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A New Approach to Subdiv. 3Ps Cod Stock Assessment

by

J. Bertrand

Institut Francais de Recherche pour l'Exploitation de la Mer
Quai de l'Alysse, B. P. 4240, 97500 St. Pierre et Miquelon

and

A. Laurec

Institut Francais de Recherche pour l'Exploitation de la Mer
66 Avenue d'Iena, 75116 Paris

and

A. Maucorps and B. Mesnil

Institut Francais de Recherche pour l'Exploitation de la Mer
Rue de l'Ile d'Yeu, B. P. 1049, 44037 Nantes Cedex 01

INTRODUCTION

The discrepancies in the results of the assessment made on the cod stock of the Subdivision 3Ps in 1987 and 1988 (ANON., 1988 a & b), and some questionnable aspects of these assessments, have lead us to make a reassessment based on new approches developped in ICES, and especially within the "Method Working Group" (Anon., 1987). The so-called LAUREC and SHEPHERD (1982) tuning method described by POPE and SHEPHERD (1985) has been applied to revise the VPA with a consistent use of groundfish survey data (part 1). Based on the estimated state of the stock in 1987, catch projections for 1989 are derived (part 2). The evolution of the stock in the last 25 years is finally discussed (part 3).

I. VPA Tuning

I.1. Method

The tuning method adopted here differs from the procedures previously used for this stock on several points. The first one concerns the partial recruitment (or exploitation) pattern which is usually assumed to yield a constant fishing mortality from ages 7 and older in NAFO reports.

This assumption is not backed by our experience with the cod stocks in the Eastern Atlantic area, and seems not consistent with the evidence of changes from quarter to quarter in the relative importance of young adults (up to age 8) and older individuals in the commercial catches as suggested by the age composition of the SPM fleet landings (annnexe 1).

We have therefore assumed that the fishing mortality at age 14 is equal to the average value over ages 9 to 13. The fishing pattern is thus made more flexible than previously assumed.

The tuning technique itself is an extension of the conventional VPA, the fishing mortalities for the final year (1987) being infered through an iterative tuning procedure described by POPE and

SHEPHERD (1985), which makes use of the information brought in by time series of abundance indices at age (e.g., survey results or c.p.u.e. by fleets corrected for changes of fishing power). We have checked that the results obtained are robust to the number of iterations, and to the starting values adopted for the terminal fishing mortalities (on the age 14 and for the year 1987).

The iterative search can be summarised as follows :

A VPA using input values of terminal F in 1987 provides estimates of stock numbers at age. An array of abundance indices at age obtained in routine groundfish surveys being available for the years considered, the ratios of these indices to the numbers at age provide for each age a time series of catchability estimates.

The basic tuning technique assumes that the true catchabilities for a given age vary without trend (only random white noise), as is expected when surveys are designed. An estimate of the catchability at age for the final year can thus be obtained by calculate an arithmetic mean over the past years, which is preferably computed after a logarithmic transformation of the data.

For each age, the abundance index in the last year can be multiplied by the infered catchability to yield an estimate of stock size at that age. The ratio of partial catch in the survey over stock size can be solved for partial fishing mortality which is eventually expanded to the total fishing mortality corresponding to total catches at the same age in the last data year. The fishing mortalities for age 14 in each year can then be taken as the averages over an appropriate range of ages. The VPA can now be started again using the new terminal fishing mortalities. Currently, the iterations stop after a fixed number of loops (here equal to 20).

When several indices series are available (for example, we have here the French and Canadian survey results, table 2 a, b), each series yields its own estimate of abundance at age in the final year. For each age, a combined estimate is formed as the weighted mean of the individual log abundance estimates, the weighting factors being the inverse of the variances of the log catchabilities over the years within each serie for that age.

It must be stressed that in this method the tuning is performed successively and independently on each age. Any attempt to combine abundance indices over various ages would imply taking into account the pattern of catchabilities at age, which are unknown.

Finally one can notice that no attempt was made to use the commercial catch rates although these might be less affected by the timeliness of surveys. The expected trouble with these data is that the assumption of constant catchabilities at age over time is unlikely to hold true and some modelling of their evolution is required. This is done for example in the so called hybrid tuning method which allows for a linear trend of the log catchabilities at each age for commercial fleets (or exponential trend of the untransformed q's).

I.2. VPA results

The VPA was made on catch at age data given in table 1 and tune using Canadian and french survey results in 1978-1987. Mean weights at age (table 3) and maturity ogives used to calculate biomasses are identical to those used in the June assessment of the 3Ps cod stock.

Fishing mortality and stock numbers calculated back to 1959 are given in tables 4 and 5. The trends of the mean fishing mortality over ages 7 to 11, of spawning stock biomass and of recruitment at age 3, resulting from the present assessment are given in figures 1 and 2 respectively.

These trends are similar to those from the previous assessment in which the terminal F was set at 0.50 on ages 7 and older. The absolute values of the mean F7-11 do not differ significantly between both assessments for most of the years even though they are slightly lower in the present one.

After a period of rather intense exploitation with an increasing fishing mortality in the late sixties and early seventies, fishing mortality dropped drastically in 1976-77 and has remained at a stable and moderate level thereafter. The fishing mortality exerted on this stock over the last ten years had no adverse effect on the spawning stock biomass which increased in the mean time by a factor of about 3.5-4. Despite noticeable fluctuations, recruitment also shows an increasing trend.

Catch-biomass ratios (Fig.3) have been calculated over the last 25 years and smoothed values (3 years running averages) to reduce noise are plotted in figure 3. This clearly shows that the stock is currently exploited at quite low levels compared to the period 1960-1975, and even the increase of catches in recent years did not reverse the trend since both stock biomass and recruitment are increasing faster.

I.3. Discussion

I.3.1. Underlying assumptions

The crucial assumption is that the catchabilities at age in surveys are only subject to random fluctuations over time. The series of average catchabilities over ages 3 to 5 (fig. 4) tends to indicate that this assumption is probably violated.

A careful examination of table 6 shows that for the younger ages (3 to 5), two major changes have occured in the Canadian results, one between 1982 and 1983, the other between 1983 and 1984. These are apparently related to switches of the research vessels used. For older ages, the changes in catchability seem to be just in the opposite direction, which suggests changes in selectivity.

In the French surveys, some changes seem to have occured between 1980 and 1981 (Fig 4 a & b). But it has not been possible to find any satisfactory explanation for these.

It must be pointed out that the same assumption is involved in most tuning techniques, even though a critical examination of the estimated catchability series is seldom performed.

In order to reduce the departures from the assumption it can be envisaged to restrict the tuning period by removing the earlier years. This however would increase the sensitivity (see paragraph I.3.2.). It would also be possible to eliminate the apparently less reliable series (the Canadian ones : cf standard errors in table 6), but again this would increase the sensitivity of the results.

I.3.2. Sensitivity

Several attempts have been made in addition to the run yielding what is considered to be the most reliable results. The number of ages over which the average mortality is computed to estimate F at age 14 has been reduced down to 2 without significant impact.

The tuning has been performed with consideration of either the French surveys only, or the Canadian surveys only. In both cases this leads cases to higher TAC for 1989 but the critical point is the sensitivity to the survey results in the last year. This explains a significant part of the discrepancy between the results that would have been obtained using the same technique in 1987, and the 1988 assessment (see Fig. 6).

This later assessment suggests that in 1987 the surveys showed abnormally high catchabilities at ages 4 to 6 which are dominant in the catches, whereas an assessment conducted in 1987 would have assumed average ones.

Examination of the past series indicates that the variances of survey results are quite large. Although the tuning method used here seems largely preferable to the ad hoc techniques used previously, the sensitivity of the diagnosis on the status of the stock in the last year is likely to remain high. However, due to the convergence property of VPA, the diagnosis for the past years is much more robust.

II. CATCH PROJECTION

II.1. Technical considerations

II.1.1. Yield per recruit

The weight at age data are the same as those used in June 1988 which seem more reliable than those used in previous assessments, and the exploitation pattern is the average over 1977-1986. The ways in which fish over age 14 can be treated have been explored by performing three yield per recruit calculations :

- the first one ignores any survival of fish beyond age 14,
- the second one considers age 14 to be a plus group (14 +),
- the third one considers explicity a survival from ages 15 to 20, at age 14 is continued up to age 20.

Under the reference exploitation pattern, the yields per recruit were calculated by applying increasing effort multipliers (PAULIK and BAYLIFF, 1967). As the usage goes, the normalised average over ages 7 to 11 is also given for each value of the multiplier. The yield per recruit curves obtained in calculations 2 and 3 are quite similar. The third one has been retained and the conventional reference points (F0.1 and Fmax) have been computed.

Since F was not assumed here to be constant beyond age 6, it is difficult to compare directly the values obtained to those calculated in previous assessments, but the differences in terms of average F are small.

II.1.2. 1989 projections

Input data and fishing pattern options in 1988 and 1989 were set up with the same approach as used in the June 1988 assessment. The weights at age in 1988 and 1989 are averages of those in commercial catches in 1985-87. The exploitation pattern has been taken exactly as indicated by the F vector from the tuned VPA for 1987 although it would have been more realistic to use an average over, say, the last 3 years. Although this is questionable, the size of the 1985 and 1986 year classes at recruitment (age 3) was assumed to be equal to that of the 1980 year class ; a consistent utilisation of survey indices for these classes yields larger recruitments but the predicted catches are not greatly increased.

Two scenarii were considered when making the catch projections, based on different catch levels for the interim year (1988). In the first scenario, this catch is set at 57 000 t -a figure comparable to the level for 1987 retained by STACFIS at the June meeting-. The second sets the constraint at a somewhat lower level to account the reduced access experienced in 1988 by a component of the fishing fleet i. e. the French offshore trawler fleet; the overall international catch was thus set at the arbitrary level of 50 000 t.

The projections for 1989 have been made for exploitation levels corresponding to F0.1 and Fmax, but also for a status quo option (same Fs as estimated in 1987), and finally for an effort level satisfying the constraint of maintaining the spawning biomass at the start and at the end of 1989.

II. 2. Results

II.2.1. 1988 catches constrained at 57 000t

1988			1989				1990
SSB	F7-11	Catch	SSB	Option	F7-11	Catch	SSB
170	.44	57.0	181.9	$F_{0.1}$	0.15	24.6	238.4
				F_{max}	0.27	42.4	219.8
				F_{97}	0.50	72.9	188.1
				SSB=182	0.57	80.3	180.6

Predicted catches and biomasses in thousand tonnes.

II.2.2. 1988 catch constrained at 50 000 t.

1988 SSB	F7-11	Catch	1989 SSB	Option	F7-11	Catch	1990 SSB
170	.38	50.0	189.3	$F_{0.1}$	0.15	25.5	246.1
				F_{max}	0.27	43.9	222.7
				F_{87}	0.50	75.5	193.9
				SSB=189	0.57	81.7	187.5
				SSB=182	0.61	88.6	180.5

Predicted catches and biomasses in thousand tonnes.

II.2.3. Comments

Whichever scenario is considered, the predicted catch corresponding to the $F_{0.1}$ level will be about 25 000 t in 1989 whereas the catch at F^{max} will range from 42 000 to 44 000 t. It must be noted that in all options the resulting 1990 spawning stock biomass continues to increase above the 1988 figure and reaches a level comparable to the historical high ones at the start of the period under consideration. Only if the 1989 catch did exceed 80 000 t, would the SSB in 1990 decrease slightly under its level at the start of 1989.

III. HISTORICAL TREND AND PRESENT STATE OF THE STOCK

III.1. Biomass and exploitation rate

The spawning biomass has been severely reduced from 1960 to 1976, however a steady increase has taken place since then. This appears clearly in figure 2 of the present paper, as well as in figure 10 in the provisionnal report of the NAFO Scientific Council (Anon 1988 a). Simultaneously fishing mortality has decreased in 1976, and has been levelling therafter at a moderate level, resulting in quite low catch/biomass ratios . Despite some uncertainties on VPA results in the final year or possible differences arising from the choice of alternative tuning method, these conclusions appear to be very robust mainly as a consequence of the convergence properties of VPA.

Thus, the basic feature of this stock is a quick recovery, associated with moderate exploitation rates since 1976.

This optimistic statement is backed by a calculation of spawning biomass per recruit, as defined by Suda (1974), and recently promoted by Sissenwine and Shepherd (1984).

As suggested in Anon. 1984, the F high, F med, and Flow lines have been drawn on the stock-recruitment plot based on VPA results.

The current situation corresponds to a spawning biomass per recruit close to F med (and even slightly lower). This confirms the healthy situation of this stock, and the absence of immediate biological danger associated with excessive fishing.

This is true even with a status quo fishing mortality option, wich would let the spawning biomass increase during 1989. In fact it appears that even a catch of 80 000 tonnes in 1989 according to the present assessment, or 75 000 tonnes in the June assessment, would allow the spawning biomass to increase .

Finally, set aside the argument about the 1989 TAC, it must be recalled that considering an average recruitment of 60 million fish and a yield of 0.9 kg per recruit (quite similar whether considering either F0.1 or Fmax) a long term equilibrium yield around 55 000 tonnes would be forecasted.

III.2. Management strategies

Since no recruitment overfishing is to be feared for this stock, the choice of an exploitation rate corresponding to F0.1 or Fmax is only a matter of sociological, economic and political choices which have not to be considered here. Any scientific assessment should however recognize that the fishery is at present far from optimum and that for any long term goal for the exploitation rate, several strategies can be envisaged to achieve it.

Because of the unavoidable uncertainties in the VPA estimates for the last data year, the implementation of TAC's with reference to either Fmax or F0.1 on a yearly basis is bound to create large fluctuations of recommended catches. These are detrimental to both the acceptability by the industry and the credibility of the scientific community.

Other strategies can be considered. It seems that any 1989 TAC below 73/75 000 tonnes according to our assessment, or below 65 000 tonnes according to the previous 1988 assessment would decrease the current fishing mortalities.

It should be emphasized that a TAC close to 45 000 tonnes corresponding to the Fmax option in the present assessment (and close to the TAC set for 1988) would, according to the June assessment, lead to a reduction of the exploitation rate and to an increase in the spawning biomass.

CONCLUSION

The use of a tuning technique experienced and discussed by several ICES working groups attented by scientists from various countries results in a more optimistic assessment of the present status of the stock.

Further work should however be devoted to the tuning problem since regardless of the tuning technique itself, significant uncertainties affect the estimation of the stock in the last year. The incorporation of commercial effort data may reduce these uncertainties provided that disaggregated data should be collected and/or made available routinely; if these were defined on a fleet basis, this would increase significantly our understanding of the stock and fisheries and also make it possible to analyse the interactions between fleets having different fishing patterns.

Management objectives could then be set and measures taken with more consideration being given to the implications for the different fleet components.

In any case it is essential to consider management strategies avoiding dramatic year to year changes in the recommended TAC's. For the 3Ps cod stock in particular which has considerably increased in recent years and is not facing any recruitment overfishing, this seems to be achievable without imposing additional restrictions to the industry.

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ANNEXE I

Quarter	I	II	III1	IV	TOTAL
Age					
2	0	0	0	0	0
3	0	8	0	69	78
4	85	37	1	391	514
5	852	1329	43	1035	3259
6	1187	1115	36	884	3222
7	615	338	11	384	1348
8	228	57	2	108	395
9	194	12	0	52	258
10	40	0	0	24	64
11	29	0	0	6	35
12	0	6	0	0	6
13	7	0	0	7	15
14	0	0	0	0	0
15	0	0	0	0	0
Total (no)	3238	2902	93	2960	9193
Catch (t)	5585	3820	122	5689	15216

1) same age distribution used as in the second quarter.

Catch at age (* 000) per quarter in 1987 for the trawler fleet from Saint-Pierre et Miquelon

Table 1 : Total catch at age (*ooo) of cod in Subdivision 3 Ps

Year	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Age										
3	1001	567	450	1245	961	1906	2314	949	2871	1143
4	13940	5496	5586	6749	4499	5785	9636	13662	10913	12602
5	7525	23704	10357	9003	7091	5635	5799	13065	12900	13135
6	7265	6714	15960	4533	5275	5179	3609	4621	6392	5853
7	4875	3476	3616	5715	2527	2945	3254	5119	2349	3572
8	942	3484	4680	1367	3030	1881	2055	1586	1364	1308
9	1252	1020	1849	791	898	1891	1218	1833	604	549
10	1260	827	1376	571	292	652	1033	1039	316	425
11	631	406	446	187	143	339	327	517	380	222
12	545	407	265	140	99	329	68	389	95	111
13	44	283	560	135	107	54	122	32	149	5
14		27	58	241	92	27	36	22	3	107
Catch t	60170	72636	83620	52639	51821	56567	51854	66207	62774	77556

Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Age										
3	774	756	2884	731	945	1887	1840	4110	935	502
4	7098	8114	6444	4944	4707	6042	7329	12139	9156	5146
5	11585	12916	8574	4591	11386	9987	5397	7923	8326	6096
6	7178	9763	7266	3552	4010	6365	4541	2875	3209	4006
7	4554	6374	8218	4603	4022	2540	5867	1305	920	1753
8	1757	2456	3131	2636	2201	1857	723	495	395	653
9	792	730	1275	833	2019	1149	1196	140	265	235
10	717	214	541	463	515	538	105	53	117	178
11	61	178	85	205	172	249	174	17	57	72
12	120	77	125	117	110	80	52	21	43	27
13	67	121	62	48	14	32	6	4	31	17
14	110	14	57	45	29	17	2	3	11	10
Catch t	63799	76858	62448	44213	52641	46712	35373	37133	32245	27221

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age									
3	135	368	1022	130	760	203	206	277	580
4	3072	1625	2888	5092	2682	4521	4718	4924	2917
5	10321	5054	3136	4430	9174	4538	11473	10159	10799
6	5066	8156	4652	2348	4080	7018	6118	11180	9490
7	2353	3379	5855	2861	1752	2221	5072	4247	5171
8	721	1254	1622	2939	1150	584	1496	2144	1355
9	233	327	539	640	1041	542	417	639	1187
10	84	114	175	243	244	338	377	220	324
11	53	56	67	83	91	134	333	168	157
12	24	45	35	30	37	35	131	141	76
13	13	21	18	11	18	8	24	78	120
14	10	25	2	7	8	8	12	23	50
Catch t	33006	37568	38892	33902	38451	36950	51367	57290	57301

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	1.57	0.39	1.72	4.91	1.96	5.40	7.64	14.49	4.21	11.51	14.89
4	3.08	2.08	0.50	4.94	8.32	2.98	15.07	7.47	15.19	2.83	9.22
5	2.05	7.29	2.67	5.14	7.97	7.21	8.74	3.93	26.47	8.30	3.62
6	1.20	3.27	4.52	7.45	6.06	6.11	18.97	1.06	21.66	12.49	6.53
7	0.89	1.82	1.66	5.64	4.55	4.55	5.59	1.95	9.12	8.32	4.69
8	0.52	0.96	0.67	1.60	5.30	2.77	2.13	1.14	6.97	2.95	1.60
9	0.30	0.38	0.29	1.19	1.58	2.08	3.09	0.78	3.85	1.94	0.78
10	0.22	0.22	0.22	0.47	0.87	0.75	2.21	0.86	0.79	0.95	0.35
11	0.02	0.29	0.18	0.15	0.42	0.25	0.61	1.09	0.59	0.20	0.35
12	0.04	0.09	0.11	0.14	0.15	0.19	0.16	1.32	0.72	0.36	0.16
13	0.01	0.10	0.08	0.06	0.21	0.08	0.13	0.12	0.22	0.15	0.15

Table 2a : Mean numbers of cod at age per tow from French research vessel surveys in NAFO Subdivision 3Ps adjusted for missing strata.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	3.63	1.20	0.71	1.79	4.03	2.26	1.84	0.49	2.20	0.71	1.06	1.01
4	3.19	4.52	6.57	0.89	6.62	11.11	1.01	0.89	5.61	3.04	2.39	1.47
5	2.96	1.97	15.76	2.35	7.23	5.12	5.48	0.68	7.23	5.44	10.89	2.15
6	0.88	1.43	2.49	2.10	9.31	2.40	2.80	2.88	3.25	5.52	8.15	5.90
7	0.24	1.03	0.83	0.53	8.72	3.21	0.98	1.15	2.96	2.22	3.83	5.03
8	0.19	0.72	0.44	0.61	1.73	3.32	1.92	0.59	0.93	1.84	1.62	2.96
9	0.30	0.43	0.18	0.19	1.70	0.90	3.58	0.74	0.55	1.08	1.08	1.19
10	0.11	0.39	0.15	0.17	0.39	0.24	1.66	1.15	0.54	0.38	0.46	0.78
11	0.02	0.14	0.03	0.13	0.07	0.17	0.80	0.28	0.56	0.32	0.34	0.69
12	0.05	0.05	0.02	0.15	0.11	0.07	0.30	0.21	0.62	0.37	0.30	0.36
13	0.05	0.05	0.02	0.06	0.11	0.03	0.12	0.09	0.26	0.20	0.30	0.20

Table 2b : Mean numbers of cod at age per tow from Canadian research vessel surveys in NAFO Subdivision 3Ps including factors used to adjust for missing strata and for seasonality.

Table 3 : Mean weigt (Kg) at age in the catch

Year / Age	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
3	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28
4	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69
5	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
6	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
7	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
8	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21
9	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
10	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
11	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
12	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
13	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05
14	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16

Year / Age	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
3	.28	.28	.28	.28	.28	.28	.28	.28	.55	.45
4	.69	.69	.69	.69	.69	.69	.69	.69	.68	.70
5	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.30	1.08
6	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.86	1.75
7	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.67	2.45
8	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.42	2.99
9	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.19	4.10
10	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	4.94	5.16
11	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	5.92	5.17
12	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.76	7.20
13	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.78	7.75
14	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	10.90	8.72

Year / Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
3	.41	.52	.48	.45	.58	.66	.64	.54	.55
4	.65	.72	.79	.77	.84	1.04	.98	.75	.74
5	1.01	1.13	1.32	1.17	1.33	1.40	1.36	1.18	1.20
6	1.65	1.66	1.80	1.78	1.99	1.97	1.93	1.84	1.75
7	2.55	2.48	2.30	2.36	2.58	2.64	2.51	2.43	2.48
8	3.68	3.60	3.27	2.88	3.26	3.77	3.43	3.15	3.20
9	4.30	5.40	4.36	3.91	3.77	4.75	4.35	4.30	4.26
10	6.49	6.95	5.68	5.28	5.04	5.56	5.06	5.50	5.06
11	7.00	7.29	7.41	6.18	6.56	6.01	5.42	6.19	6.10
12	8.20	8.64	9.04	8.62	8.45	9.04	9.37	8.72	7.07
13	9.53	9.33	8.39	8.64	10.06	11.20	11.95	8.05	7.40
14	10.84	9.58	9.56	11.41	11.82	10.40	10.85	11.91	8.34

Table 4: Fishing mortality at age

Year	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Age										
3	.019	.011	.010	.029	.025	.030	.032	.013	.033	.018
4	.159	.135	.138	.202	.139	.208	.210	.269	.196	.197
5	.276	.442	.404	.342	.338	.257	.332	.488	.439	.382
6	.404	.424	.609	.310	.344	.443	.261	.483	.471	.365
7	.392	.344	.427	.459	.285	.329	.557	.718	.487	.528
8	.206	.540	1.103	.283	.473	.355	.403	.586	.421	.555
9	.376	.360	.623	.543	.304	.616	.411	.772	.465	.298
10	.578	.459	1.217	.397	.395	.379	.836	.749	.284	.706
11	.255	.370	.484	.509	.162	1.134	.331	1.564	.691	.330
12	.387	.259	.441	.274	.560	.673	.733	.835	1.859	.441
13	.400	.357	.681	.423	.348	.691	.572	.966	.941	.440
14	.000	.357	.681	.423	.348	.691	.572	.966	.941	.440
7-11	.361	.415	.771	.438	.324	.563	.508	.878	.470	.484

Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Age										
3	.016	.024	.055	.021	.035	.053	.039	.083	.014	.014
4	.151	.232	.289	.126	.183	.326	.295	.379	.268	.100
5	.280	.447	.410	.345	.471	.723	.542	.601	.486	.288
6	.372	.404	.490	.297	.575	.528	.887	.631	.524	.459
7	.541	.667	.711	.667	.645	.911	1.480	.698	.423	.614
8	.541	.638	.837	.523	.806	.715	.730	.439	.469	.607
9	.792	.455	.830	.558	1.014	1.519	1.657	.296	.447	.570
10	.799	.512	.731	.852	.824	.851	.519	.268	.432	.617
11	.200	.467	.393	.690	.942	1.384	.756	.145	.514	.520
12	.299	.416	.709	1.580	1.043	2.067	1.435	.184	.652	.492
13	.524	.558	.704	.662	.843	1.057	1.026	.365	.451	.587
14	.524	.558	.704	.662	.843	1.057	1.026	.365	.451	.587
7-11	.575	.548	.700	.658	.846	1.076	1.028	.369	.457	.586

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	77-86
Age										
3	.007	.011	.018	.003	.010	.002	.003	.008	.006	.009
4	.114	.103	.117	.115	.081	.072	.066	.080	.110	.112
5	.297	.277	.293	.263	.310	.190	.264	.197	.252	.287
6	.412	.405	.442	.373	.412	.414	.422	.444	.286	.431
7	.540	.536	.573	.539	.529	.414	.600	.586	.379	.535
8	.556	.625	.537	.643	.433	.336	.547	.552	.373	.531
9	.455	.530	.609	.420	.496	.375	.427	.479	.688	.481
10	.410	.422	.610	.620	.280	.295	.487	.420	.478	.459
11	.374	.530	.472	.667	.501	.244	.530	.418	.604	.477
12	.326	.631	.760	.401	.725	.365	.399	.449	.339	.520
13	.468	.528	.563	.576	.448	.333	.460	.441	.880	.485
14	.468	.528	.563	.576	.448	.333	.460	.441	.598	.485
7-11	.467	.529	.560	.578	.448	.333	.518	.491	.504	

Table 5 : Stock in number (*000) at age and Total/ Spawning stock/ biomasses (t)

Year	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Age										
3	59423	59060	50043	48125	42391	70332	80206	83353	97784	69369
4	104062	47747	47842	40565	38277	33839	55861	63578	67386	77466
5	34259	72640	34139	34135	27136	27284	22497	37061	39767	45345
6	23949	21283	38209	18655	19860	15847	17270	13209	18629	20986
7	16493	13087	11401	17010	11200	11522	8329	10893	6671	9520
8	5559	9128	7593	6090	8801	6898	6787	3906	4349	3356
9	4377	3703	4354	2064	3757	4489	3958	3713	1779	2337
10	3135	2460	2116	1911	981	2269	1984	2148	1405	915
11	3085	1440	1272	513	1052	541	1272	704	831	866
12	1860	1958	814	642	252	733	143	748	121	341
13	146	1034	1237	429	399	118	306	56	265	15
14	0	99	128	766	343	59	90	39	5	329
TT B	289777	283688	252918	206265	190946	188739	194355	204522	200564	215702
SSB	175523	181401	173112	137634	129879	123943	115542	111464	97752	109733

Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Age										
3	53422	35261	59342	38683	30168	40506	53619	56746	73790	38957
4	55762	43039	28186	45981	31010	23846	31460	42238	42752	59569
5	52077	39258	27936	17284	33189	21150	14095	19169	23683	26768
6	25334	32221	20556	15178	10027	16963	8401	6708	8607	11925
7	11926	14297	17618	10315	9234	4621	8188	2834	2922	4173
8	4596	5687	6010	7087	4333	3965	1522	1526	1155	1567
9	1577	2189	2461	2130	3439	1585	1588	601	806	591
10	1419	585	1138	878	999	1022	284	248	366	422
11	370	523	287	449	307	359	357	138	155	195
12	510	248	268	159	184	98	74	137	98	76
13	180	309	134	108	27	53	10	14	94	42
14	295	36	123	101	55	28	3	11	33	25
TT B	219233	208319	184027	153041	141639	118178	101331	94438	136153	130610
SSB	125674	134092	123679	90086	87868	72078	53920	36698	46959	52671

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Age										
3	22539	35671	64363	46716	88023	99632	86205	37942	106965	
4	31442	18332	28872	51773	38131	71381	81388	70393	30814	87052
5	44130	22973	13543	21035	37797	28799	54359	62375	53191	22598
6	16435	26853	14264	8269	13237	22701	19493	34187	41921	33834
7	6170	8910	14666	7505	4662	7177	12288	10470	17961	25790
8	1849	2945	4269	6768	3583	2248	3883	5524	4772	10063
9	699	869	1290	2043	2914	1902	1316	1840	2603	2691
10	274	363	418	574	1099	1453	1071	703	933	1071
11	186	149	195	186	253	680	886	539	378	474
12	95	105	72	100	78	125	436	427	290	169
13	38	56	46	27	55	31	71	240	223	169
14	29	67	5	17	24	31	36	71	121	76
TT B	131451	145349	155474	150888	203085	275456	311908	274235	301473	
SSB	70639	89964	87218	74838	86844	107847	130251	129936	149696	

Table 6 : Research vessel catchability

CANADA

Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Mean	Std error
3	-10.28	-10.26	-9.80	-9.57	-9.84	-10.67	-12.12	-10.84	-10.78	-11.35	-10.55	.81
4	-9.34	-8.32	-9.79	-8.23	-8.29	-10.40	-11.16	-9.45	-9.91	-9.31	-9.42	1.006
5	-9.28	-7.70	-8.96	-7.30	-8.10	-8.59	-10.46	-8.70	-9.15	-8.28	-8.65	.94
6	-8.74	-8.50	-9.17	-7.03	-7.87	-8.17	-8.68	-8.40	-8.43	-8.31	-8.33	.602
7	-7.95	-8.60	-9.38	-7.07	-7.41	-8.12	-8.45	-7.96	-8.09	-8.18	-8.12	.663
8	-7.33	-8.04	-8.15	-7.46	-7.23	-7.23	-7.99	-7.99	-7.65	-7.72	-7.68	.369
9	-6.95	-8.00	-8.16	-6.35	-7.43	-6.37	-7.58	-7.48	-7.12	-7.38	-7.28	.633
10	-6.61	-7.35	-7.44	-6.74	-7.56	-6.25	-6.90	-7.27	-7.23	-7.30	-7.07	.441
11	-6.58	-8.47	-6.90	-7.72	-6.84	-5.70	-7.57	-7.02	-7.13	-6.64	-7.06	.783
12	-7.63	-7.69	-6.18	-6.39	-7.13	-5.57	-6.51	-6.25	-6.74	-6.62	-6.67	.691
13	-6.83	-8.12	-5.46	-5.70	-7.06	-6.04	-6.24	-5.84	-6.75	-6.12	-6.42	.83
Mean	-7.96	-8.28	-8.13	-7.23	-7.71	-7.56	-8.51	-7.93	-8.09	-7.93	-7.93	
3-7	-9.118	-8.676	-9.42	-7.84	-8.302	-9.19	-10.17	-9.07	-9.272	-9.086	-9.01	
3-5	-9.41	-8.695	-9.43	-8.033	-8.525	-9.458	-10.61	-9.348	-9.568	-9.313	-9.24	

FRANCE

Year Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Mean	Std error
3	-10.01	-10.86	-9.84	-9.37	-9.98	-9.60	-9.38	-8.59	-9.00	-8.96	-9.56	.684
4	-9.72	-9.47	-10.36	-8.52	-8.58	-9.32	-8.33	-9.17	-8.30	-9.14	-9.09	.7
5	-9.24	-8.47	-8.83	-7.64	-7.66	-8.32	-7.91	-9.31	-7.57	-8.55	-8.35	.681
6	-8.91	-8.23	-8.40	-7.25	-6.95	-7.39	-6.80	-9.52	-7.06	-7.89	-7.84	.957
7	-8.10	-7.81	-8.24	-7.50	-7.06	-6.59	-6.87	-8.38	-6.68	-7.40	-7.46	.687
8	-7.66	-7.26	-8.06	-7.54	-6.76	-6.86	-6.71	-7.78	-6.32	-7.12	-7.21	.577
9	-7.31	-7.25	-7.74	-6.70	-6.86	-6.92	-6.15	-7.13	-5.85	-6.79	-6.87	.581
10	-7.18	-6.97	-7.18	-6.55	-6.27	-7.05	-6.25	-6.80	-6.50	-6.57	-6.73	.37
11	-8.53	-6.20	-6.58	-6.95	-5.93	-6.86	-6.79	-6.36	-6.52	-7.17	-6.79	.748
12	-7.86	-6.18	-6.49	-6.15	-6.36	-6.03	-6.78	-5.50	-6.08	-6.43	-6.39	.65
13	-8.44	-6.51	-5.17	-6.31	-5.11	-6.44	-5.87	-6.62	-6.66	-6.81	-6.39	.984
Mean	-8.45	-7.75	-7.90	-7.32	-7.05	-7.40	-7.08	-7.74	-6.96	-7.53	-7.52	
3-7	-9.196	-8.968	-9.134	-8.056	-8.046	-8.244	-7.858	-8.994	-7.722	-8.388	-8.46	
3-5	-9.657	-9.6	-9.677	-8.51	-8.74	-9.08	-8.54	-9.023	-8.29	-8.883	-9.00	

Table 7 : Input for catch prediction (based on 1988)

Age	stock no (*000)	$\bar{W}$ catch	$\bar{W}$ stock	M	ref. F	Matur.
3	88000.00	.530	.530	.200	.006	.010
4	81057.00	.780	.780	.200	.110	.050
5	22590.00	1.210	1.210	.200	.252	.300
6	33838.00	1.800	1.800	.200	.286	.680
7	25785.00	2.500	2.500	.200	.379	.920
8	10062.00	3.300	3.300	.200	.373	.990
9	2691.00	4.370	4.370	.200	.688	1.000
10	1071.00	5.610	5.610	.200	.478	1.000
11	474.00	6.360	6.360	.200	.604	1.000
12	169.00	8.130	8.130	.200	.339	1.000
13	169.00	9.110	9.110	.200	.880	1.000
14	76.00	10.520	10.520	.200	.598	1.000

Fig. 1 : Fishing mortality

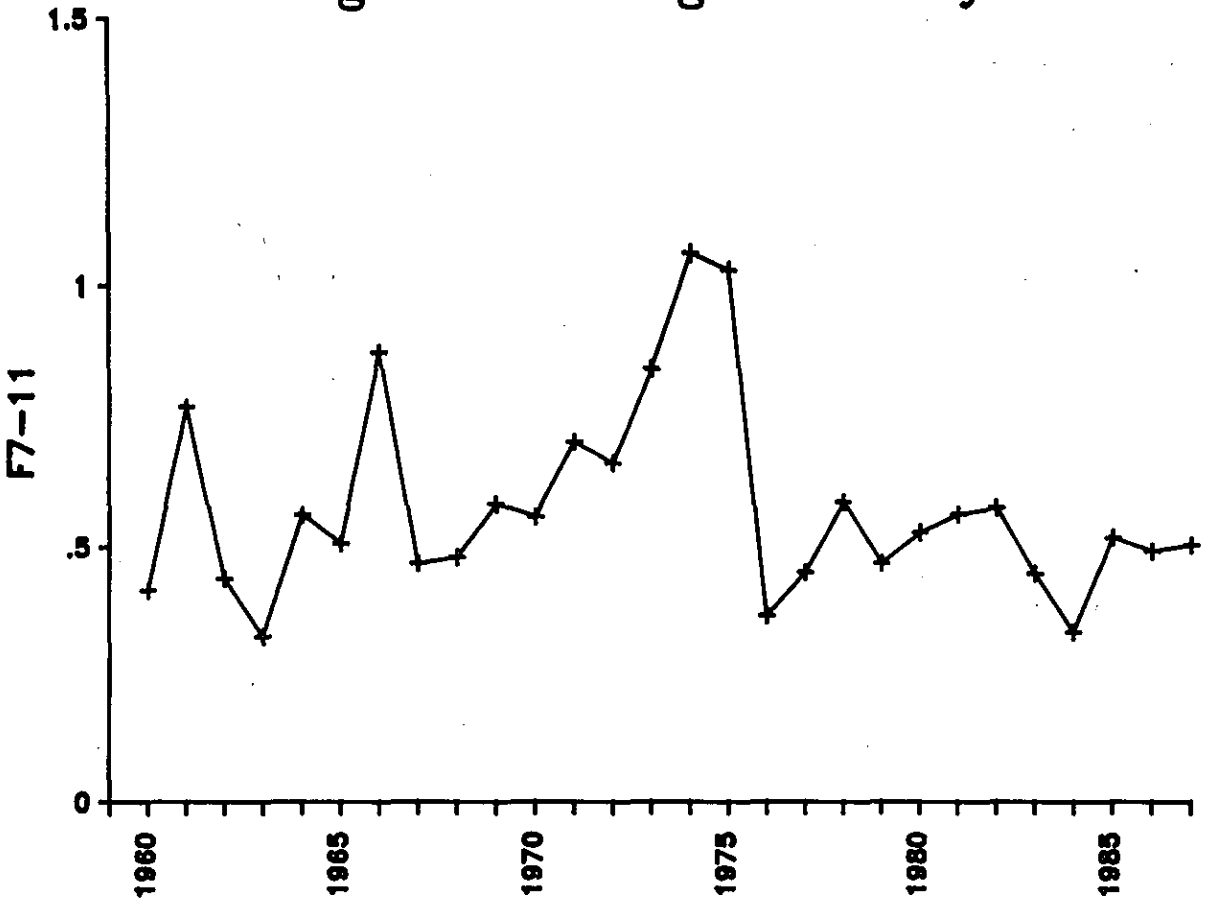

Fig. 2 : Biomass and Recruitment

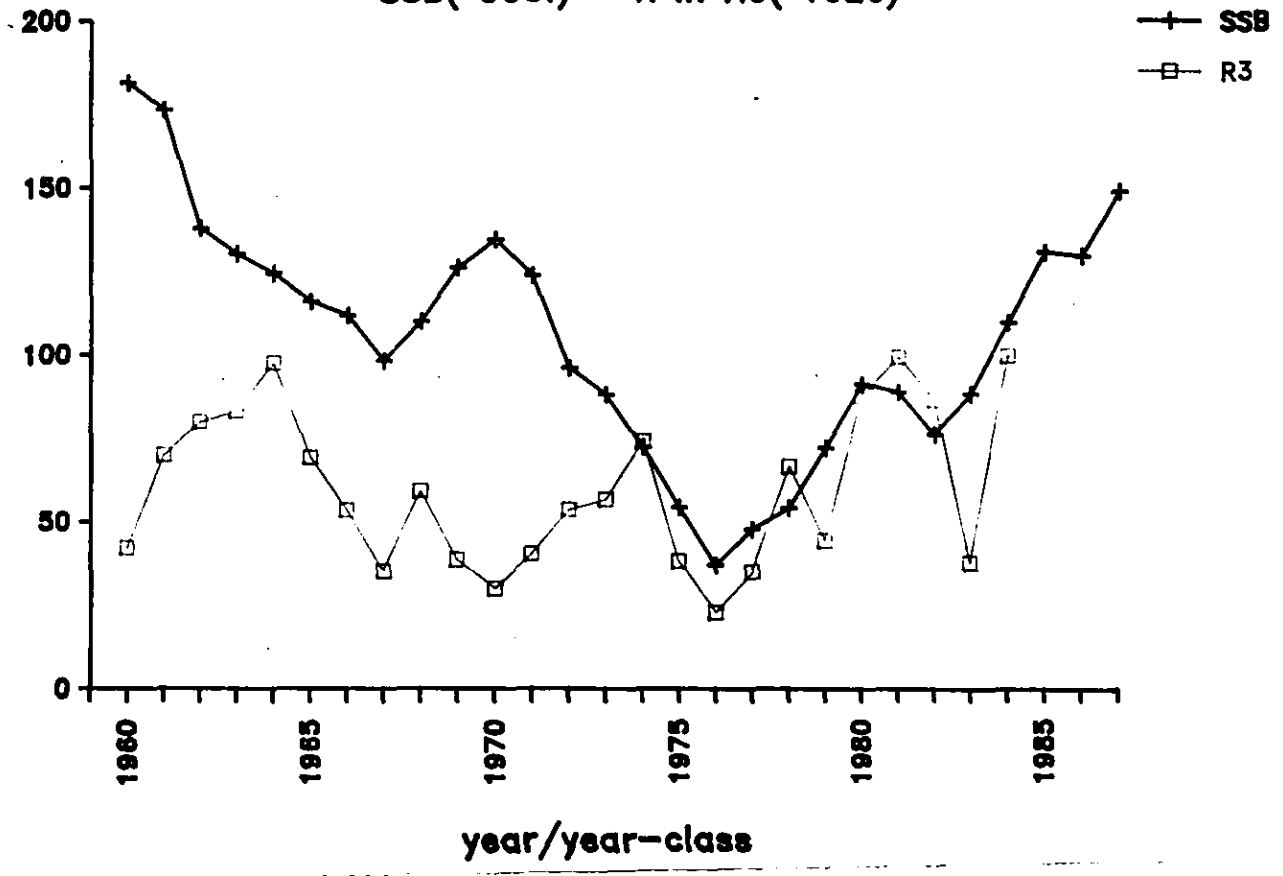

Fig. 3 : Catch/Biomass ratio

Running means over 3 years

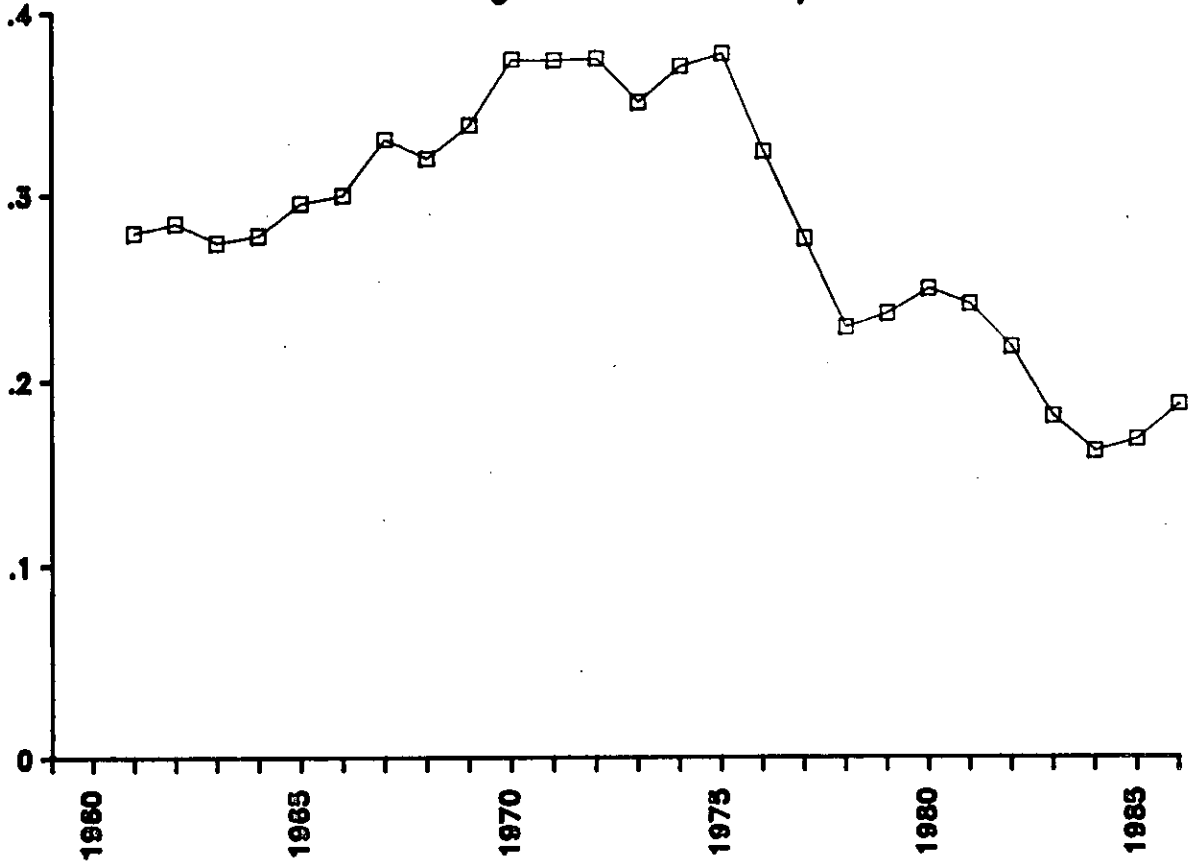

Fig. 4 : Research vessel catchability

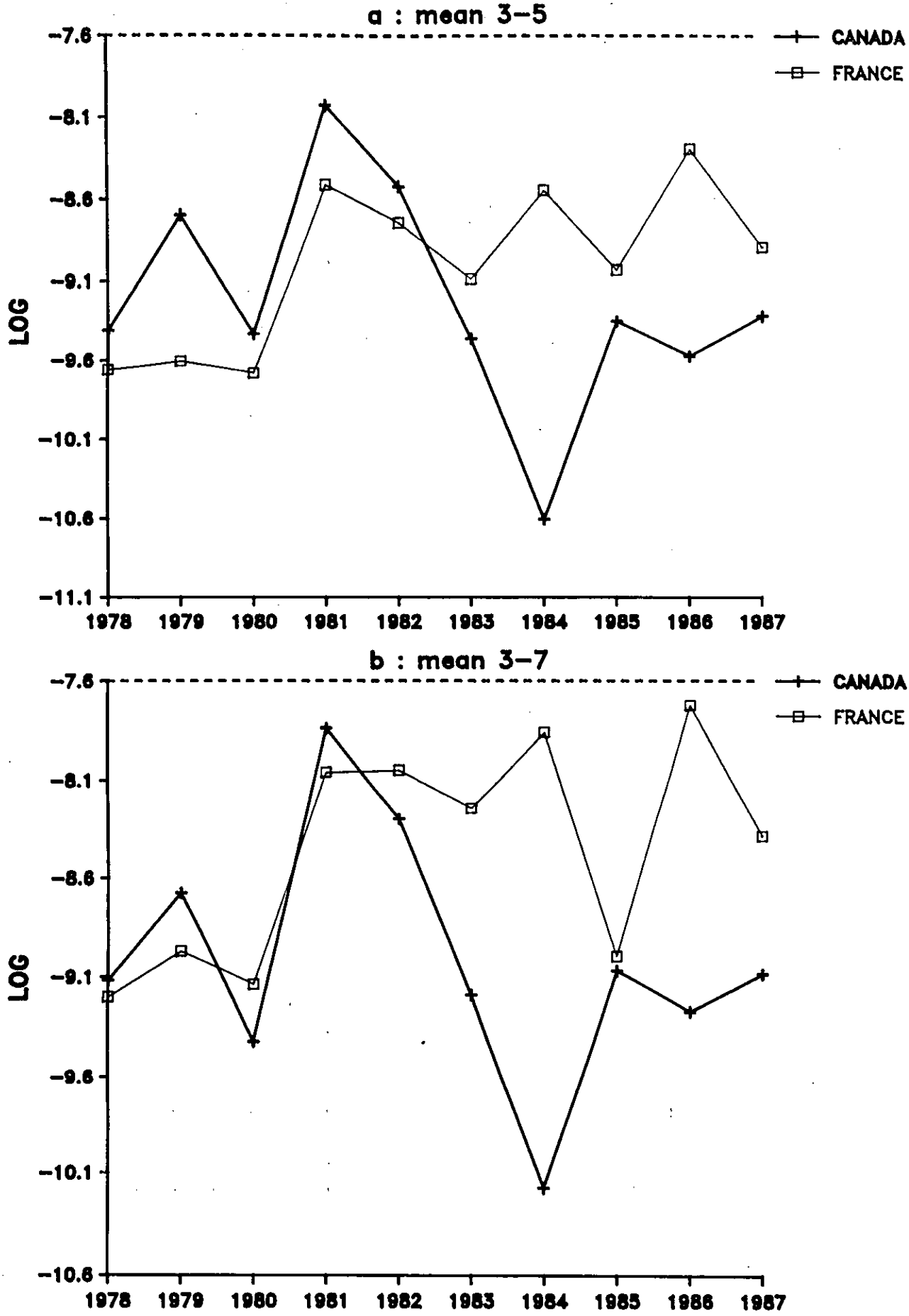

Fig. 5 : PREDICTED CATCHES and SSB

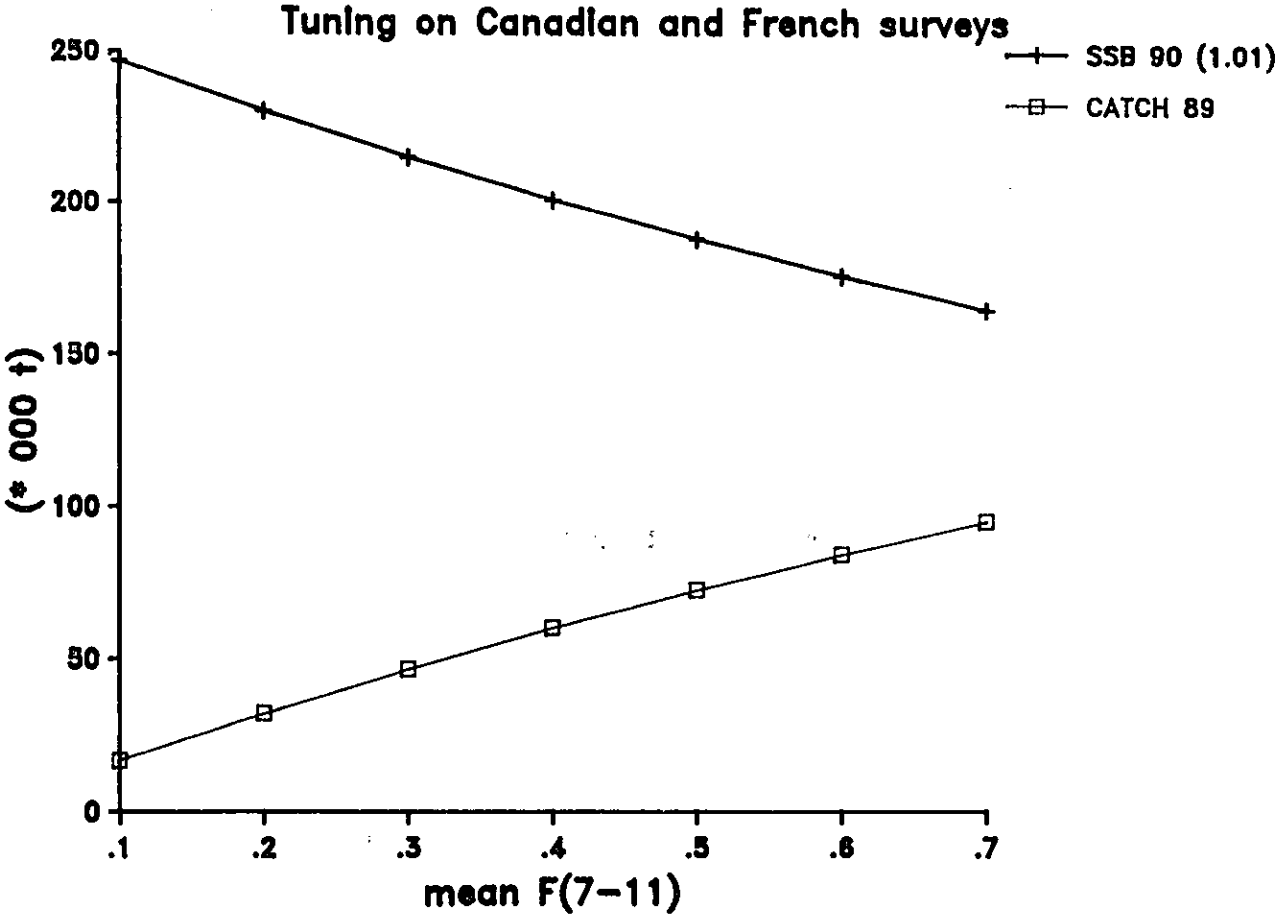

Fig. 6a: Trend in fishing mortality

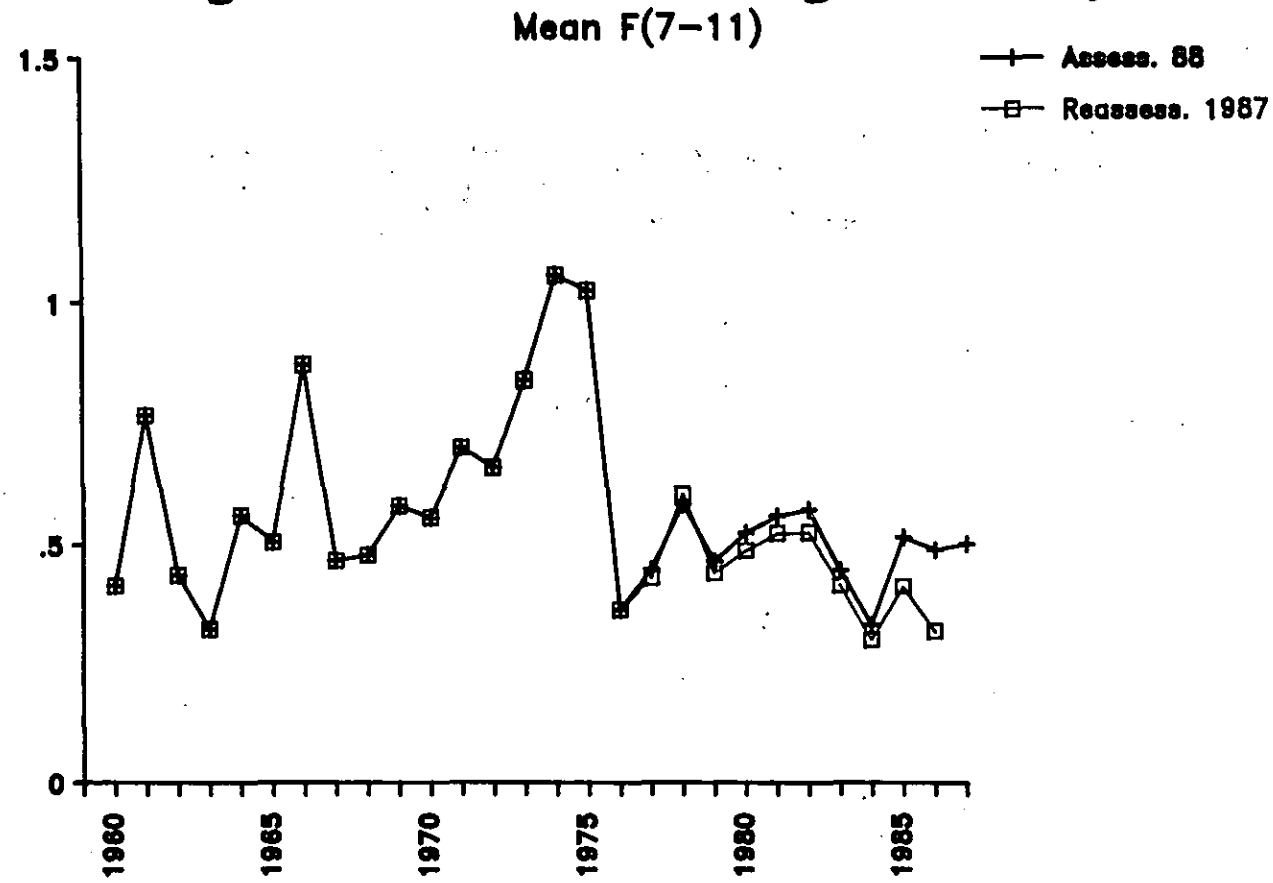

Fig. 6b: Trend in Spawning Stock Biomass

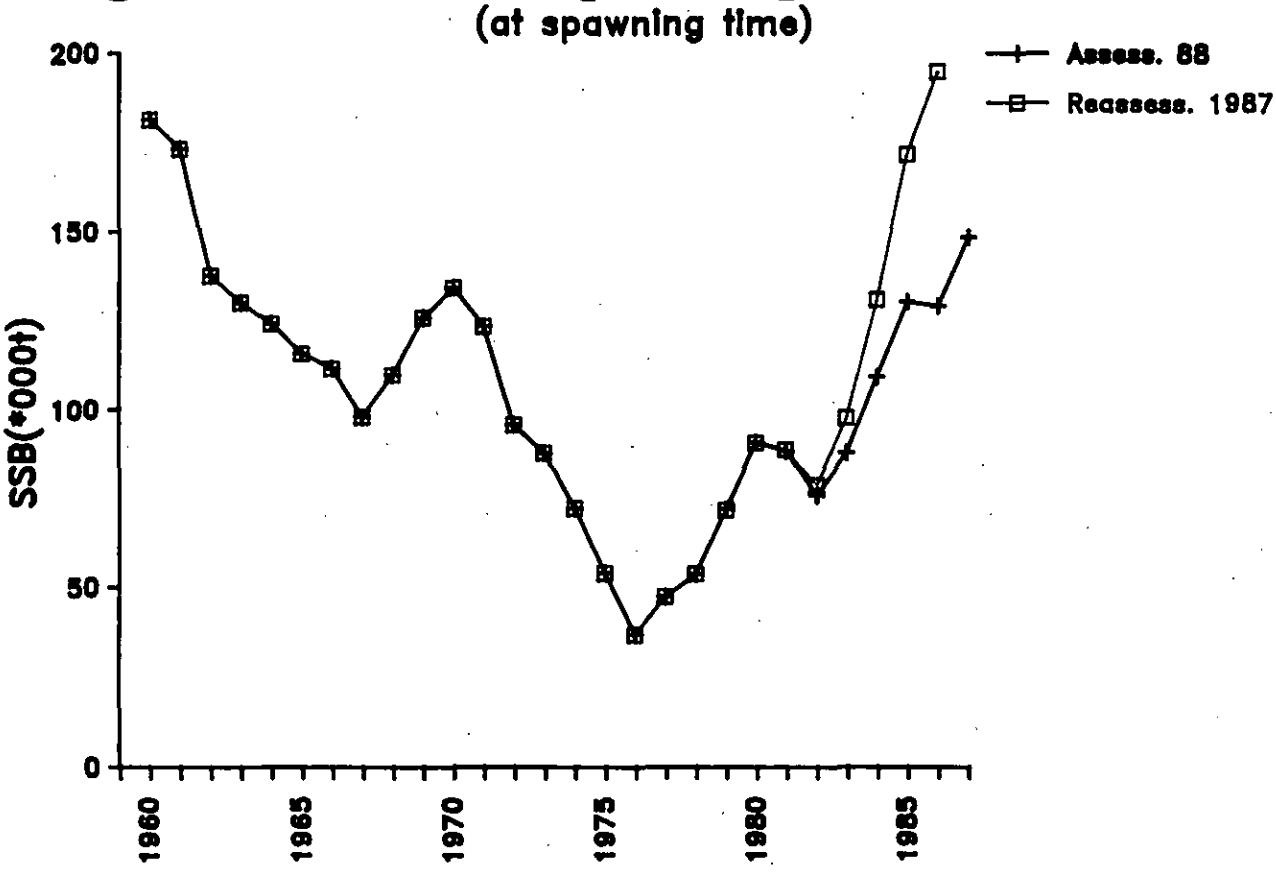

Fig. 7 : Stock recruitment diagram