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Haddock in 4TVW — Population Status and Catch Projection for 1988

by

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Abstract

This evaluation of 4TVW haddock is consistent with the previous assessment of this resource in that it continues to show below average recruitment, a reduction in the abundance of age classes 8 and older, and a concentration of biomass into the 1981 and 1982 year-classes. The previous assessment resulted in the formulation of advice which led to the closure of the directed fishery in 1987 as well as the exclusion of mobile gear fisheries from the major 4TVW haddock nursery area. In 1986 the nominal catch totalled just under 17,000 t representing approximately 98% of the TAC while in 1987 the allowable by-catch has totalled just under 1,400 t for the first half of the year. In 1986, 86% of the catch biomass was accounted for by the 1981 and 1982 year-classes. The same year-classes have so far accounted for approximately 76% of the 1987 catch. A linear relationship between research survey catch rates-at-age and SPA numbers-at-age for ages 2 to 5 was assumed. This model was fit to the data by minimizing the age-specific residual SUMS of Squares (SSQ) for 1970-83 and the cohort-specific residual SSQ for the most recent year-classes. This procedure provided a 1986 fully recruited fishing mortality of 0.84. They also indicated that 75% of the beginning of year biomass in 1986 was contributed by two year-classes (1981-1982) and that incoming biomass estimated at ages 1 and 2 remains low relative to previous years. The distribution of residuals around the RV/SPA regression line at this value of F_t indicate a trend from negative to positive over time at ages 4 and 5. Possible causes of this result are discussed although their potential effects on the estimation of stock size have not yet been satisfactorily determined. Assuming that the 1987 $F_{0.1}$ catch of 3,825 t is taken, the $F_{0.1}$ catch for 1988 was projected to be 4,501 t.

Résumé

La présente évaluation du stock d'aiglefin de 4TVW s'accorde avec l'évaluation antérieure de cette ressource du fait qu'elle révèle encore un taux de recrutement sous la moyenne, une baisse de l'abondance des classes de 8 ans et plus et une concentration de la biomasse dans les classes de 1981 et 1982. Les conseils formulés d'après les résultats de l'évaluation antérieure ont mené à la fermeture de la pêche sélective en 1987 ainsi qu'à l'exclusion des engins mobiles dans la principale nourricerie de l'aiglefin dans 4TVW. En 1986, les prises nominales ont totalisé proches de 17 000 t ce qui représente environ 98 % du TPA tandis qu'en 1987, les prises accessoires totales autorisées ont atteint environ 1 400 t au cours du premier semestre. En 1986, les classes de 1981 et 1982 constituaient 86 % de la biomasse des prises tandis qu'en 1987, elles constituent jusqu'à maintenant environ 76 % des prises. On a formulé l'hypothèse qu'il existait une relation linéaire entre les taux de capture selon les âges obtenus au cours de levés expérimentaux et les effectifs des âges 2 à 5 obtenus par APS. On a ajusté ce modèle en fonction des données en minimisant les sommes des carrés résiduelles selon l'âge pour la période 1970-1983 et les sommes des carrés résiduelles selon les cohortes dans le cas des classes d'âge plus récentes. Ce traitement des données a généré un taux de mortalité par pêche au plein recrutement de 0,84 en 1986. Il a aussi révélé que 75 % de la biomasse au début de 1986 se composait de deux classes d'âge (1981-1982) et que la biomasse potentielle que l'on croit sera composée de poissons d'un et de deux ans sera faible par rapport aux années précédentes. La distribution de la variance résiduelle de la courbe de régression VR/APS pour cette valeur de F_t indique une tendance allant de négative à positive en fonction du temps pour les âges 4 et 5. On traite des causes possibles de ce résultat quoique leurs incidences potentielles sur l'estimation de la taille des effectifs n'aient pas été adéquatement déterminées. Si l'on suppose que les prises à $F_{0,1}$ s'élèveront à 3 825 t en 1987, on prévoit que les prises à $F_{0,1}$ en 1988 s'élèvront à 4 501 t.

Introduction

The previous assessment of this resource indicated that the 1985 fishery was being supported largely by the 1980 and 1981 year-classes (85% of the 1985 catch by numbers) (Zwanenburg, et al. 1986). The 1981 year-class alone contributed 57% of the numbers caught in 1986. Research vessel surveys gave little evidence of strong incoming year-classes since that of 1982. The analysis also showed that the proportional contribution of older fish to the population had declined since the early 1980's, this being apparent both in the commercial and research vessel. This decline in the numbers of fish at older ages had resulted in a decrease of the spawning stock biomass to levels (11,000 t) where the probability of observing the production of large year-classes is low.

The combination of poor recruitment over several successive years, coupled with low levels of spawning stock biomass and the concentration of the fishery on the two year-classes of any appreciable size remaining in the population, resulted in recommending a TAC of just over 3800 t in 1987, assuming a 12,000 t catch in 1986. Management reacted by setting a TAC of 0 t for the 1987 fishery and restricting the catch of haddock to by-catches of between 5 and 10% (depending on vessel size and season). This was calculated to result in a 1987 catch of 3000-4000 t. In addition to a TAC of 0 t, management requested advice on the location and size of known haddock nursery areas within 4VW to allow imposition of a fishing closure in the two areas shown in Figure 1 (Fanning, et al. 1987). The ban on fishing in area 2 was lifted after further research indicated that this was an overspill area frequented by juvenile haddock following the production of relatively large year-classes. The total ban on fishing in area 1 was modified to allow a fixed gear fishery (limited to a 5% haddock by-catch) after analyses indicated that the impact of fixed gear fisheries on the capture of juvenile haddock is likely to be minimal.

In the previous assessment of 4TVW haddock we employed an age by age calibration procedure which minimizes cohort specific residuals across age-specific research vessel catch rate and SPA relationships. This same procedure was again employed in this assessment, although the form of the underlying model relating research vessel catch rates at age and SPA estimated numbers at age was changed.

Trends in Reported Landings

Landings

The 1986 nominal catch of 4TVW haddock totalled 16,728 t (Table 1) representing 98.4% of the TAC. The provisional total nominal catch in the first half of 1987 is 1364 t, this having been taken exclusively as by-catch. Recent TACs and catches for 4TVW haddock are:

	1979	1980	1981	1982	1983	1984	1985	1986	1987
TAC (000s t)	2	15	23	23	15	15	15	17	0
Nominal catch (000s t)	3	15	20	15	9	8	12[1]	17[1]	1[2]

[1] provisional statistics
[2] provisional statistics for landings ending 30-06-87 (by-catch only)

Through the 1950s and early 1960s, nominal catches of 4TVW haddock averaged approximately 25,000 t annually. Between 1966 and 1976 catches declined, as the result of a collapsing stock, to a minimum of just under 1400 t (Table 1). Haddock catches in Division 4T, although significant through the 1950s and early 1960s, have totalled less than 600 t annually since then.

Landings statistics for 4TVW haddock indicate that Subdivision 4Vs and 4W have generally contributed the largest proportions of the total catches (Table 1). It is noteworthy that in 1985 and 1986 catches in 4Vs exceed those of 4W for the first time since 1954. The catches in 4T have also risen in recent years. Prior to 1980, landings of haddock from 4V represented only a small fraction of that taken in 4W; however, since then the proportion of landings from 4V (mainly Subdivision 4Vs) has increased:

	1980	1981	1982	1983	1984	1985	1986
4W Jan - June	42	75	76	74	36	21	18
July - Dec	43	13	8	6	16	1	21
4V Jan - June	6	8	6	12	16	56	32
July - Dec	9	4	11	8	32	22	29

The increase in 4Vs was particularly apparent in 1985 when 4W was closed to trawlers from May until the end of the year to prevent the capture and discarding of numerous unmarketably small fish (probably belonging to the 1981 and 1982 year-classes). During 1986 the fishery was again distributed according to historical patterns with the majority of the 1st and 4th quarter catches taken in 4W while 2nd and 3rd quarter catches were concentrated in 4V.

Landings in both 4Vs and 4W increased in 1986. Shifts in the focus of this fishery on a resource which shows some degree of age specific spatial segregation and age or season related migratory patterns could affect the relative match between exploited and surveyed populations. This could have significant effects on the tuning and calibration of sequential population analyses (SPA).

Age Composition of Removals

In the recent history of this stock, most of the catch has been taken by trawlers with longliners representing 15-20% of the catch (Table 2). Since

1980, Danish and Scottish seiners have also taken a small but consistent proportion of the catch. 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 was obviated in 1987 by 100% Observer coverage of all foreign fisheries including silver hake. The estimates of removals at length were converted to removals at age by application of the appropriate RV age-length key for each year.

Removals by domestic gears were calculated on a semi-annual basis for trawlers and an annual basis 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 1987 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. 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 observed catch at age differed from that predicted by the 1986 assessment in that the contribution of age 3 fish was significantly higher (7.1% vs 1.3%). The comparison of observed and predicted age composition for 1986 is as follows:

Age	% Observed	% Predicted	Ratio
1	0.07	0.43	0.16
2	0.28	0.34	0.82
3	7.10	1.38	5.14
4	55.24	46.13	1.20
5	32.49	44.90	0.72
6	4.17	5.77	0.72
7	0.55	0.92	0.60
8	0.07	0.07	1.00
9	0.01	0.01	1.00
10	0.01	0.01	1.00
11	0 01	0 01	1.00

The differences between the age 3 observed and predicted age compositions were large and may be related to changes in the spatial distribution of the fishery. The increase in the numbers of age 3 fish in the fishery is consistent with the fisheries increased exploitation 4W where younger (ages 0-3) fish are known to occur at higher abundances than in 4V. (Fanning, et al. 1987, Zwanenburg, et al. 1986).

Abundance Indices

Commercial Catch Rates

Catch rates by Scotia-Fundy otter trawlers, tonnage class (TC) 4 and 5, are difficult to interpret owing to the shift in location of these fisheries. The by-catch nature of the fishery in 1987 makes this catch rate incomparable to those of earlier years since these were calculated from directed fisheries. During 1986, catch rates by TC 4 trawlers fishing in Division 4W increased sharply following a slow decline since 1980. However, effort has been extremely low since 1984 (Tables 8 and 9). Tonnage class 5 vessels fishing in 4W during the first half of the year show a substantial increase in catch rates in 1986 but again at reduced effort levels relative to the 1980-1984 period. These low effort values could reduce the overall precision of the CPUE estimates through a reduction in overall sampling rate.

Recent catch rates in Subdivision 4Vs are based on substantial expenditures of fishing effort and show an increase for TC 4 vessels in 1985 with a continued high catch rate in 1986. Catch rates for TC 5 vessels increased from 1983 to 1985 and declined in 1986. It is possible that these increases in catch rates in recent years are the results of the targetted exploitation of the abundant 1981 and 1982 year-classes (ages 4 and 5 in 1986) which are now fully recruited to the fishery.

Given the shifts in location of this fishery in recent years, coupled with potential targetting of specific year-classes or groups of year-classes, the reliability of the recent values in these catch rate series as indicators of overall stock abundance is questionable.

Research Vessel Index

The July groundfish survey series from 1970 though 1987 was recalculated using arithmetic stratum means. This is a departure from the method used in 1986 and is based on the observation that delta means are not robust to deviations from a strict delta distribution for the set of observations from which the means are estimated. Given that survey catch per tow values are not realizations of a strict delta distribution, it was decided that the more robust arithmetic mean would be a more reliable estimator of central tendency. The resulting stratified mean catch per tow at age values are given in Table 10 while the grand mean catch rate across all ages is shown in Figure 2. The 1987 value continues a decline in abundance which started in 1983.

The mean catches per tow for age group 8+ (Figure 3) is the lowest in the survey series. The numbers of juveniles (ages 0-3) are also very low, the lowest since 1976. The intermediate age groups are more abundant than during the 1970's, but below the levels of the last three years (1984-1986). The overall picture is of a population with virtually no older age groups, relatively abundant intermediate age groups and no indications of good recruitment in recent years.

A more detailed examination of the juvenile age groups (Figure 4) lends further support to the conclusion of weak haddock recruitment in recent years

in that the overall number of juveniles in the population has been declining since 1983 indicating no significant recruitment in the intervening period. The 1984 year-class at age 3 is the lowest estimate of numbers at age 3 since the 1978 year-class. Research vessel data collected in July 1987 are consistent with the heterogeneous spatial distribution of age classes first reported by Zwanenburg, et al. (1986). These data indicate that Division 4V contains relatively fewer fish aged 0-3 than Division 4W.

Year-Class Strengths

Relative year-class strength based on research vessel surveys were estimated by ranking the mean catch per tow at age across years and then calculating the mean rank for a given year-class. Only ages 1 to 5 were included, allowing ranking of only the 1969 to 1982 year-classes. The year-classes were then ranked by their mean ranks. The same procedure was applied to the year-classes in the catch at age for ages 1 to 5 and the year-class ranks for the two sets of data were compared (Figure 5). It is apparent that both the RV survey and the fishery agree on the best and worst year-classes, however, there is considerable variation about the level of agreement on the relative strength of intermediate sized year-classes.

Estimation of Stock Abundance

Estimation of Partial Recruitment and Terminal F

The SPA using estimated total removals at age for 1970 through 1987 (Table 6) and RV arithmetic mean catch rates at age (Table 10) was calibrated using a modification of an iterative procedure developed by O'Boyle (1986). This model assumes a linear relationship between RV catch rate at age and SPA numbers at age of the form:

$$U = (a + qN) \cdot \epsilon$$

where U = July research vessel catch rate x 1000
a = intercept
q = catchability coefficient
N = mid-year number of fish from SPA
ϵ = multiplicative error term.

Variance was stabilized in the regression analysis by employing the natural log transformation:

$$\ln U = \ln (a + qN) + \ln \epsilon$$

This relationship was defined for years 1970-1983, since the most recent years of SPA generated data (1984-1987) are determined almost entirely by the final year's input data. The part of the SPA matrix chosen corresponds to the converged part of the matrix, defined by Pope (1972) as that for which the cumulative fishing mortality estimates for the cohort exceed 2.0.

Partial recruitment and terminal F for 1987 were estimated simultaneously be iterative minimization of along cohort residuals for ages 2 through 5. Age-by-age calibration for ages 6+ was not possible due to non-significant correlation coefficients of the age-specific relationships at these older ages. This required assumptions on the shape of the 6+ partial recruitment vector to use. These ranged from flat-topped PR of 1.0 for ages 5+ to a knife-edged reduction of PR = 0.5 at age 6+. The effects of these various PR patterns had little effect on the F values at which along cohort residuals at younger ages (ages 2-5) were minimized. Lacking any discriminatory power, it was assumed that PR at ages 5+ in 1987 was flat-topped at 1.00.

Results of the final calibration run are given on Table 11 and Figures 6-10. As shown in both Table 11 and Figure 6, the model fits the data reasonably well. The distribution of residuals against predicted RV numbers (Figure 7) and observed SPA mid-year population numbers (Figure 8) show no evidence of model error. However, the temporal trends and discontinuities in residuals for ages 4 and 5 indicate a potential violation of the assumption of a linear relationship between RV and SPA mid-year numbers (Figures 9 and 10). These trends have been observed in this assessment since 1984 (Mahon, et al. 1984, 1985; Zwanenburg, et al. 1986) and neither their cause nor their potential effect on the estimation of stock size have been satisfactorily determined. Possible reasons for the observed distribution of residuals with time include:

1. Variation in the annual ratios of reported vs actual catches. This variability could be induced by over or underreporting of catches in response to imposed management measures and would result in inconsistencies in the relationship between RV and SPA numbers-at-age. Furthermore this ratio may not be constant across all ages if, for example, unreported discarding of smaller fish were to occur. Age specific biases in reporting rates could manifest themselves as patterned residuals in the age specific RV/SPA relationships.

2. Changes in availability of the population to the survey gear. Changes in the spatial patterns of either the population as a whole or of specific portions (age classes/cohorts) of the population which result in changes in their availability to the survey gear, could strongly influence the relationship between RV and SPA numbers. If the population (or some part thereof) moved into and out of the surveyed area with some annual or multi-year periodicity this could induce patterns into the residuals by changing the apparent RV/SPA relationship.

3. Density dependence of the RV/SPA relationship. It is conceivable that the RV/SPA relationship could vary as a function of density, either of the entire population or of individual cohorts. In a population such as 4TVW haddock which has age related spatial patterns, it may be that particularly abundant cohorts are targetted by the fishery resulting in biased estimates of their abundance relative to the remainder of the population. This biased estimate may be reflected in cohort related changes in the RV/SPA relationships in years while these cohorts are being targetted by the fishery.

The above list of potential causes for the observed trend in residuals is by no means exhaustive but does serve to indicate their potentially complex nature especially since they are not mutually exclusive but may work in concert or individually and over varying time periods.

Estimation of Population Abundance

The estimated 1987 half year catch-at-age and F vector were used as input to SPA to estimate the 1986 Fs-at-age and PR vectors. The results are shown below:

Age	F_{1986}	F_{1987}
1	0.002	0.000
2	0.007	0.027
3	0.127	0.040
4	0.595	0.066
5	0.762	0.108
6	1.328	0.108
7	0.634	0.108
8	29.320[1]	0.108
9	26.835[1]	0.108
10	26.835[1]	0.108
11	27.325[1]	0.108
5+*	0.839	

[1] - These extremely high F values are the result of an absence of any catch-at-age 9, 10, and 11 in 1987.
* - Mean fully-recruited F weighed by numbers.

The 1986 Fs were in turn used as input to SPA using the full catch-at-age matrix given in Table 6 and omitting the 1987 values (since these are based on half year catches only). This final run of SPA generated the results shown in Tables 12-16. These tables list (for 1948-1986) estimated population numbers-at-age (Table 12), mean population biomass-at-age (Table 13), catch biomass-at-age (Table 14), population biomass-at-age at the beginning of each year (Table 15), and the fishing mortality-at-age including the average weighted fully recruited fishing mortality for each year (Table 16). The average weighted fully recruited F in 1986 (0.84) remains well above the $F_{0.1}$ level as has been the case for most of the recent history of this stock (Figure 11c).

The 1986 beginning of year biomass estimate at 32,000 t is less than that estimated for 1985 (35,000 t) (Figure 11b). Since 1975, beginning of year biomass has fluctuated between approximately 10,000 and 50,000 t. The 1981 and 1982 year-classes (ages 5 and 4, respectively in 1986) are estimated to account 75% of the total beginning of year biomass in 1986 (Table 15) and 86% of the catch biomass in that year (Table 14). The results also show that the declining biomass at ages 6+ which started in 1981 has continued in 1986. This may reverse in 1987 and 1988 with the progression of the 1981 and 1982

year-classes through the population (Table 15). Incoming biomass estimated at ages 1 and 2 in 1986 also remains low relative to previous years. Estimated recruitment at age 1 has declined since 1982 and in the range of the low values previously seen during the early 1970s (Figure 11a).

Prognosis

Catch projections to 1988 were made using the input data given below:

Age	Population Nos. Projected 1987	PR[1] 1987	Weights[2] 1987
1	14,800	0.0044	0.103
2	5,673	0.0079	0.243
3	6,700	0.0675	0.553
4	8,384	0.4988	0.749
5	10,869	1.000	1.027
6	4,552	1.000	1.487
7	241	1.000	2.047
8	100	1.000	2.261
9	0	1.000	2.736
10	0	1.000	3.067
11	0	1.000	4.414

[1] - Mean 1984-86
[2] - Mean 1984-86

The following table shows the results of the catch projections to 1988. Since the previous assessment of this resource indicated that female spawning stock biomass was low relative to previous years, these calculations have also been included).

	1986	1987	1988
F	0.84	0.21	0.21
Catch (t)	16,728	3,825	4,501
Mean Population Biomass (t)	31,224	29,363	31,854
Female Spawning Stock Biomass (t)	9,173	9,192	10,721

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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	489					593				59	7294				3	2862		275		79	11654	15000
*1986	569					873					8722				4	6170		312		78	16728	17000
**1987	55					205					543					229		152		180	1364	0

+ — Between 1954 and 1958 catches for 4Vn and 4Vs were combined as 4V.
* — Provisional data
** — Provisional to 30/06/87

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

Year	Otter Trawler	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	9885	----------	1731	----------	11616
86	13939	1101	1188	105	16334
87*	767	132	129	4	1032

* Landings to 30-06-86 only

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 1970 to 1983. 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***	82,783	0.60	-	500
1987***	57,462	0.58	308	332

* Mean of 1977-1979 weighted by-catch observed.

** FLASH

*** Preliminary data (1987 preliminary to 30-06-87)

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	24	355	4645	973	0.00877372	3.043829	Needler #85/86/87 July 1987

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	24			
	Longliners	-			
	Danish seine	-			

Table 6. Commercial removal-at-age (numbers in 000s) for 4VW haddock. For 1987 removals for first half of year only.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
1	0	0	0	50	0	0	0	0	0	0	0	0	0	2
2	0	10	0	0	6	3	12	0	213	0	63	8	0	31
3	177	855	83	765	449	349	211	504	1926	647	2115	2938	455	409
4	2194	1126	2389	4967	1915	2324	2881	1021	11209	3634	3817	6803	6408	4901
5	3269	4330	2823	6056	6626	4113	10071	2592	2400	13199	2504	5559	7580	8501
6	1297	3090	5018	2216	4654	4445	2159	5132	2539	2045	8128	3388	3339	4298
7	1412	483	3227	1794	1831	1407	2466	1765	2866	1538	1076	7071	2164	1362
8	1088	357	293	1306	1079	457	1318	1642	963	1233	777	809	1964	1062
9	556	303	575	98	405	247	431	620	1334	341	788	528	372	727
10	433	228	230	66	96	25	265	313	340	244	276	534	157	193
11	253	142	358	79	65	18	68	51	89	92	164	213	161	61

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	205	1287	2591	53595	2127	89	5	31	306	268	306	487	59	279	431
2	436	924	3073	32161	9696	181	13	42	129	667	288	1178	233	61	676
3	1491	511	4074	24140	9638	1006	398	438	679	888	671	646	975	470	157
4	2039	3471	2368	15192	8887	2622	1806	1408	1743	2189	751	1467	254	805	249
5	7794	3673	6023	7775	4645	2836	2926	2039	1400	2740	924	811	464	282	323
6	6190	6594	2069	4057	1217	1113	2494	1955	1365	1208	668	723	298	185	189
7	1957	3190	2906	1282	1637	441	793	939	1163	944	345	342	114	63	132
8	839	1243	1562	1234	499	597	379	279	389	1177	191	159	47	30	36
9	317	287	403	402	272	212	406	131	88	277	159	60	8	8	8
10	223	126	81	72	89	174	116	118	38	39	9	99	17	4	10
11	59	113	45	54	12	55	78	39	19	21	18	2	16	1	3

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	213	714	1	332	870	530	497	10	133	12	28
2	283	433	268	376	318	433	470	360	69	50	72
3	965	811	423	2372	262	1520	1084	1514	411	1257	125
4	335	2412	1120	4334	5072	764	3207	4158	8006	9770	258
5	513	436	675	3238	5081	5629	2040	2225	4162	5747	542
6	283	715	159	1702	3010	1957	1677	821	881	738	227
7	117	203	149	249	1178	1220	530	410	232	98	12
8	80	61	16	129	139	214	235	90	47	12	5
9	19	23	5	39	105	48	29	30	14	1	0
10	15	8	6	9	30	28	18	5	2	1	0
11	6	2	2	7	10	5	19	2	1	1	0

Table 7. Mean weights-at-age (kg) for 4VW haddock commercial removals. For 1987, estimates for first half of year only.

	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
1	.090	.120	.100	.107
2	.263	.197	.270	.222
3	.577	.462	.620	.412
4	.738	.698	.810	.800
5	1.036	.986	1.050	1.154
6	1.462	1.429	1.570	1.604
7	1.794	1.926	2.420	2.223
8	2.154	2.350	2.280	2.210
9	2.664	2.964	2.580	2.752
10	3.240	2.200	3.760	2.566
11	3.182	5.590	4.470	3.764

Table 8. Catch rates by stern and side trawlers in 4Vs and 4W for January to June (inclusive). Effort (hours) given in brackets.

	Tons/h (hours)			
	TC 4		TC 5	
Year	4Vs	4W	4Vs	4W
1968	0.29 (542)	0.68 (4043)	0.60 (190)	1.02 (601)
69	0.54 (80)	0.55 (5094)	0.38 (372)	0.94 (3490)
1970	0.27 (217)	0.38 (3939)	0.46 (406)	0.82 (1020)
71	0.49 (429)	0.54 (5541)	0.50 (915)	0.73 (4249)
72	0.57 (86)	0.29 (1399)	0.35 (230)	0.34 (1195)
73	0.29 (92)	0.34 (1820)	0.17 (148)	0.55 (822)
74	0.12 (137)	0.12 (140)	0.43 (10)	0.57 (42)
75	- (0)	0.22 (101)	0.69 (25)	0.29 (94)
76	0.18 (138)	0.44 (181)	0.10 (35)	0.17 (285)
77	0.11 (36)	0.21 (503)	0.11 (91)	0.30 (562)
78	0.18 (105)	0.65 (1065)	0.43 (413)	0.70 (874)
79	0.43 (47)	0.22 (73)	- (0)	0.48 (112)
1980	0.46 (102)	0.68 (2223)	0.74 (61)	1.54 (1502)
81	0.33 (176)	0.63 (5215)	0.72 (187)	1.00 (3855)
82	0.54 (117)	0.73 (3264)	0.54 (76)	1.25 (3436)
83	0.48 (71)	0.48 (2201)	0.30 (100)	0.77 (3180)
84	0.14 (15)	0.45 (271)	0.61 (24)	0.67 (1881)
85	0.71 (485)	0.40 (34)	0.70 (1485)	0.97 (247)
86	0.77 (574)	2.28 (96)	0.60 (1427)	1.35 (253)
87*	- (0)	0.23 (4)	0.91 (6)	0.99 (20)

* — by-catch rates only

Table 9. Catch rates by stern and side trawlers in 4Vs and 4W for July to December (inclusive). Effort (hours) given in brackets.

	Tons/h (hours)			
	TC 4		TC 5	
Year	4Vs	4W	4Vs	4W
1968	- (0)	0.41 (2828)	0.24 (90)	0.55 (916)
69	- (0)	0.40 (814)	0.26 (90)	0.26 (226)
1970	0.15 (80)	0.37 (1276)	- (0)	3.30 (30)
71	0.63 (37)	0.48 (159)	- (0)	0.28 (161)
72	- (0)	0.21 (91)	- (0)	0.35 (128)
73	- (0)	0.14 (70)	- (0)	0.21 (38)
74	- (0)	0.11 (46)	- (0)	0.10 (50)
75	0.12 (32)	0.49 (146)	- (0)	0.35 (19)
76	- (0)	0.29 (20)	0.22 (5)	0.40 (76)
77	- (0)	0.39 (692)	- (0)	0.60 (1037)
78	0.18 (11)	0.35 (192)	0.36 (54)	0.46 (394)
79	- (90)	0.28 (90)	0.95 (77)	0.47 (175)
1980	- (0)	0.46 (2625)	0.47 (84)	0.76 (3230)
81	0.69 (47)	0.38 (534)	- (0)	0.92 (314)
82	0.71 (90)	0.36 (663)	0.40 (246)	0.46 (566)
83	0.11 (33)	0.47 (164)	0.03 (15)	0.36 (219)
84	0.50 (243)	0.09 (4)	0.67 (573)	0.53 (291)
85	0.35 (15)	- (0)	0.45 (500)	0.14 (56)
86	0.80 (406)	0.77 (473)	0.59 (2243)	1.05 (1211)

Table 10. 4VW haddock arithmetic mean catch (numbers) per tow at age.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	.105	.062	.047	.000	.228	.074	.620	.256	.000	1.491	1.485
1	2.723	1.743	1.308	.635	.373	4.846	2.758	6.050	7.826	.100	3.680
2	1.018	3.619	.947	1.954	2.138	.945	3.154	11.206	10.164	9.515	.344
3	1.788	1.136	1.268	.527	2.835	1.936	.481	9.053	13.649	9.855	15.468
4	2.118	1.615	.583	.422	.599	1.732	.975	1.348	7.650	10.431	15.008
5	.993	.640	.496	.150	.546	.474	.941	1.908	.451	2.921	9.237
6	.618	.373	.339	.237	.243	.833	.215	.724	.444	.369	1.991
7	.629	.151	.156	.064	.217	.215	.222	.216	.119	.307	.298
8	.405	.253	.099	.064	.098	.092	.056	.110	.012	.074	.099
9	.145	.009	.039	.031	.045	.050	.020	.000	.000	.000	.017
10	.033	.000	.012	.044	.033	.060	.016	.046	.011	.038	.000
11	.040	.000	.000	.000	.030	.000	.020	.015	.016	.015	.000
12	.025	.000	.000	.000	.000	.018	.060	.000	.000	.000	.000
13	.007	.000	.000	.000	.008	.000	.003	.039	.025	.013	.000

Age	1981	1982	1983	1984	1985	1986	1987
0	22.353	.760	.153	.276	.011	.137	.109
1	15.705	18.254	21.340	.304	4.223	.604	1.889
2	9.327	15.943	15.038	10.782	1.027	1.932	1.697
3	.980	13.204	30.072	17.299	11.007	8.183	4.633
4	7.328	2.568	11.074	29.309	21.764	26.191	15.973
5	4.766	7.768	2.686	5.196	4.770	11.678	5.945
6	1.966	3.077	2.385	2.393	1.243	1.374	.530
7	.300	.982	.801	1.310	.330	.326	.072
8	.093	.224	.250	.244	.074	.060	.000
9	.119	.030	.065	.086	.000	.000	.041
10	.026	.016	.027	.022	.002	.000	.000
11	.000	.000	.000	.006	.000	.000	.000
12	.000	.000	.011	.000	.000	.000	.000
13	.000	.011	.024	.016	.004	.007	.002

Table 11. Calibration results using catch at age and survey catch rate at age (1970-1987) and calibrating ages 2 through 5.

Age	a	q	R 1970-1983	R 1970-1987	SSQ Age Specific ln Residuals	SSQ Cohort Specific ln Residuals
2	-448.676244	0.4206915	0.8567937	0.8310098	9.4145372	0.0000001
3	-1070.4652939	0.7571744	0.7483093	0.6901060	5.9698362	0.1891239
4	-467.4265324	0.7601014	0.8474207	0.7810343	9.1399693	3.8052486
5	-276.3723375	0.7791675	0.9014086	0.8075450	8.7464248	1.0298349

ln Residuals

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	-0.457	0.676	0.197	0.136	0.227	0.003	-0.560	0.361	0.115	-0.092	-2.117	0.588	0.832	0.092	-0.225	-1.577	-0.326	0.000
3	-0.695	-0.319	-0.370	0.314	0.733	0.047	-0.627	0.237	0.243	-0.250	0.103	-1.297	0.704	1.178	-0.098	-0.558	0.245	0.288
4	-0.654	-0.305	-0.660	-0.927	0.302	0.642	-0.552	0.328	0.425	0.202	0.524	-0.210	-0.148	1.033	1.599	0.577	0.795	1.121
5	-0.713	-0.965	-0.652	-1.128	0.258	0.490	0.599	0.426	-0.355	-0.132	0.514	0.203	0.808	0.646	1.264	1.016	0.760	-0.189

Table 12. Population numbers (000s) at age (1948-1986) estimated by SPA using input parameters listed in the text.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
1	69398	39915	72501	34774	26582	122467	42932	44346	64374	80081	70010	29730	48482	33463	58683	84522	91796	91520
2	44286	56819	32680	59359	28426	21764	100267	35150	36307	52705	65565	57320	24341	39694	27396	47860	68036	72812
3	21080	36258	46510	26756	48599	23268	17816	82081	28778	29533	43151	53622	46922	19928	32470	22035	38348	52923
4	25221	17099	28912	38004	21214	39383	18734	14395	66746	21819	23594	33415	41244	38005	15946	25235	17579	27710
5	17524	18664	12980	21509	26621	15636	30142	12732	10862	44505	14576	15863	21203	27970	26682	11211	17520	12250
6	3180	11390	11362	8073	12131	15800	9081	15565	8079	6721	24495	9668	7958	10500	15207	14793	5856	8895
7	3578	1430	6529	4763	4604	5721	8914	5481	8100	4317	3652	12701	4850	3494	4708	6850	6145	2922
8	2455	1652	734	2425	2276	2113	3411	5067	2891	4039	2143	2016	4001	2013	1628	2084	2722	2402
9	2365	1025	1030	336	804	886	1317	1600	2663	1495	2191	1051	919	1498	687	574	581	815
10	1174	1434	565	323	186	291	502	688	749	973	915	1081	383	415	569	276	210	111
11	941	569	967	255	205	66	216	172	281	305	576	500	403	172	166	264	112	98
1+	191202	186254	214771	196576	171647	247395	233331	217277	229829	246493	250868	216967	200703	177153	184143	215703	248905	272458
2+	121804	146339	142269	161802	145065	124928	190399	172931	165455	166412	180858	187238	152221	143689	125460	131181	157108	180938
3+	77518	89520	109590	102443	116639	103165	90132	137782	129148	113707	115293	129918	127881	103996	98064	83321	89073	108126
4+	56438	53262	63080	75687	68040	79897	72316	55701	100369	84174	72142	76296	80958	84067	65594	61286	50725	55203

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	15283	14750	10773	6718	8150	4428	8085	7605	4574	19928	27168	31056	35875	10863	18637	24891	45974	45075	17387	10193	6931
2	26435	10588	11996	8816	5473	6396	3383	6342	5786	3692	16063	21853	25233	28727	8893	14958	19592	37161	36455	14226	8225
3	30513	12870	8505	9810	7179	4363	4632	2510	4127	4526	2967	12540	17636	20268	23277	6941	11958	15649	30000	29521	11585
4	21487	16261	9627	6603	7636	5263	2769	3185	1471	2496	3280	2287	9393	13705	16211	16911	5446	8415	11831	23192	23798
5	8942	9551	10941	6248	4132	4675	2329	1587	1280	974	1315	2460	1570	5508	10207	9350	9257	3767	3988	5924	11744
6	2994	3118	5253	6310	3270	2116	1348	1071	565	628	543	785	1550	891	3898	5427	3057	2485	1238	1252	1084
7	3612	1351	1545	2044	3397	1442	640	499	222	194	347	273	386	621	585	1651	1720	732	518	271	228
8	1232	1476	707	548	824	1729	326	211	99	79	101	164	118	132	374	254	286	304	120	53	12
9	850	557	668	236	196	322	351	95	30	39	38	50	62	41	94	189	82	40	37	17	1
10	304	449	264	180	75	81	13	143	23	17	25	23	24	30	29	41	60	24	7	3	1
11	26	169	210	111	40	27	31	2	28	3	10	11	5	13	19	16	7	24	3	1	1
1+	111678	71140	60491	47625	40372	30843	23907	23252	18205	32575	51856	71502	91853	80798	82225	80630	97439	113678	101583	84654	63610
2+	96394	56389	49717	40907	32222	26415	15822	15647	13631	12648	24688	40447	55977	69935	63588	55739	51465	68603	84196	74461	56679
3+	69959	45801	37721	32091	26750	20019	12438	9304	7845	8956	8625	18594	30744	41208	54695	40781	31873	31441	47741	60234	48454
4+	39446	32932	29216	22281	19570	15656	7806	6795	3718	4430	5658	6054	13108	20941	31419	33840	19915	15793	17742	30713	36869

Table 13. Mean population biomass (kg) at age (1948-1986) estimated by SPA using input parameters listed in the text.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
1	5158	2966	5388	21416	1976	9102	3191	3296	4784	5952	5203	2210	3603	1820	2601	7522	8358	5383	1151
2	12242	35015	9034	16409	17517	11440	61792	9717	16402	14570	31479	41558	6729	6819	4924	6096	16880	12333	5034
3	21493	27189	34576	23817	38802	19955	13942	58310	18843	20148	26812	32054	28232	14182	12999	7180	14579	14679	8072
4	25889	17775	25683	34300	20019	39143	16851	13023	48749	17706	19006	23941	31179	28784	11091	19863	10469	11857	10271
5	22930	20496	14306	21159	28066	18303	25235	13278	10798	39713	15111	13384	16696	24019	20598	9451	13944	7318	5718
6	4927	15907	14126	10043	14176	21919	11225	16871	9165	7833	26440	10316	7671	11019	14148	13352	5696	7602	2751
7	6710	2574	8973	7008	6758	10064	13302	7338	10051	5636	4816	13464	5901	4562	5587	7818	6551	3773	3702
8	4947	3850	1342	3425	3853	4649	5090	8037	4501	6266	3221	3034	5583	2744	2206	2361	3043	3333	1851
9	5763	2307	1561	409	1508	2148	2361	2682	3738	2801	3283	1591	1560	2310	1231	852	666	1253	1445
10	2826	3748	1106	361	291	973	829	1180	1128	1808	1689	1882	711	750	1033	464	401	162	613
11	2527	1472	2479	440	375	180	492	361	587	640	1054	1002	750	409	414	439	187	185	51
1+	115412	133300	118573	138785	133340	137875	154311	134092	128745	123070	138114	144436	108614	97417	76831	75399	80774	67880	40660
2+	110255	130334	113185	117370	131365	128774	151120	130796	123961	117118	132911	142227	105011	95597	74230	67877	72416	62497	39509
3+	98013	95319	104151	100961	113848	117334	89328	121080	107559	102549	101432	100668	98283	88779	69306	61781	55536	50163	34475
4+	76520	68130	69575	77144	75045	97378	75385	62770	88717	82401	74620	68614	70050	74597	56308	54601	40957	35484	26403

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1626	1054	601	782	462	703	765	502	2850	2246	3926	2573	886	1338	1771	2485	2843	1418	1101	628
2	3653	1891	1737	1628	1832	819	1792	2088	812	5249	10122	7904	8677	1817	5139	4647	6231	8651	2534	2036
3	5966	3261	5658	3940	2191	2265	1266	2085	3295	1373	10097	10387	12864	14271	4227	6363	7183	15249	12262	6126
4	10527	6250	4655	5510	3314	2028	2041	1354	2217	3469	2352	7768	13853	12851	12116	4358	4876	6303	11746	13296
5	8257	9405	5795	3879	3483	2176	1360	1517	1160	1651	2982	1810	7236	10297	7127	6196	2637	2447	2811	7920
6	3326	5417	7602	3493	2008	1566	1008	686	1013	795	1070	1998	1469	4828	5412	2613	1791	931	859	872
7	1757	2077	3058	5119	1449	846	550	341	349	555	433	611	1192	920	1706	1761	582	366	160	374
8	2208	939	950	1387	1990	450	239	179	156	169	263	196	331	723	411	348	242	113	31	1
9	1000	957	465	408	276	689	164	64	94	96	100	145	114	200	347	147	52	38	17	0
10	886	548	310	190	179	24	224	33	40	45	41	62	84	74	66	137	20	10	4	0
11	381	501	258	93	45	68	4	56	9	22	22	14	44	51	32	17	19	4	2	0
1+	39588	32301	31091	26428	17228	11635	9412	8907	11994	15670	31409	33469	46750	47370	38353	29074	26476	35530	31527	31224
2+	37962	31247	30489	25647	16766	10932	8647	8404	9144	13424	27483	30895	45864	46031	36582	26589	23633	34112	30426	30597
3+	34309	29356	28752	24019	14934	10113	6855	6316	8332	8175	17361	22991	37186	44214	31444	21942	17402	25461	27892	28590
4+	28343	26095	23094	20080	12743	7848	5589	4231	5036	6802	7264	12604	24323	29943	27216	15579	10219	10212	15630	22464

Table 14. Catch biomass (kg) at age (1948-1986) estimated by SPA using input parameters listed in the text.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	0	0	0	34	0	0	0	0	0	0	0	0	0	0	10	127	264	5505	191	11
2	0	7	0	0	4	2	8	0	107	0	34	6	0	6	87	131	862	8156	2590	69
3	200	717	68	763	398	333	184	397	1443	493	1489	1997	304	324	675	186	1814	10161	3435	537
4	2608	1340	2452	5328	2096	2632	3124	1060	9957	3584	3726	6067	5845	4407	1683	3261	1680	10856	6200	2056
5	5265	6032	3909	7825	8965	6240	11522	3364	3005	15641	3165	6492	8310	9749	7965	4210	6600	8660	4805	3258
6	2918	5628	9338	3603	7736	8098	3399	7575	3876	3183	11967	5004	4723	6558	8358	8944	2792	5261	1621	1653
7	3801	1190	6988	3734	3868	3170	4816	3199	4936	2793	1883	12640	3958	2543	3396	5575	4778	2472	2540	780
8	3289	1044	772	3047	2823	1262	2803	3531	2049	2556	1633	1758	4304	2362	1832	2495	3007	2754	1087	1293
9	1721	904	1474	158	1210	784	1050	1484	2970	809	1645	1271	916	1748	865	676	946	971	626	541
10	1466	722	653	91	241	97	712	812	777	584	678	1462	423	532	579	320	221	201	236	490
11	884	470	1287	183	160	62	209	141	250	257	394	629	432	201	202	276	107	168	37	169
1+	22152	18052	26941	24766	27501	22679	27827	21563	29369	29900	26614	37326	29214	28431	25652	26201	23072	55165	23370	10856
2+	22152	18052	26941	24732	27501	22679	27827	21563	29369	29900	26614	37326	29214	28431	25642	26073	22807	49660	23178	10846
3+	22152	18045	26941	24732	27497	22677	27819	21563	29262	29900	26581	37320	29214	28425	25555	25942	21945	41504	20588	10776
4+	21952	17329	26872	23970	27099	22344	27636	21167	27819	29407	25091	35323	28910	28100	24880	25756	20131	31343	17153	10239

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1	3	33	32	30	56	7	44	40	30	57	0	27	70	32	35	1	16	1
2	2	9	43	224	81	409	95	15	249	146	151	90	87	122	115	88	95	14	14
3	173	286	434	555	393	420	627	401	83	895	540	300	1699	180	959	570	873	190	779
4	1444	1244	1591	2016	718	1433	285	968	303	413	2574	1307	4468	4838	731	2638	3069	5590	7914
5	3271	2570	1802	3567	1241	1114	768	443	519	777	659	1049	4406	6433	6772	2367	2305	4104	6034
6	3974	3159	2136	1965	1224	1350	588	396	384	540	1407	321	3142	5048	3144	2394	1200	1259	1159
7	1711	2138	2410	1821	755	759	282	155	300	273	525	363	578	2580	2629	912	735	447	237
8	829	775	1010	2711	459	411	132	83	84	202	165	47	345	376	596	447	194	110	27
9	1043	433	275	795	472	196	24	24	26	52	74	16	123	324	150	81	79	41	3
10	360	394	153	135	35	314	60	14	25	50	29	20	32	101	98	38	15	4	4
11	260	126	68	77	70	6	53	4	10	19	9	8	26	36	20	34	7	6	4
1+	13067	11136	9957	13898	5477	6469	2922	2546	2024	3397	6190	3521	14931	20108	15246	9603	8573	11781	16176
2+	13066	11133	9924	13866	5447	6413	2914	2502	1984	3367	6133	3521	14904	20038	15214	9569	8572	11765	16175
3+	13064	11124	9881	13643	5366	6004	2820	2487	1735	3221	5982	3431	14818	19916	15099	9481	8477	11751	16161
4+	12891	10838	9447	13087	4973	5583	2193	2086	1652	2327	5441	3131	13119	19736	14140	8911	7605	11562	15382

Table 15. Population biomass (kg) at beginning of year (1948-1986) estimated by SPA using input parameters listed in the text.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
1	1976	1137	3083	1479	18076	3776	1222	1885	2138	3405	2258	780	2061	1805	1929	2433	5398	5920	974
2	8149	13417	5168	9387	19330	4746	23677	5559	7352	8335	13668	14681	3849	4949	3001	3992	11339	11710	4379
3	23219	18330	34751	14758	25254	18740	12648	60023	13760	18225	19998	32183	34284	9806	9515	5946	9643	18187	9174
4	27696	19823	26810	35665	22170	39438	19053	13672	55787	18759	20342	26479	32476	29440	12907	16461	8934	15631	11644
5	26542	24018	16657	24768	32071	20154	34313	15104	12381	45664	16273	16936	20964	28608	25577	10903	17777	10890	7688
6	6836	19506	18296	12112	17779	24808	14035	20228	11373	9382	32357	13210	10228	13581	18923	17416	7283	10604	3648
7	9242	3369	12965	9373	8533	11072	16816	9259	12915	7188	6026	20606	7972	5678	7661	10523	9177	4714	5123
8	7463	4636	1871	5451	5309	5104	7467	10386	5675	7633	4186	3931	7918	4060	3287	3888	4992	4601	2524
9	7249	3079	2819	692	2121	2555	3416	3610	5827	3356	4561	2364	2124	3440	1694	1301	1261	1758	1925
10	4013	4487	1646	609	375	990	1469	1731	1750	2244	2210	2587	976	1083	1423	728	532	284	772
11	3127	1906	3261	653	379	197	743	470	758	770	1380	1346	1090	512	512	666	278	287	75
1+	125511	113707	127326	114945	151396	131578	134859	141927	129716	124961	123260	135103	123942	102963	86429	74257	76613	84585	47925

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	643	1101	511	440	271	627	396	280	1716	2836	1208	3182	425	1048	910	2021	1535	628	620	554
2	1969	1748	1353	993	1217	618	1170	1252	638	3890	4755	5576	4702	1282	2620	2852	3929	4949	1894	1481
3	4861	3473	3304	2678	1989	2053	1072	1951	2665	1065	7334	10327	10073	11401	2761	5882	5842	9831	10292	4049
4	8597	6291	4088	5892	4035	2139	2410	1258	2195	3339	1842	9344	12086	13850	13978	4411	6063	7373	14714	14554
5	8550	10242	6271	4406	5097	2590	1818	1628	1295	1829	3339	2143	7092	12863	10681	9917	3969	3682	5054	10055
6	3864	7106	8480	4591	3063	2082	1696	932	1182	969	1373	2674	1556	6602	8199	4360	3258	1613	1524	1349
7	2073	2767	3893	6217	2505	1206	1007	477	426	764	595	856	1363	1267	3320	3270	1218	828	455	424
8	2705	1390	1341	2003	3778	703	503	247	207	242	392	296	365	955	635	706	617	231	109	25
9	1312	1577	636	578	879	918	265	80	112	113	128	177	122	286	542	238	112	83	42	2
10	1143	742	526	274	266	43	440	76	49	69	76	76	101	98	135	197	60	20	8	3
11	483	645	351	138	105	112	9	91	11	30	33	20	48	69	55	27	60	7	5	3
1+	36199	37083	30755	28211	23206	13092	10786	8272	10496	15145	21075	34671	37933	49719	43837	33883	26661	29244	34717	32500

Table 16. Fishing mortality at age (1948-1986) estimated by SPA using input parameters listed in the text.

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1	.000	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.004	.017	.032	1.042	.167	.007	.001	.005	.042
2	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.001	.000	.000	.001	.018	.022	.051	.670	.520	.019	.001	.005	.026
3	.009	.026	.002	.032	.010	.017	.013	.007	.077	.025	.056	.062	.011	.023	.052	.026	.125	.701	.429	.090	.053	.051	.110
4	.101	.076	.096	.156	.105	.067	.186	.082	.205	.203	.197	.255	.188	.154	.152	.165	.161	.931	.611	.196	.232	.269	.291
5	.231	.296	.275	.373	.322	.343	.461	.255	.280	.397	.211	.490	.503	.409	.390	.449	.478	1.209	.854	.398	.350	.447	.469
6	.599	.356	.670	.361	.552	.372	.305	.453	.427	.410	.457	.490	.623	.602	.598	.679	.495	.701	.596	.502	.744	.419	.619
7	.573	.467	.790	.539	.579	.317	.365	.440	.496	.500	.394	.955	.679	.564	.615	.723	.739	.664	.695	.448	.836	.708	.475
8	.673	.273	.582	.904	.743	.273	.557	.443	.459	.411	.512	.586	.782	.875	.843	1.077	1.006	.839	.594	.592	.897	.828	.739
9	.301	.395	.961	.389	.815	.368	.449	.559	.807	.291	.506	.811	.594	.768	.712	.805	1.457	.786	.437	.547	1.112	.948	.683
10	.524	.193	.598	.254	.839	.100	.872	.697	.698	.325	.405	.788	.602	.719	.567	.699	.559	1.264	.389	.559	.664	1.299	.819
11	.350	.319	.519	.416	.428	.346	.425	.392	.425	.402	.374	.628	.576	.492	.489	.629	.573	.908	.720	.444	.518	.488	.739
5+	.362	.320	.544	.425	.438	.346	.428	.397	.435	.403	.381	.649	.580	.500	.497	.641	.591	.941	.733	.448	.546	.501	.537

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	.069	.043	.073	.014	.016	.018	.008	.022	.000	.020	.039	.013	.012	.001	.015	.002
2	.123	.099	.230	.046	.018	.048	.014	.019	.010	.048	.024	.025	.014	.011	.005	.007
3	.255	.175	.334	.303	.122	.060	.089	.052	.023	.119	.043	.151	.080	.057	.016	.127
4	.615	.356	.712	.212	.441	.088	.176	.334	.095	.350	.403	.168	.547	.492	.480	.595
5	1.043	.577	.832	.511	.385	.317	.262	.367	.146	.432	.918	1.115	.913	.958	1.498	.762
6	.997	.793	1.371	.871	.394	.487	.509	.714	.220	.659	.949	1.229	1.369	1.319	1.503	1.328
7	1.286	.908	1.414	.839	.448	.547	.638	.873	.307	.637	1.553	1.532	1.609	2.075	2.911	.634
8	1.395	1.038	1.767	.746	.537	.503	.778	.853	.141	.481	.931	1.761	1.910	1.771	3.766	29.320
9	3.017	.695	1.225	.381	.253	.274	.524	.516	.138	.622	.951	1.038	1.599	2.173	2.608	26.835
10	.765	1.452	1.439	1.849	.351	.574	1.256	.463	.244	.431	1.570	.723	1.911	1.537	1.028	26.835
11	1.707	1.024	1.478	.949	.406	.462	.882	.621	.184	.513	1.136	1.199	1.798	1.830	2.380	27.325
5+	1.187	.720	1.162	.662	.398	.400	.375	.583	.169	.500	.992	1.199	1.187	1.157	1.568	.839

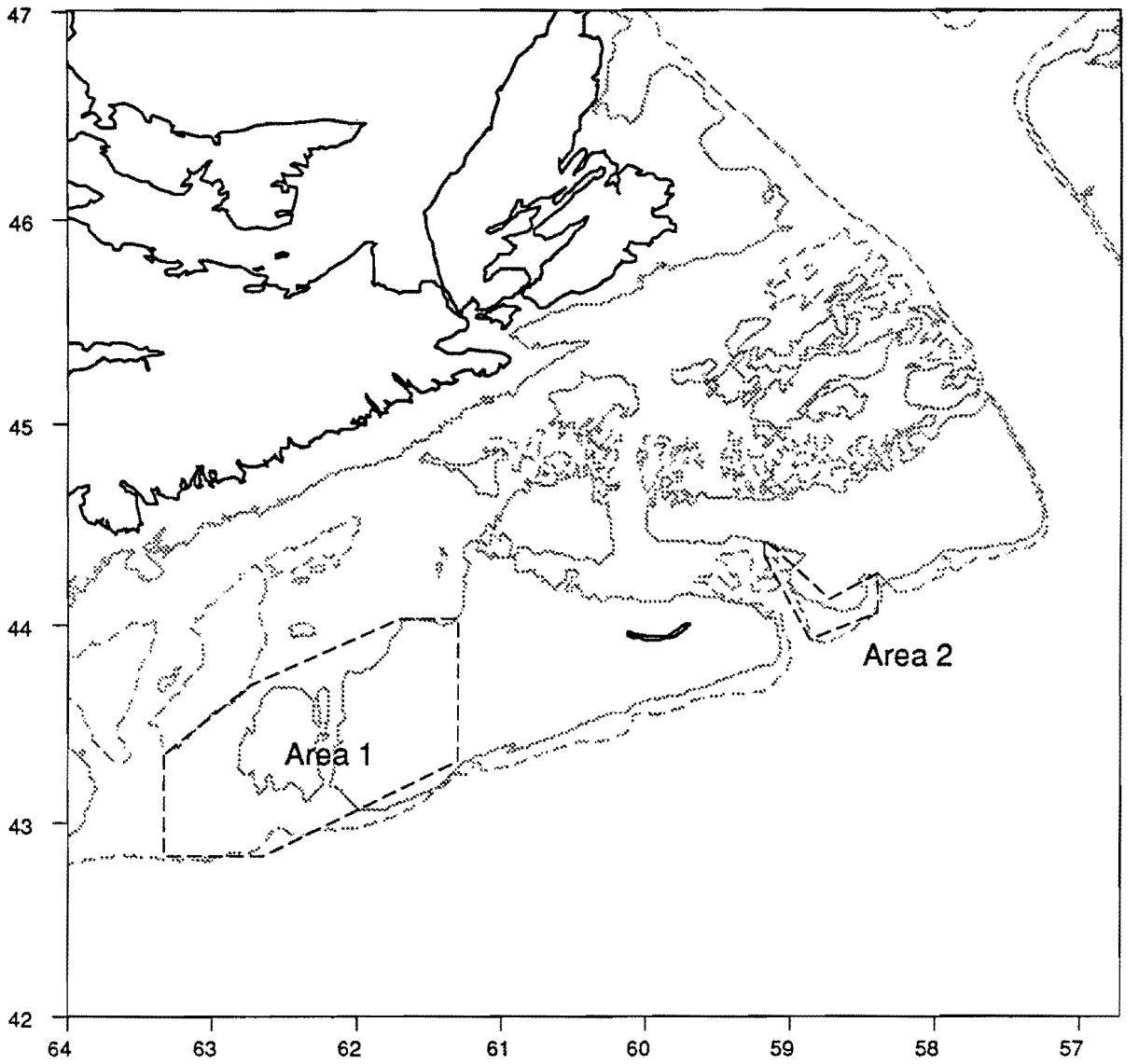
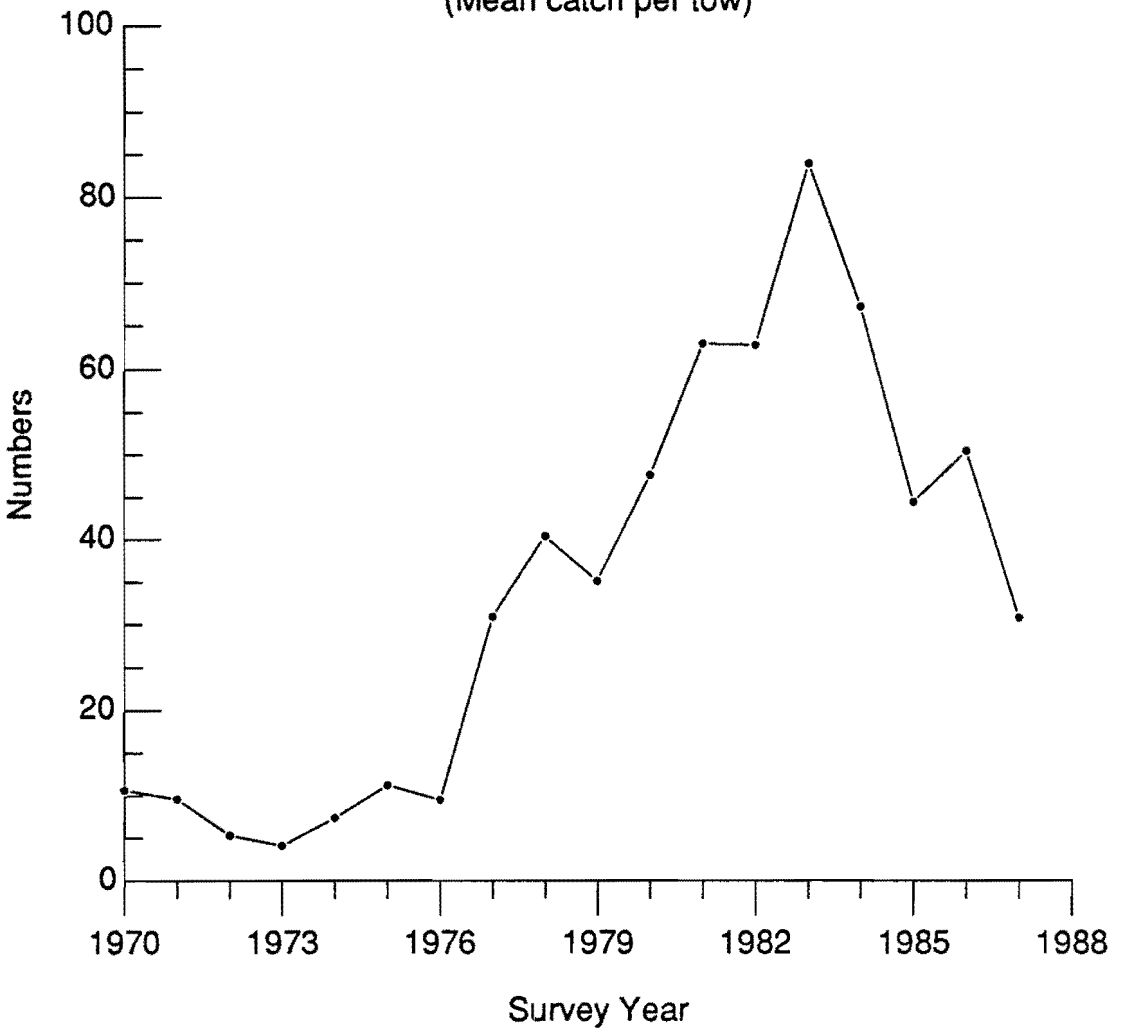


Figure 1. Location of groundfish closed areas in 4VW.

Figure 2. 4VW Haddock July research vessel index
(Mean catch per tow)



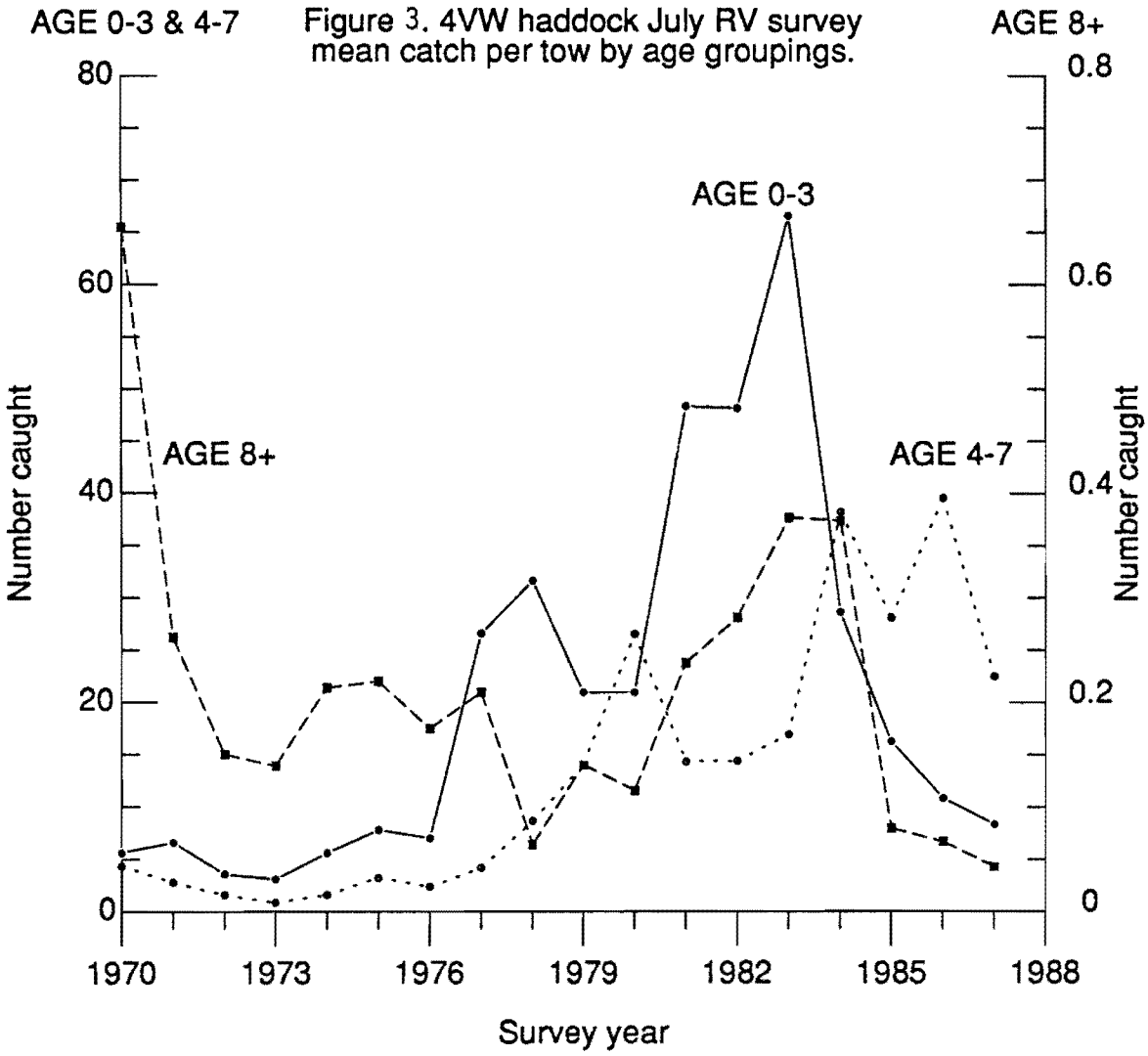


Figure 3. 4VW haddock July RV survey mean catch per tow by age groupings.

Figure 4. 4VW juvenile Haddock age composition in July research vessel surveys

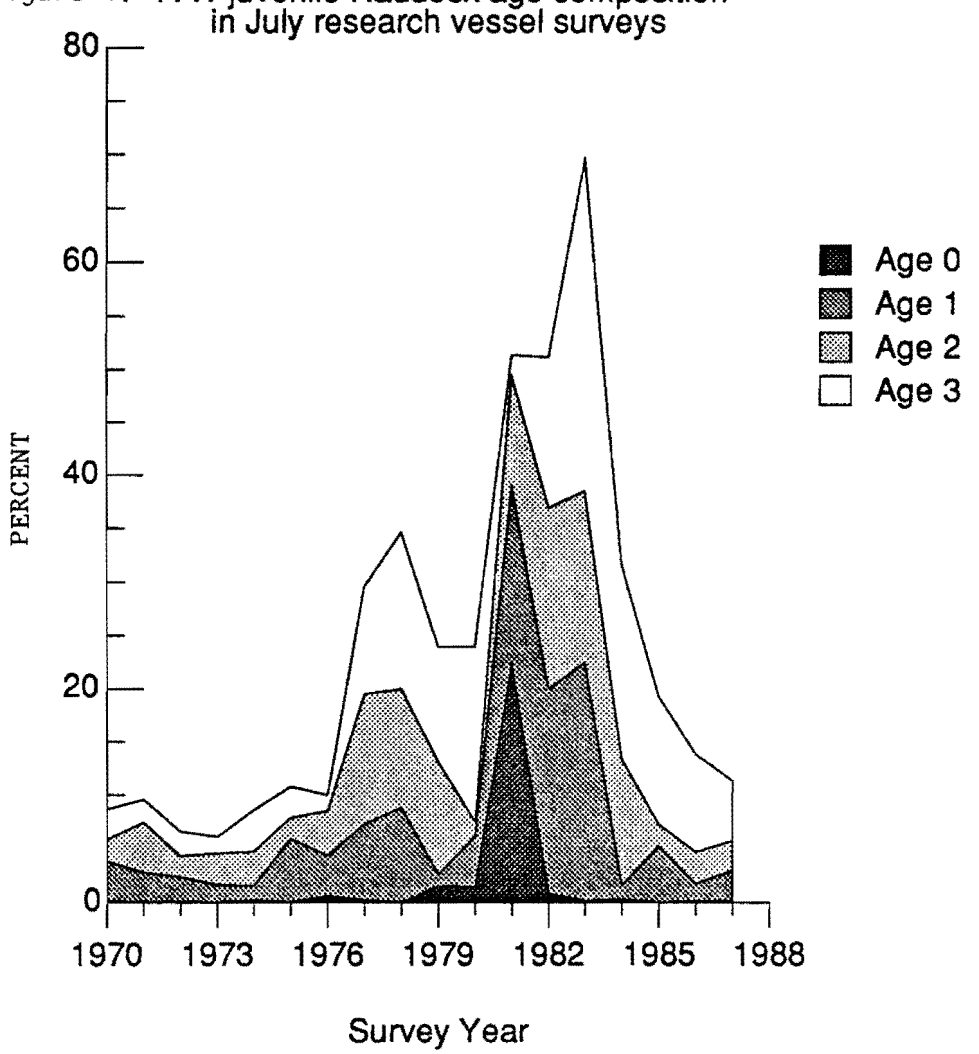
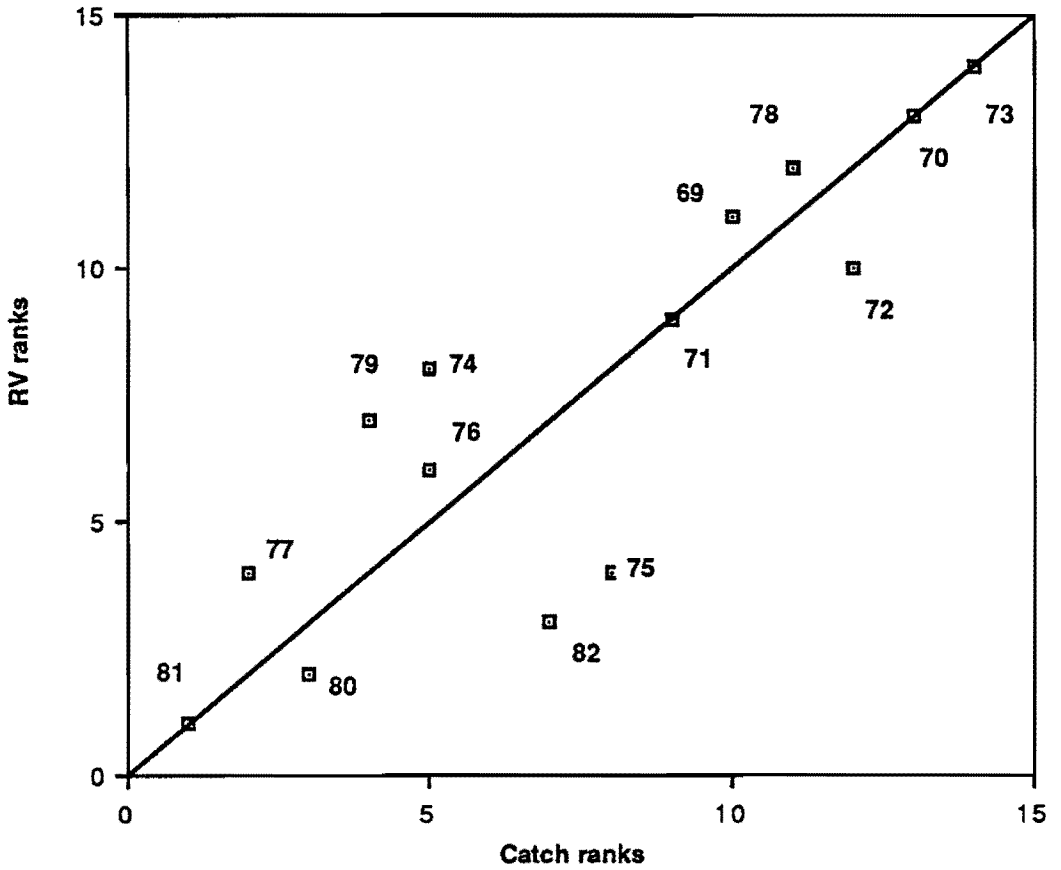


Figure 5. 4VW haddock year class rankings based on numbers caught in the RV survey against rankings by numbers in the catch.



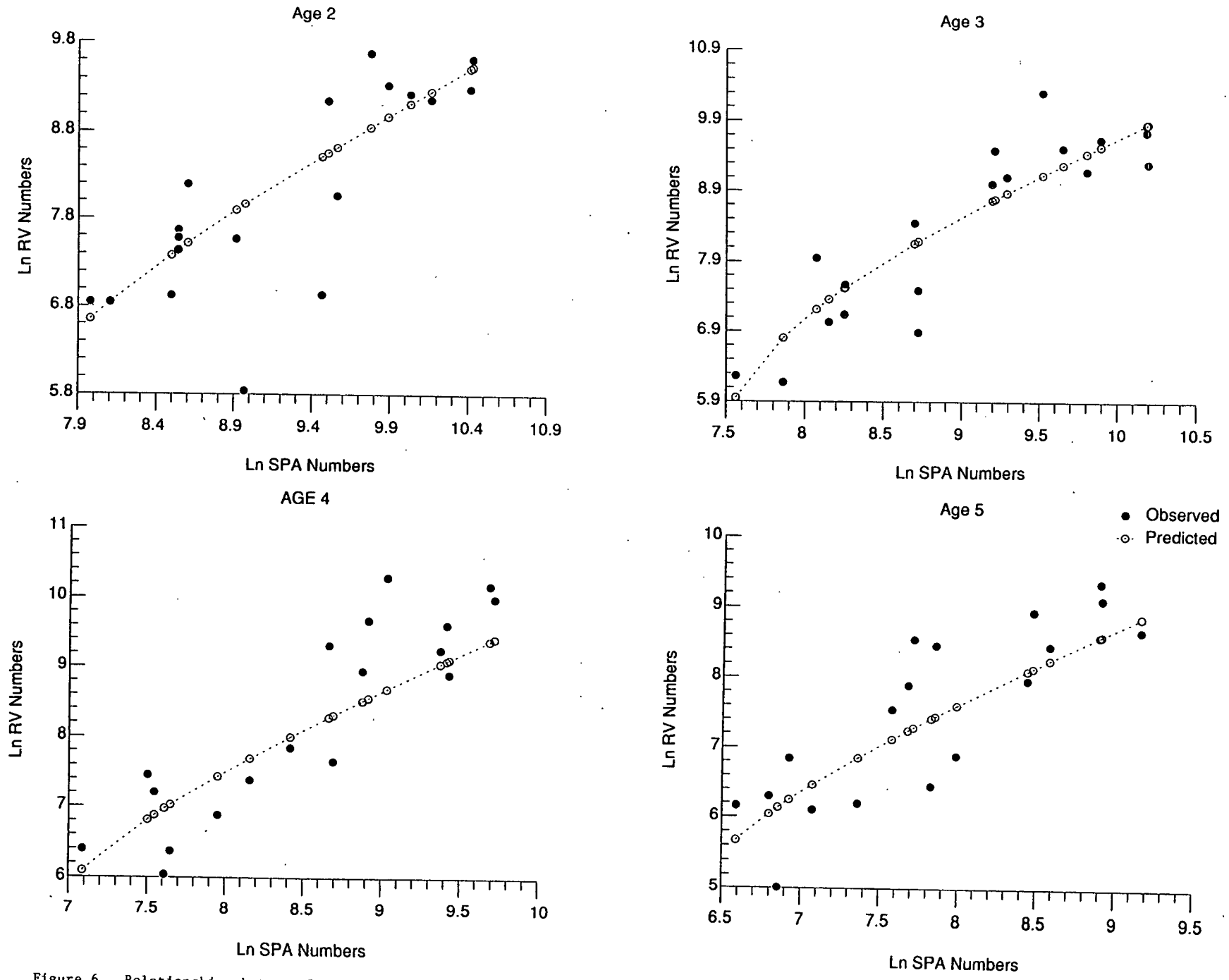


Figure 6. Relationships between ln survey catch rates-at-age and ln SPA numbers-at-age using the ln form of the calibration model as given in the text.

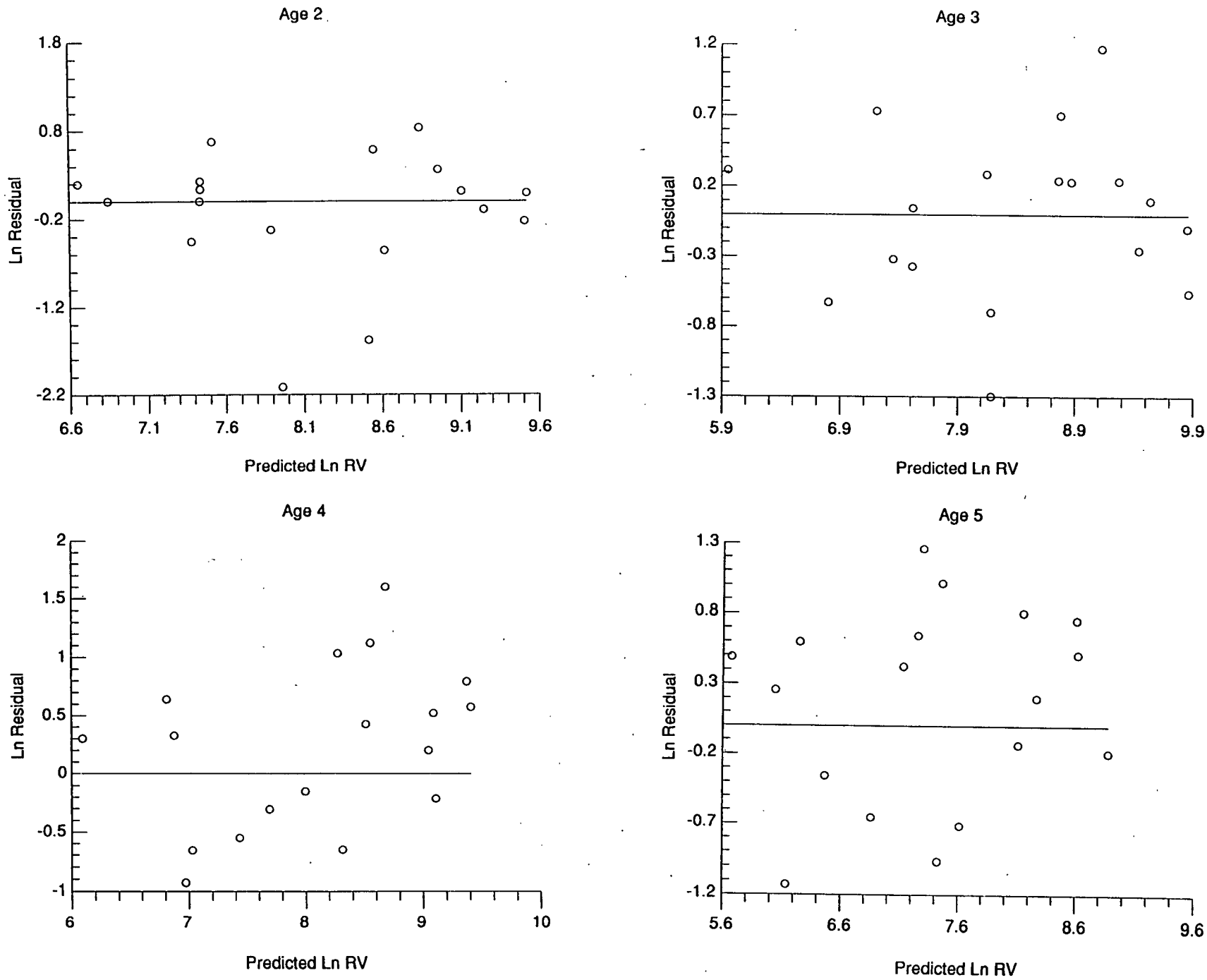


Figure 7. Relationships between ln residuals around the RV/SPA regression line and predicted ln RV catch rate-at-age values.

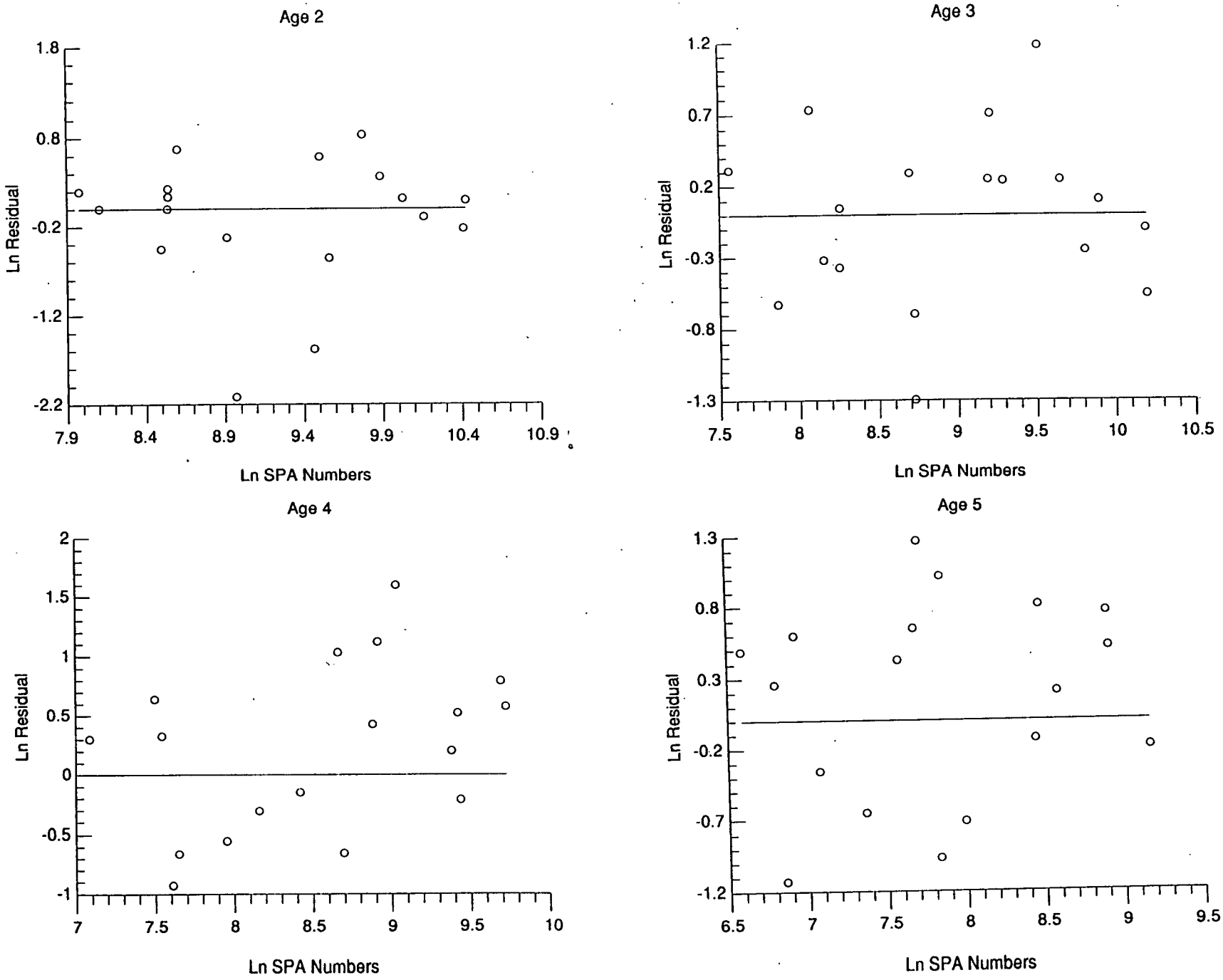


Figure 8. Relationships between the ln residuals around the RV/SPA regression line and ln SPA values.

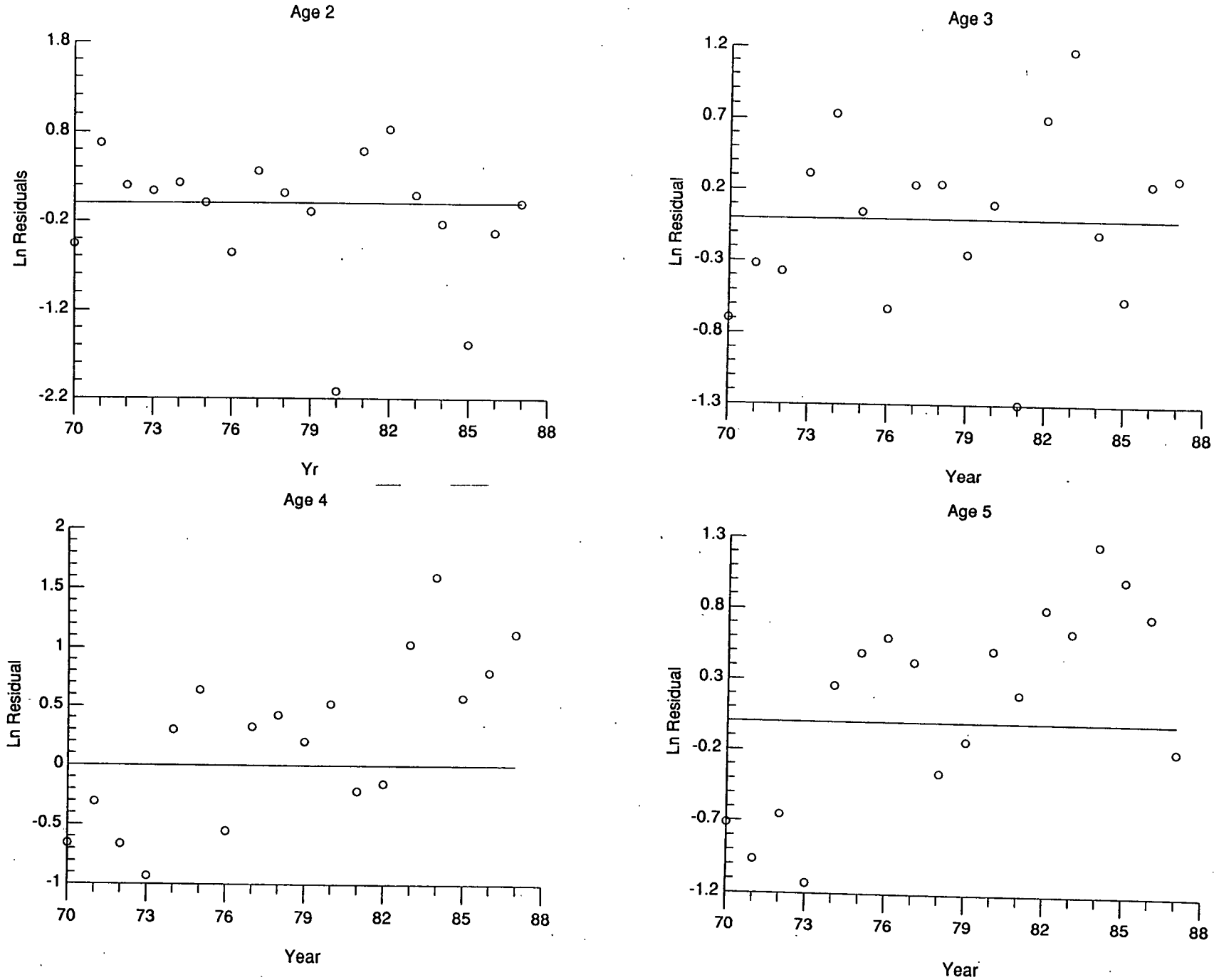


Figure 9. Relationship between ln residuals around the RV/SPA regression line and time.

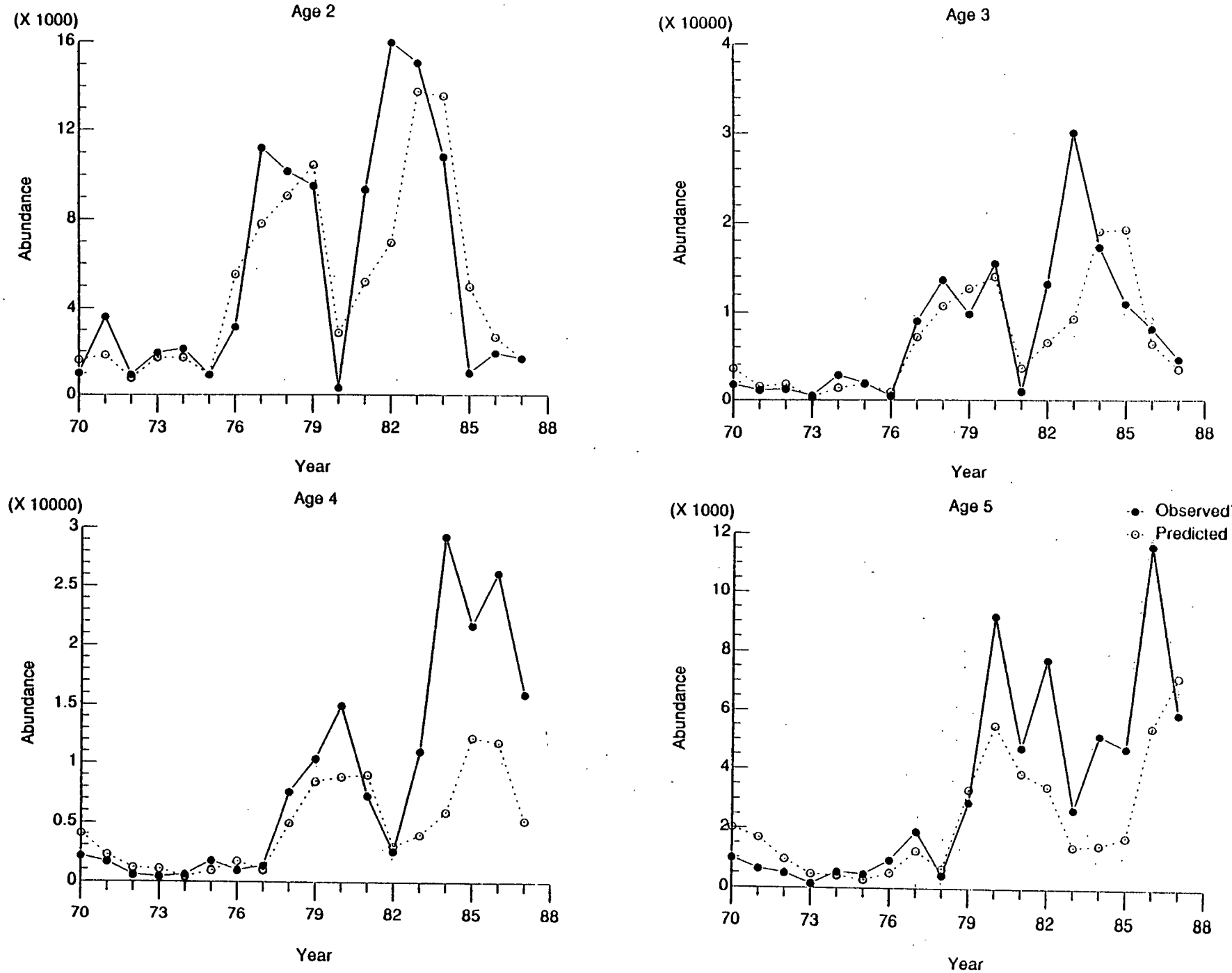


Figure 10. Time trends in observed survey numbers per tow at age and that predicted from SPA numbers at age (rescaled for comparison). Predicted RV values were derived from the ln form of the model listed in the text.

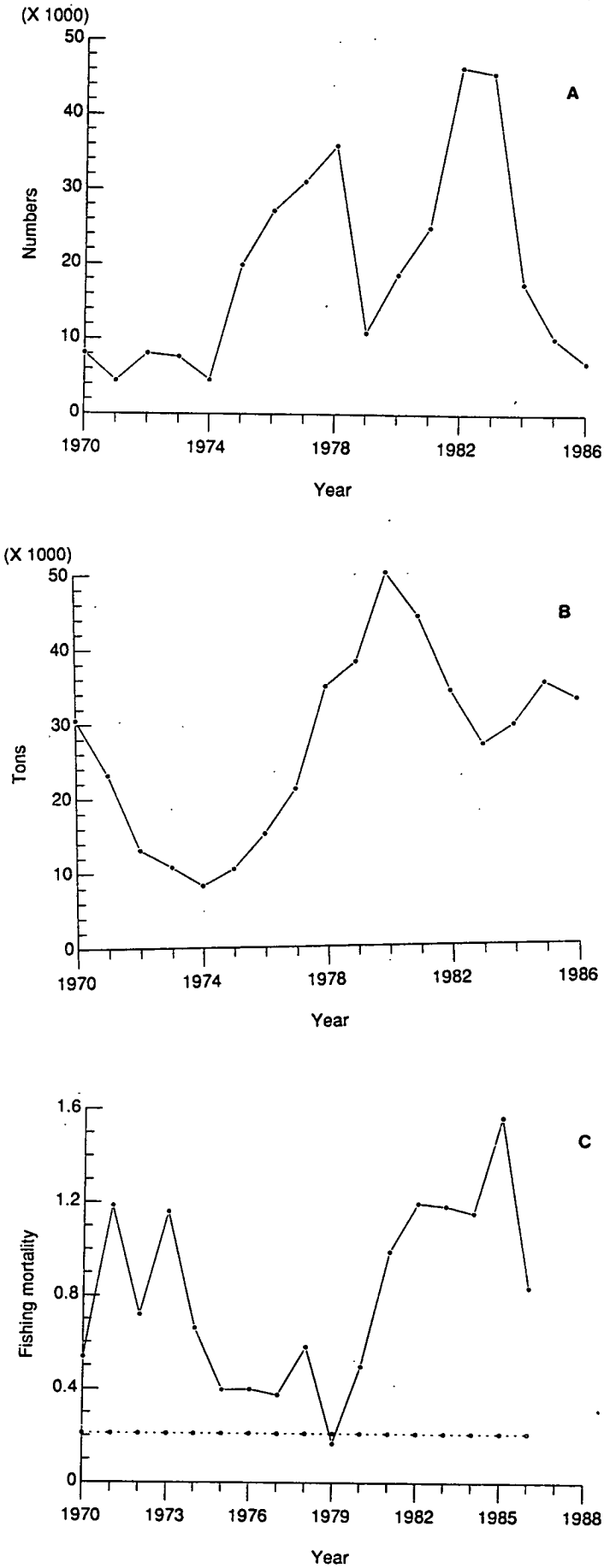


Figure 11. Trends in population numbers at age 1 (a) beginning of year population biomass, (b) and fully recruited fishing mortality, (c) of 4TVW haddock. These figures are the result of the current (1987) assessment.