Northwest Atlantic Fisheries Organization

Serial No. N2903 NAFO SCR Doc. 97/69

SCIENTIFIC COUNCIL MEETING - JUNE 1997

Assessment of the 4VWX Silver Hake Population in 1996

by

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Management and Current Fishery

The silver hake fishery on the Scotian Shelf has traditionally been pursued by large (TC 7) vessels of the distant waters fleets of Russia, Cuba, and Japan. Prior to 1977, fishing on the Scotian Shelf was unrestricted in terms of area, mesh size, and season. During this period fishing occurred over the entire shelf, and the use of trawl mesh as small as 40 mm was common. In 1977, Canada implemented the Coastal Fisheries Protection Act, which restricted fishing for this species to the seaward side of the Small Mesh Gear Line (Fig. 1a), west of 60° W longitude, with a minimum mesh size of 60 mm. On an experimental basis a portion (4-6 vessels) of the fleet was allowed to fish inside the line during 1978 and 1979. From 1980 through 1983 fishing was permitted by condition of licence in an eastern extension of the box as far as 57° W longitude; from 1984 to present this eastern extension has been restricted to 59° W longitude. In 1994 further restrictions were introduced to minimize incidental catches of cod, haddock and pollock in the silver hake fishery. These included a repositioning of the small mesh gear line to prevent fishing in depths of less than 190 m (Fig. 1a) and use of a separator grate in the lengthening piece of the trawl.

By regulation the fishery opens April 1 and closes November 15 each year; however, in recent years vessels have been allowed to commence fishing earlier under experimental permit.

Canadian fishing interests have been engaged in experimental harvesting of this species since 1987, although until 1995 these efforts were developmental in nature (Showell and Cooper, MS1997). In 1995 and 1996 a commercial fishery for this species was conducted by Canada in and around Emerald and LaHave basins (Fig. 1b). Catches by Canada in 1996 were substantially higher than 1995, at 3500 mt compared to 300 mt. A fishery was also conducted under Canadian allocations through charter arrangements with Cuban and Russian fishing companies. The total catch for this fishery in 1996 was 22,500 mt.

Nominal catches from this stock have ranged from 300,000 tons in 1973 to 8,000 tons in 1994 (Table 1). The provisional catch in 1996 was 26,000 tons, of 60,000 tons allocated. The NAFO Scientific advice (tons) on catch levels, Total Allowable Catches (TAC's) established, and total catches from 1986 are as follows:

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Advice	100	100	167	235		100	105	75	51 (40[3])	79 (59[4])	64	50
TAC	100	100	120	135	135	100	105	86[2]	30	50	60	50
Catch	83	62	74	91	69	68	32[1]	29[1]	8[1]	18[1]	26[1]	--

[1] Preliminary
[2] Includes additional 11,000 tons allocated by Canada in the expectation that not all allocations would be harvested.
[3] Adjustment for retrospective; see Special comments, NAFO Sci. Counc. Rep., 1993.
[4] Adjustment for retrospective; see Special comments, NAFO Sci. Counc. Rep., 1994.

Removals and Weights at Age

Sampling for length composition and otoliths in the 1996 commercial catch was conducted for the Canadian and foreign fisheries by Canadian observers. Observer coverage levels were substantial, at 100% of the foreign fishery, and 25% of the domestic fishery, on a trip basis. More than 1,300 samples and 2,226 otolith pairs were collected from the foreign fishery; 200 length frequency samples were collected in the domestic fishery. A summary of length and age sampling for both fisheries is presented in Table 2a and 2b.

The commercial removals at age for the foreign fishery in 1996 were calculated using the same procedure as the previous assessment, using Canadian length frequency data and monthly age/length keys constructed from Canadian aging data. Removals at age for the Canadian fishery were calculated using length data collected by Canadian observers and monthly age/length keys from the foreign fishery (Showell and Cooper, MS1997), and combined with those from the foreign fishery to provide estimates of total removals (Table 3). Regressions of lengths and weights from the Canadian July research vessel survey were used to calculate yearly alpha and beta values (Table 4) used in the calculation of sample weights and weight-at-age. As the Canadian fishery appears to target smaller fish than the foreign fishery, an aggregate commercial mean weight-at-age was calculated using data from both fisheries, weighted by catch. The removals at age and weight-at-age for 1977-1995 were taken from the previous assessment (Showell, MS1996) to provide estimates for the period 1977-96 inclusive (Tables 5 and 6).

As was noted in the previous assessment, commercial mean weight-at-age has shown a declining trend since 1992. Although mean weight at age 1 dropped slightly in 1996, most ages remain at levels the same, or very close to, those seen in 1994-95 (Fig. 2).

Commercial Catch Rates

Multiplicative analysis of catch rates in this fishery (Smith and Showell, MS1996) indicated country, month and NAFO area were not significant, and that a model with year alone had as much explanatory power as one which includes all four factors. Based on this analysis, a non-standardized catch rate series was produced using Canadian observer data (Table 7, Fig. 3). The catch rates for this stock have dropped from high levels in the period 1984-89, to relatively low levels in 1992 though 1996. An analysis of the effect of separator grates on silver hake catch rates by Halliday and Cooper (MS1997) indicates that a grate reduces the catch rate by about 5%. CPUE and effort (hrs), adjusted for this factor, is presented in Table 7.

Canadian Bottom Trawl Surveys

The July stratified random groundfish survey has been conducted on the Scotian Shelf from 1970 using three Canadian research vessels (*A.T. Cameron*, *Lady Hammond*, and the *Alfred Needler*). A conversion factor of 2.3 is applied to the series prior to 1982 to account for the effect of vessel and gear changes between the *A.T. Cameron* and the other two vessels (Fanning, MS1985). No conversion factor is required between the *Lady Hammond* and the *Alfred Needler*.

Survey trends in both total numbers and biomass show relatively high abundance in the early to mid 80's, followed by a decline to relatively low levels over the period 1988-94 (Fig. 4). Results of the 1996 survey indicate a modest increase in both numbers and biomass over those seen in 1995.

In numbers at age (Table 8) the 1994 year classes appears to be above average in size at age 2, while the 1993 and 1995 year classes are average at ages 1 and 3 respectively.

Juvenile Survey

A standardized IYGPT O-group survey for this species has been conducted since 1981 (1992 excluded) during the October-November period. Analysis of the 1996 survey produced a stratified mean number per tow of 444.1 This point is the second highest in the time series, and suggests the possibility of a strong 1996 year class. However, it should be noted that this estimate has a very high coefficient of variation (0.42). These data, as well as those of previous years for the core strata (60-78) are presented in Table 9.

Estimation of Parameters

Sequential Population Analysis

The sequential population analysis was calibrated by means of the adaptive framework, ADAPT (Gavaris, 1993) using the Canadian July R/V survey (1979-96), age disaggregated CPUE (1979-96), and the O-group survey (1983-1996) as tuning indices. The formulation included a catch at age from 1979 to 1996, ages 1 to 9, fully recruited ages 3, 4 and 5, natural mortality of 0.4, and a dome shaped recruitment pattern, with F at age 9 set at 10% of fully recruited. Results of this analysis are shown in Table 10 a,b, & c. In the past (Showell, MS1996) the analytical assessment of this resource has shown changes with the addition of additional data, with a tendency for the current estimate of population size to be optimistic. As a result, an analysis for a retrospective pattern was conducted. Fishing mortality for the fully recruited age groups was underestimated by approximately 50% in some years (Fig 5). The retrospective effect on estimates of population numbers was also examined for ages 2 though 4, which are most important in the commercial fishery (Fig. 6). When the initial estimate of 2-4 numbers was compared to the estimate with several more years data added, a difference of approximately 20% was seen. However, in one case (1994) poor estimation of age 2 fish resulted in a difference of over 100% between the initial estimate and current estimate.

Beginning of the year population numbers, biomass, and fishing mortality at age are shown in Table 11. In 1996 the estimated average F over ages 3-5 was low, at approximately 0.2.

To examine the effect of the dome shaped recruitment pattern, two additional analyses were conducted using the same formulation, one with a dome of 50% and the second with a flat topped PR (no dome). The results of this analysis are compared (Fig.7a) for fishing mortality over ages 3 to 5 (which are seen to be fully recruited with a 10% dome), and for numbers at ages 2 to 4 (which are the predominant ages in the commercial catch) (Fig. 7b). A dome of 0.5 or 1.0 resulted in higher estimates for fishing mortality and consequently lower estimates for numbers.

Recruiting Yearclass Sizes

The estimates of the 1994 and earlier yearclasses can be accepted from the SPA; however, the strength of the 1995 and 1996 yearclasses must be inferred from research vessel data.

The 1996 yearclass will make a significant contribution to the catch in 1998 at age 2. The only available data to estimate the size of this age class is the O-group survey. The index from this survey was regressed against age 1 numbers from the SPA for the same year class for 1983-94. Although an O-group index is available for 1981 and 1982, these were not included due to concerns over standardization of survey protocol during these years. The regression was significant ($p < 0.05$), with an R^2 of 0.34 (Table 12a, Fig. 8). The predicted size of the 1996 year class from this relationship is relatively large at 1.8 billion fish.

The 1995 yearclass will be fully recruited at age 3 in 1998. Yearclass estimates from the survey at age 1 were regressed against estimates from the SPA for the 1982-1994 yearclasses, using the model SPA=a + b(lnRV) (Table 12b). Data for yearclasses prior to 1982 were excluded due to questions of comparability between research vessels. The data fit the model well (R^2=0.78), and the predicted size of the 1995 yearclass was 0.79 billion fish, while the estimate from the O-group survey was 1.2 billion. As was the case in the 1996 assessment, the size of the 1995 yearclass was taken as an average of the two estimates, at 996 million fish.

The 1997 year class was taken as the 10 year geometric mean for age 1 fish from the VPA (800 million).

Projection

An $F_{0.1}$ value of 0.70 was used, based on the yield-per-recruit analysis conducted in the 1994 assessment. The commercial mean weights-at-age have declined sharply since 1992, and have stabilized at lower levels in recent years. This decline is also seen in survey data, and appears to be a biological phenomenon rather than a result of sampling or other bias. Consequently, a short series (1994-96) of weights-at-age was averaged for projection. As was the case in the previous assessment, the partial recruitment was averaged for the last 5 years. To quantify the effect of the retrospective pattern, an analysis of initial estimates of population

numbers compared to the 1996 estimates was conducted, and the proportion of the 1996 estimate to the initial estimate averaged for the past 5 years (Table 13). The numbers for ages 3+ from the SPA were adjusted, on an age-by-age basis, by these proportions for catch projection purposes. Weight-at-age, numbers, and partial recruitment were:

age	avg. wt.	PR	numbers[1]
1	0.050	0.04	1,800,000
2	0.100	0.34	660,335
3	0.136	0.85	371,498
4	0.170	1.00	79,440
5	0.202	0.92	70,361
6	0.291	0.73	18,214
7	0.432	0.64	5,130
8	0.431	0.84	842
9	0.685	0.09	239

[1] Jan 1, 1997 numbers, age 3+ adjusted for retrospective pattern.

The 1997 silver hake fishery is still in progress, and the exact total catch cannot be determined at this time. Based on preliminary catch rates, level of participation, and historical trends in resource availability, the final catch for the foreign fleet was predicted to be 17,000 tons, and that of the Canadian fleet 3,500 tons, for a total of 20,500 tons. The catch at a target fishing level of F0.1 is estimated to be 65,600 tons (Table 14).

References

Fanning, L.P 1985. Intercalibration of research survey results obtained by different vessels. CAFSAC Res. Doc. 85-3. 43p.

Gavaris, S. 1993. Analytical estimates of reliability for the projected yield from commercial fisheries. p 185-191. In: S.J. Smith, J.J. Hunt, and D. Rivard (ed). Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Aquat. Sci. 120.

Halliday, R.G. and C.G. Cooper MS1997. The effect of codend separator grates on silver hake otter trawl catch rate. NAFO SCR Doc. 97/51, Serial No. N2885, 14p.

Showell, M.A. MS1996. Assessment of the 4VWX silver hake population in 1995. NAFO SCR Doc. 96/78, Serial No. N2753, 24p.

Showell, M.A. and C.G. Cooper MS1997. Development of the Canadian silver hake fishery, 1987-96. NAFO SCR Doc. 97/54, Serial No. N2888, 10p.

Smith, S.J. and M.A. Showell 1996. Analysis of catch-per-unit effort data for Scotian Shelf silver hake. NAFO Scr. Doc. 96/17 10pp.

Table 1. Nominal catches for 4VWX silver hake 1970-1996 (1993-1996 preliminary).

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Bulgaria	0	0	0	0	0	1722	3088	862	606	4639	817	0	0
Canada	0	0	0	0	11	101	26	10	26	13	104	6	38
Cuba	0	0	201	0	0	1724	12572	1847	3436	1798	2287	642	11969
France	0	0	0	0	0	0	0	15	0	0	0	0	2[1]
FRG	0	0	10	0	296	106	97	684	0	0	0	0	0
GDR	0	0	0	0	0	0	0	0	3	0	0	0	0
Ireland	0	0	0	0	0	108	106	0	0	9	0	0	0
Italy	0	0	0	0	0	0	0	38	106	5	0	541	37[1]
Japan	129	8	63	88	67	54	78	19	161	219	239	120	937
Poland	0	0	0	0	0	0	0	295	2	0	0	1[1]	31[2]
Portugal	0	0	0	0	0	0	0	0	0	0	56	2044	2[1]
Romania	0	0	0	0	0	0	0	10	0	1	0	0	0
Spain	0	15	0	0	0	6	0	0	2	0	40	0	0
USA	0	1	1	1	1	7	1	14	0	0	0	3	2
USSR/Russia	168916	128633	113774	298533	95371	112566	81216	33301	44062	45076	40982	41243	47261
Total	169045	128657	114048	298621	95745	116394	97184	37095	48404	51760	44525	44600	60251

Country	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Bulgaria	0	0	0	0	0	0	0	88	0	0	0	0	0	0
Canada	15	10	2	9	13	9	337	10	34	4	73[1]	57[1]	300[1]	3485
Cuba	7418	14496	17683	16041	20219	9016	14541	13888	23708	16528	22018[1]	7788[1]	16835[1]	21773
France	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GDR	0	93	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	2[2]	0	0	0	0	0	0	0	0	0	0	0	0	0
Japan	649	530	120	66	144	0	194	315	781	547	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	378	1714	1338	0	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA	0	0	0	1	0	0		0	0	0	0	0	0	0
USSR	27377	57423	56337	66571	41329	65349	72917	55429	40786	14716	7139[1]	0	0	669
Total	35839	74266	75480	82688	61705	74374	87989	69730	65309	31795	29230	7845	17835	25927

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data

Table 2a. Commercial sampling from the foreign 4VWX silver hake fishery, 1977-1996.

Year	No. Lengths	No. Ages
1977	34379	600
1978	137468	674
1979	101908	1108
1980	247369	1462
1981	195493	987
1982	160878	1152
1983	134226	986
1984	203314	1255
1985	216912	1163
1986	197654	1311
1987	377527	681
1988	309767	1158
1989	300100	1135
1990	447587	1817
1991	556765	1712
1992	336562	1721
1993	350440	1563
1994	138199	914
1995	206928	1347
1996	298014	2226

Table 2b. Commercial sampling from the domestic 4VWX silver hake fishery.

Year	No. Lengths	No. Ages
1996	45000	0

Table *3*. Commercial catch numbers at age from 4VWX silver hake in 1996, from the Canadian and foreign fisheries.

age	Canada	Cuba/Russia	Total
1	6900	26601	33501
2	17200	74830	92030
3	4726	38960	43686
4	3287	19947	23234
5	526	4402	4928
6	54	834	888
7	8	140	148
8	3	72	75
9	0	0	0

Table 4 Length/weight regressions: Male and female alpha and beta's used in the construction of the silver hake catch at age used in this assessment. Lengths (cm) and weights (kg) used were from the Canadian July Research Vessel Survey of the Scotian Shelf (4VWX).

Year	Male - Alpha	Female - Alpha	Male - Beta	Female - Beta
1977	0.000006260	0.000006930	3.0626	3.0350
1978	0.000004630	0.000003070	3.1366	3.2531
1979	0.000010200	0.000005880	2.9001	3.0675
1980	0.000002330	0.000001800	3.3417	3.3989
1981	0.000006830	0.000005080	3.0206	3.1172
1982	0.000011600	0.000006740	2.8575	3.0232
1983	0.000006480	0.000003320	2.9935	3.2034
1984	0.000018300	0.000006490	2.7052	3.0284
1985	0.000013500	0.000004530	2.7848	3.1235
1986	0.000007970	0.000003820	2.9384	3.1685
1987	0.000009990	0.000004240	2.8798	3.1456
1988	0.000014300	0.000004800	2.7942	3.1241
1989	0.000006750	0.000004440	3.0114	3.1416
1990	0.000034320	0.000021000	2.5234	2.6958
1991	0.000007773	0.000003488	2.9582	3.2036
1992	0.000003938	0.000003157	3.1824	3.2533
1993	0.000003461	0.000003089	3.178	3.2202
1994	0.000003336	0.000003147	3.2009	3.2228
1995	0.000003340	0.000002367	3.2151	3.3233
1996	0.000002548	0.000002466	3.2909	3.3033

Table 5 Commercial catch numbers at age for 4VWX silver hake.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	17911	20940	20569	16588	2358	20189	5849	59588	14970	45598
2	72529	70302	57893	70696	25214	52976	96852	45828	130814	70269
3	59862	80196	72891	70391	109035	75876	56158	206900	98346	229126
4	15070	35025	36669	32032	37573	68400	29282	82911	128365	84097
5	2218	12709	22380	14465	11928	31752	11388	19344	34110	28635
6	725	5227	9970	5184	3234	5945	3395	4268	9327	8760
7	97	1906	3168	1431	1201	2042	819	1038	2344	1436
8	91	1168	495	451	290	465	253	183	226	497
9	4	338	374	98	141	64	88	10	85	111
Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	6804	5110	24264	6516	5738	7461	31572	1651	3498	33501
2	214235	62791	85846	209620	117305	76663	83140	13265	35925	92030
3	114417	265307	158745	142862	201243	73526	70735	35250	45615	43686
4	54211	39242	145105	41215	46414	27777	35222	8847	31316	23234
5	13063	21303	20025	11741	12154	3461	5511	1283	5183	4928
6	6045	3106	9369	1648	3954	1247	595	150	457	888
7	347	2133	1569	640	290	159	71	18	58	148
8	156	208	1166	107	181	33	30	8	41	75
9	117	143	39	40	50	5	3	0	3	0

Table 6: Silver hake commercial mean weights at age.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.065	0.074	0.076	0.04	0.061	0.066	0.067	0.07	0.068	0.053
2	0.183	0.153	0.178	0.151	0.168	0.169	0.128	0.146	0.136	0.145
3	0.264	0.229	0.227	0.223	0.215	0.231	0.196	0.181	0.177	0.184
4	0.34	0.266	0.274	0.287	0.276	0.275	0.239	0.224	0.21	0.25
5	0.446	0.335	0.304	0.341	0.326	0.317	0.289	0.272	0.244	0.25
6	0.632	0.405	0.389	0.391	0.401	0.394	0.365	0.353	0.295	0.274
7	0.886	0.438	0.455	0.531	0.553	0.446	0.395	0.405	0.41	0.392
8	0.922	0.54	0.838	0.839	0.923	0.513	0.457	0.624	0.582	0.514
9	2.12	0.892	0.838	0.859	1.137	0.506	0.444	0.65	0.669	0.644
Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.045	0.045	0.06	0.063	0.047	0.08	0.06	0.050	0.060	0.040
2	0.119	0.139	0.135	0.139	0.139	0.14	0.11	0.100	0.100	0.100
3	0.168	0.185	0.195	0.184	0.189	0.19	0.15	0.130	0.140	0.139
4	0.211	0.227	0.224	0.217	0.215	0.21	0.19	0.170	0.170	0.169
5	0.248	0.26	0.278	0.24	0.263	0.26	0.23	0.190	0.210	0.207
6	0.286	0.292	0.349	0.315	0.471	0.28	0.28	0.270	0.310	0.293
7	0.453	0.401	0.403	0.37	0.471	0.37	0.38	0.380	0.410	0.505
8	0.422	0.497	0.511	0.401	0.511	0.41	0.32	0.420	0.440	0.433
9	0.518	0.688	0.82	0.545	0.568	0.69	0.96	---	0.620	---

Table 7: CPUE (t/hr) and effort (hrs), raw and (corrected) for the effect of separator grates, for the Cuban and Russian 4VWX silver hake fishery, 1979-96.

year	CPUE	effort (hrs)
1979	1.71	30,271
1980	2.04	21,811
1981	1.71	26,083
1982	3.20	18,841
1983	1.76	20,406
1984	2.94	25276
1985	2.82	26,791
1986	3.48	23,755
1987	2.75	22,433
1988	2.80	26,535
1989	3.89	22,624
1990	1.89	37,288
1991	1.70	39,911
1992	1.32	24,148
1993	1.43	20,369
1994	1.36 (1.43)	5,726 (5,440)
1995	1.34 (1.41)	12,563 (11,935)
1996	1.28 (1.34)	17,532 (16,655)

Table 8 Scotian Shelf silver hake Canadian July research vessel survey catch numbers ('000) at age.

Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	7737	26740	89437	17730	32839	192025	114273	188970	102726	552598
2	27660	23257	152705	55638	84724	293420	108957	70369	172576	84325
3	21421	16266	67003	97253	131420	80348	38209	208723	34402	70625
4	4592	8874	20048	45862	60469	60487	19340	37926	71191	22623
5	1348	6733	11522	10684	16241	32426	10632	11828	21488	13448
6	1278	3046	5055	4525	5127	8257	2882	7942	9445	4235
7	984	1286	2664	2001	2367	3549	876	2860	2667	1622
8	336	502	969	589	794	2535	401	1136	1175	673
9	283	865	275	385	564	327	337	522	215	376
1+	65639	87569	349678	234667	334545	673374	295907	530276	415885	750525
Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	146007	69740	172095	117089	66678	45284	166402	78069	156447	99503
2	266663	89508	63810	125952	84743	56347	91306	59547	68898	192521
3	46095	81458	24151	42329	35293	46180	74838	37734	84328	51155
4	18982	16709	13405	13022	13257	11097	25736	15082	56947	39144
5	6048	14249	4130	4173	6577	4477	3296	6734	15317	9456
6	4168	2502	1868	1169	2456	2237	805	1173	3367	1584
7	1199	2338	769	432	402	424	524	305	1295	295
8	672	468	282	227	143	139	98	204	614	566
9	471	121	129	82	124	192	38	131	652	156
1+	490305	277093	280639	304475	209904	168890	363061	199067	387866	394380

Table 9: Stratified mean catch per tow for the Canada-Russia juvenile silver hake survey, core strata (60-78).

Year Class	1981	1982	1983	1984	1985	1986	1987	1988	1989
mean catch/tow	579.0	8.8	232.2	43.4	284.8	198.0	102.0	204.8	131.5
std.error	64.4	1.2	24.4	7.1	62.2	37.9	23.0	35.3	19.0
CV	0.11	0.14	0.11	0.16	0.22	0.19	0.23	0.17	0.14
number of sets	77	61	64	71	82	74	105	79	74
July RV age 1 #'s (10^6)	192	114	189	103	553	146	70	172	117

Year Class	1990	1991	1992[1]	1993	1994	1995	1996
mean catch/tow	187.4	78.6	-	186.5	105.4	252.0	444.1
std.error	24.1	10.4	-	17.2	8.4	60.5	186.5
CV	0.13	0.13	-	0.09	0.08	0.24	0.42
number of sets	68	71	-	95	73	83	81
July RV age 1 #'s (10^6)	67	45	166	78	156	100	--

[1] no survey in 1992.

Table 10a: Parameter estimates from ADAPT for 4VWX silver hake using Canadian July RV survey (ages 1-9), commercial CPUE (ages 1-9) and O-group index (age 1).

PAR-STATS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.003343
MEAN SQUARE RESIDUALS 0.690082

PARAMETER	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
age 2	1.414E1	5.027E-1	3.556E-2	1.798E-3	1.272E-4
age 3	1.306E1	4.314E-1	3.302E-2	-6.179E-3	-4.730E-4
age 4	1.176E1	4.203E-1	3.573E-2	-1.449E-2	-1.232E-3
age 5	1.182E1	3.562E-1	3.013E-2	-6.971E-4	-5.896E-5
age 6	1.056E1	3.576E-1	3.388E-2	1.416E-3	1.342E-4
age 7	9.289E0	3.609E-1	3.885E-2	-5.289E-4	-5.694E-5
age 8	7.481E0	3.710E-1	4.959E-2	-5.067E-3	-6.773E-4
age 9	6.218E0	3.737E-1	6.009E-2	-1.121E-2	-1.802E-3
RV age 1	-1.120E1	2.008E-1	-1.794E-2	-3.312E-3	2.959E-4
RV age 2	-1.063E1	1.990E-1	-1.872E-2	-2.774E-3	2.611E-4
RV age 3	-1.032E1	1.983E-1	-1.921E-2	-2.334E-3	2.261E-4
RV age 4	-1.001E1	1.980E-1	-1.978E-2	-2.411E-3	2.409E-4
RV age 5	-9.699E0	1.986E-1	-2.047E-2	-1.365E-3	1.407E-4
RV age 6	-9.489E0	1.991E-1	-2.098E-2	2.934E-4	-3.092E-5
RV age 7	-9.399E0	1.988E-1	-2.115E-2	1.463E-3	-1.557E-4
RV age 8	-9.372E0	1.985E-1	-2.118E-2	2.994E-3	-3.194E-4
RV age 9	-9.566E0	1.978E-1	-2.068E-2	3.832E-3	-4.006E-4
CPUE 1	-8.760E0	2.283E-1	-2.606E-2	-3.487E-3	3.980E-4
CPUE 2	-1.420E1	2.008E-1	-1.414E-2	-3.312E-3	2.333E-4
CPUE 3	-1.178E1	1.990E-1	-1.690E-2	-2.774E-3	2.356E-4
CPUE 4	-1.061E1	1.983E-1	-1.868E-2	-2.334E-3	2.199E-4
CPUE 5	-1.026E1	1.980E-1	-1.929E-2	-2.411E-3	2.349E-4
CPUE 6	-1.027E1	1.986E-1	-1.934E-2	-1.365E-3	1.330E-4
CPUE 7	-1.038E1	1.991E-1	-1.918E-2	2.934E-4	-2.826E-5
CPUE 8	-1.089E1	1.988E-1	-1.826E-2	1.463E-3	-1.344E-4
CPUE 9	-1.124E1	1.985E-1	-1.765E-2	2.994E-3	-2.662E-4
Juv 1	-1.265E1	1.978E-1	-1.563E-2	3.832E-3	-3.029E-4

Table 10b: Results of bias adjustment for population estimates.

	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
age 2	1377164	692302	0.50	176462	0.13
age 3	471421	203371	0.43	40948	0.09
age 4	128296	53925	0.42	9473	0.07
age 5	136304	48549	0.36	8550	0.06
age 6	38428	13743	0.36	2512	0.07
age 7	10818	3904	0.36	699	0.06
age 8	1774	658	0.37	113	0.06
age 9	502	187	0.37	29	0.06
age 10	8	2	0.20	0	-0.02

Table 10c: Residuals from ADAPT analysis

RV

	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1979.00	-0.12	0.58	0.39	-0.15	-0.50	-0.25	-0.92	-0.86	-2.46
1980.00	-1.42	-0.67	0.49	0.64	0.06	-0.70	-0.06	-1.82	-1.07
1981.00	-1.08	0.03	0.61	0.52	0.25	0.22	-0.72	-0.22	-1.19
1982.00	0.12	1.00	0.32	0.59	0.83	0.45	1.08	-0.11	-0.34
1983.00	0.23	-0.55	-0.77	-0.64	-0.42	-0.53	-0.93	0.21	-1.45
1984.00	0.25	-0.36	0.53	-0.21	-0.60	-0.13	0.21	-0.09	1.41
1985.00	0.23	0.13	-0.71	0.31	0.28	-0.01	-0.53	-0.05	-1.05
1986.00	1.02	-0.02	-0.13	-0.20	-0.30	0.31	-0.98	-1.24	-0.45
1987.00	0.51	0.27	-0.08	-0.58	-0.39	-0.52	0.42	-1.33	-0.88
1988.00	-0.17	-0.06	-0.34	-0.26	-0.01	-0.33	-0.17	0.27	-2.38
1989.00	0.36	-0.30	-0.70	-0.77	-0.21	-0.44	-0.33	-1.05	-0.09
1990.00	0.58	0.12	0.03	-0.21	-0.39	0.35	-0.11	-0.50	-1.08
1991.00	0.14	0.31	-0.11	0.49	0.57	1.08	0.92	0.32	-0.29
1992.00	-0.53	-0.04	0.39	0.15	1.22	1.09	1.56	1.22	1.93
1993.00	0.46	0.13	0.82	0.97	0.16	1.19	0.61	1.82	0.92
1994.00	0.13	-0.70	-0.44	-0.25	0.54	-0.09	1.41	0.16	3.42
1995.00	0.13	-0.10	-0.17	0.32	0.06	0.19	0.39	3.22	1.95
1996.00	-0.85	0.25	-0.13	-0.72	-1.16	-1.87	-1.84	0.03	3.08

CPUE

	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1979.00	0.31	-0.35	-0.34	-0.40	-0.38	0.22	-0.37	-0.77	-0.17
1980.00	0.74	-0.06	-0.32	-0.25	0.15	-0.45	0.31	-0.99	-0.13
1981.00	-1.67	-0.99	-0.25	-0.66	-0.45	-0.30	-0.87	-0.31	-0.45
1982.00	0.24	-0.19	-0.08	0.34	0.74	0.38	1.38	-0.57	0.48
1983.00	-0.45	-0.23	-0.81	-0.68	-0.49	-0.18	-0.23	0.91	-0.42
1984.00	1.18	-0.57	-0.12	-0.10	-0.46	-0.79	-0.24	-0.97	-0.38
1985.00	0.33	0.01	-0.35	0.17	0.32	-0.12	-0.16	-0.81	0.13
1986.00	0.67	0.08	0.47	0.51	0.15	1.07	-0.48	-0.53	0.55
1987.00	-0.36	0.39	0.32	-0.08	0.14	-0.06	-0.14	-1.72	0.01
1988.00	-0.75	-0.24	0.16	-0.13	-0.01	-0.20	0.25	0.36	-0.11
1989.00	0.59	0.33	0.66	1.05	1.11	1.25	1.06	1.43	0.98
1990.00	-0.62	0.46	0.22	-0.12	-0.11	0.27	0.45	-0.70	-0.02
1991.00	-0.70	0.47	0.61	0.69	0.43	1.13	0.76	1.11	0.57
1992.00	-0.21	0.50	0.27	0.44	0.65	0.51	1.18	0.78	0.48
1993.00	1.09	0.47	0.35	0.83	0.53	1.07	-0.61	1.80	0.75
1994.00	-0.11	-0.45	0.39	0.08	0.05	-0.64	0.68	-0.59	-0.06
1995.00	-0.84	0.22	-0.67	-0.19	-0.63	-1.09	-1.40	2.21	-0.52
1996.00	0.55	0.15	-0.51	-1.49	-1.76	-2.07	-1.55	-0.63	-1.69

JUV

1982.00	0.88
1983.00	-2.67
1984.00	0.10
1985.00	-0.97
1986.00	0.01
1987.00	0.48
1988.00	-0.12
1989.00	0.19
1990.00	0.35
1991.00	0.83
1993.00	-0.32
1994.00	0.67
1995.00	0.28
1996.00	0.30

Table 11a: 4VWX silver hake beginning of year population numbers

AGE	1979	1980	1981	1982	1983	1984	1985
1	906114	660678	861813	1529829	810865	1338797	733035
2	468922	590673	429388	575773	1009064	538783	849049
3	217673	267495	338740	267371	343035	597948	324020
4	88642	87616	122770	139793	118354	184602	235466
5	53516	30249	33164	52193	39614	55796	57962
6	17795	18075	8827	12706	10165	17420	21942
7	11982	4095	7958	3336	3808	4099	8246
8	3599	5487	1601	4364	640	1893	1913
9	5817	2012	3313	839	2549	228	1121
10	0	3596	1269	2106	511	1637	145
age 1+	1774060	1669976	1808843	2588310	2338605	2741203	2232899
age 2+	867946	1009298	947030	1058481	1527740	1402406	1499864
age 3+	399024	418625	517642	482708	518676	863623	650815
age 4+	181351	151130	178902	215337	175641	265675	326795

AGE	1986	1987	1988	1989	1990	1991	1992
1	1795349	782088	735265	1076852	587404	512919	672400
2	479203	1166412	518718	488708	702120	388451	339156
3	463466	264437	609068	296906	258320	302627	166382
4	138393	129553	86367	197562	73989	60831	46632
5	56833	27023	43732	26772	20966	17204	5310
6	12131	15480	7778	12465	2600	4829	2153
7	7295	1388	5560	2741	1181	459	254
8	3647	3732	652	2026	606	288	81
9	1100	2043	2375	270	444	320	52
10	682	647	1274	1476	150	265	174
age 1+	2958099	2392803	2010789	2105778	1647780	1288193	1232594
age 2+	1162750	1610715	1275524	1028926	1060376	775274	560194
age 3+	683547	444303	756806	540218	358256	386823	221038
age 4+	220081	179866	147738	243312	99936	84196	54656

AGE	1993	1994	1995	1996	1997
1	910712	578230	1127978	1831853	
2	444658	584828	386257	753260	1200702
3	167370	231014	381243	229813	430473
4	53162	55959	126377	218648	118823
5	9514	8284	30365	59539	127754
6	868	2056	4517	16171	35916
7	465	121	1257	2658	10119
8	46	254	67	795	1661
9	28	8	164	13	472
10	31	17	5	108	8
age 1+	1586854	1460771	2058230	3112858	
age 2+	676142	882541	930252	1281005	1925928
age 3+	231484	297713	543995	527745	725226
age 4+	64114	66699	162752	297932	294753

Table 11b: 4VWX silver hake beginning of year population biomass (t)

	1979	1980	1981	1982	1983	1984	1985
1	45306	13214	34473	76491	40543	66940	36652
2	56271	64974	34351	57577	90816	53878	84905
3	43535	53499	60973	53474	61746	89692	51843
4	22161	22780	30693	33550	27221	38766	44739
5	15520	9377	10281	15658	11092	13949	13331
6	6050	6146	3266	4574	3456	5574	6144
7	5032	1843	3661	1401	1485	1558	3133
8	2231	3402	1121	2313	288	947	937
9	4886	1710	3247	571	1224	125	729
10	0	3021	1104	2780	189	671	113
1+	200991	179965	183168	248390	238060	272101	242526
2+	155686	166751	148696	171898	197517	205161	205874
3+	99415	101777	114345	114321	106701	151283	120969
4+	55881	48278	53371	60847	44955	61591	69126

	1986	1987	1988	1989	1990	1991	1992
1	71814	23463	22058	43074	23496	15388	47068
2	47920	93313	41497	39097	63191	34961	27132
3	74155	42310	91360	47505	41331	48420	26621
4	29063	25911	17273	39512	15538	12166	9326
5	13072	6756	10058	6693	4822	4129	1274
6	3154	4180	2100	3740	780	1304	581
7	2480	486	1890	932	425	179	86
8	1678	1530	306	912	242	124	36
9	671	1062	1283	173	235	154	31
10	471	440	662	1299	158	148	118
1+	244477	199450	188489	182936	150218	116972	112275
2+	172663	175987	166431	139862	126722	101585	65207
3+	124742	82674	124934	100765	63531	66624	38074
4+	50588	40364	33574	53260	22200	18204	11453

	1993	1994	1995	1996	1997
1	45536	23129	56399	91593	
2	40019	46786	27038	60261	96056
3	23432	27722	45749	27578	51657
4	10101	8953	18957	32797	17823
5	2093	1574	5769	11312	24273
6	234	514	1084	4043	8979
7	153	40	415	1063	3542
8	16	102	27	334	681
9	18	4	84	7	245
10	25	25	5	81	9
1+	121626	108849	155527	229069	
2+	76091	85720	99128	137476	203266
3+	36072	38933	72090	77215	107209
4+	12640	11212	26341	49638	55553

Table 11c: 4VWX fishing mortality, from ADAPT analysis

	1	2	3	4	5	6	7	8	9	F_3-5
1979	0.028	0.161	0.510	0.675	0.685	1.069	0.381	0.181	0.081	0.623
1980	0.031	0.156	0.379	0.571	0.832	0.420	0.539	0.105	0.061	0.594
1981	0.003	0.074	0.485	0.455	0.559	0.573	0.201	0.246	0.053	0.500
1982	0.016	0.118	0.415	0.861	1.236	0.805	1.250	0.138	0.097	0.837
1983	0.009	0.123	0.220	0.352	0.422	0.508	0.299	0.634	0.043	0.331
1984	0.055	0.109	0.532	0.758	0.533	0.348	0.362	0.124	0.055	0.608
1985	0.025	0.205	0.451	1.021	1.164	0.701	0.416	0.154	0.096	0.879
1986	0.031	0.195	0.875	1.233	0.901	1.768	0.270	0.180	0.130	1.003
1987	0.011	0.250	0.719	0.686	0.845	0.624	0.356	0.052	0.072	0.750
1988	0.008	0.158	0.726	0.771	0.855	0.643	0.609	0.480	0.076	0.784
1989	0.028	0.238	0.989	1.843	1.932	1.957	1.109	1.119	0.191	1.588
1990	0.014	0.442	1.046	1.059	1.068	1.335	1.012	0.239	0.115	1.058
1991	0.014	0.448	1.470	2.039	1.678	2.546	1.329	1.316	0.209	1.729
1992	0.014	0.306	0.741	1.189	1.411	1.132	1.307	0.656	0.124	1.114
1993	0.043	0.255	0.696	1.459	1.132	1.569	0.203	1.410	0.137	1.096
1994	0.003	0.028	0.203	0.211	0.207	0.092	0.197	0.039	0.016	0.207
1995	0.004	0.119	0.156	0.353	0.230	0.130	0.058	1.260	0.022	0.246
1996		0.160	0.260	0.137	0.105	0.069	0.070	0.121	0.010	0.167

Table 12a: Regression of 4VWX silver hake juvenile survey O-group index vs age 1 numbers from SPA.

```
Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..    SPA1

Block Number  1.  Method:  Enter       OGRP


Variable(s) Entered on Step Number
   1..     OGRP


Multiple R              .59912
R Square                .35894
Adjusted R Square       .28771
Standard Error       332.20400

Analysis of Variance
                    DF        Sum of Squares        Mean Square
Regression           1          556129.22039       556129.22039
Residual             9          993235.50688       110359.50076

F =        5.03925       Signif F =  .0514

---------------------- Variables in the Equation -----------------

Variable                B         SE B        Beta         T  Sig T

OGRP             3.237208     1.442074     .599116     2.245  .0514
(Constant)     387.181306   250.885844                 1.543  .1572
```

Table 12b: Regression of 4VWX silver hake age 1 numbers from the Canadian July survey vs SPA age 1.

```
Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..    SPA1_01

Block Number  1.  Method:  Enter       LNRV1


Variable(s) Entered on Step Number  1..     LNRV1


Multiple R              .88431
R Square                .78201
Adjusted R Square       .76220
Standard Error       175.68061

Analysis of Variance
                    DF        Sum of Squares        Mean Squar
Regression           1         1217927.56808      1217927.5680
Residual            11          339500.43192        30863.6756

F =       39.46152       Signif F =  .0001

------------------------------ Variables in the Equation ------------------------------

Variable                B         SE B     95% Confdnce Intrvl B        Beta         T  Sig T

LNRV1          510.290751    81.232681    331.498852    689.082649     .884314     6.282  .0001
(Constant)   -1560.234858   394.187804  -2427.836231   -692.633486                -3.958  .0022
```

Table 3. Comparisons of 1996 estimates of population numbers to initial estimates from retrospective analysis, age by age.

age 1	1996 est	initial est	proportion	mean
1991	512919	576382	0.889894	0.931342
1992	672400	487269	1.379936	
1993	910712	1954349	0.465993	
1994	578230	743517	0.777696	
1995	1127978	986691	1.143193	
age 2				
1991	388451	495469	0.784007	0.870774
1992	339156	405363	0.836672	
1993	444658	436951	1.017638	
1994	584828	660279	0.885729	
1995	386257	465469	0.829823	
age 3				
1991	302627	384410	0.787251	0.863075
1992	166382	224693	0.740486	
1993	167370	236958	0.706328	
1994	231014	228033	1.013073	
1995	381243	356889	1.06824	
age 4				
1991	60831	67953	0.895192	0.668556
1992	46632	77894	0.59866	
1993	53162	101339	0.524596	
1994	55959	122613	0.456387	
1995	126377	145605	0.867944	
age 5				
1991	17204	19068	0.902245	0.550757
1992	5310	11514	0.461178	
1993	9514	17611	0.540231	
1994	8284	29820	0.2778	
1995	30365	53055	0.572331	
age 6				
1991	4829	6349	0.760592	0.507129
1992	2153	4306	0.5	
1993	868	2680	0.323881	
1994	2056	4046	0.508156	
1995	4517	10196	0.443017	

Table 14 Results of projection with new parameters; 1996 YC = 1.8 billion, 1995 YC = 0.996 billion

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1997.00	1800000	660335	371498	79400	70361	18214	5130	842	239	10
1998.00	800000	1193674	403982	198165	40680	36833	10034	2895	450	156
1999.00	800000	521449	630676	149362	65963	14321	14811	4297	1078	283

Fishing Mortality

	1	2	3	4	5	6	7	8	9
1997.00	0.011	0.091	0.228	0.269	0.247	0.196	0.172	0.226	0.024
1998.00	0.028	0.238	0.595	0.700	0.644	0.511	0.448	0.588	0.063

Weight (Beginning Year)

	1	2	3	4	5	6	7	8	9	10
1998.00	0.05	0.08	0.12	0.15	0.19	0.25	0.36	0.41	0.53	0.97
1999.00	0.05	0.08	0.12	0.15	0.19	0.25	0.36	0.41	0.53	0.97

Projected Population Biomass

	1	2	3	4	5	6	7	8	9	10
1998.00	40000	95494	48478	29725	7729	9208	3612	1187	239	152
1999.00	40000	41716	75681	22404	12533	3580	5332	1762	571	275

Projected Catch Numbers

	1	2	3	4	5	6	7	8	9
1997.00	15869	47672	63008	15561	12808	2692	672	141	5
1998.00	18223	210022	152260	84128	16260	12352	3031	1082	23

Weight (Average for Catch)

	1	2	3	4	5	6	7	8	9
1997.00	0.05	0.10	0.14	0.17	0.20	0.29	0.43	0.43	0.69
1998.00	0.05	0.10	0.14	0.17	0.20	0.29	0.43	0.43	0.69

Projected Catch Biomass

	1	2	3	4	5	6	7	8	9	
1997.00	793	4767	8569	2645	2587	783	290	61	3	20498
1998.00	911	21002	20707	14302	3284	3595	1309	466	16	65600

Table 15. 95% confidence intervals for 0-group index (top) and ln (RV age 1 #'s) vs SPA age 1 from Table 12a and b.

0-GRP

SPA 1	O-GRP	Predicted	L95ci	U95ci	SPA 1			
1339	43.4	473.6416	-463.345	1410.628	733			
733	78.6	617.3343	-275.532	1510.201	672	s=	358.823	
1795	102	712.8572	-157.973	1583.688	735	t(.025,9)=	2.26	
782	105.4	726.7367	-141.412	1594.886	1128	xbar=	167.2167	
735	131.5	833.2815	-18.8914	1685.454	587	SSx=	60909.9	
1077	186.5	1057.801	211.3734	1904.229	578			
587	187.4	1061.475	214.8209	1908.13	513			
513	198	1104.746	254.6543	1954.838	782			
672	204.8	1132.505	279.466	1985.544	1077			
578	232.2	1244.357	373.7146	2114.999	1339			
1128	252	1325.184	436.3454	2214.023	1810			
1810	284.8	1459.08	530.8024	2387.357	1795			
	444.1	2109.371	868.3448	3350.396	2109.371			

Ln RV

SPA 1	Ln RV	Predicted	L95ci	U95ci	SPA 1			
672	3.81	383.6806	-130.297	897.6578	672			
513	4.2	582.803	136.7983	1028.808	513	s=	174.826	
735	4.25	608.3315	169.059	1047.604	735	t(.025,9)=	2.228	
578	4.36	664.4942	238.1455	1090.843	578	xbar=	4.77	
733	4.63	802.3481	395.4895	1209.207	733	SSx=	1.3874	
811	4.74	858.5109	454.1731	1262.849	811			
587	4.76	868.7223	464.4927	1272.952	587			
782	4.98	981.0477	570.9097	1391.186	782			
1128	5.05	1016.788	602.1022	1431.473	1128			
911	5.11	1047.422	627.8601	1466.984	911			
1077	5.15	1067.845	644.5463	1491.143	1077			
1339	5.24	1113.796	680.7288	1546.863	1339			
1795	6.32	1665.212	1012.435	2317.988	1795			

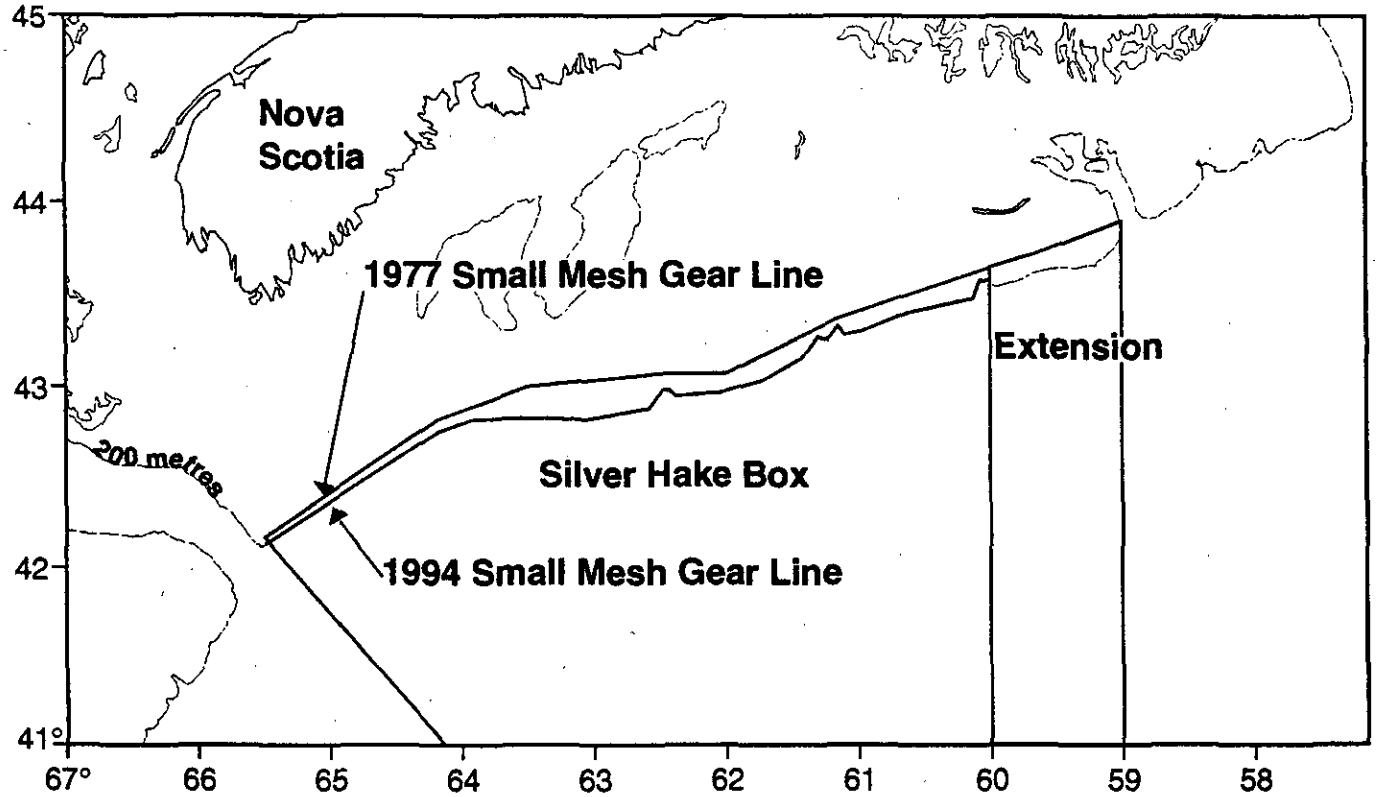

Fig. 1a: The location of the new and old Small Mesh Gear Line (SMGL).

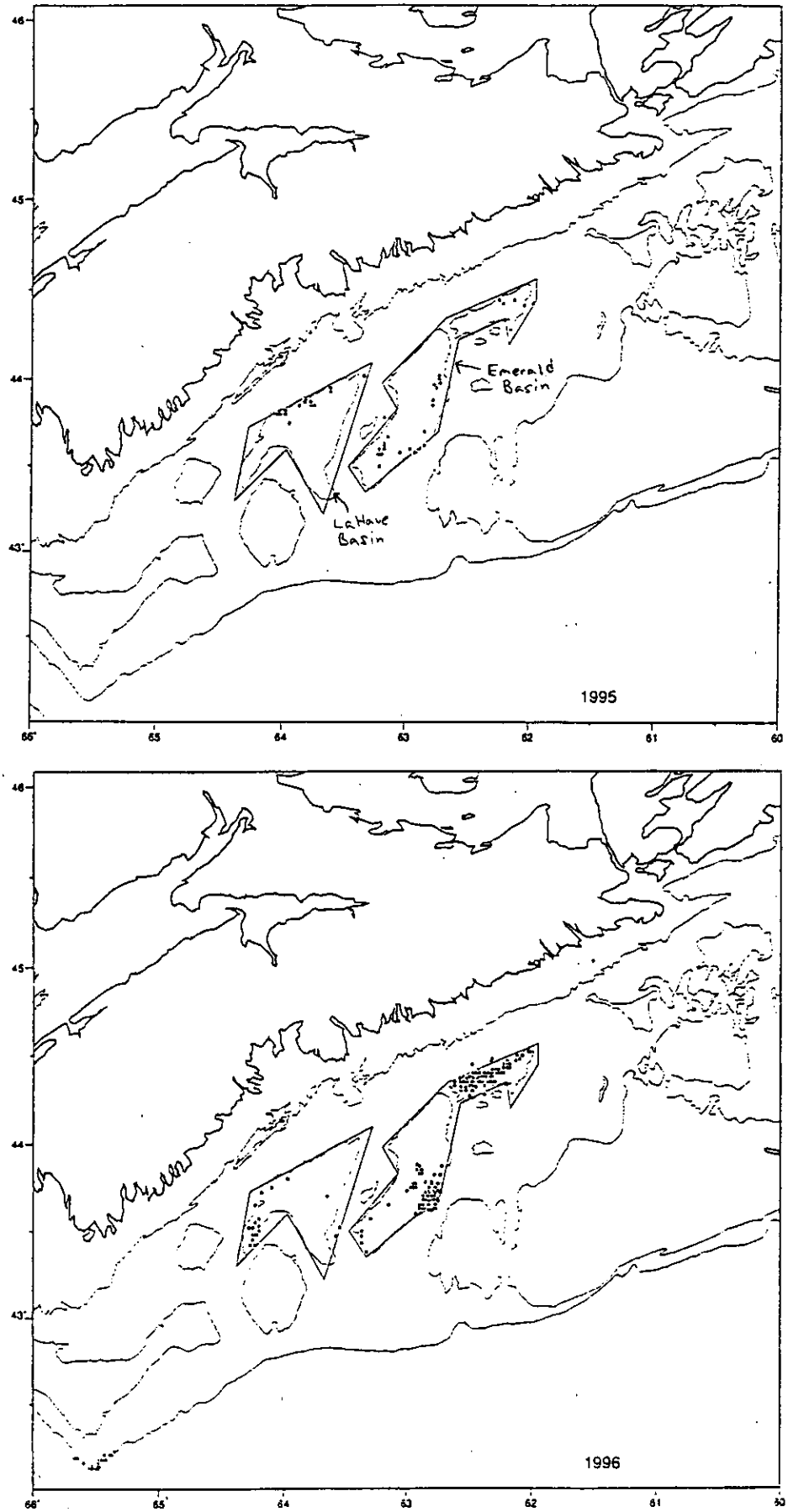

Figure 1b Locations of silver hake directed fishing activity by Canadian vessels in 1995 and 1996, from Canadian observer data.

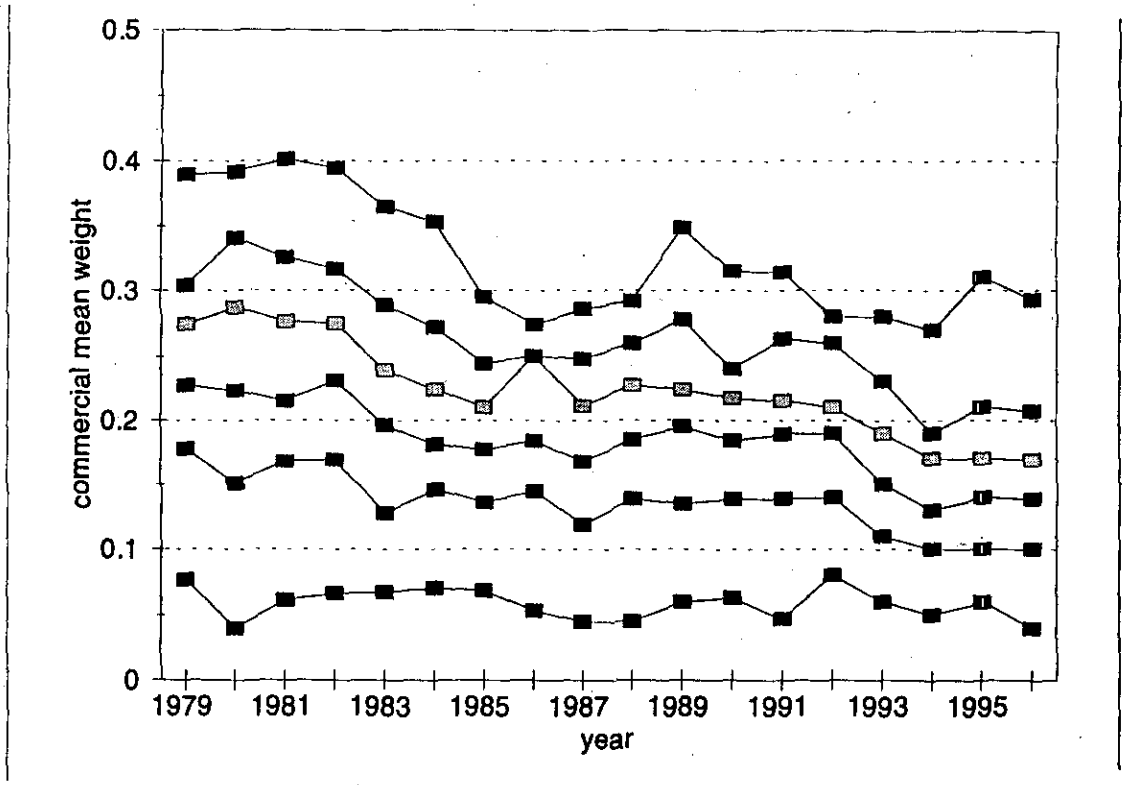

Fig. 2: Mean wt (kg) at age (1-6) from the commercial fishery for 4VWX silver hake.

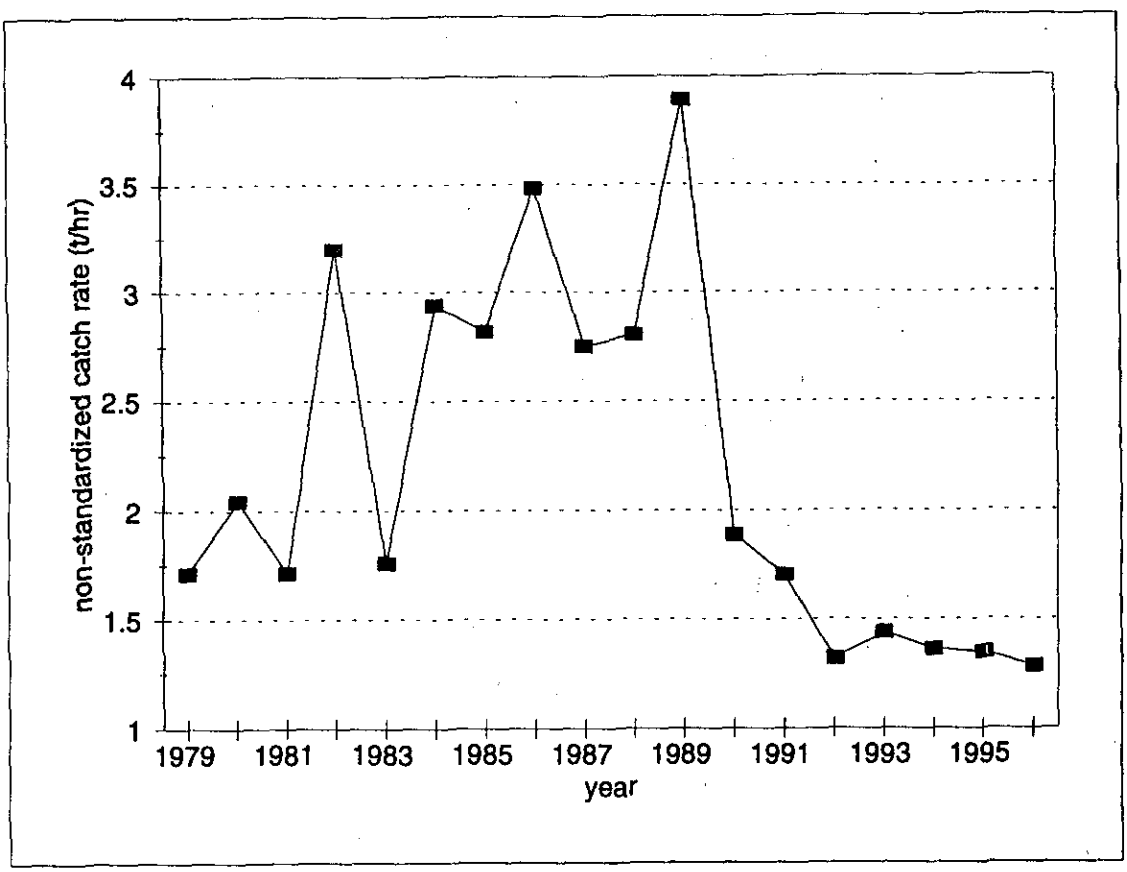

Fig. 3: Non-standardized commercial catch rates for 4VWX silver hake, based on Canadian observer data, 1979-96.

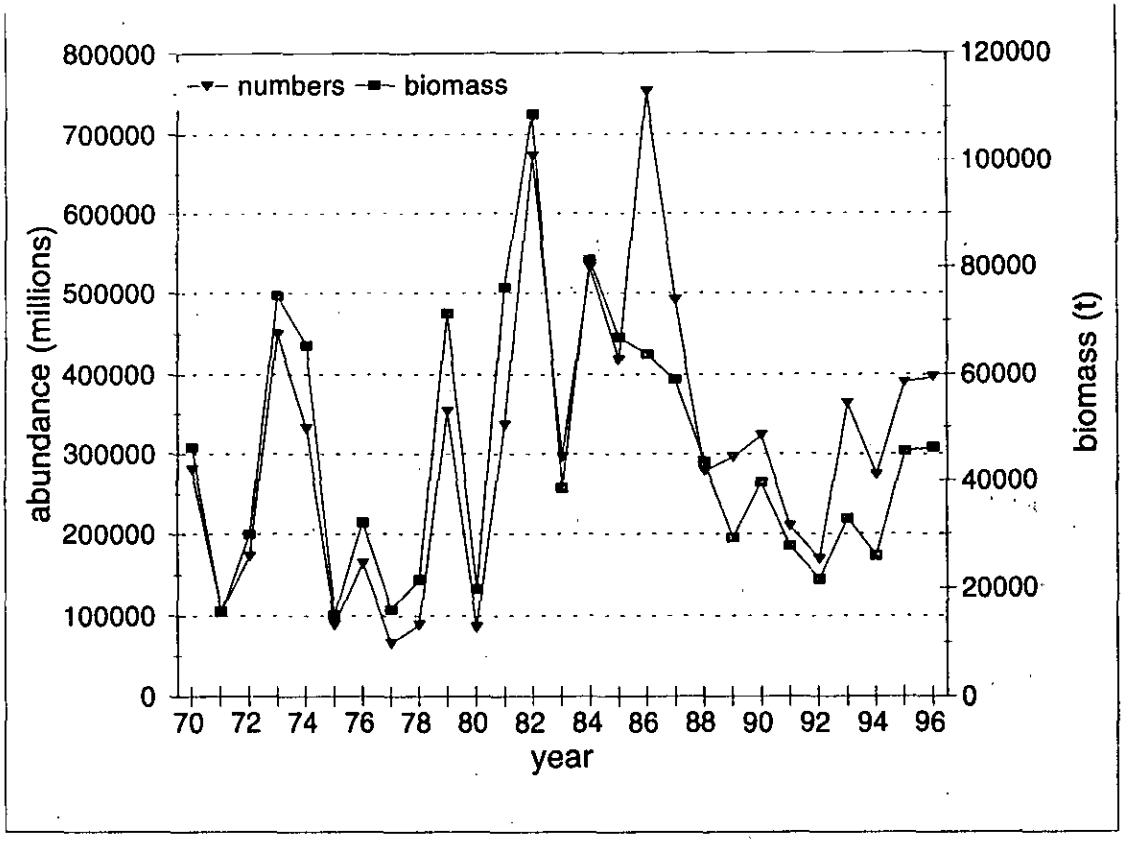

Fig. 4: 4VWX silver hake Canadian July survey estimates of age 1+ numbers and biomass.

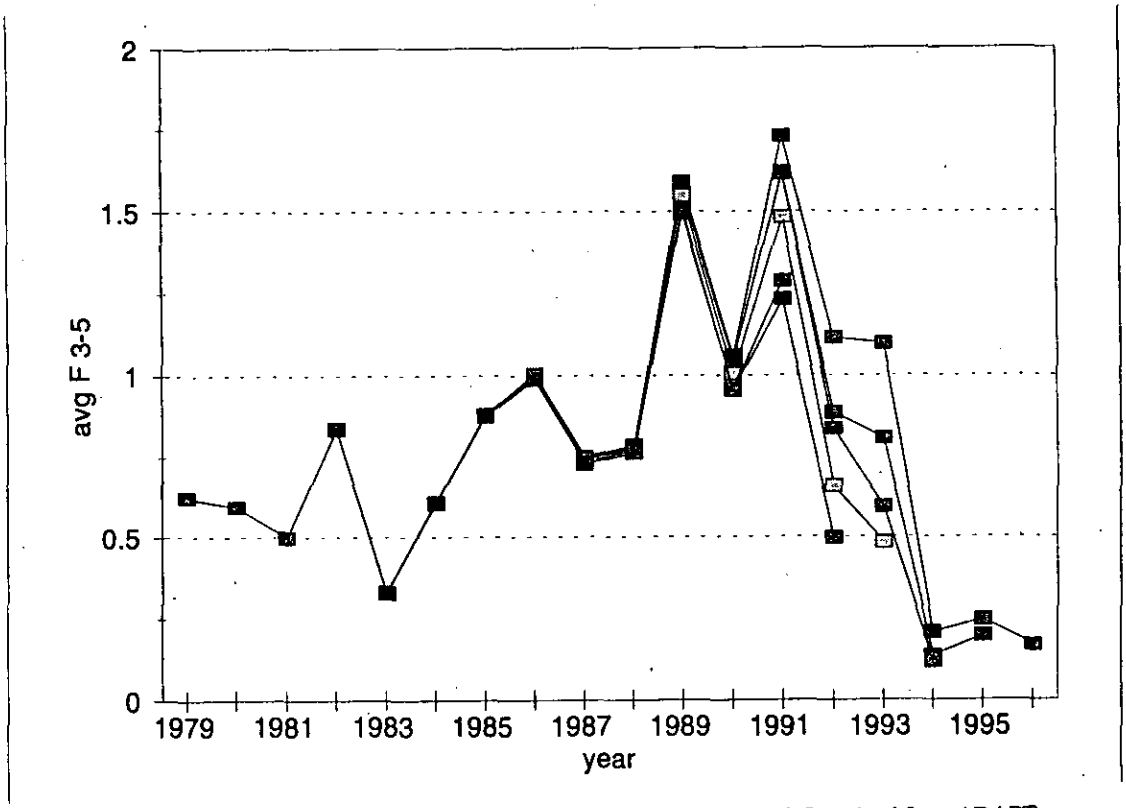

Fig 5: Results of retrospective analysis for average F, ages 3-5, derived from ADAPT.

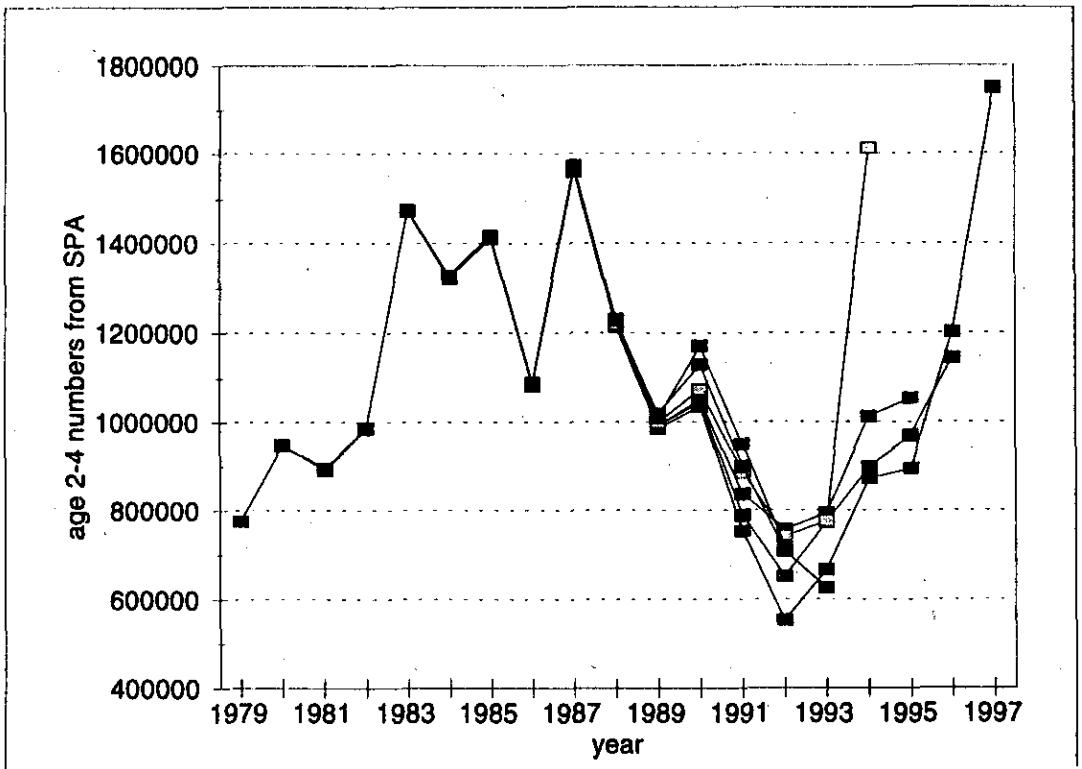

Fig. 6: Results of retrospective analysis for age 2-4 numbers, derived from ADAPT.

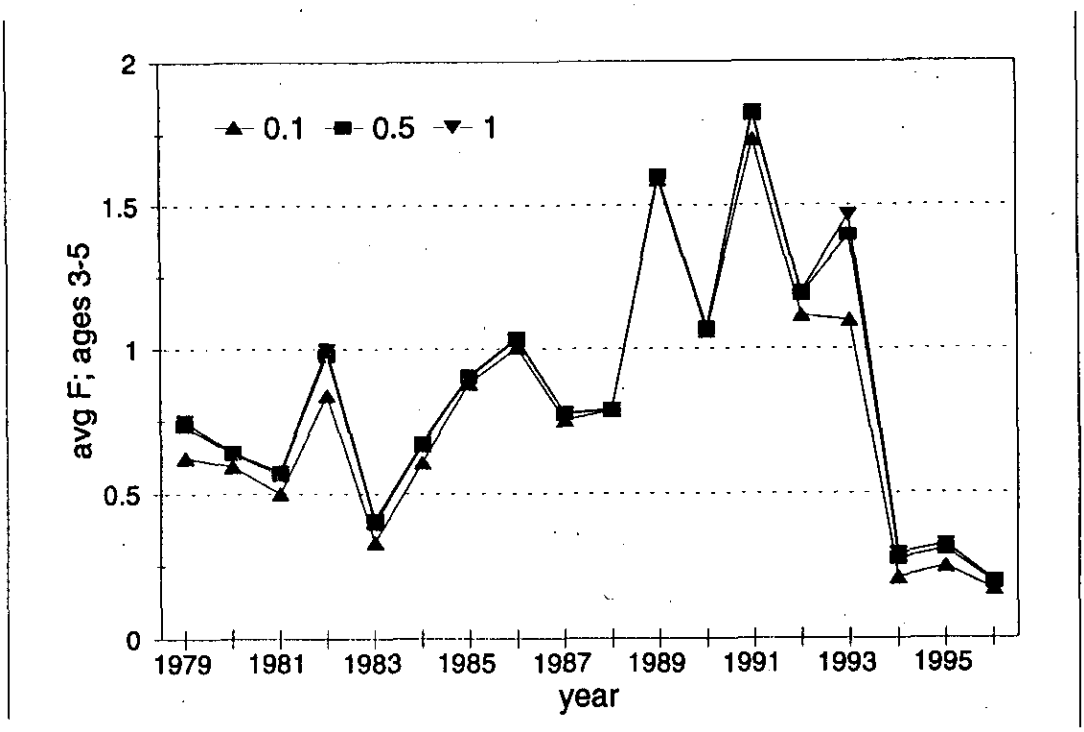

Fig 7a: Comparison of average F, ages 3-5, from ADAPT analysis with dome set to 1.0, 0.5, and 0.1.

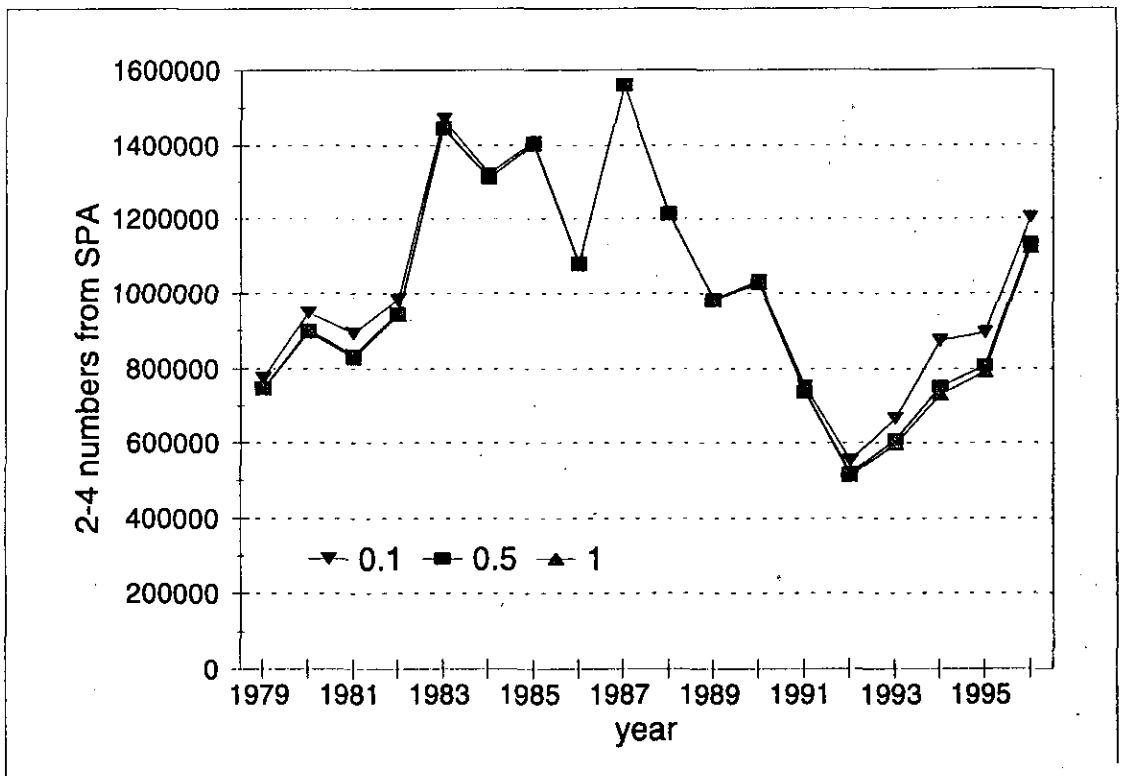

Fig 7b: Comparison of age 2-4 numbers, from ADAPT analysis with dome set to 1.0, 0.5, and 0.1.

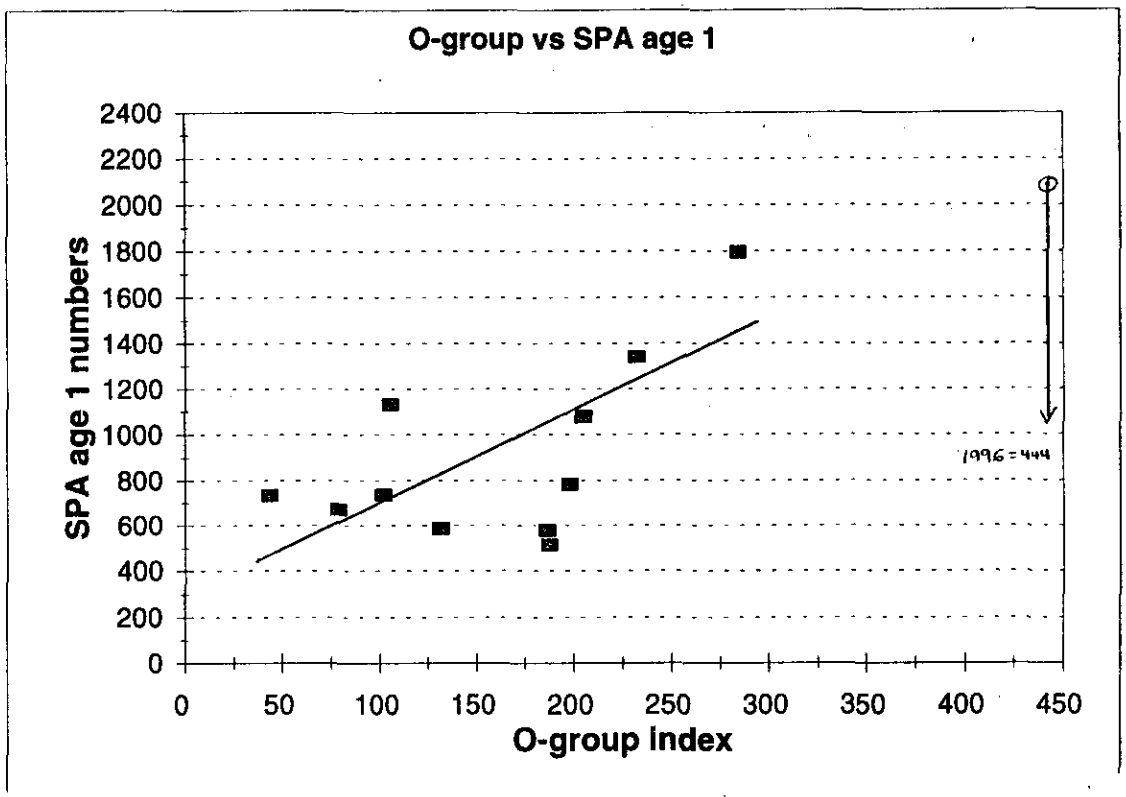

Fig. 8: Plot of O-group survey index vs age 1 numbers from SPA, for 4VWX silver hake.

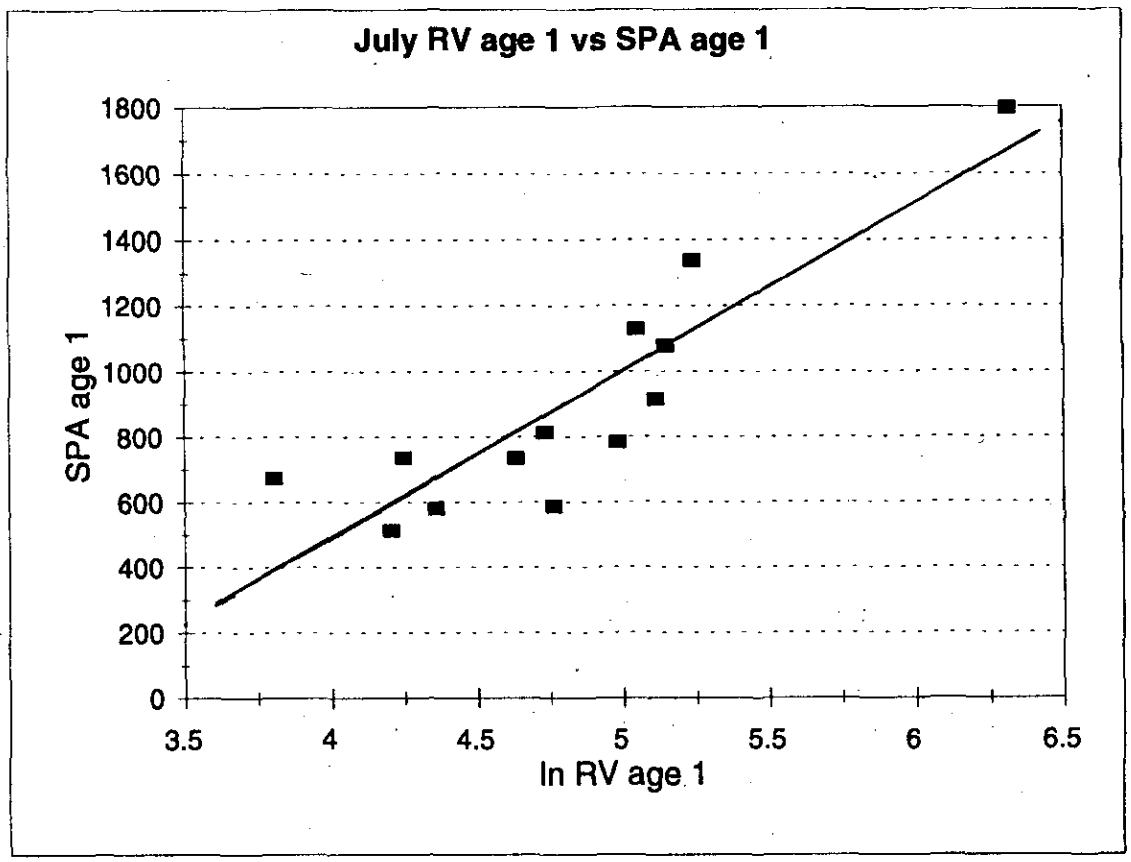

Fig. 9: Plot of ln(numbers) at age 1 from the Canadian July survey vs age 1 numbers from SPA, for 4VWX silver hake.

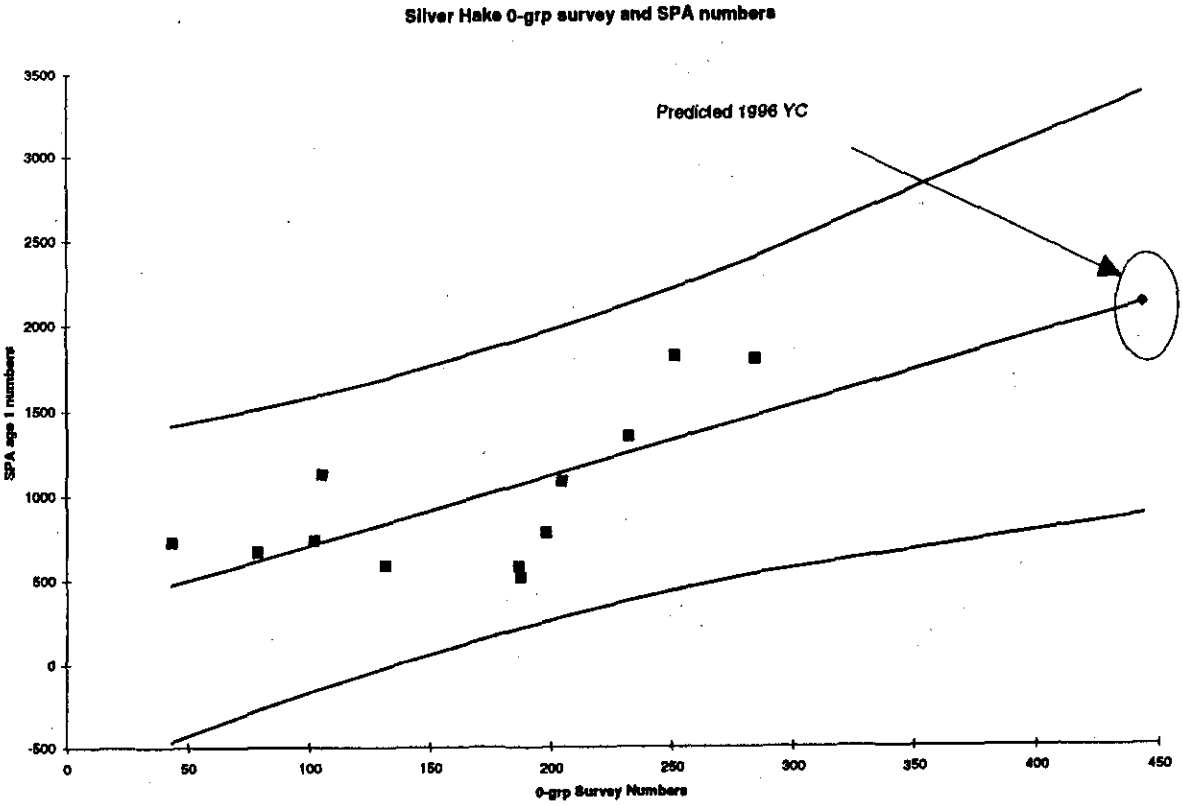

Fig. 10. Plot of 0-group survey index vs SPA age 1 numbers, with 95% confidence limits.

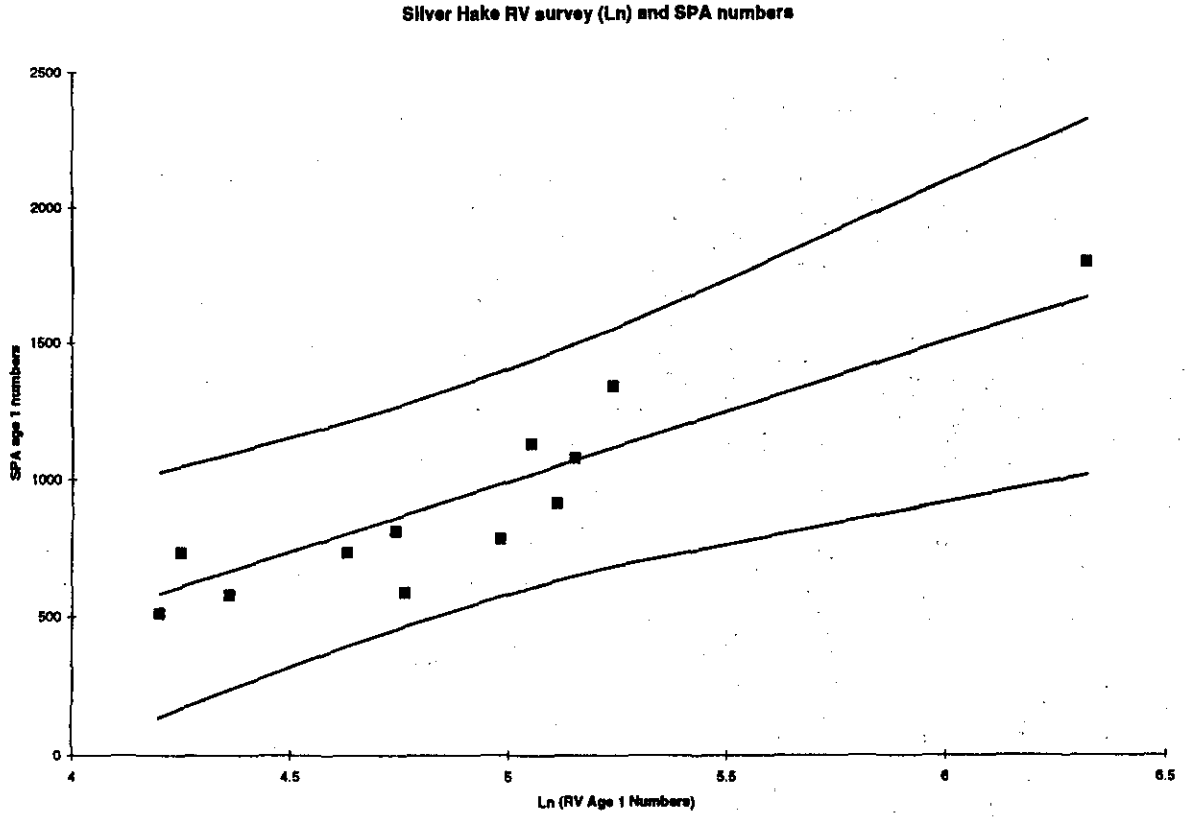

Fig. 11. Plot of ln (numbers) at age 1 from Canadian research vessel survey vs age 1 numbers from SPA, with 95% confidence intervals.