Atlantic Mackerel of the Northwest Atlantic in 2003

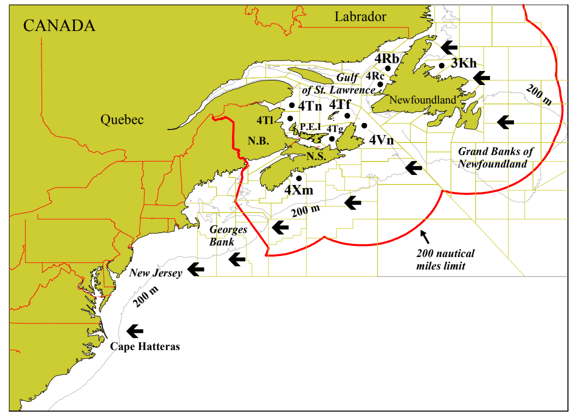

Figure 1. Distribution (←) of Atlantic mackerel (Scomber scombrus L.) in the Northwest Atlantic. The main fishing areas (●) in Canadian waters are shown.

Background

Atlantic mackerel (Scomber scombrus L.) belong to the scombrids, a major family that includes a very large number of fish species occurring in tropical and temperate waters throughout the world. In the Northwest Atlantic, Atlantic mackerel range from Cape Hatteras, North Carolina to the Gulf of St. Lawrence and the east coast of Newfoundland (Figure 1). This vast region is characterized by the presence of two spawning stocks. In Canadian waters, mackerel spawn chiefly in the southern Gulf of St Lawrence, in June and July. This spawning is preceded by a long migration that begins in early spring on Georges Bank. In U.S. waters, mackerel spawn in March and April, along the New Jersey coast.

In the Maritime Provinces, Newfoundland and Quebec, over 15,000 commercial fishers participate in the mackerel fishery. They fish mainly inshore, using gillnets, jiggers, purse seines and traps. The type of gear used varies with the location and the time of year. The mackerel landings reported by Canadian fishers are generally stable from one year to the next and have averaged about 22,000 t per year since 1990. However, landings can vary widely from one region to another, because of changes in mackerel migration routes. One of the reasons for these changes is the mackerel's sensitivity to water temperature. Fishers who catch mackerel for bait in the Gulf of St. Lawrence are not required to maintain logbooks, so their catch is not recorded. Neither is the catch of recreational fishers who fish for mackerel in the summer months all along the Atlantic coast.

Mackerel abundance in the Gulf of St. Lawrence is estimated from data gathered in an egg-sampling survey. This survey, which is unique in the Northwest Atlantic, also gathers information on the abundance and diversity of the plankton communities that are present in the southern Gulf of St. Lawrence in June.

Summary

- In 2003, the most striking feature of the commercial mackerel catch was the presence of a high abundance and a very large proportion of fish from the 1999 year-class. Over the past four years, this year-class has accounted for 63%, 68%, 77% and 75% of the total number of fish caught. This is the first time that fish ages 1 to 4 have been so predominant among the year-classes sampled since 1973. However, these high percentages may reflect the preponderance of the 1999 year-class throughout the stock.
- In Canadian waters, commercial landings of mackerel went from 34,402 t in 2002 to a preliminary figure of 34,413 t in 2003, a peak level not seen since 1960. Actual landings will be higher than this value, since the Prince Edward Island and New Brunswick catch data are not yet available. Close to 76% of the total landings in 2003, or 26,295 t, were made on the west coast of Newfoundland. In American waters, between 2002 and 2003, the landings of U.S. commercial fishers rose from 26,452 t to 30,375 t.

- The spawning biomass is currently estimated from an egg-sampling survey and an empirical model that can be used to calculate seasonal or total egg production. Using this approach, the spawning biomass was estimated at 314,752 t in 2003, which represents a 17% decrease from 2002.
- The lower biomass value obtained in 2003 could be due to unusual oceanographic conditions rather than an actual decrease in abundance. Abnormally cold water temperatures were recorded throughout the northern and central portions of the area sampled; as a result, the largest egg concentrations were found only in the warmer waters—which are more favourable for spawning—located very near the coast of Prince Edward Island and New Brunswick. This is an unusual situation, which may have resulted in an underestimation of egg production.
- According to the egg survey, the spawning biomass of mackerel hit a record low level in 1998. The abundance increases measured in 2002 are essentially attributable to the members of the 1999 year-class. However, given the factors of uncertainty mentioned earlier, we recommend that the TAC be maintained at 75,000 t in 2004.

Biology

Atlantic mackerel (*Scomber scombrus* L.) are members of the large family of fishes called Scombridae, which occur in temperate and tropical seas around the world. Tuna and bonita species are among the better known members of this family. Within the genus *Scomber*, Atlantic mackerel is the species with the most northerly distribution, and, unlike the other two species in this genus, it has no swim bladder. This biological characteristic forces mackerel to swim continuously so they will not sink. They are thus able to change their position in the water column quickly and they swim fast, which makes them harder to catch compared with other pelagic species. During their long annual migrations, mackerel move in schools that are sometimes very dense, especially in spring and fall. These schools generally consist of individuals that are the same size and swim at the same speed.

Spawning

Although some spawning does take place along the coast of Nova Scotia during the spring migration, the mackerel that frequent Canadian waters spawn mainly in the southern Gulf of St. Lawrence (Figure 1), in June and July. The largest egg concentrations are found in waters south of the Laurentian Channel, west of the Magdalen Islands. Peak spawning occurs at water temperatures between 9°C and 12°C, and the eggs will hatch in about a week at these temperatures. Spawning in this species is termed “multiple”, because each female spawns several times, and “asynchronous”, because it can occur at any time of the day or night. Spawning takes place near the surface, and during the incubation period the eggs remain suspended in the layers of water above the thermocline. On hatching, mackerel are about 3 mm long. They go through three development stages: (1) yolk sac, (2) larva and (3) juvenile. The first stage lasts a few days, and the second about two months. During the larval phase, the yolk sac is used up and the fins develop. The larvae become juveniles at a size of about 50 mm and these juveniles form schools. Some schools of juveniles migrate from the spawning grounds toward the coast, where they have been observed in inshore waters. Not much is known about what proportion of the juvenile population participates in this migration, or about what roles these inshore habitats play in the growth and survival of the juveniles.

Growth

Mackerel grow very fast, reaching a length of 270 mm and a weight of 200 g, on average, by the end of their second year

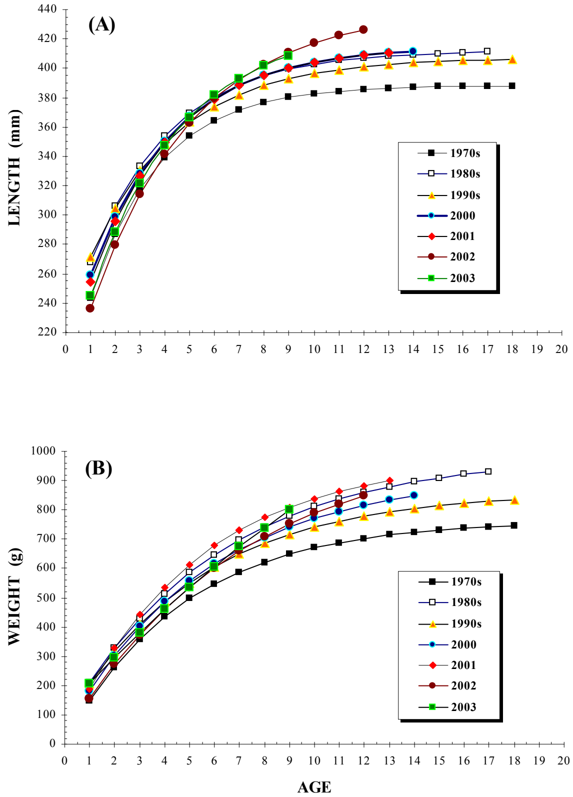

Figure 2. Mean length (mm) (A) and weight (g) at age (B), calculated using von Bertalanffy's growth model, for mackerel sampled along Canadian coastlines since 1973.

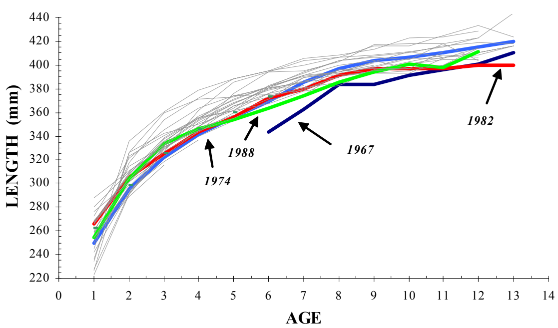

Figure 3. Mean length (mm) at age for the mackerel year-classes sampled since 1973 (the 4 largest year-classes that have dominated the fishery in recent years are identified).

(Figures 2A and 2B). Growth rates can vary not only from one year or period to another, but also from one year-class to another. For example, the growth rate was slower in the abundant year-classes of 1967, 1974, 1982 and 1988 (Figure 3). These year-classes can be readily identified in the distributions of mean length at year and at age (Figure 4).

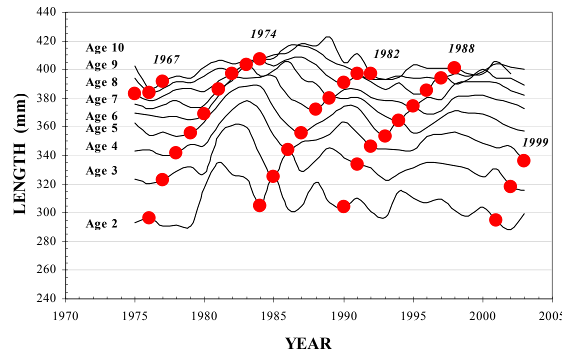

Figure 4. Mean length (mm) calculated by year-class for mackerel sampled since 1973 (the ages are indicated as are the year-classes that have dominated the fishery in recent years).

Condition

Mackerel condition is poorest in spring, whereas the highest values are recorded in the fall. Up to and including 1984, the condition of mackerel on their arrival in the Gulf of St. Lawrence and during spawning was higher than the average value for the period 1973 to 2002 (Figure 5). Between 1985 and 2003, however, their annual condition was below this average (except in 1999). The annual variations in mackerel condition follow a pattern very similar to average water temperature in the upper portion (30–100 m) of the cold intermediate layer (CIL) (Figure 5). The possible relationships between mackerel condition and these temperatures are not very well known, but it is assumed that a decline in condition like that observed in the 1980s and 1990s may have had a negative impact on natural mortality in mackerel.

Maturity

Mackerel reach sexual maturity early compared with many other fish species. The size at which 50% of mackerel (L_{50}) were

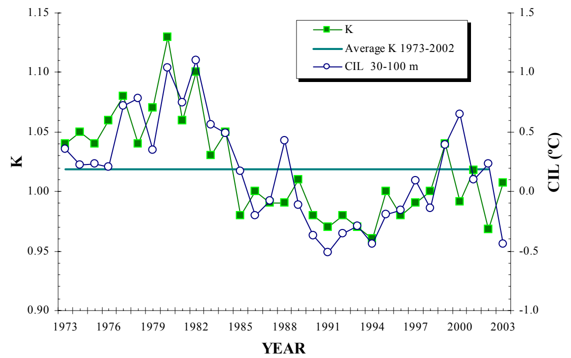

Figure 5. Mean condition factor (Fulton) calculated in June, and mean temperature (°C) in the upper portion (30 to 100 m) of the cold intermediate layer, or CIL (preliminary data for 2003) (Denis Gilbert, DFO, MLI, pers. comm.).

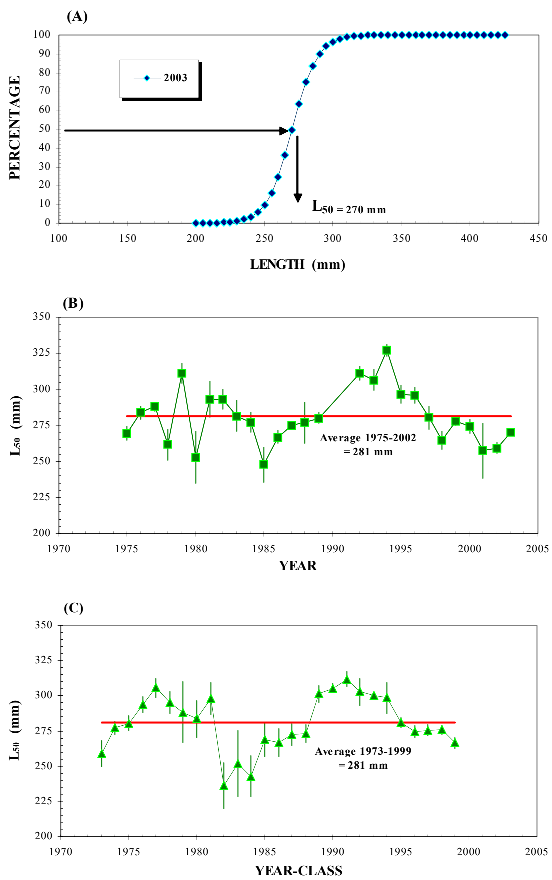

Figure 6. Mean percentages of mature fish at length in 2003 (A) and mean L_{50} values calculated by year (B) and by year-class (C) for mackerel sampled along Canadian coastlines since 1973 (L_{50} represents the length at which 50% of individuals are mature; the vertical lines denote 95% confidence intervals).

mature was only 270 mm in 2003 (Figure 6A). This figure varies with the year (Figure 6B) and the year-class (Figure 6C). Lower L_{50} values have been recorded in recent years and for recent year-classes. All mackerel reach maturity by the time they are 340 mm long.

Less than 50% of mackerel are mature at age 1, but more than 60% are mature at age 2 (Figure 7). During the past few years, the proportion of fish mature at age 2 and age 3 has been higher than in previous years.

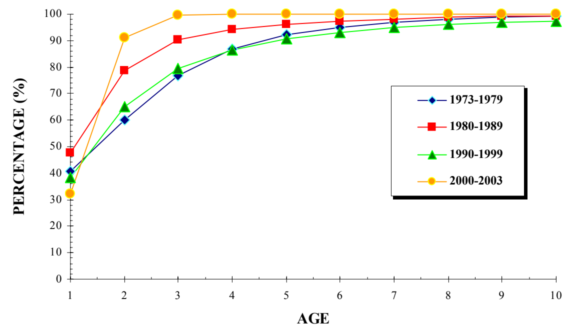

Figure 7. Mean percentages of mature fish at age for mackerel sampled along Canadian coastlines since 1973.

Diet

Data collected in the mid-1980s show that the mackerel in the northern Gulf of St. Lawrence fed mainly on small (< 5 mm) and large (≥ 5 mm) zooplankton (Figure 8A). New estimates derived in the mid-1990s indicate that small and large zooplankton were still the main prey items (Figure 8B). However, capelin (*Mallotus villosus*) make up nearly 10% of the mackerel diet.

In the southern Gulf, the main prey items recorded in the mid-1980s were large and small zooplankton, along with small pelagic species such as herring (*Clupea harengus harengus*) (Figure 9A). In the mid-1990s, capelin and shrimp (*Pandalus borealis*) were also key prey items for mackerel (Figure 9B).

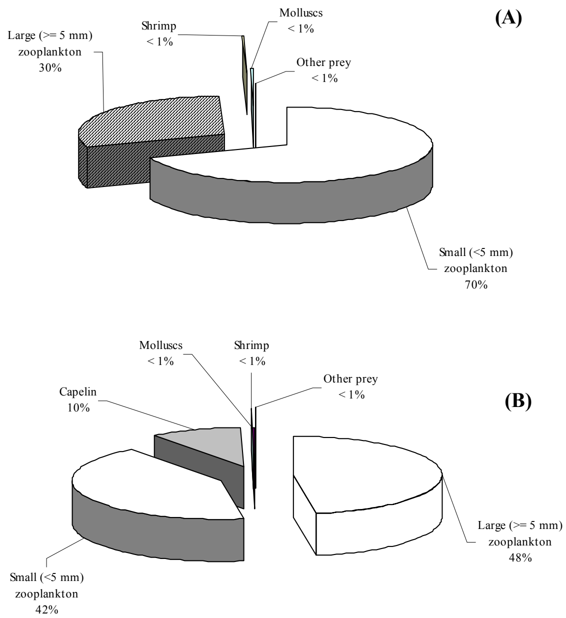

Figure 8. Diet (%) of mackerel in the northern Gulf of St. Lawrence in the mid-1980s (A) and the mid-1990s (B) (C. Savenkoff and M. Castonguay, DFO, MLI, pers. comm.).

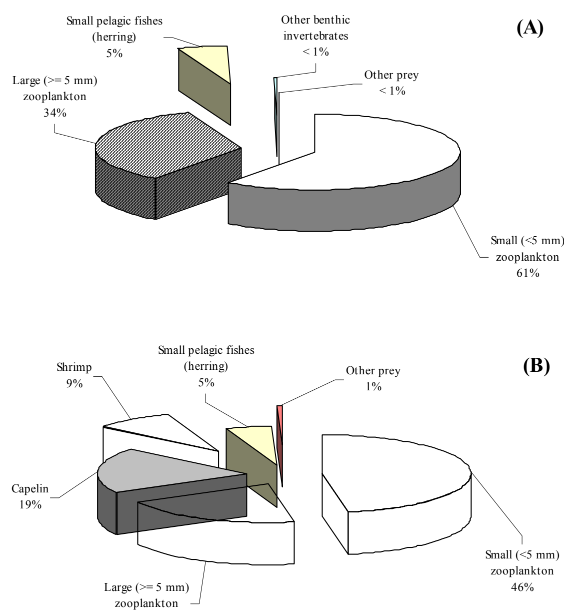

Figure 9. Diet (%) of mackerel in the southern Gulf of St. Lawrence in the mid-1980s (A) and the mid-1990s (B) (C. Savenkoff and M. Castonguay, DFO, MLI, pers. comm.).

The fishery

Historical overview

Mackerel landings in the Northwest Atlantic, which ranged from 300,000 t to 400,000 t in the early 1970s (Figure 10), dropped considerably with the introduction of the 200-nautical-mile economic exclusion zone (EEZ). In the early 1980s, owing to agreements between the United States and what was then the USSR, landings increased significantly, peaking at close to 85,000 t in 1988. In the ensuing years, landings dropped considerably as the United States gradually reduced its mackerel quotas, eventually closing this fishery completely in 1992.

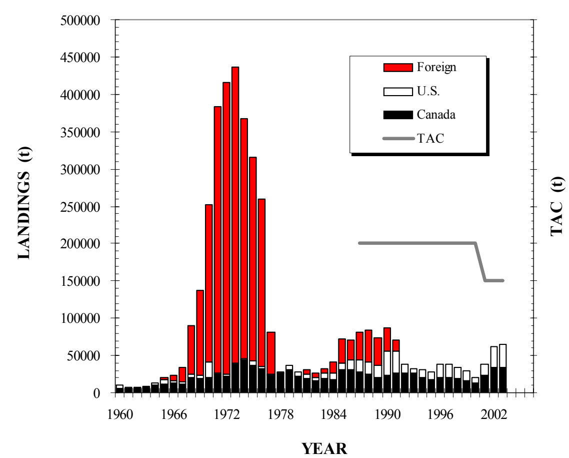

Figure 10. Annual landings (t) of mackerel and TAC (t) for the Northwest Atlantic (since 1987, Canada has proposed dividing the TAC equally with the United States; in 2001, the Canadian share of the TAC fell from 100,000 t to 75,000 t).

Since 1987, Canada has been proposing that the TAC of 200,000 t for the entire Northwest Atlantic be divided equally with the United States. In light of the low biomass estimates derived from the 1996, 1998 and 2000 egg surveys, the Canadian share of the TAC was reduced from 100,000 t to 75,000 t in 2001.

Table 1. Annual mackerel landings (t) from 1990 to 2003 in NAFO Subareas 2 to 6.

YEAR	CANADA		USA			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	-	8 479	1 249	0	**27 378**
1996	20 364	-	16 137	1 416	0	**37 917**
1997	21 309	-	15 400	1 735	0	**38 444**
1998	19 334	-	14 523	690	0	**34 547**
1999	16 561	-	12 026	1 335	0	**29 922**
2000	13 383	-	5 646	1 448	0	**20 477**
2001	23 868	-	12 336	1 538	0	**37 742**
2002	34 402	-	26 452	1 286	0	**62 140**
2003*	34 413	-	30 375	724	0	**65 512**
AVERAGE:						
1960-2002	**18 459**	**3 241**	**7 273**	**1 789**	**62 708**	**93 471**
1970-2002	**21 212**	**3 704**	**8 763**	**2 126**	**75 281**	**111 087**
1980-2002	**22 150**	**545**	**11 682**	**1 972**	**11 092**	**47 442**
1990-2002	**21 693**	**630**	**14 965**	**1 356**	**3 569**	**42 212**

* Preliminary data

Landings in 2003

In 2003, preliminary reported landings of mackerel in eastern Canada totalled 34,413 t (Table 1), which is virtually identical to the figure for 2002. The figure for 2003 is still higher than the average for recent years, and it represents a peak level not seen since 1960. Nonetheless, the landings are at present underestimated, since the catch data for New Brunswick and Prince Edward Island are not available yet.

U.S. commercial landings stood at 30,375 t in 2003, up nearly 4,000 t from 2002. Recreational landings in the United States totalled 724 t in 2003 compared with 1,286 t in 2002, and no foreign vessels are reported to have fished in U.S. waters since 1992. For the Northwest Atlantic as a whole, mackerel landings totalled 65,512 t in 2003, which exceeds the annual averages calculated since 1980 and 1990 (Table 1).

Of the total reported mackerel catch in Canada in 2003, 26,295 t or 76% was landed on the west coast of Newfoundland (Table 2). The purse seine was the main fishing gear used, followed by jiggers and traps (Table 3).

Description of landings

In 2003, for the fourth consecutive year, mackerel landings were characterized by the presence of a very large proportion of fish from the 1999 year-class (Figure 11). Up until now, these fish, at ages 1 to 4, have accounted for 63%, 68%, 77% and 75% of the total catch in number for the years 2000, 2001, 2002 and 2003 respectively. Such a predominance of fish ages 1 to 4 has never before been observed among the year-classes sampled since 1973. However, these high percentages may reflect the preponderance of the 1999 year-class throughout the stock.

Table 2. Annual mackerel landings (t) since 1995, by Canadian province.

PROVINCE	YEAR									AVERAGE	
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003***	(1995-2002)	(1990-2002)
Nova Scotia	6 681	5 517	5 669	4 562	4 797	4 546	4 058	3 989	3 738	**4 977**	**6 173**
New Brunswick	2 206	2 683	1 990	1 682	1 373	972	2 199	2 182		**1 911**	**2 045**
Prince Edward Island	2 518	4 017	6 693	6 784	3 842	4 134	5 886	6 181		**5 007**	**4 441**
Quebec	3 382	4 317	5 769	4 066	5 104	1 711	2 904	4 095	4 380	**3 918**	**3 581**
Newfoundland	2 862	3 830	1 188	2 149	1 445	2 019	8 820	17 955	26 295	**5 034**	**5 424**
Not known	0	0	0	91	0	0	0	0		**11**	**7**
TOTAL	**17 650**	**20 364**	**21 309**	**19 334**	**16 561**	**13 382**	**23 867**	**34 402**	**34 413**	**20 859**	**21 672**

* Preliminary data

Table 3. Annual mackerel landings (t) since 1995, by gear type.

GEAR	YEAR									AVERAGE	
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003***	(1995-2002)	(1990-2002)
Trawl	59	68	92	9	12	1	3	5	0	**31**	**453**
Purse seine	2 720	3 607	1 116	1 572	1 348	1 840	8 022	16 907	26 295	**4 641**	**5 270**
Other seine	0	0	9	0	0	0	0	0		**1**	**17**
Gillnet	4 442	6 419	6 657	7 638	5 128	5 294	6 554	5 000	644	**5 892**	**6 300**
Trap	4 719	3 821	3 889	3 999	4 057	3 920	3 148	2 073	3 543	**3 703**	**3 617**
Longline	0	0	0	7	3	3	20	18		**6**	**9**
Handline	899	1 231	3 029	1 998	569	90	160	169	0	**1 018**	**796**
Jigger	3 821	4 705	6 204	3 651	5 435	2 229	5 676	9 839	3 855	**5 195**	**4 898**
Weir	177	0	1	141	8	0	46	48	74	**53**	**58**
Other	812	510	313	320	0	5	237	344		**318**	**253**

* Preliminary data

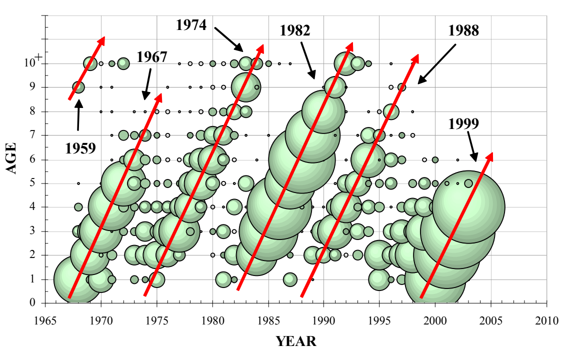

Figure 11. Canadian mackerel catch at age (%) for the period 1968 to 2003 (year-classes that dominated the fishery for several years are identified; age group 10 consists of all fish age 10 and older).

In 2003, the mean length of fish in the 1999 year-class was 348 mm, and their mean weight was 490 g. These fish have been observed for several years in the annual length frequencies derived from sampling of the commercial line fishery in Division 4T and the commercial seine fishery in Division 4R (Figure 12). Furthermore, they can now be seen in the length frequency distributions for the gillnet fishery in Division 4T. Before 2003, this year-class was not present in this fishery owing to the high selectivity of gillnets.

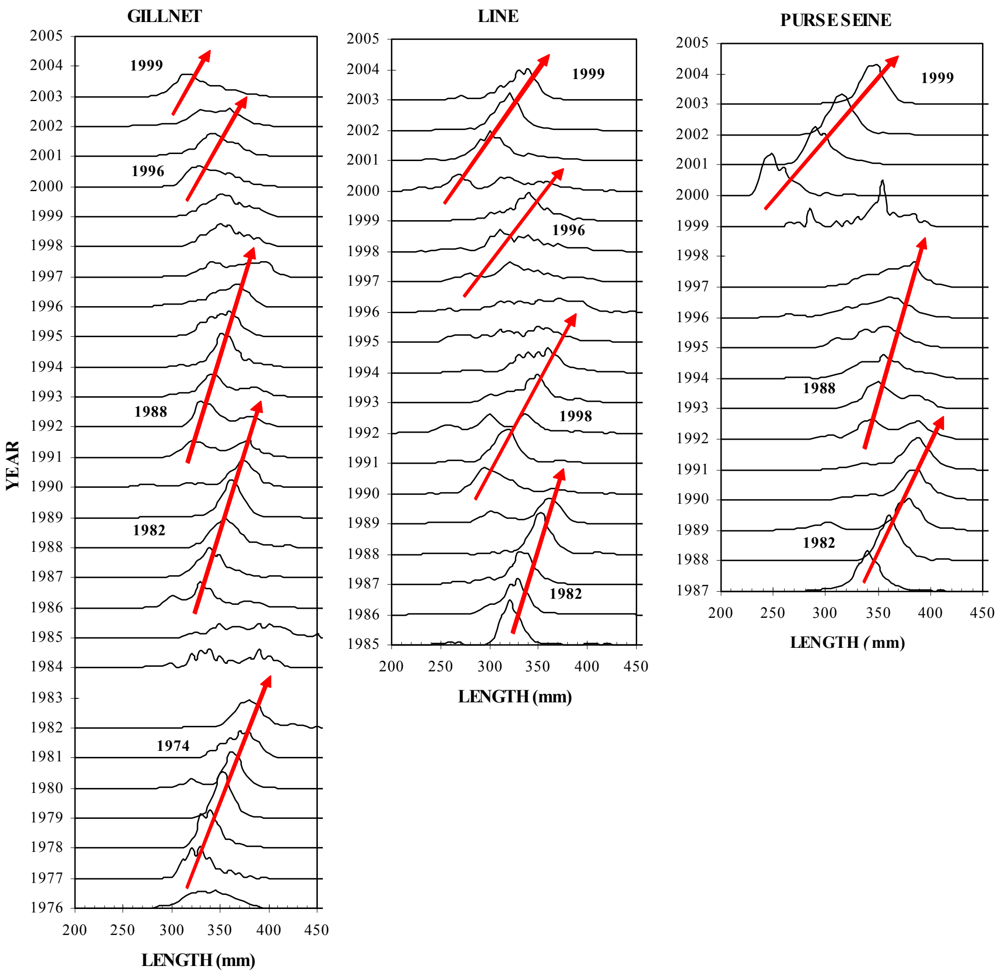

Figure 12. Annual length frequencies (mm) of mackerel caught with gillnets and lines in Division 4T and with purse seines in Division 4R (the year-classes that dominated these fisheries are indicated).

Industry comments

While the comments received from the industry vary from one region or fishing area to another, for the past few years, and particularly in 2003, they have consistently focussed on the high abundance of the 1999 year-class. More and more fishers are also drawing attention to possible links between their catch levels and certain environmental variables such as water temperatures, winds and tides. Some fishers are now using satellite maps of surface water temperatures to locate warm water masses in which they then set their fishing nets. Other comments, made in 2002 and again in 2003, dealt specifically with the following points: (1) the larger numbers of seals found around fishing gear such as gillnets and traps, (2) the presence of very cold water and problems associated with clogging of nets (“slub”), (3) the capture of very small fish with certain types of gear at certain times of the year, (4) the delay in enforcing requirements that all fishers, including bait fishers, keep logbooks, (5) recreational catches that are quite large but not officially recorded, (6) U.S. catches which have been steadily increasing for the past few years, (7) problems related to fishery statistics, particularly the lack of agreement between catches made by local fishers on the east coast of Cape Breton and official DFO statistics for this region, and (8) the absence in recent years of species such as salmon (*Salmo salar*), cod (*Gadus morhua*) and lumpfish (*Cyclopterus lumpus*) in mackerel traps set off Cape Breton. In earlier years, these species were observed regularly in the spring mackerel fishery.

Lastly, comments were received from the west coast of Newfoundland and the Magdalen Islands about the abundance of mackerel in the fall. A number of fishers said it was the first time in many years that they had seen so many mackerel.

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 timing of spawning was deduced from a review of the mean daily values of the gonado-somatic index, which stood at only 5% on June 1, 1999 (day 158 of the year) compared with a mean value of 12% in preceding years (Figure 13). A number of fishers also mentioned that the mackerel had arrived in the Gulf of St. Lawrence earlier in 1999 and left it later than usual.

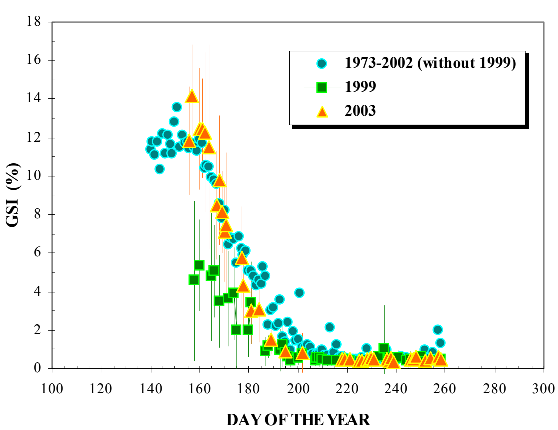

Figure 13. Mean daily gonado-somatic index (GSI) values for 1973-2002 (excluding 1999) and for 1999 and 2003 (vertical bars represent standard deviations).

Egg abundance index

In 2003, the egg survey took place from June 16 to 23, 2003, compared with June 15 to 22, a year earlier. The largest egg concentrations were found very near the coast, at stations located in the southern and southwestern part of the area sampled (Figure 14A). This is the most restricted distribution of eggs ever seen, and the cause appears to be the cold waters that covered much of the southern Gulf of St. Lawrence at the time of the survey (Figure 14B). Very few eggs were sampled north of the 10°C isotherm and none were collected north of the 8°C isotherm.

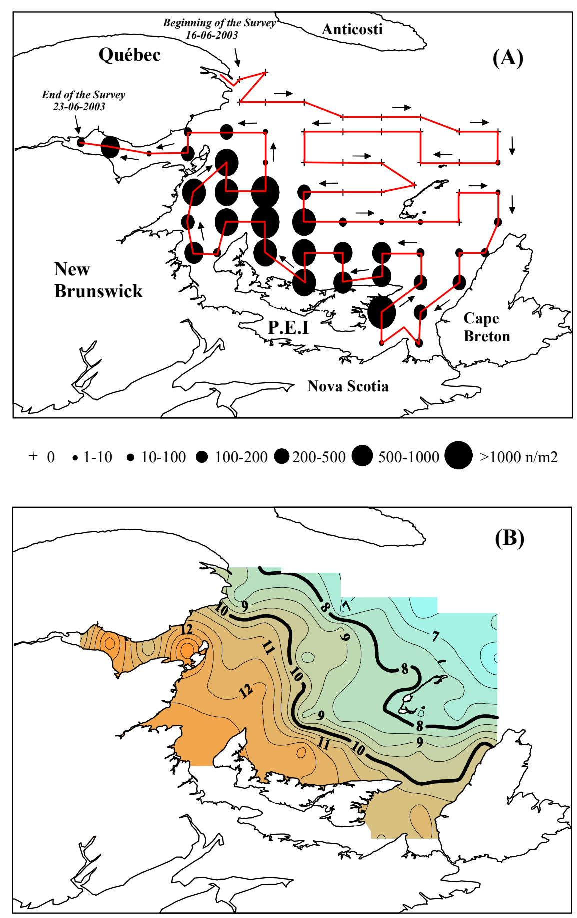

Figure 14. Survey route, distribution of mackerel eggs (number per square metre) (A) and water temperatures (mean 0-10 m) (B) measured during the 2003 survey. Mackerel are known to undertake their annual migrations when water temperatures reach 8°C. Most of the eggs were found in water masses with a temperature of 10°C and over.

Abundance estimate

An increase in daily egg production was measured throughout the area sampled, in comparison with 2002. However, when the daily proportion of egg production during the survey is taken into account, the result obtained actually shows a decrease in spawning biomass in 2003. This decrease would have been even greater had the value of the daily proportion of egg production been estimated using the theoretical density curve, a tool traditionally used in the past (Figure 15). The tool used at present is a curve constructed from the parameters of a logistic model, which describes the decrease in the daily means of the gonado-somatic index during spawning.

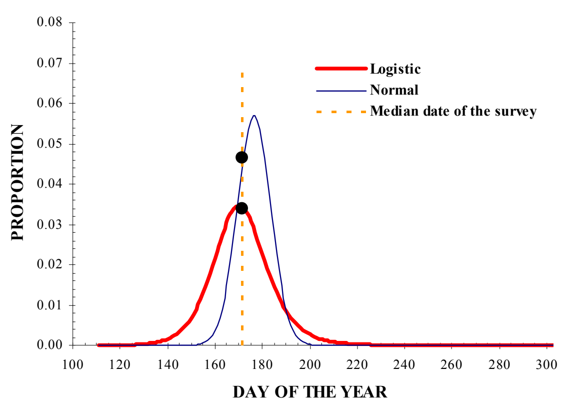

Figure 15. Density curves describing the proportion of daily egg production. The theoretical density curve, traditionally used in the past, has been replaced by a curve constructed from the parameters of a logistic model, which describes the decline in the mean daily GSI values during the spawning season (for each model, circles represent the proportion of eggs produced as at the median date of the survey).

In 2003, the spawning biomass was estimated at 314,752 t by the Total Egg Production Method (TEPM), which corresponds to a decrease of 64,316 t or 17% from 2002 (Figure 16). This drop in the biomass may reflect the abnormally cold water temperatures that prevailed during the survey, rather than an actual decrease in abundance. The largest egg densities were found only in areas of warmer water, which are more favourable for spawning, near the coast of Prince Edward Island and New Brunswick. This is an unusual situation which may have caused an underestimation of actual egg production.

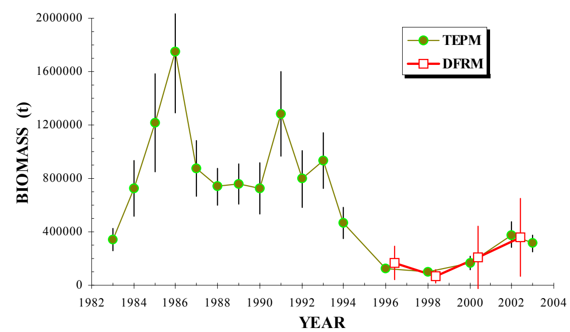

Figure 16. Spawning biomass (t) of mackerel calculated by two different methods (TEPM: Total Egg Production Method; DFRM: Daily Fecundity Reduction Method).

A sharp decrease in water temperature was recorded in the upper portion (30-100 m) of the cold intermediate layer (CIL) in 2003. The lower water temperature appears to be implicated in the drop in the plankton abundance index, which is derived during the egg survey. The interannual variations in this index are quite similar to those of water temperature in the CIL (Figure 17A). Surprisingly, the three abundant year-classes (1982, 1988 and 1999) recorded most recently for mackerel occurred in years when the CIL and the plankton index values were highest (Figure 17B).

Outlook

According to the results of the egg survey, the spawning biomass of mackerel hit a record low level in 1998. The increase in abundance estimated in 2002 is essentially attributable to fish in the 1999 year-class. An increase in abundance had been forecast for 2003 as well, given the predominance of this year-class in catches and the fact that nearly all the fish in the

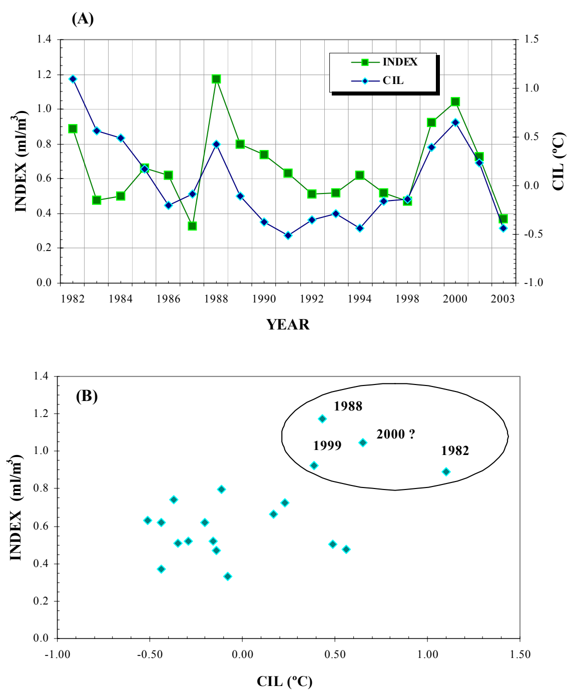

Figure 17. Interannual variations in the plankton abundance index (ml/m^3) calculated by kriging and in water temperatures in the upper portion (30 to 100 m) of the cold intermediate layer or CIL (preliminary data for 2003) (Denis Gilbert, MLI, Mont-Joli, pers. comm.) (A). Year-classes (1982, 1988 and 1999) that have dominated the fishery in past years are associated with the highest values for the CIL and the plankton index (B).

year-class were mature in 2003. The lower abundance measured in 2003 may be attributable to the presence of this year-class alone in the population and/or to the unusual oceanographic conditions encountered during the survey. In view of these factors of uncertainty, we recommend that the TAC be maintained at 75,000 t in 2004.

Sources of uncertainty

The mackerel that are caught for bait do not appear in the Department's official statistics, which are based on purchase slips from sales to processing plants. Recreational fishing for mackerel, which is very popular in summer, does not give rise to recorded statistics either. Since these activities are carried out in many parts of the Maritimes, Newfoundland and Quebec, the actual total catch of mackerel is thus greatly underestimated.

Management considerations

To improve the collection of statistics on the fishery in the Gulf of St. Lawrence, a mandatory logbook should be distributed to all mackerel fishers, including those who use mackerel as bait. The use of logbooks would also provide better information on the location of the fish, 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 weigh the mackerel and enter the catch data at dockside, as is currently done in Nova Scotia. However, at least for some regions of the province, this system appears to present major deficiencies since the official statistics are much lower than the catch figures reported by fishers.

Recreational catches are a significant part of the overall picture, considering that this fishing is carried out by a large number of fishers, including tourists, all along the Atlantic coast. With a view to managing this activity in future and improving the catch statistics as a whole, some thought should be given soon to ways of estimating these catches. Note that the United States produces annual estimates of recreational catches of mackerel. Finally, taking into account these catches, those made by bait fishers, which are also not recorded, and the problems mentioned above with the current fishery statistics system, actual mackerel landings may be closer to the TAC of 75,000 t than currently estimated.

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