

*Remarks*                    These equations provide reasonable estimates of  $M$  for fish, and perhaps shrimps and squids as well, but should not be applied to bivalves for which  $M \approx K$  may provide a better approximation. The models assume  $L_{\infty}$  to be in cm, and  $W_{\infty}$  in g; FiSAT II automatically performs any required transformation. Also, values of  $T$  down to  $-2^{\circ}\text{C}$  can be entered and are adjusted internally.

*Readings*                    Pauly (1980, 1984a)

## Recruitment patterns

This routine reconstructs the recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse.

*Required file*                Length-frequency data with constant class size.

*Input parameters*        Growth parameters:  $L_{\infty}$ ,  $K$ ,  $(C, WP)$ , and  $t_0$  if available.

*Functions*                    Backward projection, along a trajectory defined by the VBGF, of the frequencies onto the time axis of a time-series of samples (one single, but well-structured sample may also be used).

Two options are provided;

**Option 1**, use of the length-frequency data.

**Option 2**, use of restructured data.

*Output* Plot showing the seasonal pattern of recruitment.

*User interface* The user interface for this routine contains three tabs. The first tab is to identify the file to analyse and options for data transformation (Fig. 4.30). Another option is provided to the user, i.e. the use of the length frequency data as it is and use of restructured data as is done in ELEFAN I.

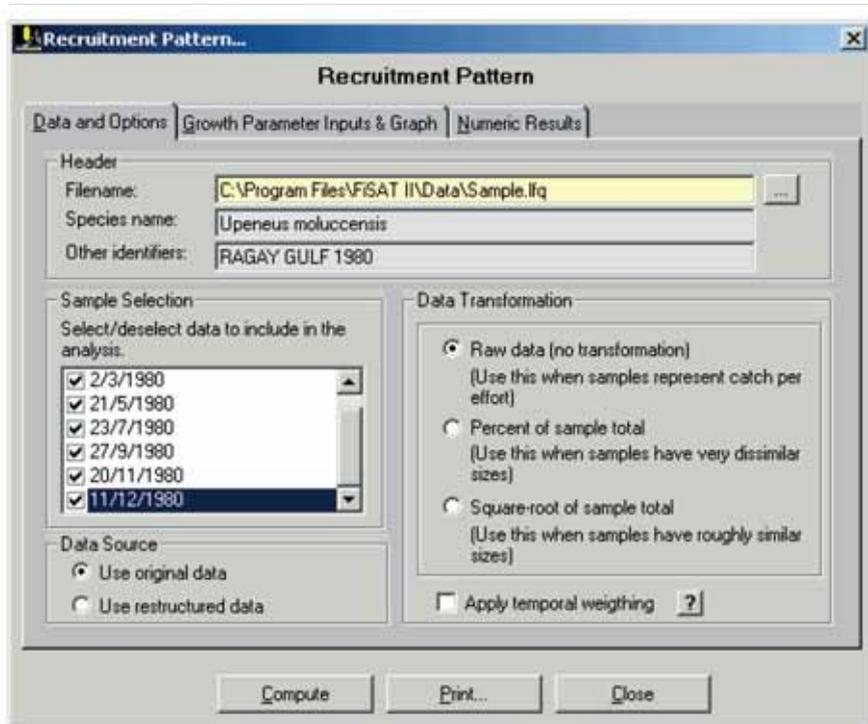


Fig. 4.30. File identification tab and options to temporarily transform data before data analysis.

The growth parameters are required inputs and clicking the “Compute” command button will compute the recruitment pulse(s) (Fig. 4.31). In cases where there are two recruitment

pulses, the composite data can be decomposed using the approach as implemented in NORMSEP (see above). In this case, starting estimates of the mean (in months) are required to compute the Gaussian distributions. The numeric results are given on the third tab.

When  $t_0$  is set equal to zero, the ordinate scale of the plot will be relative, not calendar time.

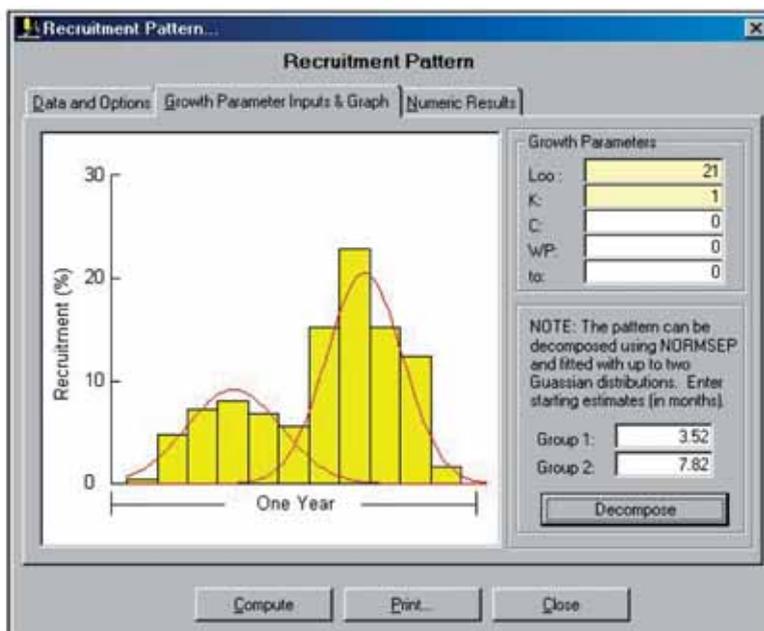


Fig. 4.31. User interface to estimate the recruitment pulses in FISAT II.

*Remarks*

The results generated by this routine should be treated as approximations because, while allowing statements on the number of annual pulses and on their relative strength, this model is based on two assumptions that are rarely met in reality: (i) all fish in the

sample grow as described by a single set of growth parameters and (ii) one month out of twelve always has zero recruitment. When using restructured data, the temporal spread reduces and thus probably better reflects the actual seasonality of recruitment. As an additional option, FiSAT II also allows the user to analyse recruitment patterns using a maximum likelihood approach (see section on NORMSEP) to fit a Gaussian distribution.

*Readings* Moreau and Cuende (1991)  
Pauly (1983)

## **Probabilities of capture**

"Probabilities of capture..." leads, in FiSAT II, to those routines that can be used to determine gear-specific selection curves.

### **Trawl-type selection**

Trawl-type selection curves are characterized by left-hand selection, i.e. small fishes escape through the mesh and hence are not caught. In most cases, this type of data is obtained from trawl selection experiments, which usually consist of covering the cod-end whose selectivity is to be assessed with a fine-mesh cover. However, similar information may also be obtained from length-converted catch curves, by backward extrapolation of the catch curve, and comparison of the numbers actually caught with those that "ought" to have been caught.

To estimate selection parameters, ( $L_{25}$ ,  $L_{50}$ ,  $L_{75}$ ), FiSAT II provides the user with the options of either: (1) using the logistic curve, which assumes selection to be symmetrical

or nearly so or (2) using moving averages over three classes and interpolating the selection parameters.

*Required file*      Probability data file

*Input parameters*    **Option 1:** Logistic curve

Visual selection of the points of a logits plot to be used for the regression analysis.

**Option 2:** Moving average

None

*Functions*            **Option 1:** Logistic curve

$$\ln((1/P_L)-1) = S1 - S2 \cdot L$$

where  $P_L$  is the probability of capture for length  $L$ , and

$$L_{25} = (\ln(3)-S1)/S2$$

$$L_{50} = S1/S2$$

$$L_{75} = (\ln(3)+S1)/S2$$

**Option 2:** Moving average

$$P_{L,i(\text{new})} = (P_{L,i-1} + P_{L,i(\text{old})} + P_{L,i+1})/3,$$

which provides a smoothed series of probabilities from which  $L_{25}$ ,  $L_{50}$  and  $L_{75}$  are estimated through linear interpolation.

*Outputs*                Estimates of  $L_{25}$ ,  $L_{50}$  and  $L_{75}$

*User interface*        This routine (Fig. 4.32) requires a probability of capture file that can be created based on selection experiments

or from a length-converted catch curve routine (see above). This routine can also be accessed directly from a length-converted catch curve routine.

Two options are provided to the user to estimate the selection parameters. The use of the logistic transformation plot (also referred to as logits; Fig. 4.33) will require the user to identify at least three data points to be included in the analysis (default is all data points will be used). The use of the running average technique will not require additional user intervention to estimate the parameters.

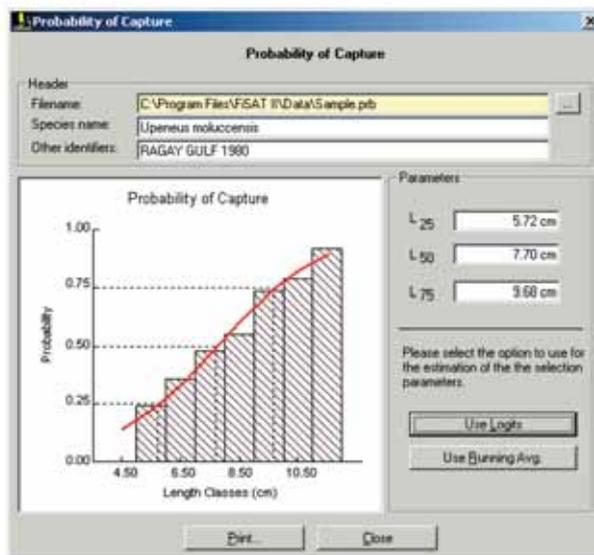


Fig. 4.32. The user interface for the estimation of the selection parameters using either logistic transformation or running average technique.

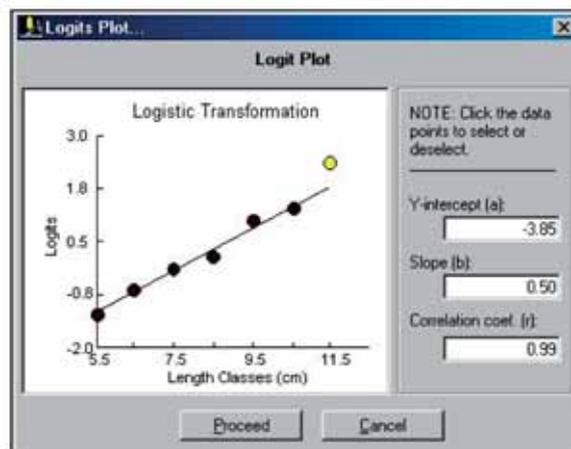


Fig. 4.33. Logistic transformation of the data points to identify points to be included in the analysis.

*Remarks* This routine may also be accessed directly from the length-converted catch curve analysis. The selection curve can be saved to a file for subsequent analysis of L/F data for the effects of gear selection and incomplete recruitment or as an input to yield per recruit analysis.

*Reading* Pauly (1984a)

### **Gillnet selection**

The selection curves of gillnets (and some other gears such as hooks) are characterized by strong left-hand *and* right-hand selection. This selection type can be modelled using normal (**Option 1**) or log-normal (**Option 2**) selection curves.

*Required file* Length-frequency data file with constant class size with two samples representing the catches (in numbers) of two gillnets of different mesh sizes, with at least 3 overlapping non-zero length classes.

*Input parameters* Mesh sizes of the two selected samples ( $m_A$  and  $m_B$ ), where one ( $m_A$ ) should be smaller than the other.

*Functions* The probability of capture for mesh size  $m_A$  and  $m_B$  at a given length  $L$  is,

$$P_{A,L} = \exp(-((L-L_A)^2/(2 \cdot \sigma^2))),$$

$$P_{B,L} = \exp(-((L-L_B)^2/(2 \cdot \sigma^2))),$$

where  $L_A$  and  $L_B$  (the optimum length for mesh sizes  $m_A$  and  $m_B$  respectively) are given by

$$L_A = SF \cdot m_A,$$

$$L_B = SF \cdot m_B,$$

and where  $SF$  is the selection factor computed from,

$$SF = (-2a)/(b \cdot (m_A + m_B)).$$

The coefficients  $a$  and  $b$  are estimated from the regression:

$$\ln(C_{i,B}/C_{i,A}) = a + b \cdot L_i$$

where the index  $i$  denotes length classes, and  $C_{i,A}$  and  $C_{i,B}$  are the observed catches (in numbers) for class  $i$  of gears A and B, respectively.

The standard deviation ( $\sigma$ ), assumed equal for both mesh sizes, is then computed from

$$\sigma = ((2 \cdot a \cdot (m_A - m_B)/(b \cdot (m_A + m_B)))^{1/2}$$

For **Option 2**, the logarithms of the variables referring to length ( $L_i$ ,  $m_A$ ,  $m_B$ ) are first taken before the functions are applied.

*Outputs* Probabilities of capture by length for each mesh size and the joint standard deviation ( $\sigma$ ).

*User interface* The user interface of this routine has two tabs. The first tab (Fig. 4.34) is to identify the length frequency file (with at least two samples). In addition, the two samples have to be identified and corresponding mesh sizes encoded.

The screenshot shows a dialog box titled "Gillnet Selection" with two tabs: "General" and "Gillnet Selection Plot". The "Data" section contains the following fields:

- Filename: C:\Program Files\FISAT I\Ndata\Sample 1.q
- Species name: Upeneus moluccensis
- Other identifiers: RAGAY GULF 1980
- Class size: 1
- Largest class size: 18.5
- Unit of measurement: cm

The "Mesh Sizes" section contains the following fields:

- Catches from two gillnets with two different mesh sizes:
- Select sample representing smaller mesh size: 1 (dropdown) what is the mesh size? 3.5 (text box)
- Select sample representing bigger mesh size: 7 (dropdown) what is the mesh size? 5.2 (text box)

Buttons at the bottom: Compute, Print, Save, Close.

Fig. 4.34. User interface to identify the length frequency file, the samples and corresponding mesh sizes used to generate the catches.

Once the required inputs have been entered, clicking on the “Compute” command button will plot the distribution (Fig. 4.35) and estimate the probability curve that can be saved as probability data for further analysis.

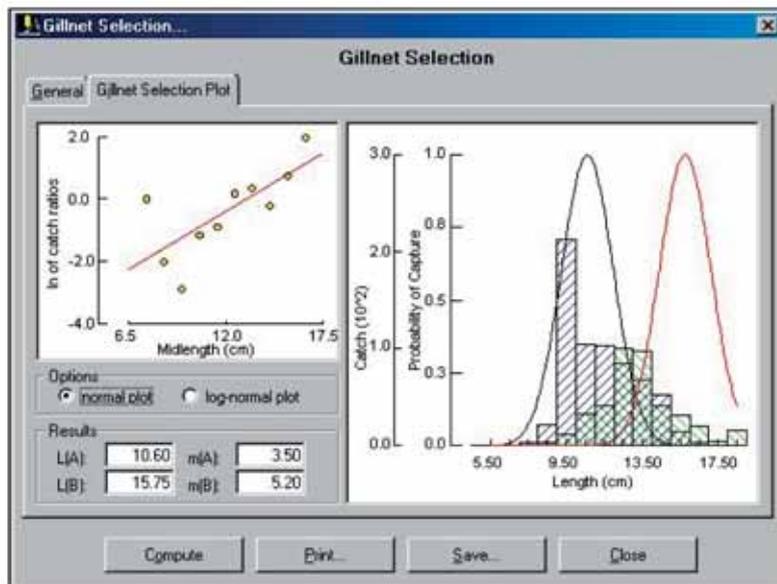


Fig. 4.35. Computed probability curve based on catch data from two gillnets of different sizes.

*Remarks*

The mesh sizes ( $m_A$ ,  $m_B$ ) will be read from the "Gear description" field in sample sub-headers (default values) if they are not entered at run time. Also, note that the normal and log-normal models are performed concurrently and that the user can toggle between the results from both models.

*Readings*

Pauly (1984a)  
Pauly (1983)

## 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

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

with population sizes ( $N_i$ ) computed from,

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

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.

**Age-structured VPA...**

**Age-Structured Virtual Population Analysis (VPA)**

Data | Graphic Results | Tabular Results

Header

Filename: C:\Program Files\FISAT II\Data\Sample.caa

Species name: Sardina pilchardus

Other identifiers: Caught off Morocco

Unit of catch measurement: numbers Unit of age measurement: years

Parameters

Natural mortality (M /yr): .8

Terminal fishing mortality (Ft /yr): .3

Time interval between age groups (in yr): .25

Proceed Print... Close

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

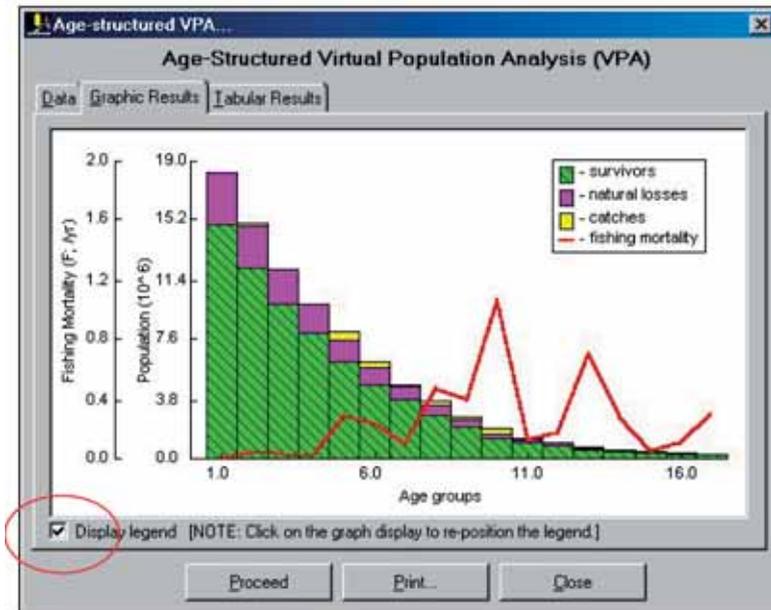


Fig. 4.37. VPA plot of the results. Note the option to display the legend and position it anywhere on the graph.

*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*  $L_{\infty}$  and  $K$ . Note that  $L_{\infty}$  must be at least 10% larger than the largest fish in the file. If you need to increase  $L_{\infty}$ , use  $\phi'$  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,

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

where

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

and

$$t_i = t_0 - (1/K) \cdot \ln(1 - (L_i / L_\infty))$$

where population sizes ( $N_i$ ) are computed from

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

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).

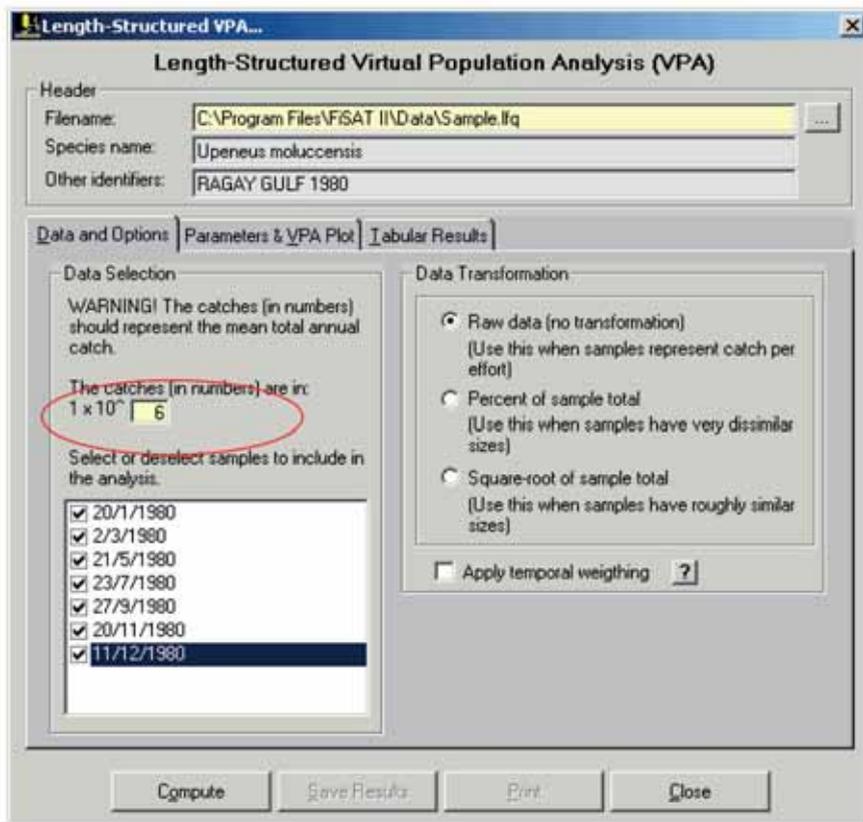


Fig. 4.38. Data identification tab of the length-structured VPA routine in FiSAT II.

The required parameters, including the initial estimate of the terminal fishing mortality ( $F_t$ ) 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.

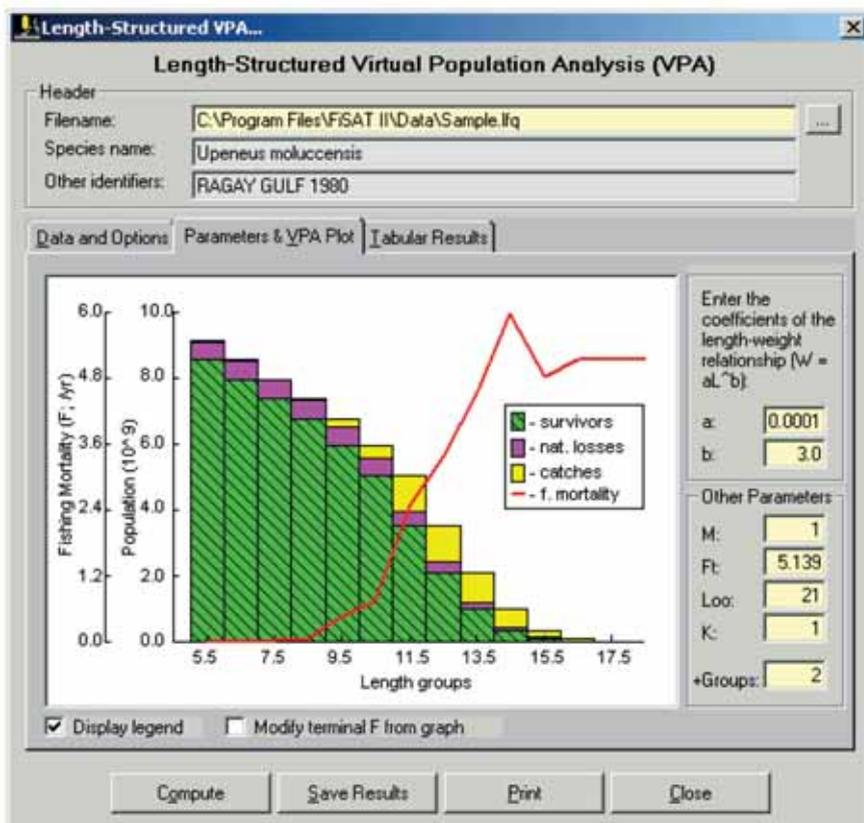


Fig. 4.39. Results of the length-structured Virtual Population Analysis (VPA). The terminal F may be modified directly from the graph.

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