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Petrale sole (*Eopsetta jordani*) in British Columbia, Canada:Stock Assessment for 2006/07 and Advice to Managers for 2007/08

Plie de Californie (*Eopsetta jordani)* en Colombie-Britannique (Canada) : Évaluation des stocks pour 2006-2007 et conseils aux gestionnaires pour 2007-2008

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ABSTRACT

Information pertaining to Petrale sole (*Eopsetta jordani)* in British Columbia was reviewed and updated for inclusion in a delay-difference stock assessment model. This model was used to determine the status of this coastwide stock and to provide quantitative advice on levels of catch and the associated risk relative to selected management performance indicators.

A range of model uncertainties was explored through sensitivity runs which varied model assumptions which could not be easily reconciled through inspection of the model fits to the data. Four pairs of alternative model assumptions were investigated: a) estimating *M*, the rate of instantaneous natural mortality through the use of mean weight data sampled from the fishery or fixing *M* at the preferred value of 0.20 and dropping the mean weight data; b) varying the age of knife-edged recruitment between age 6 and age 7; c) applying a single CPUE series for the entire model period, effectively assuming that the fishery catchability has been constant for 40 years or splitting the CPUE series between 1995 and 1996 in recognition of the severe management restrictions that were applied at that time; d) estimating alternative standardised CPUE series based on different data selection criteria: one set of criteria was suggested by fishing industry representatives to optimise the data for Petrale sole and the other data set used criteria that allowed more peripheral data into the data set.

Model results showed that within the range of the criteria investigated, the effects of fixing or estimating *M* and the age of knife-edge recruitment were relatively minor, with the management advice almost identical across these options. However, the effect of splitting the CPUE series was major, with the model estimating a drop in catchability in recent years and consequently being much more optimistic about stock status. Finally, the CPUE series optimised for Petrale sole indicated a much stronger recent rebuild for this species and thus also provided more optimistic advice.

The split CPUE series model runs using the CPUE series optimised for Petrale sole predicted that the stock would increase over the next 5 years as well as stay above the B_{ref} and B_{min} reference points with a high probability (greater than 90%) at removals equal to the 2006 TAC (600 t). The split CPUE series using the wider data selection criteria did not predict that the stock would increase over the next five years, but there was an 80 to 100% probability that the stock would stay above the B_{ref} and B_{min} reference points (again at levels of removal equal to the 2006 TAC). On the other hand, the runs which assumed a single CPUE series with constant catchability over the past 40 years had a low probability of increasing at the beginning of 2012 (31–41%) while there were even lower probabilities of exceeding B_{ref} (9 to 43%) at levels of removal equal to the 2006 TAC. The probability for the single CPUE runs exceeding the B_{min} reference point were acceptable, ranging from 64–81%. The lack of capacity to predict a stock size increase over the next 5 years at levels equivalent to the 2006 TAC in several of the model runs was a result which may originate from the use of mean recruitment to drive the predictions. There is some evidence from the model fits that recruitment over the most recent 10 years is about 10% above the mean which may mean that the stock projections are conservative.

RÉSUMÉ

L’information concernant la plie de Californie (Eopsetta jordani) en Colombie-Britannique a été passée en revue et mise à jour afin d’être incluse dans un modèle d’évaluation des stocks à différence retardée. Le modèle a été utilisé pour déterminer l’état de ce stock d’un bout à l’autre de la côte et pour formuler un avis quantitatifs sur les niveaux de prises et les risques s’y rattachant relativement aux indicateurs de rendement de gestion sélectionnés.

Une plage d’incertitudes liées au modèle a été explorée en exécutant le modèle aux fins de l’analyse de la sensibilité. Ces incertitudes offraient une variété d’hypothèses de modèle qui ne pouvaient pas faire l’objet d’un rapprochement facile par l’inspection des degrés d’adaptation des modèles aux données. Quatre paires d’hypothèses de modèle de rechange ont fait l’objet d’enquêtes : a) l’estimation de M, le taux de mortalité naturelle instantanée en utilisant les données de poids moyen échantillonnées à partir des pêches ou en établissant M à la valeur préférée de 0,20 et en laissant tomber les données de poids moyen; b) la variation de l’âge de recrutement bien tranché entre l’âge de 6 ans et l’âge de 7 ans; c) l’application d’une simple série de CPUE pour la période complète du modèle, en assumant réellement que la capturabilité des pêches a été constante pendant 40 ans ou en divisant la série de CPUE entre 1995 et 1996 en reconnaissance des restrictions de gestion rigoureuses qui s’appliquaient à l’époque; d) l’estimation d’autres séries normalisées de CPUE fondées sur des critères de sélection de données différents : un ensemble de critères a été suggéré par les représentants de l’industrie de la pêche pour optimiser les données relatives à la plie de Californie, et l’autre ensemble de données a utilisé des critères qui rendaient possibles des données plus périphériques dans l’ensemble de données.

Les résultats de modèle ont démontré qu’à l’intérieur de la plage des critères étudiés, les effets de l’établissement ou de l’estimation de M et de l’âge de recrutement bien tranché étaient relativement peu significatifs, les conseils de gestion étant presque identiques pour toutes les options. Par contre, l’effet résultant de la division de la série de CPUE était considérable, le modèle estimant une baisse de la capturabilité ces dernières années; par conséquent, il aboutissait à des résultats beaucoup plus optimistes en ce qui a trait à l’état des stocks. Finalement, la série de CPUE optimisée pour la plie de Californie indiquait un rétablissement récent beaucoup plus robuste de cette espèce et, ainsi, formulait également des conseils plus optimistes.

Les séquences d’utilisation du modèle de la série de CPUE divisée au moyen de la série de CPUE optimisée pour la plie de Californie prévoyaient que les stocks seraient à la hausse au cours des cinq prochaines années et qu’ils resteraient au-dessus des points de référence Bref et Bmin avec une grande probabilité (au-delà de 90 %) à des prélèvements égaux au TAC de 2006 (600 t). La série de CPUE divisée en utilisant les critères de sélection de données plus vastes ne prévoyait pas que les stocks augmenteraient au cours des cinq prochaines années, mais il y avait de 80 à 100 % de probabilité que les stocks resteraient au-dessus des points de référence Bref et Bmin (encore une fois à des niveaux de prélèvement égaux au TAC de 2006). D’autre part, les séquences d’utilisation du modèle qui présupposaient une simple série de CPUE avec une capturabilité constante au cours des 40 dernières années avaient une faible probabilité d’augmentation au début de l’année 2012 (de 31 à 41 %), tandis qu’il y avait des probabilités encore plus faibles d’excéder le point de référence Bref (de 9 à 43 %) à des niveaux de prélèvement égaux au TAC de 2006. La probabilité que les séquences d’utilisation de la série simple de CPUE excèdent le point de référence Bmin était acceptable, variant de 64 à 81 %. Le manque de capacité de prévoir une augmentation de la taille des stocks au cours des cinq prochaines années à des niveaux équivalents au TAC de 2006 dans plusieurs des séquences d’utilisation de modèle constituait un résultat qui pouvait avoir son origine dans l’utilisation du recrutement moyen apte à déclencher des prévisions. En apportant des ajustements au modèle, il existe certaines preuves que le recrutement au cours des 10 années les plus récentes se situe approximativement à 10 % au-dessus de la moyenne, ce qui peut signifier que les prévisions de stocks sont conservatrices.

INTRODUCTION

The groundfish resource in British Columbia (B.C.) increased in importance in the late 1970s with the implementation of Extended Jurisdiction in 1977 and subsequent expansion of the domestic fleet. Recommendations for quota management of groundfish species were not forthcoming until 1979 (Ketchen 1980). Since that time, detailed and interim assessments for various flatfish species have been conducted annually including recommendations for catch limitations. Assessments of Petrale sole (brill) were conducted in 1998 (Fargo 1999) and 2003 (Starr and Fargo 2004).

It is thought that Canadian landings of Petrale sole in the B.C. trawl fishery averaged near 3000 t per year between the late 1940s and the late 1950s, but catch information from that period are only available in summarised form without access to underlying data and are considered unreliable. U.S. trawlers that were allowed to fish in Canadian waters also landed substantial amounts. By the mid 1960s, landings had decreased (Figure 1) and it is thought that Petrale sole abundance had declined substantially (Ketchen and Forrester 1966).

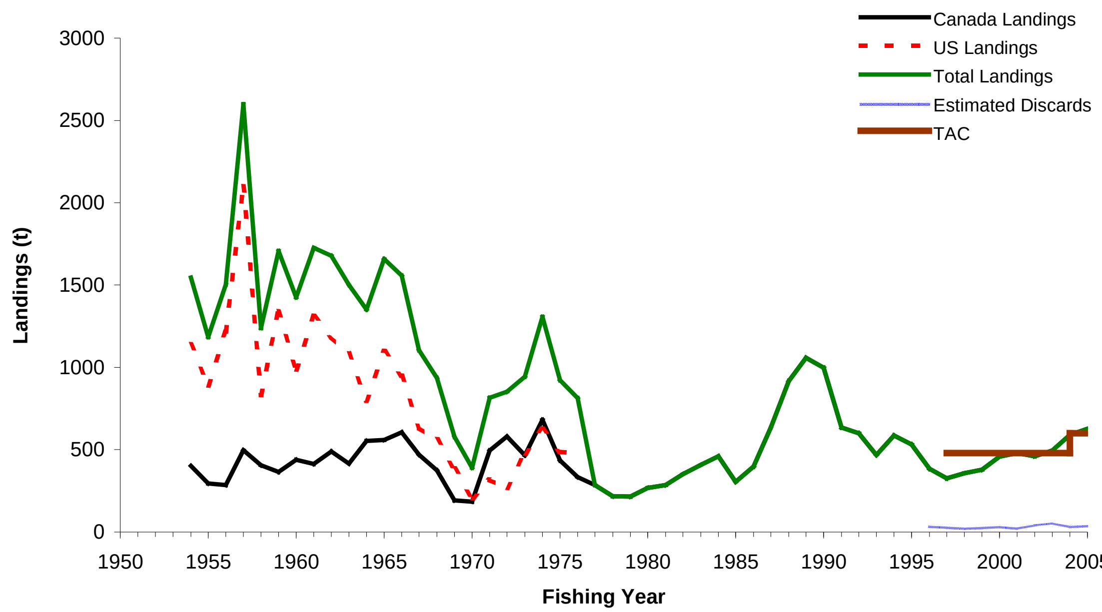

Figure 1. Historical landings of Petrale sole: 1954–2006. Years represent the first half of the 1 April–31 March fishing year (e.g. 2005=2005/06). US catches from Fargo (1999); Canadian catches from the *GFCatch* and *PacHarvTrawl* databases.

By the 1970s, analyses were conducted which concluded that Petrale sole were at a low level of abundance compared to the 1940s and 1950s, but also concluded that environmental factors were probably the main cause of the decline in abundance (Pedersen 1975). Stocks remained at apparent low abundance in the 1980s and 1990s and a TAC of 497 t was established for this species in 1997 (Figure 1). This level of catch reduced the capacity to target this species while permitting bycatch when fishing for other associated groundfish species. Reports from operators that the abundance of Petrale sole was increasing led to an assessment of this species in late 2003. That assessment indicated that stock abundance had most likely increased and that an incremental increase in harvest could be allowed. Accordingly, the coastwide TAC for Petrale sole was increased in April 2004 to 600 t (Figure 1). However, operators on the west coast have continued to report that abundance for this species has increased and that a high level of incidental catch is causing difficulties when fishing for other associated species.

Petrale sole is an important component of the offshore ecosystem. This is particularly relevant as investigators shift their emphasis from single species to multi-species or ecosystem assessment. Previous studies indicate that this species is a top end predator whose diet overlaps with that of Arrowtooth flounder (adult and juvenile), dogfish, Pacific cod (adult and juvenile), Pacific halibut, sand sole and several rockfish species. The adults also show more dependence on herring as a food item than any other allied species. Petrale sole also consume cephalopods, euphausiids and shrimp (Pearsall & Fargo 2007). Juvenile Petrale sole are prey items for large pollock, Pacific cod and spiny dogfish.

A general increase in catch and effort across groundfish species and areas beginning in about 1988 and peaking in the early 1990s was at least in part the result of competition for fishing history in anticipation of the application of individual quota management (IVQ). The IVQ qualification period ran from 1988 to 1992 and the formula based in part on aggregate landings in this period was used to allocate the total allowable catch by species. Consequently many species showed marked increases in landings and effort during this period which are unlikely to be related to changes in abundance. This may be a possible explanation for the large increase in Petrale sole landings, with a noticeable peak spanning from 1988 to about 1992 (Figure 1).

The objectives of this working paper are taken from the "Request for a working paper" submitted by DFO Groundfish Management in September 2006:

> "*To provide an assessment of the Petrale sole population in all the waters off Vancouver Island, Queen Charlotte Sound and Hecate Strait (Areas 3C, 3D, 5A, 5B, 5C and 5D). These assessments will provide estimates of stock status relative to an agreed target reference point as well as recommendations for levels of removals which will allow this population to reach the target. The assessment should include all available information, including surveys, biological sampling, catch records, logbooks, observer reports and fishing practices for Petrale sole. This assessment will provide the basis for the management of the 2007/08 fishery for Petrale sole in the designated management areas.*"

The above objectives have been interpreted as follows:

1. Review the available stock assessment data for Petrale sole in B.C. and evaluate their potential for supporting quantitative stock assessment;
2. Summarise the biological information for Petrale sole
3. Conduct quantitative stock assessments for all of B.C. to describe current stock status and summarise stock projections relative to selected performance measures;

This document consists of a main document with supporting Appendices A through E that contain the detailed analyses supporting the conclusions presented in the main section of the document. A list of the documents and their contents can be found in the text table immediately following. Tables and figures referred to in the main text are sequentially numbered. Tables and figures in appendices are labelled with the letter code of the appendix and a sequential number, e.g., Table B.2 for the second table in Appendix B. Equations presented in the main text are numbered sequentially, as are equations within each appendix.

Description of document components

Document number	Contents
Main document	Introduction, summary of the assessment results and recommendations
Appendix A	Biological information used in the assessment
Appendix B	Results of GLM modelling used to generate fishery dependent abundance indices for use in the stock assessment model
Appendix C	Generation of fishery independent survey indices for use in the stock assessment model
Appendix D	Description and modelling results for the delay-difference stock assessment model
Appendix E	Comparison of current decision table results with the equivalent decision tables presented to PSARC (DFO [2007])
Appendix F	Request for Working Paper for updated Petrale sole assessment

STOCK ASSESSMENT FOR 3CD5ABCD PETRALE SOLE

Methods

The Petrale sole stock in the combined regions of 3CD5ABCD (west coast Vancouver Island, Queen Charlotte Sound and Hecate Strait) were assessed using a combined sex delay-difference model tuned to biomass indices derived from fishery catch per unit effort (CPUE) data confined to the areas listed above (Appendix B) and to mean fish weight data derived from samples of commercial landings in any area of B.C. (Appendix A). Data from the west coast of the Queen Charlotte Islands were not included in the CPUE analysis due to the small amount of catches in this region and the concern that it may possibly be indexing another population (Appendix B).

A number of surveys exist which potentially index Petrale sole. These are listed in the text table below, including whether they were used in the assessment, as well as some reasons for not using the survey if that was done. While the survey data were included in the model they generally have less impact on the results than the CPUE series.

Survey	Period covered	Status	Comments
WCVI Shrimp survey	1975–2006	Not used	Concerned only indexing Petrale sole juveniles; very erratic indices requiring too much process error to be added
WCVI Triennial survey	1980–2001	Used	Transect survey; treated as if random stratified (documented in Starr & Fargo 2004)
QC Sound synoptic	2003–2005	Used	Good CVs in 2003 and 2004; ongoing survey (Appendix C)
QC Sound shrimp	1999–2006	Not used	Concerned only indexing Petrale sole juveniles; erratic indices
Hecate Strait Pacific cod monitoring survey	2002–2004	Not used	Short time series; designed for Pacific cod; unclear if it will be repeated
Hecate Strait assemblage	1983–2003	Used	Treated as if a random stratified design (documented in Starr & Fargo 2004)

A delay-difference model approach (Appendix D) was adopted for this assessment because there are insufficient catch-at-age data to adequately inform a statistical catch-at-age model (Appendix A). However, the delay-difference model is fundamentally a reduced age-structured model which requires some age information to establish the age for knife-edged recruitment. The delay-difference model assumes that all fish older than this age are vulnerable to the fishery while younger fish do not enter the fishery. This is a simplistic assumption and the generally poor model residuals may reflect the failure of this assumption in some situations. The approach adopted for this assessment was to generate growth and length-weight parameter estimates outside of the model using the available growth and the length-weight information. This information was then used to establish the most likely age which would result in the observed mean weights in the fishery. This approach reduced the leverage resulting from potential model misspecification when fitting to the mean weight data, a problem that has been criticised by reviewers in previous assessments using this model (e.g., Starr et al. 2006).

Commercial catch rates were standardised using a generalised linear model (GLM) procedure, and two sets of standardised indices were fitted, each representing a different biomass trajectory in the most recent few years (Appendix B). One CPUE series was generated using a wide definition of the time, area and depth range where Petrale sole might be taken. The second standardised CPUE series was developed in consultation with members of the fishing industry who recommended specific time periods, areas and depth ranges for evaluating this species, with the exclusion of the remaining data. This process retained about ¼ of the data used in the analysis based on the wider selection criteria (Appendix B). The second analysis resulted in a trajectory similar to the model based on the “wide” selection criteria, differing mainly in the most recent two or three years where the more restricted data set showed a much greater upturn in CPUE compared to the series using the “wide” data selection criteria. Both CPUE series were used in this assessment.

Previous assessments on the west coast of Canada have treated the CPUE series as having a constant proportional relationship to biomass throughout the time period. This assumption is very strong, linking historical catch rates from the 1960s and 1970s to the present by assuming that catchability (i.e., the proportion of biomass taken by a unit of effort) has not changed over the entire period. This assumption is tenuous in the most recent 10 years, when most commercially important species have had TAC limits applied, accompanied with 100% observer coverage to ensure that every vessel accounts for its entire catch and bycatch by species. This is in marked contrast with the earliest years (the 1960s and 1970s) when there were essentially no management constraints, followed by the application of trip limits by species and other management tools which would likely affect catch rates. There are other trends, such as the introduction of GPS (global positioning), better instrumentation (such as depth sounders) and larger and more powerful vessels which should likely increase the relative catchability per unit of effort. In an attempt to acknowledge the existence of these changes, this model has included the capacity to fit multiple CPUE series, thus estimating separate catchability parameters for each series. This capacity was investigated by splitting the CPUE series between 1995/96 and 1996/97. This is one year prior to the establishment of the current transferable quota system, but it also is when the high level of mandatory observer coverage was introduced. The split was moved as far back in time as was reasonable to make the second series as long as possible. It is felt that this approach should work well in the context of the delay-difference model because this type of model treats the mean weight as absolute (i.e. total annual biomass divided by number of vulnerable fish), thus not allowing large changes in biomass over the period of the split.

The stock assessment model used here is nearly identical to the model used by Sinclair and Starr (2005) to assess Pacific cod in Hecate Strait and by Starr et al. (2006) to assess rock sole in Queen Charlotte Sound, with a few exceptions:

- no environmental variable was available to tune the recruitment deviations;
- five year projections using randomly drawn recruitment deviations were used;
- the CPUE indices could be split into multiple series and fitted separately.
- An error was discovered in the code used in previous versions of this delay-difference model (Sinclair et al. 2001, Starr et al. 2002, Starr & Fargo 2004, Sinclair & Starr 2005, Starr et al. 2006) and it was present in the version of this assessment presented to the Groundfish Subcommittee of PSARC in January 2007 (DFO 2007). This error concerned the method by which the mean weight in the initial year was calculated and resulted in always using the mean weight associated with the unfished biomass in the first year of the assessment reconstruction. This error has been corrected in the current version (see Appendix D for a more detailed description of the nature of the error and how it was fixed. A comparison between the decision table results presented in DFO(2007) and Appendix D can be found in Appendix E).

The stock assessment investigated the following factors which contribute to the overall uncertainty through a series of 12 alternative model runs (listed in Table 1), each of which incorporated various aspects of the hypotheses listed below:

1. the effect of using a single or split CPUE series to describe the relationship between the catch and abundance. A split series recognises that changes in the management of the fleet has affected the proportion of the biomass which is taken by the fleet;
2. the effect of applying two alternative CPUE series: one based on a restricted selection of data proposed by representatives of the fishing industry and the second based on a wider definition for selecting the data;
3. the effect of estimating or fixing the M parameter. An informed Bayesian prior was applied to the M parameter when it was estimated and the weight data were not fitted when M was fixed at its preferred value of 0.2;
4. the age of knife-edge recruitment was tested by fitting models using growth models based on a knife-edge recruitment age (r) of r=6 or r=7. Note that the previous delay-difference model for Petrale sole used a knife-edge recruitment age r=4 (Starr & Fargo 2004).

Stock assessment projections

A Bayesian approach, based on the Markov Chain Monte Carlo (MCMC) algorithm (Gelman et al. 1995), was used to estimate the joint posterior distributions of model parameters and to make projections for five years from 2007 to 2011 across a range of fixed catch options. Four of the 12 investigated model runs (Table 1) exhibited poor MCMC convergence behaviour after an initial exploration involving 40 X 10^6 sample iterations (sampled once in every 40,000 iterations). Extending the MCMC sampling to 500 X 10^6 sample iterations, with sampling once every

500,000 iterations, markedly improved the convergence performance for two of these four model runs, marginally improved a third and left the fourth and final model run still unconverged (see discussion on this point Appendix D, beginning on page D.8). Therefore, results for this final model run (`split CPUE series/`*r*`=6/wide rules/fix`*M*) should be interpreted with caution and probably should not be considered when proposing management advice.

Five year projections were made from the posterior distribution of the terminal biomass with recruitments drawn randomly from a distribution in log-space of mean=0 and standard deviation=0.4 (which is the assumption for recruitment variation during the fitting phase). The projections are made starting from the 2007 beginning year biomass across a number of fixed catch options, ranging from 0 to 1000 t in 100 t steps. The resulting biomass levels for each year from 2008 were evaluated against four performance indicators to generate a decision tables that can be used to provide management advice.

The performance indicators selected for this stock assessment are:

1. Exploitation rate in 2007–2011 relative to the average exploitation rate from 1966 to 2006 $\left(U_{ref} = \text{mean}\left\{U_t\right\}_{t=1966}^{2006}\right)$;

2. Beginning year biomass in 2008–2012 compared to the minimum biomass over the 1966-2006 period $\left(B_{ref} = \min\left\{B_t\right\}_{t=1966}^{2006}\right)$;

3. Beginning year biomass in 2008–2012 compared to the average biomass from the 1977-1984 period: $\left(B_{ref} = \text{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$. This period was selected as one of relative stability from which the stock has declined and recovered;

4. Beginning year 2008–2012 biomass compared to the beginning year biomass in 2007 $\left(B_{ref} = B_{2007}\right)$.

Two quantities were calculated for the three performance indicators that reference biomass levels (indicators 2, 3 and 4):

The cumulative probability that each draw from the MCMC posterior distribution would exceed one of the three biomass reference levels in year *y*: $\mathrm{P}\left(\tilde{B}_y > B_{ref}\right)$;

The expected value from the MCMC posterior distribution of the ratio of the biomass in year *y* relative to one of the three biomass reference levels: $\mathrm{E}\left(\tilde{B}_y \big/ B_{ref}\right)$;

Only the cumulative probability in year 2011 that the exploitation rate would be below the reference exploitation was calculated for the first performance indicator $\mathrm{P}\left(U_{2011} < U_{ref}\right)$.

These performance measures are based on management targets selected from the historical biomass trajectory. Such management targets are necessarily arbitrary but are preferred over model-based reference points that use derived parameters such as B_0 or B_{MSY} because these latter parameters are usually poorly estimated, being very sensitive to assumptions made for parameters that are difficult to estimate, such as *M* or *h*. B_0 and B_{MSY} are also sensitive to the relative weighting among catch, average fish weight, or survey indices, and often change over time as more data are added to the analysis or as the stock assessment model evolves, while historical management targets tend to be more stable because they are defined as relative targets.

The B_{min} reference point does not work well for series where the biomass trend is continuously downward. This is the case for some of the single CPUE series MPD fits, where the stock has not recovered above the average biomass for the reference period (e.g., see Figure D.7 and Figure D.8). Therefore, this reference point should be discounted for the single CPUE series model runs which use the “wide selection” for generating the CPUE abundance indices. However, this is not the case for the split CPUE model runs or the single CPUE runs based on the “CGRCS selection rules”, where there is a clearly defined minimum and the stock has moved above the average biomass for the reference period (e.g., Figure D.9 to Figure D.12).

Another advantage of using reference points which are based on a historical period is that such reference levels are more comprehensible to stakeholders and there frequently exists institutional memory of these periods. In addition, there is always the option of changing the reference period if, once attained, it seems for some reason to be unsuitable. Reference points which are external to the model estimation process also tend to be better behaved when evaluated with MCMC search algorithms (see discussion on this point in Appendix D, page D.10).

Results

Two of the four sources of model uncertainty investigated in this assessment appear to be relatively unimportant while two others are sources of considerable uncertainty which cannot be resolved on the basis of the available data. The two sources of relatively minor uncertainty are a) the choice of the age of knife-edge recruitment between age 6 and age 7; and b) whether M is fixed at a value of 0.20 (and the mean weight data are discarded) or estimated using an informed prior with mean 0.20 and standard deviation of 0.20 as well as including the mean weight data. Fixing M=0.20 is like specifying an extremely tight informed prior because no variation is allowed around this value. For this latter reason, the models which estimate M are preferred to the fixed M models because they allow additional uncertainty in the model runs which estimate this parameter without straying too far from the commonly accepted values.

Examples of the lack of sensitivity to these two sources of uncertainty can be seen when comparing the cumulative probabilities of the performance indicator $\mathrm{P}\left(B_{2012} > \mathrm{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for model runs which differ in how M is estimated or in the value used for r while holding the other factors constant such as the rules used to evaluate the CPUE data: the “CGRCS rules” (Figure 2) or the “wide rules” (Figure 3). The cumulative curves for the four options nearly lie on top of each other when using the “CGRCS rules” (Figure 2) but there is some divergence between runs when using the “wide rules” (Figure 3). Because these alternative model runs overlap, the management advice arising from these model runs would be nearly identical. Comparisons between the same runs based on the other three performance measures have similar outcomes: the management advice will be similar across these runs. Note that it is the run $\texttt{split CPUE series}|r=6|\texttt{wide rules}|\texttt{fix}M$ which is quite different than the other runs in Figure 3. This is the run that has poorly converged (see Figure D.28) and the fact that this run differs from other similar runs may be caused by the lack of convergence.

The other two sources of model uncertainty are much more important. These are a) whether we choose to use a single CPUE series or split the series into two in recognition of the changes in management that were instituted in 1996 and 1997 and b) whether we choose to use the CPUE series that is based on relatively narrow data selection rules targeted at Petrale sole ("CGRCS rules") or use the CPUE series that resulted from a wide, and more inclusive, data selection procedure ("wide rules").

Examples of the greater sensitivity of the management advice to these two sources of uncertainty can be seen when comparing the cumulative probabilities of the performance indicator $\mathrm{P}\left(B_{2012} > \mathrm{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for model runs which differ in whether a single or a split CPUE series is applied while holding other factors relatively constant. Figure 4 holds the age of recruitment to r=6 and uses the "CGRCS rules", comparing across the number of CPUE series and the M estimation type while Figure 5 also holds the age of recruitment to r=6 and uses the "wide rules", thus also comparing across the number of CPUE series and the M estimation type. For both graphs, the cumulative probability curves differ more for the change in the number of CPUE series than for the M estimation type , indicating that different management advice would be given, depending on which assumption for number of CPUE series is used.

The assumption of constant catchability over a forty-year period is very strong and the models using this assumption appear to be extremely pessimistic, which contradicts the anecdotal reports which are being received from the fishery. It seems likely that, given these reports and the strong likelihood that catchability has changed over time, the model which splits the CPUE between 1995/96 and 1996/97 should be preferred over the model which treats the CPUE as single series. It should be noted, however, that there was insufficient time to investigate alternative splits in the CPUE series. Note again that it is the run `split CPUE series|`r`=6|wide rules|fix`M which appears to be outside the range of the other runs, again confirming the non-convergence with this model run.

The choice between which sets of selection rules should be used to construct the two CPUE series is less clear. The cumulative probability curves are less divergent than was the case for the single and split CPUE series (Figure 6 and Figure 7), but the management advice will differ depending on which set of data selection rules is considered to be more reliable for the construction of the CPUE series used in the assessment. The "CGRCS selection rules" focussed specifically on optimising the data for Petrale sole while the "wide selection rules" procedure allowed data into the model which would be considered more peripheral to this species. On this basis, the "CGRCS" series should probably be preferred, simply because it is more targeted at Petrale sole. However, this has resulted in an unbalanced model which was forced to make some relatively strong assumptions in how to deal with possible areaXyear interactions. It should be noted that the "wide" selection model is also unbalanced and is probably affected by similar problems, but may benefit from having more data to use for estimating explanatory coefficients. Therefore, selecting between the two CPUE series is not straightforward. A possible recommendation would be to use the "CGRCS" series as the primary source of advice but to consider the probabilities provided by the "wide" CPUE series before finalising the advice.

The two CPUE series derived from the alternative selection process (“CGRCS” and “wide”) agree that the current TAC provides a high probability (nearly 100% for all runs) that the stock will stay above the $\min\{B_t\}_{t=1966}^{2006}$ reference point, with little attenuation over the range of catch levels presented (Figure 8 and Figure 9). Note that these observations only apply to the model runs with split CPUE series and the single CPUE series using the “CGRCS selection rules” because the probabilities and expected values for the B_{min} performance indicator for the single CPUE model runs using the “wide selection rules” should be severely discounted (page 7).

The split CPUE runs using the “CGRCS selection rules” predict that there is a 70–80% probability that the biomass will increase over the next five years if removals equal the current TAC (Figure 10 and Figure 11). The equivalent runs using the “wide selection rules” predict that the biomass will decrease over the same period, with the exception of the unconverged run $(\texttt{split CPUE series}|r=6|\texttt{wide rules}|\texttt{fix}M)$ (Figure 10 and Figure 11). All the single CPUE runs predict that there is a less than 50% probability the biomass will decrease, regardless of the selection rules, at removals equal to the current TAC (Table 2).

Table 1. Mean exp(recruitment_deviations) for the entire series and the most recent 10 years from the MPD fits for each of the 10 runs presented in this assessment. Detailed descriptions of each of these model runs, including the hypotheses tested and assumptions can be found in Appendix D.

Run Number	**Run description**	$e^{\left(\frac{\sum_{t=1966}^{t=2006-r+1}(\phi_t)}{\left[(2006-r+1)-1966\right]}\right)}$	$e^{\left(\frac{\sum_{t=2006-r-9}^{t=2006-r+1}(\phi_t)}{\left[(2006-r+1)-(2006-r-9)\right]}\right)}$
Case 1	single CPUE series | r = 6 | CGRCS rules | est M	1.000	1.089
Case 2	single CPUE series | r = 6 | CGRCS rules | fix M	1.000	1.101
Case 3	single CPUE series | r = 6 | wide rules | est M	1.000	1.028
Case 4	single CPUE series | r = 6 | wide rules | fix M	1.000	1.044
Case 5	split CPUE series | r = 7 | CGRCS rules | est M	1.000	1.085
Case 6	split CPUE series | r = 7 | CGRCS rules | fix M	1.000	1.069
Case 7	split CPUE series | r = 7 | wide rules | est M	1.000	1.164
Case 8	split CPUE series | r = 7 | wide rules | fix M	1.000	1.122
Case 9	split CPUE series | r = 6 | CGRCS rules | est M	1.000	1.146
Case 10	split CPUE series | r = 6 | CGRCS rules | fix M	1.000	1.043
Case 11	split CPUE series | r = 6 | wide rules | est M	1.000	1.219
Case 12	split CPUE series | r = 6 | wide rules | fix M	1.000	1.129

So while the biomass is predicted to stay above the selected reference levels using either the “CGRCS” or the “wide” CPUE series, Petrale sole were predicted to decline in size over the next five years under landings equivalent to the present TAC for the model runs using the “wide selection rules” or which assume a constant catchability over the past 40 years (e.g., single CPUE series assumption). Figure 1 shows that there have been relatively few years when the reported landings of Petrale sole have exceeded the current TAC since 1966 (15 of the last 40 years), most of which occurred during the 1960s and 1970s. The average landings from 1966 to 2005 have been 610 t. This model assumes average recruitment when making the projections, so it is not surprising that a catch level of around 600 t per year is found to be near the average surplus production. An alternative approach might have been to select randomly from the recent recruitment deviations because the last 10 years have had higher than average recruitment for all model runs (Table 1). The projections presented here could be considered conservative as current recruitment is probably above average, which accounts for the reports of good Petrale sole abundance and which was not taken into account when making these projections.

The probabilities for the beginning year biomass in 2012 for each run and performance indicator are given for the current TAC of 600 t in Table 2. These runs are arranged in pairwise fashion where every paired comparison that can be made is shown side-by-side so that the specific differences can be compared. This table provides the exact probabilities for comparison at the current TAC and at the end of the 5 year projections. All the conclusions presented above are confirmed: the method of dealing with *M* and the age at knife-edge recruitment have relatively small effects compared to the differences generated by the number of CPUE series used in the model or which CPUE selection procedure is used. There are a few model runs where the *M* estimation method makes a difference. For instance, $\mathrm{P}\left(B_{2012} > B_{2007}\right)$ for the "`CPUEx2 r=6 CGRCS`" model run is much better for the run which fixes *M* than the run which estimates *M* (Table 2).

Appendix D provides decision tables for all 12 runs and each performance indicator at catch levels that range from 0 to 1000 t per year in steps of 100 t.

Limitations of this stock assessment

There are insufficient survey data available to serve as fishery-independent abundance indices for population dynamics modelling, and the surveys which are available with longer time series (WCVI shrimp, WCVI triennial and Hecate St assemblage) all have a large amount of process error which reduces their capacity to contribute to the assessment model. The WCVI shrimp survey in particular had so much process error that it had to be dropped after attempting a number of initial fits. Therefore, the CPUE series derived from trawl fishery catch rates is the primary source of stock abundance information in these runs. But there are serious problems with relying on fishery dependent information to assess stock status. For instance, we are generating abundance indices for a single species from commercial data which are likely confounded by the complex multi-species components of this fishery. Management restrictions imposed on other species, especially the necessity to "avoidance fish" because of reaching limits for any number of species, will affect the catch rates. This is in addition to market requirements which will affect targeting behaviour as well as the size of the bags being brought on board. It is now well accepted that restrictions on the catch of Pacific cod in Hecate Strait have affected the catch rates of allied species in the same area since the restrictions were imposed in 2001. In addition, the GLM analyses presented in this paper have not attempted to account for technological improvements over time in fishing gear or vessel electronics (e.g., colour plotters, GPS and other navigational aids) which may cause hyper-stability of catch rates due to increased efficiency. But there is little alternative to the use of these catch rates if a stock assessment is to be prepared for any of these species.

The decision tables provided in this paper give guidance to the selection of short-term TAC recommendations and describe a range of possible future outcomes over the projection period at fixed levels of annual catch. The accuracy of the projections is predicated on the model being correct. Uncertainty in the parameters is explicitly addressed using the Bayesian approach but this only reflects the specified model, which includes the weights assigned to the various data components. Projection accuracy also depends on highly uncertain future recruitment values and the adoption of static harvest policies. For instance, it is likely that the data and the stock assessment will be updated during the time period covered by the projections which in turn would lead to different levels of catch through revised decision tables. A simple projection based on the assumption of a fixed catch policy provides an evaluation of alternative management decisions without any form of feedback. More complex feedback management evaluations are potentially possible but are beyond the scope of this analysis. However, there is value in continuing with this type of analysis in the short term because it can identify possible approaches that can be expanded into the more complex formal feedback evaluations. Analyses such as this one also can identify the strengths and weaknesses of the available data.

Data limitations and research priorities

The following issues should be considered when planning future stock assessments and management evaluations for Petrale sole.

1. There should be a general ageing review for flatfish species: it appears that the current practise is to use port samples to provide ages to monitor the fishery. However, there is a major process of sorting which occurs at sea, with a large proportion of several flatfish species being discarded. This is especially true for species which exhibit sexual dimorphism, such as rock sole and English sole, because most males are discarded for being commercially too small. However, this process is likely to affect other species as well. This seems to be less of a problem for Petrale sole, as is demonstrated by the large proportion of males in the landings. But the entire system of flatfish data collection should be reviewed and possibly updated to reflect current management requirements.

2. There are insufficient ages available to properly assess Petrale. There are about 1600 aged structures in total, which are insufficient to determine if there are regional or annual differences.

3. Single species stock assessments are limited in value when considered in the context of multi-species nature of the fisheries which take these species. More thought should be given to how to progress the management of the species suites that are taken in the BC trawl fleet and what information needs to be collected to accomplish this management.

4. Continue the fishery-independent surveys for regions 3CD, 5AB, and 5CD to reduce the dependency on fishery CPUE data for Petrale sole.

5. While the delay-difference stock assessment model has some advantages because it makes fewer demands for high quality data compared to statistical catch-at-age models, the properties of this model are not well understood. Further use of this model to assess fish stocks should be preceded by simulation modelling to demonstrate the capacity of this methodology to evaluate stock status.

Summary and Recommendations

1. A delay-difference stock assessment model for Petrale sole was fitted to two alternative CPUE series, one was targetted at Petrale sole through using a set of data selection rules optimised for this species that was suggested by fishing industry representatives while the second series was based on selection rules that allowed a wider set of data into the analysis. The standardised CPUE series resulting from the narrower "CGRCS" data selection procedure diverged from the CPUE series based on "wide" data selection mainly at the beginning and end of the series; the difference was most pronounced at the end of the series where the "CGRCS selected series" suggested that the stock had recovered more quickly and strongly than the indices derived from the "wide selection rule". Models fitted to the CPUE series generated from the "CGRCS selection rules" were more optimistic relative to the selected performance indicators than the models fitted to the CPUE series based on the "wide selection rules".

2. The stock assessment modelling explored alternative procedures for dealing with the *M* parameter and the mean weight data, either fixing *M* to a value of 0.20 and dropping the mean weight data or estimating *M*, constrained by an informed Bayesian prior where the mode equalled 0.20 and was fitted to the mean weight data. Comparison of models fitted using either *M* assumption showed that there were relatively small differences between the two alternatives in terms of meeting the performance indicators across the range of the other investigated assumptions. These included the two knife-edged recruitment ages investigated: age 6 and age 7. These two ages were selected because a comparison of the mean weight data from the fishery with the theoretical mean weight of an unexploited population, given a fixed value for M=0.20, was more in line with knife-edge recruitment age r=6 or r=7, rather than r=4 as used in the previous assessment (Starr & Fargo 2004).

3. The stock assessment also investigated using the CPUE indices as either a single series driven by a single catchability parameter, implying a constant relationship between the fishery and abundance over the 40 year period in the model, or splitting the CPUE series between 1995/96 and 1996/97 in recognition of the major changes in the management of the fishery that took place in this fishery during the mid-1990s. The assessments using the single CPUE series were much more pessimistic than the assessments based on the split series, regardless of which set of data selection rules were used, resulting in a strong leftward shift in the performance measures from the split the single CPUE series. It seems unlikely that the models fitted to the single CPUE series are realistic, given the long-term changes in the management of this fishery and general optimism that currently exists within the commercial fleet for this stock. However, model estimates of q for the second series were less than ½ the estimates for the first part of the series, implying that the current fishery is considerably less effective at harvesting this species, which also seems unrealistic. The choice between a single or split CPUE series hypothesis is dependent on whether it is reasonable to conclude that the fishery is presently much less effective than previously.

4. Twelve stock assessment runs investigating four alternative pairs of options are presented in this report. Of these, the effect of estimating *M* and the age of knife-edge recruitment is small in the context of the overall uncertainty in this assessment. It is recommended that the decision tables using knife-edge recruitment age r=6 and the "estimate *M*" options be used to form management recommendations. The "split CPUE" runs explicitly address

recent management changes in the context of the stock assessment model, and it is recommended that the runs using this option be used to form management recommendations. Finally, the choice between the "CGRCS" selected CPUE series and the "wide" selected CPUE series is not clear-cut. It is recommended that the "CGRCS" series be preferred but that the "wide" series also be taken into account when making management recommendations.

5. Both of the recommended runs (`split CPUE series|`$r=6$`|CGRCS rules|est`M and `split CPUE series|`$r=6$`|wide rules|est`M) predict that the stock will stay above the $B_{\min}=\min\{B_t\}_{t=1966}^{2006}$ and $B_{ref}=\text{mean}\{B_t\}_{t=1977}^{1984}$ performance indicators at removals equal to the current TAC (range of probabilities from 85% to 100%). The probabilities that the stock will remain above B_{ref} are still above 70% at catch levels up to 900 t/year for the "CGRCS rules" and up to 700 t/year for the "wide rules". The model using the "CGRCS rules" predicts with a 70% probability that the stock size will increase over the next five years at removals equal to the current TAC while the "wide rules" model predicts (P=27%) a decline under this catch level. The current TAC is near the average catch for the entire period and the projections were done assuming average recruitment. However, examination of recent recruitment deviations indicate that recruitment is about 10% higher than average over the last 10 years and that consequently the projections presented in this assessment may be pessimistic.

6. The reliance of the stock assessment on fishery dependent data is its biggest weakness as it is likely that many considerations other than stock abundance will cause changes in the "abundance" index. The available survey data show large amounts of process error which reduce the usefulness of these data in the model. Finally, the decision tables which form the centre of the management advice in this paper assume constant catch strategies without any form of feedback into the process. As such, these decision tables are only useful for comparing potential alternative management strategies and should not be taken as an actual prediction of the next five years.

7. Considerable uncertainty surrounds much of the available data for Petrale sole and other flatfish species. In particular, the practise of taking the majority of the ageing structures from landed fish should be reviewed in the context of an overall strategy for sampling flatfish in B.C. It may be that ages need to be collected both at-sea and in ports to properly characterise these fisheries.

8. The delay-difference model should be simulation tested to better understand its behaviour before it is used again in a B.C. groundfish stock assessment. The discovery of the error described in detail in Appendix D demonstrates the importance of this step.

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Table 2. Pairwise comparisons of probabilities associated with the four performance indices across related runs (Table 1) in projection year 2011 after applying the current TAC (600 t) for 5 years. Each block of runs compares the probabilities across a single pair of factors while holding the other three factors constant. A complete set of decision tables for all runs and levels of catch for the four performance indicators is provided in Appendix D.

	Performance Indicator							
Factors held constant:	$P\left(U_{2011} > \text{mean}\{U_t\}_{t=1966}^{2006}\right)$		$P\left(B_{2012} > \min\{B_t\}_{t=1966}^{2006}\right)$		$P\left(B_{2012} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$		$P\left(B_{2012} > B_{2007}\right)$	
Estimate or fix *M*:	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***
CPUEx1_*r*=6_CGRCS	0.29	0.37	0.78	0.79	0.31	0.43	0.31	0.39
CPUEx1_*r*=6_wide	0.16	0.14	0.81	0.64	0.12	0.09	0.41	0.33
CPUEx2_*r*=7_CGRCS	0.97	0.98	1.00	1.00	0.98	0.99	0.78	0.73
CPUEx2_*r*=7_wide	0.75	0.90	0.98	0.99	0.82	0.93	0.34	0.51
CPUEx2_*r*=6_CGRCS	0.98	0.97	1.00	1.00	0.98	0.99	0.70	0.77
CPUEx2_*r*=6_wide	0.79	0.96	1.00	1.00	0.85	0.96	0.29	0.73
Age of knife-edge recruitment:	***r*=6**	***r*=7**	***r*=6**	***r*=7**	***r*=6**	***r*=7**	***r*=6**	***r*=7**
CPUEx2_CGRCS_estM	0.98	0.97	1.00	1.00	0.98	0.98	0.70	0.78
CPUEx2_CGRCS_fixM	0.97	0.98	1.00	1.00	0.99	0.99	0.77	0.73
CPUEx2_wide_estM	0.79	0.75	1.00	0.98	0.85	0.82	0.29	0.34
CPUEx2_wide_fixM	0.96	0.90	1.00	0.99	0.96	0.93	0.73	0.51
Number of CPUE series	**CPUEx1**	**CPUEx2**	**CPUEx1**	**CPUEx2**	**CPUEx1**	**CPUEx2**	**CPUEx1**	**CPUEx2**
r=6_CGRCS_estM	0.29	0.98	0.78	1.00	0.31	0.98	0.31	0.70
r=6_CGRCS_fixM	0.37	0.97	0.79	1.00	0.43	0.99	0.39	0.77
r=6_wide_estM	0.16	0.79	0.81	1.00	0.12	0.85	0.41	0.29
r=6_wide_fixM	0.14	0.96	0.64	1.00	0.09	0.96	0.33	0.73
Data selection criteria for CPUE analysis	**CGRCS**	**wide**	**CGRCS**	**wide**	**CGRCS**	**wide**	**CGRCS**	**wide**
CPUEx1_*r*=6_estM	0.29	0.16	0.78	0.81	0.31	0.12	0.31	0.41
CPUEx1_*r*=6_fixM	0.37	0.14	0.79	0.64	0.43	0.09	0.39	0.33
CPUEx2_*r*=6_estM	0.98	0.79	1.00	1.00	0.98	0.85	0.70	0.29
CPUEx2_*r*=6_fixM	0.97	0.96	1.00	1.00	0.99	0.96	0.77	0.73

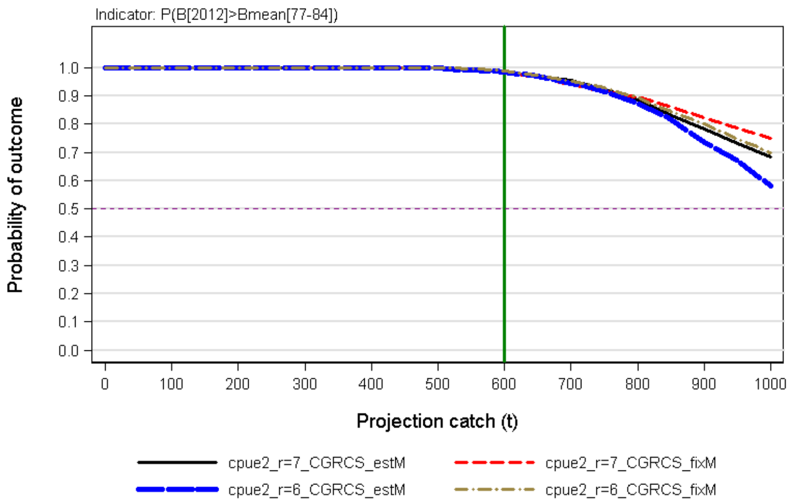


Figure 2. Comparison of $P\left(B_{2012} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$ for four split CPUE series runs using the "CGRCS rules": knife-edge recruitment at age 7 with estimated and fixed *M* and knife-edge recruitment at age 6 with estimated and fixed *M*. Vertical line marks the 2006 Petrale sole TAC (600 t).

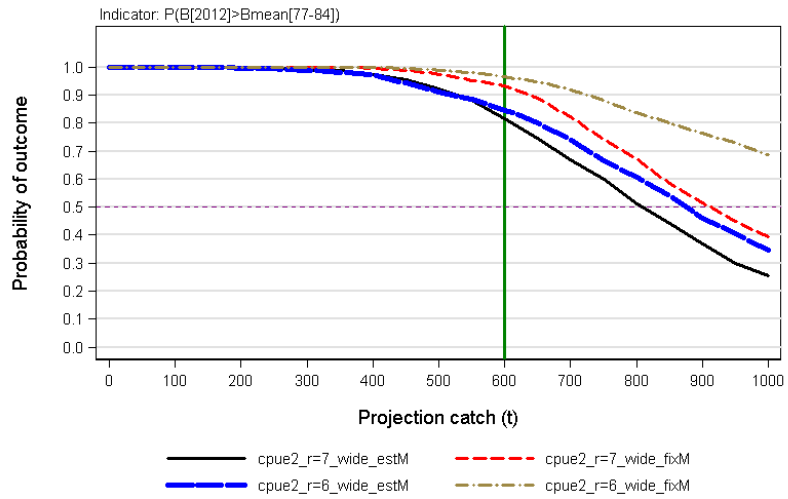


Figure 3. Comparison of $P\left(B_{2012} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$ for four split CPUE series runs using the "wide rules": knife-edge recruitment at age 7 with estimated and fixed *M* and knife-edge recruitment at age 6 with estimated and fixed *M*. Vertical line marks the 2006 Petrale sole TAC (600 t).

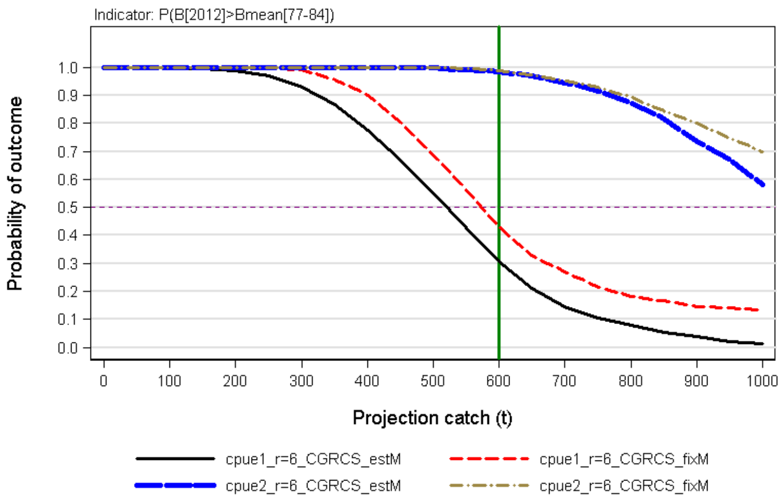


Figure 4. Comparison of $\mathrm{P}\left(B_{2012} > \text{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for four model runs with knife-edge recruitment at age 6 using the CPUE series based on the "CGRCS rules": single CPUE series with estimated and fixed *M* and split CPUE series with estimated and fixed *M*. Vertical line marks the 2006 Petrale sole TAC (600 t).

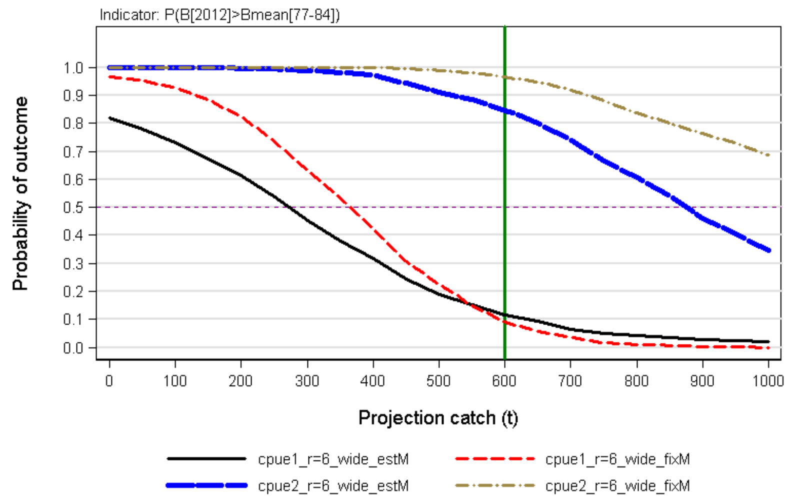


Figure 5. Comparison of $\mathrm{P}\left(B_{2012} > \text{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for four model runs with knife-edge recruitment at age 6 using the CPUE series based on the "wide rules": single CPUE series with estimated and fixed *M* and split CPUE series with estimated and fixed *M*. Vertical line marks the 2006 Petrale sole TAC (600 t).

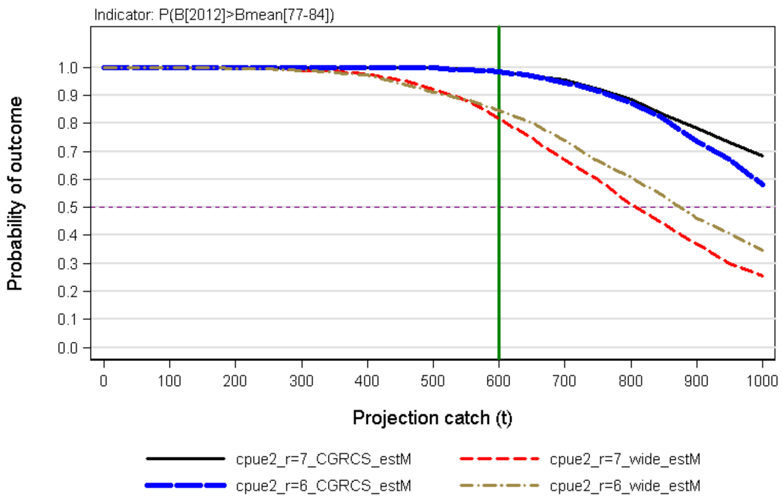


Figure 6. Comparison of $\mathrm{P}\left(B_{2012} > \mathrm{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for four split CPUE series runs which also estimated M: CPUE based on "CGRCS rules" with knife-edge recruitment at age 6 or age 7 and CPUE based on "wide rules" with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

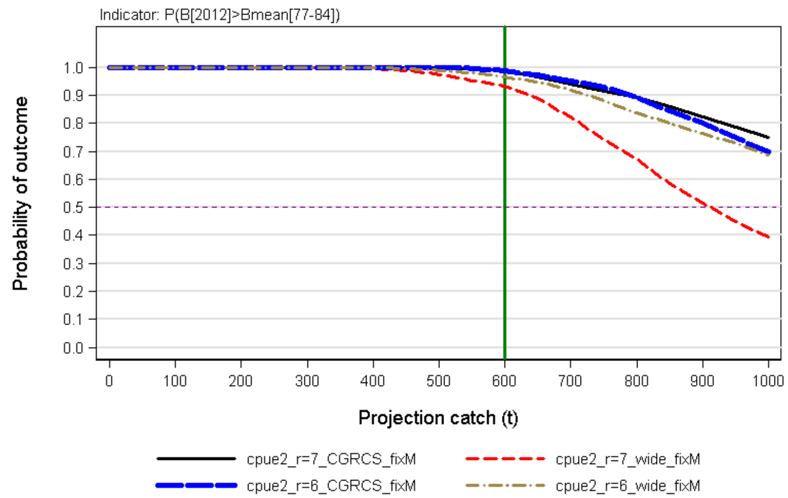


Figure 7. Comparison of $\mathrm{P}\left(B_{2012} > \mathrm{mean}\left\{B_t\right\}_{t=1977}^{1984}\right)$ for four split CPUE series runs which fixed M: CPUE based on "CGRCS rules" with knife-edge recruitment at age 6 or age 7 and CPUE based on "wide rules" with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

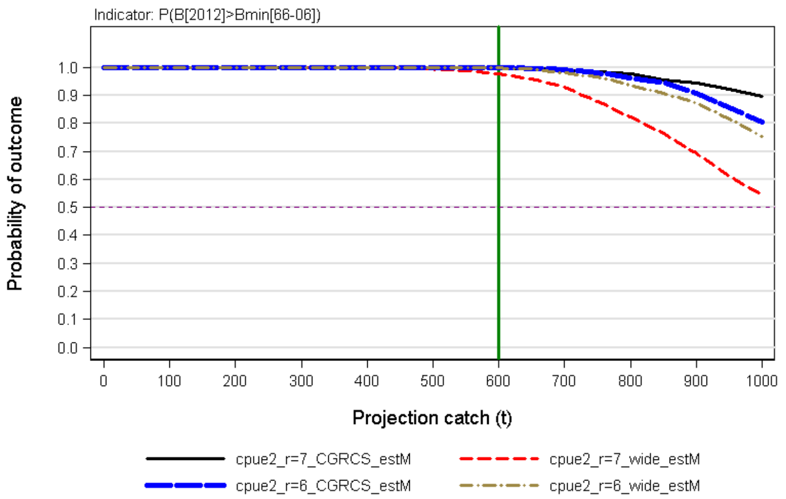


Figure 8. Comparison of $\mathrm{P}\left(B_{2012} > \min\left\{B_t\right\}_{t=1966}^{2006}\right)$ for four split CPUE series runs which also estimated M: CPUE based on "CGRCS rules" with knife-edge recruitment at age 6 or age 7 and CPUE based on "wide rules" with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

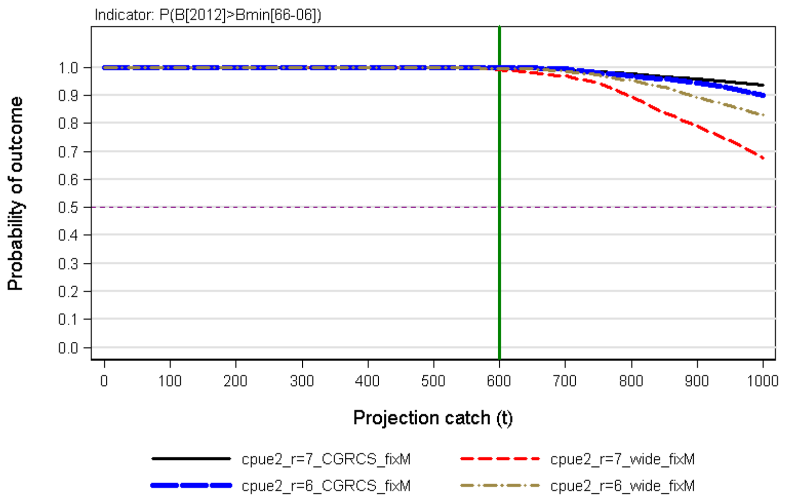


Figure 9. Comparison of $\mathrm{P}\left(B_{2012} > \min\left\{B_t\right\}_{t=1966}^{2006}\right)$ for four split CPUE series runs which fixed M: CPUE based on "CGRCS rules" with knife-edge recruitment at age 6 or age 7 and CPUE based on "wide rules" with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

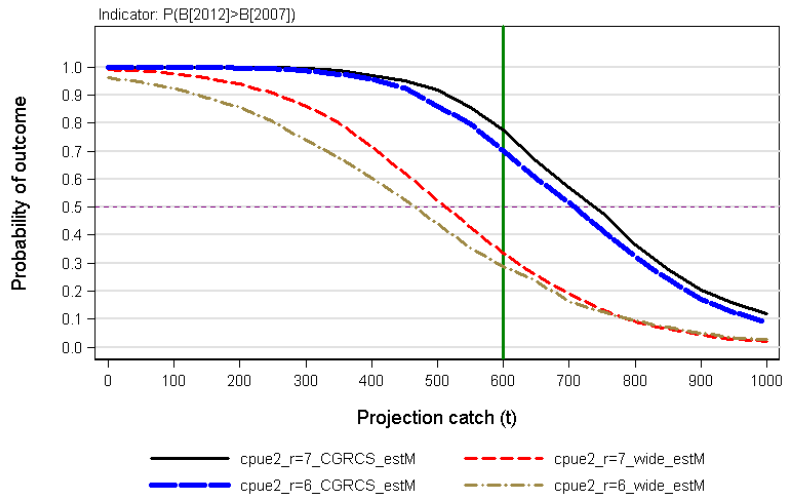


Figure 10. Comparison of $\mathrm{P}\left(B_{2012} > B_{2007}\right)$ for four split CPUE series runs which also estimated *M*: CPUE based on “CGRCS rules” with knife-edge recruitment at age 6 or age 7 and CPUE based on “wide rules” with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

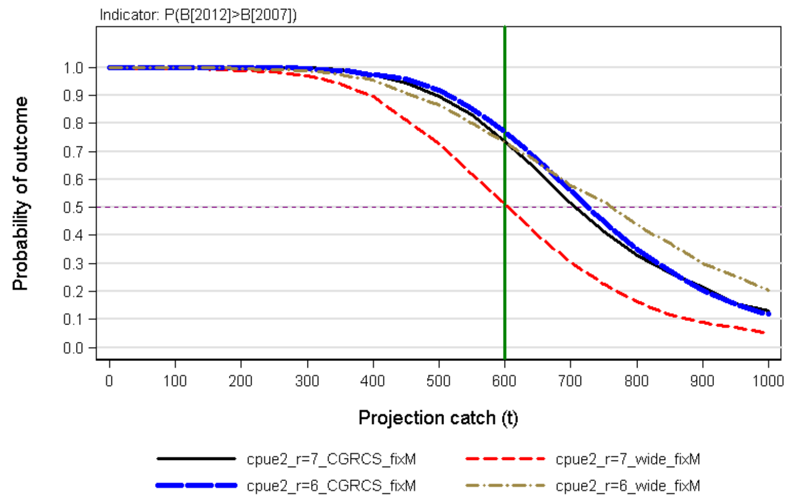


Figure 11. Comparison of $\mathrm{P}\left(B_{2012} > B_{2007}\right)$ for four split CPUE series runs which fixed *M*: CPUE based on “CGRCS rules” with knife-edge recruitment at age 6 or age 7 and CPUE based on “wide rules” with knife-edge recruitment at age 6 or age 7. Vertical line marks the 2006 Petrale sole TAC (600 t).

Appendix A. BIOLOGICAL ANALYSES FOR PETRALE SOLE

Estimation of length-weight parameters

Every record with Petrale sole data was extracted from the biological sample data available in GFBio (extract obtained 05 September 2006). This resulted in recovering 165,888 records distributed by year, sex and combined major area as reported in Table A.1. An additional 6,148 records are missing either sex, length, or date of sampling information.

Table A.1. Distribution of records by sex and combined major DFO reporting region for Petrale sole as recorded in the GFBio database (current to 05 September 2006). These records all have a valid sex code, major DFO area code and a length observation. Records missing one of these values are not included in this table.

	Males						Females					
Year	3CD	4B	5AB	5CD	5E	Total	3CD	4B	5AB	5CD	5E	Total
1953	2,851		443	366		3,660	4,969		679	666		6,314
1954	2,552	53	265			2,870	5,264	67	422			5,753
1955	1,691		69			1,760	3,427		97			3,524
1956	1,199		342	53		1,594	2,059		800	295		3,154
1957	837		879	1,009		2,725	3,012		1,604	2,032		6,648
1958	2,031		1,051	1,535		4,617	3,282		1,910	1,754		6,946
1959	990		462	90		1,542	1,915		1,033	328		3,276
1960	1,151		554	674		2,379	2,304		1,186	1,327		4,817
1961	1,153		423	857		2,433	3,426		1,124	1,009		5,559
1962	1,702		2,494	1,213		5,409	3,089		4,374	1,200		8,663
1963	610		2,018	310		2,938	826		3,015	330		4,171
1964	1,807		1,697	464		3,968	3,813		2,595	787		7,195
1965	1,529		598	703		2,830	3,438		856	1,456		5,750
1966	1,229		1,215	497		2,941	2,848		1,508	962		5,318
1967	1,869		1,123	477		3,469	3,047		1,409	605		5,061
1968	494		475	443		1,412	1,127		810	819		2,756
1969	896					896	1,052					1,052
1970	840			110		950	1,369			173		1,542
1971	1,692			170		1,862	1,564			167		1,731
1972	931					931	1,198					1,198
1973	1,431		153			1,584	2,229		81			2,310
1974	1,408					1,408	2,725					2,725
1975	132					132	204					204
1976	58		32			90	233		187			420
1977	312					312	972					972
1978	390					390	643					643
1979	104					104	229					229
1980	324					324	275					275
1981	851		55	3		909	374		244	6		624
1982	206				279	485	68				20	88
1983	208		232			440	92		68			160
1986	118					118	182					182
1988	277		288			565	37		100			137
1989	206			63		269	94			119		213
1990	199		63	20	134	416	208		86	25	81	400
1991	28			12		40	119			19		138
1992	28			5		33	23			19		42
1993	20		17	19	18	74	29		39	17	19	104

	Males						Females					
Year	**3CD**	**4B**	**5AB**	**5CD**	**5E**	**Total**	**3CD**	**4B**	**5AB**	**5CD**	**5E**	**Total**
1994	7		41	5		53	31		7	4		42
1995	129		86		22	237	125		12		19	156
1996					26	26					21	21
1997	31					31	18					18
1998	76		16	23		115	59		19	52		130
1999	155		7			162	118		18			136
2000			14	63	19	96			83	124	25	232
2001			49	55	4	108			39	83	29	151
2002	55		43	116		214	43		68	258		369
2003	20		192	268	42	522	54		101	510	22	687
2004	304		260	54	64	682	375		216	59	6	656
2005	154		149	331	64	698	244		117	399	42	802
2006	138		6		23	167	141		7		56	204
Total	35,423	53	15,811	10,008	695	61,990	62,973	67	24,914	15,604	340	103,898

A linear regression model (Eq. A.1) was fitted to all available length-weight pairs categorised by sex and major combined DFO region (Table A.2) to see if there were major differences in the estimated parameters between the areas for each sex. The length data were trimmed to the 1 and 99 percentiles in each area to drop length outliers. The length data were trimmed to the 1 and 99 percentiles in each area to drop length outliers. However, the weight data were not trimmed once the length data were selected for each model.

$$
\begin{aligned}
&W = \alpha L^{\beta} \\
&\ln\left(W_i\right) = \ln(\alpha) + \beta \ln\left(L_i\right) + \varepsilon_i \\
&\hat{\alpha} = \exp\left[\ln(\alpha)\right]
\end{aligned}
\qquad \text{Eq. A.1}
$$

Table A.2. Distribution of available length-weight pairs for Petrale sole by year, sex and combined major DFO areas.

	Males						Females					
Year	**3CD**	**4B**	**5AB**	**5CD**	**5E**	**Total**	**3CD**	**4B**	**5AB**	**5CD**	**5E**	**Total**
1994				5		5				4		4
1998				23		23				52		52
1999			7			7			18			18
2000				63		63				124		124
2001				55		55				83		83
2002			11	109		120			39	250		289
2003	20		107	259	42	428	54		72	455	22	603
2004	220		163	17	64	464	292		168	30	6	496
2005	64		108	239	57	468	125		72	267	8	472
2006	46		6		3	55	68		7		42	117
Total	350	0	402	770	166	1,688	539	0	376	1,265	78	2,258

Model fits and residual plots are provided for the fit to the total B.C. data (males: Figure A.1; females: Figure A.2). Parameter estimates and some diagnostics from the fitted models are presented in Table A.3 and are plotted for comparison by sex and area in Figure A.3. Residuals for all models show poor fits to the data at the tails of each residual distribution. These are probably caused by data outliers which may be data errors. The parameter estimates for total B.C. by sex (Table A.3) do not differ greatly from the estimates used by Fargo & Starr (2004).

Examination of the parameter estimates by major DFO region shows systematic differences between the sexes, with females having consistently greater estimates for β and lower estimates for α than for males (Figure A.3). However, it is not clear whether there are sufficiently strong differences in the length-weight parameter estimates across the three areas to justify providing separate length-weight estimates for each of the areas.

Table A.3. Length-weight parameter estimates for Petrale sole by sex and major combined area (3CD, 5AB and 5CD) and for all areas combined (including 5E). All available length-weight pairs were used, regardless of data origin except that the each length distribution was truncated at the 1% and 99% of the empirical distribution to reduce the effect of outliers. Also shown is the estimate used in the 2003 assessment for total B.C. Petrale sole (Fargo & Starr 2004).

Area	**N**	**Parameter**	**Estimate**	**Transformed**	**SE**	**LB**	**UB**
							Males
3CD	312	β	3.05	3.05	0.11	2.84	3.27
		α	-11.77	7.77E-06	0.66	-13.06	-10.47
5AB	391	β	2.94	2.94	0.06	2.83	3.06
		α	-11.06	1.57E-05	0.35	-11.75	-10.38
5CD	676	β	3.14	3.14	0.03	3.09	3.19
		α	-12.23	4.87E-06	0.15	-12.53	-11.93
Total	1409	β	3.08	3.08	0.03	3.02	3.14
		α	-11.92	6.68E-06	0.18	-12.27	-11.56
Previous[1]		β	3.10	3.10			
		α	-12.02	6.01E-06			
							Females
3CD	492	β	3.25	3.25	0.06	3.13	3.37
		α	-12.83	2.69E-06	0.37	-13.55	-12.10
5AB	365	β	3.37	3.37	0.05	3.26	3.47
		α	-13.56	1.30E-06	0.32	-14.18	-12.93
5CD	1121	β	3.18	3.18	0.02	3.14	3.22
		α	-12.46	3.88E-06	0.12	-12.69	-12.23
total	1906	β	3.22	3.22	0.02	3.18	3.26
		α	-12.68	3.11E-06	0.13	-12.94	-12.42
Previous[1]		β	3.24	3.24			
		α	-12.80	2.77E-06			

[1] Starr & Fargo (2004)

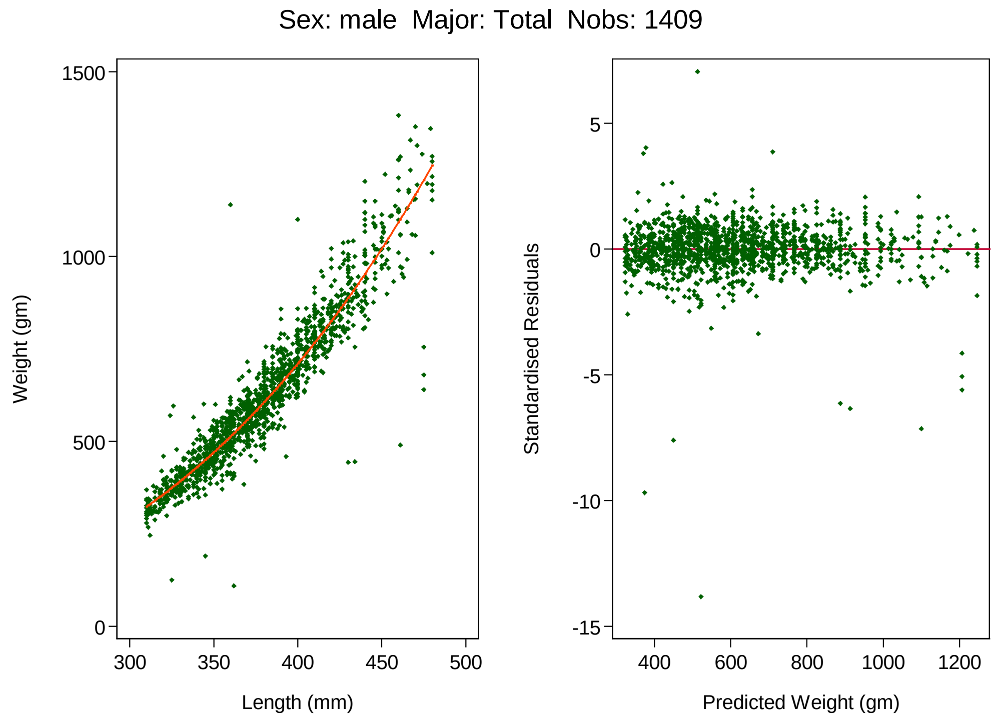


Figure A.1. Plot of the fit for length-weight data for males in all areas combined (3CD5ABCD). All available length-weight pairs for the area were used in the analysis, regardless of data origin.

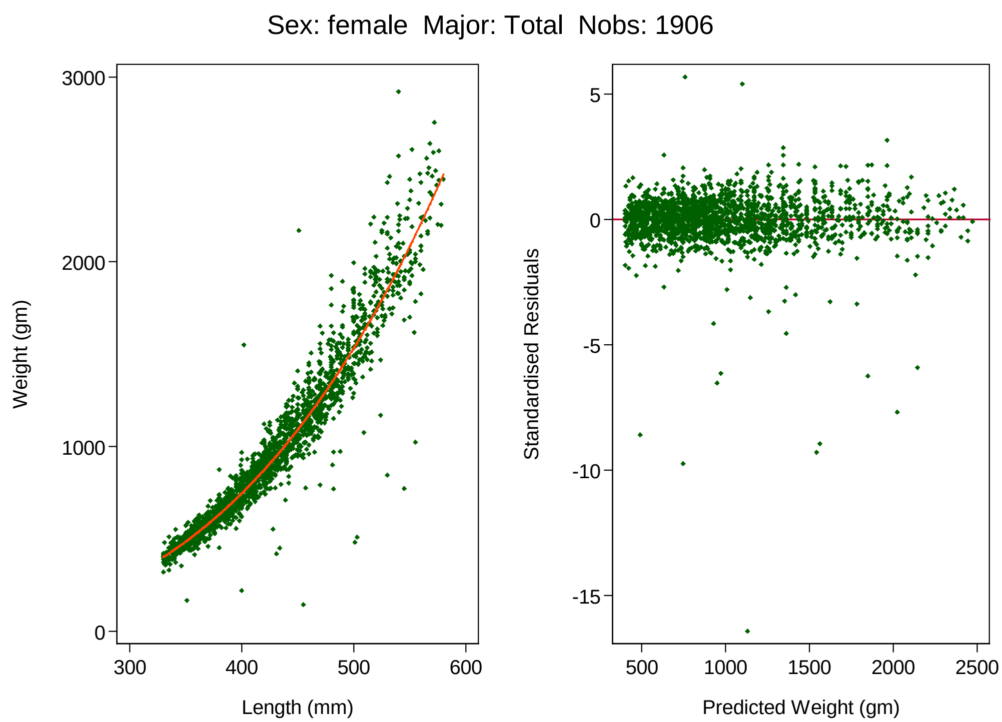


Figure A.2. Plot of the fit for length-weight data for females in all areas combined (3CD5ABCD). All available length-weight pairs for the area were used in the analysis, regardless of data origin.

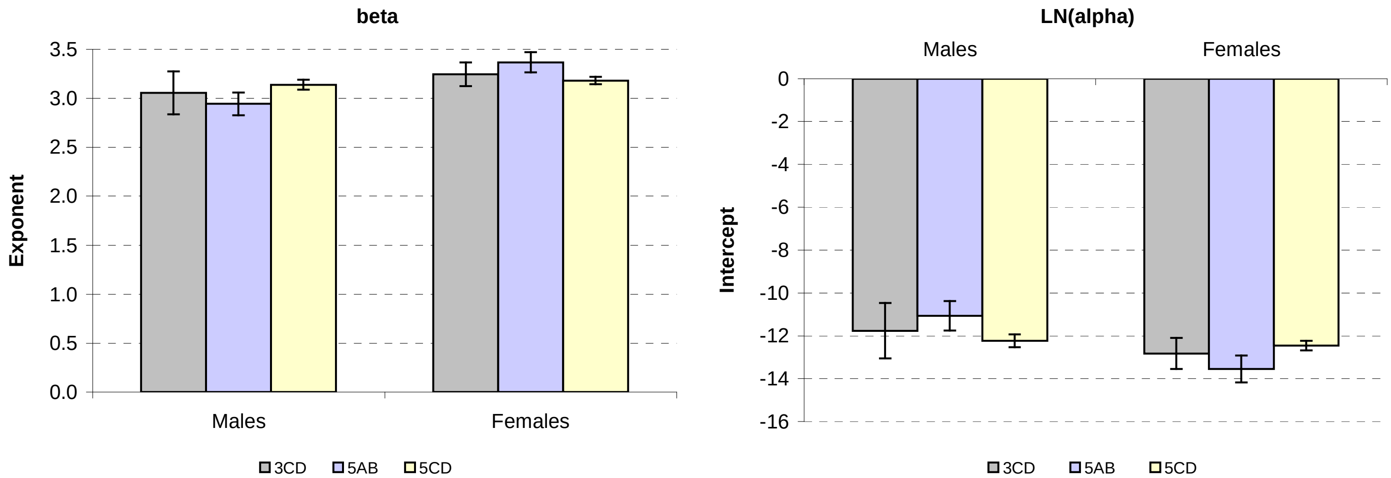


Figure A.3. Comparison of the estimates for each of the parameters in Table A.3 by combined major area and for total B.C. by sex, showing the 95% confidence bounds.

Estimation of von-Bertalanffy growth parameters

A non-linear von-Bertalanffy model (Eq. A.2) was fitted to all available age-length pairs categorised by sex and major combined DFO region (Table A.4) as well as to a model using data from all areas to see if there were major differences in the estimated parameters between the areas for each sex. Neither the length nor the age data were trimmed to remove outliers prior to the analysis.

$$L_i = L_\infty e^{\left(-k\left[a_i - t_0\right]\right)} \qquad \text{Eq. A.2}$$

Model fits and residual plots are provided for the fit to the total B.C. data (males: Figure A.4; females: Figure A.5). Parameter estimates and some diagnostics from the fitted models are presented in Table A.5 and are plotted for comparison by sex and area in Figure A.6. Residuals for all models show reasonable fits to the data except at the older ages where there appears to be some patterns in the residuals, as seen in the total B.C. models for both males (Figure A.4) and females (Figure A.5). These may be caused by ageing errors at the older ages or the lack of a full range of samples at these older ages. The parameter estimates for all of B.C. by sex (Table A.5) do not differ greatly from the estimates used by Starr & Fargo (2004) for males but the female parameter estimates show a larger estimate for L_∞ and a lower estimate for k. Examination of the parameter estimates by major DFO region shows systematic differences between the sexes, with females having consistently greater estimates for L_∞ and lower estimates for k than for males (Table A.5; Figure A.6). The differences in the L_∞ parameter are not large across the three areas except for 3CD where this parameter is clearly poorly estimated. However, there is an increasing trend in the magnitude of the k parameter with a corresponding drop in the L_∞ parameter as the areas become more northern, with the lowest L_∞ parameter and the highest k parameter estimates being estimated by the total B.C. model. Given the uncertainty in these estimates and the relatively small number of age samples, it is likely that there is little justification for using separate parameter estimates for growth in these three areas.

Table A.4. Distribution of available age-length pairs for Petrale sole by year, sex and combined major DFO areas.

	Males						Females					
Year	3CD	4B	5AB	5CD	5E	Total	3CD	4B	5AB	5CD	5E	Total
1990	14		11		18	43	36		39		19	94
1991	24			12		36	71			19		90
1992	28			5		33	23			19		42
1993	20		17	19	18	74	28		39	17	19	103
1994	7		39			46	31		7			38
1995	33		51		22	106	23		7		19	49
1997	31					31	18					18
1998			16			16			19			19
1999			7			7			18			18
2000				63	17	80				123	21	144
2001			49	12	4	65			39	26	29	94
2002				100		100				189		189
Total	157	0	190	211	79	637	230	0	168	393	107	898

Table A.5. Von-Bertalanffy parameter estimates for Petrale sole by sex and major combined area (3CD, 5AB and 5CD) and for all areas combined (including 5E). All available age-length pairs were used, regardless of data origin. Also shown are the estimates used in the 2003 assessment for total B.C. Petrale sole (Starr & Fargo 2004).

		Males					Females				
Area	Parameter	N	Estimate	SE	LB	UB	N	Estimate	SE	LB	UB
3CD	L_∞	157	517	65	389	644	230	783	120	547	1020
	k		0.074	0.039	-0.002	0.150		0.045	0.018	0.009	0.081
	t_0		-11.1	4.9	-20.6	-1.5		-11.0	3.2	-17.3	-4.7
5AB	L_∞	190	484	12	460	507	168	618	26	567	669
	k		0.117	0.023	0.072	0.163		0.098	0.019	0.060	0.135
	t_0		-6.8	2.0	-10.7	-2.9		-4.5	1.4	-7.4	-1.7
5CD	L_∞	211	498	15	470	527	393	582	16	551	614
	k		0.183	0.020	0.143	0.223		0.164	0.016	0.132	0.196
	t_0		-1.0	0.3	-1.7	-0.4		-1.1	0.3	-1.7	-0.5
Total	L_∞	637	458	3	451	465	898	563	6	551	576
	k		0.239	0.011	0.218	0.260		0.172	0.009	0.155	0.189
	t_0		-0.6	0.2	-1.0	-0.3		-1.2	0.2	-1.6	-0.8
Previous[1]	L_∞		453					537			
	k		0.243					0.214			
	t_0		-0.6					-0.6			

[1] Starr & Fargo (2004)

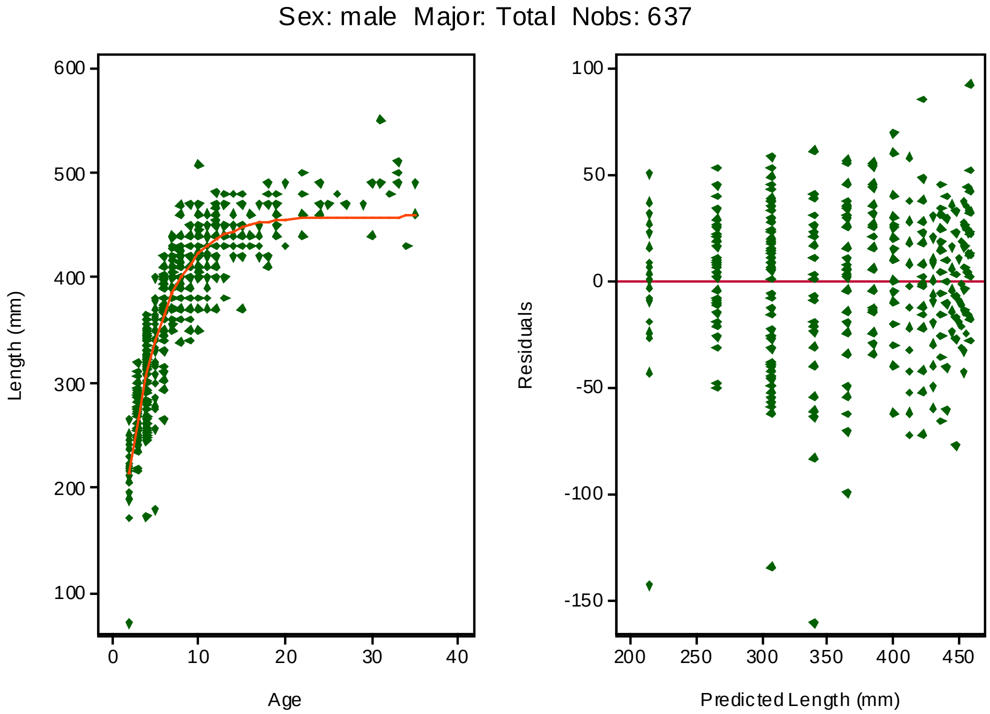


Figure A.4. Plot of the fit for age-length data for males in all areas combined (3CD5ABCDE). All available age-length pairs were used in the analysis, regardless of data origin.

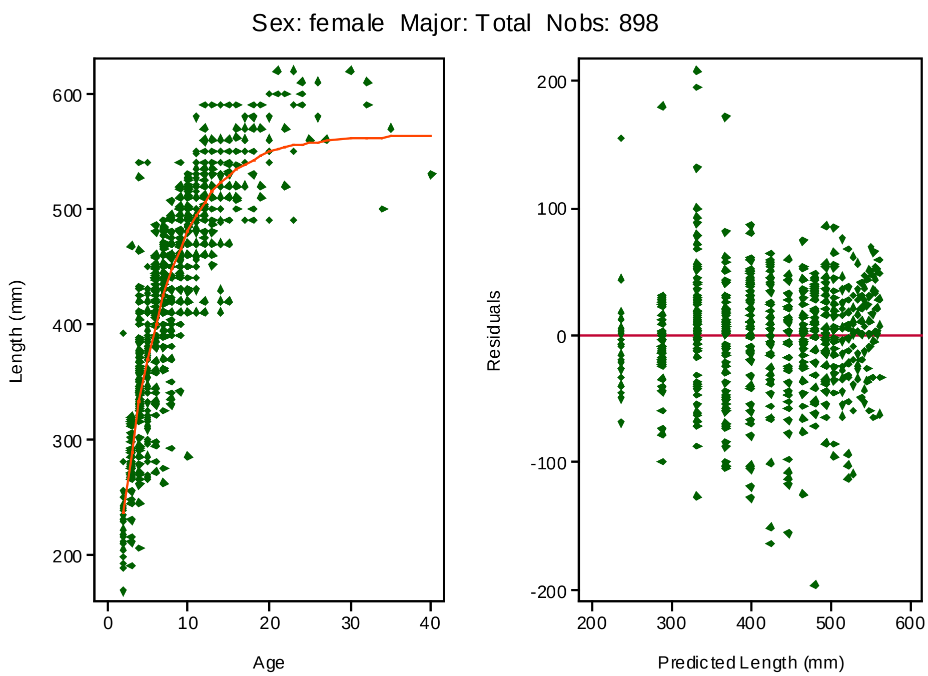


Figure A.5. Plot of the fit for age-length data for females in all areas combined (3CD5ABCDE). All available age-length pairs were used in the analysis, regardless of data origin.

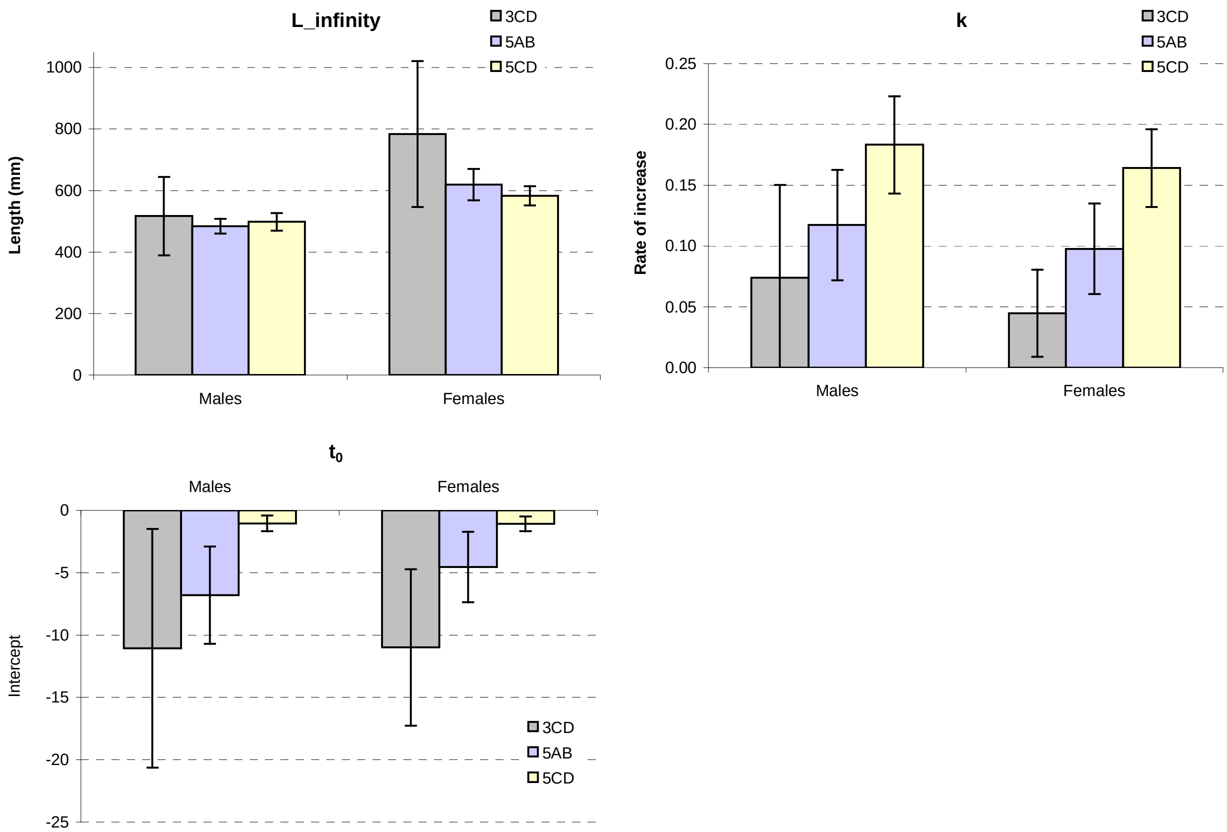


Figure A.6. Comparison of the estimates for each of the parameters in Table A.5 by combined major area and sex, showing the 95% confidence bounds. Research and port sampling data have been combined.

Table A.6. Number of age samples by sex, sample origin, year and DFO major region for Petrale sole.

	Males						Females					
	3CD	5AB		5CD		5E	3CD	5AB		5CD		5E
Year	Port	Port	Research	Port	Research	Port	Port	Port	Research	Port	Research	Port
1990	14	11				18	36	39				19
1991	24			12			71			19		
1992	28			5			23			19		
1993	20	17		19		18	28	39		17		19
1994	7	39					31	7				
1995	33	51				22	23	7				19
1997	31						18					
1998		16						19				
1999			7						18			
2000					63	17					123	21
2001		49			12	4		39			26	29
2002					100						189	
Total	157	183	7	36	175	79	230	150	18	55	338	107

The research and port sampling age data were fitted separately to see if there were differences in the estimated growth parameters between sample origins as for Petrale sole. Unfortunately the availability of data is unbalanced between the sample types, with the research samples only available from major areas 5AB and 5CD while there are age samples available from 3CD and 5E from the port samples, as well as from 5AB and 5CD (Table A.6). Models were fitted to the available data twice, once using all the data in Table A.6 and other time fitting only data from 5AB and 5CD. Neither fit showed what appeared to be significant strong differences between the data from each sample origin (Figure A.7), although only the parameters estimated from the fit to the 5ABCD data are presented. Therefore, the growth model used in the Petrale sole stock assessment has been based on data from both sample origins which is fortunate given the scarcity of useable age-length pairs.

Parameters for the combined sex model selected for use in the Petrale sole stock assessment are presented in Table A.7. A combined sex stock assessment model was used because of the consistent high proportion of male Petrale sole in the landings (Figure A.8). This is in contrast to the skewed sex ratios observed for Petrale sole and rock sole (refs.). There also appears to be no trend in the proportion of males over the 40-year period, with the proportion male being highly variable around an average of approximately 50% males by number and 35% males by weight for the full time series. No attempt was made to distinguish between males and females in the landings or the growth model for the Petrale sole total B.C. stock assessment. Also, it can be seen that the growth model presented in Table A.7 fits the observed weight at age data well (Figure A.9).

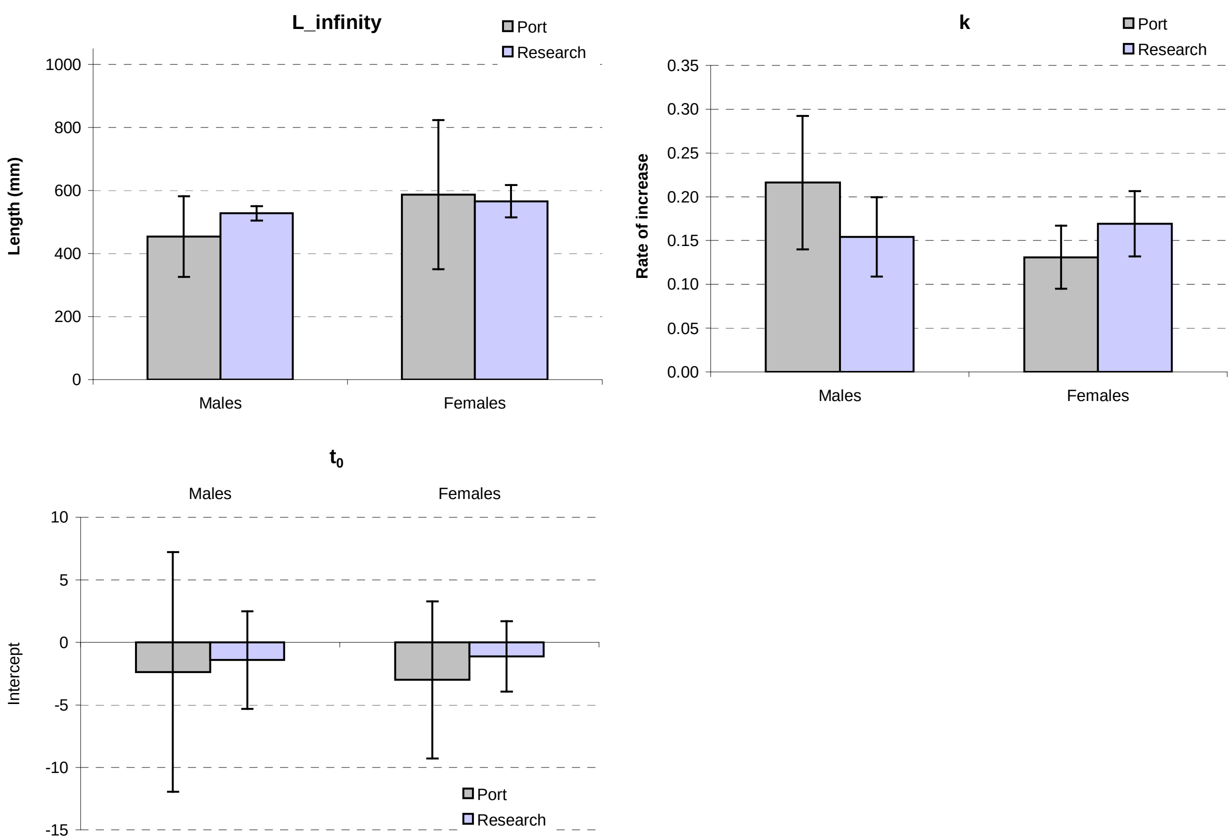


Figure A.7. Comparison of growth model parameter estimates based separately on port and research sampling data. Data have been restricted to DFO areas 5AB and 5CD.

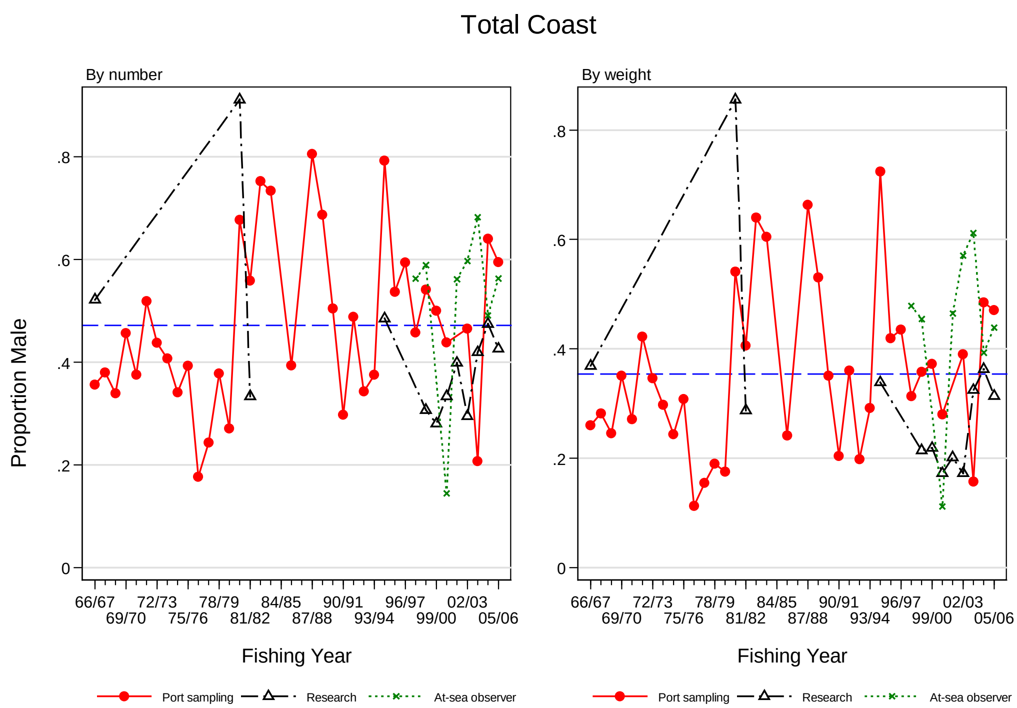


Figure A.8. Time series of the proportion of male Petrale sole from the total B.C. sampling data by sample origin, expressed in terms of sample numbers or sample weight. The long-term average proportion males from the port sampling data is 0.47 by number and 0.35 by weight (shown as horizontal dashed lines).

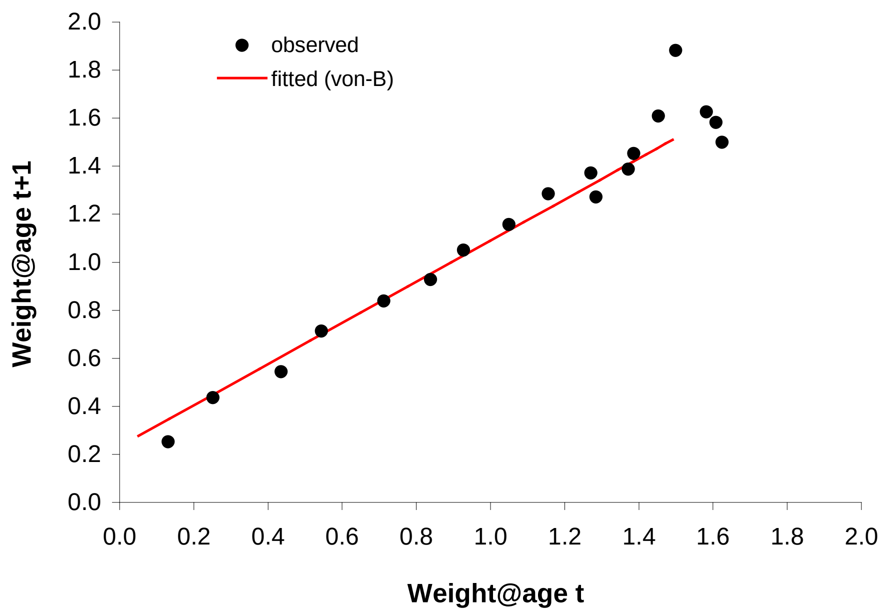


Figure A.9. Walford plot for Petrale sole using the “Total” growth parameters in Table A.5. Also plotted are the ‘observed’ W_a and W_{a+1} for port sampling derived by converting the mean length at age (Table A.3) to weight at age using a length-weight conversion model.

Table A.7. Growth and length-weight parameter estimates selected for the Petrale sole stock assessment. Each combined model was estimated using the indicated sex ratio and fitting the length-weight model or the von-Bertalanffy model to the interpolated mean weights at length or the mean lengths at age, assuming equal weight at each length or age.

Parameter	Male	Female	Combined
β	3.08	3.22	3.18
α	6.68E-06	3.11E-06	3.93E-06
L_∞	458	563	510
k	0.24	0.17	0.20
t_0	-0.64	-1.17	-1.02
Sex ratio	0.5	0.5	

Petrale sole biological information

The sample age distributions by year and sex for total B.C. Petrale sole from port samples are presented in Figure A.10. The data are sparse and the number of available samples is low (Table A.8). There are additional data available from research samples from the early 2000s, but these data were not used in the stock assessment model (except to calculate the growth model) because they are not representative of the landings. The growth model appears to be reasonably well specified because when the age distribution information from port samples is converted into the implied mean weight using the growth model presented in Table A.7 and length-weight conversion parameters from Table A.3, the resulting mean weights match well with the mean weights calculated directly from the sampled lengths (Figure A.11).

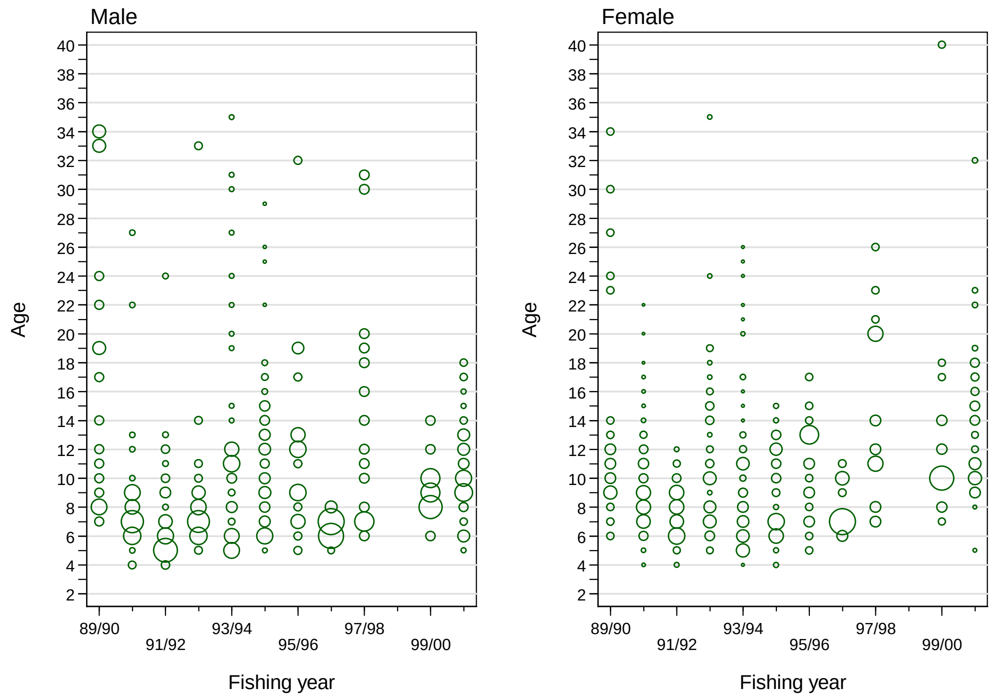


Figure A.10. Relative proportion of each age class of Petrale sole by sex and fishing year. Vertical columns sum to one from age 4 to age 40, which are the minimum and maximum ages in the data set. Only port sampled ages have been used in this plot.

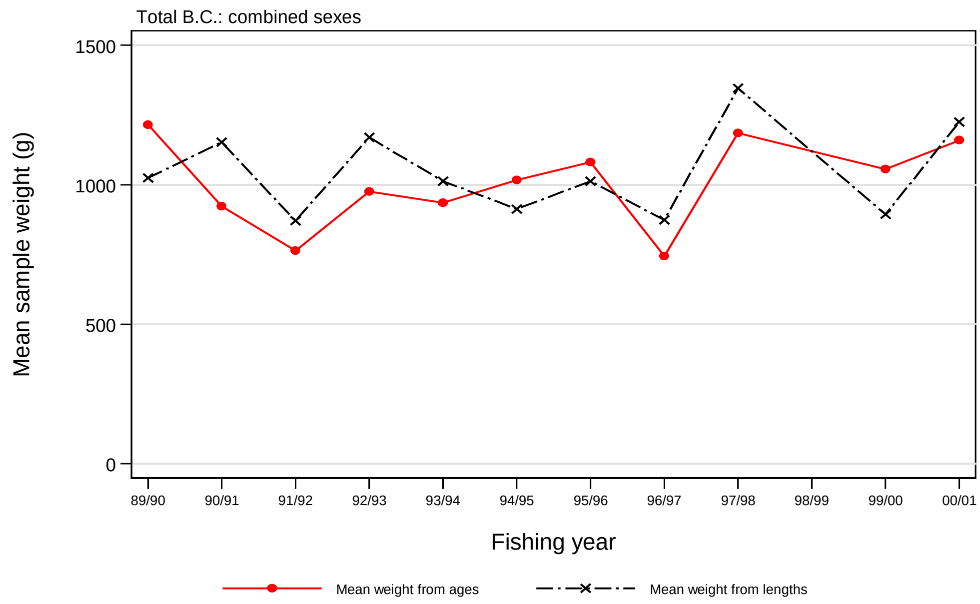


Figure A.11. Mean weight (g) for port sampled Petrale sole from total B.C. calculated under two assumptions: a) converting the sample age distribution into the implied mean weight by using the predicted mean length at age based on the Von-Bertalanffy growth model (Table A.7) and the length-weight parameters; b) converting all sampled lengths to weight using the parameters from Table A.3. Only fishing years where there were both age and length port samples are presented.

Table A.8. Number of age-length observations and number samples available by sample type and fishing year for Petrale sole in all B.C.

Fishing	Males		Females		Number samples	
Year	Port	Research	Port	Research	Port	Research
89/90	18		19		1	
90/91	49		146		4	
91/92	40		42		2	
92/93	25		47		2	
93/94	61		106		4	
94/95	123		37		3	
95/96	22		19		1	
96/97	31		18		1	
97/98	16		19		1	
99/00	17	7	21	18	1	12
00/01	53	63	68	123	3	38
01/02		12		26		10
02/03		100		189		39
Total	455	182	542	356	23	99

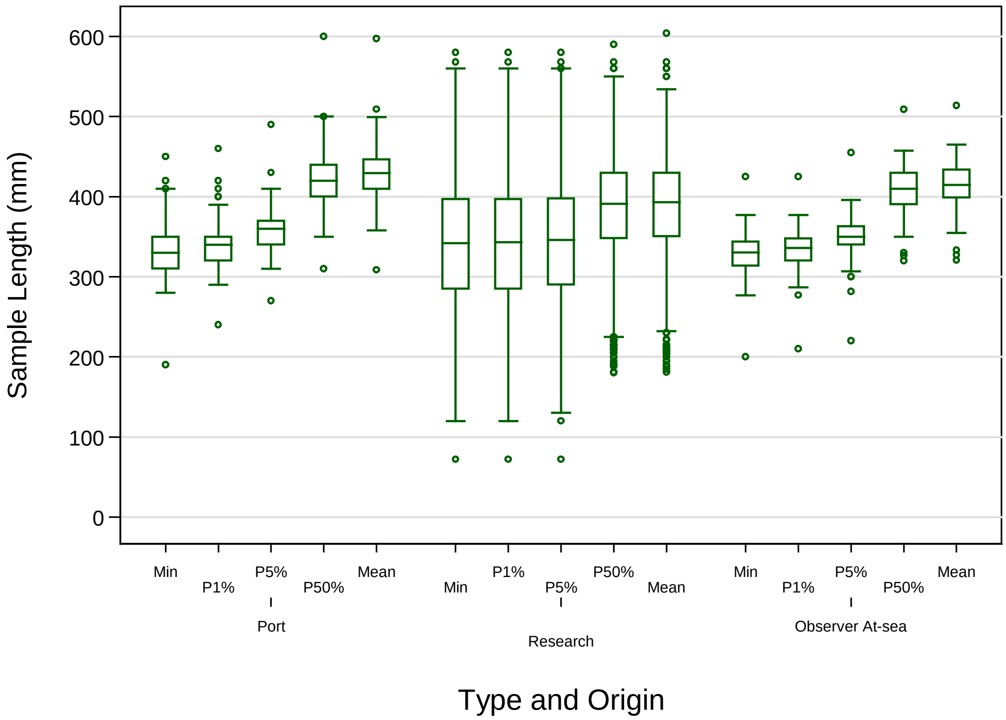


Figure A.12. Box plots of the distribution of statistics (minimum, P[1%], P[5%], median and mean lengths [mm]) derived from all samples within an origin type for total B.C. Petrale sole.

Distributions of sample statistics for total B.C. Petrale sole derived from samples from different origins show that the port sample data are generally larger and have less variability than the research samples, regardless of the statistic (Figure A.12). The at-sea samples seem to be similar to the port samples in these statistics (Figure A.12), but they were not used in the stock assessment model because most of these samples are coded as being random samples from the total catch and thus were not considered to be representative of the landings.

When the distributions of the port sampled mean weights were compared with model predicted mean weight for unfished equilibrium recruited fish, assuming M=0.2 (derived parameter $\overline{w}$; see Appendix D for equation), the port sampled mean weights are generally higher than the unfished equilibrium mean weights for age=5, only slightly below that for age=6 and below the mean weight for age=7 (Figure A.13). On this basis, age 6 was selected as a likely candidate age for knife-edge recruitment to use in the delay-difference assessment model. This assumption was tested by also fitting models which used age=7 for the age of knife-edge recruitment.

Annual mean weights were derived for input into the total B.C. delay-difference stock assessment model by calculating the mean length for each major DFO region (3CD, 5AB, 5CD and 5E) from all the samples obtained in a fishing year. An annual mean length was then calculated using these region-specific mean lengths weighted by the annual commercial catch from each of these regions. The annual mean length was then converted to a mean weight using the length-weight parameters from Table A.3. Annual mean weights were included in the stock assessment model only when there were at least 4 samples available for a fishing year and at least two of the four regions were represented. Only eleven of a possible 37 mean weight estimates (some years had no samples at all) were consequently used in the stock assessment model (Figure A.14).

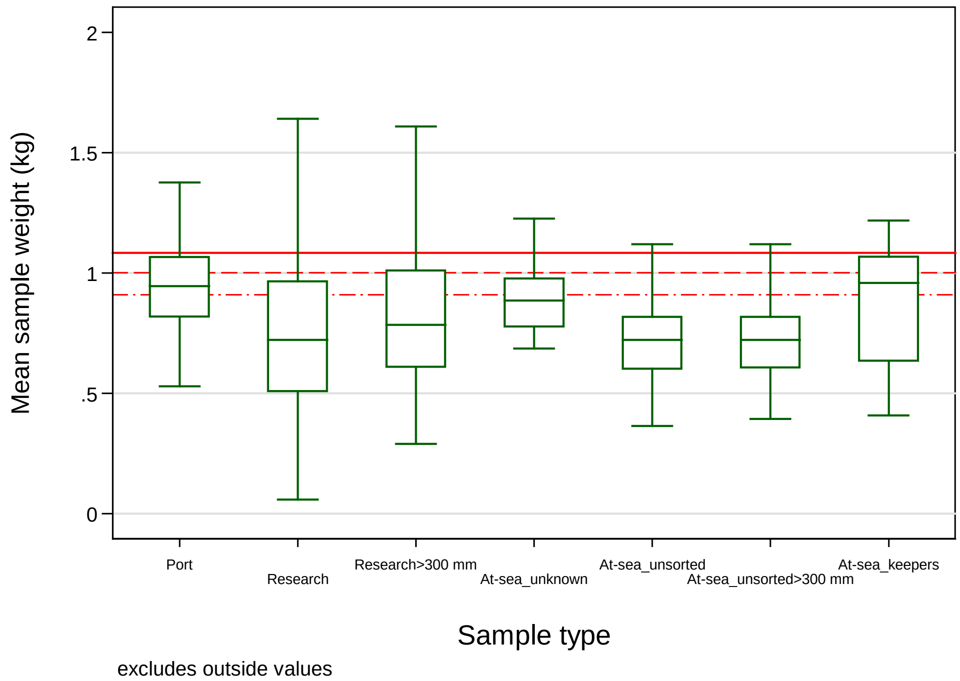


Figure A.13. Distribution of mean sample weight by sample type category for all samples of Petrale sole (sexes combined) collected beginning in 1966/67. Horizontal lines show the predicted equilibrium values for the model parameter $\overline{W}$ when the age of knife-edge recruitment is 5, 6 or 7 and M=0.2. Mean weights are also provided for research and unsorted at-sea samples which have been truncated at 300 mm to simulate the fishery sorting process, where 300 mm is an approximate lower bound for sorting.

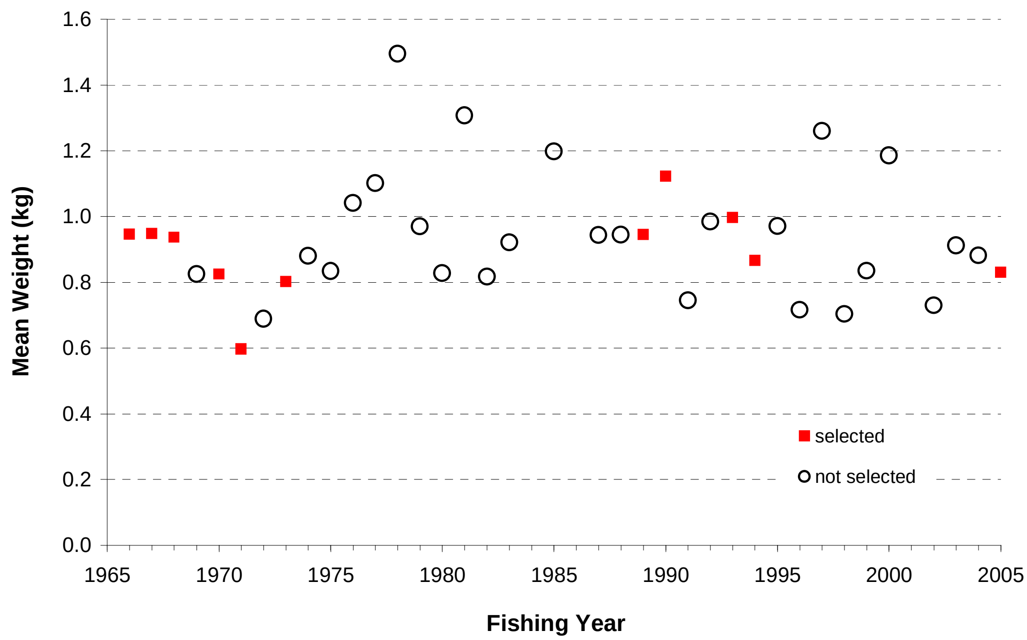


Figure A.14. Time series of port sampled mean weights used in the total B.C. delay-difference stock assessment model. All annual mean weights are shown but the open circle estimates were not used in the model because they did not satisfy the four annual sample over at least two of the major areas in the year.

Appendix B. PETRALE SOLE GLM

Methods

A stepwise general linear model (GLM) regression procedure was used to estimate an annual series of the relative changes in Petrale sole abundance over time. The regression was based on the relationship between CPUE for Petrale sole and available predictive factors. The data were derived from the DFO *PacHarvestTrawl* and *GFCatch* commercial catch and effort databases. This approach is commonly used to analyse fisheries catch and effort data and has been described by various authors (e.g., Hilborn and Walters 1992, Quinn and Deriso 1999).

Quinn and Deriso (1999; page 19) described a general linear model based on the lognormal distribution:

$$U_{ijk} = U_0 \prod_i \prod_j P_{ij}^{X_{ij}} e^{\varepsilon_{ijk}} \qquad \text{Eq. B.1}$$

where U_{ijk} is an observed CPUE, U_0 is the reference CPUE, P_{ij} is a factor i at level j, and X_{ij} takes a value of 1 when the jth level of the factor P_{ij} is present and 0 when it is not. The random deviate ε_{ijk} for observation k is a normal random variable with 0 mean and standard deviation σ.

Taking the logarithm of Eq. B.1 yields an additive linear regression model:

$$\ln U_{ijk} = \ln U_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i - 1} X_{ij} \ln P_{ij} + \varepsilon_{ijk}$$

or Eq. B.2

$$Y_{ijk} = \beta_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i - 1} \beta_{ij} X_{ij} + \varepsilon_{ijk}$$

In the second form of the model, β_0 is the intercept of the model and β_{ij} is the logged coefficient of the factor j at level i under consideration.

The model described by Eq. B.1 and Eq. B.2 is overparameterised and constraints must be imposed to allow estimation of model parameters. A common solution is to create a reference level by setting a factor coefficient to zero, usually the first. The remaining n_i-1 coefficients of each factor i represent incremental effects relative to the reference level.

The estimated factor coefficients are not unique: coefficients obtained by fixing a factor level will differ with the choice of reference level. However, the relative differences among the estimated coefficients will not be affected by the choice of constraint. Following the suggestion of Francis (1999), coefficients for factor i were transformed to "canonical" coefficients over all levels j calculated relative to their geometric mean $\bar{\beta} = \sqrt[n]{\prod_1^n \beta_j}$ (including the level where β_j=0), so that

$$\beta_j^{'} = \beta_j \big/ \overline{\beta}$$ Eq. B.3

As the analysis is done in log space, this is equivalent to:

$$b_j^{'} = \mathrm{e}^{(\beta_j - \overline{\beta})}$$ Eq. B.4

The use of the canonical form allows the computation of standard errors for every coefficient, including the fixed coefficient (Francis 1999). Ordinarily, the use of a fixed reference coefficient sets the standard error for that coefficient to zero and spreads the error associated with that coefficient to the other coefficients in the variable.

A range of factors (P_{ij}) are available in the data which may be used to account for variability in the observed CPUE. These include factors such as the date of capture (usually year and month), the vessel, and the depth and location of capture. The year of capture is usually given special significance in these analyses as variations in the estimated year coefficients are interpreted as relative changes in the annual abundance. The resulting series of ‘year’ or ‘fishing year’ canonical coefficients is termed the “Standardised” annual CPUE index $\left[Y_j^{'}\right]$ in this report.

A selection procedure (Vignaux 1993, Vignaux 1994; Francis 2001) was applied to determine the relative importance of these factors in the model to the prediction of CPUE. The procedure involves a forward stepwise fitting algorithm which generates regression models iteratively, starting with the simplest model (one dependent and one independent variable) that progressively adds terms to the model subject to a stopping rule designed to include only the most important factors.

The following general procedure was used to fit the models, given a data set with candidate predictor variables:

1. Calculate a regression for each predictive factor (variable) against the natural log of CPUE (kg/h).
2. Generate the Akaike Information Criterion (AIC) (Akaike 1974) and select the predictor variable that has the lowest AIC. The AIC is used for model selection to account for variables which may have equivalent explanatory power in terms of residual deviance but require fewer degrees of freedom for the model (Francis 2001).
3. Repeat Steps 1 and 2, accumulating the number of selected predictor variables and increasing the model degrees of freedom, until the increase in residual deviance (as measured by R^2) for the final iteration is less than 0.01. The selection of 0.01 as the threshold is arbitrary but adding factors which explain small amounts of the total variance has little effect on the year coefficients and other coefficients of interest.

Other annual indices can be generated from the catch and effort data used for the linear modelling described above. The simplest estimate of mean annual CPUE is given by:

$$R_j = \frac{\sum_{k=1}^{M_j} C_{jk}}{\sum_{k=1}^{M_j} E_{jk}} \qquad \text{Eq. B.5}$$

where C_{jk} denotes that catch and E_{jk} denotes the effort for each record *k* in year *j*. The series of annual estimates is termed the “Arithmetic” CPUE index in this report.

Another annual index is specified by

$$U_j = \exp\left[\frac{\sum_{k=1}^{M_j} \ln\left(\frac{C_{jk}}{E_{jk}}\right)}{M_j}\right] \qquad \text{Eq. B.6}$$

where U_j is the annual geometric mean of the CPUE observations. The resulting annual index is termed the “Unstandardised” CPUE index in this report. Annual estimates obtained using Eq. B.6 are equivalent to the results obtained from a linear model where year is the only predictive factor.

Like the scaling described for the standardised index, the series specified by Eq. B.5 and Eq. B.6 can be scaled relative to their geometric means. This is done to provide comparability with the standardised index. Given *n* years in each series, the geometric means of the arithmetic and unstandardised series are given by $\overline{R} = \sqrt[n]{\prod_1^n R_j}$ and $\overline{U} = \sqrt[n]{\prod_1^n U_j}$, respectively. Thus, each series can be scaled to the corresponding geometric mean as:

$$R_j^{'} = {R_j}/{\overline{R}} \qquad \text{Eq. B.7}$$

and

$$U_j^{'} = {U_j}/{\overline{U}} \qquad \text{Eq. B.8}$$

The procedures described by Eq. B.1, Eq. B.2 and Eq. B.6 are necessarily confined to the positive catch observations in the data set as ln(0) is undefined. Observations with zero catch can be handled in a number of ways:

1. Zero catch records are frequently dropped from further consideration, usually because they are not accurately recorded. This is particularly true for catch records which are maintained by fishermen who frequently discount small amounts of catch as being inconsequential.
2. A small increment can be added to the zero catch records so that ln(0) can be calculated. This is not a satisfactory solution because model parameter estimates have been shown to be sensitive to the value selected for the increment.

3. A linear regression model based on a binomial distribution and using the presence/absence of the fish species as the dependent variable can be estimated using the same data set. Explanatory factors are estimated in this model in the manner described in Eq. B.1 and Eq. B.2. Such a model will provide another series of standardised coefficients of relative annual changes that may be analogous to the series estimated from the lognormal regression, depending on whether the probability of presence/absence can be considered an index of abundance. Such an approach should only be used for data sets where zero catch records are known to have good reliability, which is not the case for the long term series presented here.

4. A combined model which integrates the two series of relative annual changes estimated by the lognormal and binomial models can be estimated using the delta distribution which allows zero and positive observations (Vignaux 1994):

$$C_i = \frac{L_i}{\left(1 - P_0\left[1 - \frac{1}{B_i}\right]\right)} \qquad \text{Eq. B.9}$$

where C_i = combined index for year i
L_i = lognormal index for year i
B_i = binomial index for year i
P_0 = proportion zero for base year 0

It is relatively straightforward to calculate standard errors for the indices L_i and B_i. However, this is not the case for the combined index C_i because the standard errors of the two sets of indices are likely be correlated because they come from the same dataset. Francis (2001) suggests that a bootstrap procedure is the appropriate way to estimate the variability of the combined index.

Data sources

Trawl catch and effort data pertaining to Petrale sole are available from two DFO databases: *GFCatch* which covers the period from 1954 to December 1995 (Rutherford 1995) and *PacHarvestTrawl* which covers the period from 1996 to the present. Data were obtained from *PacHarvestTrawl* in July 2006 that included data to the end of March 2006.

Catches

Total annual landings and discards for Petrale sole are presented by major DFO region from 1979/80 to 2005/06 (Table B.1). Landings are generated from dockside monitoring programmes which have been in place since 1995. Prior to that year, landings are available from logbooks maintained by fishermen which have been cross-validated with landing slips issued by the receiving processing plant. Discard estimates are considered to be unreliable prior to 1996 because they were based on voluntary reporting and are known to be incomplete. Discards since

February 1996 are based on estimates made by an independent at-sea observer and are considered more reliable than those obtained from logbooks

Table B.1. Total landed and discarded catches for Petrale sole in the combined GFCatch/PacHarvestTrawl databases, summarised by 1 April–31 March fishing year for the major DFO reporting areas, combined as indicated. Data from 1 April 1979 to 27 December 1995 are from the GFCatch database (Rutherford 1995). Data from 16 February 1996 to 31 March 2006 are from the PacHarvestTrawl database. The groundfish fishery was closed from 28 December 1995 to 15 February 1996. These catches have been summarised without data selection criteria.

	DFO Major Region						
Year	**Other[1]**	**3CD**	**4B**	**5AB**	**5CD**	**5E**	**Total**
Landed Catches (t)							
79/80		117.1	2.4	58.4	40.8	1.5	220.2
80/81		183.8	2.1	38.6	38.8	7.6	271.0
81/82		187.1	5.0	42.2	37.9	19.8	292.0
82/83		228.2	6.0	98.8	14.2	9.9	357.1
83/84	0.0	217.5	5.8	128.7	34.8	26.6	413.3
84/85		327.6	7.7	75.8	24.7	33.0	468.8
85/86		162.0	1.7	85.8	21.0	36.4	306.8
86/87		220.9	2.7	111.1	35.3	30.6	400.6
87/88		335.2	0.5	177.1	102.0	21.2	636.0
88/89		567.6	3.8	192.5	126.0	30.5	920.4
89/90		675.5	0.1	193.0	149.6	41.4	1,059.7
90/91		660.0	0.4	178.0	134.7	25.4	998.4
91/92		396.8	0.6	114.9	86.1	37.6	636.0
92/93		403.0	5.9	104.1	69.8	22.6	605.4
93/94		249.6	0.9	91.7	68.3	59.6	470.1
94/95		176.8	1.8	313.5	43.4	53.1	588.5
95/96	0.5	239.9	0.2	213.8	39.9	37.5	531.8
96/97	14.4	261.6	0.6	70.0	26.8	11.5	385.0
97/98	3.4	202.9	0.9	76.0	24.4	20.4	328.0
98/99	3.5	235.3	1.5	69.2	18.6	30.8	359.0
99/00	3.0	181.9	1.0	116.7	43.5	34.6	380.8
00/01	5.9	233.7	0.8	103.6	48.9	67.8	460.7
01/02	6.6	254.2	0.2	171.1	34.6	13.7	480.4
02/03	3.3	246.8	0.8	149.4	53.2	8.8	462.4
03/04	3.2	251.3	0.9	182.3	45.7	13.3	496.7
04/05	3.9	332.9	0.7	177.5	46.7	29.1	591.0
05/06	4.5	357.1	0.3	179.8	47.7	38.9	628.2
Total[2]	52.3	7,906.4	55.5	3,513.4	1,457.4	763.2	13,748.3
Discarded (t)							
96/97	0.0	15.1	0.0	8.0	9.0	0.7	32.8
97/98	0.0	5.1	0.0	9.8	9.1	2.0	26.1
98/99	0.0	8.0	0.0	8.6	4.8	0.4	21.8
99/00	0.0	7.7	0.0	10.3	7.4	0.1	25.5
00/01	0.0	15.8	0.0	8.2	7.5	0.1	31.7
01/02	0.0	10.4	0.0	7.5	3.2	0.0	21.0
02/03	0.0	23.1	0.1	16.1	3.0	0.0	42.3
03/04	0.0	29.4	0.0	16.3	6.6	0.0	52.4
04/05	0.0	17.8	0.3	8.3	4.6	0.5	31.6
05/06	0.0	18.2	0.1	12.5	4.9	0.1	35.8
Total[3]	0.0	150.6	0.5	105.5	60.2	4.2	321.0

Year	Other[1]	3CD	4B	5AB	5CD	5E	Total
	DFO Major Region						
Sum(Landed + Discarded) (t)							
96/97	14.4	276.7	0.6	78.0	35.8	12.2	417.8
97/98	3.4	208.0	0.9	85.8	33.5	22.4	354.1
98/99	3.5	243.3	1.5	77.8	23.4	31.2	380.8
99/00	3.0	189.6	1.0	127.0	50.9	34.7	406.3
00/01	5.9	249.5	0.8	111.8	56.4	67.9	492.4
01/02	6.6	264.6	0.2	178.6	37.8	13.7	501.4
02/03	3.3	269.9	0.9	165.5	56.2	8.8	504.7
03/04	3.2	280.7	0.9	198.6	52.3	13.3	549.1
04/05	3.9	350.7	1.0	185.8	51.3	29.6	622.6
05/06	4.5	375.3	0.4	192.3	52.6	39.0	664.0
Total[3]	52.3	8,057.0	56.0	3,618.9	1,517.6	767.4	14,069.3

[1] includes catches in unknown areas and areas outside of Canadian waters
[2] 01 April 1979 to 31 March 2006
[4] 01 April 1996 to 31 March 2006

Long-term model: GFCatch and PacHarvestTrawl Data (1966/67–2005/06)

This analysis explored most of the period for which catch/effort data were available (from 1 April 1966 to 31 March 2006), using data from both the GFCatch and PacHarvestTrawl databases (Table B.2). Data earlier than 1 April 1966 were excluded because previous analyses had indicated that these data appear to be less reliable (Starr et al. 2006). The analysis was based on landed catch estimates because discard data prior to the establishment of the on-board observer programme are considered to be extremely unreliable. The fishing events archived in the database reflect the aggregated grouping individual sets prior to 1991 (Rutherford 1995). Also, a limited number of data fields have been collected consistently throughout the 1966 to 2006 period. These include the DFO "locality" (Rutherford 1995) for the aggregated fishing event, the mean depth of the aggregated sets, and the date associated with the aggregated fishing event. This data may possibly be the landing date for the trip. Data prior to 1991 are only available at this aggregated level of trip, DFO locality and mean depth. Data from 1991 onwards are available on a tow-by-tow basis. The post-1990 tow-by-tow data have been stratified to the pre-1991 level of stratification for comparability, which has the effect of reducing the resolution of the spatial and temporal data for the later data. As well, a small number possible "duplicate" observations, where the same trip fished in the same locality and depth, were dropped from the analysis (230 records from over 31,000 records pre-1991 records, including records with no reported Petrale sole landings).

Table B.2. Data criteria used to select records from the GFCatch and PacHarvestTrawl databases.

Tow start date from 1 April 1966 and 31 March 2006
Bottom trawl type
Fished in one of the following DFO Major regions: 3C, 3D, 5A, 5B, 5C, or 5D
Fishing success code <=1 (code 0= unknown; code 1= useable)
Catch of at least one fish or invertebrate species (no water hauls)
Valid depth field
Valid estimate of time towed that was greater than 0 hours

Five predictive factors (Table B.3) were available for incorporation into the models, using the selection procedure listed in Table B.2. The primary explanatory variables are year and month of catch, DFO locality and 30 m depth band (Table B.3). The DFO major area (3C to 5D, depending on the model) was also added in case there was additional explanatory power from this category. Vessel was not used as an explanatory variable because it seemed unlikely that vessels would behave consistently over such a long period. There is also uncertainty that vessel codes have been applied consistently over such a long period. The effort variable used in these analyses was the number of hours fished.

Table B.3. List of predictive factors available for long-term analyses from the GFCatch and PacHarvestTrawl databases.

Fishing year (1 April–31 March)
Month
DFO locality (Rutherford 1995)
Depth aggregated into 50 m depth bands
DFO Major region (3C, 3D, 5A, 5B, 5C, 5D or 5E)

Combined Areas 3C, 3D, 5A, 5B, 5C, 5D: Long-term standardised GLM (1966/67 to 2005/06):

Data from the *PacHarvestTrawl* database were used to define the preferred depth distribution for Petrale sole in combined areas 3CD5ABCD, based on all bottom trawl records which recorded the capture of Petrale sole. The depth distribution of this data set ranged from about 20 m to a few observations deeper than 900 m, but with large majority of observations between 50 and 500 m (Figure B.1). The GLM model for 3CD5ABCD used all valid tows occurring between 50 and 500 m aggregated into 50 m bins.

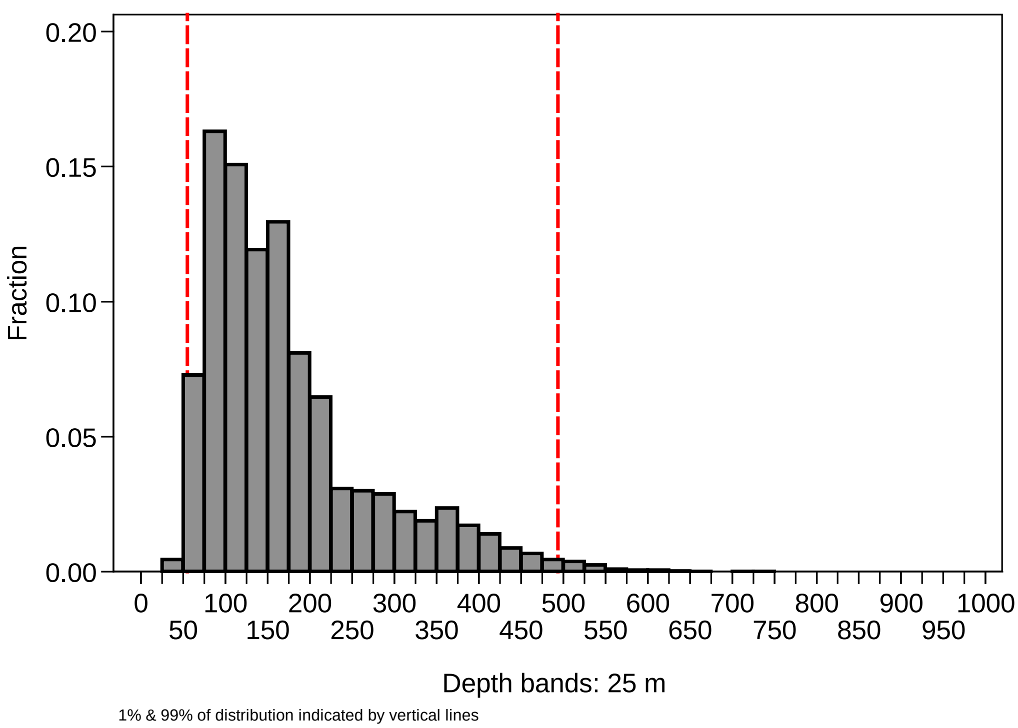


Figure B.1. Depth distribution of tows with reported Petrale sole catch in DFO combined regions 3C, 3D, 5A, 5B, 5C, 5D from 1996/97 to 2005/06 in 25 m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1%=55 m; 99%=494 m.

The available explanatory variables used in the analysis are described in Table B.3. The data qualifications (Table B.2) included restricting the depth observations to between 50 and 500 m. DFO locality (56 categories) and 50m depth band (9 categories) explained the most deviance. There appears to be little seasonality in the data, as month only explained slightly more than 1% of the deviance. The total explained deviance for this model was 27% (Table B.4).

Table B.4: Order of acceptance of variables into the 1966/67–2005/06 3CD5ABCD west coast BC model of positive landed catches of Petrale sole with the amount of explained deviance (R^2) for each additional model variable. Variables accepted into the model are marked with an *. Year was forced as the first variable.

Variable	1	2	3	4	5
Year*	**0.045**				
DFO locality*	0.155	**0.206**			
Depth bands*	0.108	0.156	**0.260**		
Month*	0.019	0.071	0.216	**0.271**	
DFO major area	0.102	0.148	0.214	0.266	0.278
Improvement in deviance	0.000	0.161	0.054	0.011	0.007

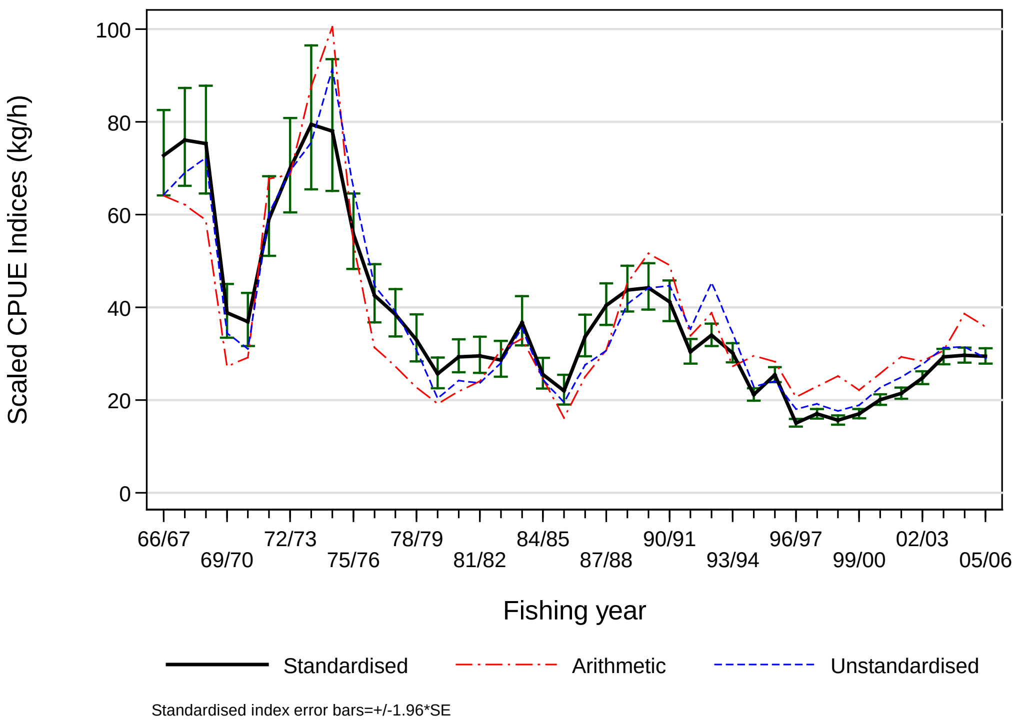


Figure B.2. Three annual series based on CPUE analyses (landed catch per hour) for 3CD5ABCD landed Petrale sole catches from 1966/67 to 2005/06. The solid line is a standardised analysis correcting for year of catch, DFO locality, depth band category, and month (Eq. B.2). The other two series correspond to annual indices calculated using Eq. B.5 and Eq. B.6 respectively.

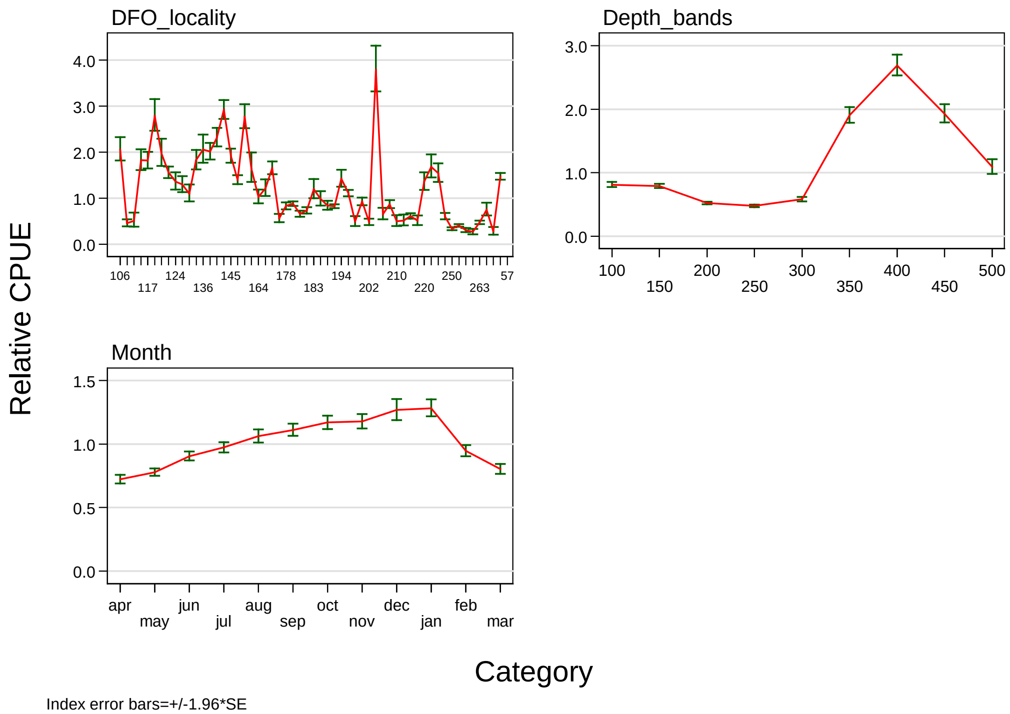


Figure B.3. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure B.2.

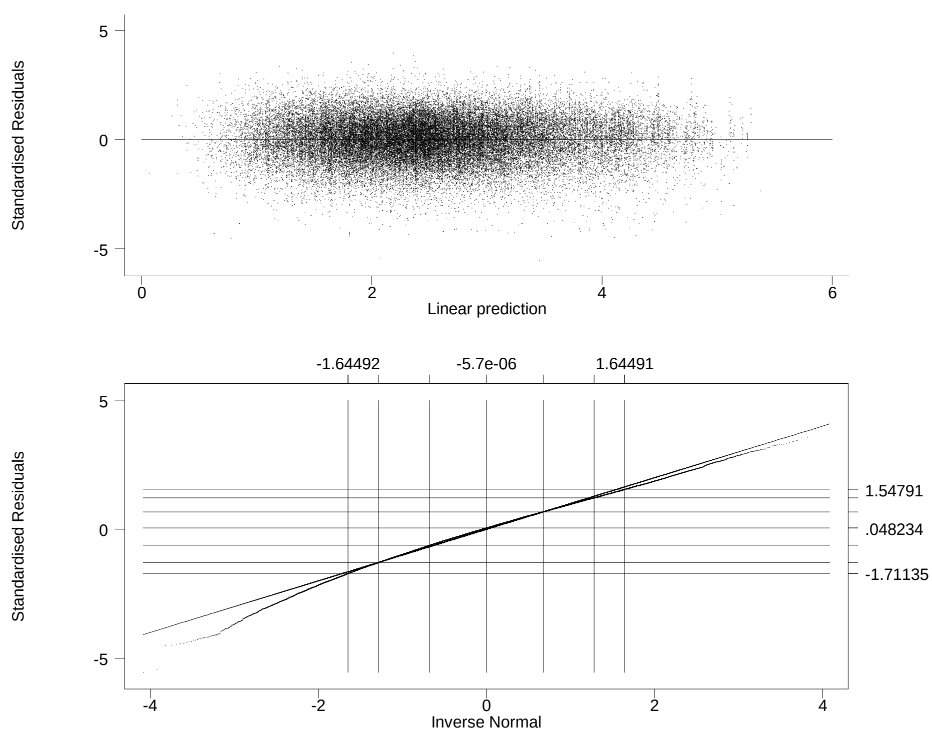


Figure B.4. Standardised (Pearson) residuals for the GLM analysis presented in Figure B.2. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

Table B.5. Arithmetic and standardised CPUE indices (kg/h) with standard errors and upper and lower bounds of the standardised index for the total west coast BC model of non-zero catches of Petrale sole. The standardised series has been scaled to the geometric mean of the arithmetic series.

Year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
66/67	64.1	72.8	64.1	82.5	0.0643
67/68	62.1	76.0	66.2	87.3	0.0705
68/69	58.8	75.3	64.5	87.8	0.0784
69/70	27.2	38.8	33.4	45.0	0.0757
70/71	29.2	36.9	31.6	43.1	0.0786
71/72	67.7	59.0	51.1	68.3	0.0742
72/73	68.6	69.9	60.5	80.8	0.0740
73/74	87.6	79.4	65.4	96.5	0.0991
74/75	100.5	78.0	65.1	93.5	0.0924
75/76	53.7	55.8	48.2	64.5	0.0742
76/77	31.3	42.6	36.7	49.3	0.0750
77/78	27.2	38.5	33.7	43.9	0.0678
78/79	22.7	33.0	28.3	38.4	0.0781
79/80	19.2	25.6	22.5	29.2	0.0656
80/81	21.9	29.3	26.0	33.1	0.0619
81/82	24.0	29.5	25.8	33.7	0.0674
82/83	30.7	28.6	25.0	32.7	0.0688
83/84	33.2	36.7	31.7	42.4	0.0737
84/85	24.5	25.5	22.4	29.1	0.0659
85/86	16.1	22.0	19.0	25.5	0.0740
86/87	25.0	33.6	29.5	38.4	0.0678
87/88	30.7	40.4	36.2	45.1	0.0562
88/89	45.2	43.7	39.1	48.9	0.0574
89/90	51.6	44.2	39.5	49.5	0.0578
90/91	49.1	41.2	37.0	45.8	0.0542
91/92	33.8	30.4	27.8	33.2	0.0448
92/93	38.8	34.0	31.6	36.5	0.0362
93/94	27.3	30.1	28.1	32.2	0.0346
94/95	29.5	21.1	19.8	22.5	0.0323
95/96	28.3	25.4	23.8	27.1	0.0329
96/97	20.6	15.1	14.2	15.9	0.0285
97/98	22.9	17.0	16.0	18.0	0.0305
98/99	25.1	15.6	14.7	16.7	0.0318
99/00	22.2	17.0	16.1	18.1	0.0297
00/01	25.7	20.1	18.9	21.2	0.0291
01/02	29.3	21.4	20.3	22.7	0.0289
02/03	28.4	24.8	23.4	26.2	0.0289
03/04	30.6	29.3	27.7	31.0	0.0287
04/05	38.6	29.6	28.0	31.3	0.0283
05/06	35.8	29.5	27.9	31.2	0.0287

The standardised series shows fluctuations in the late 1960s (which may be an artefact of the data), followed by a period of decline from mid-1970s to the end of the decade (Figure B.2; Table B.5). Following this period, the series is variable around an apparent mean over the 1980s, or even possibly rising, but then starts to decline again to the mid-1990s, which is the start of a changed management regime and full observer coverage (Figure B.2). The series then shows an increasing trend up to the present. The arithmetic CPUE (Eq. B.5) series shows similar trends to the standardised index with more variability and greater extremes. The recovery since the mid-1990s as shown by the arithmetic series appears to be quicker and perhaps stronger than the recovery shown by the standardised (Eq. B.3) and unstandardised series (Eq. B.6; Figure B.2). A plot of the explanatory locality coefficients shows strong peaks associated with Fingers (index=118), South Estevan (index=140), Esperanza East (index=147) and "outside Cape St. James" (index=203; Figure B.3). These are all areas which are known to have high Petrale sole catch rates. The depth bin coefficients peak with the 350-400 m bin, with very low predicted catch rates below 300 m. This is consistent with reports that Petrale sole are reported caught in the summer as bycatch to other fisheries while catch rates increase in the winter when the fish are aggregated in deeper water to spawn. The monthly coefficients confirm this pattern with an increasing trend in catch rate which peaks in January. Model residuals show some deviations from the log-normal assumption at the lower tail of the distribution (Figure B.4).

Investigations into the effect of interactions in the 3CD5ABCD long-term CPUE analysis:

Interaction effects were investigated for the 3CD5ABCD long-term model through two additional models. One model discarded the DFO locality information and relied on the month and depth explanatory variables along with an added monthXdepth interaction term to account for a known pattern in the Petrale sole fishery where vessels move to deeper water in the winter to capture spawning or mature fish. This model had less explanatory power than the base model, with only 24% of the deviance explained compared to 27% for the base model (Table B.6). However, the resulting year indices are virtually identical to the base model, indicating that most of the shift in the base model from the arithmetic series may be due to the month and depth variables (Figure B.5). A second model begins with the fit presented in Table B.4 by offering the base model two additional interaction terms (DFOLocalityXdepth and MonthXDepth) after the base model had been fit. This model explained an additional 9% of deviance, raising the overall deviance explained to 36% from 27% (Table B.7). However once again, the year indices estimated by this model differ very little from the year indices from the base model (Figure B.5).

Table B.6: Order of acceptance of variables into the 1966/67–2005/06 combined areas 3CD5ABCD model of positive landed catches of Petrale sole with the amount of explained deviance (R^2) for each additional model variable. The model was restricted to the depth and month primary variables followed by offering the model a single depthXmonth interaction term after the two primary variables had been accepted. Year was forced as the first variable.

Variable	1	2	3	4
Year*	**0.043**			
Depth bands*	0.103	**0.150**		
Month*	0.021	0.071	**0.162**	
MonthXDepth*				**0.235**
Improvement in deviance	0.000	0.107	0.012	0.073

Interactions with the year variable were not directly investigated because it is not clear how to interpret such effects. If there is such an interaction, then the appropriate interpretation is that each of area should be analysed and assessed independently. However, such an analysis is not always useful or feasible when the assessment is expected to provide management advice for large areas of the coast or given the availability of auxiliary data. Accordingly, it was assumed that, for the purposes of this assessment, that the year indices calculated from the base model provided useable estimates of abundance trends for Petrale sole in the combined regions of 3CD5ABCD from 1966/67 to 2005/06.

Table B.7: Order of acceptance of variables into the 1966/67–2005/06 3CD5ABCD model of positive landed catches of Petrale sole with the amount of explained deviance (R^2) for each additional model variable. The model was then offered two interaction terms after all the primary variables had been accepted. Year was forced as the first variable.

Variable	1	2	3	4	5	6
Year	**0.045**					
DFO locality	0.155	**0.206**				
Depth bands	0.108	0.156	**0.260**			
Month	0.019	0.071	0.216	**0.271**		
MonthXDepth					**0.319**	
DepthXLocality					0.316	**0.356**
Improvement in deviance	0.000	0.161	0.054	0.011	0.048	0.037

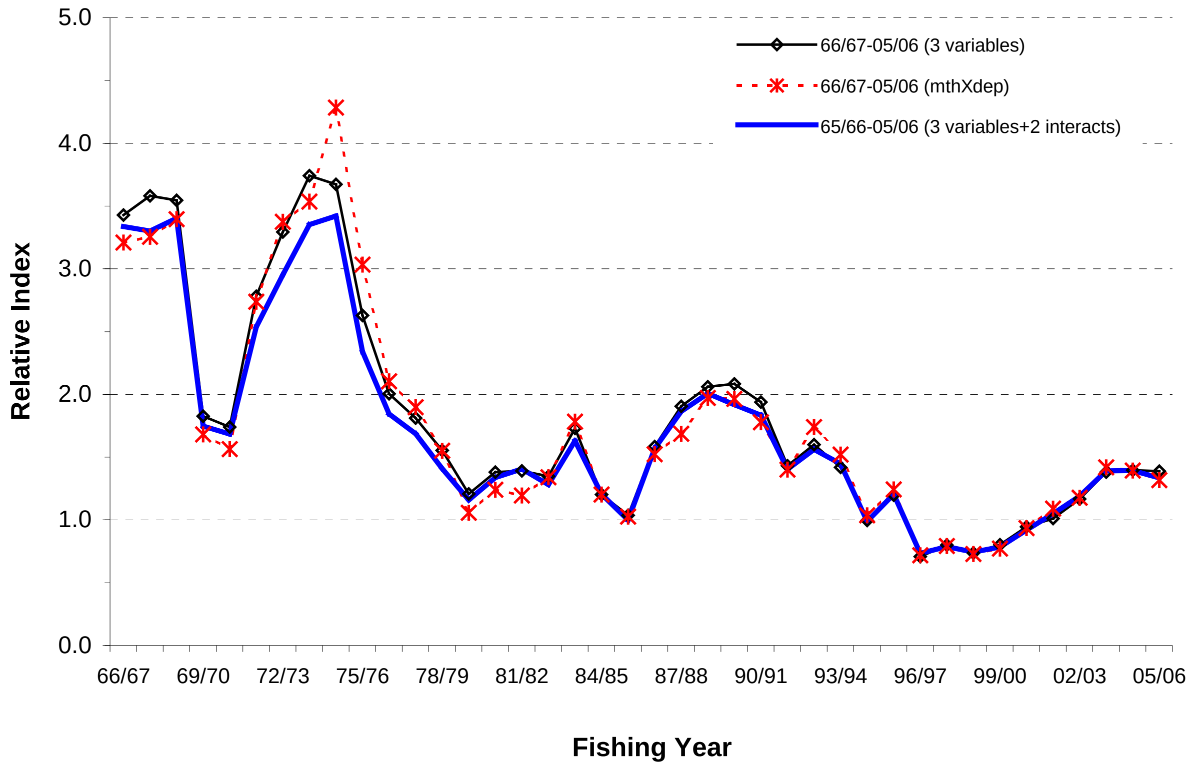


Figure B.5. Plots of year indices for three standardised models: a) base model with 4 explanatory variables (Table B.4); b) model with year, month, depth, and monthXdepth variables only (Table B.6); c) base model with two additional interaction terms (Table B.7). Each series has been normalised relative to its mean.

Suggestions from fishing industry representatives for improving the Petrale sole CPUE analysis:

In December 2006, Ron Gorman and Brian Mose, both west coast trawl skippers of considerable experience and at the request of the Canadian Groundfish and Conservation Society (CGRCS), provided a set of rules that characterised the Petrale sole fisheries on the west coast of Vancouver Island (Areas 3C and 3D) and the Queen Charlotte Sound (Areas 5A and 5B; Table B.8). These rules were used to select data to be incorporated into an alternative long-term standardised CPUE analysis which could be compared to the original analysis based on a more complete data set (Table B.4). These selection rules are based on the observations that Petrale sole tend to be dispersed in shallower depths during the summer months and thus are captured as a bycatch in tows targeted at other species. On the other hand, there is a winter fishery targeted at Petrale sole which tend to be concentrated to spawn in deeper, more outside areas. Most of this winter fishery is confined to the west coast of Vancouver Island because the best outside, deeper areas of Queen Charlotte Sound have been closed to fishing in the winter for most years to protect spawning Pacific ocean perch (B. Mose, *pers. comm.*). By way of illustration, Figure B.6 provides the mean catch rates for Petrale sole from a recent year (2004), arranged in approximately 60 km^2 grids. The left panel corresponds to the January–March catches, recorded by on-board observers, with high catch rates concentrated on the outer edge of the shelf, primarily off the west coast of Vancouver Island, but also with some areas of high catch rates at the southern tip of Moresby Island and in Dixon Entrance (Figure B.6). The right panel, corresponding to July–September, shows that the areas of high catch rates have moved to the inside areas of Queen Charlotte Sound, Hecate St. and on the shelf off WCVI (Figure B.6).

Table B.8. List of characteristics used to define Petrale sole fisheries on the west coast of Canada to select data for standardised CPUE analyses.

	CGRCS selection rules	**Wide analysis selection rules (page B.42)**
Most representative areas	3CD & 5AB	3CD & 5AB & 5CD
Representative depth range	3CD: 310–390 m (170–210 fathoms) 5AB: 80-120 m (45–65 fathoms)	3CD5ABCD: 50–500 m
Representative season	3CD: Nov.–Apr. 5AB: May–Oct.	3CD5ABCD: April–March

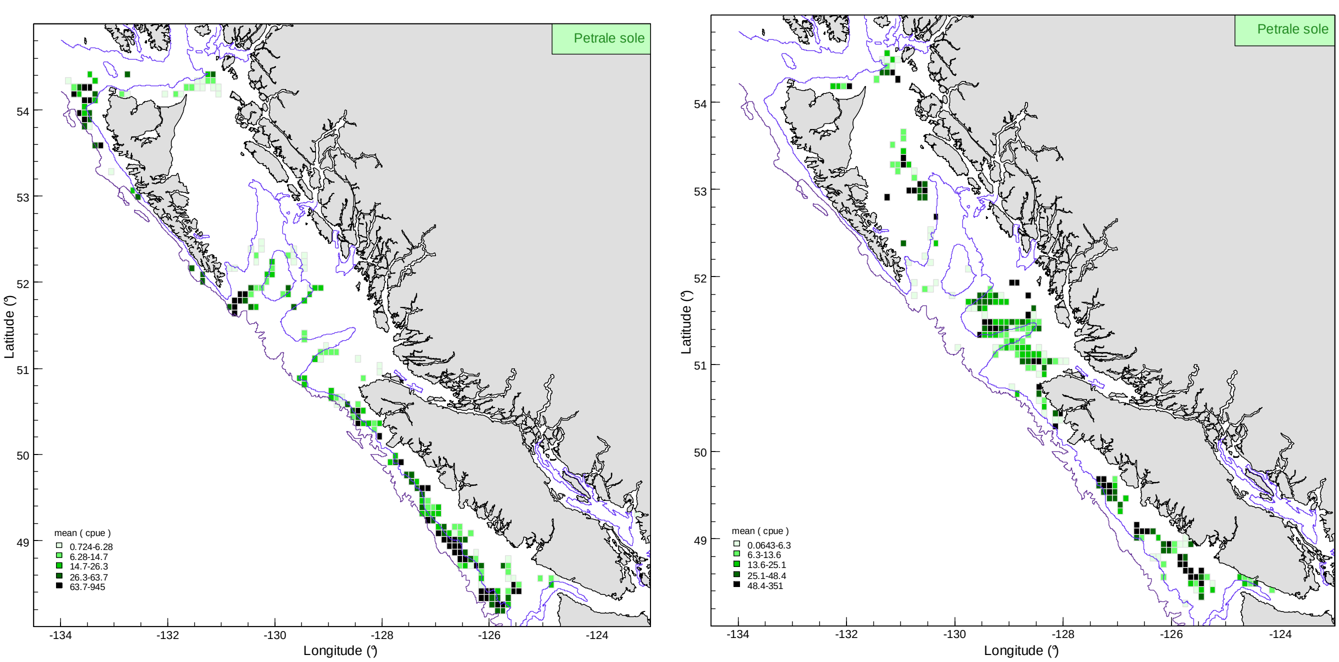


Figure B.6. Plots of Petrale sole catch rates (kg/h) for two periods of three months, summarised into grids of 0.10° longitude by 0.075° latitude. [left panel] January–March, 2004; [right panel] July–September, 2004

Analyses were performed separately on 3CD and 5AB Petrale sole using the "CGRCS selection rules" (Table B.8), which were then compared to the equivalent analyses based on a larger and more complete data set confined to the same regions, using the "wide analysis selection rules" presented in Table B.8 and which are equivalent to the analysis presented in Table B.4 and Table B.5. Note that the analyses for these smaller regions (3CD and 5AB) are not presented in detail because they were not subsequently used in the stock assessment. The 3CD analyses differ substantially when compared in terms of the absolute CPUE: the trajectory based on the "CGRCS selection rules" lies well above the "wide analysis rules" and appears considerably more optimistic in terms of the recent rebuild (Figure B.8 [left panel]). However, the difference between the two series is less pronounced when they are normalised against the same period, although the degree of recent rebuild is still stronger for the trajectory based on the "CGRCS selection rules" (Figure B.8 [right panel]). Note also that the trajectory based on the "GGRCS selection rules" only begins in 1989/90 because there was virtually no fishing at the preferred depths, particularly in winter, before that year.

There is less difference originating from the selection criteria for the two series using data from the combined region 5AB: the series based on the "CGRCS selection rules" lies almost on top of the "wide analysis selection rules", regardless of whether each series is treated in terms of kg/h or as a relative index (Figure B.9). This indicates that there was little difference caused by the two sets of data selection criteria with the exception that the series based on the "CGRCS selection rules" appears to recover more quickly in the final two years of the series compared to the "wide analysis selection rules".

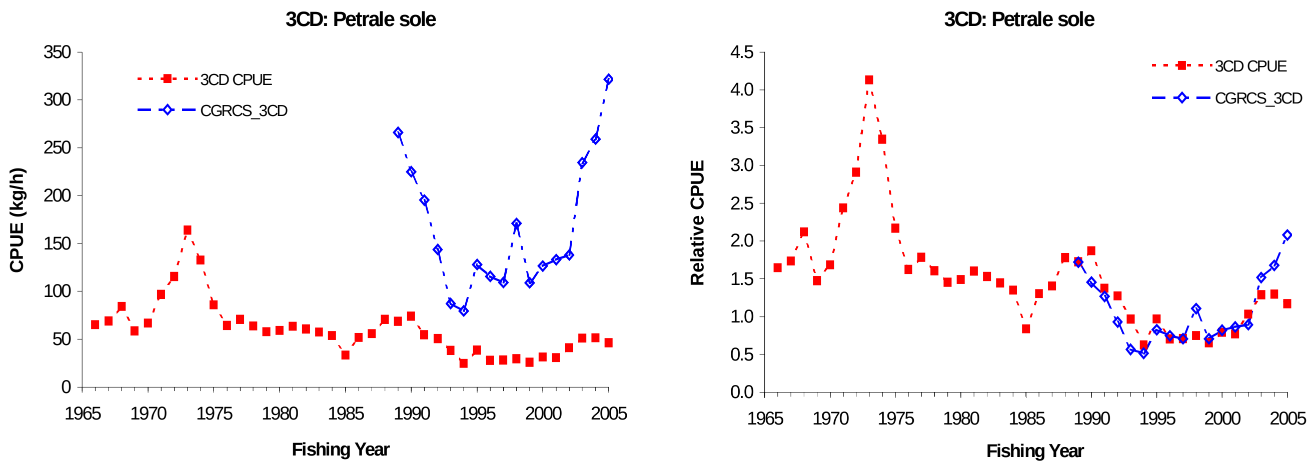


Figure B.8. 3CD Petrale sole CPUE for the period 1966/67 to 2005/06 using the two sets of data selection "rules" described in Table B.8. [left panel]: CPUE plotted as kg/h; [right panel]: CPUE plotted as an index relative to the average 1989/90–2005/06 CPUE.

The different behaviour observed between the 3CD and the 5AB series raises the spectre of areaXyear interaction effects that require separate assessments for each area. Unfortunately, the fact that the 3CD series only effectively begins in 1989/90 means that there is a strongly unbalanced data set, with the longer term series only representing the shallower summer bycatch fishery (in 5AB) while the deeper more targeted fishery (in 3CD) has a shorter series. The 5E fishery was also not analysed as this fishery began later than the 3CD fishery and thus the amount of catch and effort data from that fishery is even less than for the other fisheries. And it would be difficult to combine separate assessments based on the 3CD series and 5AB series, given the different lengths of these series.

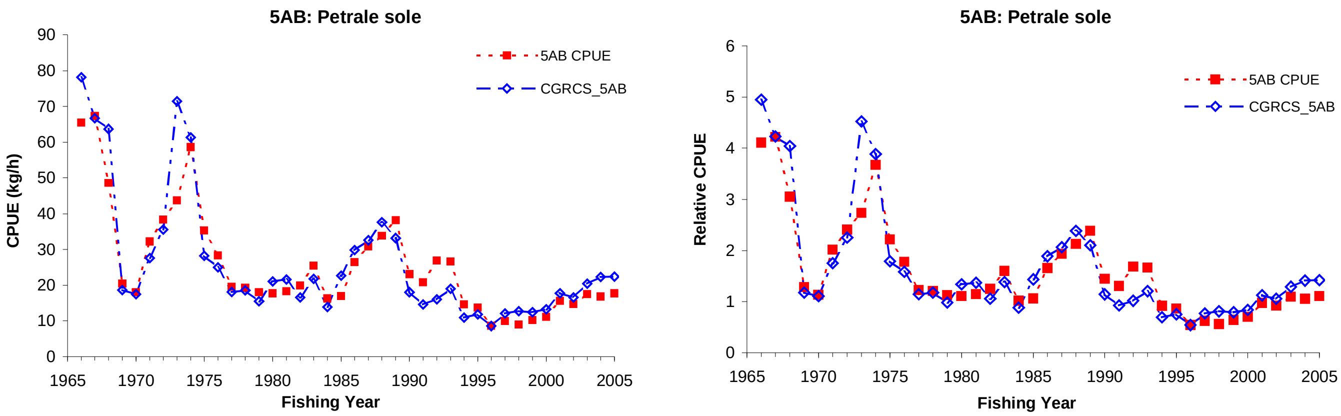


Figure B.9. 5AB Petrale sole CPUE for the period 1966/67 to 2005/06 using the two sets of data selection "rules" described in Table B.8. [left panel]: CPUE plotted as kg/h; [right panel]: CPUE plotted as an index relative to the average CPUE 1966/67–2005/06 CPUE.

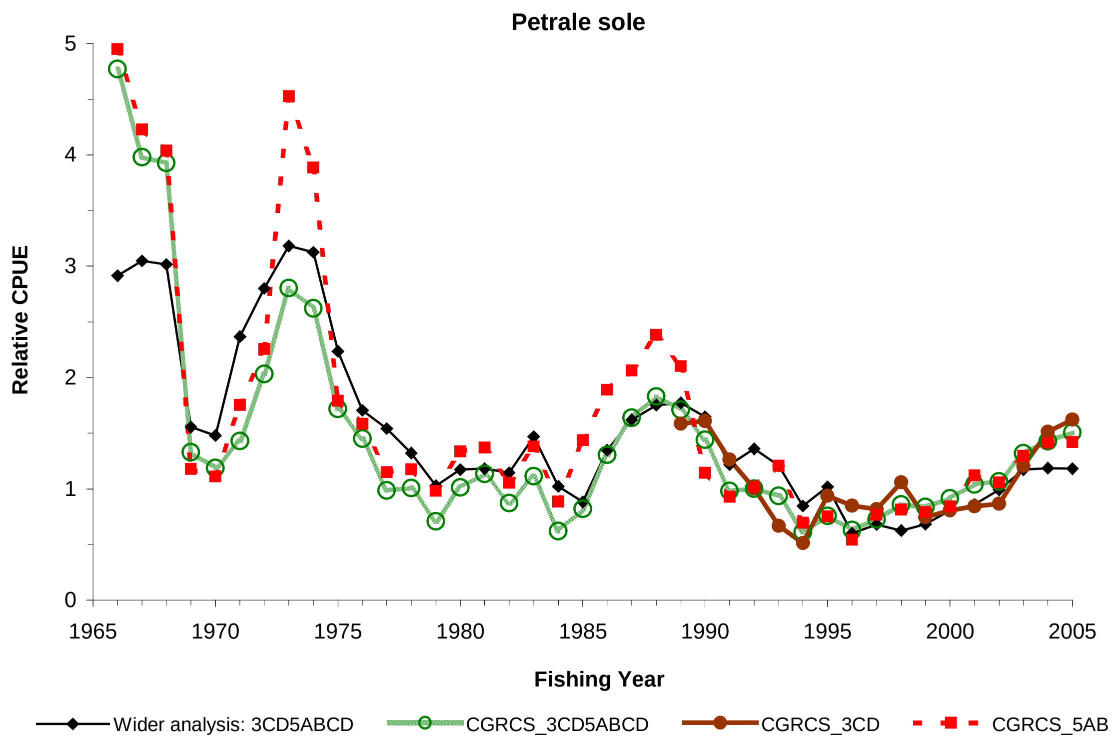


Figure B.10. Comparison of three CPUE series using the "CGRCS selection rules" (Table B.8) with the combined 3CD5ABCD series based on the "Wide analysis selection rules" (Table B.8 and page B.42). Each series is plotted as an index relative to the average 1989/90–2005/06 CPUE.

As there appears to be no satisfactory solution which does not involve substantial assumptions, it was decided to continue the practice of lumping data to provide a single series from which a model representing the entire coast-wide fishery can be constructed. The reasoning behind this decision is as follows:

- The pattern of movement between a shallow summer bycatch fishery and a deeper spawning fishery is indicative of within year movement and fairly widely ranging stock. It is probably incorrect to treat these areas as separate stocks and it would be difficult, given the small amount of available data, to model this aspect of the biology of Petrale sole;
- The standardisation procedure should be able to adjust for some of the area/seasonal/depth effects. The consistency between the series based on separate sets of "rules" is indicative of this effect. Figure B.9 shows that there is considerable overlap between series based on separate "rules", with the major divergence being in the most recent few years;
- The main difference between the trajectories based on separate selection criteria lies in the behaviour of the series in the last 2 to 3 years. The sensitivity of the stock assessment model to these different trajectories can be investigated by evaluating models based on each trajectory independently.

Combined Areas 3C, 3D, 5A, 5B, 5C, 5D: Long-term standardised GLM (1966/67 to 2005/06) based on the CGRCS selection rules:

A GLM model for 3CD5ABCD was fitted using the "CGRCS selection rules" presented in Table B.8. This model is presented as an alternative interpretation of the catch/effort data pertaining to Petrale sole in contrast to the analysis based on the "wide selection rules" (Table B.8), described beginning on page B.42. Note that the "CGRCS selection rules" greatly reduced the amount of data available for analysis, with the total number of observations used in the analysis dropping from about 44,700 to around 11,900.

The available explanatory variables used in this analysis are the same as those described in Table B.3. Depth and seasonal data were restricted differently, depending on the area of catch: the 3CD data were confined to the depth range 310 to 390 m and to the months of November to April; the 5ABCD data were confined to the depth range 80 to 120 m and the months of May to October. Depth was treated as single explanatory variable binned into 10 m depth intervals, resulting in 12 depth bins. DFO major area was not offered to the model. DFO locality (22 categories) and month (12 categories) explained the most deviance, with DFO locality accounting for 31% of the deviance on its own (Table B.9). Depth was forced into the regression although it did not satisfy the 1% deviance requirement. This was done to provide comparability with the model based on the "wide analysis selection rules". The total explained deviance for this model was 40%, which is greater than the model presented in Table B.4.

Table B.9: Order of acceptance of variables into the 1966/67–2005/06 3CD5ABCD west coast BC model of positive landed catches of Petrale sole using the "CGRCS selection rules" (Table B.8) with the amount of explained deviance (R^2) for each additional model variable. Variables accepted into the model are marked with an *. Year was forced as the first variable.

Variable	1	2	3	4	5
Year*	**0.050**				
DFO locality*	0.301	**0.356**			
Month*	0.268	0.323	**0.397**		
Depth bands*	0.234	0.289	0.364	**0.402**	
Improvement in deviance	0.000	0.307	0.041	0.005	0.000

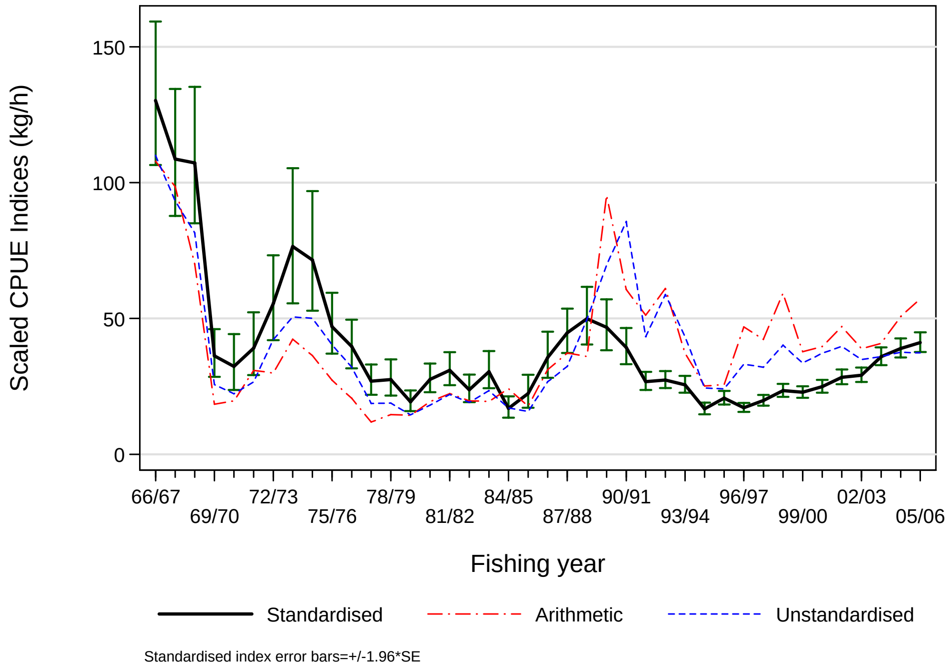


Figure B.10. Three annual series based on CPUE analyses (landed catch per hour) for 3CD5ABCD landed Petrale sole catches from 1966/67 to 2005/06, using the "CGRCS selection rules" (Table B.8). The solid line is a standardised analysis correcting for year of catch, DFO locality, depth band category, and month (Eq. B.2). The other two series correspond to annual indices calculated using Eq. B.5 and Eq. B.6 respectively.

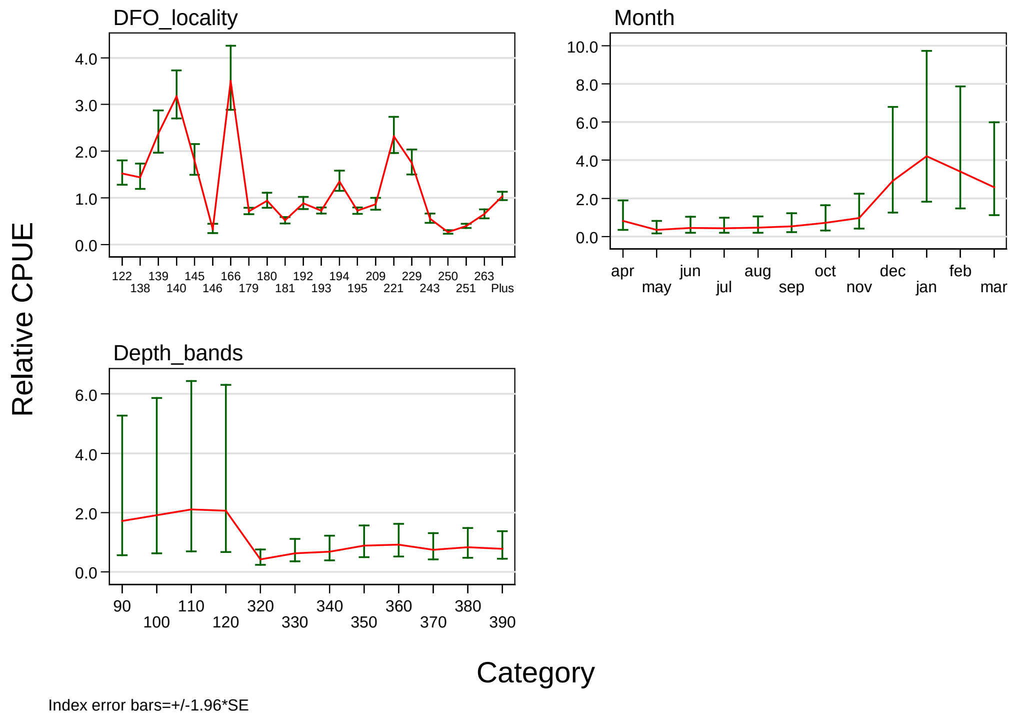


Figure B.12. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure B.11.

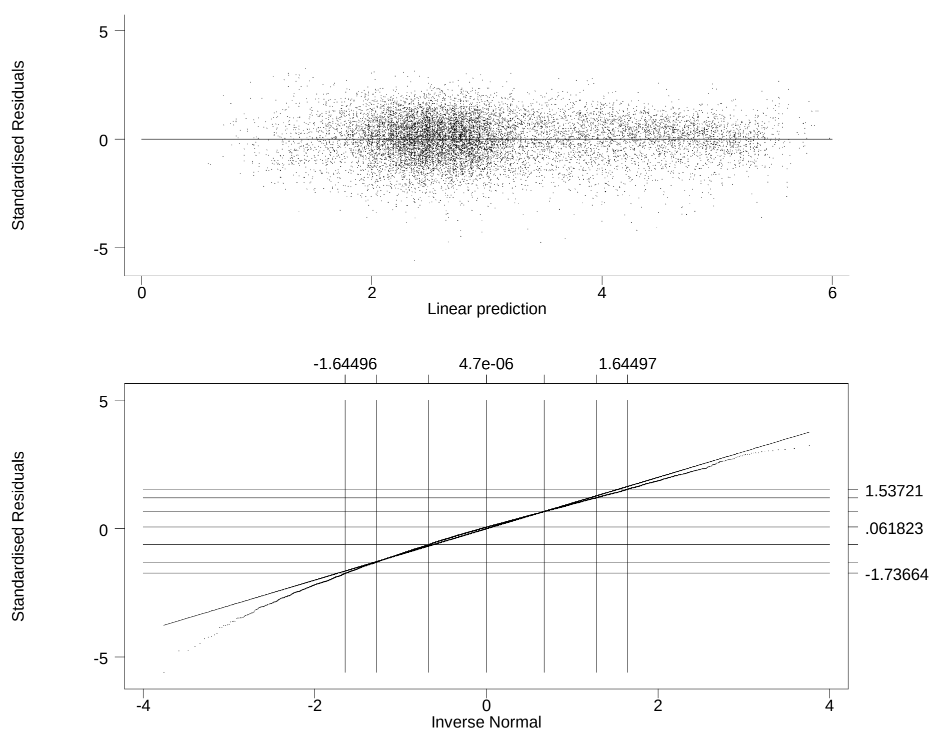


Figure B.13. Standardised (Pearson) residuals for the GLM analysis presented in Figure B.11. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

This standardised series shows considerable uncertainty (as evidenced by the wide error bars) in the early part of the time series, becoming somewhat less variable around the middle of the 1970s (Figure B.11; Table B.10). Following this period, the series resembles the series based on a wider selection of data, where the series rises to a mode in the late 1980s, then to a minimum in the early to mid-1990s and from there a steady rise (compare Figure B.2 with Figure B.11). Both the arithmetic CPUE (Eq. B.5) and the unstandardised CPUE (Eq. B.6) series show large deviations from the standardised index beginning from the late 1980s, indicating that the unstandardised catch rates are very high in the selected data and that the standardisation procedure has had a considerable influence in this analysis. A plot of the explanatory locality coefficients shows strong peaks associated with Clayquot Canyon (index=139), South Estevan (index=140), Quatsino Sound (index=166) and South Bonilla (index=221; Figure B.12). Among these four localities, only South Estevan stood out in the previous analysis (Figure B.3). However, the three other localities listed as having relatively large coefficients in this analysis also had above average coefficients in the previous analysis. For instance, Clayquot Canyon was the highest of these, having a value of 2.3 in the previous analysis (Figure B.3). The monthly coefficients showed a peak in January as in the previous analysis, although there is considerable uncertainty in the winter estimates of these coefficients. The depth coefficients show little contrast and the four shallow coefficients have large error bars (Figure B.12). This is consistent with low explanatory power for this variable. Model residuals are similar to those presented for the previous analysis, which both show deviations from the log-normal assumption at the lower tail of the distribution (Figure B.13). An alternative analysis was run which dropped the depth explanatory variable to see if this variable was causing any substantive changes to the estimated year coefficients. However, the resulting year coefficients were virtually unchanged compared to the original analysis (Figure B.14).

Table B.10. Arithmetic and standardised CPUE indices (kg/h) with standard errors and upper and lower bounds of the standardised index for the total west coast BC model of non-zero catches of Petrale sole, using the “CGRCS selection rules” (Table B.8; Figure B.11). The standardised series has been scaled to the geometric mean of the arithmetic series.

Year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
66/67	107.9	130.2	106.5	159.3	0.1027
67/68	98.6	108.6	87.8	134.5	0.1089
68/69	70.0	107.3	85.1	135.3	0.1184
69/70	18.5	36.3	28.5	46.1	0.1225
70/71	19.7	32.4	23.7	44.3	0.1601
71/72	30.9	39.1	29.2	52.3	0.1484
72/73	29.9	55.5	42.0	73.3	0.1418
73/74	42.4	76.5	55.6	105.3	0.1630
74/75	36.4	71.6	52.9	96.9	0.1545
75/76	27.3	47.0	37.1	59.5	0.1205
76/77	20.6	39.6	31.7	49.6	0.1142
77/78	11.9	26.9	22.0	33.1	0.1044
78/79	14.7	27.5	21.6	35.0	0.1224
79/80	14.4	19.3	15.9	23.5	0.0992
80/81	19.4	27.6	22.8	33.4	0.0971
81/82	22.4	31.0	25.5	37.6	0.0991
82/83	19.7	23.8	19.2	29.4	0.1080
83/84	19.5	30.4	24.4	38.0	0.1135
84/85	24.2	17.0	13.5	21.4	0.1170
85/86	17.7	22.4	17.2	29.3	0.1369

Year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
86/87	31.1	35.7	28.2	45.2	0.1204
87/88	37.3	44.7	37.3	53.6	0.0926
88/89	36.0	50.0	40.5	61.6	0.1073
89/90	95.5	46.7	38.3	57.0	0.1015
90/91	60.7	39.3	33.2	46.5	0.0861
91/92	51.3	26.8	23.7	30.4	0.0634
92/93	61.1	27.4	24.4	30.7	0.0585
93/94	37.3	25.6	22.7	28.9	0.0615
94/95	25.2	16.8	14.7	19.0	0.0652
95/96	25.7	20.7	18.3	23.3	0.0615
96/97	46.9	17.2	15.7	18.9	0.0480
97/98	42.3	19.8	17.9	21.9	0.0508
98/99	59.3	23.4	21.2	26.0	0.0518
99/00	37.8	22.8	20.9	25.0	0.0466
00/01	39.7	25.0	22.7	27.4	0.0482
01/02	47.0	28.4	25.8	31.2	0.0488
02/03	38.9	29.2	26.7	31.9	0.0460
03/04	40.8	36.0	32.9	39.4	0.0459
04/05	50.7	39.0	35.6	42.7	0.0458
05/06	57.2	41.1	37.7	44.9	0.0449

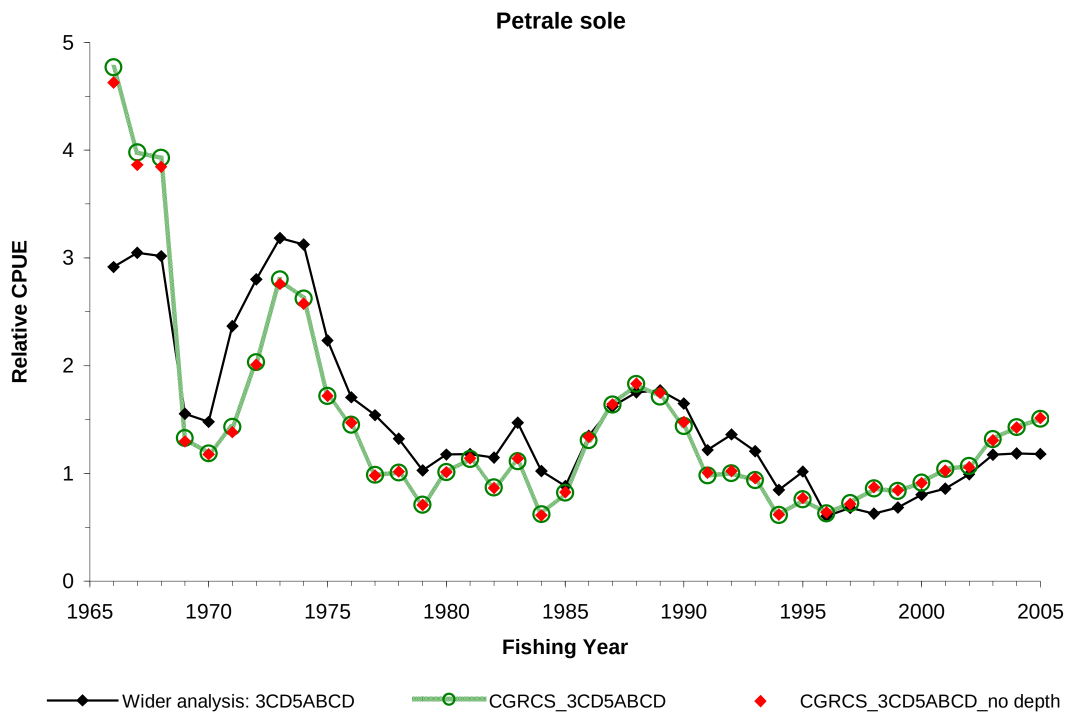


Figure B.14. Comparison of two CPUE series using the "CGRCS rules" (Table B.8 and Figure B.11) with the combined 3CD5ABCD series based on the "Wide analysis rules" (Table B.8 and Figure B.2). Each CGRCS series is based on the same data, with one including depth as a categorical explanatory variable (Table B.9) and the other dropping this variable. Each series is plotted as an index relative to the average 1989/90–2005/06 CPUE.

The model based on the CGRCS data selection rules can be compared directly with the model using the wider data selection rules (Figure B.14), with the two models diverging mainly at the beginning and the end of the time series. The divergence in the early part of the series is not surprising, given the relatively large uncertainty associated with this period, particularly for the CGRCS series (Figure B.11). The correspondence between the two series is good in the centre of the time series and it is likely that the stock assessment model cannot distinguish between either series, given the relatively large amount of error that is associated with these series in the model. The two series begin to diverge again from 1996 or 1997, with a stronger recovery being shown by the series based on the CGRCS selection rules (Figure B.14).

Application of these series to the Petrale sole stock assessment

The stock assessment model for Petrale sole will be offered two trajectories based on the CPUE analyses presented in Appendix B:

1. One model will be based on data from combined regions 3CD5ABCD using the "wide selection analysis rules" as described beginning on page B.42 and in Table B.8. This model is presented in Table B.5;
2. The other model will also be based on data from combined regions 3CD5ABCD, applying separately the "CGRCS selection rules" (Table B.8) for 3CD to the 3CD data and the rules for 5AB to the data from 5ABCD. This model is presented in Table B.10.

Appendix C. QUEEN CHARLOTTE SOUND SYNOPTIC TRAWL SURVEY

Introduction

Three trawl survey indices were used in the west coast B.C. Petrale sole assessment. These were the west coast Vancouver Island (WCVI) Triennial survey, the Queen Charlotte (QC) Sound synoptic survey and the Hecate Strait (HS) assemblage survey. The indices for the WCVI Triennial and the HS assemblage surveys were documented in Starr & Fargo (2004) and there have been no additional surveys operated since then. Two other surveys, the WCVI shrimp trawl survey and the QC shrimp trawl survey, may potentially provide information that would be useful in a quantitative stock assessment for Petrale sole. The WCVI shrimp survey was used in the 2004 Petrale sole assessment and the indices up to 2003 were documented in that assessment (Starr & Fargo 2004). However, close examination of these indices indicate that it is unlikely that they are providing useful indices of abundance for this species. The trajectory for the WCVI shrimp survey is characterised by a few high indices in the early part of the series, followed by a long period of about 20 years where low biomass levels predominated and which showed contrast (Figure C.1). The most recent ten years show higher biomass levels, but these fluctuate greatly from year to year, indicating a very high level of process error in these estimates. The QC Sound shrimp survey, a more recent addition, appears to be following a similar erratic process (Figure C.1). Early attempts at using these surveys in the assessment model indicated that it would not be possible to fit the large variations in abundance and these two indices were discarded from the assessment. A third survey, the Hecate Strait Pacific cod monitoring survey, only operated for three years from 2002 to 2004 and the three indices for Petrale sole showed almost no contrast (2002: 500 t; 2003: 570 t; 2004: 440 t). Therefore, this survey was also not included in the assessment.

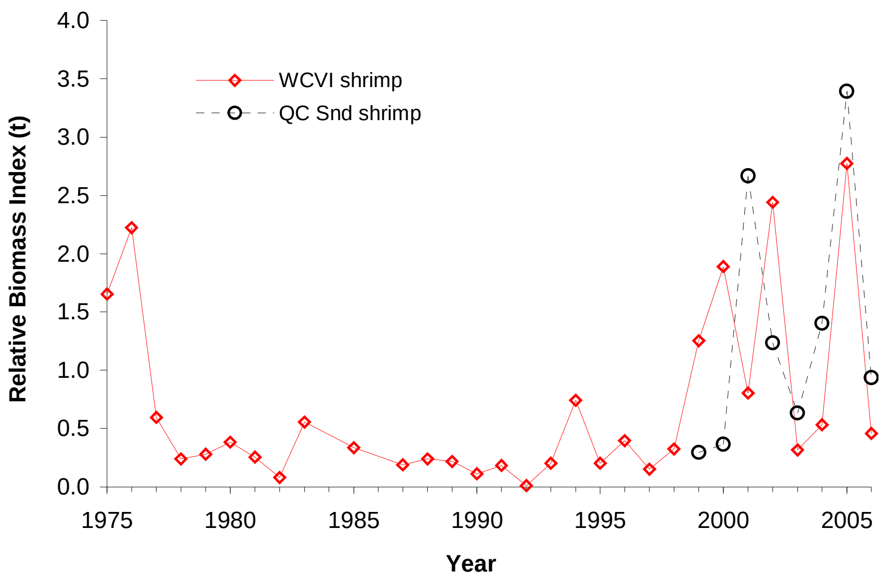


Figure C.1. Petrale sole biomass indices from the WCVI and QC Sound shrimp surveys, plotted as indices relative to the 1999–2006 mean, which is the period covered by the QC Sound shrimp survey.

Although the QC Sound survey also only provides three data points for this assessment, the data from this survey have been included because this is an on-going survey which will be continued into the foreseeable future. The following notes document the preparation of the indices for this assessment.

Methods

All data from the Queen Charlotte Sound synoptic trawl survey, including the catches of Petrale sole caught in each tow over the three years of this survey, were made available (N. Olsen *pers. comm.*). This survey operated 3 times in the Queen Charlotte Sound between Vancouver Island and Moresby Island between 2003 and 2005. This survey also operated in the lower part of Hecate Strait between Moresby Island the mainland. It is divided into two large aerial strata which roughly correspond to the DFO Regions 5A and 5B (Figure C.2). Each of these two areas is divided into four depth strata: 50–120 m; 120–250 m; 250–370 m; and 370–500 m (Table C.1; Figure C.2).

A doorspread density value (Eq. C.2) was generated for each tow based on the catch of Petrale sole, the mean doorspread for the tow and the distance travelled. The distance travelled was calculated by multiplying the mean vessel speed for the tow by the total time on the bottom as determined from the bottom contact sensor. Missing values for the doorspread field were filled in using the mean doorspread for the stratum in the survey year (27 values over all three years). Missing values in the vessel speed field were filled in using the mean value for the entire survey in that year (11 values in the first two years). Missing values in the bottom contact time field substituted the winch time (time from winch lockup to winch retrieval; 7 values over the three survey years).

Table C.1. Stratum designations, number of useable tows, number of tows that captured Petrale sole (PEL) and total PEL catch weight (kg) for all three years of the Queen Charlotte Sound survey. Also shown is the area (in km^2) of each stratum

			2003			2004			2005			
Stratum number	Area designation	Depth zone	No. tows	No. PEL tows	Catch wt (kg)	No. tows	No. PEL tows	Catch wt (kg)	No. tows	No. PEL tows	Catch wt (kg)	Area (km^2)
18	5AB-South	50-125 m	30	15	42.2	46	18	150.7	31	10	125.2	5,334
19		125-200 m	56	19	60.9	49	24	200.5	61	24	93.9	5,873
20		200-330 m	30	1	3.0	31	3	2.2	29	5	16.6	3,134
21		330-500 m	6	0	0.0	8	0	0.0	8	0	0.0	625
22	5AB-North	50-125 m	5	4	26.8	20	9	48.3	8	4	28.7	2,279
23		125-200 m	39	23	133.1	39	19	77.9	45	22	164.8	4,926
24		200-330 m	54	5	10.5	40	3	2.6	38	1	1.0	4,688
25		330-500 m	19	0	0.0	7	0	0.0	8	0	0.0	1,343
Total			239	67	276.5	240	76	482.2	228	66	430.2	28,202

These data were analysed using the following equations which assume that tow locations were selected randomly within a stratum relative to the biomass of Petrale sole. This was an assumption made by the original survey design using the area stratification definition in Figure C.2. The biomass in any year y was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata i:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \qquad \text{Eq. C.1}$$

where C_{y_i} = mean CPUE density (kg/km^2) for species s in stratum i

A_i = area of stratum i (km^2), and

B_{y_i} = biomass of Petrale sole in stratum i for year y.

k = number of strata

CPUE $\left(C_{y_i}\right)$ for Petrale sole in stratum i for year y was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \text{Eq. C.2}$$

where $W_{y_i j}$ = catch weight (kg) for Petrale sole in stratum i for year y and tow j

$D_{y_i j}$ = distance travelled (km) by tow j in stratum i for year y

$w_{y_i j}$ = net opening (km) by tow j in stratum i for year y

n_{y_i} = number of tows in stratum i

The variance of the survey biomass estimate V_y for Petrale sole in year y is calculated in kg^2 as follows:

$$V_y = \sum_{i=1}^{k} \sigma_{y_i}^2 A_i^2 \big/ n_{y_i} = \sum_{i=1}^{k} V_{y_i} \qquad \text{Eq. C.3}$$

where $\sigma_{y_i}^2$ = variance of CPUE (kg^2/km^4) for species s in stratum i

V_{y_i} = variance of Petrale sole in stratum i for year y

The CV for Petrale sole for each year y was calculated as follows:

$$CV_y = \frac{\sqrt{V_y}}{B_y} \qquad \text{Eq. C.4}$$

Five thousand bootstrap replicates with replacement were made on the survey data to estimate bias corrected 95% confidence regions for each survey year (Effron 1982).

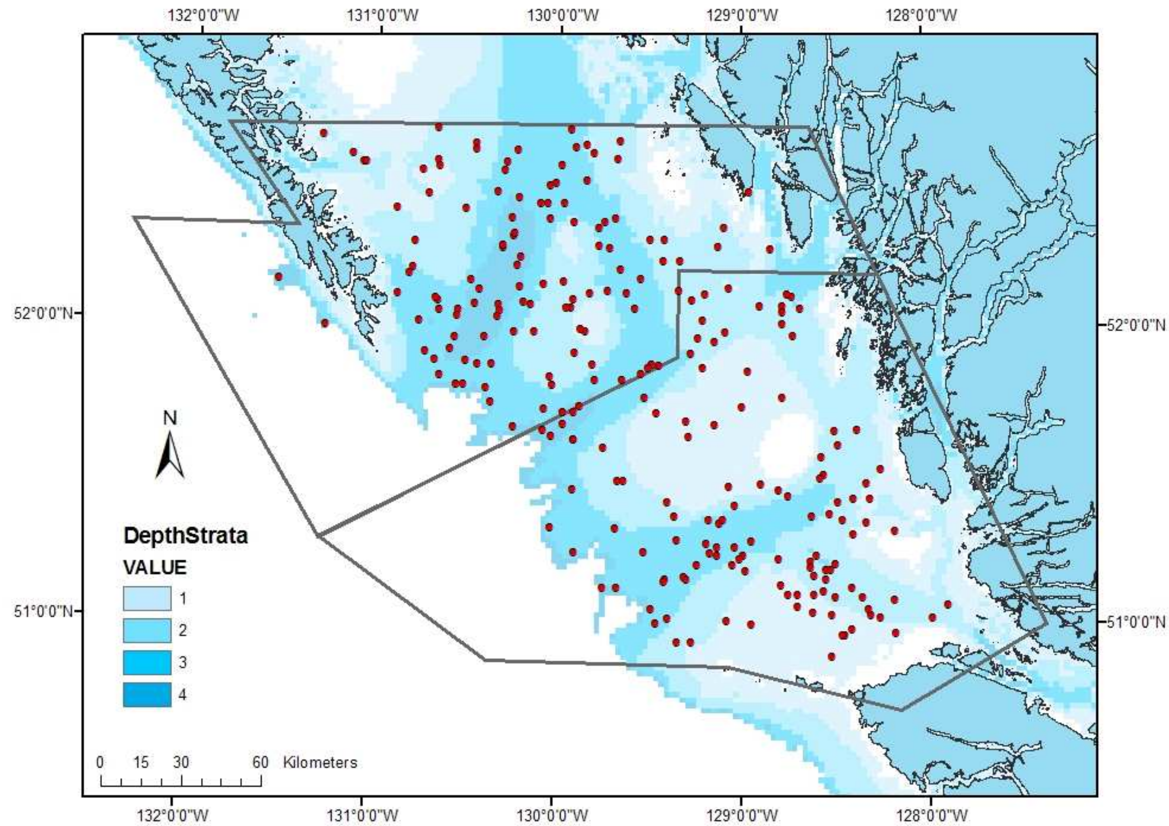


Figure C.2. Map showing the two aerial strata and the four depth zones used in the Queen Charlotte Sound survey. The red dots indicate the locations of the start positions for each useable tow from the 2003 survey. Depth zone codes: 1=50-125 m; 2=125-200 m; 3=200-330 m; 4=330-500 m.

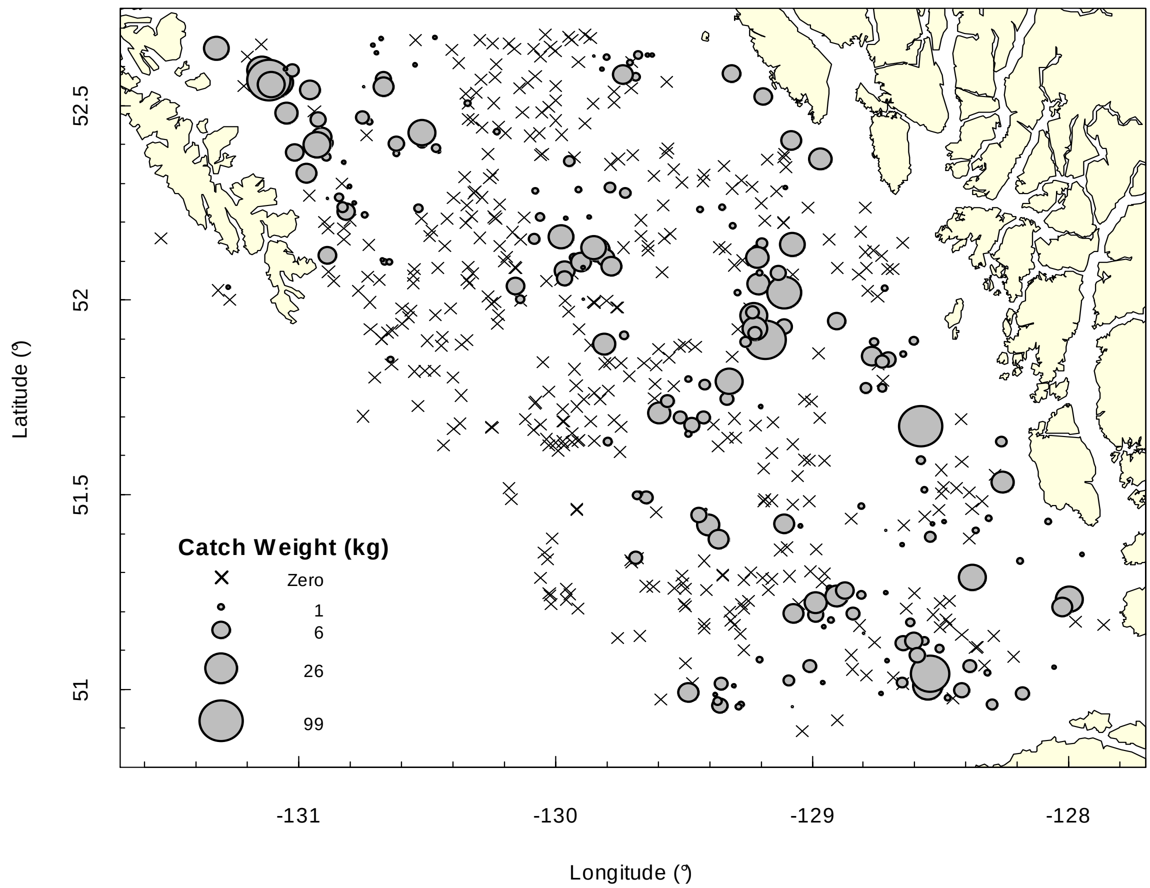


Figure C.3. Map of the locations of all trawls from the Queen Charlotte Sound synoptic trawl survey (2003–2005): those that caught Petrale sole are marked with circles proportional to the catch weight while those that caught no Petrale sole are marked with an X.

Results

Catches of Petrale sole are widely distributed throughout the entire survey area (Figure C.3). Petrale sole were mainly taken at depths from 70 to 200 m, but range from 66 to 328 m overall (Figure C.4).

Estimated biomass levels for Petrale sole from the QC Sound synoptic trawl survey have changed little over the 3 survey years, with mean biomass near 400 t (Figure C.5; Table C.2). The estimated CVs for Petrale sole from this survey were good in the first two years, at 0.20 and 0.21 respectively (Table C.2). However, the CV in 2005 for Petrale sole was very high, at 0.37.

The proportion of tows which took Petrale sole was nearly constant over the three survey years, with values of 0.28, 0.32, and 0.29 for 2003, 2004, and 2005 respectively.

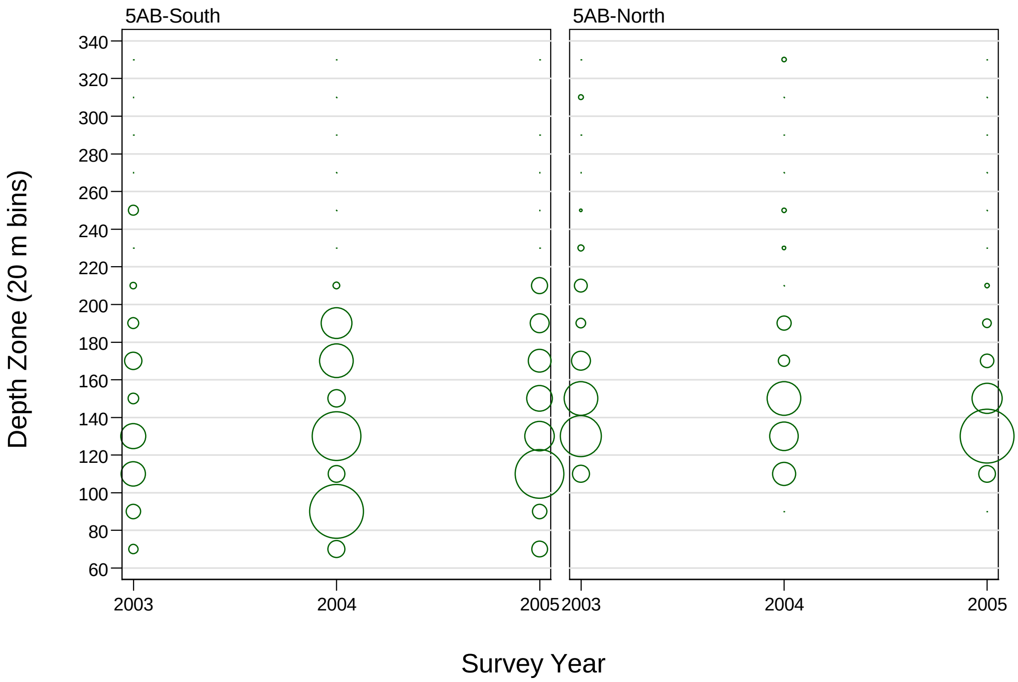


Figure C.4. Distribution of catch weight of Petrale sole by large area stratum (Table C.1), survey year and 20 m depth zone. Depth zones are indicated by the centre of the depth interval. Maximum circle size: 5AB-South=124 kg (90 m bin); 5AB-North=129 kg (130 m bin). Minimum depth observed for PEL: 66 m; maximum depth observed for PEL: 328 m. Depth is the mean of the start and end depths for the tow.

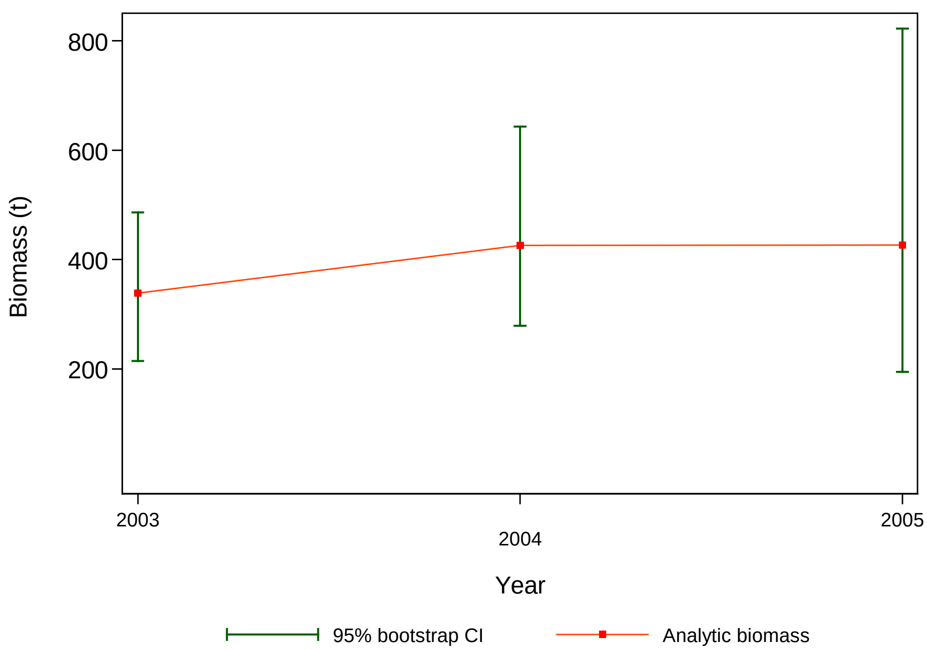


Figure C.5. Plot of biomass estimates for Petrale sole from the QC Sound synoptic trawl survey for 2003 to 2005. Bias corrected 95% confidence intervals from 5000 bootstrap replicates are plotted.

Table C.2. Biomass estimates for Petrale sole from the QC Sound synoptic trawl survey for the survey years 2003 to 2005. Bootstrap bias corrected confidence intervals and CVs are based on 5000 random draws with replacement. The analytic CV (Eq. C.4) is based on the assumption of random tow selection within a stratum.

Survey Year	Biomass (t)	Mean bootstrap biomass (t)	Lower bound biomass (t)	Upper bound biomass (t)	Bootstrap CV	Analytic CV (Eq. C.4)
2003	338.8	338.1	214.6	486.5	0.201	0.200
2004	426.0	426.3	278.6	643.1	0.215	0.217
2005	426.4	423.1	194.4	822.6	0.366	0.363

Comparison of the available survey estimates with the standardised CPUE series

Figure C.6 presents a comparison of the indices generated by the two longer term fishery independent series with the two standardised fishery dependent series (see Appendix B for a discussion of how these series were generated). Neither series matches the fishery independent surveys particularly well, but this could be for a number of reasons: a) the surveys are not tracking the Petrale sole abundance; b) the CPUE indices are not tracking abundance; c) the surveys are taking younger fish than the fishery and hence are showing recovery sooner than would be seen in the fishery.

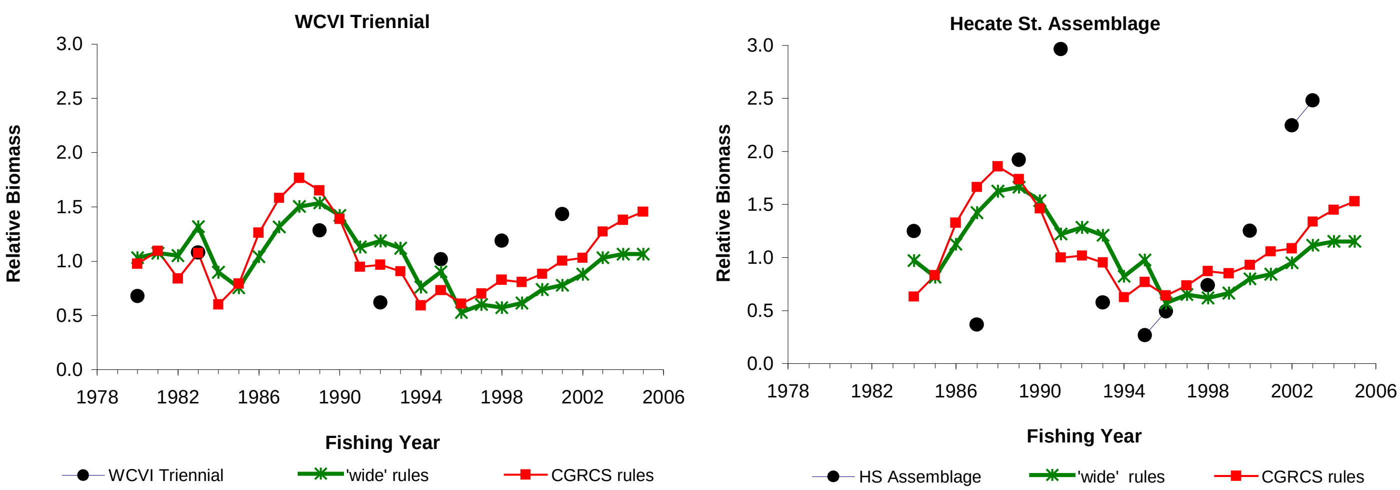


Figure C.6. Comparison of the survey series with the two coastwide fishery dependent standardised series ("wide" and "CGRCS" selection rules; see Appendix B) used in the Petrale sole stock assessment. Each series is standardised to the same years that the fishery independent series operated. [left panel]: WCVI Triennial survey; [right panel]: HS assemblage survey.

Appendix D. DELAY DIFFERENCE MODEL

Model description

A delay-difference stock production model (Quinn and Deriso 1999, Starr et al. 2002; Sinclair and Starr 2005) was used to estimate stock size, parameters and reference points relevant to management for Petrale sole in DFO combined areas 3CD5ABCD. The model uses two age groups, recruits and spawners. A Beverton-Holt stock-recruitment function was used to link the two groups.

Delay-difference models assume knife-edge selectivity to the fishery at a specific age. Age 6 and age 7 were adopted for Petrale sole based on comparing the distribution of sample mean weights taken by port sampling with the equilibrium mean average weight predicted by the model under different ages of knife edge selectivity and a fixed value for M=0.2 (see Appendix B, Section B.3 for a presentation of this information). Comparison of predicted model trajectories for vulnerable biomass from a delay-difference model fitted to 5CD rock sole data with an age-structured model fitted to data from the same area showed that the best correspondence between the two model trajectories was obtained when the age of knife-edge recruitment corresponded approximately to the mid-point of the selectivity curve estimated by the age-structured model (Figure F-1; Starr et al. 2006).

The same comparisons between the 5CD rock sole delay-difference and age-structured models indicated that 1966 was a good point at which to begin the delay-difference model. Data extend further back into time but the correspondence between all years becomes more tenuous the further back in time the data are extended. The year 1966 was selected as a good starting point for the 5CD rock sole models (both delay-difference and age-structured) and this starting point was also used for modelling Petrale sole. The delay-difference model estimates the ratio of the initial biomass to unfished biomass, which allows it to begin in a non-equilibrium state.

Growth was assumed to follow a von-Bertalanffy function and both growth and the weight-length relationship was assumed to be constant over time. Input parameters for growth were estimated as presented in Appendix B and were assumed to be known without error. The model represents the stock vulnerable to fishing. Strong differences were not detected when growth parameter estimates based on research and port sampling ages were compared (Appendix B). Therefore, a growth model based on the combined male and female growth using age samples taken by both research and port sampling was used as the growth model in the stock assessment model. The model should be considered a model of vulnerable biomass and estimates of discards were not included in catch data. The model was conditioned on fishing effort, estimated as the ratio of total landings divided by the catch per unit effort. Models were fitted to a standardised fishery-dependent stock abundance index developed for the combined regions 3CD5ABCD as described in Appendix C as well as to three surveys: the WCVI NFMS triennial survey, the Queen Charlotte Sound synoptic survey and the Hecate St. assemblage survey. The objective function included terms for minimising the differences between the predicted and the observed catch, the predicted and observed mean fish weight, the predicted and observed biomass indices from the appropriate surveys, a term to minimise the recruitment deviations relative to the mean recruitment and terms penalising deviations from the informed priors placed on the M and recruitment deviation parameters.

This assessment chose to estimate the natural mortality parameter *M* instead of the stock-recruitment steepness parameter ***h***. This choice was made for two reasons, the first being that it was felt that the fitted mean weight information would be more informative for *M* than for *h* and the second being that it was felt that the *h* parameter cannot be reliably estimated.

The model used in this assessment is very similar to the model used to assess Hecate Strait Pacific cod (*Gadus macrocephalus*), except that an environmental parameter was not fitted (Sinclair and Starr 2005). Several improvements have been made to this model over the one used by Sinclair & Starr (2005):

- The model now allows the estimation of multiple catch and effort series, in recognition that the relationship between CPUE and biomass may have changed over the history of the fishery. This feature was added in recognition that fishing has evolved considerably on the west coast of Canada since the 1960s and that the current management of the fishery provides very different incentives for catching fish that those existed prior to about 1996. Accordingly, a number of the model runs investigated in this assessment estimated separate catchability coefficients by splitting the series between 1995/96 and 1996/97.
- Predictions are made over five years instead of a single year and recruitment is selected randomly based on the recruitment standard deviation. Predictions are also constrained by a maximum exploitation rate which means that high catch levels are not achieved if the predicted exploitation rate exceeds the maximum exploitation rate.
- Provision is made for informed priors for all model parameters.
- Added log-normal bias correction to recruitment deviation predictions.
- An error was discovered in the code used in previous versions of this delay-difference model (Sinclair et al. 2001, Starr et al. 2002, Starr & Fargo 2004, Sinclair & Starr 2005, Starr et al. 2006) and was present in the version of this assessment presented to the Groundfish Subcommittee of PSARC in January 2007 (DFO 2007). This error concerned the method by which the mean weight in the initial year was calculated and resulted in always using the mean weight associated with the unfished biomass in the first year of the assessment reconstruction. This is not a problem for assessments which assume that the reconstruction begins with an unfished equilibrium biomass. However, previous assessments performed using this model for west coast Canadian stocks assumed that the initial biomass was at equilibrium at some fraction of the unfished biomass (estimated as a free parameter) and therefore a lower mean weight would be expected. The model used in this assessment now calculates the mean weight for an equilibrium biomass using the fishing mortality in the initial year. As this fishing mortality is derived from an estimated model parameter and the input effort data, the associated mean weight can be calculated analytically, as well as the initial biomass (see equations below). Therefore, there is no longer any need to estimate, using an additional free parameter, the fraction of the unfished biomass in the initial year of the reconstruction.

The following tables describe the model parameters, data, dynamics and likelihoods.

Estimated Parameters

Parameter	Description
B_0	Unfished equilibrium population biomass
M	Instantaneous natural mortality rate
${}^{C}q_z$	Fishery catchability: one parameter for each series z
${}^{S}q_j$	Catchability for survey j: Three survey series were fitted (Hecate St. assemblage, WCVI NFMS Triennial and Queen Charlotte Sound synoptic)
ϕ_t	Recruitment anomalies in year t (there are 35 of these parameters from 1966 to 2000 with recruitment knife-edged at age 7 and 36 parameters up to 2001 with recruitment knife-edged at age 6)

Fixed parameters

Parameter	Value	Description
h	0.75	"Steepness" of the Beverton-Holt stock-recruitment curve, where the fraction defines the proportion of the maximum recruitment which is available when the spawning stock size is 20% B_0 (Francis 1992)
L_∞	510.0	Asymptotic length in von-Bertalanffy growth equation (mm)
k	0.197	Growth rate parameter in von-Bertalanffy growth equation
t_0	-1.016	Time at L_0 in von-Bertalanffy growth equation
b_0	3.931E-09	Slope of weight-length relationship (mm to kg)
b_1	3.176	Exponent of length – weight relationship
r	6	Age of knife edge recruitment to fishery and spawning population (age=7 investigated as a sensitivity)
ρ	0.8578	Slope of the Ford-Walford plot, age r=7 to 19 ($\rho = 0.8650$ for $r = 6$)
α	0.2281	Intercept of Ford-Walford plot, age r=7 to 19 ($\alpha = 0.2188$ for $r = 6$)
${}^{R}\sigma$	0.4	Standard deviation for recruitment
$U_{\max}$	0.9	Maximum exploitation on vulnerable biomass

Annual input data

Data series	Description
$C_{z,t}$	Weight (t) of catch for series z in year t: models were fitted either as a single series or split between 1995/96 and 1996/97 in recognition of the major change in the management of the fishery
$E_{z,t}$	Fishing effort (h) for series z in year t: where $E_{z,t} = C_{z,t} / \mathrm{CPUE}_{z,t}$, and $\mathrm{CPUE}_{z,t}$ is the CPUE index for series z in year t
w_t	Mean weight (kg) of the recruited population in year t
$I_{j,t}$	Index for trawl survey j in year t
$X_{j,t}$	Standard error for trawl survey j in year t

Derived parameters

Equation	Description
$w_r = b_0\left(L_\infty\left(1-e^{-k(r-t_0)}\right)\right)^{b_1}$	Weight at the age of recruitment
$S = e^{-M}$	Natural survival rate
$\overline{w} = \dfrac{S\alpha + w_r(1-S)}{(1-S\rho)}$	Average body weight in the unfished equilibrium population
$N_0 = \dfrac{B_0}{\overline{w}}$	Equilibrium population numbers at B_0
$R_0 = N_0(1-S)$	Equilibrium recruitment at B_0

Equation	Description
$a = \frac{B_0}{R_0}\left(1-\frac{(h-0.2)}{(0.8h)}\right)$	Beverton-Holt 'alpha' parameter expressed in terms of the steepness parameter (Francis 1992)
$b = \frac{5h-1}{4hR_0}$	Beverton-Holt 'beta' parameter expressed in terms of the steepness parameter (Francis 1992)

Model equations

Equation	Description
$F_{z,t} = {}^{C}q_z E_{z,t}$	Instantaneous fishing mortality for series *z* in year *t*
$N_t = N_{t-1}e^{(-M-F_{z,t-1})} + R_{t-r+1}$	Population numbers in year *t*
$B_t = (\alpha N_{t-1} + \rho B_{t-1})e^{(-M-F_{z,t-1})} + w_r R_{t-r+1}$	Population biomass at beginning of year *t*
$\hat{w}_t = B_t / N_t$	Predicted mean weight of individuals in the population in year *t*
$\hat{w}_1 = \frac{S_1^{'}\alpha + w_r(1-S_1^{'})}{(1-S_1^{'}\rho)}$	Predicted weight in year 1, assuming biomass is at equilibrium with the fishing mortality $(F_{z,1} = {}^{C}q_z E_{z,1})$ in year 1: $(S_1^{'} = e^{-M-F_{z,1}})$
$\hat{B}_1 = \frac{(\hat{w}_1/(1-S_1^{'}) - a)}{b}$	Predicted biomass in year 1 using a Beverton-Holt stock-recruitment function
$R_{t+r} = \frac{B_t}{(a+bB_t)}e^{\phi_t}e^{\delta v_t}$	Recruitment in year *t*+*r* using a Beverton-Holt stock-recruitment function
$\hat{C}_{z,t} = \frac{B_t\left(1-e^{(-M-F_{z,t})}\right)F_{z,t}}{M+F_{z,t}}$	Predicted catch in year *t*
$\hat{I}_{j,t} = {}^{S}q_j B_t$	Predicted trawl survey biomass index for survey *j* in year *t*
$C_{z,t} = \frac{B_t\left(1-e^{(-M-F_{z,t})}\right)F_{z,t}}{M+F_{z,t}}$	Find $F_{z,t} = {}^{C}q_z E_{z,t}$ that achieves Projection $C_{z,t}$ for *t*=2007 – 2011
$U_{z,t} = 1-\exp^{(-{}^{C}q_z E_{z,t})}$	Exploitation rate for series *z* in year *t*

Objective function

The objective function consisted of likelihood components corresponding to the recruitment deviations and the contributions from the catch, fish weight, and the survey index data sources. There was one likelihood component for each weight, survey and catch series component. Let *O* represent the observations, *P* represent the fitted values, and σ represent the standard deviation of the observation in the likelihood functions. The following text table summarises the specific values for the various data sets:

Data:	*O*	*P*	σ
Catch	$C_{z,t}$	$\hat{C}_{z,t}$	${}^{C}\sigma_z$
Survey	$I_{j,t}$	$\hat{I}_{j,t}$	$\sqrt{X_{j,t}^2 + {}^{S}\sigma_j^2}$
Weight	w_t	$\hat{w}_t$	${}^{W}\sigma$

A lognormal distribution was assumed for each of the above data components, with the negative log-likelihood for observation *O*:

$$-\log(L)=\ln(\sigma)+0.5\left(\frac{\ln(O/P)+0.5\sigma}{\sigma}\right)^2,$$

and calculating the Pearson residuals as:

$$\left(\ln(O/P)+0.5\sigma\right)/\sigma$$

The assumption of a log-normal distribution (mean zero and standard deviation ${}^{R}\sigma$) for the recruitment residuals results in the following contribution to the objective function for observations ϕ_t:

$$-\log(L)=\sum_{t=1966}^{t=2006-r+1}\left(\ln\left({}^{R}\sigma\right)+0.5\left(\frac{\phi_t}{{}^{R}\sigma}\right)^2\right).$$

The standard deviation of the Pearson residuals were calculated for each data set and the value for σ adjusted so that this standard deviation was approximately 1.0, the theoretical value for a normal distribution. This was done to ensure that each data set received approximately the same relative weight in the model fit. For the survey indices, a single process error term was added to each index value to bring the standard deviation of the survey residuals to the re-weighting target (Francis et al. 2001). The CVs used for each model run are provided in table reporting the MPD results.

An assumed uniform distribution with wide bounds was used as Bayesian priors to prevent the estimation from being restricted by the choice of the bounds. The exception to this was the use of informed priors for the natural mortality and the recruitment deviation parameters. The recruitment deviations were assumed to be normally distributed in log space, with a mean of zero and a standard deviation of 0.4. Natural mortality was also assumed to be normally distributed, with a mean of 0.2 which is the assumed value used for this parameter in previous Petrale sole assessments (Fargo 1998; Starr & Fargo 2004). The value of 0.2 selected for the standard deviation of the prior was an arbitrary choice, meant to allow the model scope for estimating a different value for *M* if supported by the data.

The following penalties were added to the objective function as the prior contribution:

$$-\log(L)=0.5\left(p-\mu/\sigma\right)^2 \qquad \text{for normal prior}$$

$$-\log(L)=\log(p)+0.5\left(\log(p/\mu)/\sigma+0.5\sigma\right)^2 \qquad \text{for log-normal prior}$$

where p is the prior mean, σ is the prior standard deviation and μ is the parameter estimate.

Table of priors used in all model runs. NA indicates not applicable.

Parameter	Prior type	Lower bound	Upper bound	Mean	SD
B_0	Uniform	500	1000000	NA	NA
${}^{C}q_z$	Uniform	5.00E-08	5.00E-03	NA	NA
${}^{S}q_j$	Uniform	5.00E-08	10	NA	NA
M	Normal	0.01	1	0.2	0.2
ϕ_t (log space)	Normal	-5	5	0	0.4

Bayesian estimation procedure

A Bayesian procedure was used to assess parameter uncertainty for current biomass and the biomass projections:

1. Model parameters were estimated by minimising the sum of the log likelihood and log priors. The resultant maximum posterior density (MPD) estimates represent the mode of the joint posterior distributions of the parameters;
2. Forty million samples from the joint posterior distribution of parameters were generated using the Markov chain–Monte Carlo (MCMC) procedure. The Hastings-Metropolis algorithm (Gelman et al. 1995) was used to generate the chain. Each chain was sampled once every 40,000 draws to produce an approximation of the posterior density based on 1000 points. Four model runs exhibited poor convergence performance with 40 X 10^6 samples. For these runs, the number of samples was increased to 500 X 10^6, which was also thinned to 1000 points, a sampling intensity of one in 500,000;
3. For each sample of the posterior for the beginning year 2007 biomass, a five-year projection was made up to the beginning year 2012 biomass over a catch range of 0 to 1000 t, in 100 t increments. Recruitment deviations were drawn randomly with mean 0 and ${}^{R}\sigma = 0.40$, beginning in year $t = 2006 - r + 2$;
4. The marginal posterior distribution for each parameter of interest was approximated by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by the mean, 5^{th}, 50^{th}, and 95^{th} percentiles.

Model Results

Runs investigated

Runs were made to investigate model predictions across a range of assumptions which could not be easily reconciled (Table D.1). Model runs were varied between applying a single CPUE series or a CPUE series split between 1995 and 1996 in recognition of the substantial changes in management of the fishery made in the mid-1990s. Two versions for the CPUE series were investigated: a CPUE series based on a set of selection rules proposed by representatives of the Canadian Research and Groundfish Society (CGRCS) and a CPUE series based on wider and less restrictive ("wide") selection rules. These two CPUE series are described in Appendix B. Each of the four combinations of a CPUE series which could be either split or left as a single series was investigated using either a fixed or estimated *M* assumption (Table D.1). The fixed *M* assumption used the preferred value of *M*=0.2 and did not use the weight data. The estimated *M* assumption used an informed prior for this parameter and was fitted to the weight data. These eight runs were based on an assumed age for the knife-edged recruitment to the fishery of six $(r = 6)$. The sensitivity of the model predictions to the age of recruitment was investigated by refitting each of the split CPUE series using either the CGRCS CPUE series or the "wide" CPUE series with an assumed age of knife-edged recruitment to the fishery of seven ($r = 7$ instead of $r = 6$). This was done for both the estimated and fixed *M* assumptions for a further 4 runs (Table D.1).

Table D.1. Description of the 12 model runs used to assess 3CD5ABCD Petrale sole. See text for an explanation for the components of each cell of the table below. Years reference the first year of fishing year pairs.

	Single CPUE series: 1966–2005		**Split CPUE series: 1966–1995 & 1996–2005**	
	CGRCS selection rules	**Wide analysis selection rules**	**CGRCS selection rules**	**Wide analysis selection rules**
Estimate *M*	$r = 6$: Case 1	$r = 6$: Case 3	$r = 7$: Case 5 $r = 6$: Case 9	$r = 7$: Case 7 $r = 6$: Case 11
Fix *M*=0.20	$r = 6$: Case 2	$r = 6$: Case 4	$r = 7$: Case 6 $r = 6$: Case 10	$r = 7$: Case 8 $r = 6$: Case 12

Preliminary maximum posterior density fits

Table D.2 provides maximum posterior density (MPD) results for all 12 runs described in Table D.1. The range of estimated vulnerable unfished biomass is from 7,000 to 15,000 t, with little discernible pattern. Both the highest and lowest estimates come from models which assume knife-edge recruitment at age 7 rather than at age 6 and there are equally high and low estimates for B_0 for models which either estimate or fix *M*. For models with split CPUE series, the catchability for the second catch series ranges from one-half to less than one-third of the catchability for the first catch series. This seems like a low result: although management since 1996 has been directed at reducing the effectiveness of the fleet, a reduction of over 50% seems unreasonably large.

All the models which estimated *M* did not stray far from the mean of the prior of 0.2, with the lowest estimate at *M*=0.17 and the highest at *M*=0.25 (Table D.2). This result implies either that there is relatively little information to inform this parameter in the data used in these models or that the available data are consistent with the prior. The survey *q*'s estimated for the Triennial survey appear to be high, approaching or exceeding 1. This is not a surprising result, given that this model is for vulnerable fish only and it is likely that the surveys include fish below the age of recruitment in the indices. There are insufficient data for all of the surveys to estimate an index which pertains to vulnerable fish only.

All of the models underestimate the total catches over the forty year period, with the sum of the total observed catch exceeding the model estimated catch on the order of 5 to 10% (Table D.2). There is no difference between the single and split CPUE models in this behaviour. Average exploitation rates tend to be high, often greater than 50%. This may in part be the result of the failure of the knife-edge recruitment assumption, with fish of younger ages contaminating the landing totals.

Example MPD data fits and population trajectories are listed in the text table below. Space precludes showing the fit to the data for all 12 of the runs listed in Table D.1 and the results given in Table D.2.

Number CPUE series	Run description	Figure reference for MPD fit to data	Figure reference for MPD population trajectory
1	Single CPUE series | CGRCS selection rules | r=6 | estimate M	Figure D.1	Figure D.7
1	Single CPUE series | wide selection rules | r=6 | fix M	Figure D.2	Figure D.8
2	Split CPUE series | CGRCS selection rules | r=7 | estimate M	Figure D.3	Figure D.9
2	Split CPUE series | wide selection rules | r=7 | fix M	Figure D.4	Figure D.10
2	Split CPUE series | CGRCS selection rules | r=6 | estimate M	Figure D.5	Figure D.11
2	Split CPUE series | wide selection rules | r=6 | fix M	Figure D.6	Figure D.12

Fits to the catch data were good and similar between runs, indicating that the available data can be fit adequately by all competing runs, which means in turn that we cannot use the data fits to distinguish between the competing assessment hypotheses. The fits to the weight data are the poorest among the data sets, which is not surprising, given the low number of samples available to generate these estimates. None of the available hypotheses fit the upturn observed in the final survey points from the Triennial and Hecate Strait Assemblage surveys, although the split CPUE runs make a better approximation.

The period between 1977 to 1984 was selected as a reference biomass level for this stock because of the relative stability during this period and that the vulnerable biomass trajectory has gone below this level at least twice and has recovered (Figure D.9 is an example). This is true for the models fit to the split CPUE series (all of which had a period where biomass levels were below the reference period average and which are presently above that level). This observation is also true for the two single CPUE series using the CGRCS selection rules but not for the models fitted to the “wide” CPUE selection rules. The population trajectories for the single CPUE series model runs show downward trajectories after reaching a peak in the early 1970s, ending near to or below the long-term average biomass (Figure D.7 is an example of this). On the other hand, the eight split CPUE series model runs all show increasing biomass trends after reaching a low point in the early to mid-1990s. Current biomass levels are either at, or very near to, the highest observed biomass levels since the beginning of the reconstruction in 1966. Therefore, all the split CPUE series have current biomass estimates which were well above the selected reference period (Table D.2), while the single CPUE series models tended to be near or below this level (Table D.2). Current levels of biomass for all model runs were above or near to the minimum biomass observed in the time series, although the single CPUE series models ranged from 0.8 to 1.0 of the minimum level while the split series were 1.3 to 2.6 times larger than the minimum level (Table D.2).

Model residuals show some evidence of temporal patterns in the fit to most of the data sets by year: weight (Figure D.13), first catch series (Figure D.14), second catch series (Figure D.15), Hecate St. assemblage survey (Figure D.16), and the WCVI Triennial survey (Figure D.17). Similarly there are some poor patterns of fit when the residuals are plotted against the predicted values: weight (Figure D.18), first catch series (Figure D.19), second catch series (Figure D.20), Hecate St. assemblage survey (Figure D.21), and the WCVI Triennial survey (Figure D.22). However, model residuals appear to fit the lognormal distribution assumptions reasonably well for all five data sets: weight (Figure D.23), first catch series (Figure D.24), second catch series (Figure D.25), Hecate St. assemblage survey (Figure D.26), and the WCVI Triennial survey (Figure D.27). As noted earlier, there is a strong similarity in the pattern of residuals across all model fits, indicating that there are probably processes in the data that are not being modelled.

Bayesian MCMC results

Initially, forty million MCMC iterations were completed for all model runs listed in Table D.1, with samples drawn from the MCMC chain every 40,000 iterations, thus providing a total of 1,000 samples. While the traces for eight of the 12 model runs appeared to have converged satisfactorily, the remaining four models had not (Figure D.28). The four models which had not converged were:

- `split CPUE series|`$r=7$`|CGRCS rules|est`M,
- `split CPUE series|`$r=7$`|CGRCS rules|fix`M,
- `split CPUE series|`$r=6$`|CGRCS rules|est`M and
- `split CPUE series|`$r=6$`|wide rules|fix`M.

Apart from the fact that all four series were from models which assumed a split in the CPUE series between 1995/96 and 1996/97, there was no common thread to explain the lack of convergence between the various assumptions held by the runs. For instance, two of the split CPUE $r=7$ runs converged while two did not (Figure D.28). Two of the split CPUE "estimate *M*" runs converged while two did not and three of split CPUE using the wide rules converged while the remaining one was probably the worst example of non-convergence amongst the 4 runs (Figure D.28). Convergence is important because unless this occurs, there is doubt as to whether the parameter space was adequately sampled by the MCMC search.

Two potential solutions were explored to solve this problem. The preferred solution would have been to recode the model with an alternative set of equations describing the population, but which did not have the property of non-convergence. This attempted solution failed (options that were explored included alternate parameterisations for the mean weight of the initial biomass as well as expressing the ratio of the initial biomass relative to B_0 without including a biomass component in the equation). The remaining solution was to extend the MCMC search to demonstrate that the parameter space had been adequately sampled. This is the approach which was adopted here: the four unconverged runs were extended to 500 X 10^6 iterations and sampled once in every 500,000 draws, providing 1,000 sample points to describe the posterior. This approach improved the traces for at least two of the model runs (`split CPUE series|`$r=7$`|CGRCS rules|est`M and `split CPUE series|`$r=7$`|CGRCS rules|fix`M) and marginally improved the `split CPUE series|`$r=6$`|CGRCS rules|est`M model run. Figure D.28 provides traces for the B_0 parameter from all 12 runs, including the four runs which were taken to 500 X 10^6 iterations.

Since only the split CPUE runs were affected by the non-convergence problem, scatter plots of the parameter pairs ${}^{C}q_1$ and ${}^{C}q_2$ were examined for possible explanations which might distinguish the converged from non-converged runs. It was possible that, because these parameters had freedom to act independently due to the broad uniform priors that were adopted which were not linked, the non-convergence could have been caused by the model runs moving into unrealistic parameter space. However, the behaviour of these parameters seemed reasonable for all runs (with the exception of one), with ${}^{C}q_2 < {}^{C}q_1$ in all cases and strong linear relationships between the two CPUE parameters where there were the greatest number of points (Figure D.29). Furthermore, the pairwise traces (Figure D.29) and the marginal posterior distributions for the ratio ${}^{C}q_2 / {}^{C}q_1$ (Figure D.30) appear to be as well behaved for the poorly converged runs as for the better converged runs (with the obvious exception of the run `split CPUE series|`$r=6$`|CGRCS rules|fix`M which is bimodal and unrealistically low estimates for ${}^{C}q_2/{}^{C}q_1$). Therefore, it seemed unlikely that this was the source of the non-convergence problem.

The failure to achieve good MCMC convergence in some of the model runs also illustrates one of the advantages of adopting reference points which are external to the model parameter estimates. Figure D.31 provides a trace for each model run of the derived parameter B_{2007}/B_0. This ratio moves reciprocally with the B_0 trace in Figure D.28, with a strong drop mirroring the excursion to very large B_0 estimates for the run: `split CPUE series|`$r=6$`|CGRCS rules|est`M. Figure D.32 provides equivalent traces for the derived parameter $B_{2007}/\text{mean}\{B_t\}_{t=1977}^{1984}$, which seem to be better converged, even for the run: `split CPUE series|`$r=6$`|CGRCS rules|est`M. The conclusion in this case is that, while there are reasons to believe that several of these models runs have not converged completely for some of the main parameters and derived parameters, the convergence properties of the reference points which depend on an externally selected year interval are much more credible (MCMC trace plots for the other reference points used in this assessment are very similar to the one shown in Figure D.32). These reference points form the basis on which management advice has been formulated. However, it is likely that the model run `split CPUE series|`$r=6$`|wide rules|fix`M has not converged well and the results presented for this run should be viewed with caution.

Traces are presented for the main parameters from eight representative runs:

- `single CPUE series/`r`=6/CGRCS rules/est`M: – Figure D.33 (a);
- `single CPUE series/`r`=6/wide rules/fix`M: – Figure D.33 (b);
- `split CPUE series/`r`=7/ CGRCS rules/est`M: – Figure D.33 (c);
- `split CPUE series/`r`=7/wide rules/est`M: – Figure D.33 (d);
- `split CPUE series/`r`=7/wide rules/fix`M: – Figure D.33 (e);
- `split CPUE series/`r`=6/CGRCS rules/est`M: – Figure D.33 (f);
- `split CPUE series/`r`=6/wide rules/est`M: – Figure D.33 (g);
- `split CPUE series/`r`=6/wide rules/fix`M: – Figure D.33 (h).

These have been plotted to show that the MCMC procedure has reasonably sampled the available parameter space. The lack of trends or sudden shifts in these traces is taken as evidence that the MCMC procedure has converged successfully for ten of these runs. The remaining two appear more problematic. There was a very strong excursion to large values of B_0 for run `split CPUE series/`r`=6/CGRCS rules/est`M: [Figure D.33 (f)]. The MCMC search did not return to this area in spite of the 500 X 10^6 samples taken and the subsequent samples appear to be relatively stable. Run `split CPUE series/`r`=6/wide rules/fix`M: [Figure D.33 (h)] seems to oscillate with a regular pattern for all the parameters and is likely to be the least well converged of the model runs. As indicated above, results from this model should be treated with caution.

Marginal posterior distributions [Figure D.34 (a–h)] for the same main parameters from the representative runs listed in the previous paragraph show that the distributions are reasonably well formed for the ten runs which appear to have converged and are centred in many cases near the MPD estimate for the split CPUE runs. Note that most of these distributions are shifted relative to the MPD value for the two single CPUE runs presented, particularly for the one where *M* is fixed [Figure D.34 (b)]. The marginal posteriors for run: `split CPUE series/r=6/wide rules/fixM`: [Figure D.34 (h)] are all bimodal, reflecting the two regions in parameter space that are occupied by this model. The marginal posterior distributions for *M* tend to be symmetrical for most of the example runs where this parameter was estimated [Figure D.34 (a, c, and g)], indicating that the model data may not be very informative for this parameter and that the resulting posterior distribution is being driven by the prior. The marginal posterior for *M* in [Figure D.34 (f)] is rectangular, with the MPD estimate situated well to the right of the distribution while there is a long tail to the posterior distribution of B_0 for the same run. These characteristics are likely due to the high values accepted for B_0 in the initial part of the MCMC search and reflect that the data are to some extent consistent with a large biomass under the assumptions made by this model run.

Projections were made for five years, starting with the beginning year biomass in 2007/08, which is the biomass remaining at the end of the current (2006/07) fishing year, along with 2006/07 landings of 550 t. Catch strategies ranging from 0 to 1,000 t in 100 t steps were applied to each of the 1,000 MCMC trajectories available from the twelve model runs (Table D.1). Recruitments were randomly drawn in each year from a log-normal distribution with mean=0 and standard deviation=0.40, which was the recruitment standard deviation used in the model fitting phase. Random recruitments were started in the first year after the cessation of the estimation of recruitment deviates (2000 for *r*=7 and 2001 for *r*=6). The distribution of the beginning year biomass in each year from 2008 to 2012 resulting from each of these catch projections was then tested against four performance indicators to judge the effect of the removals. The four performance indicators are:

1. Exploitation rate in 2007–2011 relative to the average exploitation rate from 1966 to 2006 $\left(U_{ref} = \text{mean}\{U_t\}_{t=1966}^{2006}\right)$;
2. Beginning year biomass in 2008–2012 compared to the minimum biomass over the 1966-2006 period $\left(B_{ref} = \min\{B_t\}_{t=1966}^{2006}\right)$;
3. Beginning year biomass in 2008–2012 compared to the average biomass from the 1977-1984 period: $\left(B_{ref} = \text{mean}\{B_t\}_{t=1977}^{1984}\right)$. This period was selected as one of relative stability from which the stock has declined and recovered;
4. Beginning year 2008–2012 biomass compared to the beginning year biomass in 2007 $\left(B_{ref} = B_{2007}\right)$.

Two quantities were calculated for the three performance indicators that reference biomass levels (indicators 2, 3 and 4):

1. The cumulative probability that each draw from the MCMC posterior distribution would exceed one of the three biomass reference levels in year *y*: $\mathrm{P}\left(\tilde{B}_y > B_{ref}\right)$;
2. The expected value from the MCMC posterior distribution of the ratio of the biomass in year *y* relative to one of the three biomass reference levels: $\mathrm{E}\left(\tilde{B}_y / B_{ref}\right)$;

Only the cumulative probability in year 2011 that the exploitation rate would be below the reference exploitation was calculated for the first performance indicator $\mathrm{P}\left(U_{2011} < U_{ref}\right)$.

These performance indicators were selected over model-based reference points that use derived parameters such as B_0 or B_{MSY} because these latter parameters are usually poorly estimated, being very sensitive to assumptions made for parameters that are difficult to estimate, such as M or h. B_0 and B_{MSY} are also sensitive to the relative weighting among catch, average fish weight, or survey indices, and often change over time as more data are added to the analysis or as the stock assessment model evolves, while historical management targets are more stable because they are defined as relative targets. The B_{min} reference point does not work well for series where the biomass trend is either continuously downward or when the biomass has not recovered from the lowest value observed. This latter observation is the case for the two single CPUE runs (`estM` and `fixM`) fitted to the "wide" CPUE rules, where the current stock size has only increased to about 80% of the reference period (see Figure D.8). Therefore, this reference point should be discounted for the single CPUE series model runs using the wide CPUE rules. However, this is not the case for the split CPUE model runs or the single CPUE model runs which used the CGRCS selection rules, where there is a well defined minimum and the stock has moved above the selected average period after reaching the minimum level (e.g., Figure D.9 to Figure D.12).

Another advantage of using reference points which are based on a historical period is that such reference levels are more comprehensible to stakeholders and there frequently exists institutional memory of these periods. In addition, there is always the option of changing the reference period if, once attained, it seems for some reason to be unsuitable. Reference points which are external to the model estimation process also tend to be better behaved when evaluated with MCMC search algorithms (compare Figure D.31 with Figure D.32 for an example of this effect). The text table below provides the figure and table references by run number and run description for all the MCMC output.

References to tables and figures for all MCMC output by run (Table D.1)

Run Number	**Run description**	**Tabular output reference**	**Decision table reference**	**Biomass trajectory figure reference**	**Cumulative probability graph reference**
Case 1	single CPUE series | $r = 6$ | CGRCS rules | est M	Table D.3	Table D.6	Figure D.35	Figure D.47
Case 2	single CPUE series | $r = 6$ | CGRCS rules | fix M			Figure D.36	Figure D.48
Case 3	single CPUE series | $r = 6$ | wide rules | est M		Table D.7	Figure D.37	Figure D.49
Case 4	single CPUE series | $r = 6$ | wide rules | fix M			Figure D.38	Figure D.50
Case 5	split CPUE series | $r = 7$ | CGRCS rules | est M	Table D.4	Table D.8	Figure D.39	Figure D.51
Case 6	split CPUE series | $r = 7$ | CGRCS rules | fix M			Figure D.40	Figure D.52
Case 7	split CPUE series | $r = 7$ | wide rules | est M		Table D.9	Figure D.41	Figure D.53
Case 8	split CPUE series | $r = 7$ | wide rules | fix M			Figure D.42	Figure D.54
Case 9	split CPUE series | $r = 6$ | CGRCS rules | est M	Table D.5	Table D.10	Figure D.43	Figure D.55
Case 10	split CPUE series | $r = 6$ | CGRCS rules | fix M			Figure D.44	Figure D.56
Case 11	split CPUE series | $r = 6$ | wide rules | est M		Table D.11	Figure D.45	Figure D.57
Case 12	split CPUE series | $r = 6$ | wide rules | fix M			Figure D.46	Figure D.58

Box plots of the biomass trends for all 12 model runs include a five year projection at 600 t, the current TAC for Petrale sole. The projections for the single CPUE runs indicate that the stock will either remain stable or decline slightly with removals equal to the current TAC. Biomass trends for the split CPUE series model runs are more complex, with the four model runs which assume the CGRCS selection rules all showing a strong increasing trend under removals equal to the current TAC. The split CPUE model runs which were based on the "wide" selection rules project either a slightly declining trend for the runs which estimate *M* or a slightly increasing trend for the runs with a fixed *M* under removals equal to the current TAC. All four of the single series CPUE runs appear to be pessimistic, with a prediction that the current biomass levels are among the lowest experienced. This result appears to be at odds with most reports from the fishery for this species, where there is general optimism regarding the status of this stock and its apparent abundance. The single CPUE model runs should be downgraded for this lack of consistency with the current apparent abundance for this species in the fishery and the strong assumption that the catchability of a unit of effort by the fleet taking Petrale sole has been unchanged over the past 40 years.

The split CPUE model runs tend to be more optimistic because they have the capacity to adjust the relative catchability at the specified break in 1995/96 – 1996/97. Model results differ as well, depending on whether the CPUE series generated using the "CGRCS selection rules" or the CPUE series using the "wide" selection rules is used. As indicated in the preceding paragraph, the model runs using the "CGRCS selection rules" predict that the stock will be strongly increasing over the next 5 years compared to the models based on the "wide" selection rules while the remaining four model runs either predict a slightly declining stock trend (estimate *M*) or a slightly increasing stock trend (fixed *M*). These results are all independent of the age of initial recruitment to the fishery.

There appears to be little sensitivity to whether *M* is estimated or not. This is likely because of the use of the informed prior on *M* which kept the estimate near to the fixed value used as the "best estimate" for this parameter. Also, the age of knife-edge recruitment was selected to ensure that the model estimates of absolute mean weight would be in the neighbourhood of the mean weight observed in the fishery. Therefore, in these instances, the mean weight data and the estimation of *M* tend to have little leverage over fixing *M* at the preferred value of 0.20. Model results also do not appear to be very sensitive to the choice of the two ages of knife-edge recruitment that were tested in this assessment.

The general comments on the relative performance of the 12 model runs carry through to the decision tables and the cumulative probability plots that graph the information in the decision tables. The four single CPUE model runs and two of the split CPUE predict that the stock will not increase in size under removals equal to the current TAC, while the remaining 6 model runs, particularly those using the "CGRCS selection rules", strongly predict that the stock size will increase at these levels of removal. Furthermore, all the split CPUE runs indicate that the probabilities that the stock will stay above the 1977–1984 reference level (B_{ref}) and the B_{min} reference point at levels of removal consistent with the current TAC are very high. The single CPUE model runs are less optimistic, predicting that the stock will go below B_{ref} reference point at the end of the five years at TAC levels of removal. However, these runs also indicate that the stock will stay above the B_{min} reference point with high probability at levels of removal consistent with the current TAC. The cautionary comments made earlier about the B_{min} reference point for the "wide selection rules" single CPUE series (top of page 74) apply here with the caveat that the B_{min} reference point for these model runs has been very poorly determined.

Table D.2. Maximum posterior density (MPD) results for the 3CD5ABCD Petrale sole delay-difference stock assessment model for each of the 12 runs described in Table 1. Fishing years are coded by first year in pair. All biomass levels are for the beginning year. Parameters fixed at indicated values are shown in greyed cells. N/A or –: not applicable. SD: standard deviation of Pearson residuals for the indicated data set. Median: median of the absolute value of Pearson residuals for the indicated data set.

Number CPUE series	**Single CPUE series: 1966–2005**				**Split CPUE series: 1966–1995 and 1996–2005**							
Age at knife-edge recruit:	$r = 6$	$r = 6$	$r = 6$	$r = 6$	$r = 7$	$r = 7$	$r = 7$	$r = 7$	$r = 6$	$r = 6$	$r = 6$	$r = 6$
Type of CPUE series:	**CGRCS**	**CGRCS**	**Wide**	**Wide**	**CGRCS**	**CGRCS**	**Wide**	**Wide**	**CGRCS**	**CGRCS**	**Wide**	**Wide**
Estimate or fix *M*:	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***
Parameters												
B_0	8,800	10,346	12,323	9,073	15,364	11,661	7,098	8,147	10,070	14,403	10,466	8,918
M	0.186	0.200	0.236	0.200	0.167	0.200	0.251	0.200	0.182	0.200	0.238	0.200
$^{C}q_1$	1.391E-5	6.520E-5	4.372E-6	8.771E-6	8.250E-5	1.239E-4	1.789E-5	2.959E-5	2.573E-5	1.242E-4	8.294E-6	2.152E-5
$^{C}q_2$					2.901E-5	3.455E-5	8.148E-6	1.161E-5	1.412E-5	3.703E-5	4.070E-6	9.195E-6
$^{S}q_{\text{HS\_assemblage}}$	0.163	0.521	0.056	0.111	0.438	0.501	0.153	0.224	0.218	0.519	0.078	0.177
$^{S}q_{\text{WCVI\_Triennial}}$	0.347	1.105	0.115	0.226	1.029	1.178	0.353	0.523	0.498	1.197	0.176	0.409
$^{S}q_{\text{QC Snd\_synoptic}}$	0.131	0.424	0.050	0.101	0.223	0.252	0.089	0.125	0.119	0.266	0.047	0.102
Sigmas												
Weight	0.170	N/A	0.156	N/A	0.173	N/A	0.171	N/A	0.180	N/A	0.164	N/A
Catch(1)	0.368	0.326	0.325	0.330	0.385	0.391	0.324	0.352	0.398	0.388	0.324	0.357
Catch(2)	–	–	–	–	0.022	0.022	0.051	0.053	0.035	0.024	0.061	0.056
q_HC assemblage	0.654	0.697	0.724	0.732	0.558	0.553	0.586	0.582	0.574	0.569	0.597	0.587
q_Triennial	0.247	0.119	0.313	0.335	0.000	0.000	0.125	0.087	0.000	0.000	0.191	0.143
q_QC Snd synoptic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rdevs	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
Negative Log Likelihoods												
Weight	-3.986	N/A	-5.325	N/A	-2.202	N/A	-4.275	N/A	-1.222	N/A	-4.296	N/A
Catch(1)	16.959	12.248	11.940	12.582	14.101	14.493	8.998	11.917	14.840	14.436	8.915	12.031
Catch(2)	–	–	–	–	-28.942	-28.954	-19.676	-19.343	-23.876	-28.065	-17.272	-18.510
q_HC assemblage	12.047	12.592	12.913	13.005	10.727	10.645	11.139	11.044	10.971	10.861	11.284	11.130
q_Triennial	1.468	-0.910	2.506	2.857	-4.040	-4.249	-0.523	-1.544	-2.272	-4.226	0.496	-0.575
q_QC Snd synoptic	-1.183	-1.319	-1.135	-1.153	-1.294	-1.298	-1.145	-1.166	-1.287	-1.303	-1.139	-1.165
Recruitment deviations	1.423	3.358	2.259	2.187	2.694	2.652	4.569	4.352	3.664	2.861	4.723	4.043
Priors	1.387	3.263	2.570	2.091	2.949	2.559	5.274	4.260	3.666	2.765	5.085	3.948
Total likelihood	28.116	29.232	25.728	31.569	-6.007	-4.151	4.362	9.520	4.484	-2.671	7.796	10.903
$\text{Catch}_{\text{observed}}/\text{Catch}_{\text{predicted}}$	1.081	1.090	1.085	1.087	1.083	1.092	1.065	1.071	1.054	1.098	1.065	1.069

Number CPUE series	Single CPUE series: 1966–2005				Split CPUE series: 1966–1995 and 1996–2005							
Age at knife-edge recruit:	$r=6$	$r=6$	$r=6$	$r=6$	$r=7$	$r=7$	$r=7$	$r=7$	$r=6$	$r=6$	$r=6$	$r=6$
Type of CPUE series:	**CGRCS**	**CGRCS**	**Wide**	**Wide**	**CGRCS**	**CGRCS**	**Wide**	**Wide**	**CGRCS**	**CGRCS**	**Wide**	**Wide**
Estimate or fix *M*:	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***	**Estimate *M***	**Fix *M***
Derived Reference Parameters												
B_{MSY}/B_0	0.265	0.263	0.259	0.263	0.258	0.254	0.247	0.254	0.265	0.263	0.258	0.263
$\text{mean}\{U_t\}_{t=1966}^{2006}$	0.189	0.611	0.063	0.125	0.640	0.759	0.196	0.302	0.291	0.762	0.099	0.234
$\text{mean}\{B_t\}_{t=1977}^{1984}$	3,038	879	9,592	5,013	832	690	2,798	1,851	1,904	682	5,708	2,434
$\min\{B_t\}_{t=1966}^{2006}$	2,082	650	6,775	3,303	569	499	2,149	1,327	1,368	516	4,426	1,784
Year of $\min\{B_t\}_{t=1966}^{2006}$	1996	1992	1997	1997	1992	1992	1992	1992	1992	1992	1996	1992
$B_{2007}/\text{mean}\{B_t\}_{t=1977}^{1984}$	0.989	1.043	0.819	0.766	2.366	2.489	1.413	1.574	1.788	2.557	1.349	1.505
$B_{2007}/\min\{B_t\}_{t=1966}^{2006}$	1.444	1.411	1.160	1.163	3.459	3.438	1.839	2.196	2.488	3.379	1.740	2.054
Standardised Normal (Pearson) Residuals												
SD_weight	0.997	N/A	0.999	N/A	1.002	N/A	1.004	N/A	0.997	N/A	1.003	N/A
SD_catch(1)	1.005	1.008	1.003	1.004	1.023	1.020	1.025	1.039	1.012	1.026	1.022	1.029
SD_catch(2)	–	–	–	–	0.089	0.070	0.423	0.410	0.303	0.093	0.549	0.474
SD_HC assemblage	1.001	1.001	1.000	1.000	1.000	0.999	1.001	0.997	1.001	0.997	1.001	0.999
SD_Triennial	1.004	0.974	0.995	0.997	0.520	0.449	1.022	0.943	0.926	0.457	1.004	0.963
SD_QC Snd synoptic	0.454	0.266	0.504	0.485	0.311	0.305	0.493	0.471	0.322	0.297	0.498	0.473
Median_weight	0.550	0.000	0.610	0.000	0.903	0.000	0.627	0.000	0.940	0.000	0.796	0.000
Median_catch(1)	0.581	0.664	0.682	0.677	0.888	0.804	0.659	0.673	0.746	0.872	0.657	0.607
Median_catch(2)	–	–	–	–	0.096	0.058	0.192	0.265	0.203	0.085	0.415	0.268
Median_HC assemblage	0.724	0.575	0.723	0.675	0.810	0.861	0.814	0.769	0.791	0.822	0.858	0.806
Median_Triennial	0.861	0.973	0.851	0.898	0.236	0.315	0.698	0.730	0.473	0.389	0.659	0.715
Median_QC Snd synoptic	0.391	0.209	0.428	0.403	0.310	0.304	0.397	0.382	0.310	0.296	0.403	0.386

Table D.3. Model parameter and derived parameter estimates (mean and Bayesian 90% confidence bounds) for the 3CD5ABCD Petrale sole delay-difference stock assessment model for four runs using a single CPUE series from 1966 to 2005. All runs assume knife-edge recruitment occurs at age 6. Performance probabilities for a projection to beginning year 2012, assuming landed mortalities of 600 t (the current TAC), are presented relative to the management reference points.

Number CPUE series	**Single CPUE series (1966–2005)**											
Knife-edge recruitment age	***r*=7**											
Type of CPUE series:	**CPUE series based on “CGRCS rules”**						**CPUE series based on “wide rules”**					
Estimate or fix *M*:	**Estimate *M***			**Fix *M***			**Estimate *M***			**Fix *M***		
	5%	**Mean**	**95%**	**5%**	**Mean**	**95%**	**5%**	**Mean**	**95%**	**5%**	**Mean**	**95%**
Parameters												
B_0	7,182	10,569	17,729	7,538	9,624	13,488	7,021	9,504	13,581	6,918	7,996	10,041
${}^{C}q_1$	1.1E-5	1.9E-5	2.9E-5	2.5E-5	5.8E-5	1.1E-4	3.6E-6	8.2E-6	1.4E-5	7.1E-6	1.8E-5	3.7E-5
${}^{S}q_{\text{HS\_assemblage}}$	0.121	0.232	0.376	0.252	0.499	0.848	0.045	0.111	0.207	0.086	0.227	0.441
${}^{S}q_{\text{WCVI\_Triennial}}$	0.269	0.469	0.712	0.565	0.983	1.482	0.094	0.216	0.369	0.180	0.438	0.816
${}^{S}q_{\text{QC Snd\_synoptic}}$	0.101	0.184	0.291	0.203	0.388	0.641	0.041	0.096	0.166	0.078	0.196	0.369
M	0.106	0.164	0.224	0.2	0.2	0.2	0.173	0.223	0.278	0.2	0.2	0.2
Derived Reference Parameters												
$\text{mean}\{U_t\}_{t=1966}^{2006}$	0.16	0.25	0.36	0.31	0.53	0.78	0.05	0.11	0.19	0.10	0.23	0.42
U_{2011}	0.14	0.33	0.73	0.26	0.62	0.90	0.06	0.15	0.29	0.12	0.38	0.90
$U_{2011}/\text{mean}\{U_t\}_{t=1966}^{2006}$	0.71	1.32	2.41	0.56	1.20	1.95	0.86	1.31	1.92	0.82	1.58	2.83
$B_{2007}/\min\{B_t\}_{t=1966}^{2006}$	1.18	1.58	2.08	1.08	1.75	2.69	1.01	1.27	1.58	0.94	1.28	1.69
$B_{2007}/\text{mean}\{B_t\}_{t=1977}^{1984}$	0.72	0.97	1.27	0.68	1.08	1.61	0.63	0.80	0.99	0.53	0.74	0.98
$B_{2012}/\min\{B_t\}_{t=1966}^{2006}$	0.62	1.41	2.38	0.65	1.66	3.26	0.80	1.24	1.74	0.48	1.15	1.90
$B_{2012}/\text{mean}\{B_t\}_{t=1977}^{1984}$	0.38	0.87	1.47	0.40	1.03	1.96	0.50	0.78	1.10	0.26	0.67	1.11
B_{2012}/B_{2007}	0.45	0.89	1.34	0.41	0.97	1.79	0.68	0.98	1.36	0.41	0.90	1.42
Year of $\min\{B_t\}_{t=1966}^{2006}$ [1]	1992	1996	1997	1985	1995	1998	1995	1998	2003	1995	1998	2004.5

Probability of exceeding a reference value

	Probability	**Probability**	**Probability**	**Probability**
$P\left(B_{2007} > \min\{B_t\}_{t=1966}^{2006}\right)$	0.99	0.98	0.97	0.91
$P\left(B_{2007} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$	0.40	0.56	0.05	0.04
$P\left(B_{2012} > \min\{B_t\}_{t=1966}^{2006}\right)$	0.78	0.79	0.81	0.64
$P\left(B_{2012} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$	0.31	0.43	0.12	0.09
$P\left(B_{2012} > B_{2007}\right)$	0.31	0.39	0.41	0.33

[1] median instead of mean for this row

Table D.4. Model parameter and derived parameter estimates (mean and Bayesian 90% confidence bounds) for the 3CD5ABCD Petrale sole delay-difference stock assessment model for four runs using a split CPUE series from 1966 to 1995 and from 1996 to 2005. All runs assume knife-edge recruitment at age 7. Performance probabilities for a projection to beginning year 2012, assuming landed mortalities of 600 t (the current TAC), are presented relative to the management reference points.

Number CPUE series	Split CPUE series (1966–1995 & 1996–2005)											
Knife-edge recruitment age	r=7											
Type of CPUE series:	CPUE series based on "CGRCS rules"						CPUE series based on "wide rules"					
Estimate or fix M:	Estimate M			Fix M			Estimate M			Fix M		
	5%	Mean	95%	5%	Mean	95%	5%	Mean	95%	5%	Mean	95%
Parameters												
B_0	8,086	17,739	31,087	8,353	11,399	15,685	5,803	7,500	9,714	7,304	8,976	12,683
${}^{C}q_1$	3.4E-5	6.4E-5	1.1E-4	4.1E-5	1.5E-4	5.0E-4	1.2E-5	2.4E-5	4.2E-5	1.6E-5	5.5E-5	1.7E-4
${}^{C}q_2$	1.5E-5	2.3E-5	3.5E-5	1.9E-5	3.0E-5	4.6E-5	5.7E-6	1.0E-5	1.6E-5	7.0E-6	1.5E-5	3.0E-5
${}^{S}q_{\mathrm{HS\_assemblage}}$	0.236	0.387	0.581	0.280	0.470	0.726	0.098	0.199	0.340	0.128	0.305	0.578
${}^{S}q_{\mathrm{WCVI\_Triennial}}$	0.575	0.866	1.192	0.687	1.069	1.470	0.242	0.439	0.702	0.316	0.688	1.252
${}^{S}q_{\mathrm{QC\ Snd\_synoptic}}$	0.120	0.192	0.277	0.141	0.230	0.345	0.061	0.111	0.181	0.075	0.162	0.291
M	0.115	0.157	0.214	0.2	0.2	0.2	0.175	0.229	0.285	0.2	0.2	0.2
Derived Reference Parameters												
$\mathrm{mean}\{U_t\}_{t=1966}^{2006}$	0.36	0.54	0.73	0.41	0.69	0.97	0.14	0.24	0.39	0.18	0.41	0.82
U_{2011}	0.12	0.23	0.44	0.14	0.29	0.55	0.10	0.21	0.38	0.12	0.25	0.47
$U_{2011}/\mathrm{mean}\{U_t\}_{t=1966}^{2006}$	0.22	0.45	0.86	0.18	0.44	0.86	0.48	0.85	1.32	0.28	0.66	1.15
$B_{2007}/\min\{B_t\}_{t=1966}^{2006}$	2.46	3.87	5.78	2.44	4.22	7.04	1.59	2.13	2.95	1.73	2.79	4.71
$B_{2007}/\mathrm{mean}\{B_t\}_{t=1977}^{1984}$	1.53	2.37	3.48	1.55	2.61	4.19	1.09	1.48	1.99	1.17	1.82	2.95
$B_{2012}/\min\{B_t\}_{t=1966}^{2006}$	2.09	5.11	9.12	2.11	5.51	10.89	1.14	1.99	3.22	1.36	3.06	6.61
$B_{2012}/\mathrm{mean}\{B_t\}_{t=1977}^{1984}$	1.35	3.12	5.68	1.30	3.40	6.72	0.79	1.39	2.22	0.93	2.00	4.12
B_{2012}/B_{2007}	0.75	1.29	2.03	0.69	1.28	2.11	0.60	0.93	1.33	0.65	1.07	1.67
Year of $\min\{B_t\}_{t=1966}^{2006}$ [1]	1977	1992	1994	1977	1986	1994	1985	1993	1996	1977	1992	1995
Probability of exceeding a reference value												
		Probability			Probability			Probability			Probability	
$\mathrm{P}\left(B_{2007} > \min\{B_t\}_{t=1966}^{2006}\right)$		1.00			1.00			1.00			1.00	
$\mathrm{P}\left(B_{2007} > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$		1.00			1.00			0.99			1.00	
$\mathrm{P}\left(B_{2012} > \min\{B_t\}_{t=1966}^{2006}\right)$		1.00			1.00			0.98			0.99	
$\mathrm{P}\left(B_{2012} > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$		0.98			0.99			0.82			0.93	
$\mathrm{P}\left(B_{2012} > B_{2007}\right)$		0.78			0.73			0.34			0.51	

[1] median instead of mean for this row

Table D.5. Model parameter and derived parameter estimates (mean and Bayesian 90% confidence bounds) for the 3CD5ABCD Petrale sole delay-difference stock assessment model for four runs using a split CPUE series from 1966 to 1995 and from 1996 to 2005. All runs assume knife-edge recruitment at age 6. Performance probabilities for a projection to beginning year 2012, assuming landed mortalities of 600 t (the current TAC), are presented relative to the management reference points.

Number CPUE series	**Split CPUE series (1966–1995 & 1996–2005)**											
Knife-edge recruitment age	***r*=6**											
Type of CPUE series:	**CPUE series based on "CGRCS rules"**						**CPUE series based on "wide rules"**					
Estimate or fix *M*:	**Estimate *M***			**Fix *M***			**Estimate *M***			**Fix *M***		
	5%	**Mean**	**95%**	**5%**	**Mean**	**95%**	**5%**	**Mean**	**95%**	**5%**	**Mean**	**95%**
Parameters												
B_0	8,832	21,207	58,448	8,937	12,346	18,075	7,464	9,728	12,414	8,168	14,934	21,721
${}^{C}q_1$	1.9E-5	3.1E-5	4.6E-5	3.4E-5	9.0E-5	2.1E-4	6.5E-6	1.2E-5	1.8E-5	1.8E-5	2.1E-4	5.0E-4
${}^{C}q_2$	1.0E-5	1.6E-5	2.2E-5	1.6E-5	2.9E-5	4.4E-5	3.2E-6	5.7E-6	9.2E-6	7.5E-6	2.4E-5	4.6E-5
${}^{S}q_{\text{HS\_assemblage}}$	0.154	0.264	0.412	0.246	0.446	0.699	0.058	0.115	0.188	0.147	0.458	0.809
${}^{S}q_{\text{WCVI\_Triennial}}$	0.366	0.565	0.784	0.582	0.971	1.402	0.140	0.249	0.394	0.347	1.061	1.730
${}^{S}q_{\text{QC Snd\_synoptic}}$	0.085	0.135	0.197	0.124	0.222	0.341	0.037	0.067	0.112	0.084	0.228	0.395
M	0.089	0.140	0.202	0.2	0.2	0.2	0.168	0.217	0.270	0.2	0.2	0.2
Derived Reference Parameters												
$\text{mean}\{U_t\}_{t=1966}^{2006}$	0.23	0.34	0.46	0.35	0.61	0.89	0.08	0.14	0.21	0.20	0.66	0.97
U_{2011}	0.10	0.17	0.27	0.13	0.25	0.45	0.06	0.12	0.19	0.12	0.23	0.45
$U_{2011}/\text{mean}\{U_t\}_{t=1966}^{2006}$	0.28	0.52	0.86	0.19	0.44	0.83	0.59	0.85	1.18	0.14	0.45	0.96
$B_{2007}/\min\{B_t\}_{t=1966}^{2006}$	2.19	3.08	4.33	2.46	3.95	6.26	1.59	1.92	2.36	1.84	4.05	7.59
$B_{2007}/\text{mean}\{B_t\}_{t=1977}^{1984}$	1.43	2.00	2.79	1.58	2.47	3.75	1.08	1.38	1.71	1.27	2.60	4.70
$B_{2012}/\min\{B_t\}_{t=1966}^{2006}$	1.84	3.75	6.78	2.15	5.28	10.09	1.25	1.78	2.48	1.59	6.21	14.17
$B_{2012}/\text{mean}\{B_t\}_{t=1977}^{1984}$	1.22	2.42	4.16	1.38	3.31	6.17	0.87	1.28	1.80	1.10	3.96	8.76
B_{2012}/B_{2007}	0.76	1.19	1.72	0.74	1.31	2.13	0.68	0.93	1.21	0.74	1.42	2.47
Year of $\min\{B_t\}_{t=1966}^{2006}$ [1]	1977	1993	1995	1977	1992	1994	1991	1995	1996	1977	1991	1995
Probability of exceeding a reference value												
		Probability			**Probability**			**Probability**			**Probability**	
$P\left(B_{2007} > \min\{B_t\}_{t=1966}^{2006}\right)$		1.00			1.00			1.00			1.00	
$P\left(B_{2007} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$		1.00			1.00			0.99			1.00	
$P\left(B_{2012} > \min\{B_t\}_{t=1966}^{2006}\right)$		1.00			1.00			1.00			1.00	
$P\left(B_{2012} > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$		0.98			0.99			0.85			0.97	
$P\left(B_{2012} > B_{2007}\right)$		0.70			0.77			0.29			0.73	

[1] median instead of mean for this row

Table D.6. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 1 and Case 2 Petrale sole runs (Table D.1).

	single CPUE series | $r = 6$ | CGRCS rules									
Project Catch					**Estimate *M***					**Fix *M***
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
	$P\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$									
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	0.99	1.00	1.00	1.00	1.00	0.98	0.99	1.00	1.00	1.00
400	0.98	0.99	0.99	0.99	0.99	0.95	0.96	0.97	0.98	0.98
500	0.97	0.96	0.94	0.94	0.94	0.93	0.91	0.91	0.91	0.91
600	0.96	0.90	0.87	0.81	0.78	0.88	0.82	0.78	0.79	0.79
700	0.93	0.82	0.71	0.64	0.56	0.83	0.72	0.66	0.65	0.65
800	0.88	0.70	0.54	0.43	0.34	0.77	0.63	0.56	0.56	0.56
900	0.83	0.58	0.39	0.26	0.19	0.72	0.56	0.50	0.50	0.50
1000	0.76	0.46	0.25	0.15	0.11	0.68	0.50	0.47	0.48	0.48
	$E\left(\tilde{B}_y / \min\{B_t\}_{t=1966}^{2006}\right)$									
0	1.98	2.36	2.71	3.02	3.31	2.68	3.54	4.28	4.99	5.60
100	1.90	2.22	2.50	2.76	3.00	2.51	3.22	3.82	4.43	4.94
200	1.83	2.08	2.30	2.50	2.69	2.34	2.89	3.36	3.84	4.25
300	1.76	1.94	2.09	2.24	2.37	2.17	2.57	2.89	3.24	3.54
400	1.68	1.80	1.89	1.97	2.05	2.01	2.24	2.43	2.65	2.83
500	1.61	1.65	1.68	1.70	1.73	1.85	1.94	2.00	2.10	2.17
600	1.54	1.51	1.47	1.44	1.41	1.70	1.68	1.64	1.66	1.66
700	1.47	1.37	1.27	1.19	1.12	1.57	1.47	1.38	1.37	1.35
800	1.39	1.24	1.09	0.97	0.88	1.46	1.31	1.21	1.21	1.19
900	1.32	1.11	0.93	0.80	0.71	1.36	1.21	1.12	1.13	1.11
1000	1.25	0.99	0.79	0.68	0.61	1.29	1.14	1.07	1.09	1.08
	$P\left(\tilde{B}_y > \text{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	0.82	0.97	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00
100	0.75	0.93	0.98	1.00	1.00	0.93	0.99	1.00	1.00	1.00
200	0.69	0.85	0.94	0.97	0.99	0.87	0.97	0.99	1.00	1.00
300	0.61	0.75	0.83	0.89	0.93	0.79	0.91	0.95	0.97	0.99
400	0.52	0.61	0.68	0.74	0.77	0.69	0.76	0.82	0.87	0.90
500	0.45	0.48	0.50	0.52	0.55	0.58	0.60	0.61	0.64	0.69
600	0.36	0.35	0.33	0.32	0.31	0.47	0.45	0.44	0.45	0.43
700	0.30	0.25	0.21	0.17	0.15	0.38	0.33	0.28	0.28	0.27
800	0.24	0.18	0.12	0.09	0.08	0.30	0.25	0.20	0.20	0.18
900	0.19	0.11	0.07	0.05	0.04	0.24	0.20	0.16	0.16	0.15
1000	0.14	0.06	0.04	0.02	0.01	0.20	0.16	0.14	0.14	0.14
	$E\left(\tilde{B}_y / \text{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	1.21	1.45	1.66	1.85	2.02	1.66	2.19	2.65	3.10	3.47
100	1.17	1.36	1.53	1.69	1.84	1.55	1.99	2.37	2.74	3.06
200	1.12	1.28	1.41	1.53	1.65	1.45	1.79	2.08	2.38	2.63
300	1.08	1.19	1.28	1.37	1.45	1.34	1.59	1.79	2.01	2.20
400	1.04	1.10	1.16	1.21	1.26	1.24	1.39	1.50	1.64	1.76
500	0.99	1.02	1.03	1.05	1.06	1.14	1.20	1.24	1.30	1.35
600	0.95	0.93	0.91	0.89	0.87	1.05	1.04	1.02	1.03	1.03
700	0.90	0.85	0.79	0.73	0.69	0.97	0.91	0.86	0.85	0.84
800	0.86	0.76	0.67	0.60	0.55	0.90	0.81	0.75	0.75	0.74
900	0.82	0.68	0.57	0.49	0.44	0.84	0.75	0.70	0.70	0.69
1000	0.77	0.61	0.49	0.42	0.38	0.80	0.71	0.66	0.68	0.67

Project Catch	single CPUE series | $r = 6$ | CGRCS rules									
					Estimate *M*					**Fix *M***
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
					$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$					
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	0.99	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00
300	0.92	0.94	0.95	0.97	0.97	0.97	0.96	0.98	0.99	1.00
400	0.75	0.77	0.81	0.85	0.86	0.82	0.82	0.86	0.90	0.92
500	0.54	0.56	0.55	0.58	0.60	0.59	0.59	0.60	0.64	0.68
600	0.33	0.34	0.32	0.32	0.31	0.34	0.37	0.37	0.38	0.39
700	0.18	0.19	0.16	0.14	0.13	0.20	0.24	0.22	0.23	0.22
800	0.09	0.11	0.09	0.06	0.04	0.12	0.19	0.17	0.17	0.16
900	0.05	0.06	0.05	0.03	0.02	0.07	0.16	0.14	0.14	0.14
1000	0.02	0.03	0.02	0.01	0.01	0.05	0.14	0.13	0.14	0.13
					$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$					
0	1.25	1.50	1.72	1.92	2.11	1.54	2.07	2.53	2.97	3.35
100	1.20	1.41	1.59	1.76	1.91	1.43	1.87	2.25	2.62	2.94
200	1.15	1.31	1.46	1.59	1.71	1.33	1.67	1.96	2.26	2.52
300	1.11	1.22	1.32	1.42	1.50	1.23	1.47	1.67	1.89	2.08
400	1.06	1.13	1.19	1.25	1.30	1.13	1.28	1.39	1.53	1.65
500	1.01	1.04	1.06	1.07	1.09	1.03	1.10	1.14	1.20	1.26
600	0.96	0.95	0.92	0.90	0.89	0.95	0.95	0.94	0.96	0.97
700	0.92	0.86	0.80	0.74	0.70	0.87	0.84	0.80	0.81	0.80
800	0.87	0.77	0.68	0.61	0.55	0.81	0.76	0.71	0.72	0.71
900	0.83	0.69	0.58	0.50	0.45	0.76	0.70	0.67	0.68	0.67
1000	0.78	0.62	0.50	0.43	0.39	0.72	0.67	0.64	0.66	0.65

Table D.7. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 3 and Case 4 Petrale sole runs (Table D.1).

	single CPUE series | $r = 6$ | Wide rules									
Project Catch	**Estimate *M***					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
$\mathrm{P}\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$										
0	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
100	0.99	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
200	0.98	0.99	1.00	1.00	1.00	0.97	0.99	1.00	1.00	1.00
300	0.96	0.98	0.99	0.99	0.99	0.95	0.97	0.98	0.99	1.00
400	0.94	0.95	0.96	0.96	0.96	0.91	0.93	0.94	0.95	0.96
500	0.93	0.91	0.91	0.91	0.92	0.85	0.83	0.83	0.83	0.83
600	0.90	0.86	0.83	0.81	0.81	0.80	0.73	0.69	0.65	0.64
700	0.86	0.79	0.72	0.69	0.65	0.72	0.60	0.52	0.47	0.41
800	0.82	0.70	0.61	0.56	0.51	0.65	0.47	0.37	0.31	0.26
900	0.78	0.63	0.50	0.41	0.36	0.57	0.36	0.27	0.20	0.13
1000	0.72	0.53	0.39	0.30	0.25	0.49	0.28	0.18	0.13	0.09
$\mathrm{E}\left(\tilde{B}_y / \min\{B_t\}_{t=1966}^{2006}\right)$										
0	1.44	1.60	1.73	1.84	1.94	1.65	2.00	2.29	2.56	2.78
100	1.41	1.54	1.65	1.75	1.82	1.58	1.87	2.11	2.33	2.51
200	1.38	1.49	1.58	1.65	1.71	1.52	1.74	1.93	2.10	2.24
300	1.35	1.43	1.50	1.55	1.59	1.45	1.61	1.74	1.86	1.96
400	1.32	1.37	1.42	1.45	1.48	1.38	1.48	1.55	1.63	1.68
500	1.29	1.32	1.34	1.35	1.36	1.31	1.35	1.37	1.39	1.41
600	1.26	1.26	1.26	1.25	1.24	1.25	1.23	1.20	1.18	1.15
700	1.23	1.21	1.18	1.15	1.13	1.18	1.11	1.04	0.99	0.94
800	1.20	1.15	1.10	1.05	1.01	1.12	1.01	0.91	0.84	0.78
900	1.17	1.09	1.02	0.95	0.90	1.06	0.91	0.80	0.73	0.68
1000	1.14	1.04	0.94	0.86	0.79	1.01	0.83	0.71	0.65	0.60
$\mathrm{P}\left(\tilde{B}_y > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$										
0	0.22	0.46	0.62	0.75	0.82	0.35	0.68	0.86	0.94	0.97
100	0.20	0.36	0.52	0.64	0.73	0.29	0.57	0.77	0.87	0.93
200	0.17	0.29	0.39	0.51	0.61	0.22	0.44	0.62	0.75	0.82
300	0.15	0.24	0.30	0.39	0.45	0.17	0.33	0.44	0.56	0.63
400	0.13	0.19	0.23	0.28	0.32	0.13	0.24	0.30	0.36	0.42
500	0.11	0.15	0.17	0.19	0.19	0.10	0.15	0.19	0.20	0.23
600	0.09	0.12	0.13	0.12	0.12	0.08	0.10	0.11	0.10	0.09
700	0.07	0.09	0.10	0.08	0.07	0.05	0.06	0.06	0.05	0.04
800	0.06	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.01
900	0.05	0.06	0.04	0.03	0.03	0.03	0.02	0.01	0.01	0.00
1000	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00
$\mathrm{E}\left(\tilde{B}_y / \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$										
0	0.90	1.00	1.08	1.15	1.21	0.95	1.15	1.32	1.47	1.60
100	0.88	0.97	1.04	1.09	1.14	0.92	1.08	1.22	1.34	1.44
200	0.87	0.93	0.99	1.03	1.07	0.88	1.00	1.11	1.21	1.29
300	0.85	0.90	0.94	0.97	1.00	0.84	0.93	1.00	1.07	1.13
400	0.83	0.86	0.89	0.91	0.93	0.80	0.86	0.90	0.94	0.97
500	0.81	0.83	0.84	0.85	0.85	0.76	0.78	0.80	0.81	0.82
600	0.79	0.79	0.79	0.79	0.78	0.73	0.71	0.70	0.69	0.67
700	0.77	0.76	0.74	0.72	0.71	0.69	0.65	0.61	0.58	0.55
800	0.75	0.72	0.69	0.66	0.64	0.65	0.59	0.53	0.49	0.46
900	0.74	0.69	0.64	0.60	0.57	0.62	0.53	0.47	0.43	0.39
1000	0.72	0.65	0.60	0.54	0.50	0.59	0.49	0.42	0.38	0.35

Project Catch	single CPUE series | $r = 6$ | Wide rules									
	Estimate *M*					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$										
0	0.98	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
100	0.96	0.95	0.96	0.97	0.98	1.00	0.99	1.00	1.00	1.00
200	0.91	0.91	0.92	0.94	0.95	0.98	0.98	0.99	0.99	1.00
300	0.83	0.83	0.85	0.88	0.89	0.91	0.92	0.95	0.97	0.98
400	0.71	0.70	0.73	0.76	0.79	0.76	0.77	0.81	0.83	0.86
500	0.55	0.55	0.57	0.59	0.63	0.55	0.57	0.56	0.58	0.61
600	0.40	0.41	0.43	0.42	0.41	0.36	0.36	0.35	0.35	0.33
700	0.31	0.33	0.30	0.29	0.28	0.22	0.23	0.20	0.19	0.17
800	0.21	0.23	0.20	0.18	0.16	0.12	0.13	0.12	0.11	0.07
900	0.16	0.16	0.13	0.11	0.09	0.06	0.08	0.07	0.06	0.04
1000	0.12	0.11	0.09	0.06	0.05	0.04	0.06	0.04	0.03	0.03
$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$										
0	1.13	1.27	1.37	1.46	1.54	1.28	1.56	1.81	2.02	2.20
100	1.11	1.22	1.31	1.39	1.45	1.23	1.46	1.66	1.84	1.99
200	1.09	1.18	1.25	1.31	1.36	1.18	1.36	1.51	1.65	1.77
300	1.06	1.13	1.18	1.23	1.26	1.12	1.25	1.36	1.46	1.55
400	1.04	1.08	1.12	1.15	1.17	1.07	1.15	1.21	1.27	1.32
500	1.01	1.04	1.06	1.07	1.08	1.01	1.05	1.07	1.09	1.10
600	0.99	0.99	0.99	0.99	0.98	0.96	0.95	0.93	0.92	0.90
700	0.97	0.95	0.93	0.91	0.89	0.91	0.86	0.81	0.77	0.74
800	0.94	0.90	0.86	0.83	0.80	0.86	0.78	0.71	0.66	0.62
900	0.92	0.86	0.80	0.75	0.71	0.82	0.71	0.62	0.57	0.53
1000	0.90	0.82	0.74	0.68	0.62	0.77	0.64	0.56	0.51	0.48

Table D.8. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 5 and Case 6 Petrale sole runs (Table D.1).

	split CPUE series | $r = 7$ | CGRCS rules									
Project Catch					**Estimate *M***					**Fix *M***
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
					$\mathrm{P}\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$					
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
700	1.00	1.00	0.99	0.99	0.99	1.00	1.00	0.99	0.99	0.99
800	1.00	0.99	0.98	0.97	0.98	1.00	0.99	0.99	0.98	0.98
900	1.00	0.98	0.95	0.95	0.94	1.00	0.99	0.96	0.96	0.96
1000	1.00	0.97	0.93	0.91	0.90	1.00	0.97	0.93	0.94	0.94
					$\mathrm{E}\left(\tilde{B}_y \big/ \min\{B_t\}_{t=1966}^{2006}\right)$					
0	4.98	6.10	7.16	8.25	9.33	5.62	6.97	8.20	9.45	10.58
100	4.82	5.78	6.71	7.68	8.65	5.41	6.57	7.64	8.75	9.77
200	4.65	5.46	6.25	7.10	7.95	5.20	6.17	7.07	8.03	8.93
300	4.49	5.14	5.79	6.51	7.25	4.99	5.76	6.50	7.32	8.08
400	4.32	4.83	5.33	5.92	6.54	4.78	5.36	5.93	6.59	7.23
500	4.16	4.51	4.86	5.32	5.83	4.57	4.96	5.35	5.87	6.37
600	3.99	4.19	4.40	4.73	5.11	4.36	4.56	4.78	5.14	5.51
700	3.83	3.87	3.94	4.13	4.39	4.15	4.16	4.22	4.43	4.67
800	3.67	3.56	3.49	3.56	3.70	3.94	3.78	3.69	3.78	3.91
900	3.51	3.25	3.06	3.03	3.08	3.74	3.42	3.22	3.24	3.31
1000	3.35	2.95	2.66	2.57	2.58	3.54	3.09	2.82	2.82	2.87
					$\mathrm{P}\left(\tilde{B}_y > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$					
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600	1.00	0.99	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99
700	0.99	0.97	0.96	0.95	0.96	0.99	0.98	0.95	0.95	0.94
800	0.98	0.95	0.92	0.90	0.89	0.98	0.95	0.89	0.88	0.89
900	0.97	0.91	0.84	0.80	0.78	0.96	0.90	0.83	0.81	0.82
1000	0.95	0.86	0.74	0.69	0.68	0.94	0.85	0.76	0.74	0.75
					$\mathrm{E}\left(\tilde{B}_y \big/ \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$					
0	3.05	3.73	4.37	5.05	5.70	3.47	4.30	5.06	5.83	6.53
100	2.95	3.54	4.10	4.70	5.29	3.34	4.06	4.72	5.40	6.03
200	2.85	3.34	3.82	4.34	4.86	3.21	3.81	4.36	4.96	5.51
300	2.75	3.15	3.54	3.98	4.43	3.08	3.56	4.01	4.52	4.99
400	2.65	2.95	3.26	3.62	4.00	2.95	3.31	3.66	4.07	4.47
500	2.55	2.76	2.97	3.26	3.56	2.82	3.06	3.30	3.62	3.93
600	2.45	2.57	2.69	2.89	3.12	2.69	2.81	2.95	3.17	3.40
700	2.35	2.37	2.41	2.53	2.69	2.56	2.57	2.60	2.74	2.88
800	2.25	2.18	2.14	2.18	2.27	2.44	2.33	2.28	2.33	2.42
900	2.15	1.99	1.87	1.85	1.89	2.31	2.11	1.98	1.99	2.04
1000	2.05	1.81	1.63	1.58	1.58	2.19	1.91	1.74	1.74	1.77

	split CPUE series | $r = 7$ | CGRCS rules									
Project Catch	**Estimate *M***					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$										
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	0.97	0.98	0.98	1.00	1.00	0.97	0.98	0.98	1.00	1.00
400	0.90	0.92	0.94	0.97	0.97	0.88	0.90	0.93	0.96	0.97
500	0.73	0.77	0.83	0.88	0.92	0.72	0.76	0.80	0.86	0.90
600	0.55	0.61	0.64	0.70	0.78	0.51	0.58	0.60	0.67	0.73
700	0.39	0.41	0.44	0.52	0.57	0.36	0.37	0.41	0.46	0.52
800	0.26	0.27	0.28	0.34	0.36	0.23	0.24	0.26	0.31	0.33
900	0.16	0.17	0.18	0.19	0.21	0.14	0.14	0.16	0.19	0.22
1000	0.09	0.11	0.10	0.10	0.12	0.08	0.10	0.10	0.13	0.13
$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$										
0	1.28	1.58	1.86	2.14	2.42	1.33	1.66	1.97	2.27	2.55
100	1.24	1.49	1.74	1.99	2.24	1.27	1.56	1.83	2.10	2.35
200	1.19	1.41	1.61	1.83	2.05	1.22	1.46	1.69	1.92	2.14
300	1.15	1.32	1.49	1.68	1.87	1.17	1.36	1.54	1.74	1.93
400	1.11	1.24	1.37	1.52	1.68	1.12	1.26	1.40	1.56	1.71
500	1.06	1.15	1.24	1.36	1.49	1.06	1.16	1.26	1.38	1.50
600	1.02	1.07	1.12	1.20	1.29	1.01	1.06	1.12	1.20	1.28
700	0.97	0.98	1.00	1.04	1.10	0.96	0.97	0.98	1.02	1.08
800	0.93	0.90	0.88	0.89	0.92	0.91	0.87	0.85	0.87	0.90
900	0.89	0.82	0.77	0.76	0.77	0.86	0.79	0.74	0.74	0.76
1000	0.85	0.74	0.66	0.64	0.64	0.81	0.71	0.65	0.65	0.67

Table D.9. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 7 and Case 8 Petrale sole runs (Table D.1).

Project Catch	split CPUE series | $r = 7$ | wide rules									
	Estimate M					Fix M				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
$P\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$										
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
600	1.00	1.00	0.99	0.98	0.98	1.00	1.00	1.00	1.00	0.99
700	1.00	0.99	0.97	0.95	0.93	1.00	0.99	0.99	0.97	0.97
800	1.00	0.96	0.92	0.88	0.82	1.00	0.98	0.95	0.93	0.89
900	0.99	0.94	0.86	0.75	0.69	0.99	0.97	0.90	0.84	0.79
1000	0.98	0.89	0.77	0.63	0.54	0.99	0.92	0.82	0.75	0.68
$E\left(\tilde{B}_y / \min\{B_t\}_{t=1966}^{2006}\right)$										
0	2.44	2.74	3.00	3.22	3.41	3.50	4.17	4.78	5.33	5.82
100	2.38	2.63	2.84	3.02	3.18	3.38	3.96	4.47	4.94	5.38
200	2.31	2.51	2.67	2.82	2.94	3.26	3.73	4.16	4.55	4.92
300	2.25	2.39	2.51	2.62	2.71	3.15	3.51	3.85	4.16	4.46
400	2.19	2.28	2.35	2.41	2.47	3.03	3.29	3.54	3.77	4.00
500	2.13	2.16	2.18	2.21	2.23	2.92	3.07	3.22	3.37	3.53
600	2.06	2.04	2.02	2.01	1.99	2.80	2.85	2.91	2.98	3.06
700	2.00	1.92	1.86	1.80	1.76	2.69	2.64	2.60	2.59	2.61
800	1.94	1.81	1.70	1.60	1.53	2.57	2.42	2.31	2.23	2.19
900	1.88	1.70	1.54	1.42	1.31	2.46	2.22	2.04	1.92	1.84
1000	1.82	1.58	1.39	1.24	1.13	2.35	2.03	1.81	1.67	1.58
$P\left(\tilde{B}_y > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$										
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00
400	0.97	0.97	0.97	0.97	0.97	0.99	0.99	0.99	1.00	1.00
500	0.95	0.94	0.93	0.93	0.92	0.98	0.98	0.98	0.98	0.97
600	0.93	0.89	0.86	0.83	0.82	0.97	0.95	0.94	0.93	0.93
700	0.91	0.82	0.77	0.71	0.67	0.95	0.91	0.86	0.83	0.82
800	0.88	0.74	0.66	0.56	0.51	0.93	0.85	0.76	0.70	0.67
900	0.84	0.68	0.55	0.44	0.37	0.91	0.75	0.65	0.57	0.52
1000	0.80	0.59	0.41	0.31	0.26	0.87	0.67	0.53	0.45	0.39
$E\left(\tilde{B}_y / \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$										
0	1.70	1.90	2.08	2.23	2.36	2.28	2.71	3.11	3.46	3.78
100	1.65	1.82	1.97	2.10	2.20	2.20	2.57	2.91	3.21	3.49
200	1.61	1.74	1.86	1.96	2.04	2.13	2.43	2.70	2.96	3.19
300	1.57	1.66	1.74	1.82	1.88	2.05	2.29	2.50	2.70	2.90
400	1.52	1.58	1.63	1.68	1.72	1.98	2.15	2.30	2.45	2.60
500	1.48	1.50	1.52	1.53	1.55	1.90	2.00	2.10	2.19	2.30
600	1.44	1.42	1.40	1.39	1.39	1.83	1.86	1.90	1.94	2.00
700	1.39	1.34	1.29	1.25	1.22	1.76	1.72	1.70	1.69	1.70
800	1.35	1.26	1.18	1.12	1.07	1.68	1.58	1.51	1.46	1.43
900	1.31	1.18	1.07	0.99	0.92	1.61	1.45	1.34	1.26	1.21
1000	1.26	1.10	0.97	0.87	0.79	1.54	1.33	1.19	1.09	1.03

Project Catch	split CPUE series | $r = 7$ | wide rules									
	Estimate *M*					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
	$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$									
0	0.98	0.97	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00
100	0.95	0.95	0.96	0.97	0.98	0.99	0.99	0.99	0.99	1.00
200	0.87	0.88	0.90	0.93	0.94	0.96	0.97	0.98	0.98	0.99
300	0.74	0.76	0.79	0.82	0.86	0.89	0.90	0.93	0.95	0.97
400	0.57	0.60	0.64	0.68	0.72	0.75	0.77	0.81	0.86	0.90
500	0.42	0.44	0.48	0.50	0.52	0.59	0.60	0.66	0.70	0.73
600	0.27	0.31	0.32	0.33	0.34	0.40	0.41	0.44	0.47	0.51
700	0.18	0.21	0.20	0.20	0.19	0.26	0.28	0.28	0.30	0.30
800	0.12	0.14	0.13	0.11	0.09	0.17	0.19	0.18	0.18	0.16
900	0.07	0.09	0.08	0.06	0.04	0.10	0.12	0.11	0.10	0.09
1000	0.05	0.06	0.06	0.03	0.02	0.07	0.08	0.07	0.06	0.05
	$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$									
0	1.14	1.28	1.41	1.51	1.60	1.23	1.47	1.68	1.87	2.04
100	1.11	1.23	1.33	1.42	1.49	1.19	1.39	1.57	1.73	1.88
200	1.08	1.17	1.25	1.32	1.38	1.15	1.31	1.46	1.60	1.72
300	1.05	1.12	1.17	1.22	1.27	1.11	1.24	1.35	1.46	1.56
400	1.02	1.06	1.10	1.13	1.16	1.07	1.16	1.24	1.32	1.39
500	0.99	1.01	1.02	1.03	1.04	1.03	1.08	1.13	1.18	1.23
600	0.96	0.95	0.94	0.94	0.93	0.99	1.00	1.02	1.04	1.07
700	0.93	0.90	0.87	0.84	0.82	0.95	0.93	0.91	0.91	0.91
800	0.90	0.84	0.79	0.75	0.71	0.91	0.85	0.81	0.78	0.76
900	0.87	0.79	0.72	0.66	0.61	0.87	0.78	0.72	0.67	0.64
1000	0.84	0.74	0.65	0.58	0.53	0.83	0.72	0.64	0.58	0.55

Table D.10. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 9 and Case 10 Petrale sole runs (Table D.1).

	split CPUE series | $r = 6$ | CGRCS rules									
Project Catch	**Estimate *M***					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
	$P\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$									
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
700	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99
800	1.00	1.00	0.99	0.98	0.96	1.00	1.00	0.99	0.97	0.97
900	1.00	0.99	0.97	0.95	0.91	1.00	0.98	0.97	0.95	0.94
1000	1.00	0.98	0.94	0.87	0.81	1.00	0.97	0.94	0.92	0.90
	$E\left(\tilde{B}_y / \min\{B_t\}_{t=1966}^{2006}\right)$									
0	3.73	4.37	5.06	5.74	6.38	5.26	6.53	7.75	8.90	9.94
100	3.64	4.18	4.78	5.38	5.96	5.07	6.17	7.24	8.27	9.19
200	3.54	3.99	4.50	5.02	5.52	4.88	5.81	6.72	7.62	8.43
300	3.44	3.80	4.22	4.66	5.08	4.69	5.44	6.20	6.96	7.65
400	3.34	3.61	3.94	4.30	4.64	4.50	5.08	5.68	6.30	6.87
500	3.25	3.42	3.66	3.93	4.20	4.31	4.72	5.16	5.63	6.08
600	3.15	3.23	3.38	3.56	3.75	4.13	4.35	4.64	4.97	5.28
700	3.05	3.04	3.10	3.19	3.30	3.94	3.99	4.12	4.30	4.48
800	2.95	2.85	2.81	2.82	2.84	3.76	3.64	3.61	3.66	3.73
900	2.86	2.65	2.53	2.46	2.40	3.57	3.29	3.15	3.11	3.09
1000	2.76	2.46	2.26	2.10	1.98	3.39	2.97	2.75	2.66	2.62
	$P\left(\tilde{B}_y > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600	0.99	0.99	0.99	0.99	0.98	1.00	1.00	0.99	0.99	0.99
700	0.99	0.98	0.97	0.96	0.94	1.00	0.98	0.96	0.95	0.95
800	0.99	0.96	0.93	0.90	0.87	0.99	0.95	0.91	0.90	0.89
900	0.99	0.93	0.87	0.80	0.73	0.98	0.90	0.85	0.81	0.80
1000	0.98	0.88	0.77	0.68	0.58	0.96	0.84	0.77	0.72	0.70
	$E\left(\tilde{B}_y / \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	2.41	2.82	3.26	3.69	4.11	3.29	4.08	4.84	5.56	6.21
100	2.35	2.70	3.08	3.47	3.83	3.17	3.85	4.53	5.17	5.75
200	2.29	2.58	2.90	3.24	3.55	3.05	3.63	4.20	4.76	5.27
300	2.22	2.46	2.72	3.00	3.27	2.93	3.40	3.88	4.35	4.79
400	2.16	2.33	2.54	2.77	2.99	2.81	3.17	3.55	3.94	4.30
500	2.10	2.21	2.36	2.53	2.70	2.70	2.95	3.23	3.52	3.81
600	2.04	2.09	2.18	2.30	2.42	2.58	2.72	2.90	3.11	3.31
700	1.97	1.96	2.00	2.06	2.13	2.46	2.50	2.58	2.69	2.81
800	1.91	1.84	1.82	1.82	1.83	2.35	2.27	2.26	2.29	2.34
900	1.85	1.72	1.64	1.59	1.55	2.23	2.06	1.97	1.94	1.94
1000	1.79	1.59	1.46	1.36	1.28	2.12	1.85	1.72	1.67	1.64

Project Catch	split CPUE series | $r = 6$ | CGRCS rules									
	Estimate M					**Fix M**				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$										
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	0.99	0.99	1.00	0.99	1.00	0.99	0.99	1.00	1.00	1.00
300	0.95	0.96	0.98	0.98	0.99	0.97	0.98	0.99	0.99	0.99
400	0.88	0.89	0.92	0.95	0.96	0.91	0.91	0.94	0.96	0.97
500	0.75	0.74	0.80	0.84	0.86	0.77	0.78	0.83	0.89	0.92
600	0.57	0.56	0.61	0.67	0.70	0.58	0.59	0.67	0.72	0.77
700	0.38	0.38	0.43	0.47	0.51	0.40	0.42	0.46	0.50	0.56
800	0.23	0.24	0.27	0.30	0.32	0.26	0.28	0.30	0.33	0.35
900	0.13	0.14	0.16	0.17	0.17	0.16	0.18	0.19	0.20	0.20
1000	0.08	0.08	0.09	0.09	0.09	0.10	0.11	0.11	0.12	0.12
$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$										
0	1.20	1.41	1.63	1.85	2.05	1.32	1.65	1.97	2.26	2.52
100	1.17	1.35	1.54	1.73	1.91	1.27	1.56	1.83	2.09	2.33
200	1.14	1.29	1.45	1.61	1.77	1.22	1.46	1.70	1.92	2.13
300	1.11	1.22	1.36	1.49	1.62	1.18	1.37	1.56	1.75	1.93
400	1.08	1.16	1.26	1.37	1.48	1.13	1.27	1.43	1.58	1.73
500	1.04	1.10	1.17	1.25	1.34	1.08	1.18	1.29	1.41	1.52
600	1.01	1.03	1.08	1.13	1.19	1.03	1.08	1.15	1.23	1.31
700	0.98	0.97	0.99	1.01	1.04	0.98	0.99	1.02	1.06	1.10
800	0.95	0.91	0.89	0.89	0.89	0.93	0.90	0.89	0.90	0.91
900	0.92	0.85	0.80	0.77	0.75	0.88	0.81	0.77	0.76	0.75
1000	0.89	0.78	0.71	0.66	0.62	0.84	0.73	0.67	0.65	0.64

Table D.11. Tables of the probability and the expected value of the beginning year biomass in the projection year exceeding the minimum observed biomass for one to five year projections starting from the beginning year biomass in 2007 for the Case 11 and Case 12 Petrale sole runs (Table D.1).

	split CPUE series | $r = 6$ | wide rules									
Project Catch					**Estimate *M***					**Fix *M***
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
	$\mathrm{P}\left(\tilde{B}_y > \min\{B_t\}_{t=1966}^{2006}\right)$									
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
700	1.00	1.00	0.99	0.99	0.98	1.00	0.99	0.99	0.99	0.98
800	1.00	1.00	0.98	0.97	0.94	1.00	0.99	0.98	0.97	0.95
900	1.00	0.99	0.96	0.92	0.87	1.00	0.98	0.96	0.94	0.89
1000	1.00	0.98	0.93	0.84	0.75	1.00	0.97	0.93	0.89	0.83
	$\mathrm{E}\left(\tilde{B}_y / \min\{B_t\}_{t=1966}^{2006}\right)$									
0	2.07	2.23	2.36	2.47	2.55	5.60	7.12	8.65	10.07	11.37
100	2.03	2.16	2.27	2.36	2.43	5.39	6.73	8.09	9.37	10.55
200	2.00	2.10	2.18	2.25	2.30	5.19	6.32	7.51	8.65	9.70
300	1.97	2.04	2.09	2.13	2.17	4.98	5.92	6.94	7.92	8.84
400	1.93	1.97	2.00	2.02	2.04	4.77	5.52	6.36	7.18	7.97
500	1.90	1.91	1.91	1.91	1.91	4.56	5.12	5.78	6.44	7.09
600	1.87	1.85	1.83	1.80	1.78	4.36	4.72	5.20	5.70	6.21
700	1.83	1.79	1.74	1.69	1.65	4.15	4.33	4.64	4.98	5.34
800	1.80	1.72	1.65	1.58	1.51	3.95	3.95	4.11	4.31	4.53
900	1.77	1.66	1.56	1.47	1.38	3.75	3.60	3.63	3.72	3.84
1000	1.73	1.60	1.47	1.35	1.25	3.56	3.27	3.22	3.23	3.29
	$\mathrm{P}\left(\tilde{B}_y > \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
200	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
300	0.99	0.98	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00
400	0.98	0.97	0.97	0.96	0.97	1.00	1.00	1.00	1.00	1.00
500	0.96	0.95	0.93	0.93	0.91	1.00	1.00	0.99	0.99	0.99
600	0.95	0.92	0.89	0.87	0.85	1.00	0.98	0.98	0.97	0.96
700	0.94	0.88	0.84	0.77	0.74	0.99	0.95	0.93	0.94	0.92
800	0.92	0.83	0.76	0.67	0.61	0.98	0.92	0.90	0.88	0.84
900	0.90	0.78	0.66	0.55	0.46	0.96	0.88	0.83	0.80	0.76
1000	0.87	0.71	0.56	0.44	0.35	0.94	0.82	0.76	0.73	0.69
	$\mathrm{E}\left(\tilde{B}_y / \mathrm{mean}\{B_t\}_{t=1977}^{1984}\right)$									
0	1.49	1.60	1.70	1.77	1.83	3.59	4.56	5.53	6.44	7.27
100	1.47	1.56	1.63	1.69	1.74	3.46	4.30	5.17	5.99	6.74
200	1.44	1.51	1.57	1.61	1.65	3.32	4.05	4.80	5.53	6.20
300	1.42	1.47	1.51	1.54	1.56	3.19	3.79	4.44	5.06	5.65
400	1.39	1.42	1.44	1.46	1.47	3.06	3.53	4.07	4.59	5.09
500	1.37	1.38	1.38	1.38	1.37	2.92	3.28	3.70	4.12	4.53
600	1.35	1.33	1.31	1.30	1.28	2.79	3.02	3.33	3.65	3.96
700	1.32	1.29	1.25	1.22	1.19	2.66	2.77	2.97	3.19	3.41
800	1.30	1.24	1.19	1.14	1.09	2.53	2.53	2.63	2.76	2.89
900	1.27	1.20	1.12	1.06	1.00	2.41	2.30	2.32	2.38	2.45
1000	1.25	1.15	1.06	0.98	0.90	2.29	2.10	2.06	2.07	2.10

Project Catch	split CPUE series | $r = 6$ | wide rules									
	Estimate *M*					**Fix *M***				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
	$\mathrm{P}\left(\tilde{B}_y > B_{2007}\right)$									
0	0.93	0.92	0.93	0.96	0.96	1.00	1.00	1.00	1.00	1.00
100	0.87	0.87	0.89	0.91	0.92	1.00	1.00	1.00	1.00	1.00
200	0.77	0.78	0.82	0.83	0.86	0.98	0.99	0.99	1.00	0.99
300	0.64	0.68	0.70	0.71	0.74	0.94	0.96	0.97	0.98	0.99
400	0.52	0.53	0.55	0.58	0.60	0.88	0.90	0.92	0.95	0.95
500	0.37	0.40	0.41	0.42	0.44	0.77	0.76	0.82	0.86	0.86
600	0.26	0.30	0.30	0.29	0.29	0.62	0.61	0.67	0.72	0.73
700	0.18	0.21	0.21	0.19	0.16	0.44	0.44	0.51	0.56	0.58
800	0.12	0.15	0.14	0.12	0.10	0.29	0.32	0.36	0.41	0.44
900	0.08	0.11	0.10	0.07	0.05	0.19	0.22	0.25	0.29	0.30
1000	0.05	0.07	0.07	0.04	0.03	0.12	0.15	0.17	0.20	0.20
	$\mathrm{E}\left(\tilde{B}_y / B_{2007}\right)$									
0	1.08	1.16	1.23	1.29	1.33	1.35	1.70	2.06	2.39	2.68
100	1.06	1.13	1.18	1.23	1.27	1.30	1.61	1.92	2.22	2.48
200	1.04	1.09	1.14	1.17	1.20	1.24	1.51	1.78	2.04	2.27
300	1.02	1.06	1.09	1.11	1.13	1.19	1.41	1.64	1.87	2.06
400	1.01	1.03	1.04	1.05	1.06	1.14	1.31	1.50	1.69	1.85
500	0.99	0.99	1.00	1.00	1.00	1.09	1.21	1.36	1.50	1.64
600	0.97	0.96	0.95	0.94	0.93	1.04	1.12	1.22	1.32	1.42
700	0.95	0.93	0.90	0.88	0.86	0.99	1.02	1.08	1.15	1.21
800	0.94	0.90	0.86	0.82	0.79	0.94	0.93	0.96	0.99	1.02
900	0.92	0.86	0.81	0.76	0.72	0.90	0.85	0.85	0.86	0.86
1000	0.90	0.83	0.76	0.70	0.65	0.85	0.77	0.75	0.75	0.74

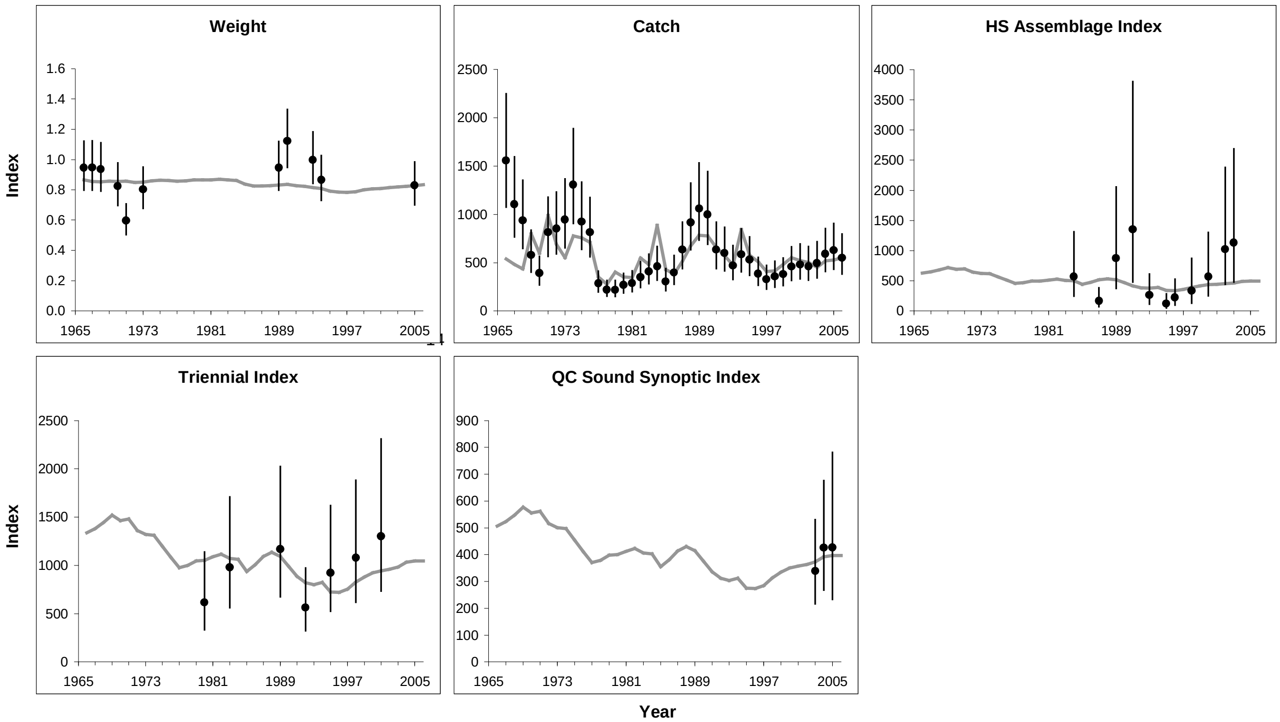


Figure D.1. Model fits to the observed data for the single CPUE series | $r = 6$ | CGRCS rules | est M model run (Table D.1).

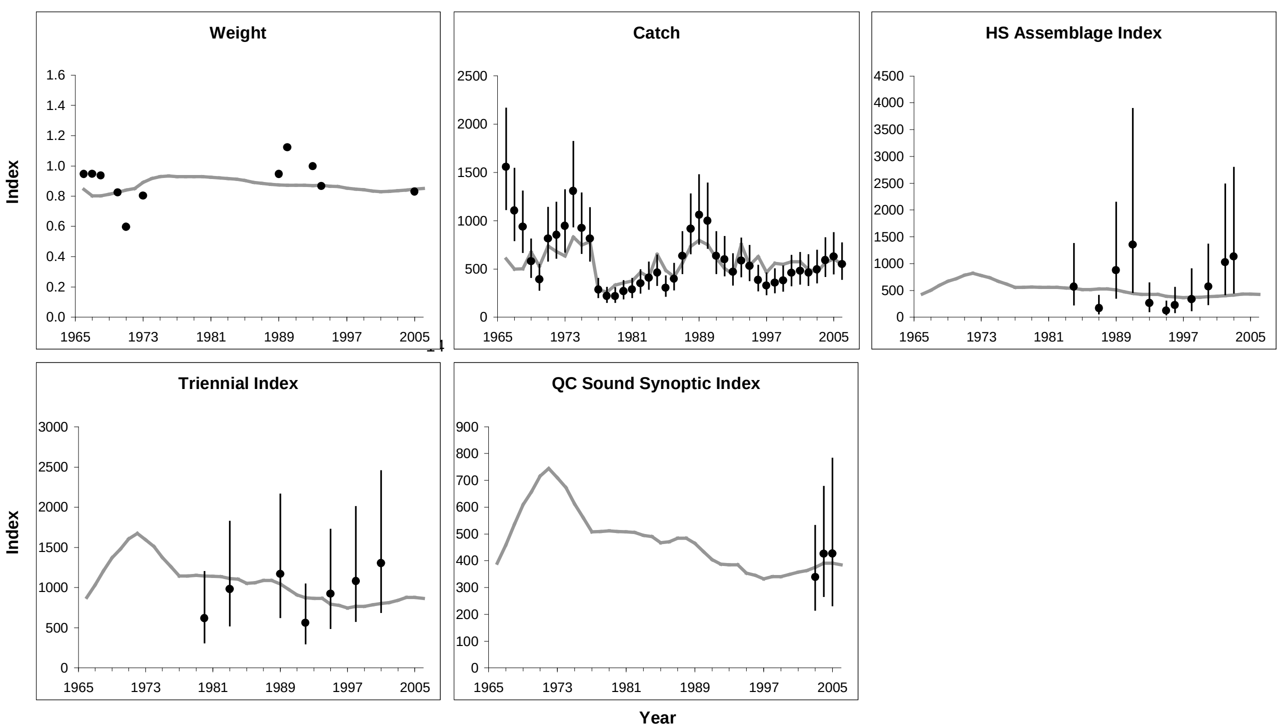


Figure D.2. Model fits to the observed data for the single CPUE series | $r = 6$ | wide rules | fix M model run (Table D.1).

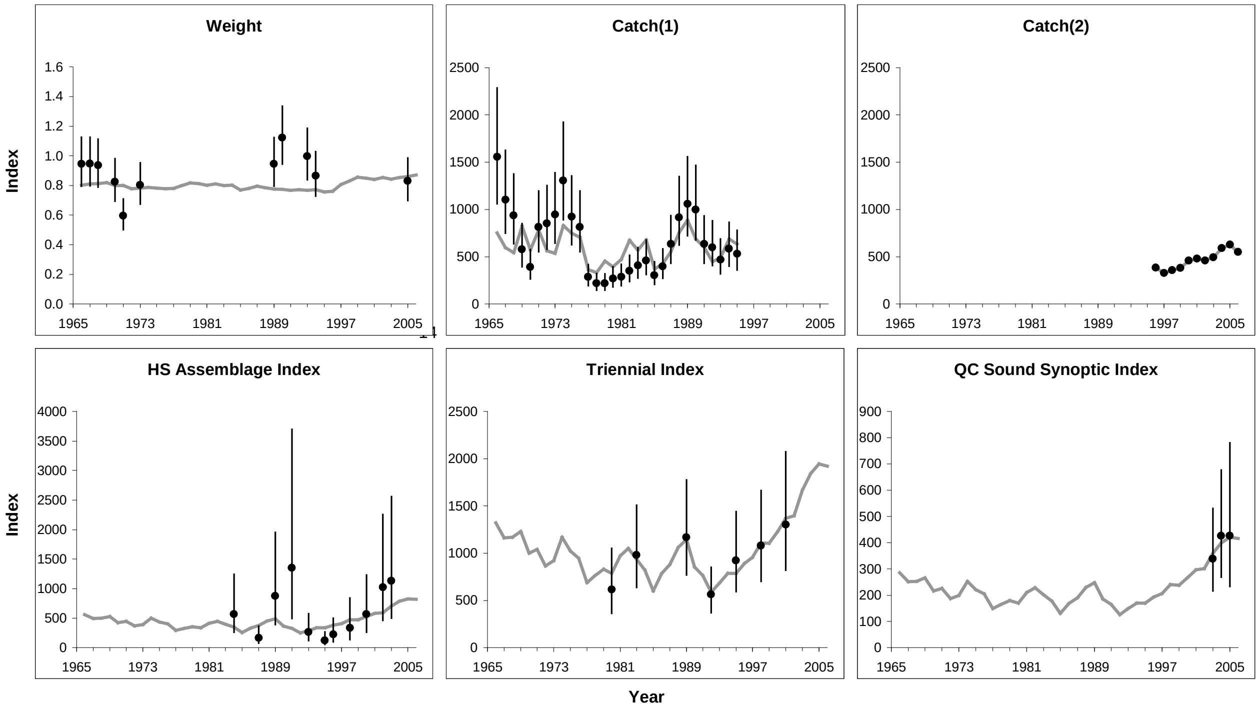


Figure D.3. Model fits to the observed data for the split CPUE series | $r = 7$ | CGRCS rules | est M model run (Table D.1).

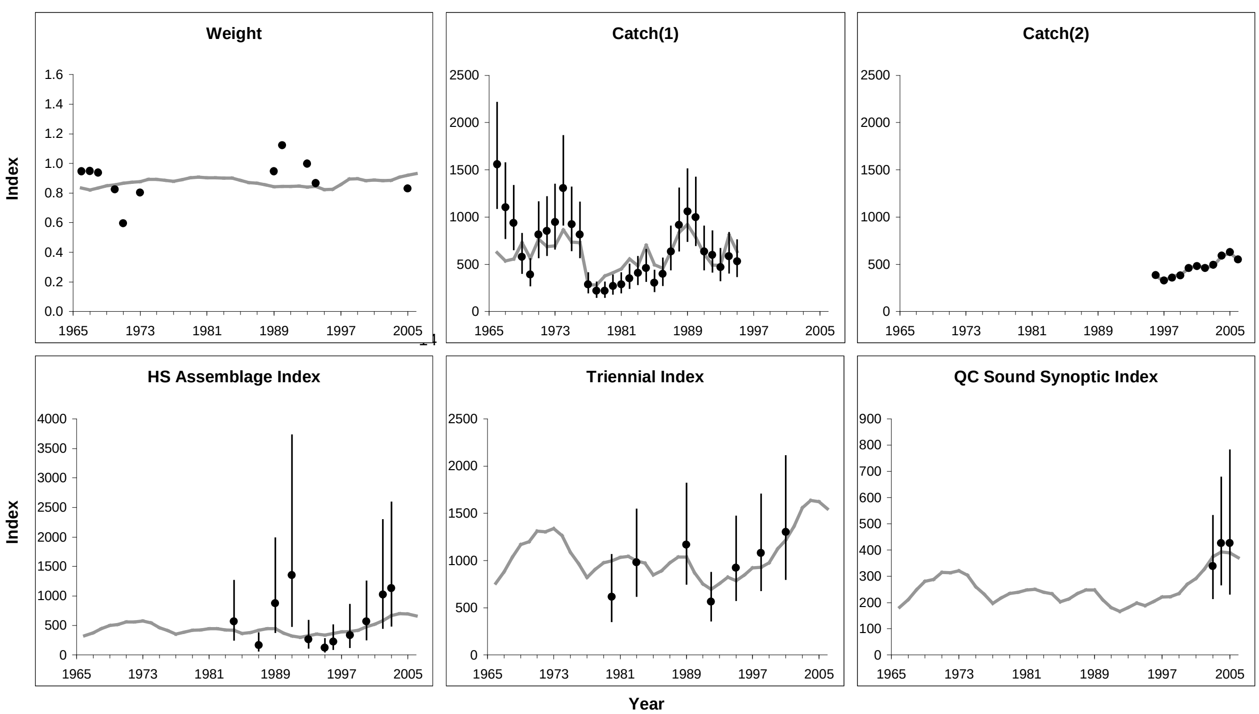


Figure D.4. Model fits to the observed data for the split CPUE series | $r = 7$ | wide rules | fix M model run (Table D.1).

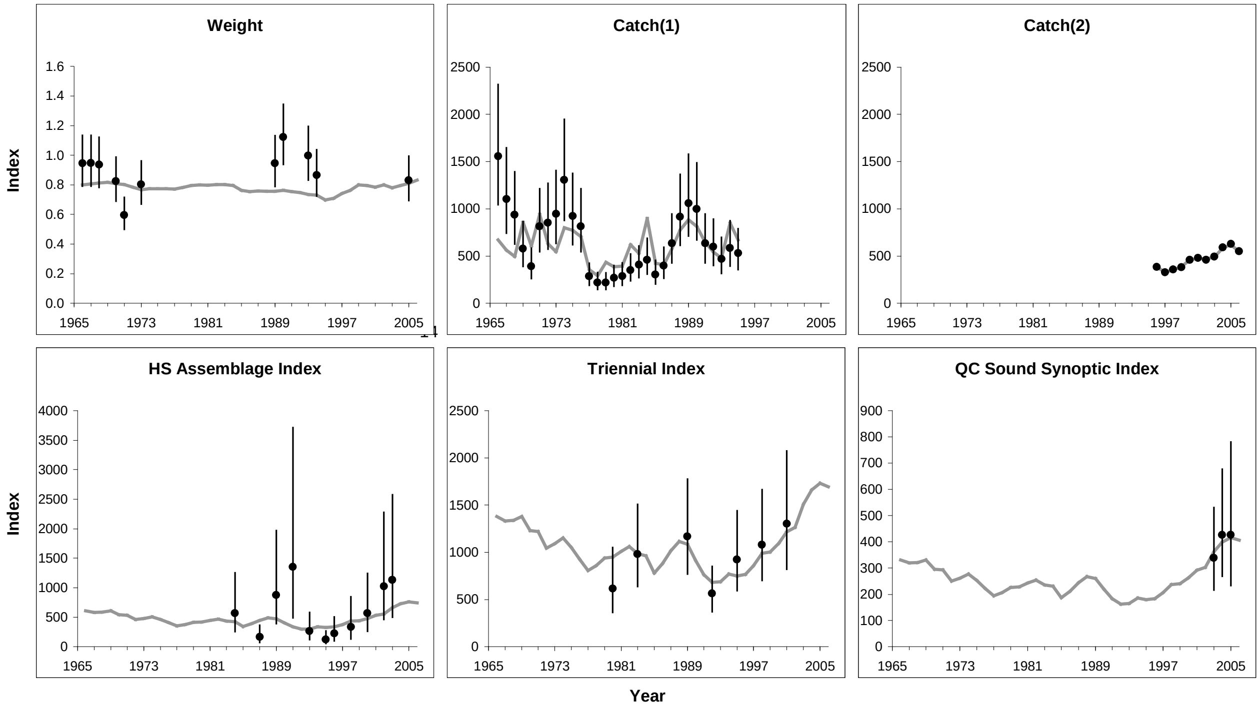


Figure D.5. Model fits to the observed data for the split CPUE series | $r = 6$ | CGRCS rules | est M model run (Table D.1).

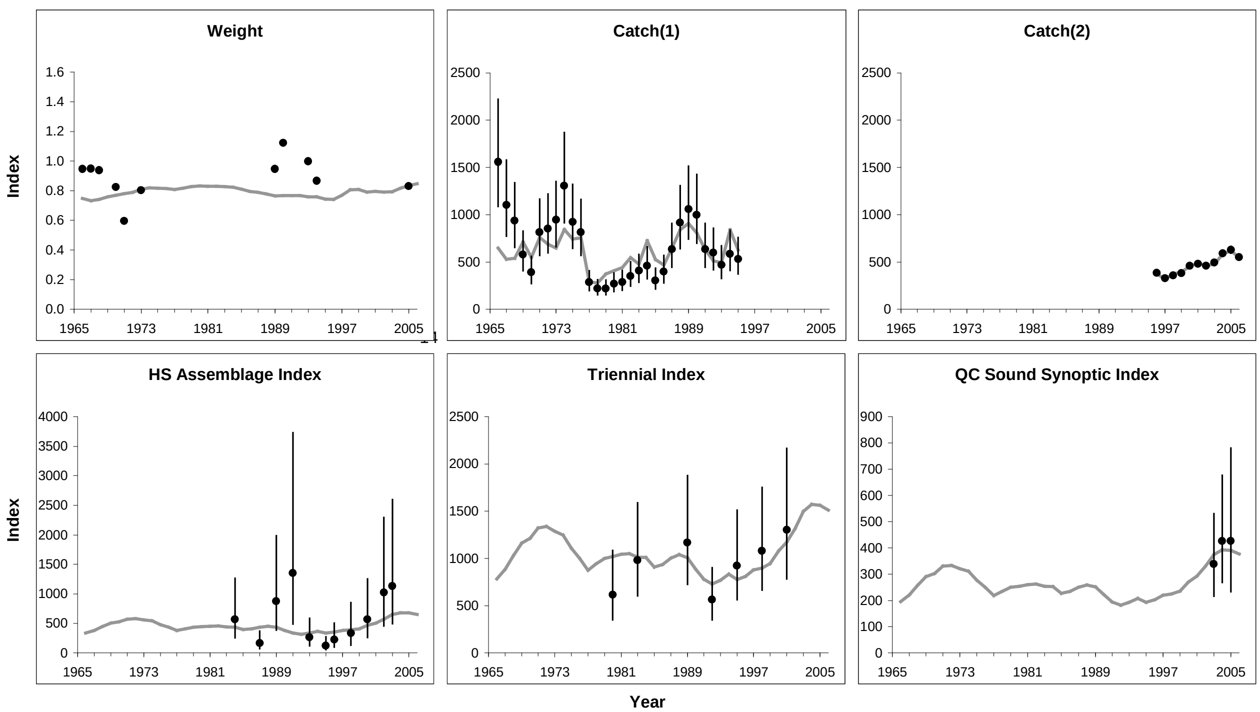


Figure D.6. Model fits to the observed data for the split CPUE series | $r = 6$ | wide rules | fix M model run (Table D.1).

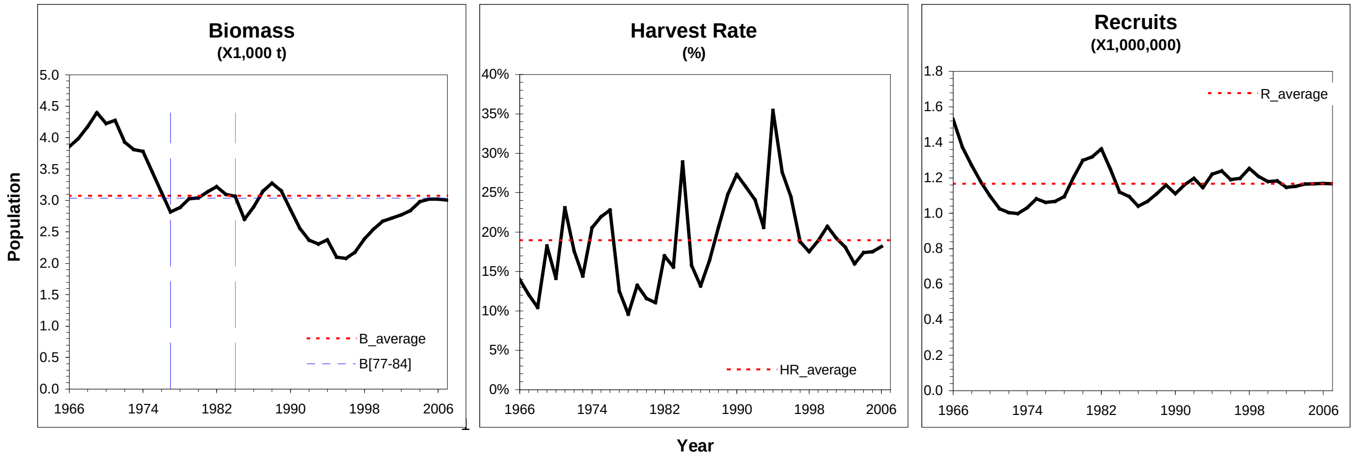


Figure D.7. MPD population trajectories for the single CPUE series | $r = 6$ | CGRCS rules | est M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

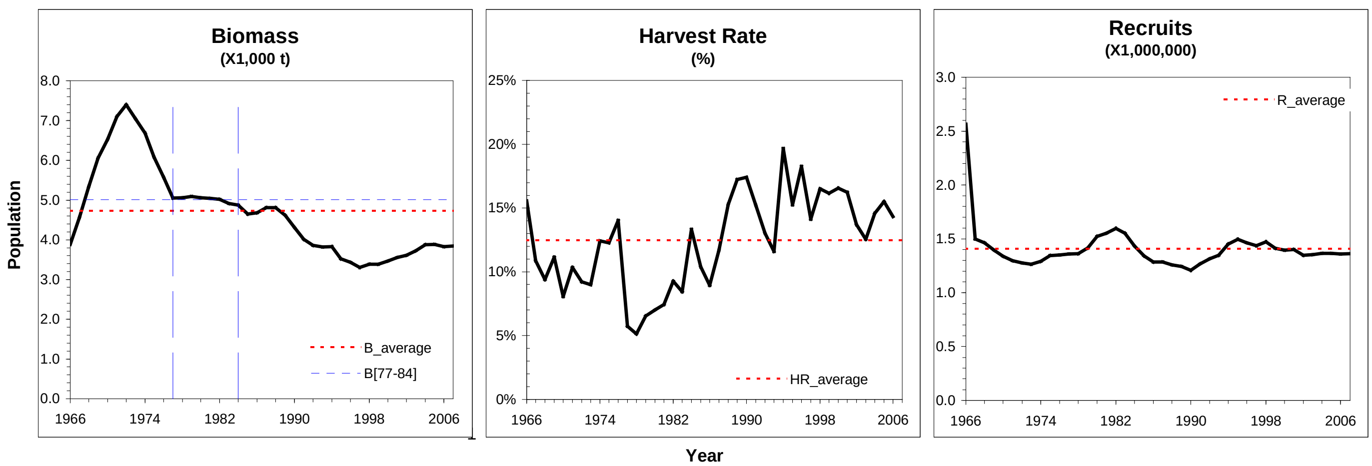


Figure D.8. MPD population trajectories for the single CPUE series | $r = 6$ | wide rules | fix M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

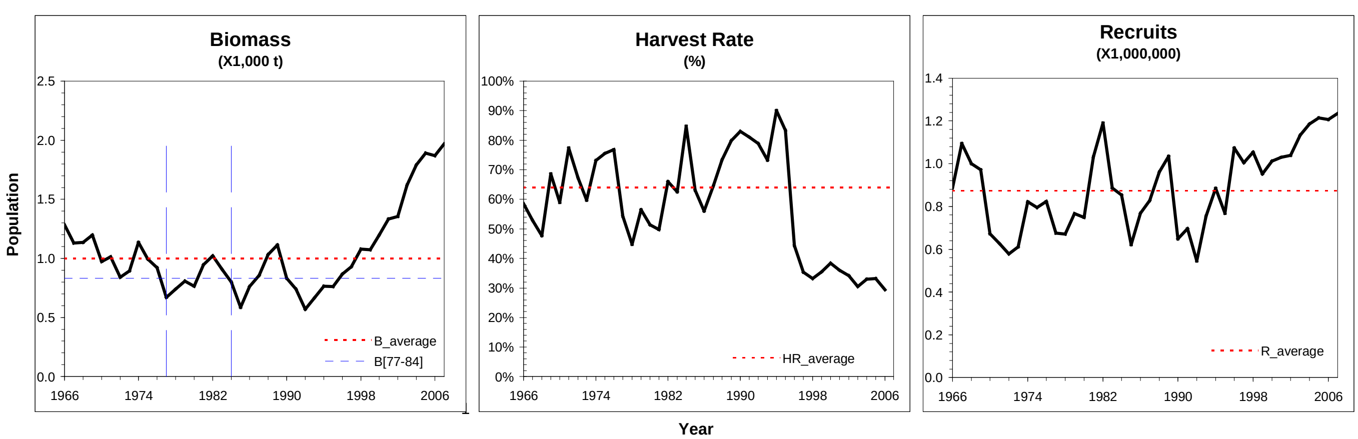


Figure D.9. MPD population trajectories for the split CPUE series | $r = 7$ | CGRCS rules | est M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

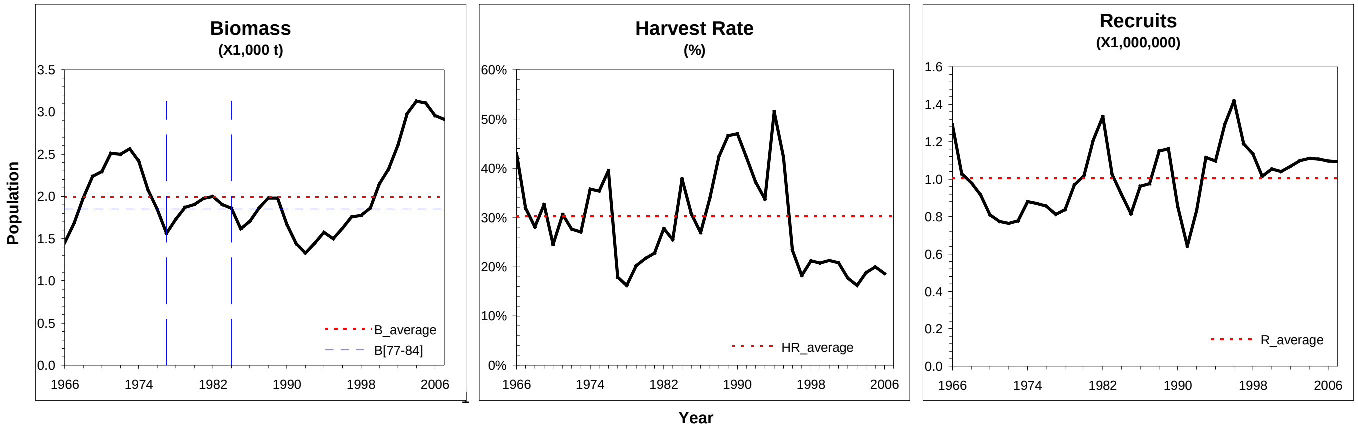


Figure D.10. MPD population trajectories for the split CPUE series | $r = 7$ | wide rules | fix M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

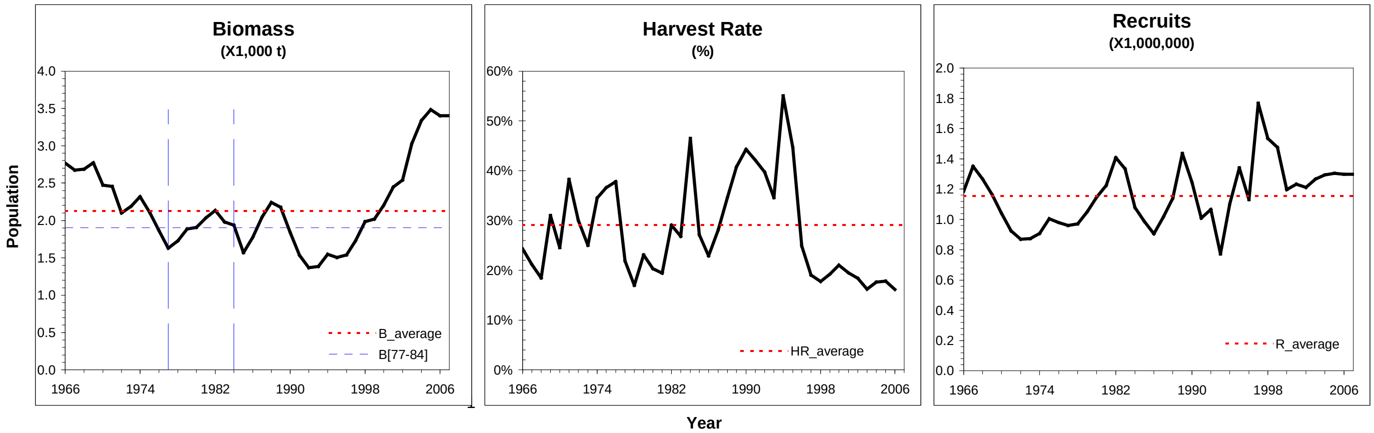


Figure D.11. MPD population trajectories for the split CPUE series | $r = 6$ | CGRCS rules | est M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

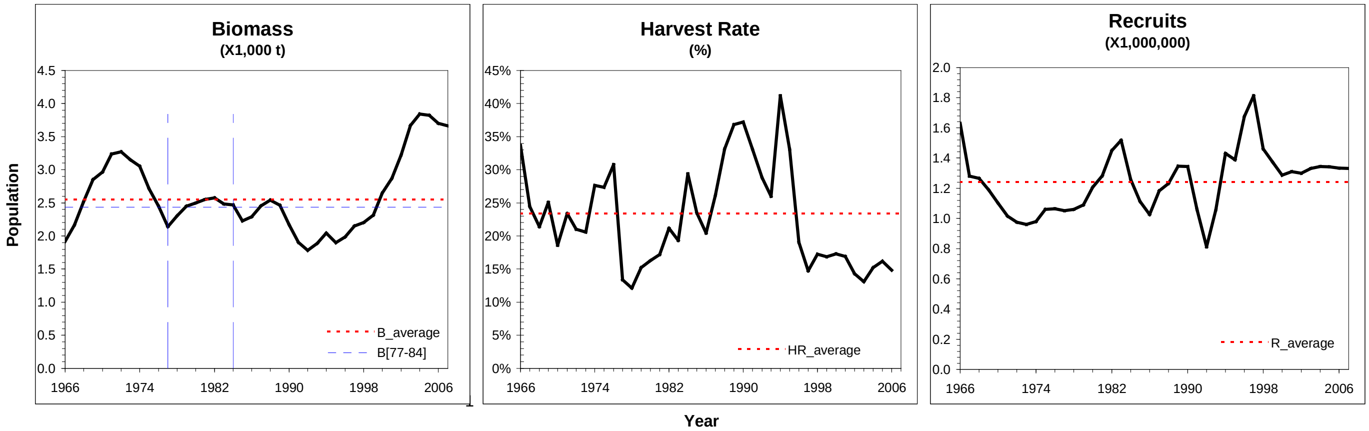


Figure D.12. MPD population trajectories for the split CPUE series | $r = 6$ | wide rules | fix M model run (Table D.1). Vertical lines in the Biomass subgraph bracket the 1977 to 1984 reference period.

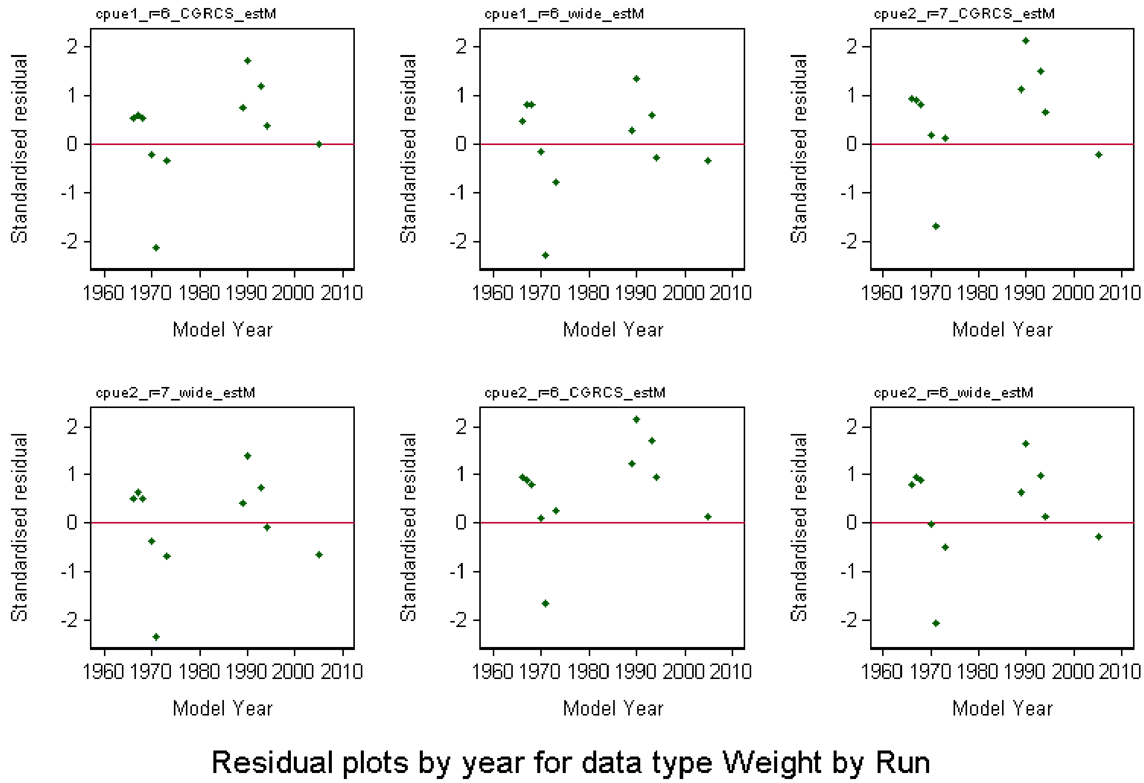


Figure D.13. Standardised (Pearson) residuals for the fit to the weight data plotted by year for the runs which used the weight data (Table D.1).

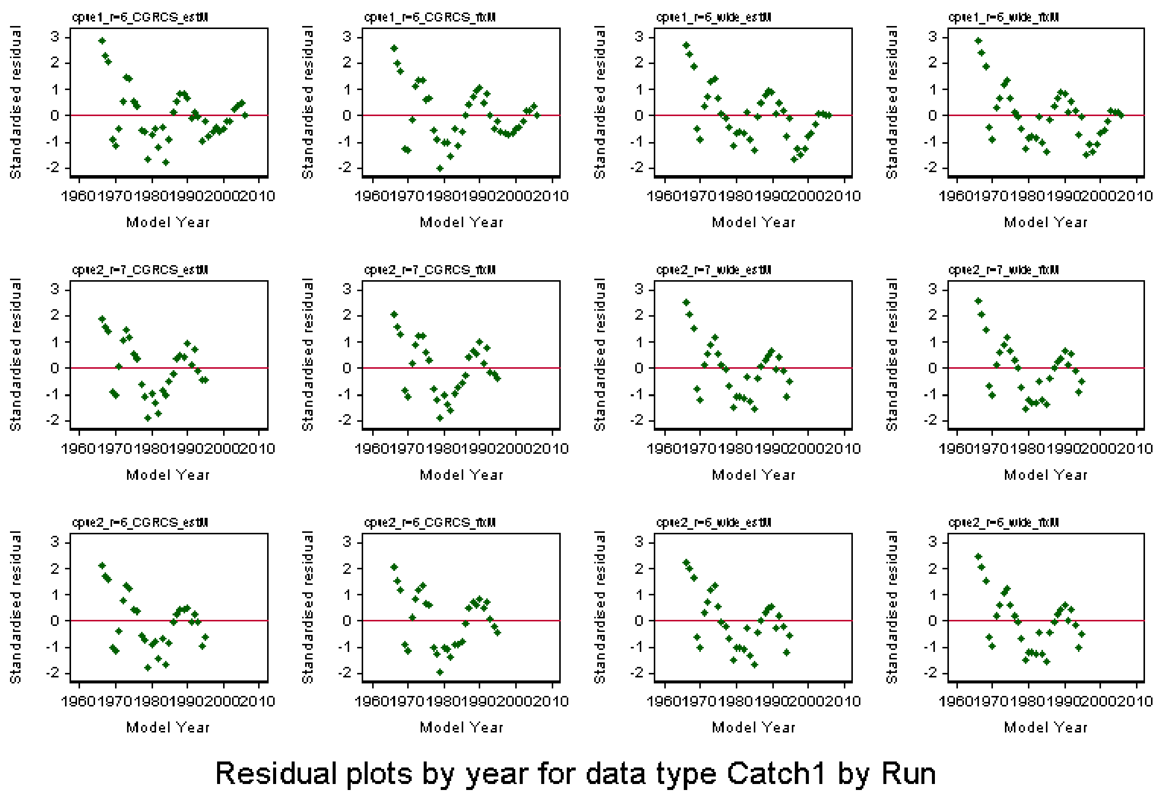


Figure D.14. Standardised (Pearson) residuals for the fit to the first series of catch data plotted by year (Table D.1).

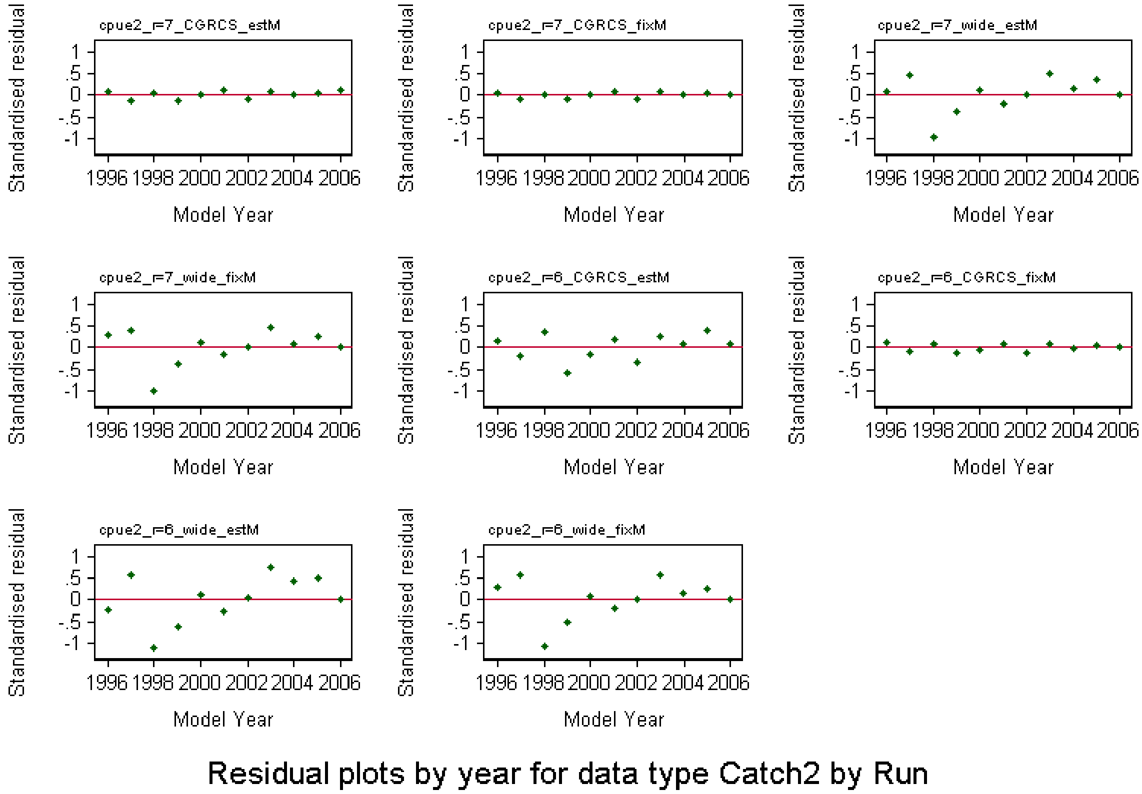


Figure D.15. Standardised (Pearson) residuals for the fit to the second series of catch data for the split CPUE runs plotted by year (Table D.1).

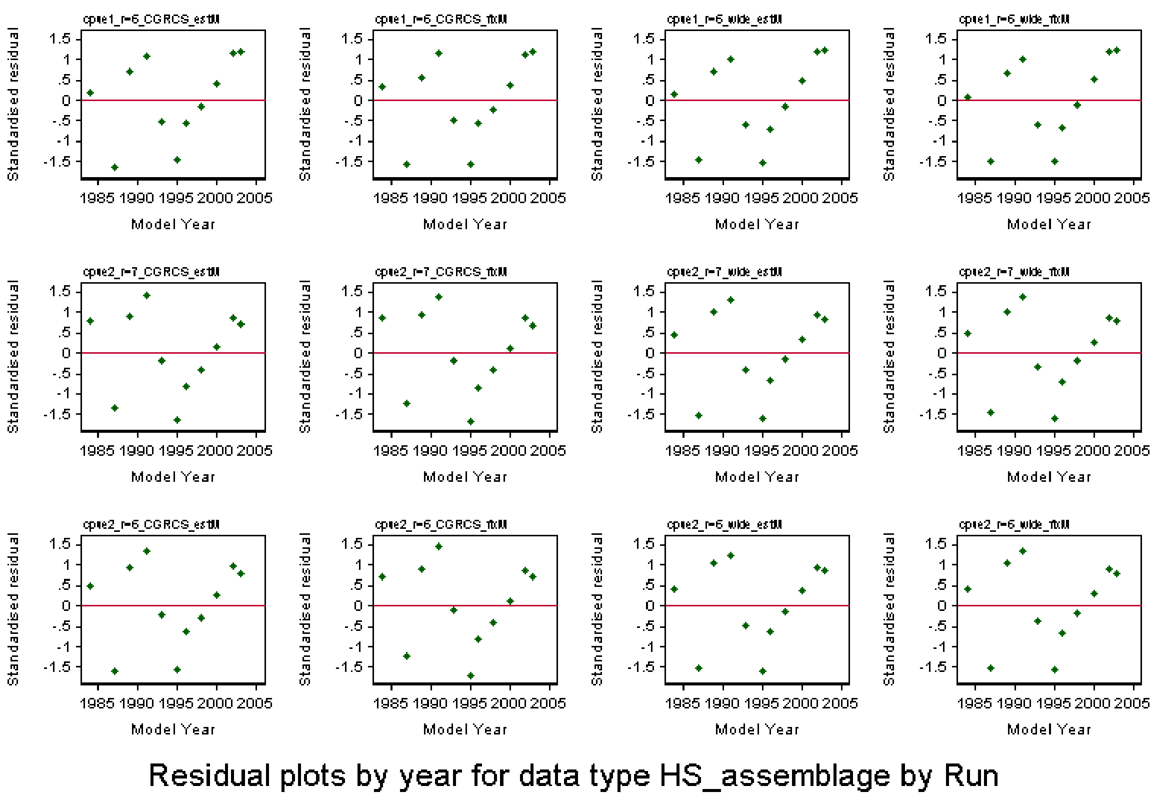


Figure D.16. Standardised (Pearson) residuals for the fit to the Hecate St. assemblage survey plotted by year (Table D.1).

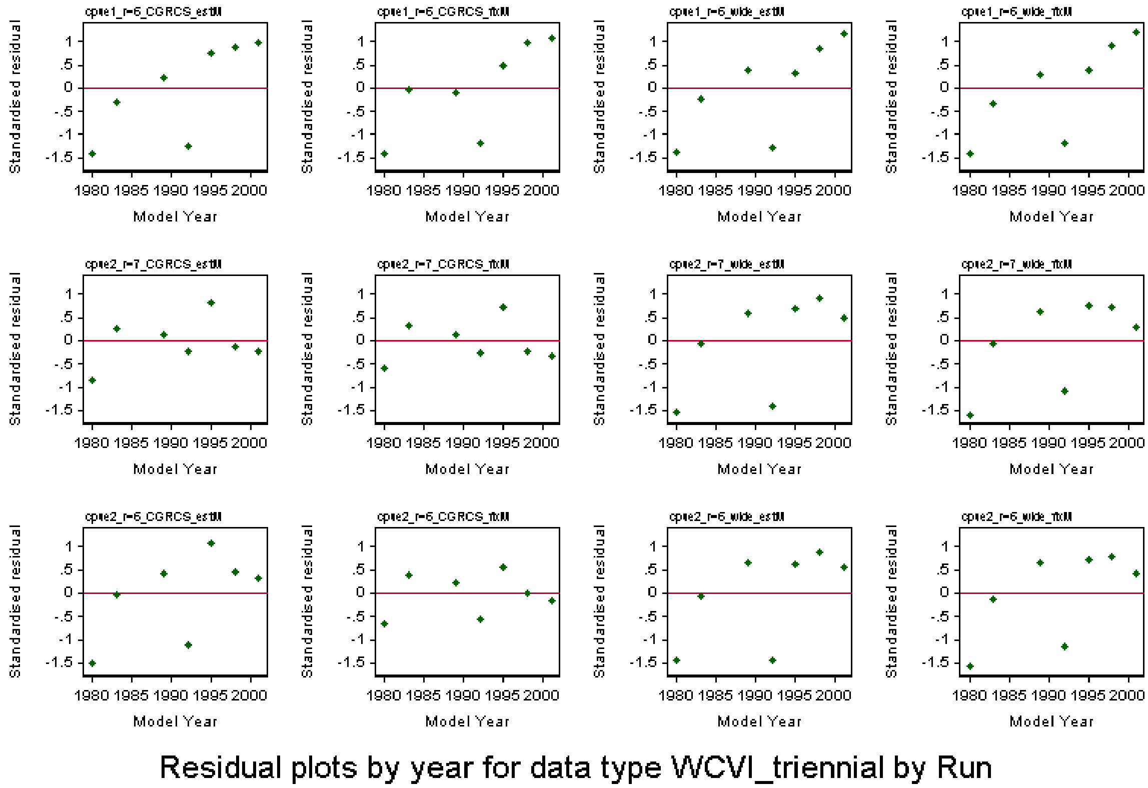


Figure D.17. Standardised (Pearson) residuals for the fit to the WCVI Triennial survey plotted by year (Table D.1).

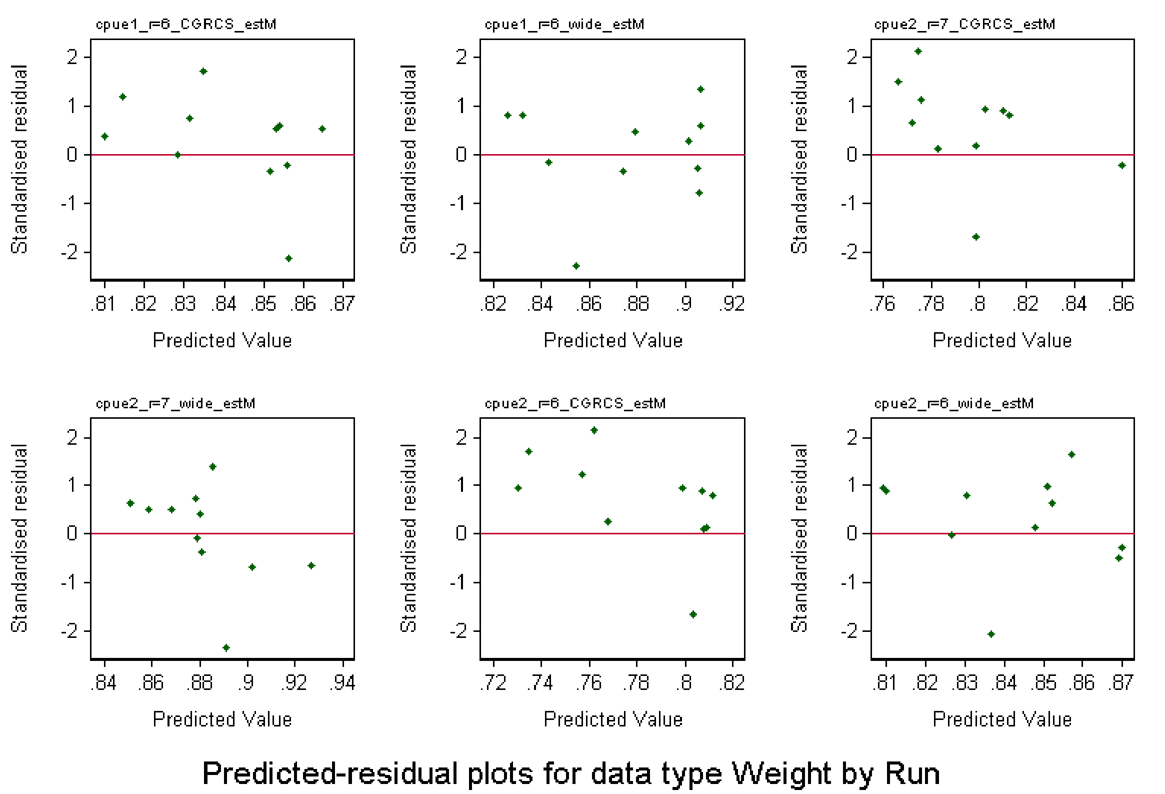


Figure D.18. Standardised (Pearson) residuals for the fit to the weight data plotted against the predicted value for the runs which used the weight data (Table D.1).

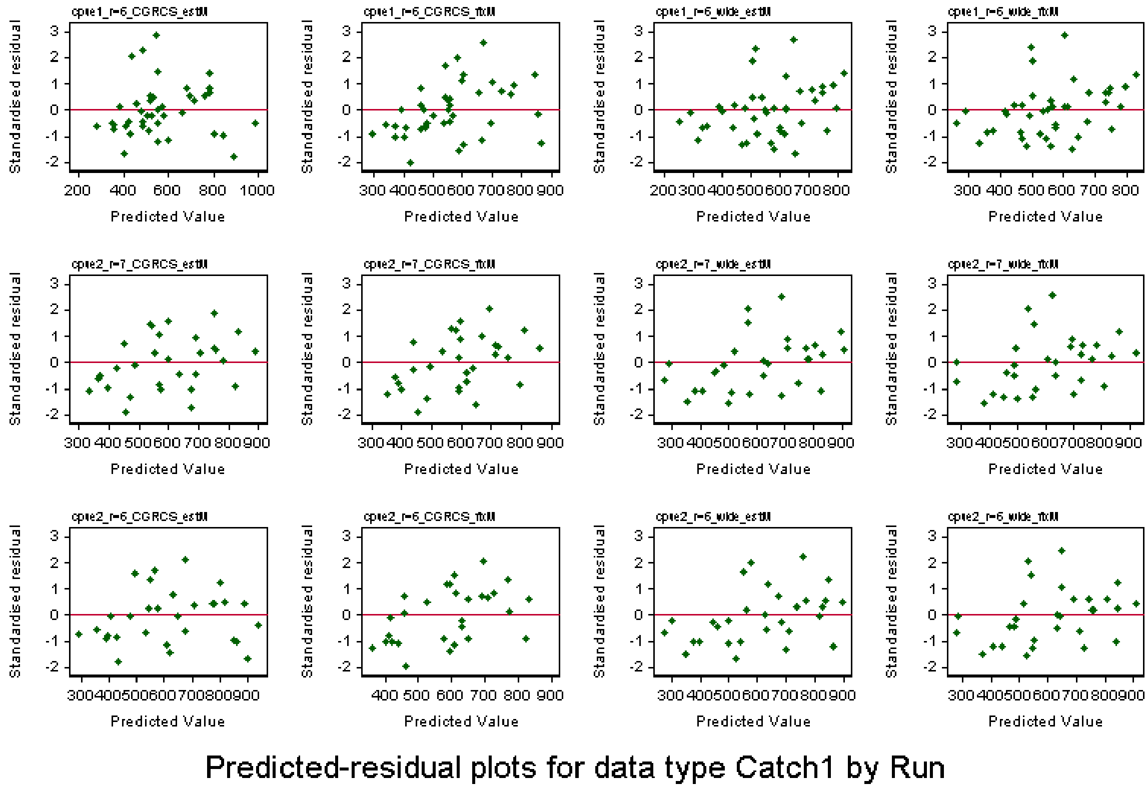


Figure D.19. Standardised (Pearson) residuals for the fit to the first series of catch data plotted against the predicted value (Table D.1).

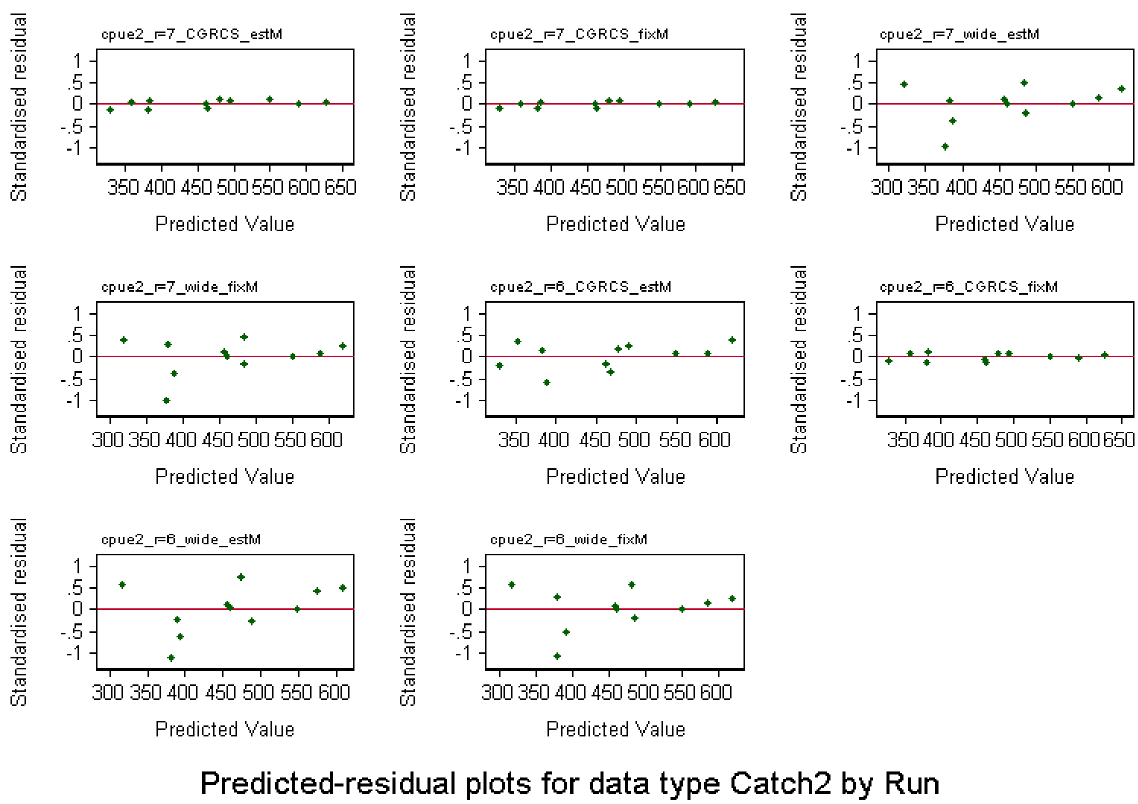


Figure D.20. Standardised (Pearson) residuals for the fit to the second series of catch data for the split CPUE runs plotted against the predicted value (Table D.1).

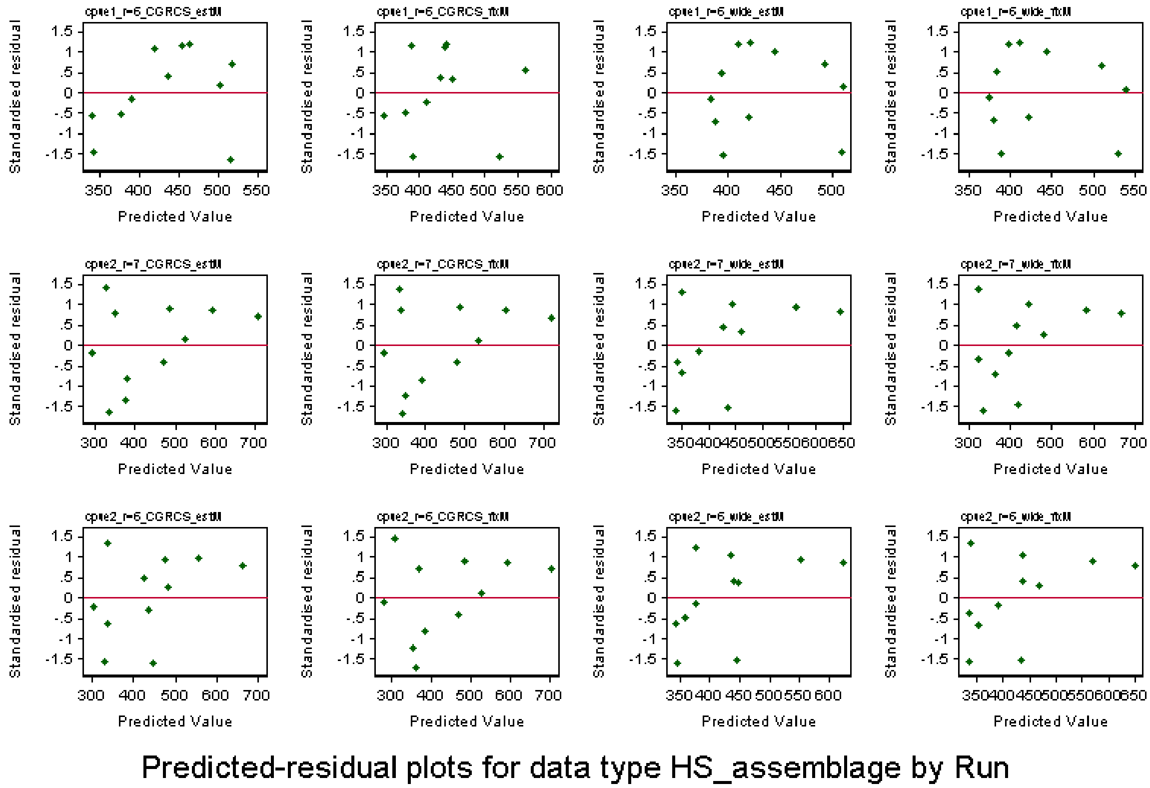


Figure D.21. Standardised (Pearson) residuals for the fit to the Hecate St. assemblage survey plotted against the predicted value (Table D.1).

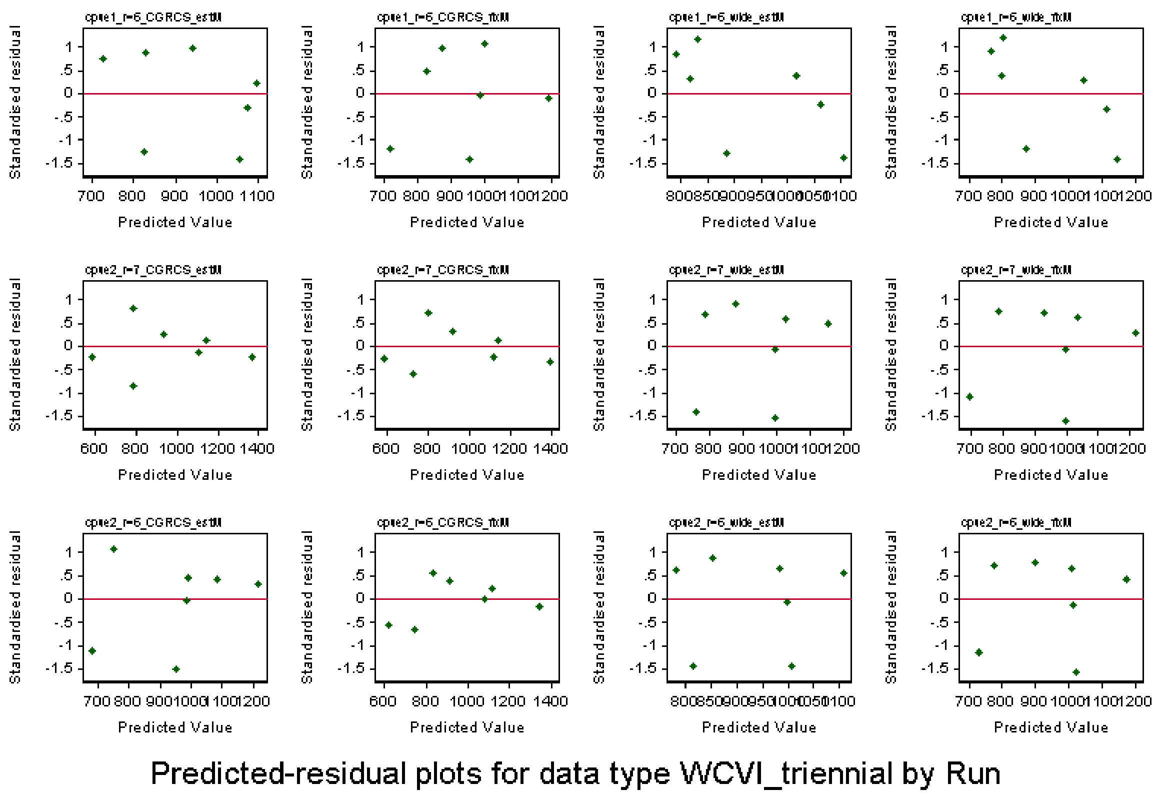


Figure D.22. Standardised (Pearson) residuals for the fit to the WCVI Triennial survey plotted against the predicted value (Table D.1).

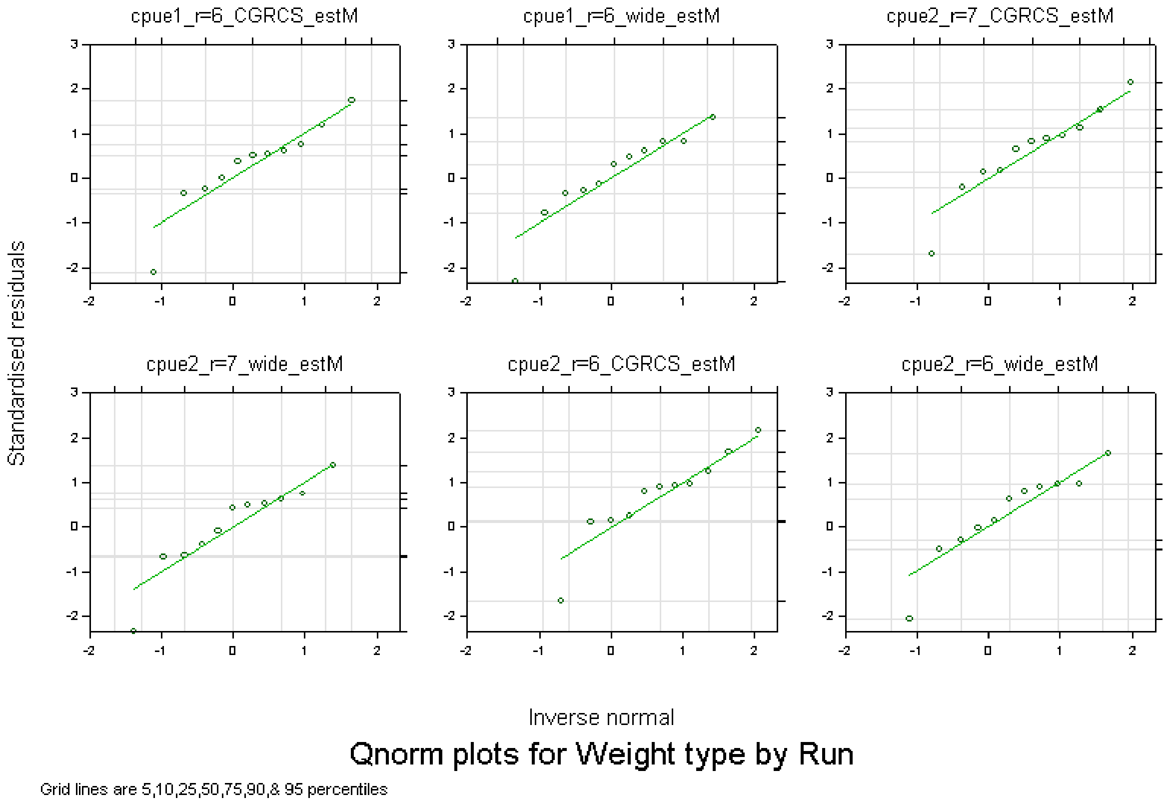


Figure D.23. Q-Q plots of the standardised (Pearson) residuals for the fit to the weight data for the runs which used the weight data (Table D.1).

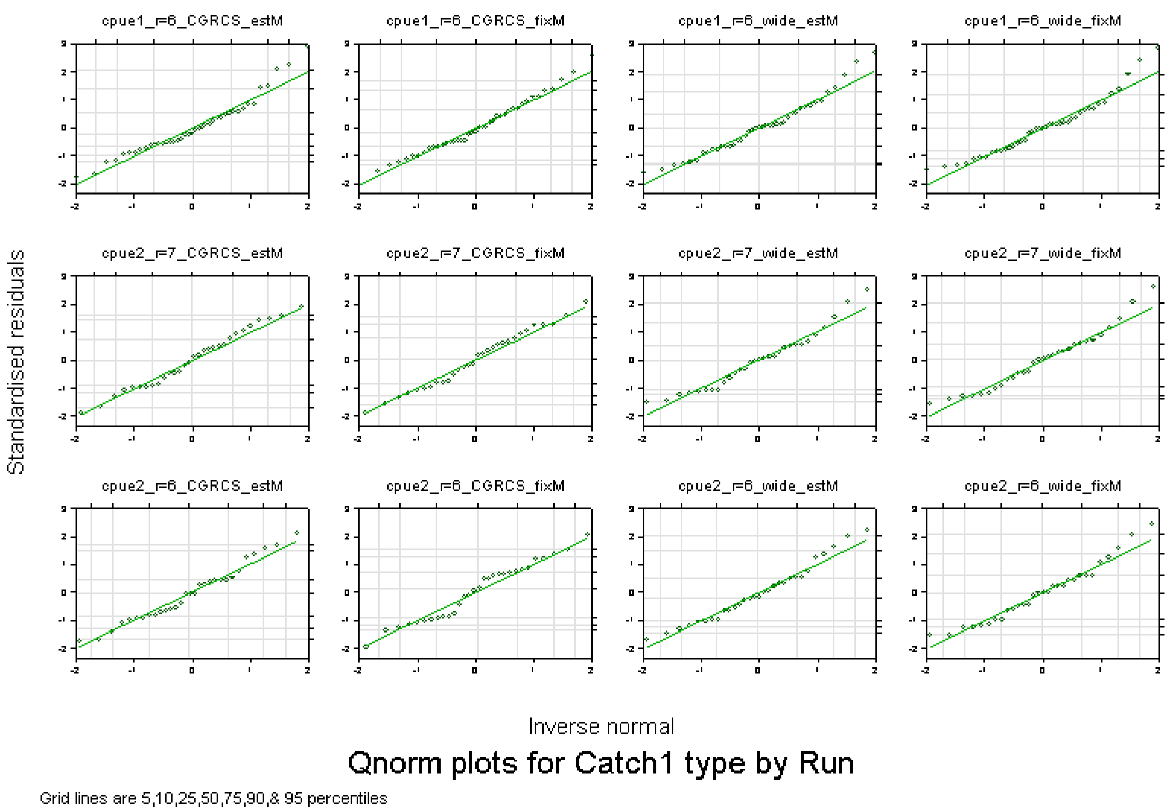


Figure D.24. Q-Q plots of the standardised (Pearson) residuals for the fit to the first series of catch data (Table D.1).

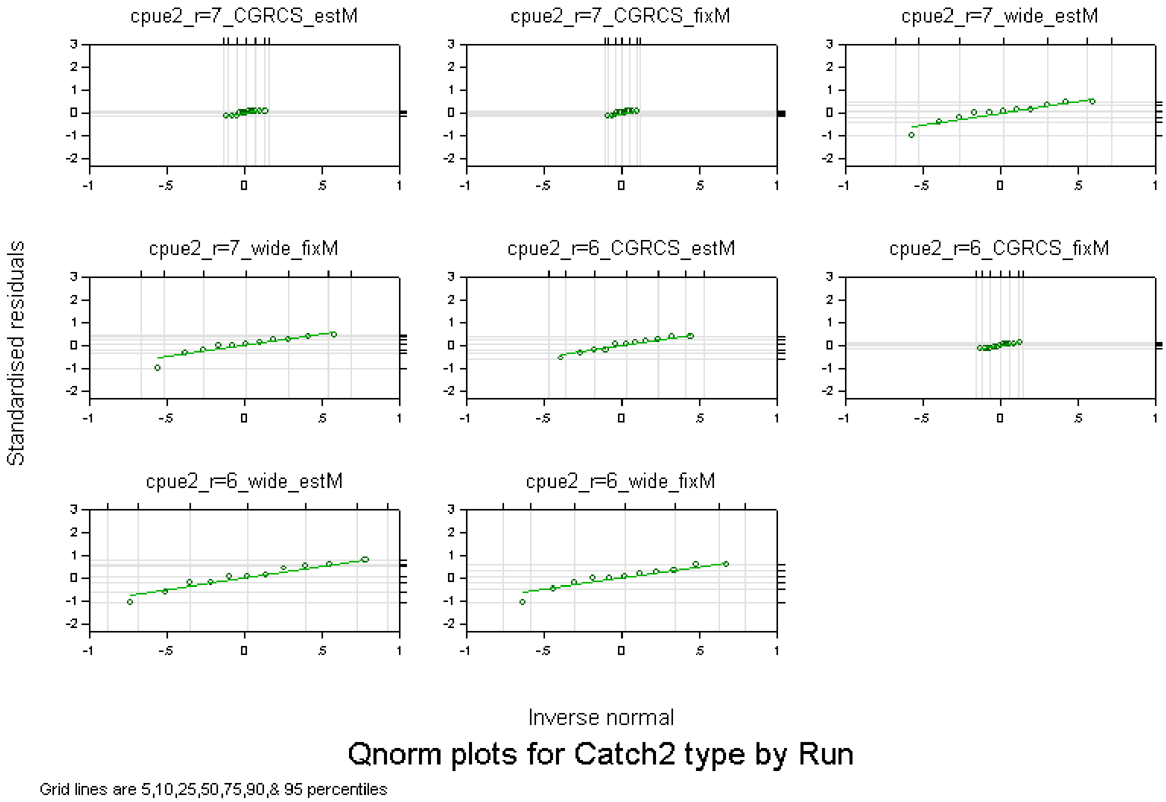


Figure D.25. Q-Q plots of the standardised (Pearson) for the fit to the second series of catch data for the split CPUE runs (Table D.1).

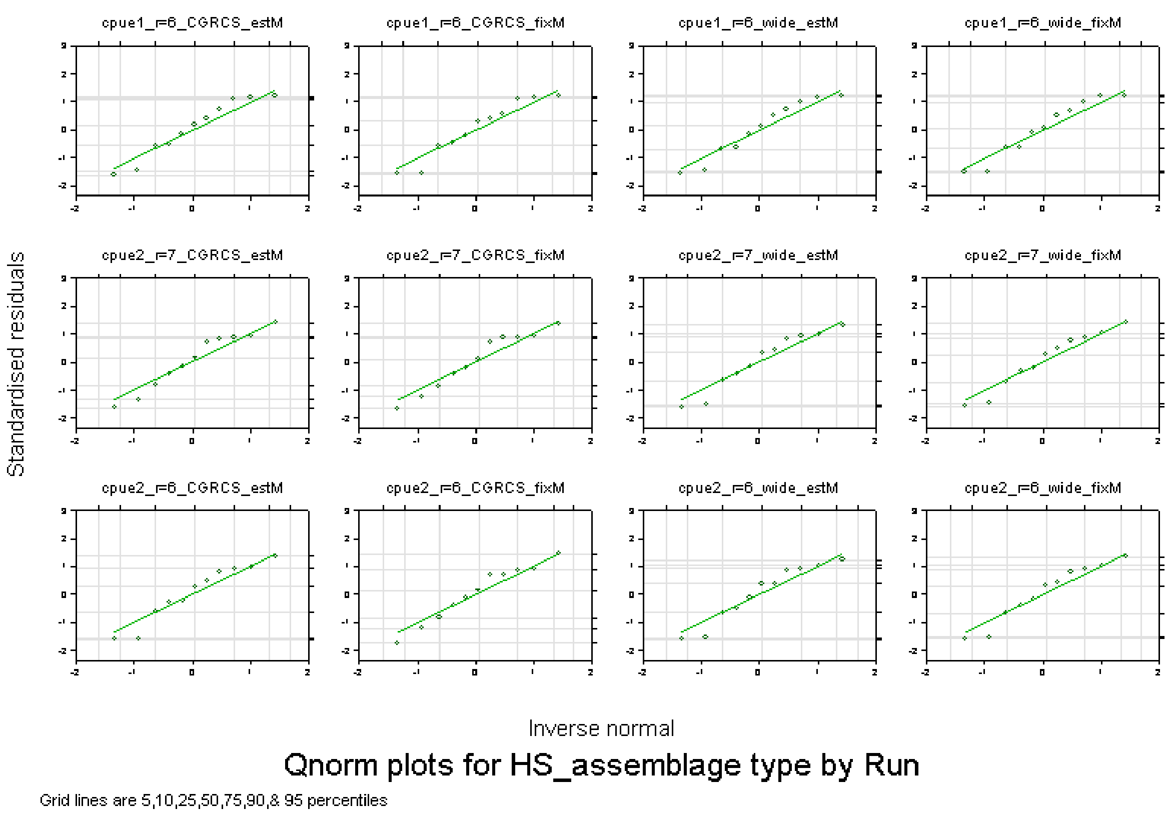


Figure D.26. Q-Q plots of the standardised (Pearson) for the fit to the Hecate St. assemblage survey (Table D.1).

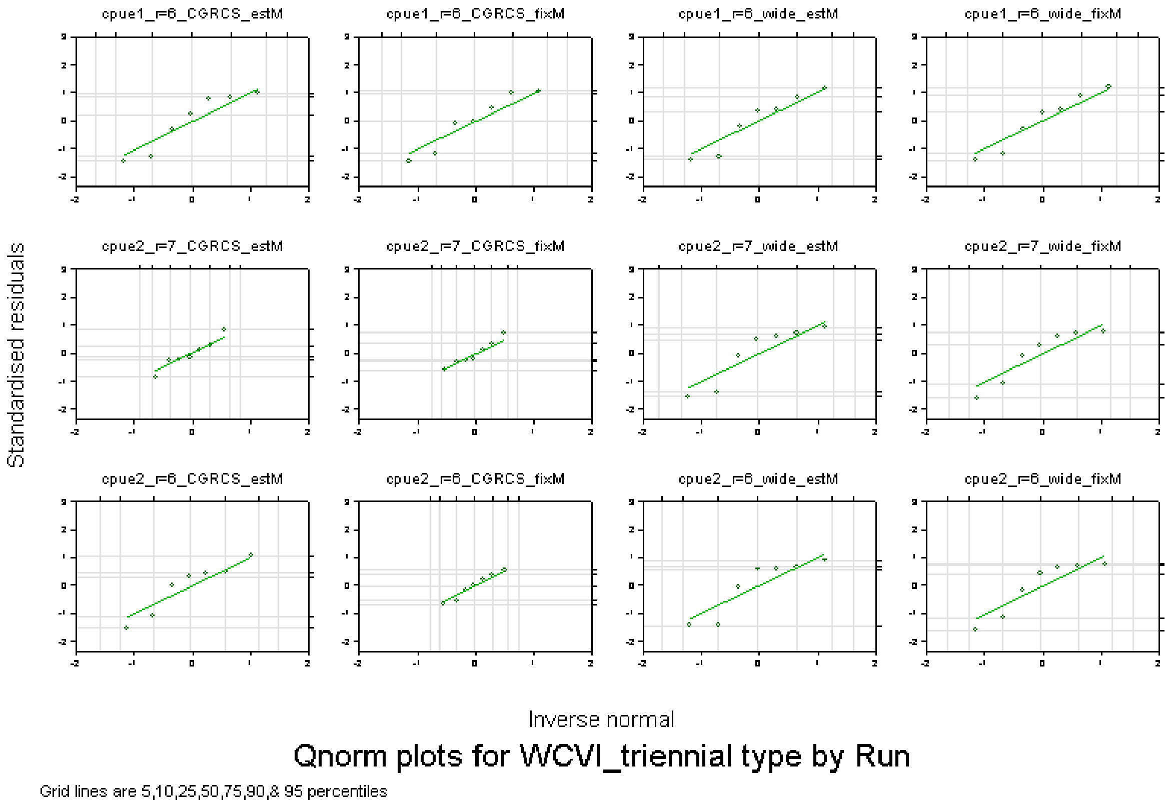


Figure D.27. Q-Q plots of the standardised (Pearson) for the fit to the WCVI Triennial survey (Table D.1).

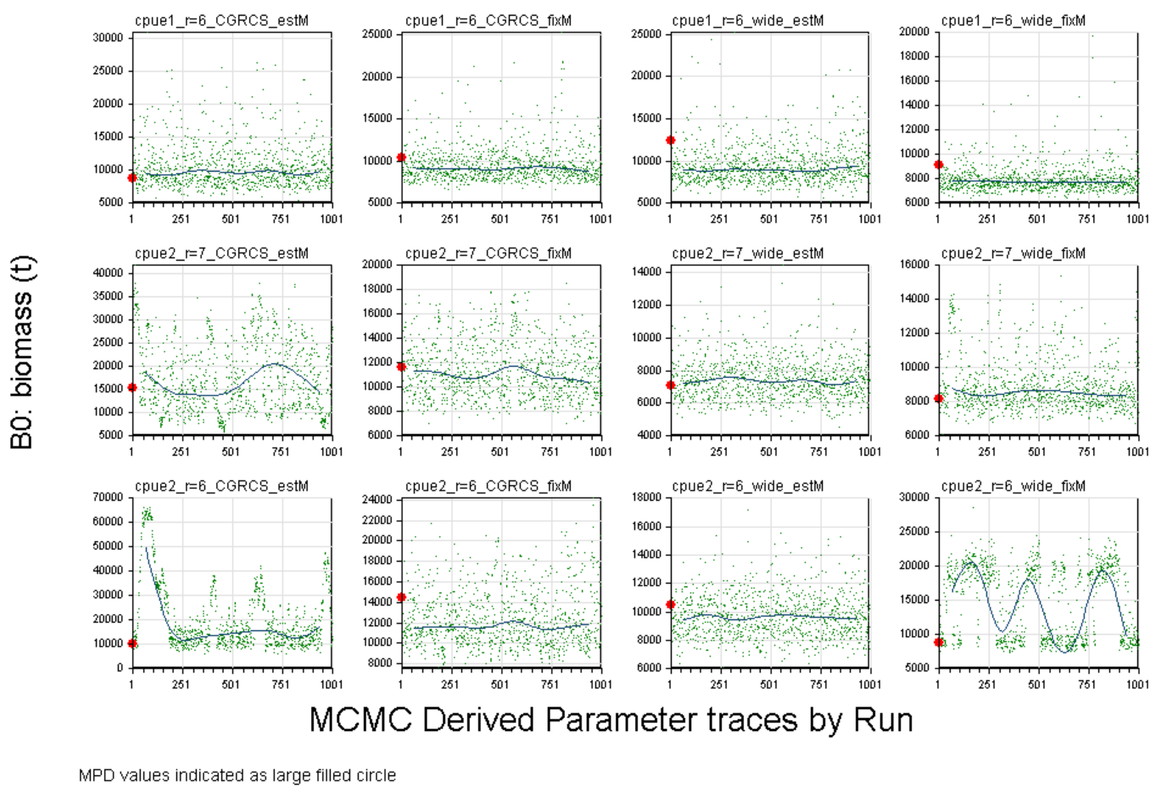


Figure D.28. MCMC traces of the B_0 parameter for all 12 model runs listed in Table D.1, based on 1,000 samples from each of the chains

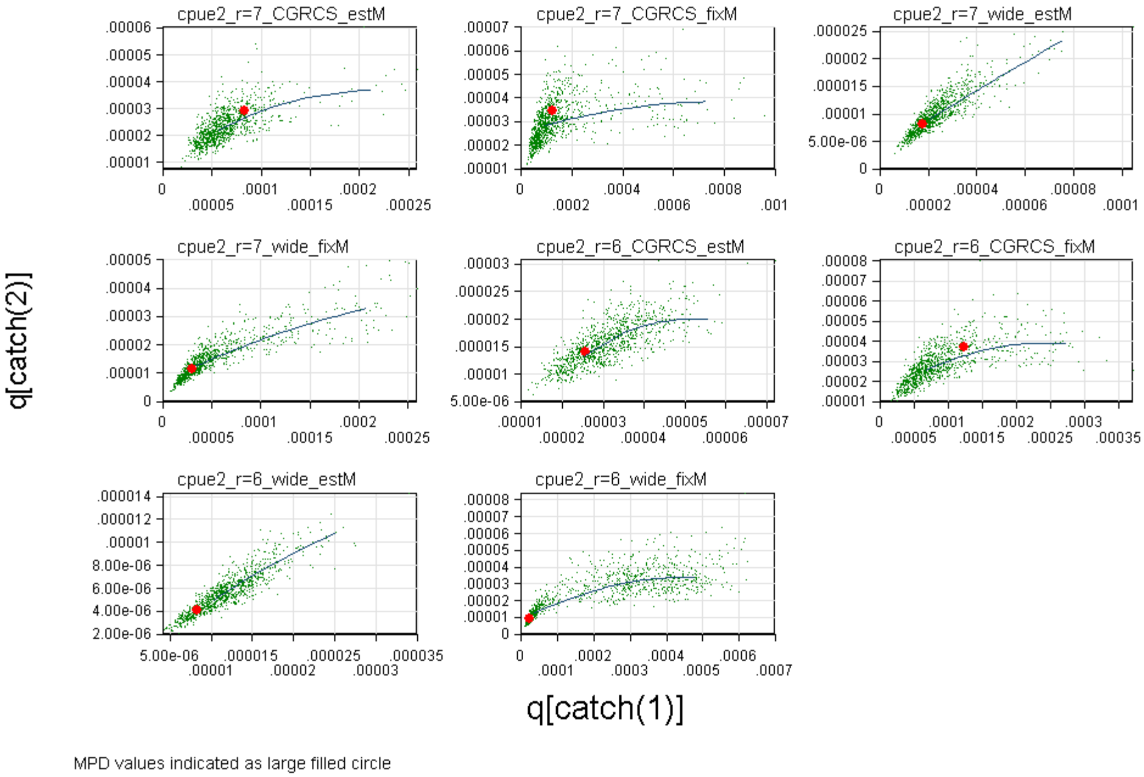


Figure D.29. Scatter plot of the paired MCMC samples of ${}^{C}q_1$ and ${}^{C}q_2$ for the eight model runs with split CPUE series (Table D.1). A cubic spline has been fitted to the data to aid the eye

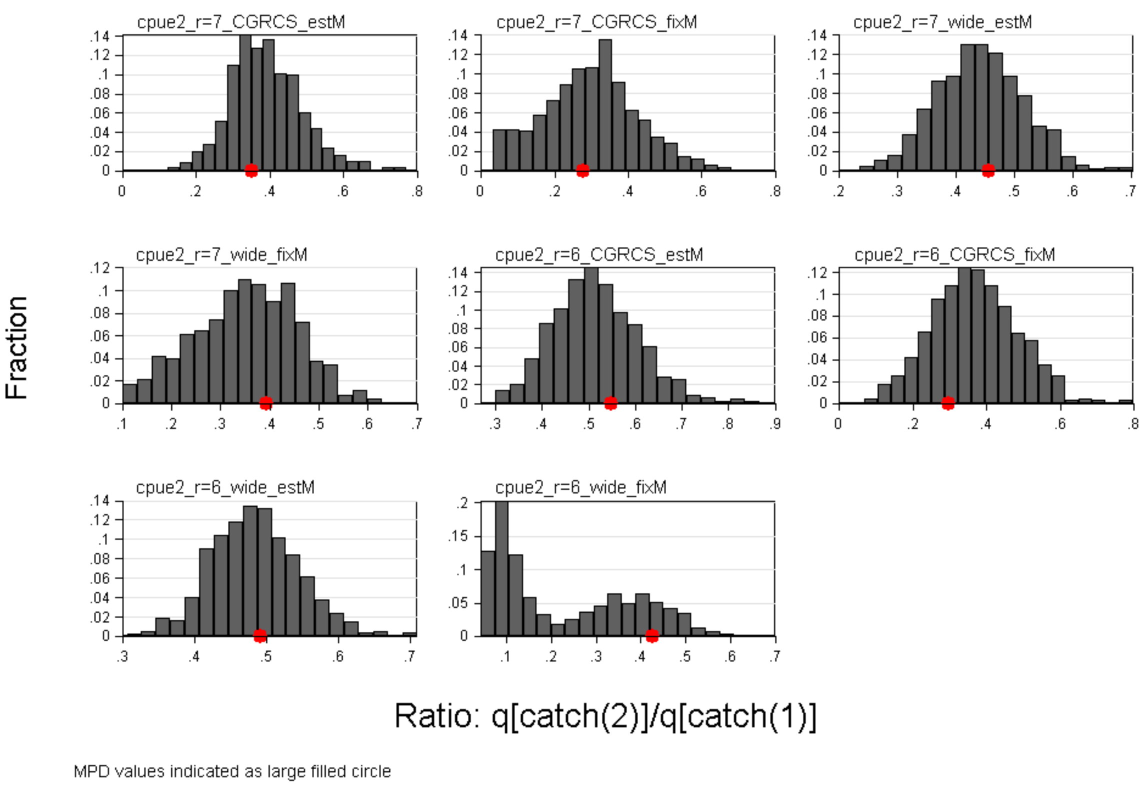


Figure D.30. Frequency distributions of the ratio ${}^{C}q_2 / {}^{C}q_1$ for the eight model runs with split CPUE series (Table D.1) derived from the MCMC chains of 1,000 samples

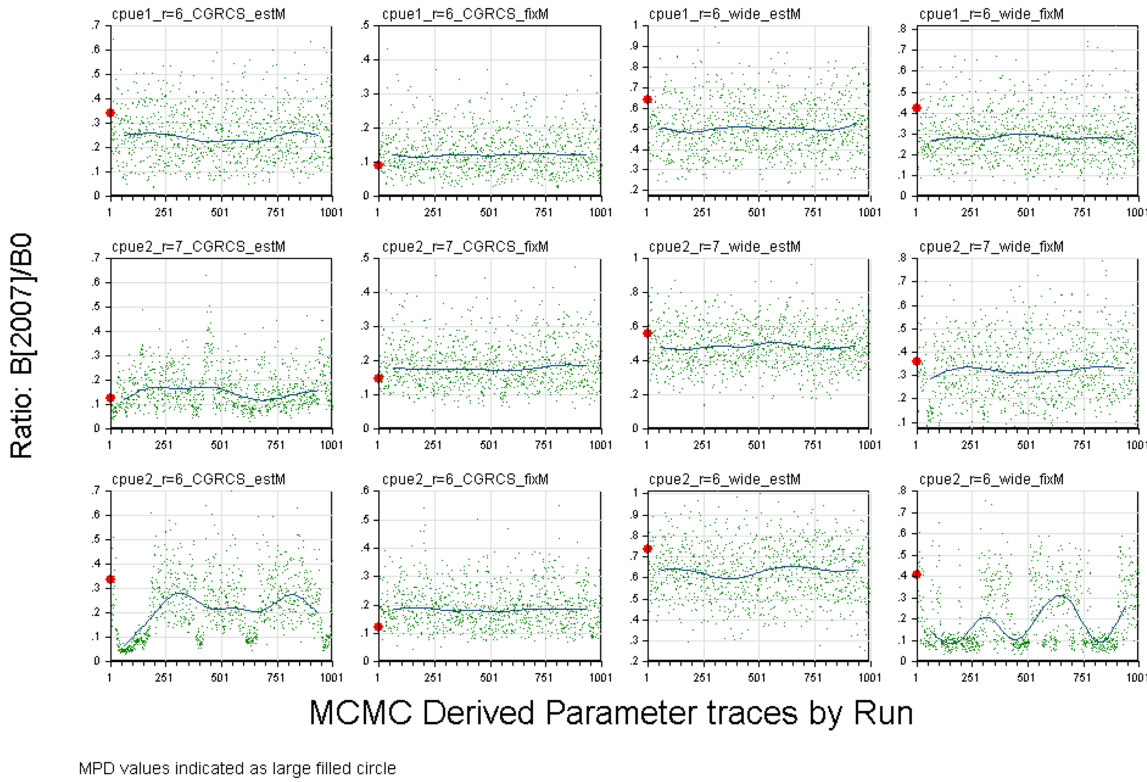


Figure D.31. MCMC traces of the B_{2007}/B_0 derived parameter for all 12 model runs listed in Table D.1, based on 1,000 samples from each the chains

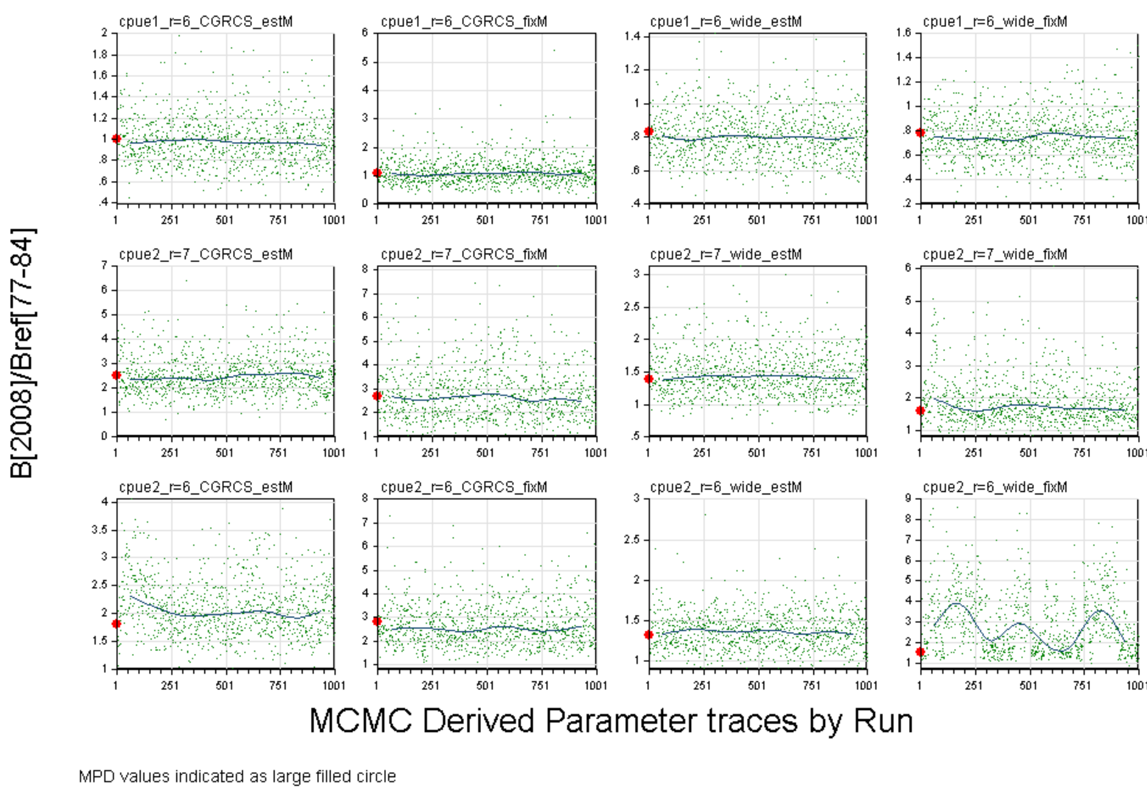
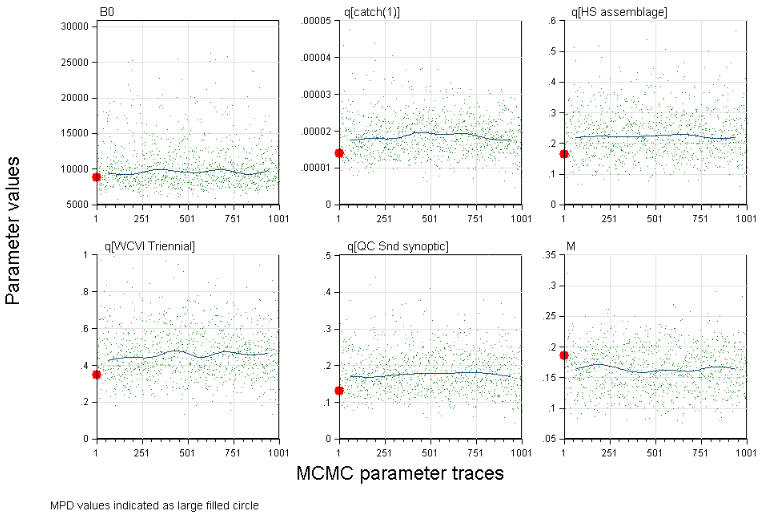
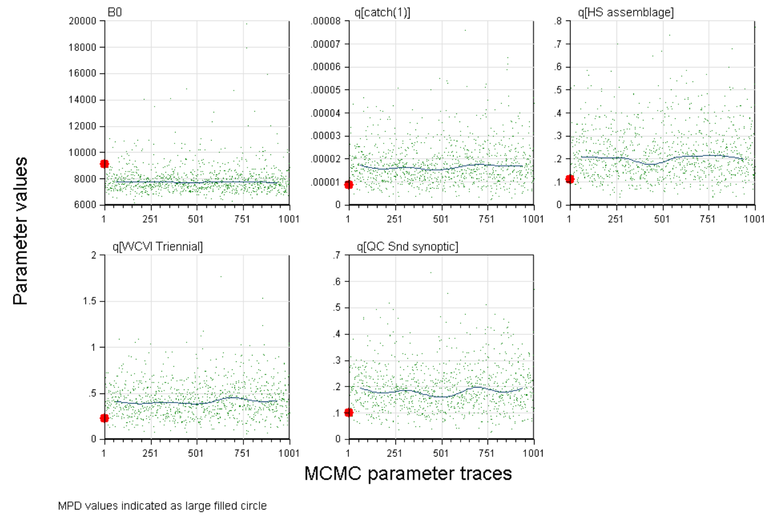


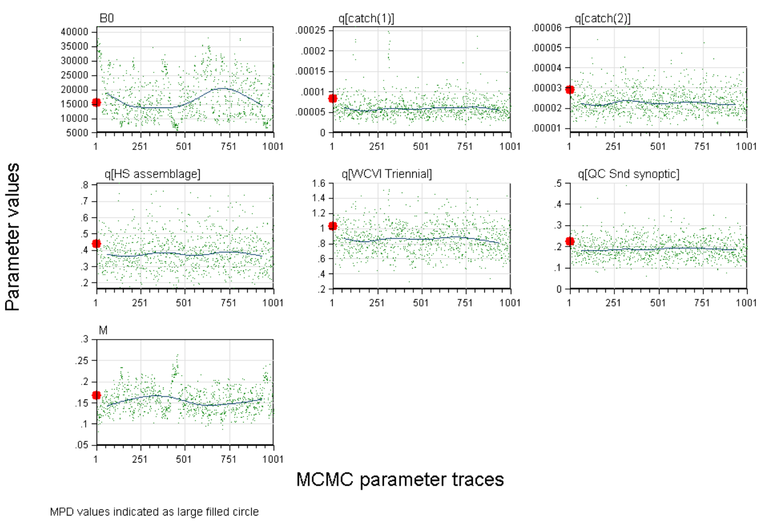
Figure D.32. MCMC traces of the $B_{2007}/\mathrm{mean}\{B_t\}_{t=1977}^{1984}$ derived parameter for all 12 model runs listed in Table D.1, based on 1,000 samples from each of the chains



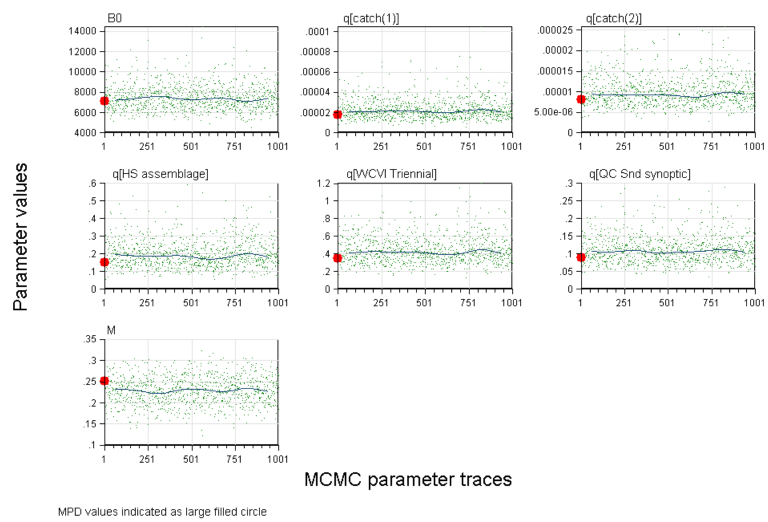
a) single CPUE series | $r = 6$ | CGRCS rules | est M



b) single CPUE series | $r = 6$ | wide rules | fix M

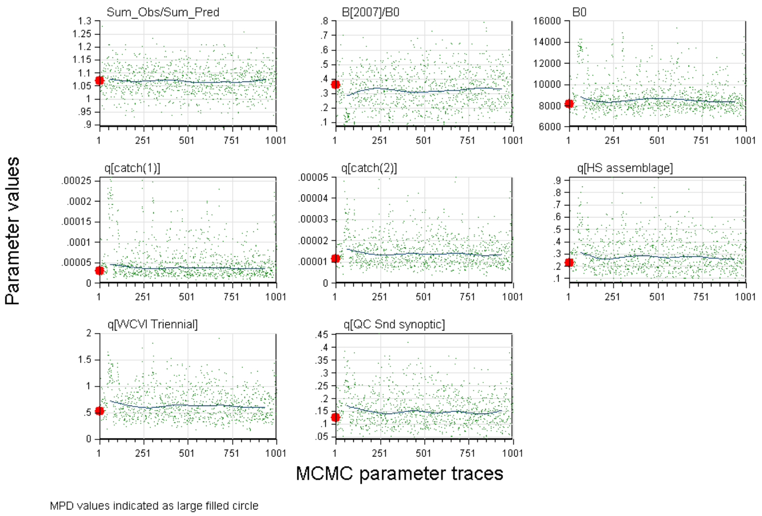


c) split CPUE series | $r = 7$ | CGRCS rules | est M

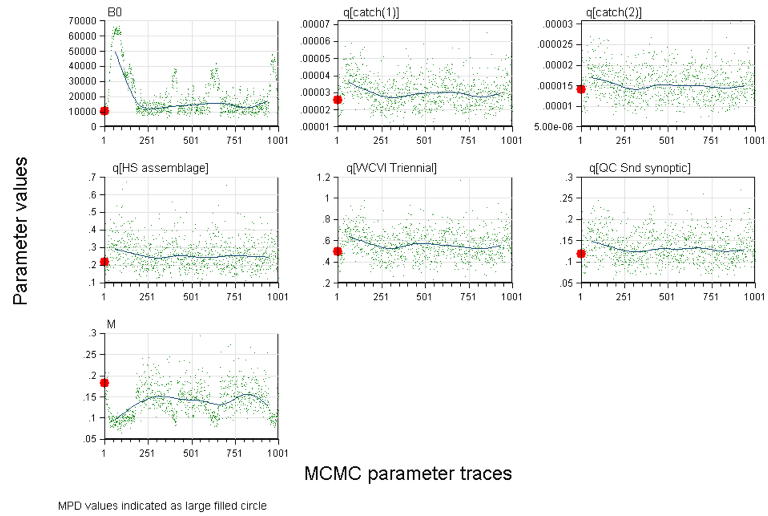


d) split CPUE series | $r = 7$ | wide rules | est M

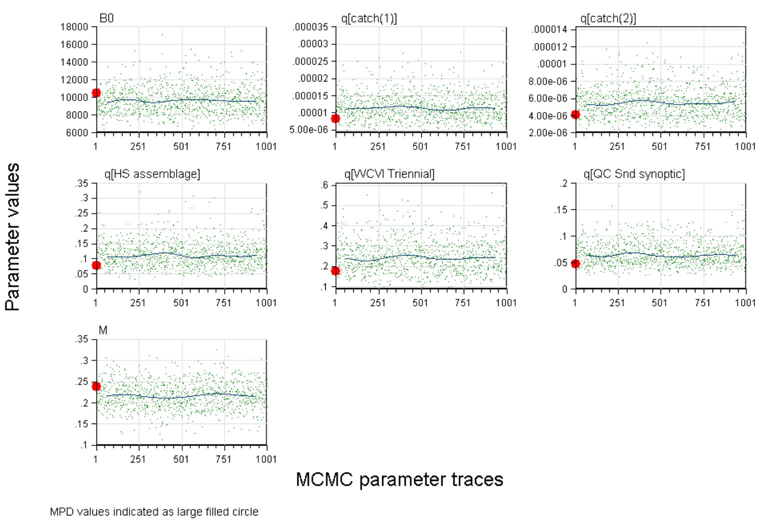
Figure D.33. MCMC traces of the main model parameters based on 1,000 samples from the chains for eight of the model runs listed in Table D.1



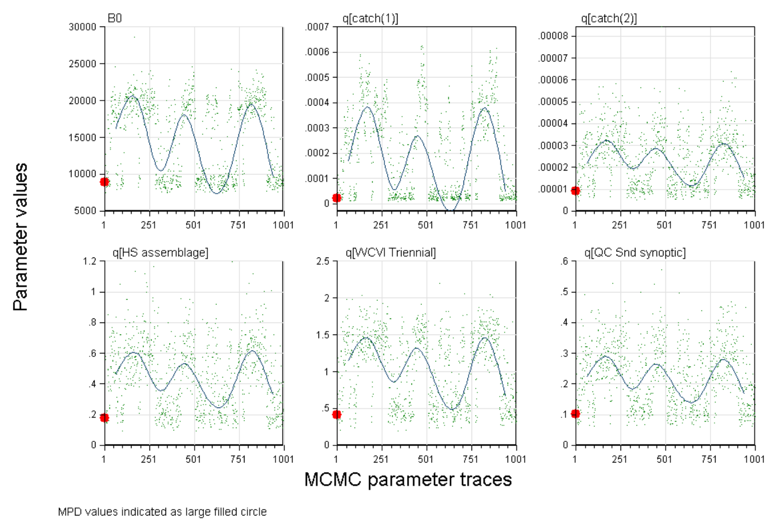
e) split CPUE series | $r = 7$ | wide rules | fix M



f) split CPUE series | $r = 6$ | CGRCS rules | est M

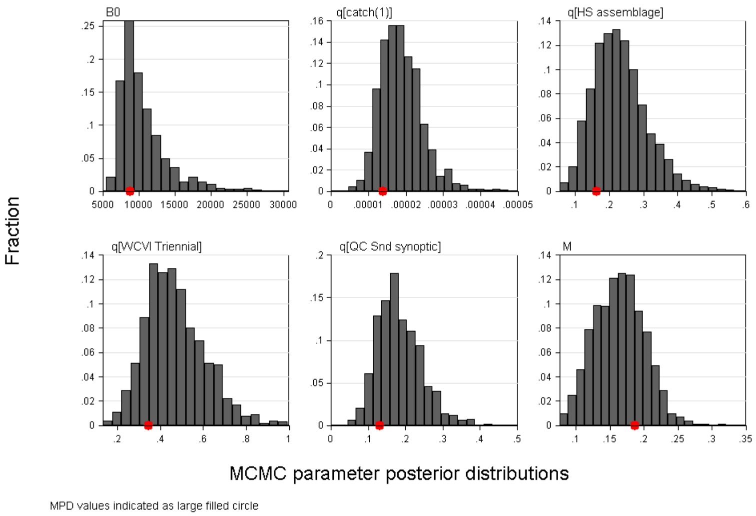


g) split CPUE series | $r = 6$ | wide rules | est M

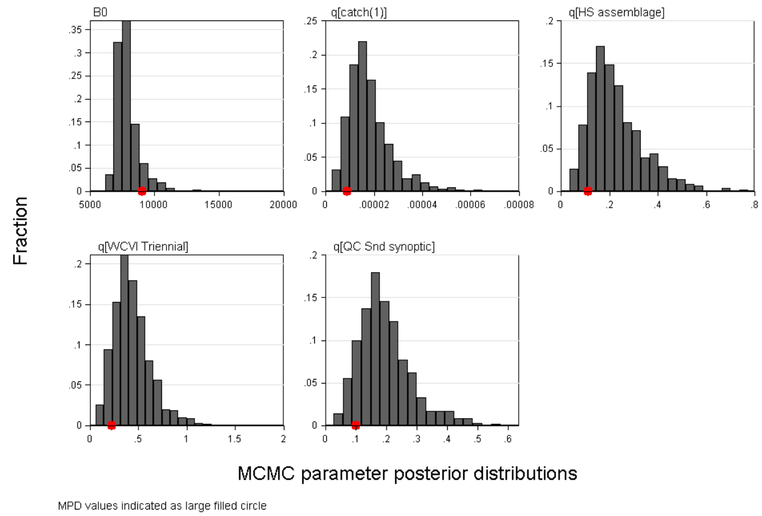


h) split CPUE series | $r = 6$ | wide rules | fix M

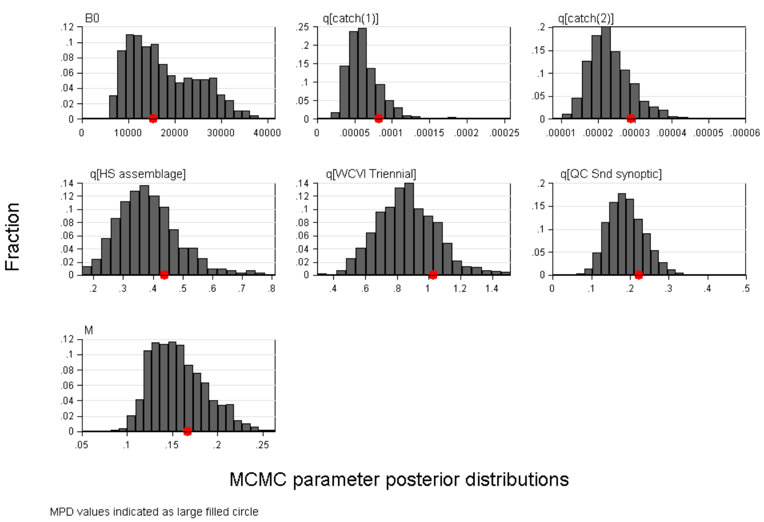
Figure D.33 (cont.). MCMC traces of the main model parameters based on 1,000 samples from the chains for eight of the model runs listed in Table D.1



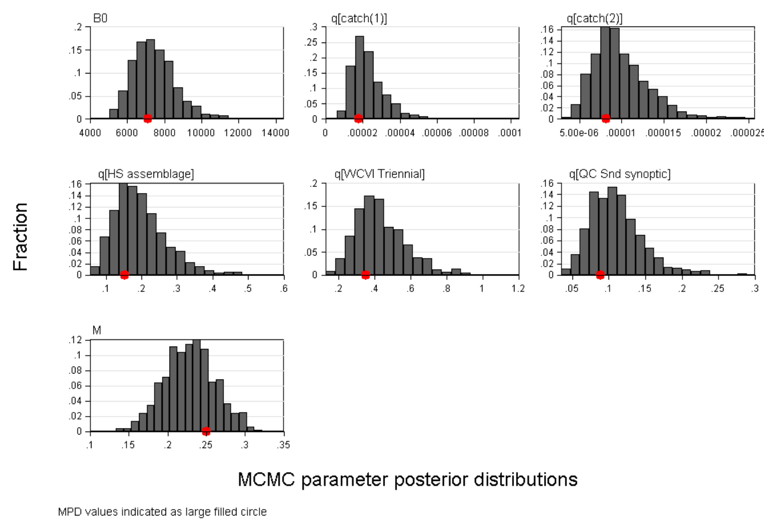
a) single CPUE series | $r = 6$ | CGRCS rules | est M



b) single CPUE series | $r = 6$ | wide rules | fix M

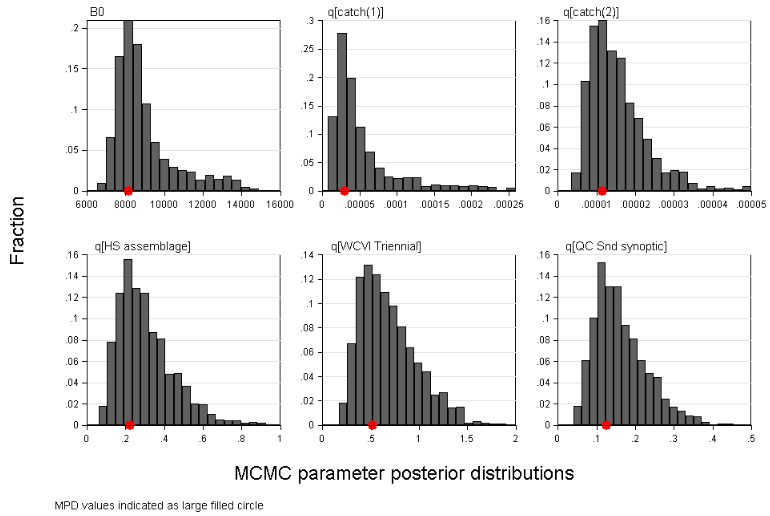


c) split CPUE series | $r = 7$ | CGRCS rules | est M

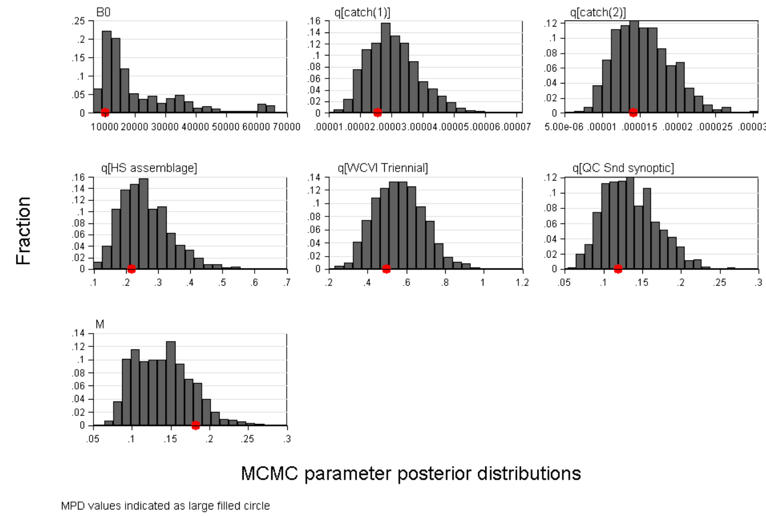


d) split CPUE series | $r = 7$ | wide rules | est M

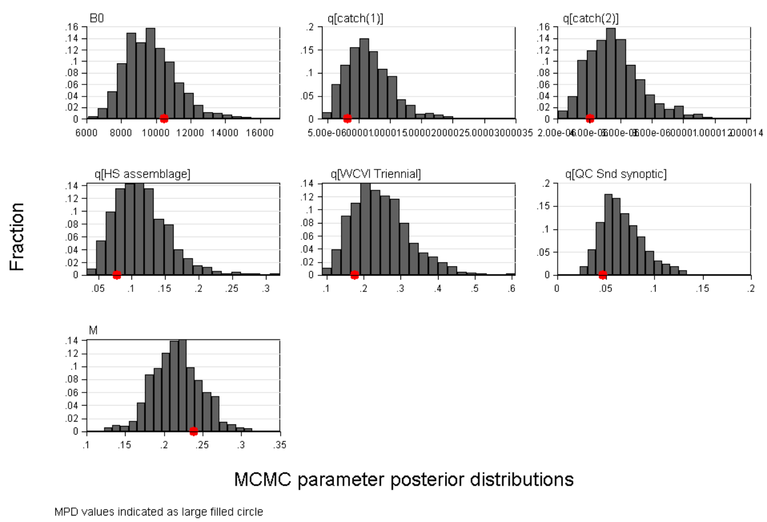
Figure D.34. MCMC marginal posterior distributions of the main model parameters based on 1,000 samples from the chains for eight of the model runs listed in Table D.1



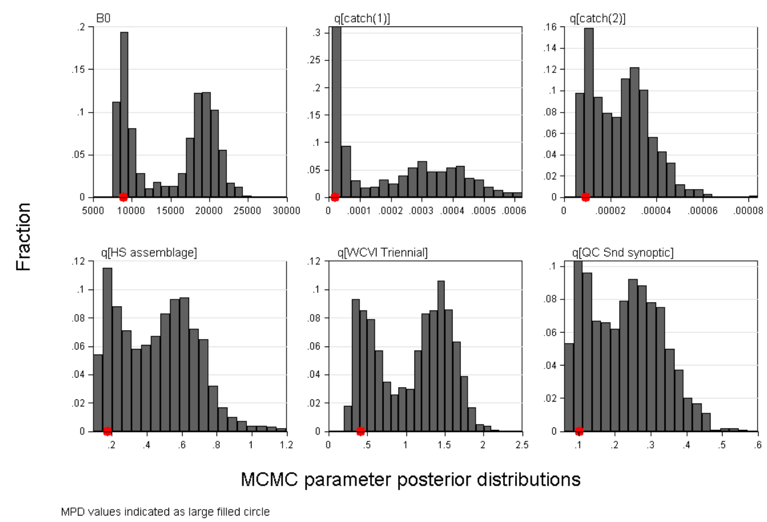
e) split CPUE series | $r = 7$ | wide rules | fix M



f) split CPUE series | $r = 6$ | CGRCS rules | est M



g) split CPUE series | $r = 6$ | CGRCS rules | est M



h) split CPUE series | $r = 6$ | wide rules | fix M

Figure D.34 (cont.). MCMC marginal posterior distributions of the main model parameters for eight of the model runs listed in Table D.1

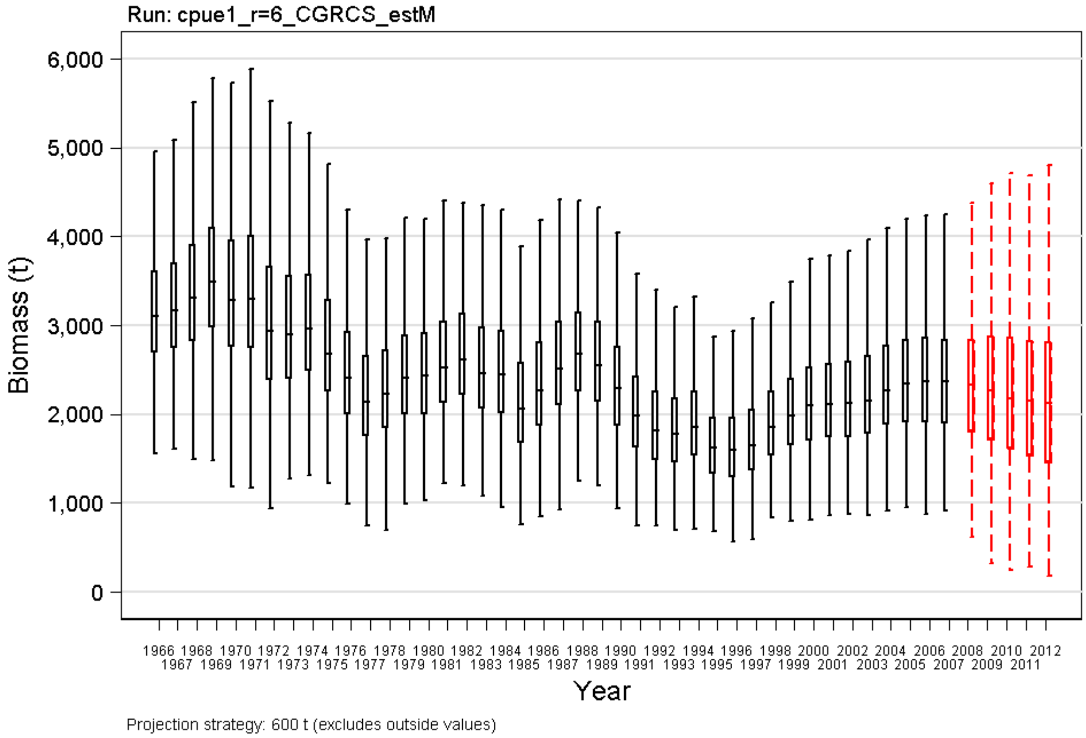


Figure D.35. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the single CPUE series | $r = 6$ | CGRCS rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

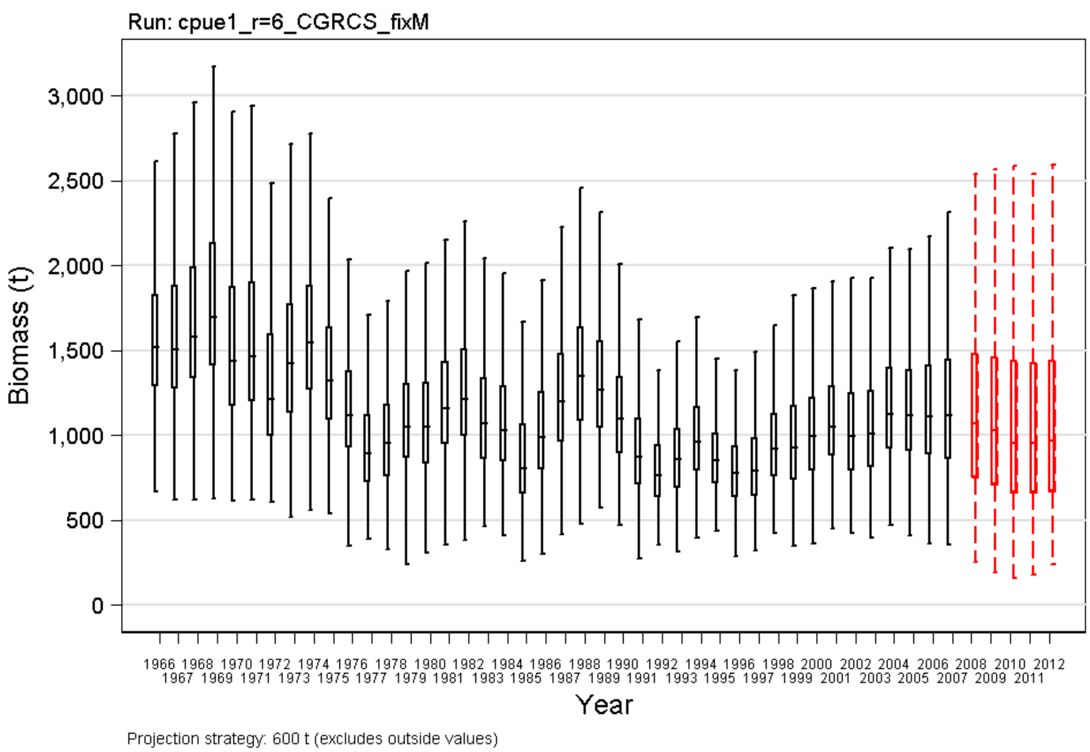


Figure D.36. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the single CPUE series | $r = 6$ | CGRCS rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

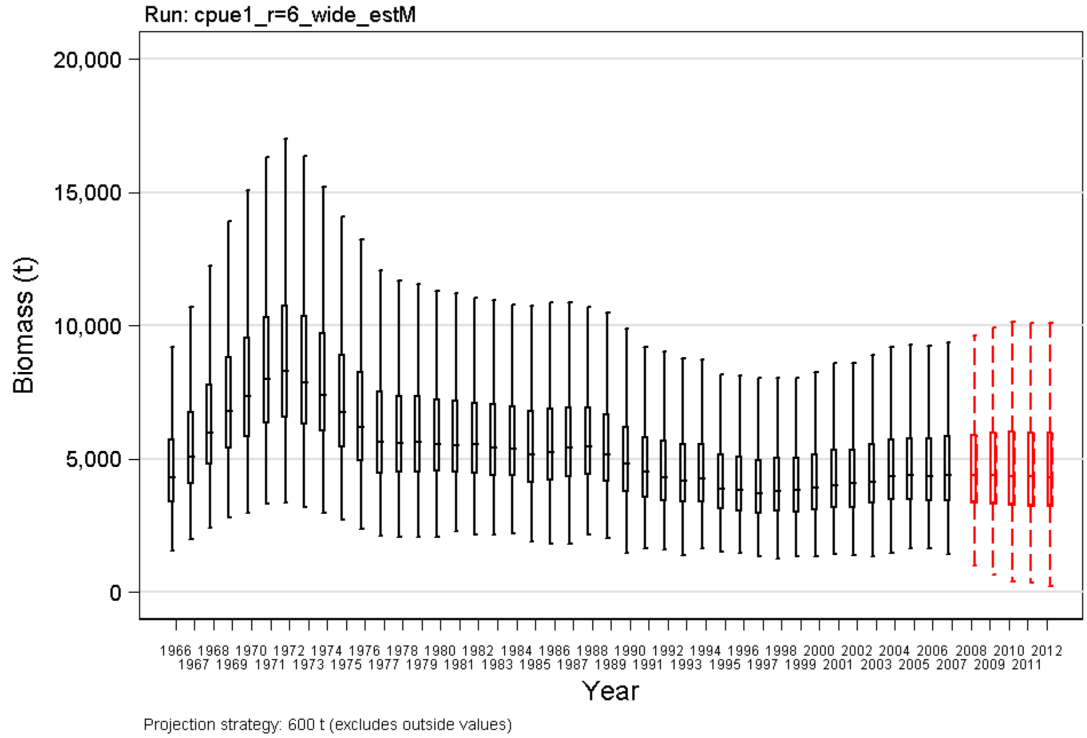


Figure D.37. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the single CPUE series | $r = 6$ | wide rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

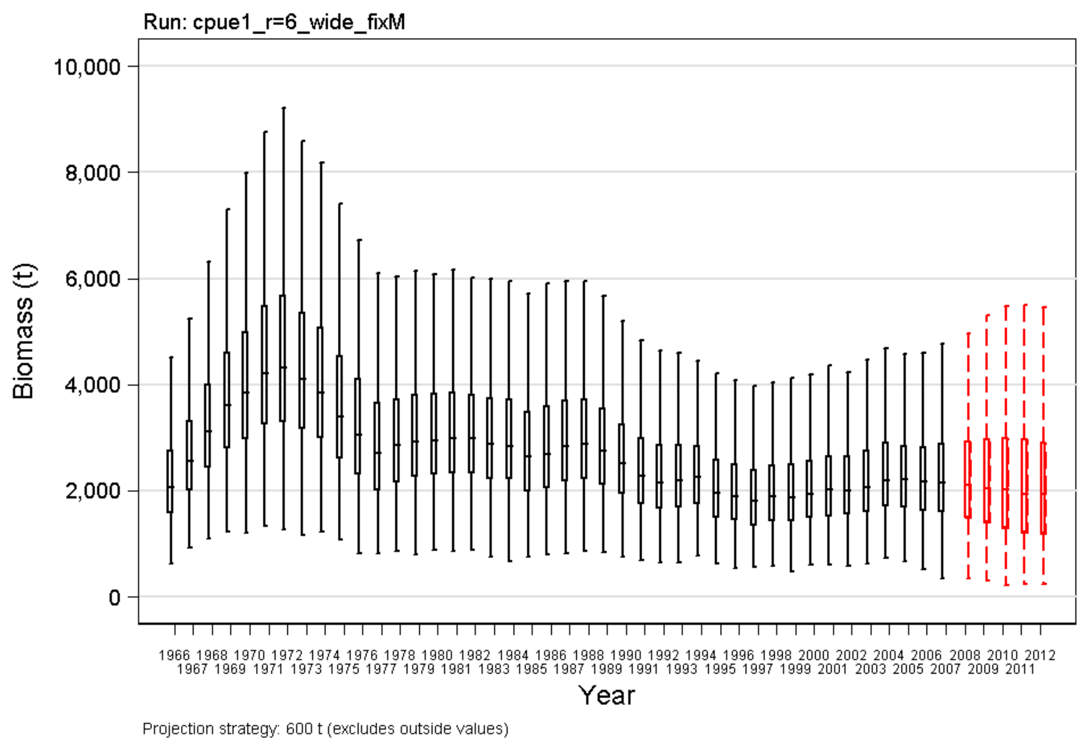


Figure D.38. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the single CPUE series | $r = 6$ | wide rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

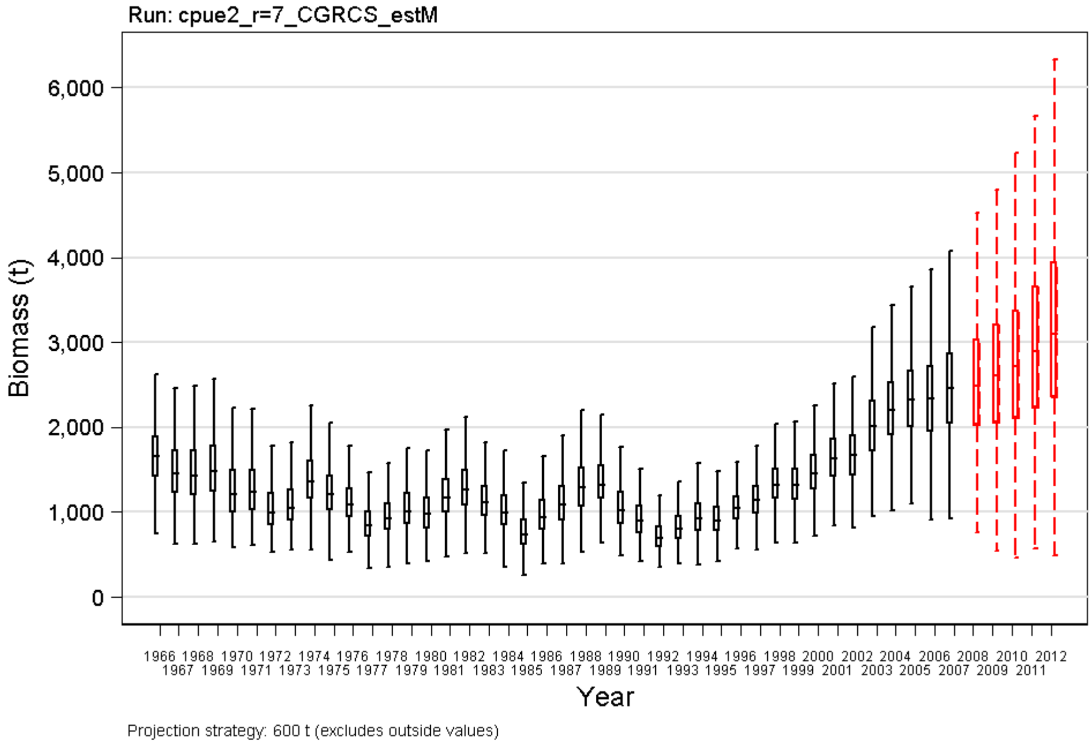


Figure D.39. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 7$ | CGRCS rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

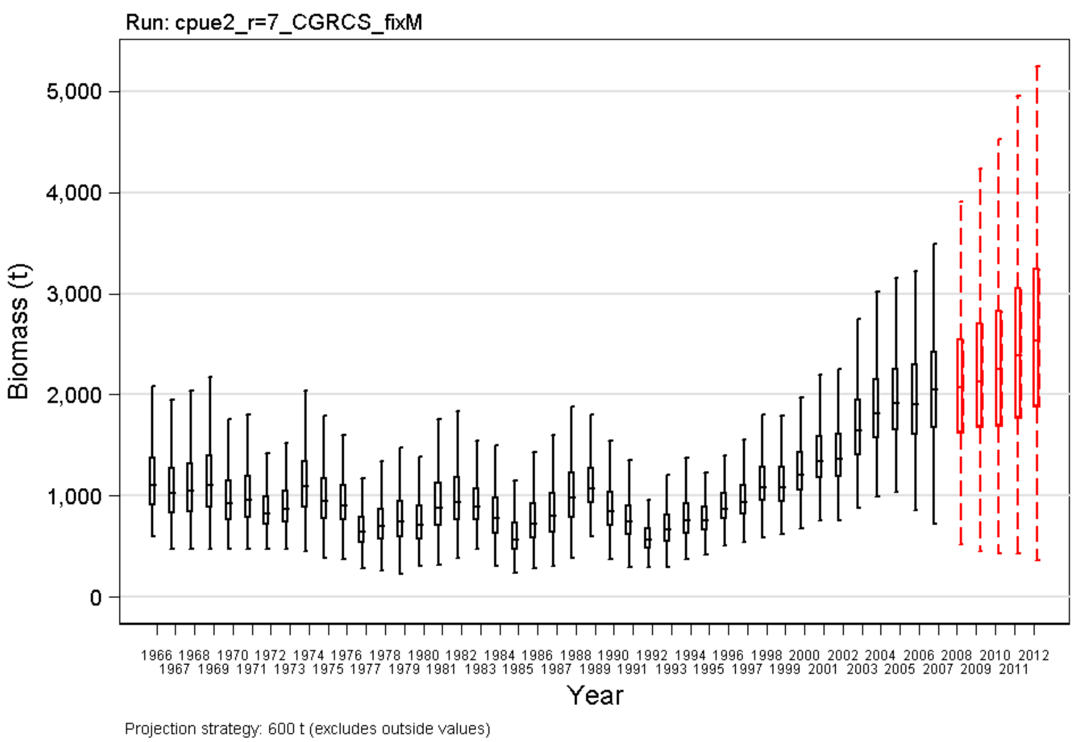


Figure D.40. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 7$ | CGRCS rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

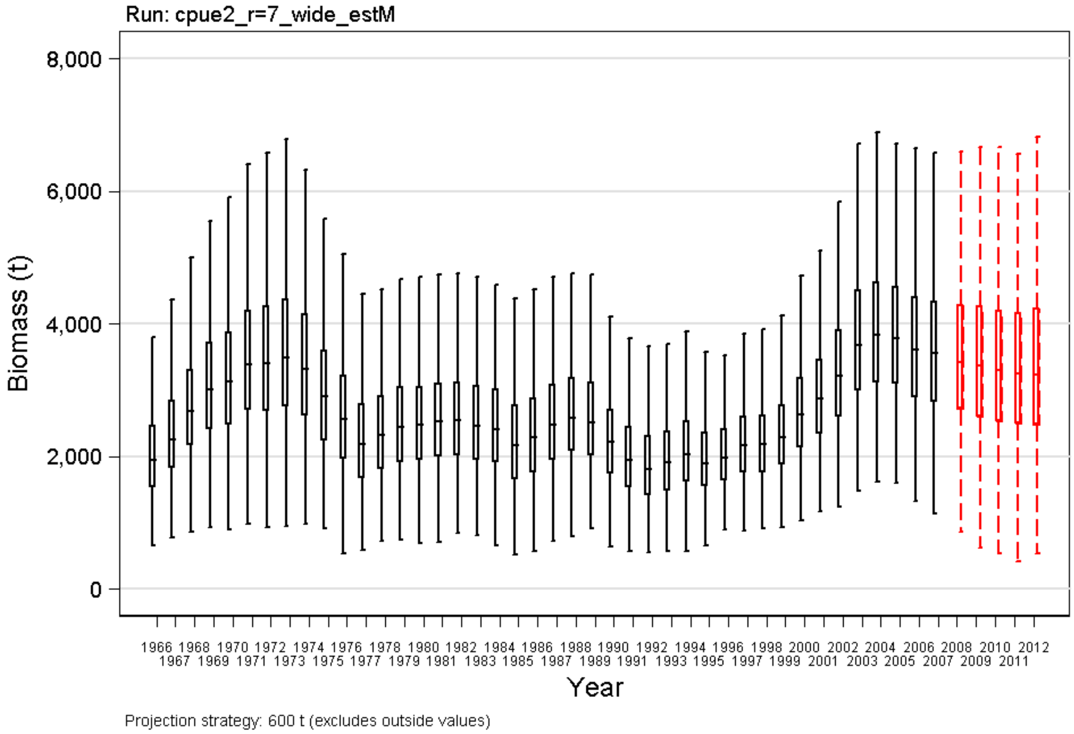


Figure D.41. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 7$ | wide rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

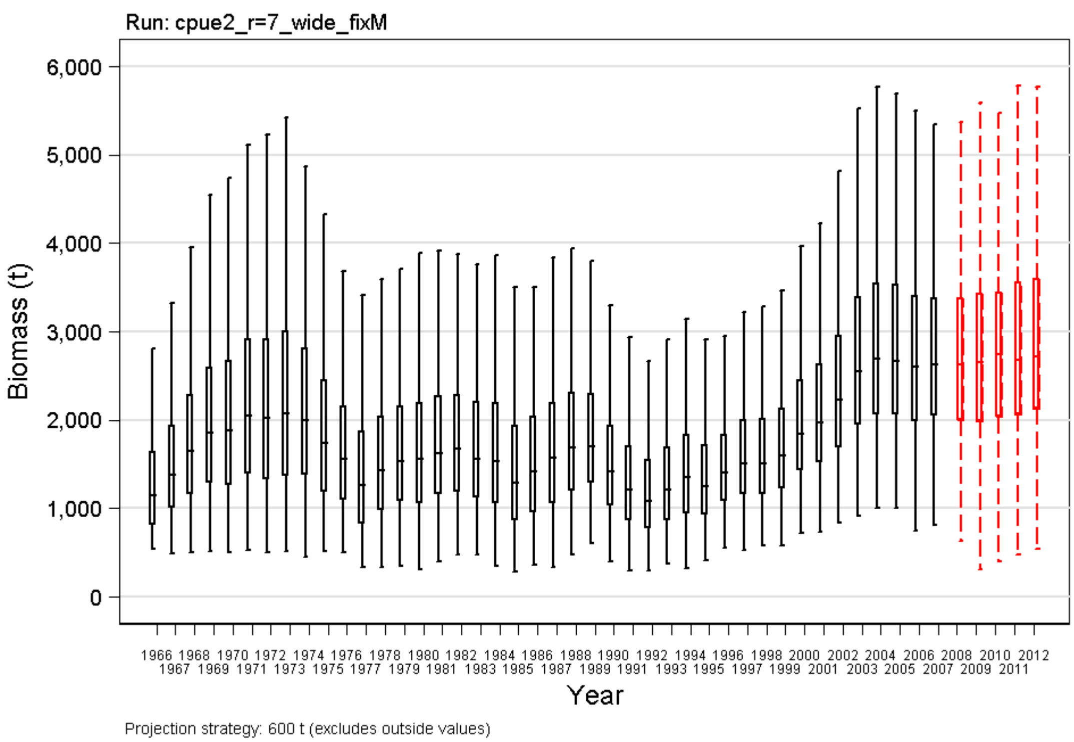


Figure D.42. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 7$ | wide rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

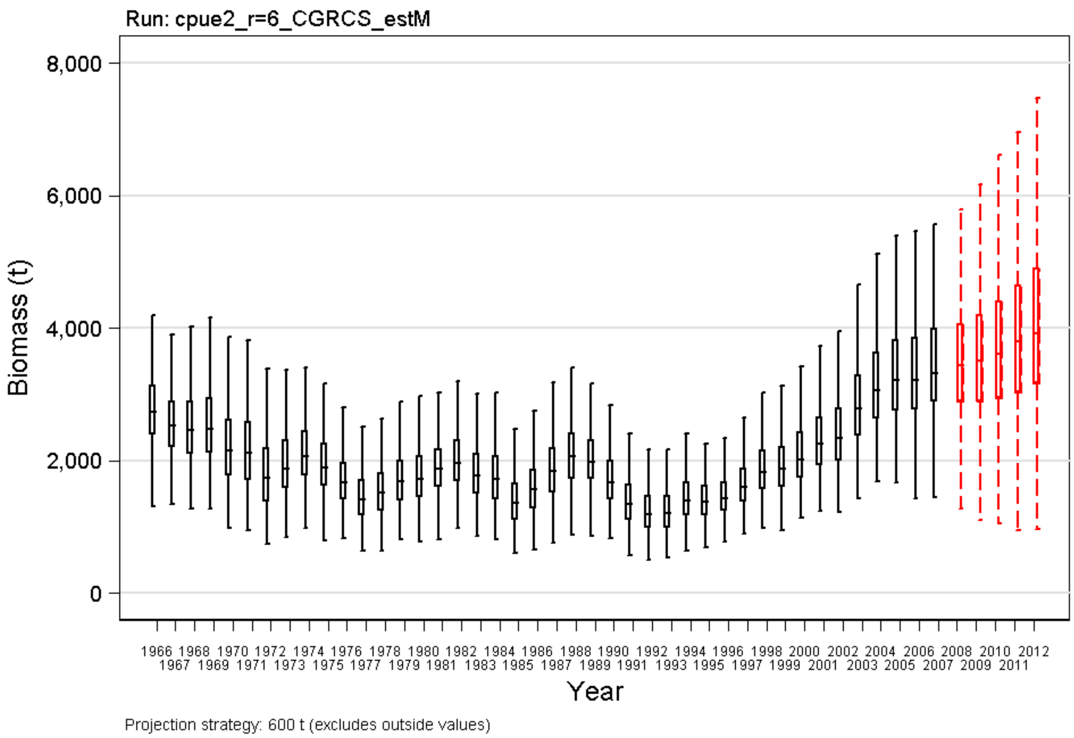


Figure D.43. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 6$ | CGRCS rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

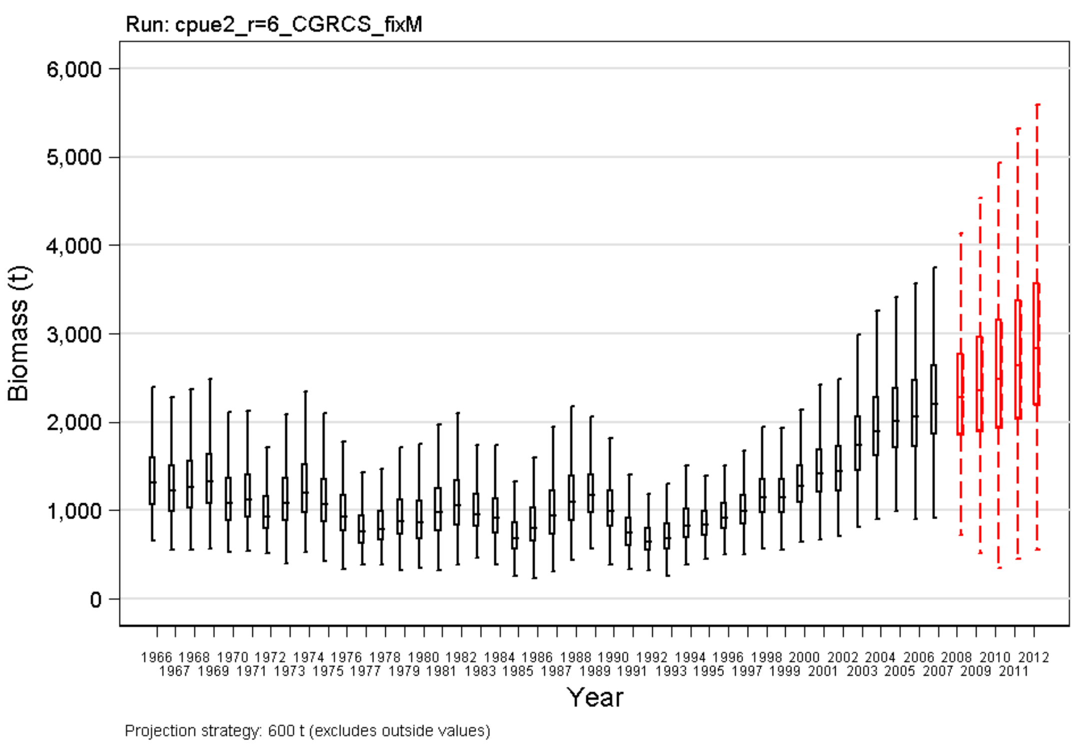


Figure D.44. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 6$ | CGRCS rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

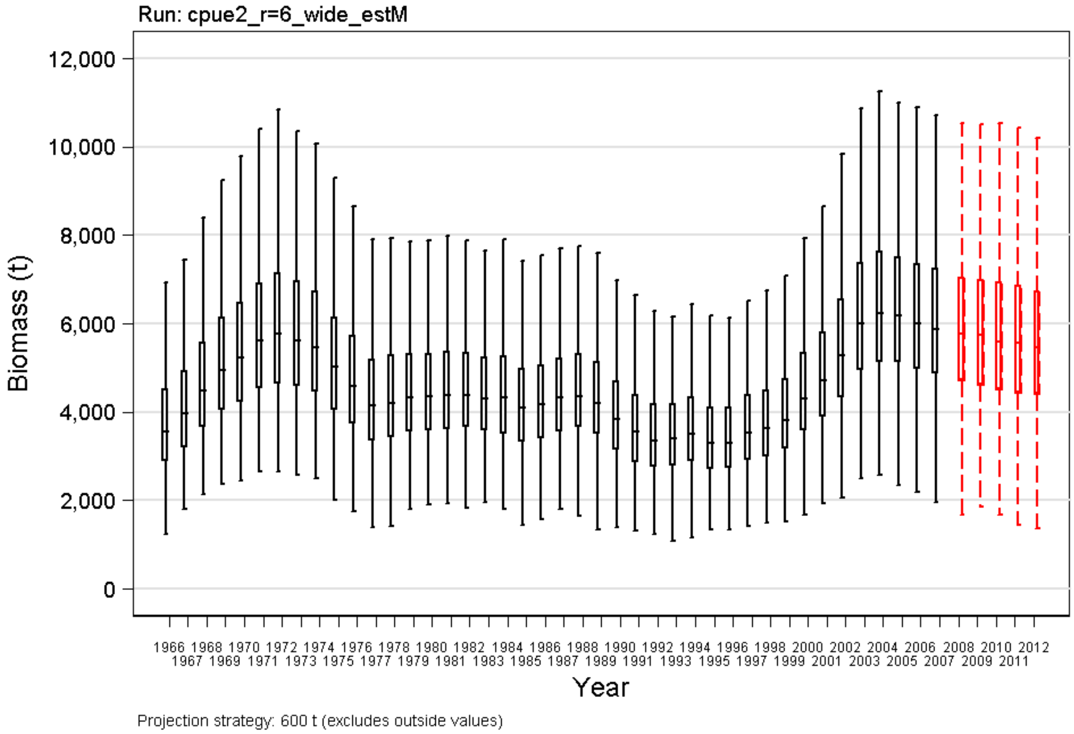


Figure D.45. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 6$ | wide rules | est M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

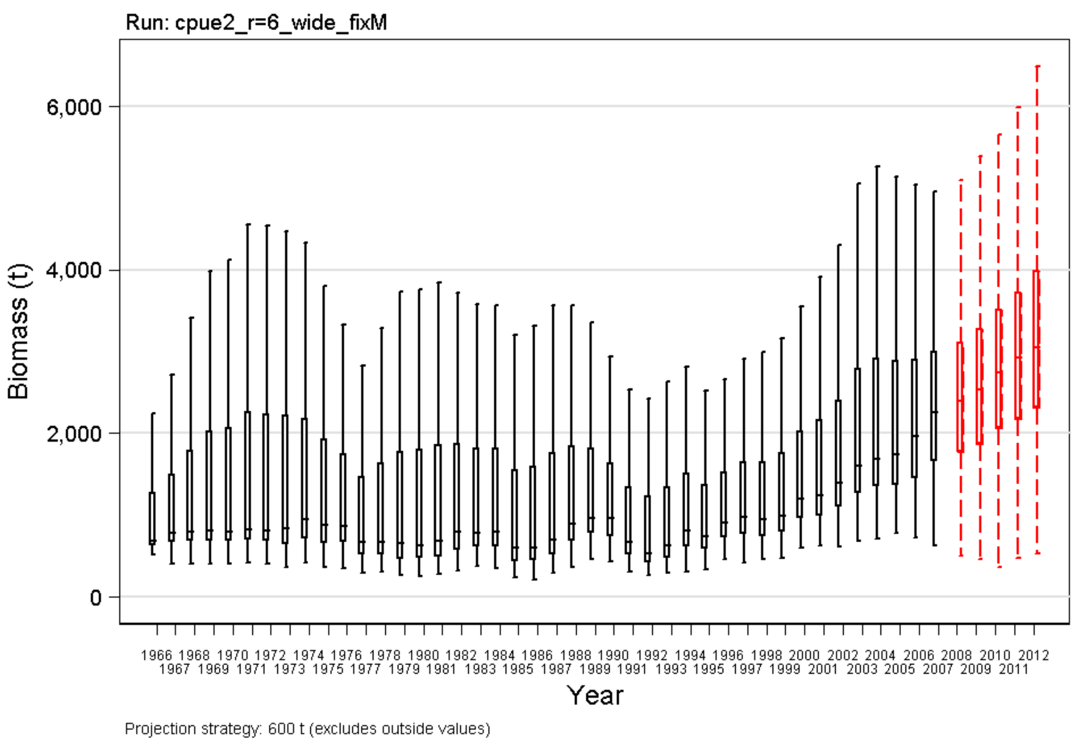


Figure D.46. Box plots of beginning year biomass distributions based on 1,000 samples from the chain for the split CPUE series | $r = 6$ | wide rules | fix M model. Biomass for 2008–2012 projected assuming landings of 600 t per year. Boxes describe the 25th and 75th percentiles and the whiskers extend ±1.5*(75th-25th percentiles).

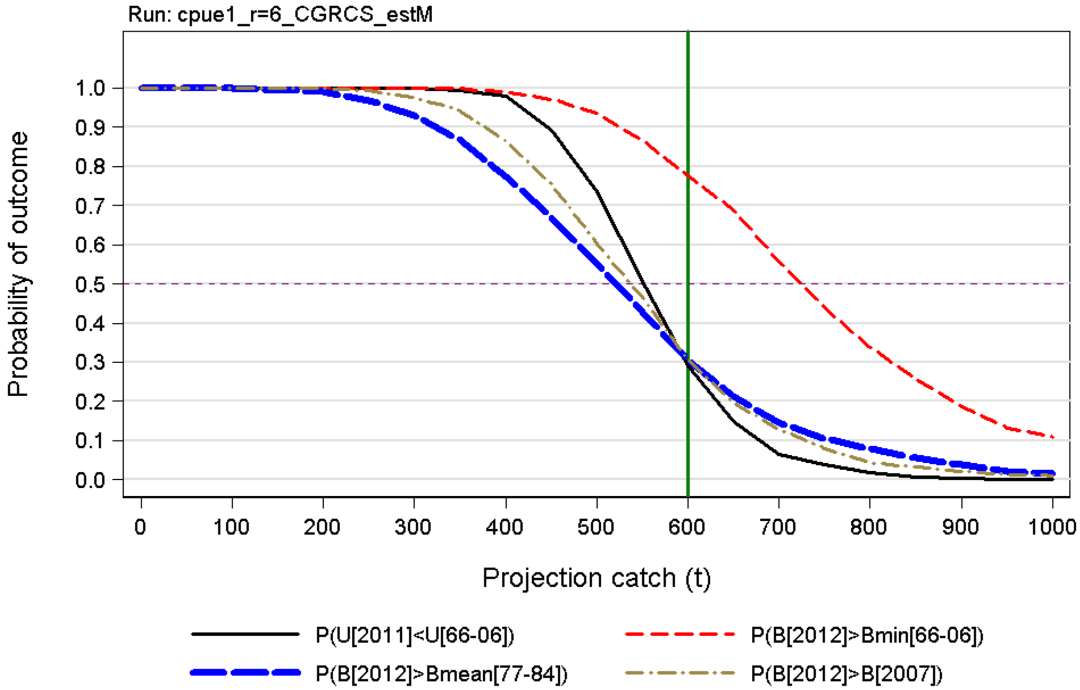


Figure D.47. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the single CPUE series | $r = 6$ | CGRCS rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

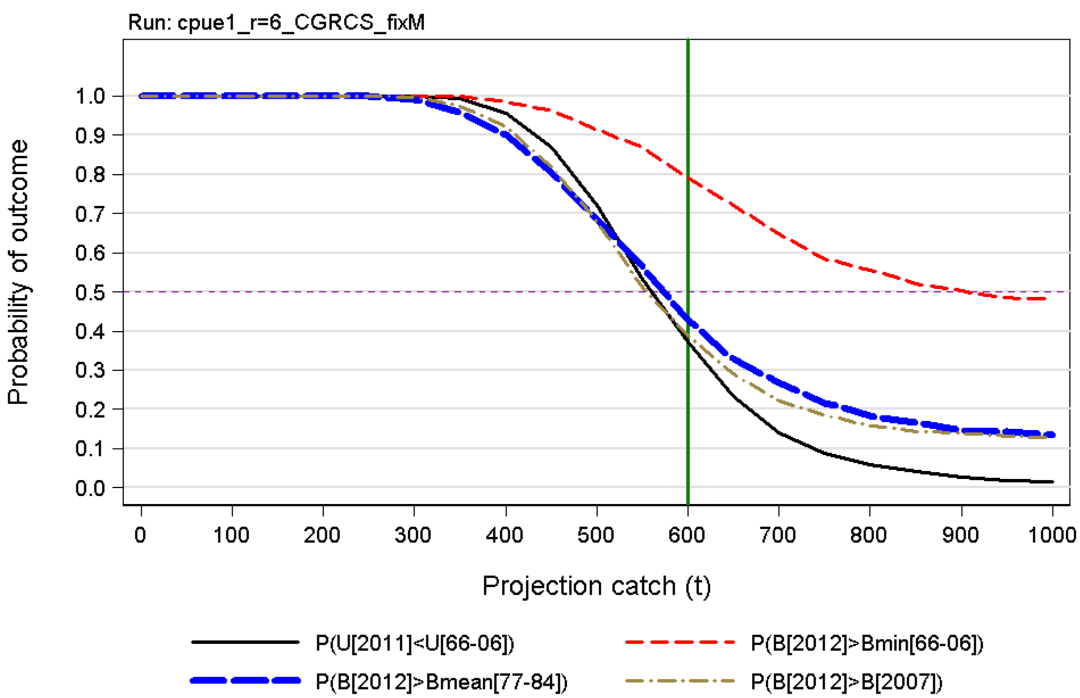


Figure D.48. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the single CPUE series | $r = 6$ | CGRCS rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

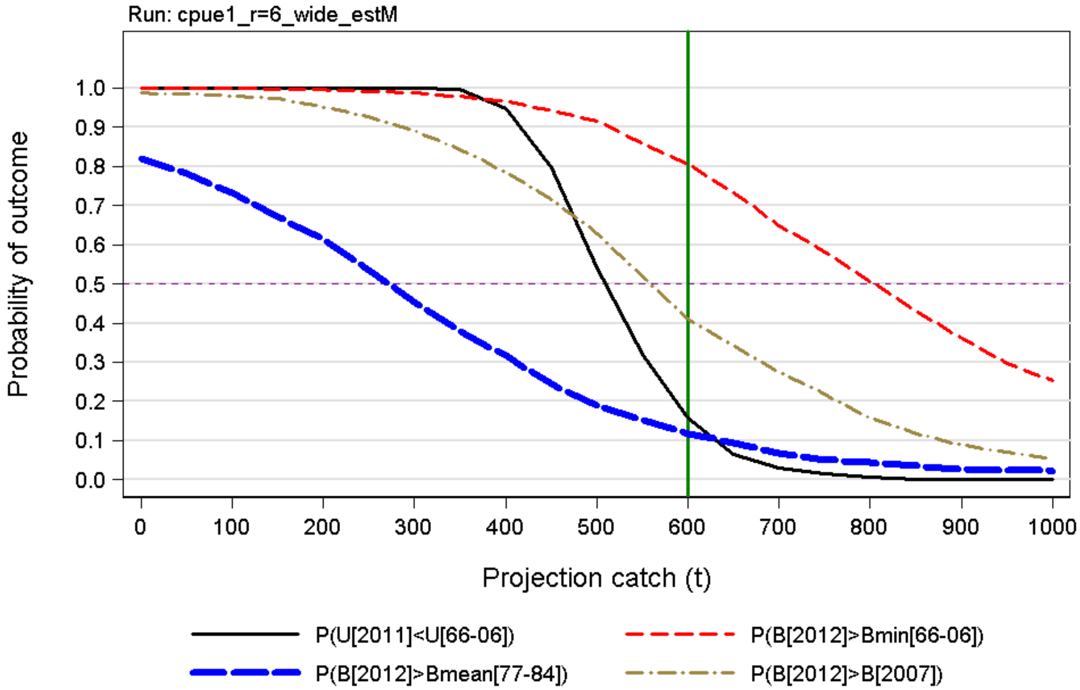


Figure D.49. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the single CPUE series | $r = 6$ | wide rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

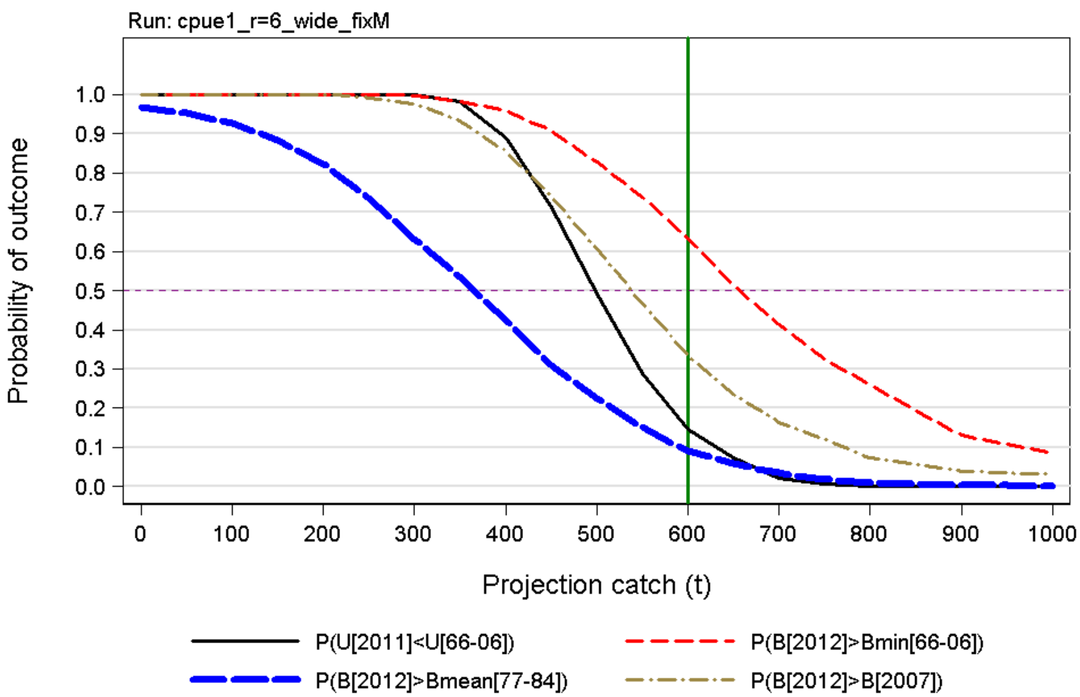


Figure D.50. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the single CPUE series | $r = 6$ | wide rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

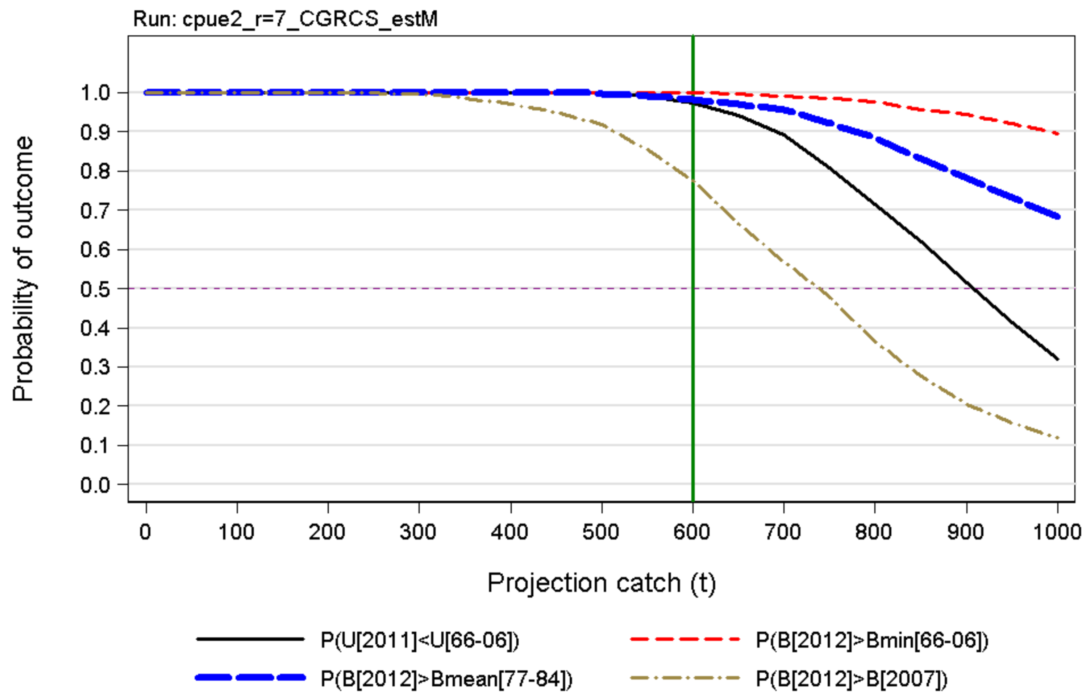


Figure D.51. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 7$ | CGRCS rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

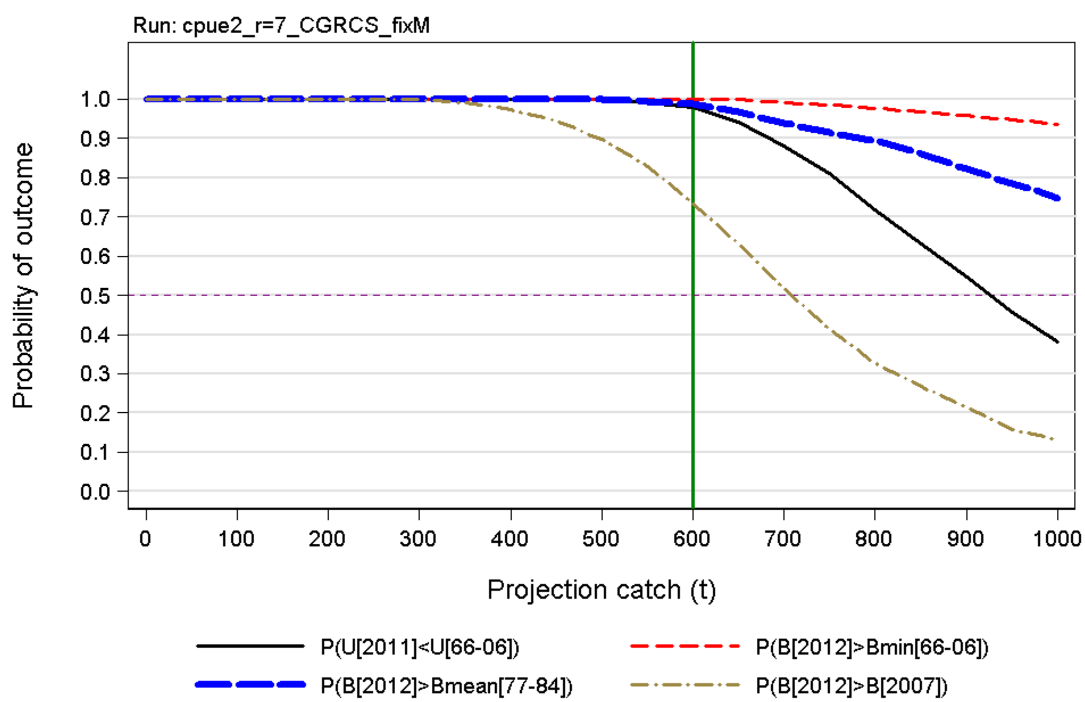


Figure D.52. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 7$ | CGRCS rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

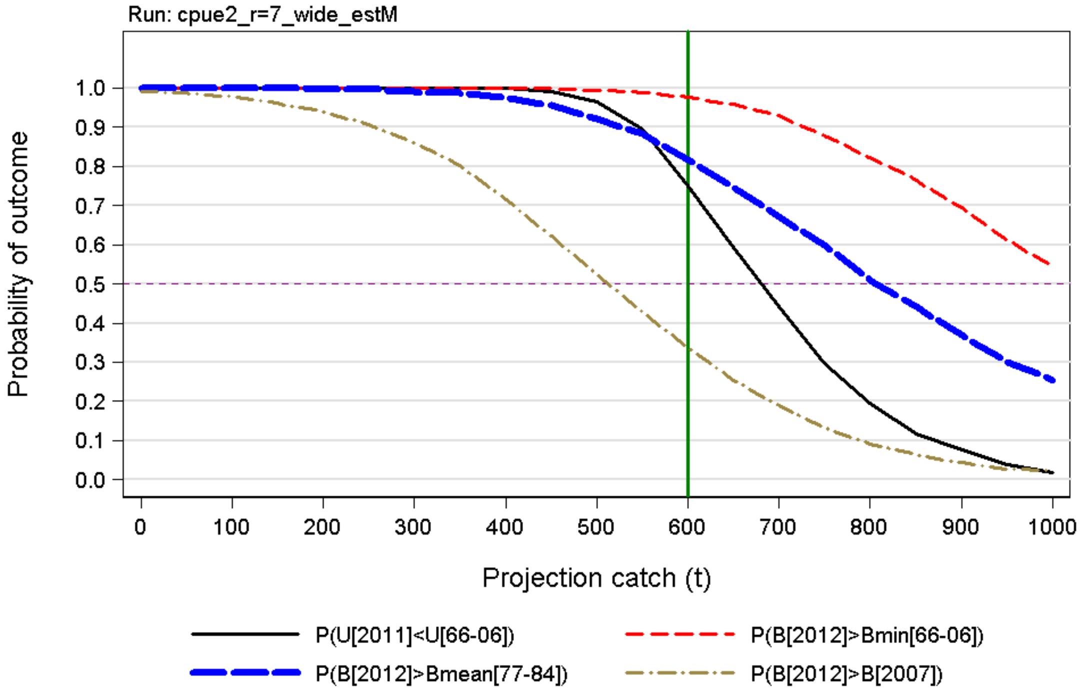


Figure D.53. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 7$ | wide rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

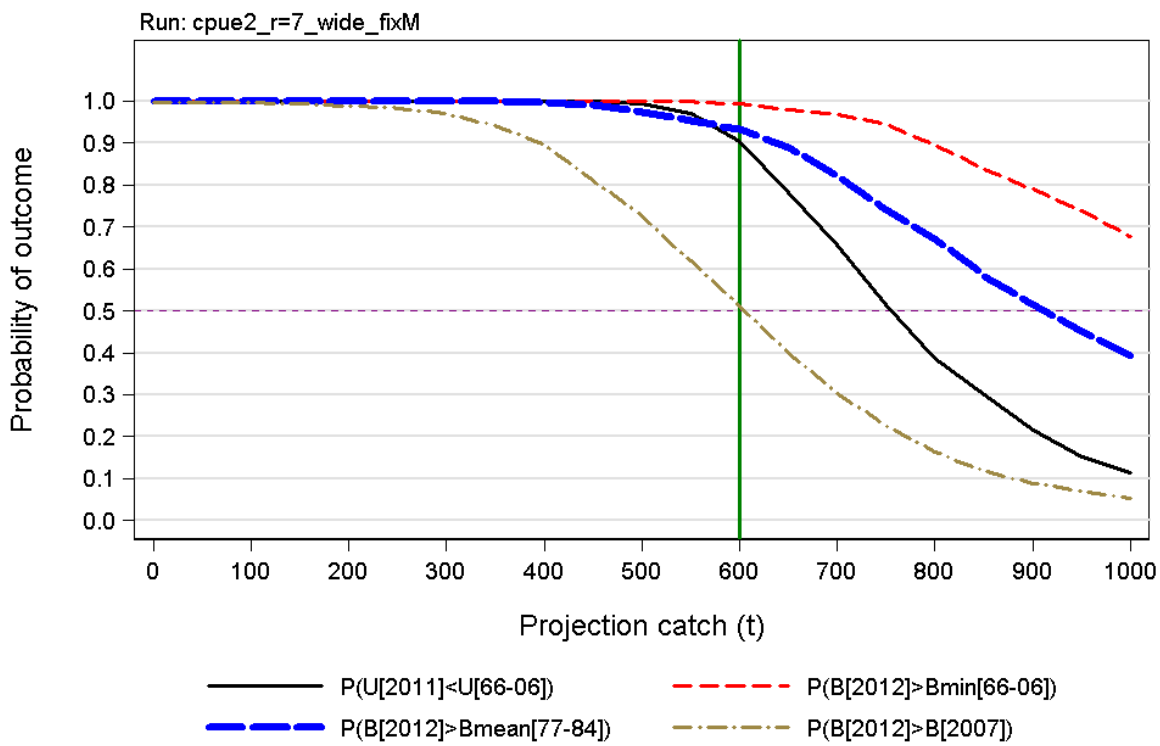


Figure D.54. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 7$ | wide rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

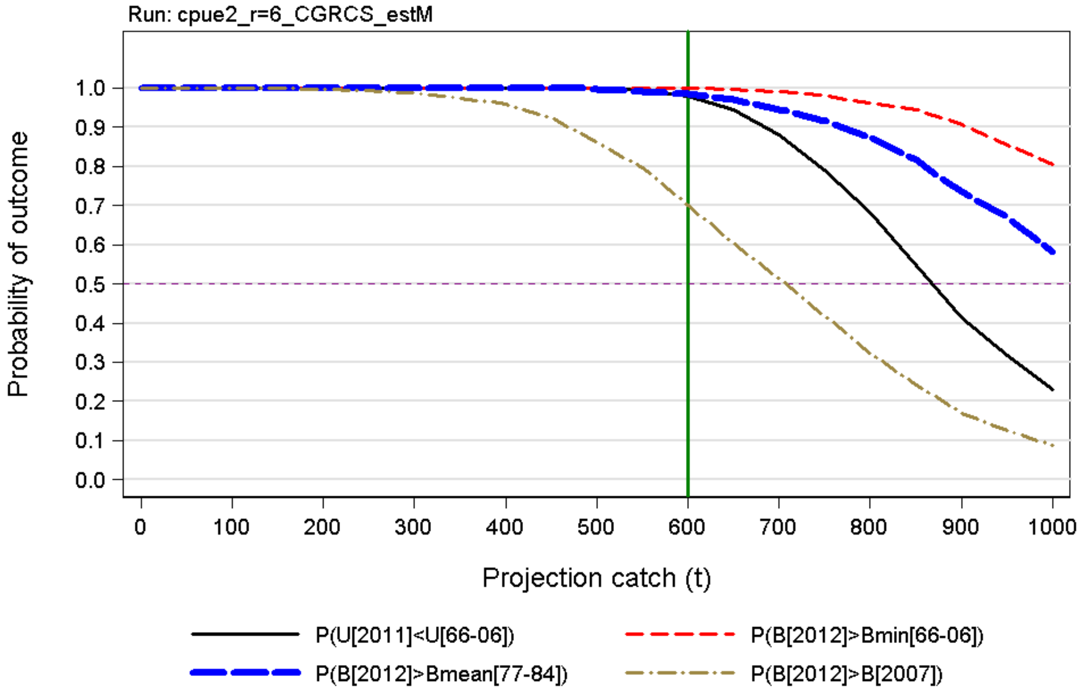


Figure D.55. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 6$ | CGRCS rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

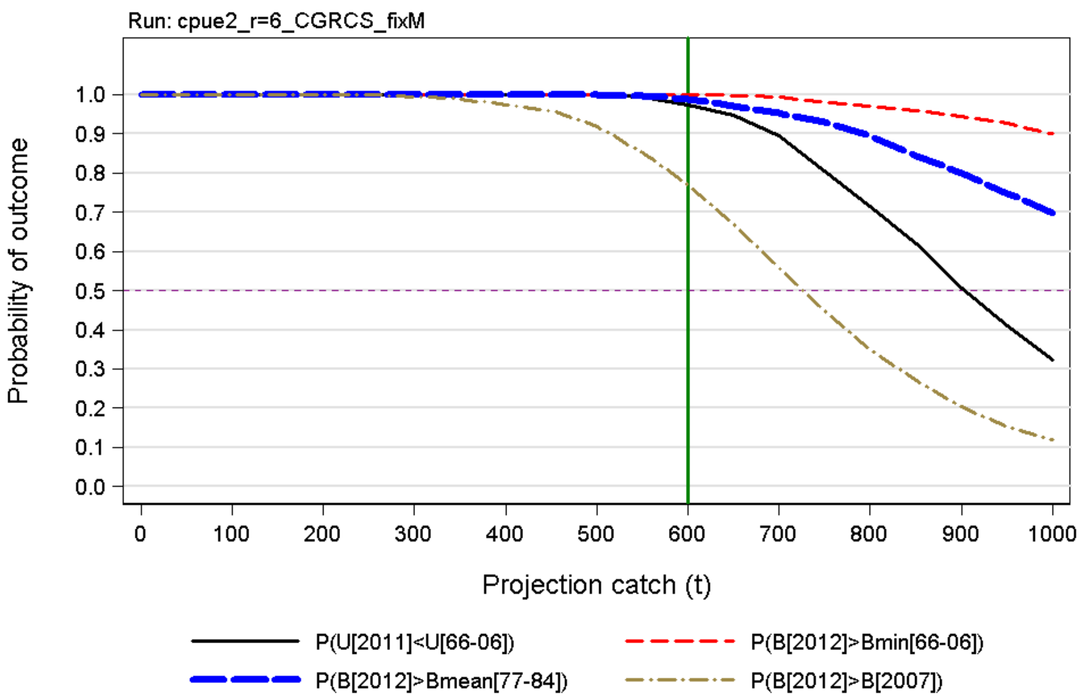


Figure D.56. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 6$ | CGRCS rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

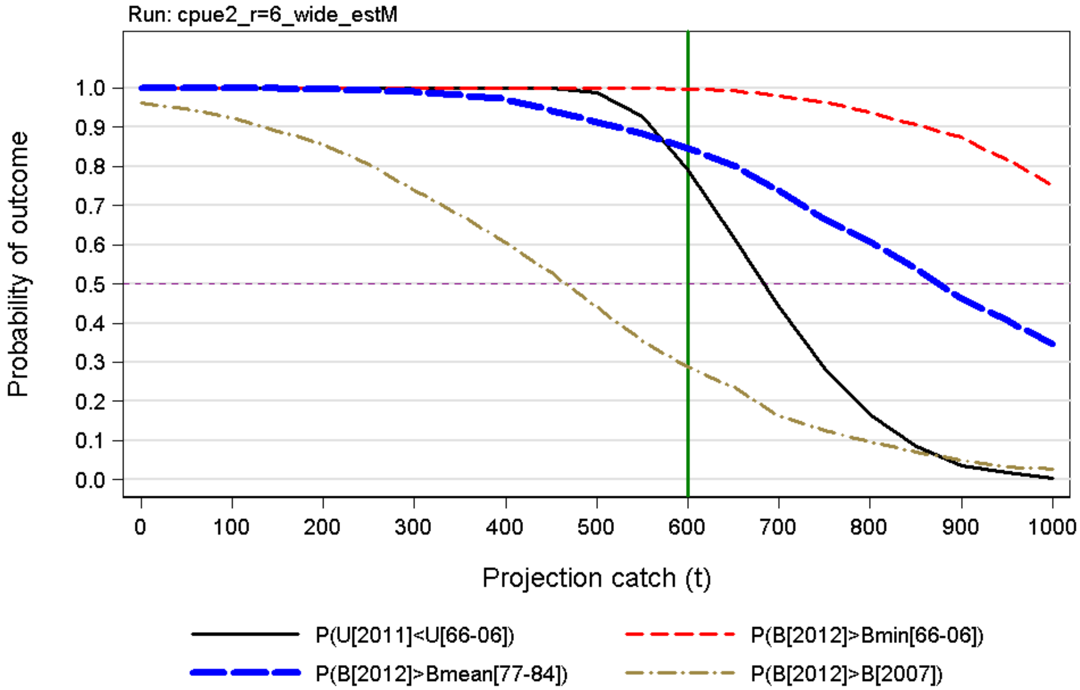


Figure D.57. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 6$ | wide rules | est M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

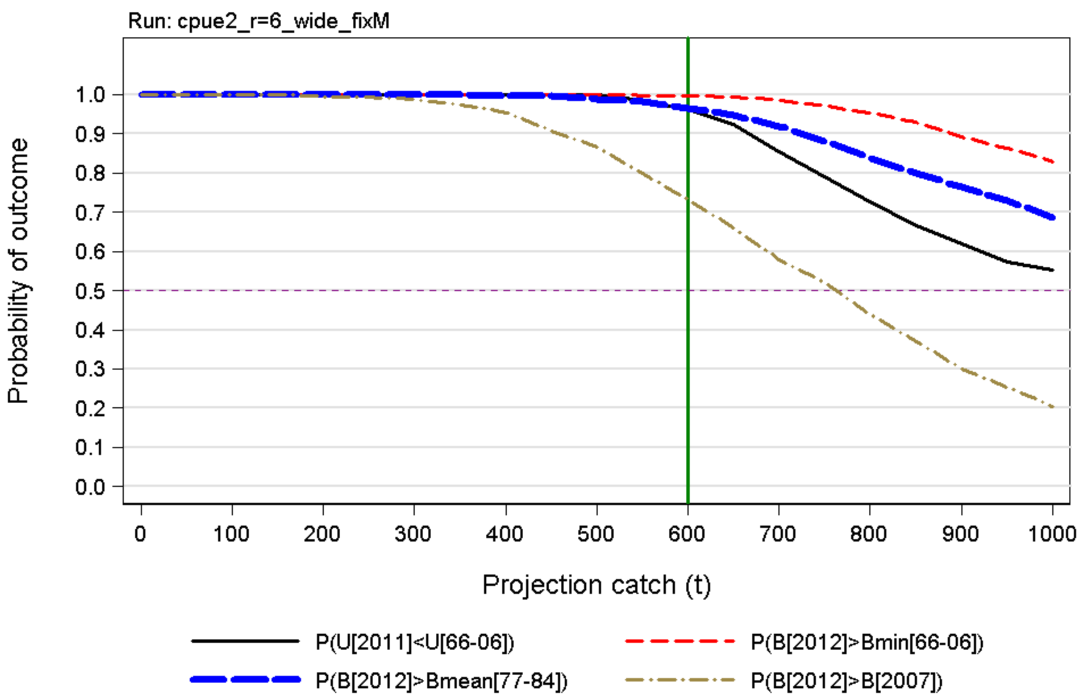


Figure D.58. Cumulative probabilities for four performance measures for the last year of five projection years over a range of constant catch strategies for the split CPUE series | $r = 6$ | wide rules | fix M model based on 1,000 samples from the chain. Vertical line marks the current Petrale sole TAC (600 t).

Appendix E. REVISIONS TO DECISION TABLES PRESENTED IN DFO (2007)

Introduction

A preliminary version of this assessment was presented to the Groundfish Subcommittee of Pacific Stock Assessment Review Committee in January 2007 (DFO 2007). This version of the of the stock assessment contained the error that is described in Appendix D. The stock assessment was accepted with revisions by the Subcommittee (DFO 2007) and the subsequent report contained a set of decision tables that were based on the assessment model which contained the error. The error has been corrected in this version of the Petrale sole assessment presented and this Appendix compares the output of the decision tables presented in DFO (2007) with those in Tables D.6 to D.11, comparing, for each run (Table E.1), the four performance indicators presented in Appendix D.

Results

The assessment presented in Appendix D is either the same or more optimistic (in many instances much more optimistic) than the assessment presented in early 2007 (DFO 2007). In nearly every comparison, the probability function derived from the assessment which has had the error fixed either lies on top of the equivalent 2007 function or lies to its right. This is true in the instances where the assessments where only a single CPUE series was assumed (Runs 1 to 4: Figure E.1 to Figure E.4) and even more so for the assessments where the CPUE series have been split between 1995 and 1996 (Runs 5 to 12: Figure E.5 to Figure E.12).

The four assessment runs (Figure E.1 to Figure E.4) which assumed a single CPUE series show relatively less divergence between the current and previous assessments than the runs with split CPUE series. While the current assessments tend to lie to the right of the original 2006 assessments, none of the shifts would likely lead to a change in management advice because the shifts were not sufficiently large to move the probability function into the upper righthand quadrant of plots. PSARC accepted Run "1" from the runs with a single CPUE series (`"CGRCS selection rules", `*r*`=6 and estimate `*M*: Figure E.1). This run shows no change relative to the 1977–84 reference period and small shifts to the right for the other three indicators.

The eight assessment runs (Runs 5 to 12: Figure E.5 to Figure E.12) which assumed a split CPUE series between 1995 and 1996 are now much more optimistic and the observed shifts could possibly lead to revised management advice. The PSARC preferred option from these runs with a split CPUE series was Run "9" (`"CGRCS selection rules", `*r*`=6 and estimate `*M*: Figure E.9). This run shows large shifts to the right for all four performance indicators, including a shift in the 50% probability of an increase from 2007 to 2012 from just over 550 t to around 800 t (lower right, Figure E.9). Similarly, the 50% probability of being over the 1977–84 reference period shifts from just under 800 t to near 1100 t (lower left, Figure E.9).

Run “12” (`split CPUE series, “wide selection rules”,` *r*=6 `and fix` *M*: Figure E.12) shows very large shifts to the right of the equivalent run presented in DFO (2007). This run should be discounted because it is likely that it is poorly converged (see Figure D.28) and consequently the results are not reliable.

Table E.1. List of runs investigated in the Petrale sole stock assessment [Appendix D and DFO (2007)] showing the run descriptors and the numbering scheme used in this Appendix. Refer to Appendix D for a more complete description of the assumptions which underlie each of these runs.

Run Number	**Run description**
Run 1	single CPUE series | $r = 6$ | CGRCS rules | est M
Run 2	single CPUE series | $r = 6$ | CGRCS rules | fix M
Run 3	single CPUE series | $r = 6$ | wide rules | est M
Run 4	single CPUE series | $r = 6$ | wide rules | fix M
Run 5	split CPUE series | $r = 7$ | CGRCS rules | est M
Run 6	split CPUE series | $r = 7$ | CGRCS rules | fix M
Run 7	split CPUE series | $r = 7$ | wide rules | est M
Run 8	split CPUE series | $r = 7$ | wide rules | fix M
Run 9	split CPUE series | $r = 6$ | CGRCS rules | est M
Run 10	split CPUE series | $r = 6$ | CGRCS rules | fix M
Run 11	split CPUE series | $r = 6$ | wide rules | est M
Run 12	split CPUE series | $r = 6$ | wide rules | fix M

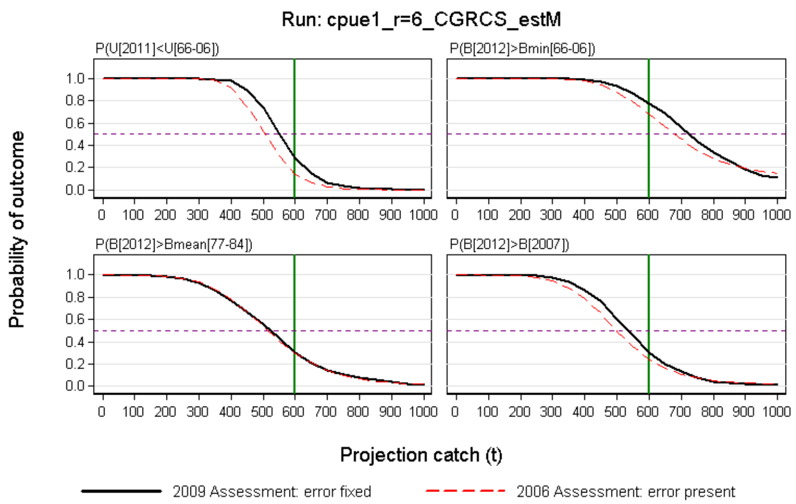


Figure E.1. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "1" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

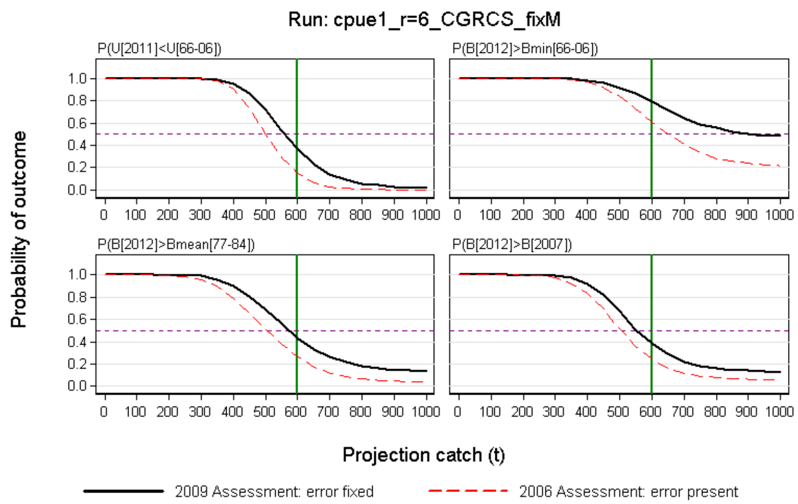


Figure E.2. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "2" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

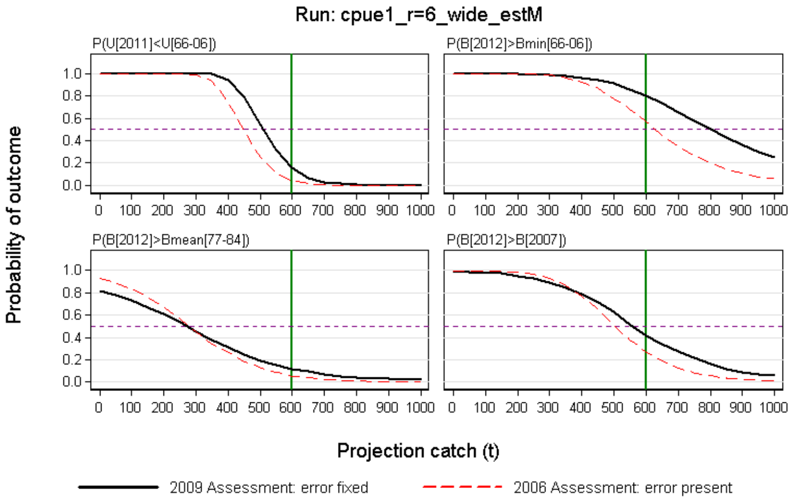


Figure E.3. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “3” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

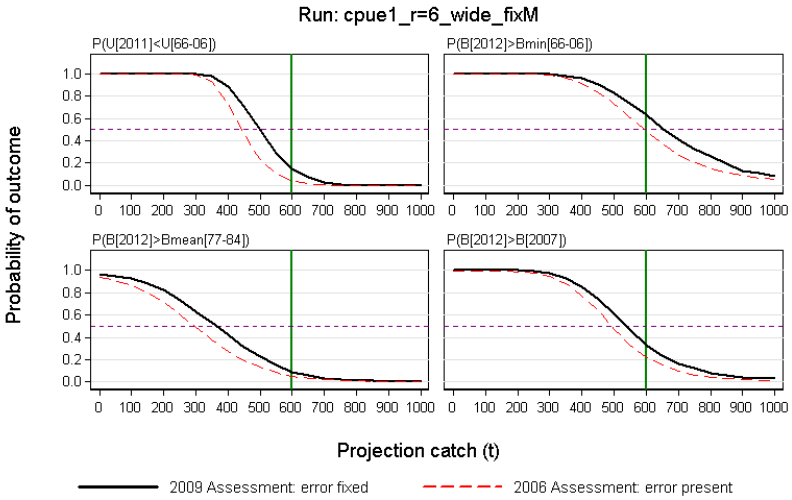
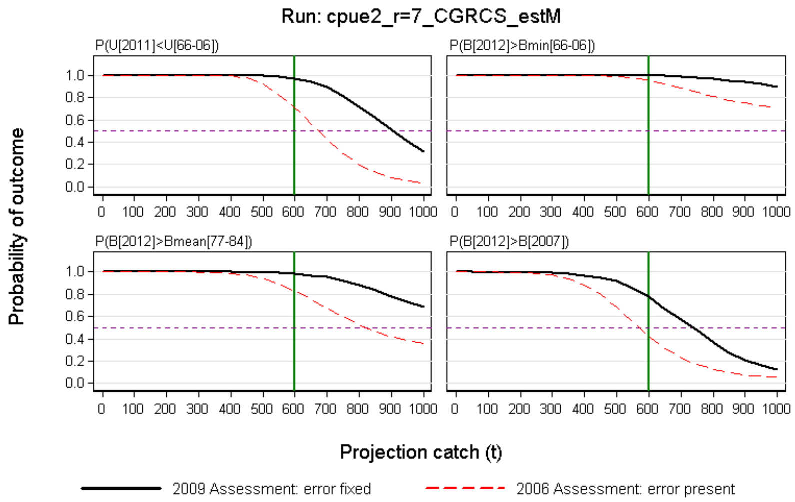


Figure E.4. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “4” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.



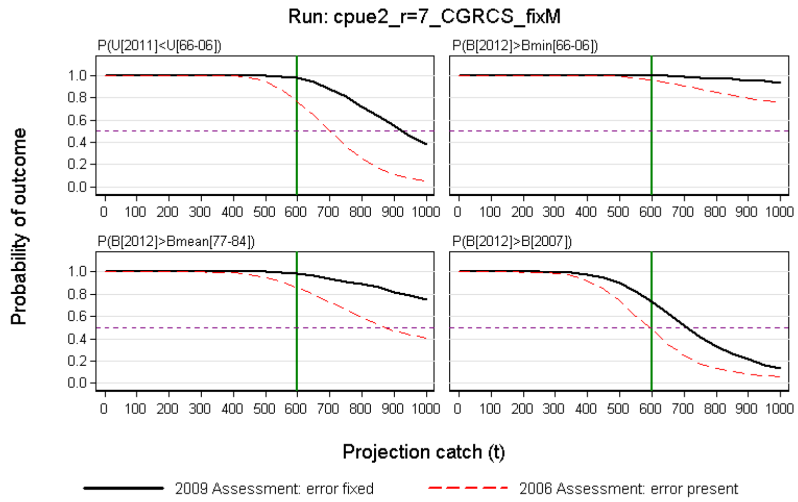


Figure E.5. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “5” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

Figure E.6. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “6” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

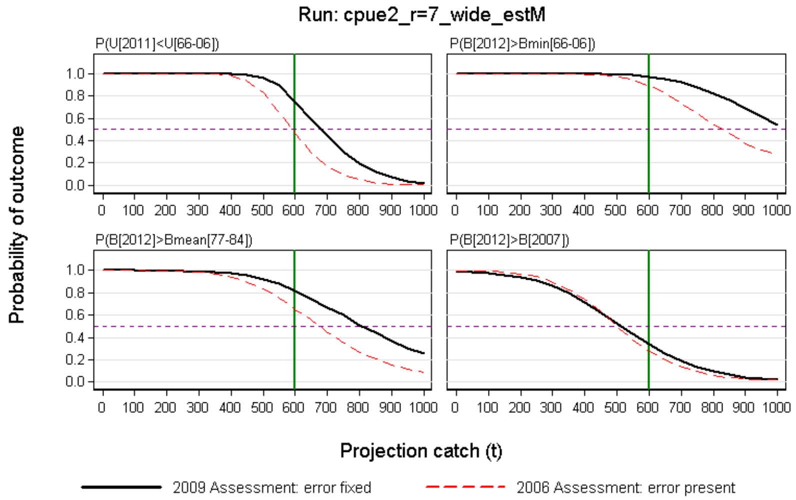


Figure E.7. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “7” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

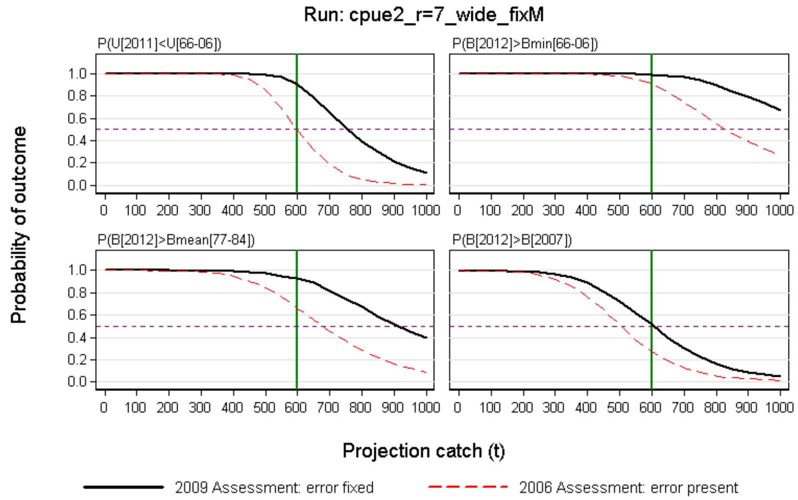
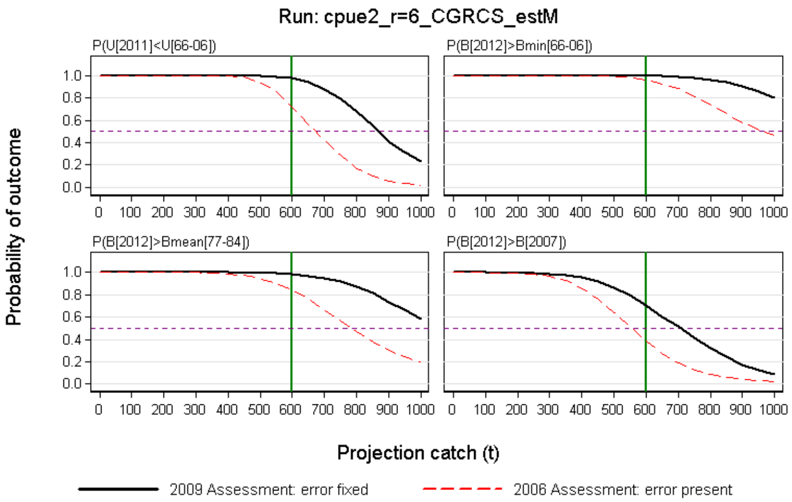


Figure E.8. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run “8” (Table E.1). Vertical line indicates the 2006 TAC of 600 t.



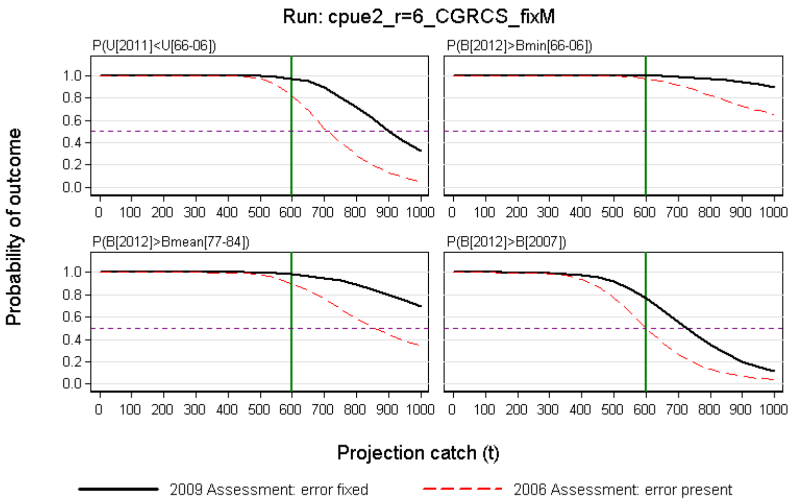


Figure E.9. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "9" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

Figure E.10. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "10" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

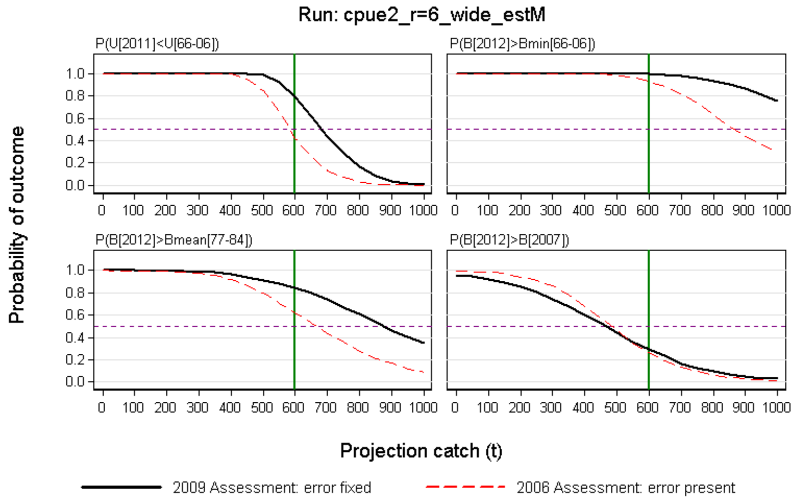


Figure E.11. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "11" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

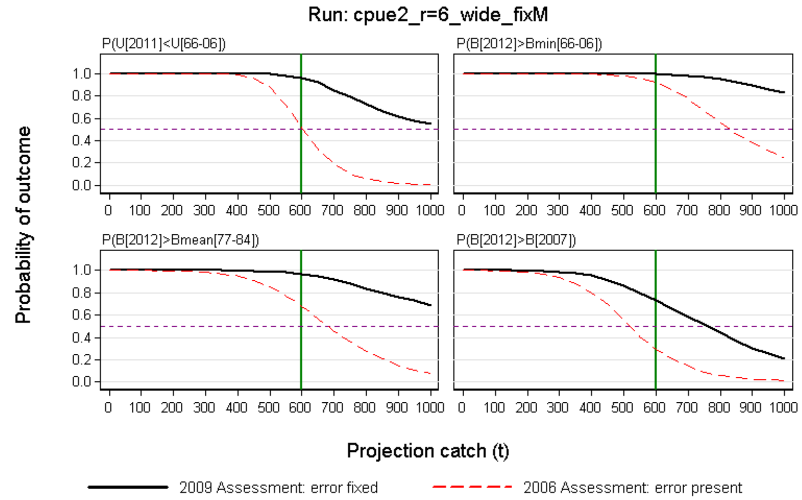


Figure E.12. Comparison between the 2009 and 2006 Petrale sole assessments of the trajectories from four performance indicators derived from Run "12" (Table E.1). Vertical line indicates the 2006 TAC of 600 t.

Appendix F. PSARC REQUEST FOR WORKING PAPER[1]

Date Submitted:

August 2006

Regional sector requesting advice:

(FAM, OHEB, Policy, Science)

Proposed PSARC Presentation Date:

Fall 2006 or January 2007

Subject of paper (title if developed):

Petrale sole Assessment

Science lead author:

Jeff Fargo / Paul Starr

Resource Management lead author:

Diana Trager

Rationale for request:

(What is the issue, what will it address, importance, etc.)

Over the past several years fishermen have reported changes in Petrale sole abundance in all management areas, to the point where species avoidance has become difficult and may limit industry's ability to maximize harvest opportunities for other groundfish species commonly caught with Petrale sole.

Objective of working paper including assessment of environment/climate impacts:

(To be developed by FAM, OHEB, Policy, Science)

To provide an assessment of the Petrale sole population in all the waters off Vancouver Island, Queen Charlotte Sound and Hecate Strait (Areas 3C, 3D, 5A, 5B, 5C and 5D). These assessments will provide estimates of stock status relative to an agreed target reference point as well as recommendations for levels of removals which will allow this population to reach the target. The assessment should include all available information, including surveys, biological sampling, catch records, logbooks, observer reports and fishing practices for Petrale sole. This assessment will provide the basis for the management of the 2007/08 fishery for Petrale sole in the designated management areas.

Question(s) to be addressed in the working paper:

(To be developed by initiator)

1. What is the status of the Petrale sole population in 3CD5ABCD relative to an agreed target reference point?

2. What level of catch in 2007/08 and beyond will allow this populations to reach this target reference point in XX years?

[1] Science – append approved RFWP to working paper.
Sector initiator – send approved RFWP to PSARC after sign off, and before significant work begins on the paper.

Stakeholders affected:

Commercial groundfish harvesters

How advice may impact the development of a fishing/recovery plan:

The advice will be used in the development of annual integrated fishery management plans to ensure sustainable harvest levels on a stock/area specific basis.

Timing issues related to when advice is necessary:

Advice required by January 2007 in time for inclusion is the development of the 2007/08 integrated groundfish management plans.

Initiating sector approval:

Regional Director/Designated Authority: ______________________

Date:_____________________