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**INTERNATIONAL COMMISSION FOR THE CONSERVATION  
OF ATLANTIC TUNAS**

**COMMISSION INTERNATIONALE POUR LA CONSERVATION  
DES THONIDES DE L'ATLANTIQUE**

**COMISION INTERNACIONAL PARA LA CONSERVACION  
DEL ATUN ATLANTICO**

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**ASSESSMENT PROGRAM DOCUMENTATION**

**Program:**

**ASPIC (vers. 5.05)**

Fits a generalized stock production model to catch and effort data without making an equilibrium approximation.

**Current Catalog Entry:**

**August 2004**

**First Cataloged by ICCAT:**

**July 2000 (vers. 3.82)**

**Catalog Committee**

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NOTE: As part of its efforts to carry out Quality Management, ICCAT's Standing Committee on Research and Statistics is developing a catalog of stock assessment applications. The purpose of the catalog is not to evaluate the relative merits of various assessment methods, but rather whether the software implementing the method works as intended and is adequately documented.

## **1. PROGRAM NAME**

ASPIC Suite (ASPIC and related programs ASPICP, FTEST, and AGRAPH)

## **2. VERSION (DATE)**

Version 5.05, dated August, 2004

## **3. LANGUAGE**

FORTRAN 95 (compiled)

## **4. PROGRAMMER / CONTACT PERSON**

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## **5. DISTRIBUTION LIMITATIONS**

For legal reasons, only executable code and support files can be distributed freely, along with user's manual and sample files. However, source code is available from the author upon written request and with agreement to certain restrictions on redistribution. These restrictions are necessary because ASPIC includes a proprietary optimization routine from the book *Numerical Recipes*.

The program can be downloaded from the author's Web site as a self-installing executable file. Go to Web site

<http://shrimp.ccfhrb.noaa.gov/~mprager/>

and follow the links for ASPIC.

## **6. COMPILER NEEDS / STAND-ALONE**

Does not require other software, except operating system. Presently available from author for 32-bit Windows (Windows 9x, Windows NT, Windows 2000, Windows XP). Versions for Linux or other operating systems may be available on request.

## **7. PURPOSE**

ASPIC fits a several forms of surplus-production model to catch and relative abundance (or effort) data. The program does not use the equilibrium approximation. It uses an observation-error estimator. Production model forms available include the logistic (Schaefer), exponential-yield (Fox), and generalized (Pella-Tomlinson in parameterization of Fletcher) models. ASPIC uses bootstrapping to provide estimates of precision

ASPICP provides projections of up to 15 years from ASPIC bootstrap results. The projections include bias-corrected confidence intervals on trajectories of relative biomass and relative fishing mortality rate, among other information.

AGRAPH provides quick, presentation-quality graphics of certain ASPIC and ASPICP results. Graphs are visible on screen and may be sent to a Windows printer or graphics file in one of several formats.

FTEST performs a statistical F-test on ASPIC models.

## 8. DESCRIPTION

The program uses forward projection methods to fit a stock-production model to catch and effort data without making an equilibrium approximation. A Nelder-Mead (1965) “polytope” or “simplex” optimizer is used to minimize the sum of squared residuals in catch, CPUE, or effort; in each case, minimization is done in log transform, under assumption of lognormal observation error and no process error. To increase the chance of locating a global minimum (in the objective function), the optimizer is repeatedly restarted until it converges to the same solution several times in a row. An optional Monte-Carlo search can be invoked if necessary. The program uses an analytical solution of the catch and biomass projection equations of the logistic model, and corresponding numerical approximations for the Fox and generalized models. Numerous data checking features are used to promote reliable estimation.

Please see equations and description in Prager (1994) and Prager (1995). The method is also described in Quinn and Deriso (1999), p. 77. The parameterization of the Pella–Tomlinson (generalized) production model is that of Fletcher (1978)

## 9. REQUIRED INPUTS

1. One to ten series of data on (1) relative abundance or fishing effort and (2) removals
2. Starting guesses and constraints on parameters ( $K$ ,  $MSY$ ,  $q$ ,  $B_1/K$ ).
3. Some control parameters are required (e.g., convergence criteria), but the sample input files provide values that are sufficient, and most changes results in worse results.
4. Items for user convenience, such as run title and text description of each data series.

## 10. PROGRAM OUTPUTS

An ASCII file (120 columns wide) is written after each ASPIC run. It contains the following information

### For all runs:

1. ASPIC version information, author contact information, run date and time, title of run, name of input file, reference to primary-literature citation.
2. Values of control variables and starting guesses from input file.
3. If more than one data series was used, a correlation matrix among relative abundance measures derived from or supplied in each series.
4. Program status information (i.e., did the program seem to converge on estimates?).
5. Goodness of fit information (ANOVA table and R-squared for each data series)
6. Estimates of the following parameters and management quantities:

- Starting biomass relative to  $K$
- Maximum sustainable yield ( $MSY$ )
- $K$  (carrying capacity)
- $\phi$  (shape of production curve expressed as ratio  $B_{msy}/K$ )
- $q$  (catchability coefficient) for each data series
- $B_{msy}$  (biomass yielding  $MSY$ )
- $F_{msy}$  (fishing mortality rate yielding  $MSY$  at  $B_{msy}$ )
- $n$  (exponent in production function, functionally related to  $\phi$ )
- $B./B_{msy}$  (ratio of final year biomass to  $B_{msy}$ )
- $F./F_{msy}$  (ratio of final year fishing mortality rate to  $F_{msy}$ )
- $F_{msy}/F.$  (reciprocal of preceding quantity)
- $Y.(MSY)$ , yield available in next period at  $F_{msy}$  (approximation)
- $fmsy$  (fishing-effort rate at  $MSY$ ) for each data series

5. Estimated population trajectory through time, both absolute (not recommended for assessment use) and relative to  $B_{msy}$ .

6. Estimated F trajectory through time, both absolute (not recommended for assessment use) and relative to Fmsy.
7. For each data series, trajectories of estimated and observed CPUE through time.
8. For each data series, plot of residuals through time.

**For non-bootstrapped runs:**

1. For each data series, plot of observed and fitted CPUE over time.
2. Plot of the estimated population trajectory (B) and fishing mortality (F) over time. These quantities are plotted relative to their respective benchmarks (Bmsy and Fmsy).

**For bootstrapped runs:**

1. A table of parameter and benchmark estimates, with bias-corrected 50% and 80% confidence intervals.
2. Files with detailed data on the bootstrap, for use by ASPICP in making projections.

**Optionally, for all runs:**

Two special ASCII output files. First, a \*.prn file with observed and estimated time trajectories in an format that can be read easily by S-Plus, R, SAS, Excel, etc. This file is intended for making graphs and such. Second a \*.sum file that contains summary results of every ASPIC run made in the current directory, and is intended to facilitate simulation studies. This can also be read easily by S-Plus or R (and possibly other programs).

## 11. DIAGNOSTICS

1. Goodness-of-fit information (ANOVA table and R-squared).
2. Plots of estimated vs. observed CPUE.
3. Time plots of residuals for each series.
4. Checks that parameters are not at constraints; warning messages if they are.
5. Plots of population trajectories.
6. Values of coverage index and nearness index (experimental).
7. When fitting generalized model, the Akaike Information Criterion value for both the logistic and generalized fits; also, an F-test comparing the two models.
8. Limits on number of iterations allowed for convergence.
9. Error codes and error messages on screen, on the output, and in the summary files whenever a recognized error condition is encountered.

## 12. OTHER FEATURES

ASPIC is the main program in a related set of four programs, termed by the author the "ASPIC Suite." The four programs are

ASPIC	Fits stock-production model to data
ASPICP	Makes stochastic projections from ASPIC bootstrap runs
FTEST	Compares two statistically nested ASPIC runs
AGRAPH	GUI program to make simple, publication-quality graphs of ASPIC runs

Special features of ASPIC include the following

1. Can analyze up to 10 data series, including series with removals (fisheries) and series without removals (indices).
2. Can set any parameter constant, rather than estimating it.
3. Can apply constraints to most parameters.
4. Can condition fit on either catch or effort.

5. When conditioning on catch, can estimate missing values of effort or CPUE.
6. When conditioning on effort, can in many cases estimate missing values of catch.
7. In multi-data-series problems, can use iteratively reweighted least squares to obtain maximum-likelihood estimates of appropriate statistical weights for each series.
8. Uses bootstrapping to obtain bias-corrected nonparametric confidence intervals
9. Provides standard (least squares) and robust (least absolute values) fitting methods.
10. Can fit generalized model either directly or at a grid of shape parameters.

### **13. HISTORY OF METHOD PEER REVIEW**

The basic model underlying ASPIC was described by Lotka (1924). It was introduced to fishery science in a quantitative way by Schaefer (1954, 1957). The fitting algorithm (forward projection) was applied to this problem by Pella (1967), who also derived the analytical solution conditioned on effort, and by Pella and Tomlinson (1969). Both of the preceding authors described applications to yellowfin tuna. A system of equations similar to that used in ASPIC was described by Schnute (1977). The polytope optimization method is described in Nelder and Mead (1965). The specific combination of theory, fitting algorithm, and optimization technique, along with several characteristic extensions, are detailed in Prager (1994). Some aspects of application to Atlantic swordfish are described in Prager et al. (1995). Prager et al. (1996) examined performance under changing gear selectivity. Prager and Goodyear (2001) examined performance with inconsistently measured data. Prager (2002) compared logistic and generalized estimates from ASPIC; in the course of doing so, the correctness of the generalized estimates was examined. Williams and Prager (2002) compared ASPIC to PRODFIT in fitting the generalized model. Shertzer and Prager (2002) compared two objective functions (SSE and LAV) available in ASPIC to a third objective function (LMS) that was temporarily implemented (and found problematic). ASPIC has been used in numerous peer-reviewed assessments in the U.S. and by several international fish conservation and management bodies, including NAFO, ICES, and ICCAT.

### **14. STEPS TAKEN BY PROGRAMMER FOR VALIDATION**

Great care has been taken to write the program in standard-compliant Fortran 95 and to use the error-checking facilities of that language. The program has been compiled under several compilers with all error-checking options enabled to detect any errors in array bounds, argument matching, undefined or nonstandard language (Fortran) features, and so on. Collaborators have reviewed many sections of the source code.

The author has written a simulation program and used it to generate numerous simulated data sets. These have been analyzed by ASPIC to verify that correct answers are obtained. As well, the author has offered to correct any bug encountered or suspected by others, and has analyzed several such incidents. ASPIC was used in a simulation study of the generalized production model in which nearly 50,000 simulated data sets were fit (Williams and Prager 2002). Any unexpected behavior of the program was analyzed and corrected.

### **15. TESTS CONDUCTED BY OTHERS**

Several simulation studies have been published using ASPIC. One that comes to mind is Cadrin et al. (1999). Also, Polacheck (1993) compared statistical assumptions and preferred observation-error estimators such as ASPIC to process-error estimators.

### **16. NOTES BY ICCAT**

An early release of ASPIC 5.0 was tested by the catalog committee. Some problems were found in cases when input data series included records with missing values or zeroes. The author addressed these concerns, as reflected in Table 3 (Section 6.4.1) of the User's Manual.

### **17. SOURCES CITED**

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- Williams, E. H., and M. H. Prager. 2002. Comparison of equilibrium and nonequilibrium estimators for the generalized production model. *Can. J. Fish. Aquat. Sci.* 59: 1533-1552.

## 18. AUTHOR-S NOTES

This version of ASPIC contains several improvements; most notably, the inclusion of the generalized (and as a special case, the Fox) production model. To improve ease of use, the programs are now distributed as a self-installing executable file for 32-bit Windows. The installer includes program files, support files, documentation, and sample input and output files. It also installs shortcuts that allow command-line or drag-and-drop operation and makes necessary adjustments to the user's system. An uninstall program is also provided, which reverses all the preceding actions.

The installer also includes REPAST, a program written by the author and others (Prager et al. 2003) for computing target reference points. REPAST has not been reviewed by ICCAT.

The author is evaluating the practicality of expanding ASPIC to include features such as the NISS fitting algorithm described by Punt (2003) or Bayesian estimation.

## **APPENDIX 1. ALGORITHM**

Please refer to Prager (1994) and Prager (2002).

## **APPENDIX 2. USER'S GUIDE**

The user's guide is included in the installation as Adobe Acrobat document ASPICMAN.PDF. A Quick Reference Guide is also included.

## **APPENDIX 3. WORKED EXAMPLE**

The sample files installed with the ASPIC Suite include several worked examples. Also, typing "aspic -help" on the command line will cause ASPIC to generate a sample input file that is heavily commented. That sample can be edited and used as a template for the user's input files. ASPIC can be run on the sample input file with the command "aspic sample" and the output file examined.

## **APPENDIX 4. SOURCE CODE**

Available on request.