ASSESSMENT OF THE ATLANTIC MACKEREL FOR THE NORTHWEST ATLANTIC (SUBAREAS 3 AND 4) IN 2005

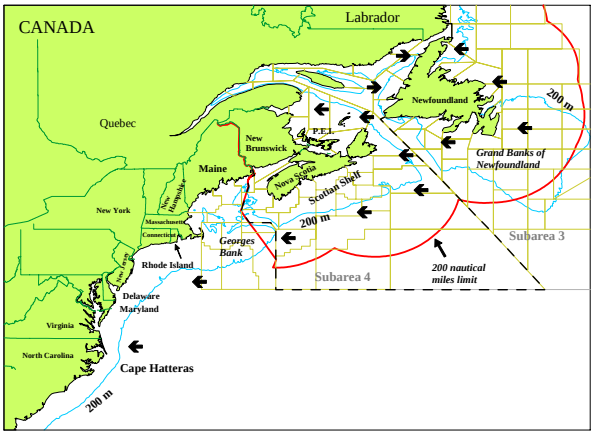

Figure 1. Distribution (←) of Atlantic mackerel (Scomber scombrus L.) in the Northwest Atlantic. The dotted line indicates the borders between Subareas 3 and 4 of the Northwest Atlantic Fisheries Organization (NAFO).

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 in deeper 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, hand-lines, purse sennes 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 1990. However, there has been a significant increase since the early 2000s, reaching a record high of 53,365 t in 2004. At regional levels, there can be significant differences in mackerel landings, which can be explained by changes in migration routes. These changes are caused by the species' sensitivity to water temperature among other things. 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

- From 2004 to 2005, mackerel landings in NAFO Subareas 3 and 4 decreased slightly from 53,365 t to 51,918 t. Despite this drop, landings in 2005 are more than double the 25,323 t average calculated for the 1990-2004 period.

- Landings in 2005 account for 70% of the Total Allowable Catches (TAC) of 75,000 t. However, the allotted quota for small senners (<65') and fixed gear (60% of the TAC or 45,000 t) was exceeded by around 2,000 t. This excess represents a first since the introduction of a TAC in 1987 for Subareas 3 and 4.

- The marked increase of landings on the east coast of Newfoundland (Divisions 3K and 3L) represents the main highlight in recent mackerel fishing seasons. In 2004 and 2005, landings in these two Divisions were 16,419 t and 26,589 t respectively. Mackerel occurrence in this area and in such significant numbers is unusual.

- From 2004 to 2005, landings by American fishermen dropped from 53,652 t to 41,594 t. For the entire Northwest Atlantic (NAFO Subareas 2-6), preliminary landings for 2005 were 93,512 t. Only in 2004 was a higher tonnage recorded (107,532 t) and during the 1970s offshore fishery.

- Since the early 2000s, mackerel catches have been greatly dominated by fish from the 1999 year-class. Between 2000 and 2004, fish from this year-class accounted for 45% to 77% of all catches in numbers, which had never previously been seen for a single year-class since the beginning of the data series (1968). In 2005, landings were dominated by the 2003 and 1999 year-classes, accounting for 32% and 30% of the catches respectively.

- According to the egg survey, the calculated spawning biomass in 2005 was 86,487 t, which represents a significant drop since 2002 and an all-time low. This drop in abundance would be the result of particular environmental conditions (cold waters) that have been occurring for a few years in the mackerel's traditional spawning area.

- The actual proportion of TAC that is caught could 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 the Canadian landings. Because of this imprecision, of a recent increase in fishing effort and of the uncertainty regarding results from recent egg surveys, the current TAC level could be lowered over the next year.

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 are tuna and bonitos. Among the three *Scomber* genus species, Atlantic mackerel has the most northerly distribution. Atlantic mackerel is also the only species 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 tend to be 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 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, 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 can be 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 can reach 257 mm and 197 g respectively (Figures 2A and 2B). Growth can not only vary 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 readily identified in the distributions of mean length at year and at age (Figure 4).

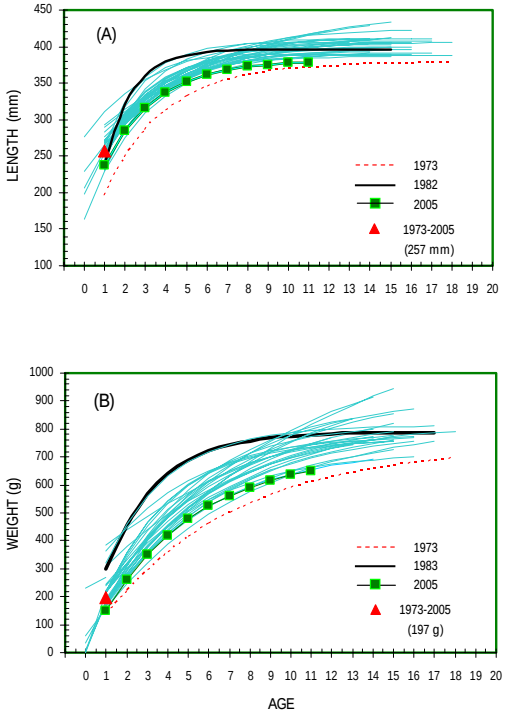

Figure 2. Mean annual length (mm) (A) and weight (g) (B) at age calculated using commercial samples collected in NAFO Subareas 3 and 4 since 1973. The fastest and slowest growth years are indicated as well as mean length and weight at one year for all the data.

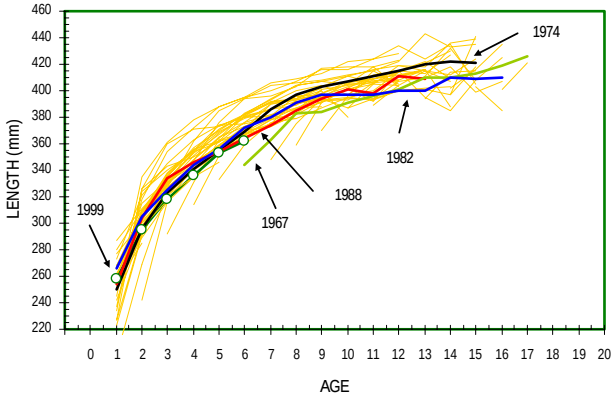

Figure 3. Mean length (mm) at age and per year-class calculated using commercial samples collected in NAFO Subareas 3 and 4 since 1973. The five most significant year-classes that have dominated the fishery over recent years are indicated.

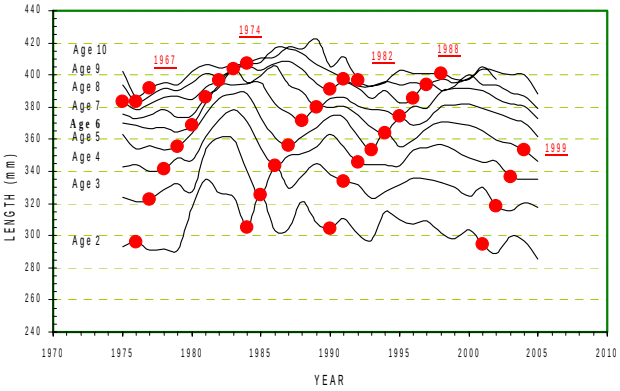

Figure 4. Mean length (mm) calculated per year-class using commercial samples collected in NAFO Subareas 3 and 4 since 1973. Ages are indicated as well as year-classes which dominated the fishery over recent years.

Maturity

Compared with other fish species, mackerel reach sexual maturity early in life. For example, the size at which 50% of the fish were mature, or L_{50}, was only 254.9 mm in 2005 (Figure 5A) and all fish above 340 mm were mature. L_{50} varies according to year (Figure 5B) and year-class (Figure 5C). Since 1999, the annual L_{50} values have been below or slightly above the minimum legal catch size of 250 mm.

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

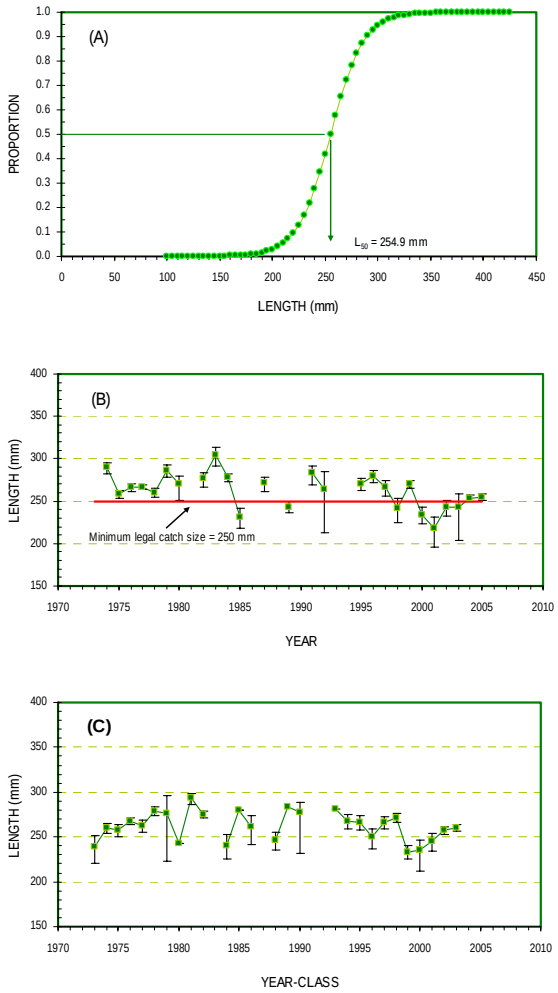

Figure 5. Mean proportion of mature fish at length in 2005 (A) and mean L_{50} values calculated per year (B) and per year-class (C) using commercial samples collected in June and July in NAFO Subareas 3 and 4 since 1973 (L_{50} represents the size at which 50% of the fish are mature; vertical lines represent 95% confidence intervals). The current minimum legal catch size is 250 mm.

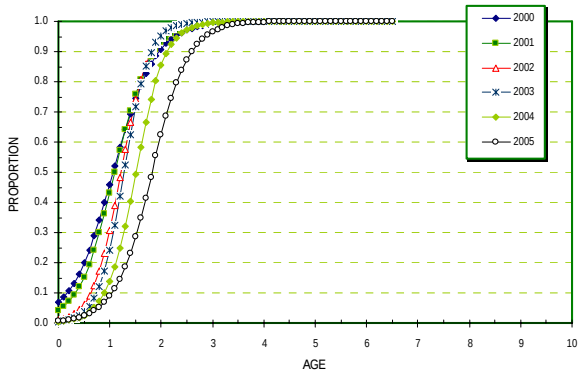

Figure 6. Mean proportion of mature fish at age calculated during the 2000s using commercial samples collected in June and July in NAFO Subareas 3 and 4.

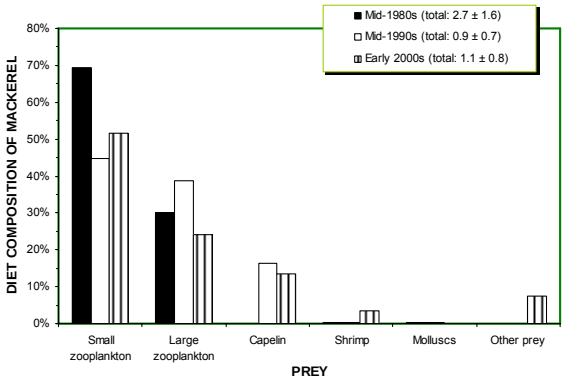

Figure 7. Mackerel diet composition (%) in the Northern Gulf of St. Lawrence from the mid-1980s to the early 2000s. Total annual consumption by mackerel in t km^{-2} yr^{-1} is presented in the legend.

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 their 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 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.

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 the main predators of mackerel in the Northern Gulf. The same model 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.

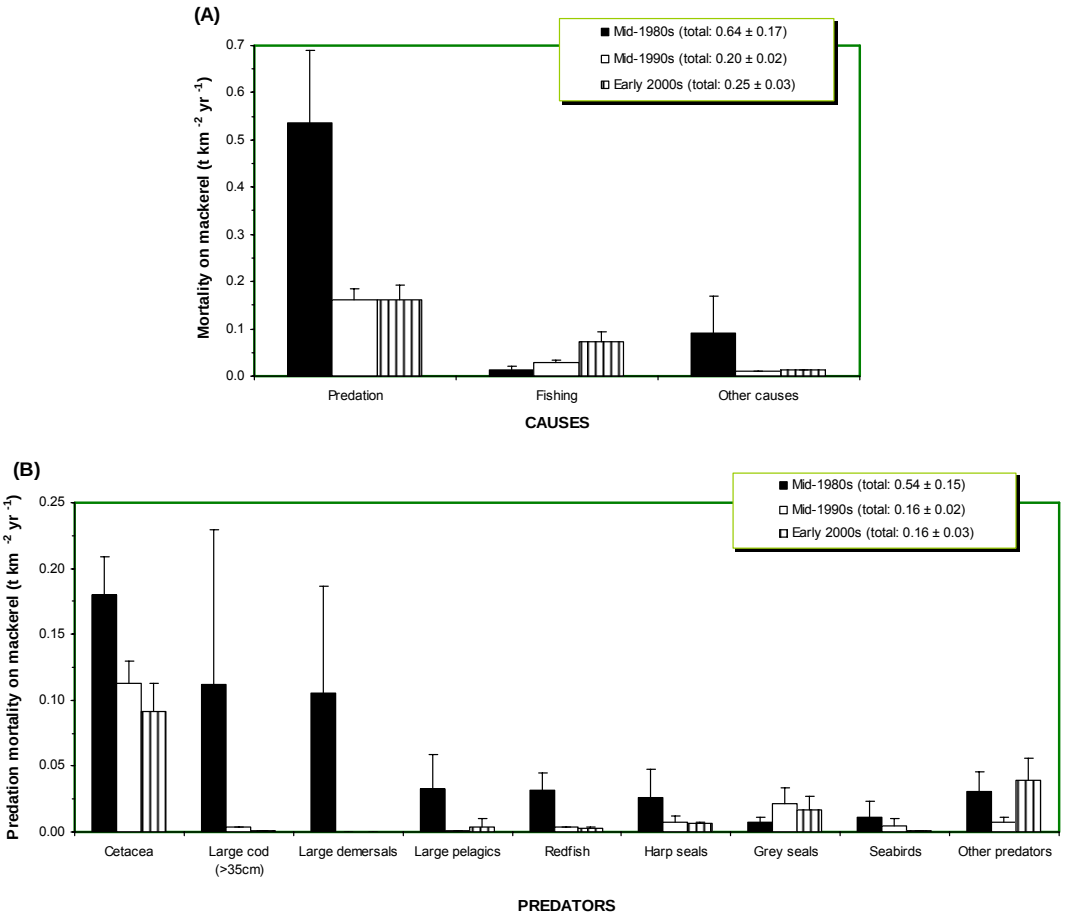

Figure 8. Main causes of mortality (t km^{-2} yr^{-1}) (A) and detail of predation related mortality (B) for mackerel according to different models of the Northern Gulf of St. Lawrence marine ecosystem from the mid-1980s to the early 2000s.

The Fishery

Historical Overview

Mackerel landings in the Northwest Atlantic (NAFO Subareas 2-6) reached significant values in the early 1970s (between 300,000 t to 400,000 t per year). Landings then dropped considerably in 1977 with the introduction of the 200-nautical-mile economic exclusion zone (EEZ) (Figure 9). Owing to agreements between the United States and the USSR, landings increased again in the early 1980s, peaking at close to 85,000 t in 1988. In the ensuing years, landings dropped considerably as the United States gradually reduced their mackerel quotas 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.

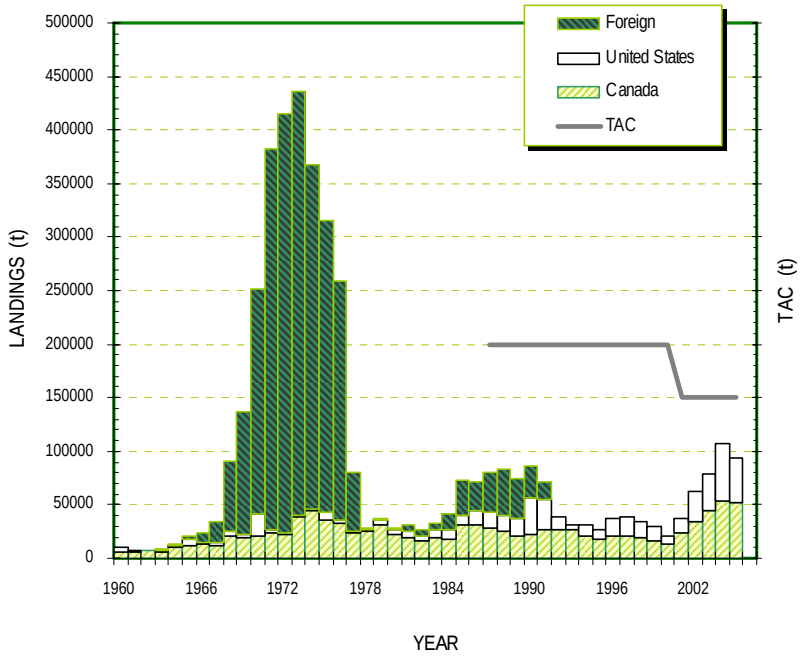

Figure 9. Annual landings (t) of mackerel and TAC (t) for the Northwest Atlantic (NAFO Subareas 2-6). Since 1987, Canada has proposed that the TAC be divided equally with the United-States; in 2001, the Canadian portion of the TAC was lowered from 100,000 t to 75,000 t.

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.

Landings in 2005

Reported mackerel landings in Eastern Canada (NAFO Subareas 3 and 4) totalled 51,918 t in 2005, compared with 53,365 t in 2004 (Table 1). Despite this drop, landings in 2005 are more than double the 25,323 t average calculated for the 1990-2004 period. U.S. commercial landings reached 41,594 t in 2005, which represents a slight drop from 2004. Recreational landings in the United States (chartered trips) weren't available at the time of the assessment,

but totalled 515 t in 2004, compared with an annual average of 1,257 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 totalled 93,512 t in 2005 (Table 1). Only in 2004 was a higher tonnage recorded (107,532 t) and during the 1970s offshore fishery.

Table 1. Annual mackerel landings (t) between 1990 and 2005 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	17 650	0	8 479	1 249	0	27 378
1996	20 364	0	16 137	1 416	0	37 917
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	23 868	0	12 336	1 538	0	37 742
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	53 652	515	0	107 532
2005*	51 918	0	41 594		0	93 512
AVERAGE:						
1990-2004	25 323	546	18 825	1 257	3 093	49 044
1995-2004	26 471	0	19 884	1 192	0	47 546

* Preliminary

Table 2. Annual 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*	(1995-2004)	(1990-2004)
Nova Scotia	6 681	5 517	5 669	4 562	4 797	4 546	4 058	3 989	7 187	5 325	4 476	5 233	6 184
New Brunswick	2 206	2 683	1 990	1 682	1 373	972	2 199	2 182	1 734	1 398	922	1 842	1 981
Prince Edward Island	2 518	4 017	6 693	6 784	3 842	4 134	5 886	6 181	4 543	4 692	4 762	4 929	4 465
Quebec	3 382	4 317	5 769	4 066	5 104	1 711	2 904	4 095	4 380	1 618	1 035	3 735	3 503
Newfoundland	2 862	3 830	1 188	2 149	1 445	2 019	8 820	17 955	26 631	40 333	40 724	10 723	9 166
Not known	0	0	0	91	0	0	0	0	0	0	0	9	570
TOTAL	17 650	20 364	21 309	19 334	16 561	13 383	23 868	34 402	44 475	53 365	51 918	26 471	25 869

* Preliminary

Of the 51,918 t of mackerel caught in Canadian waters in 2005, 40,724 t or 78% were landed in Newfoundland (Table 2), i.e. 26,639 t in Divisions 3K (22,605 t), 3L (3,984 t) and 3P (50 t), and 14,086 t in Division 4R (Table 3). The purse senne was the main fishing gear used, totalling 33,242 t, followed by the "tuck-ring" senne, jiggers, gillnets and traps, with landings totalling 5,158 t, 4,749 t, 3,686 t and 3,248 t respectively (Table 4). The "tuck-ring" senne is an effective fishing gear that is being used more and more in Newfoundland for the pelagic fishery. It is considered a fixed gear.

Table 3. Annual 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*	(1995-2004)	(1990-2004)
3K	11	3	0	0	0	0	322	6 566	588	16360	22605	2 385	2 020
3L	6	0	0	0	0	0	10	3	0	59	3984	8	54
3P	86	60	8	65	7	19	102	135	105	30	50	62	59
4R	2 760	3 767	1 181	2 175	1 438	2 001	8 385	11 251	25938	23885	14086	8 278	7 036
4S	30	9	1	1	2	0	17	2	0	0	35	6	19
4T	8 184	11 355	15 358	12 739	10 562	7 005	11 915	14 251	14106	8790	8475	11 427	10 728
4V	1 475	1 591	838	554	762	576	125	308	60	13	121	630	1 046
4W	621	1 181	716	138	127	120	248	115	9	59	36	333	784
4X	4 478	2 399	3 208	3 662	3 663	3 663	2 743	1 771	3669	4 169	2 527	3 342	3 560
Scotian Shelf (4VWX)	6 574	5 170	4 762	4 355	4 552	4 358	3 117	2 194	3 737	4 241	2 685	4 306	5 390
Gulf of St. Lawrence (4RST)	10 973	15 131	16 540	14 914	12 002	9 006	20 317	25 504	40 044	32 676	22 596	19 711	17 783
East and South coasts of Newfoundland (3KLP)	103	63	8	65	7	19	434	6 704	693	16 449	26 638	2 454	2 133
TOTAL	17 650	20 364	21 309	19 334	16 561	13 383	23 868	34 402	44 475	53 365	51 918		

* Preliminary

Table 4. Annual 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*	(1995-2004)	(1990-2004)
Trawl	59	68	92	9	12	1	3	5	0	2	1	25	393
'Tuck" senne	0	0	0	0	0	0	0	0	0	2 448	5 158	245	163
Purse senne	2 720	3 607	1 116	1 572	1 348	1 840	8 022	16 907	26 313	36 946	33 242	10 039	8 785
Other senne	0	0	9	0	0	0	0	0	0	0	779	1	15
Gillnet	4 442	6 419	6 657	7 638	5 128	5 294	6 554	5 000	4 541	4 734	3 686	5 641	6 078
Trap	4 719	3 821	3 889	3 999	4 057	3 920	3 148	2 073	3 628	4 690	3 248	3 794	3 689
Longline	0	0	0	7	3	3	20	18	13	3	21	7	9
Handline	899	1 231	3 029	1 998	569	90	160	169	9	694	1 007	885	736
Jigger	3 821	4 705	6 204	3 651	5 435	2 229	5 676	9 839	9 856	3 843	4 749	5 526	5 159
Weir	177	0	1	141	8	0	46	48	74	2	20	50	55
Other	812	510	313	320	0	5	237	344	40	2	1	258	222
Not known	0	0	0	0	0	0	0	0	0	0	6	0	564
TOTAL	17 650	20 364	21 309	19 334	16 561	13 383	23 868	34 402	44 475	53 365	51 918	26 471	25 869

* Preliminary

For several years, 40% of the TAC has been allocated to mobile gear over 65' (19.8 m) or for all exploratory fishing, and 60% to mobile gear under 65' and to coastal fixed gear such as traps, gillnets, lines and weirs. In the first case, nearly 17% of the quota was reached in 2005, compared with 49% and 39% in 2003 and 2004 respectively (Table 5). In the second case, the quota was exceeded by 4% or approximately 2,000 t in 2005, which is a first since the 1987 introduction of a TAC in Subareas 3 and 4. The excess was caused by small purse senne catches, which on their own totalled 28,177 t.

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*	(1995-2004)
-- QUOTA 40% --												
Purse senne >65'	1 312	1 782	315	167	304	492	3 579	6 074	14 645	11 612	5 065	4 028
Quota	*40 000*	*40 000*	*40 000*	*40 000*	*40 000*	*40 000*	*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	13
-- QUOTA 60% --												
Purse senne <65'	1 408	1 826	801	1 406	1 044	1 348	4 443	10 833	11 668	25 334	28 177	6 011
Other	14 929	16 756	20 193	17 762	15 213	11 543	15 845	17 495	18 162	16 419	18 676	16 432
Total	16 338	18 582	20 995	19 168	16 257	12 891	20 288	28 328	29 830	41 753	46 853	22 443
Quota	*60 000*	*60 000*	*60 000*	*60 000*	*60 000*	*60 000*	*45 000*	*45 000*	*45 000*	*45 000*	*45 000*	
%	27.23	30.97	34.99	31.95	27.10	21.49	45.09	62.95	66.29	92.78	104.12	44
TOTAL	17 650	20 364	21 309	19 334	16 561	13 383	23 868	34 402	44 475	53 365	51 918	

* 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 2000 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. These high percentages could be reflecting the predominance of this single year-class in all the stock. However, in 2005, 50% of the catch at age was composed of fish from the 2 and 3-year-old age group, i.e. 2003 and 2002 year-classes, compared with 30% for the 1999 year-class (Figure 11).

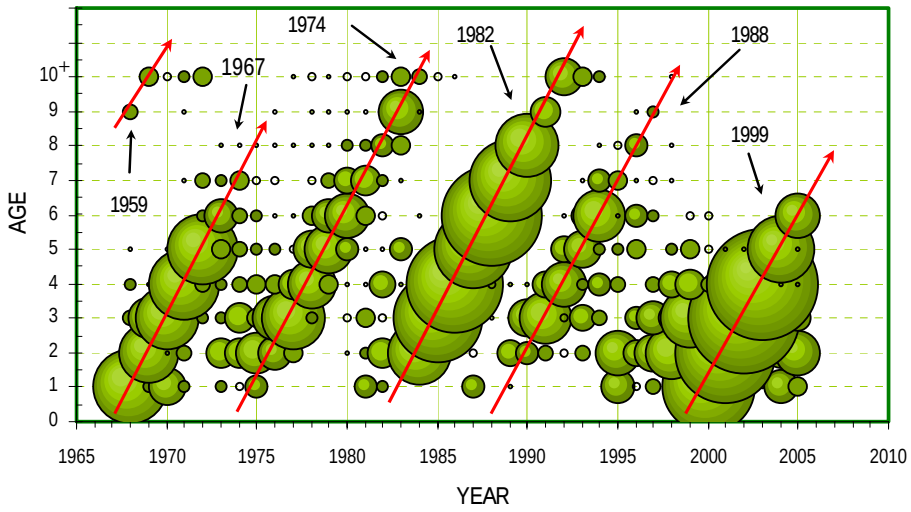

Figure 10. Catch at age (%) of mackerel from NAFO Subareas 3 and 4 for the period between 1968 and 2005 (the year-classes that dominated the fishery over several years are indicated; the 10+ age group represents all fish older than 10 years old).

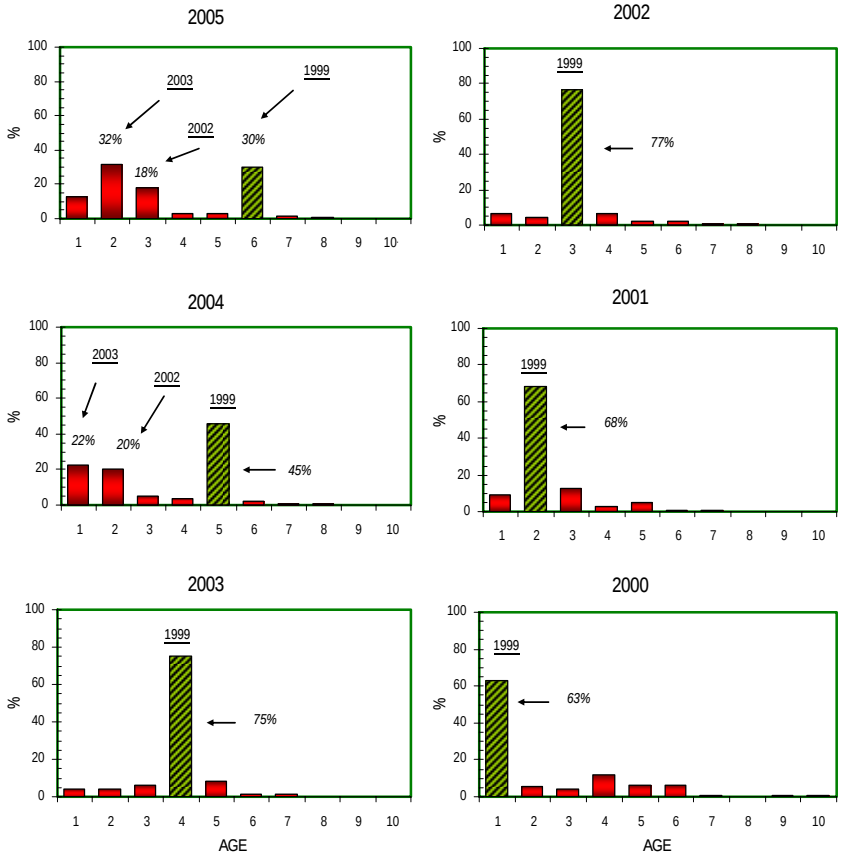

Figure 11. Catch at age (%) of mackerel from the 1999 year-class since 2000, and from the 2002 and 2003 year-classes in 2004 and 2005.

Length Frequencies

In 2005, the mean length and weight of fish from the 1999 year-class was respectively 372 mm and 618 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 commercial purse senne 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.

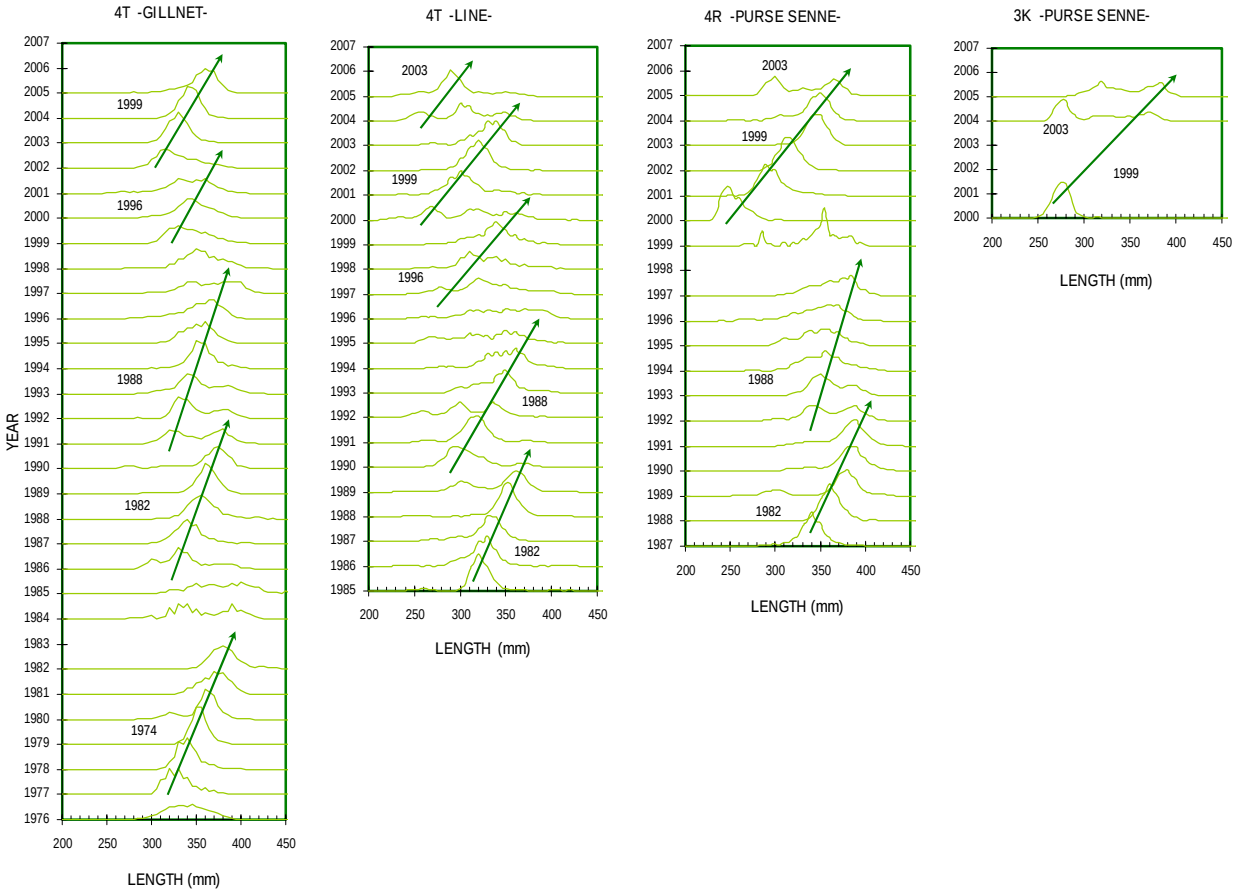

Figure 12. Annual length (mm) frequencies (%) of mackerel caught with gillnets and lines in Division 4T and with purse sennes in Divisions 3K and 4R (the year-classes that dominated these fisheries are also indicated).

In the fall of 2005, fish from the 1 and 2-year-old age group dominated catches made in the commercial line fishery in Division 4T, compared with age groups 2 and 6 caught in the purse senne fishery in Divisions 3K and 4R (Figure 13). Fish from these two age groups caught in Division 3K were longer that those from the same age groups caught in Division 4R. This difference in growth could suggest that these fish were not spawned in the same area (Gulf of St. Lawrence vs. southern and eastern coast of Newfoundland) and did not experience the same environmental conditions during their first year of life.

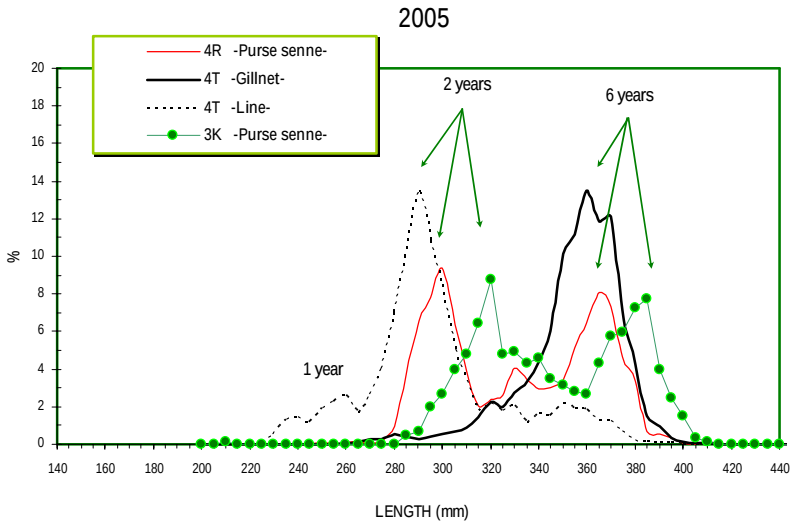

Figure 13. Length (mm) frequencies (%) of mackerel caught in 2005 with purse sennes, gillnets and lines in NAFO Divisions 3K, 4R and 4T (modes corresponding to age groups 1, 2 and 6 are indicated).

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 14). Several fishermen also mentioned that the mackerel had arrived earlier in the Gulf of St. Lawrence in 1999. Samples from bottom trawl surveys conducted offshore Nova Scotia during the winter of 1999 indicate that gonads 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.

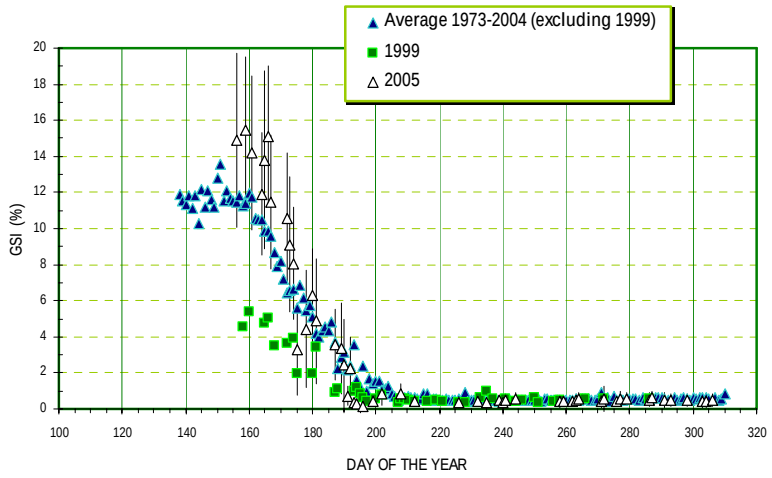

Figure 14. Daily averages of gonado-somatic index (GSI) values for 1973-2004 (excluding 1999) and for 1999 and 2005 (vertical bars represent standard deviations).

Egg Survey

The egg survey was conducted between June 16 and 22, 2005. The most significant concentrations of eggs were found in a restricted area located in the south-western portion of the sampled area (Figure 15A). Such restricted egg distribution has only been observed for a few years and is probably related to the presence of colder waters covering a significant portion of the southern Gulf of St. Lawrence during the surveys (Figure 15B). It is generally recognised 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.

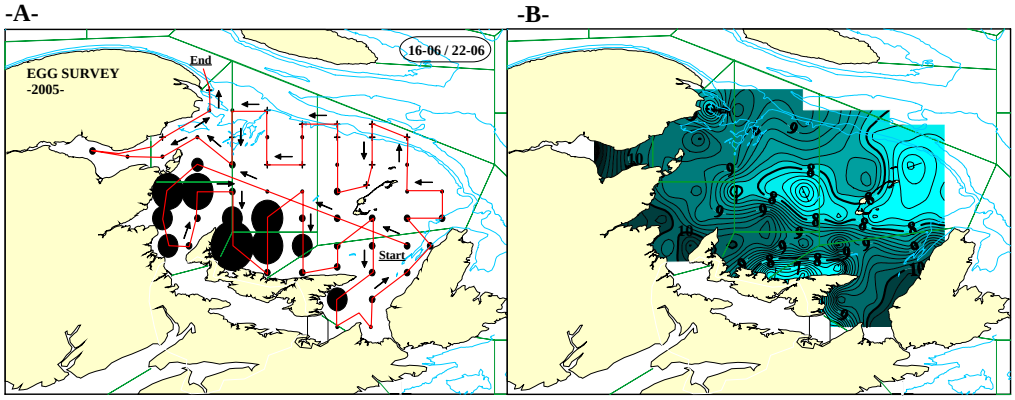

Figure 15. Pattern of sampling, mackerel egg distribution (number per square meter) (A) and water temperature (mean 0-10 m) (B) measured during the 2005 survey. It is generally recognised that mackerel undertake migrations when water temperature reaches 8° C and eggs for the most part are found in waters with temperatures of 10° C and over.

Spawning Biomass Assessment

During the 2005 survey, a reduction in daily and total egg productions was measured for the entire sampled area. As in earlier years, total egg production was converted into spawning biomass using the daily proportion of egg production. The latter was evaluated using the parameters of a logistic model describing the reduction in mean daily values of the gonado-somatic index (Figure 14). A similar result was obtained using normal theoretical curve traditionally used (Figure 16). Spawning biomass calculated for 2005 is 86,487 t, which represents a significant drop since 2002, and an all-time low (Figure 17).

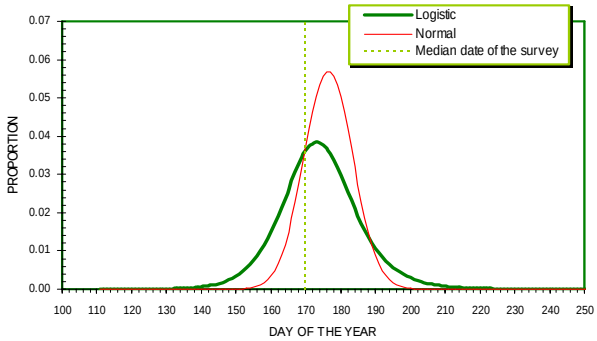

Figure 16. Density curve describing the daily proportion of egg production in 2005. The normal theoretical curve traditionally used has now been replaced by a curve derived from the parameters of a logistic model describing the reduction in mean daily GSI values during the spawning season.

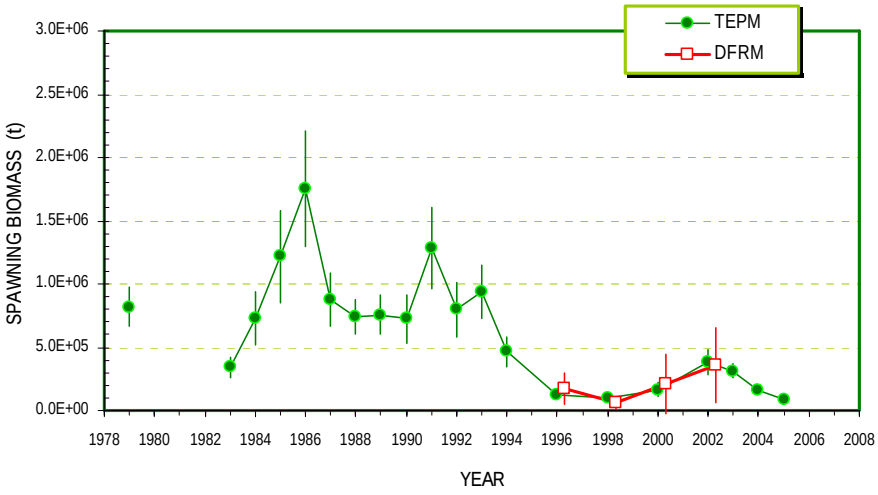

Figure 17. Spawning biomass (t) of mackerel calculated according to two different approaches (TEPM: Total Egg Production Method; DFRM: Daily Fecundity Reduction Method).

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, and these statistics aren't recorded either. Since these activities are carried out throughout Eastern Canada, the actual total number of mackerel caught is largely underestimated.

Discards of Small Mackerel

A disturbing observation was reported during the last two 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.

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) in 2004 and 2005. 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. Spring migration for mackerel 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 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 monitor the catch data at dockside, as is currently done in Nova Scotia. However, at least for some regions of this province, 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. For the eventual management of this activity and in order to further improve statistics on fisheries, we recommend 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. Because of this imprecision, of a recent increase in fishing effort and of the uncertainty regarding results from recent egg surveys, the current TAC level could be lowered over the next year. Finally, when there are discards of small mackerel in a specific area, we recommend that fishing activities be suspended until these smaller fish have left the area.

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