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Tutorial for Estimation of Population Abundance with ADAPT

by

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Abstract

This document is intended as a tutorial to assist the first users of the ADAPT software. The ADAPTive Framework uses a non-linear least-squares fit to calibrate a virtual population analysis against independent indices of abundance. The tutorial is based on a data set mimicking a gadoid stock having four indices of abundance exhibiting various anomalies (trends in catchability, year effects, conflicting trends in indices). The tutorial outlines working procedures that would permit a user to analyze the results using the various diagnostics available and to explore the impact of various formulations of the estimation problem. It aims not only at showing how the ADAPT software works but also at establishing good working practices to analyze the results.

An adaptive framework - its origin.

The ADAPTive framework, commonly called "ADAPT", was developed in the mid-1980s to allow the exploration of various formulations for the calibration of virtual population analysis (VPA) against indices of stock abundance. Earlier methods of calibration for VPA were sensitive to the value of the index for the most recent years. ADAPT, like survivor analyses, was designed to reduce the sensitivity of the estimates of stock abundance upon the most recent year of data. This is particularly important in situations where there is only one, or a few, indices of abundance available. Another objective was to bring the estimation process within a statistical framework that would allow for the estimation of the uncertainty (variance, bias) attached with the estimates of stock abundance. For the estimation of unknown parameters and their associated uncertainty, an approach based on non-linear least-squares was adopted.

Typically, in an ADAPT formulation, the unknown parameters are:

- the catchability coefficients at age for each index;
- the estimates of survivors at the end of the period covered by the VPA-data.

It is also possible to estimate the survivors at the end of the last age-group covered by the VPA-analysis. However, most often, the population abundance for the oldest age group is calculated by relating the fishing mortality on the

last age group to the fishing mortality on younger ages. The recent version of ADAPT (Version 2.1) also allows the estimation of natural mortality for certain ages or years.

A detailed description of the population dynamics model behind ADAPT is provided in Gavaris and Van Eeckhaute (1998), together with a description of the estimation procedure. A description of the approaches used to measure uncertainty is provided in Gavaris (1991, 1993) and Smith and Gavaris (1993).

Data set for tutorial.

We will use the "blackfin" data, corresponding to data for a gadoid (saithe) stock with trends in the tuning data for two of four fleets (C. Darby, CEFAS, Lowestoft, U.K., pers. com.). This data set includes a number of difficulties (e.g. conflicting trends in indices of abundance, poor consistency between consecutive estimates of the cohorts, poor convergence of the VPA, sensitivity of results to model assumptions). The tutorial outlines working procedures that would permit a user to analyze the results using the various diagnostics available and to explore the impact of various formulations of the estimation problem. It aims not only at showing how the ADAPT software works but also at establishing good working practices to analyze the results.

Preparing your data using the spreadsheet template (ADAPT Template.xls).

There are two approaches to data input: 1) data could be copied from Excel through the Windows Clipboard (e.g. from the Excel Template describe above), or they could be loaded from TAB-delimited text files. In this tutorial, we will use the Windows Clipboard to transfer your data from the Excel spreadsheet to ADAPT.

To assist in the preparation of your own data for using ADAPT, the Excel spreadsheet "ADAPT Template.xls" is provided. Essentially, the template provides placeholders for your input data. The template also provides a means to display your data in a graphical form. In the template, placeholders for your data are colored in light yellow. The template can also be used to transfer the results of ADAPT back to your spreadsheet for displaying graphically or for further analysis. You do not have to use the template to prepare data for input to ADAPT (any of your own spreadsheet will do). However, the template includes some data validation and formatting, thereby reducing the possibility of erroneous entries. The Excel template has been formatted to allow easy copying between Excel and ADAPT.

If you use your own spreadsheet (instead of the template provided) to copy data to ADAPT, please note the following:

Warning for matrices or arrays with blank entries:

In ADAPT, TABs are necessary to mark empty cells in matrices. When copying data to the clipboard from Excel, there are situations where TABs are not generated and transferred via the clipboard. To ensure that the TABS are created and transferred, format (e.g. to 2 decimals) the cells containing your data before copying to the clipboard. Also, do not format the numbers in the cells so that they could include separators, such "," (e.g. to delimit thousands). Note that in some computers installed with international keyboards, Excel may default to formats which include separators. In such a case, you should overwrite that default.

Alternatively, if you input your data via text files, you should verify that your text editor generates the necessary TABs.

Data are to be input in individual sheets acting as placeholders for the following:

Sheet	Data description	Comments
LA	landings	
Cn	catch at age, in numbers	
Cw	catch weight at age	
Sw	stock weight at age	Beginning of year weight at age for calculating biomass
MO	maturity ogives	For calculation of stock spawning biomass
NM	natural mortality	
TunX	index X: effort and catch at age	One sheet per index

[Note: sheet names have been selected to be consistent with input files for the Lowestoft Tuning Package]

For this tutorial, data have been pre-assembled in the Excel spreadsheet "ADAPT Tutorial.xls". Load this spreadsheet now and inspect its content to gain some familiarity with its design. To assist you in completing the tutorial, the "completed" spreadsheet is printed in Annex 1 and given in file "ADAPT Template - Blackfin").

Landings (sheet LA):

This data sheet can be used to tabulate the landings (landed quantities in weight). Input your landing data in this sheet as follows:

Cell	Input
B1	Title for your project
B3	First year covered by your landing data
B7-B56	Landings in tonnes

The "landings" sheet is provided for your convenience as ADAPT does not typically require that input.

Catch at age, in numbers (sheet Cn):

This data sheet can be used to tabulate the catch-at-age information. Catches should be provided in numbers (i.e. number of fish caught). Take note of the scaling factor used when entering your data (e.g. 1000 for thousands). Input your catch at age data in this sheet as follows:

Cell	Input
B3	First year covered in your catch at age data
B4	First age-group covered in your catch at age data
B10-P59	Catch at age data (in number of fish)
F8	Scale multiplier for your catch at age data

Weight at age from commercial sampling (sheet Cw):

This data sheet can be used to tabulate the weight information corresponding to the catch at age. This information generally comes from the sampling of commercial fisheries. Weights should be provided in kilograms (kg). Input your weight at age data in this sheet as follows:

Cell	Input
B10-P59	Weight at age data from sampling of commercial fisheries

Stock weight at age (sheet Sw):

This data sheet serves to tabulate the weight at age (at the beginning of year) to be applied to population numbers. The beginning of year weights can be interpolated from the catch weight at age or can come from survey information. Weights are provided in kilograms (kg). Input your weight at age data in this sheet as follows:

Cell	**Input**
B10-P59	Weight at age corresponding to the beginning of the year, to be applied to the population numbers.

Maturity ogives (sheet MO):

This data sheet serves as a placeholder for maturity data to be used in the calculation of the stock spawning numbers and biomass. This data takes the form of maturity ogives given as the percent mature at each age. Input your maturity at age data in this sheet as follows:

Cell	**Input**
B10-P59	Maturity at age

Natural Mortality (sheet NM):

This data sheet serves as a placeholder for natural mortality data to be used in the virtual population analysis. This data takes the form of a matrix providing the natural mortality rate at a given age in a given year. If a constant is used for all ages or a vector for all years, copy these values to the relevant cells to simplify data entry. Input your natural mortality data in this sheet as follows:

Cell	**Input**
B10-P59	Natural mortality at age

Tuning indices (sheets TunX):

You will need to create one data sheet per index. Four template sheets are provided in the template but you can add sheets by copying one of the four empty templates. Each data sheet can be used to tabulate the effort and catch at age information for a given index; when such data are provided, catch rate at age (your index of abundance) is calculated from the input. Alternatively, someone can input the index directly, generally in the form of catch rate at age or relative abundance estimates at age, directly into the sheet. Input your data for each index in these sheets as follows:

Cell	Input
B3	Name of index (e.g. Trawl survey)
B4	First year of index data
B5	First age-group in index
B6	Month of survey
B12-B61	Effort data (optional)
E12-S61	Catch at age data, in number of fish. (optional)
E67-S116	Index at age: catch rate or relative abundance estimate. Note that this index will be used to calibrate population numbers; consequently, its units should be numbers or counts of individual fish. [Note: if you are entering the index directly, overwrite the formula in the cells]
D67-D116	Time of survey. Note that a default value has been calculated from year and month of the survey. Adjust entries as necessary to account for missing years, multiple surveys per year or seasonal changes in the timing of the surveys.
G65	Scalar for the Index at age
K65	Unit for your index
E121-S170	Weight at age corresponding to your index. Required if the index is meant as an index of biomass.
E181-S230	Maturity at age corresponding to this index. Required if the index is meant as an index of spawning biomass.

The entry cells for effort and catch at age are hidden in the template as the index at age data have typically been input directly in ADAPT. The effort and catch at age fields are provided for convenience (and consistency with other packages such as the Lowestoft Tuning Package) and, if you need to use these fields, expand them by selecting the "+ button" appearing in the left margin.

Data visualization.

Graphical representations of your data are given in the "In-G" sheet. The initial scale for each graph is determined from your input and from the full range of years and ages permitted in the template. It may be necessary to adjust the scale of certain graphs (the bubble graphs in particular), to zoom on the years and ages of interest. Adjust the scales as necessary.

The first printable page of this sheet gives the time trajectory for the landings and the numbers taken in the catch. It also provides time trajectories for the weight at age data (from the commercial fishery data and for the stock) and for maturity data. Use these to get an appreciation of temporal changes or shifts in these entities.

The second printable page of this sheet gives the time trajectory for the indices (all ages aggregated). It also provides bubble plots of the indices at age. For these, each age has been normalized by its mean to remove the age-effect. Use these graphs to get insight about year trends or year effects, or about cohort effects.

> Blackfin Example:
>
> These graphs serve to illustrate some of the difficulties in the indices for this particular example. Conflicting trends are obvious between the aggregated catch rates for the seine fleet and the light trawl. The prawn trawl shows a peak in the earlier years, peak that is not reflected in other indices. There is a "year effect" apparent in the otter trawl catch rates at age in 1991 (see bubble chart). There is poor consistency between consecutive estimates of year classes (try to follow cohorts in the bubble graphs). This could be due to the absence of a strong signal in the year class strength over the time period covered by these surveys but could also be an indication that these stock indices are not tracking year class strength consistently.

Loading ADAPT.

The following assumes that you have already installed the runtime version of ADAPT V2.1. Activate ADAPT V2.1 from the Windows Start/Program Menu or as indicated in the installation guide. In a typical installation, the ADAPT program can be activated from the Start/Program Menu or by typing the following in the Start/Run Box:

C:/aplwr20/aplwr.exe C:/adapt2_1/ADAPT.W3 6000000

The directories leading to the files *aplwr.exe* and *ADAPT.W3* should match those of your installation.

Data Input.

You can input the catch matrix and the four indices prepared in the Excel Tutorial-sheet as follows:

Input the catch at age data:

1. Go to Excel
2. Go to the "Cn" sheet
3. Highlight the cells A9-K42 which contain the data. [Note: *Row 42 contains the "year" label followed by "blank" entries for each age. It is important to include these "blank" entries as part of your selection so that the population matrix can be dimensioned properly. Essentially, that additional year is a placeholder for ADAPT to put its estimates of survivors. Accordingly, if you estimate survivors for the last age-group in each year, you will need to include in your catch matrix an extra age-column with 0 values for the catches.*]
4. Copy to the Clipboard.
5. Go to ADAPT
6. Select Insert
7. Select "From Clipboard"
8. Select "Catch"
   A message will appear reminding you to copy your data to the clipboard before selecting OK. If your data has already been copied to the clipboard, select OK. If not, do steps 1-5 and select OK when you return to this message.
9. Message: "Is the last age-group a plus group?" Select "Yes" or "No", as appropriate, and select OK.
10. Your catch at age data will appear in the Session-log (which is displayed on the screen).

Input the indices at age:

11. Go to Excel
12. Go to the "Tun1" sheet, which contains data for the first index
13. Highlight the cells D66-I86 which contain the data.
14. Copy to the Clipboard.
15. Go to ADAPT
16. Select Insert
17. Select "From Clipboard"
18. Select "Index"
19. Select "Pop. Numbers"
    A message will appear, reminding you to copy your data to the clipboard before selecting OK. If your data has already been copied to the clipboard, select OK. If not, do steps 11-15 and select OK when you return to this message.
20. Data for this index will appear in the Session-log (which is displayed on the screen).

The same process is followed to input an index of the population biomass or spawning biomass, with the exception that at step "19", you select the relevant entry. Also, you will be asked to provide data on weight at age and maturity at age, as appropriate. The year-range and age-range specified on the weight at age and maturity at age data must match those for the indices.

To add new indices to ADAPT, repeat steps 11-20 for each index, with the exception that, at step 13, adjust the selection so as to include the cells containing your data. Using the Blackfin example, proceed to input data the for three other indices of abundance, i.e. data for the "Seine" index, for the "Light trawl" index and for the "prawn trawl" index.

At this point, you have provided ADAPT with your data on catches and indices of stock size (abundance, biomass or spawning biomass). The next step consists of setting up the estimation model.

Setting up the estimation.

In this step, you specify which parameters are to be estimated using the non-linear estimation procedure.

21. In ADAPT
22. Select Setup
23. Select "VPA"
24. The template of the "Population" tab will appear. Using this template, you have to specify one, and only one, estimation process per cohort. In this particular case, you are allowed either a) to estimate the abundance corresponding to the cell(s) identified, b) to assign a fix value to the abundance corresponding to these cells, or c) to base the estimation of abundance from the fishing mortality at age.
25. Click the boxes corresponding to 1995, ages 1 and 2. This indicates to ADAPT that you wish to specify one of the estimation process for these cohorts. REMINBER: Click one or more boxes first to identify cohorts, then select a procedure for the estimation of these cohorts.
26. Select "Assign N" from the top bar. You will be prompt to enter a value for these cells. Enter 15000. These boxes will be marked in red and the corresponding entries along these cohorts will be grayed.
27. Click the box corresponding to 1995, age 3. Then, select "Estimate N" from the top bar. You will be prompt to enter a value for that cell, the initial guess to start the non-linear estimation process. Enter 25000. This box will be marked in green and the corresponding entries along that cohort will be grayed.
28. Repeat step 27 for <u>each</u> age (4 to 10) in 1995. In doing so, specify 25000 for age 4, 20000 for 5, 15000 for 6, 10000 for 7, 5000 for 8, 5000 for 9, and 5000 for 10. You have now specified initial guesses for <u>each</u> of these age groups.
29. Click the boxes corresponding to 1994, age 10, followed by 1993, age 10, and so on… until all boxes along age 10 have been selected (the last one will be age 10 in 1963). In doing so, you are going up the template. Use the scroll bar of that window to display hidden boxes.
30. Then, select from the top bar "Calculate F". You will be prompt to enter F Ratios for specific ages. In each of the cells corresponding to ages 4, 5 and 6, enter the value of 1 (unity). Select OK.
31. You will be prompt to select the method to average these fishing mortality values (unweighted or weighted by population numbers). Select "Unweighted" and then OK. Through steps 29 to 31, you have specified that the average (unweighted) fishing mortality values for these ages will be applied to age 10.
32. Select the "Natural Mortality" tab. You will be selected with a template similar to the preceding one with the exception that all boxes have to be specified to identify the process by which natural mortality will be calculated: "estimated" or "fixed". To simplify your task, you can select blocks of cells at once. Click on the first box

(1963 age 1); then go to the bottom right corner of the template and "Shift-click" the box corresponding to 1994, age 10). Check marks will fill the boxes selected.

33. Select "Assign M" from the top bar. You will be presented with a prompt to enter a value. Enter 0.2. Then click OK. The template will appear (the selected boxes will now appear in red).
34. When finished, select the "Done" button.
35. The model specified by your entries will be described in the Session-log.

Steps 25 to 33 are important as they allow you to specify the parameters to be estimated through the non-linear estimation procedure. After completion of these steps, you have specified initial "guess" values for each of the parameters. You have also specified some of the fishing mortality constraints to be applied in the form of functional relationships linking the F for the oldest age group and F values for younger age groups.

In step 26, you have assigned fixed values for ages 1 and 2 in 1995. If this is your final formulation, the fixed values are typically replaced by the geometric mean of population-size estimates for each of these ages for the most recent time period (e.g. for the last decade covered by your data). You can do these adjustments in sheet "N" of the Excel template.

You may find that the process of setting up your model is not always successful. While the interface allows quite a bit of flexibility for specifying your estimation model, the drawback of such flexibility is that some of the formulations may not be feasible. As you gain experience with the program, setting up ADAPT for estimation of population abundance should get easier. Many of the issues related to formulation of the estimation model can be related to one of the warnings given below. Read them carefully, mainly those that are underlined.

Warnings:

It is recommended that you assign fixed cohorts first, then the cohorts to be estimated, and last the cohorts having to be calculated from fishing mortality values.

For the lower left corner, it is necessary to "Assign N" (i.e. to fix these values) if these cohorts are not represented in any of the indices. It is not possible to estimate survivors for cohorts not represented in the indices [you have no data to estimate them].

You can "Estimate N" for the oldest age only if that cohort is represented in one of the indices. It is not possible to estimate population size for cohorts that are not represented in the indices. These cohorts have to be assigned a fixed value or should be determined by relating the fishing mortality for the oldest age to previous ages.

When you assign a fixed value or an initial guess for a population value, ensure that it is greater than the magnitude of the catch or you will get a computation error.

If you select multiple boxes and then chose to estimate population abundance, the selected cohorts will have a common abundance for the time periods that are checked. If you wish population abundance to be estimated independently for each cohort, they must be selected individually.

Defining the catchability model.

You can specify various functional relationships to link the indices of stock size to the stock size calculated through the VPA. Three options are available: 1) indices are proportionally related to population abundance; 2) they are

related to population abundance through a power function; and 3) they are related to population abundance through a time trend model.

36. In ADAPT
    37. Select Setup
        38. Select "Catchability model"
            39. Select "Pop. numbers".
                40. You will be presented with a menu allowing you to select the catchability models available. For this example, we will use the default ("Proportional"). Select OK. [Note that you can select a specific catchability model for one or some of the indices by selecting the relevant entries from the list.]
    41. A description of the catchability model will appear in the Session-log.

Estimating parameters.

Once the VPA formulation and the catchability model have been specifies, you are ready to start the non-linear least-squares estimation process.

42. In ADAPT
    43. Select "Compute"
        44. Select "NLLS fit" (i.e. use Non-Linear Least-Squares to fit the data)
            45. The output scrolls off the top of the active window and the top bar will likely blink, indicating that the program is operating. This is normal behavior.
    46. When the estimation is completed, the output appears in the Session-log. You should inspect the results by using the scrolling bar. In particular, you should verify that the estimation completed normally (i.e. no error messages).

If the iterative process completed normally, you are can then compute the statistics of the estimates.

47. In ADAPT
    48. Select "Compute"
        49. Select "Analytical" (i.e. Compute the bias and variance of parameter estimates analytically)
            50. Select "Statistics".
    51. This generally takes a few seconds. Wait for the results to appear in the session-log.

The results take the form of tables showing the parameter estimates, their standard error, the relative error, the bias and relative bias. These results are given both in the log-scale and arithmetic-scale.

The next step is to inspect the results. Special attention should be given to the coefficient of variation of the parameter estimates and to their bias estimates. Large values for the coefficient of variation (say greater than 50%) indicate poor precision.

> In the Blackfin example, the coefficients of variation of parameter estimates are of the order of 40% or more, and the bias generally less than 10%.

The estimates of population and o fishing mortality can be adjusted for bias as follows:

52. In ADAPT
    53. Select "Compute"
        54. Select "Analytical" (i.e. Compute from the bias and variance estimated analytically)
            55. Select "VPA bias adjusted".
    56. The results, namely the bias-adjusted estimates of the population and of the fishing mortality at age, appear in the session-log.

Output

Other diagnostics are available to assist you in evaluating the performance of your model or the "goodness" of fit. We explore them in this section.

Residuals.

57. In ADAPT
    58. Select "Output"
        59. Select "To Session log"
            60. Select "Residuals".
                61. Select "Diagnostics".
62. The results appear in the Session-log.

It is generally easier to inspect the residuals for "year-effects" or "age-effects" with graphs. Copying the residuals to the "Clipboard", instead of the "Session log", and transferring them to your Excel spreadsheet allows graphical representation of the residuals or further analyses on them. Placeholders are provided in the ADAPT-template, in the "TunX" tabs, to put the residuals in a matrix form. However, because of the format for the residuals, you will need first to copy the residuals to a worksheet and select the relevant columns. The columns are 1) time, 2) ln of the observed index, 3) ln of the predicted index, 4) residuals and 5) ln of the population numbers. These columns are repeated for each index, age by age.

63. In ADAPT
    64. Select "Output"
        65. Select "To Clipboard"
            66. Select "Residuals". A menu will appear allowing you to select the residuals to be copied. Select all ages for the first index (Otter trawl). Click OK.
    67. A message will appear in the Session log indicating that the data were copied to the clipbooard.
68. In Excel:
    69. Go to the "WS-Res" sheet (Working Sheet - Residuals). Copy the content of the clipboard to cell A3. In the next steps, we will reconstruct the matrix of residuals and paste it in the index sheets ("TunX").
    70. Go to D3. Do "Ctrl-Shift-Down Arrow", followed by "Shift-F8".
    71. Go to I3. Do "Ctrl-Shift-Down Arrow", followed by "Shift-F8".
    72. Go to N3. Do "Ctrl-Shift-Down Arrow", followed by "Shift-F8".
    73. Go to S3. Do "Ctrl-Shift-Down Arrow", followed by "Shift-F8".
    74. Go to X3. Do "Ctrl-Shift-Down Arrow"
    75. Copy to Clipboard.
    76. Go to the "Tun1" sheet. Go to cell X67. Paste the content of the clipboard using "Paste Special [Value]".

Once you have done that, "bubble" plots, which are a convenient way to identify year-effects or age-effects, will be generated automatically. Go to the "Res-G" Sheet. Re-scale your graph so that the bubbles are spread over the entire area of the graph.

Copy the residuals of the other indices in a similar way and adjust the scale of the corresponding graphs accordingly. Prior to copying the information for the otter indices, make sure to delete previous entries in the "WS-Res" sheet. Note that all graphs use the same maximum size for the bubbles, as determined from the maximum observed in all variables. This allows you to make comparisons between graphs.

In the catchability model selected ("proportional"), the catchability coefficients at age are assumed to be constant over time. When this assumption is violated for a given index, the residuals aggregated for all ages in any given year will usually show trends or patterns over time. These (i.e. the residuals aggregated for all ages in any given year) are presented in the "Res-G" sheet.

> In the Blackfin example, the Prawn trawl index shows runs in residuals (consecutive years with predominantly positive or negative values) indicating a lack of fit. A similar effect is apparent for the seine index, to a lesser degree. Also noticeable is a "year" effect in 1990 for the Otter trawl index, as indicated by large positive residuals for most ages in that year.
>
> Also, look at the time trends in the residual aggregated by year for the prawn trawl index. This, together with the age-by-age bubble plot for this index, indicates a significant trend in the catchability of this index.
>
> In our initial inspection of the data, we had already noted the value of the otter trawl index for 1990 was anomalous. Many of these anomalies are more obvious here and someone would take the observations made using the diagnostics to make adjustments to the ADAPT formulation (e.g. drop an index series, drop age groups that have little information content and are poorly estimated, etc.).

Correlation matrix of parameter estimates.

77. In ADAPT
    78. Select "Output"
        79. Select "To Session log"
            80. Select "Correlation (parameter)".
81. The correlation of parameter estimates appears in the session-log.

Typically, when the estimation model has been over-specified (too many parameters in relation to the information contained in the data), the absolute values which are off the diagonal in the correlation matrix should be lowed than 0.3, indicating a relative independence of parameter estimates. Absolute values higher than 0.7 indicate a serious over-specification and the number of parameter should be reduced. Values between 0.3 and 0.7 are in a "gray" zone and, if they are too numerous, the "absolute value" of population estimates should be interpreted with caution. In addition, if carried forward into stochastic projections, the correlation between parameter estimates should be taken into account.

> In the Blackfin Example, as most values are below 0.15, the formulation used did not result in over-specifying number of parameters to be estimated.

Abundance and fishing mortality estimates.

If you are satisfied with these results, you should copy the population estimates and fishing mortality estimates obtained with ADAPT to the spreadsheet:

82. In ADAPT
    83. Select "Output"
        84. Select "To Clipboard"
            85. Select "Population numbers".
                86. Select "Adjusted for bias (Anal.)".
    87. The estimates of population numbers, adjusted for bias, are copied to the clipboard.
88. In Excel
    89. Go to the "N" sheet.
        90. Paste the content of the clipboard to cell A9.

To complete the data transfer, also copy the bias-adjusted estimates of fishing mortality to the "F" sheet of the template.

When the data transfer has been completed, the biomass and stock spawning biomass are calculated. The time trajectory of these entities are given in the "Out-G" Sheet. Inspect these for consistency with other sources of information you may have.

> In the Blackfin Example, the trends in population numbers are inconsistent with some indices. In essence, the aggregated results confirm the observations made in the inspection of residuals. Typically, someone would evaluate the "value" of each index as a possible indicator of stock abundance and decide which indices are to be kept in a subsequent ADAPT-formulation. Some indices may be affected by changes in survey gear, changes in commercial practices, etc. These aspects are key considerations in evaluating the potential of an index as an indicator of stock abundance.

Printing the Session-log.

At this point, you should save your Session log for future reference.

91. In ADAPT
    92. Select "File"
        93. Select "Save"
            94. You will be asked to provide a name for your file. When finished, select OK.
95. The Session log has been saved.

You can also copy the Session-log via the Clipboard directly into your word processor. This is a convenient way to prepare technical annexes on your ADAPT analyses for your assessment documents. There are a few steps to take to ensure that the file will print properly.

96. In ADAPT
    97. Select "Output"
        98. Select "To Clipboard"
            99. Select "Session log".

100. The Session log will be copied to the clipboard. Go to your word processor and paste the content of the clipboard in the first row of a new document.

The log file has been prepared by ADAPT using the APL character set. You need to change the font of your work processor to an APL font. To do so, select the entire document and change the font to "APL Win+", "APLPLUS", or any other APL-font.

In addition, the "-" character appears as "*y*¯" in this file. To change this character to "-", do a global replace for that character. The easiest way to generate that character is to locate its first occurrence in the file, copy it to the clipboard and paste it in the "Replace [Find what]?" field. The Session log for this tutorial appears in Annex 2.

Sensitivity to assumptions.

When using ADAPT, or any other VPA-calibration technique, it is important to verify the sensitivity of the results to various assumptions.

Blackfin Example:

The next steps in the formulation of this estimation problem would be to:

1. Try estimating the oldest age-groups. The Session log for this formulation appears in Annex 3. The correlation matrix of parameter estimates gives very high values for all entries in the matrix, indicating that the estimation problem is over-specified. Also, the relative errors of parameter estimates are much higher than the preceding formulation.
2. Formulate a model that accounts for the trend in catchability for the "Spawn trawl" index.
3. Verify the sensitivity to the assumptions used for defining the fishing mortality for the last age. You will see that the time trajectories for the stock are sensitive to the way the fishing mortality for the oldest age is determined.
4. See what influence data points leading to year effects in residuals have on the population estimates.
5. Carry out a retrospective analysis to evaluate if the assessment procedure has a tendency to over- or under-estimate population abundance. Retrospective analyses are typically done by repeating the estimation with the same formulation but by dropping the most recent years from the time series; the results are then compared to the results obtained for the corresponding years with the full series.

This completes the tutorial for estimation of population abundance with ADAPT. The ADAPT software also provides ways to carry out projections and risk analyses from the results. These functions are explored in a separate tutorial (Rivard and Gavaris, 2000).

References and related reading:

Gavaris S. and L. Van Eeckhaute. 1998. Assessment of Haddock on Eastern Georges Bank. Canadian Stock Assessment Secretariat Research Document 98/66. 75 pages.

Gavaris, S. 1991. Experience with the Adaptive Framework as a Calibration Tool. ICES C.M. 1991/D:19. 8 pages.

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Gavaris S. 1999. ADAPT (ADAPTive framework) User's Guide. Mimeographed. 25 pages.

Mohn R.K. 1993. Bootstrap estimates of ADAPT parameters, their projection in risk analysis and their retrospective patterns. p. 173-184. *In* S. J. Smith, J.J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Rivard D. and S. Gavaris. 2000. Tutorial for projections and risk analysis with ADAPT. NAFO SCR Doc. 00/57 (Serial No. N4297), 42 pages.

Smith S. and S. Gavaris. 1993. Evaluating the Accuracy of Projected Catch Estimates From Sequential Population Analysis and Trawl Survey Abundance Estimates. p. 163-172. *In* S. J. Smith, J.J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Annex 1. "ADAPT Template - Blackfin.xls"

The Excel template named "ADAPT Template.xls" could serve as a front-end to ADAPT. The spreadsheet is useful to transfer input data and results to/from ADAPT and to dis play them in a graphical form.

You will find in the next pages a printout of the Excel template once completed for the "blackfin" example used in this tutorial.

Title: **Blackfin: NAFO SC Workshop - ADAPT Tutorial**
Data: **Landings**
First year: 1963

	Tonnes
1963	6,594
1964	13,596
1965	18,395
1966	18,584
1967	16,034
1968	12,787
1969	17,124
1970	14,536
1971	19,863
1972	29,219
1973	33,832
1974	35,973
1975	30,800
1976	41,747
1977	27,210
1978	31,370
1979	21,604
1980	22,102
1981	23,574
1982	23,884
1983	28,890
1984	21,641
1985	26,595
1986	39,886
1987	31,369
1988	34,178
1989	25,577
1990	19,865
1991	16,995
1992	11,804
1993	13,943
1994	10,429
1995	
1996	
1997	
1998	
1999	
2000	
2001	
2002	
2003	
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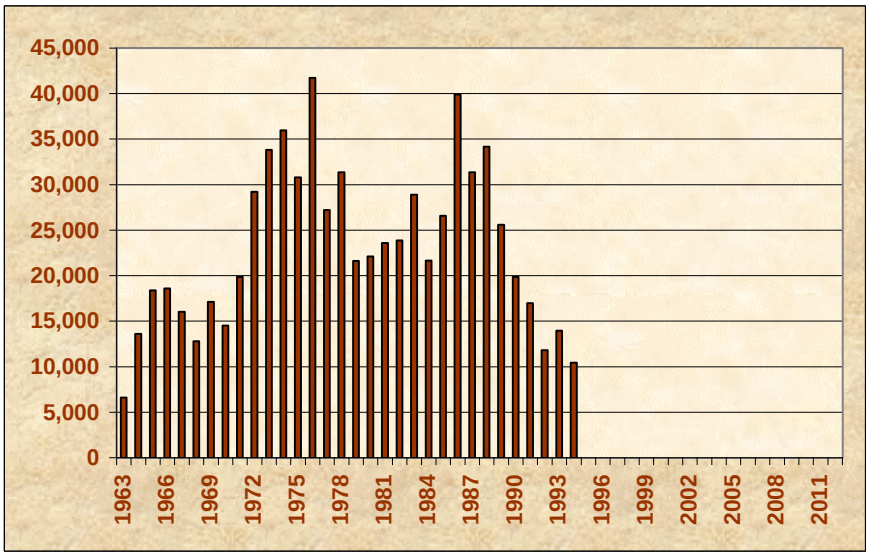

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Catch numbers at age
First year: 1963
First age: 1

Catch numbers at age **Scale:** 1000

Cn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1963	0	155	1483	688	327	215	73	149	50	49						3190
1964	0	117	2136	2340	700	339	159	42	49	93						5975
1965	0	231	3327	3060	1757	512	271	92	69	137						9457
1966	0	68	2838	4909	1220	693	135	39	27	48						9977
1967	0	385	2053	2885	1934	268	454	91	44	75						8189
1968	2	49	2435	2287	1197	621	148	126	29	58						6952
1969	0	335	1983	4618	1498	507	568	106	79	71						9765
1970	0	33	2857	2335	1805	599	240	196	41	122						8228
1971	0	382	1385	4444	1891	1085	465	362	300	238						10552
1972	57	3973	8419	3894	2256	456	333	160	92	162						19803
1973	350	7753	7665	5251	1946	883	468	336	199	472						25322
1974	897	3374	6062	2417	2158	617	949	925	502	869						18769
1975	25	2592	6672	2546	1328	873	1013	711	198	343						16300
1976	36	2826	8274	2782	1806	1122	662	518	586	1365						19979
1977	160	1257	4680	2734	1687	743	562	386	290	922						13421
1978	38	4452	4278	2362	1306	701	293	244	163	1326						15163
1979	10	1000	1836	1205	1181	724	372	157	191	757						7433
1980	46	1023	3351	954	685	638	471	194	91	817						8270
1981	154	2490	3932	1981	588	410	341	223	154	673						10947
1982	43	1403	4633	1687	1250	574	388	247	136	461						10824
1983	35	3519	4761	2574	834	764	509	158	105	506						13765
1984	157	3026	5590	2407	880	685	302	140	57	160						13404
1985	6	2288	5122	3051	1459	1230	610	187	105	225						14283
1986	232	773	7101	8441	3787	1399	1056	470	186	347						23792
1987	1	1698	2194	6967	1928	1359	779	454	261	210						15850
1988	21	3591	5702	3518	2627	1051	892	698	330	329						18759
1989	22	759	7291	5703	2255	1400	376	258	157	184						18406
1990	58	1485	5595	3729	1194	786	525	245	132	157						13906
1991	153	1243	3594	2946	1175	607	424	235	96	223						10697
1992	28	861	1773	3093	968	354	107	61	54	93						7392
1993	15	2511	2668	2827	1185	270	112	56	43	83						9768
1994	3	2408	2029	1080	492	280	109	65	50	110						6627
1995																0
1996																0
1997																0
1998																0
1999																0
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2007																0
2008																0
2009																0
2010																0
2011																0
2012																0

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Catch weight at age (kg)
First year 1963
First age 1

Catch weight at age (kg)

Cw	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1963	0.00	0.92	1.30	1.77	2.35	3.21	4.17	3.76	5.31	7.54					
1964	0.00	0.80	1.45	2.01	2.76	3.76	4.27	5.06	6.26	7.30					
1965	0.00	0.74	1.16	1.68	2.47	3.85	4.48	5.43	6.79	7.50					
1966	0.00	0.65	1.09	1.74	2.74	3.23	4.62	5.81	6.55	8.07					
1967	0.00	1.07	1.19	1.58	2.24	3.53	3.76	5.26	5.95	7.23					
1968	0.48	0.63	1.19	1.68	2.19	2.99	4.05	4.47	5.28	7.39					
1969	0.00	0.78	1.04	1.43	2.28	2.95	3.51	4.93	5.73	7.58					
1970	0.00	0.60	1.08	1.42	1.98	2.95	3.67	4.88	6.26	7.16					
1971	0.00	0.65	0.95	1.26	1.79	2.74	3.51	4.70	5.28	7.34					
1972	0.51	0.75	1.08	1.71	2.47	2.52	2.91	4.89	6.01	8.09					
1973	0.31	0.62	1.09	1.37	2.49	3.03	3.61	4.74	6.68	8.11					
1974	0.31	0.59	0.97	1.61	1.72	3.52	4.52	4.99	6.01	8.28					
1975	0.46	0.74	0.93	1.49	2.57	3.48	4.77	5.59	6.53	8.55					
1976	0.44	0.69	1.02	1.46	2.79	3.30	4.26	5.04	5.91	7.92					
1977	0.46	0.66	0.84	1.40	2.25	3.26	4.34	5.13	5.95	7.91					
1978	0.48	0.50	1.13	1.70	2.64	3.89	4.82	5.48	6.14	8.57					
1979	0.51	0.70	1.32	1.97	2.39	3.34	4.58	5.78	6.95	9.33					
1980	0.42	0.65	1.17	1.93	2.65	3.55	4.56	5.53	6.53	9.65					
1981	0.40	0.68	1.11	1.72	3.00	4.10	5.18	6.36	7.35	9.94					
1982	0.43	0.71	1.07	1.77	2.72	3.87	5.29	6.14	7.75	10.68					
1983	0.38	0.67	1.25	1.84	3.09	3.66	5.04	6.32	6.99	10.87					
1984	0.47	0.73	1.11	1.79	2.67	3.52	4.74	5.84	7.67	10.88					
1985	0.40	0.70	1.05	1.67	2.61	3.23	4.30	5.98	7.35	11.05					
1986	0.67	0.74	0.87	1.33	2.20	3.14	4.11	5.15	6.37	9.47					
1987	0.45	0.61	0.96	1.18	1.99	3.05	4.42	5.65	7.24	10.97					
1988	0.56	0.70	1.03	1.34	1.71	3.21	4.41	5.55	7.18	9.96					
1989	0.50	0.74	0.93	1.16	1.60	2.58	4.39	5.67	6.95	8.75					
1990	0.55	0.75	0.89	1.23	1.85	2.62	3.77	5.70	6.95	8.86					
1991	0.56	0.87	0.97	1.24	1.80	2.37	3.25	4.64	6.54	8.71					
1992	0.52	0.79	1.12	1.34	2.04	2.72	4.16	5.04	6.51	9.74					
1993	0.62	0.85	1.10	1.43	1.97	2.89	3.89	4.94	6.37	8.55					
1994	0.63	0.94	1.17	1.61	2.32	3.00	4.38	5.38	6.40	8.86					
1995															
1996															
1997															
1998															
1999															
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2004															
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2006															
2007															
2008															
2009															
2010															
2011															
2012															
Mean	**0.36**	**0.72**	**1.08**	**1.56**	**2.32**	**3.22**	**4.24**	**5.31**	**6.49**	**8.77**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Stock weight at age (kg) - Beginning of year
First year: 1963
First age: 1

Stock weight at age (kg) - Beginning of year

Sw	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1963	0.000	0.920	1.300	1.769	2.350	3.210	4.170	3.759	5.309	7.542					
1964	0.000	0.800	1.450	2.010	2.760	3.760	4.270	5.060	6.260	7.297					
1965	0.000	0.740	1.160	1.680	2.470	3.850	4.480	5.431	6.791	7.504					
1966	0.000	0.650	1.090	1.740	2.740	3.229	4.620	5.810	6.549	8.069					
1967	0.000	1.070	1.190	1.581	2.240	3.530	3.761	5.260	5.951	7.233					
1968	0.480	0.630	1.190	1.680	2.190	2.989	4.050	4.470	5.280	7.386					
1969	0.000	0.780	1.040	1.430	2.280	2.950	3.511	4.931	5.730	7.578					
1970	0.000	0.600	1.080	1.419	1.980	2.949	3.670	4.879	6.259	7.158					
1971	0.000	0.650	0.950	1.260	1.790	2.740	3.510	4.701	5.280	7.344					
1972	0.508	0.748	1.082	1.708	2.474	2.521	2.908	4.889	6.014	8.088					
1973	0.310	0.620	1.089	1.374	2.487	3.025	3.605	4.736	6.681	8.105					
1974	0.309	0.589	0.973	1.607	1.716	3.522	4.519	4.985	6.012	8.276					
1975	0.463	0.736	0.928	1.491	2.573	3.483	4.774	5.587	6.533	8.554					
1976	0.444	0.686	1.019	1.458	2.786	3.298	4.264	5.038	5.905	7.915					
1977	0.459	0.659	0.844	1.396	2.252	3.259	4.339	5.132	5.946	7.907					
1978	0.481	0.502	1.129	1.697	2.639	3.891	4.816	5.480	6.137	8.572					
1979	0.510	0.697	1.318	1.974	2.391	3.341	4.583	5.784	6.951	9.326					
1980	0.415	0.650	1.165	1.928	2.645	3.552	4.555	5.533	6.525	9.652					
1981	0.399	0.677	1.105	1.717	2.997	4.095	5.182	6.362	7.353	9.944					
1982	0.432	0.714	1.070	1.768	2.722	3.874	5.290	6.143	7.752	10.679					
1983	0.380	0.674	1.251	1.841	3.089	3.656	5.040	6.315	6.985	10.867					
1984	0.471	0.726	1.108	1.791	2.671	3.522	4.743	5.837	7.672	10.877					
1985	0.403	0.702	1.047	1.670	2.610	3.230	4.301	5.979	7.352	11.052					
1986	0.671	0.736	0.866	1.333	2.199	3.140	4.112	5.148	6.368	9.469					
1987	0.453	0.608	0.955	1.184	1.985	3.054	4.421	5.650	7.236	10.973					
1988	0.560	0.700	1.034	1.344	1.706	3.210	4.414	5.545	7.176	9.959					
1989	0.500	0.740	0.929	1.159	1.597	2.577	4.387	5.665	6.946	8.750					
1990	0.550	0.747	0.891	1.229	1.849	2.618	3.771	5.696	6.952	8.864					
1991	0.564	0.865	0.969	1.235	1.797	2.366	3.249	4.640	6.536	8.705					
1992	0.524	0.791	1.123	1.340	2.040	2.717	4.164	5.043	6.509	9.744					
1993	0.615	0.852	1.102	1.434	1.974	2.893	3.888	4.937	6.372	8.547					
1994	0.632	0.939	1.168	1.612	2.322	2.998	4.377	5.381	6.397	8.861					
1995															
1996															
1997															
1998															
1999															
2000															
2001															
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2004															
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2009															
2010															
2011															
2012															
Mean	**0.360**	**0.725**	**1.082**	**1.558**	**2.323**	**3.220**	**4.242**	**5.306**	**6.491**	**8.775**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Maturity ogive
First year: 1963
First age: 1

	Maturity at age (%)														
MO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1963	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1964	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1965	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1966	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1967	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1968	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1969	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1970	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1971	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1972	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1973	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1974	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1975	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1976	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1977	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1978	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1979	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1980	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1981	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1982	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1983	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1984	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1985	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1986	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1987	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1988	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1989	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1990	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1991	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1992	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1993	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1994	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1995															
1996															
1997															
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2003															
2004															
2005															
2006															
2007															
2008															
2009															
2010															
2011															
2012															
Mean	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Natural Mortality
First year: 1963
First age: 1

Natural Mortality (per year)

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1963	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1964	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1965	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1966	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1967	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1968	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1969	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1970	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1971	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1972	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1973	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1974	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1975	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1976	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1977	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1978	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1979	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1980	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1981	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1982	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1983	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1984	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1985	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1986	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1988	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1989	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1990	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1991	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1992	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1993	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1994	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2					
1995															
1996															
1997															
1998															
1999															
2000															
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2009															
2010															
2011															
2012															

Title Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Index 1
Index Name: Otter trawl
First year: 1975
First age: 2
Month of survey: 7

Effort and Catch

Catch Rate	Index 1	Scalar:	10000				Units:	number/tow									Total
	Otter trawl	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Otter trawl
	1975.5	132.69	70.39	14.56	11.60	12.41											241.64
	1976.5	88.95	168.20	25.83	5.87	7.63											296.49
	1977.5	36.01	36.30	19.17	4.94	2.90											99.31
	1978.5	55.08	39.29	10.66	7.90	6.52											119.45
	1979.5	70.07	52.70	13.47	10.78	18.27											165.29
	1980.5	33.51	58.90	7.11	3.55	4.57											107.65
	1981.5	86.12	126.47	15.52	0.00	1.55											229.67
	1982.5	164.86	81.02	78.20	2.11	0.70											326.90
	1983.5	337.87	55.52	10.84	9.98	1.73											415.94
	1984.5	232.29	125.12	4.98	5.98	15.45											383.83
	1985.5	253.26	28.37	4.20	1.05	3.15											290.04
	1986.5	202.26	150.21	13.38	4.46	4.46											374.78
	1987.5	25.89	19.80	35.02	3.81	6.09											90.60
	1988.5	95.54	141.34	39.26	28.79	5.23											310.17
	1989.5	16.93	213.98	47.38	14.30	16.34											308.92
	1990.5	11.65	287.13	244.91	115.78	64.29											723.76
	1991.5	139.62	158.19	57.36	31.66	10.25											397.08
	1992.5	39.05	82.23	30.41	11.66	6.20											169.55
	1993.5	61.01	61.13	6.45	3.31	2.32											134.21
	1994.5	31.89	76.09	27.87	17.16	7.71											160.71
	1995.5																#N/A
	1996.5																#N/A
	1997.5																#N/A
	1998.5																#N/A
	1999.5																#N/A
	2000.5																#N/A
	2001.5																#N/A
	2002.5																#N/A
	2003.5																#N/A
	2004.5																#N/A
	2005.5																#N/A
	2006.5																#N/A
	2007.5																#N/A
	2008.5																#N/A
	2009.5																#N/A
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	2013.5																#N/A
	2014.5																#N/A
	2015.5																#N/A
	2016.5																#N/A
	2017.5																#N/A
	2018.5																#N/A
	2019.5																#N/A
	2020.5																#N/A
	2021.5																#N/A
	2022.5																#N/A
	2023.5																#N/A
	2024.5																#N/A
	Mean	105.73	101.62	35.33	14.73	9.89	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

Title Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Index 2
Index Name: Seine
First year: 1975
First age: 2
Month of survey: 7

Effort and Catch

Catch Rate **Index 1** **Scalar:** 10000 **Units:** number/tow

Seine	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total Seine
1975.5	6.20	31.90	15.07	2.13												55.30
1976.5	2.71	12.01	9.68	1.94												26.34
1977.5	1.60	11.76	1.60	1.07												16.03
1978.5	15.22	8.39	1.24	0.93												25.78
1979.5	0.75	0.50	1.01	3.02												5.28
1980.5	3.83	1.49	0.85	0.43												6.60
1981.5	8.21	5.16	1.88	0.23												15.48
1982.5	14.99	18.53	1.09	0.82												35.43
1983.5	16.02	5.25	3.15	2.89												27.31
1984.5	60.89	10.15	0.34	1.01												72.39
1985.5	5.31	14.79	9.48	0.76												30.34
1986.5	7.01	28.56	27.56	12.53												75.65
1987.5	47.64	4.57	3.05	0.38												55.64
1988.5	14.50	13.56	4.68	4.21												36.95
1989.5	5.13	15.78	5.30	0.63												26.84
1990.5	6.30	13.68	4.82	1.50												26.31
1991.5	39.63	35.11	8.24	1.82												84.80
1992.5	74.88	34.46	44.54	7.15												161.03
1993.5	147.70	44.69	8.35	3.45												204.18
1994.5	111.82	89.67	34.04	11.29												246.82
1995.5																#N/A
1996.5																#N/A
1997.5																#N/A
1998.5																#N/A
1999.5																#N/A
2000.5																#N/A
2001.5																#N/A
2002.5																#N/A
2003.5																#N/A
2004.5																#N/A
2005.5																#N/A
2006.5																#N/A
2007.5																#N/A
2008.5																#N/A
2009.5																#N/A
2010.5																#N/A
2011.5																#N/A
2012.5																#N/A
2013.5																#N/A
2014.5																#N/A
2015.5																#N/A
2016.5																#N/A
2017.5																#N/A
2018.5																#N/A
2019.5																#N/A
2020.5																#N/A
2021.5																#N/A
2022.5																#N/A
2023.5																#N/A
2024.5																#N/A
Mean	29.52	20.00	9.30	2.91	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

Title Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Index 3
Index Name: Light trawl
First year: 1975
First age: 2
Month of survey: 7

Effort and Catch

Catch Rate	Index 1	Scalar:	10000				Units:	nb/tow									Total
	Light trawl	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Light trawl
	1975.5	31.51	86.21	28.11	5.36	5.36	0.60										157.16
	1976.5	31.52	68.64	39.30	7.24	3.04	1.40										151.13
	1977.5	22.65	66.61	29.83	10.07	4.51	2.15										135.82
	1978.5	181.68	78.48	9.58	4.75	0.91	0.82										276.22
	1979.5	13.52	4.40	6.70	24.62	12.42	3.08										64.74
	1980.5	20.67	19.71	15.00	9.16	7.93	3.14										75.60
	1981.5	51.82	53.99	12.62	1.75	0.36	0.42										120.96
	1982.5	22.92	49.75	13.38	3.99	2.66	1.63										94.32
	1983.5	41.84	16.29	8.99	1.87	2.40	0.36										71.75
	1984.5	22.54	74.73	3.10	2.87	1.74	0.91										105.89
	1985.5	18.42	49.15	25.84	2.10	3.08	0.56										99.15
	1986.5	4.58	44.18	26.16	10.19	1.58	1.26										87.96
	1987.5	51.20	12.99	6.53	1.90	1.14	0.91										74.67
	1988.5	25.73	17.64	4.74	5.75	0.63	0.25										54.74
	1989.5	5.35	29.52	7.52	1.80	1.67	0.48										46.35
	1990.5	16.45	32.19	17.61	2.84	1.12	1.25										71.48
	1991.5	17.39	16.76	11.02	4.95	1.37	0.84										52.32
	1992.5	11.49	12.26	8.97	1.75	0.72	0.37										35.57
	1993.5	25.70	13.72	3.95	0.88	1.02	0.75										46.01
	1994.5	11.68	18.65	7.42	3.35	2.23	0.61										43.94
	1995.5																#N/A
	1996.5																#N/A
	1997.5																#N/A
	1998.5																#N/A
	1999.5																#N/A
	2000.5																#N/A
	2001.5																#N/A
	2002.5																#N/A
	2003.5																#N/A
	2004.5																#N/A
	2005.5																#N/A
	2006.5																#N/A
	2007.5																#N/A
	2008.5																#N/A
	2009.5																#N/A
	2010.5																#N/A
	2011.5																#N/A
	2012.5																#N/A
	2013.5																#N/A
	2014.5																#N/A
	2015.5																#N/A
	2016.5																#N/A
	2017.5																#N/A
	2018.5																#N/A
	2019.5																#N/A
	2020.5																#N/A
	2021.5																#N/A
	2022.5																#N/A
	2023.5																#N/A
	2024.5																#N/A
	Mean	31.43	38.29	14.32	5.36	2.80	1.09	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

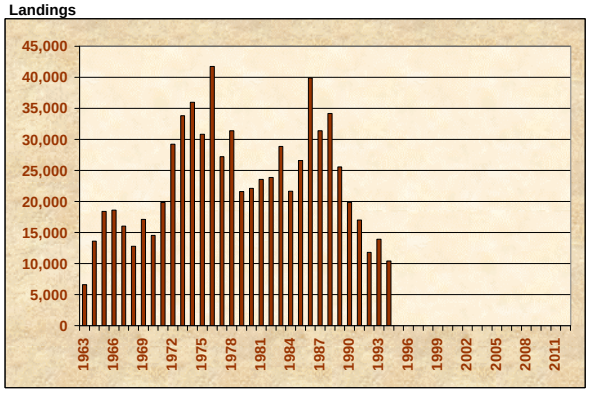
Title Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Index 4
Index Name: Prawn trawl
Year Range: 1975
Age Range: 2
Month of survey: 7

Effort and Catch

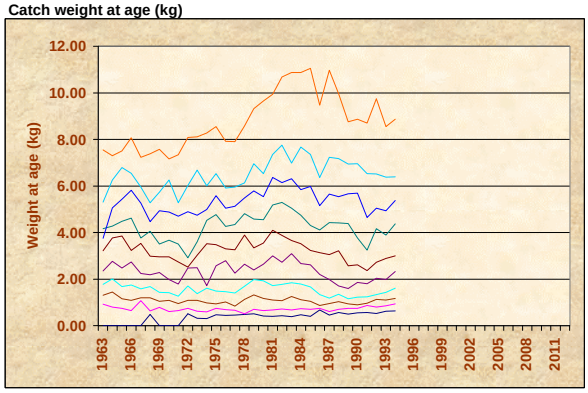
Catch Rate	Index 1	Scalar:	10000			Units:	Nb per tow									Total
	Prawn trawl	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Prawn trawl
	1975.5	23.64	91.85	17.24													132.72
	1976.5	24.57	26.28	8.72													59.56
	1977.5	2.35	51.37	10.51													64.24
	1978.5	2.16	4.84	2.01													9.01
	1979.5	4.92	0.74	1.23													6.88
	1980.5	7.80	2.79	0.76													11.35
	1981.5	15.71	3.08	0.85													19.64
	1982.5	2.25	2.11	0.42													4.78
	1983.5	11.86	1.70	0.68													14.25
	1984.5	8.79	5.94	0.16													14.89
	1985.5	4.97	5.39	0.83													11.19
	1986.5	2.03	14.50	0.49													17.02
	1987.5	3.87	1.04	0.28													5.19
	1988.5	4.40	0.18	0.03													4.60
	1989.5	0.36	2.55	0.18													3.09
	1990.5	1.62	0.25	0.37													2.24
	1991.5	0.67	0.25	0.12													1.03
	1992.5	0.78	0.13	0.13													1.03
	1993.5	0.51	0.11	0.09													0.71
	1994.5	0.16	0.24	0.06													0.46
	1995.5																#N/A
	1996.5																#N/A
	1997.5																#N/A
	1998.5																#N/A
	1999.5																#N/A
	2000.5																#N/A
	2001.5																#N/A
	2002.5																#N/A
	2003.5																#N/A
	2004.5																#N/A
	2005.5																#N/A
	2006.5																#N/A
	2007.5																#N/A
	2008.5																#N/A
	2009.5																#N/A
	2010.5																#N/A
	2011.5																#N/A
	2012.5																#N/A
	2013.5																#N/A
	2014.5																#N/A
	2015.5																#N/A
	2016.5																#N/A
	2017.5																#N/A
	2018.5																#N/A
	2019.5																#N/A
	2020.5																#N/A
	2021.5																#N/A
	2022.5																#N/A
	2023.5																#N/A
	2024.5																#N/A
	Mean	6.17	10.77	2.26	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

Blackfin: NAFO SC Workshop - ADAPT Tutorial

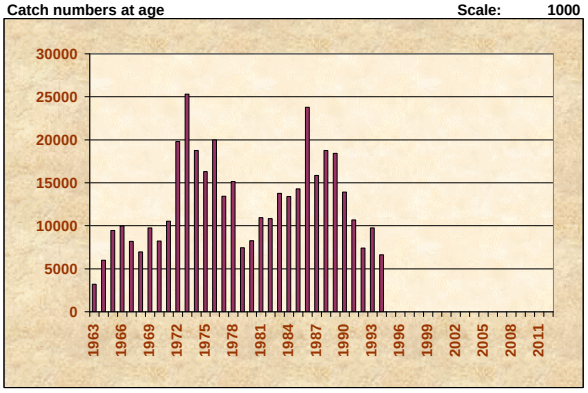
Landings



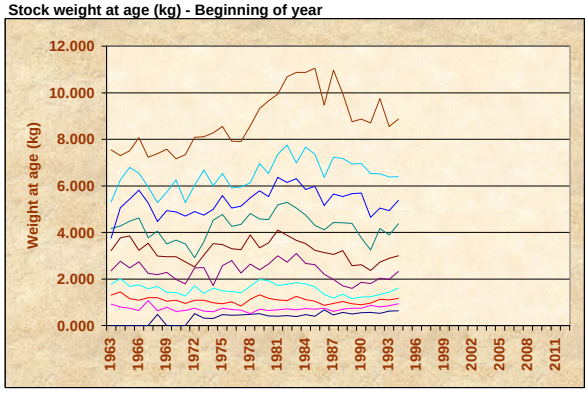
Catch weight at age (kg)



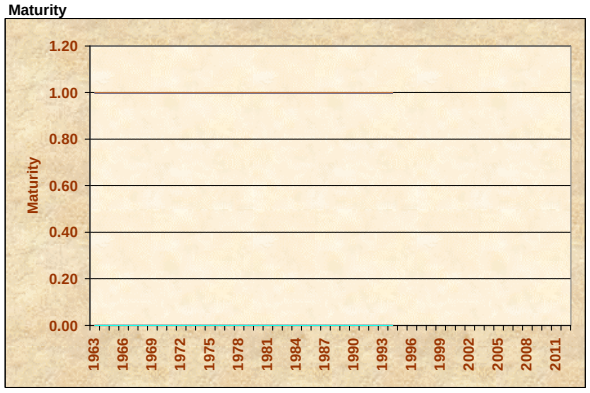
Catch numbers at age Scale: 1000



Stock weight at age (kg) - Beginning of year

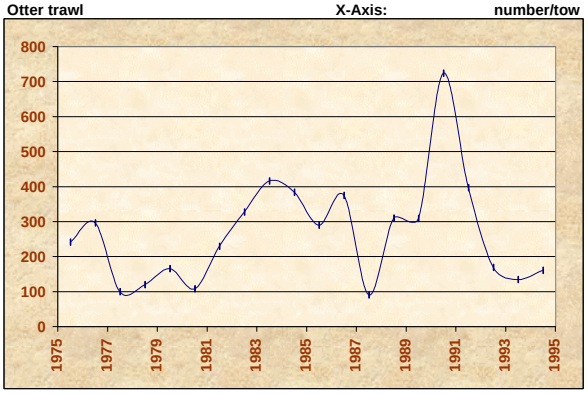


Maturity

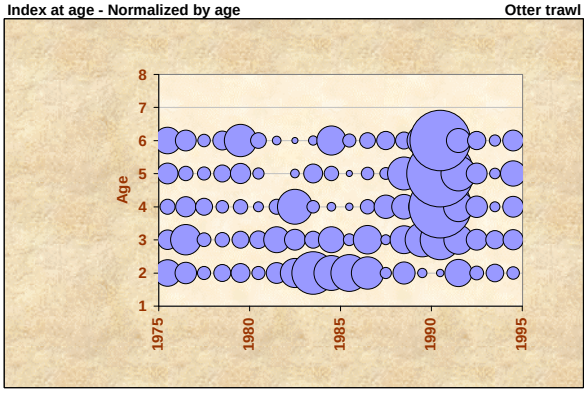


Blackfin: NAFO SC Workshop - ADAPT Tutorial

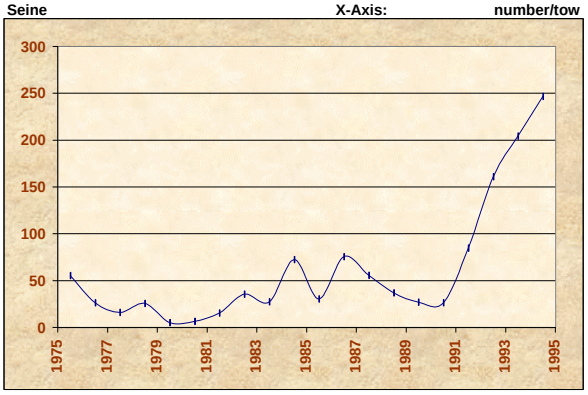
Otter trawl X-Axis: number/tow



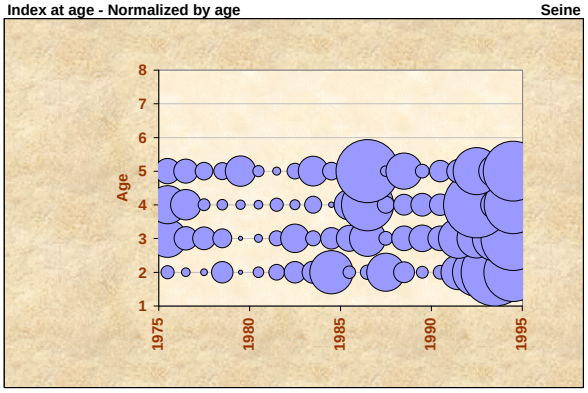
Index at age - Normalized by age Otter trawl



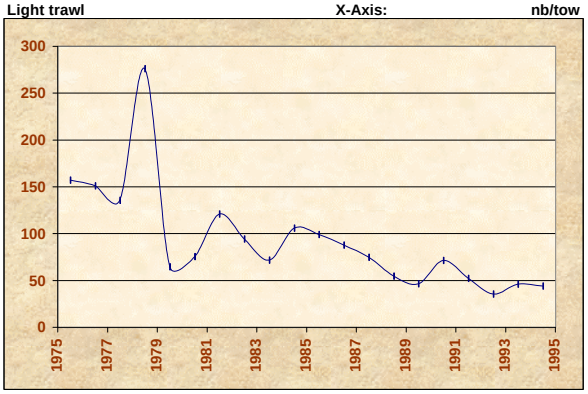
Seine X-Axis: number/tow



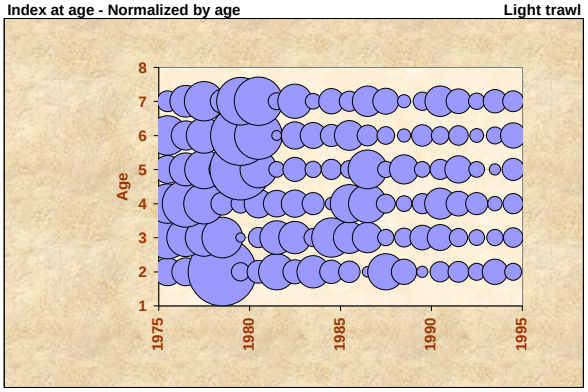
Index at age - Normalized by age Seine



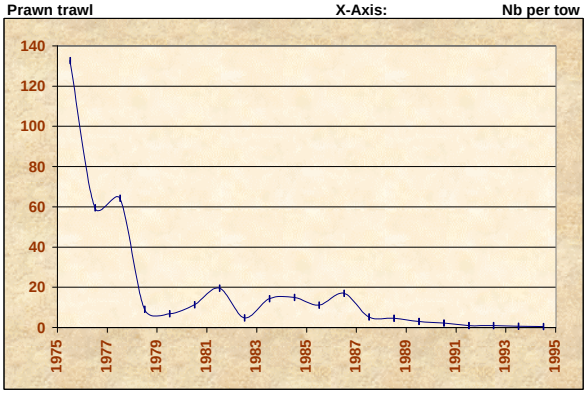
Light trawl X-Axis: nb/tow



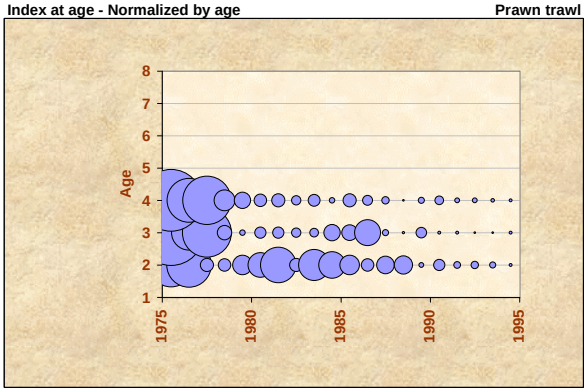
Index at age - Normalized by age Light trawl



Prawn trawl X-Axis: Nb per tow



Index at age - Normalized by age Prawn trawl



Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Population numbers
First year: 1963
First age: 1

Population numbers **Scale:** 1000

999	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1963	42057	26415	19484	5852	3859	2200	796	1330	817	489						103299
1964	48620	34433	21487	14615	4171	2865	1607	585	954	624						129962
1965	89711	39807	28086	15666	9858	2785	2040	1172	441	737						190304
1966	53604	73449	32382	19996	10073	6490	1819	1426	877	299						200417
1967	92257	43888	60074	23953	11960	7148	4689	1368	1132	694						247162
1968	76195	75534	35584	47331	17011	8051	5610	3430	1038	887						270671
1969	79295	62381	61798	26937	36687	12848	6031	4460	2694	823						293955
1970	70305	64921	50771	48805	17897	28685	10061	4426	3556	2134						301562
1971	70718	57561	53123	38990	37851	13026	22944	8021	3447	2874						308554
1972	62055	57899	46782	42243	27917	29283	9686	18365	6240	2551						303021
1973	46351	50755	43819	30724	31074	20821	23563	7630	14892	5026						274656
1974	48704	37633	34572	28977	20428	23686	16250	18869	5943	12013						247076
1975	30643	39066	27769	22849	21544	14780	18835	12448	14614	4413						206961
1976	23547	25066	29646	16739	16412	16441	11313	14507	9550	11786						175007
1977	22978	19246	17975	16843	11200	11809	12448	8665	11410	7290						139864
1978	23076	18668	14624	10513	11328	7650	8998	9685	6746	9080						120367
1979	27484	18858	11283	8133	6484	8098	5631	7103	7709	5376						106158
1980	32766	22493	14538	7584	5573	4245	5977	4275	5673	6139						109264
1981	33880	26785	17492	8890	5350	3946	2901	4469	3325	4563						111601
1982	45472	27599	19685	10786	5497	3850	2861	2068	3457	2583						123859
1983	43249	37190	21330	11952	7312	3377	2635	1993	1471	2708						133217
1984	45414	35378	27276	13183	7471	5235	2078	1700	1489	1109						140332
1985	28713	37040	26236	17303	8627	5323	3669	1429	1265	1168						130774
1986	38465	23503	28262	16872	11420	5750	3253	2455	1002	941						131922
1987	44006	31283	18545	16758	6286	5955	3450	1716	1587	653						130239
1988	28176	36028	24080	13206	7490	3417	3654	2124	997	1064						120236
1989	27972	23049	26260	14590	7652	3778	1855	2190	1113	521						108979
1990	25086	22881	18186	14953	6841	4241	1839	1180	1560	770						97539
1991	20256	20487	17394	9870	8892	4526	2765	1035	746	1158						87128
1992	28934	16446	15651	11008	5437	6221	3159	1882	636	524						89898
1993	16115	23664	12688	11216	6236	3580	4774	2490	1486	472						82720
1994	18324	13181	17111	7988	6643	4039	2688	3808	1988	1178						76947
1995	15000	15000	8624	12180	5567	4995	3054	2102	3059	1582						71164
1996																#N/A
1997																#N/A
1998																#N/A
1999																#N/A
2000																#N/A
2001																#N/A
2002																#N/A
2003																#N/A
2004																#N/A
2005																#N/A
2006																#N/A
2007																#N/A
2008																#N/A
2009																#N/A
2010																#N/A
2011																#N/A
2012																#N/A
	42407	35078	27352	18712	12365	8762	6453	4861	3725	2855	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Fishing mortality
First year: 1963
First age: 1

Fishing mortality

999	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean
1963	0.000	0.006	0.088	0.139	0.098	0.114	0.107	0.132	0.070	0.117						0.117
1964	0.000	0.004	0.116	0.194	0.204	0.140	0.115	0.082	0.058	0.179						0.179
1965	0.000	0.006	0.140	0.242	0.218	0.226	0.158	0.090	0.189	0.228						0.228
1966	0.000	0.001	0.102	0.314	0.143	0.125	0.085	0.031	0.035	0.194						0.194
1967	0.000	0.010	0.038	0.142	0.196	0.042	0.113	0.076	0.044	0.127						0.127
1968	0.000	0.001	0.078	0.055	0.081	0.089	0.030	0.041	0.031	0.075						0.075
1969	0.000	0.006	0.036	0.209	0.046	0.044	0.109	0.027	0.033	0.100						0.100
1970	0.000	0.001	0.064	0.054	0.118	0.023	0.027	0.050	0.013	0.065						0.065
1971	0.000	0.007	0.029	0.134	0.057	0.096	0.023	0.051	0.101	0.096						0.096
1972	0.001	0.079	0.220	0.107	0.093	0.017	0.039	0.010	0.016	0.073						0.073
1973	0.008	0.184	0.214	0.208	0.072	0.048	0.022	0.050	0.015	0.109						0.109
1974	0.021	0.104	0.214	0.096	0.124	0.029	0.067	0.056	0.098	0.083						0.083
1975	0.001	0.076	0.306	0.131	0.070	0.067	0.061	0.065	0.015	0.090						0.090
1976	0.002	0.133	0.365	0.202	0.129	0.078	0.067	0.040	0.070	0.136						0.136
1977	0.008	0.075	0.336	0.197	0.181	0.072	0.051	0.050	0.028	0.150						0.150
1978	0.002	0.304	0.387	0.283	0.136	0.106	0.037	0.028	0.027	0.175						0.175
1979	0.000	0.060	0.197	0.178	0.223	0.104	0.076	0.025	0.028	0.168						0.168
1980	0.002	0.051	0.292	0.149	0.145	0.181	0.091	0.051	0.018	0.158						0.158
1981	0.005	0.108	0.283	0.281	0.129	0.122	0.139	0.057	0.052	0.177						0.177
1982	0.001	0.058	0.299	0.189	0.287	0.179	0.162	0.141	0.044	0.218						0.218
1983	0.001	0.110	0.281	0.270	0.134	0.286	0.239	0.091	0.082	0.230						0.230
1984	0.004	0.099	0.255	0.224	0.139	0.155	0.174	0.095	0.043	0.173						0.173
1985	0.000	0.071	0.241	0.215	0.206	0.293	0.202	0.155	0.096	0.238						0.238
1986	0.007	0.037	0.323	0.787	0.451	0.311	0.439	0.236	0.228	0.516						0.516
1987	0.000	0.062	0.140	0.605	0.410	0.288	0.285	0.343	0.200	0.434						0.434
1988	0.001	0.116	0.301	0.346	0.484	0.411	0.312	0.446	0.450	0.414						0.414
1989	0.001	0.037	0.363	0.557	0.390	0.520	0.252	0.139	0.169	0.489						0.489
1990	0.003	0.074	0.411	0.320	0.213	0.228	0.375	0.259	0.098	0.254						0.254
1991	0.008	0.069	0.257	0.396	0.157	0.160	0.185	0.287	0.153	0.238						0.238
1992	0.001	0.059	0.133	0.368	0.218	0.065	0.038	0.036	0.098	0.217						0.217
1993	0.001	0.124	0.263	0.324	0.234	0.087	0.026	0.025	0.032	0.215						0.215
1994	0.000	0.224	0.140	0.161	0.085	0.079	0.046	0.019	0.028	0.109						0.109
1995																#N/A
1996																#N/A
1997																#N/A
1998																#N/A
1999																#N/A
2000																#N/A
2001																#N/A
2002																#N/A
2003																#N/A
2004																#N/A
2005																#N/A
2006																#N/A
2007																#N/A
2008																#N/A
2009																#N/A
2010																#N/A
2011																#N/A
2012																#N/A
Mean	0.002	0.074	0.216	0.252	0.183	0.150	0.130	0.103	0.083	0.195	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	

Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Biomass
First year: 1963
First age: 1

Biomass

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1963	0	24302	25329	10352	9070	7061	3317	4999	4338	3691	0	0	0	0	0	92460
1964	0	27547	31156	29375	11512	10772	6863	2963	5975	4553	0	0	0	0	0	130715
1965	0	29457	32580	26319	24350	10721	9139	6368	2998	5532	0	0	0	0	0	147465
1966	0	47742	35297	34794	27601	20956	8405	8286	5743	2415	0	0	0	0	0	191238
1967	0	46960	71488	37870	26791	25232	17635	7194	6739	5017	0	0	0	0	0	244925
1968	36574	47586	42345	79516	37254	24064	22722	15330	5479	6554	0	0	0	0	0	317424
1969	0	48658	64270	38520	83647	37901	21176	21991	15437	6239	0	0	0	0	0	337838
1970	0	38953	54833	69255	35437	84591	36924	21594	22254	15278	0	0	0	0	0	379119
1971	0	37415	50467	49127	67754	35691	80534	37705	18199	21107	0	0	0	0	0	397998
1972	31524	43308	50618	72151	69066	73823	28167	89788	37527	20636	0	0	0	0	0	516608
1973	14369	31468	47719	42215	77282	62985	84946	36134	99491	40734	0	0	0	0	0	537343
1974	15050	22166	33639	46566	35054	83421	73435	94064	35731	99416	0	0	0	0	0	538541
1975	14188	28752	25769	34068	55433	51477	89919	69548	95474	37751	0	0	0	0	0	502381
1976	10455	17195	30209	24405	45724	54222	48238	73085	56394	93288	0	0	0	0	0	453215
1977	10547	12683	15171	23513	25222	38486	54013	44468	67841	57644	0	0	0	0	0	349589
1978	11099	9371	16510	17840	29895	29767	43335	53072	41399	77830	0	0	0	0	0	330118
1979	14017	13144	14870	16055	15502	27054	25808	41081	53584	50134	0	0	0	0	0	271251
1980	13598	14621	16936	14623	14742	15080	27225	23653	37019	59253	0	0	0	0	0	236749
1981	13518	18134	19329	15264	16034	16158	15034	28430	24448	45372	0	0	0	0	0	211721
1982	19644	19706	21062	19070	14964	14915	15135	12704	26802	27586	0	0	0	0	0	191588
1983	16435	25066	26684	22004	22587	12346	13281	12585	10272	29427	0	0	0	0	0	190686
1984	21390	25684	30221	23611	19954	18437	9856	9920	11424	12065	0	0	0	0	0	182564
1985	11572	26002	27469	28896	22517	17194	15779	8546	9302	12905	0	0	0	0	0	180183
1986	25810	17298	24475	22490	25114	18054	13375	12636	6379	8912	0	0	0	0	0	174543
1987	19935	19020	17710	19842	12478	18186	15254	9696	11481	7163	0	0	0	0	0	150765
1988	15778	25219	24899	17749	12777	10968	16127	11780	7156	10597	0	0	0	0	0	153052
1989	13986	17057	24395	16910	12221	9736	8136	12405	7734	4555	0	0	0	0	0	127134
1990	13798	17092	16204	18377	12649	11104	6936	6722	10847	6827	0	0	0	0	0	120556
1991	11424	17721	16855	12189	15978	10708	8984	4800	4875	10084	0	0	0	0	0	113619
1992	15161	13009	17577	14751	11091	16903	13153	9492	4138	5108	0	0	0	0	0	120382
1993	9911	20162	13982	16084	12309	10357	18562	12291	9468	4032	0	0	0	0	0	127158
1994	11581	12377	19985	12877	15425	12109	11763	20488	12715	10436	0	0	0	0	0	139757
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
	7827	16297	19201	18534	18349	17810	17264	16476	15373	16043	0	0	0	0	0	

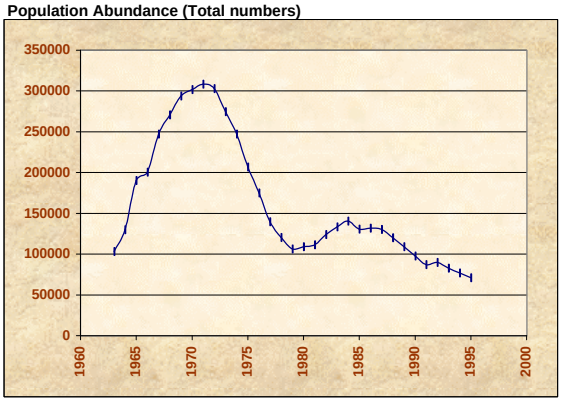
Title: Blackfin: NAFO SC Workshop - ADAPT Tutorial
Data: Stock Spawning Biomass
First year: 1963
First age: 1

Stock Spawning Biomass

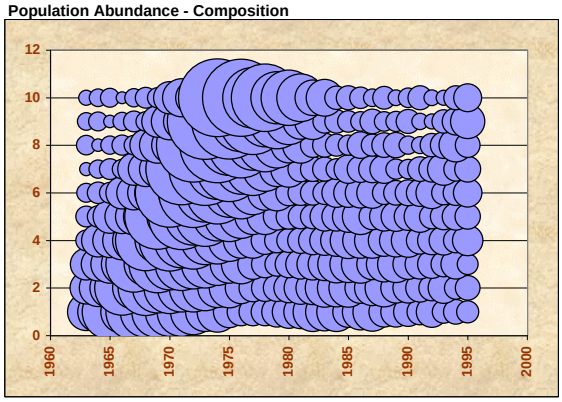
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1963	0	0	0	0	9070	7061	3317	4999	4338	3691	0	0	0	0	0	32476
1964	0	0	0	0	11512	10772	6863	2963	5975	4553	0	0	0	0	0	42637
1965	0	0	0	0	24350	10721	9139	6368	2998	5532	0	0	0	0	0	59109
1966	0	0	0	0	27601	20956	8405	8286	5743	2415	0	0	0	0	0	73406
1967	0	0	0	0	26791	25232	17635	7194	6739	5017	0	0	0	0	0	88608
1968	0	0	0	0	37254	24064	22722	15330	5479	6554	0	0	0	0	0	111403
1969	0	0	0	0	83647	37901	21176	21991	15437	6239	0	0	0	0	0	186391
1970	0	0	0	0	35437	84591	36924	21594	22254	15278	0	0	0	0	0	216079
1971	0	0	0	0	67754	35691	80534	37705	18199	21107	0	0	0	0	0	260989
1972	0	0	0	0	69066	73823	28167	89788	37527	20636	0	0	0	0	0	319007
1973	0	0	0	0	77282	62985	84946	36134	99491	40734	0	0	0	0	0	401572
1974	0	0	0	0	35054	83421	73435	94064	35731	99416	0	0	0	0	0	421122
1975	0	0	0	0	55433	51477	89919	69548	95474	37751	0	0	0	0	0	399604
1976	0	0	0	0	45724	54222	48238	73085	56394	93288	0	0	0	0	0	370951
1977	0	0	0	0	25222	38486	54013	44468	67841	57644	0	0	0	0	0	287674
1978	0	0	0	0	29895	29767	43335	53072	41399	77830	0	0	0	0	0	275297
1979	0	0	0	0	15502	27054	25808	41081	53584	50134	0	0	0	0	0	213164
1980	0	0	0	0	14742	15080	27225	23653	37019	59253	0	0	0	0	0	176971
1981	0	0	0	0	16034	16158	15034	28430	24448	45372	0	0	0	0	0	145476
1982	0	0	0	0	14964	14915	15135	12704	26802	27586	0	0	0	0	0	112105
1983	0	0	0	0	22587	12346	13281	12585	10272	29427	0	0	0	0	0	100498
1984	0	0	0	0	19954	18437	9856	9920	11424	12065	0	0	0	0	0	81657
1985	0	0	0	0	22517	17194	15779	8546	9302	12905	0	0	0	0	0	86244
1986	0	0	0	0	25114	18054	13375	12636	6379	8912	0	0	0	0	0	84470
1987	0	0	0	0	12478	18186	15254	9696	11481	7163	0	0	0	0	0	74258
1988	0	0	0	0	12777	10968	16127	11780	7156	10597	0	0	0	0	0	69407
1989	0	0	0	0	12221	9736	8136	12405	7734	4555	0	0	0	0	0	54787
1990	0	0	0	0	12649	11104	6936	6722	10847	6827	0	0	0	0	0	55085
1991	0	0	0	0	15978	10708	8984	4800	4875	10084	0	0	0	0	0	55430
1992	0	0	0	0	11091	16903	13153	9492	4138	5108	0	0	0	0	0	59884
1993	0	0	0	0	12309	10357	18562	12291	9468	4032	0	0	0	0	0	67019
1994	0	0	0	0	15425	12109	11763	20488	12715	10436	0	0	0	0	0	82937
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#N/A
	0	0	0	0	18349	17810	17264	16476	15373	16043	0	0	0	0	0	

Blackfin: NAFO SC Workshop - ADAPT Tutorial

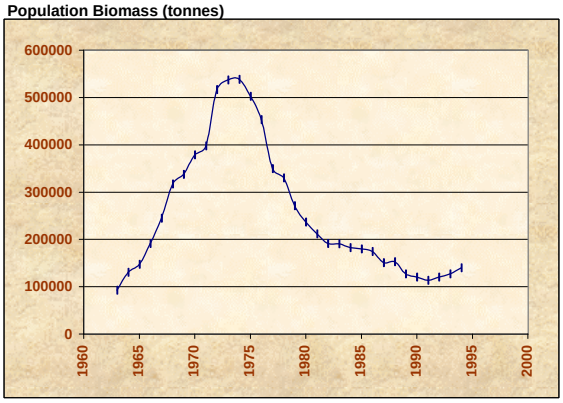
Population Abundance (Total numbers)



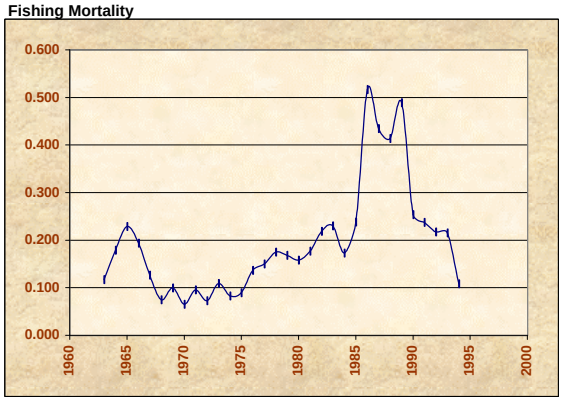
Population Abundance - Composition



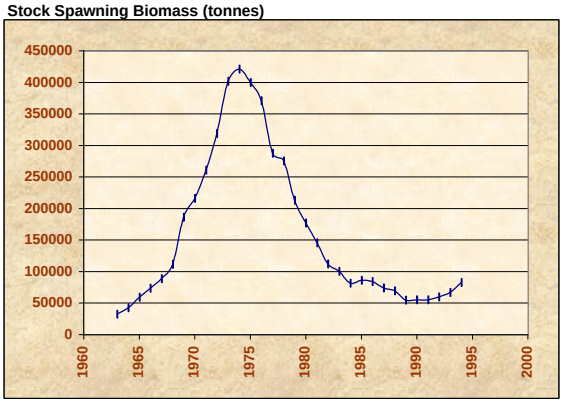
Population Biomass (tonnes)



Fishing Mortality

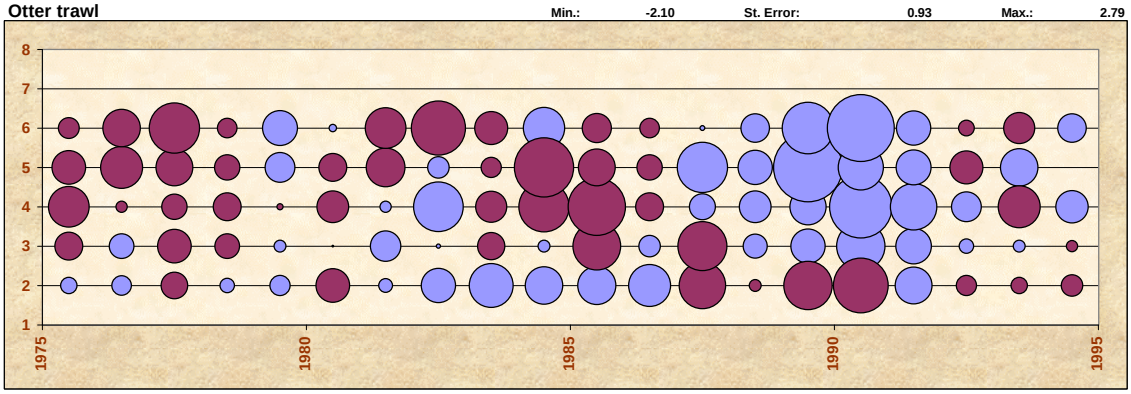


Stock Spawning Biomass (tonnes)

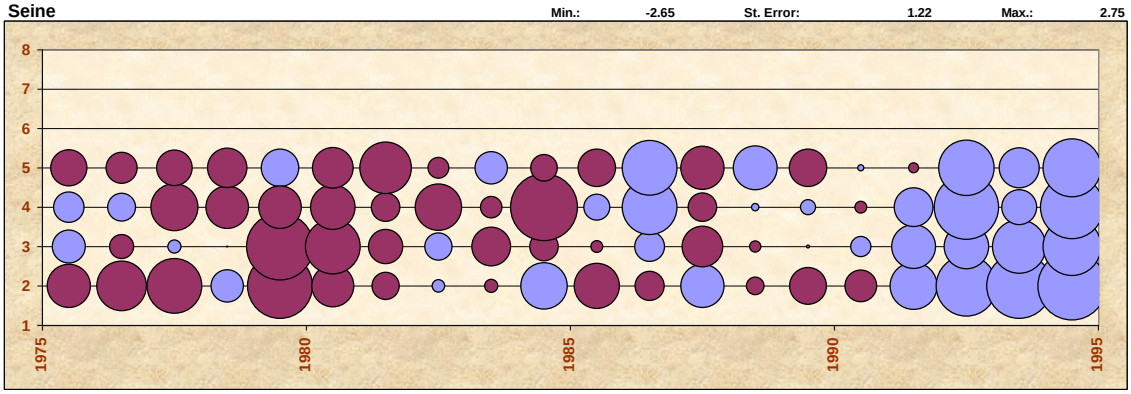


Blackfin: NAFO SC Workshop - ADAPT Tutorial **Residuals**

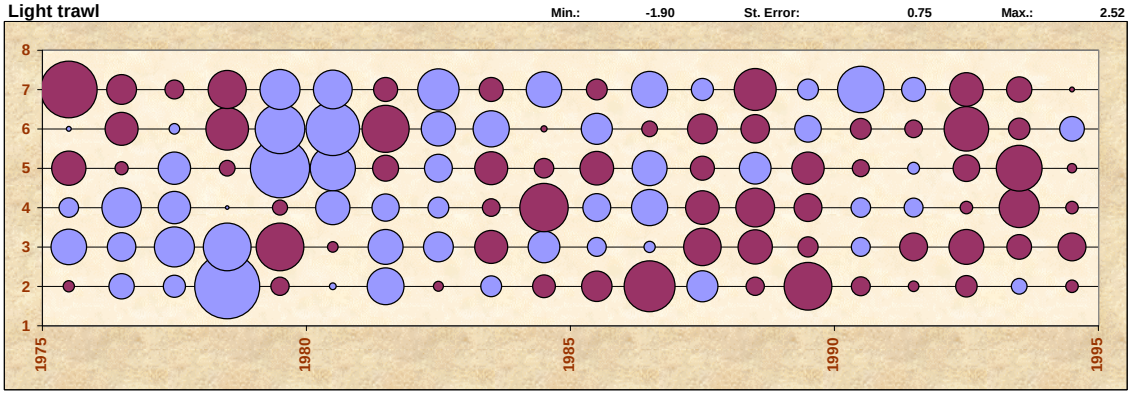
Otter trawl Min.: -2.10 St. Error: 0.93 Max.: 2.79



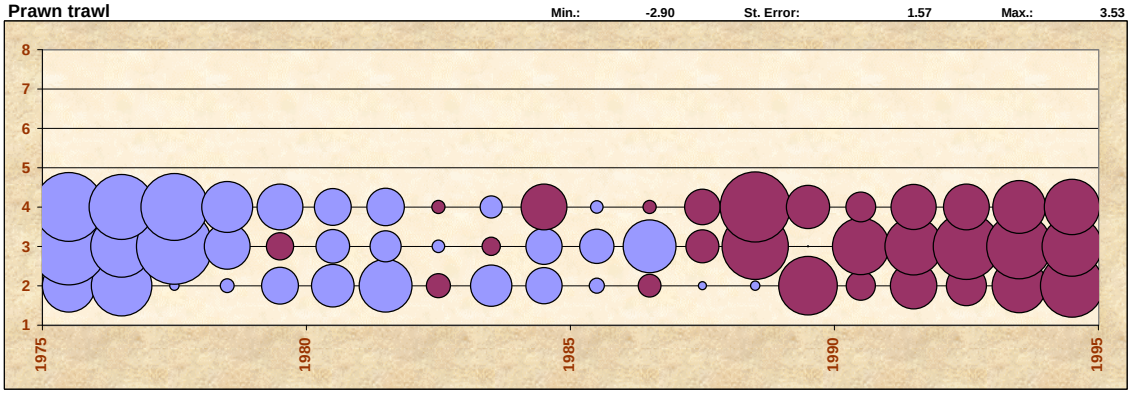
Seine Min.: -2.65 St. Error: 1.22 Max.: 2.75



Light trawl Min.: -1.90 St. Error: 0.75 Max.: 2.52



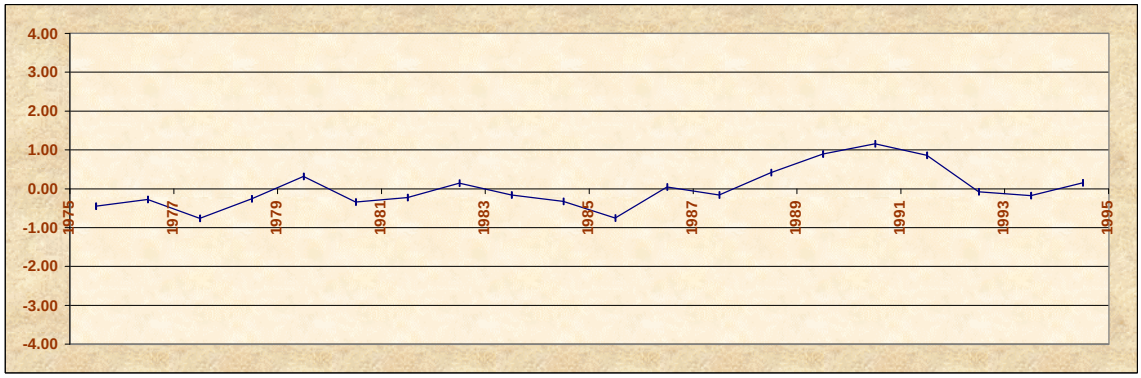
Prawn trawl Min.: -2.90 St. Error: 1.57 Max.: 3.53



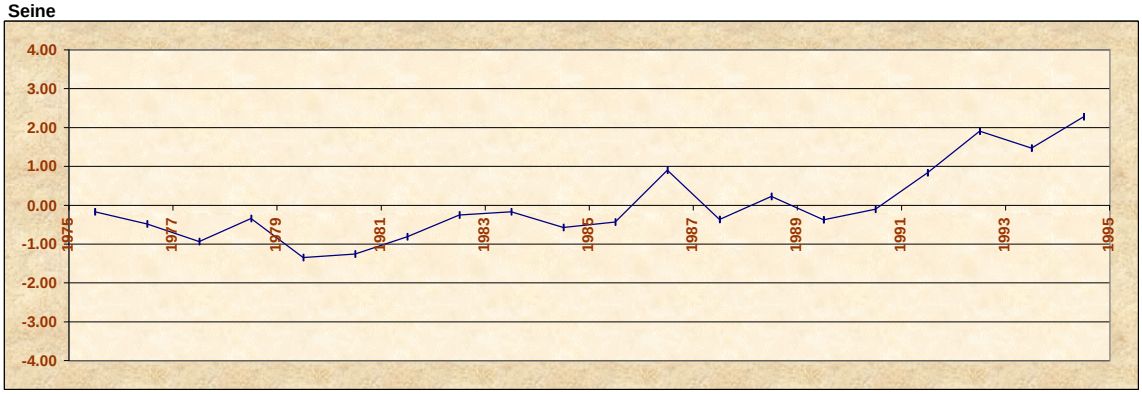
NOTE: All graphs are normalized to the same maximum bubble size.

Blackfin: NAFO SC Workshop - ADAPT Tutorial **Residuals - Averaged by year**

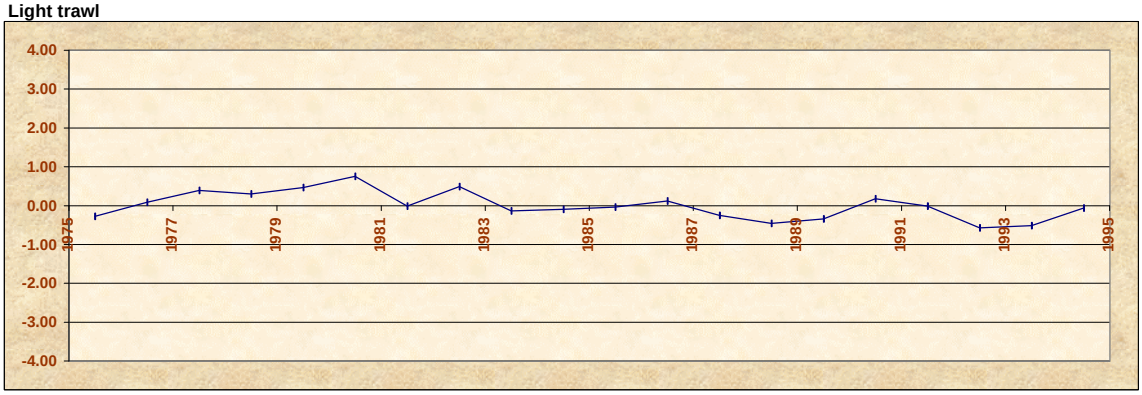
Otter trawl



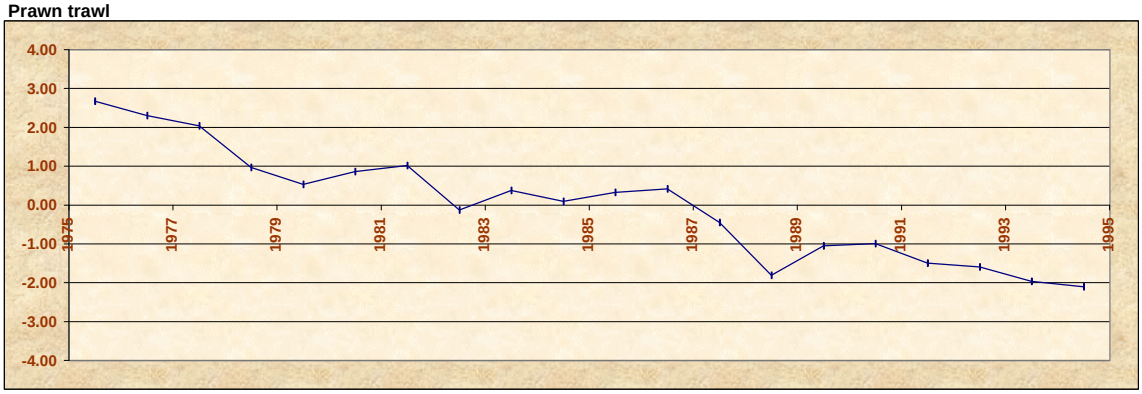
Seine



Light trawl



Prawn trawl



SCR Doc. 00/56 – ANNEX 2. – ADAPT Session Log

```
SATURDAY, JULY 29, 2000  9:55:59.900 AM
Portions of this program are copyrighted works of APL2000, Inc.
Copyright 1996 APL2000, Inc.
APL  Ver. 2.0.00
ADAPT_W  Ver. 2.1
Workspace size = 6000000

Cn
              1       2       3       4       5       6       7       8       9      10
 1963.00      0     155    1483     688     327     215      73     149      50      49
 1964.00      0     117    2136    2340     700     339     159      42      49      93
 1965.00      0     231    3327    3060    1757     512     271      92      69     137
 1966.00      0      68    2838    4909    1220     693     135      39      27      48
 1967.00      0     385    2053    2885    1934     268     454      91      44      75
 1968.00      2      49    2435    2287    1197     621     148     126      29      58
 1969.00      0     335    1983    4618    1498     507     568     106      79      71
 1970.00      0      33    2857    2335    1805     599     240     196      41     122
 1971.00      0     382    1385    4444    1891    1085     465     362     300     238
 1972.00     57    3973    8419    3894    2256     456     333     160      92     162
 1973.00    350    7753    7665    5251    1946     883     468     336     199     472
 1974.00    897    3374    6062    2417    2158     617     949     925     502     869
 1975.00     25    2592    6672    2546    1328     873    1013     711     198     343
 1976.00     36    2826    8274    2782    1806    1122     662     518     586    1365
 1977.00    160    1257    4680    2734    1687     743     562     386     290     922
 1978.00     38    4452    4278    2362    1306     701     293     244     163    1326
 1979.00     10    1000    1836    1205    1181     724     372     157     191     757
 1980.00     46    1023    3351     954     685     638     471     194      91     817
 1981.00    154    2490    3932    1981     588     410     341     223     154     673
 1982.00     43    1403    4633    1687    1250     574     388     247     136     461
 1983.00     35    3519    4761    2574     834     764     509     158     105     506
 1984.00    157    3026    5590    2407     880     685     302     140      57     160
 1985.00      6    2288    5122    3051    1459    1230     610     187     105     225
 1986.00    232     773    7101    8441    3787    1399    1056     470     186     347
 1987.00      1    1698    2194    6967    1928    1359     779     454     261     210
 1988.00     21    3591    5702    3518    2627    1051     892     698     330     329
 1989.00     22     759    7291    5703    2255    1400     376     258     157     184
 1990.00     58    1485    5595    3729    1194     786     525     245     132     157
 1991.00    153    1243    3594    2946    1175     607     424     235      96     223
 1992.00     28     861    1773    3093     968     354     107      61      54      93
 1993.00     15    2511    2668    2827    1185     270     112      56      43      83
 1994.00      3    2408    2029    1080     492     280     109      65      50     110
 1995.00
```

Otter trawl

	2	3	4	5	6
1975.50	132.69	70.39	14.56	11.60	12.41
1976.50	88.95	168.20	25.83	5.87	7.63
1977.50	36.01	36.30	19.17	4.94	2.90
1978.50	55.08	39.29	10.66	7.90	6.52
1979.50	70.07	52.70	13.47	10.78	18.27
1980.50	33.51	58.90	7.11	3.55	4.57
1981.50	86.12	126.47	15.52	0.00	1.55
1982.50	164.86	81.02	78.20	2.11	0.70
1983.50	337.87	55.52	10.84	9.98	1.73
1984.50	232.29	125.12	4.98	5.98	15.45
1985.50	253.26	28.37	4.20	1.05	3.15
1986.50	202.26	150.21	13.38	4.46	4.46
1987.50	25.89	19.80	35.02	3.81	6.09
1988.50	95.54	141.34	39.26	28.79	5.23
1989.50	16.93	213.98	47.38	14.30	16.34
1990.50	11.65	287.13	244.91	115.78	64.29
1991.50	139.62	158.19	57.36	31.66	10.25
1992.50	39.05	82.23	30.41	11.66	6.20
1993.50	61.01	61.13	6.45	3.31	2.32
1994.50	31.89	76.09	27.87	17.16	7.71

Seine

	2	3	4	5
1975.50	6.20	31.90	15.07	2.13
1976.50	2.71	12.01	9.68	1.94
1977.50	1.60	11.76	1.60	1.07
1978.50	15.22	8.39	1.24	0.93
1979.50	0.75	0.50	1.01	3.02
1980.50	3.83	1.49	0.85	0.43
1981.50	8.21	5.16	1.88	0.23
1982.50	14.99	18.53	1.09	0.82
1983.50	16.02	5.25	3.15	2.89
1984.50	60.89	10.15	0.34	1.01
1985.50	5.31	14.79	9.48	0.76
1986.50	7.01	28.56	27.56	12.53
1987.50	47.64	4.57	3.05	0.38
1988.50	14.50	13.56	4.68	4.21
1989.50	5.13	15.78	5.30	0.63
1990.50	6.30	13.68	4.82	1.50
1991.50	39.63	35.11	8.24	1.82
1992.50	74.88	34.46	44.54	7.15
1993.50	147.70	44.69	8.35	3.45
1994.50	111.82	89.67	34.04	11.29

Light trawl

	2	3	4	5	6	7
1975.50	31.51	86.21	28.11	5.36	5.36	0.60
1976.50	31.52	68.64	39.30	7.24	3.04	1.40
1977.50	22.65	66.61	29.83	10.07	4.51	2.15
1978.50	181.68	78.48	9.58	4.75	0.91	0.82
1979.50	13.52	4.40	6.70	24.62	12.42	3.08
1980.50	20.67	19.71	15.00	9.16	7.93	3.14
1981.50	51.82	53.99	12.62	1.75	0.36	0.42
1982.50	22.92	49.75	13.38	3.99	2.66	1.63
1983.50	41.84	16.29	8.99	1.87	2.40	0.36
1984.50	22.54	74.73	3.10	2.87	1.74	0.91
1985.50	18.42	49.15	25.84	2.10	3.08	0.56
1986.50	4.58	44.18	26.16	10.19	1.58	1.26
1987.50	51.20	12.99	6.53	1.90	1.14	0.91
1988.50	25.73	17.64	4.74	5.75	0.63	0.25
1989.50	5.35	29.52	7.52	1.80	1.67	0.48
1990.50	16.45	32.19	17.61	2.84	1.12	1.25
1991.50	17.39	16.76	11.02	4.95	1.37	0.84
1992.50	11.49	12.26	8.97	1.75	0.72	0.37
1993.50	25.70	13.72	3.95	0.88	1.02	0.75
1994.50	11.68	18.65	7.42	3.35	2.23	0.61

Prawn trawl

	2	3	4
1975.50	23.64	91.85	17.24
1976.50	24.57	26.28	8.72
1977.50	2.35	51.37	10.51
1978.50	2.16	4.84	2.01
1979.50	4.92	0.74	1.23
1980.50	7.80	2.79	0.76
1981.50	15.71	3.08	0.85
1982.50	2.25	2.11	0.42
1983.50	11.86	1.70	0.68
1984.50	8.79	5.94	0.16
1985.50	4.97	5.39	0.83
1986.50	2.03	14.50	0.49
1987.50	3.87	1.04	0.28
1988.50	4.40	0.18	0.03
1989.50	0.36	2.55	0.18
1990.50	1.62	0.25	0.37
1991.50	0.67	0.25	0.12
1992.50	0.78	0.13	0.13
1993.50	0.51	0.11	0.09
1994.50	0.16	0.24	0.06

VPA setup

Plus Group : No plus group

Population

	1	2	3	4	5	6	7	8	9	10
1995.00	(15000)	(15000)	25000	25000	20000	15000	10000	5000	5000	5000

F ratios

	1	2	3	4	5	6	7	8	9	10
1963.00				1.00	1.00	1.00				(1.00)
1964.00				1.00	1.00	1.00				(1.00)
1965.00				1.00	1.00	1.00				(1.00)
1966.00				1.00	1.00	1.00				(1.00)
1967.00				1.00	1.00	1.00				(1.00)
1968.00				1.00	1.00	1.00				(1.00)
1969.00				1.00	1.00	1.00				(1.00)
1970.00				1.00	1.00	1.00				(1.00)
1971.00				1.00	1.00	1.00				(1.00)
1972.00				1.00	1.00	1.00				(1.00)
1973.00				1.00	1.00	1.00				(1.00)
1974.00				1.00	1.00	1.00				(1.00)
1975.00				1.00	1.00	1.00				(1.00)
1976.00				1.00	1.00	1.00				(1.00)
1977.00				1.00	1.00	1.00				(1.00)
1978.00				1.00	1.00	1.00				(1.00)
1979.00				1.00	1.00	1.00				(1.00)
1980.00				1.00	1.00	1.00				(1.00)
1981.00				1.00	1.00	1.00				(1.00)
1982.00				1.00	1.00	1.00				(1.00)
1983.00				1.00	1.00	1.00				(1.00)
1984.00				1.00	1.00	1.00				(1.00)
1985.00				1.00	1.00	1.00				(1.00)
1986.00				1.00	1.00	1.00				(1.00)
1987.00				1.00	1.00	1.00				(1.00)
1988.00				1.00	1.00	1.00				(1.00)
1989.00				1.00	1.00	1.00				(1.00)
1990.00				1.00	1.00	1.00				(1.00)
1991.00				1.00	1.00	1.00				(1.00)
1992.00				1.00	1.00	1.00				(1.00)
1993.00				1.00	1.00	1.00				(1.00)
1994.00				1.00	1.00	1.00				(1.00)

Natural Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1964.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1965.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1966.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1967.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1968.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1969.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1970.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1971.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1972.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1973.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1974.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1975.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1976.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1977.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1978.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1979.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1980.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1981.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1982.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1983.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1984.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1985.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1986.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1987.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1988.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1989.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1990.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1991.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1992.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1993.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1994.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)

Virtual Population Analysis using initial values

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	42717	26978	19837	5948	3948	2244	809	1356	833	499
1964.00	50006	34974	21948	14904	4250	2937	1644	596	976	637
1965.00	93765	40942	28528	16044	10095	2849	2099	1202	450	755
1966.00	55080	76768	33312	20358	10382	6683	1872	1474	901	306
1967.00	96039	45096	62791	24714	12256	7401	4847	1411	1172	714
1968.00	78709	78630	36573	49555	17634	8293	5817	3559	1073	920
1969.00	82593	64440	64333	27747	38508	13357	6230	4629	2800	852
1970.00	72744	67621	52456	50881	18560	30176	10478	4588	3694	2221
1971.00	73816	59558	55334	40369	39550	13568	24165	8362	3580	2988
1972.00	64021	60435	48417	44053	29046	30674	10130	19365	6520	2660
1973.00	47749	52364	45896	32062	32556	21746	24702	7993	15710	5255
1974.00	50400	38778	35889	30676	21523	24899	17007	19802	6241	12683
1975.00	31653	40454	28706	23926	22935	15676	19828	13068	15378	4657
1976.00	24718	25893	30782	17505	17294	17579	12046	15320	10057	12411
1977.00	23922	20205	18652	17771	11827	12531	13380	9265	12075	7706
1978.00	23908	19441	15409	11066	12088	8163	9589	10448	7237	9624
1979.00	29891	19539	11915	8774	6936	8719	6051	7586	8333	5778
1980.00	34821	24464	15095	8102	6098	4615	6486	4619	6069	6650
1981.00	37532	28468	19106	9346	5773	4375	3204	4885	3606	4887
1982.00	50960	30590	21062	12106	5870	4197	3213	2316	3798	2814
1983.00	46626	41684	23778	13078	8392	3682	2919	2281	1673	2987
1984.00	49621	38143	30954	15185	8392	6119	2327	1932	1725	1275
1985.00	43642	40484	28499	20312	10265	6077	4392	1633	1455	1361
1986.00	59223	35725	31081	18723	13882	7090	3869	3046	1169	1097
1987.00	53654	48278	28551	19063	7789	7965	4546	2220	2071	789
1988.00	39972	43927	37994	21397	9367	4645	5298	3021	1409	1460
1989.00	51076	32707	32726	25972	14351	5310	2858	3534	1846	857
1990.00	52307	41797	26093	20238	16136	9719	3090	2001	2661	1370
1991.00	52394	42773	32880	16332	13214	12134	7248	2057	1417	2060
1992.00	52300	42758	33897	23680	10720	9759	9386	5552	1473	1074
1993.00	40553	42794	34230	26153	16601	7904	7670	7588	4490	1157
1994.00	18324	33188	32771	25619	18864	12523	6227	6179	6162	3638
1995.00	15000	15000	25000	25000	20000	15000	10000	5000	5000	5000

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	0.000	0.006	0.086	0.136	0.096	0.111	0.105	0.129	0.068	0.114
1964.00	0.000	0.004	0.113	0.190	0.200	0.136	0.113	0.081	0.057	0.175
1965.00	0.000	0.006	0.137	0.235	0.212	0.220	0.153	0.088	0.185	0.223
1966.00	0.000	0.001	0.099	0.307	0.139	0.121	0.083	0.030	0.034	0.189
1967.00	0.000	0.009	0.037	0.138	0.191	0.041	0.109	0.074	0.042	0.123
1968.00	0.000	0.001	0.076	0.052	0.078	0.086	0.028	0.040	0.030	0.072
1969.00	0.000	0.006	0.035	0.202	0.044	0.043	0.106	0.026	0.032	0.096
1970.00	0.000	0.001	0.062	0.052	0.113	0.022	0.026	0.048	0.012	0.062
1971.00	0.000	0.007	0.028	0.129	0.054	0.092	0.021	0.049	0.097	0.092
1972.00	0.001	0.075	0.212	0.102	0.089	0.017	0.037	0.009	0.016	0.069
1973.00	0.008	0.178	0.203	0.199	0.068	0.046	0.021	0.047	0.014	0.104
1974.00	0.020	0.101	0.205	0.091	0.117	0.028	0.063	0.053	0.093	0.079
1975.00	0.001	0.073	0.295	0.125	0.066	0.063	0.058	0.062	0.014	0.085
1976.00	0.002	0.128	0.349	0.192	0.122	0.073	0.062	0.038	0.066	0.129
1977.00	0.007	0.071	0.322	0.185	0.171	0.068	0.047	0.047	0.027	0.141
1978.00	0.002	0.290	0.363	0.267	0.127	0.099	0.034	0.026	0.025	0.164
1979.00	0.000	0.058	0.186	0.164	0.207	0.096	0.070	0.023	0.026	0.156
1980.00	0.001	0.047	0.279	0.139	0.132	0.165	0.083	0.047	0.017	0.145
1981.00	0.005	0.101	0.256	0.265	0.119	0.109	0.125	0.052	0.048	0.164
1982.00	0.001	0.052	0.277	0.166	0.266	0.163	0.143	0.125	0.040	0.199
1983.00	0.001	0.098	0.248	0.244	0.116	0.259	0.213	0.079	0.072	0.206
1984.00	0.003	0.091	0.221	0.192	0.123	0.132	0.154	0.083	0.037	0.149
1985.00	0.000	0.064	0.220	0.181	0.170	0.252	0.166	0.135	0.083	0.201
1986.00	0.004	0.024	0.289	0.677	0.356	0.244	0.356	0.186	0.192	0.426
1987.00	0.000	0.040	0.088	0.511	0.317	0.208	0.209	0.255	0.149	0.345
1988.00	0.001	0.094	0.180	0.199	0.368	0.286	0.205	0.293	0.297	0.284
1989.00	0.000	0.026	0.281	0.276	0.190	0.341	0.156	0.084	0.098	0.269
1990.00	0.001	0.040	0.269	0.226	0.085	0.093	0.207	0.145	0.056	0.135
1991.00	0.003	0.033	0.128	0.221	0.103	0.057	0.067	0.134	0.078	0.127
1992.00	0.001	0.022	0.059	0.155	0.105	0.041	0.013	0.012	0.041	0.100
1993.00	0.000	0.067	0.090	0.127	0.082	0.038	0.016	0.008	0.011	0.082
1994.00	0.000	0.083	0.071	0.048	0.029	0.025	0.019	0.012	0.009	0.034

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Models selected
Otter trawl 2 Proportional
Otter trawl 3 Proportional
Otter trawl 4 Proportional
Otter trawl 5 Proportional
Otter trawl 6 Proportional
Seine       2 Proportional
Seine       3 Proportional
Seine       4 Proportional
Seine       5 Proportional
Light trawl 2 Proportional
Light trawl 3 Proportional
Light trawl 4 Proportional
Light trawl 5 Proportional
Light trawl 6 Proportional
Light trawl 7 Proportional
Prawn trawl 2 Proportional
Prawn trawl 3 Proportional
Prawn trawl 4 Proportional


LAMBDA       1.00000E-2
RSS          4.51364E2
NPHI         4.51364E2

Parameters
   1.01266E1      1.01266E1      9.90349E0      9.61581E0      9.21034E0      8.51719E0
   8.51719E0      8.51719E0

LAMBDA       1.00000E-3
RSS          4.15005E2
NPHI         4.15005E2

Parameters
   9.21491E0      9.45684E0      8.66336E0      8.59416E0      8.10329E0      7.66734E0
   7.94553E0      7.44161E0

LAMBDA       1.00000E-4
RSS          4.14815E2
NPHI         4.14815E2

Parameters
   9.26865E0      9.51054E0      8.70897E0      8.58918E0      8.10566E0      7.73432E0
   8.09045E0      7.46342E0
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LAMBDA       1.00000E-5
RSS          4.14814E2
NPHI         4.14814E2

Parameters
   9.26792E0      9.51026E0      8.70557E0      8.58697E0      8.10223E0      7.72350E0
   8.09144E0      7.45383E0

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.00001

LAMBDA       1.00000E-2
RSS          4.14814E2
NPHI         4.14814E2

Parameters
   9.26792E0      9.51026E0      8.70557E0      8.58697E0      8.10223E0      7.72350E0
   8.09144E0      7.45383E0     -5.71299E0     -5.26109E0     -6.19060E0     -6.71967E0
  -6.68427E0     -7.49187E0     -7.17500E0     -7.73313E0     -8.30475E0     -6.90287E0
  -6.28343E0     -6.77241E0     -7.45870E0     -7.80999E0     -8.32394E0     -8.93198E0
  -8.99187E0     -9.85030E0

LAMBDA       1.00000E-3
RSS          4.14814E2
NPHI         4.14814E2

Parameters
   9.26804E0      9.51039E0      8.70603E0      8.58709E0      8.10261E0      7.72498E0
   8.09215E0      7.45432E0     -5.71310E0     -5.26121E0     -6.19076E0     -6.71986E0
  -6.68448E0     -7.49197E0     -7.17512E0     -7.73328E0     -8.30494E0     -6.90297E0
  -6.28355E0     -6.77257E0     -7.45889E0     -7.81020E0     -8.32417E0     -8.93208E0
  -8.99199E0     -9.85046E0

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.00001
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Estimated VPA (biased)

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	42088	26443	19502	5857	3864	2202	796	1331	818	490
1964.00	48688	34459	21510	14629	4175	2868	1609	586	956	625
1965.00	89916	39862	28107	15685	9871	2788	2043	1174	442	738
1966.00	53681	73617	32428	20014	10089	6500	1822	1428	878	300
1967.00	92450	43951	60211	23990	11974	7161	4697	1370	1134	695
1968.00	76315	75692	35636	47444	17042	8062	5621	3436	1039	889
1969.00	79452	62479	61927	26979	36779	12873	6041	4468	2700	825
1970.00	70426	65050	50851	48911	17932	28760	10082	4434	3563	2139
1971.00	70880	57660	53229	39055	37938	13054	23006	8037	3453	2880
1972.00	62159	58032	46863	42329	27970	29354	9709	18416	6254	2557
1973.00	46419	50840	43928	30791	31145	20865	23621	7649	14933	5037
1974.00	48780	37688	34642	29066	20482	23744	16286	18917	5959	12046
1975.00	30693	39128	27814	22906	21617	14824	18883	12478	14653	4426
1976.00	23610	25107	29696	16776	16459	16500	11349	14546	9574	11818
1977.00	23031	19298	18008	16884	11230	11848	12497	8695	11441	7310
1978.00	23117	18711	14666	10540	11362	7675	9030	9725	6770	9105
1979.00	27583	18893	11318	8167	6506	8125	5652	7128	7742	5396
1980.00	32850	22574	14566	7613	5602	4264	6000	4292	5694	6166
1981.00	34094	26854	17559	8913	5374	3969	2916	4487	3339	4580
1982.00	45814	27775	19741	10841	5516	3870	2880	2080	3473	2594
1983.00	43407	37471	21474	11998	7356	3392	2651	2008	1480	2720
1984.00	45578	35507	27505	13301	7508	5271	2090	1713	1502	1117
1985.00	29231	37174	26342	17491	8723	5354	3698	1440	1276	1178
1986.00	39349	23927	28371	16959	11574	5829	3278	2479	1010	950
1987.00	45051	32007	18892	16848	6357	6080	3515	1737	1607	660
1988.00	28838	36883	24673	13490	7563	3474	3756	2177	1014	1080
1989.00	28801	23591	26960	15075	7884	3837	1902	2274	1156	534
1990.00	26086	23560	18630	15525	7236	4431	1888	1219	1629	805
1991.00	21308	21305	17950	10232	9359	4849	2920	1074	777	1215
1992.00	31338	17307	16321	11463	5733	6604	3423	2009	668	550
1993.00	19056	25632	13393	11765	6607	3822	5087	2706	1590	498
1994.00	18324	15588	18722	8565	7091	4343	2886	4064	2165	1263
1995.00	15000	15000	10594	13499	6039	5362	3303	2264	3269	1727

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	0.000	0.006	0.087	0.138	0.098	0.114	0.106	0.132	0.070	0.117
1964.00	0.000	0.004	0.116	0.193	0.204	0.139	0.115	0.082	0.058	0.179
1965.00	0.000	0.006	0.140	0.241	0.218	0.225	0.158	0.090	0.188	0.228
1966.00	0.000	0.001	0.101	0.314	0.143	0.125	0.085	0.031	0.034	0.194
1967.00	0.000	0.010	0.038	0.142	0.196	0.042	0.113	0.076	0.044	0.127
1968.00	0.000	0.001	0.078	0.055	0.081	0.089	0.029	0.041	0.031	0.075
1969.00	0.000	0.006	0.036	0.209	0.046	0.044	0.109	0.027	0.033	0.100
1970.00	0.000	0.001	0.064	0.054	0.117	0.023	0.027	0.050	0.013	0.065
1971.00	0.000	0.007	0.029	0.134	0.057	0.096	0.023	0.051	0.101	0.095
1972.00	0.001	0.078	0.220	0.107	0.093	0.017	0.039	0.010	0.016	0.072
1973.00	0.008	0.184	0.213	0.208	0.071	0.048	0.022	0.050	0.015	0.109
1974.00	0.020	0.104	0.214	0.096	0.123	0.029	0.066	0.055	0.097	0.083
1975.00	0.001	0.076	0.306	0.131	0.070	0.067	0.061	0.065	0.015	0.089
1976.00	0.002	0.132	0.365	0.201	0.129	0.078	0.066	0.040	0.070	0.136
1977.00	0.008	0.074	0.336	0.196	0.181	0.072	0.051	0.050	0.028	0.149
1978.00	0.002	0.303	0.385	0.282	0.135	0.106	0.036	0.028	0.027	0.175
1979.00	0.000	0.060	0.196	0.177	0.223	0.103	0.075	0.025	0.028	0.168
1980.00	0.002	0.051	0.291	0.148	0.145	0.180	0.090	0.051	0.018	0.158
1981.00	0.005	0.108	0.282	0.280	0.128	0.121	0.138	0.056	0.052	0.176
1982.00	0.001	0.057	0.298	0.188	0.286	0.178	0.160	0.140	0.044	0.217
1983.00	0.001	0.109	0.279	0.269	0.133	0.284	0.237	0.091	0.081	0.229
1984.00	0.004	0.099	0.253	0.222	0.138	0.154	0.173	0.094	0.043	0.171
1985.00	0.000	0.070	0.240	0.213	0.203	0.291	0.200	0.154	0.095	0.236
1986.00	0.007	0.036	0.321	0.781	0.444	0.306	0.435	0.234	0.226	0.510
1987.00	0.000	0.060	0.137	0.601	0.404	0.282	0.279	0.338	0.197	0.429
1988.00	0.001	0.113	0.293	0.337	0.478	0.403	0.302	0.433	0.441	0.406
1989.00	0.001	0.036	0.352	0.534	0.376	0.509	0.245	0.133	0.162	0.473
1990.00	0.002	0.072	0.399	0.306	0.200	0.217	0.364	0.250	0.094	0.241
1991.00	0.008	0.066	0.248	0.379	0.149	0.148	0.174	0.275	0.146	0.225
1992.00	0.001	0.056	0.127	0.351	0.205	0.061	0.035	0.034	0.093	0.206
1993.00	0.001	0.114	0.247	0.306	0.220	0.081	0.025	0.023	0.030	0.202
1994.00	0.000	0.186	0.127	0.149	0.080	0.074	0.043	0.018	0.026	0.101

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.001027
MEAN SQUARE RESIDUALS 1.245688

Estimates for parameters

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
9.27E0	6.28E-1	0.068	-1.09E-2	-0.001
9.51E0	4.59E-1	0.048	-7.43E-3	-0.001
8.71E0	4.09E-1	0.047	-5.32E-3	-0.001
8.59E0	4.02E-1	0.047	-1.24E-2	-0.001
8.10E0	4.42E-1	0.055	-2.24E-2	-0.003
7.72E0	4.42E-1	0.057	-2.61E-2	-0.003
8.09E0	4.15E-1	0.051	-2.18E-2	-0.003
7.45E0	4.96E-1	0.067	-3.92E-2	-0.005
-5.71E0	2.55E-1	-0.045	-3.75E-3	0.001
-5.26E0	2.55E-1	-0.048	-2.37E-3	0.000
-6.19E0	2.56E-1	-0.041	1.85E-4	0.000
-6.72E0	2.66E-1	-0.040	4.10E-3	-0.001
-6.68E0	2.60E-1	-0.039	6.96E-3	-0.001
-7.49E0	2.55E-1	-0.034	-3.75E-3	0.001
-7.18E0	2.55E-1	-0.035	-2.37E-3	0.000
-7.73E0	2.56E-1	-0.033	1.85E-4	0.000
-8.30E0	2.59E-1	-0.031	3.95E-3	0.000
-6.90E0	2.55E-1	-0.037	-3.75E-3	0.001
-6.28E0	2.55E-1	-0.041	-2.37E-3	0.000
-6.77E0	2.56E-1	-0.038	1.85E-4	0.000
-7.46E0	2.59E-1	-0.035	3.95E-3	-0.001
-7.81E0	2.60E-1	-0.033	6.96E-3	-0.001
-8.32E0	2.60E-1	-0.031	8.64E-3	-0.001
-8.93E0	2.55E-1	-0.029	-3.75E-3	0.000
-8.99E0	2.55E-1	-0.028	-2.37E-3	0.000
-9.85E0	2.56E-1	-0.026	1.85E-4	0.000

[NOTE: The labels appearing below to identify the parameters were added with the word processor.]

Parameters in linear scale

	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
N(1995, 3)	1.06E4	6.65E3	0.628	1.97E3	0.186
N(1995, 4)	1.35E4	6.19E3	0.459	1.32E3	0.098
N(1995, 5)	6.04E3	2.47E3	0.409	4.72E2	0.078
N(1995, 6)	5.36E3	2.16E3	0.402	3.67E2	0.068
N(1995, 7)	3.30E3	1.46E3	0.442	2.49E2	0.075
N(1995, 8)	2.26E3	1.00E3	0.442	1.62E2	0.072
N(1995, 9)	3.27E3	1.36E3	0.415	2.10E2	0.064
N(1995,10)	1.73E3	8.57E2	0.496	1.45E2	0.084
Otter trawl 2	3.30E-3	8.43E-4	0.255	9.52E-5	0.029
Otter trawl 3	5.19E-3	1.32E-3	0.255	1.56E-4	0.030
Otter trawl 4	2.05E-3	5.25E-4	0.256	6.77E-5	0.033
Otter trawl 5	1.21E-3	3.21E-4	0.266	4.76E-5	0.039
Otter trawl 6	1.25E-3	3.25E-4	0.260	5.10E-5	0.041
Seine 2	5.58E-4	1.42E-4	0.255	1.61E-5	0.029
Seine 3	7.65E-4	1.95E-4	0.255	2.30E-5	0.030
Seine 4	4.38E-4	1.12E-4	0.256	1.45E-5	0.033
Seine 5	2.47E-4	6.40E-5	0.259	9.26E-6	0.037
Light trawl 2	1.00E-3	2.57E-4	0.255	2.90E-5	0.029
Light trawl 3	1.87E-3	4.75E-4	0.255	5.61E-5	0.030
Light trawl 4	1.14E-3	2.94E-4	0.256	3.79E-5	0.033
Light trawl 5	5.76E-4	1.49E-4	0.259	2.16E-5	0.037
Light trawl 6	4.06E-4	1.06E-4	0.260	1.66E-5	0.041
Light trawl 7	2.43E-4	6.31E-5	0.260	1.03E-5	0.042
Prawn trawl 2	1.32E-4	3.37E-5	0.255	3.81E-6	0.029
Prawn trawl 3	1.24E-4	3.17E-5	0.255	3.74E-6	0.030
Prawn trawl 4	5.27E-5	1.35E-5	0.256	1.74E-6	0.033

VPA using analytical bias adjusted parameters (linear scale)
Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	42057	26415	19484	5852	3859	2200	796	1330	817	489
1964.00	48620	34433	21487	14615	4171	2865	1607	585	954	624
1965.00	89711	39807	28086	15666	9858	2785	2040	1172	441	737
1966.00	53604	73449	32382	19996	10073	6490	1819	1426	877	299
1967.00	92257	43888	60074	23953	11960	7148	4689	1368	1132	694
1968.00	76195	75534	35584	47331	17011	8051	5610	3430	1038	887
1969.00	79295	62381	61798	26937	36687	12848	6031	4460	2694	823
1970.00	70305	64921	50771	48805	17897	28685	10061	4426	3556	2134
1971.00	70718	57561	53123	38990	37851	13026	22944	8021	3447	2874
1972.00	62055	57899	46782	42243	27917	29283	9686	18365	6240	2551
1973.00	46351	50755	43819	30724	31074	20821	23563	7630	14892	5026
1974.00	48704	37633	34572	28977	20428	23686	16250	18869	5943	12013
1975.00	30643	39066	27769	22849	21544	14780	18835	12448	14614	4413
1976.00	23547	25066	29646	16739	16412	16441	11313	14507	9550	11786
1977.00	22978	19246	17975	16843	11200	11809	12448	8665	11410	7290
1978.00	23076	18668	14624	10513	11328	7650	8998	9685	6746	9080
1979.00	27484	18858	11283	8133	6484	8098	5631	7103	7709	5376
1980.00	32766	22493	14538	7584	5573	4245	5977	4275	5673	6139
1981.00	33880	26785	17492	8890	5350	3946	2901	4469	3325	4563
1982.00	45472	27599	19685	10786	5497	3850	2861	2068	3457	2583
1983.00	43249	37190	21330	11952	7312	3377	2635	1993	1471	2708
1984.00	45414	35378	27276	13183	7471	5235	2078	1700	1489	1109
1985.00	28713	37040	26236	17303	8627	5323	3669	1429	1265	1168
1986.00	38465	23503	28262	16872	11420	5750	3253	2455	1002	941
1987.00	44006	31283	18545	16758	6286	5955	3450	1716	1587	653
1988.00	28176	36028	24080	13206	7490	3417	3654	2124	997	1064
1989.00	27972	23049	26260	14590	7652	3778	1855	2190	1113	521
1990.00	25086	22881	18186	14953	6841	4241	1839	1180	1560	770
1991.00	20256	20487	17394	9870	8892	4526	2765	1035	746	1158
1992.00	28934	16446	15651	11008	5437	6221	3159	1882	636	524
1993.00	16115	23664	12688	11216	6236	3580	4774	2490	1486	472
1994.00	18324	13181	17111	7988	6643	4039	2688	3808	1988	1178
1995.00	15000	15000	8624	12180	5567	4995	3054	2102	3059	1582

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	0.000	0.006	0.088	0.139	0.098	0.114	0.107	0.132	0.070	0.117
1964.00	0.000	0.004	0.116	0.194	0.204	0.140	0.115	0.082	0.058	0.179
1965.00	0.000	0.006	0.140	0.242	0.218	0.226	0.158	0.090	0.189	0.228
1966.00	0.000	0.001	0.102	0.314	0.143	0.125	0.085	0.031	0.035	0.194
1967.00	0.000	0.010	0.038	0.142	0.196	0.042	0.113	0.076	0.044	0.127
1968.00	0.000	0.001	0.078	0.055	0.081	0.089	0.030	0.041	0.031	0.075
1969.00	0.000	0.006	0.036	0.209	0.046	0.044	0.109	0.027	0.033	0.100
1970.00	0.000	0.001	0.064	0.054	0.118	0.023	0.027	0.050	0.013	0.065
1971.00	0.000	0.007	0.029	0.134	0.057	0.096	0.023	0.051	0.101	0.096
1972.00	0.001	0.079	0.220	0.107	0.093	0.017	0.039	0.010	0.016	0.073
1973.00	0.008	0.184	0.214	0.208	0.072	0.048	0.022	0.050	0.015	0.109
1974.00	0.021	0.104	0.214	0.096	0.124	0.029	0.067	0.056	0.098	0.083
1975.00	0.001	0.076	0.306	0.131	0.070	0.067	0.061	0.065	0.015	0.090
1976.00	0.002	0.133	0.365	0.202	0.129	0.078	0.067	0.040	0.070	0.136
1977.00	0.008	0.075	0.336	0.197	0.181	0.072	0.051	0.050	0.028	0.150
1978.00	0.002	0.304	0.387	0.283	0.136	0.106	0.037	0.028	0.027	0.175
1979.00	0.000	0.060	0.197	0.178	0.223	0.104	0.076	0.025	0.028	0.168
1980.00	0.002	0.051	0.292	0.149	0.145	0.181	0.091	0.051	0.018	0.158
1981.00	0.005	0.108	0.283	0.281	0.129	0.122	0.139	0.057	0.052	0.177
1982.00	0.001	0.058	0.299	0.189	0.287	0.179	0.162	0.141	0.044	0.218
1983.00	0.001	0.110	0.281	0.270	0.134	0.286	0.239	0.091	0.082	0.230
1984.00	0.004	0.099	0.255	0.224	0.139	0.155	0.174	0.095	0.043	0.173
1985.00	0.000	0.071	0.241	0.215	0.206	0.293	0.202	0.155	0.096	0.238
1986.00	0.007	0.037	0.323	0.787	0.451	0.311	0.439	0.236	0.228	0.516
1987.00	0.000	0.062	0.140	0.605	0.410	0.288	0.285	0.343	0.200	0.434
1988.00	0.001	0.116	0.301	0.346	0.484	0.411	0.312	0.446	0.450	0.414
1989.00	0.001	0.037	0.363	0.557	0.390	0.520	0.252	0.139	0.169	0.489
1990.00	0.003	0.074	0.411	0.320	0.213	0.228	0.375	0.259	0.098	0.254
1991.00	0.008	0.069	0.257	0.396	0.157	0.160	0.185	0.287	0.153	0.238
1992.00	0.001	0.059	0.133	0.368	0.218	0.065	0.038	0.036	0.098	0.217
1993.00	0.001	0.124	0.263	0.324	0.234	0.087	0.026	0.025	0.032	0.215
1994.00	0.000	0.224	0.140	0.161	0.085	0.079	0.046	0.019	0.028	0.109

[Residuals]

Otter trawl
Age : 2
Ln calibration constant : -5.71310

Year	Observed	Predicted	Residual	Ln Pop.
1975.50	4.88802	4.72359	0.16443	10.43668
1976.50	4.48807	4.25164	0.23643	9.96474
1977.50	3.58380	4.01740	-0.43360	9.73050
1978.50	4.00879	3.87242	0.13637	9.58552
1979.50	4.24949	4.00337	0.24612	9.71647
1980.50	3.51184	4.18583	-0.67399	9.89893
1981.50	4.45574	4.33121	0.12454	10.04430
1982.50	5.10510	4.39015	0.71495	10.10324
1983.50	5.82266	4.66362	1.15904	10.37672
1984.50	5.44799	4.61511	0.83287	10.32821
1985.50	5.53442	4.67516	0.85926	10.38826
1986.50	5.30955	4.25151	1.05804	9.96461
1987.50	3.25386	4.53044	-1.27659	10.24354
1988.50	4.55955	4.64571	-0.08617	10.35881
1989.50	2.82909	4.23748	-1.40839	9.95058
1990.50	2.45531	4.21823	-1.76292	9.93132
1991.50	4.93892	4.12036	0.81856	9.83346
1992.50	3.66484	3.91758	-0.25274	9.63068
1993.50	4.11104	4.28143	-0.17039	9.99453
1994.50	3.46229	3.74805	-0.28576	9.46115

Average squared residual : 0.63995

Otter trawl
Age : 3
Ln calibration constant : -5.26121

Year	Observed	Predicted	Residual	Ln Pop.
1975.50	4.25405	4.71928	-0.46523	9.98049
1976.50	5.12515	4.75525	0.36990	10.01646
1977.50	3.59182	4.26955	-0.67773	9.53076
1978.50	3.67097	4.03937	-0.36840	9.30057
1979.50	3.96462	3.87470	0.08992	9.13590
1980.50	4.07584	4.07962	-0.00378	9.34083
1981.50	4.84001	4.27097	0.56903	9.53218
1982.50	4.39470	4.38026	0.01444	9.64147
1983.50	4.01674	4.47387	-0.45713	9.73508
1984.50	4.82927	4.73458	0.09470	9.99578

..... {there is one table for each index-age combination }

[Correlation matrix for paramterer estimates - As this matrix is symmetric around its diagnonal, only the bottom part is shown to improve readability]

```
 1.00
 0.04  1.00
 0.04  0.06  1.00
 0.04  0.06  0.05  1.00
 0.04  0.05  0.06  0.09  1.00
 0.03  0.05  0.10  0.11  0.13  1.00
 0.03  0.05  0.09  0.11  0.13  0.12  1.00
 0.03  0.05  0.09  0.11  0.14  0.12  0.12  1.00
-0.13 -0.09 -0.09 -0.08 -0.08 -0.07 -0.07 -0.07  1.00
-0.02 -0.10 -0.10 -0.09 -0.09 -0.09 -0.09 -0.08  0.04  1.00
-0.02 -0.02 -0.12 -0.11 -0.12 -0.12 -0.11 -0.11  0.04  0.04  1.00
-0.02 -0.03 -0.06 -0.14 -0.15 -0.15 -0.14 -0.14  0.04  0.05  0.06  1.00
-0.02 -0.03 -0.07 -0.08 -0.18 -0.17 -0.15 -0.16  0.04  0.05  0.06  0.07  1.00
-0.13 -0.09 -0.09 -0.08 -0.08 -0.07 -0.07 -0.07  0.04  0.04  0.04  0.04  0.04  1.00
-0.02 -0.10 -0.10 -0.09 -0.09 -0.09 -0.09 -0.08  0.04  0.04  0.04  0.05  0.05  0.04  1.00
-0.02 -0.02 -0.12 -0.11 -0.12 -0.12 -0.11 -0.11  0.04  0.04  0.05  0.06  0.06  0.04  0.04  1.00
-0.02 -0.03 -0.06 -0.14 -0.15 -0.14 -0.14 -0.14  0.04  0.04  0.06  0.07  0.07  0.04  0.04  0.06  1.00
-0.13 -0.09 -0.09 -0.08 -0.08 -0.07 -0.07 -0.07  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  1.00
-0.02 -0.10 -0.10 -0.09 -0.09 -0.09 -0.09 -0.08  0.04  0.04  0.04  0.05  0.05  0.04  0.04  0.04  0.04  1.00
-0.02 -0.02 -0.12 -0.11 -0.12 -0.12 -0.11 -0.11  0.04  0.04  0.05  0.06  0.06  0.04  0.04  0.05  0.06  0.04  1.00
-0.02 -0.03 -0.06 -0.14 -0.15 -0.14 -0.14 -0.14  0.04  0.04  0.06  0.07  0.07  0.04  0.04  0.06  0.07  0.04  0.06  1.00
-0.02 -0.03 -0.07 -0.08 -0.18 -0.17 -0.15 -0.16  0.04  0.05  0.06  0.07  0.08  0.04  0.05  0.06  0.07  0.04  0.05  0.06  0.07  1.00
-0.02 -0.03 -0.08 -0.09 -0.12 -0.18 -0.16 -0.17  0.04  0.05  0.06  0.07  0.08  0.04  0.05  0.06  0.07  0.04  0.05  0.06  0.07  0.08  1.0
0
-0.13 -0.09 -0.09 -0.08 -0.08 -0.07 -0.07 -0.07  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.0
4
-0.02 -0.10 -0.10 -0.09 -0.09 -0.09 -0.09 -0.08  0.04  0.04  0.04  0.05  0.05  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.05  0.0
5 -0.02 -0.02 -0.12 -0.11 -0.12 -0.12 -0.11 -0.11  0.04  0.04  0.05  0.06  0.06  0.04  0.04  0.05  0.06  0.04  0.04  0.05  0.06  0.06  0
.06

...                                                                                                                                 1.00
...                                                                                                                                 0.04  1.0
...                                                                                                                                 0.04  .04  1.0
```

SCR Doc. 00/56 – ANNEX 3. ADAPT Session Log for a formulation whereby all cohorts are estimated (including bottom row).

```
MONDAY, JULY 31, 2000  11:27:24.980 AM
Portions of this program are copyrighted works of APL2000, Inc.  Copyright 1996 APL2000, Inc.
APL  Ver. 2.0.00
ADAPT_W  Ver. 2.1
Workspace size = 6000000

[ Data entry was the same as that for Annex 2 for Catch at age and the four indices of abundance,
  except for the Line trawl for which only the ages 2-6 were taken. ]


VPA setup
Plus Group : No plus group

Population
             1       2       3       4       5       6       7       8       9      10
 1979.00                                                                          5000
 1980.00                                                                          5000
 1981.00                                                                          5000
 1982.00                                                                          5000
 1983.00                                                                          5000
 1984.00                                                                          5000
 1985.00                                                                          5000
 1986.00                                                                          5000
 1987.00                                                                          5000
 1988.00                                                                          5000
 1989.00                                                                          5000
 1990.00                                                                          5000
 1991.00                                                                          5000
 1992.00                                                                          5000
 1993.00                                                                          5000
 1994.00                                                                          5000
 1995.00 (15000) (15000) (15000)   5000    5000    5000    5000    5000    5000    5000

F ratios
             1       2       3       4       5       6       7       8       9      10
 1963.00                         1.00    1.00    1.00                         (1.00)
 1964.00                         1.00    1.00    1.00                         (1.00)
 1965.00                         1.00    1.00    1.00                         (1.00)
 1966.00                         1.00    1.00    1.00                         (1.00)
 1967.00                         1.00    1.00    1.00                         (1.00)
 1968.00                         1.00    1.00    1.00                         (1.00)
 1969.00                         1.00    1.00    1.00                         (1.00)
 1970.00                         1.00    1.00    1.00                         (1.00)
 1971.00                         1.00    1.00    1.00                         (1.00)
 1972.00                         1.00    1.00    1.00                         (1.00)
```

1973.00	1.00	1.00	1.00		(1.00)
1974.00	1.00	1.00	1.00		(1.00)
1975.00	1.00	1.00	1.00		(1.00)
1976.00	1.00	1.00	1.00		(1.00)
1977.00	1.00	1.00	1.00		(1.00)
1978.00	1.00	1.00	1.00		(1.00)

Natural Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1964.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1965.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1966.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1967.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1968.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1969.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1970.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1971.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1972.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1973.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1974.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1975.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1976.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1977.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1978.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1979.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1980.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1981.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1982.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1983.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1984.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1985.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1986.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1987.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1988.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1989.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1990.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1991.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1992.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1993.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
1994.00	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)

Virtual Population Analysis using initial values

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	48889	28299	19641	5841	4174	2461	866	1362	835	518
1964.00	51847	40027	23029	14743	4162	3122	1821	643	981	639
1965.00	87176	42449	32666	16928	9964	2777	2251	1348	489	759
1966.00	52849	71374	34545	23745	11106	6576	1813	1598	1020	338
1967.00	104674	43269	58374	25724	15025	7993	4759	1363	1273	811
1968.00	95080	85700	35078	45940	18460	10559	6302	3487	1034	1003
1969.00	129216	77843	70121	26523	35548	14034	8085	5026	2741	820
1970.00	68027	105793	63430	55620	17558	27752	11032	6107	4019	2173
1971.00	63818	55696	86586	49354	43430	12748	22181	8816	4823	3254
1972.00	64705	52249	45255	69640	36400	33851	9459	17740	6891	3678
1973.00	61004	52924	39194	29475	53503	27766	27303	7444	14380	5559
1974.00	62606	49630	36348	25193	19406	42048	21936	21931	5791	11594
1975.00	54235	50447	37590	24301	18447	13943	33868	17103	17121	4289
1976.00	46770	44381	38964	24770	17601	13905	10628	26815	13361	13838
1977.00	47571	38260	33787	24460	17773	12782	10373	8104	21486	10410
1978.00	49430	38803	30190	23446	17561	13030	9795	7985	6287	17329
1979.00	51338	40435	27757	20864	17067	13200	10035	7755	6318	5000
1980.00	59959	42023	32203	21069	15994	12908	10154	7881	6207	5000
1981.00	59548	49048	33482	23344	16389	12477	9992	7888	6277	5000
1982.00	68803	48614	37910	23869	17326	12887	9845	7873	6257	5000
1983.00	70514	56293	38535	26863	18020	13058	10033	7710	6223	5000
1984.00	72989	57700	42913	27260	19673	14001	10001	7755	6170	5000
1985.00	51895	59617	44510	30098	20148	15313	10845	7916	6223	5000
1986.00	59223	42482	46745	31826	21891	15179	11427	8329	6312	5000
1987.00	53654	48278	34083	31876	18475	14514	11166	8404	6395	5000
1988.00	39972	43927	37994	25926	19833	13388	10658	8440	6471	5000
1989.00	34452	32707	32726	25972	18057	13871	10013	7921	6280	5000
1990.00	25100	28187	26093	20238	16136	12752	10095	7859	6253	5000
1991.00	18991	20498	21738	16332	13214	12134	9731	7791	6213	5000
1992.00	15834	15410	15660	14561	10720	9759	9386	7584	6167	5000
1993.00	25632	12939	11840	11224	9140	7904	7670	7588	6154	5000
1994.00	18324	20972	8334	7295	6649	6416	6227	6179	6162	5000
1995.00	15000	15000	15000	5000	5000	5000	5000	5000	5000	5000

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	0.000	0.006	0.087	0.139	0.090	0.101	0.097	0.128	0.068	0.110
1964.00	0.000	0.003	0.108	0.192	0.205	0.127	0.101	0.075	0.057	0.175
1965.00	0.000	0.006	0.119	0.222	0.216	0.226	0.142	0.078	0.169	0.221
1966.00	0.000	0.001	0.095	0.258	0.129	0.123	0.086	0.027	0.030	0.170
1967.00	0.000	0.010	0.040	0.132	0.153	0.038	0.111	0.076	0.039	0.107
1968.00	0.000	0.001	0.080	0.056	0.074	0.067	0.026	0.041	0.031	0.066
1969.00	0.000	0.005	0.032	0.212	0.048	0.041	0.081	0.024	0.032	0.100
1970.00	0.000	0.000	0.051	0.047	0.120	0.024	0.024	0.036	0.011	0.064
1971.00	0.000	0.008	0.018	0.104	0.049	0.098	0.023	0.046	0.071	0.084
1972.00	0.001	0.087	0.229	0.064	0.071	0.015	0.040	0.010	0.015	0.050
1973.00	0.006	0.176	0.242	0.218	0.041	0.036	0.019	0.051	0.015	0.098
1974.00	0.016	0.078	0.203	0.112	0.131	0.016	0.049	0.048	0.100	0.086
1975.00	0.001	0.058	0.217	0.123	0.083	0.071	0.034	0.047	0.013	0.092
1976.00	0.001	0.073	0.266	0.132	0.120	0.093	0.071	0.022	0.050	0.115
1977.00	0.004	0.037	0.165	0.131	0.110	0.066	0.062	0.054	0.015	0.103
1978.00	0.001	0.135	0.169	0.118	0.085	0.061	0.034	0.034	0.029	0.088
1979.00	0.000	0.028	0.076	0.066	0.079	0.062	0.042	0.023	0.034	0.182
1980.00	0.001	0.027	0.122	0.051	0.048	0.056	0.052	0.028	0.016	0.198
1981.00	0.003	0.058	0.138	0.098	0.040	0.037	0.038	0.032	0.027	0.160
1982.00	0.001	0.032	0.144	0.081	0.083	0.050	0.044	0.035	0.024	0.107
1983.00	0.001	0.071	0.146	0.112	0.052	0.067	0.058	0.023	0.019	0.118
1984.00	0.002	0.060	0.155	0.102	0.051	0.055	0.034	0.020	0.010	0.036
1985.00	0.000	0.043	0.135	0.118	0.083	0.093	0.064	0.026	0.019	0.051
1986.00	0.004	0.020	0.183	0.344	0.211	0.107	0.107	0.064	0.033	0.080
1987.00	0.000	0.040	0.074	0.275	0.122	0.109	0.080	0.061	0.046	0.047
1988.00	0.001	0.094	0.180	0.162	0.158	0.090	0.097	0.096	0.058	0.075
1989.00	0.001	0.026	0.281	0.276	0.148	0.118	0.042	0.037	0.028	0.041
1990.00	0.003	0.060	0.269	0.226	0.085	0.070	0.059	0.035	0.024	0.035
1991.00	0.009	0.069	0.201	0.221	0.103	0.057	0.049	0.034	0.017	0.050
1992.00	0.002	0.064	0.133	0.266	0.105	0.041	0.013	0.009	0.010	0.021
1993.00	0.001	0.240	0.284	0.324	0.154	0.038	0.016	0.008	0.008	0.018
1994.00	0.000	0.135	0.311	0.178	0.085	0.049	0.019	0.012	0.009	0.025

[Non-linear Estimation: iterations]

LAMBDA	1.00000E-2
RSS	4.51893E2
NPHI	4.51893E2

Parameters

8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0
8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0
8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0
8.51719E0	8.51719E0	8.51719E0	8.51719E0	8.51719E0	

LAMBDA 1.00000E-3
RSS 3.68220E2
NPHI 3.68220E2

Parameters

1.00605E1	9.37805E0	9.73547E0	9.86258E0	9.87178E0	9.54798E0
8.38474E0	8.05192E0	8.25053E0	8.95524E0	8.81634E0	7.62892E0
9.42465E0	8.75410E0	9.38143E0	8.35641E0	1.05535E1	9.91090E0
9.78857E0	9.42812E0	9.03886E0	9.63226E0	9.05529E0	

LAMBDA 1.00000E-4
RSS 3.67339E2
NPHI 3.67339E2

Parameters

9.77755E0	9.16618E0	9.53861E0	9.66578E0	9.59638E0	9.33441E0
8.25261E0	7.87276E0	8.10121E0	8.80086E0	8.66910E0	7.17401E0
9.21215E0	8.61864E0	9.13816E0	8.22161E0	1.02720E1	9.68501E0
9.52070E0	9.19955E0	8.85165E0	9.42020E0	8.87787E0	

LAMBDA 1.00000E-5
RSS 3.67327E2
NPHI 3.67327E2

Parameters

9.90668E0	9.29921E0	9.65752E0	9.77813E0	9.71115E0	9.45262E0
8.38597E0	8.01429E0	8.25768E0	8.93548E0	8.81524E0	7.42346E0
9.34079E0	8.76039E0	9.27749E0	8.39093E0	1.03625E1	9.78865E0
9.63701E0	9.33012E0	8.99299E0	9.53869E0	9.01442E0	

LAMBDA 1.00000E-5
RSS 3.67320E2
NPHI 3.67320E2

Parameters

9.80402E0	9.19380E0	9.56341E0	9.68853E0	9.61913E0	9.35949E0
8.28270E0	7.90276E0	8.13500E0	8.83006E0	8.70211E0	7.19349E0
9.23743E0	8.65341E0	9.16644E0	8.25328E0	1.02914E1	9.70788E0
9.54644E0	9.22821E0	8.88227E0	9.44525E0	8.90730E0	

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LAMBDA       1.00000E-5
RSS          3.67317E2
NPHI         3.67317E2

Parameters
   9.88787E0      9.27978E0      9.64053E0      9.76207E0      9.69454E0      9.43574E0
   8.36695E0      7.99348E0      8.23422E0      8.91589E0      8.79400E0      7.37765E0
   9.32179E0      8.74113E0      9.25680E0      8.36456E0      1.03501E1      9.77433E0
   9.62059E0      9.31129E0      8.97222E0      9.52178E0      8.99447E0

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.00001

LAMBDA       1.00000E-2
RSS          3.67317E2
NPHI         3.67317E2

Parameters
   9.88787E0      9.27978E0      9.64053E0      9.76207E0      9.69454E0      9.43574E0
   8.36695E0      7.99348E0      8.23422E0      8.91589E0      8.79400E0      7.37765E0
   9.32179E0      8.74113E0      9.25680E0      8.36456E0      1.03501E1      9.77433E0
   9.62059E0      9.31129E0      8.97222E0      9.52178E0      8.99447E0     -6.41006E0
  -6.09725E0     -7.20270E0     -7.89043E0     -7.97847E0     -8.18894E0     -8.01116E0
  -8.74523E0     -9.45376E0     -7.59994E0     -7.11959E0     -7.78451E0     -8.60771E0
  -9.10419E0     -9.62905E0     -9.82803E0     -1.08624E1

LAMBDA       1.00000E-3
RSS          3.67313E2
NPHI         3.67313E2

Parameters
   9.83117E0      9.22156E0      9.58876E0      9.71297E0      9.64371E0      9.38425E0
   8.31015E0      7.93237E0      8.16630E0      8.85756E0      8.73193E0      7.24659E0
   9.26500E0      8.68307E0      9.19522E0      8.28665E0      1.03109E1      9.72967E0
   9.57036E0      9.25463E0      8.91026E0      9.47017E0      8.93487E0     -6.37460E0
  -6.05660E0     -7.15670E0     -7.83952E0     -7.92427E0     -8.15347E0     -7.97051E0
  -8.69922E0     -9.40306E0     -7.56447E0     -7.07894E0     -7.73850E0     -8.55701E0
  -9.04999E0     -9.59358E0     -9.78738E0     -1.08164E1
```

LAMBDA 1.00000E-4
RSS 3.67312E2
NPHI 3.67312E2

Parameters

9.86726E0	9.25858E0	9.62178E0	9.74431E0	9.67620E0	9.41716E0
8.34622E0	7.97092E0	8.20927E0	8.89467E0	8.77110E0	7.32572E0
9.30102E0	8.71969E0	9.23437E0	8.33640E0	1.03362E1	9.75839E0
9.60259E0	9.29089E0	8.95001E0	9.50316E0	8.97295E0	-6.39703E0
-6.08233E0	-7.18582E0	-7.87176E0	-7.95857E0	-8.17590E0	-7.99624E0
-8.72835E0	-9.43516E0	-7.58691E0	-7.10467E0	-7.76763E0	-8.58911E0
-9.08429E0	-9.61602E0	-9.81311E0	-1.08455E1		

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.00001

Estimated VPA (biased)

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	76536	46046	28287	8194	7178	4215	1310	2059	1255	812
1964.00	104924	62663	37559	21821	6088	5582	3257	1007	1551	983
1965.00	175153	85905	51198	28823	15756	4354	4264	2523	786	1226
1966.00	87311	143403	70124	38916	20840	11316	3103	3247	1983	581
1967.00	217631	71484	117347	54851	27438	15961	8640	2419	2623	1599
1968.00	200118	178181	58178	94222	42305	20720	12826	6664	1898	2108
1969.00	277605	163841	145838	45435	75077	33555	16403	10367	5342	1528
1970.00	154536	227284	133839	117611	33035	60115	27015	12917	8392	4303
1971.00	97088	126523	186055	106998	94184	25418	48677	21901	10399	6834
1972.00	125793	79489	103243	151078	83591	75403	19831	39434	17604	8243
1973.00	133986	102939	61495	76935	120176	66402	61323	15936	32141	14330
1974.00	128801	109382	77286	43441	58252	96635	53568	49784	12744	26135
1975.00	98404	104643	86508	57809	33385	45745	78560	43001	39925	9981
1976.00	42013	80544	83334	64809	45032	26135	36664	63405	34564	32509
1977.00	34829	34365	63393	60768	50550	35239	20385	29420	51444	27769
1978.00	41406	28371	27001	47680	47285	39864	28180	16182	23739	41857
1979.00	65217	33866	19219	18254	36905	37535	32005	22807	13028	19288
1980.00	68710	53386	26825	14080	13858	29149	30077	25867	18531	10494
1981.00	38440	56213	42785	18942	10667	10728	23289	24200	21003	15090
1982.00	104831	31333	43776	31484	13723	8203	8413	18760	19612	17057
1983.00	77320	85790	24387	31664	24255	10108	6198	6538	15136	15934
1984.00	104758	63273	67062	15683	23603	19105	7587	4615	5210	12298
1985.00	46886	85627	49072	49864	10672	18530	15024	5939	3652	4214
1986.00	76713	38381	68040	35559	38073	7423	14062	11750	4694	2896
1987.00	95319	62597	30726	49305	21527	27757	4819	10560	9196	3675
1988.00	50971	78040	49717	23177	34091	15886	21499	3244	8236	7293
1989.00	53863	41713	60653	35566	15808	25542	12058	16797	2028	6445
1990.00	51771	44079	33466	43087	23984	10911	19649	9533	13519	1519
1991.00	46381	42334	34748	22363	31914	18559	8224	15613	7584	10949
1992.00	62923	37835	33538	25210	15655	25068	14647	6351	12571	6122
1993.00	25632	51492	30199	25859	17853	11944	20205	11895	5144	10243
1994.00	18324	20972	39892	22319	18623	13547	9535	16441	9688	4173
1995.00	15000	15000	15000	30829	17299	14803	10839	7708	13402	7887

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1963.00	0.000	0.004	0.060	0.097	0.052	0.058	0.063	0.083	0.045	0.069
1964.00	0.000	0.002	0.065	0.126	0.135	0.069	0.055	0.047	0.035	0.110
1965.00	0.000	0.003	0.074	0.124	0.131	0.139	0.073	0.041	0.102	0.131
1966.00	0.000	0.001	0.046	0.149	0.067	0.070	0.049	0.013	0.015	0.095
1967.00	0.000	0.006	0.019	0.060	0.081	0.019	0.060	0.042	0.019	0.053
1968.00	0.000	0.000	0.047	0.027	0.032	0.034	0.013	0.021	0.017	0.031
1969.00	0.000	0.002	0.015	0.119	0.022	0.017	0.039	0.011	0.016	0.053
1970.00	0.000	0.000	0.024	0.022	0.062	0.011	0.010	0.017	0.005	0.032
1971.00	0.000	0.003	0.008	0.047	0.022	0.048	0.011	0.018	0.032	0.039
1972.00	0.001	0.057	0.094	0.029	0.030	0.007	0.019	0.004	0.006	0.022
1973.00	0.003	0.087	0.148	0.078	0.018	0.015	0.008	0.024	0.007	0.037
1974.00	0.008	0.035	0.090	0.063	0.042	0.007	0.020	0.021	0.044	0.037
1975.00	0.000	0.028	0.089	0.050	0.045	0.021	0.014	0.018	0.005	0.039
1976.00	0.001	0.039	0.116	0.048	0.045	0.048	0.020	0.009	0.019	0.047
1977.00	0.005	0.041	0.085	0.051	0.037	0.024	0.031	0.015	0.006	0.037
1978.00	0.001	0.189	0.191	0.056	0.031	0.020	0.012	0.017	0.008	0.036
1979.00	0.000	0.033	0.111	0.076	0.036	0.022	0.013	0.008	0.016	0.044
1980.00	0.001	0.021	0.148	0.078	0.056	0.024	0.017	0.008	0.005	0.090
1981.00	0.004	0.050	0.107	0.122	0.063	0.043	0.016	0.010	0.008	0.050
1982.00	0.000	0.051	0.124	0.061	0.106	0.080	0.052	0.015	0.008	0.030
1983.00	0.000	0.046	0.241	0.094	0.039	0.087	0.095	0.027	0.008	0.036
1984.00	0.002	0.054	0.096	0.185	0.042	0.040	0.045	0.034	0.012	0.014
1985.00	0.000	0.030	0.122	0.070	0.163	0.076	0.046	0.035	0.032	0.061
1986.00	0.003	0.022	0.122	0.302	0.116	0.232	0.086	0.045	0.045	0.141
1987.00	0.000	0.030	0.082	0.169	0.104	0.055	0.196	0.049	0.032	0.065
1988.00	0.000	0.052	0.135	0.183	0.089	0.076	0.047	0.270	0.045	0.051
1989.00	0.000	0.020	0.142	0.194	0.171	0.062	0.035	0.017	0.089	0.032
1990.00	0.001	0.038	0.203	0.100	0.056	0.083	0.030	0.029	0.011	0.121
1991.00	0.004	0.033	0.121	0.157	0.041	0.037	0.059	0.017	0.014	0.023
1992.00	0.000	0.025	0.060	0.145	0.071	0.016	0.008	0.011	0.005	0.017
1993.00	0.001	0.055	0.102	0.128	0.076	0.025	0.006	0.005	0.009	0.009
1994.00	0.000	0.135	0.058	0.055	0.030	0.023	0.013	0.004	0.006	0.030

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION
ORTHOGONALITY OFFSET..... 0.012596
MEAN SQUARE RESIDUALS 1.228467

Estimates for parameters

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
9.87E0	1.15E0	0.116	-6.44E-2	-0.007
9.26E0	9.77E-1	0.105	-6.90E-2	-0.007
9.62E0	8.36E-1	0.087	-2.89E-2	-0.003
9.74E0	7.89E-1	0.081	-1.96E-2	-0.002
9.68E0	7.65E-1	0.079	-1.72E-2	-0.002
9.42E0	7.69E-1	0.082	-1.89E-2	-0.002
8.35E0	8.71E-1	0.104	-6.23E-2	-0.007
7.97E0	9.68E-1	0.121	-1.14E-1	-0.014
8.21E0	9.81E-1	0.120	-1.22E-1	-0.015
8.89E0	8.57E-1	0.096	-5.82E-2	-0.007
8.77E0	9.63E-1	0.110	-1.15E-1	-0.013
7.33E0	1.85E0	0.253	-9.98E-1	-0.136
9.30E0	8.80E-1	0.095	-6.81E-2	-0.007
8.72E0	9.91E-1	0.114	-1.18E-1	-0.014
9.23E0	8.94E-1	0.097	-7.17E-2	-0.008
8.34E0	9.84E-1	0.118	-1.19E-1	-0.014
1.03E1	6.90E-1	0.067	3.24E-2	0.003
9.76E0	7.07E-1	0.072	1.50E-2	0.002
9.60E0	7.43E-1	0.077	-3.74E-3	0.000
9.29E0	8.04E-1	0.087	-2.99E-2	-0.003
8.95E0	8.32E-1	0.093	-3.98E-2	-0.004
9.50E0	7.75E-1	0.082	-1.93E-2	-0.002
8.97E0	8.39E-1	0.094	-4.40E-2	-0.005
-6.40E0	5.37E-1	-0.084	-4.70E-2	0.007
-6.08E0	6.03E-1	-0.099	-3.81E-2	0.006
-7.19E0	6.70E-1	-0.093	-1.68E-2	0.002
-7.87E0	7.33E-1	-0.093	6.65E-3	-0.001
-7.96E0	7.77E-1	-0.098	2.89E-2	-0.004
-8.18E0	5.37E-1	-0.066	-4.70E-2	0.006
-8.00E0	6.03E-1	-0.075	-3.81E-2	0.005
-8.73E0	6.70E-1	-0.077	-1.68E-2	0.002
-9.44E0	7.30E-1	-0.077	6.43E-3	-0.001
-7.59E0	5.37E-1	-0.071	-4.70E-2	0.006
-7.10E0	6.03E-1	-0.085	-3.81E-2	0.005
-7.77E0	6.70E-1	-0.086	-1.68E-2	0.002
-8.59E0	7.30E-1	-0.085	6.43E-3	-0.001
-9.08E0	7.77E-1	-0.086	2.89E-2	-0.003
-9.62E0	5.37E-1	-0.056	-4.70E-2	0.005
-9.81E0	6.03E-1	-0.061	-3.81E-2	0.004
-1.08E1	6.70E-1	-0.062	-1.68E-2	0.002

Parameters in linear scale

	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
N(1995, 4)	1.93E4	2.22E4	1.149	1.15E4	0.595
N(1995, 5)	1.05E4	1.03E4	0.977	4.28E3	0.408
N(1995, 6)	1.51E4	1.26E4	0.836	4.84E3	0.321
N(1995, 7)	1.71E4	1.35E4	0.789	4.97E3	0.292
N(1995, 8)	1.59E4	1.22E4	0.765	4.39E3	0.276
N(1995, 9)	1.23E4	9.45E3	0.769	3.40E3	0.276
N(1995, 10)	4.21E3	3.67E3	0.871	1.34E3	0.317
N(1994, 10)	2.90E3	2.80E3	0.968	1.03E3	0.354
N(1993, 10)	3.67E3	3.61E3	0.982	1.32E3	0.360
N(1992, 10)	7.29E3	6.25E3	0.857	2.25E3	0.309

N(1991, 10)	6.45E3	6.21E3	0.963	2.25E3	0.349
N(1990, 10)	1.52E3	2.81E3	1.852	1.09E3	0.717
N(1989, 10)	1.09E4	9.64E3	0.880	3.50E3	0.319
N(1988, 10)	6.12E3	6.07E3	0.992	2.29E3	0.374
N(1987, 10)	1.02E4	9.16E3	0.894	3.36E3	0.328
N(1986, 10)	4.17E3	4.11E3	0.984	1.52E3	0.365
N(1985, 10)	3.08E4	2.13E4	0.690	8.33E3	0.270
N(1984, 10)	1.73E4	1.22E4	0.707	4.59E3	0.265
N(1983, 10)	1.48E4	1.10E4	0.743	4.03E3	0.272
N(1982, 10)	1.08E4	8.72E3	0.804	3.18E3	0.293
N(1981, 10)	7.71E3	6.41E3	0.832	2.36E3	0.306
N(1980, 10)	1.34E4	1.04E4	0.775	3.77E3	0.281
N(1979, 10)	7.89E3	6.62E3	0.839	2.43E3	0.308
Otter trawl 2	1.67E-3	8.96E-4	0.537	1.62E-4	0.097
Otter trawl 3	2.28E-3	1.38E-3	0.603	3.27E-4	0.143
Otter trawl 4	7.57E-4	5.07E-4	0.670	1.57E-4	0.208
Otter trawl 5	3.81E-4	2.80E-4	0.733	1.05E-4	0.275
Otter trawl 6	3.50E-4	2.72E-4	0.777	1.16E-4	0.331
Seine 2	2.81E-4	1.51E-4	0.537	2.74E-5	0.097
Seine 3	3.37E-4	2.03E-4	0.603	4.83E-5	0.143
Seine 4	1.62E-4	1.09E-4	0.670	3.36E-5	0.208
Seine 5	7.99E-5	5.83E-5	0.730	2.18E-5	0.273
Light trawl 2	5.07E-4	2.73E-4	0.537	4.94E-5	0.097
Light trawl 3	8.21E-4	4.95E-4	0.603	1.18E-4	0.143
Light trawl 4	4.23E-4	2.84E-4	0.670	8.79E-5	0.208
Light trawl 5	1.86E-4	1.36E-4	0.730	5.08E-5	0.273
Light trawl 6	1.13E-4	8.81E-5	0.777	3.75E-5	0.331
Prawn trawl 2	6.67E-5	3.58E-5	0.537	6.49E-6	0.097
Prawn trawl 3	5.47E-5	3.30E-5	0.603	7.85E-6	0.143
Prawn trawl 4	1.95E-5	1.31E-5	0.670	4.05E-6	0.208

[Correlation matrix of parameter estimates]

1.00																	
0.56	1.00																
0.60	0.72	1.00															
0.61	0.74	0.79	1.00														
0.62	0.74	0.80	0.82	1.00													
0.62	0.74	0.80	0.82	0.83	1.00												
0.62	0.74	0.80	0.82	0.83	0.83	1.00											
0.62	0.74	0.79	0.82	0.83	0.83	0.83	1.00										
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	1.00									
0.62	0.74	0.80	0.82	0.83	0.83	0.83	0.83	0.83	1.00								
0.62	0.74	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	1.00							
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	1.00						
0.62	0.74	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	1.00					
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	1.00				
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	1.00			
0.53	0.64	0.68	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	1.00		
0.58	0.70	0.75	0.78	0.79	0.79	0.79	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.69	1.00
0.60	0.73	0.78	0.81	0.82	0.82	0.82	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.71	0.78
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.72	0.79
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.72	0.79
0.62	0.74	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.72	0.79
0.62	0.75	0.80	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.72	0.79
-0.60	-0.72	-0.77	-0.79	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.72	-0.78
-0.61	-0.74	-0.79	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.84	-0.74	-0.80
-0.63	-0.75	-0.82	-0.84	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.73	-0.81
-0.63	-0.78	-0.83	-0.85	-0.86	-0.86	-0.86	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.74	-0.80
-0.68	-0.79	-0.84	-0.86	-0.87	-0.87	-0.87	-0.86	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.74	-0.81
-0.60	-0.72	-0.77	-0.79	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.72	-0.78
-0.61	-0.74	-0.79	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.84	-0.74	-0.80
-0.63	-0.75	-0.82	-0.84	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.73	-0.81
-0.63	-0.78	-0.83	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.74	-0.81
-0.60	-0.72	-0.77	-0.79	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.72	-0.78
-0.61	-0.74	-0.79	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.84	-0.74	-0.80
-0.63	-0.75	-0.82	-0.84	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.73	-0.81
-0.63	-0.78	-0.83	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.74	-0.81
-0.68	-0.79	-0.84	-0.86	-0.87	-0.87	-0.87	-0.86	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.87	-0.74	-0.81
-0.60	-0.72	-0.77	-0.79	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.72	-0.78
-0.61	-0.74	-0.79	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.83	-0.84	-0.84	-0.84	-0.84	-0.74	-0.80
-0.63	-0.75	-0.82	-0.84	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.73	-0.81

[Correlation matrix - continued]

```
 1.00
 0.82  1.00
 0.82  0.83  1.00
 0.82  0.83  0.83  1.00
 0.82  0.83  0.83  0.83  1.00
-0.80 -0.81 -0.81 -0.81 -0.81  1.00
-0.82 -0.84 -0.84 -0.84 -0.84  0.81  1.00
-0.84 -0.85 -0.85 -0.85 -0.85  0.82  0.85  1.00
-0.85 -0.86 -0.86 -0.86 -0.86  0.83  0.85  0.87  1.00
-0.84 -0.87 -0.87 -0.87 -0.87  0.84  0.86  0.88  0.89  1.00
-0.80 -0.81 -0.81 -0.81 -0.81  0.79  0.81  0.82  0.83  0.84  1.00
-0.82 -0.84 -0.84 -0.84 -0.84  0.81  0.83  0.85  0.85  0.86  0.81  1.00
-0.84 -0.85 -0.85 -0.85 -0.85  0.82  0.85  0.86  0.87  0.88  0.82  0.85  1.00
-0.85 -0.86 -0.86 -0.86 -0.86  0.83  0.86  0.87  0.88  0.89  0.83  0.86  0.87  1.00
-0.80 -0.81 -0.81 -0.81 -0.81  0.79  0.81  0.82  0.83  0.84  0.79  0.81  0.82  0.83  1.00
-0.82 -0.84 -0.84 -0.84 -0.84  0.81  0.83  0.85  0.85  0.86  0.81  0.83  0.85  0.86  0.81  1.00
-0.84 -0.85 -0.85 -0.85 -0.85  0.82  0.85  0.86  0.87  0.88  0.82  0.85  0.86  0.87  0.82  0.85  1.00
-0.85 -0.86 -0.86 -0.86 -0.86  0.83  0.86  0.87  0.88  0.89  0.83  0.86  0.87  0.88  0.83  0.86  0.87  1.00
-0.84 -0.87 -0.87 -0.87 -0.87  0.84  0.86  0.88  0.89  0.90  0.84  0.86  0.88  0.89  0.84  0.86  0.88  0.89
-0.80 -0.81 -0.81 -0.81 -0.81  0.79  0.81  0.82  0.83  0.84  0.79  0.81  0.82  0.83  0.79  0.81  0.82  0.83
-0.82 -0.84 -0.84 -0.84 -0.84  0.81  0.83  0.85  0.85  0.86  0.81  0.83  0.85  0.86  0.81  0.83  0.85  0.86
-0.84 -0.85 -0.85 -0.85 -0.85  0.82  0.85  0.86  0.87  0.88  0.82  0.85  0.86  0.87  0.82  0.85  0.86  0.87
```

[Correlation matrix - continued]

```
  1.00
  0.84  1.00
  0.86  0.81  1.00
  0.88  0.82  0.85  1.00
```

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Population Dynamics Model

Consider an age structured model. Mortality is partitioned into two components, fishing mortality, F, associated with the fishery harvest and natural mortality, M, associated with all other causes of death. Denoting population abundance in numbers by N and time by *t*, the mortality dynamics are described by the system of differential equations

$$\frac{dN}{dt} = -(F+M)N$$

$$\frac{dC}{dt} = FN$$

Solving the differential equations using year as the unit of time yields the familiar exponential decay and catch equation used for Virtual Population Analysis (VPA).

$$N_{a+\Delta t,t+\Delta t} = N_{a,t}e^{-(F_{a,t}+M_{a,t})\Delta t}$$

$$C_{a,t} = \frac{F_{a,t}\Delta t N_{a,t}\left(1-e^{-(F_{a,t}+M_{a,t})\Delta t}\right)}{(F_{a,t}+M_{a,t})\Delta t}$$

With year as the unit of time, ages are expressed in years and mortality rates are annual instantaneous rates. The catch, designated $C_{a,t}$, represents the number caught during the time interval Δt but are indexed by the age and time at the beginning of the interval.

It is not possible to estimate a complete array of age and time varying natural mortality. Often a single common value, or at most, a few values common over large blocks, is prescribed. Although it is desirable to estimate natural mortality, the data may not support any estimation at all. In many applications natural mortality is assumed known.

Though estimation of a complete array of age and time varying fishing mortality is technically possible, results tend to be unreliable and such practice is not common. One prevalent technique for reducing the number of parameters required to be estimated is to assume that the errors in the catch at age are negligible. This is the conventional "VPA" assumption, i.e. the catch equation may be applied deterministically. This form of population dynamics model only requires the estimation of one parameter for each year-class, typically the survivors at the oldest age or in the last time period.

Frequently, the stability of the solution and the reliability of the results may be enhanced by making the further assumption that the fishing mortality rate for the oldest age may be calculated from the fishing mortality rate for younger ages in the same age group. The number of parameters required to be estimated are reduced further through such practice. This feature is implemented as follows (for simplicity, age group and time period subscripts are not shown and are the same for all quantities):

$$N_c = C(F_c + M)/F_c(1-e^{-(F_c+M)\Delta t})$$

F_c is the calculated fishing mortality rate obtained from

$F_c = \sum_i R_i F_i / n$ for unweighted

$F_c = \sum_i N_i R_i F_i / \sum_i N_i$ for population weighted

R_i is the assumed ratio of the fishing mortality rate for the cohort being calculated relative to the fishing mortality rate for cohort i.

Some analyses involve a plus group. Two methods for handling a plus group have been implemented. Let A represent the oldest non-plus group age and A' represent a plus group. Also, let T represent the terminal time in the VPA.

For the FIRST method, all cohorts must be specified. In addition, the population abundance of the plus group in the first time of the VPA must be specified. Therefore we have $N_{A,1}$ and $N_{A',1}$. We can compute

$$N_{A',2} = N_{A,1}e^{-(F_{A,1}+M_{A,1})\Delta t_1} + N_{A',1}e^{-(F_{A',1}+M_{A',1})\Delta t_1}$$

and

$$N_{A,2} = N_{A-1,1}e^{-(F_{A-1,1}+M_{A-1,1})\Delta t_1}.$$

These calculations are repeated for all times moving forwards.

For the FRATIO method all the cohorts in the terminal time must be specified. In addition, the population abundance for the plus group in the terminal time must be specified. Solve for $F_{(A-1)',T-1}$ using $C_{(A-1)',T-1}$ and $N_{A',T}$ in the catch equation. Then

$$F_{A,T-1} = F_{(A-1)',T-1}\left(C_{A',T-1} + R_{t'}C_{A,T-1}\right) \Big/ R_{t'}C_{(A-1)',T-1}$$

where $R_{t'}$ is an F ratio which may be assigned or estimated. The ratio may be specified for each time period but typically a common ratio is specified for blocks of time periods. Now

$$N_{A,T-1} = C_{A,T-1}\left(F_{A,T-1} + M_{A,T-1}\right) \Big/ F_{A,T-1}\left(1 - e^{-(F_{A,T-1}+M_{A,T-1})\Delta t_j}\right)$$

Also $F_{A',T-1} = R_{t'}F_{A,T-1}$ therefore $N_{A',T-1}$ can be calculated in a similar manner.

These calculations are repeated for all times moving backwards.

Catchability Model

It is well known that stock status is not reliably determined from information on catch at age alone. Most methods of fishery stock assessment also use information on relative abundance trends provided by indices. The model relationships that link the indices to the population must be defined. Indices of abundance may be compared to population numbers, population biomass or spawning biomass, either age by age or age aggregated. Typically, measures are taken to obtain indices that are proportional to the population.

$$I_{a',t} = q_{a'}P_{a',t}$$

where a' is a single age or an aggregate of ages, $I_{a',t}$ is the index for age(s) a' at time t and $P_{a',t}$ is the population (numbers, biomass or spawning biomass) for age(s) a' at time t. In addition to the more common proportional model, two other models are implemented, a power model

$$I_{a',t} = q_{a'}P_{a',t}^{a}$$

and a time trend model

$$I_{a',t} = \left(q_{a'} b^{\,t-t_1}\right) P_{a',t}$$

Error Model

As noted earlier, the error in the catch at age is assumed to be negligible. The errors for the observed indices about the model fit are assumed to be independent and identically distributed on the logarithmic scale. It is not necessary to make any assumptions about the form of the parametric distribution.

Estimation

Model parameters are transformed to the logarithmic scale.

$\eta_{a',t'} = lnN_{a',t'}$ for survivors being estimated

$\kappa_{s,a'} = lnq_{s,a'}$ for each age specific or age aggregated index, *s*

$\mu_{a',t'} = lnM_{a',t'}$ for designated age/time blocks if *M* is estimated

$\rho_{t'} = lnR_{t'}$ for designated time blocks if *F* ratios on plus group is estimated

Solve for the parameters by minimizing the objective function

$$\Psi(\hat{\theta}) = \sum_{s,a,t} \left(y_{s,a,t}(\hat{\theta})\right)^2 = \sum_{s,a,t} \left(lnI_{s,a,t} - \left(\hat{\kappa}_{s,a} + lnN_{a,t}\right)\right)^2$$

where θ represents the parameter vector of all estimated parameters. The objective function requires the calculation of population numbers from a VPA. The VPA population numbers are functions the estimated parameters log survivors, log *M* and log *F* ratio, $N_{a,t}(\hat{\eta}, \hat{\mu}, \hat{\rho})$, but for convenience, it is abbreviated by $N_{a,t}$. At time t', the population abundance was obtained directly from the parameter estimates, $N_{a',t'} = e^{\hat{\eta}_{a',t'}}$. For all other times, the population abundance was computed using the virtual population analysis algorithm. This involves solving for *F* in the catch equation using an iterative Newton-Raphson algorithm and then using the derived *F* in the exponential decay equation to calculate $N_{a,t}$. A Levenberg-Marquardt nonlinear minimization is used to obtain the least squares estimates of parameters.

Statistics for model parameters and for interest parameters, e.g. fully recruited exploitation rate or spawning stock biomass, derived from the model parameters may be obtained from analytical approximations or from bootstrap.
Analytical

The covariance matrix of the model parameters, θ, is estimated using the common linear approximation (Kennedy and Gentle 1980 p.476)

$$\text{cov}(\hat{\theta}) = \hat{\sigma}^2 \left[J^T(\hat{\theta}) J(\hat{\theta})\right]^{-1}$$

where $\hat{\sigma}^2$ is the mean square residual and $J(\hat{\theta})$ is the Jacobian matrix of the vector of residuals. The variance of an interest parameter, $\psi = g(\hat{\theta})$ where *g* is the transformation function, is estimated using the Delta approximation (Ratkowsky 1983).

$$Var(\hat{\psi}) = tr\left[GG^T \text{cov}(\hat{\theta})\right]$$

where *G* is the vector of first derivatives of *g* with respect to parameters.

Due to nonlinearity, estimation bias is expected. The bias of the model parameters was estimated using Box's (1971) approximation, which assumes that the errors are normally distributed:

$$Bias(\hat{\theta}) = \frac{-\hat{\sigma}^2}{2}\left(\sum_{i'} J_{i'}(\hat{\theta}) J_{i'}^T(\hat{\theta})\right)^{-1}\left(\sum_{i} J_i(\hat{\theta})\right) tr\left[\left(\sum_{i'} J_{i'}(\hat{\theta}) J_{i'}^T(\hat{\theta})\right)^{-1} H_i(\hat{\theta})\right]$$

where $J_i(\hat{\theta})$ = $J_{i'}(\hat{\theta})$ are vectors of the first derivatives for each residual and $H_i(\hat{\theta})$ are the Hessian matrices of second derivatives for each residual. The bias of interest parameters is then derived using the method described in Ratkowsky (1983).

$$Bias(\hat{\eta}) = G^T Bias(\hat{\theta}) + tr\left[W \operatorname{cov}(\hat{\theta})\right] / 2$$

where *W* is the matrix of second derivatives of *g* with respect to parameters.

Bootstrap

Statistical properties of model parameters or derived interest parameters can be obtained from a bootstrap simulation Efron (1979). Again letting η represent any interest parameter, (with estimate $\hat{\eta}$ corresponding to the least-squares solution), its statistical properties are derived from the bootstrap replicate estimates $\hat{\eta}^b$. The replicates are computed by applying the estimation formulae to bootstrap samples. Nonparametric bootstrap replications are obtained when bootstrap samples are generated by random sampling with replacement from the observed data. Here, model-conditioned bootstrap replications are obtained from bootstrap samples generated by sampling with replacement from all the observed abundance index residuals (nonparametric) and adding these to the model predicted values for the abundance indices. The bootstrap estimates of variance and bias are:

$$Var(\hat{\eta}) = \sum_{b=1}^{B}\left(\hat{\eta}^b - \bar{\eta}\right)^2 \Big/ B - 1$$

$$Bias(\hat{\eta}) = \bar{\eta} - \hat{\eta} \text{ where } \bar{\eta} = \sum_{b=1}^{B} \hat{\eta}^b \Big/ B .$$