New Zealand Fisheries
Assessment Report
2009/49
October 2009
ISSN 1175-1584

Stock assessment of TRE 7

A. D. Langley
M. Maunder

Stock assessment of TRE 7

A. D. Langley[1]
M. Maunder[2]

[1]7 Van Diemen Street
Nelson 7010

[2]Quantitative Resource Assessment LLC
San Diego, California
USA

New Zealand Fisheries Assessment Report 2009/49
October 2009

Published by Ministry of Fisheries
Wellington
2009

ISSN 1175-1584

Langley, A.D.; Maunder, M. (2009).
Stock assessment of TRE 7.
New Zealand Fisheries Assessment Report 2009/49. 42 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Langley, A.D.; Maunder, M. (2009). Stock assessment of TRE 7.
***New Zealand Fisheries Assessment Report 2009/49.* 42p.**

A stock assessment of TRE 7 was conducted using a statistical, age-structured population model implemented using the Stock Synthesis (SS) software. Primary differences in the models used in the previous (2005) and current (2009) assessments are as follows:

- additional data, including three years catch-at-age and an updated CPUE index;
- a refinement of the assumed level of unreported catch since 1986;
- a change in model software from CASAL to Stock Synthesis. This was demonstrated to have minimal effect on the model results;
- a change in the definition of adult biomass with knife-edge maturity at 5 years old (it was previously assumed that all fish were mature);
- the estimation of separate fishery selectivities for the periods pre and post 1986 to account for an increase in trawl mesh size associated with the introduction of a minimum legal size.

A range of sensitivity analyses was also conducted to investigate some of the key sources of uncertainty in the model, specifically natural mortality, the weighting of the age frequency data, the catch from the early period of the model (pre 1970), the inclusion of an additional CPUE series, and the assumption of equivalent selectivity for the single- and pair trawl fisheries.

There is little contrast in the CPUE indices and estimates of current (2008) biomass are strongly influenced by the recent (1997–08 to 2000–01 and 2005–06 to 2007–08) age frequency data from the commercial fishery and the assumed value of natural mortality. Three levels of natural mortality were initially considered (0.075, 0.087, and 0.10) based on a likelihood profile of this parameter.

The alternative values of natural mortality result in contradictory conclusions regarding the status of the stock. The higher value of *M* results in an estimate of current biomass well above the *MSY* based reference point (B_{2008}/B_{MSY}= 1.87) while the lowest value of *M* (0.075) predicts that current spawning biomass is below the B_{MSY} level (B_{2008}/B_{MSY} = 0.89).

An MCMC approach was applied to estimate model uncertainty for the models with different values of natural mortality. Reasonable results were obtained for the two higher values of natural mortality (0.087 and 0.10); however, problems were encountered for the lower value of natural mortality (0.075) with MCMC parameter values being constrained by the bounds of key parameters (particularly selectivity parameters), thereby resulting in biased estimates of stock status. On this basis, the MCMC results for the lower value of natural mortality were rejected and it was concluded that the lower value of natural mortality was less plausible than the other two values.

Spawning biomass is estimated to have declined gradually during the 1940s and 1950s. The rate of decline increased in the 1960s and 1970s, consistent with the increase in the total annual catch. Female spawning biomass is predicted to have remained stable (*M*= 0.087) or to have increased (*M*= 0.1) since the 1980s, with moderate–high probability that the current biomass was above the B_{MSY} level in 2008 (61% and 100%, respectively).

Stock projections, for a five-year period, were conducted for the two accepted models (M= 0.087 and M= 0.10). The projections assumed a constant catch based on the TAC and an allowance for recreational and customary catch. For both models, the stock size is predicted to remain at about the current level over the next five years, and remain at or above the B_{MSY} level (probability of 61% and 100% for natural mortality of 0.087 and 0.10, respectively) with a high probability (95% and 100%, respectively) that the biomass will remain above 20% of the unexploited level (B_0). For both models the stock was virtually certain to remain above 10% of B_0 (probability of 100% in both cases).

1. INTRODUCTION

Trevally (*Pseudocaranx dentex*) comprise a major component of the catch from the inshore fishery off the west coast of the North Island. This area accounts for almost all of the catch from the TRE 7 fishstock. Reported landings from the fishery peaked in the late 1970s and early 1980s at 2500–3000 t. Catches were reduced considerably in the late 1980s and since the early 1990s catches have fluctuated about the level of the current TACC of 2153 t (Ministry of Fisheries Science Group 2008).

This report documents the results of a stock assessment of TRE 7 undertaken as a component of the Ministry of Fisheries research project TRE2008-02. The principal objective of the project is "to conduct a stock assessment for trevally (*Pseudocaranx dentex*) in TRE 7, including estimating biomass and sustainable yields".

A number of assessments of the TRE 7 fishstock have been undertaken over the last decade (Hanchet 1999, Maunder & Langley 2004, McKenzie 2008). The assessments have principally been based on a time series of standardised CPUE indices from the commercial trawl fishery and age frequency data from the sampling of the commercial catch. Primary differences in the models used in the previous (2005) and current (2009) assessments are as follows.

- Additional data, including three years catch-at-age and an updated CPUE index.
- Refinement of the assumed level of unreported catch since 1986.
- Change in model software from CASAL to Stock Synthesis. This was demonstrated to have minimal effect on the model results.
- A change in the definition of adult biomass with knife-edge maturity at 5 years old (it was previously assumed that all fish were mature).
- Estimation of separate fishery selectivities for the periods pre and post 1986 to account for an increase in trawl mesh size associated with the introduction of a minimum legal size.

2. MODEL DATA SETS

The model incorporates four sources of observational data from the TRE 7 fishery: annual catches, a time series of standardised CPUE indices, age frequency distributions from research trawl surveys (from the 1970s), and age frequency distributions from market sampling of the commercial catch during the 1970s and from 1997–98 onwards.

2.1 Catch

Catch data are available from 1944 to the 2007–08 fishing year. The catch history was configured in a similar manner to previous assessments, including the reported catch, an assumed level of discarded catch during 1944–69, a non-reported catch, and a small recreational and customary harvest (Figure 1, Appendix 1). The annual non-reported catch was assumed equal to 20% of the reported catch for the years before 1986–87; reduced to 10% of the reported catch in 1986–87 and assumed to decrease by 1% of the reported catch each year until 1995–96, after which it was fixed at 1% of the reported catch.

The reported commercial catch principally comprises catches from the single and pair trawl fisheries. Catches from both methods are amalgamated in a composite commercial fishery in the stock assessment model (as in previous assessments) due to the lack of separate catch statistics for the historical catch data. A sensitivity analysis was conducted to investigate the influence of combining the two fishing methods (see Section 6.5).

2.2 CPUE indices

Recent stock assessments of TRE 7 have included a time series of standardised CPUE indices from the bottom trawl fishery as the principal series of abundance indices (McKenzie 2008). The annual indices are derived from catch and effort data from single bottom trawls targeting either trevally or snapper in TRE 7. The indices begin in 1990 as catch and effort data from the earlier years are not available in a comparable format. Kendrick & Bentley (unpublished results) recently updated the principal CPUE index to include the period 1989–90 to 2007–08 (1990–2008 model years).

2.3 Age compositions

Age frequency data from the commercial fishery were available from two distinct periods: the 1970s and 1997–08 to 2007–08. Data from the 1970s were described in detail by McKenzie (2008). Five years of data are available from the 1970s (1974–76, 1978, and 1979) and comprise samples from both single trawl and pair trawl methods. These data have an accumulated age class of 13+ years.

Recent age frequency data from the TRE 7 single trawl fishery are summarised in Walsh et al. (unpublished results). Annual age distributions are available from 1997–08 to 2000–01 and 2005–06 to 2007–08. The age classes greater than 19 years are amalgamated in a single plus group (20+).

Three years of age frequency data (1971, 1972, and 1974) were available from research trawls conducted by R.V. *James Cook*. Details of the calculation of the age frequency distributions were provided by McKenzie (2008). An accumulating age class of 13+ years was applied to these data.

3. MODEL STRUCTURE AND ASSUMPTIONS

A statistical, age-structured population model was implemented using the Stock Synthesis (SS) software (version 3.02C) (Methot 2009). For simplicity and compatibility with previous assessments, the stock assessment model adopts an annual structure with a single (12 month) fishing season. Catches and other observational data are assigned to the calendar year of the end of the fishing year (for example, the 2002–03 fishing year is denoted 2003).

The model encompasses the 1944–2008 period. The model structure includes two sexes, 1–20 year age classes, and an accumulating age class for older fish (20+ years). Recruitment is defined as fish entering the model population (age 0 year). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state. The catch is removed throughout the fishing season using a hybrid method to calculate fishing mortality that combines Pope's approximation and continuous F (see Methot 2009).

Biological parameters are those used in previous assessments and are equivalent for the two sexes (see Table 1). For the base model, natural mortality was invariant with age at a value of 0.1. A Beverton-Holt spawning stock – recruitment relationship (SRR) was assumed with steepness (*h*) fixed at 0.75 and the standard deviation of the natural logarithm of recruitment (σ_R) is fixed at 0.6. Recruitment deviates were estimated for 1960–2006 as these years encompass the year classes for which there are at least two observations in the age frequency data (with the exceptions of the 1978 and 1979 year classes for which there is only one observation).

Combining single and pair trawl catches for the base model assumes a common selectivity function for both fishing methods. However, during the mid 1980s there were two specific regulatory changes in the fishery that are likely have influenced the selectivity of the trawl fishery: i) the introduction of the minimum legal size of 25 cm for trevally and ii) the increase in the minimum size of the codend mesh size (from 100 to 125 mm). To model the likely change in selectivity, the trawl fishery was split into two time periods: 1944–86 and 1987 onwards.

The selectivities for the two commercial fisheries were parameterised using a logistic function. The selectivity of the research survey was parameterised using a double normal functional form.

The CPUE index was assumed to have a selectivity equivalent to the post 1986 commercial fishery and catchability was temporally invariant. The coefficient of variation (c.v.) for the CPUE indices was determined by iterative reweighting to achieve a standard deviation of the normalised residuals (SDNR) approximating 1.0.

The sample size assigned to each of the three age frequency datasets was determined using an iterative reweighting approach (following McAllister & Ianelli 1997). Sample size was allowed to vary among data sets, while the sample size was held constant within each data set (i.e., by year).

The ageing error associated with the otolith readings has not been quantified; however, ageing error is considered to be low (about 10–15%) for the 4–9 age classes and slightly higher for younger and older age classes (C. Walsh, Stock Monitoring Services Ltd, pers. comm.). Age specific ageing error, parameterised as the standard deviation of age, was incorporated in the model to approximate the following assumed levels: age classes 1–9 years, s.d. = 0.35; age classes 10–19 years, s.d. = 0.4; 20+ years, s.d. = 0.35. The same age specific ageing error was assumed for all age frequency observations.

The CPUE indices are assumed to have a lognormal error structure, while the age frequency distributions are assumed to have a multinomial error structure. The contribution of each component of the objective function was described by Methot (2005).

The model provided estimates of reference (B_0 and B_{MSY}) and current biomass (B_x) and fishing mortality. These management quantities are defined in Table 2.

Model projections were conducted for a 22 year period (2009–30) with annual catches assumed equivalent to the TACC plus an allowance for customary, recreational, and non-reported commercial catch (of total catch of 2257 t). The projections are based on deterministic recruitment (2007–30 year classes) with the assumed value of steepness (0.75) for the Beverton and Holt SRR.

Model uncertainty was estimated using a Markov chain Monte Carlo (MCMC) approach. Recruitment variation in the projection period was incorporated by treating the projection period as part of the model estimation and estimating a recruitment deviate parameter for each year in the projection (see Maunder et al. 2006). The MCMC routine used to implement the Bayesian analysis automatically assigns the uncertainty in future recruitment based on the probability distribution assumed for the recruitment deviates. This is equivalent to randomly drawing deviates from the assumed variation in the recruitment deviates ($\sigma R = 0.60$).

4. PRELIMINARY MODEL RUNS

The previous TRE 7 stock assessment was conducted using the CASAL software (Bull et al. 2005, McKenzie 2008). To ensure comparability of the current assessment results with the previous assessment, preliminary model runs were conducted using SS that attempted to replicate the results of McKenzie (2008). The input data sets were equivalent between the two model platforms and the model structural assumptions, parameterisation, and priors used in the CASAL assessment were replicated (as closely as possible) in the SS model.

The preliminary model runs yielded results very similar to the base results reported by McKenzie (2008) (Table 3). The biomass trajectories are very similar, although the two model platforms use a different definition of spawning biomass; SS defines spawning biomass as mature, female biomass whereas CASAL includes both sexes in the definition (Bull et al. 2005).

Commercial and research trawl selectivity functions computed by the two platforms were very similar. There were some notable differences in the individual annual recruitment deviates although the overall trend in the recruitment deviates was similar.

5. BASE MODEL

5.1 Fits to observational data

The model likelihood is dominated by the age frequency observations, particularly from the recent period. These data were assigned a relatively high weight in the iterative re-weighting fitting procedure.

The SDNR for the CPUE indices approximates the target of 1.0 (Table 4); however, the SDNR values for the three sets of age frequency data are above the target level. This is partly due a lack of convergence of the values of the effective sample size resulting from effective sample sizes being assigned by fishery rather than individual sample. It was also considered that the final values of effective sample size were approaching unrealistically high levels and the iterative re-weighting procedure was halted.

The CPUE indices decline sharply between 1990 and 1993 and then tend to increase gradually during 1993–2008. The base model exhibits a very poor fit to the 1990–95 CPUE indices, in particular the model fails to fit the initial strong decline in CPUE. The fit is considerably better for the latter indices, although the model does not represent a very good fit to the general trend in the indices (Figure 2).

In general, the base model represents a good fit to the two sets of catch-at-age from the commercial fishery (pre- and post 1986) (Figure 3). The earlier years of data are dominated by a large accumulated age class of fish older than 12 years (13+ age class), while the recent catch-at-age data have a 20+ year accumulated age class. The model tends to reliably predict the proportion of fish in the accumulated age class in all years. For the recent data, there is some indication of a lack of fit to the 4–10 year age classes in some years. There is no consistent pattern in the residuals with respect to age, indicating that the lack of fit is due to inter-annual variation in the age composition of the catch that is most likely attributable to changes in the relative vulnerability of individual age classes among years. For example, the 9–14 year age classes appear to be more vulnerable in 2001 than in other years.
The model fits indicate that the strength of recent year classes is not well determined. The 2003 year class is over-estimated as 4 year olds in the 2007 catch-at-age and substantially under-estimated as 5 year olds in 2008 (Figure 3 and Figure 4).

There is a good fit to the older age classes in the research survey age compositions (Figure 4 and Figure 5). However, there is a poor fit to the proportions of fish in the younger age classes (1–3 years) in 1972 and 1974. This may indicate that these age classes were not accurately sampled by the research survey and/or a conflict with the catch-at-age data from the subsequent years.

The residuals from the fit to the age frequency distributions reveal no strong trends in the residuals; however, for the recent catch-at-age data, the variance of the residuals is not consistent with respect to age (Figure 4 and Figure 5). There is a higher degree of variability for the younger age classes (3–7 years) suggesting that the individual year classes are not consistently sampled by the fishery over successive years.

5.2 Model parameterisation

The selectivities for the two commercial fisheries (pre- and post 1986) were parameterised with a logistic function. For the post 1986 fishery, selectivity increased sharply to attain almost full selectivity at 4 years (Figure 6). The early trawl fishery had a higher selectivity for younger fish, reaching full selectivity at 3 years. This is consistent with the changes in fishing regulations in the mid to late 1980s that are likely to have reduced the observations of small (young) fish in the catch.

The selectivity of the research survey is further shifted towards young fish, with a relatively high selectivity for 1 year old fish and full selectivity at 2 years (Figure 6). The selectivity of fish older than about 5 years declines steadily with age.

Recruitment is estimated to have been relatively low during the late 1960s–mid 1970s followed by a very strong 1977 year class (Figure 7). Recruitment fluctuated over the remainder of the model estimation period with recent recruitments (2000–06) at or above the long-term average level. There is a high level of uncertainty associated with the most recent recruitment estimates (2005 and 2006) and high uncertainty associated with future recruitment (Figure 7).

The exceptionally high recruitment estimate for the 1977 year class is strongly influenced by the relatively high proportion of fish in the accumulated age class (20+ years) of the recent commercial catch-at-age data. There are only two observations of the 1977 year class in the age composition data sets (at age 1 and 2 in the 1979 and 1978 market sampling age compositions) and neither age class is fully selected by the fishery. Consequently, the model has considerable freedom to estimate a very strong single year class that sustains the relatively high proportion of fish in the plus group from 1998 onwards.

5.3 Biomass trajectory

During the early model period (1944–67), spawning biomass remains at about the initial unexploited level (Figure 8). Biomass is estimated to decline sharply from the late 1960s to 1980 due to the lower levels of recruitment and large catches during that period. The base model (M = 0.10) predicts that biomass has remained relatively stable since the early 1980s, fluctuating at about 45% of the unexploited level, and increasing since 2000; although there is a high level of uncertainty associated with recent biomass levels (Figure 8). The model with natural mortality of 0.087 has a comparable biomass trajectory up until the early 1990s, but does not exhibit an increase in spawning biomass in the recent period (Figure 8).

Fishing mortality, expressed as a proportion of $F_{40\%SPR}$, was low before the early 1960s and then rapidly increased to reach a peak in the early 1980s, exceeding the $F_{40\%SPR}$ level (Figure 9). Fishing mortality declined in the mid–late 1980s and over the subsequent period fishing mortality has fluctuated around 90% of the $F_{40\%SPR}$ level.

There is no evidence from the model estimates of spawning biomass and recruitment for a strong stock-recruitment relationship, at least over the observed range of spawning biomass (Figure 10).

Variation is future recruitment is incorporated in the model projections by estimating recruitment deviates based on the assumed variation in recruitment (σR = 0.6) (see Figure 7). Stock projections are conducted with a relatively high constant catch. Under these catch assumptions, spawning biomass and average annual recruitment are predicted to decline slightly through the projection period (see Figure 8). Incorporating uncertainty into the recruitment deviates results in a steady increase in the uncertainty associated with the total spawning biomass over the projection period. The assumption of constant catch through the projection period results in a low probability that the spawning biomass would be driven down to very low levels by the end of the projection period (see Figure 8) and this only occurs at unrealistically high levels of fishing mortality (Figure 9).

6. SENSITIVITY ANALYSES

A range of sensitivity analyses was defined in consultation with the Northern Inshore Fishery Working Group. The analyses examined the sensitivity of the assessment results to assumptions regarding natural mortality, the weighting of the age frequency data, the catch from the early period of the model (pre 1970), the inclusion of an additional CPUE series, and the assumption of equivalent selectivity for the single and pair trawl fisheries. Details of the specific sensitivity analyses, where they deviate from the base model, are outlined below. Section 6.6 summarises the results of the sensitivities relative to the base model.

6.1 Natural mortality

The base model assumes natural mortality is equal to 0.10 for all age classes. The validity of this assumption was examined by deriving a likelihood profile for the parameter from the base model. The maximum likelihood value of *M* from the likelihood profile was 0.087 with a 95% confidence interval of 0.072–0.105 (Figure 11). The assumed value of *M* is close to the upper end of this range. On this basis, two separate sensitivity analyses were conducted: a model run with *M* set to the median value of the likelihood profile (0.087) and *M* set to a value close to the lower bound of the likelihood profile (0.075).

6.2 Age frequency data

The iterative reweighting procedure resulted in the three sets of age frequency data being assigned a high effective sample size in the base model (see Table 4). The influence of the age frequency data was investigated by down-weighting these data, assigning an effective sample size of 50 to each observation.

6.3 Exclude pre 1970 catch

The catch data from 1944–69 are highly uncertain. A high level of discarding in the fishery has been documented (James 1984) and the catch history included in the base model incorporates an allowance for this component of the catch from 1944 to 1969. This period also includes an allowance for a significant level of unreported catch. However, the estimates of these sources of catch are derived from some highly subjective assumptions and, consequently, the catch history before 1970 is highly uncertain.

The sensitivity of the model to the early catch data was investigated by starting the model in 1970. The initial, exploited (1970) population age composition was determined via the estimation of recruitment deviates for the preceding period (1960–69) and the estimation of an initial fishing mortality parameter which were informed by the observed age composition in the 1970s.

6.4 Early CPUE

Previous TRE 7 stock assessments (Hanchet 1999, Maunder & Langley 2004) incorporated a second standardised CPUE index – based on data aggregated by month, vessel class, and statistical area – for the period 1978 to 1997 (Francis et al. 1999) . The CPUE indices are relatively stable through the entire period. These indices were included in the current assessment as a sensitivity analysis. The indices were linked to the selectivity function estimated for the post 1986 trawl fishery and were assumed to have a c.v. of 32% (as per Hanchet 1999).

6.5 Single- and pair trawl fisheries

The model structure was reconfigured to include a separate pair trawl fishery that encompassed the entire model period. Historical trawl catches were not available by gear type. Instead, the single and pair trawl catches were apportioned as per the split of the SNA 8 trawl catch (from Davies et al. 2006) on the basis that the two fisheries are closely associated, particularly during the 1970s and 1980s when the pair trawl fishery was the most dominant method.

Additional age frequency data derived from the pair trawl catch for 1997–98 (Walsh et al. 1999) and 1998–99 (Walsh et al. 2000) were incorporated into the model. An examination of the market sampling data from the 1970s revealed that the 1978 and 1979 age compositions were derived exclusively from the sampling of pair trawl landings, while the 1974–76 samples were a composite of the two methods. On this basis, the 1978 and 1979 age compositions were assigned to the new pair trawl fishery. The 1974–76 data were duplicated and assigned to the two method fisheries (single and pair trawl) with an effective sample size half of the value assigned in the base model.

A logistic selectivity function was estimated for the pair trawl fishery, while the selectivity functions of the two single trawl fisheries were estimated using a double normal parameterisation. This was intended to allow for the estimation of a lower selectivity of the older age classes for the two single trawl fisheries (relative to the pair trawl fishery). When the constraint on the pair trawl fishery selectivity of the older age classes is relaxed, the model estimates that the selectivity of the older age classes is similar to the single trawl fishery; i.e., a declining selectivity of the older age classes.

6.6 Comparison with base model

The two sensitivities to M have similar spawning biomass trajectories to 1980 and deviate in the subsequent years (Figure 12). From 1980 onwards, the base model maintains spawning biomass at a higher level than the two sensitivities with a lower value of M. For the model with the lowest M (0.075), spawning biomass is estimated to decline from 1980 onwards and is at an historical low level in 2008. For higher values of M, the spawning biomass is estimated to fluctuate through the 1980–2008 period and, in the case of the base model (M= 0.10), the spawning biomass is estimated to have increased since 2000 (Figure 12).

The differences in the biomass trajectories for the three M scenarios are also evident in the estimated recruitment series. Overall levels of recruitment are correlated with the assumed M value (Figure 13), while recent trends in recruitment deviate between the model runs with the base model estimating a general increase in recruitment from 1990 onwards. Conversely, the low M scenario estimates a general decline in recruitment over the last decade (Figure 13).

For the remainder of the other model sensitivities, the estimated spawning biomass trajectories were similar to the base, with the exception of the model that included a separate pair trawl fishery (BPT) (Figure 14). The model that began in 1970 (start1970) estimated an initial biomass level (in 1970) very similar to the level of biomass in 1970 estimated by the models that commenced from unexploited conditions in 1944. However, recent biomass levels from the start1970 model were lower than for the other models (Figure 14).

Down-weighting of the age frequency data resulted in a slightly lower level of current biomass compared to the base model (Figure 14), with a slight improvement to the fit to the CPUE indices.

The BPT model estimated a slightly higher overall biomass level and a lower level of depletion during the late 1960s and 1970s and a sharp increase in spawning biomass in the early 1980s (Figure 14). This increase in biomass was driven by the very high level of recruitment estimated for the 1977 year class (Figure 15). The model has very limited data to inform the model regarding the strength of the year class as there are only two observations of the year class in the age frequency data (at age 1 and 2 in the 1979 and 1978 market sampling age compositions). The high recruitment estimate is driven by the relatively high proportion of fish in the 20+ age class in the recent catch-at-age samples and it is exaggerated compared to the base model due to the *BPT* model estimating a decline in the selectivity of the older age classes for the single trawl fishery. There are also two additional catch-at-age samples from recent years included in the *BPT* model which may also influence the model estimates of year class strength.

7. MCMC RUNS

As noted above, of the range of model sensitivities investigated, the uncertainty associated with the value of natural mortality introduced the highest level of uncertainty into the estimates of the current stock status. On that basis, MCMC runs were limited to the models with the three alternative values of natural mortality. For the two higher values of natural mortality (0.087 and 0.10), there is a moderate–high probability that the 2008 biomass was above the B_{MSY} level (61% and 100%, respectively) (Table 5). Stock size is also predicted to remain at about the current level over the next five years, albeit increasing slightly, and remain at or above the B_{MSY} level (probability of 62% and 100% for natural mortality of 0.087 and 0.10, respectively) and there is a high probability (95% and 100%, respectively) that the biomass will remain above 20% of the unexploited level (B_0).

For the lower value of natural mortality (0.075), problems were encountered in running the MCMCs. MCMC parameter estimates were constrained by the bounds of key parameters (particularly selectivity parameters), thereby, biasing the estimates of stock status. On this basis, the MCMC results for the lower value of natural mortality were rejected and it was concluded that the lower value of natural mortality was less plausible than the other two values.

8. STOCK ASSESSMENT CONCLUSIONS

For most of the model sensitivities, maximum likelihood estimates (MLEs) of current (2008) spawning biomass are well above the B_{MSY} level and the recent level of catch (1838 t) was lower than the *MSY* level (Table 6). The exception was the model run with the lowest value of *M*. This model yielded a similar estimate of B_0 to the base case, but the lower values of *M* resulted in a higher level of depletion (lower B_{2008}). This highlights the strong influence of the age frequency data in the model, particularly the data from the late 1990s and 2000s, especially given the lack of any trend in the CPUE index. For example, for the lowest value of M, the model estimates recruitment over the last decade to be relatively low, resulting in a relatively low current spawning biomass (and vice versa).

Within the age composition data, the proportion of fish in the aggregated oldest age class is likely to be highly influential in the estimation of current biomass. Trials that reduced the proportion of fish in the aggregated age classes of the catch-at-age data resulted in a considerable increase in B_{2008}/B_0 and B_{2008}/B_{MSY} for lower values of *M*. Conversely, for higher values of *M,* estimates of B_{2008}/B_0 and B_{2008}/B_{MSY} decreased. The sensitivity of the model results to the magnitude of the aggregated age class is potentially problematic as the model can estimate a large "plus group" either via low natural mortality or by estimating a high level of recruitment at the appropriate time, thereby confounding estimates of the two sets of parameters. In the current assessment model, the fit to the aggregated age classes in the recent age frequency data is achieved by the estimation of a single strong year class (1977) for which limited observations are available (from the catch-at-age).

There is limited information to inform the model regarding the value of *M*. The likelihood profile indicates the most likely value of *M* given the other observations from the fishery. However, given the limited time series of age frequency data incorporated in the model, it is unrealistic for the model to estimate an accurate value for *M*. Instead, the likelihood profile is likely to provide an indicative range of values for *M* and the values within this range (approximately 0.075–0.100) were initially considered equally plausible.

This leads to contradictory conclusions regarding the status of the stock. A higher value of *M* results in current biomass well above the *MSY* based reference point, B_{MSY}, and a high probability that the stock will remain above B_{MSY} (and also above 20% of B_0 level) over the next 5 years (
Table 5**Table 1**). Conversely, for the lowest value of *M* (0.075), the current spawning biomass is estimated to be below the B_{MSY} level (B_{2008}/B_{MSY}= 0.89).

An MCMC approach was applied to estimate model uncertainty for the models with different values of natural mortality. Reasonable results were attained for the two higher values of natural mortality (0.087 and 0.10); however, problems were encountered for the lower value of natural mortality (0.075) with MCMC parameter values being constrained by the bounds of key parameters (particularly selectivity parameters), thereby resulting in biased estimates of stock status. On this basis, the MCMC results for the lower value of natural mortality were rejected and it was concluded that the lower value of natural mortality was less plausible than the other two values.

Spawning biomass is estimated to have declined gradually during the 1940s and 1950s. The rate of decline increased in the 1960s and 1970s consistent with the increase in the total annual catch. Female spawning biomass is predicted to have remained stable (M = 0.087) or to have increased (M = 0.10) since the 1980s, with moderate–high probability that the current biomass is above the B_{MSY} level in 2008 (61% and 100%, respectively).

Stock projections, for a five-year period, were conducted for the two accepted models (M = 0.087 and M = 0.10). The projections assumed a constant catch based on the TAC and an allowance for recreational and customary catch. For both models, the stock size is predicted to remain at about the current level over the next five years, and remain at or above the B_{MSY} level (probability of 61% and 100% for natural mortality of 0.087 and 0.10, respectively) with a high probability (95% and 100%, respectively) that the biomass will remain above 20% of the unexploited level (B_0). For both models the stock was virtually certain to remain above 10% of B_0 (probability of 100% in both cases).

9. ACKNOWLEDGMENTS

The project was funded by the Ministry of Fisheries under project TRE2008/02. The members of the Northern Inshore Fisheries Science Working Group, particularly Marc Griffiths and Paul Starr, provided valuable input during the assessment process and in reviewing the draft manuscript.

10. REFERENCES

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H. (2005). CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.07-2005/08/21. *NIWA Technical Report 127.* 272 p.

Davies, N.M.; McKenzie, J.R.; Gilbert, D.J. (2006). Assessment of the SNA 8 stock for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/09*. 58 p.

Francis, M.P.; Bradford., E.; Paul, L.J. (1999). Trevally catch per unit effort in TRE 7. New Zealand Fisheries Assessment Research Document 99/13. 27 p. (Unpublished report held in NIWA library, Wellington.)

Hanchet, S.M. (1999). Stock assessment of trevally (*Caranx georgianus*) in TRE 7. New Zealand Fisheries Assessment Research Document 99/55. 27 p. (Unpublished report held in NIWA library, Wellington.)

James, G.D. (1984). Trevally, *Caranx georgianus* Cuvier: age determination, population biology, and the fishery. *Fisheries Research Bulletin 25.* 52 p.

McAllister, M.K.; Ianelli, J.N. (1997). Bayesian stock assessment using catch-at-age data and the sampling-importance resampling algorithm. *Canadian Journal of Fisheries and Aquatic Sciences 54*: 284–300.

McKenzie, A. (2008). Standardised CPUE analysis and stock assessment of the west coast trevally fishery (TRE 7). *New Zealand Fisheries Assessment Report 2008/44*. 74 p.

Maunder, M.N.; Harley, S.J.; Hampton, J. (2006). Including parameter uncertainty in forward projections of computationally intensive statistical population dynamic models. *ICES Journal of Marine Science*, 63: 969–979.

Maunder, M.N.; Langley, A.D. (2004). Integrating the standardisation of catch-per-unit-effort into stock assessment models: testing a population dynamics model and using multiple data types. *Fisheries Research 70 (2-3)*: 389–395.

Methot, R. D. (2005). Technical description of the Stock Synthesis II Assessment Program Version 1.17 – March 2005.

Methot, R. D. (2009). User manual for Stock Synthesis, model version 3.02C.

MFish Science Group (Comps.) (2008): Report from the Fishery Assessment Plenary, May 2008: stock assessments and yield estimates. (Unpublished report held in NIWA library, Wellington.)

Walsh, C.; McKenzie, J.; Ó Maolagáin, C.; Stevens, D.; Tracey, D. (1999). Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1997–98. *NIWA Technical Report 66.* 39 p.

Walsh, C.; McKenzie, J.; Ó Maolagáin, C.; Stevens, D. (2000). Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1998–99. Final Research Report to Ministry of Fisheries. (Unpublished report held by Ministry of Fisheries, Wellington.)

Walsh, C.; McKenzie, J.; Ó Maolagáin, C.; Buckthought, D.; Blackwell, R.; James, G.D.; Rush, N. (2009). Length and age composition of trevally in commercial landings inTRE 1 and TRE 7, 2006–07. Draft *New Zealand Fisheries Assessment Report 2009/##*

Table 1: Model parameters and priors for the base model.

Parameter			**Parameter values, assumptions**	**Number of parameters**
Length-wt relationship	fixed	*a*	3.064	-
$W(kg) = aL(cm)^b$		*b*	1.6e-005	-
Growth parameters	fixed	*k*	0.285	-
(Von Bertalanffy)		L_∞	46.21	-
		L_{age1}	13.64	-
Natural mortality	fixed	*M*	0.1	-
Maturity	fixed		Ages 1–4 0; ages ≥5 1	-
BH steepness	fixed	*h*	0.75	-
Virgin recruitment	estimated	R_0	lognormal prior (mean 10.3, sd 10)	1
Std.dev. of log recruitment	fixed	σ_R	0.6	-
Recruitment deviations	Estimated (1960–2006)		Lognormal	45
Initial F	fixed		0	-
Catchability				
Selectivity				
Commercial pre 1986	estimated		Logistic	2
Commercial post 1986	estimated		Logistic	2
James Cook trawl	estimated		double normal	6
			Total	

Table 2: Definition of symbols for the various management quantities.

Symbol	**Definition**
B_0	The equilibrium, unexploited mid season female mature biomass.
B_x	The mid season female mature biomass in year *x*.
MSY	The maximum sustainable yield, expressed in tonnes based on the recent fishing mortality at age.
B_{MSY}	The equilibrium, mid season female mature biomass that produces the *MSY*.

Table 3: MCMC biomass estimates (medians, with the 95% confidence interval in parentheses) for the base case run from McKenzie (2008) and the comparable SS model run. For comparative purposes the SS spawning biomass has been doubled to account for both sexes. The estimates of R_0 are also presented.

	B_0	B_{2005}	B_{2005} (% B_0)	R_0
McKenzie (2008)	62 900 (56 700–74 600)	28 300 (19 500–45 900)	45 (34–61)	5.21E6
Current study	62 900 (55 300–71 900)	27 500 (18 900–38 200)	44 (34–53)	5.36E6

Table 4: The relative weighting of each of the components of the observational data and the associated standard deviation of the normalised residuals (SDNR) for the base model (*M* = 0.10). The contribution of each component to the total model likelihood is also included.

Data source	Error structure	c.v.	Effective sample size	SDNR	Likelihood component
CPUE index	Log-normal	0.22		1.06	-18.47
Age frequency					
Commercial pre 1986	Multinomial		139	1.30	45.41
Commercial post 1986	Multinomial		234	1.11	81.13
Research	Multinomial		134	1.62	39.94

Table 5: Current and 5-year projected spawning biomass (female only) relative to the biomass based reference points. Median of MCMC runs and the 95% confidence interval.

	B_0	B_{2008}	B_{MSY}	MSY	B_{MSY}/B_0	B_{2008}/B_0	B_{2008}/B_{MSY}	B_{2013}/B_0	B_{2013}/B_{MSY}	$Pr(B_{2008} > 0.2\,B_0)$	$Pr(B_{2008} > 0.1\,B_0)$	$Pr(B_{2013} > 0.2\,B_0)$	$Pr(B_{2013} > 0.1\,B_0)$	$Pr(B_{2013} > B_{MSY})$
M = 0.10	31 968 (29 177–38 119)	16 889 (11 067–24 506)	8 956 (8 172–10 683)	2 461 (2 246–2 924)	0.280 (0.279–0.281)	0.53 (0.38–0.67)	1.87 (1.34–2.38)	0.55 (0.40–0.73)	1.95 (1.43–2.60)	1.00	1.00	1.00	1.00	1.00
M = 0.087	30 729 (28 223–33 736)	9 171 (5 121–14 613)	8 619 (7 914–9 468)	2 106 (1 932–2 309)	0.280 (0.279–0.281)	0.30 (0.18–0.44)	1.07 (0.64–1.55)	0.31 (0.15–0.47)	1.08 (0.55–1.68)	0.95	1.00	0.95	1.00	0.61

Table 6: Maximum likelihood estimates and standard deviations (in parentheses) of derived parameters from the range of model runs investigated. The total likelihood for each model is also presented although in many cases the likelihood values are not directly comparable.

Model run	B_0	B_{2008}	B_{MSY}	MSY	B_{2008}/B_0	B_{2008}/B_{MSY}	Total likelihood
M = 0.10	31 539 (2 111)	15 807 (3 120)	8 834 (593)	2 430 (161)	0.50 (0.07)	1.79 (0.25)	160.4
M = 0.087	30 143 (1 171)	9 592 (1 548)	8,455 (329)	2 065 (80)	0.32 (0.04)	1.13 (0.15)	128.9
M = 0.075	30 155 (888)	7 547 (1 145)	8 481 (250)	1 848 (56)	0.25 (0.03)	0.89 (0.12)	131.4
Age frq. weighting	31 858 (2 333)	13 220 (2 946)	8 923 (658)	2 454 (176)	0.42 (0.07)	1.48 (0.24)	36.5
Exclude pre 1970 catch	28 925 (1 456)	11 304 (1 860)	8 100 (408)	2 231 (112)	0.39 (0.05)	1.40 (0.17)	171.7
Early CPUE	31 054 (2 134)	15 298 (2 921)	8 698 (599)	2 390 (163)	0.49 (0.07)	1.76 (0.24)	148.8
Pair trawl fishery	34 163 (3 624)	17 871 (4 058)	9 294 (992)	2 531 (264)	0.52 (0.07)	1.92 (0.26)	202.1

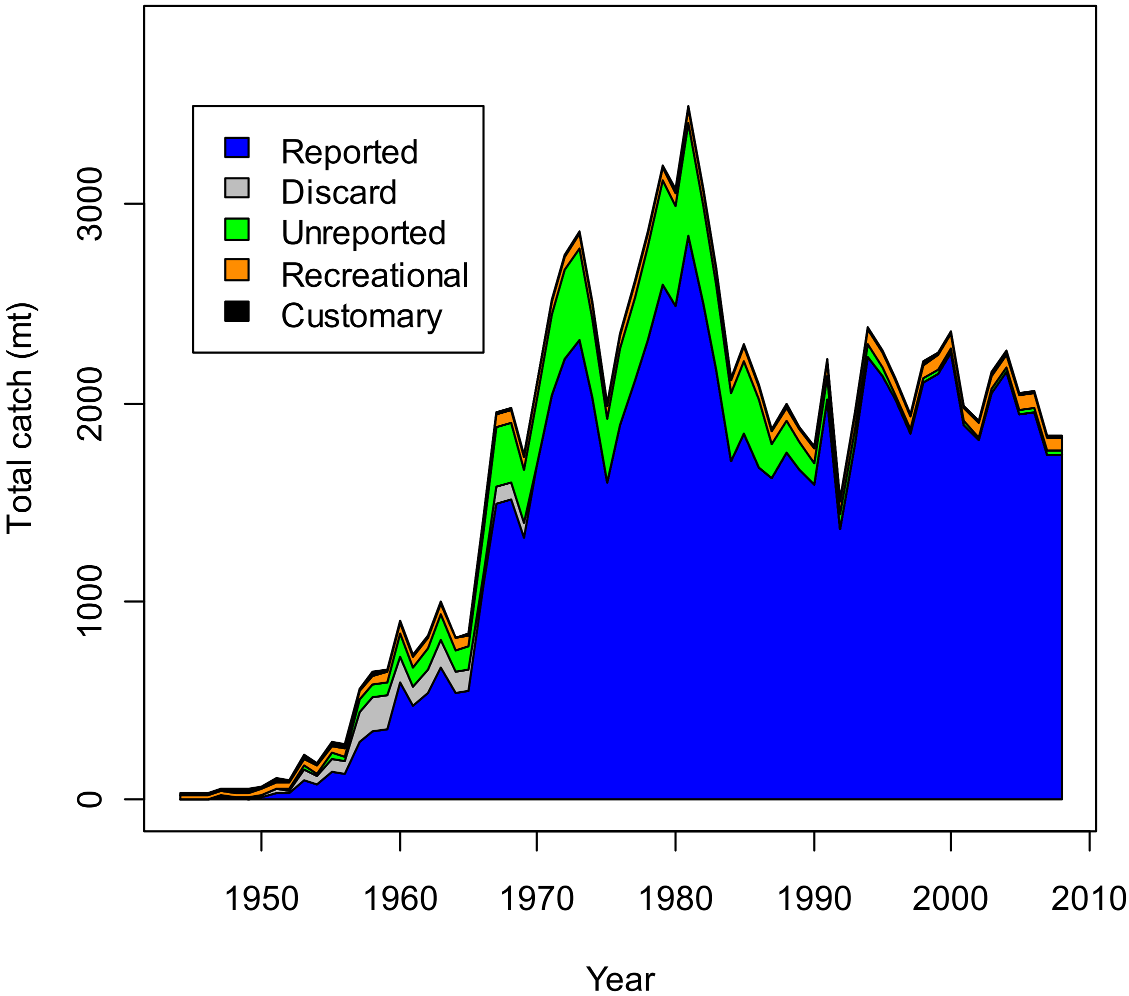

Figure 1: Catch history of TRE 7 incorporated in the stock assessment.

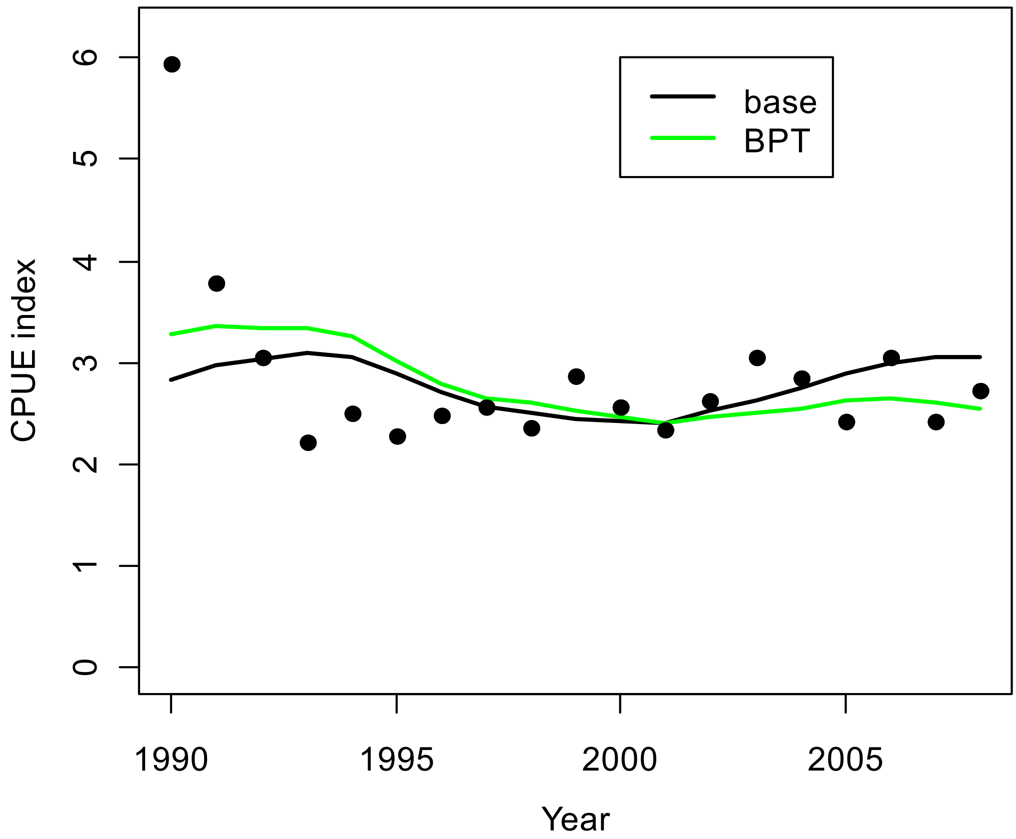

Figure 2: Fit to the CPUE indices (points) from the base model (*M* = 0.10) (black line) and the sensitivity with the inclusion of the pair trawl fishery (grey line) (*BPT*).

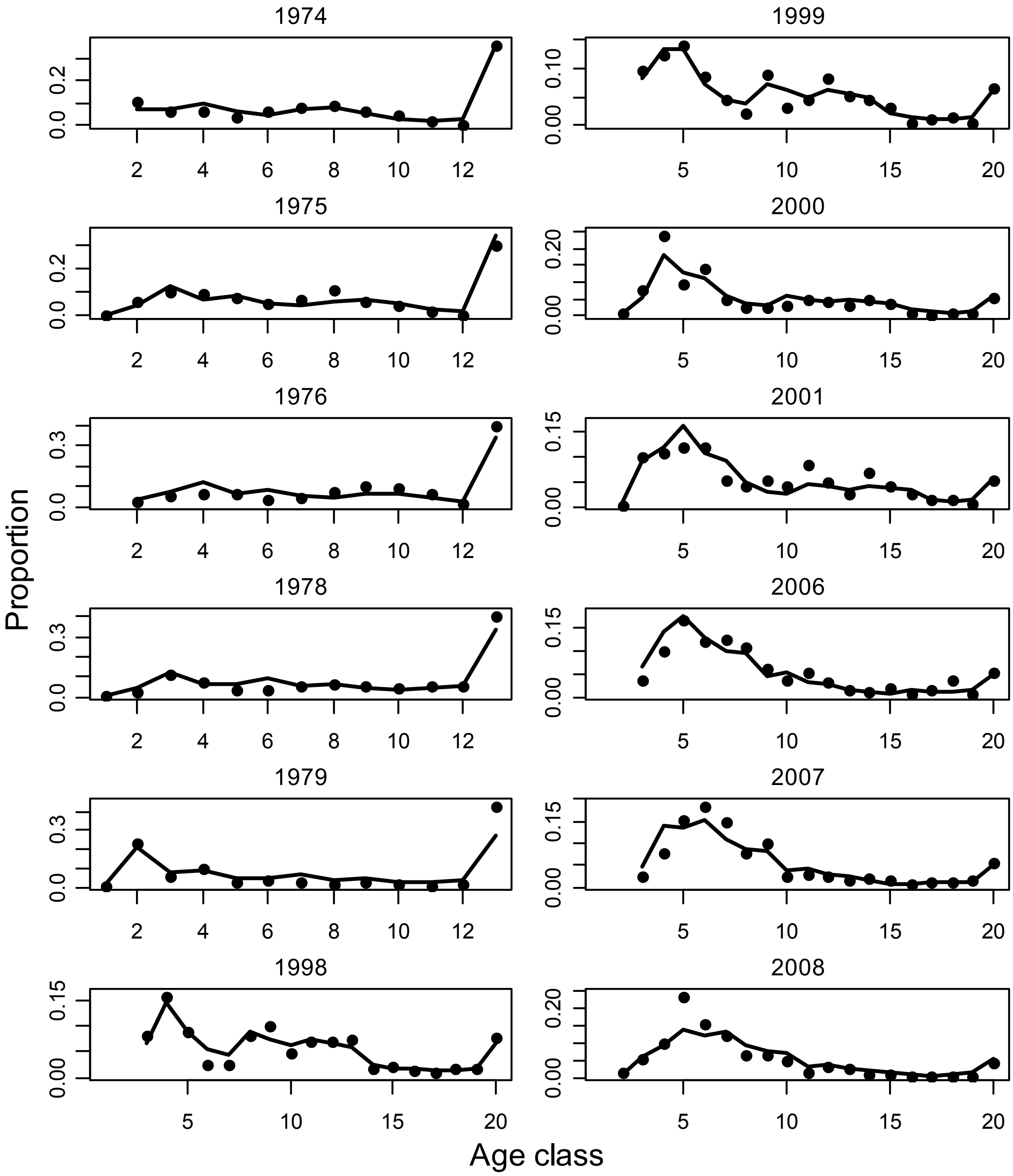

Figure 3: The predicted (lines) and observed (points) annual age frequency distributions from the catch sampling data for the pre- and post 1986 trawl fisheries (base model, *M* = 0.10). The oldest age class represents an accumulated age class of older fish (13+ or 20+ age classes).

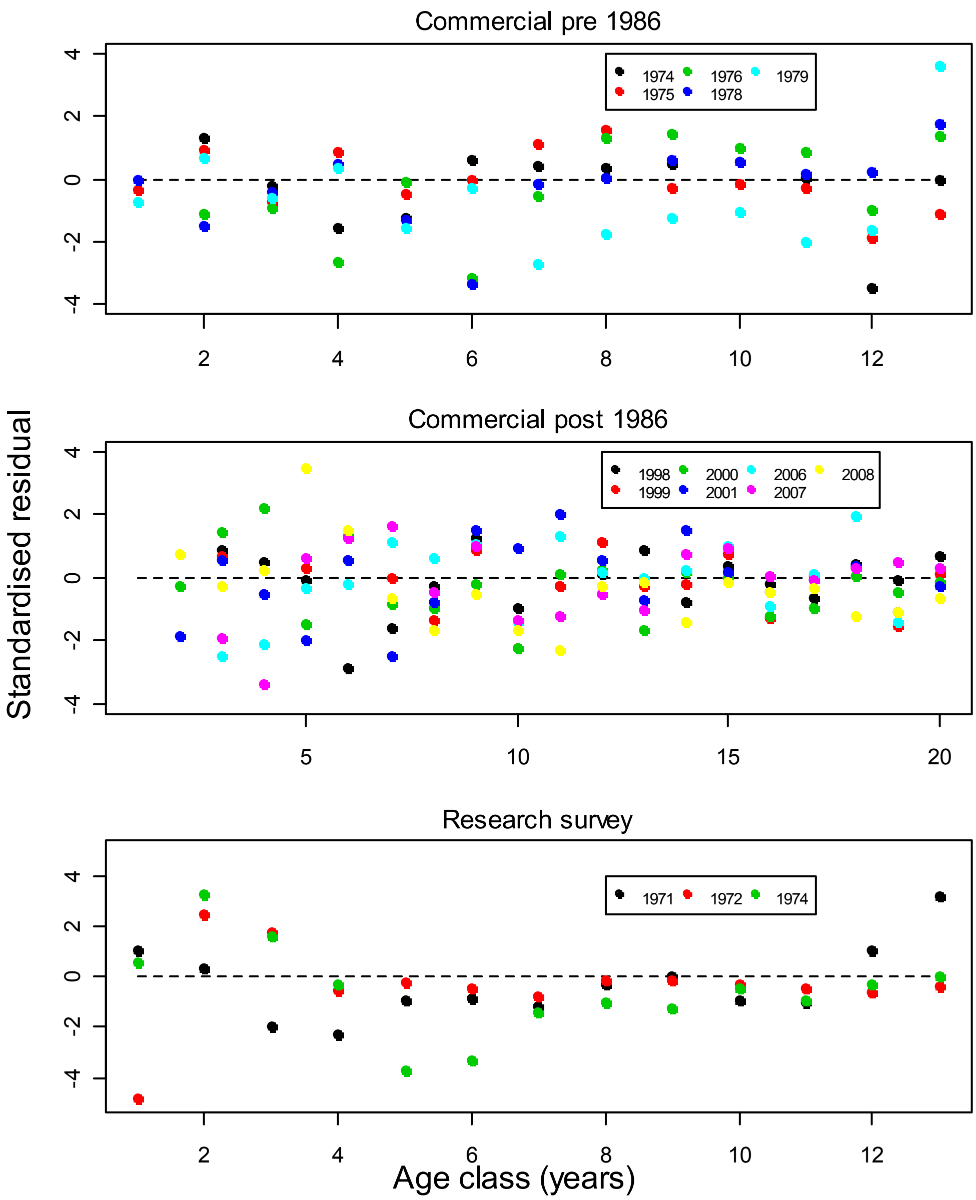

Figure 4: Standardised residuals of the fit to the three sets of age frequency data for the base model (M = 0.10).

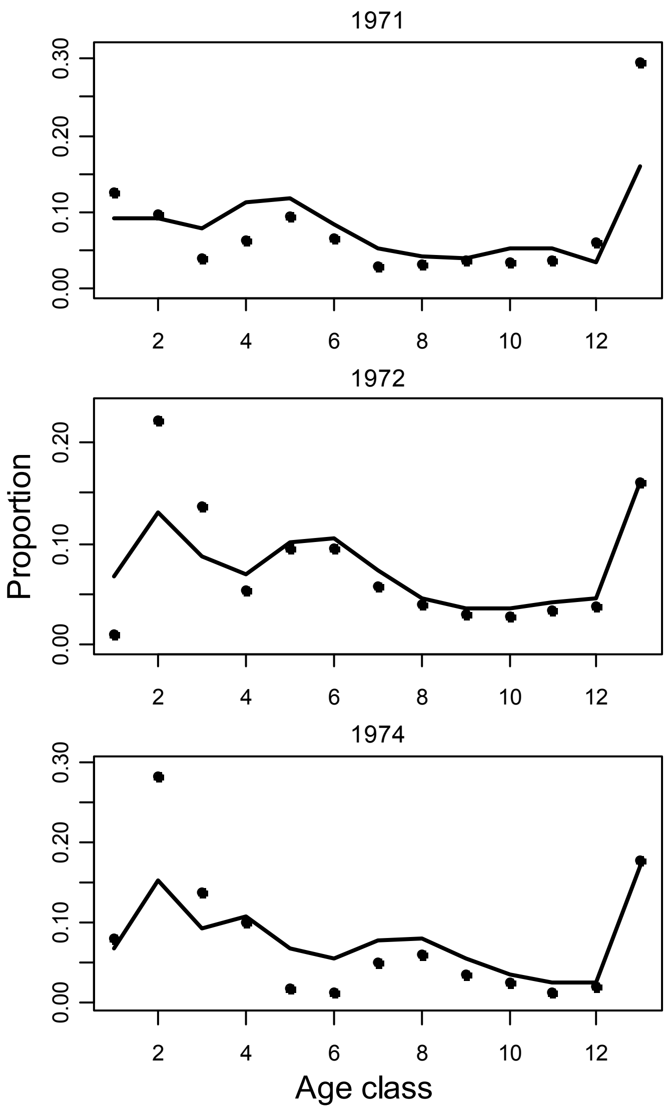

Figure 5: The predicted (lines) and observed (points) age frequency distributions from the *James Cook* research trawl surveys (base model, M = 0.10). The oldest age class represents an accumulated age class of older fish (13+ age classes).

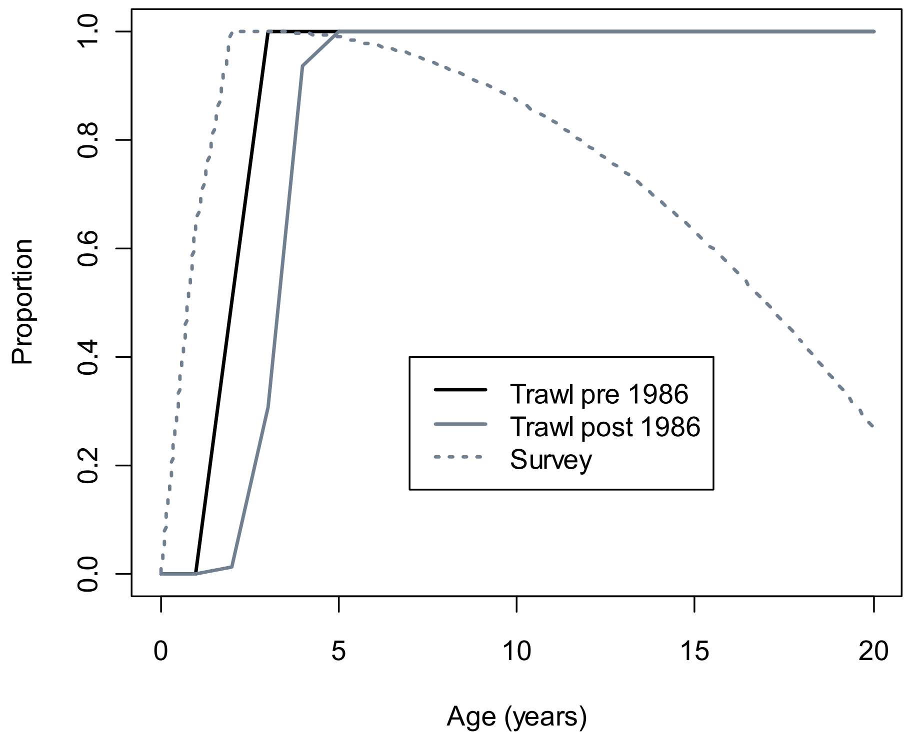

Figure 6: Estimated selectivity at age for the pre- and post 1986 trawl fisheries and the research survey (base model).

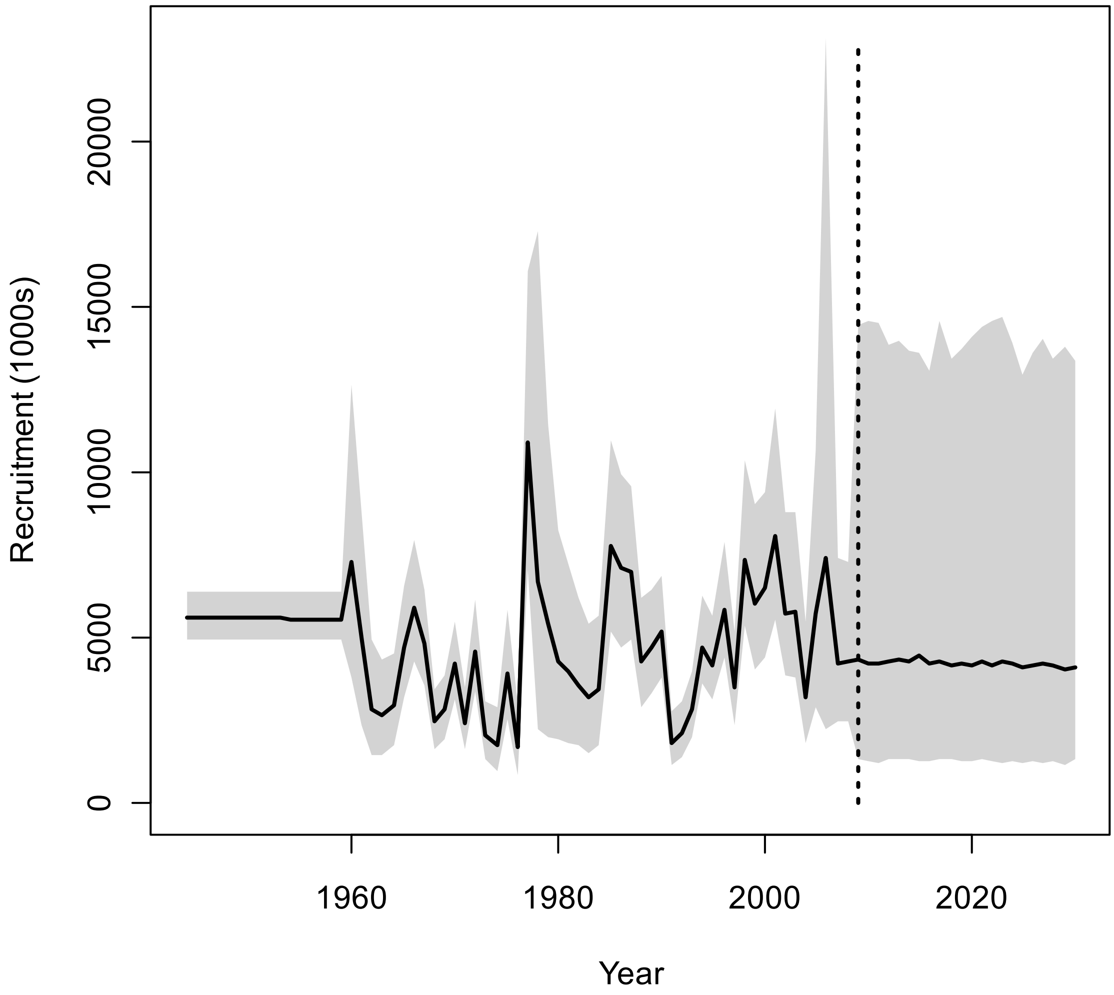

Figure 7: Recruitment (numbers of fish, thousands) by year (median of MCMCs) for the base model (*M* = 0.10). The shaded region represents the 95% confidence interval. The dashed vertical line represents the first year of the projection period (2009).

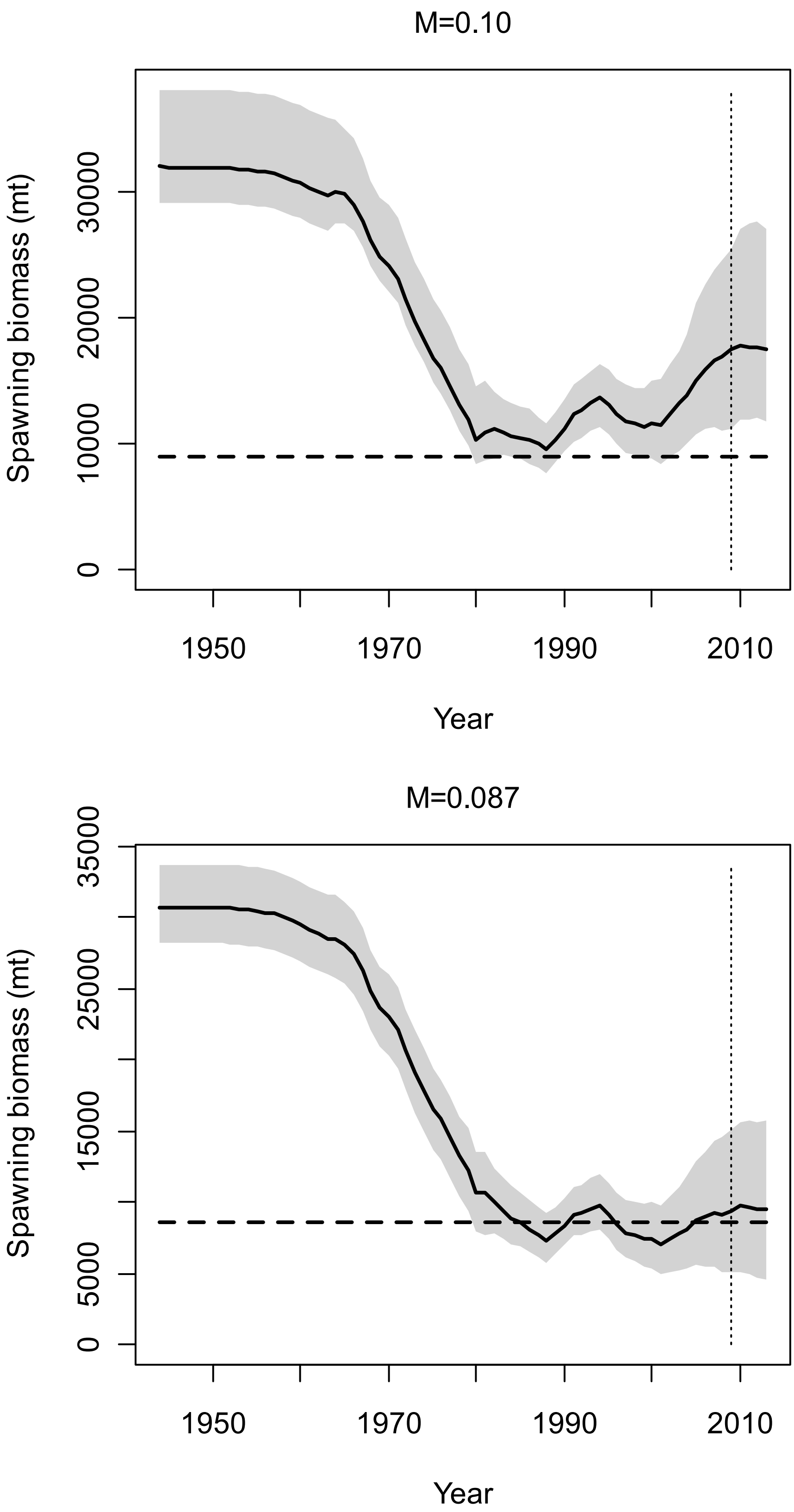

Figure 8: Spawning biomass (female only) trajectories (median of MCMCs) for the model runs with natural mortality at 0.10 and 0.087. 95% confidence intervals (shaded) were derived from MCMC. The horizontal line represents the B_{MSY} and dashed vertical line represents the first year of the projection period (2009).

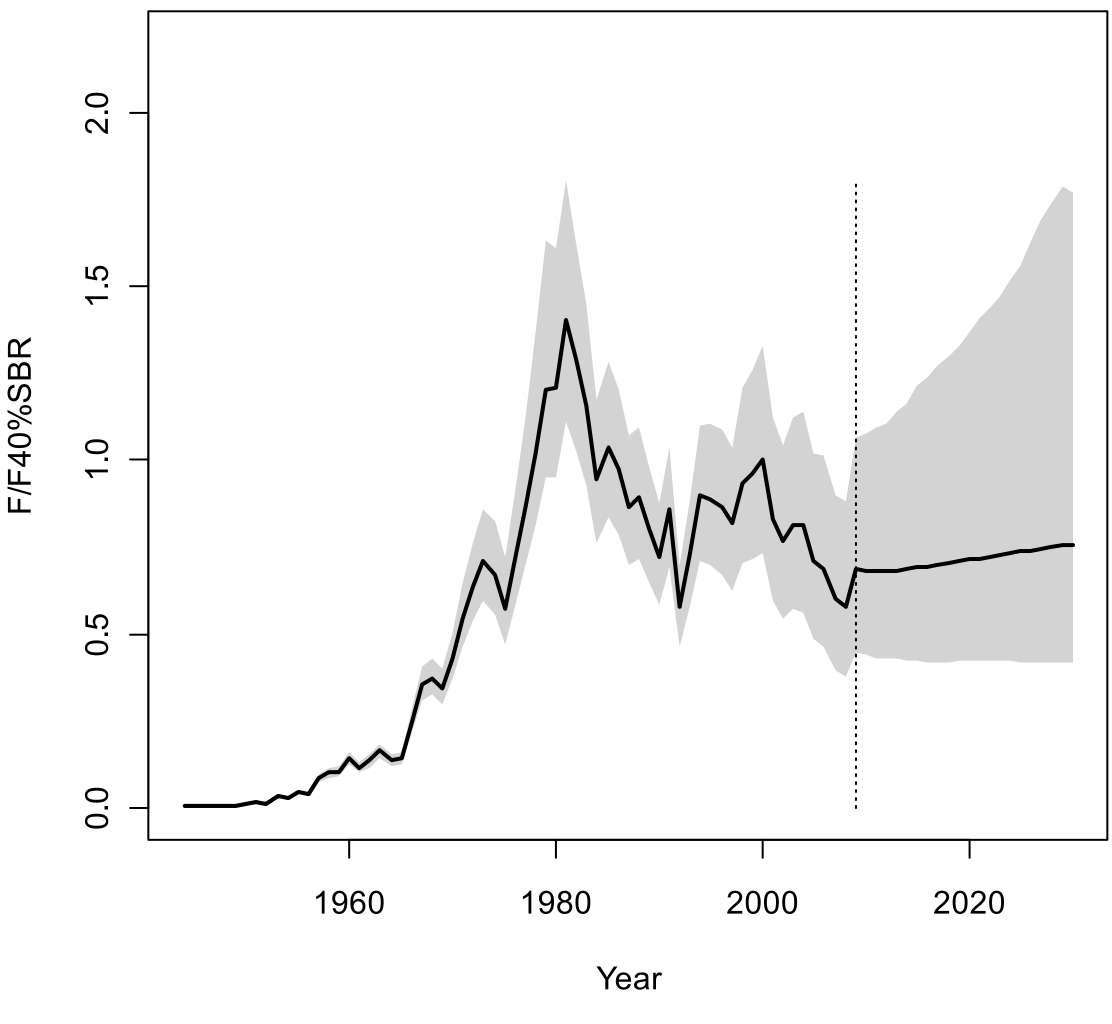

Figure 9: Annual fishing mortality, expressed as a proportion of $F_{40\%SPR}$, for the base model (M = 0.10). The shaded region represents the 95% confidence interval. The dashed vertical line represents the first year of the projection period (2009).

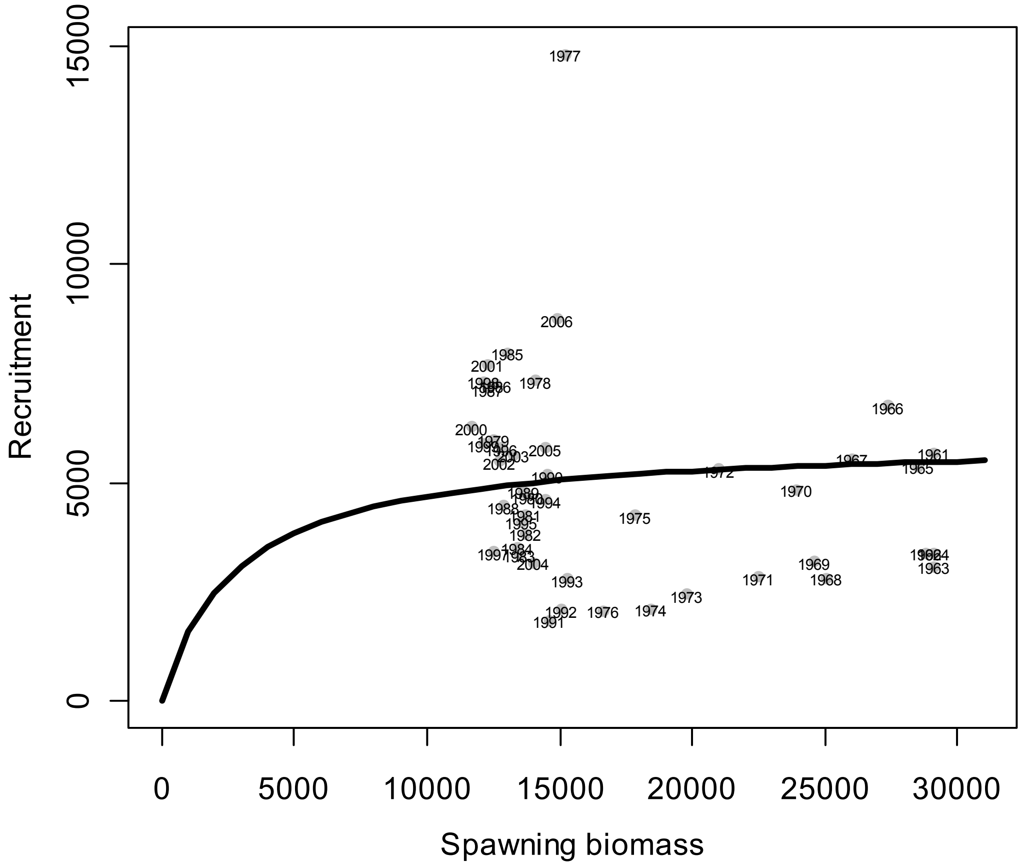

Figure 10: The assumed relationship between spawning biomass and recruitment with the steepness fixed at a value of 0.75 (line). The points represent the estimated recruitment (numbers of fish, thousands) and the spawning biomass (t) from the base model (*M* = 0.10).

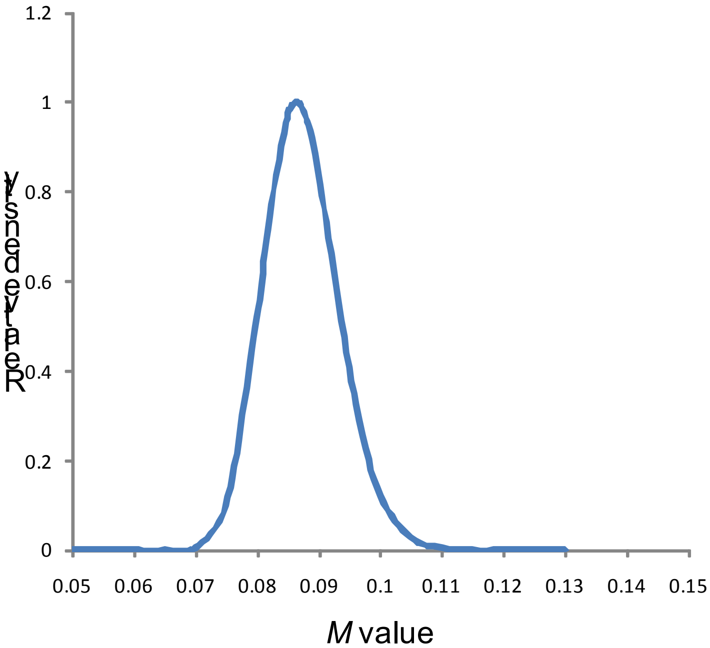

Figure 11: Likelihood profile for *M* from the base model.

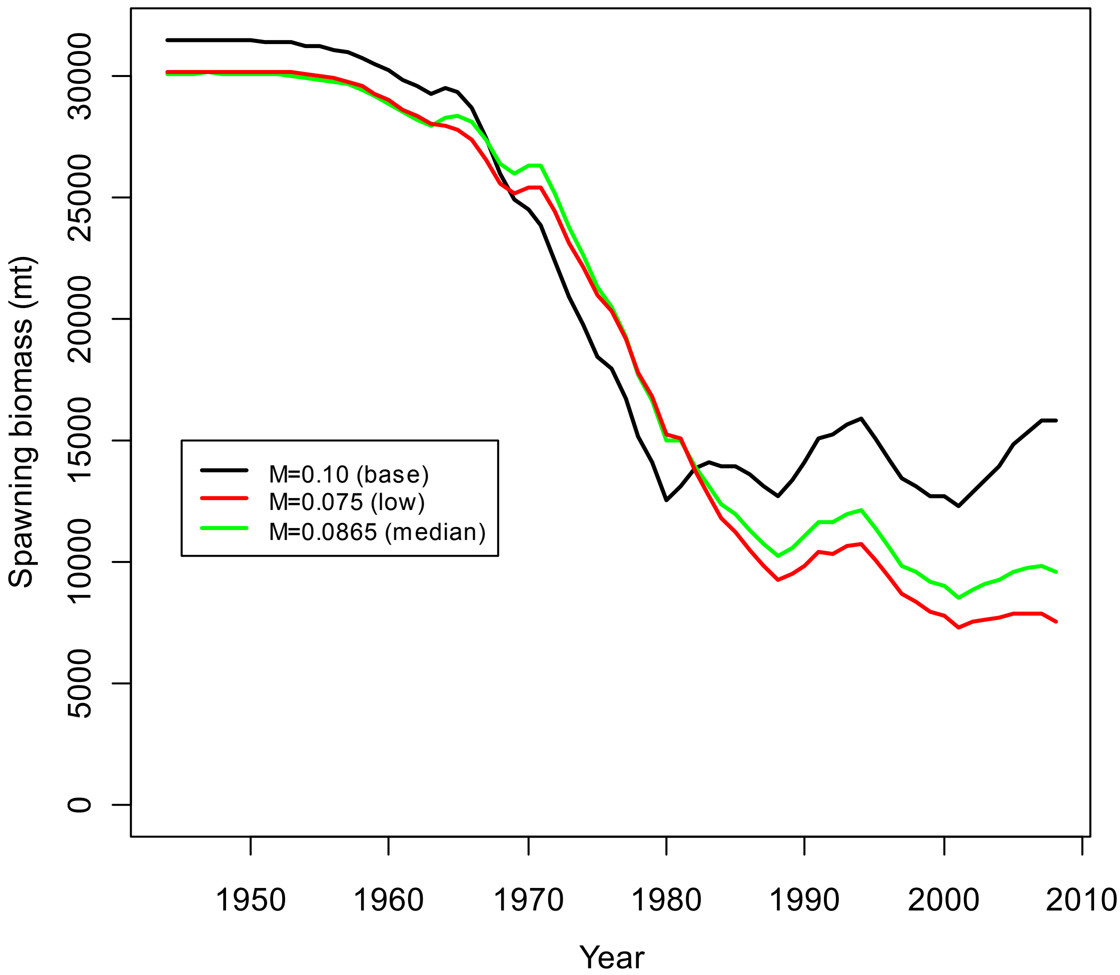

Figure 12: A comparison of the trend in spawning biomass for the model runs with different assumed levels of natural mortality.

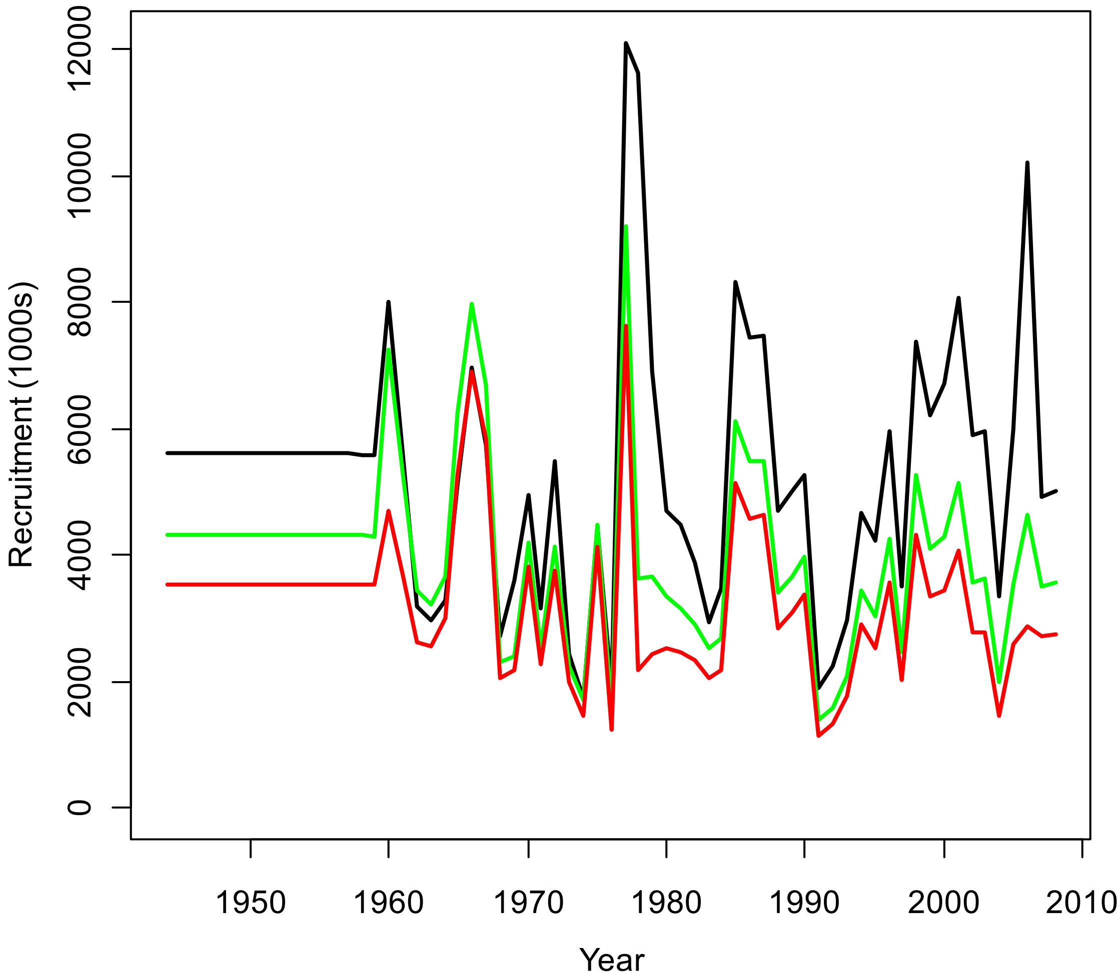

Figure 13: A comparison of the trend in recruitment for the model runs with different assumed levels of natural mortality.

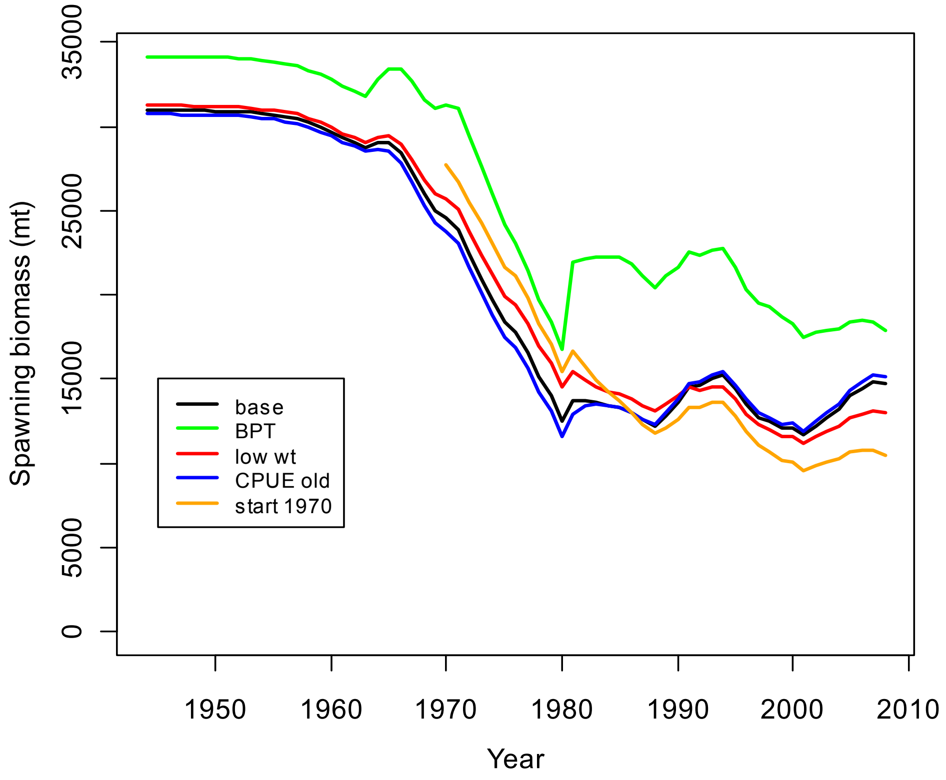

Figure 14: A comparison of the trend in spawning biomass for the base model (M = 0.10) and various model sensitivities (see Section 6 for details).

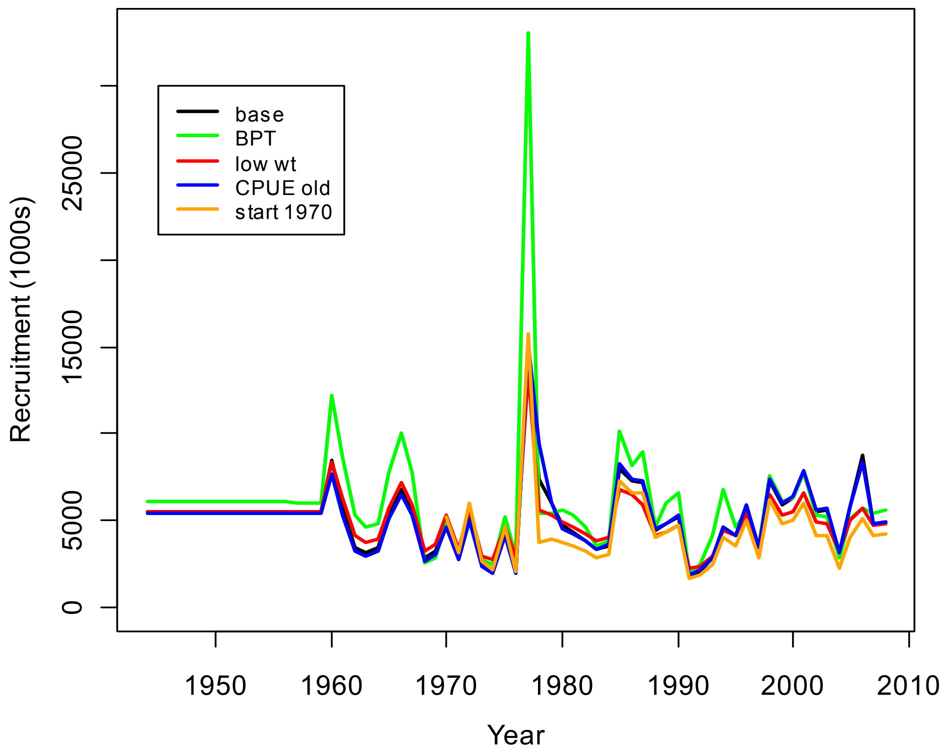

Figure 15: A comparison of the trend in recruitment for the base model (M = 0.10) and various model sensitivities (see Section 6 for details).

Appendix 1. Catch history included in the TRE 7 stock assessment model.

Year	Reported landings	Discarded	Unreported	Recreational	Customary	Total
1944	3	2	1	14	15	34
1945	3	2	1	16	15	36
1946	3	2	1	18	15	38
1947	14	7	3	20	15	59
1948	8	4	2	23	15	52
1949	7	4	1	25	15	52
1950	15	8	3	27	15	68
1951	36	18	7	29	15	105
1952	31	16	6	31	15	99
1953	103	52	21	33	15	223
1954	78	39	16	36	15	184
1955	138	69	28	38	15	288
1956	130	65	26	40	15	276
1957	296	148	59	42	15	560
1958	343	172	69	44	15	642
1959	351	176	70	46	15	658
1960	595	128	119	48	10	900
1961	471	101	94	51	10	727
1962	543	116	109	53	10	831
1963	662	142	132	55	10	1001
1964	534	114	107	57	10	822
1965	544	117	109	59	10	839
1966	1080	60	216	61	10	1427
1967	1493	83	299	64	10	1949
1968	1515	84	303	66	10	1978
1969	1322	73	264	68	10	1737
1970	1682	0	336	70	10	2098
1971	2037	0	407	70	10	2524
1972	2226	0	445	70	10	2751
1973	2320	0	464	70	10	2864
1974	2024	0	405	70	10	2509
1975	1598	0	320	70	10	1998
1976	1894	0	379	70	10	2353
1977	2113	0	423	70	10	2616
1978	2322	0	464	70	10	2866
1979	2600	0	520	70	10	3200
1980	2493	0	499	70	12	3074
1981	2844	0	569	70	12	3495
1982	2497	0	499	70	12	3078
1983	2165	0	433	70	12	2680
1984	1707	0	341	70	12	2130
1985	1843	0	369	70	12	2294

Year	Reported landings	Discarded	Unreported	Recreational	Customary	Total
1986	1678	0	336	70	12	2095
1987	1626	0	163	70	12	1871
1988	1752	0	158	70	12	1992
1989	1665	0	133	70	12	1880
1990	1589	0	111	70	12	1782
1991	2016	0	121	70	12	2219
1992	1367	0	68	70	12	1517
1993	1796	0	72	70	12	1950
1994	2231	0	67	70	12	2380
1995	2138	0	43	70	12	2263
1996	2019	0	20	70	12	2121
1997	1844	0	18	70	12	1944
1998	2103	0	21	70	12	2206
1999	2148	0	21	70	12	2251
2000	2254	0	23	70	12	2359
2001	1888	0	19	70	12	1989
2002	1810	0	18	70	12	1910
2003	2050	0	21	70	12	2153
2004	2156	0	22	70	12	2260
2005	1945	0	19	70	12	2046
2006	1957	0	20	70	12	2059
2007	1739	0	17	70	12	1838
2008	1739	0	17	70	12	1838

Appendix 2. Stock Synthesis input files.

TRE7.ctl file

```
#C fishing mortality uses the hybrid method
#_data_and_control_files: simple.dat // simple.ctl
#_SS-V3.01-g-opt;_09/01/08;_Stock_Synthesis_by_Richard_Methot_(NOAA);_using_Otter_Research_ADMB_7.0.1
1  #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
0 #_Nblock_Designs
0.5 #_fracfemale
3 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented
1 #_Growth_Age_for_L1
999 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A)
3 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity
# Plenary report has maturity at length 32-37 cm equates to age class 5.
0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
#_placeholder for empirical age-maturity by growth pattern
1 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
2 #_env/block/dev_adjust_method (1=standard; 2=with logistic trans to keep within base parm bounds)
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
# 0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP:1_
 1 45 13.64 36 0 10 -2 0 0 0 0 0.5 0 0 # L_at_Amin_Fem_GP_1_
 40 90 46.21 70 0 10 -4 0 0 0 0 0.5 0 0 # L_at_Amax_Fem_GP_1_
 0.05 0.285 0.28 0.15 0 0.8 -4 0 0 0 0 0.5 0 0 # VonBert_K_Fem_GP_1_
 0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1_
 0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1_
# 0.05 0.15 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP:1_
 1 45 13.64 36 0 10 -2 0 0 0 0 0.5 0 0 # L_at_Amin_Fem_GP_1_
 40 90 46.21 70 0 10 -4 0 0 0 0 0.5 0 0 # L_at_Amax_Fem_GP_1_
 0.05 0.285 0.28 0.15 0 0.8 -4 0 0 0 0 0.5 0 0 # VonBert_K_Fem_GP_1_
 0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1_
 0.05 0.25 0.1 0.1 0 0.8 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1_
 -3 3 1.6e-005 1.6e-005 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen1_Fem
 -3 4 3.064 3.064 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen2_Fem
 -3 3 -9999 55 -1 0.8 -3 0 0 0 0 0 0 0 # Mat50-Fem
 -3 3 -0.25 -0.25 0 0.8 -3 0 0 0 0 0 0 0 # Matslp-Fem
 -3 3 1 1 0 0.8 -3 0 0 0 0 0.5 0 0 # Eggs1_Fem
 -3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 # Eggs2_Fem
 -3 3 1.6e-005 1.6e-005 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen1_Mal
 -3 4 3.064 3.064 0 0.8 -3 0 0 0 0 0.5 0 0 # Wtlen2_Mal
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_GP_1_
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Area_1_
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Seas_1_
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # CohortGrowDev
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Spawner-Recruitment
3 #_SR_function
#_LO HI INIT PRIOR PR_type SD PHASE
 3 31 6.71 10.3 0 10 1 # SR_R0
 0.2 1 0.75 0.7 2 0.2 -1 # SR_steep
 0 2 0.6 0.6 0 0.8 -4 # SR_sigmaR
-5 5 0 0 0 1 -3 # SR_envlink
 -5 5 0 0 0 1 -4 # SR_R1_offset
 0 0 0 0 -1 0 -99 # SR_autocorr
```

1 #_SR_env_link
1 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness

1 #do_recdev: 0=none; 1=devvector; 2=simple deviations
1960 # first year of main recr_devs; early devs can preceed this era
2006 # last year of main recr_devs; forecast devs start in following year
3 #_recdev phase
1 # (0/1) to read 11 advanced options
0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
-4 #_recdev_early_phase
0 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
5 #_lambda for prior_fore_recr occurring before endyr+1; 5 is a moderate constraint on the devs
1970
1985
2002 #_last_yr_fullbias_adj_in_MPD
2009 #_first_recent_yr_nobias_adj_in_MPD
-5 #min rec_dev
5 #max rec_dev
0 #_read_recdevs
#_end of advanced SR options

#Fishing Mortality info
0.3 # F ballpark for tuning early phases
2004 # F ballpark year
3 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
2.9 # max F or harvest rate, depends on F_Method
4 # N iterations for tuning F in hybrid method (recommend 3 to 7)

#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
 0 1 0 0.01 0 99 -2 # InitF_1_FISHERY1_
 0 1 0 0.01 0 99 -2 # InitF_1_FISHERY1_

#_Q_setup
 # A=do power, B=env-var, C=extra SD, D=devtype(<0=mirror, 0/1=none, 2=cons, 3=rand, 4=randwalk); E=0=num/1=bio, F=err_type
 #_A B C D E F
 0 0 0 0 1 0
 0 0 0 0 1 0
 0 0 0 0 1 0
 0 0 0 0 1 0
#_size_selex_types
#_Pattern Discard Male Special
 0 0 0 0 # 1
 0 0 0 0 # 2 # CPUE index
 0 0 0 0 # 2 # CPUE index
 0 0 0 0 # 3 James Cook trawl survey
#_age_selex_types
#_Pattern Discard Male Special
12 0 0 0 # 1
 12 0 0 0 # 1
 15 0 0 2 # 2 CPUE index
 20 0 0 0 # 3 James Cook trawl survey

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
 #fishery 1 - logistic 2 parameters
-5 14 9 9 0 1000 3 0 0 0 0 0 0 0 # AgeSel_3_P_1_ 7
-5 14 4 4 0 1000 3 0 0 0 0 0 0 0 # AgeSel_3_P_2_ 8
fishery 2
-5 14 9 9 0 1000 3 0 0 0 0 0 0 0 # AgeSel_3_P_1_ 7
-5 14 4 4 0 1000 3 0 0 0 0 0 0 0 # AgeSel_3_P_2_ 8
James Cook research age frq data
 1 40 3 3 0 1000 3 0 0 0 0 0 0 0 # AgeSel_3_P_1_ 1
 -6 4 -3 -3 0 1000 -5 0 0 0 0 0 0 0 # AgeSel_3_P_2_ 2
 -6 9 -3 -3 0 1000 4 0 0 0 0 0 0 0 # AgeSel_3_P_3_ 3
-5 9 5 5 0 1000 4 0 0 0 0 0 0 0 # AgeSel_3_P_4_ 4
-10 9 -6 -6 0 1000 -5 0 0 0 0 0 0 0 # AgeSel_3_P_5_ 5

```
-9 9 -1 -1 0 1000 -5 0 0 0 0 0 0 0 # AgeSel_3_P_6_ 6

# Tag loss and Tag reporting parameters go next
0  # TG_custom:  0=no read; 1=read if tags exist
#Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  #_placeholder if no parameters
1 #_Variance_adjustments_to_input_values
#_1 2 3
 0 0 0 0 #_add_to_survey_CV
 0 0 0 0 #_add_to_discard_stddev
 0 0 0 0 #_add_to_bodywt_CV
 1 1 1 1 #_mult_by_lencomp_N
 1 1 1 1 #_mult_by_agecomp_N
 1 1 1 1 #_mult_by_size-at-age_N
30 #_DF_for_discard_like
30 #_DF_for_meanbodywt_like
1 #_maxlambdaphase
1 #_sd_offset

0  #3 # number of changes to make to default Lambdas (default value is 1.0)
0
999
```

TRE7.dat file

```
#C data generated using SS bootstrap feature
1944 #_styr
2008 #_endyr
1 #_nseas
 12 #_months/season
1 #_spawn_seas
2 #_Nfleet
2 #_Nsurveys
1 #_N_areas
FISHERY1%FISHERY2%SURVEY1%SURVEY2
 0.5 0.5 0.5 0.5 #_surveytiming_in_season
 1 1 1 1 #_area_assignments_for_each_fishery_and_survey
 1 1 #_units of catch:  1=bio; 2=num
 0.01 0.01 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3
2 #_Ngenders
20 #_Nages
 0 0 #_init_equil_catch_for_each_fishery
65 #_N_lines_of_catch_to_read
#_catch_biomass(mtons):_columns_are_fisheries,year,season
# TRE catch as per Plenary report - EXCEPT that it now has a lower rate of underreporting
# for 1986 onwards.. 10% in 1986 declining by 1% each year - then 1% from 1996 onwards.
34	0	1944	1
36	0	1945	1
38	0	1946	1
59	0	1947	1
52	0	1948	1
52	0	1949	1
68	0	1950	1
105	0	1951	1
99	0	1952	1
223	0	1953	1
184	0	1954	1
288	0	1955	1
276	0	1956	1
560	0	1957	1
642	0	1958	1
658	0	1959	1
900	0	1960	1
727	0	1961	1
831	0	1962	1
```

1001	0	1963	1
822	0	1964	1
839	0	1965	1
1427	0	1966	1
1949	0	1967	1
1978	0	1968	1
1737	0	1969	1
2098	0	1970	1
2524	0	1971	1
2751	0	1972	1
2864	0	1973	1
2509	0	1974	1
1998	0	1975	1
2353	0	1976	1
2616	0	1977	1
2866	0	1978	1
3200	0	1979	1
3074	0	1980	1
3495	0	1981	1
3078	0	1982	1
2680	0	1983	1
2130	0	1984	1
2294	0	1985	1
2095	0	1986	1
0	1871	1987	1
0	1992	1988	1
0	1880	1989	1
0	1782	1990	1
0	2219	1991	1
0	1517	1992	1
0	1950	1993	1
0	2380	1994	1
0	2263	1995	1
0	2121	1996	1
0	1944	1997	1
0	2206	1998	1
0	2251	1999	1
0	2359	2000	1
0	1989	2001	1
0	1910	2002	1
0	2153	2003	1
0	2260	2004	1
0	2046	2005	1
0	2059	2006	1
0	1838	2007	1
0	1838	2008	1

19 #_N_cpue_and_surveyabundance_observations
CV = 0.2 start, before iterative reweight
#_year seas index obs se(log)

1990	1	3	5.94	0.22
1991	1	3	3.79	0.22
1992	1	3	3.06	0.22
1993	1	3	2.22	0.22
1994	1	3	2.51	0.22
1995	1	3	2.29	0.22
1996	1	3	2.48	0.22
1997	1	3	2.56	0.22
1998	1	3	2.36	0.22
1999	1	3	2.88	0.22
2000	1	3	2.57	0.22
2001	1	3	2.34	0.22
2002	1	3	2.62	0.22
2003	1	3	3.05	0.22
2004	1	3	2.86	0.22
2005	1	3	2.43	0.22
2006	1	3	3.05	0.22

2007 1 3 2.42 0.22
2008 1 3 2.73 0.22

2 #_discard_type (1=bio or num; 2=fraction)
0 #_N_discard_obs
0 #_N_meanbodywt_obs
2 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
2 # binwidth for population size comp
10 # minimum size in the population (lower edge of first bin and size at age 0.00)
100 # maximum size in the population (lower edge of last bin)
1e-005 #_comp_tail_compression
use this to deal with different age of plus group in age structure
1e-007 #_add_to_comp
0 #_combine males into females at or below this bin number
25 #_N_LengthBins
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 68 72 76 80 90
0 #_N_Length_obs
#Yr Seas Flt/Svy Gender Part Nsamp datavector(female-male)
20 #_N_age_bins
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1 #_N_ageerror_definitions
0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5
13.5 14.5 15.5 16.5 17.5 18.5 19.5 20.5
0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.4 0.4
0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.35
15 #_N_Agecomp_obs using full size range
1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
1 #_combine males into females at or below this bin number
#Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
SEASON - single season
1974 1 1 0 0 1 1 -1 139 0.0000 0.1110 0.0683
0.0627 0.0374 0.0602 0.0838 0.0856 0.0655 0.0429 0.0252 0.0000 0.3574 0 0
0 0 0 0 0 0.0000 0.1110 0.0683 0.0627 0.0374 0.0602
0.0838 0.0856 0.0655 0.0429 0.0252 0.0000 0.3574 0 0 0 0 0
0 0
1975 1 1 0 0 1 1 -1 139 0.0002 0.0616 0.1045
0.0936 0.0749 0.0528 0.0674 0.1076 0.0631 0.0470 0.0233 0.0047 0.2993 0 0
0 0 0 0 0 0.0002 0.0616 0.1045 0.0936 0.0749 0.0528
0.0674 0.1076 0.0631 0.0470 0.0233 0.0047 0.2993 0 0 0 0 0
0 0
1976 1 1 0 0 1 1 -1 139 0.0000 0.0217 0.0525
0.0616 0.0639 0.0289 0.0394 0.0692 0.0981 0.0900 0.0621 0.0147 0.3980 0 0
0 0 0 0 0 0.0000 0.0217 0.0525 0.0616 0.0639 0.0289
0.0394 0.0692 0.0981 0.0900 0.0621 0.0147 0.3980 0 0 0 0 0
0 0
1978 1 1 0 0 1 1 -1 139 0.0029 0.0217 0.1105
0.0738 0.0363 0.0366 0.0490 0.0644 0.0525 0.0422 0.0504 0.0549 0.4047 0 0
0 0 0 0 0 0.0029 0.0217 0.1105 0.0738 0.0363 0.0366
0.0490 0.0644 0.0525 0.0422 0.0504 0.0549 0.4047 0 0 0 0 0
0 0
1979 1 1 0 0 1 1 -1 139 0.0105 0.2358 0.0618
0.0988 0.0224 0.0384 0.0267 0.0157 0.0267 0.0161 0.0042 0.0142 0.4287 0 0
0 0 0 0 0 0.0105 0.2358 0.0618 0.0988 0.0224 0.0384
0.0267 0.0157 0.0267 0.0161 0.0042 0.0142 0.4287 0 0 0 0 0
0 0
1998 1 2 0 0 1 1 -1 234 0 0 0.0822
0.1584 0.0882 0.0242 0.0269 0.0828 0.0995 0.0495 0.0696 0.0702 0.0738 0.018
0.0211 0.0139 0.0095 0.0178 0.0165 0.0775 0 0 0.0822 0.1584 0.0882
0.0242 0.0269 0.0828 0.0995 0.0495 0.0696 0.0702 0.0738 0.018 0.0211 0.0139
0.0095 0.0178 0.0165 0.0775
1999 1 2 0 0 1 1 -1 234 0 0 0.0971
0.1247 0.1422 0.0851 0.0454 0.0228 0.0895 0.0336 0.0452 0.0827 0.0518 0.0454
0.0306 0.0054 0.0133 0.015 0.0048 0.0649 0 0 0.0971 0.1247 0.1422
0.0851 0.0454 0.0228 0.0895 0.0336 0.0452 0.0827 0.0518 0.0454 0.0306 0.0054
0.0133 0.015 0.0048 0.0649

2000	1	2	0	0	1	1	-1	234	0	0.006	0.079	0.24
	0.097	0.14	0.048	0.026	0.028	0.032	0.049	0.045	0.03	0.048	0.039	
	0.008	0.005	0.011	0.01	0.057	0	0.006	0.079	0.24	0.097	0.14	
	0.048	0.026	0.028	0.032	0.049	0.045	0.03	0.048	0.039	0.008	0.005	
	0.011	0.01	0.057									
2001	1	2	0	0	1	1	-1	234	0	0.0011	0.1003	
	0.1072	0.1186	0.1172	0.0519	0.0388	0.0534	0.0392	0.0833	0.0485	0.0257	0.0665	
	0.039	0.0264	0.0134	0.0122	0.0051	0.0522	0	0.0011	0.1003	0.1072	0.1186	
	0.1172	0.0519	0.0388	0.0534	0.0392	0.0833	0.0485	0.0257	0.0665	0.039	0.0264	
	0.0134	0.0122	0.0051	0.0522								
2006	1	2	0	0	1	1	-1	234	0	0	0.034	0.1
	0.168	0.122	0.124	0.109	0.063	0.034	0.052	0.03	0.016	0.012	0.018	
	0.008	0.014	0.037	0.006	0.053	0	0	0.034	0.1	0.168	0.122	
	0.124	0.109	0.063	0.034	0.052	0.03	0.016	0.012	0.018	0.008	0.014	
	0.037	0.006	0.053									
2007	1	2	0	0	1	1	-1	234	0	0	0.023626	
	0.079224	0.152324	0.184234	0.147746	0.076905	0.101773	0.024817	0.027598	0.022985	0.01462	0.02127	
	0.01727	0.007268	0.011882	0.013429	0.016781	0.056208	0	0	0.023626	0.079224	0.152324	
	0.184234	0.147746	0.076905	0.101773	0.024817	0.027598	0.022985	0.01462	0.02127	0.01727	0.007268	
	0.011882	0.013429	0.016781	0.056208								
2008	1	2	0	0	1	1	-1	234	0	0.01578	0.054158	
	0.095054	0.232001	0.155526	0.118252	0.066192	0.065253	0.047133	0.012655	0.033778	0.023389	0.00978	
	0.010775	0.004143	0.003932	0.003621	0.00543	0.043052	0	0.01578	0.054158	0.095054	0.232001	
	0.155526	0.118252	0.066192	0.065253	0.047133	0.012655	0.033778	0.023389	0.00978	0.010775	0.004143	
	0.003932	0.003621	0.00543	0.043052								
1971	1	4	0	0	1	1	-1	134	0.1245	0.0960	0.0379	
	0.0614	0.0944	0.0643	0.0286	0.0317	0.0357	0.0342	0.0371	0.0588	0.2953	0	0
	0	0	0	0	0	0.1245	0.0960	0.0379	0.0614	0.0944	0.0643	
	0.0286	0.0317	0.0357	0.0342	0.0371	0.0588	0.2953	0	0	0	0	0
	0	0										
1972	1	4	0	0	1	1	-1	134	0.0102	0.2221	0.1373	
	0.0544	0.0956	0.0951	0.0571	0.0396	0.0295	0.0278	0.0340	0.0379	0.1593	0	0
	0	0	0	0	0	0.0102	0.2221	0.1373	0.0544	0.0956	0.0951	
	0.0571	0.0396	0.0295	0.0278	0.0340	0.0379	0.1593	0	0	0	0	0
	0	0										
1974	1	4	0	0	1	1	-1	134	0.0789	0.2830	0.1374	
	0.0988	0.0161	0.0114	0.0496	0.0583	0.0336	0.0248	0.0115	0.0180	0.1787	0	0
	0	0	0	0	0	0.0789	0.2830	0.1374	0.0988	0.0161	0.0114	
	0.0496	0.0583	0.0336	0.0248	0.0115	0.0180	0.1787	0	0	0	0	0
	0	0										

0 #_N_MeanSize-at-Age_obs
1 #_N_environ_variables
0 #_N_environ_obs
0 # no wtfreq data
0 # no tag data
0 # no morphcomp data
999
ENDDATA