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Practical Use of Adaptive Framework for Stock Assessment

by

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INTRODUCTION

Adaptive Framework suggested by Gavaris (1988) for commercial population stock assessment has been widely used in recent years. Already in 1989 during the NAFO Session the stock assessment of some commercial species was made by the above-mentioned method (Waldron D.E *et al.*,1989),(Baird J.W.,Bishop C.A.,1989). There have been known cases of its use in other International Fisheries Organizations (Conser R.J.,1988). The method is of great flexibility and allows for using as an initial one the information obtained from different sources. In particular, it is possible to use data on catch rate as an index of stock state, indices of abundance obtained by the data of trawl surveys for a number of years and estimates of recruitment. It may be expected that in future the method will be widely used.

However, its practical use produces a number of problems. For instance, what age groups in a terminal year are to be used for tuning of Sequential Population Analysis (SPA)? Is it always reasonable to use all the initial information available or it is enough to use a certain set of data? What object functions when determening parameters are to be used? These problems and a number of other problems require their solution and one of possible approach is represented below.

DESCRIPTION OF METHOD AND CRITERION FOR VERSION CHOOSING

Algoritm of SPA is in the base of the Adaptive Framework by Gavaris(1988). As it is known, to realize the method it is nessessery to determine tuning parameters namely, fishing mortality coefficientes (or abundance by ages) in the terminal year and for the older age group by fishing years.

It is assumed that the abundance index observed for the number of years which reflects the stock state is known. In other words, this index is the function of populational parameters, such as abundance and biomass that in turn allows for the possibility of obtaining the index values, if the estimates for this populational parameters are known. Then the task of determination of unknown values may be formulated as the task of their search attaining the proximity of values observed and calculated for abundance index.

Gavaris formulated the task in a general aspect suggesting that a set of indices may be considered as the values observed.

This may be formally described as follows. Let the population state (abandance, biomass) at the moment t be P_t vector. Then the variation of state from t to $t+1$ may be represented as difference equation

$$P_{t+1} = \phi\left[P_t \;, \theta\right] \qquad (1)$$

where ϕ - transition operator;

θ - vector for parameters determaning dynamics.

P_t state is related to values observed (for instance, J_t abundance indicis) with the observation equations

$$\begin{aligned} J_t^{1} &= H_1\left(P_t\right) \\ &\ldots \\ J_t^{l} &= H_l\left(P_t\right) \\ &\ldots \\ J_t^{k} &= H_k\left(P_t\right) \end{aligned} \qquad (2)$$

where top index determines a set of values observed, $l=1,2,\ldots,K$. Catch rates, abundance and biomass estimates for trawl surveys, etc. may be considered as members of this set.

Having observed J_t^{l} values in a sequence of time moments Adaptive Framework by Gavaris may be written as the following problem:

- To determine the vector of θ parameters using set of observations J_t^{l} , $l=1,2,\ldots,K$; at moments $t=1,2,\ldots,T$, minimizing the difference between values observed and their estimates J' with the aid of (1) and (2)

$$\min_{\theta} \sum_{l} W_l \left[J^l - J^{l\,'}\right]^2 \qquad (3)$$

where Wl - multipliers designated to equalize the contribution of certain elementes from an observational set.

It was recommended that standard errors for certain observation had been used as multipliers.

The question of multipliers choosing from (3) is important for practical method realization. The same problem arised when realizing other methods for stock assessments which were constructed basing on close ideas(Deriso *et al.*,1985),(Fournier D.A *et al,1987)*. However, as it may be suggested it was not solved. One of possible approaches in this respect may be as follows.

First of all, let us specify that (3) is equivalent to another problem. Let us define J_1 as one of the main abundence indices. Therefore, the problem (3) may by formulated as follows: find θ parameters from the condition of function minimum

$$\min_{\theta} \sum \left[J_1 - J_2'\right]^2 \qquad (4)$$

providing that other members of indices set satisfy the constraints

$$\sum \left[J_2 - J_2'\right]^2 \leq V_2$$
$$\dots$$
$$\sum \left[J_k - J_k'\right] \leq V_k \qquad (5)$$

This means that θ parameters are determined by a criterion of minimum difference between observed and calculated values for J_1 index providing the deviations of calculated and observed values for $J_2,\dots,J_k$ will be less than given numbers of $V_2,\dots,V_k$. Such formulation (3) represents the opportunity to use "moving check" procedure for determination of W_t multipliers(Vapnik V.N.1982).

One of the typic problems of using difference equations (1) and (2) is in obtaining the best estimate of J_t interpolated values. Let us suggest that in the sequence 1,2 ,...,T at t moment the observation was not done. Thus, solving the problem (3) with W_t values given we shall determine the parameters vector θ and with (1) and (2) we shall calculate a "missed" observation at t_i the moment.

If this calculation is made with each t_i, i=1,2,...,T in a sequence each time following the interpolation error, we may consider the best that combination of W_i multiplier with which summary error of interpolation will be minimum.

Such an approach is mainly different as compered with the problem (3), since the indices J_{t_i} at the t_i moment are not used when determining θ parameters and therefore the deviation estimate of observed and interpolated values is an independent estimate.

The sequence of calculations in "moving check" procedure is the following.

1.Let us define the main index of abundance J_1.

2.Let us define the set of multipliers W_t ,t=1,2,...K.

3.Let us select from a number of moments 1,2,...T t_t moment and corresponding observation .J_{t_t}.. will be withdrawn from J_t.

4.Solving the problem (3) with the set of observation $\{J_1-J_{1t_t}\},J_2,\ldots,J_k$, used let define the vector parameter θ.

5.Using (1) and (2) and θ vector the value of J'_{t_t} and the difference $J_{t_t} - J'_{t_t}$ are calculated.

6.Repeat the calculations Nos.3-5 for other t_t.

7.Changing W_t multipliers repeat Nos.3-6 with new W_t.

8.Define W_t set with which we have the minimum$\sum|J_{1t_t}-J'_{1t_t}|$.

9.The final θ parameters are determined with W_t optimum multipliers obtained using the whole sample of J_1.

It is required to discuss the No.2. As it is indicated in the paper by Deriso R.B. *et al.(1985)* the results of solving the problem are low sensitive to small changes of multipliers. That is why it is reasonable to fulfill the calculations by rough grid of points with further detailization of values in the minimum area.

It is evident that the "moving check" procedure gives an unique creterion for selection of specific initial information, tuning parameters and even the type of object function.

The weak point of the method suggested for determening the multipliers consist of numerous calculations required.

THE DATA USED

The above mentioned approach was applied to solve a real problem of multipliers determination when estimating the silver hake stock for the NAFO 4VWX areas with the Adaptive Framework. That is why the initial data described by D.Waldron *et al.*(1989) were used. These data were used for the silver hake stock assessment for 1989.

The natural mortality rate for silver hake was adopted to be equal to 0.4.

The matrix of catches by ages and fishing years, mean weight of fish, indices of abundance by trawl surveys and their standard errors are given in Tables 1 - 4.

Standardized values of catch rates and their standard errors obtained by using multiplicative model(Gavaris S.1980) are given in Table 5.

RESULTS OF CALCULATIONS

The results are obtained when using the following object functions:

1. $$\sum_{t=1}^{T}\left[\frac{cpue_t - cpue_t'}{SE_{cpue}}\right]^2 \qquad (6)$$

2. $$\sum_{t=1}^{T}\left[\frac{cpue_t - cpue_t'}{SE_{cpue}}\right] + W_1 \sum_{t=1}\sum_{a=1}\left[\frac{J_{at} - J_{at}'}{SE_{at}}\right] \qquad (7)$$

3. $$\sum_{t=1}^{T}\left[LNcpue_t - LNcpue_t' \right]^2 + W_1 \sum_{t=1}\sum_{a=1}\left[LNJ_{at} - LNJ_{at}' \right] \qquad (8)$$

4. $$\sum_{t=1}^{T}\left[LNcpue_t - LNcpue_t' \right] + W_1 \sum_{t=1}\sum_{a=1}\left[\frac{J_{at} - J_{at}'}{SE_J}\right] \qquad (9)$$

5. $$\sum_{t=1}^{T}\left[\frac{cpue_t - cpue_t'}{SE_{cpue}}\right]^2 + W_1 \sum_{t=1}\sum_{a=1}\left[LNJ_{at} - LNJ_{at}' \right]^2 \qquad (10)$$

The following age groups for tuning are used for each object function:

1. 3-th age group,
2. 4-th age group,
3. 3,4,5-th age groups.

Thus, each version of calculation is characterized by two figures n_1n_2, the first of which is the object function variant and the second one is the calibration age group version. So 11 means that the parameters of calculation are determined by minimization of the 1-th object function with selection of the 3 age group for tuning. Correspondingly 53 means that the parameters are determined by minimization of the 6-th function using for tuning 3,4,5 age groups.

Results of calculations are given in Table 6. These results show that indeed the selection of object function, as well as the selection of age groups for tuning, are rather important. The best results may be obtained if the assessment of silver hake stock is made by SPA with .5. object function and 3,4,5 age groups for tuning. Therefore, a random selection of those may lead to a considerable worsening of SPA tuning.

Besides, the results also show that the estimate of silver hake assessment made with Adaptive Framework is worse when the catch rate is used as an additional information than the combined using of data on catch rate and abundance indices by trawl surveys. With this the multiplier is to be equal to ....

It is not worthy to compare the results of the silver hake stock assessment with the Adaptive Framework using the 1-th object function and 4-th age group for tuning and optimum version of such calculation. In table 7 the corresponding results are given and in firgure 1 graphs of observed and calculated values of main abundance indices are plotted. It is evident that the optimum calculation version provides the better approximation especially for recent years which are the most important for the etimation of modern stock state.

CONCLUSION

The Adaptive Framework for estimation of stocks is a prospective method. Results of this method depend in a degree on the selection of initial information, selection of object function for population parameters determination and age groups which are used when tunning.

The "moving check" procedure may serve as one of the ways of optimum selection of variables.

This procedure using relatively to the silver hake stock assessment in 4VWX subareas shows that the best version concerning the criterion of minimum error of interpolation value "missed" index is:

- combined using of the data on trawl surveys and standardized catch rate as the initial information;
- using of (10) function as object function for populatinal parameters determination;
- search of this object function minimum is to be made with multiplier W_1=0.01.

The problem of the silver hake stock assessment is not limited by the versions considered. Thus, we can use the data of joint USSR-Canada juvenile surveys , the estimate of recrutment indices by the data surveys with the corresponding modification of object function as the initial informatian. The selection of optimum version is evidently to be made considering the whole set of all the possibilities.

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Table 1.Catch by age groups and years for the silver hake fishing in the NAFO 4VWX subareas

	77	78	79	80	81	82	83	84
1	18372	17505	19260	14612	2431	16948	6334	72261
2	74356	66439	53960	75735	27596	49079	94529	48496
3	61512	81552	68542	71647	110845	75919	56666	207702
4	14899	36433	34693	32879	36939	69673	29443	79166
5	2050	13036	21108	.14629	11141	32184	11445	18583
6	571	5321	9245	5153	2748	5812	3556	4397
7	78	1943	2935	1398	986	1955	820	1201
8	40	1149	475	431	259	412	236	214
9	1	296	308	108	181	51	67	18

	85	86	87	88
1	13319	53559	6831	6098
2	132410	67950	227946	62755
3	98008	225764	104160	263757
4	124261	84348	53140	38118
5	33256	29225	9056	21058
6	9220	8465	6891	3126
7	2326	1235	612	2420
8	245	577	186	244
9	70	198	138	182

Table 2.Silver hake mean weight for the NAFO 4VWX subareas

	77	78	79	80	81	82	83	84	85	86	87	88
1	.06	.08	.08	.05	.06	.07	.07	.07	.07	.05	.04	.05
2	.18	.15	.19	.14	.17	.17	.13	.15	.14	.15	.12	.14
3	.26	.23	.24	.22	.21	.23	.20	.18	.18	.19	.17	.19
4	.34	.27	.29	.28	.28	.28	.24	.22	.21	.21	.22	.23
5	.43	.33	.33	.33	.32	.32	.29	.28	.25	.25	.27	.26
6	.56	.40	.41	.38	.40	.40	.37	.37	.30	.27	.30	.30
7	1.01	.43	.48	.53	.59	.46	.42	.43	.43	.44	.46	.42
8	.92	.53	.90	.85	.95	.56	.47	.60	.59	.67	.49	.53
9	2.27	.88	.88	.88	1.22	.55	.47	.65	.82	.80	.51	.73

Table 3.Abundance indices by silver hake trawl surveys in the NAFO 4VWX subareas

	77	78	79	80	81	82	83
1	7737	26740	89437	17730	32839	192025	114273
2	27660	23257	152705	55638	84724	293420	108957
3	21421	16266	67003	97253	131420	80348	38209
4	4592	8874	20048	45862	60469	60487	19340
5	1348	6733	11522	10684	16241	32426	10632
6	1278	3046	5055	4525	5127	8257	2882
7	984	1286	2664	2001	2367	3549	876
8	336	502	969	589	794	2535	401
9	283	865	275	385	564	327	337

	84	85	86	87	88
1	188970	102726	552598	146007	69740
2	70369	172576	84325	266663	89508
3	208723	34402	70625	46095	81458
4	37926	71191	22623	18982	16709
5	11828	21488	13448	6048	14249
6	7942	9445	4235	4168	2502
7	2860	2667	1622	1199	2338
8	1136	1175	673	672	468
9	522	215	376	471	121

Table 4.Standard errors of the silver hake abundance indices by trawl surveys in the NAFO 4**VWX** subareas

	77	78	79	80	81	82
1	1997.79	5058.88	6241.96	5390.62	8119.90	48811.29
2	6014.72	4847.42	26710.95	14143.88	20180.14	116920.75
3	2618.81	3124.20	7097.70	37247.78	40053.00	42847.05
4	576.04	1911.95	5727.28	20055.95	20148.67	34197.76
5	212.83	1421.57	3620.57	4336.79	4715.28	18425.25
6	205.32	686.23	2051.32	1821.59	1670.26	3853.05
7	302.25	396.25	1097.12	1375.81	985.72	1378.65
8	110.17	194.15	637.85	382.35	338.01	1155.66
9	139.75	329.28	425.80	301.54	231.74	119.29

	83	84	85	86	87	88
1	15146.89	44983.58	20354.66	147308.63	42633.09	10285.18
2	20234.04	16608.72	42265.22	13798.26	47907.94	29730.04
3	10834.23	50183.92	11852.81	12362.59	8892.47	32834.05
4	6523.32	8625.18	28886.19	3953.36	3722.17	6757.74
5	3430.81	2489.28	7341.33	2050.95	1032.31	4431.13
6	623.46	1684.41	3460.44	703.82	561.74	615.43
7	154.49	613.35	734.61	293.28	220.47	538.85
8	82.59	301.70	285.49	135.08	159.15	117.40
9	99.68	155.57	65.07	85.78	116.65	57.01

Table 5.Standardized values of catch rate for the silver hake fisheries in the NAFO 4**VWX** subareas

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 1 5 450 2 1

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	S.E.	EFFORT
77	37095	0.703	2.546	0.452	14569
78	48404	0.879	2.039	0.308	23739
79	51751	0.827	2.483	0.423	20843
80	44525	0.920	1.723	0.344	25845
81	44599	0.833	1.976	0.361	22572
82	60207	0.958	4.940	1.052	12187
83	35837	0.921	2.444	0.510	14662
84	74266	0.967	4.005	0.840	18544
85	75480	0.981	3.486	0.731	21653
86	82689	0.427	6.644	1.562	12446
87	61704	0.926	6.613	1.567	9331
88	74482	0.879	4.639	1.090	16057
89	86729	0.984	6.804	1.559	12747

AVERAGE C.V. FOR THE MEAN: .205

Table 6.Sum of modules of approximational errors by the "moving check" procedure with the different W_1 coefficients and different versions of calculation

VERSION	MULTIPLIERS						
	–	0.001	0.01	0.1	1.0	10.0	100.0
1 1	21.62	–	–	–	–	–	–
1 2	21.61	–	–	–	–	–	–
1 3	23.31	–	–	–	–	–	–
2 1	–	–	21.61	21.32	13.98	13.17	13.60
2 2	–	–	21.61	21.48	16.77	14.62	14.58
2 3	–	–	23.35	20.58	14.21	13.65	13.65
3 1	–	–	21.77	21.38	14.82	16.67	–
3 2	–	–	16.90	16.89	15.16	21.39	–
3 3	–	–	16.46	15.70	16.09	16.51	–
4 1	–	–	21.70	17.71	13.77	13.69	–
4 2	–	–	21.74	19.70	14.95	14.77	–
4 3	–	–	20.61	15.46	14.04	13.98	–
5 1	–	–	21.61	21.60	19.70	16.38	16.26
5 2	–	–	21.61	21.60	19.70	16.32	16.38
5 3	–	23.30	10.58	22.27	14.02	16.14	16.16

Table 7.Observed and calculated values of catch rate by optimum version and version with object function (6) and tuning by the 4 age group (version 12)

	Observed	$CPUE_{opt}$	$CPUE_{12}$
77	2.44	2.69	2.74
78	2.01	2.12	2.17
79	2.44	1.92	1.95
80	1.70	2.16	2.18
81	1.96	2.18	2.19
82	4.92	2.13	2.16
83	2.43	2.69	2.75
84	3.99	3.19	3.31
85	3.47	2.68	2.88
86	6.40	2.58	3.04
87	6.38	6.02	3.34
88	4.48	4.71	13.68

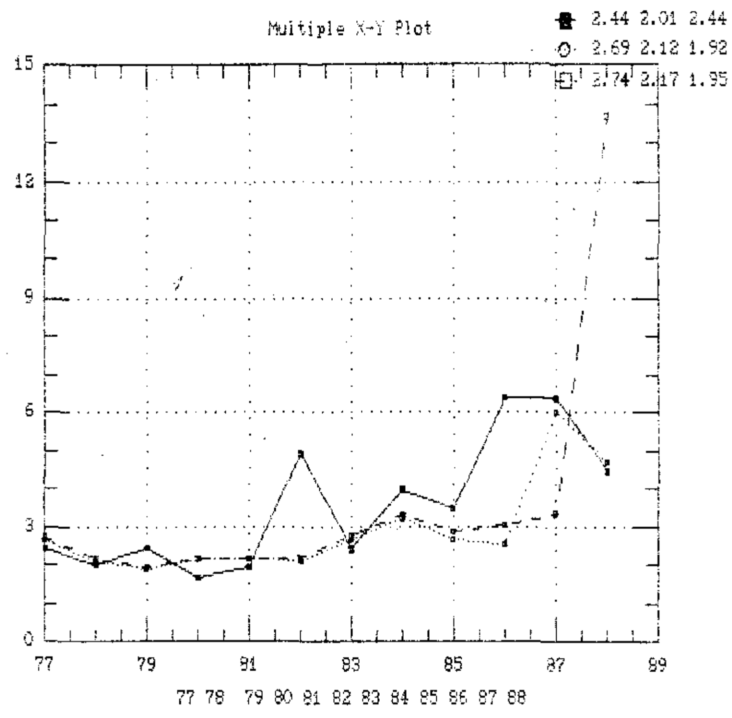

Fig. 1. Main abundance indices calculated from ADAPT.