Assessment of Haddock in 4TVW -- Population Status and Catch Projections for 1989

by

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Abstract

In 1987 the nominal catch of 4TVW haddock totalled 3,903 t. The fishery on this resource has been restricted to by-catches since January 1987. Catches have totalled roughly 1,200 t to the middle of 1988. In 1987 the 1981 and 1982 year-classes contributed approximately 70% of the catch biomass while in 1988 they accounted for about 28% of the catch to date. Recruitment from 1983 through 1985 has been significantly lower than the relatively large 1981 and 1982 year-classes. Early indications are that the 1986 year-class may be as large as any observed since 1970. Estimates of the size of this year class are however based on only two observations of partially recruited ages. This year's assessment of 4TVW haddock utilized an adaptive framework for non-linear least squares minimization to estimate fishing mortality at age. This framework provides an objective method of evaluating the relationships between survey catch rates-at-age and SPA population numbers at age to estimate fishing mortality by using the Marquhart algorithm to minimize the residual sums of squares for a predetermined block of ages and years. The present formulation calibrated ages 2 through 5 from 1970 to 1987. Fishing mortalities at ages 6 through 11 in 1987 were assumed to be equal to that estimated for age 5. Results of these analyses indicated a fully recruited fishing mortality of 0.14 in 1987. These analyses also indicated that the beginning of year biomass for 1987 is marginally lower than the 1986 estimate but is still approximately equal to the average biomass observed between 1977 and 1987. It has been observed that older fish (ages 7+) disappear from the population at rates in excess of that which can be accounted for by the observed catch at age and assumed natural mortality. Assuming that the 1988 $F_{0.1}$ catch of 4,501 t is taken, the $F_{0.1}$ catch for 1989 is projected to be 6,747 t.

Résumé

En 1987, la prise nominale d'aiglefins de 4TW s'est élevée à 3 903 t. L'exploitation de cette ressource a été limitée aux prises accidentelles depuis janvier 1987. Jusqu'au milieu de l'année 1988, les prises se sont élevées à peu près à 1 200 t. En 1987, les classes d'âge 1981 et 1982 ont fourni approximativement 70 % de la biomasse des prises, tandis qu'en 1988, ces classes d'âge ont contribué pour environ 28 % de la prise jusqu'à présent. Le recrutement de 1983 à 1985 a été nettement inférieur aux classes d'âge relativement importantes de 1981 et 1982. Les premières indications veulent que la classe d'âge 1986 soit aussi importante que celles qu'on a observées depuis 1970. Toutefois, l'estimation de la taille de cette classe d'âge est fondée sur seulement deux observations portant sur des âges partiellement recrutés. L'évaluation de cette année du stock d'aiglefins de 4TW a fait appel à un cadre adapté pour la minimisation non linéaire des moindres carrés pour estimer la mortalité par pêche en fonction de l'âge. Ce cadre fournit une méthode objective pour évaluer les relations entre les taux de prise selon l'âge des relevés et l'effectif selon l'âge des populations d'après l'ASP pour estimer la mortalité par pêche en utilisant l'algorithme de Marquhart pour minimiser les sommes des carrés résiduels pour un bloc prédéterminé d'âges et d'années. Dans la présente formulation, on a étalonné les âges 2 à 5 de 1970 à 1987. On a supposé que la mortalité par pêche aux âges 6 à 11 en 1987 a été égale à celle que l'on a estimée pour l'âge 5. Les résultats de ces analyses indiquent une mortalité par pêche pour un stock pleinement recruté de 0,14 en 1987. Ces analyses indiquent également que la biomasse en début d'année pour 1987 est légèrement plus faible que l'estimation de 1986, mais qu'elle est tout de même à peu près égale à la biomasse moyenne observée entre 1977 et 1987. On a constaté que les poissons plus âgés (âges 7+) disparaissent de la population plus rapidement que ne peuvent l'expliquer les prises par âge observées et la mortalité naturelle supposée. Si l'on suppose que la prise à $F_{0,1}$ de 1988, fixée à 4 501 t, se matérialise, les prises à $F_{0,1}$ pour 1989 devraient être de 6 747 t selon les projections.

Trends in Reported Landings and Description of the Fishery

Catches have averaged 26,500 t per year from 1950 to 1969, 5,000 t from 1970 to 1979 and ranged between 8,000 and 20,000 t until 1986 (Table 1). The nominal catch in 1987 was taken exclusively as by-catch in other groundfish fisheries operating in divisions 4T, 4V, and 4W and totalled 3,903 t in 1987. This represents 102% of the advised $F_{0.1}$ catch of 3,825 t. The estimated nominal catch for the first half of 1988 is 1,223 t, again taken exclusively as by-catch. The Recommended TAC for 1988 was 4,501 t. Recent TACs and nominal catches are given below:

	1982	1983	1984	1985	1986	1987	1988
CAFSAC Advice	23	19	12	15	17	3.8	4.5
TAC	23	19	15	15	17	-[3]	-[3]
Nominal Catch	15	9	8	11	17[1]	4[1]	1[2]

1 - Provisional
2 - As of July 7, 1988, Atlantic Quota Reports (by-catch only)
3 - No TAC -- by-catch only

Until 1984, most of the catch from this stock was taken in Division 4W by large OTBs (TC4 and TC5) fishing in the spring. In 1984-1986, Subdivision 4Vs accounted for an increasing proportion of the total catch. In 1986 and 1987, the combination of apparently poor recruitment over several successive years (1983-1985), coupled with low levels of spawning stock biomass and the concentration of the fishery on the only two remaining year-classes of any appreciable size (1981, 1982), resulted in the recommendation of catches for 1987 and 1988 of 3,800 t and 4,500 t, respectively. The TACs were felt to be too low to allow for directed fisheries, thus resulting in the restriction of catches from this stock to by-catches in the other groundfish fisheries active in divisions 4T, 4V and 4W for both 1987 and 1988. Management further imposed a year-round ban on mobile gear fisheries in areas identified as haddock nursery grounds, mainly Western and Emerald banks (Fanning, et al., 1987).

Age Composition of Removals

The recent catch history of this stock indicates that most of the catch has been taken by trawlers with longliners taking approximately 10% of the annual total since 1980. Between 1970 and 1979 longliners took on the order of 20% of the annual totals (Table 2). Since 1980 Danish and Scottish seiners have accounted for about 5% of annual landings.

Removals at age for small mesh and non-small mesh gears were estimated separately. Small mesh gear removals (realized as by-catch in the Soviet and Cuban silver hake fisheries) were estimated by applying the summer research vessel survey age length keys (4VW combined) to haddock length frequency estimates obtained by observers on foreign vessels. Sample length frequencies were weighted to total catch in the observed fraction of the silver hake fishery (as numbers at length) and then weighted by total silver hake catch in that year (Table 3) to arrive at an estimate of total numbers of haddock caught at length in the entire fishery. This second weighting has been unnecessary since 1987 when observer coverage of all foreign fisheries was increased to 100%.

Removals by domestic gears were calculated semi-annually for trawlers and annually for all other gears. Age-length keys used were applied to landings by trawlers in January-June and July-

September, and to landings by other gears from January-December. Removals-at-age for the first half of 1988 were determined for trawlers and other gears separately using summer RV length-weight coefficients. The slopes and intercepts of the length-weight relationships used in generating age-length keys since 1970 are given in Table 4. For this assessment the length weight parameters used in calculation of catch at age were estimated using all observations from the July RV surveys conducted between 1970 and 1988. This analysis indicated a relationship between length and weight (R^2 = 0.98253, s.e. = 0.13386) of

$$wt = -4.86574\ (\pm 0.01229)\ l^{3.07261(\pm 0.00337)}$$

from a total of 15,519 observations. A summary of available samples from commercial landings since 1970 is presented in Table 5. Details of the calculation of removals at age prior to 1970 are given by Mahon et al. (1985). Annual removals at age and weighted (by numbers) mean weights at age since 1948 are shown in Tables 6 and 7.

The most significant differences between the observed and predicted catch at age for 1987 are the higher than expected catches of age 1 through 3 fish. This disparity is probably the result of the small-mesh gear by-catch which, with a closed domestic fishery in 1987, contributed a greater proportion to the total landings than would be the case in other years. The higher prevalence of younger fish in the small mesh catches couples with their greater contribution to the overall total probably resulted in their overrepresentation.

Age	% Catch at Age Observed in 1987	% Catch at Age Predicted for 1987	Ratio Observed/Expected
1	0.93	0.35	2.66
2	2.36	0.24	9.83
3	4.92	2.39	2.06
4	29.66	21.15	1.40
5	50.08	52.32	0.96
6	11.08	21.91	0.50
7	0.68	1.16	0.50
8	0.19	0.48	1.40
9	0.03	0.00	-
10	0.03	0.00	-
11	0.03	0.00	-

Abundance Indices

Commercial Catch Rates

The by-catch nature of this fishery in 1987-1988 makes present catch rates incomparable to those of earlier years from directed fisheries. The recent catch rates are not representative indices of abundance for this stock.

Research Vessel Index

The research survey series stratified mean catch per tow at age from 1970 to 1988 (Table 8) indicates a decline in overall abundance from 1983 to 1987 with a subsequent increase in 1988 (Figure 1). Decomposition of the overall index to age groups and areas reveals that abundance in all age-classes in subdivisions 4Vn (Figure 3) and 4Vs (Figure 4) continued to decline in 1988, whereas those in Division 4W increased (Figure 4). Furthermore, the abundance of age-classes 0-3 in 4W showed a larger increase than the abundance of age-classes 4-7, and were indeed largely responsible for the increase in overall abundance. These observations may be indicative of an

increase in the number of fish recruiting to this population; however, as those are based on a single year of data, it is premature to draw firm conclusions.

Estimation of Stock Abundance

Stock size was estimated using the adaptive framework for non-linear least squares minimization as outlined by Gavaris (1988). It was assumed that errors in the commercial catch at age were negligible relative to the errors in the RV abundance index. Preliminary analyses of the RV index and population estimates showed that these relationships at age 1 and ages older than 5 were poorly estimated. We therefore chose a calibration block of ages 2 through 5. Attempts to estimate all year class sizes resulted in high correlations between the estimated parameters. We therefore assumed that F at ages 6 through 10 was equal to F at age 5 and that F at age 11 was equal to the population numbers weighted mean F at age 5-7. The final formulation of the adaptive framework applied is summarized in Table 9. Natural log transformations were used to stabilize error variance. The final estimated calibration relationships in the form $\hat{I}_i = a+bN_i$ (where I_i is the predicted survey catch rate at age i and N_i are the SPA estimated numbers at age i) are presented below:

Age	a	b
2	-0.14525	0.0003061
3	-0.95341	0.0007415
4	-0.95135	0.0011231
5	-0.47525	0.0011044

Model diagnostics are presented in Tables 10a-c and Figures 5 to 9. Population and F estimates resulting from these analyses are presented in Table 10d.

Table 10a shows that population sizes in 1987 at ages 2 through 5 are well estimated and that the slopes of the relationship are also well estimated; the intercepts for ages 2 and 5 are not significantly different from 0, while the intercepts for ages 3 and 4 are. The correlation between the estimated parameters is generally low indicating relative independence of the estimates. High correlations are, however; observed between the slopes and intercepts. The overall fit of the model is depicted on Figure 5 while the relationship between predicted and expected RV catch rates over time are given on Figure 6. Examination of model residuals over time (Figure 7) continue to show the temporal trends and discontinuities which have been observed in this assessment since 1984 (Mahon et al. 1984, Zwanenburg et al. 1986). Possible reasons for these temporal trends in residuals have been discussed (Zwanenburg and Fanning 1987) and continue to be investigated. The distribution of residuals against SPA mid-year population numbers (Figure 8) and predicted RV numbers (Figure 9) show no evidence of model error.

The 1987 Fs at age (1987) estimated by the adaptive framework were used as input to SPA using the full catch at age matrix (Table 6), which generated the results in Tables 11-15.

The trend in population numbers at age 1 shows low values in the early 1970s followed by two pulses of good recruitment in the late 1970s and early 1980s. Recruitment in 1987 (1986 year-class) may be equal to the highest observed since 1970 (Figure 10a). The mid-year biomass estimated (approx. 40,000 t) for 1987 (1+) is approximately equal to the average biomass observed between 1977-1987 (37,000 t) (Figure 10b). Weighted mean Fs (population numbers) for fully recruited age groups (5, 6, 7) (table 10d and Figure 10c) indicate a significant reduction in fully

recruited F as a result of the closure of the fishery. The Fs of greater than 1.0 which have been observed over the past few years are associated with stock biomass estimates which are approximately equal to the mean biomass for 1977-1987. The paucity of older (7+) fish in both the surveys and the catch make it difficult to estimate the Fs at these ages. Based on the historical F matrix, these age-classes are assumed to be fully recruited. There are indications that fish in what are estimated to be abundant year-classes disappear from the population at rates in excess of what can be accounted by the observed catch at age and assumed natural mortality. This may indicate that catches are underreported; that natural mortality is age and perhaps year specific or that fish emigrate from the stock areas as they age. These latter possibilities are being investigated through an extensive mark-recapture experiment.

Prognosis

Recruitment at age 1 in 1988 was set to the geometric mean (16.4 million) of values observed from 1970-1985. The extremely large estimate of the 1986 year-class in 1987 (67,181,000 at age 1) was set equal to the 1982 year-class at age 1 (55,666). The adjustment was made because the size of the 1986 year-class is based on only two observations, both at ages not yet fully recruited to the survey gear and for which estimates are known to be variable.

Catch projections were made using the following parameters:

Age	1988 Beginning of Year Population Numbers	PR[1]	Weights[2]
1	16414	.002	.104
2	45545	.005	.225
3	10775	.032	.495
4	9354	.332	.779
5	7536	1.000	1.067
6	10967	1.000	1.518
7	2426	1.000	2.102
8	150	1.000	2.319
9	41	1.000	2.834
10	7	1.000	3.078
11	7	1.000	4.057

[1] Weighted (population numbers) mean 1984-86.
[2] Weighted (population numbers) mean 1985-87.

The expected catch of 4,500 t in 1988 would approximate $F_{0.1} = 0.21$. The projected 1989 $F_{0.1}$ catch is 6,747 t.

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Table 1. Nominal catches (t) of eastern Scotian Shelf haddock (4TVW) by NAFO Division and country as reported to NAFO (from NAFO Statistical Bulletin).

Year	4T					4Vn+					4Vs					4W					Total	TAC
	Canada	USA	USSR	Spain	Other	Canada	USA	USSR	Spain	Other	Canada	USA	USSR	Spain	Other	Canada	USA	USSR	Spain	Other		
1954	5918	1044			40	5549	405		1058	24						12323	1956		17		28334	
1955	3101	31				3339	450		1183	13						12777	1217				22111	
1956	2861					4899	147		1350	12						18273	1661		354		29557	
1957	1740	1				5869	120		747	9						19960	1533		132		30111	
1958	2599			151		3166	71		1343	6						17572	427		1593		26928	
1959	2996	1		64		1594	159		69		3456	111		2870		21156	4804		640		37920	
1960	2041					1317	6		97		1187	18		3926	1	20093	127		1024		29837	
1961	1297			273	2	1055	1		47	1	846			1526	7	22277	23	151	1441	16	28963	
1962	1132			10		1097	1		5	2	1235			1076		15566	51	2567	3224		25966	
1963	1019			46		1213	1	6	64		1061	1		2828	195	11002	60	3295	4915	866	26572	
1964	461			1		958			59	52	677	11		2057	2	9810	42	4391	2884	1889	23294	
1965	432			3	3	402			53	84	1201			1806	47	7007	8	42876	1500	96	55518	
1966	149			1		311		516	30		1494			940	9	8259	19	9985	1885	51	23649	
1967	112			9		203		95	26	31	898			839	9	7180	5	459	1046		10912	
1968	144				4	127			70	6	1128		59	1702	23	8392		195	1458	10	13318	
1969	167				3	245				112	726			631	66	8270		235	864	1	11320	
1970	160					395	2		75	1	620		34	830	16	4754	574	636	1332		9429	
1971	151					466			215	1	1133		11	1114		7940	497	464	1477		13469	
1972	60					362	3		136	19	421		3	599	37	2096	70	103	737	102	4748	
1973	21				2	286			76	164	233			431	9	2830	173	76	95	18	4414	
1974	17				14	161			3	1	147		30	174	196	907	6	102	521	78	2357	0
1975	35				2	67			15	4	107	1		48	3	1393	20	52	63	59	1868	0
1976	12					40				1	52	1	9		1	1198	31	15			1360	2000
1977	8					189				8	144				1	2845	1	14		38	3248	2000
1978	18					119				3	441		3		38	4949	82	139		109	5901	2000
1979	59					194				11	650				2	2339		104		73	3433	2000
1980	81					188				42	1841					12448		209		31	14840	15000
1981	177					119				25	1796					17684		187		21	20009	23000
1982	47					183				23	2373					12498		53		49	15226	23000
1983	30					206				17	1542					7302		149		166	9412	15000
1984	120					299				11	3195		2		1	3992		168		233	8021	15000
1985	498					598				59	7291				2	2862		275		79	11664	15000
*1986	579					880					8764				4	6169		312		78	16786	17000
*1987	459					488				13	1587				1	994		207		154	3903	0

+ — Between 1954 and 1958 catches for 4Vn and 4Vs were combined as 4V.
* — Provisional data

Table 2. Canadian (M, Q, & Nfld.) nominal catches (t) of eastern Scotian Shelf haddock (4TVW) by gear.

Year	Otter Trawler	Danish/Scottish Longliner	Danish/Scottish Seiner	Miscellaneous	Total
1960	20835	1077	23	696	22631
61	22060	448	52	1377	23937
62	16453	665	76	705	17899
63	11943	511	147	526	13127
64	10679	70	62	874	11685
1965	8033	352	66	160	8611
66	10222	233	19	130	10604
67	7855	126	25	573	8579
68	8819	296	16	364	9495
69	8603	289	30	341	9263
1970	5056	479	20	262	5817
71	8709	538	77	179	9503
72	2141	528	76	138	2883
73	2459	628	28	232	3347
74	543	493	17	162	1215
1975	593	873	10	82	1558
76	383	657	10	75	1125
77	2198	729	26	170	3123
78	4009	1069	67	340	5485
79	1745	1232	66	147	3190
1980	13063	933	229	270	14495
81	17859	1253	464	113	19689
82	12346	1567	890	249	15052
83	6969	1254	541	235	8997
84	6188	908	451	112	7659
85	9548	822	830	50	11249
86	13939	1101	1188	105	16334
87*	1942	723	301	66	3031
88**	1100	123	-	-	1223

* Provisional Statistics
** Catches to 30/06/88 from Scotia-Fundy Quota Reports

Table 3. Estimation of small mesh removals of haddock in 4VW in silver hake directed fisheries by Cuba, Bulgaria, Romania, Japan, Portugal, and the USSR. In 1984 The GDR also carried out directed fisheries for silver hake.

Year	Nominal Catch of Silver Hake (t)	IOP Haddock By-Catch Ratio (%)	Reported Catch of Haddock (t)	Estimated By-Catch Of Haddock (t)
1970	164,013	0.82*	670	1345
1971	122,616	0.82*	475	1005
1972	108,828	0.82*	106	892
1973	269,420	0.82*	76	2209
1974	87,497	0.82*	132	717
1975	98,994	0.82*	109	812
1976	90,483	0.82*	24	742
1977	30,019	0.64	33	192
1978	45,966	1.25	229	575
1979	50,374	0.51	176	257
1980	37,709	0.75	229	283
1981	37,554	0.80	201	300
1982	58,132	0.40	94	233
1983	34,259	1.64	326**	562
1984	72,297	1.33	557**	959
1985	76,003**	0.72	357	547
1986***	82,467	0.60	-	500
1987***	61,675	0.58	308	332
1988***	61,753	-	-	391

* Mean of 1977-1979 weighted by-catch observed.
** FLASH
*** Preliminary data (1988 preliminary to 30-06-88)

Table 4. Grouping of catch by gears and time period for estimation of removals-at-age. Trawlers are primarily stern and side bottom trawls but also pair trawls, other is primarily longline, Danish seine, and Scottish seine (for 1948-1969 see Mahon et al. 1985).

Year	Period	Gears	No. of Samples	Number Aged	Number Measured	Catch (t)	Weight-Length Relationship a	b	Cruise
1970	Jan - Dec	Trawlers	11	405	2172	7986	0.0062	3.136	Cameron #170 March 1970
	Jan - Dec	Other	3	107	602	779	0.0112	2.989	Cameron #175/176 July 1970
1971	Jan - Dec	Trawlers	24	966	5930	12174	0.0052	3.168	Cameron #184 March 1971
	Jan - Dec	Other	5	197	966	820	0.0088	3.035	Cameron #188/189 July 1971
1972	Jan - Dec	Trawlers	7	255	1661	3802	0.0036	3.261	Cameron #196 March 1972
	Jan - Dec	Other	1	29	200	817	0.0133	2.943	Cameron #200/201 July 1972
1973	Jan - Dec	Trawlers	8	299	1831	3407	0.0036	3.261	Cameron #196 March 1972
	Jan - Dec	Other	3	100	652	927	0.0096	3.017	Cameron #212/213 July 1973
1974	Jan - Dec	Trawlers	1	37	364	1545	0.0089	3.035	Cameron #225/226 July 1974
	Jan - Dec	Other	2	70	459	680	0.0089	3.035	Cameron #225/226 July 1974
1975	Jan - Dec	Trawlers	4	136	1048	778	0.0045	3.204	Cameron #219 March 1974
	Jan - Dec	Other	1	30	200	982	0.0094	3.023	Cameron #236/237 July 1975
1976	Jan - Dec	Trawlers	3	106	850	424	0.0191	2.837	Cameron #250/251 July 1976
	Jan - Dec	Other	3	89	478	912	0.0191	2.837	Cameron #250/251 July 1976
1977	Jan - June	Trawlers	3	105	616	548	0.0103	2.983	Cameron #259 March 1977
	July - Dec	Trawlers	11	319	2419	1684	0.0108	2.996	Cameron #265/266 July 1977
	Jan - Dec	Other	4	133	885	982	0.0108	2.996	Cameron #265/266 July 1977
1978	Jan - June	Trawlers	18	582	5776	3453	0.0019	3.425	Cameron #274 March 1978
	July - Dec	Trawlers	2	55	507	649	0.0103	3.000	Cameron #279/280 July 1978
	Jan - Dec	Other	5	164	1068	1536	0.0103	3.000	Cameron #279/280 July 1978
1979	Jan - June	Trawlers	3	80	650	847	0.0063	3.117	Hammond #13/14 March 1979
	July - Dec	Trawlers	6	189	1324	878	0.0050	3.187	Hammond #26/27 Oct-Nov 1979
	Jan - Dec	Other	12	347	2675	1528	0.0057	3.155	Cameron #292/293 July 1979
1980	Jan - June	Trawlers	24	759	5527	7077	0.0069	3.091	Hammond #33/34 March 1980
	July - Dec	Trawlers	22	619	5021	6122	0.0049	3.197	Hammond #42/43 October 1980
	Jan - Dec	Other	6	180	1421	1412	0.0117	2.970	Cameron #306/307 July 1980
1981	Jan - June	Trawlers	29	642	7450	15709	0.0070	3.102	Hammond #48/49 March 1981
	July - Dec	Trawlers	14	374	3062	2067	0.0087	3.049	Hammond #64/65 October 1981
	Jan - Dec	Other	15	407	2793	2025	0.0093	3.037	Cameron #321/322 July 1981
1982	Jan - June	Trawlers	48	1339	11563	10702	0.0059	3.143	Hammond #71/72 March 1982
	July - Dec	Trawlers	13	379	2682	1657	0.0068	3.100	Needler #2/3 October 1982
	Jan - Dec	Other	18	472	3337	2676	0.0123	2.954	Hammond #80/81 July 1982
1983	Jan - June	Trawlers	39	694	9253	6068	0.0086	3.026	Hammond #94/95 March 1983
	July - Dec	Trawlers	17	133	3642	936	0.0085	3.045	Needler #17/18 October 1983
	Jan - Dec	Other	15	131	2676	2060	0.0116	2.961	Needler #12/13 July 1983
1984	Jan - June	Trawlers	33	535	7716	3546	0.0079	3.052	Needler #24/25 March 1984
	July - Dec	Trawlers	33	315	7279	2655	0.0049	3.178	Needler #36/37 October 1984
	Jan - Dec	Other	11	256	2329	1471	0.0097	3.005	Needler #31/32 July 1984
1985	Jan - June	Trawlers	33	615	7285	7174	0.0235	2.739	Needler #41 March 1985
	July - Dec	Trawlers	14	85	3019	2358	0.0049	3.178	Needler #36/37 October 1984
	Jan - Dec	Other	6	109	1087	1731	0.0129	2.921	Needler #48/49 July 1985
1986	Jan - June	Trawlers	48	531	10651	7151	0.006073	3.133906	Needler #65/66 July 1986
	Jul - Dec	Trawlers	27	329	5768	6628	0.006073	3.133906	Needler #65/66 July 1986
	Jan - Dec	Other	27	504	3954	1986	0.006073	3.133906	Needler #65/66 July 1986
1987	Jan - June	Trawlers	25	410	4827	954	0.00770612	3.072610	All summer surveys 70-88
	Jul - Dec	Trawlers	15	272	3036	987	0.00770612	3.072610	All summer surveys 70-88
	Jan - Dec	Other	8	150	1403	1090	0.00770612	3.072610	All summer surveys 70-88
1988	Jan - June	Trawlers	16	264	3363	1100	0.00770612	3.072610	All summer surveys 70-88
	Jan - June	Other	4	56	747	123	0.00770612	3.072610	All summer surveys 70-88

Table 5. Summary of samples of commercial catch by year, quarter, and gear type for 4VW haddock. (For 1948-1969 see Mahon et al. 1985.)

Year	Gear	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec
1970	Otter trawlers	5	5	0	1
	Longliners	0	0	2	1
1971	Otter trawlers	16	7	0	1
	Longliners	0	0	1	4
1972	Otter trawlers	5	1	0	1
	Longliners	0	0	0	1
1973	Otter trawlers	6	1	1	0
	Longliners	0	2	0	1
1974	Otter trawlers	1	0	0	0
	Longliners	0	0	1	1
1975	Otter trawlers	1	2	0	1
	Longliners	0	0	0	1
1976	Otter trawlers	0	1	1	1
	Longliners	1	0	1	1
1977	Otter trawlers	1	2	4	7
	Longliners	1	2	0	0
	Danish seine	0	1	0	0
1978	Otter trawlers	11	7	1	1
	Longliners	1	4	0	0
1979	Otter trawlers	1	2	4	3
	Longliners	1	3	5	3
1980	Otter trawlers	18	8	9	14
	Longliners	0	0	4	0
	Danish seine	0	2	0	0
1981	Otter trawlers	21	13	8	6
	Longliners	2	0	6	4
	Danish seine	0	0	2	0
	Gillnet	0	0	1	0
1982	Otter trawlers	19	29	6	7
	Longliners	4	3	7	1
	Danish seine	0	2	1	0
1983	Otter trawlers	12	34	13	3
	Pair trawlers	0	1	1	1
	Longliners	0	5	3	0
	Danish seine	0	3	0	1
	Gillnet	0	3	0	0
1984	Otter trawlers	8	25	12	18
	Pair trawlers	0	0	2	1
	Longliners	0	3	1	0
	Danish seine	2	0	3	1
	Gillnet	0	1	0	0
1985	Otter trawlers	12	21	6	8
	Longliners	0	1	3	1
	Danish seine	0	0	1	0
		Jan-June	July-Dec		
1986	Otter trawlers	46	27		
	Longliners	3	20		
	Danish seine	1	2		
1987	Otter trawlers	25	15		
	Longliners	–	6		
	Danish seine	–	–		
	Gillnets	–	1		
	Handlines	–	1		
1988	Otter trawlers	16			
	Longliners	4			
	Danish seine	1			

Table 6. Commercial removals at age (numbers in 000's) for 4TVW haddock. For 1988 removals are estimated to 30 June 1988 from Atlantic Quota Reports.

Commercial Removals at Age 4TVW Haddock

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
1	0	0	0	50	0	0	0	0	0	0	0	0
2	0	10	0	0	6	3	12	0	213	0	63	8
3	177	855	83	765	449	349	211	504	1926	647	2115	2938
4	2194	1126	2389	4967	1915	2324	2881	1021	11209	3634	3817	6803
5	3269	4330	2823	6056	6626	4113	10071	2592	2400	13199	2504	5559
6	1297	3090	5018	2216	4654	4445	2159	5132	2539	2045	8128	3388
7	1412	483	3227	1794	1831	1407	2466	1765	2866	1538	1076	7071
8	1088	357	293	1306	1079	457	1318	1642	963	1233	777	809
9	556	303	575	98	405	247	431	620	1334	341	788	528
10	433	228	230	66	96	25	265	313	340	244	276	534
11	253	142	358	79	65	18	68	51	89	92	164	213

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
1	0	2	205	1287	2591	53595	2127	89	5	31	306	268
2	0	31	436	924	3073	32161	9696	181	13	42	129	667
3	455	409	1491	511	4074	24140	9638	1006	398	438	679	888
4	6408	4901	2039	3471	2368	15192	8887	2622	1806	1408	1743	2189
5	7580	8501	7794	3673	6023	7775	4645	2836	2926	2039	1400	2740
6	3339	4298	6190	6594	2069	4057	1217	1113	2494	1955	1365	1208
7	2164	1362	1957	3190	2906	1282	1637	441	793	939	1163	944
8	1964	1062	839	1243	1562	1234	499	597	379	279	389	1177
9	372	727	317	287	403	402	272	212	406	131	88	277
10	157	193	223	126	81	72	89	174	116	118	38	39
11	161	61	59	113	45	54	12	55	78	39	19	21

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	306	487	59	279	431	213	714	1	332	870	530	497	10
2	288	1178	233	61	676	283	433	268	376	318	433	470	360
3	671	646	975	470	157	965	811	423	2372	262	1520	1084	1514
4	751	1467	254	805	249	335	2412	1120	4334	5072	764	3207	4158
5	924	811	464	282	323	513	436	675	3238	5081	5629	2040	2225
6	668	723	298	185	189	283	715	159	1702	3010	1957	1677	821
7	345	342	114	63	132	117	203	149	249	1178	1220	530	410
8	191	159	47	30	36	80	61	16	129	139	214	235	90
9	159	60	8	8	8	19	23	5	39	105	48	29	30
10	9	99	17	4	10	15	8	6	9	30	28	18	5
11	18	2	16	1	3	6	2	2	7	10	5	19	2

	1985	1986	1987	1988
1	133	12	34	56
2	69	50	86	67
3	411	1257	179	44
4	8006	9770	1080	262
5	4162	5747	1823	709
6	881	738	403	265
7	232	98	25	23
8	47	12	7	0
9	14	1	1	3
10	2	1	1	1
11	1	1	1	0

Commercial Weights at Age 4VW Haddock

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
1	.082	.082	.082	.680	.082	.082	.082	.082	.082	.082	.082	.082
2	.305	.680	.305	.305	.680	.580	.680	.305	.500	.305	.530	.800
3	1.130	.838	.821	.997	.885	.954	.869	.786	.750	.762	.704	.680
4	1.189	1.189	1.026	1.073	1.095	1.133	1.084	1.038	.888	.986	.976	.892
5	1.611	1.393	1.385	1.292	1.353	1.517	1.144	1.298	1.252	1.185	1.264	1.168
6	2.250	1.821	1.861	1.626	1.662	1.822	1.574	1.476	1.527	1.557	1.472	1.477
7	2.692	2.465	2.165	2.081	2.113	2.253	1.953	1.813	1.722	1.816	1.749	1.788
8	3.022	2.925	2.634	2.332	2.615	2.761	2.127	2.151	2.127	2.074	2.102	2.173
9	3.097	2.986	2.562	1.612	2.986	3.175	2.438	2.392	2.227	2.370	2.089	2.405
10	3.383	3.162	2.838	1.391	2.514	3.868	2.691	2.597	2.283	2.388	2.460	2.740
11	3.490	3.315	3.593	2.316	2.463	3.540	3.063	2.780	2.815	2.791	2.407	2.946

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
1	.082	.060	.049	.099	.102	.103	.090	.122	.108	.099	.108	.119
2	.305	.190	.200	.142	.281	.254	.267	.384	.174	.218	.332	.335
3	.667	.794	.453	.364	.445	.421	.356	.534	.434	.652	.638	.625
4	.912	.899	.825	.939	.710	.715	.698	.784	.800	.883	.913	.921
5	1.096	1.147	1.022	1.146	1.096	1.114	1.034	1.149	1.118	1.260	1.288	1.302
6	1.414	1.526	1.350	1.356	1.350	1.297	1.332	1.485	1.593	1.616	1.565	1.627
7	1.829	1.867	1.735	1.748	1.644	1.928	1.551	1.767	2.159	2.277	2.072	1.930
8	2.191	2.225	2.182	2.007	1.925	2.232	2.177	2.167	2.188	2.774	2.595	2.303
9	2.461	2.406	2.730	2.356	2.345	2.418	2.300	2.548	2.572	3.313	3.137	2.867
10	2.703	2.762	2.597	2.547	2.724	2.791	2.670	2.816	3.103	3.324	4.044	3.435
11	2.678	3.298	3.455	2.443	2.393	3.119	3.040	3.065	3.343	3.210	3.553	3.752

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	.098	.115	.122	.159	.092	.140	.080	.090	.080	.080	.060	.070
2	.280	.347	.407	.245	.369	.515	.349	.335	.231	.383	.265	.186
3	.586	.651	.643	.852	.526	.927	.666	.708	.716	.686	.631	.526
4	.955	.976	1.123	1.203	1.217	1.234	1.067	1.167	1.031	.954	.957	.822
5	1.344	1.374	1.656	1.572	1.607	1.514	1.511	1.554	1.361	1.266	1.203	1.160
6	1.832	1.866	1.978	2.137	2.027	1.905	1.967	2.020	1.846	1.677	1.606	1.428
7	2.187	2.218	2.468	2.447	2.271	2.345	2.582	2.444	2.319	2.190	2.154	1.721
8	2.407	2.593	2.789	2.800	2.327	2.505	2.687	2.965	2.662	2.708	2.779	1.905
9	2.971	3.248	2.841	3.036	3.194	2.811	3.276	3.273	3.128	3.082	3.138	2.802
10	3.861	3.174	3.435	3.131	2.611	3.328	3.497	3.435	3.402	3.409	3.513	2.065
11	3.830	3.630	3.395	4.120	3.102	3.196	3.846	4.208	3.654	3.664	4.496	1.816

	1984	1985	1986	1987	1988
1	.090	.120	.100	.101	.113
2	.263	.197	.270	.213	.293
3	.577	.462	.620	.450	.578
4	.738	.698	.810	.861	.844
5	1.036	.986	1.050	1.110	1.145
6	1.462	1.429	1.570	1.532	1.455
7	1.794	1.926	2.420	2.071	1.823
8	2.154	2.350	2.280	2.300	2.798
9	2.664	2.964	2.580	2.752	2.210
10	3.240	2.200	3.760	2.566	2.690
11	3.182	5.590	4.470	3.764	3.764

Table 7. Mean weights at age (kg) for 4VW haddock commercial removals.

Table 8. Research vessel arithmetic mean catch rates at age for haddock in Divisions 4VW.

RV Catch Rates at Age 1988

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	.105	.062	.000	.000	.228	.074	.295	.197	.000	1.488
1	2.736	1.724	1.319	.531	.373	5.073	2.760	6.075	9.899	.088
2	1.004	3.630	.886	1.733	2.146	.721	3.130	11.379	11.071	9.133
3	1.839	1.197	1.295	.537	2.903	1.938	.478	8.969	14.806	9.937
4	2.044	1.576	.585	.472	.526	1.734	.950	1.217	8.320	10.330
5	.993	.627	.488	.169	.541	.461	.931	1.940	.513	2.895
6	.621	.355	.367	.349	.270	.833	.206	.722	.488	.372
7	.695	.163	.150	.074	.201	.220	.230	.204	.124	.289
8	.348	.255	.071	.096	.080	.088	.052	.108	.015	.098
9	.139	.012	.043	.023	.045	.047	.016	.000	.000	.000
10	.044	.000	.019	.046	.033	.054	.015	.050	.011	.038
11	.038	.000	.000	.000	.039	.000	.016	.009	.014	.018
12	.033	.000	.000	.000	.000	.018	.060	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000	.021	.000	.000
14	.009	.000	.000	.000	.000	.000	.000	.000	.000	.007
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	1.441	22.353	.774	.146	.276	.000	.137	.083	1.043
1	3.512	15.615	18.189	21.800	.302	4.223	.604	1.929	4.695
2	.276	9.378	15.752	14.486	10.836	1.040	2.251	1.733	13.432
3	14.882	.991	14.215	30.222	16.893	11.084	7.777	4.671	10.201
4	13.921	7.375	2.048	11.631	29.115	21.685	26.058	15.570	16.163
5	8.650	4.679	7.212	3.078	5.247	4.731	11.879	6.174	9.257
6	2.090	2.015	3.053	2.742	2.572	1.263	1.299	.552	1.129
7	.333	.308	.965	.946	1.361	.305	.401	.092	.106
8	.119	.088	.227	.238	.303	.062	.067	.000	.032
9	.019	.095	.020	.070	.108	.000	.000	.053	.000
10	.000	.028	.016	.059	.025	.002	.000	.000	.000
11	.000	.000	.000	.000	.006	.000	.000	.000	.000
12	.000	.000	.000	.045	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.003	.000	.000	.000	.000
14	.000	.000	.000	.024	.000	.000	.000	.000	.000
15	.000	.000	.021	.000	.000	.000	.000	.000	.000

Table 9. Formulation of the non-linear least squares adaptive framework used in this assessment of stock size. The parameters estimated were population numbers at ages 2 through 5, and slopes of the relationships between population numbers and RV estimates of numbers at these ages.

Parameters:

- Year-class estimates

  $N_{i,1987}$ $\quad i = 2$ to 5

- Calibration slopes and intercept for mid-year RV numbers

  K_{oi}, K_{1i} $\quad i = 2$ to 5

Structure:

- assumed no error in catch at age
- F at ages 6 to 11 in 1987 set equal to age 5
- F at oldest age (11) set equal to weighted (population numbers) mean ages 5, 6, 7
- natural mortality set equal to 0.2

Input:

- $C_{i,t}$ $\quad i = 1$ to 11 $\quad t = 1970$ to 1987, and half year 1988
- $FV_{i,t}$ $\quad i = 2$ to 5 $\quad t = 1970$ to 1988

Objective Function:

- minimize

$$\sum_i \sum_t (\text{obs } (\ln RV_{i,t}) - \text{pred } (\ln RV_{i,t}))^2$$

Summary:

- number of observations = 76
- number of parameters = 12

Table 10. Results of the adaptive framework analysis summarized on Table 9. Table 10a lists the final estimates of cohort sizes in 1987 for ages 2 through 5, the intercept and slope values relating the RV and SPA estimates of cohort sizes, and the standard errors and t statistics for each estimate. Table 10b shows the level of correlation between the parameters being estimated as a measure of the level of independence between parameters. Table 10c lists the final residuals from the model listed on Table 9.

Table 10a. APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.009651
MEAN SQUARE RESIDUALS 0.559375

	PAR. EST.	STD. ERR.	T-STATISTIC
I2	1.32791E0004	6.55610E0003	2.02546E0000
I3	1.16455E0004	4.67243E0003	2.49239E0000
I4	1.04318E0004	3.57178E0003	2.92061E0000
I5	1.54638E0004	5.89236E0003	2.62438E0000
a2	-1.45251E-001	5.11876E-001	-2.83763E-001
b2	3.06130E-004	8.74124E-005	3.50213E0000
a3	-9.53407E-001	4.70215E-001	-2.02760E0000
b3	7.41499E-004	1.67509E-004	4.42663E0000
a4	-9.51350E-001	4.20526E-001	-2.26229E0000
b4	1.12308E-003	2.47494E-004	4.53780E0000
a5	-4.75251E-001	2.97186E-001	-1.59917E0000
b5	1.10489E-003	2.82168E-004	3.91572E0000

Table 10b. PARAMETER CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	.063	.057	.085	.089	-.173	.149	-.204	.026	-.032	.029	-.035
2	.063	1.000	.072	.102	.089	-.159	.133	-.178	.142	-.180	.035	-.043
3	.057	.072	1.000	.141	.095	-.153	.120	-.156	.135	-.169	.172	-.208
4	.085	.102	.141	1.000	.237	-.327	.138	-.173	.171	-.207	.269	-.325
5	.089	.089	.095	.237	1.000	-.800	.054	-.070	.055	-.067	.072	-.088
6	-.173	-.159	-.153	-.327	-.800	1.000	-.087	.113	-.082	.101	-.103	.124
7	.149	.133	.120	.138	.054	-.087	1.000	-.848	.049	-.060	.051	-.062
8	-.204	-.178	-.156	-.173	-.070	.113	-.848	1.000	-.063	.078	-.065	.078
9	.026	.142	.135	.171	.055	-.082	.049	-.063	1.000	-.859	.061	-.074
10	-.032	-.180	-.169	-.207	-.067	.101	-.060	.078	-.859	1.000	-.075	.091
11	.029	.035	.172	.269	.072	-.103	.051	-.065	.061	-.075	1.000	-.879
12	-.035	-.043	-.208	-.325	-.088	.124	-.062	.078	-.074	.091	-.879	1.000

Table 10c. STANDARDIZED RESIDUALS (se=1 for log model)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	-.277	.899	.198	.238	.428	-.165	-.273	.681	.507	.178	-2.087	.894
3	-.641	-.247	-.334	.261	.781	.048	-.674	.262	.359	-.211	.105	-1.273
4	-.996	-.547	-.799	-.892	.399	.573	-.834	.089	.205	-.151	.124	-.523
5	-.970	-1.193	-.867	-1.060	.162	.448	.439	.180	-.410	-.441	.166	-.055

	1982	1983	1984	1985	1986	1987	1988
2	1.126	.445	-.109	-1.476	-.505	-.688	-.013
3	.830	1.224	-.005	-.731	-.002	-.352	.607
4	-.672	.831	1.304	.368	.180	.579	.784
5	.516	.579	1.135	.892	.762	-.781	.499

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	8153	4438	8085	7649	4579	19929	27173	31127	35934	10915	18472	24860	43237
2	5479	6398	3391	6343	5822	3696	16064	21857	25292	28774	8935	14823	19566
3	7181	4369	4634	2516	4127	4555	2971	12541	17639	20315	23316	6976	11848
4	7683	5265	2773	3187	1476	2497	3304	2290	9394	13708	16250	16943	5474
5	4136	4713	2330	1590	1282	979	1315	2480	1572	5508	10210	9382	9283
6	3270	2120	1380	1072	568	630	546	785	1566	893	3899	5429	3084
7	3416	1442	642	525	223	196	348	276	386	635	587	1652	1722
8	825	1745	326	214	121	79	103	165	120	132	385	255	287
9	210	323	363	95	31	56	38	52	62	43	94	198	83
10	84	93	13	154	23	18	39	24	26	31	31	41	67
11	52	34	40	3	36	3	11	23	6	14	20	17	7

	1983	1984	1985	1986	1987
1	55666	21114	17554	16203	67181
2	34920	45126	17278	14251	13255
3	15628	28165	36620	14084	11623
4	8325	11814	21690	29610	10393
5	3791	3914	5910	10514	15402
6	2507	1258	1192	1073	3408
7	754	535	287	178	211
8	306	138	68	25	57
9	41	38	31	13	10
10	25	7	4	13	10
11	30	4	1	2	10

FISHING MORTALITY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	.042	.069	.043	.073	.014	.016	.018	.008	.022	.000	.020	.039
2	.026	.122	.098	.230	.045	.018	.048	.014	.019	.010	.048	.024
3	.110	.255	.174	.333	.303	.121	.060	.089	.052	.023	.119	.042
4	.289	.615	.356	.711	.211	.441	.087	.176	.334	.095	.349	.402
5	.468	1.028	.576	.829	.511	.383	.316	.260	.366	.146	.432	.913
6	.619	.994	.765	1.369	.864	.393	.483	.509	.703	.219	.659	.948
7	.472	1.286	.901	1.271	.835	.442	.545	.629	.873	.299	.634	1.552
8	.737	1.369	1.037	1.715	.568	.532	.491	.773	.827	.141	.464	.923
9	.620	2.978	.661	1.222	.353	.167	.270	.504	.510	.131	.622	.883
10	.694	.631	1.328	1.244	1.825	.314	.323	1.213	.435	.239	.403	1.564
11	.514	1.060	.680	1.073	.640	.392	.394	.344	.571	.169	.500	.989

	1982	1983	1984	1985	1986	1987
1	.014	.010	.001	.008	.001	.001
2	.025	.015	.009	.004	.004	.007
3	.153	.080	.061	.012	.104	.017
4	.167	.555	.493	.524	.454	.122
5	1.109	.903	.989	1.506	.927	.140
6	1.209	1.344	1.278	1.699	1.428	.140
7	1.528	1.501	1.869	2.242	.934	.140
8	1.755	1.885	1.286	1.464	.758	.140
9	1.014	1.572	1.970	.688	.090	.140
10	.615	1.724	1.422	.711	.090	.140
11	1.182	1.124	1.135	1.566	.972	.140

Table 10d. Population numbers and fishing mortality rates estimated for 4TVW using the formulation of the adaptive framework summarized on Table 9.

POPULATION NUMBERS

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
1	69398	39915	72501	34774	26582	122467	42932	44346	64374	80081	70010	29730	48482	33463	58683
2	44286	56819	32680	59359	28426	21764	100267	35150	36307	52705	65565	57320	24341	39694	27396
3	21080	36258	46510	26756	48599	23268	17816	82081	28778	29533	43151	53622	46922	19928	32470
4	25221	17099	28912	38004	21214	39383	18734	14395	66746	21819	23594	33415	41244	38005	15946
5	17524	18664	12980	21509	26621	15636	30142	12732	10862	44505	14576	15863	21203	27970	26682
6	3180	11390	11362	8073	12131	15800	9081	15565	8079	6721	24495	9668	7958	10500	15207
7	3578	1430	6529	4763	4604	5721	8914	5481	8100	4317	3652	12701	4850	3494	4708
8	2455	1652	734	2425	2276	2113	3411	5067	2891	4039	2143	2016	4001	2013	1628
9	2365	1025	1030	336	804	886	1317	1600	2663	1495	2191	1051	919	1498	687
10	1174	1434	565	323	186	291	502	688	749	973	915	1081	383	415	569
11	941	569	967	255	205	66	216	172	281	305	576	500	403	172	166
1+	191202	186254	214771	196576	171647	247395	233331	217277	229829	246493	250868	216967	200703	177153	184143
2+	121804	146339	142269	161802	145065	124928	190399	172931	165455	166412	180858	187238	152221	143689	125460
3+	77518	89520	109590	102443	116639	103165	90132	137782	129148	113707	115293	129918	127881	103996	98064
4+	56438	53262	63080	75687	68040	79897	72316	55701	100369	84174	72142	76296	80958	84067	65594

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	84522	91796	91520	15283	14750	10773	6718	8150	4428	8085	7605	4574	19928	27168	31127	35934	10915
2	47860	68036	72812	26435	10588	11996	8816	5473	6396	3383	6342	5786	3692	16063	21853	25292	28774
3	22035	38348	52923	30513	12870	8505	9810	7179	4364	4632	2510	4127	4526	2967	12540	17636	20315
4	25235	17579	27710	21487	16261	9627	6603	7636	5263	2769	3185	1471	2496	3280	2287	9393	13705
5	11211	17520	12250	8942	9551	10941	6248	4132	4675	2329	1587	1280	974	1315	2460	1570	5508
6	14793	5856	8894	2994	3118	5253	6310	3270	2116	1348	1071	565	628	543	785	1550	891
7	6850	6145	2922	3612	1351	1545	2044	3397	1442	640	500	222	194	347	273	386	621
8	2084	2722	2402	1232	1476	707	548	824	1729	326	211	99	79	101	164	118	132
9	574	581	815	850	557	668	236	196	322	351	95	30	39	38	50	62	41
10	276	210	111	304	449	264	180	75	81	13	143	23	17	25	23	24	30
11	264	112	98	26	169	210	111	40	27	31	2	28	3	10	11	5	13
1+	215703	248905	272458	111678	71140	60491	47625	40372	30843	23907	23252	18205	32575	51856	71573	91969	80946
2+	131181	157108	180938	96394	56389	49717	40907	32222	26415	15822	15647	13631	12648	24688	40447	56036	70030
3+	83321	89072	108126	69959	45801	37721	32091	26750	20020	12438	9304	7845	8956	8625	18594	30744	41256
4+	61286	50724	55203	39446	32932	29216	22281	19570	15656	7806	6795	3718	4430	5658	6054	13108	20941

	1980	1981	1982	1983	1984	1985	1986	1987
1	18472	24858	43214	55581	21043	17694	16651	37529
2	8935	14823	19565	34902	45056	17220	14366	13622
3	23316	6976	11848	15627	28150	36563	14036	11717
4	16250	16943	5474	8325	11813	21677	29563	10354
5	10207	9382	9283	3791	3914	5909	10503	15364
6	3898	5427	3084	2507	1257	1191	1072	3399
7	585	1651	1720	754	535	287	178	210
8	374	254	286	304	137	68	25	57
9	94	189	82	40	37	31	13	10
10	29	41	60	24	7	3	13	10
11	19	16	7	24	3	1	1	10
1+	82181	80561	94623	121877	111952	100644	86421	92281
2+	63709	55702	51408	66296	90909	82950	69771	54752
3+	54774	40880	31844	31395	45853	65730	55404	41130
4+	31458	33904	19996	15768	17704	29168	41368	29414

Table 11. Population numbers (000's) at age (1948-1987) estimated by SPA using input parameters as described in the text.

MEAN POPULATION BIOMASS (KG)

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
1	5158	2966	5388	21416	1976	9102	3191	3296	4784	5952	5203	2210	3603	1820	2601	7522
2	12242	35015	9034	16409	17517	11440	61792	9717	16402	14570	31479	41558	6729	6819	4924	6096
3	21493	27189	34576	23817	38802	19955	13942	58310	18843	20148	26812	32054	28232	14182	12999	7180
4	25889	17775	25683	34300	20019	39143	16851	13023	48749	17706	19006	23941	31179	28784	11091	19863
5	22930	20496	14306	21159	28066	18303	25235	13278	10798	39713	15111	13384	16696	24019	20598	9451
6	4927	15907	14126	10043	14176	21919	11225	16871	9165	7833	26440	10316	7671	11019	14148	13352
7	6710	2574	8973	7008	6758	10064	13302	7338	10051	5636	4816	13464	5901	4562	5587	7818
8	4947	3850	1342	3425	3853	4649	5090	8037	4501	6266	3221	3034	5583	2744	2206	2361
9	5763	2307	1561	409	1508	2148	2361	2682	3738	2801	3283	1591	1560	2310	1231	852
10	2826	3748	1106	361	291	973	829	1180	1128	1808	1689	1882	711	750	1033	464
11	2527	1472	2479	440	375	180	492	361	587	640	1054	1002	750	409	414	439
1+	115412	133300	118573	138785	133340	137875	154311	134092	128745	123070	138114	144436	108614	97417	76831	75399
2+	110255	130334	113185	117370	131365	128774	151120	130796	123961	117118	132911	142227	105011	95597	74230	67877
3+	98013	95319	104151	100961	113848	117334	89328	121080	107559	102549	101432	100668	98283	88779	69306	61781
4+	76520	68130	69575	77144	75045	97378	75385	62770	88717	82401	74620	68614	70050	74597	56308	54601

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	8358	5383	1151	1626	1054	601	782	462	703	765	502	2850	2246	3935	2578	890	1326	1768
2	16880	12333	5034	3653	1891	1737	1628	1832	819	1792	2088	812	5249	10122	7922	8692	1826	5092
3	14579	14679	8072	5966	3261	5658	3940	2191	2265	1266	2085	3295	1373	10097	10387	12894	14296	4249
4	10469	11857	10271	10527	6250	4656	5510	3314	2028	2041	1354	2217	3469	2352	7768	13853	12888	12144
5	13944	7318	5718	8257	9405	5795	3879	3483	2176	1360	1517	1160	1651	2982	1810	7236	10297	7166
6	5696	7602	2751	3326	5417	7602	3493	2008	1566	1008	686	1013	795	1070	1998	1469	4828	5412
7	6551	3773	3702	1757	2077	3058	5120	1449	846	550	341	349	555	433	611	1192	920	1706
8	3043	3333	1851	2208	939	950	1387	1990	450	240	179	156	169	263	196	331	723	411
9	666	1253	1445	1000	957	465	408	276	689	164	64	94	96	100	145	114	200	347
10	401	162	613	886	548	310	190	179	24	224	33	40	45	41	62	84	74	66
11	187	185	51	381	501	258	93	45	68	4	56	9	22	22	14	44	51	32
1+	80773	67880	40660	39588	32301	31091	26428	17228	11635	9412	8907	11994	15670	31419	33491	46799	47429	38393
2+	72416	62496	39509	37962	31247	30489	25647	16766	10932	8647	8404	9144	13424	27483	30913	45909	46103	36624
3+	55536	50163	34475	34309	29356	28752	24019	14934	10113	6855	6316	8332	8175	17361	22991	37217	44276	31533
4+	40957	35484	26403	28343	26095	23094	20080	12743	7848	5589	4231	5036	6802	7264	12604	24323	29980	27284

	1982	1983	1984	1985	1986	1987
1	2335	3509	1716	1917	1509	3434
2	4641	5849	10703	3068	3509	2621
3	6300	7173	14282	15209	7503	4740
4	4383	4807	6291	10767	17573	7622
5	6227	2663	2372	2795	6612	14457
6	2657	1823	960	762	830	4415
7	1761	623	405	207	258	369
8	348	242	154	77	37	112
9	147	52	38	61	29	22
10	137	20	10	4	42	21
11	17	19	4	2	0	30
1+	28953	26780	36935	34869	37901	37843
2+	26619	23271	35219	32952	36392	34409
3+	21978	17422	24516	29884	32883	31788
4+	15678	10249	10234	14675	25380	27048

Table 12. Mean population biomass (t) at age (1948-1987) estimated by SPA using input parameters as described in the text.

CATCH BIOMASS

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
1	0	0	0	34	0	0	0	0	0	0	0	0	0	0	10	127	264	5505
2	0	7	0	0	4	2	8	0	107	0	34	6	0	6	87	131	862	8156
3	200	717	68	763	398	333	184	397	1443	493	1489	1997	304	324	675	186	1814	10161
4	2608	1340	2452	5328	2096	2632	3124	1060	9957	3584	3726	6067	5845	4407	1683	3261	1680	10856
5	5265	6032	3909	7825	8965	6240	11522	3364	3005	15641	3165	6492	8310	9749	7965	4210	6600	8660
6	2918	5628	9338	3603	7736	8098	3399	7575	3876	3183	11967	5004	4723	6558	8358	8944	2792	5261
7	3801	1190	6988	3734	3868	3170	4816	3199	4936	2793	1883	12640	3958	2543	3396	5575	4778	2472
8	3289	1044	772	3047	2823	1262	2803	3531	2049	2556	1633	1758	4304	2362	1832	2495	3007	2754
9	1721	904	1474	158	1210	784	1050	1484	2970	809	1645	1271	916	1748	865	676	946	971
10	1466	722	653	91	241	97	712	812	777	584	678	1462	423	532	579	320	221	201
11	884	470	1287	183	160	62	209	141	250	257	394	629	432	201	202	276	107	168
1+	22152	18052	26941	24766	27501	22679	27827	21563	29369	29900	26614	37326	29214	28431	25652	26201	23072	55165
2+	22152	18052	26941	24732	27501	22679	27827	21563	29369	29900	26614	37326	29214	28431	25642	26073	22807	49660
3+	22152	18045	26941	24732	27497	22677	27819	21563	29262	29900	26581	37320	29214	28425	25555	25942	21945	41504
4+	21952	17329	26872	23970	27099	22344	27636	21167	27819	29407	25091	35323	28910	28100	24880	25756	20131	31343

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	191	11	1	3	33	32	30	56	7	44	40	30	57	0	27	70	32	35	1
2	2590	69	2	9	43	224	81	409	95	15	249	146	151	90	87	122	115	88	95
3	3435	537	173	286	434	555	393	420	627	401	83	895	540	300	1699	180	959	570	873
4	6200	2056	1444	1244	1591	2016	718	1433	285	968	303	413	2574	1307	4468	4838	731	2638	3069
5	4805	3258	3271	2570	1802	3567	1241	1114	768	443	519	777	659	1049	4406	6433	6772	2367	2305
6	1621	1653	3974	3159	2136	1965	1224	1350	588	396	384	540	1407	321	3142	5048	3144	2394	1200
7	2540	780	1711	2138	2410	1821	755	759	282	155	300	273	525	363	578	2580	2629	912	735
8	1087	1293	829	775	1010	2711	459	411	132	83	84	202	165	47	345	376	596	447	194
9	626	541	1043	433	275	795	472	196	24	24	26	52	74	16	123	324	150	81	79
10	236	490	360	394	153	135	35	314	60	14	25	50	29	20	32	101	98	38	15
11	37	169	260	126	68	77	70	6	53	4	10	19	9	8	26	36	20	34	7
1+	23370	10856	13067	11136	9957	13898	5477	6469	2922	2546	2024	3397	6190	3521	14931	20108	15246	9603	8573
2+	23178	10846	13066	11133	9924	13866	5447	6413	2914	2502	1984	3367	6133	3521	14904	20038	15214	9569	8572
3+	20588	10776	13064	11124	9881	13643	5366	6004	2820	2487	1735	3221	5982	3431	14818	19916	15099	9481	8477
4+	17153	10239	12891	10838	9447	13087	4973	5583	2193	2086	1652	2327	5441	3131	13119	19736	14140	8911	7605

	1985	1986	1987
1	16	1	3
2	14	14	18
3	190	779	81
4	5590	7914	930
5	4104	6034	2024
6	1259	1159	618
7	447	237	52
8	110	27	16
9	41	3	3
10	4	4	3
11	6	4	4
1+	11781	16176	3752
2+	11765	16175	3748
3+	11751	16161	3730
4+	11562	15382	3650

Table 13. Catch biomass (t) at age (1948-1987) estimated by SPA using input parameters as described in the text.

POPULATION BIOMASS AT BEGINNING OF YEAR

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
1	1976	1137	3083	1479	18076	3776	1222	1885	2138	3405	2258	780	2061	1805	1929	2433
2	8149	13417	5168	9387	19330	4746	23677	5559	7352	8335	13668	14681	3849	4949	3001	3992
3	23219	18330	34751	14758	25254	18740	12648	60023	13760	18225	19998	32183	34284	9806	9515	5946
4	27696	19823	26810	35665	22170	39438	19053	13672	55787	18759	20342	26479	32476	29440	12907	16461
5	26542	24018	16657	24768	32071	20154	34313	15104	12381	45664	16273	16936	20964	28608	25577	10903
6	6836	19506	18296	12112	17779	24808	14035	20228	11373	9382	32357	13210	10228	13581	18923	17416
7	9242	3369	12965	9373	8533	11072	16816	9259	12915	7188	6026	20606	7972	5678	7661	10523
8	7463	4636	1871	5451	5309	5104	7467	10386	5675	7633	4186	3931	7918	4060	3287	3888
9	7249	3079	2819	692	2121	2555	3416	3610	5827	3356	4561	2364	2124	3440	1694	1301
10	4013	4487	1646	609	375	990	1469	1731	1750	2244	2210	2587	976	1083	1423	728
11	3127	1906	3261	653	379	197	743	470	758	770	1380	1346	1090	512	512	666
1+	125511	113707	127326	114945	151396	131578	134859	141927	129716	124961	123260	135103	123942	102963	86429	74257

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	5398	5920	974	643	1101	511	440	271	627	396	280	1716	2836	1211	3187	427	1038	908
2	11339	11710	4379	1969	1748	1353	993	1217	618	1170	1252	638	3890	4755	5589	4710	1288	2596
3	9643	18187	9174	4861	3473	3304	2678	1989	2053	1072	1951	2665	1065	7334	10327	10097	11420	2775
4	8934	15631	11644	8597	6291	4088	5892	4035	2139	2410	1258	2195	3339	1842	9344	12086	13884	14005
5	17777	10890	7688	8550	10242	6271	4406	5097	2590	1818	1628	1295	1829	3339	2143	7092	12863	10718
6	7283	10604	3648	3864	7106	8480	4591	3063	2082	1696	932	1182	969	1373	2674	1556	6602	8199
7	9177	4714	5123	2073	2767	3893	6217	2505	1206	1007	477	426	764	595	856	1363	1267	3320
8	4992	4601	2524	2705	1390	1341	2003	3778	703	503	247	207	242	392	296	365	955	635
9	1261	1758	1925	1312	1577	636	578	879	918	265	80	112	113	128	177	122	286	542
10	532	284	772	1143	742	526	274	266	43	440	76	49	69	76	76	101	98	135
11	278	287	75	483	645	351	138	105	112	9	91	11	30	33	20	48	69	55
1+	76613	84585	47925	36199	37083	30755	28211	23206	13092	10786	8272	10496	15145	21078	34689	37967	49768	43889

	1982	1983	1984	1985	1986	1987
1	1900	1893	760	1076	1332	2571
2	2848	3690	6116	2293	2586	1988
3	5828	5833	9224	12747	4905	4084
4	4435	5997	7362	13753	18080	7565
5	9945	3993	3613	5041	8993	14568
6	4397	3286	1638	1450	1334	4311
7	3270	1253	856	481	332	379
8	706	617	265	139	52	135
9	238	112	83	78	31	24
10	197	60	20	8	43	25
11	27	60	7	5	3	36
1+	33792	26795	29944	37072	37691	35687

Table 14. Beginning of year population biomass (t) at age (1948-1987) estimated by SPA using input parameters as described in the text.

FISHING MORTALITY

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	.000	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.004	.017	.032	1.042	.167	.007
2	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.001	.000	.000	.001	.018	.022	.051	.670	.520	.019
3	.009	.026	.002	.032	.010	.017	.013	.007	.077	.025	.056	.062	.011	.023	.052	.026	.125	.701	.429	.090
4	.101	.076	.096	.156	.105	.067	.186	.082	.205	.203	.197	.255	.188	.154	.152	.165	.161	.931	.611	.196
5	.231	.296	.275	.373	.322	.343	.461	.255	.280	.397	.211	.490	.503	.409	.390	.449	.478	1.209	.854	.398
6	.599	.356	.670	.361	.552	.372	.305	.453	.427	.410	.457	.490	.623	.602	.598	.679	.495	.701	.596	.502
7	.573	.467	.790	.539	.579	.317	.365	.440	.496	.500	.394	.955	.679	.564	.615	.723	.739	.664	.695	.448
8	.673	.273	.582	.904	.743	.273	.557	.443	.459	.411	.512	.586	.782	.875	.843	1.077	1.006	.839	.594	.592
9	.301	.395	.961	.389	.815	.368	.449	.559	.807	.291	.506	.811	.594	.768	.712	.805	1.457	.786	.437	.547
10	.524	.193	.598	.254	.839	.100	.872	.697	.698	.325	.405	.788	.602	.719	.567	.699	.559	1.264	.389	.559
11	.350	.319	.519	.416	.428	.346	.425	.392	.425	.402	.374	.628	.576	.492	.489	.629	.573	.908	.720	.444
5+1	.362	.320	.544	.425	.438	.346	.428	.397	.435	.403	.381	.649	.580	.500	.497	.641	.591	.941	.733	.448

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1	.001	.005	.042	.069	.043	.073	.014	.016	.018	.008	.022	.000	.020	.039	.014	.010	.001	.008
2	.001	.005	.026	.123	.099	.230	.046	.018	.048	.014	.019	.010	.048	.024	.025	.015	.009	.004
3	.053	.051	.110	.255	.175	.334	.303	.122	.060	.089	.052	.023	.119	.042	.153	.080	.061	.013
4	.232	.269	.291	.615	.356	.712	.212	.441	.088	.176	.334	.095	.349	.402	.167	.555	.493	.525
5	.350	.447	.469	1.043	.577	.832	.511	.385	.317	.262	.367	.146	.432	.913	1.109	.903	.989	1.507
6	.744	.419	.619	.997	.793	1.371	.871	.394	.487	.509	.714	.220	.659	.949	1.209	1.344	1.278	1.700
7	.836	.708	.475	1.286	.908	1.414	.839	.448	.547	.638	.873	.307	.637	1.553	1.532	1.502	1.870	2.243
8	.897	.828	.739	1.395	1.038	1.767	.746	.537	.503	.778	.853	.141	.481	.931	1.761	1.910	1.287	1.466
9	1.112	.948	.683	3.017	.695	1.225	.381	.253	.274	.524	.516	.138	.622	.951	1.038	1.599	2.173	.689
10	.664	1.299	.819	.765	1.452	1.439	1.849	.351	.574	1.256	.463	.244	.431	1.570	.723	1.911	1.537	1.028
11	.518	.488	.739	1.707	1.024	1.478	.949	.406	.462	.882	.621	.184	.513	1.136	1.199	1.798	1.830	2.380
5+1	.546	.501	.537	1.187	.720	1.162	.662	.398	.400	.375	.583	.169	.500	.989	1.191	1.164	1.146	1.562

	1986	1987
1	.001	.001
2	.004	.007
3	.104	.017
4	.455	.122
5	.928	.140
6	1.430	.140
7	.935	.140
8	.759	.140
9	.091	.140
10	.091	.140
11	27.325	.140
5+1	.974	.140

Table 15. Fishing mortality at age (1948-1987) estimated by SPA using parameters as described in the text.

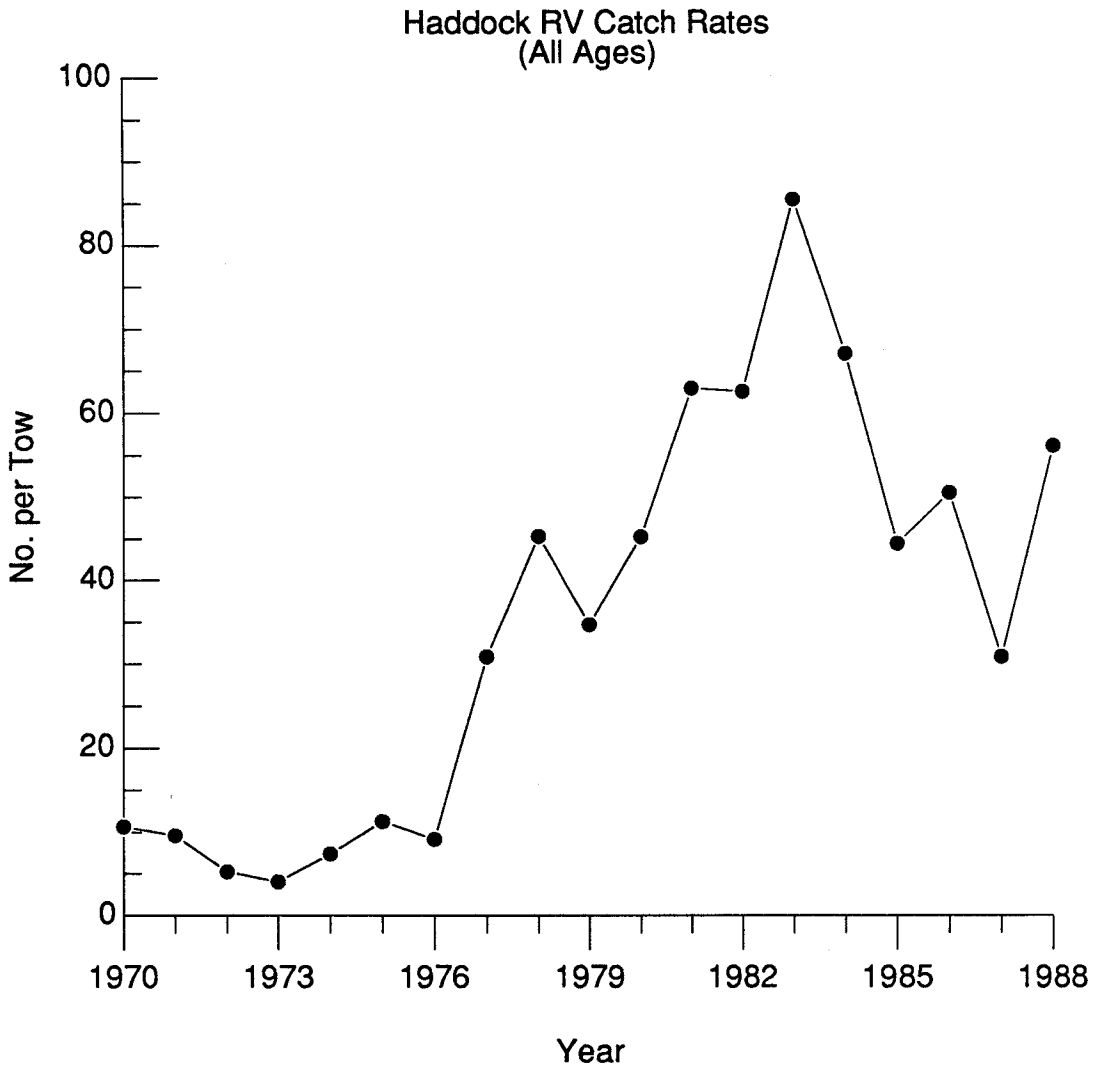


Figure 1. Research vessel arithmetic mean catch rates at age for haddock in Subdivision 4Vn.

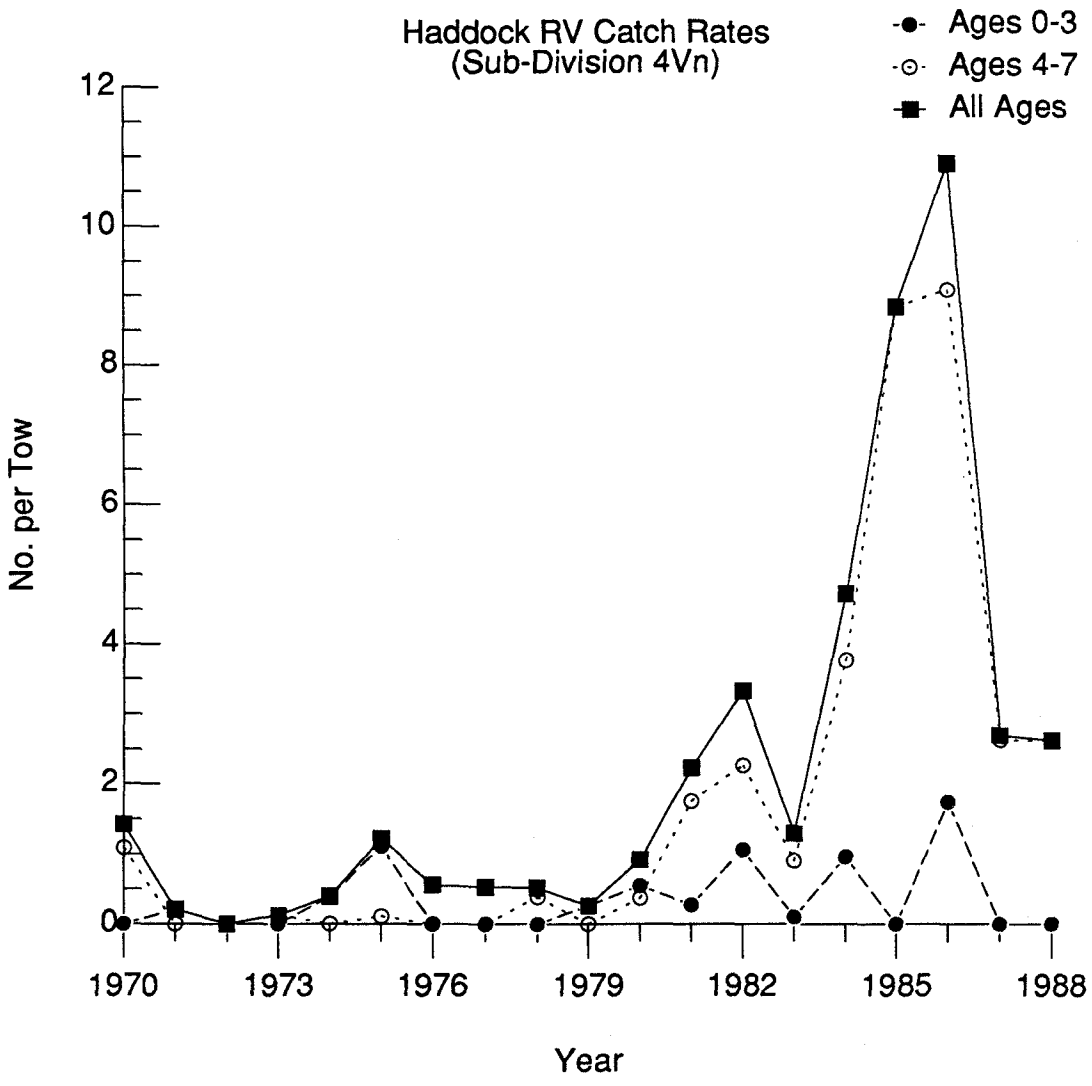


Figure 2. Research vessel arithmetic mean catch rates at age for haddock in Subdivision 4Vn.

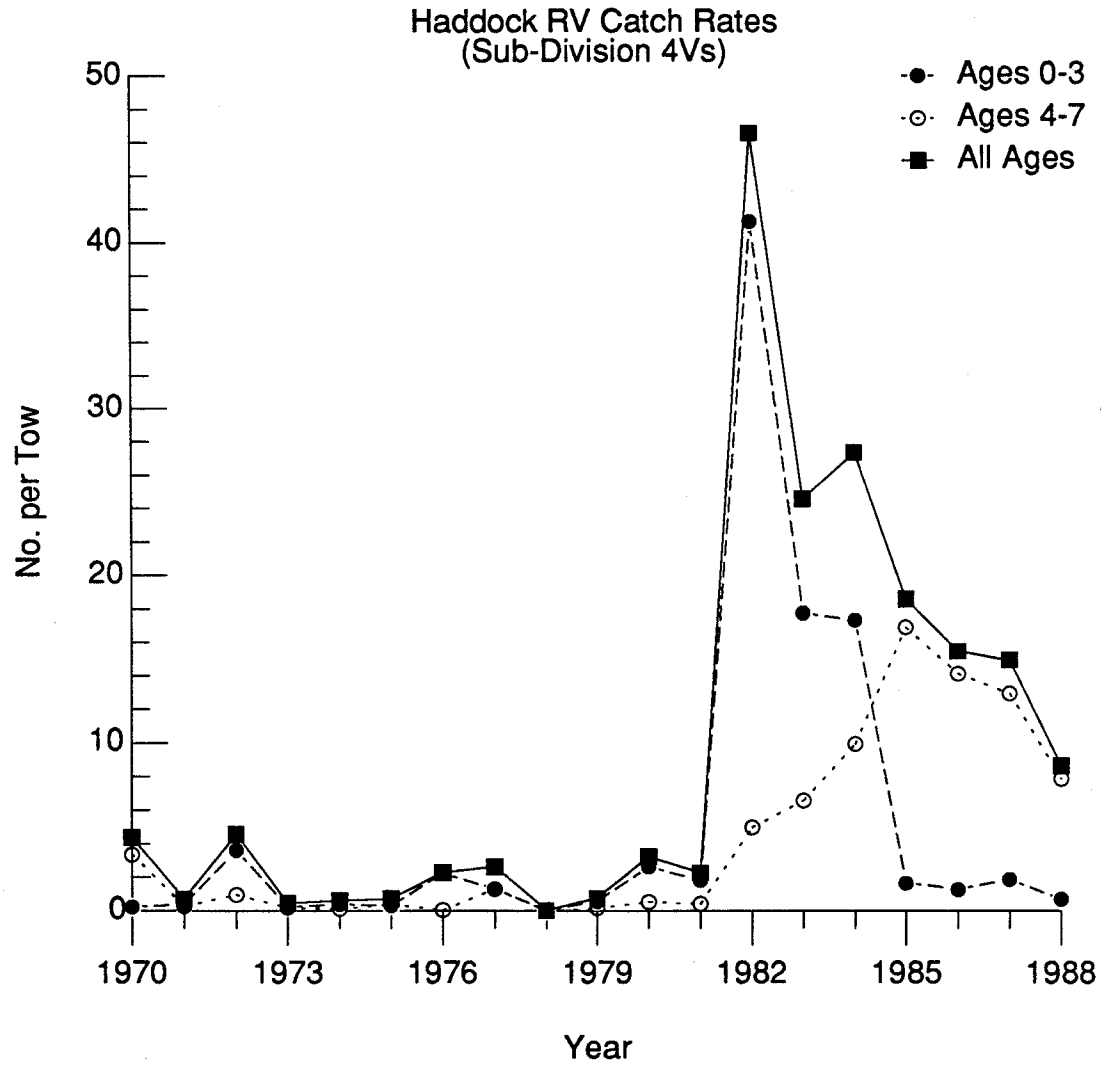


Figure 3. Research vessel arithmetic mean catch rates at age for haddock in Subdivision 4Vn.

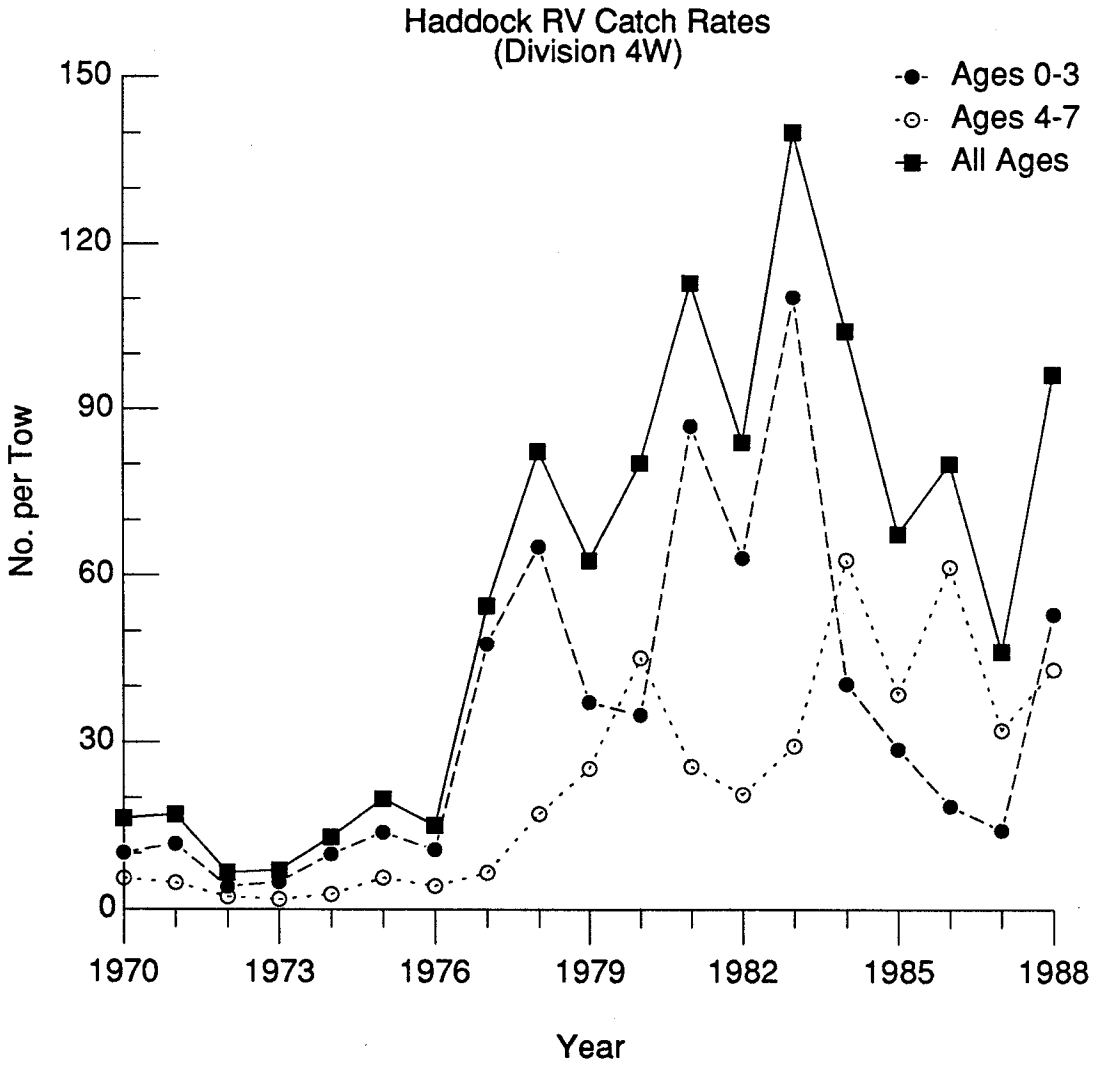
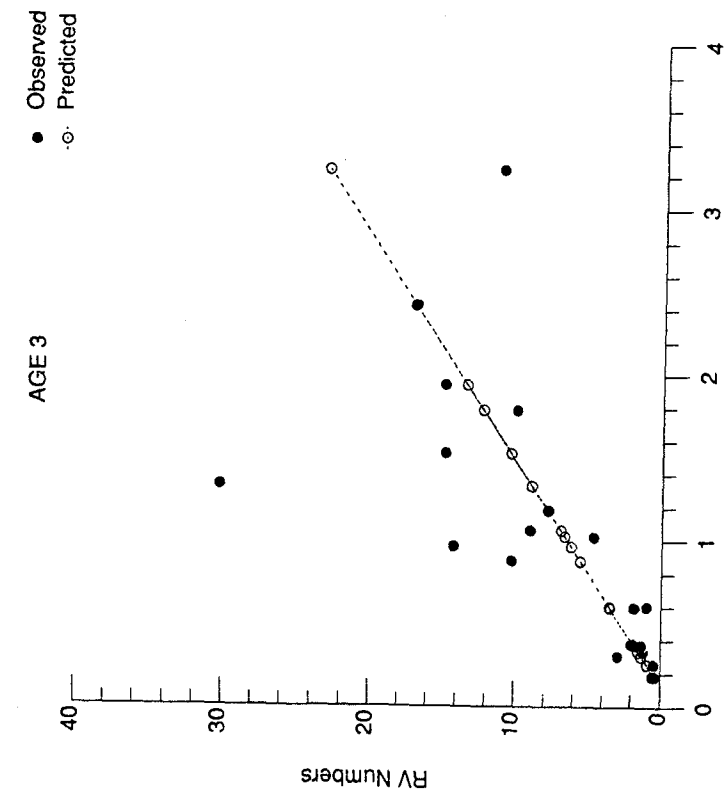
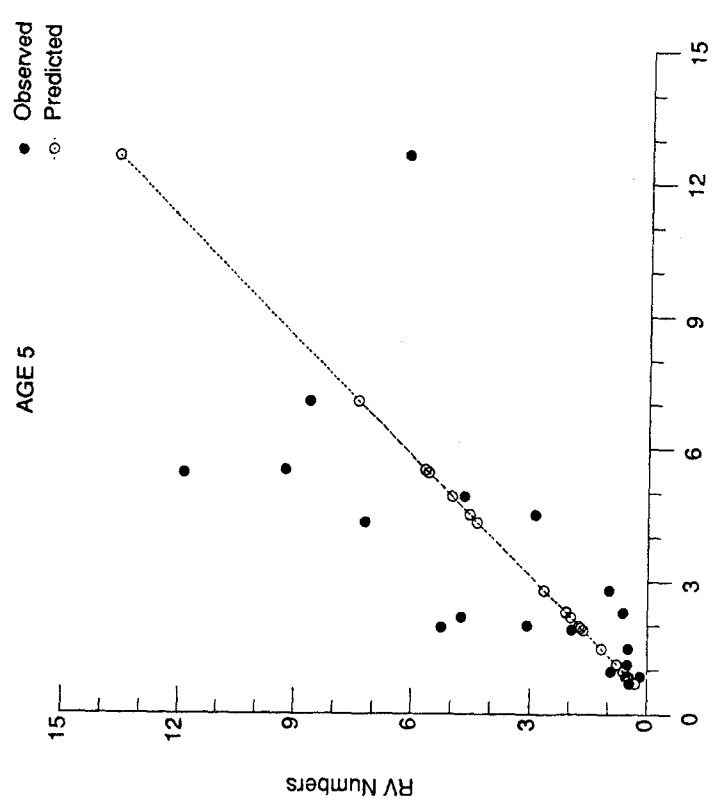
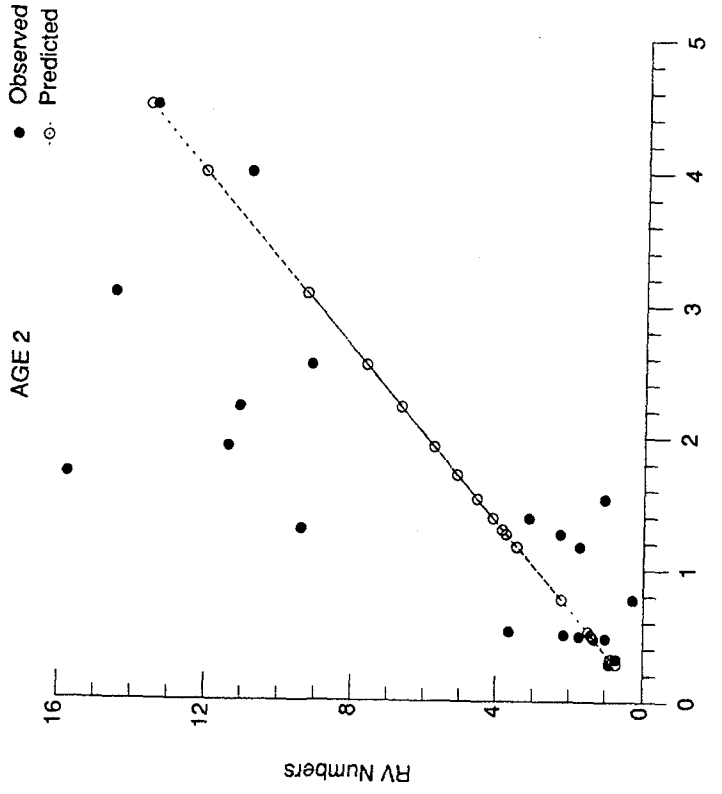


Figure 4. Research vessel arithmetic mean catch rates at age for haddock in Subdivision 4W.







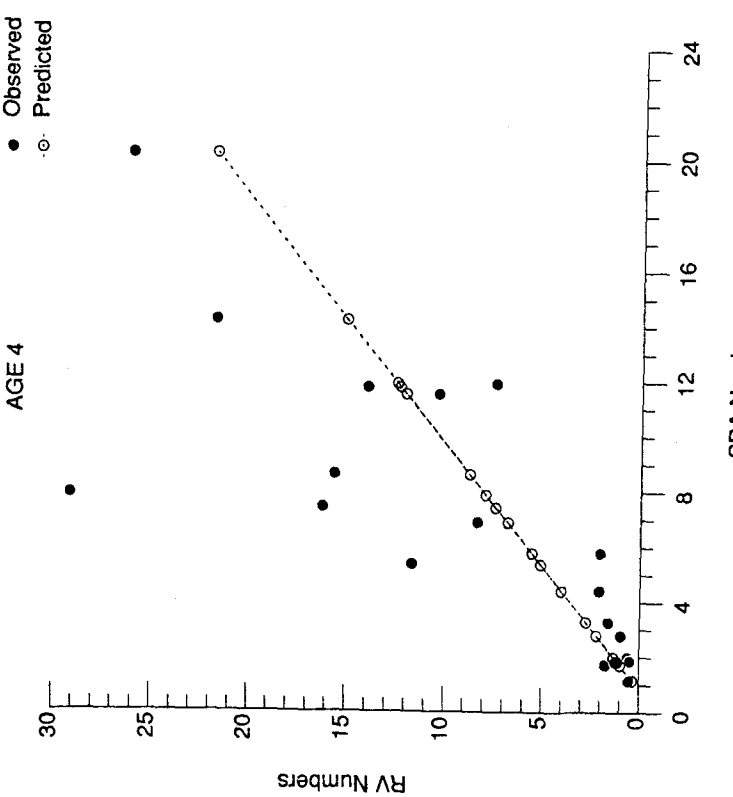


Figure 5. Calibration plots of SPA vs RV numbers at ages 2 through 5 for 4TVW haddock. Displayed are the best fits of the model as summarized on Table 9.

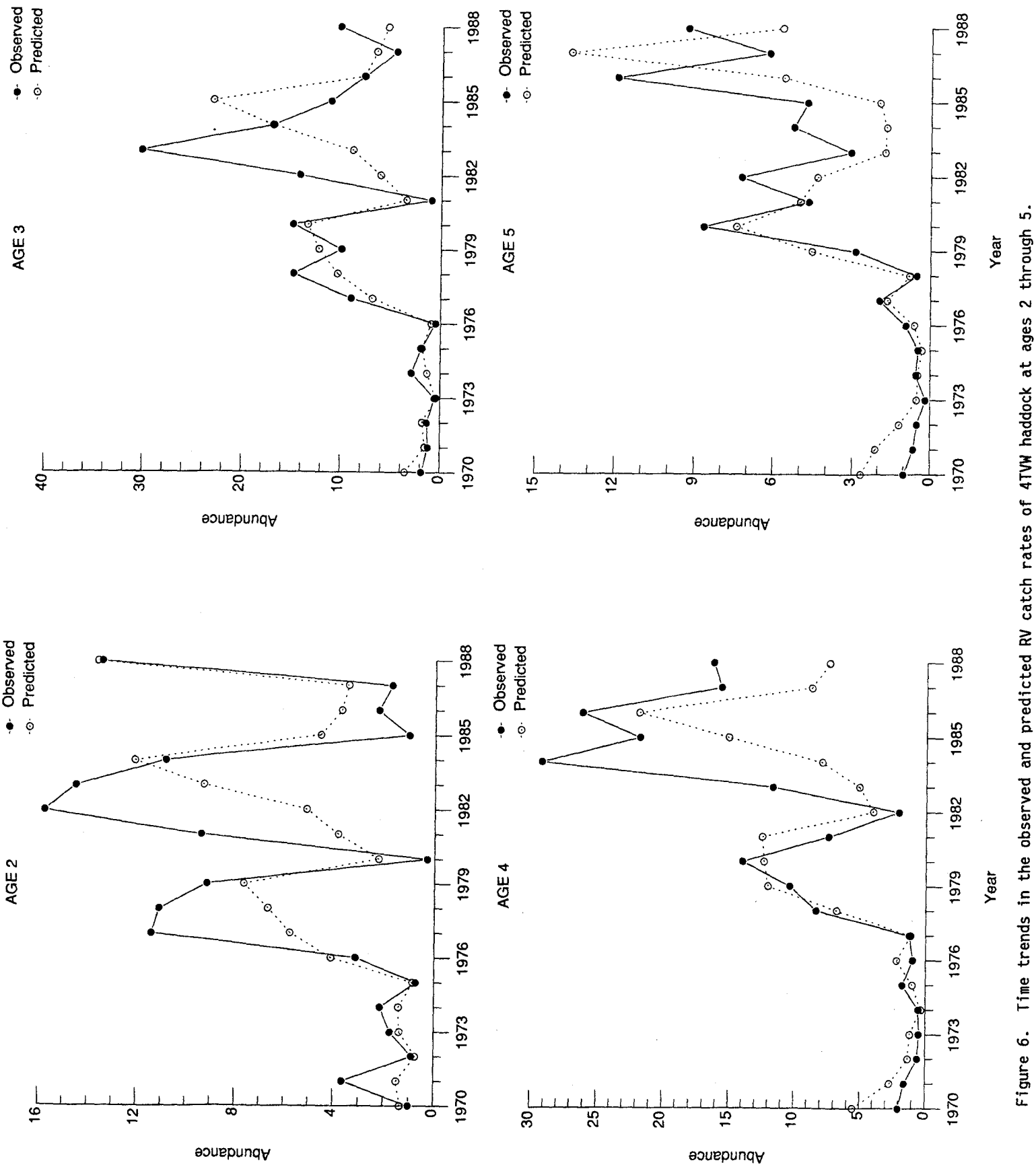


Figure 6. Time trends in the observed and predicted RV catch rates of 4TVW haddock at ages 2 through 5.

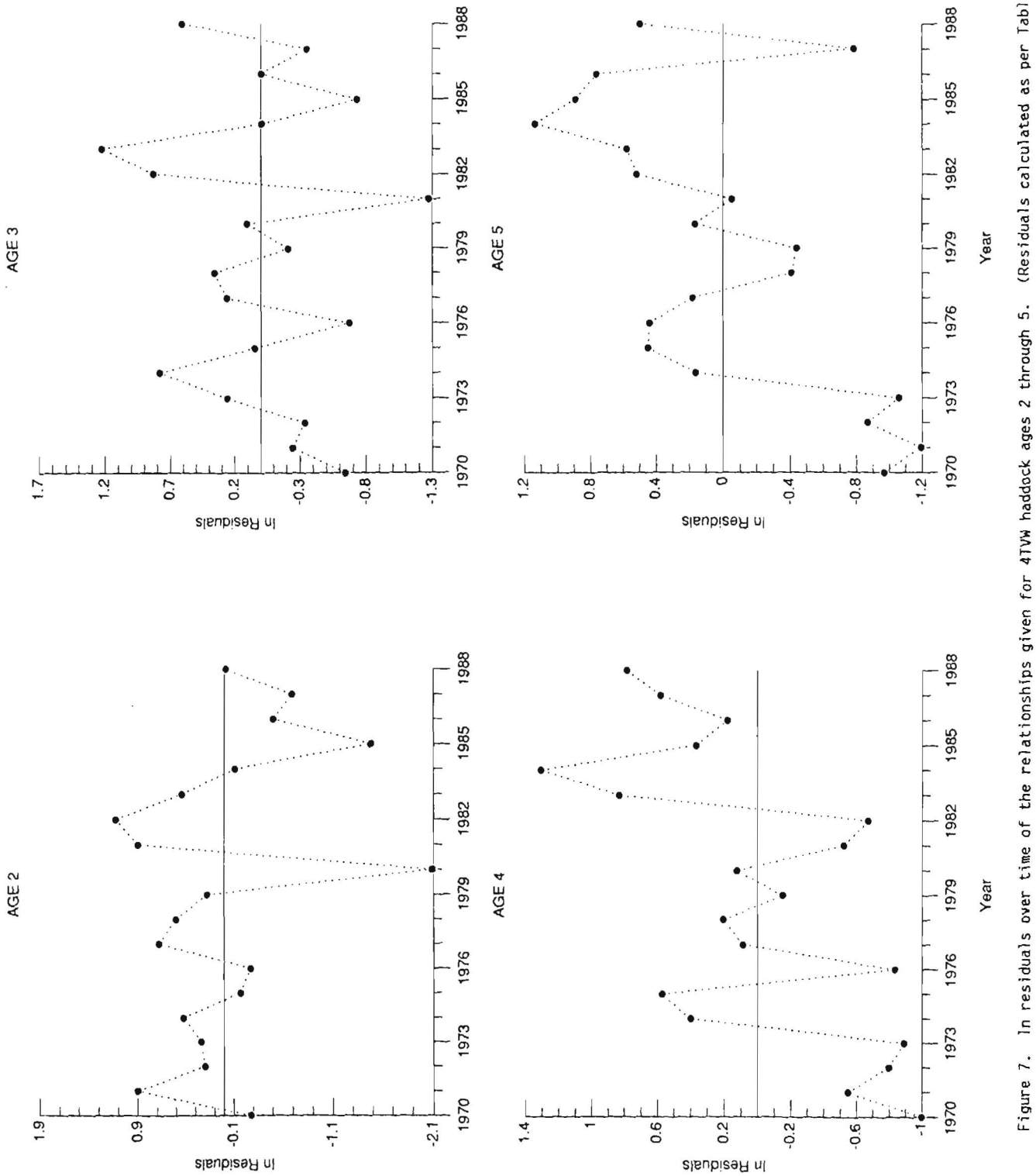


Figure 7. ln residuals over time of the relationships given for 4TVW haddock ages 2 through 5. (Residuals calculated as per Table 9.)

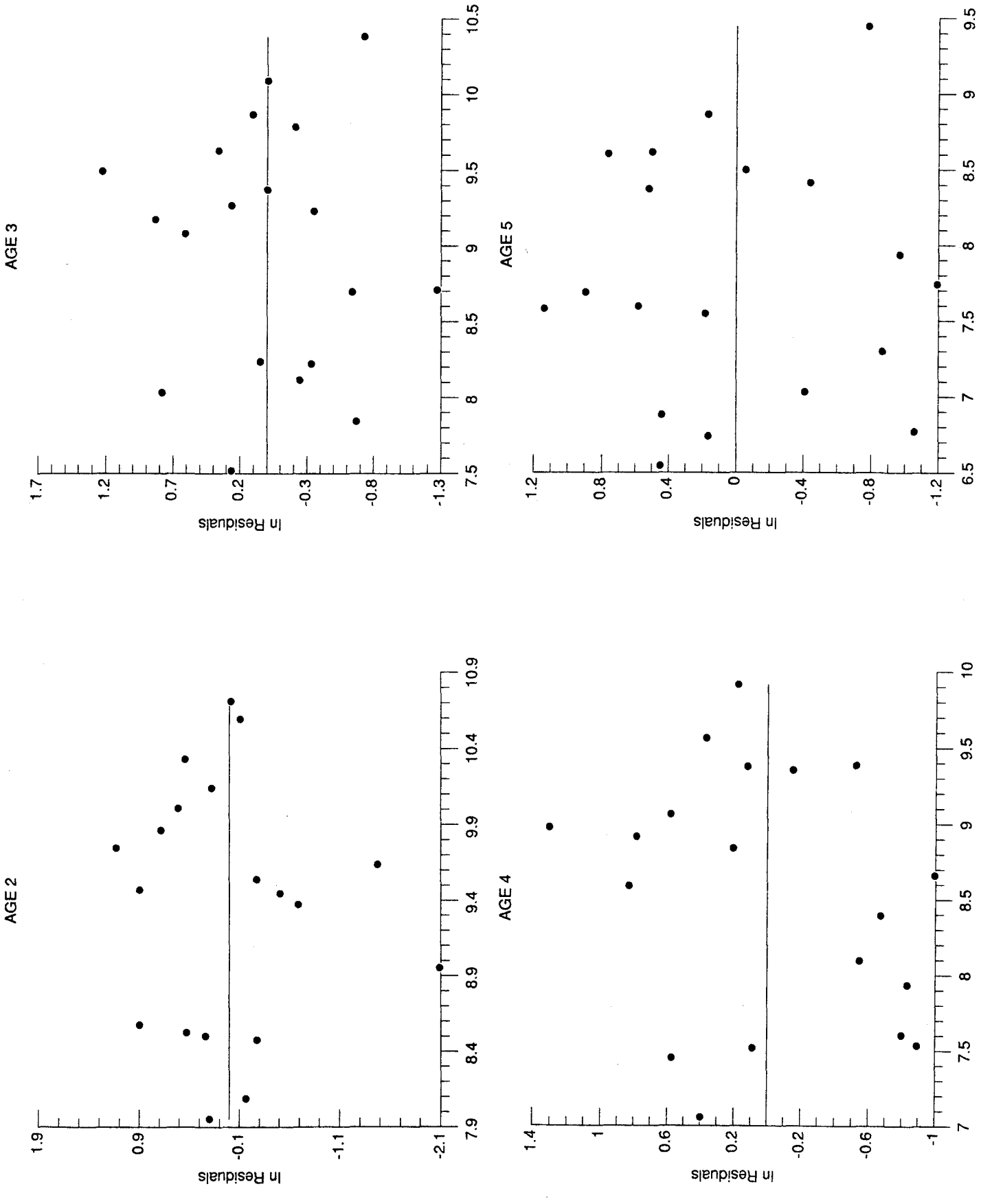


Figure 8. ln residuals vs SPA numbers for 4TVW haddock ages 2 through 5. (Residuals calculated as per Table 9.)

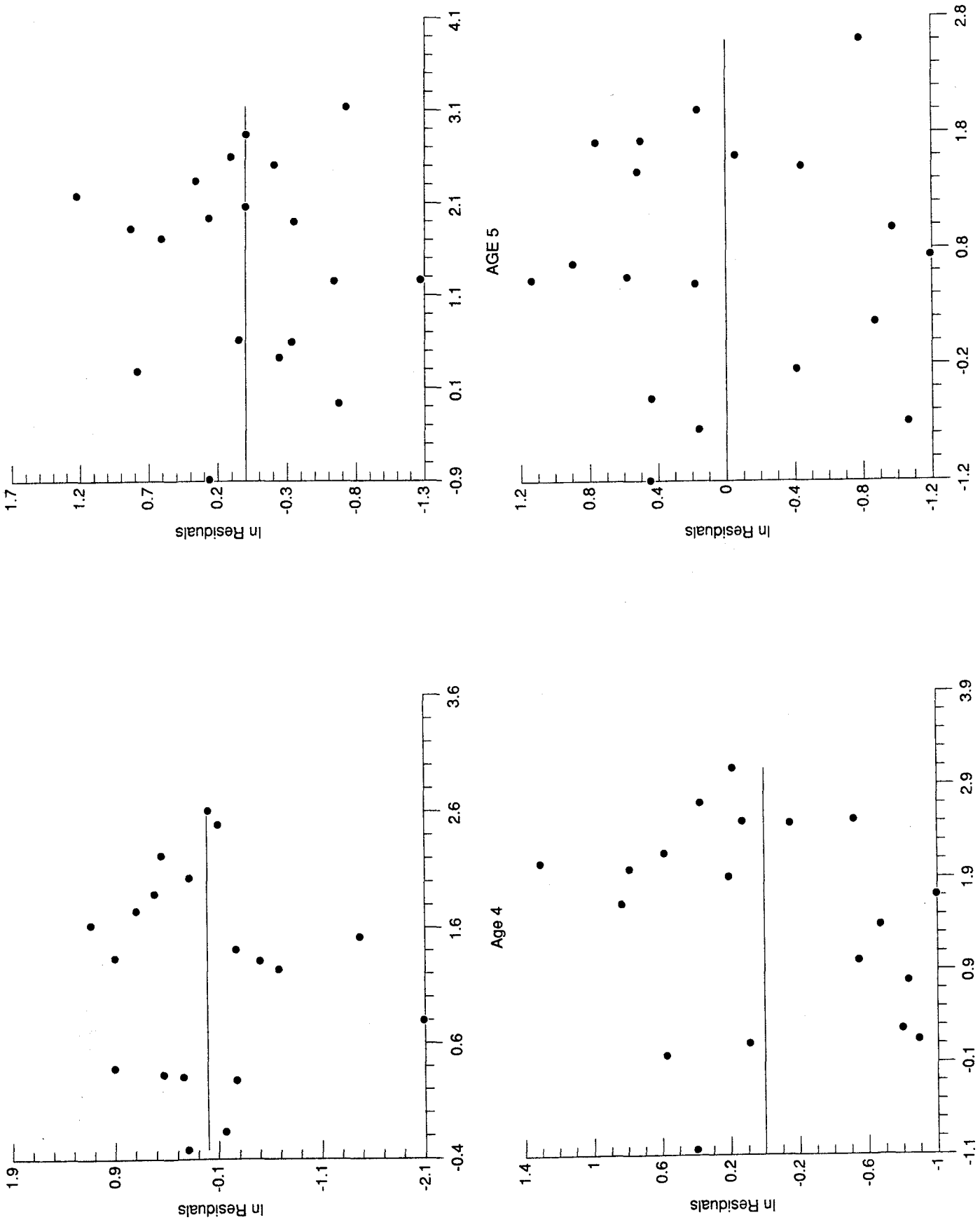


Figure 9. ln residuals vs predicted RV catch rates for 4TVW haddock ages 2 through 5. (Residuals calculated as per Table 9.)

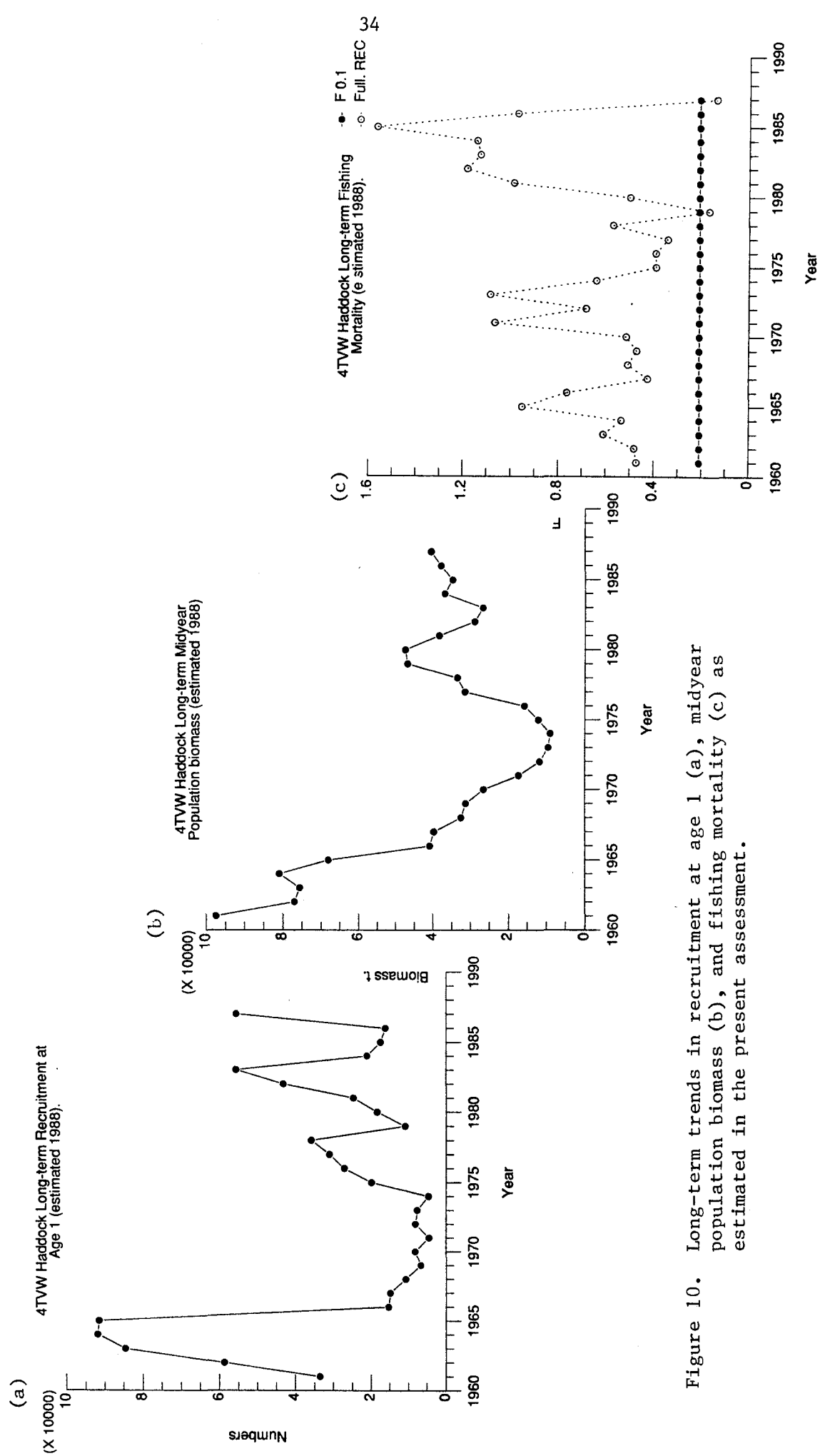


Figure 10. Long-term trends in recruitment at age 1 (a), midyear population biomass (b), and fishing mortality (c) as estimated in the present assessment.