ADCAM User Manual

(Draft Version)

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Contents

Part I

Model overview

Chapter 1

Introduction

ADCAM is a statistical catch-at-age model, originally developed for Icelandic cod stock assessment. It is designed and written by Hoskuldur Bjornsson, with contributions by Arni Magnusson. The model is in continuous development and has many optional variations. This draft version of the manual does not describe all model variations in detail.

The main difference between the current version of ADCAM and recent versions is that the current model can handle projections many years into the future. Previous versions were designed to evaluate harvest rules that depend on future biomass estimates, but this model's harvest rule depends only on the current and previous year, which simplifies the model implementation.

Previous versions of ADCAM have been used in the Icelandic cod stock assessment in recent years (ICES 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009). It is written in the AD Model Builder programming language (ADMB Project 2008).

Chapter 2

Population dynamics

2.1 Annual step

The population dynamics are governed by the equation:

$$N_{t+1,a+1} = N_{t,a} e^{-(F_{t,a}+M_a)} \tag{2.1}$$

where $N_{t,a}$ is population size at time t and age a, F is fishing mortality rate, and M is natural mortality rate.

Plus group acccumulation is optional:

$$N_{t+1,A} \quad = \quad N_{t,A-1} e^{-(F_{t,A-1}+M_{A-1})} + N_{t,A} e^{-(F_{t,A}+M_A)} \tag{2.2}$$

where A is the oldest age in the model.

2.2 Initial stock structure

The population size at the start of the first year is modelled as free parameters, implemented as deviates from an overall geometric mean:

$$N_{\text{init},a} = \mu_{\text{init}} \times \exp({}_{\text{init}}\varepsilon_a), \quad a \in \{2, \ldots, A\} \tag{2.3}$$

where 'init' is the first year, μ_{init} is the geometric mean population size across ages in the first year, ${}_{\text{init}}\varepsilon_a$ are exponential deviates that are forced to sum to zero, $\sum {}_{\text{init}}\varepsilon_a = 0$. The initial population size at age 1 is modelled as recruitment.

2.3 Recruitment

Historical recruitment is modelled as free parameters, implemented as deviates from a long-term geometric mean:

$$N_{t,1} = \mu_R \times \exp({}_R\varepsilon_t) \tag{2.4}$$

where μ_R is the long-term geometric mean recruitment and ${}_R\varepsilon_t$ are exponential deviates that are forced to sum to zero, ${}_R\varepsilon_t = 0$.

For cohorts that have few or no years of catch-at-age data, a likelihood component (Eq. 4.10) is used to pull the recruitment slightly towards a Ricker stock-recruitment function:

$$N_{t,1} = R_{\max} \times \frac{SSB}{SSB_{\max}} \times \exp\left(1 - \frac{SSB}{SSB_{\max}}\right) \tag{2.5}$$

where $R_{\max}$ is the deterministic maximum recruitment, SSB is spawning biomass, and $SSB_{\max}$ is the spawning biomass that gives $R_{\max}$.

Alternatively, the user can choose between several other recruitment functions, including Beverton-Holt, segmented regression, or a fixed geometric mean. Furthermore, egg production can be used instead of spawning biomass, and a negative time trend can be applied after 1985.

2.4 Migration events

Migration events can be modelled as free parameters, where fish in a specific year at a specific age can exit or enter the population permanently:

$$N_{t,a} = N_{t-1,a-1} e^{-(F_{t-1,a-1}+M_{a-1})} + \lambda_{t,a} \tag{2.6}$$

where $\lambda_{t,a}$ are migrants exiting (negative) or entering (positive) the population at time t and age a. In the case of Icelandic cod, this is used to estimate the magnitude of documented migration events from Greenland into Icelandic waters.

2.5 Fishing mortality and selectivity

Fishing mortality is a product of annual fishing mortality rate and age-specific selectivity:

$$F_{t,a} = F_t S_a \tag{2.7}$$

Annual fishing mortality rate is modelled as free parameters, implemented as deviates from a long-term geometric mean:

$$F_t = \mu_F \times \exp({}_F\varepsilon_t) \tag{2.8}$$

where μ_F is the long-term geometric mean fishing mortality rate (of fully selected ages) and ${}_F\varepsilon_t$ are exponential deviates that are forced to sum to zero, $\sum {}_F\varepsilon_t = 0$.

Selectivity is modelled as free parameters for ages a_r, the lowest age present in catch at age data (recruited), up to but not including a_f, the first age that is fully selected:

$$S_a = \begin{cases} 0, & a < a_r \\ \theta_a, & a_r \le a < a_f \\ 1, & a \ge a_f \end{cases} \tag{2.9}$$

where S is selectivity and θ are estimated parameters.

Different selectivity patterns can be used for different periods. In the case of Icelandic cod, there is a priori reason to believe that the selectivity pattern changed around 1976 when the foreign fleets left, and again around 1994 after the

TAC was reduced considerably. With period-specific selectivities, the functions become:

$$F_{t,a} = F_t S_{t,a} \tag{2.10}$$

$$S_{t,a} = \begin{cases} 0, & a < a_r \\ \theta_{P,a}, & a_r \leq a < a_f, \quad t \in P \\ 1, & a \geq a_f \end{cases} \tag{2.11}$$

where P is a period, a defined set of years.

Chapter 3

Biomass calculations

3.1 Spawning stock

The spawning biomass is:

$$SSB_t = \sum_a N_{t,a}\phi_{t,a}w'_{t,a} \times \exp\left[-({}_{FS}p_a F_{t,a} + {}_{MS}p_a M_a)\right] \tag{3.1}$$

where ϕ is maturity, w' is weight at age during the spawning season, and ${}_{FS}p$ and ${}_{MS}p$ are proportions of annual fishing and natural mortalities that occur before spawning.

3.2 Reference stock

The reference biomass is the biomass of ages 4 and older:

$$B_{4+,t} = \sum_{a=4}^{A} N_{t,a}w_{t,a} \tag{3.2}$$

Chapter 4

Likelihood components

4.1 Objective function

The objective function consists of four likelihood components:

$$f = -\log L_Y - \log L_C - \log L_I - \log L_R \tag{4.1}$$

describing the model fit to landings, commercial catch at age, and survey catch at age, as well as recruitment process error. These likelihood components are described below.

4.2 Landings

The uncertainty about observed landings is assumed to be lognormal:

$$-\log L_Y = \sum_t \left[\frac{(\log Y_t - \log \hat{Y}_t)^2}{2_Y\sigma^2} + \log {}_Y\sigma \right] \tag{4.2}$$

where Y is the observed landings, $\hat{Y}$ is the predicted landings, and ${}_Y\sigma$ is the magnitude of the uncertainty. The predictions are calculated using the catch equation multiplied by the weight at age:

$$\hat{Y}_t = \sum_a N_{t,a} \frac{F_{t,a}}{F_{t,a} + M_a} \left[1 - e^{-(F_{t,a}+M_a)} \right] w_{t,a} \tag{4.3}$$

4.3 Commercial catch at age

The uncertainty about observed commercial catch at age is assumed to be lognormal:

$$-\log L_C = \sum_t \sum_a \left[\frac{(\log[C_{t,a} + \alpha_C] - \log[\hat{C}_{t,a} + \alpha_C])^2}{2_C\sigma_a^2} + \log {}_C\sigma_a \right] \tag{4.4}$$

where C is the observed commercial catch at age in numbers, $\hat{C}$ is the predicted commercial catch at age, α_C is a small log-transformation constant, and ${}_C\sigma$ is the magnitude of the uncertainty. The predictions are calculated using the catch equation:

$$\hat{C}_{t,a} = N_{t,a} \frac{F_{t,a}}{F_{t,a} + M_a} \left[1 - e^{-(F_{t,a}+M_a)}\right] \tag{4.5}$$

For estimation purposes, the magnitude of the uncertainty is separated into age-specific relative coefficients (ξ) and an overall scaler (τ):

$$_C\sigma_a = {_C\xi_a} \times {_C\tau} \tag{4.6}$$

4.4 Survey catch at age

The uncertainty about observed survey catch at age is assumed to be lognormal:

$$-\log L_I = \sum_t \sum_a \left[\frac{(\log[I_{t,a} + \alpha_I] - \log[\hat{I}_{t,a} + \alpha_I])^2}{2{_I\sigma_a^2}} + \log {_I\sigma_a} \right] \tag{4.7}$$

where I is the observed survey catch at age in numbers, $\hat{I}$ is the predicted survey catch at age, α_I is a small log-transformation constant, and $_I\sigma$ is the magnitude of the uncertainty. The predictions are calculated using an optional power relationship:

$$\hat{I}_{t,a} = q_a \big(N_{t,a} \exp\left[-({_{FI}p}F_{t,a} + {_{MI}p}M_a)\right]\big)^{_I\beta_a} \tag{4.8}$$

where q is survey catchability, $_{FI}p$ and $_{MI}p$ are proportions of annual fishing and natural mortalities that occur before the survey.

For estimation purposes, the magnitude of the uncertainty is separated into age-specific relative coefficients (ξ) and an overall scaler (τ):

$$_I\sigma_a = {_I\xi_a} \times {_I\tau} \tag{4.9}$$

4.5 Recruitment

Process error recruitment deviates from the deterministic stock-recruitment function are assumed to be lognormal:

$$-\log L_R = \sum_t \left[\frac{(\log N_{t,1} - \log \hat{N}_{t,1})^2}{2{_R\sigma_t^2}} + \log {_R\sigma_t} \right] \tag{4.10}$$

where $_R\sigma_t$ is the magnitude of this process error. The predictions are calculated using the stock-recruitment function (Eq. 2.5).

The time-specific magnitude of the process error is estimated with one overall scaler ($_RCV$) with an optional power relationship:

$$_R\sigma_t = \frac{_RCV}{(SSB_t/SSB_{\text{ref}})^{_R\beta}} \tag{4.11}$$

where SSB_{ref} is a defined reference spawning biomass and $_R\beta$ is a power coefficient. When $_R\beta$ is zero, the relationship simplifies to $_R\sigma_t = {_RCV}$.

Chapter 5

Fitting the model

5.1 List of estimated parameters

In order of appearance in the ADMB model code and output files:

$\lambda_{t,a}$	Migration events
μ_R	Geometric mean recruitment
${}_R\varepsilon_t$	Recruitment deviates
μ_{init}	Geometric mean of initial population
${}_{\text{init}}\varepsilon_a$	Initial population deviates
θ_a	Selectivities
${}_C\tau$	Commercial catch at age uncertainty scaler
${}_I\tau$	Survey catch at age uncertainty scaler
${}_I\beta_a$	Survey catchability power coefficient
q	Survey catchability
μ_F	Geometric mean fishing mortality rate
${}_F\varepsilon_t$	Fishing mortality deviates
$R_{\max}$	Recruitment shape parameter
$SSB_{\max}$	Recruitment shape parameter
${}_RCV$	Recruitment process error scaler

5.2 Minimization

The objective function is minimized using automatic differentiation (ADMB Project 2008).

5.3 Uncertainty

Two different approaches can be used to evaluate the uncertainty about estimated parameters and other quantities of interest: the delta method and Markov-chain Monte Carlo (MCMC).

Chapter 6

Future projections

(Described in the report on Icelandic cod harvest rule.)

Part II

Running the model

Chapter 7

Command line interface

7.1 Prerequisites

ADCAM can be run on Windows and Linux machines. The source code is in one file, `islcod.tpl`, and the compiled version is one executable file called `islcod.exe` (Windows) or simply `islcod` (Linux). It requires several input files to run, as described below.

7.2 General run

The model fitting is invoked from the shell command line by typing the name of the executable:

```
$ islcod
```

Once the model has converged, output files have been created in the current directory. These include point estimates and standard errors of estimated parameters and other quantitites of interest.

7.3 MCMC analysis

To evaluate the uncertainty using Markov-chain Monte Carlo (MCMC) analysis, there are three command line options. First, the model is invoked with `-mcmc` and the desired number of MCMC iterations, as well as `-mcsave` and the interval between iterations that are saved to MCMC chains to be analyzed, e.g.:

```
$ islcod -mcmc 1000000 -mcsave 1000
```

Once the iterations are finished, usually after some hours, the chains are written to MCMC output files with `-mceval`:

```
$ islcod -mceval
```

Chapter 8

Input files

All input and output files are plain text files. Several input values are from previous versions of ADCAM and are ignored in the current version. The following description uses excerpts from input and output files from a model run called `RickerSeperable3periods1Rmax`.

8.1 islcod.dat

The main input file specifies the names of other input files, dimensions, flags, and parameters that the user is likely to change between runs:

```
catchandstockdata.dat
catchresiduals.dat

1955  2008 55 2008
1 14 3 0 0

stockparameters.dat
catchparameters.dat
likelihoodparameters.dat
outputparameters.dat
# nsurveys
1
1985 2009  1 10 10 6 1 1
surveypar.dat surveydata.dat surveyresid.dat
# SSBRectype etc.
2  200000 500 1 0.1 0 0
2 2 3 -1 -1 -1
# Migrations
11 # number of
# Prognosisfile
codprognosis.dat
nofile1
3
```

The first block specifies the first and last assessment year, number of projected years, last year with catch at age data, first and last age in model, first age in catch data, plus group flag (0:no, 1:yes), and the delay between hatching and survey (0 if survey includes age 1 and survey conducted in the assessment year is included).

The second block specifies the number of surveys, first and last year of survey data, first and last age in survey data, first fully selected age in surveys, first age with survey catchability power coefficient set to 1, years between final catch data and final survey data, and the survey type (currently ignored).

The third block specifies the recruitment function (1:Beverton-Holt, 2:Ricker, 3:Ricker based on egg production instead of SSB, 4:Beverton-Holt based on egg production instead of SSB, 5:segmented regression, 6:fixed mean, all functions implemented with optional time drift), $R_{\max}$, $SSB_{\max}$, ${}_{R}CV$, autocorrelation of residuals (currently ignored), ${}_{R}\beta$, and a negative time trend in recruitment after 1985, followed by the estimation phases for the recruitment parameters (negative means not estimated).

The last block specifies the number of migration events and the number of selectivity periods.

8.2 catchandstockdata.dat

The catch and stock data file has one row per `year` and `age` combination:

```
# year age     cno       cwts     stockwts  sexmat   ssbwts
1955    1        -1       -1       15       -1       -1
1955    2        -1       -1       141      -1       -1
1955    3        4790     827      250      0.019    645
1955    4        25164    1307     588      0.022    1019
...
2008    14       4        17320    17320    1        17320
```

where `cno` is catch at age (thousands), `cwts` is the average body weight (g) in the catch, `stockwts` is the average body weight in the spring survey, `sexmat` is the maturity ogive from the spring survey, and `ssbwts` is the average body weight (g) of mature fish in the spring survey.

8.3 stockparameters.dat

The stock parameters file specifies age-specific M, the proportion of M and F applied before spawning, youngest age included in the spawning biomass, and year and age of migrations arriving from Greenland:

```
# Natural mortality
#Natural mortality
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2  0.2
# PropofM and PropofF before spawning
0.085 0.180 0.248 0.296 0.382 0.437 0.477 0.477 0.477  0.477 0.477 0.477
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25
# min ssbage
4
# 11 migrations
1958  1959 1960 1962  1964 1969 1970  1972 1980 1981 1990  # year
 9     9    10   9     10   8     8    9    7     8   6    #age
```

8.4 catchparameters.dat

The catch parameters file specifies the years when selectivity periods end, an age-specific vector called `ProcessError` (currently ignored) and a matrix called `basfunc` (currently ignored):

```
1976 1994
#ProcessError
# 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
#           1     2     3     4
 1.0000000000 0.00000000 0.00000000 0.0000000000
 0.7513148009 0.22539444 0.02253944 0.0007513148
```

```
0.5477084899 0.36513899 0.08114200 0.0060105184
0.3846731781 0.43275733 0.16228400 0.0202854996
0.2577009767 0.44177310 0.25244177 0.0480841473
0.1622839970 0.40570999 0.33809166 0.0939143501
0.0939143501 0.33809166 0.40570999 0.1622839970
0.0480841473 0.25244177 0.44177310 0.2577009767
0.0202854996 0.16228400 0.43275733 0.3846731781
0.0060105184 0.08114200 0.36513899 0.5477084899
0.0007513148 0.02253944 0.22539444 0.7513148009
0.0000000000 0.00000000 0.00000000 1.0000000000
```

8.5 likelihoodparameters.dat

The likelihood parameters file determines the likelihood functions in the model:

```
#SigmaCInp
1 1 0.181  0.144  0.122  0.110  0.105  0.106  0.114  0.130 0.157  0.202 ...
# CatchReslution should maybe set as  lower percent if robust
0.005
#Sigmatotalcatch
0.1
# CatchRobust - SurveyRobust surveyrobust might have to be a vector
0 0
# Likelihood weights 10.  Might have to have one for each survey so
# Number might change
1 1 1 1 1 1 1 1 3 1
```

where `SigmaCInp` is a vector with relative age-specific uncertainty about observed catch at age, `CatchResolution` is a small constant added to catch at age before log-transforming, `Sigmatotalcatch` is the uncertainty about observed annual landings, `CatchRobust` and `SurveyRobust` are flags to use alternative likelihood functions for commercial and survey catch at age, and the likelihood weights refer to (1) commercial catch at age, (2) recruitment, (3) survey catch at age, and (4) landings. Likelihood component 9 stabilizes the estimation of the geometric mean fishing mortality rate, and ends up very small.

8.6 codprognosis.dat

The cod prognosis file describes future projections:

```
# Data for prognosis
3       # Catcrule icecod
0.12    # CV in weights
0.6     # weightcorr
0.15    # Assessmentcv
0.45    # Assessmentcorr
5       # Selection in prognosis mean of last 5 years.
3       # Mean weight in prognosis mean of last 3 years.

# Only for harvest rule 3
0.2     #Ratio caught
150     #Current Tac
139     #Tac left.
```

The first block specifies the catch rule (1:TAC, 2:F, 3:current harvest rule for Icelandic cod), annual variability and autocorrelation in weight at age, annual variability and autocorrelation in assessment error, number of recent years to base future selectivity on, and number of recent years to base future weight at age on.

The second block specifies the annual harvest rate relative to B_{4+}, the current TAC, and how much of that TAC is remaining when future projections start.

8.7 outputparameters.dat

The output parameters file describes quantities that are reported, but do not play a role inside the model:

```
#MeanSel
0 0 0 1  1 1 1 1 1 1 1 1 1 1
#Refage1 # Refage2 WeightedF
5 10 0
```

where `MeanSel` is a selectivity to calculate vulnerable biomass, `Refage1` and `Refage2` are first and last age in the reference F, and `WeightedF` (currently ignored) is whether the reference F is the weighted average (0:no, 1:yes).

8.8 surveydata.dat

The survey data file has one row per `year` and `age` combination:

```
#year   age     ObsSurveyNr
1985    1       16.54
1985    2       111.11
1985    3       34.86
...
2009    10      1.15
```

where `ObsSurveyNr` is the survey catch at age (thousands).

8.9 surveypar.dat

The survey par file specifies the proportions of annual fishing and natural mortalities that occur before the survey, a small constant added to catch at age before log-transforming, a flag indicating whether a fourth column in `surveydata.dat` contains weight at age from the survey (0:no, 1:yes), first and last age in survey data, and a vector with relative age-specific uncertainty about observed catch at age:

```
0.2
0.2
# Resolution should probably be a vector
0.7
# Survey weight not given
0
1 10
0.413 0.156 0.207 0.224 0.189 0.158 0.191 0.235 0.270 0.265
```

Chapter 9

General output files

9.1 islcod.cor

The `islcod.cor` file contains the point estimate, delta-method standard error, and covariance for all estimated parameters and reported quantities.

```
The logarithm of the determinant of the hessian = 950.301
index   name                      value      std dev       1       2      ...
    1   lnMigrationAbundance    9.4092e+00 3.5989e-01   1.0000
    2   lnMigrationAbundance    9.6922e+00 4.5331e-01   0.0876  1.0000
    3   lnMigrationAbundance    9.2618e+00 5.2138e-01  -0.0082 -0.6575  ...
  ...
  838   RelSpawningstock        2.5081e+00 2.7979e-01  -0.0147 -0.0188  ...
```

It is a superset of the `.std` file, and is only created when the model converges properly, giving a positive definite Hessian.

9.2 islcod.par

The `islcod.par` file contains the number of estimated parameters, objective function value, maximum gradient component, and point estimates for all estimated parameters.

```
# Number of parameters = 184  Objective function value = -1121.19  Maximum ...
# lnMigrationAbundance:
 9.40918 9.69221 9.26176 9.73003 1.00002 10.3137 9.53212 9.72217 9.43828 ...
# lnMeanRecr:
12.4060687361
# lnRecr:
 -0.0154664092733 0.267555306899 0.626313604443 -0.0724797574865 ...
# lnMeanInitialpop:
10.2955049067
# lnInitialpop:
 1.77705402801 1.62950746585 1.96697675297 1.90341377097 1.31198416550 ...
# EstimatedSelection:
 -2.23909557205 -2.72795548271 -3.50883540331
 -1.18305725276 -1.11062367593 -2.11561791654
 -0.878030616784 -0.508396756090 -1.36068880508
 -0.803883974223 -0.178181932762 -0.964652823554
 -0.607736398687 0.0649039658054 -0.734913122800
 -0.415533031922 0.199999970168 -0.607228881334
 -0.319238766404 0.184727319530 -0.463207040934
 -0.126141415995 0.126572375191 -0.282024582086
# Catchlogitslope:
2.24819425926
# Catchlogitage50:
6.10462371836
```

```
# logSigmaCmultiplier:
0.278109181157
# AbundanceMultiplier:
0.00000000000
# SurveyPowerest:
 2.28657022593 2.06189629987 1.84623772560 1.85766498735 1.62460967376 ...
# SigmaSurveypar:
 -0.0712967697216
# SurveylnQest:
 -26.0900980774 -21.8357297819 -18.3956690963 -17.9763591528 ...
# lnMeanEffort:
-0.144435463543
# lnEffort:
 -0.410121410544 -0.414095021426 -0.305386586185 -0.187201062764 ...
# estSSBRecParameters[1]:
12.6337104382
# estSSBRecParameters[2]:
6.10228931516
# estSSBRecParameters[3]:
-1.04291648872
# estSSBRecParameters[4]:
-2.30258509299
# estSSBRecParameters[5]:
0.00000000000
# estSSBRecParameters[6]:
0.00000000000
```

9.3 islcod.rep

The `islcod.rep` file contains the value of each likelihood component and the age-specific uncertainty about observed survey catch at age.

```
LnLikelicomp -701.078 -29.3175 -269.462 -121.501 0 0 0 0 0.0572808 0

SigmaSurvey
 0.38458 0.145265 0.192755 0.208586 0.175994 0.147127 0.177856 0.218829 ...
```

9.4 islcod.std

The `islcod.std` file contains the point estimate and delta-method standard error for all estimated parameters and reported quantities.

```
   index   name                       value      std dev
     1   lnMigrationAbundance    9.4092e+00 3.5989e-01
     2   lnMigrationAbundance    9.6922e+00 4.5331e-01
     3   lnMigrationAbundance    9.2618e+00 5.2138e-01
   ...
   838   RelSpawningstock        2.5081e+00 2.7979e-01
```

It is a subset of the `.cor` file, and is only created when the model converges properly, giving a positive definite Hessian.

9.5 resultsbyage

The results by age file contains age-specific estimates.

```
age      meansel  progsel  SigmaC   SigmaSurvey1     SurveylnQ1       SurveyPower1
1        0        0        0        0.38458 4.6689e-12       2.28657
2        0        0        0        0.145265         3.28748e-10      2.0619
3        0.107698          0.0589687        0.239034         0.192755         ...
4        0.373905          0.237513         0.190171         0.208586         ...
5        0.605724          0.505301         0.161117         0.175994         ...
6        0.768261          0.750838         0.145269         0.147127         ...
```

```
7       0.958976        0.944758        0.138666        0.177856        ...
8       1.11998 1.07343 0.139987        0.218829        0.000592096     1
9       1.20135 1.23971 0.150552        0.25142 0.000559185     1
10      1.34571 1.48596 0.171682        0.246764        0.000587263     1
11      1.50554 1.97011 0.207339        0       1       1
12      1.50554 1.97011 0.266767        0       1       1
13      1.50554 1.97011 0.364494        0       1       1
14      1.50554 1.97011 0.529573        0       1       1
```

meansel is mean selectivity, progsel is the selectivity used in the projections, SigmaC is the uncertainty about observed commercial catch at age, SigmaSurvey1 is the uncertainty about observed survey catch at age, SurveylnQ1 is survey catchability, and SurveyPower1 is the survey catchability power coefficient.

9.6 resultsbyyear

The results by year file contains year-specific estimates.

```
year     RefF     CalcCatchIn1000tons     CatchIn1000tons Spawningstock ...
1955    0.351866         538.463 545.25  706.431 27.0662 1599.42 1647.74 ...
1956    0.350471         461.147 486.909 565.53  21.0788 1396.57 1445.15 ...
1957    0.390718         454.707 455.182 556.447 20.826  1241.18 1321.39 ...
...
2063    0.303631         286.938 -1      614.502 19.4079 1156.91 1211.03 ...
```

RefF is the reference F_{5-10}, CalcCatchIn1000tons is modelled landings, CatchIn1000tons is observed landings, Spawningstock is spawning biomass, Eggproduction is egg production, CbioR is vulnerable biomass, RefBio1 is B_{4+} using survey weight at age, RefBio2 is B_{4+} using weight at age from commercial catch (current definition of B_{4+}), PredictedRecruitment is recruitment, N1, N3, and N6 is numbers at age 1, 3, and 6, CalcSurveyBiomass1 is modelled survey biomass, and ObsSurveyBiomass1 is observed survey biomass.

9.7 resultsbyyearandage

The results by year and age file has one row per year and age combination.

```
year     age      N        Z         StockWeights     M         F         CalcCno ...
1955    1       240531  0.2     15      0.2     0       0       0       0 ...
1955    2       175003  0.2     141     0.2     0       0       0       0 ...
1955    3       150997  0.261197        250     0.2     0.0611973       ...
...
2063    14      529.338 0.798184        14291.7 0.2     0.598184        ...
```

N is numbers at age, Z is Z, StockWeights is weight at age in survey catch, M is M, F is F, CalcCno is modelled commercial catch at age, CatchWeights is weight at age in commercial catch, SSBWeights is weight at age of mature fish, StockMaturity is maturity, ObsCno is observed commercial catch at age, CatchDiff is the log difference between observed and modelled commercial catch at age, CalcSurveyNr1 is modelled survey catch at age, ObsSurveyNr1 is observed survey catch at age, and SurveyResiduals1 is the log difference between observed and modelled survey catch at age.

Chapter 10

MCMC output files

All MCMC output files have the file extension `.mcmc`. They contain chains for analyzing in an external program, such as the R packages "coda" (Plummer et al. 2006) and "scapeMCMC" (Magnusson 2005).

Part III

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