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Assessment of Status of 4Vn Cod (May – Oct.): 1997

by

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ABSTRACT

The 4Vn (May - Oct.) cod fishery has been closed since September 1993. Nevertheless, the stock shows little sign of recovery, largely due to lack of recruitment. About 45 tonnes of cod were taken commercially as bycatch in redfish, flatfish and halibut fisheries in both 1996 and 1997. The stock is monitored by annual DFO groundfish trawl surveys in July and in September of 1994-95 by an extension into 4Vn of the regular 4T groundfish survey. In addition, a "sentinel survey" employing commercial longliners, inaugurated in September 1994, has conducted July and September surveys on annual basis since. All these surveys gave a similar picture of the stock status. Until there is substantial recruitment, there are no prospects for a reopening of this fishery.

RÉSUMÉ

Bien que la pêche de la morue dans 4Vn (mai - oct.) ait été fermée depuis septembre 1993, le stock montre peu de signes de rétablissement, ce qu'on attribue principalement à la faiblesse du recrutement. Au cours de 1996 et de 1997, les prises accessoires de morue lors de la pêche commerciale du sébaste, de poissons plats et du flétan s'élevaient à 45 tonnes. En 1994 et en 1995, le MPO a suivi l'évolution du stock au moyen de relevés au chalut de fond, effectués en juillet et en septembre en élargissant simplement à la zone 4Vn le relevé habituel du poisson de fond de 4T. De plus, une pêche sentinelle utilisant des palangriers commerciaux a été instaurée en septembre 1994 et effectue des relevés tous les ans aux mois de juillet et de septembre. Tous ces relevés, renvoient une image similaire de l'état du stock. A moins d'un recrutement substantiel, rien ne permet d'envisager une réouverture prochaine de cette pêche.

INTRODUCTION

Cod landings in NAFO Subdivision 4Vn have declined since 1985 until the closure in 1993. Throughout most of the 80's catch quotas restrained the fishery, but after 1990 the catch was substantially less than the TAC. In September 1993 the cod fishery was closed and this moratorium is still in effect. In the few years prior to the closure, vessels using mobile gear generally managed to maintain a catch close to their allocation, whereas the longline fleet fared less well. Mixing of Gulf of St. Lawrence (4T) cod with the resident stock and the inability to accurately apportion landings according to stock has complicated the assessment and management of 4Vn cod. Prior to 1993 the fishery was defined for the months May – November, afterwards it was re-specified from May – October to more closely correspond to the migration of fish from the Gulf of St. Laurence.

4T cod overwinter along the shelf edge form Sydney Bight as far as Banquereau Bank, migrating out of the Gulf in the late autumn and returning in the spring. During this period the catch of cod in 4Vn comprised both Gulf and resident cod, although 4T made up the bulk, being a much larger stock. In the years preceding closure of the 4Vn fishery, the dragger fleet which had traditionally caught most of its catch between May and October, began to shift its activities more toward the autumn with the effect of increasing the proportion of 4T cod in its take. Thus the overall catch for 4Vn was maintained while the abundance of resident cod fell. After a review of tagging studies and patterns of movement of commercial fishing boats it was decided to change the management unit definition by reducing the May to December window to May to October.

At present, with no commercial fishery, information on stock status comes mainly from two sources. The DFO July groundfish survey and a "Sentinel" survey conducted by commercial longliners. These data are supplemented by a DFO inshore survey of the western part of Sydney Bight and from limited port sampling of commercial bycatch from flatfish, redfish and to a lesser extent halibut fisheries.

We present an analytical assessment for the first time since the late 1980's. While the degree of separation of 4Vn cod from its neighbours to the north-east (4T) and to the south (4VsW) is still a topic of research, the analysis was performed for two reasons. The first is the conservation principle; if to some degree 4Vn is a self-sustaining population, it is more precautionary to treat it as a separate entity than to merge it with larger neighbouring stocks. The second is scientific. The analysis of the cod stocks from say 4W to eastern 4T as a complex will require preliminary population analysis of the constituent, interacting units. In an effort to focus more closely on the resident stock, the catch at age matrix has been recalculated based on a May-October period for 1982 to 1997. This action assumes that the migration timing has not changed significantly over the period of analysis.

This assessment differs from earlier versions in that a new value for natural mortality, which has traditionally been 0.2 for all ages and years, has been changed to bring it into closer accord with the models have been adopted for 4VsW and 4X cod. The new assumed M is much larger than 0.2 and particularly affects recruitment estimates. A comparison of SPA results between the two modelled natural mortalities is included in Appendix A.

DATA

COMMERCIAL CATCH

For the past few years somewhat less than to 50 tonnes of cod has been taken in 4Vn as bycatch between May 1 and October 31 (Table 1, Figure 1). The bulk of this bycatch was taken along with redfish, flatfish and halibut. In 1997, Danish seiners and longliners caught about 20 tonnes each with stern draggers being responsible for the remainder (Table2). Most of the catch was taken in May (17 t) with 11 t during October and the remainder evenly distributed across the intervening months. About 5 t of the October cod catch was caught by longliners during a commercial phase of the 4Vn Sentinel Survey. In addition, there is a certain amount of unreported catch, some of which stems from charter boat operations which take people fishing for recreational purposes. These boats are required to adhere to marine safety regulations but do not require a fishing licence per se, thus it is difficult to quantify the amount of cod taken this way. However, these operations appear to be few and mainly in rural areas. Information from some involved in this business indicates no more than 5 t are caught legally (no more than 10 fish per person aboard a boat) but that perhaps as much as another 5 t is taken above the legal limit.

JULY GROUNDFISH SURVEY

The July survey for 4Vn is more variable than other stocks due to low numbers of sets and also no doubt due to high natural variability. Although the greatest mixing of stocks in 4Vn occurs in the winter, there appears to be a degree of mixing of cod stocks in this area during all months of the year. Although the index rose slightly in 1995, the downward trend that began in the late eighties continues, 30 per tow in 1996 and 24 per tow in 1997 (Table 3, Figure 2). The distribution of catch between strata in 1997 was much the same as in 1996. No cod were taken in the deepest stratum with values of 56 and 16 per tow being recorded for mid-depth and shallow strata, respectively. As is often the case in this survey, most of the catch was taken in two sets of 236 and 65 per tow, respectively; the remainder of the sets were all well below 20 per tow. The 1992, 1993 and 1994 year classes formed most of the catch with four year-olds being the most abundant. A higher than usual (for the 90's at least) number of one and two year-old fish have appeared in the last two years' surveys, but recruitment levels continue to be very low. The last good year-class seen in this survey was 1987.

INSHORE SURVEY

The inshore survey covers approximately the western third of Sydney Bight and includes an area to the south-west which is not surveyed by the larger July groundfish survey. The smaller survey samples one year-old fish well, whereas the larger groundfish survey, in 4Vn at least, does not (age one cod have been caught in only 6 of 28 years). In 1996, high numbers of age one cod were caught in the inshore survey over a much wider area than usual. However, in 1997, the

increase in two year-old cod that might have been expected from this year-class (1995) did not occur (Figure 3). The lack of change in numbers of age two fish from 1996 to 1997 was also evident in the July RV survey. The 1996 year-class appears to be the strongest in recent years.

Good concentrations of cod eggs and subsequently larvae were collected in this area during the spring of 1991 and 1992 in a since discontinued ichthyoplankton phase of the inshore survey. Also, ripe, spawning and spent cod have been prevalent in survey catches in May and June since 1991, thus it seems likely that production of progeny is normal. However, the same may not be true of subsequent survival through the juvenile stage based on indications of apparent high mortality of the 1995 year-class between ages one and two.

SENTINEL SURVEY

Recently, sentinel surveys have formed an adjunct to DFO groundfish surveys that have been carried out in this area during the past nearly three decades. The 4Vn Sentinel survey is conducted by commercial longliners and provides an index of abundance and detailed seasonal biological information on 4Vn cod and also monitors the migration of 4T cod in and out of 4Vn. The area is surveyed twice a year, in July and September, following a random design, stratified by depth, similar to that used by the July groundfish survey. The area surveyed by the sentinel survey is the similar to the DFO survey with the exception of there being no sets deeper than 100 fathoms and the stratification schemes being slightly different. The RV survey uses three strata: <50 fathom, 50-100 fathom, and >100 fathom. The sentinel also has three strata; however, the deep stratum was dropped, the mid-depth retained and the shallow stratum was divided in two: hence, <30 fathom, 30 to 50 fathom, and 51 to 100 fathom. The distribution of catch in September for 1997 is shown in Figure 4. The catch was fairly evenly distributed with somewhat higher concentrations in deeper water in the "Gutter" and Smokey Bank toward the north of the area and Scaterie Bank to the south. The September index in 1997 (Figure 5), although similar to 1996, continued to fall. From a high of 110 kg/1000 hooks in 1994, the catch rate has now fallen to about 70 kg/1000 hooks. The July index approximated that of September in 1997 and did not display the strong seasonal effect of the past two years when July catch rates were less than a quarter of the autumn levels. The reason for this is not clear.

Although cod dominates catches in July and September, 1997, dogfish plaice and skate are also prevalent in both months. Dogfish are particularly abundant in July, occurring in numbers close to that of cod with plaice and thorny skate ranking third and fourth, respectively. The numbers of dogfish drop in September, whereas plaice and skate increase.

In 1997, the boat monitoring the movement of cod out of the Gulf experienced the lowest catch rates in four years. This survey operates from the middle of October to the end of November. As in other years extremely high numbers of dogfish were encountered. On one trip, dogfish were taken from over 90% of the hooks. The 4Vn Sentinel Fishery Association (4VnSFA) obtained some of the available quota allowed for fishing of the 4TVn stock in the area, approximately 6 tons. This was used for a commercial phase, additional to normal survey operations. A percentage of proceeds from sale of fish is returned to the 4VnSFA in return for the right to fish a proportion of the Association's quota. Half of the boats engaged in this operation abandoned

fishing before attaining their quota due to poor catch rates. This would indicate that not only are 4Vn cod scarce but that 4T fish which would normally be entering the area around this time are also scarce or moved in a different route, perhaps well offshore, in deep water out of the reach of longline gear.

ANALYSIS

i) Total mortality from survey data

As well as indices of abundance, surveys may be used to directly estimate the survivorship and hence the total mortality rate, Z. Only the summer survey series was used for this analysis because of its longer history. The data were combined into three year age blocks to help smooth the Z estimates. Because the catchablility of the gear has not been corrected for, especially for the youngest age series, these estimates are only relative. The results were also smoothed with a 3 year moving average. The results for ages 2-4, 5-7 and 8-10 are shown in Figure 6. It is important to note that the closure in 1993 has had little effect on survivorship as estimated form the survey data.

ii) Sequential population analysis

A standard age-based population analysis (SPA) was used to estimate the current status of the stock. This analysis assumes that the stock is closed. As 4Vn is a known area of stock mixing, the degree to which the area contains cod from other stocks will bias the results. To minimise this effect, the catch at age has been reconstructed to the May to October period for the years 1982 - 1997 (Table 4).

The age-based sequential population analysis was performed for this stock using ACON software to fit the model which is described as:

Parameters:

Log survivors - $\ln(N_{i,1997})$ i = 3 to10
Calibration coefficients - q_i, i = 3 to10 for July RV survey
(estimated algebraically)

Structure Imposed:

Error in catch assumed negligible

Partial recruitment fixed for ages 11-15 in terminal year.

F on oldest age (15) set to the average F ages 8,9 &10
No intercept was fitted
M = 0.2 for all ages in 1981-1984, then linear ramp from 0.4-0.8 over 1985-97

Input:

$C_{i,t}$, i = 1 to 15; t = 1981 to 1997 (May to October catch at age)
$J_{i,t}$, i = 4 to 10; t = 1985 to 1997 (July RV index)

Objective function:

Minimise: $\Sigma \Sigma \{\ln J_{i,t} - \ln(q_i N_{i,t})\}^2$

Summary

Number of observations: 104 from July RV
Number of parameters: 16; 8 estimated by NLLS, 8 algebraically

RESULTS

This stock has not been analytically assessed since the late 1980s. This was mainly due to the problems of stock definition and the noisiness of the summer RV survey in 4Vn. With more data available, we have tried an SPA and the results, although not as good as one would want or indeed as seen with other Scotian Shelf groundfish stocks, did provide a useful synthesis of the data. The results are fairly clear and agree with the raw survey data.

SPA

The diagnostic statistics and residuals from the SPA are given in Table 5. The fit was poor compared to other groundfish assessments. This is in part due to the fewer samples causing more noise in the index and probably also a result of the migration to and from the larger neighbouring stocks. The residuals from the NLLS (Table 5b) instead of being random, show a tendency to have columns all of one sign (Figure 7), which is consistent with a 'year effect' in the RV data. A conditioned bootstrap analysis of the SPA including bias is given in Table 5c. Figure 8 shows age aggregated data and estimated population size over the ages fit in the SPA. Three indices of population size are shown in Figure 8. The solid line is 'aged' ahead to match the timing of the survey and is what the model actually fits. Also for reference are the first of year numbers before and after bias correction.

Results after bias correction are provided in Tables 6 to 8 and Figs 9 to 12. Figure 9 shows a loss of biomass since 1986.with the current biomass almost one tenth of that peak. The exploitation rate(Figure 10) varies around 20% in the 1990s then falls to almost zero with the fishery closure in 1993. The recruits (age 3) in Figure 11 show a recovery after the 1990 year-class. Figure 12 is a stock-recruit relationship and suggests that the recruitment is not strongly dependent on spawning stock biomass. A retrospective analysis is given in Figure 13 for average F (3-10) and total biomass (3-10). Although divergence is seen this would not considered to be a bad retrospective pattern.

Further, some results of predictive and risk analyses are provided. Figure 14 shows the response of the SSB and fishing mortality as a function of yield. Yield per recruit analysis were not carried out because of the unstable natural mortality. Instead a target F of 0.2 is shown for illustration as well as the yield which produced no change in biomass for 1998. Both of the implied yields are near 700 tons; a yield which is not to be treated as a recommendation.

Risk plots are provided in Figure 15 which show that there is a probability greater than 0.5 of the biomass falling for any level of harvest. Another representation of risk is shown in Figure 16. The SSB and average F (7-9) are plotted for each year in the SPA. The irregular contours associated with the recent years are the contours of the 50% most probable regions as defined by bootstrap analysis. Similarly bootstrapped stock projections at yield of 700 t are shown for 1998

and 2000. The location of the mean for each point is marked by the year. The lower left corners of the numbers are the means of each distribution, which do not fall in the middle contours because of the distributions of the unseen tails.

In this assessment natural mortality was set as a ramp from 0.4 to 0.8 over the period 1985 to 1997 over all ages (1-15). This model of M was chosen because of the high total mortality seen in the summer RV survey and because a high mortality used in the analysis of the larger, neighbouring 4VsW and 4T stocks. In 4VsW the natural mortality was modelled with explicit predation of seals which while increasing over time did not affect the older cod. Appendix A compares the principal SPA outputs of the currently assumed natural mortality model to the previously used M= 0.2 for all years and ages. The biomass comparison (Figure A1, top panel) show a similar pattern with the M=0.2 results falling much lower but have a slight recent recovery. The average F over ages 7-9 are again similar patterns with the M= 0.2 peaking much higher in 1992. The recruitment series is most sensitive to the natural morality in terms of magnitude but shows a generally similar decrease until the early 90s and then a degree of recovery. Figure A2 shows the stock-recruit relationship for M=0.2 which may be compared to Figure 12. Figure A2 has a trend toward the origin suggesting a strong dependence on SSB. Figure 12 has more fluctuations about a mean with less of a dependence on SSB. Which of these is the more correct will have implications on the expected rate of recovery.

CONCLUSIONS

The status of this stock remains unchanged. Spawning stock biomass remains at a low level, and has not recovered since the closure in 1993. The 4 indices of recruitment (Figure 3) and the SPA results, suggest that year-class strengths have been slowly improving since the weak 1990-92 year-classes. However, the benefits of this improving trend have not appeared in the spawning stock. When considered with the high total mortality implied by the summer survey, the poor recruitment of the spawning biomass is consistent. Any increase in population biomass at this time would probably be a result of growth since a decrease in population numbers is indicated. As has been said before for this stock and others in the area, there can be no thought of reopening the fishery until substantial recruitment occurs.

Table 1. Nominal catch (tonnes) of 4Vn cod (May to December) by gear type.

YEAR	OTTER TRAWL	SEINE	LONGLINE	HANDLINE	MISC.	TOTAL	TAC
1970	4,859	83	3,229	495	1,222	9,888	
1971	5,308	109	3,728	696	790	10,631	
1972	4,418	121	3,185	286	1,094	9,104	
1973	2,099	143	1,982	404	1,120	5,748	
1974	2,842	138	1,469	568	967	5,984	10,000
1975	1,851	100	875	360	812	3,998	10,000
1976	4,375	83	620	310	569	5,957	10,000
1977	4,613	554	1,805	595	354	7,921	3,500
1978	1,600	326	3,035	466	122	5,549	3,500
1979	624	278	4,483	640	349	6,374	3,400
1980	1,150	561	6,440	1,820	219	10,190	5,000
1981	1,488	557	9,801	741	61	12,648	10,000
1982	2,785	724	7,287	1,360	177	12,333	14,000
1983	2,448	863	5,101	924	26	9,362	14,000
1984	3,344	1,112	4,831	1,112	45	10,444	14,000
1985	5,081	1,162	4,823	1,408	20	12,494	12,000
1986	3,552	1,258	5,764	1,182	15	11,771	12,000
1987	2,034	1,285	6,369	848	16	10,552	9,000
1988	1,377	1,109	5,858	626	31	9,001	7,500
1989	2,129	851	3,610	718	157	7,465	7,500
1990	2,029	593	1,889	591	8	5,110	7,500
1991	2,213	694	1,249	389	49	4,602	10,000
1992	2,629	468	1,043	232	88	4,461	10,000
1993	138	60	406	77	21	702	1,800
1994*	26	16	4	8	<1	54	
1995*	15	16	8	<1	<1	40	
1996*	20	16	8	<1	<1	46	
1997*	1	20	23			44	

* Redefinition of assessment period: Summed over six months (May to October)

Table 2. Monthly commercial catch (t) of cod in 4Vn by gear and tonnage class in 1997.

Mobile	May	June	July	August	Sept.	October	Total
OTB1			0.156				
OTB2		0.040	0.056		0.005		
OTB3	0.326		0.094	0.024	0.029		
OTB5			0.282				
	0.326	**0.040**	**0.588**	**0.024**	**0.034**		**1.012**
DS1	5.028	0.499	0.124	0.124	0.128	0.009	
DS2	10.860	2.228	0.246	0.246	0.015	0.160	
	15.888	**2.727**	**0.370**	**0.370**	**0.143**	**0.169**	**19.518**
SS	**0.230**		**0.170**				**0.410**
Fixed							
LL1	0.063	1.069	0.932	1.788	3.307	4.924	
LL2	0.014	1.145	2.153	0.590	0.758	6.128	
	0.077	**2.214**	**3.085**	**2.378**	**4.065**	**11.052**	**22.871**
Total	**16.521**	**4.981**	**4.222**	**2.623**	**4.242**	**11.221**	**43.811**

OTB = Otter trawl (stern) DS = Danish Seine SS = Scottish Seine LL = Longline
1 = 0 – 25 t, 2 = 25-50 t, 3 = 50 – 150 t, 5 = 500 – 1000 t.

Table 3. Research survey numbers per standard tow and total over ages 1 to 12.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6.35	1.17	0.52	0.00	0.00	0.61	6.49	0.25	0.66	1.30
3	1.77	42.40	0.28	2.62	0.61	6.42	2.25	6.26	9.13	0.79
4	4.78	10.09	2.35	4.48	1.36	8.58	1.48	4.01	19.31	5.15
5	10.90	26.51	0.30	18.59	2.79	4.65	1.93	2.74	5.54	2.51
6	10.46	16.16	1.61	0.73	3.21	0.81	1.55	1.90	4.38	0.59
7	4.50	10.65	1.47	3.06	0.40	1.00	0.73	0.72	1.53	1.72
8	2.59	3.59	0.39	2.91	0.50	0.58	1.79	0.21	1.17	0.56
9	0.84	1.97	0.27	0.46	0.26	0.21	1.65	0.24	0.44	0.29
10	0.00	0.54	0.25	0.22	0.22	0.33	1.41	0.14	0.43	0.15
11	0.29	0.00	0.19	0.00	0.11	0.00	0.24	0.21	0.00	0.00
12	0.14	0.00	0.00	0.00	0.00	0.11	0.23	0.24	0.00	0.17
Sum 1-12	42.62	113.08	7.63	33.07	9.46	23.30	19.75	16.92	42.59	13.23

Age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0.00	0.33	0.00	0.00	2.83	0.00	0.00	0.00	0.61	0.00
2	1.88	4.36	2.53	4.37	7.25	0.48	1.33	0.21	0.55	4.60
3	10.52	16.91	1.74	22.11	10.02	3.75	6.36	3.70	2.49	4.39
4	3.97	36.48	5.77	7.90	10.48	19.10	11.13	4.14	17.05	11.60
5	23.58	12.02	10.22	10.64	13.51	125.95	8.11	5.13	13.18	29.76
6	16.40	25.45	7.61	10.04	8.75	52.13	17.55	8.89	31.89	17.64
7	5.15	11.50	9.25	1.70	3.58	22.38	6.38	6.63	26.45	32.08
8	1.16	1.26	3.41	3.41	1.81	7.26	4.92	2.80	18.93	25.53
9	0.45	0.93	1.32	1.52	1.58	1.44	2.17	1.18	6.24	8.25
10	0.37	0.86	0.45	0.66	0.85	0.77	1.02	0.62	1.70	1.30
11	0.37	0.24	0.10	0.25	0.32	0.67	0.55	0.97	0.50	0.33
12	0.00	0.16	0.23	0.00	0.41	0.00	0.10	0.31	0.24	0.00
Sum 1-12	63.85	110.50	42.63	62.60	61.39	233.93	59.62	34.58	119.83	135.48

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	0.00	0.27	0.00	0.00	0.00	0.00	0.91	0.54	0.21
2	0.24	1.00	0.66	0.40	0.08	1.13	1.66	1.86	1.54
3	15.07	0.05	3.44	3.18	1.57	4.47	4.00	5.44	3.48
4	9.03	11.10	5.13	6.18	3.87	7.93	7.82	8.67	3.17
5	3.29	5.34	44.36	5.70	7.22	7.89	5.39	2.56	3.35
6	3.87	3.21	15.15	14.67	1.66	6.18	2.75	1.82	1.72
7	2.05	0.74	4.88	7.36	7.28	2.93	3.49	1.61	0.59
8	2.29	0.70	3.66	1.74	1.88	3.64	1.87	0.55	0.54
9	0.73	0.14	1.31	0.50	0.08	0.94	1.53	0.06	0.52
10	0.81	0.30	0.82	0.05	0.34	0.10	0.87	0.34	0.12
11	0.13	0.30	0.23	0.06	0.00	0.07	0.07	0.08	0.14
12	0.09	0.00	0.40	0.07	0.00	0.06	0.00	0.00	0.06
Sum 1-12	37.60	23.15	80.04	39.91	23.98	35.34	30.37	23.53	15.46

Table 4. Catch Numbers ('000) at age and total over ages 1 - 15.

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0
3	64	27	14	13	7	5	24	16	11	34	32
4	291	299	329	374	133	138	128	230	331	225	346
5	420	1057	729	922	1400	946	726	382	958	365	657
6	570	526	561	1308	1255	2195	1047	796	628	381	252
7	725	813	440	730	1419	850	1285	707	624	190	150
8	443	606	383	343	786	716	590	764	397	281	121
9	205	229	231	243	272	319	332	346	293	108	107
10	108	92	119	160	177	163	192	154	104	94	27
11	31	52	36	72	60	81	100	72	46	18	22
12	32	25	28	24	30	40	42	41	10	12	10
13	25	12	14	9	12	18	29	18	4	5	12
14	2	5	1	5	4	6	6	4	5	2	0
15	8	4	3	5	10	7	3	7	2	1	1
Sum 1-15	2925	3748	2888	4208	5565	5484	4504	3536	3413	1715	1737

Age	1992	1993	1994	1995	1996	1997
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	6	1	0	0	0	1
4	62	45	0	0	1	7
5	741	54	2	1	2	4
6	714	165	4	5	3	1
7	255	157	14	8	6	4
8	115	41	10	7	4	4
9	56	14	3	2	6	2
10	21	5	1	1	1	2
11	23	1	0	0	1	0
12	16	4	0	0	0	0
13	3	1	0	0	0	0
14	2	0	0	0	0	0
15	1	0	0	0	0	0
Sum 1-15	2015	489	34	24	23	25

Table 5. Summary statistics and residuals from SPA.

5a. Summary statistics from NLLS fit.

Mean Square of the Residuals = 0.820951

Est.	Param	SE
1	9.48147	0.953029
2	8.33684	0.679447
3	7.17198	0.558006
4	6.14234	0.485422
5	5.50954	0.439502
6	5.20276	0.3985
7	3.65337	0.363205

5b. Residuals

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
3	0.00	0.00	0.00	0.00	-0.17	0.94	0.09	0.18	0.26	0.78	-3.26
4	0.00	0.00	0.00	0.00	0.03	-0.31	-0.68	0.47	0.63	-0.11	-0.58
5	0.00	0.00	0.00	0.00	1.06	-1.02	-1.25	0.36	1.02	-0.64	-0.61
6	0.00	0.00	0.00	0.00	0.67	-0.72	-0.70	0.84	1.05	-0.65	-0.28
7	0.00	0.00	0.00	0.00	-0.04	-1.04	-1.22	0.93	1.47	-0.44	-1.79
8	0.00	0.00	0.00	0.00	-0.55	-0.93	-1.23	0.56	1.76	-0.19	-0.59
9	0.00	0.00	0.00	0.00	-0.99	-0.43	-0.99	1.14	1.25	-0.20	-0.97
10	0.00	0.00	0.00	0.00	-1.26	-0.90	-1.00	0.03	0.52	-0.36	-0.42
Ave 3-10	0.00	0.00	0.00	0.00	-0.16	-0.55	-0.87	0.56	0.99	-0.23	-1.06

Age	1992	1993	1994	1995	1996	1997
3	0.20	0.47	-0.15	0.57	0.06	0.03
4	0.35	-0.22	-0.31	0.53	0.23	-0.04
5	0.81	0.46	-0.06	0.44	0.21	-0.79
6	1.04	0.00	-0.50	0.07	-0.29	-0.52
7	1.07	1.16	-0.27	0.52	-0.02	-0.32
8	0.54	1.16	0.49	-0.43	0.67	-1.26
9	0.31	-0.10	-0.48	1.02	-0.06	-1.49
10	2.45	0.64	-0.11	0.17	1.36	-1.12
Ave 3-10	1.10	0.45	-0.17	0.36	0.27	-0.69

5c Bootstrap bias summary

Age	Base	Bootstrap Mean	Bias	Relative Bias	Corrected	Bootstrap CV
1	0	0	0	1.00	0	1.00
2	20983	21851	868	0.04	20115	0.24
3	9748	10151	403	0.04	9345	0.24
4	13114	18191	5077	0.39	8038	0.61
5	4175	4773	598	0.14	3577	0.42
6	1302	1452	150	0.12	1153	0.42
7	465	506	41	0.09	424	0.35
8	247	265	18	0.07	229	0.38
9	182	197	15	0.08	167	0.35
10	39	41	2	0.06	36	0.35
11	106	112	7	0.06	99	0.38
12	10	10	0	0.00	10	0.24
13	2	2	0	0.00	2	0.24
14	4	4	0	0.00	4	0.24
15	0	0	0	0.00	0	0.24

Table 6. Bias corrected SPA population numbers in thousands at age and total for ages 3 - 15.

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	42283	27413	27963	19439	34089	22941	40726	84905	17630
2	20083	34618	22444	22894	15915	22851	14874	25539	51497
3	16905	16442	28343	18376	18744	10668	14815	9327	15490
4	10044	13782	13437	23192	15033	12559	6913	9272	5645
5	5301	7960	11013	10704	18650	9968	8032	4234	5445
6	4245	3960	5560	8357	7929	11355	5701	4461	2271
7	2960	2959	2767	4045	5658	4288	5595	2746	2086
8	1488	1767	1687	1867	2651	2631	2095	2491	1115
9	558	817	899	1034	1218	1134	1130	847	915
10	348	272	462	527	627	594	479	446	244
11	183	187	139	270	287	276	253	148	151
12	91	121	106	82	156	143	114	79	33
13	53	45	77	62	45	81	60	38	17
14	17	21	26	50	42	20	38	15	9
15	23	12	12	21	36	26	8	19	6
Sum 3-15	104581	110378	114935	110919	121082	99533	100831	144565	102553

Age	1990	1991	1992	1993	1994	1995	1996	1997
1	41189	31175	31369	45198	71939	80173	44767	44767
2	10342	23371	17109	16651	23205	35724	38508	20797
3	30211	5868	12826	9082	8549	11523	17158	17889
4	9079	17117	3197	6804	4662	4245	5535	7971
5	3058	4982	9138	1652	3461	2315	2039	2571
6	2460	1460	2247	4311	809	1717	1112	946
7	851	1109	615	673	2095	399	821	514
8	746	340	498	141	233	1030	186	377
9	350	212	97	180	43	109	490	83
10	312	117	37	11	83	19	51	223
11	64	106	44	4	2	41	9	23
12	53	23	42	7	1	1	19	4
13	12	21	5	11	0	0	0	9
14	7	3	3	0	5	0	0	0
15	2	3	2	0	0	2	0	0
Sum 3-15	98735	85907	77228	84724	115087	137300	110695	96176

Table 7. Bias corrected SPA biomass in tons at age and total for ages 5 - 15.

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	2441	1583	1614	1122	1968	1325	2351	4902	1018
2	4491	5996	3887	3965	2757	3958	2576	4423	8920
3	7776	6618	11924	7665	7113	3963	6072	3789	6840
4	8253	9396	9367	16033	10240	7927	4322	6167	3697
5	6445	8559	11351	11216	17843	9351	7709	4056	4815
6	8404	6115	7800	11922	10399	14077	6764	5699	2649
7	8203	6343	5450	7397	10014	7055	8356	4121	3403
8	5790	5289	4215	4451	5963	5527	4469	4805	2107
9	2847	3378	3193	3158	3346	3009	3020	2403	2114
10	1878	1447	2054	2135	2168	1948	1579	1783	805
11	1480	1245	881	1383	1382	1239	1100	700	677
12	819	937	862	704	1062	935	696	534	215
13	454	433	685	608	424	727	478	277	156
14	126	188	312	566	496	211	401	148	41
15	217	118	125	281	506	335	101	206	87
Sum 5-15	36662	34050	36929	43821	53603	44412	34673	24733	17069

Age	1990	1991	1992	1993	1994	1995	1996	1997
1	2378	1800	1811	2610	4153	4629		
2	1791	4048	2963	2884	4019	6188	6670	
3	13029	2340	4331	2225	3349	4514	6721	6645
4	6983	11594	1862	3025	1744	2699	3562	5256
5	2959	4893	7161	1247	2711	1817	1729	2459
6	3008	1953	2337	4119	874	2215	1156	1156
7	1317	1956	869	815	2744	574	1341	792
8	1636	674	939	229	380	1707	319	852
9	783	615	199	399	84	214	1006	200
10	846	360	114	28	229	33	150	566
11	284	402	132	17	4	131	20	88
12	279	138	153	19	4	2	78	13
13	107	155	37	43	1	2	1	29
14	56	49	19	2	27	1	1	0
15	11	28	30	1	0	16	1	1
Sum 5-15	11284	11223	11990	6919	7059	6712	5803	6157

Table 8. Bias corrected fishing mortality at age and average over years 5 to 7.

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
4	0.03	0.02	0.03	0.02	0.01	0.01	0.02	0.03	0.08	0.03	0.03	0.02
5	0.09	0.16	0.08	0.10	0.10	0.13	0.12	0.12	0.26	0.17	0.20	0.11
6	0.16	0.16	0.12	0.19	0.21	0.27	0.26	0.26	0.45	0.23	0.26	0.57
7	0.32	0.36	0.19	0.22	0.37	0.28	0.34	0.40	0.50	0.35	0.20	0.84
8	0.40	0.48	0.29	0.23	0.45	0.41	0.44	0.50	0.63	0.69	0.66	0.37
9	0.52	0.37	0.33	0.30	0.32	0.43	0.46	0.74	0.54	0.53	1.15	1.58
10	0.42	0.47	0.33	0.41	0.42	0.42	0.71	0.58	0.81	0.51	0.38	1.58
11	0.21	0.37	0.33	0.35	0.30	0.45	0.69	0.99	0.51	0.47	0.33	1.25
12	0.50	0.26	0.34	0.39	0.26	0.43	0.63	1.06	0.47	0.35	0.86	0.70
13	0.74	0.34	0.22	0.18	0.40	0.32	0.91	0.96	0.33	0.74	1.42	2.10
14	0.10	0.31	0.04	0.12	0.11	0.46	0.22	0.38	1.09	0.39	0.03	2.51
15	0.45	0.44	0.32	0.31	0.40	0.42	0.54	0.61	0.66	0.58	0.73	1.18
Ave 5-7	0.19	0.23	0.13	0.17	0.23	0.23	0.24	0.26	0.40	0.25	0.22	0.50

Age	1993	1994	1995	1996	1997
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.01	0.00	0.00	0.00	0.00
5	0.04	0.00	0.00	0.00	0.00
6	0.05	0.01	0.00	0.00	0.00
7	0.38	0.01	0.03	0.01	0.01
8	0.51	0.06	0.01	0.03	0.02
9	0.11	0.10	0.03	0.02	0.03
10	1.10	0.01	0.04	0.02	0.01
11	0.66	0.48	0.00	0.09	0.02
12	2.19	0.27	0.00	0.01	0.02
13	0.09	0.31	0.00	0.22	0.02
14	0.56	0.01	0.00	0.00	0.02
15	0.57	0.06	0.03	0.02	0.02
Ave 5-7	0.16	0.01	0.01	0.00	0.00

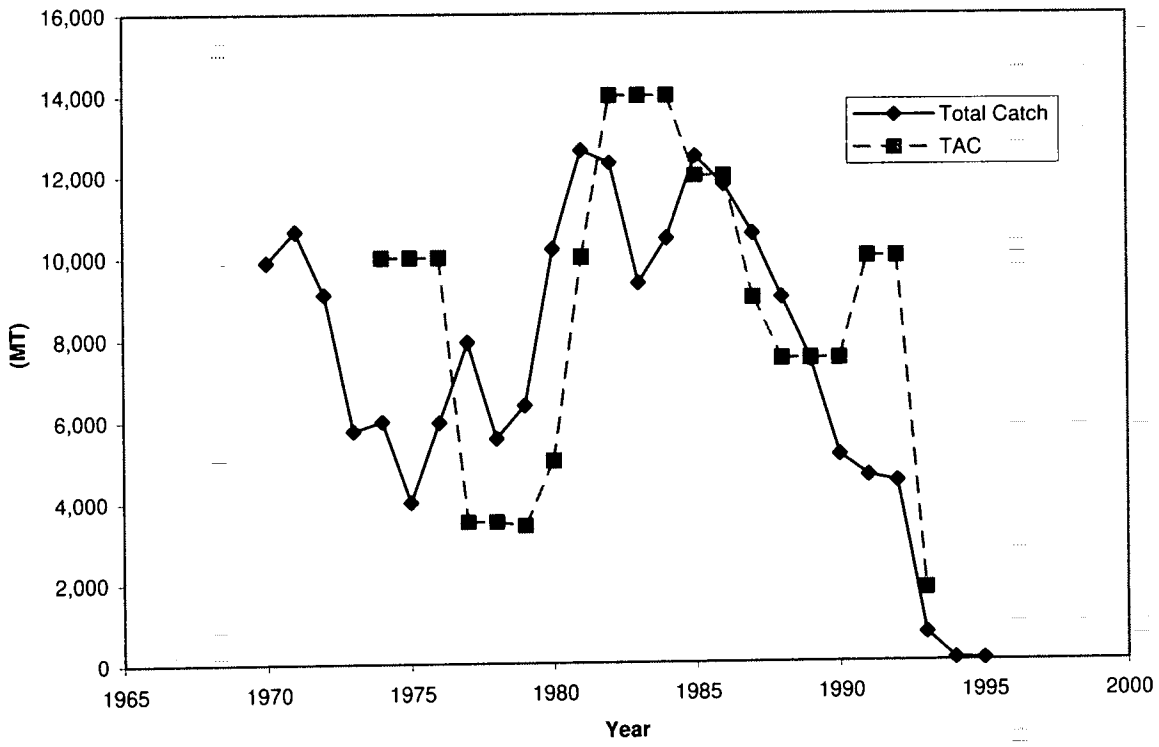
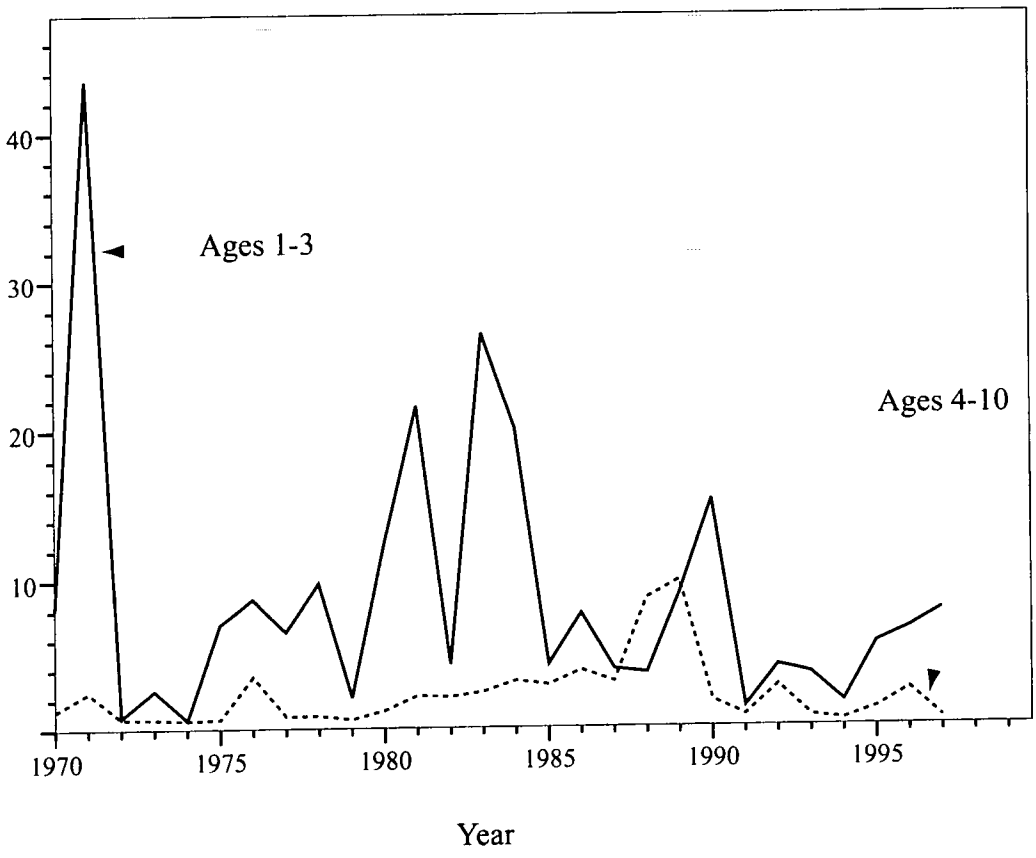


Figure 1. Total catch and TAC for 4Vn cod.

Figure 2. Summer survey numbers per standard tow for ages1-3 and 4-12.



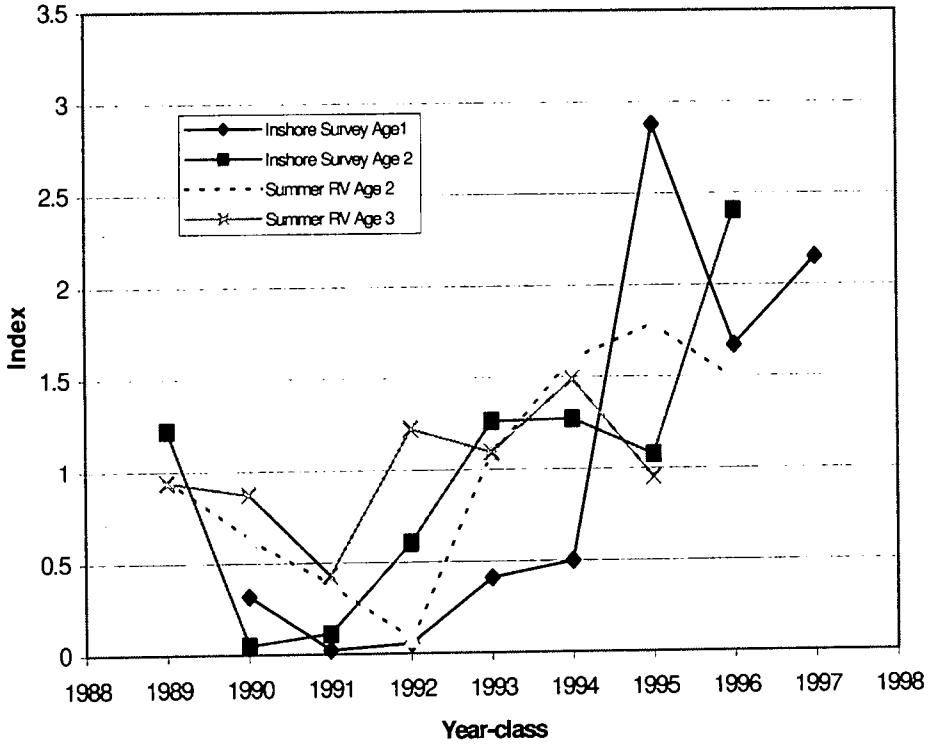
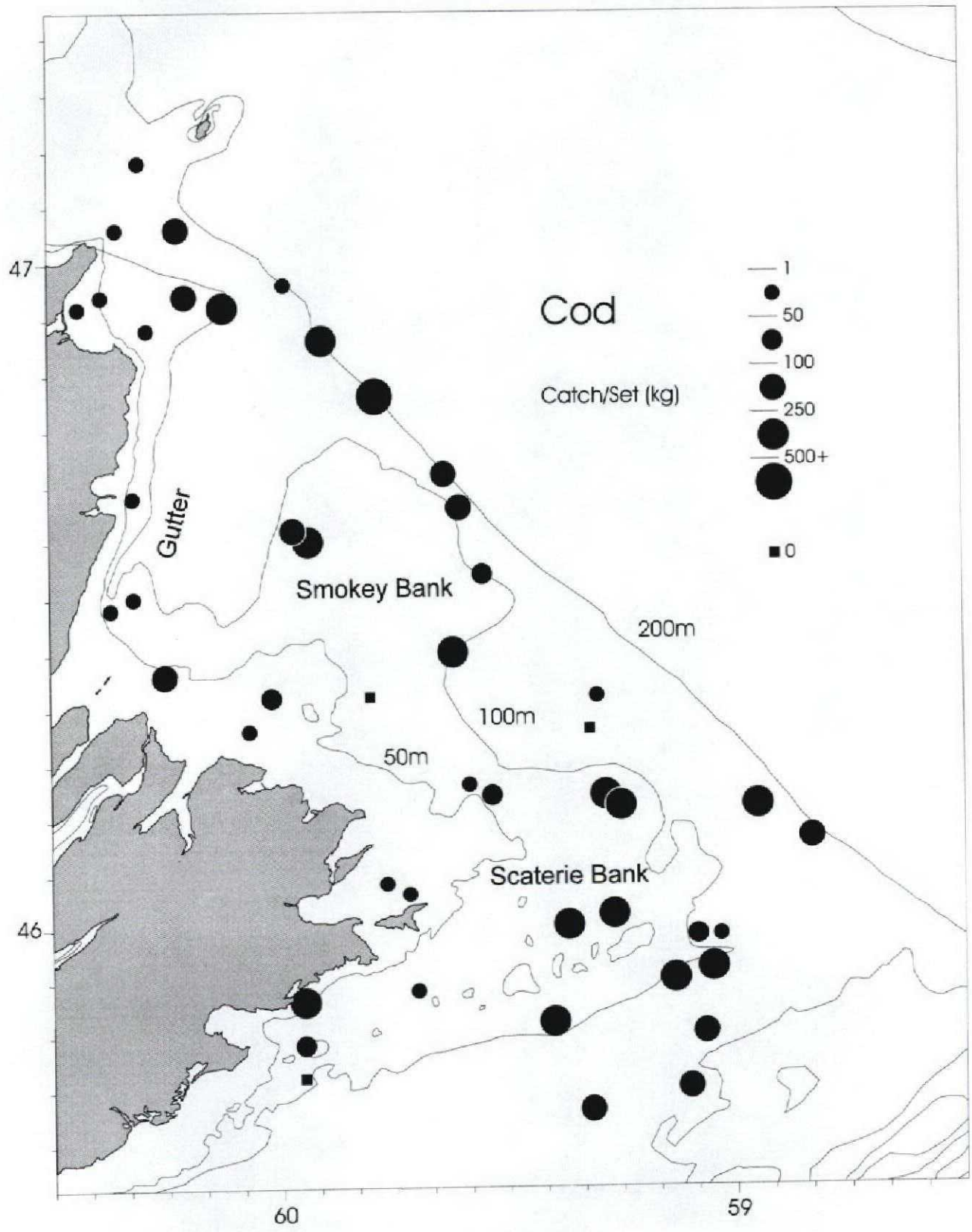


Figure 3. Estimates of year class strength from Inshore and Summer RV survey series.

Figure 4. 4Vn Sentinel Fishery Abundance survey - fall 1997.



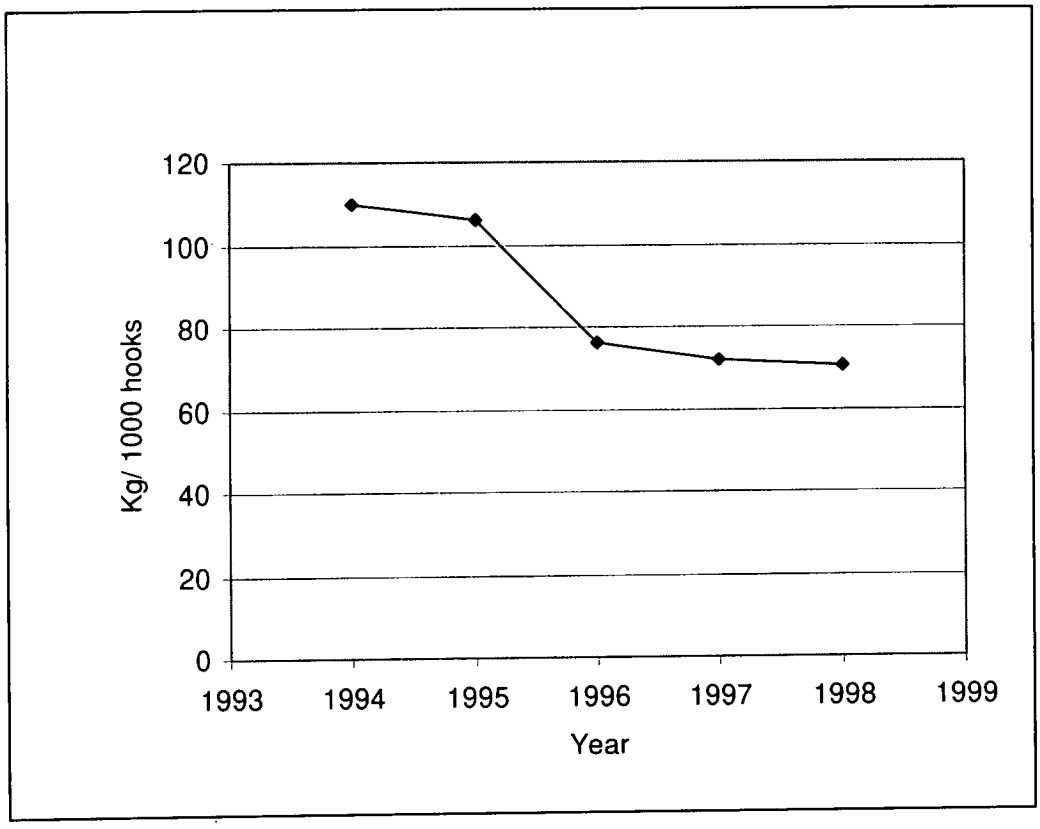


Figure 5. Sentinel Survey catch rate.

Figure 6. Summer RV Z's for age classes 2-4, 5-7, 8-10

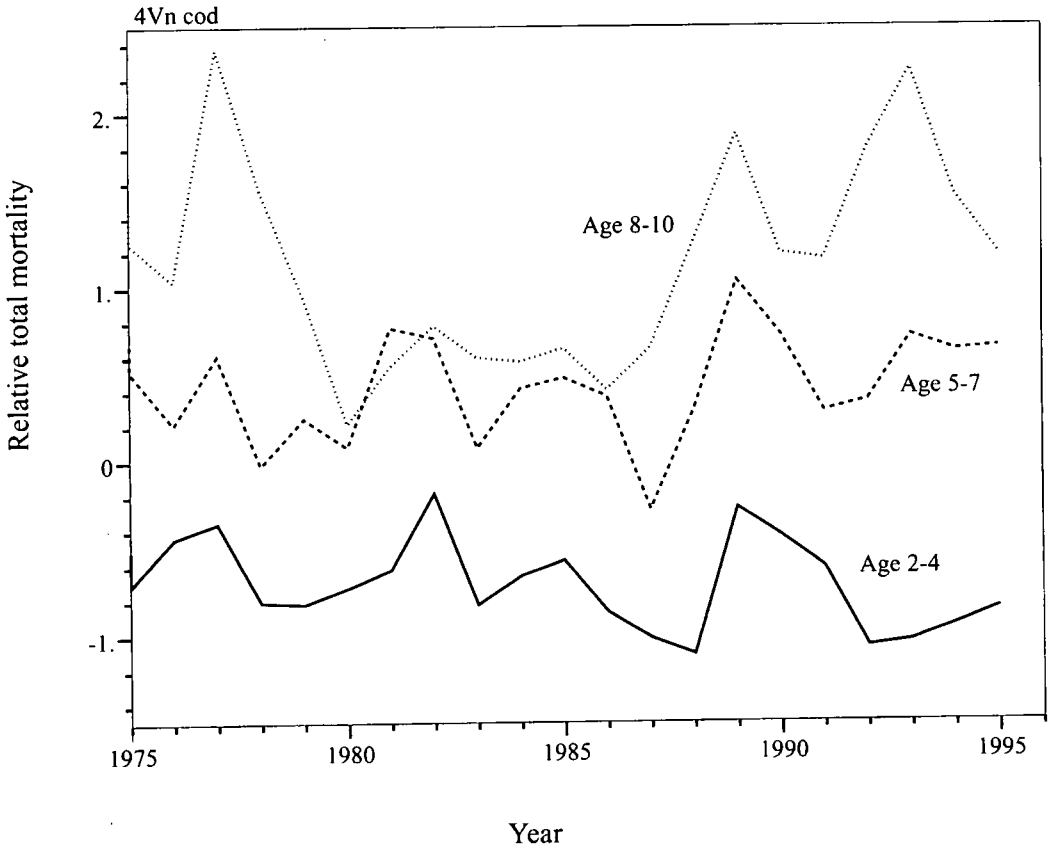


Figure 7. Residual surface plot. The circles are scaled negative residuals and the plus sugns positive

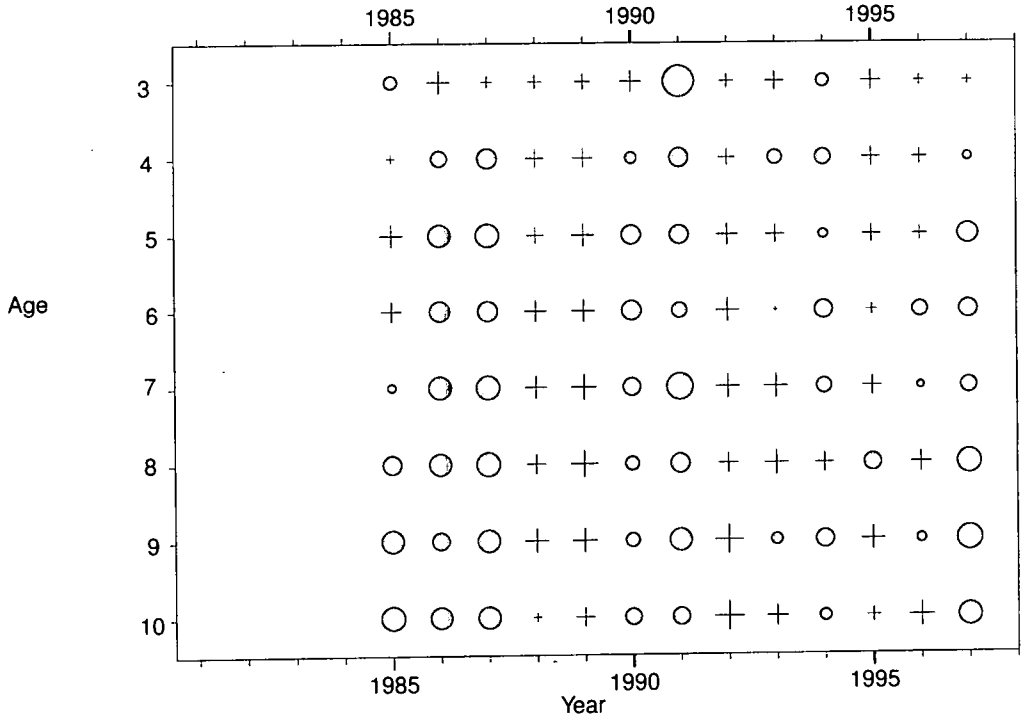


Figure 8. Q adjusted RV indices and bias corrected, uncorrected and uncorrected aged to time of survey numbers at age summed over ages 3-10. ('000)

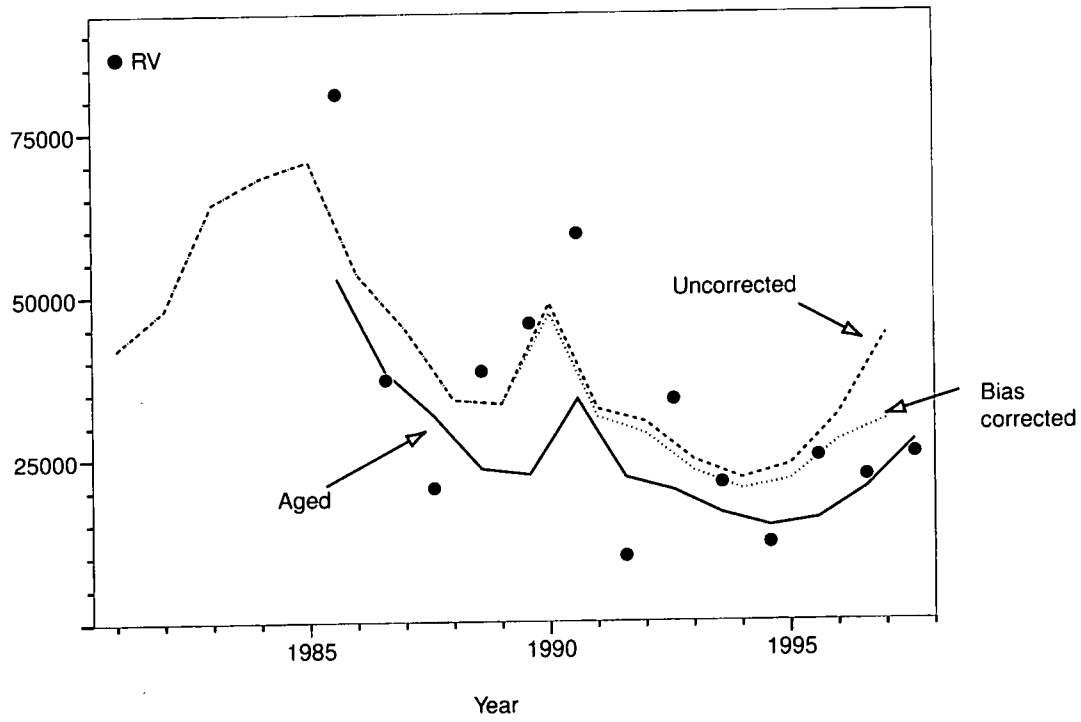


Figure 9. 4Vn cod Spawning Stock Biomass (Bias corrected)

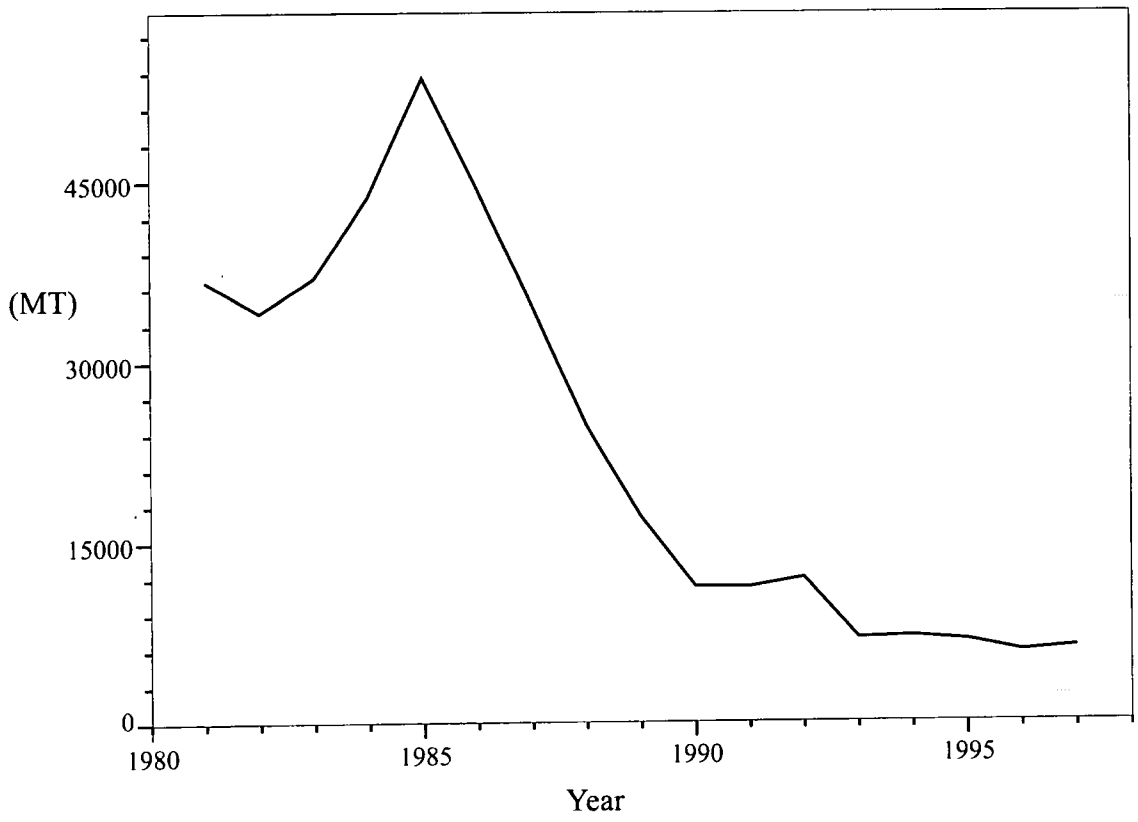


Figure 10. 4Vn cod Average Exploitation Rate (Bias corrected) over ages 5-7.

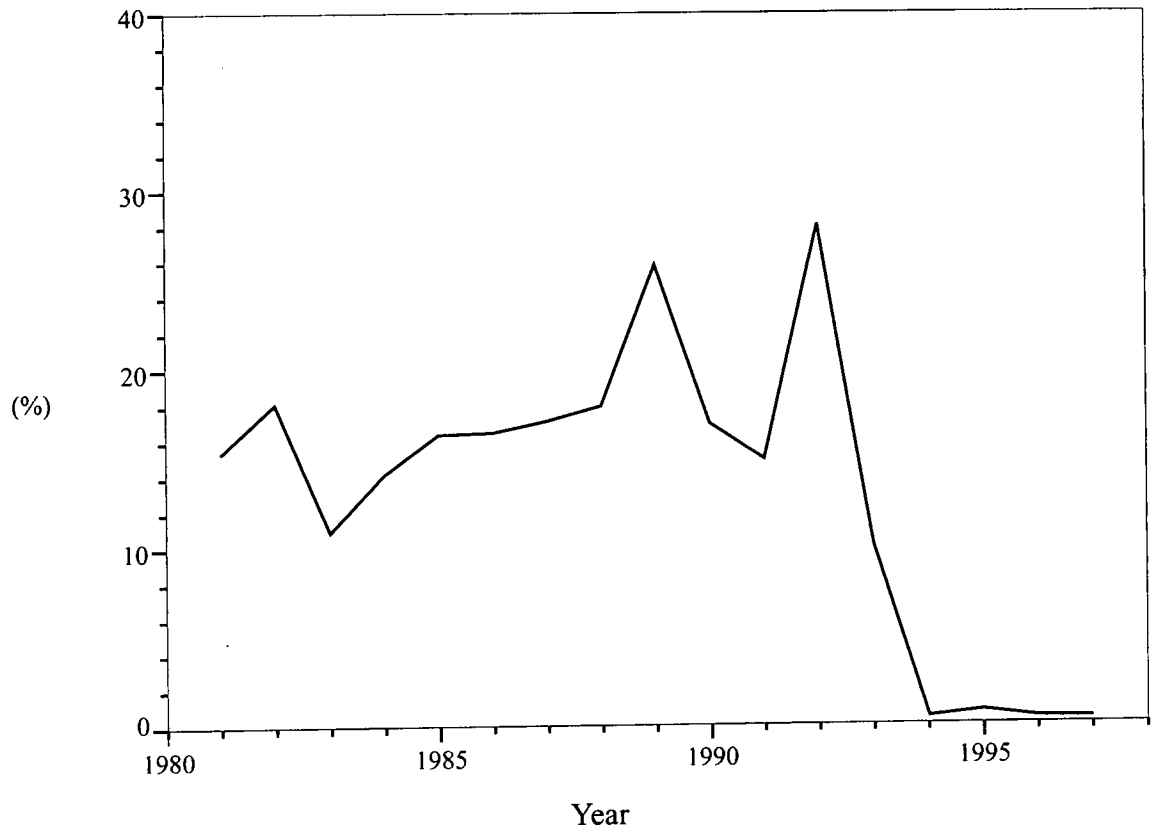


Figure 11. 4Vn Cod Age 3 Recruitment (Bias corrected)

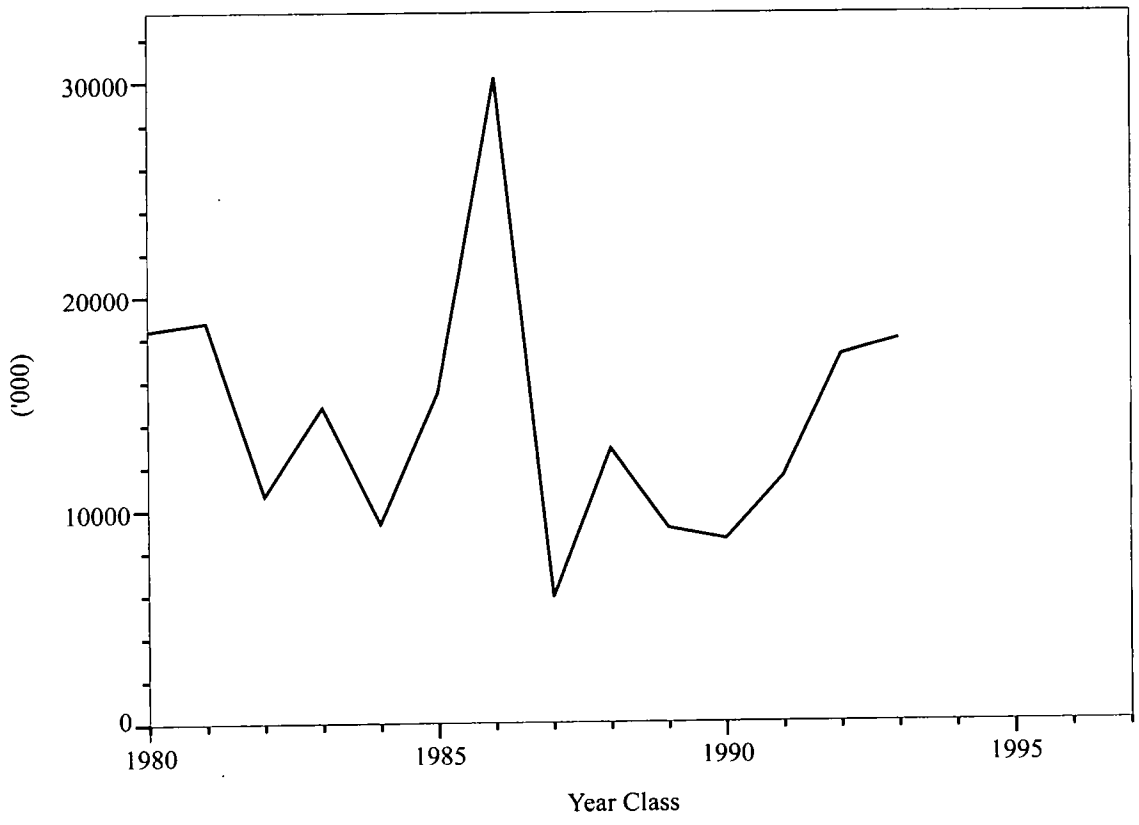


Figure 12. Stock (5+ biomass) and Recruts (age 3) for 4Vn cod.

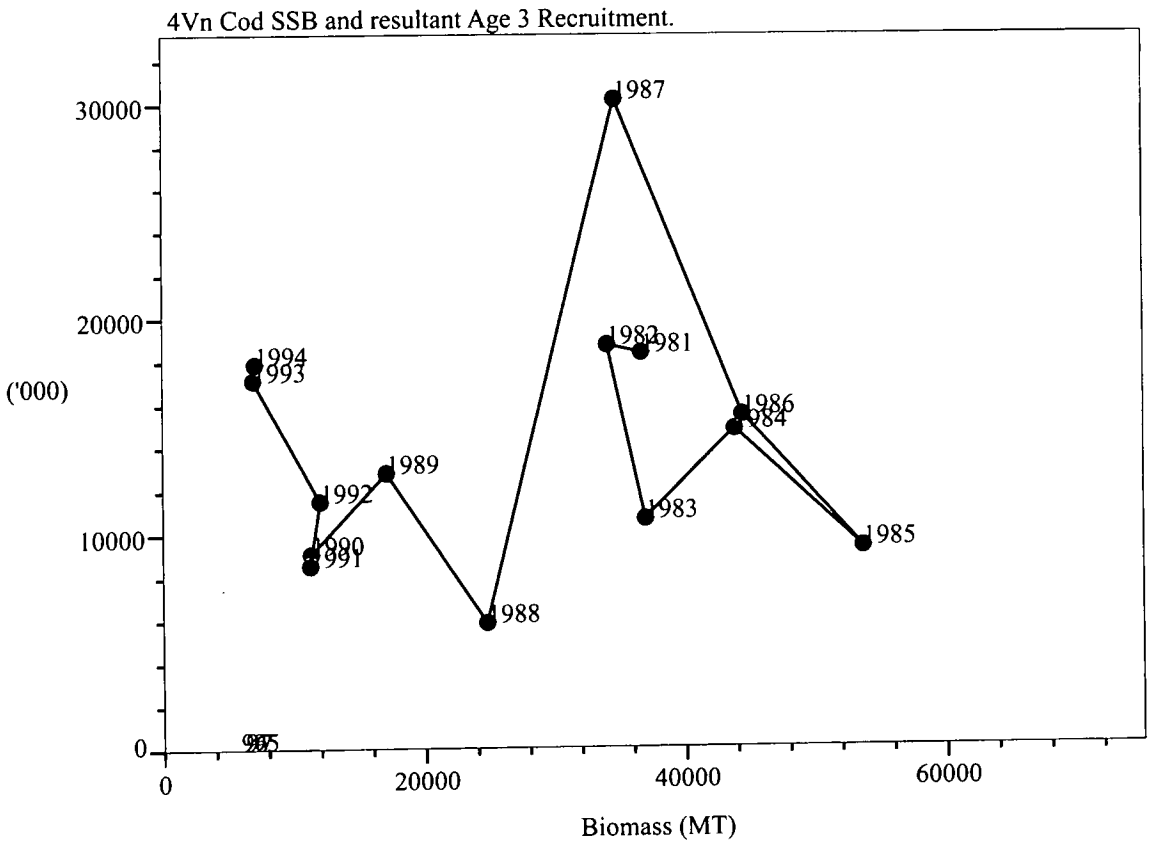
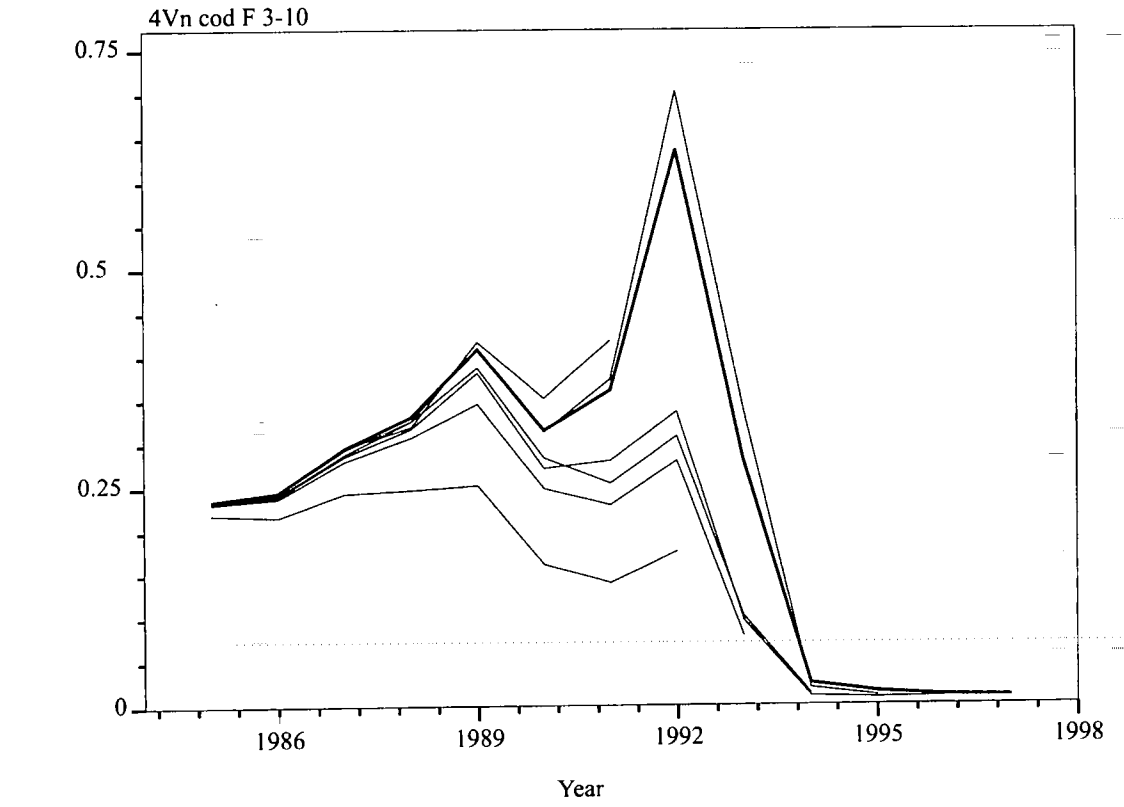


Figure 13. 4Vn Cod Retrospective analysis.



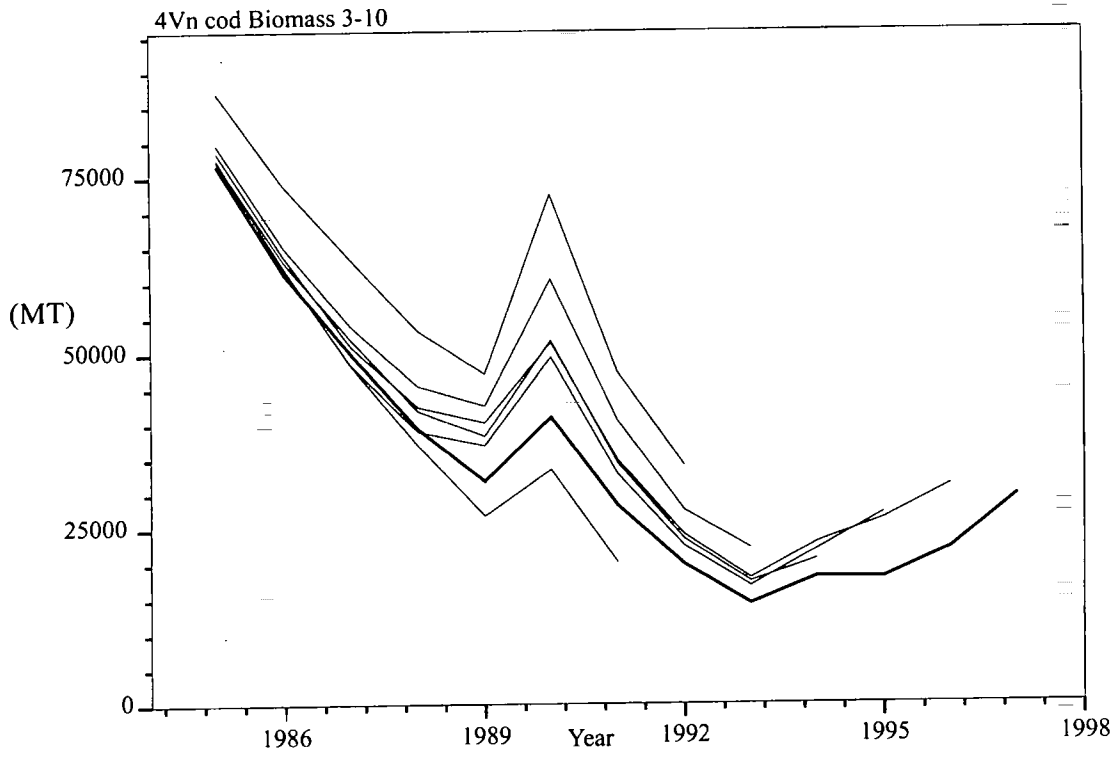


Figure 14. Exploitation rate and and change in surviving SSB as a function of yield in 1999.

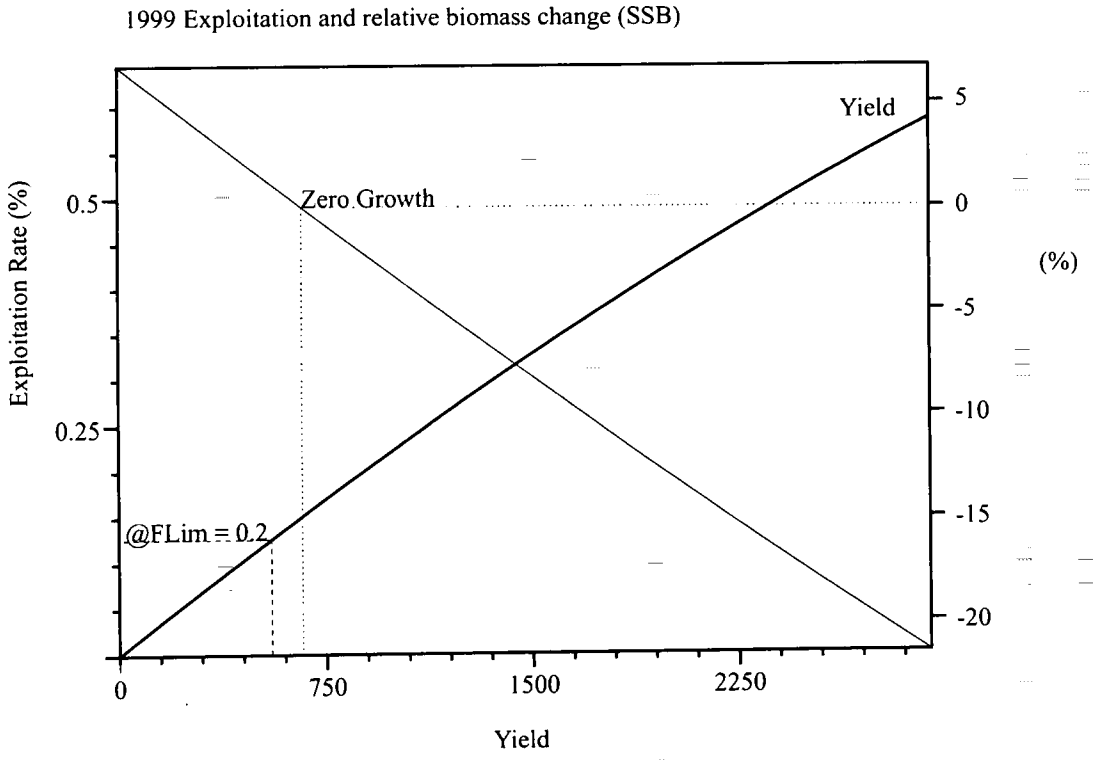


Figure 15. Probablility of biomass decreasing (upper) and F exceeding FLim (lower) for 1 and 3 year projections.

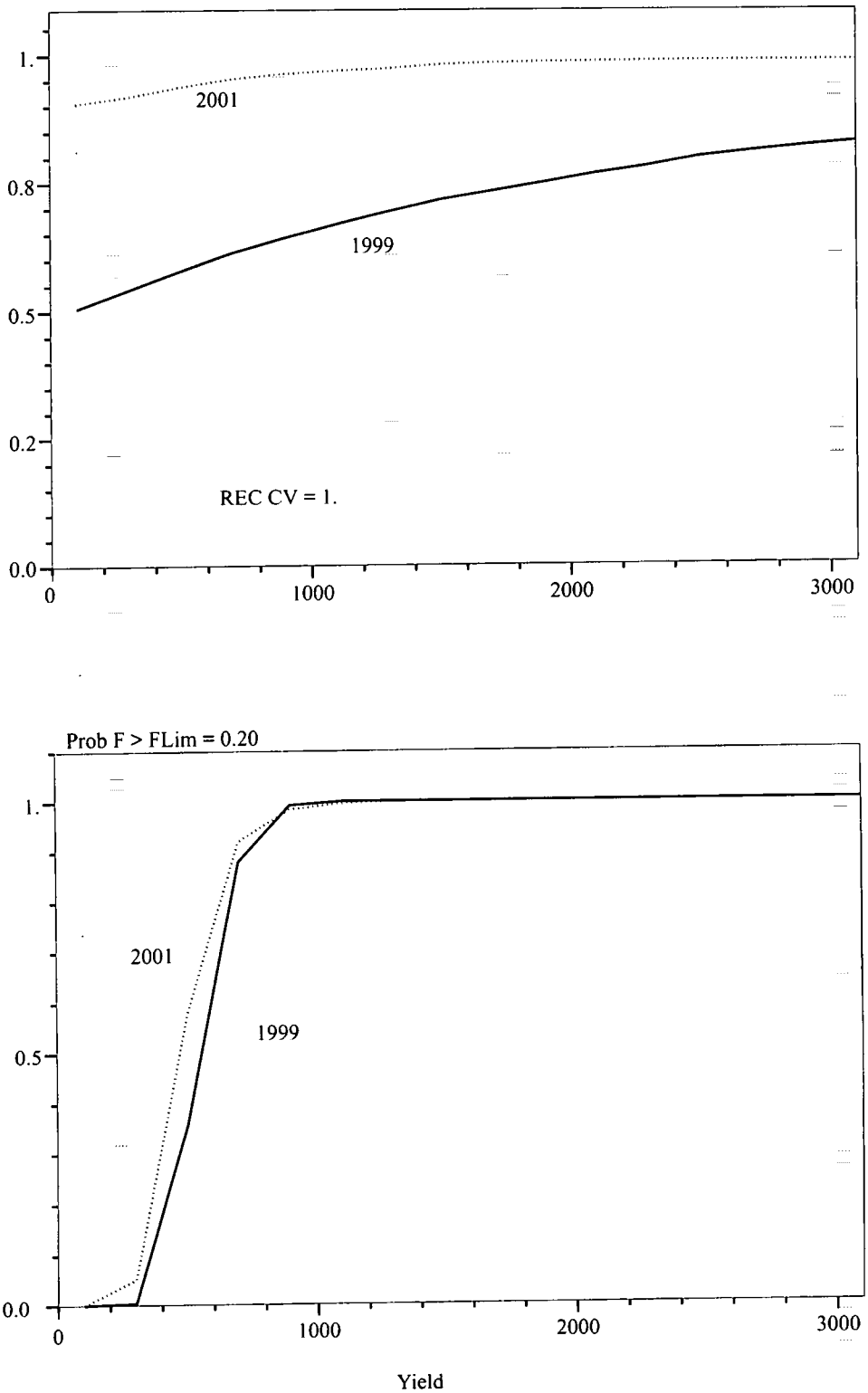
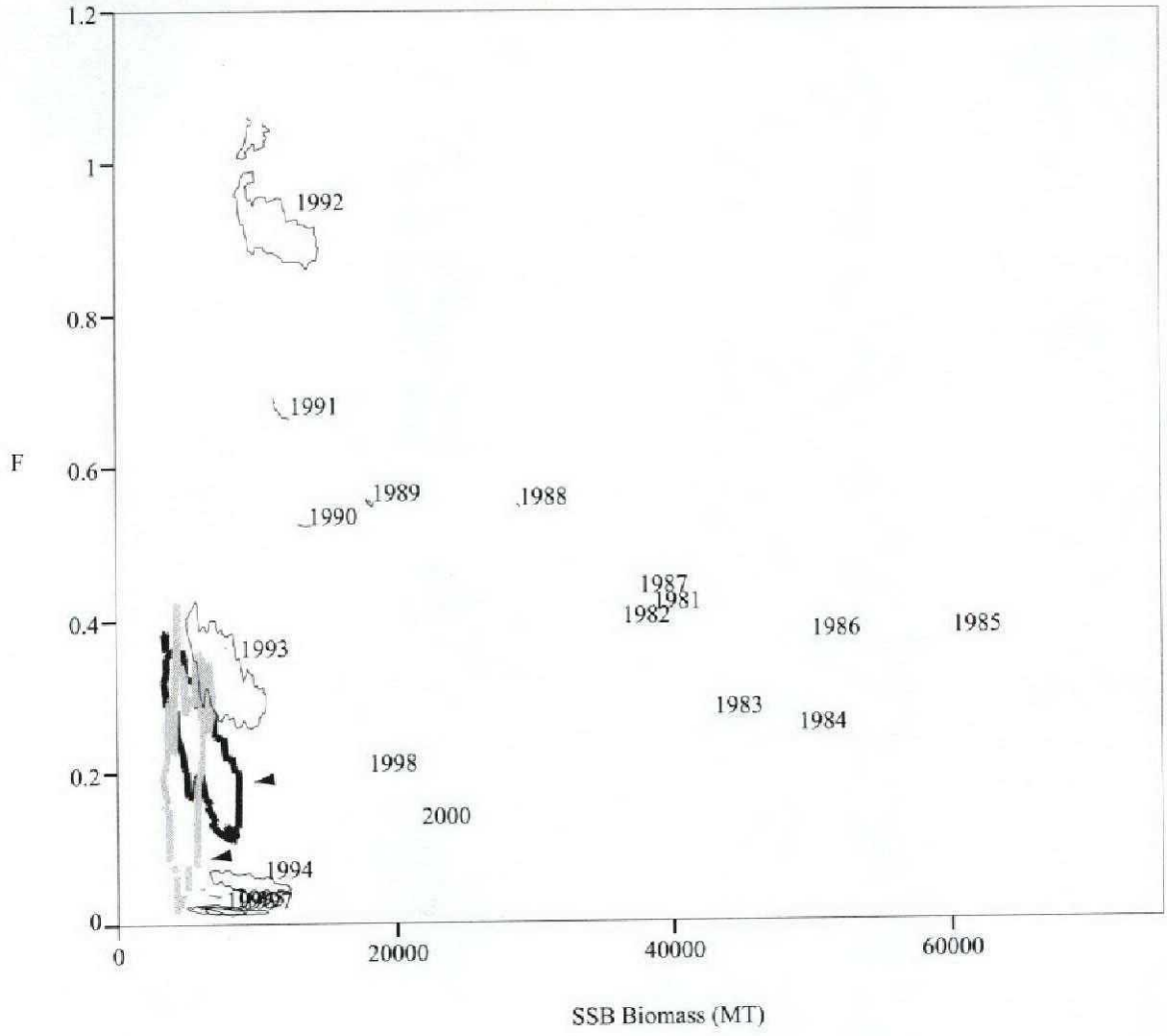


Figure 16. 4Vn Cod history and projections for 1998 and 2000 with TACs of 700 MT. The irregular shapes associated with each year are the 50% propability contours.



Appendix A

Appendix A compares the principal SPA outputs of the currently assumed natural mortality model to the previously used M= 0.2 over all years and ages. The biomass comparison (Figure A1, top panel) show a similar pattern with the M=0.2 results falling much lower but have a slight recent recovery. The average F over ages 7-9 are again similar patterns with the M= 0.2 peaking much higher in 1992. The recruitment series is most sensitive to the natural morality in terms of magnitude but shows a generally similar decrease until the early 90s and then a degree of recovery. Figure A2 shows the stock-recruit relationship for M=0.2 which may be compared to Figure 12. Figure A2 has a trend toward the origin suggesting a strong dependence on SSB.

Figure A1. Comparison of SSB F(7-9) and recruits (Age 3) for natural mortality as used in the assessment (solid lines) to an M of 0.2 (dashed lines).

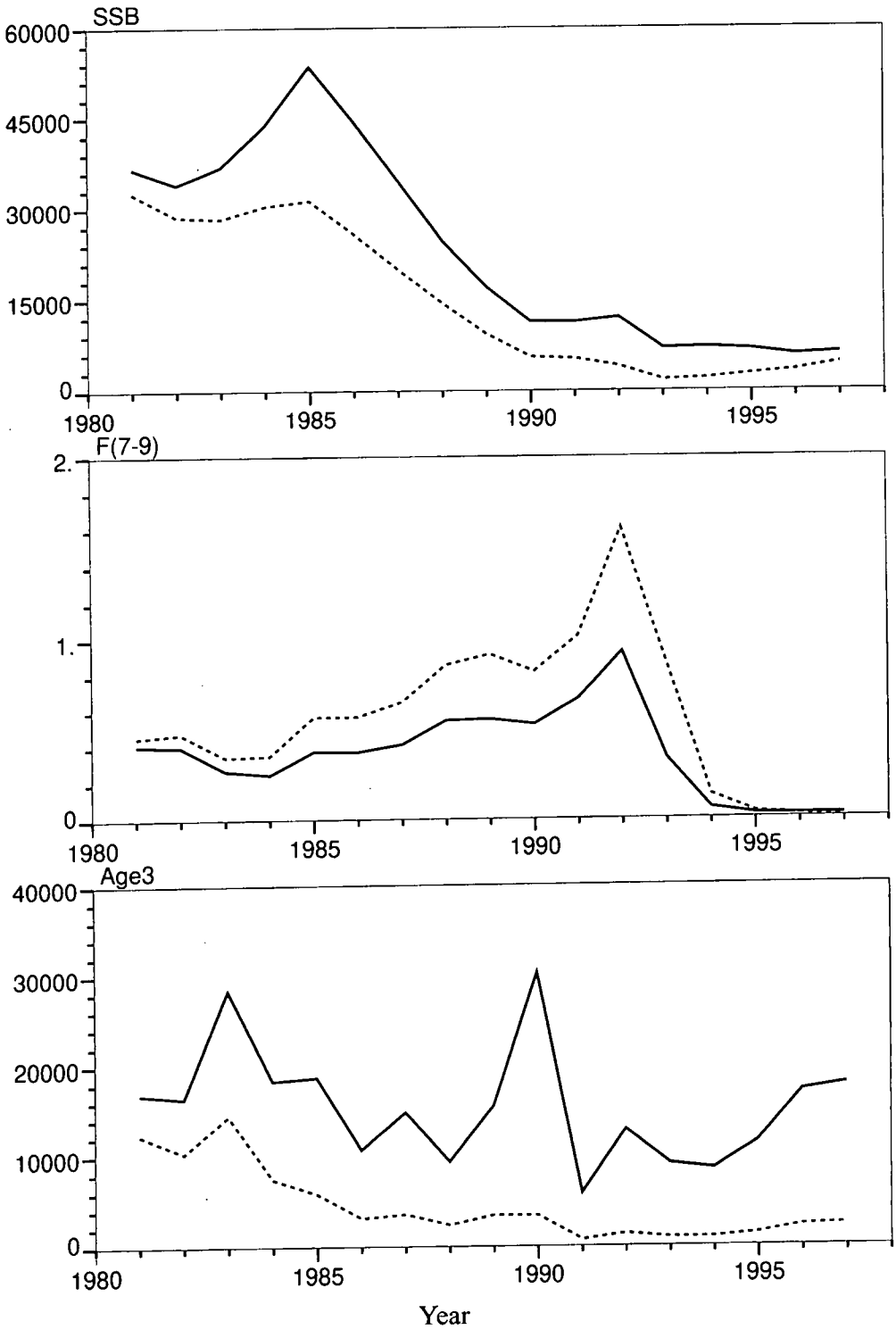


Figure A2. Stock-recruit relationship when natural mortality is 0.2 for all ages and years.