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Likelihood profile diagnostic tool

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Likelihood profile as diagnostic tool and of data's importance used in JJM model.

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1. Introduction

In a modern stock assessment, integration of several sources of information includes knowledge about the fishery, biology of the resource, as well as the influence of each data set in determining the stock size and the condition of the population. The poor specification of the model, such as selectivity suggestions or catchability may determine that an apparently valuable data set fails to provide information regarding key population parameters.

The use of likelihood profiles in respect of the parameter that defines the population scale is a technique recently used, and allows to conduct a diagnosis on the marginal contribution of each data source in the population assessment, as well as to identify potential problems involving poor specification of the model (Lee et al., 2014, Wang et al, 2014).

This work includes an analysis of the likelihood profiles of the parameter that defines the population scale of the JJM model used by the SC of the SPRFMO for the jack mackerel assessment, in order to evaluate the influence of the different pieces of information and performance of the JJM model.

2. Materials and methods

A computational routine was implemented to evaluate both the statistical performance of the JJM model and the information level contained in the data regarding the parameter that defines the population scale corresponding to the long-term average recruitment (meanR), which is unknown in the model and estimated in the stock assessment process. Works conducted by Francis (2011), Lee at al (2014), Wang et al (2014) and Maunder & Piner (2014) were considered as reference documents.

The JJM code was slightly modified in order to set a specific value of "meanR" and to run the model once, obtaining the value of each marginal component of the likelihood function. These components respond to measures of the error of each set used in the assessment, together with penalties regarding parameters of interest, such as the recruitment deviate in respect of the S/R relationship.

2.1. Modification of the code of the JJM model

The configuration of the model used in the second meeting of the SC-SPRFMO held in Hawaii, 2014 was considered and called mod2.0. This configuration was used to establish the capture and diagnosis recommendations for jack mackerel within the Convention Area for 2015. Control file “mod2.ctl” was modified, adding a couple of lines below the definition of the recruitment standard error (sigmaR), with the option of including an average R value with its deviation and estimation phase:

```
#SigmaR
0.6 15 -4
#mean _Rec   //New!! To use it in likelihood profile over mean_R.
5784.0 300  -1
```

In this case and for example, the value of “meanR” is 5780 known assumption and means that the recruitments vary around this value in logarithmic scale following a normal distribution with deviation sigmaR=0.6. Similarly, the code of the model “jjm.tpl” should be modified in order to read the input values of “meanR” provided in the file in “jjm.ctl. The detail of the new code was shared in github:
https://github.com/SPRFMO/jack_mackerel/commit/1be54721be4730676639f3c09cc880325f5cfa12

2.2. Generation of the likelihood profile on average R

Once the model is fitted to the data and known the maximum estimate a posteriori MAP of meanR (estimated parameter), 18 intervals of potential values of meanR within a variation range of [-90%; +80%]. Each value was set and the model was run 18 times through a "bat" file, recording in each run the respective 26 values of the components of the likelihood function (Table 1) defined by 4 fleets and their respective age/size compositions and catches, 9 indices of abundance plus penalties referred to: nonparametric selectivities of fleets and indices of abundance, recruitment deviates, fishing mortality, and catchability regarding their priors.

As a result, a matrix with the value of the log-likelihood for each of the 26 error components and each of the 18 scenarios of meanR was generated. The magnitude of the differences for each component and above the range of "meanR" was evaluated based on the Likelihood-ratio test, considering the value Chi-2 of 1.92 from the difference between LL_i - min(LL_i), where LL is the negative of the log likelihood of certain error term integrated on the total range (i=1,2,...18) of meanR values.

Table 1. Error sources (data) used in the stock assessment model of Jack mackerel

		Fleet			Surveys
Fleet/zone	Catch	CAGE	CSIZE	Indexes	CAGE
F1 (North)	CatchF1	CageF1	-	Index 2, 3 y 4	Cage_index 2
F2 (South)	CatchF2	CageF2	-	index 1	Cage_index 1 y 4
F3 (Farnorth)	CatchF3	-	CsizeF3	Index 5 y 6	
F4 (Offshore)	CatchF4	CageF4	-	Index 7, 8 y 9	-

index 1	Chile_AcousCS	index 6	Peru_CPUE
index 2	Chile_AcousN	index 7	Chinese_CPUE
index 3	Chile_CPUE	index 8	EU_CPUE
index 4	DEPM	index 9	USSR_CPUE
index 5	Peru_Acoustic		

2.3. Sensitivity tests

Seven cases were analyzed in respect of the base model, modifying the selectivity configuration, excluding data, and modifying the relative weight of some pieces of information. Details are provided in **Table 2**.

Table 2. Scenarios configuration for sensitivity analysis of likelihood profile of JJM model

Scenario	Configuration
S1	Base case (mod2.0.ctl)
S2	As S1 but simulated data (predicted values from S1)
S3	As S1 without use ageing error matrix
S4	As S3 plus some additional selectivity settings
S5	As S4 but F4 considers a similar wt at age as F2
S6	As S4 but reducing the sample size for F4 fleet (at 25%)
S7	As S5 but changing sigmaR=10.

In S4, the file *.ctl was slightly modified in order to adapt selectivity according to data source. The selectivity code for the acoustic survey of the North of Chile was modified from "1" to "2" since CAGE is available for these surveys and therefore does not correspond to assume those from the fleet F1.

3. Results

Ideally, likelihood profiles of each data source should exhibit the form of an upside down parabola (Maunder & Piner, 2014) which minimum represents the maximum a posteriori estimate (MAP) of meanR for each error source. If data sources are consistent among themselves, the respective MAP should be close between them, as well as the difference of log likelihood in respect of the minimum is expected to increase above the statistical criterion Chi-2=1.92. Values above this criterion indicate that such data source contains significant information regarding the meanR parameter. Likewise, it may be expected that the total likelihood and its curvature will be more influenced by data than by penalties or a priori distributions (assumptions).

Results show that in base scenario S1, very few data provide information on the population scale, there is inconsistency between them, and the MAP value of meanR is strongly influenced by the penalty on the recruitment deviate regarding the S/R model (rec_like). All the other significant sources such as CAGE of F2, F4, CPUE USSR and penalty of fleet selectivity suggest that the population scale should be much lower (respective MAP are on the left) (**Table 3**). Lack of convexity and the logarithmic pattern displayed by these profiles also suggest issues of specification either at selectivity pattern or catchability assumptions levels. (**Figure 1a**). One way of evaluating this is using simulated information from the same model and introduce it as data, allowing to evaluate the contribution of data if the model is well specified (Maunder & Piner, 2014). In this case, only CAGE F2 and F4 are informative and consistent between themselves, although their minimum are far below total MAP, which is still strongly influenced by recruitment and selectivity penalties (**Figure 1b**). Lack of consistency and little information contained in the other data sets is observed. This, since the differences in likelihood do not exceed 1.92 and their respective MAP are far from the confidence region at 5%.

On the other hand and if only the error matrix of the age reading (case S3) is eliminated from the base model (S1), significant changes are observed, such as the decline of the influence of selectivity penalty and convexity, as the CAGE of the fleet F2 and the acoustic index from Peru (**Figure 2a**). Based on this and after the correction of the configuration of the selectivity defined in the case S4, an increase of 10% in the MAP value of meanR is registered and the influence of the CAGE of the abundances índices (acoustic biomass of Chile and DEPM) is increased (**Figure 2b**). This situation does not occur if, in an exploratory manner, the same growth pattern in weight in the fishery F3 in respect of the total is assumed (**Figure 3a**), where the influence of CAGE of the offshore fleet (F4) with the acoustic signal from Peru are still the most relevant together with recruitment and selectivity penalties. This situation is not reversed, even if the size of the simple of the CAGE F4 is reduced by 25%, in which case the population scale increases (meanR) while CAGE of the fleet F1 and F2 assumes greater relative importance. Therefore, the definition of sizes of samples should be reviewed.

An extension of the analysis indicates that when the assumptions on the deviate of the recruitments in respect of the S/R model is relaxed (S7), the population scale grows to realistic values and data cease to be informative. (**Figure 4**)

4. Conclusions

The analysis of the likelihood profile of meanR has allowed to establish that the data sources used in the jack mackerel assessment show significant levels of inconsistency (extreme MAP) and very few are informative in respect of the population scale. In this sense, and on the basis of the scenario S4, age compositions of fleet F2, of surveys, and the acoustic signal from Peru are so far the most significant pieces of information in the stock assessment.

In fact, the modification in the configuration of the model based on the elimination of the error matrix and the configuration of survey selectivities (S4), made possible to point a higher level of information contained in the age compositions of the latter. Notwithstanding the above, penalty of the selectivities of the fleet causes a high influence that would reflect more significantly in the abnormal shape of the likelihood profile of the age composition of fleet 4. Likewise, the pattern observed in the likelihood profile of the acoustic survey from Peru suggests that the hypothesis regarding changes in catchability or weighting should be reviewed.

The analysis conducted allowed the evaluation of the information level regarding the population scale contained in data used in the jack mackerel assessment. Unfortunately, there are very little relevant or useful data for these purposes and the penalty on recruitment and selectivity deviates of the fleet are now determining in the model results.

Finally, it is recommended to extend these analyses to other sources of uncertainties in order to establish the best configuration of both the JJM model and the weighting of the data used.

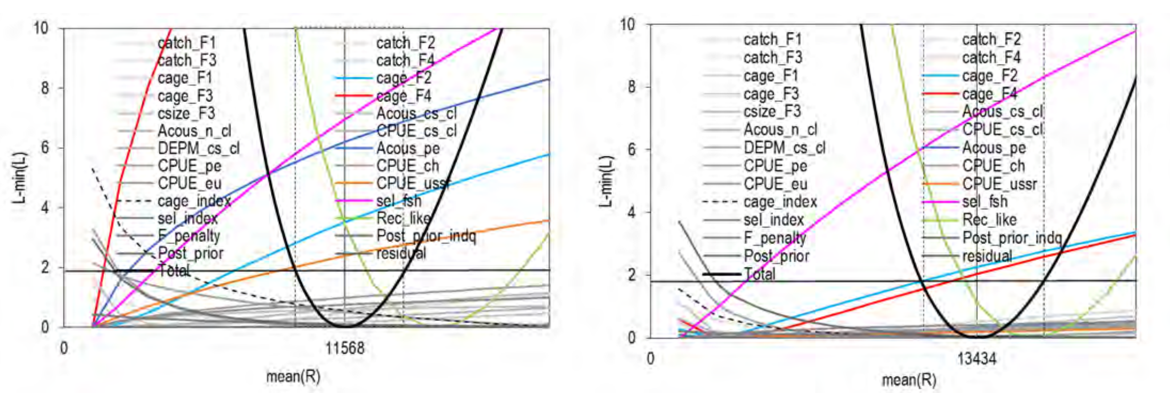

Figure 1. Likelihood profile case S1 (a) and S2 (b). Horizontal line represents the critical level for Chi^2 test and dotted lines is the 95% confidence interval for mean(R).

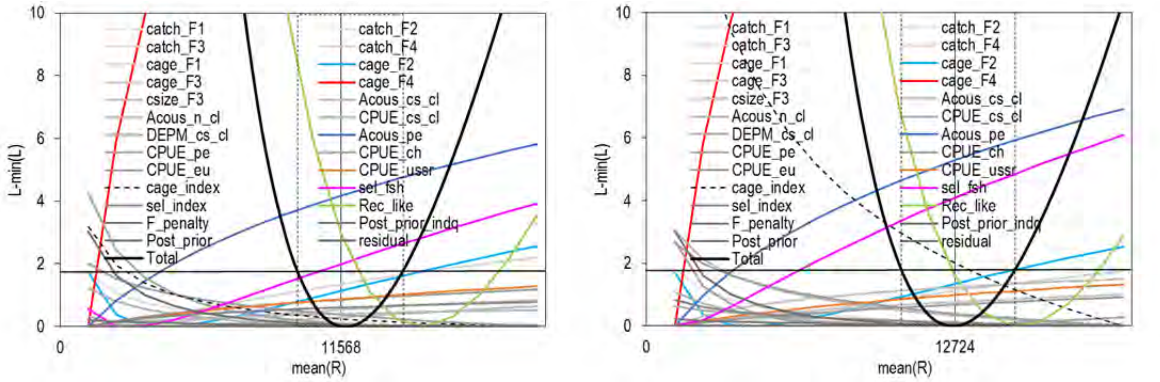

Figure 2. Likelihood profile case S3 (a) and S4 (b). Horizontal line represents the critical level for Chi^2 test and dotted lines is the 95% confidence interval for mean(R).

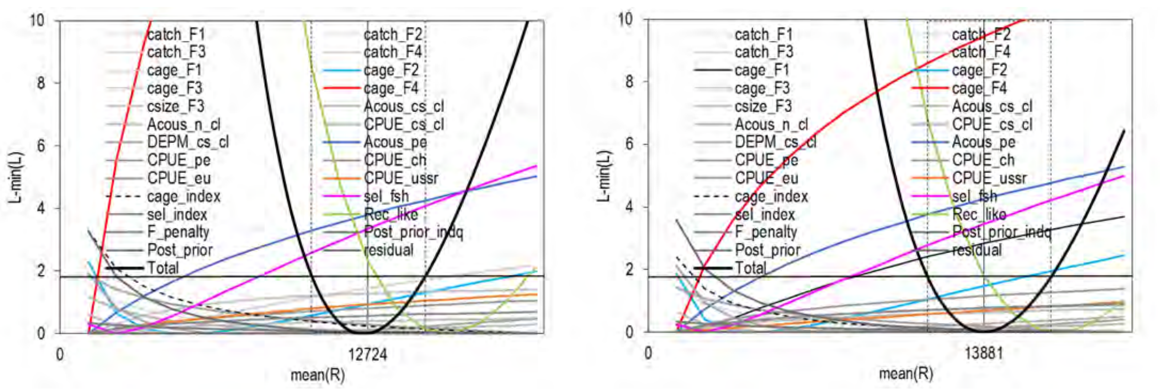

Figure 3. Likelihood profile case S5 (a) and S6 (b). Horizontal line represents the critical level for Chi^2 test and dotted lines is the 95% confidence interval for mean(R).

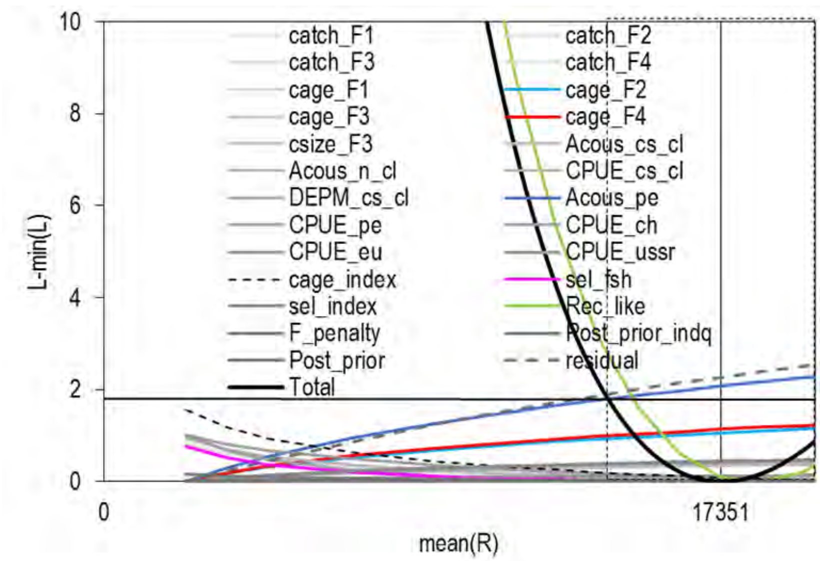

Figure 4. Likelihood profile case S7. Horizontal line represents the critical level for Chi^2 test and dotted lines is the 95% confidence interval for mean(R).

Table 3. Likelihood profile over fixed values of meanR in base case (S1). Values represent the negative log-likelihood for each component minus the minimum component across profile. In bold the maximum at posteriori (MAP) of meanR is displayed.

Component	1157	2314	3470	4627	5784	6941	8098	9254	10411	**11568**	12725	13882	15038	16195	17352	18509	19666	20822
catch F1	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
catch F2	1	1	1	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
catch F3	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
catch F4	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
cage F1	1	0	0	0	0	0	0	0	0	**0**	1	1	1	1	1	1	1	1
cage F2	0	0	1	1	1	2	2	3	3	**4**	4	4	5	5	5	5	6	6
cage F3	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
cage F4	0	5	8	10	12	14	15	16	17	**18**	19	19	20	21	21	22	22	23
csize F3	2	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Acous cs cl	0	0	0	0	0	0	1	1	1	**1**	1	1	1	1	1	1	1	1
Acous n cl	0	0	0	0	0	0	0	0	1	**1**	1	1	1	1	1	1	1	1
CPUE cs cl	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	1	1	1	1
DEPM cs cl	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Acous pe	0	2	3	3	4	5	5	5	6	**6**	7	7	7	7	8	8	8	8
CPUE pe	3	2	1	1	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
CPUE ch	2	2	1	1	1	1	1	1	1	**0**	0	0	0	0	0	0	0	0
CPUE eu	0	0	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1
CPUE ussr	0	0	1	1	1	2	2	2	2	**2**	3	3	3	3	3	3	4	4
cage index	5	3	2	2	2	1	1	1	1	**1**	0	0	0	0	0	0	0	0
sel fsh	0	1	2	3	3	4	5	6	6	**7**	8	8	9	9	10	10	11	11
sel index	0	0	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1
Rec like	295	158	97	63	42	28	18	11	7	**3**	1	0	0	0	1	2	3	4
F penalty	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Post prior indq	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Post prior	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
residual	3	2	1	1	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Total	268	131	73	42	24	13	6	3	1	**0**	0	2	3	6	8	11	14	17

5. References

Francis, R. I. C. 2011 Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138 (2011).

Lee, H. H., Piner, K. R., Methot, R. D., Maunder, M. N. 2014. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: An example using blue marlin in the Pacific Ocean. Fisheries Research 158 (2014) 138–146.

Wang, Sheng-Ping, Mark N. Maunder, Kevin R. Piner, Alexandre Aires-da-Silva, Hui-Hua Lee. 2014. Evaluation of virgin recruitment profiling as a diagnostic for selectivity curve structure in integrated stock assessment models . Fisheries Research 158 (2014) 158–164.

Maunder, Mark N., and Kevin R. Piner. 2015. Contemporary fisheries stock assessment: many issues still remain. ICES Jour. Mar. Sci., 72 (1): 7-18.