MULTIFAN-CL TRAINING

TUTORIAL 1: CATCH-CONDITIONED METHOD FOR ESTIMATING FISHING MORTALITY

10 FEBRUARY 2022

Aims

- A recap of the session 16 Dec. for theory of catch-conditioned (CC) method and its implementation in MULTIFAN-CL
- Review of the flags associated with the various CC components
- Using an example, make a conversion from an existing catch-errors (CE) model to the CC model

But first…

- Penguin Tutorial directory:
- nouofplinuxfs01:/home/shares/assessments/Stock assessment_training/MFCL_training_2022/**tutorial_1_ccond**
  - This presentation
  - A draft CC overview and Guide
  - The example model for the conversion
- Please now set up a working directory on your WSL for running the example: (copy the complete directory from Penguin)

But second…

- Current benchmark MULTIFAN-CL executables:
- nouofplinuxfs01:/home/shares/assessments/MFCL/**2021-12-03_devvsn14**
  - -rwxrwxrwx 1 nickd domain users 4720128 Jan 26 09:08 mfclo64.exe
  - -rwxrwxrwx 1 nickd domain users 9548440 Jan 26 09:10 **mfclo64_lin**
  - -rwxrwxrwx 1 nickd domain users 88680712 Jan 26 09:22 mfclo64_mac
  - -rwxrwxrwx 1 nickd domain users 82356648 Jan 26 09:21 mfclsdbg64_lin
  - -rwxrwxrwx 1 nickd domain users 103215972 Jan 26 09:22 mfclsdbg64_mac
- Please now copy the Linux executable from Penguin)

Catch-conditioned method (CC)

- “Standard method” in MULTIFAN-CL is the **catch-errors** model – estimates a LARGE number of independent parameters:
  - effort and catchability deviates
  - average catchability
  - and, a total catch likelihood is calculated
- CC is an alternative approach for estimating fishing mortalities for each fishing incident ($\mathbf{F_i}$) with fewer parameters

Catch-errors method

$$F_{atf} = s_{af} q_{tf} B_{tr_f}{}^{\beta} E_{tf}{}^{\zeta} e^{\varepsilon_{tf}}$$

and where

s_{af}	is the selectivity coefficient of fishery f for age-class a fish,
q_{tf}	is the catchability coefficient for fishery f in time period t,
B_{tr_f}	is a biomass index for region of the fishery r_f and time period t,
β	is the parameter for effect of biomass on catchability (default$=0$),
E_{tf}	is the fishing effort of fishery f in time period t, and
ζ	is the parameter for effect of effort on catchability (default$=1$),
ε_{tf}	represents transient deviations in effort.

Likelihood term for fitting to total observed catch

Catch-errors method

Key feature of this method:

- Fishing mortality parameters are estimated along with all other parameters within the integrated likelihood
- Therefore, parameters for deriving fishing mortality are available for all fishing incidents starting from the first model period

Catch-conditioned model

- Currently employs the **Baranov catch equation**
- Uses a Newton-Raphson fitting procedure to estimate the $\mathbf{F_i}$ that generates the observed catches within each period
- Applies d-double precision for the N-R solving procedure
- Entails substantially **fewer** parameters
- Pope’s approximation not yet completed

Four Elements to the CC method:

1. **Newton-Raphson procedure** to estimate $\mathbf{F_i}$ among the fisheries
2. **Regression of observed effort to $\mathbf{F_i}$** for each fishery (or grouping) – fml_effort_reltnshp

   - allows for incidents with **missing observed catches**
3. Calculation of the **initial population conditions** based upon the average fishing mortalities in the specified initial time periods
4. Survey fishery **CPUE likelihood**

First Element: Newton-Raphson

- **Unlike catch-errors fishing mortalities are not "known" for any periods at the initial model period**
- **Newton-Raphson fitting procedure** to estimate $\mathbf{F_i}$ among the fisheries having incidents within a given: region and period. (Inner minimization)
- Estimated $\mathbf{F_i}$ produces predicted catches = observed catches (no error)
- **Solves** for the fishing mortality levels among the fisheries given:
  - Selectivity
  - Fraction of natural mortality
- Generally only takes several iterations to solve, not a large processing overhead (noting fewer parameters for gradient calcs)
- Where **catch is missing**, the fml_effort_reltnshp is used to predict $\mathbf{F_i}$ based upon the observed effort

Second Element: fishing mortality levels : observed effort relationship (fml_effort_rltnshp)

- **Newton-Raphson procedure** provides $\mathbf{F_i}$ in all cases where an observed catch is available
- Regression of estimated $\mathbf{F_i}$: observed effort is done for such incidents
- orthogonal-polynomial regression model (c.f. orth-poly recrs):
  - Gram-Schmidt (G-S) design matrix (rows = obs.; cols = coefficients)
  - **Polynomial function** for the relationship
- Regression penalty is integrated to the overall minimization likelihood
- Where catch is unavailable, the fml_effort relationship is used to predict $\mathbf{F_i}$ based upon the observed effort

Third Element: Initial population

- **Typically initial population (N_{init}) is assumed to be at <u>exploited equilibrium</u>**
- **Average Z_t over specified initial periods *t***, c.f. age_flags(94,95) – used to derived **actual initial survival**
- **Newton-Raphson fitting procedure** estimates F_i
- But this is done sequentially **<u>after</u>** N_{init} is available
- The <u>actual</u> Z_t i.e. the survival rate, is not known at the beginning of year 1. Is only available after the model evaluation.

How to do this?

Third Element: Initial population

Method:

- Uses the integrated likelihood to solve for a “kludged” initial survival: **est_Z_t**
- **est_Z_t** is parameterized using cubic spline functions (few parameters)
- Derive the initial population using **est_Z_t**
- Complete the full model evaluation, and derive the **actual dynamic model survival over the specified initial periods: Z_t**
- Add the **penalty term** in respect of the: **est_Z_t** and **Z_t** ; this is integrated to the overall minimization likelihood
- With minimization **est_Z_t** and **Z_t** should converge

Fourth Element: survey fishery CPUE index likelihood

- Catch-errors method fits standardized effort via penalties on effort deviates and assumed constant catchability – **normal extraction fisheries**
- Catch-conditioned method identifies **survey fisheries** - data are input as a "normal" fishery but treated differently
- Survey fishery is controlled in how the data is treated in the model:
  - Extraction fishery – indices fitted via fml_effort_rltnshp
  - Non-extraction fishery – indices fitted via CPUE likelihood

CC Flags and optional settings

Newton-Raphson:

parest_flags(373) – 1 activates the catch-conditioned option

age_flags(92) – specifies the catch-conditioned option:

2 - Baranov equation (N-R)

3 - Pope's Approximation (not complete)

age_flags(116) – specifies max. allowable fishing mortality level, Zmax_fish

parest_flags(382) – weight for Zmax_fish penalty, default=100

age_flags(189) – fraction of Zmax_fish above which the penalty is calculated

fml_effort_rltnshp:

parest_flags(378) – n; n>0 activates G-S design matrix and adds the regression penalty to the integrated likelihood; n specifies option for the regression: 1 and 2 - robust; 3 – student-t

parest_flags(377) – 1 activates estimation of fml_effort_rltnshp parameters and implements the normal penalty

parest_flags(383) – weight for normal penalty on estimated parameters

fish_flags(81) – 1 activates estimation of robust regression parameters

parest_flags(362) – option for fixed variance for robust-normal mixture regression (where fish_flags(81) = 0)

fish_flags(93) – 1 activates estimation of student-t regression DOF parameters

fish_flags(73) – n specifies degrees of polynomial relationhsip; 0 estimates only the mean catchability – coff 1

fish_flags(29) – n grouping of catchability among fisheries, i.e. for the fml_effort_rltnshps to be grouped among fisheries

fish_flags(27) – 1 applies seasonal catchability for the polynomial, coffs 2 & 3

Initial survival:

age_flags(94) – 1 specifies N_{init} as a function of M; 2 – specifies N_{init} in exploited equilibrium relative to average total mortality over a defined period

age_flags(95) – specifies initial periods used for calculating average total mortality for deriving N_{init} in exploited equilibrium

parest_flags(393) – 1 activates the estimation of parameters: kludged_equilib_coffs, and implements the normal penalty

parest_flags(379) – weight on the normal penalty of the higher level (>4) spline degree coefficients

parest_flags(374) – spline degree for kludged initial survival relationship

parest_flags(376) – no. of additional spline nodes to be added to the degree

parest_flags(375) – weight of penalty on estimated initial survival : actual survival

Survey fishery index likelihood:

fish_flags(i,92) – 1 specifies the fisheries having a survey CPUE index of relative abundance, and determines penalty weight

fish_flags(i,66) – 1 activates the option for index-specific variance is to be included in likelihood calculation

fish_flags(i,99) – specifies the grouping to be used for survey fisheries assumed to have stationary catchability (relative to regions)

data_fish_flags(1,fi) – for the grouped survey fisheries should be all identical (either all 0 or all 1, i.e. frequency or biomass indices)

ADVICE ON THE FLAGS

fml_effort_rltnshp:

- Know your fishery data, kludged effort fisheries should have 0 degrees or no seasonality estimated
- Take care over the fishery grouping in respect of the regression specification; must be consistent among fish_flags for the relevant fisheries

Newton-Raphson:

- penalty weight on Zmax_fish (maximum fishing mortality) – set light in early phases, then increase in later phases

Catch-errors method flags **must** be de-activated:
fish_flags(i,1); fish_flags(i,4); fish_flags(i,10); fish_flags(i,23); fish_flags(i,15); fish_flags(i,13); age_flags(35); age_flags(34); age_flags(144); fish_flags(i,45)

fish_flags(i,66) – set = 0; **unless fitting survey CPUE likelihood with** λ_i