

Modeling Recruitment in Stock Synthesis

Outline

- Spawner-recruit curves
- Temporal variation
 - deviates
 - bias correction
 - autocorrelation
 - initial recruitment
- Covariate
- Recruitment cycles
- Fecundity

Note about recruitment

- Recruitment is treated differently from other model parameters because there is usually more focus put on recruitment in stock assessment models.
- Therefore, there are more options available for recruitment.

Spawner-recruit curves

- Beverton-Holt
- Beverton-Holt with flat-top beyond B_0
- Ricker
- CAGEAN
 - estimated parameter for each recruitment
 - no distributional assumption
- Survival-based
 - constrained so that the recruitment rate cannot exceed fecundity

Temporal deviates

- Estimated as parameters and penalized based on a distributional assumption
- Essentially treating recruitment as random effect
- Distribution assumed to be lognormal and the standard deviation (σ_R) of the distribution is an estimable parameter
- Constrained so they average zero
 - constraint optional, but interpretability of reference points depends on central tendency = 0
- May be autocorrelated

More on recruitment devs

- Can have rec devs before first year of model to populate initial age structure
- Can be broken into three vectors
 - early, main, forecast
 - only main vector is zero-centered
 - prevents zero-centering of main vector from influencing recruitments in years which should be totally uninformed by data (i.e. forecast)

Bias correction

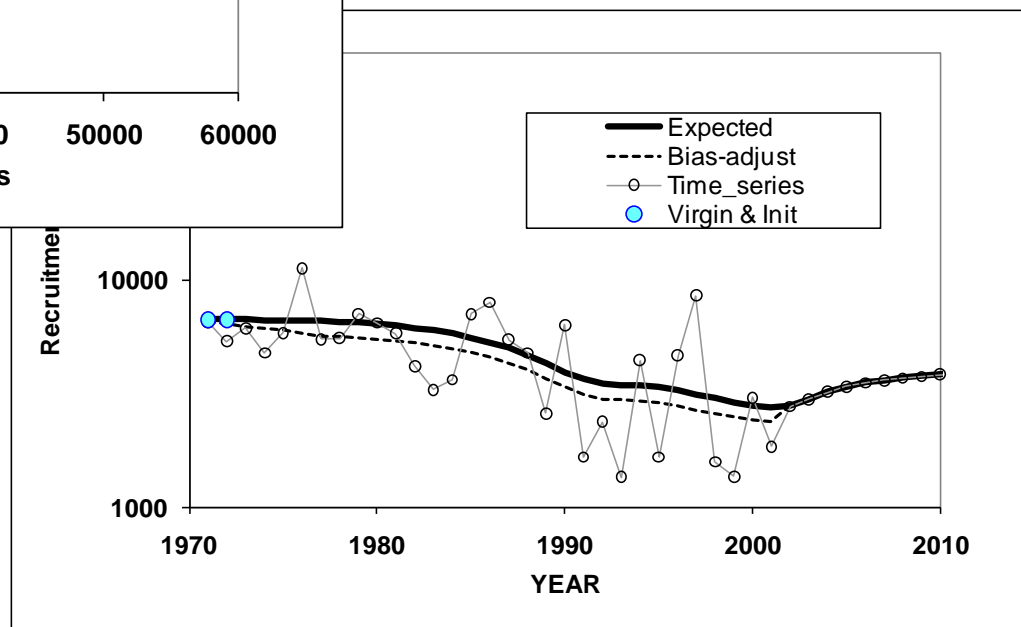
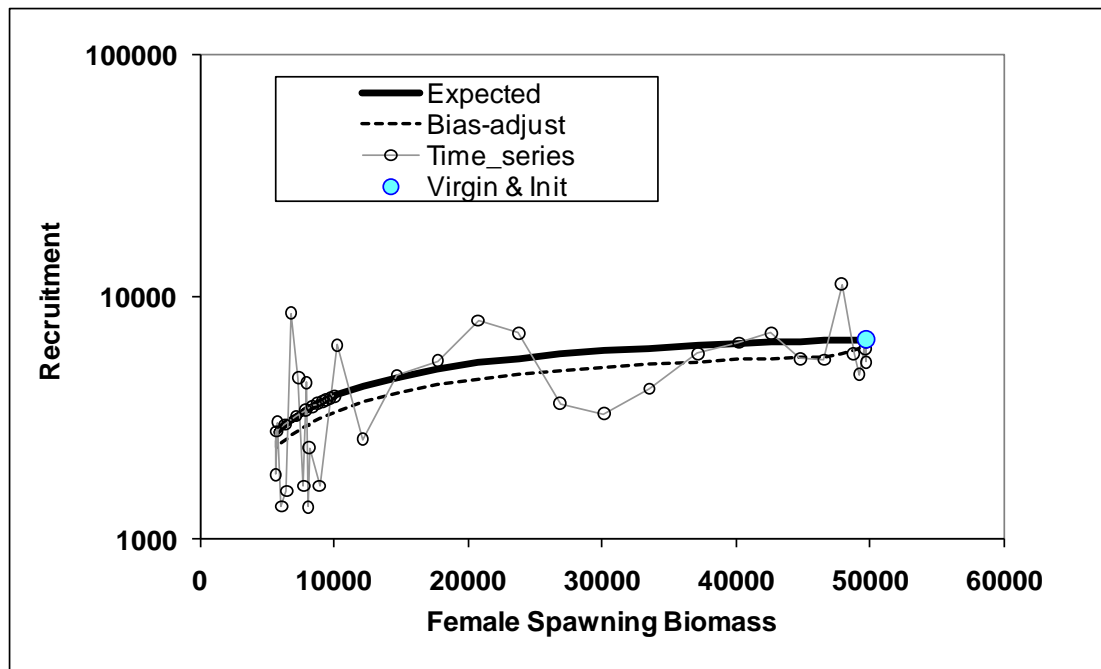
- Added to the temporal deviate to make the recruitments mean unbiased.
- Only appropriate in a penalized likelihood context where there is sufficient information about recruitment
- Options available to reduce the bias correction in early and late years with little information about recruitment
- See paper by Methot & Taylor on bias correction

Spawner-Recruitment in SS

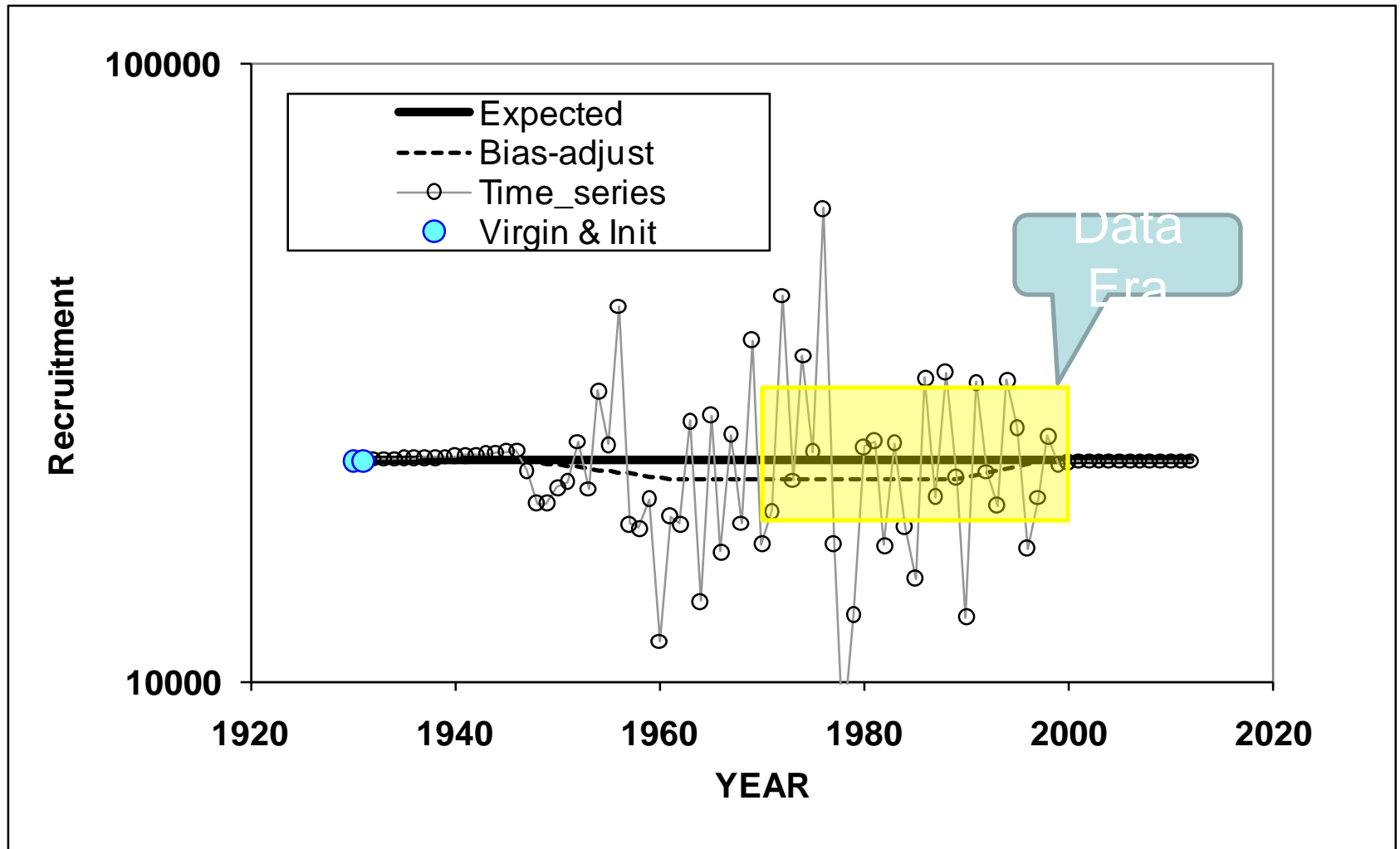
$$R_y = f(SSB, env) * e^{-0.5 * A_y \theta^2} * e^{dev_y}$$

- **$f(SSB, env)$ is either Beverton-Holt or Ricker function with optional environmental effects**
 - Provides arithmetic mean recruitment
- **Dev_y is the estimated recruitment deviation in year, y**
- **A_y is the specified fraction of the bias adjustment to apply in year, y , such that $E(\text{mean } R)$ is unbiased**
 - A_y goes to 1.0 where data are perfectly informative about recruitment deviations (0.85 is typical max)
 - A_y goes to 0.0 where there are no data to inform model about recruitment deviations

Recruitment in SS



Longer Example



Recruitment Controls

Time		Deviation Era	MPD bias adjustment
Startyr	1970	age 10	first early recr dev
	1971	age 9	
	1972	age 8	
	1973	age 7	
	1974	age 6	
	1975	age 5	
	1976	age 4	
	1977	age 3	
	1978	age 2	
	1979	age 1	
	1980	age 0, recr 80	
	1981	age 0, recr 81	last early recrdev
	1982	etc.	recdev-start
	1983		
	1984		
	1985		
	1986		
	1987		
	1988		
	1989		last recr dev
Endyr	1990		first forecast dev
	1991		
	1992		

Initial recruitment

- Separate values for average recruitment used to generate the initial conditions (R_1) and average recruitment used to generate the dynamics (R_0)
- R_1 treated as exponential offset from R_0

Covariates

Recruitment can be modeled as a function of a covariate (i.e. environmental index):

- As a multiplicative factor applied to value drawn from the stock-recruit curve
- As an adjustment to the stock-recruit curve
 - Virgin recruitment (R_0) is a function of the covariate
 - Steepness (h) is a function of the covariate

Recruitment indices

- An alternative approach instead of modeling recruitment deviates as a function of covariates
- Selectivity options allow inclusion of indices of
 - recruitment
 - recruitment deviation
 - $\exp(\text{recruitment deviation})$
 - $\exp(\text{recruitment deviation}) * \text{Spawning Biomass}$
(i.e. pre-recruit survey before density dependence)
- Fit of model to recruitment indices depends on variability of index values

Seasonal models

- Models with seasons within year can specify which seasons have recruitment
 - separate cohorts for each “birth season”
 - parameters for fraction of total annual recruitment distributed to each season
- Models that use season as the time step (redefine year as season) can use cycles
 - vector of estimated recruitment deviates
 - exponentiated parameters centered around 1

Other divisions of recruits

- Spatial models:
 - global recruitment distributed among areas
 - parameters for fraction of total annual recruitment distributed to each season
(similar to seasons within years)
 - May model deviates around distribution parameters
- Growth patterns
 - may define separate growth patterns and distribute recruitment between them
 - growth patterns can be assigned separate areas or movement patterns in spatial models