Report of the Herring Stock Assessment Model Review

Sponsored by the Herring Conservation & Research Society
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Executive Summary

A review of the BC herring stock assessment model was conducted June 17-18, 2010 at the Coast Bastion Inn, Nanaimo, B.C. The review was sponsored by the Herring Research and Conservation Society. This report summarizes the discussions and recommendations of the review Expert Panel, tasked with addressing the specific questions in the Terms of Reference. Additional meeting participants included science, management and industry representatives involved in BC and Alaska herring fisheries.

Panel recommendations related to the herring stock assessment model include changes in the way that some data are used, and assumptions and modifications to model structure. Some suggested changes will require further investigation to better understand model behaviour which could lead to improved parameterization. In some cases the recommendations will be relatively simple to implement while in other cases significant work may be required. Also, some of the recommendations may have a substantial effect on management advice, while others would be expected to have minimal effect.

The model parameterization of q could potentially have the single greatest effect on estimation of management parameters, and as such further investigation is recommended. The Panel concluded that the assumption that q=1 (spawn surveys since 1988 provide an absolute estimate of abundance) is inappropriate; however they could not recommend an alternative parameterization. A number of suggestions are made on how to further investigate this issue. Within the model, parameterization of q, M, and selectivity are confounded, so these should be explored jointly. The goals for an alternative model formulation include: (1) reduction in correlation structure in spawn residuals, (2) plausible alternatives for the estimation of q, and (3) alternative explanations for apparent changes in M.

The Panel recommendations are not mutually exclusive and need to be evaluated in conjunction with one another and in the context of their impacts on the estimation of management parameters.

1 Background

A review of the BC herring stock assessment model (HCAM) was conducted June 17-18, 2010 at the Coast Bastion Inn, Nanaimo, B.C. The review, sponsored by the Herring Research and Conservation Society (HCRS), focussed on specific questions outlined in the Terms of Reference (TOR, Appendix A). Meeting participants included: DFO herring science and management staff; Alaskan herring science and management staff; BC herring industry representatives; consultants working on BC herring; and external scientists with stock assessment expertise (Appendix B). The Expert Panel (Appendix B), tasked with responding to the TOR, prepared this report.

Key points from meeting discussions and Panel recommendations related to the TOR are presented in Section 2. Section 3 summarizes the Panel recommendations. Additional Panel recommendations related to the assessment and HCAM implementation are given in Section 4. Some additional analyses conducted during the meeting are presented in Appendix C.

2 Panel response to TOR questions

Meeting discussions and deliberations focussed on the questions outlined in the review TOR. These questions and a summary of the Panel discussions and recommendations follow.

2.1 Spawn survey proportionality coefficient

The herring spawn index is assumed to be a minimum estimate of spawning abundance. The HCAM currently assumes the proportionality constant between observed spawn deposition (estimates of female spawner biomass from egg deposition surveys) and actual spawn (q) is equal to 1, for the period where the majority of spawns were surveyed by divers (1988-current). This assumption likely creates a bias because a) not all spawns are surveyed, and b) some eggs are lost between the spawning and survey events (largely due to predation). Is the assumption that q=1 appropriate? What is the appropriate error structure of the spawn survey data? Is there potential for bias when spawning abundance is low (easier to miss small spawn events than large ones)?

The current implementation of the HCAM assumes that the herring spawn survey biomass estimates (egg deposition converted to spawning biomass) provide an absolute measure of spawning stock biomass from 1988 onward (ie. q_2=1). For the period prior to 1988, the model assumes the spawn survey data are proportional to total spawning stock biomass and a spawn conversion coefficient (q_1) is estimated. During the 1980s dive survey methods to estimate spawn deposition were developed and these began to replace the surface surveys. By 1988 the majority of herring spawns were being surveyed using the dive method. The current q formulation (q_2=1) was suggested during an earlier herring stock assessment review conducted in 2001.

For herring spawn surveys conducted using surface methods, the spawn width is generally underestimated. The survey width estimates are therefore not used in calculating egg deposition: rather, the median width of all dive transects surveyed in the same general location is assumed. Egg layer estimates from both surface and dive spawn surveys are converted to density estimates based on equations developed from previous research dive surveys. In general, it appears that estimates of spawn lengths from surface surveys are unbiased (relative to dive survey methods). Given the above treatment of the herring surface spawn data, there is no *a priori* reason to believe that spawning biomass estimates from surface spawn surveys are biased relative to those from dive spawn surveys.

The Panel concluded that the assumption of *q*=1 was inappropriate: not all spawns are measured; there is egg loss prior to the surveys; and fixing *q* will reduce estimates of uncertainty in the assessment. Also, this assumption will negatively bias the assessment stock abundance estimates. In general, fixing *q*'s (proportionality constants between survey indices and abundance estimates) is not the standard approach in fisheries stock assessments.

The Panel could not recommend an alternative parameterization for the HCAM *q*'s. There were two primary concerns with model fits to the spawn data that were not resolved in the alternative parameterizations for *q* evaluated during the review meeting (one *q* estimated for entire time series; two *q*'s estimated). First, the patterns in spawn survey residuals were non-random with high serial correlations throughout the time series. The residual patterns suggest some form of model misspecification. Second, parameter values were unrealistically low for some of the stocks when either a single *q* or two *q*'s were estimated (the survey spawn biomass estimates were estimated to 25% or less of the true spawning stock abundance).

Improvements in model fit were highly significant when a single *q* or two *q*'s were estimated in the HCAM model (even if the spawn data were under-weighting). Most of the improvement in model fit was to the spawn index data. Model parameters of management interest (e.g. depletion) were strongly affected by the *q* assumptions, indicating the *q* parameterization is integral to management advice.

Discussion focussed on approaches that could be used to understand what aspect(s) of the data drive the problematic results described above and hence which alternative *q* parameterizations should be explored in future work. Ultimately the goal would be to remove the serial correlation in the spawn residuals and obtain more realistic *q* estimates.

Parameterizing *q* as a random walk may provide a better understanding of the reasons for the non-random residual patterns in the fits to the spawn data. An abrupt shift in *q* is unrealistic, and the random walk approach may indicate where apparent shifts occur. Ultimately, a random walk *q* parameterization is unlikely to be an appropriate form for stock assessments (because of confounding of *q* with other model parameters), but it could be a useful diagnostic tool.

Prospective analysis (leaving out several early years of data) may also provide some insight into issues with the *q* parameterization. It is also possible that some of the early reduction period data (catch and age-composition) are not attributed to the correct stock assessment region.

Further investigation of the conversion factors used to standardize the surface spawn survey data observations to equivalent diver survey observations is warranted. For example, is the implicit assumption that surface survey spawn widths are time invariant at each location appropriate? This could be examined by investigating the location-specific variation in dive survey spawn widths – are these correlated with spawn abundance or other factors? Also, comparison of egg layers and vegetation types between surface and dive surveys is warranted, as the method used to convert spawn surface area to density estimates assumes the data observations will be equivalent for the two methods. It is possible that the appropriate conversions are area-specific, and this could be a reason for the differences in *q*'s and *q* ratios (when 2 *q*'s estimated) among stock assessment regions. Temporal variation in spawn width should also be considered.

Additional work is required to determine an appropriate parameterization for the spawn survey q's. It is likely that there is some form of model misspecification underlying the serial correlation in the spawn residuals.

Additional points related to the model q parameterization include:
- Check if analytical q is implemented correctly in the likelihood (Walters and Ludwig, 1994)
- Correct the calculation of q and residuals so correct if there is missing spawn data

2.2 Herring harvest control rule and biological reference points

Certain aspects of the herring harvest control rule (HCR) should be considered:
- *Should CUTOFF estimates change annually in concert with model estimates of B_0?*
- *What is the best method for calculating B_0 and B_{msy}?*
- *Are the recruitment assumption rules the best approach to capturing uncertainty in these components of the stock projection?*
- *What are appropriate assumptions about stock-recruitment steepness?*

2.2.1 CUTOFFs

The current herring CUTOFF values (used in the herring HCR) were estimated as 25% B_0, based on the 1996 stock assessments. The Panel conclusion is that CUTOFF values can be fixed or annually updated. However, if the intention is that the CUTOFF represents 25% B_0 then it should be updated in conjunction with stock assessment updates.

Internationally, some commercial fish stocks are managed with fixed minimum stock thresholds, generally set based on ecological considerations (e.g. to ensure adequate forage).

Whether it is better to fix the herring CUTOFF levels or to update them regularly in conjunction with stock assessment updates is a question that could potentially be addressed within a management strategy evaluation (MSE) process. Fisheries assessment models are generally more reliable at estimating trends in abundance than in estimating absolute values (Walters and Martell, 2004), supporting the calculation of annual reference points.

2.2.2 B_0 and B_{msy}

Specific issues with estimating B_0 and B_{msy} are:
- Should they be calculated within the assessment model?
- What is the most appropriate assumption about natural mortality in the unexploited populations?
- What is the best average weight-at-age to assume for the unexploited populations?

Given the length of the BC herring data time-series, a model-based approach to estimating B_0 and B_{msy} is appropriate. The complexities of time-varying natural mortality rates in the assessment model and trends in average weights-at-age suggest that the "dynamic B_0" approach (McCall et al., 1985) would best capture any correlations among recruitment estimates, M estimates, and other time-varying parameters.

B_{msy} related statistics are sensitive to the assumed form of the stock-recruitment relationship, and minimally both a Ricker and a Beverton-Holt parameterization should be investigated.

If sigmaR were estimated within the assessment model analysis (currently it is not), it is necessary to parameterize a "ramp-in" (Taylor et al., 2009) so that marginal posterior distribution (MPD) estimates are not biased. Bias is not a problem for the MCMC, but the MPD could influence the MCMC chain when using ADMB.

2.2.3 Recruitment forecasting

During the review, alternative approaches for determining the recruitment assumption in stock forecasts were examined, including the recruitment rule in the HCR and year-class strength estimates from the assessment model.

Results were preliminary and further examination of this question is warranted. Additional analyses should include evaluation of the "offshore survey age-composition" and "Strait of Georgia juvenile survey" recruitment forecasts. Ideally, these should be integrated into the assessment model. An additional/alternative summary statistic, residual mean square error (RMSE), should be used to evaluate the precision of alternative recruitment forecasting approaches, as this statistic will be more sensitive to large outliers.

The current decision rule evolved to allow some modification of the HCR. That is, an above average recruitment assumption is supported when stock levels are high (two successive GOOD recruitments) and a below average recruitment assumption when stock levels are low (stock below the CUTOFF level). If this is the intent of the forecasting rules, it would be more appropriate to directly modify the HCR with stepped or variable harvest rates. Examination of alternative recruitment forecasting methods in conjunction with alternative HCRs could be tested within the MSE framework.

2.3 Natural Mortality

In the current version of HCAM, natural mortality rate is modelled as a "random walk" process, varying annually but constant across ages. Past assessments have used fixed values of natural mortality, while recent studies have explored age-specific as well as density-dependent natural mortality for the BC herring populations. The data provide some support for both these alternatives. What is the best way to parameterize natural mortality? How should the unfished population abundance (B_0) be calculated, given the natural mortality parameterization?

In the current HCAM implementation, natural mortality (*M*) is parameterized as a random walk process. Estimates of *M* are unusually high, in particular during the late 1960's and, for most stocks, also in recent years. Estimation of time-varying or annual estimates of *M* is not commonly done in fisheries assessments and requires careful validation.

In part, the rationale for estimating time-varying *M* in the herring assessment model is that this approach minimizes the retrospective patterns. The Panel advised that retrospective patterns should not be the basis for model selection; rather standard statistical approaches (e.g. AIC) and residual patterns are more appropriate criteria for model selection.

Natural mortality rate estimates are likely confounded with other model parameters, potentially including trends in recruitment, *q*, selectivity and availability. For most stocks, a sharp increase in *M* is estimated in the late 1960's. The apparent increase in *M* may be aliasing for a shift in fishery selectivity: pit lamps introduced to the fishery at that time may have selectively attracted younger fish. Change in fishery selectivity should be investigated in conjunction with changes in natural mortality.

Additional analyses were conducted during the meeting to investigate whether the spawn data or the age-composition data are influencing the apparent increases in *M* estimated for recent years. These analyses involved dropping either the last 7 years of spawn data or age-composition data from the model fitting process. For three of the stocks (QCI, PRD, and SoG), the effect of removing either the recent spawn data or the age-composition data was minimal (see Appendix C). For the CC stock, removing both recent data sets decreased the upward trend in *M* but the effect was greater for the spawn data. For the WCVI, removing the recent spawn data removed the upward trend in *M* whereas removing the recent age-composition data increased the upward *M* trend. These results warrant further investigation.

A model formulation with age-specific natural mortality estimated *M* increasing with age for all stocks except for SOG where *M* decreased with age. An additional model run conducted during the review meeting investigated both age-specific *M* and estimating a single *q* for the time series (Appendix C). For this run, *M* increased with age for all stocks. Due to the uncertainties in the mechanisms driving the recent increase in *M* (time-variant trend), further work on estimating age-specific *M* is not warranted at this time.

2.4 Model Priors

BC herring assessments are conducted in a Bayesian framework. Are parameter priors appropriate? Is assessment uncertainty appropriately reflected in the assessments?

Generally, the parameter priors assumed in HCAM are appropriate but a few changes were suggested during the review.

Currently, sigmaR is pre-specified. However, if it is to be estimated, a weakly informative prior (hyper-prior) should be used as it has been shown that the MLE estimates of these variance parameters are normally biased downwards. The inverse gamma distribution is the conjugate prior for the normal variance (Gelman et al., 2004). There are, however, technical issues around the use of weakly informative inverse gamma priors for hierarchical variance parameters (Gelman, 2006), and it might be more appropriate to use a more informative prior, or estimate the precision with a gamma distribution as the prior density, rather than estimating the variance. Also, better mixing properties in the MCMC chain are usually achieved when estimating the precision. Alternatively, the scaled inverse chi-square (Dorn, 2002) would be an appropriate prior for sigmaR.

The current HCAM formulation uses three priors related to the natural mortality parameterization, where only two parameters are estimated. The model parameters are the initial natural mortality rate and the variance of the natural mortality random walk process. There is an additional prior on the average natural mortality rate. The model should be reformulated replacing the initial natural mortality rate parameter with an average mortality rate parameter.

The HCAM prior on the stock-recruitment steepness parameter comes from the meta-analysis conducted by Myers et al. (1999). The database underlying that meta-analysis has been updated and the herring steepness prior could now be updated. An updated clupeoid meta-analysis should not include data from the BC herring stocks. The HCAM steepness prior, currently a truncated normal, should be changed to either a beta distribution or steepness should be logit-transformed and parameterized on 0.2 – 1.0.

Model parameters are confounded and it is useful to investigate the effects of parameter priors on model parameters and derived outputs. Running the model (MCMC) without data will show the effective priors for the derived quantities of management interest (e.g. depletion).

2.5 Selectivity versus Availability

Herring assessments have been conducted using either "availability" or "selectivity" assumptions. Under the "availability" parameterization the non-spawning component of the population is not available to the seine roe fishery, and availability parameters which are assumed to represent the proportion mature are estimated. Under the "selectivity" parameterization all fish are assumed available to the roe fisheries and seine gear selectivity parameters are estimated.

a) *Is one assumption preferable to the other?*
b) *Currently, age-composition data from pre-fishery charter samples collected during the spawning season are added to seine roe fishery age-composition data to represent the seine roe fishery catch. The rationale for this approach has been that, under the availability assumption, the combined fishery and charter age-composition data better reflects the age-composition of the spawning populations. Is this approach reasonable for either the "availability" assumption or the "selectivity" assumption?*

HCAM is currently formulated setting "availability" parameters at the assumed maturation schedule and estimating selectivity parameters for all fisheries. Previous formulations assumed the SN fisheries were non-selective but caught only available (ie. mature) fish.

There is a lack of data to directly resolve the issue of what is on the grounds and vulnerable to fishing and what is spawning. In Alaska a cast net survey on the spawning beds addresses the question by directly estimating the age-composition of the spawning population.

A model run estimating "availability" parameters suggested a high degree of variation in the maturation ogive among the stocks, but this model formulation was not supported statistically based on the change in objective function value. The panel felt that the selectivity formulation was preferred over availability since in theory maturity-at-age data could be collected.

Currently charter fishery age-compositions are combined with the SN fishery age-compositions to represent the age structure of the SN catch. The validity of this approach was discussed and it was suggested that the data should be disaggregated and the charter fishery data treated as a separate fishery. It may be possible to select years where the charter samples are representative of the spawning populations (ie. spatial and temporal coverage consistent with spawning) and treat these data as reflecting the mature component of the populations. However, additional work investigating the differences between these two sets of data is warranted.

Further work to investigate time-varying selectivity is warranted. Previous formulations of the HCAM model that included time-varying selectivity led to local minima problems, but resolution of the time-variant M issues may resolve these problems. The herring fisheries have not operated consistently over time (eg. pit lamping during reduction fisheries, shift to earlier roe fisheries), and incorrect selectivity assumptions will be confounded with other model parameters. In particular there may be temporal changes in the GN fishery selectivity (changes in mesh size, hanging ratios, fishery timing), and a better approach may be to treat this fishery as removals rather than assume some form of selectivity. One Panel member recommended investigating domed-shaped selectivity for the GN fishery.

2.6 Risk neutral or risk-averse science advice

The DFO "decision-making framework incorporating the precautionary approach" specifies the need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules. Clearly, reference points and decision rules need to be designed to be risk averse. Should stock assessments be conducted on a risk-neutral or risk-averse basis?

It is important that science remain objective and therefore scientific advice should remain risk neutral. A clear, defined separation between the role of science and management is required. Uncertainty should be clearly stated such that it can be incorporated into the decision making framework.

The use of informative priors that have *ad hoc* variance parameters should be examined in terms of their influence on median values of key policy parameters. For example, a high variance on the lognormal prior on B_0 may reflect appropriate uncertainty in this parameter. If however, the data are uninformative about B_0 the median value for B_0 will be highly influenced by the assumed prior variance. Minor changes in the assumed variance of B_0 can result in large changes in the median estimate of B_0. The Panel recommended examining the influence of the priors alone on policy advice. This can be done by turning the likelihood of the data off and examining the implied information about policy advice based only on the prior assumptions.

2.7 Management strategy evaluation (MSE)

DFO plans to conduct a herring MSE over the next few years. What assumptions are appropriate for a base case operating model and what assumptions are important to consider in robustness trials?

Recent commitments to International Agreements such as the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), the UN Fish Stock Agreement (UN, 1995) and the Johannesburg Agreement (UN, 2002) have shaped the development of a national Sustainable Fisheries Framework (SFF; DFO, 2009a). There are two components of the SFF that were discussed in the context of this workshop: conservation objectives for rebuilding depleted stocks and the harvest strategy compliant with the precautionary approach.

Within the SFF, DFO identifies conservation objectives in the context of stock rebuilding: *Ensure spawning stock biomass remains above the limit reference of* $0.4B_{MSY}$ *with 95% certainty over a time frame of two generations.*

There is also an implied target objective for stock maintenance: *Maintain spawning stock biomass above* B_{MSY} *at least 50% of time.*

Also included under the SFF is a formal "DFO Harvest Policy compliant with the Precautionary Approach" (DFO, 2006), which reaffirms Canada's commitment to the precautionary approach (PA) as well as to restoring stocks to B_{MSY} levels. The DFO harvest policy recommends establishment of stock status zones, limit (LRP) and upper (USR) stock reference points delimiting these zones, and the requirement to reduce fishing effort as stock biomass falls below the USR in order to avoid breaching the LRP. The default limit and upper stock reference points are defined as $0.4B_{MSY}$ and $0.8B_{MSY}$, respectively (DFO, 2009b).

There a number of similarities as well as differences between the existing HCR used for management of the BC herring stocks and the DFO rule. The herring rule consists of: (1) a single lower reference point below which fishing is not permitted, (2) a fixed harvest rate, and (3) decision rules around when fishing is permitted. The reference points of the DFO rule are based on B_{MSY} whereas reference points for herring are based on B_0. The SFF indicates that for fisheries where there is an existing operational HCR that differs from the default rule, deviation from the default rule should be justified.

Herring and MSE

Given the terms of the SFF, the primary objective of DFO stock assessment should be to evaluate components of the herring management system against the achievement of conservation objectives. This can be accomplished using a feedback control loop, or management strategy evaluation (MSE), to help identify which components of the system we should be concerned with, and which components are sound.

Operational components of a MSE include:

1) Objectives: Compliant with DFO policy and also that of managers and stakeholders. Defined in ways that scientists can measure.
2) Operating Models (OM) or scenarios: Range of hypotheses about stock structure and productivity.
3) Management Procedures (MP): Data, methods, and HCR for setting TACs. Can be data or model based.
4) Performance Measures: Statistics to evaluate performance of MPs relative to objectives.

OM's should consider alternative stock structure (meta-populations, sub-populations within stock assessment regions) and time-trends in productivity.

Investigation of the effect of steepness on performance measures can be done by constructing OMs at different steepness values rather than integrating across steepness (fix steepness at fixed points of the marginal posterior distribution rather than integrate across the distribution).

3 Additional recommendations on HCAM implementation

Throughout the two-day workshop a number of additional ideas were brought up and discussed, either by Panel members or invited members of the audience. In no particular order, these include:

Ageing error:

Has there has been a shift in ageing standards? This could be investigated by having a sample of ageing structures from the past (e.g., 10-15 years ago) aged by readers currently conducting the ageing. Additionally, data from dual-aged structures could be used to include ageing error in the model.

Single sex/ sex-specific:

HCAM is currently run as a one sex model, although sex-specific age-composition and size-at-age data are available. Analysts may want to consider the merits of disaggregating data by sex in order to increase the available data as well as to capture any sex-specific dynamics. Additionally, the egg deposition estimates can then be tied directly to female spawning biomass.

Data weighting:

The data weightings (spawn and age-composition) in the current HCAM implementation have not been "tuned" to balance the residuals. For Bayesian estimation this "tuning" is necessary so that parameter priors have the appropriate "influence" on the posterior distribution.

Missing data:
Individual data observations should be used only once in the assessment model. If data are missing, say age-composition for a fishery, those data cells should remain empty rather than ‘borrowing’ ageing information from neighbouring cells.

Biological data: Test fishery vs. commercial data
Examine the merits of treating biological data collected through the test fishery and commercial catch as one source of data vs. two-independent sources.

Time series:
Currently assessments are conducted using data time series beginning in 1951. Catch and age-composition data from the reduction fishery period (pre-1970) may be incorrectly attributed to stock assessment region because of the seasonal timing of those fisheries. Stock assessments that begin in 1970 could be investigated.

4 Panel Recommendations

The Panel recommendations arising from the review of the herring stock assessment model fall into two categories: some relate to changes to the model structure and others involve independent projects to better understand the data used in the model.

Model-based recommendations include modifications to the model formulation and further investigations to understand model behaviour that could lead to improved parameterization. In some cases the recommendations will be relatively simple to implement because the required model structure already exists while in other cases substantial programming changes may be required, either directly to the assessment model or to the herring stock assessment database. Also, some of the recommendations are likely to have a substantial effect on management advice (eg. q_2=1), while others are expected to have minimal effect. As such, prioritizing the Panel recommendations is not straightforward and we have not attempted to do so.

The model parameterization of *q* could potentially have the single greatest impact on estimation of management parameters, and as such further investigation is recommended. Within the model, parameterization of *q*, *M*, and selectivity are confounded, so these should be explored jointly. Time-varying selectivity and alternative GN selectivity assumptions also merit further work. The goals for an alternative model formulation include: (1) reduction in correlation structure in spawn residuals, (2) plausible alternatives for the estimation of *q*, and (3) alternative explanations for apparent changes in *M*.

Some of the Panel recommendations are relatively straightforward to implement, and should be considered prior to other investigations. These include:

- “Tune” model to balance data weighting
- Implement as sex specific model
- Treat charter fishery data as separate fishery
- Include ageing error
- Include hyper-prior on sigmaR
- Change *M* parameterization (avgM is estimated parameter)
- Ramp-in sigmaR bias correction
- Change steepness prior (currently and improper prior)

Panel recommendations related to model outputs and reporting include:

- Report should: list all data sources, and if not used in the assessment provide rationale; provide tables of all data used in assessment; improve (and correct) model documentation
- Calculate posterior distributions of model parameters without data (effect of all priors)
- Calculate B_0 using the "dynamic" formulation; B_{msy} through long-term deterministic forward projections

Panel recommendations related to herring data - projects that are independent of the assessment model but could lead to better model formulations. These include:

- Analyze spawn survey data to determine if the assumptions of constant (time-invariant) location-specific spawn widths for surface surveys and equivalent vegetation type/layers observations for surface and dive surveys are appropriate
- Investigate if there has been a shift in ageing
- Update steepness prior using current Myer's database

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Appendix A: Terms of reference for a review of B.C. herring stock assessments.

Context:

Stock assessments for BC herring are conducted annually using a statistical herring catch-age model (HCAM) with stock projections forming the basis for setting fishery quotas. The assessments are reviewed annually through the Pacific Stock Assessment Review process (PSARC), however in depth reviews of the analytical methods are reviewed only periodically in conjunction with significant changes to the model structure.

Members of the BC herring industry have expressed concern that recent herring stock assessments are sometimes inconsistent with their "on the grounds" observations, and they are questioning the reliability of the stock assessment model. The Herring Industry Advisory Board (HIAB) convened a meeting to formulate these concerns, and the Herring Conservation and Research Society (HCRS) is funding a review of the HCAM model to begin to address the industry concerns. The HCRS, an industry based non-profit organization that funds herring research and management programs, reports to HIAB.

Overall, the objectives of the HCRS stock assessment model review are to ensure: analytical approaches are consistent with state-of-the-art world standards; the best use is made of available data, and; the pre-cautionary approach to which DFO subscribes is appropriately applied in the herring stock assessment process.

The Review:

The BC herring stock assessment review will be a peer review process, including scientists with international experience in fishery stock assessment reviews and DFO scientists responsible for the herring assessments. The review will be conducted during a two day workshop on June 17- 18, 2010 at the Coast Bastion Inn, Nanaimo. Documents pertaining to the review TOR will be made available 1 to 2 weeks prior to the workshop.

The review panel is tasked with preparing a summary report documenting the workshop findings, in particular as they relate to the specific TOR described below. The panel report should represent consensus view where appropriate and minority opinions where they exists. The review panel Chair will lead preparation of the panel summary report which should be completed within 2 weeks of the workshop.

A select group of invitees will also participate in the review workshop. These participants, representing industry, DFO and outside agencies, all have an interest in the Pacific Northwest herring resource, and as such can contribute positively to the review workshop. However, the panel's terms of reference concern technical aspects of the stock assessment and meeting discussions will necessarily be of a highly technical nature. The panel Chair will ensure that workshop discussions remain on task.
This review process is not intended to replace the PSARC process, and should any of the panel recommendations be incorporated into the 2010 stock assessment (or future years), a working paper will be prepared for review through the PSARC process.

Background:

BC herring stock assessments are conducted annually for 5 major and 2 minor stock assessment regions, generally using a single formulation of the HCAM model. One-year ahead stock projections in conjunction with a harvest control rule (HCR) form the basis for determining the recommended harvest for each region.

The herring HCR is comprised of 3 components:

a) A limit reference point of 25% B_0. Commercial fisheries are curtailed to ensure spawning biomass remains above the limit reference point.
b) A 20% harvest rate.
c) Rules that determine what recruitment assumption to use.

The first two components of the HCR have been in place since the mid-1980s. The limit reference point, termed "CUTOFF", is not calculated annually, and the values used currently have been in place since 1996.

Formal harvest management guidelines were developed by DFO in 2006 ("DFO Harvest policy compliant with the Precautionary Approach"). Furthermore, formal conservation objectives related to rebuilding strategies have been declared by DFO (DFO 2009), specifically: "Ensure stock biomass remains above the limit reference point of $0.4B_{MSY}$ with 95% certainty over a time frame of two generations." DFO plans to conduct a management strategy evaluation (MSE) over the next 2 years to evaluate the herring HCR against the formal harvest policy and the achievement of conservation objectives. Objectives of this review are intended to be complementary to these policies.

Specific Terms of Reference for the review:

The Panel is tasked with addressing the following questions:

2) The herring spawn index is assumed to be a minimum estimate of spawning abundance. HCAM currently assumes the proportionality constant between observed spawn deposition (estimates of female spawner biomass from egg deposition surveys) and actual spawn (*q*) is equal to 1, for the period where the majority of spawns were surveyed by divers (1988-current). This assumption likely creates a bias because a) not all spawns are surveyed, and b) some eggs are lost between the spawning and survey events (largely due to predation). Is the assumption that q=1 appropriate? What is the appropriate error structure of the spawn survey data? Is there potential for bias when spawning abundance is low (easier to miss small spawn events than large ones)?

3) Certain aspects of the herring harvest control rule should be considered:
   a) Should CUTOFF estimates change annually in concert with model estimates of B_0?
   b) What is the best method for calculating B_o and B_{msy}?
   c) Are the recruitment assumptions rules the best approach to capturing uncertainty in these components of the stock projection?
   d) What are appropriate assumptions about stock-recruitment steepness?

4) In the current version of HCAM, natural mortality rate is modelled as a "random walk" process, varying annually but constant across ages. Past assessments have used fixed values of natural

mortality, while recent studies have explored age-specific as well as density-dependent natural mortality for the BC herring populations. The data provide some support for both these alternatives. What is the best way to parameterize natural mortality? How should the unfished population abundance (B_0) be calculated, given the natural mortality parameterization?

5) BC herring assessments are conducted in a Bayesian framework. Are parameter priors appropriate? Is assessment uncertainty appropriately reflected in the assessments?

6) Herring assessments have been conducted using either “availability” or “selectivity” assumptions. Under the “availability” parameterization the non-spawning component of the population is not available to the seine roe fishery, and availability parameters which are assumed to represent the proportion mature are estimated. Under the “selectivity” parameterization all fish are assumed available to the roe fisheries and seine gear selectivity parameters are estimated.
   a) Is one assumption preferable to the other?
   b) Currently, age-composition data from pre-fishery charter samples collected during the spawning season are added to seine roe fishery age-composition data to represent the seine roe fishery catch. The rationale for this approach has been that, under the availability assumption, the combined fishery and charter age-composition data better reflects the age-composition of the spawning populations. Is this approach reasonable for either the “availability” assumption or the “selectivity” assumption?

7) The DFO “decision-making framework incorporating the precautionary approach” specifies the need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules. Clearly, reference points and decision rules need to be designed to be risk averse. Should stock assessments be conducted on a risk-neutral or risk-averse basis?

8) DFO plans to conduct a herring MSE over the next few years. What assumptions are appropriate for a base case operating model and what assumptions are important to consider in robustness trials?

Appendix B: List of Workshop Participants.

Expert Panel:
- André Punt, University of Washington
- Steve Martell, University of British Columbia
- Jaclyn Cleary, Fisheries and Oceans, Canada
- Vivian Haist, Consultant
- Jake Schweigert, Fisheries and Oceans, Canada

Other Participants:
- Doug Hay, Consultant
- Dennis Chalmers, Province of BC
- Randy Webb, Fisheries and Oceans Canada
- Greg Taylor, Herring Industry Advisory Board
- Brenda Spence, Fisheries and Oceans Canada
- Lorena Hamer, Herring Conservation and Research Society
- Rob Morley, Herring Industry Advisory Board
- Ron Tanasichuk, Fisheries and Oceans Canada
- Bob Rezansoff, Herring Conservation and Research Society, Herring Industry Advisory Board
- Scott Kelly, Alaska Department of Fish and Game
- Sherri Dressel, Alaska Department of Fish and Game
- Steve Reifenstuhl, Alaska Department of Fish and Game
- Jennifer Boldt, Fisheries and Oceans Canada

Appendix C: Additional analyses presented during meeting.

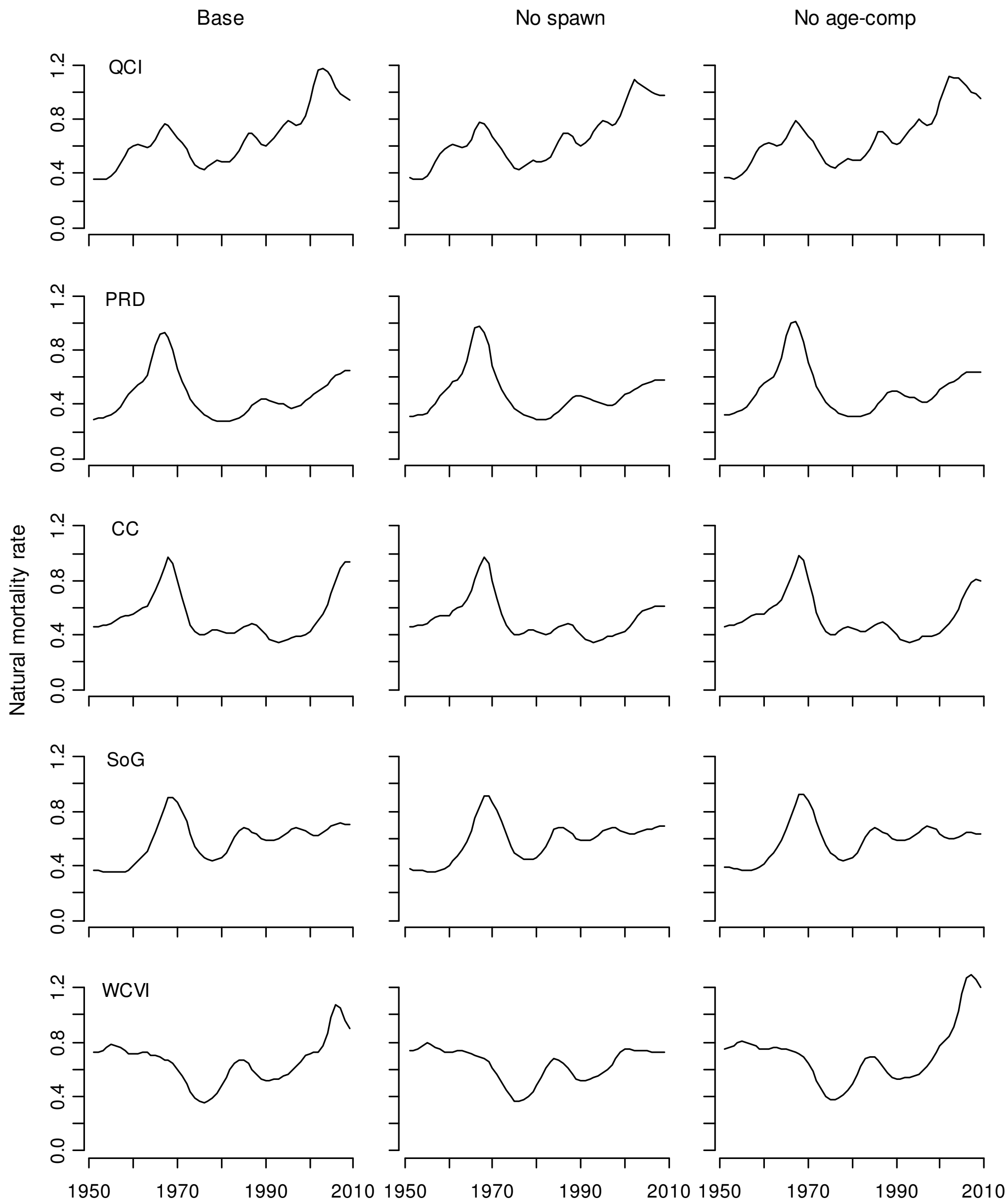
Additional HCAM model runs conducted during the review meeting include:

1) Availability parameterization with 1 *q* estimated (run S8a)
2) Age-specific M with 1 *q* estimated (run S9)
3) Removing last 7 years of spawn data (run S10)
4) Removing last 7 years of age-composition data (run S11)

Summary statistics for these extra runs (and some of the initial runs, for comparison) are presented in Appendix Table 1. Natural mortality rate estimates for runs S10 and S11 are compared with run S1 (base run) in Appendix Figure 1.

Appendix Table 1. Model outputs for alternative runs:

Parameter		S1	S2	S4	S7	S8	S8a	S9	S10	S11
Posterior	Total	2588.4	2530.44	2566.95	2446.17	2541.11	2498.19	2358.44	2548.77	2259.36
	Pars	1174	1174	1179	1179	1189	1189	1179	1174	1160
Likelihoods	Spawn	-70.6	-96.8	-70.2	-52.6	-158.4	-164.5	-94.2	-94.0	-83.7
	age-comp	2518.6	2512.8	2535.4	2354.7	2514.7	2524.4	2344.1	2509.9	2213.2
	catch	9.3	5.4	9.4	6.1	4.2	1.5	2.2	9.3	9.4
MARs	spawn	0.27	0.25	0.28	0.27	0.21	0.22	0.25	0.24	0.26
	age-comp	0.65	0.65	0.66	0.61	0.63	0.63	0.60	0.65	0.66
	catch	0.04	0.03	0.04	0.04	0.02	0.01	0.02	0.04	0.03
SDNRs	spawn	0.44	0.42	0.44	0.45	0.36	0.35	0.42	0.42	0.43
	age-comp	1.42	1.43	1.42	1.38	1.55	1.56	1.39	1.42	1.42
	catch	0.19	0.15	0.19	0.16	0.13	0.08	0.09	0.19	0.20
B_0	QCI	27.9	54.9	28.9	28.0	23.3	81.6	62.2	29.2	29.3
	PRD	66.4	97.6	68.0	79.1	46.6	69.4	110.0	71.9	67.6
	CC	55.8	102.0	54.5	69.4	39.5	105.0	139.8	60.1	58.0
	GS	173.0	201.7	116.8	191.2	92.3	103.2	209.9	174.5	168.7
	WCVI	62.1	68.4	52.4	62.0	32.9	40.5	75.2	66.5	56.0
Depletion	QCI	0.26	0.69	0.25	0.25	0.33	0.91	0.70	0.35	0.23
	PRD	0.22	0.42	0.21	0.32	0.30	0.45	0.68	0.48	0.20
	CC	0.18	0.52	0.18	0.20	0.22	0.55	0.58	0.51	0.15
	GS	0.28	0.40	0.44	0.24	0.50	0.57	0.41	0.35	0.27
	WCVI	0.08	0.12	0.10	0.08	0.16	0.17	0.12	0.33	0.13
Average M	QCI	0.66	0.79	0.67	0.71	1.16	1.23	0.79	0.66	0.67
	PRD	0.47	0.66	0.47	1.35	1.02	1.14	0.58	0.48	0.51
	CC	0.54	0.77	0.54	1.88	1.07	1.18	0.86	0.52	0.54
	GS	0.58	0.80	0.63	0.30	0.74	0.84	0.84	0.59	0.58
	WCVI	0.65	0.70	0.63	1.34	1.13	1.11	0.83	0.64	0.70
Steepness	QCI	0.74	0.73	0.74	0.74	0.80	0.90	0.75	0.77	0.77
	PRD	0.67	0.58	0.66	0.72	0.63	0.64	0.75	0.67	0.66
	CC	0.86	0.79	0.87	0.75	0.90	0.89	0.77	0.89	0.88
	GS	0.72	0.67	0.81	0.71	0.93	0.90	0.67	0.72	0.74
	WCVI	0.70	0.72	0.71	0.72	0.83	0.82	0.75	0.76	0.82
q- early	QCI	0.27	0.18	0.27	0.27	0.33	0.10	0.16	0.27	0.27
	PRD	0.52	0.32	0.52	0.41	0.82	0.43	0.32	0.49	0.47
	CC	0.28	0.17	0.28	0.26	0.41	0.15	0.13	0.28	0.28
	GS	1.03	0.51	0.84	1.12	0.99	0.75	0.48	1.02	1.01
	WCVI	0.66	0.62	0.71	0.76	1.08	0.77	0.52	0.65	0.63
q-late	QCI	1	0.18	1	1	1	0.10	0.16	1	1
	PRD	1	0.32	1	1	1	0.43	0.32	1	1
	CC	1	0.17	1	1	1	0.15	0.13	1	1
	GS	1	0.51	1	1	1	0.75	0.48	1	1
	WCVI	1	0.62	1	1	1	0.77	0.52	1	1
Empirical sigmaR	QCI	0.26	0.69	0.25	0.25	0.33	0.91	0.83	0.35	0.23
	PRD	0.22	0.42	0.21	0.32	0.30	0.45	0.74	0.48	0.20
	CC	0.18	0.52	0.18	0.20	0.22	0.55	0.73	0.51	0.15
	GS	0.28	0.40	0.44	0.24	0.50	0.57	0.47	0.35	0.27
	WCVI	0.08	0.12	0.10	0.08	0.16	0.17	0.65	0.33	0.13



Appendix Figure 1. Natural morality rate estimates for alternative HCAM formulations (base model - S1; remove last 7 years spawn data – S10; and remove last 7 years age-composition data – S11).