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FAO-ICLARM
stock assessment tools II
Revised version

User's guide

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Revised version

User's guide

F.C. Gayanilo, Jr
National Center for Caribbean Coral Reef Research, University of Miami
Miami, United States of America

P. Sparre
Danish Institute for Fisheries and Marine Research
Charlottenlund, Denmark

D. Pauly
Fisheries Centre, University of British Columbia
Vancouver, Canada

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Preparation of this document

FAO-ICLARM[*] Stock Assessment Tools (FiSAT) is the software that resulted from the merging of LFSA (Length-based Fish Stock Assessment) developed by FAO and the ELEFAN (Electronic Length Frequency Analysis) package developed at ICLARM* (International Center for Living Aquatic Resources Management), and the addition of some routines found useful for the analysis of length frequencies.

The MS DOS version of FiSAT was converted to a Windows compatible version, hereafter referred to as FiSAT II. This work was carried out between 2000 and 2002 through the European Union support project, Fisheries Information and Analysis System (FIAS).

Development of the FISAT II software was carried out by Felimon Gayanilo. The new software was thoroughly tested during an FAO working group meeting at Cidade da Praia, Cape Verde, in August 2003, under the leadership of Ana Maria Caramelo and Merete Tandstad, from the FAO Fisheries Department, producing a detailed report of the major errors then detected in the software.

The errors and bugs in the software detected during the workshop, as well as those that were discovered during the later testing phase were corrected by Pedro de Barros, Professor at the University of Algarve.

This User's Guide is an update of the previous version (Gayanilo, Sparre and Pauly, 1996). In addition to the printed document, a compact disk is provided with the software.

Acknowledgements

Thanks are due to all scientists around the world and to Ana Maria Caramelo, Denis Berthier and Merete Tandstad from FAO for their technical inputs in the development and testing of the various modules of FiSAT II; to Marie-Thérèse Magnan, Stephen Cofield and Françoise Schatto-Terribile, for editing the last version of this manual; to Ms Maria Concesa Gayanilo for her free services in painstakingly encoding the revisions made to this document.

Special thanks to Prof. Pedro de Barros, for correcting errors found by the users in the software.

[*] ICLARM is now called WorldFish Center.

Gayanilo, F.C.Jr.; Sparre, P.; Pauly, D.
FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised version. User's guide.
FAO Computerized Information Series (Fisheries). No. 8, Revised version. Rome, FAO. 2005. 168 p.
(Includes a CD-ROM with the software)

ABSTRACT

FiSAT II is a program package consisting of methodologies for use with computers, enabling users to formulate some management options for fisheries, especially in data-sparse, tropical contexts.

The FiSAT II was developed for computers running on Microsoft Windows operating systems. The new version utilizes the standard Windows graphic user interface.

FiSAT II was developed mainly for the analysis of length-frequency data, but also enables related analyses, of size-at-age, catch-at-age, selection and others.

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Chapter 5. **SUPPORT menu**

Appendixes

Chapter 1. Getting started

What you will learn from this chapter

In this chapter, you will be introduced to terminologies used in this guide, shown how to install the package, and understand the objects used in the graphic user interfaces of FiSAT II. At the end of the chapter, you will be introduced to the revised menus of FiSAT.

About the package

FiSAT (FAO-ICLARM Stock Assessment Tools) is the product that resulted from merging the LFSA (Length-based Fish Stock Assessment) developed at FAO (Sparre, 1987) with the Compleat ELEFAN (Electronic Length Frequency Analysis) package developed at ICLARM* (International Center for Living Aquatic Resources Management) (Gayanilo, Soriano and Pauly,1989). All routines in the earlier packages are included in FiSAT II.

Descriptions of many models used in this package may also be found in Pauly (1984a), Sparre and Venema (1992) and the FiSAT reference manual (Gayanilo and Pauly, 1998).

System requirements

FiSAT II, which is distributed on a compact disk, can be installed and made executable on many computer platforms or computing environments that run on the Microsoft Windows NT/2000/98/95 operating system. The minimum system requirements are as those identified when installing Microsoft Windows operating systems:

* WorldFish Center.

- Microsoft Windows 95/98/2000,
- 64MB of RAM,
- 1 024 x 768 high-resolution monitor, and
- at least 5 MB free disk space in the Windows directory and another 6 megabytes of free disk space for the destination address.

Installing and starting FiSAT II

The CD-ROM that comes with the package contains the setup.exe. Run the SETUP.EXE found in the root directory of the CD-ROM. The installation wizard will require user responses to prompts (Fig. 1.1).

DO NOT use other methods for installing the package to a hard disk. The SETUP program does not only transfer the files from the source to the destination disk but also initializes other files to be used by FiSAT II.

The installation routine will also install sample data files that can be used and an item (icon and title) in the Windows Programs menu. Selecting the item activates FiSAT II.

Input parameters None

Function None

User interface The routine will access the standard dialog box (Fig. 3.24) for exporting a file. A tab-delimited file will be generated that is standard to most commercially available electronic spreadsheets and word processors.

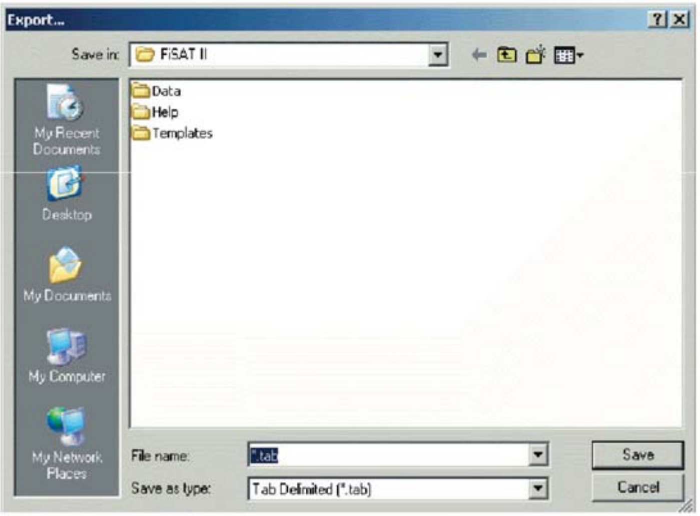

Fig. 3.24. Dialog box used when identifying the destination file of the data to be exported.

Remarks The sub-headers will not be exported other than the date of sampling.

Chapter 4. ASSESS menu

What you will learn from this chapter

This chapter presents routines for analysis of the various types of data presented in the previous chapter. However, these are presented in a summarized form, and we remind FiSAT users to read the FiSAT reference manual (Gayanilo and Pauly, 1998), and other documents explaining the background of these routines.

The format in module description

The Assess menu is divided into two parts, (i) the routines to estimate parameters (e.g., L_∞, K, C, M, Z, etc.) and (ii) the routines to predict yield or stock-related attributes given certain fishing scenarios. In the following, the modules are presented as given in Chapter 3, with one description added:

Output(s) *This section defines the output of the model or methodology being described. Examples will be provided when necessary.*

Parameter estimation

The step that should immediately follow data entry and manipulation is the estimation of population parameters. These are required inputs to the second set of analytical routines that deals with predictions.

Direct fit of length-frequency data

The set of routines classified under this heading are those which estimate growth parameters directly from the length composition of the stock, without previously translating the length scale into an age scale, as an alternative to the MPA approach described below.

ELEFAN I

ELEFAN I is a routine that can be used to identify the (seasonally oscillating) growth curve that "best" fits a set of length-frequency data, using the value of R_n as a criterion. FiSAT II provides three options to the user to identify that "best" growth curve: (1) curve fitting by eye (plotting of the histogram or restructured data may also be accessed from the Support Menu): (2) scan of K-values (Fig. 4.1), and (3) response surface analysis (Fig. 4.2). The plotting and curve fitting by eye is described in detail in the Support Menu below.

Note that in ELEFAN I, the parameter t_o is replaced by the coordinates of a point (any point actually) through which the curve must pass, and whose coordinates consist of SS (a starting sample) and of SL (a starting length).

Required file Time series of length-frequency data with constant class size.

Input parameters **Option 1**: Scanning of K-values

Fixed value of L_∞, C and WP and, as an option, a fixed starting point.

Option 2: Response surface analysis

Range of values for two parameters (e.g., L_∞ and K), fixed value for the two others (e.g., C and WP), and, as an option, a fixed starting point.

Functions In ELEFAN I, data are reconstructed to generate "peaks" and "troughs", and the goodness of fit index (R_n) is defined by $R_n = 10^{ESP/ASP}/10$

where the ASP ("Available Sum of Peaks") is computed by adding the 'best' values of the available 'peaks' and the ESP ("Explained Sum of Peaks") is computed by summing all the peaks and troughs "hit" by a growth curve of the form,

$$L_t = L_\infty (1 - EXP(-K(t - t_o) + S_{ts} + S_{to})$$

where

$S_{ts} = (CK/2\pi) \cdot \sin(2\pi(t\text{-}ts))$,
$S_{to} = (CK/2\pi) \cdot \sin(2\pi(t_o\text{-}ts))$, and
L_t is the length at time t.

Outputs **Option 1**: Scanning of K-values

This plots R_n values for a range of K values (0.10 to 10) on a log-scale.

We recommend use of this plot for all growth analyses, if only to assess how reliable an estimate of K is.

Option 2: Response surface analysis

This outputs an 11 by 11 matrix showing R_n values and in which the 10 best values are highlighted, thus enabling selection of the "best" combination of growth parameters.

User interface ELEFAN I contains three tabs. The first tab is only to identify the length frequency file to use. The tab, “K Scan” (Fig. 4.1), would allow the user to view the behaviour of the scores given estimates of L_∞.

The starting point can be set to variable or fixed starting point (see red arrow in Fig. 4.1). If starting point is set to a fixed value, the starting sample and starting length can be selected from a drop-down list.

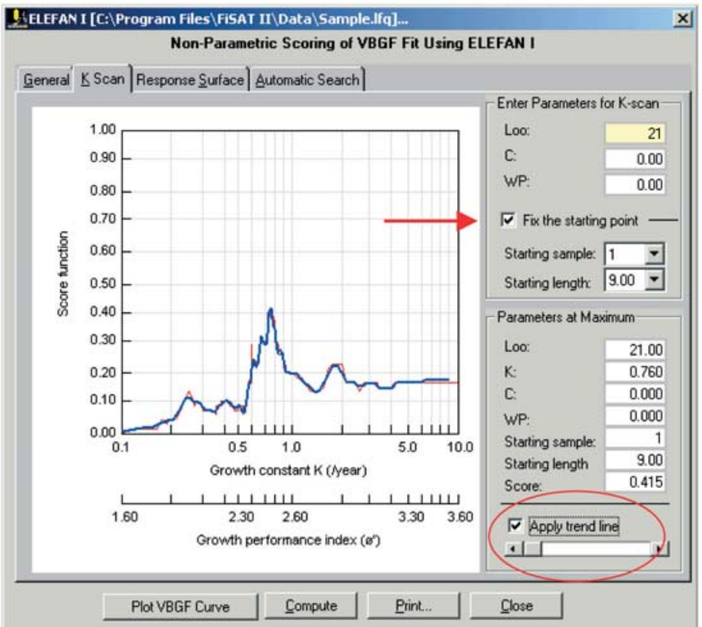

Fig. 4.1. User interface of ELEFAN I, K-scan routine. The red line in the plot is the actual score and the thick blue line is the overlaid trend line.

The behaviour of the scores may be so erratic that assessment of the possible solution is difficult. A trend line (see red circle in Fig. 4.1) may be applied.

The scroll bar is used to change the resolution of the trend line.The third tab is to execute a response surface analysis (Fig. 4.2). The starting point is a requirement of this subroutine. Note that the value of the L_∞ cannot be less than the starting length.

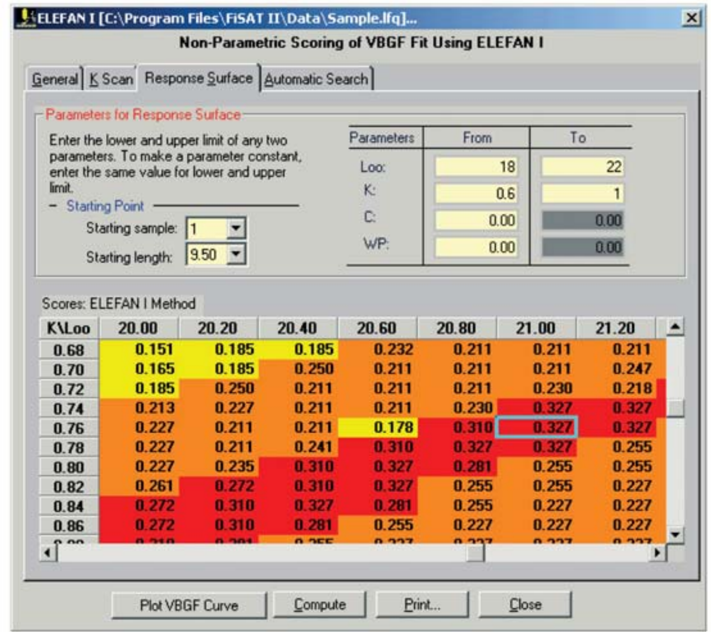

Fig. 4.2. User interface of ELEFAN I, Response surface analysis. Note the change of colour indicating improvement on the score.

Remarks It is imperative that users of ELEFAN I read detailed accounts of this method.

Readings Pauly (1982)
Pauly and David (1981)
Pauly and Morgan (1987)

<u>Shepherd's method</u>

Conceptually, this approach is similar to ELEFAN I in that it is designed to maximize a non-parametric scoring function. Two options for identifying optional values of L_∞ and K are available: (1) response surface analysis and (2) scan of K-values, both of which are very similar, in display and operations, to those of the ELEFAN I routine (see above).

Required file Time series of length-frequency data with constant class size.

Input parameters **Option 1**: Response surface analysis

Range of values for L_∞ and K.

Option 2: K-scanning

Fixed value of L_∞.

Functions The score (S) for Shepherd's method is defined by:

$$S = (s_A^2 + s_B^2)^{1/2}$$

where s_A and s_B are the goodness-of-fit scores (s_{tz}) obtained with the origin of the VBGF in calendar time (t_z) set to 0 and 0.25, respectively. s_{tz} is defined by:

$$s_{tz} = \sum_i T_i \cdot \sqrt{N_i}$$

where

N_i = frequency for length group i,
$T_i = D \cdot \cos 2\pi\,(t-t_i)$,
$D = (\sin\pi\,(\Delta t)/\pi(\Delta t))$,
$t = \Delta t/2$,
$\Delta t = t_{max} - t_{min}$,
$t_i = t_z - (1/K)\cdot\ln(1-(L_i/L_\infty))$, and
$t_z = (1/2\pi) \cdot \tan^{-1}(s_B/s_A)$.

Outputs **Option 1**: This outputs an 11 by 11 matrix of S values (with S_{max} standardized to 1) and in which the 10 best scores are highlighted, thus enabling selection of the "best" combination of L_∞ and K;

Option 2: This generates a plot of S values (with S_{max} standardized to 1) for a range of K values (0.1 to 10 year^{-1}) on a log scale, thus enabling the identification of the best value of K for a given value of L_∞.

User interface The user interface of this routine is very similar to that in ELEFAN I. It also contains three tabs where the first tab is used only to identify the file to be analysed. The second tab (Fig. 4.3) is to examine the S values given a fixed L_∞ and a fixed range of K values.

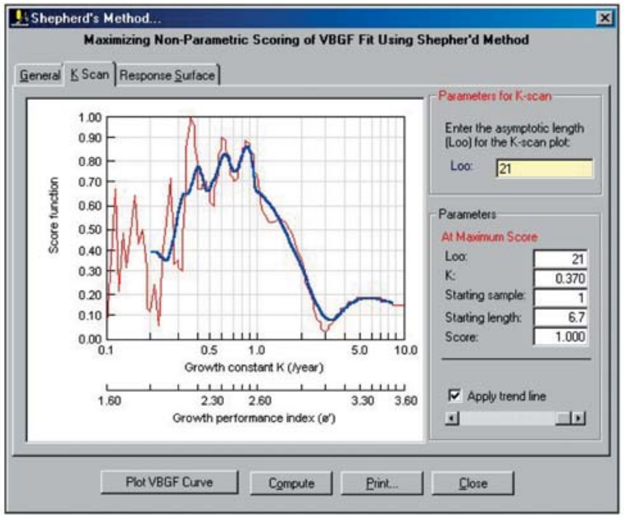

Fig. 4.3. User interface of Shepherd's method. The trend line indicates a K value in the same range as that generated by ELEFAN I in Fig. 4.1.

The third tab (Fig. 4.4) is the response surface analysis given a range of L_∞ and K values. The main difference with ELEFAN I is that, in this approach, the starting point and seasonality parameters (C and WP) are not identified.

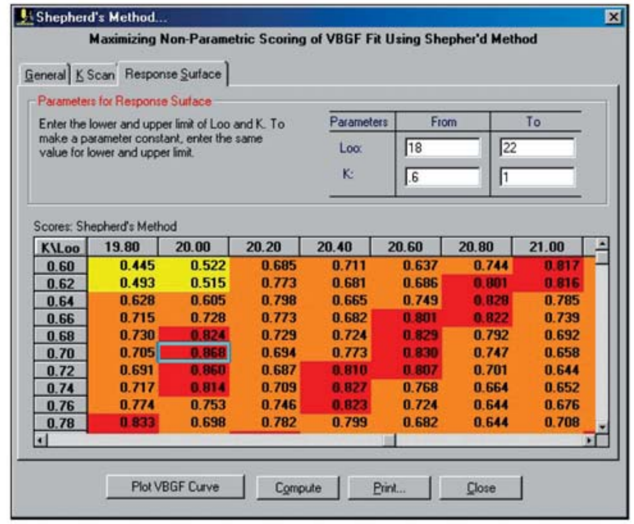

Fig. 4.4. Results of the response surface analysis where red (i.e. darker coloured cells) indicates improvement on the score.

Remarks

As for the ELEFAN I routine, this method is best applied when L_∞ has been estimated using another method (e.g., the Powell-Wetherall plot, see below). Note however, that this method differs from ELEFAN I in that it cannot deal with seasonal growth oscillations. Also, note that in this implementation, the score function is standardized to 1, i.e. S_{max} is made equal to unity. Further, the parameter "t_z" (which is *not* similar to t_o), is here replaced by a "starting point" (as for ELEFAN I, see above), and hence the ELEFAN I output routine can be used to display growth curves whose parameters have been estimated using Shepherd's method.

Readings

Shepherd (1987) and Isaac (1990)

Virtual population analysis

Virtual population analyses (VPA) are methods which allow the reconstruction of the population from total catch data by age or size.

Age-structured VPA

This is the version of VPA proposed by Gulland (1965).

Required file Catch-at-age data file

Input parameters Natural mortality (M), an initial guess of terminal fishing mortality (F_t), and the time interval between age groups (in years).

Functions The reconstruction of the population starts by estimating the terminal population (N_t) given the inputs, from

$$N_t = C_t \cdot (M + F_t)/F_t$$

where C_t is the terminal catch (i.e. the catch taken from the oldest age group).

Then, starting from N_t, successive values of F in the previous age group are estimated, by iteratively solving

$$C_i = N_{i+1} \cdot (F_i/Z_i) \cdot (\mathrm{EXP}(Z_i)\text{-}1)$$

with population sizes (N_i) computed from,

$$N_i = N_{i+1} \cdot \mathrm{EXP}(Z_i)$$

The last two equations are used alternatively, until the population sizes and fishing mortality for all age groups have been computed.

Outputs Plot of the reconstructed population and fishing mortality for each age group.

User interface The routine (Fig. 4.36) requires catch-at-age data and inputs of the required parameters (in years). The second tab (Fig. 4.37) presents the results of the analysis. The stacked histograms present the survivors, population lost to natural causes and the catches. Overlaid in the stacked histograms is the computed F-array. The numeric results are presented in the third tab.

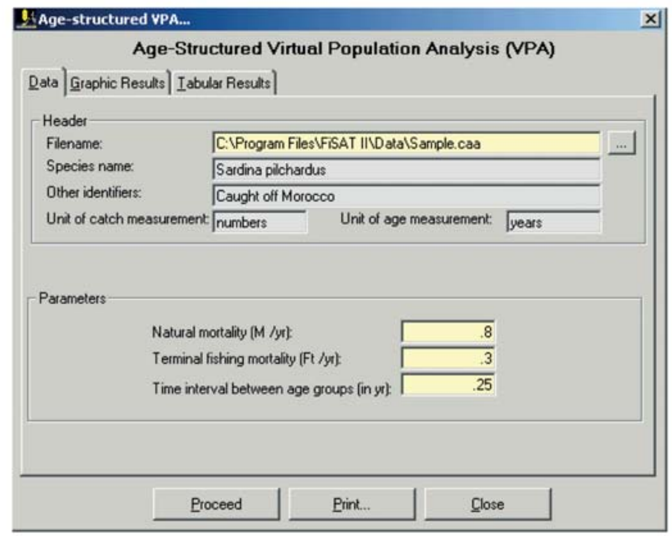

Fig. 4.36. File identification and input of parameters when analysing catch-at-age data using the age-structure VPA in FiSAT II.

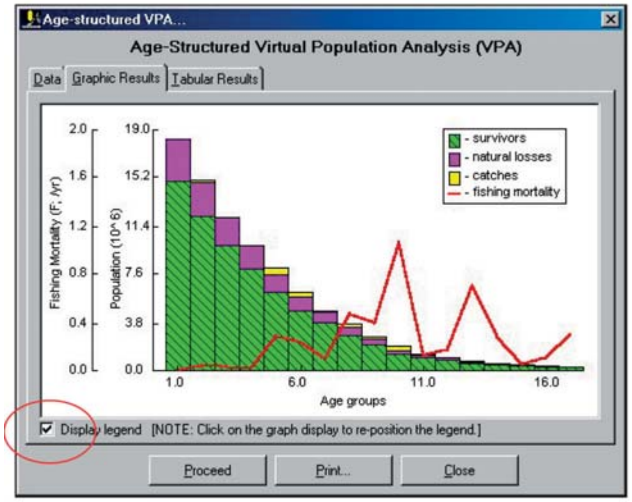

Fig. 4.37. VPA plot of the results. Note the option to display the legend and position it anywhere on the graph.

Readings Gulland (1965)
Mesnil (1985)
Pauly (1984a)
Pope (1972)

Length-structured VPA

This routine modified from Jones and van Zalinge (1981) utilizes basically the same approach as the previous routine (age-structured VPA), but is adapted to accommodate length frequencies.

Required file Length-frequency data file (representing mean annual catch at length, see below).

Input parameters L_∞ and K. Note that L_∞ must be at least 10% larger than the largest fish in the file. If you need to increase L_∞, use ø' to

reduce K accordingly. Alternatively a plus group may be created.

Functions The initial step is to estimate the terminal population (N_t) given the inputs, from

$$N_t = C_t \cdot (M + F_t)/F_t$$

where C_t is the terminal catch (i.e. the catch taken from the largest length class).

Then, starting from N_t, successive values of F are estimated, by iteratively solving,

$$C_i = N_{i+\Delta t} \cdot (F_i/Z_i) \cdot (\mathrm{EXP}\,(Z_i \cdot \Delta t_i)-1)$$

where

$$\Delta t_i = (t_{i+1} - t_i),$$

and

$$t_i = t_o - (1/K) \cdot \ln(1-(L_i/L_\infty))$$

where population sizes (N_i) are computed from

$$N_i = N_{i+\Delta t} \cdot \mathrm{EXP}\,(Z_i)$$

The last two equations are used alternatively, until the population sizes and fishing mortality for all length groups have been computed.

Outputs An F-array representing the fishing mortality for each length group, the reconstructed population (in numbers), and the mean stock biomass by length class.

User interface The user interface of this routine contains three tabs. The first tab (Fig. 4.38) is to identify the file to use and data transformations. Note that if data were raised by some value, this should be re-transformed to represent catches (in numbers; red circle in Fig. 4.38).

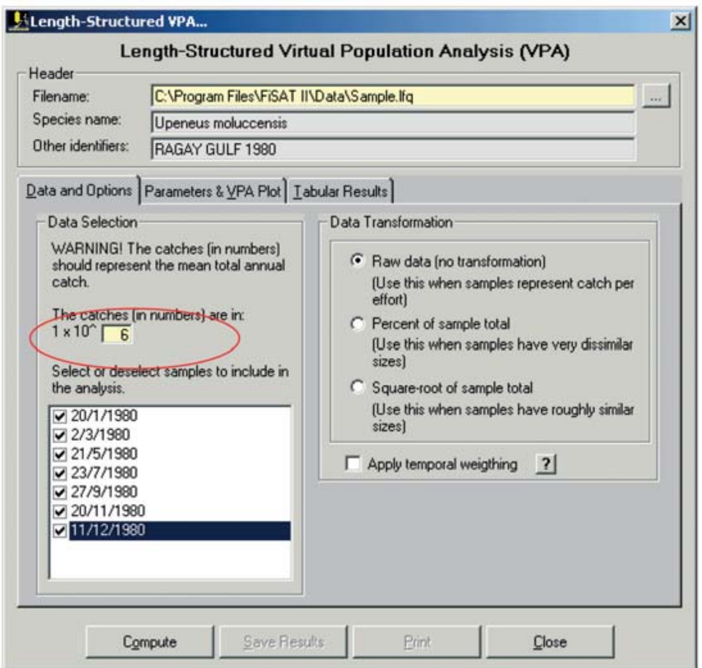

Fig. 4.38. Data identification tab of the length-structured VPA routine in FiSAT II.

The required parameters, including the initial estimate of the terminal fishing mortality (Ft) are given in the second tab (Fig. 4.39).

As in the age-structured VPA, the legend can be displayed and re-positioned on the graph.

To alter the value of the terminal F graphically, check the "Modify terminal F from Graph" option and click on the graph to represent the position of the terminal F. If the mouse is pointing to a length group less than the largest recorded length, a +Group will be generated.

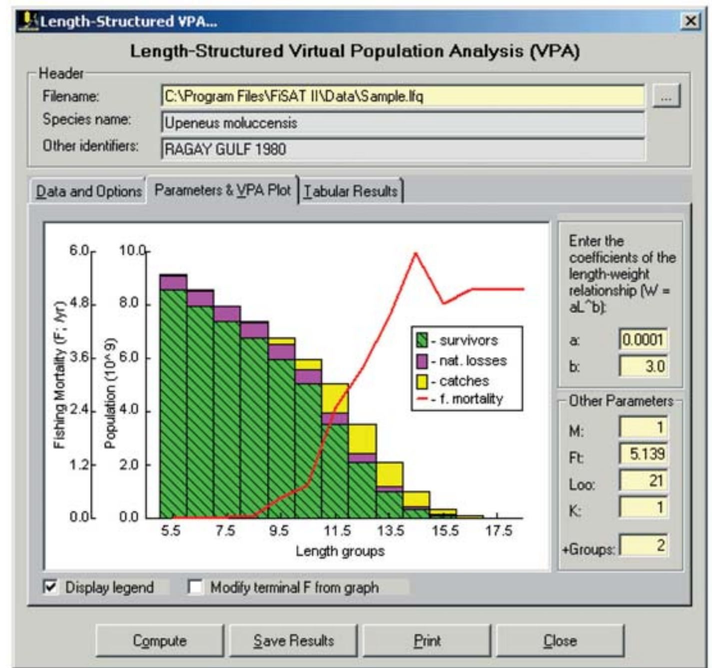

Fig. 4.39. Results of the length-structured Virtual Population Analysis (VPA). The terminal F may be modified directly from the graph.

The numeric equivalent of the graph is given in the third tab.

The resulting F-array can be saved as a Species Table that can be accessed directly when creating Scenario Files for the Thompson and Bell routine of FiSAT II.

Remarks The "length-frequency" file used here must in fact consist of total annual catch-at-length data, in numbers. It may be the average total catch of several years.

Reading Pauly (1984a)

Predictions

While the previous routines of ASSESS are used to estimate the value of certain parameters, the routines below, which *require* these inputs, are meant to be used for yield and stock predictions, and hence, to identify appropriate management regimes.

Relative Y/R and B/R analysis: Knife-edge selection

The relative yield-per-recruit model based on the Beverton and Holt model of 1966.

Required file None

Input parameters L_c/L_∞ ratio (from 0.05 to 0.95) and M/K ratio (from 0.10 to 9.99)

Functions Relative yield-per-recruit (Y'/R) is computed from:

$$Y'/R = E \cdot U^{M/K}\left\{1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

where

$U = 1-(L_c/L_\infty)$
$m = (1-E)/(M/K) = (K/Z)$
$E=F/Z$

Relative biomass-per-recruit (B'/R) is estimated from the relationship

$B'/R = (Y'/R)/F$, while

E_{max}, $E_{0.1}$ and $E_{0.5}$ are estimated by using the first derivative of this function.

Outputs Plots of Y'/R vs E (=F/Z) and of B'/R vs E, from which E_{max} (exploitation rate which produces maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of relative yield-per-recruit is $1/10^{th}$ of its value at E=0) and $E_{0.5}$ (value of E under which the stock has been reduced to 50% of its unexploited biomass) are also estimated.

User interface FiSAT II automatically plots the Y'/R isopleths diagram with M/K set to 1.00. If the user changes the M/K value (red circle in Fig. 4.40), a new isopleths diagram will be plotted automatically.

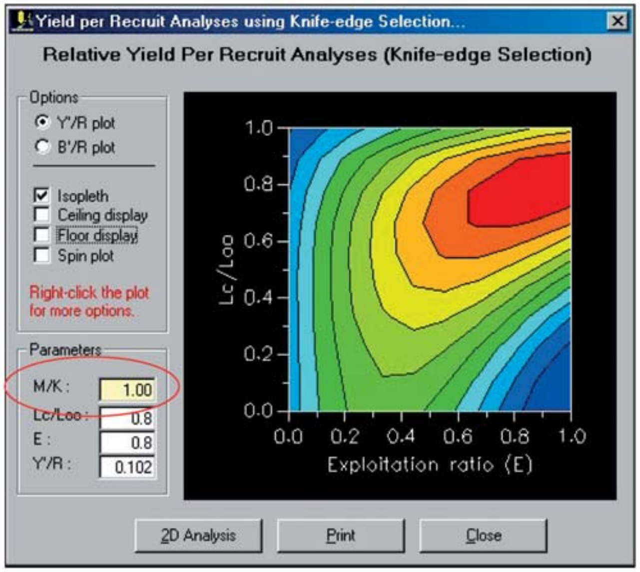

Fig. 4.40. Y'/R isopleths diagram with M/K value set to 1.0 (see figures 4.41 and 4.44 for facsimile presentations of other possible options in the presentation of the results).

The user interface also provides other options for viewing the results. Fig. 4.41 is an example of a 3D presentation of results for B'/R using the same M/K value. Note that the ceiling display, floor display and spin plot options are applicable only when the plot is presented in 3D.

To manually spin the plot in all axes, click both buttons of the mouse and drag the plot to the desired viewing angle.

Whether the results are presented as isopleths or in 3D, moving the mouse over the plot identifies the numeric values of the plot.

A 2D plot of the results (see a similar plot in Fig. 4.44) may also be plotted by clicking on the "2D Analysis" command button.

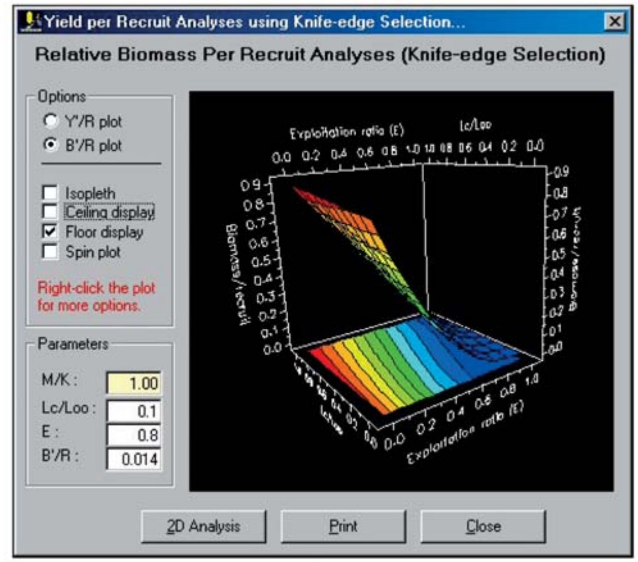

Fig. 4.41. 3D presentation of the B'/R plot with a floor display of the results.

Remarks An example of the 2D graph is given in Fig. 4.44.

Readings Beverton and Holt (1966)

Relative Y/R and B/R analysis: Using selection ogive

The relative yield-per-recruit model presented in the following is based on the Beverton and Holt model of 1966, modified by Pauly and Soriano (1986).

Required file Probabilities of capture data

Input parameters L_∞, K and M

Functions Relative yield-per-recruit (Y'/R) is computed from

$$Y'/R = \Sigma P_i((Y'/R)_i \cdot G_{i-1})-((Y'/R)_{i+1} \cdot G_i))$$

where

$(Y'/R)_i$ refers to the relative yield-per-recruit computed from the lower limit of class i using

$$(Y'/R)_i = E \cdot U^{M/K} \left\{1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

where U and m are defined as above,

P_i is the probability of capture between L_i and L_{i+1}, while G_i is defined by

$$G_i = \Pi\, r_j$$

where

$r_j = (1-c_i)^{Si}/(1-c_{i-1})^{Si}$, and

$S_i = (M/K)(E/(1-E))P_i$.

Here, B'/R is estimated from

$$(B'/R)_i = (1-E) \cdot A/B$$

where

$$A = \left\{1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

$$B = \left\{1 - \frac{3U}{(1+m')} + \frac{3U^2}{(1+2m')} - \frac{U^3}{(1+3m')}\right\}$$

and where m' = 1/(M/K) = m/(1-E).

E_{max}, $E_{0.1}$ and $E_{0.5}$ are estimated by using the first derivative of the function.

Outputs Plots of Y'/R vs E (=F/Z) and of B'/R vs E, from which the E_{max}, $E_{0.1}$ and $E_{0.5}$ (as defined above) are also estimated.

In addition to these two-dimensional outputs, the user has the option to plot yield-isopleths diagrams, which can be used to assess the impacts on yields of changes of E (corresponding to the level of exploitation) and of c (= L_{50}/L_∞, corresponding to a change of mesh size).

User interface The user interface of this module is very similar to the presentation of the results using the knife-edge assumption. The display options are the same. However, a selection data (probability file) has to be loaded before any calculations are done by the routine (Fig. 4.42).

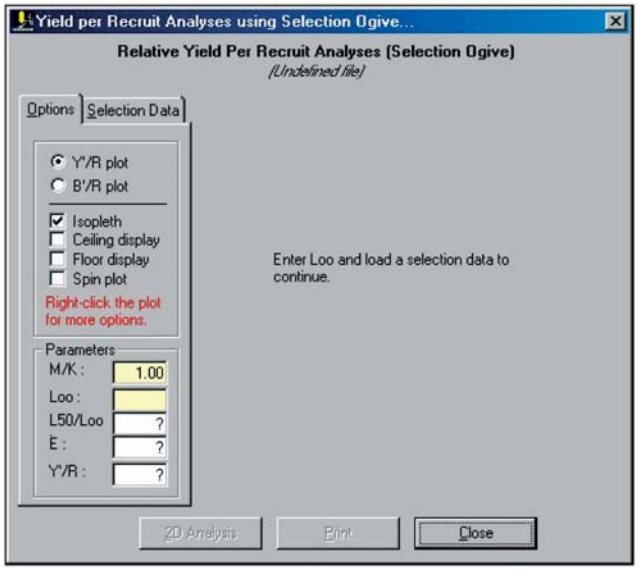

Fig. 4.42. Initial display of FiSAT II when the Beverton and Holt Y/R model using selection ogive routine is accessed. A probability of capture file is required by the routine.

The L_∞ used in previous calculations using the file or associated files are used as defaults. The user may change the value to compute new points of the plot.

As in the previous routine, the results may be plotted in three dimensions (Fig. 4.43) with options to also plot the ceiling and floor displays.

The 2D plot (Fig. 4.44) is the graphical representation of the results for a specific c (= L_{50}/L_∞) value. The user has the option to change the value or may slide the scroll bar to examine changes of the c value (simulating a change of the mesh size).

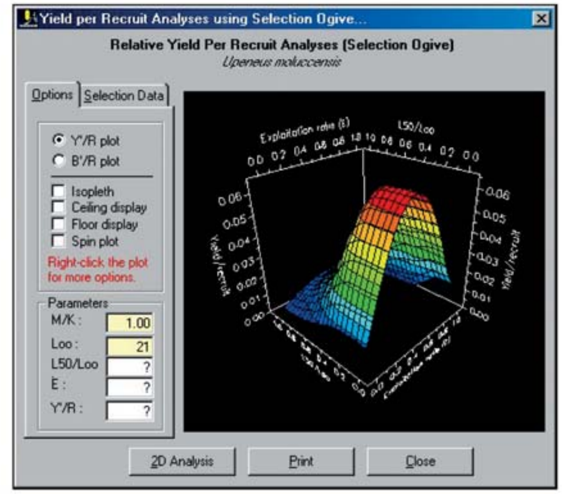

Fig. 4.43. A 3D presentation of the Y'/R plot using the selection data.

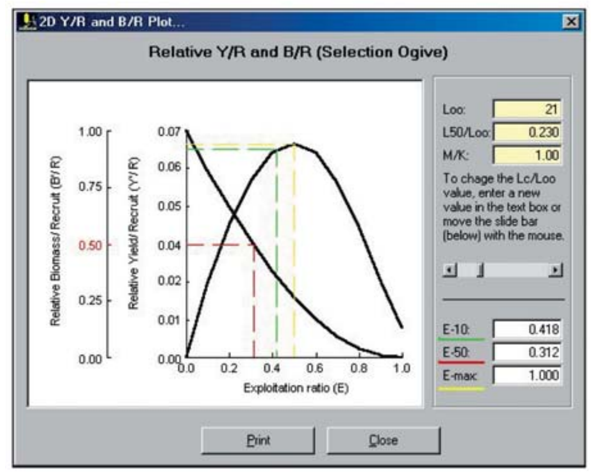

Fig. 4.44. 2D presentation of the results for specific L_{50}/L_∞ value. The scroll bar may be used to examine changes of the L_{50}/L_∞ values.

Remarks Using probabilities of capture which abruptly change from zero to 1 at $L_{50}(=L_c)$ enables this model to simulate the behaviour of the same model assuming a knife–edge selection, and thus allows comparison between the two approaches.

Readings Pauly (1984a)
Pauly and Soriano (1986)
Beverton and Holt (1966)
Silvestre *et al.* (1991)

Thompson and Bell yield and stock prediction

This model combines features of Beverton and Holt's Y'/R model with those of VPA, which it inverts. The version presented here can be used to analyse either a single species, exploited by a single gear, or several species, exploited by several fleets. Naturally, the data requirements increase with the complexity of the analysis required. It is for this reason that this routine is presented through a series of "options".

Five options are provided: (1) Create, edit, save or print a Species Table, containing population parameters, value by length groups and the F-array associated with one species, (2) Create, edit, save or print a Fleet Table, containing a text description of the fleet, (3) Create, edit, save or print a Relations Table linking the Species and Fleet Tables, data on selection and catch indexes used, to split the F-array if the species is (are) exploited by several fleets, (4) Run a Predict routine, which executes the model and outputs the graphical and numeric results, (5) Help, which contains a short description of the procedure and data requirements.

Required file Scenario File

Input parameters Species Table(s), Fleet Table(s), and relations between the species and the fleets.

Functions The sum of the yields ($Y = \Sigma Y_i$) is computed from

$$Y_i = C_i \cdot \overline{w}_i$$

where the mean body weight

$$\overline{w}_i = \left(\frac{1}{L_{i+1} - L_i}\right) \cdot \left(\frac{a}{b+1}\right) \cdot \left(L_{i+1}^{\ b+1} \cdot L_i^{\ b+1}\right)$$

and where a and b are the coefficients of the length-weight relationship and L_i and L_{i+1} are the lower limit and upper limit of the length class, respectively; also we have

$$C_i = (N_i - N_{i+1})(F_i/(M+F_i))$$

where the predicted population (N_i) is given by

$$N_{i+1} = N_i \cdot \text{EXP}(-(M+F_i) \cdot \Delta t_i), \text{ and}$$

$$\Delta t_i = (1/K) \cdot \ln((L_\infty - L_i)/(L_\infty - L_{i+1}))$$

The biomass is computed from

$$B_i = ((N_i - N_{i+1})/(M+F_i)) \cdot \Delta t_i \cdot \overline{w}_i$$

and

the value (V_i) is computed by

APPENDIX B. References

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