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Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index

Tendances pour les stocks de morue (*Gadus morhua*) de la sous-division 3Ps de Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) selon un modèle de mortalité totale séparable et l'indice des relevés par navire scientifique du MPO

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ABSTRACT

We describe a cohort model based on a separable total mortality assumption that can be fitted using only survey information. It is very similar to the SURBA model (see Needle 2008; Mesnil et al. 2009). The model produces relative estimates of stock size but absolute estimates of total mortality. We apply the model to the DFO RV survey age-based indices of abundance for 3Ps cod. This application was presented at the 2009 winter cod ZAP using data for 1983 to 2008, and the Fall 2009 3Ps RAP using data for 1983-2009. Both analyses indicated that there were substantial risks that SSB in the last assessment year (either 2008 for the ZAP or 2009 for the RAP) was below the limit reference point for 3Ps cod.

RÉSUMÉ

Nous décrivons un modèle de cohorte reposant sur une hypothèse de mortalité totale séparable qui peut être ajusté selon les renseignements fournis par le relevé. Il est très semblable au modèle SURBA (voir Needle 2008, Mesnil et coll. 2009). Le modèle donne des estimations relatives pour les stocks, mais des estimations absolues pour la mortalité totale. Nous appliquons le modèle aux indices d'abondance de morue selon l'âge de la zone 3Ps dérivés des relevés par navire scientifique du MPO. Cette application a été présentée pour le PCSZ sur la morue de l'hiver 2009 en utilisant les données pour la période entre 1983 et 2008 et pour le PCR de la zone 3Ps de l'automne 2009 en utilisant les données pour la période entre 1983 et 2009. Les deux analyses indiquaient qu'il y a des risques sérieux que la BSR de la dernière année d'évaluation (soit 2008 pour la PCSZ et 2009 pour le PCR) soit inférieure au point de référence limite pour la morue de la zone 3Ps.

INTRODUCTION

No analytic model (i.e., ADAPT, etc.) has been used recently in the stock assessment of 3Ps cod, primarily because of concerns about stock structure, the accuracy of landings statistics, variability in the DFO Spring RV index, and inconsistencies between offshore trawl surveys indices and inshore sentinel fixed gear catch rate indices. However, some inferences about total mortality rates and relative year class strength have been made recently (Brattey et al. 2008) for the offshore stock component that is measured by the DFO and industry (e.g., GEAC) offshore trawl surveys. This offshore component is thought to comprise most of the 3Ps cod stock.

The DFO RV index for 3Ps cod has been historically quite variable, with interannual variations in survey mean numbers per tow that far exceed what could occur in the stock as a whole. The sources of variability are not well understood; however, one likely source is inter-annual variations in the fraction of the stock available to the survey. The RV survey in 3Ps does not cover all of the range of 3Ps cod, and if the fraction of the stock in the survey area and at the time of the survey varies from year to year then this will add extra variability to the survey index of cod abundance. 3Ps cod are highly migratory, moving seasonally in the offshore, perhaps in response to water temperatures, and moving to the inshore in the spring and summer to spawn and feed (DFO 2009).

Stock assessments based only on research vessel surveys or other fishery independent sources of information have become more common recently, partly because more stringent quota restrictions and other management measures have lead to less reliable landing statistics in Europe and elsewhere. The SURBA stock assessment model (Needle, 2008; Mesnil et al. 2009) provides a more comprehensive approach to estimating relative year class strength and total mortality rates from surveys than the above approaches used for 3Ps cod. SURBA is based on the separable mortality model developed by Cook (1997). SURBA is a simple cohort model in which annual age-specific total mortality rates are decomposed into age and year effects. These mortality rates can be cumulated along a cohort and applied to estimates of recruitment to provide age-based estimates of stock size. However, most surveys only provide relative measures of stock size, and consequently SURBA can only provide relative estimates of stock size. However, SURBA can provide absolute estimates of total mortality rates.

In this article we present a SAS (Cary, NC) implementation of the basic SURBA model. The advantage of the SAS implementation is that it provides us with greater flexability in model settings compared to the basic SURBA package. This approach is applied to the spring DFO RV survey index for 3Ps cod, with the survey strata extended to include inshore strata to minimize variability due to changes in distribution. We produce estimates of relative stock size, absolute total mortality rates, and stock status relative to the limit reference point for this stock which is spawning stock biomass (SSB) in 1994.

METHODS

SEPARABLE TOTAL MORTALITY (Z) MODEL

We use the standard population dynamics model:

$$N_{a,y} = N_{a-1,y-1}\exp(-Z_{a-1,y-1}). \tag{1}$$

Without loss of generality we assume $a=1,\ldots,A$ and $y=1,\ldots,Y$. In SURBA Z_{ay} is decomposed into age and year effects. We assume

$$\log(Z_{ay}) = s_a + f_y, \tag{2}$$

which is commonly referred to as a separable model. In any event, if the Z_{ay} 's are know for all ages in a cohort then Eq. 1 can be used to derive N_{ay} 's given the size of the cohort at age 1 (i.e., recruitment, $N_{1,y-a+1}$),

$$N_{a,y} = N_{1,y-a+1}\exp(-\sum_{i=1}^{a-1} Z_{i,y-a+i}). \tag{3}$$

The parameters to estimate in a SURBA model are the abundances-at-age in year 1 (N_{a1}, $a=1,\ldots,A$), the recruitments in other years (N_{1y}, $y=2,\ldots,Y$), and the age effects (s_a, $a=1,\ldots,A$) and year effects (f_y, $y=1,\ldots,Y$) in log total mortality. Stock size at all ages and years can be inferred from these parameter values using Eq.s (2) and (3).

PARAMETER ESTIMATION

Surveys are used to estimate model parameters. In principal multiple surveys could be used; however, for simplicity we only used the 3Ps DFO RV survey. The GEAC industry survey covered some of the same area as the DFO survey and could also be used for estimation, but it was discontinued after 2005 (a variant was conducted only in 2007) and would not supply information about more recent stock size.

Let I_{ay} denote the survey index for age a fish in year y. Let t be the midpoint of the survey dates, which we express in a fraction of the year. For example, if the survey occurs in June then $t=0.5$. We use the usual observation equation to estimate parameters,

$$E\{I_{ay}(t)\} = q_a N_{ay}\exp(-tZ_{ay}). \tag{4}$$

We assume that the indices have a lognormal distribution and we use the maximum likelihood method to estimate parameters. This is described in more detail below.

The scale of the N_{ay}'s is confounded with the scale of the q_a's in Eq. 4. We fixed $q_1=1$ to remove this confounding. This means that the scale of model estimates of recruitment is the same as the survey scale (e.g., number per tow, etc), and other quantities are catchability corrected to this scale. Also, the age pattern in the q_a's is confounded with the age patterns in the s_a's. For example, it is possible to get almost identical values for $E\{I_{ay}(t)\}$ using flat q_a's and s_a's that increase with a, versus domed q_a's and flat s_a's. All the q_a's are poorly determined in a typical

SURBA-type model. Therefore, we fixed the values for all q_a's, and conducted sensitivity analyses to examine how key results were affected by the values we chose for q_a's.

Some other parameters are also not determined (or well determined) and must be constrained. These are itemized as follows:

1. The scale of the s_a's and f_y's, which are added to give $log(Z_{ay})$'s, are under-determined. We fixed $s_6=0$ to remove this confounding. Age six was selected because it is roughly the first fully recruited age.
2. The f parameter for year Y may not be well determined unless t is large (i.e., $t>0.5$). If $t=0$ then the data and model are uninformative about f_Y because this parameter is not used in Eq. 1 to derive N_{aY}. This parameter is only used to project N_{aY} to stock size at the time of the survey in year Y in Eq. 4. We assumed $f_Y = (f_{Y-1} + f_{Y-2} + f_{Y-3})/3$.
3. Similarly, s_A may not be well determined because it is not used in Eq. 1. We assumed $s_A = s_{A-1}$.
4. There is only one survey observation to estimate N_{A1}, (stock size at the oldest age in the first year) and this can lead to some spurious results, particularly in terms of the shrinkage penalty terms we describe below. We assumed N_{A1} was the geometric mean of the three previous ages in year 1.

Parameter Shrinkage

Even with the above constraints, the model is still highly parameterized. There are AY observations and $2A+2Y-5$ parameters. In our 3Ps cod example for the winter cod ZAP there were 273 survey observations and 72 parameters, or about 3.8 observations per parameter. The 3Ps cod survey index is highly variable as well, and consequently we should expect high variability in parameter estimates. For the approach to be useful it is necessary to constrain the parameter variation.

Ideally we should consider some of the parameters as types of random effects for more reliable statistical inferences, especially those parameters with year subscripts (i.e., f_y and N_{1y}). This is because the data-information about these parameters does not increase as the sample size increases because the number of parameters increases as well. Fixed effect parameters should be estimated using the marginal likelihood (with random effects integrated out) and the random effects could be "predicted" using empirical Bayes. However, the SAS software we utilized (i.e., PROC NLMIXED) is limited in the types of random effects that can be incorporated so for simplicity we added penalty terms to the likelihood to constrain parameter variation. This is easy to do but probably does not lead to reliable Hessian-based asymptotic standard errors or confidence intervals.

We penalized between-age variations in the s_a values,

$$\Delta s_a = \begin{cases} 0, & a = 1, \\ s_a - s_{a-1}, & a > 1, \end{cases}$$

and between-year variations in the f_Y values. However, the fishing moratorium in 1994 to1996 was accounted for in the f penalties,

$$\Delta f_y = \begin{cases} 0, & y = 1983, 1994, 1997, \\ f_y - f_{y-1}, & \textit{otherwise.} \end{cases}$$

These penalty terms were squared and added to the fit function (described below). A weighting terms (λ) was applied to each penalty to control the amount of shrinkage.

Weighted Loglikelihood Fit Function

Let e_{ay} be the model residuals,

$$e_{ay} = \log\left(I_{ay} \big/ q_a N_{ay} \right).$$

Recall that N_{ay} is a function of the initial numbers-at-age (N_{a1}) and recruitments (N_{1y}), and also age effects (s_a) and year effects (f_y) in *log(Z)*. Let θ be a vector of all these parameters. The weighted (w) loglikelihood fit function is

$$l(\theta) = -\frac{1}{2}\sum_{a,y} w_{ay} \left\{ \log(2\pi) + \log(\sigma^2) + \sigma^{-2}\left(e_{a,y}^2 + \lambda_f \Delta f_y^2 + \lambda_s \Delta s_a^2 \right) \right\}. \quad (5)$$

For convenience any zero's or missing values (i.e., all ages in 1996 for 3Ps RV index) were assigned values of one but external weights $w_{ay}=0$. These "observations" were omitted from the likelihood.

The λf and λs terms are external weights that control the contribution of the penalties to the parameter estimation. In effect these weights control how smooth the parameter estimates are. For example, if we choose a very large value for λf then there will be little between-year variation on the estimates of the f_y 's.

The Data

The data used for estimation at the 2009 Winter cod ZAP were from the DFO 3Ps RV survey, for ages 1 to 12 and from 1983 to 2008. At the 2009 Fall 3Ps cod RAP we used survey indices from 1983 to 2009. The 3Ps survey gear and tow duration were changed in 1996 from 30 minute tows with an Engels groundfish trawl to 15 minute tows with a modified Campelen shrimp trawl. Consistent with the treatment of indices in earlier assessments, the age 1 and 2 indices for the Engels portion of the RV index time-series (i.e., 1983 to 1995) were given zero weight in estimation (i.e., way=0 in Eq. 5 for a=1,2 and y=1983,…,1995). This was because of concerns about the reliability of Engels-Campelen conversion factors produced for ages 1 and 2.

Adjusting the DFO RV Index

The 3Ps survey area was extended to include inshore strata starting in 1996. A consistent set of inshore strata have been sampled during 1997-2009. The inshore strata increased the areal coverage of the survey by 12%. Including these additional inshore strata in the calculation of the 3Ps cod index should result in a more reliable index of abundance, with fewer "year effects". However, it is also desirable for population modeling to have a long time series of survey data.

The 3Ps survey has been conducted fairly consistently since 1983 except for the addition of the inshore strata in 1996. A time series from 1983 to 2009 is available for the offshore strata, and a time series is available for 1997 to 2009 for the offshore+inshore strata.

To construct a longer time series of indices for the offshore+inshore region we adjusted the historic "offshore" survey index (for 1983 to 1996) to make it more comparable, in terms of means numbers per tow, with the newer offshore+inshore index. We computed an overall survey mean numbers-at-age for 1997 to the last year (2008 at the ZAP, 2009 at the RAP) for the offshore+inshore strata, and divided this by the same survey means for the offshore strata only to produce an age-based adjustment that we multiplied the offshore survey index with for 1983-1996. In fact, we used the actual survey indices and applied the age-based adjustment in the model, as an additive offset (lq_offset in Appendix III) to the log index.

RESULTS

Figures are presented in Appendix IA (Winter ZAP results) and 1B (Fall RAP results). A table of fit statistics for various model formulations presented at the winter cod ZAP is given in Appendix II. Some computer output for the ZAP flat-q run is presented in Appendix III.

We first present model results from the 2009 cod ZAP (conducted in late February – early March) followed by some comparisons of updated runs (including the addition of the 2009 spring RV indices for 3Ps cod) conducted at the 2009 Fall 3Ps cod RAP.

An important error in the way SSB was calculated was discovered at the Fall RAP. The error affected SSB estimates provided at the ZAP. Ages in the maturity dataset used at the ZAP were off by one (a cut and paste problem). This problem was actually corrected before the ZAP but unfortunately the incorrect data file was used for the survey cohort modeling. In this paper we provide both the estimates of 3Ps cod survey SSB obtained at the ZAP and estimates using the correct maturity data. All calculations at the RAP used the correct maturity data. This problem only affected SSB calculations. The estimates of stock abundance and total biomass provided at the ZAP were not affected by this problem.

2009 WINTER ZAP RESULTS

The survey coverage adjustments used to make the 1983-1996 offshore indices more comparable with the 1997 to 2008 offshore+inshore indices are shown in Figure 1. They are not large but suggest more young fish occur in the inshore strata because offshore+inshore mean numbers per tow are as much as 20% greater than offshore mean numbers per tow at age 2, but only 90% of the offshore means for ages 9 - 12.

Flat Survey Catchability Run

This is the run illustrated in the 2009 SAR for 3Ps cod developed at the winter cod ZAP. In this formulation the values for survey catchabilities were fixed at:

Flat-q run: q_a = 1, 2, and 5 for a = 1, 2, and 3; q_a = 10 for a > 3.

These q's are also shown in Fig. 2. The objective function penalty weights (see Equation 5) were set as λ_f=0.1 and λ_s=0.01.

Estimates of trends in stock size are presented in Fig. 3. The units of the recruitment estimates are the same as the survey units at age1, and the biomass estimates are scaled using the assumed q's in Fig. 2, and also weights and maturities. Recruitment was estimated to be below average for most year classes since the 1991 one, except for the 1997, 2004, and 2005 year classes. SSB increased during 1994-2004 but declined thereafter. Both SSB and total biomass estimated in 2008 were close to the values in 1994, for which the SSB value is the precautionary limit reference point for 3Ps cod. There is a substantial risk that stock size in 2008 was less than 1994 (Fig. 4).

The error in maturities resulted in SSB that was too high. This was because at the ZAP the maturity at age a was incorrectly taken as the value for age a -1; hence, the error lead to a greater fraction of the population being immature, and consequently lower estimates of SSB. Correcting the error did not lead to a change in inference about the size of 2008 SSB relative to the limit reference point (Fig. 4).

Model estimates indicate increasing total mortality since 1997 (Fig. 5). The slight decrease in 2008 in this figure is the average of the last three years and not a direct estimate from survey data. However, total mortality in 2005 to 2007 was not estimated to be as high as the levels in 1991 to 1993.

The productivity of the stock (Fig. 6; top panel) has generally been lower since 1997 than during 1987 to 1991, although the productivity in 2007 was close to that in 1990 (involving the large 1989 year class which was counted as recruitment at age 1 in 1990). There was little evidence of a stock recruitment relationship (Fig. 6; bottom panel). Note that this figure is based on the corrected maturities, but the trends are very similar to the results presented at the ZAP.

Confidence intervals, especially those in Figure 4, were quite wide. This is because there is considerable inter-annual variability in the survey index which the model could not explain (see Fig. 7). Year effects were apparent in 1993, 1995, and 1997 (Fig. 8 and 10), but otherwise there were no systematic residual patterns versus cohort or predicted values. Some of the year-effects persist for a 2 to 3 years (Fig. 10). There is some evidence of a trend in residuals at young ages (3rd panel in Fig. 8; also see Fig. 10), which may indicate problems in the assumptions about catchability (q's) at these ages.

The input data file, computer code from the SAS PROC NLMIXED software, and the output file are presented in Appendix III. The SAS file requires many macro variables, whose definitions should be self-evident. We used some SAS code to set these automatically (i.e., using symput calls) but the macro variables could also be set manually using %let macro commands. The use of macro variables makes the code much easier to modify for different stocks.

Sensitivity Runs

Separability Assumption for Z: An important assumption in the survey cohort model is that Z can be estimated as an age effect times a year effect. There have been major changes in the gear compositions used in 3Ps cod fisheries before and after the fishing moratorium in 1993. This could affect the size selectivity of fisheries as a whole. If fishing mortality if a large component of total mortality then we may expect a change in the age patterns in Z. To test the sensitivity of results to the separability assumption we estimated the sa parameters independently for two blocks of years: 1) 1983 to 1993, and 2) 1994 to 2008. We doubled λs (i.e., 0.02) to "encourage" the same amount of smoothing as in the fully separable (i.e., for all years) run.

The stock size estimates were not substantially different compared to the flat-q run (Fig. 11), although the 2006 year class did not seem as strong based on the "split separable" run. This formulation did not greatly improve the fit either (Table 1). The AIC goodness-of-fit statistic was lower, but the AICC and BIC fit statistics were higher.

Dome q: In this formulation the values for survey catchabilities were fixed at:

Dome-*q* run: q_a = *1, 2, 5, 10, 10, 10, 9, 8, 7, 6, 5, 4 for a = 1,…,12.*

These q's are also shown in Fig. 12. The trends in biomass and SSB relative to 1994 values were similar to the flat-q results, although the 2008 estimate of biomass and SSB were slightly larger than the 1994 values with the dome q assumption, while they were almost identical for the flat-q run. In both runs the confidence intervals suggest there is a substantial probability that stock size in 2008 was less than the limit reference point.

Goodness-of-fit statistics (Table 1) were all higher (i.e., worse fit) compared to the flat-q run.

Flatter q: In this formulation the values for survey catchabilities were fixed at:

Dome-*q* run: q_a = *1, 1.25, and 2.5 for a = 1, 2, and 3;* q_a *= 5 for a > 3.*

These q's are also shown in Fig. 14. The trends in biomass and SSB relative to 1994 values were similar to the flat-q results (Fig. 15).

Goodness-of-fit statistics (Table 1) were all higher (i.e., worse fit) compared to the flat-q run.

Low Shrinkage: In the previous runs the between year variations in Z were fairly smooth because of the amount of shrinkage applied (i.e., λ_f=0.1). In this run we reduced the shrinkage substantially, using λ_f=0.0001 and λ_s=0.0001. As expected the stock size estimates were more variable (Fig. 16) but the basic trends were not different, especially since 2000. Note that this run suggests that stock biomass and SSB in 1993 and 1997 were lower than in 1994.

The survey index for 1995 was anomalously high but estimates from the low shrinkage run suggested biomass in 1996 was higher. The explanation for the discrepancy is in the estimated Z's (Fig. 17). They were estimated to be low in 1993 to 1995, during the moratorium, but high in 1996 as a result of the high 1995 survey year effect. The beginning of year stock size estimates in Fig. 16 were required, in conjunction with the Z estimates in Fig. 17, to fit the March survey results which are reduced by 0.3×Z from beginning of year numbers. The predicted survey index in 1995 was higher than in 1996 in this run (Fig. 18).

2009 FALL RAP RESULTS

Flat Survey Catchability Update Run

This run was identical to the formulation presented at the 2009 cod ZAP, and those details were described above.

Biomass and SSB relative to 1994 values are shown in Fig. 19. Also shown are the results from the 2009 cod ZAP. For most of the time period results from the two models are nearly identical; however, in the last couple of years the updated RAP results are slightly more optimistic in that the 2008 estimate of stock size is higher relative to 1994, compared to the ZAP results. Nonetheless, there is a substantial risk (i.e., 39% probability) that SSB in 2009 was less than SSB in 1994.

The reason why the RAP model results were slightly more optimistic than the ZAP results is that the 2009 survey available for the RAP (but not the ZAP) was substantially higher than in the past several years (Fig. 20), and this resulted in more optimistic estimates. The RAP model basically split the difference between the relatively low 2008 indices and the high 2009 indices, whereas at the ZAP the model fitted the 2008 indices much more closely.

Dome Survey Catchability Update Run

This formulation was identical to that presented at the 2009 ZAP. Model results from the RAP and ZAP were similar (Fig. 21), except for the last few years. The dome formulation indicated there was a 20% probability that SSB in 2009 was less than SSB in 1994.

All fit statistics (Table 2) were higher for the dome-q run compared to the flat-q run, which indicated that the flat-q assumption was better.

DISCUSSION

The survey modeling approach (i.e., SURBA) can be used to simultaneously estimate total mortality rates and trends in stock size, albeit with assumptions about the separability of total mortality into age and year effects. The approach seems useful for extracting the stock signal from the noisy 3Ps cod DFO survey indices.

Based on the information available at the ZAP and RAP assessments, there were substantial risks that SSB in the last assessment year (either 2008 for the ZAP or 2009 for the RAP) was below the limit reference point (LRP). The probability that SSB in 2008 was below the LRP was different in the ZAP and RAP because the RAP had more data available to evaluate the probability. This probability is with respect to the data available, and evaluations of it will naturally change over time as more data becomes available.

It was identified that there is a need to develop:

1. Projection software for SURBA. This will require decomposing Z into fishing and natural mortality. It should then be possible to do F-multiplier projections.
2. More objective shrinkage approaches.
3. The efficacy of the survey cohort model should be examined with simulation-testing.

Other points:

- A useful diagnostic to develop is retrospective plots.
- Survey year-effects probably add considerable retrospective noise to assessment results, and if the year-effects could be explicitly accounted for by the model then this might result in much more consistent model results from year to year.
- It may be useful to add the GEAC survey index to try and reconcile the differences between SURBA estimates of the size of recent cohorts and those produced by the year class strength model used in the 3Ps cod stock assessment.

- The approach outlined in Cadigan (2004) may be better for dealing with the addition of inshore strata in the 3Ps survey. This change in survey design, while beneficial, represents a source of uncertainty that should be accounted for in the survey cohort model.

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APPENDIX IA: FIGURES for Winter Cod ZAP

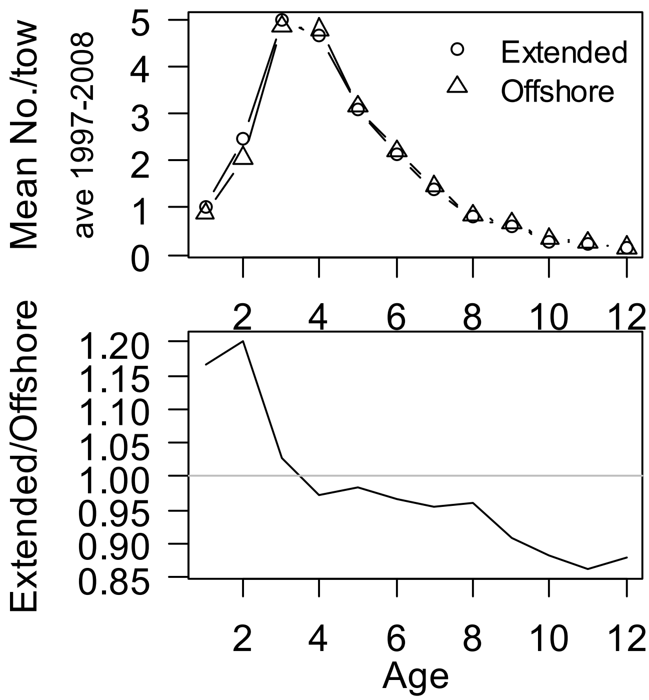

Figure 1. Top Panel: DFO RV survey age-disaggregated mean number per tow for 3Ps cod, for offshore strata (circles) and extended offshore+inshore strata (triangles). The means are averages over 1997 to 2008. The offshore strata are the index strata that have been consistently sampled since 1983, and the offshore+inshore strata have been consistently sampled since 1997. Bottom Panel: Mean numbers per tow for the offshore+inshore strata divided by the means for the offshore strata. A grey reference line at one is also shown.

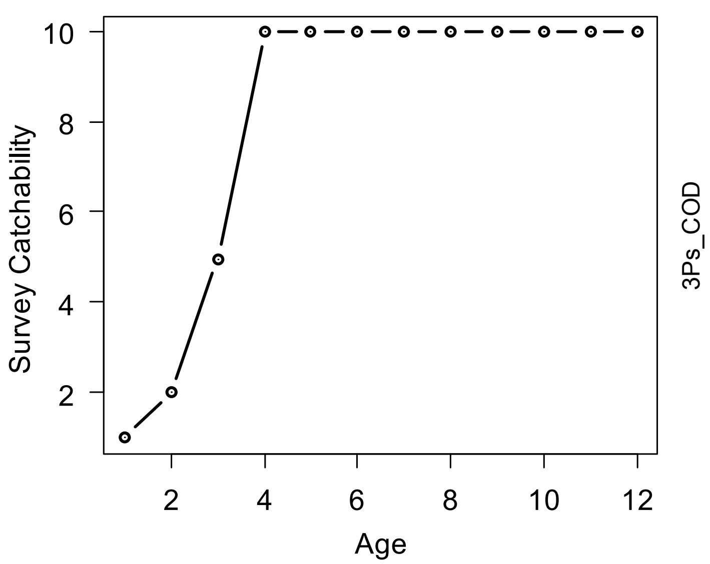

Figure 2. Values assumed for survey catchability (q) used in the “flat-q” run.

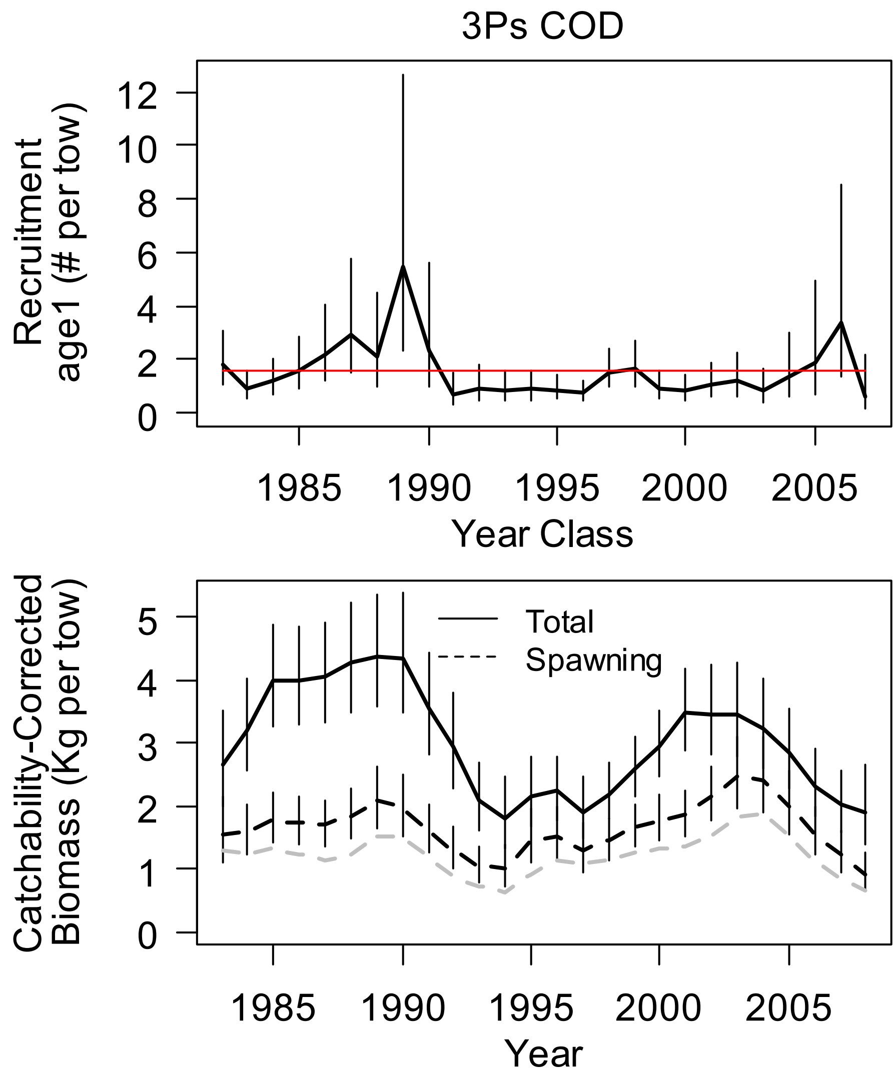

Figure 3. Top panel: Estimates of recruitment (number per tow at age one) from the survey model based on a "flat-q" assumption. The red line indicates the mean of the time series. Bottom panel: Catchability corrected trends in stock biomass. The biomass scales are relative to age 1 via the q assumptions in Figure 2. Total biomass is for ages 3-12. The grey dashed line shows the SSB estimates based on incorrect maturities, and the black dashed line shows the corrected estimates. In both panels the vertical lines indicate 95% confidence intervals.

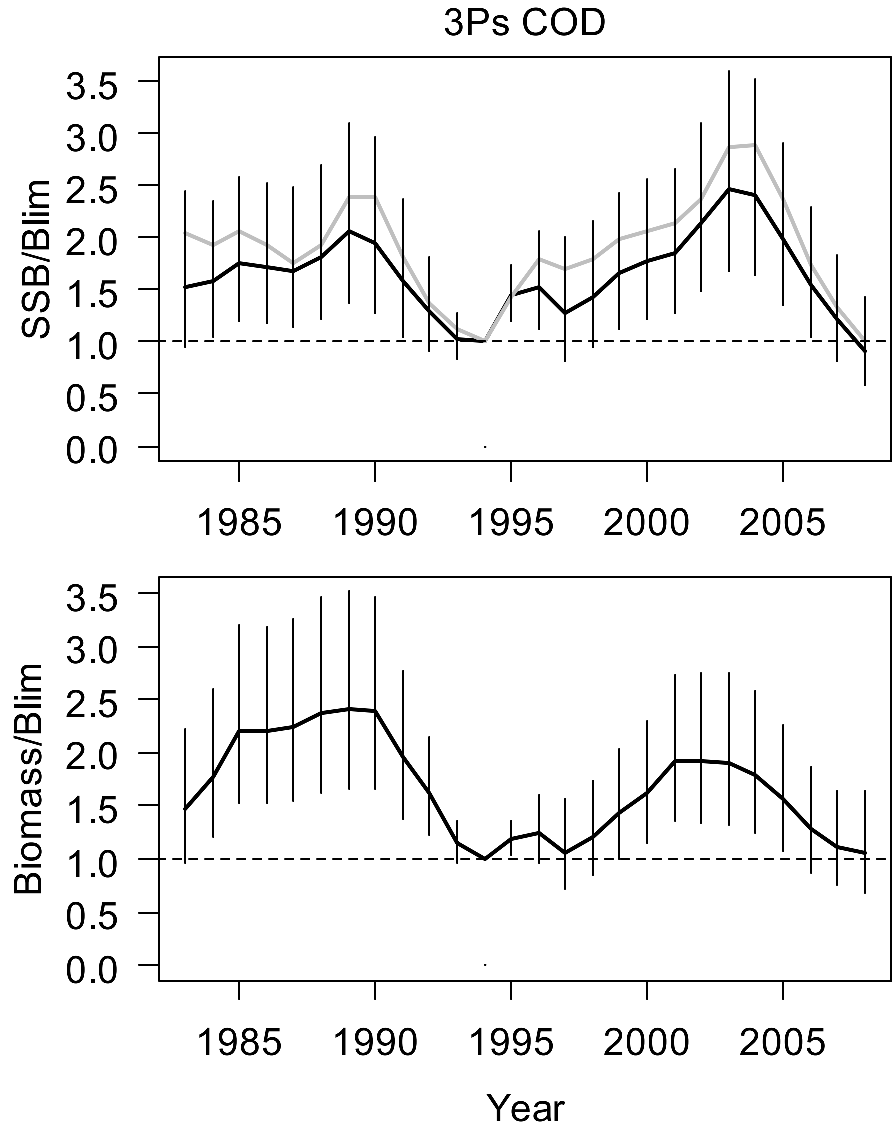

Figure 4. Trends in SSB (top panel) and biomass (bottom panel; ages 3-12) relative to values in 1994. SSB in 1994 is the precautionary limit reference point for 3Ps cod. The grey dashed line in the top panel shows the SSB estimates based on incorrect maturities, and the black dashed line shows the corrected estimates. Vertical lines are 95% confidence intervals for stock size relative to the 1994 value, which is why there are no confidence intervals for 1994. Dashed horizontal lines at one are shown for reference.

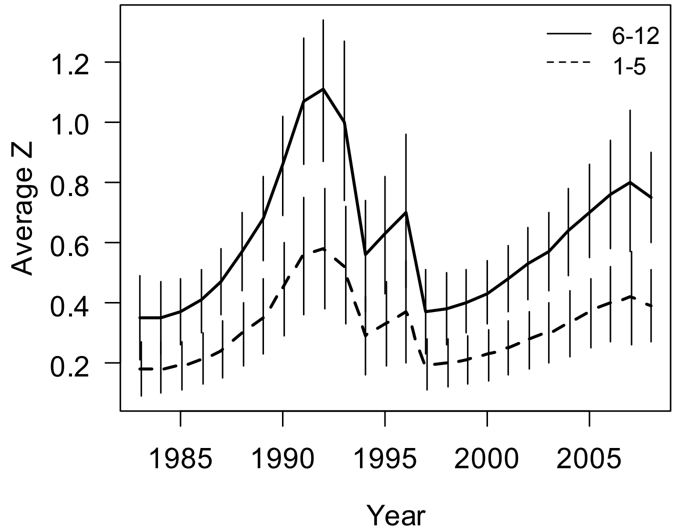

Figure 5: Average total mortalities (Z's) for young (ages 1-5) and old (ages 6-12) cod. Vertical lines indicate 95% confidence intervals.

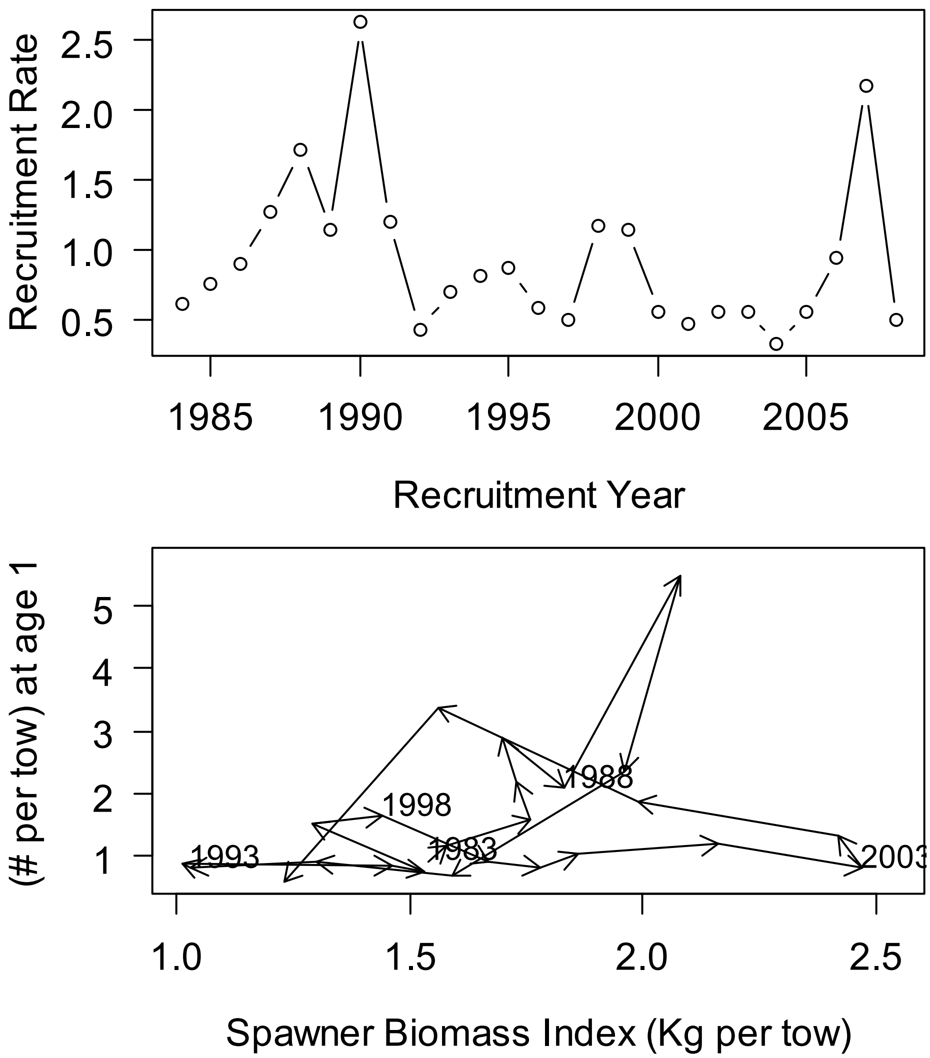

Figure 6 Top panel: Estimates of recruitment divided by SSB (corrected), plotted versus recruitment (i.e., age 1) year. Bottom panel: Stock-recruitment scatter plot. Arrows connect points in chronological order, and some years are indicated for reference.

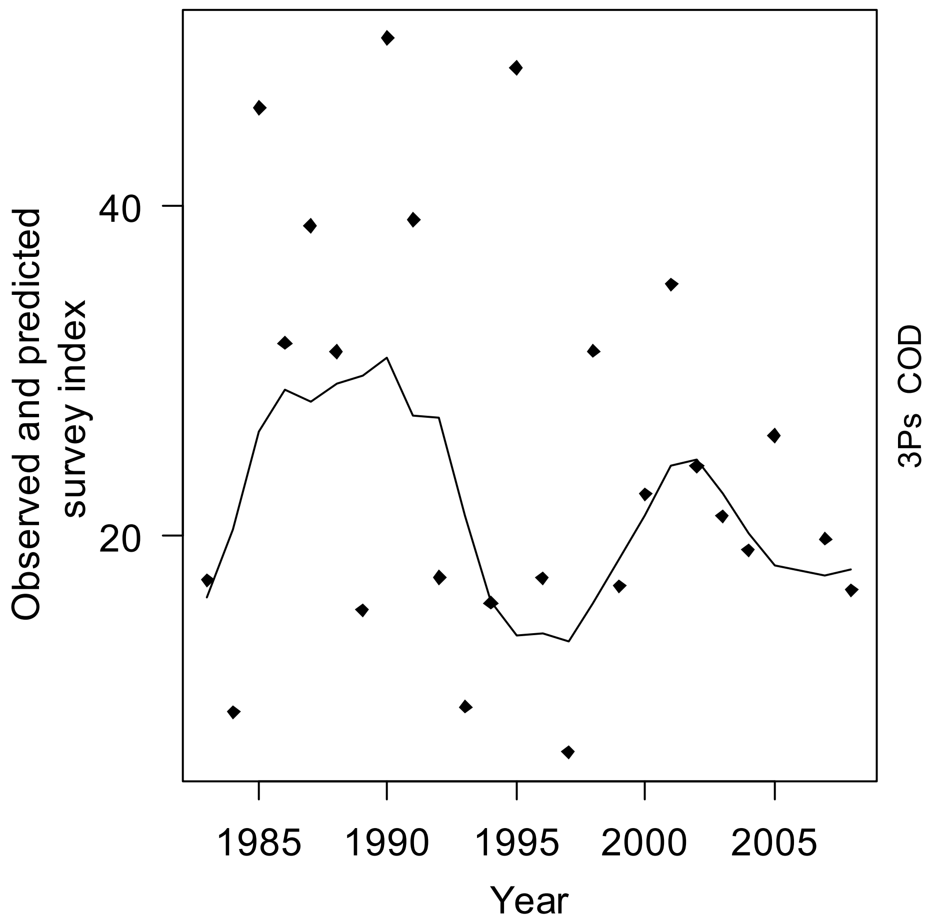

Figure 7. Observed (points) versus predicted (lines) survey indices, summed across ages each year.

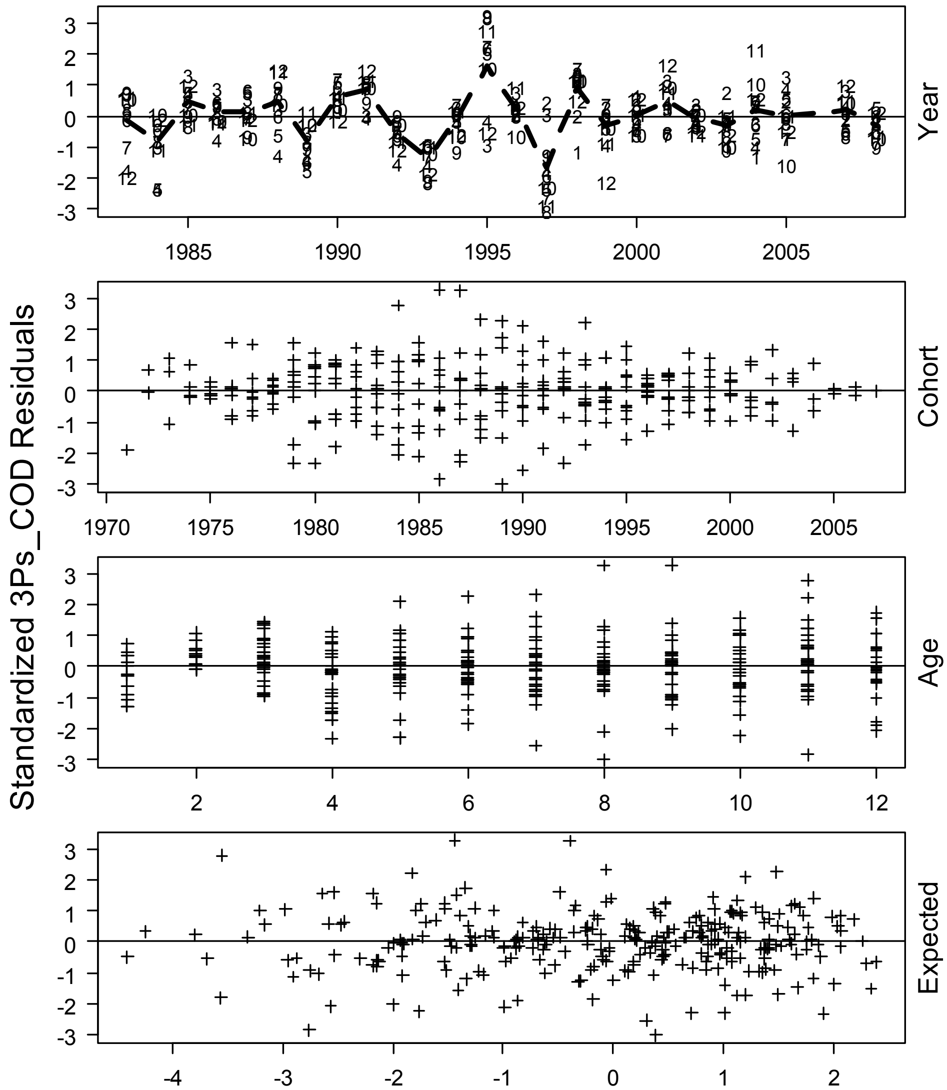

Figure 8. Top panel: Standardized residuals versus year. Ages are used for plotting symbols, and the dashed lines connect the average residual each year. 2nd panel: Residuals versus cohort. 3rd panel: residuals versus age. Bottom panel: residuals versus predicted value on the log scale.

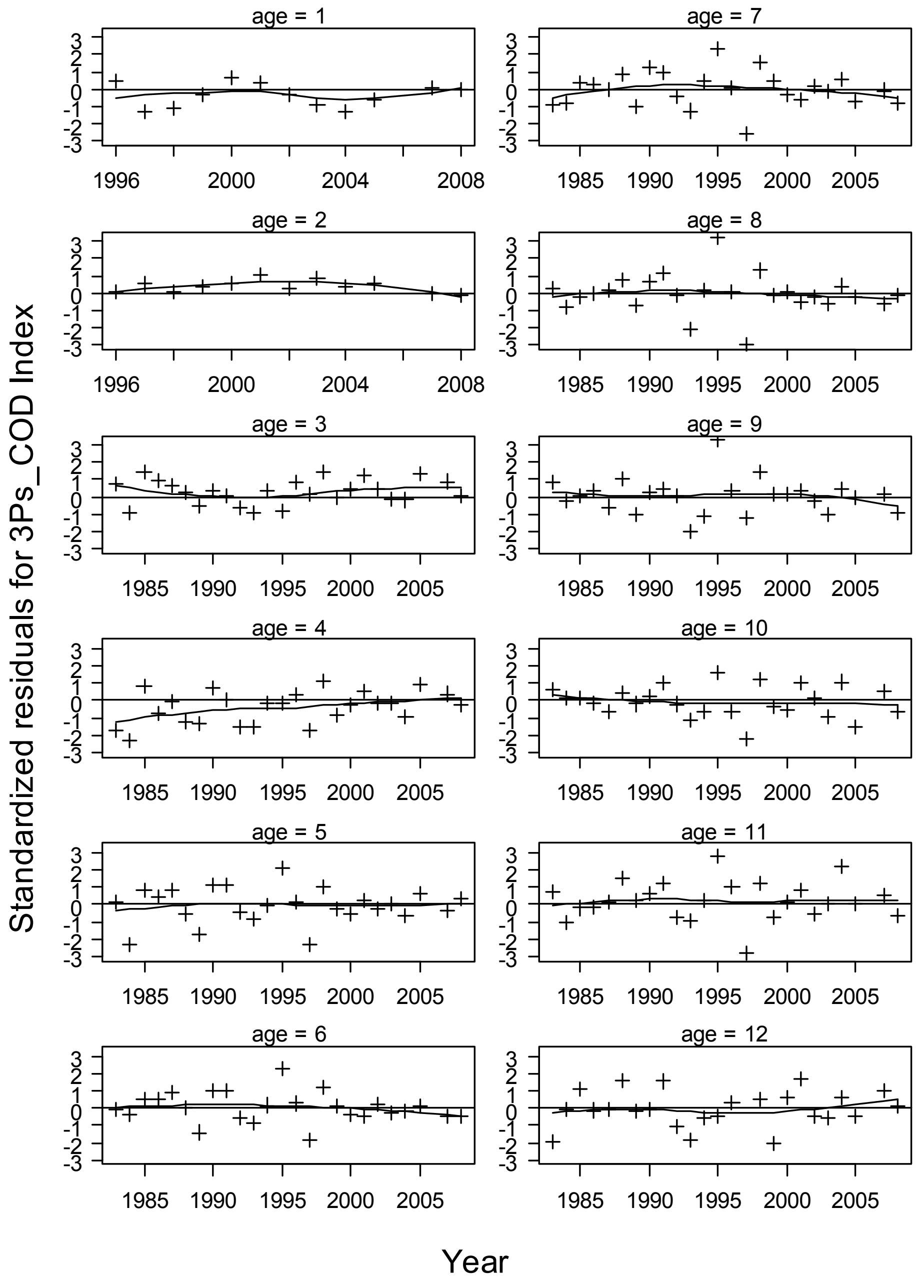

Figure 9. Each panel shows a residual time series for each index age, with a loess smoother (loess() in R software package).

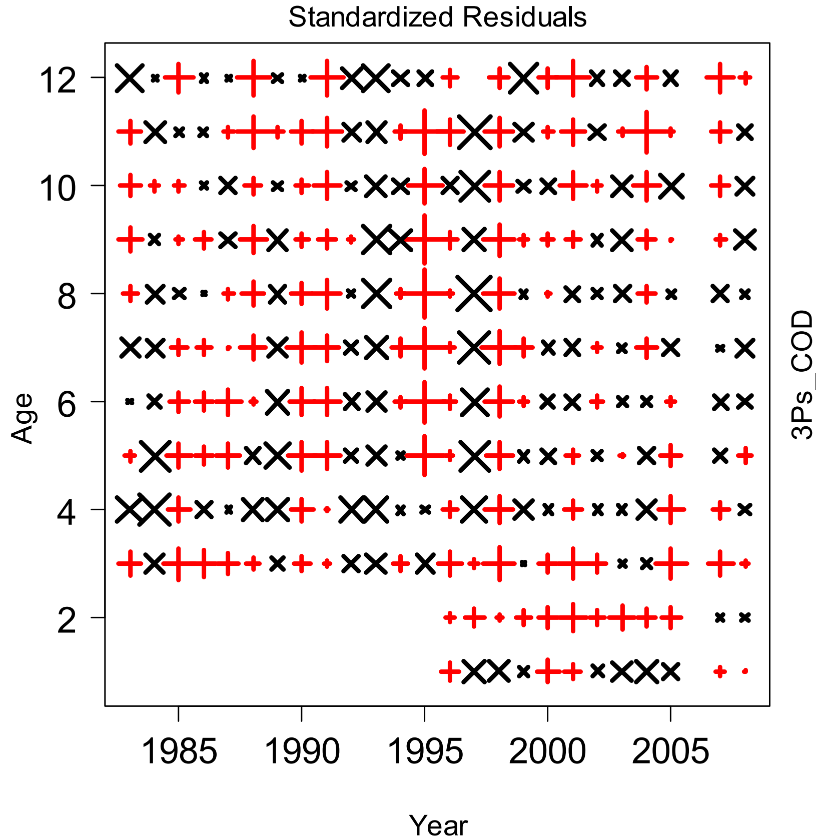

Figure 10. Matrix plot of residuals. Red symbols indicate positive and black symbols indicate negative. The size of the symbol is proportional to the absolute value of the residual.

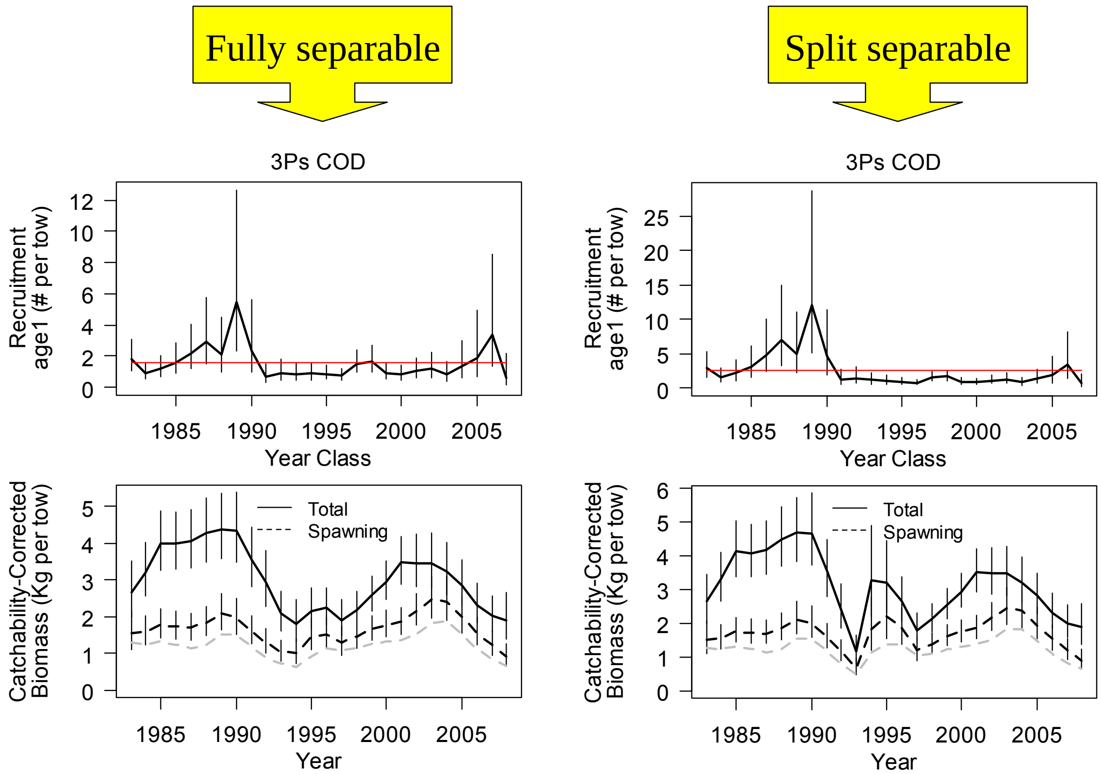

Figure 11. Comparison of population size estimates from the model with separable Z throughout 1983 to 2008 (left hand side) and a model with age effects estimated separately for two blocks of years: 1) 1983 to 1993, and 2) 1994 to 2008 (right hand side). Total biomass is for ages 3-12. The grey dashed lines in the bottom panels show the SSB estimates based on incorrect maturities, and the black dashed lines show the corrected estimates.

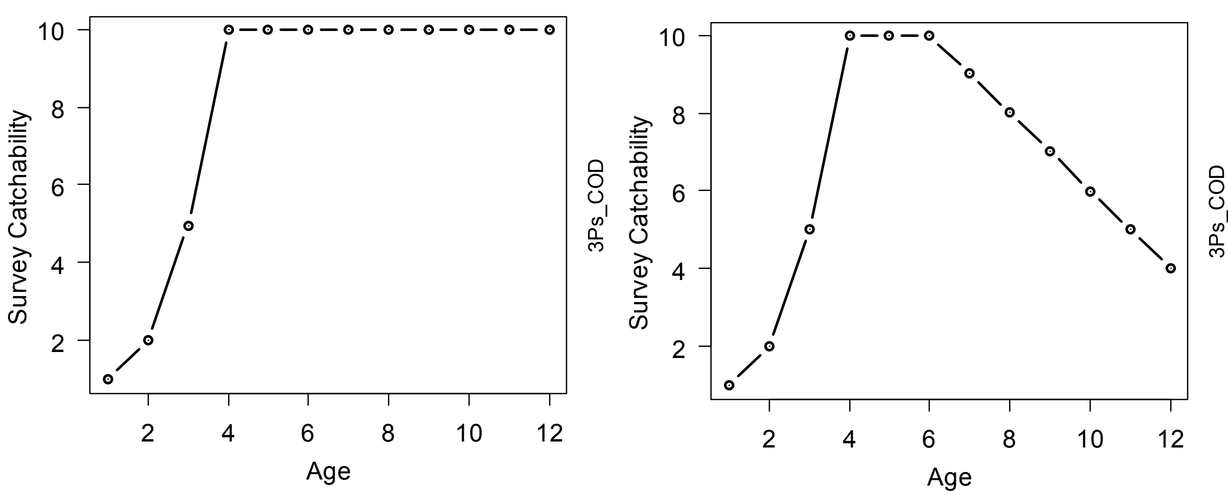

Figure 12. Comparison of survey catchability (q) used in the "flat-q" run (left hand panel) and the "dome-q" run (right hand panel).

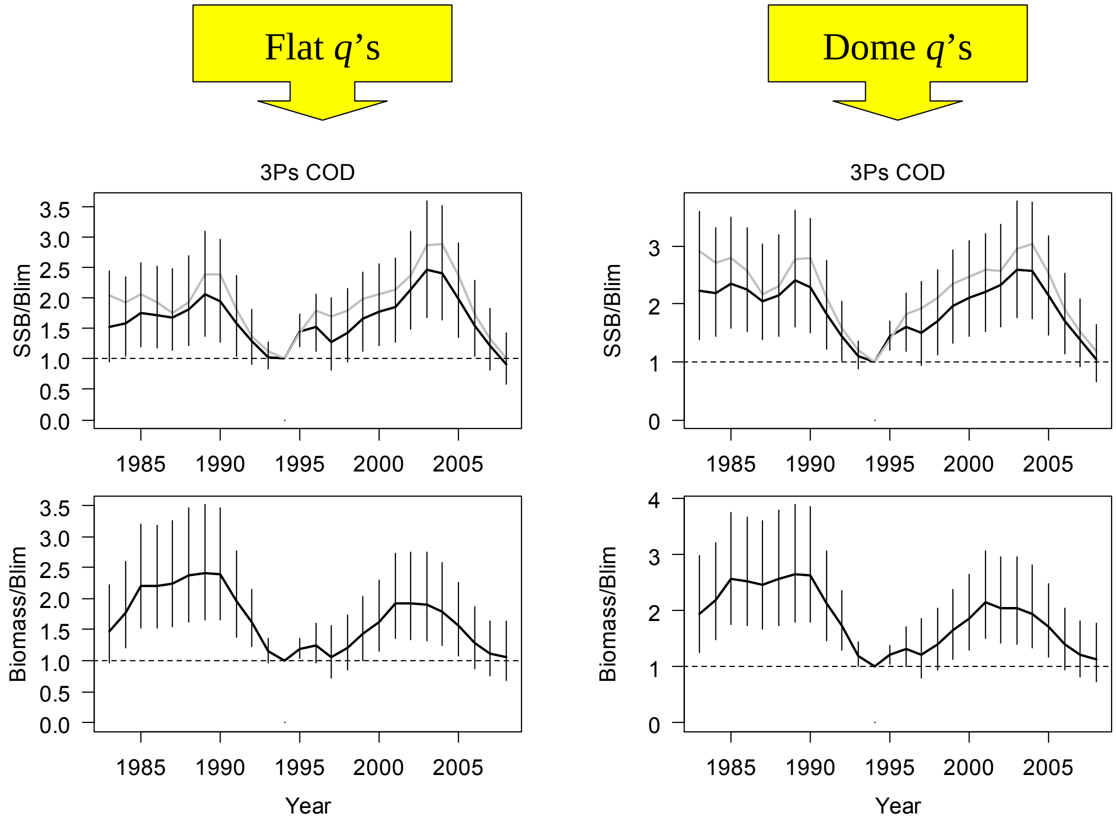

Figure 13. Comparison of trends in SSB (top panels) and biomass (bottom panels; ages 3-12) relative to values in 1994, for the "flat-q" run (left hand panel) and the "dome-q" run (right hand panel). SSB in 1994 is the precautionary limit reference point for 3Ps cod. The grey dashed lines in the top panels show the SSB estimates based on incorrect maturities, and the black dashed lines show the corrected estimates. Vertical lines are 95% confidence intervals.

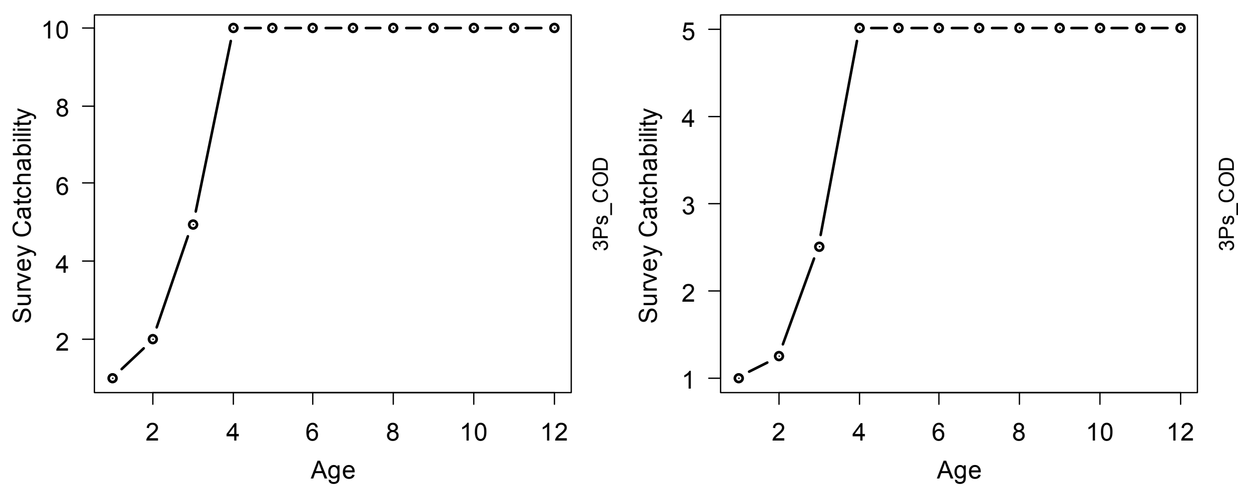

Figure 14. Comparison of survey catchability (q) used in the "flat-q" run (left hand panel) and the "flatter-q" run (right hand panel.

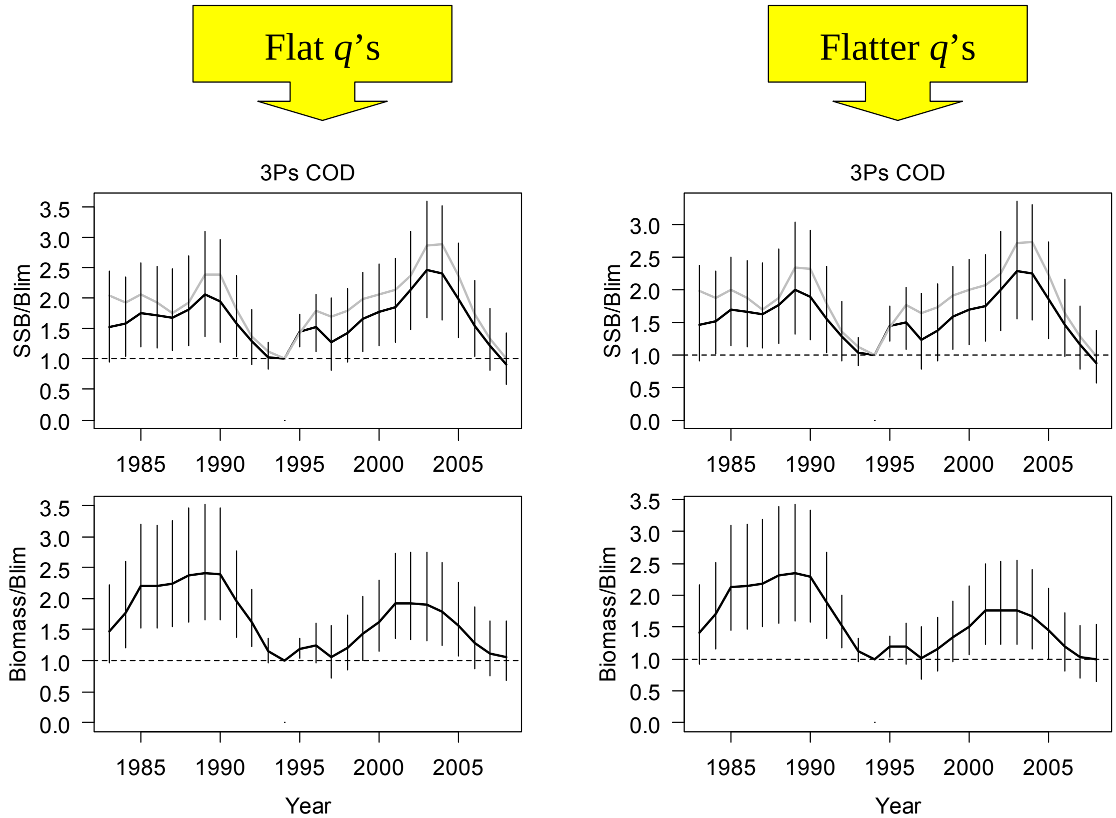

Figure 15. Comparison of trends in SSB (top panels) and biomass (bottom panels; ages 3-12) relative to values in the 1994, for the "flat-q" run (left hand panel) and the "flatter-q" run (right hand panel). SSB in 1994 is the precautionary limit reference point for 3Ps cod. The grey dashed lines in the top panels show the SSB estimates based on incorrect maturities, and the black dashed lines show the corrected estimates. Vertical lines are 95% confidence intervals.

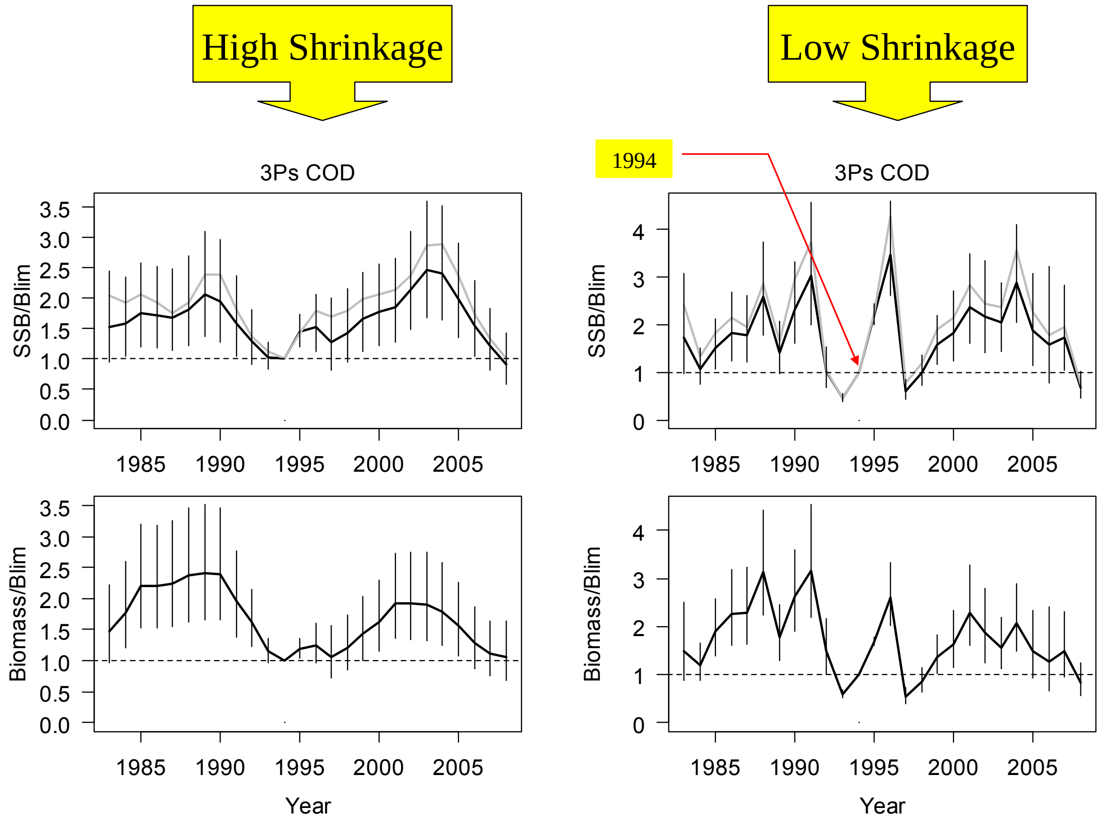

Figure 16. Comparison of trends in SSB (top panels) and biomass (bottom panels; ages 3-12) relative to values in 1994, for the "flat-q" run with high shrinkage (left hand panel) and the "flat-q" run with low shrinkage (right hand panel). SSB in 1994 is the precautionary limit reference point for 3Ps cod. The grey dashed lines in the top panels show the SSB estimates based on incorrect maturities, and the black dashed lines show the corrected estimates. Vertical lines are 95% confidence intervals.

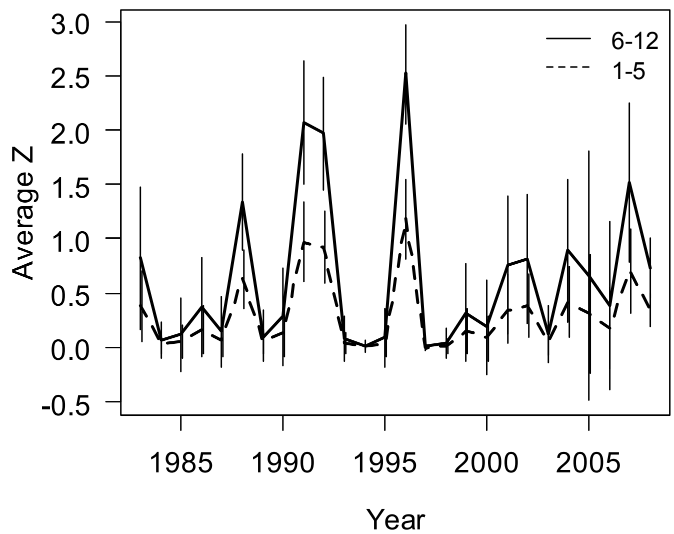

Figure 17. Average total mortalities (Z's) for young and old cod from the "flat-q" run with low shrinkage. Vertical lines indicate 95% confidence intervals.

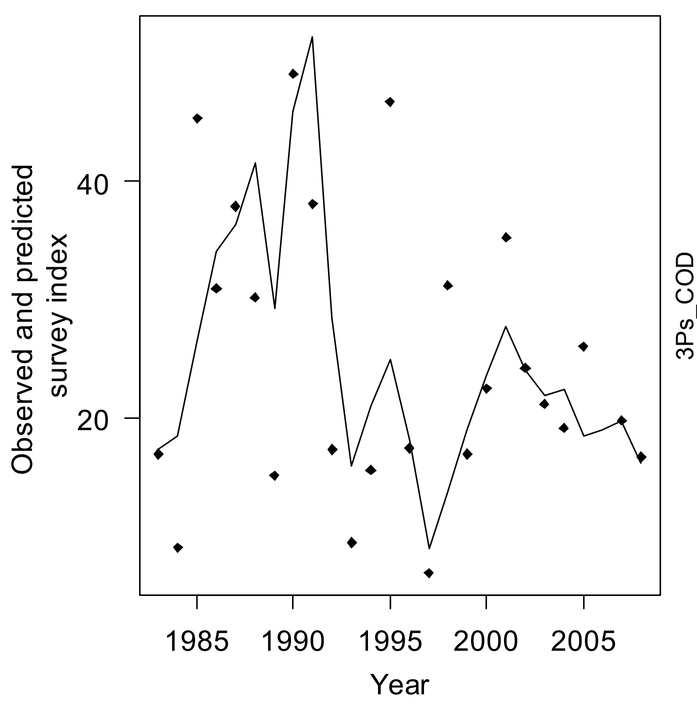

Figure 18. Observed (points) versus predicted (lines) survey indices, summed across ages each year, from the "flat-q" run with low shrinkage.

APPENDIX IB: FIGURES for Autumn 3Ps Cod RAP

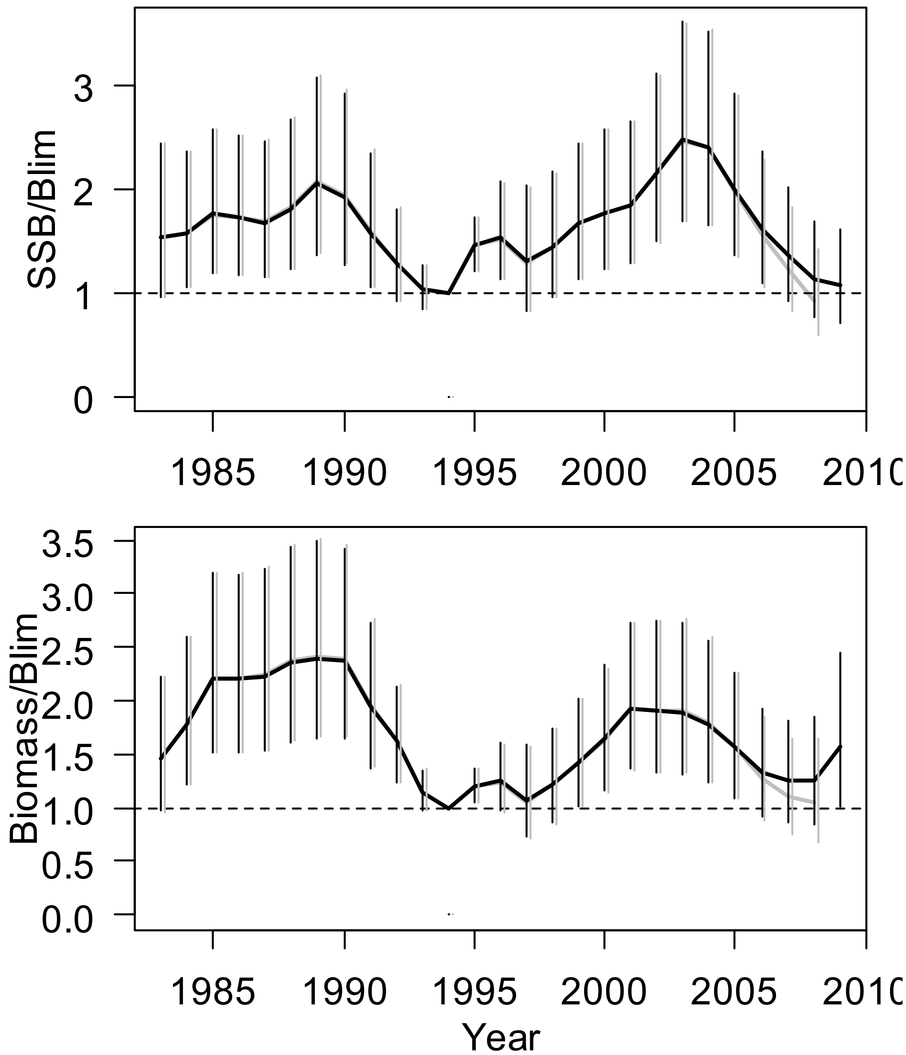

Figure 19. Trends in SSB (top panel) and biomass (bottom panel; ages 3-12) relative to values in 1994, based on the "flat-q" model formulation. SSB in 1994 is the precautionary limit reference point for 3Ps cod. Grey dashed lines show results from the last assessment (i.e., cod ZAP). Vertical lines are 95% confidence intervals for stock size relative to the 1994 value, which is why there are no confidence intervals for 1994. Dashed horizontal lines at one are shown for reference.

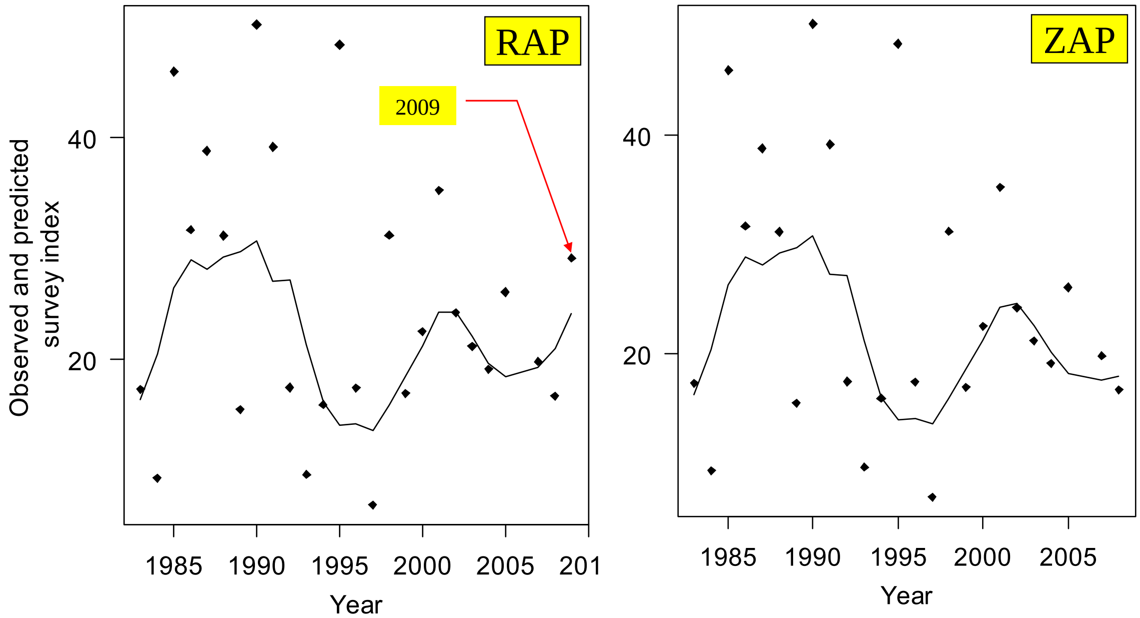

Figure 20. Observed (points) versus predicted (lines) survey indices, summed across ages each year, from the "flat-q" ZAP run with high shrinkage (right-hand panel) and the updated RAP run (left-hand panel).

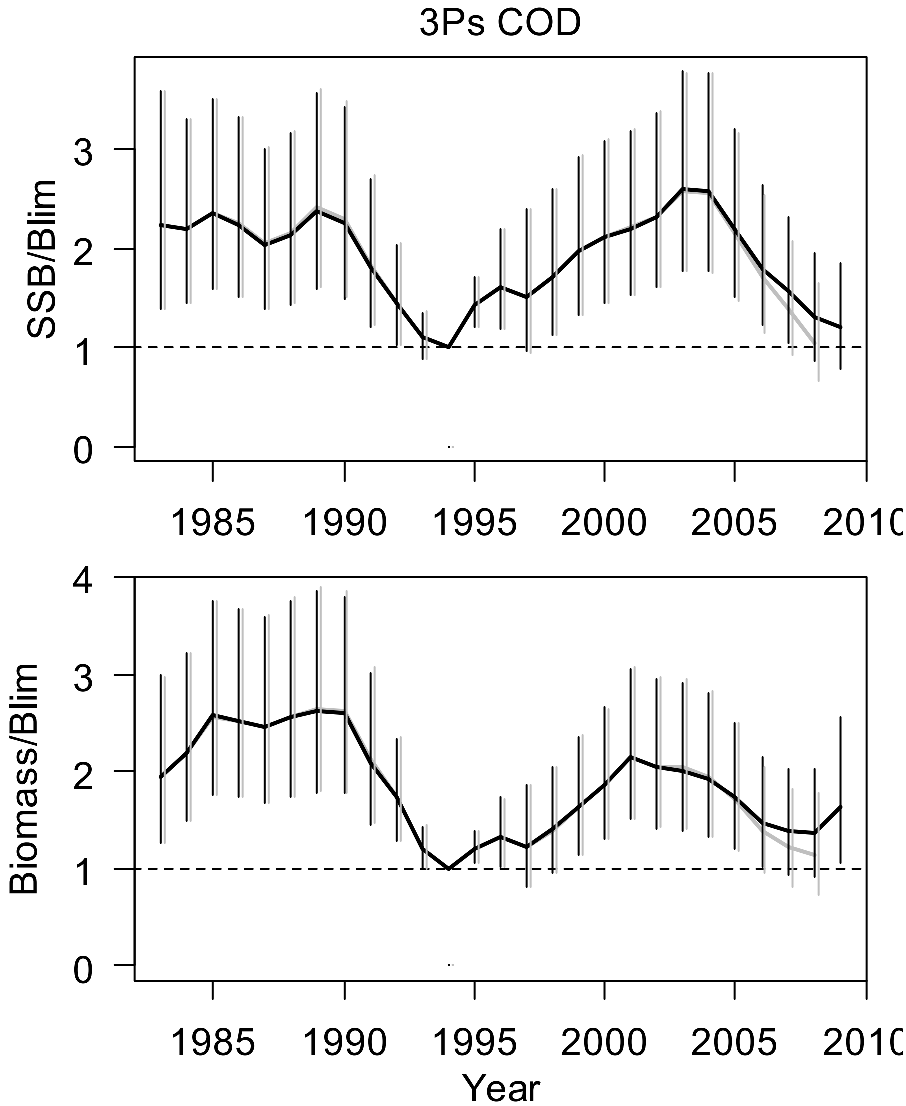

Figure 21. Trends in SSB (top panel) and biomass (bottom panel; ages 3-12) relative to values in 1994, based on the “dome-q” model formulation. SSB in 1994 is the precautionary limit reference point for 3Ps cod. Grey dashed lines show results from the last assessment (i.e., cod ZAP). Vertical lines are 95% confidence intervals for stock size relative to the 1994 value, which is why there are no confidence intervals for 1994. Dashed horizontal lines at one are shown for reference.

APPENDIX II: TABLES

Table 1: Comparison of fit statistics for the 2009 ZAP runs. The best fit is in bold; however, the Split sa run had more parameters and its -2logL is not comparable to the other models that had the same number of parameters (but fewer than the Split sa run).

Fit Statistic	Constant s_a Flat q_a	Split s_a Flat q_a	Constant s_a Dome q_a	Constant s_a Flatter q_a
-2logL	536.5	**512.9**	546.5	546.7
AIC	680.5	**672.9**	690.5	690.7
AICC	724.5	729.0	734.5	734.7
BIC	**950.0**	972.3	960.0	960.2

Table 2: Comparison of fit statistics for the 2009 RAP runs. The best fit is in bold.

Fit Statistic	Constant s_a Flat q_a	Constant s_a Dome q_a
-2logL	**559.6**	569.4
AIC	**707.6**	717.4
AICC	**752.1**	762.0
BIC	**987.3**	997.2

APPENDIX III: Input Data file, SAS PROC NLMIXED Code, and Output Results

3Ps Cod Input Data for 2009 Cod ZAP

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
1	1983	1	0.3	-0.15	1982	0	1.86	0.00	0.00	0.2	1
2	1983	2	0.3	-0.18	1981	0	2.30	0.00	0.00	0.2	2
3	1983	3	0.3	-0.03	1980	1	1.87	0.43	0.01	0.2	3
4	1983	4	0.3	0.03	1979	1	0.13	0.62	0.09	0.2	4
5	1983	5	0.3	0.02	1978	1	1.31	1.01	0.15	0.2	5
6	1983	6	0.3	0.04	1977	1	0.48	1.53	0.42	0.2	1
7	1983	7	0.3	0.05	1976	1	-0.73	2.14	0.71	0.2	2
8	1983	8	0.3	0.04	1975	1	-0.12	2.77	0.96	0.2	3
9	1983	9	0.3	0.10	1974	1	0.48	3.30	0.99	0.2	4
10	1983	10	0.3	0.13	1973	1	-0.29	4.44	0.99	0.2	5
11	1983	11	0.3	0.15	1972	1	-1.02	5.89	1.00	0.2	6
12	1983	12	0.3	0.13	1971	1	-1.97	7.23	1.00	0.2	7
13	1984	1	0.3	-0.15	1983	0	-1.20	0.00	0.00	0.2	1
14	1984	2	0.3	-0.18	1982	0	1.69	0.00	0.00	0.2	2
15	1984	3	0.3	-0.03	1981	1	0.85	0.58	0.00	0.2	3
16	1984	4	0.3	0.03	1980	1	0.44	0.78	0.02	0.2	4
17	1984	5	0.3	0.02	1979	1	-0.46	1.08	0.21	0.2	5
18	1984	6	0.3	0.04	1978	1	0.75	1.62	0.50	0.2	1
19	1984	7	0.3	0.05	1977	1	-0.26	2.29	0.90	0.2	2
20	1984	8	0.3	0.04	1976	1	-0.99	3.12	0.90	0.2	3
21	1984	9	0.3	0.10	1975	1	-0.78	3.94	0.99	0.2	4
22	1984	10	0.3	0.13	1974	1	-0.34	4.58	1.00	0.2	5
23	1984	11	0.3	0.15	1973	1	-1.71	5.50	1.00	0.2	6
24	1984	12	0.3	0.13	1972	1	-1.90	7.70	1.00	0.2	7
25	1985	1	0.2	-0.15	1984	0	-0.97	0.00	0.00	0.2	1
26	1985	2	0.2	-0.18	1983	0	2.05	0.00	0.00	0.2	2
27	1985	3	0.2	-0.03	1982	1	2.70	0.58	0.00	0.2	3
28	1985	4	0.2	0.03	1981	1	2.53	0.75	0.01	0.2	4
29	1985	5	0.2	0.02	1980	1	2.30	1.13	0.09	0.2	5
30	1985	6	0.2	0.04	1979	1	1.19	1.58	0.43	0.2	1
31	1985	7	0.2	0.05	1978	1	0.98	2.35	0.86	0.2	2
32	1985	8	0.2	0.04	1977	1	-0.24	3.01	0.99	0.2	3
33	1985	9	0.2	0.10	1976	1	-0.73	4.35	0.97	0.2	4
34	1985	10	0.2	0.13	1975	1	-0.87	5.34	1.00	0.2	5
35	1985	11	0.2	0.15	1974	1	-0.87	5.83	1.00	0.2	6
36	1985	12	0.2	0.13	1973	1	-0.71	6.57	1.00	0.2	7
37	1986	1	0.2	-0.15	1985	0	-1.61	0.00	0.00	0.2	1
38	1986	2	0.2	-0.18	1984	0	1.89	0.00	0.00	0.2	2
39	1986	3	0.2	-0.03	1983	1	1.73	0.45	0.00	0.2	3
40	1986	4	0.2	0.03	1982	1	1.87	0.69	0.01	0.2	4
41	1986	5	0.2	0.02	1981	1	2.07	1.00	0.04	0.2	5
42	1986	6	0.2	0.04	1980	1	1.85	1.50	0.30	0.2	1
43	1986	7	0.2	0.05	1979	1	0.76	2.09	0.68	0.2	2
44	1986	8	0.2	0.04	1978	1	0.39	2.98	0.97	0.2	3
45	1986	9	0.2	0.10	1977	1	-0.17	3.85	1.00	0.2	4
46	1986	10	0.2	0.13	1976	1	-1.24	5.26	0.99	0.2	5
47	1986	11	0.2	0.15	1975	1	-1.43	6.10	1.00	0.2	6
48	1986	12	0.2	0.13	1974	1	-1.24	7.30	1.00	0.2	7
49	1987	1	0.2	-0.15	1986	0	0.09	0.00	0.00	0.2	1
50	1987	2	0.2	-0.18	1985	0	2.14	0.00	0.00	0.2	2
51	1987	3	0.2	-0.03	1984	1	1.74	0.46	0.00	0.2	3

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
52	1987	4	0.2	0.03	1983	1	1.60	0.65	0.01	0.2	4
53	1987	5	0.2	0.02	1982	1	2.63	0.95	0.04	0.2	5
54	1987	6	0.2	0.04	1981	1	2.12	1.39	0.18	0.2	1
55	1987	7	0.2	0.05	1980	1	1.21	2.06	0.64	0.2	2
56	1987	8	0.2	0.04	1979	1	0.25	2.71	0.86	0.2	3
57	1987	9	0.2	0.10	1978	1	-0.37	3.69	1.00	0.2	4
58	1987	10	0.2	0.13	1977	1	-1.27	4.69	1.00	0.2	5
59	1987	11	0.2	0.15	1976	1	-1.47	5.84	1.00	0.2	6
60	1987	12	0.2	0.13	1975	1	-1.83	6.57	1.00	0.2	7
61	1988	1	0.1	-0.15	1987	0	-0.87	0.00	0.00	0.2	1
62	1988	2	0.1	-0.18	1986	0	2.21	0.00	0.00	0.2	2
63	1988	3	0.1	-0.03	1985	1	1.78	0.56	0.00	0.2	3
64	1988	4	0.1	0.03	1984	1	1.09	0.68	0.01	0.2	4
65	1988	5	0.1	0.02	1983	1	1.04	0.92	0.08	0.2	5
66	1988	6	0.1	0.04	1982	1	1.87	1.42	0.22	0.2	1
67	1988	7	0.1	0.05	1981	1	1.76	1.88	0.55	0.2	2
68	1988	8	0.1	0.04	1980	1	1.29	2.60	0.88	0.2	3
69	1988	9	0.1	0.10	1979	1	0.40	3.29	0.94	0.2	4
70	1988	10	0.1	0.13	1978	1	-0.17	4.64	1.00	0.2	5
71	1988	11	0.1	0.15	1977	1	-0.30	5.35	1.00	0.2	6
72	1988	12	0.1	0.13	1976	1	-1.05	6.40	1.00	0.2	7
73	1989	1	0.1	-0.15	1988	0	-0.71	0.00	0.00	0.2	1
74	1989	2	0.1	-0.18	1987	0	1.87	0.00	0.00	0.2	2
75	1989	3	0.1	-0.03	1986	1	1.54	0.54	0.00	0.2	3
76	1989	4	0.1	0.03	1985	1	1.15	0.71	0.01	0.2	4
77	1989	5	0.1	0.02	1984	1	0.41	0.98	0.09	0.2	5
78	1989	6	0.1	0.04	1983	1	0.15	1.33	0.37	0.2	1
79	1989	7	0.1	0.05	1982	1	0.77	1.94	0.68	0.2	2
80	1989	8	0.1	0.04	1981	1	0.19	2.70	0.88	0.2	3
81	1989	9	0.1	0.10	1980	1	-0.40	3.46	0.97	0.2	4
82	1989	10	0.1	0.13	1979	1	-0.99	4.31	0.98	0.2	5
83	1989	11	0.1	0.15	1978	1	-0.89	5.60	1.00	0.2	6
84	1989	12	0.1	0.13	1977	1	-2.04	6.40	1.00	0.2	7
85	1990	1	0.1	-0.15	1989	0	0.00	0.00	0.00	0.2	1
86	1990	2	0.1	-0.18	1988	0	0.39	0.00	0.00	0.2	2
87	1990	3	0.1	-0.03	1987	1	2.28	0.51	0.01	0.2	3
88	1990	4	0.1	0.03	1986	1	2.67	0.74	0.02	0.2	4
89	1990	5	0.1	0.02	1985	1	2.39	1.01	0.07	0.2	5
90	1990	6	0.1	0.04	1984	1	1.74	1.47	0.49	0.2	1
91	1990	7	0.1	0.05	1983	1	1.35	2.00	0.80	0.2	2
92	1990	8	0.1	0.04	1982	1	1.14	2.60	0.94	0.2	3
93	1990	9	0.1	0.10	1981	1	0.14	3.77	0.98	0.2	4
94	1990	10	0.1	0.13	1980	1	-0.34	4.57	0.99	0.2	5
95	1990	11	0.1	0.15	1979	1	-1.14	5.74	0.99	0.2	6
96	1990	12	0.1	0.13	1978	1	-1.83	6.91	1.00	0.2	7
97	1991	1	0.1	-0.15	1990	0	0.26	0.00	0.00	0.2	1
98	1991	2	0.1	-0.18	1989	0	3.32	0.00	0.00	0.2	2
99	1991	3	0.1	-0.03	1988	1	1.62	0.56	0.00	0.2	3
100	1991	4	0.1	0.03	1987	1	2.30	0.66	0.05	0.2	4
101	1991	5	0.1	0.02	1986	1	2.42	1.00	0.24	0.2	5
102	1991	6	0.1	0.04	1985	1	1.75	1.49	0.54	0.2	1
103	1991	7	0.1	0.05	1984	1	1.04	2.09	0.90	0.2	2
104	1991	8	0.1	0.04	1983	1	0.46	2.67	0.96	0.2	3

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
105	1991	9	0.1	0.10	1982	1	0.17	3.33	0.99	0.2	4
106	1991	10	0.1	0.13	1981	1	-0.30	4.23	1.00	0.2	5
107	1991	11	0.1	0.15	1980	1	-0.58	5.68	1.00	0.2	6
108	1991	12	0.1	0.13	1979	1	-1.51	6.98	1.00	0.2	7
109	1992	1	0.1	-0.15	1991	0	0.00	0.00	0.00	0.2	1
110	1992	2	0.1	-0.18	1990	0	0.59	0.00	0.00	0.2	2
111	1992	3	0.1	-0.03	1989	1	1.94	0.38	0.02	0.2	3
112	1992	4	0.1	0.03	1988	1	0.75	0.65	0.05	0.2	4
113	1992	5	0.1	0.02	1987	1	1.42	0.88	0.34	0.2	5
114	1992	6	0.1	0.04	1986	1	0.71	1.35	0.81	0.2	1
115	1992	7	0.1	0.05	1985	1	0.03	1.97	0.95	0.2	2
116	1992	8	0.1	0.04	1984	1	-0.63	2.62	0.99	0.2	3
117	1992	9	0.1	0.10	1983	1	-1.35	3.47	0.99	0.2	4
118	1992	10	0.1	0.13	1982	1	-1.43	4.52	1.00	0.2	5
119	1992	11	0.1	0.15	1981	1	-2.53	5.21	1.00	0.2	6
120	1992	12	0.1	0.13	1980	1	-3.22	7.04	1.00	0.2	7
121	1993	1	0.3	-0.15	1992	0	0.00	0.00	0.00	0.2	1
122	1993	2	0.3	-0.18	1991	0	0.00	0.00	0.00	0.2	2
123	1993	3	0.3	-0.03	1990	1	0.69	0.23	0.02	0.2	3
124	1993	4	0.3	0.03	1989	1	1.40	0.56	0.10	0.2	4
125	1993	5	0.3	0.02	1988	1	0.40	0.87	0.46	0.2	5
126	1993	6	0.3	0.04	1987	1	0.30	1.24	0.83	0.2	1
127	1993	7	0.3	0.05	1986	1	-0.76	1.82	0.98	0.2	2
128	1993	8	0.3	0.04	1985	1	-2.30	2.51	1.00	0.2	3
129	1993	9	0.3	0.10	1984	1	-3.22	3.54	1.00	0.2	4
130	1993	10	0.3	0.13	1983	1	-3.51	4.22	1.00	0.2	5
131	1993	11	0.3	0.15	1982	1	-3.22	5.10	1.00	0.2	6
132	1993	12	0.3	0.13	1981	1	-4.61	6.94	1.00	0.2	7
133	1994	1	0.3	-0.15	1993	0	0.00	0.00	0.00	0.2	1
134	1994	2	0.3	-0.18	1992	0	0.49	0.00	0.00	0.2	2
135	1994	3	0.3	-0.03	1991	1	0.38	0.53	0.00	0.2	3
136	1994	4	0.3	0.03	1990	1	1.46	0.54	0.11	0.2	4
137	1994	5	0.3	0.02	1989	1	1.81	0.94	0.41	0.2	5
138	1994	6	0.3	0.04	1988	1	0.55	1.42	0.93	0.2	1
139	1994	7	0.3	0.05	1987	1	0.48	1.74	0.98	0.2	2
140	1994	8	0.3	0.04	1986	1	-0.69	2.42	1.00	0.2	3
141	1994	9	0.3	0.10	1985	1	-2.53	3.19	1.00	0.2	4
142	1994	10	0.3	0.13	1984	1	-3.22	4.36	1.00	0.2	5
143	1994	11	0.3	0.15	1983	1	-3.51	5.20	1.00	0.2	6
144	1994	12	0.3	0.13	1982	1	-3.91	6.03	1.00	0.2	7
145	1995	1	0.3	-0.15	1994	0	0.00	0.00	0.00	0.2	1
146	1995	2	0.3	-0.18	1993	0	-1.17	0.00	0.00	0.2	2
147	1995	3	0.3	-0.03	1992	1	0.15	0.38	0.01	0.2	3
148	1995	4	0.3	0.03	1991	1	0.51	0.72	0.04	0.2	4
149	1995	5	0.3	0.02	1990	1	2.57	1.13	0.43	0.2	5
150	1995	6	0.3	0.04	1989	1	2.98	1.63	0.82	0.2	1
151	1995	7	0.3	0.05	1988	1	1.48	2.14	1.00	0.2	2
152	1995	8	0.3	0.04	1987	1	1.75	2.39	1.00	0.2	3
153	1995	9	0.3	0.10	1986	1	0.78	3.08	1.00	0.2	4
154	1995	10	0.3	0.13	1985	1	-1.39	3.93	1.00	0.2	5
155	1995	11	0.3	0.15	1984	1	-1.61	4.32	1.00	0.2	6
156	1995	12	0.3	0.13	1983	1	-4.61	5.12	1.00	0.2	7
157	1996	1	0.3	-0.15	1995	1	-0.11	0.00	0.00	0.2	1
158	1996	2	0.3	-0.18	1994	1	0.08	0.00	0.01	0.2	2

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
159	1996	3	0.3	-0.03	1993	1	1.30	0.58	0.02	0.2	3
160	1996	4	0.3	0.03	1992	1	1.29	0.72	0.07	0.2	4
161	1996	5	0.3	0.02	1991	1	0.28	1.12	0.33	0.2	5
162	1996	6	0.3	0.04	1990	1	0.99	1.79	0.82	0.2	1
163	1996	7	0.3	0.05	1989	1	1.07	2.26	0.97	0.2	2
164	1996	8	0.3	0.04	1988	1	-0.62	2.70	1.00	0.2	3
165	1996	9	0.3	0.10	1987	1	-0.78	3.00	1.00	0.2	4
166	1996	10	0.3	0.13	1986	1	-2.41	3.73	1.00	0.2	5
167	1996	11	0.3	0.15	1985	1	-2.41	4.55	1.00	0.2	6
168	1996	12	0.3	0.13	1984	1	-3.91	4.47	1.00	0.2	7
169	1997	1	0.3	0.00	1996	1	-1.14	0.00	0.00	0.2	1
170	1997	2	0.3	0.00	1995	1	0.52	0.00	0.00	0.2	2
171	1997	3	0.3	0.00	1994	1	0.89	0.48	0.03	0.2	3
172	1997	4	0.3	0.00	1993	1	0.01	0.78	0.09	0.2	4
173	1997	5	0.3	0.00	1992	1	-0.78	1.13	0.50	0.2	5
174	1997	6	0.3	0.00	1991	1	-1.39	1.67	0.86	0.2	1
175	1997	7	0.3	0.00	1990	1	-1.35	2.27	0.96	0.2	2
176	1997	8	0.3	0.00	1989	1	-1.56	2.86	0.99	0.2	3
177	1997	9	0.3	0.00	1988	1	-2.12	3.20	1.00	0.2	4
178	1997	10	0.3	0.00	1987	1	-3.22	3.38	1.00	0.2	5
179	1997	11	0.3	0.00	1986	1	-4.61	4.30	1.00	0.2	6
180	1997	12	0.3	0.00	1985	0	0.00	5.54	1.00	0.2	7
181	1998	1	0.3	0.00	1997	1	-0.33	0.00	0.00	0.2	1
182	1998	2	0.3	0.00	1996	1	0.25	0.00	0.00	0.2	2
183	1998	3	0.3	0.00	1995	1	1.84	0.51	0.02	0.2	3
184	1998	4	0.3	0.00	1994	1	2.00	0.79	0.15	0.2	4
185	1998	5	0.3	0.00	1993	1	1.59	1.19	0.40	0.2	5
186	1998	6	0.3	0.00	1992	1	1.26	1.64	0.93	0.2	1
187	1998	7	0.3	0.00	1991	1	0.55	2.13	0.99	0.2	2
188	1998	8	0.3	0.00	1990	1	0.78	2.79	0.99	0.2	3
189	1998	9	0.3	0.00	1989	1	0.89	3.62	1.00	0.2	4
190	1998	10	0.3	0.00	1988	1	-0.97	3.79	1.00	0.2	5
191	1998	11	0.3	0.00	1987	1	-1.35	4.04	1.00	0.2	6
192	1998	12	0.3	0.00	1986	1	-2.81	4.89	1.00	0.2	7
193	1999	1	0.3	0.00	1998	1	0.27	0.00	0.00	0.2	1
194	1999	2	0.3	0.00	1997	1	1.12	0.00	0.00	0.2	2
195	1999	3	0.3	0.00	1996	1	0.92	0.62	0.02	0.2	3
196	1999	4	0.3	0.00	1995	1	0.82	0.76	0.10	0.2	4
197	1999	5	0.3	0.00	1994	1	0.88	1.27	0.46	0.2	5
198	1999	6	0.3	0.00	1993	1	0.75	1.90	0.82	0.2	1
199	1999	7	0.3	0.00	1992	1	0.43	2.28	0.99	0.2	2
200	1999	8	0.3	0.00	1991	1	-0.94	2.61	1.00	0.2	3
201	1999	9	0.3	0.00	1990	1	-0.39	3.49	1.00	0.2	4
202	1999	10	0.3	0.00	1989	1	-0.65	4.64	1.00	0.2	5
203	1999	11	0.3	0.00	1988	1	-2.66	4.54	1.00	0.2	6
204	1999	12	0.3	0.00	1987	1	-3.91	4.93	1.00	0.2	7
205	2000	1	0.3	0.00	1999	1	0.32	0.00	0.00	0.2	1
206	2000	2	0.3	0.00	1998	1	1.35	0.00	0.00	0.2	2
207	2000	3	0.3	0.00	1997	1	1.90	0.48	0.00	0.2	3
208	2000	4	0.3	0.00	1996	1	1.26	0.79	0.08	0.2	4
209	2000	5	0.3	0.00	1995	1	0.81	1.12	0.38	0.2	5
210	2000	6	0.3	0.00	1994	1	0.56	1.80	0.81	0.2	1
211	2000	7	0.3	0.00	1993	1	0.10	2.52	0.97	0.2	2
212	2000	8	0.3	0.00	1992	1	-0.22	2.67	1.00	0.2	3

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
213	2000	9	0.3	0.00	1991	1	-1.17	2.98	1.00	0.2	4
214	2000	10	0.3	0.00	1990	1	-1.27	4.25	1.00	0.2	5
215	2000	11	0.3	0.00	1989	1	-0.78	5.90	1.00	0.2	6
216	2000	12	0.3	0.00	1988	1	-2.21	5.53	1.00	0.2	7
217	2001	1	0.3	0	2000	1	-0.01	0.00	0.00	0.2	1
218	2001	2	0.3	0	1999	1	1.06	0.00	0.00	0.2	2
219	2001	3	0.3	0	1998	1	2.44	0.57	0.03	0.2	3
220	2001	4	0.3	0	1997	1	2.36	0.79	0.07	0.2	4
221	2001	5	0.3	0	1996	1	1.31	1.14	0.35	0.2	5
222	2001	6	0.3	0	1995	1	0.55	1.62	0.76	0.2	1
223	2001	7	0.3	0	1994	1	0.08	2.31	0.96	0.2	2
224	2001	8	0.3	0	1993	1	-0.42	3.06	1.00	0.2	3
225	2001	9	0.3	0	1992	1	-0.51	3.00	1.00	0.2	4
226	2001	10	0.3	0	1991	1	-1.14	3.30	1.00	0.2	5
227	2001	11	0.3	0	1990	1	-0.84	5.07	1.00	0.2	6
228	2001	12	0.3	0	1989	1	-0.22	7.50	1.00	0.2	7
229	2002	1	0.3	0	2001	1	-0.24	0.00	0.00	0.2	1
230	2002	2	0.3	0	2000	1	0.43	0.00	0.00	0.2	2
231	2002	3	0.3	0	1999	1	1.31	0.44	0.03	0.2	3
232	2002	4	0.3	0	1998	1	1.96	0.84	0.16	0.2	4
233	2002	5	0.3	0	1997	1	1.60	1.25	0.63	0.2	5
234	2002	6	0.3	0	1996	1	0.95	1.71	0.75	0.2	1
235	2002	7	0.3	0	1995	1	0.55	2.12	0.94	0.2	2
236	2002	8	0.3	0	1994	1	-0.16	2.83	0.99	0.2	3
237	2002	9	0.3	0	1993	1	-0.80	3.84	1.00	0.2	4
238	2002	10	0.3	0	1992	1	-1.17	3.53	1.00	0.2	5
239	2002	11	0.3	0	1991	1	-2.66	3.66	1.00	0.2	6
240	2002	12	0.3	0	1990	1	-2.21	5.82	1.00	0.2	7
241	2003	1	0.3	0	2002	1	-0.49	0.00	0.00	0.2	1
242	2003	2	0.3	0	2001	1	0.96	0.00	0.01	0.2	2
243	2003	3	0.3	0	2000	1	0.81	0.57	0.02	0.2	3
244	2003	4	0.3	0	1999	1	1.30	0.75	0.14	0.2	4
245	2003	5	0.3	0	1998	1	1.77	1.27	0.58	0.2	5
246	2003	6	0.3	0	1997	1	1.26	1.81	0.97	0.2	1
247	2003	7	0.3	0	1996	1	0.29	2.19	0.94	0.2	2
248	2003	8	0.3	0	1995	1	-0.46	2.47	0.99	0.2	3
249	2003	9	0.3	0	1994	1	-1.27	3.47	1.00	0.2	4
250	2003	10	0.3	0	1993	1	-1.83	4.53	1.00	0.2	5
251	2003	11	0.3	0	1992	1	-1.77	4.09	1.00	0.2	6
252	2003	12	0.3	0	1991	1	-3.22	4.54	1.00	0.2	7
253	2004	1	0.3	0	2003	1	-1.11	0.00	0.00	0.2	1
254	2004	2	0.3	0	2002	1	0.81	0.00	0.00	0.2	2
255	2004	3	0.3	0	2001	1	0.92	0.46	0.04	0.2	3
256	2004	4	0.3	0	2000	1	0.62	0.81	0.10	0.2	4
257	2004	5	0.3	0	1999	1	0.66	1.15	0.52	0.2	5
258	2004	6	0.3	0	1998	1	1.25	1.79	0.91	0.2	1
259	2004	7	0.3	0	1997	1	1.28	2.30	1.00	0.2	2
260	2004	8	0.3	0	1996	1	0.08	2.53	0.99	0.2	3
261	2004	9	0.3	0	1995	1	-0.39	2.74	1.00	0.2	4
262	2004	10	0.3	0	1994	1	-0.56	4.41	1.00	0.2	5
263	2004	11	0.3	0	1993	1	-0.40	5.64	1.00	0.2	6
264	2004	12	0.3	0	1992	1	-2.04	4.75	1.00	0.2	7
265	2005	1	0.3	0	2004	1	-0.22	0.00	0.00	0.2	1
266	2005	2	0.3	0	2003	1	0.49	0.00	0.01	0.2	2

Obs	year	age	sf	lq_offset	cohort	est_wt	log_ index	weight	mat	m	nz
267	2005	3	0.3	0	2002	1	1.99	0.51	0.02	0.2	3
268	2005	4	0.3	0	2001	1	1.98	0.74	0.21	0.2	4
269	2005	5	0.3	0	2000	1	1.25	1.16	0.41	0.2	5
270	2005	6	0.3	0	1999	1	0.73	1.59	0.87	0.2	1
271	2005	7	0.3	0	1998	1	0.42	2.24	0.99	0.2	2
272	2005	8	0.3	0	1997	1	0.18	2.69	1.00	0.2	3
273	2005	9	0.3	0	1996	1	-0.89	2.94	1.00	0.2	4
274	2005	10	0.3	0	1995	1	-2.41	3.04	1.00	0.2	5
275	2005	11	0.3	0	1994	1	-1.90	4.68	1.00	0.2	6
276	2005	12	0.3	0	1993	1	-2.81	6.42	1.00	0.2	7
277	2006	1	0.3	0	2005	0	0.00	0.00	0.00	0.2	1
278	2006	2	0.3	0	2004	0	0.00	0.00	0.00	0.2	2
279	2006	3	0.3	0	2003	0	0.00	0.46	0.02	0.2	3
280	2006	4	0.3	0	2002	0	0.00	0.80	0.10	0.2	4
281	2006	5	0.3	0	2001	0	0.00	1.21	0.61	0.2	5
282	2006	6	0.3	0	2000	0	0.00	1.64	0.80	0.2	1
283	2006	7	0.3	0	1999	0	0.00	2.00	0.98	0.2	2
284	2006	8	0.3	0	1998	0	0.00	2.60	1.00	0.2	3
285	2006	9	0.3	0	1997	0	0.00	3.16	1.00	0.2	4
286	2006	10	0.3	0	1996	0	0.00	3.31	1.00	0.2	5
287	2006	11	0.3	0	1995	0	0.00	3.19	1.00	0.2	6
288	2006	12	0.3	0	1994	0	0.00	4.63	1.00	0.2	7
289	2007	1	0.3	0	2006	1	1.20	0.00	0.00	0.2	1
290	2007	2	0.3	0	2005	1	0.85	0.00	0.00	0.2	2
291	2007	3	0.3	0	2004	1	1.67	0.47	0.01	0.2	3
292	2007	4	0.3	0	2003	1	1.18	0.71	0.08	0.2	4
293	2007	5	0.3	0	2002	1	0.75	1.20	0.39	0.2	5
294	2007	6	0.3	0	2001	1	0.13	1.73	0.90	0.2	1
295	2007	7	0.3	0	2000	1	-0.27	2.07	0.96	0.2	2
296	2007	8	0.3	0	1999	1	-1.05	2.33	1.00	0.2	3
297	2007	9	0.3	0	1998	1	-0.58	3.14	1.00	0.2	4
298	2007	10	0.3	0	1997	1	-0.99	4.07	1.00	0.2	5
299	2007	11	0.3	0	1996	1	-2.12	4.30	1.00	0.2	6
300	2007	12	0.3	0	1995	1	-2.30	3.79	1.00	0.2	7
301	2008	1	0.3	0	2007	1	-0.60	0.00	0.00	0.2	1
302	2008	2	0.3	0	2006	1	1.41	0.00	0.00	0.2	2
303	2008	3	0.3	0	2005	1	1.46	0.47	0.01	0.2	3
304	2008	4	0.3	0	2004	1	1.18	0.75	0.05	0.2	4
305	2008	5	0.3	0	2003	1	0.69	1.19	0.25	0.2	5
306	2008	6	0.3	0	2002	1	0.20	1.65	0.79	0.2	1
307	2008	7	0.3	0	2001	1	-0.69	2.10	0.98	0.2	2
308	2008	8	0.3	0	2000	1	-1.08	2.54	0.99	0.2	3
309	2008	9	0.3	0	1999	1	-2.12	3.08	1.00	0.2	4
310	2008	10	0.3	0	1998	1	-1.97	3.45	1.00	0.2	5
311	2008	11	0.3	0	1997	1	-2.53	4.00	1.00	0.2	6
312	2008	12	0.3	0	1996	1	-3.22	4.83	1.00	0.2	7

SAS PROC NLMIXED Code

```
title "SAS Standard SURBA for &sname";
ods output ParameterEstimates = parm_est;
proc nlmixed data=input tech=quanew ds=0.5 maxit=2000;
  parms logR1972 - logR&last_cohort = 1
        f&first_year - f&second_last_year = -1
        s1=0 s2=0 s3=0 s4=0 s5=0 s7 - s&last_age_minus1 = 0
        S_std = 0.1;
 logR1971=(logR1972+logR1973+logR1974)/3;
 array lR[&n_cohort] logR&first_cohort - logR&last_cohort;

 array S_lQ[12] 0.00 0.69 1.60 2.30 2.30 2.30 2.30 2.30 2.30 2.30 2.30 2.30;
** flat q's;
* array S_lQ[12] 0.000 0.693 1.610 2.300 2.300 2.300 2.200 2.080 1.950 1.790
1.610 1.390; **  dome q's;
* array S_lQ[12] 0.000 0.223 0.916 1.610 1.610 1.610 1.610 1.610 1.610 1.610
1.610 1.610; ** flatter q's;

 s6 = 0;
 s&last_age = s&last_age_minus1;
 array ls[&n_age] s&first_age-s&last_age;
 f&last_year = (f2005+f2006+f2007)/3;
 array lf[&n_year] f&first_year- f&last_year;

** assign recruitment parameters;
  logrec = 0;
  ic= cohort - &first_cohort + 1;
  logrec = lR[ic];

** assign catchability (Q) parameters;
  logq = 0;
  ia = age - &first_age + 1;
  logq = S_lQ[ia];

** compute z;
  z = 0;
  fy=0;
  iy = year - &first_year + 1;
  z= exp(ls[ia])*exp(lf[iy]);
  fy = exp(lf[iy]);
  pz = sf*z;

** compute cumulative z;
  cz=0;
  do a = &first_age_plus1 to &last_age;
    ia= a - &first_age + 1;
    y = cohort + a;
    iy = y - &first_year + 1;
    if age>=a and iy>1 then cz=cz + exp(ls[ia-1])*exp(lf[iy-1]);
  end;

  log_number = logrec - cz;
  Elog_index = logq + log_number - pz;
  Eindex = exp(Elog_index);

  index_var = S_std**2;

  pen_fy=0;pen_sa=0;
  do i=2 to &n_year-1;
```

```
    yi = i + &first_year - 1;
    if ((yi^=1994)&(yi^=1997)) then do;
      pen_fy = pen_fy + (lf[i]-lf[i-1])**2;

    end;
  end;
  do i=2 to &n_age;
    pen_sa = pen_sa + (ls[i]-ls[i-1])**2;
  end;

  sse = (log_index - Elog_index)**2 + &pen_wt_fy*pen_fy + &pen_wt_sa*pen_sa;
  loglike = est_wt*(-0.9189385 - log(S_std) - sse/(2*index_var));
  model index ~ general(loglike);

  id z Elog_index logq index_var fy;
  predict log_number out=num_est(rename=(pred=log_number));
  predict logq out=Q_est(rename=(pred=logq1));

  number = exp(log_number);
  biomass_age = weight*number;
  ssb_age = mat*biomass_age;
  biomass+biomass_age;
  ssb+ssb_age;
  sum_z+z;
  abundance+number;

  if age=&first_age then do;
    biomass = biomass_age;
    ssb = ssb_age;
    sum_z = z;
    abundance=number;
  end;
  if age=&al then sum_z = z;
  lbiomass=.;
  if biomass>0 then lbiomass=log(biomass);
  labundance = log(abundance);
  ave_z = sum_z/nz;
  lssb=.;
  if ssb>0 then lssb=log(ssb);

** code to get ci for ssb relative to 1994 ssb;
  temp = 0;
  if year=1994 and age=&last_age then temp=lssb;
  temp1+temp;
  if year<1994 then lssb_1994=temp1;
  if year=1994 and age<&last_age then lssb_1994=temp1;
  if year=1994 and age=&last_age then lssb_1994=temp1/2;
  if year>1994 then lssb_1994=temp1/2;
  lssb_diff = lssb - lssb_1994;
  *lssb_diff = lssb_1994;

** code to get ci for ssb relative to 1994 ssb;
  tempa = 0;
  if year=1994 and age=&last_age then tempa=lbiomass;
  tempa1+tempa;
  if year<1994 then lbiomass_1994=tempa1;
  if year=1994 and age<&last_age then lbiomass_1994=tempa1;
  if year=1994 and age=&last_age then lbiomass_1994=tempa1/2;
  if year>1994 then lbiomass_1994=tempa1/2;
  lbiomass_diff = lbiomass - lbiomass_1994;
```

```
  predict lbiomass out=bms_est(rename=(pred=log_biomass));
  predict lssb out=ssb_est(rename=(pred=log_ssb));
  predict lssb_diff out=ssb_trend(rename=(pred=rssb_Brec));
  predict lbiomass_diff out=bms_trend(rename=(pred=rbms_Brec));
  predict ave_z out=z_est(rename=(pred=ave_z));
  predict labundance out=abund_est(rename=(pred=log_abundance));
run;
```

Output Results

SAS Standard SURBA for 3Ps_COD 40

The NLMIXED Procedure

Specifications

Data Set	WORK.INPUT
Dependent Variable	index
Distribution for Dependent Variable	General
Optimization Technique	Dual Quasi-Newton
Integration Method	None

Dimensions

Observations Used	312
Observations Not Used	0
Total Observations	312
Parameters	72

Parameters

logR1972	logR1973	logR1974	logR1975	logR1976	logR1977	logR1978	logR1979	logR1980	logR1981
1	1	1	1	1	1	1	1	1	1

Parameters

logR1982	logR1983	logR1984	logR1985	logR1986	logR1987	logR1988	logR1989	logR1990	logR1991
1	1	1	1	1	1	1	1	1	1

Parameters

logR1992	logR1993	logR1994	logR1995	logR1996	logR1997	logR1998	logR1999	logR2000	logR2001
1	1	1	1	1	1	1	1	1	1

Parameters

logR2002	logR2003	logR2004	logR2005	logR2006	logR2007	f1983	f1984	f1985	f1986
1	1	1	1	1	1	-1	-1	-1	-1

Parameters

f1987	f1988	f1989	f1990	f1991	f1992	f1993	f1994	f1995	f1996
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Parameters

f1997	f1998	f1999	f2000	f2001	f2002	f2003	f2004	f2005	f2006
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Parameters

f2007	s1	s2	s3	s4	s5	s7	s8	s9	s10
-1	0	0	0	0	0	0	0	0	0

Parameters

s11	S_std	NegLogLike
0	0.1	42450.2472

Iteration History

Iter	Calls	NegLogLike	Diff	MaxGrad	Slope
1	14	1415.90019	41034.35	4171.688	-7.297E9
2	22	665.391495	750.5087	906.4489	-14.1079
3	24	510.635581	154.7559	350.9483	-145.941
4	26	427.284004	83.35158	53.44808	-47.9035
5	28	414.227645	13.05636	20.78623	-14.5117
6	30	408.055406	6.172239	27.8729	-3.21648
7	32	398.707872	9.347534	69.91727	-4.48402
8	34	390.343479	8.364393	62.21508	-4.31978
9	36	386.170206	4.173273	62.17051	-2.20307
10	38	378.409306	7.760899	46.74405	-5.2478

11	40	366.507891	11.90142	52.74747	-13.4467
12	42	359.222416	7.285475	43.57543	-9.80988
13	43	355.711674	3.510742	16.14559	-6.05961
14	45	346.274474	9.4372	20.02134	-4.28075
15	46	341.720314	4.554161	22.34543	-9.58204
16	48	339.828992	1.891322	26.24696	-2.88148
17	50	335.199526	4.629466	29.7879	-2.00542
18	51	330.660148	4.539378	23.02909	-8.32932
19	53	327.637494	3.022654	10.03842	-5.36155
20	55	325.559428	2.078066	16.59522	-1.55098
21	57	319.250516	6.308912	30.43334	-1.9438
22	59	317.739951	1.510565	10.68238	-1.00804
23	61	312.585576	5.154375	29.25592	-2.58683
24	63	307.356805	5.228771	26.67238	-6.75099
25	64	304.998659	2.358146	16.44417	-3.73602
26	66	299.451752	5.546907	36.58264	-3.53913
27	68	294.706853	4.744899	10.76405	-5.06127
28	70	293.149677	1.557176	27.2602	-1.77321
29	72	289.114594	4.035083	21.5027	-2.07199
30	74	286.892173	2.222421	16.48037	-2.63305
31	76	285.261705	1.630469	9.158383	-1.15331
32	78	282.654755	2.60695	10.89936	-1.97414
33	79	281.598508	1.056247	16.14489	-1.77431
34	81	280.193593	1.404914	17.38561	-0.84075
35	83	278.537803	1.65579	32.34165	-1.53908
36	84	277.770943	0.766861	15.23094	-1.12302
37	86	276.69613	1.074813	27.63268	-1.03979
38	88	275.089207	1.606923	5.469588	-1.15728
39	90	274.629351	0.459855	4.155615	-0.44888
40	92	273.471595	1.157756	11.67032	-0.51026
41	94	272.840205	0.63139	9.435597	-0.68802
42	96	272.21039	0.629814	11.77481	-0.45193
43	98	271.57958	0.630811	6.793453	-0.71719
44	99	271.375399	0.204181	3.392609	-0.29909
45	101	271.100938	0.27446	7.10547	-0.24732
46	103	270.777968	0.32297	5.604265	-0.20279
47	105	270.540938	0.23703	3.346017	-0.12687
48	107	270.151416	0.389523	2.390822	-0.2801
49	109	270.05415	0.097266	6.480411	-0.09002
50	111	269.879966	0.174184	1.72509	-0.08473
51	112	269.82465	0.055316	1.257159	-0.08098
52	114	269.782634	0.042017	1.220639	-0.04194
53	116	269.667128	0.115505	2.170059	-0.03484

54	118	269.552643	0.114485	5.571198	-0.04216
55	119	269.48404	0.068603	2.980516	-0.09935
56	121	269.455965	0.028075	0.786279	-0.04011
57	123	269.398672	0.057294	0.713241	-0.01298
58	125	269.374783	0.023888	1.483237	-0.02899
59	127	269.329153	0.04563	1.237167	-0.01919
60	129	269.278654	0.050499	1.013931	-0.03784
61	131	269.228472	0.050182	1.154623	-0.01585
62	133	269.158997	0.069476	1.226688	-0.04262
63	135	269.126597	0.0324	1.282497	-0.0273
64	137	269.010019	0.116578	1.538739	-0.02485
65	139	268.941899	0.06812	1.866997	-0.05786
66	141	268.776462	0.165436	1.797156	-0.04761
67	142	268.74236	0.034102	1.600964	-0.0501
68	144	268.708458	0.033902	0.912902	-0.03228
69	146	268.664458	0.044	1.660927	-0.02642
70	148	268.636939	0.027519	1.876567	-0.02939
71	150	268.539855	0.097084	1.132037	-0.03597
72	151	268.517244	0.022611	1.423872	-0.03288
73	153	268.491074	0.026169	1.076597	-0.02327
74	155	268.445308	0.045766	1.406538	-0.02572
75	157	268.415636	0.029673	1.518793	-0.02126
76	159	268.373176	0.042459	0.713824	-0.02723
77	161	268.356122	0.017054	0.675855	-0.01121
78	163	268.331114	0.025009	0.580848	-0.01335
79	165	268.318748	0.012366	0.650469	-0.00871
80	167	268.301964	0.016784	0.612435	-0.00838
81	169	268.296412	0.005552	0.404439	-0.00504
82	171	268.280343	0.016069	0.377496	-0.0056
83	172	268.277192	0.003151	0.428709	-0.00466
84	174	268.274406	0.002785	0.35349	-0.00253
85	176	268.268802	0.005604	0.352209	-0.00232
86	178	268.263473	0.005329	0.265591	-0.00139
87	180	268.261999	0.001474	0.295727	-0.00184
88	182	268.259941	0.002058	0.174959	-0.00102
89	184	268.258003	0.001939	0.169674	-0.00166
90	186	268.257142	0.00086	0.176597	-0.00025
91	188	268.256337	0.000805	0.169307	-0.00072
92	190	268.255465	0.000872	0.135633	-0.00037
93	192	268.254828	0.000637	0.222894	-0.0006
94	194	268.25391	0.000917	0.243025	-0.00015
95	195	268.253399	0.000511	0.194507	-0.00077
96	197	268.253211	0.000189	0.101787	-0.00024

97	200	268.250839	0.002371	0.19233	-0.00013
98	201	268.250357	0.000482	0.108886	-0.00072
99	203	268.25011	0.000248	0.15664	-0.00025
100	206	268.246971	0.003138	0.2213	-0.00024
101	208	268.246705	0.000266	0.140502	-0.00021
102	210	268.244653	0.002053	0.247876	-0.00033
103	211	268.244269	0.000384	0.123675	-0.00062
104	213	268.243944	0.000325	0.136136	-0.0002
105	215	268.242788	0.001155	0.068648	-0.00037
106	217	268.242622	0.000166	0.070166	-0.00005
107	219	268.241695	0.000927	0.03866	-0.00022
108	221	268.241662	0.000033	0.056434	-0.00003
109	224	268.24132	0.000342	0.068533	-0.00003
110	225	268.241182	0.000138	0.023631	-0.0002
111	227	268.241158	0.000024	0.018351	-0.00004
112	230	268.241059	0.000099	0.013307	-3.91E-6
113	231	268.241055	4.641E-6	0.007831	-8.12E-6
114	233	268.241053	1.263E-6	0.007058	-7.83E-7

NOTE: GCONV convergence criterion satisfied.

The NLMIXED Procedure

Fit Statistics

-2 Log Likelihood	536.5
AIC (smaller is better)	680.5
AICC (smaller is better)	724.5
BIC (smaller is better)	950.0

Parameter Estimates

Parameter	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper	Gradient
logR1972	-3.8010	0.4514	312	-8.42	<.0001	0.05	-4.6892	-2.9128	0.001706
logR1973	-3.0120	0.3776	312	-7.98	<.0001	0.05	-3.7550	-2.2690	-0.00111
logR1974	-2.3485	0.3390	312	-6.93	<.0001	0.05	-3.0155	-1.6816	-0.00152
logR1975	-2.5416	0.3190	312	-7.97	<.0001	0.05	-3.1692	-1.9140	-0.00204
logR1976	-2.3989	0.2992	312	-8.02	<.0001	0.05	-2.9875	-1.8102	-0.00323
logR1977	-1.7480	0.2813	312	-6.21	<.0001	0.05	-2.3015	-1.1944	0.005724

logR1978	-1.0367	0.2642	312	-3.92	0.0001	0.05	-1.5566	-0.5168	0.002756
logR1979	-1.0321	0.2507	312	-4.12	<.0001	0.05	-1.5254	-0.5389	-0.0011
logR1980	-0.1229	0.2441	312	-0.50	0.6150	0.05	-0.6032	0.3574	-0.00056
logR1981	0.09556	0.2554	312	0.37	0.7085	0.05	-0.4069	0.5981	0.001627
logR1982	0.5733	0.2732	312	2.10	0.0367	0.05	0.03567	1.1108	-0.00102
logR1983	-0.07618	0.2718	312	-0.28	0.7794	0.05	-0.6109	0.4585	-0.00397
logR1984	0.1672	0.2772	312	0.60	0.5467	0.05	-0.3781	0.7126	0.001183
logR1985	0.4623	0.2957	312	1.56	0.1190	0.05	-0.1195	1.0441	-0.00154
logR1986	0.7820	0.3098	312	2.52	0.0121	0.05	0.1724	1.3916	0.002389
logR1987	1.0697	0.3433	312	3.12	0.0020	0.05	0.3943	1.7451	0.000025
logR1988	0.7377	0.3864	312	1.91	0.0572	0.05	-0.02259	1.4981	-0.00204
logR1989	1.7005	0.4268	312	3.98	<.0001	0.05	0.8608	2.5402	-0.00007
logR1990	0.8544	0.4426	312	1.93	0.0545	0.05	-0.01653	1.7254	0.001028
logR1991	-0.3891	0.4070	312	-0.96	0.3397	0.05	-1.1899	0.4116	0.004453
logR1992	-0.1012	0.3561	312	-0.28	0.7766	0.05	-0.8019	0.5996	-0.0021
logR1993	-0.1804	0.3204	312	-0.56	0.5739	0.05	-0.8109	0.4501	-0.00145
logR1994	-0.1445	0.2979	312	-0.49	0.6280	0.05	-0.7306	0.4416	0.003893
logR1995	-0.1651	0.2579	312	-0.64	0.5224	0.05	-0.6725	0.3423	0.002523
logR1996	-0.2712	0.2354	312	-1.15	0.2502	0.05	-0.7345	0.1920	-0.00298
logR1997	0.4142	0.2411	312	1.72	0.0869	0.05	-0.06028	0.8887	0.001749
logR1998	0.4994	0.2519	312	1.98	0.0483	0.05	0.003712	0.9951	-0.00331
logR1999	-0.08355	0.2662	312	-0.31	0.7538	0.05	-0.6074	0.4402	0.005603
logR2000	-0.1891	0.2831	312	-0.67	0.5045	0.05	-0.7462	0.3679	0.000511
logR2001	0.02961	0.3025	312	0.10	0.9221	0.05	-0.5657	0.6249	0.001718
logR2002	0.1809	0.3267	312	0.55	0.5802	0.05	-0.4619	0.8236	-0.00706
logR2003	-0.2108	0.3610	312	-0.58	0.5596	0.05	-0.9211	0.4994	0.002289
logR2004	0.2760	0.4118	312	0.67	0.5032	0.05	-0.5343	1.0862	-0.00428
logR2005	0.6265	0.4979	312	1.26	0.2092	0.05	-0.3531	1.6062	0.00007
logR2006	1.2221	0.4689	312	2.61	0.0096	0.05	0.2995	2.1448	-0.00033
logR2007	-0.5089	0.6476	312	-0.79	0.4326	0.05	-1.7830	0.7653	-0.00658
f1983	-1.3239	0.2830	312	-4.68	<.0001	0.05	-1.8808	-0.7670	0.004796
f1984	-1.3201	0.2589	312	-5.10	<.0001	0.05	-1.8296	-0.8106	0.000401
f1985	-1.2717	0.2420	312	-5.26	<.0001	0.05	-1.7477	-0.7956	0.000659
f1986	-1.1751	0.2345	312	-5.01	<.0001	0.05	-1.6364	-0.7138	-0.00038
f1987	-1.0342	0.2305	312	-4.49	<.0001	0.05	-1.4877	-0.5807	-0.00106
f1988	-0.8437	0.2263	312	-3.73	0.0002	0.05	-1.2890	-0.3985	0.000301
f1989	-0.6659	0.2184	312	-3.05	0.0025	0.05	-1.0957	-0.2361	-0.0028
f1990	-0.4359	0.2138	312	-2.04	0.0423	0.05	-0.8565	-0.01535	0.000114
f1991	-0.2096	0.2162	312	-0.97	0.3329	0.05	-0.6349	0.2157	0.001567
f1992	-0.1783	0.2209	312	-0.81	0.4200	0.05	-0.6129	0.2562	0.002657
f1993	-0.2757	0.2329	312	-1.18	0.2374	0.05	-0.7341	0.1826	-0.00011
f1994	-0.8681	0.2416	312	-3.59	0.0004	0.05	-1.3435	-0.3927	-0.00268
f1995	-0.7455	0.2370	312	-3.15	0.0018	0.05	-1.2119	-0.2791	-0.00042

f1996	-0.6296	0.2560	312	-2.46	0.0145	0.05	-1.1334	-0.1259	-0.0007
f1997	-1.2694	0.2672	312	-4.75	<.0001	0.05	-1.7951	-0.7437	0.001723
f1998	-1.2381	0.2469	312	-5.02	<.0001	0.05	-1.7238	-0.7524	0.000582
f1999	-1.1860	0.2357	312	-5.03	<.0001	0.05	-1.6498	-0.7222	-0.00016
f2000	-1.1148	0.2298	312	-4.85	<.0001	0.05	-1.5670	-0.6625	-0.00065
f2001	-1.0133	0.2262	312	-4.48	<.0001	0.05	-1.4584	-0.5682	0.002361
f2002	-0.9172	0.2228	312	-4.12	<.0001	0.05	-1.3556	-0.4787	0.000075
f2003	-0.8364	0.2224	312	-3.76	0.0002	0.05	-1.2740	-0.3987	0.00107
f2004	-0.7329	0.2243	312	-3.27	0.0012	0.05	-1.1743	-0.2915	-0.00083
f2005	-0.6329	0.2239	312	-2.83	0.0050	0.05	-1.0735	-0.1923	0.00074
f2006	-0.5544	0.2256	312	-2.46	0.0145	0.05	-0.9982	-0.1105	-0.00217
f2007	-0.4984	0.2436	312	-2.05	0.0416	0.05	-0.9777	-0.01907	-0.00072
s1	-0.6230	0.4841	312	-1.29	0.1991	0.05	-1.5756	0.3295	-0.00121
s2	-0.4847	0.3992	312	-1.21	0.2257	0.05	-1.2702	0.3009	-0.00118
s3	-0.2615	0.3548	312	-0.74	0.4616	0.05	-0.9595	0.4365	0.001856
s4	-0.3215	0.3261	312	-0.99	0.3250	0.05	-0.9632	0.3202	-0.00032
s5	-0.2281	0.2981	312	-0.77	0.4446	0.05	-0.8146	0.3583	-0.00195
s7	0.1922	0.2904	312	0.66	0.5087	0.05	-0.3792	0.7635	-0.00153
s8	0.3334	0.2922	312	1.14	0.2547	0.05	-0.2415	0.9082	0.002145
s9	0.3919	0.2714	312	1.44	0.1498	0.05	-0.1422	0.9259	0.002764
s10	0.2963	0.2631	312	1.13	0.2610	0.05	-0.2214	0.8141	0.005828
s11	0.3451	0.2677	312	1.29	0.1982	0.05	-0.1816	0.8718	0.001037
S_std	0.6464	0.02766	312	23.37	<.0001	0.05	0.5919	0.7008	0.000595