# DEVELOPMENT OF THE SCAS (STATISTICAL-CATCH-AT-SIZE) SOFTWARE[1]

October 2021

Tom Nishida[1/], Toshihide Kitakado[2/] and Kazuharu Iwasaki[3/]

*1/ Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Shizuoka, Japan (aco20320@par.odn.ne.jp)*
*2/ Tokyo University of Marine Science and Technology, Tokyo, Japan*
*3/ Environmental Simulation Laboratory Inc., Saitama, Japan*

**Abstract**

We have been developing Statistical-Catch-At-Size (SCAS) software since 2019 to improve our previous joint Age Structured Production Model (ASPM)/Statistical-Catch-At-Age (SCAA) software because of problems of uncertainties in the estimated CAA and usage of model-free selectivity. SCAS is integrated age-structured stock assessment model based on abundance indices and size composition data, and implemented by an AD Model Builder like Stock Synthesis 3 (SS3) and the ASPM/SCAA software. This SCAS software uses simpler specifications than in SS3, i.e., the season aggregated model without spatial components, thus requires less numbers of inputs and parameters to be estimated. The SCAS software has two parts, [Part I] Point estimation and [Part II] Uncertainties and Risk assessments. In each Part, there are three menus, i.e., [Part I]: (a) Grid search, (b) Initial graphs, (c) Diagnoses (retrospective analyses) and [Part II]: (d) Markov Chain Monte Carlo (MCMC), (e) Diagnoses (hindcasting), and (f) Final graphs. As this software is based on the simpler specification than in SS3 and driven by menus thus no programming is required. Hence this software is suitable for those who wish to run the simpler integrated stock assessments. This document describes the progress on menus (a) and (b) and the plans for the remaining menus, which are due for completion in 2022.

**Contents**



---

[1] ***Submitted to the IOTC WPTT23 (AS) (October 25-30, 2021) (online)***

# 1. INTRODUCTION

## 1.1 Backgrounds

The first IOTC Working Party of Method (WPM) took place in the IRD office, Sète, France in 2001. The WPM01 discussed what types of stock assessment models need to be applied for the most important IOTC tuna species such as yellowfin tuna and bigeye tuna under the biological data limit situation especially size data at the beginning stage of the Scientific Committee (SC) started in 1998. After the extensive discussion, the WPM01 recommended to apply Age-Structured Production Model (ASPM) as the assumed selectivity can be substituted without any size data.

Since then, ASPM was used for stock assessments of yellowfin tuna, bigeye tuna and albacore. Initially the FORTRAN implemented ASPM developed by Restrepo (1997) in ICCAT was used (2002-2009). Afterwards the AD Model Builder implemented ASPM software was developed by Rademeyer and Nishida (ver. 1 in 2010 and ver. 2 in 2012) driven by menus. Later we improved the software in ver. 3 (Nishida and Kitakado, 2014) to be able to execute Statistical-Catch-At-Age (SCAA) within the same software as more size data became available and CAA could be used. As a result, the ASPM/SCAA software was used in the past 18 years (2002-2019). To 2014, results of ASPM, SCAA, SS3 and/or MFCL were used as the management advices for bigeye tuna, yellowfin tuna, and albacore tuna. Afterwards, results of SS3 were used for the primary advices, while results of SCAA/ASPM and/or other models were utilized as the supporting information for SS3.

We had been recognizing the problems on the estimated CAA including biases and the model free selectivity in the SCAA part of the software. To solve these problems, we started to develop the size based SCAS software in 2019 incorporating models for selectivity, and plan to complete all functions in 2022. This document describes the progress of the development of the SCAS software to now.

## 1.2 Objectives

SCAS that we are currently developing is the annual based model without considering spatial components (movements), while SS3 is the quarterly based model incorporating spatial components such as movements. If the quarterly and movements information is less biased, SS3 will provide more plausible results than SCAS as such detail information are fully incorporated, unless otherwise, the situation will be vice versa. Therefore, it is important to compare results between two models to evaluate reliability of results. It is also ideal to compare with other stock assessment models with different specifications such as productions models for more meaningful evaluations. In fact, these comparisons have been recommended by the SC and taken place in various stock assessments in IOTC.

SS3 needs to estimate many parameters due to the quarterly and space-based (complex) model, while SCAS requires less parameters as it is the simpler integrated model. It is noted that the maximum number of information to be entered to the SCAS is 73 (> 200 for SS3) and the maximum number of parameters to be estimated is 7 (> 50). Hence, time (duration) for one SCAS run is much shorter than SS3, so that users can explore large numbers of grids in a short time.

Under such circumstances, the main objective of this menu driven SCAS software development is to provide to those who wish to run the simpler integrated age structured stock assessment model based on size with the simpler specifications and also to compare results of other stock assessments especially to SS3.

## 2. OUTLINE OF THE SOFTWARE

Fig. 1 shows the flowchart of the SCAS software including two parts, i.e. [Part 1] Point estimation and [Part II] Uncertainties and risk assessments. In each part, there are three menus to implement various tasks (Fig. 2). The outline of two parts of this software is described as below.

### [Part I] Point estimation

This part will execute various SCAS runs typically for the base case and sensitivities, to estimate parameters using six input files. For this task, [a] the grid search menu automatically implements the batch job by following combinations of five parameters, i.e., steepness, M (natural mortality), depletion, σ (recruitment deviation) and/or CAS weight. All results (outputs) are stored in the excel file (for details, refer to Fig. 5, page 9). Users will select the most optimum run referring to the excel output file including criteria and references for selection, i.e., error messages, likelihood, $r^2$, and graphs made by [b] the initial graph (menu) including residuals, time series of various parameters, Kobe plot etc. The most optimum run selected may be the base case, one of sensitivities or the combined (integrated) one among them. Finally, users will conduct the diagnostics to evaluate results (robustness, accuracy and reliability of parameters estimated and fitness to the models) using Jitter analysis, residual analyses, [c] the retrospective analyses (menu), R0 likelihood profile and ASPM analyses for the integrated models if applicable. If results are not satisfied, users need to select the other optimum point estimation until diagnostic analyses satisfy the results.

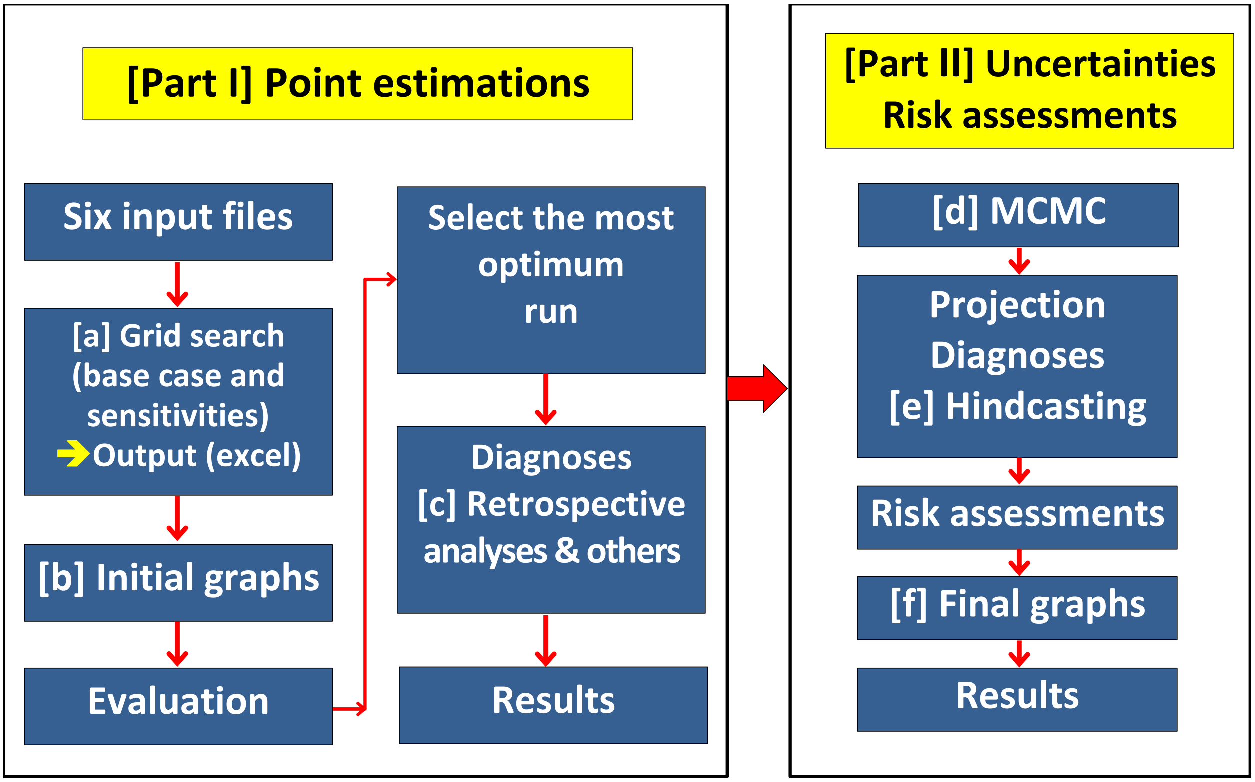



Fig. 1 The flowchart of the menu driven SCAS software

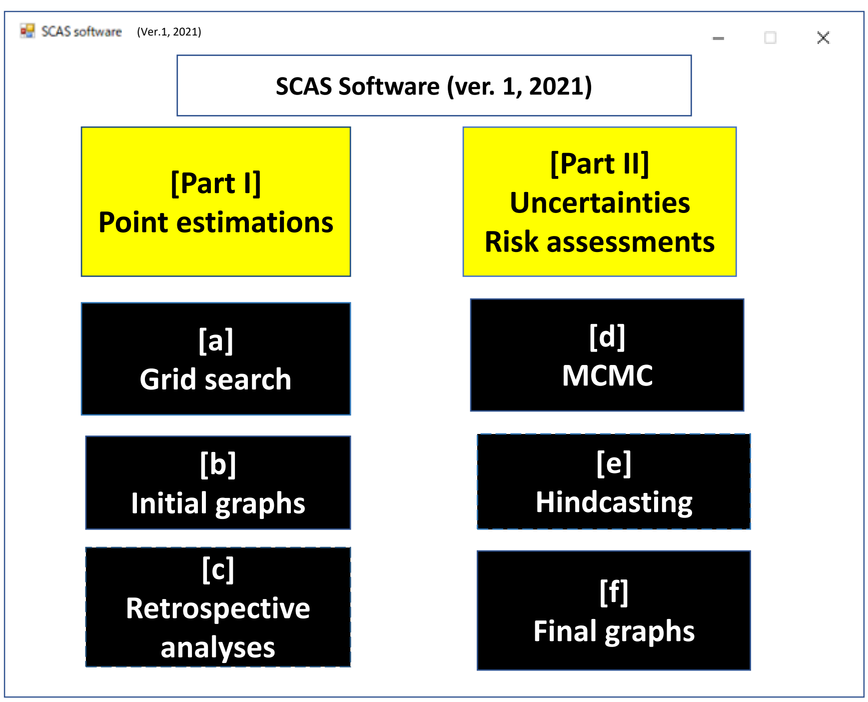



Fig. 2 Six menus in the SCAS software

*(Note) [a] & [b] has been completed, while others are partially completed. The whole software will be completed in 2022.*

### [Part II] Uncertainties and Risk assessment

Using the most optimum point estimation selected in [Part I], MCMC will be implemented to evaluate uncertainties around the point estimate, then future projections will be estimated on total biomass and F under the current catch level, then uncertainties around the projection are evaluated. Then hindcasting analyses will be conducted using [e] the hindcasting (menu) to evaluate the projection. Finally, risk assessments (Kobe II) will be implemented to estimate risk probabilities (%) violating MSY levels of biomass and fishing mortality (F) by different catch levels in the projection period. This will be the important source for management advice. Finally, final graphs for the report will be made using [f] the final graph (menu) to depict trends and show relevant parameters with uncertainties, so that results are easily understood.

# 3. [PART I] INPUT FILES

## 3.1 Input files

There are six input files to run the SCAS software as shown in Fig 3. The actual contents of files and detail descriptions are provided in Annex A using the sample data. Table 1 shows the list of the information to be entered to the 6 input files of the SCAS software.

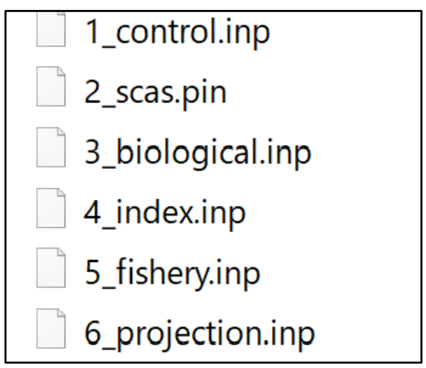



Fig.3 Six input files in the SCAS software

Table 1 List of input information (codes, values, and numbers) to be entered to the 6 input files of the SCAS software (max. 73 entries and max. seven parameters to be estimated).

*(Note1) Yellow marker indicates default codes, numbers or values, while sky blue marker for parameters to be estimated.*

*(Note2) If parameters need to be estimated, any positive integers will be assigned, while, for the non-estimation option, any negative integers.*

| Input file name | Section | Information | Information to be entered | | | Contents |
|---|---|---|---|---|---|---|
| | | | Code | Default value/example | No. of entries | |
| *1_Control.inp* | 0 | Verbose | 0 or 1 | | 1 | # 1 to write out stuff while running or 0 not to write |
| | 1 | year, age, size & fleet | | | 7 | # 1st year, # Last year, # Min age, # Plus group age, # Min size (cm) =1, # Max size (cm) and # No. of fleets. |
| | 2-1 | S-R relation | 1 or 2 | | 1 | # SR relation 1=Beverton-Holt or 2=Ricker |
| | | | | 1950 (e.g.) | 1 | # First year with recruitment residuals |
| | | | | 2020 (e.g.) | 1 | # Last year with recruitment residuals |
| | | | | 0.6 or estimated | 1 | # Standard deviation for recruitment (sigma R). Deterministic model if sigmaR=0 |
| | 2-2 | Growth eq. | 1 or 2 | | 1 | # Select growth function (1=VB, 2=Two-stanza) |
| | 3 | Initial population | 1 or 2 | | 1 | # Initial condition (1=pre or 2= after exploitation) [note] 1 means the virgin stock. |
| | | | | 8 (e.g.) | 1 | # If initial condition=2, the maximum age to estimate |
| | 4 | Error(catch) | | 0.2 | 1 | # Sigma (standard deviation) for the catches |
| | | Error (CAS) | | 0.02 | 1 | # Minimum proportion for CAS |
| | | | 1 or 2 | | 1 | # CAS error type: 1=adj log-normal (Punt-Kennedy) 2=sqrt(p) (approximation of multinomial) |
| | 5 | Selectivity | | | 1 | # Fleet number |
| | | | 1 or 2 | | 1 | # Shape (1=logistic, 2=double logistic), |
| | | | | | 1 | # Number of selectivity changes |
| | | | | | 1 | # Years selectivity changes for each fleet |
| | | | 1 or 2 | | 1 | # Dynamic MSY (1=yes, 2=fixed) [Note] when 1 is selected, MSY by year will be estimated, while, for 2, only one MSY for the last year will be estimated. |
| | 6 | Phase of parameter estimation | | | 1 | # Phase for estimation of M |
| | | | | | 1 | # Phase for estimation of steepness |
| | | | | | 1 | # Phase for estimation of TB0 if the initial condition =1 (virgin) in Section 3. |
| | | | | | 1 | # Phase for estimation of the numbers-at-age in the first year (from age-at-recruitment+1 to mm) |
| | | | | | 1 | # Phase for estimation of phi (initial F) *(see 2_scas.pin)* |
| | | | | | 1 | # Phase for estimation of indices additional variance |
| | | | | | 1 | # Phase for estimation of recruitment residuals |
| | | | | | 1 | # Phase for estimation of Bi (growth eq.) |
| | | | | | 1 | # Phase for estimation of commercial selectivity by fleet |
| | 7 | Weight for CAS | | | 1 | # Weight for CAS by fleet [note] Small decimal (for example 0.1) is suggested. |

*(Table 1 continued)*

| Input file name | information | Information to be entered | | | Contents |
|---|---|---|---|---|---|
| | | Code | Value | No. of entries | |
| *2_scas.pin* | TB0 | | Guess value (Log$_e$ TB0) | 1 | # Log of virgin TB (tons) if the initial condition =1 (virgin) in Section 3 and the positive integer *in Section 6, 1_Control.inp file*. |
| | Initial population size | | Guess value log$_e$ TN (age 0) log$_e$ TN (age 1) | 2 | # Initial population size for age 0 and 1 (number) when the initial condition=2 is selected in *Section 3, 1_Control.inp file*. [note] Log$_e$ TN (age 0) < 20 |
| | Initial F | | Guess value | 1 | # Initial F |
| | Additional variance (CPUE CV) | | 0.1 | 1 | # add variance to CPUE CV (0.2) if the phase for estimation of indices additional variance is positive integer (*Section 6, 1_Control.inp file)* |
| | Additional variance (Recruitment residuals) | | 0.2 | 1 | # Add variance to sigma if phase for estimation of recruitment residuals is the positive integer (*Section 6, 1_Control.inp file)* |
| | Selectivity | | Guess values | 1 | # Selectivity: enter parameters of selectivity by fleet |
| *3_Biological.inp* | Steepness (h) | | 0.7-0.9 or estimated | 1 | # h value if # Phase for estimation of h is the positive integer *in Section 6, 1_control.inp.* |
| | Natural mortality (M) | | Fixed values or estimated | 1 | # M vector by age if # Phase for estimation of M is the positive integer i*n Section 6, 1_control.inp.* |
| | CAS (CV) | | 0.2 | 1 | # Enter the value (0.2 for default) |
| | Growth equation (parameters) | 1 or 2 | | 1 or 4 | # Parameters for VB (∞ and Kappa) if code=1 or parameters for 2 stanza (∞,Kappa1, Kappa2, Alpha and Beta) if code=2 *(refer to Section 2.2, Control.inp)* |
| | Fraction of mortality | | 0 | 1 | # Fraction of mortality that occurs before spawning |
| | Maturity-at-age | | | 1 | # Maturity-at-age vector by age (%) |
| | LW relation | | | 1 | # 2 parameters for the LW relation |
| *4_Indiex.inp* | CPUE | | | 1 | # Number of index series |
| | | | | 1 | # Number of observations (years) for each index |
| | | | | 1 | # To which fleet the index corresponds to |
| | | 1,2 or 3 | | 1 | # Units (1=numbers, 2=biomass, 3=spawning) |
| | | | | 1 | # Timing (month in which index is taken) |
| | | | | 1 | # Minimum age indexed |
| | | | | 1 | # Maximum age indexed |
| | | | | 1 | # Weight given to each index |
| | | 1 or 2 | | 7 | # Compute sigma (=1), or use input CV (=2) |
| *5_Fishery.inp* | Catch | | | 1 | # Total catch in tons by fleet |
| | CAS | | | 4 | # Min and max length (cm)<br># Length classes (cm)<br># Number of CAS series (fleet)<br># Number of CAS vector for each series (fleet) |
| *6_Projection file* | Projection | | | 1 | # Number of years for projections |
| | | | | 1 | # Future catch for each fleet for projection |
| Max no. of input to be entered | | | | | 73 |
| Max no. of parameters to be estimated | | | | | 7 |

### 3.2 Grid search, output and selection of the plausible run

Applying the grid search menu, users can search the most optimum parameters from the base case and the sensitivity scenarios by setting minimum, maximum and intervals values of five key parameters i.e., CAS weight, h (steepness), B1/K (depletion), σ value (standard deviation in the spawner - recruit relation) and M (natural mortality). The grid search menu will automatically make the batch jobs for number of combinations of five parameters assigned. Fig. 4 shows one example of the batch job set-up, i.e., in this case, 16 runs will be conducted with CAS weightings (2 different values),σ(2), h(2) and B1/K(2).

If users want to make no combinations for particular parameters, untick relevant boxes in the batch job window (below), so that the parameter values set up in the input files set, will be read in the batch job. If users want to make a single run without any combination, use the DOS prompt and just type ‘scas’ then enter to make a single run.

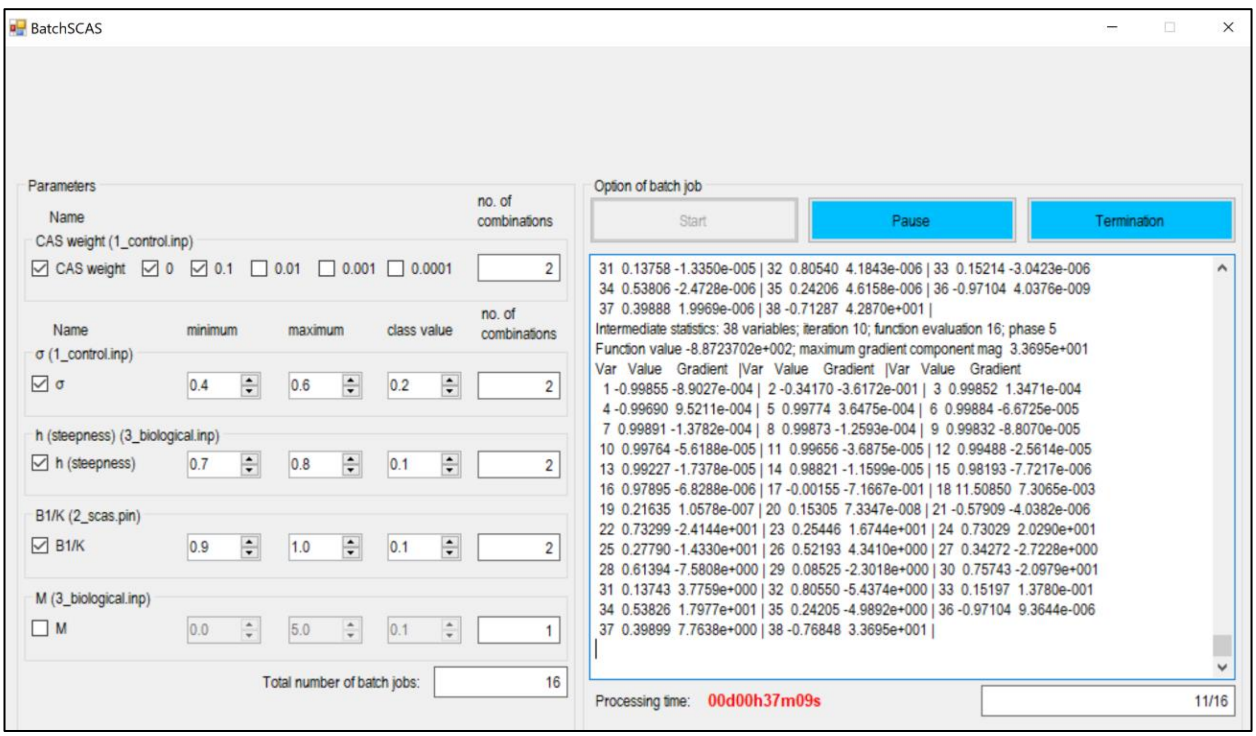



Fig. 4 Batch job window showing the sample set-up of five parameters and the actual runs.

The output (results) in all batch job runs will be stored in one excel file composed of two sheets, i.e., (a) results with convergences and (b) results without convergences and/or errors (Fig. 5). Estimated parameters and results in the output are shown in Fig. 5. Non conversion results in the lower Table 5, are indicated by *'Warning -- Hessian does not appear to be positive definite'* in the error message. Yellow markers in Error Message indicate that estimated parameters are out of ranges. For example, extreme values, MSY > SSB (current) etc. Using the converged results (the upper panel in Table 5), users will evaluate and select the most optimum run by referring to likelihood, and parameters values estimated.

| Time | 00h30m | No. of jobs | 10 | Average | 3.1 | min/job |
|---|---|---|---|---|---|---|

| | Range (step) of 5 parameters | | | | | Likelihood components | 1,000 tons |
|---|---|---|---|---|---|---|---|
| | CAS weight | Sigma (SR) | h (steepness) | depletion (B0/K) | M | | |
| | 0,0.1,0.01 | 0.3-0.6 (0.1) | 0.7-0.9 (0.1) | fixed | fixed | | |

| Run no. | CAS weight | Sigma (SR) | h (steepness) | depletion (B0/K) | M | Total | Indices | CAS | SR_fitS | CT_fits | r2 | SSB0 | SSBmsy | SSB (current) | MSY | Catch (current) | Depletion | SSB /SSBmsy | F/Fmsy | Error Message |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 0.1 | 0.4 | 0.7 | 0.82 | | -1019 | -4 | -867 | 5 | -153 | | 585 | 164 | 205 | 38 | 34 | 0.35 | 1.25 | 0.78 | |
| 19 | 0.1 | 0.5 | 0.7 | 0.82 | | -1004 | -4 | -868 | 20 | -153 | | 614 | 142 | 227 | 47 | 34 | 0.37 | 1.59 | 0.54 | |
| 24 | 0.1 | 0.6 | 0.9 | 0.82 | | -991 | -5 | -867 | 33 | -153 | | 672 | 92 | 262 | 63 | 34 | 0.39 | 2.84 | 0.28 | |
| 25 | 0.01 | 0.3 | 0.7 | 0.82 | | -262 | -6 | -85 | -18 | -153 | | 538 | 168 | 142 | 31 | 34 | 0.26 | 0.85 | 1.27 | |
| 28 | 0.01 | 0.4 | 0.7 | 0.82 | | -243 | -8 | -85 | 3 | -153 | | 537 | 160 | 132 | 33 | 34 | 0.25 | 0.83 | 1.19 | |
| 29 | 0.01 | 0.4 | 0.8 | 0.82 | | -243 | -8 | -85 | 3 | -153 | | 537 | 160 | 132 | 33 | 34 | 0.25 | 0.83 | 1.19 | |
| 31 | 0.01 | 0.5 | 0.7 | 0.82 | | -228 | -10 | -85 | 19 | -153 | | 544 | 155 | 124 | 35 | 34 | 0.23 | 0.80 | 1.13 | |
| 32 | 0.01 | 0.5 | 0.8 | 0.82 | | -228 | -10 | -85 | 19 | -153 | | 545 | 155 | 125 | 35 | 34 | 0.23 | 0.80 | 1.13 | |
| 35 | 0.01 | 0.6 | 0.8 | 0.82 | | -216 | -11 | -84 | 32 | -153 | | 570 | 157 | 122 | 38 | 34 | 0.21 | 0.78 | 1.07 | |
| 34 | 0.01 | 0.6 | 0.7 | 0.82 | | -214 | -11 | -83 | 32 | -153 | | 466 | 106 | 89 | 36 | 34 | 0.19 | 0.83 | 0.99 | |

(note) M Values in 3_biological.inp were used as they were not assigned in the batch job, I.e. 0.4000 0.3552 0.3104 0.2655 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207

Converged | Not converged or Errors

| Time | 01h07m | No. of jobs | 25 | Average | 2.7 | min/job |
|---|---|---|---|---|---|---|

| | Range (step) of 5 parameters | | | | | Likelihood components | 1,000 tons |
|---|---|---|---|---|---|---|---|
| | CAS weight | Sigma (SR) | h (steepness) | depletion (B0/K) | M | | |
| | 0,0.1,0.01 | 0.3-0.6 (0.1) | 0.7-0.9 (0.1) | fixed | fixed | | |

| Run no. | CAS weight | Sigma (SR) | h (steepness) | depletion (B0/K) | M | Total | Indices | CAS | SR_fitS | CT_fits | r2 | SSB0 | SSBmsy | SSB (current) | MSY | Catch (current) | Depletion | SSB /SSBmsy | F/Fmsy | Error Message |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.3 | 0.7 | 0.82 | | -168 | -1 | 0 | -15 | -153 | | > 10,000 | > 10,000 | > 10,000 | > 10,000 | 34 | 0.78 | 1.56 | 0.00 | Warning -- Hessian does not appear to be positive definite |
| 2 | 0 | 0.3 | 0.8 | 0.82 | | -169 | 4 | 0 | -21 | -153 | | 442 | 108 | 60 | 33 | 34 | 0.14 | 0.56 | 1.90 | Warning -- Hessian does not appear to be positive definite |
| 3 | 0 | 0.3 | 0.9 | 0.82 | | -184 | -14 | 0 | -18 | -152 | | 1227 | 372 | 226 | 71 | 34 | 0.18 | 0.61 | 1.21 | Warning -- Hessian does not appear to be positive definite |
| 4 | 0 | 0.4 | 0.7 | 0.82 | | -163 | -15 | 0 | 4 | -153 | | 5591 | 2642 | 2069 | 47 | 34 | 0.37 | 0.78 | 0.80 | Warning -- Hessian does not appear to be positive definite |
| 5 | 0 | 0.4 | 0.8 | 0.82 | | -162 | -14 | 0 | 4 | -153 | | 960 | 350 | 237 | 44 | 34 | 0.25 | 0.68 | 1.23 | Warning -- Hessian does not appear to be positive definite |
| 7 | 0 | 0.5 | 0.7 | 0.82 | | 9810 | 4624 | 0 | 5311 | -126 | | > 10,000 | > 10,000 | > 10,000 | < 1 | 34 | > 10 | > 10 | 0.00 | Warning -- Hessian does not appear to be positive definite |
| 8 | 0 | 0.5 | 0.8 | 0.82 | | -150 | -18 | 0 | 21 | -153 | | 1052 | 1052 | 225 | < 1 | 34 | 0.21 | 0.21 | 0.16 | Warning -- Hessian does not appear to be positive definite |
| 9 | 0 | 0.5 | 0.9 | 0.82 | | 239602 | 67 | 0 | 5388 | 234147 | | > 10,000 | > 10,000 | > 10,000 | < 1 | 34 | > 10 | > 10 | 0.00 | |
| 10 | 0 | 0.6 | 0.7 | 0.82 | | nan | 17 | 0 | 29 | nan | | < 1 | < 1 | < 1 | < 1 | 34 | > 10 | > 10 | > 10 | |
| 11 | 0 | 0.6 | 0.8 | 0.82 | | -119 | 3 | 0 | 29 | -152 | | 516 | 110 | 38 | 45 | 34 | 0.07 | 0.35 | 1.96 | Warning -- Hessian does not appear to be positive definite |
| 12 | 0 | 0.6 | 0.9 | 0.82 | | -138 | -19 | 0 | 33 | -152 | | 410 | 59 | 28 | 37 | 34 | 0.07 | 0.47 | 1.12 | Warning -- Hessian does not appear to be positive definite |
| 13 | 0.1 | 0.3 | 0.7 | 0.82 | | -1036 | -3 | -864 | -16 | -153 | | 562 | 170 | 189 | 34 | 34 | 0.34 | 1.11 | 0.98 | Warning -- Hessian does not appear to be positive definite |
| 14 | 0.1 | 0.3 | 0.8 | 0.82 | | -1036 | -3 | -864 | -16 | -153 | | 562 | 170 | 189 | 34 | 34 | 0.34 | 1.11 | 0.98 | Warning -- Hessian does not appear to be positive definite |
| 15 | 0.1 | 0.3 | 0.9 | 0.82 | | -1036 | -3 | -864 | -16 | -153 | | 562 | 170 | 189 | 34 | 34 | 0.34 | 1.11 | 0.98 | Warning -- Hessian does not appear to be positive definite |
| 17 | 0.1 | 0.4 | 0.8 | 0.82 | | -1017 | -4 | -866 | 5 | -153 | | 584 | 162 | 206 | 39 | 34 | 0.35 | 1.27 | 0.77 | Warning -- Hessian does not appear to be positive definite |
| 18 | 0.1 | 0.4 | 0.9 | 0.82 | | -1017 | -4 | -866 | 5 | -153 | | 584 | 162 | 206 | 39 | 34 | 0.35 | 1.27 | 0.77 | Warning -- Hessian does not appear to be positive definite |
| 20 | 0.1 | 0.5 | 0.8 | 0.82 | | -1003 | -4 | -866 | 20 | -153 | | 613 | 138 | 229 | 48 | 34 | 0.37 | 1.65 | 0.52 | Warning -- Hessian does not appear to be positive definite |
| 21 | 0.1 | 0.5 | 0.9 | 0.82 | | -1003 | -4 | -866 | 20 | -153 | | 613 | 138 | 228 | 48 | 34 | 0.37 | 1.65 | 0.52 | Warning -- Hessian does not appear to be positive definite |
| 22 | 0.1 | 0.6 | 0.7 | 0.82 | | 1390 | 301 | -170 | 1372 | -112 | | > 10,000 | > 10,000 | > 10,000 | > 10,000 | 34 | > 10 | > 10 | 0.00 | Warning -- Hessian does not appear to be positive definite |
| 23 | 0.1 | 0.6 | 0.8 | 0.82 | | -991 | -5 | -867 | 33 | -153 | | 672 | 92 | 262 | 63 | 34 | 0.39 | 2.84 | 0.28 | Warning -- Hessian does not appear to be positive definite |
| 26 | 0.01 | 0.3 | 0.8 | 0.82 | | -261 | -6 | -85 | -18 | -153 | | 540 | 168 | 143 | 31 | 34 | 0.26 | 0.85 | 1.27 | Warning -- Hessian does not appear to be positive definite |
| 27 | 0.01 | 0.3 | 0.9 | 0.82 | | -261 | -6 | -85 | -18 | -153 | | 550 | 173 | 147 | 31 | 34 | 0.27 | 0.85 | 1.27 | Warning -- Hessian does not appear to be positive definite |
| 30 | 0.01 | 0.4 | 0.9 | 0.82 | | -242 | -8 | -85 | 3 | -153 | | 553 | 167 | 138 | 33 | 34 | 0.25 | 0.83 | 1.20 | Warning -- Hessian does not appear to be positive definite |
| 33 | 0.01 | 0.5 | 0.9 | 0.82 | | -228 | -10 | -85 | 19 | -153 | | 548 | 156 | 126 | 36 | 34 | 0.23 | 0.81 | 1.13 | Warning -- Hessian does not appear to be positive definite |
| 36 | 0.01 | 0.6 | 0.9 | 0.82 | | -216 | -11 | -84 | 32 | -153 | | 570 | 157 | 122 | 38 | 34 | 0.21 | 0.78 | 1.07 | Warning -- Hessian does not appear to be positive definite |

(note) M Values in 3_biological.inp were used as they were not assigned in the batch job, I.e. 0.4000 0.3552 0.3104 0.2655 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207

Converged | Not converged or Errors

Fig. 5. Sample output of the batch jobs stored in one excel file composing of two sheets, i.e., (above) converged results, and (below) results with errors including non-convergences and/or errors (out of ranges) heighted by yellow markers.

### 3.3 Initial graphs

After users select the most plausible run, they can quickly check the key results by the graphs using [b] the initial graph menu. This menu will read key results available in the scas.rep (output) file containing all the results and produce relevant graphs automatically. Figs. 6-10 show five types of graphs to be produced by this application, i.e., "Basic results 1 (catch by fleet, catch vs. MSY, F vs. Fmsy and depletion)", "Basic results 2 (SSB vs SSBmsy, Spawner-Recruit relation and Kobe plot)", "Selectivity by fleet", "Fitness of CPUE" and "Fitness of the size frequency distribution", respectively. If users find unplausible trends of parameters and/or unplausible behaviors, then users need to re-select the optimum and plausible run.

### 3.4 Retrospective analyses

To evaluate the consistency of the point estimation, retrospective analyses can be conducted by its menu. This menu will be completed in 2022. Other relevant evaluation methods such as Jitter analysis, residual analyses, R0 likelihood profile and ASPM analyses (if applicable) can be done separately by users. Residual analyses can be conducted refereeing to graphs of residuals made by [b] initial graphs menu. If results are not satisfied, users need to consider other specifications to obtain reasonable point estimation until the results of the diagnostic analysis are satisfactory. If users want to make addition menus for other methods (Jitter analysis, residual analyses, R0 likelihood profile and ASPM analyses), we will consider to add these in the future.

## 4. [PART II] UNCERTAINTIES AND RISK ASSESSMENTS

4.1 MCMC
4.2 Projections and Hindcasting
4.3 Risk assessments (Kobe II strategic rusk matrix)
4.4 Final graphs

These four functions (menus) have been nearly completed and will be terminated in 2022.

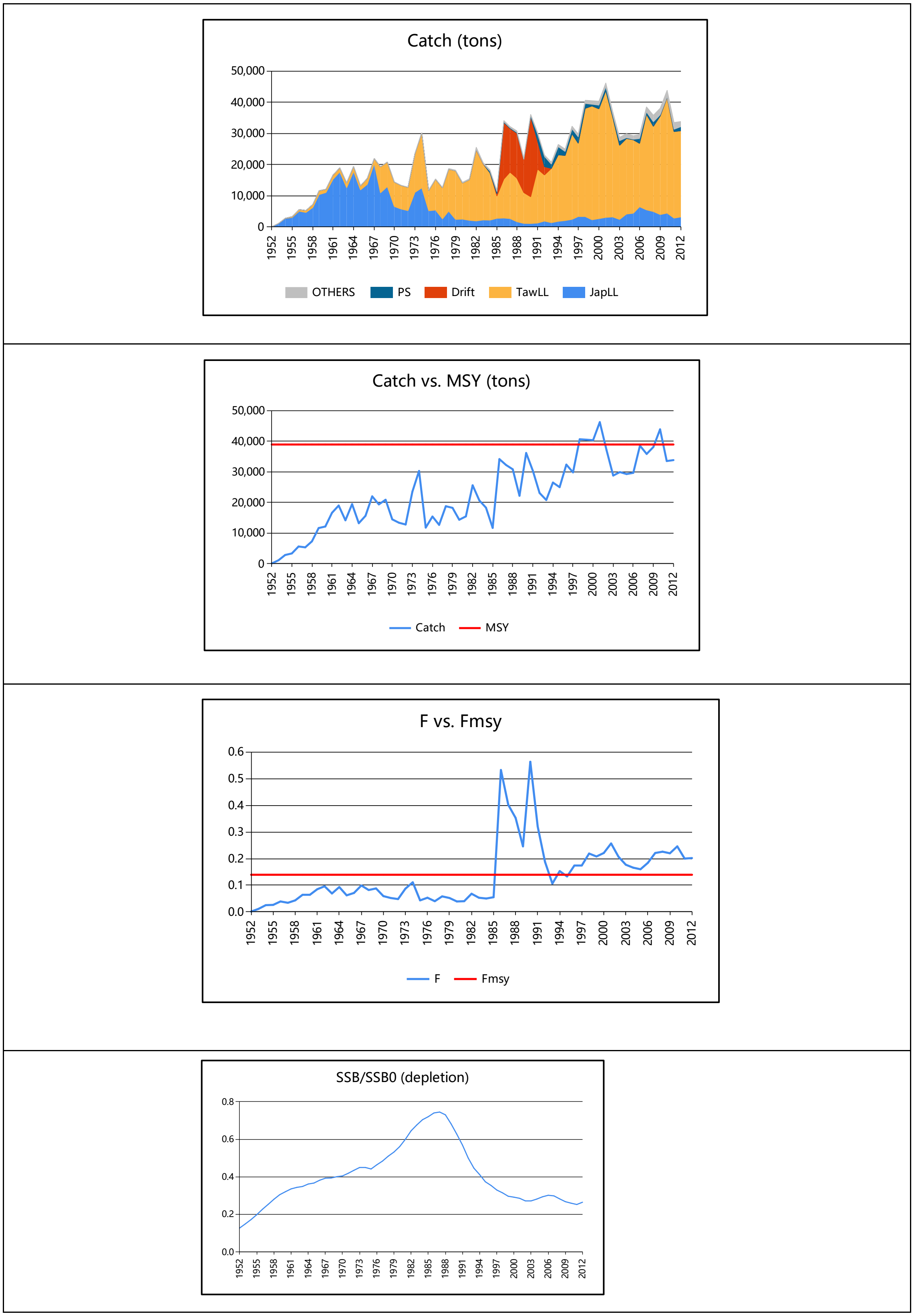



Fig. 6 Basic results 1 (example) *(catch, catch vs MSY, F vs. Fmsy and TB/TB0)*

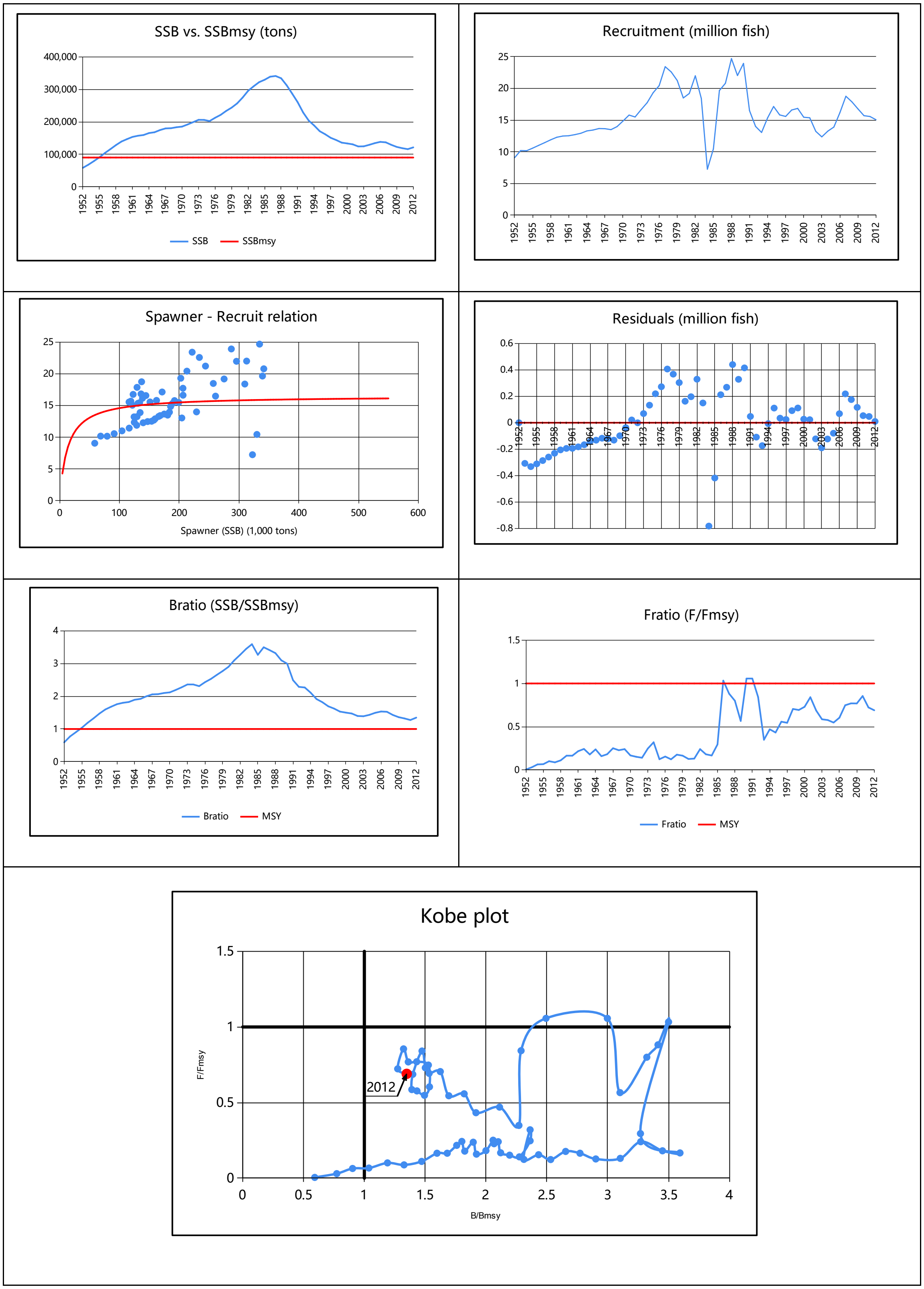



Fig. 7 Basic results 2 (example)

*(TB vs TBmsy, recruitment, Spawner-Recruit relation, TB/TBmsy, F/Fmsy and the Kobe plot)*

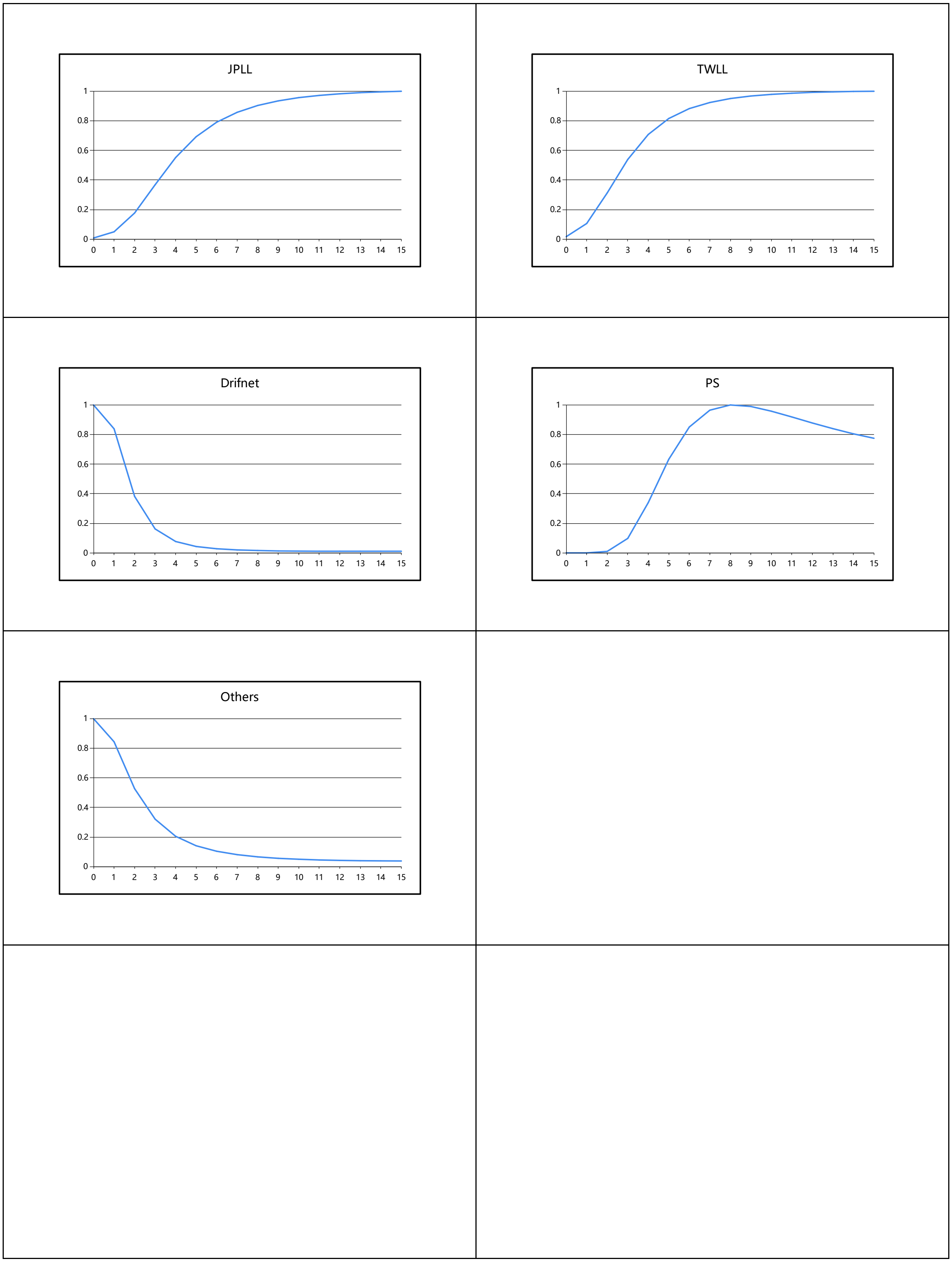
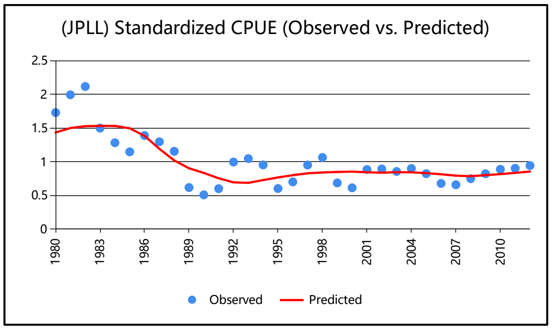



Fig. 8 Selectivity by fleet (examples)



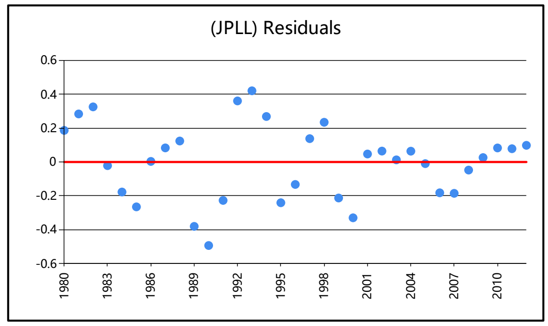




Fig. 9 Fitness of CPUE (example)

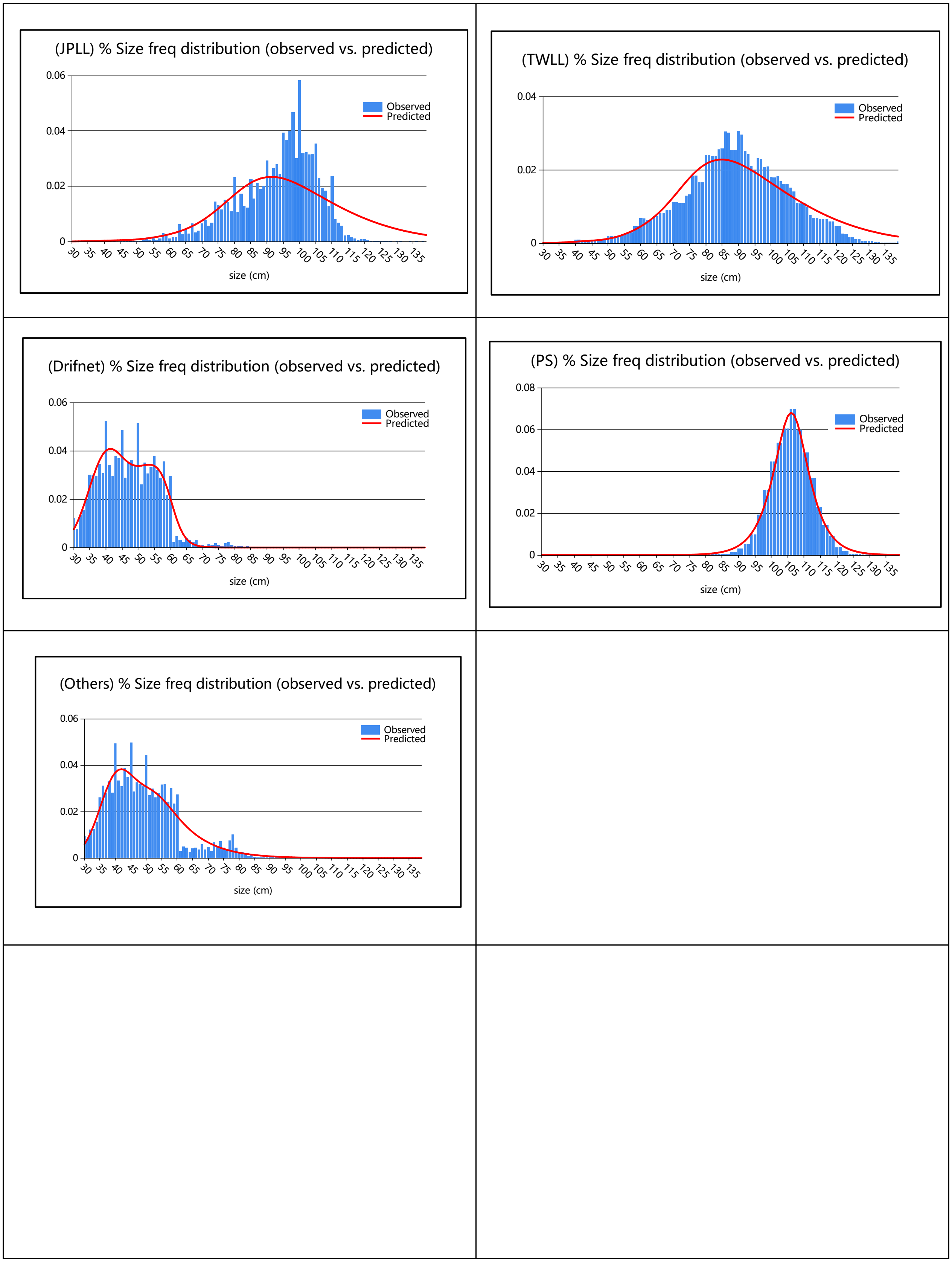



Fig. 10 Fitness of the size frequency distribution (examples)

## Acknowledgements

We sincerely appreciate Fisheries Resources Institute (*formerly National Research Institute of Far Seas Fisheries*), Japan Fisheries Research and Education Agency, to provide the fund for the SCAS software development project.

## References

IOTC (2001) Report of the IOTC ad hoc working party on methods, Sète, France 23-27, April, 2001.

IOTC (2018) Report of the 20th Session of the IOTC Working Party on Tropical Tunas, Seychelles. IOTC–2018–WPTT20–R[E].

Nishida, T., Rademeyer, R., Ijima, H., Sato, K., Matsumoto, T., Kitakado, T. and Fonteneau, A. (2012) Stock and risk assessments on yellowfin tuna (*Thunnus albacares*) in the Indian Ocean based on ADMB implemented ASPM and Kobe I + II software (IOTC–2012–WPTT14–40 Rev_2).

Nishida, T, Kitakado, T, Iwasaki, K. and Itoh, K. (2014) User's manual for AD Model Builder Implemented ASPM/SCAA joint software (Version 3, 2014) (IOTC-2014-WPTT16-54 REV_1).

Nishida T. and Kitakado, T. (2019) Preliminary stock assessments of albacore (*Thunnus alalunga*) in the Indian Ocean using Statistical-Catch-At-Age (SCAA) (IOTC–2019–WPTmT07(AS)–17).

Nishida, T. (2020) Stock assessment software for capacity buildings (CPUE standardization, ASPIC, Kobe plot and Risk assessment) *http://ocean-info.ddo.jp/kobeaspm/all(2020)*

Rademeyer, R. and Nishida, T. (2010 and 2012) Uses' Guide for AD Model Builder Implemented Age-Structured Production Model (ASPM) software. Ver. 1 (IOTC-WPTT13-2010-46 (rev 1)) and Ver.2 (IOTC-2012-WPM04-06).

Restrepo, V. (1997) A stochastic implementation of an Age-structured Production model (ICCAT/ SCRS/97/59), 23pp. with Appendix

# ANNEX A SIX INPUT FILES *(Example using the sample data)*

## A.1 Control file (*1_control.inp*)

In this control file, basic information controlling the SCAS run will be entered. There are seven sections as follows:

```
#------------------------------------------------------------------------------------------------------
# File 1: "1_control.inp"
#------------------------------------------------------------------------------------------------------
# Section 0: Just for pre-setting
# Section 1: Year, age, length, and number of fleets
# Section 2: Recruitment
# Section 3: Dynamics
# Section 4: Setting regarding quality/distribution of data
# Section 5: Selectivity
# Section 6: Phase (negative phase values mean "non-estimated" parameters
# Section 7: Likelihood setting
#------------------------------------------------------------------------------------------------------

#---------------------------------------------------------------------------------------------
# Section 0
0                        # Verbose (=1 to write out stuff while running)
#---------------------------------------------------------------------------------------------

#-------------------------------------------------------------------------------
# Section 1 Basic information
1952       # First year
2012       # Last year
0          # Minimum age
15         # Overall plus group age
1          # Minimum length considered
300        # Maximum length considered
5          # Number of fleets
#-------------------------------------------------------------------------------

#------------------------------------------------------------------------------------------------------------
# Section 2-1 SR relation
1          # Which stock-recruit shape (1=Beverton-Holt, 2=Ricker)
1953       # First year with recruitment residuals
2012       # Last year with recruitment residuals
0.6        # Standard deviation for recruitment (sigma R). Deterministic model if sigmaR=0
# Section 2-2
1          # Which growth function shape (1=VB, 2=Two-stanza)
#------------------------------------------------------------------------------------------------------------

#---------------------------------------------------------------------------------------------------------------------------------------
# Section 3 Initial population
1          # initial condition (1=at pre-exploitation/virgin level, 2=estimate N)
1          # if initial condition=1 then enter either the positive integer to estimate or the negative integer to fix.
           # If initial condition=2, then enter the maximum age to estimate
#---------------------------------------------------------------------------------------------------------------------------------------

#------------------------------------------------------------------------------------------------------------------------------------------------
# Section 4    Errors for catch and CAS
0.2        # Sigma for the catches (0.2 for default)
0.02       # Minimum proportion for CAS (0.02 for default)
1          # CAS error type (1=adj log-normal (Punt-Kennedy), 2=sqrt(p) (approximation of multinomial)) (1 for default)
#------------------------------------------------------------------------------------------------------------------------------------------------
```

```
#---------------------------------------------------------------------------------------------------------------------------------------------------------
# Section 5 selectivity
#    1      2      3      4      5       # Fleet
     1      1      2      2      2       # Shape (1=logistic, 2=double logistic)
     0      0      0      0      0       # Number of selectivity changes
1952 1952 1952 1952 1952                 # Years selectivity changes for each fleet
1                                        # dynamic MSY for Bratio and Fratio? (1=yes, 2=fixed)
#---------------------------------------------------------------------------------------------------------------------------------------------------------

#---------------------------------------------------------------------------------------------------------------------------------------------
# Section 6 Parameters to estimate or fix
-1000       # Phase for estimation of M
-1000       # Phase for estimation of steepness
 2          # Phase for estimation of SSB0
 3          # Phase for estimation of the numbers-at-age in the first year (from age-at-recruitment+1 to mm)
 4          # Phase for estimation of phi
 5          # Phase for estimation of indices additional variance
 6          # Phase for estimation of recruitment residuals
-1000       # Phase for estimation of SSBi
# Phase for estimation of commercial selectivity
1       1                               #       1952    JPLL
1       1                               #       1952    TWLL
1       1       1       1               #       1952    Driftnet
1       1       1       1               #       1952    PS
1       1       1       1               #       1952    Others
#---------------------------------------------------------------------------------------------------------------------------

#-------------------------------------------------------------------------------
# Section 7 Weight for CAS
0.1 0.1 0.1 0.1 0.1
#-------------------------------------------------------------------------------

#-------------------------------------------------------------------------------
# Section 9999
11111       # for check1
------------------------------------------------------------
```

## A.2 Parameter guess file (*2_scas.pin*)

This input file is to enter guess values of the initial population size, F, and selectivity.

```
#-------------------------------------------------------------------------------
# File 2: "2_scas.pin" file for initial values
#-------------------------------------------------------------------------------
# Log of virgin TB and initial N-distribution (by "maxNsyr_age" set in control file)
13.0                # lnTB0 (if estimated in the control file)
16.5 16.0           # lnN0 (Age0) and lnN1(Age1) (in numbers)
0.2                 # Initial F
0.10                # Additional variance (0.10 for default)
# Selectivity
4.5 2.0                     #       1952    JLL
4.5 2.0                     #       1952    TWLL
4.0 2.0 4.0 1.0             #       1952    Driftnet
4.5 1.0 -2.0 2.0            #       1952    PS
4.0 2.0 -5.0 2.5            #       1952    Others
#-------------------------------------------------------------------------------
22222       # Check2
```

## A.3 Biological data file (*3_biological.inp*)

```
#-----------------------------------------------------------------------------
# File 3: "3_biological.inp" file for biological parameters
#-----------------------------------------------------------------------------
# Steepness
0.7
# Natural mortality (age-specific, given)
#0     1      2      3      4      5      6      7      8      9      10     11     12     13     14     15
0.4000 0.3552 0.3104 0.2655 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207
# For length-at-age and growth
0.20                                    # CV
124.10    -2.239    0.164               #GR=1: Linf, to, Kappa
#124.10   -2.239    0.164 0.164, 3, 20  #GR=2: Linf, to, Kappa1, Kappa2, Alpha, Beta
# Fraction of mortality that occurs before spawning
0.0
# Maturity-at-age
#0     1      2      3      4      5      6      7      8      9      10     11     12     13     14     15
0.4000 0.3552 0.3104 0.2655 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207 0.2207
0      0      0      0      0.09   0.47   0.75   0.88   0.94   0.97   0.99   0.99   1.00   1.00   1.00   1.00
1.3718E-5           # Length-weight parameter A
3.0973              # Length-weight parameter B
#-----------------------------------------------------------------------------
33333     # Check3
```

## A.4 Index file (*4_index.inp*)

```
#-----------------------------------------------------------------------------
# File 4: "4_index.inp" file for CPUE data
#-----------------------------------------------------------------------------
1                         # Number of index series
33                        # Number of observations for each index
1                         # To which fleet the index corresponds to
1                         # Units (1=numbers, 2=biomass, 3=spawning)
6                         # Timing (month in which index is taken)
1                         # Minimum age indexed
9                         # Maximum age indexed
1                         # Weight given to each index
2                         # Compute sigma (=1), or use input CV (=2)
#-----------------------------------------------------------------------------
#Fleet    year    CPUE      CV
1         1980    1.7311    0.20
1         1981    1.9958    0.20
1         1982    2.1189    0.20
1         1983    1.5011    0.20
1         1984    1.284     0.20

          (omitted)

1         2006    0.6799    0.20
1         2007    0.6607    0.20
1         2008    0.7508    0.20
1         2009    0.8234    0.20
1         2010    0.8895    0.20
1         2011    0.9043    0.20
1         2012    0.9447    0.20
#-----------------------------------------------------------------------------
44444 #check4
```

## A.5 Fishery file (*5_fisherey.inp*)

This input file is to enter catch and CAS by fleet.

```
#-------------------------------------------------------------------------------
# File 5: "5_fishery.inp" file for catch and CAS data
#-------------------------------------------------------------------------------
# Total catch in tons by fleet

# Total catch in tons by fleet
#year   JapLL   TawLL   Drift   PS      OTHERS
1952    61      0       0       0       19
1953    1094    0       0       0       20
1954    2734    90      0       0       23
1955    3059    276     0       0       23
1956    5075    530     0       0       24
1957    4662    656     0       0       23
1958    6285    991     0       0       23
1959    10410   1228    0       0       23

                (omitted)

2004    4155    24259   0       232     1288
2005    4413    23575   0       164     1147
2006    6489    20347   0       1548    1307
2007    5504    30688   0       725     1653
2008    4965    27352   0       1424    2137
2009    3988    31648   0       392     2105
2010    4454    37139   0       207     2119
2011    2845    27779   0       725     2203
2012    3234    27672   0       1297    1650

#-------------------------------------------------------------------------------
# Commercial catch-at-length
30 139                                  # data min and max length
1                                       # length classes
5                                       # Number of CAS series
61 59 10 30 61                          # number of CAS vector for each series
#       Longline-Japan
NO      Year    L039    L040    L041    L042    L043    L044    L045    L046    L047
        L048    L049    L050    L051    L052    L053    L054    L055    L056    L057
        L058    L059    L060    L061    L062    L063    L064    L065    L066    L067
        L068    L069    L070    L071    L072    L073    L074    L075    L076    L077
        L078    L079    L080    L081    L082    L083    L084    L085    L086    L087
        L088    L089    L090    L091    L092    L093    L094    L095    L096    L097
        L098    L099    L100    L101    L102    L103    L104    L105    L106    L107
        L108    L109    L110    L111    L112    L113    L114    L115    L116    L117
        L118    L119    L120    L121    L122    L123    L124    L125    L126    L127
        L128    L129    L130    L131    L132    L133    L134    L135    L136    L137
        L138    L139
#       Longline-Japan
1       1952    0       0       0       0       0       0       0       0       0       0
        0       0       0       0       0       0       0       0       0       0       0
        0       0       0       0       0       0       0       0       0       0       0
        0       0       0       0       0       0       0       0       0       0       0
```

```
		0.038358849	0	0	0	1.352405015	1.352405015	0
		5.409620059	2.70481003	2.70481003	0	0	4.057215044
		13.562409	8.114430089	10.89595782	25.69569528	36.82180619	42.00127316
		55.64039985	84.15598171	97.56495531	143.8919555	128.7469883
		134.0798907	147.6806586	138.2521823	209.8145715	111.0122878
		151.6611559	120.4024052	125.7736664	159.6988683	102.7827811
		121.7164513	129.945958	73.1833062	120.5174817	48.68658053
		31.18203304	16.30557788	5.409620059	12.21000398	4.057215044
		8.114430089	5.409620059	4.057215044	4.057215044	0	1.352405015
		4.095573893	0	2.70481003	1.352405015	0	2.70481003	0
		0	0	0	0	0	0	0	0	0	0
1		1953	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
```

*(Omitted¥)*

```
#		Others
5		2012	5133.576431	3461.324598	5916.833265	6666.868715	8452.591753
		13129.57331	13672.33331	13228.38603	15364.0256	13483.96062
		23261.49617	15264.47858	13494.51269	17136.40554	16367.86208
		22056.61378	13002.95869	15610.99573	15830.21788	14937.83926
		22313.5732	11851.53609	15123.55159	13297.21	14348.34398	16509.57106
		14466.07625	12444.85684	15349.43284	9892.294454	13532.61465
		1299.62439	2361.541176	2020.861857	1114.951767	1979.033473
		2086.227559	1725.611978	3025.008803	1987.553445	2468.004769
		1560.302567	3552.071126	2775.064582	3899.197453	2345.184366
		2063.613637	4006.129996	5518.929886	2410.903712	1273.821486
		1273.821486	988.1343476	599.6310759	893.9839631	116.9774197
		175.917945	175.917945	97.9703382	97.9703382	164.5878722
		164.5878722	162.0710352	162.0710352	67.84257521	67.84257521
		264.7370664	264.7370664	140.1024341	140.1024341	321.4644799
		321.4644799	203.6913437	203.6913437	448.0222554	448.0222554
		727.8599936	727.8599936	388.3913973	388.3913973	638.2257697
		638.2257697	205.4667301	205.4667301	214.9435576	214.9435576
		430.8560397	430.8560397	19.88901018	19.88901018	203.5878518
		203.5878518	24.13920668	24.13920668	29.30044926	29.30044926
		54.22842237	54.22842237	0.59523214	0.59523214	28.15407003
		28.15407003	0	0	1.197653868	1.197653868	0.301210864
		0.301210864	0	0
#-------------------------------------------------------------------------------
55555		# Check5
```

## A.6 Projection file (*6_projection.inp*)

```
#-------------------------------------------------------------------------------
# File 6: "6_projection.inp" file for projection spec
#-------------------------------------------------------------------------------
# Number of years for projections
10
# Future catch for each fleet for projection (normally current catch by fleet to be entered)
3234	27672	0	1297	1650
#-------------------------------------------------------------------------------
66666 #check6
```