An investigation of Northwest Atlantic mackerel partial recruitment vector

by

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ABSTRACT

Recent assessments of the northwest Atlantic mackerel have estimated the partial recruitment vector (P.R.) to be done shaped with peak P.R. at age 6. An investigations of the temporal changes of mackerel P.R. is presented along with an evaluations of the SVPA technique.

RESUMÉ

Les plus récentes évaluations de stocks du maquereau de l'Atlantique du nord-ouest ont estimé la vecteur de recrutement partiel était connexe avec un maximum à 6 ans. Une étude de la variabilité temporelle du recrutement partiel est présentée, ainsi qu'une évaluation de la méthode SVPA.

INTRODUCTION

Recent assessments of the Northwest Atlantic mackerel stock have estimated the partial recruitment vector for recent years to be dome shaped. In most cases, it appeared as if full recruitment did not occur until about age 6. This represents a significant change over the partial recruitment estimated for the mid-1970's. This dome shaped partial recruitment was obtained using the technique of Separable VPA (SVPA) of Pope and Shepherd (1982).

Full recruitment at age 6 only is difficult to reconcile with the rapid growth of mackerel and small differences in length at age between fish ages 3 and 6. In principle, fish of similar sizes should be equally available to the fishing gears and thus be equally recruited to the fishery. A possible explanation could be a change in the relative contributions of different gears which could result in changes in partial recruitment if the gears involved do indeed have different selectivities.

This document presents an analysis of mackerel catches and catches at age in order to first, estimate if the apparent change in partial recruitment is real and second, attempt to find an explanation for such changes if they occurred.

MATERIAL AND METHODS

This analysis uses information on catch at age for 1962 to 1982 taken in Anderson (1983) and nominal catch data from ICNAF/NAFO bulletins.

Table 1a gives the nominal catches of Atlantic mackerel in the Northwest Atlantic since 1964 by major gear type. Table 1b gives the percentage contribution of each of these gear types. For the purposes of this analysis, the gear types have been defined as follows:

OT	:	all other trawl gears (NAFO gear codes 08 to 18)
SDN	:	danish, scottish, pair and beach seines
PS	:	purse seines
GN	:	all gillnets, set on drift
LG	:	all line gears including longlines (set or drift), handlines, troll lines, mechanized jiggers, etc...
FIX	:	all traps, pound nets and weirs
MIS	:	all other gears whether known or not.

These tables show that the relative contributions of gillnets to the total catch has increased significantly from 1978 onwards. After declining drastically from 1978 to 1980, the proportion of the total catches by otter trawlers has increased in recent years (also shown in figure 1).

Table 2a gives the catch at age for Northwest Atlantic mackerel for 1968 to 1982. Table 2b gives the percentage contribution of each ages to the yearly totals for the same period. These tables indicate that the contribution of ages younger than 4-5 has generally decreased after 1976.

Pope and Shepherd (1982) state that SVPA should be run on at least five years of catch-at-age data. Their algorithm and its APL implementation written by the author of this document were tested using simulated data for NW Atlantic mackerel. A motive for such a test was, among others, the frequent occurrence of dome shaped partial recruitment vectors as a result of the application of SVPA. Although such frequent occurrences may reflect reality, they did look suspicious. In order to test if the technique was biassed towards producing partial recruitment vectors of that shape, the 1968 population numbers at age from the 1984 assessment WORKING PAPER were used along with SPA population estimates at age 1 for 1969 to 1975 to make catch projections under 2 options of partial recruitment: one with a flat topped P.R. and the other with a dome shaped one (table 3a). The resulting catch at age are given in table 3b. The yearly fishing mortalities used in the projection program were approximately equal to those observed in the regular SPA. The results of the 1984 W.P. were used instead of the results of Anderson (1983) because that author uses a different assumption for natural mortality (M=0.20).

These generated catches at age were then used as input catches in SVPA under correct assumptions about the partial recruitment vector.

Input parameters for SVPA are:
- natural mortality
- terminal fishing mortality
- reference age of partial recruitment of 1.0
- partial recruitment on the oldest age.

The reference age of partial recruitment of 1.0 should generally be the age contributing most to the catch. This input parameter is required, along with the partial recruitment on the oldest age-group, to reduce the number of possible solutions to the iterative process of solving the system for F(i) and S(j) (Pope and Shepherd, 1982).

Simulated data:

The behavior of SVPA was investigated with regards to the influence of assumptions about one paramater on the results for the other parameters. The following runs were made:

P.R.	Reference age	Terminal S	Terminal F
Flat	4	1	.65 (correct)
"	3	1	.65
"	5	1	.65
"	6	1	.65
"	4	.5	.65
"	4	1.5	.65
"	4	1	1.0
"	4	1	.10
Dome	4	.15	.65 (correct)
"	3	.15	.65
"	5	.15	.65
"	6	.15	.65
"	4	.50	.65
"	4	1.0	.65
"	4	.15	1.0
"	4	.15	.10

Real data:

Prior to 1968, biological sampling of the mackerel catch was limited and the resulting catch at age is not very reliable. That is one reason why the 1968 population numbers were used to start the projections to generate catches at age for the test of SVPA, the other being that SPA should have converged by that year. Thus, for the practical application of SVPA, data prior to 1968 were excluded from the analysis.

The following SVPA runs were made:

Period	Reference age	Terminal F	Terminal S
1968-82	4	.1	.5
"	"	"	1.0
"	"	.4	.5
"	"	"	1.0
1968-72	4	.2	.5
"	"	"	1.0
"	"	.8	.5
"	"	"	1.0
1973-77	3	.1	.5
"	"	"	1.0
"	"	.4	.5
"	"	"	1.0
1978-82	6	.1	.5
"	"	"	1.0
"	"	.3	.5
"	"	"	1.0

The runs should give an indication of the true partial recruitment by assuming different terminal selectivities and fishing mortalities. The fact that for each individual period the reference age is the same results from preliminary SVPA runs which lead to the selection of an appropriate reference age for each period.

RESULTS

Simulated data

The results of SVPA using simulated data and correct assumptions about the partial recruitment vector (tables 4a and 4b) indicate that the method provides estimates of yearly fishing mortalities that are the same as those used to generate the catch at age.

The results of the SVPA runs investigating the influence of various parameters are summarized in tables 5a and 5b. They are also shown graphically in figure 2. These indicate that there is little information in the SVPA results that could allow a choice between different sets of parameters. It is, however, interesting to note that assumptions about terminal fishing mortalities have little influence on the estimated partial recruitment and vice-versa. The influence of erroneous assumptions about the partial recruitment is more pronounced on the fishing mortalities than the converse because of the basic assumption of SVPA that the fishing mortality can be decomposed in an age and a year effect. Thus, one can have reasonable confidence in the partial recruitment estimated even without precise knowledge of terminal fishing mortality. This is probably one of the greatest advantage of SVPA over regular SPA.

The results indicate that with a flat topped partial recruitment, the reference age does not influence the S(j) as long as it is chosen above the age at which the partial recruitment is 1.0. If the reference age is set below the age of full recruitment and a flat topped P.R. is more or less assumed by setting the P.R. on the oldest age-group to one, the calculations result in selectivity values on intermediate ages that are above 1. Such results should thus be indications that either the reference age is too low or that the P.R. on the oldest age-group has been underestimated. The resulting log catch ratio residuals (table 6a) were not randomly distributed in this case, indicating that some of the assumptions were probably erroneous. However, the residuals do not allow to discriminate between different kinds of erroneous assumptions as will be seen later.

The same pattern of residuals (table 6a) resulted when the partial recruitment on the oldest age-group was underestimated even if the reference age is correctly assumed. If the terminal selectivity is overestimated, the resulting P.R. vector is almost correct for ages below the reference age. Above that age, however, the P.R. values are progressively overestimated and the pattern of residuals is characterized by negative values at the upper left and lower right hand corners of the table. These observations are likely to be of little value with real data as noise in the data will probably mask these patterns.

With a dome shaped P.R., (table 5b) the method again indicates if the reference age has been assumed too low by giving selectivity values greater than 1 for ages older than the assumed reference age. If the reference age is assumed to be greater than the first fully recruited age but still an age having a P.R. of 1, the method gives correct results. If the reference age is correctly assumed but the terminal P.R. is overestimated, the results are similar to assuming a reference age that is too young, i.e. S(j) on ages above the reference age are greater than 1. Thus, there is no way of differentiating between an age of full recruitment that is assumed too low and a terminal selectivity that is too high from the resulting selectivity coefficients alone. The residuals (table 6b) become useful at this point as they appear to be quite different under the two sets of erroneous assumptions. In the first case, the residuals were negative on both sides of the diagonal. In the second case, the residuals are negative on and around the diagonal.

The resulting S(j)'s appear to be rather resilient to errors in terminal fishing mortalities with both partial recruitments used to generate the catch at age and especially so for the flat topped partial recruitment. Indications of this resilience are given by the closeness or overlapping of curves when different terminal fishing mortalities are assumed (table 5 and figure 2).

Real data

The results from the SVPA runs on real data are plotted in figure 3. They all clearly show that the assumptions about terminal fishing mortality have little influence on the resulting estimates of S(j) considering the level of precision we are usually encountering in fish stock assessment.

For the entire period considered (1968-1982) the partial recruitment appears to be slightly dome shaped with age 4 being fully recruited. When a terminal selectivity of 1 is assumed for the oldest age-group, the P.R. values on ages 5 to 7 decrease regularly, suggesting that the value of 1 may be too high. The terminal selectivity of 0.5 seems to give more consistent results.

The very strong 1967 year-class supported the development of the winter mackerel fishery by the Distant Water Fleet (DWF). The results of SVPA for the period 1968-1972 suggest that the DWF fishery was indeed targetting that strong year-class. The resulting P.R. for that period is clearly dome-shaped and the runs presented indicate that ages 8 to 10 are likely to have been less than 50% recruited to the fishery.

The 1967 year-class was followed by a succession of above average year-classes until the 1976 year-class was produced. This knowledge of relative year-class strength agrees with the results of SVPA for the period 1973-1977. Indications are that for that period, several year-classes were fully recruited and that full recruitment may have extended to age 10 for part of the period.

The year-classes from 1976 to 1979 were all extremely weak. The period 1978-1982 also coincided with the almost complete exclusion of the DWF vessels from the mackerel fishery with the extension of jurisdiction to 200 miles by both Canada and the U.S.A.. These two factors may have interacted to produce the partial recruitment vector that results from SVPA for 1978-1982. The results suggest either dome shaped or flat topped P.R. but clearly indicate that the age of full recruitment has increased to age 6.

This could be explained either by a behavioral change on the part of the fishermen targetting older fish as they appeared to be the only ones available or by changes in the gear mixture catching mackerel. Changes in the seasonality of the fishery and its geographic location may also have played a role (figure 5).

Examination of the residuals (table 7) for these data is not conclusive. This was more or less expected as was indicated earlier. The residuals change only slightly and the patterns are the same under all sets of assumptions. No clear trends can be seen.

Regular VPA was run for the period under investigation, using a flat topped partial recruitment vector (full recruitment at age 6 and older) with values for younger ages equal to the results of SVPA with reference age=6, F_T=.1 and S_T=1.0. Fishing mortality on the oldest age group was calculated using the APL function AUTOF (Rivard, 1982) with age 6 specified as the first fully recruited age. Partial recruitments were calculated (by averaging F) by 5 year periods corresponding to those used in SVPA (table 8). The resulting P.R. vectors are shown in figure 4. It is not surprising to note that the partial recruitments for 1978-1982 are quite similar to those resulting from SVPA. Given the low fishing mortalities in recent years, VPA does not converge during that period. For the other two periods, the VPA should have converged and it still gives results that are quite similar to those of SVPA.

CONCLUSION

It is concluded from this analysis that the partial recruitment vector of mackerel has changed over the period 1968-1982. The increase in age of full recruitment since 1978 appears to be real and not an artifact of SVPA calculations. However, no firm explanation for the increase in partial recruitment can be offered.

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Table 1a: Northwest Atlantic mackerel. Nominal catches by gear type for NAFO Subareas 3-6, 1964-1983

YEAR	OT	PS	GN	LG	FIX	MIS	SDN	TOTAL
1964	692	1850	82	27	588	9992	0	13231
1965	3001	774	1750	17	3391	3453	0	12386
1966	7991	4345	3277	4	3441	3165	0	22223
1967	19029	4096	3230	1099	3359	3243	63	34119
1968	65086	4005	4043	7	1681	5776	212	80810
1969	113635	4606	4357	944	4438	3776	55	131811
1970	207417	8466	4826	213	5165	4174	362	230623
1971	354760	6081	5187	546	3514	2647	505	373240
1972	381412	16433	4401	539	2853	3296	790	409724
1973	360390	45354	5987	107	3549	3795	532	419714
1974	321865	6630	5275	585	3585	1431	209	339580
1975	272315	2817	5178	258	4768	1417	484	287237
1976	224235	4301	3824	720	3984	3452	1217	241733
1977	56742	7129	5891	539	4685	950	1870	77806
1978	1358	8653	6533	1327	4343	787	4874	27875
1979	1267	10036	8754	1314	4656	945	5702	32674
1980	1682	7498	8979	1056	2118	2294	1758	25385
1981	7595	3740	7196	1120	2886	1596	3463	27596
1982	8713	465	6688	1962	4496	3664	235	26223
1983	5948	5160	5638	1148	3044	2214	2530	25682

Table 1b: Northwest Atlantic mackerel. Percent nominal catches by gear type for NAFO Subareas 3-6, 1964-1983

YEAR	OT	PS	GN	LG	FIX	MIS	SDN	TOTAL
1964	5.2	14.0	0.6	0.2	4.4	75.5	0.0	100.0
1965	24.2	6.2	14.1	0.1	27.4	27.9	0.0	100.0
1966	36.0	19.6	14.7	0.0	15.5	14.2	0.0	100.0
1967	55.8	12.0	9.5	3.2	9.8	9.5	0.2	100.0
1968	80.5	5.0	5.0	0.0	2.1	7.1	0.3	100.0
1969	86.2	3.5	3.3	0.7	3.4	2.9	0.0	100.0
1970	89.9	3.7	2.1	0.1	2.2	1.8	0.2	100.0
1971	95.0	1.6	1.4	0.1	0.9	0.7	0.1	100.0
1972	93.1	4.0	1.1	0.1	0.7	0.8	0.2	100.0
1973	85.9	10.8	1.4	0.0	0.8	0.9	0.1	100.0
1974	94.8	2.0	1.6	0.2	1.1	0.4	0.1	100.0
1975	94.8	1.0	1.8	0.1	1.7	0.5	0.2	100.0
1976	92.8	1.8	1.6	0.3	1.6	1.4	0.5	100.0
1977	72.9	9.2	7.6	0.7	6.0	1.2	2.4	100.0
1978	4.9	31.0	23.4	4.8	15.6	2.8	17.5	100.0
1979	3.9	30.7	26.8	4.0	14.2	2.9	17.5	100.0
1980	6.6	29.5	35.4	4.2	8.3	9.0	6.9	100.0
1981	27.5	13.6	26.1	4.1	10.5	5.8	12.5	100.0
1982	33.2	1.8	25.5	7.5	17.1	14.0	0.9	100.0
1983	23.2	20.1	22.0	4.5	11.9	8.6	9.9	100.0

Table 2a: Northwest Atlantic mackerel. Total catch at age (million fish) for NAFO Subareas 3-6, 1968-1982

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	141.4	7.1	193.5	74.6	22.1	161.8	95.9	373.7	12.5	2.0	0.1	0.4	1.2	10.1	4.0
2	61.5	262.1	54.5	294.2	85.7	283.2	242.2	431.4	353.5	27.0	0.2	0.6	10.9	4.7	11.0
3	59.3	160.7	522.1	127.4	256.2	285.1	264.4	113.7	272.5	101.0	4.7	1.3	1.0	8.4	3.0
4	38.1	65.8	162.9	558.9	182.6	233.6	101.5	100.8	85.7	54.0	17.4	7.1	1.0	1.9	9.3
5	14.3	5.7	27.6	203.5	390.4	192.4	114.3	58.6	52.4	12.0	13.3	18.6	6.9	2.7	1.3
6	6.6	3.0	7.0	34.6	87.3	197.2	111.8	67.8	27.3	9.9	8.4	13.1	13.7	7.7	2.9
7	0.7	2.0	5.3	8.9	24.0	31.2	108.3	51.9	40.5	5.6	4.7	6.2	4.7	12.6	4.9
8	1.0	3.1	9.9	3.6	4.2	11.0	25.7	50.5	34.6	6.3	2.2	2.6	2.0	5.4	8.9
9	6.1	2.2	10.0	4.3	8.2	4.1	6.4	12.5	22.6	3.8	4.5	2.2	1.0	2.6	2.9
10	0.1	8.3	3.8	8.1	3.8	3.8	2.5	2.3	13.4	3.6	1.5	2.2	0.9	0.9	1.4

Table 2b: Northwest Atlantic mackerel. Percent catch at age for NAFO Subareas 3-6, 1968-1982

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	43.0	1.4	19.4	5.7	2.1	11.5	8.9	29.6	1.4	0.9	0.2	0.7	2.8	17.7	8.1
2	18.7	50.4	5.5	22.3	8.1	20.2	22.6	34.2	38.6	12.0	0.4	1.1	25.2	8.2	22.2
3	18.0	30.9	52.4	9.7	24.1	20.3	24.6	9.0	29.8	44.8	8.2	2.4	2.3	14.7	6.0
4	11.6	12.7	16.3	42.4	17.2	16.6	9.5	8.0	9.4	24.0	30.5	13.1	2.3	3.3	18.8
5	4.3	1.1	2.8	15.4	36.7	13.7	10.7	4.6	5.7	5.3	23.3	34.3	15.9	4.7	2.6
6	2.0	0.6	0.7	2.6	8.2	14.1	10.4	5.4	3.0	4.4	14.7	24.1	31.6	13.5	5.8
7	0.2	0.4	0.5	0.7	2.3	2.2	10.1	4.1	4.4	2.5	8.2	11.4	10.9	22.1	9.9
8	0.3	0.6	1.0	0.3	0.4	0.8	2.4	4.0	3.8	2.8	3.9	4.8	4.6	9.5	17.9
9	1.9	0.4	1.0	0.3	0.8	0.3	0.6	1.0	2.5	1.7	7.9	4.1	2.3	4.6	5.8
10	0.0	1.6	0.4	0.6	0.4	0.3	0.2	0.2	1.5	1.6	2.6	4.1	2.1	1.6	2.8

Table 3a: Northwest Atlantic mackerel. Input values (M=0.30) used to generate simulated catch at age for SVPA tests.

AGE	POP. NUMBERS 1968	P.F. FLAT	P.R. DOME
1	7341	.10	.10
2	2220	.30	.30
3	545	.75	.75
4	152	1.00	1.00
5	102	1.00	1.00
6	65	1.00	.75
7	64	1.00	.50
8	21	1.00	.25
9	71	1.00	.20
10	1	1.00	.15

YEAR:	1969	1970	1971	1972	1973	1974	1975
F :	.060	.250	.350	.450	.450	.600	.650

Table 3b: Northwest Atlantic mackerel. Simulated catch at age from input parameters in table 3a.

		1969	1970	1971	1972	1973	1974	1975
FLAT TOP P.R.	1	15	67	48	64	51	100	152
	2	82	136	196	128	130	134	213
	3	61	574	301	377	188	244	196
	4	18	217	612	270	253	158	153
	5	4	47	167	393	128	149	68
	6	3	11	37	108	185	75	64
	7	2	8	8	23	51	109	32
	8	2	6	7	5	11	30	47
	9	1	6	4	4	3	7	13
	10	2	2	5	3	2	1	3

		1969	1970	1971	1972	1973	1974	1975
DOME SHAPED P.R.	1	15	67	48	64	51	100	152
	2	82	136	196	128	130	134	213
	3	61	574	301	377	188	244	196
	4	18	217	612	270	253	158	153
	5	4	47	167	393	128	149	68
	6	2	8	29	85	146	60	52
	7	1	5	5	14	31	70	22
	8	1	2	2	2	4	13	22
	9	0	1	1	1	1	3	7
	10	0	0	1	1	1	1	2

Table 4: Northwest Atlantic mackerel. Results of SVPA calculations under correct assumptions about F_T and S_T

a) Flat topped P.R.

AGE	P.R.	YEAR	F
1	.10	1969	.06
2	.30	1970	.25
3	.75	1971	.35
4	1.0	1972	.45
5	1.0	1973	.45
6	1.0	1974	.60
7	1.0	1975	.65
8	1.0		
9	1.0		
10	1.0		

b) Dome Shaped P.R.

AGE	P.R.	YEAR	F
1	.10	1969	.06
2	.30	1970	.25
3	.75	1971	.35
4	1.0	1972	.45
5	1.0	1973	.45
6	.75	1974	.60
7	.50	1975	.65
8	.25		
9	.20		
10	.15		

Table 5a: Northwest Atlantic mackerel. SVPA results using different assumptions (flat top. P.R.)

Reference Age		4.		3.		5.		6.		4.		4.		4.		4.	
Terminal F		.65		.65		.65		.65		.65		.65		1.0		.10	
Terminal S		1.0		1.0		1.0		1.0		.5		1.5		1.0		1.0	
SSQ		0.00		.01		0.00		0.00		.03		.02		.02		.09	
Approx. C.V.		.12		1.12		.12		.12		1.94		1.37		1.57		3.35	
Year (I)	Age (J)	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ
1969	1	.06	.10	.044	.142	.06	.10	.06	.10	.052	.107	.064	.097	.061	.108	.041	.072
1970	2	.25	.30	.189	.410	.25	.30	.25	.30	.229	.315	.258	.293	.258	.310	.159	.261
1971	3	.35	.75	.271	1.00	.35	.75	.35	.75	.330	.771	.356	.740	.367	.755	.193	.729
1972	4	.45	1.0	.359	1.318	.45	1.0	.45	1.0	.433	1.0	.453	1.0	.487	1.0	.202	1.0
1973	5	.45	1.0	.373	1.301	.45	1.0	.45	1.0	.442	.959	.450	1.014	.512	1.0	.155	1.0
1974	6	.60	1.0	.531	1.276	.60	1.0	.60	1.0	.597	.899	.598	1.041	.750	1.0	.146	1.0
1975	7	.65	1.0	.650	1.239	.65	1.0	.65	1.0	.650	.820	.650	1.081	1.0	1.0	.10	1.0
	8		1.0		1.183		1.0		1.0		.725		1.149		1.0		1.0
	9		1.0		1.105		1.0		1.0		.615		1.266		1.0		1.0
	10		1.0		1.00		1.0		1.0		.500		1.500		1.0		1.0

Table 5b: Northwest Atlantic mackerel. SVPA results using different assumptions (Dome shaped P.R.)

Reference Age		4.		3.		5.		6.		4.		4.		4.		4.	
Terminal P		.65		.65		.65		.65		.65		.65		1.0		.10	
Terminal S		.15		.15		.15		.15		.5		1.0		.15		.15	
SSQ		0		.02		0		.03		.04		.10		.04		.10	
Approx. C.V.		.20		1.46		.18		1.87		2.15		3.50		2.14		3.45	
Year (I)	Age (J)	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ	FI	SJ
1969	1	.06	.10	.043	.143	.06	.10	.04	.155	.083	.083	.043	.078	.064	.104	.025	.097
1970	2	.251	.301	.186	.411	.25	.301	.172	.443	.315	.261	.336	.251	.268	.30	.10	.324
1971	3	.351	.751	.270	1.0	.35	.752	.251	1.073	.416	.692	.434	.676	.383	.738	.126	.819
1972	4	.451	1.0	.360	1.314	.451	1.002	.339	1.406	.513	1.0	.527	1.0	.511	1.0	.139	1.0
1973	5	.450	1.0	.378	1.295	.451	1.00	.360	1.381	.491	1.139	.498	1.186	.539	1.039	.115	.879
1974	6	.600	.751	.539	.946	.60	.749	.524	1.0	.627	1.033	.628	1.151	.786	.811	.123	.598
1975	7	.650	.502	.650	.603	.65	.50	.650	.629	.650	.869	.650	1.071	1.0	.55	.10	.388
	8		.251		.285		.251		.292		.544		.758		.271		.204
	9		.20		.214		.20		.216		.536		.866		.209		.179
	10		.15		.150		.15		.150		.50		1.0		.150		.150

Table 6a: Log catch ratio residuals Flat topped P.R. Simulated data. (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity)

RA = 4 F_T = 0.65 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.002	-0.001	0.000	0.000	0.000	0.000
2	-0.002	-0.001	0.000	0.000	0.000	0.000
3	-0.002	0.000	0.000	0.000	0.000	0.000
4	-0.002	0.000	0.000	0.000	0.000	0.000
5	-0.002	0.000	0.000	0.000	0.000	0.000
6	-0.002	0.000	0.000	0.000	0.000	0.000
7	-0.002	0.000	0.000	0.000	0.000	0.000
8	-0.002	0.000	0.000	0.000	0.000	0.000
9	-0.002	0.000	0.000	0.000	0.000	0.000

RA = 3 F_T = 0.65 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.010	-0.016	-0.015	-0.008	0.006	0.044
2	0.005	-0.003	-0.007	-0.006	-0.004	0.008
3	0.018	0.010	0.003	-0.001	-0.009	-0.021
4	0.019	0.012	0.005	-0.001	-0.010	-0.030
5	0.015	0.010	0.005	0.000	-0.008	-0.025
6	0.008	0.007	0.004	0.001	-0.005	-0.017
7	-0.002	0.002	0.003	0.002	0.000	-0.007
8	-0.016	-0.005	0.001	0.003	0.007	0.009
9	-0.037	-0.017	-0.003	0.004	0.015	0.029

RA = 4 F_T = 0.65 S_T = 0.5

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	0.031	0.008	-0.002	-0.005	-0.012	-0.024
2	0.036	0.013	0.002	-0.004	-0.013	-0.027
3	0.036	0.016	0.005	-0.003	-0.014	-0.030
4	0.028	0.014	0.006	-0.001	-0.011	-0.025
5	0.012	0.005	0.001	-0.003	-0.009	-0.017
6	-0.004	-0.002	0.001	0.001	0.001	-0.001
7	-0.025	-0.011	0.001	0.005	0.012	0.019
8	-0.050	-0.022	0.000	0.011	0.025	0.043
9	-0.079	-0.035	-0.001	0.016	0.038	0.070

RA = 4 F_T = 0.65 S_T = 1.5

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.024	-0.007	-0.001	0.002	0.007	0.015
2	-0.025	-0.007	0.000	0.004	0.010	0.018
3	-0.022	-0.005	0.003	0.008	0.014	0.023
4	-0.025	-0.010	-0.003	0.002	0.008	0.016
5	-0.017	-0.004	0.000	0.005	0.009	0.015
6	-0.010	-0.002	0.000	0.003	0.005	0.008
7	0.003	0.004	0.001	0.002	0.000	-0.002
8	0.024	0.013	0.001	-0.001	-0.010	-0.020
9	0.065	0.032	0.005	-0.004	-0.025	-0.050

RA = 5 F_T = 0.65 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.002	-0.001	0.000	0.000	0.000	0.000
2	-0.002	-0.001	0.000	0.000	0.000	0.000
3	-0.002	0.000	0.000	0.000	0.000	0.000
4	-0.002	0.000	0.000	0.000	0.000	0.000
5	-0.002	0.000	0.000	0.000	0.000	0.000
6	-0.002	0.000	0.000	0.000	0.000	0.000
7	-0.002	0.000	0.000	0.000	0.000	0.000
8	-0.002	0.000	0.000	0.000	0.000	0.000
9	-0.002	0.000	0.000	0.000	0.000	0.000

RA = 6 F_T = 0.65 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.002	-0.001	0.000	0.000	0.000	0.000
2	-0.002	-0.001	0.000	0.000	0.000	0.000
3	-0.002	0.000	0.000	0.000	0.000	0.000
4	-0.002	0.000	0.000	0.000	0.000	0.000
5	-0.002	0.000	0.000	0.000	0.000	0.000
6	-0.002	0.000	0.000	0.000	0.000	0.000
7	-0.002	0.000	0.000	0.000	0.000	0.000
8	-0.002	0.000	0.000	0.000	0.000	0.000
9	-0.002	0.000	0.000	0.000	0.000	0.000

RA = 4 F_T = 1.0 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.044	-0.038	-0.029	-0.015	0.015	0.095
2	-0.022	-0.018	-0.014	-0.006	0.006	0.041
3	-0.003	0.000	0.000	0.000	-0.002	-0.006
4	0.003	0.005	0.004	0.002	-0.003	-0.022
5	0.003	0.005	0.004	0.002	-0.003	-0.022
6	0.003	0.005	0.004	0.002	-0.003	-0.022
7	0.003	0.005	0.004	0.002	-0.003	-0.022
8	0.003	0.005	0.004	0.002	-0.003	-0.022
9	0.003	0.005	0.004	0.002	-0.003	-0.022

RA = 4 F_T = 0.10 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	0.126	0.083	0.035	-0.014	-0.072	-0.160
2	0.063	0.042	0.019	-0.010	-0.032	-0.084
3	-0.005	-0.003	-0.001	-0.001	0.005	0.004
4	-0.032	-0.021	-0.009	0.004	0.017	0.040
5	-0.032	-0.021	-0.009	0.004	0.017	0.040
6	-0.032	-0.021	-0.009	0.004	0.017	0.040
7	-0.032	-0.021	-0.009	0.004	0.017	0.040
8	-0.032	-0.021	-0.009	0.004	0.017	0.040
9	-0.032	-0.021	-0.009	0.004	0.017	0.040

Table 6b: Log catch ratio residuals dome shaped P.R. Simulated data. (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity)

RA = 4 F_T = 0.65 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	0.000	-0.001	-0.002	-0.002	-0.002	-0.001
2	-0.001	-0.002	-0.004	-0.004	-0.004	-0.003
3	-0.001	-0.002	-0.003	-0.004	-0.003	-0.002
4	0.001	0.000	-0.001	-0.002	-0.001	0.000
5	0.003	0.001	0.000	0.000	0.000	0.002
6	0.003	0.002	0.000	0.000	0.000	0.001
7	0.001	0.000	-0.001	-0.002	-0.001	0.000
8	-0.001	-0.002	-0.003	-0.004	-0.003	-0.002
9	-0.001	-0.002	-0.003	-0.004	-0.003	-0.002

RA = 3 F_T = 0.65 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.008	-0.013	-0.013	-0.007	0.002	0.023
2	0.009	0.002	-0.002	-0.004	-0.009	-0.012
3	0.024	0.017	0.009	0.000	-0.015	-0.043
4	0.027	0.022	0.014	0.003	-0.014	-0.049
5	0.016	0.014	0.010	0.003	-0.007	-0.031
6	-0.001	0.001	0.001	0.001	0.002	-0.001
7	-0.016	-0.013	-0.008	-0.003	0.007	0.025
8	-0.022	-0.020	-0.014	-0.006	0.009	0.037
9	-0.025	-0.022	-0.016	-0.007	0.011	0.043

RA = 4 F_T = 0.65 S_T = 0.5

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.048	-0.008	0.011	0.014	0.018	0.026
2	-0.055	-0.016	0.006	0.014	0.023	0.040
3	-0.053	-0.024	-0.004	0.009	0.022	0.046
4	-0.028	-0.018	-0.007	0.004	0.014	0.034
5	0.011	-0.003	-0.007	-0.005	-0.002	0.002
6	0.045	0.014	-0.002	-0.009	-0.016	-0.029
7	0.054	0.022	0.004	-0.012	-0.019	-0.042
8	0.041	0.022	0.007	-0.004	-0.018	-0.037
9	0.047	0.023	0.006	-0.008	-0.023	-0.047

RA = 4 F_T = 0.65 S_T = 1.0

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.080	-0.015	0.013	0.019	0.026	0.042
2	-0.091	-0.027	0.006	0.019	0.033	0.059
3	-0.087	-0.035	-0.002	0.017	0.037	0.072
4	-0.057	-0.030	-0.008	0.010	0.026	0.057
5	-0.002	-0.010	-0.008	-0.001	0.005	0.017
6	0.051	0.014	-0.005	-0.011	-0.017	-0.030
7	0.078	0.028	0.001	-0.019	-0.027	-0.058
8	0.072	0.032	0.003	-0.012	-0.034	-0.063
9	0.115	0.048	0.002	-0.019	-0.050	-0.094

RA = 5 F_T = 0.65 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	0.003	0.003	0.003	0.002	0.001	0.002
2	0.001	0.002	0.001	0.000	-0.001	0.000
3	-0.001	-0.001	-0.001	-0.003	-0.003	-0.003
4	-0.002	-0.001	-0.002	-0.003	-0.004	-0.004
5	-0.001	0.000	0.000	-0.002	-0.002	-0.002
6	0.002	0.003	0.002	0.001	0.000	0.001
7	0.002	0.003	0.002	0.001	0.001	0.001
8	0.002	0.001	0.000	-0.001	-0.002	-0.001
9	-0.002	-0.001	-0.002	-0.003	-0.003	-0.003

RA = 6 F_T = 0.65 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.008	-0.013	-0.012	-0.005	0.006	0.031
2	0.013	0.005	0.001	0.000	-0.007	-0.014
3	0.030	0.023	0.015	0.005	-0.016	-0.054
4	0.033	0.029	0.020	0.008	-0.015	-0.064
5	0.018	0.018	0.014	0.006	-0.008	-0.041
6	-0.005	-0.002	0.001	0.001	0.002	-0.002
7	-0.022	-0.017	-0.010	-0.002	0.011	0.033
8	-0.026	-0.022	-0.013	-0.002	0.017	0.052
9	-0.029	-0.024	-0.015	-0.003	0.019	0.060

RA = 4 F_T = 1.0 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	-0.036	-0.028	-0.019	-0.006	0.014	0.057
2	-0.010	-0.005	-0.001	0.003	0.003	0.009
3	0.018	0.018	0.015	0.010	-0.006	-0.040
4	0.034	0.029	0.021	0.011	-0.014	-0.068
5	0.034	0.025	0.016	0.005	-0.014	-0.062
6	0.015	0.007	0.003	-0.002	-0.007	-0.027
7	-0.013	-0.014	-0.011	-0.007	0.005	0.021
8	-0.030	-0.025	-0.017	-0.006	0.014	0.054
9	-0.034	-0.027	-0.016	-0.003	0.021	0.070

RA = 4 F_T = .10 S_T = .15

	LOG CATCH RATIO RESIDUALS					
	1969	1970	1971	1972	1973	1974
1	0.074	0.035	0.005	-0.019	-0.038	-0.078
2	0.011	-0.003	-0.008	-0.017	-0.006	-0.016
3	-0.060	-0.038	-0.016	-0.001	0.031	0.063
4	-0.089	-0.048	-0.013	0.013	0.048	0.101
5	-0.072	-0.033	-0.005	0.019	0.038	0.084
6	-0.023	-0.007	0.000	0.010	0.010	0.027
7	0.026	0.015	0.001	-0.004	-0.022	-0.034
8	0.060	0.029	0.002	-0.016	-0.040	-0.073
9	0.074	0.037	0.006	-0.015	-0.043	-0.081

Table 7a: Log catch ratio residuals for 1968-1982. (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity)

RA = 4 F_T = .10 S_T = .5

	LOG CATCH RATIO RESIDUALS													
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.392	-0.313	0.727	0.808	-1.404	0.302	-0.880	0.754	-1.125	2.193	-0.469	-2.345	0.037	0.701
2	-0.708	0.267	-0.495	0.277	-0.884	-0.076	0.537	0.323	0.090	0.875	-1.305	-0.311	0.893	0.456
3	-0.180	0.611	-0.059	-0.576	0.047	0.508	0.367	-0.225	0.093	0.552	-0.172	0.132	-0.342	-0.434
4	1.587	1.260	-0.446	-0.090	-0.327	-0.044	-0.283	-0.088	0.195	-0.045	-0.063	-0.339	-0.928	-0.190
5	1.285	0.226	-0.402	0.451	0.469	-0.148	-0.245	0.084	-0.050	-1.051	0.055	-0.024	-0.004	-0.597
6	0.830	-0.220	-0.491	-0.100	0.752	-0.149	-0.060	-0.227	-0.207	-0.750	0.255	0.609	0.107	-0.154
7	-1.710	-1.106	0.287	0.441	0.664	-0.386	0.103	-0.173	0.229	-0.415	0.685	0.859	0.029	-0.110
8	-0.910	-0.578	0.835	-1.032	0.010	0.066	0.166	0.330	0.682	-0.912	0.193	0.783	0.006	0.265
9	-0.604	-0.125	0.042	-0.254	0.590	-0.147	0.300	-0.712	0.136	-0.494	0.735	0.547	0.201	0.090

RA = 4 F_T = .40 S_T = .5

	LOG CATCH RATIO RESIDUALS													
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.401	-0.306	0.743	0.837	-1.365	0.361	-0.815	0.826	-1.041	2.235	-0.438	-2.302	0.083	0.783
2	-0.702	0.268	-0.491	0.289	-0.875	-0.067	0.535	0.312	0.096	0.886	-1.296	-0.303	0.883	0.445
3	-0.175	0.609	-0.062	-0.574	0.040	0.487	0.327	-0.284	0.045	0.543	-0.175	0.122	-0.380	-0.498
4	1.597	1.265	-0.443	-0.083	-0.326	-0.058	-0.317	-0.139	0.145	-0.052	-0.057	-0.341	-0.952	-0.243
5	1.295	0.231	-0.397	0.461	0.476	-0.149	-0.261	0.057	-0.078	-1.049	0.067	-0.016	-0.012	-0.622
6	0.816	-0.237	-0.506	-0.108	0.747	-0.157	-0.077	-0.250	-0.238	-0.764	0.251	0.604	0.096	-0.172
7	-1.677	-1.076	0.320	0.483	0.711	-0.335	0.149	-0.128	0.272	-0.373	0.732	0.908	0.076	-0.057
8	-0.915	-0.587	0.830	-1.028	0.018	0.078	0.173	0.337	0.688	-0.907	0.202	0.795	0.015	0.281
9	-0.641	-0.164	0.007	-0.278	0.573	-0.158	0.286	-0.724	0.114	-0.519	0.715	0.532	0.189	0.087

Table 7a: Log catch ratio residuals for 1968-1982 (Continued) (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity)

RA = 4 F_T = 0.1 S_T = 1.0

	LOG CATCH RATIO RESIDUALS													
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.403	-0.295	0.769	0.870	-1.320	0.408	-0.782	0.841	-1.065	2.210	-0.457	-2.330	0.046	0.709
2	-0.730	0.249	-0.495	0.295	-0.852	-0.030	0.571	0.347	0.099	0.861	-1.321	-0.325	0.875	0.439
3	-0.217	0.574	-0.085	-0.588	0.043	0.509	0.356	-0.247	0.064	0.521	-0.201	0.105	-0.374	-0.465
4	1.567	1.239	-0.461	-0.095	-0.326	-0.044	-0.296	-0.109	0.170	-0.062	-0.074	-0.349	-0.944	-0.206
5	1.281	0.218	-0.407	0.454	0.473	-0.146	-0.253	0.068	-0.064	-1.052	0.059	-0.019	-0.008	-0.603
6	0.819	-0.235	-0.506	-0.109	0.744	-0.163	-0.083	-0.256	-0.234	-0.759	0.253	0.606	0.093	-0.171
7	-1.657	-1.062	0.328	0.486	0.703	-0.352	0.130	-0.150	0.265	-0.360	0.746	0.918	0.076	-0.068
8	-0.880	-0.563	0.838	-1.030	-0.006	0.038	0.132	0.294	0.676	-0.879	0.233	0.820	0.027	0.280
9	-0.587	-0.126	0.019	-0.284	0.536	-0.225	0.219	-0.792	0.090	-0.479	0.762	0.570	0.206	0.085

RA = 4 F_T = .40 S_T = 1.0

	LOG CATCH RATIO RESIDUALS													
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.355	-0.341	0.725	0.831	-1.350	0.397	-0.769	0.888	-0.998	2.212	-0.474	-2.330	0.071	0.785
2	-0.743	0.237	-0.507	0.284	-0.860	-0.033	0.575	0.359	0.125	0.864	-1.327	-0.325	0.878	0.460
3	-0.206	0.585	-0.075	-0.579	0.050	0.513	0.355	-0.255	0.057	0.524	-0.197	0.107	-0.380	-0.479
4	1.579	1.251	-0.450	-0.085	-0.318	-0.042	-0.300	-0.123	0.146	-0.065	-0.070	-0.349	-0.950	-0.228
5	1.290	0.227	-0.399	0.460	0.479	-0.145	-0.256	0.060	-0.080	-1.054	0.063	-0.018	-0.011	-0.616
6	0.822	-0.232	-0.503	-0.107	0.747	-0.161	-0.082	-0.255	-0.247	-0.762	0.256	0.607	0.098	-0.173
7	-1.659	-1.063	0.327	0.485	0.704	-0.351	0.132	-0.147	0.264	-0.361	0.745	0.918	0.077	-0.067
8	-0.871	-0.554	0.847	-1.022	0.001	0.042	0.132	0.286	0.670	-0.878	0.235	0.819	0.018	0.264
9	-0.569	-0.108	0.036	-0.269	0.549	-0.218	0.217	-0.806	0.068	-0.479	0.769	0.572	0.199	0.059

Table 7b: Log catch ratio residuals. (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity)

RA = 4 F_T = .2 S_T = .50

	LOG CATCH RATIO RESIDUALS			
	1968	1969	1970	1971
1	-0.002	-0.717	0.315	0.397
2	-0.539	0.425	-0.341	0.436
3	-0.120	0.657	-0.019	-0.534
4	1.007	0.681	-1.026	-0.663
5	0.881	-0.173	-0.783	0.088
6	0.811	-0.236	-0.488	-0.077
7	-1.198	-0.596	0.809	0.979
8	-0.492	-0.168	1.249	-0.608
9	-0.363	0.105	0.267	-0.025

RA = 3 F_T = .10 S_T = 0.50

	LOG CATCH RATIO RESIDUALS			
	1973	1974	1975	1976
1	0.540	-0.645	0.984	-0.876
2	-0.288	0.315	0.097	-0.126
3	0.337	0.183	-0.418	-0.107
4	0.027	-0.225	-0.041	0.236
5	-0.045	-0.153	0.166	0.031
6	0.021	0.102	-0.073	-0.047
7	-0.323	0.159	-0.122	0.291
8	-0.233	-0.143	0.017	0.363
9	-0.032	0.408	-0.611	0.233

RA = 6 F_T = 0.10 S_T = .50

	LOG CATCH RATIO RESIDUALS			
	1978	1979	1980	1981
1	0.057	-1.817	0.557	1.212
2	-1.241	-0.242	0.961	0.523
3	0.024	0.335	-0.140	-0.227
4	0.314	0.045	-0.552	0.193
5	0.205	0.128	0.134	-0.458
6	0.063	0.413	-0.104	-0.372
7	0.330	0.499	-0.344	-0.493
8	-0.108	0.479	-0.311	-0.060
9	0.354	0.164	-0.194	-0.315

RA = 4 F_T = 0.2 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1968	1969	1970	1971
1	-0.012	-0.719	0.323	0.407
2	-0.548	0.423	-0.332	0.451
3	-0.126	0.655	-0.015	-0.521
4	1.004	0.681	-1.025	-0.660
5	0.877	-0.174	-0.784	0.085
6	0.808	-0.236	-0.488	-0.080
7	-1.194	-0.593	0.810	0.976
8	-0.477	-0.161	1.247	-0.615
9	-0.336	0.116	0.258	-0.044

RA = 3 F_T = 0.10 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1973	1974	1975	1976
1	0.549	-0.638	0.987	-0.897
2	-0.280	0.322	0.101	-0.139
3	0.344	0.189	-0.413	-0.115
4	0.031	-0.221	-0.038	0.230
5	-0.044	-0.151	0.168	0.028
6	0.018	0.100	-0.075	-0.045
7	-0.330	0.154	-0.125	0.302
8	-0.241	-0.149	0.015	0.379
9	-0.043	0.401	-0.614	0.259

RA = 6 F_T = 0.10 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1978	1979	1980	1981
1	0.062	-1.818	0.551	1.198
2	-1.235	-0.241	0.960	0.516
3	0.030	0.339	-0.138	-0.228
4	0.313	0.044	-0.553	0.193
5	0.197	0.123	0.131	-0.455
6	0.058	0.410	-0.102	-0.365
7	0.330	0.500	-0.341	-0.486
8	-0.110	0.478	-0.314	-0.057
9	0.352	0.160	-0.199	-0.318

Table 7b: Log catch ratio residuals. (RA=Reference age, F_T=Terminal fishing mortality, S_T=Terminal selectivity) (Continued)

RA = 4 F_T = 0.8 S_T = 0.5

	LOG CATCH RATIO RESIDUALS			
	1968	1969	1970	1971
1	-0.028	-0.733	0.324	0.435
2	-0.513	0.437	-0.341	0.415
3	-0.046	0.698	-0.034	-0.620
4	1.048	0.715	-1.036	-0.727
5	0.862	-0.180	-0.782	0.102
6	0.768	-0.259	-0.480	-0.028
7	-1.233	-0.616	0.820	1.028
8	-0.502	-0.173	1.257	-0.583
9	-0.358	0.109	0.270	-0.023

RA = 3 F_T = 0.40 S_T = 0.5

	LOG CATCH RATIO RESIDUALS			
	1973	1974	1975	1976
1	0.489	-0.674	0.986	-0.801
2	-0.271	0.322	0.082	-0.132
3	0.372	0.200	-0.430	-0.142
4	0.050	-0.213	-0.047	0.211
5	-0.034	-0.147	0.162	0.019
6	0.026	0.104	-0.075	-0.054
7	-0.322	0.158	-0.125	0.289
8	-0.242	-0.145	0.032	0.356
9	-0.065	0.395	-0.585	0.255

RA = 6 F_T = 0.30 S_T = 0.50

	LOG CATCH RATIO RESIDUALS			
	1978	1979	1980	1981
1	0.031	-1.830	0.565	1.245
2	-1.260	-0.252	0.966	0.546
3	0.013	0.330	-0.138	-0.214
4	0.315	0.046	-0.555	0.195
5	0.219	0.137	0.127	-0.473
6	0.082	0.422	-0.107	-0.397
7	0.342	0.504	-0.345	-0.510
8	-0.101	0.483	-0.312	-0.069
9	0.355	0.163	-0.190	-0.319

RA = 4 F_T = 0.8 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1968	1969	1970	1971
1	-0.056	-0.746	0.335	0.467
2	-0.544	0.421	-0.331	0.452
3	-0.071	0.684	-0.027	-0.587
4	1.035	0.709	-1.034	-0.711
5	0.854	-0.181	-0.780	0.108
6	0.762	-0.260	-0.477	-0.025
7	-1.229	-0.614	0.820	1.022
8	-0.470	-0.160	1.248	-0.619
9	-0.281	0.145	0.245	-0.110

RA = 3 F_T = 0.40 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1973	1974	1975	1976
1	0.478	-0.678	0.999	-0.799
2	-0.284	0.318	0.095	-0.130
3	0.359	0.197	-0.417	-0.139
4	0.039	-0.216	-0.036	0.213
5	-0.042	-0.150	0.170	0.021
6	0.023	0.103	-0.073	-0.053
7	-0.317	0.160	-0.133	0.290
8	-0.223	-0.139	0.015	0.347
9	-0.033	0.404	-0.620	0.249

RA = 6 F_T = 0.30 S_T = 1.0

	LOG CATCH RATIO RESIDUALS			
	1978	1979	1980	1981
1	0.030	-1.833	0.564	1.236
2	-1.261	-0.253	0.969	0.547
3	0.011	0.330	-0.133	-0.206
4	0.306	0.042	-0.552	0.204
5	0.206	0.129	0.127	-0.461
6	0.077	0.419	-0.107	-0.387
7	0.347	0.508	-0.346	-0.508
8	-0.089	0.489	-0.320	-0.079
9	0.376	0.171	-0.201	-0.344

Table 8: Partial recruitment from regular VPA.

PARTIAL RECRUITMENT FROM VPA (INPUT PR FROM SVPA)

	1968	1969	1970	1971	1972	Average
1	0.076	0.012	0.239	0.127	0.032	.097
2	0.104	0.252	0.096	0.404	0.184	.208
3	0.441	0.501	0.584	0.237	0.500	.453
4	1.000	1.000	0.612	0.785	0.463	.772
5	0.454	0.310	0.531	1.000	0.921	.643
6	0.299	0.179	0.438	0.836	0.726	.495
7	0.023	0.166	0.354	0.670	1.000	.442
8	0.073	0.178	1.000	0.265	0.473	.398
9	0.079	0.287	0.670	0.559	0.906	.500
10	0.100	0.191	0.579	0.678	0.767	.463

	1973	1974	1975	1976	1977	Average
1	0.281	0.100	0.383	0.036	0.057	.171
2	0.603	0.629	0.779	0.420	0.383	.563
3	1.000	0.999	0.569	0.710	0.728	.801
4	0.765	0.646	0.887	0.550	1.000	.770
5	0.821	0.637	0.756	0.679	0.482	.675
6	0.890	0.871	0.765	0.463	0.889	.775
7	0.428	0.920	0.909	0.640	0.578	.695
8	0.895	0.535	1.000	1.000	0.662	.818
9	0.771	1.000	0.477	0.683	0.883	.763
10	0.781	0.841	0.825	0.664	0.743	.771

PARTIAL RECRUITMENT FROM VPA (INPUT PR FROM SVPA)

	1978	1979	1980	1981	1982	Average
1	0.008	0.005	0.056	0.053	0.013	.027
2	0.010	0.081	0.293	0.193	0.097	.135
3	0.127	0.117	0.319	0.200	0.210	.195
4	0.252	0.339	0.212	0.549	0.380	.347
5	0.523	0.486	0.812	0.516	0.668	.601
6	0.681	0.984	0.893	0.852	1.000	.882
7	0.912	0.973	0.914	0.772	1.000	.914
8	0.455	1.000	0.809	1.000	1.000	.853
9	1.000	0.856	1.000	0.998	1.000	.971
10	0.742	0.975	0.898	0.853	1.000	.894

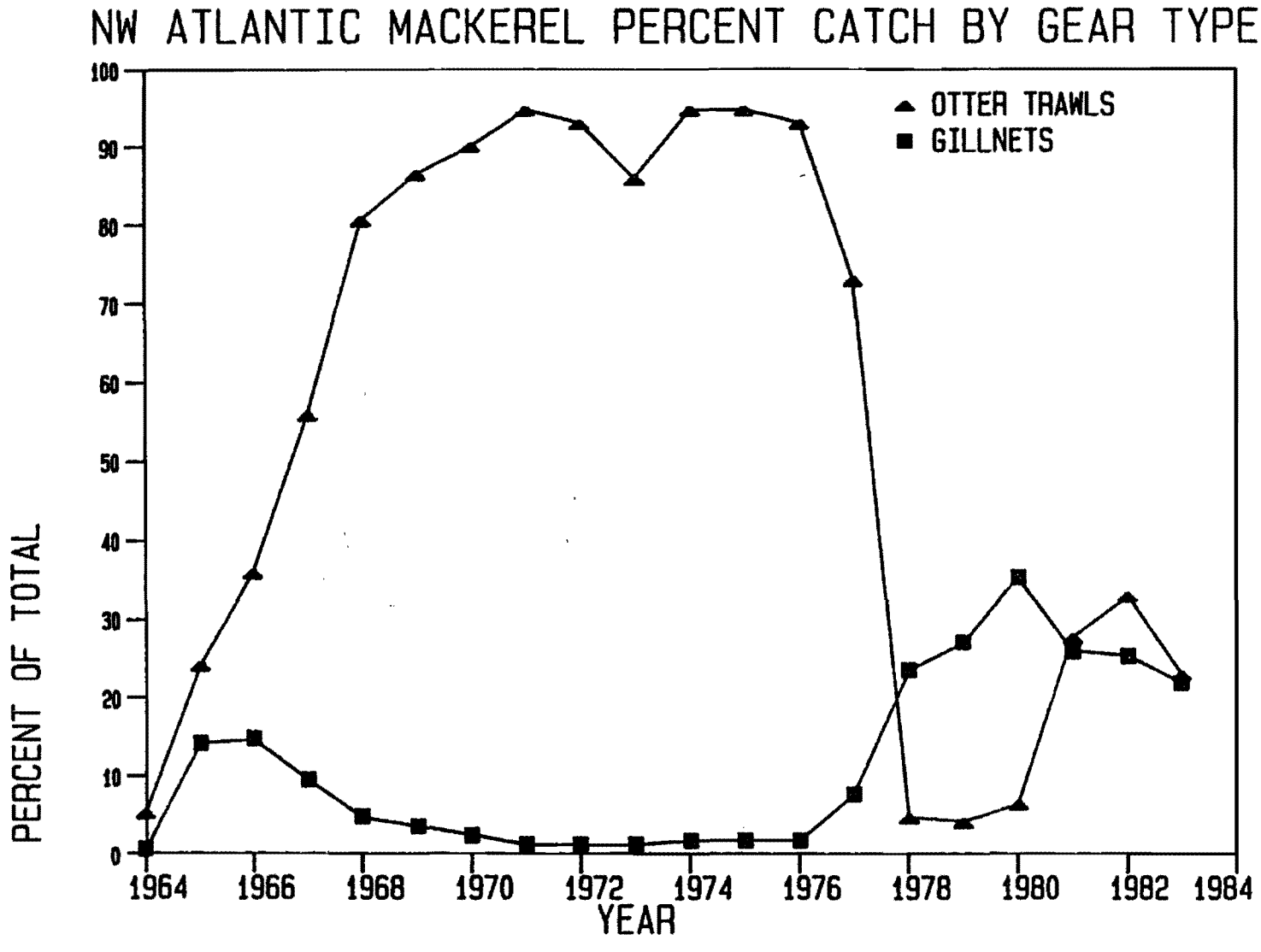

Figure 1. Northwest Atlantic mackerel. Percentage nominal catch by otter trawls and gillnets in NAFO Subareas 3-6, 1964-1983.

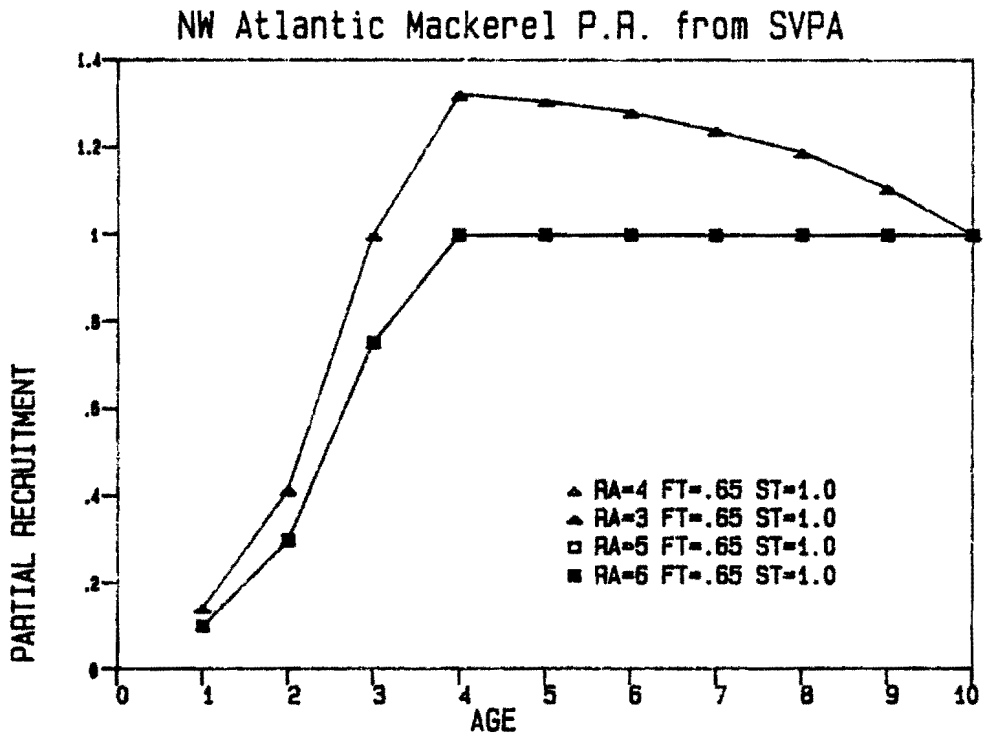

Figure 2a. Flat top P.R. Simulated data. Effects of varying reference age.

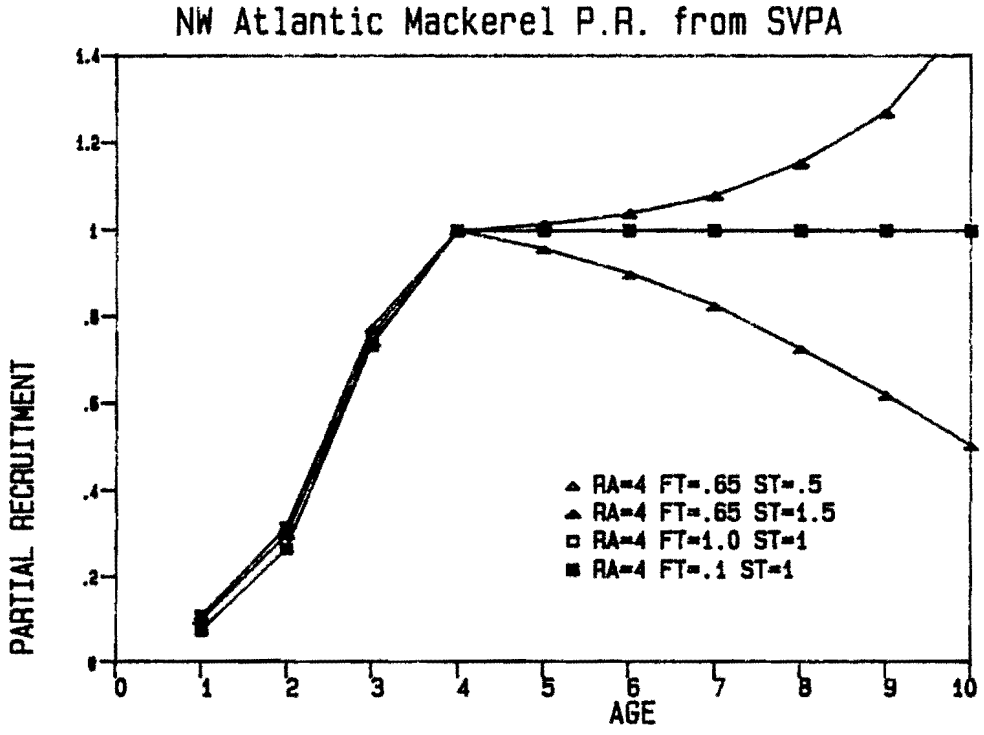

Figure 2b. Flat top P.R. Simulated data. Effects of varying terminal fishing mortality and terminal selectivity.

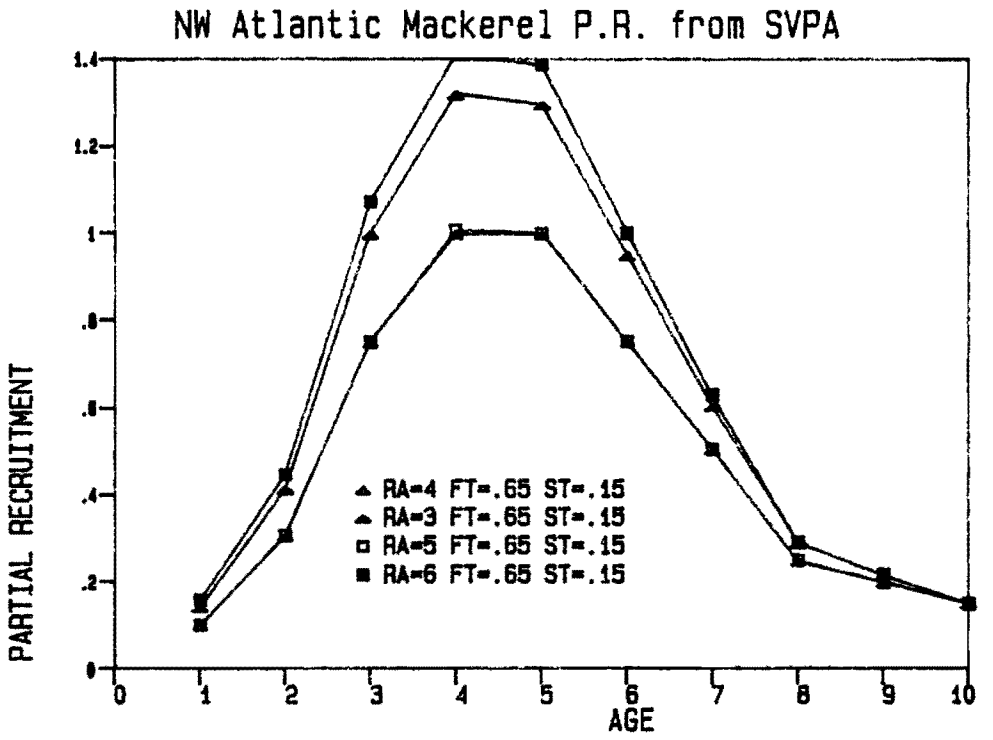

Figure 2c. Dome shaped P.R. Simulated data. Effects of varying reference age.

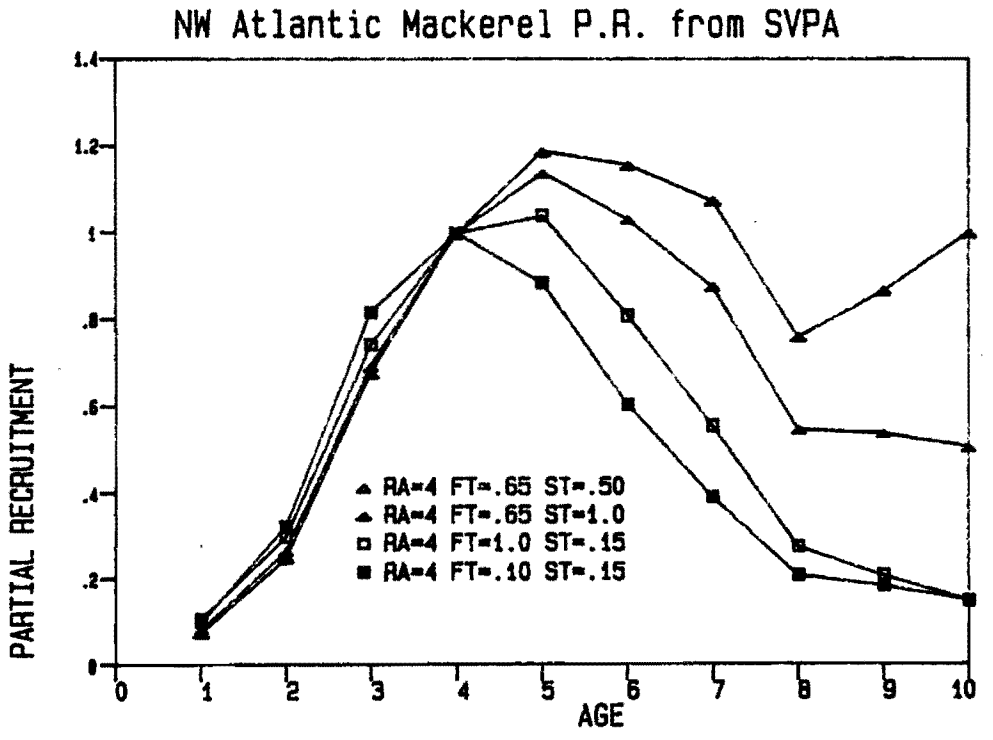

Figure 2d. Dome shaped P.R. Simulated data. Effects of varying terminal fishing mortality and terminal selectivity.

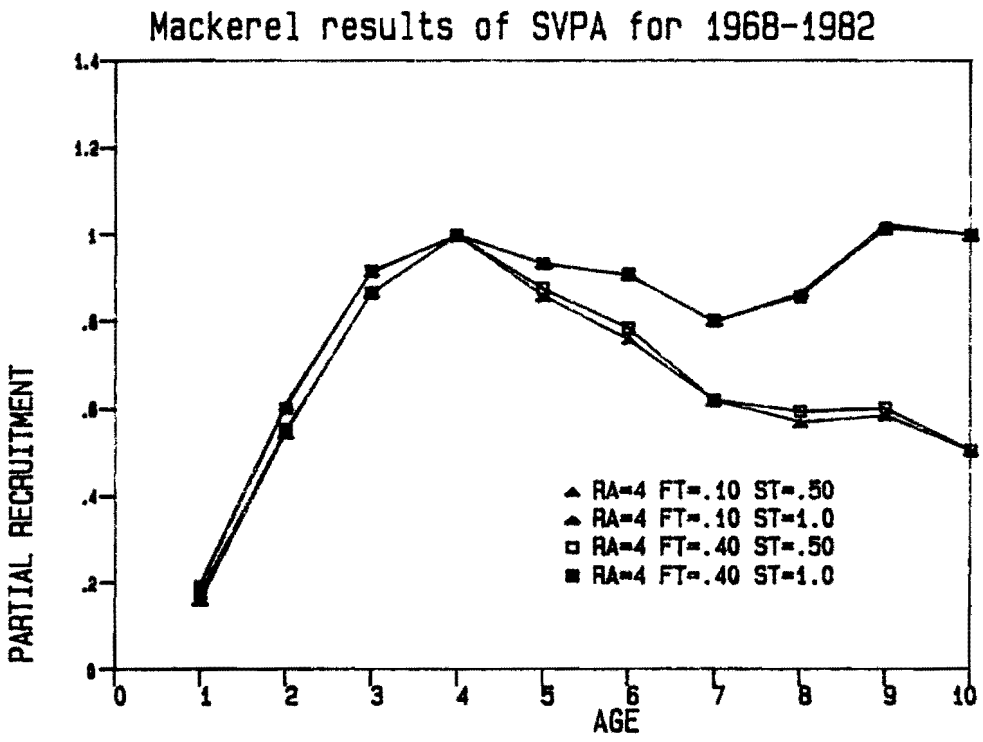

Figure 3a. Northwest Atlantic mackerel. Partial recruitment values (S(j)) estimated by SVPA for 1968-1982 under two assumptions about F_T and S_T. Real data.

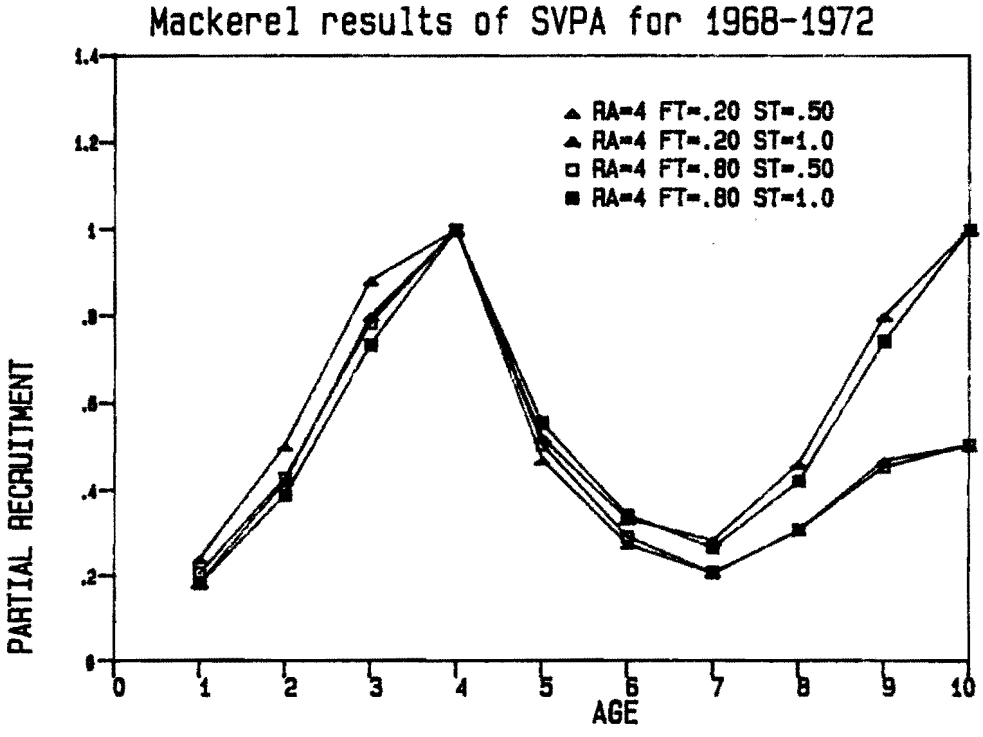

Figure 3b. Northwest Atlantic mackerel. Partial recruitment values (S(j)) estimated by SVPA for 1968-72 under two assumptions about F_T and S_T. Real data.

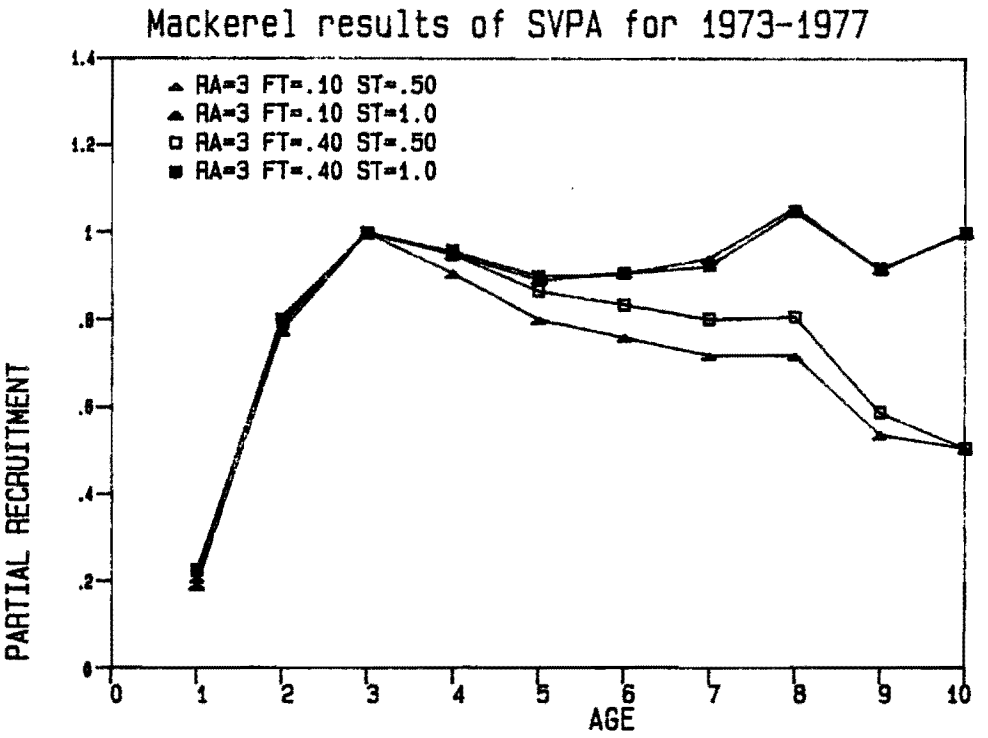

Figure 3c. Northwest Atlantic mackerel. Partial recruitment values (S(j)) estimated by SVPA for 1973-77 under two assumptions about F_T and S_T. Real data.

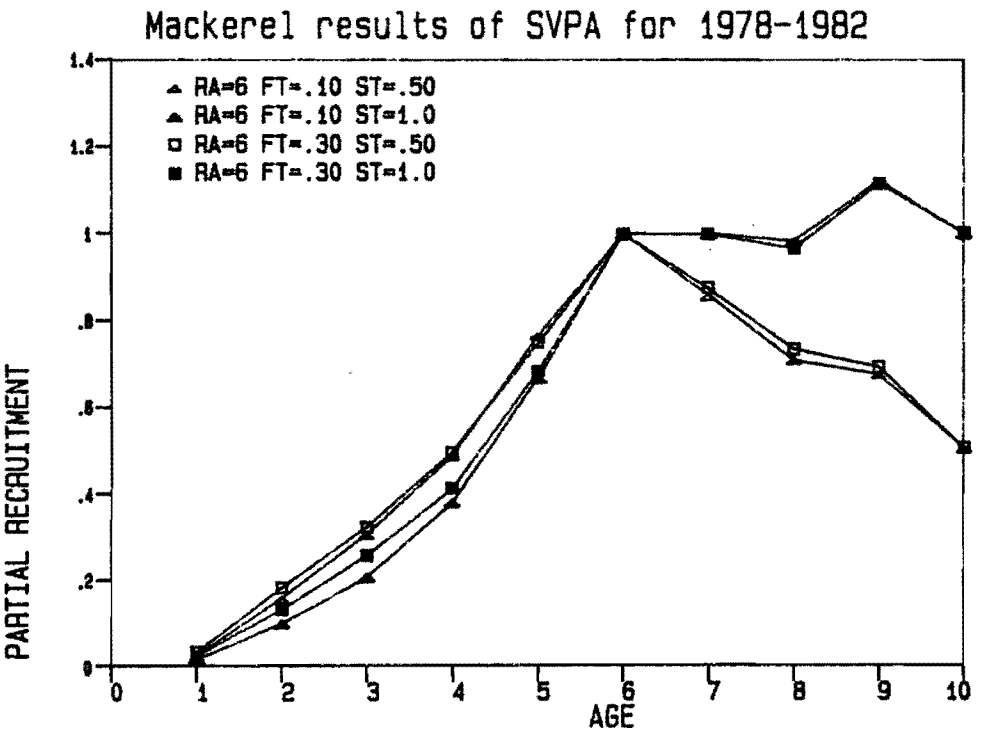

Figure 3d. Northwest Atlantic mackerel. Partial recruitment values (S(j)) estimated by SVPA for 1978-82 under two assumptions F_T and S_T. Real data.

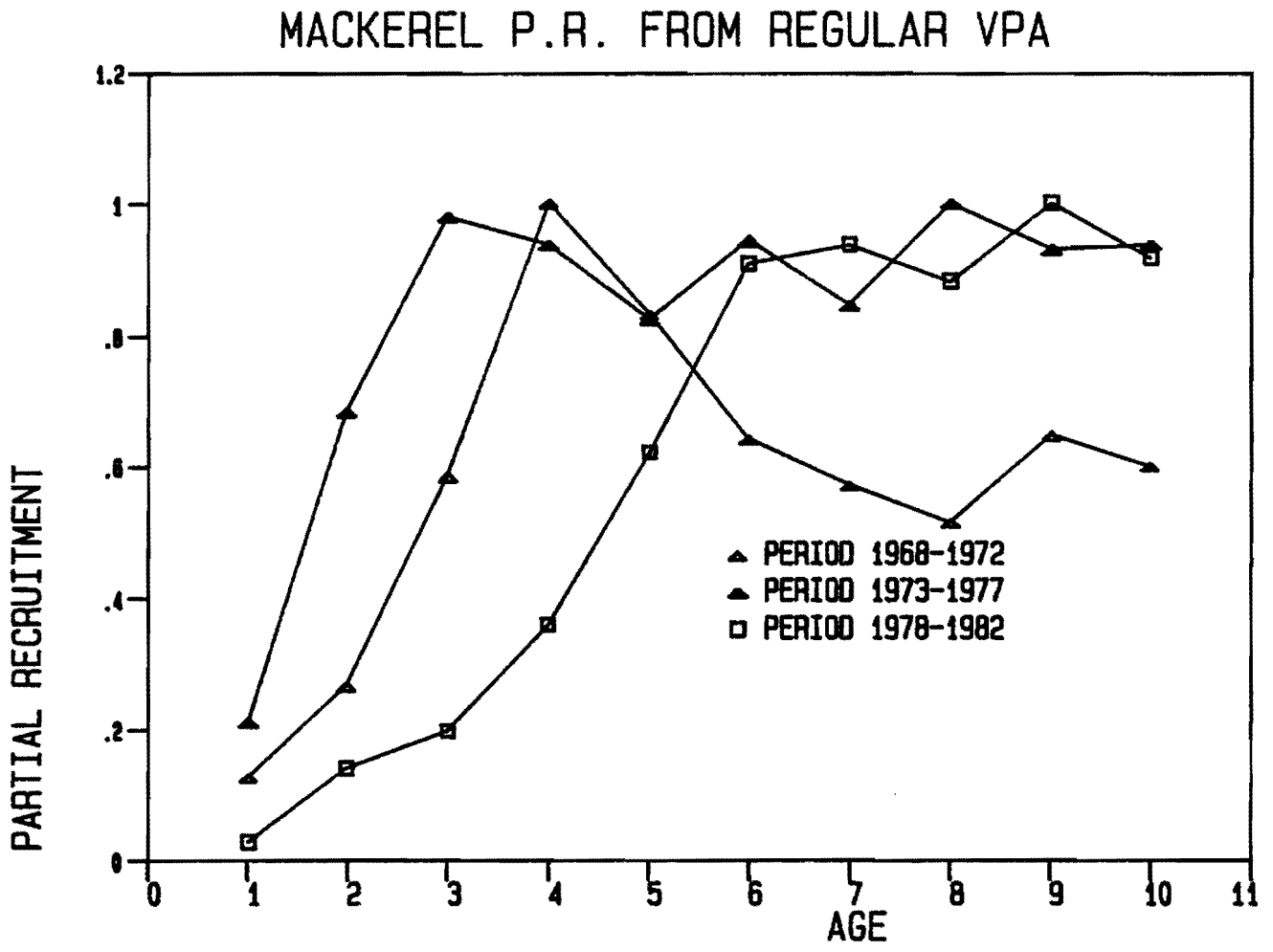

Figure 4. Northwest Atlantic mackerel. Partial recruitment values estimated from regular VPA. P.R. used to initiate VPA was similar to the S(j) resulting from SVPA (for 1978-82) using RA=6, F_T=0.10 and S_T= 1.0.

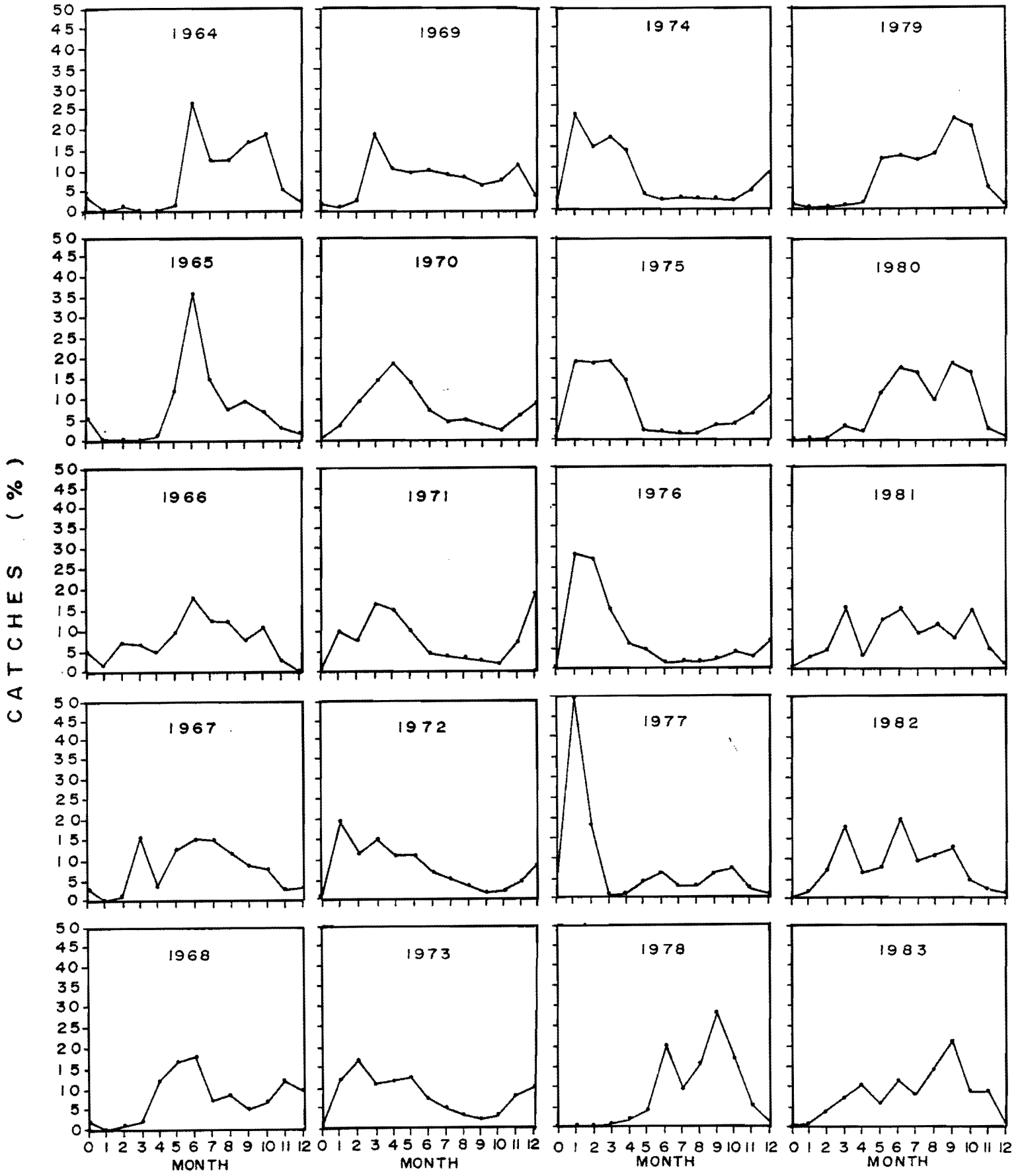

Figure 5: Northwest Atlantic mackerel. Monthly catch distribution (percentage) in NAFO Subareas 2-6 for 1964-1983.