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An update of the analysis of SNA 7 trawl CPUE indices and other recent data from the SNA 7 fishery

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A.D. Langley

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EXECUTIVE SUMMARY

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The preferred CPUE index for monitoring the SNA 7 fishery is the delta lognormal (all years) index derived from the combined single trawl fishery, targeting flatfish, snapper and barracouta within Tasman Bay and Golden Bay (approximated by statistical area 038). This index is also generally comparable with the trend in CPUE indices derived independently from the SNA7 BPT trawl fishery. Both sets of indices exhibit a very strong increase in CPUE over the last 5 years, but particularly during the 2010/11 and 2011/12 fishing seasons. Standardised CPUE from the single trawl and pair trawl fisheries are estimated to have increased during 2008/09 to 2011/12 by 450% and 700%, respectively.

The fine-scale trawl catch and effort data collected from the fishery from 2007/08 onwards reveal no obvious temporal changes in the operation of the fishery that might contribute towards the recent large increase in the CPUE indices. Further, the CPUE indices obtained from the standardised CPUE analysis of these recent data are comparable to the indices derived from the longer-term CPUE models (all years).

It is reasonable to conclude that the recent increase in the CPUE indices is partly driven by a recent period of strong recruitment. The analysis of the SNA 7 size grade data is generally consistent with this assertion, with an increase in the proportion of smaller fish in the catch from 2008/09 onwards. There is also supporting information from the time series of Tasman Bay/Golden Bay *Kaharoa* trawl surveys which have caught higher numbers of juvenile snapper in recent years (pers. comm. Michael Stevenson, NIWA).

However, the results of population modelling of the SNA 7 stock indicate that exceptionally high recent annual recruitments (approximately ten times the average recruitment level) would be required to produce the magnitude of the recent increase in recruited biomass indicated by the CPUE indices. Recruitments of that magnitude, or anywhere near that magnitude, were not estimated in the time series of recruitment deviates from the preceding period.

Another potential explanation for the recent increase in the CPUE indices is a very large increase in the catchability of snapper, primarily driven by a change in the prevailing oceanographic conditions in recent years. The available *in situ* sea temperature data were examined and, while there was some indication of warmer water temperatures in spring 2011/12 there was no indication that the prevailing sea conditions were contributing substantially to the increase in the CPUE indices. However, given the very short time-series of sea temperature data available and the lack of other alternative environmental indicators (e.g. current flow) it is not possible to entirely dismiss the potential for some exogenous influence on the catchability of snapper in recent years. Nonetheless, it is highly unlikely that the observed variation in environmental conditions could directly account for the large increase in the CPUE indices.

The results of population modelling indicated that the scale of the recent increase in CPUE indices is generally inconsistent with the population dynamics of the stock. This may indicate that the CPUE indices are not directly proportional to population abundance with the vulnerability of snapper to the trawl fishery increasing at higher stock sizes. The increased vulnerability could potentially be due to a) an increase in the schooling behaviour of snapper, including a prolongation of the spawning period, b) an increase in the spatial distribution of snapper in the main area of the fishery, and c) increased

targeting of snapper by the trawl fleet. The fishery data does indicate that the duration of the seasonal period of higher snapper catch rates has increased in recent years, although there is no indication of an extension of the spatial domain of the main fishery area. An increase in the directed targeting within SNA 7 is considered unlikely due to the limited availability of ACE and the high deemed value penalties associated with over-catch of ACE. The operation of the trawl fleet is changing to actively avoid catching snapper, although these changes are unlikely to be detectable in the reported catch and effort data.

While not intended to represent a comprehensive assessment of the SNA 7 stock, the population modelling conducted during this study suggests that the stock abundance has increased considerably over the last 5 years from a relatively low level during the 1990s and early 2000s. The extent of the rebuild of the stock, relative to the B_{MSY} benchmark, will be sensitive to the key biological parameters included in the models (primarily natural mortality and the stock-recruitment relationship) and assumptions regarding the reliability of the CPUE indices as an index of stock abundance. Hence, additional stock modelling, encompassing a range of plausible assumptions, would be required to enable the formulation of a definitive statement regarding the current stock status of SNA 7.

1. INTRODUCTION

Hartill & Sutton (2011) conducted a characterisation and analysis of catch per unit effort (CPUE) data from the SNA 7 fishery. The analysis included data from the 1989/90 to 2008/09 fishing years. During the study period, most of the SNA 7 catch was taken by the single and pair trawl fisheries operating in Tasman Bay and Golden Bay during spring-summer (approximately 75% of the total SNA 7 catch). The single trawl fishery primarily catches snapper as the target species and as a bycatch of flatfish and, to a lesser extent, barracouta trawl fisheries. During the period, the target pair trawl fishery accounted for approximately 20% of the snapper catch from Tasman Bay/Golden Bay.

Hartill & Sutton (2011) considered that CPUE indices derived from the combined single trawl fishery (flatfish, snapper and barracouta) in Tasman Bay/Golden Bay represented the most reliable source of information available to monitor the relative abundance of SNA 7. Standardised CPUE indices were derived for the 1989/90 to 2008/09 with the highest proportion of the data records derived from the flatfish target fishery (72% of records) and, consequently, the fishery had the greatest influence in the final CPUE indices. The resulting indices were relatively stable for the 1996/97 to 2008/09 fishing years.

The indices are principally derived from CELR records and do not account for the changes to the spatial management of the fishery over the time series, specifically the introduction of the seasonal (November–April) closure of the trawl fishery in the inshore areas of Tasman Bay and Golden Bay in 1991.

The purpose of the current study is to document recent trends in the SNA 7 fishery and extend the time-series of CPUE indices to include the 2009/10 to 2011/12 fishing years. Since October 2007, the inshore trawl fleet has been required to report catch and effort data by detailed fishing location. These data provide the opportunity to undertake a more detailed analysis of the factors influencing snapper catch rate. A separate time-series of CPUE indices is derived from these data for the 2007/08 to 2011/12 fishing years.

In addition, other recent data from the fishery are reviewed, primarily size grade data and *in situ* sea temperature data from Tasman Bay. The recent CPUE indices and size grade data are evaluated within the framework of a population model for SNA 7.

2. INITIAL DATA SET

Catch and effort data were sourced from the Ministry of Primary Industries (MPI) (Report number 8614). The initial data set included all fishing effort and catch (all species) from fishing trips that targeted and/or caught snapper or flatfish during a fishing trip that conducted trawling (single trawl or pair trawl) within the MPI Fishery Statistical Areas that comprise SNA 7 (Statistical Areas 034, 035, 036, 037, 038 and 017). The estimated catch of all species was provided for each fishing effort record (day of fishing or trawl) and the associated landed catch from each fishing trip was provided for all fish stocks.

The data set included the 1989/90 to 2011/12 fishing years. Catch from the 2011/2012 fishing year were incomplete but included the main period of SNA7 catch (October 2011–April 2012).

The data set did not include the minor snapper catch taken by the Danish seine fishery operating within Tasman Bay/Golden Bay.

The annual SNA 7 total landed catch and estimated catch included within the data set was comparable to the documented annual catch (from QMRs and MHRs) (Ministry of Fisheries 2011) (Figure 1).

The SNA 7 catch data were groomed following the approach of Starr (2007). For each fishing trip, the landed catch (greenweight kilograms) from the SNA 7 fish stock was compared to the cumulative estimated catch of snapper from the statistical areas that correspond to the SNA 7 Quota Management Area (statistical areas 033, 034, 035, 036, 038 and 017). A third of trips (33% of total trips) reported no estimated catch of snapper despite recording a landing of SNA 7 (Figure 2). Most (77%) of the landings included a landed catch of SNA 7 of less than 30 kg.

A small component (8%) of the individual fishing trips reported a cumulative estimated catch that was considerably larger (at least 50%) than the landed catch (Figure 2). Most of these trips were from vessels that were operating in the target pair trawl fishery and are attributable to the recording of the shared catch between the individual vessels in the pair unit.

For a third of the trips (34%) there was a reasonable correspondence between the estimated and the landed catch (within 20%) (Figure 2).

For all fishing trips, the estimated catch from each fishing trip was corrected to be consistent with the SNA 7 landed catch recorded from the trip. For those fishing trips that recorded one or more estimated snapper catches, the individual estimated catches were rescaled by the ratio of the landed catch to the total estimated catch from the trip. For those fishing trips that did not record any estimated snapper catch, the landed snapper catch from the trip was distributed among the individual effort records in proportion to the number of trawls included in each effort record.

Individual fishing trips were then assigned to specific fisheries based on the definitions from Bentley et al. (2012) (Table 1). A fishing trip was assigned to a specific fishery if more than 50% of the fishing effort (trawls) was included within the fishery definition. For most fishing trips, almost all fishing effort was included within a specific fishery definition. Fishing trips that did not meet these criteria were assigned to the "Other" category. These fishing trips accounted for 13% of the total SNA 7 landed catch (Table 1).

3. RECENT CATCH TRENDS

Overall the total SNA 7 catch increased from about 150 t in the late 1990s, and since 2002/03 annual catches have fluctuated about the level of the current TACC (200 t) (Figure 3). Annual catches from the flatfish trawl fishery in Tasman Bay/Golden Bay have fluctuated around 50 t per annum since 2002/03 with considerable inter-annual variation in catches between years. The level of target snapper catch from the Tasman Bay/Golden Bay single trawl fishery steadily increased from about 10 t per annum in the mid 1990s to about 45 t in 2006/07 and has remained at that level in recent years. The snapper pair trawl fishery yielded annual catches of about 35 t over the last six years (Figure 3).

Annual snapper catches from the barracouta/tarakihi trawl fishery operating in statistical areas 038 and 017 declined from about 35 t in 1998/99 to 2002/03 to about 10–15 t from 2004/05 (Figure 3). The decline in catch is consistent with a decline in the level of fishing effort in the fishery during the period (Bentley et al. 2012). Annual catches from the west coast South Island trawl fisheries increased from about 10 t in the late 1990s to 35 t in recent years.

Over recent years, there has been a tendency for a higher proportion of the total SNA 7 trawl catch to be caught earlier in the fishing year (Figure 4).

4. CPUE ANALYSIS

4.1 Updated CPUE Analysis

The first objective of the study was to replicate the CPUE analysis conducted by Hartill & Sutton (2011). The CPUE data set was constructed based on the subset of data included within the three single trawl fisheries defined for the Tasman Bay/Golden Bay area: snapper single trawl, flatfish single trawl and barracouta/tarakihi single trawl. Catch and effort records were limited to fishing effort within statistical area 038 and target species was restricted to SNA, FLA (including constituent species) or BAR. The data set was further limited to the fishing activity of individual vessels that had operated in the fishery for a minimum of four fishing years (at least 10 days fishing per year). All catch and effort records were aggregated in a manner equivalent to the CELR data format (aggregated by fishing vessel, fishing day, statistical area and target species).

The data set was limited to the catch and effort records with a catch of snapper (non zero catch records). For comparative purposes, the initial model was restricted to the time period of the Hartill & Sutton (2011) analysis (1989/90 to 2008/09). The equivalent CPUE model structure was also implemented (with lognormal error structure).

log(SNA_scaled_catch)~fyear+month+vessel_key+target_species_new
+fishing_duration+fishing_duration^2*+fishing_duration*^{3}*+target_species_new:month*
+ target_species_new: vessel_key

The resulting CPUE indices were very similar to the indices derived by Hartill & Sutton (2011) (Figure 5). On that basis, it was considered that the data grooming and data selection procedures developed for the current study are consistent with those of the original study.

The complete data set includes the additional data from 2009/10 to 2011/12 (three years). A summary of the data included in the model data set is provided in Table 2.

The updated CPUE model (all years), including data from 2009/10–2011/12, had the equivalent model structure to the original CPUE model (Hartill & Sutton 2011). Again, the annual indices for 1989/90 to 2008/09 were very similar to the indices derived from the previous study (Figure 5). The index for 2009/10 was of a similar magnitude to the 2008/09 year; however, there was a large increase in the CPUE indices in 2010/11 and 2011/12; the CPUE indices increased by 360% during this two year period (Figure 5). The standard error associated with the CPUE indices remained relatively low throughout the model period.

The influence of the data from the individual trawl fisheries was investigated by sequentially excluding the data from the barracouta fishery and the snapper trawl fishery. The resulting three sets of CPUE indices were very similar, primarily due to the influence of the data from the flatfish trawl fishery which dominates the combined data set (Figure 6).

There were a relatively high proportion of fishing trips in the target flatfish and barracouta Tasman Bay/Golden Bay fishery data sets that caught no snapper (SNA 7). Following the methodology of Hartill & Sutton (2011), these records were excluded from the combined CPUE analysis (non zero indices from the combined model). However, since the late 1990s, there was a general decline in the proportion of zero catch records in the complete data set (Table 2 and Figure 7).

A simple model of the presence/absence of snapper catch was fitted (with a binomial error structure) to the entire data set from the FLA, SNA, BAR single trawl fishery within Statistical Area 038 (binomial model).

Pr(SNA_scaled_catch > 0)~fyear+month+vessel_key+target_species_new+
fishing_duration+fishing_duration^2*+fishing_duration*^{3}

The resulting annual indices from the binomial model were combined with the lognormal indices (*combined model, all years*) to derive the delta-lognormal CPUE indices for the combined fisheries.

The delta-lognormal indices exhibited greater contrast than the lognormal (non zero) indices, in particular the increase in the CPUE indices during the two most recent years (Figure 8).

The potential for developing CPUE indices from the catch and effort data from the west coast South Island trawl fisheries was also investigated. However, preliminary modelling results yielded annual indices with a very high associated standard error and, on that basis, it was considered unlikely that the resulting indices would be sufficiently reliable for monitoring stock abundance.

Initially, the target bottom pair trawl (BPT) catch and effort data were not considered in the analysis as considerably more (manual) error checking would be required to construct a groomed data set. However, for comparative purposes a simple CPUE model was fitted to the catch and effort data from the SNA 7 target bottom pair trawl (BPT) fishery operating in Tasman Bay/Golden Bay (Statistical Area 038).

log(SNA_scaled_catch)~fyear+month+vessel_key+
fishing_duration+fishing_duration^2*+fishing_duration*^{3}

The general trends in the resulting BPT CPUE indices are comparable to the combined and delta-lognormal CPUE indices (Figure 9). The indices decline from the early 1990s to a relatively low level in the early 2000s and subsequently increase from 2003/04 to 2009/10. The indices then virtually double from 2009/10 to 2011/12. The 2000/01 index from was poorly determined (very high standard error) and is excluded from Figure 9.

4.1.1 Influence of new reporting forms

Since October 2007, the inshore trawl vessels operating in the Challenger FMA have been required to report detailed catch and effort data from each trawl using the Trawl Catch Effort Return (TCER). The higher resolution data records the position at the start of the trawl, the bottom depth at the start of the trawl, start and end time of the trawl, target species, and trawling speed and has provision for the recording of the estimated catch of up to eight species. The wingspread and the headline height of the trawl gear are also recorded.

The CPUE data sets compiled for the various CPUE analyses aggregate the recent TCER effort data in a format that is comparable to the CELR format; i.e. the number of trawls and hours fished are aggregated by vessel, date, fishing method (BT), statistical area and target species. However, the configuration of the snapper catch data differs somewhat between the two data formats (CELR and TCER) due to the higher resolution of the catch recording.

The catch data were further standardised between the two form types by aggregating the snapper estimated catches from the TCER forms in a manner that is more comparable to the CELR format. TCER estimated catches for all species were aggregated by CELR strata and the combined species catches from the strata were ranked from largest to smallest. If the snapper catch was recorded within the top five species (equivalent to CELR format) then the estimated snapper catch was retained in the data set otherwise the estimated snapper catch was set to zero. The rescaling of the SNA 7 landed catch from the trip to the individual CELR format records was then conducted as described above.

The CPUE indices for 2007/08 and 2008/09 derived from the base model (lognormal, non zero catch) were sensitive to the treatment of the snapper estimated catches (Figure 10). This appears to be related to snapper being less frequently reported in the top five species caught during these two years compared to the more recent years (2009/10–2011/12).

4.2 CPUE Analysis of location based trawl catch, effort data

The TCER catch and effort data set was limited to individual records that occurred within the main area of the SNA 7 single trawl fishery – trawls within Tasman Bay and Golden Bay and in depths shallower than 70 m. Only 2% of the total snapper catch from the fishery is taken during winter (June–September) and this period was excluded from the final data set. The data set was also limited to the fishing activity of individual vessels that had operated in the fishery for a minimum of four fishing years (at least 10 days fishing per year).

The location data (latitude and longitude) were provided by MPI rounded to the nearest one tenth of a degree (approximately 6 nautical miles). This spatial resolution is adequate to describe the distribution of fishing activity as an individual trawl typically covers a distance of 6–10 nautical miles. The location data were used to assign individual trawl records to the three main fishing areas within Tasman Bay/Golden Bay: Golden Bay, western Tasman Bay (TBw) and eastern Tasman Bay (TBe) (Figure 11).

Within Tasman Bay/Golden Bay most of the qualifying trawls were fishing within the 8–30 m depth range (trawl start depth) (Figure 12).

The TCER data set is dominated by trawls targeting flatfish (81%) with a smaller number (13%) of target snapper trawls (Table 3). The remainder of trawls (6%) primarily targeted red gurnard or red cod.

In recent years, there was considerable inter-annual variability in the seasonal catch of snapper from the single trawl fishery (Figure 13). Significant catches of snapper were taken earlier in 2011/12 compared to the previous four fishing years, while in 2007/08 the catch of snapper by the single trawl fishery during spring was comparatively low. Conversely, the level of fishing effort (number of trawls) during spring of 2011/12 was considerably lower than previous years, while the overall number of trawls conducted during 2007/08 was considerably higher than the other years (Figure 13).

The higher level of fishing effort in 2007/08 may be related to a higher level of flatfish catch and catch rate during that year. Flatfish catches (and catch rates) declined from 2007/08 to 2009/10 (Table 3).

During 2007/08 to 2011/12, there was also considerable inter-annual variation in the seasonal trend in snapper (unstandardised) catch rates (Figure 14). In 2008/09 and 2009/10, catch rates tended to peak during November–December and then remained relatively low from February to May. However, in 2010/11 and 2011/12 the period of higher catch rates was maintained through until June (Figure 14). The 2011/12 fishing season was also characterised by very high catch rates during October and November. In contrast, catch rates were very low for the first three months of the 2007/08 fishing year (October–December 2007) followed by a short peak in catch rates during January 2008. There was also a second peak in catch rates during March 2008 (Figure 14).

A total of 11 342 records were included in the complete TCER data set. Three separate CPUE model options were considered:

1) a lognormal model including the complete data set (including zero snapper catches). An offset of 1 kg was added to all catch records to enable the zero catch records to be included (number of records 11 342). Dependent variable is the natural logarithm of the (scaled) snapper catch (plus 1 kg).
2) A non zero, lognormal model. Zero snapper catch records excluded (number of records 4863). Dependent variable is the natural logarithm of the (scaled) snapper catch.
3) Binomial model of the presence/absence of snapper in the individual catch. (number of records 11 342). Dependent variable is the presence (1) or absence (0) of snapper in the catch.

The variables available for inclusion in the CPUE analysis are described in Table 4. A number of potential explanatory variables were derived from extraneous data sources. The *TACCcaught* variable related the cumulative daily total catch for the fishing year (all fisheries combined) to the TACC. The day of fishing was also related to the moon phase by determining the number of days pre/post the new moon.

There were no strong annual trends in any of the main continuous variables available to the model (Figure 15).

The CPUE models were fitted using the step-wise fitting procedure *step* implemented in *R*. The models were formulated to include *Fyear* as the first variable included in the model. All continuous variables were included in the fitting procedure as third order polynomial functions. A range of first order interactions were included as potential explanatory variables (interactions between *vessel_key* and *month*, *area* and *TACCcaught* and *bottom_depth* and *month*). The fitting procedure iteratively adds successive variables to the CPUE model based on the improvement in AIC.

The three models all included the same set of principal explanatory variables (*fishing year*, *vessel_key*, *target_species_new* and *month*), while the effort variable *distance* was included at the next tier (Table 5). An examination of the residuals from the lognormal (all data) model revealed a considerable divergence from the assumption of a lognormal error structure. The distribution of the residuals from the non zero, lognormal model more closely approximated a normal distribution (Figure 16).

The non zero, lognormal model does not account for the increased probability of the catch of snapper in recent years. To incorporate this component, the annual CPUE indices from the lognormal, non zero model and the binomial model were combined to derive a delta lognormal CPUE index. The resulting index increases substantially from 2007/08 to 2011/12 and is very similar to the annual indices derived from the lognormal (all data) model (Figure 17). The increase in the indices is more pronounced than the indices obtained from the base (all years) model, but similar to the indices derived from the delta lognormal (all years) model (Figure 8). These indices indicate that the relative abundance of snapper has increased by about 600% in the last five years. The large increase in the CPUE indices reflects the increase in the proportion of trawls with snapper catches exceeding 25 kg and a reduction in the proportion of nil snapper catch trawls (Figure 18).

The performance of the lognormal, non zero model was examined in more detail. The model standardisation is having a considerable effect on the index from the 2011/12 fishing year, with the standardised index being considerably higher than the unstandardised CPUE data. An examination of the step-wise fitting process indicated that the *vessel_key* categoric variable was having the strongest influence in the CPUE standardisation (Figure 19) with the overall CPUE data set being increasingly dominated by the vessels in the fleet that tend to have a lower catch rate of snapper (the vessels more able to avoid catching snapper, perhaps). The CPUE indices were further modified by the inclusion of *month* (iteration 3) and *target_species_new* (iteration 4) and the interaction terms *vessel_key*: *TACCcaught* (iteration 11) and *vessel_key:month* (iteration 12) (Figure 19).

The residuals from the lognormal, non zero model do not reveal strong spatial patterns that might be indicative of a large shift in the distribution of snapper between years (Figure 20).

There are high (average) residuals (positive and negative) associated with individual fishing vessels indicating that relative snapper catch rates for an individual vessel may vary considerably between years (Figure 21). Monthly residuals also vary between years indicating different seasonal patterns in the snapper fishery. For example, model residuals from January–April of the 2008/09 fishing year were generally negative indicating lower than predicted snapper catch rates during the period. Conversely, model residuals in January–April of 2011/12 were generally positive and catch rates were higher than predicted by the model (Figure 21).

The delta lognormal (all years) model was considered to represent the preferred CPUE index for the stock on the basis that it incorporated all available information from the fishery. The confidence intervals for the individual indices were computed using a bootstrapping procedure (Table 6 and Figure 22).

5. SNA 7 SIZE GRADE DATA

A large proportion of the total annual commercial catch from SNA7 is processed by Talley Group Ltd in Motueka. A considerable proportion (45–70%) of the landed catch is graded by fish size and packed in 10 kg cartons (Table 7). The five grading categories are based on the number of fish included in each carton (2–5 fish, 6–7 fish, 8–15 fish, 16–25 fish and 26+ fish) (Table 8). Most of the remainder of the catch (i.e. ungraded) is specified as “SNAPPER - GREEN FRESH OVER 25CM”.

The decision to pack the snapper catch by size grade is not based on the size of fish in the landed catch. On that basis, the graded component of the catch can be considered to be reasonably representative of the total trawl catch from the fishery (single and pair trawl combined). However, a more thorough analysis of the data (resolved by fishing trip) is warranted to verify this assumption.

Size grade data were available from the 2004/05 to 2012/13 fishing years, although data from 2012/13 was provisional (complete to 31/1/2013 and representing a total SNA 7 catch of 122 t). The packing list data are presented as annual weight frequency distributions (Table 7). The data were also converted to approximate length compositions by determining the number of fish in each weight category assuming a mean fish weight for each weight category (the mid-point between the bounds of the weight category). The weight categories can be assigned to an approximate range of age classes based on the SNA 7 growth curve (Figure 23).

The time series of weight frequency data reveal considerable variability in the proportion of small fish (grades 26+ fish and 16–25 fish) among years (Figure 24). These fish approximate the recently recruited age classes (3 and 4 years). In recent years, these weight categories have accounted for a relatively high proportion of the total catch (in numbers). There was also an increase in the proportion of fish in the third category (8–15 fish) in 2011/12 and a corresponding reduction in the proportion of fish in the largest weight category (Figure 24). This is consistent with an increase in recruitment in recent years, particularly when considered in conjunction with the trends in the CPUE indices. The trend towards an increasing proportion of fish in the third category persisted in the 2012/13 fishing year (Figure 24).

6. SNA 7 POPULATION MODELING

A recent MPI research project developed an age structured population model for SNA 7 as an operating model for the evaluation of potential management procedures for the fishery (Langley 2011). The operating model was implemented in the Stock Synthesis software (Methot 2005). The formulation of the operating model was similar to the SNA 7 stock assessment model previously implemented by Harley & Gilbert (2000). Many of the historical data sets included in the operating model were sourced directly from Harley & Gilbert (2000) rather than the original source materials. A number of additional data sets were also incorporated in the current analysis and these are described in more detail below.

The operating model was updated for this study to incorporate the recent CPUE indices and SNA 7 size grade data to enable an evaluation of these data within the framework of the population dynamics of the stock. It is not intended for the results of the population modelling to be considered as a formal stock assessment of SNA 7.

Input data

i. Annual commercial catch from the SNA 7 fishery 1931–2011 (Ministry of Fisheries 2011) (the 2011 year represents the 2011/12 fishing year).
ii. An assumed non commercial catch history (Langley 2011).
iii. 1987 biomass estimate from tagging programme (Harley & Gilbert (2000), Table 8).
iv. Age compositions of the commercial catch from the earlier period of the fishery. Nine annual observations from 1970, 1973, 1974, 1975, 1978, 1979, 1980, 1981 and 1984 (Harley & Gilbert (2000), Table 3).
v. Age compositions of the commercial catch from the more recent period of the fishery. Seven annual observations 1993–2007 (1993 and 1998, Harley & Gilbert 2000, Table 3; 1999 ; 2000; 2001; 2004 and 2007 Hartill & Sutton 2011).
vi. Age composition of the tagged component of the population in 1988 (Harley & Gilbert 2000, Table 4).
vii. Age composition of the snapper sampled by trawl surveys in 1969, 1971 and 1972 (Harley & Gilbert 2000, Table 4).
viii. Annual standardised delta-lognormal CPUE indices from the Tasman Bay/Golden Bay inshore trawl fisheries, 1989–2011 (this study) (Figure 22).
ix. Commercial weight frequency data of the annual catch from 2004–2011 derived from fish size grade data provided by Talley Group Ltd.

Model structure and assumptions

The SNA 7 population model was configured as follows:

- A single region with two sexes and 30 age classes (including plus group).
- A single (12 month) fishing season.
- The commercial trawl fishery divided into two time periods (pre and post 1986) and configured as separate model fisheries. The model also included a non commercial (recreational) fishery.
- Biological parameters (natural mortality, maturity and growth) fixed at the documented values (Ministry of Fisheries 2011).
- Model period 1931–2011, assuming equilibrium, unexploited conditions in 1931.
- Annual recruitment parameterised by a Beverton Holt stock-recruitment relationship with steepness fixed at 0.95. Recruitment deviates were estimated for 1950–2009. Standard deviation of the recruitment deviates fixed at 0.6.
- A common age-specific selectivity for all fisheries parameterised using a logistic function (base model). There are no size/age composition data for the non commercial fishery and selectivity for the non commercial fishery is assumed equivalent to the commercial fisheries.
- A double normal function for estimation of the age based selectivity of the early trawl surveys.
- The tagging biomass estimate was assigned a coefficient of variation (c.v.) of 5%. This is an unrealistically high level of precision; however, it was considered that the tagging biomass estimate represented the most important observation regarding the recent and historical levels of stock biomass and should be afforded considerable influence in the assessment model.
- The individual observations in each of the age frequency data sets were assigned an effective sample size of 10 following the weighting approach recommended by Francis (2011). The weight frequency observations were also assigned an effective sample size of 25.
- The CPUE indices were assigned a c.v. of 15%. The assumed c.v. is higher than the empirical c.v. of approximately 5% (Hartill & Sutton 2011); however, the assumed c.v. is likely to be lower than the true uncertainty associated with the CPUE indices representing a reliable abundance index for the stock (process error). Nonetheless, for model options with a higher c.v., as the age and weight frequency data had considerable influence in the assessment and the resulting trend in stock biomass deviated considerably from the trend in the CPUE indices. The final c.v. of 15% was adopted to ensure that the trend in stock biomass was generally consistent with the CPUE indices.

The performance of the SNA 7 operating model, including the sensitivity to many of the key model assumptions, is presented in Langley (2011). This report simply presents additional model runs to evaluate the influence of the recent data sets.

For the base model run (CPUE c.v. 15%), the model provides a reasonable fit to the CPUE indices with the exception of the last two years (2010 and 2011). For these years, the estimated stock biomass is substantially lower than the corresponding CPUE indices (Figure 25). Nonetheless, the model attempts to fit the increase in stock abundance via the estimation of an exceptionally strong 2007 year class (Figure 26).

Two alternative models were configured to examine the influence of the two recent data sets (CPUE and size grade data): 1) the CPUE indices were assigned a c.v. of 5% to increase the relative weighting of these data (size grade data ESS 25) and 2) the CPUE indices were down-weighted with a c.v. of 35% and the relative weighting of the size grade data was increased (ESS 5 per sample). These relative weightings are extreme but they are simply intended to contrast the influence of the two data sets.

For the three model options, the fits to the CPUE indices and the catchability coefficient for the trawl fishery varies in accordance with the relative weight associated with the CPUE indices (Figure 25). However, the absolute level of current (2011) stock biomass does not vary substantially largely due to the constraint imposed on the model to fit the tagging biomass estimate.

The fits to the size grade data from the three model options are comparable for 2004–2009 but deviate considerably for the last two years (2010 and 2011) (Figure 27). In those years, the model option with the higher weight associated with the CPUE indices predicts a considerably higher proportion of fish in the 3rd and 4th weight categories and a lower proportion in the largest weight category. This corresponds to the different patterns in the recruitment deviates with an exceptionally high 2005 year class estimated for the high CPUE weighting model option, while the recent positive recruitment deviates are more moderate for the alternative model (high weighting to size grade data) (Figure 26). For all model options, recruitment deviates are estimated to be positive from 2004–2009. It is worth noting that these deviates are positive for an additional model run (CPUE c.v. 35%, ESS 5) that excluded the last two CPUE indices (2010 and 2011).

The large proportion of fish predicted in the 3rd weight category is evident in the size grade data from the 2012/13 fishing year (Figure 24). These data were not included in the operating models.

The modelling results indicate that the magnitude of the increase in the CPUE indices in the last two years (2010/11 and 2011/12) is not consistent with the underlying stock dynamics and the other recent observations from the fishery. While the recent size grade data are generally consistent with an increase in stock abundance, the extent of the increase is considerably lower than indicated by the CPUE indices. This discrepancy between the two data sources may suggest that the selectivity of the fishery may vary among years, possibly in relation to abundance. However, it is more likely that the overall catchability of the fishery may vary among years and, hence, the CPUE indices may not be directly proportional to stock abundance.

7. RECENT OCEANOGRAPHIC CONDITIONS

Recent oceanographic data were compiled to investigate whether the recent increase in SNA 7 catch rates could be attributable to changes in the prevailing oceanographic conditions resulting in an increase in the availability and/or vulnerability of snapper to the trawl fleet.

Direct observations of oceanographic conditions are available from a hydrological buoy anchored off the mouth of the Motueka River in western Tasman Bay (http://www.cawthron.org.nz/coastalfreshwater-resources/tascam.php) (Figure 28). The TASCAM buoy and the predecessor have been collecting sea temperature data at hourly intervals from a depth of 4–8 m from January 2006. The sea temperature data were provided by Ben Knight, Cawthron Institute. Wind speed and direction, current speed and direction and salinity are also available from TASCAM from April 2011 onwards.

The sea temperature data were summarised to derive a weekly average sea temperature. Data recording was not continuous throughout the period with considerable disruptions in collection during the 2007/08 and 2010/11 fishing years.

There is a steady increase in sea temperature from early October to the end of January (Figure 29 and Figure 30). Water temperatures start to decline from about mid-March. During October–January of the 2011/12 fishing year, sea temperatures were somewhat higher than the previous years, although the seasonal peak in temperature was lower than in 2007/08 and 2009/10.

The differences in sea temperatures may indicate a difference in the prevailing oceanographic conditions between years. The potential influence of sea temperature was investigated by the inclusion of the weekly SST variable in the lognormal, non zero model. Insufficient sea temperature data were available from the 2010/11 fishing year and, hence, the year was excluded from the CPUE model. A strongly significant relationship was determined between weekly sea temperature and snapper CPUE (Figure 31); however, the inclusion of the SST in the CPUE model did not result in a discernible change in the annual CPUE. Nonetheless, the short time-series (four years) and the interaction between sea temperature and other important variables in the model (*month* and *fishing year*) means that the direct influence on sea temperature on snapper CPUE cannot be reliably quantified.

Previous population modelling of the SNA 7 stock (Langley 2011) revealed a positive relationship between annual average SOI and snapper recruitment. *La Nina* conditions (positive SOI) prevailed during 2007/08, 2010/11 and 2011/12 (Figure 32) and, hence, these years could be expected to generate above average snapper recruitment.

Hartill & Sutton (2011) did not detect a significant relationship between monthly SOI and snapper catch rates for the period 1989/90 to 2007/08. The current study did not incorporate SOI as a potential explanatory variable in the various CPUE models.

Positive SOI conditions correspond to an increased frequency of northerly conditions in Tasman Bay and Golden Bay. These conditions could potentially result in the concentration of snapper in shallower waters and, thereby, increase the vulnerability of snapper to the trawl fishery. However, a comparison of the average SOI during October–December and the annual CPUE indices (delta lognormal, all years) revealed no strong correlation between the two data sets (correlation coefficient 0.282). This may suggests that the prevailing SOI conditions during the main fishing period are not strongly influencing the SNA 7 CPUE indices.

8. CONCLUSIONS

The preferred CPUE index for monitoring the SNA 7 fishery is the delta lognormal (all years) index derived from the combined single trawl fishery, targeting flatfish, snapper and barracouta within Tasman Bay and Golden Bay (approximated by statistical area 038). This index is also generally comparable with the trend in CPUE indices derived independently from the SNA 7 BPT trawl fishery. Both sets of indices exhibit a very strong increase in CPUE over the last 5 years, but particularly during the 2010/11 and 2011/12 fishing seasons. Standardised CPUE from the single trawl and pair trawl fisheries are estimated to have increased during 2008/09–2011/12 by 450% and 700%, respectively.

The fine-scale trawl catch and effort data collected from the fishery from 2007/08 onwards reveal no obvious temporal changes in the operation of the fishery that might contribute towards the recent large increase in the CPUE indices. Further, the CPUE indices obtained from the standardised CPUE analysis of these recent data are comparable to the indices derived from the longer-term CPUE models (all years).

It is reasonable to conclude that the recent increase in the CPUE indices is partly driven by a recent period of strong recruitment. The analysis of the SNA 7 size grade data is generally consistent with this assertion, with an increase in the proportion of smaller fish in the catch from 2008/09 onwards. There is also supporting information from the time series of Tasman Bay/Golden Bay *Kaharoa* trawl surveys which have caught higher numbers of juvenile snapper in recent years (pers. comm. Michael Stevenson, NIWA).

However, the results of population modelling of the SNA 7 stock indicate that exceptionally high recent annual recruitments (approximately 10 times the average recruitment level) would be required to produce the magnitude of the recent increase in recruited biomass indicated by the CPUE indices. Recruitments of that magnitude, or anywhere near that magnitude, were not estimated in the time series of recruitment deviates from the preceding period.

Another potential explanation for the recent increase in the CPUE indices is a very large increase in the catchability of snapper, primarily driven by a change in the prevailing oceanographic conditions in recent years. The available *in situ* sea temperature data were examined and, while there was some indication of warmer water temperatures in spring 2011/12 there was no indication that the prevailing sea conditions were contributing substantially to the increase in the CPUE indices. However, given the very short time-series of sea temperature data available and the lack of other alternative environmental indicators (e.g. current flow) it is not possible to entirely dismiss the potential for some exogenous influence on the catchability of snapper in recent years. Nonetheless, it is highly unlikely that the observed variation in environmental conditions could directly account for the large increase in the CPUE indices.

The results of population modelling indicated that the scale of the recent increase in CPUE indices is generally inconsistent with the population dynamics of the stock. This may indicate that the CPUE indices are not directly proportional to population abundance with the vulnerability of snapper to the trawl fishery increasing at higher stock sizes. The increased vulnerability could potentially be due to a) an increase in the schooling behaviour of snapper, including a prolongation of the spawning period, b) an increase in the spatial distribution of snapper in the main area of the fishery, and c) increased targeting of snapper by the trawl fleet. The fishery data does indicate that the duration of the seasonal period of higher snapper catch rates has increased in recent years, although there is no indication of an extension of the spatial domain of the main fishery area. An increase in the directed targeting within SNA 7 is considered unlikely due to the limited availability of ACE and the high deemed value penalties associated with over-catch of ACE. The operation of the trawl fleet is changing to actively avoid catching snapper, although these changes are unlikely to be detectable in the reported catch and effort data.

While not intended to represent a comprehensive assessment of the SNA 7, the population modelling conducted during this study suggests that the stock abundance has increased considerably over the last five years from a relatively low level during the 1990s and early 2000s. The extent of the rebuild of the stock, relative to the B_{MSY} benchmark, will be sensitive to the key biological parameters included in the models (primarily natural mortality and the stock-recruitment relationship) and assumptions regarding the reliability of the CPUE indices as an index of stock abundance. Hence, additional stock modelling, encompassing a range of plausible assumptions, would be required to enable the formulation of a definitive statement regarding the current stock status of SNA 7.

9. ACKNOWLEDGMENTS

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Table 1: Fishery definitions for the main inshore trawl fisheries within FMA 7. The number of trips represents the number of fishing trips that recorded a landed catch of SNA 7. The total SNA 7 landed catch is also reported.

Fishery	Gear type	Target species	Statistical areas	Number of trips	SNA 7 catch
Flatfish trawl Tasman/Golden Bay	BT	FLA, GUR, RCO	038, 017	8 982	1 049
Snapper single trawl Tasman/Golden Bay	BT	SNA	038, 017	676	663
Snapper pair trawl Tasman/Golden Bay	BPT	SNA	038, 017	910	651
Mix trawl Tasman Bay/Cook Strait	BT	TAR, BAR, WAR	038, 017	1 566	460
Flatfish trawl WCSI	BT	FLA	033,034,035,036	1 553	129
Mixed trawl WCSI	BT	TAR, BAR, RCO, WAR, STA	033,034,035,036	1 223	394
Other				3 112	505

Table 2: A summary of the data included in the *combined* model (following Hartill & Sutton 2011) by target species and fishing year. The fishing year is denoted by the calendar year at the start of the fishing year.

Number of records (non zero snapper catch)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
BAR	25	76	109	85	80	120	138	57	52	50	101	93	112	103	163	144	70	37	77	53	49	21	26
FLA	508	396	374	586	441	509	472	467	383	289	287	231	262	409	687	567	657	1003	518	498	607	434	348
SNA	95	95	53	44	32	24	23	23	45	60	49	52	25	58	59	57	96	106	121	77	100	100	68
Total	628	567	536	715	553	653	633	547	480	399	437	376	399	570	909	768	823	1146	716	628	756	555	442

Total SNA 7 catch (t)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
BAR	1.6	10.1	8.7	9.7	12.1	6.4	16.1	6.6	8.0	4.9	15.6	22.5	20.5	13.2	28.4	12.6	7.4	4.8	8.9	2.3	2.8	5.1	4.7
FLA	13.5	13.4	18.0	31.1	22.6	29.2	20.5	28.9	23.2	16.3	27.7	15.2	18.3	23.1	35.1	15.9	40.6	67.7	25.2	38.1	23.1	26.3	30.4
SNA	30.8	24.9	18.7	13.8	18.0	4.5	10.7	7.0	12.8	25.1	23.5	20.8	8.7	19.7	18.0	16.6	35.6	41.1	47.3	25.3	29.0	42.7	42.7
Total	45.9	48.5	45.5	54.7	52.7	40.1	47.3	42.6	43.9	46.4	66.8	58.5	47.5	56.0	81.4	45.1	83.6	113.6	81.4	65.8	54.9	74.1	77.9

Proportion of zero SNA catch records included in the total data set (note that the zero catch records were not included in the *combined* model).

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
BAR	0.51	0.40	0.42	0.55	0.32	0.33	0.47	0.54	0.45	0.65	0.43	0.50	0.42	0.43	0.38	0.43	0.31	0.44	0.38	0.55	0.20	0.15	0.26
FLA	0.49	0.43	0.52	0.51	0.54	0.50	0.57	0.63	0.73	0.69	0.67	0.65	0.70	0.57	0.46	0.63	0.54	0.45	0.56	0.55	0.53	0.48	0.17
SNA	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.02	0.02	0.00	0.04	0.06	0.00	0.05	0.02	0.02	0.05	0.01	0.01	0.01

Table 3: Summary of records included in the TCER data set by fishing year and target species and fishing area. *Other target species are principally RCO and GUR. The fishing year is denoted by the calendar year at the start of the fishing year.

Number of records.

Target species	2007	2008	2009	2010	2011
FLA	2 977	1 977	1 965	1 305	980
SNA	466	287	285	251	149
Other	323	161	78	75	63

Total SNA catch (t)

Target species	2007	2008	2009	2010	2011
FLA	20.37	32.99	20.92	24.03	29.62
SNA	26.54	29.22	23.34	36.32	38.59
Other	1.64	1.73	4.76	4.77	4.23

Proportion of records with no SNA catch.

Target species	2007	2008	2009	2010	2011
FLA	0.76	0.67	0.58	0.49	0.23
SNA	0.50	0.41	0.08	0.09	0.11
Other	0.83	0.80	0.28	0.40	0.30

Total FLA catch (t)

Target species	2007	2008	2009	2010	2011
FLA	224.58	114.2	76.75	56.64	41.01
SNA	17.5	7.29	5.13	4.75	2.16
Other	25.23	7.51	1.48	3.24	0.92

Number of trawls by fishing area

Fishing area	2007	2008	2009	2010	2011
Golden Bay	1 516	933	745	621	562
Other	266	192	78	74	48
Tasman Bay East	733	352	498	155	251
Tasman Bay West	1 251	948	1007	781	331

SNA catch by fishing area

Fishing area	2007	2008	2009	2010	2011
Golden Bay	9.04	27.86	22.13	12.51	27.07
Other	9.93	9.05	3.11	6.36	2.33
Tasman Bay East	6.26	3.06	5.33	6.54	9.77
Tasman Bay West	23.33	23.97	18.45	39.7	33.28

Table 4: Potential explanatory variables included in the CPUE model fitting procedure.

Variable	Definition	Type	Comment
Fyear	Fishing year	Categoric (5)	2007–2011 years
Month	Month of year	Categoric (8)	October–May only
Start_time	Start time of the trawl (hour)	Continuous	Range (0–24)
Vessel_key	Unique vessel id	Categoric (21)	Vessels operating at least four years.
target_species_new	Declared target species of trawl	Categoric (3)	FLA, SNA or Other
Area	Sub area of TB/GB	Categoric (3)	TBw, TBe, GB or Other. Assigned to area based on start position of trawl.
TACCcaught	Proportion of the annual TACC caught prior to the fishing day	Continuous	Range (0–1)
effort_speed	Trawling speed, knots	Continuous	Range (2–4)
fishing_duration	Duration of trawl (hrs)	Continuous	Computed from trawl start and end times, range (1–5)
distance	Distance of trawl (nautical miles)	Continuous	Product of *effort_speed* and *duration*, range(2–20)
bottom_depth	Bottom depth (m) at the start of the trawl.	Continuous	Range (5–70)
newmoondays	Number of days pre or post the most recent new moon.	Continuous	Range(-14,+14)

Table 5: Step-wise inclusion of variables and interaction terms in the three CPUE models. The change in AIC at each step of the fitting procedure is also included.

Iter	Lognormal model Variable	AIC	R^2	Lognormal, non zero model Variable	AIC	R^2
1	fyear	44 551	0.098	fyear	19 922	0.015
2	target_species_new	42 614	0.240	vessel_key	18 203	0.314
3	vessel_key	41 560	0.310	month	17 388	0.422
4	bottom_depth	41 328	0.324	target_species_new	17 100	0.455
5	month	41 003	0.344	distance	17 027	0.464
6	distance	40 952	0.347	bottom_depth	16 962	0.472
7	area	40 927	0.349	effort_speed	16 949	0.474
8	start_time	40 918	0.350	start_time	16 946	0.475
9	effort_speed	40 878	0.353	area	16 922	0.478
10	fishing_duration	40 878	0.353	newmoondays	16 913	0.480
11	vessel_key*TACCcaught	40 479	0.382	vessel_key*TACCcaught	16 513	0.533
12	vessel_key*month	40 041	0.417	vessel_key*month	16 037	0.595
13	bottom_depth*month	39 893	0.427	bottom_depth*month	15 867	0.612
14	vessel_key*area	39 879	0.432	vessel_key*area	15 819	0.623

Iter	Binomial model Variable	AIC
1	fyear	14 030
2	vessel_key	13 168
3	target_species_new	12 783
4	month	12 551
5	bottom_depth	12 433
6	area	12 362
7	distance	12 348
8	start_time	12 347
9	newmoondays	12 348
10	vessel_key*TACCcaught	12 116
11	vessel_key*month	11 945
12	bottom_depth*month	11 878

Table 6: Annual CPUE indices and the upper and lower bounds of the confidence intervals from the delta-lognormal (all years) model.

Fishing year	Index	LCI	UCI
1989/90	0.548	0.438	0.671
1990/91	0.565	0.450	0.692
1991/92	0.488	0.390	0.597
1992/93	0.491	0.396	0.609
1993/94	0.676	0.534	0.850
1994/95	0.389	0.311	0.489
1995/96	0.466	0.370	0.585
1996/97	0.291	0.228	0.366
1997/98	0.242	0.188	0.304
1998/99	0.130	0.098	0.167
1999/2000	0.390	0.296	0.498
2000/01	0.181	0.135	0.240
2001/02	0.174	0.131	0.229
2002/03	0.263	0.202	0.330
2003/04	0.403	0.328	0.492
2004/05	0.131	0.104	0.167
2005/06	0.329	0.261	0.405
2006/07	0.423	0.345	0.524
2007/08	0.289	0.231	0.362
2008/09	0.296	0.232	0.372
2009/10	0.362	0.292	0.442
2010/11	0.794	0.626	0.994
2011/12	1.937	1.548	2.428

Table 7: The total annual SNA 7 catch landed to Talley's Limited and the magnitude of the catch graded by fish count. The proportion (by weight) of the catch in each grade is also presented. Data from 2012/13 are complete to 31/1/2013.

Fishing Year	Total landed catch	Graded catch (t)	Proportion by packing grade (by weight)				
			26+	16–25	8–15	6–7	2–5
2004/05	178.2	146.9	0.003	0.016	0.091	0.094	0.470
2005/06	173.6	98.8	0.001	0.147	0.274	0.318	0.260
2006/07	248.4	118.0	0.001	0.001	0.117	0.364	0.517
2007/08	171.9	76.6	0.001	0.004	0.144	0.288	0.562
2008/09	164.0	116.0	0.004	0.068	0.104	0.252	0.573
2009/10	152.0	83.2	0.000	0.013	0.117	0.013	0.858
2010/11	158.0	95.7	0.004	0.106	0.030	0.062	0.798
2011/12	160.6	95.4	0.055	0.097	0.151	0.143	0.554
2012/13		*75.6*	*0.000*	*0.144*	*0.473*	*0.095*	*0.288*

Table 8: The bounds of the packing grades and the approximate range of the individual fish weights (kg) included within each grade. The approximate minimum fish length (FL cm) in each grade is also presented.

Container weight (kg)	Number of fish		Individual fish weight		Fish length
	Max	Min	Min	Max	Min
10	5	2	2.000	5.000	46.3
10	7	6	1.429	1.667	41.0
10	18	8	0.556	1.250	31.2
10	25	15	0.400	0.667	26.0
10	34	26	0.294	0.385	25.0

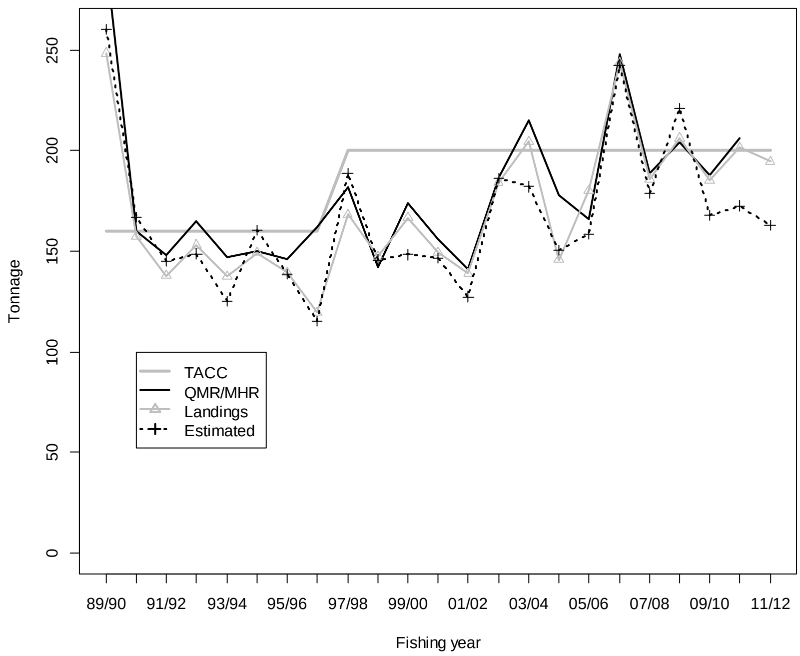

Figure 1: A comparison of the annual SNA 7 TACC and catch from various sources. The landings data and uncorrected estimated catches are the catches included in the data set used in the current study.

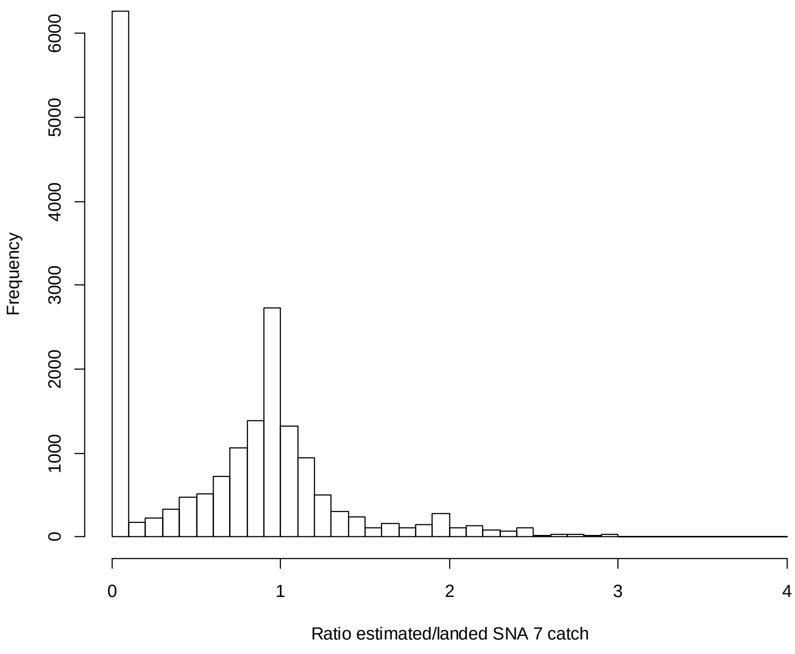

Figure 2: The ratio of total snapper estimated catch (from SNA 7) to the landed catch from SNA7 from individual fishing trips.

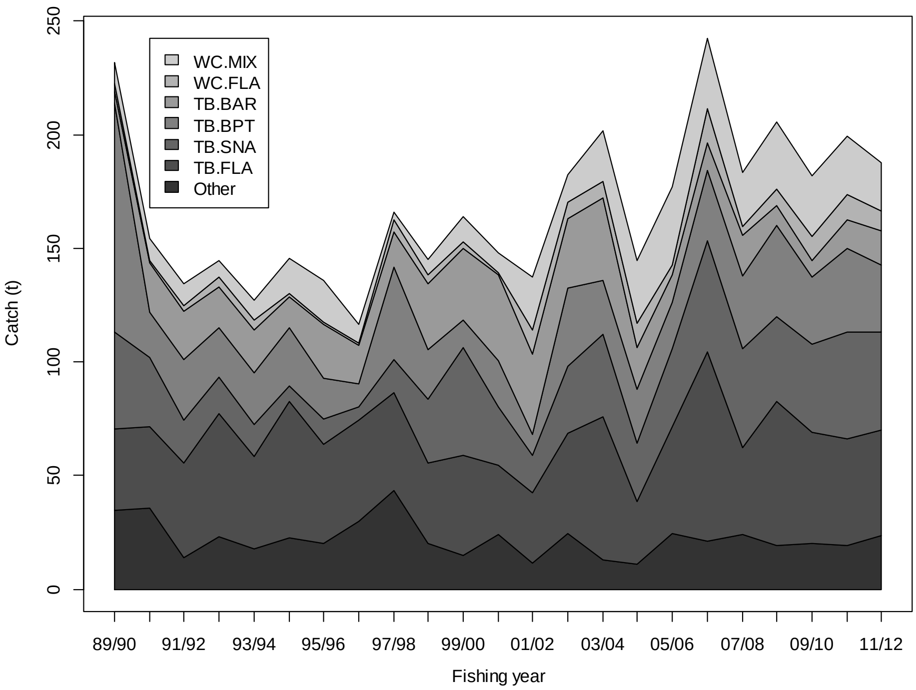

Figure 3: Annual SNA 7 landed catch from the main inshore trawl fisheries within the Challenger FMA (FMA 7). Data from 2011/12 are complete to about May 2012.

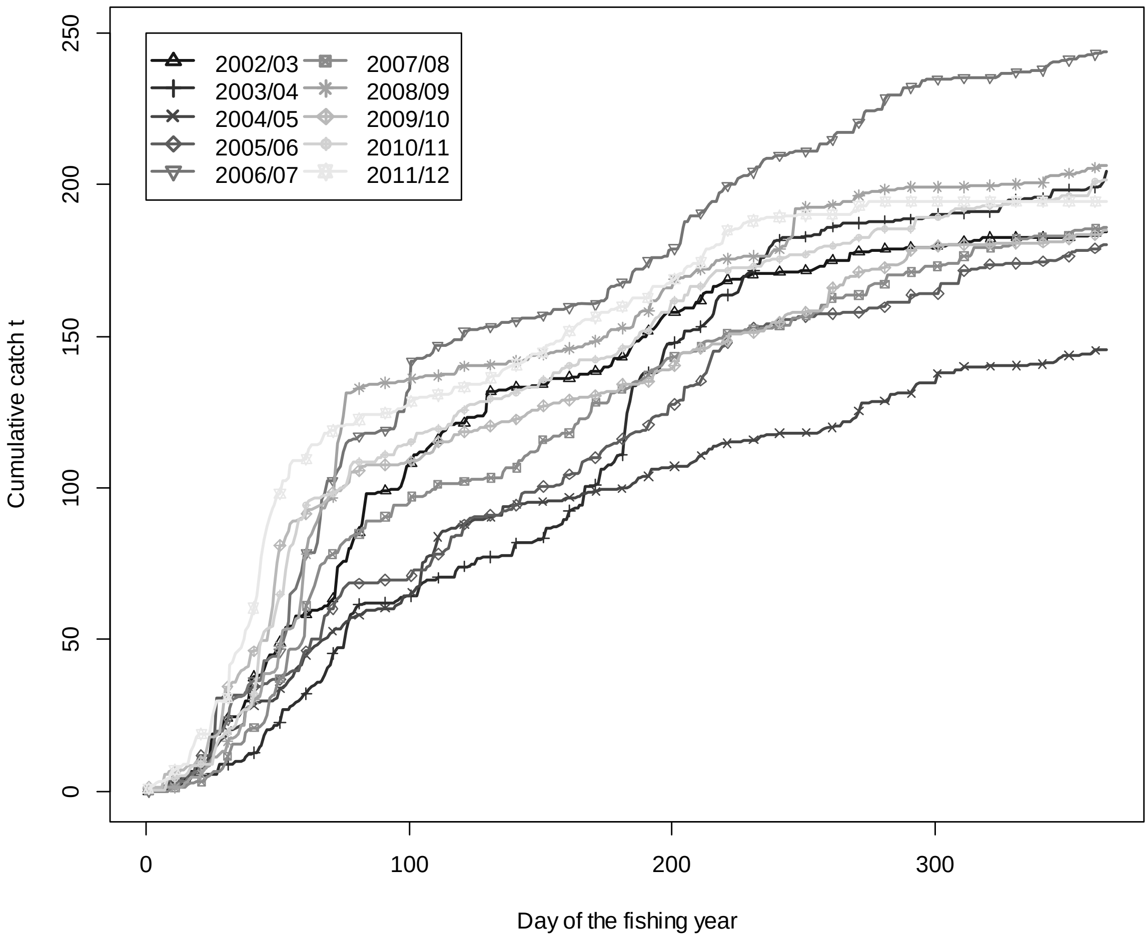

Figure 4: Cumulative daily SNA7 trawl catch by fishing year from 2002/03 to 2011/12 (data from 2011/12 are complete to about May 2012). Day 1 is 1 October.

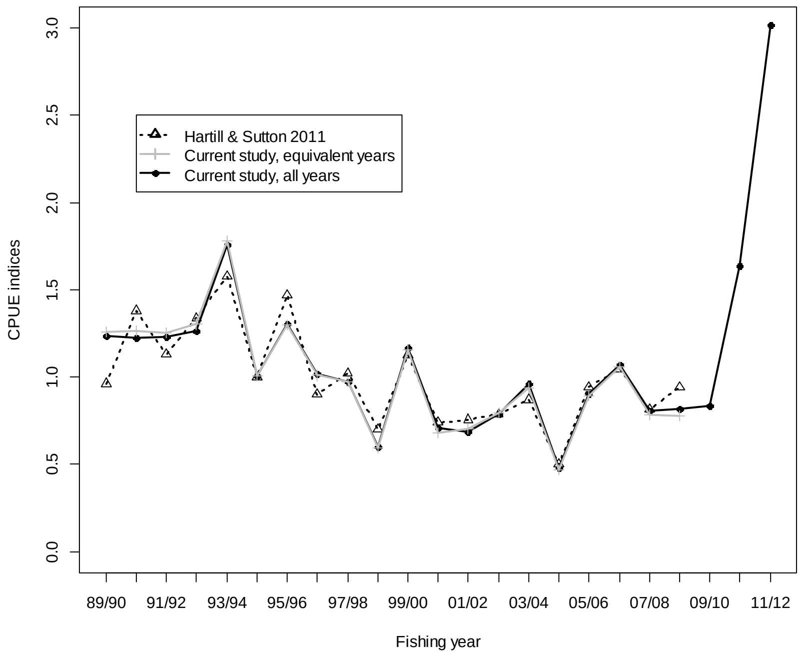

Figure 5: A comparison of the annual CPUE indices from the *combined* CPUE model of Hartill & Sutton (2011) and the indices derived following a similar approach (current study). The combined model is based on catch and effort data from the FLA, BAR and SNA single trawl fisheries operating within statistical area 038 (non zero SNA catch records only).

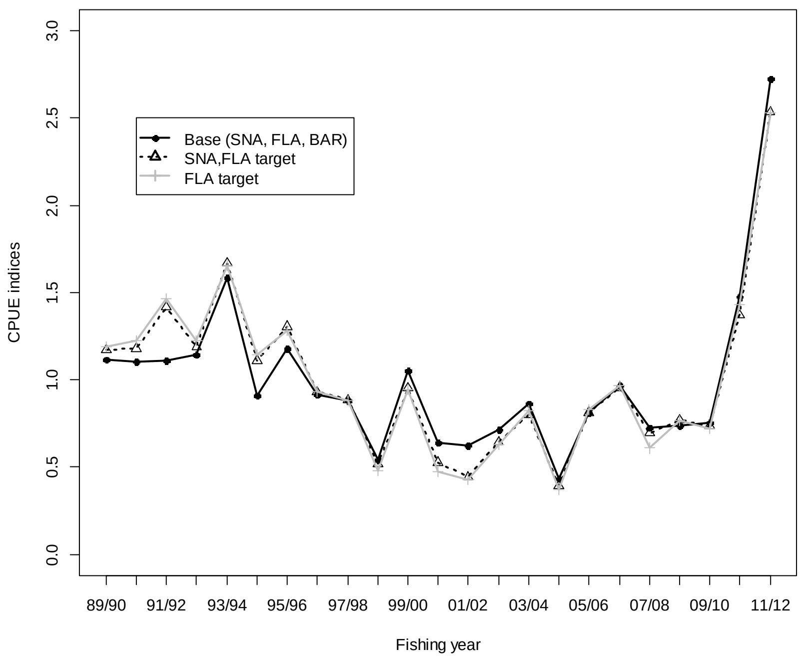

Figure 6: A comparison of the CPUE indices derived from the all years, combined model (*base*) with similar models excluding BAR target effort (SNA, FLA target) and excluding BAR and SNA target effort (FLA target).

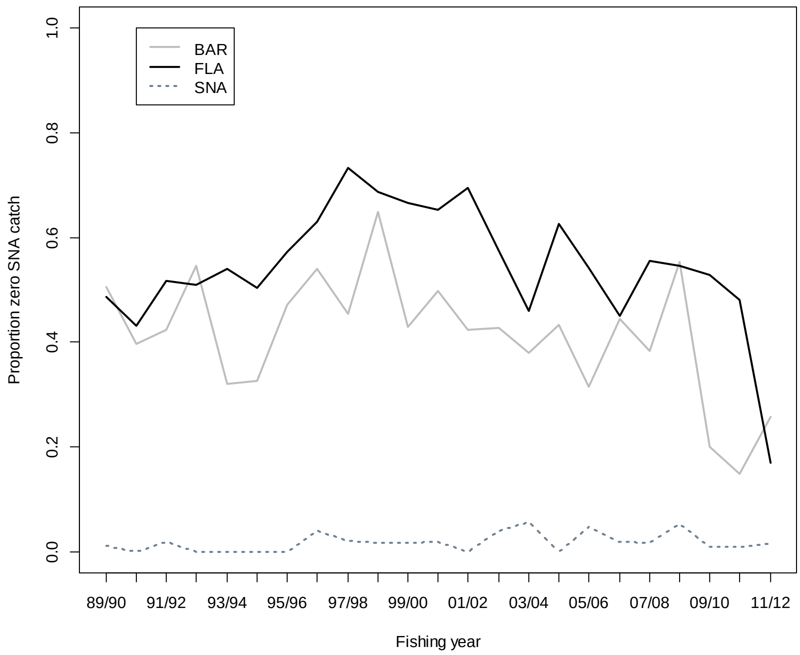

Figure 7: Annual proportion of zero snapper catch records by target species for the main target single trawl fisheries operating within stat area 038.

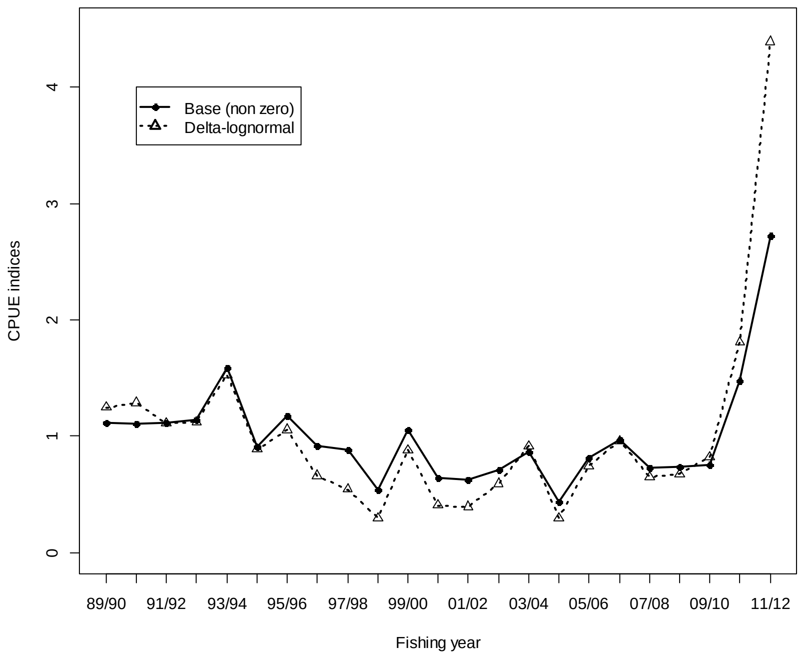

Figure 8: Annual indices from the all years, combined model (base, non zero) and the delta-lognormal model from the FLA, SNA and BAR inshore trawl fisheries within Tasman Bay/Golden Bay (Statistical Area 038).

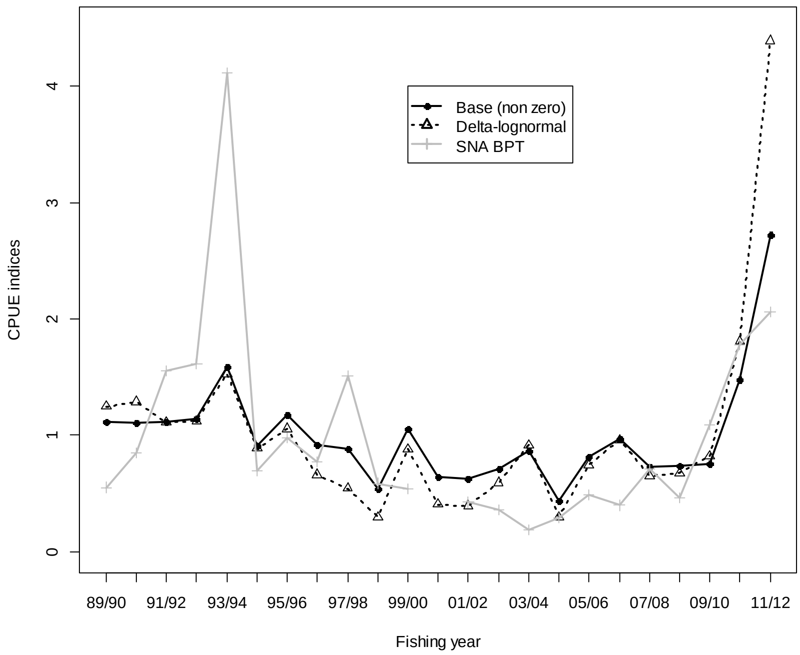

Figure 9. A comparison of the annual CPUE indices derived from the target bottom pair trawl fishery with the CPUE indices from the *base* and the delta-lognormal CPUE indices.

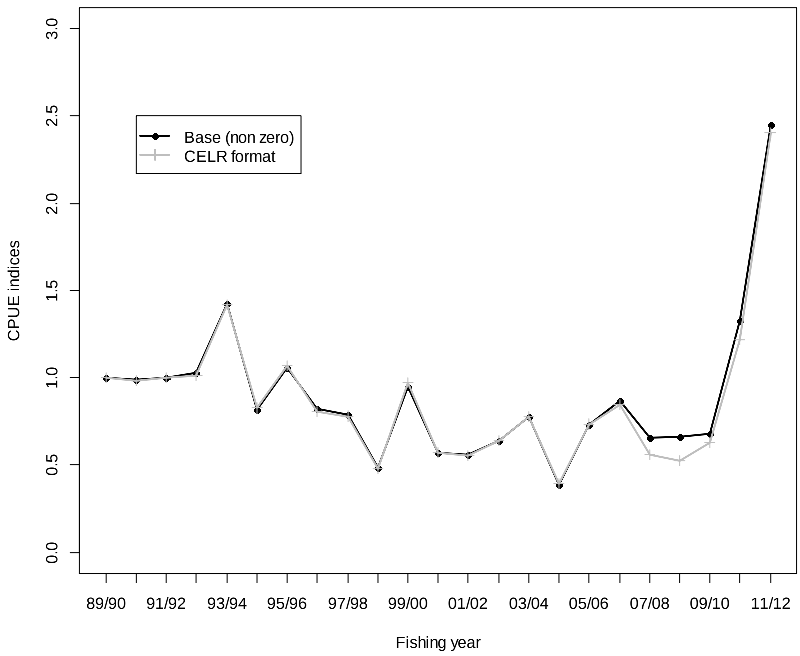

Figure 10: A comparison of the annual CPUE indices derived from the *combined* (base) CPUE model and the equivalent model with snapper catches standardised in the CELR format.

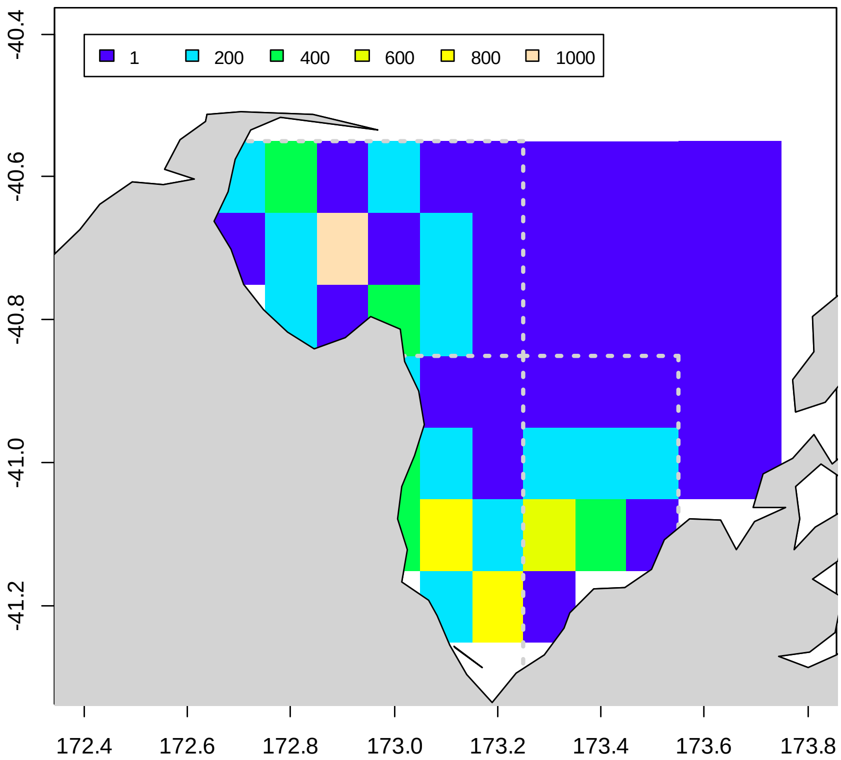

Figure 11: The spatial distribution (0.1 degree) of the individual trawl records included in the TCER data set from 2007/08 to 2011/12. The legend represents the lower bound of the number of trawls in each 0.1 degree cell. The dashed lines represent the boundaries of the main fishery areas within TB/GB.

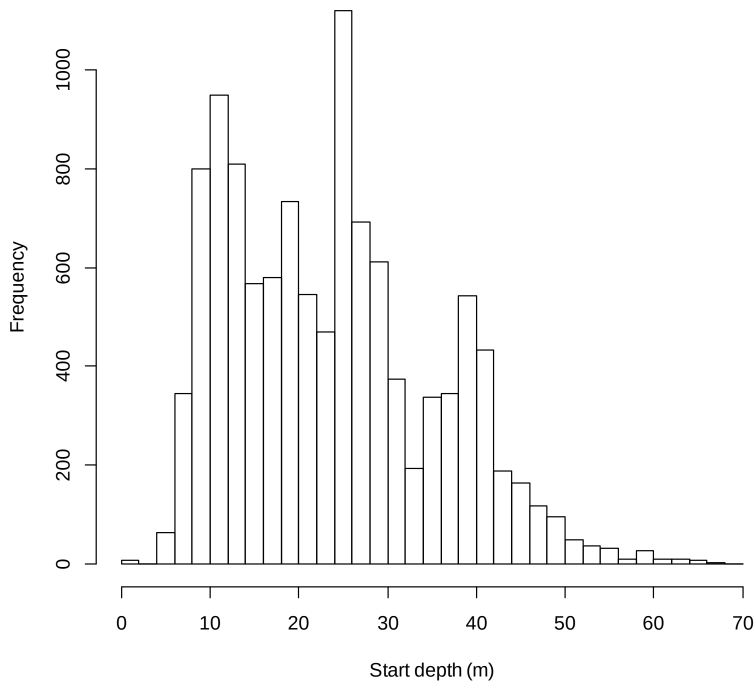

Figure 12: Depth distribution of trawl records included within the TCER data set.

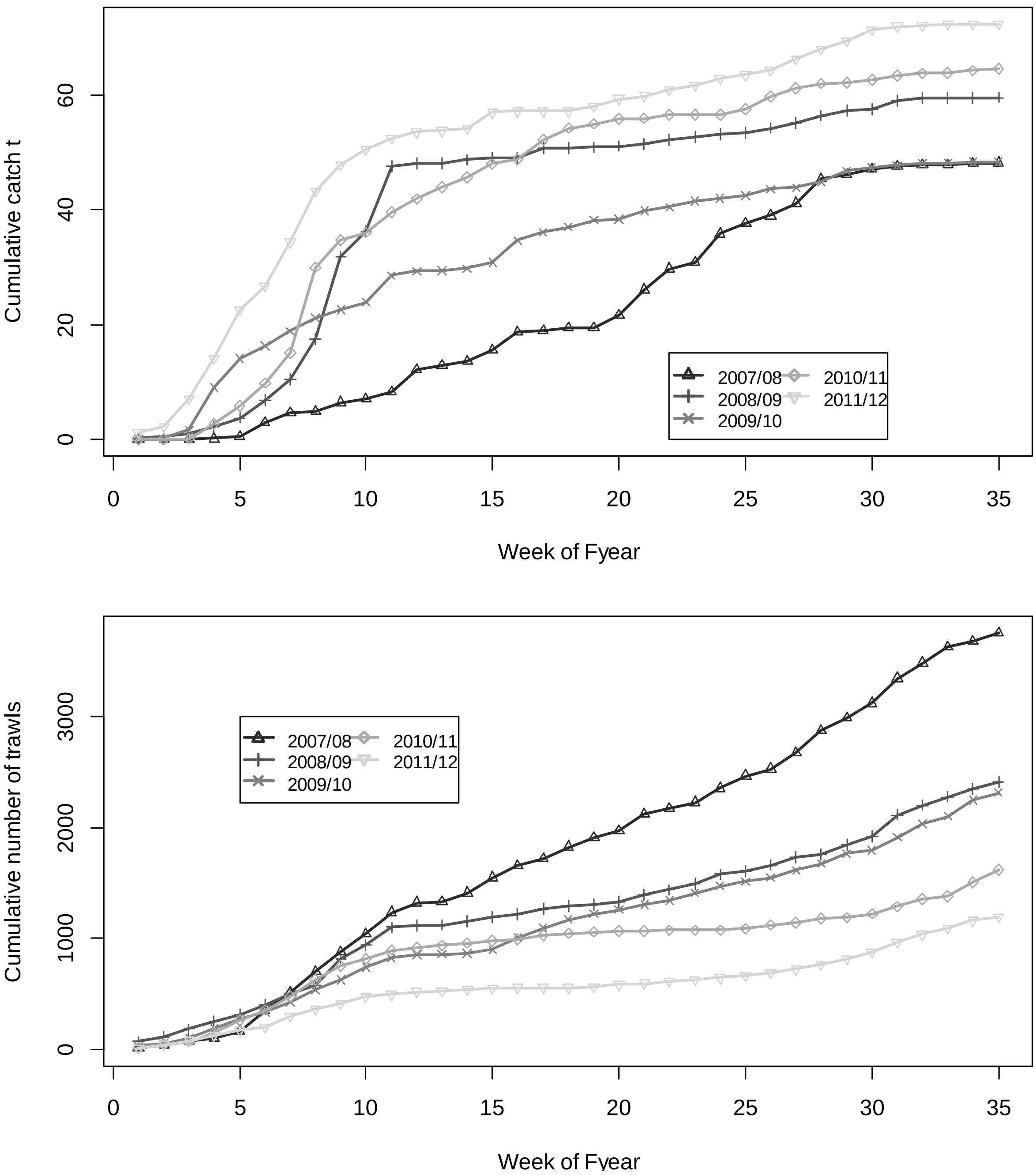

Figure 13: The cumulative weekly snapper catch (top) and number of trawls by fishing year (from the TCER data set).

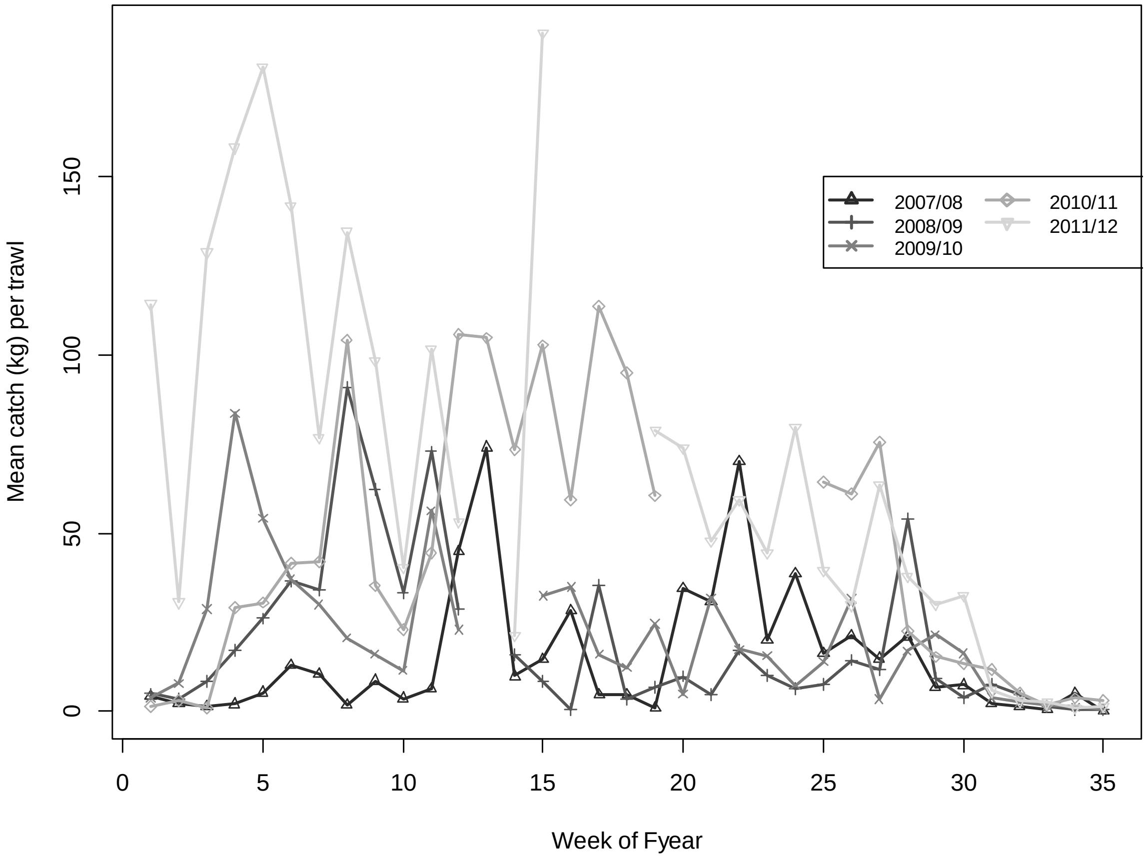

Figure 14: A comparison of the weekly unstandardised catch rate of snapper (catch per trawl) by fishing year (TCER data set).

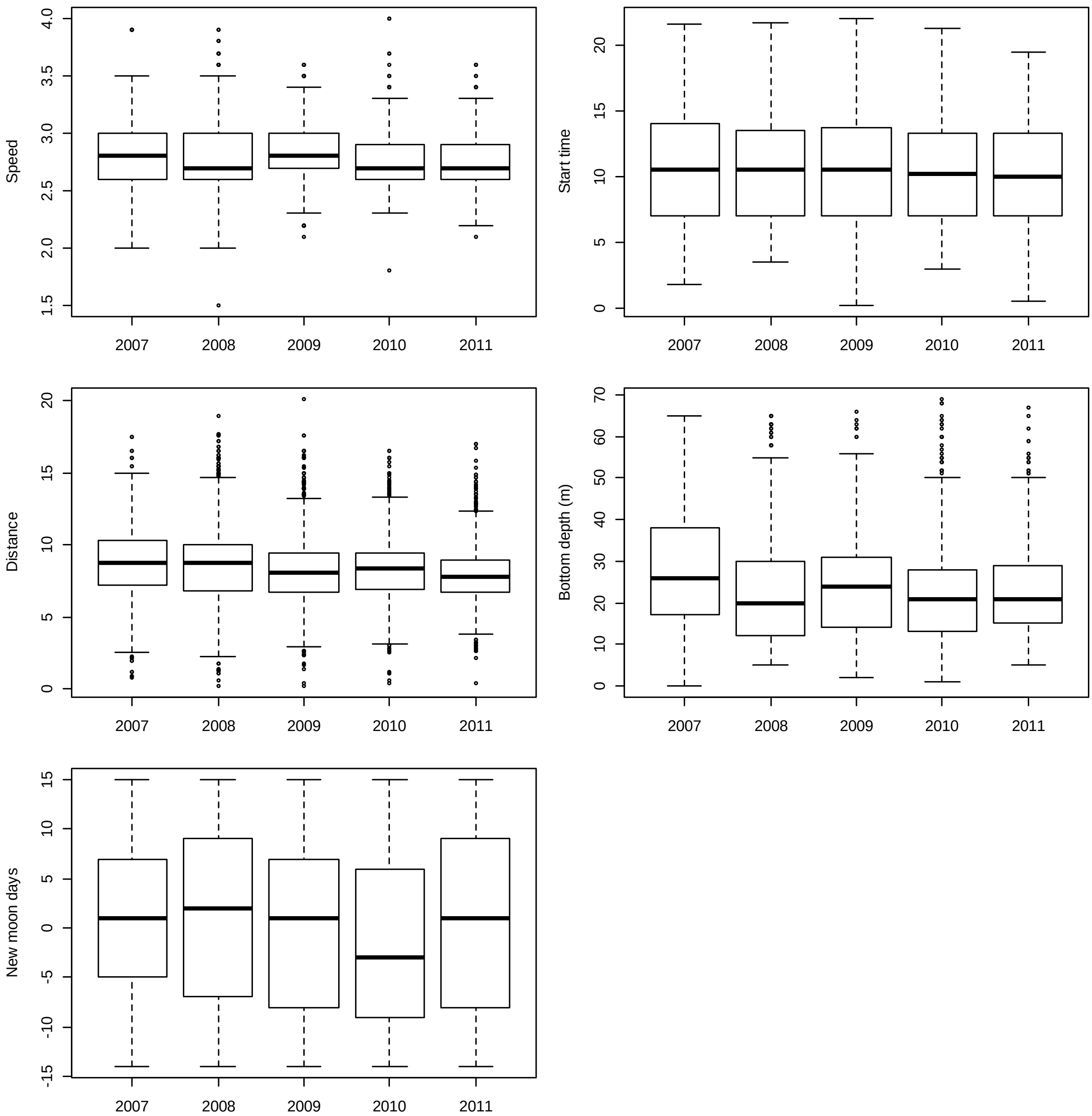

Figure 15. Annual boxplots of the continuous variables included in model fitting procedure.

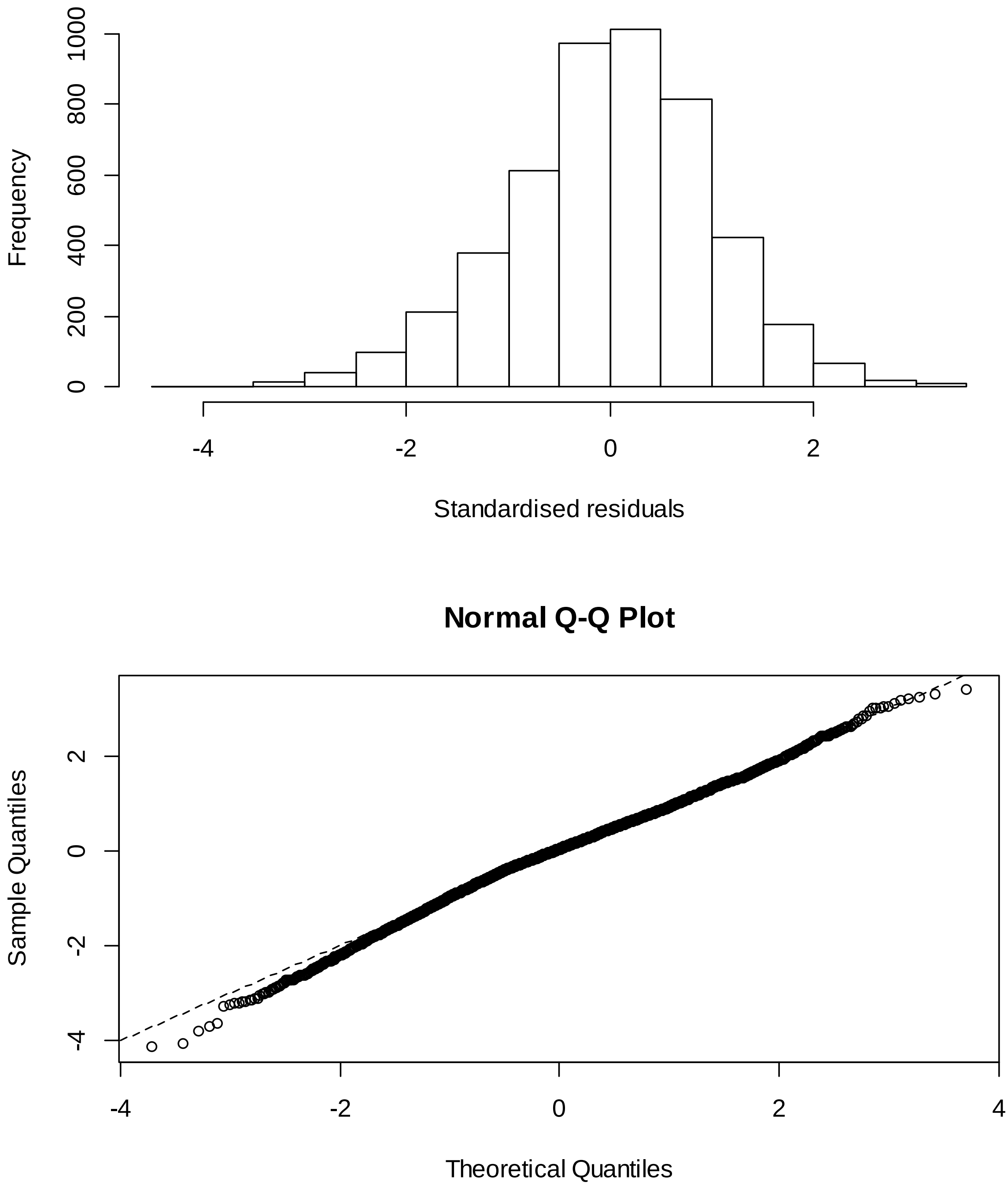

Figure 16: Distribution of the standardised residuals (top) and quantile-quantile plot from the lognormal, non zero snapper catch model.

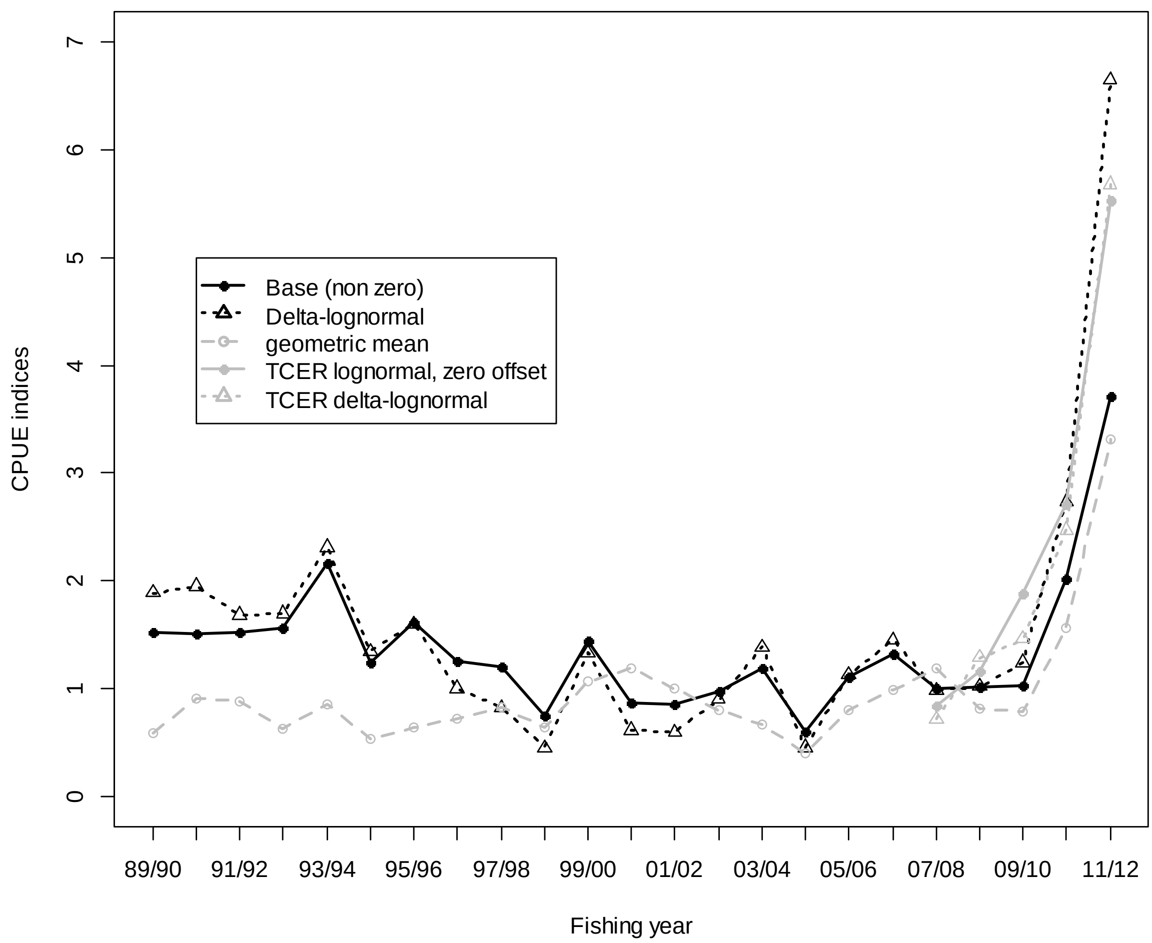

Figure 17: A comparison of the various sets of annual CPUE indices from a range of model options. The base model represents the update of the *combined* (non zero snapper catch) indices from Hartill & Sutton (2011). The geometric mean of the data included in the *combined* model is also presented. The lognormal model (lognorn+offset) and the delta-lognormal (delta-logn) model indices derived from the TCER data are also presented.

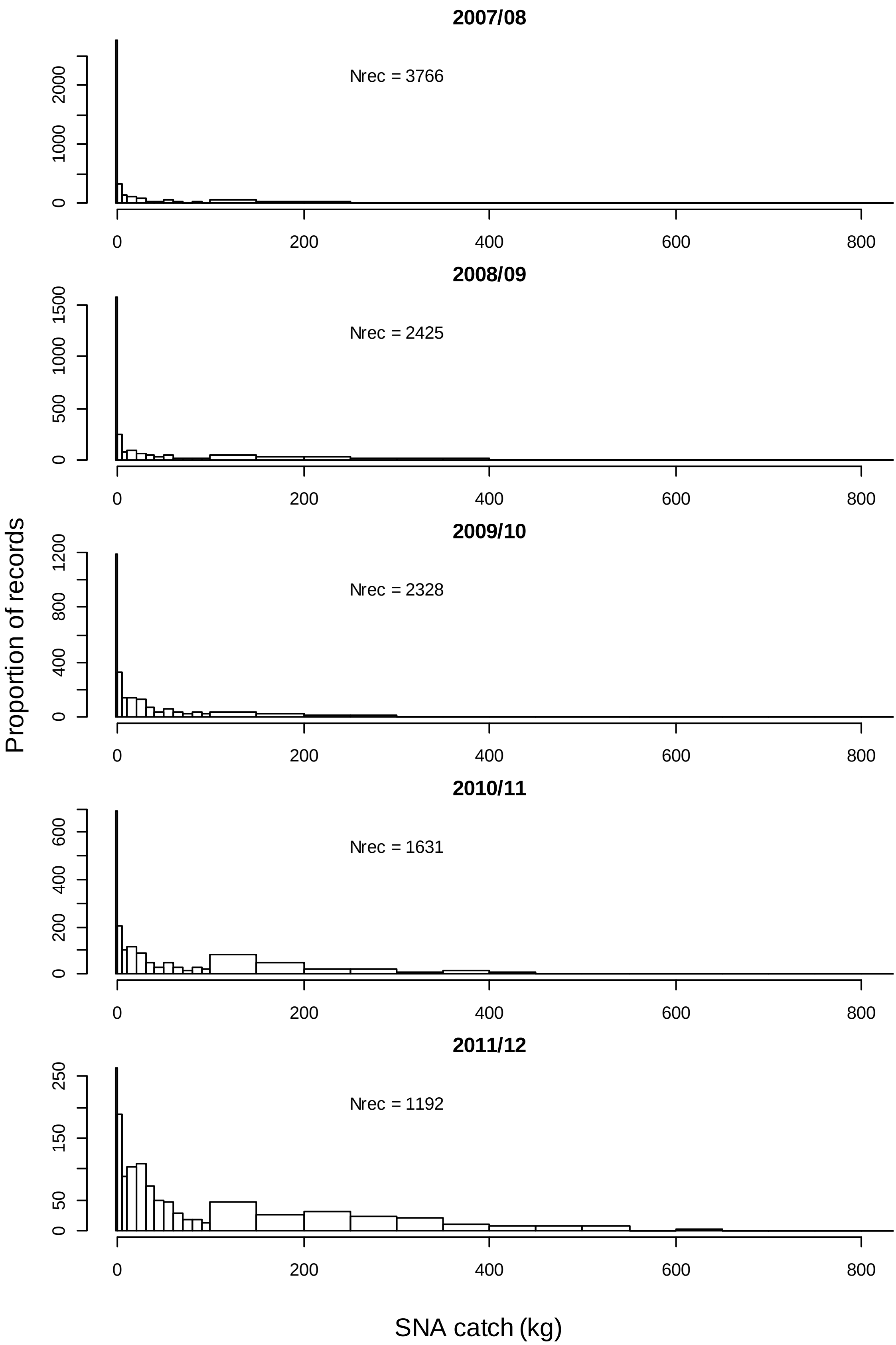

Figure 18: Histograms of the snapper catch per trawl by fishing year from 2007/08 (top) to 2011/12 (bottom) from the complete TCER data set (including zero snapper catches). Nrec is the total number of records per year.

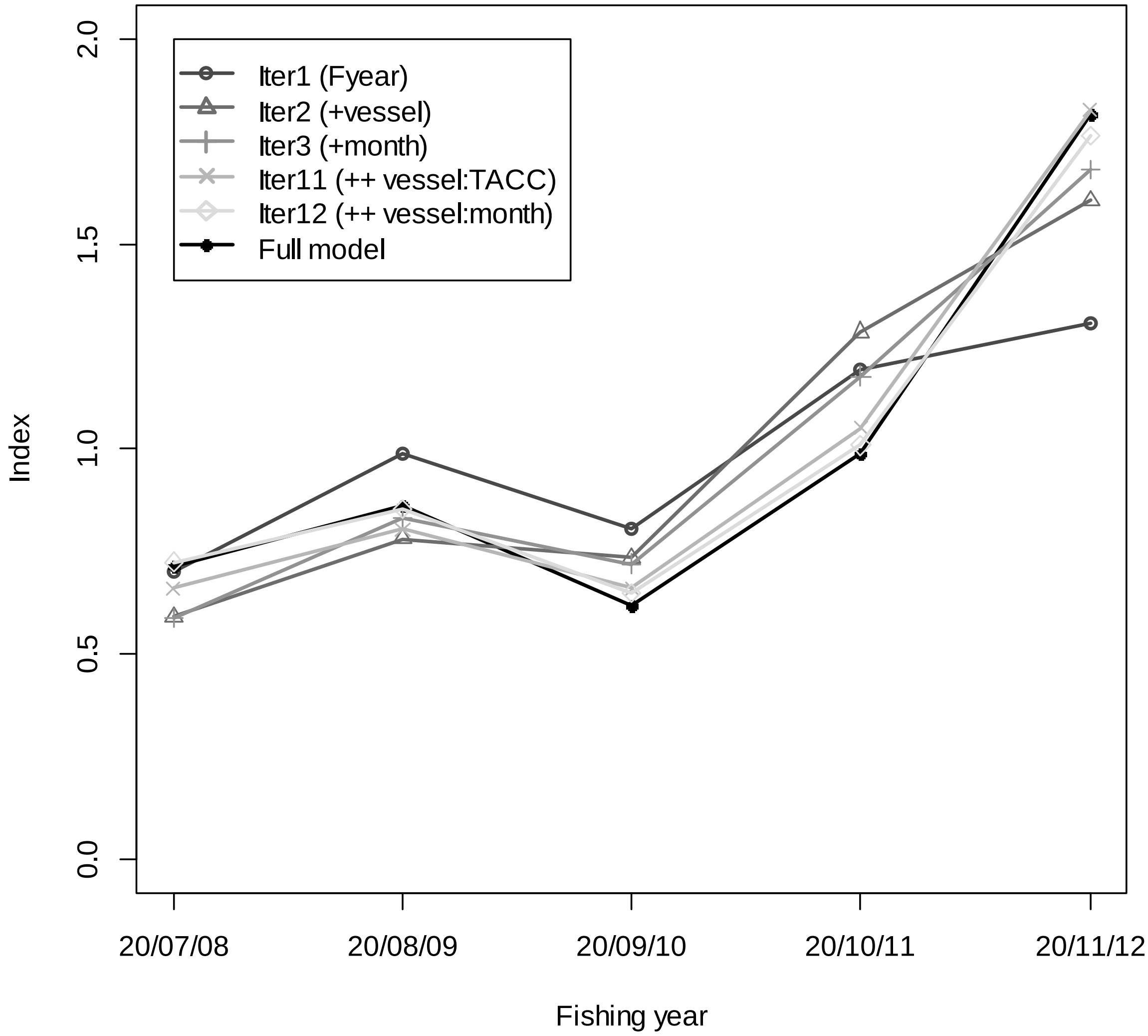

Figure 19: A comparison of the annual indices from the unstandardised CPUE data and the standardised CPUE indices from the TCER lognormal, non zero model.

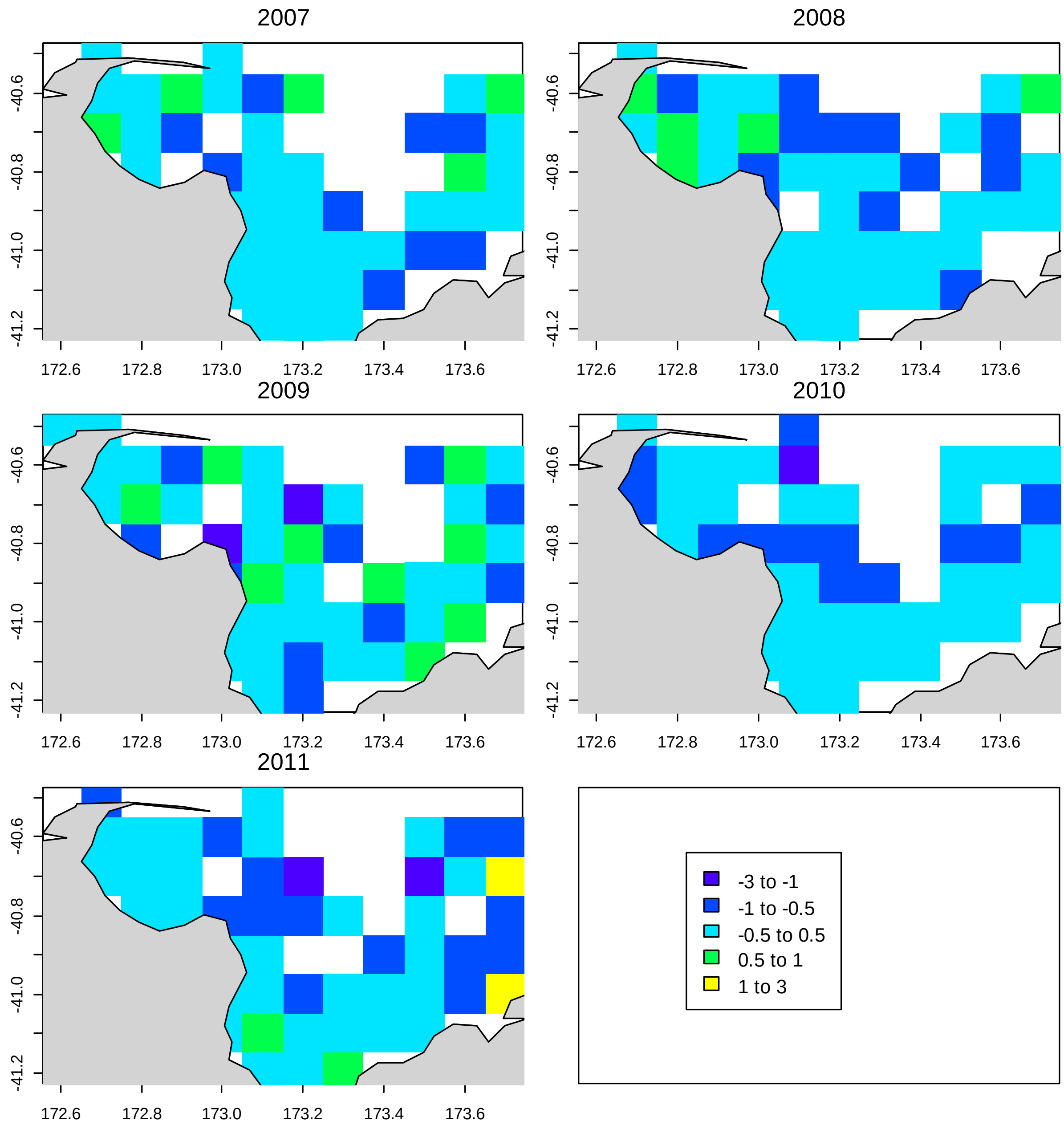

Figure 20: Average spatial residuals (0.1 deg lat/long) from the lognormal, non zero model by fishing year. The legend represents the upper bound for the individual colours.

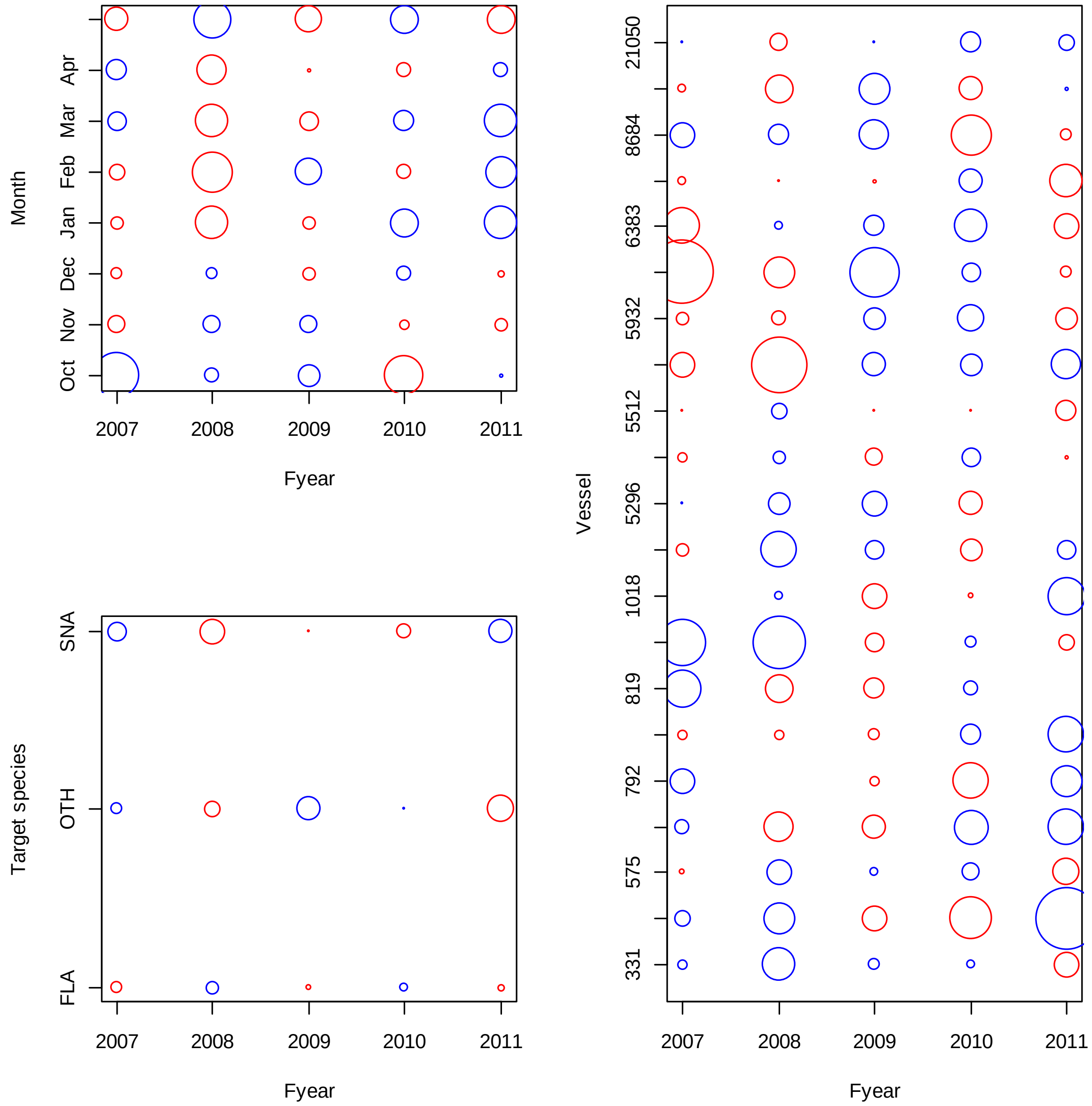

Figure 21: Mean positive (blue) and negative (red) residuals from the lognormal, non zero CPUE model presented by fishing year for three main model parameters (*month*, *vessel* and *target species*). The residuals are scaled to be equivalent for the three plots. The maximum circle area represents an absolute mean residual of 1.4.

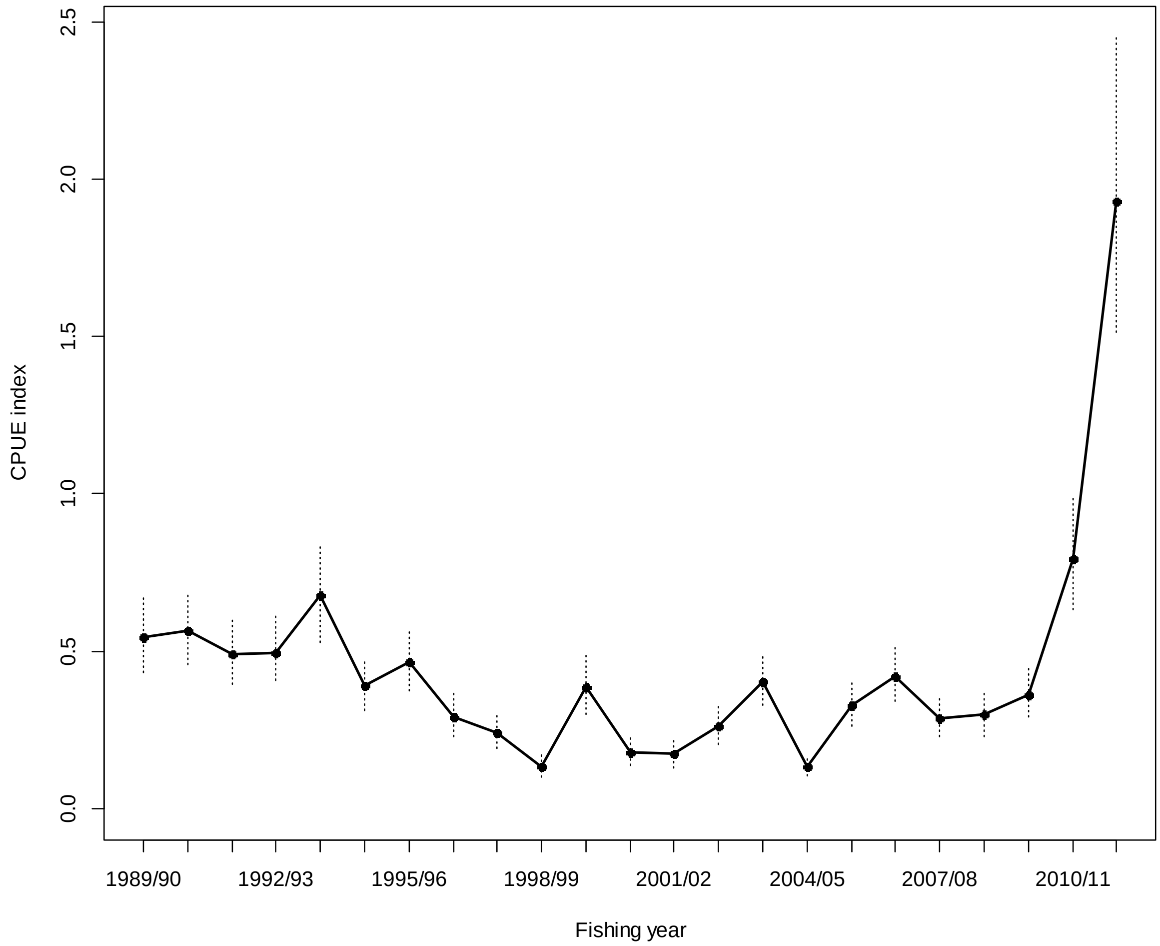

Figure 22: Relative CPUE indices derived from the delta lognormal (all years) model for the combined single trawl fishery. The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure.

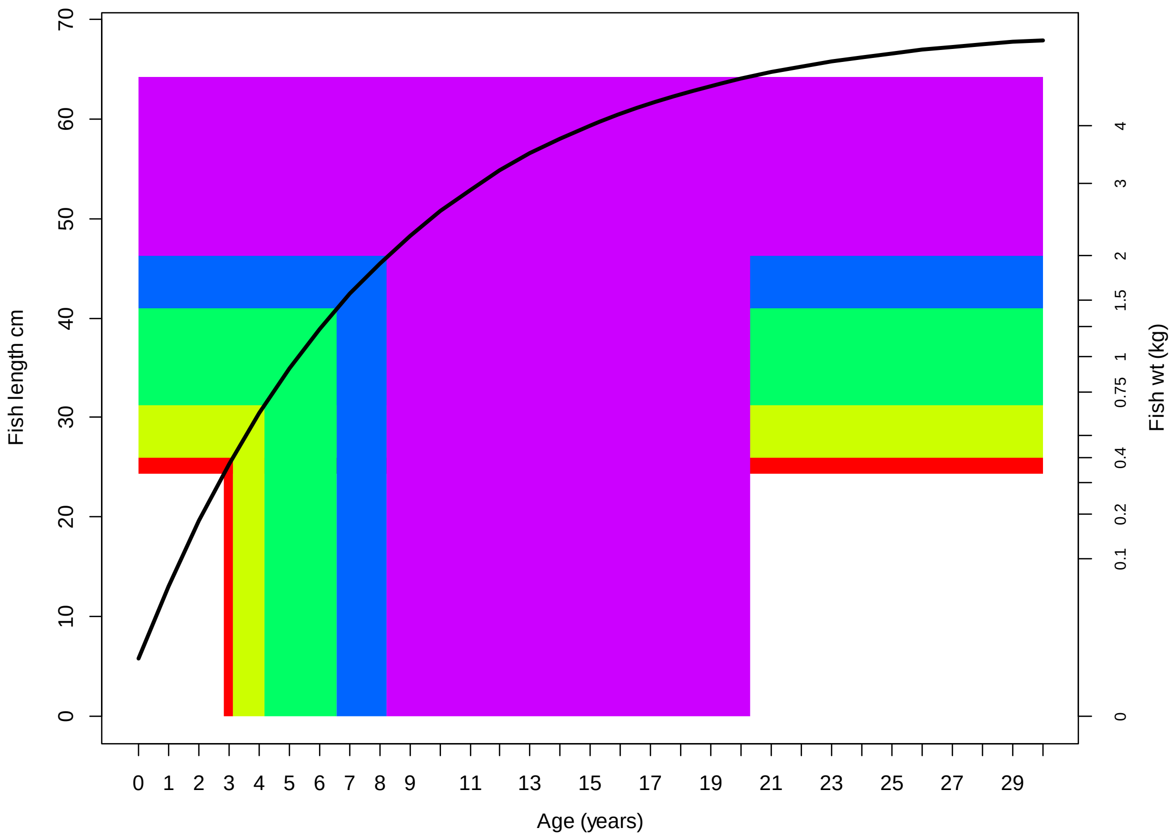

Figure 23: Relationship between fish weight, fish length and fish age for the individual size grade categories.

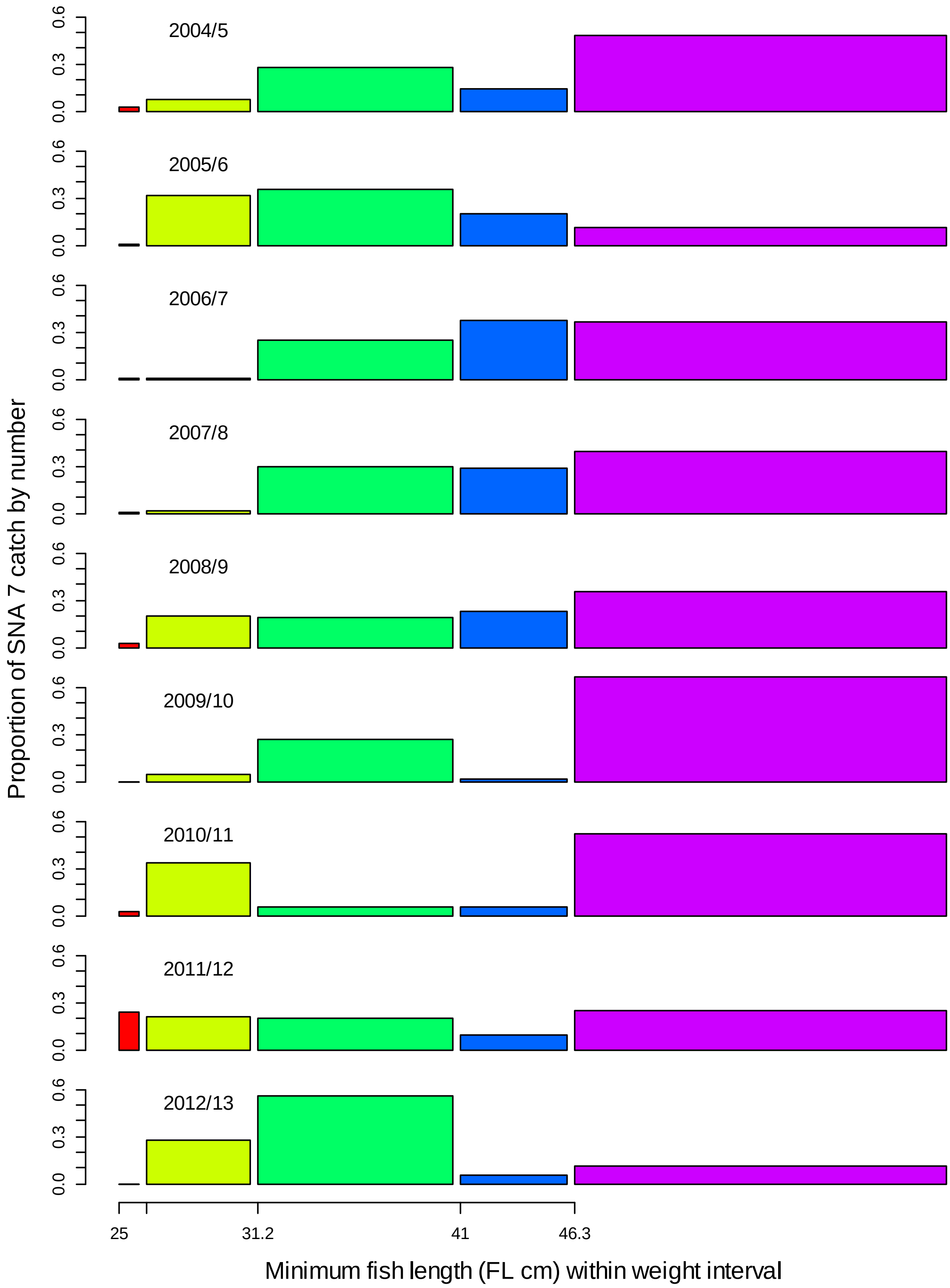

Figure 24: Annual length compositions (expressed in numbers of fish) derived from size grade data from the SNA 7 trawl catch (pair trawl and single trawl) from 2004/05 to 2012/13 (data from 2012/13 are complete to 31/1/2013). Individual size grade categories are assigned a minimum fish length. Data from 2012/13 are provisional.

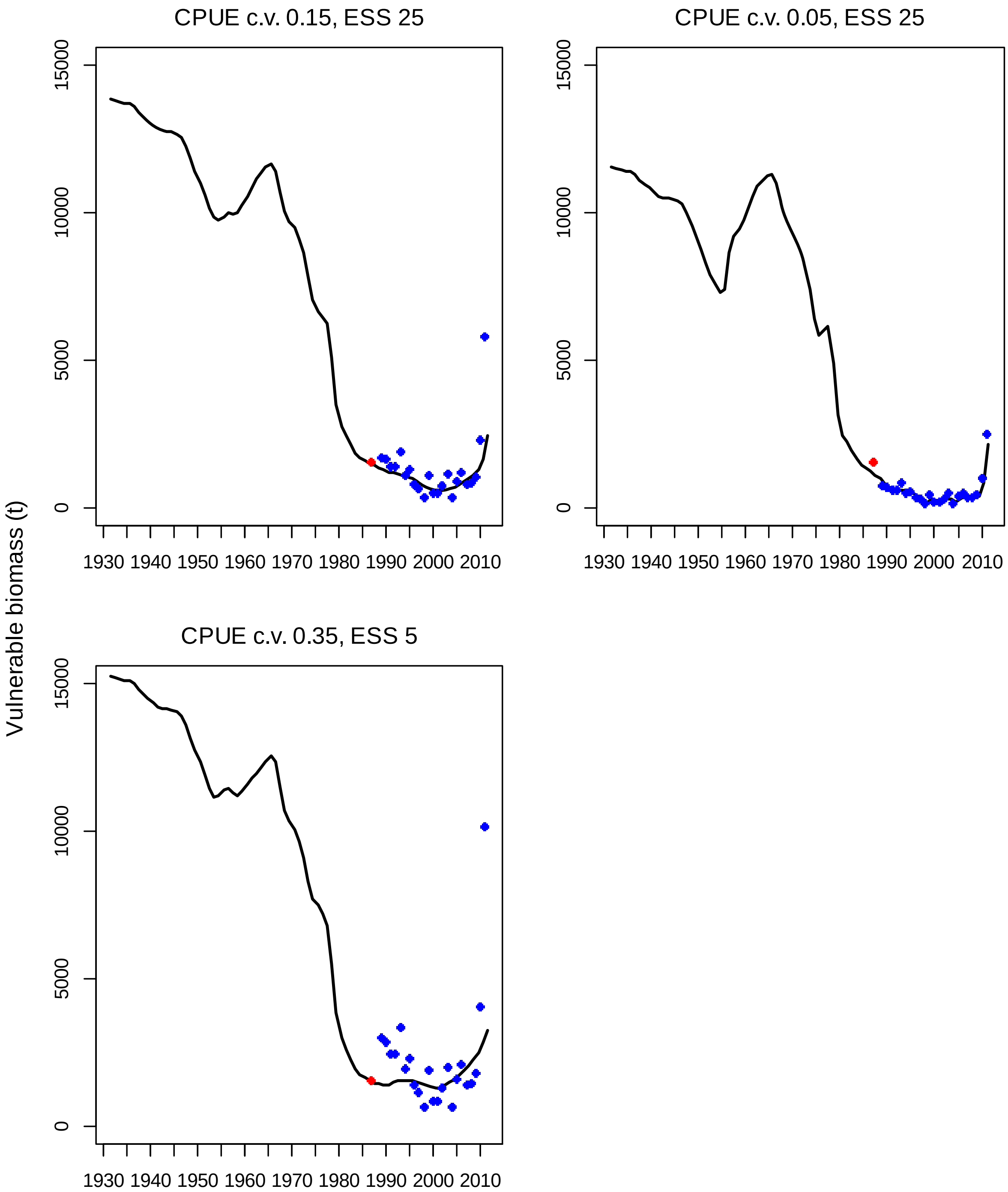

Figure 25: Biomass trajectories for three alternative model options with different weighting of the CPUE indices (blue points) and the recent size grade data. The red point in 1987 represents the biomass estimate from the SNA 7 tagging programme.

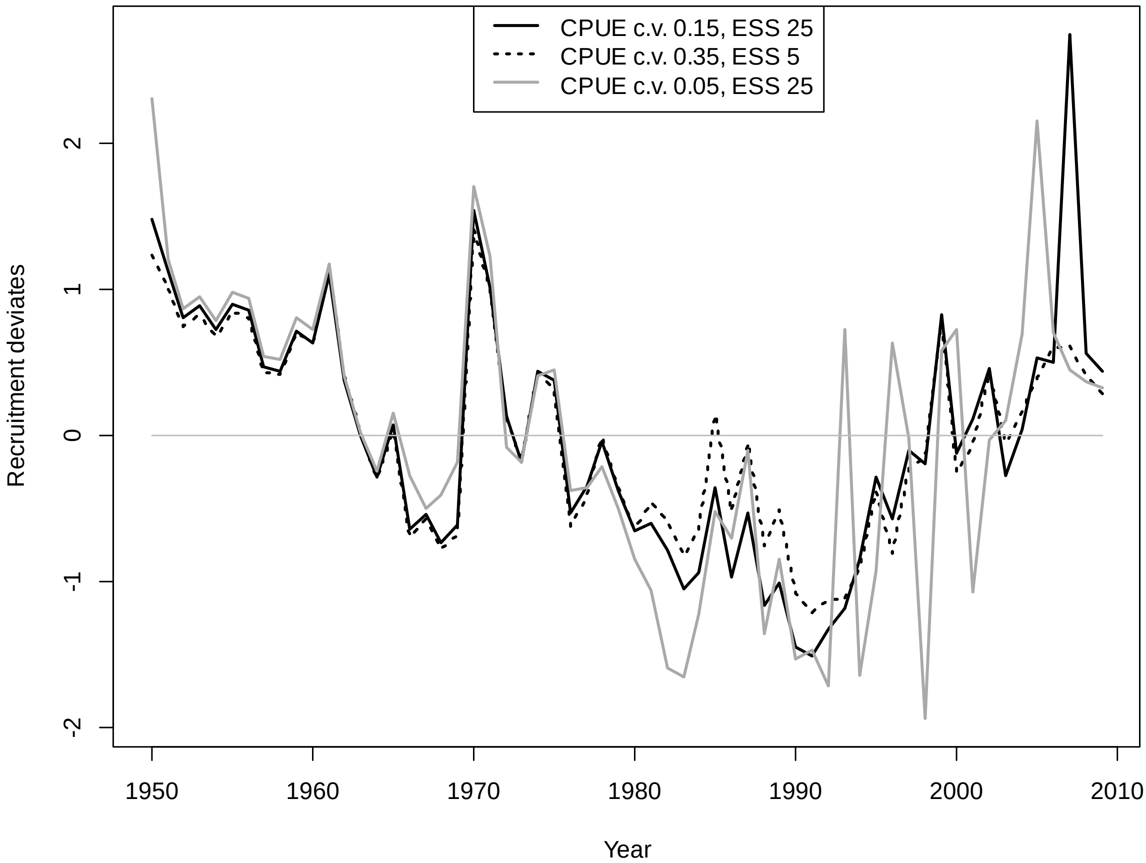

Figure 26: Annual recruitment deviates estimated from three alternative model options.

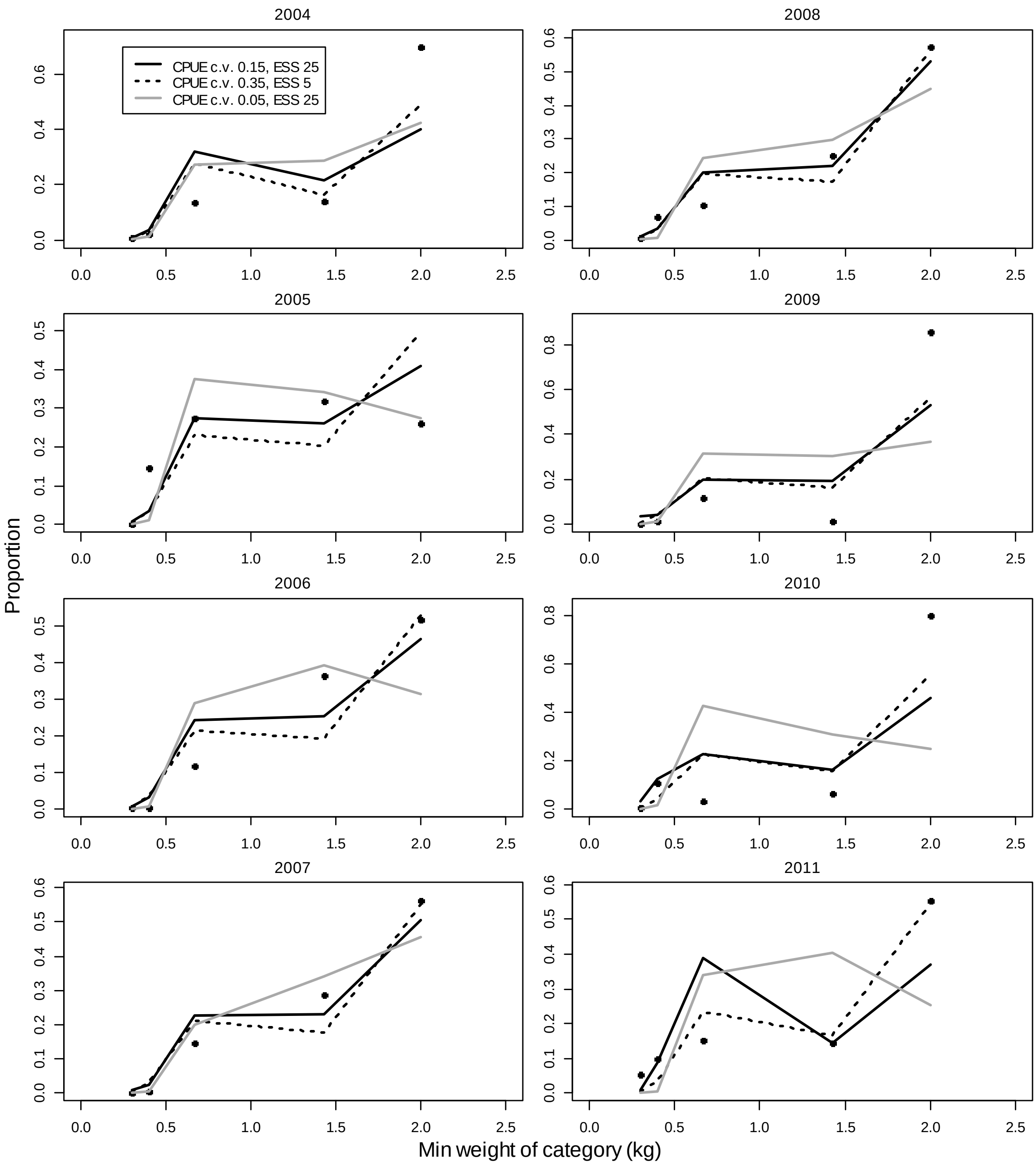

Figure 27: The fit to the weight composition of the SNA 7 catch from the size grade data (points) for the three model options with different weighting of the CPUE indices and the size grade data.

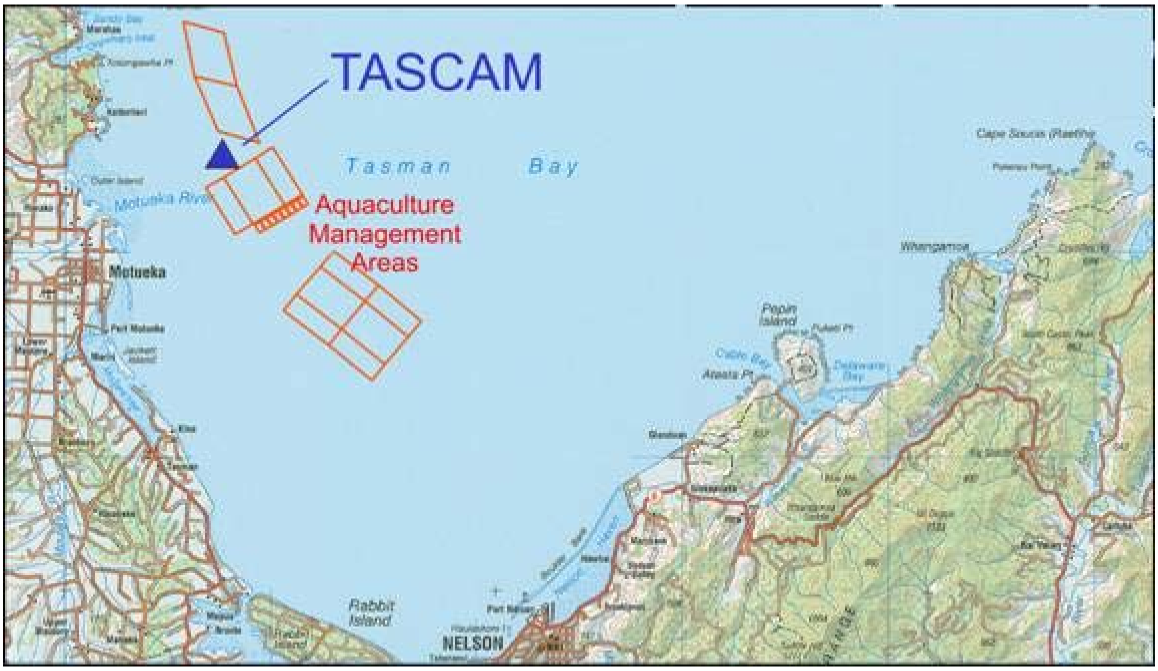

Figure 28: Location of the TASCAM buoy.

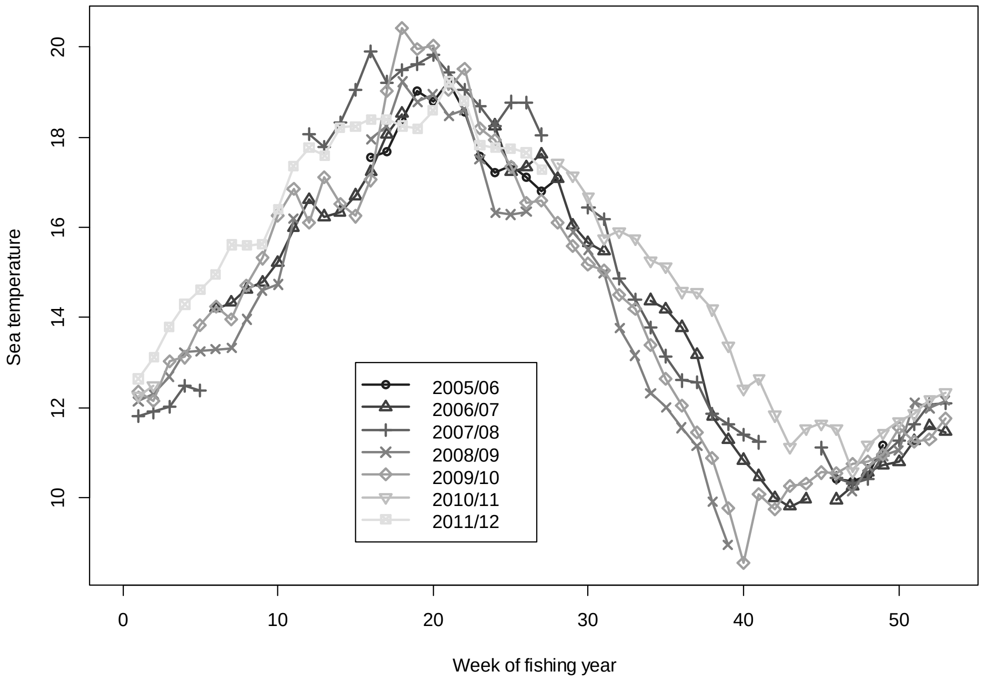

Figure 29: Weekly sea temperature from ICM and TASCAM (at 4–8 m depth) by fishing year.

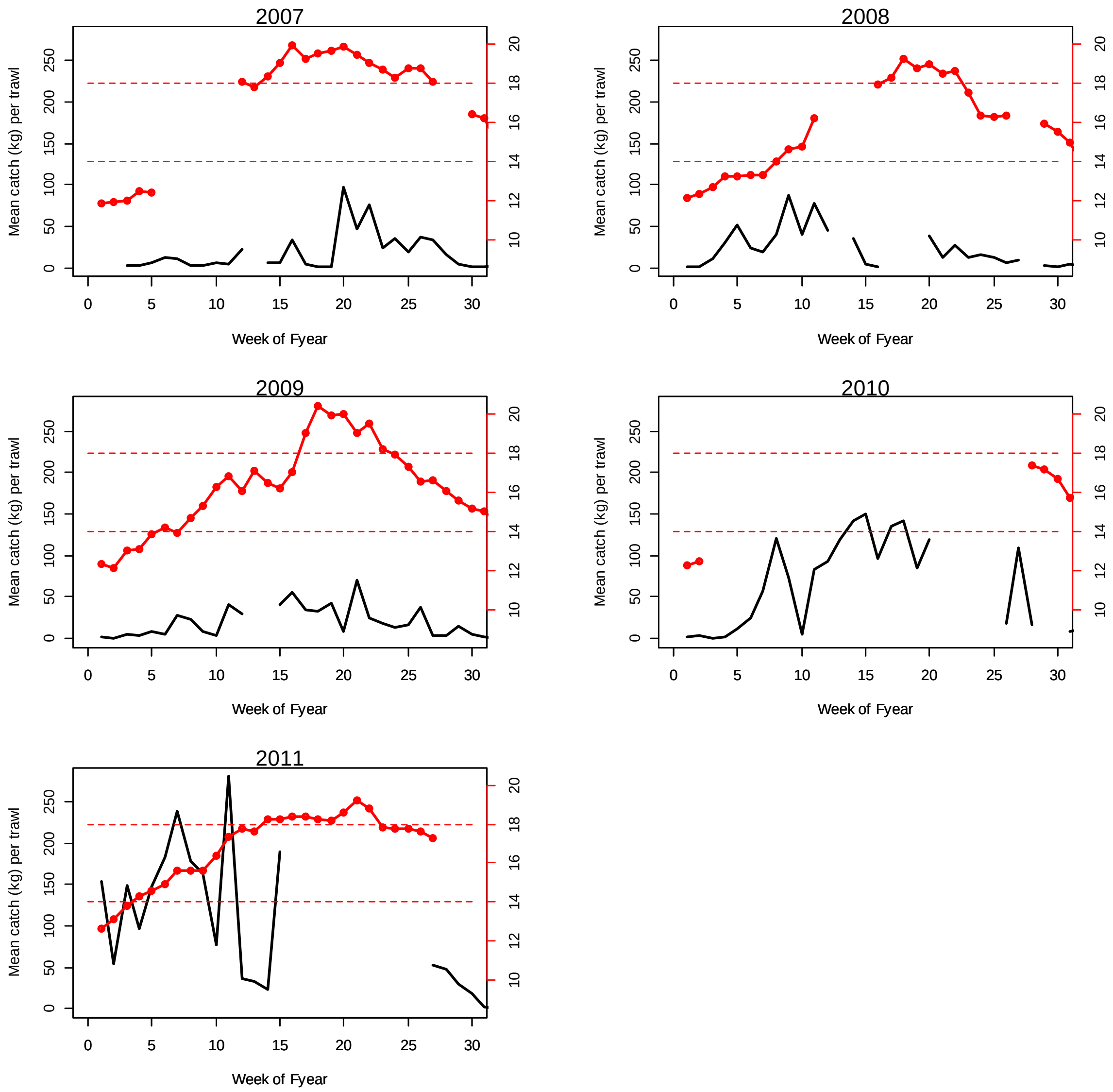

Figure 30: A comparison between weekly unstandardised snapper catch rates (kg per trawl) from the TBw area (black line) and weekly average sea temperature (C) measured at 4–8 m depth (source: Cawthron Institute) (red line) by fishing year.

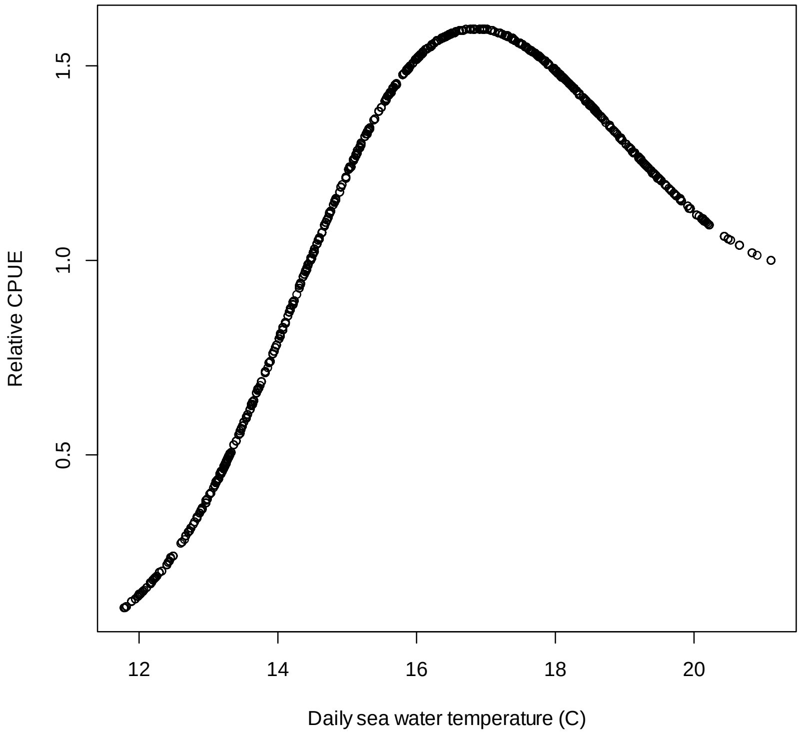

Figure 31: Predicted relationship between weekly average sea temperature (from western Tasman Bay) and the relative catch rate of snapper from the trawl fishery derived from the TCER lognormal, non zero CPUE model with the inclusion of a weekly sea temperature variable.

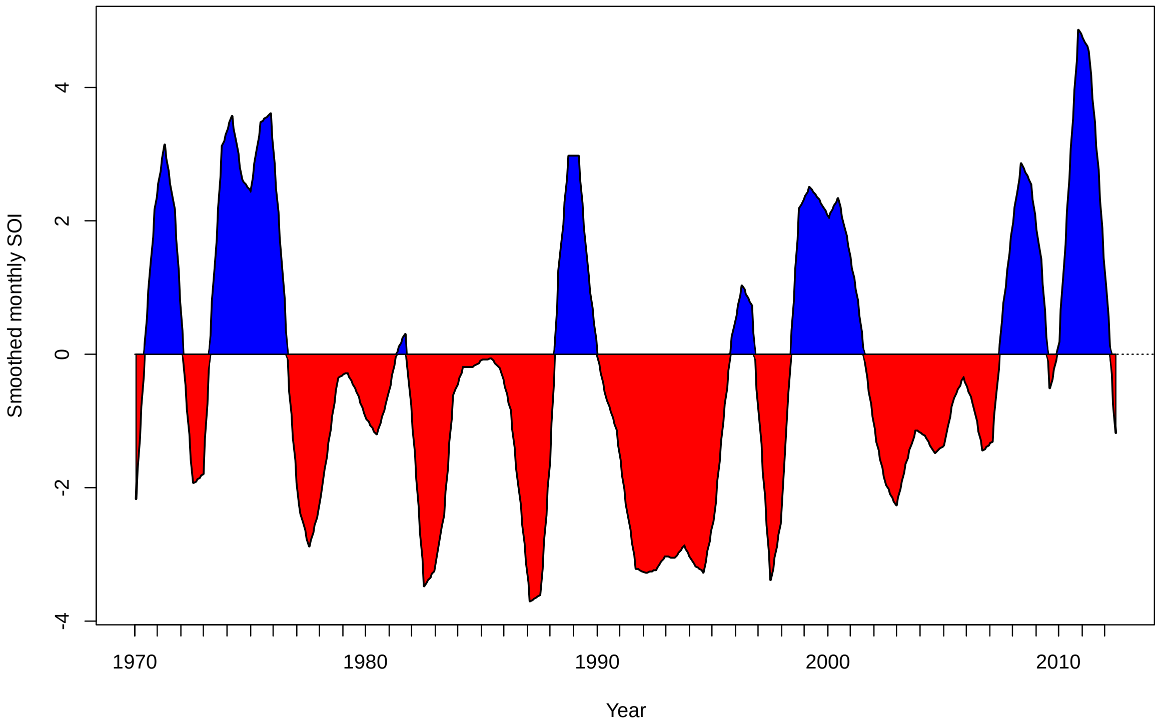

Figure 32: Smoothed monthly SOI index from January 1970 to June 2012. A lowess function was applied to derive the smoothed monthly values. The original monthly SOI data were sourced from http://www.cgd.ucar.edu/cas/catalog/climind/SOI.signal.annstd.ascii.