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Status of Silver Hake Stocks in NAFO Divisions 4VWX in 1992 and TAC for 1994

by

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1. Introduction

Some results of silver hake stock assessment in NAFO Divisions 4VWX for 1992 and TAC calculation for 1994 are presented.

As in previous years the Gavaris adaptive framework (Gavaris,1988) was used to determine the stock size.

The results presented should be considered as preliminary ones as all necessary data were not available in time.

2. Data Used for Calculations

2.1. Management and Fishery

Retrospective description of silver hake fishery are given in a series of papers (Waldron et al., 1992; Waldron et al.,1991; Waldron et al.,1990).

In accordance with the decision of the Scientific Council taken in 1991 the silver hake TAC in NAFO Divisions 4VWX for 1992 was set at 105,000 tons.

According to the preliminary data the total catch of silver hake accounted for 31,000 tons.

2.2 Age Composition of Catches and Average Weight

Data on age composition of catches and average weight of fish for 1977-1992 presented in Tables 1 and 2. Data for 1977-1991 correspond to those presented by D.E.Waldron (Waldron et al., 1992).

Data for 1992 were obtained basing the results of length frequency measurements made by the Canadian observers and the age-length key constructed in AtlantNIRO. Totaly 284,701 specimens were measured and 531 pairs of otoliths were taken for the subsequent ageing.

The 1992 age-length key only contained data for age-groups 1-7. Thus, due to the small volume of observations for the older age-groups size of catch, for age-groups 7-9 was determined conditionally as 1 mln specimens. The estimates of average weight for age-groups 7-9 were assumed to be equal to the mean long-term values for 1977-1991.

2.3. Standardized Catch-per-Unit-Effort Values and Fishing Effort

Standardization of catch-per-unit-effort values is made basing Robson-Gavaris' multiplicative model (Gavaris, 1980). The input data for 1977-1992 were prepared by D.E.Waldron. By their structure they correspond to those used in previons year (Waldron et al., 1992).

Results of standardization are presented in Tables 3,4,5 and Figures 1,2,3. It can be seen that tendency to the decrease of the CPUE values observed in 1990 and 1991 is clearly traced in 1992 as well.

2.4. Canadian Trawl Surveys on Abundance

Abundance indices for silver hake are given in Table 6 (Waldron et al., 1991). Data were collected by the Canadian scientists during the annual July surveys from 1977 to 1991.

No age data were available for 1992. Nevertheless, total abundance and biomass estimates calculated by Dr.Waldron basing the 1992 July survey data indicate that the stock size of silver hake either slightly decreased as compared to 1991 or remained at the same level (with confidence intervals of the estimates in mind). Temporal variation of the abundance indices is shown in Figure 4.

Unfortunately, the Russian size was not able to conduct the juvenile trawl survey in 1992 though it had been traditionaly conducted since 1981. Data of those surveys for 1981-1991 are given in Table 7.

2.5. Population parameters

Natural mortality coefficient was assumed to be constant and equal to 0.4.

3. Sequential Population Analysis.

3.1. Descreption of the model

As in previons studies on silver hake objective function formulation for the ADAPT framework includes CPUE-at-age values, abundance indices from the July trawl surveys by age-groups and data collected in the juvenile hake surveys. However, in contrast to the previons studies objective function formulation contains an addidion term called "stabilizer".

Its origin is connected with unstability of the abundance and biomass estimates calculated basing the conventional NAFO procedure and necessity to stablize them (Gasuikov,1993). To achieve this method of solution of ill-pozed problems are applied (Tikhonov, Arsenin,1986; Morozov, 1987). They provide for the inclusion of stabilizer in the objective function and concordance of its value with accuracy of the input data.

The accepted formulation of ADAPT

Unknown parameters:
- abundance indices for age-groups 2-8 in 1992.

The following model relationships are used:
- abundance for age-group 1 in 1992 is the mean value for 1977-1991;
- fishing mortality for the older age-group is a mean weighted value of fishing mortality coefficients for age-groups 3-8.

Input data:
- data for age-groups 1-9;
- observation period from 1977 to 1992;
- natural mortality was set at 0.4;
- catch-at-age estimates for 1977-1992;
- to calculate cpue-at-age standardized fishing effort values for 1977-1992 are used;
- abundance indices from 1977-1991 botlom trawl surveys on abundance;
- abundance indices for age-groups 0 from the 1982-1991 juvenile surveys.

Objective function:

$$SS = \lambda_{RV} \cdot SS_{RV} + \lambda_{cpue} \cdot SS_{cpue} + \lambda_{juv} \cdot SS_{juv} + \alpha \cdot |N_a - N^*| \quad (1)$$

$$SS_{RV} = \sum_{a=1}^{a_k} \sum_{y=1}^{y_k} \left(obs\ ln\ I_{ay}^{RV} - calc\ ln\ I_{ay}^{RV} \right)^2 \quad (2)$$

$$SS_{cpue} = \sum_{a=1}^{a_k} \sum_{y=1}^{y_k} \left(obs\ ln\ I_{ay}^{cpue} - calc\ ln\ I_{ay}^{cpue} \right)^2 \quad (3)$$

$$SS_{juv} = \sum_{y=1}^{y_k} \left(obs\ ln\ I_{y}^{juv} - calc\ ln\ I_{y}^{juv} \right)^2 \quad (4)$$

Where

obs = observed values;

calc = estimated values;

λ_{RV}, λ_{cpue}, λ_{juv} = weight multipliers;

I^{RV}_{ay} = trawl survey abundance index;

I^{cpue}_{ay} = CPUE-at-age;

I^{juv}_{y} = juvenile survey abundance index for age-groups 0;

a_k = older age group;
y_k = terminal year;
N_a = vector of the unknown abundance values for 1992 (age-groups 2-8);
N^{*} = test element which is assumed to be equal to the mean abundance values of the corresponding age-groups;
$\| \|$ = sign of the Euclid norm of vector;
α = regularization parameter.

Estimated values for the objective function are obtained by setting up the corresponding regression equations assuming that errors are of multiplicative character:

$$I^{RV}_{ay} = q^{RV}_{a} \cdot N_{ay} \cdot \xi^{RV} \qquad (5)$$

$$I^{cpue}_{ay} = q^{cpue}_{a} \cdot N_{ay} \cdot \xi^{cpue} \qquad (6)$$

$$I^{juv}_{y} = q^{juv} \cdot N_{1,y+1} \cdot \xi^{juv} \qquad (7)$$

where

q^{RV}_{a}, q^{cpue}_{a} И q^{juv} = appropriate proportionality coefficiens;
ξ^{RV}, ξ^{cpue} И ξ^{juv} = random errors;
N_{ay} - VPA abundance estimate for age-group a in year y.

If the test element is 0 the above-mentioned formulation of the objective function corresponds to the vector of abundances with minimum norm selected from a set of vectors which provide for equality of the mean-square errors (2),(3),(4) analogous to the functions of the corresponding observation errors. If the test element is equal to the sought vector stabilizer converts into "0".

It is assumed that λ_{RV}= I.

The test element, regularization parameter and weight multipliers are calculated by Gasiukov (Gasiukov P.S., 1993). Their following values are accepted in the calculations:

$$\alpha = (8.612E-8)**2$$
$$\lambda_{cpue} = (1.3788)**2$$
$$\lambda_{juv} = (0.13787)**2$$

Age-group	2	3	4	5	6	7	8
Test element	589152	320356	114776	34513	9653	2697	846

3.2. Retrospective analysis

Retrospective analysis has been carried out using the above-mentioned model. Period from 1984 to 1990 was covered.

The estimates of total abundance at age 2+, total biomass, biomass at age 2+ and weighted means of the fishing mortality are presented in Figure 5. The results of the analysis show that the estimate values mentioned above are in close agreement with the VPA retrospective estimates obtained for the whole time interval (1977-1992). For a example, biomass deviation at age 2+ does not execeed 13,000 tons, i.e. 8%. A close agreement between the estimates during the recent years should be noted.

3.3. Results of calculations

Tables 8-14 contain the VPA results (abundance and biomass estimates, fishing mortality coefficients, residuals for different abundance indices and statistical characteristics for the model parameters).

Bearing in mind that very high values can be found among the residuals for the july trawl survey abundance indices and CPUE estimates by age-group the second run of calculations was carried out in which the above-mentioned data were masked and, thus, did not influenced the objective function behaviour. The corresponding estimates are presented in Tables 15-21.

Comparison of data resulted from these two runs of calculations showed that exclusion of data leading to large residuals did not change the estimates greatly. This fact should be regarded as a property of the regularization algorithm.

Abundance indices for age-group 1 from the 1992 july juvenile survey were defined more exactly. It was made using the equation of regression between abundance indices and abundance of age-group 1 for the next year:

$$N_{1,y} = 625778 + 2.05 \cdot I_{y-1}^{juv} \qquad (8)$$

Correlation coefcient was found to be 0.701. The 1992 abundance and biomass estimates for age-group 1 obtained by this equation were 786.908 mln fish and 22.033 thousand tons, respectively.

Thus, silver hake biomass by the start of 1992 accounted for 145,000 tons.

4. Prognosis of state of stock and TAC estimation for 1994

Prognosis of silver hake state of stock for 1994 was made under the following assumptions:

- abundance estimate for 1992 corresponds to the estimates obtained by the adaptive framework using abundance index for age-group 1 adjusted by the equation (8);

- recruitment estimates for 1993 and 1994 will be at the level of the mean value and amount to 982,769 fish;

- the 1993 catch will be close to the 1992 level and account for 31,000 tons;

- mean weight value corresponds to the long-term mean;

- partial recrutment coefficients (Pr) have the following values:

Age-group	I	2	3	4	5	6	7	8	9
Pr	.022	.249	I.0	I.0	I.0	I.0	I.0	I.0	I.0

- optimal fishing mortality coefficient ($F_{0.1}$) corresponding to the partial recruitment coefficients and long-term weight means was found to be 0.5517.

Calculation has been made using a series of programs(Rivard,1993).

Data on silver hake abundance and biomass for 1993 and 1994 and TAC value for 1994 are given in table 22. Basing the results obtained a TAC of 61,000 tons may be advised for 1994.

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Table 1. Silver hake catches by age-group in NAFO Div.4VWX

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	17911	20940	20569	16588	2358	20190	5849	59588	14970	45598	6804	5110	21549	6516	5738	5151
2	72529	70302	57893	70696	25214	52976	26852	45828	130814	70269	214235	62771	115939	209620	117305	80305
3	59862	80196	72891	70391	109035	75876	56158	206900	98346	229126	114417	265307	172700	142862	201243	70043
4	15070	35025	36669	32032	37573	68400	27282	82911	128365	84097	54211	39242	107956	41215	46414	21127
5	2218	12709	22380	14465	11928	31752	11388	19344	34111	28635	13063	21303	17640	11741	12154	3471
6	725	5227	9970	5184	3234	5945	3375	4268	9327	8760	6045	3106	6689	1648	3954	314
7	97	1906	3168	1431	1201	2042	819	1038	2344	1436	347	2133	1574	640	290	39
8	91	1168	495	451	290	465	253	183	226	497	156	208	742	107	181	1
9	4	338	374	78	141	64	88	10	85	111	117	143	130	48	50	1

Table 2. Silver hake mean weight by age-group in NAFO Div. 4VWX

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.065	.074	.076	.040	.061	.066	.067	.070	.068	.053	.045	.045	.055	.063	.047	.058
2	.183	.153	.178	.151	.168	.169	.128	.146	.136	.145	.119	.139	.139	.137	.139	.141
3	.264	.229	.227	.223	.215	.231	.196	.181	.177	.184	.168	.185	.198	.193	.189	.192
4	.340	.266	.274	.287	.276	.275	.239	.224	.210	.250	.211	.227	.228	.213	.215	.230
5	.446	.335	.304	.341	.326	.317	.289	.272	.244	.250	.248	.260	.279	.240	.263	.281
6	.632	.405	.389	.391	.401	.394	.365	.353	.295	.274	.286	.292	.332	.301	.314	.361
7	.886	.438	.455	.531	.553	.446	.395	.405	.410	.392	.453	.401	.434	.366	.471	.469
8	.922	.540	.838	.839	.923	.513	.457	.624	.582	.514	.422	.497	.464	.438	.511	.606
9	2.120	.892	.838	.859	1.137	.506	.444	.650	.669	.644	.518	.688	1.019	.644	.568	.813

Table 3. Analysis of variance in the multiplicative model

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............ .721
MULTIPLE R SQUARED..... .520

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	7.739E0001	7.739E0001	
REGRESSION	26	2.812E0001	1.082E0000	7.255
TYPE 1	1	8.102E-001	8.102E-001	5.435
TYPE 2	6	5.992E0000	9.986E-001	6.698
TYPE 3	15	1.976E0001	1.317E0000	8.834
TYPE 4	2	3.842E-001	1.921E-001	1.288
TYPE 5	1	1.246E0000	1.246E0000	8.357
TYPE 6	1	3.366E-001	3.366E-001	2.258
RESIDUALS	174	2.594E0001	1.491E-001	
TOTAL	201	1.315E0002		

Table 4. Regression coefficients of the multiplicative model

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	1	INTERCEPT	1.134	0.204	201
2	5				
3	77				
4	460				
5	1				
6	1				
1	2	1	-0.340	0.146	119
2	3	2	0.371	0.176	6
	4	3	0.210	0.095	28
	6	4	-0.153	0.079	52
	7	5	-0.174	0.085	40
	8	6	-0.330	0.101	24
	9	7	-0.470	0.192	5
3	78	8	-0.223	0.128	26
	79	9	-0.020	0.130	21
	80	10	-0.391	0.165	9
	81	11	-0.245	0.166	9
	82	12	0.636	0.185	7
	83	13	-0.079	0.178	8
	84	14	0.413	0.177	8
	85	15	0.275	0.177	8
	86	16	0.915	0.201	10
	87	17	0.910	0.204	9
	88	18	0.561	0.203	10
	89	19	0.983	0.194	13
	90	20	0.322	0.187	16
	91	21	0.201	0.190	16
	92	22	0.062	0.192	14
4	450	23	0.187	0.141	10
	470	24	-0.044	0.069	51
5	2	25	-0.452	0.156	180
6	2	26	-0.108	0.072	57

Table 5. Standardized CPUE values

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 1 5 460 1 1

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
77	37095	0.703	3.280	0.664	11311
78	48404	0.879	2.632	0.492	18390
79	51760	0.827	3.211	0.675	16121
80	44525	0.920	2.213	0.470	20118
81	44600	0.833	2.559	0.552	17432
82	60251	0.957	6.168	1.360	9768
83	35839	0.921	3.021	0.653	11862
84	74266	0.967	4.944	1.066	15022
85	75480	0.981	4.303	0.928	17540
86	82689	0.427	7.948	2.469	10404
87	61704	0.926	7.911	2.458	7800
88	74374	0.880	5.582	1.726	13324
89	91505	0.934	8.526	2.595	10733
90	68582	0.966	4.406	1.324	15564
91	67848	0.959	3.903	1.180	17384
92	31000	0.895	3.394	1.031	9134

AVERAGE C.V. FOR THE MEAN: .252

Table 6. Abundance indices for 4VWX silver hake

(trawl surveys, '000)

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
1	7737	26740	89437	17730	32839	192025	114273	188970	102726	552598	146007	69740	172095	117089	66678
2	27660	23257	152705	55633	84724	293420	108957	70369	172576	84325	266663	87508	63810	125952	84741
3	21421	16266	67003	97253	131420	80348	38209	208723	34402	70625	46095	81458	24151	42329	35275
4	4592	8874	20048	45862	60469	60487	19340	37926	71191	22623	18782	16709	13405	13022	13235
5	1348	6733	11522	10684	16241	32426	10632	11828	21488	13448	6048	14249	4130	4173	6560
6	1278	3046	5055	4525	5127	8257	2882	7942	9445	4235	4168	2502	1868	1169	2451
7	984	1286	2664	2001	2367	3549	876	2860	2667	1622	1199	2338	769	432	402
8	336	502	969	587	794	2535	401	1136	1175	673	672	468	282	227	143
9	283	865	275	385	564	327	337	522	215	376	471	121	129	82	124
1+	65638	87569	349677	234668	334545	673374	295908	530276	415885	750524	490304	277092	280640	304476	209609
2+	57902	60829	260242	216937	301705	481350	181635	341306	313158	197926	344297	207352	108545	187387	142931
3+	30242	37572	107537	161299	216992	187930	72678	270937	140583	113602	77634	117844	44735	61434	58190

Table 7. Abundance indices for 0-group from juvenile surveys and age-group 1 from July trawl surveys

Year class	0-group abundance index	Standard error	Coefficient of variation	Abundance index for age-group 1
81	579.0	64.4	.11	192
82	8.8	1.2	.14	114
83	232.2	24.4	.11	189
84	43.4	7.1	.16	103
85	284.8	62.2	.22	553
86	198.0	37.9	.19	146
87	102.0	23.0	.11	70
88	204.8	35.3	.17	172
89	131.5	19.0	.10	117
90	187.4	24.1	.12	67
91	78.6	3.9	.05	–

Table 8. Abundance of silver hake ('000)

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	623140	721060	883124	622130	887693	1557724	831626	1355414	742095	1714104	844180	857348	1314574	904690	883694	786908
2	434908	403038	466197	575135	403445	593107	1027644	552667	859774	485185	1111666	560300	570514	863542	601097	587660
3	234861	232146	212606	265102	327643	249794	354198	609555	332943	469223	267698	569771	324171	287504	407227	306886
4	77255	108421	89953	82836	120072	130356	105320	191448	239201	142659	126937	85767	164714	75904	75754	108209
5	24713	39447	44001	30275	29302	49725	31379	46624	60450	55245	26775	40704	25363	22024	17136	12779
6	5692	14749	16037	11171	8452	9876	7335	11710	15415	12593	13587	7252	9843	2559	5151	1536
7	4250	3892	5607	2588	3244	3019	1753	2137	4355	2697	1269	4159	2318	1122	366	215
8	1559	2770	1048	1165	563	1191	351	504	582	1000	632	567	1041	265	228	8
9	18	971	900	297	411	140	418	28	188	205	263	296	209	91	90	5
1+	1407396	1526495	1719474	1590700	1780825	2594930	2360023	2770086	2255003	2882911	2393007	2126163	2412748	2157700	1990743	1804276

Table 9. Silver hake biomass (tons)

Population Biomass at beginning of years (tons) 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	26418	30569	42369	33522	17157	56527	39099	61794	37321	79914	30113	21644	33883	31527	37440	21657
2	71209	40167	53644	61653	32899	60022	94349	54742	84010	48263	88534	44148	45221	74959	56311	47974
3	61594	47482	39578	52823	59088	49114	64398	92864	53552	74341	41825	84471	53818	47090	65511	50123
4	26423	28704	22500	21119	29786	31704	24741	40109	46644	30032	25008	16734	33801	15588	15417	22535
5	11572	13309	12519	9249	8951	14720	8841	11899	14133	12667	6672	9532	6377	5152	4054	3136
6	5080	6268	5789	3852	3126	3535	2496	3737	4371	3252	3634	1953	2894	742	1413	473
7	4827	2047	2407	1176	1508	1276	691	822	1656	917	447	1407	825	391	138	83
8	1462	1916	635	720	394	534	158	250	283	459	257	269	449	116	99	4
9	19	881	606	252	402	96	199	15	122	126	136	159	149	50	45	3
1+	208604	171343	180047	184367	153310	217629	234973	266232	242091	249972	196626	180318	177418	175614	180427	145988
2+	182187	140774	137678	150845	136153	161102	195874	204438	204771	170058	166513	158674	143535	144087	142987	124331
3+	110978	100607	84034	89192	103254	101080	101525	149695	120761	121795	77979	114526	98314	69128	86676	76357

Table 10. Silver hake fishing mortality coefficients

FISHING MORTALITY 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.036	.036	.029	.033	.003	.016	.009	.055	.025	.033	.010	.007	.020	.009	.008	.006
2	.229	.240	.164	.163	.079	.116	.122	.107	.206	.195	.268	.147	.285	.352	.272	.180
3	.373	.548	.543	.392	.522	.464	.215	.535	.448	.907	.738	.841	1.052	.934	.925	.320
4	.272	.502	.689	.639	.432	1.024	.415	.753	1.066	1.273	.737	.818	1.612	1.088	1.380	.268
5	.116	.500	.971	.876	.688	1.514	.586	.707	1.169	1.003	.906	1.020	1.894	1.053	2.012	.393
6	.142	.567	1.424	.837	.630	1.329	.833	.589	1.343	1.895	.784	.741	1.772	1.545	2.775	.282
7	.028	.912	1.171	1.125	.602	1.752	.846	.900	1.071	1.050	.406	.985	1.768	1.194	3.442	.248
8	.074	.724	.860	.641	.992	.647	2.133	.586	.642	.934	.359	.596	2.042	.679	3.520	.167
9	.323	.536	.678	.500	.525	.774	.293	.595	.766	1.010	.748	.848	1.286	.975	1.052	.309

Table 11 Logs of residuals for trawl survey abundance indices

LOG RESIDUALS FOR RV INDEX 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	-1.92	-.83	.17	-1.09	-.85	.36	-.47	.51	.49	1.34	.70	-.06	.43	.41	-.13	.00
2	-.85	-.94	.75	-.47	.26	1.14	-.40	-.23	.29	.14	.50	.03	-.25	.05	-.03	.00
3	-.72	-.88	.62	.68	.85	.59	-.64	.70	-.55	.09	.13	.00	-.52	.09	-.45	.00
4	-1.51	-1.05	.06	.94	.75	.99	-.30	-.02	.57	.06	-.31	.00	-.41	.03	.22	.00
5	-2.09	-.73	-.03	.22	.56	1.20	.01	-.21	.39	-.08	-.21	.29	.04	-.30	.96	.00
6	-1.29	-.96	-.04	-.13	.15	.88	-.16	.24	.58	.30	-.44	-.35	-.34	.40	1.16	.00
7	-1.60	-.73	-.22	.24	-.12	1.03	-.36	.66	-.02	-.05	.02	-.16	-.23	-.41	1.94	.00
8	-1.85	-1.64	.07	-.66	.57	.78	1.03	.80	.72	-.20	-.08	-.20	-.47	-.11	1.23	.00
9	2.13	-.61	-1.60	-.26	-.19	.49	-.85	2.47	-.23	.39	.21	-1.21	-.54	-.33	.13	.00

SUM OF RV RESIDUALS : -5.773159728E-15 MEAN RESIDUAL : -4.403893699E-17

Table 12. Logs of residuals for juvenile survey abundance indices for age-group 0

LOG RESIDUALS FOR JUV. RV INDEX 5/ 4/93

77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
.00	.00	.00	.00	.00	.00	.12	-.96	.09	.43	-.25	.02	-.05	.33	-.64	.00

SUM OF RV RESIDUALS : -0.9095518686 MEAN RESIDUAL : -0.1010613187

Table 13 Logs of residuals for CPUE values

RESIDUALS FROM CPUE INDEX 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.37	.50	.41	.32	-1.84	.32	-.48	1.11	.18	.98	.07	-.77	.46	-.73	-.95	-.55
2	.36	-.06	-.27	-.50	-1.03	-.10	-.24	-.60	-.15	.32	.90	-.18	.63	.44	.11	.36
3	-.13	-.31	-.19	-.66	-.30	.19	-.65	-.13	-.42	.60	.76	.31	.66	.22	.10	-.06
4	-.56	-.54	-.18	-.45	-.52	.57	-.25	-.05	.01	.63	.59	.13	.70	.14	.15	-.38
5	-1.40	-.61	-.02	-.31	-.32	.71	-.05	-.16	.00	.43	.66	.20	.70	.06	.23	-.11
6	-1.24	-.55	.15	-.37	-.42	.62	.16	-.31	.04	.70	.54	-.03	.64	.22	.28	-.43
7	-2.70	-.12	.16	-.09	-.34	.84	.27	.08	.02	.54	.16	.25	.75	.20	.42	-.44
8	-1.69	-.19	.06	-.36	.07	.37	.79	-.13	-.22	.55	.14	.00	.86	-.06	.50	-.71
9	-.36	-.43	-.12	-.58	-.40	.47	-.49	-.15	-.12	.58	.67	.22	.69	.15	.09	-.22

SUM OF CPUE RESIDUALS : 2.43624565E-14 MEAN RESIDUAL : 1.722305973E-16

Table 14. Statistical characteristies for parameter estimates

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.001465
MEAN SQUARE RESIDUALS 0.000031

PAR. EST.	STD. ERR.	T-STATISTIC
5.95130E0005	5.96289E0004	9.98056E0000
3.12226E0005	5.07885E0004	6.14757E0000
1.09901E0005	3.53746E0004	3.10679E0000
1.30328E0004	6.38588E0003	2.04087E0000
1.56041E0003	8.21424E0002	1.89964E0000
2.18518E0002	1.17311E0002	1.86272E0000
7.94600E0000	4.30324E0000	1.84652E0000

Parameter Correlation Matrix 5/ 4/93

	1	2	3	4	5	6	7
1	1.000	.017	.013	.005	.001	.000	.000
2	.017	1.000	-.006	.004	.002	.000	.000
3	.013	-.006	1.000	-.015	-.004	-.001	.006
4	.005	.004	-.015	1.000	.006	.001	.002
5	.001	.002	-.004	.006	1.000	.005	.001
6	.000	.000	-.001	.001	.005	1.000	.003
7	.000	.000	.006	.002	.001	.003	1.000

Table 15. Silver hake abundance ('000) (calculation includes masks)

POPULATION NUMBERS (000S) 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	623139	721060	883123	622124	887685	1557700	831566	1355409	742018	1712956	843672	849277	1295965	879075	873796	786908
2	434908	403038	466197	575135	403441	593102	1027628	552627	859771	485133	1110876	559959	565104	851068	583927	581025
3	234861	232146	212606	265102	327643	249791	354195	609544	332916	469220	267664	569255	323943	283878	398866	295376
4	77255	108421	89953	82836	120072	130356	105318	191445	239194	142642	126935	85744	164368	75751	73323	102604
5	24713	39447	44001	30275	29302	49725	31378	46623	60448	55240	26763	40703	25347	21792	17033	11150
6	6692	14749	16037	11171	8452	9876	7335	11710	15415	12592	13584	7244	9842	2548	4995	1467
7	4250	3892	5607	2588	3244	3018	1753	2137	4355	2696	1268	4157	2313	1121	359	111
8	1559	2770	1048	1165	563	1191	351	504	382	1000	632	566	1040	262	228	3
9	18	971	900	297	411	140	418	28	188	205	263	296	209	90	88	4
1+	1407395	1526494	1719473	1590694	1780813	2594898	2359943	2770027	2254887	2881685	2391677	2117201	2388132	2115585	1952615	1774451

Table 16. Silver hake biomass (tons) (calculation includes masks)

Population Biomass at beginning of years (tons) 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	26418	30569	42369	33521	17157	56526	39096	61794	37317	79861	30095	21440	33404	30634	37021	21657
2	71209	40167	53644	61653	32899	60022	94348	54739	84010	48258	88473	44121	44792	73876	54702	47433
3	61594	47482	39578	52823	59088	49114	64398	92862	53548	74341	41819	84394	53780	46496	64166	48243
4	26423	28704	22500	21119	29786	31704	24741	40109	46643	30029	25008	16730	33730	15556	14922	21368
5	11572	13309	12519	9249	8951	14720	8841	11898	14133	12566	6669	9532	6373	5098	4030	2736
6	5080	6268	5789	3852	3126	3535	2496	3737	4370	3252	3633	1951	2894	739	1370	452
7	4827	2047	2407	1176	1508	1276	691	821	1656	917	447	1407	824	391	135	43
8	1462	1916	635	720	394	634	158	250	283	459	257	269	448	114	98	2
9	19	881	606	252	402	96	199	15	122	126	136	159	149	49	44	3
1+	208604	171343	180047	184366	153310	217527	234968	266225	242081	249908	196537	180003	176394	172954	176489	141936
2+	182187	140774	137678	150845	136153	161101	195872	204431	204764	170047	166442	158563	142990	142319	139468	120279
3+	110977	100607	84034	89192	103254	101079	101524	149693	120754	121789	77969	114442	98198	68443	84766	72846

Table 17. Fishing mortality coefficients

(calculation includes masks)

FISHING MORTALITY 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.036	.036	.029	.033	.003	.016	.009	.055	.025	.033	.010	.007	.021	.009	.008	.006
2	.228	.240	.164	.163	.079	.116	.122	.107	.206	.195	.269	.147	.288	.358	.282	.182
3	.373	.548	.543	.392	.522	.464	.215	.535	.448	.907	.738	.842	1.053	.954	.958	.335
4	.272	.502	.689	.639	.482	1.024	.415	.753	1.066	1.273	.737	.819	1.621	1.092	1.483	.284
5	.116	.500	.971	.876	.688	1.514	.586	.707	1.169	1.003	.907	1.020	1.897	1.073	2.052	.465
6	.142	.567	1.424	.837	.630	1.329	.833	.589	1.343	1.895	.784	.742	1.772	1.560	3.406	.297
7	.028	.912	1.171	1.125	.602	1.752	.846	.900	1.071	1.051	.407	.985	1.780	1.195	4.321	.546
8	.074	.724	.860	.641	.992	.647	2.133	.586	.642	.935	.359	.597	2.051	.693	3.564	.468
9	.323	.536	.678	.500	.525	.774	.293	.595	.766	1.010	.748	.849	1.289	.992	1.102	.326

Table 18. Logs of residuals for trawl survey abundance indices

(calculation includes masks)

LOG RESIDUALS FOR RV INDEX 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.00	-.97	.03	.00	-.97	.22	.32	.36	.34	.00	.55	-.19	.30	.29	-.27	.00
2	-.77	-.86	.83	-.39	.34	.00	-.32	-.15	.36	.21	.58	.10	-.16	.15	.08	.00
3	-.72	-.88	.62	.68	.84	.59	-.65	.69	-.55	.09	.13	.00	-.53	.11	-.41	.00
4	.00	.00	-.15	.73	.55	.78	-.50	-.23	.36	-.15	-.52	-.21	-.61	-.17	.11	.00
5	.00	-.80	-.10	.14	.48	.00	-.07	-.29	.32	-.15	-.28	.22	-.03	-.35	.92	.00
6	.00	-.97	-.05	-.14	.14	.87	-.17	.23	.57	.29	-.45	-.36	-.35	.40	.00	.00
7	.00	-.62	-.10	.36	-.01	.00	-.24	.77	.09	.06	.14	-.04	-.11	-.30	.00	.00
8	.00	.00	-.04	-.77	.46	.67	.00	.69	.61	-.32	-.20	-.31	-.57	-.20	.00	.00
9	.00	-.45	.00	-.10	-.03	.65	-.70	.00	-.07	.54	.37	.00	-.38	-.16	.34	.00

SUM OF RV RESIDUALS : -2.486899575E-14 MEAN RESIDUAL : -2.175688828E-16

Table 19. Logs of residuals for juvenile survey abundance indices for age-group 0 (calculation includes masks)

LOG RESIDUALS FOR JUV. RV INDEX 5/ 4/93

77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
.00	.03	.00	.00	.00	.00	.11	-.76	.08	.42	-.25	.03	-.03	.33	-.65	.00

SUM OF RV RESIDUALS : -0.9042912246 MEAN RESIDUAL : -0.1004768027

Table 20. Logs of residuals for CPUE values

(calculation includes masks)

RESIDUALS FROM CPUE INDEX 5/ 4/93

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
1	.91	.44	.35	.26	.00	.26	-.54	.00	.12	.92	.02	-.81	.42	-.76	-.99	-.60
2	.31	-.13	-.34	-.57	.00	-.17	-.31	-.68	-.22	.25	.82	-.25	.57	.38	.06	.30
3	-.13	-.32	-.19	-.67	-.30	.19	-.66	-.13	-.43	.60	.75	.31	.66	.23	.12	-.02
4	-.57	-.53	-.18	-.46	-.53	.57	-.26	-.05	.01	.62	.59	.12	.70	.14	.18	-.33
5	.00	-.71	-.13	-.41	-.43	.60	-.16	-.26	-.11	.33	.56	.09	.59	-.03	.14	-.08
6	.00	-.63	.06	-.45	-.50	.53	.07	-.40	-.05	.61	.45	-.12	.56	.13	.23	-.47
7	.00	-.34	-.07	-.31	-.57	.61	.05	-.15	-.20	.31	-.07	.03	.52	-.02	.21	.00
8	.00	-.36	-.11	-.53	-.10	.20	.62	-.31	-.39	.38	-.04	-.17	.71	-.22	.33	.01
9	-.37	-.44	-.13	-.58	-.40	.46	-.50	-.16	-.13	.57	.67	.22	.68	.16	.11	-.18

SUM OF CPUE RESIDUALS : 6.983302825E-14 MEAN RESIDUAL : 4.834135615E-16

Table 21. Statistical characterestics for parameter estimates

(calculation uncludes masdks)

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET.......... 0.022171
MEAN SQUARE RESIDUALS 0.000018

PAR. EST.	STD. ERR.	T-STATISTIC
5.88454E0005	4.56999E0004	1.28765E0001
3.00651E0005	3.80099E0004	7.91006E0000
1.04266E0005	2.50365E0004	4.16456E0000
1.17975E0004	4.04527E0003	2.81748E0000
1.49134E0003	5.64298E0002	2.64282E0000
1.13877E0002	4.91273E0001	2.31801E0000
3.26929E0000	1.41709E0000	2.30705E0000

Parameter Correlation Matrix 5/ 4/93

	1	2	3	4	5	6	7
1	1.000	.020	.014	.005	.001	.000	.000
2	.020	1.000	-.002	.004	.002	.000	.000
3	.014	-.002	1.000	-.018	-.005	-.002	.006
4	.005	.004	-.018	1.000	.007	.001	.002
5	.001	.002	-.005	.007	1.000	.003	.001
6	.000	.000	-.002	.001	.003	1.000	.001
7	.000	.000	.006	.002	.001	.001	1.000

Table 22. State of stock prognosis and TAC estimation

POPULATION NUMBERS 6/ 4/93

	92	93	94	95
1	786738.00	982769.00	982769.00	982769.00
2	587239.70	523292.10	654199.75	650822.34
3	306865.97	328997.40	324196.51	382236.46
4	105238.91	149346.46	160713.65	125167.12
5	12779.10	55503.70	72955.03	62048.99
6	1535.67	5779.62	27113.29	28166.78
7	215.29	776.75	2823.32	10468.01
8	7.85	112.66	379.44	1090.04
9	4.52	4.45	55.04	146.50
1+	1804205.02	2046582.14	2225205.02	2242915.24
2+	1017297.02	1063813.14	1242436.02	1260146.24
3+	429637.32	540521.04	588236.27	609323.90
4+	122751.35	211523.64	264039.76	227087.44

POPULATION BIOMASS (AVERAGE) 6/ 4/93

	92	93	94	95
1	37348.19	48089.10	47973.26	47973.26
2	62692.70	61636.51	75016.30	74629.02
3	41889.07	47708.35	42475.69	50079.99
4	18125.92	26413.23	25680.86	20000.78
5	2475.26	11629.04	13810.44	11745.92
6	401.95	1491.54	6321.89	6567.52
7	74.33	260.10	854.16	3166.98
8	3.63	48.71	148.23	425.83
9	2.63	2.58	28.86	76.83
1+	163013.67	197279.15	212309.68	214666.13
2+	125665.48	149190.05	164336.43	166692.88
3+	62972.78	87553.54	89320.13	92063.86

CATCH BIOMASS 6/ 4/93

	92	93	94	95
1	297.72	334.77	582.27	582.27
2	11290.84	4856.34	10305.24	10252.03
3	13413.19	15096.14	23433.84	27629.13
4	4850.75	8357.82	14168.13	11034.43
5	973.95	3679.73	7619.22	6480.22
6	113.19	471.96	3487.79	3623.30
7	13.40	82.30	471.24	1747.22
8	.61	15.41	81.78	234.93
9	.81	.82	15.92	42.39
1+	30959.47	32895.29	60165.42	61625.93
2+	30661.74	32560.52	59583.15	61043.66
3+	19370.90	27704.18	49277.91	50791.63
4+	5957.71	12608.04	25844.08	23162.50

FISHING MORTALITY 6/ 4/93

	92	93	94	95
1	.00797	.00696	.01214	.01214
2	.18010	.07879	.13737	.13737
3	.32021	.31643	.55170	.55170
4	.26761	.31643	.55170	.55170
5	.39347	.31643	.55170	.55170
6	.28161	.31643	.55170	.55170
7	.24761	.31643	.55170	.55170
8	.16690	.31643	.55170	.55170
9	.30899	.31643	.55170	.55170
1+	.13571	.10706	.19159	.19506

Table 22. Continued

POPULATION BIOMASS AT BEGINNING OF YEAR 6/ 4/93

	92	93	94	95
1	21657.03	35471.74	37106.51	37106.51
2	47974.20	48436.06	61469.20	61151.86
3	50122.99	55596.41	56231.06	66321.52
4	22535.38	32527.67	36048.60	28075.40
5	3135.88	14407.20	19669.84	16729.40
6	473.00	1840.65	8830.43	9173.53
7	82.57	319.61	1162.45	4310.01
8	4.19	60.04	202.22	580.93
9	2.91	3.13	38.62	102.79
1+	145988.15	188662.53	220778.92	223551.95

PRODUCTION 6/ 4/93

SOURCE	92	93	94	95
RECRUITMENT BIOMASS	21657	35472	37107	37107
GROWTH	103370	106819	110776	111984
TOTAL PRODUCTION	125027	142291	147882	149091
LOSS THROUGH FISHING	30959	32895	60165	61626
SURPLUS PRODUCTION	59821	63379	62958	63224
NET PRODUCTION	28862	30484	2793	1599

SUMMARY OF PROJECTIONS 6/ 4/93

YEAR	92	93	94	95
POPULATION NUMBERS	1804205.02	2046582.14	2225205.02	2242915.24
POPULATION BIOMASS	163013.67	197279.15	212309.68	214666.13
CATCH	30959.47	32895.29	60165.42	61625.93
F OR QUOTA	30959.47	31000.00	.55	.55

AGE GROUPS CONSIDERED:1+

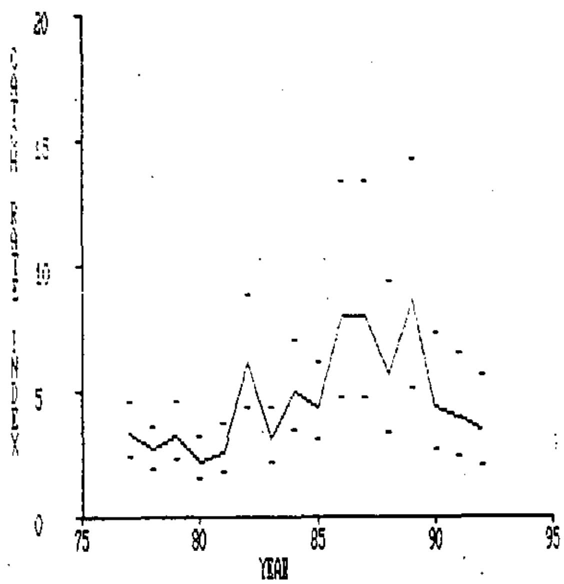

Fig 1. Temporal variation of silver hake standardizied CPUE values

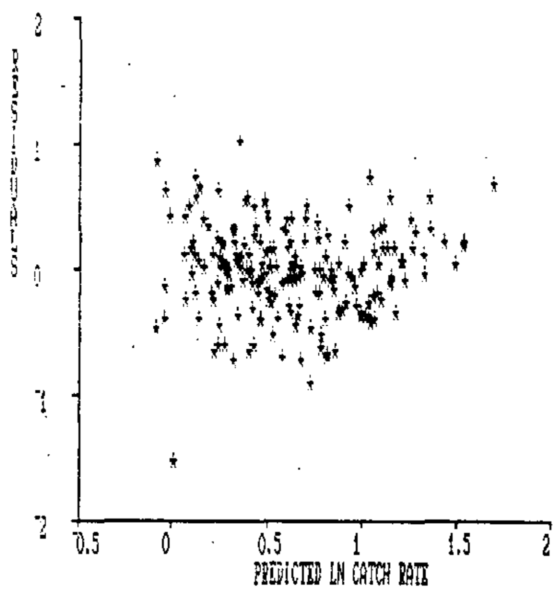

Fig 2. Residuals of multiplicative model

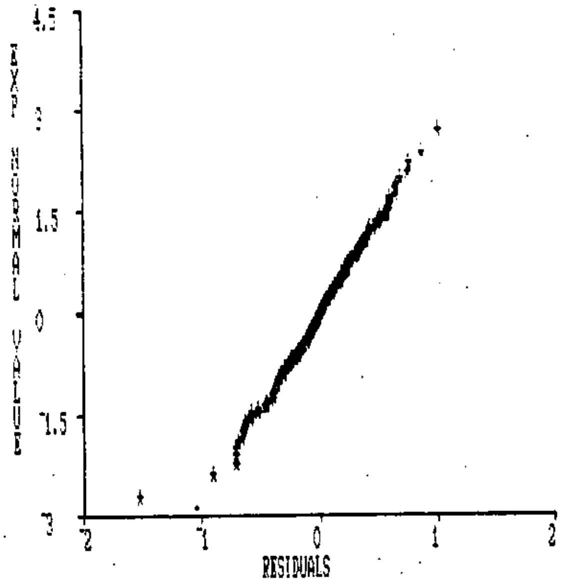

Fig 3. Expecteol noraal residuals of the multiplicative model

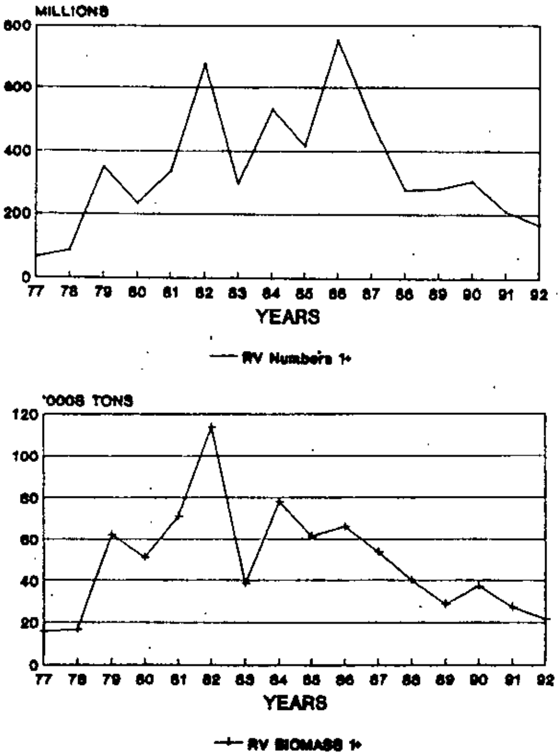

Fig 4. Temporal variation of total abundance and biomass from trawl survey data

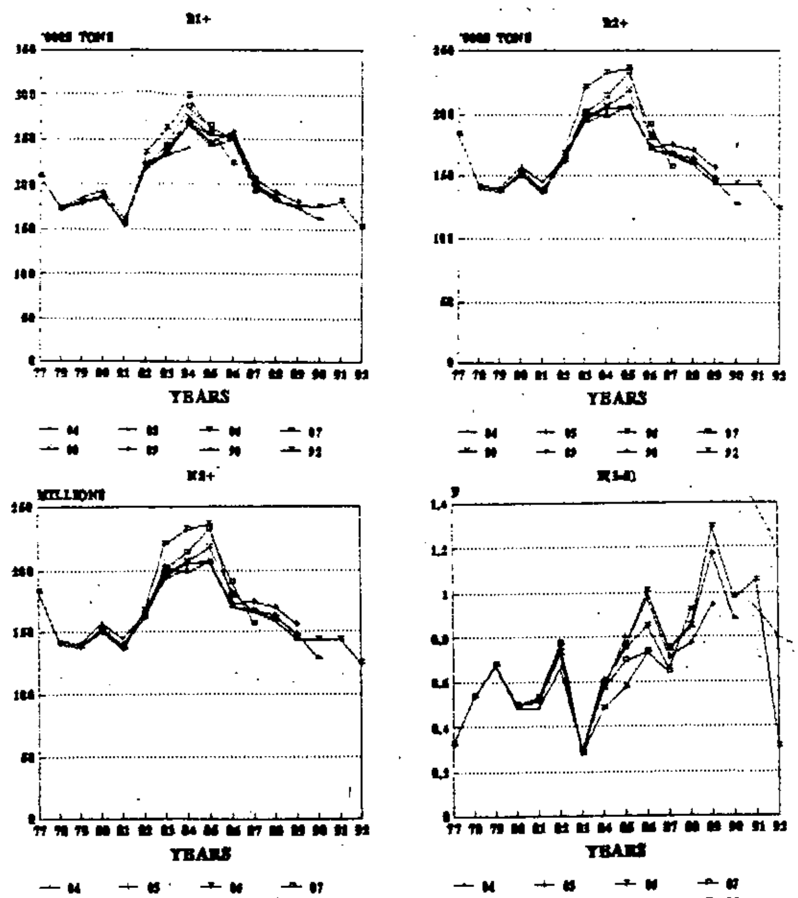

Figure 5. Results of the retrospective analysis of silver hake for 1984–1990

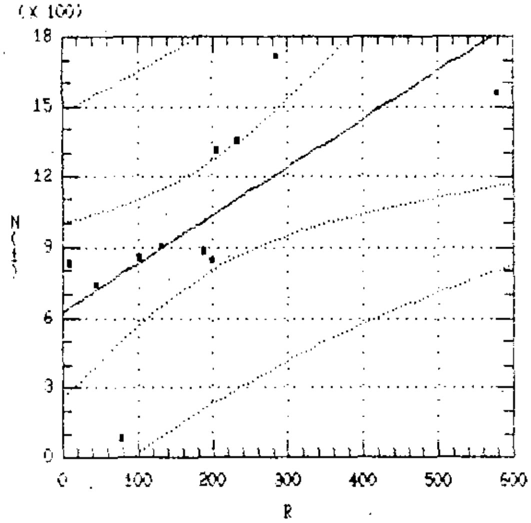

Fig 6. Relationship between 0-group abundance index derived from juvenile surveys and VPA abundance estimates for age-group 1