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Tutorial for Projections and Risk Analysis 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 explores the functions available to carry out stock forecasts and analyses of the risks associated with various scenarios. 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.

Introduction

This document is intended as a tutorial for the use of the ADAPTive Framework (ADAPT) software and, in particular, for the functions related to catch projections and risk analysis. As such, this document complements the ADAPT User's Guide (Gavaris, 1999). 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 (1993) and Smith and Gavaris (1993).

It is recommended that the tutorial for the estimation of population abundance (Rivard and Gavaris, 2000) be done first.

The ADAPT software allows you to make two types of projections: deterministic and stochastic. Deterministic projections make forecasts of stock characteristics from the point estimates of stock abundance and from fishery scenarios that you specify. Stochastic projections make forecasts using the point estimates as well as a measure of their precision. The measure of precision can either be obtained analytically, or through a bootstrap procedure.

Data set for tutorial

As was done for the tutorial on estimation of population abundance, 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.). The current tutorial outlines working procedures that would permit a user to carry out deterministic catch projections, as well as projections that take into account the uncertainty in your estimates of population abundance (or risk analysis).

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

The Excel spreadsheet "ADAPT Template.xls", which is provided to assist in the preparation of your own data for using ADAPT, also placeholders for your entries for catch projection and risk analysis. The template also provides a means to display your reslts in a graphical form. The Excel template includes some data validation and has been formatted to allow easy copying between Excel and ADAPT.

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").

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

For the purpose of this tutorial, data input has already been done and the ADAPT Session log saved as "Tutorial - Blackfin - Forecast". Open this file now. In inspecting the log file, you will see that the information on catch at age and on the four tuning indices has already been provided, and that the VPA formulation has been specified. You can proceed with the estimation of parameters.

Estimating parameters

Start the non-linear least-squares estimation process:

1. In ADAPT
2. Select "Compute"
3. Select "NLLS fit" (i.e. use Non-Linear Least-Squares to fit the data)
4. 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.
5. 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.

6. In ADAPT
7. Select "Compute"

8. Select "Analytical" (i.e. Compute the bias and variance of parameter estimates analytically)
9. Select "Statistics".
10. 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 estimates of population and fishing mortality can be adjusted for bias as follows:

11. In ADAPT
12. Select "Compute"
13. Select "Analytical" (i.e. Compute from the bias and variance estimated analytically)
14. Select "VPA bias adjusted".
15. The results, namely the bias-adjusted estimates of the population and of the fishing mortality at age, appear in the session-log.

To prepare your data for the projections, copy to the Excel-Template the bias adjusted population abundance and fishing mortality matrices.

16. In ADAPT
17. Select "Output"
18. Select "To Clipboard"
19. Select "Population numbers".
20. Select "Adjusted for bias (Anal.)".
21. The estimates of population numbers, adjusted for bias, are copied to the clipboard.
22. In Excel
23. Go to the "N" sheet.
24. Paste the content of the clipboard to cell A9.

Repeat these steps to transfer the fishing mortality information to the "F" sheet of the Excel-Template.

Deterministic projections

In this section, we explore the use of deterministic forecasts using the point estimates of population abundance for the projection. The fishery scenarios can be specified either by providing a quota or a fishing mortality level for each year of the projection horizon. The Excel sheet "Forecast" in the Excel-Template can be used to prepare your scenarios. The sheet uses the input information for adapt, as well as the estimates of stock abundance and fishing mortality to suggest "defaults" for your scenarios. The defaults are based on long-term averages; adjust the entries as you see fit.

25. In ADAPT
26. Select "Compute"
27. Select "Analytical"
28. Select "Project bias adjusted". Note that this option is active only when statistics and bias corrections have been computed. You will be provided with a menu to describe the scenario for your forecast.
29. In the box labeled "Enter subsequent years for projection", enter "1996 1997" (without the quotes).

30. In the box labeled "Enter abundance at age 1 for 1996 1997", enter 25000 25000. [If you do not know what to enter here, check the defaults in the Excel-Template.
31. In the box labeled "Enter quota (biomass) or fishing mortality for 1995 1996", enter "0.2 0.2" (without the quotes). The values "0.2" indicate that you want to make projections using a fishing mortality of 0.2 in each projection year. NOTE than an entry larger than 2 is interpreted as a quota, while an entry less than 2 is interpreted as a fishing mortality.
32. The next entries for your projection scenario have to come from Excel, using the PASTE-buttons provided in the menu. In essence, you have to provide the natural mortality, partial recruitment, stock weight at age and catch weight at age for the projection horizon.
33. In Excel
    34. Select the "Forecast" sheet.
        35. Enter 25000 in cells D6 and E6.
        36. Go to the A9 cell, which marks the beginning of the natural mortality matrix. Defaults have been calculated for you here. Adjust as necessary.
        37. Highlight the relevant data and copy to the clipboard.
38. In ADAPT [returning to the "Project Menu"]
    39. Click the PASTE-button against the "Copy M…" option.
40. In Excel
    41. Select the "Forecast" sheet (if not already selected).
        42. Go to the A22 cell, which marks the beginning of the PR (partial recruitment) matrix. Defaults have been calculated for you here. Adjust as necessary.
        43. Highlight the relevant data and copy to the clipboard.
44. In ADAPT [returning to the "Project Menu"]
    45. Click the PASTE-button against the "Copy PR…" option.
46. In Excel
    47. Select the "Forecast" sheet (if not already selected).
        48. Go to the A34 cell, which marks the beginning of the stock weight at age matrix. Defaults have been calculated for you here. Adjust as necessary.
        49. Highlight the relevant data and copy to the clipboard.
50. In ADAPT [returning to the "Project Menu"]
    51. Click the PASTE-button against the "Copy beginning of year population weight at age…" option.
52. In Excel
    53. Select the "Forecast" sheet (if not already selected).
        54. Go to the A47 cell, which marks the beginning of the catch weight at age matrix. Defaults have been calculated for you here. Adjust as necessary.
        55. Highlight the relevant data and copy to the clipboard.
56. In ADAPT [returning to the "Project Menu"]
    57. Click the PASTE-button against the "Copy average catch weight at age … " option.
    58. Click the OK-button of the "Project Menu"
59. The results of this projection scenario appear in the Session-log.

Blackfin example:

The results show that a fishing mortality of 0.2 would generate a catch of 13 330 t in 1995 and 13 790 in 1996. These catch leels would lead to a reduction of the total biomass, from 138 552 t at the beginning of 1995 to 133 345 t at the beginning of 1997.

Computation of risk

60. In ADAPT
    61. Select "Compute"
        62. Select "Analytical"
            63. Select "Risk". Note that this option is active only when statistics and bias corrections have been computed. You will be provided with a menu to describe the scenario for your forecast.
                64. In the box labeled "Enter subsequent years for projection", enter "1996 1997" (without the quotes).
                65. In the box labeled "Enter abundance at age 1 for 1996 1997", enter 25000 25000. [If you do not know what to enter here, check the defaults in the Excel-Template.
                66. In the box labeled "Enter quota (biomass) or fishing mortality for 1995", enter "20000" (without the quotes). This value indicates that you want to make projections using a quota of 20000 t for the first year of the projection. NOTE than an entry larger than 2 is interpreted as a quota, while an entry less than 2 is interpreted as a fishing mo rtality.
                67. In the box labeled "Enter starting quota, increment, # steps separated by spaces for 1995", enter "1000 2000 30" (without the quotes). Warning: The starting quota has to be larger than zero. If you enter zero as the starting quota, ADAPT will start the calculation but will quit at one point without showing the results.
                68. The next entries for your projection scenario have to come from Excel, using the PASTE-buttons provided in the menu. In essence, you have to provide the natural mortality, partial recruitment, stock weight at age and catch weight at age for the projection horizon.
69. In Excel
    70. Select the "Forecast" sheet.
        71. Enter 25000 in cells D6 and E6.
        72. Go to the A9 cell, which marks the beginning of the natural mortality matrix. Defaults have been calculated for you here. Adjust as necessary.
        73. Highlight the relevant data and copy to the clipboard.
74. In ADAPT [returning to the "Project Menu"]
    75. Click the PASTE-button against the "Copy M…" option.
76. In Excel
    77. Select the "Forecast" sheet (if not already selected).
        78. Go to the A22 cell, which marks the beginning of the PR (partial recruitment) matrix. Defaults have been calculated for you here. Adjust as necessary.
        79. Highlight the relevant data and copy to the clipboard.
80. In ADAPT [returning to the "Project Menu"]
    81. Click the PASTE-button against the "Copy PR…" option.
82. In Excel
    83. Select the "Forecast" sheet (if not already selected).
        84. Go to the A34 cell, which marks the beginning of the stock weight at age matrix. Defaults have been calculated for you here. Adjust as necessary.
        85. Highlight the relevant data and copy to the clipboard.
86. In ADAPT [returning to the "Project Menu"]
    87. Click the PASTE-button against the "Copy beginning of year population weight at age…" option.
88. In Excel
    89. Select the "Forecast" sheet (if not already selected).
        90. Go to the A47 cell, which marks the beginning of the catch weight at age matrix. Defaults have been calculated for you here. Adjust as necessary.
        91. Highlight the relevant data and copy to the clipboard.
92. In ADAPT [returning to the "Project Menu"]

93. Click the PASTE-button against the "Copy average catch weight at age … " option.
94. In Excel
95. Select the "Forecast" sheet (if not already selected).
96. Go to the A59 cell, which marks the beginning of the maturity at age matrix. Defaults have been calculated for you here from initial input. Adjust as necessary.
97. Highlight the relevant data and copy to the clipboard.
98. In ADAPT [returning to the "Project Menu"]
99. Click the PASTE-button against the "Copy maturity at age for …" option.
100. In the box labeled "Inverse exploration", enter "5"
101. In the box labeled "%Biomass change", enter "0". Note that this % change refers to a change in the Stock Spawning Biomass (SSB).
102. In the box labeled "Absolute biomass", enter "50000". Note that this value refers to the Stock Spawning Biomass (SSB).
103. Your entries must look like the Menu illustrated in Figure 1. Click the OK-button of the "Risk Menu"
104. These calculations can take many minutes. The results of this projection scenario appear in the Session-log.

Inspect the session log to explore the results. You can copy these results to the clipboard for transfer to the Excel-template.

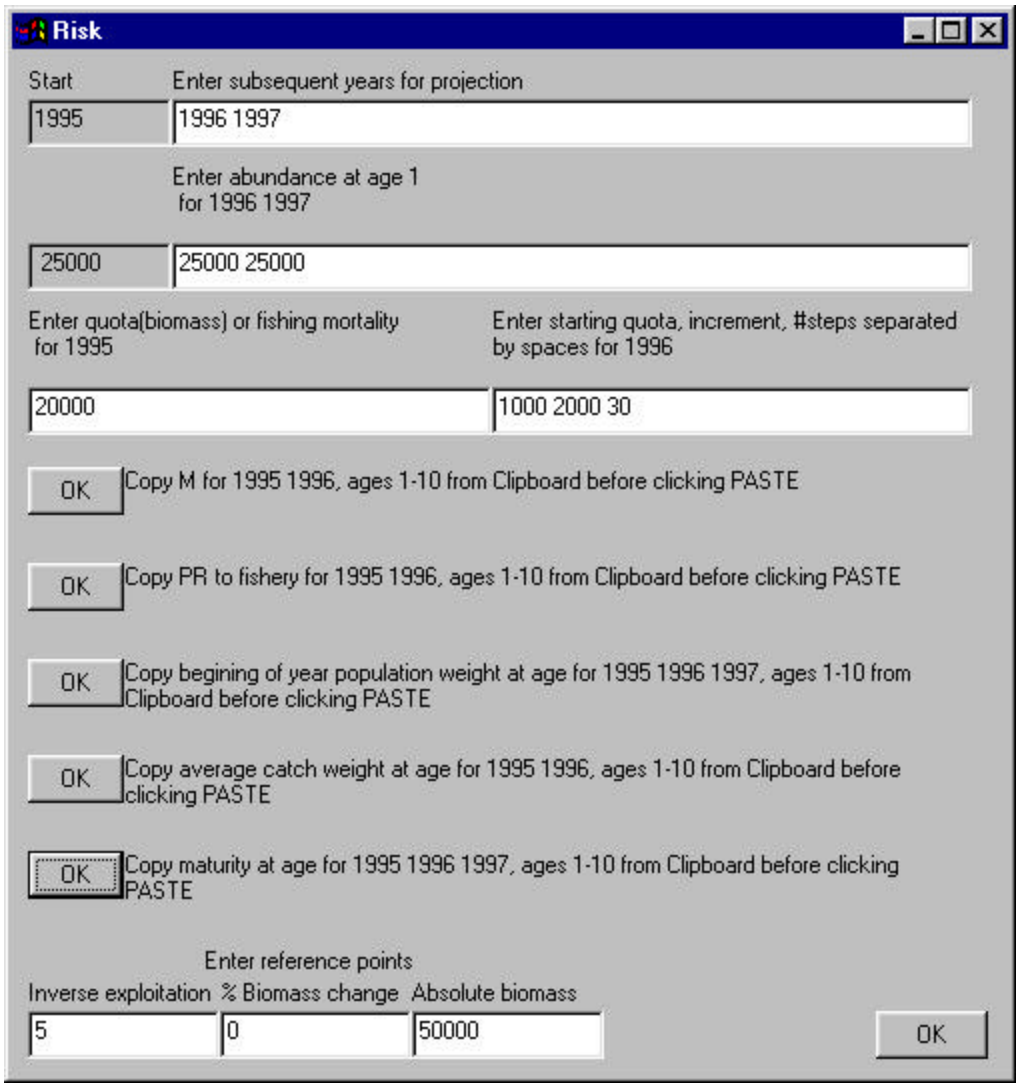


Figure 1. Risk Menu

To display the risk curves, you can copy these results to the "WS-For" sheet of the Excel Template. This is a working sheet for the forecasts.

105. In ADAPT
    106. Select "Output"
        107. Select "To Clipboard"
            108. Select "Risk".
                109. Select "Analytical".
    110. The results of this risk scenario are copied to the clipboard.
111. In Excel
    112. Go to the "WS-For" sheet.
        113. Copy the content of the clipboard to cell A3.

The risk curves will be generated in the "For-G" sheet of the Excel template (see Annex 1).

Note that the risk projections (analytical or bootstrap) are always bias-corrected. The results of the risk projections should thus be compared with bias-corrected historical re-constructions of the population metrics (abundance, biomass, SSB).

As an exercise, repeat the risk computations but, this time, use the bootstrap approach. When asked for the number of replicates in the bootstrap, enter "100". The entries for the "risk Menu" are exactly the same as those for the risk calculations using the analytical approach (see Figure 1). When the bootstrap is completed, copy the results in the second placeholder (cell A51) of the "WS-For" sheet. Provide labels for the plots as necessary. The risk curves for the bootstrap results will be generated in the "For-G" sheet of the Excel template.

Notes on bootstrap:

- The most common practice is to use the bootstrap procedure (as opposed to the analytical approach) for calculating risk curves from ADAPT results. While it takes longer to obtain results because of the re-sampling procedure, bootstrap is believed to give a better appreciation for the shape of the risk curve (assuming, of course, a sufficient number of replicates).
- For a typical bootstrap simulation, someone would do 500 or 600 replicates in a "well-behaved" estimation problem. Use 1000 replicates if uncertain. You may need more simulations if you need to pay a particular attention to some characteristics of the distribution of the results, e.g. if the "tail" of the risk curve are particularly important in management decisions.
- In the current version of ADAPT, the bootstrap is performed by re-sampling all residuals assuming that they are independent and identically distributed (i.i.d.). Despite efforts to make the residuals i.i.d when calibrating VPAs, residuals often show significant departures from this assumption. Research is ongoing on possible refinements to the bootstrap procedure so as to take such factors into account.

Conclusions

All results have been transferred to the Excel spreadsheet. You can now inspect the forecasts and interpret the results of the risk analysis.

Blackfin Example:

Pages 2 and 3 of the Annex 1 suggest that the stock spawning biomass (SSB) has a high probability of declining even with no fishing in 1996. Under no fishing in 1996, there is a probability of 10% or less that the SSB will be below 50 000 t at the beginning of 1997. That probability increases as the quota for 1996 is increased. With a catch of 60 000 t in 1996, the probability of the SSB at the beginning of 1997 to be less that 50 000 t is of the order of 70%.

The Armstrong plots indicate that the SSB would be of the order of 80 000 t at the beginning of 1997 if there is no fishing in 1996. The SSB would be about 40 000 t at the beginning of 1997 with a fishing mortality of 0.7-0.8 I 1996. Such levels of fishing mortality in 1996 would generate a catch level of the order of 60 000 t.

This concludes the tutorial for projections and risk computations using ADAPT. The ADAPT Session Log for this tutorial is printed in Annex 2.

References and related reading:

Gavaris S. 1993. Analytical estimates of reliability for the projected yield from commercial fisheries. p. 185-191. *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.

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

Rivard D. and S. Gavaris. 2000. Tutorial for estimation of population abundance with ADAPT. NAFO SCR 00/56 (Serial No. N4296). 66 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 display 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. Only the sheets relevant to the projections and risk computations are represented here.

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

Projections

Years	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
N at age 1	25000	25000	25000								
Quotas or F	20000.00	0.20									

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20					
1996	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20					

PR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77					
1996	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77					

Wgtstock	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77					
1996	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77					
1997	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77					

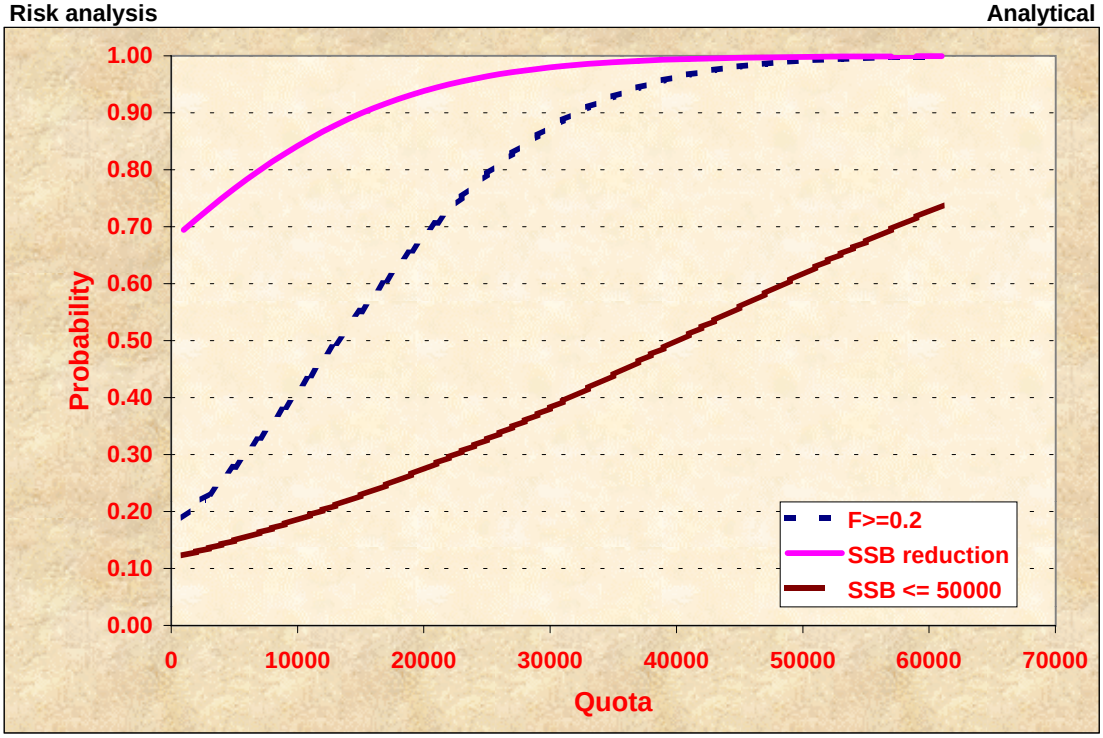
Wgt catch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77					
1996	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77					

Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1996	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					
1997	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00					

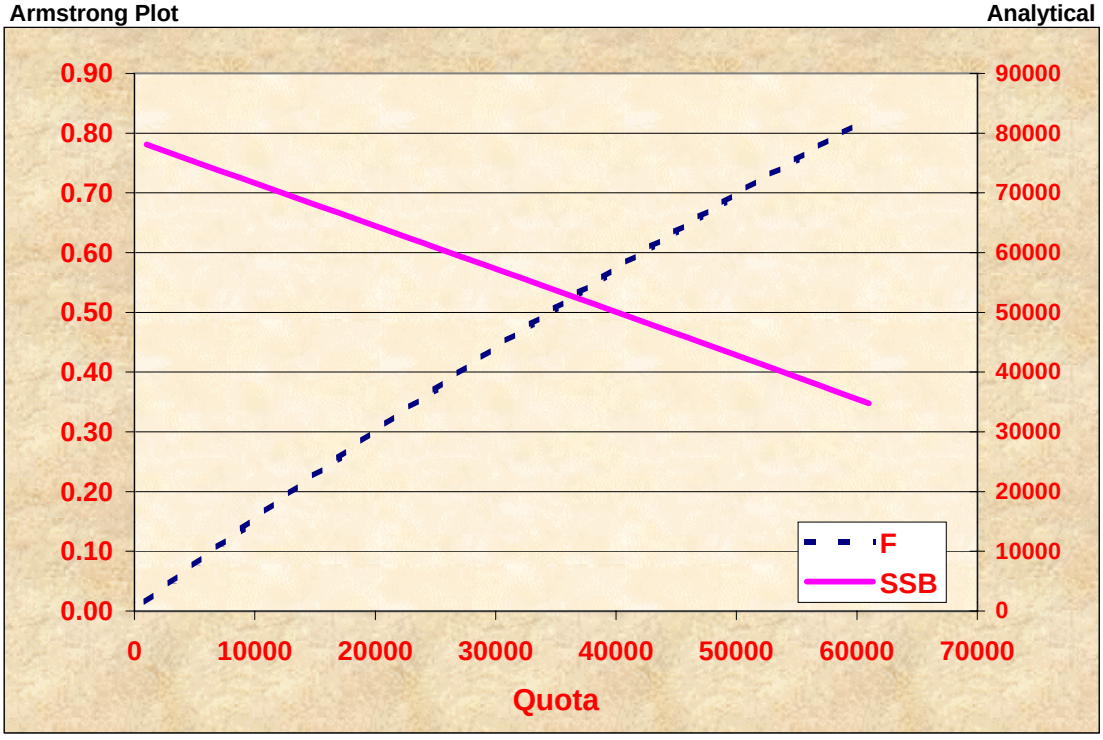
Blackfin: NAFO SC Workshop - ADAPT Tutorial
Bias adjusted

Impact of 1996 quota, assuming quota of 20000 t taken in 1995

Risk analysis **Analytical**



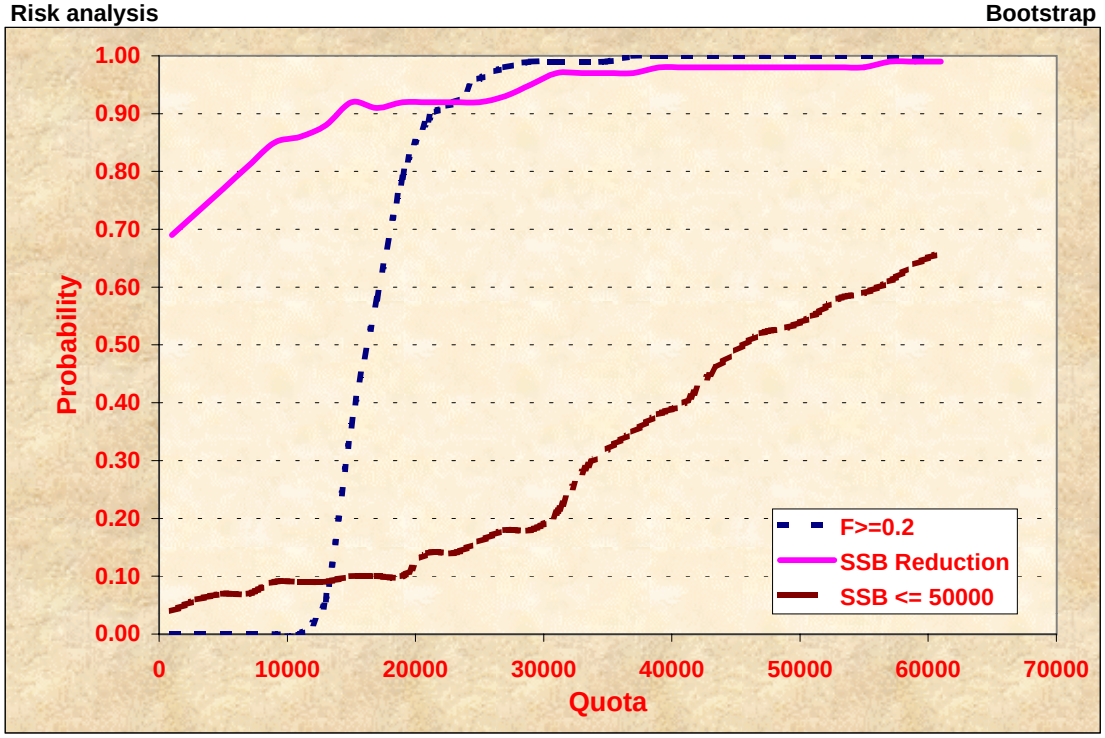
Armstrong Plot **Analytical**



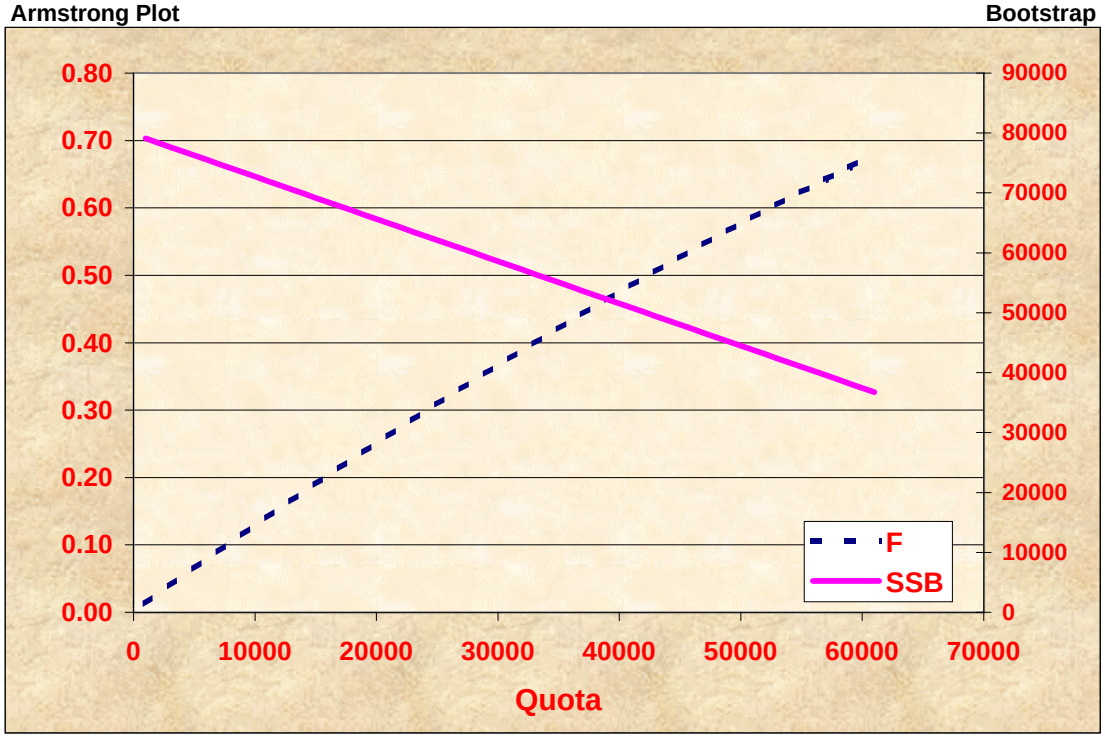
Blackfin: NAFO SC Workshop - ADAPT Tutorial
Bias adjusted

Impact of 196 quota, assuming a catch of 20000 t in 1995

Risk analysis **Bootstrap**



Armstrong Plot **Bootstrap**



Blackfin: NAFO SC Workshop - ADAPT Tutorial

Scenario: Impact of 1996 quota, assuming quota of 20000 t taken in 1995
Inverse Exploitation: 5 — **Labels for graphs (risk of..)**
SSB Change: 0 % — **F>=0.2**
SSB Reference: 50000 — **SSB reduction**
Approach: Analytical — **SSB <= 50000**

	Inverse Exploitation:					SSB Change:					SSB Reference:				
Quota	Mean	S.E.	Bias	Adj. Mean	Prob.	Mean	S.E.	Bias	Adj. Mean	Prob.	Mean	S.E.	Bias	Adj. Mean	Prob.
1000	84.10	67.13	19.94	64.17	0.19	-4.28	14.91	3.31	-7.59	0.69	88694	24218	10605	78089	0.12
3000	28.14	22.46	6.67	21.47	0.23	-5.83	14.85	3.35	-9.18	0.73	87261	24218	10606	76655	0.14
5000	16.95	13.53	4.02	12.93	0.28	-7.38	14.80	3.39	-10.77	0.77	85828	24217	10606	75222	0.15
7000	12.16	9.70	2.88	9.27	0.33	-8.92	14.76	3.44	-12.36	0.80	84395	24217	10607	73788	0.16
9000	9.49	7.58	2.25	7.24	0.38	-10.47	14.73	3.48	-13.95	0.83	82963	24215	10608	72355	0.18
11000	7.80	6.22	1.85	5.95	0.44	-12.01	14.71	3.53	-15.54	0.85	81530	24214	10610	70921	0.19
13000	6.63	5.29	1.57	5.06	0.50	-13.56	14.70	3.58	-17.13	0.88	80098	24212	10611	69487	0.21
15000	5.77	4.60	1.37	4.40	0.55	-15.10	14.70	3.62	-18.73	0.90	78666	24209	10614	68052	0.23
17000	5.11	4.08	1.21	3.90	0.61	-16.65	14.71	3.67	-20.32	0.92	77234	24207	10617	66617	0.25
19000	4.59	3.66	1.09	3.50	0.66	-18.19	14.72	3.72	-21.91	0.93	75802	24203	10620	65182	0.27
21000	4.17	3.33	0.99	3.18	0.71	-19.74	14.75	3.77	-23.50	0.94	74371	24200	10624	63747	0.28
23000	3.83	3.05	0.91	2.92	0.75	-21.28	14.79	3.81	-25.10	0.96	72939	24196	10628	62311	0.31
25000	3.54	2.82	0.84	2.70	0.79	-22.83	14.84	3.86	-26.69	0.96	71508	24191	10634	60874	0.33
27000	3.29	2.63	0.78	2.51	0.83	-24.37	14.89	3.92	-28.29	0.97	70077	24186	10640	59437	0.35
29000	3.08	2.46	0.73	2.35	0.86	-25.92	14.96	3.97	-29.89	0.98	68647	24180	10647	58000	0.37
31000	2.89	2.31	0.69	2.21	0.89	-27.46	15.03	4.02	-31.48	0.98	67216	24173	10655	56561	0.39
33000	2.73	2.18	0.65	2.08	0.91	-29.00	15.12	4.08	-33.08	0.99	65786	24166	10664	55122	0.42
35000	2.59	2.06	0.61	1.97	0.93	-30.55	15.21	4.13	-34.68	0.99	64356	24158	10675	53681	0.44
37000	2.46	1.96	0.58	1.87	0.94	-32.09	15.31	4.19	-36.28	0.99	62926	24150	10687	52240	0.46
39000	2.34	1.87	0.56	1.79	0.96	-33.63	15.42	4.25	-37.88	0.99	61497	24140	10700	50797	0.49
41000	2.24	1.79	0.53	1.71	0.97	-35.18	15.53	4.31	-39.49	0.99	60068	24130	10716	49352	0.51
43000	2.15	1.71	0.51	1.64	0.98	-36.72	15.65	4.38	-41.09	1.00	58639	24118	10733	47906	0.53
45000	2.06	1.65	0.49	1.57	0.98	-38.26	15.78	4.44	-42.70	1.00	57211	24106	10753	46458	0.56
47000	1.98	1.58	0.47	1.51	0.99	-39.80	15.92	4.51	-44.31	1.00	55783	24093	10775	45008	0.58
49000	1.91	1.53	0.45	1.46	0.99	-41.34	16.06	4.59	-45.93	1.00	54356	24078	10800	43555	0.61
51000	1.85	1.48	0.44	1.41	0.99	-42.88	16.21	4.66	-47.54	1.00	52929	24062	10829	42100	0.63
53000	1.79	1.43	0.42	1.37	0.99	-44.42	16.37	4.74	-49.16	1.00	51502	24045	10861	40641	0.65
55000	1.73	1.38	0.41	1.32	1.00	-45.96	16.53	4.83	-50.79	1.00	50076	24026	10898	39178	0.67
57000	1.68	1.34	0.40	1.28	1.00	-47.50	16.69	4.92	-52.42	1.00	48651	24005	10939	37711	0.70
59000	1.64	1.31	0.39	1.25	1.00	-49.03	16.86	5.02	-54.06	1.00	47226	23983	10987	36239	0.72
61000	1.59	1.27	0.38	1.21	1.00	-50.57	17.03	5.13	-55.70	1.00	45802	23959	11041	34761	0.74

Scenario: Impact of 196 quota, assuming a catch of 20000 t in 1995
Inverse Exploitation 5 — **Labels for graphs (risk of..)**
SSB Change 0 % — **F>=0.2**
SSB Reference: 50000 — **SSB Reduction**
Approach: Bootstrap — **SSB <= 50000**

	Inverse Exploitation:					SSB Change:					SSB Reference:				
Quota	Mean	S.E.	Bias	Adj. Mean	Prob.	Mean	S.E.	Bias	Adj. Mean	Prob.	Mean	S.E.	Bias	Adj. Mean	Prob.
1000	84.10	21.35	7.23	76.87	0.00	-4.28	14.47	0.76	-5.04	0.69	88694	29673	9590	79104	0.04
3000	28.14	7.11	2.41	25.73	0.00	-5.83	14.34	0.82	-6.65	0.73	87261	29508	9574	77687	0.06
5000	16.95	4.26	1.45	15.50	0.00	-7.38	14.21	0.89	-8.26	0.77	85828	29344	9558	76270	0.07
7000	12.16	3.04	1.03	11.12	0.00	-8.92	14.09	0.95	-9.87	0.81	84395	29181	9542	74853	0.07
9000	9.49	2.36	0.80	8.69	0.00	-10.47	13.98	1.01	-11.48	0.85	82963	29019	9526	73436	0.09
11000	7.80	1.93	0.66	7.14	0.00	-12.01	13.87	1.07	-13.09	0.86	81530	28858	9510	72020	0.09
13000	6.63	1.63	0.56	6.07	0.06	-13.56	13.77	1.13	-14.69	0.88	80098	28698	9494	70604	0.09
15000	5.77	1.41	0.48	5.28	0.36	-15.10	13.67	1.20	-16.30	0.92	78666	28539	9477	69189	0.10
17000	5.11	1.25	0.43	4.68	0.58	-16.65	13.59	1.26	-17.91	0.91	77234	28381	9460	67774	0.10
19000	4.59	1.11	0.38	4.21	0.79	-18.19	13.51	1.32	-19.51	0.92	75802	28224	9443	66359	0.10
21000	4.17	1.01	0.34	3.83	0.89	-19.74	13.43	1.38	-21.12	0.92	74371	28068	9426	64945	0.14
23000	3.83	0.92	0.31	3.51	0.92	-21.28	13.36	1.44	-22.72	0.92	72939	27913	9409	63530	0.14
25000	3.54	0.84	0.29	3.25	0.96	-22.83	13.30	1.50	-24.33	0.92	71508	27760	9391	62117	0.16
27000	3.29	0.78	0.27	3.02	0.98	-24.37	13.25	1.56	-25.93	0.93	70077	27607	9374	60704	0.18
29000	3.08	0.72	0.25	2.83	0.99	-25.92	13.21	1.62	-27.54	0.95	68647	27455	9356	59291	0.18
31000	2.89	0.68	0.23	2.66	0.99	-27.46	13.17	1.68	-29.14	0.97	67216	27305	9338	57878	0.21
33000	2.73	0.63	0.22	2.51	0.99	-29.00	13.14	1.74	-30.74	0.97	65786	27155	9320	56466	0.28
35000	2.59	0.60	0.21	2.38	0.99	-30.55	13.11	1.80	-32.34	0.97	64356	27007	9301	55055	0.32
37000	2.46	0.56	0.19	2.26	1.00	-32.09	13.10	1.85	-33.95	0.97	62926	26860	9283	53644	0.35
39000	2.34	0.53	0.18	2.16	1.00	-33.63	13.09	1.91	-35.55	0.98	61497	26713	9264	52233	0.38
41000	2.24	0.50	0.18	2.06	1.00	-35.18	13.09	1.97	-37.15	0.98	60068	26568	9245	50823	0.40
43000	2.15	0.48	0.17	1.98	1.00	-36.72	13.10	2.03	-38.75	0.98	58639	26424	9226	49414	0.45
45000	2.06	0.46	0.16	1.90	1.00	-38.26	13.11	2.09	-40.34	0.98	57211	26281	9206	48005	0.49
47000	1.98	0.44	0.15	1.83	1.00	-39.80	13.13	2.14	-41.94	0.98	55783	26140	9187	46597	0.52
49000	1.91	0.42	0.15	1.77	1.00	-41.34	13.16	2.20	-43.54	0.98	54356	25999	9167	45189	0.53
51000	1.85	0.40	0.14	1.71	1.00	-42.88	13.20	2.26	-45.14	0.98	52929	25859	9147	43782	0.55
53000	1.79	0.38	0.14	1.65	1.00	-44.42	13.24	2.31	-46.73	0.98	51502	25721	9126	42376	0.58
55000	1.73	0.37	0.13	1.60	1.00	-45.96	13.29	2.37	-48.33	0.98	50076	25583	9106	40970	0.59
57000	1.68	0.35	0.13	1.56	1.00	-47.50	13.35	2.43	-49.92	0.99	48651	25447	9085	39565	0.61
59000	1.64	0.34	0.12	1.51	1.00	-49.03	13.41	2.48	-51.52	0.99	47226	25311	9065	38161	0.64
61000	1.59	0.33	0.12	1.47	1.00	-50.57	13.48	2.54	-53.11	0.99	45802	25177	9044	36758	0.66

ANNEX 2. ADAPT Session Log

Tutorial for projections and risk analysis with ADAPT

```
FRIDAY, AUGUST 4, 2000  2:59:19.130 AM
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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	(25000)	(20000)	5000	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)
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	42325	26682	19662	5899	3897	2219	801	1343	825	494
1964.00	49210	34652	21705	14760	4210	2896	1623	590	965	630
1965.00	91593	40289	28265	15845	9978	2817	2066	1185	445	746
1966.00	54371	74990	32778	20143	10219	6587	1845	1447	887	303
1967.00	94123	44515	61336	24277	12080	7267	4769	1389	1149	702
1968.00	77262	77061	36098	48364	17276	8149	5708	3495	1055	901
1969.00	80534	63255	63048	27358	37533	13065	6112	4540	2748	838
1970.00	71386	65935	51486	49829	18241	29377	10239	4492	3621	2178
1971.00	72306	58446	53953	39575	38689	13307	23511	8166	3501	2928
1972.00	63179	59199	47507	42923	28396	29970	9917	18829	6359	2595
1973.00	46947	51675	44884	31317	31631	21214	24125	7818	15272	5123
1974.00	49327	38121	35326	29848	20913	24141	16571	19329	6098	12324
1975.00	31005	39575	28168	23465	22257	15177	19208	12711	14991	4540
1976.00	24232	25362	30063	17065	16917	17024	11638	14812	9765	12095
1977.00	23602	19807	18218	17184	11467	12222	12926	8931	11660	7466
1978.00	23493	19179	15083	10711	11607	7869	9336	10076	6964	9284
1979.00	27956	19200	11700	8508	6646	8326	5810	7379	8029	5554
1980.00	33490	22880	14817	7926	5880	4378	6164	4421	5900	6401
1981.00	35655	27378	17809	9119	5630	4197	3010	4622	3445	4748
1982.00	50960	29053	20169	11045	5684	4079	3067	2157	3583	2681
1983.00	44941	41684	22520	12348	7524	3530	2823	2161	1543	2810
1984.00	46069	36763	30954	14156	7795	5408	2203	1853	1627	1169
1985.00	29008	37576	27370	20312	9423	5589	3811	1532	1391	1280
1986.00	59223	23745	28700	17799	13882	6401	3470	2571	1086	1044
1987.00	53654	48278	18743	17117	7039	7965	3983	1893	1682	721
1988.00	39972	43927	37994	13368	7782	4031	5298	2560	1142	1142
1989.00	34452	32707	32726	25972	7785	4016	2357	3534	1469	639
1990.00	25100	28187	26093	20238	16136	4349	2033	1591	2661	1061
1991.00	18991	20498	21738	16332	13214	12134	2854	1193	1082	2060
1992.00	15834	15410	15660	14561	10720	9759	9386	1954	765	799
1993.00	10701	12939	11840	11224	9140	7904	7670	7588	1545	578
1994.00	24431	8748	8334	7295	6649	6416	6227	6179	6162	1226
1995.00	25000	20000	5000	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	0.137	0.097	0.113	0.106	0.130	0.069	0.116
1964.00	0.000	0.004	0.115	0.192	0.202	0.138	0.114	0.082	0.058	0.177
1965.00	0.000	0.006	0.139	0.239	0.215	0.223	0.156	0.089	0.187	0.226
1966.00	0.000	0.001	0.100	0.311	0.141	0.123	0.084	0.030	0.034	0.192
1967.00	0.000	0.010	0.038	0.140	0.194	0.042	0.111	0.075	0.043	0.125
1968.00	0.000	0.001	0.077	0.054	0.079	0.088	0.029	0.041	0.031	0.074
1969.00	0.000	0.006	0.035	0.205	0.045	0.044	0.108	0.026	0.032	0.098
1970.00	0.000	0.001	0.063	0.053	0.115	0.023	0.026	0.049	0.013	0.064
1971.00	0.000	0.007	0.029	0.132	0.055	0.094	0.022	0.050	0.099	0.094
1972.00	0.001	0.077	0.217	0.105	0.092	0.017	0.038	0.009	0.016	0.071
1973.00	0.008	0.180	0.208	0.204	0.070	0.047	0.022	0.049	0.014	0.107
1974.00	0.020	0.103	0.209	0.093	0.121	0.029	0.065	0.054	0.095	0.081
1975.00	0.001	0.075	0.301	0.127	0.068	0.065	0.060	0.064	0.015	0.087
1976.00	0.002	0.131	0.359	0.198	0.125	0.075	0.065	0.039	0.068	0.133
1977.00	0.008	0.073	0.331	0.192	0.177	0.069	0.049	0.049	0.028	0.146
1978.00	0.002	0.294	0.373	0.277	0.132	0.103	0.035	0.027	0.026	0.171
1979.00	0.000	0.059	0.189	0.169	0.217	0.101	0.073	0.024	0.027	0.162
1980.00	0.002	0.051	0.285	0.142	0.137	0.175	0.088	0.050	0.017	0.151
1981.00	0.005	0.106	0.278	0.273	0.122	0.114	0.133	0.055	0.051	0.170
1982.00	0.001	0.055	0.291	0.184	0.276	0.168	0.150	0.135	0.043	0.210
1983.00	0.001	0.098	0.264	0.260	0.130	0.271	0.221	0.084	0.078	0.221
1984.00	0.004	0.095	0.221	0.207	0.133	0.150	0.164	0.087	0.039	0.163
1985.00	0.000	0.069	0.230	0.181	0.187	0.277	0.194	0.144	0.087	0.215
1986.00	0.004	0.037	0.317	0.728	0.356	0.274	0.406	0.224	0.209	0.453
1987.00	0.000	0.040	0.138	0.588	0.357	0.208	0.242	0.306	0.187	0.384
1988.00	0.001	0.094	0.180	0.341	0.461	0.337	0.205	0.355	0.381	0.380
1989.00	0.001	0.026	0.281	0.276	0.382	0.481	0.193	0.084	0.125	0.380
1990.00	0.003	0.060	0.269	0.226	0.085	0.221	0.333	0.186	0.056	0.178
1991.00	0.009	0.069	0.201	0.221	0.103	0.057	0.178	0.244	0.103	0.127
1992.00	0.002	0.064	0.133	0.266	0.105	0.041	0.013	0.035	0.081	0.137
1993.00	0.002	0.240	0.284	0.324	0.154	0.038	0.016	0.008	0.031	0.172
1994.00	0.000	0.359	0.311	0.178	0.085	0.049	0.019	0.012	0.009	0.104

```
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


MONDAY, AUGUST 7, 2000  10:09:05.880 AM
APL  Ver. 2.0.00
ADAPT_W  Ver. 2.1
Workspace size = 6000000


[Non-linear least-squares estimation - NLLS]

LAMBDA       1.00000E-2
RSS          4.37151E2
NPHI         4.37151E2
Parameters
   8.51719E0      8.51719E0      8.51719E0      8.51719E0      8.51719E0      8.51719E0
   8.51719E0      8.51719E0

LAMBDA       1.00000E-3
RSS          4.14906E2
NPHI         4.14906E2
Parameters
   9.27222E0      9.54811E0      8.64229E0      8.59287E0      8.07603E0      7.70026E0
   8.08153E0      7.53472E0
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LAMBDA       1.00000E-4
RSS          4.14814E2
NPHI         4.14814E2
Parameters
   9.26829E0      9.51114E0      8.70671E0      8.58779E0      8.10720E0      7.72807E0
   8.09088E0      7.45612E0

LAMBDA       1.00000E-5
RSS          4.14814E2
NPHI         4.14814E2
Parameters
   9.26799E0      9.51034E0      8.70574E0      8.58719E0      8.10220E0      7.72442E0
   8.09187E0      7.45412E0

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.00001



LAMBDA       1.00000E-2
RSS          4.14814E2
NPHI         4.14814E2
Parameters
   9.26799E0      9.51034E0      8.70574E0      8.58719E0      8.10220E0      7.72442E0
   8.09187E0      7.45412E0     -5.71305E0     -5.26115E0     -6.19069E0     -6.71978E0
  -6.68438E0     -7.49192E0     -7.17506E0     -7.73321E0     -8.30486E0     -6.90293E0
  -6.28349E0     -6.77249E0     -7.45881E0     -7.81010E0     -8.32407E0     -8.93203E0
  -8.99193E0     -9.85039E0

LAMBDA       1.00000E-3
RSS          4.14814E2
NPHI         4.14814E2
Parameters
   9.26803E0      9.51038E0      8.70601E0      8.58707E0      8.10261E0      7.72486E0
   8.09214E0      7.45428E0     -5.71309E0     -5.26120E0     -6.19075E0     -6.71985E0
  -6.68447E0     -7.49197E0     -7.17511E0     -7.73328E0     -8.30492E0     -6.90297E0
  -6.28354E0     -6.77256E0     -7.45888E0     -7.81019E0     -8.32416E0     -8.93208E0
  -8.99198E0     -9.85045E0

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	47443	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	53228	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	18882	12478	14653	4426
1976.00	23610	25107	29696	16776	16459	16500	11349	14546	9574	11818
1977.00	23030	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	3869	2880	2080	3473	2594
1983.00	43407	37470	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	45050	32007	18892	16848	6357	6080	3515	1737	1607	660
1988.00	28837	36883	24672	13490	7563	3474	3756	2177	1014	1080
1989.00	28801	23590	26960	15074	7884	3837	1902	2273	1156	534
1990.00	26086	23560	18629	15525	7235	4431	1888	1219	1629	805
1991.00	21308	21305	17950	10231	9359	4849	2920	1074	777	1214
1992.00	31338	17307	16321	11463	5732	6604	3423	2009	668	550
1993.00	19056	25632	13393	11764	6607	3822	5087	2706	1590	498
1994.00	24431	15588	18722	8565	7091	4343	2885	4064	2165	1263
1995.00	25000	20000	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..... 0.000425
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

Parameters in linear scale

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
1.06E4	6.65E3	0.628	1.97E3	0.186
1.35E4	6.19E3	0.459	1.32E3	0.098
6.04E3	2.47E3	0.409	4.72E2	0.078
5.36E3	2.16E3	0.402	3.67E2	0.068
3.30E3	1.46E3	0.442	2.49E2	0.075
2.26E3	1.00E3	0.442	1.62E2	0.072
3.27E3	1.36E3	0.415	2.10E2	0.064
1.73E3	8.57E2	0.496	1.45E2	0.084
3.30E-3	8.43E-4	0.255	9.52E-5	0.029
5.19E-3	1.32E-3	0.255	1.56E-4	0.030
2.05E-3	5.25E-4	0.256	6.77E-5	0.033
1.21E-3	3.21E-4	0.266	4.76E-5	0.039
1.25E-3	3.25E-4	0.260	5.10E-5	0.041
5.58E-4	1.42E-4	0.255	1.61E-5	0.029
7.65E-4	1.95E-4	0.255	2.30E-5	0.030
4.38E-4	1.12E-4	0.256	1.45E-5	0.033
2.47E-4	6.40E-5	0.259	9.26E-6	0.037
1.00E-3	2.57E-4	0.255	2.90E-5	0.029
1.87E-3	4.75E-4	0.255	5.61E-5	0.030
1.14E-3	2.94E-4	0.256	3.79E-5	0.033
5.76E-4	1.49E-4	0.259	2.16E-5	0.037
4.06E-4	1.06E-4	0.260	1.66E-5	0.041
2.43E-4	6.31E-5	0.260	1.03E-5	0.042
1.32E-4	3.37E-5	0.255	3.81E-6	0.029
1.24E-4	3.17E-5	0.255	3.74E-6	0.030
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	39806	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	16738	16412	16441	11313	14507	9550	11786
1977.00	22977	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	45471	27599	19685	10786	5497	3850	2861	2068	3457	2583
1983.00	43249	37190	21330	11952	7312	3377	2635	1993	1471	2708
1984.00	45414	35377	27275	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	44005	31283	18545	16758	6286	5955	3450	1716	1587	653
1988.00	28175	36028	24080	13206	7490	3417	3654	2124	997	1064
1989.00	27972	23048	26259	14590	7652	3778	1855	2190	1113	521
1990.00	25086	22881	18185	14953	6841	4241	1839	1180	1560	770
1991.00	20256	20486	17394	9869	8892	4526	2765	1035	746	1158
1992.00	28934	16446	15651	11008	5436	6221	3159	1882	636	524
1993.00	16115	23664	12688	11216	6236	3580	4774	2489	1486	472
1994.00	24431	13180	17111	7988	6643	4039	2687	3808	1988	1178
1995.00	25000	20000	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

Population abundance was copied to clipboard

Fishing mortality was copied to clipboard

Projection results using analytical bias adjusted point estimates

Projected Population Numbers

	1	2	3	4	5	6	7	8	9	10
1995.00	25000	20000	8624	12180	5567	4995	3054	2102	3059	1582
1996.00	25000	20427	15452	5945	8165	3939	3634	2258	1585	2344
1997.00	25000	20427	15782	10652	3985	5777	2866	2687	1703	1215

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1995.00	0.002	0.058	0.172	0.200	0.146	0.118	0.102	0.082	0.066	0.154
1996.00	0.002	0.058	0.172	0.200	0.146	0.118	0.102	0.082	0.066	0.154

M

	1	2	3	4	5	6	7	8	9	10
1995.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1996.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

PR

	1	2	3	4	5	6	7	8	9	10
1995.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77
1996.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77

Wgtstock

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1997.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Projected Population Biomass

	1	2	3	4	5	6	7	8	9	10	1+	2+	3+	4+
1995.00	9000	14400	9314	19001	12916	16084	12951	11160	19851	13875	138552	129552	115152	105838
1996.00	9000	14708	16688	9274	18942	12683	15410	11991	10288	20559	139544	130544	115836	99148
1997.00	9000	14708	17045	16617	9245	18601	12151	14268	11055	10656	133345	124345	109638	92593

Projected Catch Numbers

	1	2	3	4	5	6	7	8	9	10
1995.00	45	1022	1239	2008	687	505	269	150	177	205
1996.00	45	1044	2219	980	1008	398	320	161	92	304
1997.00										

Wgt catch

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Projected Catch Biomass

	1	2	3	4	5	6	7	8	9	10	1+	2+	3+	4+
1995.00	16	736	1338	3132	1594	1626	1140	797	1150	1800	13330	13313	12577	11239
1996.00	16	752	2397	1529	2338	1282	1357	857	596	2666	13790	13773	13022	10625
1997.00														

Input for Analytical risk analysis of projection results

M

	1	2	3	4	5	6	7	8	9	10
1995.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1996.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

PR

	1	2	3	4	5	6	7	8	9	10
1995.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77
1996.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77

Wgtstock

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1997.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Wgt catch

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Maturity

	1	2	3	4	5	6	7	8	9	10
1995.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
1996.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
1997.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

Inverse Exploitation Rate (Reference = 5)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	84.102	67.129	19.936	64.166	0.189
3000	28.142	22.463	6.671	21.471	0.232
5000	16.951	13.530	4.018	12.933	0.279
7000	12.156	9.703	2.881	9.275	0.330
9000	9.493	7.577	2.250	7.243	0.384
11000	7.798	6.225	1.849	5.950	0.439
13000	6.626	5.289	1.571	5.055	0.496
15000	5.766	4.603	1.367	4.399	0.552
17000	5.109	4.078	1.211	3.898	0.606
19000	4.591	3.665	1.088	3.503	0.659
21000	4.172	3.330	0.989	3.183	0.707
23000	3.826	3.054	0.907	2.919	0.752
25000	3.536	2.822	0.838	2.698	0.793
27000	3.289	2.625	0.780	2.509	0.829
29000	3.076	2.455	0.729	2.347	0.860
31000	2.891	2.308	0.685	2.206	0.887
33000	2.729	2.178	0.647	2.082	0.910
35000	2.585	2.064	0.613	1.972	0.929
37000	2.457	1.962	0.583	1.875	0.944
39000	2.343	1.870	0.555	1.788	0.957
41000	2.240	1.788	0.531	1.709	0.967
43000	2.147	1.714	0.509	1.638	0.975
45000	2.062	1.646	0.489	1.573	0.981
47000	1.985	1.584	0.470	1.514	0.986
49000	1.914	1.528	0.454	1.460	0.990
51000	1.849	1.476	0.438	1.411	0.992
53000	1.789	1.428	0.424	1.365	0.995
55000	1.734	1.384	0.411	1.323	0.996
57000	1.683	1.343	0.399	1.284	0.997
59000	1.636	1.305	0.388	1.248	0.998
61000	1.591	1.270	0.377	1.214	0.999

% Biomass Change (Reference = 0)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	-4	15	3	-8	0.695
3000	-6	15	3	-9	0.732
5000	-7	15	3	-11	0.767
7000	-9	15	3	-12	0.799
9000	-10	15	3	-14	0.828
11000	-12	15	4	-16	0.855
13000	-14	15	4	-17	0.878
15000	-15	15	4	-19	0.899
17000	-17	15	4	-20	0.916
19000	-18	15	4	-22	0.932
21000	-20	15	4	-24	0.944
23000	-21	15	4	-25	0.955
25000	-23	15	4	-27	0.964
27000	-24	15	4	-28	0.971
29000	-26	15	4	-30	0.977
31000	-27	15	4	-31	0.982
33000	-29	15	4	-33	0.986
35000	-31	15	4	-35	0.989
37000	-32	15	4	-36	0.991
39000	-34	15	4	-38	0.993
41000	-35	16	4	-39	0.994
43000	-37	16	4	-41	0.996
45000	-38	16	4	-43	0.997
47000	-40	16	5	-44	0.997
49000	-41	16	5	-46	0.998
51000	-43	16	5	-48	0.998
53000	-44	16	5	-49	0.999
55000	-46	17	5	-51	0.999
57000	-47	17	5	-52	0.999
59000	-49	17	5	-54	0.999
61000	-51	17	5	-56	0.999

Biomass (Reference = 50000)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	88694	24218	10605	78089	0.123
3000	87261	24218	10606	76655	0.136
5000	85828	24217	10606	75222	0.149
7000	84395	24217	10607	73788	0.163
9000	82963	24215	10608	72355	0.178
11000	81530	24214	10610	70921	0.194
13000	80098	24212	10611	69487	0.210
15000	78666	24209	10614	68052	0.228
17000	77234	24207	10617	66617	0.246
19000	75802	24203	10620	65182	0.265
21000	74371	24200	10624	63747	0.285
23000	72939	24196	10628	62311	0.305
25000	71508	24191	10634	60874	0.327
27000	70077	24186	10640	59437	0.348
29000	68647	24180	10647	58000	0.370
31000	67216	24173	10655	56561	0.393
33000	65786	24166	10664	55122	0.416
35000	64356	24158	10675	53681	0.439
37000	62926	24150	10687	52240	0.463
39000	61497	24140	10700	50797	0.487
41000	60068	24130	10716	49352	0.511
43000	58639	24118	10733	47906	0.535
45000	57211	24106	10753	46458	0.558
47000	55783	24093	10775	45008	0.582
49000	54356	24078	10800	43555	0.606
51000	52929	24062	10829	42100	0.629
53000	51502	24045	10861	40641	0.651
55000	50076	24026	10898	39178	0.674
57000	48651	24005	10939	37711	0.696
59000	47226	23983	10987	36239	0.717
61000	45802	23959	11041	34761	0.738

[BOOTSTRAP Calculation]

BOOTSTRAP STATISTICS

Estimates for parameters

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
9.27E0	6.09E-1	0.066	6.25E-2	0.007
9.51E0	4.17E-1	0.044	-2.36E-2	-0.002
8.71E0	4.21E-1	0.048	4.84E-2	0.006
8.59E0	4.10E-1	0.048	-5.58E-2	-0.007
8.10E0	3.97E-1	0.049	-3.48E-2	-0.004
7.72E0	4.17E-1	0.054	-2.51E-2	-0.003
8.09E0	3.99E-1	0.049	1.06E-2	0.001
7.45E0	4.74E-1	0.064	-5.88E-2	-0.008
-5.71E0	2.48E-1	-0.043	-1.00E-2	0.002
-5.26E0	2.10E-1	-0.040	4.71E-3	-0.001
-6.19E0	2.84E-1	-0.046	-3.05E-2	0.005
-6.72E0	2.25E-1	-0.034	-3.29E-2	0.005
-6.68E0	2.35E-1	-0.035	2.46E-2	-0.004
-7.49E0	2.38E-1	-0.032	2.02E-2	-0.003
-7.18E0	2.42E-1	-0.034	7.39E-3	-0.001
-7.73E0	2.68E-1	-0.035	-2.09E-2	0.003
-8.30E0	2.30E-1	-0.028	3.42E-2	-0.004
-6.90E0	2.32E-1	-0.034	-3.29E-2	0.005
-6.28E0	2.43E-1	-0.039	8.87E-3	-0.001
-6.77E0	2.85E-1	-0.042	2.05E-2	-0.003
-7.46E0	2.37E-1	-0.032	-1.22E-2	0.002
-7.81E0	2.60E-1	-0.033	3.00E-3	0.000
-8.32E0	2.28E-1	-0.027	1.62E-2	-0.002
-8.93E0	2.54E-1	-0.028	-2.80E-2	0.003
-8.99E0	2.41E-1	-0.027	-5.34E-2	0.006
-9.85E0	2.66E-1	-0.027	-2.68E-2	0.003

Parameters in linear scale

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
1.06E4	8.80E3	0.831	2.93E3	0.276
1.35E4	5.97E3	0.442	8.37E2	0.062
6.04E3	2.92E3	0.484	8.68E2	0.144
5.36E3	2.35E3	0.438	1.50E2	0.028
3.30E3	1.33E3	0.404	1.37E2	0.041
2.26E3	9.74E2	0.430	1.35E2	0.060
3.27E3	1.37E3	0.418	2.95E2	0.090
1.73E3	8.49E2	0.492	8.58E1	0.050
3.30E-3	9.04E-4	0.274	7.37E-5	0.022
5.19E-3	1.17E-3	0.225	1.43E-4	0.028
2.05E-3	6.31E-4	0.308	2.33E-5	0.011
1.21E-3	2.80E-4	0.232	-8.53E-6	-0.007
1.25E-3	3.13E-4	0.250	6.70E-5	0.054
5.58E-4	1.45E-4	0.261	2.80E-5	0.050
7.65E-4	1.98E-4	0.258	2.89E-5	0.038
4.38E-4	1.23E-4	0.281	6.90E-6	0.016
2.47E-4	5.85E-5	0.236	1.52E-5	0.062
1.00E-3	2.50E-4	0.249	-5.04E-6	-0.005
1.87E-3	5.04E-4	0.270	7.45E-5	0.040
1.14E-3	3.40E-4	0.297	7.08E-5	0.062
5.76E-4	1.37E-4	0.237	8.93E-6	0.015
4.06E-4	1.16E-4	0.287	1.56E-5	0.038
2.43E-4	6.06E-5	0.250	1.06E-5	0.044
1.32E-4	3.52E-5	0.267	6.36E-7	0.005
1.24E-4	2.87E-5	0.231	-3.06E-6	-0.025
5.27E-5	1.44E-5	0.273	4.54E-7	0.009

Bootstrap bias adjusted VPA

Population Numbers

	1	2	3	4	5	6	7	8	9	10
1963.00	42099	26452	19508	5858	3865	2203	796	1332	818	490
1964.00	48709	34468	21517	14634	4176	2870	1610	586	956	625
1965.00	89975	39879	28114	15691	9874	2789	2044	1174	442	738
1966.00	53703	73666	32442	20019	10094	6503	1823	1429	879	300
1967.00	92508	43968	60251	24002	11979	7164	4699	1371	1135	695
1968.00	76355	75739	35651	47476	17051	8066	5624	3438	1040	889
1969.00	79503	62512	61966	26992	36806	12880	6044	4471	2701	825
1970.00	70463	65091	50878	48943	17942	28782	10088	4436	3565	2140
1971.00	70923	57690	53263	39077	37964	13062	23024	8043	3455	2881
1972.00	62190	58067	46887	42357	27988	29375	9716	18430	6258	2558
1973.00	46440	50865	43957	30811	31168	20880	23639	7654	14945	5040
1974.00	48808	37706	34663	29090	20499	23762	16298	18931	5963	12056
1975.00	30708	39150	27829	22923	21637	14837	18898	12488	14665	4430
1976.00	23626	25119	29715	16788	16473	16516	11360	14558	9582	11828
1977.00	23042	19311	18018	16899	11240	11859	12510	8704	11452	7317
1978.00	23132	18721	14676	10548	11374	7683	9039	9735	6778	9114
1979.00	27619	18905	11326	8176	6512	8136	5658	7136	7750	5402
1980.00	32880	22604	14575	7620	5609	4269	6008	4297	5701	6173
1981.00	34136	26878	17583	8921	5379	3975	2920	4494	3343	4585
1982.00	45867	27809	19761	10861	5523	3874	2885	2084	3478	2598
1983.00	43429	37514	21502	12014	7373	3398	2655	2012	1483	2725
1984.00	45670	35525	27541	13323	7522	5285	2095	1715	1505	1120
1985.00	29358	37249	26356	17520	8742	5365	3709	1443	1278	1181
1986.00	38831	24031	28433	16970	11598	5844	3287	2488	1013	952
1987.00	43587	31583	18977	16898	6366	6100	3527	1744	1614	662
1988.00	28291	35685	24325	13559	7603	3482	3772	2187	1020	1086
1989.00	28348	23144	25979	14790	7941	3871	1908	2286	1165	539
1990.00	25680	23190	18263	14722	7001	4477	1915	1224	1639	812
1991.00	19377	20973	17646	9932	8702	4657	2958	1096	781	1223
1992.00	29814	15726	16050	11214	5487	6066	3266	2040	686	553
1993.00	14690	24385	12098	11542	6403	3620	4647	2577	1615	513
1994.00	24431	12014	17700	7505	6908	4176	2721	3703	2059	1283
1995.00	25000	20000	7667	12662	5171	5212	3166	2129	2973	1641

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	0.131	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	0.195	0.042	0.112	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	0.208	0.046	0.044	0.109	0.026	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	0.056	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	0.207	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	0.305	0.130	0.070	0.067	0.061	0.065	0.015	0.089
1976.00	0.002	0.132	0.364	0.201	0.129	0.078	0.066	0.040	0.070	0.136
1977.00	0.008	0.074	0.335	0.196	0.180	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	0.174
1979.00	0.000	0.060	0.196	0.177	0.222	0.103	0.075	0.025	0.028	0.167
1980.00	0.002	0.051	0.291	0.148	0.144	0.180	0.090	0.051	0.018	0.157
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	0.187	0.286	0.178	0.160	0.140	0.044	0.217
1983.00	0.001	0.109	0.278	0.268	0.133	0.284	0.237	0.090	0.081	0.228
1984.00	0.004	0.099	0.252	0.221	0.138	0.154	0.173	0.094	0.043	0.171
1985.00	0.000	0.070	0.240	0.212	0.202	0.290	0.199	0.154	0.095	0.235
1986.00	0.007	0.036	0.320	0.780	0.441	0.304	0.433	0.233	0.225	0.508
1987.00	0.000	0.060	0.136	0.598	0.402	0.278	0.277	0.336	0.196	0.426
1988.00	0.001	0.115	0.291	0.333	0.474	0.400	0.296	0.426	0.436	0.402
1989.00	0.001	0.036	0.354	0.519	0.368	0.501	0.242	0.130	0.158	0.463
1990.00	0.002	0.071	0.398	0.303	0.186	0.209	0.353	0.244	0.090	0.233
1991.00	0.008	0.064	0.245	0.370	0.143	0.131	0.165	0.262	0.142	0.215
1992.00	0.001	0.057	0.121	0.339	0.193	0.058	0.030	0.032	0.087	0.197
1993.00	0.001	0.107	0.248	0.281	0.204	0.073	0.023	0.019	0.028	0.186
1994.00	0.000	0.171	0.114	0.145	0.069	0.065	0.038	0.017	0.021	0.093

Input for Bootstrap risk analysis of projection results

M

	1	2	3	4	5	6	7	8	9	10
1995.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1996.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

PR

	1	2	3	4	5	6	7	8	9	10
1995.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77
1996.00	0.01	0.29	0.86	1.00	0.73	0.59	0.51	0.41	0.33	0.77

Wgtstock

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1997.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Wgt catch

	1	2	3	4	5	6	7	8	9	10
1995.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77
1996.00	0.36	0.72	1.08	1.56	2.32	3.22	4.24	5.31	6.49	8.77

Maturity

	1	2	3	4	5	6	7	8	9	10
1995.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
1996.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
1997.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

Inverse Exploitation Rate (Reference = 5)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	84.102	17.669	8.375	75.727	0.000
3000	28.142	5.884	2.790	25.353	0.000
5000	16.951	3.527	1.672	15.279	0.000
7000	12.156	2.516	1.194	10.963	0.000
9000	9.493	1.955	0.928	8.565	0.000
11000	7.798	1.597	0.758	7.040	0.000
13000	6.626	1.350	0.641	5.985	0.060
15000	5.766	1.168	0.555	5.211	0.210
17000	5.109	1.029	0.489	4.620	0.550
19000	4.591	0.919	0.437	4.154	0.710
21000	4.172	0.830	0.395	3.777	0.860
23000	3.826	0.757	0.360	3.466	0.920
25000	3.536	0.695	0.331	3.205	0.970
27000	3.289	0.642	0.306	2.983	0.990
29000	3.076	0.597	0.284	2.792	1.000
31000	2.891	0.557	0.266	2.625	1.000
33000	2.729	0.522	0.249	2.480	1.000
35000	2.585	0.491	0.235	2.351	1.000
37000	2.457	0.463	0.222	2.236	1.000
39000	2.343	0.438	0.210	2.133	1.000
41000	2.240	0.415	0.199	2.041	1.000
43000	2.147	0.395	0.190	1.957	1.000
45000	2.062	0.376	0.181	1.881	1.000
47000	1.985	0.359	0.173	1.812	1.000
49000	1.914	0.343	0.165	1.749	1.000
51000	1.849	0.328	0.158	1.691	1.000
53000	1.789	0.314	0.152	1.637	1.000
55000	1.734	0.301	0.146	1.588	1.000
57000	1.683	0.289	0.141	1.542	1.000
59000	1.636	0.278	0.135	1.500	1.000
61000	1.591	0.267	0.131	1.461	1.000

	% Biomass Change (Reference = 0)				
Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	-4	14	3	-8	0.680
3000	-6	14	3	-9	0.720
5000	-7	14	3	-11	0.780
7000	-9	14	3	-12	0.850
9000	-10	14	3	-14	0.870
11000	-12	13	3	-15	0.890
13000	-14	13	3	-17	0.920
15000	-15	13	3	-19	0.950
17000	-17	13	3	-20	0.950
19000	-18	13	4	-22	0.970
21000	-20	12	4	-23	0.970
23000	-21	12	4	-25	0.970
25000	-23	12	4	-26	0.970
27000	-24	12	4	-28	0.990
29000	-26	12	4	-30	0.990
31000	-27	12	4	-31	0.990
33000	-29	12	4	-33	0.990
35000	-31	12	4	-34	0.990
37000	-32	11	4	-36	0.990
39000	-34	11	4	-37	0.990
41000	-35	11	4	-39	0.990
43000	-37	11	4	-41	0.990
45000	-38	11	4	-42	0.990
47000	-40	11	4	-44	0.990
49000	-41	11	4	-45	0.990
51000	-43	11	4	-47	0.990
53000	-44	11	4	-48	0.990
55000	-46	11	4	-50	0.990
57000	-47	11	4	-51	0.990
59000	-49	11	4	-53	0.990
61000	-51	11	4	-55	0.990

Biomass (Reference = 50000)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	88694	22652	10436	78258	0.000
3000	87261	22535	10396	76865	0.000
5000	85828	22419	10356	75472	0.000
7000	84395	22305	10316	74079	0.000
9000	82963	22191	10276	72686	0.000
11000	81530	22078	10236	71294	0.030
13000	80098	21965	10197	69901	0.030
15000	78666	21854	10157	68509	0.030
17000	77234	21744	10118	67116	0.030
19000	75802	21635	10078	65724	0.030
21000	74371	21526	10039	64332	0.120
23000	72939	21419	10000	62939	0.150
25000	71508	21312	9961	61547	0.150
27000	70077	21206	9922	60155	0.150
29000	68647	21101	9883	58763	0.190
31000	67216	20997	9845	57371	0.190
33000	65786	20894	9806	55980	0.210
35000	64356	20792	9768	54588	0.230
37000	62926	20691	9730	53197	0.280
39000	61497	20591	9692	51805	0.310
41000	60068	20491	9654	50414	0.350
43000	58639	20393	9616	49023	0.360
45000	57211	20295	9579	47632	0.460
47000	55783	20198	9542	46242	0.490
49000	54356	20102	9504	44851	0.560
51000	52929	20006	9467	43461	0.580
53000	51502	19911	9431	42071	0.600
55000	50076	19817	9394	40682	0.620
57000	48651	19724	9358	39293	0.670
59000	47226	19631	9322	37904	0.720
61000	45802	19538	9286	36515	0.720

Bootstrap risk results copied to ClipBoard

Analytical risk results copied to ClipBoard

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Projection Model

Forecast projections may be computed by specifying future fishing mortality rate or by specifying future catch quota. In either case, the partial recruitment to the fishery by age and time period, $PR_{a,t}$, must be provided.

To project with a specified fishing mortality rate for ages fully recruited to the fishery, $F_{full,t}$, first compute age specific fishing mortality rates as $F_{a,t} = F_{full,t} PR_{a,t}$ and then apply the fundamental exponential decay model

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

starting with the bias adjusted population abundance estimates in the terminal year.

To project with a specified catch quota, Q_t, first solve for the fishing mortality rate in the fundamental catch equation using the iterative algorithm

initialize $F_{a,t}^{0} = PR_{a,t}$,

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

if $0.01 \le \left| Q_t - \sum_a C_{a,t}^{j} W'_{a,t} \right|$ update $F_{a,t}^{j+1} = \dfrac{F_{a,t}^{j} Q_t}{\sum_a C_{a,t}^{j} W'_{a,t}}$ and recompute catch.

$W'_{a,t}$ is the average weight at age of fish caught in the fishery.

Almost invariably, natural mortality is considered a stationary process and forecast natural mortality for projections is drawn from the same estimated or assumed distribution used for recent years. Similarly, partial recruitment to the fishery and growth are typically deemed to be stationary over the recent past. Accordingly, both $W'_{a,t}$ and $PR_{a,t}$ are derived from observed values in previous years and are assumed to have negligible error.

Risk analysis

Risk analyses is used to determine the consequences of alternative quota tactics. The consequences are measured against reference points for fisheries management interest parameters. Three fisheries management interest parameters are considered, inverse exploitation rate on fish fully recruited to the fishery, relative change in spawning stock biomass and absolute spawning stock biomass. Inverse exploitation rate rather than exploitation rate is used for computational reasons involved with the analytical approach. These interest parameters are evaluated against their respective prescribed reference points for a specified range of potential alternative catch quotas. The requisite information can be summarized as

$$\Pr\left\{ 1/u_{full,t} > 1/u_{ref} \mid Q_t \right\}$$
$$\Pr\left\{ \Delta B_{t+1} < \Delta B_{ref} \mid Q_t \right\}$$
$$\Pr\left\{ B_{t+1} < B_{ref} \mid Q_t \right\}$$

where u is exploitation rate

$$u_{full,y_t+1} = F_{full,y_t+1} \left(1 - e^{-\left(F_{full,y_t+1} + M_{ffull,y_t+1}\right)}\right) \Big/ \left(F_{full,y_t+1} + M_{full,y_t+1}\right)$$

and ΔB is relative change in spawning stock biomass and B is the spawning stock biomass

$$B_t = \sum_a N_{a,t} W_{a,t} m_{a,t}.$$

where $W_{a,t}$ is the average weight at age of fish in the population and $m_{a,t}$ is the maturity at age.

Risk analyses can be based on the statistics from analytical approximation or bootstrap.

Analytical

The analytical method uses the approximate estimates of variance and bias for the interest parameters and couples that with an assumption about the parametric form of their sampling distribution to derive confidence distributions. A bias adjusted Delta confidence distribution is constructed by shifting results to account for the magnitude of the estimated bias and ignoring any increase in variance associated with the variance of the bias estimate. Assuming a Gaussian distribution, confidence distributions of the interest parameters are approximated as $N \sim \left(\hat{\theta} - Bias(\hat{\theta}), \sqrt{Var(\hat{\theta})}\right)$.

Bootstrap

The percentile method confidence distribution of the interest parameter is defined as the proportion of bootstrap replicates, $\hat{\theta}^b$, less than or equal to that value, $\hat{\Omega}(x) = \text{Prob}\{\hat{\theta} \le x\} = \frac{\#\{\hat{\theta}^b \le x\}}{B}$.

The bias-corrected percentile method of Efron (1982) that is reported in ADAPT results, improves on the percentile method by adjusting for differences between the median of the bootstrap percentile density function and the estimate obtained with the original data sample. The confidence distribution of the interest parameter is obtained with the bias-corrected percentile method by constructing the paired values $\left(\hat{\theta}^b_{BC}, \alpha\right)$. The α are the respective probability levels equal to $1/B, 2/B, 3/B, \Lambda\ , B-1/B$ where B is the total number of bootstrap replicates. For each α, calculate the bias adjusted quantity, $\hat{\theta}^b_{BC} = \hat{\Omega}^{-1}\left(\Phi\left(2z_0 + z_\alpha\right)\right)$. Here, Φ is the cumulative distribution function of a standard normal variate, $z_\alpha = \Phi^{-1}(\alpha)$ and $z_0 = \Phi^{-1}\left(\hat{\Omega}(\hat{\theta})\right)$. The term z_0 achieves the bias adjustment. The notation $\hat{\Omega}^{-1}(\ )$ or $\Phi^{-1}(\ )$ is used to represent the inverse distribution function, i.e. the critical value corresponding to the specified probability level. Note that computations are not carried out for $\alpha = B/B$ because $z_\alpha = \Phi^{-1}(\alpha = 1)$ is not defined.