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DFO Science

Laurentian Region

Stock Status Report B4-04 (2000)

Atlantic Mackerel of the Northwest Atlantic

Background

In the northwest Atlantic, mackerel (<u>Scomber scombrus</u> L.) occur from Cape Hatteras, off North Carolina, to the Gulf of St. Lawrence and the east coast of Newfoundland (Figure 1). There are two groups or spawning stocks of mackerel in that region, each with its own spawning area. The southern stock spawns in March and April along the New Jersey coast. Although part of the northern stock spawns along the coast of Nova Scotia and possibly on the Grand Banks of Newfoundland, the northern stock spawns mainly in the Gulf of St. Lawrence in June and July. Spawning takes place each year after a long migration that begins some months earlier in the Georges Bank area.

There are more than 15,000 mackerel fishermen in the Maritimes and Quebec. It is chiefly an inshore fishery, and the most commonly used types of gear are gillnets, purse seines, handlines and traps, in decreasing order of importance. Their utilisation depends on the area and time of year.

Overall, Canadian landings are stable from year to year, averaging about 22,000 t annually since 1990. Regionally, however, there are major variations, as migration routes change, while fishing grounds remain the same. Changes in migration patterns are caused mainly by mackerel's sensitivity to certain environmental conditions, particularly water temperature.

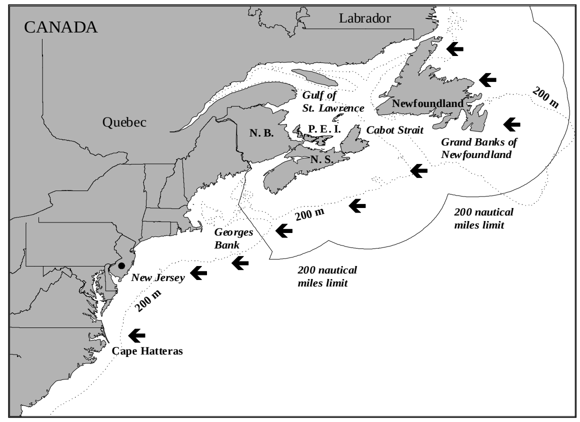


Figure 1. Distribution (🡐) of Atlantic mackerel (<u>Scomber scombrus</u> L.) in the northwest Atlantic.

Summary

- In 1999, mackerel were especially abundant along certain Canadian coasts. Landings failed to reflect this abundance, however, as a number of fish plants set daily quotas because they had few buyers.
- A review of the gonadosomatic index (GSI) reveals that in 1998 and 1999, spawning took place earlier than usual. The spawning activities were completed by the end of June, rather than late July, as in other years.
- No dominant year-class has been observed recently in commercial catches, the last one was that of 1988. Examination of annual length frequencies indicates that the 1996 year-class may be a strong one. Its true strength will be confirmed in 2000, when the fish that compose it are fully recruited to the fishery.
- According to the 1998 egg abundance survey, the spawning biomass of the Gulf of St. Lawrence mackerel was about 300,000 t. This estimate is slightly higher than the value calculated in 1996, but is still below those of recent years.

- The low abundance measured by the 1996 and 1998 surveys could be due to the lack of any dominant year-classes for several years. As the timing of the surveys did not coincide with the spawning period, however, true abundance may have been underestimated.
- The **D**aily **F**ecundity **R**eduction **M**ethod (**DFRM**) was employed to calculate mackerel biomass. This method can correct the lack of synchronism between the spawn and the survey. According to the DFRM, spawning biomass was 498,336 t in 1996 and 774,306 t in 1998, as opposed to 183,346 t and 287,168 t using the conventional method.
- **S**equential **P**opulation **A**nalysis (**SPA**) was performed using Canadian catch at age and spawning biomass from the egg survey. Preliminary SPA results suggest that methods of analysing the egg survey data significantly overestimate the true size of the stock.
- In light of these findings and the basic principles of the precautionary approach, it no longer appears advisable to maintain a Canadian TAC of 100,000 t.

Main Attributes of the Stock

ATTRIBUTE	RECENT TREND	CURRENT SITUATION
Condition Factor (June)	Above 1973–98 mean prior to 1985 and below it 1985–98.	1999 value again above mean.
Gonadosomatic Index (GSI)	Between 1973 and 1997, a peak of about 12% was reached around June 1 and spawning was over (GSI = 1%) near the end of July.	In 1998, spawning earlier than usual. In 1999, on June 1, a maximum GSI of about 4% and spawning over by the end of June.
Weight and Length at Age	Below 1973–98 mean in the 1970s and above it in the 1980s. Growth of year-classes is inversely proportional to their abundance.	Below average in the 1990s. Slow growth seen in year-classes from late 1990s.
Annual Length Frequencies	A principal mode that shifts through the years and is associated with the dominant year-classes.	Lack of such a mode throughout the 1990s.
Gear Selectivity	Mode corresponding to dominant year-classes appears earlier in length frequencies associated with handline catches.	In 1990, as in 1998, such a mode was found in length frequencies of handline catches, and appeared to correspond, in 1998, to the 1996 year-class.
Dominant Year-Classes	Last dominant year-classes were those of 1959, 1967, 1969, 1974, 1982 and 1988.	The true size of the 1996 year-class will be confirmed next year when it is fully recruited to the fishery.
Egg Survey	Spawning biomass increased between 1983 and 1988 before shrinking and stabilizing between 1990 and 1994. Fluctuations in total biomass associated with the arrival of dominant year-classes and their entry into the population. In the 1980s and until 1994, high egg concentrations were found in the middle of the Gulf of St. Lawrence.	Values obtained in 1996 and 1998 are lowest in the series, i.e., on the same order as that for 1983. The lower abundance seen recently may be due to the lack of strong recruitment and the possibility that the survey may not have coincided with the spawning period. In 1996 and 1998, high egg concentrations were found further south, near the southwest tip of the Magdalen Islands.

Biology

The Atlantic mackerel (*Scomber scombrus* L.) is a member of the family Scombridae, which is distributed widely throughout tropical and temperate waters the world over and includes a large number of species, the best known of which are tunas. Unlike tunas, however, the Atlantic mackerel's body temperature does not remain constant, but varies between 1 and 2°C above the surrounding water temperature. The species does not have a swim bladder, so it must swim continually. This feature enables it to change depth rapidly. On its long annual migrations, mackerel sometimes travel in very dense schools, especially in spring and fall. The schools tend to be composed of identical-sized individuals that swim at the same speed.

Although spawning does occur along the coasts of Nova Scotia and possibly on the Grand Banks of Newfoundland, the northern stock spawns mainly in the Gulf of St. Lawrence in June and July. The highest egg concentrations are always found south of the Laurentian Channel and west of the Magdalen Islands. Mackerel are called multiple spawners because each female spawns several times during the spawning season. Spawning takes place at any time during the day or night. Egg development time depends on water temperature. Larvae measure about 3 mm long upon hatching. At 50 mm in length, young mackerel become juveniles and begin to form schools. Some of these schools are found in inshore waters, possibly due to the migration of juveniles from spawning areas toward the coast. Little is known about the size of the juvenile contingent that participates in this migration or the importance of coastal habitats for juveniles. Although mackerel feed primarily on plankton, the adult diet includes small fish and squid. Mackerel grow very quickly, measuring more than 270 mm long and weighting over 200 g by the end of the first year (Figure 2).

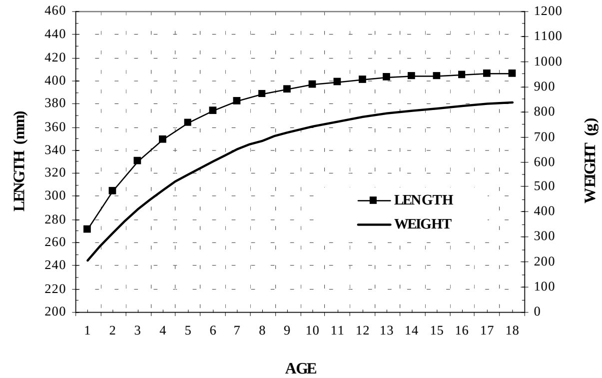


Figure 2. Length (mm) and weight (g) at age (modelled) of Atlantic mackerel sampled in Canadian coastal waters since 1990.

Most growth takes place in the first few years, with females growing more rapidly than males after the age of four. Atlantic mackerel may live for more than 15 years, but rarely exceed 450 mm in length. Fish from dominant year-classes grow more slowly (Figure 3).

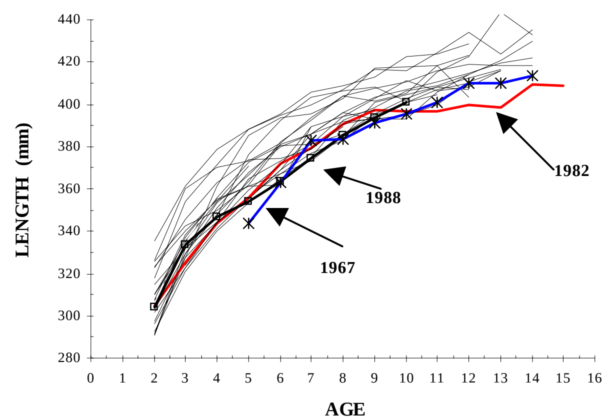


Figure 3. Mean length (mm) at age for year-classes of mackerel sampled in Canadian coastal waters. Arrows indicate three of the largest year-classes to have dominated the fishery since the late 1960s.

The condition of mackerel is at its lowest in early spring, just before and during spawning, while peak values are observed in fall. Up until and including 1984, the condition of mackerel on arrival in the Gulf was above the mean for 1973 to 1998 (Figure 4), but it fell below that mean between 1985 and 1998, a time when the Gulf water was cooling down. In 1999, it once again rose above the mean.

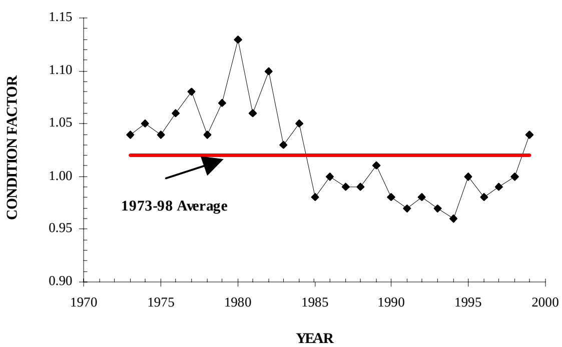


Figure 4. Mean annual condition factor (Fulton) calculated in June, during spawning which follows the arrival of mackerel in the Gulf of St. Lawrence.

Fat content is also lowest during spawning — about 5% — rising gradually thereafter to 20% or more in the fall. Year-to-year variations occur in fat content, along with variations in length and weight.

Sexual maturation is fast, and 50% of females are sexually mature at 299 mm; for males it is 270 mm (Figure 5). All mackerel reach maturity by the time they are 340 mm long. Nearly half of two-year-old mackerel and all mackerel aged four and over are sexually mature. Size rather than age is the determining factor. For example, all fish in abundant year-classes like those of 1959 and 1967, in which growth was slower, reached maturity at age five and a length of 330 mm.

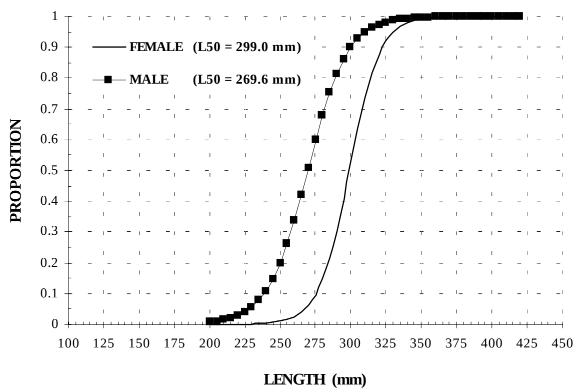


Figure 5. Maturity at length of mackerel sampled in St. Margaret's Bay, NS, 1996. L50 is the length at which 50% of fish are sexually mature.

Fishery

General

Landings of mackerel in the northwest Atlantic, which ranged from 300,000 t to 400,000 t in the early 1970s (Figure 6), declined sharply when the 200-mile limit was set. As a result of agreements with the

Table 1. Annual mackerel landings (t), by province, since 1990.

PROVINCE	YEAR										Average
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999***	(1990-1998)
Nova Scotia	9 182	8 115	8 831	7 144	7 792	6 681	5 517	5 669	4 562	3 071	**7 055**
New Brunswick	3 614	2 137	1 748	1 989	1 879	2 206	2 683	1 990	1 682	271	**2 214**
Prince Edward Island	2 458	3 922	2 299	4 580	4 441	2 518	4 017	6 693	6 784	2 431	**4 190**
Quebec	1 971	3 256	3 480	3 175	3 529	3 382	4 317	5 769	4 066	4 994	**3 661**
Newfoundland	4 041	8 341	6 915	9 343	2 775	2 862	3 830	1 188	2 149	1 030	**4 605**
Not determinated									91		**10**
TOTAL	**21 266**	**25 771**	**23 273**	**26 232**	**20 417**	**17 650**	**20 364**	**21 309**	**19 334**	**11 797**	**21 735**

* Preliminary

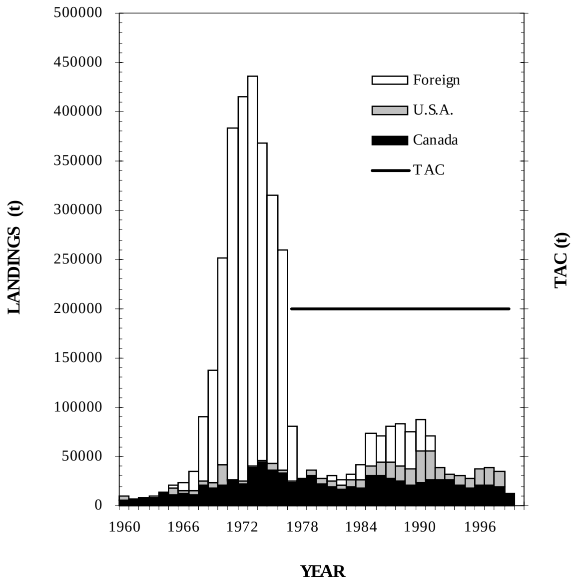


Figure 6. Annual mackerel landings (t) and proposed TAC for the entire northwest Atlantic.

United States and the Commonwealth of Independent States, catches considerably increased in the early 1980s, peaking at nearly 90,000 t in 1988. A gradual reduction in quotas set by the U.S., ending with the complete closure of this fishery in 1992, explains the major reduction in landings that occurred later.

Canadian Landings

Mackerel landings in Canadian waters are generally stable from year to year, averaging about 22,000 t in recent years (Table 1). Nova Scotia and Newfoundland are the Atlantic provinces with the highest mean landings. On a smaller geographic scale, for example statistical district or fishing community, landings may fluctuate significantly from one year to the next. The fluctuations are due to great variability in seasonal migration patterns, although fishing grounds usually remain the same.

The most commonly used types of gear in Canada are gillnets and handlines, which account for mean landings of 6,735 t and 4,394 t respectively (Table 2). Gillnets are used mostly in spring and handlines in fall. Traps are also important, accounting for mean annual landings of 3,436 t. They are used chiefly in spring in Nova Scotia. Fall catches by purse seiners on the west coast of Newfoundland are also significant. The success of this fishery is strongly dependent on environmental conditions, including water temperature and prevailing winds.

Table 2. Annual mackerel landings (t) for main fishing gear used on the east coast of Canada.

FISHING GEAR	YEAR										Average
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999***	(1990-1998)
Trawl	2 616	977	2 050	605	0	59	68	92	9	0	**720**
Purse Seine	3 707	8 453	6 798	9 556	3 229	2 720	3 607	1 116	1 572	1 030	**4 529**
Other seines	150	17	50	234	0	0	0	9	0	0	**51**
Gillnet	7 933	7 284	5 646	8 276	6 322	4 442	6 420	6 657	7 637	3 523	**6 735**
Trap	1 877	2 907	4 327	31	5 356	4 719	3 821	3 889	3 999	2 815	**3 436**
Longline	16	1	28	402	0	0	0	0	7	0	**50**
Jigger	472	448	544	4 144	338	899	1 231	3 029	1 998	36	**1 456**
Handline	4 427	5 679	3 550	2 985	4 523	3 821	4 705	6 204	3 651	4 395	**4 394**
Others	68	4	280	4	648	989	510	314	461	0	**364**

* Preliminary

Characteristics of the catches

The demographic structure of the mackerel population is characterized by the periodic arrival of a dominant year-class. Its development can be followed by examining catch at age or annual length frequency distributions. In the latter case, each of the dominant classes is clearly associated with a principal mode, which gradually shifts over the years to larger sizes. This is the case, for example, of the dominant year-classes of 1974, 1982 and 1988 (Figure 7).

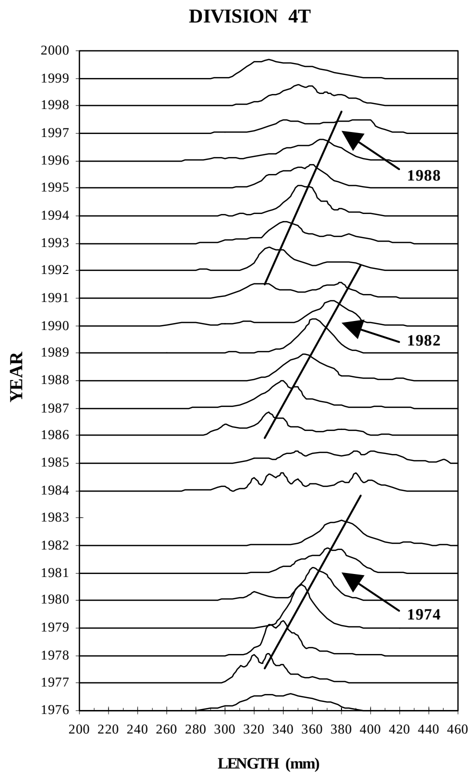


Figure 7. Annual length frequency distributions of mackerel caught by gillnet in the Gulf of St. Lawrence (Division 4T). Strong year-classes that dominated the fishery are shown.

When a year-class dominates the fishery, the size of the catch does not vary much with the type of gear used. In other words, all gears catch mackerel of the same size (Figures 8A and 8D). However, the length frequencies found in catches from less-selective gear, such as handlines, help identify the appearance of a dominant year-class earlier than the length frequencies from catches of highly selective gear such as gillnets (Figures 8B and 8C).

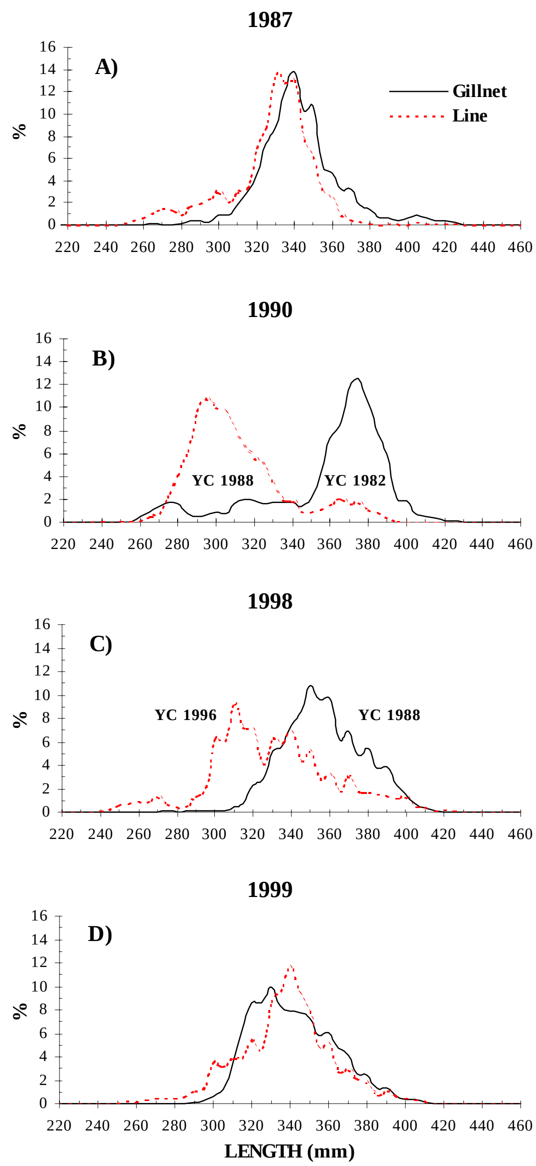


Figure 8. Annual length frequency distributions of mackerel caught by gillnet and handlines in the Gulf of St. Lawrence (Division 4T), for 1987, 1990, 1998 and 1999 (YC means year-class. In A and D, the fishery is characterized by a dominant year-class or several classes of equal size. In B and C, the arrival of a dominant year-class is seen earlier in length frequencies from handline catches).

Highlights of 1998 and 1999 Seasons

Examination of satellite maps and thermograph data from some index fishermen (Figure 9) shows that the surface water was warmer in 1998 and 1999 than in the preceding years. These conditions seem to be associated with the presence of a greater number of mackerel near some coasts, and also their earlier arrival in the Gulf of St. Lawrence. The 1999 fishing season was even opened earlier than the usual June 1.

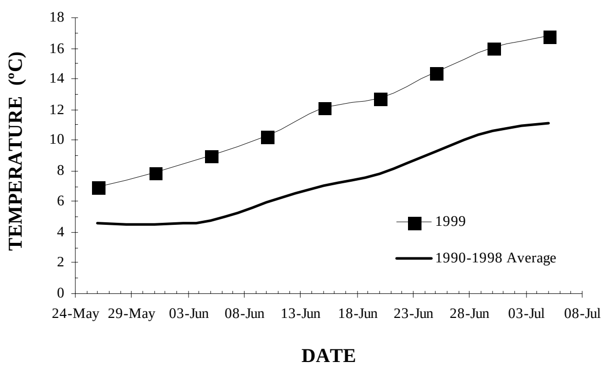


Figure 9. Mean water temperatures (ºC) recorded by the thermographs of a Cape Breton index fisherman. Thermographs are located about 10 m below the surface.

An examination of mean daily gonadosomatic index values shows that spawning took place earlier than expected in 1998 and 1999 (Figure 10). Between 1973 and 1997, the maximum GSI value, which is about 12%, was reached on June 1, and spawning ended in late July, when the GSI value dropped to about 1%. In 1998, the GSI had reached its peak of 12% by May 20, but at June 1, 1999, it was only 4 % (Figure 10). Furthermore, in the last two years, spawning has been all over by the end of June. In 1999, spawning occurred so early that feeding and growth began earlier than expected, as confirmed by a growth zone on the edge of the otoliths as early as June. The growth zone for the current year does not usually start to be deposited until the end of July.

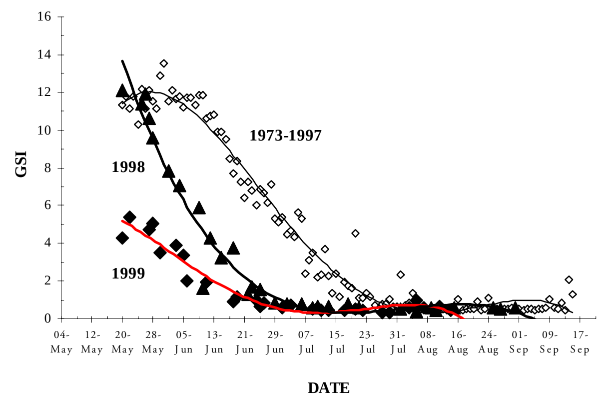


Figure 10. Mean daily gonadosomatic index (GSI) values, 1973–99. Polynomial curves are adjusted to fit the data.

Industry Comments

A great many fishermen commented in 1999 on the increased numbers of mackerel along some coasts or in particular spots and on the shortage of buyers. A number of plants actually had to set daily quotas, which was very frustrating to the fishermen, given the abundance of the resource.

Others expressed their concern on the following points: (1) fishing activities in American waters, (2) spring fishing on the Bradelle Bank, (3) the abundance of mackerel in certain places only, but not throughout the Gulf, (4) the great number of seals near fishing gear, (5) the danger of overfishing the resource, (6) a TAC of 100,000 t that seems too high, and (7) the obvious lack of financial resources to run joint projects with DFO.

Questionnaires were sent to fishermen in Nova Scotia and the Magdalen Islands over the last two years. Preliminary analysis has been done, and in 2000, more questionnaires will be sent to another group of fishermen. The Index Fishermen Program is continuing, thanks to a number of volunteers from several different regions.

Resource Status

The abundance of mackerel that spawn in the Gulf of St. Lawrence is calculated on the basis of a biennial egg survey. Samples are taken twice with plankton nets at stations set up in a regular grid pattern. Egg densities found are used to compute daily production. Until recently, this was done using the same statistical model as for bottom trawl surveys. Now, densities are calculated with the geostatistical method that takes into account spatial distribution of eggs and thus gives more accurate estimates. Daily production figures are used to calculate total or annual egg production, from which spawning biomass is calculated.

1998 Survey

During the most recent abundance survey, in June 1998, the highest concentrations of mackerel eggs were found west of the Magdalen Islands (Figure 11A). Surface water temperatures were also highest in this area. Egg densities observed in the survey were higher than those found in 1996. Furthermore, the area with very high egg concentrations, determined by kriging, shifted from the middle of the Gulf, where it had been from 1983 to 1994 (Figure 11B), to the southwest tip of the Magdalen Islands in 1996 and 1998 (Figure 11C).

For the two 1998 survey passes, spawning biomass estimates were 344,394 t and 239,942 t, for a mean of 287,168 t. This is up from 1996 (183,346 t), but is still below the values calculated for prior years (Figure 12).

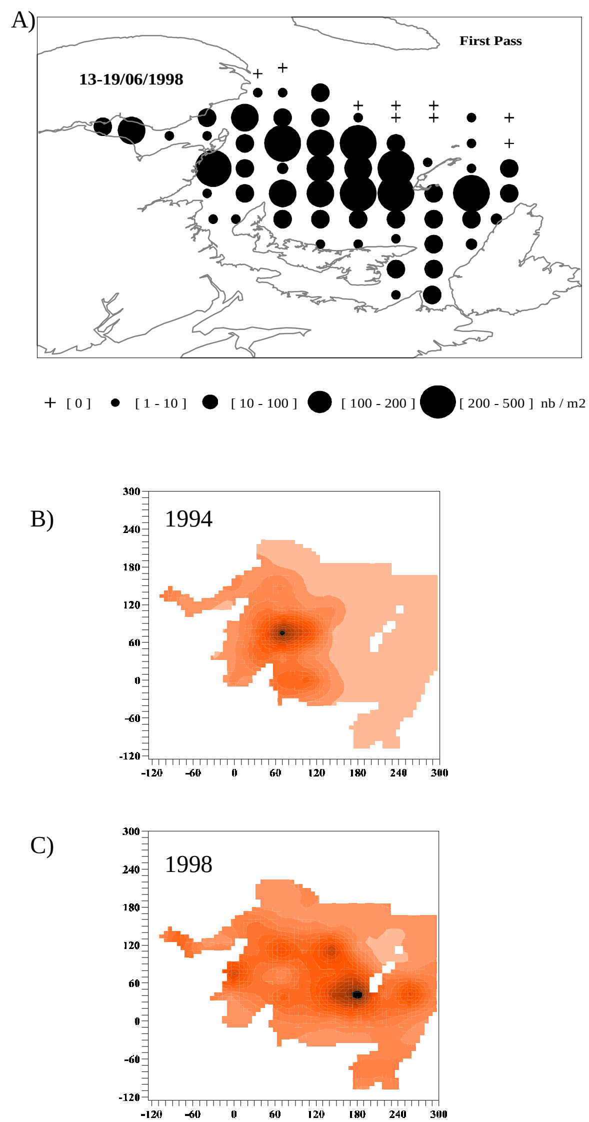
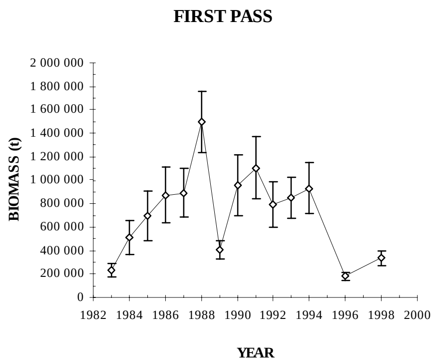


Figure 11. Distribution of mackerel eggs (number per square metre) (A) and surface kriged on first pass of 1994 (B) and 1998 (C) surveys. The area with very high egg concentrations shifted during this time from the middle of the Gulf to the southwestern tip of the Magdalen Islands.



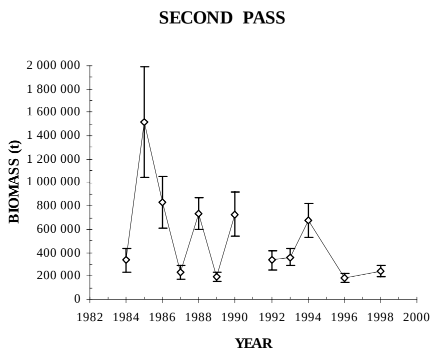


Figure 12. Spawning biomass (t) of mackerel in the Gulf of St. Lawrence, based on total or annual egg production.

Daily Fecundity Reduction Method

The model used to calculate spawning biomass from annual egg production is sensitive to mistiming between the survey and spawning. This problem could be avoided by a series of surveys covering the entire spawning period, as is done in Europe for the same species.

The **D**aily **F**ecundity **R**eduction **M**ethod (**DFRM**) was devised to address this type of problem, seen especially in 1989 and in the last two surveys. The DFRM makes it possible to calculate spawning biomass based on daily rather than annual egg production, taking into consideration the seasonal decline in female reproductive potential. This decline is measured on the basis of the seasonal decrease in the number of vitellogenic oocytes or mature eggs and the number of females with active ovaries.

With this method, mean spawning biomass for 1996 and 1998 would be 498,336 t and 774,306 t, respectively. These values are higher than those calculated using the conventional method (183,346 t and 287,168 t), which are actually underestimated, probably due to the lack of synchronism between the spawn and the corresponding surveys. As some years the timing is better and some it is worse, we cannot yet directly compare the two methods. To maintain a time series of biomass estimates, both methods will be used again in 2000.

Catch Rates

Catches per unit of effort (**CPUE**), or catch rates, vary greatly with locality and from year to year. These fluctuations are related much more to mackerel distribution and fishing power than to actual variations in the size of the stock. Therefore, CPUE is not used as an abundance index for mackerel.

Analytical assessment

Biomass estimates by the **S**equential **P**opulation **A**nalysis (**SPA**) were highly correlated with biomass values determined by the survey. This relation means that there is not necessarily a major contradiction between data from the egg survey and catch at age data. The slope of the relation also indicates that the survey seems to overestimate significantly the real biomass of the stock, which may also happen with the conventional calculation method.

For mackerel, SPA results can be useful in determining reference points and setting management objectives when (1) the **D**aily **F**ecundity **R**eduction **M**ethod receives final approval and the biomass series calculated using this new method will be longer, and/or (2) biomass calculated according to the conventional method can be corrected to account for the poor timing of some surveys with regard to spawning.

Outlook

Currently, the mackerel stock in Canadian waters can certainly support greater fishing pressure. However, the results of the analytical assessment suggest that spawning biomass could be overestimated. What is more, due to the lack of strong recruitment in the last few years, maintaining a Canadian **TAC** of 100,000 t may no longer be advisable. In fact, the current situation is quite different from that of the 1970s, when very strong year-classes made it possible to maintain catches of several hundred thousand tonnes of mackerel for a number of years running.

Sources of Uncertainty

Catches of mackerel used as bait do not appear in the DFO's official statistics, which are based on processing plant purchase receipts. Recreational fishing, which is very popular in summer, is not counted either. As these activities are common in several parts of the Maritimes and Quebec, real mackerel catches may well be underestimated.

All fishing areas are not always covered systematically by the DFO's commercial sampling program. As a result, data gathered and used as the basis for evaluating abundance and monitoring the population may not reflect the real situation accurately.

Management Considerations

To improve fishery statistics, a mandatory logbook should be distributed to all fishermen, including bait fishermen with mackerel licences. The logbooks would also help to determine where fish are, which would greatly facilitate the study of relationships between mackerel distribution and certain environmental variables.

Recreational mackerel catches are probably high, considering that many fishermen (tourists) fish for mackerel all along the Atlantic coast. With an eye to future management of this activity, and in order to improve the validity of fishery statistics, we should soon start thinking about how to estimate these catches.

Reference:

Grégoire, F. (Ed.). 2000. The Atlantic Mackerel (*Scomber scombrus* L.) of the NAFO subareas 2 to 6. Canadian Stock Assessment Secretariat. Res. Doc. 2000/021 (12 chapters).

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