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**Compte rendu 2009/037**

**Proceedings of the Pacific Scientific Advice Review Committee (PSARC) Pelagic Subcommittee Meeting: Stock assessment and management advice for BC herring fishery, 2009 assessment and 2010 forecasts and herring multi-stock analysis**

**September 2, 2009**

**Pacific Biological Station  
Nanaimo, BC**

**Linnea Flostrand**

**Compte rendu de la réunion du sous-comité sur les poissons pélagiques du Comité d'examen des évaluations scientifiques du Pacifique (CEESP) Évaluation du stock de hareng et avis scientifique pour la gestion de cette pêche en C.-B., évaluation pour 2009, prévisions pour 2010 et analyse de stocks de hareng multiples**

**2 septembre 2009**

**Station de biologie du Pacifique  
Nanaimo, CB**

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Pacific Biological Station  
3190 Hammond Bay Rd.  
Nanaimo, BC V9T 6N7

**December 2009**

**Décembre 2009**

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## **Foreword**

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

## **Avant-propos**

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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## SUMMARY

Participants from Fisheries and Oceans Canada (DFO) Science, Habitat Management and Fisheries and Aquatic Management Sectors and external participants from the non-governmental organizations (NGO) community, the Province of British Columbia and the general public including invited biological consultants attended a PSARC review on September 2 to assess and develop advice for the following working papers:

- Stock assessment and management advice for the British Columbia herring fishery, 2009 Assessment and 2010 Forecasts
- Herring multi-stock analysis: Integration of tagging data and evaluation of alternative dynamics

Comments received on the two working papers are presented in these Proceedings. The papers were accepted subject to revisions. Products of the meeting will be two CSAS Research Documents and a CSAS Science Advisory Report.

## SOMMAIRE

Le 2 septembre, des intervenants du ministère des Pêches et des Océans (MPO), secteurs des Sciences, de la Gestion de l'habitat et de la Gestion des pêches et de l'aquaculture de même que des représentants d'organismes non gouvernementaux (ONG), du gouvernement de la province de la Colombie-Britannique et du grand public, y compris des consultants en biologie, ont pris part à un examen du CEESP afin d'évaluer les documents de travail suivants et d'élaborer un avis scientifique à cet égard.

- Évaluation du stock de hareng et avis scientifique pour la gestion de cette pêche en Colombie-Britannique, évaluation pour 2009 et prévisions pour 2010
- Analyse de stocks de hareng multiples: intégration des données de marquage et évaluation de diverses dynamiques

Le présent compte rendu expose les commentaires reçus à propos de ces deux documents de travail. Les documents ont été acceptés sous réserve de certaines révisions. Les produits du SCCS pour cette réunion seront deux documents de recherche et un avis scientifique.

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## **INTRODUCTION**

The PSARC Pelagics Subcommittee met September 2, 2009 at the Pacific Biological Station, in Nanaimo, British Columbia. External participants from industry, First Nations and conservation groups attended the meeting. The Subcommittee Chair, L. Flostrand opened the meeting by welcoming the participants, reviewed the agenda and referred to the terms of reference. During the introductory remarks the objectives of the meeting were reviewed, and the Subcommittee accepted the meeting agenda.

The Subcommittee reviewed two working papers and a summary of the review process is in the main report. Summaries of each working paper are included as Appendix 1, the meeting agenda appears as Appendix 2, the terms of reference is Appendix 3 and the list of attendees is Appendix 4.

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## DETAILED COMMENTS FROM THE REVIEWS

### **Stock assessment and management advice for the British Columbia herring fishery, 2009 Assessment and 2010 Forecasts**

*Jaclyn Cleary, Jake Schweigert and Vivian Haist*

Results from the current Pacific herring stock assessment were generated using the herring catch-at-age model version 2 (HCAMv2), following the 2008 PSARC reviewed and accepted assessment methods (DFO 2009). Jaclyn Cleary presented information on: assessment methods, results and trends (including information from 2009 spring fisheries and spawning events) and associated modelling issues.

Ron Tanasichuk described results from the recent August West Coast Vancouver Island (WCVI) trawl survey and presented recruitment forecasts for the WCVI and Strait of Georgia (SOG) assessment regions based on survey age composition data. The PSARC approved methodology for forecasting recruitment to these two regions includes predictive regressions on the relationships between the proportions of age 2+ fish observed in the trawl survey and the proportions of age 2+ fish estimated by the current year's assessment model for the subsequent pre-fishery or pre-spawning season (Tanasichuk 2000, 2001). The recruitment forecasts for the 2010 pre-fishery/pre-spawning season were poor for both regions.

Tanasichuk noted that the WCVI 2008 data was again excluded from the analysis because it appears as an outlier. He indicated concern for the accuracy of the SOG 2009 data and its predictive power for a 2010 forecast because of possible 2009 age composition bias due to temporal constraints on sampling coverage.

### **General Discussion**

Several points of clarification were posed on the methods and datasets used for the current recruitment forecasts. To help clarify details related to the trawl survey in future years, it was proposed that authors of the assessment paper collaborate in the preparation of an appendix on trawl survey recruitment forecasts for presentation at future PSARC meetings and for publication within the assessment document.

Jake Schweigert briefly described additional informational from an annual SOG juvenile herring survey, which links young of the year catch observations from a given year class with age 3 recruitment estimates for that year class (Schweigert et al., 2009). He described 2007 year class observations as having particularly low catch levels, suggesting a poor 2010 recruitment. He noted that similar findings were observed for the 2005 young of the year and 2008 age 3 recruits and that the consistency between predictions from the summer trawl and juvenile surveys affirm a high likelihood of poor recruitment to the SOG in 2010.

Several points related to variations in sampling schemes were discussed. Concern was expressed over the quality of temporal sampling coverage (i.e. SOG 2009 as noted above), and possible effects or biases that may ensue from compressed sampling coverage, which may impact recruitment predictions from the trawl survey. Concerns were also voiced over possible effects due to reduced funding impacting the sampling program over the time series (i.e. pre and post Larocque). To investigate this issue, future work was suggested to look at differences in age composition and stock assessment outcomes from the inclusion of sample data across a



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spawning season. Other suggested future work was to investigate effects of spatially variation in samples within a region (i.e. in the SOG between areas 14 and 17 and in the Prince Rupert District (PRD) between areas 3, 4 and 5) and to the impact of varying the weighting between the age composition data and the spawn survey data. It was suggested that all sampling studies characterizing changes to sampling schemes should be “model independent” and that studies investigating changes in sampling schemes could be done in the context of a Management Strategy Evaluation (MSE) and associated effects on catch advice. It was noted that last year’s Subcommittee recommended that a thorough study be undertaken to evaluate different sampling strategies and cost-benefit options for providing scientific advice and that this year’s meeting should again include that recommendation. Similar to previous Subcommittee meetings, members showed concern about and recommended against any reduction in sampling coverage, (regardless of perceived strengths of stocks).

There was some discussion of residual patterns for the modelled time series (Figure 12 in the Working Paper), mostly emphasizing points made in the working paper (eg. further investigation is needed into their cause). A suggested editorial change to the document was to divide spawn index information into two time series (<1988 and  $\geq$ 1988, Figure 12). Based on the run of negative residuals for the SOG, it was suggested that modelling likely underestimates biomass in SOG for recent years because: 1)  $q$  is assumed to be 1 and spawn likely missed from predation and/or survey constraints, and, 2) age composition data may not be representative of the population. It was also suggested that the document needs more explanation on the role of  $q$  (proportionality coefficient between a spawn survey estimate and a spawning biomass estimate) to assist readers in understanding modelling approaches.

There was some discussion on the merits and difficulties of incorporating opportunistic findings and traditional knowledge into assessments. The Subcommittee discussed the effects of limited survey coverage in the remote minor area of 2W. The question was posed whether information from acoustic soundings could also be used as model input since it is perceived that spawning is frequently missed in this area.

One member stated that implications from uncertain mortality from Spawn on Kelp (SOK) operations and the assumption of high survival should be investigated. It was also stated that SOK mortality needs to be evaluated in association with fishing policies when stocks are below cutoff. There was some debate over the relevance of historic findings from a study by Shields et al. (1985) and political ramifications from potential results of further studies of mortality and disease associated with SOK practises. It was mentioned that in Prince William Sound a link between SOK operations and disease has been made and that the stock assessment in Alaska takes this into account.

During the construction of the advisory tables for the major and minor stock assessment areas, there was some discussion on wording describing forecast rules, interpretation of cutoff levels and recommendations influencing potential yield. An inquiry was made into why confidence intervals are not provided to managers to allow them to assess uncertainty of the forecasts. A participant mentioned the difficulty in generating representative confidence intervals with a set of model assumptions applied to both forecasting recruitment and estimating population abundance; furthermore, it was thought that upper confidence bounds would always be more attractive to those seeking increases in yield. Someone asked about the likelihood of acquiring Food, Social and Ceremonial (FSC) catch information in the future and was told by a manager that an initiative is in place to look at this.

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## Conclusions

- The 2010 forecasts of abundance for the Queen Charlotte Islands (QCI), Central Coast (CC) and WCVI assessment regions are below cutoff levels.
- The 2010 forecasts of abundance for the PRD and SOG assessment regions are above cutoff levels and the Subcommittee endorsed the harvest options from these regions as described by existing harvest rules.
- The 2010 forecasts of abundance for Area 27 and Area 2W minor assessment areas and the application of the 10% harvest rate rule were endorsed by the Subcommittee.

## Recommendations

1. Authors of assessment paper collaborate with the principal investigator of the summer trawl SOG and WCVI recruitment forecasting survey to incorporate findings into an appendix for the assessment document (starting next year if not this year).
2. As recommended last year, studies should be done to investigate the representativeness of the temporal and spatial sampling schemes.
3. As recommended last year, test fishing and dive survey sampling coverage should not be reduced, regardless of perceived strengths of stocks, until cost-benefit analyses outline risks and levels of uncertainty associated with changing (especially reducing) sampling efforts.
4. Abundance forecasts for the QCI, the CC and WCVI major assessment regions are below commercial fishery cutoffs. Any commercial harvest in 2010 is therefore contrary to the intent of the harvest rule designed to increase production from stocks below cutoff levels. Abundance forecasts for the PRD and the SOG are above the fishery thresholds, therefore harvest rules apply for potential yields at 20% harvest rates. Abundance forecasts for the minor assessment areas of Area 27 and Area 2W (where there are no fishery cutoff levels) result in potential yields at 10% harvest rates. Area-specific science advice is summarized in Appendices 5-11, and more briefly in the text below.
  - QCI, CC and WCVI: as in 2006, 2007 and 2008, the abundance forecasts are below their respective commercial fishery cutoffs and commercial harvests at any level are inconsistent with the intent of the harvest rule.
  - PRD - Forecast abundance is above the cutoff with a potential commercial yield of 3,100 tonnes.
  - SOG - Forecast abundance is above the cutoff with a potential commercial yield of 9,000 tonnes.
  - Area 2W - A potential commercial yield of 413 tonnes is consistent with the 10% harvest rule for Minor Areas.
  - Area 27 - A potential commercial yield of 135 tonnes is consistent with the 10% harvest rule for Minor Areas.

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## Herring multi-stock analysis: Integration of tagging data and evaluation of alternative dynamics

Vivian Haist and Jake Schweigert

*\*Working paper accepted with revisions\**

Vivian Haist presented information from the working paper pertaining to modelling options, methods undertaken, and results obtained from collectively modelling major stocks of the B.C. herring population under different assumptions of stock dynamics. In the context of the recently applied assessment model (HCAMv2) and the development of operating models for future management strategy evaluation (MSE), Haist provided theoretical explanations for three alternate stock recruitment functions (BH, ABH and R) and two forms of density dependent natural mortality (ddM1 and ddM2). Two configurations of the HCAMv2 model were also considered, one described as a base with mortality (M) estimated from a random walk and one described as a base with constant M. Haist emphasized that the current study provides comparative sets of models and model output that could be useful as reference information for further development of operating models in the management strategy evaluation (MSE) process. In addition to the information reported in the working paper, and to address an inquiry made by one of the reviewers, Haist presented results from preliminary trials investigating age-specific natural mortality. When comparing age-specific and age-invariant natural mortality, the authors found a significant improvement in model fit when applying age-specific natural mortality. Haist commented that future trials related to MSE work should further explore this approach. Haist also commented on the possibility of exploring models in the future that apply theoretical assumptions pertaining to climate regimes and other drivers affecting productivity.

### Reviewer Discussion

Both reviewers were present to provide feedback and participate in the discussion. Both reviewers noted information requiring clarification, validation or inclusion to assist in improving the paper's quality. Although some editorial revisions were presented to the authors, only major issues are included in this summary.

In addition to providing constructive feedback, the first reviewer commended the authors on their progress and endorsed their work. The first reviewer focussed on three main points, suggesting the following improvements to the paper:

- (1) Relate model performance to catch and policy advice. A suggestion was made to consider using a metric of maximum sustainable yield (i.e., changes in  $B_{MSY}$ ) as a starting point to evaluate model performance.
- (2) Present results (objective function value) by stock area to facilitate comparisons of model fit, model behaviour and statistical differences.
- (3) Clarify the confounding behaviour of density dependent mortality (Mdd) and steepness ( $h$ ).

The authors agreed with the first point but they emphasized that the objective of this project was not to develop an operating model for use in a feedback loop simulation but rather to explore stock dynamics for future consideration in the context of an MSE. Haist indicated this type of modeling work should be carried out before considering impacts on MSE-related performance measures, whereas the reviewer felt that these processes should be developed concurrently. In regards to the second point, the author presented additional results showing the objective function value and likelihood components for individual stock assessment regions. In regards to the third

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point, the authors prepared and presented a correlation table for inclusion in the paper, which addressed the reviewer's suggestion.

The second reviewer's feedback summarized concerns with modelling assumptions and biological interpretation of the results, emphasizing two main points. Firstly, the reviewer questioned model representation of herring biomass, because it confounds age-classes and associated biological parameters (by assuming permanent co-occurrence for which there is evidence against), and secondly, the reviewer questioned the modelling of natural mortality, because it was not treated as age-dependent (for which there is evidence). The authors and the second reviewer disagreed on the matter of density dependent mortality. This modelling work described a depensatory (inverse) relationship between natural mortality and stock abundance (i.e., higher mortality associated with low stock density) which could be due to higher predation effects when herring abundance is low (predators removing a constant amount regardless of prey biomass). The second reviewer refutes this theory indicating that herring biology supports a compensatory (direct) relationship between mortality and biomass, (i.e., high mortality at high stock density, driven by herring prey abundance) and that there is a lack of evidence to support depensatory mortality for herring. There was also disagreement on when in the life cycle natural mortality occurs. Haist stated this likely is a year-round occurrence while the second reviewer supports the idea that natural mortality occurs primarily in the summer and early fall. One participant stated that regardless of the mechanism it is important to include a scenario acknowledging the impacts of density dependent mortality in any future MSE model development to assess the robustness of alternative harvest policy choices for a range of population dynamics. The second reviewer was encouraged by the results from preliminary work that include age-specific mortality and requested that the paper's discussion comment on including age-specific mortality when developing operating models for MSE.

There was some general discussion in terms of possibilities for future work and applicability to MSE operating model development. One participant suggested that Mdd modelling could benefit from assessing size at age trends, such as using weight-at-age or length-at-age data, and also by using cohort-based data. It was pointed out that regime modelling of  $B_0$  versus time invariant modelling poses questions leading to other sets of assumptions (time series decisions, different reference points, roles of predation versus other mortality causes). One reviewer emphasized that in the context of an MSE the focus should be on the policy impacts under different assumptions about regime shifts.

### **Subcommittee Conclusions and Recommendations**

The Subcommittee accepted the paper subject to revisions, which include the addition of text to clarify and validate several points highlighted by reviewers (i.e. information on parameter correlations and information on significance of modelling age-specific mortality).

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## Appendix 1. Agenda

### **DRAFT AGENDA PSARC PELAGICS SUBCOMMITTEE MEETING**

Pacific Biological Station,  
Seminar Room  
Nanaimo, BC

#### **Sept 2, 2009**

- 9:00 Introductions and Opening Remarks.
- 9:30-12:00 Review Working Paper 2009/01: Stock Assessment and Management Advice for the British Columbia Herring Fishery, 2009 Assessment and 2010 Forecasts, by Jaclyn Cleary, Jake Schweigert, and Vivian Haist; Brief summary of summer trawl survey findings and recruitment forecasts for WCVI and SOG by Ron Tanasichuck
- 12:00-1:00 Lunch
- 1:00-4:00 Continue review of Working Paper 2009/01 (if required).
- Review Working Paper 2009/02: Herring multi-stock analysis: Integration of tagging data and evaluation of alternative dynamics, by Vivian Haist and Jake Schweigert.
- Draft criteria for assessment of stock status in 2009 and yield recommendations for 2010 (i.e. for inclusion as appendix tables to Working Paper 2009/01)

#### **Sept 3, 2009**

- 9:00 - 1200 Meeting possibly adjourned Sept 2 but Seminar Room booked Sept 3 to continue if time required.
- 12:00-1:00 Lunch (if required)
- 1:00- 4:00 Seminar room still available but meeting expected to be over.

**Appendix 2. List of Attendees**

<b>First Name</b>	<b>Last name</b>	<b>Affiliation</b>
<b>EXTERNAL PARTICIPANTS</b>		
Vivian	Haist	Haist Consulting
Lorena	Hamer	Herring Conservation and Research Society
Nicholas	Irving	Parks Canada
Warren	Johnny	Chemainus First Nation
Russ	Jones	Council of Haida Natoins
Steve	Martell	UBC Fisheries
Ed	Safarik	Herring Conservation and Research Society
Doug	Hay	Research Scientist Emeritus, DFO/ PBS Pelagics
Steve	Carpenter	Heiltsuk & Herring Conservation and Research Society
Earl	Newman	Heiltsuk
<b>DFO PARTICIPANTS</b>		
Jennifer	Boldt	
Al	Cass	
Jaclyn	Cleary	
Kristen	Daniel	
Linnea	Flostrand	
Chuck	Fort	
Vanessa	Hodes	
Stacey	Hrushawy	
Karen	Leslie	
Mark	Potyrala	
Jake	Schweigert	
Brenda	Spence	
Ron	Tanasichuk	
Randy	Webb	

The reviewers for the PSARC paper presented at this meeting are listed below. Their assistance is invaluable in making the PSARC process work.

Steve Martell	University of British Columbia
Ron Tanasichuk	PBS, Fisheries and Oceans

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## Appendix 3. Terms of Reference

**Terms of Reference: Regional Advisory Meeting**  
***Pacific Scientific Advice Review Committee (PSARC)***  
***Pelagics Subcommittee Review***  
**September 2 -3, 2009**  
**Seminar Room, Pacific Biological Station. Nanaimo, BC**  
**Chairperson: Linnea Flostrand**

### **Background**

The PSARC Pelagics Subcommittee will review findings and advise resulting from the application of updated datasets in association with a recently accepted version of the Pacific herring assessment model (HCAMv2) in association with a precautionary decision making framework.

Recent estimates of herring natural mortality (i.e. from HCAMv2) are at or near historical high values for all BC stocks. Multi-year tag recapture data can provide information on absolute levels of post tagging survival rates, independent of HCAM parameter estimation, which may provide insight into variability in dispersal and natural mortality. The PSARC Pelagics Subcommittee will review a working paper that investigates estimates of natural mortality and dispersal using tag-recovery data, in order to consider alternative stock dynamics that may form the basis of a management strategy evaluation for B.C. herring.

### **Objectives**

Peer review the results from the draft working paper titled “Stock Assessment and Management Advice for the British Columbia Herring Fishery, 2009 Assessment and 2010 Forecasts”, which applies the HCAMv2 assessment model to an updated herring dataset for providing scientific advice on precautionary harvest levels for 2010.

Peer review the draft working paper title “Herring multi-stock analysis: Integration of tagging data and evaluation of alternative dynamics”, which is intended to provide insight and scientific advice related to future BC Pacific herring stock assessment models.

### **Products**

- CSAS Proceedings summarizing the discussions of the two papers.
- CSAS Research documentation of approved papers
- CSAS Science Advisory Report with maximum recommended TAC tables by herring stock assessment region

### **Location and Date**

Seminar Room, Pacific Biological Station, Nanaimo, BC,  
Sept 2 (and Sept 3 only if required), 2009

### **Participants**

Participants (approx. 25) will include internal DFO representatives and invites from academia, First Nations, NGO's and industry.



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## Appendix 4: Working Paper Summaries

### **Stock assessment and management advice for the British Columbia herring fishery, 2009 Assessment and 2010 Forecasts - Jaclyn Cleary and Jake Schweigert**

The B.C. herring fishery is managed as five major and two minor stock areas. Accordingly, catch and survey information is collected independently for each of these seven areas and science advice is provided on the same scale. The 2009 stock assessment for the B.C. herring fishery was carried out using a version of a herring catch-age model (HCAMv2), developed for the 2008 assessment. Our approach involves fitting this catch-age model to the time series of commercial catch data, spawn index and proportions-at-age data within a Bayesian estimation framework. Model outputs for the time series include estimates of recruitment (3 year old fish), numbers at age, spawning stock biomass and pre-fishery forecasts of biomass, as well as estimates of natural mortality, fishing mortality and fishery selectivity by gear type. Biomass estimates represent median estimates from the marginal posterior distributions. Catch advice, presented in the form of decision tables, is based on model forecasts of repeat spawners and posterior distributions of recruitment under assumptions of poor, average and good recruitment. For the Strait of Georgia and West Coast Vancouver Island stocks, recruitment forecasts are based on results from the summer off-shore trawl survey. For the Queen Charlotte Islands, Prince Rupert District and Central Coast stocks, recruitment forecast rules are applied based on recent stock trends. For the two minor stocks, the recruitment forecast rule is to assume an average recruitment.

This year, two changes were made to the HCAMv2 model. The first relates to the way in which ageing samples are used by the model and the second relates to the way we parameterize initial fishing mortality rate. We discovered that the 2008 configuration of HCAMv2 omits a number of ageing samples from the analysis. Specifically, for a given area, ageing samples were being omitted in years where there is no catch for the roe seine fishery. This omission has been corrected in the 2009 configuration of HCAMv2 and implications of this change are discussed herein. Several points have been identified as outstanding issues in modelling herring stocks, including: understanding the relationship between natural mortality and steepness in recruitment productivity, estimating natural mortality, and applying fishing gear selectivity functions.

#### **Major stock areas:**

##### ***Queen Charlotte Islands***

The estimated spawning biomass for 2009 is approximately 7,000 tonnes, a considerable increase from the 2008 estimate of spawning biomass (~5,000 tonnes). Model estimates of recruitment for this stock have alternated between poor and average over the last 10-years, with 2009 estimated as average recruitment. For the Queen Charlotte Islands stock, the recruitment forecast rule denotes poor recruitment, thus the forecast biomass for 2010 is ~5,800 tonnes. This stock is below cutoff. Following the herring harvest control rule, the recommendation is for no commercial harvest in this area.

##### ***Prince Rupert District***

The estimated spawning biomass for 2009 is approximately 15,000 tonnes. This is somewhat lower than the 2008 estimate of spawning biomass (~17,000). The 2009 model estimates of recruitment for this stock appear to be on the divide between poor and average. For the Prince Rupert District stock, the recruitment forecast rule denotes average recruitment, thus the forecast biomass for 2010 is ~15,500 tonnes. This stock is above cutoff. Following the herring harvest control rule, the available harvest, based on a 20% harvest rate, is 3,100 tonnes.

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### **Central Coast**

The estimated spawning biomass for 2009 is approximately 10,000 tonnes, a considerable increase from the 2008 estimate of spawning biomass (~6,500 tonnes). Model estimates of recruitment for this stock have alternated between poor and average over the last 10-years, with one good recruitment year in 2003. For the Central Coast stock, the recruitment forecast rule denotes poor recruitment, thus forecast biomass for 2010 is ~7,500 tonnes. This stock is below cutoff. Following the herring harvest control rule, the recommendation is for no commercial harvest in this area.

### **Strait of Georgia**

The estimated spawning biomass for 2009 is approximately 48,000 tonnes, a considerable increase from the 2008 estimate of spawning biomass (~34,000 tonnes). Model estimates of recruitment to this stock have alternated between average and good over the last 10-years, with one poor recruitment year in 2008. Recruitment in 2009 was estimated as good, reflecting predictions provided by the 2008 off-shore recruitment forecast survey. Results from the off-shore survey indicate recruitment for 2010 will be poor, thus the forecast biomass for 2010 is ~45,000 tonnes. This stock is above cutoff. Following the herring harvest control rule, the available harvest, based on a 20% harvest rate, is 9,000 tonnes.

### **West Coast Vancouver Island**

The estimated spawning biomass for 2009 is approximately 5,000 tonnes. This is nearly double the 2008 estimate of spawning biomass (~2,700 tonnes). Model estimates of recruitment for this stock have been poor for the majority of the past 10-years. Recruitment in 2009 was estimated as poor, reflecting predictions provided by the 2008 off-shore recruitment forecast survey. Results from the off-shore survey indicate recruitment for 2010 will be poor, thus the forecast biomass for 2010 is ~6,000 tonnes. This stock is below cutoff. Following the herring harvest control rule, the recommendation is for no commercial harvest in this area.

### **Minor stock areas:**

#### **Area 27**

The estimated spawning biomass for 2009 is approximately 1,600 tonnes, up slightly from the 2008 estimate of spawning biomass (~1,400 tonnes). Model estimates of recruitment to this stock were poor in 2008 and good in 2009. For Minor Stock Area 27, the recruitment forecast rule denotes average recruitment, thus the forecast biomass for 2010 is ~1,350 tonnes. The available harvest, based on a 10% harvest rate, is 135 tonnes.

#### **Area 2W**

Estimates of spawning biomass were highly influenced by the inclusion of additional ageing samples, thus Minor Stock Area 2W results are presented using both the 2008 and 2009 configurations of the HCAMv2 model. The two estimates of spawning biomass for 2009 are ~2,900 and ~5,700 (A2W-A and A2W-B, respectively) and we conclude that the latter estimate is most representative for providing catch advice. Both model configurations indicate recruitment to this stock was good in 2009. The recruitment forecast rule denotes average recruitment, thus forecast biomass for 2010 is ~4,100 tonnes. The available harvest, based on a 10% harvest rate, is 413 tonnes.

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## **Herring multi-stock analysis: Integration of tagging data and evaluation of alternative dynamics**

*Vivian Haist and Jake Schweigert*

The work presented in this document extends the multi-stock functionality of the HCAM model through inclusion of a tag-recapture module, and investigates alternative hypotheses about the natural mortality process and its impact on stock dynamics. The primary objective of the work is to investigate alternative stock dynamics assumptions in support of a future herring MSE project.

The assumption that natural mortality is related (inversely) to stock abundance fits the herring data as well as modelling natural mortality as a random walk process, though with considerably fewer parameters estimated. General patterns in the natural mortality trends are similar between the two parameterizations. In terms of developing operating models for a future MSE project, the density-dependent natural mortality assumption is more satisfactory because natural mortality rates are driven by internal stock dynamics rather than by external and unknown factors. Some difficulty was encountered in finding formulations for the stock-recruitment and density-dependent natural mortality that did not generate implausible estimates of initial biomass ( $B_0$ ) but a Ricker stock-recruitment relationship produced reasonable results when other restricting assumptions were included in the model formulation.

The estimates of spawning site fidelity obtained from the integrated HCAM analysis are quite high, at the stock assessment region level. Spawning region fidelity estimates were 89% for QCI, 98% for PRD, 96% for CC, 98% for SoG, and for WCVI. Dispersal rate estimates were highest between regions that are geographically close.

**Appendix 5. Criteria for assessment of stock status in 2009 and yield recommendation for 2010: Queen Charlotte Islands**

Criteria	Status								
<p>1. <b>Data Quality</b>  a) All catch reported  b) All spawn surveyed  c) Good sample coverage</p> <p>2. <b>Stock status and trends</b>  a) HCAMv2  b) Spawn indices</p> <p>3. <b>Perceptions of Stock Status</b>  a) Charter skippers comments  b) Management staff</p> <p>4. <b>Recruitment</b>  a) HCAMv2</p> <p>5. <b>Forecast Abundance</b>  Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• <b>Poor</b></li> <li>• Average</li> <li>• Good</li> </ul> <p>6. <b>Additional Information</b></p> <p>7. <b>Cutoff</b></p> <p>8. <b>Recommended available harvest</b>  (following harvest control rules)</p>	<p><b>Data Quality</b>  a) No commercial fisheries in 2009, FSC amounts unknown (believed to be minimal or nil).  b) All significant spawns surveyed (~50 km) mostly by dive with some surface surveys. Quality of surface survey uncertain (training period). Possible very late minor spawn in Cumshewa Inlet missed.  c) Yes (12 samples from March test fishing). Majority of stocks present in Skincuttle Inlet and Upper Burnaby Strait which were both sampled very well. Unable to obtain samples in other areas (Louscoone, Atli, and Selwyn). Milting at Shuttle was investigated and no eggs found.</p> <p><b>Stock status and trends</b>  a) Pre-fishery biomass estimates suggest stock's been below cutoff from 2000 to 2009 and 2009 estimate similar to previous years.  b) Slight increase in 2009 from 2008 but still below cutoff.</p> <p><b>Perceptions of Stock Status</b>  a) Area appeared to show some improvement from recent years and many juveniles observed.  b) Very similar to previous 3 years. Impression that biomass has been more consistent through 2007-2009 than shown by spawn survey. Manager cautions that apparent spawn biomass increase might be an artifact of inadequate spawn survey coverage in 2008 or the different treatment of <i>Macrocystis kelp</i> spawn by dive and surface surveys.</p> <p><b>Recruitment</b>  a) Recruitment in 2009 is estimated as average 2009 and estimates alternate between poor and average for last 10 years.</p> <p><b>Forecast Abundance</b></p> <table data-bbox="714 1323 1266 1449"> <thead> <tr> <th>Abundance</th> <th>Potential Harvest</th> </tr> </thead> <tbody> <tr> <td><b>5 750</b></td> <td><b>0</b></td> </tr> <tr> <td>8 447</td> <td>0</td> </tr> <tr> <td>18 810</td> <td>3 762</td> </tr> </tbody> </table> <p><b>No Additional Information</b></p> <p><b>Cutoff:</b> 10 700 tonnes</p> <p><b>Recommended available harvest:</b> No harvest because forecast below cutoff.</p>	Abundance	Potential Harvest	<b>5 750</b>	<b>0</b>	8 447	0	18 810	3 762
Abundance	Potential Harvest								
<b>5 750</b>	<b>0</b>								
8 447	0								
18 810	3 762								

**Appendix 6. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
Prince Rupert District**

Criteria	Status								
<p><b>1. Data Quality</b>  a) All catch reported  b) All spawn surveyed  c) Good sample coverage</p> <p><b>2. Stock status and trends</b>  a) HCAMv2  b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b>  a) Charter skippers comments  b) Management staff</p> <p><b>4. Recruitment</b>  a) HCAMv2</p> <p><b>5. Forecast Abundance</b>  Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• Poor</li> <li>• <b>Average</b></li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b>  (following harvest control rules)</p>	<p><b>Data Quality</b>  a) All roe herring catch reported; FSC amounts unknown)  b) Yes (32 km dive surveyed).  c) 14 samples from roe and 22 from spring test fishing but limited sampling of second wave of Kitkatla (Area 5) spawners.</p> <p><b>Stock status and trends</b>  a) Pre-fishery biomass estimates suggest steady decline from 2003 to 2009 and 2009 estimate similar to previous years and above cutoff in recent decades.  b) Slight decrease in 2009 from 2008. Near cutoff since 2006.</p> <p><b>Perceptions of Stock Status</b>  a) Abundance appeared lower in Areas 3 / 4 and average in Kitkatla (Area 5) and spawn coverage appeared low in Area 5.  b) Same as above but stocks in Area 5 appeared much better than the actual spawn deposition. May have missed some spawn or spawning patterns or locations may have changed.</p> <p><b>Recruitment</b>  a) Recruitment in 2009 is estimated to be midway between poor and average. Abundance estimates for the past 10 years alternate between all categories but the 2005 year-class was poor.</p> <p><b>Forecast Abundance</b></p> <table border="0" style="margin-left: 40px;"> <tr> <td>Abundance</td> <td>Potential Harvest</td> </tr> <tr> <td>11 829</td> <td>0</td> </tr> <tr> <td><b>15 499</b></td> <td><b>3 100</b></td> </tr> <tr> <td>29 366</td> <td>5 873</td> </tr> </table> <p><b>No Additional Information</b></p> <p><b>Cutoff:</b> 12 100 tonnes</p> <p><b>Recommended available harvest:</b> 3100 tonnes.</p>	Abundance	Potential Harvest	11 829	0	<b>15 499</b>	<b>3 100</b>	29 366	5 873
Abundance	Potential Harvest								
11 829	0								
<b>15 499</b>	<b>3 100</b>								
29 366	5 873								

**Appendix 7. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
Central Coast**

Criteria	Status								
<p><b>1. Data Quality</b></p> <p>a) All catch reported</p> <p>b) All spawn surveyed</p> <p>c) Good sample coverage</p> <p><b>2. Stock status and trends</b></p> <p>a) HCAMv2</p> <p>b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b></p> <p>a) Charter skippers comments</p> <p>b) Management staff</p> <p><b>4. Recruitment</b></p> <p>a) HCAMv2</p> <p><b>5. Forecast Abundance</b> Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• Poor</li> <li>• Average</li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b> (following harvest control rules)</p>	<p><b>Data Quality</b></p> <p>a) No commercial fisheries in 2009, FSC amounts unknown.</p> <p>b) Yes, 71 km. Good weather for aerial and dive surveys.</p> <p>c) Ok to good. (1.5 test fishing charters over season and 34 samples from spring test fishing).</p> <p><b>Stock status and trends</b></p> <p>a) Pre-fishery biomass estimates suggest steady decline from 2004 to 2008 and 2009 abundance approximately equal to 2008. PFB estimates below cutoff since 2006.</p> <p>b) Steady decrease from 2004 to 2008 with a 2009 increase from 2008, estimates below cutoff since 2006.</p> <p><b>Perceptions of Stock Status</b></p> <p>a) Abundance appeared to have improved from previous year with better spawning coverage and more juveniles.</p> <p>b) Stock appears stable but at relatively lower levels compared to several years ago. Signs of improvement from 2008 were increases in spawning and numbers of juveniles.</p> <p><b>Recruitment</b></p> <p>a) Recruitment in 2009 is estimated as average and estimates for the past 10 years alternate between poor and average except for 2003, which was good.</p> <p><b>Forecast Abundance</b></p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Abundance</th> <th style="text-align: left;">Potential Harvest</th> </tr> </thead> <tbody> <tr> <td><b>7 577</b></td> <td><b>0</b></td> </tr> <tr> <td>10 961</td> <td>0</td> </tr> <tr> <td>19 772</td> <td>2 172</td> </tr> </tbody> </table> <p><b>No Additional Information</b></p> <p><b>Cutoff:</b> 17 600 tonnes</p> <p><b>Recommended available harvest:</b> No harvest because forecast below cutoff.</p>	Abundance	Potential Harvest	<b>7 577</b>	<b>0</b>	10 961	0	19 772	2 172
Abundance	Potential Harvest								
<b>7 577</b>	<b>0</b>								
10 961	0								
19 772	2 172								

**Appendix 8. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
Strait of Georgia**

Criteria	Status								
<p><b>1. Data Quality</b> a) All catch reported b) All spawn surveyed c) Good sample coverage</p> <p><b>2. Stock status and trends</b> a) HCAMv2 b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b> a) Charter skippers comments b) Management staff</p> <p><b>4. Recruitment</b> a) HCAMv2 b) Offshore Trawl Survey c) Juvenile survey SOG</p> <p><b>5. Forecast Abundance</b> Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• <b>Poor</b></li> <li>• Average</li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b> (following harvest control rules)</p>	<p><b>Data Quality</b> a) Yes, all roe herring catch reported. b) All significant spawns surveyed (145 km). 1 km at False Creek and unknown length at Wakefield Creek Sechelt not surveyed. Possibility of 1.5 km at Mudge Island missed also. c) Yes, (32 samples from roe and 28 from Feb-April test fishing)</p> <p><b>Stock status and trends</b> a) Pre-fishery biomass estimates suggest steady decline from 2003 to 2008 and 2009 estimate slightly higher than 2008. PFB estimates for recent decades above cutoff. b) The 2009 index shows an increase from 2008 (and continues to be above cutoff for recent decades).</p> <p><b>Perceptions of Stock Status</b> a) Compared to 2008, abundance and spawn coverage (length &amp; intensity) appeared to improve. b) Stock appeared to be stronger than in 2008 and likely close to the pre-season forecast. Spawning period was significantly extended, although the main stock spawned over a 6 or 7 day period. Subsequent and frequent spawning occurred in Areas 14 and 17N but did not appear to be intense. Generally small fish in the seine fishery (as forecasted) however very good quality gillnet fish.</p> <p><b>Recruitment</b> a) Recruitment in 2009 is estimated as good and estimates have alternated between average and good for the last 10 years, except in 2008 which was poor. b) Forecast for 2010 is "Poor" c) Abundance index of 2007 year class suggests poor recruitment in 2010.</p> <p><b>Forecast Abundance</b></p> <table data-bbox="727 1318 1263 1444"> <thead> <tr> <th>Abundance</th> <th>Potential Harvest</th> </tr> </thead> <tbody> <tr> <td><b>45 001</b></td> <td><b>9 000</b></td> </tr> <tr> <td>55 857</td> <td>11 171</td> </tr> <tr> <td>74 216</td> <td>14 843</td> </tr> </tbody> </table> <p><b>Additional Information</b> Seine and Gillnet quotas achieved in 2009. Tonnage of large fish near Bowser provided for an unexpectedly heavy and efficient gillnet fishery (i.e. best in ~ 10 years). Poor catch efficiency for FSC because small fish in 17S. Significant spawn in Baynes Sound which is unusual.</p> <p>Very low SOG juvenile survey index of 2007 year class for 2010 recruitment prediction (~ 2005 yc and 2008 recruitment).</p> <p><b>Cutoff:</b> 21 200 tonnes</p> <p><b>Recommended available harvest:</b> 9000 tonnes</p>	Abundance	Potential Harvest	<b>45 001</b>	<b>9 000</b>	55 857	11 171	74 216	14 843
Abundance	Potential Harvest								
<b>45 001</b>	<b>9 000</b>								
55 857	11 171								
74 216	14 843								

**Appendix 9. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
West Coast of Vancouver Island**

Criteria	Status								
<p><b>1. Data Quality</b> a) All catch reported b) All spawn surveyed c) Good sample coverage</p> <p><b>2. Stock status and trends</b> a) HCAMv2 b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b> a) Charter skippers comments b) Management staff</p> <p><b>4. Recruitment</b> a) HCAMv2 b) Offshore Trawl Survey</p> <p><b>5. Forecast Abundance</b> Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• <b>Poor</b></li> <li>• Average</li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b> (following harvest control rules)</p>	<p><b>Data Quality</b> a) No commercial fisheries in 2009; FSC amounts unknown. b) All significant spawns surveyed - 32 km. ROV found unsurveyed patch in 20m water in Barkley Sound. No deep spawn found in Area 25 (towed wing &amp; bottom grabs). c) Yes (23 samples from spring test fishing)</p> <p><b>Stock status and trends</b> a) Pre-fishery biomass estimates from 2003-2009 below cutoff since 2004 and 2009 estimate similar to 2008. b) The 2009 index shows a slight increase from 2008 and below cutoff since 2004.</p> <p><b>Perceptions of Stock Status</b> a) Abundance appeared to have improved from recent years and from 2009 forecast with an increase in juveniles and spawn coverage. Estimates from spawn surveys considered low compared to hydro-acoustic observations (especially Barkley Sound). Where observed, spawn deposition appeared light. b) Better returns than forecasted. Barkley spawn in particular didn't reflect tonnage sounded.</p> <p><b>Recruitment</b> a) Recruitment in 2009 is estimated as poor, which has been the case for most of the last 10 years. b) Forecast for 2010 is "Poor"</p> <p><b>Forecast Abundance</b></p> <table border="0" style="margin-left: 40px;"> <tr> <td>Abundance</td> <td>Potential Harvest</td> </tr> <tr> <td><b>6 063</b></td> <td><b>0</b></td> </tr> <tr> <td>10 333</td> <td>0</td> </tr> <tr> <td>20 490</td> <td>1 690</td> </tr> </table> <p><b>No Additional Information</b>  </p> <p><b>Cutoff:</b> 18 800 tonnes</p> <p><b>Recommended available harvest</b> No yield because forecast below cutoff.</p>	Abundance	Potential Harvest	<b>6 063</b>	<b>0</b>	10 333	0	20 490	1 690
Abundance	Potential Harvest								
<b>6 063</b>	<b>0</b>								
10 333	0								
20 490	1 690								



**Appendix 10. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
Minor Stock Area 2W**

Criteria	Status								
<p><b>1. Data Quality</b> a) All catch reported b) All spawn surveyed c) Good sample coverage</p> <p><b>2. Stock status and trends</b> a) HCAMv2 b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b> a) Charter skippers comments b) Management staff</p> <p><b>4. Recruitment</b> a) HCAMv2</p> <p><b>5. Forecast Abundance</b> Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• Poor</li> <li>• <b>Average</b></li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b> (following harvest control rules)</p>	<p><b>Data Quality</b> a) SOK amounts reported. No roe fisheries in 2009. FSC amount unknown but would be minimal or nil. b) Most spawn (27 km) surveyed (Pt Louis &amp; Tingley Cove) by dive and surface methods. Reasonable survey coverage in area but likely missed a late spawn (May) in Rennell Sound based on hydroacoustic observations from SOK operators and reports of herring observed on the beach in Ells Bay . c) Good sample coverage for Port Louis, Kano Inlet and Seal Inlet (4 from SOK and 5 from March test fishing). Poor sample coverage for Rennell Sound, West Skidegate, and Inskip due to minimal or no presence of stock at times of assessment.</p> <p><b>Stock status and trends (method B, section 6)</b> a) Prefishery biomass estimates suggest relative steady increases since 2005 varying ~2 000- 6 000 tonnes. b) Spawn indices suggest steady but slight increases since 2005.</p> <p><b>Perceptions of Stock Status</b> a) Abundance appeared down from previous year, estimated soundings 3800 tons. b) Spawn deposition similar to 2007 and 2008 but different distribution. Very good in Port Louis but light everywhere else. Observed estimate of spawn thought to be conservative.</p> <p><b>Recruitment</b> a) No recruitment forecast</p> <p><b>Forecast Abundance (method B, section 6)</b></p> <table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: left;">Abundance</th> <th style="text-align: left;">Potential Harvest</th> </tr> </thead> <tbody> <tr> <td>4 000</td> <td>400</td> </tr> <tr> <td><b>4 125</b></td> <td><b>413</b></td> </tr> <tr> <td>5 938</td> <td>594</td> </tr> </tbody> </table> <p><b>Additional Information</b> Large deviation between model and spawn index estimates in 2009.</p> <p>10 % harvest rate rule applied for minor stocks</p> <p><b>No cutoff</b></p> <p><b>Recommended available harvest: 413 tonnes</b></p>	Abundance	Potential Harvest	4 000	400	<b>4 125</b>	<b>413</b>	5 938	594
Abundance	Potential Harvest								
4 000	400								
<b>4 125</b>	<b>413</b>								
5 938	594								

**Appendix 11. Criteria for assessment of stock status in 2009 and yield recommendation for 2010:  
Minor Stock Area 27**

Criteria	Status								
<p><b>1. Data Quality</b> a) All catch reported b) All spawn surveyed c) Good sample coverage</p> <p><b>2. Stock status and trends</b> a) HCAMv2 b) Spawn indices</p> <p><b>3. Perceptions of Stock Status</b> a) Charter skippers comments b) Management staff</p> <p><b>4. Recruitment</b> a) HCAMv2</p> <p><b>5. Forecast Abundance</b> Recruitment Assumption</p> <ul style="list-style-type: none"> <li>• Poor</li> <li>• <b>Average</b></li> <li>• Good</li> </ul> <p><b>6. Additional Information</b></p> <p><b>7. Cutoff</b></p> <p><b>8. Recommended available harvest</b> (following harvest control rules)</p>	<p><b>Data Quality</b> a) Yes (No roe herring fisheries and the 3 SOK licenses had their product validated). b) Yes (12 km dive surveyed). c) 8 samples from April SOK fishing.</p> <p><b>Stock status and trends</b> a) Pre-fishery biomass estimates suggest varying but relatively similar abundance from 2002 to 2009. b) Spawn indices suggest slight increase in 2009 from 2008, following a gradual increase from 2001 to 2007 and then a drop in 2008.</p> <p><b>Perceptions of Stock Status</b> a) No test fishing in Area 27 and dive survey found light spawn. b) SOK operators impression that stocks somewhat reduced from 2008.</p> <p><b>Recruitment</b> a) No recruitment forecast</p> <p><b>Forecast Abundance</b></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 60%;">a) Abundance</td> <td style="text-align: right;">Potential Harvest</td> </tr> <tr> <td style="text-align: right;">1 000</td> <td style="text-align: right;">100</td> </tr> <tr> <td style="text-align: right;"><b>1 347</b></td> <td style="text-align: right;"><b>135</b></td> </tr> <tr> <td style="text-align: right;">2 108</td> <td style="text-align: right;">211</td> </tr> </table> <p><b>Additional Information</b> 10 % harvest rate rule applied for minor stocks</p> <p><b>No cutoff</b></p> <p><b>Recommended available harvest: 135 tonnes</b></p>	a) Abundance	Potential Harvest	1 000	100	<b>1 347</b>	<b>135</b>	2 108	211
a) Abundance	Potential Harvest								
1 000	100								
<b>1 347</b>	<b>135</b>								
2 108	211								