Science, Service, Stewardship

Stochastic Stock Reduction Analysis (SRA)

NOAA FISHERIES SERVICE

Linda Lombardi
NOAA Fisheries Service
Panama City, FL

SEDAR 22
Review Workshop
February 14-17, 2011

NOAA FISHERIES SERVICE

stochastic SRA

Designed by Carl Walters, UBC

—Walters et al. 2006 CJFAS 63:212-223

Current model executable: January 2011

Use in previous SEDARs:

—Gag, SEDAR10

—Red Grouper, SEDAR12

NOAA FISHERIES SERVICE

Model Overview:

Assumptions:

- Unfished Virgin Recruitment 1st year of data
- Stochastic variation in recruitment for all years
- Survivalship is constant for all years

NOAA FISHERIES SERVICE

Model Overview:

Uses an age structured population model

Given the initial parameters SRA:

Simulates changes in biomass by subtracting estimates mortality and adding recruits

New recruits are a function of current stock size and leading parameters (MSY, U_{MSY})

Mortality based on estimates of natural mortality

NOAA FISHERIES SERVICE

Model Overview:

Beverton-Holt stock-recruitment function

Recruitment is simulated forward in time

Recruitment anomalies

— Predicted from log normal distribution

NOAA FISHERIES SERVICE

Stock – Recruitment Parameters:

Goodyear's Recruitment Compensation Ratio (recK)

- Degree of compensation required for a fished population to persist (Goodyear 1993
- Comparable to steepness of stock-recruitment curve (Myers et al 1999)
- In Beverton-Holt stock-recruitment relationship, steepness is related to recK

NOAA FISHERIES SERVICE

Model Equations

$$N_{a+1,t+1} = N_{a,t}S_a(1-v_{a,t}U_t)$$ Numbers at age and year t

$$S = e^{-M}$$ Natural survival rate

$$U_t = \frac{C_t}{VB_t}$$ Exploitation (harvest rate) at time t

$$VB_t = \sum N_{a,t}v_{a,t}w_a$$ Vulnerable biomass at time t

NOAA FISHERIES SERVICE

Model Equations

$$f_a = w_a Mat_a$$

Fecundity at age
w_a body weight
Maturity at age

$$E_t = \sum N_{a,t} f_a$$

Number of eggs per time t

$$v_{a,t}$$

Vulnerabilities at age and time t
Calculated through VPA

NOAA FISHERIES SERVICE

Model Configuration

Model parameterized with U_{MSY} and MSY as leading parameters

Beverton-Holt stock-recruit parameters (α, β) are estimated using

See Forrest et al 2008 CJFAS 65: 286-296

1. U_{MSY} and MSY
2. Per-recruit egg production for fished
3. Per-recruit egg production for unfished
4. Vulnerable biomasses

Assume a uniform Bayes prior for U_{MSY} and MSY

NOAA FISHERIES SERVICE

Model Configuration

Sampling of parameters and recruitment anomalies using MCMC (Metropolis-Hastings) algorithm:

- Leads to full state space representation of process uncertainty, and marginal probability distributions for parameters

- Integrated over both process and observation errors

- Leading parameters estimated by summing the frequencies of occurrence of different values of parameter values through MCMC

NOAA FISHERIES SERVICE

Model Configuration

MCMC sampling:

SRA does not use multiple sample chains or tests for convergence as sample size increases

Two parameters (Par step and Anom Step) bound the maximum sizes of random parameter changes tested by the MCMC sampling procedure

NOAA FISHERIES SERVICE

Stochastic SRA does not provide measures of:

Stock Biomass (total and spawning stock)

–Total egg production is calculated for recruitment predictions, instead of using spawning stock biomass as a proxy for egg production

Fishery Selectivity

Fishing Mortality

NOAA FISHERIES SERVICE

Uncertainty, Measures of Precision

Leading parameters estimated using

- MCMC

- Bayesian and likelihood approaches to estimate leading parameters

NOAA FISHERIES SERVICE

Benchmark/Reference points

Proportion of MCMC runs

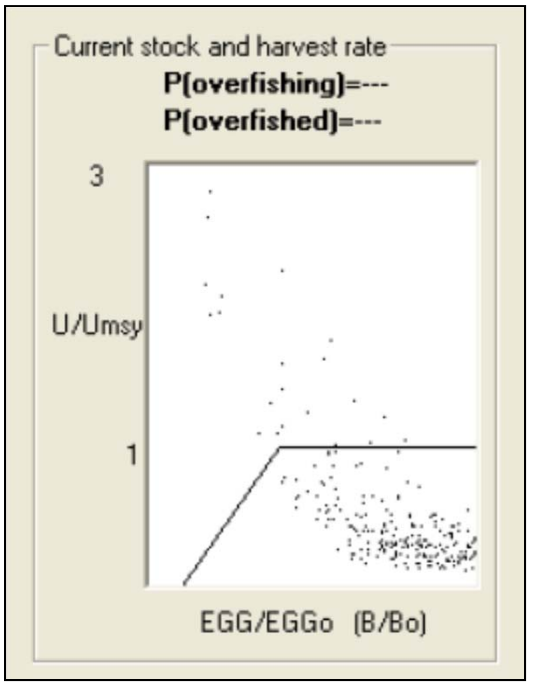
- Overfished

  $Biomass_{current}/Biomass_{MSY} > 1.0$

- Overfishing

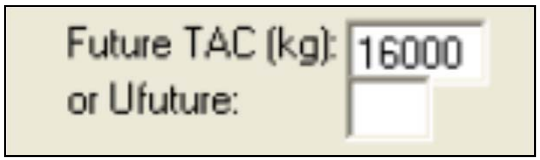
  $Exploitation_{current}/Exploitation_{MSY} < 1$

PFMC 40:10 rule



NOAA FISHERIES SERVICE

Projections



Future vulnerable biomass

- Change allocation of landings (Future TAC)

- Change estimate of exploitation) (Ufuture)

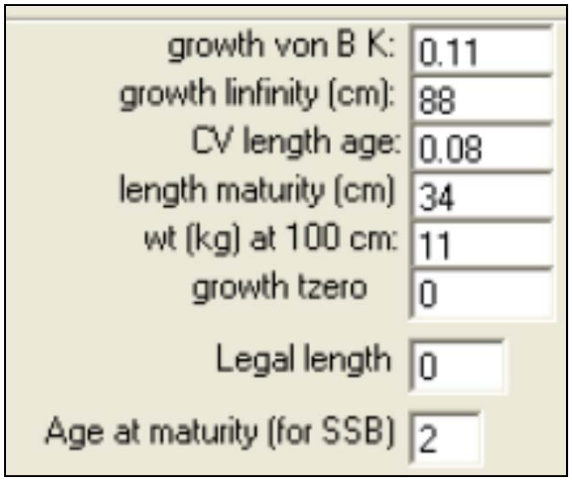
NOAA FISHERIES SERVICE

Data inputs: life history

von Bertalanffy model parameters

Length and age at maturity

Weight at 100 cm

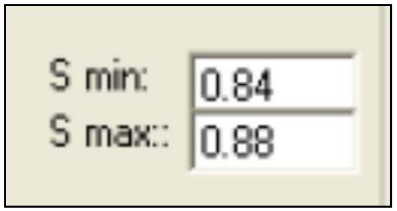


Beverton-Holt stock recruitment parameters:

- initial recruitment (R_o)
- Goodyear's recruitment compensation ratio (K)

Range of values:

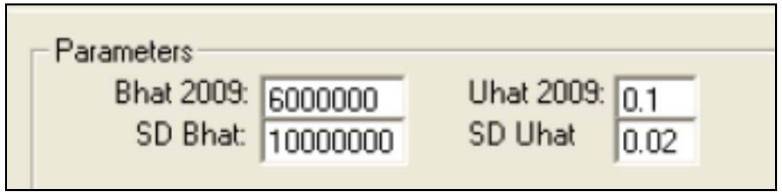
- Survivorship ($S = e^{-M}$)



NOAA FISHERIES SERVICE

Data inputs: fishery

Biomass in the last year of the fishery

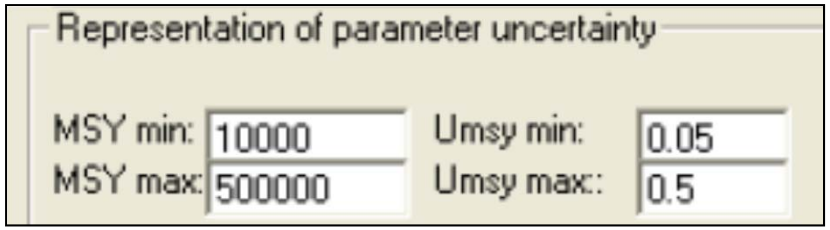


Future Catch (amount landings or exploitation)

Range of values:

- maximum sustainable yield (MSY)
- Exploitation (current and at MSY)

Total catch by year



Age-specific vulnerabilities

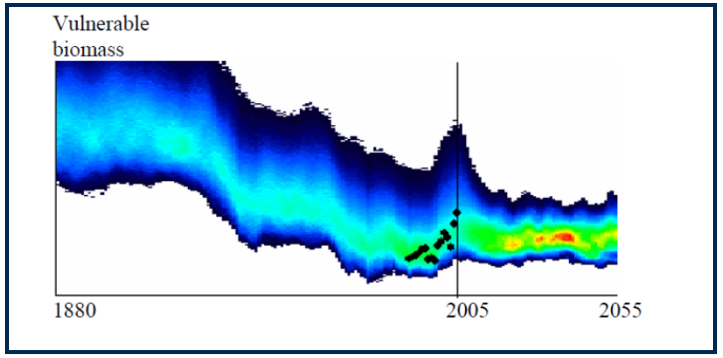
Relative abundances at time (CPUE)

NOAA FISHERIES SERVICE

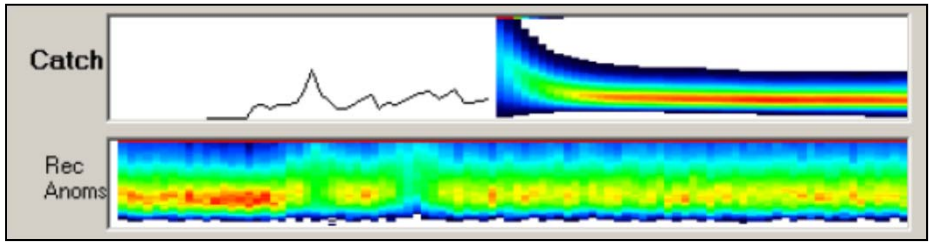
Outputs:

Probability distributions:

—Vulnerable Biomass

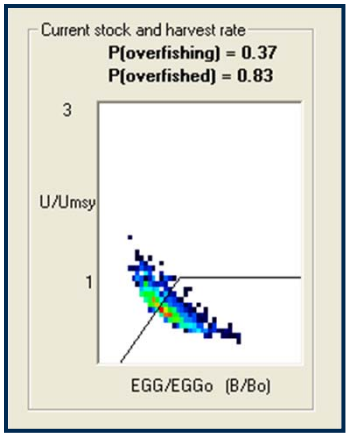


—Catch



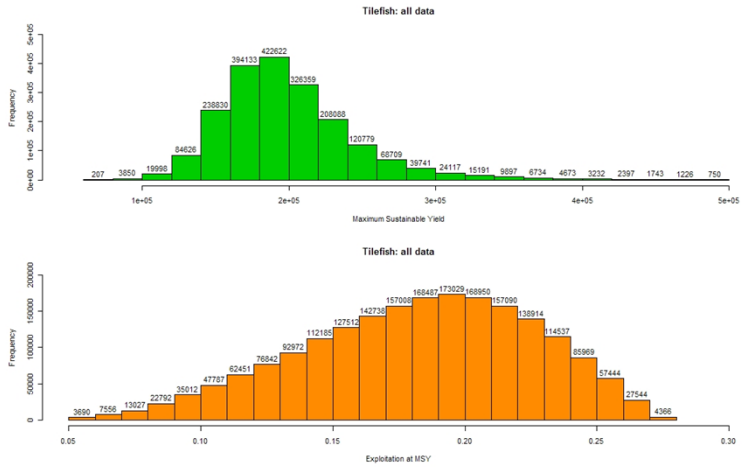
—Recruitment anomalies

—Current stock size & harvest rates



NOAA FISHERIES SERVICE

Outputs:



- MSY and U_{MSY}
- Survivorship
- Egg production (current/virgin)
- Exploitation (current/msy)
- Recruitment Compensation RAtio
- Total Biomass (current)
- Spawning Stock Biomass (current and at MSY)
- Current stock size & harvest rates
- Probabilities of Overfished & Overfishing

NOAA FISHERIES SERVICE

Primary usage

To help assess uncertainty in stock parameters

As a check on other models

—productivity estimates are consistent with catch records

For example, SEDAR12 Red grouper

—SRA in agreement with ASAP in regards to unfished and current stock size

—Larger uncertainty in historical (unfished) average biomass and extent of depletion during fishery beginning

NOAA FISHERIES SERVICE

In Summary

SRA uses historical catch data to drive the population dynamic model forward in time

Key population parameters are adjusted until simulations produce numbers near those estimated from independent estimates of abundance or produce trends similar to trends in relative abundance indices

SRA should not be a replacement for more computational complex assessment models but used more as a tool to make possible conclusions of stock status based on historical catches and recent abundances