Part I: Moving towards a sustainable fisheries framework for BC herring: data, models & alternative assumptions.
Part II: Stock assessment and management advice for BC Herring stocks (2011/2012)

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Moving towards the sustainable fisheries framework.

Overview

- Review of the HCAM model in June 17-18, 2010.
  - Model parameterization of q.
  - Parametrization of q, M, and selectivity is confounded.
- Development of a new integrated Statistical Catch Age Model (${}^{i}\mathrm{SCA}_{\mathrm{M}}$).
- Data, assumptions and Analytical methods.
- Outstanding issues.

Introduction

- Current harvest control rule for BC herring:
  - Cuttoffs set at 0.25 B_0
  - 20% exploitation rate
  - Estimates of B_0 were last updated in 1996.
- HCAM model assumed $q = 1$ for the dive survey data.
- Natural mortality is modelled as a random-walk.
- Gill net selectivity is a function of weight-at-age.

Harvest Strategy Compliant with Precautionary Approach

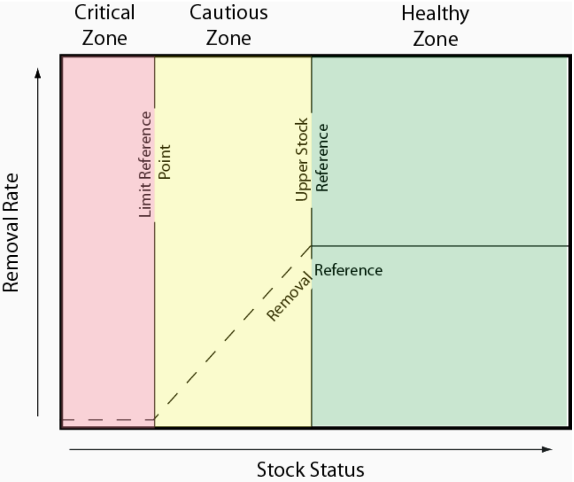

Figure: Fisheries management framework consistent with a precautionary approach.

Key elements for the new framework I

Reference points

- Limit Reference Point (LRP) & Upper Stock Reference (USR) requires knowledge of stock productivity and population scale.
- Removal Rate requires knowledge of stock productivity.
- MSY-based reference points require *a priori* allocation to different gears.

Risk & Decision making

- Onus on being able to reliably determine stock status (informative data).

Herring Stock Assessment Model Review I

Summary of Panel Recommendations

Herring Stock Assessment Model Review II

- Panel concluded that $q_2 = 1$ was inappropriate.
- CUTOFFS can be fixed or annually estimated (should be updated if management objective is 25% B_0)
- A model based approach to estimating B_0 and B_{MSY} is appropriate.
- Recruitment variation should be estimated within the model rather than fixing it at a pre-specified level.
- Issues regarding estimating selectivity vs. availability should be explored (data is limited to estimate availability).
- Science advice should be risk neutral.
- MSE should explore elements of the Sustainable Fisheries Framework (i.e., ensure that $B_t > 0.4 B_{MSY}$ with 95% certainty over two generations.)
- ...

Input data

The input data for ${}^{i}\mathrm{SCA}_{\mathrm{M}}$ is the same as HCAM:

- Catch by gear,
- Spawn survey index,
- Age-composition data for all gears,
- Empirical weight-at-age data.

Analytical methods

Integrated Statistical Catch Age Model (^{i}SCA$_{M}$)

- The model is based on a statistical catch-age framework first developed by Fournier and Archibald (1982).
- Flexible options for modelling selectivity, natural mortality, & survey catchability.
- Integrated framework: joint estimation of policy parameters (e.g., reference pionts).
- Model is implemented in AD Model Builder ADMB Project (2009), and the source code is maintained at: `http://code.google.com/p/iscam-project/`

Assumptions I

Error distributions

- Observation errors in catch are lognormal & σ is known.
- Errors in spawn survey are lognormal & σ is unknown.
- Recruitment deviations are lognormal & σ is unknown.
- Age-composition residuals follow a multivariate-logistic distribution.

Selectivity

- Seine gears: asymptotic and time invariant.
- Gillnet gear: parametric logistic function with weight anomalies as a covariate.

Assumptions II

Structural assumptions

- Age-2 recruitment with a Beverton-Holt model.
- Fishing & natural mortality occur simultaneously (Baranov catch equation).
- Natural mortality is age-independent.
- Natural mortality can vary over time (random walk, $\sigma = 0.1$).
- 100% of the total mortality occurs before spawning.
- Fecundity is proportional to mature biomass.

Equilibrium & MSY-based reference points

- B_o is based on average M and average fecundity-at-age.
- B_{MSY} is based on average (M) and fecundity in terminal year.

Objective function I

Major components of the objective function

- Likelihoods for data.
- Likelihoods for structural assumptions.
- Phased penalties to ensure regular solution.
- Prior densities for model parameters.

Objective function II

Likelihoods for data

- Normal density functions for:
  - catch residuals (log-scale) with fixed σ^2,
  - spawn survey residuals (log-scale) with estimated σ^2.
- Multivariate logistic function for age-composition evaluated at the conditional MLE of σ^2.
  - age-proportions $< 2\%$ are pooled into adjacent age class.

Objective function III

Likelihoods for structural assumptions

- Stock-recruitment

$$\ln \ell = n \ln(\tau) + \frac{\sum_t \delta_t^2}{2\tau^2},$$
$$\delta_t = \ln(N_{2,t}) - \ln(f(SB_t))$$

- Natural mortality (random walk)

$$M_{t+1} = M_t \exp(\varphi_t)$$
$$\ln \ell = n \ln(\sigma) + \frac{\sum_{t=2}^{T} (\varphi_t - \varphi_{t-1})^2}{2\sigma^2}$$

Objective function IV

Phased penalties to ensure regular solution

- Mean fishing mortality rate:

$$\ln(\sigma_{\bar{F}}) + \frac{(\ln(\bar{F}) - \ln(0.2))^2}{2\sigma_{\bar{F}}^2}, \quad \sigma_{\bar{F}}^{(1-3)} = 0.05, \quad \sigma_{\bar{F}}^{(4)} = 2.0$$

- Deviations in average recruitment:

$$\ln(\sigma_{\omega}) + \frac{\sum_t \omega_t^2}{2\sigma_{\omega}^2}, \quad \sigma_{\omega}^{(1-3)} = 0.0707, \quad \sigma_{\omega}^{(4)} = 2.0$$

$$\ln(\sigma_{\ddot{\omega}}) + \frac{\sum_t \ddot{\omega}_t^2}{2\sigma_{\ddot{\omega}}^2}, \quad \sigma_{\ddot{\omega}}^{(1-3)} = 0.0707, \quad \sigma_{\ddot{\omega}}^{(4)} = 2.0$$

Objective function V

Prior densities for model parameters

Parameter	Distribution	P1	P2
$\ln(R_0)$	Uniform	-5.0	15
Steepness	Beta	10.0	4.925373
Natural mortality ($\ln(M)$)	Normal	-0.7985077	0.2
Rbar	Uniform	-5.0	15
Rinit	Uniform	-5.0	15
Variance ratio (ρ)	Beta	17.08696	39.0559
Precision	Gamma	25.0	28.75
Survey $\ln(q)$	Normal	-0.569	0.274

Objective function VI

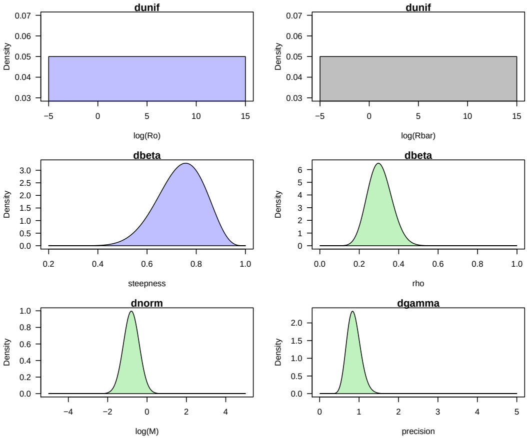

Figure: Prior densities for leading model parameters.

Bibliography

ADMB Project (2009). 2009 AD Model Builder: Automatic Differentiation Model Builder. Developed by David Fournier and freely available from admb-project.org.

Fournier, D. and Archibald, C. (1982). A general theory for analyzing catch at age data. *Canadian Journal of Fisheries and Aquatic Sciences*, 39(8):1195–1207.