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Virtual Population Analyses of the American Plaice stock in Divisions 3LNO from 1975 to 1997

by

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Abstract

The assessment of the American plaice stock in Div. 3LNO included virtual population analyses until 1994. This paper attempts a variety of formulations of ADAPT to produce an acceptable VPA. Catch at age was constructed for 1994 to 1997. Nine different formulations of ADAPT were run. The formulation using the spring index (1985 to 1997, ages 5 to 14) only, catch at ages 5 to 14 from 1975 to 1997 and M=0.2 except M=0.6 for all ages from 1989 to 1996, provided the best fit to the data and the least patterning in the residuals.

Introduction

The assessment of the American plaice stock in Div. 3LNO included virtual population analyses until 1994. Brodie et al. (1994) outlined the reasons for abandoning the VPA. These included lack of confidence in the catch and catch at age, poor fit of the model to the data and a severe retrospective pattern.

Without a VPA the relationship of the survey index to the actual population is unknown. This has been exacerbated by the introduction of a new survey trawl with a very different catchability to the trawl used previously. The lack of a VPA also makes it more difficult to set and evaluate reference points for the precautionary approach. These factors point to the usefulness of a VPA for this stock.

Two reasons may make an attempt at a VPA at this time worthwhile. Sufficient time may have passed since the uncertain catch at age of the late 1980's and early 1990's to limit their impact. Also, the introduction of risk analyses may mean that projections using VPA's with large standard errors can still be useful.

As a result of these factors we decided to attempt several formulations of ADAPT to determine if an acceptable VPA could be produced.

Reconstruction of ADAPT run of 1993

The version of ADAPT used in these analyses (Windows Version 2.1) estimates population numbers at the beginning of year n+1 while the version used in the 1993 assessment calculated population numbers at the beginning of year n. Therefore we first reconstructed the analysis of 1993 using this new version. This formulation included spring survey from 1975 to 1992 using ages 5 to 14 and catch at ages 5 to 17 from 1975 to 1992. F on ages 15 to 17 was calculated as the average of the F's on ages 12 to 14. M was set at 0.2. Output from the two versions of ADAPT were virtually identical.

Calculation of catch at age for A. plaice in Div. 3LNO from commercial fisheries in 1993-97

In 1994, a ban on directed fishing on this stock was imposed by NAFO's Fisheries Commission, followed by a complete moratorium on fishing from 1995 to the present. As a result, catches declined from 17,000 tons in 1993 to less than 1000 tons in each of 1995 and 1996. From 1995 to 1997, about 90% of the catch of American plaice in Div. 3LNO was taken as by-catch in groundfish fisheries of Spain and Portugal in the NAFO Regulatory Area (NRA), with Canada taking most of the remaining 10%.

Catch at age from the commercial fisheries on this stock was not calculated on a regular basis following the 1993 assessment (Brodie et al. 1993). That assessment used catch at age from 1974 to 1992. The following sections describe the calculation of catch at age for the years 1993-97.

Various age composition and length frequency (LF) data were taken from the Spanish (NAFO SCS Docs. 95/15, 97/10, 98/11) and Portuguese (SCS 95/13, 96/12, 97/9, 98/13, see reference list for complete details) annual research reports. Age-length keys (ALK) were taken from Canadian spring research vessel surveys in Divisions 3LNO from 1994 to 1997. From 1994 onward, data were analyzed with sexes combined, unlike in the previous years, because LF data were usually not available by sex. Mean weights (kg) at age were derived from mean lengths (cm) at age using the length weight equation

$$Log_{10}\ weight = (3.3247 * Log_{10}\ length) - 5.553.$$

This same relationship was used to generate mean weights in previous years. Overall mean weights at age for each year were taken as the average of all data for a fleet/Division, weighted by catch numbers.

1993: This was the last year in which a TAC and directed fishery existed for this stock. Catch at age for 1993 was presented in Brodie et al. (1994) for Canada (7454 tons) and Spain+Portugal (575 tons). The latter was adjusted to represent the total non-Canadian catch of 9680 tons. Due to uncertainties with total catch and mean weights at age, a sum-of-products correction was made to the catch numbers for the non-Canadian portion. This is the last year that LF and ALK data exist for the Canadian commercial fishery for A. plaice in Div. 3LNO.

1994: A TAC of 4800 tons existed for 1994, but no directed fishing was allowed. A catch of 7378 tons was estimated, about 75% of which was taken by Spain. Divisional LF data were available for Spain (Div. 3L and 3N), and corresponding ALK's from the Canadian spring surveys were used to derive age compositions. Age composition data existed for the Portuguese fishery in Div. 3N and 3O in SCS 95/13. The age compositions for Spain and Portugal were combined and applied to the total catch of 7378 tons.

1995: This was the first year of the fishery moratorium. By-catches of American plaice from various fisheries in Div. 3LNO were 637 tons. LF data were available from the Portuguese catch of 147 tons (Div 3N and 3O), and were used with survey ALK's to derive an age composition, which was then applied to the total catch.

1996: By-catches totalled 913 tons as the moratorium continued. LF data were available from Spain (Div. 3L, 3NO combined), and Portugal (Div. 3L, 3N). ALK's from the Canadian spring surveys were used to derive an age composition which was then applied to the total catch.

1997: By-catches increased to 1407 tons, mostly occurring in the Greenland halibut and skate fisheries. LF data were available from Spain and Portugal (Div. 3L, 3N for each country). ALK's from the Canadian spring surveys were used to derive age compositions which were then combined and adjusted to the total catch.

Table 1 contains the catch at age, mean weights at age, and catch biomass (number X weight for each age) for the years 1993-97. Peak ages in the catch each year were 7 or 8, and much of the catch at age consisted of fish between 6 and 10 years old. Both these observations are consistent with the pattern of catch at age in the late 1980's and early 1990's (Brodie et al. 1993). The truncation of ages in the catch after 1993, which is most evident in 1995, can be explained by the lack of a directed fishery for A. plaice in Div. 3LNO from 1994 onward, and by the reduced levels of sampling in some years, particularly 1995. The weights at age are quite variable, and generally higher in 1995-97 than historic values, particularly at ages 8+. This may be related to sampling of the catches, and the fact that ALK's from surveys over a broad area (e.g. a NAFO Division) were applied to LF's from commercial fisheries in a small

part of that area. (e.g. the NRA). In any case, mean weights at age in Div. 3N, where most of the catch was taken after 1993, are generally higher than those from Div. 3L, where much of the catch was taken in the 1970's and early 1980's. The sum-of-products (SOP) check against total catch is somewhat artificial, in that catch numbers in some instances were adjusted to catch levels based on SOP corrections.

Overall, the calculation of catch at age for 1993-97 gives a reasonable result, considering the limitations of the data. Two obvious problems are the truncation of the age distribution in 1995, with no fish older than 12 in the data, and the variation in the weights at age. Closer examination of the 1995 data shows no fish in the survey ALK in Div. 3N at the largest lengths observed in the Portuguese length frequencies. Ages at these lengths in the ALK for Div. 3O were in the range of 12 to 14 years, thus it should be acceptable to assign a small catch value at ages 13 and 14 in 1995. To use the data presented here in SPA and subsequent SSB calculations, it will be necessary to assume a small catch number at ages 15+ in some years, and to use mean weights at age for 1993-97 which are averaged over a number of years.

ADAPT formulations

No run using Campelen spring 1985 to 1992 surveys as the index were attempted. This would be comparable to the earlier 1993 run using the Engel in that the last year would be 1992. However, we felt that the shortness of the Campelen series would not provide a useful comparison between the two formulations.

Run 1 All runs used the indices and catch at age given in Table 2-4. Run 1 used Campelen spring 85 to 97 ages 5 to 14. Catch 75 to 97 ages 5 to 17. M 0.2 for all ages. F for 15-17 as average of 12-14. Zero catch for some of the older ages in recent years was set at 0.1.

Results Table 5 gives the results for Run 1. Relative error ranged from 0.310 to 0.577. Mean square of the residuals 0.303. Patterns existed in the residuals: 85 and 86 all negative, 90, 93 and 94 all positive. Some residual very large, particularly on the older ages in 1994.

Run 2 Campelen fall from 90 to 97 ages 5 to 14. Catch 75 to 97 ages 5 to 17. M 0.2 for all ages. F for 15-17 as average of 12-14. Zero catch for some of the older ages in recent years was set at 0.1.

Results Relative error ranged from 0.535 to 0.981. Mean square of the residuals 0.818. Patterns existed in the residuals: 90 and 92 all negative, 93 all positive. Residuals large on oldest ages in 1994. Numbers at age tended to be lower than those estimated using spring only.

Run 3 Same as Run 1 and Run 2 but using Campelen spring 85 to 97 and Campelen fall 90 to 97.

Results Table 6 shows the results of Run 3. Relative error ranged from 0.278 to 0.518. Mean square of the residuals 0.473. Patterns existed in the residuals: spring: 85 and 86 all negative, 90, 93 and 94 all positive; fall: 90 and 96 all negative, 93 all positive. Population numbers tend to be somewhat lower than for spring only but higher than for fall only.

Runs 4 through 8 build on Run 3.

Run 4 Same as Run 3 but calibration matrix started at age 6. Campelen spring 85 to 97 ages 6 to 14, Campelen fall 90 to 97 ages 6 to 14. Catch 75 to 97 ages 6 to 17.

Results. Relative error ranged from 0.286 to 0.538. Mean square of the residuals 0.5. Patterns in the residuals. This did not improve on Run 3.

Run 5 Same as Run 3 but indices used only ages 5 to 12. F on 13 to 17 set as 1.5 times average of F of 11 and 12.

Results Relative error ranged from 0.250 to 0.472. Mean square of the residuals 0.392. Patterns in the residuals: spring 85 and 86 all negative, 93 and 94 all positive; fall 90 and 92 all negative, 93 all positive. Population numbers tend to be slightly higher at age 5 and lower at other ages than Run 3. Did not substantially improve on Run 3.

Run 6 Same as Run 5 but used F on 13 to 17 as 1.8 times F11 and 1.4 times F12.

Results: Relative error ranged from 0.258 to 0.474. Mean square of the residuals 0.396. Patterns in the residual: spring 85 and 86 all negative, 93 and 94 all positive. Fall 90 and 92 all negative, 93 all positive. Population numbers very similar to Run 3. F similar except higher on ages 16 and 17 in this run. Did not substantially improve on run 3.

Run 7 Same as Run 3 except that catch at 13 and 14 in 1995 set at 1.0 instead of 0.1.

Results: Relative error ranged from 0.277 to 0.513. Mean square of the residuals 0.463. F on 13 and 14 in 1995 higher than Base3. Similar F in 1993 on ages 13-17 (very high). Some differences in F on these ages in 1994. No real improvement on Run 3.

Run 8 The estimates of total mortality from the spring and fall surveys indicate that mortality was very high after the moratorium on fishing was introduced (Morgan et al., 1999). The average Z for ages 5 to 10 in 1995 and 1996 was approximately 0.6. The estimates of Z were very high from 1989 through 1996 but decreased substantially in 1997 and 1998. It was therefore decided to attempt a formulation using M=0.6 for all ages from 1989 to 1996. All other aspects were the same as Run 3.

Results: Table 7 shows the results of Run 8. Relative error ranged from 0.223 to 0.441. Mean square of the residuals 0.341. Patterns in the residuals: spring 1985 all negative, 1993 all positive, fall: 1990 all negative 1993 all positive (this compares to Run 3 which had 5 patterned years in spring and 3 in fall). F quite a bit lower in 93 and 94 but still high. Much higher population numbers at age 5 to 8, effect goes back to 1979 or 1980.

Run 9 Same as Run 8 except used only the spring survey index 1985 to 1997, ages 5 to 14.

Results: Table 8 shows the results of Run 9. Relative error ranged from 0.242 to 0.484. Mean square of the residuals was 0.213. Patterns in the residuals were better than Run 3, 1993 all positive.

Comparison of 4 formulations

Based on the above results we chose 4 formulations of ADAPT to compare.

Run 1: Spring index, M=0.2 in all years
Run 3: Spring and fall RV indices, M=0.2 in all years.
Run 8: Spring and fall RV indices, M=0.6 from 1989-96
Run 9: Spring index, M=0.6 from 1989-96

Comparing residuals between 1 and 3, as well as 8 and 9, shows that the fall survey adds little to the calibration (see figures in Appendix, first part of figure number refers to run number). Residual patterns in the spring were almost identical for runs with the same M value, regardless of whether the fall survey was included or not. Looking only at the runs with just spring data (1 and 9) shows the pattern in the residuals to be much improved in run 9, with the higher M in 1989-96. In all 4 runs, there are high positive residuals at ages 13 and 14 in 1994.

Fig. 1. compares the population numbers at ages 5+ from ADAPT runs 1 and 9 with survey numbers at the same ages (Engel equivalents, 1975-95 and Campelen equivalents, 1985-98). With M=0.2, the population declines steadily from the mid 1970's to the present, while the run with M=0.6 shows a more gradual decline up to 1989, followed by a rapid drop after M is increased. The Campelen index is higher than the ADAPT population numbers in all years, while the ADAPT with M=0.6 population is higher than the Engel series in all years except 1977-82.

Fig. 2 compares mean fishing mortalities at ages 9-14 from the 4 ADAPT runs. As expected, there is little difference in the F's when comparing the pairs of runs with the same natural mortality values. The trends are the same in all 4 runs, with much higher F's estimated from 1988-94 in the runs with constant M. Even with M=0.6, F's in 1994 and 1995 were calculated to be above 1.0. All 4 runs estimate very low F's after 1994, with a slight increase in 1997.

Calibration coefficients (q's) show a similar pattern at age in runs 1and 9, although the pattern is less pronounced in the run with M=0.6 (Fig. 3). In both cases, q's are well above 1, indicating that the survey population estimate is

higher than the ADAPT for each age. This was also seen in Fig. 1. Comparison of q's between spring and fall show the fall values to be higher (Table 6 and 7), as the fall survey index has consistently produced a higher estimate of abundance than the spring survey since the fall series began in 1990 (Morgan et al. 1999).

Conclusions

The results of all formulations gave population numbers that were lower than the indices. This could be caused by a herding effect in the trawl surveys (e.g. if the actual swept area was between the doors of the survey gear rather than between the wings) or by unaccounted for mortality in the ADAPT. All runs indicate that 5+ population is at the lowest level observed in 1997-98, despite very low estimates of F in 1995-97.

Run 9 using the spring index only and M=0.6 from 1989 to 1996 gave the best fit to the data. An M of 0.6 may be considered high for American plaice. However, the estimates of total mortality from the survey indicate that mortality was very high even during the period of the moratorium (Morgan et al., 1999). As well the adjacent American plaice stock in Div. 2+3K declined by 95% during the late 1980's and early 1990's when catches were extremely low (Bowering et al., 1997). Also, increasing M in the analyses is making an adjustment for unaccounted for deaths, whatever the cause, or could be accounting for changes in catchability.

Overall, run 9 (spring index only, m=0.6 from 1989-96), provided the best fit to the data and least patterning in the residuals. We suggest using this formulation to conduct a VPA to estimate population numbers at the beginning of 1999.

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Table 1. Catch numbers at age and weight at age as well as the catch weight at age (SOP) for Div. 3LNO A. plaice from 1993 to 1997.

	Numbers(000)					Weights(kg)					SOP(t)					
Age/Year	**93**	**94**	**95**	**96**	**97**	**Age/Year**	**93**	**94**	**95**	**96**	**97**	**93**	**94**	**95**	**96**	**97**	
2						2						0	0	0	0	0	
3		79	3	15	2	3		0.053	0.064	0.103	0.059	0	4	0	2	0	
4	761	356	14	35	10	4	0.067	0.067	0.065	0.120	0.123	51	24	1	4	1	
5	1172	4316	99	181	33	5	0.114	0.119	0.179	0.148	0.164	134	512	18	27	5	
6	3713	3837	314	743	275	6	0.225	0.193	0.237	0.210	0.242	835	739	74	156	67	
7	8821	5426	453	975	853	7	0.275	0.266	0.330	0.296	0.336	2424	1441	150	289	287	
8	11591	4460	333	453	853	8	0.365	0.374	0.438	0.451	0.486	4225	1666	146	204	415	
9	5720	2777	203	211	422	9	0.496	0.533	0.709	0.657	0.652	2836	1479	144	139	275	
10	3377	737	65	52	146	10	0.589	0.757	1.034	0.918	0.844	1988	558	68	48	123	
11	1853	476	14	10	91	11	0.729	0.897	1.605	1.083	0.990	1350	426	22	11	90	
12	1002	163	4	8	54	12	0.912	1.127	1.676	1.323	1.302	914	183	7	11	71	
13	527	121		2	24	13	1.227	1.484		1.576	1.771	646	179	0	4	42	
14	355	55		1	1	14	1.438	1.701		2.907	2.349	510	93	0	3	3	
15	246	18		1	1	15	1.868	2.272		2.618	2.349	460	40	0	3	3	
16	127	10				16	2.339	2.178				297	21	0	0	0	
17	94					17	2.432					229	0	0	0	0	
18	37					18	3.614					135	0	0	0	0	
19	15					19	3.794					56	0	0	0	0	
20	6					20	4.031					24	0	0	0	0	
21	1					21	3.549					3	0	0	0	0	
UNK		52	2	11	25	UNK						17120	7367	630	899	1382	Total SOP(t)
												17122	7378	637	913	1407	Catch used(t)

Table 2. Catch at age from 1975 to 1997.

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	883.0	3128.0	7220.0	9433.0	9234.0	7903.0	5701.0	4732.0	3788.0	2617.0	1461.0	763.0	475.0
1976	837.0	3907.0	8781.0	19363.0	16597.0	12338.0	8323.0	5156.0	3024.0	2309.0	1347.0	584.0	245.0
1977	974.0	6723.0	8743.0	11730.0	13559.0	11157.0	6520.0	4257.0	2369.0	1493.0	1000.0	342.0	182.0
1978	1558.0	4467.0	9195.0	10397.0	12743.0	13881.0	9938.0	6823.0	3655.0	2239.0	1472.0	649.0	212.0
1979	1257.0	6551.0	13532.0	18747.0	14977.0	12506.0	8791.0	3775.0	1843.0	714.0	342.0	159.0	63.0
1980	263.0	2977.0	9531.0	12578.0	14111.0	14212.0	11288.0	8088.0	3732.0	1565.0	645.0	265.0	87.0
1981	154.0	554.0	2248.0	4786.0	7921.0	11425.0	13565.0	11872.0	8693.0	5591.0	2938.0	1119.0	394.0
1982	27.0	314.0	1814.0	4799.0	8946.0	12836.0	15801.0	14489.0	7942.0	4224.0	2000.0	641.0	206.0
1983	119.0	991.0	3053.0	5797.0	8343.0	7707.0	8493.0	7517.0	4588.0	2480.0	1219.0	373.0	130.0
1984	48.0	397.0	1516.0	3311.0	5853.0	9958.0	12887.0	8964.0	5072.0	2515.0	1090.0	404.0	93.0
1985	296.0	788.0	2362.0	5652.0	10694.0	15741.0	14528.0	9233.0	4108.0	1969.0	1235.0	388.0	160.0
1986	4407.0	9707.0	12556.0	12530.0	13372.0	13874.0	14246.0	10376.0	5947.0	2637.0	1416.0	542.0	162.0
1987	2237.0	4941.0	7691.0	10893.0	15867.0	17640.0	11404.0	6986.0	3076.0	1303.0	768.0	247.0	27.0
1988	2908.0	3213.0	4853.0	7269.0	10123.0	10325.0	9260.0	6040.0	2692.0	1156.0	656.0	267.0	38.0
1989	12745.0	11553.0	11432.0	9652.0	14180.0	12387.0	8405.0	4972.0	2029.0	1027.0	550.0	146.0	14.0
1990	15134.0	7694.0	4489.0	4604.0	8666.0	8666.0	6452.0	3633.0	1702.0	945.0	453.0	80.0	12.0
1991	6103.0	12152.0	7846.0	9331.0	7856.0	6589.0	4394.0	2294.0	811.0	364.0	246.0	172.0	56.0
1992	148.0	1023.0	2591.0	3395.0	3618.0	2154.0	1507.0	875.0	576.0	513.0	269.0	171.0	90.0
1993	1172.4	3712.9	8820.9	11590.5	5720.0	3376.9	1853.1	1002.5	526.9	354.7	246.4	127.2	94.2
1994	4316.3	3837.1	5426.1	4459.7	2777.0	736.9	475.6	162.8	120.9	54.7	17.7	9.8	0.1
1995	99.2	313.9	453.2	333.0	203.3	65.5	13.6	4.1	0.1	0.1	0.1	0.1	0.1
1996	180.9	742.8	975.0	452.7	211.1	51.9	10.4	8.1	2.3	1.0	1.0	0.1	0.1
1997	33.4	274.8	852.7	853.1	421.6	146.0	91.4	54.2	23.9	1.3	1.3	0.1	0.1
1998													

Table 3. Population numbers at age (millions) from Canadian spring RV surveys in Div. 3LNO from 1985 to 1997.

Age/Year	5	6	7	8	9	10	11	12	13	14
1985.5	263.811	454.551	595.652	389.798	208.007	140.238	84.297	45.199	22.716	13.977
1986.5	256.002	561.361	577.156	307.058	193.651	98.117	45.955	34.378	21.735	8.903
1987.5	460.214	747.454	656.206	398.314	184.639	101.101	41.829	33.798	19.928	11.136
1988.5	368.612	616.621	543.875	314.972	217.849	85.292	48.628	32.575	18.745	11.969
1989.5	336.143	551.765	470.169	273.725	187.637	74.679	39.843	27.071	16.825	9.65
1990.5	618.749	377.901	371.001	200.264	130.479	77.524	32.385	21.463	14.428	8.809
1991.5	398.19	364.155	180.205	112.916	67.544	35.19	22.26	13.356	7.224	5.529
1992.5	110.276	190.141	150.915	63.403	34.12	17.503	9.447	5.402	3.343	1.767
1993.5	138.054	180.137	160.064	89.449	32.226	16.51	7.626	4.264	1.783	1.325
1994.5	99.22	106.04	85.372	43.27	19.992	5.397	3.952	1.396	1.241	0.996
1995.5	41.914	57.524	59.883	49.937	27.484	8.339	2.664	0.539	0.093	0.035
1996.5	133.6784	130.513	97.1222	39.511	16.189	4.502	1.942	2.233	0.518	0.25
1997.5	65.278	84.402	79.311	48.718	18.944	6.047	2.678	1.819	0.562	0.174

Table 4. Population numbers at age (millions) from Canadian fall RV surveys in Div. 3LNO from 1990 to 1997.

Age/Year	5	6	7	8	9	10	11	12	13	14
1990.9	853.098	642.862	369.626	191.668	124.519	55.198	29.201	17.43	12.054	9.316
1991.9	724.397	578.812	249.38	116.271	81.837	44.303	25.916	13.857	12.207	6.977
1992.9	367.927	499.192	226.077	76.712	35.653	17.68	8.451	6.848	3.333	3.151
1993.9	360.452	372.076	316.567	104.116	33	15.316	6.798	5.095	3.077	2.383
1994.9	190.297	151.085	134.913	89.251	28.649	7.822	2.667	1.723	0.919	1.168
1995.9	278.383	322.484	123.253	55.26	26.66	7.981	1.619	1.211	0.452	0.307
1996.9	208.293	174.079	82.201	21.365	8.82	3.077	1.781	0.587	0.098	0.116
1997.9	153.853	159.848	119.979	53.224	23.331	7.304	3.217	1.208	0.849	0.595

Table 5. Results of Run 1. Spring survey from 1985 to 1997, ages 5 to 14. Catch from 1975 to 1997, ages 5 to 17. F on ages 15 to 17 set as average of F on ages 12 to 14. M=0.2 for all ages.

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.000820
MEAN SQUARE RESIDUALS 0.303210

Parameters in linear scale

	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
6	9.29E3	5.36E3	0.577	1.58E3	0.170
7	1.09E4	4.54E3	0.417	9.69E2	0.089
8	5.68E3	2.19E3	0.385	3.90E2	0.069
9	4.40E3	1.63E3	0.371	2.60E2	0.059
10	3.07E3	1.05E3	0.341	1.54E2	0.050
11	1.92E3	6.41E2	0.335	9.50E1	0.050
12	1.03E3	3.50E2	0.341	5.37E1	0.052
13	6.67E2	2.07E2	0.310	3.46E1	0.052
14	3.03E2	9.38E1	0.310	1.52E1	0.050
15	6.18E1	2.03E1	0.328	3.16E0	0.051
5	6.35E-3	1.07E-3	0.168	6.29E-5	0.010
6	9.59E-3	1.56E-3	0.162	9.41E-5	0.010
7	1.06E-2	1.69E-3	0.161	1.13E-4	0.011
8	7.97E-3	1.28E-3	0.160	9.10E-5	0.011
9	6.28E-3	1.00E-3	0.160	7.23E-5	0.012
10	4.45E-3	7.11E-4	0.160	5.10E-5	0.011
11	4.11E-3	6.56E-4	0.160	4.83E-5	0.012
12	5.07E-3	8.14E-4	0.160	6.57E-5	0.013
13	5.63E-3	9.05E-4	0.161	8.37E-5	0.015
14	7.52E-3	1.20E-3	0.160	1.24E-4	0.017

residuals

age	5	6	7	8	9	10	11	12	13	14
1985.5	-0.988	-0.807	-0.496	-0.492	-0.569	-0.336	-0.279	-0.482	-0.482	-0.476
1986.5	-0.672	-0.388	-0.382	-0.573	-0.599	-0.497	-0.684	-0.468	-0.247	-0.667
1987.5	0.188	0.255	-0.011	-0.096	-0.368	-0.310	-0.575	-0.322	-0.072	-0.040
1988.5	0.005	0.321	0.136	-0.123	-0.021	-0.195	-0.160	-0.132	-0.092	0.105
1989.5	0.072	0.364	0.372	0.145	0.148	-0.075	-0.070	0.020	0.042	-0.158
1990.5	0.558	0.226	0.300	0.307	0.270	0.453	0.157	0.173	0.416	0.058
1991.5	0.746	0.130	-0.080	-0.005	0.214	0.295	0.450	0.233	-0.043	0.116
1992.5	-0.130	-0.080	-0.407	-0.274	-0.171	0.146	0.152	0.012	-0.132	-0.764
1993.5	0.359	0.282	0.228	0.190	0.371	0.772	0.949	0.729	0.463	0.542
1994.5	0.094	0.112	0.141	0.253	0.219	0.212	1.217	1.021	2.181	2.203
1995.5	-0.562	-0.497	-0.129	0.501	0.787	0.424	0.160	-0.022	-0.856	0.113
1996.5	0.330	0.407	0.212	0.018	-0.106	-0.411	-0.722	-0.005	0.066	0.060
1997.5	0.000	-0.325	0.117	0.148	-0.174	-0.478	-0.596	-0.757	-1.245	-1.091

Table 5. Cont'd

Bias adjusted population numbers ('000)

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	291226.2	228716.7	191792.3	123405.6	75151.2	43357.4	25836.3	15968.3	10983.0	6171.9	3298.2	1662.9	1328.7
1976	277100.6	237638.3	184432.5	150508.8	92527.3	53207.4	28385.5	16026.8	8826.9	5597.0	2713.2	1394.8	680.0
1977	231516.2	226114.7	191033.5	143075.5	105779.3	60817.0	32471.5	15769.8	8497.5	4516.4	2517.2	1020.1	619.8
1978	215933.9	188669.7	179057.4	148514.0	106560.9	74387.5	39752.0	20720.0	9088.1	4830.0	2359.0	1166.0	528.6
1979	198156.1	175384.5	150436.3	138301.7	112213.6	75760.5	48411.9	23616.5	10846.2	4170.5	1955.3	625.8	377.2
1980	188019.8	161101.1	137679.1	110964.1	96342.5	78379.2	50768.0	31724.5	15936.4	7221.0	2771.7	1293.0	369.5
1981	169920.0	153700.1	129210.2	104123.9	79512.8	66168.9	51380.7	31415.8	18707.4	9693.0	4504.7	1689.5	820.2
1982	170720.7	138979.6	125338.5	103758.3	80929.8	57958.1	43890.0	29882.6	15090.9	7554.5	2965.9	1086.1	392.7
1983	155376.1	139749.9	113503.3	100980.3	80618.8	58196.0	35910.5	21778.3	11538.2	5280.4	2427.3	659.2	319.7
1984	143992.9	127103.7	113522.5	90172.1	77444.8	58483.8	40703.1	21767.2	11093.4	5341.0	2109.3	900.4	207.9
1985	123590.7	117848.0	103705.1	91575.2	70837.8	58126.9	38918.0	21765.5	9803.5	4552.6	2127.8	755.5	376.2
1986	89760.8	100920.1	95774.1	82773.8	69875.8	48366.0	33453.8	18853.2	9564.8	4352.9	1967.4	644.4	272.8
1987	67612.8	69512.6	73874.1	67100.3	56484.9	45177.5	27144.2	14652.9	6201.5	2555.6	1222.8	361.7	54.6
1988	65466.8	53337.2	52454.8	53549.5	45129.2	32000.1	21199.3	12026.0	5761.8	2334.0	930.9	320.1	77.8
1989	61804.8	50975.0	40769.7	38570.4	37294.0	27847.1	16939.7	9080.5	4460.5	2313.9	879.8	182.9	28.9
1990	70335.1	39137.6	31348.1	23115.3	22906.1	17837.8	11731.6	6372.9	3009.1	1839.6	976.9	232.6	21.8
1991	36197.2	43975.6	25121.0	21622.1	14783.3	10994.5	6872.5	3862.9	1987.2	949.9	663.9	395.3	118.7
1992	21635.4	24141.5	25092.4	13528.8	9361.8	5106.6	3150.3	1732.5	1125.0	901.5	451.9	323.2	169.9
1993	17031.9	17579.9	18842.0	18208.1	8026.0	4426.1	2254.9	1234.3	638.3	407.7	281.9	131.0	112.3
1994	17688.8	12886.9	11053.9	7551.5	4633.8	1523.4	654.5	225.5	133.0	62.0	25.4	16.7	0.1
1995	12144.2	10603.5	7107.3	4209.9	2220.7	1327.8	589.7	116.6	41.0	4.5	3.3	5.2	5.0
1996	15381.6	9853.3	8398.0	5410.1	3146.4	1634.8	1028.0	470.5	91.7	33.5	3.6	2.6	4.2
1997	9452.4	12430.0	7397.1	5996.9	4021.1	2385.6	1291.6	832.2	377.9	73.0	26.5	2.0	2.0
1998	100000.0	7708.8	9928.7	5287.7	4141.4	2912.2	1821.4	975.0	632.5	287.9	58.6	20.6	1.6

Bias adjusted fishing mortalities

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	0.003	0.015	0.042	0.088	0.145	0.224	0.278	0.393	0.474	0.622	0.661	0.694	0.496
1976	0.003	0.018	0.054	0.153	0.220	0.294	0.388	0.434	0.470	0.599	0.778	0.611	0.501
1977	0.005	0.033	0.052	0.095	0.152	0.225	0.249	0.351	0.365	0.449	0.570	0.457	0.389
1978	0.008	0.026	0.058	0.080	0.141	0.230	0.321	0.447	0.579	0.704	1.127	0.929	0.577
1979	0.007	0.042	0.104	0.162	0.159	0.200	0.223	0.193	0.207	0.209	0.214	0.327	0.203
1980	0.002	0.021	0.079	0.133	0.176	0.222	0.280	0.328	0.297	0.272	0.295	0.255	0.299
1981	0.001	0.004	0.019	0.052	0.116	0.211	0.342	0.533	0.707	0.984	1.223	1.259	0.741
1982	0.000	0.002	0.016	0.052	0.130	0.279	0.501	0.752	0.850	0.935	1.304	1.023	0.846
1983	0.001	0.008	0.030	0.065	0.121	0.158	0.301	0.475	0.570	0.718	0.792	0.954	0.587
1984	0.000	0.003	0.015	0.041	0.087	0.207	0.426	0.598	0.691	0.720	0.827	0.673	0.670
1985	0.003	0.007	0.025	0.070	0.182	0.352	0.525	0.622	0.612	0.639	0.995	0.819	0.624
1986	0.056	0.112	0.156	0.182	0.236	0.378	0.626	0.912	1.120	1.070	1.494	2.268	1.034
1987	0.037	0.082	0.122	0.197	0.368	0.557	0.614	0.733	0.777	0.810	1.140	1.337	0.774
1988	0.050	0.069	0.107	0.162	0.283	0.436	0.648	0.792	0.712	0.776	1.427	2.205	0.760
1989	0.257	0.286	0.367	0.321	0.538	0.664	0.778	0.904	0.686	0.662	1.131	1.928	0.751
1990	0.270	0.243	0.171	0.247	0.534	0.754	0.911	0.965	0.953	0.819	0.705	0.473	0.912
1991	0.205	0.361	0.419	0.637	0.863	1.050	1.178	1.034	0.590	0.543	0.520	0.644	0.722
1992	0.008	0.048	0.121	0.322	0.549	0.617	0.737	0.798	0.815	0.962	1.038	0.857	0.859
1993	0.079	0.264	0.714	1.168	1.462	1.711	2.103	2.028	2.132	2.574	2.624	6.829	2.245
1994	0.312	0.395	0.765	1.024	1.050	0.749	1.525	1.504	3.187	2.736	1.390	1.010	2.476
1995	0.009	0.033	0.073	0.091	0.106	0.056	0.026	0.040	0.003	0.025	0.034	0.021	0.022
1996	0.013	0.087	0.137	0.097	0.077	0.036	0.011	0.019	0.028	0.033	0.365	0.043	0.027
1997	0.004	0.025	0.136	0.170	0.123	0.070	0.081	0.074	0.072	0.020	0.056	0.056	0.056

Table 6. Results of Run 3. Spring survey from 1985 to 1997 and fall survey from 1990 to 1997, ages 5 to 14. Catch from 1975 to 1997, ages 5 to 17. F on ages 15 to 17 set as average of F on ages 12 to 14. M=0.2 for all ages.

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.003777
MEAN SQUARE RESIDUALS 0.473040

Parameters in linear scale

	PAR.	EST	STD. ERR	REL. ERR	BIAS	REL. BIAS
	6	7.55E+03	3.91E+03	0.518	1.05E+03	0.139
	7	8.10E+03	3.05E+03	0.376	5.98E+02	0.074
	8	5.36E+03	1.85E+03	0.345	3.06E+02	0.057
	9	3.72E+03	1.25E+03	0.336	1.86E+02	0.05
	10	2.22E+03	7.10E+02	0.319	9.87E+01	0.044
	11	1.39E+03	4.28E+02	0.308	5.94E+01	0.043
	12	8.07E+02	2.47E+02	0.306	3.45E+01	0.043
	13	5.57E+02	1.55E+02	0.278	2.29E+01	0.041
	14	2.28E+02	6.36E+01	0.279	9.17E+00	0.04
	15	4.66E+01	1.36E+01	0.292	1.86E+00	0.04
spring	5	6.81E-03	1.37E-03	0.201	1.11E-04	0.016
	6	1.02E-02	2.01E-03	0.197	1.66E-04	0.016
	7	1.11E-02	2.18E-03	0.196	1.89E-04	0.017
	8	8.52E-03	1.67E-03	0.196	1.50E-04	0.018
	9	6.76E-03	1.32E-03	0.196	1.21E-04	0.018
	10	4.77E-03	9.34E-04	0.196	8.57E-05	0.018
	11	4.39E-03	8.57E-04	0.195	7.99E-05	0.018
	12	5.41E-03	1.06E-03	0.196	1.04E-04	0.019
	13	6.01E-03	1.18E-03	0.196	1.24E-04	0.021
	14	7.99E-03	1.56E-03	0.195	1.74E-04	0.022
fall	5	2.29E-02	6.07E-03	0.266	6.68E-04	0.029
	6	2.61E-02	6.73E-03	0.258	7.41E-04	0.028
	7	2.13E-02	5.46E-03	0.256	6.33E-04	0.03
	8	1.46E-02	3.74E-03	0.256	4.50E-04	0.031
	9	1.20E-02	3.06E-03	0.256	3.72E-04	0.031
	10	8.33E-03	2.12E-03	0.255	2.57E-04	0.031
	11	7.67E-03	1.96E-03	0.255	2.42E-04	0.032
	12	9.51E-03	2.44E-03	0.256	3.21E-04	0.034
	13	1.26E-02	3.22E-03	0.256	4.49E-04	0.036
	14	2.65E-02	6.78E-03	0.255	1.00E-03	0.038

residuals spring

age	5	6	7	8	9	10	11	12	13	14
1985.5	-1.059	-0.869	-0.549	-0.559	-0.644	-0.406	-0.343	-0.547	-0.547	-0.537
1986.5	-0.743	-0.451	-0.436	-0.641	-0.674	-0.567	-0.748	-0.532	-0.313	-0.728
1987.5	0.118	0.193	-0.065	-0.163	-0.443	-0.379	-0.639	-0.386	-0.138	-0.102
1988.5	-0.064	0.260	0.083	-0.190	-0.096	-0.265	-0.224	-0.196	-0.158	0.044
1989.5	0.010	0.304	0.320	0.078	0.073	-0.144	-0.134	-0.044	-0.023	-0.219
1990.5	0.497	0.175	0.249	0.241	0.195	0.383	0.093	0.109	0.350	-0.002
1991.5	0.703	0.080	-0.117	-0.068	0.141	0.225	0.386	0.170	-0.106	0.054
1992.5	-0.117	-0.111	-0.444	-0.318	-0.237	0.081	0.089	-0.051	-0.194	-0.821
1993.5	0.435	0.317	0.225	0.158	0.366	0.735	0.912	0.669	0.406	0.512
1994.5	0.127	0.243	0.266	0.315	0.248	0.325	1.308	1.088	2.194	2.252
1995.5	-0.587	-0.438	0.060	0.694	0.914	0.514	0.349	0.175	-0.707	0.203
1996.5	0.546	0.392	0.291	0.217	0.104	-0.263	-0.621	0.191	0.272	0.219
1997.5	0.136	-0.094	0.117	0.237	0.052	-0.239	-0.428	-0.648	-1.037	-0.874

residuals fall

age	5	6	7	8	9	10	11	12	13	14
1990.9	-0.204	-0.055	-0.256	-0.164	-0.128	-0.132	-0.125	-0.196	-0.106	-0.738
1991.9	0.255	-0.170	-0.193	-0.243	0.189	0.399	0.530	0.137	-0.003	-0.616
1992.9	-0.039	0.015	-0.562	-0.457	-0.462	-0.138	-0.207	0.022	-0.528	-0.976
1993.9	0.300	0.297	0.633	0.327	0.513	0.882	1.171	1.176	1.150	1.026
1994.9	-0.220	-0.078	0.505	1.027	0.567	0.563	1.111	1.469	2.554	2.445
1995.9	0.179	0.440	0.247	0.380	0.444	0.019	-0.615	0.520	0.218	1.266
1996.9	-0.134	-0.145	-0.387	-0.810	-0.955	-1.103	-1.181	-1.620	-2.037	-1.653
1997.9	-0.136	-0.303	0.014	-0.060	-0.167	-0.490	-0.685	-1.507	-1.246	-0.754

Table 6. Cont'd

Bias adjusted population numbers ('000) Spring and Fall M=0.2

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	291226.2	228716.6	191792.3	123405.6	75151.2	43357.4	25836.3	15968.3	10983.0	6171.9	3298.2	1662.9	1328.7
1976	277100.5	237638.3	184432.4	150508.8	92527.3	53207.4	28385.5	16026.8	8826.9	5597.0	2713.2	1394.8	680.0
1977	231516.2	226114.7	191033.5	143075.5	105779.3	60817.0	32471.5	15769.8	8497.5	4516.4	2517.2	1020.1	619.8
1978	215933.9	188669.6	179057.3	148514.0	106560.9	74387.5	39752.0	20720.0	9088.1	4830.0	2359.0	1166.0	528.6
1979	198155.1	175384.5	150436.2	138301.6	112213.6	75760.5	48411.9	23616.5	10846.2	4170.5	1955.3	625.8	377.2
1980	188016.4	161100.3	137679.1	110964.1	96342.5	78379.2	50768.0	31724.5	15936.4	7221.0	2771.7	1293.0	369.5
1981	169916.2	153697.2	129209.5	104123.8	79512.8	66168.9	51380.7	31415.8	18707.4	9693.0	4504.7	1689.5	820.2
1982	170720.7	138976.5	125336.2	103757.7	80929.8	57958.1	43890.0	29882.6	15090.9	7554.5	2965.9	1086.1	392.7
1983	155363.5	139749.9	113500.7	100978.4	80618.3	58195.9	35910.5	21778.3	11538.2	5280.4	2427.3	659.2	319.7
1984	143981.0	127093.3	113522.4	90170.0	77443.2	58483.4	40703.0	21767.2	11093.4	5341.0	2109.3	900.4	207.9
1985	123585.0	117838.3	103696.6	91575.2	70836.1	58125.6	38917.7	21765.5	9803.5	4552.6	2127.8	755.5	376.2
1986	89755.9	100915.4	95766.1	82766.9	69875.8	48364.6	33452.8	18852.9	9564.8	4352.9	1967.3	644.4	272.8
1987	67569.3	69508.6	73870.3	67093.8	56479.3	45177.4	27143.0	14652.1	6201.3	2555.6	1222.8	361.7	54.6
1988	65352.3	53301.6	52451.5	53546.4	45123.9	31995.5	21199.3	12025.1	5761.1	2333.8	930.9	320.1	77.8
1989	61363.5	50881.2	40740.6	38567.7	37291.4	27842.8	16935.9	9080.5	4459.7	2313.4	879.7	182.9	28.9
1990	69825.6	38776.7	31271.4	23091.5	22903.9	17835.7	11728.1	6369.9	3009.1	1839.0	976.4	232.4	21.8
1991	35352.2	43558.9	24825.8	21559.4	14763.8	10992.7	6870.8	3860.1	1984.8	949.9	663.4	394.9	118.6
1992	19986.3	23450.2	24752.1	13287.8	9310.8	5090.8	3148.9	1731.1	1122.7	899.5	451.9	322.8	169.6
1993	14885.2	16229.7	18276.0	17929.5	7829.0	4384.5	2242.1	1233.2	637.2	405.8	280.3	131.0	112.0
1994	16325.0	11129.5	9949.9	7092.2	4411.0	1368.3	622.3	215.8	132.1	61.2	24.1	15.6	0.1
1995	11725.9	9488.9	5673.0	3316.3	1852.0	1149.0	464.1	91.3	33.5	3.9	2.7	4.1	4.1
1996	11762.2	9510.7	7485.5	4235.9	2414.9	1333.0	881.6	367.7	71.1	27.3	3.1	2.1	3.3
1997	7977.1	9466.7	7116.7	5250.1	3059.9	1786.8	1044.5	712.4	293.7	56.1	21.5	1.7	1.7
1998	100000.0	6500.9	7502.6	5058.2	3530.3	2125.5	1331.2	772.8	534.4	218.9	44.8	16.4	1.3

Bias adjusted fishing mortalities Spring and Fall

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	0.003	0.015	0.042	0.088	0.145	0.224	0.278	0.393	0.474	0.622	0.661	0.694	0.496
1976	0.003	0.018	0.054	0.153	0.220	0.294	0.388	0.434	0.470	0.599	0.778	0.611	0.501
1977	0.005	0.033	0.052	0.095	0.152	0.225	0.249	0.351	0.365	0.449	0.570	0.457	0.389
1978	0.008	0.026	0.058	0.080	0.141	0.230	0.321	0.447	0.579	0.704	1.127	0.929	0.577
1979	0.007	0.042	0.104	0.162	0.159	0.200	0.223	0.193	0.207	0.209	0.214	0.327	0.203
1980	0.002	0.021	0.079	0.133	0.176	0.222	0.280	0.328	0.297	0.272	0.295	0.255	0.299
1981	0.001	0.004	0.019	0.052	0.116	0.211	0.342	0.533	0.707	0.984	1.223	1.259	0.741
1982	0.000	0.002	0.016	0.052	0.130	0.279	0.501	0.752	0.850	0.935	1.304	1.023	0.846
1983	0.001	0.008	0.030	0.065	0.121	0.158	0.301	0.475	0.570	0.718	0.792	0.954	0.587
1984	0.000	0.003	0.015	0.041	0.087	0.207	0.426	0.598	0.691	0.720	0.827	0.673	0.670
1985	0.003	0.007	0.025	0.070	0.182	0.352	0.525	0.622	0.612	0.639	0.995	0.819	0.624
1986	0.056	0.112	0.156	0.182	0.236	0.378	0.626	0.912	1.120	1.070	1.494	2.268	1.034
1987	0.037	0.082	0.122	0.197	0.368	0.557	0.614	0.733	0.777	0.810	1.140	1.337	0.774
1988	0.050	0.069	0.107	0.162	0.283	0.436	0.648	0.792	0.712	0.776	1.427	2.205	0.760
1989	0.259	0.287	0.368	0.321	0.538	0.665	0.778	0.904	0.686	0.663	1.131	1.928	0.751
1990	0.272	0.246	0.172	0.247	0.534	0.754	0.911	0.966	0.953	0.820	0.705	0.473	0.913
1991	0.210	0.365	0.425	0.640	0.865	1.050	1.179	1.035	0.591	0.543	0.520	0.645	0.723
1992	0.008	0.049	0.122	0.329	0.553	0.620	0.737	0.799	0.818	0.966	1.038	0.859	0.861
1993	0.091	0.289	0.747	1.202	1.544	1.752	2.141	2.034	2.144	2.624	2.691	6.844	2.267
1994	0.343	0.474	0.899	1.143	1.145	0.881	1.719	1.664	3.320	2.918	1.563	1.145	2.634
1995	0.009	0.037	0.092	0.117	0.129	0.065	0.033	0.051	0.003	0.029	0.042	0.027	0.028
1996	0.017	0.090	0.155	0.125	0.101	0.044	0.013	0.025	0.036	0.041	0.434	0.053	0.034
1997	0.005	0.033	0.141	0.197	0.164	0.094	0.101	0.088	0.094	0.026	0.069	0.069	0.069

Table 7. Results of Run 8. Spring survey from 1985 to 1997 and fall survey from 1990 to 1997, ages 5 to 14. Catch from 1975 to 1997, ages 5 to 17. F on ages 15 to 17 set as average of F on ages 12 to 14. M=0.6 for all ages from 1989 to 1996, otherwise M=0.2.

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.003648
MEAN SQUARE RESIDUALS 0.340824

Parameters in linear scale

	PAR. EST	STD. ERR	REL. ERR	BIAS	REL. BIAS
6	2.28E+04	1.01E+04	0.441	2.31E+03	0.101
7	2.09E+04	6.64E+03	0.317	1.13E+03	0.054
8	1.15E+04	3.16E+03	0.275	4.51E+02	0.039
9	6.56E+03	1.70E+03	0.258	2.15E+02	0.033
10	3.36E+03	8.11E+02	0.242	9.41E+01	0.028
11	1.89E+03	4.40E+02	0.233	4.85E+01	0.026
12	1.08E+03	2.52E+02	0.234	2.73E+01	0.025
13	6.18E+02	1.37E+02	0.223	1.61E+01	0.026
14	2.40E+02	5.37E+01	0.224	6.14E+00	0.026
15	5.28E+01	1.27E+01	0.241	1.42E+00	0.027
spring 5	2.27E-03	3.95E-04	0.174	2.67E-05	0.012
6	4.22E-03	7.15E-04	0.169	4.85E-05	0.012
7	5.49E-03	9.20E-04	0.168	6.49E-05	0.012
8	4.79E-03	8.00E-04	0.167	5.90E-05	0.012
9	4.15E-03	6.91E-04	0.167	5.28E-05	0.013
10	3.12E-03	5.20E-04	0.166	4.05E-05	0.013
11	2.99E-03	4.98E-04	0.166	4.00E-05	0.013
12	3.77E-03	6.30E-04	0.167	5.33E-05	0.014
13	4.25E-03	7.10E-04	0.167	6.38E-05	0.015
14	5.70E-03	9.51E-04	0.167	9.05E-05	0.016
fall 5	7.53E-03	1.74E-03	0.231	1.64E-04	0.022
6	1.08E-02	2.40E-03	0.222	2.20E-04	0.02
7	1.04E-02	2.29E-03	0.219	2.16E-04	0.021
8	7.97E-03	1.74E-03	0.218	1.71E-04	0.021
9	7.02E-03	1.53E-03	0.217	1.55E-04	0.022
10	5.34E-03	1.16E-03	0.216	1.18E-04	0.022
11	5.08E-03	1.10E-03	0.217	1.19E-04	0.023
12	6.58E-03	1.44E-03	0.218	1.62E-04	0.025
13	8.85E-03	1.93E-03	0.219	2.31E-04	0.026
14	1.80E-02	3.95E-03	0.219	5.02E-04	0.028

Residuals spring M0.6

age	5	6	7	8	9	10	11	12	13	14
1985.5	-0.461	-0.354	-0.108	-0.138	-0.297	-0.088	-0.012	-0.197	-0.211	-0.220
1986.5	-0.375	-0.092	-0.123	-0.358	-0.364	-0.329	-0.536	-0.278	0.005	-0.413
1987.5	0.283	0.308	0.069	-0.043	-0.326	-0.215	-0.549	-0.338	-0.018	0.171
1988.5	-0.109	0.176	-0.029	-0.252	-0.158	-0.356	-0.274	-0.362	-0.368	-0.050
1989.5	-0.133	0.131	0.129	-0.081	-0.037	-0.273	-0.324	-0.214	-0.325	-0.547
1990.5	0.440	0.045	0.160	0.148	0.154	0.344	0.008	-0.078	0.188	-0.262
1991.5	0.555	0.001	-0.220	-0.080	0.128	0.224	0.369	0.113	-0.223	0.003
1992.5	-0.294	-0.165	-0.444	-0.347	-0.180	0.132	0.161	0.004	-0.158	-0.790
1993.5	0.219	0.232	0.185	0.129	0.236	0.748	0.909	0.824	0.520	0.475
1994.5	-0.050	0.023	0.054	0.030	-0.028	-0.044	1.002	0.768	2.056	2.043
1995.5	-0.725	-0.563	-0.116	0.455	0.590	0.263	0.098	-0.164	-1.027	-0.037
1996.5	0.520	0.410	0.343	0.256	0.128	-0.295	-0.531	0.307	0.301	0.285
1997.5	0.131	-0.152	0.100	0.282	0.154	-0.110	-0.321	-0.386	-0.740	-0.659

Residuals fall M0.6

age	5	6	7	8	9	10	11	12	13	14
1990.9	-0.164	-0.086	-0.216	-0.115	-0.054	-0.105	-0.158	-0.378	-0.256	-0.938
1991.9	0.218	-0.179	-0.223	-0.179	0.243	0.432	0.546	0.105	-0.044	-0.532
1992.9	-0.047	0.109	-0.418	-0.355	-0.280	0.013	-0.028	0.157	-0.417	-0.844
1993.9	0.229	0.302	0.605	0.277	0.317	0.850	1.108	1.347	1.256	0.915
1994.9	-0.321	-0.260	0.251	0.679	0.259	0.188	0.676	1.009	2.192	2.046
1995.9	0.210	0.468	0.218	0.307	0.296	-0.066	-0.683	0.339	0.062	1.229
1996.9	0.006	0.014	-0.195	-0.599	-0.741	-0.962	-0.903	-1.338	-1.846	-1.383
1997.9	-0.131	-0.367	-0.023	-0.014	-0.040	-0.351	-0.558	-1.241	-0.946	-0.493

Table 7. Cont'd

Bias adjusted population numbers ('000t) M=0.6

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	291320.0	228786.1	191819.8	123411.8	75155.9	43358.9	25837.4	15968.5	10983.1	6172.0	3298.2	1662.9	1328.8
1976	277500.4	237715.0	184489.3	150531.4	92532.4	53211.2	28386.8	16027.6	8827.1	5597.1	2713.3	1394.9	680.1
1977	231833.0	226442.1	191096.4	143122.0	105797.8	60821.2	32474.6	15770.9	8498.1	4516.5	2517.3	1020.2	619.8
1978	216599.9	188929.1	179325.4	148565.4	106599.0	74402.6	39755.3	20722.6	9089.0	4830.6	2359.1	1166.1	528.6
1979	203238.6	175929.8	150648.6	138521.1	112255.7	75791.7	48424.3	23619.3	10848.3	4171.2	1955.7	625.9	377.3
1980	202587.8	165262.4	138125.5	111138.0	96522.1	78413.7	50793.5	31734.6	15938.7	7222.7	2772.3	1293.4	369.6
1981	191861.6	165627.3	132617.1	104489.3	79655.1	66315.8	51408.9	31436.7	18715.6	9694.9	4506.1	1690.0	820.6
1982	197594.6	156943.9	135103.7	106547.6	81229.0	58074.6	44010.2	29905.7	15107.9	7561.2	2967.4	1087.2	393.1
1983	202001.8	161752.4	128211.2	108975.3	82902.4	58440.8	36005.7	21876.4	11556.9	5294.1	2432.7	660.3	320.6
1984	207705.2	165277.6	131536.6	102213.8	83990.1	60353.0	40903.5	21845.1	11173.3	5356.3	2120.4	904.7	208.9
1985	203817.2	170011.3	134959.3	106323.9	80696.4	63485.1	40447.4	21929.1	9866.9	4617.6	2140.1	764.6	379.8
1986	183843.3	166604.0	138481.7	108362.3	81950.1	56433.7	37832.7	20099.9	9697.9	4404.4	2020.2	654.4	280.1
1987	169959.3	146538.9	127644.9	102056.8	77426.4	55055.4	33736.5	18218.4	7209.5	2662.4	1264.2	403.5	62.1
1988	201480.6	137130.7	115515.4	97567.2	73737.5	49118.9	29254.5	17398.0	8661.7	3152.6	1017.4	353.3	111.1
1989	235850.0	162332.2	109372.0	90195.6	73324.3	51251.6	30928.8	15645.6	8831.2	4676.6	1545.7	251.7	54.4
1990	245810.0	120169.9	80699.4	51742.5	42509.1	30040.8	19254.6	10970.4	5051.1	3391.7	1829.4	458.8	37.9
1991	138781.6	123904.8	60360.0	41025.1	25057.6	17101.2	10306.6	5987.7	3441.0	1564.3	1186.8	679.7	194.1
1992	86841.9	71724.1	59192.4	27453.1	15822.6	8163.4	4734.5	2570.2	1666.5	1307.2	597.6	474.6	250.0
1993	65453.6	47551.9	38617.1	30600.1	12610.6	6089.0	2940.4	1526.9	789.9	506.2	355.6	139.6	139.4
1994	63342.9	35067.1	23401.9	14867.5	8606.5	2917.5	1013.6	354.1	160.5	78.3	40.7	30.1	0.2
1995	49684.8	31627.9	16466.4	8953.0	4982.6	2749.7	1073.8	224.1	80.5	8.5	6.4	9.9	9.6
1996	44891.3	27195.2	17128.8	8706.8	4671.1	2586.5	1461.4	579.4	120.0	44.1	4.6	3.4	5.4
1997	25077.5	24504.9	14383.9	8691.7	4449.2	2410.0	1381.7	794.4	312.1	64.2	23.5	1.8	1.8
1998	100000.0	20501.5	19814.7	11007.1	6347.0	3262.5	1841.4	1048.8	601.5	234.0	51.4	18.1	1.4

Bias adjusted fishing mortality M0.6

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	0.003	0.015	0.042	0.088	0.145	0.224	0.278	0.393	0.474	0.622	0.661	0.694	0.496
1976	0.003	0.018	0.054	0.153	0.220	0.294	0.388	0.434	0.470	0.599	0.778	0.611	0.501
1977	0.005	0.033	0.052	0.095	0.152	0.225	0.249	0.351	0.365	0.449	0.570	0.457	0.388
1978	0.008	0.026	0.058	0.080	0.141	0.229	0.321	0.447	0.579	0.704	1.127	0.928	0.577
1979	0.007	0.042	0.104	0.161	0.159	0.200	0.223	0.193	0.207	0.209	0.214	0.327	0.203
1980	0.001	0.020	0.079	0.133	0.175	0.222	0.280	0.328	0.297	0.272	0.295	0.255	0.299
1981	0.001	0.004	0.019	0.052	0.116	0.210	0.342	0.533	0.706	0.984	1.222	1.258	0.741
1982	0.000	0.002	0.015	0.051	0.129	0.278	0.499	0.751	0.849	0.934	1.303	1.021	0.844
1983	0.001	0.007	0.027	0.060	0.117	0.157	0.300	0.472	0.569	0.715	0.789	0.951	0.585
1984	0.000	0.003	0.013	0.036	0.080	0.200	0.423	0.595	0.684	0.717	0.820	0.668	0.665
1985	0.002	0.005	0.019	0.060	0.158	0.318	0.499	0.616	0.607	0.627	0.985	0.804	0.616
1986	0.027	0.066	0.105	0.136	0.198	0.314	0.531	0.825	1.093	1.048	1.411	2.156	0.989
1987	0.015	0.038	0.069	0.125	0.255	0.432	0.462	0.544	0.627	0.762	1.075	1.090	0.644
1988	0.016	0.026	0.047	0.086	0.164	0.263	0.426	0.478	0.416	0.513	1.197	1.671	0.469
1989	0.074	0.099	0.148	0.152	0.292	0.379	0.436	0.531	0.357	0.339	0.615	1.292	0.409
1990	0.085	0.089	0.077	0.125	0.311	0.470	0.568	0.559	0.572	0.450	0.390	0.260	0.527
1991	0.060	0.139	0.188	0.353	0.522	0.684	0.789	0.679	0.368	0.362	0.317	0.400	0.470
1992	0.002	0.019	0.060	0.178	0.355	0.421	0.532	0.580	0.592	0.702	0.854	0.625	0.624
1993	0.024	0.109	0.355	0.668	0.864	1.193	1.517	1.653	1.712	1.921	1.869	6.236	1.762
1994	0.095	0.156	0.361	0.493	0.541	0.399	0.909	0.881	2.336	1.908	0.812	0.547	1.709
1995	0.003	0.013	0.037	0.051	0.056	0.032	0.017	0.025	0.002	0.016	0.021	0.013	0.014
1996	0.005	0.037	0.078	0.071	0.062	0.027	0.010	0.019	0.026	0.031	0.335	0.040	0.025
1997	0.001	0.012	0.068	0.114	0.110	0.069	0.076	0.078	0.088	0.023	0.063	0.063	0.063

Table 8. Results of run 9. Spring survey from 1985 to 199, ages 5 to 14. Catch from 1975 to 1997, ages 5 to 17. F on ages 15 to 17 set as average of F on ages 12 to 14. M=0.6 for all ages from 1989 to 1996, otherwise M=0.2.

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.001205
MEAN SQUARE RESIDUALS 0.213436

Parameters in linear scale

	PAR. EST	STD. ERR	REL. ERR	BIAS	REL. BIAS
6	2.77E+04	1.34E+04	0.484	3.34E+03	0.121
7	2.67E+04	9.25E+03	0.346	1.67E+03	0.063
8	1.13E+04	3.42E+03	0.302	5.16E+02	0.046
9	7.09E+03	2.00E+03	0.282	2.66E+02	0.038
10	4.05E+03	1.05E+03	0.259	1.27E+02	0.031
11	2.25E+03	5.63E+02	0.25	6.45E+01	0.029
12	1.21E+03	3.10E+02	0.255	3.53E+01	0.029
13	6.97E+02	1.69E+02	0.243	2.15E+01	0.031
14	2.91E+02	7.04E+01	0.242	8.72E+00	0.03
15	6.67E+01	1.76E+01	0.264	2.17E+00	0.032
5	2.13E-03	3.07E-04	0.144	1.49E-05	0.007
6	4.01E-03	5.54E-04	0.138	2.67E-05	0.007
7	5.28E-03	7.18E-04	0.136	3.70E-05	0.007
8	4.57E-03	6.17E-04	0.135	3.45E-05	0.008
9	3.94E-03	5.30E-04	0.134	3.13E-05	0.008
10	2.98E-03	4.00E-04	0.134	2.44E-05	0.008
11	2.85E-03	3.83E-04	0.134	2.48E-05	0.009
12	3.59E-03	4.85E-04	0.135	3.43E-05	0.01
13	4.04E-03	5.46E-04	0.135	4.31E-05	0.011
14	5.42E-03	7.31E-04	0.135	6.42E-05	0.012

residuals spring m=0.6

age	5	6	7	8	9	10	11	12	13	14
1985.5	-0.397	-0.303	-0.071	-0.091	-0.247	-0.040	0.036	-0.146	-0.159	-0.169
1986.5	-0.311	-0.041	-0.086	-0.313	-0.313	-0.281	-0.489	-0.229	0.057	-0.362
1987.5	0.342	0.360	0.107	0.002	-0.277	-0.167	-0.503	-0.289	0.033	0.222
1988.5	-0.059	0.222	0.008	-0.206	-0.108	-0.311	-0.227	-0.313	-0.319	-0.001
1989.5	-0.102	0.169	0.162	-0.035	0.013	-0.228	-0.280	-0.164	-0.275	-0.499
1990.5	0.477	0.061	0.182	0.188	0.204	0.390	0.052	-0.033	0.239	-0.214
1991.5	0.574	0.022	-0.224	-0.054	0.170	0.271	0.414	0.157	-0.181	0.054
1992.5	-0.325	-0.160	-0.439	-0.351	-0.157	0.166	0.206	0.050	-0.118	-0.755
1993.5	0.150	0.183	0.166	0.126	0.200	0.730	0.914	0.865	0.554	0.475
1994.5	-0.046	-0.070	-0.035	-0.009	-0.064	-0.142	0.891	0.707	2.043	2.006
1995.5	-0.647	-0.575	-0.236	0.350	0.534	0.201	-0.028	-0.335	-1.127	-0.101
1996.5	0.344	0.475	0.315	0.137	0.020	-0.358	-0.595	0.181	0.126	0.182
1997.5	0.000	-0.342	0.152	0.255	0.025	-0.230	-0.390	-0.452	-0.874	-0.839

Table 8. Cont'd.

Bias adjusted population numbers ('000) spring M=0.6

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	291320.3	228786.3	191819.9	123411.8	75155.9	43359.0	25837.4	15968.5	10983.1	6172.0	3298.2	1662.9	1328.8
1976	277502.0	237715.3	184489.5	150531.4	92532.4	53211.2	28386.8	16027.6	8827.1	5597.1	2713.3	1394.9	680.1
1977	231833.8	226443.4	191096.6	143122.2	105797.9	60821.2	32474.6	15770.9	8498.2	4516.5	2517.3	1020.2	619.8
1978	216601.4	188929.7	179326.4	148565.6	106599.1	74402.6	39755.4	20722.6	9089.0	4830.6	2359.1	1166.1	528.6
1979	203259.2	175931.0	150649.1	138522.0	112255.9	75791.8	48424.3	23619.3	10848.3	4171.2	1955.7	625.9	377.3
1980	202658.7	165279.2	138126.5	111138.4	96522.8	78413.8	50793.6	31734.6	15938.7	7222.7	2772.3	1293.4	369.6
1981	191929.8	165685.4	132630.8	104490.1	79655.4	66316.4	51409.0	31436.8	18715.7	9694.9	4506.1	1690.0	820.6
1982	197597.4	156999.7	135151.3	106558.9	81229.7	58074.9	44010.7	29905.7	15107.9	7561.2	2967.4	1087.2	393.1
1983	202273.9	161754.7	128256.8	109014.3	82911.6	58441.4	36006.0	21876.7	11556.9	5294.2	2432.7	660.3	320.6
1984	207949.3	165500.4	131538.4	102251.2	84022.0	60360.5	40903.9	21845.3	11173.7	5356.3	2120.5	904.8	208.9
1985	203931.9	170211.1	135141.6	106325.4	80727.1	63511.2	40453.5	21929.5	9867.1	4617.8	2140.2	764.6	379.8
1986	183943.5	166697.9	138645.3	108511.6	81951.4	56458.8	37854.0	20104.9	9698.2	4404.6	2020.4	654.4	280.1
1987	170779.8	146621.0	127721.7	102190.8	77548.7	55056.4	33757.0	18235.7	7213.5	2662.6	1264.3	403.6	62.1
1988	204139.9	137802.4	115582.6	97630.1	73847.2	49218.8	29255.3	17414.8	8675.9	3155.9	1017.6	353.4	111.2
1989	243345.7	164509.4	109921.9	90250.6	73375.8	51341.4	31010.6	15646.2	8844.8	4688.1	1548.4	251.9	54.4
1990	252014.6	124282.5	81893.8	52044.0	42539.3	30069.0	19303.5	11014.8	5051.4	3399.1	1835.8	460.2	38.0
1991	144706.5	127308.8	62616.2	41680.3	25222.9	17117.6	10321.8	6014.1	3465.0	1564.5	1190.9	683.1	194.9
1992	95299.8	74975.2	61058.8	28689.3	16180.1	8252.9	4743.4	2578.4	1680.7	1320.3	597.7	476.8	251.8
1993	74419.6	52193.6	40401.3	31624.2	13288.0	6284.0	2989.1	1531.6	794.3	513.9	362.6	139.6	140.6
1994	66863.8	39987.6	25948.0	15841.0	9157.2	3277.3	1114.0	378.2	162.8	80.4	44.3	33.4	0.2
1995	48762.9	33559.4	19164.0	10342.5	5511.1	3048.0	1270.0	277.4	93.3	9.5	7.4	11.8	11.3
1996	56494.1	26689.2	18188.8	10187.2	5433.6	2876.6	1625.1	687.0	149.2	51.1	5.1	4.0	6.4
1997	29831.9	30872.6	14106.3	9273.3	5261.5	2828.4	1540.9	884.3	371.2	80.2	27.3	2.1	2.1
1998	100000.0	24394.1	25028.2	10779.8	6823.1	3927.5	2183.9	1179.1	675.1	282.3	64.5	21.2	1.6

Bias adjusted fishing mortalities spring M=0.6

	5	6	7	8	9	10	11	12	13	14	15	16	17
1975	0.003	0.015	0.042	0.088	0.145	0.224	0.278	0.393	0.474	0.622	0.661	0.694	0.496
1976	0.003	0.018	0.054	0.153	0.220	0.294	0.388	0.434	0.470	0.599	0.778	0.611	0.501
1977	0.005	0.033	0.052	0.095	0.152	0.225	0.249	0.351	0.365	0.449	0.570	0.457	0.388
1978	0.008	0.026	0.058	0.080	0.141	0.229	0.321	0.447	0.579	0.704	1.127	0.928	0.577
1979	0.007	0.042	0.104	0.161	0.159	0.200	0.223	0.193	0.207	0.209	0.214	0.327	0.203
1980	0.001	0.020	0.079	0.133	0.175	0.222	0.280	0.328	0.297	0.272	0.295	0.255	0.299
1981	0.001	0.004	0.019	0.052	0.116	0.210	0.342	0.533	0.706	0.984	1.222	1.258	0.741
1982	0.000	0.002	0.015	0.051	0.129	0.278	0.499	0.751	0.849	0.934	1.303	1.021	0.844
1983	0.001	0.007	0.027	0.060	0.117	0.157	0.300	0.472	0.569	0.715	0.789	0.951	0.585
1984	0.000	0.003	0.013	0.036	0.080	0.200	0.423	0.595	0.684	0.717	0.820	0.668	0.665
1985	0.002	0.005	0.019	0.060	0.158	0.317	0.499	0.616	0.607	0.627	0.985	0.804	0.616
1986	0.027	0.066	0.105	0.136	0.198	0.314	0.530	0.825	1.093	1.048	1.411	2.155	0.989
1987	0.015	0.038	0.069	0.125	0.255	0.432	0.462	0.543	0.627	0.762	1.075	1.089	0.644
1988	0.016	0.026	0.047	0.086	0.164	0.262	0.426	0.477	0.416	0.512	1.196	1.670	0.468
1989	0.072	0.098	0.148	0.152	0.292	0.378	0.435	0.531	0.356	0.338	0.613	1.291	0.408
1990	0.083	0.086	0.075	0.124	0.310	0.469	0.566	0.557	0.572	0.449	0.389	0.259	0.526
1991	0.058	0.135	0.180	0.346	0.517	0.683	0.787	0.675	0.365	0.362	0.315	0.398	0.467
1992	0.002	0.018	0.058	0.170	0.346	0.416	0.530	0.577	0.585	0.692	0.854	0.621	0.618
1993	0.021	0.099	0.336	0.639	0.800	1.130	1.467	1.642	1.691	1.852	1.785	6.209	1.728
1994	0.089	0.136	0.320	0.456	0.500	0.348	0.790	0.800	2.241	1.791	0.720	0.480	1.611
1995	0.003	0.013	0.032	0.044	0.050	0.029	0.014	0.020	0.001	0.014	0.018	0.011	0.012
1996	0.004	0.038	0.074	0.061	0.053	0.024	0.009	0.016	0.021	0.026	0.294	0.034	0.021
1997	0.001	0.010	0.069	0.107	0.092	0.059	0.068	0.070	0.074	0.018	0.054	0.054	0.054

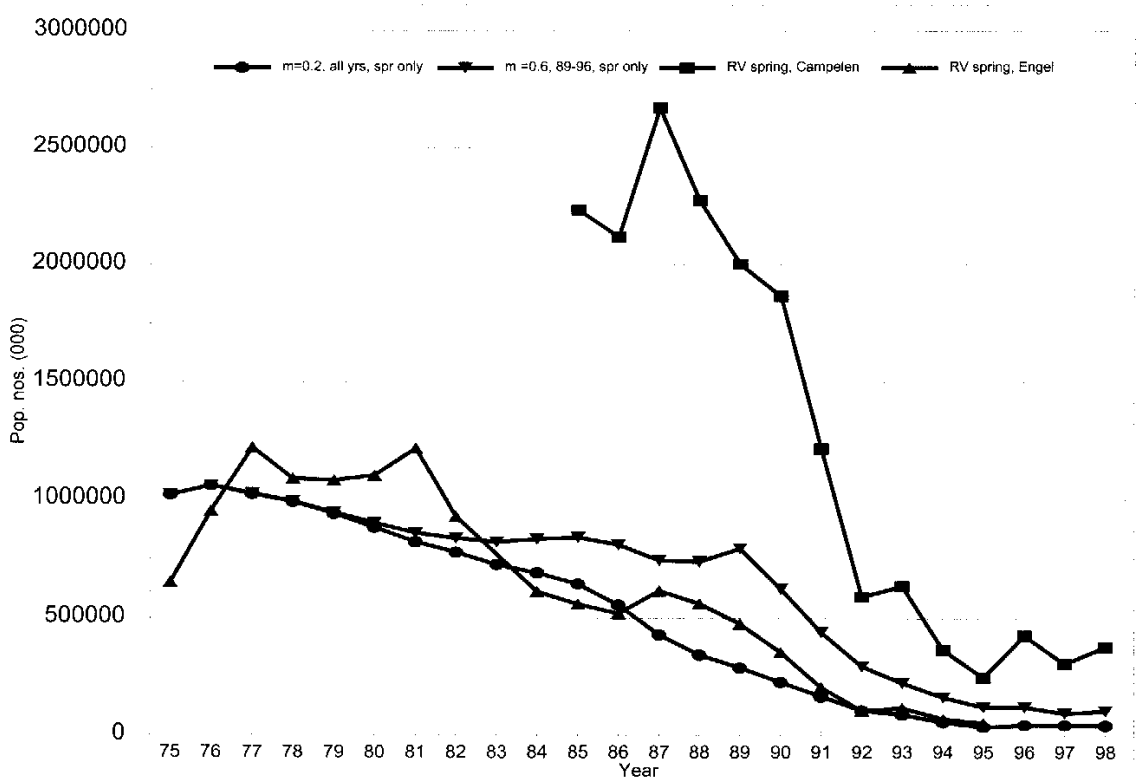

Fig. 1. Comparison of age 5+ population numbers from ADAPTs (spring index) and RV surveys.

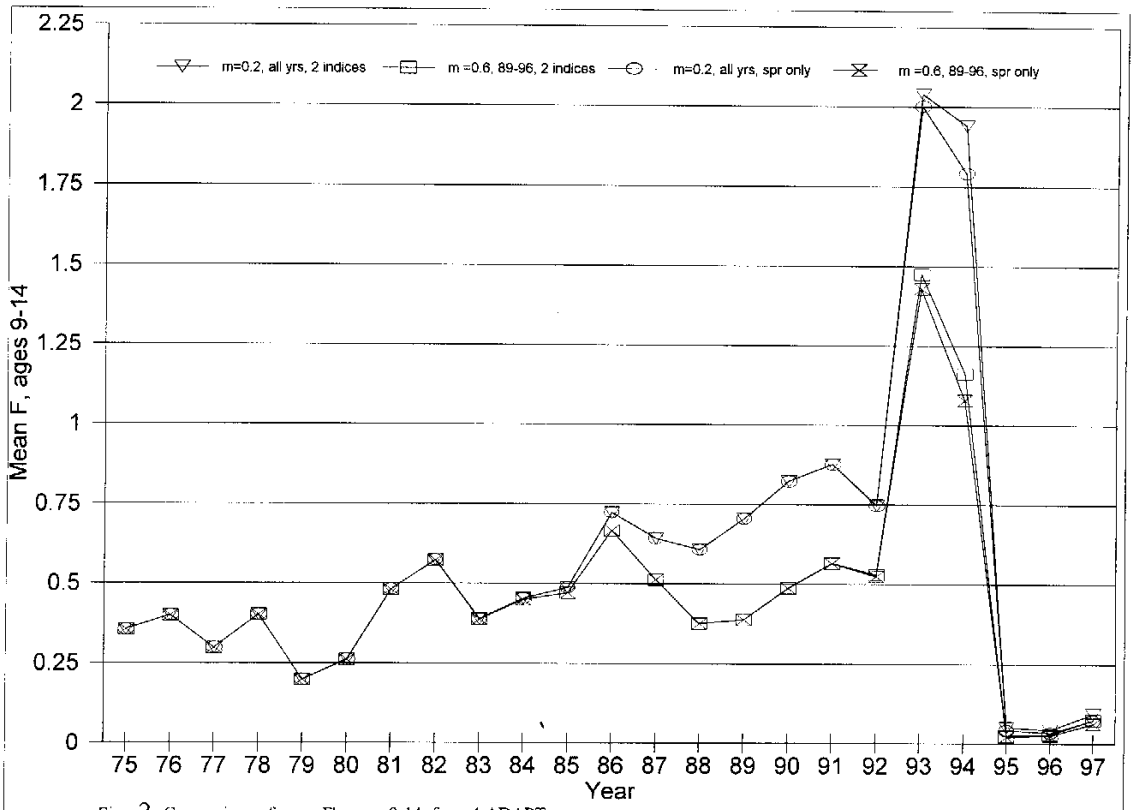

Fig. 2. Comparison of mean F's, ages 9-14, from 4 ADAPT runs.

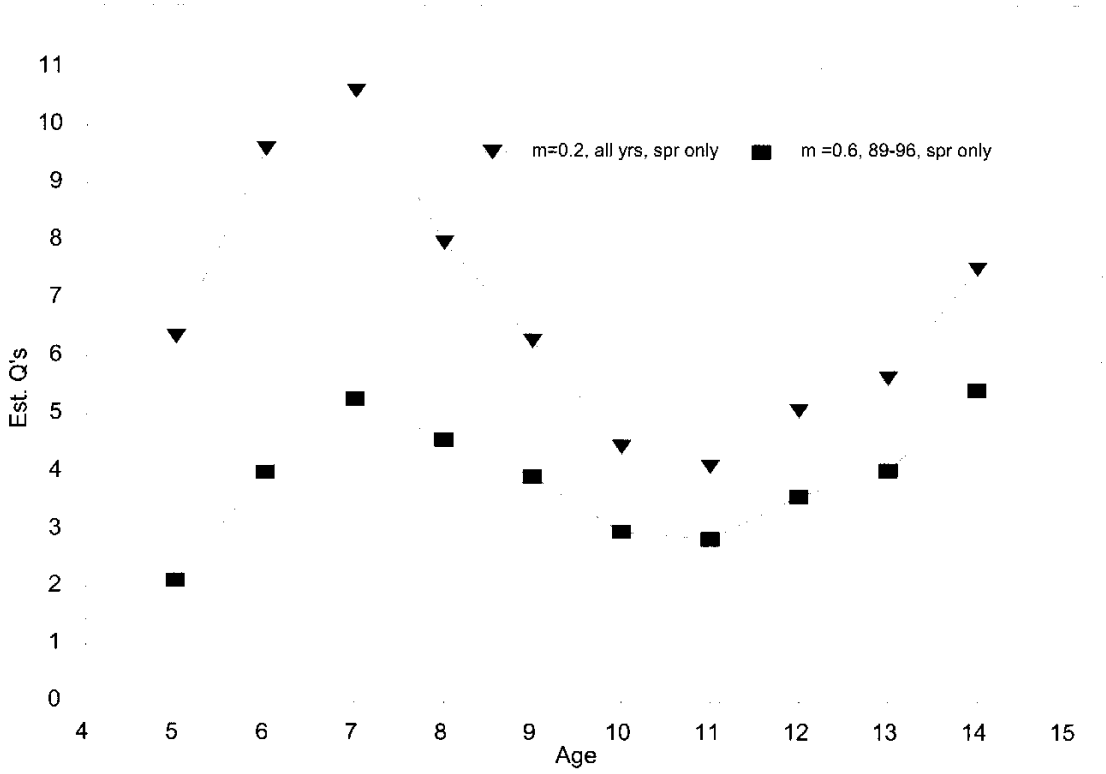

Fig. 3 . Comparison of calibration coefficients (q's) from ADAPT runs using only spring index.

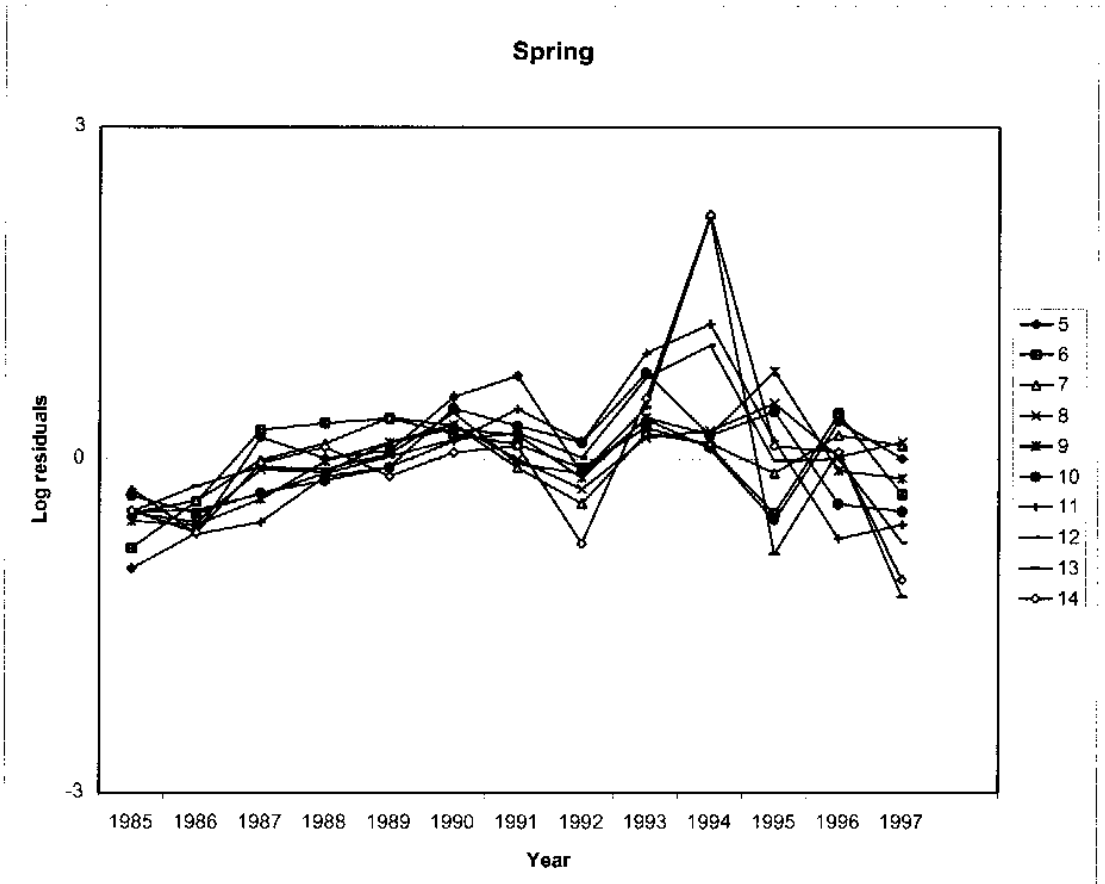

Fig. A 1.1 Log residuals from ADAPT for Canadian research vessel surveys.

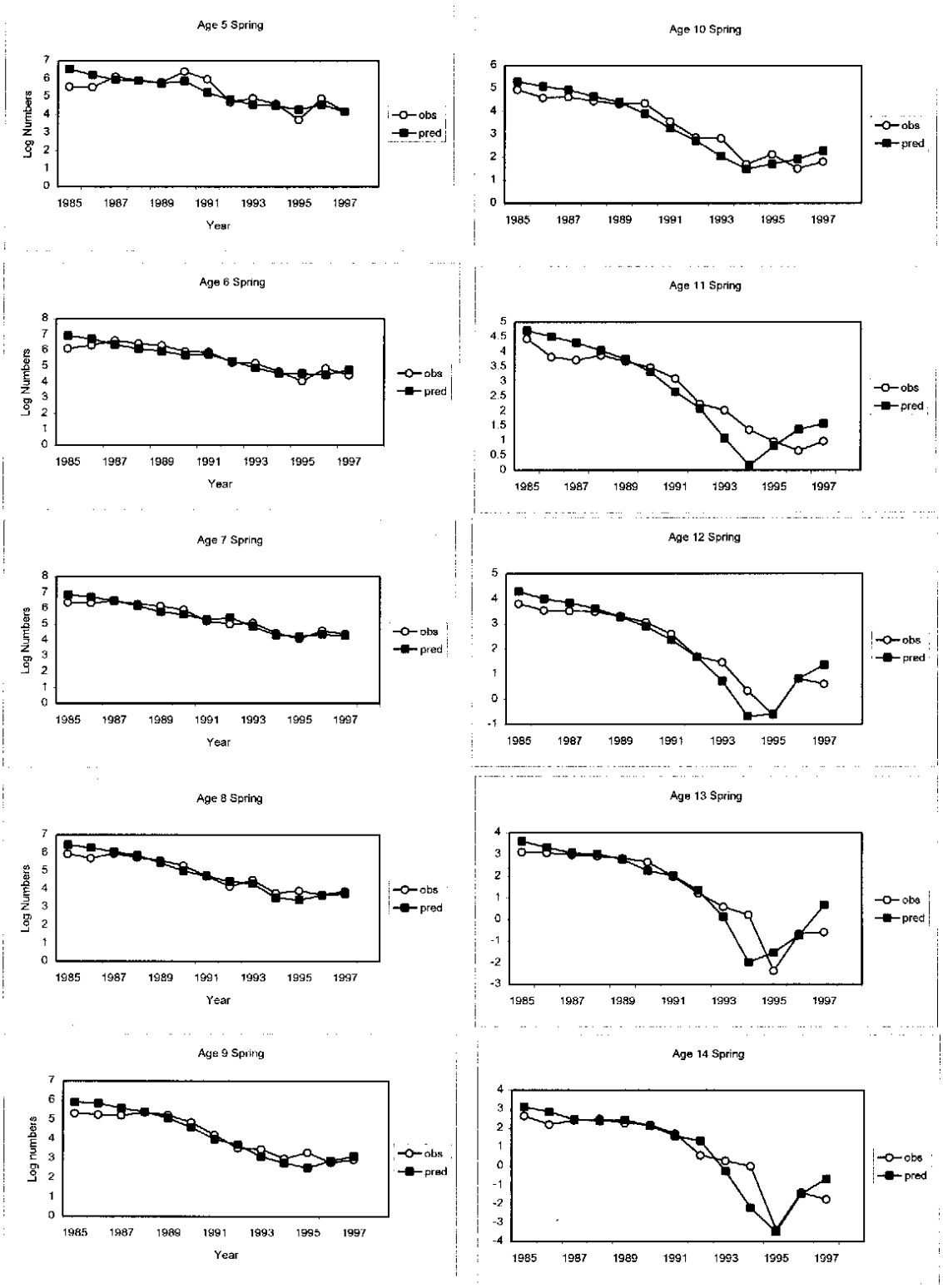

Fig. A 1.2 Age by age observed and predicted log abundance index over time from Canadian spring surveys for Am. plaice in NAFO Divisions 3LNO.

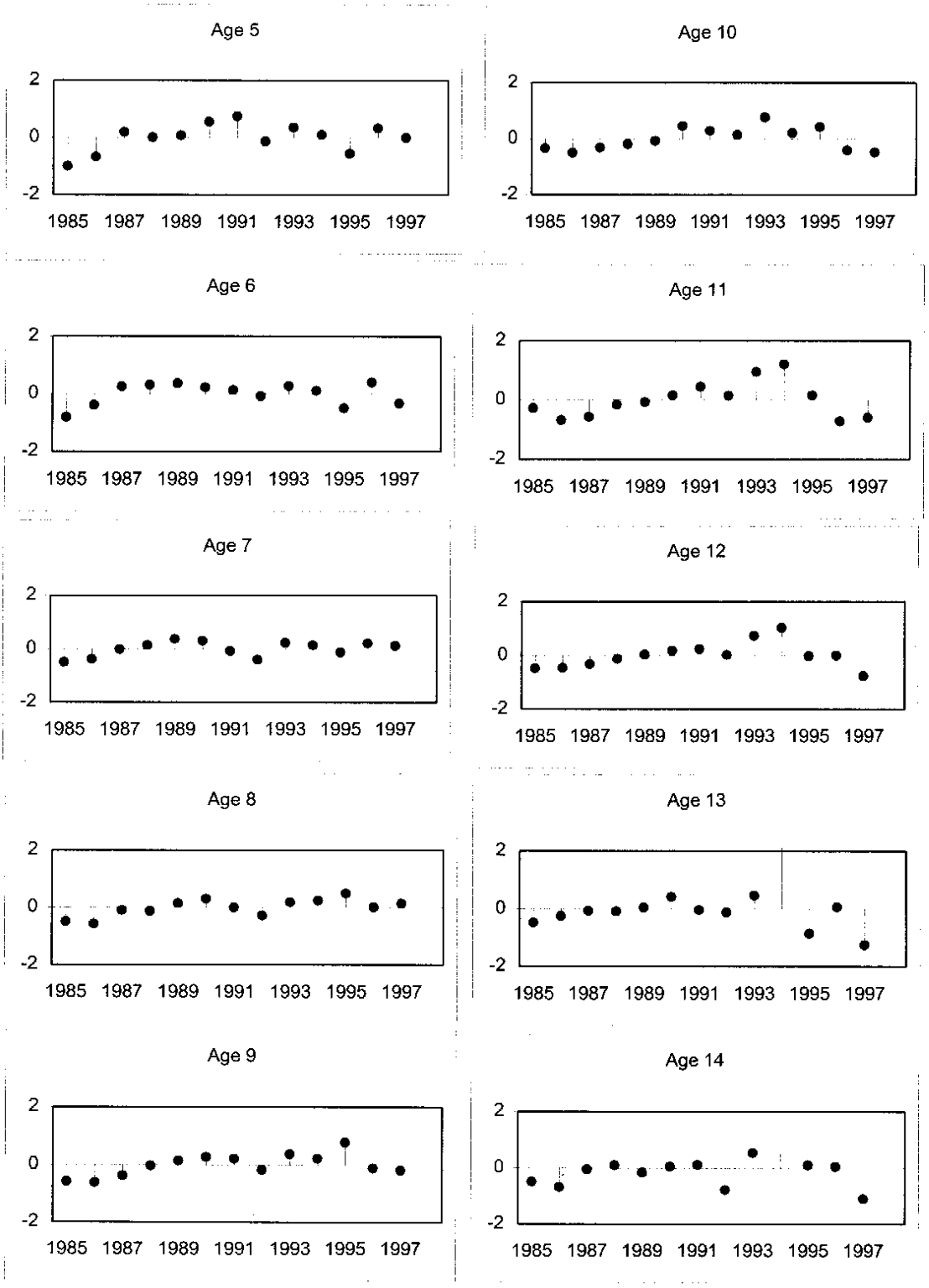

Fig. A 1.3 Age by age log residuals from Canadian spring surveys .

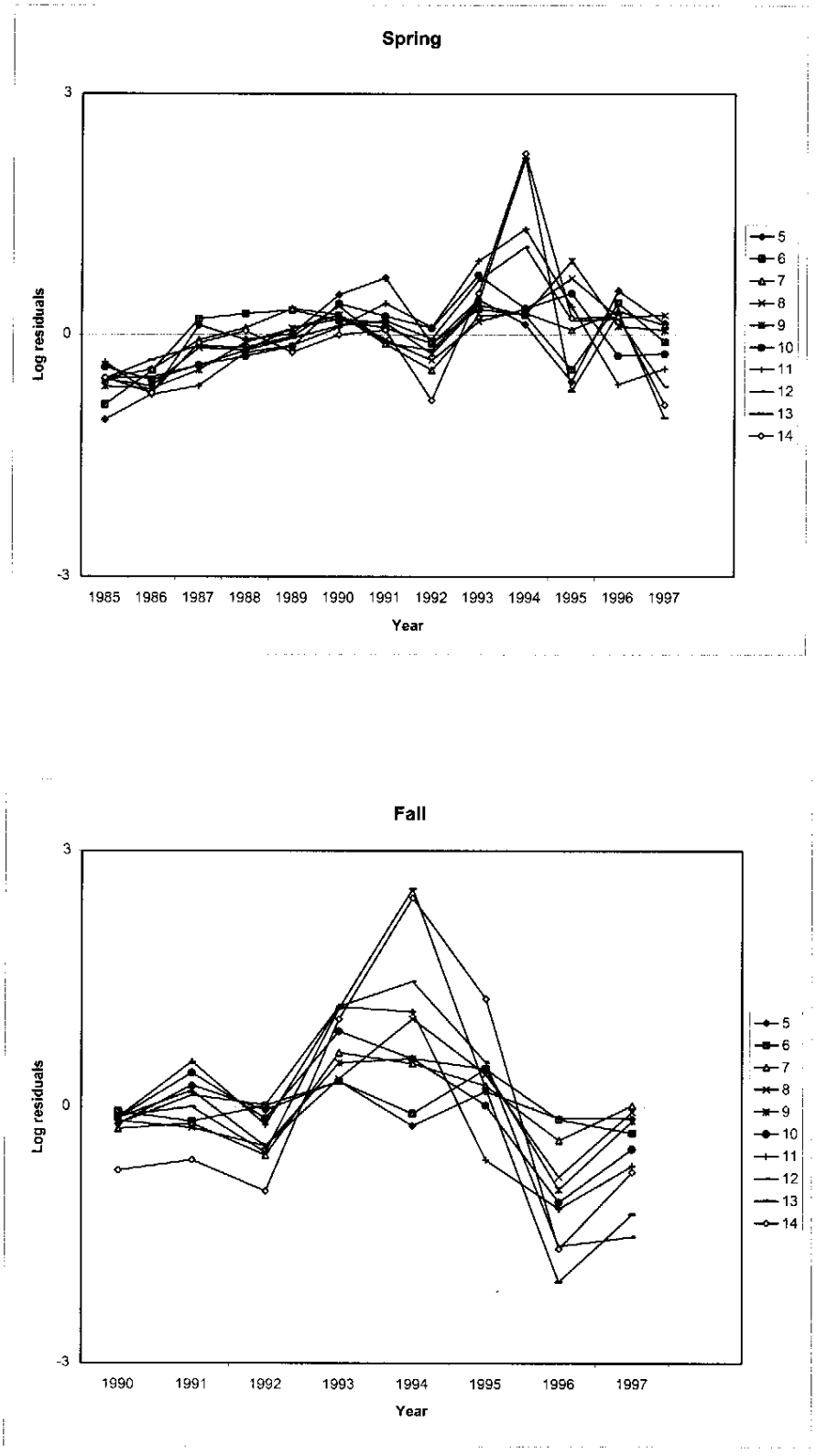

Fig. A 3.1 Log residuals from ADAPT for two Canadian research vessel surveys.

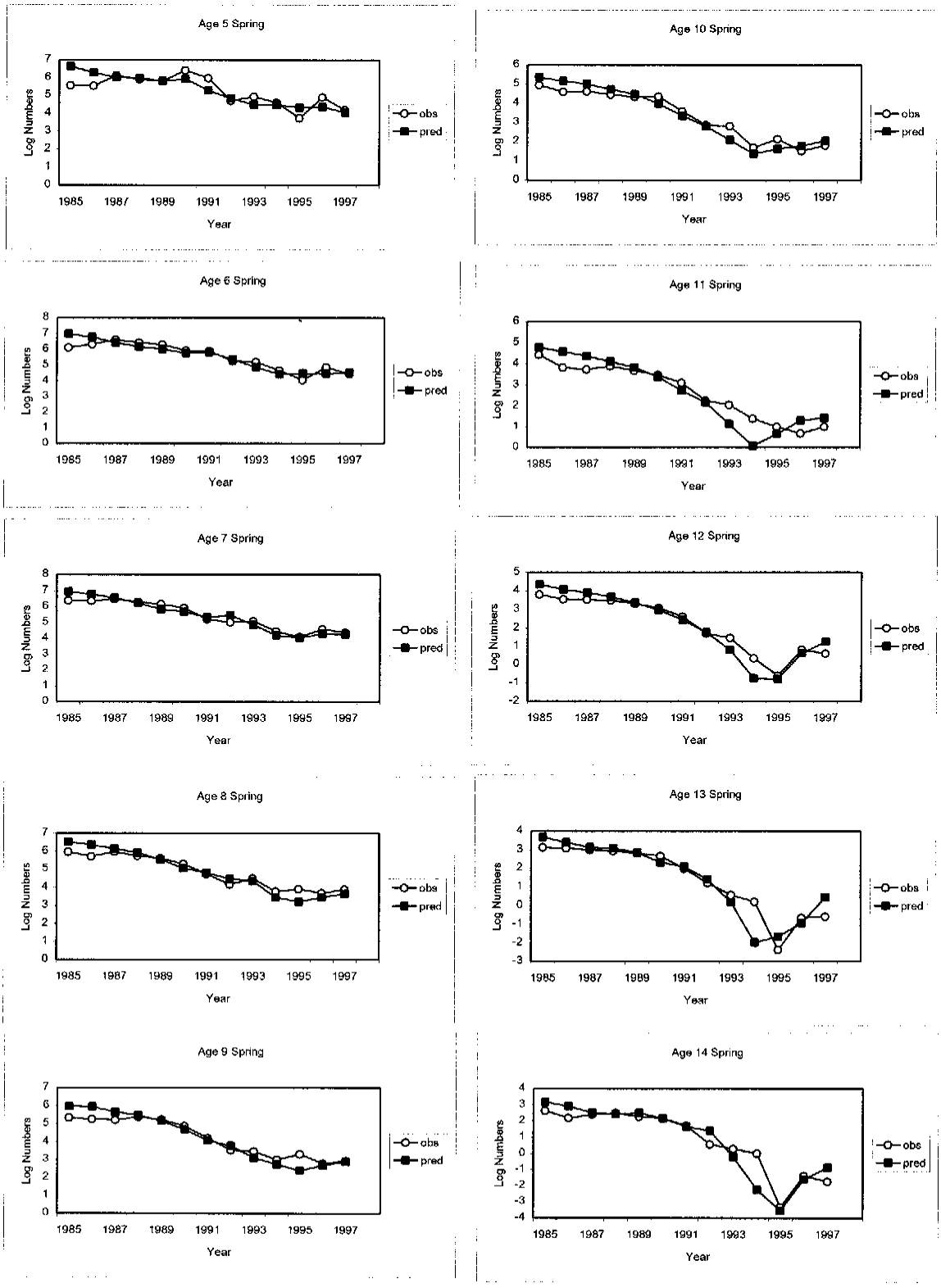

Fig. A 3.2 Age by age observed and predicted log abundance index over time from Canadian spring surveys for Am. plaice in NAFO Divisions 3LNO.

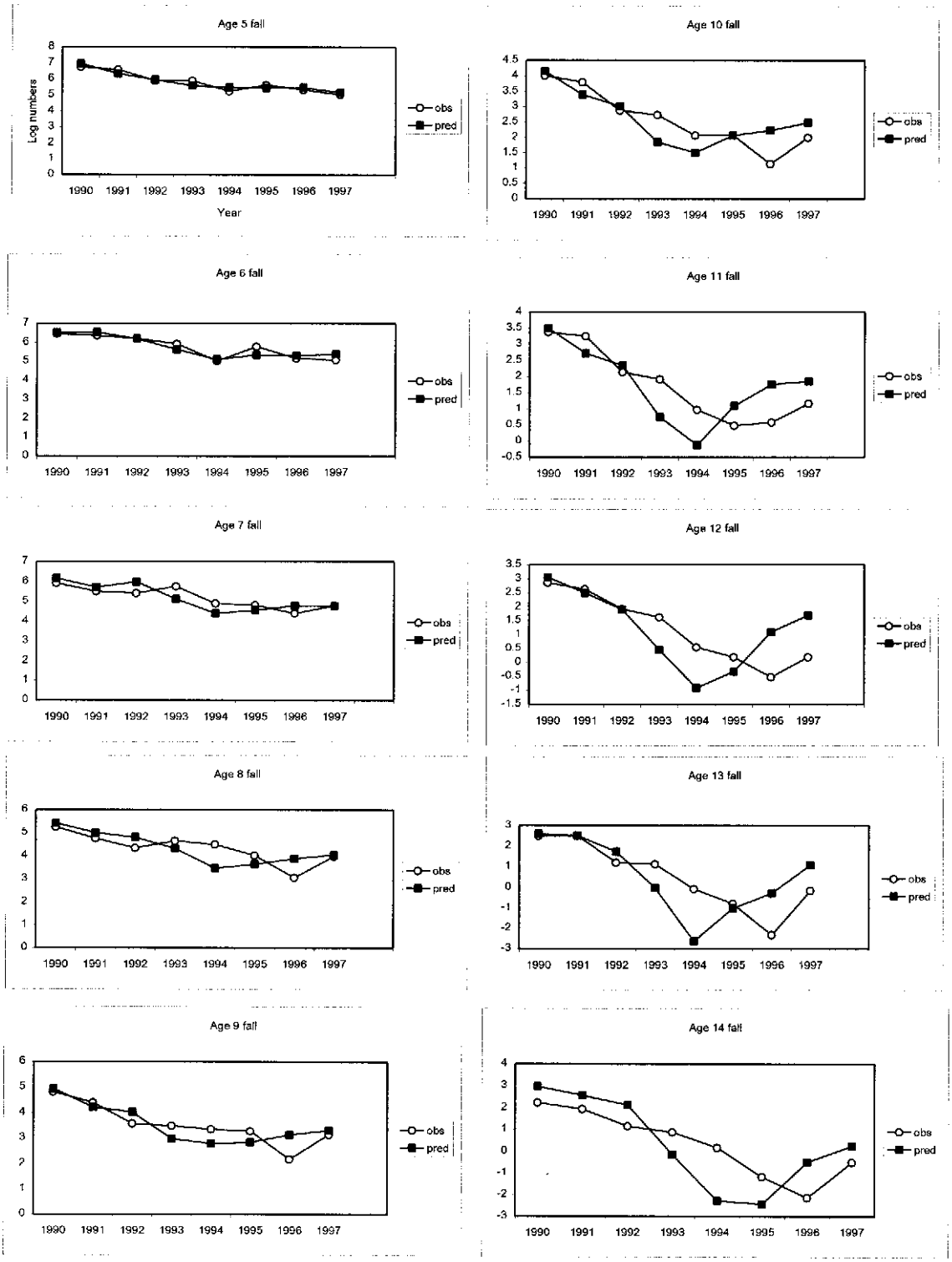

Fig. A 3.3 Age by age observed and predicted log abundance index over time from Canadian fall surveys for Am. plaice in NAFO Divisions 3LNO.

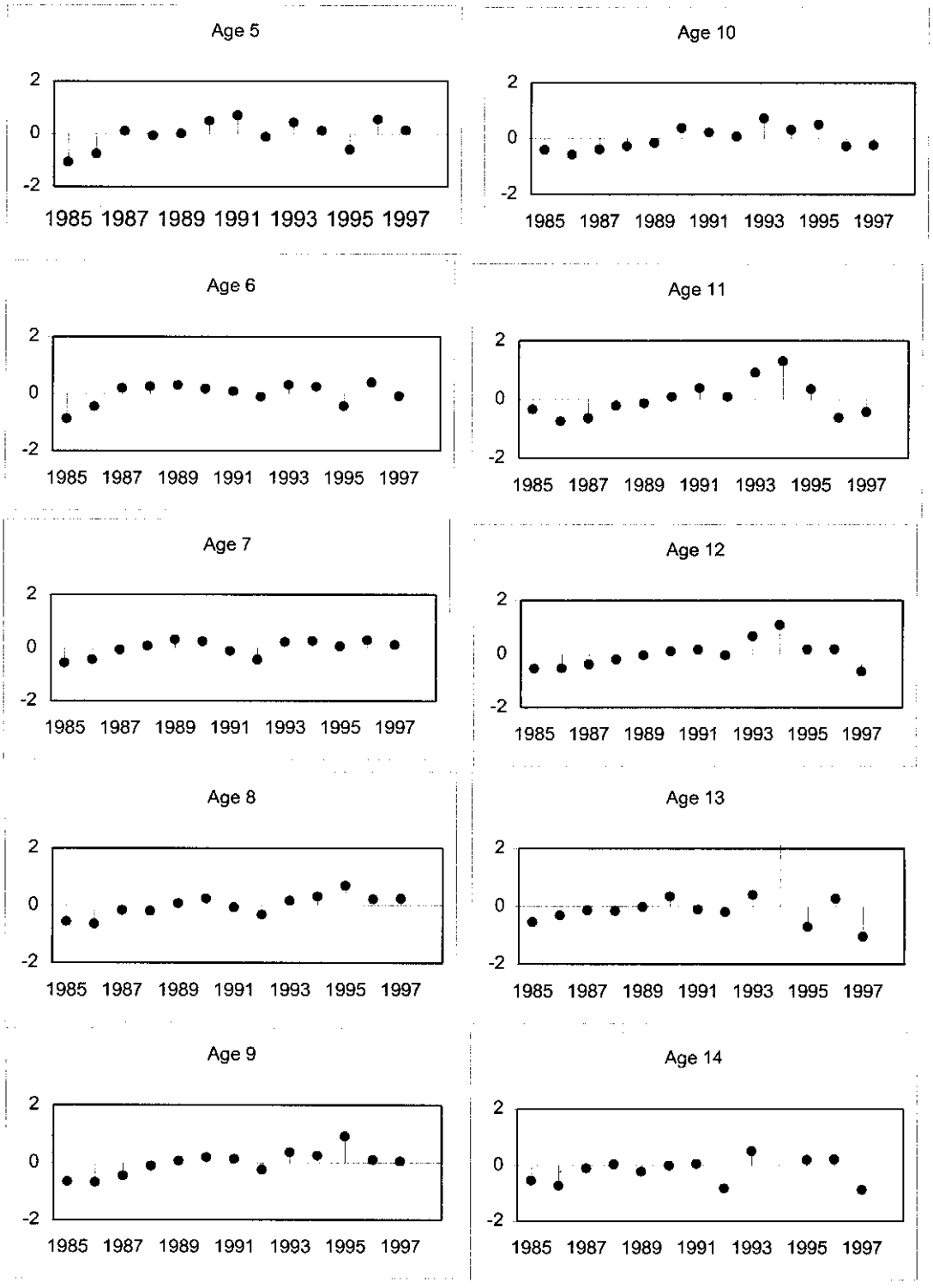

Fig. A.3.4 Age by age log residuals from Canadian spring surveys .

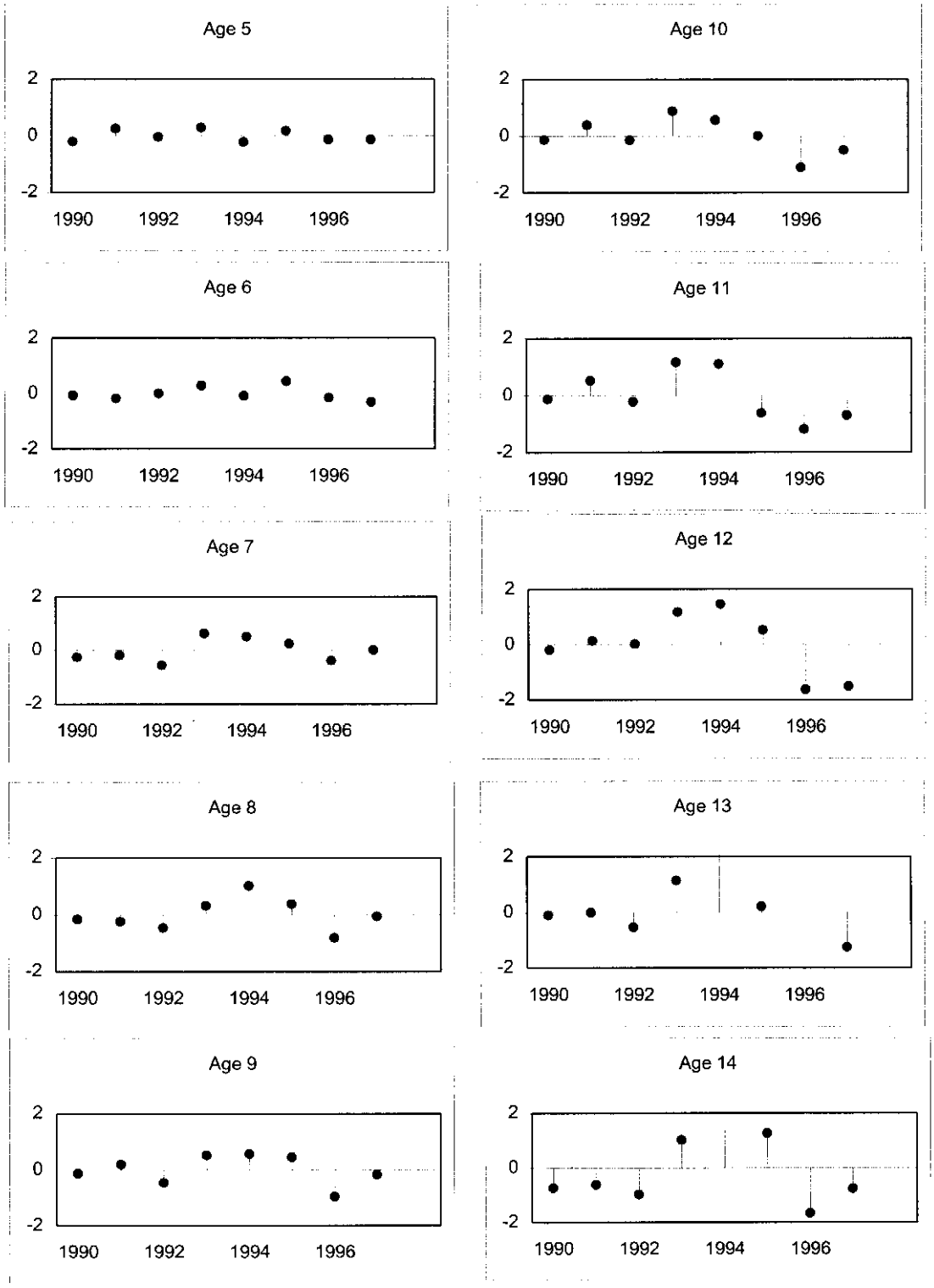

Fig. A 3.5 Age by age log residuals from Canadian fall surveys .

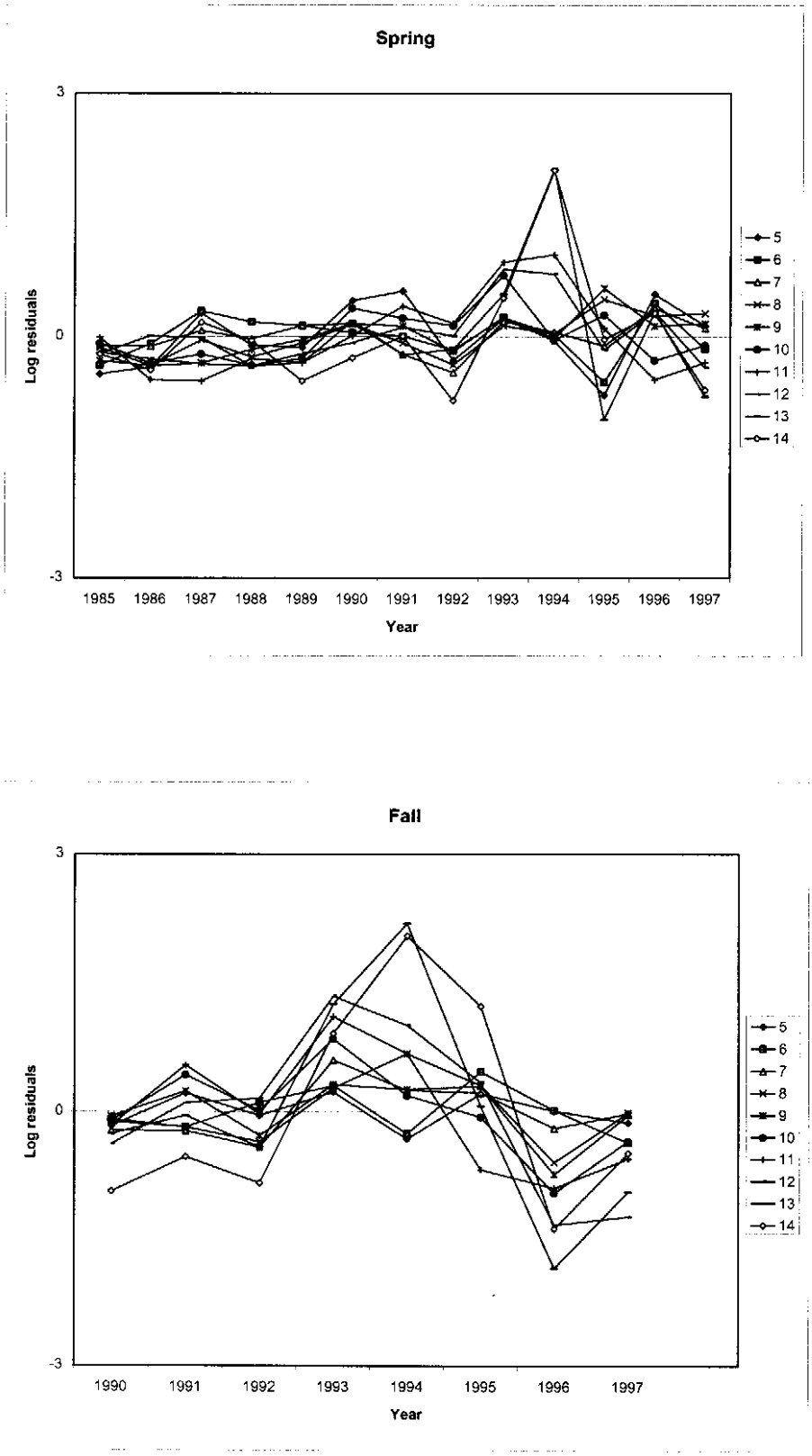

Fig. A 8.1 Log residuals from ADAPT for two Canadian research vessel surveys.

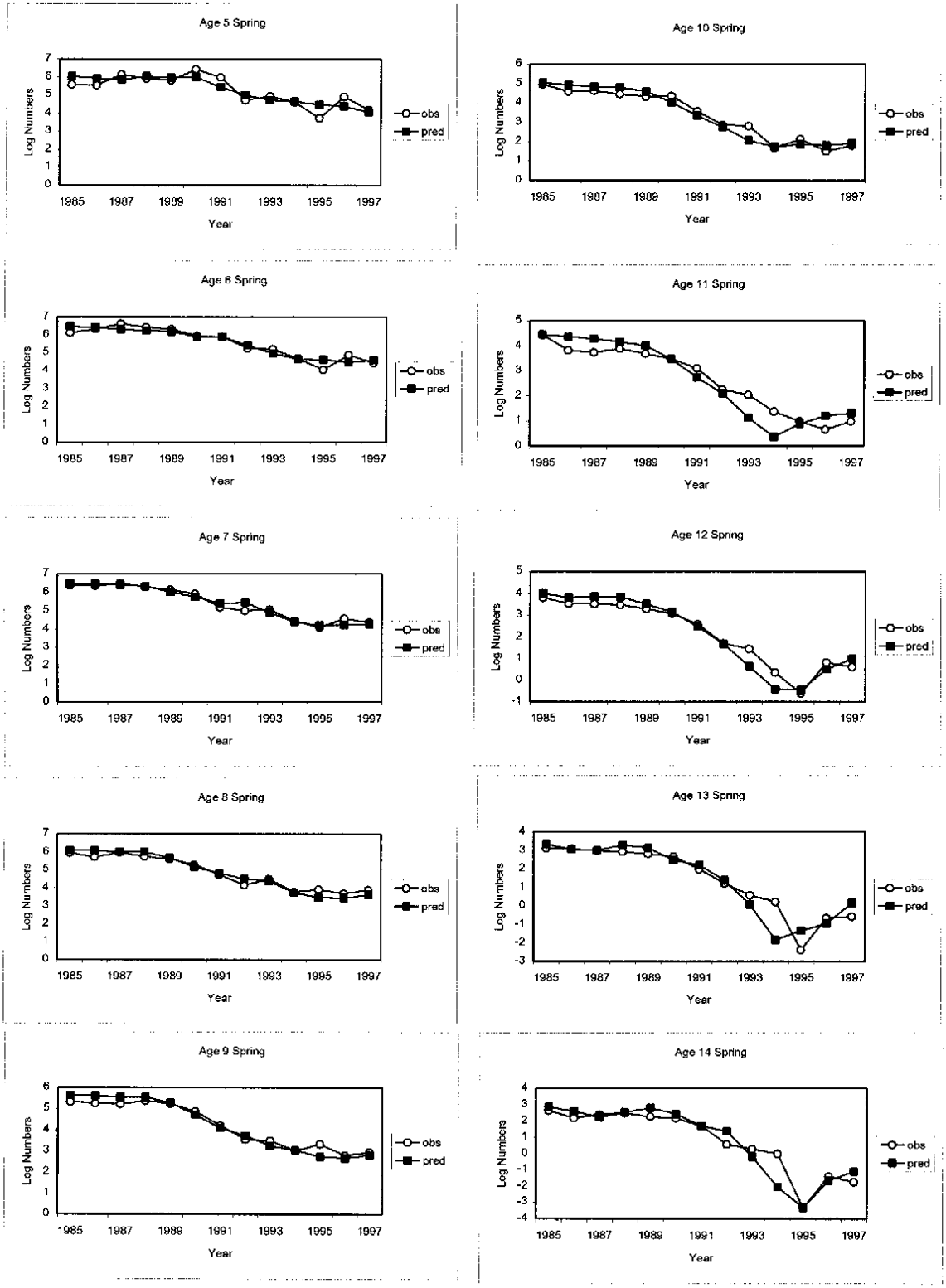

Fig. A 8.2 Age by age observed and predicted log abundance index over time from Canadian spring surveys for Am. plaice in NAFO Divisions 3LNO.

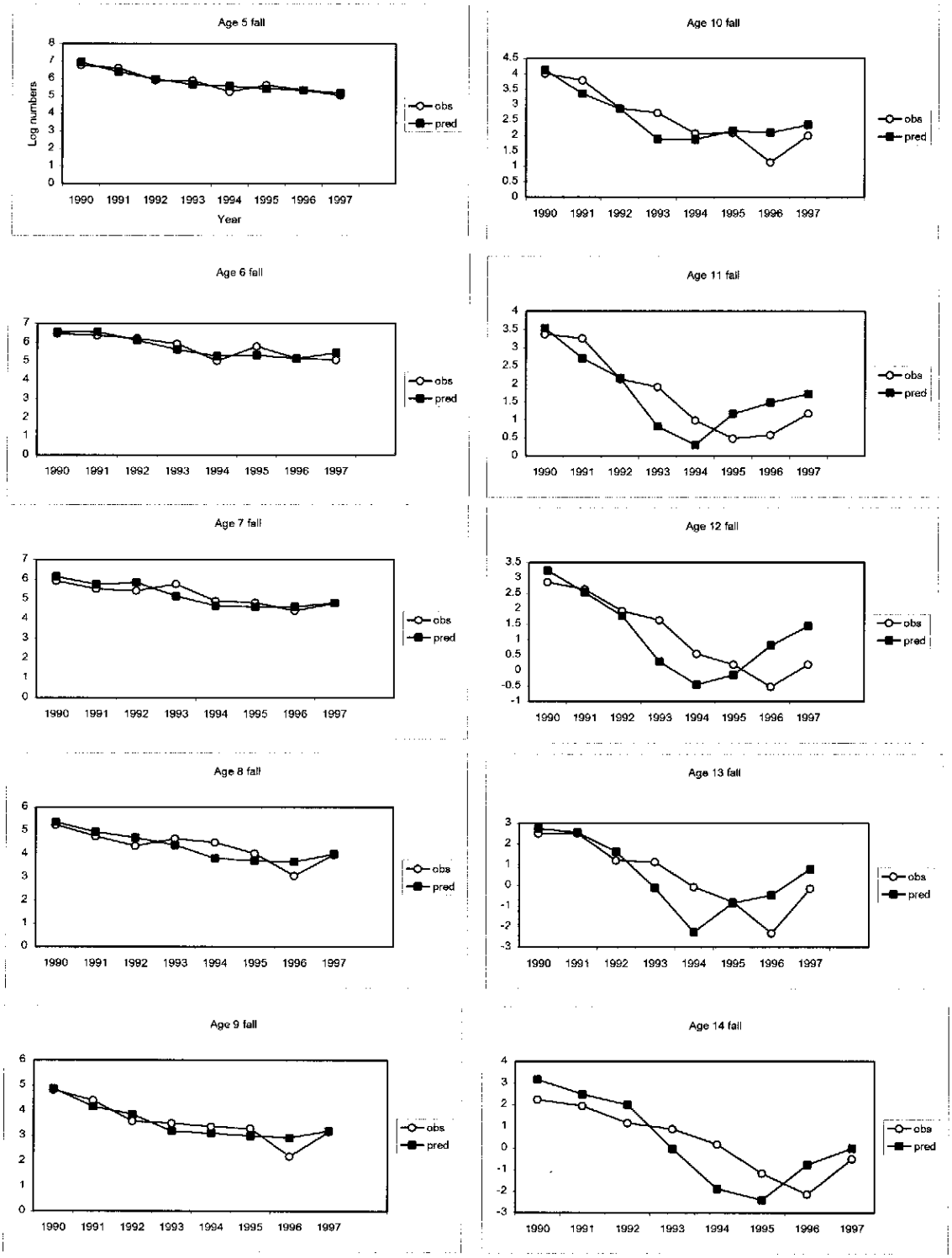

Fig. A 8.3 Age by age observed and predicted log abundance index over time from Canadian fall surveys for Am. plaice in NAFO Divisions 3LNO.

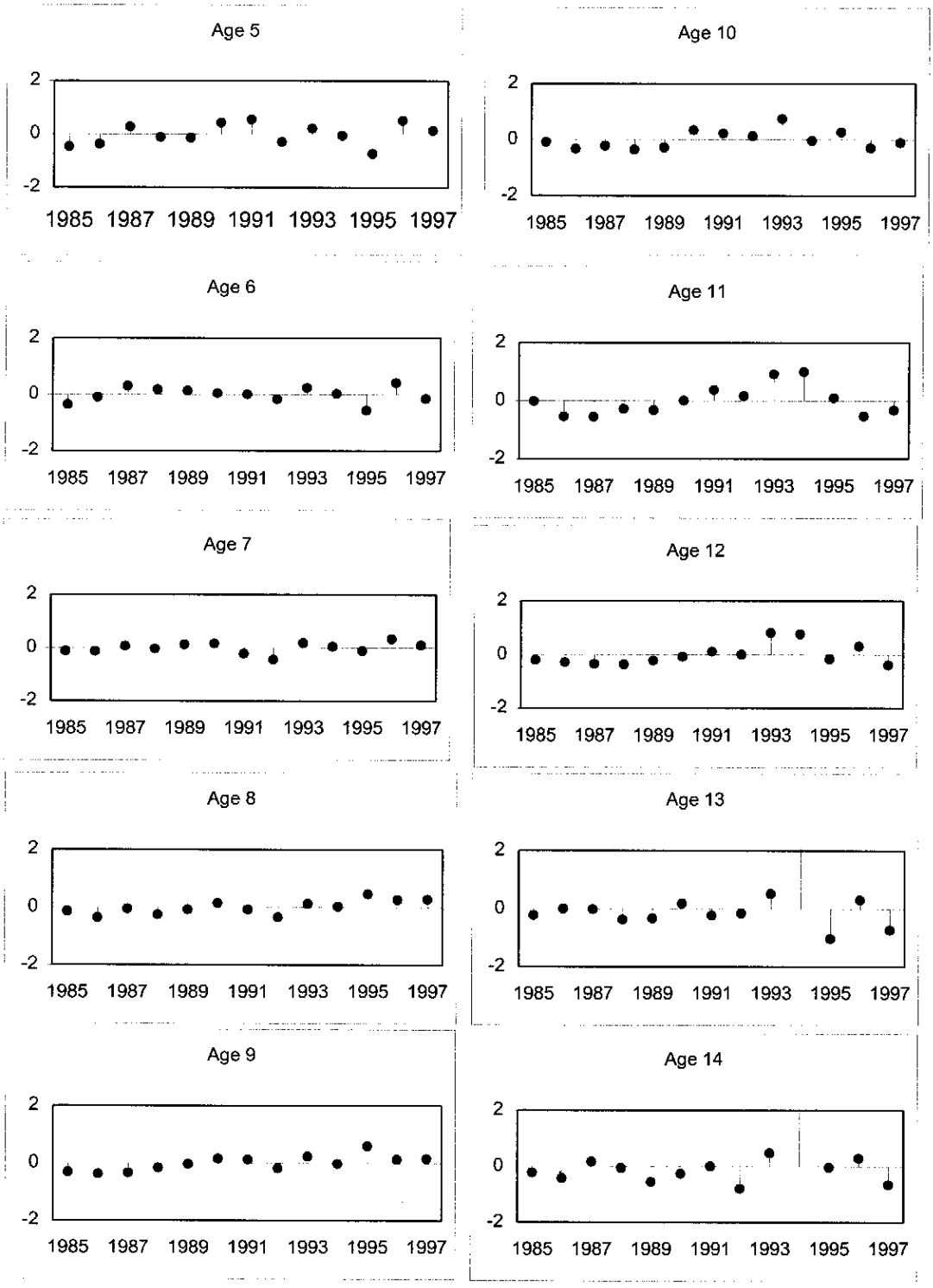

Fig. A 8.4 Age by age log residuals from Canadian spring surveys .

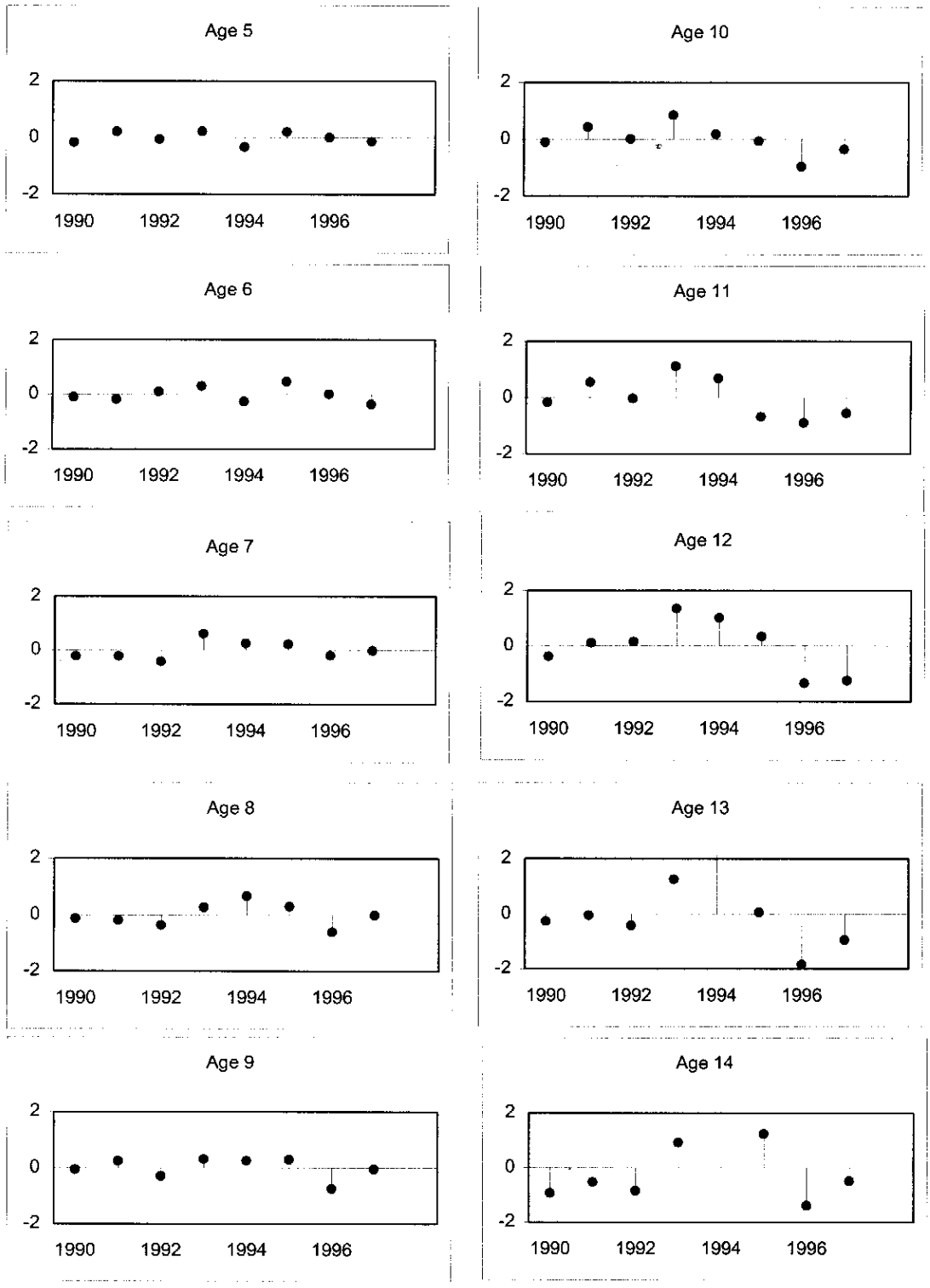

Fig. A 8.5 Age by age log residuals from Canadian fall surveys .

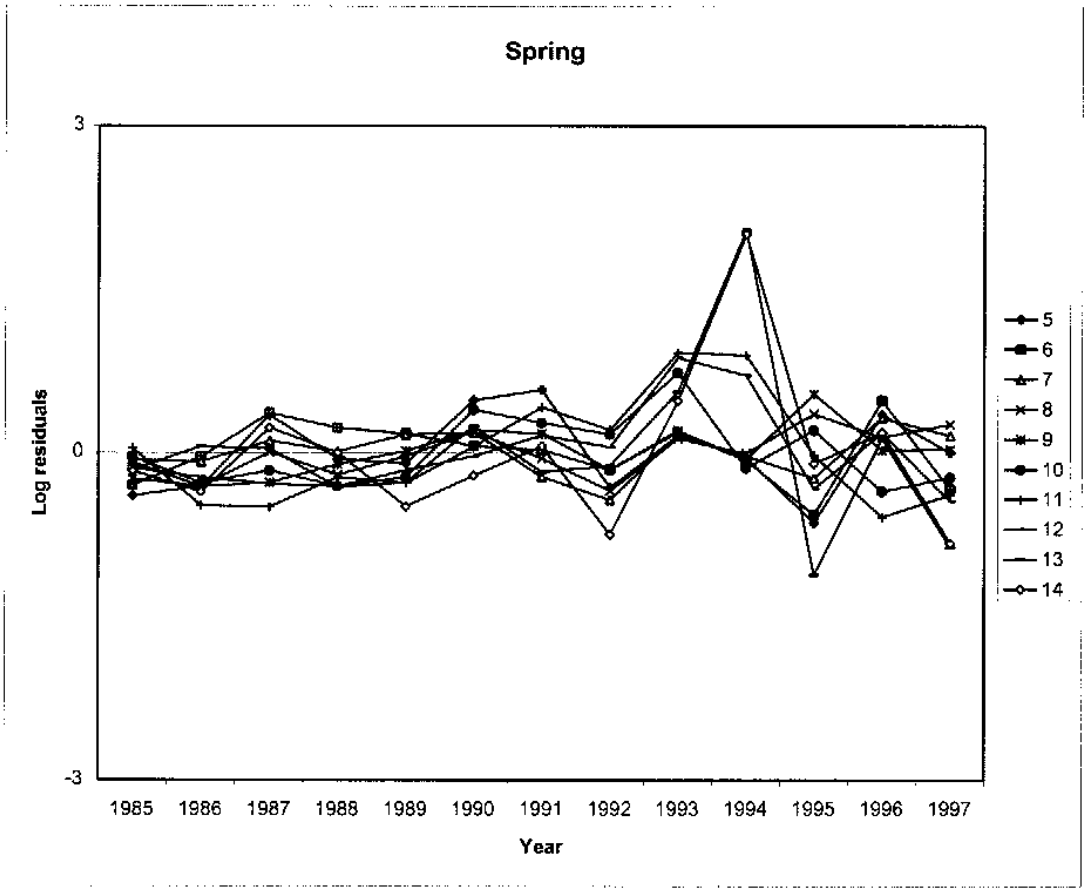

Fig. A 9.1 Log residuals from ADAPT for spring Canadian research vessel surveys.

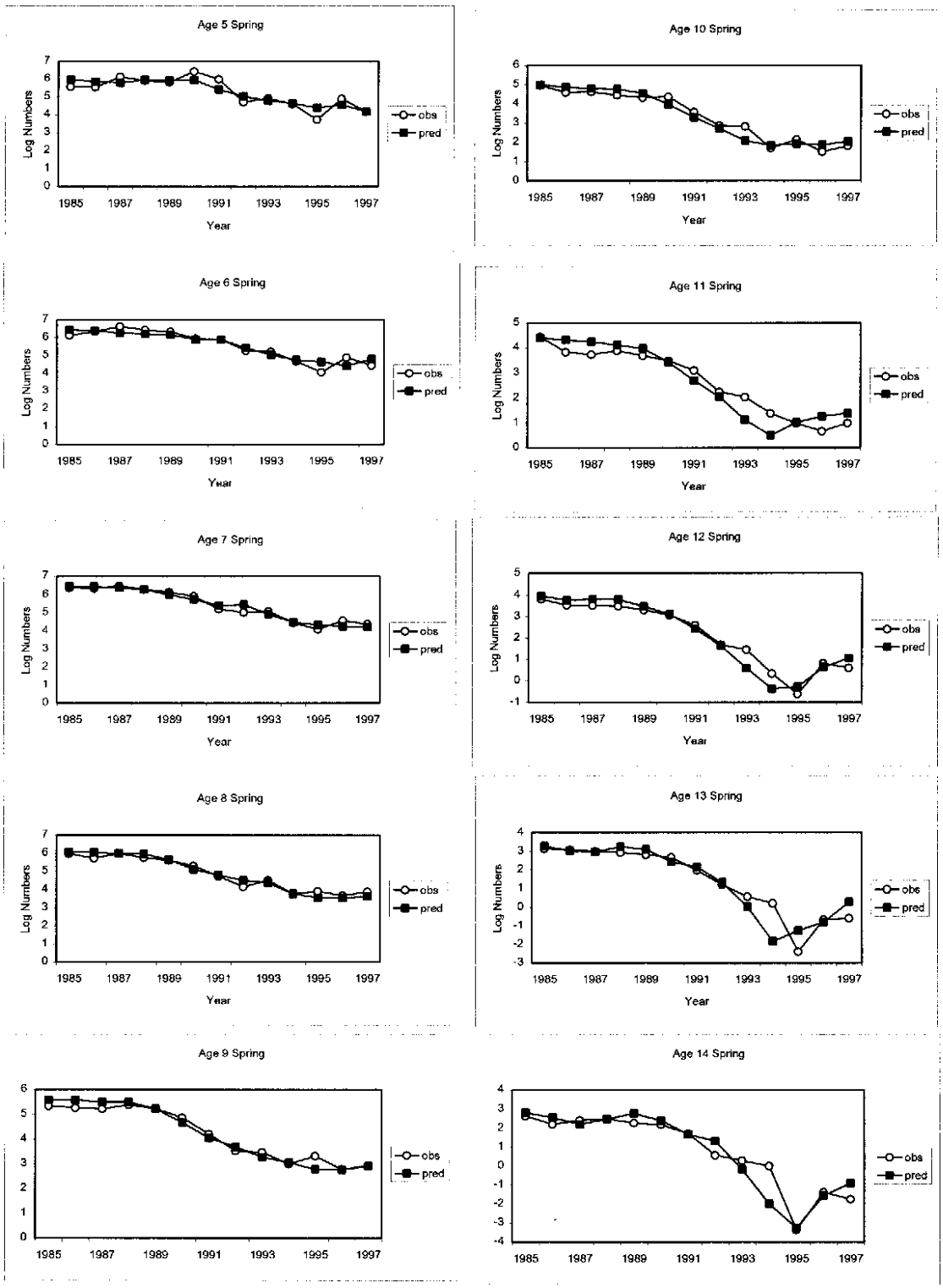

Fig. A 9.2 Age by age observed and predicted log abundance index over time from Canadian spring surveys for Am. plaice in NAFO Divisions 3LNO.

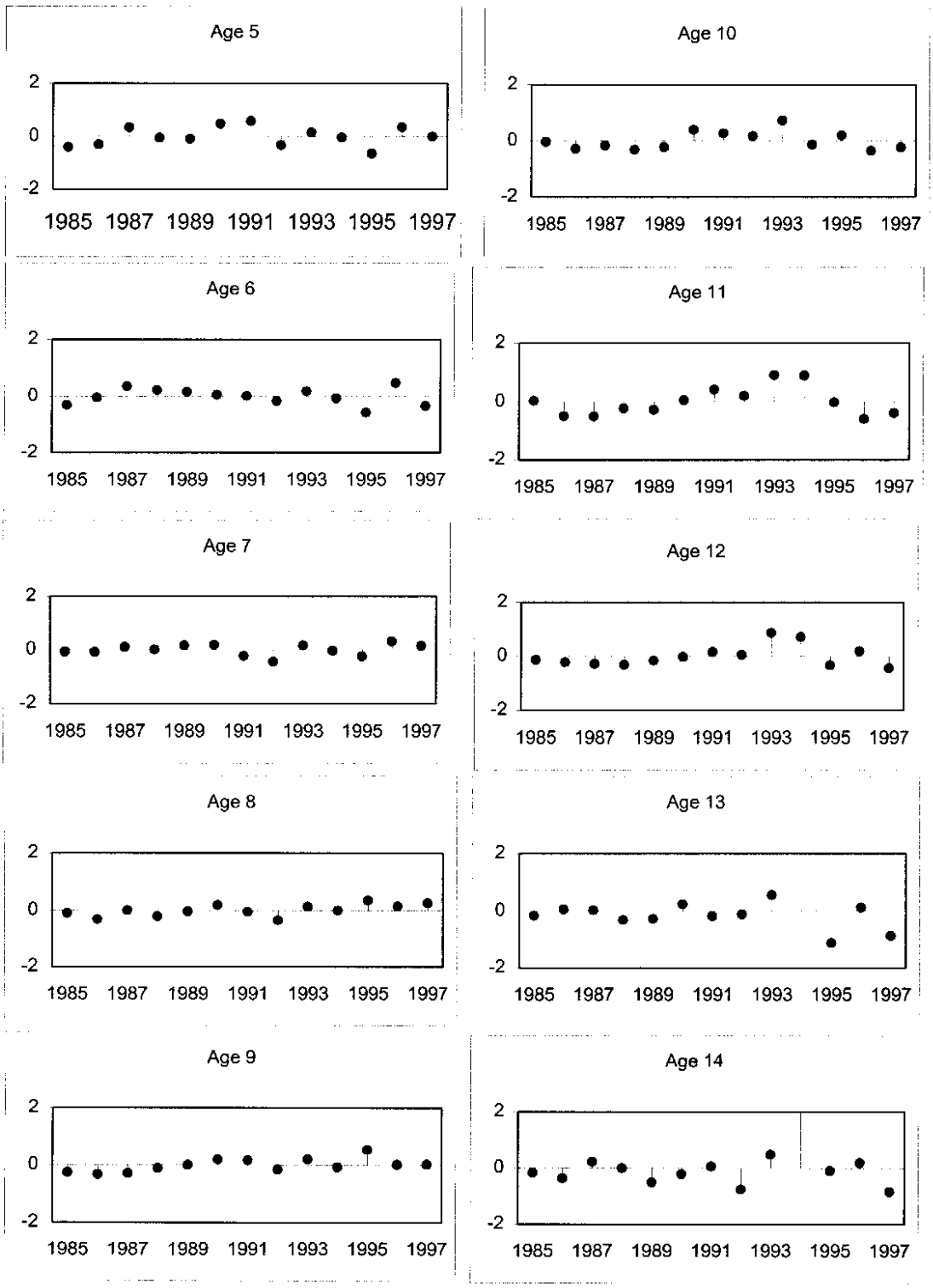

Fig. A 9.3 Age by age log residuals from Canadian spring surveys .