

Variation in Cod (*Gadus morhua*) Stock Abundance in NAFO Subdivision 3Ps, 1978–90

Philippe Moguedet

Institut Français de Recherche pour l'Exploitation de la Mer
B. P. 477, 97302 Cayenne, Guyane Française

Abstract

Variability in cod (*Gadus morhua*) stock abundance in NAFO Subdiv. 3Ps has been observed since the late-1970s. Variability has been related to a combination of biological factors and fishing activity. The biological factors have included variability of recruitment, stock distribution and migrations from neighbouring areas. The biological factors were considered to be variable because of changes in environmental conditions. These conditions are discussed in relation to stock levels, especially the spawning biomass, which were influenced by variable exploitation levels in the late-1980s along with restrictions of specific zones resulting from international (Canada and France) management activities in the area.

Key words: Cod, *Gadus morhua*, Northwest Atlantic, St. Pierre Bank, stock abundance

Introduction

Cod (*Gadus morhua*) is the major resource exploited in NAFO Subdiv. 3Ps (Fig. 1), as this fishery represents 82 to 90% of the groundfish catches in the area. Since 1978 only Canada and France have participated in it. While about 25% of Canadian catches are taken in the offshore area mainly from January to May, most of the French catches are taken from October to June by trawler fleets in offshore waters. A study of the French fishing activities has been conducted by French Fisheries Laboratory, IFREMER, at Saint-Pierre and Miquelon since 1978. Research surveys have been annually carried out in late winter, and sampling of landings from trawler fleets systematically carried out to estimate the catch-at-age composition and to conduct annual stock assessments.

In this study, variations in the annual abundance of this stock and in some of its components were examined, along with the commercial catch data. These variations are presented here, and some sources which have been identified are discussed.

Materials and Methods

The French research survey data collected since 1978 were analyzed. The standard survey process, which has been annually conducted in late winter (February–March) by French scientists, is described by Forest and Minet (1981). The sampling design consisted of a random selection of trawling stations, their number being proportional to the variance observed in cod abundance (main species sought) in each stratum of the area (Fig. 2). The standardized trawling operations were 30 min. long at 4 knots. Abundance and biomasses were estimated for each trawling set, and the average values calcu-

lated by stratum in the reference area (strata 306–325, 705–708, 715, 716). Water temperature was recorded from surface to the bottom at the end of each trawling operation by means of XBT casts. These temperature data were used to consider the environmental conditions of the study area.

From 1984 to 1988, the cod stock assessment in Subdiv. 3Ps was carried out by the Standing Committee on Fisheries Science (STACFIS) of the Scientific Council of NAFO. Since 1988, no evaluations were carried out by STACFIS, however, separate national assessments were carried out by Canada and France.

Analytical assessments are conducted annually by France. Sampling of Saint-Pierre and Miquelon trawler fleets are systematically done to obtain the annual age composition in catches. These data are exchanged with Canadians scientists. Laurec and Shepherd (1983) tuning method, with calibration by survey indices (annual abundance observed at age) and the Saint-Pierre and Miquelon trawler fleets catch-rate indices, is used to estimate the annual fishing mortality-at-age. The annual, total, exploitable and spawning biomasses, and recruitment (age 3) abundance are then estimated (Bertrand *et al.*, MS 1988; Bertrand and Moguedet, MS 1989; Moguedet, MS 1990). These assessment results were included in the evaluation of abundance variations.

Results and Discussions

Environmental conditions

From temperature measurements carried out during the French research surveys conducted in late winter, it was concluded that there was high

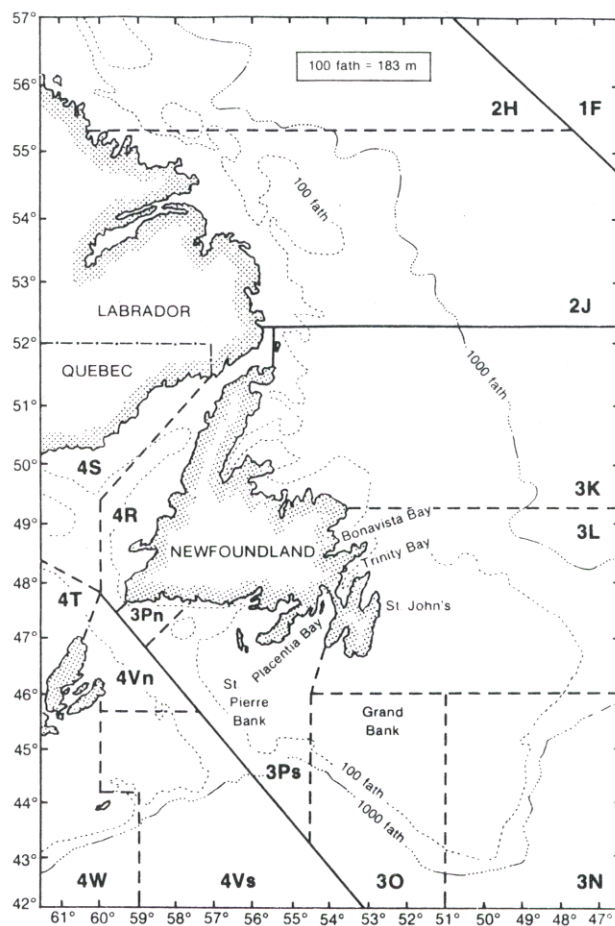


Fig. 1. Map showing NAFO Divisions and Subdivisions referred to in the text.

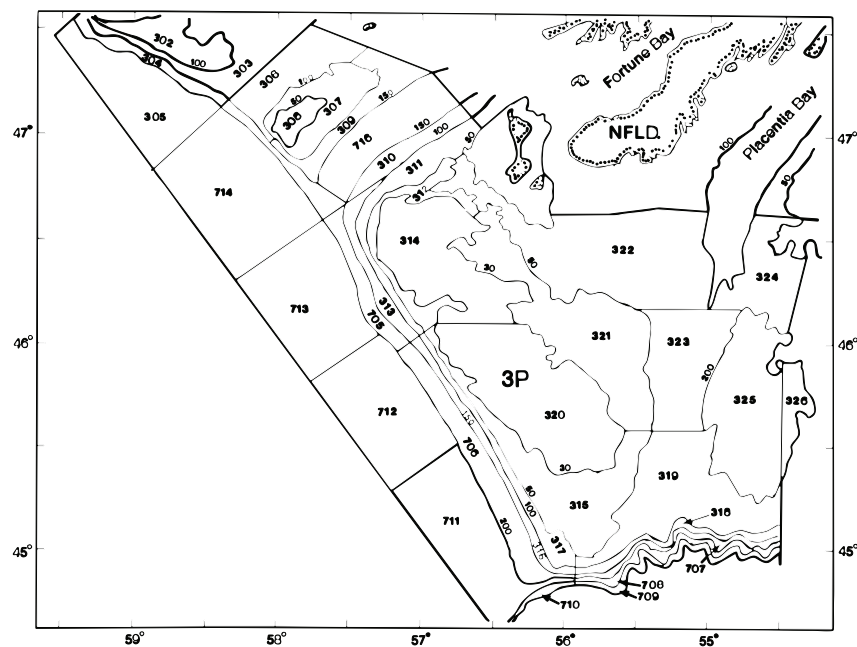


Fig. 2. Stratification scheme for NAFO Division 3P (Subdiv. 3Pn and 3Ps).

annual variability of hydrographic conditions in the area. Since 1985 all winters except 1988 could be classified as colder than normal. Largest temperature fluctuations occurred in the two upper depth ranges (0–99 m; 100–199 m) – except for the years 1982, 1984 and 1989 when important variations were encountered in the depth range 200–299 m (Fig. 3). The two upper depth ranges were strongly influenced by the Labrador current, cold water masses crossing over the St. Pierre bank in winter from the northeast to the west (Moguedet and Mahe, MS 1991).

In neighbouring areas such as the Gulf of St. Lawrence, similar high variability in water temperatures were also encountered, especially in winters when ice covered a large part of the Gulf (Gascon *et al.*, MS 1990).

Research survey indices

Annual abundance and biomass indices, estimated from research surveys, increased from 1978 until 1986 and declined strongly thereafter, to close to the 1978 level (Fig. 4, Tables 1 to 4). High values

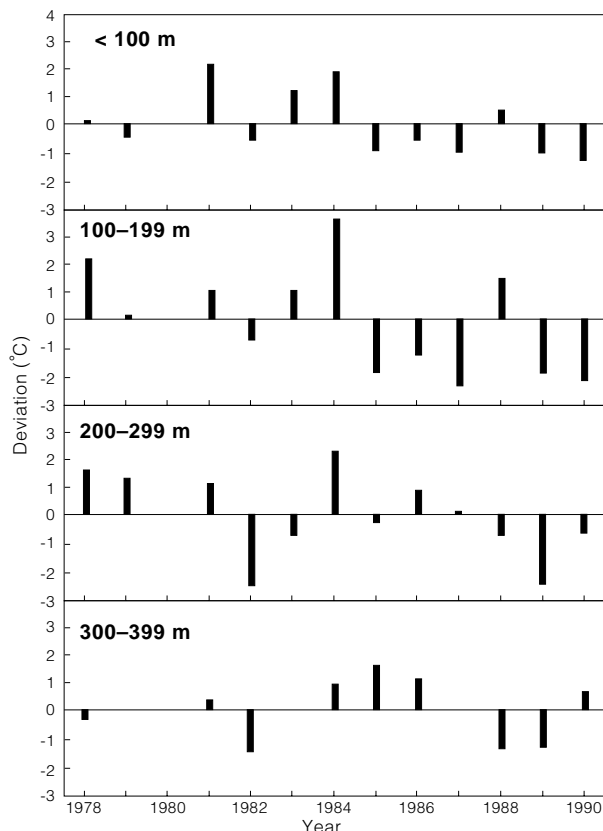


Fig. 3. Yearly deviations to the 1978–90 mean temperature in different depth ranges from the hydrographic transects (1980 excluded).

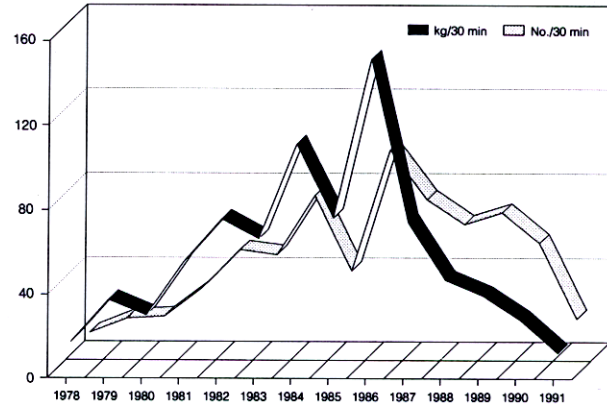


Fig. 4. Variations of cod abundance and biomass indices in Subdiv. 3Ps (French surveys in late winter), from 1978 to 1990.

were reached in 1982, 1984 and especially 1986. These fluctuations were thought to be the consequences of cod migrations into Subdiv. 3Ps from neighbouring areas of the Gulf of St. Lawrence (Div. 4RS and Subdiv. 3Pn) in the northern part and the Grand Bank (Div. 3NO) in the southern part. These migrations were believed to take place in winter and their intensity was considered variable (Bishop and Baird, MS 1988; Bertrand 1989). In the northern part of Subdiv. 3Ps they could be greatly influenced by hydrographic conditions in the Gulf of St. Lawrence as mentioned above. During the French research surveys, cod concentrations were found only in some strata nearest to the 3Pn Subdiv. (Tables 1 and 2). The extent and period of migration activity could affect the abundance and biomass indices, particularly the indices could be over estimated. The increases observed in 1982, 1984 and 1986 could be explained by this effect, because as in several areas of the Northwest Atlantic, the cod changed its distribution in Subdiv. 3Ps, particularly in the winter of 1986. Since then this species has been encountered in deeper waters (400–500 m), and particularly in Laurentian Channel area, on the Saint-Pierre Bank slope. French survey estimations do not include this area (strata 711–714) and they have not been systematically sampled in the past (Mabeau *et al.*, 1986; Bertrand and Chevalier, MS 1988). Consequently, abundance and biomass indices of this stock may have been underestimated since then, particularly for 1990.

Commercial catches

From 1978 to 1987 nominal catches have ranged from a low of 27 000 tons in 1978 to a high of 59 000 tons in 1987. From 1985 to 1987 catches averaged 50 000 tons mainly due to increased effort by France. Catches have been relatively stable at about 42 000 tons since 1987 (Fig. 5, Table 5).

TABLE 1. Estimated cod biomass (in metric tons) in Subdiv. 3Ps from annual French stratified surveys, conducted in late winter (February–March) 1978–90.

Depth		Year													
(m)	Strata	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	
<55	314	17	0	–	1 390	111	30	0	7	13	133	–	17	0	
	320	108	814	–	3 797	513	2 803	3 526	104	14	–	0	316	222	
	Total	125	814	–	5 187	624	2 833	3 526	111	27	133	0	333	222	
56–90	308	371	9	150	88	299	151	111	65	100	29	6	25	0	
	312	820	270	112	2 304	454	636	1 403	145	343	0	28	55	2	
	315	771	850	0	1 076	821	326	16 918	8	1 813	2 058	2 134	198	41	
	321	183	4 785	3 746	2 199	3 746	1 362	1 026	3	543	–	649	0	0	
	325	–	–	–	2 101	–	1 332	1 466	81	259	0	453	0	0	
	Total	2 145	5 914	4 008	7 768	5 320	3 807	20 924	302	3 058	2 087	3 270	278	43	
91–180	307	3 598	2 714	4 428	1 876	9 009	6 269	5 384	2 976	23 172	8 089	565	6 168	215	
	311	87	3 199	1 136	5 797	8 202	3 572	19 599	1 276	20 627	1 356	4 815	675	267	
	317	0	260	–	813	454	421	21 353	1 502	2 562	1 049	815	974	226	
	319	997	5 810	1 303	4 435	4 078	11 349	8 101	2 831	3 179	5 746	5 434	5 889	3 067	
	322	605	1 945	3 381	1 793	2 404	967	1 122	2 388	5 944	2 734	215	864	172	
	323	91	572	858	822	54	794	803	512	2 399	953	311	60	10	
	324	–	–	–	0	–	815	964	594	288	99	171	90	44	
Total	5 378	14 500	11 106	15 536	24 201	24 187	57 326	12 079	58 171	20 026	12 326	14 720	4 001		
181–270	306	3 080	2 660	2 162	12 197	3 716	11 967	2 296	804	23 131	8 294	4 041	4 690	663	
	309	167	2 743	804	2 176	1 122	3 318	3 852	1 581	7 434	1 901	4 827	7 947	6 726	
	310	411	190	19	481	1 683	739	229	4 675	169	503	739	164	93	
	313	113	331	1	1 099	1 279	840	170	1 753	142	562	26	373	240	
	316	91	121	39	282	544	36	332	38 395	695	334	320	2 324	4 464	
	318	42	25	–	593	34	5 282	786	1 828	28 349	259	4 558	941	2 096	
Total	3 904	6 070	3 025	16 828	8 378	22 182	7 665	49 036	59 920	11 853	14 511	16 439	14 282		
271–365	705	321	1 115	13	574	4 550	984	1 661	99	414	354	394	325	49	
	706	11	0	293	952	4 010	375	1 141	333	3 896	13 845	1 413	296	768	
	707	–	1 303	–	13	10 980	652	49	2 314	3 338	134	102	118	193	
	715	836	832	1 564	827	4 159	1 261	3 806	2 282	2 613	1 908	1 772	542	1 759	
	716	178	455	1 169	554	2 104	1 934	2 326	86	2 775	5 685	6 264	439	1 096	
	Total	1 346	3 705	3 039	2 920	25 803	5 206	8 983	5 114	13 036	21 926	9 945	1 720	3 865	
366–545	708	–	–	–	85	373	44	8	593	849	6 136	264	429	899	
	711	–	–	–	0	–	296	–	–	–	–	–	0	1 058	
	712	–	–	–	0	–	300	–	–	–	–	–	0	2 926	
	713	–	–	–	108	–	–	–	–	–	–	–	0	2 268	
	714	–	–	–	354	–	0	–	–	–	–	–	0	9 607	
	Total	–	–	–	547	373	640	8	593	849	6 136	264	429	16 758	
0–545	Total	12 899	31 002	21 178	48 787	64 699	58 856	98 433	67 235	135 061	62 164	40 316	33 918	39 169	

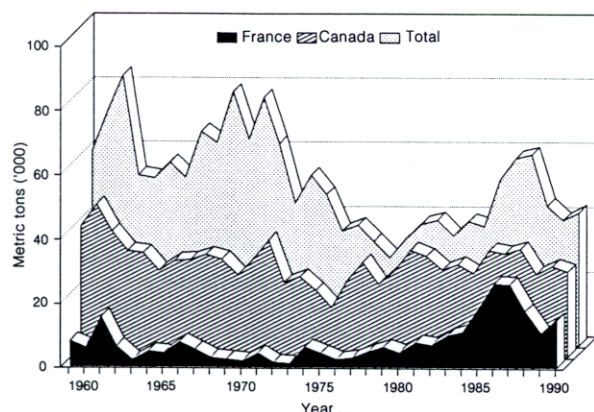


Fig. 5. Total French and Canadian cod catches in Subdiv. 3Ps from 1959 to 1990.

Since 1976 only Canada and France have participated in the fishery. Catches by inshore gears (trap, gillnet, longline and handline) have traditionally accounted for the largest portion of the total Canadian catches (Tables 6 and 7). French catches have been mainly taken by offshore fleets. Offshore catches by Saint-Pierre and Miquelon trawlers increased from 1 600 tons in 1978 to 14 800 tons in 1990. The variation in French catches was due to a variation in the fishing effort till 1986; first there was an increase in the fishing capacity combined with a management plan for the fishery activity in the Gulf, and then there was a decrease because of reduction in the activity of the Metropolitan trawler fleet.

In the period 1978–84, the cod fishery in Subdiv. 3Ps was based on the exploitation of several age-

TABLE 2. Estimated cod abundance (in thousands) in Subdiv. 3Ps from annual French stratified surveys, conducted in late winter (February–March) 1978–90.

Depth (m)	Year													
	Strata	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
<55	314	33	0	(73)	267	22	133	0	33	33	67	(354)	33	0
	320	36	241	(256)	784	90	572	663	136	45	(785)	0	90	181
	Total	69	241	329	1 051	112	705	663	169	78	852	354	123	181
56–90	308	189	12	35	35	161	46	157	50	134	31	38	65	0
	312	605	99	28	677	456	99	6 837	155	298	0	75	56	5
	315	368	57	0	269	113	85	3 597	28	321	868	265	28	28
	321	20	896	326	502	387	221	147	16	55	(628)	1 222	0	0
	325	(108)	(152)	(138)	129	(567)	275	647	65	226	0	485	0	0
	Total	1 290	1 216	527	1 612	1 684	726	11 385	314	1 034	1 527	2 085	149	33
91–180	307	1 948	1 154	3 084	640	4 662	2 958	2 624	785	21 238	4 694	1 136	8 851	1 144
	311	402	1 628	1 158	4 357	3 995	4 147	15 162	1 954	18 038	9 503	16 231	5 973	1 040
	317	0	119	(697)	724	4 940	1 696	16 436	989	1 182	8 457	5 410	7 993	859
	319	1 051	4 583	1 146	3 262	3 516	7 666	5 473	3 909	2 887	5 695	3 639	9 413	13 319
	322	939	617	5 742	1 149	4 916	5 720	2 603	4 239	4 883	11 270	4 776	6 735	912
	323	349	226	318	1 156	572	3 671	3 683	2 670	4 576	1 907	1 668	1 621	95
	324	(479)	(611)	(570)	0	(1 845)	2 605	3 147	1 607	727	237	3 164	1 878	85
Total	5 168	8 938	12 715	11 288	24 446	28 463	49 128	16 153	53 531	41 763	36 024	42 464	17 454	
181–270	306	765	870	698	9 691	2 841	6 333	947	278	14 560	2 956	2 589	3 935	2 759
	309	355	1 642	264	1 453	595	1 500	1 588	872	4 906	831	2 859	5 852	13 611
	310	396	186	15	489	1 095	935	105	9 513	175	382	2 276	146	553
	313	130	328	11	859	814	678	83	2 359	138	1 432	23	1 639	995
	316	65	95	39	165	423	30	173	4 088	826	215	667	4 871	6 236
	318	21	8	(191)	247	34	1 182	604	576	5 810	101	2 786	1 097	1 936
Total	1 732	3 129	1 218	12 904	5 802	10 658	3 500	17 686	26 415	5 917	11 200	17 540	26 090	
271–365	705	254	982	27	423	3 286	672	908	69	224	220	274	267	87
	706	22	0	98	672	3 054	179	532	163	1 981	8 977	791	158	717
	707	(140)	586	(166)	13	2 603	183	19	827	1 172	81	80	51	73
	715	922	597	895	628	2 473	588	1 636	917	1 132	961	882	276	2 048
	716	123	357	923	455	1 772	1 196	1 058	25	2 258	5353	4 836	406	1 707
Total	1 461	2 522	2 109	2 191	13 188	2 818	4 153	2 001	6 767	15 592	6 863	1 158	4 632	
366–545	708	(52)	(68)	(63)	45	353	8	4	315	381	1 543	88	172	297
	711	–	–	–	0	–	33	–	–	–	–	–	0	823
	712	–	–	–	0	–	133	–	–	–	–	–	0	2 466
	713	–	–	–	21	–	–	–	–	–	–	–	0	1 854
	714	–	–	–	137	–	0	–	–	–	–	–	0	9 877
Total	52	68	63	203	353	174	4	315	381	1 543	88	172	15 317	
0–545	Total	9 775	16 115	16 960	29 249	45 585	43 544	68 833	36 638	88 206	67 194	56 614	61 608	63 707

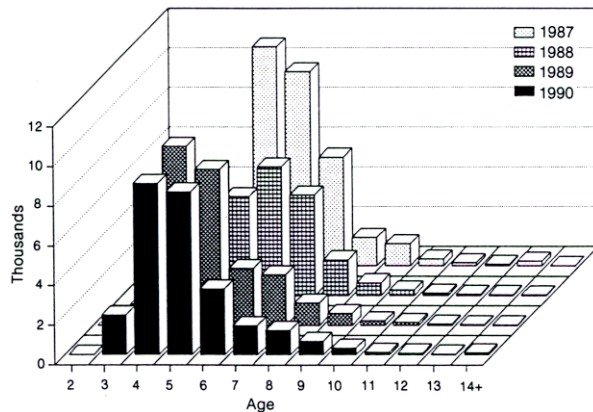


Fig. 6. Catch-at-age (all countries) of cod in Subdiv. 3Ps from 1987 to 1990.

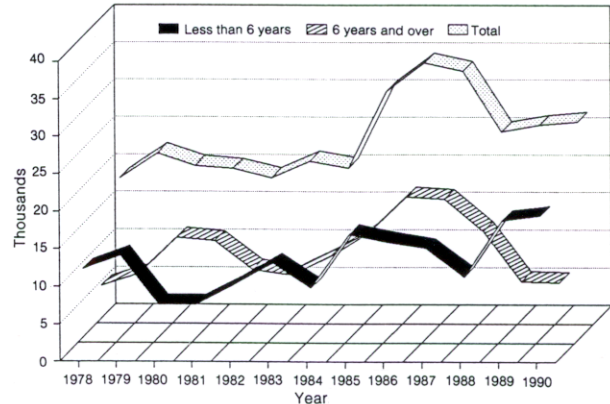


Fig. 7. Catch of cod by age groups (<6 years, 6 years+, total) in Subdiv. 3Ps from 1987 to 1990.

TABLE 3. Average number of cod per set and age in late winter surveys (strata 306–325, 705–708, 715, 716) in Subdiv. 3Ps from French research surveys, 1978–90

Age	Year												
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	–	0.07	–	0.06	1.03	4.63	0.03	0.13	0.08	3.29	5.27	1.87	0.38
2	0.73	0.43	7.38	0.18	12.00	10.79	11.58	5.49	7.24	20.62	14.86	24.70	3.11
3	1.57	0.39	1.72	4.91	1.96	5.40	7.64	14.49	4.21	11.51	14.89	16.02	21.84
4	3.08	2.08	0.50	4.94	8.32	2.98	15.07	7.47	15.19	2.83	9.22	8.20	20.12
5	2.05	7.29	2.67	5.14	7.97	7.21	8.74	3.93	26.47	8.30	3.62	5.81	5.64
6	1.20	3.27	4.52	7.45	6.06	6.11	18.97	1.06	21.66	12.49	6.53	3.48	1.20
7	0.89	1.82	1.66	5.64	4.55	4.55	5.59	1.95	9.12	8.32	4.69	4.43	0.29
8	0.52	0.96	0.67	1.60	5.30	2.77	2.13	1.14	6.97	2.95	1.60	2.03	0.49
9	0.30	0.38	0.29	1.19	1.58	2.08	3.09	0.78	3.85	1.94	0.78	1.01	0.32
10	0.22	0.22	0.22	0.47	0.87	0.75	2.21	0.86	0.79	0.95	0.35	0.27	0.17
11	0.02	0.29	0.18	0.15	0.42	0.25	0.61	1.09	0.59	0.20	0.35	0.13	0.08
12	0.04	0.09	0.11	0.14	0.15	0.19	0.16	1.32	0.72	0.36	0.16	0.06	0.07
13	0.01	0.10	0.08	0.06	0.21	0.08	0.13	0.12	0.22	0.15	0.15	0.07	0.01
14+	0.03	0.22	0.18	0.13	0.10	0.06	0.12	0.23	0.32	0.29	0.33	0.08	0.05
3+	9.94	17.12	12.80	31.82	37.49	32.42	64.46	34.43	90.11	50.25	42.64	41.59	50.28
6+	3.23	7.35	7.92	16.83	19.23	16.84	33.00	8.55	44.25	27.62	14.93	11.56	2.68
Total	10.72	17.71	20.25	32.14	50.59	47.92	76.11	40.05	97.47	74.24	62.76	68.16	53.77
No. sets	69	64	40	83	74	88	74	84	82	69	73	106	107
	21 Feb 25 Mar	21 Feb 20 Mar	03–12 Mar	24 Feb 31 Mar	05 Mar 02 Apr	10 Feb 19 Mar	15 Feb 19 Mar	09 Feb 10 Mar	09 Feb 10 Mar	04 Feb 06 Mar	Feb 09 11 Mar	Feb 15 18 Mar	26 Feb 28 Mar

TABLE 4. Cod abundance indices in weight and number, per 30 min from French research surveys in Subdiv. 3Ps, 1978–90. (1: Abundance indices; 2: Standard deviation.)

	Year												
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Kg/30 min. 1	15.21	35.43	27.98	53.46	73.85	64.45	108.8	74.38	149.4	72.05	44.88	37.52	25.79
	2	2.43	7.13	4.51	10.78	16.22	9.79	35.24	39.86	45.37	18.98	7.96	10.65
Nb/30 min. 1	10.81	17.83	18.76	32.18	50.43	47.99	76.14	40.53	97.58	74.33	62.62	68.15	53.86
	2	1.36	3.37	1.45	6.80	7.70	5.10	24.73	6.84	26.90	13.59	11.58	11.59

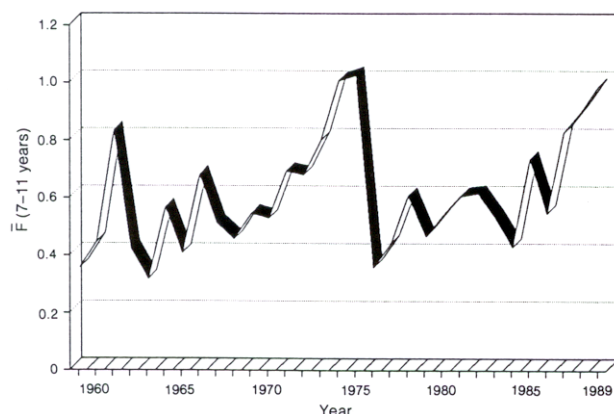
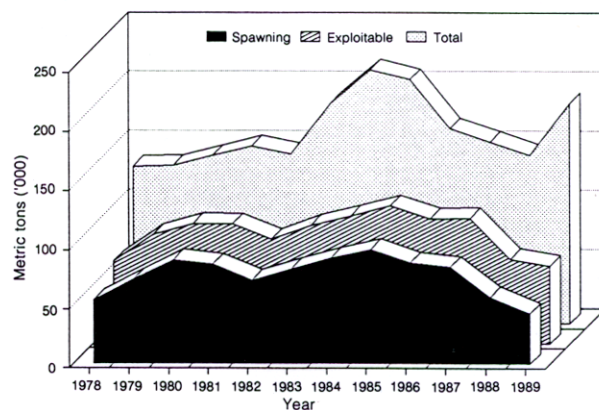
**Fig. 8.** Annual fishing mortality (cod ages 7–11 years) in Subdiv. 3Ps from 1959 to 1989.**Fig. 9.** Annual spawning, exploitable and total bio-masses of cod in Subdiv. 3Ps from 1978 to 1989.

TABLE 5. Cod landings (metric tons) in Subdiv. 3Ps by country, 1959–90. (Can (N): Canada, Newfoundland; Can (M): Canada, Maritimes; France (1) 1959–1985: SPM; since 1986: inshore SPM + OTB 5; France (2) 1959–1985: Métropolitans; since 1986: OTB 6–7.)

Year	Canada (N)			France		Total					
	Offshore	Inshore	Can (M)	1	2	Canada	France	Spain	Portugal	Others	Total
1959	2 726	32 718	4 784	3 078	4 952	40 228	8 030	7 794	3 647	471	60 170
1960	1 780	40 059	5 095	3 634	2 460	46 934	6 094	17 223	262	2 123	72 636
1961	2 167	32 506	3 883	4 140	11 490	38 556	15 630	21 015	4 985	3 434	83 620
1962	1 176	29 888	1 474	2 241	4 138	32 538	6 379	10 289	1 873	1 560	52 639
1963	1 099	30 447	331	1 757	324	31 877	2 081	10 826	209	6 828	51 821
1964	2 161	23 897	370	2 097	2 777	26 428	4 874	15 216	169	9 880	56 567
1965	2 459	25 902	1 203	2 570	1 781	29 564	4 351	13 404	–	4 535	51 854
1966	5 473	23 785	583	3 207	4 607	29 841	7 814	23 678	519	4 355	66 207
1967	3 861	26 331	1 259	2 244	3 204	31 451	5 448	20 851	980	4 044	62 774
1968	6 536	22 938	585	1 880	1 126	30 059	3 006	26 868	8	18 613	78 554
1969	4 269	20 009	849	2 477	15	25 127	2 492	28 141	57	7 982	63 799
1970	4 650	23 410	2 166	1 970	35	30 226	2 005	35 750	143	8 734	76 858
1971	8 657	26 651	731	1 651	2 730	36 039	4 381	19 169	81	2 778	62 448
1972	3 323	19 276	252	1 436	–	22 851	1 436	18 550	109	1 267	44 213
1973	3 107	21 349	181	1 165	–	24 637	1 165	19 952	1 180	5 707	52 641
1974	3 770	15 999	657	948	5 366	20 426	6 314	14 937	1 246	3 789	46 712
1975	741	14 332	122	775	3 549	15 195	4 324	12 234	1 350	2 270	35 373
1976	2 013	20 978	317	904	1 501	23 308	2 405	9 236	177	2 007	37 133
1977	3 333	23 755	2 171	1 252	1 734	29 259	2 986	–	–	–	32 245
1978	2 082	19 560	700	1 974	2 860	22 342	4 834	–	–	45	27 221
1979	2 381	23 413	863	4 289	2 060	26 657	6 349	–	–	–	33 006
1980	2 809	29 427	715	1 936	2 681	32 951	4 617	–	–	–	37 568
1981	2 696	26 068	2 321	4 101	3 706	31 085	7 807	–	–	–	38 892
1982	2 639	21 351	2 948	4 780	2 184	26 938	6 964	–	–	–	33 902
1983	2 100	23 915	2 580	5 618	4 238	28 595	9 856	–	–	–	38 451
1984	895	22 865	1 969	7 550	3 671	25 729	11 221	–	–	–	36 950
1985	4 529	24 854	3 476	10 064	8 444	32 859	18 508	–	–	–	51 367
1986	5 155	24 884	1 963	14 042	11 939	32 002	25 981	–	–	7	57 990
1987	4 087	26 781	2 517	15 854	9 965	33 385	25 819	–	–	–	59 204
1988	3 461 ^b	19 943 ^b	2 303	10 293	7 373	25 707	17 666	–	–	4	43 377
1989 ^a	2 774 ^c	22 886 ^c	2 366 ^a	9 979 ^a	892 ^a	28 026 ^a	10 871 ^a	–	–	–	38 897 ^a
1990 ^a	3 028 ^c	20 236 ^c	3 129 ^a	14 927 ^a	0	26 393 ^a	14 929 ^a	–	–	–	41 322 ^a

^a Provisional data.^b Ratio inshore/offshore from NAFO data and Fisheries and Oceans laboratory, St. John's, Newfoundland.^c Ratio inshore/offshore from provisional data and Fisheries and Oceans laboratory, St. John's, Newfoundland.

TABLE 6. Canadian and French cod landings (metric tons) by main gear type in Subdiv. 3Ps, 1978–90.

Year	France				Can (M)					Can (N)					
	Insh.	OTB (5)	OTB (6–7)	Total	OT	GN	LL	HL	Total	OT	GN	LL	HL	FPN	Total
1978	360	1 614	2 860	4 834	693	–	7	–	700	2 082	2 374	11 811	3 130	2 245	21 642
1979	495	3 794	2 060	6 349	695	–	168	–	863	2 381	3 955	14 292	3 123	2 030	25 781
1980	214	1 722	2 681	4 617	703	–	12	–	715	2 809	5 493	19 312	2 545	2 077	32 236
1981	333	3 768	3 706	7 807	826	–	1 495	–	2 321	2 696	4 998	18 980	1 142	948	28 764
1982	1 009	3 771	2 184	6 964	993	–	1 955	–	2 948	2 639	6 281	11 542	1 597	1 929	23 988
1983	843	4 775	4 238	9 856	1 479	–	1 101	–	2 580	2 100	6 144	11 588	2 540	3 643	26 015
1984	777	6 773	3 671	11 221	1 776	–	193	–	1 969	895	7 275	9 376	2 942	3 271	23 759
1985	642	9 422	8 444	18 508	3 461	–	15	–	3 476	4 529	7 086	10 261	1 832	5 674	29 382
1986	389	13 653	11 939	25 981	1 418	–	545	–	1 963	5 155	8 570	10 951	1 078	4 059	29 813
1987	550	15 304	9 965	25 819	1 667	–	850	–	2 517	4 087	9 128	10 856	1 628	4 901	30 601
1988	286	10 005	7 373	17 664	1 657	–	651	–	2 308	3 426	6 494	9 327	1 522	2 398	23 167
1989	338	9 641	892	10 871	1 232	40	1 091	3	2 366	2 774	5 885	9 264	1 664	6 074	25 661
1990	158	14 769	–	14 927	1 545	258	1 385	–	3 158	2 898	6 633	7 391	2 246	3 777	22 935

Can (N): Canada Newfoundland; Can (M): Canada, Maritime Provinces; OTB and OT: Otter trawls; GN: Gillnets; LL: Longlines; HL: Handlines; FPN: Traps (stationary uncovered poundnets); Insh: French inshore fisheries: handlines.

Year	France			Can (M)				Can (N)					FPN
	Insh.	OTB (5)	OTB (6-7)	OT	GN	LL	HL	OT	GN	LL	HL		
1978	7.4	33.4	59.2	99.0	-	1.0	-	9.6	11.0	54.6	14.5	10.4	
1979	7.8	59.8	32.4	80.5	-	19.5	-	9.2	15.3	55.4	12.1	7.9	
1980	4.6	37.3	58.1	98.3	-	1.7	-	8.7	17.0	59.9	7.9	6.4	
1981	4.3	48.3	47.5	35.6	-	64.4	-	9.4	17.4	66.0	4.0	3.3	
1982	14.5	54.1	31.4	33.7	-	66.3	-	11.0	26.2	48.1	6.7	8.0	
1983	8.6	48.4	43.0	57.3	-	42.7	-	3.8	30.6	39.5	12.4	13.8	
1984	6.9	60.4	32.7	90.2	-	9.8	-	3.8	30.6	39.5	12.4	13.8	
1985	3.5	50.9	45.6	99.6	-	1.5	-	15.4	24.1	34.9	6.2	19.3	
1986	1.5	52.5	46.0	72.2	-	27.8	-	17.3	28.7	36.7	3.6	13.6	
1987	2.1	59.3	38.6	66.2	-	33.8	-	13.4	29.8	35.5	5.3	16.0	
1988	1.6	56.6	41.7	71.8	-	28.2	-	14.8	28.0	40.3	6.6	10.3	
1989	3.1	88.7	8.2	52.1	1.7	46.1	0.1	10.8	22.9	36.1	6.5	23.7	
1990	1.0	99.0	-	48.7	8.1	43.2	-	12.6	28.9	32.2	9.8	16.5	

Age	Year												
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
3	502	135	368	1 022	130	760	203	206	277	585	946	1 118	2 006
4	5 146	3 072	1 625	2 888	5 092	2 682	4 521	4 718	4 924	2 956	4 945	9 190	8 629
5	6 096	10 321	5 054	3 136	4 430	9 174	4 538	11 473	10 159	11 023	4 848	7 973	8 195
6	4 006	5 066	8 156	4 652	2 348	4 080	7 018	6 118	11 180	9 763	6 289	2 893	3 329
7	1 753	2 353	3 379	5 855	2 861	1 752	2 221	5 072	4 247	5 453	4 971	2 546	1 483
8	653	721	1 254	1 622	2 939	1 150	584	1 496	2 144	1 416	1 783	1 089	1 237
9	235	233	327	539	640	1 041	542	417	639	1 107	627	592	692
10	178	84	114	175	243	244	338	377	220	341	281	220	350
11	72	53	56	67	83	91	134	333	168	149	121	138	142
12	27	24	45	35	30	37	35	131	141	78	77	55	104
13	17	13	21	18	11	18	8	24	78	218	126	91	47
14	10	10	25	2	7	8	8	12	23	1	1	1	109

[illegible]

TABLE 10. Fishing mortality-at-age for the Subdivision 3Ps cod stock estimated from a cohort analysis, 1978–89, conducted by IFREMER Laboratory at St. Pierre and Miquelon.

Age	Year												F(87–89)
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
3	0.0148	0.0068	0.0120	0.0188	0.0034	0.0114	0.0034	0.0050	0.0034	0.0175	0.0153	0.0108	0.0145
4	0.1020	0.1179	0.1057	0.1231	0.1223	0.0883	0.0869	0.1027	0.1272	0.1989	0.2005	0.2017	0.2003
5	0.2963	0.3046	0.2888	0.3037	0.2808	0.3358	0.2111	0.3288	0.4648	0.5966	0.5764	0.5701	0.5810
6	0.4611	0.4296	0.4201	0.4704	0.3916	0.4521	0.4654	0.4865	0.7875	0.7460	0.8356	0.8344	0.8053
7	0.6024	0.5443	0.5730	0.6095	0.5984	0.5719	0.4778	0.7358	0.8910	0.9184	1.1549	1.0324	1.0352
8	0.6426	0.5373	0.6352	0.6039	0.7211	0.5153	0.3786	0.6974	0.5737	0.7449	0.9193	0.8775	0.8472
9	0.5406	0.5005	0.5013	0.6272	0.5113	0.6124	0.4914	0.5116	0.4743	0.9829	0.9082	0.9444	0.9452
10	0.5779	0.3768	0.4914	0.5536	0.6543	0.3732	0.4098	0.7695	0.3106	0.7988	0.7351	1.0032	0.8457
11	0.6426	0.3364	0.4653	0.6064	0.5592	0.5504	0.3617	0.9272	0.4498	0.6628	0.7558	1.0441	0.8209
12	0.6012	0.4590	0.5333	0.6001	0.6089	0.5247	0.4239	0.7283	0.5399	0.8216	0.8947	0.9803	0.8988
F(7–11)	0.6012	0.4591	0.5332	0.6001	0.6088	0.5246	0.4239	0.7283	0.5399	0.8216	0.8947	0.9803	0.8988

TABLE 11. Recruitment, biomasses (total, exploitable and spawning), average fishing mortality, ratio catch/spawning biomass (7–11 years) for the cod stock of the Subdiv. 3Ps estimated, from a cohort analysis, 1978–89, conducted by IFREMER Laboratory at St. Pierre and Miquelon.

Year	Recruitment (thousands)	Total biomass (metric tons)	Exploitable biomass (metric tons)	Spawning biomass (tons)	Average F (7–11 years)	Ratio catch/spawning biomass
1978	37 693	132 626	69 799	53 930	0.6012	0.505
1979	21 978	133 303	92 152	71 949	0.4590	0.459
1980	33 981	141 807	101 350	88 071	0.5331	0.427
1981	60 390	149 917	100 982	84 276	0.6000	0.462
1982	42 736	143 076	88 228	70 762	0.6087	0.479
1983	74 596	186 165	99 983	80 426	0.5241	0.478
1984	68 446	216 491	107 529	89 478	0.4230	0.413
1985	54 952	213 894	115 437	96 940	0.7286	0.531
1986	29 681	175 935	105 190	86 606	0.5425	0.678
1987	48 255	175 780	114 562	86 880	0.8215	0.722
1988	85 448	178 542	90 981	67 958	0.8448	0.762
1989	187 435	276 546	101 159	64 417	0.8679	0.910

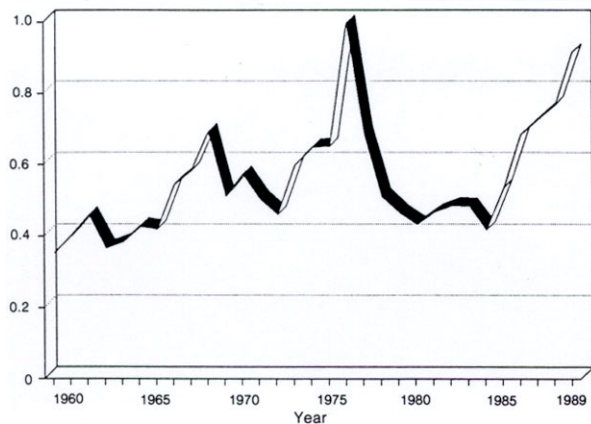


Fig. 10. Variations of the catch/spawning biomass ratio of cod in Subdiv. 3Ps from 1959 to 1989 estimated from the cohort analysis conducted by French IFREMER Laboratory at St. Pierre and Miquelon.

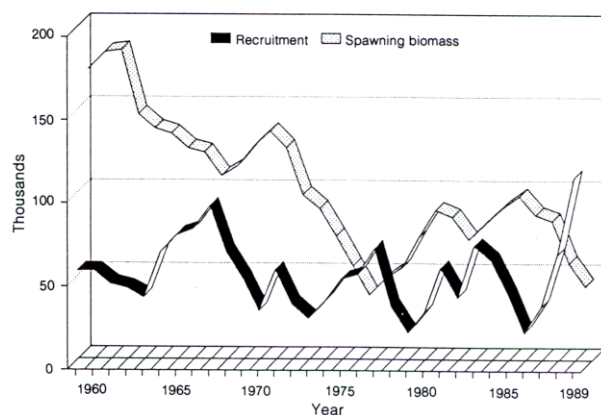


Fig. 11. Recruitment and spawning biomass variations of cod in Subdiv. 3Ps, 1959–89, estimated from the cohort analysis conducted by French IFREMER Laboratory at St. Pierre and Miquelon.

classes (ages 5 years and more), with a large part consisting of adults (Fig. 6 and 7, Tables 8 and 9). Along with the increase in the fishing activity during the period 1985–87 (Fig. 8, Table 10), the fishery was conducted on the oldest age groups and consequently their proportion in the stock have been reduced. During the same period, good recruitments came into the fishery, therefore in 1989 and 1990, the major part of catches was made up by individuals belonging to younger age groups (4 and 5), most of them being immatures.

Cod stock biomasses

In the 1978-89 period, total estimated biomass of the cod stock increased until 1985 (Fig. 9, Table 11). The international fishery activity limitation in Subdiv. 3Ps, as a result of the extension of territorial limits to 200 miles in 1977 by Canada, along with good recruitments, permitted the reconstitution of this stock. The estimated biomasses since 1985, however, have declined. Exploitable and spawning biomasses have more or less followed the same variation, but decreased more strongly in 1988 and 1989 (Fig. 9 and 10, Table 11). Limitation of the fishing activity of the French fleet in Canadian waters from 1986 to 1988, and the increase of French fishing capacity during the same period, led to the reduction of the biomass of this stock. Since the fishery was conducted on adults, this has also resulted in the decline of the spawning biomass.

Recruitment abundance (age 3)

During the period 1978-89, cod recruitment abundance in Subdiv. 3Ps was very variable, the strongest being in 1981, 1983, 1984 and 1988 (Fig. 11, Table 11). From 1983 to 1986, the recruitment abundance drastically declined but subsequently increased while the spawning biomass was still declining. Similar to most other stocks, these variations may not be directly related to the spawning

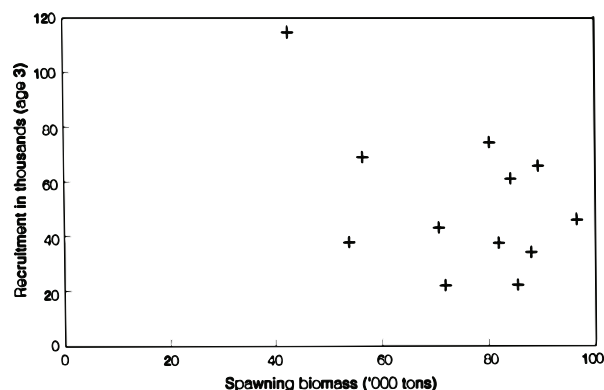


Fig. 12. Relation between recruitment and spawning biomass of cod in Subdiv. 3Ps from 1978 to 1989.

stock biomass (Fig. 12, Table 11). They are more likely due to concurrent effects between favourable hydrological conditions and abundance of eggs and larvae, and many other factors; for example the predator-prey relationships could affect the recruitment level.

Conclusions

Variations observed in cod stock abundance in Subdiv. 3Ps resulted from a combination of biological and environmental factors, and fishing activity.

Recruitment abundance, distribution and migrations of cod stock from the neighbouring Gulf of St. Lawrence and Grand Bank areas were found to vary from year to year. Some sources of variations have been identified and they were partly related to changes in environmental conditions. The intensity of the fishery exploitation by France was mainly related to the access limitations into the Canadian waters, placed on the Saint-Pierre and Miquelon trawler fleet. From 1986 to 1988 when this access was reduced and the fishing capacities was at a high level, the impact of the fishing activity on cod stock was strong. Since that time spawning biomass and abundance of adults have been at a low level. Since 1989, the increase of fishing capacity of these fleets have been compensated for by the decline of the Metropolitan trawler fleets.

References

- BERTRAND, J. 1989. Evaluation du stock de morue de la Subdivision OPANO 3Ps (évaluation 1989). *Rapport IFREMER DRV/RH Saint-Pierre et Miquelon, diffusion restreinte*, 35 p.
- BERTRAND, J., and R. CHEVALIER. MS 1988. Estimateurs d'indices d'abondance dans le cas d'échantillonnages stratifiés. *ICES C.M. Doc.*, No. D:2, Réf. G: 8 p.
- BERTRAND, J., and Ph. MOGUEDET. MS 1989. Diagnostic sur les stocks halieutiques soumis à prises maximales autorisées dans la Subdivision 3Ps de l'OPANO (évaluation 1989). *IFREMER DRV/RH Saint-Pierre et Miquelon. Doc. interne*, 31 p.
- BERTRAND, J., A. LAUREC, A. MAUCORPS, and B. MESNIL. MS 1988. A new approach to Subdivision 3Ps cod stock assessment. *NAFO SCR Doc.*, No. 96, Serial No. N1564, 20 p.
- BISHOP, C. A., and J. W. BAIRD. MS 1988. Assessment data for the cod stock in NAFO Subdivision 3Ps. *NAFO SCR Doc.*, No. 72, Serial No. N1515, 19 p.
- FOREST, A., and J. P. MINET. 1981. Abundance estimates of the trawlable resources around the islands of St. Pierre and Miquelon (NAFO Subdiv. 3Ps) methods used during the French research survey and discussion of some results. In: Bottom trawl surveys. W. G. Doubleday and D. Rivard (eds.). *Can. Spec. Publ. Fish. Aquat. Sci.*, **58**: 68–81.
- GASCON, D., M. APARICIO, and B. MERCILLE. MS 1990. Estimation de mélange entre les stocks de morue du nord du golfe du Saint-Laurent (Divisions 3Pn, 4RS) et les stocks adjacents (2J+3KL, 3Ps et

- 4TVn (janvier–avril)) à partir des résultats de marquage. *CAFSAC Res. Doc.*, No. 61, 25 p.
- LAUREC, A., and J. G. SHEPHERD. 1983. On the analysis of catch and effort data. *ICES J. Cons.*, **41**: 81–84.
- MABEAU, S., J. C. POULARD, and J. C. MAHÉ. 1986. Research survey abundance indices for the cod stock in NAFO Subdivision 3Ps, their reliability and compatibility with results of a cohort analysis. *ICES C.M. Doc.*, No. G:38, 9 p. + fig.
- MOGUEDET, Ph. MS 1990. Dynamique du stock de morue de la Subdivision 3Ps de la NAFO: évaluation de la ressource en 1990 et prédiction de captures pour 1991. *IFREMER DRV/RH Saint-Pierre et Miquelon. Doc. interne*, 60 p.
- MOGUEDET, Ph., and J. C. MAHÉ. MS 1991. Yearly variations in water temperature in NAFO Subdivision 3Ps from 1978 to 1990. *NAFO SCR Doc.*, No. 24, Serial No. N1904, 12 p.
-

Blank