Northwest Atlantic Fisheries Organization

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SCIENTIFIC COUNCIL MEETING - JUNE 1988

Report of the 1987 Ad Hoc Working Group for the Assessment of the Cod Stock in Subdivision 3Ps

by

Anon.

1. Opening - appointment of rapporteurs - adoption of agenda - plan of work

The Working Group met at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada during May 28-30, 1987 to consider the status of the cod stock in Subdivision 3Ps and matters related to its assessment. The agenda comprises Appendix 1.

Scientists from Canada and France attended the meeting and Mr. W.R. Bowering acted as Chairman. The list of participants comprises Appendix 2.

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2. Stock Definition (Doc. 1, 2, 3)

Recent information with respect to the relationships between cod in Subdiv. 3Ps and adjacent areas was examined.

2.1. Tagging

From a total of 3,190 cod tagged in March 1986 on Burgeo Bank (Fig. 1) in the northwest part of Subdiv. 3Ps (Fig. 2), there were 210 returns in the spring, summer and autumn of 1986. Forty percent of these returns came from Subdiv. 3Ps and 49% from Subdiv. 3Pn and Divisions 4RS. During the winter of 1987 most of the recaptures were from Subdiv. 3Pn, Burgeo Bank in Subdiv. 3Ps and St. George's Bay in Div. 4R.

During March 1986, 1,923 cod were tagged on the southeast slope of St. Pierre Bank. Of the 29 returns in 1986, 55% were from the tagging area and most of the remainder were reported from the neighbouring Grand Bank to the east. In the winter of 1987, most of the returns came from near the tagging area and along the southwest slope of the Grand Bank.

In March 1986, 1,341 cod were also tagged on the southern slope of Green Bank (strata 325 and 326 of the survey scheme, Fig. 3). Thirty-three percent of the 39 returns in 1986 were from the tagging area and 54% from the shallow part of the Grand Bank. In the winter of 1987, most of the recaptures reported were from the tagging area or along the southwestern slope of the Grand Bank.

In October 1980 and 1982, 2,471 cod were tagged in the shallow part of St. Pierre Bank in the area between 45°30'N-45°45'N and 55°30'W-56°00'W. Up to November 1986, 85% of the returns were from Subdiv. 3Ps, and the remainder of the returns were mainly from the Green Bank. Recaptures in the fourth quarter (October-December) were mainly near the tagging area.

The Working Group notes that the tagging results reviewed here do not take into account the influence of the different levels of fishing effort in the areas from which recaptures were reported. Further, it is not clear if the cod tagged at specific sites were representative of cod spawning in Subdiv. 3Ps or of cod spawning in other areas but present in Subdiv. 3Ps at that time.

In general, the recent tagging studies indicate that in winter cod in the northwest part of Subdiv. 3Ps include a portion of cod from the Gulf of St. Lawrence. In winter, also, cod in the south and southeast of the Subdivision include a portion of cod from the Grand Bank. These mixtures may be substantial but cannot be precisely quantified from the present data. Cod tagged in the autumn toward the centre of the Bank were recaptured mostly within the Subdivision.

2.2. Meristics

A sample of about 100 specimens was taken in winter 1987 from each of 3 areas (Rose Blanche bank in Subdiv. 3Pn, Burgeo Bank in the northwest of Subdiv. 3Ps and northern St. Pierre Bank). Two of the 6 meristic characters examined, mean number of rays in the second anal fin and mean number of vertebrae, indicated a significant difference between areas. The conclusion was that cod sampled from Burgeo Bank were different from the other two areas, but no evidence to support the proposition that cod from Rose Blanche and the northern part of St. Pierre Bank were different.

The Working Group notes that further analysis of such data including year-class differences would be helpful.

2.3. Nematodes as biological tags

The incidence of nematode worms in the fillets and napes (belly flaps) of the same samples of cod described under the meristics section, show an increasing prevalance of infestation from St. Pierre Bank to Rose Blanche Bank, with the Burgeo Bank nematode prevalence being intermediate. In all areas cod of ages 7 years and older were more heavily infested than those of age 3-6. The pattern of infestation is not inconsistent with the presence on Burgeo Bank of a mixture of cod from the Gulf of St. Lawrence and from St. Pierre Bank.

2.4. Growth

Age and growth information derived from independent samples taken from Burgeo Bank and St. Pierre Bank in 1986, and between those areas and Rose Blanche Bank in 1987 clearly indicated that the length-at-age pattern of cod on Burgeo Bank was intermediate between that of Rose Blanche Bank (Subdiv. 3Pn) and St. Pierre Bank (Subdiv. 3Ps).

2.5. Maturity at length

Values of the length at which 50% of cod were mature (males and females combined) were available for the period 1978-87 and showed that cod on Burgeo Bank matured at a smaller size than those of St. Pierre Bank except for 1979 when the values were similar. In 1986 the steep decline in the length at 50% maturity in the cod sample from Burgeo Bank may have implied a larger than usual influx of cod from the Gulf of St. Lawrence.

2.6. Conclusions

From the new material available and from consideration of previous studies, it would appear that cod in Subdiv. 3Ps comprise a stock. At the peripheries of the stock, in the northwest at Burgeo Bank and in the south and southeast parts of St. Pierre Bank, for example, there are clearly inter-relationships with other stocks. The extent of mixing cannot be defined precisely with present data. The imprecise nature of the boundary of this stock is not uncommon for cod stocks or, for stocks of other species.

3. Assessment of Cod Stock in Subdivision 3Ps

3.1. Fisheries (Doc. 1, 4, 7)

In the period, 1959-86, catches from the Subdiv. 3Ps have ranged from 84,000 t in 1961 to 27,000 t in 1978 (Table 1, Fig. 4). Up to 1976 fishing was dominated by Canada and Spain. The Canadian contribution was mainly due to inshore fleets fishing with cod-traps, gillnets, handlines and linetrawls (or longline) pratically all the year round but with higher catches in summer. Its overall catch averaged 25,500 t during this period. The highest catch of the Canadian offshore fleet was 8,700 t in 1971 but catches fluctuated generally between 2,000 and 4,000 t.

The Spanish fleet fishing in the area was composed of single and pair bottom trawlers but between 1964 and 1976 the latter accounted for the bulk of the catch. The fishing season extended usually from September to April but good catches also were made occasionally in May or August.

The other nations fishing in Subdiv. 3Ps were France, Portugal, UK, and the USSR. The catches of the latter appeared in the mid-sixties and reached a peak in 1968 with 15,500 t but declined afterwards to 2,000 to 4,000 t.

Since 1977 only Canada and France have prosecuted the fishery. In recent years catch restrictions have limited the offshore activities of the Canadian fleet, the catch of which averaged 2,400 t from 1977 to 1984. As a result of increased allocations, Canadian offshore catches rose in 1985 and 1986 to about 4,000 and 5,000 t. Inshore fleets, especially those fishing with cod-traps and gillnets have also increased their catch from 1982.

The French catches are recorded separately for the long distance freezer freezer fleet (metropolitan component) and for the Saint Pierre based fleets which land in the island. The SPM fleet is composed of medium size trawlers and of inshore boats fishing with handline between May and September. The French inshore catch decreased from about 3,500 t in early sixties to less than 400 t in 1986. During the same period the offshore fleet developed and its catch reached 14,000 t in 1986. In the most recent period this fleet fish almost all the year round but with decreased activity between June and September. The fishing season of the distant fleet (M) is concentrated between October to May; its recorded catches increased regularly from 1,500 t in 1976 to 12,000 t in 1986.

Two series of TACs are set separately by Canada and the EEC or France both including a share between Canada and France. Catches and TACs (000 t)

for the period 1976-1985 were as follows:

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Advised TAC	47.5	32.5	25	25	28	30	33	33	33	41
Effective TAC	47.5	32.5	25	25	28	39	33	33[2]	35.8[2]	44.6[2]
Catch	37	32	27	33	38	39	34	38	37	51[1]

[1] Provisional data.
[2] Effective TAC is obtained by combining the Canadian portion (as established by Canada) of the advised TAC with the EEC recommended catch as given in EEC regulations.

3.2. Commercial Catch and Fishing Effort (Doc. 1, 6, 7)

Catch and effort (hours fished) data for Canada, France (SPM) Portugal, and Spain were available from ICNAF/NAFO Statistical Bulletins for the period 1959-84 with the exception of certain years for France (SPM). Data were also available for the French fleet for 1980 and 1983-86 and for Canada for 1985-86. Analyses using the multiplicative model were completed for two time periods, 1959-86 and 1977-86. The latter period was done separately to determine if the changes in the fishery since 1976, namely the reduction of catch and the exclusion of participants other than Canada and France, had resulted in a change in the pattern of catch rates.

Both series indicated strong seasonal trends with catch rates being highest in the winter months. Each series showed an increase from 1980-85 and a substantial decrease in 1986 (Fig. 5 & 6).

Catch rates by the France (metropolitan) fleet were available as catch per day. It was noted that these catch rates should be considered to be approximate. There was nevertheless a decline from a level of about 30 t/day in 1983 and 1984 to about 20-25 t/day in 1985 and 1986.

Catch rate information from the Canadian inshore fishery was available for the period 1980-86 for traps, gillnets, handlines and linetrawls, and for two vessel categories; less than 35 feet and 35-64 feet in length. The catch rate data are in the form of catch per purchase receipt. It is assumed that the amount of gear used per purchase receipt is constant.

In general, for vessels less than 35 feet, no trends were apparent in the catch rates for gillnet and handline while there may have been a slight decline in linetrawl. The catch rates for traps increased after 1982. The catch rate of vessels between 34 and 64 feet increased for trap and gillnet since 1981 and 1982 respectively and remained stable for handline and linetrawl for the period examined. Fishing effort (all inshore vessels and gears) as measured by the number of purchase receipts declined from 1980 to 1983 and then increased to 1986.

3.3. Research Vessel Surveys (Doc. 1, 5, 7)

Stratified random surveys have been conducted in Subdiv. 3Ps by France since 1978 and by Canada since 1972. The fishing gears used in the two series were different but the stratification scheme, method of sampling and analyses of results have been the same. The Canadian surveys were conducted in different months over the years. Since there are changes in the distribution of cod during the year, the abundance estimates were seasonally adjusted to correspond to February-March surveys by the use of monthly estimates corresponding to the pattern observed in the offshore commercial fishery. Surveys conducted by France have all taken place in February-March and there was therefore no need to adjust these abundance estimates for seasonal variation.

From new material related to stock discrimination (see Section 2 above), it was concluded that areas of mixing with other stocks included the Burgeo Bank area to the northwest and areas in the south and southeast portion of the Subdivision. The degree of intermixing could not be precisely defined but for some years might be substantial. It was not considered appropriate to analyze the survey results for the Subdivision with results from Burgeo Bank removed and to include at the same time results from the southern areas of mixing. There was no basis upon which to remove these southern areas as the boundaries of these areas are not very well known. The Working Group further notes that catch rates from the commercial fishery apply to the whole of the Subdivision. For these reasons, the survey results were analyzed for the Subdivision as a whole. In the previous assessment, completed by the Scientific Council of NAFO in June 1986, survey results for Burgeo Bank had been excluded.

A comparison of 9 tows made side by side by the research vessels Cryos and W. Templeman on February 28 - March 1, 1987 on St. Pierre Bank yielded preliminary indications that; 1) for cod under 45 cm, the Cryos is much more efficient than the W. Templeman for the smallest cod and more efficient for the larger cod within this group and 2) for cod of all lengths greater than 45 cm, the Cryos is more efficient than the W. Templeman by a factor of about 2. For cod of ages 6 and older (6+) it was therefore considered appropriate to combine the French and Canadian survey results. To derive a survey index of abundance for the period 1978-87, the catch per tow of age 6+ cod from the French and Canadian surveys was each normalized to its mean and then averaged (Table 3).

Results from the surveys are variable but show clearly an increasing trend over the 10 year period. In the French series the value for 1985 seems to be an underestimate since it is smaller by a factor of 4 or 5 than the values for 1984 and 1986. On the other hand, the value for 1981 in the Canadian series appears to be an overestimate since it is 5 times larger than the 1980 value and twice as large as the 1982 value. In the combined series, the values for these years, 1981 and 1985, remain inconsistent with values for adjacent years. In these two years, the catch per tow of year-classes fully susceptible to capture by the survey gear is not consistent with the regular decline in abundance expected. As an example, from the French survey, the text table that follows shows that for year-classes 1976-1979, the sharp drop in abundance in 1985 is not consistent with the abundance in succeeding years.

	YEAR			
AGE	1984	1985	1986	1987
6	20.47	1.10		
7	6.03	2.02	10.13	
8	2.30	1.18	7.74	3.21
9		0.81	4.27	2.10
10			0.88	1.04
11				0.22

Similar inconsistences are present in the Canadian series with respect to 1981. In that case, important year-classes apparently increase sharply in abundance in 1981 and then decline sharply in 1982. The abundance indices for 1981 and 1985 are therefore considered anomalous.

3.4. Age Composition of the Catches by the Commercial Fishery (Doc. 1, 7)

The age composition of the catches in the Canadian and French fisheries in 1986 was derived from extensive sampling in both cases. The age compositions were similar with 5- and 6-year-old cod being dominant. The sum of products check, that is, calculated catch as compared with reported catch, was reasonable (less than 10% difference). Average weights at age were the average of the values provided from the Canadian and French sampling with the exception of age 10 which appeared anomalously low. The average weight at age 10 was therefore derived from Canadian sampling only as this estimate was consistent with values for previous years (Table 2.)

The age composition for 1984 was recalculated to incorporate the values for the French fishery as provided at this meeting. Age compositions for the French fishery for the period 1978-1983 were available but could not be incorporated at this meeting. The values for this later period were, however, similar to the total age compositions used in previous years and these had included apparently reasonable estimates of the age compositions of the French catches for 1978-83. It is anticipated that these new data will be incorporated into the catch-at-age matrix before the next assessment.

4. Assessment Parameters

4.1. Partial recruitment (Relative fishing mortality pattern at age)

Preliminary estimates of partial recruitment at age in the fishery in 1986 were derived by iteration from historical cohort averages over the period 1978-83. These estimates were adjusted so that the abundance of recent year-classes at age 3 showed a correspondence between cohort analysis and survey results. Survey numbers were those from a combined index at age 2 and 3 for the same year-class from the French surveys. This survey index (Table 4) indicated a significant relationship (r^2=.87) with population numbers at age 3 from the cohort analysis for year-classes from 1975 to 1980 (Fig. 7). The average partial recruitment from 1979-83 and that adjusted to reconcile cohort year-class strength are as follows:

AGE	3	4	5	6	7	8	9	10	11	12	13	14
PR (AV.)	.02	.18	.52	.72	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PR (Adjusted)	.01	.15	.45	.73	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

4.2. Cohort analysis

Catch and average weight data at age from the commercial fishery from 1959-86 (Table 2) were used in a cohort analysis. Natural mortality was assumed to be 0.20 and fishing mortality on the oldest age group (14) in each year was set equal to the total fishing mortality for the fully recruited age groups (7-11).

4.3. Fishing mortality in 1986

An age 6+ abundance index (Section 3) from Canadian and French surveys for the period 1978-86 was used to estimate fully recruiting fishing mortality in 1986 using an unweighted least squares regression analysis. The relationship, with the 1981 and 1985 values excluded, indicated that F_{1986} was between 0.40 and 0.50. Above this level the r^2 values decreased rapidly while at lower F's the difference between observed and predicted cohort abundance values (residuals) for the most recent years became larger (Table 5). Regressions of commercial catch rates on offshore exploitable biomass for the period 1977-86 were also attempted in order to estimate F_{1986}. These relationships were not significant and there was little discrimination in r^2 values over a wide range of fishing mortalities (0.3-0.6). Generally, the trends observed in the CPUE index were similar to those observed in the age 6+ survey index (Fig. 8). The Working Group concluded that results of calibration using the survey index would not be inconsistent with trends observed in the commercial catch rate. Precise determination of F_{1986} within the calculated range was not possible and it was decided that an average (0.45) would be an appropriate estimate. Population numbers, average biomass and fishing mortalities from a cohort analysis at F_t=0.45 are shown in Tables 6, 7 and 8.

The partial recruitment pattern and the fully recruited fishing mortality of 0.45 resulted in fishing mortalities in 1986 as follows:

AGE	3	4	5	6	7 (and older)
F	.0045	.0675	.2025	.3285	.45

4.4. Recruitment

Abundance estimates of ages 2 and 3 cod from Canadian and French research vessels surveys were examined as indicators of year-class strength. The objective of this examination was to determine the strength of the 1981-84 year-classes from the relationships between cohort and survey population estimates of the 1975-80 year-classes.

There was correspondence (r^2=0.61) between age 2 and age 3 estimates from French surveys so these indices were normalized to their respective 1976-84 means and averaged to arrive at a single estimate of year-class strength (Table 4). The relationship of this index with corresponding abundance estimates for the 1975-80 year-classes from cohort analysis indicated a significant regression (r^2=0.87). The survey index values for the 1981, 1982 and 1984 year-classes were larger than values observed in the relationship, therefore, the size of these year-classes was assumed to be at least the size of the largest year-class in the relationship (100 million fish). The size of the 1983 year-class was estimated to be about 68 million fish (Fig. 9).

There was no clear relationship between the abundance of age 2 and age 3 cod for the same year-classes from Canadian surveys. For this reason, each of these indices was regressed with age 3 population abundance from cohort analysis. No significant relationships were observed and the Working Group decided it was most appropriate to use only the French survey estimates as indicators of year-class strength.

4.5. Yield per recruit

Values of F_{max}=.33 and $F_{0.1}$=0.20 were available from a yield per recruit analysis published in 1981. More recent values for this calculation were available except for reliable estimates of weight at ages from 15-20 years. It was therefore decided to use the 1981 values and attempt to derive more current estimates before the next assessment.

5. Projection of stock biomass (3+) and catch levels at various options as required

Projections of catch and biomass were made from the population at the beginning of 1987 established from the population at the beginning of 1986, the catch in 1986 and fishing mortalities in 1986 as described in the assessment section. The size of the 1984 year-class as 3-year-old cod in 1987 was estimated (Section 4) at 100 million. Average weights at age were taken as the average of values in 1984-86. The partial recruitment pattern was taken as the one which was applied in 1986 as adjusted to reconcile the sizes of the 1981-83 year-classes. These parameters (Table 9) were used to project catches and biomasses to 1989. In 1987 a catch of 60,000 t was assumed, the approximate total of the Canadian and French allocations as set by the respective management authorities. The geometric mean of the abundance of 3-year-old cod in the period 1959-86 was about 55 million and that value was used as the size of the 1985 and 1986 year-classes as 3-year-olds in 1988 and 1989. Projections of 1988 catches and biomasses at various levels of fishing mortality are shown in Fig. 10. For 1988 and 1989 the catches and biomasses (000 t) implied by the use of constant fishing mortality levels of $F_{0.1}$, F_{max} and F_{1986} were as follows:

	1987				1988			1989			1990
FISHING MORTALITY	SSB JAN. 1	CATCH	3+ AV. BIOMASS	MANAGEMENT OPTIONS	SSB JAN. 1	CATCH	3+ AV. BIOMASS	SSB JAN. 1	CATCH	3+ AV. BIOMASS	SSB JAN. 1
F=0.35	159	60	319	$F_{0.1}$=.18	187	37	333	234	45	363	273
				F_{max}=.32	187	62	320	210	69	343	223
				F_{86}=.45	187	84	309	191	84	292	185

The Working Group notes that the average population biomass of cod of ages 3 years and older (3+) projected for 1987, 1988 and 1989 at about 300,000 t is well in excess of all biomasses previously observed. The highest value prior to 1984 was about 230,000 t in 1959 (Fig. 11). The Working Group was asked to provide advice for the catch level in 1987 but considers that it has not sufficient knowledge of the catch to date nor the management objective in mind for 1987 to provide such advice. Further, since the projected catch in 1989 already contains assumed abundance values for ages 3 and 4, projections beyond this year could be quite imprecise and therefore were not done.

6. Summary

Fishing mortality was at about the 0.5 level from 1959 to the early 1970s and rose to a peak of about 1.0 in 1974 and 1975. The level of fishing mortality since then has again been at about the 0.5 level. Population biomass of age 3 and older cod declined from a level of about 230,000 t in 1959 to a low of about 70,000 t in 1975. There was an increase to 1982. A very sharp increase in biomass is estimated since 1982 and the 1986 biomass was about 260,000 t. The increase from 1975 to 1982 was primarily due to the entrance of the relatively strong 1972-74 year-classes. The marked increase after 1982 is attributed to the very strong 1980 year-class and successive year-classes which have all been substantially greater than the long-term mean of 55 million.

The present size of the stock is apparently the highest since 1959. However the long-term potential and stability of the fisheries are dependent upon the level of recruitment which has shown large fluctuations over the period observed.

The Chairman expressed the sincere appreciation of the Working Group to Ms. Theresa Dugas and Ms. Dianne Geddes for the excellent secretarial and editorial support so generously given.

Appendix 1

Agenda

1. Opening-appointment of rapporteurs - adoption of agenda - plan of work
2. Stock definition
3. Assessment of cod stock in Subdivision 3Ps
4. Projection of stock biomass (3+) and catch levels at various options as required
5. Other matters
6. Adoption of report
7. Adjournment

Appendix 2

List of Participants

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Table 1. Cod catches (t) from Subdivision 3Ps, 1959-86.

YEAR	CAN (N) OFFSHORE	CAN (N) INSHORE	CAN (M)	FRANCE INSHORE	FRANCE OFFSHORE	SPAIN	PORTUGAL	OTHER	TOTAL
1959	2,726	32,718	4,784	3,078	4,952	7,794	3,647	471	60,170
1960	1,780	40,059	5,095	3,424	2,670	17,223	262	2,123	72,636
1961	2,167	32,506	3,883	3,793	11,837	21,015	4,985	3,434	83,620
1962	1,176	29,888	1,474	2,171	4,208	10,289	1,873	1,560	52,639
1963	1,099	30,447	331	1,112	969	10,826	209	6,828	51,821
1964	2,161	23,897	370	1,002	3,872	15,216	169	9,880	56,567
1965	2,459	25,902	1,203	1,863	2,488	13,404	-	4,535	51,854
1966	5,473	23,785	583	1,157	6,657	23,678	519	4,355	66,207
1967	3,861	26,331	1,259	1,494	3,954	20,851	980	4,044	62,774
1968	6,536	22,938	585	979	2,027	26,868	8	18,613	77,556
1969	4,269	20,009	849	1,415	1,077	28,141	57	7,982	63,799
1970	4,650	23,410	2,166	1,307	698	35,750	143	8,734	76,858
1971	8,657	26,651	731	1,196	3,185	19,169	81	2,778	62,448
1972	3,323	19,276	252	990	446	18,550	109	1,267	44,213
1973	3,107	21,349	181	976	189	19,952	1,180	5,707	52,641
1974	3,770	15,999	657	600	5,714	14,937	1,246	3,789	46,712
1975	741	14,332	122	586	3,738	12,234	1,350	2,270	35,373
1976	2,013	20,978	317	722	1,683	9,236	177	2,007	37,133
1977	3,333	23,755	2,171	845	2,141				32,245
1978	2,082	19,560	700	360	4,474			45	27,221
1979	2,381	23,413	863	495	5,854				33,006
1980	2,809	29,427	715	214	4,403				37,568
1981	2,696	26,068	2,321	333	7,474				38,892
1982	2,639	21,351	2,948	1,009	5,955				33,902
1983	2,100	23,915	2,580	843	9,013				38,451
1984	891	22,863	1,969	777	10,444				36,944
1985	4,150	24,044	4,516	642	17,866				51,218
1986	4,981	24,208	2,210	389	25,592				57,290

Table 2. Catch (numbers) and average weight at age of cod from the commercial fishery in Subdivision 3Ps for the period 1959-86.

CATCH AT AGE

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
3	1001	567	450	1245	961	1906	2314	949	2871	1143	774	756	2084	731	945	1887
4	13940	5496	5586	6749	4499	5785	9636	13662	10913	12602	7098	8114	6444	4944	4707	6042
5	7525	23704	10357	9003	7091	5635	5799	13065	12900	13135	11585	12916	8574	4591	11386	9987
6	7265	6714	15960	4533	5275	5179	3609	4621	6392	5853	7178	9763	7266	3552	4010	6365
7	4875	3476	3616	5715	2527	2945	3254	5119	2349	3572	4554	6374	8218	4603	4022	2540
8	942	3484	4680	1367	3030	1881	2055	1586	1364	1308	1757	2456	3131	2636	2201	1857
9	1252	1020	1849	791	898	1891	1218	1833	604	549	792	730	1275	833	2019	1149
10	1260	827	1376	571	292	652	1033	1039	316	425	717	214	541	463	515	538
11	631	406	446	187	143	339	327	517	380	222	61	178	85	205	172	249
12	545	407	265	140	99	329	68	389	95	111	120	77	125	117	110	80
13	44	283	560	135	107	54	122	32	149	5	67	121	62	48	14	32
14	0	27	58	241	92	27	36	22	3	107	110	14	57	45	29	17
3+	39280	46411	45203	30677	25014	26623	29471	42834	38336	39032	34813	41713	38662	22768	30130	30743
4+	38279	45844	44753	29432	24053	24717	27157	41885	35465	37889	34039	40957	35778	22037	29185	28856
5+	24339	40348	39167	22683	19554	18932	17521	28223	24552	25287	26941	32843	29334	17093	24478	22814
6+	16814	16644	28810	13680	12463	13297	11722	15158	11652	12152	15356	19927	20760	12502	13092	12827

AGE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	1840	4110	935	218	149	298	1000	110	783	203	198	277
4	7329	12139	9156	4308	2370	1644	2765	5079	2623	4521	4557	4924
5	5397	7923	8326	5391	9777	5096	2864	4114	9106	4538	11067	10159
6	4541	2875	3209	4203	5235	8335	4220	1979	3984	7018	5951	11180
7	5867	1305	920	1791	2588	4387	5187	2806	1705	2221	4995	4247
8	723	495	395	730	884	1420	1573	3101	1140	584	1466	2144
9	1176	140	265	243	284	349	571	725	1029	542	418	639
10	105	53	117	189	82	104	204	297	237	338	378	220
11	174	17	57	76	48	54	89	102	90	134	332	168
12	52	21	43	26	19	42	37	34	35	35	130	141
13	6	4	31	19	11	19	24	15	18	8	23	78
14	2	3	11	10	10	25	6	10	8	8	12	23
3+	27232	29085	23465	17204	21457	21773	18540	18372	20758	20150	29527	34200
4+	25392	24975	22530	16986	21308	21475	17540	18262	19975	19947	29329	33923
5+	18063	12836	13374	12678	18938	19831	14775	13183	17352	15426	24772	28999
6+	12666	4913	5048	7287	9161	14735	11911	9069	8246	10888	13705	18840

AVERAGE WEIGHT AT AGE

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
3	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.55
4	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.68
5	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.30
6	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.86
7	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.67
8	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.42
9	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.19
10	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	4.94
11	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	5.92
12	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.76
13	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.78
14	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	10.90

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	0.45	0.41	0.52	0.48	0.45	0.58	.64	0.63	0.54
4	0.70	0.65	0.72	0.79	0.77	0.84	.98	0.81	0.75
5	1.08	1.01	1.13	1.32	1.17	1.33	1.36	1.16	1.18
6	1.75	1.65	1.66	1.80	1.78	1.99	1.93	1.69	1.84
7	2.45	2.55	2.48	2.30	2.36	2.58	2.51	2.58	2.43
8	2.99	3.68	3.60	3.27	2.88	3.26	3.43	3.00	3.15
9	4.10	4.30	5.40	4.36	3.91	3.77	4.35	4.66	4.30
10	5.16	6.49	6.95	5.68	5.28	5.04	5.06	5.47	5.50
11	5.17	7.00	7.29	7.41	6.18	6.56	5.42	5.84	6.19
12	7.20	8.20	8.64	9.04	8.62	8.45	9.37	6.65	8.72
13	7.75	9.53	9.33	8.39	8.64	10.06	11.95	9.39	8.05
14	8.72	10.84	9.58	9.56	11.41	11.82	10.85	10.03	11.91

Table 3. Trends in the abundance of cod of ages 6 and older as derived from French and Canadian surveys in Subdivision 3Ps during the period 1978-87

YEAR	NUMBER CAUGHT PER TOW		NORMALIZED CATCH PER TOW		AVERAGE CATCH PER TOW
	FRANCE	CANADA	FRANCE	CANADA	
1978	3.40	3.16	0.17	0.31	0.24
1979	7.66	3.46	0.38	0.34	0.36
1980	8.10	4.03	0.41	0.39	0.40
1981	19.11	22.45	0.96	2.19	1.58
1982	19.39	10.36	0.97	1.01	0.99
1983	17.88	12.73	0.90	1.24	1.07
1984	35.62	7.24	1.79	0.71	1.25
1985	8.88	10.04	0.45	0.98	0.72
1986	49.12	12.25	2.47	1.20	1.84
1987	30.03	16.80	1.51	1.64	1.58

Table 4. Recruitment index derived from age 2 and age 3 French research survey abundance estimates

YEAR-CLASS	AGE 2 NUMBERS	AGE 3 NUMBERS	NORMALIZED AGE 2	NORMALIZED AGE 3	RECRUITMENT INDEX
1975		1.65		0.23	0.23
1976	0.77	0.41	0.10	0.06	0.08
1977	0.45	1.76	0.06	0.25	0.16
1978	7.55	5.57	1.03	0.80	0.90
1979	0.20	1.98	0.03	0.28	0.15
1980	12.10	5.73	1.65	0.82	1.24
1981	11.46	8.25	1.56	1.18	1.37
1982	12.50	15.05	1.70	2.15	1.93
1983	5.70	4.67	0.78	0.67	0.73
1984	8.04	12.51	1.10	1.79	1.45
1985	22.42		3.05		3.05
1976-84 AV.	7.34	6.99			

Table 5. Correlation of survey 6+ numbers and cohort 6+ numbers for the period 1978-87 but excluding the 1981 and 1985 data points.

P_t	.25	.30	.35	.40	.45	.50
r^2	.62	.62	.61	.59	.57	.53
Intercept	10	71	115	147	173	193
Slope	566	438	346	278	226	184
Residuals						
1978	67	36	14	-3	-15	-25
1979	83	64	52	43	36	30
1980	199	183	172	164	158	152
1982	-288	-233	-194	-165	-142	-123
1983	-311	-252	-209	-178	-155	-136
1984	-238	-177	-133	-101	- 75	- 56
1986	66	72	76	79	81	83
1987	424	306	222	161	113	76

Table 6. Population numbers ('000) at the beginning of the year of Subdivision 3Ps cod from a cohort analysis at F_{1986}=0.45.

POPULATION NUMBERS

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
3	59387	59261	50949	48670	42955	70839	80985	84407	98471	70169	54311	35484	60158	39317
4	107059	47716	48006	41306	38721	34299	56273	64211	68248	78023	56416	43766	28368	46643
5	35826	75039	34094	34250	27712	27632	22847	37354	40210	46002	52477	39767	28491	17395
6	24206	22523	39989	18542	19895	16272	17524	13459	18761	21249	25778	32482	20871	15568
7	16269	13245	12365	18299	11080	11516	8636	11082	6838	9576	12101	14610	17760	10513
8	5811	8909	7698	6852	9810	6785	6763	4127	4441	3473	4608	5787	6195	7105
9	4041	3906	4142	2068	4373	5290	3853	3678	1943	2402	1660	2183	2515	2239
10	3440	2176	2275	1718	978	2768	2620	2052	1353	1045	1470	642	1127	906
11	3663	1676	1033	617	890	536	1676	1211	740	822	471	555	332	433
12	1181	2428	1005	442	336	599	132	1076	523	262	472	330	293	195
13	153	474	1619	583	235	186	193	47	529	343	114	278	201	127
14	0	86	132	819	355	96	103	47	9	299	276	33	118	108
3+	261037	237438	203306	174167	157340	176817	201607	222750	242066	233664	210154	175917	166429	140550
4+	201650	178177	152358	125496	114385	105978	120622	138344	143596	163494	155843	140433	106271	101233
5+	94591	130460	104352	84190	75664	71679	64349	74132	75348	85471	99427	96667	77903	54589
6+	58764	55421	70258	49941	47952	44048	41501	36779	35138	39469	46950	56900	49412	37194
7+	34558	32898	30269	31399	28057	27775	23977	23320	16377	18221	21171	24418	28541	21626

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	30987	41948	56354	58915	71512	36864	21269	35146	67006	51693	105051	97287	101766	68064
4	31529	24515	32637	44474	44516	57703	29984	17279	28505	53955	42223	85300	79468	83139
5	33715	21554	14604	20089	25428	28162	43345	22405	12659	20836	39579	32196	65747	60940
6	10088	17301	8611	7073	9279	13285	18179	26642	13732	7773	13337	24165	22254	43815
7	9532	4631	8406	2941	3170	4693	7074	10147	14271	7425	4573	7314	13434	12835
8	4443	4165	1493	1573	1227	1779	2222	3450	4338	6090	3540	2202	3979	6479
9	3432	1646	1730	568	840	647	796	1019	1540	2129	2917	1867	1274	1931
10	1079	983	308	334	338	448	310	395	519	714	1087	1457	1038	665
11	323	418	318	157	225	171	196	180	229	310	340	675	887	508
12	169	109	117	103	113	133	71	117	98	107	104	197	432	426
13	54	39	16	48	65	54	85	41	58	47	57	54	130	236
14	60	31	3	8	36	25	27	60	17	26	25	30	37	85
3+	125410	117339	124595	136283	156770	143965	123559	116880	142971	151964	212833	252744	290445	279124
4+	94423	75391	68241	77369	85258	107101	102290	81734	75965	100271	107782	155457	188679	211060
5+	62894	50876	35605	32895	40742	49398	72306	64455	47460	46316	65559	70157	109211	127921
6+	29179	29322	21001	12806	15314	21236	28960	42050	34301	25480	25930	37961	43464	66981
7+	19092	12021	12390	5733	6035	7951	10781	15409	21069	17707	12643	13796	21211	23166

Table 7. Average population biomass (t) of Subdivision 3Ps cod from a cohort analysis at F_{1986}=0.45.

POPULATION BIOMASS (AVERAGE)

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
3	14935	14962	12868	12182	10770	17718	20237	21292	24598	17632	13678	8902	14872	9878
4	62171	27962	28112	23500	22677	19449	31857	35382	38913	44442	32849	24553	15481	27483
5	30955	60142	27576	26540	23206	23971	19160	29159	32106	37713	45018	31656	23093	14484
6	30539	28459	46611	24347	25747	20251	23617	16426	22945	27296	33043	40967	25377	20671
7	29333	24533	22414	32679	21017	21431	14655	17430	11920	16302	20542	23539	27913	16914
8	15394	19979	13751	17720	23495	16632	16259	7307	10650	7883	10421	12604	12476	16203
9	12352	12370	11292	5968	14389	15582	11721	9531	5936	7781	4394	6549	6461	6515
10	12463	7793	6456	6394	3734	11057	9275	6536	5411	3658	4770	2389	3686	2870
11	18109	7912	4198	2790	4431	1740	8166	4942	2777	3802	2390	2472	1553	1693
12	5418	13975	5425	2295	1775	2509	576	5396	2987	1246	2563	1821	1389	768
13	937	2150	9453	3701	1250	1130	835	187	3244	2480	526	1501	1205	721
14	0	585	810	5670	2521	669	685	286	64	1969	1762	205	697	681
3+	232604	220822	188967	165785	155011	152138	157042	155873	161551	172223	171955	157158	134204	118880
4+	217669	205860	176098	153604	144241	134420	136805	134581	136953	154571	158277	148256	119331	109002
5+	155498	177898	147987	130104	121564	114972	104949	99200	98040	110130	125428	123703	103851	81519
6+	124543	117756	120410	101564	98359	91001	85789	70041	65934	72417	80410	92047	80758	67035
7+	94005	89297	73799	77217	72612	70750	62172	53615	42989	45121	47367	51081	55381	46364

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	7735	10387	14050	14386	35399	14988	7874	16489	26917	21059	55003	58131	58048	33240
4	18096	13202	17842	23507	24288	35128	16907	10692	19332	35725	31066	78104	56534	54711
5	26570	15235	11219	15115	24315	24632	34662	20019	13224	19666	41550	37687	62688	59198
6	11774	20702	8867	8192	12513	17247	22729	32896	18463	10738	19952	36007	28924	62622
7	15558	6653	9785	4706	6451	8097	12869	16954	23462	12377	8370	14463	24608	22934
8	9041	8896	3073	3751	3100	3655	5679	8524	10148	13423	8524	6393	8498	15008
9	8030	3272	3479	1818	2613	1878	2460	4001	4770	6055	7931	6707	4365	6106
10	3539	2993	1138	1403	1212	1572	1551	2116	2054	2725	4358	6388	4056	2689
11	1185	1422	1149	808	1037	590	1071	983	1189	1006	1720	3272	3672	2311
12	621	342	542	578	540	774	451	724	628	664	644	1457	2154	2732
13	335	112	95	337	370	300	685	253	331	300	424	500	996	1395
14	358	175	14	53	294	155	207	394	114	204	217	243	272	748
3+	102844	83392	71253	74654	112132	109016	107145	114045	122632	123967	179759	249351	254813	263694
4+	95109	73005	57203	60267	76734	94028	99271	97555	93715	102908	124756	191220	196766	230454
5+	77013	59803	39361	36760	52446	58901	82364	86864	74383	67183	93690	113116	140232	175743
6+	50442	44568	28143	21645	28131	34268	47702	66845	61159	47516	52140	75429	77544	116545
7+	38668	23865	19276	13453	15618	17021	24973	33949	42656	36779	32188	39422	48620	53923

Table 8. Fishing mortalities for Subdivision 3Ps cod from a cohort analysis at F_{1986}=0.45.

FISHING MORTALITY

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
3	0.019	0.011	0.010	0.029	0.025	0.030	0.032	0.013	0.033	0.018	0.016	0.024	0.054	0.021	0.034	0.051	0.037
4	0.155	0.136	0.138	0.199	0.137	0.206	0.210	0.268	0.194	0.197	0.150	0.229	0.289	0.125	0.180	0.318	0.285
5	0.264	0.429	0.409	0.343	0.332	0.255	0.329	0.489	0.438	0.379	0.280	0.445	0.404	0.345	0.467	0.718	0.525
6	0.403	0.400	0.582	0.315	0.347	0.433	0.258	0.477	0.472	0.363	0.368	0.404	0.486	0.291	0.579	0.522	0.874
7	0.402	0.343	0.390	0.423	0.290	0.332	0.539	0.714	0.478	0.531	0.538	0.658	0.716	0.661	0.628	0.932	1.476
8	0.197	0.566	1.114	0.249	0.418	0.366	0.409	0.553	0.415	0.538	0.547	0.633	0.818	0.528	0.793	0.679	0.766
9	0.419	0.341	0.680	0.549	0.257	0.503	0.430	0.800	0.421	0.291	0.749	0.461	0.821	0.530	1.050	1.476	1.445
10	0.519	0.545	1.104	0.458	0.401	0.302	0.572	0.820	0.299	0.597	0.775	0.459	0.756	0.832	0.750	0.929	0.473
11	0.211	0.312	0.649	0.408	0.196	1.199	0.243	0.639	0.838	0.355	0.155	0.438	0.332	0.749	0.889	1.076	0.928
12	0.714	0.205	0.344	0.431	0.394	0.934	0.839	0.510	0.224	0.631	0.330	0.298	0.636	1.087	1.268	1.685	0.680
13	0.381	1.080	0.482	0.296	0.698	0.388	1.202	1.410	0.373	0.016	1.045	0.657	0.418	0.542	0.339	2.379	0.515
14	0.373	0.423	0.656	0.389	0.334	0.370	0.481	0.704	0.433	0.498	0.572	0.626	0.749	0.606	0.741	0.888	1.312

AGE	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	0.080	0.015	0.007	0.008	0.009	0.017	0.002	0.008	0.002	0.002	0.004
4	0.359	0.258	0.086	0.091	0.111	0.113	0.110	0.071	0.060	0.065	0.068
5	0.572	0.449	0.238	0.287	0.290	0.288	0.246	0.293	0.169	0.206	0.203
6	0.596	0.482	0.430	0.383	0.424	0.415	0.330	0.401	0.387	0.350	0.329
7	0.674	0.384	0.548	0.513	0.550	0.514	0.541	0.531	0.409	0.529	0.450
8	0.427	0.440	0.604	0.579	0.607	0.512	0.674	0.440	0.347	0.523	0.450
9	0.318	0.429	0.536	0.501	0.476	0.527	0.472	0.494	0.387	0.450	0.450
10	0.193	0.481	0.628	0.346	0.344	0.570	0.582	0.276	0.296	0.515	0.450
11	0.127	0.328	0.674	0.316	0.404	0.561	0.634	0.346	0.248	0.534	0.450
12	0.256	0.544	0.243	0.348	0.506	0.538	0.432	0.464	0.218	0.405	0.450
13	0.096	0.745	0.495	0.154	0.710	0.616	0.436	0.431	0.180	0.218	0.450
14	0.522	0.408	0.564	0.324	0.603	0.503	0.559	0.435	0.342	0.443	0.450

Table 9. Input parameters to project catch and biomasses for Subdivision 3Ps cod.

AGE	1987 POPULATION BEG. YEAR (000)	AVERAGE WEIGHT 1984-86 (KG)	PARTIAL RECRUITMENT	MATURITY OGIVE
3	100,000	0.61	0.01	0.01
4	55,476	0.86	0.15	0.05
5	63,682	1.24	0.45	0.30
6	40,903	1.80	0.73	0.68
7	25,942	2.53	1.00	0.92
8	6,743	3.29	1.00	0.99
9	3,399	4.56	1.00	1.00
10	1,015	5.51	1.00	1.00
11	350	6.00	1.00	1.00
12	267	7.82	1.00	1.00
13	223	10.06	1.00	1.00
14	123	10.78	1.00	1.00

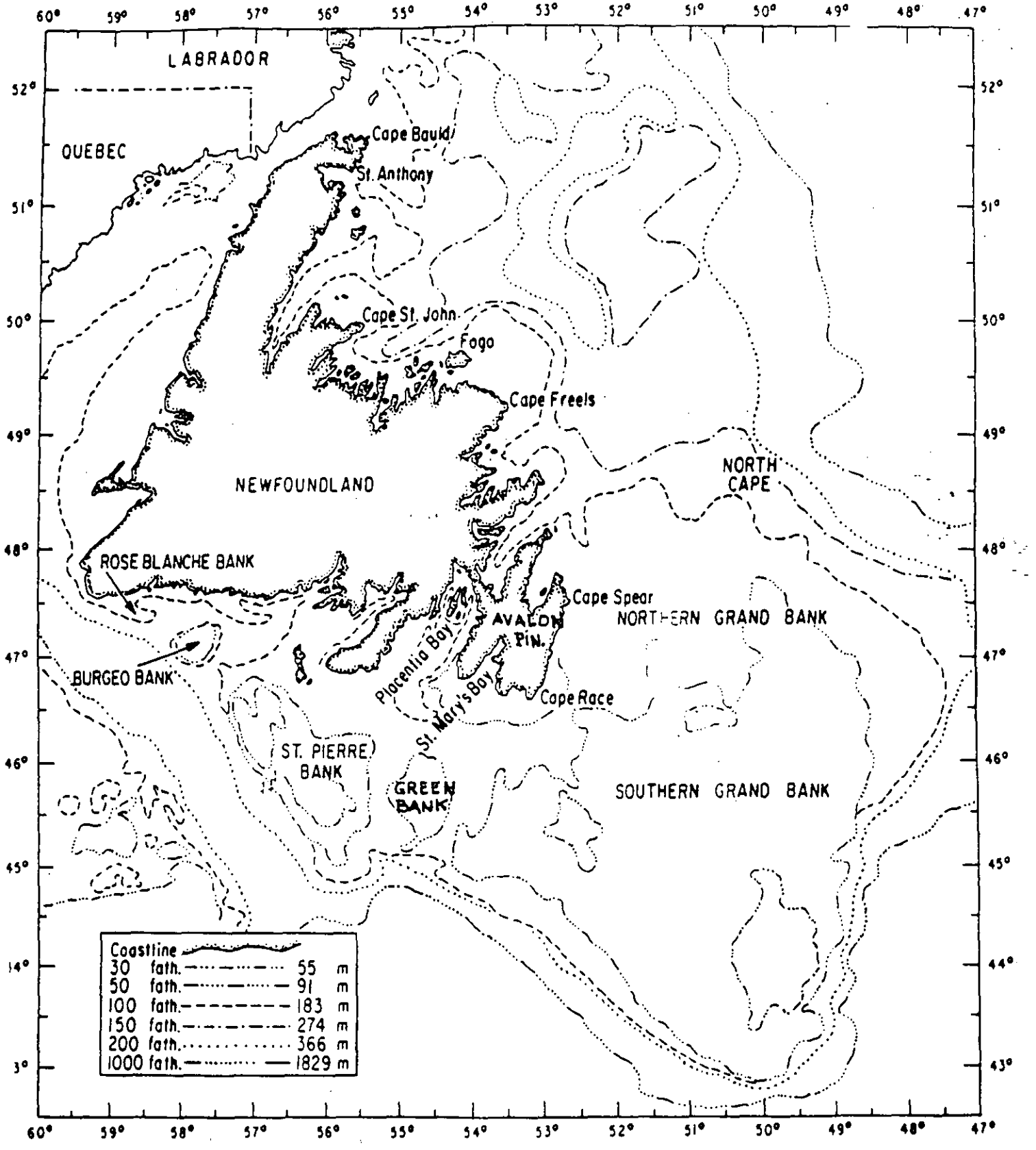

Fig. 1. Map of Subdivision 3Ps and adjacent areas.

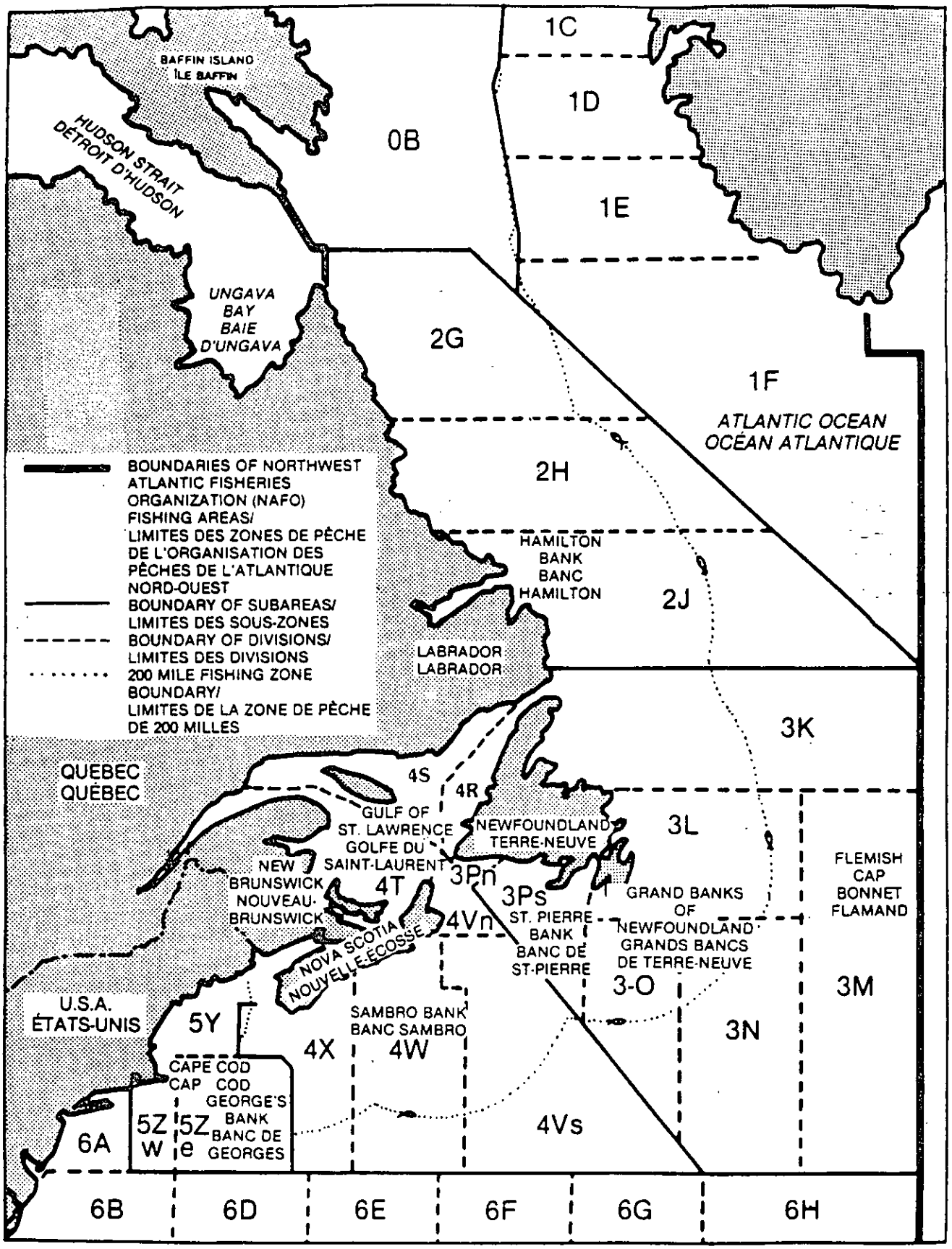

Fig. 2. NAFO convention area chart with fishing areas.

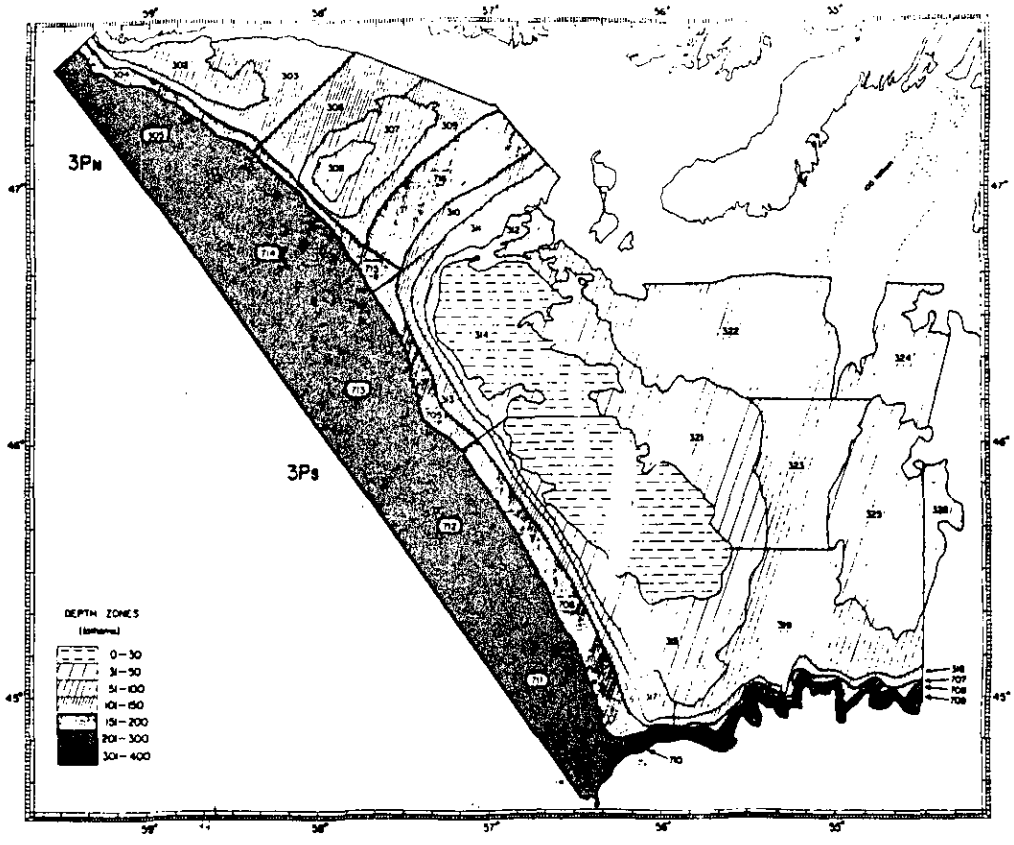

Fig. 3. Stratification scheme used for random-stratified research vessel surveys in Subdivision 3Ps.

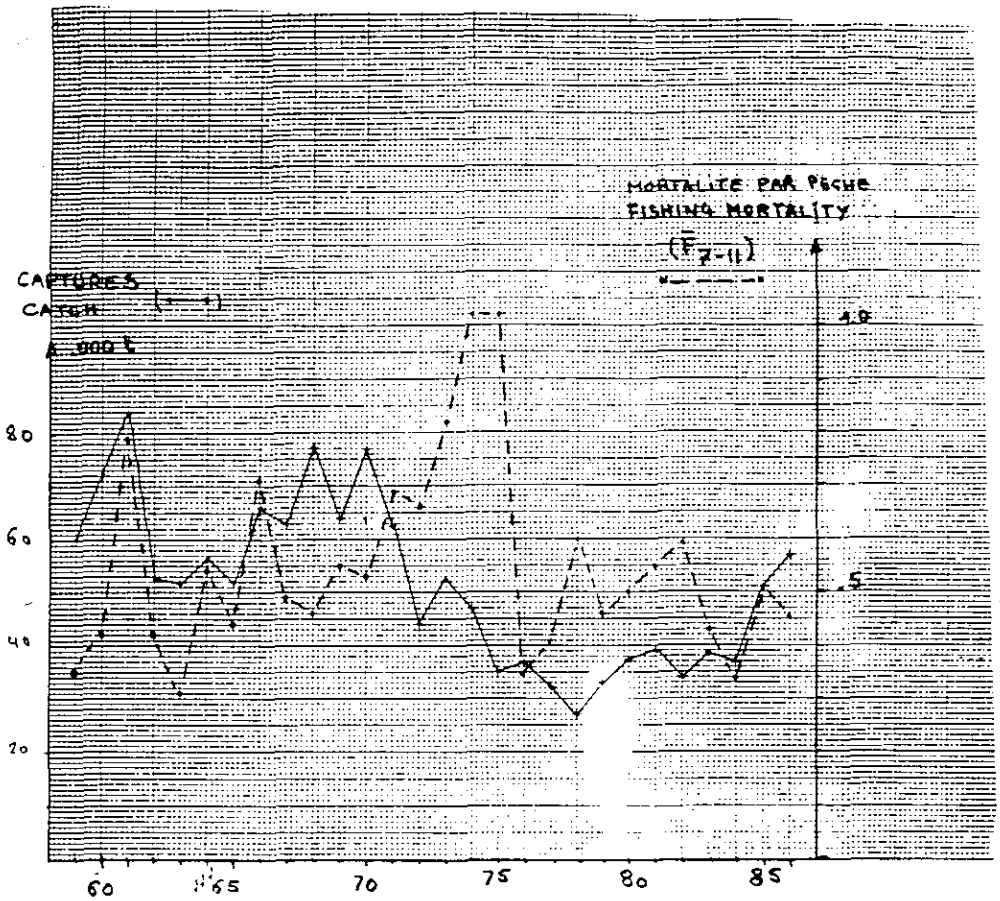

Fig. 4. Trends in catches and average (age 7 to 11) fishing mortality over the period 1959-1986.

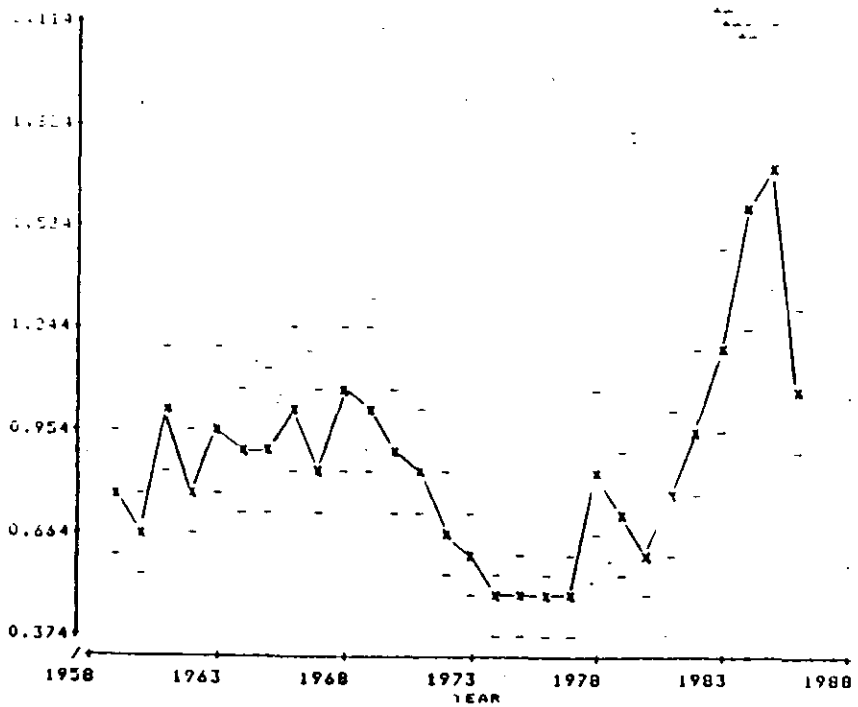

Fig. 5. Standardized catch rate index for cod in Subdivision 3Ps with approximate 90% confidence limits for the period 1959-86.

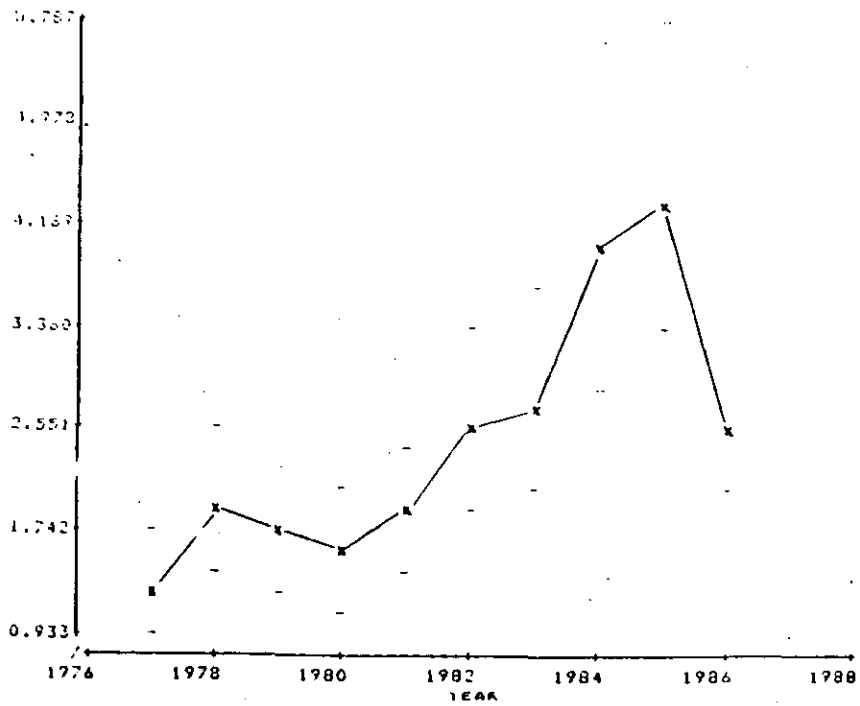

Fig. 6. Standardized catch rate index for cod in Subdivision 3Ps with approximate 90% confidence limits for the period 1977-86.

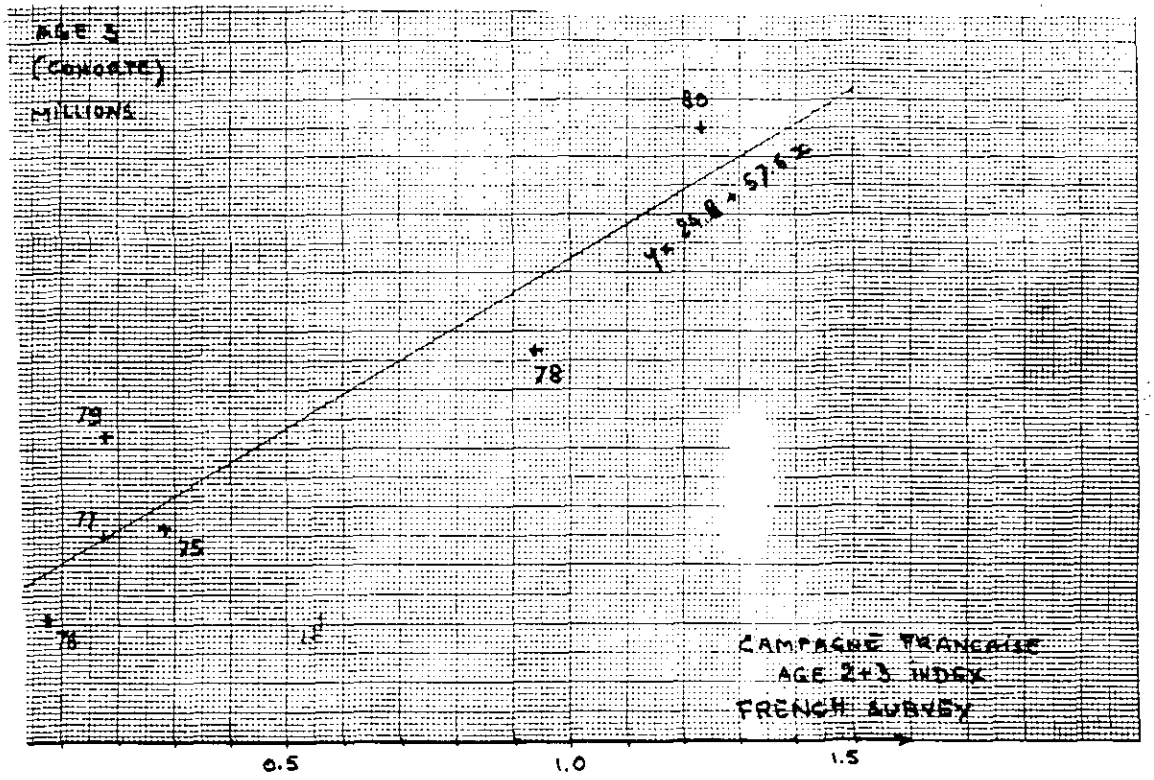

Fig. 7 Abundance relationship between age 3 from cohort analysis and ages 2+3 from French surveys.

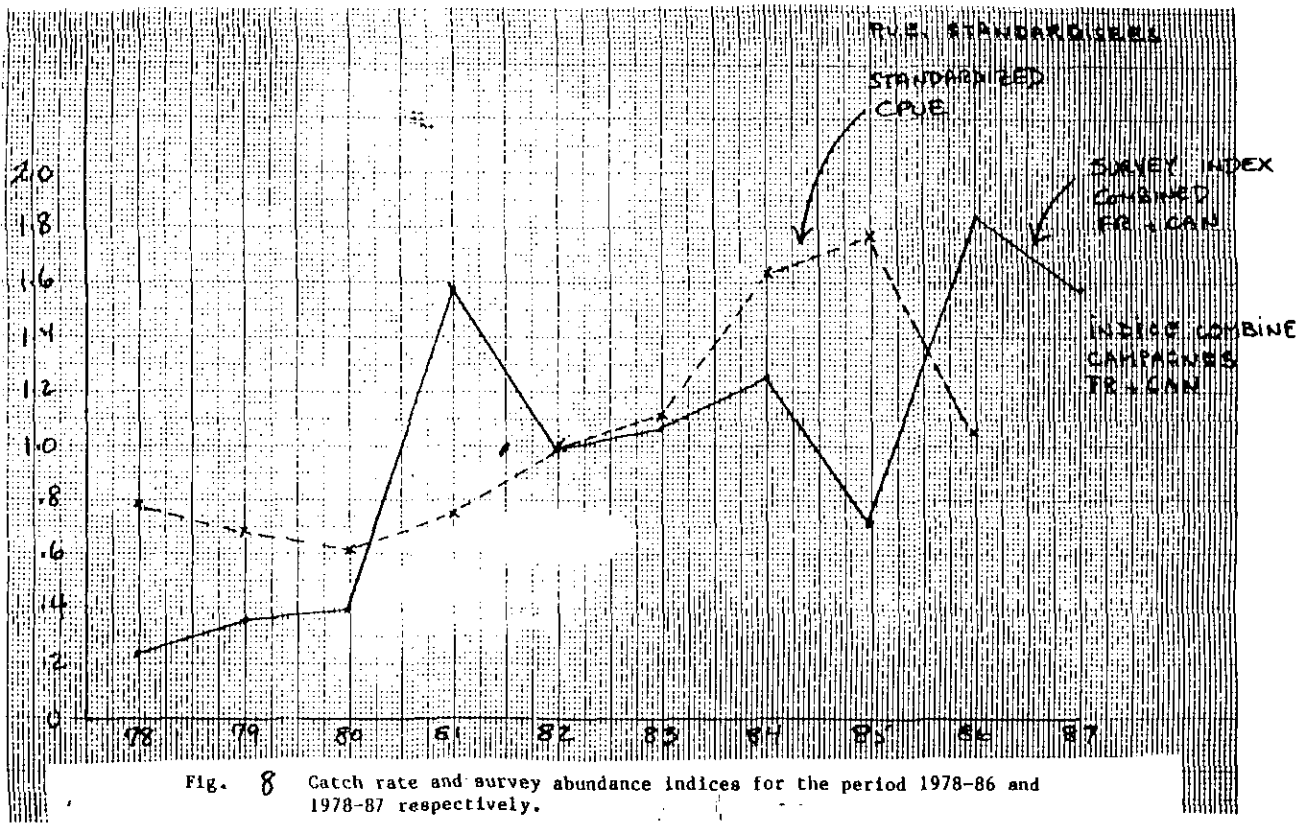

Fig. 8 Catch rate and survey abundance indices for the period 1978-86 and 1978-87 respectively.

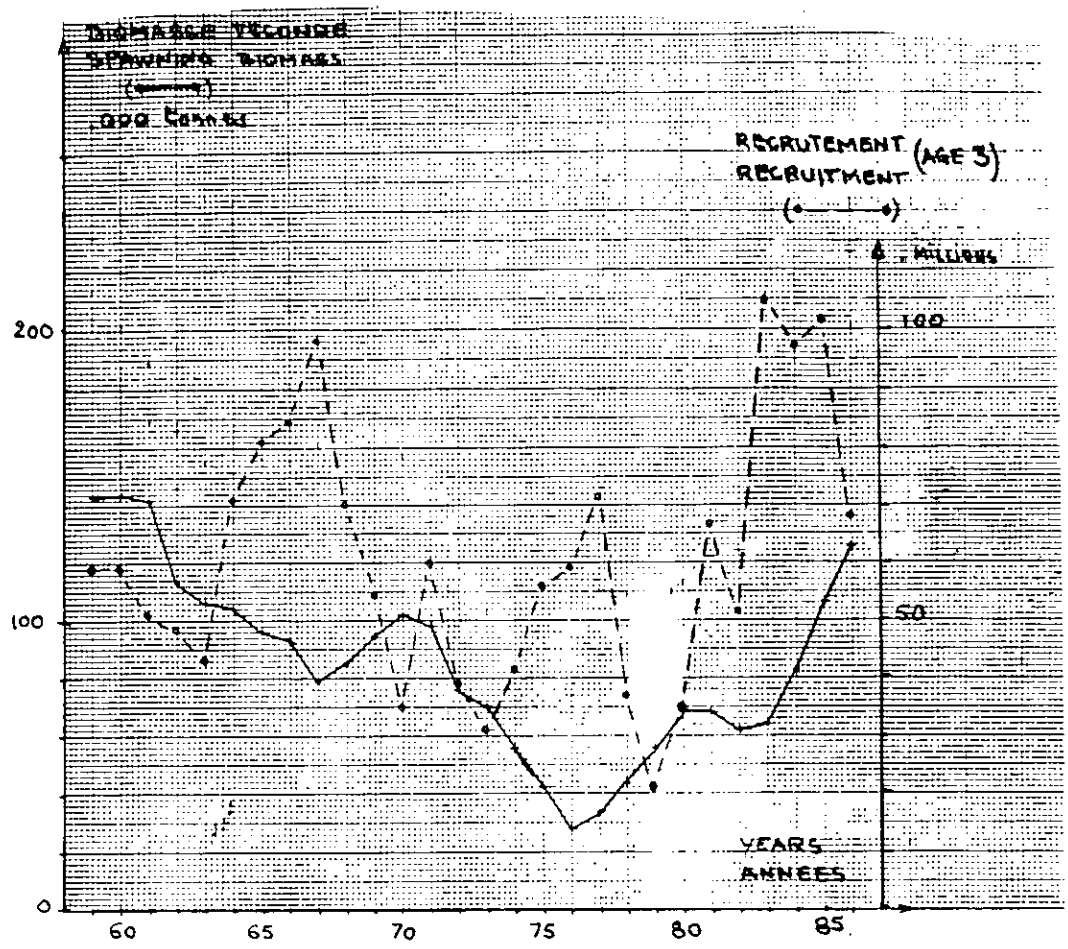

Fig. 9. Trends in spawning biomass (000 t) and recruitment (millions) at age 3 in the period 1959-1986.

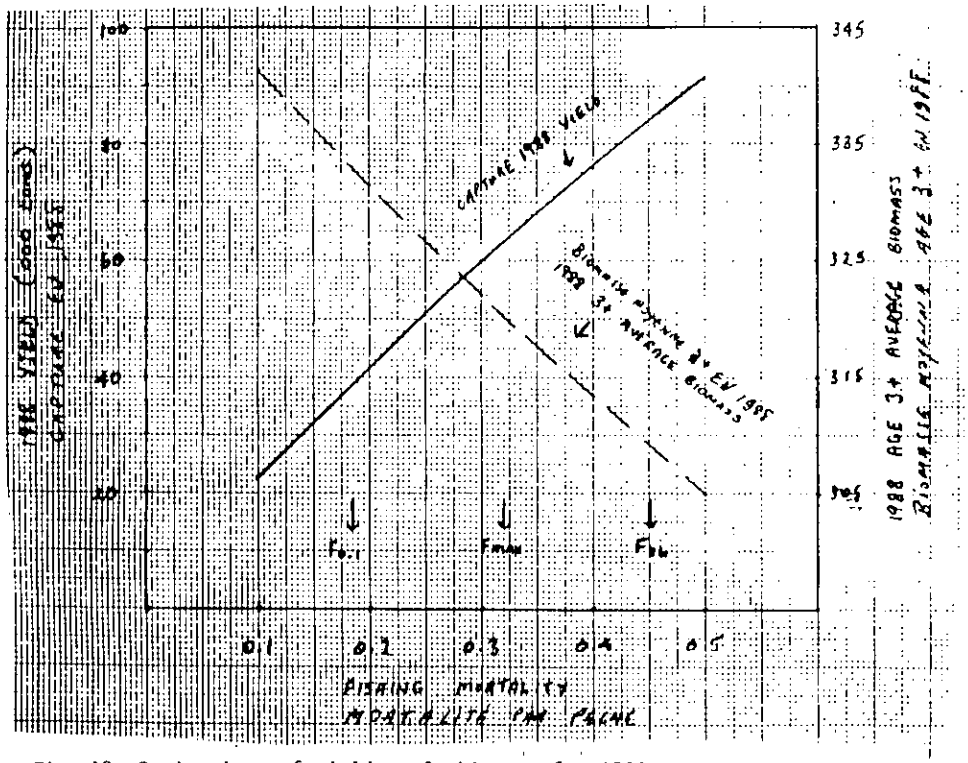

Fig. 10. Projections of yield at 3+ biomass for 1988 at various fishing mortalities.

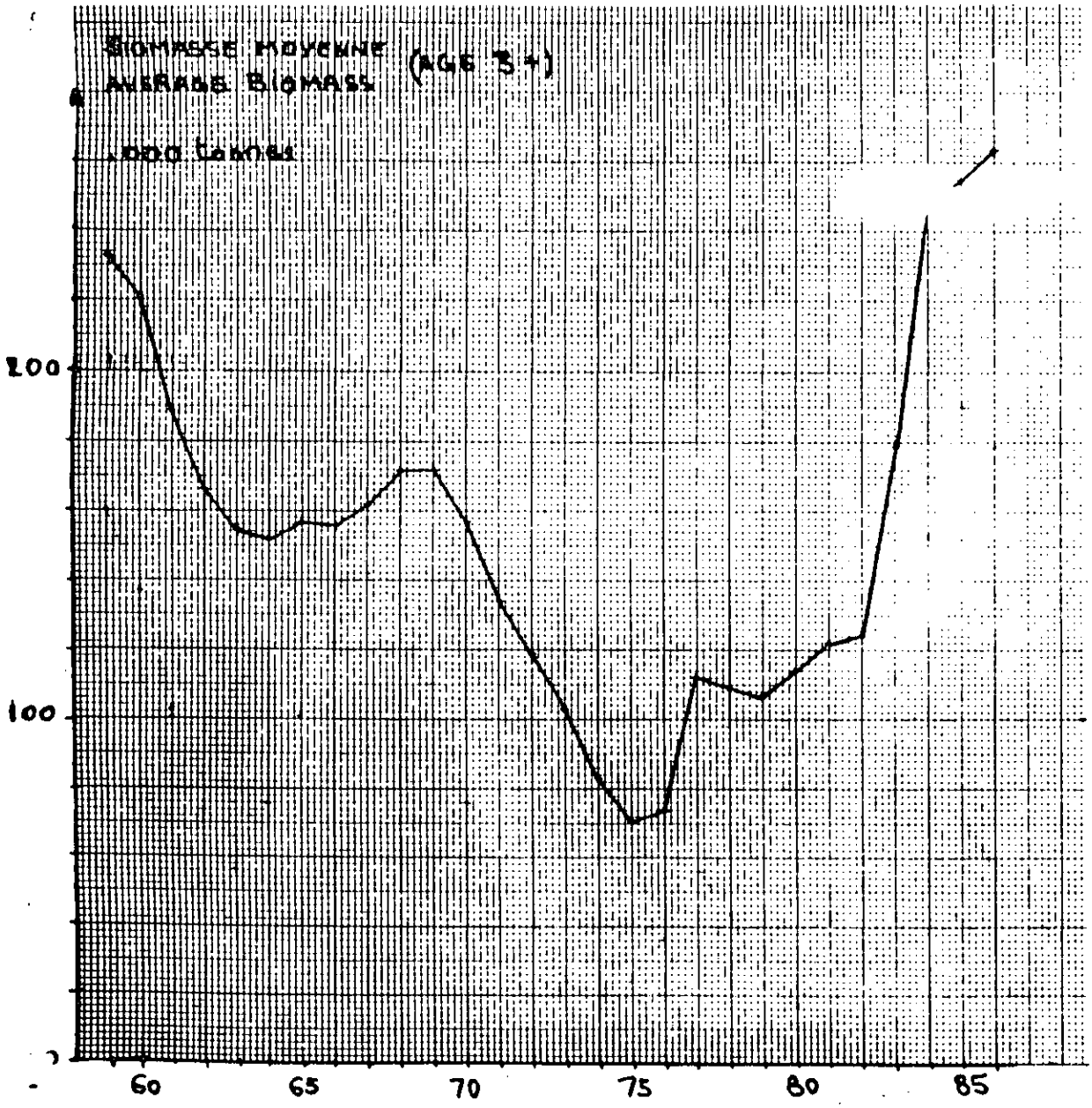

Fig. 11. Mean 3+ biomass (000 t) from 1959-1986.