Short Summary of CMSY Workshop Results, Aristotle University of Thessaloniki, 6-8 November 2019

Written by Rainer Froese, November 2019

Participants: Rainer Froese, GEOMAR (Chair); Athanassios Tsikliras, AUTH, (Host); Giuseppe Scarcella, CRN; Henning Winker, DAFF; Nazli Demirel, IU; Rishi Sarma, FAO; Donna Dimarchopoulou, AUTH; Maria Lourdes Palomares, UBC (remotely); Gianpaolo Coro, CRN (remotely).

The purpose of the workshop was to update the CMSY software for estimating exploitation and stock status from catch and resilience, taking into account lessons learned in applications to over 1000 stocks globally and from recent development of two additional data-poor methods, LBB for estimating stock status from length-frequencies and AMSY for estimating stock status and exploitation from abundance and resilience. Especially, the goal was to (1) introduce a multivariate normal distribution for r and k priors in log space, (2) simplify the estimation of the most probably r-k pair, (3) review the graphical output, (4) add more analytical graphs, and (5) review the implementation of the Bayesian Schaefer Model (BSM) which is part of the CMSY package and especially introduce the multivariate normal distribution of r-k priors in log space and fix the previously too-narrow confidence limits. Also, (6) CMSY results were to be compared with those of the sra+ model used by FAO.

1) A multivariate normal distribution for r and k priors had been proposed by the reviewers of the AMSY publication and had proven useful there. An analysis of 140 stocks analyzed with BSM showed a posterior correlation between r and k in log space of -0.607. This was used together with the standard deviations derived from prior ranges of r and k to create a corresponding cloud of potential r-k pairs to be analyzed by CMSY. As a result, after CMSY Monte-Carlo filtering, viable points that are compatible with the priors and the catch data now show an ellipsoid shape rather than the hard-bound triangular shape of the original CMSY (Figure 1b).
2) The original CMSY implementation used a relatively complicated procedure to detect the most likely r-k pair near the tip of the original triangle of viable r-k pairs. With the new typical "carrot" shape of viable r-k pairs as an ellipsoid with a thicker upper-left portion and a narrower lower-right portion (Figure 1b), the most likely r-k pair is now determined as the 75^{th} percentile of all viable r and the 25^{th} percentile of all viable k. The upper approximate 95% confidence limit of r is now determined as the $97.5+1.25=98.75^{th}$ percentile, with the lower confidence limit set to equal distance to the most likely r value in log space. Similarly, the lower approximate 95% confidence limit of k is determined as $2.5-1.25=1.25^{th}$ percentile, with the upper approximate 95% confidence limit set to equal distance to the most likely k value in log space. This determination of the most likely r-k pair takes into account the non-symmetric distribution of viable r-k pairs and showed good agreement in comparison with results of BSM for 124 stocks selected as test cases.
3) The existing graphical output of CMSY/BSM was reviewed and found overall satisfactory. Additions were the expanded ranges for showing the multivariate r-k prior space with indication of the provided r-k prior ranges (dashed rectangle in Figure 1b), indications of CMSY (blue cross) and BSM (red cross) best estimates already in Figure 1b for easy comparison with r-k prior space, showing of estimated relative biomass trajectories in Figure 1c together with the observed CPUE values (if available), and an inversion of the x-axis in Figure 1f, together with indication of first and last year in the time series.
4) It was agreed to add the following optional analytical graphs after the workshop: a) a retrospective analysis of management results (CMSY or BSM) with the last 1-3 years omitted

from analysis to evaluate the influence of recent data (to be done by GP); b) a graph comparing observed and predicted values of catch and CPUE (if available) (to be done by HW); c) and a graph showing prior, data and posterior distributions for r, k, and B/Bmsy (to be done by HW).

5) In BSM, a multivariate distribution of r-k priors in log space was introduced by taking a beta-distribution around the median log r-k correlation of -0.607, based on the examined posterior correlations in 140 stocks. Also, the interpretation of the prior k and q ranges was changed to reflect 4 (rather than 8) standard deviations in log-space, reflection more uncertainty and leading to extended and more realistic confidence limits of r and k in BSM results (Figure 1 c). Also, a new option was introduced where the user can determine whether BSM uses only the first, or the first and intermediate, or first, intermediate and file depletion priors for analysis. This is useful for setting and exploring the influence of the priors on BSM results.
6) A comparison of CMSY and sra+ results for selected stocks showed reasonable agreement for the start and end values (with a slightly more optimistic final depletion result in sra+), but in some cases strong deviation in intermediate sra+ results because sra+ lacks the intermediate relative biomass prior of CMSY. Also, intermediate sra+ predictions for exploitation showed very wide approximate confidence limits, e.g. ranging from zero to multiples of Umsy (proxy for Fmsy). Note that options for forcing it to follow a mid-point depletion are available (but were not tested in batch mode due to differences across stocks), and would provide very similar results as CMSY. The overall algorithms are very similar to CMSY (based on Stock Reduction algorithm), and the surplus production model (JABBA) is also implemented in SRA+ (same as BSM in CMSY), as well as other features like a Fishery Management Index (FMI) based prior on depletion, and Swept Area Ration (SAR) prior on depletion.

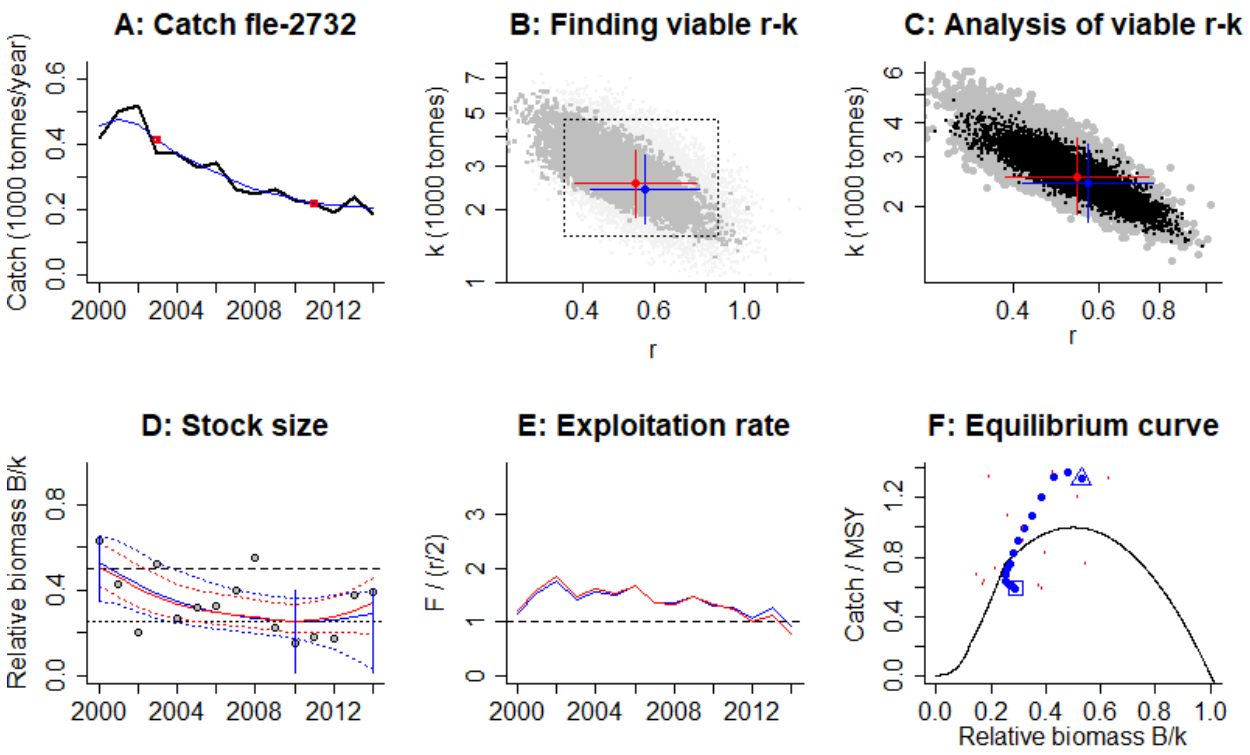

Figure 1. Standard output of CMSY, as modified during the workshop. A shows catch as provided (black) and smoothed, with red min and max values 3 years away from the end points; B shows the multivariate potential r-k pairs in log space in light grey, the dotted square shows the prior ranges containing 95% of the prior points, the dark grey dots showing the 'viable' r-k pairs based on CMSY, the blue cross shows the best r-k pair with approximate 95% confidence ranges, and the red cross shows the best BSM estimate. C is a comparison of the most likely CMSY and BSM r-k pairs; D shows the CPUE input time series as dots, in blue relative biomass predicted by CMSY and in red the one predicted by BSM; E shows predicted exploitation in blue for CMSY and in red for BSM; F shows predicted relative catch over relative biomass in comparison to the equilibrium parabola. Blue are CMSY predictions with rectangle for start and triangle for last year, and red is observed CPUE.