APPENDIX 4. Projections and Risk Analysis with ADAPT

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Appendix 4: 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. Risk analyses can be based on variance estimates from analytical approximations or bootstrap. The risks are expressed in relation to three fisheries management parameters: 1) a relative change in spawning stock biomass, 2) an absolute spawning stock biomass level (e.g. a limit biomass reference points) or 3) a given exploitation level.

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).

The tutorial for the estimation of population abundance (Rivard and Gavaris, 2000; see also Rivard and Gavaris in this publication) should be done first to develop an understanding of the procedures available for obtaining abundance estimates and their statistical properties. From these, the ADAPT software allows deterministic projections and evaluation of risks associated with alternative catch quota options.

Deterministic projections make forecasts of stock characteristics from the point estimates of stock abundance for fishery scenarios that you specify. Risk evaluations make forecasts using the point estimates as well as accounting for their uncertainty. The statistical properties can either be obtained analytically, or through a bootstrap procedure. References on approaches used to measure uncertainty were provided in Rivard and Gavaris (2000).

The uncertainty in the estimation of model parameters is translated into risk of alternative management actions as described in Gavaris and Sinclair (1998). These uncertainties are conditioned on the set of assumptions used in the analyses. Though these assumptions might be deemed most suitable, there may be other plausible assumptions. These calculations do not include uncertainty due to variations in weight at age, partial recruitment to the fishery and natural mortality, or systematic errors in data reporting and model mismatch. The fact that uncertainty associated with making a choice among competing assumptions and models is not incorporated must be considered when making management decisions. Use of relative measures, such as change in biomass, rather than absolute quantities such as biomass should be more reliable. Accordingly, these risk evaluations are suited for short-term projections where the assumed model may be adequate and the largest source of uncertainty is associated with the point estimates of population abundance. A brief description of the projection model and algorithms used in risk analyses is provided in Annex 1.

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

The spreadsheet "ADAPT Template.xls" provides placeholders for your entries for catch projection and risk analysis. The template also provides a means to display your results in a graphical form. It includes some data validation and has been formatted to allow easy copying between Excel (Microsoft Corporation, WA, USA) and ADAPT.

For this tutorial, data have been pre-assembled in the spreadsheet "ADAPT Tutorial – Forecast.xls". Load this spreadsheet now and inspect its content to gain some familiarity with its design. This data corresponds to the gadoid (saithe) stock used in the tutorial on estimation of population abundance (Rivard and Gavaris, 2000).

Loading ADAPT

Activate ADAPT V2.1 from the Windows (Microsoft Corporation, WA, USA) 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 (ADAPT Tutorial – Forecast.aw2)

For the purpose of this tutorial, data input, model specification and estimation has already been done and the ADAPT work file saved as "ADAPT Tutorial – Forecast.aw2". Open this file now and inspect its content. 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 and that the estimation has already been carried out. You are thus ready to proceed with the projections.

Deterministic projections

Deterministic projections use the point estimates of population abundance as a starting point for stock forecasts. The fishery scenarios can be specified either by providing a quota or a fishing mortality level for each year of the projection horizon. The sheet "Forecast" in the Excel-Template can be used to prepare your scenarios (see table 1). 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 necessary.

1. In ADAPT
2. Select "Compute".
3. Select "Analytical".
4. 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.
5. In the box labeled "Enter subsequent years for projection", enter "1996 1997" (without the quotes).
6. In the box labeled "Enter abundance at age 1 for 1996 1997", enter 25000 25000.
7. 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 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.
8. 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. Note that when selecting entries to Paste into ADAPT, always include the cells containing the "age" and "year" labels.

9. In Excel
10. Select the "Forecast" sheet.
11. Enter 25000 in cells D6 and E6.
12. Enter 0.2 in cells C7 and D7 (defaults are provided; change only if necessary).
13. Go to the A9 cell, which marks the beginning of the natural mortality matrix. Defaults have been calculated for you here. Adjust as necessary.
14. Highlight the relevant data and copy to the clipboard.
15. In ADAPT [returning to the "Project Menu"]
16. Click the PASTE-button against the "Copy M…" option.
17. In Excel
18. Select the "Forecast" sheet (if not already selected).
19. 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.
20. Highlight the relevant data and copy to the clipboard.
21. In ADAPT [returning to the "Project Menu"]
22. Click the PASTE-button against the "Copy PR…" option.
23. In Excel
24. Select the "Forecast" sheet (if not already selected).
25. 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.
26. Highlight the relevant data and copy to the clipboard.
27. In ADAPT [returning to the "Project Menu"]
28. Click the PASTE-button against the "Copy beginning of year population weight-at-age…" option.
29. In Excel
30. Select the "Forecast" sheet (if not already selected).
31. 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.
32. Highlight the relevant data and copy to the clipboard.
33. In ADAPT [returning to the "Project Menu"]
34. Click the PASTE-button against the "Copy average catch weight-at-age … " option.
35. Click the OK-button of the "Project Menu".
36. The results of this projection scenario appear in the Session-log.

Results (see Annex 2):

The results show that a fishing mortality of 0.2 would generate a catch of 13139 t in 1995 and 12890 t in 1996. These catch levels would lead to a reduction of the total biomass, from 131 355 t at the beginning of 1995 to 122 375 t at the beginning of 1997.

Computation of risk

Risk analyses use not only the point estimates of population abundance as a starting point for stock forecasts but use also a measure of their reliability to make inferences on the likelihood of various outcomes. The risks are expressed in relation to three specific outcomes: 1) the attainment of a given exploitation level, 2) a relative change in spawning stock biomass, or 3) the realization of an absolute spawning stock biomass level (e.g. a limit biomass reference point). The risk evaluation is for the final year in the projection time horizon.

37. In ADAPT
38. Select "Compute".
39. Select "Analytical".
40. 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.
41. In the box labeled "Enter subsequent years for projection", enter "1996 1997" (without the quotes).
42. In the box labeled "Enter abundance at age 1 for 1996 1997", enter 25000 25000.
43. 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 mortality. Also, when there is no intervening year, the label for this box will not show a year, indicating that no input is required.
44. 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.
45. 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. When selecting entries to Paste into ADAPT, always include the cells containing the labels, which identify the ages and years.
46. In Excel
47. Select the "Forecast" sheet.
48. Enter 25000 in cells D6 and E6.
49. Enter 20000 in cell C7 and 0.2 in cell D7 (defaults are provided; adjust only if necessary).
50. Go to the A9 cell, which marks the beginning of the natural mortality matrix. Defaults have been calculated for you here. Adjust as necessary.
51. Highlight the relevant data and copy to the clipboard.
52. In ADAPT [returning to the "Project Menu"]
53. Click the PASTE-button against the "Copy M…" option.
54. In Excel
55. Select the "Forecast" sheet (if not already selected).
56. 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.
57. Highlight the relevant data and copy to the clipboard.
58. In ADAPT [returning to the "Project Menu"]
59. Click the PASTE-button against the "Copy PR…" option.
60. In Excel
61. Select the "Forecast" sheet (if not already selected).
62. 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.
63. Highlight the relevant data and copy to the clipboard.
64. In ADAPT [returning to the "Project Menu"]
65. Click the PASTE-button against the "Copy beginning of year population weight-at-age…" option.
66. In Excel
67. Select the "Forecast" sheet (if not already selected).
68. 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.
69. Highlight the relevant data and copy to the clipboard.
70. In ADAPT [returning to the "Project Menu"].
71. Click the PASTE-button against the "Copy average catch weight at age … " option.
72. In Excel

73. Select the "Forecast" sheet (if not already selected).
74. 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.
75. Highlight the relevant data and copy to the clipboard.
76. In ADAPT [returning to the "Project Menu"]
77. Click the PASTE-button against the "Copy maturity-at-age for …" option.
78. In the box labeled "Inverse exploration", enter "5".
79. In the box labeled "%Biomass change", enter "0". Note that this % change refers to a change in the Stock Spawning Biomass (SSB).
80. In the box labeled "Absolute biomass", enter "50000". Note that this value refers to the Stock Spawning Biomass (SSB).
81. Your entries must look like the Menu illustrated in Fig.1.
    Click the OK-button of the "Risk Menu".
82. These calculations can take a few 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.

HINT: If the correct M, partial recruitment and weights have previously been entered for a deterministic projection and if you are doing the risk analysis for the same timeframe, you need only Paste the maturity for the calculation of the SSB. The other values will be taken from the variables previously defined.

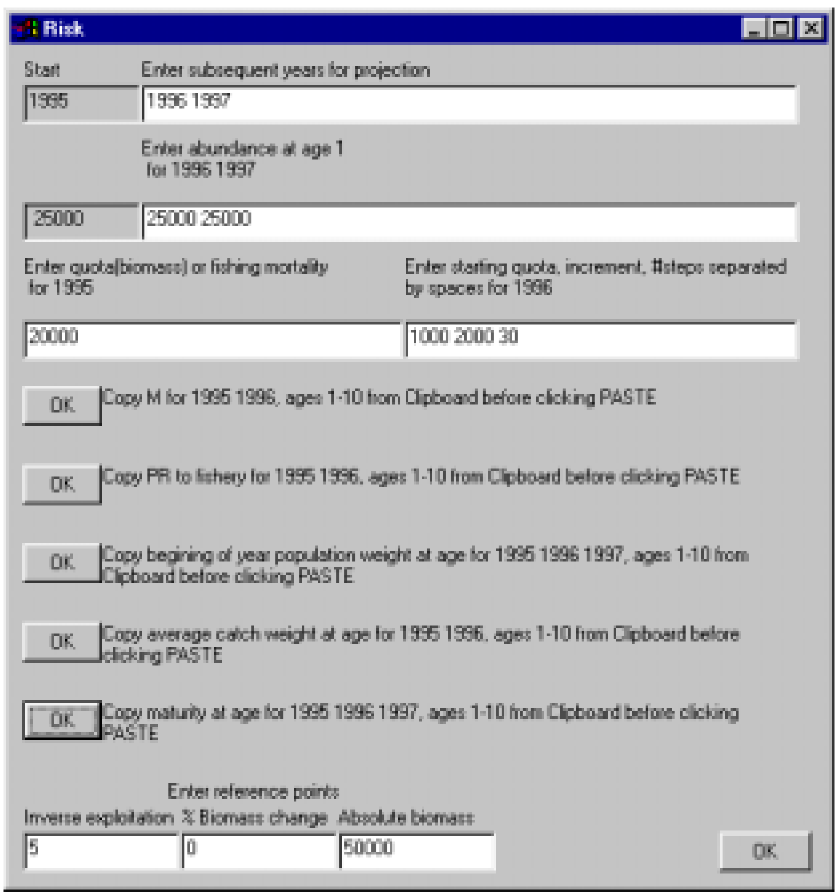

Fig. 1. Risk Menu.

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.

83. In ADAPT
84. Select "Output".
85. Select "To Clipboard".
86. Select "Risk".
87. Select "Analytical".
88. The results of this risk scenario are copied to the clipboard.
89. In Excel.
90. Go to the "WS-For" sheet.
91. Copy the content of the clipboard to cell A3.

The risk curves will be generated in the "For-G" sheet of the Excel template (Figs. 2 and 3).

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 Fig. 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) (Gavaris *et al.*, 2000).
- 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 spreadsheet. You can now inspect the forecasts and interpret the results of the risk analysis.

Results:

Figs. 2 and 3 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 75–90%.

Fig. 2 (lower panel) indicates that the SSB would be of the order of 80 000 t at the beginning of 1997 if there is no fishing in 1996. A catch of 50,000 t in 1996 would generate a fishing mortality of 0.7-0.8 in 1996 and would leave a SSB of about 40 000 t at the beginning of 1997.

This concludes the tutorial for projections and risk computations using ADAPT. You should save your work (both the ADAPT Workspace and the spreadsheet) for future reference. The ADAPT Session Log for this tutorial is printed in Annex 2 and the "completed" spreadsheet is given in file "ADAPT Template – Example".

References and Related Reading

EFRON, B. 1982. The Jacknife, the bootstrap and other resampling plans. Philadelphia: Society for Industrial and Applied Mathematics **38**: 92 p.

GAVARIS S. 1999. ADAPT (ADAPTive framework) User's Guide. Mimeographed. 25 pages. Available at http://www.mar.dfo-mpo.gc.ca/science/adapt/index.html.

GAVARIS, S. and A. SINCLAIR. 1998. From fisheries assessment uncertainty to risk analysis for immediate management actions. *In*: Fishery Stock Assessment Models. F. Funk *et al.* (eds). Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska, Fairbanks.

GAVARIS, S., K. R. PATTERSON, C. D. DARBY, P. LEWY, B. MESNIL, A. E. PUNT, R. M. COOK, L. T. KELL, C. M. O´BRIEN, V. R. RESTREPO, D. W. SKAGEN, and G. STEFÁNSSON. 2000. Comparison of uncertainty estimates in the short term using real data. *ICES C.M. Doc*. No. 2000/V:03, 30 p.

RIVARD D. and S. GAVARIS. 2000. Tutorial for estimation of population abundance with ADAPT. *NAFO SCR Doc.* No. 56, Serial No. N4296,68 pages.

TABLE 1. Example of input data for deterministic projections and risk analyses.

Years	1995	1996	1997
N at Age 1	25000	25000	25000
Quota or F	20000	0.20	

M	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1995	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1996	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

PR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
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

Wt stock	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
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

Wt catch	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
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**
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

TABLE 2. This table, which is a replicate of the Excel Sheet "WS-For" (Work Sheet for Forecasts), summarizes the risk calculations done using the analytical approach.

	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	78.70	63.04	18.72	59.98	0.19	-4.38	14.94	3.32	-7.70	0.70	88384	24218	10606	77778	0.13
3000	26.34	21.10	6.27	20.07	0.24	-6.03	14.88	3.36	-9.40	0.74	86857	24218	10606	76251	0.14
5000	15.87	12.71	3.78	12.10	0.29	-7.68	14.83	3.41	-11.10	0.77	85331	24217	10607	74724	0.15
7000	11.38	9.12	2.71	8.68	0.34	-9.33	14.79	3.46	-12.79	0.81	83804	24216	10608	73196	0.17
9000	8.89	7.12	2.12	6.78	0.40	-10.99	14.76	3.51	-14.49	0.84	82277	24215	10609	71668	0.19
11000	7.31	5.85	1.74	5.57	0.46	-12.64	14.74	3.56	-16.19	0.86	80751	24213	10611	70140	0.20
13000	6.21	4.97	1.48	4.73	0.52	-14.29	14.73	3.61	-17.90	0.89	79225	24211	10613	68612	0.22
15000	5.41	4.33	1.29	4.12	0.58	-15.94	14.74	3.66	-19.60	0.91	77699	24208	10616	67083	0.24
17000	4.79	3.84	1.14	3.65	0.64	-17.59	14.75	3.71	-21.30	0.93	76172	24205	10619	65553	0.26
19000	4.31	3.45	1.02	3.28	0.69	-19.24	14.78	3.76	-23.00	0.94	74646	24201	10623	64023	0.28
21000	3.92	3.14	0.93	2.98	0.74	-20.89	14.82	3.81	-24.70	0.95	73120	24197	10628	62493	0.30
23000	3.59	2.88	0.85	2.74	0.78	-22.54	14.87	3.86	-26.41	0.96	71595	24192	10633	60961	0.33
25000	3.32	2.66	0.79	2.53	0.82	-24.19	14.92	3.92	-28.11	0.97	70069	24186	10640	59429	0.35
27000	3.09	2.47	0.73	2.35	0.86	-25.85	14.99	3.97	-29.82	0.98	68543	24180	10647	57896	0.37
29000	2.89	2.32	0.69	2.20	0.89	-27.50	15.07	4.03	-31.53	0.98	67018	24173	10656	56362	0.40
31000	2.72	2.18	0.65	2.07	0.91	-29.15	15.16	4.09	-33.24	0.99	65492	24165	10666	54826	0.42
33000	2.57	2.06	0.61	1.96	0.93	-30.80	15.26	4.15	-34.95	0.99	63967	24157	10677	53290	0.45
35000	2.43	1.95	0.58	1.85	0.95	-32.45	15.37	4.21	-36.66	0.99	62442	24147	10691	51752	0.47
37000	2.31	1.85	0.55	1.76	0.96	-34.10	15.49	4.28	-38.37	0.99	60917	24137	10706	50212	0.50
39000	2.21	1.77	0.52	1.68	0.97	-35.75	15.61	4.34	-40.09	0.99	59392	24126	10723	48670	0.52
41000	2.11	1.69	0.50	1.61	0.98	-37.39	15.75	4.41	-41.81	1.00	57868	24113	10742	47125	0.55
43000	2.02	1.62	0.48	1.54	0.98	-39.04	15.89	4.49	-43.53	1.00	56344	24099	10765	45579	0.57
45000	1.94	1.56	0.46	1.48	0.99	-40.69	16.04	4.56	-45.26	1.00	54819	24084	10790	44029	0.60
47000	1.87	1.50	0.45	1.43	0.99	-42.34	16.20	4.64	-46.99	1.00	53295	24068	10820	42476	0.62
49000	1.81	1.45	0.43	1.38	0.99	-43.99	16.36	4.73	-48.72	1.00	51772	24050	10853	40919	0.65
51000	1.75	1.40	0.42	1.33	1.00	-45.64	16.53	4.82	-50.46	1.00	50248	24030	10891	39357	0.67
53000	1.69	1.35	0.40	1.29	1.00	-47.29	16.71	4.92	-52.20	1.00	48725	24008	10935	37790	0.69
55000	1.64	1.31	0.39	1.25	1.00	-48.93	16.89	5.02	-53.96	1.00	47203	23985	10985	36217	0.72
57000	1.59	1.27	0.38	1.21	1.00	-50.58	17.08	5.14	-55.72	1.00	45680	23959	11043	34637	0.74
59000	1.55	1.24	0.37	1.18	1.00	-52.23	17.27	5.26	-57.49	1.00	44158	23930	11110	33049	0.76
61000	1.51	1.21	0.36	1.15	1.00	-53.87	17.46	5.39	-59.27	1.00	42637	23899	11187	31451	0.78

TABLE 3. This table, which is a replicate of the Excel Sheet ":WS-For" (Work Sheet for Forecasts), summarizes the risk calculations done using the bootstrap approach.

Quota	Inverse Exploitation: Mean	S.E.	Bias	Adj. Mean	Prob.	SSB Change: Mean	S.E.	Bias	Adj. Mean	Prob.	SSB Reference: Mean	S.E.	Bias	Adj. Mean	Prob.
1000	78.70	20.49	8.07	70.63	0.00	-4.38	14.22	2.47	-6.85	0.77	88384	28359	11155	77228	0.04
3000	26.34	6.83	2.69	23.65	0.00	-6.03	14.05	2.51	-8.54	0.79	86857	28221	11124	75733	0.08
5000	15.87	4.09	1.61	14.26	0.00	-7.68	13.89	2.55	-10.23	0.85	85331	28084	11092	74238	0.08
7000	11.38	2.92	1.15	10.23	0.00	-9.33	13.74	2.59	-11.93	0.88	83804	27947	11061	72743	0.11
9000	8.89	2.27	0.90	8.00	0.00	-10.99	13.60	2.63	-13.62	0.91	82277	27812	11029	71248	0.11
11000	7.31	1.85	0.73	6.57	0.14	-12.64	13.47	2.67	-15.31	0.91	80751	27678	10997	69754	0.13
13000	6.21	1.57	0.62	5.59	0.30	-14.29	13.35	2.72	-17.01	0.92	79225	27545	10966	68259	0.13
15000	5.41	1.36	0.54	4.87	0.53	-15.94	13.24	2.76	-18.70	0.93	77699	27413	10934	66764	0.20
17000	4.79	1.20	0.47	4.32	0.73	-17.59	13.14	2.80	-20.39	0.94	76172	27283	10903	65270	0.20
19000	4.31	1.07	0.42	3.88	0.91	-19.24	13.05	2.84	-22.08	0.96	74646	27153	10871	63775	0.20
21000	3.92	0.97	0.38	3.53	0.95	-20.89	12.97	2.88	-23.77	0.96	73120	27024	10839	62281	0.20
23000	3.59	0.88	0.35	3.24	0.97	-22.54	12.90	2.92	-25.47	0.97	71595	26897	10808	60787	0.22
25000	3.32	0.81	0.32	3.00	0.99	-24.19	12.85	2.96	-27.16	0.98	70069	26771	10776	59293	0.28
27000	3.09	0.75	0.30	2.79	0.99	-25.85	12.80	3.01	-28.85	0.98	68543	26646	10744	57799	0.32
29000	2.89	0.69	0.28	2.61	0.99	-27.50	12.77	3.05	-30.54	0.98	67018	26522	10713	56305	0.34
31000	2.72	0.65	0.26	2.46	0.99	-29.15	12.75	3.09	-32.23	0.98	65492	26399	10681	54811	0.36
33000	2.57	0.61	0.24	2.32	0.99	-30.80	12.74	3.13	-33.93	0.98	63967	26277	10649	53318	0.37
35000	2.43	0.57	0.23	2.20	0.99	-32.45	12.74	3.17	-35.62	0.98	62442	26156	10618	51824	0.41
37000	2.31	0.54	0.22	2.10	1.00	-34.10	12.75	3.21	-37.31	0.99	60917	26037	10586	50331	0.44
39000	2.21	0.51	0.20	2.00	1.00	-35.75	12.78	3.25	-39.00	0.99	59392	25918	10555	48838	0.49
41000	2.11	0.48	0.19	1.92	1.00	-37.39	12.81	3.30	-40.69	0.98	57868	25801	10523	47345	0.55
43000	2.02	0.46	0.19	1.84	1.00	-39.04	12.86	3.34	-42.38	0.99	56344	25684	10492	45852	0.59
45000	1.94	0.44	0.18	1.77	1.00	-40.69	12.92	3.38	-44.07	0.99	54819	25569	10460	44359	0.62
47000	1.87	0.42	0.17	1.70	1.00	-42.34	12.99	3.42	-45.76	0.99	53295	25455	10429	42866	0.64
49000	1.81	0.40	0.16	1.64	1.00	-43.99	13.07	3.46	-47.45	0.99	51772	25342	10398	41374	0.66
51000	1.75	0.38	0.16	1.59	1.00	-45.64	13.16	3.51	-49.14	0.99	50248	25229	10367	39882	0.68
53000	1.69	0.37	0.15	1.54	1.00	-47.29	13.26	3.55	-50.83	0.99	48725	25118	10336	38390	0.71
55000	1.64	0.35	0.14	1.50	1.00	-48.93	13.36	3.59	-52.52	0.99	47203	25008	10305	36898	0.80
57000	1.59	0.34	0.14	1.45	1.00	-50.58	13.48	3.63	-54.21	0.99	45680	24898	10274	35406	0.84
59000	1.55	0.32	0.13	1.41	1.00	-52.23	13.61	3.68	-55.90	0.99	44158	24789	10244	33915	0.86
61000	1.51	0.31	0.13	1.38	1.00	-53.87	13.74	3.72	-57.59	0.99	42637	24680	10214	32423	0.88

ANNEX 1. Algorithm Used in ADAPT for Forecasts

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

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

compute catch

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

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 re-compute 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

$$N \sim \left(\hat{\eta} - Bias(\hat{\eta}), \sqrt{Var(\hat{\eta})}\right).$$

Bootstrap

The percentile method confidence distribution of the interest parameter is defined as the proportion of bootstrap replicates, $\hat{\eta}^b$, less than or equal to that value,

$$\hat{\Omega}(x) = \text{Prob}\{\hat{\eta} \le x\} = \frac{\#\{\hat{\eta}^b \le x\}}{B}$$

where B is the total number of bootstrap replicates.

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 $\left(\hat{\eta}_{BC}^b, \alpha\right)$. The α are the respective probability levels equal to $1/B, 2/B, 3/B, \cdots, B-1/B$. For each α, calculate the bias adjusted quantity,

$$\hat{\eta}_{BC}^b = \hat{\Omega}^{-1}\left(\Phi\left(2z_0 + z_\alpha\right)\right).$$

Here, Φ is the cumulative distribution function of a standard normal variate, $z_\alpha = \Phi^{-1}(\alpha)$ and $z_0 = \Phi^{-1}\left(\hat{\Omega}(\hat{\eta})\right)$. 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.

ANNEX 2. ADAPT Session Log – Tutorial for Projections and Risk Analysis with ADAPT

```
THURSDAY, OCTOBER 12, 2000  9:38:19.230 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
```

Note: Log file truncated to show only the material relevant to the forecast. See Rivard and Gavaris (2000) for description of log file relevant to the estimation.

Projection results using analytical bias adjusted point estimates

Projected Population Numbers

	1	2	3	4	5	6	7	8	9	10
1995.00	15000	15000	8624	12180	5567	4995	3054	2102	3059	1582
1996.00	25000	12256	11589	5945	8165	3939	3634	2258	1585	2344
1997.00	25000	20427	9469	7989	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	5400	10800	9314	19002	12916	16084	12951	11161	19851	13876	131355	125955	115155	105841
1996.00	9000	8825	12516	9274	18942	12683	15410	11991	10290	20559	129491	120491	111666	99150
1997.00	9000	14708	10227	12463	9246	18601	12152	14268	11055	10657	122375	113375	98668	88441

Projected Catch Numbers

	1	2	3	4	5	6	7	8	9	10
1995.00	27	767	1239	2008	687	505	269	150	177	205
1996.00	45	627	1665	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	10	552	1338	3132	1594	1626	1140	798	1150	1800	13139	13130	12578	11240
1996.00	16	451	1798	1529	2338	1282	1357	857	596	2666	12890	12874	12423	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	78.701	63.041	18.723	59.978	0.192
3000	26.342	21.100	6.267	20.075	0.237
5000	15.871	12.713	3.776	12.095	0.288
7000	11.384	9.119	2.708	8.676	0.343
9000	8.892	7.123	2.115	6.777	0.402
11000	7.307	5.853	1.738	5.569	0.461
13000	6.210	4.974	1.477	4.733	0.521
15000	5.406	4.330	1.286	4.120	0.581
17000	4.792	3.838	1.140	3.652	0.637
19000	4.307	3.450	1.025	3.282	0.691
21000	3.915	3.136	0.931	2.984	0.740
23000	3.592	2.877	0.854	2.737	0.784
25000	3.320	2.659	0.790	2.530	0.823
27000	3.089	2.475	0.735	2.354	0.858
29000	2.890	2.315	0.688	2.203	0.887
31000	2.718	2.177	0.647	2.071	0.911
33000	2.566	2.055	0.610	1.956	0.931
35000	2.432	1.948	0.579	1.853	0.947
37000	2.313	1.853	0.550	1.763	0.960
39000	2.206	1.767	0.525	1.681	0.970
41000	2.110	1.690	0.502	1.608	0.978
43000	2.023	1.620	0.481	1.542	0.984
45000	1.944	1.557	0.462	1.482	0.988
47000	1.872	1.500	0.445	1.427	0.991
49000	1.806	1.447	0.430	1.377	0.994
51000	1.746	1.398	0.415	1.331	0.996
53000	1.690	1.354	0.402	1.288	0.997
55000	1.639	1.313	0.390	1.249	0.998
57000	1.592	1.275	0.379	1.213	0.999
59000	1.548	1.240	0.368	1.179	0.999
61000	1.507	1.207	0.358	1.148	0.999

% Biomass Change (Reference = 0)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	-4	15	3	-8	0.697
3000	-6	15	3	-9	0.736
5000	-8	15	3	-11	0.773
7000	-9	15	3	-13	0.807
9000	-11	15	4	-14	0.837
11000	-13	15	4	-16	0.864
13000	-14	15	4	-18	0.888
15000	-16	15	4	-20	0.908
17000	-18	15	4	-21	0.926
19000	-19	15	4	-23	0.940
21000	-21	15	4	-25	0.952
23000	-23	15	4	-26	0.962
25000	-24	15	4	-28	0.970
27000	-26	15	4	-30	0.977
29000	-27	15	4	-32	0.982
31000	-29	15	4	-33	0.986
33000	-31	15	4	-35	0.989
35000	-32	15	4	-37	0.991
37000	-34	15	4	-38	0.993
39000	-36	16	4	-40	0.995
41000	-37	16	4	-42	0.996
43000	-39	16	4	-44	0.997
45000	-41	16	5	-45	0.998
47000	-42	16	5	-47	0.998
49000	-44	16	5	-49	0.999
51000	-46	17	5	-50	0.999
53000	-47	17	5	-52	0.999
55000	-49	17	5	-54	0.999
57000	-51	17	5	-56	0.999
59000	-52	17	5	-57	1.000
61000	-54	17	5	-59	1.000

Biomass (Reference = 50000)

Quota	Mean	Std. Err.	Bias Adj.	Mean	Prob
1000	88384	24218	10606	77778	0.126
3000	86857	24218	10606	76251	0.139
5000	85331	24217	10607	74724	0.154
7000	83804	24216	10608	73196	0.169
9000	82277	24215	10609	71668	0.185
11000	80751	24213	10611	70140	0.203
13000	79225	24211	10613	68612	0.221
15000	77699	24208	10616	67083	0.240
17000	76172	24205	10619	65553	0.260
19000	74646	24201	10623	64023	0.281
21000	73120	24197	10628	62493	0.303
23000	71595	24192	10633	60961	0.325
25000	70069	24186	10640	59429	0.348
27000	68543	24180	10647	57896	0.372
29000	67018	24173	10656	56362	0.396
31000	65492	24165	10666	54826	0.421
33000	63967	24157	10677	53290	0.446
35000	62442	24147	10691	51752	0.471
37000	60917	24137	10706	50212	0.497
39000	59392	24126	10723	48670	0.522
41000	57868	24113	10742	47125	0.547
43000	56344	24099	10765	45579	0.573
45000	54819	24084	10790	44029	0.598
47000	53295	24068	10820	42476	0.623
49000	51772	24050	10853	40919	0.647
51000	50248	24030	10891	39357	0.671
53000	48725	24008	10935	37790	0.694
55000	47203	23985	10985	36217	0.717
57000	45680	23959	11043	34637	0.739
59000	44158	23930	11110	33049	0.761
61000	42637	23899	11187	31451	0.781

Analytical risk results copied to ClipBoard

BOOTSTRAP STATISTICS
Estimates for parameters

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
9.27E0	6.35E-1	0.069	-9.87E-3	-0.001
9.51E0	4.32E-1	0.045	2.96E-3	0.000
8.71E0	4.14E-1	0.048	-1.66E-2	-0.002
8.59E0	4.46E-1	0.052	-3.14E-3	0.000
8.10E0	4.28E-1	0.053	-3.61E-2	-0.004
7.72E0	4.40E-1	0.057	-1.47E-2	-0.002
8.09E0	4.02E-1	0.050	-1.07E-2	-0.001
7.45E0	6.30E-1	0.085	-1.61E-1	-0.022
-5.71E0	2.24E-1	-0.039	-1.46E-2	0.003
-5.26E0	2.46E-1	-0.047	-2.07E-2	0.004
-6.19E0	2.53E-1	-0.041	2.65E-2	-0.004
-6.72E0	2.26E-1	-0.034	-3.34E-2	0.005
-6.68E0	2.32E-1	-0.035	-3.36E-2	0.005
-7.49E0	2.28E-1	-0.030	2.82E-2	-0.004
-7.18E0	2.27E-1	-0.032	-4.01E-2	0.006
-7.73E0	2.52E-1	-0.033	-2.92E-3	0.000
-8.30E0	2.39E-1	-0.029	-4.72E-2	0.006
-6.90E0	2.43E-1	-0.035	4.28E-2	-0.006
-6.28E0	2.30E-1	-0.037	5.32E-2	-0.008
-6.77E0	2.62E-1	-0.039	-7.32E-3	0.001
-7.46E0	2.60E-1	-0.035	6.28E-3	-0.001
-7.81E0	2.50E-1	-0.032	1.73E-2	-0.002
-8.32E0	2.69E-1	-0.032	-5.49E-3	0.001
-8.93E0	2.34E-1	-0.026	-1.36E-2	0.002
-8.99E0	2.61E-1	-0.029	1.09E-2	-0.001
-9.85E0	2.32E-1	-0.024	1.87E-3	0.000

Parameters in linear scale

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
1.06E4	9.07E3	0.856	2.19E3	0.207
1.35E4	7.26E3	0.538	1.42E3	0.105
6.04E3	2.56E3	0.424	4.08E2	0.068
5.36E3	2.64E3	0.492	5.31E2	0.099
3.30E3	1.49E3	0.451	1.82E2	0.055
2.26E3	1.21E3	0.534	2.03E2	0.090
3.27E3	1.41E3	0.430	2.31E2	0.071
1.73E3	9.26E2	0.536	1.20E1	0.007
3.30E-3	7.25E-4	0.219	3.24E-5	0.010
5.19E-3	1.30E-3	0.250	4.88E-5	0.009
2.05E-3	5.51E-4	0.269	1.23E-4	0.060
1.21E-3	2.66E-4	0.221	-9.94E-6	-0.008
1.25E-3	2.87E-4	0.229	-8.62E-6	-0.007
5.58E-4	1.43E-4	0.256	3.16E-5	0.057
7.65E-4	1.81E-4	0.237	-1.03E-5	-0.014
4.38E-4	1.14E-4	0.260	1.27E-5	0.029
2.47E-4	6.03E-5	0.244	-4.43E-6	-0.018
1.00E-3	2.55E-4	0.254	7.44E-5	0.074
1.87E-3	4.86E-4	0.260	1.56E-4	0.084
1.14E-3	3.06E-4	0.267	3.06E-5	0.027
5.76E-4	1.57E-4	0.272	2.35E-5	0.041
4.06E-4	1.13E-4	0.279	2.06E-5	0.051
2.43E-4	6.57E-5	0.271	7.29E-6	0.030
1.32E-4	3.21E-5	0.243	1.85E-6	0.014
1.24E-4	3.30E-5	0.265	5.60E-6	0.045
5.27E-5	1.21E-5	0.230	1.49E-6	0.028

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

Quota	Inverse Exploitation Rate (Reference = 5) Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	78.701	20.490	8.073	70.629	0.000
3000	26.342	6.825	2.690	23.651	0.000
5000	15.871	4.092	1.614	14.257	0.000
7000	11.384	2.920	1.152	10.232	0.000
9000	8.892	2.269	0.896	7.996	0.000
11000	7.307	1.855	0.733	6.574	0.140
13000	6.210	1.568	0.620	5.591	0.300
15000	5.406	1.357	0.537	4.869	0.530
17000	4.792	1.196	0.473	4.318	0.730
19000	4.307	1.069	0.423	3.884	0.910
21000	3.915	0.965	0.383	3.532	0.950
23000	3.592	0.880	0.349	3.242	0.970
25000	3.320	0.808	0.321	2.999	0.990
27000	3.089	0.747	0.297	2.792	0.990
29000	2.890	0.694	0.276	2.614	0.990
31000	2.718	0.648	0.258	2.459	0.990
33000	2.566	0.608	0.242	2.324	0.990
35000	2.432	0.571	0.228	2.204	0.990
37000	2.313	0.539	0.216	2.097	1.000
39000	2.206	0.510	0.204	2.002	1.000
41000	2.110	0.484	0.194	1.916	1.000
43000	2.023	0.460	0.185	1.838	1.000
45000	1.944	0.438	0.177	1.767	1.000
47000	1.872	0.418	0.169	1.703	1.000
49000	1.806	0.399	0.162	1.645	1.000
51000	1.746	0.382	0.155	1.591	1.000
53000	1.690	0.366	0.149	1.541	1.000
55000	1.639	0.351	0.144	1.495	1.000
57000	1.592	0.337	0.138	1.453	1.000
59000	1.548	0.324	0.133	1.414	1.000
61000	1.507	0.311	0.129	1.378	1.000

Quota	% Biomass Change (Reference = 0) Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	-4	14	2	-7	0.770
3000	-6	14	3	-9	0.790
5000	-8	14	3	-10	0.850
7000	-9	14	3	-12	0.880
9000	-11	14	3	-14	0.910
11000	-13	13	3	-15	0.910
13000	-14	13	3	-17	0.920
15000	-16	13	3	-19	0.930
17000	-18	13	3	-20	0.940
19000	-19	13	3	-22	0.960
21000	-21	13	3	-24	0.960
23000	-23	13	3	-25	0.970
25000	-24	13	3	-27	0.980
27000	-26	13	3	-29	0.980
29000	-27	13	3	-31	0.980
31000	-29	13	3	-32	0.980
33000	-31	13	3	-34	0.980
35000	-32	13	3	-36	0.980
37000	-34	13	3	-37	0.990
39000	-36	13	3	-39	0.990
41000	-37	13	3	-41	0.980
43000	-39	13	3	-42	0.990
45000	-41	13	3	-44	0.990
47000	-42	13	3	-46	0.990
49000	-44	13	3	-47	0.990
51000	-46	13	4	-49	0.990
53000	-47	13	4	-51	0.990
55000	-49	13	4	-53	0.990
57000	-51	13	4	-54	0.990
59000	-52	14	4	-56	0.990
61000	-54	14	4	-58	0.990

Biomass (Reference = 50000)

Quota	Mean	Std. Err.	Bias	Adj. Mean	Prob
1000	88384	28359	11155	77228	0.040
3000	86857	28221	11124	75733	0.080
5000	85331	28084	11092	74238	0.080
7000	83804	27947	11061	72743	0.110
9000	82277	27812	11029	71248	0.110
11000	80751	27678	10997	69754	0.130
13000	79225	27545	10966	68259	0.130
15000	77699	27413	10934	66764	0.200
17000	76172	27283	10903	65270	0.200
19000	74646	27153	10871	63775	0.200
21000	73120	27024	10839	62281	0.200
23000	71595	26897	10808	60787	0.220
25000	70069	26771	10776	59293	0.280
27000	68543	26646	10744	57799	0.320
29000	67018	26522	10713	56305	0.340
31000	65492	26399	10681	54811	0.360
33000	63967	26277	10649	53318	0.370
35000	62442	26156	10618	51824	0.410
37000	60917	26037	10586	50331	0.440
39000	59392	25918	10555	48838	0.490
41000	57868	25801	10523	47345	0.550
43000	56344	25684	10492	45852	0.590
45000	54819	25569	10460	44359	0.620
47000	53295	25455	10429	42866	0.640
49000	51772	25342	10398	41374	0.660
51000	50248	25229	10367	39882	0.680
53000	48725	25118	10336	38390	0.710
55000	47203	25008	10305	36898	0.800
57000	45680	24898	10274	35406	0.840
59000	44158	24789	10244	33915	0.860
61000	42637	24680	10214	32423	0.880

Bootstrap risk results copied to ClipBoard

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Blackfin: NAFO SC Workshop – ADAPT Tutorial
Bias adjusted

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

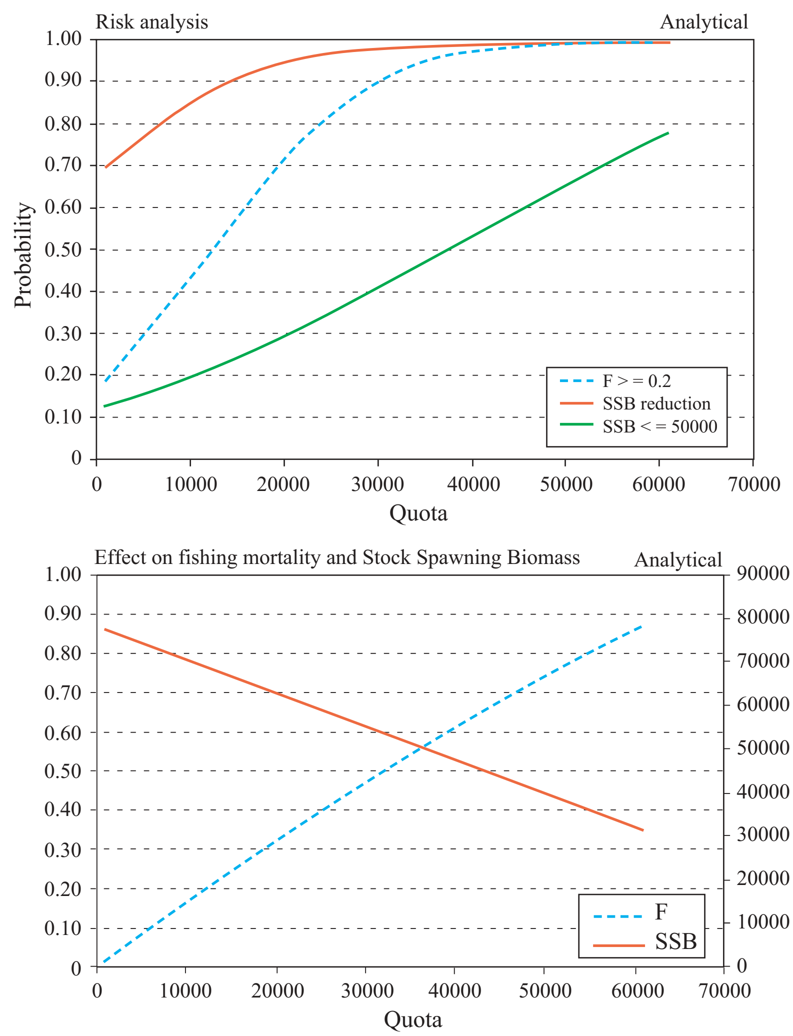
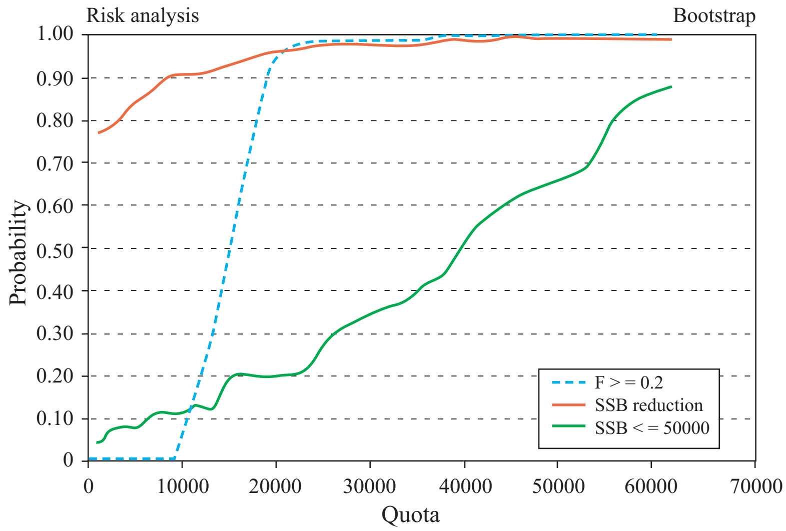


Fig. 2. Graphical representation of catch projections and risk calculations using the analytical approach.

Blackfin: NAFO SC Workshop – ADAPT Tutorial
Bias adjusted

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



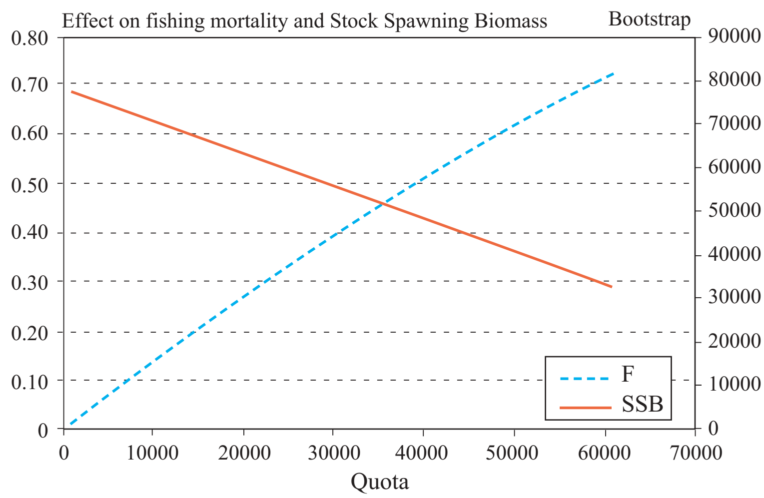


Fig. 3. Graphical representation of catch projections and risk calculations using the bootstrap approach.