

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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# Contents

- 1 Sustainable Fisheries Framework
  - HCAM Review
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- 2 Introduction
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# June 2010: HCAM Review Workshop

## Terms of Reference (paraphrased)

- Herring spawn index, is  $q = 1$  assumption appropriate?
- HCR, should CUTOFF change in concert with  $B_0$  updates?
- What is the best way to parameterize natural mortality?
- Are the priors appropriate and is uncertainty appropriately reflected in assessments?
- Preference for selectivity/availability parameterization.
- Should stock assessments be conducted on a risk-neutral or risk-averse basis?
- Appropriate assumptions for an operating model (MSE).



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# Summary of Panel Recommendations

- 1 Assumption that  $q = 1$  was inappropriate.
- 2 CUTOFFS can be fixed or updated annually.
- 3 A model based approach to estimating  $B_0$  and  $B_{MSY}$  is appropriate.
- 4 Recruitment variation  $\sigma_R$  should be estimated within the model.
- 5 Issues regarding estimation of selectivity, natural mortality and  $q$  should be explored.
- 6 Science advice should be risk neutral.

The model parameterization of  $q$  could potentially have the single greatest effect on estimation of management parameters, and as such further investigation is recommended.



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If the intention is that the CUTOFF represents 25%  $B_0$  then it should be updated in conjunction with stock assessment updates.



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Estimates of MSY based reference points are sensitive to the assumed form of the recruitment model and allocation to gears with different selectivities.



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Note that MLE estimates of  $\sigma_R$  are biased; values from the joint posterior distribution are unbiased.





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# Current Harvest Control Rule

- CUTOFF set at  $0.25 B_0$  (last updated in 1996).
- 20% exploitation rate.
- Forecast based on poor, average, good recruitment.



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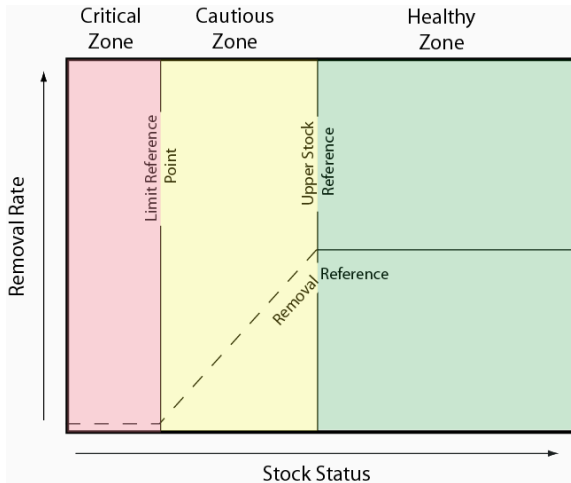


# Introduction

- Current harvest control rule for BC herring:
  - Cutoffs 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





# Herring Stock Assessment Model Review II

## Summary of Panel Recommendations

- 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  $B_t > 0.4B_{MSY}$  with 95% certainty over two generations.)
- ...



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# Input data

The input data for  $iSCA_M$  is the same as HCAM:

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



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# Analytical methods

## Integrated Statistical Catch Age Model ( *iSCA<sub>M</sub>* )

- 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 points).
- 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 &  $\sigma$  is known.
- Errors in spawn survey are lognormal &  $\sigma$  is unknown.
- Recruitment deviations are lognormal &  $\sigma$  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  $\sigma^2$ ,
  - spawn survey residuals (log-scale) with estimated  $\sigma^2$ .
- Multivariate logistic function for age-composition evaluated at the conditional MLE of  $\sigma^2$ .
  - 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 ( $\rho$ )	Beta	17.08696	39.0559
Precision	Gamma	25.0	28.75
Survey $\ln(q)$	Normal	-0.569	0.274



# Objective function VI

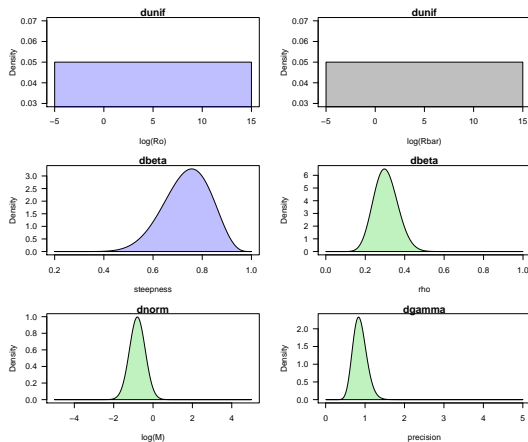


Figure: Prior densities for leading model parameters.



# Bibliography

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

