Part I: Moving towards the sustainable fisheries framework for Pacific herring: data, models, and alternative assumptions.

Part II: Stock Assessment and Management Advice for the British Columbia Pacific Herring Stocks

2011 Assessment and 2012 Forecasts

Steven Martell, Jake Schweigert, Jaclyn Cleary, Vivian Haist

July 15, 2011

Abstract

June 15, 2011. Structure of this paper has changed a bit. This document will now consist of an assessment and forecast of the five major stocks and the two minor stocks. There will be at least 5 appendixes that 1) describe the input data and the control files used for the assessment model, 2) a detailed description of ${}^{i}\mathrm{SCA}_{\mathrm{M}}$, 3) a description of the methods used to develop the prior distribution, 4) simulation testing of the ${}^{i}\mathrm{SCA}_{\mathrm{M}}$model, 5) moving toward the sustainable fisheries framework (see Cleary and Cox paper) and include discussion of the issues of developing an MSY-based framework for a multigear fishery with changing selectivities and natural mortality rates, and finally 6) a list of research recommendations.

Summary: Three major themes of the paper: 1) a comparing HCAM and iSCAM (where iSCAM is set up with nearly the same assumptions as 2010 HCAM assessment), 2) an iSCAM assessment with several scenarios addressing (a) q with various priors, (b) time-varying versus constant M, (c) alternative selectivity models, and (d) the interactions of all three of these confounded variables, and 3) an iSCAM assessment with the test fishery and seine roe fishery data separated into specific fleets. The side by side comparison will examine similarities/differences between trends in biomass, fishing mortality rates, and residual fits to the spawn survey data an age-composition data. These two models have some fundamental differences in the statistical assumptions about the catch-at-age data, so results are likely to be slightly different. Results for all three themes will focus on reconstructing table 5 from last years assessment, with the addition of LRP and USRP to be compared with the cuttoffs and catch advice for low med and high recruitment.

Contents

List of Figures

1 Introduction

There are four major objectives of this paper: (1) to describe in detail an alternative integrated statistical catch-age model (iSCAM), (2) examine parameter estimation performance using iSCAM, (3) perform a side-by-side comparison of the previous HCAM and iSCAM on the five major herring stocks, and (4) explore alternative assumptions about selectivity, catchability, and natural mortality using iSCAM. The most recent assessment of BC herring stocks was conducted in 2010 using the Herring Catch Age Model (HCAMv2) which is documented in Cleary and Schweigert (2010). Furthermore, a review sponsored by the Herring Research and Conservation Society (HRCS) was conducted June 17-18, 2010 in Nanaimo, BC where an expert panel addressed specific questions about the current implementation of the HCAMv2 model and suggested recommendations for each of the questions. This paper also attempts to address some of the points brought up in the review.

BC herring are currently managed as five major stocks and 2 minor stocks (Figure 1). Annual catch advice for each of these areas is based on current estimates of stock status, and a 20% exploitation rate if the stock is above the cutoff level for the five major stocks and a 10% exploitation rate for the two minor stocks. Cutoff levels for the five major stocks are based on $0.25B_o$, and estimates of unfished biomass were established first in 1985 (Haist et al., 1986). These cutoffs are currently are thought to be more conservative than the current default Limit Reference Point of $0.4\mathrm{B}_{\mathrm{MSY}}$ (Fisheries and Oceans Canada, 2006). However, estimates of B_o and MSY based reference points have not been examined for Pacific herring for some time. In this paper we also describe the methods for updating estimates of B_o and MSY based reference points using the iSCAM model framework. We also compare estimates of MSY based reference points for the Strait of Georgia herring under the previously mentioned alternative assumptions (see point (4) in the previous paragraph).

We do not provide a detailed description of HCAMv2 in this paper and we refer the reader to Schweigert et al. (2009) and Cleary and Schweigert (2010) for a more detailed description. We first begin with a description of the input data required and assumptions about the data, followed by a detailed description of the analytical methods and assumptions in iSCAM. We then present the analytical methods and assumptions for exploring alternative hypotheses about selectivity, catchability and natural mortality, followed by a description of the elements that make up the joint posterior distribution (i.e., likelihoods, priors, and penalties). Parameter estimating and quantifying uncertainty is carried out using AD Model Builder (ADMB Project, 2009). We then explore estimation performance in iSCAM using simulation experiments where the model is used to generate simulated observations with known parameter values, then estimate parameter, and repeat this exercise a number of times to evaluate bias and precision in parameter estimates. Finally, we present forecast of pre-fishery biomass and available harvest options using the cutoffs (e.g., reproduce Table 5 in Cleary and Schweigert, 2010) as well as available harvest options based on the Sustainable Fisheries Framework (i.e., Fisheries and Oceans Canada, 2006) for comparison.

2 Methods

2.1 Input data & assumptions

2.1.1 Catch data

For each of the statistical areas, the required input data for $^{i}\mathrm{SCA}_{\mathrm{M}}$ consists of a catch time series for each of the fishing fleets. For the BC herring fishery, the annual total removals has been partitioned into three distinct fishing fleets (or fishing periods, see Figure 2). The first fleet is a winter seine fishery that has been in operation since the start of the assessment in 1951, the second is a seine-roe fishery that commenced in 1972 in the Strait of Georgia, and the third fleet is a gillnet fishery that targets females on the spawning grounds. The model is fit to the catch time series information and assumes measurement errors are lognormal, independent and identically distributed. The assumed standard deviation in the catch observations must be specified in the control file and it is assumed that measurement errors in the catch is the same for all fishing periods. The units of the catch are given in 1000s of metric tons.

In addition to the commercial catch, removals from fisheries independent surveys must also be specified in $^{i}\mathrm{SCA}_{\mathrm{M}}$. Two additional fleets are specified to represent the spawn survey, where the spawn survey is

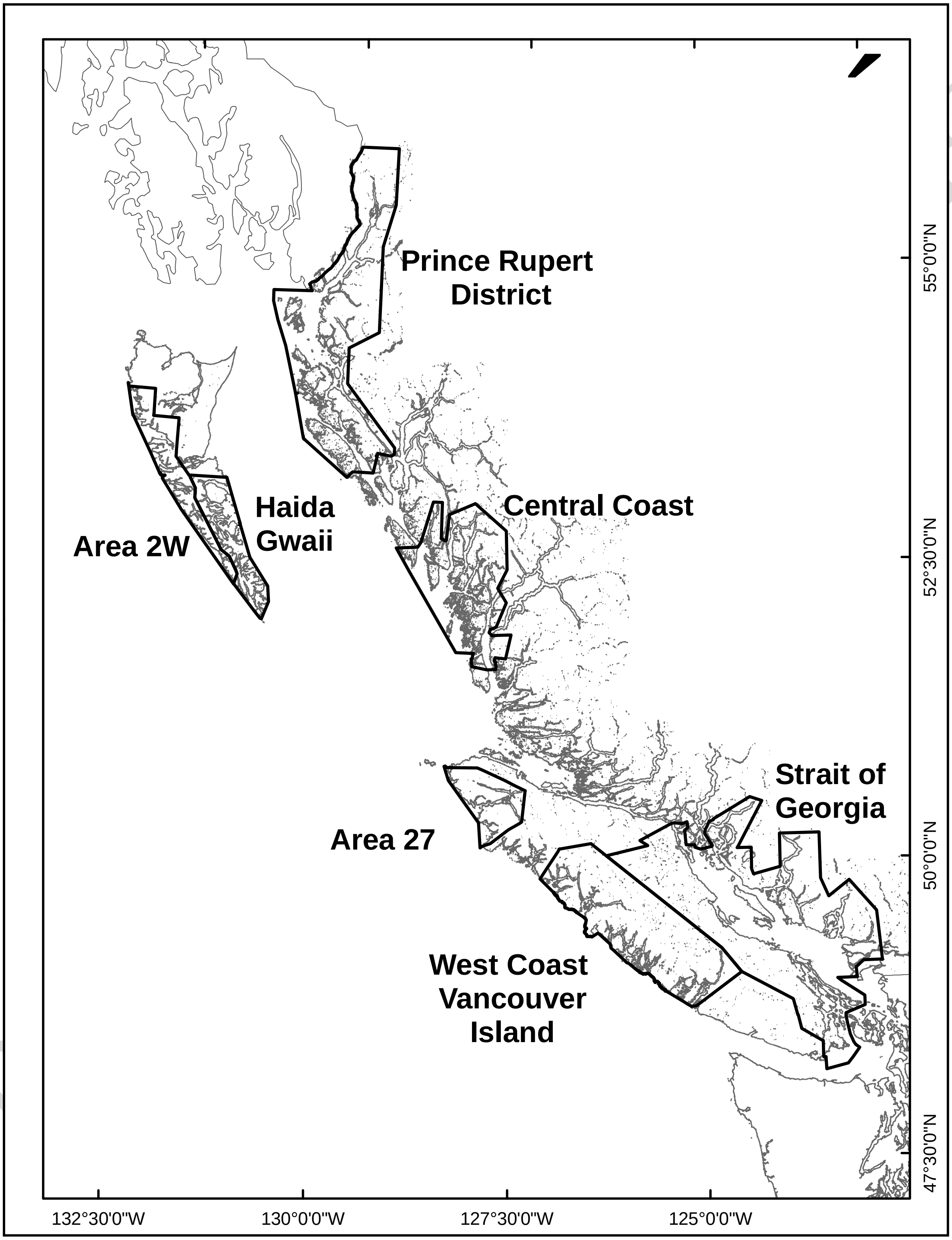


Figure 1: B.C. herring major stock areas: Haida Gwaii (HG or QCI 2E), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG), West Coast Vancouver Island (WCVI), and minor stock areas: Area 2W and Area 27.

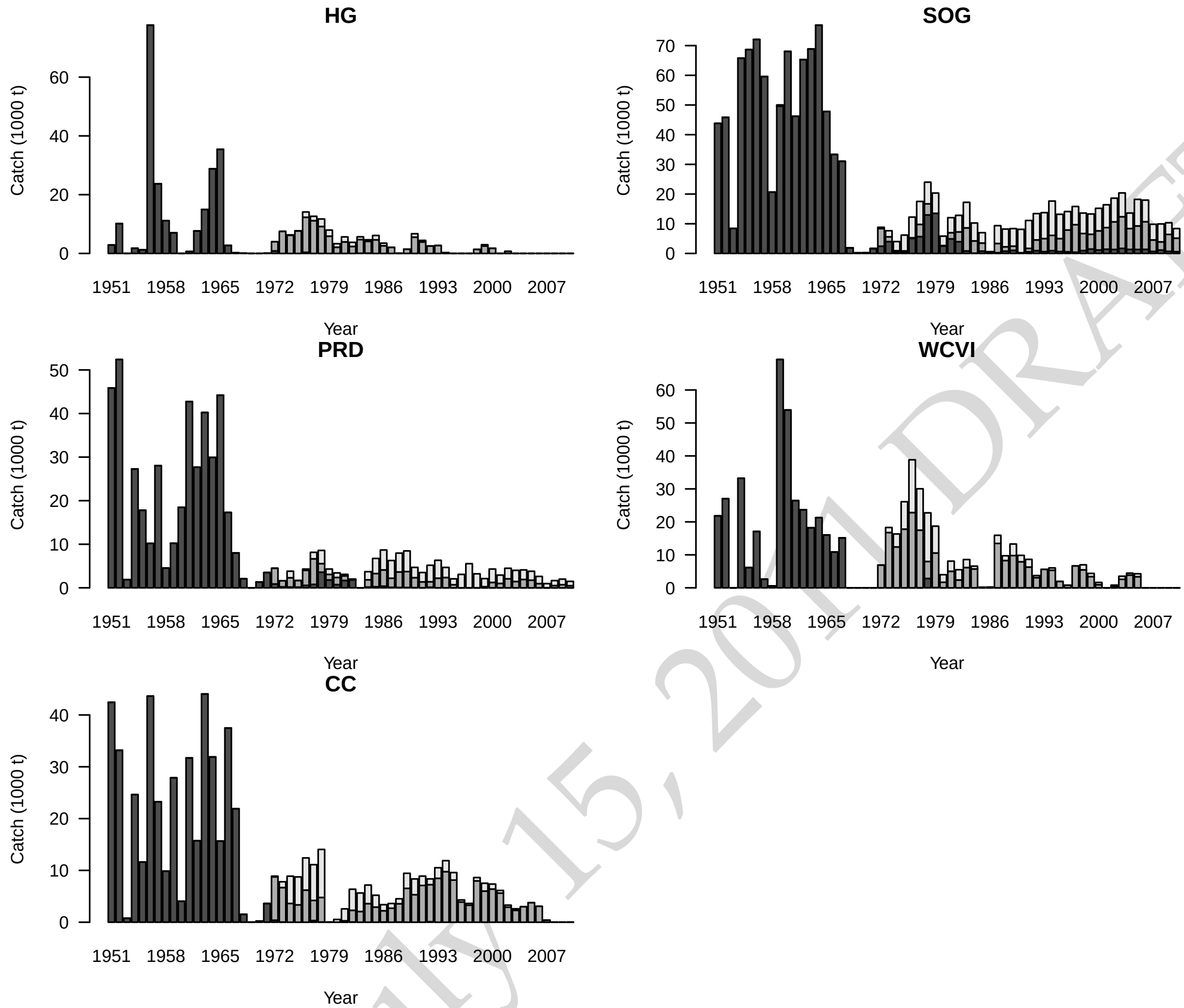


Figure 2: Historical catch of herring in the five major stock areas between 1951 and 2010 for the winter purse seine fishery (dark bars), seine-roe fishery (grey bars), and gill net fishery (light grey bars). Units of catch are in thousands of metric tons.

broken into two distinct time periods pre-1988 and post-1988, the year when the survey switched from surface surveys to dive surveys. This partitioning of the data is done for two reasons: (1) to allow for different catchability coefficients to be specified for the early and late periods, and to allow for more weight to be placed on the contemporary data due to improved precision in the estimates of egg layers.

In the case where the test fishery data has been separated from the seine roe fishery, an additional fleet is specified in the data file and fishing mortality rates for the test fishery are also estimated in years when the catch is greater than 0.

2.1.2 Relative abundance data

Herring spawn surveys have been conducted throughout the B.C. coast beginning in the 1930s. Prior to 1988, spawn surveys were conducted from the surface either by walking the beach at low tide or using a drag from a skiff to estimate the shoreline length and width of spawn. Egg layers were sampled visually and are used to calculate egg densities following the methods of Schweigert (2001). Beginning in 1988, herring spawn surveys using SCUBA methods were introduced and were implemented coastwide within a couple of years initially being conducted by DFO staff and eventually through contract divers hired through the test fishing program. Prior to the 2006 Larocque ruling, the test fishing program was funded through an allocation of fish by industry. In years since the 2006 Larocque ruling, the availability of resources to conduct dive surveys in all areas has been reduced. For the 2010 survey, dive surveys were conducted in all major and minor assessment regions, with the exception of Area 2W where snorkeling and surface survey methods were also used. As in earlier years, a few minor spawning beds outside the main assessment areas were surveyed by SCUBA or surface methods where resources permitted.

The locations of the spawning beds for the five major and two minor stock areas are shown in Figure 3. Egg density estimates are used to claculate a fishery-independent index of herring spawning biomass, referred to as the spawn survey index hereafter (Schweigert et al., 2001).

The spawn survey is conducted after the fisheries in the area have been conducted; therefore, it is assumed that all the mortality for the year has occurred just prior to commencing the spawning survey. The fisheries independent survey estimates egg density and total spawn area, and from this information the total female spawning biomass can be estimated assuming the 227 eggs per gram of female or 114 eggs per gram of mature spawning individuals (Hardwick, 1973). The assumed selectivity for the spawn survey is fixed to the maturity schedule for herring.

2.1.3 Biological samples

Biological samples are collected from both commercial catch and from the test fishery program. Commencing in 1975, test fishery charters supplemented biological samples in areas with poor sampling that was not representative of the stock in that area (i.e., fishing solely on spawning aggregations), or in closed areas. Prior to 2006, test fishing charters were funded through an allocation of fish to the test program; the program is now fully funded by DFO. Through a contract with DFO, the Herring Conservation and Research Society (HCRS) sub-contracts a number of vessels to collect biological samples. Industry also conducts preseason test sets for roe-quality testing in open areas and supplementary biological samples are provided as part of this program. The following data are collected for all biological samples: fish length, weight, sex, and maturity. Subsequently these sources of data are combined and information on weight-at-age and proportion-at-age become input data for the stock assessment model.

During the 2010/2011 season a total of XXX biological samples were collected, of which XXX were collected from the test fishery, XXX were collected from the roe fishery, XXX from the food & bait fishery, XXX from Spawn on Kelp (SOK) operations, and XXX from the summer trawl research survey (Table **??**)

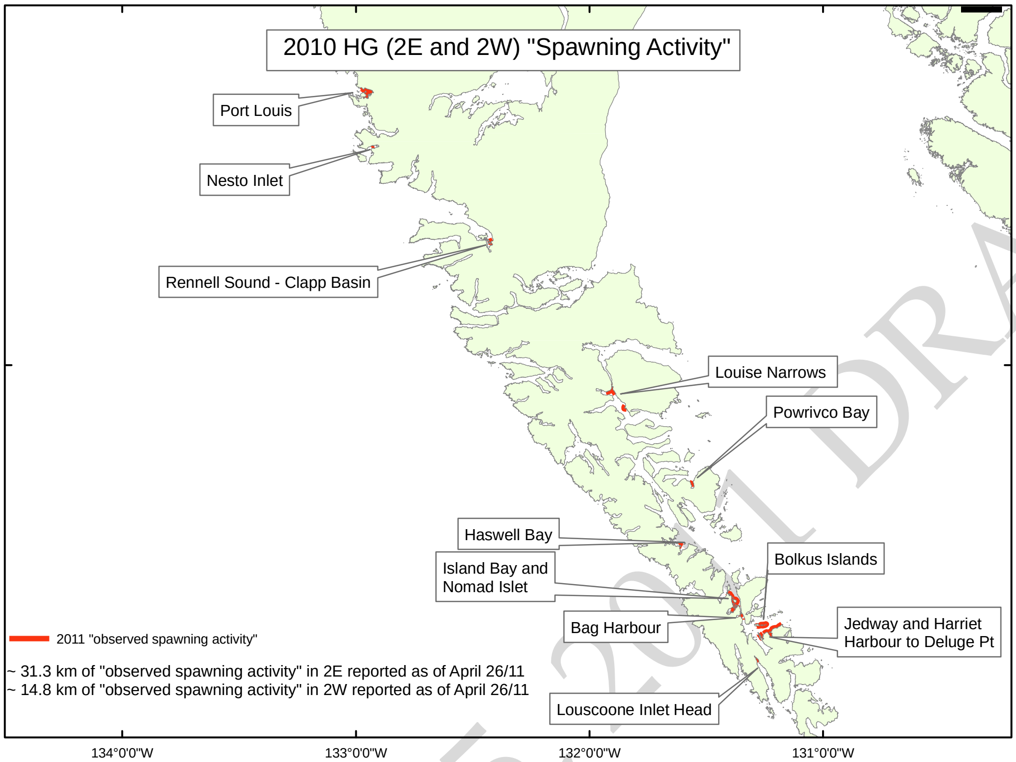
2.1.4 Age composition data

Ageing data, through the reading of fish scales, are collected from the biological samples taken from the commercial fisheries and test fishery charters. Age composition data is used to determine proportions-at-age and is an essential source of input data to the herring stock assessment model.

Catch-at-age data from the winter seine fishery (top panels of Figures 5-9) indicate that this fishery primarily targets younger fish in comparison to the seine-roe and gill net fleets. The winter seine fishery appears not to capture older fish in comparison to the gill net fleet. The shaded polygons in Figures 5-9 approximates the 95% distribution of ages in the catch. Roughly 90% of the fish landed in the winter seine fishery are younger than age-7, and younger than age-6 in recent years. In both the winter seine and seine-roe fishery age-2 fish are frequently landed; whereas, age-2 fish are rarely landed in the gill net fisher, and fish to appear to fully recruit to the gear until at least 4-5 years of age. The mean age of the catch appears to be increasing between 2008 and 2010 in both the gill net and winter seine fishery, and there is no obvious trend in the seine roe fishery. There is however a declining trend in the older ages caught in the seine-roe fishery since 2006 (erosion of age-structure).

2.1.5 Mean weight-at-age data

From the mid-1970s until the present, there has been a measurable decline in weight-at-age for all ages in all major stock areas (Figure 10). Samples collected during the 2009/10 fishing year indicate weights-at-age that are among the lowest on record. This declining weight-at-age may be attributed to any number of



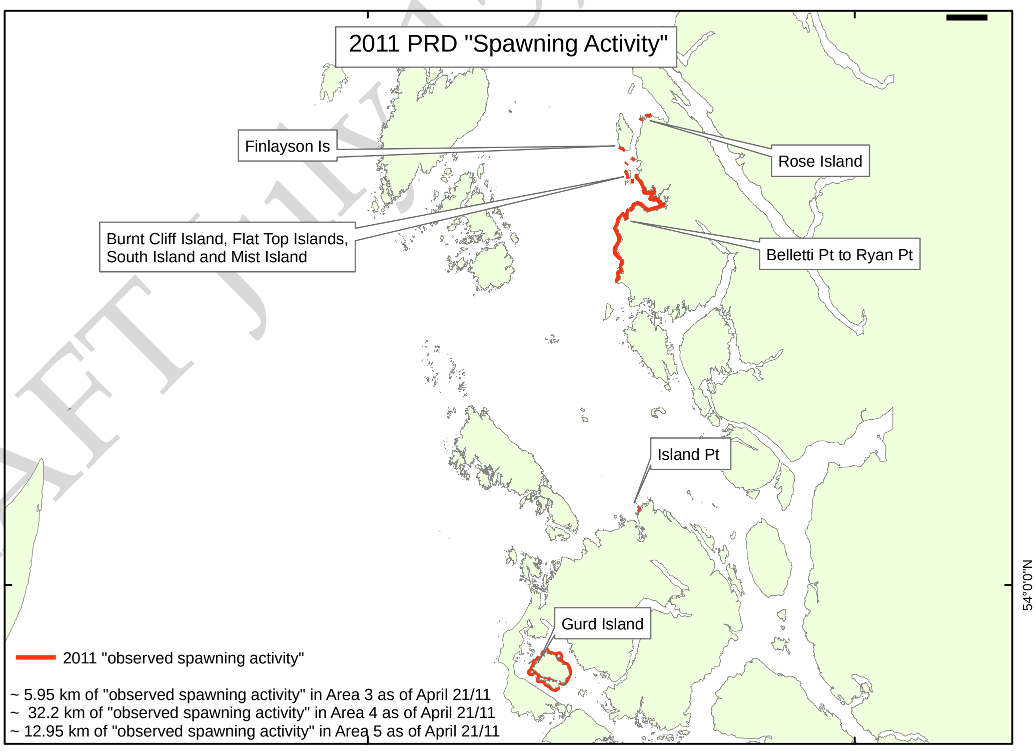
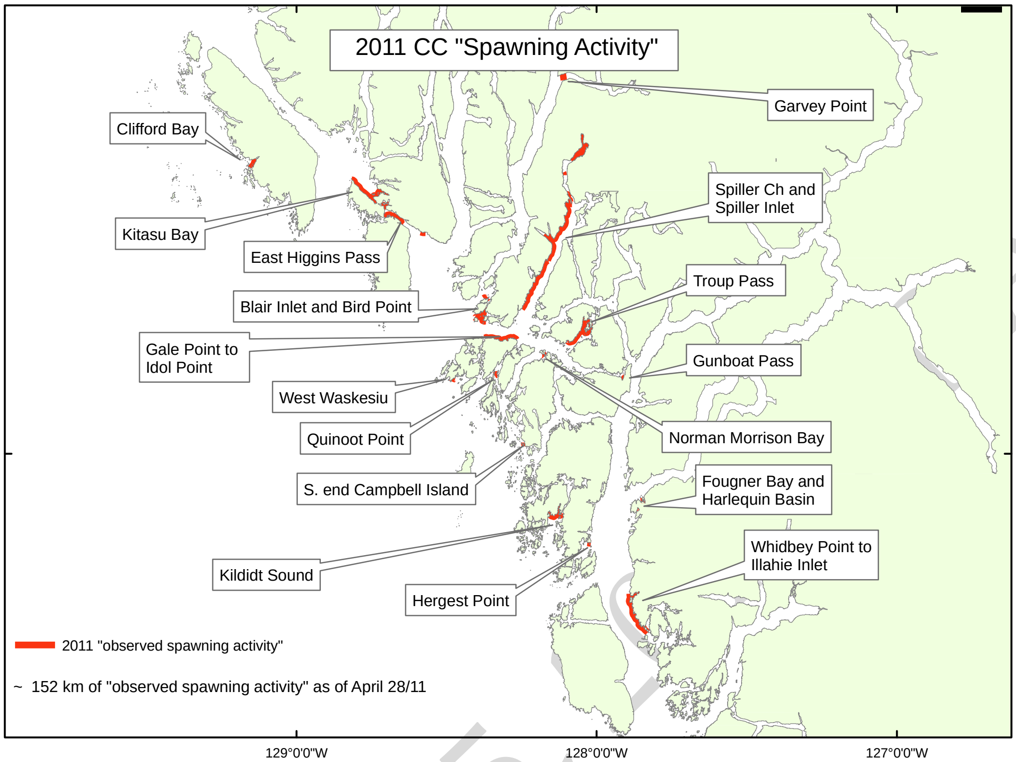


Figure 3: Preliminary Spawning activity for Haida Gwaii (top panel) and Prince Rupert District (bottom) in 2011.



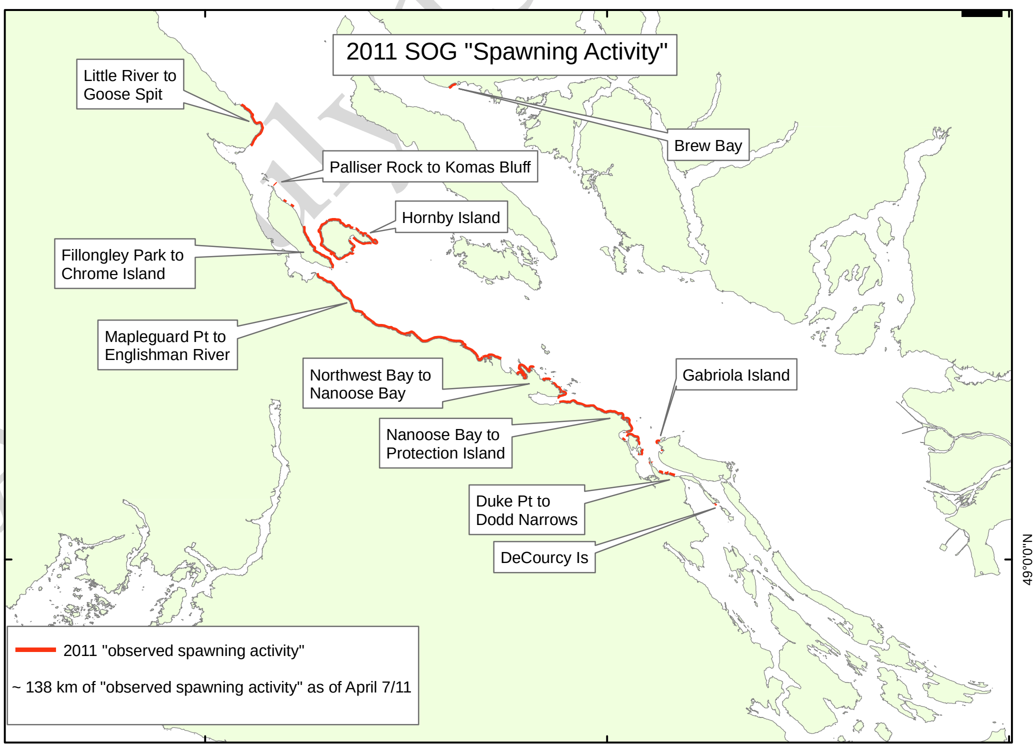


Figure 3: Preliminary Spawning activity for Central Coast (top panel) and Strait of Georgia (bottom) in 2011.

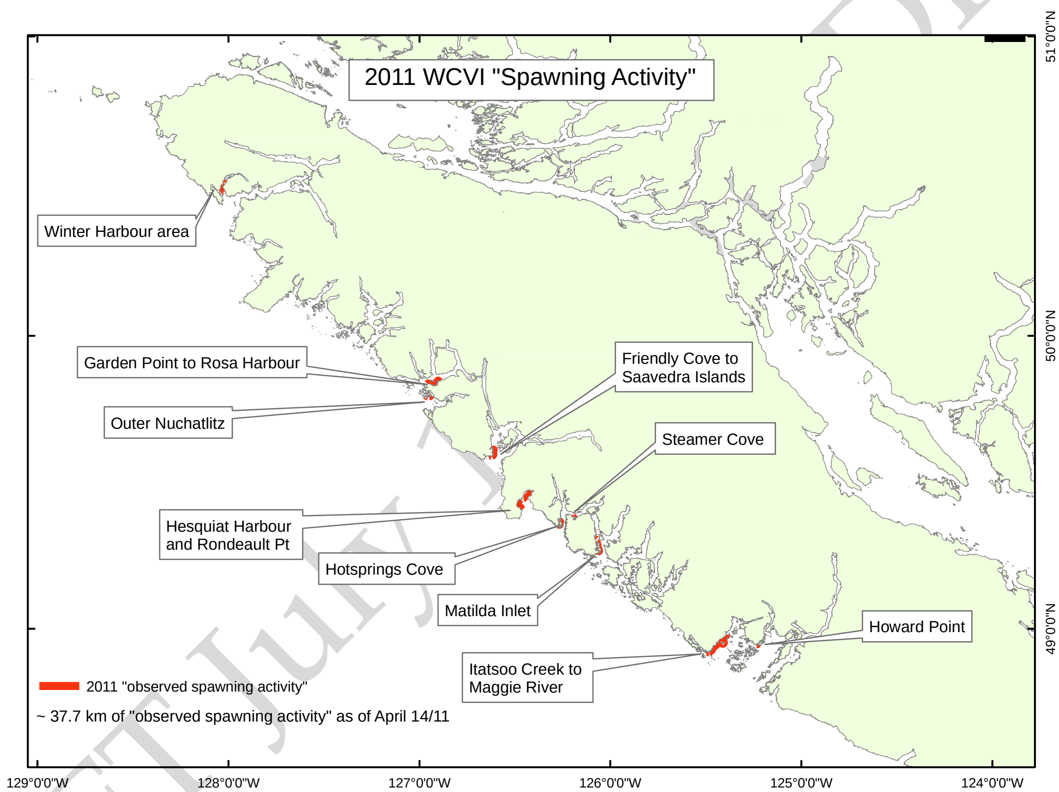


Figure 3: Preliminary Spawning activity in 2011 for the West Coast of Vancouver Island (includes minor stock area 27).

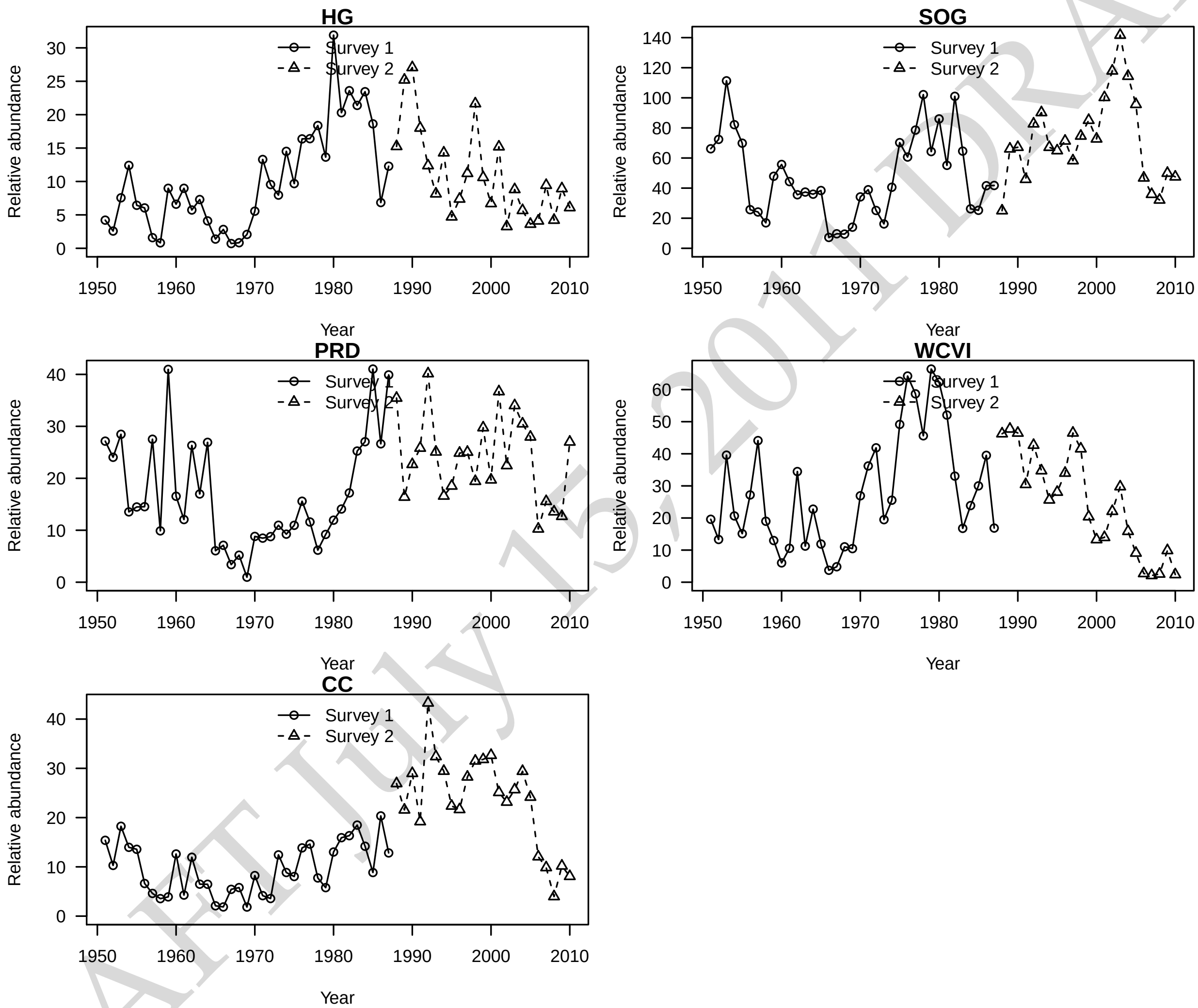


Figure 4: Spawn survey index for Strait of Georgia between 1951 and 2010. The units are actual estimates of spawning biomass (1000s tons), but only the trend information is used in the model fitting.

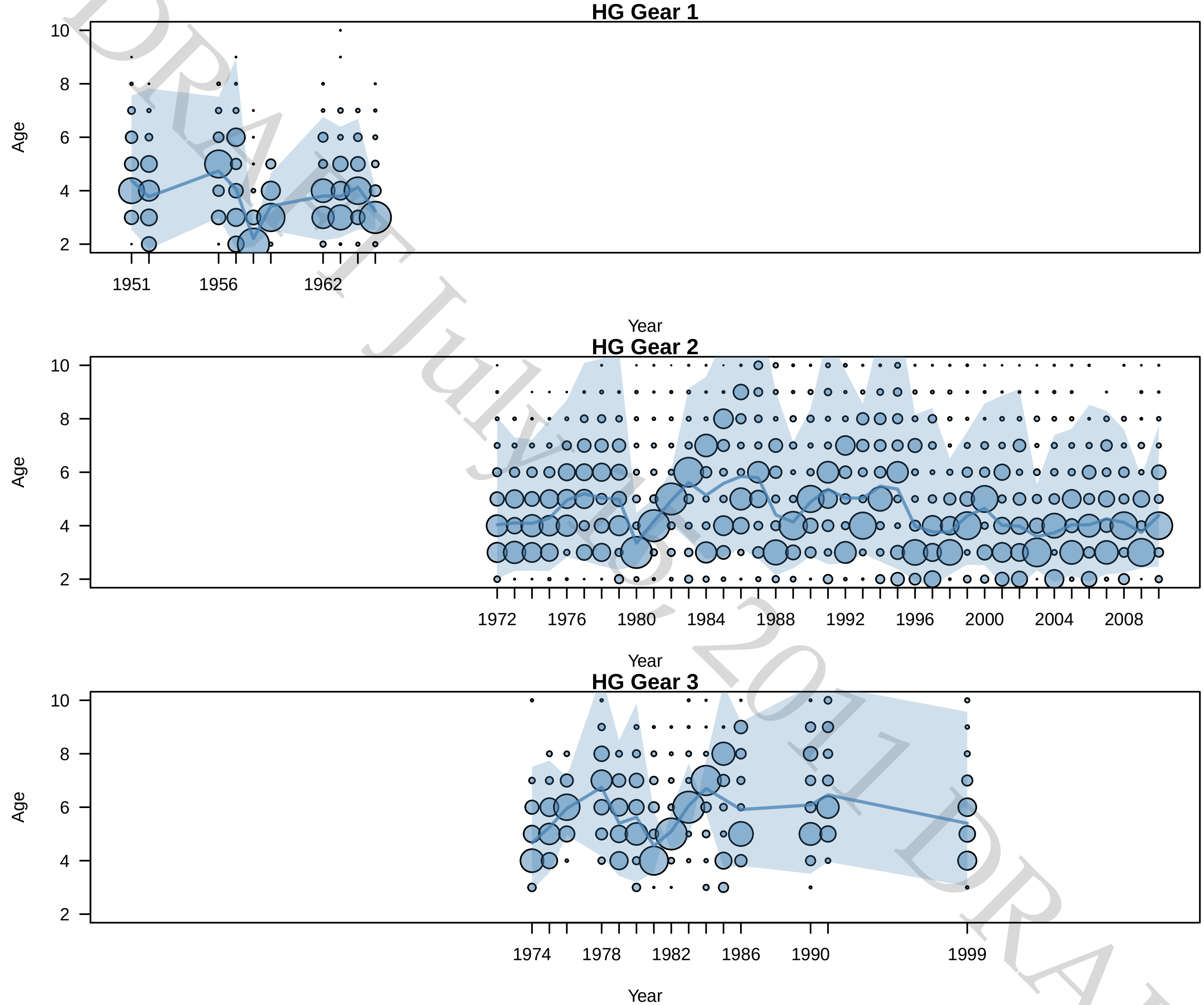


Figure 5: Bubble plots showing the proportions-at-age versus time for the winter purse seine fishery (top), seine roe fishery (middle) and the gill net fishery (bottom) in Haida Gwaii. The area of the circle is proportional to cohort abundance, each column sums to 1, zeros are not shown, and age 10 is a plus group. Also shown is the mean age of the catch (line) and the approximate 95% distribution of ages (shaded polygon) for each year.

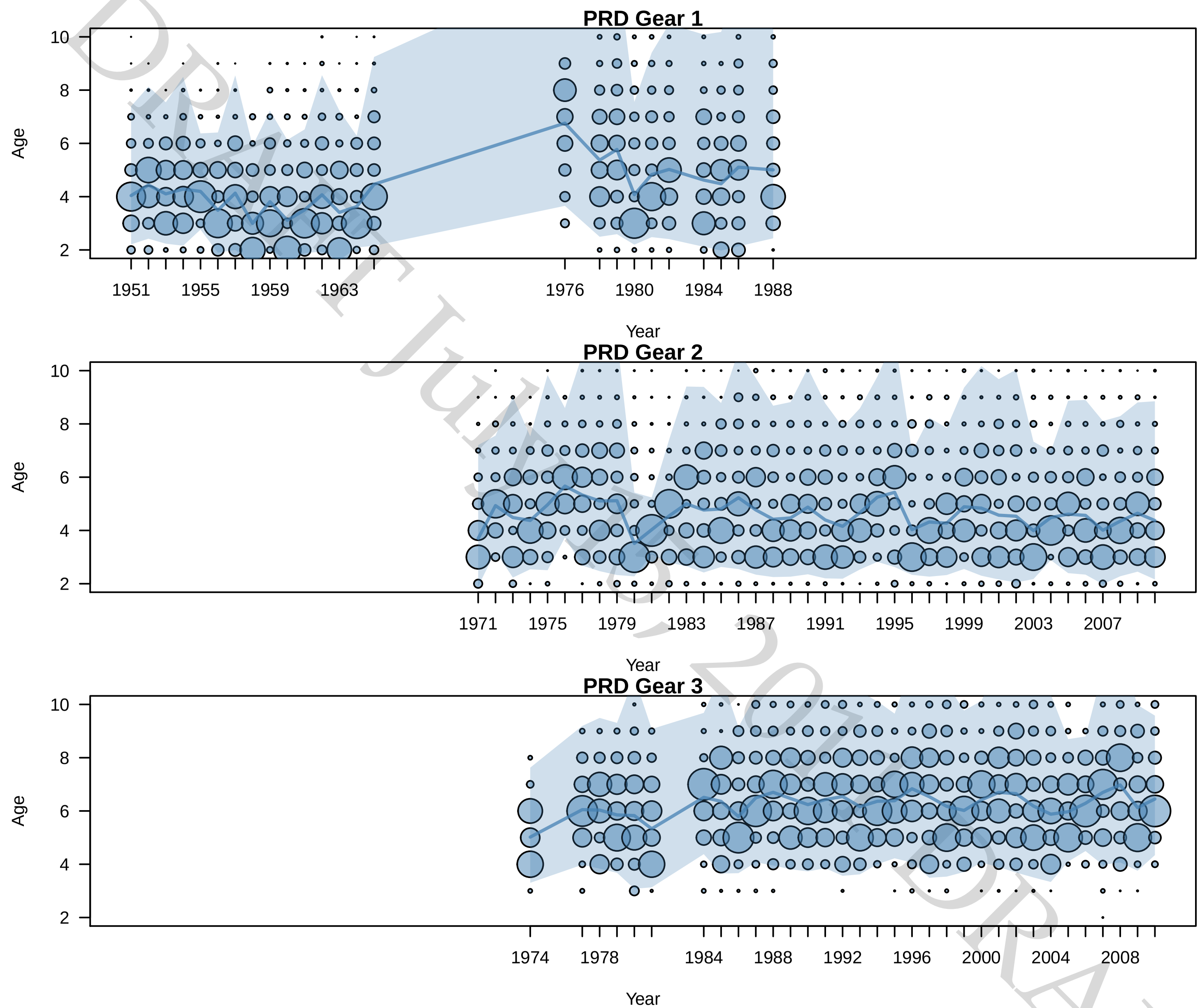


Figure 6: Bubble plots showing the proportions-at-age versus time for the winter purse seine fishery (top), seine roe fishery (middle) and the gill net fishery (bottom) in Prince Rupert District. The area of the circle is proportional to cohort abundance, each column sums to 1, zeros are not shown, and age 10 is a plus group. Also shown is the mean age of the catch (line) and the approximate 95% distribution of ages (shaded polygon) for each year.

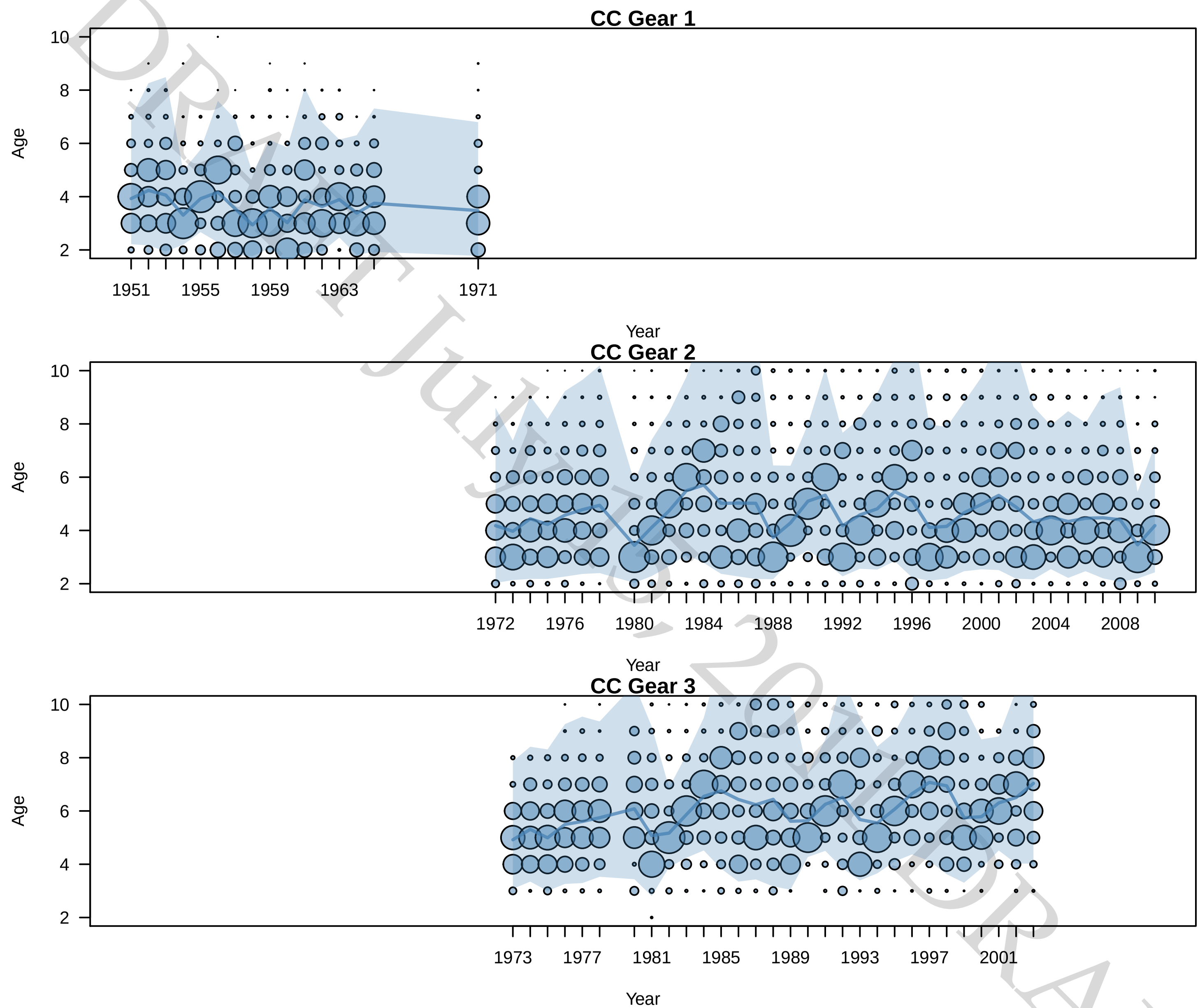


Figure 7: Bubble plots showing the proportions-at-age versus time for the winter purse seine fishery (top), seine roe fishery (middle) and the gill net fishery (bottom) in the Central Coast region. The area of the circle is proportional to cohort abundance, each column sums to 1, zeros are not shown, and age 10 is a plus group. Also shown is the mean age of the catch (line) and the approximate 95% distribution of ages (shaded polygon) for each year.

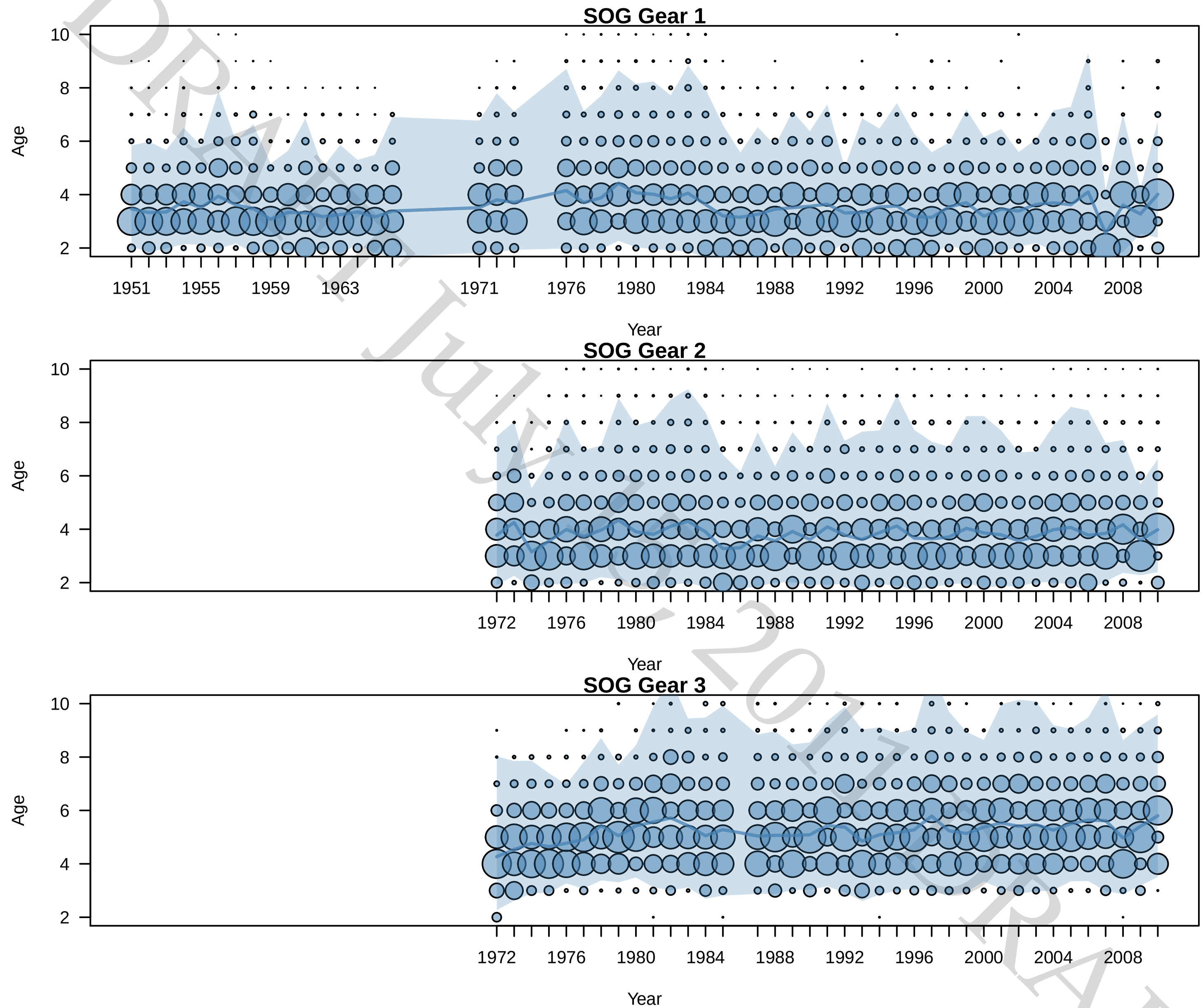


Figure 8: Bubble plots showing the proportions-at-age versus time for the winter purse seine fishery (top), seine roe fishery (middle) and the gill net fishery (bottom) in the Strait of Georgia. The area of the circle is proportional to cohort abundance, each column sums to 1, zeros are not shown, and age 10 is a plus group. Also shown is the mean age of the catch (line) and the approximate 95% distribution of ages (shaded polygon) for each year.

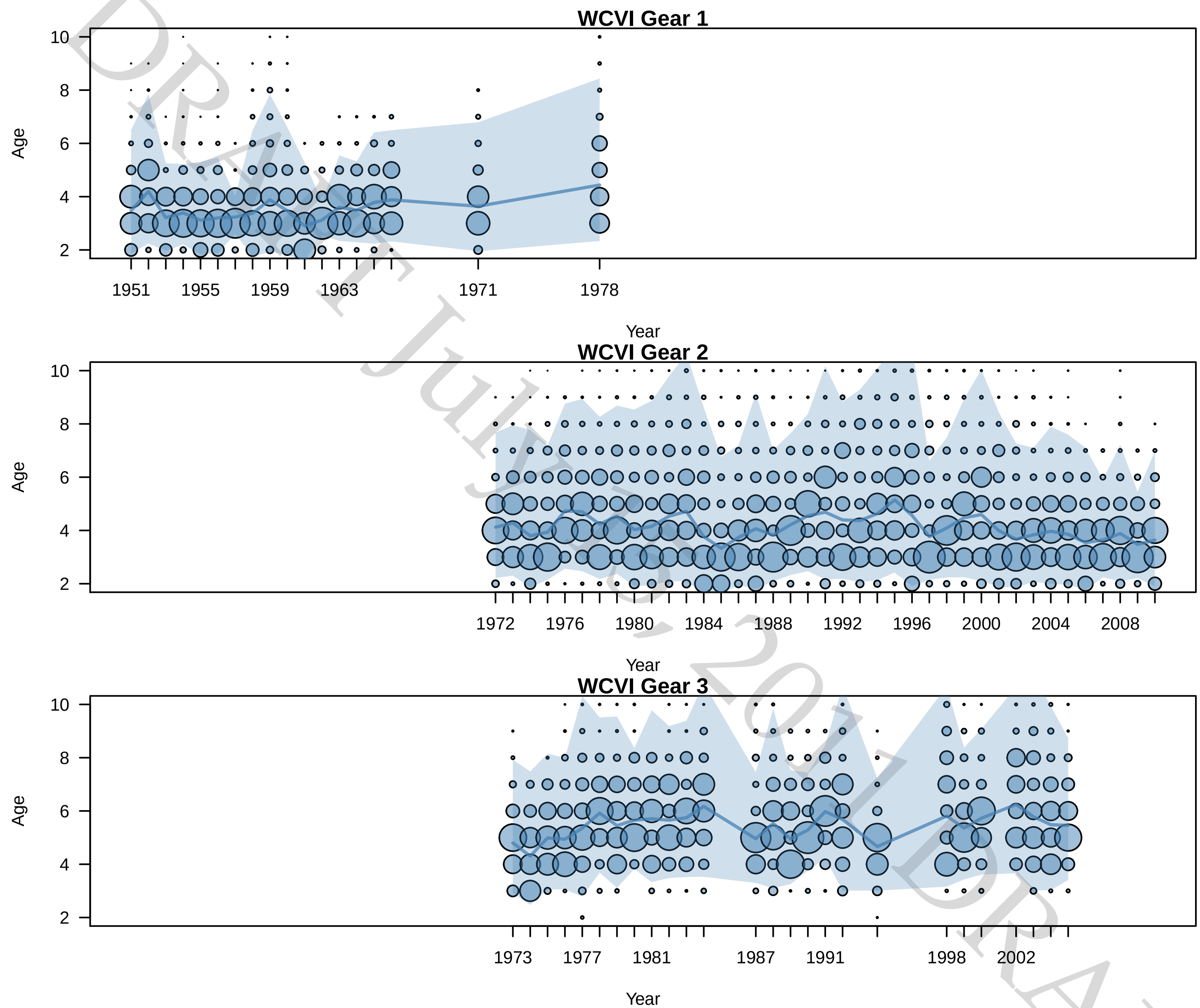


Figure 9: Bubble plots showing the proportions-at-age versus time for the winter purse seine fishery (top), seine roe fishery (middle) and the gill net fishery (bottom) in the West Coast Vancouver Island region. The area of the circle is proportional to cohort abundance, each column sums to 1, zeros are not shown, and age 10 is a plus group. Also shown is the mean age of the catch (line) and the approximate 95% distribution of ages (shaded polygon) for each year.

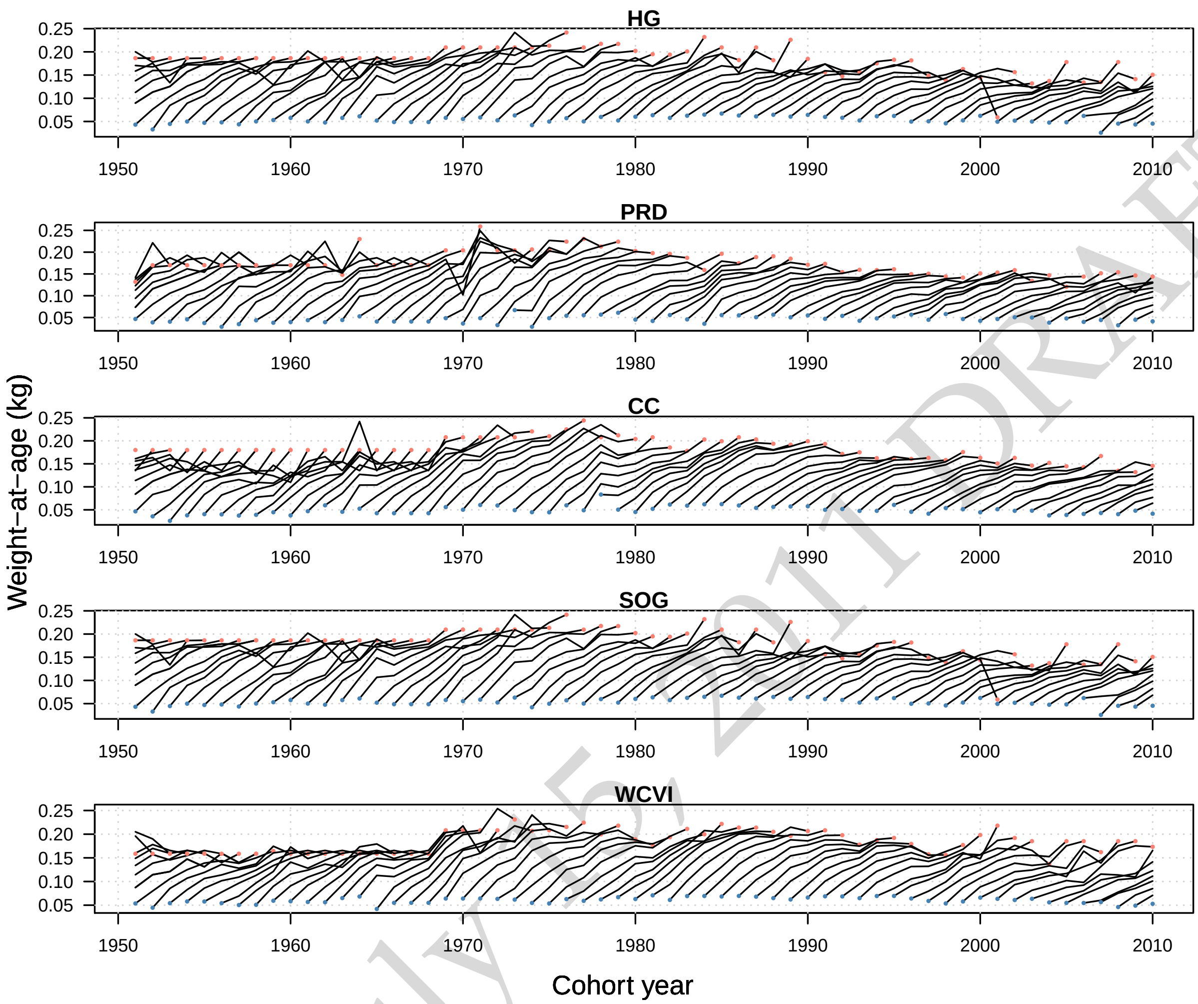


Figure 10: Empirical mean weight-at-age data by cohort from 1951 to 2010 for ages 2 to 10 in the five major Stock Assessment Regions.

factors, including: fishing effects (i.e., gear selectivity), environmental effects (changes in ocean productivity), or it may even be attributed to changes in sampling protocols (shorter time frame over which samples are collected). Declining weight-at-age has been observed in all five of the major stocks, and despite area closures over the last 10-years, has continued to occur in the QCI and WCVI stocks. Although the direct cause of this decline is still to be investigated, this trend has been observed in B.C. and U.S. waters, from California to Alaska (Schweigert, 2002), and merits further research. The observed mean weight-at-age data appear to have a few erroneous errors that need to be investigated as well; for example, see the apparently small age-10 fish in 2001 in Figure 10.

2.2 Analytical methods

A new stock assessment platform has been used for the 2011 Pacific herring assessment and this platform is based on the general statistical catch age model first described by Fournier and Archibald (1982). The software platform used is called ^{i}SCAM, which stands for integrated Statistical Catch Age Model. The source code and documentation for ^{i}SCAM is freely available from `https://sites.google.com/site/iscamproject/`, or from a subversion repository at `http://code.google.com/p/iscam-project/`. Ideally, the results of this report could easily be repeated just by downloading the necessary software and using the data and control files presented in the appendix of this paper. A complete technical description of $^i\mathrm{SCA_M}$ is provided in Appendix A.

In short, for each stock a two input files are required for $^i\mathrm{SCA_M}$: (1) a data file that contains the historical catch, survey, life-history and age-composition information, and (2) a control file that specifies initial parameter values, priors, selectivity options, and various other controls that specify options for time-varying natural mortality, type of recruitment model, etc. Each major and minor stock has its own data and control file and these are provided in Appendix B such that these results can be verified by an independent reviewer using the $^i\mathrm{SCA_M}$ software.

Estimated model parameters includes the initial numbers-at-age, annual age-2 recruits, annual fishing mortality rates for each gear, selectivity parameters, natural mortality rates, parameters that describe the observation error and process error variance, and the unfished age-2 recruits and the steepness of the stock recruitment relationship. The total number of estimated parameters differs for each stock assessment region depending on the number of years of active fishing, assumptions about selectivity, and the number of assumed nodes in natural mortality rates. In general the total number of estimated parameters ranges from

2.3 Simulation testing

The purpose of conducting simulation testing is two fold: (1) to demonstrate that the model is capable of estimating model parameters given perfect information, and (2) to examine precision and bias in parameter estimates (and corresponding management quantities) in the presence of observation and process errors. To conduct simulation testing using $^i\mathrm{SCA_M}$, the following command line option `-sim 1234` is used, where 1234 is a unique random number seed. There is also a special seed number `-sim 000` that generates data with no error. That is the simulation model is deterministic, the relative abundance data are directly proportional with 0 observation error, and the age-composition data is exactly replicates the true vulnerable proportions-at-age. The model is conditioned on the historical catch data specified in the data file, and the true parameter values used to simulate the data are those that are specified in the control file.

2.3.1 Estimation performance with perfect information

When simulating data with perfect information, there are a couple of things that need to be highlighted here when trying to estimate parameters from data that contain no error. First, the phases for the precision and variance partitioning parameters (ϑ and ρ) should be set to a negative number. There are no error in the data, therefore, there is no need to estimate the variance terms for the error distributions. Second, in the control file, the initial value for the precision (ϑ) should be set to an extremely large number (e.g., 4999.999, assuming the upper bound is 5000). The reason to set this number large is to minimize the slight bias due to the lognormal bias correction in the stock recruitment relationship (i.e., the $-0.5\tau^2$ term in T3.13, or T3.14). The control file used to simulate the fake data is provided in Table **??**.

2.3.2 Bias & precision with observation & process errors

To determine bias and precision of parameter estimates when the model is confronted with both observation error and process error, a series of Monte Carlo trials are performed and $\log_2$ ratios are used to measure the distribution of estimated parameters ($\acute{\theta}$) from the true value(θ). The log2 ratio

$$\log_2\left(\frac{\acute{\theta}}{\theta}\right)$$

is zero when $\acute{\theta} = \theta$, is 1 when $2\acute{\theta} = \theta$, and is -1 when $0.5\acute{\theta} = \theta$. Box plots are used to examine the distribution of 50 trials where a unique random number seed is used for each trial. For the purposes of the simulation experiments only, we assume that the proportion of the total variance associated with observation error is known ($\rho = 0.25$) and estimate the total variance. The total precision is set to 2.50 which is equivalent to a total standard deviation of 0.4. The control file used for the Monte Carlo procedures is provided in Table **??**.

2.4 Comparison of HCAM with ^{i}SCA$_{\mathrm{M}}$

There are a number of different statistical assumptions and structural differences between the previous assessments using HCAM (Herring Catch Age Model) and ^{i}SCA$_{\mathrm{M}}$. Here I briefly summarize the differences and similarities between the two approaches, and we first attempt to formulate the ^{i}SCA$_{\mathrm{M}}$ model to be as similar as possible to the last implementation of HCAM used in Cleary and Schweigert (2010).

The objective function in the HCAM model has four major components to it: 1) the likelihood of the age composition data, 2) the likelihood of the commercial catch data, 3) the likelihood of the spawn data, and 4) the prior densities for estimated model parameters. In the following subsections are more detailed descriptions of how the ^{i}SCA$_{\mathrm{M}}$ model was set up to best approximate the HCAM implementation.

For the GN fishery, HCAM implements a time varying selectivity scheme as a function of the average weight-at-age. At present this is not implemented in ^{i}SCA$_{\mathrm{M}}$, and after a day of investigation I (SJDM) was not able to come up with a feasible solution to make the models more comparable. Alternative options for changes in selectivity will be investigated further later in this paper.

2.4.1 Age-composition data

There are two alternative likelihoods specified for the age-composition data in the HCAM model (see Table 8 in Appendix B in Cleary and Schweigert, 2010). It is unclear which likelihood is actually used, the multinomial likelihood (T8.1), or the robust normal approximation (T8.2), or both in the assessment. In any event, ^{i}SCA$_{\mathrm{M}}$ implements a multivariate logistic negative log-likelihood for age-composition data (see equation 10 above), with the intention of weighting these data based on the conditional maximum likelihood estimate of the variance. In addition, we require a minimum observed proportion of at least 1% in each age class, in years and ages where the observed proportion is less than 1% the consecutive ages grouped into a single age-class which reduces the effective number of age-classes (this is some what analogous to a plus group).

2.4.2 Commercial catch data

In the HCAM assessment, commercial catch was assumed to be know with a high degree of certainty; observation errors were assumed lognormal, and the standard deviation specified in the code is fixed at 0.0707 (variance of 0.005) for all three periods. The analogous setup in ^{i}SCA$_{\mathrm{M}}$ is to fix the assumed standard deviation for the catches in the last phase to 0.0707.

2.4.3 Spawn survey data

For the Strait of Georgia spawn survey, the assumed standard deviations in HCAM were specified at 0.35 and 0.3 for the pre and post 1988 periods. To carry out the same assumptions in ^{i}SCA$_{\mathrm{M}}$ the relative weights for the pre and post 1988 survey data were fixed at 1.0 and 1.1666, respectively. In ^{i}SCA$_{\mathrm{M}}$ the total error (or precision=1/variance) is estimated and partitioned into components of observation error (spawn survey residuals) and process error (recruitment deviations). To implement the same observation error and process errors in the ^{i}SCA$_{\mathrm{M}}$ model (standard deviations of 0.35 and 0.8, respectively for observation errors and process errors in HCAM) the total precision was fixed at $\vartheta = 1/1.15$, and the proportion assigned to observation error was fixed at $\rho = 0.35/1.15$.

2.4.4 Specification of prior distributions

Starting with the prior density for natural mortality in HCAM, the average natural mortality rate is assumed to be normal with a mean of 0.45, and a standard deviation of 0.2 (see Table 3 in Cleary and Schweigert, 2010). The average natural mortality rate in ^{i}SCA$_{\mathrm{M}}$ is estimated in the log scale; using a normal prior for the $\ln(M)$ is equivalent to a lognormal prior for M. A lognormal prior is appropriate for this parameter as natural mortality rates must be positive; however, there is no equivalent analytical transformation to the normal distribution that was used in the HCAM assessment. Here we have specified a normal prior for $\ln(M)$ with a log mean of $\ln(0.45) = -0.7985$ and a log standard deviation of 0.4 to approximate the variance specified in the normal distribution used in the previous HCAM assessment.

The base HCAM model also allows for a random walk in natural mortality rate implemented as:

$$M_t = \begin{cases} \psi, & t = t' \\ M_{t-1}\exp(d_t^M), & t > t' \end{cases}$$

where d_t^M are annual natural mortality deviations that are assumed to be normally distributed with a mean 0 and a standard deviation of 0.10, and ψ is an estimated initial value for natural mortality. The implementation of time varying natural mortality is similar in ${}^{i}\text{SCA}_\text{M}$ in that it is a random walk process, but the components of the objective function include a prior for the initial value of M (as specified in the previous paragraph) and that the first differences between natural mortality deviations are normally distributed. Again, this structure allows natural mortality rates to drift away from central tendency and long-term changes in M could have profound effects on reference point calculations. For the comparison with the HCAM model, the first differences in annual natural mortality deviations were assumed to have a mean 0 and a standard deviation of 0.10.

Annual recruitment deviations in the HCAM implementation were assumed to be normally distributed on a log scale with a mean of zero and a standard deviation of 0.8. To set up an equivalent assumption in ${}^{i}\text{SCA}_\text{M}$, the total variance ($\vartheta$) and ratio of the total variance (ρ) that explains observation error in the spawn survey must be specified *a priori*. In the HCAM model the variance terms for the observation errors and process errors are not estimated and assumed to be known; the standard deviation for recruitment variation was set at 0.8 and the standard deviation for observation errors in the spawn survey was fixed at 0.35 and 0.3 for the pre and post 1988 data, respectively. These variance terms can be estimated within the ${}^{i}\text{SCA}_\text{M}$ model, or treated as fixed constants; however, ${}^{i}\text{SCA}_\text{M}$ estimates the total error and partitions the variance into observation (σ^2) and process error (τ^2) components. To make the same assumptions about the variance terms in ${}^{i}\text{SCA}_\text{M}$ as those that were used in HCAM the following values were used $\vartheta = 1/1.15 = 0.8695652$, and $\rho = 0.3043478$, and the weights assigned to the post 1988 spawn data were set at 1.1666 and 1.0 for the pre 1988 spawn data.

The prior for steepness in the HCAM model was based on a lognormal distribution with a logmean of 0.67 and a standard deviation of 0.17. For the Beverton-Holt stock recruitment model, steepness must lie in the interval of $0.2 < h \leq 1.0$; a Beta distribution is an appropriate density function for this parameter. In the ${}^{i}\text{SCA}_\text{M}$ implementation, a Beta distribution is used and to approximate the distribution used in the HCAM model, the shape and rate parameters specified are 10.0 and 4.925373, respectively. These values corresponds to a mean of 0.67 and a standard deviation of 0.1178 for the Beta prior.

The last informative prior that is not explicit in the table of priors in the HCAM model is the scaling parameter (q) for the spawn survey. The spawn survey data are broken into two separate time series, pre and post 1988 when the survey switch from from a surface estimate to dive surveys for estimating total egg deposition. In the HCAM implementation, a very informative prior for q in the post 1988 period was used where the mean was fixed at $q = 1.0$ and not permitted to vary (i.e., $\sigma_q = 0$). The scaling parameter in the first period was then freely estimated. Again, to emulate these assumptions in the ${}^{i}\text{SCA}_\text{M}$ implementation a normal prior for $\ln(q)$ with a mean =0 and a standard deviation of 0.001 was used for the post 1988 data and a uniform prior for the pre 1988 data.

2.5 Forecasts of pre-fishery biomass based on SFF reference points

3 Results

3.1 Simulation testing

3.1.1 Estimation performance with perfect information

Given perfect information about trends in relative abundance and age composition information, and a deterministic stock-recruitment relationship, ${}^{i}\text{SCA}_\text{M}$ was able to estimate 216 parameters without any substantial errors. Estimation performance is easily demonstrated by comparing estimates of spawning biomass and fishing mortality rates to the true values that were used to simulate the data. As shown in Figure 11 estimates of spawning biomass and fishing mortality rates were exactly the same as the true values. There is

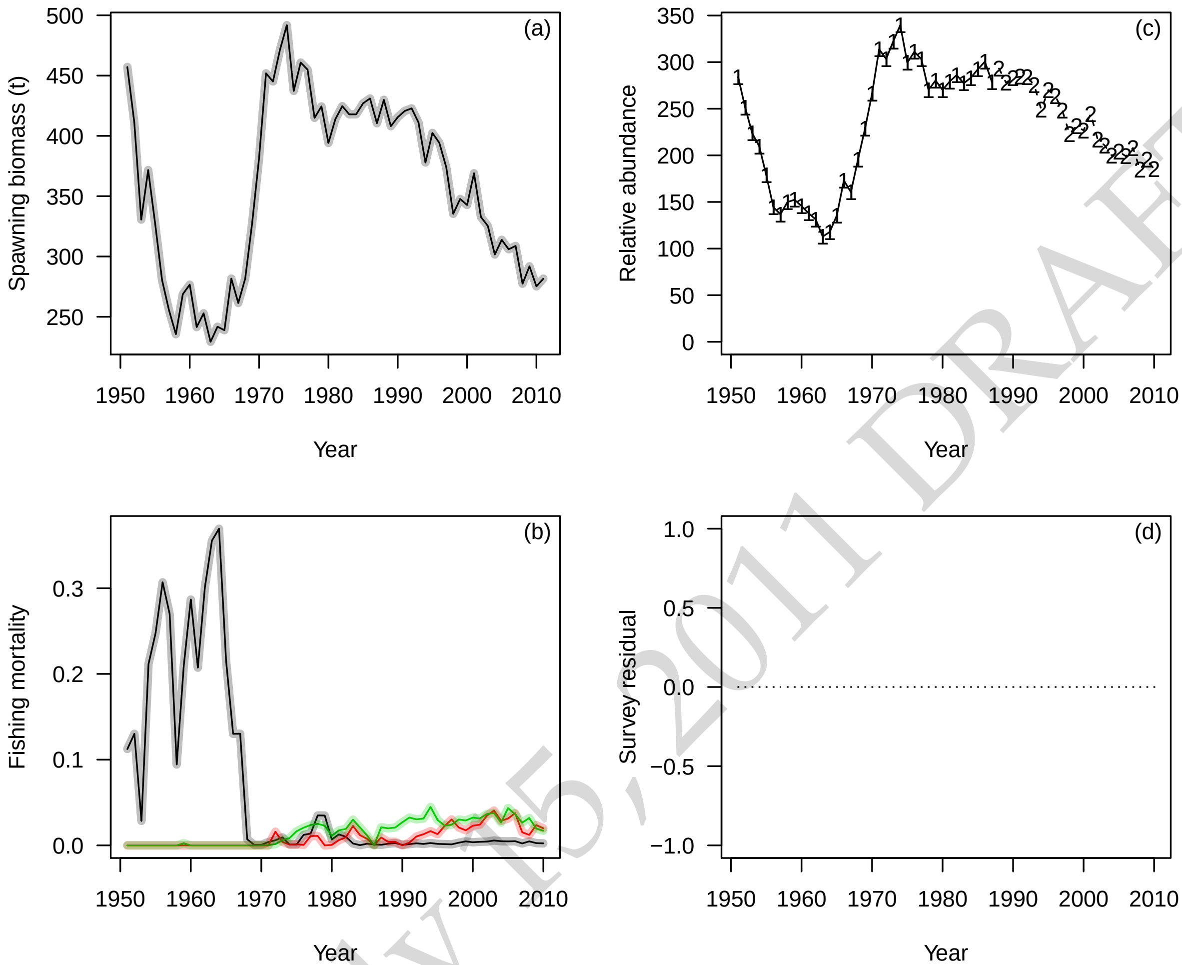


Figure 11: True (thin line) and estimated (thick shaded line) spawning biomass (a), fishing mortality rates (b), observed and predicted relative abundance (c), and residuals between observed and predicted relative abundance (d) for the SOG herring simulation with perfect information and a deterministic stock-recruitment relationship.

no measurable difference between the observed and predicted trends in the relative abundance information (Figs. 11cd).

Residuals between the observed and predicted age-composition data (not shown) were also extremely small and are easily summarized by the conditional maximum likelihood estimates of the residual variance $\widehat{\tau}^2$ for the winter seine fishery $\widehat{\tau}^2 = 2.49e-03$, the seine roe fishery $\widehat{\tau}^2 = 1.25e-27$, and the gill net fishery $\widehat{\tau}^2 = 1.24e-27$.

This perfect fit to the data is used only to judge if the code is syntactically correct and to determine if it is capable of estimating model parameters exactly given perfect information. In the following section, observation errors and process errors are introduced to determine bias and precision in parameter estimates.

3.1.2 Bias & precision with observation & process errors

In the simulation experiments conducted with both observation error and process error included in the simulated data, there was no appreciable bias in the estimates of unfished biomass ($\ln(R_o)$) and the natural

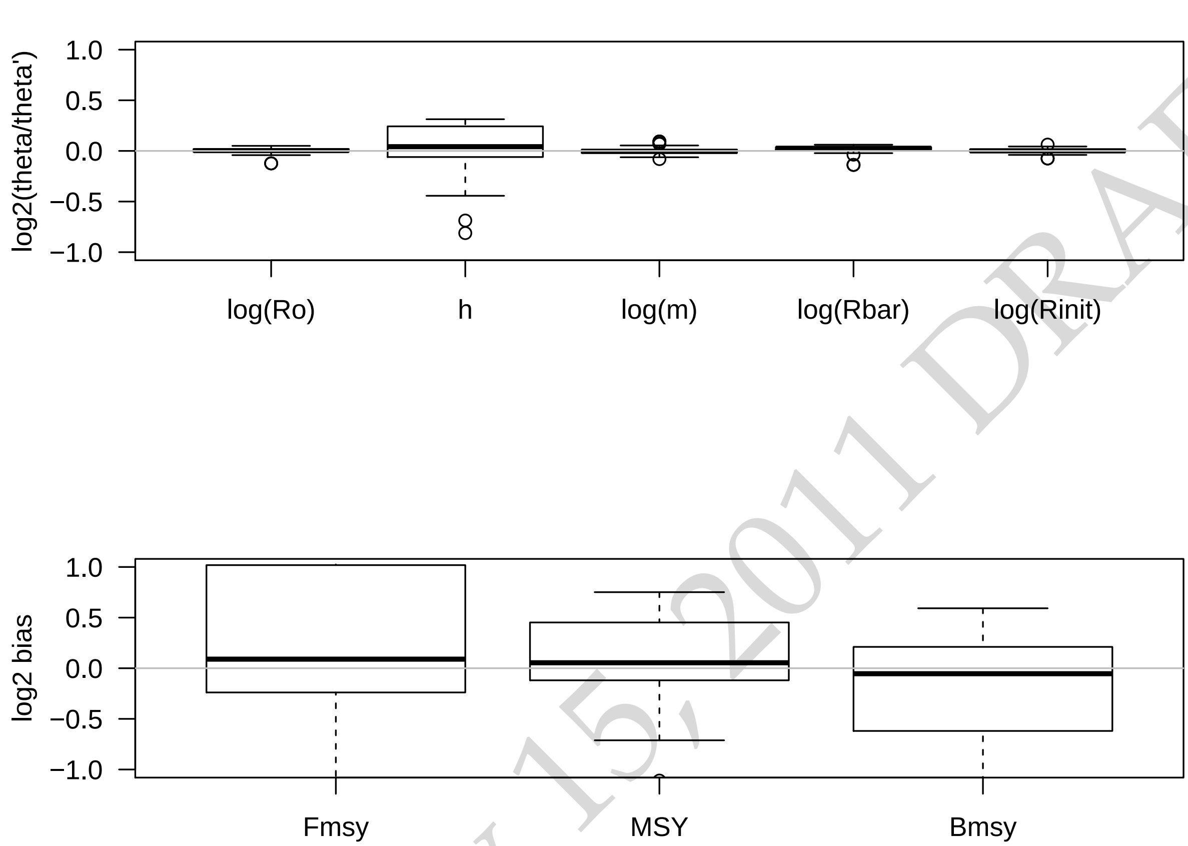


Figure 12: Estimates of precision and bias in key model parameters and MSY based reference points for 50 simulated data sets conditioned on the Strait of Georgia herring catch. The log2 ratio of estimated versus true value is plotted; values of 1 and -1 correspond to a twice or half the true value, respectively.

mortality rate ($\ln(M)$), the average recruitment ($\ln(\bar{R})$ and the initial recruitment ($\ln(\dot{R})$, Figure 12). There was, however, a very slight upward bias in the estimate of the steepness parameter for the Beverton-Holt stock recruitment relationship. Also, steepness was estimated with the least amount of precision. The estimability of steepness depends on many factors including the precision of the observations, but also the history of exploitation, the true value of steepness and the natural mortality rate (Conn et al., 2010).

Its not surprising to see a slight upward bias in h for these simulations because the true value of natural mortality was set quite high ($M = 0.45$) along with steepness ($h = 0.8$). Furthermore, the simulated exploitation history involved a strong depletion signal between the 1950s and 1960's followed by very light exploitation from 1970 onward. On average the assumed parameter values for the simulation and the catch time series generated sufficient contrast to reliably estimate key model parameters without the use of informative priors.

The lower panel of Figure 12 shows the apparent precision and bias in the estimates of MSY based reference points. There is a very slight upward bias in the estimate of F_{MSY} associated with the slight upward bias in steepness. Estimates of B_{MSY} are also slightly biased in a downward direction, and MSY in a slight upward direction. Overall, MSY is the most precisely estimated and F_{MSY} is the least precisely estimated management variable.

3.2 Comparison of HCAM with ^{i}SCA$_\mathrm{M}$

Based on the description of the priors and model setup in Section 2.4 on page 15, a comparison of the spawning stock biomass between ^{i}SCA$_\mathrm{M}$ and HCAM were very similar (Figure 13a). Between 1951 and 1969 the absolute difference in spawning biomass is minimal and post 1970 estimates of spawning biomass are slightly higher for the HCAM model. The only real difference between the two models during this period is a structural differences in selectivity for the gill net fishery.

Estimates of spawning depletion are based on the post fishery spawning biomass relative to the estimated unfished spawning biomass (Figure 13b). Note how ever the predicted 2011 estimate is the pre-fishery spawning biomass. The three coloured zones demarcate the critical zone, cautious zone, and healthy zones which are defined by $0.4\mathrm{B}_{\mathrm{MSY}}$ and $0.8\mathrm{B}_{\mathrm{MSY}}$, respectively.

Maximum likelihood estimates of key model parameters for both ^{i}SCA$_\mathrm{M}$ and HCAM are summarized in Table 1. Estimates of B_o and MSY based reference points are sensitive to the initial starting conditions and the phase in which some of the parameters are estimated. The ^{i}SCA$_\mathrm{M}$ model tends to have a lower estimate of B_o in comparison to the HCAM model and a higher value of steepness (h). These two parameters are usually negatively correlated and it is expected that if B_o was higher in one model in comparison to the other, then h would normally be lower to compensate. Information to estimate B_o and h come from the apparent stock-recruitment data and the structural form of the stock recruitment relationship. In ^{i}SCA$_\mathrm{M}$ annual recruitment is freely estimated and the residuals are based on the Beverton-Holt stock recruitment model and the estimates of spawning stock biomass. Similarly, in HCAM recruitment is a function of the spawning stock biomass and the Beverton-Holt model and the annual deviations are estimated and assumed to be normally distributed random variables.

Table 1: A comparison of key parameters from ^{i}SCA$_\mathrm{M}$ and the HCAM model

Parameter	^{i}SCA$_\mathrm{M}$	HCAM
Unfished spawning biomass (B_o 1000 t)	151.492	190.817
Steepness (h)	0.763	0.683
Average natural mortality rate	0.504	0.334
Survey q for period 1	1.213	1.1105

Average natural mortality rates are similar between the two models, and the survey q for the pre-1988 spawn survey data is slightly higher in the ^{i}SCA$_\mathrm{M}$ model. The more contemporary survey data were both forced to scale with $q = 1.0$. There is some pattern in the residuals for the overall fits to the survey data (Figure 13d), the model fails to predict the large increases in abundance in the late 1970s and early 2000s and the recent decline in the late 2000s. The assumed standard deviation for the survey errors was 0.35 and 0.3 for the pre and post 1988 survey data, the standard deviation of the residual errors in Figure 13d is 0.424 and 0.32, respectively.

Estimates of the components of total mortality for the comparison with the HCAM model are shown in Figure 14. The fishing mortality rates for each gear represent the average fishing mortality rate over all age-classes, and the natural mortality rate is assumed to be age-independent. During the 1950s through to 1968, fishing mortality rates for Pacific herring in the Strait of Georgia were extremely high; this period was almost exclusively a purse-seine fishery where fish were taken for fishmeal. After the fishery reopened in the early 1970s fishing mortality rates were greatly reduced and targeted the spawning component of the stock as the market was for herring roe.

Estimates of natural mortality are based on a random walk process, initially starting at a value of 0.367 in 1951 and declining to a very low value of 0.068 in 1959, then increasing to a maximum of 1.02 in 1970 (Figure 14a). Information to estimate natural mortality rates comes from the age-composition data, and assumptions about selectivity in the fishery. In this comparison, the ^{i}SCA$_\mathrm{M}$ model assumes selectivity is invariant and much of the residual variation in the age-composition is explained by variation in M and

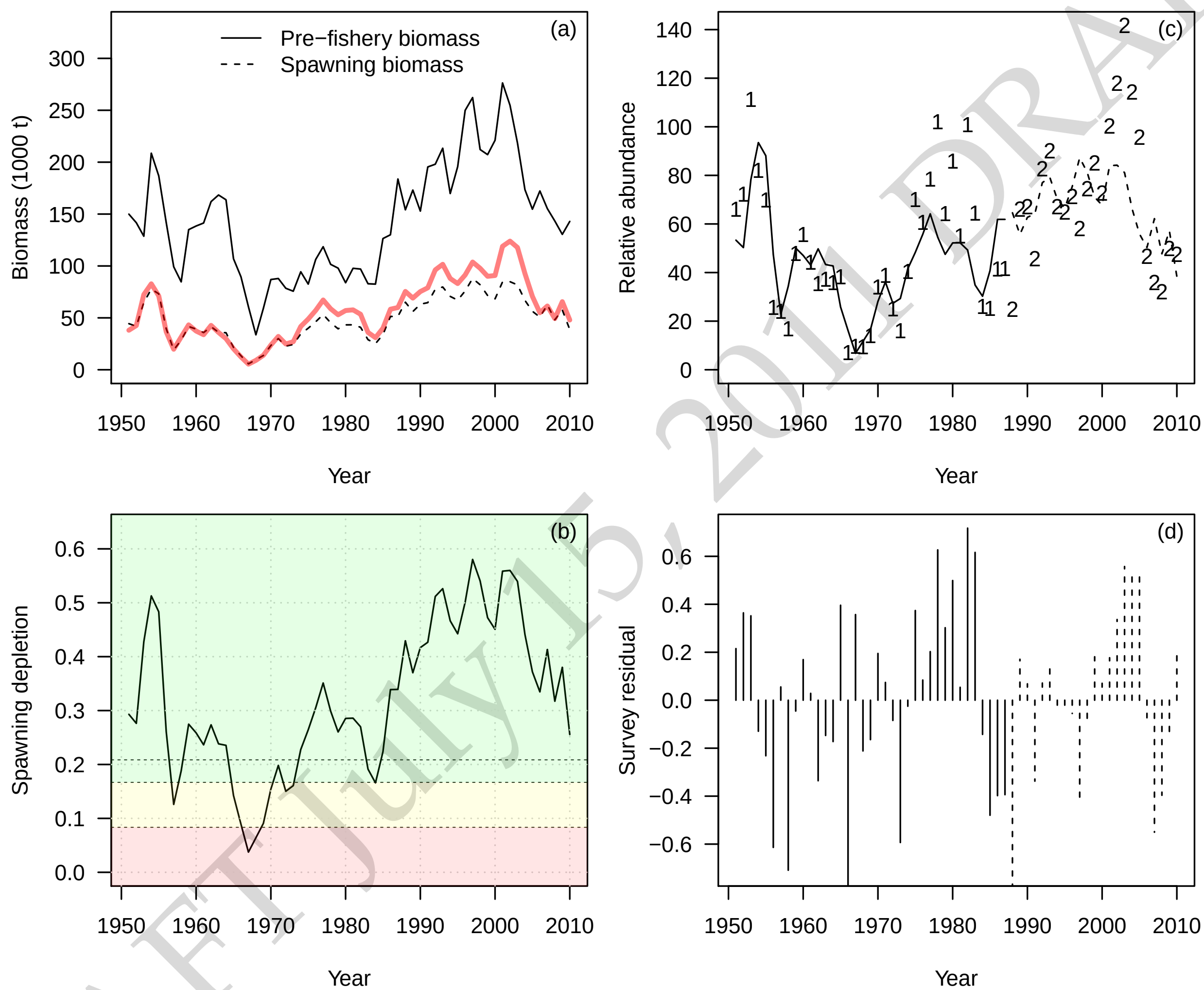


Figure 13: Maximum likelihood estimates of pre-fishery biomass and post fishery spawning biomass (a), spawning biomass depletion (b), observed (points) and predicted (lines) spawn survey data (c), and spawn survey residuals. These results are based on trying to configure the $^{i}SCA_{M}$ model as similar as possible to the previous HCAM assessment; the red line in panel (a) is the MLE estimate of spawning biomass from HCAM.

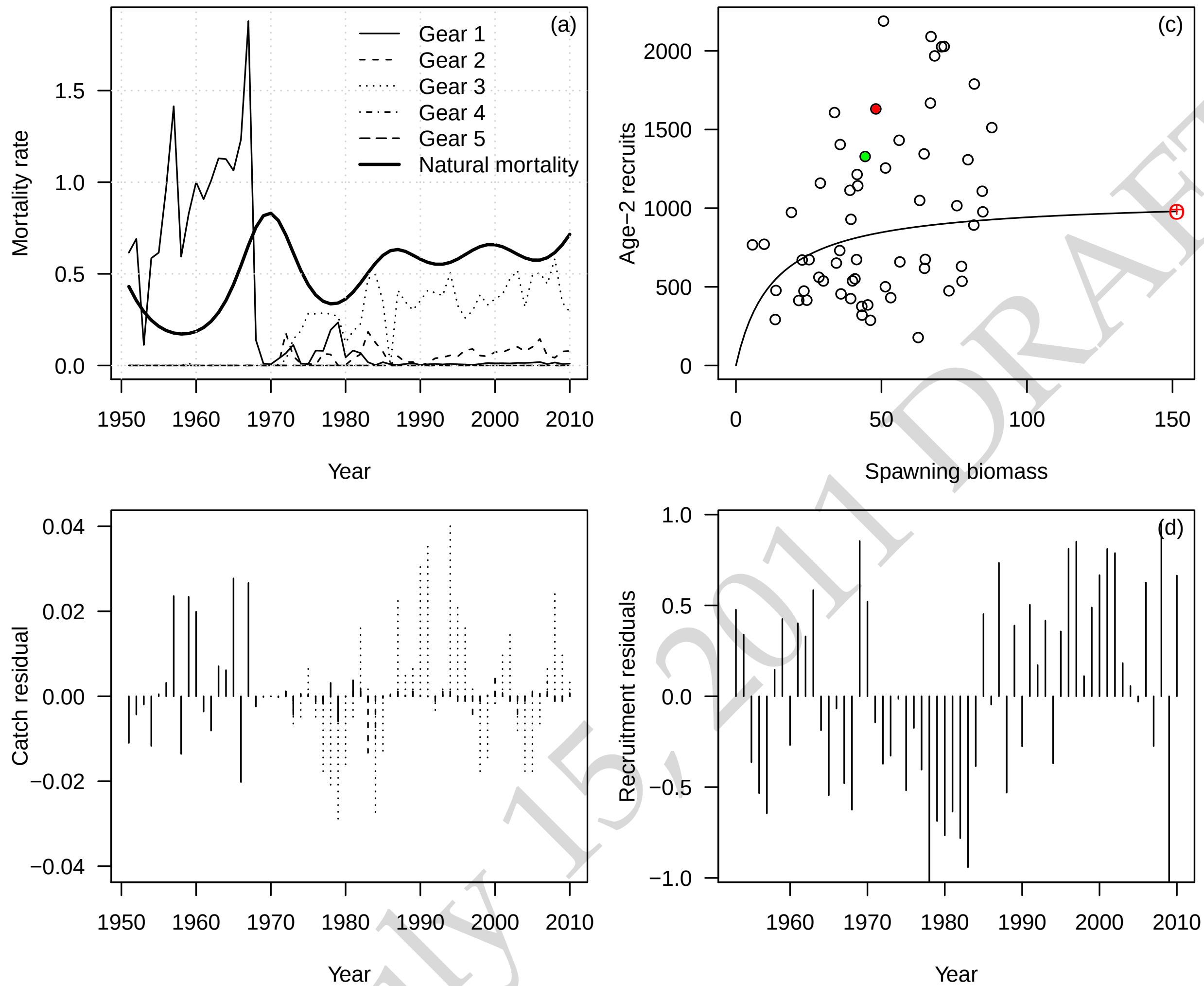


Figure 14: Components of total mortality rate (a), residuals between the observed and predicted catch (b), the spawning stock biomass versus age-2 recruits and stock recruitment relationship (estimates of unfished spawning biomass and unfished recruitment are denoted by the circle with the + symbol inside, c), and the residuals in the stock recruitment relationship (d).

variation in age-2 recruits (see Figure 15 for residual patterns and age-2 recruitment). The HCAM model has a very similar trend in the estimates of natural mortality but the variability is much less than that of the ^{i}SCA$_{\mathrm{M}}$ assessment. This is almost certainly due to the changes in selectivity for the gill net fishery associated with changes in mean body weight in the HCAM implementation.

There is good correspondence between the observed and predicted catch, however, the residual patterns does not appear to be iid for each of the fleets.

There was some lack of fit to the age-composition data for the purse seine fisheries and the best fits were actually obtained for the gill net fisheries. The conditional maximum likelihood estimates of the standard deviations of the age-composition data are 0.797, 0.672, and 0.326 for the winter purse seine, seine-roe, and gill net fisheries, respectively. The smaller the standard deviation, the better correspondence between the observed and predicted age-composition data.

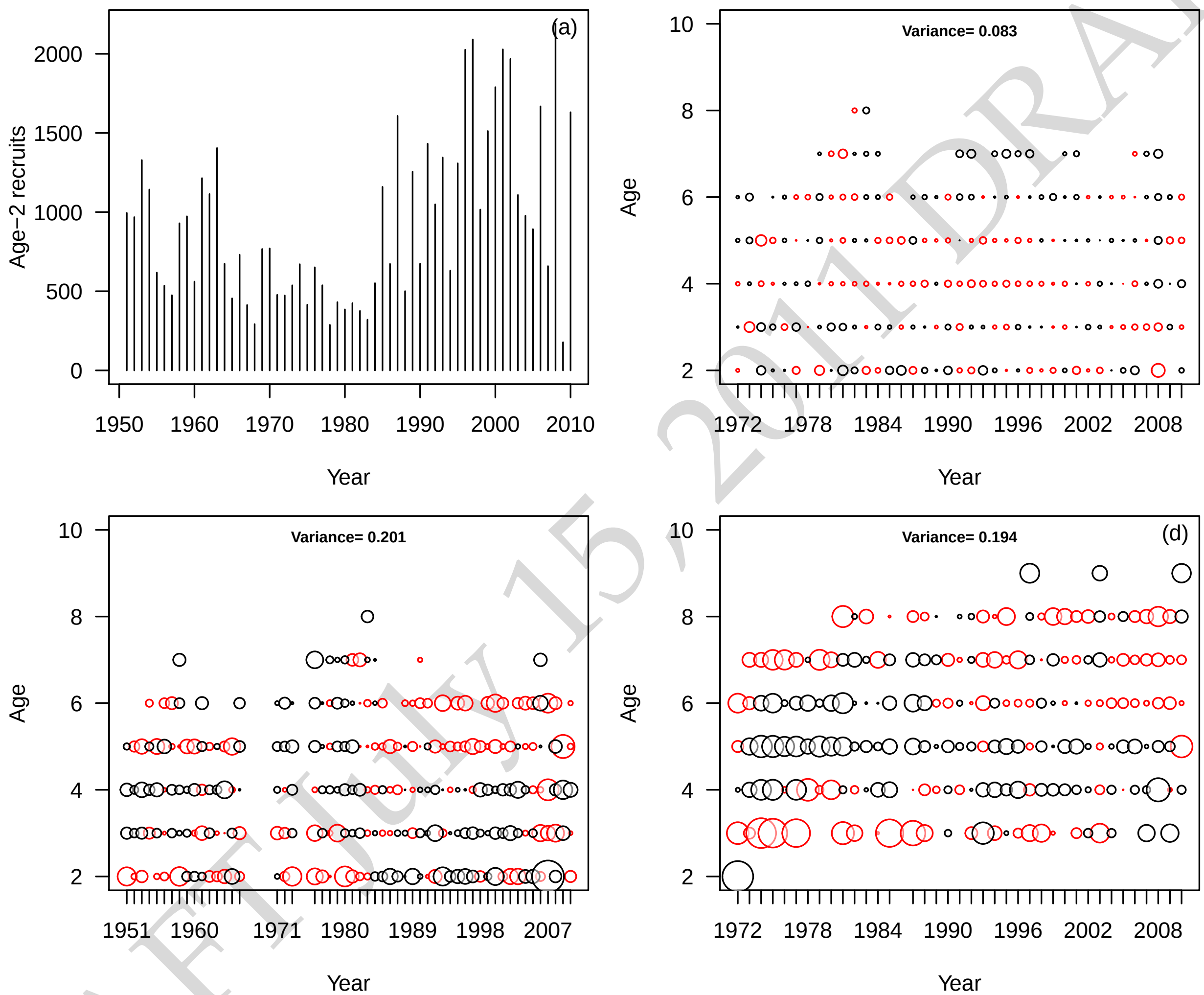


Figure 15: Estimates of age-2 recruits (a) and the residuals (observed-predicted, positive shown in black) in the age-composition data for the winter purse seine fishery (lower left), seine-roe fishery (upper right) and gill net fishery (lower right). The area of each circle is proportional to the residual error, and zeros are not shown. Note that observed age-proportions less than 2% were pooled into the adjacent (younger) age class and the conditional maximum likelihood estimates of the variance is displayed on the top of each panel.

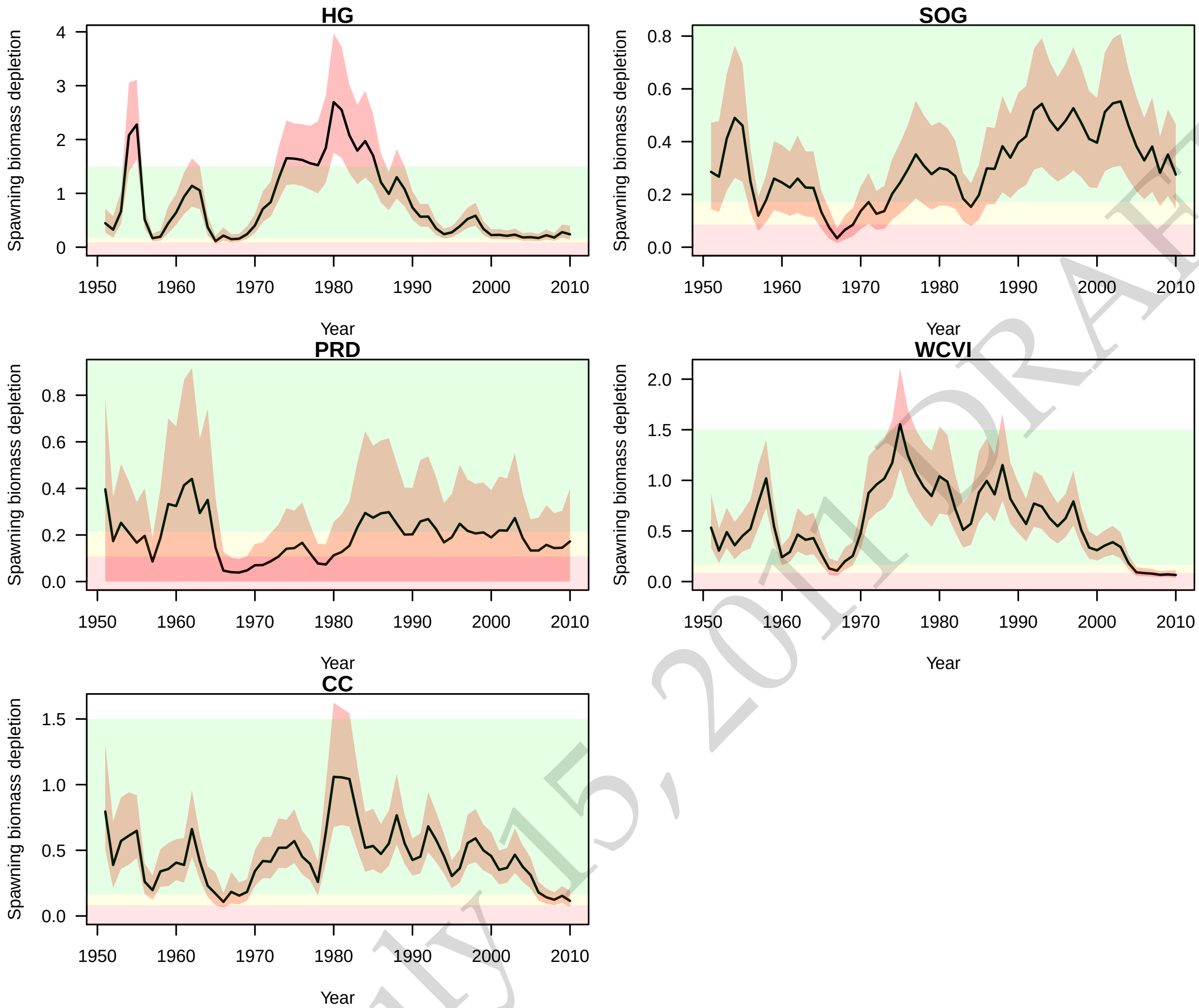


Figure 16: Cap.

3.2.1 Strait of Georgia herring assessment

3.2.2 Retrospective and prospective analyses

3.3 Alternative assumptions about catchability, mortality & selectivity

3.3.1 Impacts of informative priors on q's

3.3.2 Implications of variable natural mortality rate M_t

3.3.3 Implications of variable selectivity in directed fisheries

3.4 Separating test fishery data from the purse seine roe fishery data

3.5 Preliminary assessments for all other areas

4 Discussion

References

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

Cleary, J. and Schweigert, J. (2010). Stock Assessment and Management Advice for the British Columbia Herring Stocks: 2010 Assessment and 2011 Forecasts. *Canadian Science Advisory Secretariat*, 2010:90.

Conn, P., Williams, E., and Shertzer, K. (2010). When can we reliably estimate the productivity of fish stocks? *Canadian Journal of Fisheries and Aquatic Sciences*, 67(3):511–523.

Fisheries and Oceans Canada (2006). A harvest strategy compliant with the precautionary approach. *Canadian Science Advisory Secretariat Sci. Adv. Rep. No. 2006/023*.

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

Gavaris, S. and Ianelli, J. (2002). Statistical Issues in Fisheries' Stock Assessments*. *Scandinavian Journal of Statistics*, 29(2):245–267.

Haist, V., Schweigert, J., Stocker, M., Station, P., of Fisheries, C. D., and Oceans (1986). *Stock assessments for British Columbia herring in 1985 and forecasts of the potential catch in 1986*. Fisheries and Oceans, Canada.

Hardwick, J. (1973). Biomass estimates of spawning herring, clupea harengus pallasi, herring eggs, and associated vegetation in tomales bay. *Calif. Fish Game*, 59(1):36–61.

McAllister, M. K. and Ianelli, J. (1997). Bayesian stock assessment using catch-age data and the sampling: importance resampling algorithm. *Canadian journal of fisheries and aquatic sciences(Print)*, 54(2):284–300.

Richards, L., Schnute, J., and Olsen, N. (1997). Visualizing catch-age analysis: a case study. *Canadian Journal of Fisheries and Aquatic Sciences*, 54(7):1646–1658.

Schnute, J. and Richards, L. (1995). The influence of error on population estimates from catch-age models. *Canadian Journal of Fisheries and Aquatic Sciences*, 52(10):2063–2077.

Schweigert, J. (2002). Herring size-at-age variation in the North Pacific. *PICES-GLOBEC INTERNATIONAL PROGRAM ON CLIMATE CHANGE AND CARRYING CAPACITY*, page 47.

Schweigert, J., Christensen, L., Haist, V., and Secretariat, C. S. A. (2009). *Stock Assesment for British Columbia Herring in 2008 and Forecasts of the Potential Catch in 2009*. Canadian Science Advisory Secretariat= Secrétariat canadien de consultation scientifique.

Schweigert, J., Secretariat, C. S. A., of Fisheries, C. D., and Oceans (2001). Stock assessment for british columbia herring in 2001 and forecasts of the potential catch in 2002. *Can. Sci. Adv. Secr.*, 2001(140):84.

Walters, C. and Ludwig, D. (1994). Calculation of Bayes posterior probability distributions for key population parameters. *Canadian Journal of Fisheries and Aquatic Sciences*, 51(3):713–722.

A Technical description of ^{i}SCAM

A.1 Analytic methods

The section contains the documentation in mathematical form of the underlying age structured model, and its steady state version that is used to calculate MSY-based reference points, the observation models used in predicting observations, and the components of the objective function that formulate the statistical criterion that is used to estimate model parameters. All of the model equations are laid out in tables and are intended to represent the order of operations, or pseudocode, in which to implement the model. ^{i}SCA$_{\text{M}}$was implemented in AD Model Builder version 10.1 ADMB Project (2009). This appendix also describes some of the optional features in ^{i}SCA$_{\text{M}}$for estimating nonparametric selectivities.

A.1.1 Equilibrium considerations

Steady-state conditions are presented in Table A-1, in here we assume the parameter vector Θ in (T1.1) is unknown and would eventually be estimated by fitting ^{i}SCA$_{\text{M}}$ to time series data. For a given set of growth parameters and maturity-at-age parameters defined by (T1.3), growth is assumed to follow the von Bertalanffy model (T1.4), mean weight-at-age is given by the allometric relationship in (T1.5), and the age-specific vulnerability is given by a logistic function (T1.6). Note, however, there are alternative selectivity functions implemented in ^{i}SCA$_{\text{M}}$, the logistic function used here is simply for demonstration purposes. Mean fecundity-at-age is assumed to be proportional to the mean weight-at-age of mature fish, where maturity at age is specified by the parameters $\dot{a}$ and $\dot{\gamma}$ for the logistic function.

Survivorship for unfished and fished populations is defined by (T1.8) and (T1.9), respectively. It is assumed that all individuals ages A and older (i.e., the plus group) have the same total mortality rate. The incidence functions refer to the life-time or per-recruit quantities such as spawning biomass per recruit (ϕ_E) or vulnerable biomass per recruit (ϕ_b). Note that upper and lower case subscripts denote unfished and fished conditions, respectively. Spawning biomass per recruit is given by (T1.10), the vulnerable biomass per recruit is given by (T1.11) and the per recruit yield to the fishery is given by (T1.12). Unfished recruitment is given by (T1.13) and the steady-state equilibrium recruitment for a given fishing mortality rate F_e is given by (T1.14). Note that in (T1.14) we assume that recruitment follows a Beverton-Holt model of the form:

$$R_e = \frac{s_o R_e \phi_e}{1 + \beta R_e \phi_e}$$

where

$$s_o = \kappa/\phi_E,$$

$$\beta = \frac{(\kappa - 1)}{R_o \phi_E},$$

which simplifies to (T1.14). The equilibrium yield for a given fishing mortality rate is (T1.15). These steady-state conditions are critical for determining various reference points such as F_{MSY} and B_{MSY}.

A.1.2 MSY based reference points

^{i}SCA$_{\text{M}}$ calculates MSY-based reference points by finding the value of F_e that results in the zero derivative of the steady-state catch equation (T1.15). This is accomplished numerically using a Newton-Raphson method where an initial guess for F_{MSY} is set equal to $1.5M$, then use (1) to iteratively find F_{MSY}. Note that the partial derivatives in (1) can be found in Table A-2.

Table A-1: Steady-state age-structured model assuming unequal vulnerability-at-age, age-specific natural mortality, age-specific fecundity and Beverton-Holt type recruitment.

Parameters

$$\Theta = (B_o, \kappa, M_a, \hat{a}, \hat{\gamma}) \tag{T1.1}$$

$$B_o > 0; \kappa > 1; M_a > 0 \tag{T1.2}$$

$$\Phi = (l_\infty, k, t_o, a, b, \dot{a}, \dot{\gamma}) \tag{T1.3}$$

Age-schedule information

$$l_a = l_\infty(1 - \exp(-k(a - t_o))) \tag{T1.4}$$

$$w_a = a(l_a)^b \tag{T1.5}$$

$$v_a = (1 + \exp(-(\hat{a} - a)/\gamma))^{-1} \tag{T1.6}$$

$$f_a = w_a(1 + \exp(-(\dot{a} - a)/\dot{\gamma}))^{-1} \tag{T1.7}$$

Survivorship

$$\iota_a = \begin{cases} 1, & a = 1 \\ \iota_{a-1}e^{-M_{a-1}}, & a > 1 \\ \iota_{a-1}/(1 - e^{-M_a}), & a = A \end{cases} \tag{T1.8}$$

$$\hat{\iota}_a = \begin{cases} 1, & a = 1 \\ \hat{\iota}_{a-1}e^{-M_{a-1}-F_e v_{a-1}}, & a > 1 \\ \hat{\iota}_{a-1}e^{-M_{a-1}-F_e v_{a-1}}/(1 - e^{-M_a - F_e v_a}), & a = A \end{cases} \tag{T1.9}$$

Incidence functions

$$\phi_E = \sum_{a=1}^{\infty} \iota_a f_a, \quad \phi_e = \sum_{a=1}^{\infty} \hat{\iota}_a f_a \tag{T1.10}$$

$$\phi_B = \sum_{a=1}^{\infty} \iota_a w_a v_a, \quad \phi_b = \sum_{a=1}^{\infty} \hat{\iota}_a w_a v_a \tag{T1.11}$$

$$\phi_q = \sum_{a=1}^{\infty} \frac{\hat{\iota}_a w_a v_a}{M_a + F_e v_a} \left(1 - e^{(-M_a - F_e v_a)}\right) \tag{T1.12}$$

Steady-state conditions

$$R_o = B_o/\phi_B \tag{T1.13}$$

$$R_e = R_o \frac{\kappa - \phi_E/\phi_e}{\kappa - 1} \tag{T1.14}$$

$$C_e = F_e R_e \phi_q \tag{T1.15}$$

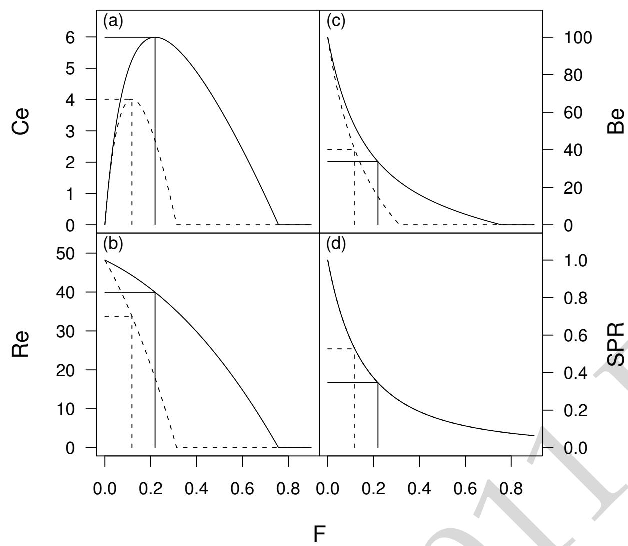


Figure 17: Equilibrium yield (a), recruits (b), biomass (c) and spawner per recruit (ϕ_e/ϕ_E) (d) versus instantaneous fishing mortality F_e for two different values of the recruitment compensation ratio ($\kappa = 12$ solid lines, $\kappa = 4$ dashed lines). Vertical lines in each panel correspond to F_{MSY} and horizontal lines correspond to various reference points that would achieve MSY.

$$F_{e+1} = F_e - \frac{\dfrac{\partial C_e}{\partial F_e}}{\dfrac{\partial^2 C_e}{\partial F_e}} \tag{1}$$

where

$$\frac{\partial C_e}{\partial F_e} = R_e\phi_q + F_e\phi_q\frac{\partial R_e}{\partial F_e} + F_eR_e\frac{\partial \phi_q}{\partial F_e}$$

$$\frac{\partial^2 C_e}{\partial F_e} = \phi_q\frac{\partial R_e}{\partial F_e} + R_e\frac{\partial \phi_q}{\partial F_e}$$

The algorithm usually converges in less than 10 iterations depending on how close the initial guess of F_{MSY} is to the true value. A maximum of 20 iterations are allowed in ^{i}SCA$_M$, however, if $\frac{\partial C_e}{\partial F_e} < 10^{-5}$ the algorithm stops. Note also, that this is only performed on data type variables and not differentiable variables within AD Model Builder.

Given an estimate of F_{MSY}, other reference points such as MSY are calculated use the equations in Table A-1 where each of the expressions is evaluated at F_{MSY}. A graphical representation of MSY based reference points for two alternative values of the recruitment compensation parameter κ is show in Figure 17.

There are some additional technical details about calculating MSY based reference points when considering multiple fishing gears with different selectivities. The maximum sustainable yield summed over all fishing gears is a function of the selectivities of each gear type and what fraction of the total catch is allocated to each gear. In the Pacific herring fishery, there are three distinct fleets that all have different selectivities; the purse-seine gears tend to catch smaller younger fish, while the gill net fishery tends to target larger mature females. The optimum fishing mortality rate for each gear that would maximize the yield depends on what the other gears are removing; this in itself is another optimization problem that fisheries management must contend with. For the purposes of this assessment, ^{i}SCA$_M$ requires an allocation of the total catch (summed across gear type) to each gear before it proceeds with calculating reference points.

Table A-2: Partial derivatives, based on components in Table A-1, required for the numerical calculation of F_{MSY} using (1).

Mortality & Survival

$$Z_a = M_a + F_e v_a \tag{T2.1}$$

$$S_a = 1 - e^{-Z_a} \tag{T2.2}$$

Partial for survivorship

$$\frac{\partial \hat{\iota}_a}{\partial F_e} = \begin{cases} 0, & a = 1 \\ e^{-Z_{a-1}} \left(\dfrac{\partial \hat{\iota}_{a-1}}{\partial F_e} - \hat{\iota}_{a-1} v_{a-1} \right), & 1 < a < A \\ \dfrac{\frac{\partial \hat{\iota}_{a-1}}{\partial F_e}}{(1 - e^{-Z_a})} - \dfrac{\hat{\iota}_{a-1} e^{-Z_{a-1}} v_a e^{-Z_a}}{(1 - e^{-Z_a})^2}, & a = A \end{cases} \tag{T2.3}$$

Partials for incidence functions

$$\frac{\partial \phi_e}{\partial F_e} = \sum_{a=1}^{\infty} f_a \frac{\partial \hat{\iota}_a}{\partial F_e} \tag{T2.4}$$

$$\frac{\partial \phi_q}{\partial F_e} = \sum_{a=1}^{\infty} \frac{w_a v_a S_a}{Z_a} \frac{\partial \hat{\iota}_a}{\partial F_e} + \frac{\hat{\iota}_a w_a v_a^2}{Z_a} \left(e^{-Z_a} - \frac{S_a}{Z_a} \right) \tag{T2.5}$$

Partial for recruitment

$$\frac{\partial R_e}{\partial F_e} = \frac{R_o}{\kappa - 1} \frac{\phi_E}{\phi_e^2} \frac{\partial \phi_e}{\partial F_e} \tag{T2.6}$$

For this herring assessment, the average catch over the past 20 years was arbitrarily used to determine the allocation scheme for each of the stock assessment regions. For the Strait of Georgia this corresponds to 6.9% for the winter seine fishery, 41.4% for the seine roe fishery, and 51.8% for the gill net fishery. We further assume that 100% of the total mortality takes place prior to spawning.

A.1.3 Dynamic age-structured model

The estimated parameter vector in ^{i}SCA$_{\text{M}}$ is defined in (T3.1), where R_0, κ and M are the leading unknown population parameters that define the overall population scale in the form of unfished recruitment and productivity in the form of recruitment compensation and natural mortality. The total variance ϑ^2 and the proportion of the total variance that is associated with observation errors ρ are also estimated, then the variance is partitioned into observation errors (σ^2) and process errors (τ^2) using (T3.2).

The unobserved state variables (T3.3) include the numbers-at-age year year t ($N_{t,a}$), the spawning stock biomass (B_t) and the total age-specific total mortality rate ($Z_{t,a}$).

The initial numbers-at-age in the first year (T3.4) and the annual recruits (T3.5) are treated as estimated parameters and used to initialize the numbers-at-age matrix. Age-specific selectivity for gear type k is a function of the selectivity parameters γ_k (T3.6), and the annual fishing mortality for each gear k in year t ($\digamma_{k,t}$). The vector of log fishing mortality rate parameters $\digamma_{k,t}$ is a bounded vector with a minimum value of -30 and an upper bound of 3.0. In arithmetic space this corresponds to a minimum value of 9.36e-14 and a maximum value of 20.01 for annual fishing mortality rates. In years where there are 0 reported catches for a given fleet, no corresponding fishing mortality rate parameter is estimated and the implicit assumption is there was no fishery in that year.

There is an option to treat natural mortality as a random walk process (T3.7), where the natural mortality rate in the first year is the estimated leading parameter (T3.1) and in subsequent years the mortality rate deviates from the previous year based on the estimated deviation parameter φ_t. If the mortality deviation

Table A-3: Statistical catch-age model using the Baranov catch equation and C^* and F^* as leading parameters.

Estimated parameters

$$\Theta = \left(R_0, \kappa, M, \bar{R}, \ddot{R}, \rho, \vartheta, \vec{\gamma}_k, \digamma_{k,t}, \{\ddot{\omega}_a\}_{a=\acute{a}+1}^{a=A}, \{\omega_t\}_{t=1}^{t=T}, \{\varphi_t\}_{t=2}^{T}\right) \tag{T3.1}$$

$$\sigma = \rho/\vartheta, \quad \tau = (1-\rho)/\vartheta \tag{T3.2}$$

Unobserved states

$$N_{t,a}, B_t, Z_{t,a} \tag{T3.3}$$

Initial states ($t = \acute{t}$)

$$N_{t,a} = \ddot{R}e^{\ddot{\omega}_a}\exp(-M_t)^{(a-\acute{a})}; \quad t = \acute{t}; \acute{a} \le a \le A \tag{T3.4}$$

$$N_{t,a} = \bar{R}e^{\omega_t}; \quad \acute{t} \le t \le T; a = \acute{a} \tag{T3.5}$$

$$v_{k,a} = f(\vec{\gamma}_k) \tag{T3.6}$$

$$M_t = M_{t-1}\exp(\varphi_t), \quad t > 1 \tag{T3.7}$$

$$F_{k,t} = \exp(\digamma_{k,t}) \tag{T3.8}$$

State dynamics ($t > \acute{t}$)

$$B_t = \sum_a N_{t,a} f_a \tag{T3.9}$$

$$Z_{t,a} = M_t + \sum_k F_{k,t} v_{k,t,a} \tag{T3.10}$$

$$\hat{C}_{k,t} = \sum_a \frac{N_{t,a} w_a F_{k,t} v_{k,t,a} \left(1 - e^{-Z_{t,a}}\right)^{\eta_t}}{Z_{t,a}} \tag{T3.11}$$

$$N_{t,a} = \begin{cases} N_{t-1,a-1}\exp(-Z_{t-1,a-1}) & a > \acute{a} \\ N_{t-1,a}\exp(-Z_{t-1,a}) & a = A \end{cases} \tag{T3.12}$$

Recruitment models

$$R_t = \frac{s_o B_{t-k}}{1 + \beta B_{t-k}} e^{\delta_t - 0.5\tau^2} \quad \text{Beverton-Holt} \tag{T3.13}$$

$$R_t = s_o B_{t-k} e^{-\beta B_{t-k} + \delta_t - 0.5\tau^2} \quad \text{Ricker} \tag{T3.14}$$

parameters are not estimated, then M is assumed to be time invariant.

State variables in each year are updated using equations T3.9–T3.12, where the spawning biomass is the product of the numbers-at-age and the mature biomass-at-age (T3.9). The total mortality rate is given by (T3.10), and the total catch (in weight) for each gear is given by (T3.11) assuming that both natural and fishing mortality occur simultaneously throughout the year. The numbers-at-age are propagated over time using (T3.12), where members of the plus group (age A) are all assumed to have the same total mortality rate.

Recruitment to age k can follow either a Beverton-Holt model (T3.13) or a Ricker model (T3.14) where the maximum juvenile survival rate (s_o) in either case is defined by $s_o = \kappa/\phi_E$. For the Beverton-Holt model, β is derived by solving (T3.13) for β conditional on estimates of κ and R_o:

$$\beta = \frac{\kappa - 1}{R_o \phi_E},$$

Table A-4: List of symbols, constants and description for variables used in ^{i}SCA$_{\mathrm{M}}$.

Symbol	Constant value	Description
Indexes		
a		index for age
t		index for year
k		index for gear
Model dimensions		
$\acute{a}, A$	2, 10	youngest and oldest age class (A is a plus group)
$\acute{t}, T$	1951, 2010	first and last year of catch data
K	5	Number of gears including survey gears
Observations (data)		
$C_{k,t}$		catch in weight by gear k in year t
$I_{k,t}$		relative abundance index for gear k in year t
$p_{k,t,a}$		observed proportion-at-age a in year t for gear k
Estimated parameters		
R_o		Age-$\acute{a}$ recruits in unfished conditions
κ		recruitment compensation
M		instantaneous natural mortality rate
$\bar{R}$		average age-$\acute{a}$ recruitment from year $\acute{t}$ to T
$\ddot{R}$		average age-$\acute{a}$ recruitment in year $\acute{t} - 1$
ρ		fraction of the total variance associated with observation error
ϑ		total precision (inverse of variance) of the total error
$\vec{\gamma}_k$		vector of selectivity parameters for gear k
$\digamma_{k,t}$		logarithm of the instantaneous fishing mortality for gear k in year t
$\ddot{\omega}_a$		age-$\acute{a}$ deviates from $\ddot{R}$ for year $\acute{t}$
ω_t		age-$\acute{a}$ deviates from $\bar{R}$ for years $\acute{t}$ to T

and for the Ricker model this is given by:

$$\beta = \frac{\ln(\kappa)}{R_o \phi_E}$$

A.1.4 Options for selectivity

At present, there are six alternative age-specific selectivity options in ^{i}SCA$_{\text{M}}$. The simplest of the selectivity options is a simple logistic function with two parameters where it is assumed that selectivity is time-invariant. The more complex selectivity options assume that selectivity may vary over time a may have as many as (A-1)·T parameters. For time-varying selectivity, cubic and bicubic splines are used to reduce the number of estimated parameters. Prior to parameter estimation, ^{i}SCA$_{\text{M}}$ will determine the exact number of selectivity parameters that need to be estimated based on which selectivity option was chosen for each gear type. It is not necessary for all gear types to have the same selectivity option. For example it is possible to have a simple two parameter selectivity curve for say a survey gear, and a much more complicated selectivity option for a commercial fishery.

Logistic selectivity The logistic selectivity option is a two parameter model of the form

$$v_a = \frac{1}{1 + \exp\left(-(a - \mu_a)/\sigma_a\right)}$$

where μ_a and σ_a are the two estimated parameters representing the age-at-50% vulnerability and the standard deviation, respectively.

Age-specific selectivity coefficients The second option also assumes that selectivity is time-invariant and estimates at total of A-1 selectivity coefficients, where the plus group age-class is assumed to have the same selectivity as the previous age-class. For example, if the ages in the model range from 1 to 15 years, then a total of 14 selectivity parameters are estimated, and age-15+ animals will have the same selectivity as age-14 animals.

When estimating age-specific selectivity coefficients, there are two additional penalties that are added to the objective function that control how much curvature there is and limit how much dome-shaped can occur. To penalize the curvature, the square of the second differences of the vulnerabilities-at-age are added to the objective function:

$$\lambda_k^{(1)} \sum_{a=2}^{A-1} (v_{k,a} - 2v_{k,a-1} + v_{k,a-2})^2 \tag{2}$$

The dome-shaped term penalty as:

$$\begin{cases} \lambda_k^{(2)} \sum_{a=1}^{A-1} (v_{k,a} - v_{k,a+1})^2 & (if) v_{k,a+1} < v_{k,a} \\ 0 & (if) v_{k,a+1} \geq v_{k,a} \end{cases} \tag{3}$$

For this selectivity option the user must specify the relative weights ($\lambda_k^{(1)}, \lambda_k^{(2)}$) to add to these two penalties.

Cubic spline interpolation The third option also assumes time-invariant selectivity and estimates a selectivity coefficients for a series age-nodes (or spline points) and uses a natural cubic spline to interpolate between these nodes (Figure 18). Given $n+1$ distinct knots x_i, selectivity can be interpolated in the intervals defined by

$$S(x) = \begin{cases} S_0(x) & x \in [x_0, x_1] \\ S_1(x) & x \in [x_1, x_2] \\ \dots \\ S_{n-1}(x) & x \in [x_{n-1}, x_n] \end{cases}$$

where $S''(x_0) = S''(x_n) = 0$ is the condition that defines a natural cubic spline.

The same penalty functions for curvature and dome-shaped selectivity are also invoked for the cubic spline interpolation of selectivity.

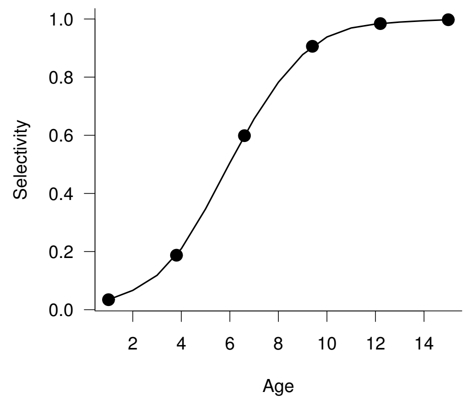


Figure 18: Example of a natural cubic spline interpolation for estimating selectivity coefficients. In ^{i}SCA$_{\text{M}}$ the user specifies the number of nodes (circles) to estimate; then age-specific selectivity coefficients are interpolated using a natural cubic spline.

Time-varying selectivity with cubic spline interpolation A fourth option allows for cubic spline interpolation for age-specific selectivity in each year. This option adds a considerable number of estimated parameters but the most extreme flexibility. For example, given 40 years of data and estimated 5 age nodes, this amounts 200 (40 years times 5 ages) estimated selectivity parameters. Note that the only constraints at this time are the dome-shaped penalty and the curvature penalty; there is no constraint implemented for say a random walk (first difference) in age-specific selectivity). As such this option should only be used in cases where age-composition data is available for every year of the assessment.

Bicubic spline to interpolate over time and ages The fifth option allows for a two-dimensional interpolation using a bicubic spline (Figure 19). In this case the user must specify the number of age and year nodes. Again the same curvature and dome shaped constraints are implemented. It is not necessary to have age-composition data each and every year as in the previous case, as the bicubic spline will interpolate between years. However, it is not advisable to extrapolate selectivity back in time or forward in time where there are no age-composition data unless some additional constraint, such as a random-walk in age-specific selectivity coefficients is implemented (as of July 15, 2011, this has not been implemented).

A.1.5 Options for natural mortality

There is an option in ^{i}SCA$_{\text{M}}$ to estimate a time series of deviations in natural mortality rates (φ_t). If not estimated, natural mortality M is assumed to be invariant over time and age. If, however, M is thought to vary over time, then ^{i}SCA$_{\text{M}}$ models natural mortality as a random walk process (T3.7). In such cases where M is allowed to freely vary over time, the user must specify two additional components in the control file. First, the phase in which the vector of deviations φ_t is estimated must be specified (use a -ve phase to turn off the estimation), and the user must also specify a standard deviation in the deviation parameters. If estimated, then an additional component is added to the objective function to constrain the first differences in the deviation parameters. This first difference constraint only limits how quickly M may increase or decrease over time and does not penalize deviations from an underlying mean. Thus it is possible for M to drift (increase or decrease) away from some central tendency. This drifting can have profound effects on reference point calculations as it also allows for non-stationarity in the underlying production function.

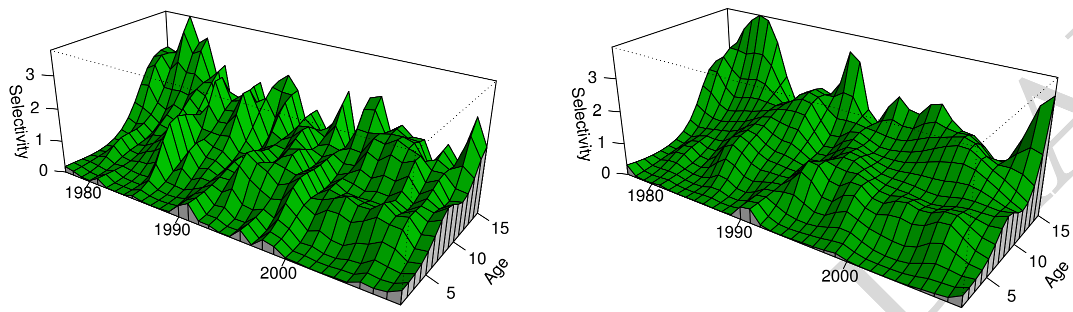


Figure 19: Example of a time-varying cubic spline (left) and bicubic spline (right) interpolation for selectivity. The panel on the left contains 165 estimated selectivity parameters and the bicubic interpolation estimates 85 selectivity parameters, or 5 age nodes and 17 year nodes. There are 495 actual nodes (selectivity parameters) being interpolated.

A.2 Residuals, likelihoods & objective function value components

There are 3 major components to the overall objective function that are minimized. These components consist of the likelihood of the data, prior distributions and penalty functions that are invoked to regularize the solution during intermediate phases of the non-linear parameter estimation. This section discusses each of these in turn, starting first with the residuals between observed and predicted states followed by the negative loglikelihood that is minimized for the catch data, relative abundance data, age-composition, and stock-recruitment relationships.

A.2.1 Catch data

It is assumed that the measurement errors in the non-zero catch observations are log-normally distributed, and the residuals is given by:

$$\eta_{k,t} = \ln(C_{k,t}) - \ln(\hat{C}_{k,t}), \tag{4}$$

The residuals are assumed to be normally distributed with a user specified standard deviation σ_C. At present, it is assumed that observed catches for each gear k is assumed to have the same standard deviation. To aid in parameter estimation, two separate standard deviations are specified in the control file: the first is the assumed standard deviation used in the first, second, to N-1 phases, and the second is the assumed standard deviation in the last phase. The negative loglikelihood (ignoring the scaling constant) for the catch data is given by:

$$\ell_C = \sum_k \left[T_k \ln(\sigma_C) + \frac{\sum_{t \in \hat{C}_{k,t} \neq 0} (\eta_{k,t})^2}{2\sigma_C^2} \right], \tag{5}$$

where T_k is the total number of non-zero catch observations for gear type k.

A.2.2 Relative abundance data

The relative abundance data are assumed to be proportional to biomass that is vulnerable to the sampling gear:

$$V_{k,t} = \sum_a N_{t,a} e^{-\lambda_{k,t} Z_{t,a}} v_{k,a} w_{a,t}, \tag{6}$$

where $v_{k,a}$ is the age-specific selectivity of gear k, and w_a is the mean-weight-at-age. A user specified fraction of the total mortality $\lambda_{k,t}$ adjusts the numbers-at-age to correct for survey timing. In the case of Pacific herring spawn surveys, the vulnerability is fixed to the assumed maturity ogive and the empirical weight-at-age data are used to construct the predicted relative abundance. Also, it was assumed that all the mortality (post-fishing) had occurred during the time the survey took place (i.e., $\lambda_{k,t} = 1$). The residuals between the observed and predicted relative abundance index is given by:

$$\epsilon_{k,t} = \ln(I_{k,t}) - \ln(q_k) + \ln(V_{k,t}), \tag{7}$$

where $I_{k,t}$ is the observed relative abundance index, q_k is the catchability coefficient for index k, and $V_{k,t}$ is the predicted vulnerable biomass at the time of sampling. The catchability coefficient q_k is evaluated at its conditional maximum likelihood estimate:

$$q_k = \frac{1}{N_k} \sum_{t \in I_{k,t}} \ln(I_{k,t}) - \ln(V_{k,t}),$$

where N_k is the number of relative abundance observations for index k (see Walters and Ludwig, 1994, for more information). The negative loglikelihood for relative abundance data is given by:

$$\ell_I = \sum_k \sum_{t \in I_{k,t}} \ln(\sigma_{k,t}) + \frac{\epsilon_{k,t}^2}{2\sigma_{k,t}^2} \tag{8}$$

where

$$\sigma_{k,t} = \frac{\rho\vartheta^2}{\omega_{k,t}},$$

where $\rho\varphi^2$ is the proportion of the total error that is associated with observation errors, and $\omega_{k,t}$ is a user specified relative weight for observation t from gear k. The $\omega_{k,t}$ terms allow each observation to be weighted relative to the total error $\rho\varphi^2$; for example, to omit a particular observation, set $\omega_{k,t} = 0$, or to give 2 times the weight, then set $\omega_{k,t} = 2.0$. To assume all observations have the same variance then simply set $\omega_{k,t} = 1$. Note that if $\omega_{k,t} = 0$ then equation (8) is undefined; therefore, ^{i}SCA$_{\mathrm{M}}$ adds a small constant to $\omega_{k,t}$ (1.e-10, which is equivalent to assuming an extremely large variance) to ensure the likelihood can be evaluated.

In the case of the Pacific herring assessment, the spawn survey data post-1988 were assumed to be twice as precise as the pre-dive survey data (1951-1987). To implement this, weights for the 1951-1987 data were set equal to $\omega_{k,t} = 1.0$ and the contemporary data was assigned $\omega_{k,t} = 2.0$. The standard deviation in the observation errors is conditional on estimated values of ρ and φ^2.

A.2.3 Age composition data

Sampling theory suggest that age composition data are derived from a multinomial distribution (Fournier and Archibald, 1982); however, ^{i}SCA$_{\mathrm{M}}$ assumes that age-proportions are obtained from a multivariate logistic distribution (Schnute and Richards, 1995; Richards et al., 1997). The main reason ^{i}SCA$_{\mathrm{M}}$ departs from the traditional multinomial model has to do with how the age-composition data are weighted in the objective function. First, the multinomial distribution requires the specification of an effective sample size; this may be done arbitrarily or through iterative re-weighting (McAllister and Ianelli, 1997; Gavaris and Ianelli, 2002), and in the case of multiple and potentially conflicting age-proportions this procedure may fail to converge properly. The assumed effective sample size can have a large impact on the overall model results.

A nice feature of the multivariate logistic distribution is that the age-proportion data can be weighted based on the conditional maximum likelihood estimate of the variance in the age-proportions. Therefore, the contribution of the age-composition data to the overall objective function is "self-weighting" and is conditional on other components in the model.

Ignoring the subscript for gear type for clarity, the observed and predicted proportions-at-age must satisfy the constraint

$$\sum_{a=1}^{A} p_{t,a} = 1$$

for each year. The multivariate logistic residuals between the observed ($p_{t,a}$) and predicted proportions ($\widehat{p_{t,a}}$) is given by:

$$\eta_{t,a} = \ln(p_{t,a}) - \ln(\widehat{p_{t,a}}) - \frac{1}{A}\sum_{a=1}^{A}\left[\ln(p_{t,a}) - \ln(\widehat{p_{t,a}})\right]. \tag{9}$$

The conditional maximum likelihood estimate of the variance is given by

$$\widehat{\tau}^2 = \frac{1}{(A-1)T}\sum_{t=1}^{T}\sum_{a=1}^{A}\eta_{t,a}^2,$$

and the negative loglikelihood evaluated at the conditional maximum likelihood estimate of the variance is given by:

$$\ell_A = (A-1)T\ln(\widehat{\tau}^2). \tag{10}$$

In short, the multivariate logistic likelihood for age-composition data is just the log of the residual variance weighted by the number observations over years and ages.

There is also a technical detail in (9), where observed and predicted proportions-at-age must be greater than 0. It is not uncommon in catch-age data sets to observe 0 proportions for older, or young, age classes. ^{i}SCA$_{\mathrm{M}}$ adopts the same approach described by Richards et al. (1997) where the definition of age-classes is altered to require that $p_{t,a} \geq 0.02$ for every age in each year. This is accomplished by grouping consecutive ages, where $p_{t,a} < 0.02$, into a single age-class and reducing the effective number of age-classes in the variance calculation ($\widehat{\tau}^2$) by the number of groups created. The choice of 2% is arbitrary and the user can specify the minimum proportion (including 0) to consider when pooling age-proportion data. In the case of an exact 0 in the observed age-proportions the pooling of the adjacent age-class still occurs, this ensures that (9) is defined.

In the Strait of Georgia herring example, we set the minimum proportion to 2% to reduce the influence of the large numbers of 0 proportions in the purse-seine fleets, especially prior to 1970 during the reduction fishery.

A.2.4 Stock-recruitment

There are two alternative stock-recruitment models available in ^{i}SCA$_{\mathrm{M}}$: the Beverton-Holt model and the Ricker model. Annual recruitment and the initial age-composition are treated as latent variables in ^{i}SCA$_{\mathrm{M}}$, and residuals between estimated recruits and the deterministic stock-recruitment models are used to estimate unfished spawning stock biomass and recruitment compensation. The residuals between the estimated and predicted recruits is given by

$$\delta_t = \ln(\bar{R}e^{w_t}) - f(B_{t-k}) \tag{11}$$

where $f(B_{t-k})$ is given by either (T3.13) or (T3.14), and k is the age at recruitment. Note that a bias correction term for the lognormal process errors is included in (T3.13) and (T3.14).

The negative log likelihood for the recruitment deviations is given by the normal density (ignoring the scaling constant):

$$\ell_\delta = n\ln(\tau) + \frac{\sum_{t=1+k}^{T}\delta_t^2}{2\tau^2} \tag{12}$$

Equations (11) and (12) are key for estimating unfished spawning stock biomass and recruitment compensation via the recruitment models. The relationship between (s_o, β) and (B_o, κ) is defined as:

$$s_o = \kappa/\phi_E \tag{13}$$

$$\beta = \begin{cases} \frac{\kappa-1}{B_o} & \text{Beverton-Holt} \\ \frac{\ln(\kappa)}{B_o} & \text{Ricker} \end{cases} \tag{14}$$

where s_o is the maximum juvenile survival rate, β is the density effect on recruitment, and B_o is the unfished spawning stock biomass. Unfished steady-state spawning stock biomass per recruit is given by ϕ_E, which is the sum of products between age-specific survivorship and relative fecundity. In cases where the natural mortality rate is allowed to vary over time, the calculation of ϕ_E, and the corresponding unfished spawning stock biomass (B_o) is based on the average natural mortality rate over the entire time period. This subtle calculation has implications for reference point calculations in cases where there are increasing or decreasing trends in natural mortality rates over time; as estimates of natural mortality rates trend upwards, estimates of B_o decrease.

For the Strait of Georgia Pacific herring example, only the Beverton-Holt recruitment model was considered. The description of the Ricker model is included here for the sake of completely documenting the features in the ${}^{i}\mathrm{SCA_M}$ platform.

A.3 Parameter Estimation and Uncertainty

Parameter estimation and quantifying uncertainty was carried out using the tools available in AD Model Builder (ADMB Project, 2009). AD Model Builder (ADMB) is a software for creating computer programs to estimate the parameters and associated probability distributions for nonlinear statistical models. The software is freely available from `http://admb-project.org/`. This software was used to develop ${}^{i}\mathrm{SCA_M}$, and the source code and documentation for ${}^{i}\mathrm{SCA_M}$ is freely available from `https://sites.google.com/site/iscamproject/`, or from a subversion repository at `http://code.google.com/p/iscam-project/`.

Suffice it to say that there is a lot more going on in the ${}^{i}\mathrm{SCA_M}$ software than just minimizing the sum of the four negative loglikelihood functions defined in the previous section. There are actually five distinct components that make up the objective function that ADMB is minimizing:

$$f = \text{negative loglikelihoods} + \text{constraints} + \text{priors for parameters} + \text{survey priors} + \text{convergence penalties.}$$

The purpose of this section is to completely document all of the components that make up the objective function. Such transparency is absolutely necessary to better understand estimation performance, as well as, to ensure the results are repeatable.

A.3.1 Negative loglikelihoods

The negative loglikelihoods pertain specifically elements that deal with the data and variance partitioning and have already been described in detail in section A.2. There are four specific elements that make up the vector of negative loglikelihoods:

$$\vec{\ell} = \ell_C, \ell_I, \ell_A, \ell_\delta. \tag{15}$$

To reiterate, these are the likelihood of the catch data ℓ_C, likelihood of the survey data ℓ_I, the likelihood of the age-composition data ℓ_A and the likelihood of the stock-recruitment residuals ℓ_δ. Each of these elements are expressed in negative log-space, and ADMB attempts to estimate model parameters by minimizing the sum of these elements.

A.3.2 Constraints

There are two specific constraints that are described here: 1) parameter bounds, and 2) constraints to ensure that a parameter vector sums to 0. In ${}^{i}\mathrm{SCA_M}$ the user must specify the lower and upper bounds for the leading parameters defined in the control file $(\ln(R_o), h, \ln(M), \ln(\bar{R}), \rho, \vartheta)$. All estimated selectivity parameters

$\vec{\gamma}_k$ are estimated in log space and have a minimum and maximum values of -5.0 and 5.0, respectively. These values are hard-wired into the code, but should be sufficiently large/small enough to capture a wide range of selectivities. Estimated fishing mortality rates are also constrained (in log space) to have a minimum value of -30, and a maximum value of 3.0. Log annual recruitment deviations are also constrained to have minimum and maximum values of -15.0 and 15.0 and there is an additional constraint to ensure the vector of deviations sums to 0. This is necessary in order to be able to estimate the average recruitment $\bar{R}$. Finally, the annual log deviations in natural mortality rates are constrained to lie between -2.0 and 2.0.

An array of selectivity parameters (i.e., `init_bounded_matrix_vector`) is estimated within ^{i}SCA$_{\text{M}}$ where each matrix corresponds to a specific gear type, and the number of rows and columns of each depends on the type of selectivity function assumed for the gear and if that selectivity changes over time. In cases where the nodes of a spline are estimated these nodes also have an additional constraint to sum to 0. This is effectively implemented by adding to the objective function:

$$1000\left(\frac{1}{N_{\vec{\lambda}_k}}\sum\vec{\lambda}_k\right)^2.$$

This additional constraint is necessary to ensure the model remains separable and the annual fishing mortality rates are less confounded with selectivity parameters.

A.3.3 Priors for parameters

Each of the six leading parameters specified in the control file ($\ln(R_o), h, \ln(M), \ln(\bar{R}), \rho, \vartheta$) are declared as bounded parameters and in addition the user can also specify an informative prior distribution for each of these parameters. Five distinct prior distributions can be implemented: uniform, normal, lognormal, beta and a gamma distribution. For the Strait of Georgia herring, a bounded uniform prior was specified for the log of unfished recruitment U(-5.0,15), a non-informative beta prior was assumed for steepness Beta(1.01,1.01), a normal prior was specified for the log of natural mortality rate N(-1.0966,0.05), a bounded uniform prior for the log of average recruitment U(-5.0,15.0), a beta prior for the variance partitioning parameter ρ Beta(15,60), and a gamma prior for the precision parameter ϑ, Gamma(156.25,125.0). An example of these prior distributions based on the parameter specified above is show in Figure 20.

In addition to the priors specified for the six leading parameter, there are several other informative distributions that are invoked for the non-parametric selectivity parameters. In cases were age-specific selectivity coefficients are estimated, or nodes of a spline function are estimated, two additional penalties are added to the objective function to control how smooth the selectivity changes (2) and how much dome-shape is allowed in the nonparametric selectivities (3).

A.3.4 Survey priors

The scaling parameter q for each of the surveys is not estimated; rather, the maximum likelihood estimate for q conditional on all other parameters is used to scale the predicted spawning biomass to the observed spawn survey index. In the case of Pacific herring, the relationship between fecundity and mature female biomass is relatively invariant at about 227 eggs per gram (Hardwick, 1973). This relationship has been used to convert total egg deposition from the spawn survey to total female spawning biomass, and assuming all spawning was accounted for, then a reasonable estimate for q should be 1.0.

In the Strait of Georgia herring assessment, we specified an informative normal prior on $\ln(q)$ with a mean of 0, and a a standard deviation of 0.05 for the contemporary data. For the pre-1988 spawn survey data, we explored three alternative priors including a non-informative prior, and a normal prior with a mean 0 and standard deviations of 0.05, or 0.1. The informative prior for the contemporary data implies a 95% confidence interval of 0.82 to 1.22 for q.

A.3.5 Convergence penalties

For the Strait of Georgia herring assessment, there are well over 200 estimated parameters, the exact number depends on the model configuration. Needless to say, non-linear parameter estimation is often very sensitive to the initial starting conditions, and the end results may differ depending on the initial values of the

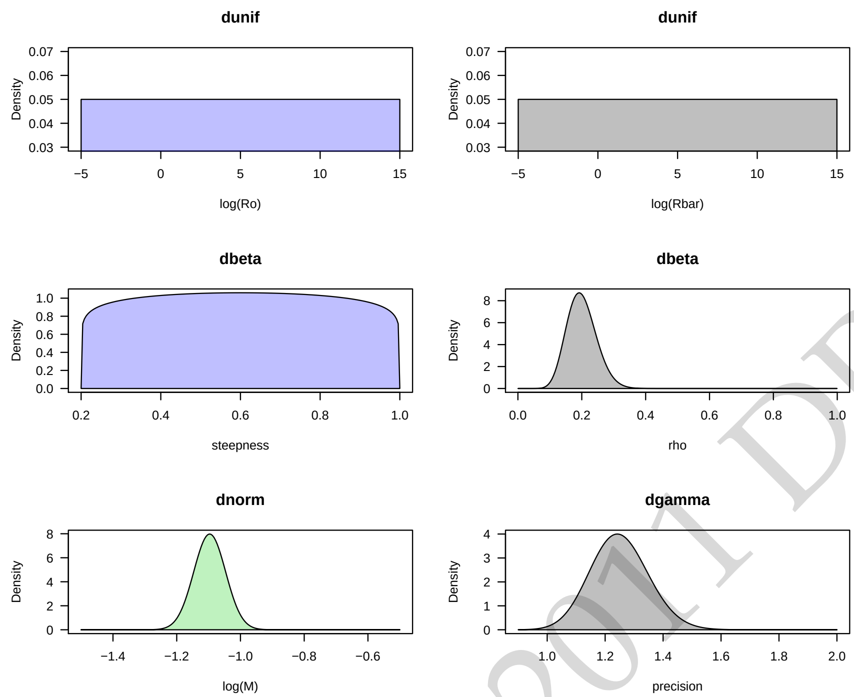


Figure 20: An example of the prior distributions used for $\ln(R_o), h, \ln(M), \ln(\bar{R}), \rho, \vartheta$. The actual values used for the SOG herring assessment can be found in the control file in the appendix.

model parameters or even the phase at which parameters are included into the estimation problem. There is no guarantee that the algorithm will converge to the global minimum every time. AD Model Builder is unique in that the estimation process can be conducted in a series of phases where more and more parameters are 'freed up' as the model progress through each phase. Furthermore, the actual objective function can change between phases such that during the initial phases large penalties can be used to, as Dave Fournier would say, "regularize the solution". For example, in the initial phases of parameter estimation ^{i}SCA$_\mathrm{M}$ uses fairly steep quadratic penalties for the annual recruitment deviations and average fishing mortality rates to initially aid in finding reasonable values of the average recruitment, natural mortality and selectivity parameters. In the final phase, these quadratic penalties are relaxed.

In the case of the annual recruitment deviations, the quadratic penalty term is:

$$100 \sum_{t=1-A}^{T} \omega_t^2,$$

which is approximately a normal density with a standard deviation equal to 0.07. In the last phase this constraint is relaxed with a large standard deviation of 5.0.

A similar penalty (a normal distribution for the log mean fishing rate) is also invoked for the mean fishing mortality rate, but in this case the user specifies the mean fishing mortality rate and the standard deviations in the initial phases and the last phase. Normally, a rather small standard deviation is used in the initial phases (e.g., 0.01) and this is then relaxed to a much larger value (e.g., 5.0) in the last phase. These standard deviations are specified by the user in the control file.

B Data and Control files

B.1 Haida Gwaii

```
 #NB The data herein were taken from qci2010_final.dat for the HCAM model.
## _______________________
## ____Model Dimensions____
1951        #first year of data
2010        #last year of data
2           #age of youngest age class
10          #age of plus group
5           #number of gears (ngear)
## flags for fishery (1) or survey (0) in ngears
#1  1   1   0   0
0.100 0.405 0.495 0.0 0.0
## _______________________
## _______________________
#Age-schedule and population parameters
#natural mortality rate (m)
0.334
#growth parameters (linf,k,to)  (from fishbase)
27.0, 0.48, 0
#length-weight allometry (a,b)
4.5e-6, 3.1270
#maturity at age (am=log(3)/k) & gm=std for logistic
2.055, 0.05
## _______________________
#Time series data
#Observed catch (1951-2010, 1000s metric t)
#Year P1 P2 P3 S1 S2
1951  2.847  0.000 0.000 0 0
1952 10.147  0.000 0.000 0 0
1953  0.000  0.000 0.000 0 0
1954  1.786  0.000 0.000 0 0
1955  1.234  0.000 0.000 0 0
1956 77.681  0.000 0.000 0 0
1957 23.711  0.000 0.000 0 0
1958 11.166  0.000 0.000 0 0
1959  7.027  0.000 0.000 0 0
1960  0.000  0.000 0.000 0 0
1961  0.653  0.000 0.000 0 0
1962  7.632  0.000 0.000 0 0
1963 14.980  0.000 0.000 0 0
1964 28.777  0.000 0.000 0 0
1965 35.448  0.000 0.000 0 0
1966  2.746  0.000 0.000 0 0
1967  0.213  0.000 0.000 0 0
1968  0.080  0.000 0.000 0 0
1969  0.000  0.000 0.000 0 0
1970  0.000  0.000 0.000 0 0
1971  0.102  0.000 0.000 0 0
1972  0.849  3.124 0.000 0 0
1973  0.000  7.520 0.000 0 0
1974  0.000  6.191 0.127 0 0
1975  0.000  7.619 0.105 0 0
1976  0.374 11.939 1.802 0 0
1977  0.000 11.146 1.489 0 0
1978  0.000  9.172 2.553 0 0
1979  0.000  5.867 2.086 0 0
1980  0.000  2.106 1.210 0 0
1981  0.000  3.926 1.705 0 0
1982  0.000  2.371 1.407 0 0
1983  0.067  4.661 0.929 0 0
1984  0.096  4.016 0.535 0 0
1985  0.000  4.616 1.493 0 0
1986  0.000  2.613 0.890 0 0
1987  0.000  2.061 0.000 0 0
1988  0.000  0.032 0.000 0 0
1989  0.000  1.461 0.000 0 0
1990  0.000  5.542 1.170 0 0
1991  0.000  3.899 0.543 0 0
1992  0.000  2.524 0.000 0 0
1993  0.000  2.699 0.000 0 0
1994  0.000  0.299 0.000 0 0
1995  0.000  0.000 0.000 0 0
1996  0.000  0.000 0.000 0 0
1997  0.000  0.000 0.000 0 0
1998  0.000  1.372 0.000 0 0
1999  0.000  2.500 0.473 0 0
2000  0.000  1.764 0.000 0 0
2001  0.000  0.000 0.000 0 0
2002  0.000  0.706 0.000 0 0
2003  0.000  0.000 0.000 0 0
2004  0.000  0.000 0.000 0 0
2005  0.000  0.000 0.000 0 0
2006  0.000  0.000 0.000 0 0
2007  0.000  0.000 0.000 0 0
2008  0.000  0.000 0.000 0 0
2009  0.000  0.000 0.000 0 0
2010  0.000  0.000 0.000 0 0
#Relative Abundance index from fisheries independent survey (it) 1970-2008
#nit
#60
2
#nit_nobs
37      23
#survey type
## 1 = survey is proportional to vulnerable numbers
## 2 = survey is proportional to vulnerable biomass
## 3 = survey is proportional to spawning biomass (e.g., herring spawn survey)
3   3
#iyr     it gear wt     survey timing
1951  4.213    4  1  1
```

```
1952  2.578    4  1  1
1953  7.555    4  1  1
1954 12.408    4  1  1
1955  6.437    4  1  1
1956  6.042    4  1  1
1957  1.592    4  1  1
1958  0.815    4  1  1
1959  8.981    4  1  1
1960  6.599    4  1  1
1961  8.981    4  1  1
1962  5.730    4  1  1
1963  7.297    4  1  1
1964  4.104    4  1  1
1965  1.378    4  1  1
1966  2.824    4  1  1
1967  0.710    4  1  1
1968  0.833    4  1  1
1969  2.075    4  1  1
1970  5.552    4  1  1
1971 13.291    4  1  1
1972  9.542    4  1  1
1973  7.960    4  1  1
1974 14.510    4  1  1
1975  9.686    4  1  1
1976 16.374    4  1  1
1977 16.408    4  1  1
1978 18.371    4  1  1
1979 13.649    4  1  1
1980 31.904    4  1  1
1981 20.294    4  1  1
1982 23.593    4  1  1
1983 21.391    4  1  1
1984 23.439    4  1  1
1985 18.625    4  1  1
1986  6.847    4  1  1
1987 12.289    4  1  1
1988 15.245    5  1.1666  1
1989 25.201    5  1.1666  1
1990 27.058    5  1.1666  1
1991 17.998    5  1.1666  1
1992 12.376    5  1.1666  1
1993  8.152    5  1.1666  1
1994 14.293    5  1.1666  1
1995  4.701    5  1.1666  1
1996  7.377    5  1.1666  1
1997 11.215    5  1.1666  1
1998 21.649    5  1.1666  1
1999 10.610    5  1.1666  1
2000  6.698    5  1.1666  1
2001 15.195    5  1.1666  1
2002  3.257    5  1.1666  1
2003  8.801    5  1.1666  1
2004  5.668    5  1.1666  1
2005  3.614    5  1.1666  1
2006  4.097    5  1.1666  1
2007  9.436    5  1.1666  1
2008  4.213    5  1.1666  1
2009  8.935    5  1.1666  1
2010  6.091    5  1.1666  1
#Age composition data by year, gear (ages 2-15+)
#na_gears
3
#na_nobs
10  39  15
#a_sage
2   2   2
#a_page
10  10  10
#yr gear        V2   V3   V4   V5   V6   V7   V8 V9 V10  #Number aged.
1951  1    1  226  781  226  170   62    9   1   0
1952  1  381  485  760  479   92   25    2   0   0
1956  1    2  216  130  838  113   37   10   0   0
1957  1  901 1116  718  423 1167  111   21   5   0
1958  1 2259  462   35    5    4    4    0   0   0
1959  1    1   60   27    7    0    0    0   0   0
1962  1    7  106  120   16   20    2    1   0   0
1963  1    3  402  218  146   17   16    0   1   1
1964  1    5   78  294   81   26    6    0   0   0
1965  1   17  833  105   41   15    6    2   0   0
1972  2   36  386  454  190   72   29   11   5   1
1973  2    3  700  372  471  138   29   13   0   0
1974  2    2  471  593  255  125   25    5   1   0
1975  2   38 1521 2056 1677  573  117   22   6   0
1976  2   18  114 1495 1186  940  260   39   3   0
1977  2    3  625  258  944  728  466  141  13   0
1978  2    2  308  202  112  311  165   58  11   2
1979  2   57   45  298  167  186  130   28   4   0
1980  2   70 3361  168  179  100   62   46  26   3
1981  2   34  234 5380  322  177  111   45  18  11
1982  2   30  165  158 2973   87   54   35  19   1
1983  2   96  103   69  135 1434   77   31  18   4
1984  2   94 1268  158  100  352 1455   39  12   6
1985  2   47  531 1132  144  160  404 1119  16   1
1986  2   10  134 1041 1902  191  155  380 905  15
1987  2   57  342  192  799 1239  126  142 190 190
1988  2   61  855  126   80  197  249   23  28  32
1989  2   81  622 2364  143   56  139   99  22  15
1990  2   11  487  918 3033  199   93  193  86  14
1991  2  227  140  361  972 1303  125   61 135  51
```

```
1992  2    23 1243   159   270   402   992    77   19   27
1993  2    12  128  2240   165   225   448   436   43    9
1994  2    75   52    61   590   129   133   132   39    5
1995  2    68   75    11    21   178    46    38   25   11
1996  2   103  515    89    31    32   149    23   11    2
1997  2   372  430   549    86    25    73    88   14    3
1998  2    10 1470   758   315    73    18    33   30    7
1999  2   108   58  1610   433   204    64    16   10    9
2000  2   107  398    84  1270   171    97     9   10    3
2001  2   175  363   256    58   240    35    16    3    1
2002  2   602  750   706   369    86   371    42   13    3
2003  2     2 1685   453   159    80    28    52   10    3
2004  2   248   20   428    74    34    22    12    5    2
2005  2    17  606   205   374    51    31    16    6    3
2006  2   136   72   305    67   108    20     3    0    2
2007  2     6  247    78   114    32    56    12    1    0
2008  2    86   68   583    70    79    17    15    0    2
2009  2     1  645    76   222    20    29     4    5    1
2010  2    39   70   644    62   170    18    13    3    2
1974  3     0    9    76    40    26     5     0    0    1
1975  3     0    0     9    16    12     2     1    0    0
1976  3     0    0     1    29    81    19     3    0    0
1978  3     0    0     6    17    29    56    29    6    1
1979  3     0    0    48    44    46    26     6    0    0
1980  3     0   29    27   229   104    93    27    9    0
1981  3     0    2   583    61    77    44    19    4    0
1982  3     0    1    16   425    16    11     5    2    0
1983  3     0    0     7    14   532    16    14    3    3
1984  3     0   11     5    18    35   313     7    1    1
1985  3     0   20    59     7    11    30   113    1    0
1986  3     0    0    41   172    13    17    29   49    1
1990  3     0    2    32   174    39    33    68   33    2
1991  3     0    0     8    79   153    34    25   36   16
1999  3     0    4   185   137   175    60    16    8   11
#n_wt_obs
60
#Mean weight-at-age in kilograms (interpolated: from HCAM.rep)
#A$yr     V1      V2      V3      V4      V5      V6      V7      V8      V9
1951 0.0417 0.0897 0.1126 0.1376 0.1586 0.1706 0.2001 0.1865 0.1865
1952 0.0432 0.0896 0.1133 0.1385 0.1599 0.1756 0.1677 0.1780 0.1865
1953 0.0329 0.0763 0.0958 0.1255 0.1498 0.1599 0.1335 0.1784 0.1865
1954 0.0447 0.0847 0.1036 0.1278 0.1571 0.1721 0.1751 0.1860 0.1865
1955 0.0499 0.0893 0.1043 0.1262 0.1448 0.1738 0.1720 0.1784 0.1865
1956 0.0471 0.0845 0.1060 0.1205 0.1410 0.1587 0.1785 0.1733 0.1865
1957 0.0481 0.0828 0.1089 0.1371 0.1506 0.1640 0.2100 0.1784 0.1865
1958 0.0438 0.0763 0.1081 0.1421 0.1535 0.1647 0.1762 0.1885 0.1865
1959 0.0502 0.0836 0.0993 0.1314 0.1596 0.1677 0.1523 0.1580 0.1865
1960 0.0530 0.0902 0.1125 0.1279 0.1597 0.1290 0.1770 0.1784 0.1865
1961 0.0576 0.0786 0.1111 0.1170 0.1372 0.1650 0.1720 0.1784 0.1865
1962 0.0501 0.0880 0.0993 0.1366 0.1449 0.1530 0.2020 0.1784 0.1865
1963 0.0477 0.0832 0.1049 0.1116 0.1494 0.1778 0.1790 0.1784 0.1865
1964 0.0576 0.0993 0.1159 0.1378 0.1586 0.1850 0.1400 0.1784 0.1865
1965 0.0611 0.1051 0.1224 0.1451 0.1452 0.1770 0.1440 0.1784 0.1865
1966 0.0520 0.1067 0.1487 0.1681 0.1783 0.1888 0.1720 0.1784 0.1865
1967 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1968 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1969 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1970 0.0578 0.0888 0.1175 0.1399 0.1608 0.1733 0.1871 0.1927 0.2096
1971 0.0553 0.1056 0.1319 0.1537 0.1742 0.1895 0.1690 0.1927 0.2096
1972 0.0586 0.0897 0.1290 0.1478 0.1671 0.1778 0.1973 0.1850 0.2096
1973 0.0525 0.0993 0.1274 0.1588 0.1749 0.1928 0.1977 0.2010 0.2096
1974 0.0630 0.0877 0.1392 0.1653 0.2093 0.1733 0.2420 0.1927 0.2096
1975 0.0421 0.0828 0.1115 0.1423 0.1694 0.1934 0.1995 0.2122 0.2096
1976 0.0498 0.0849 0.1234 0.1455 0.1743 0.1914 0.2033 0.2248 0.2133
1977 0.0571 0.0888 0.1173 0.1389 0.1616 0.1910 0.2010 0.2027 0.2418
1978 0.0501 0.0853 0.1099 0.1321 0.1513 0.1672 0.1683 0.1999 0.2095
1979 0.0597 0.0848 0.1178 0.1405 0.1604 0.1754 0.1990 0.2051 0.2174
1980 0.0522 0.0780 0.1083 0.1352 0.1584 0.1718 0.1831 0.1984 0.2172
1981 0.0602 0.0857 0.1085 0.1348 0.1561 0.1706 0.1873 0.1802 0.2022
1982 0.0635 0.0945 0.1153 0.1292 0.1531 0.1618 0.1696 0.1688 0.1950
1983 0.0576 0.0898 0.1174 0.1349 0.1431 0.1580 0.1707 0.1851 0.1941
1984 0.0624 0.0881 0.1146 0.1388 0.1569 0.1590 0.1666 0.1762 0.2010
1985 0.0647 0.0867 0.1141 0.1345 0.1564 0.1703 0.1869 0.1926 0.2320
1986 0.0670 0.0895 0.1108 0.1324 0.1495 0.1700 0.1971 0.1954 0.2096
1987 0.0628 0.0874 0.1056 0.1226 0.1366 0.1522 0.1660 0.1550 0.1823
1988 0.0609 0.0900 0.1138 0.1302 0.1423 0.1547 0.1642 0.2006 0.2096
1989 0.0644 0.0841 0.1068 0.1273 0.1390 0.1474 0.1561 0.1580 0.1820
1990 0.0604 0.0851 0.1060 0.1283 0.1468 0.1572 0.1609 0.1453 0.2260
1991 0.0642 0.0894 0.1101 0.1280 0.1426 0.1553 0.1634 0.1508 0.1850
1992 0.0598 0.0905 0.1118 0.1319 0.1494 0.1592 0.1738 0.1739 0.1563
1993 0.0579 0.0922 0.1118 0.1286 0.1411 0.1529 0.1565 0.1600 0.1475
1994 0.0522 0.0809 0.1047 0.1207 0.1350 0.1405 0.1512 0.1609 0.1563
1995 0.0612 0.0856 0.1106 0.1314 0.1446 0.1617 0.1631 0.1791 0.1753
1996 0.0619 0.0829 0.1061 0.1264 0.1457 0.1557 0.1719 0.1694 0.1830
1997 0.0497 0.0826 0.1017 0.1197 0.1368 0.1463 0.1541 0.1670 0.1817
1998 0.0504 0.0725 0.0939 0.1086 0.1194 0.1331 0.1438 0.1559 0.1485
1999 0.0460 0.0795 0.0991 0.1134 0.1255 0.1341 0.1434 0.1508 0.1390
2000 0.0523 0.0724 0.0948 0.1110 0.1291 0.1387 0.1530 0.1599 0.1630
2001 0.0622 0.0853 0.0990 0.1197 0.1332 0.1483 0.1552 0.1454 0.1440
2002 0.0494 0.0793 0.0959 0.1076 0.1254 0.1324 0.1413 0.1640 0.0590
2003 0.0518 0.0772 0.0930 0.1050 0.1113 0.1282 0.1401 0.1280 0.1563
2004 0.0498 0.0729 0.0888 0.0993 0.1091 0.1125 0.1241 0.1219 0.1320
2005 0.0476 0.0741 0.0910 0.1064 0.1175 0.1257 0.1305 0.1215 0.1373
2006 0.0483 0.0714 0.0882 0.1023 0.1113 0.1208 0.1279 0.1394 0.1780
2007 0.0620 0.0753 0.0831 0.0994 0.1154 0.1230 0.1301 0.1432 0.1340
2008 0.0257 0.0658 0.0858 0.0936 0.1030 0.1105 0.1155 0.1331 0.1350
2009 0.0453 0.0644 0.0688 0.1033 0.1156 0.1251 0.1347 0.1542 0.1780
2010 0.0435 0.0580 0.0790 0.0850 0.1118 0.1189 0.1158 0.1119 0.1413
#eof
999
```

```
 ## ____________________________________________________________________________ ##
##                              SOG HERRING CONTROLS
## __________________CONTROLS FOR ESTIMATED PARAMETERS________________________ ##
##  Prior descriptions:
##                    -0 uniform (0,0)
##                    -1 normal (p1=mu,p2=sig)
##                    -2 lognormal (p1=log(mu),p2=sig)
##                    -3 beta (p1=alpha,p2=beta)
##                    -4 gamma(p1=alpha,p2=beta)
## ____________________________________________________________________________ ##
7   ## npar
##  ival        lb      ub      phz     prior   p1      p2      parameter name
## ____________________________________________________________________________ ##
    7.60        -5.0    15        4       0     -5.0    15        #log_ro
    0.67        0.2     1.0       4       3     10.0    4.925373  #steepness
    -0.7985077  -5.0    5.0       3       1     -0.7985077 0.4    #log.m
    7.40        -5.0    15        1       0     -5.0    15        #log_avgrec
    7.20        -5.0    15        1       0     -5.0    15        #log_recinit
    0.3043478   0.001   0.999    -3       3     15.0    60.0      #rho
    0.8695652   0.01    5.0      -3       4     156.25  125.0     #kappa (precision)
## ____________________________________________________________________________ ##

## ____________________________________________________________________________ ##
## ________________________SELECTIVITY PARAMETERS_____________________________ ##
## OPTIONS FOR SELECTIVITY:
##      1) logistic selectivity parameters
##      2) selectivity coefficients
##      3) a constant cubic spline with age-nodes
##      4) a time varying cubic spline with age-nodes
##      5) a time varying bicubic spline with age & year nodes.
##      6) fixed logistic (set isel_type=6, and estimation phase to -1)
##      7) logistic function of body weight.
##      sig=0.05 0.10 0.15 0.20 0.30 0.40 0.50
##      wt =200. 50.0 22.2 12.5 5.56 3.12 2.00
## Gear 1:3 fishery:  Gear 4-5 survey
## isel_type
   1        1          7       6       6
## Age at 50% selectivity (logistic)
   2.0      3.0        0.6     2.055   2.055
## STD at 50% selectivity (logistic)
   0.25      0.25      0.15    0.05    0.05
## No. of age nodes for each gear (0 to ignore).
   5        5          5       0       0
## No. of year nodes for each gear (0 to ignore).
   12       3          10      0       0
## Estimation phase
   2        2           2      -1      -1
## Penalty weight for 2nd differences w=1/(2*sig^2)
   125.     125.       12.5    12.5    12.5
## Penalty weight for dome-shaped selectivity 1=1/(2*sig^2)
   50.0     50.0      200.0   200.0   200.0
## ____________________________________________________________________________ ##

## ____________________________________________________________________________ ##
##                            Priors for Survey q                              ##
## ____________________________________________________________________________ ##
## nits  #number of surveys
   2
## priors 0=uniform density     1=normal density
   0       1
## prior log(mean)
   0       0 #-0.662
## prior sd
   1.0     0.1 #0.226
## ____________________________________________________________________________ ##

## _______________________OTHER MISCELLANEOUS CONTROLS_________________________ ##
0           ## 1  verbose ADMB output (0=off, 1=on)
1           ## 2  recruitment model (1=beverton-holt, 2=ricker)
0.100       ## 3  std in observed catches in first phase.
0.0707      ## 4  std in observed catches in last phase.
0           ## 5  Assume unfished in first year (0=FALSE, 1=TRUE)
0.05        ## 6  Minimum proportion to consider in age-proportions for dmvlogistic
0.20        ## 7  Mean fishing mortality for regularizing the estimates of Ft
0.01        ## 8  std in mean fishing mortality in first phase
2.00        ## 9  std in mean fishing mortality in last phase
3           ## 10 phase for estimating m_deviations (use -1 to turn off mdevs)
0.1         ## 11 std in deviations for natural mortality
12 ## 12 number of estimated nodes for deviations in natural mortality
1.00        ## 13 fraction of total mortality that takes place prior to spawning
1           ## 14 switch for age-composition likelihood (1=dmvlogistic,2=dmultinom)
## ____________________________________________________________________________ ##


## eofc
999
```

B.2 Prince Rupert District

```
 #NB The data herein were taken from qci2010_final.dat for the HCAM model.
## ________________________
## ____Model Dimensions____
1951 #first year of data
2010 #last year of data
2 #age of youngest age class
10 #age of plus group
5 #number of gears (ngear)
## flags for fishery (1) or survey (0) in ngears
#1 1 1 0 0
0.0446192 0.3503630 0.6050178 0.0000000 0.0000000 #Based on last 30 years of catch.
## ________________________
## ________________________
#Age-schedule and population parameters
#natural mortality rate (m)
0.334
#growth parameters (linf,k,to)  (from fishbase)
27.0, 0.48, 0
#length-weight allometry (a,b)
4.5e-6, 3.1270
#maturity at age (am=log(3)/k) & gm=std for logistic
2.055, 0.05
## ________________________
#Time series data
#Observed catch (1951-2010, 1000s metric t)
#Year P1 P2 P3 S1 S2
1951 45.865 0.000 0.000 0 0
1952 52.379 0.000 0.000 0 0
1953  1.865 0.000 0.000 0 0
1954 27.277 0.000 0.000 0 0
1955 17.806 0.000 0.000 0 0
1956 10.182 0.000 0.000 0 0
1957 28.035 0.000 0.000 0 0
1958  4.523 0.000 0.000 0 0
1959 10.224 0.000 0.000 0 0
1960 18.476 0.000 0.000 0 0
1961 42.746 0.000 0.000 0 0
1962 27.660 0.000 0.000 0 0
1963 40.228 0.000 0.000 0 0
1964 29.930 0.000 0.000 0 0
1965 44.211 0.000 0.000 0 0
1966 17.295 0.000 0.000 0 0
1967  7.998 0.000 0.000 0 0
1968  2.068 0.000 0.000 0 0
1969  0.000 0.000 0.000 0 0
1970  1.330 0.000 0.000 0 0
1971  3.500 0.000 0.000 0 0
1972  0.877 3.613 0.004 0 0
1973  0.218 1.388 0.000 0 0
1974  0.182 2.122 1.515 0 0
1975  0.155 1.536 0.011 0 0
1976  0.564 3.466 0.276 0 0
1977  0.792 5.856 1.494 0 0
1978  3.582 1.974 3.031 0 0
1979  1.810 1.271 1.236 0 0
1980  0.738 1.641 1.046 0 0
1981  1.682 1.051 0.356 0 0
1982  1.815 0.170 0.000 0 0
1983  0.000 0.000 0.000 0 0
1984  0.173 1.653 1.880 0 0
1985  0.253 3.018 3.476 0 0
1986  0.375 3.732 4.573 0 0
1987  0.122 2.077 4.071 0 0
1988  0.079 3.550 4.340 0 0
1989  0.071 3.657 4.745 0 0
1990  0.043 2.285 2.361 0 0
1991  0.000 1.366 2.143 0 0
1992  0.142 1.238 3.797 0 0
1993  0.000 2.208 4.112 0 0
1994  0.000 2.363 2.324 0 0
1995  0.000 0.706 1.355 0 0
1996  0.000 0.000 3.086 0 0
1997  0.000 0.000 5.541 0 0
1998  0.000 0.000 3.217 0 0
1999  0.000 0.256 1.859 0 0
2000  0.000 1.239 3.076 0 0
2001  0.000 1.012 1.906 0 0
2002  0.000 2.061 2.432 0 0
2003  0.000 1.451 2.562 0 0
2004  0.000 1.919 2.192 0 0
2005  0.000 1.750 2.050 0 0
2006  0.000 0.957 1.661 0 0
2007  0.000 0.000 0.969 0 0
2008  0.000 0.513 1.148 0 0
2009  0.000 0.713 1.286 0 0
2010  0.000 0.475 1.010 0 0
#Relative Abundance index from fisheries independent survey (it) 1970-2008
#nit
#60
2
#nit_nobs
37 23
#survey type
## 1 = survey is proportional to vulnerable numbers
## 2 = survey is proportional to vulnerable biomass
## 3 = survey is proportional to spawning biomass (e.g., herring spawn survey)
3 3
#iyr     it gear wt survey timing
1951 27.149 4 1 1
1952 24.047 4 1 1
1953 28.468 4 1 1
1954 13.535 4 1 1
1955 14.482 4 1 1
1956 14.533 4 1 1
1957 27.518 4 1 1
1958  9.882 4 1 1
1959 40.961 4 1 1
1960 16.545 4 1 1
1961 12.059 4 1 1
1962 26.329 4 1 1
1963 16.981 4 1 1
1964 26.919 4 1 1
1965  6.055 4 1 1
1966  7.105 4 1 1
1967  3.386 4 1 1
1968  5.197 4 1 1
1969  0.965 4 1 1
1970  8.814 4 1 1
1971  8.480 4 1 1
1972  8.774 4 1 1
1973 10.959 4 1 1
1974  9.244 4 1 1
1975 10.949 4 1 1
1976 15.587 4 1 1
1977 11.589 4 1 1
1978  6.164 4 1 1
1979  9.195 4 1 1
1980 11.937 4 1 1
1981 14.087 4 1 1
1982 17.186 4 1 1
1983 25.247 4 1 1
1984 27.041 4 1 1
1985 41.028 4 1 1
1986 26.638 4 1 1
1987 39.905 4 1 1
1988 35.444 5 1.1666  1
1989 16.379 5 1.1666  1
1990 22.679 5 1.1666  1
1991 25.811 5 1.1666  1
1992 40.145 5 1.1666  1
1993 25.071 5 1.1666  1
1994 16.589 5 1.1666  1
1995 18.516 5 1.1666  1
1996 24.854 5 1.1666  1
1997 25.037 5 1.1666  1
1998 19.420 5 1.1666  1
1999 29.745 5 1.1666  1
2000 19.694 5 1.1666  1
2001 36.684 5 1.1666  1
2002 22.449 5 1.1666  1
2003 34.007 5 1.1666  1
2004 30.493 5 1.1666  1
2005 27.956 5 1.1666  1
2006 10.251 5 1.1666  1
2007 15.562 5 1.1666  1
2008 13.553 5 1.1666  1
2009 12.684 5 1.1666  1
2010 26.988 5 1.1666  1
#Age composition data by year, gear (ages 2-15+)
#na_gears
3
#na_nobs
25 40 33
#a_sage
2 2 2
#a_page
10 10 10
#yr gear    V2   V3   V4   V5  V6  V7  V8 V9 V10  #Number aged.
1951  1  203  852 2739  486  263 124  12   2  1
1952  1  282  522 1994 2679  364  61  18   2  0
1953  1   17  541  327  361  158  14   1   0  0
1954  1   56  753  772  638  351  69  16   1  0
1955  1   31   55  795  177   59  12   2   0  0
1956  1  169  978  160  319   43   9   3   2  0
1957  1  401  610 1482  597  558  45  12   1  0
1958  1  339  256   64   82   13  17   0   0  0
1959  1   54  973  539  144  157  34  35   3  0
1960  1 1903  252  972  286  119  71  16   7  0
1961  1  400 2348  276  649  155  54  16   5  0
1962  1   30  153  190   38   58  17   3   5  1
1963  1 1326  434  550  673  100  89  13   2  0
1964  1  109 2174  339  371  300  23  20   4  1
1965  1  184  412 1603  336  350 312  58  14  4
1976  1    0    8   11   16   27  29  57  14  0
1978  1   11   80  265  188  191 145  64  22 12
1979  1   22  125  140  348  234 216 113  75 31
1980  1   13  708   76   90   90  62  48  23  9
1981  1   69  459 3366  586  604 562 266 145 68
1982  1   37  288  485 1005  246 161 124  52 16
1984  1   18  237  103   91   64 107  18   7  5
1985  1   92   48  110  165   69  24  23   5  0
1986  1  198  182  155  451  266 152  95  82 20
1988  1    1   53  159   46   43  46  17  16  4
1971  2   39  309  211   64   34  11   4   1  0
1972  2    0   38  128  460   42  27  17   1  1
1973  2   37  336   47  262  219  31  12   6  0
1974  2    1  113  336   47  104  28   2   1  0
1975  2   41  298  695 1362  355 306  78  20  4
1976  2    0    6   49  226  357  52  17   6  0
1977  2    3  327  125  406  564 240  72  20  6
1978  2   10  100  269   79  163 158  23   7  2
1979  2   27  181  113  290  104 166  53  14  3
1980  2   57 2507  239  164  129 104  45  17  5
1981  2   36  494 3840  170   79  68  20  10  6
1982  2   42  290  114 1024   44  21   6   3  0
1983  2   62  954  813  241 2253 171  52  27  9
```

```
1984  2   17 1138  436  314  448 721  31   9  4
1985  2   18  330 2288  528  268 439 329   8  4
1986  2   99  778  534 2616  611 298 401 313  3
1987  2   42 1904  490  327 1423 281 165 136 59
1988  2   19 1303 1638  251  351 485  82  61 10
1989  2   22  784 1307 1001  178 162 129  23  8
1990  2   33  920 1143 1431 1040 203 168 109 13
1991  2   39 1979  391  519  649 391  68  36 39
1992  2   15 1699 1587  251  228 287 146  26 17
1993  2    5  432 1783 1216  162 177 175  63  4
1994  2   44  325  885 3246 1487 276 248  96 31
1995  2  140  673  297  495 1898 692 107  56 25
1996  2   29 1763  241   76  115 316 140  10  5
1997  2   35  615 1447  216   68 133 128  50  5
1998  2    4  702  465  768   94  30  23  27  2
1999  2   17   95  706  350  425  76  18  15 13
2000  2   77 1111  381 1132  498 646  89  20 10
2001  2   79 1430  875  235  702 315 260  39  4
2002  2  240  867 1553  871  187 442 167  82 10
2003  2   16 2387  538  605  313  92 131  47 20
2004  2   23   50 1700  273  238  98  19  28  2
2005  2   21  856  268 1297  279 166  59  13 10
2006  2   29  327  887  176  460  78  32   9  2
2007  2   27  355  161   78   22  72   9   7  1
2008  2   69  578 2062  448  310  65 135  29  9
2009  2   11  847  703 1723  286 197  45  59  2
2010  2   41 1095  888  377  676 108  54  10 12
1974  3    0    1   41   22   36   3   1   0  0
1977  3    0    3    6   56  152  41  19   4  0
1978  3    0    0   31    9   49  50  10   2  0
1979  3    0    0   24  120   54  66  22   5  0
1980  3    0   13   20   92   52  51  22   9  1
1981  3    0    1  105   44   62  39  12   5  0
1984  3    0    5   10   65  108 290  17   6  4
1985  3    0    2   90   82   87 120 164   2  3
1986  3    0    5   54  713  249 115 101  80  1
1987  3    0   10   55  125 1041 293 163 108 60
1988  3    0    3   46   51  153 318  83  36 13
1989  3    0    0   22  145   65 112 104  16 11
1990  3    0    0   34  116  231  56  63  33  8
1991  3    0    0   39  171  288 287  61  40 28
1992  3    0    3  123   85  219 236 183  37 31
1993  3    0    0   62  302   71 138  99  61  7
1994  3    0    0   24  160  434 110 101  54 15
1995  3    0    1   10  144  295 334  35  16 10
1996  3    0    4   21   29  132 167 135  16  6
1997  3    0    1  123   73   88 128 130  70 15
1998  3    0    7   33  466  222 107 122  76 40
1999  3    0    0   78  119  357  97  33  14 21
2000  3    0    1   17  187  166 342  76   9 10
2001  3    0    3   58   97  337 215 266  55  9
2002  3    0    1   87  243  117 285 161 145 16
2003  3    0    3   40  323  226  92 107  46 32
2004  3    0    1  244  151  412 172  55  53 17
2005  3    0    0    6  350  136 195  44  10  7
2006  3    0    0   17   58  332  90  72   8  0
2007  3    1   11   40  208  108 630 150  65 14
2008  3    0    1  126  102  224 108 519  77 36
2009  3    0    1   20  406  187 144  53  92  9
2010  3    0    0   19   72  492 145  78  31 26
#n_wt_obs
60
#Mean weight-at-age in kilograms (interpolated: from HCAM.rep)
#A$yr     V1      V2      V3      V4      V5      V6      V7      V8      V9
1951 0.0383 0.0737 0.0940 0.1128 0.1229 0.1316 0.1420 0.1380 0.1320
1952 0.0467 0.0838 0.1158 0.1308 0.1496 0.1657 0.1672 0.2215 0.1700
1953 0.0388 0.0803 0.1108 0.1307 0.1433 0.1572 0.1690 0.1871 0.1700
1954 0.0405 0.0724 0.1057 0.1308 0.1453 0.1617 0.1826 0.1930 0.1700
1955 0.0458 0.0808 0.1013 0.1215 0.1429 0.1593 0.1540 0.1871 0.1700
1956 0.0373 0.0764 0.0944 0.1136 0.1405 0.1518 0.1700 0.1990 0.1700
1957 0.0287 0.0752 0.1041 0.1225 0.1368 0.1654 0.1887 0.2000 0.1700
1958 0.0348 0.0758 0.1216 0.1414 0.1393 0.1679 0.1690 0.1871 0.1700
1959 0.0436 0.0857 0.1022 0.1205 0.1494 0.1547 0.1659 0.1480 0.1700
1960 0.0380 0.0674 0.1038 0.1211 0.1396 0.1545 0.1689 0.1700 0.1700
1961 0.0395 0.0740 0.1074 0.1306 0.1443 0.1594 0.1554 0.1930 0.1700
1962 0.0439 0.0791 0.1086 0.1388 0.1641 0.1797 0.1807 0.2020 0.1700
1963 0.0393 0.0662 0.1042 0.1281 0.1545 0.1664 0.1902 0.2250 0.1700
1964 0.0442 0.0724 0.0932 0.1224 0.1333 0.1590 0.1520 0.1560 0.1480
1965 0.0527 0.0983 0.1143 0.1400 0.1566 0.1637 0.1797 0.2001 0.2300
1966 0.0408 0.0774 0.1054 0.1270 0.1442 0.1599 0.1690 0.1871 0.1700
1967 0.0408 0.0774 0.1054 0.1270 0.1442 0.1599 0.1690 0.1871 0.1700
1968 0.0408 0.0774 0.1054 0.1270 0.1442 0.1599 0.1690 0.1871 0.1700
1969 0.0408 0.0774 0.1054 0.1270 0.1442 0.1599 0.1690 0.1871 0.1700
1970 0.0485 0.0831 0.1134 0.1382 0.1571 0.1734 0.1836 0.1913 0.2042
1971 0.0362 0.0688 0.1104 0.1317 0.1445 0.1766 0.1720 0.1020 0.2042
1972 0.0485 0.1004 0.1370 0.1628 0.1991 0.2247 0.2331 0.2490 0.2590
1973 0.0326 0.0826 0.1172 0.1641 0.1791 0.1976 0.2103 0.2158 0.2042
1974 0.0670 0.0863 0.1212 0.1655 0.1845 0.1947 0.2040 0.1750 0.2042
1975 0.0288 0.0658 0.1138 0.1375 0.1648 0.1673 0.1827 0.1786 0.2063
1976 0.0485 0.0887 0.1325 0.1583 0.1734 0.2029 0.2106 0.2270 0.2042
1977 0.0540 0.0862 0.1178 0.1510 0.1688 0.1838 0.1955 0.1956 0.2242
1978 0.0554 0.0984 0.1249 0.1491 0.1701 0.1856 0.2022 0.2323 0.2304
1979 0.0566 0.0966 0.1289 0.1483 0.1661 0.1844 0.1911 0.2136 0.2129
1980 0.0609 0.0807 0.1165 0.1471 0.1697 0.1792 0.1879 0.2094 0.2241
1981 0.0452 0.0811 0.0999 0.1306 0.1551 0.1692 0.1827 0.2014 0.2028
1982 0.0421 0.0775 0.1083 0.1162 0.1483 0.1703 0.1778 0.1833 0.1978
1983 0.0556 0.0795 0.1042 0.1222 0.1349 0.1536 0.1697 0.1914 0.1961
1984 0.0457 0.0752 0.0897 0.1112 0.1237 0.1351 0.1568 0.1769 0.1870
1985 0.0356 0.0787 0.0975 0.1095 0.1219 0.1336 0.1490 0.1766 0.1590
1986 0.0555 0.0919 0.1185 0.1369 0.1472 0.1578 0.1685 0.1795 0.1963
1987 0.0549 0.0835 0.1070 0.1283 0.1418 0.1526 0.1596 0.1719 0.1746
1988 0.0507 0.0742 0.0967 0.1165 0.1351 0.1514 0.1519 0.1642 0.1887
1989 0.0565 0.0751 0.0964 0.1156 0.1361 0.1471 0.1659 0.1596 0.1906
1990 0.0504 0.0890 0.1078 0.1222 0.1379 0.1524 0.1655 0.1763 0.1850
1991 0.0548 0.0763 0.1056 0.1205 0.1290 0.1413 0.1483 0.1601 0.1711
1992 0.0470 0.0764 0.0935 0.1201 0.1334 0.1405 0.1486 0.1671 0.1732
1993 0.0538 0.0767 0.0964 0.1093 0.1264 0.1367 0.1417 0.1514 0.1543
1994 0.0425 0.0717 0.0935 0.1061 0.1160 0.1340 0.1375 0.1413 0.1594
1995 0.0480 0.0741 0.0920 0.1123 0.1207 0.1309 0.1487 0.1577 0.1589
1996 0.0524 0.0723 0.0947 0.1111 0.1290 0.1343 0.1429 0.1485 0.1608
1997 0.0565 0.0677 0.0839 0.1039 0.1190 0.1308 0.1377 0.1454 0.1496
1998 0.0448 0.0670 0.0799 0.0924 0.1018 0.1204 0.1303 0.1462 0.1505
1999 0.0579 0.0791 0.0956 0.1040 0.1155 0.1189 0.1363 0.1390 0.1443
2000 0.0465 0.0695 0.0852 0.1042 0.1099 0.1185 0.1303 0.1308 0.1416
2001 0.0424 0.0674 0.0917 0.1051 0.1245 0.1264 0.1368 0.1376 0.1513
2002 0.0466 0.0660 0.0847 0.1047 0.1176 0.1287 0.1334 0.1476 0.1532
2003 0.0505 0.0701 0.0853 0.1096 0.1262 0.1400 0.1457 0.1521 0.1588
2004 0.0500 0.0649 0.0865 0.1003 0.1148 0.1312 0.1432 0.1524 0.1340
2005 0.0382 0.0644 0.0709 0.1000 0.1059 0.1194 0.1376 0.1392 0.1470
2006 0.0479 0.0631 0.0796 0.0908 0.1097 0.1213 0.1309 0.1434 0.1205
2007 0.0399 0.0581 0.0702 0.0902 0.1069 0.1104 0.1196 0.1274 0.1440
2008 0.0442 0.0580 0.0816 0.0947 0.1078 0.1175 0.1316 0.1323 0.1516
2009 0.0322 0.0725 0.0823 0.1017 0.1134 0.1198 0.1292 0.1374 0.1540
2010 0.0449 0.0661 0.0869 0.0985 0.1121 0.1180 0.1266 0.1068 0.1464
#eof
999


 ## ---------------------------------------------------------------------------- ##
##                             SOG HERRING CONTROLS
## __________________CONTROLS FOR ESTIMATED PARAMETERS________________________ ##
##  Prior descriptions:
##                    -0 uniform (0,0)
##                    -1 normal (p1=mu,p2=sig)
##                    -2 lognormal (p1=log(mu),p2=sig)
##                    -3 beta (p1=alpha,p2=beta)
##                    -4 gamma(p1=alpha,p2=beta)
## ---------------------------------------------------------------------------- ##
7   ## npar
##  ival        lb      ub      phz     prior    p1      p2      parameter name
## ---------------------------------------------------------------------------- ##
    7.60        -5.0    15       4       0       -5.0    15        #log_ro
    0.67        0.2     1.0      4       3       10.0    4.925373  #steepness
    -0.7985077  -5.0    5.0      3       1       -0.7985077 0.4    #log.m
    7.40        -5.0    15       1       0       -5.0    15        #log_avgrec
    7.20        -5.0    15       1       0       -5.0    15        #log_recinit
    0.3043478   0.001   0.999   -3       3       15.0    60.0      #rho
    0.8695652   0.01    5.0     -3       4       156.25  125.0     #kappa (precision)
## ---------------------------------------------------------------------------- ##

## ---------------------------------------------------------------------------- ##
## ______________________SELECTIVITY PARAMETERS__________________________________ ##
## OPTIONS FOR SELECTIVITY:
##      1) logistic selectivity parameters
##      2) selectivity coefficients
##      3) a constant cubic spline with age-nodes
##      4) a time varying cubic spline with age-nodes
##      5) a time varying bicubic spline with age & year nodes.
##      6) fixed logistic (set isel_type=6, and estimation phase to -1)
##      7) logistic function of body weight.
##      sig=0.05 0.10 0.15 0.20 0.30 0.40 0.50
##      wt =200. 50.0 22.2 12.5 5.56 3.12 2.00
## Gear 1:3 fishery:  Gear 4-5 survey
## isel_type
   1        1          7       6       6
## Age at 50% selectivity (logistic)
   2.0      3.0        0.6     2.055   2.055
## STD at 50% selectivity (logistic)
   0.25      0.25      0.15    0.05    0.05
## No. of age nodes for each gear (0 to ignore).
   5        5          5       0       0
## No. of year nodes for each gear (0 to ignore).
   12       3          10      0       0
## Estimation phase
   2        2           2      -1      -1
## Penalty weight for 2nd differences w=1/(2*sig^2)
   125.     125.       12.5    12.5    12.5
## Penalty weight for dome-shaped selectivity 1=1/(2*sig^2)
   50.0     50.0      200.0   200.0   200.0
## ---------------------------------------------------------------------------- ##

## ---------------------------------------------------------------------------- ##
##                              Priors for Survey q                             ##
## ---------------------------------------------------------------------------- ##
## nits  #number of surveys
   2
## priors 0=uniform density     1=normal density
   0       1
## prior log(mean)
   0      -0.662
## prior sd
   1.0      0.226
## ---------------------------------------------------------------------------- ##

## ______________________OTHER MISCELLANEOUS CONTROLS__________________________ ##
0           ## 1  verbose ADMB output (0=off, 1=on)
1           ## 2  recruitment model (1=beverton-holt, 2=ricker)
0.100       ## 3  std in observed catches in first phase.
0.0707      ## 4  std in observed catches in last phase.
0           ## 5  Assume unfished in first year (0=FALSE, 1=TRUE)
0.02        ## 6  Minimum proportion to consider in age-proportions for dmvlogistic
0.20        ## 7  Mean fishing mortality for regularizing the estimates of Ft
0.01        ## 8  std in mean fishing mortality in first phase
2.00        ## 9  std in mean fishing mortality in last phase
3           ## 10 phase for estimating m_deviations (use -1 to turn off mdevs)
0.1         ## 11 std in deviations for natural mortality
12 ## 12 number of estimated nodes for deviations in natural mortality
1.00        ## 13 fraction of total mortality that takes place prior to spawning
1           ## 14 switch for age-composition likelihood (1=dmvlogistic,2=dmultinom)
## ---------------------------------------------------------------------------- ##


## eofc
999
```

B.3 Central Coast

```
 #NB The data herein were taken from qci2010_final.dat for the HCAM model.
## ________________________
## ____Model Dimensions____
1951 #first year of data
2010 #last year of data
2 #age of youngest age class
10 #age of plus group
5 #number of gears (ngear)
## flags for fishery (1) or survey (0) in ngears
#1 1 1 0 0
0.004190067 4.493316190 0.794911714 0.000000000 0.000000000
## ________________________
## ________________________
#Age-schedule and population parameters
#natural mortality rate (m)
0.334
#growth parameters (linf,k,to)  (from fishbase)
27.0, 0.48, 0
#length-weight allometry (a,b)
4.5e-6, 3.1270
#maturity at age (am=log(3)/k) & gm=std for logistic
2.055, 0.05
## ________________________
#Time series data
#Observed catch (1951-2010, 1000s metric t)
#Year P1 P2 P3 S1 S2
1951 42.458 0.000 0.000 0 0
1952 33.195 0.000 0.000 0 0
1953  0.768 0.000 0.000 0 0
1954 24.616 0.000 0.000 0 0
1955 11.594 0.000 0.000 0 0
1956 43.627 0.000 0.000 0 0
1957 23.261 0.000 0.000 0 0
1958  9.849 0.000 0.000 0 0
1959 27.870 0.000 0.000 0 0
1960  4.037 0.000 0.000 0 0
1961 31.704 0.000 0.000 0 0
1962 15.709 0.000 0.000 0 0
1963 44.054 0.000 0.000 0 0
1964 31.895 0.000 0.000 0 0
1965 15.670 0.000 0.000 0 0
1966 37.482 0.000 0.000 0 0
1967 21.890 0.000 0.000 0 0
1968  1.528 0.000 0.000 0 0
1969  0.000 0.000 0.000 0 0
1970  0.209 0.000 0.000 0 0
1971  3.614 0.000 0.000 0 0
1972  0.388 8.367 0.137 0 0
1973  0.035 6.653 1.112 0 0
1974  0.000 3.621 5.267 0 0
1975  0.000 3.343 5.395 0 0
1976  0.000 6.198 6.213 0 0
1977  0.320 3.881 6.904 0 0
1978  0.046 4.723 9.277 0 0
1979  0.000 0.005 0.000 0 0
1980  0.010 0.000 0.528 0 0
1981  0.000 0.269 2.304 0 0
1982  0.041 2.258 4.071 0 0
1983  0.000 2.061 3.579 0 0
1984  0.000 3.588 3.582 0 0
1985  0.000 2.915 2.294 0 0
1986  0.038 2.173 1.176 0 0
1987  0.000 2.695 0.920 0 0
1988  0.028 3.529 0.970 0 0
1989  0.000 6.531 2.911 0 0
1990  0.000 5.305 3.046 0 0
1991  0.000 7.097 1.806 0 0
1992  0.088 7.163 1.111 0 0
1993  0.000 8.478 2.038 0 0
1994  0.000 9.757 2.122 0 0
1995  0.000 8.131 1.451 0 0
1996  0.000 3.897 0.402 0 0
1997  0.000 3.276 0.344 0 0
1998  0.000 7.976 0.646 0 0
1999  0.000 6.013 1.511 0 0
2000  0.000 6.394 0.972 0 0
2001  0.000 5.613 0.517 0 0
2002  0.000 2.894 0.399 0 0
2003  0.000 2.299 0.289 0 0
2004  0.000 2.988 0.000 0 0
2005  0.000 3.778 0.000 0 0
2006  0.000 3.072 0.000 0 0
2007  0.000 0.398 0.000 0 0
2008  0.000 0.000 0.000 0 0
2009  0.000 0.000 0.000 0 0
2010  0.000 0.000 0.000 0 0
#Relative Abundance index from fisheries independent survey (it) 1970-2008
#nit
#60
2
#nit_nobs
37 23
#survey type
## 1 = survey is proportional to vulnerable numbers
## 2 = survey is proportional to vulnerable biomass
## 3 = survey is proportional to spawning biomass (e.g., herring spawn survey)
3 3
#iyr     it gear wt survey timing
1951 15.390 4 1 1
1952 10.295 4 1 1
1953 18.237 4 1 1
1954 13.967 4 1 1
1955 13.564 4 1 1
1956  6.626 4 1 1
1957  4.607 4 1 1
1958  3.549 4 1 1
1959  3.904 4 1 1
1960 12.615 4 1 1
1961  4.265 4 1 1
1962 11.948 4 1 1
1963  6.485 4 1 1
1964  6.464 4 1 1
1965  2.097 4 1 1
1966  1.863 4 1 1
1967  5.434 4 1 1
1968  5.790 4 1 1
1969  1.837 4 1 1
1970  8.230 4 1 1
1971  4.156 4 1 1
1972  3.572 4 1 1
1973 12.434 4 1 1
1974  8.852 4 1 1
1975  8.037 4 1 1
1976 13.849 4 1 1
1977 14.613 4 1 1
1978  7.747 4 1 1
1979  5.779 4 1 1
1980 13.012 4 1 1
1981 15.919 4 1 1
1982 16.333 4 1 1
1983 18.482 4 1 1
1984 14.185 4 1 1
1985  8.850 4 1 1
1986 20.342 4 1 1
1987 12.827 4 1 1
1988 26.916 5 1.1666 1
1989 21.561 5 1.1666 1
1990 28.980 5 1.1666 1
1991 19.183 5 1.1666 1
1992 43.274 5 1.1666 1
1993 32.392 5 1.1666 1
1994 29.432 5 1.1666 1
1995 22.348 5 1.1666 1
1996 21.646 5 1.1666 1
1997 28.255 5 1.1666 1
1998 31.503 5 1.1666 1
1999 31.813 5 1.1666 1
2000 32.652 5 1.1666 1
2001 25.109 5 1.1666 1
2002 23.147 5 1.1666 1
2003 25.679 5 1.1666 1
2004 29.407 5 1.1666 1
2005 24.158 5 1.1666 1
2006 12.051 5 1.1666 1
2007  9.857 5 1.1666 1
2008  3.971 5 1.1666 1
2009 10.183 5 1.1666 1
2010  8.075 5 1.1666 1
#Age composition data by year, gear (ages 2-15+)
#na_gears
3
#na_nobs
16 38 30
#a_sage
2 2 2
#a_page
10 10 10
#yr gear    V2   V3   V4   V5  V6   V7   V8 V9 V10  #Number aged.
1951  1 129 1518 2693  638  269   66    3   0   0
1952  1 267 1035 1551 1966  232   79   23   2   0
1953  1 274  822  702  779  297   39   13   0   0
1954  1 126 2198  640  147   41    5    0   2   0
1955  1 156  181 1749  213   36    9    0   0   0
1956  1 852  683  458 2862  145   17    2   0   1
1957  1 758 2357  501  284  688   33    1   0   0
1958  1 880 2272  439   45   20   17    0   0   0
1959  1 189 2430 1831  401   40   22   21   1   0
1960  1 545  309  364   77   16    1    1   0   0
1961  1 450  902  301  826  276   22    3   1   0
1962  1  43  308  117   16   64   13    1   0   0
1963  1   4  324  604   58   30   30    2   0   0
1964  1 164  549  320  118   17    1    0   0   0
1965  1 143  637  591  277   95    6    1   0   0
1971  1 137  377  351   36   40    9    1   1   0
1972  2  75  530  494  448  120   76   19   1   0
1973  2  15  615  228  198  150   25    6   2   0
1974  2  44  278  602  287  187  100   14   3   0
1975  2 103 2932 2269 2477  764  283   60   6   2
1976  2 163  637 2234 1132  912  246   80  13   1
1977  2  18  492  587  818  408  221   51  10   1
1978  2   3  356  212  278  322  151   49  15   5
1980  2 186 2305  214  266  121   76   21  13   1
1981  2 197  759 3325  408  314  146   35  19   6
1982  2  59  548  376 2112  182  160   51  17   0
1983  2  29  381  840  589 3109  274 169  40  11
1984  2 274  460  637 1143 1016 2563 142  52   6
1985  2 149 2052  410  457  698  638 987  24   7
1986  2 240  972 2378  516  384  404 367 697  25
1987  2 256 1169  744 1626  289  230 294 235 275
1988  2  59 3528  606  326  370   87  76  78  44
1989  2  72  260 4300  517  202  158  42  45  36
1990  2  66  383  346 4973  511  258 202  51  28
1991  2 144 1337  480  440 3947  453 166 105  23
1992  2 146 4241  828  199  250 1362 155  44  34
1993  2 252  586 5608  848  177  225 916  98  28
1994  2  85 1538  620 3888  549  148 199 257  22
```

```
1995  2  74  581 2250  894 4604  609 192 220 155
1996  2 667 1114  323  926  388 1698 325  83  43
1997  2 146 3892 1161  249  422  274 583 106  27
1998  2  34 2393 2793  553  155  202 198 192  41
1999  2  39  440 2141 1709  326   81 106  97  55
2000  2  16  865  490 1572 1186  263  53  41  26
2001  2 112  340 1194  517 1173  831 181  38  15
2002  2 269 1851  579  971  338 1124 475  78  13
2003  2  22 2144 1138  365  400  183 317 120  24
2004  2  37  225 2085  542  112  147  75  70  17
2005  2  42 2311 1037 2101  566  125 112  60  30
2006  2  53  702 3246  585  967  199  44  31   3
2007  2  32  700  444  739  190  185  37  10   1
2008  2 144  146  659  184  246   44  43   8   1
2009  2  60 2059  308  238   67   63   8  10   2
2010  2  41  387 1597  133  189   51  52   2   6
1973  3   0    4   28   43   21    2   1   0   0
1974  3   0    2  106  184  116   58   8   0   0
1975  3   0   16   99  171   59   21   9   0   0
1976  3   0   10  230  364  431  144  37   5   1
1977  3   0    5   59  161  143   61  18   6   0
1978  3   0    7   74  277  345  149  30   3   1
1980  3   0    6    1   39   24   21  13   7   0
1981  3   4   22  722  194  213  153  74  27   7
1982  3   0   31   75  944   84   71  28   8   1
1983  3   0    9  124  224 1177   87  67  11   4
1984  3   0    3   34  141  190  655  51  12   6
1985  3   0   43   84  137  303  349 558  18  13
1986  3   0   18  248  126  101  166 134 219   6
1987  3   0    8   76  440  115   77  97  80  84
1988  3   0   23   56   80  144   72  37  51  46
1989  3   0    2  180  159  107   91  33  23  16
1990  3   0    0    8  529  133   50  62   9  12
1991  3   0    3   13   34  377   51  38  19   5
1992  3   0   66   87   61  101  659  98  35  10
1993  3   0    2  342  112   44   45 211  17   8
1994  3   0   30   94 1287  237   69  83 135  12
1995  3   0    3  112  101  823  135  23  29  37
1996  3   0    2    8  102   65  306  59  12   7
1997  3   0    7   15   32  117   99 197  37   7
1998  3   0    5  149  142   90  183 164 217  62
1999  3   0    1  123  382  151   51  44  46  35
2000  3   0    3   14  277  285   71  11   6  14
2001  3   0    0   39   46  422  225  57   9   0
2002  3   0    3   30  105   38  237  83   7   1
2003  3   0    4   33  103  238  104 306 114  20
#n_wt_obs
60
#Mean weight-at-age in kilograms (interpolated: from HCAM.rep)
#A$yr     V1     V2     V3     V4     V5     V6     V7     V8     V9
1951 0.0480 0.0842 0.1138 0.1371 0.1465 0.1559 0.1610 0.1352 0.1800
1952 0.0466 0.0869 0.1121 0.1311 0.1476 0.1578 0.1636 0.1730 0.1800
1953 0.0358 0.0833 0.1078 0.1273 0.1474 0.1616 0.1699 0.1352 0.1800
1954 0.0260 0.0626 0.0937 0.1167 0.1378 0.1330 0.1545 0.1310 0.1800
1955 0.0380 0.0725 0.0966 0.1204 0.1429 0.1347 0.1545 0.1352 0.1800
1956 0.0406 0.0834 0.1107 0.1269 0.1436 0.1581 0.1220 0.1352 0.1800
1957 0.0400 0.0821 0.1082 0.1222 0.1322 0.1487 0.1730 0.1352 0.1800
1958 0.0374 0.0725 0.0956 0.1157 0.1282 0.1465 0.1545 0.1352 0.1800
1959 0.0391 0.0774 0.0938 0.1098 0.1069 0.1316 0.1345 0.1270 0.1800
1960 0.0447 0.0639 0.0810 0.1034 0.1078 0.1470 0.1240 0.1352 0.1800
1961 0.0379 0.0771 0.0985 0.1206 0.1241 0.1317 0.1223 0.1100 0.1800
1962 0.0470 0.0808 0.1074 0.1314 0.1436 0.1554 0.1220 0.1352 0.1800
1963 0.0598 0.0825 0.1035 0.1236 0.1425 0.1543 0.1655 0.1352 0.1800
1964 0.0457 0.0858 0.1080 0.1271 0.1282 0.1540 0.1545 0.1352 0.1800
1965 0.0525 0.1037 0.1271 0.1474 0.1675 0.1757 0.2420 0.1352 0.1800
1966 0.0426 0.0799 0.1039 0.1240 0.1365 0.1497 0.1545 0.1352 0.1800
1967 0.0426 0.0799 0.1039 0.1240 0.1365 0.1497 0.1545 0.1352 0.1800
1968 0.0426 0.0799 0.1039 0.1240 0.1365 0.1497 0.1545 0.1352 0.1800
1969 0.0426 0.0799 0.1039 0.1240 0.1365 0.1497 0.1545 0.1352 0.1800
1970 0.0559 0.0897 0.1165 0.1386 0.1573 0.1713 0.1850 0.1978 0.2077
1971 0.0502 0.0934 0.1275 0.1576 0.1712 0.1819 0.1760 0.1780 0.2077
1972 0.0605 0.0945 0.1172 0.1418 0.1576 0.1654 0.1973 0.1930 0.2077
1973 0.0594 0.0986 0.1312 0.1560 0.1730 0.1834 0.1972 0.2340 0.2077
1974 0.0492 0.0869 0.1209 0.1416 0.1658 0.1788 0.1974 0.2167 0.2077
1975 0.0448 0.0836 0.1187 0.1444 0.1662 0.1862 0.1989 0.2037 0.2205
1976 0.0445 0.0814 0.1081 0.1356 0.1553 0.1754 0.1913 0.2004 0.2100
1977 0.0598 0.0891 0.1164 0.1382 0.1660 0.1839 0.1987 0.2219 0.2250
1978 0.0490 0.0856 0.1142 0.1338 0.1612 0.1864 0.2160 0.2269 0.2442
1979 0.0832 0.1065 0.1286 0.1534 0.1755 0.1913 0.2116 0.2350 0.2077
1980 0.0504 0.0815 0.0998 0.1244 0.1440 0.1614 0.1688 0.1981 0.2120
1981 0.0452 0.0749 0.0990 0.1156 0.1338 0.1500 0.1755 0.1747 0.2040
1982 0.0521 0.0880 0.1094 0.1300 0.1392 0.1519 0.1683 0.1824 0.2077
1983 0.0614 0.0907 0.1107 0.1292 0.1424 0.1493 0.1567 0.1727 0.1855
1984 0.0590 0.0900 0.1082 0.1223 0.1352 0.1419 0.1556 0.1761 0.1782
1985 0.0620 0.0951 0.1234 0.1399 0.1502 0.1653 0.1734 0.1753 0.2029
1986 0.0623 0.0989 0.1268 0.1422 0.1551 0.1667 0.1734 0.1802 0.1992
1987 0.0594 0.0918 0.1221 0.1491 0.1683 0.1790 0.1845 0.1957 0.2077
1988 0.0541 0.0842 0.1143 0.1390 0.1711 0.1844 0.1889 0.1957 0.2031
1989 0.0563 0.0830 0.1032 0.1301 0.1465 0.1728 0.1797 0.1804 0.1936
1990 0.0572 0.0843 0.1065 0.1262 0.1476 0.1685 0.1787 0.1877 0.1916
1991 0.0577 0.0846 0.1062 0.1288 0.1447 0.1650 0.1784 0.1868 0.1992
1992 0.0500 0.0860 0.1055 0.1236 0.1362 0.1511 0.1683 0.1874 0.1932
1993 0.0517 0.0858 0.1052 0.1201 0.1330 0.1404 0.1538 0.1674 0.1716
1994 0.0476 0.0831 0.1066 0.1225 0.1339 0.1481 0.1581 0.1630 0.1750
1995 0.0478 0.0796 0.1057 0.1233 0.1348 0.1438 0.1522 0.1561 0.1624
1996 0.0607 0.0781 0.1025 0.1258 0.1397 0.1476 0.1581 0.1655 0.1617
1997 0.0456 0.0761 0.0888 0.1054 0.1320 0.1432 0.1493 0.1596 0.1607
1998 0.0415 0.0716 0.0874 0.1006 0.1173 0.1404 0.1462 0.1540 0.1629
1999 0.0538 0.0681 0.0902 0.1054 0.1138 0.1292 0.1478 0.1545 0.1582
2000 0.0514 0.0771 0.0881 0.1127 0.1268 0.1377 0.1450 0.1660 0.1756
2001 0.0445 0.0734 0.0974 0.1061 0.1255 0.1358 0.1468 0.1569 0.1631
2002 0.0512 0.0670 0.0878 0.1084 0.1187 0.1295 0.1366 0.1414 0.1507
2003 0.0478 0.0773 0.0885 0.1111 0.1264 0.1371 0.1433 0.1508 0.1629
2004 0.0481 0.0696 0.0912 0.0962 0.1125 0.1248 0.1362 0.1365 0.1461
2005 0.0378 0.0675 0.0752 0.1062 0.1091 0.1259 0.1360 0.1404 0.1521
2006 0.0388 0.0605 0.0786 0.0919 0.1106 0.1147 0.1281 0.1347 0.1447
2007 0.0410 0.0651 0.0750 0.0955 0.1025 0.1184 0.1202 0.1397 0.1430
2008 0.0430 0.0606 0.0757 0.0873 0.1034 0.1153 0.1260 0.1344 0.1670
2009 0.0405 0.0664 0.0727 0.0921 0.1035 0.1219 0.1346 0.1315 0.1350
2010 0.0481 0.0667 0.0841 0.0928 0.1046 0.1034 0.1228 0.1540 0.1320
#eof
999
```

```
 ## ___________________________________________________________________________ ##
##                             SOG HERRING CONTROLS
## __________________CONTROLS FOR ESTIMATED PARAMETERS_________________________ ##
##  Prior descriptions:
##                    -0 uniform (0,0)
##                    -1 normal (p1=mu,p2=sig)
##                    -2 lognormal (p1=log(mu),p2=sig)
##                    -3 beta (p1=alpha,p2=beta)
##                    -4 gamma(p1=alpha,p2=beta)
## ___________________________________________________________________________ ##
7   ## npar
##  ival        lb      ub      phz     prior   p1      p2       parameter name
## ___________________________________________________________________________ ##
    7.60        -5.0    15       4       0      -5.0    15         #log_ro
    0.67        0.2     1.0      4       3      10.0    4.925373   #steepness
    -0.7985077  -5.0    5.0      3       1      -0.7985077 0.4     #log.m
    7.40        -5.0    15       1       0      -5.0    15         #log_avgrec
    7.20        -5.0    15       1       0      -5.0    15         #log_recinit
    0.3043478   0.001   0.999   -3       3      15.0    60.0       #rho
    0.8695652   0.01    5.0     -3       4      156.25  125.0      #kappa (precision)
## ___________________________________________________________________________ ##

## ___________________________________________________________________________ ##
## ______________________SELECTIVITY PARAMETERS_______________________________ ##
## OPTIONS FOR SELECTIVITY:
##      1) logistic selectivity parameters
##      2) selectivity coefficients
##      3) a constant cubic spline with age-nodes
##      4) a time varying cubic spline with age-nodes
##      5) a time varying bicubic spline with age & year nodes.
##      6) fixed logistic (set isel_type=6, and estimation phase to -1)
##      7) logistic function of body weight.
##      sig=0.05 0.10 0.15 0.20 0.30 0.40 0.50
##      wt =200. 50.0 22.2 12.5 5.56 3.12 2.00
## Gear 1:3 fishery:  Gear 4-5 survey
## isel_type
   1        1          7       6       6
## Age at 50% selectivity (logistic)
   2.0      3.0        0.6     2.055   2.055
## STD at 50% selectivity (logistic)
   0.25      0.25      0.15    0.05    0.05
## No. of age nodes for each gear (0 to ignore).
   5        5          5       0       0
## No. of year nodes for each gear (0 to ignore).
   12       3          10      0       0
## Estimation phase
   2        2           2      -1      -1
## Penalty weight for 2nd differences w=1/(2*sig^2)
   125.     125.       12.5    12.5    12.5
## Penalty weight for dome-shaped selectivity 1=1/(2*sig^2)
   50.0     50.0      200.0   200.0   200.0
## ___________________________________________________________________________ ##

## ___________________________________________________________________________ ##
##                            Priors for Survey q                              ##
## ___________________________________________________________________________ ##
## nits  #number of surveys
   2
## priors 0=uniform density     1=normal density
   0       1
## prior log(mean)
   0       -0.662
## prior sd
   1.0      0.226
## ___________________________________________________________________________ ##

## ______________________OTHER MISCELLANEOUS CONTROLS_________________________ ##
0           ## 1  verbose ADMB output (0=off, 1=on)
1           ## 2  recruitment model (1=beverton-holt, 2=ricker)
0.100       ## 3  std in observed catches in first phase.
0.0707      ## 4  std in observed catches in last phase.
0           ## 5  Assume unfished in first year (0=FALSE, 1=TRUE)
0.02        ## 6  Minimum proportion to consider in age-proportions for dmvlogistic
0.20        ## 7  Mean fishing mortality for regularizing the estimates of Ft
0.01        ## 8  std in mean fishing mortality in first phase
2.00        ## 9  std in mean fishing mortality in last phase
3           ## 10 phase for estimating m_deviations (use -1 to turn off mdevs)
0.1         ## 11 std in deviations for natural mortality
12 ## 12 number of estimated nodes for deviations in natural mortality
1.00        ## 13 fraction of total mortality that takes place prior to spawning
1           ## 14 switch for age-composition likelihood (1=dmvlogistic,2=dmultinom)
## ___________________________________________________________________________ ##


## eofc
999
```

B.4 Strait of Geogia

```
 #NB The data herein were taken from sog2010_final.dat for the HCAM model.
## ________________________
## ____Model Dimensions____
1951 #first year of data
2010 #last year of data
2 #age of youngest age class
10 #age of plus group
5 #number of gears (ngear)
## flags for fishery (1) or survey (0) in ngears
#1 1 1 0 0
0.0686819 0.4137555 0.5175626 0.0000000 0.0000000
## ________________________

## ________________________
#Age-schedule and population parameters
#natural mortality rate (m)
0.334
#growth parameters (linf,k,to)  (from fishbase)
27.0, 0.48, 0
#length-weight allometry (a,b)
4.5e-6, 3.1270
#maturity at age (am=log(3)/k) & gm=std for logistic
2.055, 0.05
## ________________________

#Time series data
#Observed catch (1951-2010, 1000s metric t)
#yr p1 p2 p3  survey
1951 43.798  0.000  0.000  0  0
1952 45.846  0.000  0.000  0  0
1953  8.412  0.000  0.000  0  0
1954 65.767  0.000  0.000  0  0
1955 68.641  0.000  0.000  0  0
1956 72.062  0.000  0.000  0  0
1957 59.608  0.000  0.000  0  0
1958 20.628  0.000  0.000  0  0
1959 49.644  0.000  0.381  0  0
1960 68.037  0.000  0.000  0  0
1961 46.215  0.000  0.000  0  0
1962 65.303  0.000  0.000  0  0
1963 68.847  0.000  0.000  0  0
1964 76.881  0.000  0.000  0  0
1965 47.819  0.000  0.000  0  0
1966 33.333  0.000  0.000  0  0
1967 31.043  0.000  0.000  0  0
1968  1.891  0.000  0.000  0  0
1969  0.194  0.000  0.000  0  0
1970  0.221  0.000  0.022  0  0
1971  1.610  0.000  0.084  0  0
1972  2.434  5.921  0.456  0  0
1973  3.980  1.604  2.064  0  0
1974  0.479  0.425  3.095  0  0
1975  0.378  0.469  5.331  0  0
1976  5.061  0.202  6.975  0  0
1977  5.676  4.098  7.736  0  0
1978 12.963  3.723  7.316  0  0
1979 13.513  0.000  6.825  0  0
1980  2.470  0.169  3.180  0  0
1981  4.904  2.081  5.067  0  0
1982  3.937  3.312  5.583  0  0
1983  0.824  7.780  8.613  0  0
1984  0.087  4.126  6.039  0  0
1985  0.772  2.726  3.495  0  0
1986  0.432  0.162  0.000  0  0
1987  0.244  3.111  5.998  0  0
1988  0.756  1.471  5.988  0  0
1989  1.033  1.417  5.919  0  0
1990  0.233  0.000  7.886  0  0
1991  0.562  1.131  9.410  0  0
1992  0.939  3.610  8.870  0  0
1993  0.617  4.391  8.733  0  0
1994  0.942  5.134 11.572  0  0
1995  0.641  4.359  8.190  0  0
1996  0.541  7.338  6.233  0  0
1997  0.402  9.274  6.148  0  0
1998  0.954  5.755  6.895  0  0
1999  1.471  4.976  6.837  0  0
2000  1.156  6.455  7.593  0  0
2001  1.424  7.274  7.682  0  0
2002  1.328  9.299  7.986  0  0
2003  1.696 10.670  8.010  0  0
2004  1.356  7.019  5.226  0  0
2005  1.332  7.928  8.954  0  0
2006  1.371  9.308  7.277  0  0
2007  0.672  3.865  5.285  0  0
2008  1.139  2.752  6.046  0  0
2009  0.709  5.685  3.937  0  0
2010  0.595  4.540  3.244  0  0


#Relative Abundance index from fisheries independent survey (it) 1970-2008
#nit
#60
2
#nit_nobs
37 23
#survey type
## 1 = survey is proportional to vulnerable numbers
## 2 = survey is proportional to vulnerable biomass
## 3 = survey is proportional to spawning biomass (e.g., herring spawn survey)
3 3
#iyr     it gear wt survey timing
 1951  66.143  4  1  1
 1952  72.376  4  1  1
 1953 111.307  4  1  1
 1954  82.141  4  1  1
 1955  69.854  4  1  1
 1956  25.667  4  1  1
 1957  24.126  4  1  1
 1958  16.911  4  1  1
 1959  47.864  4  1  1
 1960  55.709  4  1  1
 1961  44.326  4  1  1
 1962  35.574  4  1  1
 1963  37.381  4  1  1
 1964  35.954  4  1  1
 1965  38.390  4  1  1
 1966   7.211  4  1  1
 1967   9.647  4  1  1
 1968   9.442  4  1  1
 1969  14.039  4  1  1
 1970  34.163  4  1  1
 1971  38.921  4  1  1
 1972  25.139  4  1  1
 1973  16.191  4  1  1
 1974  40.571  4  1  1
 1975  70.211  4  1  1
 1976  60.642  4  1  1
 1977  78.562  4  1  1
 1978 102.115  4  1  1
 1979  64.266  4  1  1
 1980  85.991  4  1  1
 1981  55.121  4  1  1
 1982 100.987  4  1  1
 1983  64.575  4  1  1
 1984  26.227  4  1  1
 1985  25.247  4  1  1
 1986  41.575  4  1  1
 1987  41.737  4  1  1
 1988  24.976  5  1.1666  1
 1989  66.052  5  1.1666  1
 1990  67.152  5  1.1666  1
 1991  45.830  5  1.1666  1
 1992  82.714  5  1.1666  1
 1993  90.198  5  1.1666  1
 1994  67.144  5  1.1666  1
 1995  64.899  5  1.1666  1
 1996  71.326  5  1.1666  1
 1997  58.232  5  1.1666  1
 1998  74.616  5  1.1666  1
 1999  85.095  5  1.1666  1
 2000  72.688  5  1.1666  1
 2001 100.248  5  1.1666  1
 2002 117.864  5  1.1666  1
 2003 141.651  5  1.1666  1
 2004 114.352  5  1.1666  1
 2005  95.643  5  1.1666  1
 2006  46.752  5  1.1666  1
 2007  35.865  5  1.1666  1
 2008  32.103  5  1.1666  1
 2009  49.909  5  1.1666  1
 2010  47.480  5  1.1666  1
#Age composition data by year, gear (ages 2-15+)
#na_gears
3
#na_nobs
54 39 38
#a_sage
2 2 2
#a_page
10 10 10
#yr gear    V2   V3   V4   V5  V6  V7  V8 V9 V10  #Number aged.
1951    1  326 4413 2371  556  110  27   8   2  0
1952    1 1008 4997 2262  608  119  24   6   1  0
1953    1  900 6177 3380  447  119  18   6   0  0
1954    1  200 6011 4845 1520  432 124  27   3  0
1955    1  233 2562 2065  355   57   6   0   0  0
1956    1  704 3798 3502 2801  627 106  28   6  3
1957    1   98 4344 1639  782  374  44   5   1  2
1958    1  564 3278 1171  278  244 177  25   4  0
1959    1 1533 5878 1460  223   48  21  11   2  0
1960    1  398 2049 1391  127   15   4   3   0  0
1961    1 1425 1395 1153  607  166  16   2   0  0
1962    1  270 2019  363  116   45  10   1   0  0
1963    1  364 1290  660   94   24   9   2   0  0
1964    1  190 2173 1157  110   26   4   3   0  0
1965    1  500 1703  775   73   22   3   1   0  0
1966    1  168  256  166  100   16   7   0   0  0
1971    1  175  568  516  101   40  13   1   0  0
1972    1  245  740  770  448   96  33   6   1  0
1973    1   58  520  253  176   48  10   4   1  0
1976    1  248  770 1463  788  225 112  37  17  2
1977    1   89  947  383  274   76  26  12   4  1
1978    1  110  919  958  236  166  62   9   8  3
1979    1   58  665 1545 1093  323 159  47   7  3
1980    1   84 1627  874  716  363  93  57  15  3
1981    1  340 2634 2479 1091  636 242  54  21  1
1982    1  223 1824 1378  625  201 131  36   2  4
1983    1  392 2093 1603  833  429 146 149  77 10
1984    1  639 1398  798  443  203 103  22  10  6
1985    1  749 1063  491  193   79  26   9   2  0
1986    1  230  832  245   60   18   4   1   0  0
1987    1  295  406  328   93   18   4   2   0  0
1988    1   77 1051  248  202   37   9   2   1  0
1989    1  331  219  532   85   73  10   2   0  0
1990    1   62  544  118  164   21  19   0   0  0
```

```
1991    1  101  223  265   51   50    7    1    0   0
1992    1   37  645  125   69    8    3    3    0   0
1993    1  252  302  316   67   26    3    6    1   0
1994    1   42  287  134   81    9    5    0    0   0
1995    1  222  311  409  123   54    8    2    0   1
1996    1  419  821  199  157   41   18    3    0   0
1997    1   52  201   50   10    3    1    2    1   0
1998    1   60  758  626   99   13    7    1    1   0
1999    1  151  361  564  176   36    5    2    0   0
2000    1  250  536  169   90   24    8    0    0   0
2001    1   77  414  223   44   28   10    0    1   0
2002    1   46  570  243   55    9    3    1    0   1
2003    1   12  189  181   36    9    1    0    0   0
2004    1   57  156  203   71   18    2    0    0   0
2005    1   22   72   36   28    9    2    0    0   0
2006    1   29   39   47   26   29    6    2    1   0
2007    1   39   17    3    1    2    0    0    0   0
2008    1  231   94  458  118   24    5    1    1   0
2009    1    4  172   49    5    3    0    0    0   0
2010    1   34   19  249   20   18    7    1    2   0
1972    2  564 2514 2354 1282  260   77   10    1   0
1973    2   51 1306 1510 1157  588   77   11    1   0
1974    2  144  533  155   37   13    1    1    0   0
1975    2  288 3117 1506  417  180   85   25   10   0
1976    2  183  505 1002  395   97   41   23    6   2
1977    2  100 1717  675  506  133   37   19    6   5
1978    2   30 1253 1545  423  277   53   11    1   2
1979    2   92  765 1121  898  270  126   38   15   5
1980    2  350 3800 1344 1341  694  174   93   22   7
1981    2 1230 4902 3605 1200 1002  398   87   31   6
1982    2  337 1852 1334 1124  254  273  125   29   2
1983    2  434 4122 3745 2285 1428  411  385  161  28
1984    2  604 2784 2099  936  522  244   82   35  10
1985    2 2024 3592 1519  628  268  104   46    5   1
1986    2  889 3799 1477  409  128   53    9    5   0
1987    2  781 2623 2945 1201  276   86   29   10   4
1988    2  301 3848  924  935  250   63   13    4   0
1989    2  651 1177 3491  610  460  104   20    2   1
1990    2  452 3337  652 1159  182  105   23    4   1
1991    2  542 1173 2123  476  775  116   75   10   1
1992    2  257 2762  691  843  176  260   30   16   0
1993    2  832 2096 1737  379  326   76   84    8   2
1994    2  279 2518 1594 1120  238  168   42    9   0
1995    2  580 1251 2048 1005  627  155   62   20   6
1996    2 1059 3984 1160 1192  481  280   57   19   6
1997    2  618 3806 1671  433  464  184  107    9   3
1998    2  383 4176 2784 1049  228  171   64   17   2
1999    2  268 1054 1716  792  274   75   28    7   2
2000    2  859 2759 1385 1591  627  149   21   15   1
2001    2  458 2981 1939  603  559  181   45    7   2
2002    2  490 3042 1535  673  140  116   22    4   0
2003    2  330 3994 3368 1099  322   81   35    9   0
2004    2  251 1353 1982  972  237   74   14    9   1
2005    2  353 1420 1468 1183  387   98   32   11   4
2006    2  968 1257 1134  754  448  103   33    8   1
2007    2  107 2951 1666  749  346  188   42   10   1
2008    2  160  582 3191  717  259  105   41    8   1
2009    2   20 3164  665  606  180   60   25   10   1
2010    2  583  228 3843  297  311   73   26    8   4
1972    3   46  118  468  286   68   15    2    1   0
1973    3    0   39   68   84   25    7    1    0   0
1974    3    0   45  390  283  158   39    9    0   0
1975    3    0    8   76   53   21    5    1    0   0
1976    3    0    5  322  342   89   22    5    1   0
1977    3    0   56  480  779  270   62    9    2   0
1978    3    0    2  110  165  195   59    8    2   0
1979    3    0    6  121  286   72   29    8    0   1
1980    3    0    4   26  117   90   23    2    1   0
1981    3    1   25  207  262  426  183   32    3   1
1982    3    0   27   94  180   89  123   69    5   2
1983    3    0    2  113  120   96   38   30    7   0
1984    3    0   54  229  234  144   71   12    5   7
1985    3    1   34  286  356  259  101   41    9   9
1987    3    0   48  684  642  317  163   50   11   5
1988    3    0   82  132  426  179   47   20    3   2
1989    3    0   13  331  181  213   64   18    3   0
1990    3    0  115  160  771  167  133   20    4   1
1991    3    0   14  306  187  436   79   51   13   1
1992    3    0   74  174  510  137  221   31   17   5
1993    3    0  104  363  154  196   37   49    2   2
1994    3    1   45  300  537  183   95   30    8   2
1995    3    0   21  243  341  242   52   22    4   2
1996    3    0   21   86  247  119   56   10    4   0
1997    3    0   30  113  104  202  108   54   16   6
1998    3    0   45  450  438  185  191   57   26   5
1999    3    0   18  245  307  176   56   28    5   1
2000    3    0   13  170  530  330  107   25    4   0
2001    3    0   31  190  263  345  154   34    7   2
2002    3    0   45  206  285  149  178   45    5   2
2003    3    0   30  283  439  305  137   83   28   3
2004    3    0   25  278  451  276  116   25   13   1
2005    3    0    5   91  352  207   80   28    9   1
2006    3    0    6  108  265  268  124   30    8   0
2007    3    0  140  384  760  744  512  134   36   6
2008    3    1   32  841  458  309  153   54   17   1
2009    3    0   42   63  466  166   99   29   11   1
2010    3    0    1  222   67  428  114   60   23   7

#n_wt_obs
60
#Mean weight-at-age in kilograms (interpolated: from HCAM.rep)
#A$yr    V1     V2     V3     V4     V5     V6     V7     V8     V9
1951 0.0417 0.0897 0.1126 0.1376 0.1586 0.1706 0.2001 0.1865 0.1865
1952 0.0432 0.0896 0.1133 0.1385 0.1599 0.1756 0.1677 0.1780 0.1865
1953 0.0329 0.0763 0.0958 0.1255 0.1498 0.1599 0.1335 0.1784 0.1865
1954 0.0447 0.0847 0.1036 0.1278 0.1571 0.1721 0.1751 0.1860 0.1865
1955 0.0499 0.0893 0.1043 0.1262 0.1448 0.1738 0.1720 0.1784 0.1865
1956 0.0471 0.0845 0.1060 0.1205 0.1410 0.1587 0.1785 0.1733 0.1865
1957 0.0481 0.0828 0.1089 0.1371 0.1506 0.1640 0.2100 0.1784 0.1865
1958 0.0438 0.0763 0.1081 0.1421 0.1535 0.1647 0.1762 0.1885 0.1865
1959 0.0502 0.0836 0.0993 0.1314 0.1596 0.1677 0.1523 0.1580 0.1865
1960 0.0530 0.0902 0.1125 0.1279 0.1597 0.1290 0.1770 0.1784 0.1865
1961 0.0576 0.0786 0.1111 0.1170 0.1372 0.1650 0.1720 0.1784 0.1865
1962 0.0501 0.0880 0.0993 0.1366 0.1449 0.1530 0.2020 0.1784 0.1865
1963 0.0477 0.0832 0.1049 0.1116 0.1494 0.1778 0.1790 0.1784 0.1865
1964 0.0576 0.0993 0.1159 0.1378 0.1586 0.1850 0.1400 0.1784 0.1865
1965 0.0611 0.1051 0.1224 0.1451 0.1452 0.1770 0.1440 0.1784 0.1865
1966 0.0520 0.1067 0.1487 0.1681 0.1783 0.1888 0.1720 0.1784 0.1865
1967 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1968 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1969 0.0488 0.0880 0.1104 0.1332 0.1530 0.1677 0.1720 0.1784 0.1865
1970 0.0578 0.0888 0.1175 0.1399 0.1608 0.1733 0.1871 0.1927 0.2096
1971 0.0553 0.1056 0.1319 0.1537 0.1742 0.1895 0.1690 0.1927 0.2096
1972 0.0586 0.0897 0.1290 0.1478 0.1671 0.1778 0.1973 0.1850 0.2096
1973 0.0525 0.0993 0.1274 0.1588 0.1749 0.1928 0.1977 0.2010 0.2096
1974 0.0630 0.0877 0.1392 0.1653 0.2093 0.1733 0.2420 0.1927 0.2096
1975 0.0421 0.0828 0.1115 0.1423 0.1694 0.1934 0.1995 0.2122 0.2096
1976 0.0498 0.0849 0.1234 0.1455 0.1743 0.1914 0.2033 0.2248 0.2133
1977 0.0571 0.0888 0.1173 0.1389 0.1616 0.1910 0.2010 0.2027 0.2418
1978 0.0501 0.0853 0.1099 0.1321 0.1513 0.1672 0.1683 0.1999 0.2095
1979 0.0597 0.0848 0.1178 0.1405 0.1604 0.1754 0.1990 0.2051 0.2174
1980 0.0522 0.0780 0.1083 0.1352 0.1584 0.1718 0.1831 0.1984 0.2172
1981 0.0602 0.0857 0.1085 0.1348 0.1561 0.1706 0.1873 0.1802 0.2022
1982 0.0635 0.0945 0.1153 0.1292 0.1531 0.1618 0.1696 0.1688 0.1950
1983 0.0576 0.0898 0.1174 0.1349 0.1431 0.1580 0.1707 0.1851 0.1941
1984 0.0624 0.0881 0.1146 0.1388 0.1569 0.1590 0.1666 0.1762 0.2010
1985 0.0647 0.0867 0.1141 0.1345 0.1564 0.1703 0.1869 0.1926 0.2320
1986 0.0670 0.0895 0.1108 0.1324 0.1495 0.1700 0.1971 0.1954 0.2096
1987 0.0628 0.0874 0.1056 0.1226 0.1366 0.1522 0.1660 0.1550 0.1823
1988 0.0609 0.0900 0.1138 0.1302 0.1423 0.1547 0.1642 0.2006 0.2096
1989 0.0644 0.0841 0.1068 0.1273 0.1390 0.1474 0.1561 0.1580 0.1820
1990 0.0604 0.0851 0.1060 0.1283 0.1468 0.1572 0.1609 0.1453 0.2260
1991 0.0642 0.0894 0.1101 0.1280 0.1426 0.1553 0.1634 0.1508 0.1850
1992 0.0598 0.0905 0.1118 0.1319 0.1494 0.1592 0.1738 0.1739 0.1563
1993 0.0579 0.0922 0.1118 0.1286 0.1411 0.1529 0.1565 0.1600 0.1475
1994 0.0522 0.0809 0.1047 0.1207 0.1350 0.1405 0.1512 0.1609 0.1563
1995 0.0612 0.0856 0.1106 0.1314 0.1446 0.1617 0.1631 0.1791 0.1753
1996 0.0619 0.0829 0.1061 0.1264 0.1457 0.1557 0.1719 0.1694 0.1830
1997 0.0497 0.0826 0.1017 0.1197 0.1368 0.1463 0.1541 0.1670 0.1817
1998 0.0504 0.0725 0.0939 0.1086 0.1194 0.1331 0.1438 0.1559 0.1485
1999 0.0460 0.0795 0.0991 0.1134 0.1255 0.1341 0.1434 0.1508 0.1390
2000 0.0523 0.0724 0.0948 0.1110 0.1291 0.1387 0.1530 0.1599 0.1630
2001 0.0622 0.0853 0.0990 0.1197 0.1332 0.1483 0.1552 0.1454 0.1440
2002 0.0494 0.0793 0.0959 0.1076 0.1254 0.1324 0.1413 0.1640 0.0590
2003 0.0518 0.0772 0.0930 0.1050 0.1113 0.1282 0.1401 0.1280 0.1563
2004 0.0498 0.0729 0.0888 0.0993 0.1091 0.1125 0.1241 0.1219 0.1320
2005 0.0476 0.0741 0.0910 0.1064 0.1175 0.1257 0.1305 0.1215 0.1373
2006 0.0483 0.0714 0.0882 0.1023 0.1113 0.1208 0.1279 0.1394 0.1780
2007 0.0620 0.0753 0.0831 0.0994 0.1154 0.1230 0.1301 0.1432 0.1340
2008 0.0257 0.0658 0.0858 0.0936 0.1030 0.1105 0.1155 0.1331 0.1350
2009 0.0453 0.0644 0.0688 0.1033 0.1156 0.1251 0.1347 0.1542 0.1780
2010 0.0435 0.0580 0.0790 0.0850 0.1118 0.1189 0.1158 0.1119 0.1413

#eof
999
```

```
 ## ___________________________________________________________________________ ##
##                              SOG HERRING CONTROLS
## __________________CONTROLS FOR ESTIMATED PARAMETERS________________________ ##
##  Prior descriptions:
##                     -0 uniform (0,0)
##                     -1 normal (p1=mu,p2=sig)
##                     -2 lognormal (p1=log(mu),p2=sig)
##                     -3 beta (p1=alpha,p2=beta)
##                     -4 gamma(p1=alpha,p2=beta)
## ___________________________________________________________________________ ##
7   ## npar
##  ival        lb      ub      phz     prior   p1      p2      parameter name
## ___________________________________________________________________________ ##
    7.60        -5.0    15       4       0      -5.0    15        #log_ro
    0.67        0.2     1.0      4       3      10.0    4.925373  #steepness
    -0.7985077  -5.0    5.0      3       1      -0.7985077 0.4    #log.m
    7.40        -5.0    15       1       0      -5.0    15        #log_avgrec
    7.20        -5.0    15       1       0      -5.0    15        #log_recinit
    0.3043478   0.001   0.999   -3       3      15.0    60.0      #rho
    0.8695652   0.01    5.0     -3       4      156.25  125.0     #kappa (precision)
## ___________________________________________________________________________ ##

## ___________________________________________________________________________ ##
## ________________________SELECTIVITY PARAMETERS_____________________________ ##
## OPTIONS FOR SELECTIVITY:
##      1) logistic selectivity parameters
##      2) selectivity coefficients
##      3) a constant cubic spline with age-nodes
##      4) a time varying cubic spline with age-nodes
##      5) a time varying bicubic spline with age & year nodes.
##      6) fixed logistic (set isel_type=6, and estimation phase to -1)
##      7) logistic function of body weight.
##      sig=0.05 0.10 0.15 0.20 0.30 0.40 0.50
##      wt =200. 50.0 22.2 12.5 5.56 3.12 2.00
## Gear 1:3 fishery:  Gear 4-5 survey
## isel_type
   1        1         7      6       6
## Age at 50% selectivity (logistic)
   2.0      3.0       0.6    2.055   2.055
## STD at 50% selectivity (logistic)
   0.25     0.25      0.15   0.05    0.05
## No. of age nodes for each gear (0 to ignore).
   5        5         5      0       0
## No. of year nodes for each gear (0 to ignore).
   12       3         10     0       0
## Estimation phase
```

```
   2        2           2      -1      -1
## Penalty weight for 2nd differences w=1/(2*sig^2)
   125.     125.       12.5    12.5    12.5
## Penalty weight for dome-shaped selectivity 1=1/(2*sig^2)
   50.0     50.0      200.0   200.0   200.0
## ___________________________________________________________________________ ##

## ___________________________________________________________________________ ##
##                              Priors for Survey q                            ##
## ___________________________________________________________________________ ##
## nits  #number of surveys
   2
## priors 0=uniform density     1=normal density
   0       1
## prior log(mean)
   0       -0.662
## prior sd
   1.0      0.226
## ___________________________________________________________________________ ##

## ______________________OTHER MISCELLANEOUS CONTROLS_________________________ ##
0           ## 1  verbose ADMB output (0=off, 1=on)
1           ## 2  recruitment model (1=beverton-holt, 2=ricker)
0.100       ## 3  std in observed catches in first phase.
0.0707      ## 4  std in observed catches in last phase.
0           ## 5  Assume unfished in first year (0=FALSE, 1=TRUE)
0.02        ## 6  Minimum proportion to consider in age-proportions for dmvlogistic
0.30        ## 7  Mean fishing mortality for regularizing the estimates of Ft
0.01        ## 8  std in mean fishing mortality in first phase
2.00        ## 9  std in mean fishing mortality in last phase
3           ## 10 phase for estimating m_deviations (use -1 to turn off mdevs)
0.1         ## 11 std in deviations for natural mortality
12 ## 12 number of estimated nodes for deviations in natural mortality
1.00        ## 13 fraction of total mortality that takes place prior to spawning
1           ## 14 switch for age-composition likelihood (1=dmvlogistic,2=dmultinom)
## ___________________________________________________________________________ ##


## eofc
999
```

B.5 West Coast of Vancouver Island

```
 #NB The data herein were taken from sog2010_final.dat for the HCAM model.
## ________________________
## ____Model Dimensions____
1951 #first year of data
2010 #last year of data
2 #age of youngest age class
10 #age of plus group
5 #number of gears (ngear)
## flags for fishery (1) or survey (0) in ngears
1 1 1 0 0
## ________________________
##
## ________________________
#Age-schedule and population parameters
#natural mortality rate (m)
0.334
#growth parameters (linf,k,to)  (from fishbase)
27.0, 0.48, 0
#length-weight allometry (a,b)
4.5e-6, 3.1270
#maturity at age (am=log(3)/k) & gm=std for logistic
2.055, 0.05
## ________________________
##
#Time series data
#Observed catch (1951-2010, metric t)
#yr p1 p2 p3  survey
1951 21.821  0.000  0.000  0  0
1952 27.008  0.000  0.000  0  0
1953  0.020  0.000  0.000  0  0
1954 33.209  0.000  0.000  0  0
1955  6.123  0.000  0.000  0  0
1956 17.098  0.000  0.000  0  0
1957  2.612  0.000  0.000  0  0
1958  0.556  0.000  0.000  0  0
1959 69.223  0.000  0.000  0  0
1960 53.911  0.000  0.000  0  0
1961 26.435  0.000  0.000  0  0
1962 23.684  0.000  0.000  0  0
1963 18.206  0.000  0.000  0  0
1964 21.266  0.000  0.000  0  0
1965 16.046  0.000  0.000  0  0
1966 10.843  0.000  0.000  0  0
1967 15.145  0.000  0.000  0  0
1968  0.000  0.000  0.000  0  0
1969  0.000  0.000  0.000  0  0
1970  0.000  0.000  0.000  0  0
1971  0.000  0.000  0.000  0  0
1972  0.000  6.894  0.000  0  0
1973  0.000 16.766  1.537  0  0
1974  0.000 12.394  3.940  0  0
1975  0.000 17.799  8.309  0  0
1976  0.000 22.820 16.005  0  0
1977  0.029 17.458 12.556  0  0
1978  2.839  5.151 14.755  0  0
1979  0.084 10.472  8.138  0  0
1980  0.000  1.682  2.300  0  0
1981  0.000  5.008  3.079  0  0
1982  0.000  2.370  3.115  0  0
1983  0.000  6.141  2.434  0  0
1984  0.000  5.718  0.858  0  0
1985  0.000  0.177  0.000  0  0
1986  0.000  0.203  0.000  0  0
1987  0.000 13.463  2.471  0  0
1988  0.000  8.276  1.448  0  0
1989  0.000  9.774  3.515  0  0
1990  0.000  7.890  1.959  0  0
1991  0.000  6.299  2.336  0  0
1992  0.000  3.086  0.627  0  0
1993  0.000  5.612  0.000  0  0
1994  0.000  5.332  0.706  0  0
1995  0.000  1.947  0.000  0  0
1996  0.000  0.790  0.000  0  0
1997  0.000  6.656  0.000  0  0
1998  0.000  5.450  1.534  0  0
1999  0.000  3.405  0.968  0  0
2000  0.000  0.926  0.700  0  0
2001  0.000  0.000  0.000  0  0
2002  0.000  0.433  0.388  0  0
2003  0.000  2.571  0.945  0  0
2004  0.000  3.861  0.593  0  0
2005  0.000  3.373  0.896  0  0
2006  0.000  0.000  0.000  0  0
2007  0.000  0.000  0.000  0  0
2008  0.000  0.000  0.000  0  0
2009  0.000  0.000  0.000  0  0
2010  0.000  0.000  0.000  0  0
#
#
#Relative Abundance index from fisheries independent survey (it) 1970-2008
#nit
2
#nit_nobs
37 23
#survey type
## 1 = survey is proportional to vulnerable numbers
## 2 = survey is proportional to vulnerable biomass
## 3 = survey is proportional to spawning biomass (e.g., herring spawn survey)
3 3
#iyr     it gear wt survey timing
1951 19.597    4  1      1
1952 13.310    4  1      1
1953 39.571    4  1      1
```

```
1954 20.648    4  1      1
1955 15.112    4  1      1
1956 27.183    4  1      1
1957 44.114    4  1      1
1958 18.986    4  1      1
1959 12.979    4  1      1
1960  6.015    4  1      1
1961 10.556    4  1      1
1962 34.470    4  1      1
1963 11.245    4  1      1
1964 22.761    4  1      1
1965 11.891    4  1      1
1966  3.722    4  1      1
1967  4.813    4  1      1
1968 11.029    4  1      1
1969 10.465    4  1      1
1970 26.912    4  1      1
1971 36.206    4  1      1
1972 41.857    4  1      1
1973 19.481    4  1      1
1974 25.540    4  1      1
1975 49.149    4  1      1
1976 64.222    4  1      1
1977 58.679    4  1      1
1978 45.607    4  1      1
1979 66.397    4  1      1
1980 62.308    4  1      1
1981 52.063    4  1      1
1982 33.047    4  1      1
1983 16.771    4  1      1
1984 23.872    4  1      1
1985 30.010    4  1      1
1986 39.514    4  1      1
1987 16.858    4  1      1
1988 46.242    5  1      1
1989 47.718    5  1      1
1990 46.464    5  1      1
1991 30.456    5  1      1
1992 42.687    5  1      1
1993 34.728    5  1      1
1994 25.625    5  1      1
1995 28.057    5  1      1
1996 33.986    5  1      1
1997 46.490    5  1      1
1998 41.556    5  1      1
1999 20.390    5  1      1
2000 13.267    5  1      1
2001 13.955    5  1      1
2002 22.086    5  1      1
2003 29.750    5  1      1
2004 15.844    5  1      1
2005  9.075    5  1      1
2006  2.705    5  1      1
2007  2.089    5  1      1
2008  2.548    5  1      1
2009  9.876    5  1      1
2010  2.373    5  1      1
#
#Age composition data by year, gear (ages 2-15+)
#na_gears
3
#na_nobs
18 39 26
#a_sage
2 2 2
#a_page
10 10 10
#
```

```
#yr gear    V2   V3   V4   V5   V6  V7  V8 V9 V10  #Number aged.
1951    1  508 1519 1666  272   58   12   1   1  0
1952    1   97 1431 1224 1809  241   72  16   2  0
1953    1  465 2220 1086   65   19    2   0   0  0
1954    1  163 3852 1681  338   42    9   5   1  1
1955    1  418 1471  484   86   16    1   0   0  0
1956    1  575 2990  743  282   52    7   2   2  0
1957    1   16  423  146    2    1    0   0   0  0
1958    1  193  770  376   81   34   20   5   1  0
1959    1  148 1607  993  519  140   88  74  21  3
1960    1  254 1561  662  246   80   27  10   4  2
1961    1  226  224  113   26    1    0   0   0  0
1962    1   56  957  112   28   10    0   0   0  0
1963    1   37  804  907   96   14    4   0   0  0
1964    1   16  677  284  118    9    3   0   0  0
1965    1   18  269  372   75   27    3   0   0  0
1966    1    1  101   78   53    6    3   0   0  0
1971    1   25  193  160   34   12    7   2   0  0
1978    1    0  180  156  105  106   20   6   4  2
1972    2   50  279  716  356   51   18  11   1  0
1973    2   18  776  620  817  276   40   7   2  0
1974    2  433 2324 1290  731  476  120  12   2  1
1975    2   60 5405 1983 1140  804  498 128  17  1
1976    2   19  818 4332 1828 1196  746 251  40  0
1977    2   35  830 2077 2487  828  294 112  18  3
1978    2   63 3164 1407 1177 1294  287  87  14  5
1979    2   30  513 1848  525  398  293  59  19  4
1980    2  232 1640  582  747  238  198  82  13  2
1981    2  232 1868 1423  499  603  261 103  29  7
1982    2  156 1144 1309 1244  260  454 130  65  5
1983    2  135  719  696  699  562  142 172  34 26
1984    2  669 1146  418  282  309  182  33  33  5
1985    2  613 1606  426  111   82   95  51   4  6
1986    2  157 2094 1233  344  130   93  73  24  3
1987    2  783  863 1709 1053  351  123  71  52 13
```

```
1988     2  193 4587  584 1110  738  209   55   33 15
1989     2  155  960 3693  450  534  271   44   10  3
1990     2   33 1856  849 3233  307  406  125   16  4
1991     2  482 1565 1543  780 2420  220  251   48  2
1992     2  104 2960  662  827  362 1029  129   75 12
1993     2  214 1528 2255  380  416  226  423   51 27
1994     2  183 1407 1485 1875  492  311  330   98 15
1995     2   44  667 1304 1087 1335  348  226  166 31
1996     2 1079 1505  909 1457  945  968  204   85 42
1997     2  145 4109  487  266  402  294  198   32 20
1998     2  123 1224 3239  347  155  176  104   60 11
1999     2   65  960 1044 1641  325  112   63   31 14
2000     2  284 1170  984  894 1374  196   67   35  9
2001     2  165 1074  475  197  178  222   31    5  3
2002     2  348 2658 1136  371  140  157  131   15  1
2003     2   96 2191 2042  705  135   62   42   33  4
2004     2  390 1295 2431 1002  283   64   21   11  0
2005     2  157 1655  939  680  237   71   12    2  3
2006     2  174  430  387   91   62    9    1    0  0
2007     2    7  303  211   66   11    4    0    0  0
2008     2   54  255  559  119   32    8    6    1  1
2009     2   44 1202  283  230   41   10    0    0  0
2010     2  211  577  839  105   88   14    2    0  0
1973     3    0   49  131  286   68   17    4    1  0
1974     3    0   46   43   43   16    6    0    0  0
1975     3    0    7   78   88   48   19    1    0  0
1976     3    0    8  495  408  179   73   31    4  1
1977     3    2   12   58  144   56   37   17    5  1
1978     3    0    6   23   90  207   74   20    1  1
1979     3    0    5  118  136  113   86   15    2  1
1980     3    0    0   19  188   80   43   26    1  1
1981     3    0    5   59   42  102   53   20    0  0
1982     3    0    4   69  254   67  158   19    2  1
1983     3    0    2   81  136  256   37   56    2  1
1984     3    0   10   40  107  194  190   32   20  1
1987     3    0   10  135  340   30   12   16    5  2
1988     3    0   25   33  192  133   60   14    6  2
1989     3    0    1  208   42   85   36    6    4  0
1990     3    0    6   35  307   37   46   11    3  0
1991     3    0    1   21   39  198   21   25    2  0
1992     3    0   35   75  171   77  166   16   14  2
1994     3    1   35  199  340   33    7    4    1  0
1998     3    0    5  344   99   87  181  111   51 19
1999     3    0    9  113  612  193   58   38   18  2
2000     3    0    8   47  169  330   39   16   14  1
2002     3    0    0   55  154   82  110  120   12  2
2003     3    0   13   87  159   99   49   64   25  3
2004     3    0    5  179  154  158   92   24   14  5
2005     3    0    4   54  249  119   53   19    1  1
#n_wt_obs
60
#Mean weight-at-age in kilograms (interpolated: from HCAM.rep)
#A$yr     V1        V2        V3        V4        V5        V6        V7        V8        V9
1951 0.0503000 0.0873000 0.1144000 0.1339000 0.1489000 0.1600000 0.2050000 0.1960000 0.1586000
1952 0.0536000 0.0896000 0.1144000 0.1386000 0.1569000 0.1699000 0.1781000 0.1900000 0.1586000
1953 0.0446000 0.0799000 0.1001000 0.1210000 0.1473000 0.1455000 0.1594143 0.1656286 0.1586000
1954 0.0542000 0.0854000 0.1056000 0.1258000 0.1474000 0.1658000 0.1550000 0.1656286 0.1586000
1955 0.0579000 0.0827000 0.1070000 0.1249000 0.1514000 0.1310000 0.1594143 0.1656286 0.1586000
1956 0.0577000 0.0860000 0.1064000 0.1192000 0.1389000 0.1440000 0.1594143 0.1400000 0.1586000
1957 0.0543000 0.0775000 0.1016000 0.1139000 0.1360000 0.1440000 0.1420000 0.1400000 0.1586000
1958 0.0503000 0.0693000 0.0965000 0.1093000 0.1248000 0.1281000 0.1383000 0.1690000 0.1586000
1959 0.0508000 0.0808000 0.0970000 0.1130000 0.1241000 0.1332000 0.1371000 0.1499000 0.1527000
1960 0.0594000 0.0897000 0.1060000 0.1212000 0.1336000 0.1446000 0.1604000 0.1745000 0.1645000
1961 0.0583000 0.0908000 0.1159000 0.1410000 0.1730000 0.1484429 0.1594143 0.1656286 0.1586000
1962 0.0567000 0.0922000 0.1093000 0.1241000 0.1282000 0.1484429 0.1594143 0.1656286 0.1586000
1963 0.0562000 0.0883000 0.1116000 0.1222000 0.1366000 0.1448000 0.1594143 0.1656286 0.1586000
1964 0.0650000 0.0931000 0.1145000 0.1362000 0.1452000 0.1300000 0.1594143 0.1656286 0.1586000
1965 0.0683000 0.1040000 0.1292000 0.1474000 0.1733000 0.1580000 0.1594143 0.1656286 0.1586000
1966 0.0420000 0.1128000 0.1351000 0.1489000 0.1627000 0.1793000 0.1594143 0.1656286 0.1586000
1967 0.0549750 0.0880875 0.1102875 0.1275375 0.1455187 0.1484429 0.1594143 0.1656286 0.1586000
1968 0.0549750 0.0880875 0.1102875 0.1275375 0.1455187 0.1484429 0.1594143 0.1656286 0.1586000
1969 0.0549750 0.0880875 0.1102875 0.1275375 0.1455187 0.1484429 0.1594143 0.1656286 0.1586000
1970 0.0639778 0.0949000 0.1248556 0.1501222 0.1697500 0.1844389 0.1957944 0.2034412 0.2082571
1971 0.0640000 0.1174000 0.1485000 0.1660000 0.1689000 0.1991000 0.2175000 0.2034412 0.2082571
1972 0.0642000 0.1036000 0.1382000 0.1596000 0.1737000 0.1807000 0.2032000 0.1600000 0.2082571
1973 0.0633000 0.1037000 0.1349000 0.1598000 0.1836000 0.1924000 0.1903000 0.2540000 0.2082571
1974 0.0617000 0.0854000 0.1234000 0.1487000 0.1717000 0.1856000 0.1836000 0.2175000 0.2310000
1975 0.0547000 0.0918000 0.1279000 0.1652000 0.1893000 0.2071000 0.2202000 0.2406000 0.2070000
1976 0.0536000 0.0873000 0.1202000 0.1518000 0.1811000 0.1951000 0.2112000 0.2223000 0.2082571
1977 0.0628000 0.0885000 0.1253000 0.1435000 0.1695000 0.1828000 0.1918000 0.1962000 0.2153000
1978 0.0591000 0.0797000 0.1082000 0.1341000 0.1539000 0.1736000 0.1883000 0.2038000 0.2244000
1979 0.0621000 0.0831000 0.1104000 0.1412000 0.1672000 0.1835000 0.2003000 0.2034000 0.1995000
1980 0.0669000 0.0825000 0.1079000 0.1314000 0.1590000 0.1789000 0.1928000 0.2083000 0.2180000
1981 0.0630000 0.0906000 0.1104000 0.1377000 0.1527000 0.1755000 0.1830000 0.1879000 0.1891000
1982 0.0708000 0.0892000 0.1094000 0.1251000 0.1423000 0.1500000 0.1712000 0.1795000 0.1774000
1983 0.0611000 0.0938000 0.1190000 0.1405000 0.1552000 0.1660000 0.1737000 0.1954000 0.1936000
1984 0.0692000 0.1013000 0.1306000 0.1535000 0.1662000 0.1767000 0.1863000 0.1891000 0.2112000
1985 0.0694000 0.1016000 0.1351000 0.1609000 0.1818000 0.1857000 0.2076000 0.1848000 0.1997000
1986 0.0683000 0.1028000 0.1311000 0.1601000 0.1809000 0.1919000 0.1984000 0.2045000 0.2217000
1987 0.0695000 0.1026000 0.1367000 0.1634000 0.1810000 0.2001000 0.2030000 0.2050000 0.2139000
1988 0.0679000 0.1033000 0.1302000 0.1597000 0.1775000 0.1952000 0.2019000 0.2062000 0.2138000
1989 0.0649000 0.0967000 0.1268000 0.1476000 0.1700000 0.1869000 0.1936000 0.1966000 0.2050000
1990 0.0620000 0.1008000 0.1295000 0.1542000 0.1721000 0.1881000 0.1993000 0.2148000 0.1963000
1991 0.0662000 0.0942000 0.1235000 0.1412000 0.1608000 0.1773000 0.1858000 0.1978000 0.2065000
1992 0.0687000 0.1006000 0.1256000 0.1493000 0.1638000 0.1773000 0.1879000 0.1973000 0.2082000
1993 0.0685000 0.0973000 0.1217000 0.1406000 0.1593000 0.1694000 0.1784000 0.1873000 0.1979000
1994 0.0648000 0.0949000 0.1194000 0.1358000 0.1498000 0.1605000 0.1642000 0.1748000 0.1779000
1995 0.0693000 0.0979000 0.1216000 0.1432000 0.1599000 0.1749000 0.1823000 0.1888000 0.1874000
1996 0.0695000 0.0855000 0.1160000 0.1363000 0.1520000 0.1646000 0.1766000 0.1814000 0.1921000
1997 0.0641000 0.0914000 0.1055000 0.1316000 0.1492000 0.1610000 0.1756000 0.1729000 0.1794000
1998 0.0589000 0.0796000 0.1037000 0.1133000 0.1321000 0.1424000 0.1494000 0.1557000 0.1575000
1999 0.0536000 0.0832000 0.0991000 0.1195000 0.1257000 0.1440000 0.1521000 0.1634000 0.1562000
2000 0.0578000 0.0868000 0.1074000 0.1301000 0.1468000 0.1584000 0.1609000 0.1681000 0.1771000
2001 0.0659000 0.0885000 0.1074000 0.1242000 0.1408000 0.1564000 0.1563000 0.1478000 0.1983000
2002 0.0634000 0.0840000 0.1032000 0.1249000 0.1440000 0.1566000 0.1704000 0.1868000 0.2180000
2003 0.0609000 0.0934000 0.1031000 0.1207000 0.1387000 0.1544000 0.1763000 0.1670000 0.1920000
2004 0.0635000 0.0814000 0.1028000 0.1100000 0.1242000 0.1340000 0.1557000 0.1657000 0.1852235
2005 0.0559000 0.0755000 0.0913000 0.1122000 0.1204000 0.1332000 0.1375000 0.1525000 0.1370000
2006 0.0548000 0.0693000 0.0877000 0.1020000 0.1169000 0.1103000 0.1280000 0.1754278 0.1852235
2007 0.0546000 0.0727000 0.0805000 0.0924000 0.0981000 0.1313000 0.1642400 0.1754278 0.1852235
2008 0.0565000 0.0603000 0.0877000 0.1034000 0.1156000 0.1315000 0.1450000 0.1390000 0.1620000
2009 0.0461000 0.0753000 0.0777000 0.1038000 0.1101000 0.1138000 0.1642400 0.1754278 0.1852235
2010 0.0490000 0.0714000 0.0855000 0.0923000 0.1069000 0.1170000 0.1095000 0.1754278 0.1852235
#
#eof
999
```

```
 ## ------------------------------------------------------------------------------ ##
##                             PACIFIC HAKE CONTROLS
## __________________CONTROLS FOR ESTIMATED PARAMETERS________________________ ##
##  Prior descriptions:
##                     -0 uniform (0,0)
##                     -1 normal (p1=mu,p2=sig)
##                     -2 lognormal (p1=log(mu),p2=sig)
##                     -3 beta (p1=alpha,p2=beta)
##                     -4 gamma(p1=alpha,p2=beta)
## ____________________________________________________________________________ ##
7   ## npar
##  ival        lb      ub      phz     prior   p1      p2      parameter name
## ____________________________________________________________________________ ##
    7.60        -5.0    15       4       0      -5.0    15       #log_ro
    0.67        0.2     1.0      4       3      10.0    4.925373 #steepness
    -0.7985077  -5.0    5.0      3       1      -0.7985077 0.4   #log.m
    7.40        -5.0    15       1       0      -5.0    15       #log_avgrec
    7.20        -5.0    15       1       0      -5.0    15       #log_recinit
    0.3043478   0.001   0.999   -3       3      15.0    60.0     #rho
    0.8695652   0.01    5.0     -3       4      156.25  125.0    #kappa (precision)
## ____________________________________________________________________________ ##

## ____________________________________________________________________________ ##
## ________________________SELECTIVITY PARAMETERS____________________________ ##
## OPTIONS FOR SELECTIVITY:
##      1) logistic selectivity parameters
##      2) selectivity coefficients
##      3) a constant cubic spline with age-nodes
##      4) a time varying cubic spline with age-nodes
##      5) a time varying bicubic spline with age & year nodes.
##      6) fixed logistic (set isel_type=6, and estimation phase to -1)
##      7) logistic function of body weight.
##      sig=0.05 0.10 0.15 0.20 0.30 0.40 0.50
##      wt =200. 50.0 22.2 12.5 5.56 3.12 2.00
## Gear 1:3 fishery:  Gear 4-5 survey
## isel_type
1        1 7 1 1
## Age at 50% selectivity (logistic)
1.5      2.0 0.6 2.05 2.05
## STD at 50% selectivity (logistic)
0.75      0.5 0.15 0.05 0.05
## No. of age nodes for each gear (0 to ignore).
5        5 5 0 0
## No. of year nodes for each gear (0 to ignore).
12       3 10 0 0
## Estimation phase
2        2 2 -2 -2
## Penalty weight for 2nd differences w=1/(2*sig^2)
125.0     12.5 12.5 12.5 12.5
## Penalty weight for dome-shaped selectivity 1=1/(2*sig^2)
3.125    200.0 200.0 200.0 200.0
##-------------------------------------------------------------------------- ##

##-------------------------------------------------------------------------- ##
##                          Priors for Survey q                               ##
##-------------------------------------------------------------------------- ##
## nits  #number of surveys
2
## priors 0=uniform density 1=normal density
0 1
## prior log(mean)
0 -0.662
## prior sd
1 0.226
##-------------------------------------------------------------------------- ##

##____________________OTHER MISCELLANEOUS CONTROLS_________________________ ##
0 ## verbose ADMB output (0=off, 1=on)
1 ## recruitment model (1=beverton-holt, 2=ricker)
0.100 ## std in observed catches in first phase.
0.0707 ## std in observed catches in last phase.
0 ## Assume unfished in first year (0=FALSE, 1=TRUE)
0.02 ## Minimum proportion to consider in age-proportions for dmvlogistic
0.20 ## Mean fishing mortality for regularizing the estimates of Ft
0.01 ## std in mean fishing mortality in first phase
5.00 ## std in mean fishing mortality in last phase
3 ## phase for estimating m_deviations (use -1 to turn off mdevs)
0.1 ## std in deviations for natural mortality
12 ## number of estimated nodes for deviations in natural mortality
0.99        ## fraction of total mortality that takes place prior to spawning
1           ## 14 switch for age-composition likelihood (1=dmvlogistic,2=dmultinom)
##-------------------------------------------------------------------------- ##

## eofc
999
```

Table B-1: Observed catch by gear type and year for each stock.

Stock	HG			PRD			CC			SOG			WCVI		
Year	Gear 1	Gear 2	Gear 3	Gear 1	Gear 2	Gear 3	Gear 1	Gear 2	Gear 3	Gear 1	Gear 2	Gear 3	Gear 1	Gear 2	Gear 3
1951	2.850			45.900			42.700			44.300			21.600		
1952	10.200			53.400			33.400			46.100			27.100		
1953				1.870			0.768			8.430			0.020		
1954	1.790			27.900			24.900			66.600			34.300		
1955	1.230			18.200			11.600			68.700			6.120		
1956	74.700			10.200			43.400			72.000			16.900		
1957	23.800			27.200			23.800			58.500			2.610		
1958	11.200			4.560			9.900			20.900			0.556		
1959	7.000			10.300			27.700			48.700		0.381	69.300		
1960				18.600			4.010			66.800			52.400		
1961	0.653			41.400			31.300			46.500			25.600		
1962	7.650			27.200			15.700			66.000			23.700		
1963	14.900			39.400			43.800			68.700			18.400		
1964	28.500			28.700			31.100			76.600			21.200		
1965	35.100			44.000			15.800			46.600			16.100		
1966	2.750			17.100			37.200			34.000			10.900		
1967	0.213			8.050			21.700			30.500			15.100		
1968	0.080			2.070			1.530			1.890					
1969										0.194					
1970				1.320			0.209			0.221		0.022			
1971	0.102			3.420			3.620			1.610		0.084			
1972	0.850	3.140		0.877	3.640	0.004	0.388	8.360	0.137	2.430	5.900	0.456		6.940	
1973		7.650		0.218	1.400		0.035	6.620	1.110	4.000	1.610	2.080		16.900	1.540
1974		6.210	0.127	0.182	2.120	1.520		3.620	5.320	0.479	0.425	3.110		12.200	3.930
1975		7.600	0.105	0.155	1.530	0.011		3.330	5.420	0.378	0.469	5.300		17.600	8.200
1976	0.374	11.900	1.800	0.565	3.480	0.276		6.130	6.160	5.070	0.202	7.020		22.900	16.100
1977		11.200	1.490	0.798	5.890	1.510	0.320	3.860	6.840	5.690	4.110	7.870	0.029	17.500	12.800
1978		9.190	2.560	3.610	1.950	3.020	0.046	4.750	9.350	13.000	3.730	7.460	2.840	5.140	15.200
1979		5.920	2.100	1.810	1.270	1.240		0.005		13.600		6.990	0.084	10.400	8.220
1980		2.110	1.210	0.741	1.660	1.060	0.010		0.529	2.470	0.169	3.220		1.680	2.300
1981		3.930	1.710	1.690	1.050	0.357		0.269	2.300	4.890	2.080	5.090		4.990	3.070
1982		2.370	1.410	1.830	0.170		0.041	2.250	4.050	3.930	3.300	5.510		2.370	3.100
1983	0.067	4.650	0.929					2.060	3.570	0.825	7.850	8.590		6.170	2.430
1984	0.096	4.010	0.535	0.173	1.650	1.890		3.580	3.580	0.087	4.160	6.180		5.720	0.858
1985		4.610	1.490	0.253	3.010	3.490		2.910	2.290	0.772	2.730	3.530		0.177	
1986		2.620	0.890	0.375	3.720	4.530	0.038	2.170	1.170	0.432	0.162			0.203	
1987		2.070		0.122	2.080	4.070		2.710	0.923	0.244	3.110	5.850		13.400	2.450
1988		0.032		0.079	3.550	4.440	0.028	3.540	0.975	0.756	1.470	5.950		8.250	1.450
1989		1.460		0.071	3.660	4.860		6.520	2.940	1.030	1.420	5.880		9.720	3.520
1990		5.510	1.170	0.043	2.280	2.380		5.290	3.060	0.233		7.710		7.870	1.960
1991		3.900	0.543		1.360	2.140		7.140	1.820	0.562	1.130	9.180		6.300	2.340
1992		2.530		0.142	1.240	3.740	0.088	7.150	1.120	0.939	3.620	8.960		3.090	0.627
1993		2.690			2.210	4.080		8.410	2.040	0.617	4.380	8.790		5.610	
1994		0.299			2.370	2.360		9.660	2.120	0.942	5.120	11.300		5.320	0.706

Table B-1: *(continued)*

Year		Gear 1	Gear 2	Gear 3		Gear 1	Gear 2	Gear 3		Gear 1	Gear 2	Gear 3		Gear 1	Gear 2	Gear 3		Gear 1	Gear 2	Gear 3
1995							0.707	1.370			8.130	1.450		0.641	4.360	8.070			1.950	
1996								3.110			3.900	0.402		0.541	7.340	6.140			0.790	
1997								5.370			3.290	0.344		0.402	9.290	6.130			6.670	
1998			1.370					3.180			8.030	0.648		0.954	5.760	6.990			5.460	1.540
1999			2.500	0.473			0.256	1.850			6.010	1.520		1.470	4.980	6.920			3.410	0.971
2000			1.770				1.240	3.050			6.380	0.975		1.160	6.440	7.620			0.927	0.702
2001							1.010	1.900			5.620	0.518		1.420	7.280	7.640				
2002			0.707				2.070	2.460			2.900	0.400		1.330	9.330	7.970			0.433	0.389
2003							1.450	2.610			2.300	0.289		1.700	10.700	8.140			2.570	0.949
2004							1.920	2.220			2.990			1.360	7.030	5.330			3.860	0.594
2005							1.750	2.050			3.790			1.330	7.920	9.170			3.420	0.902
2006							0.958	1.640			3.080			1.370	9.300	7.390				
2007								0.949			0.398			0.672	3.850	5.280				
2008							0.513	1.140						1.140	2.760	5.930				
2009							0.713	1.290						0.709	5.700	3.900				
2010							0.475	1.010						0.595	4.540	3.230				

Table B-2: Abundance for each survey by year for each stock.

HG			
Year	Survey 1	Year	Survey 2
1951	4.213	1988	15.245
1952	2.578	1989	25.201
1953	7.555	1990	27.058
1954	12.408	1991	17.998
1955	6.437	1992	12.376
1956	6.042	1993	8.152
1957	1.592	1994	14.293
1958	0.815	1995	4.701
1959	8.981	1996	7.377
1960	6.599	1997	11.215
1961	8.981	1998	21.649
1962	5.730	1999	10.610
1963	7.297	2000	6.698
1964	4.104	2001	15.195
1965	1.378	2002	3.257
1966	2.824	2003	8.801
1967	0.710	2004	5.668
1968	0.833	2005	3.614
1969	2.075	2006	4.097
1970	5.552	2007	9.436
1971	13.291	2008	4.213
1972	9.542	2009	8.935
1973	7.960	2010	6.091
1974	14.510		
1975	9.686		
1976	16.374		
1977	16.408		
1978	18.371		
1979	13.649		
1980	31.904		
1981	20.294		
1982	23.593		
1983	21.391		
1984	23.439		
1985	18.625		
1986	6.847		
1987	12.289		

PRD			
Year	Survey 1	Year	Survey 2
1951	27.149	1988	35.444
1952	24.047	1989	16.379
1953	28.468	1990	22.679
1954	13.535	1991	25.811
1955	14.482	1992	40.145
1956	14.533	1993	25.071
1957	27.518	1994	16.589
1958	9.882	1995	18.516
1959	40.961	1996	24.854
1960	16.545	1997	25.037
1961	12.059	1998	19.420
1962	26.329	1999	29.745
1963	16.981	2000	19.694
1964	26.919	2001	36.684
1965	6.055	2002	22.449
1966	7.105	2003	34.007
1967	3.386	2004	30.493
1968	5.197	2005	27.956
1969	0.965	2006	10.251
1970	8.814	2007	15.562
1971	8.480	2008	13.553
1972	8.774	2009	12.684
1973	10.959	2010	26.988
1974	9.244		
1975	10.949		
1976	15.587		
1977	11.589		
1978	6.164		
1979	9.195		
1980	11.937		
1981	14.087		
1982	17.186		
1983	25.247		
1984	27.041		
1985	41.028		
1986	26.638		
1987	39.905		

CC			
Year	Survey 1	Year	Survey 2
1951	15.390	1988	26.916
1952	10.295	1989	21.561
1953	18.237	1990	28.980
1954	13.967	1991	19.183
1955	13.564	1992	43.274
1956	6.626	1993	32.392
1957	4.607	1994	29.432
1958	3.549	1995	22.348
1959	3.904	1996	21.646
1960	12.615	1997	28.255
1961	4.265	1998	31.503
1962	11.948	1999	31.813
1963	6.485	2000	32.652
1964	6.464	2001	25.109
1965	2.097	2002	23.147
1966	1.863	2003	25.679
1967	5.434	2004	29.407
1968	5.790	2005	24.158
1969	1.837	2006	12.051
1970	8.230	2007	9.857
1971	4.156	2008	3.971
1972	3.572	2009	10.183
1973	12.434	2010	8.075
1974	8.852		
1975	8.037		
1976	13.849		
1977	14.613		
1978	7.747		
1979	5.779		
1980	13.012		
1981	15.919		
1982	16.333		
1983	18.482		
1984	14.185		
1985	8.850		
1986	20.342		
1987	12.827		

SOG			
Year	Survey 1	Year	Survey 2
1951	66.143	1988	24.976
1952	72.376	1989	66.052
1953	111.307	1990	67.152
1954	82.141	1991	45.830
1955	69.854	1992	82.714
1956	25.667	1993	90.198
1957	24.126	1994	67.144
1958	16.911	1995	64.899
1959	47.864	1996	71.326
1960	55.709	1997	58.232
1961	44.326	1998	74.616
1962	35.574	1999	85.095
1963	37.381	2000	72.688
1964	35.954	2001	100.248
1965	38.390	2002	117.864
1966	7.211	2003	141.651
1967	9.647	2004	114.352
1968	9.442	2005	95.643
1969	14.039	2006	46.752
1970	34.163	2007	35.865
1971	38.921	2008	32.103
1972	25.139	2009	49.909
1973	16.191	2010	47.480
1974	40.571		
1975	70.211		
1976	60.642		
1977	78.562		
1978	102.115		
1979	64.266		
1980	85.991		
1981	55.121		
1982	100.987		
1983	64.575		
1984	26.227		
1985	25.247		
1986	41.575		
1987	41.737		

WCVI			
Year	Survey 1	Year	Survey 2
1951	19.597	1988	46.242
1952	13.310	1989	47.718
1953	39.571	1990	46.464
1954	20.648	1991	30.456
1955	15.112	1992	42.687
1956	27.183	1993	34.728
1957	44.114	1994	25.625
1958	18.986	1995	28.057
1959	12.979	1996	33.986
1960	6.015	1997	46.490
1961	10.556	1998	41.556
1962	34.470	1999	20.390
1963	11.245	2000	13.267
1964	22.761	2001	13.955
1965	11.891	2002	22.086
1966	3.722	2003	29.750
1967	4.813	2004	15.844
1968	11.029	2005	9.075
1969	10.465	2006	2.705
1970	26.912	2007	2.089
1971	36.206	2008	2.548
1972	41.857	2009	9.876
1973	19.481	2010	2.373
1974	25.540		
1975	49.149		
1976	64.222		
1977	58.679		
1978	45.607		
1979	66.397		
1980	62.308		
1981	52.063		
1982	33.047		
1983	16.771		
1984	23.872		
1985	30.010		
1986	39.514		
1987	16.858		

Table B-3: Reference points

Stock	F_{MSY}	MSY	B_0	$0.25B_0$	B_{MSY}	$0.8B_{MSY}$	$0.4B_{MSY}$	Spawn depletion
HG	1.92	5,829	34,773	8,693	6,864	5,492	2,746	0.32
PRD	0.75	6,917	78,601	19,650	20,598	16,479	8,239	0.26
CC	0.87	8,021	56,732	14,183	10,750	8,600	4,300	0.11
SOG	1.11	18,126	117,444	29,361	24,339	19,471	9,736	0.43
WCVI	0.93	7,928	45,844	11,461	9,536	7,629	3,814	0.08

Table B-4: Estimated spawning stock biomass, age-4+ biomass and pre-fishery biomass for poor average and good recruitment, cutoffs, and available harvest based on a normal prior ($\mu = 0, \sigma = 0.274$) for q in both surveys.

			Pre-fishery forecast biomass				**Available harvest**		
Stock	SSB	4+ Biomass	Poor	Average	Good	Cutoff	Poor	Average	Good
HG	10,474	7,147	9,241	12,159	19,292	10,700	0	1,459	3,858
PRD	17,754	11,125	13,092	15,210	21,643	12,100	992	3,042	4,329
CC	6,441	2,486	4,366	6,487	11,538	17,600	0	0	0
SOG	50,927	26,807	38,502	49,288	65,667	21,200	7,700	9,858	13,133
WCVI	3,835	1,284	4,447	7,688	13,333	18,800	0	0	0

Table B-5: Estimated spawning stock biomass, age-4+ biomass and pre-fishery biomass for poor average and good recruitment, cutoffs based on 25% of the median B_0 estimate, and available harvest based on a normal prior ($\mu = 0, \sigma = 0.274$) for q in both surveys.

			Pre-fishery forecast biomass				**Available harvest**		
Stock	SSB	4+ Biomass	Poor	Average	Good	Cutoff	Poor	Average	Good
HG	10,474	7,147	9,241	12,159	19,292	9,032	209	2,432	3,858
PRD	17,754	11,125	13,092	15,210	21,643	25,055	0	0	0
CC	6,441	2,486	4,366	6,487	11,538	14,969	0	0	0
SOG	50,927	26,807	38,502	49,288	65,667	31,256	7,246	9,858	13,133
WCVI	3,835	1,284	4,447	7,688	13,333	11,970	0	0	1,363

Table B-6: Reference points

Stock	F_{MSY}	MSY	B_0	$0.25B_0$	B_{MSY}	$0.8B_{MSY}$	$0.4B_{MSY}$	Spawn depletion
HG	2.14	7,461	41,309	10,327	8,178	6,543	3,271	0.38
PRD	1.01	7,321	73,708	18,427	19,989	15,991	7,996	0.35
CC	0.97	9,050	57,502	14,375	11,312	9,050	4,525	0.15
SOG	1.26	20,194	118,712	29,678	24,941	19,953	9,976	0.5
WCVI	1.02	9,618	50,569	12,642	10,673	8,538	4,269	0.11

Table B-7: Estimated spawning stock biomass, age-4+ biomass and pre-fishery biomass for poor average and good recruitment, cutoffs, and available harvest based on a normal prior ($\mu = -0.569, \sigma = 0.274$) for q in both surveys.

			Pre-fishery forecast biomass				**Available harvest**		
Stock	SSB	4+ Biomass	Poor	Average	Good	Cutoff	Poor	Average	Good
HG	15,244	10,395	13,285	17,149	27,002	10,700	2,585	3,430	5,400
PRD	22,828	13,037	15,574	18,263	25,897	12,100	3,115	3,653	5,179
CC	8,696	3,458	5,890	8,437	14,690	17,600	0	0	0
SOG	59,247	30,220	45,204	57,184	75,655	21,200	9,041	11,437	15,131
WCVI	5,587	1,893	6,308	10,303	17,272	18,800	0	0	0

Table B-8: Estimated spawning stock biomass, age-4+ biomass and pre-fishery biomass for poor average and good recruitment, cutoffs based on 25% of the median B_0 estimate, and available harvest based on a normal prior ($\mu = -0.569, \sigma = 0.274$) for q in both surveys.

			Pre-fishery forecast biomass				**Available harvest**		
Stock	SSB	4+ Biomass	Poor	Average	Good	Cutoff	Poor	Average	Good
HG	15,244	10,395	13,285	17,149	27,002	10,546	2,657	3,430	5,400
PRD	22,828	13,037	15,574	18,263	25,897	21,386	0	0	4,511
CC	8,696	3,458	5,890	8,437	14,690	15,341	0	0	0
SOG	59,247	30,220	45,204	57,184	75,655	31,659	9,041	11,437	15,131
WCVI	5,587	1,893	6,308	10,303	17,272	13,127	0	0	3,454

Were not completely comfortable with the q estimates, but we believe the approach used to develop the informative prior for q is better than the ad hoc q=1 assumption. Assuming q=1 is more conservative.