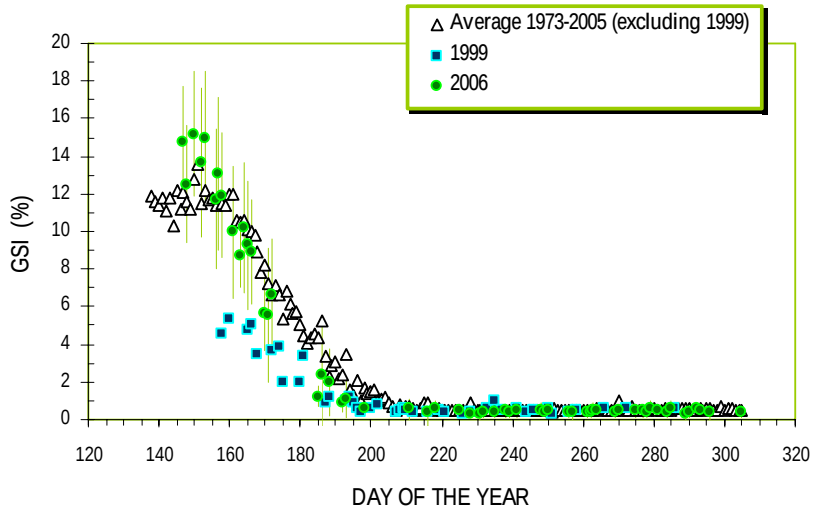

Figure 13. Daily means of the gonado-somatic index (GSI) for the 1973-2005 period (except for 1999) and for 1999 and 2006 (vertical lines represent standard deviations).

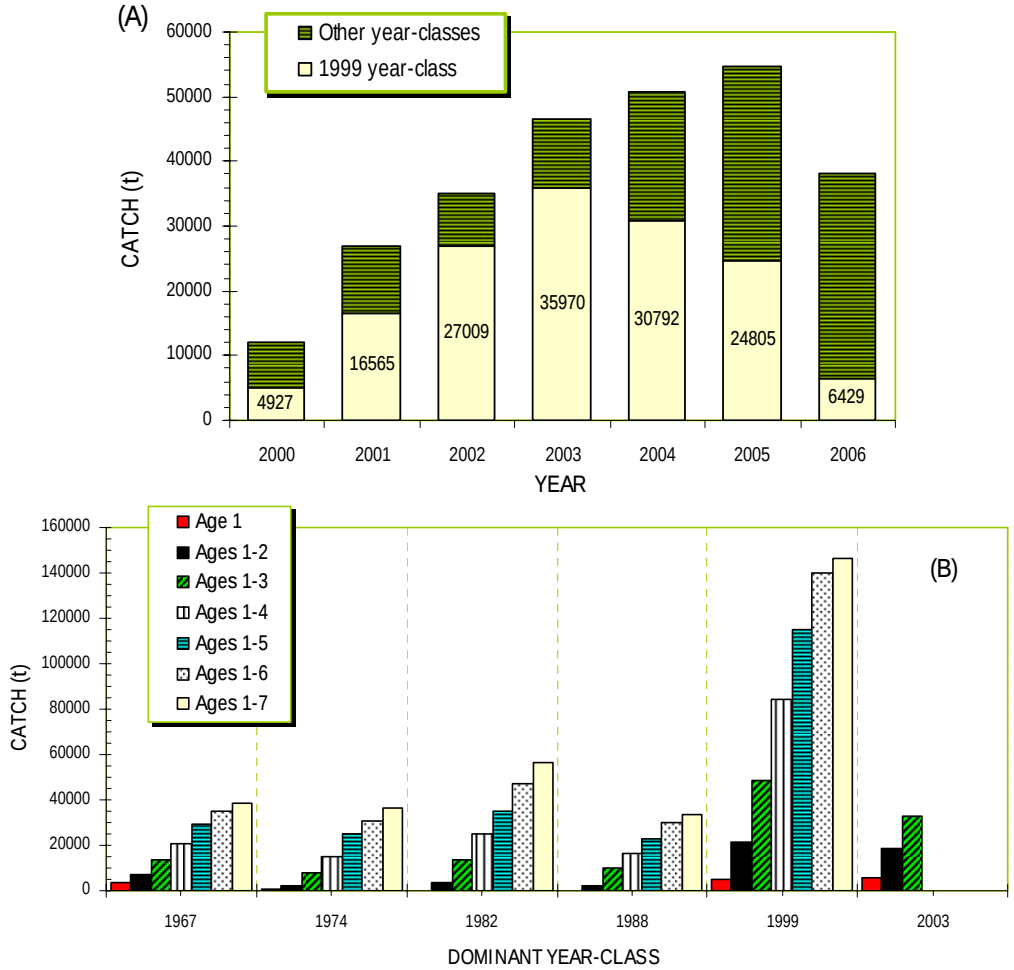

Figure 14. Annual catches (t) attributed to the 1999 year-class between 2000 and 2006 (A) and cumulative catches (t) at age for year-classes which dominated the fishery in recent years (B).

surveys conducted offshore Nova Scotia during the winter of 1999 indicate that ovaries were at a more advanced stage of development than in previous years. Such a degree of maturity could involve an earlier spawning in the Gulf of St. Lawrence and even a more important one on the Scotian Shelf. It should be noted that the winter and spring of 1999 were exceptionally warm on the Scotian Shelf.

From 2000 to 2003, annual landings attributed to the 1999 year-class ranged from 4,927 t to 35,970 t (Figure 14A). They dropped from 30,792 t and 24,805 t in 2004 and 2005 to only 6,429 t in 2006. The 1999 year-class had the most significant catches at each age among the most dominant year-classes in the fishery in recent years. At age 7, cumulative catches for this year-class was close to 150,000 t (Figure 14B).

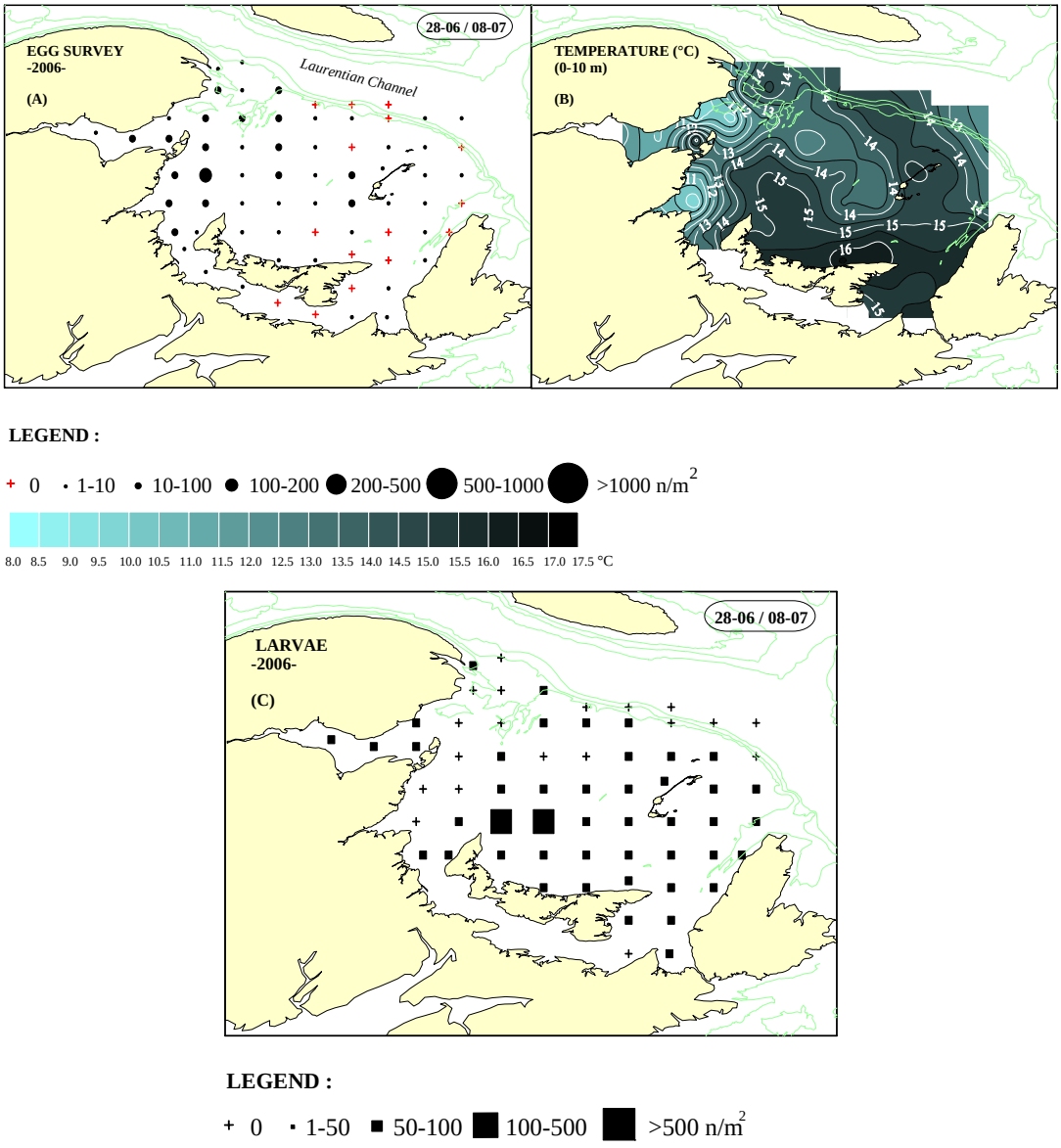

Figure 15. Egg distribution (number per square meter) (A) and water temperature (° C) (mean 0-10 m) (B) and larvae distribution (number per square meter) (C) measured during the 2006 survey. It is generally recognized that mackerel undertake migrations when water temperature reaches 8° C and eggs for the most part are found in waters with temperatures of 10° C and over.

Egg Survey

The egg survey was conducted between June 28 and July 8, 2006. Due to a lack of scientific vessels and the resulting schedule conflicts, it was impossible to conduct the survey at a more appropriate time. Most of eggs found were in the northwestern part of the sampled area (Figure 15A). Recorded concentrations were low, with a maximum reaching only 153 eggs/m^2. Water temperature (Figure 15B) was very high compared with previous years, and mackerel larvae were sampled at almost every station (Figure 15C).

Spawning Biomass Assessment

Compared to surveys in previous years, a reduction in daily and total egg productions was measured in 2006. Total egg production was evaluated using the parameters of a logistic model describing the reduction in mean daily values of the gonado-somatic index (Figure 16). This model indicates that the survey (median date) was conducted at the very end of the spawning season. Spawning biomass calculated for 2006 would be 54,133 t, which represents an all-time low (Figure 17).

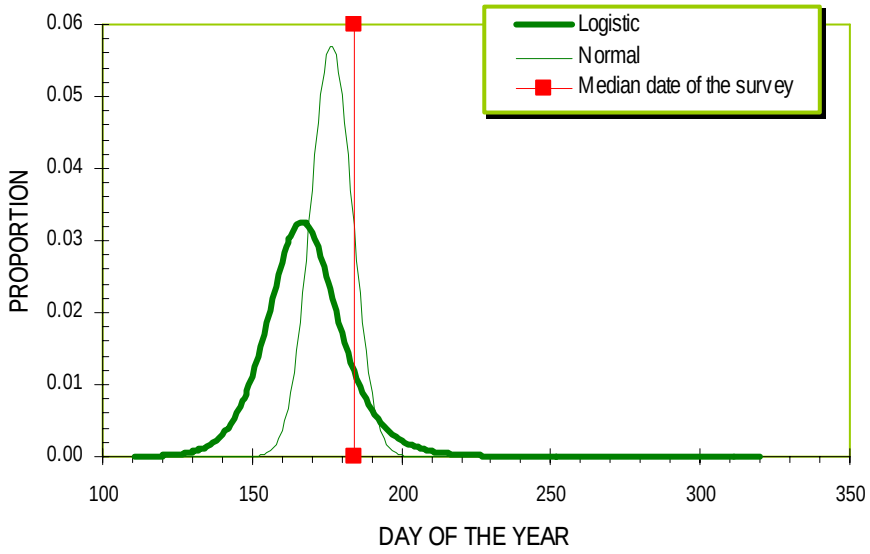

Figure 16. Density curves describing the daily proportion of egg production in 2006. The normal theoretical curve traditionally used has now been replaced by a curve derived from the parameters of a logistic model describing the decrease in mean daily gonado-somatic values during the spawning season.

Sources of Uncertainty

Unrecorded Catches

The mackerel that are caught and then used for bait do not appear in the Department's official statistics, which are based on purchase slips from sales to processing plants or from dockside monitoring. Recreational fishing is very popular in summer, but these statistics aren't recorded either. Since these activities are carried out throughout Eastern Canada, the actual total

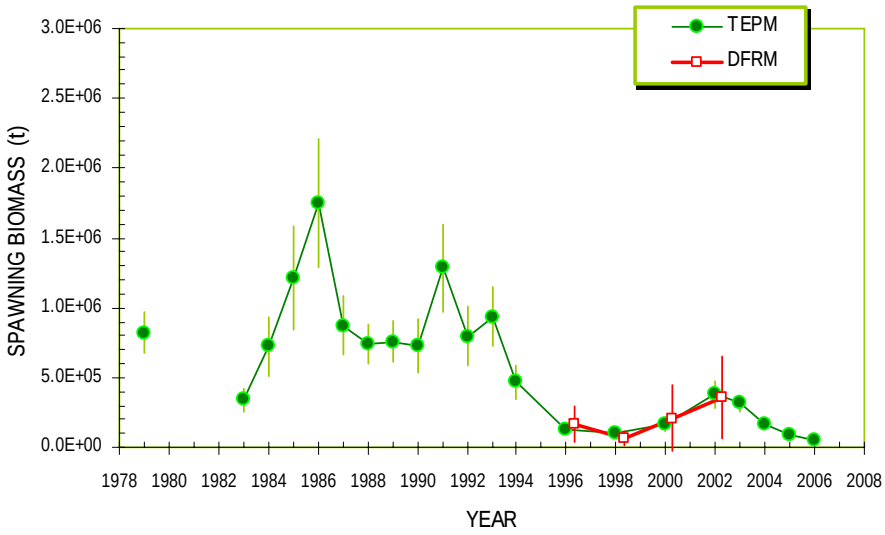

Figure 17. Spawning biomass (t) of mackerel calculated according to two different approaches (TEPM: Total Egg Production Method; DFRM: Daily Fecundity Reduction Method).

number of mackerel caught is largely underestimated. This issue has been mentioned every year for a number of years and to this date, no corrective measures have been undertaken.

Discards of Small Mackerel

A troubling observation has been reported by a number of fishermen over recent years in the Southern Gulf of St. Lawrence concerning the discards of a large number of small mackerel whose length was under the minimum legal catch size or below what industry requires. These discards, from line fishery, caused mortalities that are difficult to quantify. Nevertheless, they were certainly significant given the fact that this type of fishery is predominant in the Southern Gulf during the fall.

Fishing Gear Definitions

Mechanical jiggers are being used more frequently by fishermen in the southern Gulf of St. Lawrence. The current data collecting system does not differentiate this gear from the traditional jigger or the handline.

Recent Changes in Migration Routes

Recent changes in mackerel migration routes are responsible for the marked increase of landings on the east coast of Newfoundland (Divisions 3K and 3L) since 2004. This increase in landings is also accompanied by a significant drop in the number of catches in the southern Gulf of St. Lawrence (e.g. Magdalen Islands).

The unusual oceanographic conditions that have been occurring in the southern Gulf of St. Lawrence in recent years could be the reason for this change in migration routes. Mackerel spring migration may be delayed or occur elsewhere in order to avoid the cold waters in the Gulf of St. Lawrence.

CONCLUSION AND ADVICE

To improve the statistics on the fishery occurring in the Gulf of St. Lawrence, we **recommend** that a mandatory logbook be used by all fishermen, including those who harvest mackerel as bait. The use of logbooks would also provide better information on the location where the fishery is conducted, which would greatly facilitate analysis of the relationships between mackerel distribution and certain environmental variables. A possible alternative to the use of logbooks would be to collect catch data at dockside, as is currently done in Nova Scotia. However, at least for some regions of this province (Cape Breton), this system appears to present major flaws since the official statistics are much lower than the catch figures reported by some fishermen.

Recreational catches are significant, considering that this fishing is carried out by a very large number of fishermen, including tourists, all along the Atlantic coast. In view of the eventual management of this activity and in order to further improve statistics on fisheries, we **recommend** (as in recent years) that some thought soon be given to ways of estimating these catches. Furthermore, catches in American waters of mackerel that come from the Gulf of St. Lawrence are not included in the Canadian landings.

When small mackerel are being discarded in a given area, we **recommend** that fishing activities be interrupted until these small fish have left the area. We also **recommend** implementing a protocol on small fish for non-selective fisheries.

In order to improve abundance assessments and our knowledge on mackerel distribution, we **recommend** an international egg survey covering the spawning areas located in American and Canadian waters. Such a survey has never been done before in the Northwest Atlantic. In Europe, an international egg survey is conducted every three years. Results are used to calculate spawning biomass as well as to calibrate a sequential population analysis.

Because mackerel is a transboundary species, the issue of stock identity and resource sharing is significant. We **recommend** that stock discrimination studies be carried out as soon as possible.

The 1999 year-class supported the fishery like no other abundant year-class ever had before. Despite the uncertainties concerning the fishery statistics and the results from recent egg surveys, it appears that this year-class in no longer contributing to the fishery or to the spawning stock. Consequently, the 2007 catches should no exceed those of recent years. We **recommend** that the TAC, which is much higher than the highest landings recorded, be brought back down to 50,000 t. This reduction of the TAC is very important since it is very likely that catches of this level cannot be supported if post-1999 year-classes are only of average abundance.

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