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Assessment of the Status of 4Vn Cod (May to October) 2000

Évaluation de l'état du stock de morue de 4Vn (mai à octobre) en 2000

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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 50 tonnes of cod were taken commercially as Sentinel activity and bycatch in redfish, flatfish and halibut fisheries in both 2000 and 2001 (to date Oct 1). The stock is monitored by annual DFO groundfish trawl surveys in July and since 1991, an inshore survey. In addition, a Sentinel Survey employing commercial longliners was inaugurated in September 1994, and has since been conducting annual surveys in July and September. All these surveys give a similar picture of the stock status. Until there is substantial recruitment, and it survives to reproductive age, there are no prospects for a reopening of this fishery.

RÉSUMÉ

Bien que la pêche de la morue dans 4Vn (mai-octobre) soit fermée depuis septembre 1993, le stock montre peu de signe de rétablissement, en grande partie à cause d'un manque de recrutement. Les pêcheurs commerciaux ont capturé environ 50 t de morue en 2000 et 2001 (au 1er octobre) dans le cadre de pêches sentinelles et à titre de prises accessoires de la pêche du sébaste, de poissons plats et du flétan. Le MPO assure la surveillance du stock par le biais de relevés annuels du poisson de fond au chalut effectués en juillet et, depuis 1991, d'un relevé côtier. De plus, un relevé par pêche sentinelle faisant appel à des palangriers commerciaux, instauré en septembre 1994, est effectué tous les ans en juillet et septembre. Tous ces relevés brossent le même tableau de l'état du stock. La pêche ne pourra être rouverte que lorsque le recrutement se redressera et que les morues recrutées se reproduiront.

INTRODUCTION

Cod landings in NAFO Subdivision 4Vn have declined from 1985 until closure of the fishery in 1993 (Figure 1). Throughout most of the 1980'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 4Vn cod fishery was defined for the months May to December. Afterwards, it was re-specified from May to October to more closely correspond to the migration of fish from the Gulf of St. Laurence.

Div. 4T cod overwinter along the shelf edge from 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 is comprised of 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 4Vn 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.

In addition to updated surveys, this assessment differs from earlier versions in that a new value for natural mortality (M), which has traditionally been 0.2 for all ages and years, has been changed to bring it into closer accord with the models adopted for 4VsW and 4X cod. The new assumed M is much larger than 0.2 and particularly affects recruitment estimates. The larger M's were first applied in the 1997 Research Document (Mohn et al. 1998) and have been updated here using estimates from the Research Survey data. Also, all catch at age data was reworked to a consistent May to October basis.

DATA

COMMERCIAL CATCH

All commercial catch statistics have been recompiled since the last assessment. (Mohn et al.1998). The catch at age has been re-examined on the basis of a consistent (May-Oct.) stock definition. Table 1 contains landings by country redefined for May to October. Similarly, Table 2 is landings broken out by gear type (May-Oct.). Figure 1 shows the landings for May to October and TAC as defined. Figure 2 shows similar data but the landings now match the same time

period as the TAC. Figure 3 shows the distribution of landings by all gears from 1990 to 1993, before the closure. For the period after the closure, all gears are shown as well as the longline catch.

The commercial catch at age was constructed by first extracting commercial samples from the MFD Virtual Data Centre. As 4Vn is a known area of stock mixing, only samples taken between May and October from 1981 to 2001 were used to minimize biasing the results. Total catches were also extracted for the same period and used to calculate the final catch at age. The samples were examined and combined where gears were similar or where samples were limited. (Table 3). The combined samples along with the July RV survey length weight parameters (a's and b's) for the 4Vn area (Table 4) were used to compute the commercial catch at age (Table 5) using the standard MFD Catch At Age application.

SENTINEL PROGRAM

Since its inception, the Sentinel Program has carried out many experiments that have formed an adjunct to the DFO groundfish surveys that have been carried out in this area during the past nearly three decades. The two principle indices though are the Sentinel Survey and the Commercial Index. A summary of the various activities is shown in the following table. Two codes were used to define the experiment type. The older code used 2 letters (FM, SS, CI etc.) and the newer one uses a numeric code.

Inventory of experiments conducted under Sentinel Survey (# of sets)

	1994	1995	1996	1997	1998	1999	2000
Fall Migration (FM) (4*)	10	16					
Fall Migration (FM) (6*)			12	11		10	4
Sentinel Survey (SS) (5*)	53	60	45	45	52	36	51
Sentinel Survey (SS) (6*)			10	23			
Hook Experiment (HE) (9*)		32					
July Survey (JS) (5*)		50	47	48			
July Survey (JS) (6*)			10	8			
Spring Migration (6*)		12	12	12	2	12	12
Commercial Index (CI) (6*)				44	364		36
Commercial Index (CI) (10*)						320	239
Gear Comparison (GC) (6*)					25		
Gear Comparison (GC)(10*)					10		
Monthly Monitoring (MM) (4*)					34	99	30
Bras d'Or Lakes Study (BL) (4*)						24	
Bras d'Or Lakes Study (BL) (6*)							20

* see set code table below

*Set Code	Description
4	Survey - Fixed Station
5	Survey - Random
6	Survey - Captain's Choice
9	Experimental - Captain's Choice
10	Commercial Index

The 4Vn Sentinel Program is conducted by commercial longliners and provides an index of abundance and detailed seasonal biological information on 4Vn cod as well as monitors the migration of 4T cod in and out of 4Vn. The Sentinel Survey (SS) component of this program includes only sets coded as '5' as in the above table. This survey takes place 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 similar to the DFO July RV survey (Figure 22) although there are no sets deeper than 100 fathoms and the stratification schemes are slightly different. The July 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.

For the purposes of this analysis, the Commercial Index was defined as those trips of type CI, or those SS's that are Captain's Choice (set code 6). Figure 4 shows the distribution of the Sentinel Survey (SS) and Commercial Index (CI) effort for all years (1994 – 2000, SS; 1996-2000, CI). (Sets seen on land are the result of some unedited data). The SS survey is re-randomised each year and appears to cover 4Vn well. The CI is fishermen directed and is seen to focus on a few areas of traditional fishing. Figure 5 shows the catch rates as expanded symbols for the two surveys. As expected the CI has higher catch rates. The annual rates (non stratified) from each survey are shown in Figure 6. Both simple mean and stratified estimates are shown below.

Year	Simple	Stratified
1994	0.1123	0.1298
1995	0.1025	0.1061
1996	0.0724	0.0881
1997	0.0753	0.0903
1998	0.0816	0.0991
1999	0.0711	0.0784
2000	0.0421	0.0472

Figure 7 shows the length frequencies for the SS. The mode is very similar from year to year and no individual age modes are evident. Figure 8 compares the SS and CI length compositions. The CI catches slightly larger fish.

The Sentinel Survey index was aged and the resultant numbers at age are shown in Table 6.

JULY GROUNDFISH SURVEY

The July RV survey for 4Vn has been carried out since 1970 and is more variable than other stocks due to low numbers of sets and also 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. However, it is generally accepted that from May to October, 4Vn is dominated by resident fish.

Figure 9 shows the summary catch rate, both in terms of numbers and biomass per tow, as well as the average size of fish in a tow. The average size is seen to be falling since the early 1970s. Figure 10 contains the distribution of research tows summarised, in general, over 5 year blocks. The length frequencies from the survey are summarised in Figure 11. The numbers on the right hand side of the plot are the relative magnitude of each plot; that is a value of 20 would mean that the peak of the plot is twice as high as the peak of a plot with the value 10. The modes from this survey are considerably smaller than those seen in the Sentinel program. The size of cod over the 32 year survey are summarised in Figure 12. The upper most line in this figure represents the size of the biggest 10% of the survey catch and is seen to be falling for a couple of decades. On the other hand the lowest line is the smallest 10% and it does not show a trend.

The condition factor for 30 cm and 50 cm fish (Figure 13) shows an early decrease, but little trend thereafter. The lengths at age (Figure 14) for ages 2-4 show little change over the period of the survey (upper panel). However, ages 5-7 (lower panel) display a drop in the mid-1980s. After the drop the interval between ages is about the same as before suggesting that the fish are still growing (as opposed to 4VW haddock, Frank et al. 2001). This discontinuity in growth did not affect immature fish (< age 5).

The updated numbers at age, weights at age and lengths at age from the summer survey are given in Tables 7-9. Figure 15 displays the numbers at age as expanding symbols. Year effects are seen in these data (a column of symbols that are larger than the neighbouring columns) as well as a couple of traceable cohorts. The survivorship down cohorts is estimated, and its log, which is the total mortality rate, is shown in Figure 16. The total mortality of the oldest plotted age group (7-9) has not responded to the closure of the fishery, September 1993. Also the youngest group (2-3) show a recent increase which corresponds to a recent increase in grey seal abundance. The survey numbers at ages 2-4 were combined into a recruitment index, by normalising them and then averaging the cohorts, Figure 17. This index is seen to increase recently, although not up to historical levels.

Two spatial indices for the survey were compiled; the concentration index and an index of the area covered. The area covered by the resource (proportion of non-zero sets) (Figure 18) shows a decreasing trend in recent years for both adults and juveniles. The adult concentration index (Figure 19) although quite noisy, follows the population biomass (Fig. 9). The juvenile index (Fig. 20) is also quite noisy and shows little indication of trend.

The only environmental data considered are shown in Figure 21, which is the proportion of the bottom from the July RV survey at temperatures less than 2° C. This temperature was chosen arbitrarily as defining suitable habitat for cod.

Figures 22 and 23 are comparisons of the July RV survey, CI and SS as a function of depth. Figure 22 shows sampling frequency while Figure 23 shows catch rates. The CI and July RV survey are shown to behave similarly with peak catches around 150m.

 INSHORE SURVEY

DFO has been conducting an inshore survey since 1991 with the majority of trips occurring during September and October. It covers approximately the western third of Sydney Bight and includes an area to the Southwest, which is not surveyed by the larger July groundfish survey (Figure 24). This survey samples small fish well. The left-hand panel shows fish less than or equal to 25 cm, caught over the ten-year period of this survey, were concentrated in a small inshore area. The right-hand panel shows where fish over 25 cm were caught and they are seen throughout the survey area. The size distribution inside the box is shown in Figure 25, which may be compared to the July RV survey and SS size frequencies (Figures 7 and 11). Figure 25 has clear modes at smaller lengths which may be broken up into approximate age groups. To aid in defining the cut-points between ages a summary of all the aged cod in 4Vn and 4Vs was compiled in Figure 26. Because there were no zero ages and very few age 1's seen in 4Vn, data in the neighbouring area were also compiled, although 4Vs has a slightly higher growth rate. Based on these observations, cut-points were applied to the length frequency data and are shown in Figure 25. The resulting indices for young fish are shown in Figure 27.

Good concentrations of cod eggs and 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 RV survey catches in May and June since 1991. Thus it seems likely that production of progeny is normal.

ANALYSIS

i) TOTAL MORTALITY FROM SURVEY DATA

Total mortality from July RV surveys was discussed above. From this, a simplified model of natural mortality is shown. (Figure 28). The total mortality rates, estimated from the July RV survey (Figure 16) have remained high even after closure of the reported fishery activity in 1993. This suggests that mortality due to causes other than reported fishing activity has been higher than the level of 0.2 used in previous analyses. For this reason, a time and age varying natural mortality was assumed. The scenario used here is derived from examination of July RV survey total mortality estimates at age and by analogy with observed trends in adjacent cod stocks. The sources of this mortality could involve incidental mortality in other fisheries, mortality due to ocean climate changes, emigration and/or predation by seals and other species feeding in the area.

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 5).

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 - $q1_i$, i = 3 to10 for July RV survey
Calibration coefficients - $q2_i$, i = 5 to10 for Sentinel survey
(q's estimated algebraically)

Structure Imposed:
Error in catch assumed negligible
Partial recruitment fixed for ages 11-12 in terminal year.
F on oldest age (12) set to the average F ages 9 &10
No intercept was fitted
M function of age and time as described above

Input:
$C_{i,t}$, i = 1 to 12; t = 1981 to 2000 (May to October catch at age)
$J_{i,t}$, i = 3 to 10; t = 1981 to 2000 (July RV index)
$S_{i,t}$, i = 5 to 10; t = 1994 to 2000 (SS index)

Objective function:
Minimise: $\Sigma \Sigma \{\ln J_{i,t} - \ln(q1_i N_{i,t})\}^{2 +} \{\ln S_{i,t} - \ln(q2_i N_{i,t})\}^2$

Summary
Number of observations: 202 from July RV and SS
Number of parameters: 21;   8 estimated by NLLS, 14 algebraically

RESULTS

SPA - diagnostics

The summary statistics from the SPA are given in Table 10. The coefficients of variation (CV) are worse than those seen in most assessed gadoids. This is expected because of the relatively short time series used in the SPA and the poorer sampling in 4Vn. Table 11 shows the effects of bias correction in the estimation process and contains the ratios of the estimates after correction divided by the uncorrected estimates at age. These corrections were quite small, only a few percent at the most. Another diagnostic is the coefficient of variation from bootstrapping the residuals from the SPA fit. They are shown in Table 12 and as expected are the worst for young ages in the most recent years.

This assessment was the first for this stock to incorporate Sentinel Survey data. The effects of the SS data are shown in Table 13, which contains the ratio of the numbers at age estimated with SS and July RV survey data to the estimates for RV data alone. The inclusion of SS is seen to reduce the estimates of stock size by about 20 % in 2000, and the effect decreases further back the

cohorts. A final trial configuration (Table 14) was tested in which the SPA was tuned to SS, RV and the estimates of age zero from the DFO inshore survey. The age zero index acted in the opposite direction and increased the numbers at age back to the approximate values using the RV alone. Because age 0 estimates are very uncertain, this index was not included and a final configuration using RV and SS data was chosen. The residuals at age from the final model are given in Table 15. The summed residuals after adjusting for the efficiency of each survey (q) are shown in Figure 29 while the residuals at age are shown in Figure 30. The upper half of Figure 30 shows vertical bands which are diagnostic of year effects, as would be expected with the low sampling rates (8-12 per year) in the July RV survey.

Finally, three more diagnostics appear in Figures 31-33. Figure 31 compares three different SPA models with different natural mortality assumptions (solid versus dotted lines) and the effects of the SS data (solid versus dashed lines). The general pattern is the same but the $M = 0.2$ line dips much lower than the estimated biomass in 1994. Figure 32 is the standard retrospective plots for biomass and average F. The biomass retrospective follows one trajectory for the 3 longest time series then switches to another grouping for the other 5 time windows. These results may be compared to a retrospective run using $M = 0.2$ which is shown in Figure 33, wherein the pattern is much worse.

SPA - estimates

The three principal estimates of the SPA, (numbers at age, F at age and biomass at age) are given in Tables 16-18. Also, SPA estimates of biomass, exploitation rate and recruitment are shown in Figures 34-36. The recruitment estimates are for ages 3 and 4 and for comparison the RV index is also shown. In general the recruitment estimates are poor since the1988 year-class but display an upward trend.

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 indices of recruitment from the July RV survey (Figure 36) and 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.

ACKNOWLEDGEMENTS:

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Table 1. Total landings by country (May to October) for NAFO Div. 4Vn cod.

Year	Canada	Russia	Spain	France	Norway	Portugal	Misc	Total	TAC
1960	3700		138	18			4	3860	
1961	3491		134	0		1	1	3627	
1962	6771		52	429				7252	
1963	6292	31	125	0		229		6677	
1964	7806		182	707		320		9015	
1965	7129	383	257	1679		465		9913	
1966	6879	543	45	210				7677	
1967	5415		99	0			15	5529	
1968	4524		47	41				4612	
1969	6575		38	85				6698	
1970	7210		1114	34			7	8365	
1971	7022		2052	1				9075	
1972	5573		810	745		459		7587	
1973	4210		41	0		189		4440	
1974	3906		4	0	83	84	75	4152	10000
1975	2657			0	186	360		3203	10000
1976	2029			0				2029	10000
1977	3254			2				3256	3500
1978	4421			0				4421	3500
1979	4601			73				4674	3400
1980	7384			214				7598	5000
1981	10506			172				10678	10000
1982	8625			232				8857	14000
1983	6547			170				6717	14000
1984	8358			0			1	8359	14000
1985	10659			0				10659	12000
1986	10345			4			1	10350	12000
1987	9056			10			1	9067	9000
1988	7858							7858	7500
1989	5786							5786	7500
1990	3184							3184	7500
1991	2782							2782	10000
1992	2266							2266	10000
1993	659							659	1800
1994	57							57	
1995	46							46	
1996	58							58	
1997	106							106	
1998	277							277	
1999	305							305	
2000	56							56	
2001	59							59	

Note: Landings data to 1985 from NAFO (plus foreign landings only for 1986 and 1987;
    Subsequent landings data from ZIFF.

Table 2. Nominal landings (tonnes) of 4Vn cod (May to October) by gear type.

Year	Trawl	Seine	Handline	Longline	Gn/Trap	Misc	Total
1970	4266	78	481	2461	174	905	8365
1971	4433	97	670	3136	45	694	9075
1972	3634	115	742	2503	219	374	7587
1973	1411	112	585	1477	588	267	4440
1974	1521	111	626	1023	753	118	4152
1975	1144	89	357	769	636	208	3203
1976	565	53	288	512	364	247	2029
1977	877	343	410	1320	204	102	3256
1978	1309	296	359	2175	178	104	4421
1979	473	200	464	3476	8	53	4674
1980	925	443	981	5056	16	177	7598
1981	942	313	735	8623	17	48	10678
1982	1170	637	1316	5587	143	4	8857
1983	1548	769	908	3417	69	6	6717
1984	2736	996	1071	3511	37	8	8359
1985	4428	1049	1392	3770	16	4	10659
1986	3331	1268	1154	4579	15	3	10350
1987	1752	1124	825	5351	16	0	9067
1988	1209	1071	604	4946	12	14	7858
1989	1302	723	703	2900	157	0	5786
1990	743	496	580	1355	9	1	3184
1991	1057	337	379	955	54	0	2782
1992	827	339	232	783	85	0	2266
1993	134	58	78	368	20	0	659
1994	27	16	8	6	0	0	57
1995	19	16	0	11	1	0	46
1996	5	12	0	41	0	0	58
1997	1	20	0	85	0	0	106
1998	13	16	1	247	0	0	277
1999	2	32	1	271	0	0	305
2000	3	17	0	36	0	0	56
2001	1	11	0	47	0	0	59

Note: Landings data to 1985 from NAFO (plus foreign landings only for 1986 and 1987;
    Subsequent landings data from ZIFF.

Table 3 . Commercial sampling information used in the construction of the catch-at-age for NAFO Div. 4Vn cod. (May to October only).

KEYS	YEAR	GEAR	# SAMPLES	# LENGTHS	# AGES	CATCH (t)
	1981	HAND & LONGLINE	7	1884	432	
		HANDLINE	2	569	96	
1		Comb fix	9	2453	528	9423
2		STERN OTT TRWL	1	303	34	1255
1	1982	HANDLINE	10	3323	655	7050
2		DANISH SEINE	2	675	102	1807
1	1983	HAND & LONGLINE	10	3457	381	4400
		DANISH SEINE	3	1013	98	
		STERN OTT TRWL	2	692	45	
2		comb mobile	5	1705	143	2317
	1984	HAND & LONGLINE	19	6423	1109	
		HANDLINE	2	464	39	
1		comb fix	21	6887	1148	4627
2		DANISH SEINE	16	4782	344	996
3		STERN OTT TRWL	15	5375	566	2736
1	1985	HAND & LONGLINE	11	4031	448	5182
		DANISH SEINE	5	1639	125	
		SIDE OTT TRWL	1	203	26	
		STERN OTT TRWL	9	3274	212	
2		comb mobile	15	5116	363	5477
	1986	HAND & LONGLINE	13	5266	658	
		HANDLINE	3	807	95	
1		comb fix	16	6073	753	5752
2		DANISH SEINE	5	1578	180	1268
3		STERN OTT TRWL	10	3786	394	3331
	1987	HAND & LONGLINE	17	5380	678	
		HANDLINE	3	807	142	
1		comb fix	20	6187	820	6192
		DANISH SEINE	1	346	34	
		STERN OTT TRWL	3	869	127	
2		comb mobile	4	1215	161	2876
	1988	HANDLINE	1	184	44	
		LONGLINE	15	5404	916	
1		comb fix	16	5588	960	5578
2		DANISH SEINE	6	1515	302	1071
3		STERN OTT TRWL	5	1625	244	1209
1	1989	LONGLINE	12	4110	483	3761
		DANISH SEINE	1	244	47	

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	STERN OTT TRWL	2	519	93	
2	comb mobile	3	763	140	2025
	1990 HAND & LONGLINE	1	245	59	
	HANDLINE	2	574	77	
	LONGLINE	21	7208	1098	
1	comb fix	24	8027	1234	1945
2	DANISH SEINE	4	845	167	496
3	STERN OTT TRWL	5	1379	217	743
	1991 HAND & LONGLINE	2	483	0	
	HANDLINE	8	1666	0	
	LONGLINE	15	4710	223	
1	comb fix	25	6859	223	1388
	DANISH SEINE	7	2124	0	
	STERN OTT TRWL	14	4343	283	
2	comb mobile	21	6467	283	1394
	1992 HANDLINE	4	1083	0	
	LONGLINE	16	4951	405	
1	comb fix	20	6034	405	1099
	DANISH SEINE	6	2241	135	
	STERN OTT TRWL	9	2671	262	
2	comb mobile	15	4912	397	1166
	1993 HAND & LONGLINE	1	234	0	
	HANDLINE	3	798	33	
	LONGLINE	8	2341	302	
	TRAPNET	1	79	0	
1	comb fix	13	3452	335	466
2	DANISH SEINE	6	1187	166	192
1	1994 DANISH SEINE	6	903	419	57
1	1995 DANISH SEINE	3	502	83	46
1	1996 LONGLINE	2	979	85	41
2	DANISH SEINE	3	505	104	17
1	1997 LONGLINE	7	1457	103	85
	DANISH SEINE	4	683	125	
	STERN OTT TRWL	1	199	41	
2	comb mobile	5	882	166	21
1	1998 LONGLINE	16	3506	585	248
	DANISH SEINE	3	536	69	
	STERN OTT TRWL	3	616	119	
2	comb mobile	6	1152	188	29
	1999 LONGLINE	16	4193	320	

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			1	39	6	
		DANISH SEINE	1	39	6	
1		comb	17	4232	326	305
1	2000	LONGLINE	25	5220	221	36
		DANISH SEINE	6	932	224	
		STERN OTT TRWL	1	203	51	
2		comb mobile	7	1135	275	20

Table 4. July RV survey length weight parameters used in catch at age determinations for NAFO Div. 4Vn cod.

Year	a	b	R^2
1970	0.00961	2.97536	0.99033
1971	0.01172	2.94045	0.98347
1972	0.00533	3.13109	0.98063
1973	0.01208	2.93713	0.96085
1974	0.01489	2.86689	0.96695
1975	0.01941	2.81916	0.98098
1976	0.006	3.11566	0.99363
1977	0.0115	2.96657	0.984
1978	0.00946	2.99658	0.9876
1979	0.00515	3.14363	0.99025
1980	0.01314	2.9043	0.98194
1981	0.01247	2.91822	0.99012
1982	0.00999	2.96084	0.98792
1983	0.01155	2.93406	0.98933
1984	0.00864	3.01183	0.98573
1985	0.00669	3.06956	0.98694
1986	0.01349	2.89227	0.98465
1987	0.00815	3.01408	0.97839
1988	0.01185	2.93856	0.98249
1989	0.00813	3.01788	0.98561
1990	0.00868	3.00341	0.98178
1991	0.00826	3.02134	0.99096
1992	0.00776	3.03447	0.98915
1993	0.00833	3.01005	0.98239
1994	0.00891	2.99149	0.98044
1995	0.0074	3.04609	0.9887
1996	0.01173	2.93009	0.97985
1997	0.00743	3.03961	0.99116
1998	0.01295	2.90374	0.95251
1999	0.01151	2.9322	0.98011
2000	0.00683	3.06103	0.99282
2001	0.01115	2.93137	0.98824

Table 5. Commercial catch at age (000's) for 4Vn cod (May to October).

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	0	0	0	0	0	0	0	1
3	159	26	17	11	6	2	6	14	12	47	46
4	497	268	247	352	94	198	122	172	237	276	533
5	532	1007	703	896	1241	948	682	382	916	365	742
6	452	567	833	1214	1230	1970	913	860	783	354	253
7	620	811	453	674	1468	868	1314	776	766	201	134
8	501	586	490	337	785	612	551	742	484	271	120
9	222	217	197	262	316	284	328	344	281	119	102
10	174	105	87	157	212	159	220	167	117	91	30
11	52	59	45	65	73	87	111	77	48	15	27
12	61	25	25	20	23	42	55	46	10	11	7
13	46	12	8	10	13	21	32	20	4	5	9
14	7	6	0	5	4	8	11	5	5	1	0
15	10	5	3	5	12	7	4	7	2	1	0
16	26	23	9	7	6	28	18	12	0	0	0
Sum	3364	3715	3118	4016	5481	5234	4366	3624	3666	1758	2004

	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	4	2	0	0	0	1	2	1	0
4	62	47	0	0	2	23	11	20	1
5	665	61	2	1	3	13	42	41	8
6	586	166	4	6	4	5	40	75	7
7	205	168	14	9	8	12	27	23	8
8	87	40	9	9	5	6	22	9	4
9	49	10	3	3	9	4	15	20	2
10	23	4	1	1	1	4	7	7	1
11	17	1	0	0	0	1	9	3	1
12	15	3	0	0	0	0	1	1	0
13	4	1	0	0	0	0	1	1	0
14	3	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Sum	1723	505	34	28	32	70	177	202	32

Table 6. Sentinel abundance index at age.

Age	1994	1995	1996	1997	1998	1999	2000
1	0.09	0.14	0.02	0.01	0.00	0.00	0.00
2	0.15	0.77	0.06	0.07	0.02	0.40	0.04
3	1.58	1.79	2.40	0.37	0.65	3.48	1.18
4	8.68	10.54	6.43	9.81	8.07	12.77	7.45
5	34.58	22.64	12.84	23.09	26.09	19.12	12.41
6	17.64	38.63	18.70	12.14	24.51	18.67	10.10
7	48.59	13.97	22.44	12.87	10.93	9.53	9.55
8	13.31	23.70	7.52	14.43	12.84	5.58	3.46
9	4.42	2.33	15.32	8.99	8.58	4.07	1.36
10	0.64	0.49	1.73	8.82	4.27	2.74	0.71
11	0.24	0.00	0.54	0.96	2.44	1.38	0.58
12	0.10	0.00	0.00	0.44	0.61	0.16	0.20
13	0.00	0.00	0.00	0.00	0.00	0.06	0.06
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Mean numbers at age per tow for 4Vn cod from July RV surveys.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
2	6.3	0.96	0.52	0	0	0.72	6.49	0.4	0.66	1.3
3	1.67	42.44	0.28	2.62	0.61	6.58	2.25	6.26	9.09	0.79
4	4.72	10.1	2.35	4.49	1.36	8.58	1.49	4.01	19.21	5.15
5	10.64	26.54	0.3	18.64	2.81	4.73	1.93	2.74	5.6	2.51
6	10.69	16.17	1.58	2.73	3.27	0.88	1.55	1.9	4.44	0.59
7	4.63	10.66	1.47	3.06	0.33	1	0.73	0.72	1.55	1.72
8	2.63	3.59	0.39	2.91	0.54	0.57	1.79	0.21	1.17	0.56
9	0.87	1.97	0.27	0.46	0.23	0.22	1.64	0.24	0.44	0.29
10	0	0.54	0.26	0.22	0.22	0.35	1.41	0.14	0.43	0.15
11	0.3	0	0.19	0	0.11	0	0.24	0.21	0	0
12	0.14	0	0	0	0	0.11	0.23	0.24	0	0.17
13+	0.13	0.56	0.38	0	0	0	0.46	0.15	0.11	0.45
Sum	42.72	113.53	7.99	35.13	9.48	23.74	20.21	17.22	42.7	13.68

Age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0.33	0	0	2.83	0	0	0	0.61	0	0
2	1.88	4.2	2.53	4.38	7.25	0.48	1.33	0.21	0.55	4.6	0.24
3	10.52	17.08	1.74	22.16	10.02	3.75	6.36	3.7	2.49	4.39	15.07
4	3.97	36.48	5.77	7.91	10.48	19.11	11.13	4.14	17.05	11.6	9.03
5	23.6	12.02	10.22	10.66	13.51	125.98	8.11	5.13	13.17	29.78	3.29
6	16.42	25.45	7.61	10.11	8.75	52.14	17.55	8.89	31.86	17.65	3.87
7	5.16	11.5	9.25	1.74	3.58	22.38	6.38	6.63	26.43	32.1	2.05
8	1.16	1.26	3.41	3.45	1.81	7.26	4.92	2.8	18.92	25.55	2.29
9	0.45	0.93	1.32	1.52	1.58	1.44	2.17	1.18	6.24	8.26	0.73
10	0.37	0.86	0.45	0.66	0.85	0.77	1.02	0.62	1.7	1.3	0.81
11	0.37	0.24	0.1	0.25	0.32	0.67	0.55	0.97	0.5	0.33	0.13
12	0	0.16	0.23	0	0.41	0	0.1	0.31	0.24	0	0.09
13+	0	0.31	0	0.44	0.46	0.37	0.22	0	0.32	0	0.05
Sum	63.9	110.82	42.63	63.28	61.85	234.35	59.84	34.58	120.08	135.56	37.65

Age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	0	0	0	0	0	0	0	0	0	0.32	0
1	0.34	0	0	0	0	0.91	0.54	0.21	0.25	0.41	0
2	1.25	0.66	0.4	0.08	1.13	1.66	1.86	1.54	1.12	1.32	2.61
3	0.63	3.44	3.18	1.57	4.47	4.13	5.44	3.48	3.19	3.77	13.43
4	13.88	5.13	6.18	3.87	7.93	7.7	8.67	3.17	5.99	3.5	8.55
5	6.67	44.36	5.7	7.22	7.85	5.35	2.56	3.35	3.33	4.56	5.90
6	4.01	15.15	14.67	1.66	6.18	2.73	1.82	1.72	1.24	3.55	2.71
7	0.92	4.88	7.36	7.28	2.93	3.49	1.61	0.59	0.34	1.68	0.90
8	0.87	3.66	1.74	1.88	3.64	1.87	0.55	0.54	0.11	0.69	0.45
9	0.18	1.31	0.5	0.08	0.94	1.53	0.06	0.52	0.11	0.76	0.26
10	0.37	0.82	0.05	0.34	0.1	0.87	0.34	0.12	0	0.08	0
11	0.37	0.23	0.06	0	0.07	0.07	0.08	0.14	0	0.08	0
12	0	0.4	0.07	0	0.06	0	0	0.06	0	0	0
13+	0.08	0.3	0.05	0	0	0	0	0	0.08	0	0
Sum	29.57	80.34	39.96	23.98	35.3	30.31	23.53	15.44	15.76	20.72	34.81

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Table 8. Mean Weights (gms) at age for 4Vn cod from July RV surveys.

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
1	0	0	0	0	0	0	0	0	0	0	
2	122	167	42	0	0	470	164	129	334	161	
3	258	441	337	495	359	673	548	503	534	397	
4	740	704	635	833	915	973	952	1015	1043	646	
5	1056	1241	1346	1226	1318	1457	1295	1656	2048	1437	
6	1548	1376	1261	1760	1659	2426	2121	2373	3046	2386	
7	2163	1531	1398	1884	2801	2616	2961	3159	3577	3250	
8	3229	2306	3227	2406	2331	3885	2898	5568	5410	5434	
9	2634	1781	1872	2328	2099	2392	4291	2567	6740	8300	
10	0	3600	2215	8800	2784	5152	4631	3200	5950	5600	
11	2970	0	0	0	4900	0	3300	5341	0	0	
12	17500	0	0	0	0	3900	5200	3275	0	9500	

AGE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0	63	0	0	70	0	0	0	107	0	0
2	144	201	143	124	150	136	173	140	135	113	164
3	428	436	445	331	457	270	340	268	355	309	316
4	816	889	798	814	878	576	563	593	669	698	639
5	1268	1315	1302	1223	1438	983	890	721	873	1001	1104
6	1605	1798	1785	1611	1794	1346	1266	1090	1180	1272	1291
7	2512	2475	2001	2410	2859	1555	1713	1387	1492	1646	1622
8	4242	4152	2992	2822	3717	2379	2728	2000	1579	1345	1977
9	5860	4822	3562	4339	4141	2033	3705	3804	2289	1998	3307
10	5964	7348	5701	7838	5110	1850	5813	4826	7055	3487	1826
11	5224	12281	4550	7216	13157	5202	4798	6023	6888	7400	5174
12	0	11000	11050	0	13013	0	2300	5966	11891	0	14400

AGE	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	0	0	0	0	0	94	82	60	92	54	0
2	34	158	126	300	185	259	225	251	175	180	252
3	266	340	339	377	394	399	509	389	444	371	415
4	606	568	619	644	591	616	632	680	642	613	639
5	985	890	844	884	741	829	862	968	949	890	825
6	1413	1473	1150	1108	1208	1134	1113	1270	1195	1177	1233
7	2016	1621	1438	1313	1467	1463	1395	1337	1578	1740	1082
8	1315	2018	2181	1568	1765	1996	2527	2342	2599	1912	1839
9	7048	2164	2729	2205	2105	2395	4165	2179	2494	2102	2787
10	2042	2784	5100	3650	3280	2555	2849	2807	0	2062	0
11	10253	10663	11500	0	2634	5270	1528	2525	0	1795	0
12	0	2705	3300	0	10270	0	0	4076	0	0	0

Table 9. Mean lengths (cm) at age for 4Vn cod from July RV surveys.

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
1	0	0	0	0	0	0	0	0	0	0	
2	23.68	25.34	23	0	0	37.34	26.26	23.72	31.94	26.93	
3	30.51	35.32	31.81	37.1	34.12	40.65	38.35	36.37	38.03	34.61	
4	43.44	41.66	41.37	43.94	46.76	45.78	45.47	45.66	47.95	41.85	
5	49.53	50.26	52.46	50.7	52.61	52.63	51.17	54.52	59.78	52.76	
6	55.89	52.94	51.63	56.29	57.55	63.38	59.57	61.62	68.18	61.47	
7	61.93	54.54	52.48	58.76	68.11	67.78	66.97	67.52	71.74	69.57	
8	67.82	60.53	69.33	62.35	63.98	77.1	66.56	81.09	80.04	82.1	
9	64.7	59.61	59.62	62.52	65.46	63.49	76.82	66.94	89.9	94	
10	0	73	65.38	103	66.86	81.58	77.48	67	87.08	82	
11	69.29	0	91	0	82	0	70	81.09	0	0	
12	109	0	0	0	0	73	79	70	0	100	

AGE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0	20.5	0	0	21.12	0	0	0	19.97	0	0
2	24.44	27.93	25.83	23.77	25.42	26.08	26.37	26.77	24.41	23.63	25.71
3	35.18	35.6	36.22	32.69	35.21	31.91	33.32	31.27	32.97	32.51	32.76
4	43.68	45.03	44.13	43.78	43.73	39.9	39.54	40.36	41.24	43.67	41.42
5	51.35	52.57	52.74	50.57	54.04	47.52	45.97	44.11	45.27	48	49.27
6	56.45	57.76	58.63	56.19	58.45	51.42	51.57	49.81	50.09	52.87	52.78
7	66	64.57	61.66	65.1	69.26	55.22	57.99	53.76	54.12	56.99	55.92
8	76.96	77.8	71.38	68.87	74.12	64.45	67.48	60.78	56.23	55.13	60.01
9	91.15	80.28	76.23	79.2	75.77	64	73.67	73.49	60.45	61.28	70.4
10	88.12	94.59	88.3	95.58	81.63	61	86.19	77.51	87.46	70.51	59
11	88.12	111.15	79	93.89	106.43	82.14	80.48	83.57	88.11	91	76.89
12	0	109	103	0	103.8	0	64	84.96	101.89	0	112

AGE	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	15.18	0	0	0	0	20.62	21.03	18.99	20.55	18.73	0.00
2	18.47	25.84	24.99	31	27	28.67	29.42	30.28	26.3	27.2	30.71
3	30.31	32.48	33.23	34.67	34.81	35.03	37.91	33.98	35.67	34.54	35.45
4	40.05	40.34	41.13	42.01	39.82	39.94	41.34	41.43	41.53	40.94	41.34
5	47.08	46.11	46.1	46.39	43.66	44.74	46.21	46.97	46.9	46.73	45.76
6	54.12	54.97	51.27	49.3	50.33	48.47	49.2	52.32	51.71	51.32	52.18
7	60.04	55.17	54.8	52.49	54.8	53.54	53.81	52.52	56.94	55.59	50.23
8	51.42	57.45	61.37	56.25	57.52	60.48	66.11	63.49	66.69	59.23	59.18
9	90	60.14	62.59	64	61.08	63.25	79	61.82	63.69	61.23	68.59
10	57.41	66.91	79	76	67	63.82	68.07	68.22	0	61	0.00
11	100.85	103	103	0	70	82	61	65.61	0	58	0.00
12	0	67.54	64	0	97	0	0	79	0	0	0.00

Table 10. Summary statistics from SPA

```
Param        Est.          SE          CV         Bias
N Age 3      8.18115     1.20056     0.146747    -0.0165661
N Age 4      6.98953     0.853379    0.122094    -0.00329279
N Age 5      6.28295     0.617222    0.0982375   -0.0224165
N Age 6      5.31289     0.511063    0.0961929   -0.0238088
N Age 7      4.43458     0.457388    0.103141     0.0318639
N Age 8      3.21535     0.448643    0.139532     0.00909016
N Age 9      2.20243     0.443929    0.201563     0.226711
N Age 10     1.55861     0.466592    0.299364     0.62337
RV 3       0.00070725    0.000202    0.286352    -3.98102
RV 4       0.00229214    0.000638    0.278388    -3.77137
RV 5       0.0044323     0.001215    0.274183    -3.67263
RV 6       0.00691089    0.001876    0.271567    -3.63096
RV 7       0.00830346    0.002241    0.269897    -3.64383
RV 8       0.0103143     0.002777    0.269285    -3.73116
RV 9       0.00973476    0.002621    0.269341    -3.91391
RV 10      0.00916669    0.002466    0.269074    -4.08562
SS 5       0.0262467     0.012857    0.489868    -11.6397
SS 6       0.0635556     0.030591    0.481344    -11.4251
SS 7       0.131881      0.063106    0.478512    -11.4787
SS 8       0.276686      0.131172    0.474082    -11.5582
SS 9       0.451714      0.21526     0.47656     -12.2264
SS 10      0.525325      0.250382    0.476623    -12.7696
```

Table 11. Effects of Bias correction from bootstrapping.

Age 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000

```
    1.00 1.00 1.00 0.99 0.98 0.96 0.97 0.99 0.98 0.99 0.99 1.01 0.96 1.00 1.00
    1.00 1.00 1.00 1.00 0.99 0.98 0.96 0.97 0.99 0.98 0.99 0.99 1.01 0.96 1.00
    1.00 1.00 1.00 1.00 1.00 0.99 0.98 0.96 0.97 0.99 0.98 0.99 0.99 1.01 0.96
    1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.98 0.96 0.97 0.99 0.98 0.99 0.99 1.01
    1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99 0.98 0.96 0.97 0.99 0.98 0.99 0.99
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99 0.98 0.96 0.97 0.99 0.98 0.99
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.98 0.99 0.98 0.96 0.97 0.99 0.98
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.98 0.99 0.98 0.96 0.97 0.99
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 1.00 0.98 0.98 0.97 0.96 0.97
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99 1.00 0.97 0.98 0.97 0.95
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99 1.00 0.96 0.98 0.97
    1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.98 0.97 0.96 0.97
```

Table 12. Estimates of coefficient of variation from bootstrapping

```
 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
 0.00 0.00 0.04 0.08 0.19 0.36 0.31 0.32 0.32 0.37 0.43 0.48 0.65 0.36 0.36
 0.00 0.00 0.00 0.04 0.08 0.19 0.36 0.31 0.32 0.32 0.37 0.43 0.48 0.65 0.36
 0.00 0.00 0.00 0.00 0.04 0.08 0.19 0.36 0.31 0.32 0.32 0.37 0.43 0.48 0.65
 0.00 0.00 0.00 0.00 0.00 0.04 0.08 0.19 0.36 0.31 0.32 0.32 0.37 0.43 0.48
 0.00 0.00 0.00 0.00 0.00 0.00 0.04 0.09 0.20 0.36 0.31 0.32 0.32 0.37 0.43
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.08 0.10 0.20 0.36 0.31 0.32 0.32 0.37
 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.13 0.10 0.20 0.36 0.31 0.32 0.32
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.00 0.14 0.12 0.22 0.37 0.33 0.34
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.05 0.00 0.16 0.13 0.24 0.39 0.36
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.05 0.07 0.01 0.22 0.16 0.28 0.47
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.06 0.09 0.01 0.30 0.19 0.31
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.02 0.04 0.06 0.19 0.22 0.31 0.31
```

Table 13. Effect of adding SS to July RV survey as tuning data

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
0.99	1.00	0.92	0.91	0.84	0.78	0.77	0.97	0.91	0.84	0.82	0.93	0.93	0.79	0.79
1.00	0.99	1.00	0.92	0.91	0.84	0.78	0.77	0.97	0.91	0.84	0.82	0.93	0.93	0.79
1.00	1.00	0.99	1.00	0.92	0.91	0.84	0.78	0.77	0.97	0.91	0.84	0.82	0.93	0.93
1.00	1.00	1.00	0.99	1.00	0.92	0.91	0.84	0.78	0.77	0.97	0.91	0.84	0.82	0.93
1.00	1.00	1.00	1.00	0.99	1.00	0.92	0.91	0.84	0.78	0.77	0.97	0.91	0.84	0.82
1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.89	0.90	0.84	0.78	0.77	0.97	0.91	0.84
1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	0.86	0.90	0.84	0.78	0.77	0.97	0.91
1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96	1.00	0.85	0.89	0.83	0.78	0.76	0.97
1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.92	0.99	0.84	0.88	0.82	0.76	0.74
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.90	0.99	0.80	0.87	0.80	0.72
1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	0.94	0.89	0.99	0.77	0.85	0.79
1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.96	0.94	0.83	0.83	0.77	0.79

Table 14. Effect of adding SS and DFO inshore age 0 to July RV survey as tuning data

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09	1.11	2.22	1.93	0.94	0.94
1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09	1.11	2.22	1.93	0.94
1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09	1.11	2.22	1.93
1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09	1.11	2.22
1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09	1.11
1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83	1.09
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.99	1.01	0.83	0.83
1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.98	0.96	0.99	1.01	0.82
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.97	0.95	0.98	1.01
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	0.97	0.95	0.98
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	0.98	0.96	0.94
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.97	0.98	0.94

Table 15. Residuals from SPA.

Residuals

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
RV 3	0.08	-2.04	0.16	0.01	-0.74	0.36	-0.31	-0.52	-0.33	1.19	-0.61
4	0.35	-1.70	-1.21	-1.28	-0.04	-0.35	-0.75	0.55	0.40	-0.24	0.56
5	-0.51	-1.01	-1.23	-0.78	1.11	-0.97	-1.20	0.33	1.27	-0.83	-0.49
6	0.09	-0.95	-0.98	-1.36	0.71	-0.66	-0.67	0.82	0.98	-0.33	-0.32
7	-0.44	-0.56	-2.16	-1.74	0.07	-0.95	-1.07	0.99	1.45	-0.56	-1.11
8	-2.04	-1.19	-1.17	-1.84	-0.54	-0.83	-1.23	0.67	1.73	-0.39	-0.68
9	-1.34	-1.27	-1.27	-1.31	-1.42	-0.88	-1.31	0.68	0.94	-0.80	-1.47
10	-0.86	-1.26	-1.22	-1.07	-1.25	-1.01	-1.06	0.19	0.46	-0.26	-0.59
SS 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Age	1992	1993	1994	1995	1996	1997	1998	1999	2000
RV 3	0.88	0.02	-0.28	0.67	0.44	0.73	0.15	0.14	0.00
4	0.95	0.92	-0.33	0.81	0.73	0.73	-0.24	0.29	-0.14
5	2.02	1.09	1.03	0.33	0.40	-0.37	-0.19	-0.13	0.11
6	1.18	1.67	0.20	1.19	-0.40	-0.33	-0.39	-0.79	0.34
7	1.03	2.26	1.84	1.49	1.33	-0.22	-0.70	-1.24	0.30
8	1.59	1.58	2.41	1.87	1.80	0.22	-0.59	-1.62	0.26
9	1.58	1.67	0.00	3.14	2.14	-0.57	1.21	-1.10	1.37
10	2.12	0.76	2.80	1.35	4.47	1.82	1.19	-6.29	-0.31
SS 5	0.00	0.00	0.92	-0.29	-0.40	0.16	0.20	-0.05	-0.55
6	0.00	0.00	0.52	0.98	-0.52	-0.47	0.24	-0.11	-0.64
7	0.00	0.00	1.13	0.46	0.59	-0.75	-0.38	-0.49	-0.56
8	0.00	0.00	1.35	0.66	0.11	0.39	-0.51	-0.78	-1.21
9	0.00	0.00	0.39	0.46	0.81	0.79	0.37	-1.13	-1.70
10	0.00	0.00	-0.45	-0.96	1.32	1.20	0.87	0.03	-2.01

Table 16. Estimates of population numbers from SPA ('000)

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	36715	19310	15356	8624	9885	8206	12195	9673	2755	3695
2	17478	24611	12944	10294	5781	6626	5500	8174	6484	1767
3	14587	12315	17343	9121	7254	4074	4669	3876	5760	4397
4	8767	10751	9100	12836	6746	5368	3013	3439	2858	4120
5	4481	6571	8109	6797	9666	5136	4059	2234	2475	1877
6	3746	3186	4278	5792	4579	6432	3237	2578	1435	1074
7	2670	2551	2132	2995	3559	2613	3281	1703	1390	587
8	1265	1530	1353	1347	1792	1630	1370	1523	755	555
9	506	634	704	761	793	756	687	588	555	249
10	284	229	312	368	403	403	331	262	168	182
11	95	135	104	148	156	170	182	97	76	42
12	65	50	63	53	56	73	66	58	14	19
Sum										
1-12	90659	81873	71799	59136	50670	41487	38591	34205	24725	18564

Age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	8870	6603	7994	10285	11296	14231	14619	21958	14424	14424
2	2268	5211	3712	4300	5295	5565	6709	6595	9479	5959
3	1153	1424	3148	2158	2405	2850	2882	3343	3162	4374
4	3021	748	920	1977	1311	1414	1621	1586	1781	1630
5	2843	1874	470	587	1305	842	883	980	938	1024
6	1101	1530	718	283	399	868	545	556	604	563
7	504	515	306	214	123	170	367	226	223	238
8	292	208	93	33	86	48	68	150	87	85
9	186	93	28	14	8	32	18	26	56	32
10	99	35	9	4	4	2	10	6	9	19
11	59	43	3	1	1	2	1	3	2	3
12	17	21	6	1	0	0	0	0	1	1
Sum										
1-12	20415	18304	17406	19857	22235	26025	27724	35428	30767	28351

Table. 17. Estimates of fishing mortality SPA ('000)

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	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03	0.01
4	0.04	0.03	0.04	0.03	0.02	0.03	0.05	0.08	0.14	0.07	0.15	0.11
5	0.11	0.20	0.11	0.17	0.18	0.23	0.22	0.21	0.58	0.25	0.31	0.63
6	0.18	0.20	0.16	0.29	0.36	0.47	0.44	0.42	0.67	0.51	0.33	1.00
7	0.36	0.43	0.26	0.31	0.58	0.45	0.57	0.61	0.70	0.45	0.46	1.11
8	0.49	0.58	0.38	0.33	0.66	0.66	0.65	0.81	0.89	0.85	0.72	1.39
9	0.59	0.51	0.45	0.44	0.48	0.63	0.76	1.05	0.89	0.68	1.24	1.70
10	0.55	0.59	0.55	0.66	0.66	0.59	1.03	1.04	1.17	0.88	0.42	1.74
11	0.45	0.55	0.48	0.77	0.56	0.75	0.94	1.74	1.16	0.66	0.63	1.29
12	0.78	0.80	0.65	0.68	0.86	0.90	1.16	1.38	1.41	1.14	1.14	2.30
Ave												
5-7	0.22	0.28	0.17	0.26	0.37	0.38	0.41	0.41	0.65	0.41	0.37	0.91

Age	1993	1994	1995	1996	1997	1998	1999	2000
1	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
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.06	0.00	0.00	0.00	0.01	0.00	0.00	0.01
5	0.15	0.00	0.00	0.00	0.01	0.00	0.00	0.00
6	0.42	0.02	0.02	0.01	0.00	0.02	0.01	0.00

```
 7 1.44   0.10   0.10   0.06   0.02   0.06   0.05   0.03
 8 1.07   0.58   0.14   0.15   0.10   0.08   0.08   0.08
 9 1.29   0.39   0.56   0.33   0.19   0.15   0.18   0.10
10 1.72   0.27   0.22   0.54   0.29   0.16   0.10   0.15
11 0.98   1.20   0.06   0.75   0.74   0.03   0.49   0.16
12 1.95   0.59   0.44   0.49   0.28   0.19   0.18   0.16
Ave -------------------------------------------------
5-7 0.67  0.04   0.04   0.02   0.01   0.02   0.02   0.01
```

Table 18. Estimates of biomass (t) from SPA ('000)

```
Age   1981   1982   1983   1984   1985   1986   1987   1988   1989   1990   1991
------------------------------------------------------------------------------------
 1    2120   1115    887    498    571    474    704    558    159    213    512
 2    3908   4263   2242   1783   1001   1148    953   1416   1123    306    393
 3    6710   4957   7297   3805   2753   1513   1914   1574   2544   1896    460
 4    7204   7330   6344   8873   4595   3388   1884   2287   1872   3169   2046
 5    5447   7065   8358   7122   9248   4818   3896   2140   2189   1816   2793
 6    7417   4919   6002   8263   6005   7974   3842   3293   1674   1313   1472
 7    7400   5468   4200   5478   6298   4300   4899   2557   2268    908    889
 8    4921   4579   3381   3213   4030   3424   2923   2938   1427   1217    579
 9    2580   2622   2503   2323   2178   2006   1836   1668   1282    557    541
10    1534   1218   1389   1491   1394   1322   1091   1049    554    493    305
11     770    897    658    757    754    765    791    458    339    186    225
12     536    383    515    455    381    481    405    392     89    100    103
Sum -------------------------------------------------------------------------------
5-12 30605  27152  27005  29102  30289  25090  19682  14495   9823   6592   6907

Age   1992   1993   1994   1995   1996   1997   1998   1999   2000
-----------------------------------------------------------------
 1     381    462    594    652    822    844   1268    833    833
 2     903    643    745    917    964   1162   1142   1642   1032
 3     481    771    842    939   1112   1071   1305   1235   1625
 4     435    409    740    831    907   1065    956   1142   1071
 5    1468    354    460   1024    714    845    848    795    980
 6    1591    686    306    515    903    666    702    628    688
 7     728    371    281    177    277    565    363    364    367
 8     393    150     54    142     83    154    277    149    191
 9     190     63     28     16     67     42     61    116     76
10     108     24     10      8      6     25     13     26     47
11     129     14      2      4      3      2     10      5     12
12      76     19      2      0      2      1      0      5      2
Sum -------------------------------------------------------------
5-12  4684   1681   1143   1886   2055   2301   2273   2088   2363
```
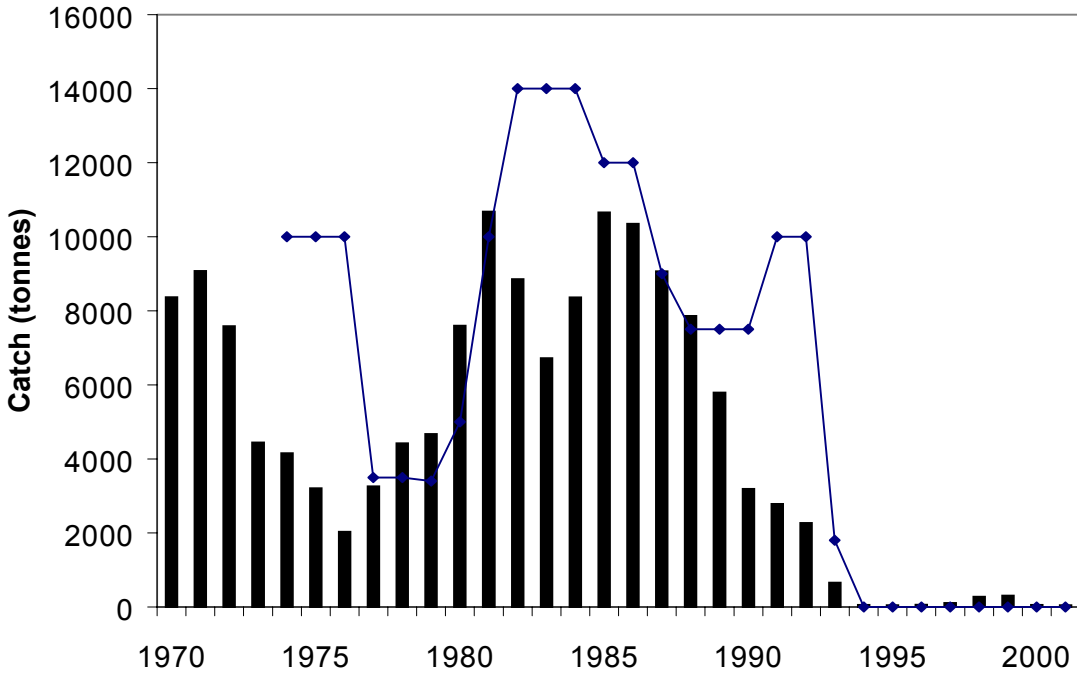
Figure 1. Landings (May to October) and TAC (tonnes).
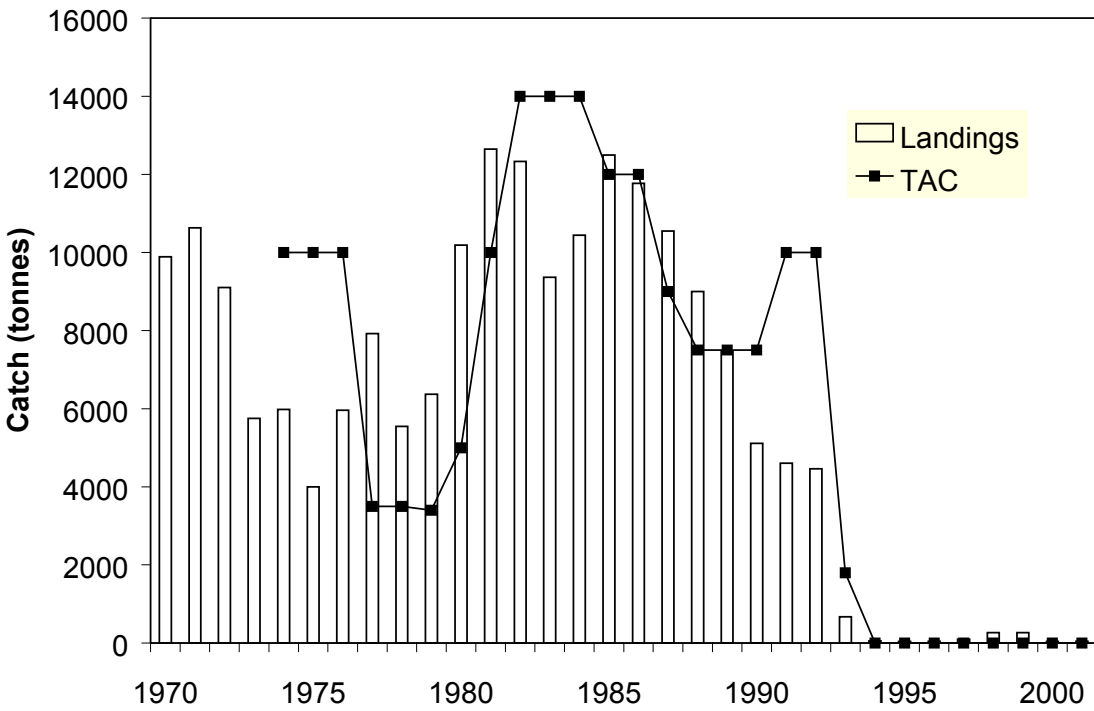
Figure 2. Total landings and TAC (tonnes).

All gear 1990-1993

4VN Cod, Landed MAY-OCT 1990-1993
Live_Wt (from Scotia-Fundy Region) from ZIF Data

2969 subtrips
2334 Metric tonnes shown

Metric tonnes
● 4
● 10
● 20
● 40
· 0

3P

5 minute sq. agg.
5014 Metric tonnes Overall (including data with no lat lon)

All gear 1994-2001

4VN Cod, Landed MAY-OCT 1994-2001
Live_Wt (from Scotia-Fundy Region) from ZIF Data

3054 subtrips
572 Metric tonnes shown

Metric tonnes
● 1
● 2.5
● 5
● 10
+ 0

3P

200 m
5 minute sq. agg.
812 Metric tonnes Overall (including data with no lat lon)

Longlines 1994-2001

4VN Cod, Landed MAY-OCT 1994-2001 from linglines only
Live_Wt (All Regions) from ZIF Data

Line

837 subtrips
435 Metric tonnes shown

Metric tonnes
● 1.5
● 3.8
● 7.5
● 15

3P

5 minute sq. agg.
673 Metric tonnes Overall (including data with no lat lon)

Figure 3. Distribution of catches before (1990 - 1993) and after (1994-2001) closure

Sentinel Survey All years effort
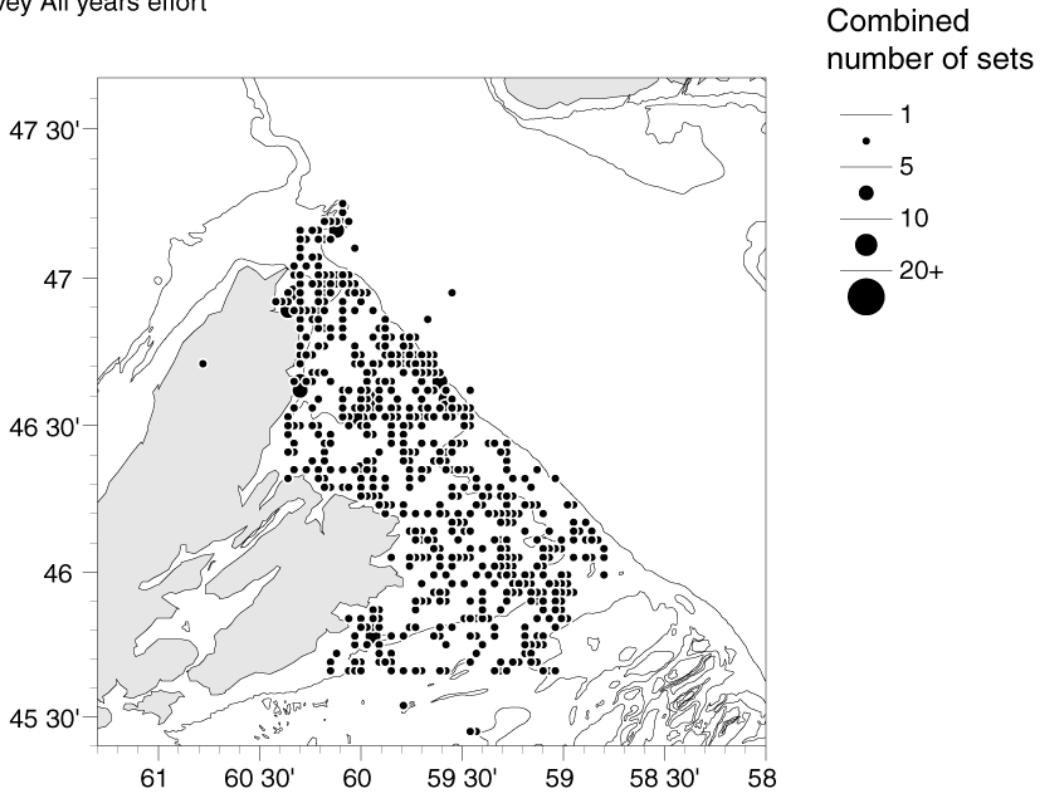
Commercial Index All years effort

Combined
number of sets

———— 1
· 5
● 10
⬤ 20+
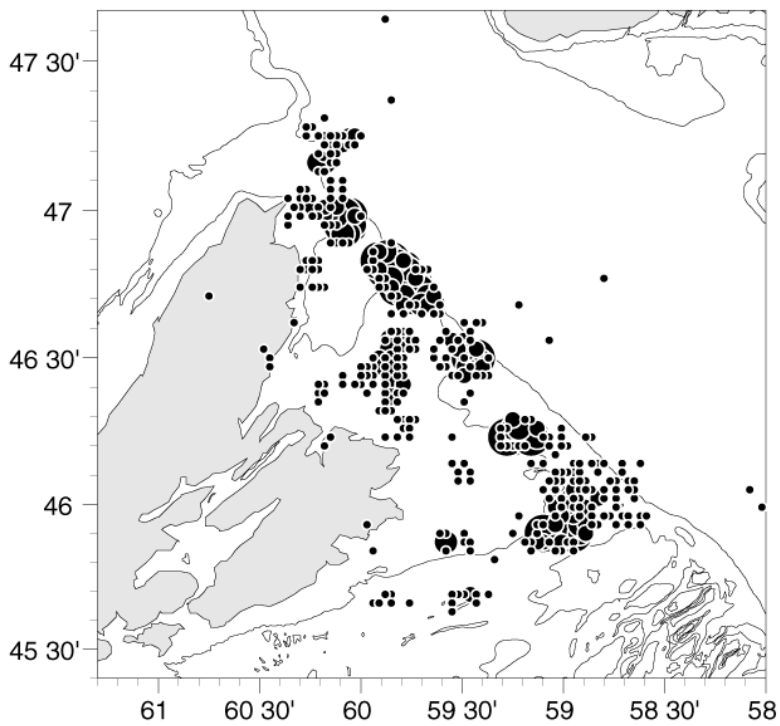
Figure 4. Distributions of Sentinel Survey and Commercial Index sets.

Sentinel Survey All years catch rate

Average catch
rate (kg/hk)
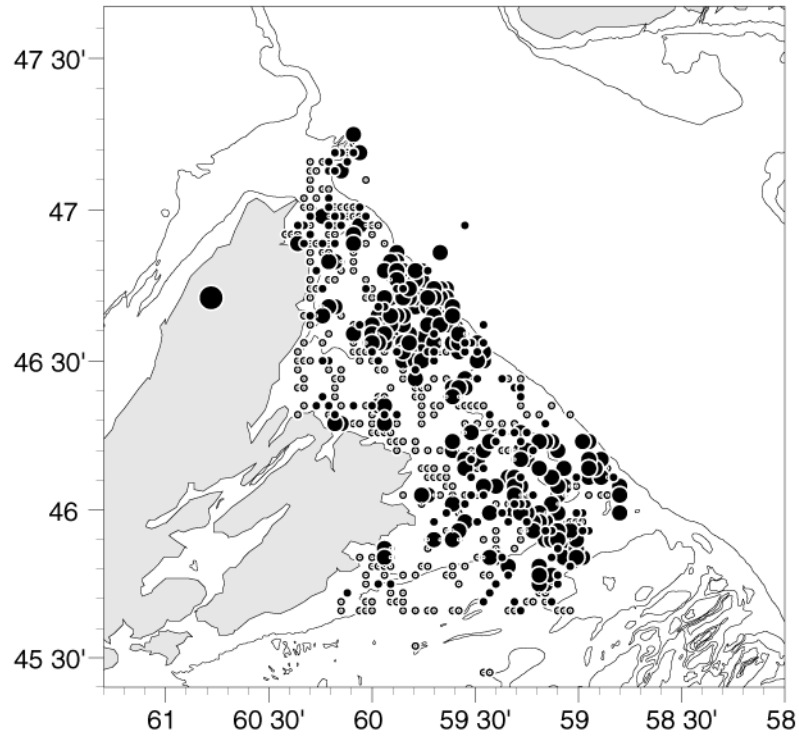
Commercial Index All years Catch rate
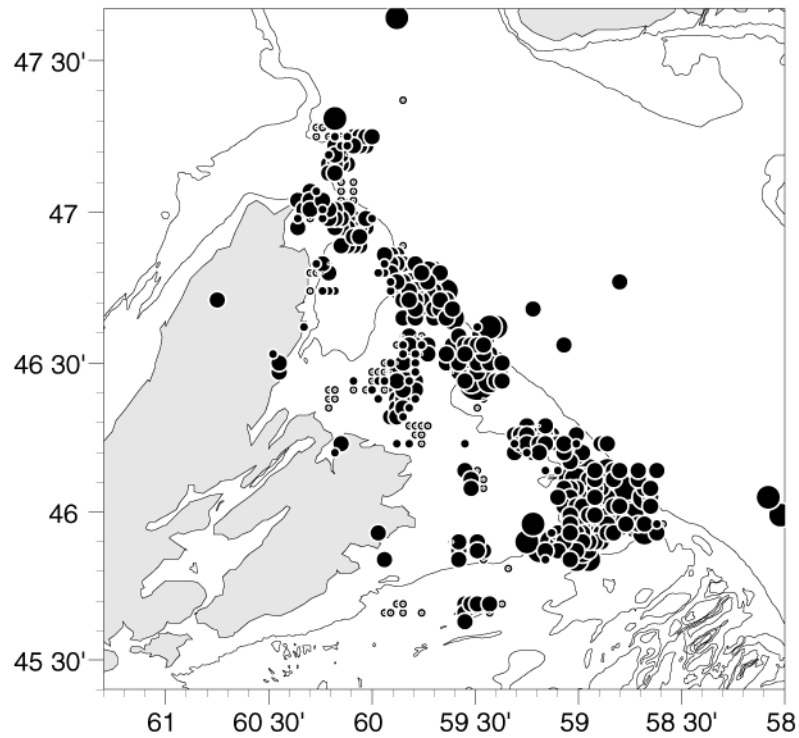
Figure 5. Distributions of SS and CI catch rates.
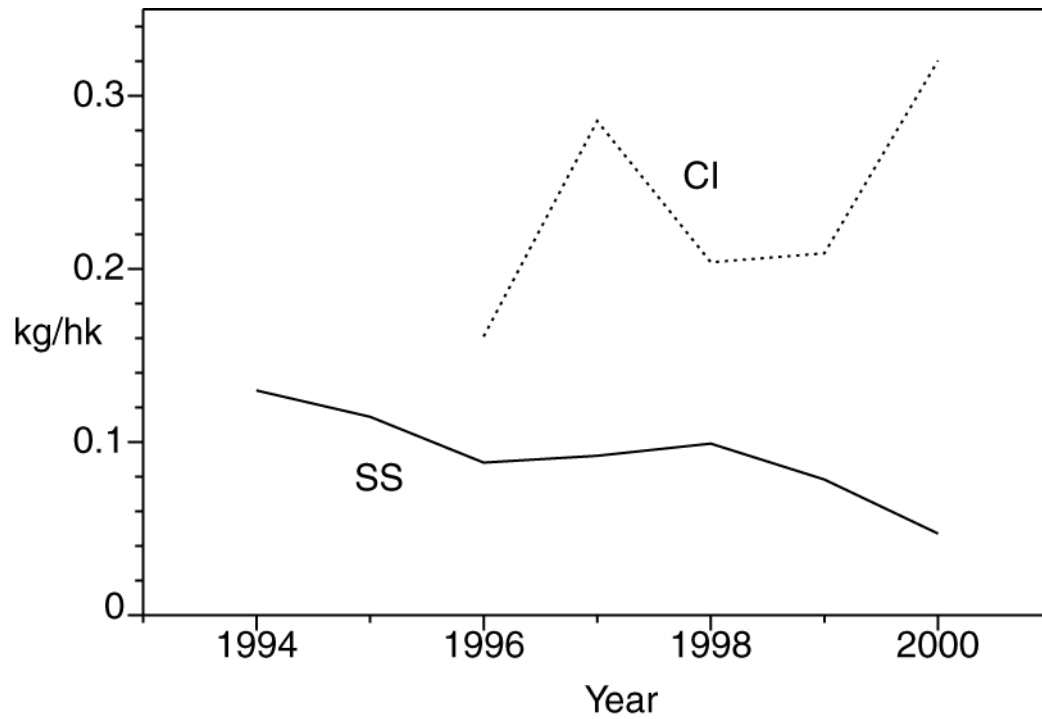
Figure 6. Stratified Sentinel Survey (SS) and Commercial Index (CI) catch rates.
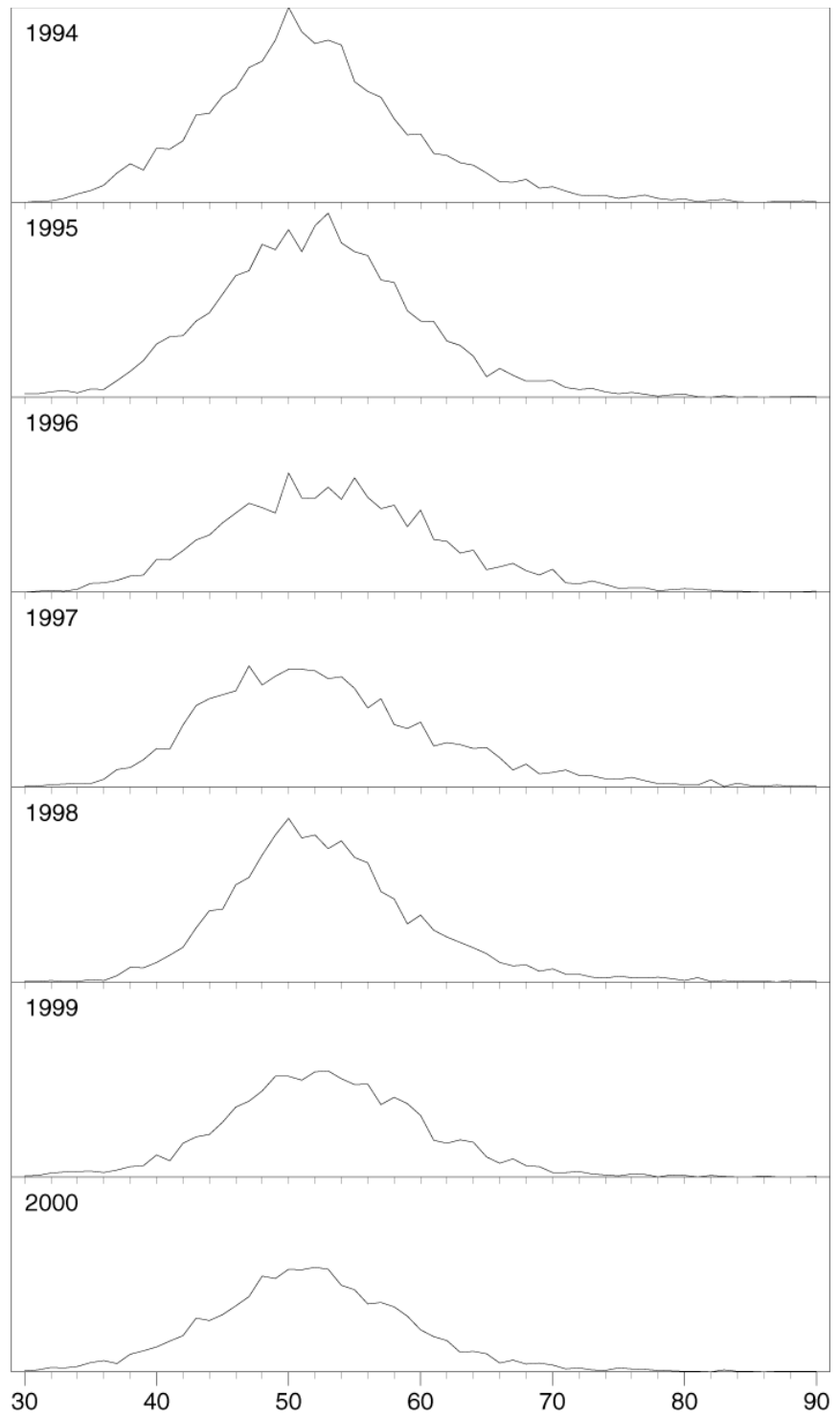
Figure 7. Length frequencies from SS. Common scale used for all years.
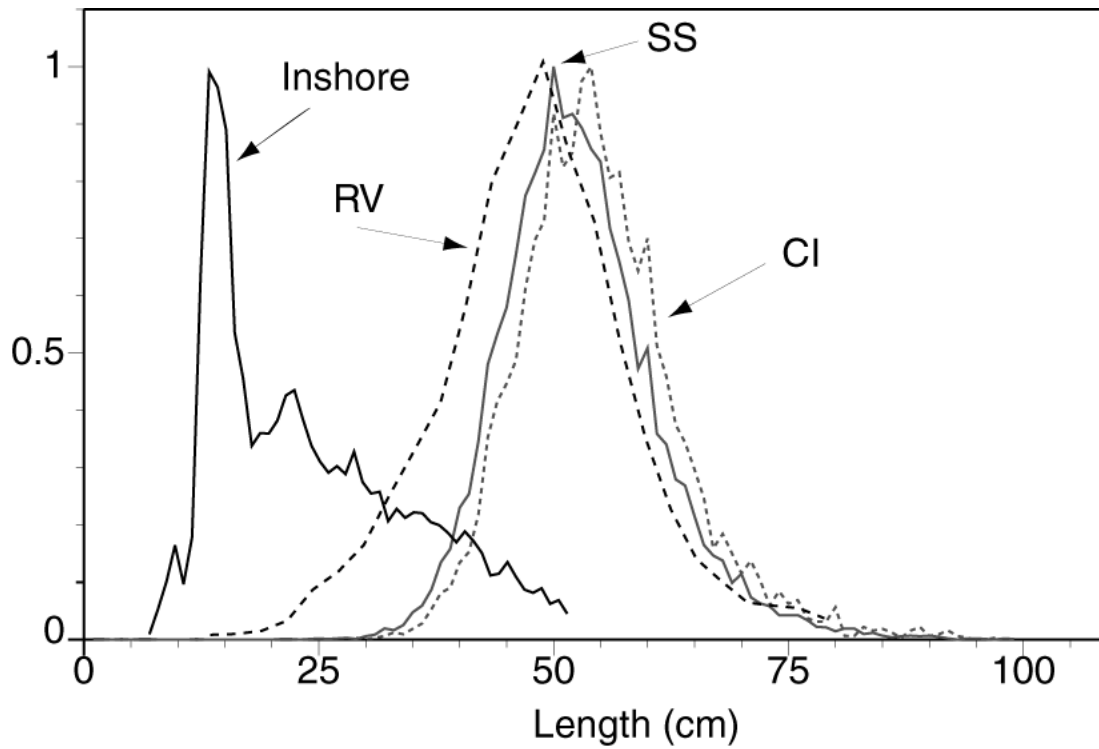
Figure 8. Comparison of Sentinel Survey (SS), Commercial Index (CI), Inshore Survey and RV survey size frequencies.
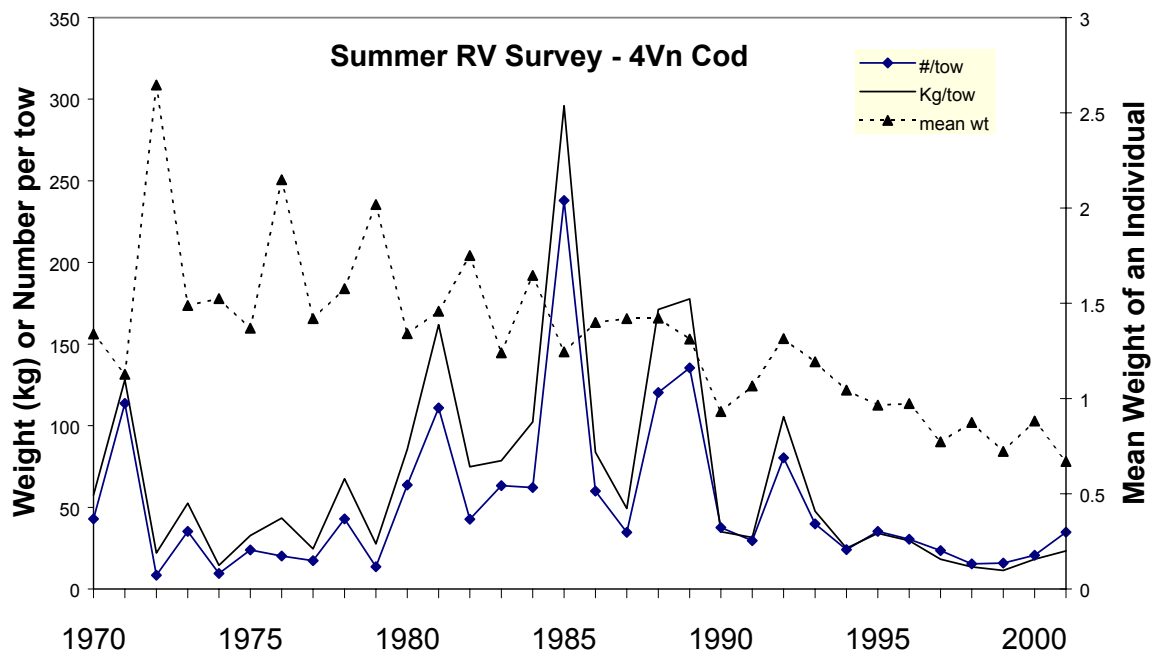
Figure 9. Mean weight/ number per tow as well as mean weight (kg) of a fish in a tow for 4Vn cod from July RV surveys.
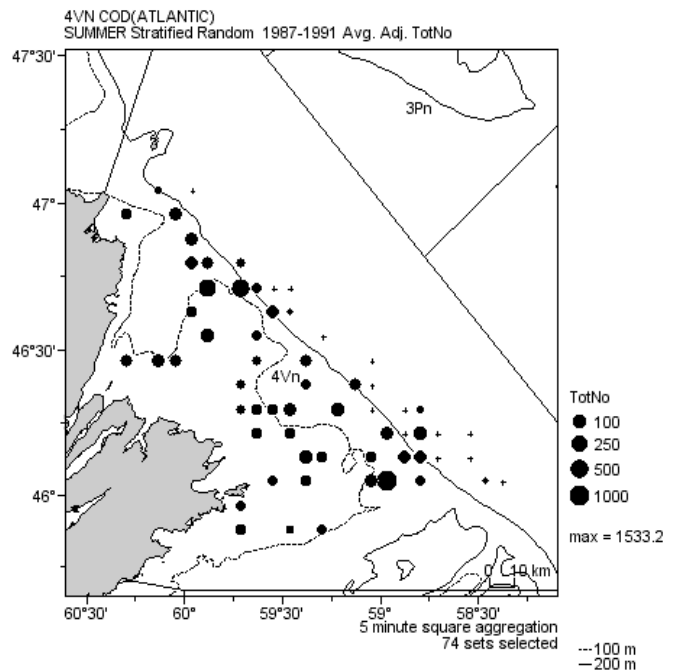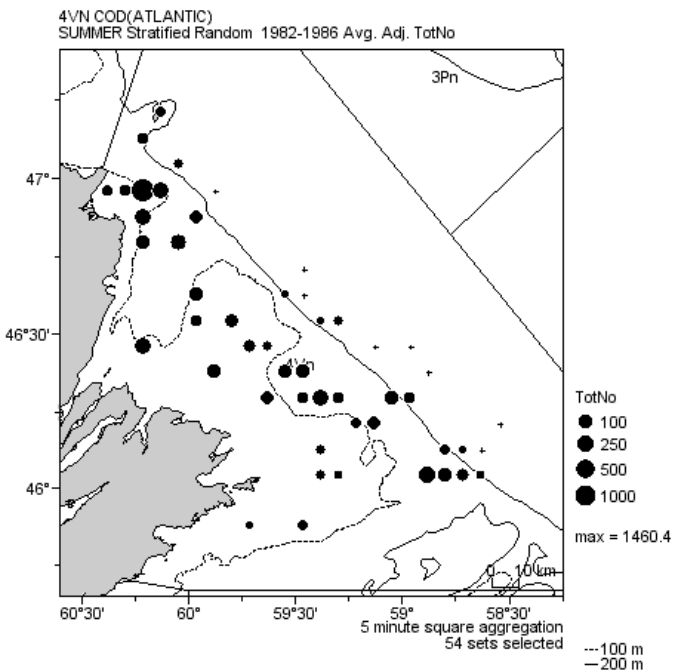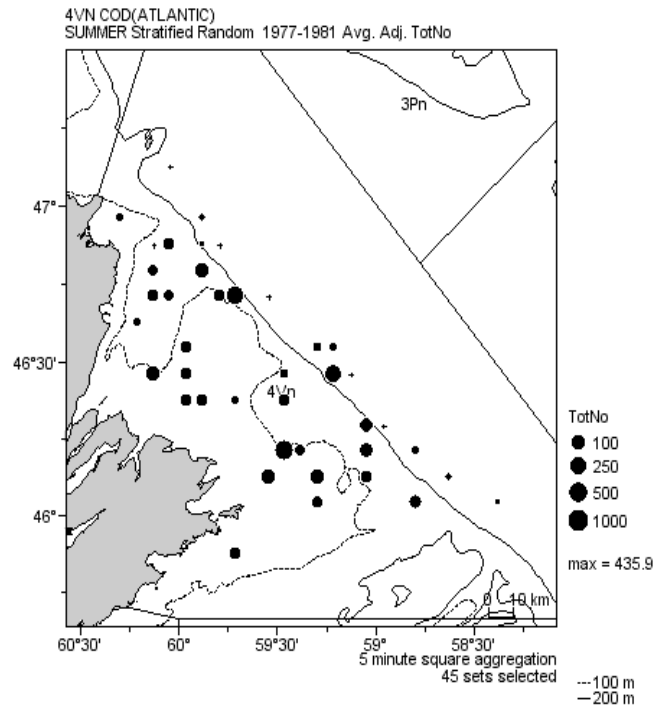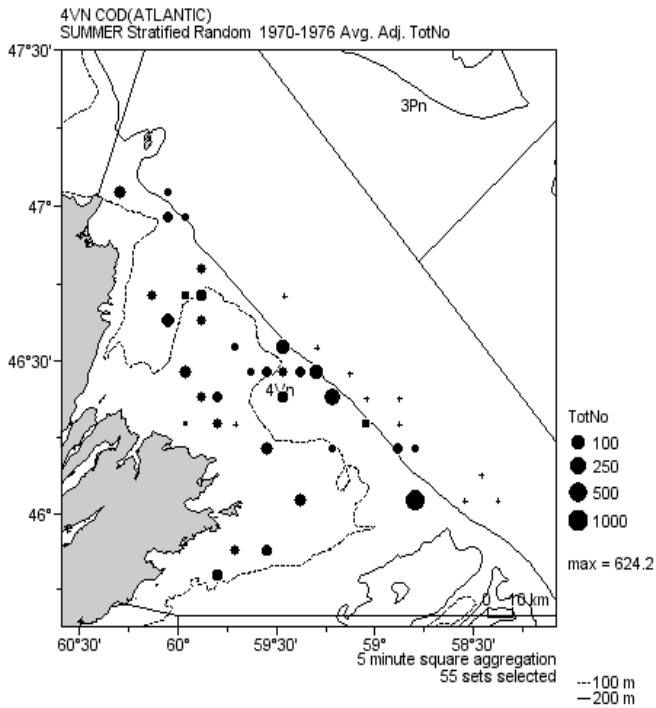
Figure 10. Distribution of 4Vn Cod from July RV surveys.

4VN COD(ATLANTIC)
SUMMER Stratified Random 1992-1996 Avg. Adj. TotNo

4VN COD(ATLANTIC)
SUMMER Stratified Random 1997-2001 Avg. Adj. TotNo
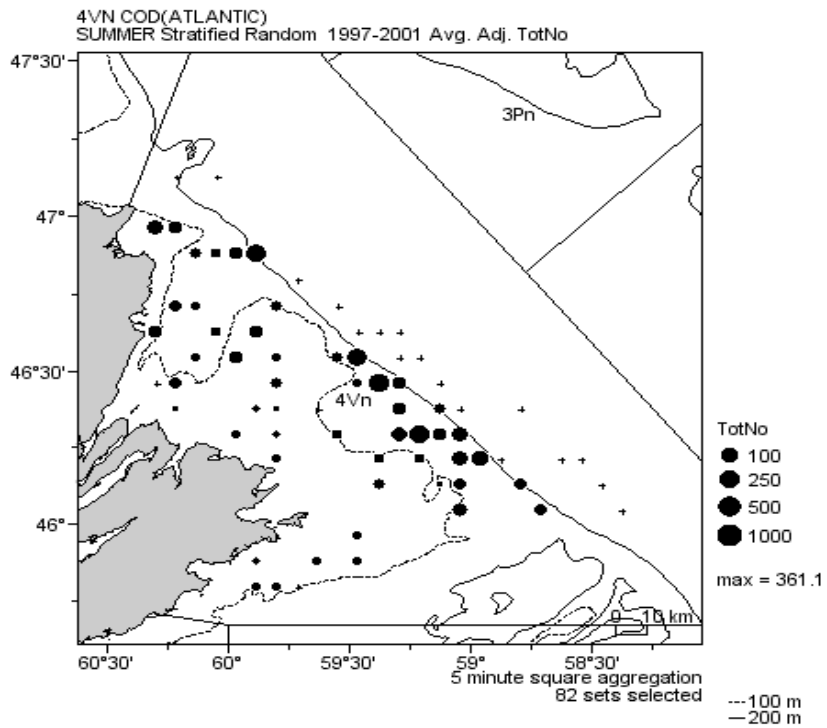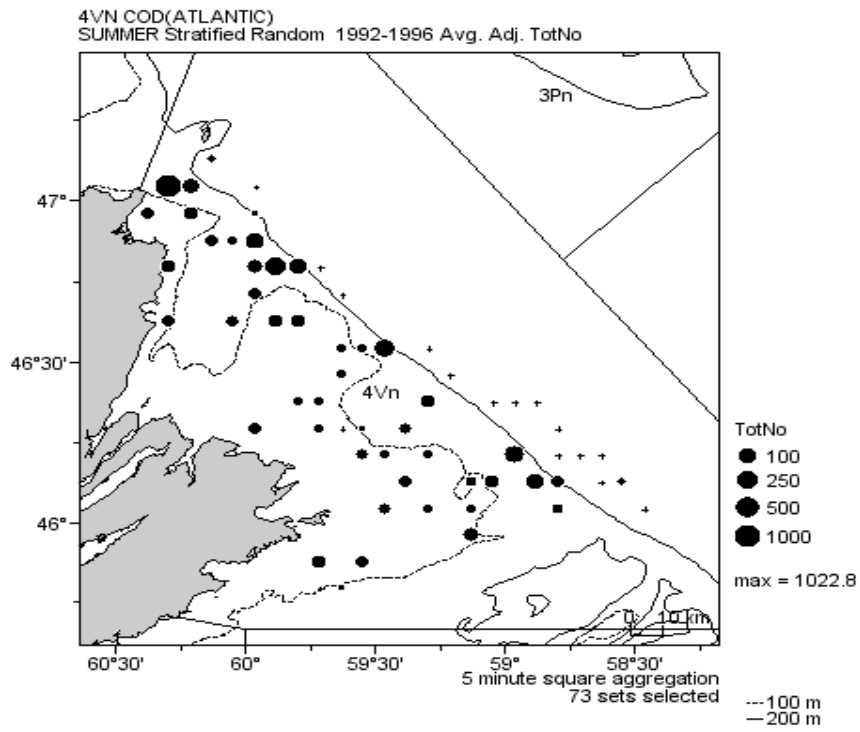
Figure 10.   (Cont.)
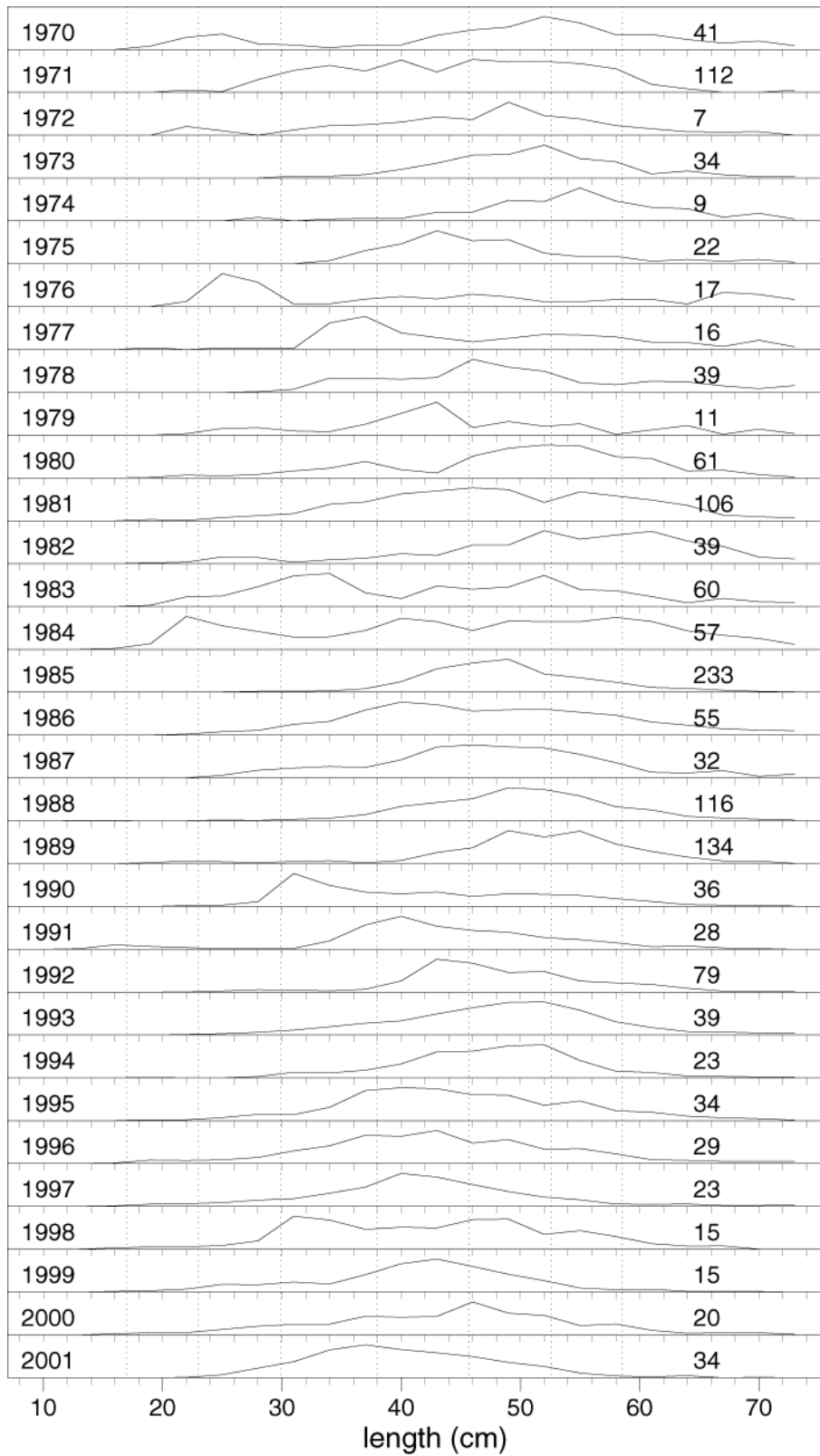
Figure 11. NAFO Div. 4Vn cod length frequencies from July RV survey. (Numbers on the right indicate relative magnitude of each plot.)
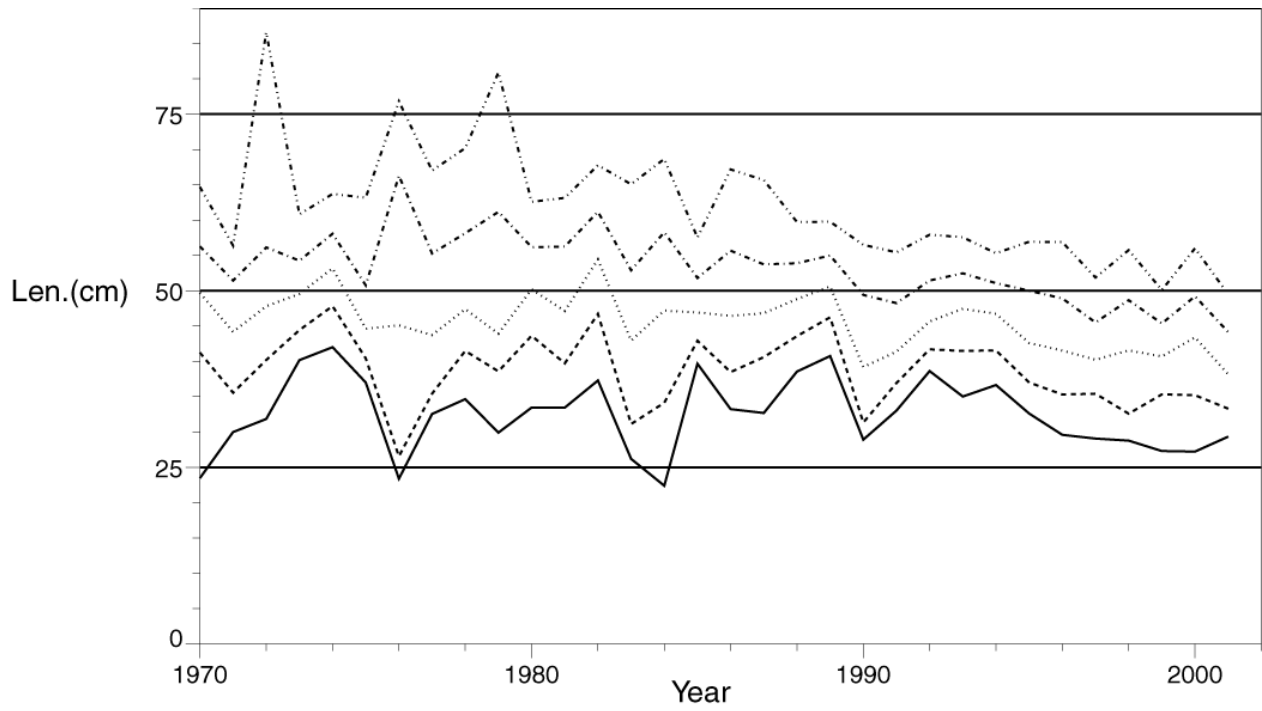
Figure 12. Cumulative distributions of NAFO Div. 4Vn cod lengths from July RV survey. 10, 25, 50, 75 and 90th percentiles.
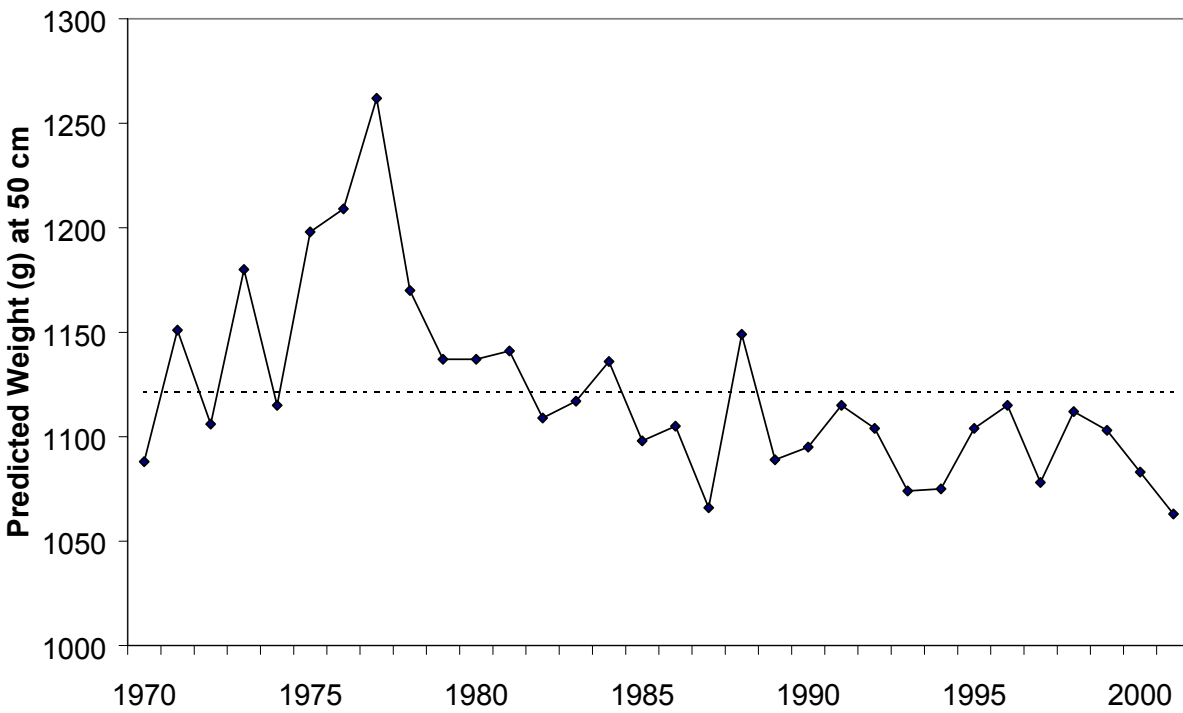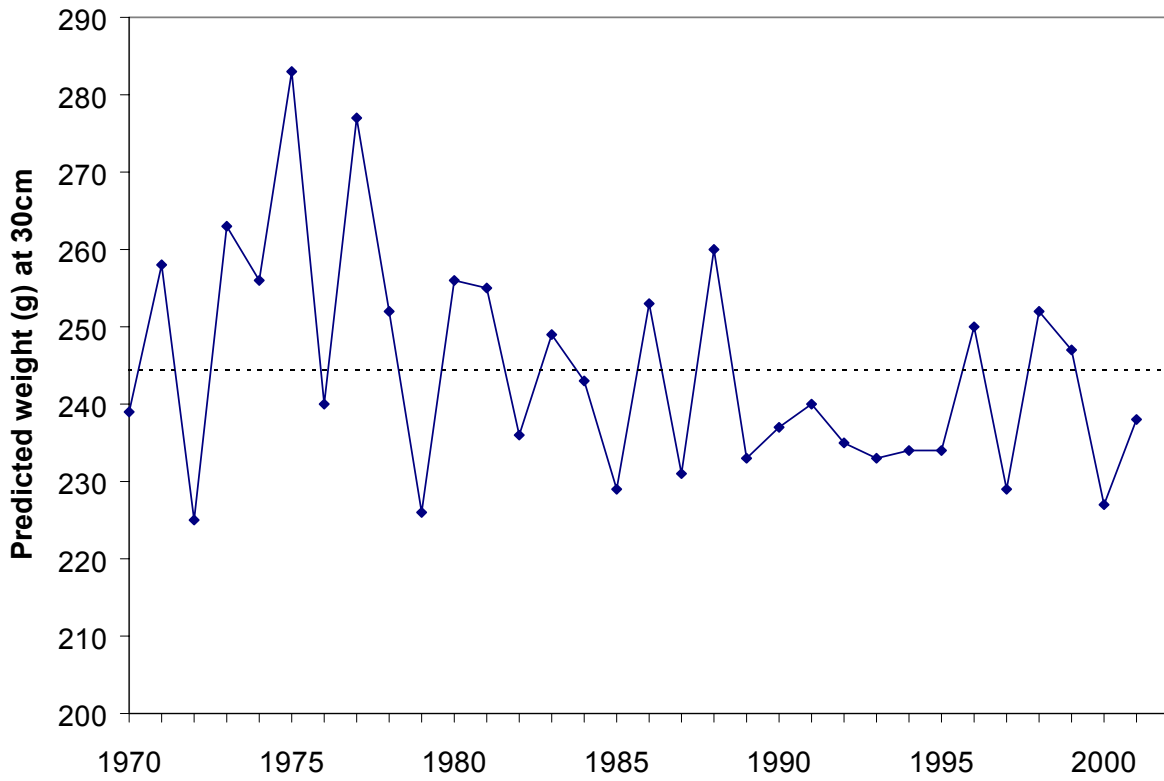
Figure 13. NAFO Div. 4Vn cod condition factor at length 30 and 50 cm from the July RV Survey.
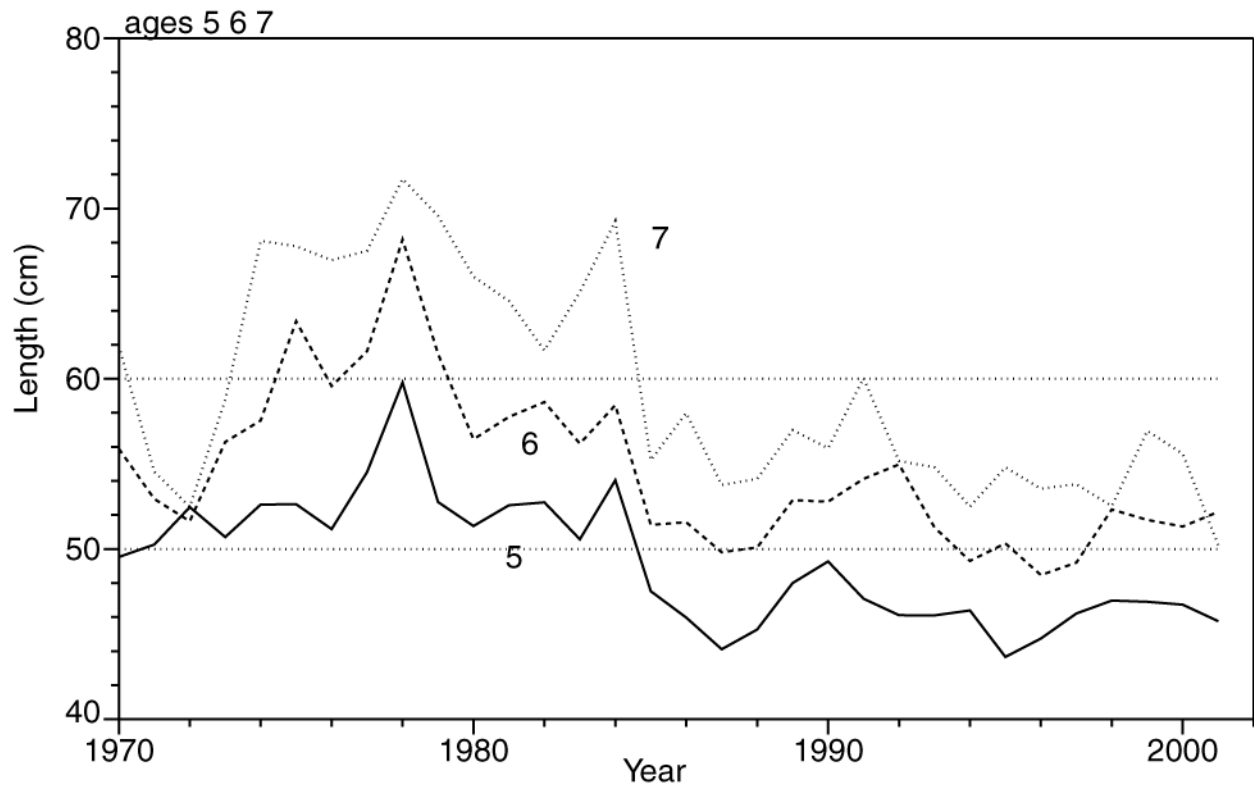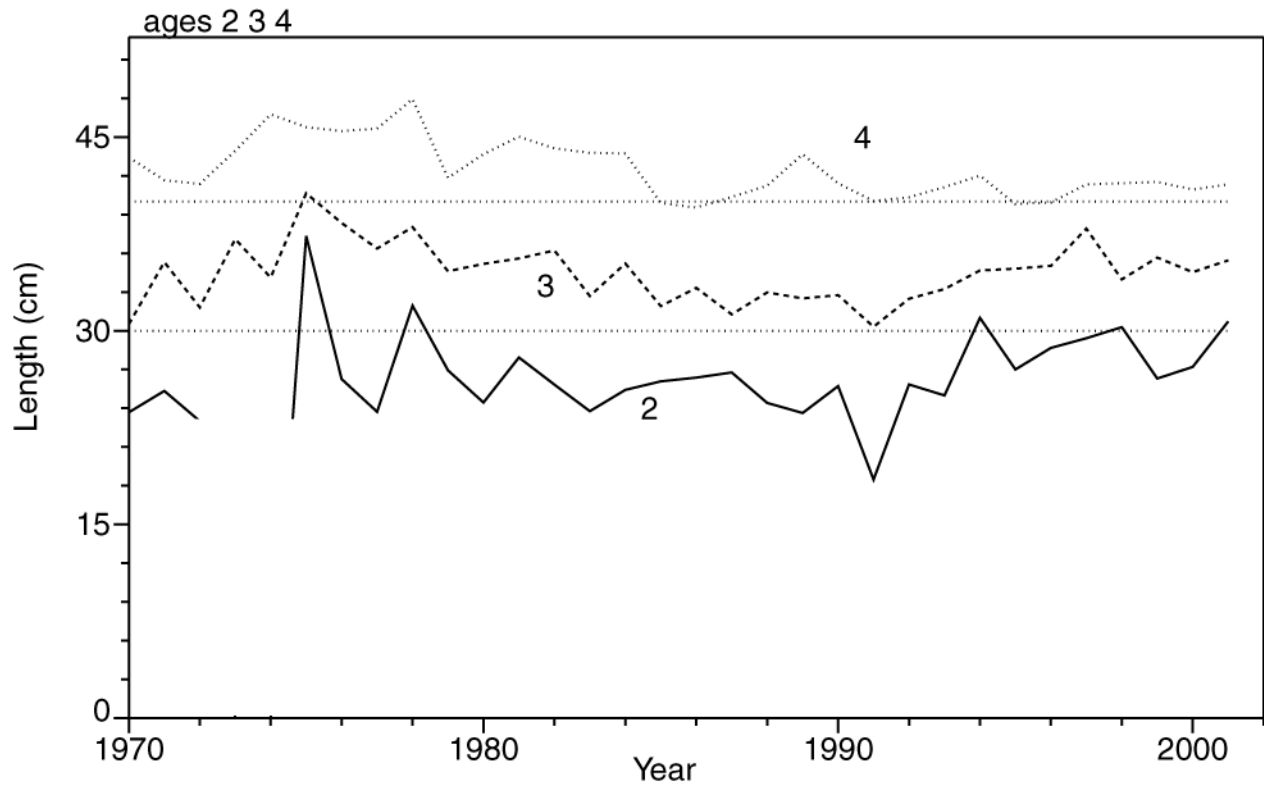
Figure 14. Length at age from July RV survey. Ages 2-4 above and 5-7 below.
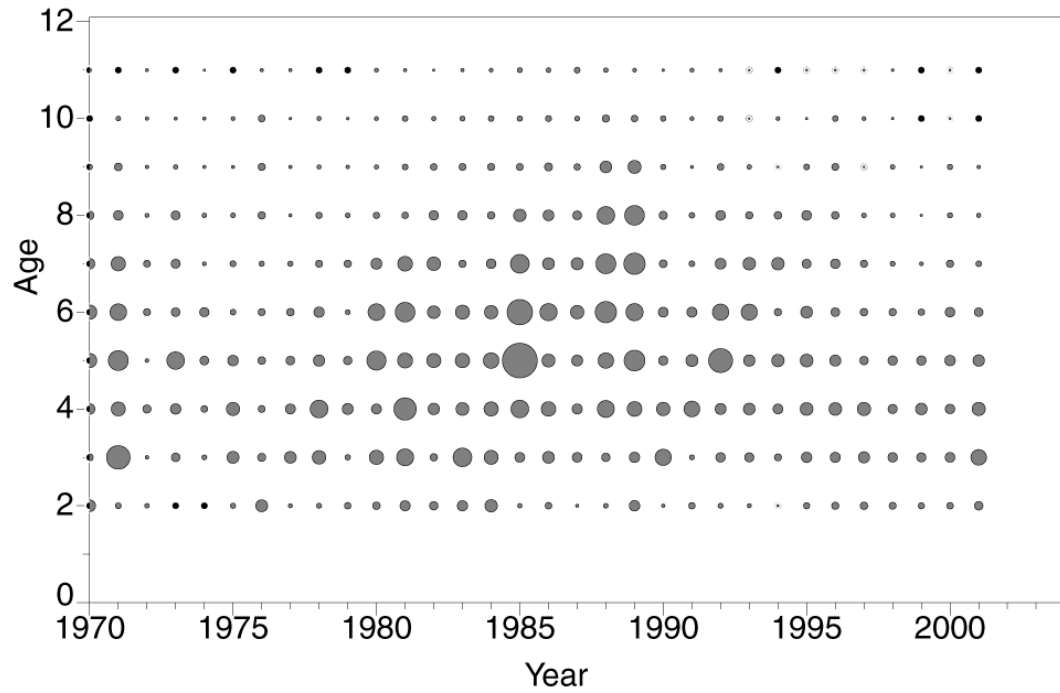
Figure 15. Expanded symbol plot of numbers at age from the July RV survey.
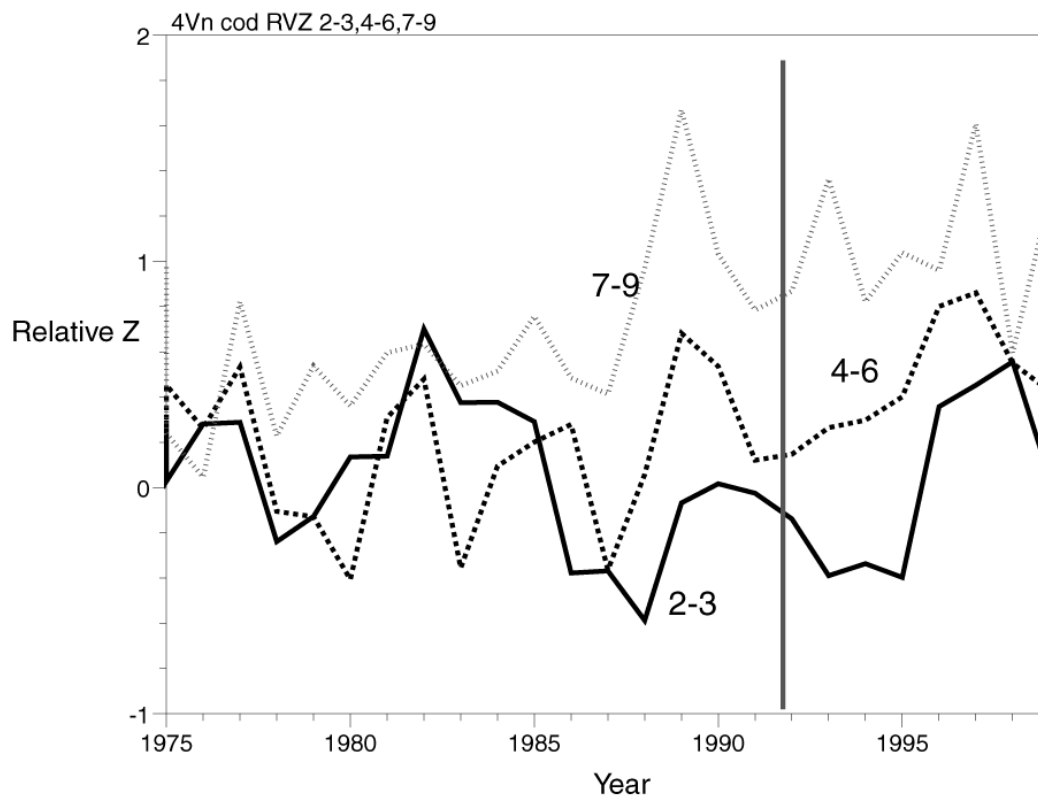
Figure. 16. Estimates of total mortality rates (Z) from July RV surveys.
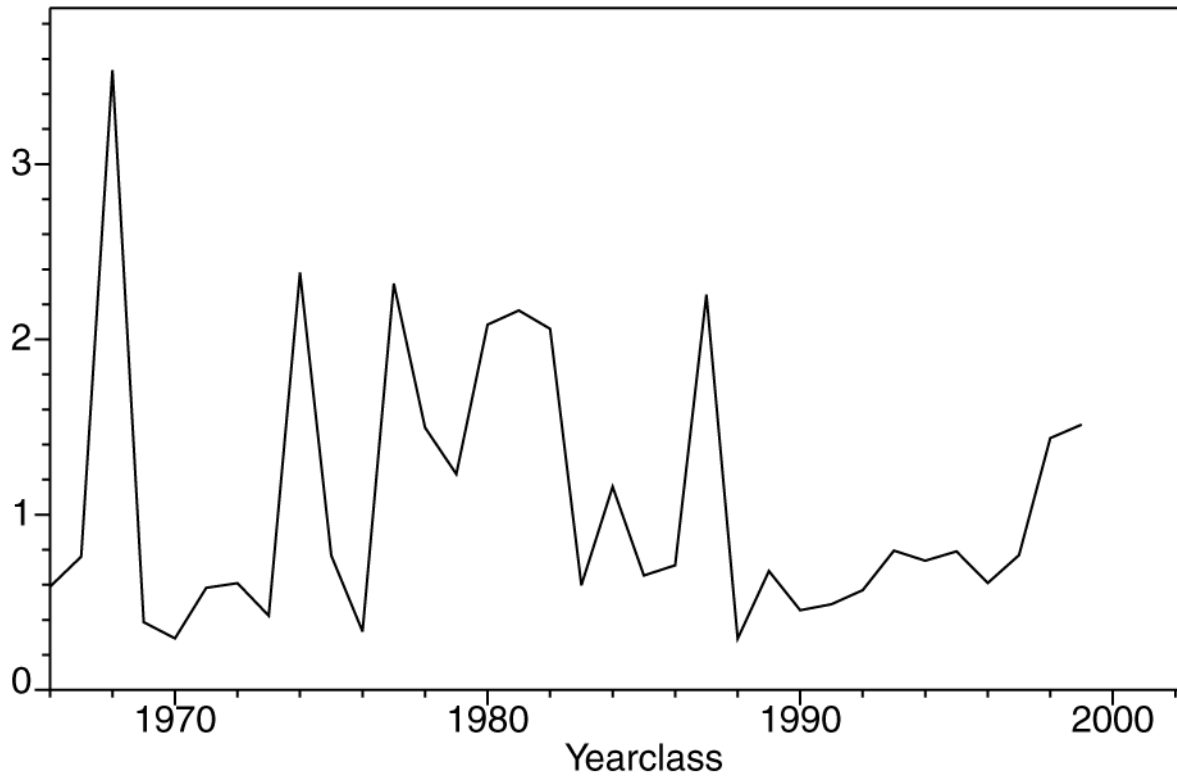
Figure 17. Recruitment index from July RV survey (ages 2 - 4).
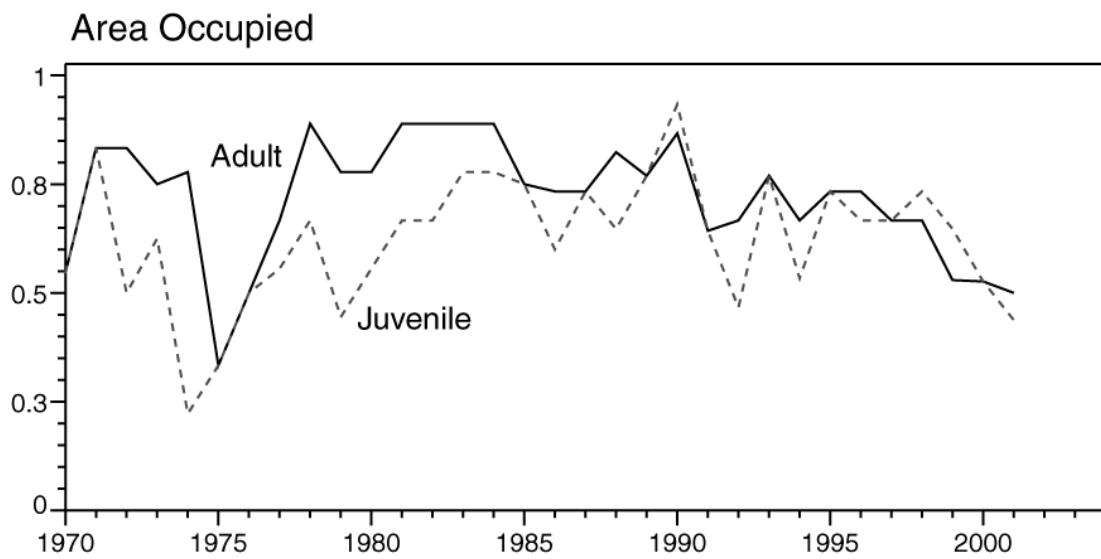
Figure 18. Spatial indices (proportion area occupied) for adult population (solid) and juveniles
30 to 40 cm (dashed) from the July RV survey.
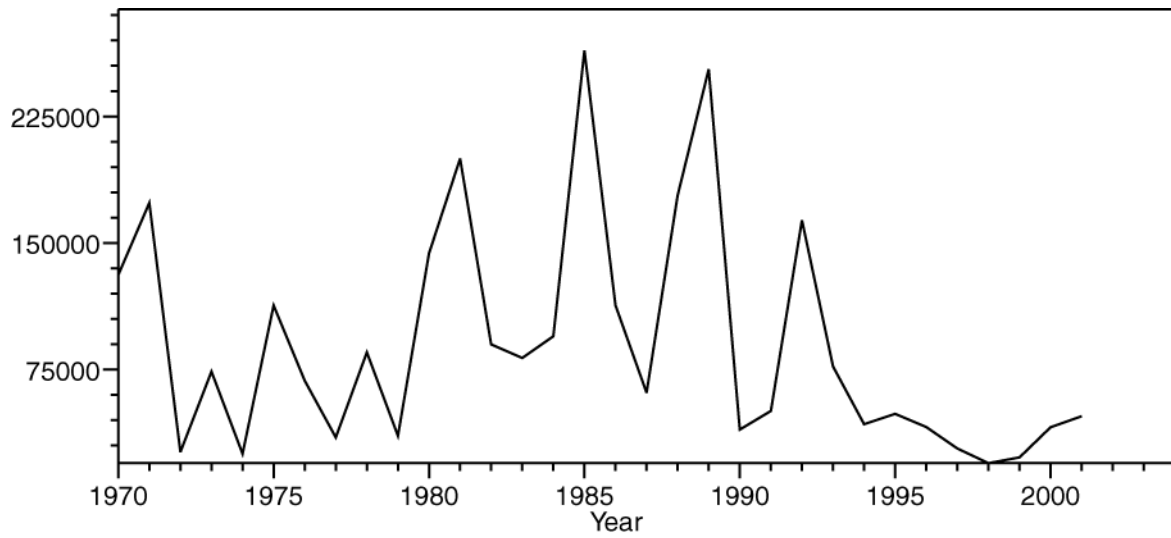
Figure 19. Local density of adults (40+ cm) from the July RV survey in NAFO Div. 4Vn.
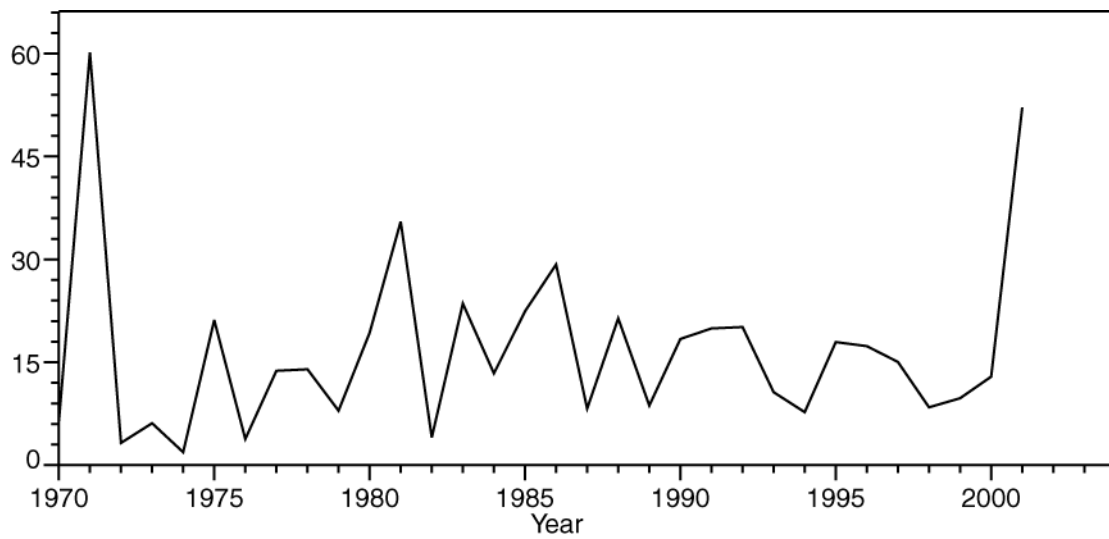
Figure 20. Local density of juveniles (30 to 40 cm) from the July RV survey in NAFO Div. 4Vn.

Figure 21. Proportion of bottom less than 2° C from the July RV survey.
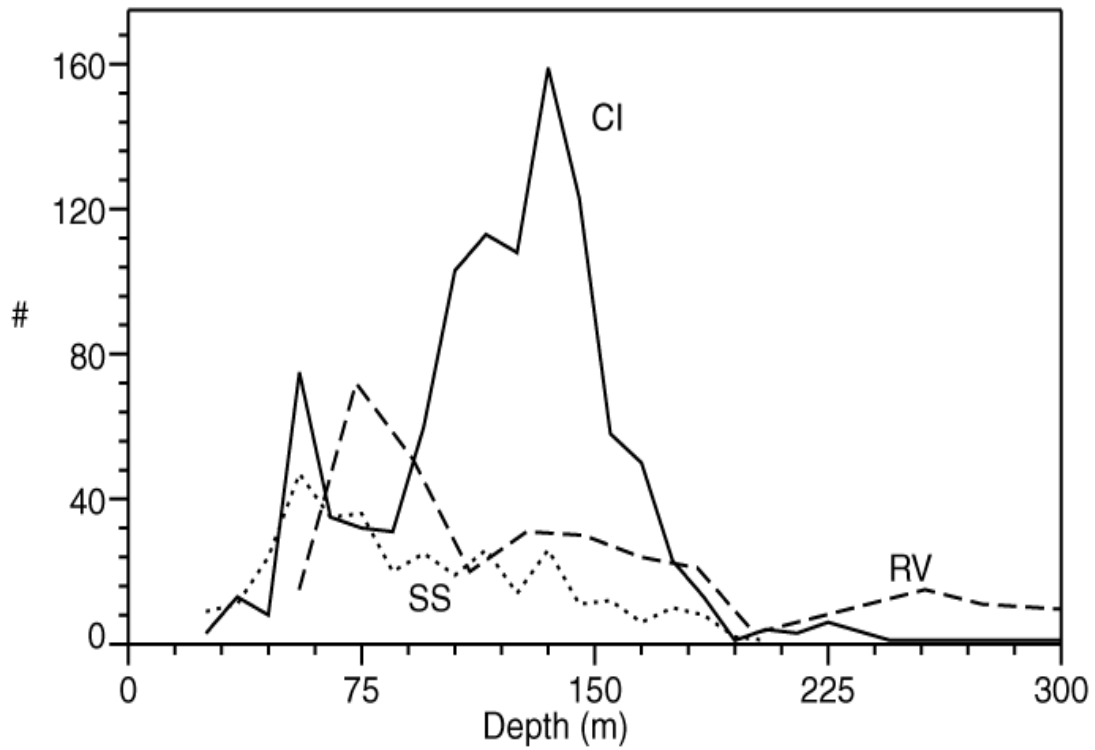
Figure 22. Comparison of sampling (# of sets) as a function of depth for CI, SS and RV
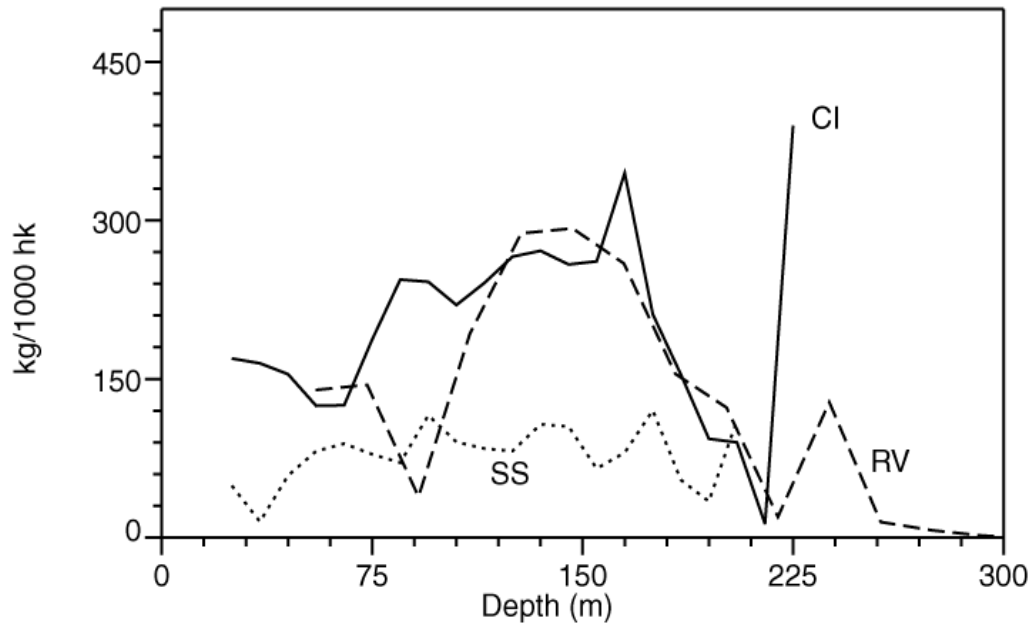
Figure 23. Comparison of catch rates from CI, SS and RV.
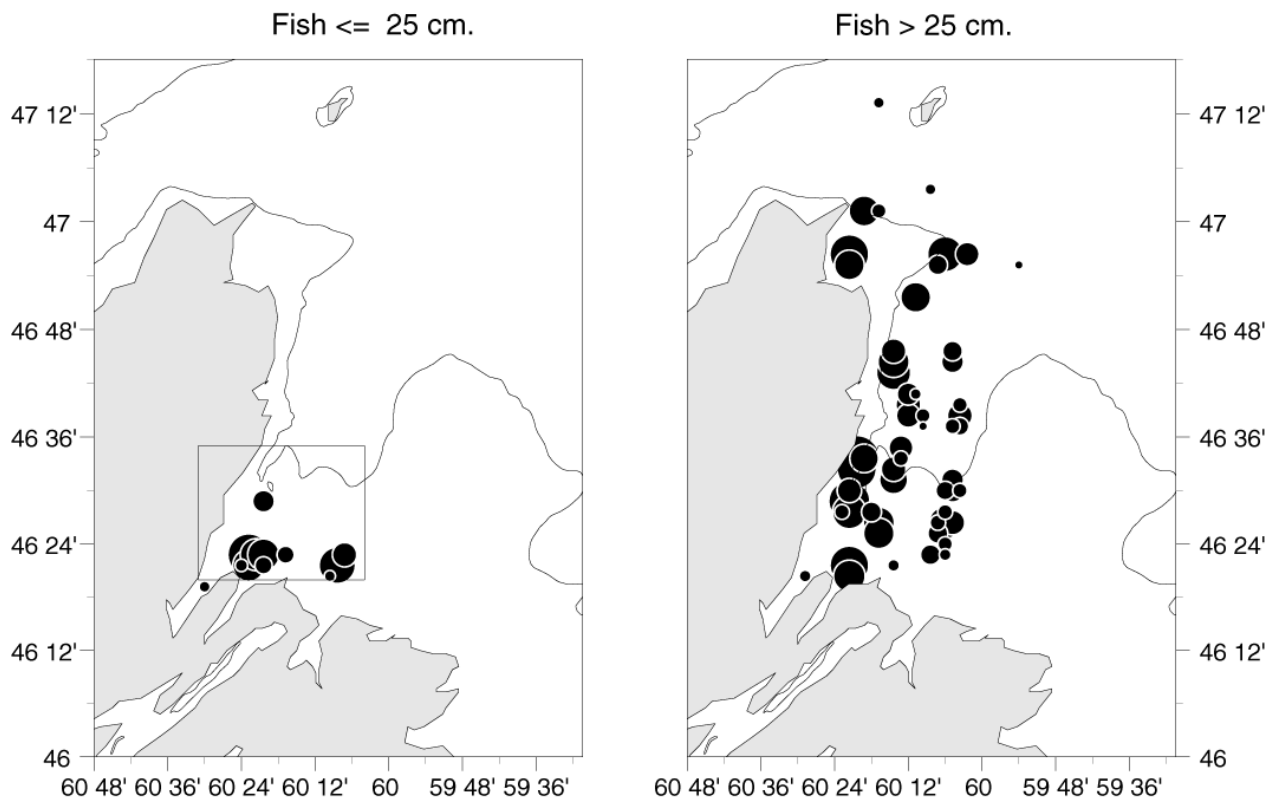
Figure 24. 4Vn cod DFO Inshore Survey all years (1991 - 2000). The small fish box is shown in the left panel.
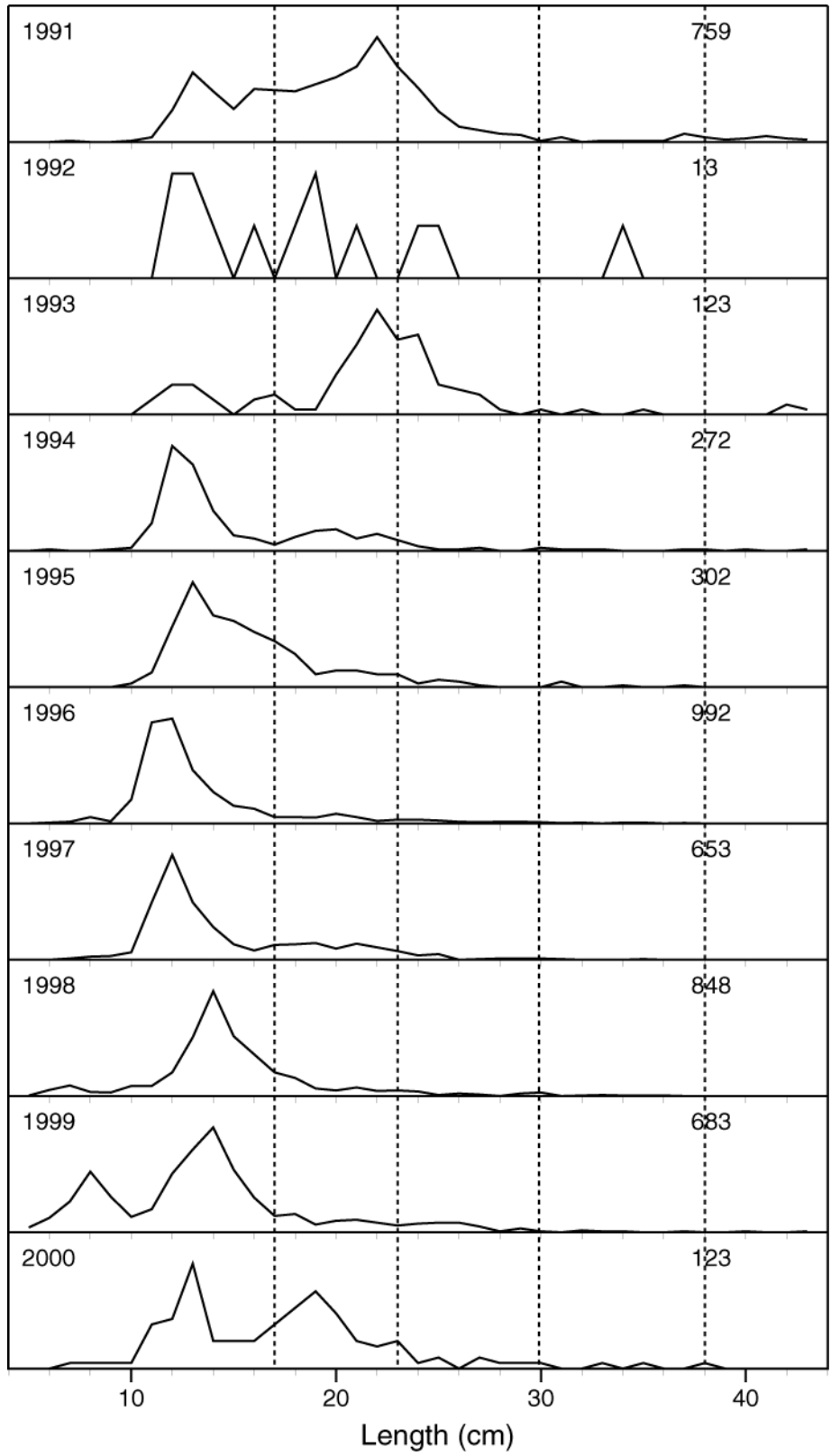
Figure 25. Inshore Survey length frequencies from inside the small fish box. (Numbers on the right indicate the relative magnitude of the curve.)
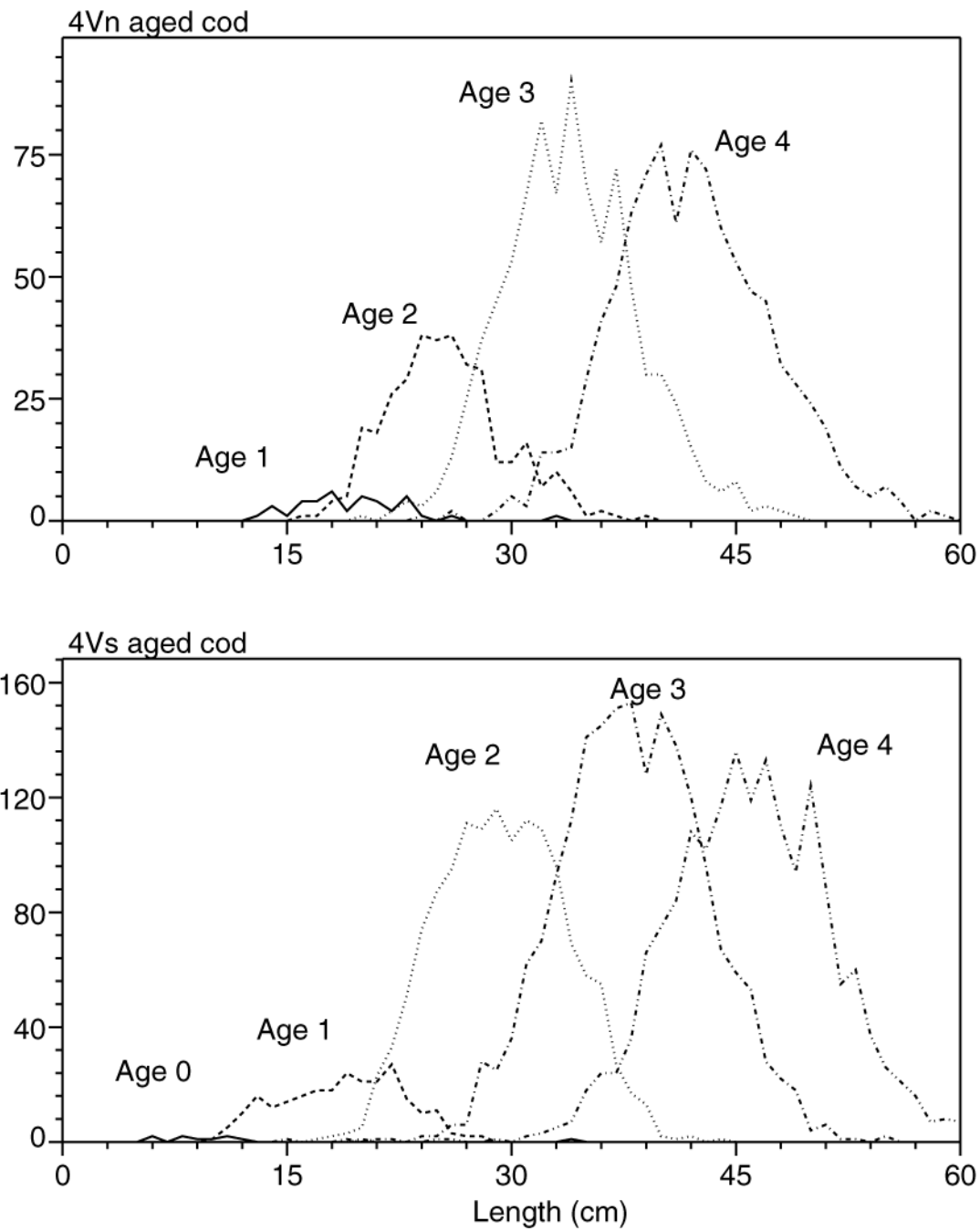
Figure 26. Summary of length at age for cod from July RV surveys (1970 – 2000).
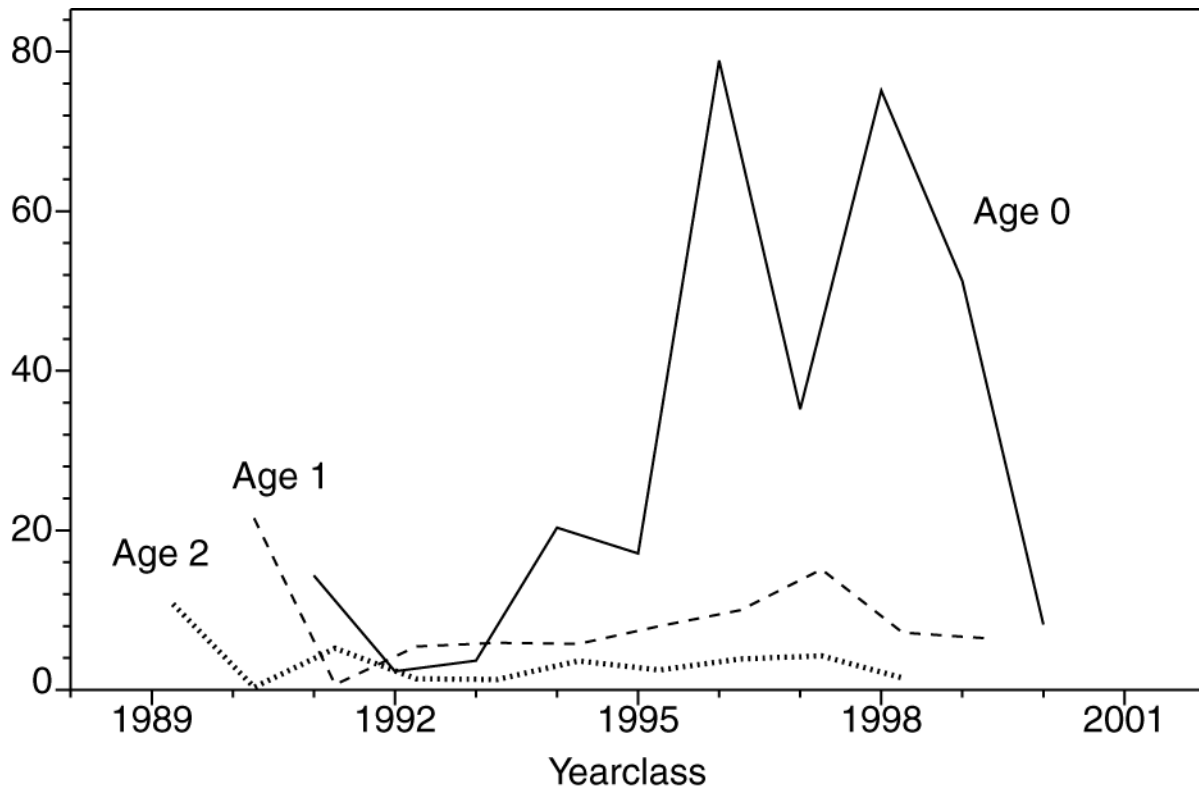
Figure 27. Recruitment indices from DFO Inshore Survey.
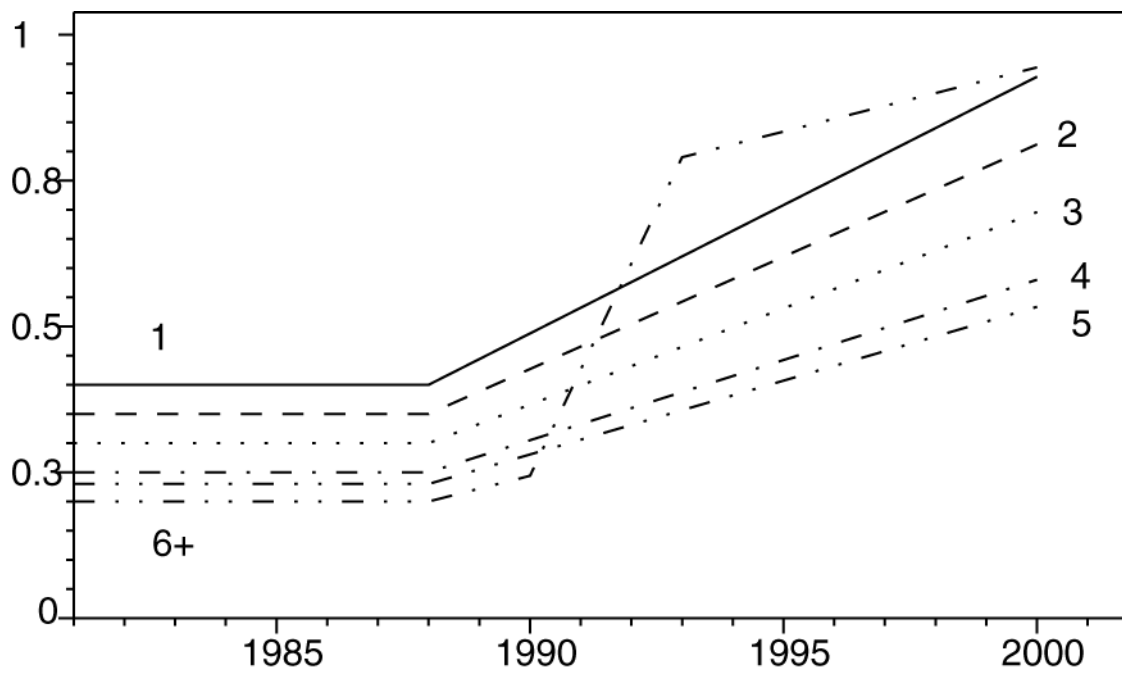
Figure 28. Mortality at age model.
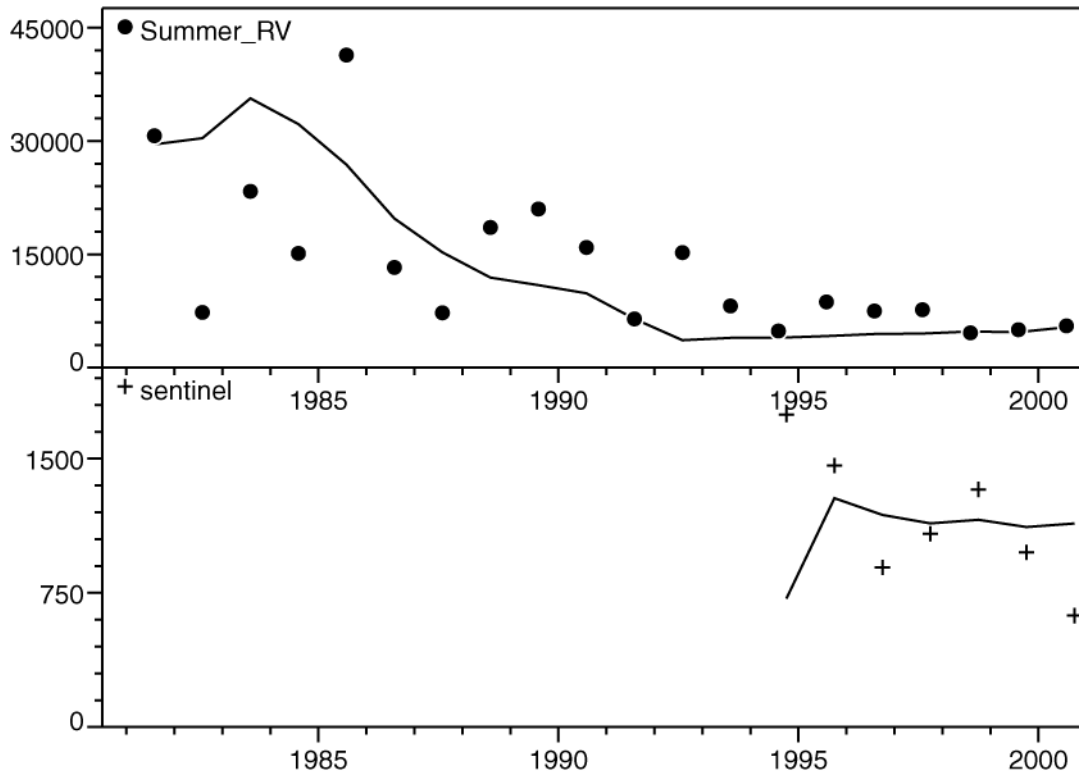
Figure 29. Estimated population numbers and q- adjusted surveys.
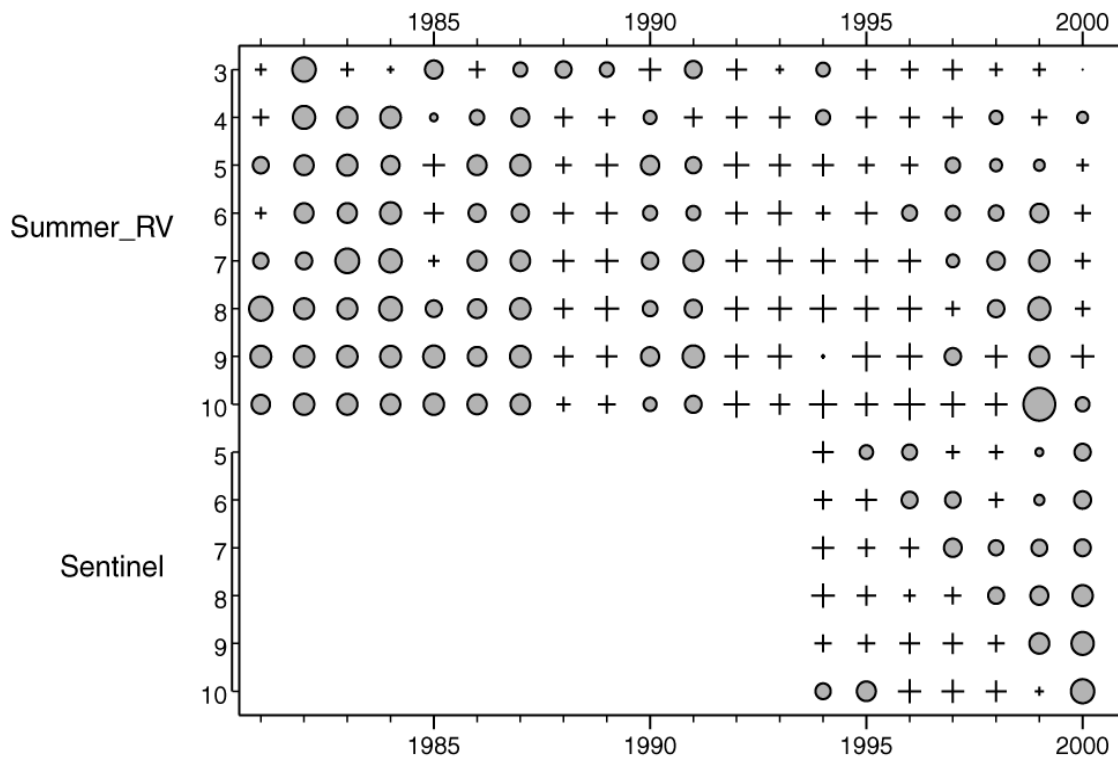
Figure 30. Bubble plot of residuals.

Figure 31. Comparison of natural mortality models (in terms of total biomass): solid line is 'model' with RV only, dashed line is 'model' with RV and SS, and dotted line is 'model' with m = 0.2 with RV and SS.
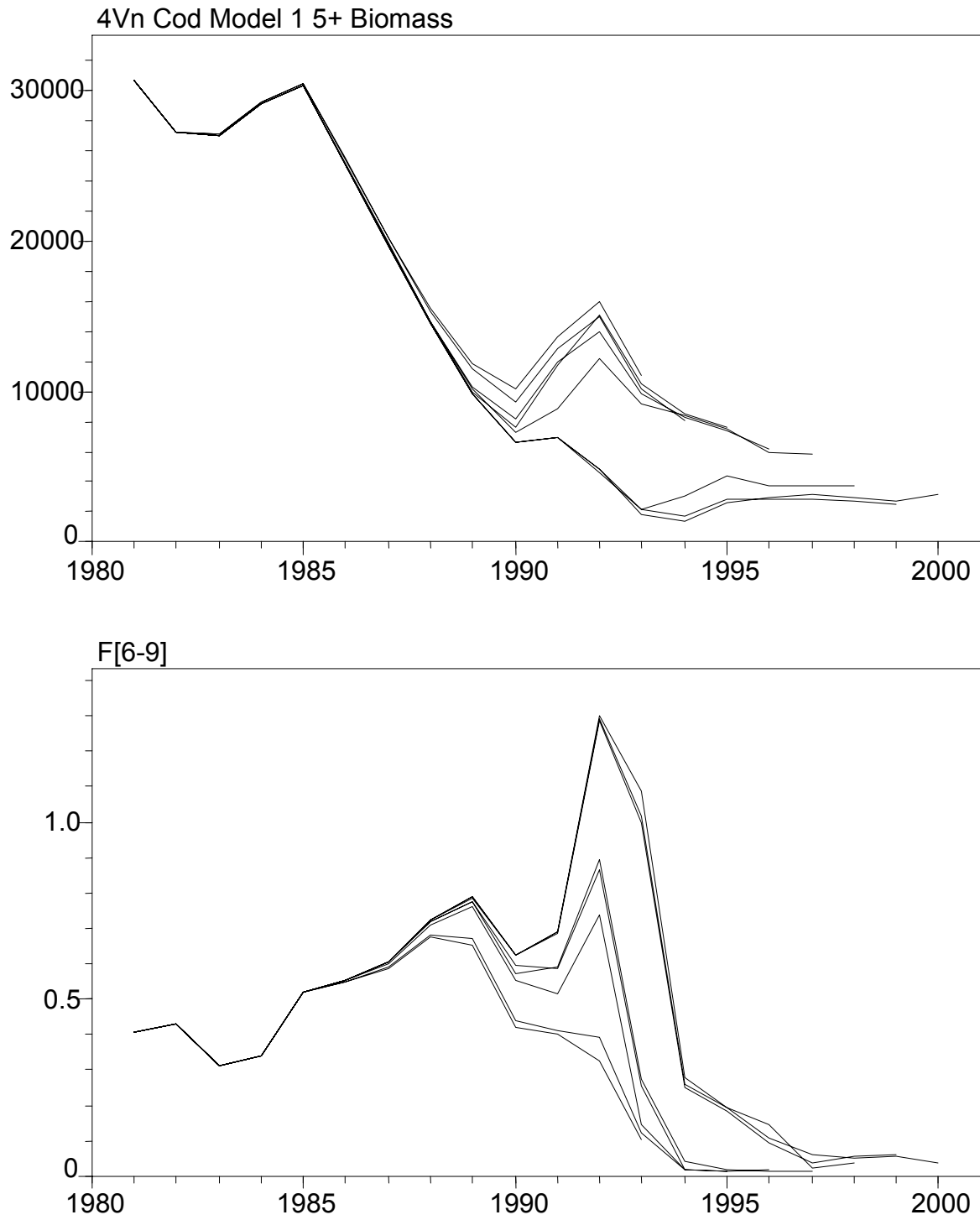
Figure 32. Retrospective patterns of 5+ biomass and fishing mortality (6-9) using the age and time dependent natural mortality model.
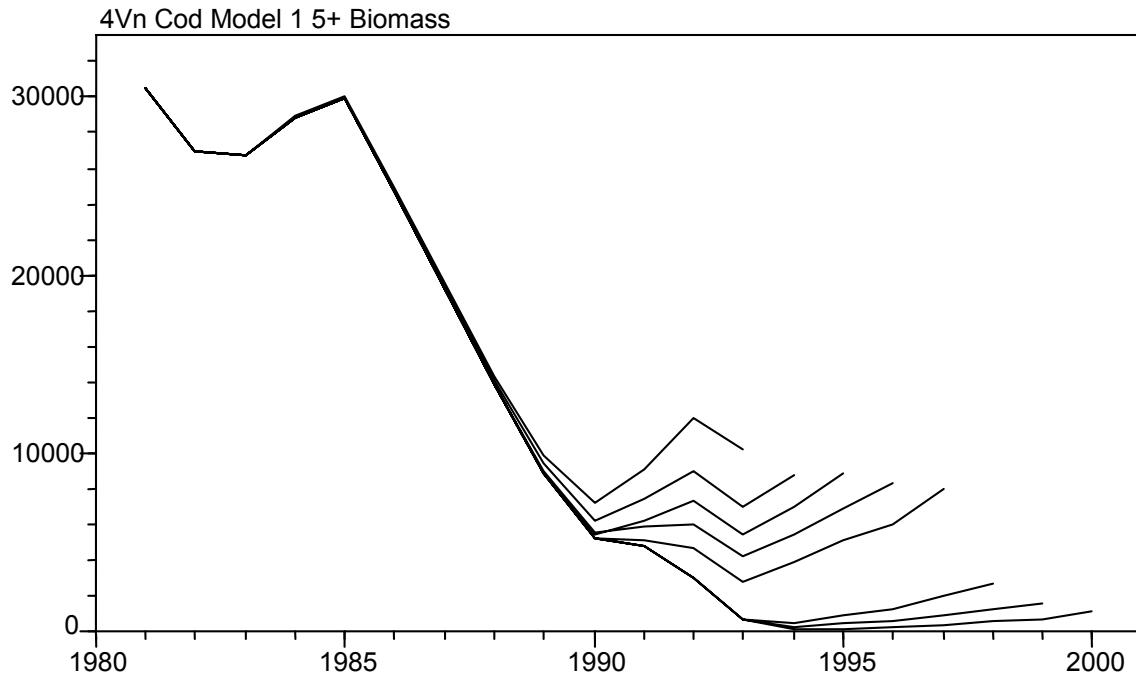
Figure 33. Retrospective pattern of 5+ biomass for m = 0.2.
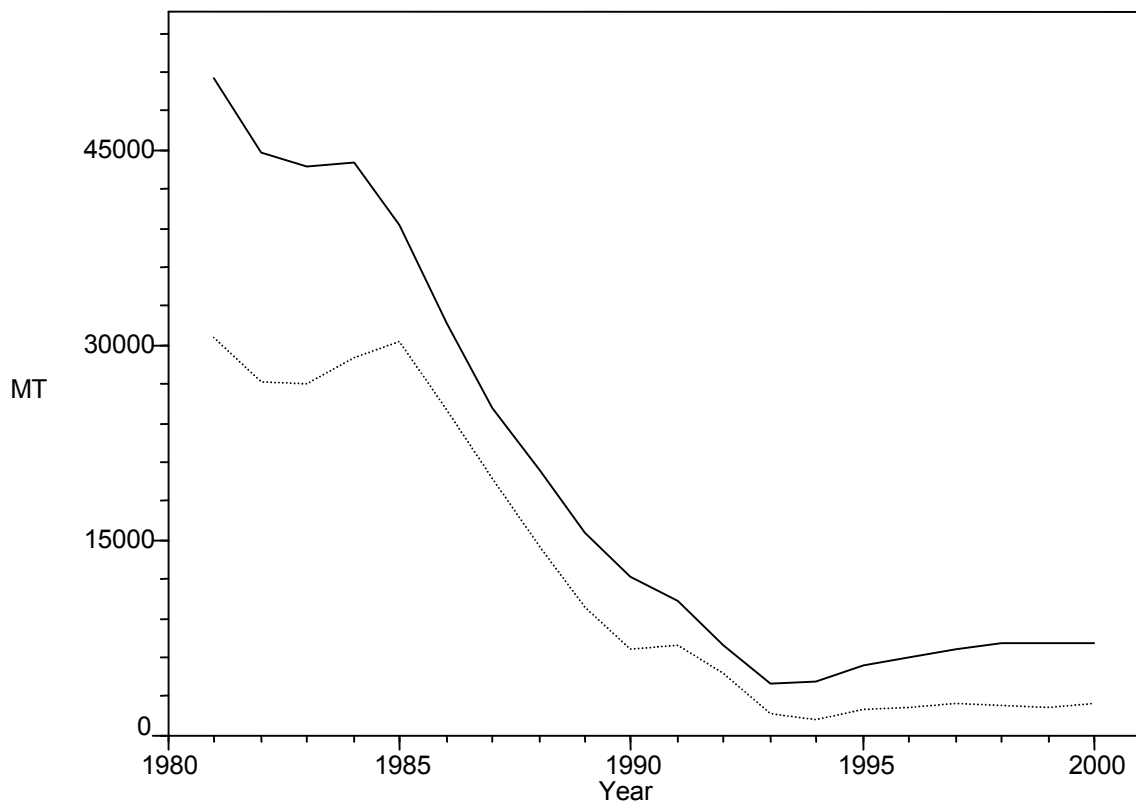
Figure 34. Total and Spawning Stock Biomass (t).

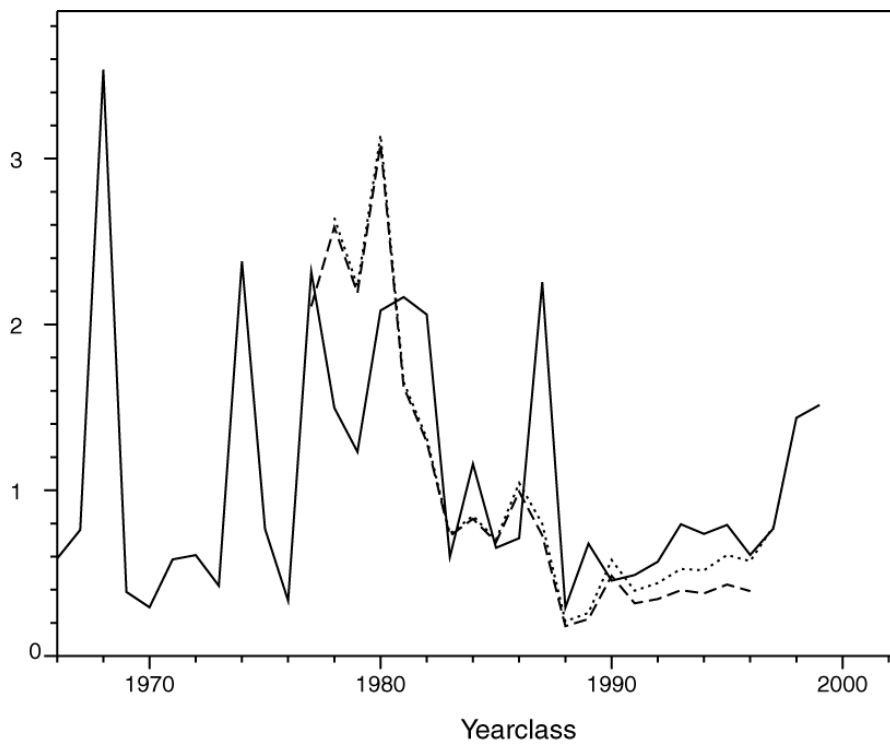Figure 35. SPA exploitation rate (%) averaged over ages 5-7.

Figure 36. Comparison of July RV recruitment index (solid line), SPA age 3 (dotted line) and SPA age 4 (dashed line) estimates.
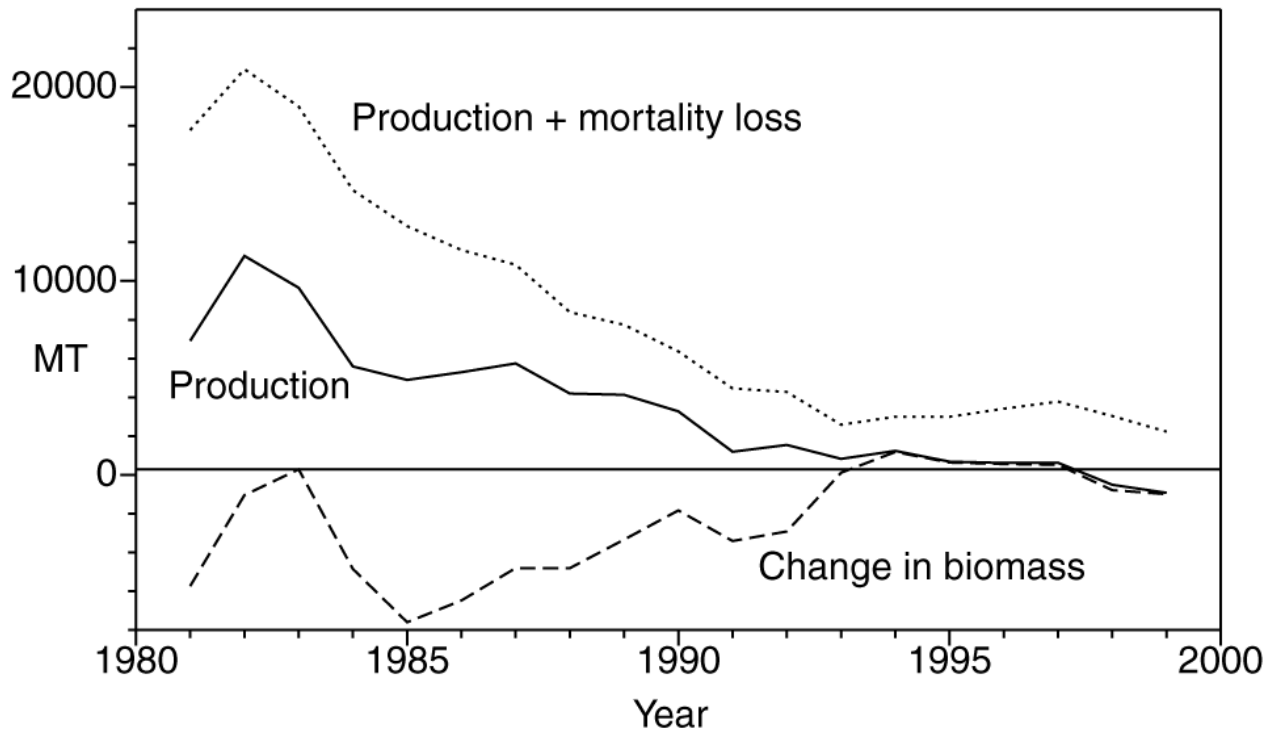
Figure 37. SPA annual change in biomass, production and production plus loss to natural mortality.