**EqSimWHM Simulations**

The code developed by ICES for the estimation of MSY based reference points (known as *EqSim*) has been modified in order to carry out simulations for exploring potential Western Horse Mackerel management strategies.

The ICES github repository for *EqSim* can be found here

<https://github.com/ices-tools-prod/msy>

In addition to the source code, it contains a useful description of the software and it’s use.

For the purposes of this exercise, the base code has been modified. Developments are contained in the WKREBUILD github repository

<https://github.com/ices-eg/wk_WKREBUILD/tree/master/EqSimWHM>

The principal updates are to

1. Enable initialisation of a simulation from a number of population replicates. As a long term equilibrium simulation tool, EqSim by default uses the point estimates from a recent stock assessment. However, as we are more focussed on the near term, it is more appropriate that the current assessment uncertainty is represented.
2. Allow development of alternative harvest rules (base EqSim scans over a range of fishing mortalities, projecting forward with a constant F or applying the ICES advice rule).
3. Encapsulate information on operating model and management procedure settings.
4. Apply constraints during the projection *e.g.* catch constraints, IAV limitations, min/max TAC
5. Generate a suite of statistics/plots

Stock-recruit modelling

The eqSim function eqsr\_fit is used to fit candidate functional forms to the SBB-Recruit pairs estimated by the WGWIDE 2019 assessment. The base case scenario for these simulations fits a constrained segmented regression (breakpoint is constrained at Blim), using WGWIDE 2019 recruitment estimates from 1995-2017. The terminal (2018) value is highly uncertain and is not considered. In addition, data prior to 1995 corresponds to a period when the stock dynamics were heavily influenced by the extraordinary 1982 year-class and is also disregarded (consistent with the approach adopted by the IBP established to estimate reference points in 2019).

The function eqsr\_fit generates 1000 realisations based on bootstrap resamples of the data and the functional forms to fit. The fit can be plotted using eqsr\_plot, supplying the object returned by eqsr\_fit.



Initial populations

Based on the parameter estimates and covariance matrix from the SS3 update assessment carried out in 2019, a sample of 1000 sets of parameter values are drawn from a multivariate normal distribution (using the mvrnorm function from R’s MASS package). SS3 is then rerun for each parameter set and to generate 1000 replicates of numbers at age. These are used to generate 1000 FLStock objects which are appended to the list object generated by eqsr\_fit(), the primary input for the call to eqsim\_run.

Stock and Catch Weights, Selectivity

EqSim incorporates stochasticity in catch and stock weight and selectivity at age by resampling from or averaging over from a defined historical period. The default period is the most recent 10 years although this can be shortened in the event there have been significant changes in these data. The data is derived from the FLStock object upon which the SRR fit was performed.

The SS3 assessment is not configured to directly use the catch and stock weights at age (fitting a time invariant LW relationship to the time series) and hence the time series of catch and stock weight at age was manually inserted into the stock object in order that they were available to eqsim\_run(). The time series of catch and stock weight at age is shown below. The red line corresponds to the SS3 time invariant estimate.

Catch Weight



Stock Weight



Weights have been relatively stable in the recent past such that the last 10 years is the period selected from which to select weight at age for the simulation. The same approach is used for selectivity.

Natural mortality is assumed to be time and age invariant (0.15)

Simulation start date

The simulation begins on 1/1/18.

Catch constraints are applied in each of 2018 (101672 – WGWIDE 2019 estimate), 2019 (110381 – STF estimate at WGWIDE 2019) and 2020 (83954t – ICES advice) such that the first management year of the simulation is 2021.

By default, eqSim runs projections over a range of target fishing mortalities, each for 200 years with output from the final 50 years used for analysis. The code has been modified such that the target F can be modified by a bespoke HCR function. For this exercise, the projection time has been reduced to 50 years. Additional functionality has been developed to retrieve statistics, both annual values and also for predefined periods e.g. short, medium and long term year ranges.

Assessment and Advice Error

The estimates of the parameters for assessment and advice error required by eqSim are Fcv=0.215, Fphi=0.03. The basis for these calculations can be found in the github repository <https://github.com/AndyCampbell/WHMFcvphi_SSBcvphi>