Fishing mortality (F) in SS3

SS3 Webinar – Q&A
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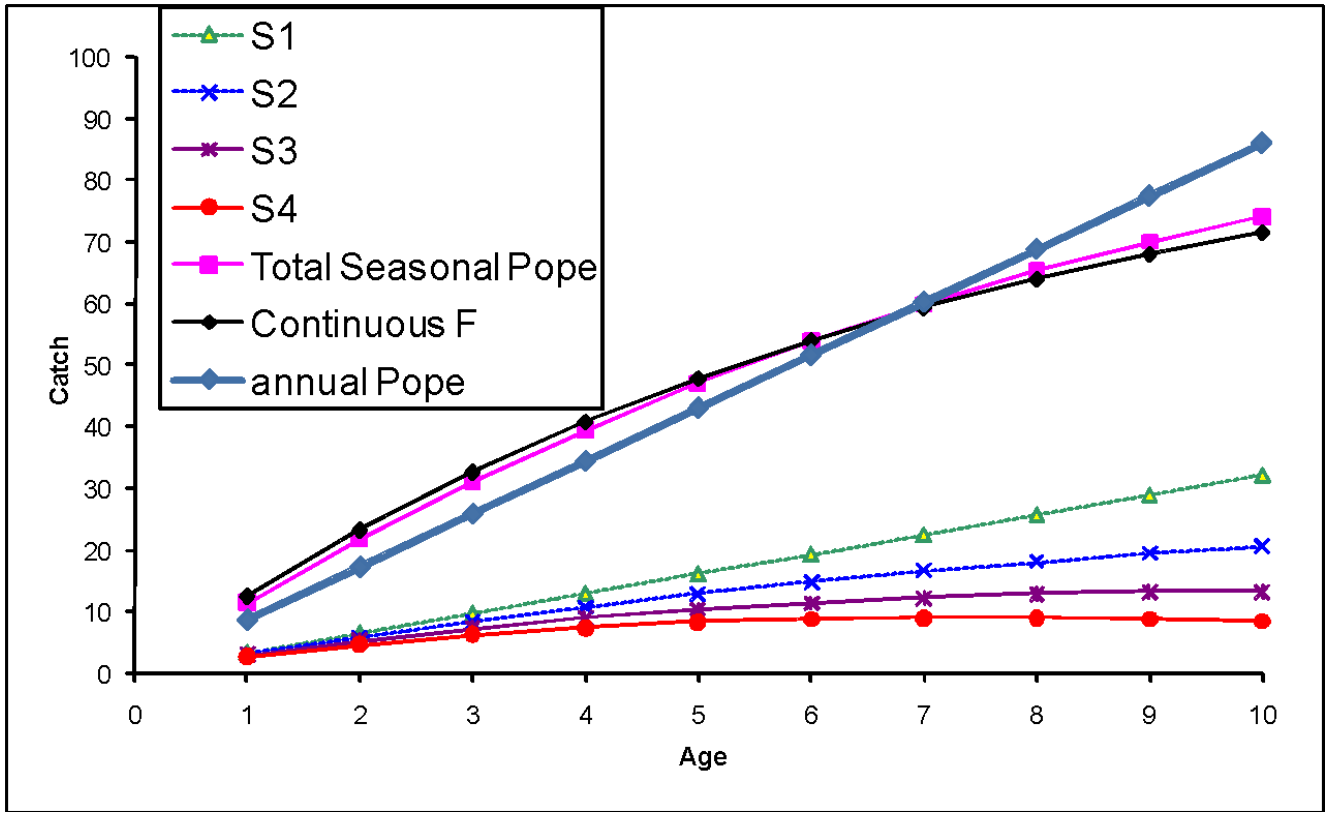
Continuous F vs. Pope's Approx.

- **With Pope's**
  - Decays N-at-age to mid-season using M
  - Removes catch instantaneously using Hrate * selectivity, with Hrate calculated to exactly match the observed landed catch
  - Decays fishery survivors to end of season using M
  - Z calculated as $\log(N_{t+1} / N_t)$
  - Ignores se of catch data, no –logL calculated
  - Calculation error if selectivity > 1.0
- **With continuous F**
  - Uses M1 + M2 + F to calculate Z at age, then catch using Baranov's equation
- **Both**
  - Z used to interpolate N at age within the season if using defined timing for surveys

Selectivity with Pope vs F



With N-at-age constant (100) and linear ramp in selectivity, we need multiple seasons for Pope's to approximate continuous F if F is high (here, 1.8).

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Hybrid F

- Start by doing a Pope's calculation of mid-season exploitation rate:

  $Hrate_{f,t} = catch\_ret\_obs_{f,t} / vbio_{f,t}$
- Then convert to an estimate of equivalent F

  F=-log(1.-Hrate)
- Then tune the F values in a fixed number (~3) of iterations to converge towards the observed catch
- The tuning converges quickly because algorithm anticipates what Z will be after F's are adjusted

Hybrid vs. Parameter

- Both use the same F calculations
- Hybrid best when F is low
- At high F, hybrid's algorithm to maintain match to catch inhibits movement towards convergence
- Parameter approach can be configured to get starting value for F parameter during early phases using hybrid, then converts to parameter to finish the run
- F method = 4 gives best flexibility because it allows hybrid vs parameter conversion on a fleet-specific basis

F Method Comparison

	Fmethod		
	1	2	3
	Pope's	parameters	hybrid
N_iter:	458	846	469
runtime(sec):	85	130	95
LIKELIHOOD	1327.64	1327.68	1327.68
endspbio	6017.21	5797.93	5798.08
se(endspbio)	1331.46	1293.99	1293.93

F using many parameters vs F using many internally calculated factors has no impact on the variance of derived quantities.

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F and Discards

- ***F*** creates total catch
- Retention can partition into retained and discarded catch
- Pope's and Hybrid tune using only retained catch
- Tuning to retained catch can result in poor fit to discard data
- ***F*** as parameter tries, by minimizing total –logL, to fit to both retained and discarded catch. This is best approach if the ***se*** of discards is comparable to ***se*** of retained catch

Estimating F without catch

- Bycatch only fleets can estimate F if there are discard data for that fleet; also be aware that every F affects the population, so affects the -logL for all data
- Init_F parameter has very large effect on the age composition of the population in the starting year, so can be estimated even with just a dummy value for init_catch and very low lambda for that data type

Catch Multiplier

- Catch_mult was created to allow dealing with IUU, recalibration of MRIP, and long-term catch reconstructions
- e(catch) = catch_mult * (catch | F)
- Catch_mult is a parameter, so can be time-varying

F and Selectivity

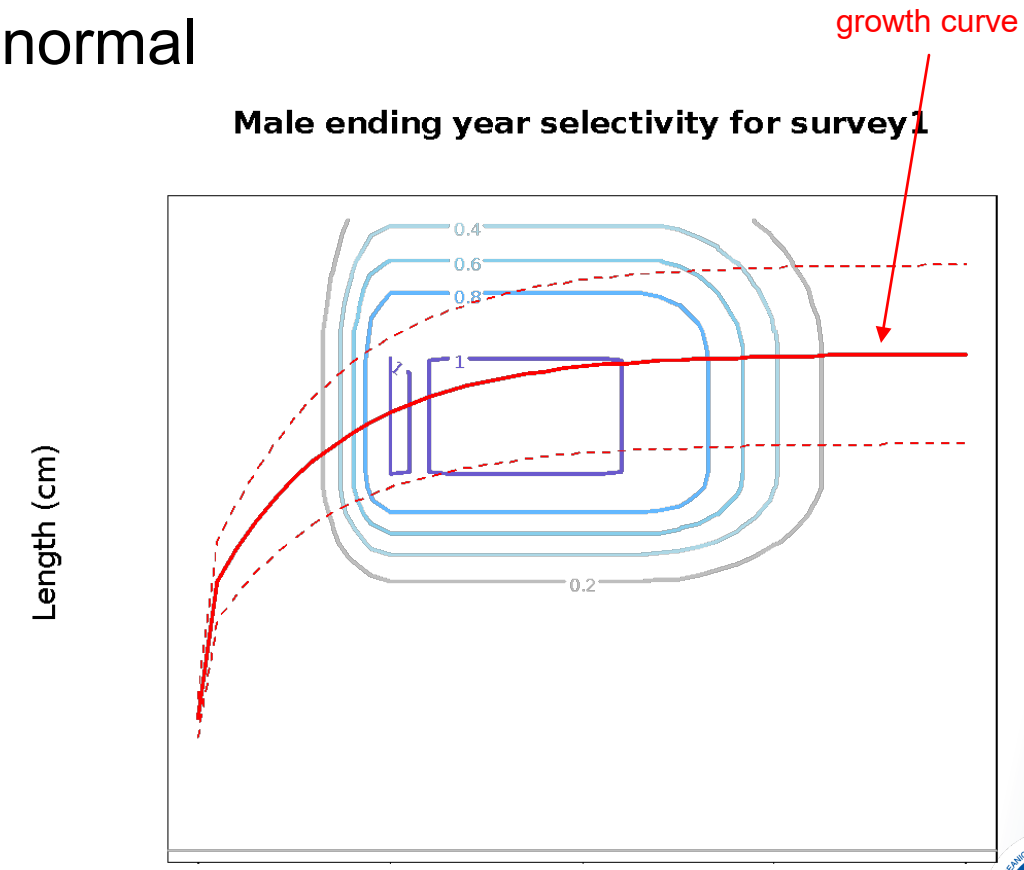
- $\boldsymbol{F_a = F' * s_a}$
- If max ($\boldsymbol{s_a}$) ≠ 1.0, then $\boldsymbol{F'}$ compensates
- Even if no age has $\boldsymbol{s_a}$ = 1.0, the $\boldsymbol{F'}$ is still relative to hypothetical age with $\boldsymbol{s_a}$ = 1.0
- The $\boldsymbol{F'}$ are what SS3 adjusts in hybrid or gets from a parameter
- When SS3 reports the $\boldsymbol{F'}$ and the $\boldsymbol{s_a}$, it does not rescale them to show max($\boldsymbol{s_a}$) = 1.0 and corresponding counter-adjustment to the $\boldsymbol{F'}$

Combining selectivity w/ length at age

- Age-only and Length selectivity act in combination
- Example with two double normal
- Results in Asel2

maximum_ASEL2

Fleet	fleet_name	year	seas	max
1	FISHERY	1971	1	0.89529
2	SURVEY1	1971	1	0.99996
3	SURVEY2	1971	1	1



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Reporting $F_{f,a}$

- ***F_AT_AGE report:39***
  - Area Fleet Sex Morph Yr Seas Era 0 1 2
  - Where each fleet operates in only one area
  - Where "Morph" is all morphs, settlement events, platoons; e.g. looping all the "g" and reporting their sex.
- ***CATCH_AT_AGE report:40***
- ***DISCARD_AT_AGE report:41***

Reporting ***total F_a***

Two sets of tables in the Dynamic_Bzero report:59

Z_AT_AGE_Annual_2 With_fishery

Bio_Pattern Sex Yr 0 1 2 .....

Where Z comes from ln($N_{t=1}$ / N_t) based on begin of year N's summed across all areas and the subdivisions within Bio_Pattern x Sex

Report_Z_by_area_morph_platoon_2 With_fishery

Area Bio_Pattern Sex BirthSeas Settlement Platoon Morph Yr Seas ..... 0 1 2 ……

Where "Morph" is each "g"

This is the actual Z and provides value for max_age

Also report same for: _1 No_fishery _for_Z=M

Reporting overall F: F_std

- The complexities of multiple fleets, areas, growth patterns, seasons, dome-selectivity, etc. wreck havoc with calculation of a single annual total "F" statistic
- Initially, SS3 focused on reporting an annual value for equilibrium SPR and the total exploitation rate (catch/summary biomass)
- Sum of the F' values across fleets is also available, but it is easily misleading in complex setups
- Options 4 & 5 get F_bar based on age-specific total F
- Uses Z-M approach, where:
  - $Z=\ln(N_{t+1,a+1} / N_{t,a})$ on annual not seasonal basis, and
  - $M=\ln(N_{t+1,a+1} / N_{t,a})$ with fishery turned off

EXPLOITATION report:14
F_std by method = 3

```
Info: Displays.various.annual.F.statistics
Info: F_Method:=4;.Continuous_F;.fleet.F.will.be.multiplied.by.season.duration
Info: Displayed.fleet-specific.F.values.are.the.F.for.ages.with.asel2 = 1.0
Info: F_std_basis:._abs_F;_with_F=sum(full_Fs)
F_std averaged over N years: 0
Info: Annual_F.shown.here.is.done.by.the.Z-M.method.for.nages/2=20
```

Yr	Seas	Seas_dur	F_std	annual_F	annual_M	FISHERY
Catchunits	_	_	_	_	_	Bio
FleetType:	_	_	_	_	_	Catch
FleetArea:	_	_	_	_	_	1
FleetID:	_	_	_	_	_	1
INIT	1	1	_	_	_	0.00107
1971	1	1	0.00107	0.00095	0.1	0.00107
1972	1	1	0.00214	0.00189	0.1	0.00214

- Note that F_std = full_F here
- Annual_F is by different method and for different age range.

EXPLOITATION report:14
F_std by method = 5

```
Info: F_std_basis:._abs_F;_with_F=Z-M;_for_ages_unweighted_38_38
F_std averaged over N years: 0
Info: Annual_F.shown.here.is.done.by.the.Z-M.method.for.ages:.38-38
```

Yr	Seas	Seas_dur	F_std	annual_F	annual_M	FISHERY
Catchunits:	_	_	_	_	_	Bio
FleetType:	_	_	_	_	_	Catch
FleetArea:	_	_	_	_	_	1
FleetID:	_	_	_	_	_	1
INIT	1	1	_	_	_	0.00107
1971	1	1	0.00097	0.00097	0.1	0.00107
1972	1	1	0.00194	0.00194	0.1	0.00214

Max(asel2) = 0.8953

- Now F_std < full_F because asel2 at age 38 is < 1.0.
- Annual_F is now by same Z-M method and uses same age range.

Scaling F in Benchmark and Forecast

- With multiple fleets, there is now relF among the fleets: $relF_f = F'_f / sum(F'_f)$
- Also Fmult such that $F'_f = Fmult * relF_f$
- RelF based on year averaged from time series, or user input. Overrides for bycatch fleets
- In benchmark, use Fmult to scale all the F' in sync to find MSY, SPR, etc.
- Save that Fmult and use it in forecast to apply the selected F approach

More F tidbits

- If F_ballpark is specified in the control.ss file, its units are the same as ann$F$, so is not fleet-specific.
- F as parameter has units of $F'_{t,f}$.
- In the forecast.ss file there is an option to input a vector of rel$F$ values. These are dimensionless and will be rescaled to sum to 1.0.
- In the forecast.ss file there is an option to specify an F scalar for the forecast. The units of F scalar are the same as the Fmult values calculated in benchmark. There are a full set of options for forecast F scalar that can be selected in the forecast file. For example, if the forecast F scalar is set as FSPR, then SS3 will use SPR_Fmult calculated in benchmark and reported in Forecast-report.sso. If user selects the option to input an annual F scalar, option 5, then the value is input on a following line. Whichever method the user selects for forecast F scalar (Fmult), SS3 will create a fleet-specific vector of forecast F'_f values from Fmult $*$ relF_f.
- Also in the forecast.ss file, the last section of inputs allows for input of time and fleet specific $F'_{t,f}$ values that override the basic forecast F specification described above.

Summary: F terms

- **F'** = **full_F** = fully selected F
- **Apical_F** sometimes mistakenly used to mean full_F, but only true if selectivity = 1.0
- **relF**$_f$ = F'$_f$ / sum(F'$_f$)
- **Fmult** same as **Fscalar**. Works with relF in benchmark and forecast
- **F_std** is the F reported to ss_summary and is usually divided by a benchmark or other comparable F value
- **Annual F** same as **annF.** It is calculated by Z-M and may be used in F_std

Testing Internal Consistency

- Can we set init_F = F_timeseries = F_forecast = F_MSY and get a constant population at B_MSY?
- MSY depends only on steepness, biology, selectivity and scales with R0. Time series of actual F and recdevs do not affect F_MSY.

1. Start with a run that includes placeholder for init_catch (and init_F). Set forecast to use a few years of input catch.
2. Control.ss_new will contain final parameter values; copy control.ss_new to control.ss to contain the converged biology, steepness, selectivity, R0 parameters.
3. Get F_MSY and MSY from the output

Testing Internal Consistency

4. Set init_F and starting F = F_MSY

```
4 # F_Method:  1=Pope midseason rate; 2=F as parameter
2.95 # max F (methods 2-4) or harvest fraction (method
# Read list of fleets that do F as parameter; unlisted
# (A) fleet;
# (B) F_starting_value (ignored if start_PH=1 or readi
# (C) start_PH for fleet's Fparms (99 to stay in hybri
# Terminate list with -9999 for fleet (use -9998 to re
# (A) (B) (C)
 1 0.094107 -1 # FISHERY
-9999 1 1 # end of list
#F_detail template: Fleet Yr Seas F_value catch_se pha
3 #_number of loops for hybrid tuning; 4 precise; 3 fa
#
#_initial_F_parms; for each fleet x season that has in
#_for unconstrained init_F, use an arbitrary initial c
#_ LO HI INIT PRIOR PR_SD  PR_type  PHASE
 0 1 0.094107 10.3 10 0 1 # InitF_seas_1_flt_1FISHERY
```


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Testing Internal Consistency

5. Set spawner-recruitment for constancy

```
3 #_Spawner-Recruitment; Options: 1=NA; 2=Ricker; 3=std_B-H; 4=SCA
1  # 0/1 to use steepness in initial equ recruitment calculation
```

```
-3 #_max_bias_adj_in_MPD (typical ~0.8; -3 sets all years to 0.0;
```

With these settings, R in the initial equilibrium will behave like R in the equilibrium MSY calculations.
Then during the time series the constant recruitments will stay at the R0 level and not be bias-adjusted down in anticipation of being estimated to a lognormal pdf.

Testing Internal Consistency

6. Forecast settings

```
1 # Control rule method (0: none; 1: ramp does catch=f(SSB), buffer on F;
# values for top, bottom and buffer exist, but not used when Policy=0
0.3 # Control rule inflection for constant F (as frac of Bzero, e.g. 0.40)
0.1 # Control rule cutoff for no F (as frac of Bzero, e.g. 0.10)
1 # Buffer:  enter Control rule target as fraction of Flimit (e.g. 0.75),
```

```
2 # basis for input Fcast catch: -1=read basis with each obs; 2=dead catch;
#enter list of Fcast catches or Fa; terminate with line having year=-9999
#_Yr Seas Fleet Catch(or_F)
 2002 1 1 3031.83
 2003 1 1 3031.83
 2004 1 1 3031.83
 2005 1 1 3031.83
 2006 1 1 3031.83
-9999 1 1 0
```

With these settings:
Control rule will not reduce F_ABC below F_MSY
First 5 years of 10 year projection will find F to match catch set to MSY
Next 5 years will get forecast catch from F_MSY.

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Testing Internal Consistency

- Run:
  - reading from control file, not ss3.par
  - And with –stopph 0, so no parameter estimation

- Result:
  - Biomass, recruitment, F and catch are the same for every year from initial equilibrium through the last year of the forecast.

```
SSB_Virgin 50047 0
SSB_Initial 16355.9 0
SSB_1971 16355.9 0
SSB_1972 16355.9 0
SSB_1973 16355.9 0
SSB_1974 16355.9 0
SSB_1975 16355.9 0
SSB_1976 16355.9 0
SSB_1977 16355.9 0
SSB_1978 16355.9 0
SSB_1979 16355.9 0
SSB_1980 16355.9 0
SSB_1981 16355.9 0
SSB_1982 16355.9 0
SSB_1983 16355.9 0
SSB_1984 16355.9 0
SSB_1985 16355.9 0
SSB_1986 16355.9 0
SSB_1987 16355.9 0
SSB_1988 16355.9 0
SSB_1989 16355.9 0
SSB_1990 16355.9 0
SSB_1991 16355.9 0
SSB_1992 16355.9 0
SSB_1993 16355.9 0
SSB_1994 16355.9 0
SSB_1995 16355.9 0
SSB_1996 16355.9 0
SSB_1997 16355.9 0
SSB_1998 16355.9 0
SSB_1999 16355.9 0
SSB_2000 16355.9 0
SSB_2001 16355.9 0
SSB_2002 16355.9 0
SSB_2003 16355.9 0
SSB_2004 16355.9 0
SSB_2005 16355.9 0
SSB_2006 16355.9 0
SSB_2007 16355.9 0
SSB_2008 16355.9 0
SSB_2009 16355.9 0
SSB_2010 16355.9 0
```


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